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IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies

São José dos Campos, Brazil
15-18 September 2015

Workshop Report

Edited by:
Thomas F. Stocker, Qin Dahe, Gian-Kasper Plattner, Melinda Tignor

This workshop was agreed in advance as part of the IPCC workplan, but this does not imply Working Group or Panel endorsement or approval of the proceedings or any recommendations or conclusions contained herein.

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Preface

Regional climate change projections provide the quantitative basis for studies of projected impacts from climate change and associated risks, which are essential building blocks for the comprehensive assessment of climate change science by the IPCC. There exist a number of climate modelling initiatives aimed at producing regional climate change projections, but they overall have not yet reached the maturity necessary for their wide spread use by the impacts and risk assessment community and relevant stakeholders. This workshop provided an opportunity to strengthen the link between the assessment of regional projections and the assessment of the projected impacts and risks, with the goal to enhance the information the IPCC can provide to its users and stakeholders in its Sixth Assessment Report.

The Workshop brought together 110 experts from 52 countries to discuss regional climate projections and their use in impacts and risk analysis studies. The workshop included experts from the Working Group I and Working Group II communities, including scientists from the climate modelling community, the regional modelling and downscaling community, and the climate impacts and risk analysis communities. The workshop provided an opportunity for the participants to reflect on the assessment of regional climate change projections and the regional projections of climate change impacts and risks in the IPCC Fifth Assessment Report, discuss developments made since the IPCC Fifth Assessment Report, and explored ways to facilitate the collaboration and exchange between the different communities in advance of and during the IPCC Sixth Assessment Report, with the goal to enhance the information IPCC can provide its users and stakeholders.

This Workshop Report includes a concise Information Paper that provides recommendations to the IPCC for the Sixth Assessment Cycle, in particular to the leadership of Working Groups I and II. This Report also contains summaries of the discussions in the plenary sessions and in the breakout groups. It further includes the abstracts of the keynote and perspective presentations as well as the poster abstracts presented during the Workshop.

We sincerely thank all the participants who contributed to a very constructive and fruitful meeting. The exchange of views and knowledge resulted in more clarity on the issues involved and pragmatic recommendations for consideration by the IPCC for its Sixth Assessment Cycle. We very much appreciate the guidance of the WGI Bureau and the advice of the members of the Scientific Steering Committee who helped shape the Workshop programme and assisted in carrying it out.

We thank the Government of Brazil and the Instituto Nacional de Pesquisas Espaciais (INPE) for hosting the workshop, and in particular Dr Thelma Krug, IPCC TFI Co-Chair during the Fifth Assessment Cycle, for leading the local organisational efforts. The excellent arrangements and the hospitality provided to participants contributed greatly to the success of the meeting. The financial support of the IPCC Trust Fund and of the Swiss Federal Office for the Environment is also gratefully acknowledged. The excellent and efficient work of the Technical Support Unit of Working Group I of the IPCC AR5 at all stages of the Workshop organisation and production of this report is much appreciated.

In summary, this was a very successful and stimulating meeting that brought together, for the first time in IPCC, key communities to discuss topics relevant for a better understanding of regional climate projections and their use in impacts and risk analysis studies. We are convinced that this will be of great value in the preparation of the Sixth Assessment Report and hope that the product of this Workshop will provide a starting platform for a better and more effective exchange of information on regional climate projections, impacts, and risk analysis between Working Groups I and II. A crucial next step will be the scoping of the Sixth Assessment Report to which the Information Paper of this workshop will contribute some key considerations that should enable and facilitate this emerging cross-working group collaboration.

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Qin Dahe

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Thomas F. Stocker, Co-Chair, IPCC Working Group I
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on behalf of the Working Group I Bureau

Executive Summary

Based on the expert contributions and discussions at the Workshop, and taking into account the current status of the science on regional climate projections and their use in impacts and risk analysis studies reported in the scientific literature, we submit the following key recommendations to the IPCC for the scoping and production of its Sixth Assessment Report (AR6):

- Develop the approach to present regional information in the assessment reports, with the goal to enhance regionalization of the assessment throughout. To this end it will be important to set up a process of close collaboration with the World Climate Research Programme (WCRP), with its Coordinated Model Intercomparison Project (CMIP) and with CORDEX (Coordinated Regional Climate Downscaling Experiment), early on in the assessment process. This should foster research on distilling across multi-model multi-method ensemble data, in particular the further evolution of Atlas products.
- Prepare a pair of AR6 WGI and WGII climate Atlases covering global and regional climate projections as well as climate impacts and risks. The AR6 Atlases should be based on coordinated, multi-model initiatives for global and regional climate models and downscaling products. The WGII Atlas should be complementary and closely coordinated with the AR6 Climate Projections Atlas in WGI. A coordinated cross-WG process early in the process will help facilitate the production of the pair of Atlases.
- Support the integration of the assessment across WGs by dealing with topics of high-regional relevance in a coordinated manner. This could be achieved by joint chapters supported by meetings of the Lead Authors of the joint chapter teams from across WGs. Examples of unifying challenges for IPCC WGs I and II include changes in the hydrological cycle and related impacts, the regional expression of sea level rise and extreme sea level events, or climate and weather extreme events.
- Make use of IPCC Expert Meetings and Workshops that are cross-WG organized, to activate the research communities for the assessment and foster coordination across WGs. Well planned, well designed, and well coordinated cross-WG IPCC Expert Meetings and Workshops are the most effective tool of IPCC to activate the research communities for the assessment.

More details on these key recommendations as well as further recommendations to the IPCC for the AR6 are provided below. A good overview of the engaged, constructive and fruitful discussions that ultimately formed the basis of the set of recommendations provided in this Information paper is given in the series of Breakout Group Reports. The Breakout Group Reports include additional recommendations to the IPCC, the scientific community and decision-makers regarding research needs and improved cross-discipline collaboration.

Introduction

Regional climate change projections provide the quantitative basis for studies of projected impacts from climate change and associated risks, which are essential building blocks for the comprehensive assessment of climate change science by the IPCC. There exist a number of climate modelling initiatives aimed at producing regional climate change projections, but they overall have not yet reached the maturity necessary for their wide spread use by the impacts assessment community and relevant stakeholders. Therefore there is a real opportunity to strengthen the link between regional projections and the assessment of projected impacts and risks by the IPCC. This will enhance the information the IPCC can provide to its users and stakeholders.

Working Group I (WGI) in its contribution to the IPCC Fifth Assessment Report (AR5) did provide a comprehensive assessment of climate change projections from global to regional scales. A new approach to assess regional climate change through the lens of modes of variability such as El Niño-Southern Oscillation, the Interdecadal Pacific Oscillation, The Southern Annular Mode, and many others, was presented in an entire chapter. This has generated a deeper and more physically based understanding of future regional climate change. In addition, WGI has complemented its regional assessment with an Atlas of Global and Regional Climate Projections, a new feature of the WGI AR5 that provides maps and regionally averaged time series of annual and seasonal multi-model means, with uncertainties, of changes in surface temperature and precipitation over the 21st century for 37 regions covering the entire world.

This assessment, however, relied largely on information derived from large-scale, multi-model initiatives using global climate models. The WGI AR5 Atlas of Global and Regional Climate Projections, for example, is based exclusively on global climate models. Although model data underlying the WGI AR5 Atlas is electronically available from the IPCC websites as part of the WGI AR5 Supplementary Material, it is not yet widely used in studies of regional impacts and risks of climate change to human and natural systems around the world. In particular, it was not used in the WGII contribution to AR5. Regional impacts and risks studies would substantially benefit from the inclusion of information coming from regional climate models or from statistical downscaling methods used to drive impacts models (e.g., crop models, hydrology models, etc.).

Since the finalization of the WGI AR5 in September 2013, important activities in the physical science community have evolved which will be crucial for an enhanced interaction between IPCC WGI and WGII in the area of assessing projections of climate change impacts at a regional scale. These concern, for example, the design and the start of Phase 6 of the Coupled Model Intercomparison Project (CMIP6) which will include the next generation of comprehensive climate models. It is expected that there will be a further increase in model resolution which will provide even more regional detail to users and stakeholders from global models. A second area of rapid progress is the Coordinated Regional Climate and Downscaling Experiment (CORDEX) of the World Climate Research Programme (WCRP). The initial focus was on Africa, but currently 14 regional domains around the world are being considered in CORDEX, and the data base of this coordinated regional modelling initiative is rapidly growing.

It was therefore timely for the IPCC to convene a Workshop to explore ways how to enhance the convergence and regionalization of information on projections of climate change and resulting risks and impacts, and to improve the consistent use and application of information in the next IPCC assessment cycle well ahead of the start of the scoping process for AR6. The Panel approved at its 41st Session in February 2015 a proposal submitted by the WGI Bureau to hold such a Workshop.

Outline of the Workshop

From 15 to 18 September 2015, 110 experts from 52 countries, including world leading experts in the areas of regional climate projections and impacts and risk analysis studies, gathered at the Instituto Nacional de Pesquisas Espaciais (INPE) in São José dos Campos, Brazil, to discuss and review the status of the science and to strengthen the link between the assessment of regional projections and the assessment of the projected impacts and risks, with the goal to enhance the information the IPCC can provide to its users and stakeholders in its Sixth Assessment Report.

Goals of the Meeting

The Workshop addressed directly the interface between regional climate projections, a topic that is traditionally assessed by WGI of the IPCC, and risk analyses which has been a focus of WGII. Participants across the traditional IPCC WGI-WGII boundaries were therefore invited, covering a wide range of expertise and perspectives.

IPCC WGII had proposed risk as an underlying concept in their contribution to the AR5. Risk directly speaks to stakeholders and practitioners who need this information for better strategies to adapt and mitigate climate change and its impacts. However, the assessment of risks from climate change has still remained, in many areas, at a qualitative level, and the link to quantitative projections assessed by WGI has been tenuous at most.

One of the most important advances that can be made in the forthcoming cycle is therefore to carry out quantitative impact assessment and risk analysis by using, as much as possible, the information from a hierarchy of climate models and related tools. This ranges from the CMIP6 ensemble simulations providing the global context, to regional climate modelling efforts such as those pioneered by CORDEX, and emerging highest-resolution models at kilometer-scale, combined with downscaling approaches.

The goals of the meeting were to

- Critically reflect on the assessment of regional climate change projections and of regional projections of climate change impacts and risks, and their limitations, in the IPCC AR5;
- Collect views and perspectives on how IPCC assessment of regional projections of climate, impacts and risks could be better supported/improved;
- Discuss the latest, post IPCC AR5 results from regional climate modelling and downscaling efforts;
- Obtain an overview of the status of information currently available and expected on a time scale relevant for the next assessment cycle for all regions of the world;
- Explore ways how the IPCC could facilitate the collaboration and exchange between the climate modelling and impact and risk communities, including ensuring an effective flow and quality control of information and data;
- Identify numerical data requirements (climate variables, derived quantities, proxies, and statistics) by the impacts and risk communities from the climate modelling community that could help facilitate the IPCC assessment process in the future.

Summary of the Discussions and Conclusions of the Workshop

The Workshop consisted of three elements: plenary sessions, poster sessions, and breakout groups (BOGs). The goal of the Workshop was to arrive at a set of recommendations to a range of addressees: to the IPCC, the IPCC Working Group's for the AR6, as well as the scientific community and the decision-/policymakers. Discussions during the meeting ranged from issues related to the interaction and cohesion between climate and climate impacts/risks research communities, the distillation and translation of climate information for use by decision makers, to the case of extreme climate and weather events and how to better deal with these high risk–low probability events in a decision-making context, and finally the specific, rather technical yet important topic of bias correction.

Here we provide a set of, in our view, high-level, highest priority recommendations distilled from the Workshop with immediate impacts on the early stages of the assessment process in the AR6. The recommendations are presented on behalf of the WGI Bureau, but have been heavily informed by the expert contributions in presentations and discussions at the Workshop. We focus on recommendations that are actionable and can be implemented, and where an active facilitator role by the IPCC is crucial. More detailed information on the discussions during the Workshop is available in the subsequent sections of the Workshop Report, most importantly in the summaries for the individual Breakout Group Reports.

General Recommendations for the IPCC

(1) Engage in a dialogue with the World Climate Research Programme (WCRP), with its Coordinated Model Intercomparison Project (CMIP) and with CORDEX (Coordinated Regional Climate Downscaling Experiment), for fostering research on distilling across multi-model multi-method ensemble data, in particular the further evolution of Atlas products. This could be achieved through the following, non-exclusive approaches:

   i) An IPCC Expert Meeting on how CMIP and CORDEX can best contribute to the AR6. Such a meeting would be organized by IPCC WGI and ideally take place before the scoping of the AR6.

   ii) A [1-day] roundtable meeting very early in the AR6 process involving WG Co-Chairs, WG TSU Science Directors, IPCC AR5 CLAs of relevant projections chapters, the members of the Scientific Steering Committees of CMIP and CORDEX. Such a meeting would be organized by IPCC WGI and ideally take place before the scoping of the AR6. Also, such a roundtable meeting would ideally be organized just before or after meetings of the Scientific Steering Committees of these programs.

(2) Engage in a dialogue with the Global Programme of Research on Climate Change Vulnerability, Impacts and Adaptation (PROVIA) and Future Earth for fostering coordinated quantitative research on projections of vulnerability, impacts and risks, in particular the design of Atlas products. This could be achieved through the following, non-exclusive approaches:

   i) An IPCC Expert Meeting on how PROVIA and Future Earth can best contribute to the AR6. Such a meeting would be organized by IPCC WGII and ideally take place before the scoping of the AR6. Ideally, WGII would make use of the already approved 'IPCC Workshop on AR5 Lessons Learned' and reframe its purpose from a Workshop that is backward looking and comes at a very late stage and long after the completion of the AR5, to a targeted, forward looking Expert Meeting that effectively informs the WGII AR6 scoping process.

   ii) A [1-day] roundtable meeting very early in the AR6 process involving WG Co-Chairs, WG TSU Science Directors, IPCC AR5 CLAs of relevant projection chapters, the members of the Scientific Steering Committees of PROVIA and Future Earth. Such a meeting would be organized by IPCC WGII and ideally take place before the scoping of the AR6. Also, such a roundtable meeting would ideally be organized just before or after meetings of the Scientific Steering Committees of these programs.

(3) Engage in a dialogue with the Global Framework on Climate Services (GFCS) and related climate services partnerships for issues of communication and user needs. This could be achieved through the following, non-exclusive approaches:

   i) An IPCC Expert Meeting on how Climate Services can best contribute to the AR6. Such a meeting would be organized by IPCC WGI and ideally take place before the scoping of the AR6.

   ii) A [1-day] roundtable meeting very early in the AR6 process involving WG Co-Chairs, WG TSU Science Directors, IPCC AR5 CLAs of relevant chapters, the Management Committee of the Intergovernmental Board on Climate Services (IBCS) as the main governing body of GFCS, and possibly further selected representatives of the GFCS or of national weather services. Such a meeting would be organized by IPCC WGI and ideally take place before the scoping of the AR6. Also, such a roundtable meeting would ideally be organized just before or after meetings of the Management Committee of the IBCS.

(4) Consider options to contribute to or facilitate the development of scientific guidance on national or regional climate assessments. As a first step, an IPCC Expert Meeting with the involvement of member governments could review the currently available various approaches to national or regional climate assessments. National or regional assessments, carried out by government agencies and academic institutions could become a valuable resource of regional information that hitherto has not found its way into IPCC assessments. In particular, such national or regional assessments would serve as a first digestion step of material in other languages and indigenous knowledge to be then considered in the IPCC assessment.

    The goal of the IPCC Expert Meeting would be to reflect on and discuss the benefits of a more unified approach which would facilitate the consideration of such information in IPCC assessments. This would be an effective additional step towards more regionalization, while recognizing the need for differentiated approaches depending on countries and regions. Ideally this would result in a set of minimum standards that help enable more and more national and regional assessments worldwide, which could then be considered by the IPCC in its future assessments.

General Recommendations for the IPCC AR6 Cycle

(1) Rethink the approach to present regional information in the assessment reports. The goal should be to enhance regionalization of the assessment throughout, not to add more separate regional chapters to one or more WG Reports. A regionalized assessment would be facilitated by

   i) The early coordination between WG Co-Chairs/Bureaux as part of the WG scoping process; and

   ii) The setup of joint discussion platforms and/or cross-WG meetings with the relevant WGI and WGII Lead Authors right at the start of the process of report development by the author teams.

iii) 1-day side events before or after regular WG Lead Author meetings could be an efficient way to help develop a more coordinated assessment across WGs without, however, jeopardizing the work on the individual WG contributions during regular Lead Author meetings.

(2) Support the integration of the assessment across WGs by dealing with topics of high-regional relevance in a coordinated manner. This could be achieved by joint chapters supported by meetings of the Lead Authors of the joint chapter teams from across WGs. Examples of unifying challenges for IPCC WGs I and II include changes in the hydrological cycle and related impacts, the regional expression of sea level rise and extreme sea level events, or climate and weather extreme events, as already highlighted in the AR5 cycle Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. In AR6, for example, the assessment of climate and weather extreme events could now be done in a coordinated, consistent manner in a joint WGI-WGII chapter.

(3) Make use of IPCC Expert Meetings and Workshops that are cross-WG organized, to activate the research communities for the assessment and foster coordination across WGs. Well planned, well designed, and well coordinated cross-WG IPCC Expert Meetings and Workshops are the most effective tool of IPCC to activate the research communities for the assessment. Such meetings can also help prepare the science for the assessment, and can facilitate the coordination of important topics within or across-WGs in the AR6. Bringing together experts across disciplines and WGs early in the assessment cycle in a coordinated way, focusing on the topic of regional climate projections and impacts and risk, will be a prerequisite for a successful, more integrated end-to-end assessment in the AR6. The IPCC Workshop on Sea Level Rise and Ice Sheet Instabilities organized by WGI in AR5 can serve as a model here. This IPCC Workshop was essential for successfully addressing the then controversial and contentious topic of sea level rise. It brought together experts from very diverse disciplines with a wide range of expertise, covering oceanography, ice sheet dynamics, glacier research and hydrology to discuss latest science from both observations and modelling relevant for sea level change. At this Workshop, the Lead Author teams of the relevant WGI AR5 Chapters 'Observations: Cryosphere' and 'Sea Level Change' prepared the ground for their comprehensive assessment of sea level changes early in the AR5 assessment process.

(4) Prepare IPCC Guidance Documents, e.g., Good Practice Guidance Papers on important cross-WG themes and topics to help the assessment process in AR6. Good Practice Guidance Papers can facilitate the assessment process on cross-WG topics. This was successfully done in AR5 with guidance papers on, e.g., Consistent Treatment of Uncertainties (WGs I, II, III), Detection and Attribution Related to Anthropogenic Climate Change (WGs I and, II), and Assessing and Combining Multi-Model Climate Projections (WGI), which were central for the Lead Authors of the relevant WGs and chapters. The preparation of such guidance documents is best supported by corresponding IPCC Expert Meetings (see previous point (3)), where the basis for the guidance is being discussed and agreed to by the invited experts. Guidance papers, available early in the assessment process, substantially assist the scientists in arriving at a coherent and consistent assessment. If guidance papers are agreed to by more than one WG, they facilitate cross-WG collaboration and later synthesis - an excellent example is the above mentioned Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties. For the AR6 and the assessment of regional climate projections and impacts/risks, the following topics could be considered, among others, for more coordinated guidance for the author teams:

i) Guidance on integrated, cross-WG assessments and end-to-end analyses in AR6. Using the example of, e.g., extreme weather and climate events as a case study, a guidance paper could illustrate the process and highlight the difficulties and benefits of an integrated, end-to-end assessment. Such a guidance paper would also need to cover the consistent, coherent approach of addressing uncertainties along the modelling chain from climate change projections to projections of impacts and risks.

ii) Guidance on (the assessment of) integrated indices for vulnerability and risks. In order to support the AR6, there is an urgent need to develop agreed and robust definitions of indices of vulnerability and exposure that can then be combined with physical climate information to prepare world maps of risks, parallel to the world maps of physical climate change. This is a prerequisite for the further down proposed AR6 WGII Atlas of Global and Regional Climate Impacts and Risks.

iii) Guidance on bias correction of regional and downscaled model projections, addressing the science and user communities, emphasizing the limitations of bias adjustments and considering the consistent handling of uncertainties. This might include guidance on the development of a code of best practices in bias correction, establishment of a consistent terminology that could be applied across the AR6 assessment, including clear and agreed on definitions of 'bias' and 'bias correction', and guidance on the availability, use, interpretation and limitations of bias correction methods in the broader context of other available post-processing methods.

(5) Facilitate the distillation and the use of climate information from the assessment across WGs. To be most efficient, this should be done primarily at the level of the WG authors, with technical and logistical support provided by the WG TSUs.

(6) Facilitate guidance and technical support on transfer of data and information across WGs by the WG TSUs early in the process. The WG TSUs work closely with the WG Co-Chairs, the WG Bureau, and the author teams and are well equipped to provide fast and efficient support.

Specific Recommendations for the IPCC AR6 Scoping Process

(1) Scope IPCC Atlases of Climate Projections, Impacts and Risks in WGs I and II

  i) Prepare an AR6 WGI Atlas of Global and Regional Climate Projections. The AR6 Climate Projections Atlas should, however, be based on coordinated, multi-model initiatives for Global Climate Models (CMIP6) as well as on coordinated, multi-model initiatives for Regional Climate Models and downscaling products (CORDEX). As part of the early preparatory work for the AR6 Atlas, the utility of the AR5 Atlas should carefully be evaluated, ideally at an IPCC Expert Meeting, with a range of stakeholders and users, and areas of improvements should be elaborated on. Issues of scenario differences between projections using a range of models should be addressed early for a meaningful expansion of the WGI Atlas to regional model projections.

  ii) Prepare an AR6 WGII Atlas of Global and Regional Climate Impacts and Risks. This has the potential to become a key element of the WGII contribution to AR6 that is of high policy relevance. The WGII Atlas should be complementary and closely coordinated with the AR6 Climate Projections Atlas in WGI. A coordinated cross-WG process early in the process will help facilitate the production of the pair of Atlases.

  iii) Assess the uncertainty in climate projections in a comprehensive, end-to-end manner in the AR6 and in particular in the proposed WGI and WGII Atlases. The assessment of uncertainty needs to consider the propagation of uncertainty arising from both global and regional climate model biases as well as bias correction along the modelling chain from climate change projections to projections of impacts and risks. The coordinated assessment of uncertainty along the modelling chain will be facilitated by the above suggested joint WG chapters supported by joint WG chapter Lead Author meetings.

Conclusions

The intensive and constructive discussions at the IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies has shown that a dialogue and coordination between IPCC WGs I and II, the scientific communities of the physical climate modelling (e.g., through programmes such as CMIP6 and CORDEX), and the impact and risk modelling (e.g., through programmes such as PROVIA and Future Earth), and organisations involved in national climate assessments and climate services (GFCS) would significantly enhance the amount, quality, scope, and specificity of regional information that will emerge from IPCC AR6. In order to be successful, it is essential that this coordination is developed with no delay, ideally before the scoping of the IPCC AR6. Effective enabling components are IPCC Expert Meetings and IPCC Workshops which may produce guidance material for the Lead Authors of the AR6. A more rapid and less formal way towards coordination are roundtables among the leadership of these science programmes, IPCC Working Groups, relevant IPCC chapters, and stakeholders.

B. Summary of Plenary Discussions

The format of the Workshop consisted of three elements: plenary sessions with invited scientific keynote and perspective presentations; poster sessions, including 2-minutes/1-slide introductory presentations; and three breakout group (BOG) sessions on a number of core themes that were scheduled over the 3.5 days of the Workshop. The structure allowed for extensive discussions and thoughtful exchanges of ideas among participants.

The first day was dedicated to scientific presentations by the WGI Co-Chairs, keynote speakers and invited expert participants through a first poster session. Days two and three combined scientific presentations, poster sessions and breakout group discussions. Day four was dedicated to a synthesis of the discussions from the three previous days.

Plenary Sessions

The *Introductory Plenary* provided an initial overview of the WGI, WGII and Synthesis assessments and key conclusions from the IPCC Fifth Assessment Report (AR5) central to the topic of the Workshop. The need to bridge the gaps between science and practice for information from regional climate projections was highlighted. The expectations and needs from decision-makers were addressed.

Theme Plenary I dealt with lessons from AR5 and provided a concise summary of AR5 results relevant for the topic of the Workshop. The presentations focused on the WGI assessment of regional climate projections, including the Climate Phenomena Chapter and the WGI Atlas of Global and Regional Climate Projections, and the experiences and potential needs resulting from the WGII assessments of impacts modelling and risk modelling

Theme Plenary II dealt with coordinated modelling projects and provided a general overview of projects across research fields. Specific consideration was given to coordinated climate modelling activities and related applications, such as the World Climate Research Programme (WCRP), with its Coordinated Model Intercomparison Project (CMIP) and the Coordinated Regional Climate Downscaling Experiment (CORDEX). Similarly coordinated impacts and risk modelling projects, such as the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP), the Agricultural Model Intercomparison and Improvement Project (AGMIP) and others, were introduced and discussed.

Theme Plenary III covered the topic of how to better connect science and practice. Nine individual perspective presentations, followed by extensive general discussions, provided for an excellent overview with many experiences across a wide range of topics being reported. Perspective presentations covered the following themes:

- Decision-centered approaches to the use of climate information
- Challenges of the science-policy interface from the policy and administration perspective
- The importance of bias correction for impact assessments of water-related disasters on a regional scale
- Water resources management and climate change
- Climate change impacts on the Caribbean's biodiversity
- Marine projections for natural resource management regions of Australia
- Roles of culture in flood risk management
- Livelihood perspective or why is it so difficult to quantify risk and to facilitate the co-production of knowledge
- Regional climate projections, precipitation changes and flooding: the connection between science and practice

Theme Plenary IV dealt with preparing the science for AR6 and served as critical input to the discussions in the three breakout groups which all dealt with certain aspects of the Workshop's core theme, i.e., the translation or distillation of pure climate projections into information relevant for practitioners and decisionmakers (see Breakout Group Reports).

The presentations all dealt with the need to bridge the gap between science and practice for information from regional climate projections. They focused on key issues, requirements necessary to make progress, and possible sets of targeted recommendations to a range of addressees: the science community, to decisionmakers and policymakers, and also to the IPCC for the preparation of the AR6. An additional keynote presentation covered the important topic of decision making under uncertainty

Theme Plenary V then dealt with regional climate assessment from the global to the national scale. Eight individual perspective presentations, followed by extensive general discussions, provided for an excellent overview of national and regional experiences with climate and climate change assessments, with contributions from all six WMO regions. Perspective presentations covered the following themes:

- A Brazilian vulnerability index towards natural disasters and climatic change – flashfloods, landslides, droughts
- Australian national climate projections: use of downscaling, and the importance of distinguishing knowledge and data
- China's national assessment report on climate change
- Main characteristics of the 3rd national communication of Argentina to UNFCCC
- Regional climate projections in the Baltic Sea basin: current state and future perspectives
- Providing high resolution climate information in the Southeast Asian region for impacts and local planning applications
- Regional climate change assessments – the case of Zambia
- Climate change impacts in the United States – the case of the Northwest: implications for landscapes, waters, and communities

The *Synthesis Plenary* on the final day provided an opportunity to summarize the discussions from the three breakout groups and beyond. The focus for the synthesis was on the development of few high-level recommendations resulting from the meeting targeted to the science community, decisionmakers and policymakers, potential funding agencies, and to the IPCC for the preparations of the IPCC AR6.

C. Breakout Group Reports

The Workshop included three topical breakout groups. The breakout group sessions provided an opportunity for participants to discuss in small groups some of the key topics related to regional climate projections and their use in impacts and risk analysis studies. Each of the breakout groups addressed issues of relevance to their topic with a particular focus on requirements and recommendations in advance of the IPCC Sixth Assessment cycle. During the Workshop, a more technical sub-group was established as a spin-off from the third breakout group (BOG3). This sub-group (BOG3bis) focused on the strengths and weaknesses of bias corrections methods and their applications in studies on climate change impacts and risk projections.

Each breakout group was supported by members of the Scientific Steering Committee and led by a Chair and Rapporteur team, who reported back to the Plenary a summary of the discussions and conclusions from their breakout group. These were then further discussed in the Plenary. Following the Workshop, the Chair and Rapporteur were tasked with preparing a report that provided a synthesis of the discussions and conclusions. Those reports are given hereafter:

Breakout Group 1: National/Regional Assessments: Linking Coordinated Climate Model Projection Efforts with Impacts and Risk Modelling Efforts

Chair: Jana Sillmann, Center for International Climate and Environmental Research, Norway
Rapporteur: Tereza Cavazos, Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, Mexico

Scientific Steering Committee Members: Filippo Giorgi, International Centre for Theoretical Physics, Italy; Judy Omumbo, Kenya Medical Research Institute, Kenya; Fredolin Tangang, National University of Malaysia, Malaysia

The overarching topic addressed by this breakout group was how interactions and flow of information between climate modelling and impacts and risk modelling efforts could best be facilitated within the IPCC framework. These interactions were recognized as occurring both between researchers whose work is assessed by different IPCC Working Groups (WGs) as well as between IPCC authors working on the assessment in the respective WGs. In this respect, ***a fundamental issue concerns the sustained and timely cross-community communication***, especially when scoping the assessment report (e.g., to define common approaches), but also throughout the entire Assessment Report (AR) process, to ensure close interactions across WGs. Key recommendations on how to address this communication challenge in the next IPCC assessment report (AR6) are bullet pointed below and related issues and requirements are elaborated in more detail in the following report.

- Distillation of climate information across WGs;
- Joint chapters, special reports or good practice guidance papers including a consistent approach of addressing uncertainties;
- Common benchmarks for risk analysis and exploration of scenario uncertainties;
- Risk and vulnerability indices;
- Better inclusion of downscaled data and information;
- Evaluating the utility of the WGI AR5 Atlas and designing an improved Atlas-type product for the AR6;
- Better guidance and technical support on transfer of data and information across WGs;
- Engagement in a dialog with Climate Services.

<u>Distillation of climate information across WGs</u>. Models and model hierarchies are becoming increasingly complex across WGs, with large amounts of climate information being derived from multiple sources including an ensemble of global atmospheric-ocean general circulation models (AOGCMs) and Earth system models (ESMs), regional climate models (RCMs), Empirical Statistical Downscaling (ESD), observations and reanalysis. In this complex landscape, a priority issue for facilitating data flow and use across communities concerns the distillation of credible and robust information for use in regional risk assessments, including quantitative measures of uncertainty. Distillation can be seen, on the one hand, as assessment and extraction of robust climate information at multiple scales across regions, and on the other hand, as a translation of information from one WG to the other. This is an emerging area of research, which needs to be understood in depth before the climate information is used for vulnerability, impacts and adaptation (VIA) applications. It is therefore recommended that guidance on distillation methods and definitions are included in the ARs. This could be accomplished with a chapter on distillation methods in one or more WG reports and summary sections presenting distilled information within the regional chapters.

Joint chapters, special reports, and good practice guidance papers including a consistent approach of addressing uncertainties. It is recommended to develop joint chapters or Special Reports across WGs on overarching topics, such as methodologies, extremes, food, or water, which would facilitate cross-WG communication and collaboration. This should include communicating uncertainties that may propagate through different steps of analysis (e.g., originating from an ensemble of AOGCMs and ESMs participating in the Coupled Model Intercomparison Project (CMIP), RCMs, ESD, impact models, socioeconomic scenarios, or risk analyses). An Expert Meeting involving representatives of all three WGs, resulting in a good practice guidance paper describing how risks and uncertainties are characterized is recommended to improve cross-WG treatment of uncertainties.

Common benchmarks for risk analysis and exploration of scenario uncertainties. It is recommended to adopt common benchmarks (e.g., idealized scenarios of a 2°C, 3°C or 4°C warmer world) in the assessment of changes in risk due to climate change. This could be accomplished, for example, by using a more general framing of the questions and results that describe outcomes or responses as a function of degrees of warming rather than according to specific scenarios (e.g., Representative Concentration Pathways (RCPs)). This should encompass the use of idealized simulations to explore scenario uncertainty and idealized sensitivity studies relating to how risk changes in a warmer world.

Risk and vulnerability indices. As emphasized in the Special Report on Managing the Risks of Extreme Events (SREX; IPCC, 2012), risk needs to be addressed in a holistic approach. Risk and vulnerability indices (or indicators) should span across a range of physical processes, impacts and socioeconomic sectors. Thus, integrated indices are recommended, which include not only physical variables describing hazards (e.g., temperature and precipitation, or modes of variability), but also quantities describing exposure and vulnerability, such as for biodiversity, socio-economic factors or demographic distribution. An extensive compilation of indices being used in the different WGs and communities is required to enable an assessment of the current status and usefulness of indices across WGs for risk assessment. An expert meeting (and subsequent task team) with representatives from all three WGs is therefore recommended, which should focus on coordinating the assessment and development of integrated indices (e.g., for the use in global vulnerability maps to compare risk across regions). This also requires availability of data characterizing some of the baseline socioeconomic variables. An example in which global data on socioeconomic and environmental variables were presented systematically alongside climate information is the IPCC Special Report on The Regional Impacts of Climate Change (IPCC, 1997). Data or maps showing up-to-date distributions of socioeconomic variables, which are widely applied in VIA and mitigation analyses and in the development of indices, could therefore be a valuable addition to the AR6. Along with these efforts, the development of an understanding of the value of these indices in assessing risk and the communication of their limitations is crucial.

Better inclusion of downscaled data and information. When moving from global to more regional and local aspects of risk, the use of downscaled climate information across WGs becomes a critical issue. Use of downscaled information has been limited in previous ARs, however new opportunities arise from the inception of recent and increasingly mature coordinated efforts, in particular the COordinated Regional Downscaling EXperiment (CORDEX). Within this context, homogeneity of downscaled information across regions and relevance for VIA applications and process studies need to be ensured. It is recommended that downscaled information deriving from CORDEX and related programs acquire a greater role in the AR6 (including the design and content of the Atlas-type product as discussed below). The IPCC could facilitate this process by establishing a task force (or team) with participants from relevant cross-WG activities, (e.g., CORDEX, VIACS (VIA and Climate Services) Advisory Board for CMIP6, and Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP)) to jointly discuss and provide suggestions for optimizing the design of new CORDEX experiments and data management practices, also in view of its more fruitful inclusion in the AR6. In this regard, feedbacks from the VIA community concerning questions related to the experimental framework of upcoming CORDEX activities is crucial (e.g., choice of driving global models, scenarios, optimal compromises between spatial resolution and ensemble size). Since a subset of models participating in CMIP6 will be running experiments at ~25 km or finer horizontal resolution, it is recommended to have a common assessment of regional climate information from high resolution AOGCMs and RCMs in comparison to results with lower horizontal resolution.

Evaluating the utility of the WGI AR5 Atlas and designing an improved Atlas-type product for the AR6. In the IPCC WGI AR5, the Atlas of Global and Regional Climate Projections (IPCC, 2013) based on CMIP5 simulations and corresponding results assessed in the main report (primarily Chapters 9, 12 and 14) was an important element for communicating climate change information across regions and WGs. In the next IPCC AR process, the quality and relevance of this Atlas as an effective communication tool needs to be ensured and optimized with clear guidance on how to rely on assessed material in the main reports. Towards this goal, it is recommended that the CMIP5-based Atlas is revisited at the outset of the next AR phase by scientists from all WGs. Based on the evaluation of the use and value of the WGI AR5 Atlas for VIA applications, recommendations on how to improve the Atlas, or develop an alternative Atlas-type product, in the AR6 should follow. It is further recommended to have cross-WG communication early on in the process on how dynamical and statistical downscaled climate information (e.g., from CORDEX) can be most usefully presented in the revised Atlas-type product together with CMIP results.

Better guidance and technical support on data and information transfer. The timing of the ARs from the three WGs is considered as an issue as the VIA and risk modelling communities receive information and data from WGI too late in the AR process in order for WGII to assess publication results based on the most recent climate information available. As a result, WGII assesses work that may not be consistent with the latest scenarios used in WGI, but rather using SRES or RCP-based forcing scenarios or alternative climatological baseline periods instead of the SSP-RCP scenarios that will form the basis for future climate simulations in CMIP6. Clear information that translates across the scenarios is required (see also common benchmarks above). Another key issue for the VIA research community is further the accessibility, inter-operability and formats of data provided from the climate modelling community. Timely transfer of the data requires an efficient infrastructure. An important part of CMIP is the standardization of model output that is archived in a common format (NetCDF) and structure at the Earth System Grid Federation (ESGF). Further standardization might be required to enable a subset of the variables to be easily translated to formats more familiar to the VIACS communities (e.g., GIS). The engagement of dedicated data distribution centres such as ESGF, boundary organisations or national climate service centres able to advise on the acquisition, selection, application and interpretation of climate information is therefore a necessary requirement to ensure easy and timely climate data exchanges. Guidance documents are recommended, for instance under the stewardship of the IPCC Task Group on Data and Scenarios for Climate and Impact Analysis (TGCIA) in collaboration with the VIACS Advisory Board for CMIP6, to define the required information and to facilitate the transfer, offering an authoritative good practice reference source for use by boundary organisations, data centres and climate services operating at regional and national scales.

Engagement in a dialog with Climate Services. While the scope of Climate Service (CS) activities extends well beyond climate change applications (including, for example, weather observations and operational forecasting), CSs play an important role in initiating and fostering dialogue with stakeholders and end-users of climate information. The IPCC has its role in providing the best available assessment on climate observations and climate change projections used in CS for VIA applications. Current activities related to the establishment of national and regional CS centres and the overarching Global Framework of Climate Services (GFCS) should be considered as a valuable opportunity for facilitating data distribution and communication among research communities. It is, therefore, recommended that the IPCC promotes and facilitates a dialog with the GFCS and regional/national climate service centres and that climate data needs of CS are taken into consideration when designing or scoping the next AR.

References

IPCC, 2013: Annex I: Atlas of Global and Regional Climate Projections [van Oldenborgh, G.J., M. Collins, J. Arblaster, J.H. Christensen, J. Marotzke, S.B. Power, M. Rummukainen and T. Zhou (eds.)]. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1311–1394.

IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* A Special Report of Working Group II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

IPCC, 1997: *The Regional Impacts of Climate Change: An Assessment of Vulnerability.* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Watson, R.T., M.C. Zinoyewera, and R.H. Moss (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 517 pp.

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Breakout Group 2: National/Regional Assessments: How to Optimize Climate Information for Use by Decisionmakers at Regional Scales

Chair: Andrew Tait, National Institute of Water & Atmospheric Research, New Zealand
Rapporteur: Kiyoshi Takahashi, National Institute for Environmental Studies, Japan

Scientific Steering Committee Members: Bruce Hewitson, University of Cape Town, South Africa; Jose Marengo, National Center for Monitoring and Early Warning of Natural Disasters, Brazil; Kathleen McInnes, Commonwealth Scientific and Industrial Research Organisation, Australia; Carolina Vera, Centro de Investigaciones del Mar y la Atmósfera, Argentina

Introduction

The breakout group met for three sessions over two days to discuss the topic of 'National/Regional Assessments: How to Optimize Climate Information for Use by Decisionmakers at Regional Scales'. Around 40 people from the workshop attended the sessions.

At the first session, the chair explained that the purpose of the discussion was to identify some key issues with respect to the topic. Following from this, the group was tasked with identifying some requirements of researchers and decisionmakers to help address these issues, and finally, to propose some tangible recommendations to IPCC and the research and end-user communities that could partially or fully meet these requirements.

An early point of clarification was requested regarding the term 'regional', as this word can be used to mean 'large areas of the world, such as West Africa' as well as 'sub-national areas, such as Hawkes Bay in New Zealand'. It was agreed that whilst the use of the word in the workshop title referred to larger areas (with respect to climate modelling), the use of the word for the purposes of the breakout group referred to sub-national areas, as it is at this and up to the national scale where decisionmakers are most active and influential.

The ensuing discussion throughout all the breakout group sessions was excellent and involved contributions from almost all the participants. This included perspectives from the modelling community, social science, applied physical science, policy analysts, and advisors to decisionmakers. Most, if not all, of the participants were researchers who often take up the role to communicate climate science with public and decision makers at national and regional level, and many in the group had been involved in IPCC activities in the past.

The following three sections in this report describe: 1) the state of the discussion after the first breakout group session (which was reported back to the plenary the following morning); 2) a synthesised summary of all the discussion, broken down according to key issues, requirements and recommendations (again, reported to the plenary); and 3) three high-level recommendations.

Session 1: Brainstorm

The first session of the breakout group produced many excellent ideas, concepts, issues, concerns, and questions around the topic. The discussion was wide-ranging and not limited to climate change or regional modelling, but was more broadly related to the derivation, sharing and use of climate 'information', which includes observed and modelled data, short-term forecasts and seasonal outlooks, as well as climate change. The concept of a continuum of information was raised numerous times.

The discussion evolved into a brainstorm session, which (upon reflection) clustered around three principal questions plus an 'other' category. The primary questions were: 1) What is 'regional'? 2) What is 'information'? and 3) Who are these 'decisionmakers' anyway? What follows are the key points taken from the session, which were presented back to plenary the following morning.

What is 'regional'?

- Multiple definitions (e.g., West Africa or Hawke's Bay);
- Commonly used definitions according to IPCC, WMO, CORDEX, biogeographical, political, …
- Assessments of very large regions have less policy relevance, although global/large regional information is useful contextual information.

- Is there a need for standardisation – whose definition to use?
- Assessment scale is completely a function of users' needs.
- IPCC regional assessments will never be entirely satisfactory ('Thanks for that, but what I really need is…').

What is 'information'?

- Does climate information include maps, fact sheets, guidance manuals, historical data, seasonal outlooks…or are we limiting ourselves here to global and regional climate model output?
- Treating data as information problematically conflates multiple sources of error with natural variability and scenario uncertainty, and separating out the anthropogenic forced response is necessary but challenging.
- The Global Framework for Climate Services (GFCS) can be used as one model (among many) for information sharing and knowledge co-production.
- Decisionmaking at the national level depends on various types and sources of information. How accessible and reliable is it?
- Have to identify the users' needs for information. This informs the level of sophistication, accuracy, and information mode.
- Information can be in the form of narratives and storylines (e.g., related to large-scale weather (or other) phenomena).
- Storylines that relate to personal experiences are very powerful and provide context; climate information can be very abstract.
- Distilling information from complex datasets is difficult, but the storyline process is a useful mechanism for helping to do this.
- There is a skill in distilling information and packaging it (e.g., games, pictures, dance…) in a way that is useful for the practitioners.
- Scenarios/storylines/narratives can be used to explore possibilities, examine system sensitivities and convey uncertainty.

Who are these 'decisionmakers' anyway?

- Multiple 'users' (scientists, policy analysts, engineers, politicians, economists, business owners, village elders, teachers…) operating and making decisions all the time at multiple scales;
- Need to start with a dialogue (interrogate assumptions!);
- Focus efforts on understanding the decision-making process and on the impacts (find out what matters);
- Look for ways to facilitate cooperation between similarly-challenged communities/states; seek commonalities;
- Use 'intermediaries' as trusted communicators in the distilment process.

Other

- Attribution of impacts to anthropogenic climate change can be extremely powerful when possible, some tools are available;
- High impact events are opportunities to evaluate adaptation options;
- Climate model output would be easier to explain/communicate if (for example) urban heat islands were represented;
- Useful to define the adaptation space (location/system/decision dependent) within which decisions are made and evaluated;
- Will small incremental adaptation suffice (and for how long), or will greater changes result in completely different conditions (tipping points) requiring transformational change;
- Framing climate change information in the context of development and sustainability can be useful;
- How much can IPCC actually help with these scale-dependent user-specific part-of-bigger-picture user requirements and needs?
- IPCC can identify where research is needed, and identify what has changed since the last assessment;
- Provide more guidance on SSPs and use of scenarios;
- Key messages are great; think about additional outputs (pictograms!);
- Final point: Stop messing around with the emission scenarios / RCPs and the comparison periods, please!

Sessions 2 and 3: Focus and Synthesis

The goal of sessions 2 and 3 of the breakout group was to take the brainstorm from the previous day and focus and synthesize the ideas around key issues, requirements and recommendations. This took all of the time allocated (plus more), but was again a very valuable exercise that involved most of the participants. The end result was a synthesis of the discussion into four key issues, presented below.

It should be noted that a significant proportion of the group discussion over all the sessions related to the first issue. This was, in fact, originally separated into two issues but later logically collapsed into one. This emphasis does not discount the importance of the other three issues, but it does suggest that in terms of the relative importance, the first issue is a priority.

Issue 1: Complex climate information needs to be distilled, packaged and shared in a way that is meaningful and useful for multiple users, each with specific needs

Requirements

- Understand the user needs, start with a dialogue;
- Focus efforts on understanding the decision-making process and on the impacts of climate change (find out what matters);
- Upskill climate communicators and produce outputs that are relevant to users' needs;
- More social science studies needed on how climate information is perceived and processed by the users;
- Frame climate change as part of the sustainable development agenda;
- Work with users to define their adaptation space (location/system/decision dependent) within which decisions are made and evaluated;
- Look for ways to facilitate cooperation between similarly-challenged communities/states; seek commonalities;
- Find mechanisms for WGI to understand what WGII is saying and vice versa.

Recommendations

IPCC could:

- work more closely with the GFCS and related climate services partnerships;
- produce a special report on methods of distilling and communicating climate change information to user groups beyond policy-makers who operate at regional, national and sub-national levels;
- provide training on communicating major results from assessments (particularly to people who are communicating climate advice to their people and governments);
- closely work with Future Earth and other relevant organizations and initiatives to co-design, co-produce and co-deliver information;
- encourage its authors to assess a broader literature (e.g., behavioural studies, psychology);

IPCC and/or other researchers and stakeholders could:

- leverage the resources of TGICA, WCRP and similar organizations to develop tailored products;
- promote and facilitate the use of quantitative or qualitative scenarios, storylines and narratives to explore possibilities, examine system sensitivities and consider trade-offs;
- use case studies to demonstrate different user needs and information-generating tools;
- look for common needs (and distinctiveness) and consider what might be influencing these;
- use 'intermediaries' as trusted communicators to end users.

Issue 2: There is a need for IPCC scientists from Working Groups I, II and III to be better informed about how risk-based climate-sensitive decisions are made

Requirements

- Learn from the decisionmaker about the information and process that is used;
- Assess what additional climate information could be used;
- Identify the optimal format that the additional information needs to be in;
- Consider whether models could be improved to produce more decision-relevant information.

Recommendations

IPCC could:

- consider a joint WGI, II and III (plus invited end user) workshop and publication that focuses on a specific (real world) problem and decision process, and addresses the following topics:
    - how is the problem framed?
    - who is involved in the process and what are their roles?
    - at what stage is climate information needed?
    - what level of climate information sophistication is being used?
    - has the information been tailored?
    - are there barriers to using climate information, and if so, why?
    - what strategies for problem solving and management of risk are being used?
    - what time frames are being considered?
    - are scenarios or narratives being used?
    - are ethics being considered?

Issue 3: Heat island and air quality issues in cities are not well studied using regional climate models, resulting in sub-optimal information being used by urban decisionmakers

Requirements

- Determine what are the relevant processes for inclusion in the models;
- Frame the problem in terms of vulnerability to determine where certain processes need to be included in models;
- Understand the impacts of certain processes in the models (e.g., urban areas, air quality) to prioritise their implementation for specific regions

Recommendations

CORDEX modellers could:

- design a set of pilot studies to model the effects of processes such as urban heat islands and/or air quality in developing country megacities

IPCC could:

- expand its interaction with WCRP regarding future ESM plans

Issue 4: Critical research is not being prioritised and performed, compounded by inefficient communication of identified research gaps

Requirements

- There need to be improved mechanisms for identifying research gaps;
- Data observations and modelling efforts need to be focused on areas with greatest information needs.

Recommendations

IPCC could:

- look through previous IPCC assessments and collate all the identified research gaps (by the chapters) as well as the findings where insufficient evidence led to low confidence and communicate this information to relevant organisations for research prioritization;
- be consistent across all future chapters in terms of identifying research gaps;
- explore mechanisms that allow people to investigate alternative futures (e.g., 1.5°C).

CORDEX modellers could:

- ideally include RCP's 6.0 and 2.6 in some of their experiments (after consulting with CMIP6 to get access to the necessary global data)

High Level Recommendations

Of all the recommendations listed above, for each of the four key issues discussed in the breakout group, the following three recommendations are highest priority and actionable. They are:

1. **IPCC** could work more closely with the WCRP (for fostering research on distilling across multi-model multi-method ensemble data) and GFCS and related climate services partnerships (for issues of communication and user needs), and produce a special report on methods of distilling and communicating climate change information to user groups beyond policy-makers who operate at regional, national and sub-national levels.
2. **IPCC** could consider a joint WGI, II and III (plus invited end user) workshop and publication that focuses on a specific (real world) problem and decision process.
3. **CORDEX** modellers could design a set of pilot studies to model the effects of processes such as urban heat islands and/or air quality in developing country megacities.

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Breakout Group 3: Dealing with High Risk–Low Probability Events: What Climate Scientists Can Provide and What Decisionmakers Need to Deal with Climate/Weather Extremes and Natural Disasters (including bias correction)

Chair: Erich Fischer, ETH Zurich, Switzerland
Rapporteur: Sara Pryor, Cornell University, USA

Scientific Steering Committee Members: Linda Mearns, National Center for Atmospheric Research, USA; Taikan Oki, University of Tokyo, Japan

Statement of Purpose

Understanding, quantifying and predicting low probability–high impact events is a major challenge that can only be addressed through a sustained close collaboration across working groups. Below we identify key issues in the current state of research and practice and provide recommendations how those may be tackled within the IPCC framework and beyond.

Key Recommendations

- Research: Improved understanding of the causes of high impact-low probability events is key to better quantification of the intensity, frequency, duration and spatial extent of extreme events in the current climate and for development of more reliable future projections. IPCC should articulate the need for greater research emphasis on high impact-low probability events and encourage that resources be allocated to understanding their combined physical and human dimensions.
- Collaboration: Given their importance to climate dynamics and impacts on natural and human systems high-impact extreme events represent a unifying challenge for WGI and II. WGI and II participants should collaborate to develop historical records of impacts from, and physical dimensions of, extreme events. IPCC could conduct workshops for an integrated assessment and end-to-end analyses of specific high-impact extreme events that may serve as case studies and good practice guidance. Further, there is a need for an enhanced dialogue between working groups and decision makers to understand to what extent the climate information on low probability extreme events provided meets the needs of different groups of decision makers.
- Special Reports/Workshops: The IPCC Special Report on Extreme Events (IPCC, 2012) is a useful resource and a clear mechanism to integrate WGI and WGII. An update and extension of this report should be undertaken and extremes should be dealt with in a coordinated way in other special reports. Best practice guidance papers covering aspects such as bias adjustment and extreme event attribution are desirable.

Elaboration on Issues, Requirements and Recommendations

Issue 1: Understanding of the causes and magnitude of high impact low probability events remains incomplete even from a purely physical science perspective.

- Requirement: There is a need for better access to high-quality observational data and for improved reanalysis data sets. Dense networks of long in-situ measurement series, high-resolution gridded observational data sets, reanalyses and high-resolution downscaled data sets are critically important to (i) facilitate more robust estimation of return periods for a range of extreme events under past/current climate, (ii) evaluate model skill in a process-based and statistical sense and (iii) improve understanding and potential predictability of extreme events. Recommendation: IPCC should articulate the importance of sharing existing observational and reanalysis data set as well as developing and evaluating new observational and reanalysis data sets.
- Requirement: Some extreme events possible in the future have intensities and return periods beyond those that can be directly assessed with confidence from the observational record using Generalized Extreme Value theory. More research is warranted to investigate the potential nature of these events based on our physical process understanding and to assess limits on 'predictability' and associated uncertainty. Recommendation: IPCC should articulate the importance of building and evaluating these resources to stimulate investment from national funding agencies.

- Requirement: There is a need to better articulate emerging risks such as possible tipping points leading to abrupt changes. Recommendation: Abrupt changes and tipping points were a focus of a 2000 National Research Council workshop and National Academies Press report (National Research Council, 2002) and a 2003 IPCC Co-Sponsored Workshop on abrupt change/tipping points in the context of drought (IPCC, 2004). It may be time for IPCC to convene/co-sponsor a workshop on abrupt changes and tipping points in the context of climate non-stationarity.

Issue 2: There is insufficient knowledge regarding what types of extreme events we can currently represent using our suite of numerical and statistical models and to what extent multi-model experiments sample the uncertainties in regional projections.

- Requirement: As acknowledged in the WCRP Grand Challenges, there is a need for process-oriented verification and validation exercises with a focus on extreme events. Further understanding of skillful scale is needed along with the model ability to quantify the scale of effect, which will be strongly linked to the magnitude of consequence. There is a great potential for Regional Climate Models (RCMs) as well as for Earth System Models (ESMs) run at high-resolution or with adaptive grids to advance our understanding of extreme events. Recommendation: The added value of RCMs and high-resolution ESMs for the representation of extremes needs to be rigorously quantified and evaluated in view of relative computational costs and benefits. A workshop should be convened to examine the value added of statistical and dynamical RCM downscaling with a focus on extreme events. Recommendation: There is a need to re-evaluate to what extent multi-model RCM experiments such as CORDEX are exploring the full uncertainty range in regional projections of extreme events. IPCC WGI should offer guidance on selection of driving models, so that statistical and dynamical downscaling does not inadvertently under-sample ESM uncertainty ranges. Recommendation: Given the continued need of bias adjustment of model output for impact assessments there is a need for IPCC guidance (see report from BOG3bis). Recommendation: In general, many realizations of a specific model (initial condition members) are required to evaluate present-day return periods and robust estimates of changes in low-probability extreme events. There is a need for careful consideration of the relative costs and benefits of high model resolution versus increasing number of ensemble members. This should form part of a special IPCC workshop on characterizing climate extremes.
- Requirement: There is a need for consistent communication of uncertainty and for co-development of knowledge by the climate science and vulnerability, impacts and adaptation community regarding tools for managing uncertainty. Recommendation: Provide examples of where the credibility of the science has been successfully established, and of model output being used as a point of departure for co-development of scenarios for use in decision-making. These could be documented in an IPCC guidance document. Recommendation: IPCC should provide guidance on best practice on delivering actionable information on extremes, and effective information distillation.

Issue 3: Extreme event attribution remains challenging but is important.

- Requirement: Event attribution is needed; (1) to identify observed extreme events that may serve as analogues for future conditions (2) to build credibility and allowing discussion regarding likelihood in the future (key to enhancing resilience), (3) for those impacted to be able to access funds such as those from the UNFCCC for adaptation (this would naturally incorporate many considerations and would require comprehensive robust attribution) and (4) to modify perception and public commitment to respond to climate change. Recommendation: Different extreme event attribution methodologies exist and should be followed but depend on good quality observational records and/or reliable representation of key driving physical processes in climate models (see above). There is a need for inter-comparison and evaluation of different attribution methods. More fundamentally, different approaches in framing the event attribution question need to be explored such as the question on how climate change and in particular thermodynamic effects have contributed to recent extreme events. IPCC could sponsor a synthesis of different event attribution approaches and provide best practice guidance. Recommendation: There is a need for more literature on attribution of events outside N America, Australia and Europe and more careful quantification of uncertainty in attribution.

Issue 4: Regarding extreme events that manifest as systemic disasters, there is a mismatch between the information provided by climate scientists and the needs of decision makers.

- Requirement: Enhanced dialogue with stakeholders (maybe via industry/planning/policy organizations) to improve understanding of decision makers needs on climate information and enable co-design statements of research priorities. Knowing and understanding what climate information decision makers currently use for hazard mitigation may help increase the willingness of climate scientists to share projections even if they are uncertain. Recommendation: Key leaders from the decision making types (asset managers, reinsurance, planners, policy makers) can provide critical information on scales of governance and how those correspond to scales of phenomena and information needs. They should be invited to AR6 scoping meetings.
- Requirement: There is a need to make reliable estimates of design events in the current climate (in collaboration with decision makers) and how these may change through time. The needs of different groups of decision makers should be assessed and information should be collected from national assessment exercises. Recommendation: A workshop should be organized bringing together decision makers and climate scientists from WGI and WGII to discuss the needs and the ability to supply relevant climate information on reasonable time scales.

Issue 5: Bridging the gap between climate science and decision makers will be enhanced by climate scientists organizing their knowledge around the information requirements of specific decision contexts.

- Requirement: Climate scientists have extensive knowledge relevant to climate-related decisions, but current communication channels are not effective enough to provide all policy-relevant information. Recommendation: IPCC could conduct a workshop to explore several case studies in which WGII provides to WGI the results of climate stress tests in several impact sectors and/or geographic regions. WGI and II members would organize all available information relevant to those stress tests and policy responses, the key drivers of potential policy-relevant changes, and model-based estimates of event probability ranges. Such a workshop might also include some of the themes of Issue 4. Recommendation: Increased use of electronic reports should be used to facilitate cross-cutting themes (value demonstrated by electronic dynamic version of US NCA). Also, storylines associated with extreme events could be articulated in the synthesis report thus linking WGI and II. Co-approval and production of call-out boxes for one WG report by authors from the other could also enable this linkage

Issue 6: For many decision makers near-term information on extreme events is key.

- Requirement: Our goal should be seamless climate prediction from initialized weekly, seasonal and decadal predictions, to projections on centennial time scales. Reliable observation-based and model-based present-day and near-term return period estimates should receive more attention. It is important to note that for many type of extreme events, internal variability will dominate the near-term uncertainty. This requirement is in line with the aspirational goal of many climate centers to have a seamless model chain for climate products. Recommendation: Chapter 11 of the WGI AR5 (Kirtman et al., 2013) was an important first step in this direction. IPCC should endeavor to better link information on extreme events across short-term and long-term model projection chapters as well as model evaluation, observational and attribution chapters (e.g., similar metrics and integrated discussion). Recommendation: Even greater interaction between WGI and II (i.e., allowing information on regional risk portfolios to fully inform discussion in WGI). We acknowledge that this has long been part of IPCC but reemphasize its importance here. More shared authors across WGs in specific research areas seems desirable. There may be utility in allowing WGII to consider risks from extreme events even in the absence of robust climate change signals.

Issue 7: Climate atlases are helpful but may require further refinement to maximize utility.

- Requirement: There is a need to test the effectiveness of climate atlases and to collate user experiences. If climate atlases are to include information on extremes issues pertaining to uncertainty must be addressed. Recommendation: Climate atlases need to be enhanced to increase usability and enhance utility and knowledge. Accessible user guidance needs to be given for non-climate science users. Recommendation: Climate atlases have to be carefully constructed. Evaluation of their ability to effectively communicate information would be valuable. There are important issues linked to use of pixel-by-pixel bias correction and/or estimation of percentiles that may yield products that are not physically realistic or consistent. This type of issue is even more prevalent for low probability events.

References

IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* A Special Report of Working Group II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.

IPCC, 2004: *Workshop Report of the CLIVAR/PAGES/IPCC Workshop on A Multi-millennia Perspective on Drought and Implications for the Future*. IPCC Working Group I Technical Support Unit, Boulder, Colorado, USA, pp. 34. Available from: http://ipcc.ch/pdf/supporting-material/ipcc-workshop-2003-11.pdf.

Kirtman, B., S.B. Power, J.A. Adedoyin, G.J. Boer, R. Bojariu, I. Camilloni, F.J. Doblas-Reyes, A.M. Fiore, M. Kimoto, G.A. Meehl, M. Prather, A. Sarr, C. Schär, R. Sutton, G.J. van Oldenborgh, G. Vecchi and H.J. Wang, 2013: Near-term Climate Change: Projections and Predictability. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 953–1028.

National Research Council, 2002: *Abrupt Climate Change: Inevitable Surprises*. National Academy Press, Washington D.C., USA, 244 pp. Available from: http://nap.edu/catalog.php?record_id=10136.

Breakout Group 3bis: Bias Correction

Facilitator: Claudio Piani, American University of Paris, France

Background

Climate models may be affected by considerable errors when compared to observations. Consequently their output often cannot be used directly as input for impact models. In some cases, the systematic error (i.e., the bias) can be potentially reduced by statistical post-processing techniques, which are hereafter referred to as *bias correction* (BC). Bias correction (alternatively: *bias adjustment* or *bias reduction*) is a computationally inexpensive and pragmatic tool which, however, is also prone to misuse due to its mathematical simplicity. The authors of this report therefore recommend that:

1. AR6 includes a section to (i) provide clear definitions of 'bias' and 'bias correction', (ii) establish a consistent terminology and (iii) guide the users on the availability, use, interpretation and limitations of bias correction methods in the broader context of other available post-processing methods.
2. users of BC follow a - still to be established - code of best practice.
3. the IPCC, in particular the lead authors of AR6, assess whether studies to be cited in the AR6 are scrutinized with respect to the application of BC.
4. WGII encourages research that analyzes the propagation of uncertainty arising from both GCM and RCM biases as well as BC along the modeling chain.

In the following we will present the basic assumptions of BC, list some of the most common errors which we have encountered in instances of BC applications, discuss some unavoidable issues when faced with interpreting results from bias-corrected data and, finally, make some general recommendations to the AR6 community. Overall, if good practices are followed (including communicating the intrinsic limitations), BC may, in principle, be a feasible approach for post-processing climate model data for impact models.

Applicability of Bias Correction

Climate models are substantial simplifications of real world climate. Although they are based on physical principles, they contain numerical approximations, in particular semi-empirical parameterizations of sub-grid processes. These simplifications may result in considerable errors that often prevent direct input of climate model output into impact models. This holds in particular for nonlinear impact processes that respond sensitively to small errors. In those cases where a considerable portion of the error is time-independent, BC may be a useful and defensible post-processing tool to transform model output in such a way that it is more suitable as input for impact models.

Common Errors in Application (non-exhaustive list)

- Lack of cross-validation. Often bias correction is applied without cross validation, i.e., the evaluation is carried out on the same data used for calibration. This is bad practice. A perfect fit between observations and the bias corrected model's output statistics can be obtained by construction. This is a trivial result and offers no measure of performance of the BC method in question and is not capable of identifying any potential problems in the application of BC on the future projections.
- Overfitting**.** Often, statistical models with an overly large number of parameters are used to map distributions that may differ considerably, or even belong to different distribution classes. If the number of parameters used in the bias correction method (i.e., the number of quantiles) is too high compared to the number of observations (e.g., days) used to calibrate the method, such an approach is prone to over-fitting. Independent of the method used for bias correction, a considerable deviation of modelled and observed distributions could indicate that underlying model and real world processes are fundamentally different. In those cases, a bias correction cannot be justified.
- Downscaling variability. Random temporal variability at a given grid-box scale (e.g., climate model output) is generally lower than that at smaller scales, in particular at the point scale (e.g., compared to observations at a single climate station), which is especially true for precipitation. Many BC methods are deterministic in nature, implying that they do not add realistic random variability at small scales. Instead, they can only inflate grid-box variability, which has been shown to potentially lead to an overestimation of extreme events. As a result, variance adjusting methods should not be used to downscale precipitation and comparable processes to small scales.

Unavoidable issues (non-exhaustive list)

- BC adjusts specific aspects of surface variables to follow observations more closely. By construction, this procedure introduces inconsistencies between the corrected surface variables and free atmospheric variables of the input climate model. A sensible bias correction should always draw a well-informed decision on which aspects to adjust, and which inconsistencies to face in consequence.
- BC is a purely heuristic approach that cannot add any skill to the model. For some definitions of skill and BC methods, this can be shown mathematically. This is trivially true when, for instance, the model skill is measured simply by correlation with observations and the BC is reduced to an additive constant.
- BC methods potentially affect the climate signal, but it is unclear how much the signal may be degraded, and which methods are invariably the best for minimizing this degradation. A class of BC methodologies has been developed that preserves the mean climate signal in the model. However, it is not clear how this would affect the signal of e.g. percentiles or extremes. In general, it is not clear whether the underlying assumptions of changing or preserving the mean signal are justified. Users should be aware that the resulting climate signal depends on the choice of BC method applied.
- In general, BC cannot correct model biases in temporal structure. Errors such as a mistiming in the onset of the Monsoon season or the inability to simulate very long blocking events will be inherited from the climate model. Ignoring these issues may result in implausible BC results.
- BC cannot correct location biases in the large-scale atmospheric circulation, such as a wrong position of the storm track or the intertropical convergence zone. BC in such a context—by construction—might result in apparently reasonable surface fields, but automatically deteriorates the physical link between atmospheric processes and surface variables. Ignoring these issues might result in unphysical climate projections.
- In complex terrain, a simulated variable might not be a skillful predictor of an observed variable, e.g., because the mismatch between real-world and model orography might cause local circulation errors. In such a case standard bias correction might cause unphysical results.
- Cross-validation should always be carried out and, whenever possible, as a k-fold cross-validation by using more than one validation period. However, a direct evaluation of skill such as in forecast verification is impossible when bias correcting unforced climate model simulations. As a result, the interpretability of cross-validation in conjunction with widely used diagnostics, even though necessary, may not reveal problems or misapplications and provides, at best, a lower limit of the associated uncertainty. But it should be noted that a cross-validation requires the availability of an observed (reference) data set of suitable length.
- If BC is used to downscale gridded model results by a higher-resolution observational grid, the observed higher-resolution signal is simply imposed without any predictive ability or physical (dynamical-thermodynamical) consistency among different climate variables.
- There is a trade-off between robustness and number of parameters in a BC method: the projections obtained from the BC data would be more credible when using simple methods (i.e., based on a parsimonious number of parameters). Results obtained using non-parametric BC methods such as quantile mapping often appear successful because of overfitting. However, when observed and simulated distributions are fundamentally different, such BC methods may create overconfidence in the final results.
- 2D or higher-D corrections may do better at maintaining inter-variable links, but hinge on sufficient data availability to populate higher-dimensional histograms.

Recommendations to the AR6 Community

- Invite the development of methodologies to assess (and possibly correct for) the degradation of the physical links among multiple variables caused by BC.
- Bias-corrected results should always be provided together with the original raw model data, along with a clear description of the BC methodology applied and an associated uncertainty assessment.
- We strongly discourage the application of BC without prior understanding of the underlying causes of model error and bias. In particular, it is important that users of bias-corrected data understand the source model's representation of physical processes (given that BC cannot compensate for incorrect representation of physical processes in the model). We recommend that BC is ideally carried out in collaboration with experts aware of the limitations of that particular model for the considered region (e.g., the developers of that model).

- Bias correction is a simple subset of the broad class of empirical statistical downscaling methods and relies on observations of surface variables as input. If bias correction is not justified because the input variable (such as precipitation) is implausibly simulated, one should consider using other statistical downscaling methods (e.g., so-called 'perfect prognosis empirical statistical downscaling') that use large-scale variables from the free atmosphere as input, that are likely better simulated.

INTERGOVERNMENTAL PANEL ON climate change

FORTY-FIRST SESSION OF THE IPCC
Nairobi, Kenya, 24-27 February 2015

IPCC-XLI/Doc. 13
(11.II.2015)
Agenda Item: 5.5
ENGLISH ONLY

FUTURE WORK OF THE IPCC

Proposal for an IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies

(Submitted by the Co-Chairs of Working Group I on behalf of the Working Group I Bureau)

IPCC Secretariat

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WMO UNEP

Proposal for an IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies

Submitted by the Co-Chairs of Working Group I on behalf of the Working Group I Bureau

Background

Regional climate change projections provide the quantitative basis for studies of projected impacts from climate change and associated risks, which are essential building blocks for the comprehensive assessment of climate change science by the IPCC. There exist a number of climate modelling initiatives aimed at producing regional climate change projections, but they overall have not yet reached the maturity necessary for their wide spread use by the impacts assessment community and relevant stakeholders. Therefore there is a real opportunity to strengthen the link between regional projections and the assessment of projected impacts and risks by the IPCC. This will enhance the information the IPCC can provide to its users and stakeholders.

Working Group I (WGI) in its contribution to the IPCC Fifth Assessment Report (AR5) did provide a comprehensive assessment of climate change projections from global to regional scales. This assessment, however, relied largely on information derived from large-scale, multi-model initiatives using global climate models. The WGI Atlas of Global and Regional Climate Projections, for example, a new feature of the AR5 that provides maps and regionally averaged time series of annual and seasonal multi-model means, with uncertainties, of changes in surface temperature and precipitation over the 21st century for 37 regions covering the entire world, is based entirely on global climate models. Although model data underlying the WGI Atlas is electronically available from the IPCC websites as part of the WGI Supplementary Material of AR5, it is not yet widely used in studies of regional impacts and risks of climate change to human and natural systems around the world. Regional impacts and risks studies would substantially benefit from the inclusion of information coming from regional climate models or from statistical downscaling methods used to drive impacts models (e.g., crop models, hydrology models, etc.).

Since the finalization of the WGI AR5 in September 2013, important activities in the physical science community have evolved which will be crucial for an enhanced interaction between IPCC WGI and WGII in the area of assessing projections of climate change impacts at a regional scale. These concern, for example, the definitional phase of Phase 6 of the Coupled Model Intercomparison Project (CMIP6) which will include the next generation of comprehensive climate models. It is expected that there will be a further increase in model resolution which will provide even more regional details to users and stakeholders from global models. A second area of rapid progress is the Coordinated Regional Climate and Downscaling Experiment (CORDEX) of the World Climate Research Programme (WCRP). The initial focus was on Africa, but currently 14 regional domains around the world are being considered in CORDEX and the data base of this coordinated regional modelling initiative is rapidly growing.

It is therefore timely for the IPCC to convene a Workshop to explore ways how to enhance the convergence of information on projections of climate change and resulting risks and impacts, and to improve the consistent use and application of information in the next IPCC assessment cycle. The Workshop should bring together scientists from both the WGI and WGII communities, i.e., from the climate modelling community (e.g., CMIP5 and CMIP6), the regional modelling and downscaling community (e.g., CORDEX) and the climate impacts and risk community. It is important to hold such a Workshop early, and even before the decision on the scope and outline of the next IPCC assessment cycle, in order to help establish closer links between these communities and to facilitate the IPCC assessment process in the future. This would also be beneficial to the IPCC scoping process and subsequent author nomination and selection, in particular with regard to the regional representation in the WGI and WGII scopes and cross-WG topics, if the Panel decides to carry out a 6th assessment cycle.

Aims of Workshop

- Critically reflect on the assessment of regional climate change projections and of regional projections of climate change impacts and risks, and their limitations, in the IPCC AR5;
- Collect views and perspectives on how IPCC assessment of regional projections could be better supported/improved from leading world experts on issues related to regional information from climate model

projections and dynamical downscaling as well as from the broader community of impacts studies and climate risk analyses which use physical climate information;
- Discuss the latest, post IPCC AR5 results from regional climate modelling and downscaling efforts and obtain an overview of the status of information currently available or foreseen on a time scale relevant for the next assessment cycle for all regions of the world;
- Explore ways how the IPCC could facilitate the collaboration and exchange between the climate modelling and impact and risk communities in issues related to projections of climate change, risks and impacts, including ensuring an effective flow and quality control of information and data;
- Identify numerical data requirements (climate variables, derived quantities, proxies, and statistics) by the impacts and risk communities from the climate modelling community that could help facilitate the assessment process in the next IPCC assessment cycle and that would help provide the basis for a comprehensive IPCC assessment.
- Draft an Information Paper covering, inter alia, (i) how the collaboration of the climate modelling and impacts and risk analysis communities could be facilitated by the IPCC, (ii) data quality requirements and perhaps a data protocol to feed emerging data bases, and (iii) potential problems IPCC users and others need to be aware of. If available, a report would also present a few specific case studies in which regional climate model or high-resolution global climate model results are used and successfully applied for impacts studies.

Organizing Group (about 10 members)

Dahe Qin (WGI Co-Chair, China)
Thomas Stocker (WGI Co-Chair, Switzerland)
Fredolin Tangang (WGI Vice Chair, CORDEX South East Asia, Malaysia)
Bruce Hewitson (WGII Coordinating Lead Author, TGICA Co-Chair, South Africa)
Filippo Giorgi (WGII Lead Author, CORDEX Chair, Italy)
Geert Jan van Oldenborgh (WGI Lead Author, The Netherlands)
Caroline Vera (SREX Lead Author, Argentina)
Gian-Kasper Plattner (WGI TSU Head, Switzerland)

A Scientific Steering Committee with broad regional representation will be formed.

Timing: time window mid-August to mid-September

Duration: 4 days

Location: TBD

Participants

About 100 expert participants in total. In order to ensure broad international representation, it is proposed that there should be a call for governments to nominate scientific experts to attend the workshop. We envisage an allocation of 40 journeys from the IPCC Trust Fund to support experts from developing countries and countries with economies in transition. This allocation is being requested from the Panel at IPCC-XLI.

Expertise

Global climate modelling (CMIP5, CMIP6), regional climate modelling (e.g., CORDEX), downscaling, extreme events, climate statistics, impact studies, climate risk analysis.

Annex 2: Programme

IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies

Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil
15–18 September 2015

PROGRAMME

Tuesday, 15 September 2015

08:30	**Registration/Poster Set-up**
OPENING CEREMONY (Auditório Fernando de Mendonça)	
09:00	**Welcome and Opening [Chair: Thelma Krug]** **Welcome Remarks:** ◆ ***Mr Ricardo Novaes, Director, Department of the Environment, São José dos Campos*** ◆ ***Dr Leonel Fernando Perondi, Director, National Institute of Space Research*** ◆ ***Mr Everton Lucero, Director, Division of Climate, Ozone and Chemical Safety, Department of Environment and Special Themes, Ministry of Foreign Relations and IPCC Focal Point for Brazil*** ◆ ***Dr Márcio Rojas da Cruz, General Coordination for Global Climate Change, Ministry of Science, Technology and Innovation*** ◆ ***Prof Qin Dahe, Co-Chair, IPCC Working Group I*** ◆ ***Prof Vicente Barros, Co-Chair, IPCC Working Group II*** ◆ ***Prof Thomas Stocker, Co-Chair, IPCC Working Group I***
10:00	**Break** (Planta Atrium)
10:00	**Media Briefing** (Auditório Roger Honiat)
INTRODUCTORY PLENARY (Auditório Fernando de Mendonça) **[Chair: Qin Dahe]**	
10:30	***Introduction to the IPCC AR5: from WGI and WGII to the Synthesis Report*** **(Thomas Stocker)** [15 min presentation + 5 min discussion]
10:50	***Bridging the Gap Between Science and Practice for Information from Regional Climate Projections*** **(Bruce Hewitson)** [15 min presentation + 5 min discussion]
11:10	***A Decisionmaker Perspective on Climate Information from Regional Climate Projections*** **(Judy Omumbo)** [15 min presentation + 5 min discussion]
THEME PLENARY SESSION I: LESSONS FROM THE AR5 (Auditório Fernando de Mendonça) **[Chair: Vicente Barros]**	
11:30	***WGI Regional Climate Projections: Chapter 14 and Atlas*** **(Krishna Kumar Kanikicharla and Geert Jan van Oldenborgh)** [15 min presentation + 5 min discussion]
11:50	***Impact Modelling: General Needs and WGII Experience*** **(Linda Mearns)** [15 min presentation + 5 min discussion]
12:10	***Risk Modelling: General Needs and WGII Experience*** **(Roger Jones)** [15 min presentation + 5 min discussion]

12:30 Lunch (INPE Restaurant)

THEME PLENARY SESSION II: COORDINATED MODELLING PROJECTS (Auditório Fernando de Mendonça)
[Chair: Fredolin Tangang]

14:00 ***CMIP and Applications*** **(Veronika Eyring)** [20 min presentation + 10 min discussion]

14:30 ***CORDEX and Applications*** **(Filippo Giorgi)** [20 min presentation + 10 min discussion]

15:00 ***Coordinated Impacts and Risk Modelling Projects*** **(Sonali McDermid)** [20 min presentation + 10 min discussion]

15:30 General Discussion

16:00 Break (Planta Atrium)

POSTER SESSION I (Auditório Fernando de Mendonça) **[Chair: Gian-Kasper Plattner]**

16:30 Poster Presentations [2 min presentation with one ppt slide]

17:00 Poster Viewing (Planta Atrium)

18:00 Adjourn

18:00 Welcome Reception at INPE ***(Sponsored by Working Group I/Government of Switzerland)***

Wednesday, 16 September 2015

THEME PLENARY SESSION III: FROM SCIENCE TO PRACTICE (Auditório Fernando de Mendonça)
[Chair: Thomas Stocker]

08:30 ***Feedback from the IPCC TGICA Expert Meeting on Decision-Centered Approaches to the Use of Climate Information*** **(Bruce Hewitson)** [5 min presentation]

08:35 ***Perspective Presentation I*** **(Heike Huebener)** [5 min presentation]

08:40 ***Perspective Presentation II*** **(Satoshi Watanabe)** [5 min presentation]

08:45 ***Perspective Presentation III*** **(Benjamin Lamptey)** [5 min presentation]

08:50 ***Perspective Presentation IV*** **(John Charlery)** [5 min presentation]

08:55 **Discussion**

09:25 ***Perspective Presentation V*** **(Kathleen McInnes)** [5 min presentation]

09:30 ***Perspective Presentation VI*** **(Suwanna Rongwiriyaphanich)** [5 min presentation]

09:35 ***Perspective Presentation VII*** **(Petra Tschakert)** [5 min presentation]

09:40 ***Perspective Presentation VIII*** **(Ines Camilloni)** [5 min presentation]

09:45 **Discussion**

10:15 **Break** (Planta Atrium)

POSTER SESSION II (Auditório Fernando de Mendonça) **[Chair: Gian-Kasper Plattner]**

10:45 **Poster Presentations** [2 min presentation with one ppt slide]

11:15 **Poster Viewing** (Planta Atrium)

12:15 **Lunch** (INPE Restaurant)

THEME PLENARY SESSION IV: PREPARING THE SCIENCE FOR AR6 (Auditório Fernando de Mendonça)
[Chair: Jean Jouzel]

13:45 ***Decisionmaking under Uncertainty*** **(Robert Lempert)** [20 min presentation + 10 min discussion]

14:15 **Introduction to Breakout Groups and Workshop Deliverables (Thomas Stocker and Qin Dahe)**

14:30 ***Issues*** **(Kathleen McInnes, Linda Mearns and Judy Omumbo)** [10 min presentation + 5 min discussion]

14:45 ***Requirements*** **(Taikan Oki, Jose Marengo and Fredolin Tangang)** [10 min presentation + 5 min discussion]

15:00 ***Recommendations*** **(Carolina Vera, Filippo Giorgi and Bruce Hewitson)** [10 min presentation + 5 min discussion]

15:15 **General Discussion**

15:30 **Break** (Planta Atrium)

BREAKOUT GROUP SESSION I

16:00 Breakout Groups:

BOG1: ***Linking Coordinated Climate Model Projection Efforts with Impacts and Risk Modelling Efforts*** (Auditório Roger Honiat) **[Chair: Jana Sillmann; Rapporteur: Tereza Cavazos]**

BOG2: ***National/Regional Assessments: How to Optimize Climate Information for Use by Decisionmakers at Regional Scales*** (Meeting Room I) **[Chair: Andrew Tait; Rapporteur: Kiyoshi Takahashi]**

BOG3: ***Dealing with High Risk–Low Probability Events: What Climate Scientists Can Provide and What Decisionmakers Need to Deal with Climate/Weather Extremes and Natural Disasters (including bias corrections)*** (Meeting Room II) **[Chair: Erich Fischer; Rapporteur: Sara Pryor]**

18:00 Adjourn

18:30 WGI Bureau and Scientific Steering Committee Meeting (Golden Tulip Colinas Hotel Esplanada Meeting Room)

Thursday, 17 September 2015

STOCKTAKING PLENARY (Auditório Fernando de Mendonça) **[Chair: Thomas Stocker]**

08:30 Reports from Break-Out Groups (BOG Chairs)

08:45 General Discussion

THEME PLENARY SESSION V: FROM GLOBAL TO NATIONAL – REGIONAL ASSESSMENTS
(Auditório Fernando de Mendonça) **[Chair: David Wratt]**

09:00 ***Perspective Presentation I* (Jose Marengo)** [5 min presentation]

09:05 ***Perspective Presentation II* (Penny Whetton)** [5 min presentation]

09:10 ***Perspective Presentation III* (Panmao Zhai)** [5 min presentation]

09:15 ***Perspective Presentation IV* (Carolina Vera)** [5 min presentation]

09:20 Discussion

09:45 ***Perspective Presentation V* (Joanna Wibig)** [5 min presentation]

09:50 ***Perspective Presentation VI* (Gemma Teresa Narisma)** [5 min presentation]

09:55 ***Perspective Presentation VII* (Joseph Kanyanga)** [5 min presentation]

10:00 ***Perspective Presentation VIII* (Philip Mote)** [5 min presentation]

10:05 Discussion

10:30 Break (Planta Atrium)

BREAKOUT GROUP SESSION II

11:00 Breakout Groups:

BOG1: ***Linking Coordinated Climate Model Projection Efforts with Impacts and Risk Modelling Efforts*** (Auditório Roger Honiat) **[Chair: Jana Sillmann; Rapporteur: Tereza Cavazos]**

BOG2: ***National/Regional Assessments: How to Optimize Climate Information for Use by Decisionmakers at Regional Scales*** (Meeting Room I) **[Chair: Andrew Tait; Rapporteur: Kiyoshi Takahashi]**

BOG3: ***Dealing with High Risk–Low Probability Events: What Climate Scientists Can Provide and What Decisionmakers Need to Deal with Climate/Weather Extremes and Natural Disasters (including bias corrections)*** (Meeting Room II) **[Chair: Erich Fischer; Rapporteur: Sara Pryor]**

13:00 Lunch (INPE Restaurant)

POSTER SESSION III (Auditório Fernando de Mendonça) **[Chair: Gian-Kasper Plattner]**

14:30 Poster Presentations [2 min presentation with one ppt slide]

15:00 Poster Viewing (Planta Atrium)

16:00 Break (Planta Atrium)

BREAKOUT GROUP SESSION III

16:30 Breakout Groups:

BOG1: ***Linking Coordinated Climate Model Projection Efforts with Impacts and Risk Modelling Efforts*** (Auditório Roger Honiat) **[Chair: Jana Sillmann; Rapporteur: Tereza Cavazos]**

BOG2: ***National/Regional Assessments: How to Optimize Climate Information for Use by Decisionmakers at Regional Scales*** (Meeting Room I) **[Chair: Andrew Tait; Rapporteur: Kiyoshi Takahashi]**

BOG3: ***Dealing with High Risk–Low Probability Events: What Climate Scientists Can Provide and What Decisionmakers Need to Deal with Climate/Weather Extremes and Natural Disasters (including bias corrections)*** (Meeting Room II) **[Chair: Erich Fischer; Rapporteur: Sara Pryor]**

18:00 Adjourn

Friday, 18 September 2015

SYNTHESIS PLENARY (Auditório Fernando de Mendonça) **[Chair: Thomas Stocker]**	
08:30	*Synthesis Presentation*: **BOG1:** ***Linking Coordinated Climate Model Projection Efforts with Impacts and Risk Modelling Efforts*** **[Chair: Jana Sillmann; Rapporteur: Tereza Cavazos; SSC Members: Filippo Giorgi, Judy Omumbo, Fredolin Tangang]** [10 min presentation + 5 min discussion]
08:45	*Synthesis Presentation*: **BOG2:** ***National/Regional Assessments: How to Optimize Climate Information for Use by Decisionmakers at Regional Scales*** **[Chair: Andrew Tait; Rapporteur: Kiyoshi Takahashi; SSC Members: Bruce Hewitson, Jose Marengo, Carolina Vera]** [10 min presentation + 5 min discussion]
09:00	*Synthesis Presentation*: **BOG3:** ***Dealing with High Risk–Low Probability Events: What Climate Scientists Can Provide and What Decisionmakers Need to Deal with Climate/Weather Extremes and Natural Disasters (including bias corrections)*** **[Chair: Erich Fischer; Rapporteur: Sara Pryor; SSC Members: Kathleen McInnes, Linda Mearns, Taikan Oki]** [10 min presentation + 5 min discussion]
09:15	**General Discussion**
10:00	**Break** (Planta Atrium)
SYNTHESIS PLENARY CONTINUED	
10:30	**General Discussion on Recommendations**
11:45	**Closing Remarks (Qin Dahe and Thomas Stocker)**
12:00	**End of Workshop**

Annex 3: Participant List

IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies

Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil
15–18 September 2015

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Annex 4: Presentation Abstracts

IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies

Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil
15–18 September 2015

PRESENTATION ABSTRACTS

Table of Contents

†*Keynote Presentation*
**Perspective Presentation*

Regional Climate Projections, Precipitation Changes and Flooding: the Connection Between Science and Practice

Inés Camilloni

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Climate change projections indicate alterations in precipitation regimes in terms of intensity and frequency and an increase in temperature which may lead to runoff shortages or excesses and consequent water availability changes in the future in many regions. The impacts of climate change on water resources also include modifications in the frequency and intensity of floods and droughts. Quantitative estimation of the hydrological effects of climate change particularly at basin level is essential for water managers and decision makers to formulate adaptation strategies to cope with the negative impacts on hydrology. In some cases, developing projections of extremes may be necessary to investigate whether infrastructure will still provide an adequate level of protection in future or for the design of new infrastructure. Consequently, design floods and design rainfalls shows should explicitly address climate change with adjustment factors to be applied to current design estimates and may depend on design return period and projection horizon.

The increased reliability in climate outputs derived both from Global Climate Models (GCMs) promote many studies to quantify the impacts of climate change on the hydrology (e.g., Saurral, 2010; Montroull et al., 2013; Saurral et al., 2013; Mourato et al., 2015) and hydrological extremes (e.g., Taye et al., 2011; Dang Tri et al., 2012; Camilloni et al., 2013) of different catchments. However, climate change impact assessments on water resources require the consideration of the sources and relative magnitude of associated uncertainties such as climate and hydrology modeling and downscaling techniques. For example, GCMs provide credible estimates of climate change at continental and larger scales but they have significant errors at smaller scales and in the simulation of some large scale features. One important source of error is the parameterization of sub-grid scale processes. Due to these model deficiencies, GCM projections may have significant biases and cannot, in general, be directly applied for impact modelling. Statistical bias correction of the systematic errors of climate models produce long-term time series with a statistical distribution close to that of the observations making them applicable as input for hydrology models (e.g., Piani et al., 2010; Hagemann et al., 2011; Teutschbein and Seibert, 2012; Chen et al., 2013). Both downscaling and statistical correction require historical data at spatial scales appropriate for input to impact models and are key procedures when considering extremes. In particular, assessment of climate change impacts on flood frequency and duration due to projected changes in extreme precipitation requires a methodology considering a physically based approach that incorporates bias corrected meteorological information derived from climate models and a hydrologic model.

For the remaining uncertainties associated with projecting the future in the context of climate change, a variety of approaches to decision making can be considered: scenario analysis, classical decision analysis and robust decision-making. In particular, the robust decision making uses a rational approach to identify conditions under which alternatives are likely to fail. Consequently, this information can then be used by water resources planners and managers to detect and design options that are less vulnerable to failure.

References

Camilloni, I., R.Saurral and N.Montroull, 2013: Hydrological projections of fluvial floods in the Uruguay and Paraná basins under different climate change scenarios. *Int. J. of River Basin Management*, **11**, 389–399.

Chen, J., F.P. Brissette, D. Chaumont and M. Braun, 2013: Performance and uncertainty evaluation of empirical downscaling methods in quantifying the climate change impacts on hydrology over two North American river basins. *J. Hydrol.*, **479**, 200–214.

Dang Tri,V.P.; I. Popescu, A. van Griensven, D. Solomatine, N. H. Trung, and A. Green, 2012: A study of the climate change impacts on fluvial flood propagation in the Vietnamese Mekong Delta. *Hydrol. Earth Syst. Sci. Discuss*., **9**, 7227–7270.

Hagemann, S., C. Chen, J.O. Haerter, J. Heinke, D. Gerten and C. Piani, 2011: Impact of a statistical bias correction on the projected hydrological changes obtained from three GCMs and two hydrology models. *J. Hydrometeor,* **12**, 556–578.

Montroull, N., R.Saurral, I.Camilloni, R.Grimson and P.Vasquez, 2013: Assessment of climate change on the future water levels of the Iberá Wetlands, Argentina, during the 21st century. *Int. J. of River Basin Management* **11**, 401–410.

Mourato, S., M. Moreira, and J. Corte-Real, 2015: Water Resources Impact Assessment Under Climate Change Scenarios in Mediterranean Watersheds. *Water Resour. Manage*. **29**, 2377–2391.

Piani C., G.P. Weedon, M. Best, S.M. Gomes, P. Viterbo, S. Hagemann, and J.O. Haerter, 2010: Statistical bias correction of global simulated daily precipitation and temperature for the application of hydrological models, *J. Hydrol.*, **395**, 199–215.

Saurral, R.I., 2010. The hydrologic cycle of the La Plata Basin in the WCRP/CMIP3 multi-model dataset*. J. Hydrometeor*., **11**, 1083–1102.

Saurral, R., N. Montroull, and I. Camilloni, 2013: Development of statistically unbiased 21st century hydrology scenarios over La Plata basin. *Int. J. of River Basin Management*, **11**, 329–343.

Taye, M.T., V. Ntegeka, N.P. Ogiramoiand, and P. Willems, 2011: Assessment of climate change impact on hydrological extremes in two source regions of the Nile River Basin. *Hydrol. Earth Syst. Sci.,* **15**, 209–222.

Teutschbein, C., and y J. Seibert, 2012: Bias correction of regional climate model simulations for hydrological climate-change impact studies: Review and evaluation of different methods. *J. Hydrol.,* **456**, 12–29.

Climate Change Impacts on the Caribbean's Biodiversity

John Charlery

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The Caribbean Basin has been identified as one of the world's 'hot spots' for global marine biodiversity, where a significant number of its inhabitants depend heavily on coastal and marine assets for livelihood and survival support. Comprising of hundreds of islands and about 30 national territories which span almost 4 million km^{-2} of ocean, it is one of the world's greatest centers of endemic biodiversity due to the region's geography and climate, and is one of Earth's most biologically rich yet threatened areas.

The region supports critical fresh water habitats, which include rivers, streams, lakes, wetlands and underground karst networks. In addition to providing habitat for many important, unique and migratory animals and plants, these freshwater sites provide clean water, food, hydroelectricity, recreation and many other services to the local communities. These services are especially important as the small islands of the insular Caribbean are surrounded by salt water, and rely greatly on limited, land-based fresh water from functional ecosystems (CEPF, 2010).

The Caribbean basin supports a wealth of biodiversity within its terrestrial ecosystems, with a high proportion of species that are endemic, or unique, to the region. This includes about 11,000 plant species, of which 72% are endemic. 100% of 189 amphibian species and 95% of 520 reptile species are endemic. Of the more mobile birds, 26% of the 564 species are endemic and 74% of 69 mammal species (most of which are bats) are also endemic. Species endemic to the Caribbean region represent 2.6% of the world's 300,000 plant species, and 3.5% of the world's 27,298 vertebrate species.

The Caribbean is also the heart of the Atlantic marine diversity. Roughly 8–35% of species within the major marine system found globally are endemic to the Caribbean region. The shallow marine environment contains 25 coral genera, 117 sponges, 633 mollusks, more than 1,400 fishes, 76 sharks, 45 shrimps, 30 cetaceans and 23 species of seabirds. It contains approximately 10,000 km^{-2} of reef, 22,000 km^{-2} of mangrove, and as much as 33,000 km^{-2} of sea grass beds. The region also provides wintering and nursery grounds for many Northern Atlantic migratory species, including the great North Atlantic humpback whale, which reproduces in the northern Caribbean seascape (CEPF, 2010).

By the year 2100, the projected changes in climate in the Caribbean identify 3°C to 5°C increase in mean temperature, a rise in mean sea levels of 9–88 cm, an area-averaged annual mean warming of the Caribbean Sea of about 2°C by the decade of the 2050s and a further 3°C by the 2080s. The climate change projection is further characterized by fewer rain days per year but an increase in the daily precipitation intensity, which indicates a greater probability for more frequent drought and flood events. The climate projections for the 21st century do not indicate any significant change in hurricane frequency, but do suggest a possible 10–20% increase in hurricane intensity during the century (Nurse and Sem, 2001).

The implications for the Caribbean's biodiversity from these changes in climate are expected to be very significant. Impacts, which are specific to higher temperatures, could result in migration of certain species to higher altitudes and possibly higher latitudes. This can result in changes in species abundance and distribution; genetic changes in species in response to the new climatic conditions; changes in the reproduction timings and life cycles of many species; changes in the length of growing seasons for plants; increased sand temperatures can lead to changes in sex ratios (e.g., reducing male turtle production) and also, very importantly, increases in extinction rates.

The projected changes in rainfall patterns of increased droughts and higher intensity precipitation events are expected to result in drying of ecosystems leading to loss of species and changes in community composition; changes in species distribution and ecosystem composition; changes in the geographical extent of habitats and ecosystems and also flooding of nests of various species and death of young individuals.

With the changes in sea level rise will also result in changes in the structure of coral reefs and shallow water marine communities; increased inundation of coastal wetlands and lowlands; loss of estuarine, coastal species and communities; increased intrusion of salt water vegetation into freshwater ecosystems in coastal areas and loss of nesting and feeding habitats particularly for endangered turtle species and crocodiles.

The higher sea surface temperatures projected for the region could lead to coral bleaching and even coral mortality. Coral reefs provide habitats and nursery areas for numerous commercially important species and hence the elimination of the coral reefs would have dire consequences for the region. These higher sea surface temperatures are likely to change tropical near-shore communities from coral-dominance to algal-dominance and create conditions which may be suitable for some invasive species to become established in new areas.

Although the frequency of hurricanes is not projected to increase in the Caribbean region, the projected change of 10–20% increase in hurricane intensity could be equally as consequential. This increase in hurricane intensity is expected to lead to loss of vulnerable island species, changes in species competitive interactions and species and community composition, changes in the range of invasive species, increased damage to nests and nesting sites and increased destruction of sensitive habitats such as coral reefs, mangrove ecosystems and terrestrial ecosystems, especially forest ecosystems.

The Caribbean's biodiversity is already under stress from human impacts (including land use change), pollution, invasive species, and over-harvesting of commercially valuable species. Climate change is an additional stress with expected profound impacts on the region's natural ecosystems and their species.

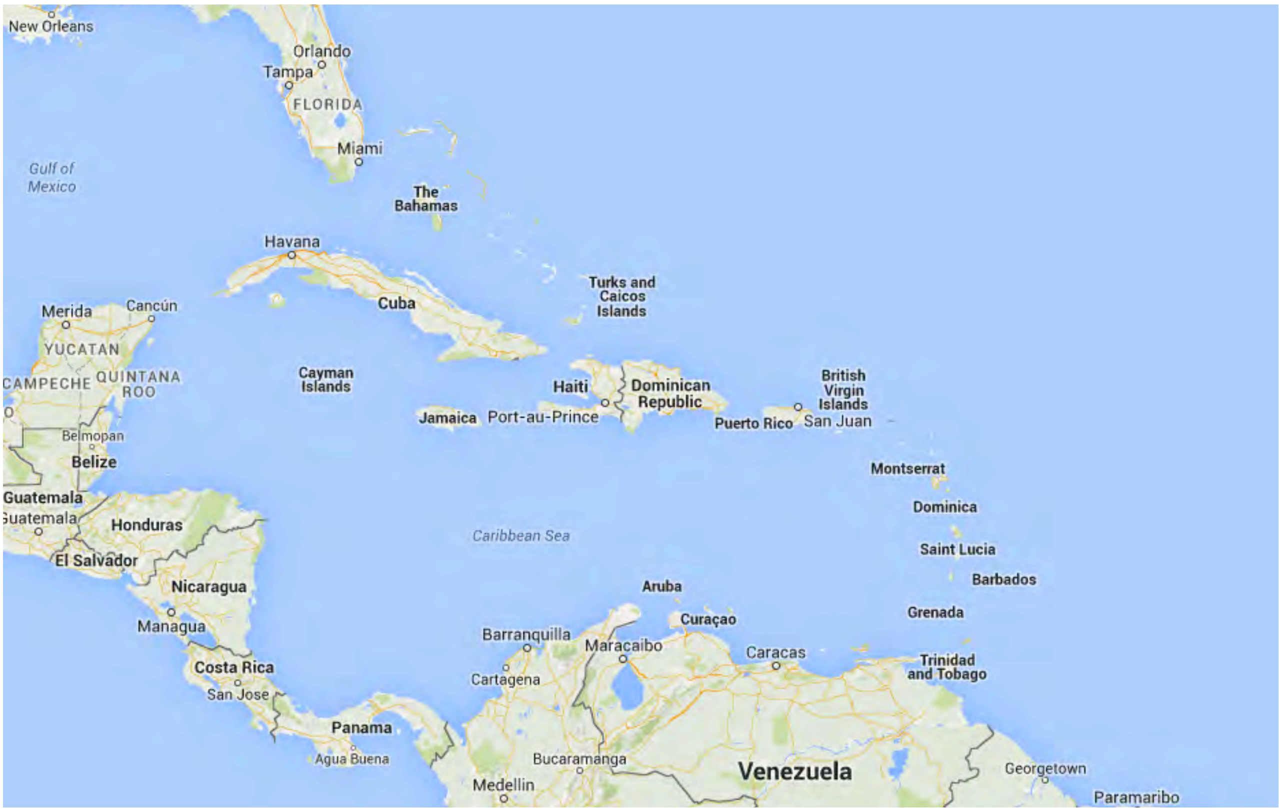

Figure 1: The Caribbean Area

References

CEO, 2004: *Caribbean Environmental Outlook* [Heileman, S., L.J. Walling, C. Douglas, M. Mason, and M. Chevannes-Creary (eds.)]. United Nations Environmental Programme, Kingston, Jamaica.

Critical Ecosystem Partnership Fund, 2010: *Caribbean Islands Biodiversity Hotspot Ecosystem Profile Summary*, pp. 20. Available at http://www.cepf.net/SiteCollectionDocuments/caribbean/Caribbean_EP_Summary.pdf

Nurse, L.A., and G. Sem, 2001: Small Island States. In: *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T., Y. Ding, D. J. Griggs, M. Noguer, P. J. Van der Linden, and D. Xiasosu (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA.

Walling, L.J., and M.M. Creary-Chevannes, 2004: *Coral Reef Monitoring for Climate Change Impact Assessment and Climate Change Adaptation Policy Development. Economic Valuation and Policy Priorities for Sustainable Management of Coral Reefs*, 183 pp.

Webber, D., 2015 *Climate Change Impacts On Jamaica's Biodiversity.* Retrieved on 20 August from http://www.nepa.gov.jm/neec/front_page/CCF/presentations/

CMIP and Applications

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The Coupled Model Intercomparison Project (CMIP) has been a major, very successful endeavor of the climate community for understanding past climate changes and for making projections and uncertainty estimates of the future in a multi-model framework. CMIP has developed in phases, with the simulations of the fifth phase (CMIP5, Taylor et al., 2012), now completed. In this talk I will describe the new design and organization of CMIP and the suite of experiments of its next phase (i.e., CMIP6), with a focus on experiments and activities related to regional climate change projections and the assessment of climate change impacts and risks.

A new aspect of CMIP6 is a more distributed organization under the oversight of the CMIP Panel, wherein an ongoing framework, CMIP, including the so-called Diagnostic, Evaluation and Characterization of Klima (DECK) experiments, is distinguished from a particular phase of CMIP, now CMIP6 (Meehl et al., 2014). CMIP6 consists of the CMIP6 Historical Simulation and additional experiments proposed by CMIP6-Endorsed Model Intercomparison Projects (MIPs). The CMIP6-Endorsed MIP experiments together with the CMIP6 Historical Simulation and the DECK will form a consistent set of freely available multi-model climate simulations that can be scientifically exploited to address the three broad scientific questions of CMIP6: (1) How does the Earth system respond to forcing?, (2) What are the origins and consequences of systematic model biases?, and (3) How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios? 21 MIPs have now been endorsed by the CMIP Panel and co-chairs of the WCRP Working Group on Coupled Modeling (WGCM), including CORDEX and the High Resolution MIP (HighResMIP) that aims at assessing the robustness of improvements in the representation of important climate processes with 'weather-resolving' global model resolutions (~25 km or finer). A historic development is the endorsement of the Vulnerability, Impacts, Adaptation and Climate Services Advisory Board (VIACS AB) as formal part of CMIP which will form a significant step forward for connections across communities.

The CMIP6 design will be described in a Geoscientific Model Development special issue with submissions of an overview paper and the CMIP6-Endorsed MIP contributions envisaged by end of March 2016. The description of the experiments and forcing data sets presented in this special issue will define CMIP6 in detail. Updated information on CMIP6 can also be found at the CMIP Panel website at http://www.wcrp-climate.org/index.php/wgcm-cmip/about-cmip.

References

Meehl, G.A., R. Moss, K.E. Taylor, V. Eyring, R.J. Stouffer, S. Bony, and B. Stevens, 2014: Climate Model Intercomparisons: Preparing for the Next Phase. *Eos Trans. AGU*, **59**, 77.

Taylor, K.E., R.J. Stouffer, and G.A. Meehl, 2012: An Overview of CMIP5 and the Experiment Design. *B. Am. Meteorol. Soc.*, **93**, 485–498.

CORDEX and Applications

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The COordinated Regional Downscaling EXperiment (CORDEX) was launched in the late 2000s under the auspices of the World Climate Research Program (WCRP) with the mission to advance and coordinate the science and application of regional climate downscaling through global partnerships. A Phase I CORDEX experimental framework was developed (Giorgi et al., 2009; Jones et al., 2011), including two simulation streams, a model evaluation and a regional projection stream, to be carried out for continental scale domains worldwide. The use of different downscaling techniques is envisaged, including regional climate models (RCMs), empirical statistical downscaling (ESD), high resolution and variable resolution atmospheric global models (HIGCM and VARGCM). To date, different regional CORDEX communities have organized themselves and completed ensembles of climate change projections virtually for all CORDEX domains, making the data available in standardized formats for Vulnerability/Impacts/Adaptation (VIA) studies. A number of scientific issues have emerged from these first CORDEX activities, in particular as an outcome of the second pan-CORDEX conference held in Brussels in November 2013. Among such issues are:

- better characterization of the added value of downscaling techniques in different contexts;
- better process-based assessment of models;
- move to very high resolution, convection-permitting modeling systems;
- coordination of the development of fully coupled regional earth system models (RESMs) including the human component;
- better integration of different downscaling methods (e.g., RCMs, ESD, HIGCM, VARGCM);
- increased focus on the role of regional forcings (e.g., land-use change, aerosols);
- increased focus on extremes, including wind systems;
- distillation of actionable information from different sources;
- characterization of uncertainties in regional projections.

These issues prompted the CORDEX community to engage in the discussion of future directions, particularly in view of the upcoming 6th report of the Intergovernmental Panel on Climate Change (IPCC) and Climate Model Intercomparison Project Phase 6 (CMIP6). Specifically, one of the approaches being discussed in order to address the scientific issues above is to develop, in addition to the standard continental scale domain framework, targeted activities over sub-continental scale regions. These activities, referred to as 'Flagship Pilot Studies (FPSs)', would be aimed at addressing specific questions based on optimal model and observational frameworks and targeted experimental designs. A key aspect of the FPSs is that they are expected to be initiated through a bottom-up approach drawing from the needs of the regional scientific communities. FPSs can also be useful means to draw research funding, whose lack has substantially affected some regional CORDEX activities.

In this paper we will first provide a brief review of the status of the current CORDEX activities, drawing illustrative examples from recent regional studies. We will then review and discuss the most outstanding emerging issues within the CORDEX framework and the ongoing debate on how they can be best addressed in future planning. Finally, an important element of CORDEX in need of strengthening is the interaction with the VIA community towards a more integrated approach to the production of robust and useful regional climate information. This is especially relevant within the context of the discussion on the provision of regional climate information for use in VIA applications within the IPCC process. CORDEX can play an important role in integrating the needs of different IPCC working groups, and feedback from the workshop participants will be welcome on how this role can be most effectively achieved. The plans for the next phase of CORDEX activities are expected to be finalized as an outcome of the upcoming third Pan-CORDEX conference to be held in Stockholm on 17–20 May 2016.

References

Giorgi, F., C. Jones, and G. Asrar, 2009: Addressing climate information needs at the regional level: the CORDEX framework. *WMO Bulletin*, **58**, 175–183.

Jones, C., F. Giorgi, and G. Asrar, 2011: The Coordinated Regional Downscaling EXperiment: CORDEX. An international downscaling link to CMIP5.

Information from Regional Climate Projections: Bridging the Gap between Science and Practice

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This presentation explores a range of issues as they pertain to the challenge of regional information and the context of the IPCC, using examples on the role of regional climate projections in managing complex socio-ecological systems (e.g., Daron et al., 2014).

A most disturbing question is 'How do I know how credible your information is for my decision?' which poses an ethical-epistemic dilemma. Users are engaged in managing a risk with real world consequences, and so to attempt to answer this question is to speak into a context of (possibly different) values—an ethical aspect—and presumes a grasp on what is known—an epistemic aspect.

If the question is posed by one climate scientist to another, this more likely leads to a vigorous discussion about uncertainty, probability, bias correction, and more. Whether such discussion is currently productive in advancing the quality of decision-centric information is open to debate. Data are being produced at finer resolution and with more sophisticated tools than ever before, leading to views such as Pielke and Wilby (2012) who (perhaps pessimistically) challenge the notion that downscaling and regional projections are 'adding value'.

Understanding the term ‚information' is central. The IAV and policy communities are adept at reading the nuanced meanings of terminology, yet with physical climate science the term 'information' is often seen by users as interchangeable with 'data'. Information is highly context dependent, yet descriptions of data commonly conflate sources of error (e.g., structural, physics, biases) with natural variability under a common term of 'uncertainty'. When communicated to users this leaves user-relevant 'information' somewhat hidden. The challenge of articulating information for regions is further compounded by the spread of climate outcomes derived from multi-model, multi-method, multi-scale, and multi-ensemble data, leaving users not surprisingly confused. This is the distillation dilemma.

Herein lies a fundamental concern; that we are in some way stuck in a linear chain of data generation, from emission scenarios to concentrations to global models to regional models or other downscaling / spatial disaggregation techniques. Chasing the ever more detailed data for 'regional climate projections' has provoked papers exploring the back and forth of added value (e.g., Feser et al., 2011; Racherlaet et al., 2012; Laprise, 2014), incited a degree of introspection among communities researching downscaling methods (e.g., Hewitson et al., 2013), and triggered vigorous debate in the online sphere as well (e.g., Climate Dialogue[1], 2015).

A consideration often missed is that of 'regional climate projections' versus 'information for regions'. The subtle distinction is that the former infers the supply chain approach to high resolution data, while the latter speaks to information relevant to regions irrespective of the source. Hence GCMs can be a basis for information on regions if they capture large scale process response to anthropogenic forcing, whilst downscaling can capture information about the influence of high resolution topography.

In an attempt to understand the information needs of users, there has been a proliferation of workshops, presupposing that needs-driven research can appropriately deliver tailored climate information. An emerging alternative is the approach of 'needs informed' in which the understanding of user contexts drives three parallel and necessary efforts: how to identify, develop, tailor, and qualify information from data, contextualized to the user needs (the distillation dilemma); addressing the required underlying and fundamental research required to inform this (e.g., improving tropical convection in models); and co-exploration whereby the scientist and user approach the data as equal partners in their exploration of relevant information.

Complementing this is the question of boundary organizations and the proliferation of portals, and the ethical dilemma these raise. The burgeoning climate services industry is expanding with competitive and commercial overtones. A new scientific journal has been established to serve this community and there are major global and regional initiatives (e.g., GFCS), yet no authority exists to assess the quality of these services and

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[1] Are regional models ready for prime time? Archived on 31 August 2015 at http://tinyurl.com/ot53zke

the information they produce. A first step seeking to catalyze a dialogue on this situation is currently underway; a white paper (Adams et al., 2015) exploring principles related to practice and products will be released[2] by the Climate Services Partnership in September 2015.

References

Adams, P., E. Eitland, B. Hewitson, C. Vaughan, R. Wilby, and S. Zebiak, 2015: Climate Services Partnership Technical Report 15WP01.

Daron, J.D., K. Sutherland, C. Jack, and B.C. Hewitson, 2014: The role of regional climate projections in managing complex socio-ecological systems. *Regional Environmental Change*, **15**(1), 1–12.

Feser, F., B. Rockel, H. von Storch, J. Winterfeldt, and M. Zahn, 2011: Regional Climate Models Add Value to Global Model Data: A Review and Selected Examples. *Bulletin of the American Meteorological Society*, **92**(9), 1181–1192.

Hewitson, B.C., J. Daron, R.G. Crane, M.F. Zermoglio, and C. Jack, 2013: Interrogating empirical-statistical downscaling. *Climatic Change*, 1–16.

Laprise, R., 2014: Comment on 'The added value to global model projections of climate change by dynamical downscaling: A case study over the continental U.S. using the GISS-ModelE2 and WRF models' by Racherla et al. *Journal of Geophysical Research: Atmospheres*, **119**(7), 3877–3881.

N.V., K., P. Kumar, R. Rasmussen, A. Ramanathan, A. Nesje, M. Engelhardt, […] and D. Jacob, 2015: Identifying climate change information needs for the Himalaya region - Results from the GLACINDIA Stakeholder Workshop and Training Program. *Bulletin of the American Meteorological Society*, doi:10.1175/BAMS-D-15-00160.1.

Pielke, R.A., and R.L. Wilby, 2012: Regional climate downscaling: What's the point? *Eos, Transactions American Geophysical Union*, **93**(5), 52. doi:10.1029/2012EO050008.

Racherla, P.N., D.T. Shindell, and G.S. Faluvegi, 2012: The added value to global model projections of climate change by dynamical downscaling: A case study over the continental U.S. using the GISS-ModelE2 and WRF models. *Journal of Geophysical Research: Atmospheres*, **117**(D20), doi:10.1029/2012JD018091.

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[2] http://www.climate-services.org/ethics

Challenges of the Science–Policy Interface from the Policy and Administration Perspective

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From the administration and policy decision making perspective a number of challenges currently limit the use of climate change simulation results for decision support.

One challenge is the ***communication of ensemble information***. Whether for global or for regional climate change projections, ensembles of climate model results should be used to assess the bandwidth of probable climate change (e.g., Gosling et al., 2010). However, when dealing with politicians (who are 'time-poor generalists'; Black, 2015) a condensed message needs to be conveyed to them. Some of these users would prefer to use only one value, i.e. the mean or median change signals. Many scientists, however, call for using the 15th and 85th percentiles (e.g., DWD, 2015) and it might even be beneficial to communicate the whole bandwidth, including outliers (e.g., Jacob et al., 2013, Tables 2 and 3; Huebener et al., 2013). From the impacts assessment and policy decision perspective, extreme events and outliers are the most important information because of their often large societal and economic impacts. Thus, while the mean and median information are the most reliable, they are not the most useful information for these users. An example of providing ensemble information is given in Figure 1. It confronts the user with the whole ensemble information but the graphics is selected so as to facilitate a visual interpretation of the results. Further suggestions for displaying regional climate change results, originating from a discussion series of German federal states environmental agencies employees can be found in Kreienkamp et al. (2013).

The second challenge is how to deal with the ***bandwidth*** of the simulation results, the 'uncertainty'. First, from a policy and administration perspective, the word 'uncertainty' should be avoided if possible. While in statistics it is a well defined term, in 'common language' it means 'we don't really know'. However, we do know quite a lot! For a large number of variables we can give answers as to their trends with high confidence (given a certain scenario), even if we still don't exactly know the magnitude of the changes (again, see Figure 1 for an example). A part of the bandwidth could be reduced by further knowledge, while another part is simply due to the internal variability of the climate system and is irreducible (Giorgi, 2010). For several questions the magnitude of the change signal is crucial (e.g., flood protection). It has to be made very clear, that there is no way out of the responsibility for the political and administrative stakeholders to decide under uncertainty, as they are used to do in other fields, too. Decisions need to be taken considering the probability of an event and the possible damage of said event. Thus, like for other decisions (like e.g., security of nuclear power plants), the decision can and will be made, even under real uncertainty.

A further challenge is the '***resolution***-challenge'. Some decisions are subject to effects that are much smaller than the model resolution. The famous hessian viticulture area along the Rhine ('Rheingau') is challenged by rising temperatures and shifting seasonal rainfall patterns. However, the Rhine valley is neither resolved in regional models using 50 km horizontal grid spacing, nor even in 12 km resolution.

Regarding heat stress as an increasingly important health issue, we need to better reproduce the impacts of cities (sealed surfaces, street canyons and anthropogenic heat sources) in the model results (Trusilova et al., 2013).

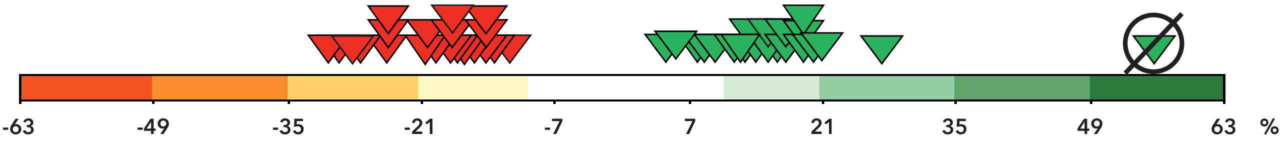

Figure 1: Precipitation change 2071–2100 compared to 1971–2000 in Hesse, Germany, for winter (green triangles) and summer (red triangles), simulated by 21 combinations of global and regional (statistical and dynamical) climate models, scenario A1B. The crossed-out triangle indicates a model that is deleted from the analysis due to an unsuitable method for winter rainfall for this time horizon.

Thus, alternative methods need to be developed to assess the impacts of climate change on small scales. One such method could be some combination of dynamical and statistical downscaling methods. While the dynamical models are capable to simulate changes in the physical climate system, the statistical methods have their strengths in the fine detail and the strong coupling to the observed station data. It should be tested how the strengths of the two methods can be combined to provide physically sound climate change information in high spatial resolution.

References

Black, R., 2015: No more summaries for wonks. *Nature Climate Change*, **5**, 282-284.

DWD, 2015: German Climate Atlas (Deutscher Klimaatlas), www.dwd.de/klimaatlas (in German)

Giorgi, F., 2010: Uncertainties in climate change projections, from the global to the regional scale. *EPJ Web of Conferences*, **9**, 115–129.

Gosling, S.N., D. Bretherton, K. Haines, and N.W. Arnell, 2010: Global hydrology modeling and uncertainty: running multiple ensembles with a campus grid. *Phil. Trans. R. Soc. A*, **368**, 4005–4021.

Huebener, H., M.G. Sanderson, I. Höschel, J. Körper, T.C. Johns, J.-F. Royer, E. Roeckner, E. Manzini, J.-L. Dufresne, O.H. Otterå, J. Tjiputra, D. Salas y Melia, M. Giorgetta, S. Denvil, and P.G. Fogli, 2013: Regional hydrological cycle changes in response to an ambitious mitigation scenario. *Climatic Change*, **120**, 389–403.

Jacob, D., et al., 2013: EURO-CORDEX: new high-resolution climate change projections for European impact research. *Regional Environmental Change*, doi:10.1007/s10113-013-0499-2.

Kreienkamp, F., H. Huebener, C. Linke, and A. Spekat, 2013: Good practice for the usage of climate model simulation results – a discussion paper. *Environmental Systems Research*, **1**, doi: 10.1186/2193-2697-1-9.

Trusilova, K., B. Früh, S. Brienen, A. Walter, V. Mason, G. Pigeon, and P. Becker, 2013: Implementation of an urban parameterization scheme into the regional climate model COSMO-CLM. *J. Appl. Meteorol. Climatol.*, **52**(10), 2296-–2311.

Risk Modelling: General Needs and WGII Experience

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In the IPCC Fifth Assessment Reports, risk was for the first time, front and center for Working Groups II and III (IPCC, 2014a, b, c). Risk was framed to not only assess the direct risks of climate change, but to support the many different contexts in which climate-related decisions could be made. Within the scope of the Working Group II report, these contexts include impact assessment, adaptation, mitigation, sustainable development, resilience, human security, livelihoods and poverty.

In the past, assessments followed the causal pathway addressed by process of emissions, climate change, impacts and adaptation. This followed the logical analytic pathway of rational decision making where the provision of scientific evidence was considered to result in better decision-making. It also maintained a clean distinction between the science/policy divide, avoiding the risk of having science and policy conflated.

The social sciences have long held that this separation of the rational aspects of decision-making from its more subjective aspects, such as political economy, multiple values and personal and group psychology, is not a useful thing to do (Rayner and Malone, 1998; Verweij et al., 2006). In AR5, a real effort was made to bring many relevant aspects of the decision making process into the assessment in Chapter 2 Foundations of Decision Making (Jones et al., 2014). Setting the context of an assessment in order to set out the assessment pathway, including the methods and models to be used is very important.

Relevant issues include all areas affected directly and indirectly by climate impacts or by responses to those impacts, covering diverse aspects of society and the environment. These issues include consideration of values, purpose, goals, available resources, the time over which actions are expected to remain effective, and the extent to which the objectives being pursued are regarded as appropriate. The purpose of the decision in question, for example, assessment, strategic planning, or implementation, will also define the framework and tools needed to enable the process (Jones et al., 2014, p. 199).

Accounting for these issues will influence decisions on the sort of climate information that is needed to support an assessment and consequent decision making. In doing so, it is important to avoid some of the scientific 'socially constructed' ideals of what an assessment needs. These include:

- False precision – sometimes highly precise spatial or temporal data is calculated where much less precise data is all that is needed.

- Over prediction – there is often a tendency to take output from a model calculated using a scenario and treat it as a prediction. Consistent language and treatment of uncertainty throughout an assessment is important.

- Gatekeeping – sometimes low confidence scientific information is withheld from impact assessments because the scientists involved are concerned about the risk of being found wrong with subsequent findings (personal or organizational reputational risk). Low confidence information can be very valuable in risk assessments when there is the potential for severe outcomes. The use of such information should ideally be a shared decision.

- When the perfect is the enemy of the good – sometimes it is better to decide under what conditions a decision can be made and aim for that rather than go for the scientifically perfect assessment that may not be finalized because of limited resources.

Key findings within the WGII AR5 reports have also reframed how risk is communicated compared to previous reports. The many different emission scenarios now in use, and methods used to assess impacts has required a different form of synthesis. Levels of global mean warming and time intervals are now the two main frames for communicating such findings, most particularly in Box SPM2, Table 1 (IPCC, 2014d). There is also a variety of different assessment types currently in use that have different climate information needs (Hewitson et al., 2014).

Other assessments are utilizing standard input data to facilitate impact model intercomparison studies or to develop a common set of inputs for integrated assessment modelling (Rosenzweig et al., 2013; Warszawski et al., 2014). How these can contribute to vulnerability, impact and adaptation assessments is still an evolving issue (van Ruijven et al., 2013).

The role of climate services acting as boundary organisations is becoming increasingly more important. As the research communities expand to meet the demands of decision making in a changing climate, the roles of those who act as brokers between the more pure research community and decision makers is becoming increasingly necessary.

In recent years, there has been a tension between the climate forecasting communities who are pursuing the pathway of developing probabilistic forecasts based on trend analysis of ensembles, and bottom-up stakeholder-driven methods where decision makers are seeking climate information that meets their specific contexts. While these two extremes are something of a caricature there is a great need for bi-directional information between the different groups involved in climate risk assessments to work out how to address both general and specific needs. My own view on these is that probabilistic methods are best used as diagnostic tools in uncertainty analyses and in straightforward situations where cause and effect are dominated by climate-related uncertainty. In more complex situations, individual scenarios that bound the uncertainty space can be tailored to address specific decision making needs.

References

Hewitson, B., A.C. Janetos, T.R. Carter, F. Giorgi, R.G. Jones, W.T. Kwon, L.O. Mearns, E.L.F. Schipper and M.v. Aalst, 2014: Regional context. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds.)] Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1133–1197.

IPCC, 2014a: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2014b: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2014c: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK and New York, USA.

IPCC, 2014d: Summary for Policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 1-32.

Jones, R.N., A. Patwardhan, S. Cohen, S. Dessai, A. Lammel, R. Lempert, M.M.Q. Mirza, and H. von Storch, 2014: Foundations for decision making. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Volume I: Global and Sectoral Aspects*. *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Rayner, S., and E.L. Malone, 1998: *Human choice and climate change*. Battelle Press, Columbus, Ohio.

Rosenzweig, C., J. Jones, J. Hatfield, A. Ruane, K. Boote, P. Thorburn, J. Antle, G. Nelson, C. Porter, and S. Janssen, 2013: The agricultural model intercomparison and improvement project (AgMIP): protocols and pilot studies. *Agricultural and Forest Meteorology*, **170**, 166–182.

van Ruijven, B.J., M.A. Levy, A. Agrawal, F. Biermann, J. Birkmann, T.R. Carter, K.L. Ebi, M. Garschagen, B. Jones, R. Jones, E. Kemp-Benedict, M. Kok, K. Kok, M.C. Lemos, P.L. Lucas, B. Orlove, S. Pachauri, T.M. Parris, A. Patwardhan, A. Petersen, B.L. Preston, J. Ribot, D.S. Rothman and V.J. Schweizer, 2013: Enhancing the relevance of Shared Socioeconomic Pathways for climate change impacts, adaptation and vulnerability research. *Climatic Change*, 1–14.

Verweij, M., M. Douglas, R. Ellis, C. Engel, F. Hendriks, S. Lohmann, S. Ney, S. Rayner and M. Thompson, 2006: Clumsy solutions for a complex world: the case of climate change. *Public Administration*, **84**, 817–843.

Warszawski, L., K. Frieler, V. Huber, F. Piontek, O. Serdeczny and J. Schewe, 2014: The Inter-Sectoral Impact Model Intercomparison Project (ISI–MIP): Project framework. *Proceedings of the National Academy of Sciences*, **111**, 3228–3232.

Climate Phenomena and Their Relevance to Regional Climate Change

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Regional climates are the complex outcome of geographical response to global forcings, local physical processes, and the non-local response to large-scale phenomena such as the El Niño-Southern Oscillation (ENSO) and other dominant modes of climate variability. The dynamics of regional climates are determined by local weather systems that control the net transport of heat, moisture, and momentum into a region. Chapter 14 of IPCC WGI AR5 assesses the physical basis of future regional climate change in the context of changes in the phenomena such as monsoons and tropical convergence zones, large-scale modes of climate variability, and tropical and extra-tropical cyclones. Assessment of future changes in these phenomena is made based on climate model projections (e.g., the CMIP3 and CMIP5 multi-model ensembles), an understanding of their importance in controlling regional climates, how well models represent the key processes in these phenomena and are able to realistically simulate them under present-day conditions. Projections of expected future changes in the seasonal mean and sub-seasonal characteristics of global and different regional monsoons; frequency, intensity and tracks of tropical and extra-tropical cyclones, shifts in the tropical convection zones etc. are assessed and their relevance to future regional climate change discussed. Assessed confidence (high, medium, low) in climate projections of regional temperature and precipitation change from the multi-model ensemble of CMIP5 models for different RCP scenarios and the relevance of projected changes in major phenomena for mean change in future regional climate will be presented having implications for the regional impacts and related risk assessments.

While the approach followed (in Chapter 14) for assessing regional climate change through the projected changes in the climate phenomena that impact it appears quite logical and scientifically sound, it is challenged by an overall lack of literature that links regional climate change with phenomena of relevance. Low confidence in the ability to simulate many important phenomena in the current generation of models coupled with the large spread in the projected future changes across models further compounds the process of regional climate change assessments. This becomes obvious from the fact that no statement from regional climate change could be raised to the SPM though not to undermine the importance of the regional climate change assessments that are provided stating clearly the current level of confidence. Delayed CORDEX simulations and publications based on these also added to the problem.

Regional Climate Projections and their Use in Impacts and Risk Analysis Studies: From Science to Practice

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The Intergovernmental Panel on Climate Change was established in 1988 by the World meteorological Organization and the United Nations Environment Program to assess the scientific, technical, and socio-economic information relevant to the understanding of climate change, its potential impacts, and options for response strategies. The IPCC Assessment currently comprises Working Groups I, II and III, on scientific basis of climate change (IPCC, 2001a), climate change impacts, adaptation and vulnerability (IPCC, 2001b) and climate change mitigation (IPCC, 2001c).

'Risk is a forward-looking concept that implies an eventuality of something that can occur. Therefore, assessing risk means looking at the possible events that can occur, quantifying how likely they are to happen and appraising consequences should they occur' (Mauro et al., 2014). To assess risk based only on past events does not provide complete information on the current state of the risk. It is important to take into account, events that may occur in the future in addition to using past records. Information about events that could occur in the future could be obtained from climate projections. Since regional impacts and risk studies require climatic information suitable for driving impact models (e.g., hydrology models, crop models, etc.), information coming from Regional Climate Models or from statistical downscaling methods would be of immense benefit to these studies.

The IPCC WGI Atlas of Global and Regional Climate Projections provided maps and regionally averaged time series of annual and seasonal multi-model means, with uncertainties of changes in surface temperature and precipitation over the 21st century for 37 regions of the world. However, the data used was based entirely on global climate models. Although the model data underlying the WGI Atlas is electronically available from the IPCC websites as part of the WGI Supplementary Material of AR5, it is not widely used in studies of regional impacts and risks of climate change to human and natural systems around the world (IPCC, 2013). Various initiatives are generating regional climate projections. The Coordinated Regional Climate and Downscaling Experiment (CORDEX) of the World Climate Research Programme (WCRP) is a recent example. Although the original focus was on Africa, the database of this initiative is rapidly growing with data covering more than 14 domains of the world (IPCC-TGICA, 2007).

One issue is to investigate how to enhance the interaction among the IPCC Working Groups or communities. That is, scientists from the climate modeling community (e.g., CMIP5 and CMIP6), the regional modeling and downscaling community (e.g. CORDEX) and the climate impacts and risk community. This is to address the mismatch of information and assumptions among the working groups, as currently the three groups prepare their reports in parallel. This issue is one of the aims of this IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies being organized in Sao Jose dos Campos, Brazil from 15–18 September 2015.

Another issue, which is the focus of this paper, is how to improve the consistent use and application of the data and information generated on projections of climate change and resulting risks and impacts. A possible approach to improve the use and application of data in practice is through the implementation of the WMO Global Framework for Climate Services (GFCS). The five pillars of the GFCS (Figure 1) are Capacity Building; Research, Modeling and Prediction; Observations and Monitoring; Climate Services Information System; and User Interface.

The GFCS provides a framework to have Research <–> Operations <–>Applications. That is, research feeds into operations which in turn feeds into applications and vice-versa, thus addressing the important issue of feedback. The GFCS can be implemented at regional and national level. The needs of the end user obviously depend on the type of user. The key is involvement of the end users at an early stage of the study to ensure the relevant products are generated, the appropriate services (e.g. education, technical guidance and perhaps advocacy) are offered and suitable channels of delivery (e.g., radio, Information Communication and Technology-based channels) are used.

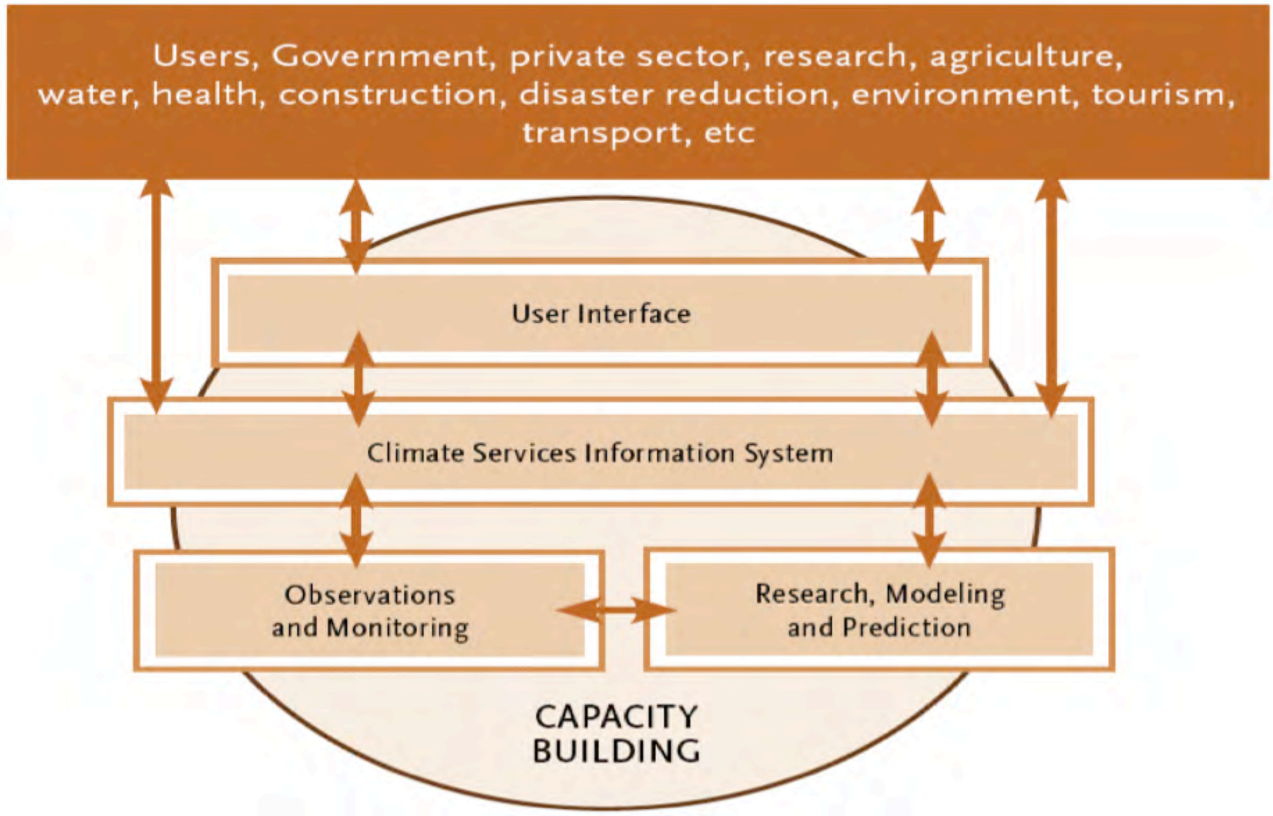

Figure 1: The five pillars of the Global Framework for Climate Services.

For instance, most developing countries have serious challenges providing adequate water and sanitation for its rural inhabitants. Different sources of water are used in poor urban communities. Tap water is mostly used for drinking and cooking while hand dug wells and river water is used for washing. However, some use water from wells and other unprotected sources for drinking. The above sources of water (tap, river, wells) are all related to rainfall in a way. Thus, impact and risk managers could use projected rainfall as input to their system to enable them make informed decisions (e.g., policy, strategies, etc.). Often, only one water company is responsible for providing, distributing, and conserving water for domestic, public, and industrial purposes. Thus, GFCS could ensure communication among stakeholders, with a more targeted exchange of information about what is needed from the end user, and what can and cannot be provided by downscaling methods.

References

IPCC, 2013: Annex I: Atlas of Global and Regional Climate Projections [van Oldenborgh, G.J., M. Collins, J. Arblaster, J.H. Christensen, J. Marotzke, S.B. Power, M. Rummukainen, and T. Zhou (eds.)]. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1311–1394.

IPCC-TGICA, 2007: *General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Version 2*. Prepared by T.R. Carter on behalf of the Intergovernmental Panel on Climate Change, Task Group on Data and Scenario Support for Impact and Climate Assessment, 66 pp.

Mauro, M.D, 2013: Quantifying Risk Before Disasters Occur: Hazard Information for Probabilistic Risk Assessment. *WMO Bulletin*, **63**(2), 36–41.

Supporting Good Climate-Related Decisions with Uncertain Climate Information

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Uncertainty complicates the use of regional climate information for impacts and risk analysis studies. There is uncertainty in our understanding of future climate conditions, the biophysical systems affected by the climate, and the myriad socio-economic factors that affect how changes in these biophysical and socio-economic factors affect humans and the things they care about. Often the most decision-relevant information is least certain (for instance, about climate extremes) and appropriate risk management strategies may require climate information whose utility may not be immediately obvious. Failure to address these challenges may result in poor uptake of climate information into decision processes and, as a result, adaptation decisions that leave people more vulnerable than they might otherwise be.

Many frameworks exist for incorporating uncertain information into decisions, each with implications for how the information is structured and used. This talk will survey several different frameworks for decision making under uncertainty and highlight their differing implications for the provision of regional climate information. For instance, the classic probabilistic risk analysis framework emphasizes a need for single, best-estimate joint probability distributions of future climate conditions as an input into risk management decisions. Broader iterative risk management frameworks often emphasize risk management strategies designed to evolve over time in response to new information (learning) and robustness over a wide range of hard-to-predict future conditions. Such frameworks often emphasize a need for information such as bounding cases and signposts that can signal a need to shift risk managements strategies.

As emphasized by introductory chapters on decision making in both the IPCC WGII and WGIII Fifth Assessment Reports (Chapter 2 in both reports) the particular decision-making context can prove crucial in understanding how to best match the need for and supply of (uncertain) climate information in any particular decision context. This talk will survey several case studies that use climate information in different ways and for different purposes.

The concept of decision support provides a useful framework to help generalize lessons from these case studies. Decision support represents set of processes intended to create the conditions for production and appropriate use of decision-relevant information. Relevant insights from this literature include: 1) the importance of focusing on decision processes in order to understand the most appropriate information products to effectively inform those processes; 2) distinguishing between 'agree on assumptions' decision processes that begin by generating consensus on the projections of relevant climate, biophysical, and socio-economic trends and 'agree on decisions' processes that seek consensus on risk management strategies even when there exists a lack of consensus on the projections of relevant trends; and 3) the distinction between decision structuring and choice. *Decision structuring* includes defining the problem in a way that opens it up to thoughtful consideration, understanding the relevant uncertainties, defining the objectives to be achieved, and assembling a menu of options that might achieve those objectives. *Choice* includes selecting the best decision among a menu of available options given estimates of their consequences.

Using this general framework and examples of decision making under uncertainty, this talk aims to inform discussion about the various ways in which regional climate information can usefully inform impacts analysis and iterative climate risk management decisions.

References

Jones, R.N., A. Patwardhan, S. Cohen, S. Dessai, A. Lammel, R. Lempert, M.M.Q. Mirza, and H. v. Storch, 2014: Chapter 2. Foundations for Decision Making. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Intergovernmental Panel on Climate Change (IPCC).

National Research Council, 2009: Informing Decisions in a Changing Climate. The National Academy Press. Washington, DC, Panel on Strategies and Methods for Climate-Related Decision Support, Committee on the Human Dimensions of Climate Change, Division of Behavioral and Social Sciences and Education.

Weaver, C.P., R.J. Lempert, C. Brown, J.A. Hall, D. Revell, and D. Sarewitz, 2013: Improving the contribution of climate model information to decision making: the value and demands of robust decision frameworks. *WIREs Climate Change*, **4**, 39–60.

Global to National – Regional Assessments of Extremes in South America and Risk of Natural Disasters in Brazil

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Experiments on dynamical downscaling on an ensemble mode of regional climate model simulations over South America started to appear since 2007 (Sanchez et al., 2014; Chou et al., 2014; Marengo et al 2012). The results are for different future periods, with the main focus on (2071–2100) forced by several global climate models, and using the SRES A1B or RCP 8.5 as emissions scenario. The common climate change signals show an overall increase of temperature for all the seasons and regions, generally larger for the austral winter season. Future climate shows a precipitation decrease over the tropical region, and an increase over the subtropical areas. Changes in extremes suggest increase in frequency of dry spells in Northeast Brazil and Amazonia, and increases in intense precipitation in western Amazonia and on the La Plata basin. These climate change signals arise independently of the driving global model and the regional climate model. The above-indicated papers allow for the identification of the common climate change signals and their associated uncertainties for several subregions within the South American continent. However, the level of uncertainty is larger for longer horizon projections for both temperature and precipitation.

Results of many of these studies have been used in vulnerability assessments for the Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). In the case of Brazil, downscaling was made of the HadGEM2 ES and MIROC 5 global models using the Eta regional model for the RCP8.5. The Eta nested in the HadGEM2 ES shows major warming area is located in the central part of Brazil. In austral summer, the reduction of precipitation in the central part and the increase in the southeastern part of the continent are common changes in these simulations, and the Eta- HadGEM2 ES intensifies the decrease of precipitation in central Brazil. In austral winter, precipitation decrease is found in the northern part of South America and in most of Central America, whereas the reduction in southeastern South America is limited to near coastal region. Heavier precipitation rates are projected in the Central-South of Brazil toward the end of the century. Increase in the length of consecutive dry days (CDD) in Northeast of Brazil and the decrease of consecutive wet days (CWD) in the Amazon region are common features in these simulations.

Observations show that there are evidences that hydrological climate extremes events have become more frequent an intense in the last decades due to climatic change. In Brazil, flashfloods and landslides were responsible for 74% of the deaths related to natural disasters in 1991–2010 period. In this sense, climate change could be considered a threat, which can further increase these numbers, if actions of adaptation and reducing vulnerability are not taken. The TNC of Brazil to UNFCC using the Eta- HadGEM2 ES projections evaluate Brazil's vulnerability hotspots to these disasters, two vulnerability indexes were developed using three sets of variables: (1) climate, with IPCC climate extreme indexes; (2) environmental, including land use, drainage systems, relief map, slope, road density and hydrography variables; (3) socioeconomic, including Gini coefficient, HDI (Human Development Index), housing conditions and poverty-related index. For the baseline period of 1961–1990, the vulnerability indexes were adjusted by an iterative process, which was validated by comparing it to the Brazilian National Disasters Data. The same indexes found at baseline were used to estimate the vulnerability until the end of the XXI century, using the RCP4.5 and 8.5. The results indicate a large increase in Brazil's vulnerability to landslides mainly in coastal zone, southern states, high lands of southeast states, and along the Amazon River due to climatic aspects only, not considering other factors such as increase in population size, etc. Flashfloods vulnerability, on the other hand, increases mostly in the south/southeast regions, the northeast coastal zone and parts of the Amazon basin.

References

Chou, S.C., et al., 2014: Assessment of Climate Change over South America under RCP4.5 and 8.5 Downscaling Scenarios. *American Journal of Climate Change*, **3**, 512–525.

Marengo, J.A., S.C. Chou, G. Kay, L.M. Alves, J.F. Pesquero, W.R. Soares, D.C. Santos, A.A. Lyra, G. Sueiro, R. Betts, D.J. Chagas, J.L. Gomes, J.F. Bustamante, and P. Tavares, 2012: Development of regional future climate change scenarios in South America using the Eta CPTEC/HadCM3 climate change projections: climatology and regional analyses for the Amazon, Sao Francisco and the Parana River basins. *Clim. Dynamics*, **38**,1829–1848.

Sanchez, E., et al., 2015: Regional climate modelling in CLARIS–LPB: a concerted approach towards twenty first century projections of regional temperature and precipitation over South America. *Clim. Dynamics*, doi:10.1007/s00382-014-2466-0.

Exploring Climate Impacts and Risks through Coordinated Regional and Global Projects

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Impacts assessments serve to elucidate the responses and sensitivities of various sectors to climate change and variability, while bracketing multi-model and method uncertainty, with the intent of better informing climate resilience policies at various levels (Schellnhuber et al., 2014). Impacts communities are now coordinating to harmonize model and assessment inputs for consistently-applied methodologies, and are attributing model differences and encouraging improvement. Emerging regional and sectoral coordinated assessments aim to replicate the success of the Coupled Model Intercomparison Project (CMIP) efforts, and build on the latter's methods and findings to identify robust impacts that result from projected climate changes (Taylor et al., 2012; IPCC, 2014). This presentation will discuss the major components included in most of these coordinated assessments, introduce some on-going efforts, and briefly describe some outstanding needs of the coordinated assessment communities.

Similarities in the architecture of coordinated assessments stem from shared goals: to identify robust impacts on various regions and sectors for given climate scenarios; to characterize the uncertainty in these projected impacts; and to ultimately increase the utility of these projections on scales relevant to decision-makers. Achieving this first requires obtaining robust changes in scale-relevant climate variables from a variety of climate modeling efforts. Secondly, multiple types of models are used to simulate impacts resulting from the future climate scenarios on important sectoral components (Figure 1, for example). Uncertainties can then be assessed between the climate and impacts models, and robust responses can be identified.

Many coordinated sectoral and regionally specific impacts assessments are now underway (IPCC, 2014). The Agricultural Model Intercomparison and Improvement Project (www.agmip.org) is among the first initiatives to take a multi-climate, crop, and economic model approach to understanding the impact of climate change on agriculture by conducting integrated assessments at regional and global scales (Rosenzweig et al., 2013). The Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) has coordinated a community effort to harmonize climate drivers for application into a range of sectoral impact models, and undertake cross-scale, cross-model and cross-sectoral assessments (Schellnhuber et al., 2014; Warszawski et al., 2014). Sectors include water resources, coastal zones, agriculture, ecosystems, and energy, and ISI-MIP also incorporates the frameworks and findings of existing model intercomparisons such as AgMIP and WaterMIP (Rosenzweig et al., 2013; Haddeland et al., 2011). A Vulnerability, Impacts, Adaptation, and Climate Services Advisory Board (VIACS AB) has been established to link the Programme for Research on Vulnerability, Impacts, and Adaptation, Climate Services, and other groups, with the intent of specifying those particular scenarios, simulations, and variables in which these communities are most interested. The solicited communities include cross-cutting initiatives like ISI-MIP and AgMIP; model intercomparisons examining impacts to fisheries, marine and coastal systems; watersheds and resources; public health modeling efforts; and a variety of climate services communities.

As coordinated assessments are scaled for multiple spatial and temporal levels, there is a pressing need to better liaise and integrate with IPCC and CMIP efforts. Demand is high across these impacts communities for sub-grid scale information and outputs from downscaling efforts. Added-value statistics of shifts in the frequency and magnitude of extreme events remain among the top priorities, as well as the distribution of key climate variables space and time. A main objective across coordinated impacts assessments is the characterization, interpretation, and communication of multi-model, multi-factor uncertainty. Much has been learned from the CMIP community on the treatment and visualization of multi-model uncertainty and spread. However, information from the climate models is often incorporated into 'chains' of impacts models for coordinated assessments, leading to the propagation/cascading of various errors and uncertainty. There is great benefit from continued engagement and feedback between the coordinated assessment and climate modeling communities to address these outstanding needs and concerns, and to pave the way for more robust regional and global impacts assessments.

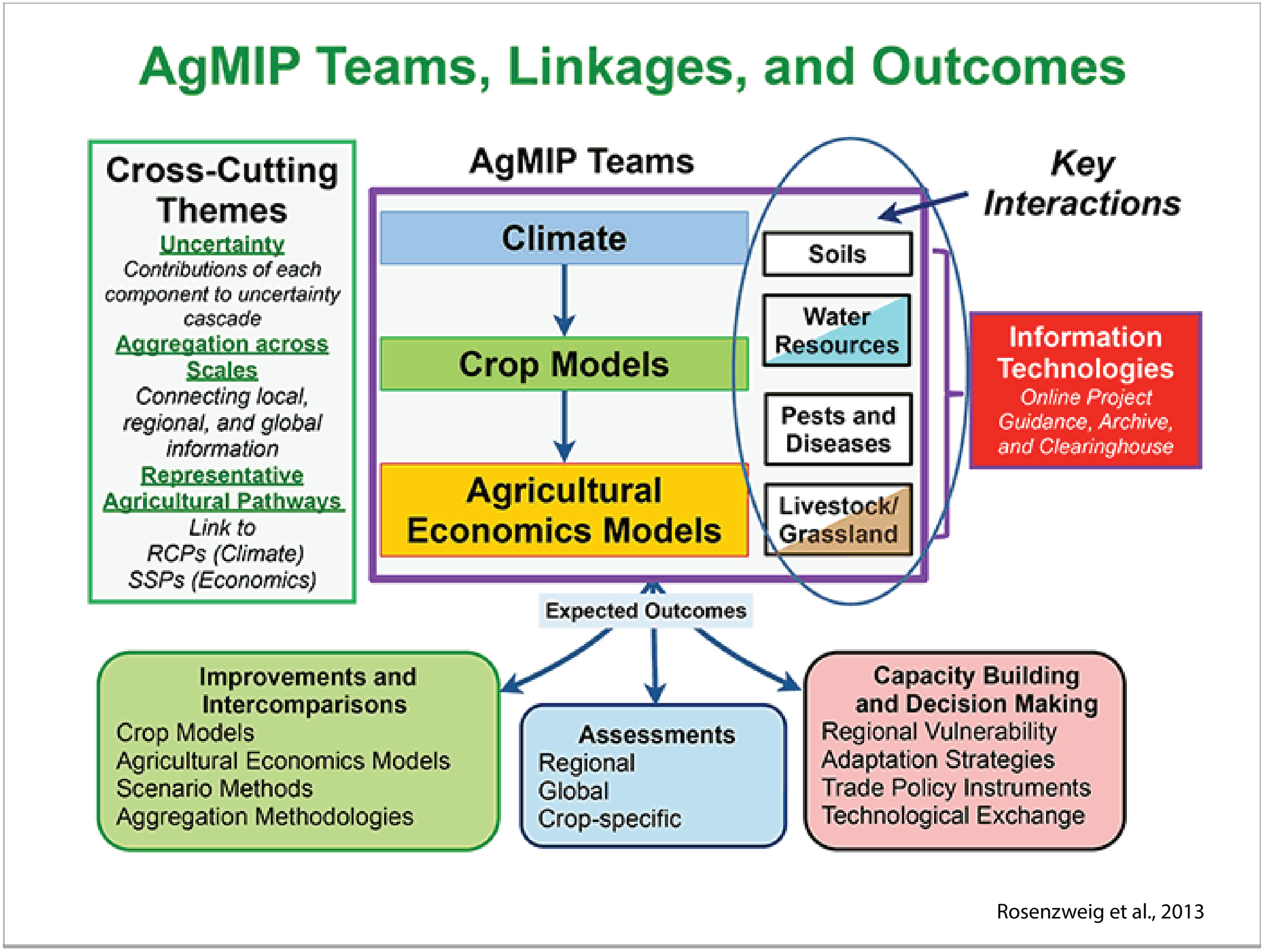

Figure 1: An example of integrated impacts assessment architecture from the Agricultural Model Intercomparison and Improvement Project. Climate information is quality-controlled and representative GCMs selected for input into other sectoral models to project climate change impacts. Adapted from Rosenzweig et al., 2013.

References

Haddeland, I., D.B. Clark, W. Franssen, F. Ludwig, F. Vob, N.W. Arnell, N. Bertrand, M. Best, S. Folwell, D. Gerten, S. Gomes, S.N. Gosling, S. Hagemann, N. Hanasaki, R. Harding, J. Heinke, P. Kabat, S. Koirala, T. Oki, J. Polcher, T. Stacke, P. Viterbo, G.P. Weedon, and P. Yeh, 2011: Multimodel Estimate of the Global Terrestrial Water Balance: Setup and First Results. *J. of Hydrometeorology*, **12**, 869–884.

IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 688 pp.

Rosenzweig, C., J.W. Jones, J.L. Hatfield, A.C. Ruane, K.J. Boote, P. Thorburn, J.M. Antle, G.C. Nelson, C. Porter, S. Janssen, S. Asseng, B. Basso, F. Ewert, D. Wallach, G. Baigorria, and J.M. Winter, 2013: The Agricultural Model Intercomparison and Improvement Project (AgMIP): Protocols and pilot studies. *Ag. For. Met*, **170**, 166–182.

Schellnhuber, H.J., K. Frieler, and P. Kabat, 2014: The elephant, the blind, and the intersectoral intercomparison of climate impacts. *Proc. Nat. Acad. Sci.*, **111**, 3225–227.

Taylor, K.E., R.J. Stouffer, and G.A. Meehl, 2012: An overview of CMIP5 and The Experiment Design. *Bull. Amer. Meteor. Soc.*, doi:10.1175/BAMS-D-11-00094.I.

Warszawski, L., K. Frieler, V. Huber, F. Piontek, O. Serdeczny, and J. Schewe, 2014: The Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP): Project framework. *Proc. Natl. Acad. Sci.*, **111**(9), 3228–3232.

From Science to Practice – Sea Level Extremes and Coastal Impacts

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In early 2015 new climate projections were released for Australia (CSIRO and BoM, 2015) based on the latest CMIP5 GCMs and other relevant information. These projections included a more comprehensive delivery of information relevant for coastal and marine environments including spatially varying mean sea level rise (SLR) and sea level allowances (McInnes et al., 2015) together with ocean acidification (OA) and sea surface temperature (SST). These variables are relevant to two distinct communities—sea level information mainly for those managing the coastal terrestrial environment while SST and OA for those managing the marine environment. Compared to the projections of many atmospheric variables such as temperature and rainfall, for which there has been much focus and engagement on end-user needs, delivery of marine and coastal projections to the impacts community is in its relative infancy. Here, progress and challenges in the area of marine and coastal projections are discussed.

A preliminary assessment of the ability of regional sea level projection methods in the Australian region indicates that the model-based SLR is consistent with the observed sea-level records allowing for natural variability. The regional-scale projections for Australia indicate that SLR in this region will be larger than global-averaged SLR, particularly along the east coast of Australia where the 95th-percentile values for RCP8.5 in 2090 are up to 0.06 m higher (Figure 1). However glacial isostatic adjustment (GIA), leads to projected SLR along much of the coast that is smaller by several cm compared to further offshore. An important limitation for using SLR projections in impact assessments is the limited knowledge on local vertical land movements and their projected changes.

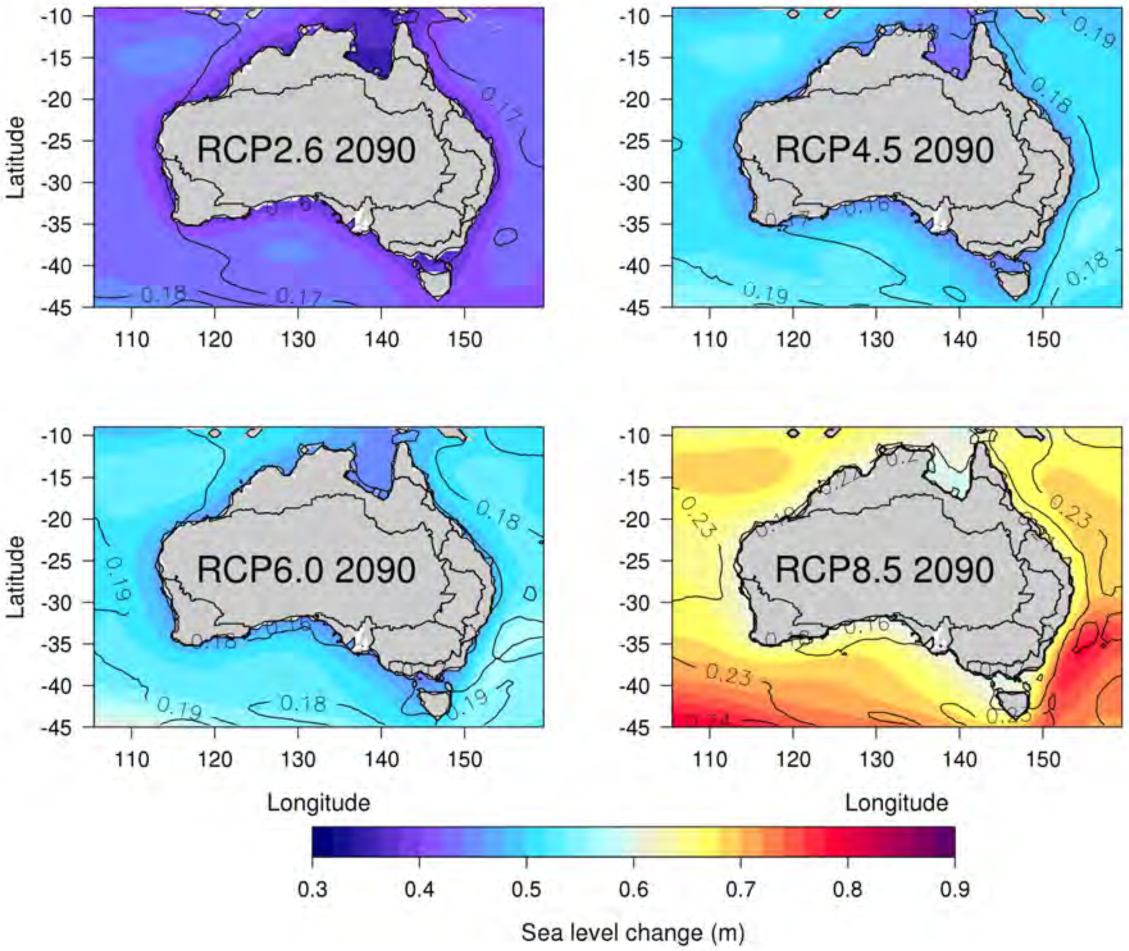

Figure 1: The regional distributions of sea level change (four emissions scenarios) for the period centered on 2090 compared to 1986 to 2005. The projections (shadings) and uncertainties (solid lines) represent the contributions from the ocean dynamical response, changes in terrestrial ice, the gravitational response of the ocean to these changes, and an ongoing GIA.

A challenge in planning for SLR relates to the large uncertainty range in the projections. The sea level allowances, derived by (Hunter, 2012) enables selection of a value within a projected range of SLR that represents the minimum height that assets, or their protective measures (e.g. sea walls) need to be raised so that the frequency of inundation events will remain unchanged from the present expected frequency. The calculation of allowances requires projections of SLR (mean and range) together with present day extreme sea level variability as characterised by an extreme sea level return period curve. Allowances are typically larger than the mean SLR by an amount which depends on the uncertainty of SLR projections and the extreme sea level variability. Therefore to provide allowances for the entire Australian coastline sea level extremes data derived from hydrodynamic models (Haigh et al., 2014) was used.

The recently released Australian climate projections did not include projected changes to storm surges and waves, both drivers of extreme sea levels and shoreline change. Projected changes to waves and in particular, storm surges are of low confidence (Church et al., 2013) due to the limited number, and regional coverage of storm surge studies and large uncertainty in the ability of GCMs to simulate severe weather events. Efforts are needed to increase confidence in these variables and consider the combination of storm surge and wave-generated extreme sea levels and their potential impact on shoreline change.

Ocean warming and ocean acidification are considered two of the key stressors in the marine environment (Wong et al., 2014). Projected changes for the Australian region reveal considerable spatial heterogeneity in central projections and model-derived uncertainty. While providing valuable information for marine impacts researchers, changes in these variables can be considerably larger on the continental shelves and strongly influenced by local factors such as shelf circulations, rainfall and terrestrial inputs such as freshwater and nutrients.

References

Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer, and A.S. Unnikrishnan, 2013: Sea Level Change. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., et al. (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

CSIRO and BoM, 2015: *NRM climate change projections project.* CSIRO Marine and Atmospheric Research and Bureau of Meteorology (CAWCR) and the Department of the Environment: Melbourne, Australia. Available from: http://climatechangeinaustralia.com.au/

Haigh, I., E.M.S. Wijeratne, L. MacPherson, C. Pattiaratchi, M. Mason, R. Crompton, and S. George, 2014: Estimating present day extreme water level exceedance probabilities around the coastline of Australia: tides, extra-tropical storm surges and mean sea level. *Climate Dynamics*, **42**, 121–138.

Hunter, J., 2012: A simple technique for estimating an allowance for uncertain sea-level rise. *Climatic Change*, **113**, 239–252.

McInnes, K.L., J.A. Church, D. Monselesan, J.R. Hunter, J.G. O'Grady, I.D. Haigh, and X. Zhang, 2015: Sea-level Rise Projections for Australia: Information for Impact and Adaptation Planning. *Australian Meteorological and Oceanographic Journal*, (in press).

Wong, P.-P., I.J. Losada, J.P. Gattuso, J. Hinkel, A. Khattabi, K.L. McInnes, Y. Saito, and A. Sallenger, 2014: Coastal Systems and Low-Lying Areas. In: *Climate Change 2014:Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, (in press).

Impact Modelling: General Needs and Working Group II Experience

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In this talk I will present a broad overview of how current and future climate information has been used over the history of the IPCC WGII, but particularly focusing on the Fifth Assessment Report (AR5). Trends in how the use has changed over the course of the different reports will be examined. Examples of recent use in various sectors, such as human health, agriculture, water resources, energy, and infrastructure will be presented particularly in the context of adaptation planning. This will also entail a discussion of the uses of uncertainty in future climate change information in the impacts context. I will give particular attention to how the use of climate information has evolved as more emphasis is placed on decision-making under uncertainty and complex vulnerability studies. These latter concerns will involve examining the use of climate information in both the bottom up and top down approaches to adaptation work. I will also discuss the growing need and use of information about other aspects of the future in addition to climate, such as population change and GDP. Finally I will comment on how impacts research is evolving in the future in the context of CMIP6.

Northwest Climate Assessment: a Risk-based Approach

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As part of the US National Climate Assessment, the Northwest region (covering the states of Washington, Oregon, Idaho, and western Montana) undertook a process of climate risk assessment. This process included an expert evaluation of previously identified impacts, their likelihoods, and consequences, and engaged experts from both academia and natural resource management practice (federal, tribal, state, private, and non-profit) in a workshop setting. An important input was a list of 11 risks compiled by state agencies in Oregon. By considering jointly the likelihoods, consequences, and adaptive capacity, participants arrived at an approximately ranked list of risks which was further assessed and prioritized through a series of risk scoring exercises to arrive at the top three climate risks facing the Northwest: a) changes in amount and timing of streamflow related to snowmelt, causing far-reaching ecological and socioeconomic consequences; b) coastal erosion and inundation, and changing ocean acidity combine with low adaptive capacity to create large risks; and c) impact of wildfire, insect outbreaks, and diseases will cause large areas of forest mortality and long-term transformation of forest landscapes. Additional work characterized the drivers of those risks on the regional scale.

The year 2015 has provided an interesting test case for many of these risks. A warm, but not particularly dry, winter produced very little snowpack in the mountains. This was followed by a series of drought declarations beginning early in the spring, and in the summer, low or record low streamflow in many streams, and record wildfires. The temperatures in 2015 are similar to those expected in the 2040s (RCP8.5) to 2080s (RCP4.5).

References

Dalton, M., P.W. Mote, and A.K. Snover (eds.), 2013: *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities.* Island Press. 224 pp.

Providing High Resolution Climate Information in the Southeast Asian Region for Impacts and Local Planning Applications

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Southeast Asia (SEA), including the Philippines, is one of the most vulnerable regions in the world to the impacts of climate change. It is significantly affected by climate and weather events that have serious implications to socio-economic development and population well-being. According to the IPCC Fourth Assessment Report (IPCC, 2013), temperatures across SEA has been increasing by 0.14°C to 0.20°C per decade since the 1960s and are projected to increase by more then 3°C by the end of the century under the RCP8.5 scenario. A ranking of countries in terms of vulnerability to climate change (Maplecroft, 2011) has identified Bangladesh, the Philippines, Vietnam, and Indonesia as countries that have high population growth rates and have emerging economies and consequently are at 'extreme risk' to climate change.

Given the potential impacts of a globally warmer world to the Southeast Asian Region, it is hence critical to have high resolution climate change projection scenarios to analyze the range of potential climatic impacts, including extreme events, that can happen in the future. These climate change scenarios will greatly assist in impacts and vulnerability studies and in the development of suitable adaptation options. Individual countries, which mostly have developing economies, in the region however are challenged with limitations in both human capacity and technological and infrastructure resources. Hence, existing studies on downscaled climate have mostly been on domains that are not large enough to cover the SEA region (e.g., Ngo-Duc et al., 2012; Tangang and Juneng, 2011; Tangang et al., 2012) and tailored to particular countries with data that are not publicly accessible for other parties to use. In this light, a Southeast Asia Regional Climate Downscaling Collaborative group (now CORDEX-SEA) has been formed to enhance climate change science in the region, to provide downscaled climate projection scenarios for impacts and adaptation applications in the Southeast Asian region, and to strengthen human capacity in the region through training and development of young climate scientists.

While CORDEX-SEA has provided a good platform for collaboration between climate scientists in the SEA region, there are challenges and opportunities ranging from science and technical issues (e.g. model performance and applicability) to bridging communications, collaboration, and application with impacts and direct user applications (from impacts modelers to local planners and risk managers). One science issue is the resolution of climate information provided. The SEA region, especially the Philippines and Indonesia, are highly archipelagic in nature with many areas that have complex topography (flat coastal areas with mountain ranges). Most climate information available are 25 kilometer-resolution at best, which are still coarse and fail to capture the relevant local climate types that are driven not just by larger scale synoptic processes but also by local scale dynamics. The resolution is also coarse in the context of impacts analysis especially for specific vulnerable communities and areas for these countries.

Given climate information, scenario-based planning can be better emphasized and mainstreamed to users and planners. This poses a challenge for initiatives such as CORDEX-SEA not only to connect with communities of users and impact modelers but also to better interface with key national agencies that may be mandated by the national government to provide climate projections data for government led initiatives. The use of information solely from government mandated agencies can severely limit the range of projections that can be utilized by government led adaptation projects for national development. Scenario based planning itself can be strategically promoted where previous and current modes of application have tend towards using a single GCM output downscaled with one regional climate model under one projection scenario. This can be coupled with better guidance on how to communicate uncertainties and how to deal with uncertainties in developing climate adaptation options and addressing future potential extreme impacts.

Lastly, moving towards trans-disciplinary approach from the generation/production to the analysis to the application of climate information to developing potential adaptation options and solutions continues to be a challenge. This will involve an interactive dynamic relationship between disciplines and different stakeholders for designing the appropriate climate information needed. Such an approach can deviate from discipline oriented methodologies but rather can tackle climate change through thematic issues and/or sectoral applications (e.g., water security, coastal cities at risk, etc.) where future climatic impacts are deemed to be significant.

References

IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 688 pp.

Maplecroft, 2011: World's fastest growing populations increasingly vulnerable to the impacts of climate change – 4th global atlas reports. Accessed 1 September 2015 from http://maplecroft.com/about/news/ccvi_2012.html

Ngo-Duc, T., Q.T. Nguyen, T.L. Trinh, T.H. Vu, V.T. Phan, and V.C. Pham, 2012: Near future climate projections over the Red River Delta of Vietnam using the Regional Climate Model Version 3, *Sains Malaysiana*, **41**(11), 1325–1334.

Tangang, FT, and L. Juneng, 2011: Climate projection downscaling for Malaysia and Sabah-Sarawak using Hadley Centre PRECIS Model. Technical Consultation Report for the National Hydraulic Research Institute of Malaysia (NAHRIM).

Tangang, F.T., L. Juneng, E. Salimun, M.S. Kwan, J.L. Loh, and H. Muhamad, 2012: Climate change and variability over Malaysia: Gaps in Science and Research Information. *Sains Malaysiana*, **14**(11),1355–1366.

A Decision-maker Perspective on Climate Information from Regional Climate Projections

Judith A. Omumbo

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The past decade has seen an increased interest in and understanding of the impacts of climate variability and trends on our environment and the recognition that these impacts are likely to increase in magnitude with climate change. In many regions there is an increasing likelihood of extreme climate events. Today, climate is central to the development agendas of most countries and is a key consideration in the achievement of the Millennium Development Goals.

Protecting populations from climate impacts has become a priority for diverse sectors including agriculture, water resources and the public health community. The need for this is greatest in developing countries, where vulnerable people do not have the basic economic choices and infrastructure to cope with the varying climate. These communities bear a disproportionately large burden of climate related disasters while having the poorest access to effective protection against their cascading and often long-term impacts. Climate change will exacerbate this inequity.

There is an urgent need for the development of climate information services to serve research, educational and operational needs of decision makers and their partners. Much as the past decade has seen a proliferation of relevant and important data and information from climate science, to date, this information is largely under-utilized by other sectors of society.

This presentation uses the example of regional climate projections to discuss some of the challenges faced by decision-makers and other users of climate information. It addresses gaps in available models and common misconceptions about decision makers. A few recommendations derived from user experiences are made that would satisfy user needs and help fill the gaps identified.

References

Connor, S.J., J. Omumbo, C. Green C J. Da Silva, G. Mantilla, C. Delacollette, S. Hales, D. Rogers, and M. Thomson, 2010: Health and Climate – Needs. *Procedia Environmental Sciences*, **1**, 27–36.

Connor, S.J., P. Ceccato, T. Dinku, J.A. Omumbo, E.K. Grover-Kopec, and M.C. Thomson, 2006: Using Climate Information for Improved Health in Africa: Relevance, Constraints and Opportunities. *Journal of Geospatial Health*, **1**, 17–31.

IPCC, 2013: Annex I: Atlas of Global and Regional Climate Projections [van Oldenborgh, G.J., M. Collins, J. Arblaster, J.H. Christensen, J. Marotzke, S.B. Power, M. Rummukainen and T. Zhou (eds.)]. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1311–1393.

Thomson, M.C., S. Mason, B. Platzer, A. Mihretie, J. Omumbo, G. Mantilla, P. Ceccato, M. Jancloes and S. Connor, 2014: Climate and health in Africa. *Earth Perspectives*, **1** (17), doi:10.1186/2194-6434-1-17.

From Science to Practice: Impact of Culture on Policy Transferability – A Case of Flood Risk Management Policies

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A high degree of transfer of policy ideas, institutions and programmes has been observed over decades. It occurred at all levels of development, including cross-regional, cross-national and sub-national levels. These transfers have significantly been fostered by globalisation processes, which have dramatically increased communication between different parts of the world. A high degree of transfer is also applied to urban planning policies to tackle with challenges in climate change. Various policies have been developed based on technocratic policy making approach, which has provided solutions and brought successful practices in many cases. Policies which resulted in good practices are often transferred to other places with an expectation of solving problems in general. However, previous experiences have shown that a policy that has been successfully applied in one place is not necessarily able to generate similar expected outcomes when applied without adaptation in other places with different contexts (Knieling and Othengrafen, 2009; Sanyal, 2005).

These unexpected results have brought a significant amount of attention to the subject of transfer in the fields of political sciences and spatial planning over recent years (Stead et al. 2008). A question 'under what circumstances and to what extent will a programme that works there also work here?' has been investigated. Evidences shown in various studies have indicated that there are more elements than formal institutions (which include, for instance, policies and organisational structure) that influence outcomes. They are, for instance, resource constraints, economic conditions, political environments and social discourses. These elements are interrelated and form complex implementation environments. Amongst these factors, many studies have pointed out the significant influence of culture on decision making in territorial management process and the determination of policy transferability (Friedmann, 2005; De Jong and Mamadouh, 2002; Sanyal, 2005; Ostrom, 2005; Knieling and Othengrafen, 2009).

Friedmann (2005) asserts that, '… a universal planning discourse must proceed by way of an acknowledgement of local, regional, and national differences in planning institutions and practices; I shall call them cultures.' The term 'culture' here refers to ideas, customs and social behaviours shared by involved actors in management of a given territory. The above statement emphasises the significance of cultures in the processes of policy-making and implementation. It implies a crucial role of culture on shaping how plans and policies are understood and reacted upon in different settings.

A comparative research conducted to understand impacts of culture on policy implementation in floodplain management by Rongwiriyaphanich (2014), using the Rhine-Meuse Delta in the Netherlands and the lower part of Chao Phraya Delta in Thailand as case studies, has confirmed the crucial role of culture as stated above. This study also validates arguments given by various studies regarding the importance of 'conformity' between policy contents and local cultures for enhancing achievement of policy implementation (such as De Jong and Mamadouh, 2002 and Stead et al., 2008). This implies that it is crucial that policy makers understand their own cultural contexts and integrate local, regional, and national differences of cultures into policy making and implementation processes in order to promote the desired outcomes that planning objectives aim for in practice.

Another significant finding of the research reveals that the values of 'cultures' are not taken-for-granted nor static. Rather, they are dynamic normative values that are subject to changes over time, underpinned by their interrelationships with other development conditions that are also dynamic. This observation corresponds to various studies, including Friedmann (2005) and Ostrom (2005), suggesting that policy makers be aware of possible consequences created by their interventions on changes of culture. For instance, flood prevention measures provided by public sector to protect highly flood-prone areas reduced extent of floods. This change likely results in urbanisation patterns and activities that are sensitive to floods. Changes in physical attributes created the conditions, leading to a higher degree of flood risks. Actors then react to the changes by calling for management actions to correspond with the increased degree of problem control in order to avoid uncertain situations which might cause greater damages to the sensitive development patterns. In simpler term, an increased degree of flood protection in planning would likely result in the development of people's higher expectation for flood protection in the planning process. Cautious design and implementation of policies and plans with awareness about this interrelation is, therefore, essential as it would help minimise undesirable effects created by planning in practice.

References

De Jong, M.W., and V. Mamadouh, 2002: Two Contrasting Perspectives on Institutional Transplantation. In: *The Theory and Practice of Institutional Transplantation: Experiences with the Transfer of Policy Institutions* [de Jong, M.W., K. Lalenis and V. Mamadouh, (eds.)]. Dordrecht ; Boston ; London: Kluwer Academic Publishers, 19–32.

Friedmann, J., 2005: Planning Cultures in Transition. In: *Comparative Planning Cultures* [Sanyal, B. (Ed.)]. Routledge, New York, London, 29–44.

Knieling, J., and F. Othengrafen (eds.), 2009: *Planning Cultures in Europe: Decoding Cultural Phenomena in Urban and Regional Planning.* Farnham, Ashgate.

Ostrom, E., 2005: Doing Institutional Analysis: Digging Deeper Than Markets and Hierarchies. In: *Handbook of New Institutional Economics* [Ménard, C., and M.M. Shirley (eds.)]. Springer, The Netherlands, 819–848.

Rongwiriyaphanich, S., 2014: Understanding Culture in Territorial Management and its Implications for Spatial Planning: the case of floodplain management in urbanised delta regions in the Netherlands and Thailand. Delft: A+BE | Architecture And The Built Environment, The Netherlands.

Sanyal, B., 2005: *Comparative Planning Cultures.* Routledge, New York, London.

Stead, D., M. de Jong, and I. Reinholde, 2008: Urban Transport Policy Transfer in Central and Eastern Europe. *The Planning Review*, **44**(1), 62–73.

From Science to Practice: Using Downscaled Projections for Participatory Scenario Building and Risk Assessments

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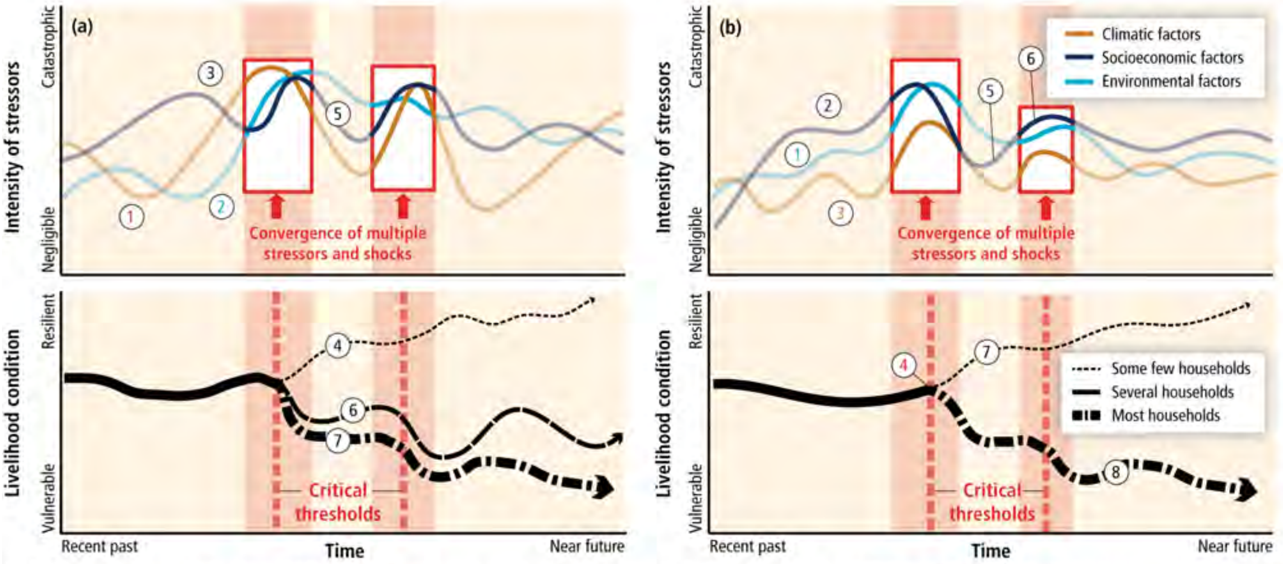
The IPCC Fifth Assessment Report, WGII, understands risk of climate-related impacts as resulting from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems (IPCC, 2014). Vulnerability is defined as the propensity or predisposition to be adversely affected; it encompasses, among other elements, sensitivity or susceptibility to harm and lack of capacity to cope and adapt. Vulnerability in social systems is unequally distributed within and between communities, countries, and regions. Differences arise from non-climatic factors and from multidimensional inequalities often produced by uneven development processes. People who are socially, economically, culturally, politically, institutionally, or otherwise marginalized are especially vulnerable to climate change (Olsson et al., 2014). This heightened vulnerability is the product of intersecting social processes that result in inequalities in socioeconomic status and income, as well as in exposure. Impact assessments and risk analysis studies, thus, need to take into account social processes that shape differential vulnerability and exposure. Therefore, the usage of regional and down-scaled climate projections needs to be coupled with an exploration of multidimensional vulnerabilities.

A suite of climate-related impacts on people's lives and livelihoods have already been observed, typically coupled with socio-economic, political, institutional, and environmental stressors (see Figure 1). Climate-related hazards, including subtle shifts and trends to extreme events, affect people's lives directly through impacts on livelihoods, such as losses in crop yields, destroyed homes, and lack of food, and indirectly through increased food prices, particularly among poor and marginalized populations (Olsson et al., 2014). Yet, some impacts are less visible and hence much harder to measure and incorporate into risks analyses, albeit not less trivial, such as loss of sense of place, emotional and psychological distress, and increased workloads (Olsson et al., 2014; Tschakert et al., 2013). Key risks of future impacts include risk of death, injury, ill-health, and disrupted or entirely lost livelihoods, food insecurity, breakdown of critical infrastructure, and loss of ecosystems and ecosystem services upon which livelihoods depend (IPCC, 2014). The use of climate projections to facilitate impact and risk analysis studies can be enhanced through creative learning environments that allow vulnerable populations to grapple with likely future climate realities and the multiple ways they may interact with their livelihoods and broader development trajectories.

Learning about and embracing change, including climate change, is increasingly important for climate change adaptation (e.g., Fazey et al., 2010; Kuruppu and Liverman, 2011; Tschakert et al., 2014). For instance, Fazey and colleagues (2010) describe processes of 'co-learning' in the Solomon Islands in which community members, researchers, and non-governmental organizations (NGOs) negotiate understandings of drivers and trajectories of change. Such co-learning facilitates reflective thinking, capacity for dialogue and problem solving, robust data generation, and local ownership and responsibility over identified solutions. One particular tool in such collective and often iterative learning processes is community-based scenario building; it can create the right space to explore change trajectories, encourage anticipatory learning, and enable adaptation planning that reduces risk under climatic uncertainty (Enfors et al., 2009; Frittaion et al., 2010; Sheppard et al., 2011).

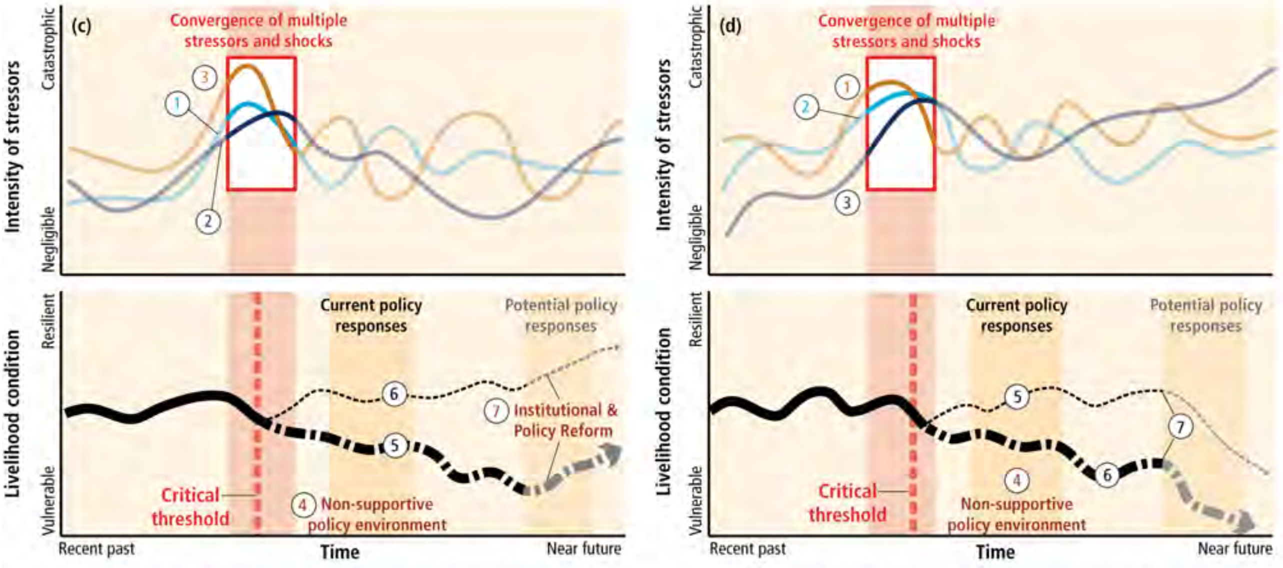
I draw from two adaptation projects—one in Ghana and Tanzania and the other one in India—to illustrate opportunities and pitfalls in the use of downscaled climate projections for participatory scenario building. Scenarios, quantitative and qualitative, constitute narratives of the future that retain perceptions and empirical knowledge while enabling people to imagine possible futures beyond everyday experiences (Frittaion et al., 2010). In these two projects, we used scenario building to enhance participants' capacity to embrace change by exploring a range of possible futures, stretching past and present insights and imaginations, and weighing feasible responses. Scenario building provides a space for participants to distill science information and complex feedbacks across scales and between the social and the natural for local relevance.

Project activities allowed participants to envision how their communities would look like in 25–30 years into the future and introduced downscaled climate projections into emerging narratives. The participants created their



(a) Botswana's drylands (Sallu et al., 2010). Over the past 30 years, rural households have faced droughts, late onset and increased unpredictability of rainfall, and frost①, drying of Lake Xau, and land degradation②. Households responded differently to these stressors, given their financial and physical assets, diversification of and within livelihood activities, family relations, and institutional and governmental support. Despite weakening of social networks and declining livestock due to lack of water ③, distinct livelihood trajectories emerged. "Accumulators" were often able to benefit from crises, for instance through access to salaried employment ④ or new hunting quotas⑤, while "dependent" households showed a degenerative trajectory, losing more and more livelihood assets, and becoming reliant on governmental support after another period of convergent stressors⑥. "Diversifiers" had trajectories fluctuating between vulnerable and resilient states⑦.

(b) Coastal Bangladesh (Pouliotte et al., 2010). In the Sunderbans, a combination of environmental and socioeconomic factors, out of which climatic stressors appear to play only a minor role, have changed livelihoods: saltwater intrusion① due to the construction and poor management of the Bangladeshi Coastal Embankment Project, the construction of a dam in India, local water diversions②, and sea level rise and storm surges③. The convergence of these stressors caused households to cross a critical threshold from rice and vegetable cultivation to saltwater shrimp farming ④. A strong export market and international donor and national government support facilitated this shift⑤. However, increasing density of shrimp farming then triggered rising disease levels ⑥. Wealth and power started to become more concentrated among a few affluent families ⑦ while livelihood options for the poorer households further diminished due to lacking resources to grow crops in salinated water, the loss of grazing areas and dung from formerly accessible rice fields⑧, and rising disease levels⑥.



(c) Mountain environments (McDowell and Hess, 2012). Indigenous Aymara farmers in highland Bolivia face land scarcity, pervasive poverty, climate change, and lack of infrastructure due in part to racism and institutional marginalization. The retreat of the Mururata glacier causes water shortages ①, compounded by the increased water requirements of cash crops on smaller and smaller "minifundios" and market uncertainties ②. High temperatures amplify evaporation, and flash floods coupled with delayed rainfall cause irrigation canals to collapse③. The current policy environment makes it difficult to access loans and obtain land titles④, pushing many farmers onto downward livelihood trajectories⑤while those who can afford it invest in fruit and vegetable trees at higher altitudes ⑥. Sustained access to land, technical assistance, and irrigation infrastructure would be effective policy responses to enhance well-being⑦.

(d) Urban flooding in Lagos (Adelekan, 2010). Flooding threatens the livelihoods of people in Lagos, Nigeria, where >70 % live in slums. Increased severity in rainstorms, sea level rise, and storm surges①coupled with the destruction of mangroves and wetlands②, disturb people's jobs as traders, wharf workers, and artisans, while destroying physical and human assets. Urban management, infrastructure for water supply, and stormwater drainage have not kept up with urban growth③. Inadequate policy responses, including uncontrolled land reclamation, make these communities highly vulnerable to flooding ④. Only some residents can afford sand and broken sandcrete blocks ⑤. Livelihood conditions in these slums are expected to further erode for most households⑥. Given policy priorities for the construction of high-income residential areas, current residents fear eviction⑦.

Figure 1: Illustrative representation of four case studies that describe livelihood dynamics under simultaneous climatic, environmental, and socioeconomic stressors, shocks, and policy responses—leading to differential livelihood trajectories over time. The red boxes indicate specific critical moments when stressors converge, threatening livelihoods and well-being. Key variables and impacts numbered in the illustrations correspond to the developments described in the captions. [Source: Olsson et al., 2014, Figure 13-3].

own plausible scenarios based on predictable trends extrapolated from the past (e.g., continuous bush fires), emerging vulnerability trends (e.g., crime), and unpredictable events or surprises (e.g., extreme flooding). From the perspective of scholars-facilitators, it is essential not only to be able to interpret downscaled projections and extract elements that are of local significance, but also to package this information in ways that allow people to engage with uncertain futures and develop some sense of ownership over them. In the case studies, the following elements extracted from downscaled projections were most meaningful: minimum and maximum temperature for different seasons, number of very hot days, number of rain days, annual precipitation, (un)predictability of the onset of the rainy season, dry spells during the rainy season (consecutive dry days), extremely wet days, and month(s) with most intense rainfall.

The scenario building created spaces to grapple with climate futures and possibly looming thresholds, embedded in local realities (Tschakert et al., 2014). The significance of participatory narratives lies not in the prediction of the future but in an injection of imagination, collaboration, and place-based meaning into science predictions. However, it is not always easy for disadvantaged populations to envision and embrace the future, hampered by religious or cultural paradigms. Such complex information, explored through iterative stages in the collective learning process, requires time to sink in. People need to examine likely future impacts and risk from various angles in order to develop flexible steps for adaptation planning, identify acceptable trade-offs, and possible winners and losers. We, as researchers, need to understand what information is 'good enough' to enable 'sympathetic navigating' in iterative learning, by amending or complementing partial knowledge, by stimulating imaginativeness, and by making space for informed deliberation, experimentation, and mistakes (Tschakert et al., 2014).

References

Enfors, E.I., L.J. Gordon, G.D. Peterson, and D. Bossio, 2008: Making investments in dryland development work: Participatory scenario planning in the Makanya Catchment, Tanzania. *Ecology and Society,* **13**(2) 42, http://www.ecologyandsociety.org/vol13/iss2/art42.

Fazey, I., M. Kesby, A. Evely, I. Latham, D. Wagatora, J.-E. Hagasua, M.S. Reed, and M. Chrisitie, 2010: A three-tiered approach to participatory vulnerability assessment in the Solomon Islands. *Global Environmental Change,* **20**, 713–728.

Frittaion, C.M., P.N. Duinker, and J.L. Grant, 2010: Narratives of the future: Suspending disbelief in forest-sector scenarios. *Futures,* **42**, 1156–1165.

IPCC, 2014: Summary for Policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1–32.

Kuruppu, N., and D. Liverman, 2011: Mental preparation for climate adaptation: The role of cognition and culture in enhancing adaptive capacity of water management in Kiribati. *Global Environmental Change,* **21**(2), 657–669.

Olsson, L., M. Opondo, P. Tschakert, A. Agrawal, S.H. Eriksen, S. Ma, L.N. Perch, and S.A. Zakieldeen, 2014: Livelihoods and Poverty. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 793–832.

Sheppard, S.R.J., A. Shaw, D. Flanders, S. Burch, A. Wiek, J. Carmichael, J. Robinson, and S. Cohen, 2011: Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualization. *Futures,* **43**(4), 400–412.

Tschakert, P., R. Tutu, and A. Alcaro, 2013: Embodied experiences of environmental and climatic changes in landscapes of everyday life in Ghana. Emotion, *Space and Society*, **7**, 13–25.

Tschakert, P., K. Dietrich, K. Tamminga, E. Prins, J. Shaffer, E. Liwenga and A. Asiedu, 2014: Envisioning and learning under climatic uncertainty: A case study on embracing change from Ghana and Tanzania. *Environment and Planning A*, **46**(5), 1049–1067.

WGI Regional Climate Projections: The WGI AR5 Atlas

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The Annex I 'Atlas' was a new element in the WGI report. Its aim was to facilitate the use of information of CMIP5 model output without the overhead of having to discuss each map. We tried many different ideas to present the projections in a way that was both easy to use and covered the main aspects that we wanted to convey. These covered the regionalisation, an extension of the SREX regions and seasonally varying projections capturing rainy and dry seasons in as much of the world as possible. We also wanted to represent the model uncertainty and natural variability to propagate the full range of possibilities rather than just the multi-model mean. In the end a format was chosen to have maps of high-end, median and low-end changes, with areas of large natural variability indicated by hatching. Next to this were time series plots of the regional averages that give a feeling for the interannual variability and the change in 20-year mean that has a large contribution from model uncertainties for each scenario.

The selection in the printed report is necessarily limited. The electronic WGI AR5 Supplementary Material (www.climatechange2013.org/report/full-report/) gives more seasons and scenarios. An interactive site (http://climexp.knmi.nl/atlas/) built from the same software offers an even wider range of options, including non-standard seasons, arbitrary regions and countries (states) and many more variables.

References

IPCC, 2013: Annex I: Atlas of Global and Regional Climate Projections [van Oldenborgh, G.J., M. Collins, J. Arblaster, J.H. Christensen, J. Marotzke, S.B. Power, M. Rummukainen and T. Zhou (eds.)]. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1311–1394.

3rd National Communication on Climate Change in Argentina

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The presentation provides a general description of the 3rd National Communication on Climate Change (3CN, 2015) elaborated by the Republic of Argentina in response to the commitments undertaken with the United Nations Framework Convention on Climate Change (UNFCCC), and based on the principle of common but differentiated responsibilities. 3CN objectives are as follows: i) to update UNFCCC on the observed and projected climate change and associated impacts in the country, ii) to strengthen, integrate and disseminate the national strategy related with climate change, and iii) to identify and develop public policies for adaptation and mitigation of climate change.

3CN development was leaded by the National Secretary of Environment and Sustainable Development in coordination with different institutions covering multiple socio-economic-political-scientific dimensions and represented by multiple sectors including public, private and civil society organizations.3CN was organized under four main components: 1) harnessing national capacities for climate change mitigation, which includes the update of the national inventory of GHG emissions and the assessment of the policies needed for mitigation; 2) strengthening of the national agenda for adaptation, which includes the assessment of the climate change impacts in the country, the identification of the sectors and regions most vulnerable and recommendations for new adaptation actions; 3) institutional strengthening, capacity building and dissemination of 3CN results; and 4) 3CN project management.

In the context of 3CN component 2, four main activities have been made which are briefly summarized here and more extended described in three companion posters also presented at the Workshop: a) implementation of a framework for determining the multi-model ensemble of climate simulations considered for the regional study b) assessment of observed and projected climate changes in Argentina, c) implementation of a climate data portal including both observed and simulated data for regional climate change impact studies, and d) assessments of climate change impacts on regional natural ecosystems and specific socio-economic sectors.

a) Climate simulation framework: as described in Camilloni et al. (2015), 3CN includes the assessment of a large set of climate model simulations from global climate models (GCM) included in CMIP5, and regional climate models (RCM) forced by CMIP3 GCMs. Quantitative metrics based on the integration of several model skill indices were made in order to rank model performance in the region. Also model systematic errors were removed from climate simulations in order to reduce the uncertainties and improve the skill of the impact model simulations.

b) Assessment of observed and projected climate changes in Argentina: A comprehensive assessment for the past decades as well as for the future was performed as it is described in Barros et al. (2015). Since the second national climate communication (2CN) made in 2007, the understanding of the observations and ability of the models to simulate the different features of the regional climate have increased substantially. The latter resulted in that 3CN provides stronger basis to justify the most important climate change signals detected in the region. Moreover, a better estimation of the uncertainties and confidence levels, inspired in IPCC uncertainty guidance, was made in 3CN as well as a quantitative assessment of observed and projected changes in extremes, which was not possible to be made in 2CN.

c) Climate Data Portal: With the objective of fulfilling the climate data needs for impact studies, a data portal was developed as described by Sörensson et al. (2015). The dataset includes information covering the country derived from different observation gridded datasets and including the set of climate simulations considered in the assessment described in b). In particular, the corrected climate projections are provided. The portal includes a web interface that facilitates the identification and downloading of the data selected by the user. The data portal is open access upon registration at http://3cn.cima.fcen.uba.ar, allowing for identification of users, accesses, and downloads.

d) Impact studies: The climate change impact on five sectors was assessed as described in Sörensson et al. (2015): agriculture, livestock, energy, work market and tourism. Also four ecological regions where studied: Patagonia, Andes mountains, Arid region and Argentinean ocean. Finally, social vulnerability assessment and climate change risk maps were carried out using both the climate data and the outcomes of the aforementioned impact studies. Results allows identifying the country regions with largest risk levels associated with extreme precipitation and extreme temperature.

References

3CN, 2015: *3rd National Communication on Climate Change in Argentina: Final Reports.* Available at: http://www.ambiente.gov.ar/?idseccion=356.

Barros, V., C. Vera, E. Agosta, D. Araneo, I. Camilloni, A. Carril, M Doyle, O. Frumento, M. Nuñez, M. Ortiz de Zárate, O. Penalba, M. Rusticucci., C. Saulo, and S. Solman, 2015: *Observed and XXI Century Projected Climate Change in Argentina*. IPCC Workshop on Regional Climate Projections, Sao Jose dos Campos, 15–18 September 2015.

Camilloni, I., S. Solman, V. Barros, A. Carril, and M. Nuñez, 2015: *Climate Change in Argentina: Third National Communication - The framework for model selection and development of high resolution climate projections.* IPCC Workshop on Regional Climate Projections, Sao Jose dos Campos, 15–18 September 2015.

Sörensson, A., C. Vera, V. Barros, and M.I. Ortiz de Zárate, 2015: *Impact studies of 3rd National Assessment of Argentina: Data Portal and Key Results.* IPCC Workshop on Regional Climate Projections, Sao Jose dos Campos, 15–18 September 2015.

The Importance of Bias Correction for Impact Assessments of Water-related Disasters on a Regional Scale

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Bias correction has an important role in linking climate projections and impact on water-related disasters. In this presentation, we will introduce our efforts to propose and compare various methods of bias correction. The key results can be summarized as follows: (i) a method to develop the climate forcings to impact models of water-related disasters on a regional scale are proposed considering the bias of the climate projections; (ii) the characteristics of bias correction approaches, which have previously been proposed in various studies, are summarized from the aspect of the difference of future change between before and after bias correction; (iii) the importance of the selection of climate projections is shown to be important for bias correction as well.

Development of climate forcings is one of the major issues in the impact assessments of climate change. For the assessment of water-related disasters, river discharge is a key variable to project. This projection can be conducted with the climate forcings. We proposed the method to develop climate forcings with considering appropriate bias correction. Since it was significant to consider the difference in GCMs, future projections by multiple GCMs were used for the development of climate forcings. In some regional assessment studies, the limited availability of reference data, which is necessary to correct the bias, is a severe problem. Consideration of the inadequacy of reference data is also included in our methodology.

Uncertainty of projection is another major issue for an impact assessment study. The difference in bias correction applied also affects the results of the assessment. Since various bias correction approaches were classified into several categories in our previous study (Watanabe et al., 2012), we compared the river discharge which was simulated by climate forcings developed among those categories. One surprising result was the large difference of river discharge, which was comparable to the spread of the future projection by GCMs. This result indicated that the difference of the future projection among GCMs were still large after bias correction. A case study in the Chao Phraya River (Watanabe et al., 2014) concluded that the river discharge simulated with climate forcings based on a future projection from a GCM that did not have sufficient ability to reproduce current and historical climates tended to show a different characteristics compared with other river discharges simulated with other climate forcings. The ability of the bias correction was affected by the ability of GCM.

Bias correction can bridge the gap between climate projection and impact assessments. Continuous efforts to study scenario development with bias correction contribute to appropriate assessments, especially in regional scales. Based on this background, our previous approaches and results, current problems, and prospects for improvement with respect to this topic will be introduced in this presentation.

References

Watanabe, S., Y. Hirabayashi, S. Kotsuki, N. Hanasaki, K. Tanaka, C.M.R. Mateo, M. Kiguchi, E. Ikoma, S. Kanae, and T. Oki, 2014: Application of performance metrics to climate models to projecting future river discharge in the Chao Phraya River basin. *Hydrological Research Letters*, **8**(1), 33–38.

Watanabe, S., S. Kanae, S. Seto, Y. Hirabayashi, and T. Oki, 2012: Intercomparison of previous and new methods for bias-corrected monthly temperature and precipitation simulated by multiple climate models. *J. Geophys. Res.*, **117**, doi:10.1029/2012JD018192.

Australian National Climate Projections: Use of Downscaling and the Importance of Distinguishing Knowledge and Data

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For more than two decades, CSIRO has had a leading role in providing national climate change projections for Australia. Projections were published in 1992, 1996, 2001 and (with the Bureau of Meteorology) 2007, and have been widely cited and used in adaptation work. Early in 2015 CSIRO and BoM released new national projections for Australia based on the CMIP5 GCM ensemble and some downscaling (CSIRO and BoM, 2015, and poster at this workshop). These were aimed specifically at supporting the needs of natural resource management, but also serve wider national needs. Here we summarise the concepts underpinning our approach and share learnings potentially relevant to this workshop.

In designing a projection system, it was useful to distinguish between two types of projection information (Figure 1). First, there is scientific knowledge about the range of plausible climate change based on an assessment process. Such knowledge can synthesise a range of relevant evidence (e.g., results from different GCM ensembles, downscaling, process understanding), may convey messages in qualitative terms only, and may also have attached confidence ratings (e.g., as in IPCC assessments, and in the 2015 Australian projections). This knowledge can be used in context setting for more detailed projection applications, but may also be sufficient information in itself for impact assessment aimed at narrative development. Secondly, there are projection data sets tailored for use in technical risk assessments (produced through downscaling or simpler approaches). Although these two products draw on similar source material (primarily global and regional climate model output), the information they can contain about future climate can be different. Often in meeting user needs, only a subset of the range of plausible future climate is considered in technical applications. This may be due to user needs for downscaled information only available from limited models, or their need to work with a small number of scenarios provided by the outputs of single climate models. In the push to create sophisticated datasets that meet demanding technical needs, the larger perspective of representativeness can go by the wayside, and there is a risk that data users will tacitly believe their data are representative of future change when in fact they may not be.

Thus a key challenge for risk assessment is for projection providers and users to ensure that the two aspects of knowledge and data are as harmonised as possible. This can be achieved in a projection system in one of two ways. The first is that the providers use the same set of GCM and downscaling simulations for both assessment and technical data supply (with all key uncertainties represented as best as possible). This requires the

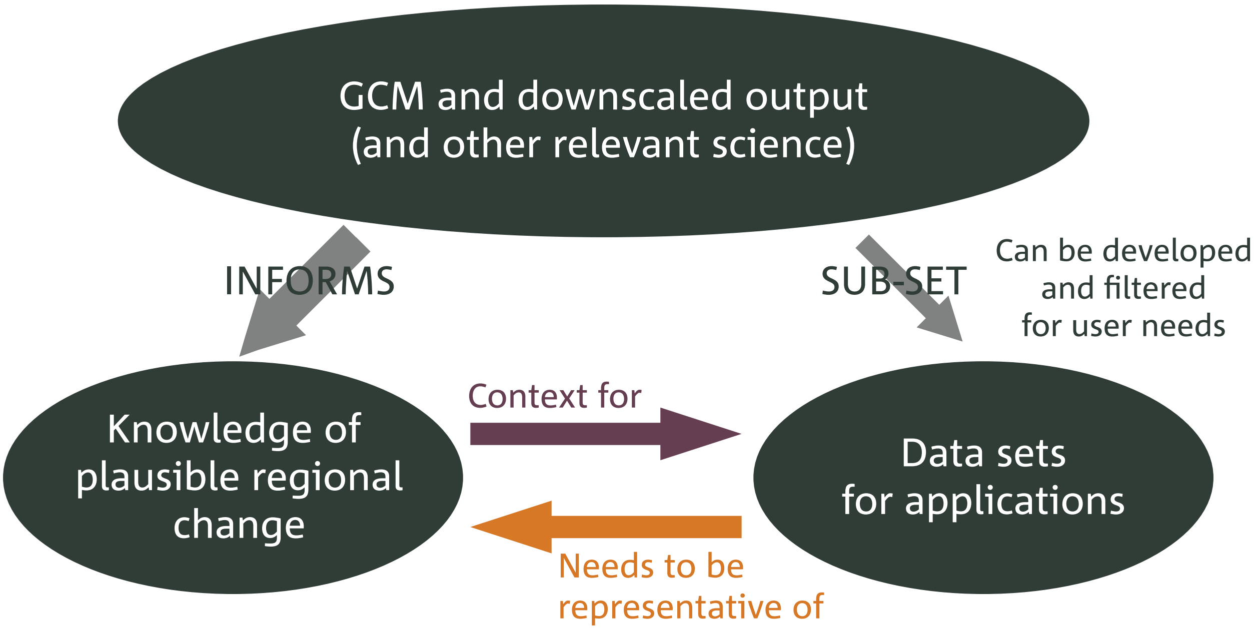

Figure 1: The relationship between types of climate change projection information.

development of large ensembles of application-ready datasets and the willingness of the user to use large ensembles. Or the second is to follow a process whereby the users' choice of projection data sets for their application is representative of current knowledge of regional climate change, or the users at least place the projection data sets they used in the context of that knowledge. In Australia's latest projections, the second alternative was used, and a tool (known as Climate Futures - Whetton et al., 2012) was provided to assist users to select a small of number projection data sets for technical application (GCM or downscaled) that contained a representative spread of projected climate changes relevant to the impact of interest. A need for such a process also arises in IPCC where impact studies to be assessed in WGII may use climate scenarios not necessarily representative of current assessment of regional climate change. It would perhaps be helpful, if over the IPCC assessment cycle, researchers (and eventually lead authors) were able to access up to date information illustrating the spread of regional results of CMIP5, and CMIP6 and CORDEX as it becomes available. Ideally, contextualisation could be done by authors of relevant papers rather than assessment by Lead Authors.

In the Australian projections, downscaled datasets were not the primary source of information, but were treated as a complementary source. Downscaling can give a different climate change signal than GCM hosts, and this can be more physically plausible due to the finer resolution of surface factors such as topography and coastlines. However, downscaling may not necessarily produce a more reliable climate change signal, different downscaling methods give different results and the downscaling may not representatively sample the uncertainty space presented by CMIP5. For Australia, limited availability of downscaled data sets means that existing resources do not comprehensively sample expected downscaling uncertainty (RCPs, CMIP5 models and differing downscaling methods). This meant that the regional change signal from available downscaling was assessed for regional insight, and then considered along with CMIP5 and other lines of evidence in assessing the full range of plausible climate change and confidence in that change. Available downscaled data may be selected for use in technical applications as part of a representative set of scenarios.

In the future, CSIRO and partner agencies will build towards the production of the next generation of climate projections and services, including building capacity to examine and combine outputs from CMIP6, CORDEX, etc., and improving methods for integrating projections with decadal prediction. Downscaling may be used in a more primary role if it is able to more fully account for the framework of uncertainties mentioned above and ideally if they add value.

References

CSIRO and BoM, 2015: *NRM climate change projections project.* CSIRO Marine and Atmospheric Research and Bureau of Meteorology (CAWCR) and the Department of the Environment: Melbourne, Australia. Available at http://climatechangeinaustralia.com.au/.

Whetton, P., K. Hennessy, J. Clarke, K. McInnes, and D. Kent, 2012: Use of Representative Climate Futures in impact and adaptation assessment. *Climatic Change*, **115**, 433–442.

Regional Climate Projections in the Baltic Sea Basin – Current State and Future Perspectives

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In the Baltic Sea Basin two assessments of Climate Change were prepared recently (2008, 2015) within so called BACC and BACC II projects (the Baltex and the Baltic Earth Assessment of Climate Change respectively). Both assessments were prepared to establish scientifically legitimised knowledge available for Baltic Sea catchment about climate change and its impacts. The programmes were focused purely on the science and documented the current consensus and dissensus on climate knowledge. The assessments were used by the intergovermental Baltic Marine Environment Protection Commission (HELCOM) as a basis of its activities and the political negotiation processes. Both BACC assessments (2008, 2015) were acompanied by a Thematic Reports by HELCOM published about one year earlier (HELCOM 2007, 2013).

The process of assessment preparation is similar to those undertaken by the IPCC. The assessments are the synthesis of available scientific literature: peer-reviewed publications, conference proceedings and reports of scientific institutions. The individual chapters are prepared by different groups of authors and peerreviewed by other groups of scientists. The overall summary for not scientists is available.

Reports assess the observed changes in atmospheric, hydrological and oceanographic conditions and present projected future changes as well as their potential impacts on the natural and socio-economical environments.

Projections of future climate change make use of general circulation models (GCMs). Such models give the description of climate in a set of grid points, regularly distributed in space and time with the same density over land and ocean. Their temporal resolution is relatively high; however, their spatial resolution is low. The grid scale (i.e. the difference between two neighbouring points) of present-day GCMs is in the range 100–300 km. To get estimates of regional climate, it is necessary to downscale the GCMs results. Downscaling is understood as a process linking large scale variables with small scale ones. There are two conceptually different ways of downscaling. One of them uses regional climate models (RCMs) nested in GCMs. RCMs have much higher resolution and can describe local features better, but still they are able to simulate the atmospheric state in a realistic manner in their skilful scales. The other group of downscaling methods uses empirical and/or statistical relations between the large scale variables being the result of GCMs and small scale variables describing regional and/or local climate conditions.

There is a long list of sources of uncertainty in models. Among them are the uncertainty related to our limited information on land use and GHG concentrations, limits in the amount of input data and their accuracy and the chaotic nature of weather. Many sub-grid processes have to be represented in models in a simplified form and are not very well described by these models. For example, the modeling of cloud formation, their optical and radiative features and creation of atmospheric precipitation are still burdened with considerable model error. The skill of methods for describing regional climate futures is limited also by the natural variability of climate.

Projections presented in both BACC assessments are based on RCMs simulations. The performance of RCMs in reproducing the climate in the Baltic Sea Basin of the recent past decades is assessed by comparison of simulations with real climate, giving an idea about possible biases (differences) between both. RCMs are able to simulate spatially coherent fields, but considerable biases have to be expected. Ensembles of RCMs were used to filter the occasional errors and assess the uncertainty. However the models are not fully independent because the shared codes.

The main limitations of RCM's simulations used for future climate projection in both BACC Assessments is that they were carried out for atmosphere only, prescribing SST (sea surface temperature) data taken from the driving model. As the GCMs only have a very crude representation of the Baltic Sea, this constitutes an additional source of uncertainty for the regional scenarios. Based on experiments with the Rossby Centre regional climate model in both coupled and uncoupled mode Meier et al. (2011) conclude that the coupled model version has the potential to improve the results of the downscaling considerably as SSTs and sea-ice conditions are more realistic than in the corresponding GCMs. The other way of improvement of simulation quality is addressing vegetation as well as biogeochemistry and ecosystem dynamics. The first trials were done (Wramneby et al., 2010) and they seem to be promising. For the Baltic Sea region they particularly find reduced albedo resulting from the snow-masking effect of forest expansion when the dynamic vegetation is included.

References

BACC Author Team, 2008: *Assessment of Climate Change for the Baltic Sea Basin*. Regional Climate Studies, Springer Verlag, Berlin, Heidelberg.

BACC II Author Team, 2015: *Second Assessment of Climate Change for the Baltic Sea Basin*. Regional Climate Studies, Springer International Publishing.

HELCOM, 2007: Climate Change in the Baltic Sea Area. HELCOM Thematic Assessment in 2007. *Baltic Sea Environment Proceedings*, **111**.

HELCOM, 2013: Climate Change in the Baltic Sea Area. HELCOM Thematic Assessment in 2013. *Baltic Sea Environment Proceedings*, **137**.

Meier, H.E.M., A. Höglund, R. Döscher, H. Andersson, U. Löptien, and E. Kjellström, 2011: Quality assessment of atmospheric surface fields over the Baltic Sea from an ensemble of regional climate model simulations with respect to ocean dynamics. *Oceanologica,* **53**, 193–227.

Wramneby, A., B. Smith, and P. Samuelsson, 2010: Hot spots of vegetation climate feedbacks under future greenhouse forcing in Europe. *J. Geophys. Res.*, doi:10.1029/2010JD014307.

From Global to National Assessment Report on Climate Change

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Up to now, IPCC has published five assessment reports. Such assessment reports have more focused on climate change issues on a global scale. From a national perspective, many countries also have published their respective national assessments. In China, two national assessment reports have been released.

China's national assessment reports aim to provide scientific basis for national socio-economic development strategy formulation, governmental participation in international activities and proper guidance of future research. The first National Assessment Report (NAR) on climate change in China was published in 2007 and the second one arrived in 2011. The Third National Assessment Report will be coming soon. A more comprehensive report on climate change science called 'Climate and Environment Change in China' (Qin, 2012) was also published.

IPCC assessment report (IAR) has established an important basis for national assessment reports. In China's NAR, the major theories and newest understandings about climate change directly come from the IAR. At the same time, the NAR also serves as a crucial supplement at the national level. It contains more specific and richer information about regional climate change, deeper understanding on climate change and the related impacts in the region. It imposes higher impact on decision makers of the country. However, for the NAR, it always faces more challenges, such as in understanding the causes of regional climate change, in certainty estimation of regional projection of future climate change, and thus leading to less confidence in evaluating impacts of future climate change in the region.

Some IPCC AR5 chapters, which mainly concerned detection and attribution of climate change at regional scale, climate phenomena and their linkage with future regional climate change, are of great value in facilitating the NAR activities. In the future, diverse tools such as those for dataset development, climate change indices (e.g., ETCCDI) definition, statistical and dynamical downscaling, and meteorological disaster cataloguing are suggested to be promoted by IPCC. Such efforts will encourage various nations to conduct NAR activities through a similar way, and further enrich our knowledge on climate change and resultant impacts through collecting information from NAR contributions.

When we realize the NAR as a supplement to IAR, the NAR products perhaps can be further improved to attract more target audience from policy-makers and general public.

References:

Editing Board, 2007: National Assessment Report on Climate Change. *China Science Press*, Beijing, 422 pp. (in Chinese).

Editing Board, 2012: The Second National Assessment Report on Climate Change. *China Science Press*, Beijing, 711 pp. (in Chinese).

Qin, D., 2012: Climate and Environment Change in China: 2012 Comprehensive Volume. *China Meteorological Press*, Beijing, (in Chinese).

Annex 5: Poster Abstracts

IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies

Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil
15–18 September 2015

POSTER ABSTRACTS

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The Cold Waves in Northern Algeria: Analysis and Impacts

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Algeria has been affected in recent years by extreme weather events. In February 2012, Algeria has been immersed in a cold snap often comparable to that of January 2005 or even further than that of February 1956. The objective of this work is to realize a typology of cold waves since 1980 on a number of stations in northern Algeria. The selected thresholds are based on a definition of "cold wave" geographically determined for Algeria.

The results indicate that the cold waves of January 2005 and February 2012, are quite exceptional. They are strongest for the past 3 decades. The World Meteorological Organization declaration (WMO-No 998 / WMO-No 1108) on the state of the global climate, class 2005 and 2012 respectively the 2nd and 9th among the hottest years of the last decade, ever observed. In order to know the characteristics and factors causing cold waves of January 2005 and February 2012, a climatic analysis and a synoptic conditions analysis of this extreme events have been effected. The results obtained shows that during the passage of these two cold waves, temperatures remained very low with even lower minima to the high plateaus regions. Snow fell in abundance. Snow has even been observed on the beaches and even progressively extended to the southern regions. Significant rainfall events were recorded with torrential rains collected on these two months, particularly in coastal areas. Indeed, the analysis of the maximum 24-hour rainfall, collected in the coastal city 'Bejaia' during a period 1970 to 2015, clearly demonstrates the exceptional character of February of 2012, with a maximum of 64 mm during the day on 03/02/2012, the highest daily value since 1971.

Intensity of these weather hazards had a negative impact on space management and social and economic life of the population, especially the population of towns and mountainous areas especially the populations of towns and mountain villages. They knew the dangers caused mainly by disturbances in the supply of gas and electricity prices soaring in wide consumption, road closures and especially a large number of deaths, many people died in road accidents road and others by asphyxiation, since the beginning of this extreme events.

References

Azzi, A, 2013: Analysis of climate change in the watershed Soummam; thinking in terms of hydrological consequences. Magister status in Earth Sciences, specialty climate, environment and sustainable development. FST-GAT.USTHB, 200 pp.

Boucharef, D, 2010: Spatiotemporal Study and seasonal forecasting temperatures in northern Algeria. Magister status in Earth Sciences, specialty climate, environment and sustainable development. FST-GAT.USTHB, 200 pp.

Medjerab A., and B. Bouzid, 2012: The cold wave in February 2012 and its impacts on space management: Case northern Algeria. The 2nd International Seminar Euro - Mediterranean on Spatial Planning, Risk Management and Civil Security. University Hadj Lakhdar- Batna-Algeria.

Sabaa S., and A. Medjerab, 2009: The cold wave in January 2005 in North-east Algeria. XXII th conference of the International Association of Climatology. Cluj-Nopoca. Roumanie.6 p.

http://www.wmo.int/pages/prog/wcp/wcdmp/documents/WMO998fr_05.pdf

http://www.wmo.int/pages/prog/wcp/wcdmp/documents/WMO_1108.pdf

Observed and XXI Century Projected Climate Change in Argentina

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In the framework of the Argentine Third national Communication to the UNFCCC it was made a study on observed and projected climate changes. Observed changes in temperature and precipitation were calculated from the monthly averages of the CRU 3.20 dataset that was based on interpolated data from the National Meteorological Service (NMS). These data have passed a double consistency process, first by the NM and then by CRU. Eleven indices of climate extremes were chosen for their relevance to potential impact studies and availability from ClimDex (Donat et al. 2013).

Projected future changes in temperature and precipitation were estimated from the four models that best simulated the observed climate in each region, selected as described by Camilloni et al. (2015).

Between 1960 and 2010 there was an increase in mean annual temperature of 0.5°C to 1°C with a national average of about 0.4°C (medium confidence). This warming was a little lower than the continental global average. The greater warming took place in the northwest of the country and in Patagonia. Changes in the extreme cold indices were in general more evident than in warm indices; for instance frost days decreased in most of the country (high confidence). There were also significant trends in days with heat waves in the north and east

In the period 1960–2010 precipitation increased in most of the country although with interannual variations, except in the Patagonian Andes where annual rainfall decreased (high confidence). In addition, there was a shift towards more intense precipitation (medium confidence) and more frequent extreme precipitations in much of the country (high confidence).

In the near future, 2015–2039, the mean temperature increase with respect to 1981–2005 present will not depend much on the RCP scenario and it would be 0.5 to 1° C, which implies and acceleration of the warming rate observes in the last 50 years, For the end of the century the increase in the mean temperature will depend on the scenario and would be between 0.5°C and 3.5°C in most of the country, but even higher in the northwest in the RCP8.5 scenario (medium confidence). As with the observed changes, except in the northwest, warming will be much lower than in most of continental areas of the world. Projected future temperature extremes are consistent with warming and would be very severe in the RCP8.5 scenario.

Projected changes in rainfall will vary geographically, but would be not important and only between the ±10% range of uncertainty, except for the RCP8.5 at the end of the century, in which there would be a moderate increase in the center and east of the country (low confidence). Therefore, it is likely that the important changes observed in the last 50 years will not be reverted.

According with the projected regional climate change, some direct risks can be identified. In the humid region it is expected an increase in the frequency and intensity of extreme precipitation. Hence a reduction of the extended floods in the rural plains and in some urban areas of the province of Buenos Aires and southern Santa Fe that took place in the last decades should be rule out during this century, unless new structural measures and adequate land use management be implemented. Extreme warm temperatures and heat waves are also expected to continue to increase their already growing frequency.

The semiarid central region is characterized by a long dry winter season. This feature is expected to be enhanced with longer periods without any rain, which combined with warmer temperatures would increase the water deficit, with negative impacts in the water provision for human consume, pasture fires and cattle raising. As in the humid region, in this region it is also expected more days with heat waves, especially in the north, and more intense extreme precipitations.

The north of the Andes region would beone of the areas of greatest warming in the world with increase of mean annual temperature over 6°C in the RCP8.5 scenario at the end of the century. This region will also face longer winter dry periods with similar consequences as the central region and more intense extreme precipitations in the north. The rise of the zero degree isotherm of about 500 m by the end of the century will enhance the already glaciers receding glaciers and the change in the annual regime of rivers, with less water during summer, the season where is most needed for irrigation in the Andean foot valleys.

The warming over the Patagonia would be moderated, but with decreasing precipitation, a general trend toward greater aridity is expected. Also the retreat of glaciers will continue endangering some great scenery areas.

References

Camilloni, I., S. Solman, V. Barros, A. Carril, and M. Nuñez, 2015: Climate Change in Argentina: Third National Communication - The framework for model selection and development of high resolution climate projections. IPCC Workshop on Regional Climate Projections, Sao Jose dos Campos.

CRU:http://badc.nerc.ac.uk/view/badc.nerc.ac.uk_ATOM_dataent_1256223773328276

Donat M.G., et al., 2013: Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2. *J. of Geophysical Research*, **118**, 2098–2118

An R-package Designed for Climate and Weather Data Analysis, Empirical-Statistical Downscaling, and Visualisation

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We present an esd R library which is made freely available by the Norwegian Meteorological Institute (https://github.com/metno/esd/wiki) and is for use by the scientific community, especially in climate and any related field. It was primarily built for statistical downscaling of climate variables and parameters from global climate model results (e.g. ENSEMBLEs, CMIP3/5 model results), and has recently been extended to deal with data I/O (e.g. global climate datasets), statistical analysis, and visualization.

Before doing the downscaling, the 'esd' main functionalities consist in i) retrieving and manipulating large samples of climate and model data from various sources, ii) computing Empirical Orthogonal Functions (EOFs), Principal Component Analysis (PCA), and Multi-Variate Regressions (MVRs) using very simple R commands and procedures. Examples about how to retrieve, process, and visualize the data will be presented.

Finally, the 'esd' tool can be used to produce projections of a set of downscaled local climate variables and parameters such as mean 24-h precipitation and temperature needed as input for most impact studies, for instance, dealing with the impact of climate change on hydrology and glaciers over the Himalayan region. These uses the CMIP3/5 global climate model results as forcings and are tailored to meet with specific user needs as those that are presented by MET Norway Indian partner within the working group 2 of the INDICE project.

Climatic Changes in Romania Since AD 1961 and Their Impact on Natural Hydrological Regime

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This study presents a country-wide trend analysis in seasonal air temperature and precipitation, over the 1961–2009 period, and tries to see how these seasonal changes impact the natural streamflow regime; trends in annual temperature and precipitation extremes are also investigated by means of 14 indices recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI).

With an area of 238,391 km^2, Romania is the largest country in southeastern Europe. The terrain is fairly equally distributed between mountainous (Carpathians), hilly and lowland territories. Elevation varies from sea level to 2544 m.a.s.l. The climate is continental-temperate with oceanic influences in the central and western parts, continental in the east and Mediterranean in the south (Bojariu et al., 2015). Most rivers are tributary to the Danube, which drains 98% of the Romanian territory (Birsan, 2015). The hydrological regime in Romania is generally of rainfall-snowmelt origin, except for the southeastern (Black Sea) area, where it is rainfall-based (Stanescu and Ungureanu, 1997).

The results of the Mann-Kendall non-parametric test (Mann, 1945; Kendall, 1975) reveals that the air temperature presents significant increasing trends in winter, spring and summer, while the precipitation amount is rather stable, with increasing trends in autumn and decreasing trends in the other seasons, at few locations. The annual thermal extremes show decreasing trends for the cold-related indices and increasing trends for the warm-related ones, with the warming signal being consistent over the region. The most striking results concern the number of summer days which is increasing at 95% of the stations and the duration of warm spells increasing at 83% of the stations. The annual precipitation extremes show mixed signals in all eight indices, with the majority of the stations presenting no significant trends. Our findings are in good agreement with recent studies on climatic variability in the region.

In order to assess the impact of regional climatic changes on water resources in the region, a statistical analysis of streamflow trends in Romania has been done, using mean daily streamflow data series from 44 pristine river basins for the period 1961–2009. Statistically significant trends were identified for each site on an annual and seasonal basis, for all deciles (minimum, maximum and $q_{0.1}$ to $q_{0.9}$ quantiles). The regional field significance of trends was tested by a bootstrap procedure.

Results show that at annual scale, the minimum flow and $q_{0.1}$ to $q_{0.6}$ show positive trends, whereas for the upper quantiles, the trends are predominantly decreasing. The increase in low flows and the decrease in high flows suggest an overall decrease in annual variability—in disagreement with most of the studies on projected impacts of greenhouse forcing on hydrology (Birsan et al., 2014).

On a seasonal basis, the winter streamflow is increasing, due to winter temperature increase, resulting in more precipitation falling as rain than as snow (Birsan and Dumitrescu, 2014).There is an increase in minimum spring streamflow, which could be explained by the increase in temperature, leading to an earlier snowmelt. The general decrease in spring streamflow might happen because of the decrease in snowpack. The downward trends in summer flow can be partially explained by the country-wide summer temperature increase (Dumitrescu et al., 2014), and consequently in evaporation. The upward trends in autumn flow are entirely justified by the increase in precipitation during this season.

References

Birsan, M.V., 2015: Trends in Monthly Natural Streamflow in Romania and Linkages to Atmospheric Circulation in the North Atlantic. *Water Resources Management*, **29**(9), 3305–3313.

Birsan, M.V., and A. Dumitrescu, 2014: Snow variability in Romania in connection to large-scale atmospheric circulation. *International Journal of Climatology*, **34**, 134–144.

Birsan, M.V., L. Zaharia, V. Chendes, and E. Branescu, 2014: Seasonal trends in Romanian streamflow. *Hydrological Processes* **28**(15), 4496–4505.

Bojariu, R., M.V. Birsan, R. Cică, L. Velea, S. Burcea, A. Dumitrescu, S.I. Dascălu, M. Gothard, A. Dobrinescu, F. Cărbunaru, and L. Marin, 2015: *Schimbările climatice – de la bazele fizice la riscuri și adaptare (Climate change – from physical basis to risk and adaptation)*. Printech, Bucharest (in Romanian). doi:10.13140/RG.2.1.1341.0729

Dumitrescu, A., R. Bojariu, M.V. Birsan, L. Marin, and A. Manea, 2014: Recent climatic changes in Romania from observational data (1961–2013). *Theoretical and Applied Climatology*, doi:10.1007/s00704-014-1290-0.

Kendall, M.G., 1975: *Rank correlation methods*. Charles Griffin, London

Mann, H.B., 1945: Nonparametric tests against trend. *Econometrica* **13**, 245–259.

Stanescu, V.A., and V. Ungureanu, 1997: Hydrological regimes in the FRIEND-AMHY area: space variability and stability. In: *FRIEND 97 – Regional Hydrology: Concepts and Models for Sustainable Water Resource Management*. IAHS Publ. No. 2, 67–75.

Climate Change in Argentina: Third National Communication- The framework for model selection and development of high resolution climate projections

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One of the main objectives of the Third National Communication on Climate Change for Argentina was assessing the climate change projections for the twenty first century. Taking advantage of the CMIP5 initiative (Taylor et al., 2012) the large number of GCMs available allowed exploring not only the capability of GCMs in reproducing the main features of current climate over Argentina but also quantifying the uncertainty in both, present climate and future projections. However, due to the horizontal resolution of GCMs is still insufficient for the impact users community, GCM-driven Regional Climate Models (RCMs) operating at higher spatial resolution (50 km) performed for the South American continent under the framework of the CLARIS-LPB Project were also used. All RCMs were forced by CMIP3-GCMs under the SRESA1B scenario. The number of simulations available, from both the CMIP5 GCM ensemble and CLARIS-LPB RCM ensemble, includes more than 50 models. However, it is well known that model evaluation is the first step in order to build objective criteria for model selection, before exploring the future climate. In this context, the main aim of this work was to assess the capability of both GCMs and RCMs in simulating present climate conditions over Argentina and developing objective criteria for model selection. Evaluating models' performance allowed identifying systematic model biases. Hence, another objective of this work was to remove systematic climate biases in the selected GCMs and RCMs in order to produce a set of high-resolution climate projection dataset (0.5°lat x 0.5°lon) appropriate for the national climate change impact studies.

An initial model selection was made on the basis of data availability. The need for daily data of temperature and precipitation under both current climate and two RCP future scenarios (RCP4.5 and RCP8.5) allowed identifying only 14 GCMs meeting the criteria. All participating RCMs were included in the analysis. The model evaluation was made for 4 selected regions within Argentina: Humid Region, encompassing northeastern Argentina, Central Region, Andean and Patagonia. The reference dataset used for evaluating models' behavior for both temperature and precipitation was the Climate Research Unit (CRU) dataset and the period considered was 1961–1990. An objective integral metric for assessing models' performance was built based on 5 indices quantifying the seasonal mean bias for summer and winter seasons, the annual mean bias, the correlation coefficient between the modeled and observed annual cycle and the ratio between the modeled and observed interannual variability for each variable. The index was computed for each individual model and for each region. After computing the objective integral metric for all the models, a ranking of model was built for each region. The best four models for each region were then selected for evaluating future climate scenarios. Overall it was found there is not a best model identified for every region, but depending on the region the selection of models with better performance differs. Overall, GCMs tend to perform better than RCMs, except over regions characterized with complex topography.

However, even for the outperforming models, both GCMs and RCMs are characterized by systematic errors in the representation of the atmospheric circulation and related variables. Accordingly, systematic biases in daily temperature and precipitation were removed by applying the "quantile-based mapping" bias correction method (Wood et al., 2002). This methodology consists in constraining the distributions of these variables produced by climate models to the observed climatology for a target period. This method was already found to be adequate to produce high-resolution bias corrected meteorological information for climate change impact studies (Vidal and Wade, 2007; Saurral, 2010; Saurral et al., 2013).

The analysis allowed building a dataset with bias-corrected model outputs for daily temperature and precipitation for both present and future climate conditions for the impact analysis community.

References

Saurral, R.I., 2010: The hydrologic cycle of the La Plata Basin in the WCRP/CMIP3 multi-model dataset. *J. Hydrometeor.*, **11**, 1083–1102.

Saurral, R., N. Montroull, and I. Camilloni, 2013: Development of statistically unbiased 21st century hydrology scenarios over La Plata Basin. *Int. J. of River Basin Management*, **11**, 329–343.

Taylor, K.E., R.J. Stouffer, and G.A. Meehl, 2012: An Overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, **93**, 485–498.

Vidal, J-P, and S. Wade. 2007: A framework for developing high-resolution multi-model climate projections: 21st century scenarios for the UK. *Int. J. of Climatol.*, **28**, 843–858.

Wood, A.W., E.P. Maurer, A. Kumar, and D.P. Lettenmaier, 2002: Long-range experimental hydrologic forecasting for the eastern United States. *J. Geophys. Res.*, **107**, 4429, doi:10.1029/2001JD000659.

IPCC TGICA: Supporting Data and Scenario Needs for Regional Impact and Adaptation Analysis

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TGICA and the DDC

The IPCC Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) facilitates distribution and application of climate change related data and scenarios. Established in 1996, the Task Group's membership brings together diverse expertise and experiences drawn from a cross section of research communities representing all three IPCC Working Groups (Parry, 2002). TGICA has placed a heavy emphasis on interpreting climate and related information, primarily from global models, for application in regional climate change impact and adaptation analysis.

TGICA oversees a Data Distribution Centre (DDC), prepares guidance material and contributes to building capacity in the use of data and scenarios for climate-related research in developing and transition-economy regions and countries. The DDC provides a means of accessing climate, socio-economic and environmental data, both from historical observations and from future scenario projections, in support of IPCC work and as used in the IPCC assessments.

Regional Dimensions of TGICA's Work

The Task Group was instrumental in developing recommendations for global climate model simulations to be undertaken in the coupled model inter-comparison project (CMIP) underpinning the Third and Fourth IPCC assessments (e.g. Swart et al., 2002), TGICA has also prepared several peer-reviewed technical guidelines on the development and application of climate, other environmental and socioeconomic scenarios for climate change impact, adaptation and vulnerability assessment (IPCC-TGICA 2007; Mearns et al., 2003; Nicholls et al., 2011; Wilby et al., 2004). Several of these describe methods of regionalising data and scenarios to scales of relevance for studying impacts and for examining adaptation options. A number of new or updated guidance documents and fact sheets focusing on the distillation of climate and related information for application in regional assessments are currently in preparation.

TGICA also facilitates expert meetings to contribute to regional capacity building. For example, an expert meeting on "Integrating analysis of regional climate change and response options" was held in 2007 to catalyse regional interdisciplinary research on climate change, impacts, adaptation, vulnerability and mitigation (Marengo et al., 2009). Another expert meeting with a regional impacts and adaptation focus: "Decision-centered approaches to the use of climate information", was held in July 2015 (Hewitson et al., 2015, in prep.).

TGICA's Future Role for Regional Impact and Adaptation Analysis

In view of the changing landscape of climate data and scenario information, the mandate of TGICA will be discussed at an IPCC meeting of experts in early 2016. A document has been prepared to map out possible visions for the future of TGICA and the DDC, focusing on ideas for strengthening their operations. Enhanced support for regional impact and adaptation assessment is a prominent part of the vision for TGICA activities, assuming that appropriate resources are available. Through targeted workshops, data exchange and common regional case studies, there are opportunities for TGICA to catalyse improved liaison across the IPCC Working Groups on the regional dimensions of climate change research. A set of qualifying criteria for linking to pertinent datasets at regional level has been produced, and some of these datasets are already accessible through the DDC. Download statistics over recent years reveal an encouraging improvement in developing country access to data held on the DDC, but there are still regions where access is difficult and alternatives to internet access need to be considered. Support for regional capacity building could be greatly enhanced by organizing regular (e.g. annual or bi-annual) TGICA workshops to serve developing region scientists. Existing technical guidelines on the application of data and scenarios in regional impact and adaptation assessments are popular among users, but require regular updating and a widened range of regional examples.

Researchers are invited to provide feedback on the utility of the DDC website for accessing and interpreting data and scenarios required in climate change research at different scales through a DDC User Survey (see DDC home page under "Highlights" at: http://www.ipcc-data.org/)

References

IPCC-TGICA, 2007: General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Version 2. Prepared by T.R. Carter as Supporting Material of the Intergovernmental Panel on Climate Change, Task Group on Data and Scenario Support for Impact and Climate Assessment, 66 pp.

Marengo, J.A., K. Averyt, B. Hewitson, N. Leary, and R. Moss, 2009 (eds). Integrating analysis of regional climate change and response options. *CR Special, Climate Research* , **40**(2-3), 121–260.

Mearns, L.O., F. Giorgi, P. Whetton, D. Pabon, M. Hulme, and M. Lal, 2003: Guidelines for Use of Climate Scenarios Developed from Regional Climate Model Experiments. Supporting Material, Intergovernmental Panel on Climate Change Task Group on Scenarios for Climate Impact Assessment (TGCIA), 38 pp.

Nicholls, R.J., S.E. Hanson, J.A. Lowe, R.A. Warrick, X. Lu, A.J. Long, and T.R. Carter, 2011: Constructing Sea-Level Scenarios for Impact and Adaptation Assessment of Coastal Areas: A Guidance Document. Supporting Material, Intergovernmental Panel on Climate Change Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA), 47 pp.

Parry, M., 2002: Scenarios for climate impact and adaptation assessment. *Global Environmental Change*, **12**, 149–153.

Swart, R., J. Mitchell, T. Morita and S. Raper, 2002: Stabilisation scenarios for climate impact assessment. *Global Environmental Change*, **12**, 155–165.

Wilby, R.L., S.P. Charles, E. Zorita, B. Timbal, P. Whetton, and L.O. Mearns, 2004: Guidelines for Use of Climate Scenarios Developed from Statistical Downscaling Methods. Supporting Material, Intergovernmental Panel on Climate Change Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA), 27 pp.

Extreme Precipitation in the North American Monsoon Derived from Regional Models

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We are in the process of analyzing the forcing mechanisms associated with daily extreme precipitation (> P95th of wet days) in the North American monsoon (NAM) region derived from two regional models that are part of the CORDEX initiative (RCA and RegCM4) for the 1979-2005 and for the 21st century. The two models were forced separately by ERA-Interim, and by Had-GEM2-ES and MPI-ESM-LR GCMs. In this poster we present a historical validation (1979–2000) for the two regional models, and preliminary results of future RCP8.5 scenarios of P95 only for the RCA model for the 2075–2099 period.

During boreal winter (DJF), the mean observed P95 threshold in the NAM region is ~15 mm/day according to observations of USA-CLICOM and NARR. HadGEM and ERA-Interim underestimate this value, while MPI overestimates it. The P95 threshold derived from the regional models is much larger than their forcing GCMs.

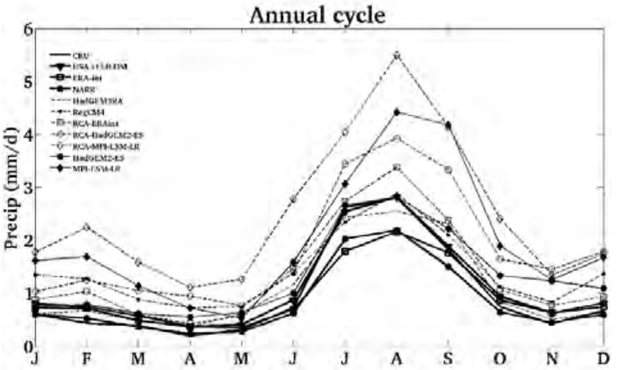

Figure 1: Annual cycle of precipitation (mm/day) in the North American monsoon region (22–36°N, 114–104°W) based on observations (CRU and US-CLICOM), reanalysis (ERA-Interim and NARR), GCMs (HadGEM2-ES and MPI-ESM-LR) and regional models (RegCM4 and RCA) forced by ERA-Interim or the GCMs for the 1979–2005 period. GCMs and regional models are shown with broken lines.

During JJA and SON, the mean observed P95 threshold from USA-CLICOM is ~20 mm/day, which MPI and RegCM4 reproduce well. In contrast, NARR, ERA-Interim and Had-GEM2 underestimate this value almost by half. Again, the regional models show much larger thresholds than their driving models. In general, the regional models forced by MPI tend to produce a stronger annual cycle of precipitation and larger P95 thresholds (Figure 1 and Figure 2), with the largest values over the Pacific Ocean.

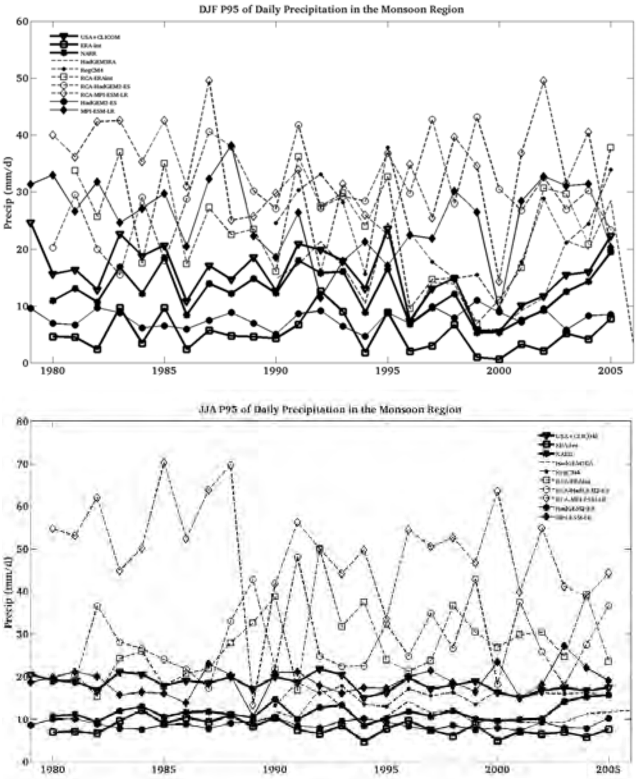

Figure 2: Interannual thresholds of extreme precipitation (P95) in the North American monsoon region according to observations, GCMs, and regional models as in Figure 1 for (a) boreal winter, DJF and (b) and boreal summer, JJA during 1979–2005. GCMs and regional models are shown with broken lines.

Analyzing the circulation and humidity at 850 hPa during summer (JJA) and autumn (SON), it is found that although ERA-Interim has large amounts of moisture in the mountains of the monsoon region during the days above the P95 threshold, the circulation over the monsoon is from the continent to the Pacific Ocean and the trade winds in the ITCZ region are strong; this may be one of the causes that ERA-Interim is too dry over the monsoon region. Interestingly, RCA forced by ERA-Interim produces a convergence in the ITCZ region and slightly more moisture advection toward the monsoon (this is also seen in RCA forced by HadGEM). In contrast, the strongest moisture advection toward the monsoon is produced by RCA forced by MPI and this is reflected in the largest P95 of all simulations.

Future scenarios of P95 derived from RCA forced by HadGEM show decreasing P95 thresholds in the Eastern Pacific close to Mexico during JJA, but increasing values of P95 over the monsoon and in the Eastern Pacific during autumn (SON) at the end of this century (2075–2099) under the RCP4.5 and RCP8.5; this result is consistent with a delayed monsoon retreat documented in several studies (e.g., Torres-Alavez et al., 2014). However, scenarios for the 21st century based on RCA forced by MPI show increases of extreme precipitation during all seasons all over the domain. The circulation and humidity patterns associated with the future scenarios of days above the P95 thresholds of RegCM4 and RCA are under preparation.

References

Torres-Alavez, A., T. Cavazos, and C. Turrent, 2014: Land-sea thermal contrast and intensity of the North American monsoon under climate change conditions. *J. Climate*, **27**, 4566–4580.

Projecting Global and Regional Marine Fisheries Catches in the 21st Century

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Previous studies projected global redistribution of potential marine fisheries catches by mid-21st century under climate change, with increases in high latitude regions and decreases in tropical areas (Barange et al., 2014; Gattuso et al., 2015; Pörtner et al., 2014). However, quantified confidence of such projection is not available, rendering it difficult to interpret the associated risk to the society (Rodgers et al., 2015). This paper quantifies the confidence of future fish stocks production using 30 ensemble member runs of a global earth system model (Cheung et al., in review) and three structural variants of a mechanistic species distribution model6. We project a 68% (likely) chance that total potential catches of 500 exploited fish and invertebrate stocks will decrease by 5% or more by 2050 relative to now under 'business-as-usual' (RCP8.5). By mid-21st century, fishing and their management remain the main factor determining future fish stocks and their catches. In addition, amongst climatic and oceanographic factors, internal variability of projected ocean conditions contributes most to the uncertainty of potential catch projections. Regionally, climate-driven decrease in potential catches in tropical oceans and increase in the Arctic are projected to be very likely (>90%), while the direction of changes in most mid-latitude regions is uncertain. Under the low emission scenario (RCP2.6), climate change impacts on potential catches may not emerge from their uncertainties by 2050 relative to now. Overall, this study provides a foundation for quantifying risks of climate change impacts on marine fisheries globally and regionally, and how such risk may be altered by policy interventions.

References

Barange, M., et al., 2014: Impacts of climate change on marine ecosystem production in societies dependent on fisheries. *Nature Climate Change*, **4**, 211–216.

Cheung, W.W.L., M.C. Jones, G. Reygondeau, and V.W.Y. Lam, Structural uncertainty in projecting global fisheries catches under climate change. *Ecological Modelling* (in review).

Cheung, W.W.L., et al., 2010: Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology*, **16**, 24–35.

Gattuso, J.-P., et al., 2015: Contrasting futures for ocean and society from different anthropogenic CO2 emissions scenarios. *Science*, **349**, doi:10.1126/science.aac4722.

Pörtner, H.-O., D. Karl, P.W. Boyd, W. Cheung, S.E. Lluch-Cota, Y. Nojiri, D.N. Schmidt, and P. Zavialov, 2014: Ocean systems. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 411–484.

Rodgers, K.B., J. Lin, and T.L. Frölicher, 2015: Emergence of multiple ocean ecosystem drivers in a large ensemble suite with an earth system model. *Biogeosciences*, **11**, 18189–18227.

Climate Simulations over Southeast of Brazil Using the 5-km non-hydrostatic Eta Regional Climate Model

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Dynamical downscaling of global climate model simulations to resolutions of about 50 to 20-km is a suitable methodology to assess climate change at regional scales. However, municipalities may extend to less than a few tens of kilometres. Therefore, to study the impact and vulnerability of climate change at local scale an additional increase of resolution may be appropriate to capture some spatial variability. The objective of this work is to evaluate the climate reproduced by the Eta Regional Climate Model at 5-km horizontal resolution over Southeast of Brazil (Chou et al., 2014a). This version of the model has received upgrades as described in Mesinger et al. (2012). This region, which includes the two major Brazilian cities, Sao Paulo and Rio de Janeiro, is densely populated and extremely active economically. However, floods and landslides occur frequently during summer in this region. The 5-km simulations result from a second downscaling. The model is nested in the 20-km resolution Eta simulations (Chou et al., 2014b), which in turn is nested in the HadGEM2-ES climate simulations output. Continuous run is carried out for the period between 1961 and 2005. Comparisons of the high-resolution downscaling simulations against observations show that the model reproduces reasonably the mean seasonal cycle of precipitation and temperature in the present climate. Comparisons of spatial pattern of the mean values are limited as density of observational network is low. In the metropolitan area of Sao Paulo, the 20-km simulations show general underestimate of precipitation during summer, the rainy season, whereas the 5-km simulations reduce this errors, and show some areas of overestimate. Temperature pattern is better captured as the low temperatures in mountain peaks are revealed at higher horizontal resolution. In winter, both resolution simulations, 5 and 20-km, overestimate precipitation in the region. The comparison between the 5-km and the 20-km RCM shows that frequency distributions of precipitation and temperature from the Eta RCM at 5-km simulations capture better the shape and the extreme values, in better agreement with the observations. Therefore, the 5-km resolution simulations show advantage over its driver model to simulate extreme events. Evaluations in the metropolitan area of Rio de Janeiro show similar results. Projections of future climate change using this 5-km resolution setup are underway.

References

Chou, S.C., A.A. Lyra, C. Mourão, C. Dereczynski, I. Pilotto, J.L. Gomes, J. Bustamante, P. Tavares, A. Silva, D. Rodrigues, D. Campos, D. Chagas, G. Sueiro, G., Siqueira, P. Nobre, and J. Marengo, 2014a: Evaluation of the Eta Simulations Nested in Three Global Climate Models. *American Journal of Climate Change*, **3**, 438–454.

Chou, S.C., A.A. Lyra, A. Silva, G. Sueiro, P. Tavares, L.H. Nunes, and J.A. Marengo, 2014b: 5-km Resolution Eta Model Downscaling of Present Climate in the City of Santos, Brazil In: Water Management in Transition Countries as Impacted by Climate Change and Other Global Changes, Lessons from Paleoclimate, and Regional Issues.1 ed.Belgrado: Institute for the Development of Water Resources and Serbian Academy of Sciences, 2014, v.1, p. 80-85.

Mesinger, F., S.C. Chou, J.L. Gomes, D. Jovic,, J.F. Bustamante, A.A. Lyra, P. Bastos, K. Veljovic, L. Lazic, S. Morelli, and I. Ristic, 2012: An upgraded version of the Eta model. *Meteorology and Atmospheric Physics*, **116**, 63–79.

Robustness of Regional Patterns of Change in Multi-model Studies; Beyond Model Spread

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Percentiles at the grid point level are often used to present model spread in temperature and precipitation changes within an ensemble of models (e.g., IPCC Atlas, Annex1, AR5, 2013). Furthermore, pattern scaling of annual mean changes of temperature and precipitation based on multiple GCMs has been used to demonstrate robustness in climate change projections (e.g., Figure 12.41 in Chapter 12 in AR5, Collins et al., 2013). This implied agreement has been used to support probabilistic approaches towards regional climate change projections in the sense that model spread in any given point or region is associated with a likelihood assigned to the regional information extracted from multi-model ensembles.

Using CMIP5 we demonstrate a substantial disproportionality between global climate sensitivity and the regional distribution of temperature change. We argue that estimating a given probability for a change in any particular region prevents a probabilistic statement about the change in a different region, as this would potentially be in conflict with the global mean being the overall constraint in any given model realization: if the largest climate change signal is chosen in each point, the global mean temperature change exceeds the change projected by any individual model. This is not physically justified. For precipitation, spread is large in all grid points; consistent with no change and a large uncertainty everywhere. Each individual model on the other hand shows a clear and statistically significant pattern of change. This implies that the physical consistency between climate variables such as temperature and precipitation is basically lost in a statistical analysis based on grid-point statistics. Further analyses at the grid point level including multiple climate variables stress that correlation between the variables needs to be addressed if physically consistent regional climate projections are to be extracted.

Here we propose an EOF approach identifying dominating patterns of regional climate change. These are used to construct globally consistent maps of the uncertainty in climate change scenarios. By going beyond the grid point level statistics, our method is designed to capture the spatial patterns in the uncertainty and maintain the physical correlations between variables. In particular, we identify that based on the EOF analysis of temperature changes; a bit more than 50% of the variance in the temperature change pattern is explained by the first EOF. To keep physical consistency, using the same PC loadings deduced from temperature on precipitation changes, only explains around 10% globally and between 15–30% of the variance in precipitation changes over land, depending on various means to separate out the most dominant individual model. This implies, however, that within the inner 50% of the explained temperature variance, the more physically consistent pattern of change in precipitation is much better constrained than it appears using grid point statistics

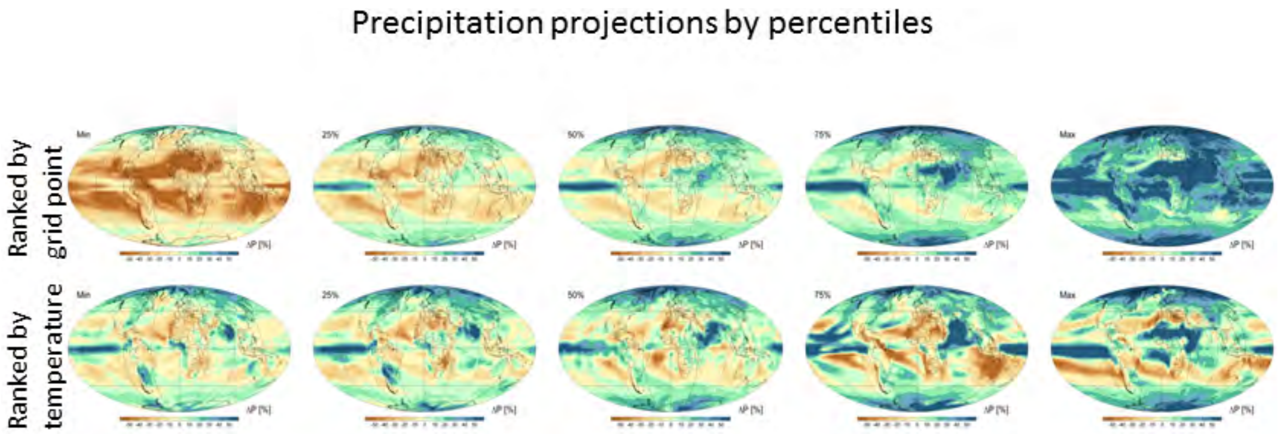

Figure 1: The spread in relative precipitation change 2081–2100 relative to 1986–2005 for 38 CMIP5 models for the RCP8.5 scenario. The top row is for grid-point by grid-point statistics and the second row shows individual model statistics based on the change in global mean temperature (i.e., ranked according global climate sensitivity).

References

Collins, M., R. Knutti, J. Arblaster, J.-L. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W.J. Gutowski, T. Johns, G. Krinner, M. Shongwe, C. Tebaldi, A.J. Weaver and M. Wehner, 2013: Long-term Climate Change: Projections, Commitments and Irreversibility. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 953–1028.

IPCC, 2013: Annex I: Atlas of Global and Regional Climate Projections [van Oldenborgh, G.J., M. Collins, J. Arblaster, J.H. Christensen, J. Marotzke, S.B. Power, M. Rummukainen and T. Zhou (eds.)]. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1311–1394.

High-resolution Climate Projections for Crop Model Application in the Philippines

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Climate changes under a globally warmer future pose a significant threat to agriculture and food security. It is therefore necessary to have reliable future climate information at a high resolution that can be used in crop impacts assessments. In this study, we produce future climate data at a daily timescale for two rice-growing sites (Nueva Ecija and Los Baños), which will be used as input to a crop model. We used the regional climate model RegCM4 to downscale output from three global climate models (CanESM2, HadGEM2-ES, and GFDL) over the Philippines at 50-km resolution for the baseline period (1981–2000) and future period (2010–2049) under the RCP4.5 scenario. This model output is further downscaled to 12-km resolution over the two sites. Comparison of model output with observed station data indicate model biases, which we addressed using bias correction techniques. Results show that the mean temperature in Nueva Ecija is projected to increase by 0.69°C and 1.17°C in the 2020s and 2040s, respectively, with similar changes in Los Baños (0.75°C and 1.22°C). We also examine future changes in the other variables relevant to agriculture, e.g., precipitation, relative humidity, solar radiation, and determine how the application of bias correction can affect the climate projections.

Effect of bias-adjustment on the projection of temperature and precipitation extremes from an ensemble of EURO-CORDEX RCMs

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In order to be used as an input for process based impact models, output from climate models are usually post-processed in order to reduce their systematic biases (i.e., the errors compared to observations over a reference, present-day period) (e.g., Foyler et al., 2007).

Amongst several techniques, often referred as bias-correction, or bias-adjustment, quantile-mapping (QM) methods employ a transfer function to match the cumulative distribution functions (CDFs) of modeled and observed data. They are increasingly used in studies of assessment of the impact of climate change on several sectors such as floods, agriculture, and forest fires (Rojas et al., 2012; Migliavacca et al., 2013; Russo et al., 2013; Gabaldón-Leal et al., 2015).

However, as QM affects directly the probability distribution function (PDF) of the climate variable, both in the present and future, the bias-adjusted climate change signal may be different than the 'original' (i.e., non bias-adjusted) one (Dosio et al., 2012).

As discussed by Boberg and Christensen (2012), climate models show temperature-dependent biases, with e.g., errors in summer often larger than those in winter. As a consequence the common assumption that climate change projections are biased by the same amount for all time may be questionable as these intensity-dependent errors can alter the temperature climate change signal. By applying a 'conditional bias correction' over regional climate models' (RCM) results, they showed that the resulting climate change signal over Southern Europe in summer is generally reduced compared to the non-corrected one.

Recently, Gobiet et al. (2015) discussed analytically the effect of QM on projected mean temperature and argue that, by removing the intensity-dependent errors, QM may potentially lead to a improved climate change signal.

However, it is important to note that impact models are significantly dependent not only on the mean climate but also on the occurrence and frequency of extreme events, which in turn depend on the value and evolution of the tails of the PDF. The effect of QM on the projected occurrence of climate extremes is less commonly investigated and it is the focus of this study.

In this work the outputs of an ensemble of RCMs from the EURO-CORDEX initiative has been bias-adjusted following Piani et al. (2010) and Dosio and Paruolo (2011). A number of ETCCDI climate indices have been calculated for the present (2981–2010) and future (2071–2100) climate under RCP4.5 and RCP8.5.

Indices include absolute thresholds indices (e.g., SU: number of days when Tmax >25°C), percentile-based thresholds indices (e.g., Tx90p: the number of days when Tmax is higher than the 90th percentile of the reference period), and indices based on the duration of an event (e.g., CDD: number of consecutive dry days).

Indices calculated with bias-adjusted models' output have been compared to the original ones for the present and future climate. Preliminary results show that absolute threshold indices are the ones most affected by the bias-adjustment, as they depend strongly on the shift of the mean value of the variable, which is usually largely biased in the original RCMs. Threshold-based indices are less affected, however some differences emerge when the QM affects not only the present-day PDF, but also its evolution in the future. For instance, the resulting PDF of bias-adjusted climate change signal may be different (e.g., more skewed) than the original one. As a result, despite a decrease in the mean value of the temperature signal, the value of extreme climate indices can remain constant, or even increase locally.

References

Boberg, F., and J.H. Christensen, 2012: Overestimation of Mediterranean summer temperature projections due to model deficiencies. *Nature Clim. Change*, **2**, 433–436.

Dosio, A., and P. Paruolo, 2011: Bias correction of the ENSEMBLES high-resolution climate change projections for use by impact models: Evaluation on the present climate. *Journal of Geophysical Research D: Atmospheres,* **116**(16), doi:10.1029/2011JD015934.

Dosio, A., P. Paruolo, and R. Rojas, 2012: Bias correction of the ENSEMBLES high resolution climate change projections for use by impact models: Analysis of the climate change signal. *Journal of Geophysical Research D: Atmospheres,* **117**(17), doi:10.1029/2012JD017968.

Fowler, H.J., S. Blenkinsopa, and C. Tebaldib, 2007: Linking climate change modelling to impacts studies: recent advances in downscaling techniques for hydrological modelling*. Int. J. Climatol*., **27**, 1547–1578.

Gabaldón-Leal C., I.J. Lorite, M.I. Mínguez, J.I. Lizaso, A. Dosio, E. Sanchez, and M. Ruiz-Ramos, 2015: Climate-change and extreme-temperature adaptation strategies for maize in Andalusia, Spain. *Climate Research,* doi:10.3354/cr01311.

Gobiet, A., M. Suklitsch, and G. Heinrich, 2015: The effect of empirical-statistical correction of intensity-dependent model errors on the climate change signal. *Hydrol. Earth Syst. Sci. Discuss.*, **12**, 5671–5701.

Migliavacca, M., A. Dosio, A. Camia, R. Houborg, T. Houston, J. Kaiser, N. Nhabarov, A. Krasovskiy, B. Marcolla, J. San Miguel-Ayanz, D. Ward, and A. Cescatti, 2013: Modeling biomass burning and related carbon emissions during the 21st century in Europe. *J. Geophys. Res. Biogeosci.,* **118**(4), 1732–1747.

Piani, C., G.P. Weedon, M. Best, S.M. Gomes, P. Viterbo, S. Hagemann, and J.O. Haerter, 2010: Statistical bias correction of global simulated daily precipitation and temperature for the application of hydrological models. *J. Hydrol.*, **395**, 199–215.

Rojas, R., L. Feyen, A. Bianchi, and A. Dosio, 2012: Assessment of future flood hazard in Europe using a large ensemble of bias-corrected regional climate simulations. *Journal of Geophysical Research D: Atmospheres,* **117**(17), doi:10.1029/2012JD017461.

Russo, S., A. Dosio, A. Sterl, P. Barbosa, and J. Vogt, 2013: Projection of occurrence of extreme dry-wet years and seasons in Europe with stationary and non-stationary Standardized Precipitation Index. *J. Geophys. Res,* **118**, 1–12.

NARCliM: Regional Climate Projections for Australia

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Including the impacts of climate change in decision making and planning processes is a challenge facing many regional governments including the New South Wales (NSW) and Australian Capital Territory (ACT) governments in Australia. NARCliM (NSW/ACT Regional Climate Modelling project – Evans et al., 2014) is a regional climate modelling project that aims to provide a comprehensive and consistent set of climate projections that can be used by all relevant government departments when considering climate change. To maximize end user engagement and ensure outputs are relevant to the planning process, a series of stakeholder workshops were run to define key aspects of the model experiment including spatial resolution, time slices, and output variables.

As with all such experiments, practical considerations limit the number of ensemble members that can be simulated such that choices must be made concerning which global climate models (GCMs) to downscale from, and which regional climate models (RCMs) to downscale with. Here a methodology for making these choices that aims to sample the uncertainty in both GCM and RCM ensembles, as well as spanning the range of future climate projections present in the GCM ensemble. The RCM selection process uses performance evaluation metrics to eliminate poor performing models from consideration, followed by explicit consideration of model independence in order to retain as much information as possible in a small model subset. In addition to these two steps the GCM selection process also considers the future change in temperature and precipitation projected by each GCM. The final GCM selection is based on a subjective consideration of the GCM independence and future change. The created ensemble provides a more robust view of future regional climate changes.

NARCliM uses version 3.3 of the Weather Research and Forecasting (WRF) regional climate model (RCM) to perform an ensemble of simulations for the present and the projected future climate. WRF is run in three different model configurations (different combinations of physical parameterizations) that have been shown to perform well in the South-East Australia. These three RCMs are used to simulate three different periods: 1990–2009, 2020–2039 and 2060–2079. Four different Global Climate Models (GCMs: MIROC-medres 3.2, ECHAM5, CCCMA 3.1 and CSIRO mk3.0) from CMIP3 are used as initial and boundary conditions for the WRF simulations. Thus a RCM ensemble of 12 simulations for each period is obtained. Additionally to the GCM-driven simulations, 3 control run simulations driven by the NCEP/NCAR reanalysis for the entire period of 1950–2009 are also performed in order to validate the RCMs performance in the area. A comprehensive dynamically downscaled climate dataset for the CORDEX-AustralAsia region at 50 km, and South-East Australia at a resolution of 10 km was created. Data is available through the AdaptNSW website (http://climatechange.environment.nsw.gov.au/).

The NARCliM ensemble has been assessed in terms of the biases, inter-model agreement and ability to capture teleconnections with large scale modes. Projected future changes have been examined for mean climate as well as extremes of precipitation and temperature, including heat waves and storm systems. In collaboration with government scientists, climate change impacts on various systems is being investigated including: coastal erosion; estuarine tidal inundation; floods; droughts; rainfall erosivity; soil properties; water quality; urban climate; air quality; and ecological change (biodiversity).

References

Evans, J.P., et al., 2014: Design of a regional climate modelling projection ensemble experiment – NARCliM. *Geosci. Model Dev.*, **7**, 621–629.

Robust Forced Signals and Irreducible Uncertainties in Projections of Extremes

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Decision makers express a strong need to shift the focus of climate projections from changes at global scale to changes at regional and local scale, from the end of the century to the coming decades, from changes multi-decadal mean temperatures to changes in extreme events. This new focus of climate projections implies an increasing contribution of internal variability to projection uncertainties. Understanding and quantifying the role of internal variability is vital to identify the limits of predictability—the irreducible uncertainty in multi-decadal projections—and the limits of model evaluation and bias correction.

Using different large initial condition ensembles, we demonstrate that models agree remarkably well on the forced signal of temperature and heavy precipitation extremes, the pattern of change in the absence of internal variability (Fischer et al., 2014). The disagreement between individual model simulations on local to regional changes in extremes primarily arises from internal variability. Thus, in the coming 3–5 decades trends towards more intense hot and less intense cold extremes may be masked or even reversed in some places even if greenhouse-gas emissions rapidly increase (Fischer et al., 2013). Likewise, despite a trend to more intense

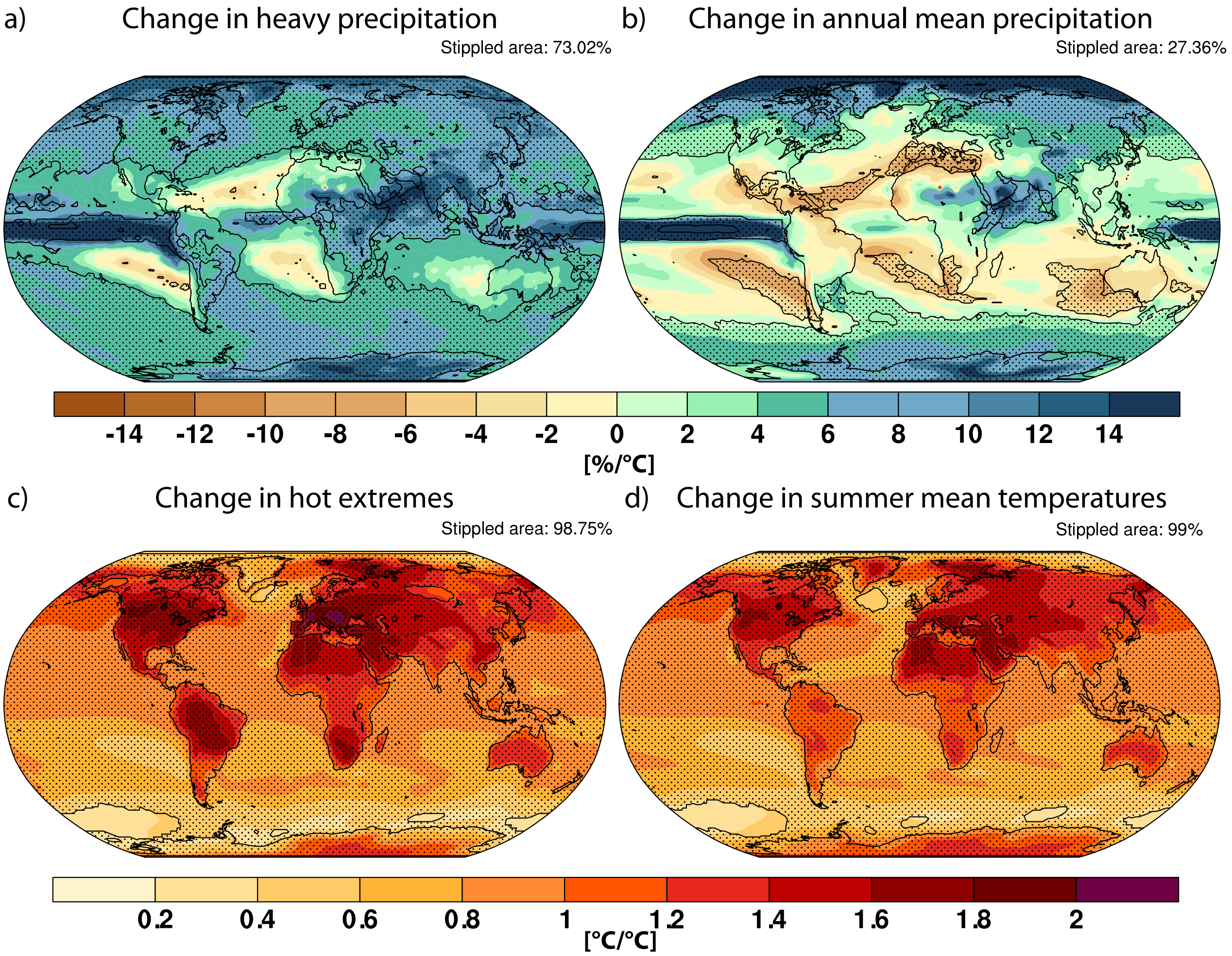

Figure 1: Model robustness in forced signal: Multi-model mean changes in (a) heavy precipitation intensity, (b) annual mean precipitation, (c) hot extremes, and (d) local summer mean temperature (June-July-August in Northern and December-January-February in Southern Hemisphere) per degree global warming in 15 CMIP models. Estimates are based on a linear regression of local changes with respect to global mean temperature change in the respective model simulation in the period 1901–2100 (historical and RCP8.5). Stippling illustrates agreement in sign of changes across at least 12 of the 15 models (80% of models) (reproduced from Fischer et al., 2014).

precipitation, opposite trends of multiple decades cannot be excluded over most land points. Despite large irreducible uncertainties at local scale, in an aggregated spatial probability perspective projections are again remarkably consistent already for the coming decades (Fischer et al., 2013).

References

Fischer, E.M., U. Beyerle, and R. Knutti, 2013: Robust spatially aggregated projections of climate extremes. *Nature Climate Change*, **3**, doi:10.1038/nclimate2051.

Fischer, E.M., J. Sedlacek, E. Hawkins, and R. Knutti, 2014: Models agree on forced response pattern of precipitation and temperature extremes. *Geophys. Res. Lett.*, **10**, doi:1002/2014GL062018.

Fischer, E.M., and R. Knutti, 2015: Anthropogenic contribution to global occurrence of heavy-precipitation and high-temperature extremes. *Nature Climate Change*, **5**, doi:10.1038/nclimate2617.

Bindoff, N.L., P.A. Stott, K.M. AchutaRao, M.R. Allen, N. Gillett, D. Gutzler, K. Hansingo, G. Hegerl, Y. Hu, S. Jain, I.I. Mokhov, J. Overland, J. Perlwitz, R. Sebbari and X. Zhang, 2013: Detection and Attribution of Climate Change: from Global to Regional. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 867–952.

Impact of Climate Change on Heating and Cooling Degree Days and Potential Energy Demand in the Household Sector of China

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Based on simulations with a regional climate model, future changes of heating and cooling degree days (HDD and CDD) in the 21st century over mainland China are projected in order to investigate the potential effects of climate change on energy consumption in the household sector. Validation of the model shows a good performance in reproducing both spatial distribution and magnitude of the present day HDD and CDD.

Significant decreases of HDD and increases of CDD are projected under the warming. These are further weighted by population for a first order assessment of future changes in energy demand. A larger decrease of population-weighted HDD compared to the increase of CDD is projected, indicating a decrease of the total energy demand. However, the simulations show a marked spatial heterogeneity in the change of energy demand, which increases in the south and decreases in the north, and a seasonal shift of increasing demand in summer and decreasing in winter. Furthermore, when the reference temperature for heating and cooling moves from currently used standard to a more commonly used 18°C, potentially large increases of energy demand are expected. These results have important implications for the energy management policies in the country.

Table 1: Population weighted HDD and CDD in the present day (1986–2005), and their changes/percentage changes in the mid (2046–2065) and end (2080–2099) of the 21st century under RCP4.5 and RCP8.5. HDD18 and CDD18 use the reference temperature of 18°C.

	Present day (°C · d)	Mid of 21st century (°C · d / %)		End of 21st century (°C · d / %)	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
HDD	1220	−145 / −12	−212 / −17	−180 / −15	−352 / −29
CDD	81	63 / 77	110 / 135	86 / 106	236 / 291
HDD18	2458	−297 / −12	−401 / −16	−352 / −14	−682 / −28
CDD18	884	227 / 26	338 / 38	262 / 30	608 / 69

References

Gao, X.J., M.L. Wang, and F. Giorgi, 2013: Climate change over China in the 21st century as simulated by BCC_CSM1.1-RegCM4.0. *Atmos. Ocean. Sci. Lett.*, **6**, 381–386.

Thom, H.C.S., 1952: Seasonal degree-day statistics for the United States. *Mon. Wea. Rev.*, **80**,143–149.

Wu, J., and X.J. Gao, 2013: A gridded daily observation dataset over China region and comparison with the other datasets. *Chin. J. Geophys.*, **56**, 1102–1111.

Statistical precipitation bias correction of gridded model data using point measurements

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It is well known that climate model output data cannot be used directly as input to impact models, e.g., hydrology models, due to climate model errors. Recently, it has become customary to apply statistical bias correction to achieve better statistical correspondence to observational data. As climate model output should be interpreted as the space-time average over a given model grid box and output time step, the status quo in bias correction is to employ matching gridded observational data to yield optimal results. Here we show that when gridded observational data are not available, statistical bias correction can be carried out using point measurements, e.g., rain gauges. Our nonparametric method, which we call scale-adapted statistical bias correction (SABC), is achieved by data aggregation of either the available modeled or gauge data. SABC is a straightforward application of the well-known Taylor hypothesis of frozen turbulence. Using climate model and rain gauge data, we show that SABC performs significantly better than equal-time period statistical bias correction.

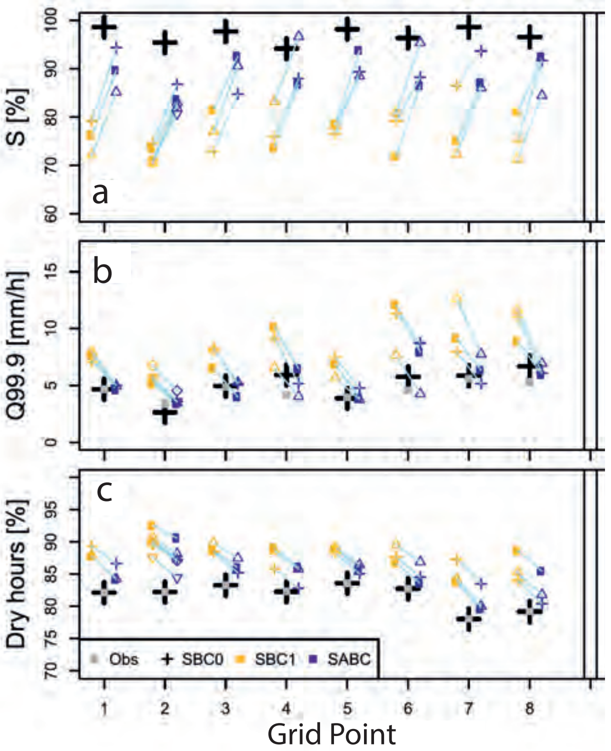

Figure 1: (a) PDF agreement, (b) 99.9th intensity percentile, and (c) dry period fraction. Black colors indicate 'perfect' correction, gray symbols indicate observations, orange is a naïve correction, and blue is the improved scale-adapted bias correction. Lines are guides to the eye, each line represents one possible correction (details: Poster).

References

Haerter, J.O., B. Eggert, C. Moseley, C. Piani, and P. Berg, 2015: Statistical precipitation bias correction of gridded model data using point measurements. *Geophys. Res. Lett.*, **42**, 1919–1929.

Eggert, B., P. Berg, J. Haerter, D. Jacob, and C. Moseley, 2015: Temporal and spatial scaling impacts on extreme precipitation. *Atmos. Chem. Phys. Discuss.*, **15**(2), 2157–2196.

Skill of CMIP5 Climate Models in Reproducing 20th Century Basic Climate Features in Central America

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A total of 107 climate runs from 48 Coupled Model Intercomparison Project 5 (CMIP5) general circulation models (GCMs) were evaluated for their ability to skillfully reproduce basic characteristics of late 20th century climate over Central America. The models were ranked according to metrics that take into consideration the mean and standard deviation of precipitation (pr) and surface temperature (tas), as well as the El Niño-Southern Oscillation (ENSO)-pr teleconnection. Verification was performed by comparing model runs to observations and a reanalysis dataset. Based on the rankings, the best 13 models were further evaluated. Not surprisingly, the models showed better skill at reproducing mean tas patterns throughout the year. The skill is generally low for mean pr patterns, except for some models during March, April, and May. With a few exceptions, the skill was low for reproducing the observed monthly standard deviation patterns for both pr and tas. The ENSO-pr teleconnection was better simulated in the best 13 model runs compared to the sea-surface temperature global pattern characteristic of ENSO which showed low skill. The Inter-tropical Convergence Zone (ITCZ) appeared better modeled in July than in January. In January, there were instances of a double ITCZ pattern. Some models skillfully reproduced the seasonal distribution of the Caribbean Low-Level Jet index (CLLJ). More detailed research evaluating the specific performance of the models on a variety of time-scales and using parameters relevant to these and other climatic features of Central America is needed. This study facilitates a pre-selection of models that may be useful for this task.

Deriving Certainty from Uncertainty via Impact Modeling

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It is generally assumed, that each step of a modeling chain leads to an amplification of the uncertainty-cascade (e.g., Giorgi, 2010), according to the error growth theory. Giorgi (2010) differentiates between the "bad" uncertainty (knowledge uncertainty: resulting from limited knowledge of processes or insufficient process implementation in the models) and the "good" uncertainty (intrinsic uncertainty: resulting from different emission pathways and internal climate variability). The knowledge uncertainty can in principle be reduced with further research. However, the intrinsic uncertainty will remain and we need to explore the whole bandwidth of possible climate results, particularly for extremes. Thus, impact modeling studies will always need to deal with bandwidths of climate projection results.

We postulate that for a number of impact assessment applications, the uncertainty stemming from the climate model results can be reduced due to the application of the impact model or the impact assessment.

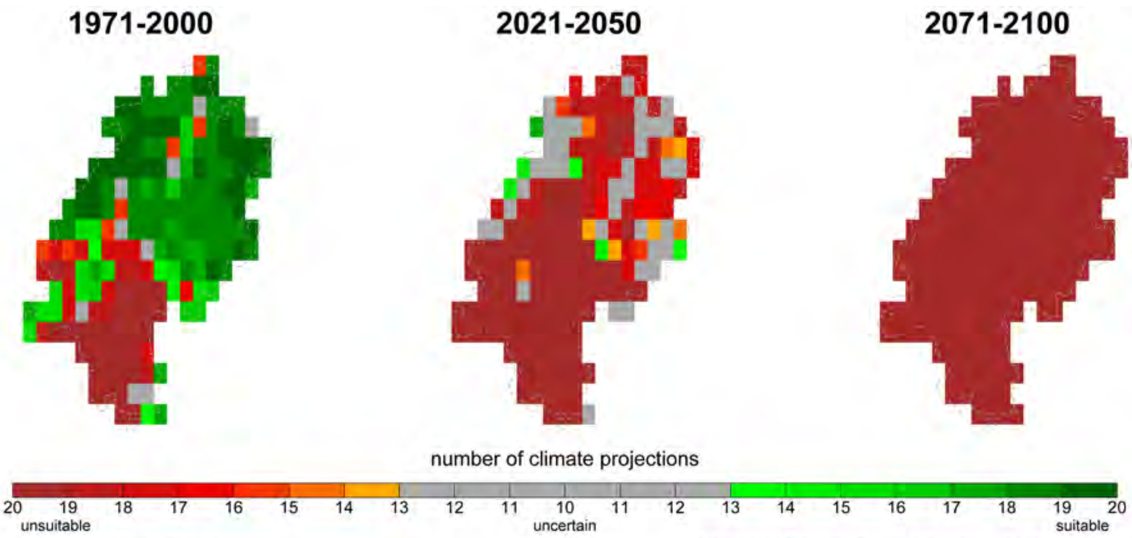
Error propagation is defined as:

$$S(T,P) \Rightarrow \Delta S \leq \left\| \left. \frac{\partial S}{\partial T} \right|_{T=T_x, P=P_x} \cdot \Delta T \right\| + \left\| \left. \frac{\partial S}{\partial P} \right|_{T=T_x, P=P_x} \cdot \Delta P \right\|$$

with S the (dependent) target variable and T and P the (independent) variables steering the outcome. From the theoretical point of view DS becomes small, at points where all derivations approach zero, i.e., when the surface defined by the function S becomes flat. This means that the error nears zero at a point where the impact system under consideration reacts constant to an ever increasing change in one of the driving variables.

To visualize this, we take an example from forestry: The suitability (S) of the common spruce (*Picea abies*) at a specific location depends on temperature (T) and precipitation (P) conditions. The regime representing the suitable climatic conditions for a given plant or animal species is referred to as a climate envelope (e.g., Kölling, 2007; Ferrise et al., 2011) in the system of an impact response surface (Fronzek et al., 2011; Weiß, 2011).

When one of the climate parameters is not in the range of the climate envelope, growing common spruce (in our case) is not suitable at the specific location. Thus, at a point where one of the two values (T_x or P_x) is unsuitable for the tree, it is irrelevant for the suitability of common spruce whether the steering variables T or P have a large spread (DT or DP). Figure 1 shows the suitability for growing common spruce in Hesse, Germany, using annual mean temperature (T_{ann}) and precipitation in the



Data: Hessian Centre on Climate Change

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Figure 1: Suitability maps for growing common spruce (*Picea abies*) in Hesse, Germany, derived from 20 different combinations of global and regional models, scenario A1B. Red colors indicate that a majority of the models result in unsuitable growing conditions, green colors indicate suitable growing conditions. Where the models give equivocal results, the boxes are colored grey.

forestry vegetation period (May to September, P_{veg}). We display the number of models that result in suitable or unsuitable conditions. Thus, a bandwidth of model results are condensed in a form the users are comfortable with.

The impact model results give a clear-cut answer with respect to the system in question for the time horizon 2071–2100. However, the climate projections used for the calculation show a bandwidth of results: DT_{ann}(2071–2100 vs. 1971–2000) ranges between +1.9°C and +3.7°C and DP_{veg}(2071–2100 vs. 1971–2000) between –21 and –5%. For all of these outcomes the area of Hesse would be unsuitable for growing common spruce. Thus, we have (in a very simple case) reduced the uncertainty of the climate information by application of an impact model.

Of course there are applications where this approach would not yield results as simple as the example shown here. However, we postulate that it would be worth the effort to develop impact modeling studies of this kind of analysis to reduce uncertainty for the stakeholders who have to derive policy or investment decisions on the results. In the next step we now test a model with slightly higher input accuracy requirements (average temperature in January and precipitation in June, July and August) to start testing the limits of our approach.

References

Ferrise, R., M. Moriondo, and M. Bindi, 2011: Probabilistic assessments of climate change impacts on durum wheat in the Mediterranean region. *Natural Hazards and Earth System Sciences*, **11**, 1293–1302.

Fronzek, S., T.R. Carter, and M. Luoto, 2011: Evaluating sources of uncertainty in modeling the impact of probabilistic climate change on sub-arctic palsa mires. *Natural Hazards and Earth System Sciences,* **11**, 2981–2995.

Giorgi, F., 2010: Uncertainties in climate change projections, from the global to the regional scale. *EPJ Web of Conferences*, **9**, 115–129.

Kölling, C. (2007): Bäume für die Zukunft. Bayerische Landesanstalt für Wald und Forstwirtschaft (LWF). *Aktuell*, **60**, 35–37. *(in German)*

Weiß, M., 2011: Future water availability in selected European catchments: a probabilistic assessment of seasonal flows under the IPCC A1B emission scenario using response surfaces. *Natural Hazards and Earth System Sciences*, **11**, 2163–2171.

Assessment of the Performance of CORDEX RCMs in Simulating East African Rainfall

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The daily precipitation simulations from ten CORDEX RCMs (Nikulin et al., 2012) for the period 1989–2008, forced by reanalysis ERA-INTERIM data were utilized in the study (Hussen et al., 2013) to assess the capability of the RCMs in reproducing the characteristics of rainfall patterns over an East African domain lying within 160°S–180°N; 220°E–520°E against the Global Precipitation Climate Project (GPCC) daily precipitation time series. The comparison of the RCMs simulations with the GPCP observations were done for three sub-regions of the study domain namely Northern (NEA), Eastern (EEA) and Southern (SEA) as classified on the basis of rainfall distribution (Favre et al., 2011).

The bulk of rainy season in NEA is from June to September (JJAS). EEA has two rainy seasons, long rains from March to May (MAM) and short rains from October to December (OND). The long rains in EEA are dominated by local factors rather than large scale drivers and the short rains tend to have stronger interannual variability and a substantial association with ENSO and Indian Ocean Dipole (IOD) (Ropelewski and Halpert, 1987, 1989; Ogallo, 1988; Nyakwada, 2009). OND is the first half of the rainy season in SEA. The CORDEX RCMs simulations were assessed in season JJAS for NEA, and in season OND for EEA and SEA.

The climatology of rainfall in East Africa during JJAS in all RCMs, ensemble mean of RCMs and observations show presence of rainfall band over NEA which is associated with northward movement of ITCZ. During OND, all RCMs and observations show concentration of rainfall band over the equator and South of equator where ITCZ is located at this time of the year. The annual rainfall cycle is well reproduced by most RCMs in NEA and SEA but some RCMs have missed the OND rainfall peak in EEA. Statistical comparison of the simulated and observed mean seasonal total rainfall based on paired t test show significant biases in individual models in the three subregions. Further analysis show that the RCMs are able to reproduce the documented regional responses to ENSO and IOD forcings. In general, the RCMs ensemble mean simulates East African rainfall more closely than individual RCMs.

References

Favre, A., D.Stone, R. Cerezo, N. Philippon, and B. Abiodun, 2011: Diagnostic of monthly Rainfall from CORDEX simulations over Africa: Focus on the annual cycles. Proceedings of the International Conference on the Coordinated Regional Climate Downscaling Experiment - CORDEX, Trieste, Italy, World Climate Research Program. Available online at: http://indico.ictp.it/indico/getFile.py/access?resId=3&materialId=1&confId=a10131.

Hussen, S.E., P. Omondi, S. Jain, C. Lennard, B. Hewitson, L. Chang'a, J.L. Awange, A. Dosio, P. Ketiem, G. Nikulin, H.J. Panitz, M. Büchner, F. Strodal, and L. Tazalika, 2013: Assessment of the Performance of CORDEX Regional Climate Models in Simulating East African Rainfall. *Journal of Climate*, **26**, 8453–8475.

Nikulin, G., and Co-authors, 2012: Precipitation climatology in an ensemble of CORDEX-Africa regional climate simulations. *J. Climate*, **25**, 6057–6078.

Nyakwada, W., 2009: Predictability of East African seasonal rainfall with sea surface temperature gradient modes. Ph.D. dissertation, University of Nairobi, 265 pp.

Ogallo, L.J., 1988: Relationships between seasonal rainfall in East Africa and the Southern Oscillation. *J. Climatol.*, **8**, 31–43.

Ropelewski, C.F., and M.S. Halpert,, 1989: Precipitation patterns associated with the high index phase of the Southern Oscillation. *J. Climate*, **2**, 268–284.

Ropelewski, C.F., and M.S. Halpert, 1987: Global and regional scale precipitation patterns associated with the El Nino/Southern Oscillation. *Mon. Wea. Rev.*, **115**, 1606–1626.

Decadal-scale Step Changes Dominate the Warming Process

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The climate research community's preferred tool for analysing the changing climate is ordinary least-squares linear trend analysis. This model and its variants have been highly successful in measuring long-term climate trends, for detection and attribution and for developing and communicating climate projections. However, trend analysis is a suitable tool for showing how much climate has changed but does not necessarily show how climate will change. This is an important distinction for decision making.

A major gap in our understanding of climate is how it changes over decadal timescales (Solomon et al., 2011). The scientific literature contains two competing hypotheses that link anthropogenic climate change and variability (Corti et al., 1999; Hasselmann, 2002):

1. Anthropogenic climate change occurs independently of climate variability (H1).

2. Anthropogenic climate change interacts with climate variability (H2).

H1 is generally interpreted as a monotonic trend driven by gradual climate forcing and mediated by climate variability producing a straight line or curve with variations away from the trend. H2 is usually conceived as non-linear interactions of climate change and variability, where both aspects of change can potentially produce significant non-linear responses (Corti et al., 1999; Solomon et al., 2011; Kirtman et al., 2013).

Here we use the Maronna-Yohai bivariate test (Maronna and Yohai, 1978) with a rule-based procedure designed to detect multiple step changes in five historical time series of surface air temperature. Globally, upward step changes occur in 1997 and 1979/1980 in all five records tested. The 1997 step is the largest recorded at 0.31°C ± 0.01°C. The 1979/1980 is the next largest at 0.22°C ± 0.03°C. In the first half of the 20th century, three records show positive steps in 1920/1921 and in 1937, and two in 1930. One record, GISS, also shows a downward step in 1903, coinciding with the northern hemisphere ocean, tropics and parts of the southern hemisphere.

Twentieth century simulations of mean global warming from the CMIP3 and CMIP5 model archives reproduce the broad patterns seen in observed global, hemispheric and zonal temperatures. The complete ensemble of 107 independent simulations from the CMIP5 archive, reproduces the major peaks for step changes in the observations. Fifty-five percent of CMIP5 ensemble members undergo a step change in 1996–1998, 40% in 1976–1978 and 19% in 1986–1988, the main peaks in the second half of the 20th century. The period of little change mid-century and shifts in the early part of the century are reproduced, but less well. The models shift in 1916 rather than 1920–1921, and the 1937 peak is reproduced less often than in observations. Downward shifts occur in both observations and the models in the late 19th century but do not coincide, the models being associated with known volcanic eruptions.

Investigation of the so-called hiatus showed that the magnitude of the 1997/1998 shift is not correlated with equilibrium climate sensitivity (ECS) or the slope of the following trend but is correlated with period length either side of the shift (0.33 before, 0.50 after) and the magnitude of the following shift (0.43). Because the models with higher ECS correlated more strongly with both greenhouse gas and volcanic forcing in other time periods, the presence of the Mt Pinatubo eruption in the early 1990s is interpreted as cancelling out the positive influence of greenhouse gas forcing on sensitivity. The current 'hiatus' is 18 years in length compared to the longest period of the 58 models that shifted in 1996–1998 of 26 years.

Analysis of steps and internal trends between those steps suggest that 64% of the intermodel variation in total 21st century warming (2006–2095) can be explained by step changes in temperature, whereas internal trends only explain 18%. Over the historical period 1861–2005, there is no substantial relationship between ECS and total warming, step changes or internal trends, implying that historical warming is a poor predictor for potential future warming.

In the model simulations, temperature follows a step-ladder like process to the late 20th century, then moves into a step and trend, or elevator-like process. The time it remains in this phase depends strongly on greenhouse gas forcing. RCP2.6 simulations stabilise as early as 2018 through to 2092, whereas RCP8.5 becomes dominated by trends rather than steps over the whole century. This we interpret as an increase in entropy resulting in many local shifts in temperature, much like a boiling pot. The RCP2.6 simulations show it may be possible to stabilise temperatures by mid-century but given the world is currently tracking at higher emissions and concentrations, would require greater efforts to stabilise global surface temperature over this time frame.

Our analysis suggests that so-called hiatus periods are an intrinsic part of the climate process. Climate occupies specific regimes that can shift under the influence of internal or external forcing and will shift more frequently under increasing external forcing. With the current record temperatures occurring in many parts of the world, we speculate that the world is entering its next shift in climate and 2016 will see a new regime of climate that is around 0.3°C or greater warmer than currently. Based on the evidence from the models, we may also be moving from step-ladder to escalator-like warming, and will continue to do so until emissions are sufficiently curbed.

The framing of climate risk as a step and trend process is very different to that assumed via gradual change. Steps affect systems as shocks and can rapidly change the incidence of extreme events, leading to critical thresholds being breached unexpectedly (Jones et al., 2013). Changes at the global scale in the order of 0.3°C in the ocean are associated with changes in the order of 0.7°C–0.8°C on land, leading to considerable changes in local climate risk.

References

Corti, S., F. Molteni, and T.N. Palmer, 1999: Signature of recent climate change in frequencies of natural atmospheric circulation regimes. *Nature*, **398**, 799–802.

Hasselmann, K., 2002: Is Climate Predictable? In: *The Science of Disasters: Climate Disruptions, Heart Attacks, and Market Crashes* [Bunde, A., J. Kropp and H.J. Schellnhuber (eds.)] Springer, Berlin Heidelberg, 141–188.

Jones, R.N., C.K. Young, J. Handmer, A. Keating, G.D. Mekala, and P. Sheehan, 2013: *Valuing Adaptation under Rapid Change*. National Climate Change Adaptation Research Facility, Gold Coast, Australia, 182 pp.

Kirtman, B., S. Power, A.J. Adedoyin, G. Boer, R. Bojariu, I. Camilloni, F. Doblas-Reyes, A. Fiore, M. Kimoto, G. Meehl, M. Prather, A. Sarr, C. Schär, R. Sutton, G.J.v. Oldenborgh, G. Vecchi, and H.-J. Wang, 2013: Near-term Climate Change: Projections and Predictability. In: *Climate Change 2013: The Physical Science Basis. Working Group I contribution to the IPCC 5th Assessment Report* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)] Cambridge University Press, Cambridge and New York, 121 pp.

Maronna, R., and V.J. Yohai, 1978: A bivariate test for the detection of a systematic change in mean. *Journal of the American Statistical Association*, **73**, 640–645.

Solomon, A., L. Goddard, A. Kumar, J. Carton, C. Deser, I. Fukumori, A.M. Greene, G. Hegerl, B. Kirtman, Y. Kushnir, M. Newman, D. Smith, D. Vimont, T. Delworth, G.A. Meehl, and T. Stockdale, 2011: Distinguishing the Roles of Natural and Anthropogenically Forced Decadal Climate Variability. *Bulletin of the American Meteorological Society*, **92**, 141–156.

Evaluation of RegCM4 Downscaling Simulations of Southeast Asia Rainfall

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Rainfall is a crucial input for simulation of hydrological processes in the assessment of climate change impact on water resources. In current study, the performance of the RegCM4 (Giorgi et al., 2012) in simulating rainfall variations over the Southeast Asia regions at 36 km resolution was examined. The study is part of the effort under the multi-nations collaborative program – CORDEX-Southeast Asia. Different combinations of six deep convective parameterization schemes, namely i) Grell scheme with Arakawa-Schubert closure assumption, ii) Grell scheme with Fritch-Chappel closure assumption, iii) Emanuel MIT scheme, iv) mixed scheme with Emanuel MIT scheme over the Ocean and the Grell scheme over the land, v) mixed scheme with Grell scheme over the land and Emanuel MIT scheme over the ocean and (vi) Kuo scheme, and three ocean flux treatments were examined. In order to account for uncertainties among the observation products, four different gridded rainfall products (i.e., Tropical Rainfall Measuring Mission, TRMM's 3B42 rainfall estimate; Climate Research Unit, CRU's TS3.21 datasets; Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources, APHRODITE's V1204 datasets and Global Precipitation Climatology Centre, GPCC's gridded dataset) were used for comparison. The simulated climate is generally drier over the equatorial regions and wetter over the mainland Indo-China compare to the observations. However, simulation with MIT cumulus scheme used over the land area consistently produces large positive rainfall biases, although it simulates more realistic annual rainfall variations. The simulations are found to be less sensitive to treatment of ocean fluxes. Although the simulations produced the rainfall climatology well, all of them simulated much stronger interannual variability compare to that of the observed. Nevertheless, the time evolution of the inter-annual variations was well reproduced particularly over the eastern part of maritime continent. Ensemble averaging all the simulations improves the interannual variability but the large biases remain consistently. Over the mainland Southeast Asia (SEA), unrealistic rainfall anomalies processes were simulated. The lacking of summer season air-sea interaction results in strong oceanic forcings over the regions, leading to positive rainfall anomalies during years with warm ocean temperature anomalies. This incurs much stronger atmospheric forcings on the land surface processes compare to that of the observed. A score ranking system was designed to rank the simulations according to their performance in reproducing different aspects of rainfall characteristics. The result suggests that the simulation with Emanuel MIT convective scheme and BATs land surface scheme produces better collective performance compare to the rest of the simulations.

References

Giorgi, F., E. Coppola, F. Solmon, L. Mariotti, M. Sylla, X. Bi, N. Elguindi, G.T. Diro, V. Nair, G. Giuliani, S. Cozzini, I. Guettler, T.A. O'Brien, A. Tawfik, A. Shalaby, A. Zakey, A. Steiner, F. Stordal, L. Sloan, and C. Brankovic, 2012: RegCM4: Model description and preliminary tests over multiple CORDEX domains. *Climate Research*, **52**, 7–29.

Overview of the CORDEX-East Asia and Its Progresses

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Coordinated Regional Downscaling Experiment (CORDEX) is a WMO WCRP sponsored research program that aims for improvements in regional climate downscaling methods, production of downscaled climate projections, and facilitation of communication between the modeling and IAV sectors. CORDEX recommends a common framework (e.g., domain, resolution, forcing) in model configuration for 14 worldwide regions in continental scales. For several years since 2009, Korea Meteorological Administration (KMA) has played the role in leading CORDEX-East Asia by carrying out several regional downscaling experiments and managing web-portal based data bank for archiving and distributing their model outputs.

Using the multi-model ensemble simulations driven by two reanalysis data forcings, prediction skills of several ensemble methods for temperature and precipitation have been investigated. In terms of conventional statistical scores (i.e., bias, RMSE, and correlation), a performance-based ensemble averaging (PEA) method by using RMSE and absolute correlation shows the best skill, irrespective of the seasons and variables (Suh et al., 2012). This result confirms that the performance-based ensemble method developed in this study can be used for the bias-corrected regional climate projection. When this method is applied for historical and projection simulations driven by a single GCM forcing, however; the results implies that multiple GCM forcing are required to represent reasonable spread of model uncertainties. In addition to efforts for developing ensemble methods, characteristics of climate extremes for 1979–2005 over East Asia by five regional climate models are investigated using the generalized extreme value (GEV) method (Park et al., 2015). RCMs show systematic bias patterns in both seasonal means and extremes. A cold bias is located along the coast, whereas a warm bias occurs in northern China. Overall, wet bias occurs in East Asia, but with a substantial dry bias centered in South Korea. Taylor diagram analyses reveal that the models simulate temperature means more accurately compared to extremes because of the higher spatial correlation, whereas precipitation extremes are better simulated than their means because of the higher spatial variability. The latter implies that extreme rainfall events can be captured more accurately by RCMs despite poor simulation of mean rainfall.

In order to answer the question if we need to provide internal anthropogenic forcing (particularly aerosol forcing) in regional climate model even though those forcing are coming from lateral boundary conditions from a GCM, a few experiments are conducted with a single regional climate model, i.e., HadGEM3-RA. In the control experiment without internal anthropogenic forcing, temperature in northwestern China and Mongolia shows significant cold biases. Meanwhile, in the experiment with the aerosol forcing, the cold biases are reduced about 15–20 % compared to the control experiment. This result implies the importance of consistent treatment of cloud-aerosol feedback process between the GCM and RCM configuration.

Now, the second phase of CORDEX-EA has begun, in which the horizontal resolution is increased to 25 km with a bit smaller domain. Potential participating regional climate modeling groups becomes much more compared to the previous phase mainly from China, Japan, Korea, but not exclusively to East Asia countries. It is quite welcome to join from everywhere if you are interested in.

References

Suh, M.-S., S.-G. Oh, D.-K. Lee, D.-H. Cha, S.-J. Choi, C.-S. Jin, and S.-Y. Hong, 2012: Development of new ensemble methods based on the performance skills of regional climate models over South Korea. *Journal of Climate*, **25,** 7067–7082.

Park C., S.-K. Min, D. Lee, D.-H. Cha, M.-S. Suh, H.-S. Kang, S.-Y. Hong, D.-K. Lee, H.-J. Baek, K.-Y. Boo, and W.-T. Kwon, 2015: Evaluation of multiple regional climate models for summer climate extremes over East Asia. *Climate Dynamics*, doi:10.1007/s00382-015-2713-x.

Possible Change in Distribution of Seaweed, *Sargassum horneri*, in Northeast Asia Under A2 Scenario of Global Warming and Consequent Effect on Some Fish

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Global warming effects on coastal marine ecosystems are already perceptible, especially in shallow water communities. The primary production of seaweed or seagrass beds in shallow waters is similar to that of tropical rain forests. Moreover, they constitute some highly valuable spawning, nursery and feeding grounds for numerous organisms in coastal waters. Geographical distributions of these plants greatly depend on water temperatures in summer and winter because they are very sensitive to maximum and minimum temperatures. As a result, it is expected that a water temperature increase will influence drastically the current distribution. To test this hypothesis, we referred to future water temperatures simulated by 12 organizations based on the SRES A2 scenario of global warming (IPCC, 2000). We processed these data to monthly mean water temperature at a resolution of about 1.1 degree of longitude and 0.6 degree of latitude in the northwestern Pacific Ocean. Using simulated surface water temperatures in February and August in 2050 and 2100, we examined changes in the spatial distribution of a specific seaweed species: *Sargassum horneri*. This species was selected due to ecological importance: formation of large seaweed beds and wide thermal tolerance. The southern limit of *S. horneri* distribution is expected to keep moving northward such that it may broadly disappear from Honshu Island, the Chinese coast, and Korean Peninsula by 2100. In offshore waters of East China Sea, surveys using resaerch vessels indicated that drifting seaweeds consisted of only *S. horneri.* On the other hand, they consisted of several *Sargassum* species including *S. horneri*. The offshore waters of East China Sea are spawning grounds for yellowtail (*Seriola quinqueradiata*), the most important fin fish for aquaculture in Japan, and jack mackerel (*Trachurus japonicus*). Their larvae accompany the drifting seaweeds there from February to May and are transported to the Kyushu and Honshu islands with drifting seaweeds. It is estimated that their habit reduces their mortality. Though the larvae of yellowtail are canibalistic, they reduce such behavior in a case with drifting seaweeds. Thus, drifting seaweeds are a key nursery ground for yellowtail and jack mackerel spawning there. Disappearance of *S. horneri* is to damage significantly not only fishes related to the coastal waters but also pelagic ones.

References

IPCC, 2000: *Emission Scenarios.* Special Report of the Intergovernmental Panel on Climate Change [Nakicenovic, N. and R. Swart (eds.)], Cambridge University Press, Cambridge, UK. 570 pp.

Downscaling by a High-Resolution Atmospheric Model

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High-resolution modeling is necessary to project weather and climate extremes and their future changes under global warming. A direct dynamical downscaling with a regional climate model (RCM) embedded within an atmosphere-ocean coupled general circulation model (AOGCM) is commonly used but is subject to systematic biases in their present-day simulations of AOGCM, which may cause unexpected effects on future projections and lead to difficult interpretation of climate change. We use a high-resolution atmospheric general circulation model (AGCM)–RCM system to minimize systematic biases (Kitoh et al., 2015). The future climate is calculated with the 'future' boundary conditions (sea surface temperature (SST) and sea-ice), which are created by adding their future changes projected by AOGCM to the observed present-day values (Mizuta et al., 2008). A Meteorological Research Institute AGCM with 20-km grids is applied to project future changes in weather extremes such as tropical cyclones and rain systems that cause heavy rainfall and strong winds at the end of the 21st century (Mizuta et al., 2012). We used four different spatial patterns in SST as boundary conditions (Mizuta et al., 2014). It is projected that heavy precipitation indices (maximum 5-day precipitation total and maximum 1-day precipitation total) increase in all regional domains, even where mean precipitation decrease (Southern Africa, South Europe/Mediterranean, Central America). It is found that South Asia is the domain of the largest extreme precipitation increase. In some domains, different SST patterns result in large precipitation changes, possibly related to changes in large-scale circulations in the tropical Pacific (Kitoh and Endo, 2015). Moreover, uncertainty of the projections is assessed using 60-km mesh AGCM ensemble experiments with different cumulus schemes and different SST change patterns (Endo et al., 2012; Murakami et al., 2012). It is found that the uncertainty from cumulus schemes is large in the precipitation changes over South Asia and Southeast Asia. Further regional downscaling with a few-km mesh RCM can be performed over a certain area to investigate local extreme rainfall events and their future changes (Sasaki et al., 2012; Murata et al., 2015).

References

Endo, H., A. Kitoh, T. Ose, R. Mizuta, and S. Kusunoki, 2012: Future changes and uncertainties in Asian precipitation simulated by multi-physics and multi-sea surface temperature ensemble experiments with high-resolution Meteorological Research Institute atmospheric general circulation models (MRI-AGCMs). *Journal of Geophysical Research*, **117**(D16118), doi:10.1029/2012JD017874.

Kitoh, A., T. Ose, and I. Takayabu, 2015: Dynamical downscaling for climate projection with high-resolution MRI AGCM-RCM. *Journal of the Meteorological Society of Japan*, doi:10.2151/jmsj.2015-022.

Mizuta, R., Y. Adachi, S. Yukimoto, and S. Kusunoki, 2008: Estimation of future distribution of sea surface temperature and sea ice using CMIP3 multi-model ensemble mean. *Technical Report Meteorological Research Institute*, **56**, 28 pp.

Mizuta, R., H. Yoshimura, H. Murakami, M. Matsueda, H. Endo, T. Ose, K. Kamiguchi, M. Hosaka, M. Sugi, S. Yukimoto, S. Kusunoki, and A. Kitoh, 2012: Climate simulations using MRI-AGCM3.2 with 20-km grid. *Journal of the Meteorological Society of Japan*, **90A**, 233–258.

Mizuta, R., O. Arakawa, T. Ose, S. Kusunoki, H. Endo, and A. Kitoh, 2014: Classification of CMIP5 future climate responses by the tropical sea surface temperature changes. *Scientific Online Letters on the Atmosphere*, **10**, 167–171.

Murakami, H., R. Mizuta, and E. Shindo, 2012: Future changes in tropical cyclone activity projected by multi-physics and multi-SST ensemble experiments using the 60-km-mesh MRI-AGCM. *Climate Dynamics*, **39**, 2569–2584.

Murata, A., H. Sasaki, H. Kawase, M. Nosaka, M. Oh'izumi, T. Kato, T. Aoyagi, F Shido, K Hibino, S Kanada, A. Suzuki-Parker, and T. Nagatomo, 2015: Projection of future climate change over Japan in ensemble simulations with a high-resolution regional climate model. *Scientific Online Letters on the Atmosphere*, **11**, 90–94.

Sasaki, H., A. Murata, M. Hanafusa, M. Oh'izumi, and K. Kurihara, 2012: Projection of future climate change in a non-hydrostatic regional climate model nested within an atmospheric general circulation model. *Scientific Online Letters on the Atmosphere*, **8**, 53–56.

Producing, Handling and Disseminating Regional Climate Change Information at the Swedish Meteorological and Hydrological Institute: Experiences from CORDEX

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The international coordinated regional downscaling experiment (CORDEX) was initiated as detailed regional climate change information was lacking for a number of world regions at the time of the fourth assessment report from the IPCC (Jones et al., 2011). The Rossby Centre at the Swedish Meteorological and Hydrological Institute (SMHI) has participated in CORDEX by contributing to its initiation and design and by performing a large number of regional climate model simulations.

The Rossby Centre regional climate model RCA4 has been used to dynamically downscale ten different coupled atmosphere ocean general circulation models (AOGCMs) from the CMIP5 project with horizontal resolution varying from about 1° to 3°. These downscaling experiments have been done for ten different CORDEX regions in most continents. For all regions downscaling has been done at 0.44° (c. 50 km) and in some cases at even higher resolution (e.g., Europe at 0.11°, i.e., c. 12.5 km). In total more than 125 simulations have been conducted covering 1951–2100 under three different scenarios for the future, the RCP2.6, RCP4.5 and RCP8.5 scenarios. It is clear that this large number of simulations and the ensemble approach of CORDEX allow for better identification of robust climate change signals and uncertainty analysis compared to what was previously possible. The large ensembles put forward in CORDEX can also be used to analyze to what extent the climate change signal is representative for the larger underlying CMIP5 ensemble. In addition to the climate change experiments at SMHI RCA4 has also been used to dynamically downscale ERA-Interim reanalysis data for all of the regions as part of the model evaluation process. Results from that work have also been used to address questions of added value by increasing the horizontal resolution for Europe where simulations at both 50 and 12.5 km grid spacing exist (e.g., Prein et al., 2015).

An important part of the work relates to data and resource management by establishing a streamlined work flow for import and preparation of boundary data, storing and post-processing result data from model simulations, production of standardized output files and quality control, and finally publication of the data through the Earth System Grid Federation (see Strandberg et al., (2015) for an illustration of the work flow at the Rossby Centre). In addition capabilities for bias-adjustment have been set up so that bias-adjusted data can be published in parallel to raw model output. All data handling steps have been put in place in order to facilitate further use and dissemination of results. In parallel to the production-oriented scenario work an important effort has been oriented towards knowledge transfer and capacity building.

One central idea in CORDEX has been to involve scientists from different regions of the world including those where the scientific knowledge on regional climate was previously less extensive or even non-existent. Currently, in August 2015, more than 1500 users worldwide have accessed and downloaded CORDEX data from the Swedish ESGF node clearly illustrating the strong impact of CORDEX as a source of regional climate information. These data serves as input to impact studies and to work on adaptation to climate change and is therefore a fundamental resource needed in climate services.

The massive amount of data available from these climate simulations (more than 400,000 NetCDF files have been submitted to the Swedish ESGF node) requires a considerable effort in terms of analyzing and digesting the information. Particularly, a dialogue with end users is important in this aspect. In this work examples are given of how information from the climate change experiments is used in a national climate service perspective which includes dissemination through the SMHI web page and direct dialogue with end users of climate information in Sweden.

References

Jones, C., F. Giorgi, and G. Asrar, 2011: The coordinated regional downscaling experiment: CORDEX. An international downscaling link to CMIP5. *CLIVAR exchanges*, **16**, 34–40.

Prein, A.F., A. Gobiet, H. Truhetz, K. Keuler, K. Goergen, C. Teichmann, C. Fox Maule, E. van Meijgaard, M. Déqué, G. Nikulin, R. Vautard, A. Colette, E. Kjellström, and D. Jacob, 2015: Precipitation in the EURO-CORDEX 0.11° and 0.44° simulations: high resolution, high benefits?, *Climate Dynamics*, doi:10.1007/s00382-015-2589-y.

Strandberg, G., L. Bärring, U. Hansson, C. Jansson, C. Jones, E. Kjellström, M. Kolax, M. Kupiainen, G. Nikulin, P. Samuelsson, A. Ullerstig, and S. Wang, 2014: CORDEX scenarios for Europe from the Rossby Centre regional climate model RCA4. *Reports Meteorology and Climatology*, **116**, SMHI, SE-60176 Norrköping, Sverige.

Atmospheric Rivers and Heavy Precipitation From a Hierarchy of Climate Simulations

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The western U.S. receives precipitation predominantly during the cold season when storms approach from the Pacific Ocean. The snowpack that accumulates during winter storms provides about 70–90% of water supply for the region. Associated with the warm sector of extratropical cyclones over the Pacific Ocean, atmospheric rivers (ARs) provide enhanced water vapor transport from the tropics to produce heavy precipitation upon landfall in the mountainous terrain of the western North America. Using a suite of idealized aqua-planet simulations and AMIP simulations with the Model for Prediction Across Scales (MPAS) coupled to the Community Atmosphere Model (CAM) physics parameterizations at resolutions ranging from 30 km to 240 km, we investigate the sensitivity of simulated AR frequency to model resolution (Hagos et al., 2015). The impacts of global warming on ARs and heavy precipitation are investigated using model outputs from the Community Earth System Model Large Ensemble Project (CESM-LE) and the multi-model ensemble of the Coupled Model Intercomparison Project Phase 5 (CMIP5) to evaluate the thermodynamical and dynamical contributions to changes in extreme precipitation (Gao et al., 2015). Analysis of the hierarchy of climate simulations highlights uncertainty in model simulation of the jet position as a major source of uncertainty in simulating AR frequency. We identified a possible dynamical convergence on the jet position and strength as model resolutions approach roughly 50 km resolution (Lu et al., 2015). To extend the modeling hierarchy for improved representation of the interactions between ARs and the complex terrain that generate high intensity precipitation and floods, MPAS global variable resolution simulations with a regional refinement down to sub-10 km resolution will be discussed.

References

Gao, Y., J. Lu, L.R. Leung, Q. Yang, S. Hagos, and Y. Qian, 2015: Dynamical and thermodynamical modulations on future changes of landfalling atmospheric rivers over western North America. *Geophys. Res. Lett*., accepted.

Hagos, S., L.R. Leung, Q. Yang, C. Zhao, and J. Lu, 2015: Resolution and dynamical core dependence of atmospheric river frequency in global model simulations. *J. Clim*., **28**, 2764–2776.

Lu, J., G. Chen, L.R. Leung, A. Burrows, Q. Yang, K. Sakaguchi, and S. Hagos, 2015: Towards the dynamical convergence on the jet stream in aquaplanet AGCMs. *J. Clim*., doi: 10.1175/JCLI-D-14-00761.1.

Evidence of Added Value in North American Regional Climate Model Simulations Using Ever-Increasing Horizontal Resolutions

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Commonly termed 'added value', the additional regional details gained by regional climate models (RCMs) have not been fully explored and efforts in determining this added value are too few. In the CORDEX project, climate modelling centres around the world are invited to perform RCM simulations over specific domains. The grid mesh of the simulations is fixed to a relatively coarse resolution of 0.44° in order to give the opportunity to centres with less computer power to participate to the project. However, centres with strong computing capabilities are invited to perform higher resolution simulations to investigate the added value of higher resolution simulations. In this work, we compare three RCM simulations with grid meshes of 0.44°, 0.22° and 0.11°, driven by ERA-Interim, for the period 1979–2012 over the North-American CORDEX domain. The analysis will focus on the identification of added value of higher resolution simulations for three specific weather processes: The orographic precipitation on the North American West Coast, the Great Lakes snowbelt and the North American Monsoon.

The RCM used in this study is the fifth-generation Canadian RCM (CRCM5), developed at Université du Québec à Montréal (Martynov et al., 2013). In the CRCM5, lakes are represented by the 1-D FLake model and the surface scheme is the Canadian land-surface scheme (CLASS3.5). No large-scale spectral nudging was applied. Sea surface temperature and sea ice fraction from ERA-Interim are prescribed once per day. All simulations use 56 levels in the vertical and the same subgrid-scale parameterization; only the time step was shortened with increasing resolution.

Orographic precipitation is caused when an air mass, pushed by the winds, is forced to move up a high mountain. The lift of the air up the side of the mountain results in adiabatic cooling, which given sufficient moisture leads to the condensation of the air mass, ultimately generating precipitation. Due to their coarse horizontal resolutions, global climate models (GCMs) and reanalyses have smooth topographies with low mountains and shallow valleys. Thus, with lower mountains, the orographic precipitation from GCMs and reanalyses is generally underestimated, as shown by the 1981-2010 DJF precipitation on the West Coast of North America for ERAI. The West Coast orographic precipitation of the CRCM5 simulations is enhanced compared to ERAI and closer to the CRU and NAOBS gridded datasets. This result agrees with the study of Leung and Qian (2003) that revealed that their 13-km RCM simulation showed added value with amplified winter precipitation along the Cascades and the Sierra Nevada range compared to a 40-km simulation.

The snowbelt describes a region near the Great Lakes where heavy snowfall is common due to the lake-effect snowfall that occurs when a cold continental air mass passes over a unfrozen lake in winter. Turbulent fluxes of heat and moisture destabilize the air mass and increase its moisture content, enhancing cloudiness and snowfall on the downwind shores of the lakes. This mesoscale feature has been simulated by some RCMs and it is recognized as an added value of higher resolution simulations (Notaro et al., 2013). As anticipated, the snowbelt next to the Great Lakes has more snow water equivalent in the 0.11° simulation compared to those at 0.22° and 0.44°. Moreover, the spatial distribution of the snowbelt at 0.11° also matches better that of the National Snow Analysis dataset.

The North American monsoon (NAM) induces a large increase of rainfall from July to mid-September in southwestern United States and northwestern Mexico. This phenomenon is a consequence of many factors such as warm land surfaces in low land areas and atmospheric moisture supplied by nearby oceanic sources. The large spatial variability of the topography in southwestern United States is also an important factor contributing to the NAM. Even though Bukovsky et al. (2013) concluded that RCMs from NARCCAP perform reasonably well in simulating the NAM, they recognized that 50-km resolution may be too coarse to resolve adequately the terrain, coastline and mesoscale circulation features in this region. The large-scale spatial distribution of precipitation in August from the CRCM5 simulations is similar to the observations. However, in detail, the precipitation is larger over the west coast of Mexico and lower in the interior of Mexico at higher resolutions. Over Colorado and New Mexico, the precipitation is also larger in the 0.11° and 0.22° simulations than that at 0.44°. The 0.11° simulation is more realistic than the 0.22° and 0.44° simulations when compared to the gridded observation CONUS.

In general, the CRCM5 simulations show similar features at the large scales. However, at smaller scales, the snowbelt around the Great Lakes, the winter orographic precipitation on the West Coast and the North American monsoon on southwestern United States in the finer resolution CRCM5 simulations match better the gridded observation datasets than the lower resolution simulation and ERA-Interim. The comprehensive evaluation of the CRCM5 simulations is challenged by the lack of a high-resolution station network, which likely results in underestimating high precipitation intensities and small-scale details that would be required to show added value and to fully determine the extent to which higher resolutions give better climate simulations. Overall, the systematic improvements of the finer resolution simulations increase the trust in the ability of RCMs to create meaningful added value.

References

Bukovsky, M.S., D.J. Gochis and L.O. Mearns, 2013: Towards Assessing NARCCAP Regional Climate Model Credibility for the North American Monsoon: Current Climate Simulations. *Journal of Climate*, **26**, 8802–8826.

Leung, L.R., and Y. Qian, 2003: The sensitivity of precipitation and snowpack simulations to model resolution via nesting in regions of complex terrain. *Journal of Hydrometeorology*, **4**, 1025–1043.

Martynov, A., R. Laprise, L. Sushama, K. Winger, L. Šeparović and B. Dugas, 2013: Reanalysis-driven climate simulation over CORDEX North America domain using the Canadian Regional Climate Model, version 5: model performance evaluation. *Climate Dynamics*, **41**, 2973–3005.

Notaro, M., A. Zarrin and S. Vavrus, 2013: Simulation of heavy lake-effect snowstorms across the Great Lakes basin in RegCM4: Synoptic climatology and variability. *Monthly Weather Review*, **141**, 1990–2014.

Adapting Cities to Climate Change: A Systemic Modelling Approach

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To answer the climate change challenge, all states have to reduce their greenhouse gas emissions, but also to adopt adaptation measures to limit the negative impacts of global warming on the population, the economy and the environment. The question arises especially for cities.

Because of complex interactions between climate change, the evolution of cities and its inhabitants, studying adaptation strategies for cities requires a strong interdisciplinary approach: urban planners, architects, meteorologists, building engineers, economists, social sciences.

Our four-step methodology consists firstly of defining interdisciplinary scenarios at several scales influencing the city evolution; secondly of simulating long term city evolution based on socio-economic and land-use models; thirdly of calculating impacts with physical models, and finally of calculating the indicators quantifying the adaptation strategies.

Interdisciplinary systemic modelling performs well to evaluate several adaptation strategies for a very broad range of topics. Some of the results obtained for the agglomeration of Paris through our interdisciplinary research projects VURCA and MUSCADE will be discussed:

A finding is that Urban planning strategies may have unexpected influence on city expansion when considered on the very long term of the climate change. Another is that the combine effect of global warming and UHI can lead in the future to larger energy consumption in summer than in winter.

Indeed, air-conditioning will probably be necessary in 2100, because of expected stronger, and longer, heat waves. Limiting the UHI intensity allows for energy savings, and hence contributes to climate change mitigation. Adaptation strategies exist to limit air-conditioning use, both in time and intensity.

Analysis of several vegetation strategies, at several spatial and planning scales (from agricultural practices in the city surroundings to urban trees and green-roofs) have been performed and evaluated. Architectural choices also allow to reduce the UHI. Finally, inhabitants' use and practices seem to be an efficient lever to reduce energy consumption in buildings and its impact on the urban climate.

Extreme Sea Levels at a Tropical High Island: Stochastic Cyclone Simulation Study for Fiji and Samoa

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In 2008, the Australian Government launched the International Climate Change Adaptation Initiative (ICCAI) to meet high priority adaptation needs of vulnerable countries within the Asia-Pacific region. Part of this initiative was addressed through the Pacific Climate Change Science Program (PCCSP) and later the Pacific-Australia Climate Change Science Adaptation Planning (PACCSAP) program. These programs were delivered by the CSIRO and Australian Bureau of Meteorology who undertook critical climate scientific research and future climate projections for East Timor and 14 Pacific Island countries and commenced important steps in capacity building in Pacific Island countries. A component of the research undertaken in these programs was concerned with developing improved understanding of extreme sea levels in the Pacific.

Tropical cyclone-induced storm surges are arguably responsible for the most damaging impacts of tropical cyclones in coastal regions. Knowing the return periods of the resultant extreme sea level events is therefore important to facilitate disaster planning and preparedness. While tide gauges potentially provide a fundamental data source for evaluating these return periods, the reality is that for many coastlines, including those of Pacific nations, the low density of tide gauges in a spatial sense (typically one per nation), together with the often short length of records, prevents a reliable estimate of extreme sea level return periods. To overcome this problem a statistical and numerical modelling technique was used to estimate extreme sea levels due to storm surge and astronomical tides for Fiji (McInnes et al., 2014) and Samoa (McInnes et al., 2015). Historical cyclones over the period 1969–2010 were analysed to develop information and empirical distributions for TC intensity, tracks (e.g., translation speed and direction), frequency and monthly occurrence. From these, characteristics were sampled to build a population of several thousand TC tracks. Spatial fields of wind and pressure were developed using the parametric cyclone model of (Holland, 2008) and a hydrodynamic model used to simulate the associated storm surge and tides (storm tides). Maps of storm tide return levels were developed for both locations and these indicated that whereas storm tides on the northwest coast of the Fiji archipelago were approximately twice as high as those at other locations around the coast, storm tides for a given return period around the Samoan archipelago were relatively uniform. The archipelago scale of these modelling studies did not allow for the additional role of wind-waves, which can cause a significant additional increase to coastal water levels through the wave breaking processes of wave setup and wave runup. These were investigated in a companion study for a small region surrounding Apia, the capitol of Samoa, using a selection of the synthetic TC ensemble.

The steep bathymetry and high wind-wave exposure of most oceanic islands result in more rapid wave dissipation (through breaking and friction) and higher wave-setup relative to continental shelf coasts (Hoeke et al., 2013). This has a number of implications, not least of which is unusually high contribution of wave-setup, run-up and associated hydrodynamics towards local sea level extremes and coastal inundation at many locations. The coast of Apia features typical high-island fringing reef morphology and was selected for detailed investigation of the role of waves because of the availability of a PACCSAP-funded bathymetric LiDAR survey. Wave and hydrodynamic models were assembled at ~10 m grid resolution to simulate the combined effects of storm tide and waves in a small ensemble of stochastically generated TCs (Hoeke et al., 2015). The results indicate that storm track and local morphology cause local differences in extreme sea levels on the order of 1 m at spatial scales of less than 1 km (Figure 1). The fact that wave and wind setup effects are minimal near the Apia tide gauge highlights how poorly the likelihood of coastal inundation predicated on tide gauge data may represent the coastal areas in the immediate vicinity, particularly in locations that lack continental shelves (e.g., oceanic islands), something noted by a number of previous studies (e.g., Hoeke et al., 2013; 2015) Wave setup is the overall largest contributor at most locations; however wind setup may exceed wave setup in some sheltered bays. When an arbitrary SLR scenario (+1 m) is introduced, overall extreme sea levels are found to modestly decrease relative to SLR, but wave energy near the shoreline greatly increases, consistent with a number of other recent studies. These differences have implications for coastal adaptation strategies.

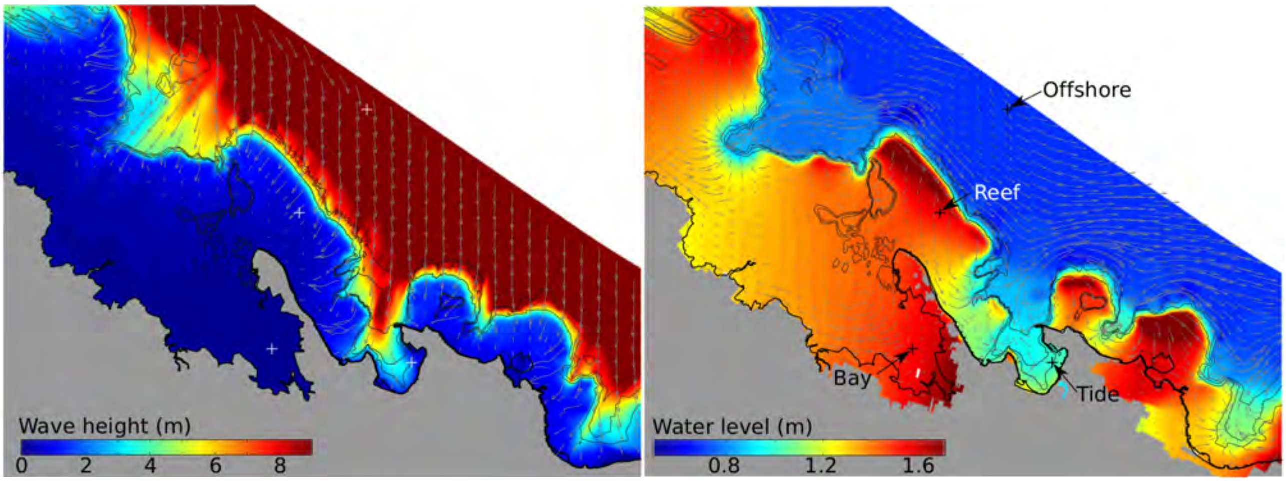

Figure 1: Apia Model output near the peak of local water levels during Cyclone Ofa. Left panel: significant wave height and peak wave direction (grey arrows). Right panel: water levels and depth-averaged current vectors (grey arrows). Locations discussed in the text are labelled in the right panel.

References

Hoeke, R.K., K.L. McInnes, J.C. Kruger, R.J. McNaught, J.R. Hunter, and S.G. Smithers, 2013: Widespread inundation of Pacific islands triggered by distant-source wind-waves. *Global and Planetary Change*, **108**, 128–138.

Hoeke, R.K., K.L. McInnes, and J.G. O'Grady, 2015: Wind and Wave Setup Contributions to Extreme Sea Levels at a Tropical High Island: a Stochastic Cyclone Simulation Study for Apia, Samoa. *J. Mar. Sci. Eng.* (in press).

Holland, G., 2008: A Revised Hurricane Pressure–Wind Model. *Monthly Weather Review*, **136**, 3432–3445.

McInnes, K.L., R.K. Hoeke, K.J.E. Walsh, J.G. O'Grady, and G.D. Hubbert, 2015: Application of a Synthetic Cyclone Method for Assessment of Tropical Cyclone Storm Tide Risk in Samoa. *Natural Hazards* (submitted).

McInnes, K.L., K.J.E. Walsh, R.K. Hoeke, J.G. O'Grady, F. Colberg, and G.D. Hubbert, 2014: Quantifying storm tide risk in Fiji due to climate variability and change. *Global and Planetary Change*, **116**, 115–129.

Representing Regional Projection Uncertainty Using Sub-Sets of CMIP5

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The large number of models in the CMIP5 archive often prohibits the inclusion of data from all GCMs when they are used in impacts and adaptation studies involving downstream modeling activities, such as dynamical downscaling or impacts modeling. The impact of using a subset of CMIP5 is that the range of plausible future climates for a region of interest is likely to be under-represented compared with that which would result from using the full range of projections from the CMIP5 ensemble.

The use of subsets can cause difficulties in the interpretation of results, particularly if we do not know what proportion or part of the projection space is not represented by the subset, and may ultimately lead to mal-adaptation if the underrepresentation of uncertainty is significant but not recognized. Furthermore, the use of different subsets may cause inconsistencies in the range of projections cited by different studies, leading to confusing or conflicting messages.

Strategic sub-selection can mitigate these issues by maximizing the fraction of CMIP5 model uncertainty that is represented in sub-set of a limited size. Sub-selection might therefore be considered to be an important element of the experimental design of impacts studies. Here we consider a number of aspects of model selection. Firstly, we use the ISI-MIP project to explore the impact of using a 5-member CMIP5 subset to represent climate model uncertainty. Secondly, we describe a proposed approach to strategic model selection.

1. Regional Projection Uncertainty in Global 'ISIMIP' Impacts Studies

One example of a project that has made use of a sub-set of CMIP5 is the Inter-Sectoral Impacts Model Intercomparison Project (ISI-MIP) (Warsazawski et al., 2014). ISI-MIP studies have directly compared the relative contributions to the uncertainty in climate impacts that can be attributed to Global Impacts Models (GIMs) uncertainty with climate model uncertainty. Five CMIP5 GCMs (the ISIMIP5) were used were used to represent climate model uncertainty and were selected to span the range of global mean temperature and precipitation changes, restricted to those which were available earliest in the CMIP5 archive.

We explore the fraction of uncertainty in mean temperature and precipitation, expressed as the Fractional Range Coverage (FRC) captured by the 'ISIMIP5' and in randomly selected samples of *n* models, where FRC is defined as:

$$\text{FRC} = \frac{\text{Range of projections across subset}}{\text{Range of projections across 36 CMIP5 models}}$$

We demonstrate that:

The fraction of CMIP5 uncertainty captured by the 'ISIMIP 5' subset varies significantly with region, particularly for precipitation. The average FRC for different SREX regions and standard seasons (DJF, MAM, JJA, SON), varies between 0.5–0.9 for temperature (median 0.75) and 0.3–0.8 for precipitation (median 0.55). These values are mapped in Figure 1.

- For a 5-member subset is that is strategically selected to optimally capture regional uncertainty globally, the average FRC is only marginally higher (median FRC 0.8 for temperature and, 0.61 for precipitation) than in the ISIMIP-5, suggesting that 5 models are insufficient to capture regional uncertainty globally.

- In order to capture at least 80% of regional uncertainty, a much larger subset is required. For example capturing 0.8 FRC in 75% or more of regions and seasons, we would require at least 13 models; to capture 0.9 FRC in 75% of regions and seasons would require 20.

- Regional precipitation uncertainty is much better represented in small subsets if the subset is optimized to each region. The median FRC achieved for precipitation by a subset of 5 optimised regionally is 0.75. To capture 0.8 FRC in 75% or more of regions and seasons, we would require 8 models if the subset can be optimized regionally; to capture 0.9 FRC in 75% of regions and seasons would require 13.

- Where it is necessary to use only small subsets, this limitation should be clearly acknowledged in order to avoid over-confidence in the range of projections used. This might be demonstrated by showing or quantifying the proportion of the full range that is captured by the subset.

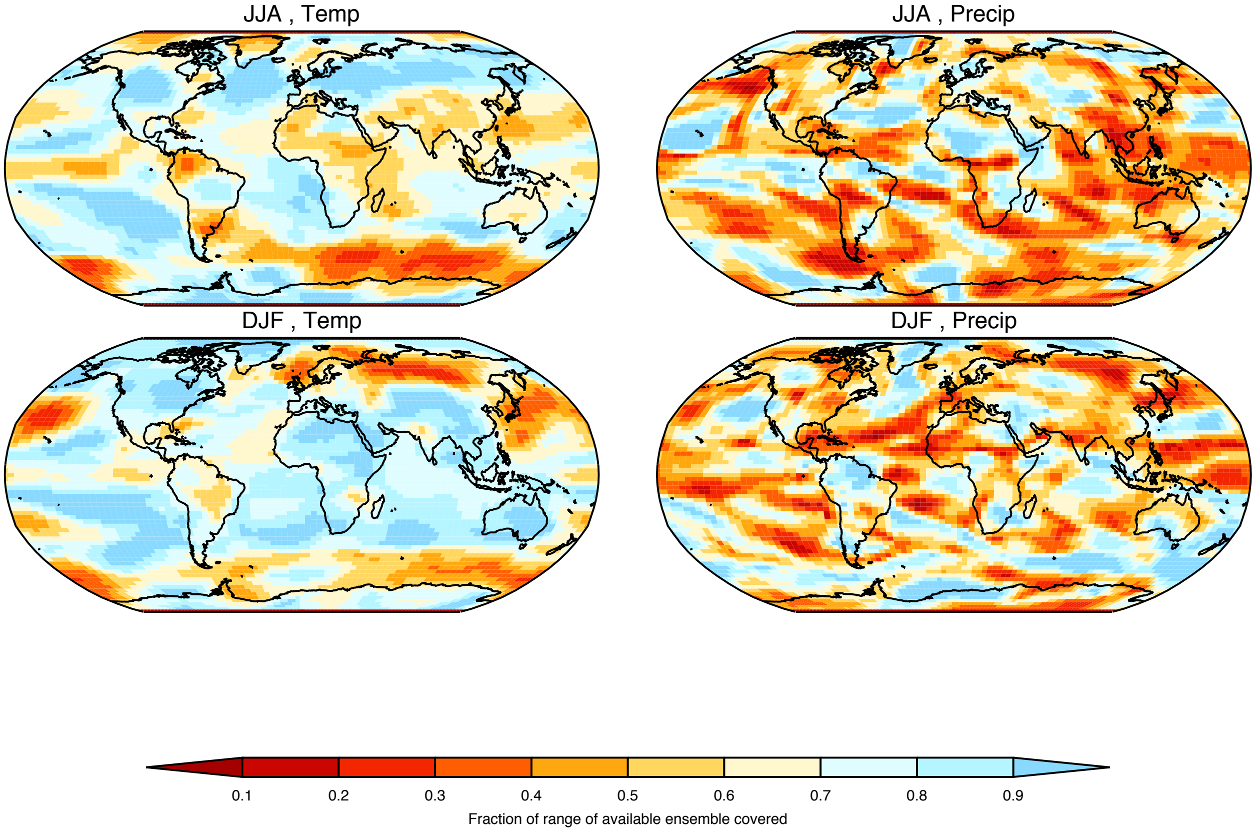

Figure 1: Fractional range coverage (FRC) globally for the 5 GCMs (of 36 for which data were available) used in the ISI-MIP project for both mean temperature and precipitation in December, January February (DJF) and June, July, August (JJA). Changes in climate are those under the RCP8.5 scenario by 2070–2100 with respect to 1961–1990 (McSweeney and Jones, *Submitted*).

2. A Strategy for Regional CMIP5 Sub-selection

We propose a sub-selection strategy that (a) avoids the inclusion of particularly unrealistic models for each region and (b) simultaneously captures the maximum possible range of changes in mean surface temperature and precipitation for the region. This approach is demonstrated in a multi-region application for Europe, Africa and South-East Asia in McSweeney et al. (2015).

The approach considers large-scale performance of the models in the regions of interest, with a view to excluding those that are considered very unrealistic, whilst also considering the effect on the spread of model projections in the final subset of 'eliminating' models that perform poorly using a 'decision making framework'. We find several models which simulate the key aspects of regional circulation so poorly for one or more of the regions of interest that we consider the projections from those models 'implausible', and choose to exclude these from our subset. A number of other models are found to have 'biases' or 'significant biases' – we exclude these models only if another model with better performance has future projections with similar characteristics. From the remaining models, we identify the sub-set that optimally samples the range of changes in mean temperature and precipitation for the different seasons in the region(s) of interest.

References

McSweeney, C.F., R.G. Jones, R.W. Lee, and D.P. Rowell, 2015: Sub-selecting CMIP5 GCMs for downscaling over multiple regions. *Climate Dynamics*, doi:10.1007/s00382-014-2418-8

McSweeney, C.F., and R.G. Jones. How representative is the model spread from the sub-set of CMIP5 models used in ISI-MIP? *Geophysical Research Letters* (submitted).

Warszawski, L., K. Frieler, V. Huber, F. Piontek, O. Serdeczny, and J. Schewe, 2014: The Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP): Project framework. *Proceedings of the National Academy of Sciences of the United States of America*, **111**(9), 3228–3232.

Comprehensive Assessment of Land Surface, Snow, and Soil Moisture–Climate Feedbacks by Multi-model Experiments of Land Surface Models in LS3MIP Under CMIP6

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The solid and liquid water stored at the land surface has a large influence on the regional climate, its variability and its predictability, including effects on the energy and carbon cycles. Notably, snow and soil moisture affect surface radiation and flux partitioning properties, moisture storage and land surface memory. They both strongly affect the atmospheric conditions, in particular, air temperature, but also large-scale circulation patterns and precipitation. However, models show divergent responses and representations of these feedbacks as well as systematic biases in the underlying processes. The Land surface, snow and soil moisture model inter-comparison project (LS3MIP) will provide the means to quantify the associated uncertainties and to better constrain climate change projections, of particular interest for highly vulnerable regions (e.g., densely populated regions, polar regions, agricultural areas, and land ecosystems).

The LS3MIP will embrace a small number of multi-model experiments, encompassing simulations driven in offline mode (land-surface only), coupled to the atmosphere (driven by prescribed sea surface temperatures), and embedded in fully coupled AOGCMs. The experiments are subdivided into two components, the first addressing systematic land biases ("LMIP", building upon the 3rd phase of global soil wetness project; GSWP3 experiments, see Dirmeyer et al., 2006 for GSWP2) and the second addressing land feedbacks in an integrated framework ("LFMIP", building upon the GLACE-CMIP blueprint (Seneviratne et al., 2013) for soil moisture, and the ESM-SnowMIP activity for snow-related processes). There are also important links to several other CMIP6 land-oriented experiments (Seneviratne et al., 2015). The LS3MIP experiments address together the following objectives:

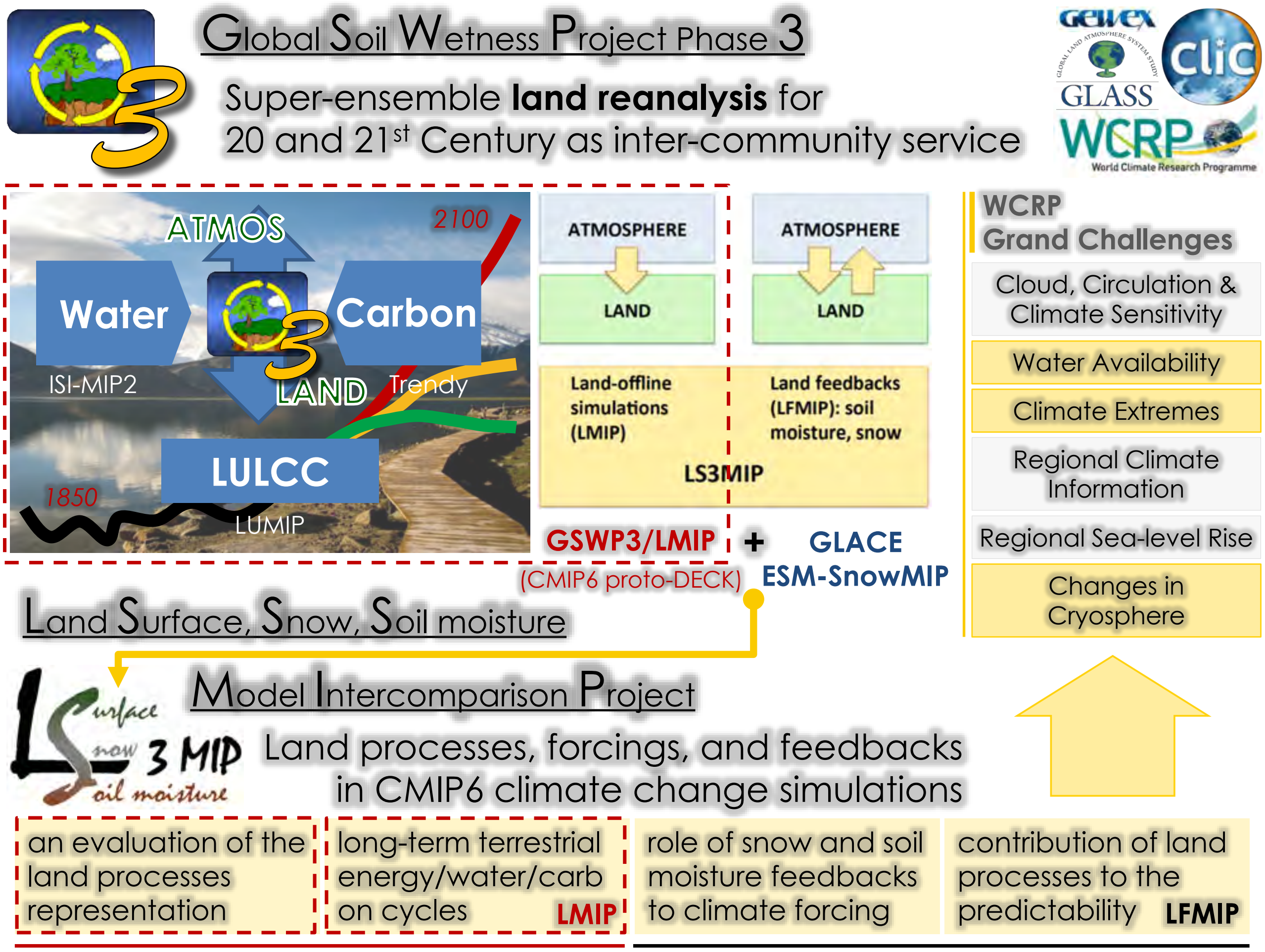
- an evaluation of the current state of land processes including surface fluxes, snow cover and soil moisture representation in CMIP6 DECK runs, revealing main systematic biases and their dependencies (LMIP-protoDECK)

- a multi-model estimation of the long-term terrestrial energy/water/carbon cycles, using the surface modules of CMIP6 models under observation constrained historical (land reanalysis) and projected future (impact assessment) conditions considering land use/land cover changes. (LMIP)

- an assessment of the role of snow and soil moisture feedbacks in the regional response to altered climate forcings, focusing on controls of climate extremes, water availability and high-latitude climate in historical and future scenario runs (addressing Arctic amplification and drought/heatwave characteristics) (LFMIP)

- an assessment of the contribution of land surface processes to the current and future predictability of regional temperature/precipitation patterns. (LFMIP)

These LS3MIP outcomes will contribute to improve climate change projections by reducing the systematic biases from the land surface component of climate models, and a better representation of feedback mechanisms related to snow and soil moisture in climate models. Further, LS3MIP will enhance the accuracy of the assessment of historical changes in energy, water, and carbon cycles over land surfaces extending more than 100 years, including spatial variability and trends in global runoff, snow cover, and soil moisture that are hard to detect purely based on observations. LS3MIP will also enable the impact assessments of climate changes on hydrological regimes and available freshwater resources including extreme events, such as floods and droughts, based on multi-model ensemble estimates. These achievements are expected to contribute considerably to the assessment of the possible changes and impacts of climate changes in the next cycle (6th Assessment Report) of the Intergovernmental Panel on Climate Change.



Global Soil Wetness Project Phase 3

Super-ensemble **land reanalysis** for
20 and 21st Century as inter-community service

GEWEX
GLASS
CliC
WCRP
World Climate Research Programme

ATMOS
2100
Water
Carbon
ISI-MIP2
LAND
Trendy
LULCC
1850
LUMIP

ATMOSPHERE
LAND
Land-offline simulations (LMIP)

ATMOSPHERE
LAND
Land feedbacks (LFMIP): soil moisture, snow

LS3MIP

GSWP3/LMIP + GLACE
(CMIP6 proto-DECK) ESM-SnowMIP

WCRP
Grand Challenges

Cloud, Circulation & Climate Sensitivity

Water Availability

Climate Extremes

Regional Climate Information

Regional Sea-level Rise

Changes in Cryosphere

Land Surface, Snow, Soil moisture

Model Intercomparison Project

LS 3 MIP — Surface, snow, soil moisture

Land processes, forcings, and feedbacks
in CMIP6 climate change simulations

an evaluation of the land processes representation

long-term terrestrial energy/water/carbon cycles **LMIP**

role of snow and soil moisture feedbacks to climate forcing

contribution of land processes to the predictability **LFMIP**

Figure 1: Schematic illustration of the land surface, snow and soil moisture model inter-comparison project (LS3MIP), consisting with ESM-SnowMIP, LFMIP, LMIP, GLACE, and GSWP3.

References

Dirmeyer, P.A., X. Gao, M. Zhao, Z. Guo, T. Oki, and N. Hanasaki, 2006: GSWP-2: Multimodel Analysis and Implications for Our Perception of the Land Surface. *Bull. Am. Meteorol. Soc.*, **87**, 1381–1397.

Seneviratne, S.I., M. Wilhelm, T. Stanelle, B.J.J.M. van den Hurk, S. Hagemann, A. Berg, F. Cheruy, M.E. Higgins, A. Meier, V. Brovkin, M. Claussen, A. Ducharne, J.-L. Dufresne, K.L. Findell, J. Ghattas, D.M. Lawrence, S. Malyshev, M. Rummukainen, and B. Smith, 2013: Impact of soil moisture-climate feedbacks on CMIP5 projections: First results from the GLACE-CMIP5 experiment. *Geophys. Res. Lett.*, **40** (19), 5212–5217.

Seneviratne, S.I., B. van den Hurk, D. Lawrence, G. Krinner, G. Hurtt, H. Kim, C. Derksen, T. Oki, A. Boone, M. Ek, V. Brovkin, P. Dirmeyer, H. Douville, P. Friedlingstein, S. Hagemann, R. Koster, N. de Noblet-Ducoudre, and A. Pitman, 2015: Land processes, forcings, and feedbacks in climate change simulations: The CMIP6 "LandMIPs". *GEWEX Newsletter*, **24**(4), 6–10.

Science to Policy: Initiatives on Climate Change Risks in Indonesia

Perdinan

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The issuance of document on Indonesian Climate Change Sectoral Roadmap by the State Ministry of National Development Planning of Indonesia (BAPPENAS) in 2010 has reflected the government awareness to the potential impacts of climate change on various economic sectors in Indonesia. Understanding the potential consequences, the government urged and promoted the development of climate change adaptation (CCA) strategies that should also be mainstreamed into the national development plan as outlined in the document on National Action Plan on Climate Change Adaptation (BAPPENAS, 2014).

Learning from the needs to develop CCA strategies, the government through the Ministry of Environment and Forestry also already drafted a ministerial decree on the development of climate change adaptation on the basis of vulnerability and climate risk assessment. The vulnerability assessment is designed to measure the level of vulnerability and adaptive capacity to climate change as mandated by the Law No. 32/2009. Furthermore, the decree will provide a guidance of procedures on how to conduct vulnerability and climate risk assessment as an essential component to provide inputs for the CCA development. The ministerial decree provides details on six procedures to mainstream CCA strategies into development plan (Figure 1). Those procedures are 1) identification of specific target for the implementation of CCA, 2) formulation of climate change impacts on specific region or sector, 3) assessment of vulnerability and climate risk, 4) development of CCA strategies, 5) prioritization of CCA strategies, and 6) mainstreaming CCA strategies into development plan. The drafting of the ministerial decree has also been made based on the lesson learnt from various climate change studies and capacity building activities on vulnerability and climate risk in various provinces, districts, cities, and areas in Indonesia.

As an example of initiatives to mainstream CCA strategies into local development plan, the KLHK and the

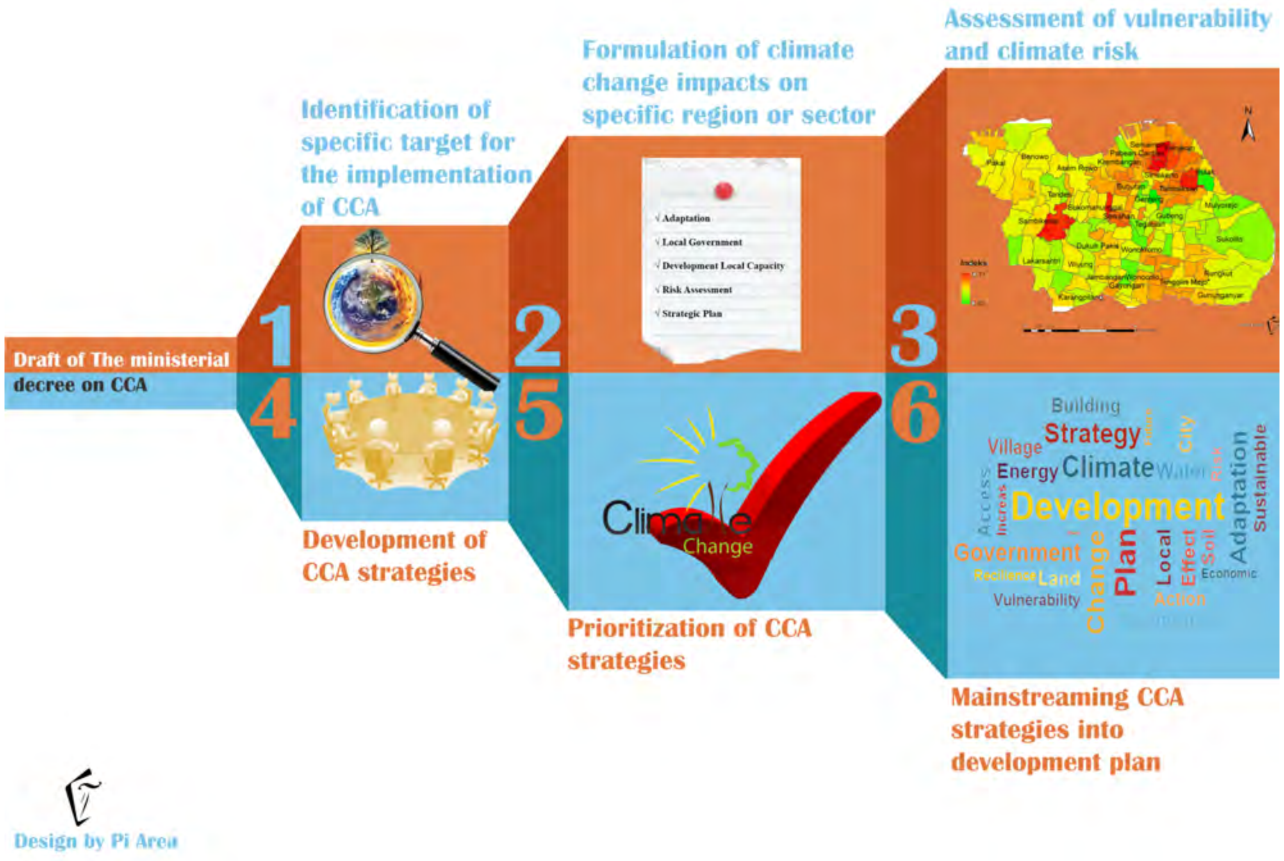

Figure 1: Procedures to mainstream climate change adaptation (CCA) strategies into development plan for a specific region or sector in Indonesia.

Provincial Government of Nusa Tenggara Timur (NTT) are currently working together to mainstream prioritized CCA strategies into the local development plan. The CCA strategies were developed considering the outputs of vulnerability and climate risk assessment in combination with the results of household surveys conducted at the three districts of NTT, i.e., Sumba Timur, Sabu Raijua, and Manggarai. The climate change projections for the province required for the risk assessment were developed based on a selected GCM-RCM combination. Stakeholders in the study region were also engaged when conducting the vulnerability and risk assessment, the household survey, and the development of CCA strategies, as an approach to strengthen the capacity of the local government officers and related stakeholders who are expected to implement the developed CCA strategies.

The other initiative is the current study purposed to converge CCA and disaster risk reduction (DRR). This initiative was proposed understanding the facts that more than 80% of disaster events reported by the National Agency for Disaster Management (BNPB) of Indonesia are categorized into climate related disasters. The BNPB in coordination with the KLHK is currently working on developing a method to integrate climate information into disaster risk assessment that is detailed in the available guidance issued by the BNPB named PERKA-BNPB 02/2012. The method is also developed considering the concept of risk assessment discussed in the recent IPCC report 'Climate Change 2014: the Impacts, Adaptation, and Vulnerability'. Stakeholders engaged in the process of developing the method through a series of focus group discussions. This initiative also aims at combining the on-line system on vulnerability index named *Sistem Informasi dan Data Indeks Kerentanan* (SIDIK) released by the KLHK with the disaster risk index named *Indeks Risiko Bencana Indonesia* (IRBI) released by the BNPB.

Concerning the availability of climate data required to support the climate risk assessment in Indonesia, another initiative is proposed to prepare a nation-wide gridded historical and projected climate information through a coordination between the KLHK and the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG). Climate data and information plays an essential element to climate risk assessment. Unfortunately, available historical climate data were frequently inadequate to support the regional risk assessment in Indonesia. Climate change projections were also frequently developed based on straightly Global Climate Model (GCM) outputs or downscaled GCM outputs using statistical techniques. The initiative is currently working on downscaling GCM outputs using a Regional Climate Model (RCM), which has been made as a part of activities within the third national communication (TNC) project that is purposed to prepare a national document on climate change submitted to UNFCCC in 2016. The initiative of supplying projected climate data is also in line with the regional initiative of nested GCMs-RCMs named Coordinated Regional Climate Downscaling Experiment (CORDEX) for the South-East Asia.

The publicly available of historical and projected climate data is a fundamental component to support climate change studies in Indonesia. This necessity rises understanding the common concerns of 'hundred-publications' of activities or studies on climate change risk, impacts, and adaptation that were collected since the issuance of ICCSR document in 2010. The review of these available publications, which works were mostly conducted by universities, research institutions, and non-government organizations at a specific study site or sector, is still in progress. The above initiatives identified here are expected to support the application of climate studies for managing future risks as a consequence of climate change in Indonesia.

References

BAPPENAS, 2014: National Action Plan for Climate Change Adaptation (RAN-API). Jakarta, BAPPENAS.

BAPPENAS, 2010: Indonesia Climate Change Sectoral Roadmap (ICCSR). Jakarta, BAPPENAS.

BNPB, 2013: Indeks Risiko Bencana Iklim. Jakarta, BNPB.

KLHK, 2014: Sistem Informasi dan Data Indeks Kerentanan. Jakarta, KLHK.

2D Bias Correction Method for Gridded Simulations of Precipitation and Temperature over Southeastern South America

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A two dimensional (2D) bias correction methodology for temperature and precipitation for gridded model output, based on the method developed by Piani and Haerter (2012) for point source data, was applied to the CCSM4 (NCAR) model output from the CMIP5 dataset and a 40-year observational gridded dataset over south-eastern South America. Copula probability density functions of observed temperature and precipitation showed significant structure when subsets of 16 grid points were pooled together. By contrast no structure was detectable in copulas of GCM data. By construction, independent one dimensional bias correction of temperature and precipitation cannot correct copula probability density distributions, hence the 2D method is applied. The method is tested, as customary, by calibrating and subsequently validating the methodology with non-overlapping 20-year time periods. Visual inspection of single copula probability density functions for all grid points is unfeasible so the 2D bias correction method is validated by calculating a two dimensional extension of the Kolmogorov-Smirnov statistic measuring the maximum distance between observed and simulated and between observed and 2D bias corrected copulas for the validation period at each grid point (Figure 1). The methodology clearly shows great potential for application to climate impact modelling and daily datasets.

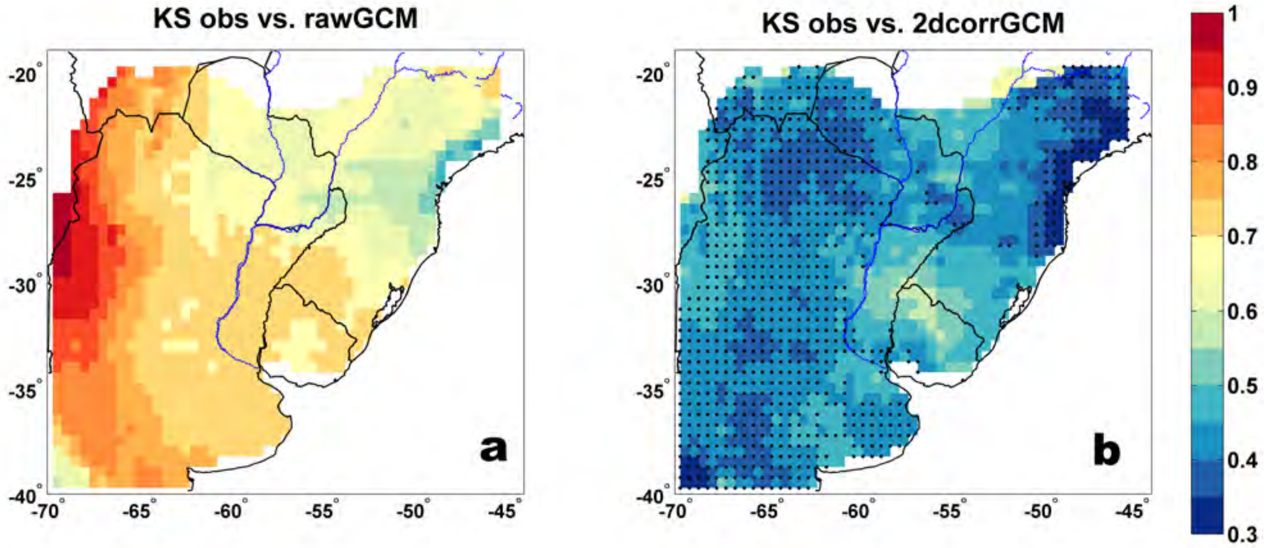

Figure 1: Two dimensional Kolmogorov-Smirnov norm measuring the distance between the observed and simulated (right panel) and between observed and bias corrected (left panel) copulas for the validation period. Grid points are marked where the two copulas are statistically indistinguishable (left panel only).

References

Piani C., and J.O. Haerter, 2012: Two dimensional bias correction of temperature and precipitation copulas in climate models. *Geophysical Research Letters*, **39**(20), doi:10.1029/2012GL053839.

Creating Versatile Climate Scenarios from GCM Projections, Targeted for Forestry Climate Change Impacts and Adaptation Research

David T. Price and members of the Canadian Forest Service Forest Change Team

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Approximately 4 million km^2 of Canada is covered by forests and woodlands, which provide significant natural, cultural and economic benefits to its citizens. Most of these forests, including nearly the entire Canadian boreal, lie north of latitude 50°N—implying they will be exposed to significantly greater climate warming than the global average. Canadian Forest Service (CFS) scientists have been studying how projected changes in climate will affect Canada's forests in coming decades, at scales ranging from local to national. Major objectives are to inform national policies on addressing consequences of climate change on forests and forestry across Canada, and to provide scientific information to forestry practitioners implementing adaptation strategies for forest management in a changing environment.

For a single general circulation model (GCM) and forcing scenario, the general method is to use monthly outputs for six simulated climate variables, namely monthly mean daily maximum and minimum temperature, monthly total precipitation, and monthly mean specific humidity, surface incident solar radiation and wind velocity. Thirty-year monthly means are also calculated for each variable from a twentieth century simulation with the same GCM using 1961–1990 as a reference period. These means are used to bias-correct the future projections: temperature means are subtracted from the projection monthly values, but other variables are expressed as ratios of the 1961–1990 means. The resulting monthly anomalies (or 'delta values') are then interpolated using ANUSPLIN thin-plate spline software treating GCM grid nodes as climate stations (but ignoring node elevation). (For details see Price et al., 2011; Joyce et al., 2011.) The fitted spline surfaces can be used in several ways to create both point-based values (e.g., at locations of climate stations or forest permanent sample plots) and grids of varying spatial resolution and extent on various map projections. The latter range from individual forest management units to all of North America (Canada, USA and Mexico). Files of gridded or point data are then distributed to end-users who must combine them with their own observed climate records (ideally monthly 'normals' for 1961–1990) at the same geographic locations. CFS has also developed spatially interpolated time series and monthly normals of temperature and precipitation which can be used as baseline data (e.g., McKenney et al., 2011).

Climate scenarios have been created from GCM output beginning with the Canadian CGCM2 forced by the IS92A GHG concentration scenario (IPCC Second Assessment), through the third and fourth IPCC Assessments using SRES A2, A1B, B2 and B1 emissions scenarios) and most recently four GCMs forced by the IPCC AR5 RCP2.6, 4.5 and 8.5 scenarios. End-users include CFS 'clients' carrying out impacts assessments, and researchers engaged in modelling impacts of climate change on forests. Example applications include:

- Provision of regional scenario data for Ontario's climate change adaptation initiative (e.g., McKenney et al., 2010).
- Intercomparison of dynamic vegetation models applied to North America's forests (Price et al., 2015)
- The US Resources Planning Act 2010 national assessment (USDA Forest Service 2012)
- Data sets in support of regional and local scale vulnerability assessments (e.g., Williamson et al., 2008)
- Projections of bioclimatic indices such as growing season length and degree day sums (e.g., Pedlar et al., 2015)
- Projecting future changes in drought occurrence and intensity in Canada's boreal forest (e.g., Wang et al., 2014).
- A review of climate change impacts on Canada's boreal forest (e.g., Price et al., 2013).

The poster illustrates several of these applications as multiple contributions to an ongoing national assessment of the impacts of climate change on Canada's timber resources. The assessment is split into several distinct 'chapters' focused on three distinct periods, the short, medium and long-term, corresponding approximately to the 2020s, 2050s and 2080s, respectively. Chapter 2 describes the national and regional trends seen in the forcing climate scenarios (RCP2.6, 4.5 and 8.5, as simulated by the Canadian CanESM2 earth system model). Chapter 3 reports on potential effects of these different scenarios on the occurrence of natural disturbances (forest fires, pests and diseases, droughts), while Chapter 4 assesses effects of a warmer climate on forest productivity, species composition and spatial distribution. Later chapters integrate the results of Chapters 3 and 4 to assess potential impacts on timber supply (Chapter 5), the wood products industry (Chapter

6) and the implications for national and regional forestry policies (Chapter 7). In Chapter 3, climate scenario data were interpolated to the centroids of homogeneous fire regime (HFR) zones (Boulanger et al., 2014) to extrapolate how fire return intervals might change in future. Scenario data were fed into the BioSIM weather simulator (e.g., Régnière et al., 2014) to generate projections of future weather conditions on a 1 km spatial grid. The grids were used to project how climatic constraints on the survival and population growth of key insect pests might change and to assess timber volumes at risk from drought effects. Chapter 4 used the same climate scenarios interpolated to three different spatial contexts: (1) hundreds of representative stands located within a region of order 50,000 km^2 each simulated with a stand-level model; (2) eight of these large regions each simulated with a landscape scale model using BioSIM output; and (3) the entire forested area of Canada simulated using a dynamic vegetation model driven by the 10 km resolution gridded data.

Other Canadian climate change research groups have contributed regionally based climate scenarios (notably for Quebec and British Columbia), but to our knowledge, only CFS has created seamless continental scale climate scenario spline surfaces focused on the needs of forestry. This work is likely to continue as new climate projections become available.

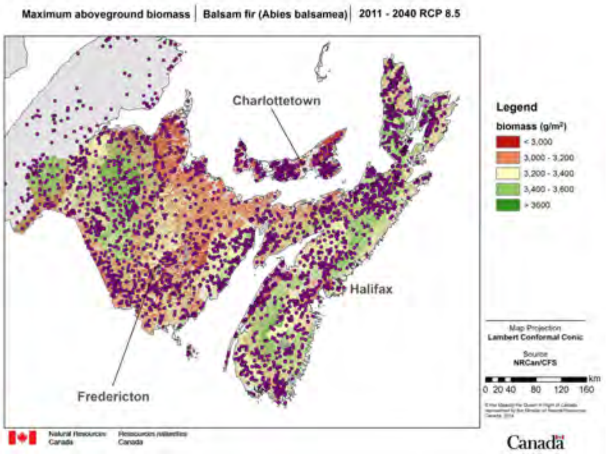

Figure 1: Map of the Canadian Maritime Provinces (New Brunswick, Prince Edward Island and Nova Scotia) showing biomass density of a single tree species (Balsam fir) simulated using the LANDIS landscape level model. Superimposed are the hundreds of plot locations where average climate conditions were interpolated from a CanESM2 climate projection forced by RCP8.5 scenario for the period 2011–2040.

References

Boulanger, Y., S. Gauthier, and P.J. Burton, 2014: A refinement of models projecting future Canadian fire regimes using homogeneous fire regime zones. Canadian Journal of Forest Research, **44**, 365–376.

Joyce, L.A., D.T. Price, D.W. McKenney, R.M Siltanen, P. Papadopol, K. Lawrence, and D.P. Coulson, 2011: High-resolution interpolation of climate scenarios for the continental USA and Alaska derived from General Circulation Model simulations. *Rocky Mt. Res. Stn. Gen. Tech. Rep. 263. US Dep. Agric., For. Serv., Rocky Mt. Res. Stn*., Ft. Collins, CO. 87 pp.

McKenney, D.W. M.F. Hutchinson, P. Papadopol, K. Lawrence, J. Pedlar, K. Campbell, E. Milewska, R.F. Hopkinson, D. Price, and T. Owen, 2011: Customized spatial climate models for North America. *Bull. American Meteorological Society*, **92**(12), 1611–1622.

McKenney, D.W., J.H. Pedlar, K. Lawrence, P.A. Gray, S.J. Colombo, and W.J. Crins, 2010: Current and projected future climatic conditions for ecoregions and selected natural heritage areas in Ontario. *Climate Change Research Report CCRR-016. Applied Research and Development Branch, Ontario Ministry of Natural Resources*, Sault Ste. Marie, Ontario.

McKenney, D.W., J. Pedlar, R.G. Rood, and D. Price, 2011: Revisiting projected shifts in the climate envelopes of North American trees using updated general circulation models. *Global Change Biology*, **17**, 2720–2730.

Price, D.T., R.I. Alfaro, K.J. Brown, M.D. Flannigan, R.A. Fleming, E.H. Hogg, M.P. Girardin, T. Lakusta, M. Johnston, D.W. McKenney, J.H. Pedlar, T. Stratton, R.N. Sturrock, I.D. Thompson, J.A. Trofymow, and L.A. Venier, 2013: Anticipating the consequences of climate change for Canada's boreal forest ecosystems. *Environmental Reviews*, **21**, 322–365.

Price, D.T., D.W. McKenney, L.A. Joyce, R.M. Siltanen, P. Papadopol, and K. Lawrence, 2011: High-resolution interpolation of climate scenarios for Canada derived from General Circulation Model simulations. *Information Report NOR-X-421. Northern Forestry Centre, Nat. Resour. Can., Can. For. Serv.*, Edmonton, Alberta. 104 pp.

Price, D.T., D. Scott, M.R. Lomas, D.W. McKenney, D. Bachelet, R.J. Drapek, J.M. Lenihan, R.P. Neilson, F.I. Woodward, and J.A. Foley, 2015: A brief description of the VINCERA Project: Vulnerability and Impacts of North American Forests to Climate Change: Ecosystem Responses and Adaptation. In: *Global vegetation dynamics: Concepts and applications in the MC1 model* [Bachelet, D. (ed.)]. Wiley. in press.

Régnière, J., R. Saint-Amant, and A. Béchard, 2014: BioSIM 10 – User's manual. *Information Report LAU-X-137E 2014. Nat. Resour. Can., Can. For. Serv., Laurentian For. Cent.*, Québec City, Quebec.

U.S. Department of Agriculture, Forest Service, 2012: Future of America's Forest and Rangelands: *Forest Service 2010 Resources Planning Act Assessment. Gen. Tech. Rep. WO-87*, Washington, DC. 198 pp.

Wang, Y., E.H. Hogg, D.T. Price, J. Edwards and T. Williamson, 2014: Past and projected future changes in moisture conditions in the Canadian boreal forest. *Forestry Chronicle*, **90**(5), 678–691.

Williamson, T.B., D.T. Price, J.L. Beverly, P.M. Bothwell, B. Frenkel, J. Park, and M.N. Patriquin, 2008: Assessing potential biophysical and socioeconomic impacts of climate change on forest-based communities: a methodological case study. *Information Report NOR-X-415. Northern Forestry Centre, Can. For. Serv., Nat. Resour. Can.*, Edmonton, Alberta, 136 pp. http://cfs.nrcan.gc.ca/publications?id=29156.

Can/Will Climate Change Impact the Wind Energy Industry?

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It is still technically possible to limit global warming to 2°C, but this scenario is unlikely. What will this mean for sectors like wind energy that are impacted by weather-related variables? In order for any climate change impact to be important the changes must be detectable on the lifetime of wind farms (of the order 30 years) and the resource and operating conditions must evolve beyond (sometimes poorly characterized) current variability and engineering design standards. Despite many challenges, progress has been made both in developing tools to project climate change impacts and in quantifying uncertainties and their sources. I present an overview of those methods, limitations and results to date using examples drawn from Northern Europe and North America. In these regions, aside from areas with significant thermo-topographic forcing, the wind resource (and to some degree operating conditions) is primarily determined by the track, translational speed and intensity of mid-latitude cyclones that are determined by a number of dynamic and thermodynamic forcings across different scales. Dynamical and statistical downscaling plus a new hybrid method to downscale the surface wind speed distributions exhibit skill in reproducing current wind climates, indicating it may be possible to make robust projections of wind resources and changes therein. Projected changes in wind resources in the two focus regions are generally modest: e.g., Model ensembles indicate small increases in resource magnitude or no change over Scandinavia and the US Great Plains regions to the middle of this century, but small decreases in wind resources for the US Northwest. In the near-term, differences in projected wind resources are equally or more pronounced across models than emission scenarios. Potential impacts from changes in operating conditions such as extreme winds and icing are more challenging to quantify. However, preliminary work indicates current standards provide a large safety margin that is not exceeded by projected changes in, for example, extreme wind speeds. Uncertainty remains regarding factors such as model skillful scale and also the robustness in model response to different forcings, and how both vary with model architecture. Possible approaches to addressing those issues and improving treatment of internal climate variability, and thus reducing uncertainty and risk, will be described.

References

Barthelmie, R.J. and S.C. Pryor, 2014: The potential contribution of wind energy to climate change mitigation. *Nature Climate Change*, **4**, 684–688.

Pryor, S.C., and R.J. Barthelmie, 2014: Hybrid downscaling of wind climates over the eastern USA. *Environ. Res. Lett.*, **9**, 024013.

Pryor, S.C., and R.J. Barthelmie, 2013: Assessing the vulnerability of wind energy to climate change and extreme events. *Climatic Change*, **121**, 79–91.

Pryor, S.C., and R.J. Barthelmie, 2013: Renewable Energy Resources- Ocean Energy: Wind/Wave/Tidal/Sea currents. Chapter 3.04. In: *Climate Vulnerability* [R. Pielke (ed.)]. Elsevier.

Pryor, S.C., and R.J. Barthelmie, 2011: Assessing climate change impacts on the near-term stability of the wind energy resource over the USA. *P. Natl. Acad. Sci. USA*, **108**, 8167–8171.

Pryor, S.C., and R.J. Barthelmie, 2010: Climate change impacts on wind energy: A review. *Renew. Sust. Energ. Rev.*, **14**, 430–437.

Pryor, S.C., and J. Ledolter, 2010: Addendum to: Wind speed trends over the contiguous USA. *J. Geophys. Res-Atmos.*, **115**, D10103.

Pryor, S.C., and J.T. Schoof, 2010: Importance of the SRES in projections of climate change impacts on near-surface wind regimes *Meteorol. Z.*, **19**, 267–274.

Pryor, S.C., R.J. Barthelmie, and J.T. Schoof, 2012: Past and future wind climates over the contiguous USA based on the NARCCAP model suite. *J. Geophys. Res-Atmos.*, **117**, D19119.

Pryor, S.C., G. Nikulin, and C. Jones, 2012: Influence of spatial resolution on Regional Climate Model derived wind climates. *J. Geophys. Res-Atmos.*, **117**, D03117.

Pryor, S.C., et al., 2012: Analyses of possible changes in intense and extreme wind speeds over northern Europe under climate change scenarios. *Clim. Dynam.*, **38**, 189–208.

Schoof, J.T., and S.C. Pryor, 2014: Assessing the fidelity of AOGCM-simulated relationships between large-scale modes of climate variability and wind speeds. *J. Geophys. Res-Atmos.*, **119**, 9719–9734.

Vose, R.S., et al., 2014: Monitoring and understanding changes in extremes: Extratropical storms, winds, and waves. *B. Am. Meteorol. Soc.*, **95,** 377–386.

Ocean Warming Impacts on Climate over Brazil with OLAM Model

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The ocean is the main driver of the global climate variability. Phenomena like El Niño, La Niña and the Atlantic Dipole usually affect the climate in several regions including the South America and Brazil. Understanding the impact of these phenomena on the regional climate is of great importance. Several studies had evaluated the impact of oceanic global changes using climate models. However, those global models have low spatial resolution and therefore, they are not able to represent the regional climate changes properly. The new model OLAM (Ocean Land Atmosphere Model) can represent simultaneously the global and regional climate phenomena through use of a grid refinement system and avoids the lateral nudging (Walko and Avissar, 2008a,b). In this study, the OLAM model was set up with a global grid having a horizontal spacing of 200 km and a grid refinement for the Brazilian region and surroundings having 32 km of grid spacing. The model was initially integrated for the period between 1960 and 1990 to build a climatological run using the monthly Sea Surface Temperature (SST) from the Atmospheric Model Intercomparison Project (AMIP). After that a new run was performed for the period between 2010 and 2100 but using the monthly SST data projections from the Hadley Center Model as surface boundary condition.

Comparison between the XXI century run and the climatological control run produced an overall near surface atmospheric warming, mainly over the Amazon region; a decrease in precipitation, mainly over the northeast Brazil and an increase over the west of the Amazon and south Brazil. The major impacts were produced by the enhancement of the greenhouse effect of the atmospheric water vapor. In general, the projections obtained with OLAM produced similar results as the ones generated by the major Global Coupled Models, however OLAM allowed a better regional evaluation of the possible climate impacts over Brazil due to its capability to better represent the local physiographical features and its interaction with the regional climate.

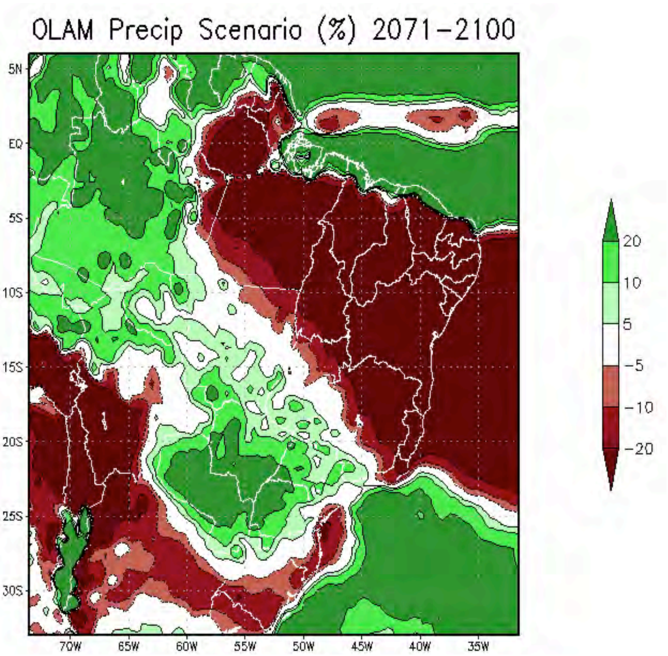

Figure 1: OLAM results for precipitation changes (%) obtained from the difference between the results for 2070-2100 and the climatological run for 1960–1990.

References

Walko, R.L., and R. Avissar, 2008a: The Ocean–Land–Atmosphere Model (OLAM). Part I: Shallow-Water Tests. *Mon. Weather Rev.*, **136**, 4033–4044.

Walko, R.L., and R. Avissar, 2008b: The Ocean–Land–Atmosphere Model (OLAM). Part II: Formulation and Tests of the Nonhydrostatic Dynamic Core. *Mon. Weather Rev.*, **136**, 4045–4062.

Cyclone Activity in the Arctic as Inferred from the MGO RCM Simulations

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Decadal long simulations of atmospheric circulation in the high latitudes have been carried out using a multiscale atmospheric modeling system that consists of MGO global and regional atmospheric models with respective resolutions of 200, 50 and 25 km in the horizontal. The detailed analysis of extratropical cyclone activity including activity of polar mesocyclones has been conducted for the winter season using an advanced cyclone identification and tracking scheme. To enhance the applicability of high-resolution regional atmospheric modeling in the context of detailed general atmospheric circulation analysis, an end-to-end approach for cyclone trajectory calculation on a unified global and regional grid has been proposed. It has been shown that increasing modeling resolution in the high latitudes allows one to more realistically simulate the activity of baroclinic waves and the thermal regime of the Arctic troposphere. The statistical structure of cyclonic activity has been investigated depending on the spatial resolution of the modeling system and compared with that in the reanalyses and satellite-derived analyses. The performance of the atmospheric models in the simulation of extreme cyclones that exhibit a threat to economic activity in polar regions is evaluated.

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Addressing Climate Extremes across Scales and Research Communities

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"Understanding and Predicting Weather and Climate Extremes" is one of the Grand Challenges of the World Climate Research Programme (WCRP) focusing on advancing research on geophysical aspects of weather and climate extremes (Zhang et al., 2014). Various challenges exist further in linking the efforts made in both the natural and social sciences communities to better understand extreme events and their changes, associated impacts and potential adaptation options and capacities (e.g., IPCC SREX, 2012). Obvious barriers lie, however, in the spatial and temporal scales between increasing confidence gained on global changes in extremes and adaptation needs to reduce their impacts on the local level.

Considerable effort had been taken by Working Group 1 (WGI) in the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2013) to assess climate extremes in a consistent manner across chapters, from observations to model evaluation and near- to long-term projections of changes in climate extremes. The climate extremes indices as defined by the Expert Team on Climate Change Detection and Indices (ETCCDI, Zhang et al., 2011) have proved to be very useful in this endeavor, providing the basis for an improved gridded observational dataset of temperature and precipitation extremes (Donat et al., 2013) and the coordination of indices calculation for multi-model climate simulations of phase 3 and 5 of the Coupled Model Intercomparison Project (CMIP3 and CMIP5) and their evaluation with observations and reanalyses (Sillmann et al. 2013a) (Figure1). Currently available software for calculating these indices (e.g., RClimdex, FClimdex, climdex.pcic.R) was synchronized in recent efforts coordinated by the ETCCDI.

Future climate change projections indicate that many temperature and precipitation extremes become more frequent and intense in a warmer climate on a global scale (Sillmann et al. 2013b), and concomitantly the risks of severe impacts to society will increase (IPCC, 2014), calling for proactive adaptation measures. In order to support the adaptation decision making process, information on climate extremes is especially needed on a regional to local scale including time scales from sub-seasons to decades.

Better coordination and communication between communities (e.g., IPCC WGI and WGII, World Weather Research Programme (WWRP) and WCRP) would allow for advances in model development and evaluation across scales (global to regional, short-term predictions to long-term projections) as well as new methodologies to develop and apply climate extremes indices on relevant scales in impact research and risk analysis. Challenges, such as how to increase the relevance of climate information provided in WGI for WGII and how to improve the data and knowledge exchange between WGs, need to be tackled early on in the IPCC assessment process to move from a global to a regional impact focus. This includes that more information on the impacts of past and present climate extremes, preferably across different regions, sectors and societal levels, are made available and utilized to improve the representation of high-impact extreme events in weather and climate models.

With the new global and regional climate simulations, CMIP6 and CORDEX respectively, being under way, coordination of activities across these communities regarding the calculation and dissemination of climate extremes indices would be of major advantage. This could ensure that extremes indices are consistently calculated and used, which would enable comprehensive inter-model comparison analyses and model evaluation and also allow for regular updates of currently used climate extremes indices, for instance, with indices addressing the needs of the climate impact community and climate change risk assessment.

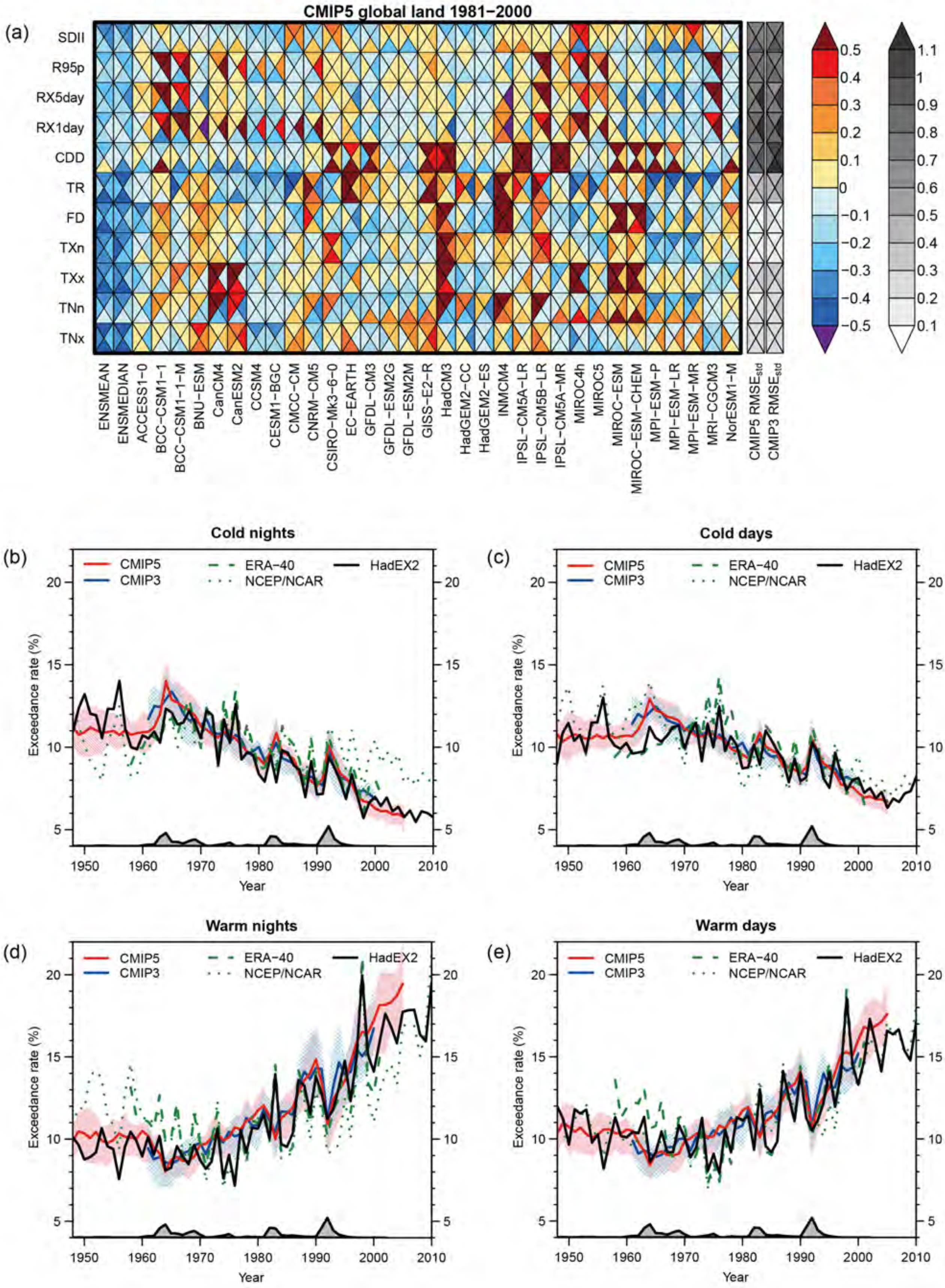

Figure 1: From IPCC, 2013, Chapter 9, Figure 9.37: (a) Portrait plot of relative error metrics for the CMIP5 temperature and precipitation extreme indices. (b)–(e) Time series of global mean temperature extreme indices over land from 1948 to 2010 for CMIP3 (blue) and CMIP5 (red) models, ECMWF 40-year reanalysis (ERA40, green dashed) and National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR, green dotted) reanalyses and HadEX2 station-based observational data set (black). In (a), reddish and bluish colours indicate, respectively, larger and smaller root-mean-square (RMS) errors for an individual model relative to the median model. The relative error is calculated for each observational data set

separately. The grey-shaded columns on the right side indicate the RMS error for the multi-model median standardized by the spatial standard deviation of the index climatology in the reanalysis, representing absolute errors for CMIP3 and CMIP5 ensembles. Results for four different reference data sets, ERA-interim (top), ERA40 (left), NCEP/NCAR (right) and NCEP- Department of Energy (DOE) (bottom) reanalyses, are shown in each box. The analysis period is 1981–2000, and only land areas are considered. The indices shown are simple daily precipitation intensity index (SDII), very wet days (R95p), annual maximum 5-day/1-day precipitation (RX5day/ RX1day), consecutive dry days (CDD), tropical nights (TR), frost days (FD), annual minimum/maximum daily maximum surface air temperature (TXn/TXx), and annual minimum/ maximum daily minimum surface air temperature (TNn/TNx). [...] In (b)–(e), shading for model results indicates the 25th to 75th quantile range of inter-model spread. Grey shading along the horizontal axis indicates the evolution of globally averaged volcanic forcing according to Sato et al. (1993). The indices shown are the frequency of daily minimum/maximum surface air temperature below the 10th percentile (b: Cold nights/c: Cold days) and that above 90th percentile (d: Warm nights/e: Warm days) of the 1961–1990 base period. [...]]

References

Donat, M. G., et al., 2013: Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2 dataset. J. *Geophys. Res. Atmos.*, **118**, 2098–2118.

IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp

Sillmann, J., V.V. Kharin, X. Zhang, F.W. Zwiers, and D. Bronaugh, 2013a: Climate extremes indices in the CMIP5 multimodel ensemble: Part 1. Model evaluation in the present climate. *J. Geophys. Res. Atmos*., **118**, 1716–1733.

Sillmann, J., V.V. Kharin, F.W. Zwiers, X. Zhang, and D. Bronaugh, 2013b: Climate extremes indices in the CMIP5 multimodel ensemble: Part 2. Future climate projections. *J. Geophys. Res. Atmos*., **118**, 2473–2493.

Zhang, X., et al., 2011: Indices for monitoring changes in extremes based on daily temperature and precipitation data. *WIREs Clim. Change*, **2**, 851–870.

Zhang, X., G. Hegerl, S. Seneviratne, R. Stewart, F. Zwiers, and L. Alexander, 2014: *WCRP Grand Challenge: Science Underpinning the Prediction and Attribution of Extreme Events*, available at: http://www.wcrp-climate.org/grand-challenges/gc-extreme-events.

Twenty-First Century Regional Sea-Level Change Projections

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Regional sea-level projections and associated uncertainty estimates for the end of the 21st century are presented. Regional variations in sea-level from changing ocean circulation, increased heat uptake and atmospheric pressure are estimated using CMIP5 climate models. These are combined with model- and observation-based regional contributions of land ice, groundwater depletion and glacial isostatic adjustment, including gravitational effects due to mass redistribution (Slangen et al., 2014).

A moderate and a warmer climate change scenario are considered, yielding a global mean sea-level rise of 0.54 ± 0.19 m and 0.71 ± 0.28 m respectively by 2100 (mean ± 1σ). Regionally however, changes reach up to 30% higher in coastal regions along the North Atlantic Ocean and along the Antarctic Circumpolar Current, and up to 20% higher in the subtropical and equatorial regions, confirming patterns found in previous studies. Only 50% of the global mean value is projected for the subpolar North Atlantic Ocean, the Arctic Ocean and off the western Antarctic coast. Uncertainty estimates for each component demonstrate that the land ice contribution dominates the total uncertainty.

Projected sea level changes for the 21st century are shown for various coastal locations around the world. Local deviations from the global mean can amount to ±20 cm and, depending on the location, differ substantially in their underlying causes (Carson et al., 2015).

The Time of Emergence (ToE) for sea-level changes relative to the reference period 1986–2005 is analysed, and emergence is found over more than 50% of the ocean area by 2020 (Lyu et al., 2014). The ToE for regional sea level is substantially earlier than that for surface air temperature and exhibits little dependence on the emission scenarios, which means that our society will face detectable regional sea-level change and its potential impacts earlier than surface air warming.

References

Carson, M., A. Köhl, D. Stammer, A.B.A. Slangen, C.A. Katsman, R.S.W. van de Wal, J.A. Church, and N.J. White, 2015: Coastal Sea Level Changes , Observed and Projected during the 20th and 21st Century. *Clim. Change*., (in review)

Lyu, K., X. Zhang, J.A. Church, A.B.A. Slangen, and J. Hu, 2014: Time of emergence for regional sea-level change. *Nat. Clim. Change*, **4**, 1006–1010.

Slangen, A.B.A., M. Carson, C.A. Katsman, R.S.W. van de Wal, A. Koehl, L.L.A. Vermeersen, and D. Stammer, 2014: Projecting twenty-first century regional sea-level changes. *Clim. Change*, **124**, 317–332.

Systematic Temperature and Precipitation Biases in the CLARIS-LPB Ensemble Simulations over South America and Possible Implications for Climate Change Projections

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Within the framework of the CLARIS-LPB EU Project, a suite of 7 coordinated Regional Climate Model (RCM) simulations over South America (SA) driven by both the ERA-Interim reanalysis and a set of CMIP3 Global Climate Models were performed. The ability of the ERA-Interim driven RCMs in reproducing the observed climate conditions was evaluated in a recent study (Solman et al., 2013) and several systematic biases were identified. In particular, most RCMs showed a systematic temperature overestimation and precipitation underestimation over the La Plata Basin (LPB) region. However, for the scenario projection analysis the RCMs are driven by GCMs, so that errors in the large scale forcing, inherited through the boundary conditions, may combine with the errors in the RCM itself. Consequently, exploring both reanalysis-driven and GCM-driven RCM simulations is necessary in order to quantify RCMs performance under current climate conditions and to identify the source of RCM errors. Moreover, exploring the behaviour of model biases may help in interpreting the potential impact of model biases on the future climate projections and also in developing strategies for bias correction. In this context, the focus of this study twofold. First, to characterize the biases in simulating the mean temperature and precipitation in the CLARIS-LPB ensemble in order to identify whether the model biases are GCM or RCM dependent, which would help identifying possible paths for model improvements. Second, to evaluate the bias behaviour in order to determine how the bias may affect the future climate change signal.

Monthly mean temperature and precipitation data from the CRU dataset was used as reference. It was found that RCMs driven by both reanalysis and GCMs share common biases in simulating the observed temperature and precipitation patterns over SA. In particular, the warm and dry bias over LPB is one of the most remarkable features in almost every RCM evaluated. It was found that the systematic model errors are more dependent on the RCMs rather than on the driving GCMs. In order to explore the validity of the invariability assumption of models biases, the bias behavior was analyzed by evaluating monthly mean values averaged with the LPB region. The monthly means for the period 1961–1990 from both models and observations were ranked independently in ascending order to produce a q-q plot which allows spanning all the range of simulated versus observed values and the correspondence among them. This analysis showed that for each individual RCM the bias is not invariant, but a temperature-dependent temperature bias and a precipitation-dependent precipitation bias was apparent. For both the reanalysis-driven and the GCM-driven RCM simulations the warm bias is amplified for warmer months and the dry bias is amplified for wetter months. In order to quantify the bias dependence on the mean climate conditions, a simple linear fit based on minimum least squares between the modelled and observed ranked variables was computed for both temperature and precipitation. It was found that for temperature, the slope of the linear fit is larger than one for almost every RCM, demonstrating that the warm bias grows for warmer conditions. For precipitation, the slope of the linear fit is smaller than one for every RCM, indicating that the dry bias is amplified for wetter conditions. Moreover, the magnitude of the slopes quantifies the amplification of model biases. The impact of the bias behaviour on the future climate projections under the SRESA1B scenario was then explored. The relationship between model bias behaviour, in terms of the slope identified for both temperature and precipitation, and the projected climate change for each individual model revealed that the models with the largest temperature bias amplification projected the largest warming and models with the largest dry bias amplification projected the smallest precipitation increase, suggesting that models' bias behaviour affect the future climate projections. Demonstrating that the model biases have the potential to grow under future climate suggests the need for designing bias correction methodologies accounting for the bias behavior in order to get more reliable estimates of the models' projected climate change signals. Similar results by Christensen et al. (2008) and Christensen and Boberg (2012) identified temperature dependent model biases influencing the projected warming over several regions of the world. Consequently, it is clear that understanding the behaviour of model biases is key in order to build criteria to assess reliability of the future climate projections from RCMs.

References

Christensen, J.H., F. Boberg, O.B. Christensen, and P. Lucas-Picher, 2008: On the need for bias correction of regional climate change projections of temperature and precipitation. *Geophysical Research Letters*, **35**, L20709.

Christensen, J.H., and F. Boberg, 2012: Temperature dependent climate projection deficiencies in CMIP5 models. *Geophysical Research Letters*, **39**, L24705.

Solman, S.A., E. Sanchez, P. Samuelsson, R.P. da Rocha, L. Li, J.A. Marengo, N. Pessacg, A. Remedio, S.C. Chou, E.H. Berbery, H. Le Treut, M. de Castro, and D. Jacob, 2013: Evaluation of an ensemble of regional climate model simulations over South America driven by the ERA-Interim reanalysis: models' performance and uncertainties. *Climate Dynamics*, **41**, 1139–1157.

Impact Studies of 3rd National Assessment of Argentina: Data Portal and Key Results

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With the objective of meeting the needs of the impact study community of Argentina, a climate data base was developed within the framework of the Third National Communication of Climate Change (TNCCC). The data base includes observed precipitation as well as maximum, minimum and mean temperature for the period 1961–2010 from various global and regional data sets. Simulated data for the periods 1961–2010, 2015–2039 (near future) and 2075–2099 (far future) is provided for the 13 best-performing global and regional climate models over Argentina for the socio-economic scenarios RCP4.5 and RCP8.5. The systematic errors of the simulated mean values and temporal distributions of the models have been corrected in order to adjust the data to observed means and variability (Camillioni et al., 2015). To facilitate the implementation of e.g., agricultural and hydrological models, all model data is interpolated to a common grid of 0.5° × 0.5°. The data base also includes 10 indices of extreme events that are relevant for impacts over Argentina.

The architecture of the data base permits fast and efficient resource management and provision to the user. The files and their metadata can be consulted through a web interface, which also permits the visualization of maps of the locations of the data. The system for exporting time series in text and shape formats is designed to be easily handled by users and the files can also be downloaded in netCDF format. The data base is open access upon registration at http://3cn.cima.fcen.uba.ar, allowing for identification of users, accesses and downloads.

10.400 locations over Argentina, Argentinean Antarctica and the Islas del Atlántico Sur are covered by the data base. The data base contains 156.413.592 observed data from 6 different sources and 23.892.134.400 simulated data for the 13 best-performing models. Up to this moment there are 430 users registered. Some of these users contributed to the impact, vulnerability and adaption studies of the TNCCC, but most of them are from universities, research centers, NGOs, the private sector and from provincial and national institutions.

The data base was used in the different studies carried out within the component 'Strengthening of the National Adaptation Agenda' of the TNCCC. The objective of this component was to identify the most vulnerable sectors and regions of Argentina, evaluate the impacts of climate change in each one of those sectors, and to design adaptation strategies and their cost estimations. Five sectorial studies were carried out: agriculture, livestock, energy, work market and tourism. Furthermore, four ecological regions where studied: Patagonia, Andes mountains, Arid region and Argentinean ocean. The tenth study, social vulnerability, was carried out using input both from the climate data base and from the aforementioned impact studies. In this presentation we give the example from the agriculture, livestock and social vulnerability studies. The final reports of all impact studies can be consulted at: http://www.ambiente.gov.ar/?idseccion=356.

To evaluate the impact of climate change on wheat, maize and soybeans, which are the three most relevant crops in Argentina, the model suite DSSAT (Decision Support System for Agrotechnology Transfer, Jones et al., 2003) with the nationally developed interface CASANDRA (Rolla et al., 2015) was employed over the Pampas region. CASANDRA-DSSAT was forced with RCP4.5 and RCP8.5 scenarios from the global climate model CCSM4, soil and management data. For the near future, wheat yield is projected to decrease with 13% for the region, with large decreases in the northern sector and with small increases in the southern sector. The decrement in the northern sector could be mitigated sowing 40 days earlier than current sowing dates. For maize and soy bean the yields are expected to increase for near future, and adaptation strategies were not considered necessary.

Impacts on livestock production and distribution of different bovine razes due to climate change were assessed with a livestock model that describe the animal biologic functions through the mathematic definition of corporal composition, heat transfer, consumption, digestion and priorities of energy and nutrient use. The results show that meat production is projected to decrease in the northern sector but increase in the southern sector of the Pampas in the near future for the CCSM4 RCP4.5 and RCP8.5 scenarios.

An index of social vulnerability was defined and evaluated on department level for the years 2001 and 2010.The index is organized in three dimensions which refer to three different aspects of social vulnerability: social, habitable and economic conditions. These dimension include seven variables (education, health, demography, housing, basic services, labor, education, family) that are measured with ten indicators from the national Census of 2001 and 2010. To estimate the risk for the population related to climate change, the social index was combined with three different indices of climate extremes representing drought, duration of warm spells and extreme precipitation. The results show that the risks associated with drought is highest in the northwest, with warm spells in the north and northeast while the risk associated with extreme precipitation is highest in the northern and central Argentina.

References

Camillioni, I., S.A. Solman, V. Barros, A. Carril and M. Nuñez 2015: Climate Change in Argentina: Third National Communication- The framework for model selection and development of high resolution climate projections. *IPCC Workshop on Regional Climate Projections and their Use in Impacts and Risk Analysis Studies*, 15-18 of September 2015, São José dos Campos, Brazil.

Jones, J.W., G. Hoogenboom, C.H. Porter, K.J. Boote, W.D. Batchelor, L.A. Hunt, P.W. Wilkens, U. Singh, A.J. Gijsman, and J.T. Ritchie, 2003: DSSAT Cropping System Model. *European Journal of Agronomy,* **18**, 235–265.

Rolla A., E. Guevara, and S. Meira, 2015: CASANDRA: Interface para la aplicacion de modelos 2586 predictivos de crecimiento y desarrollo de cultivo a escala regional. (in preparation).

Regional Assessment of CMIP3 & CMIP5 – Simulated Precipitation and Reservoir Inflow in the Chao Phraya River Basin, Thailand

Seree Supratid

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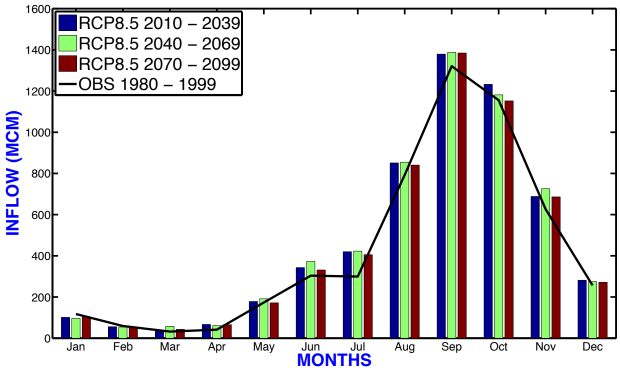
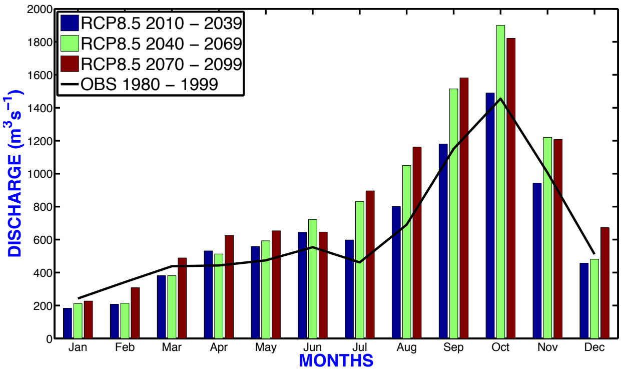
Weather and climate extremes are of many types and they result in various physical and environmental impacts (IPCC, 2007; IPCC, 2013). It is well accepted within the scientific community that an ensemble of different projections is required to achieve robust climate change information for a specific region. For this purpose we have compiled a state-of-the-art multi-model multi-scenario ensemble of global (CMIP3 & CMIP5) and performed statistical downscaling for regional precipitation projections in the Chao Phraya river basin, Thailand. The observed daily precipitation data from 83 stations around the country are interpolated to grid data by the Inverse Distance Weighted. Then, we did bias correction by the Distribution Mapping and generated changes in precipitation projection for all model pairs with three target periods, the near-future (2010–2039), the mid-future (2040–2069) and the far-future (2070–2099). The maximum precipitation increase of 32% in October, 28% in September, and 20% in September are seen for Bhumibol reservoir, Sirikit reservoir, and Nakhon Sawan, respectively.

The Nonlinear Autoregressive network with eXogenous inputs (NARX) is used to forecast the mean monthly inflow of 2 reservoirs (Bhumibol and Sirikit) and monthly discharge at Nakhon Sawan. We found very high correlation coefficients (>0.9) for all stations. The projection inflow for the near-future, mid-future, and far-future periods show seasonal variation similar to the observed inflow of the twentieth century. Continuously increase in inflow in the wet season is found from the near-future to the far-future period. However, there are decreasing trend in the dry period. The maximum inflow increase of 13% in September, 37% in August, and 35% in October are seen for Bhumibol reservoir, Sirikit reservoir, and Nakhon Sawan, respectively. The frequency of the peak inflow and the frequency of flooding in the lower Chao Phraya river basin are increasing in the future. This implies the necessity of both reservoir rule-curves improvement for the downstream flood peak reduction and a range of flood adaptation and mitigation measures to meet the impact of the changing climate.

a) Bhumibol reservoir



b) Sirikit reservoir



c) Nakhon Sawan

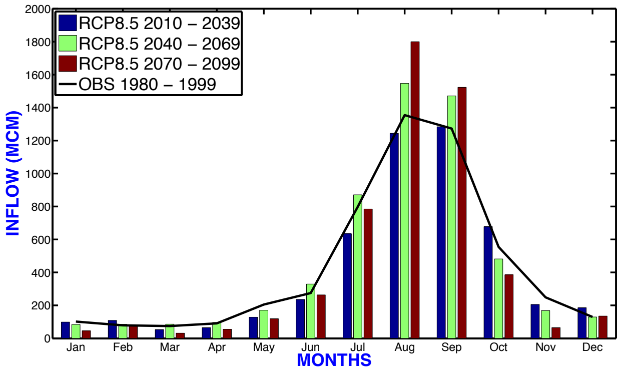


Figure 1: Mean annual cycle of reservoir inflow and mean monthly streamflow projection (RCP8.5).

References

IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on*

Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

IPCC, 2007: *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Milller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Early Detection of Drought Impact on Rice Paddies in Indonesia

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Interannual climate variability over the Indonesian archipelago is strongly affected by ENSO (El Niño Southern Oscillation) phenomenon (Harger 1995; Hendon 2003; Aldrian and Susanto, 2003; Aldrian et al. 2007; Chang et al. 2004). The warm phase of ENSO event, known as El Niño, is commonly associated with dry conditions in Indonesia causing drought over a wide area across the country. Long-term records from 1830 to 1953 have shown that 93% of droughts in Indonesia occurred during El Niño years (Quinn et al., 1978). In addition, D'Arrigo et al. (2008) reported that 17, out of the 21 drought events, coincided with El Niño (relative to 37 ENSO warm events).The Indonesian Ministry of Agriculture reported that during El Niño years, paddy damage areas due to drought ranged between 350 and 870 thousands hectares. The damage mostly occurs during dry season within May through October, correspond to for dry season planting (DSP) 1 (May to July) and DSP2 (August to October). In order to provide decision makers with useful information that can be utilized to formulate strategies for managing the associated risks, a clear picture of future predictions with regards to drought impact on crops is required prior to the planting time. As such, this paper proposes a simple and rapid method to be devised in order to develop a system of early detection of the impact of drought on rice paddy crops and production, such that the occurrence in Indonesia can be further investigated and ultimately, anticipated.

We used Niño 3.4 index as the main tool of prediction, since its significant relationships to the harvested area of paddy crops and rice production in Indonesia (Naylor et al., 2001; Falcon et al. 2004; Boer et al., 2014). In addition, the Niño 3.4 index has been measured and recorded for decades; such observational data are easily accessible via Internet, and have been widely used as an important tool for managing food security policies in Indonesia. As a method, we developed the Paddy Drought Impact Index (PDII), which is essentially the ratio of the total damaged area due to drought of rice paddy crops to their total planted area. Unlike many present agricultural drought indices, PDII is able to represent real-life paddy damage areas due to drought, as this index is calculated from the actual aftermath of drought on paddy fields in Indonesia. In addition, PDII is also able to show the relative severity of drought impact on paddy crops in different plantation districts in Indonesia by means of comparison between the different proportions of damaged area to the total planted area. PDII was invented without incorporating any actual meteorological data, considering the unavailability of their long-term records for most districts in Indonesia. For that reason, we established the necessary meteorological connection with PDII by incorporating the Standardized Precipitation Index (SPI) instead.

The connection between Niño 3.4 index and PDII was assessed using cross correlation analysis. Scatter plots of best lag time Niño 3.4 index against PDII were examined. The findings show that with 2 months lag of Niño 3.4 prior to PDII, March and June Niño 3.4 indices can be used to predict May-July and August-October PDII respectively. Critical thresholds of the March Niño 3.4 index were found to range from 0.0°C–0.5°C, which is associated with a 0.57 probability of weak El Niño occurrence during the subsequent 5 months. On the other hand, a higher probability of 0.67 for occurrences of moderate El Niño is associated with the critical thresholds of June Niño 3.4 index, which ranges from 0.5°C–1.0°C. This study has found that the potential impact of drought due to the weak and moderate El Niño occurrences in Indonesia is such that yields are reduced by about 40% in average. We also found that the most drought-prone areas are located in West Java for both DSP1 and DSP2 and in South Sulawesi for DSP2.

References

Aldrian, E., and R.D. Susanto, 2003: Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature. *International Journal Climatology*, **23**, 1435–1452.

Aldrian, E., E.D. Gates, and F.H. Widodo, 2007: Seasonal variability of Indonesian rainfall in ECHAM4 simulations and in the reanalyses: The role of ENSO. *Theoretical and Applied Climatology*, **87**, 4–59.

Chang, C.P., Z. Wang, J. Ju, and T. Li, 2004: On the relationship between Western Maritime continent monsoon rainfall and ENSO during Northern winter. *Journal of Climate*, **17**, 665–672.

D'Arrigo, R., R. Allan, R. Wilson, J. Palmer, J. Sakulich, J.F. Smerdon, S. Bijaksana, and L.O. Ngkoimani, 2008: Pacific and Indian Ocean climate signal in a tree-ring record of a Java monsoon drought. *International Journal of Climatology*, **28**, 1889–1901.

Falcon, W.P., R.L. Naylor, W.L. Smith, B.B. Marshall, and E.B. McCullough, 2004: Using climate models to improve Indonesian food security. *Bulletin of Indonesian Economic Studies*, **40**(3), 355–377.

Harger, J.R.E., 1995: Air-temperature variations and ENSO effects in Indonesia, the Phillipines, and El Salvador: ENSO Patterns and Changes from 1866–1993. *Atmospheric Environment*, **29**, 1919–1942 .

Hendon, H.H., 2003: Indonesian rainfall variability: impacts of ENSO and local Air-sea interaction. *Journal of Climate*, **16,** 1775–1790.

Naylor, R.L., W.P. Falcon, D. Rochberg, and N.Wada, 2001: Using El Niño/Southern Oscillation climate data to predict rice production in Indonesia. *Climatic Change*, **50**, 255–265

Quinn, W.H., D.O. Zopf, K.S. Short, and R.T.W. Kuo-Yang, 1978: Historical trends and statistics of the Southern Oscillation, El Niño, and Indonesian droughts. *Fisheries Bulletin*, **76**, 663–678.

Regional Climate Change over West Africa: Trends, Shift of Climate Zones and Timing of the Wet Extremes

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West African climate have evolved in recent decades to respond to elevated anthropogenic greenhouse gas (GHG) forcing. A gradual warming spatially variable reaching 0.5°C per decade in recent years is observed. In addition, the Sahel has recovered from the previous drought episodes (i.e., 1970s and 1980s), however, the precipitation amount is not at the level of the pre-drought period. Although these features are common across the different data sources, their magnitudes differ from one source to the other due to a lack of reliable observation systems. Projected climate change generated by the multimodel ensemble of the CORDEX (COordinated Regional climate Downscaling EXperiment; Giorgi et al. 2009) Regional Climate Models (RCMs) indicates continuous and stronger warming (1.5°C to 6.5°C) and a wide range of precipitation uncertainty (roughly between –30% to 30%) larger in the Sahel and increasing in the farther future. This prevent a rigorous assessment of risks and impacts associated with the anthropogenic climate change over West Africa.

To overcome this issue and provide useful climate information, we employ the revised Thornthwaite climate classification (Feddema, 2005) applied to ensembles of CMIP5, CORDEX, and higher-resolution ICTP RegCM4 experiments (HIRES) and investigate shifts in climate zones over West Africa as a response to anthropogenic climate change (Sylla et al., 2015a). Such information on projected shifts of climate zones can help policymakers to develop response strategies for the most vulnerable areas. The late 21st century projections reveal an extension of torrid climates throughout West Africa. In addition, the Sahel, predominantly semi-arid in present-day conditions, is projected to face moderately persistent future arid climate. Similarly, the Gulf of Guinea shows a tendency in the future to experience highly seasonal semi-arid conditions. Finally, wet and moist regions with an extreme seasonality around orographic zones become less extensive under future climate change. Consequently, West Africa evolves towards increasingly torrid, arid and semi-arid regimes with the recession of moist and wet zones. These features are common to all multimodel ensembles, a sign of robustness, with few disagreements in their area extents, and with more pronounced changes in the higher-resolution RCM projections. These modifications are largely due to the temperature forcing, as the contribution of precipitation change is comparatively smaller. As climate has a pervasive influence on many managed and unmanaged ecological systems, this alteration can disrupt agricultural activities and cause shifts in biological communities and entire ecosystems. For example, some plants in the Sahel growing in semi-arid climates will have to cope with arid conditions or move towards the Gulf of Guinea, and species in wet and moist areas will tend to migrate towards orographic zones. In addition, adaptation practices in water management and agriculture will need to be designed and implemented to cope with the increased water stress and reduced seasonality foreseen throughout the region. Therefore, such changes point towards an increased risk of water stress for managed and unmanaged ecosystems, and thus add an element of vulnerability to future anthropogenic climate change for West African water management, ecosystem services and agricultural activities.

These late 21st century projections are indicative of more extreme precipitation occurrences in future climate. Estimating and understanding the seasonal and sub-seasonal changes of such events is important for the formulation of adaptation and mitigation strategies, as different sectors and activities may be vulnerable to the seasonal timing of the occurrence of extremes than the yearly average. For example if an increase in high intensity rainfall events is concurrent to the peak of the rainy season, this may result in widespread flooding. In the case of pre-monsoon high intensity rainfall events, early deployment of flood control measures may be required. These projections indicate a prevailing decrease in frequency, but an increase in the intensity of very wet events, particularly in the pre-monsoon and early mature monsoon stages, more pronounced over the Sahel and in the RCP8.5 than the Gulf of Guinea and the RCP4.5. This is due to the presence of stronger moisture convergence in the boundary layer that sustains intense precipitation once convection is initiated. The pre-monsoon season experiences the largest changes in daily precipitation statistics, particularly towards an increased risk of drought associated with a decrease in mean precipitation and frequency of wet days, and increased risk of flood associated with very wet events. Both these features can produce significant stresses on important sectors such as agriculture and water resources at a time of the year (e.g., the monsoon onset) where such stresses can have stronger impacts (Sylla et al., 2015b). The results thus point towards the importance of analyzing changes of precipitation characteristics as a function of the regional seasonal and sub-seasonal cycles of monsoon rainfall.

References

Feddema, J.J., 2005: A revised Thorthwaite-type global climate classification. *Physical Geography*, **26**(6), 442–466.

Giorgi, F, C. Jones, and G. Asrar, 2009: Addressing climate information needs at the regional level. The CORDEX framework. *WMO Bulletin*, July 2009 issue.

Sylla, M.B., N. Elguindi, F. Giorgi, and D. Wisser, 2015a: Projected Robust Shift in Climatic Zones over West Africa in Response to Anthropogenic Climate Change for the Late 21st Century. *Climatic Change* (under review).

Sylla, M.B., F. Giorgi, J.S. Pal, P. Gibba, I. Kebe, and M. Nikiema, 2015b: Projected Changes in the Annual Cycle of High Intensity Precipitation Events over West Africa for the Late 21st Century. *Journal of Climate*, **28**(16), 6475–6488.

Adaptation to Climate Change in Hungary

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Multi-disciplinary research efforts for climate change impacts on different sectors have only recently started to be harmonized in Hungary. To prepare targeted and sustainable adaptation strategies, it is essential to elaborate an objective approach helping to quantify the exposure, vulnerability and adaptation capacity of any sector. A memorandum of understanding has been signed between Iceland, Liechtenstein, Norway and Hungary to establish the 2009–2014 Programme of the European Economic Area Grant entitled Adaptation to Climate Change in Hungary. The Programme has three main pillars:

1. Establishment of National Adaptation Geographical Information System (NAGiS)

To have targeted and sustainable adaptation strategies, detailed and quantitative information on regional climate change and its local impacts is of key importance. NAGiS has been built up to support strategic planning and decision making related to the adaptation in Hungary.

2. Development of climate change information available in NAGiS

To define the proper adaptation actions, scientific credibility of the information system has great importance. The most essential input of NAGiS is served by climate data. The objective of the RCMGiS project entitled "New climate scenarios based on radiative forcing change over the Carpathian Basin" is to develop available future projections. This component provides (i) detailed estimations for future climate change over Hungary conducting new climate model simulations with uncertainty assessment based on high resolution regional climate model results, (ii) quantified information for impact analyses, and (iii) training for (end-)users to properly utilize climate information.

3. Objective impact assessments

Outcomes of the impact studies based on credible climate information highlight the actions needed to mitigate or exploit climate change impacts. Elaboration of an objective approach is indispensable to quantify and compare the exposure, vulnerability and adaptation capacity of every sector. In this pillar, such a methodology is developed focusing on tourism and critical infrastructures (with emphasis on human health and road networks), and final objective is to extend NAGiS with the resulted indicators.

The poster presentation aims at introducing three key components of the adaptation programme in Hungary. For this purpose, basics and development of the information system supplying inputs for vulnerability assessments, together with some exemplary impact studies based on first NAGiS prototype will be shown in detail.

Climate Change Impacts and Implications for New Zealand to 2100

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The 'Climate Change Impacts and Implications for New Zealand to 2100' (or CCII for short) project is a 4-year project that is studying climate trends and variability and their impacts and implications for New Zealand's environment, economy, and society. CCII is generating new knowledge about the potential impacts of climate change and variability on New Zealand's environment, including our natural ecosystems and native species, and the impacts on the many productive activities which depend on the environment and enable continued growth and prosperity. CCII comprises 5 inter-related research aims:

1. Improved climate projections;

2. Case studies of key pressures, critical time steps, and potential responses for five important environments (Alpine and high elevation native forest ecosystems; high-and hill-country environments; lowland environments; coastal and estuarine systems; marine food webs);

3. Identifying feedbacks, understanding cumulative impacts and recognizing limits;

4. Increasing the relevance of climate change science and decision-making capacity to consider climate change risks through collaborative learning processes; and

5. Synthesizing the research to support coordinated, evidence-based decision-making and policy development by New Zealand organizations.

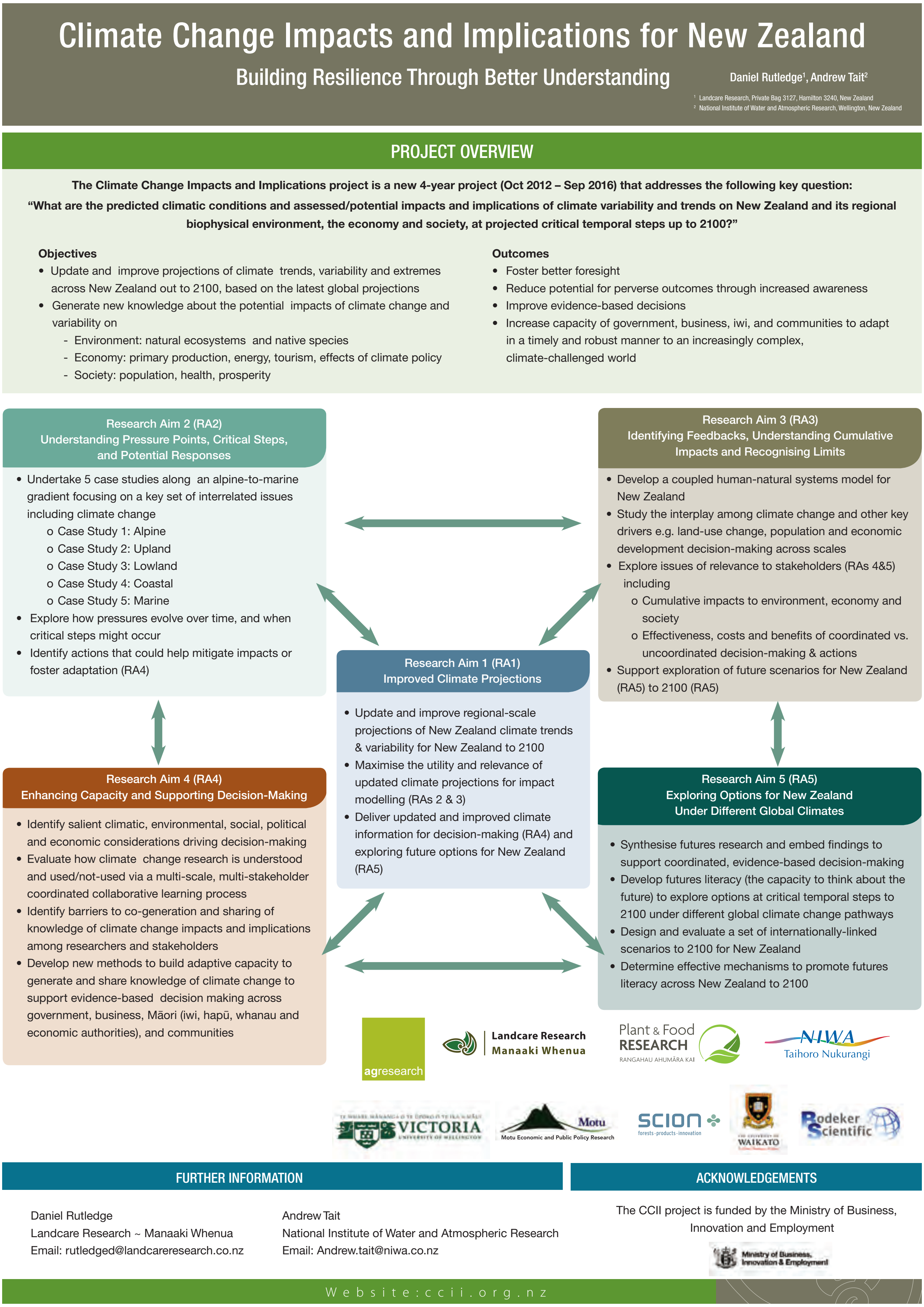
New science developed through the program includes new climate change projections for New Zealand, and significant advancements in understanding their impacts on ecosystems and environments. Existing environmental impact models (including economic models) have been adapted and are being coupled to produce new systems models integrating climate projections with management options of relevant stakeholders.

The project brings together strong groups with knowledge and modelling capabilities in climate, ecosystems, land and water use, economic, social, cultural and institutional research to address the NZ government environment sector investment plan priority of "stronger prediction and modelling systems". Team members are drawn from NIWA, Landcare Research, AgResearch, Victoria University of Wellington, Bodeker Scientific, Motu Economic Research, Plant & Food, Scion, and Waikato University.

End-users from government, business, iwi, and communities are participating directly in the program. In addition we are engaging with the broader society via targeted engagement, social media technologies, annual workshops, and webpages.

References

http://ccii.org.nz



Climate Change Impacts and Implications for New Zealand

Building Resilience Through Better Understanding

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PROJECT OVERVIEW

The Climate Change Impacts and Implications project is a new 4-year project (Oct 2012 – Sep 2016) that addresses the following key question:

"What are the predicted climatic conditions and assessed/potential impacts and implications of climate variability and trends on New Zealand and its regional biophysical environment, the economy and society, at projected critical temporal steps up to 2100?"

Objectives

- Update and improve projections of climate trends, variability and extremes across New Zealand out to 2100, based on the latest global projections
- Generate new knowledge about the potential impacts of climate change and variability on
  - Environment: natural ecosystems and native species
  - Economy: primary production, energy, tourism, effects of climate policy
  - Society: population, health, prosperity

Outcomes

- Foster better foresight
- Reduce potential for perverse outcomes through increased awareness
- Improve evidence-based decisions
- Increase capacity of government, business, iwi, and communities to adapt in a timely and robust manner to an increasingly complex, climate-challenged world

Research Aim 2 (RA2)
Understanding Pressure Points, Critical Steps, and Potential Responses

- Undertake 5 case studies along an alpine-to-marine gradient focusing on a key set of interrelated issues including climate change
  - o Case Study 1: Alpine
  - o Case Study 2: Upland
  - o Case Study 3: Lowland
  - o Case Study 4: Coastal
  - o Case Study 5: Marine
- Explore how pressures evolve over time, and when critical steps might occur
- Identify actions that could help mitigate impacts or foster adaptation (RA4)

Research Aim 3 (RA3)
Identifying Feedbacks, Understanding Cumulative Impacts and Recognising Limits

- Develop a coupled human-natural systems model for New Zealand
- Study the interplay among climate change and other key drivers e.g. land-use change, population and economic development decision-making across scales
- Explore issues of relevance to stakeholders (RAs 4&5) including
  - o Cumulative impacts to environment, economy and society
  - o Effectiveness, costs and benefits of coordinated vs. uncoordinated decision-making & actions
- Support exploration of future scenarios for New Zealand (RA5) to 2100 (RA5)

Research Aim 1 (RA1)
Improved Climate Projections

- Update and improve regional-scale projections of New Zealand climate trends & variability for New Zealand to 2100
- Maximise the utility and relevance of updated climate projections for impact modelling (RAs 2 & 3)
- Deliver updated and improved climate information for decision-making (RA4) and exploring future options for New Zealand (RA5)

Research Aim 4 (RA4)
Enhancing Capacity and Supporting Decision-Making

- Identify salient climatic, environmental, social, political and economic considerations driving decision-making
- Evaluate how climate change research is understood and used/not-used via a multi-scale, multi-stakeholder coordinated collaborative learning process
- Identify barriers to co-generation and sharing of knowledge of climate change impacts and implications among researchers and stakeholders
- Develop new methods to build adaptive capacity to generate and share knowledge of climate change to support evidence-based decision making across government, business, Māori (iwi, hapū, whanau and economic authorities), and communities

Research Aim 5 (RA5)
Exploring Options for New Zealand Under Different Global Climates

- Synthesise futures research and embed findings to support coordinated, evidence-based decision-making
- Develop futures literacy (the capacity to think about the future) to explore options at critical temporal steps to 2100 under different global climate change pathways
- Design and evaluate a set of internationally-linked scenarios to 2100 for New Zealand
- Determine effective mechanisms to promote futures literacy across New Zealand to 2100

FURTHER INFORMATION

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Website: ccii.org.nz

Figure 1: The Research Aims (RAs) and overall objectives of the CCII project

Projection of Potential Habitats for Beech (Fagus Crenata) Forests in Japan Considering Three Different Dynamic Downscaling Scenarios

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Quantification of uncertainty in climate change impacts is essential for useful support of decision making on adaptation strategies. Recently, we can find considerable number of climate change impact analyses that are explicitly taking account of plausible range of greenhouse gas emissions and uncertainties in (global) climate projections. However, for impact analyses at national/sub-national/local scale, spatial downscaling of climate projections is usually a fundamental process, which could be a source of uncertainty as well.

In this study, we estimated climate change impacts on beech forests in Japan by the end of this century with considering uncertainties derived from the choice of a regional climate model to be used for spatial downscaling in addition to uncertainties in emission scenario and climate sensitivity (Ishizaki et al., 2012). Beech is a deciduous broad-leaved tree prevailing in cool-temperate zone. Beech forest is a natural forest typical in Japan with high water retention capacity and it provides habitat of various animals and insects. In order to estimate potential habitat for beech forests under future climate situation, ENVI model (a statistical model to evaluate existence probability of beech forest for each grid cell of 1 km × 1 km spatial resolution on Japan) was used (Matsui et al., 2004).

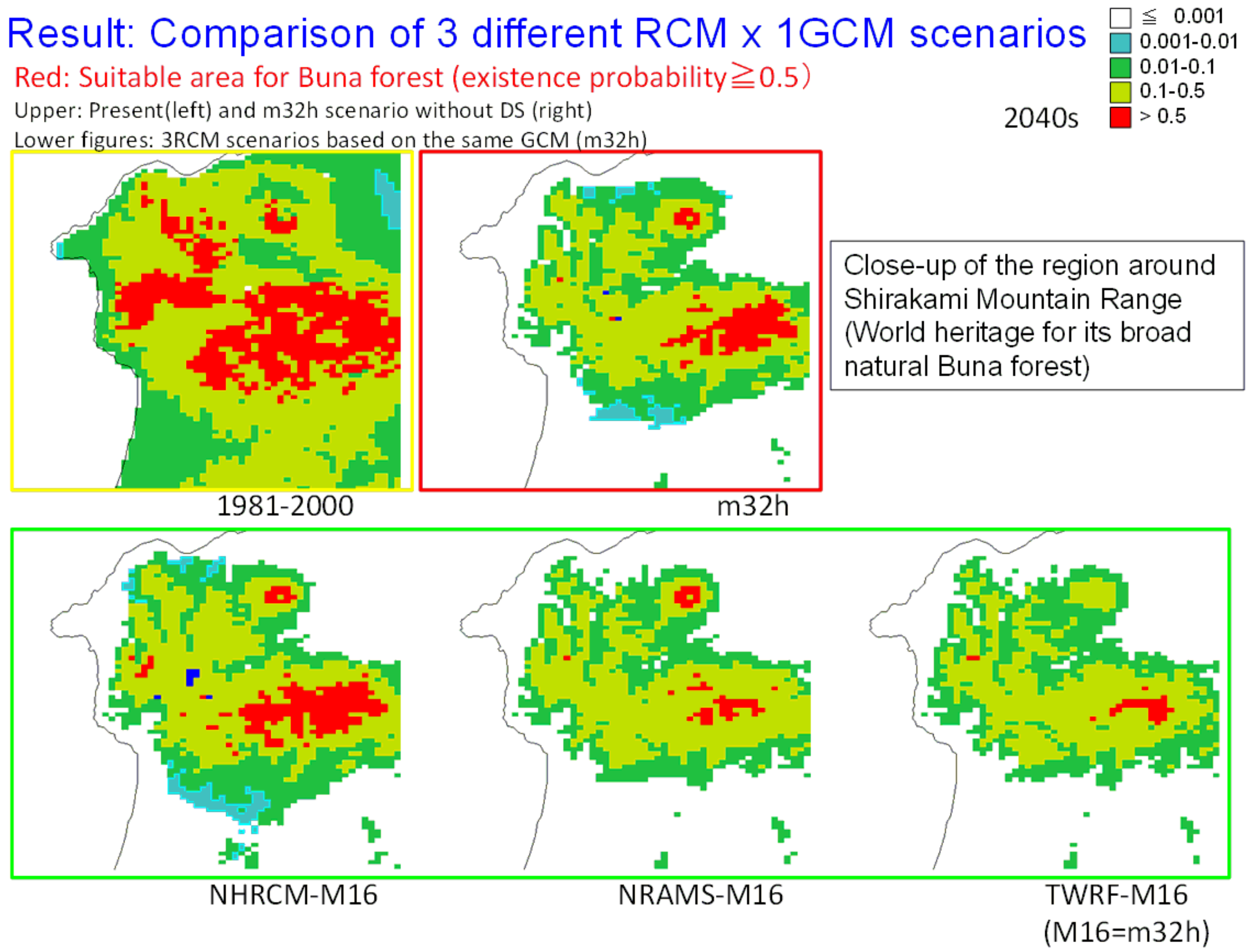

Figure 1: Suitable area for beech forest around Shirakami-Mountain Range in Japan under the present climate (upper left), under MIROC3.2h scenario without downscaling in 2040s (upper right), and under three different RCM scenarios based on MIROC3.2h in 2040s (lower).

While the uncertainty in projected suitable area for beech forest derived from the choice of a regional climate model was smaller than that derived from the choice of a global climate model with different climate sensitivity, difference of projected suitable area for beech forest among the choices of a regional climate model was not negligible at local scale. For a good design of conservation strategies at the spatial scale, it might be better or necessary to consider the uncertainty derived from the choice of a regional climate model as well as the other sources of uncertainty in impact analyses.

References

Ishizaki, N.N., I. Takayabu, M. Oh'izumi, H. Sasaki, K. Dairaku, S. Iizuka, F. Kimura, H. Kusaka, A.S. Adachi, K. Kurihara, K. Murazaki, and K. Tanaka, 2012: Improved performance of simjulated Japanese climate with a multi-model ensemble, *J. Meteor. Soc. Japan*, **90**(2), 235–254.

Matsui, T., T. Yagihashi, T. Nakaya, H. Taoda S. Yoshinaga, H. Daimaru, and N. Tanaka, 2004: Probability distributions, vulnerability and sensitivity in Fagus crenata forests following predicted climate changes in Japan. *Journal of Vegetation Science*, **15**, 605-614.

Joint Uncertainty Quantification and Propagation in Regional Climate and Ecological Models for Projections of Wildfire Extremes: A Case Study in Georgia, USA

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Anthropogenic climate change (ACC) is expected to affect the frequency of extreme wildfires. These unusually large wildfires, whether defined as individual events or expressed as area burned over time, are a type of extreme event that is constrained by climate and can be a hazard to society. However, oftentimes wildfires are also important agents of ecological disturbance and can be critical for maintaining ecosystem form and function. For example in the Southeast U.S., frequent low intensity wildfires were the defining disturbance characteristic of the species-rich pine savanna ecosystem, which once covered millions of hectares. Dominated by the longleaf pine (*pinus palustris*), this system is now critically endangered due to fire suppression and forest conversion by humans. Given the pyrophytic nature of this system, attempts at restoration could result in conflicts between societal goals of protecting biodiversity and promoting resilience in ecosystems versus reducing the costs and damages associated with catastrophic wildfires. Thus decision makers are concerned that ACC could lead to much more favorable conditions for catastrophic fires, that would inhibit restoration activities (i.e., prescribed fire) and potentially irreversibly push the system into an undesirable state (i.e., a tipping point). As such, the *tails* (i.e., extremes) of the wildfire distribution will be important and may respond differently to ACC compared to the response of the mean process.

Here we assess the potential for increased exposure to extreme wildfires due to anthropogenic climate change in a wildfire-prone region of the Southeast U.S. We focus in particular on the expected monthly land area burned by wildfires and attempt to provide a more robust projection (for a given greenhouse gas emission scenario) by quantifying and propagating multiple sources of uncertainty. Projecting these changes is complicated by the limited data available to characterize the distribution of extremes and by the multiple sources of uncertainty in climate model projections and the ecological model that relates climate and fire. Using Bayesian Model Averaging, we characterize and quantify multiple sources of uncertainty and propagate the expanded projection intervals of extreme fire months. We find non-trivial probabilities for an increasing number of extreme wildfire months for the period 2070–2099 (95% projection interval ranging from 5 fewer to 28 more extreme fire months for a high fossil fuel emissions scenario; Figure 1). The increased probabilities are due to the warmer climate increasing the likelihood of summer wildfires, while the wide projection interval is a result of the inherently large uncertainty when dealing with extreme events. Our approach illustrates that although accounting for multiple sources of uncertainty in climate change impacts studies is a difficult task, it will be necessary in order to properly assess the risk of increased exposure to these society-relevant events.

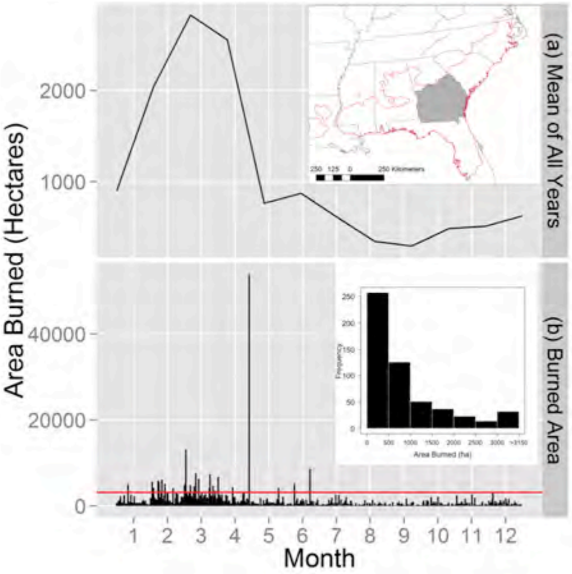

Figure 1: Wildfire characteristics for the coastal plain of Georgia, USA. (a) Mean monthly area burned over the period 1966–2010. (b) Monthly area burned over the period of record (1966–2010) and the 96th sample quantile (horizontal red line, equal to 4047 ha or ~10,000 acres). Also shown in the inset in (a) is the study area (gray shaded region) in the context of the historic range of the longleaf pine (red outline) and the histogram of observed monthly area burned by wildfires in the inset in (b).

References

Terando, A.J., B. Reich, K. Pacifici, J. Costanza, A. McKerrow, and J. Collazo, 2015: Uncertainty quantification and propagation for projections of extremes in monthly area burned under climate change: A case study in the coastal plain of Georgia, USA. Accepted. Invited chapter for AGU Monograph Series: Characterizing Uncertainties in Natural Hazard Modeling [Webley, P., K. Riley, M. Thompson, A. Patra, and M. Bursik (Eds.)]. John Wiley & Sons, Hoboken, NJ.

Is Bias Correction of Regional Climate Model (RCM) Simulations Possible for Non-Stationary Conditions?

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In hydrological climate-change impact studies, large-scale climate variables for current and future conditions are generally provided by Global Climate Models (GCMs). To resolve processes and features relevant to hydrology at the catchment scale, Regional Climate Models (RCMs) are commonly used to transfer coarse-resolution GCM data to a higher resolution (IPCC, 2013). Although this provides more detailed regional information for hydrological simulations, there is still a mismatch of scales especially for meso- and small-scale watersheds that are often captured by only one RCM grid cell. In addition, impact modelers are also facing systematic (i.e., biases) and random model errors in RCM simulations (Christensen et al., 2008), which have led to the development of several correction approaches (Teutschbein and Seibert, 2012; Chen et al., 2013; Haerter et al., 2015), which can be classified according to their degree of complexity and include simple-to-apply methods such as linear transformations but also more advanced methods such as distribution scaling. Although the correction of RCM climate variables can considerably improve hydrological simulations under current climate conditions (Teutschbein and Seibert, 2012; Chen et al., 2013), there is a major drawback: most methods follow the assumption of stationarity of model errors, which means that the correction algorithm and its parameterization for current climate conditions are assumed to also be valid for a time series of changed future climate conditions.

It is in principle not possible to test whether this underlying assumption of error stationarity is actually fulfilled for future climate conditions. In this contribution, however, we show that it is possible to evaluate how well correction methods perform for conditions different from those that they were calibrated to. We applied the idea of a differential split-sample test, originally proposed by Klemeš (1986) for hydrological models, to analyze the performance of different correction methods for use with simulations under changed conditions. The testing presented here was done for different commonly-used and rather simple correction procedures based on 15 ERA40-driven RCM-simulated temperature and precipitation series for five meso-scale catchments in Sweden. The data series were divided into cold and warm respective dry and wet years (Figure 1) to allow the cross-evaluation of the performance of different correction procedures under systematically varying climate conditions.

The differential split-sample test identified major differences in the ability of the applied correction methods to reduce model errors and to cope with non-stationary biases. More advanced correction methods performed better, whereas large deviations remained for climate model simulations corrected with simpler approaches. Therefore, the choice between bias correction algorithms plays a large role in assessing hydrological climate change impacts. For current conditions, we could easily limit this choice to the one that performed best. For simulations of future climate this is more difficult and the fundamental question is how transferable the different methods are. The differential split-sample test suggested here is a simple and yet powerful tool to evaluate this. It is possible to create two subsets of data with considerably different climate conditions and non-stationary model errors based on time series of observations and RCM simulations of current climate (no future simulations necessary). Thus, the transferability of different bias correction methods can be tested under non-stationary conditions.

The delta-change approach and the linear transformation are the two most common transfer methods and have been widely used, because they are straightforward and easy to implement due to their simplicity. Yet, our validation of these correction approaches indicated that these two methods result in large deviations and are the least reliable under changed conditions. These findings remain to be confirmed for other catchments and other geographic regions, but based on the findings in this study, we would like to recommend distribution scaling as a better-performing correction method, because it was best able to cope with non-stationary conditions. However, regardless of the used method, our results demonstrate that the—in most climate impact studies unavoidable—use of bias correction approaches for conditions different from those being used for their parameterization, might result in significant uncertainties.

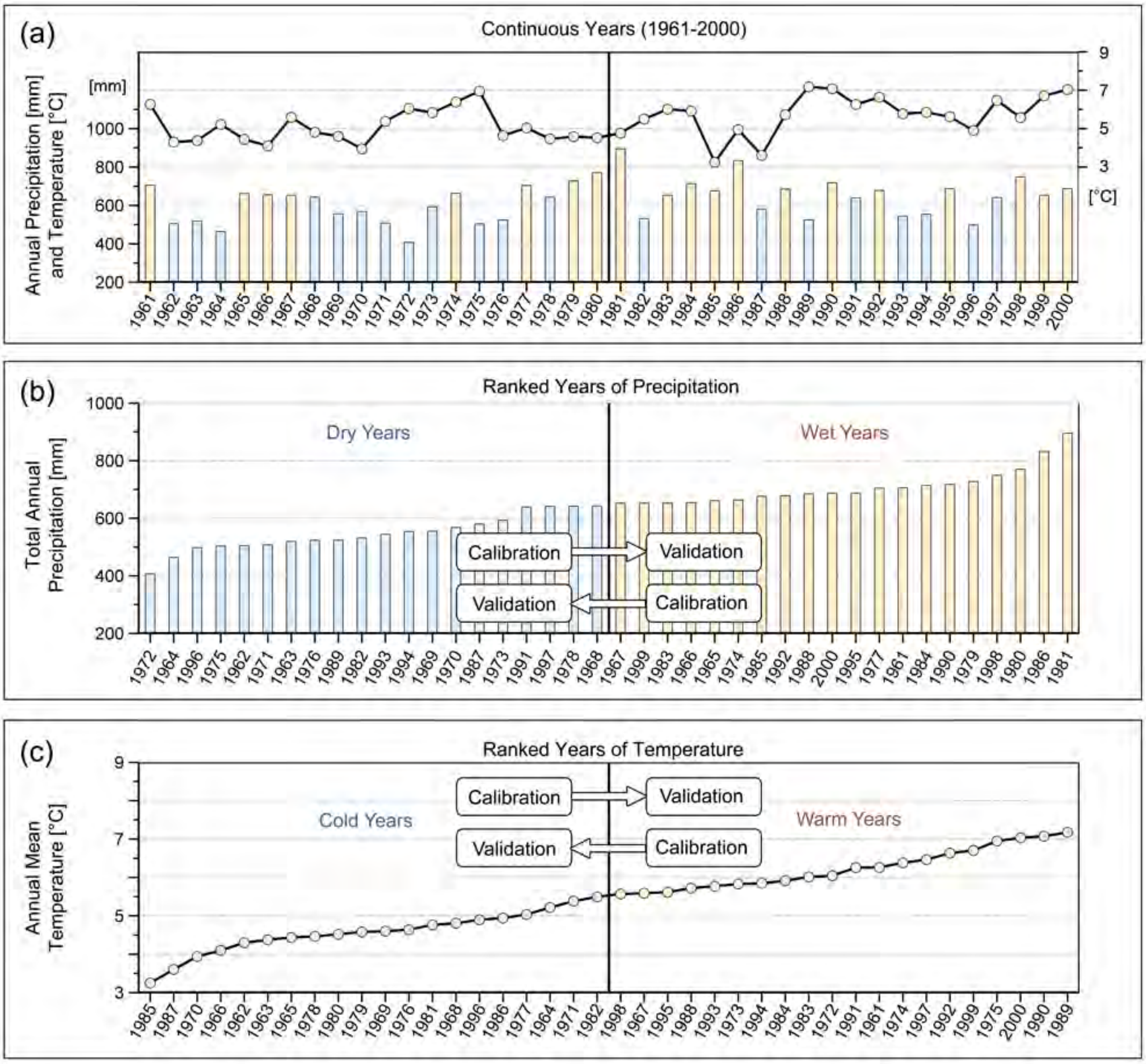

Figure 1: Exemplary procedure of the differential split-sample test. First, the annual values (a) are sorted ascending (b, c). For the twofold cross-validation, first the lower-value years were used for calibration and the higher-value years for validation. In a second step, calibration and validation periods were switched.

References

Chen, J., F.P. Brissette, D. Chaumont, and M. Braun, 2013: Performance and uncertainty evaluation of empirical downscaling methods in quantifying the climate change impacts on hydrology over two North American river basins. *Journal of Hydrology*, **479**, 200–214.

Christensen, J.H., F. Boberg, O.B. Christensen, and P. Lucas-Picher, 2008: On the need for bias correction of regional climate change projections of temperature and precipitation. *Geophysical Research Letters*, **35**, L20709, doi:10.1029/2008GL035694.

Haerter, J.O., B. Eggert, C. Moseley, C. Piani, and P. Berg, 2015: Statistical precipitation bias correction of gridded model data using point measurements. *Geophysical Research Letters*, **42**, doi:10.1002/2015GL063188.

IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Klemeš, V., 1986: Operational testing of hydrological simulation models/Vérification, en conditions réelles, des modèles de simulation hydrologique. *Hydrological Sciences Journal*, **31**, 13–24.

Teutschbein, C., and J. Seibert, 2012: Bias correction of regional climate model simulations for hydrological climate-change impact studies: Review and evaluation of different methods. *Journal of Hydrology*, **456–457**, 12–29.

Uncertainty Analysis of Hydrological Projection Focusing on the Difference in Future Climate Scenarios

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This study compared the uncertainty range in future hydrological projections derived from the various climate scenarios among the General Circulation Models (GCMs), Representative Concentration Pathways (RCPs) and bias correction methods. It is important to consider the uncertainty of projection as well as the projected results themselves, especially for an impact assessment of climate change. Since climate forcings play a significant role in hydrological processes, analysis of the impact that various climate forcings have on the spread of hydrological projection can contribute to the more meaningful assessment.

To achieve a comparison of climate change scenarios, we constructed a bias-corrected forcing dataset for multiple GCMs with several RCPs. Bias correction of GCM outputs is necessary for hydrological simulation, and it has been mentioned in previous studies that the impact of bias correction on the result is significant. Therefore, this study includes a variety of bias correction methods in addition to the GCMs and RCPs. Because the difference in bias correction methods has not been well studied yet, hydrological simulations using forcings with several bias correction methods are quite novel. Moreover, bias correction methods were classified into several types before the construction of a dataset in order to select methods that apply to this study from previous methods, and it was found that a method for a specific class had not yet been proposed. Thus, we developed a method that belongs to a specific class, and constructed a dataset using that method.

Hydrological simulations were conducted with a global hydrological model consisting of a land surface process and river routine module. River discharge was calculated on a global scale by this model in each of the 0.5-degree grids. Eight variables (temperature, precipitation, surface air pressure, air humidity, long- and short-wave radiation, wind speed and albedo) were needed for simulation. The number of GCMs we can use was selected due to this limitation. Ultimately, we compared the river discharge simulated with the forcings from 10 GCMs for two RCPs corrected with four methods using two reference datasets.

One of the surprising results of this study is the large difference in projected discharge between the bias correction methods, which is comparable to the spread of the projection of the GCMs (See Figure 1). In addition, the changing trend, which is equivalent to the difference between 21st and 20th century simulations, is less than the difference of discharge between the methods in some regions. For an area where the ratio is larger than 1 or less than −1, the changing trend can become the reverse if the method applied is different. We will present details of the differences among the GCMs, RCPs and bias correction methods at the meeting.

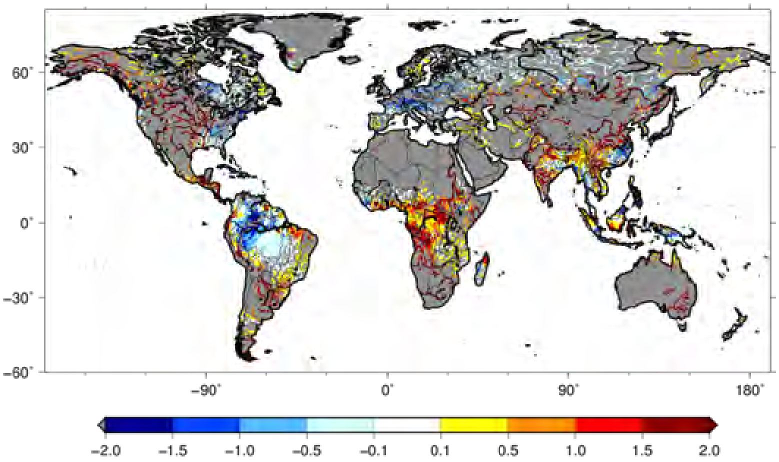

Figure 1: The ratio of the difference of annual mean river discharge averaged over 2070 to 2099 between methods compared to the changing amount under RCP8.5 scenario of a GCM.

References

Watanabe, S. Y. Hirabayashi, S. Kotsuki, N. Hanasaki, K. Tanaka, C. M. R. Mateo, M. Kiguchi, E. Ikoma, S. Kanae and T. Oki, Application of performance metrics to climate models to projecting future river discharge in the Chao Phraya River basin, Hydrological Research Letters, 8(1), 33-38, Jan 2014.

Watanabe, S., S. Kanae, S. Seto, Y. Hirabayashi and T. Oki, Intercomparison of previous and new methods for bias-corrected monthly temperature and precipitation simulated by multiple climate models, J. Geophys. Res., 117, doi:10.1029/2012JD018192, 2012.

New National Climate Change Projections for Australia

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CSIRO Ocean and Atmosphere, Australia

CSIRO and Bureau of Meteorology released new climate change projections for Australia in January 2015 (CSIRO and BoM, 2015). These were based on extensive analysis of the CMIP5 climate model ensemble and some additional downscaling, and are focused on each of fifteen regions around Australia (Figure 1). Products include printed material and an extensive website with data download capacity. These projections form part of a larger project developed with funding from the Commonwealth's Government Regional Natural Resources Management (NRM) Planning for Climate Change Fund. This fund was established to support regional NRM organisations to update their plans to account for likely climate change impacts, but the projections were also designed to be relevant to a wider range of applications.

Average temperatures will continue to increase in all seasons (*very high confidence*).

More hot days and warm spells are projected with *very high confidence*. Fewer frosts are projected with *high confidence*.

By late in the century, less rainfall is projected during the cool season, with *high confidence*. There is *medium confidence* that rainfall will remain unchanged in the warm season.

Even though mean annual rainfall is projected to decline, heavy rainfall intensity is projected to increase, with *high confidence*.

Mean sea level will continue to rise and height of extreme sea-level events will also increase (*very high confidence*).

A harsher fire-weather climate in the future (*high confidence*).

On annual and decadal basis, natural variability in the climate system can act to either mask or enhance any long-term human induced trend, particularly in the next 20 years and for rainfall.

Figure 1: Regions of Australia used for the projections and an example of summary projection information for one region: Murray Basin.

A strong motivation for the production of the projections was user uptake for planning activities. To better understand what type of information was meaningful to users, various engagement processes were set in place, including opportunities for the different communities to meet. One such vehicle of coordination was the development of the language used in the regional reports and the website. Through a review process, roadshows (face-to-face workshops) and user meetings, regional messages about climate change were discussed and the ways to describe them were progressed through workshops. Defining the processes for user engagement throughout the production process enabled the research and user communities to advance their working relationships through better appreciation of user needs and scientific limitations, and thus providing more meaningful projections and better guidance of user expectations.

The projections cover a range of variables, such as temperature, precipitation, sea level rise, humidity, radiation and fire weather, including many aspects of extremes, such as hot/cold days, drought, fire-weather, tropical cyclones, strong wind, extreme rainfall and extreme sea level. Projections are accessible with different levels of scientific detail and also over different spatial aggregation levels (the finest of which is illustrated in Figure 1). Many users appreciated key messages on regional climate change and our confidence ratings (see Figure 1 for an example), whereas some other users required projection data sets suited for technical applications (based on the results of individual GCM and downscaled simulations). To assist such users in selecting a small set of models, representative of the range of plausible change relevant to their decision making context, a software tool ('Climate Futures') was developed (see Whetton et al., 2012). This projection classification tool also has the capacity to include additional GCM and downscaling data sets (based on CMIP3 and CMIP5, and others as they become available), enabling us to address a requirement from the funders to provide an integrating projection system rather than a system in competition to other regional projection projects.

The projections were communicated through three different publications, and through a website (http://www.climatechangeinaustralia.gov.au), which as well as containing the reports and additional contextual information, presented a range of interactive tools for exploring the projections, data download facility and guidance. The lowest level of detail is communicated through a brochure, containing key messages of projected change for each region, plus quantitative ranges of change for some variables. More detail on regional current climate, projected change, evidence behind key messages and some user guidance is provided in regional reports aimed for planners and decision makers. A full description of model evaluation, projection methods as well as detailed description of national projections is provided in a Technical Report, providing reference material for researchers and decision makers. Of central importance to the success of the project was the transparency for how projection messages were derived, from the analysis of results and review of literature in the Technical report, to the key statements appearing in the regionally focused brochures. Due to the large number of authors involved in writing the different products and that the products were being produced in parallel (reminiscent of challenges presented in the IPCC assessment process), significant effort was required to ensure that messages were consistent in content, despite differences in level of detail.

In preparing these projections a number of challenges arose including meeting user needs as determined through consultation, meeting the objectives of the three funding organisations and timetable, and meeting scientific objectives formulated on previous experience of projection provision and user interaction. Amongst the community of users there is a clear demand for the provision of information at various levels in a consistent way, such as basic projections for the general public and more technical projections for use in risk assessments (including the provision of 'application-ready' data sets). An important motivation on our part was to make the projections as scientifically robust as possible, by integrating different lines of evidence into climate projection development, including understanding the processes driving regional projected changes and assessing confidence in projections. This effectively strengthened the 'assessment' component of the projections, compared to previous products, and increased its similarity to the IPCC process. In choosing methods of communication, we avoided presenting any detail which we felt was unlikely be scientifically robust. In particular this meant that ranges of change averaged over regions was the key communication device rather than maps based on gridded data (as had been used in the previous projection product), and providing only qualitative guidance when our confidence in the projection was very low.

References

CSIRO and BoM, 2015: NRM climate change projections project. CSIRO Marine and Atmospheric Research and Bureau of Meteorology (CAWCR), and the Department of the Environment, Melbourne, Australia. Available at: http://climatechangeinaustralia.com.au/.

Whetton, P., K. Hennessy, J. Clarke, K. McInnes, and D. Kent, 2012: Use of Representative Climate Futures in impact and adaptation assessment. *Climatic Change*, **115**, 433–442.

Climate and Meltwater Changes in the Himalayas: Impacts and Risk Assessment

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Regional warming was identified in the whole Himalayas in the past ~50 years, with larger warming rate in the last decade. During the same period, precipitation decreased in the most areas of Himalayas. Warming-dry regime of climate resulted in widespread retreating of glaciers. Based on in-situ investigations and mapping of satellite images, we studied glacial changes between 1970's to 2008. It shows that in the north slope of Himalayas, retreating glaciers amount to 25.3% of overall glaciers in Ganges basin, 23.3% in Yarlung Zangbo basin, 29.2% in Indus and 25% in other areas. Glacier changes in the southern slope of the Himalayas have larger amplitudes, with averaged retreated distance roughly doubled, than that of the northern slope. Darkening of glacier surface due to back carbon and other light-absorbing aerosols might have contributed to the strong melting, especially in the southern slope.

Using degree-day model (DDM), we estimate glacier mass balance as well as contributions of glacier melt-water to river runoff over different drainage basins in north Himalayas. During 1961–2006, the total mass loses of glaciers amounts to 198 km^3, equals to approximately 10 m thinning of glaciers. Among the mass lose, 40 km^3 occurred in Ganges basin (10.8 m ice thinning) which is 360.4 108 m^3 water equivalent, and 168.4 km^3 (11.4 m ice thinning) occurred in Yarlung Zangbo basin which amounts to 1515.7108 m^3 water equivalent. While glaciers in Indus basin experienced a positive mass balance before 2000 and negative after 2000. The mass balance is averaged -220 $mm \times a^{-1}$ during 2000–2006. Glacier melt water increases in the last 5 decades, contributing to an increasing amount to total river runoff in the Indus, Ganges and Yarlung Zangbo Rivers. For instance, melt water averagely contribute about 11.8% to runoff of Yarlung Zangbo during 1961–2008, with the percentage a slightly increasing trend.

Projections of future climate change by Regional Climate Model (ICTP RegCM3) shows continuously warming and drying trends in the most part of Himalayas before 2050, implying continuously retreating of glacier thus depletion of water storage over the Himalayas. Assessment of glacial lake outburst flood (GLOF) disaster risk is completed in the north slope, combined with potential dangerous glacial lakes (PDGL) outburst hazard, regional exposure, vulnerability of exposed elements and adaptation capability (risk management) using the analytic hierarchy process. The zones at highest risk of GLOF disaster are mainly located in Nyalam, Tingri, Dinggyê, Lhozhag, Kangmar and Zhongba, in the mid-eastern Himalayas.

References

Zhang, D., C. Xiao, and D. Qin, 2009: Himalayan Glacier Fluctuation over the Last Decades and Its Impact to Water Resources. *Journal of Glaciology and Geocryology*, **31**(5), 885–895. (in Chinese with English Abstract)

Ming, J., Y. Wang, Z. Du, T. Zhang, W. Guo, C. Xiao, X. Xu, M. Ding, D. Zhang, and W. Yang, 2015: Widespread Albedo Decreasing and Induced Melting of Himalayan Snow and Ice in the Early 21st Century. *PLoS ONE*, **10**(6), 0126235. doi:10.1371/journal. pone.0126235

Wang, S., C. Xiao, and D. Qin, 2014: Moraine-dammed Lake Distribution and Outburst Flood Risk in the Chinese Himalaya. *Journal of Glaciology*, **61**(225),115–126.

Assessing the Impacts of Climate Change on River Flows in Three Catchments of China Using BCC_CSM1.1-RegCM4.0 Projection

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To quantify the spatial and temporal heterogeneity of climate change impacts on hydrological processes, this study simulated river discharge in the River Huangfuchuan in semi-arid northern China, River Huaihe in semi-humid and humid middle China, and the River Xiangxi in humid southern China. We assessed the projected discharge for three time periods (2020s, 2050s and 2080s) using BCC_CSM1.1- RegCM4.0 under the Representative Concentration Pathways (RCPs)-RCP4.5 and RCP8.5.

Climate projections that were applied to semi-distributed hydrological models Soil Water Assessment Tools (SWAT) in all catchments showed trends toward warmer and wetter conditions, particularly for the River Huangfuchuan. The main projected hydrologic impact was a more pronounced increase in annual discharge in the River Huangfuchuan than in the River Xiangxi, while decrease in River Huaihe. Most of scenarios projected increased discharge in all seasons for River Huangfuchuan, although the magnitude of these increases varied among seasons and emission scenarios; while the projected increase discharge in spring for River Huaihe and River Xaingxi and decrease in flooding season. Peak flows was projected to increase than usual in River Huangfuchuan and earlier than usual in River Huaihe and River Xiangxi. The uncertainty analysis provided an improved understanding of future hydrologic behaviour in the watershed under different RCPs and that should always be considered in analysis of climate change impacts and adaptation.

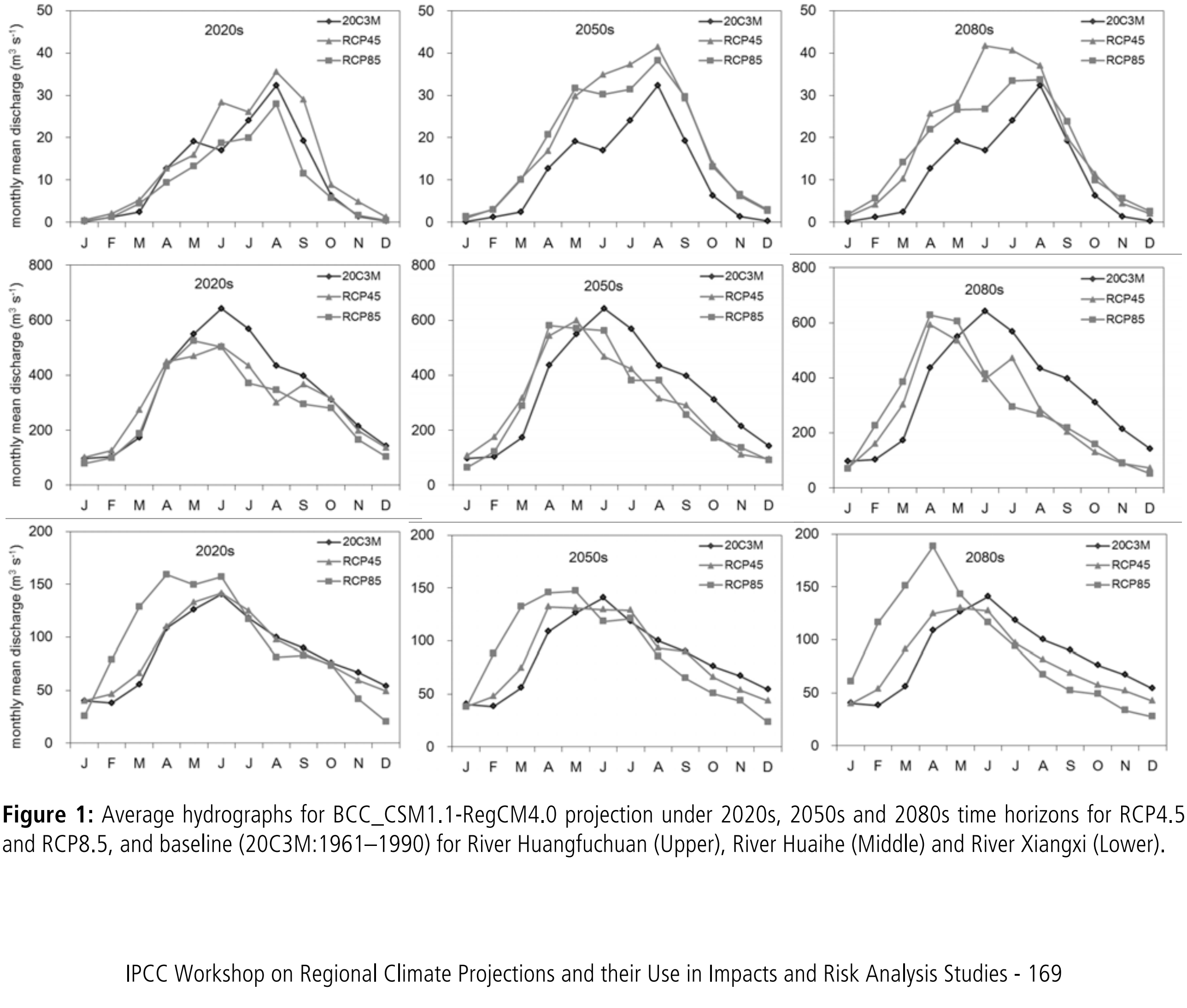

Figure 1: Average hydrographs for BCC_CSM1.1-RegCM4.0 projection under 2020s, 2050s and 2080s time horizons for RCP4.5 and RCP8.5, and baseline (20C3M:1961–1990) for River Huangfuchuan (Upper), River Huaihe (Middle) and River Xiangxi (Lower).

References

Gao, X.J., M.L. Wang, and F. Giorgi, 2013: Climate change over China in the21st century as simulated by BCC_CSM1.1-RegCM4.0. *Atmospheric and Oceanic Science Letters*, **6**(5), 381–386.

Xu, H., R. Taylor, and Y. Xu, 2011: Quantifying uncertainty in the impacts of climate change on river discharge in sub-catchments of the Yangtze and Yellow River Basins, China. *Hydrology and. Earth System Science*, **15**, 333–344.

Projected Extreme Climate Events and Flood Risk in China based on CMIP5

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The changes in extreme climate indices TXx, TNn, R95p, and CDD were projected using multi-model results from CMIP5. The results suggest that TXx and TNn will increase in the future. R95p is projected to increase and CDD to decrease significantly. The multi-model simulations show remarkable consistency in their projection of the extreme temperature indices, but poor consistency with respect to the extreme precipitation indices. The uncertainty in the future changes of the extreme climate indices increases with the increasing severity of the emissions scenario. Based on the simulations and in combination with data on population, GDP, arable land, and terrain elevation, the spatial distributions of the flood and heat wave risk levels are calculated and analyzed under RCP8.5.

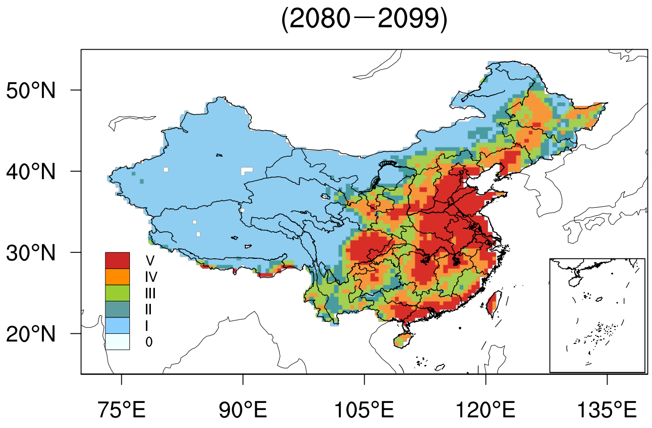

Figure 1: Spatial distribution of flood risk levels in 2080–2099 over China under RCP8.5.

References

Xu Y., Wu J., Shi Y., Zhou Bo-Tao. 2015: Change in Extreme Climate Events over China Based on CMIP5, Atmospheric and Oceanic Science Letters, 8(4):185-192

Xu Ying, Zhang Bing, Zhou Bo-Tao, 2014: Projected Flood Risks in China Based on CMIP5, Advances in Climate Change Research, 5(2): 57-65.