DOC 8

IRRELEVANT INFORMATION REMOVED FROM THIS DOCUMENT - s22.

BOM – 2013 ANNUAL CLIMATE SUMMARY

KEY MESSAGES

- The Bureau of Meteorology released its Annual Climate Statement for 2013 on 3 January 2014, stating that:
  - Overall, 2013 was Australia's warmest year on record with an annual national mean temperature +1.20 °C above average.
  - Summer 2012–13 was the warmest on record nationally, spring was the warmest on record and winter the third warmest.
  - Sea surface temperatures around Australia were unusually warm throughout the year with 2013 being the third highest on record (since 1910) and the warmest over southern waters.
  - National rainfall was slightly below average for the year.
- Warmer than average conditions have continued into January 2014 with several heatwaves across the country.
- Recent warming trends for Australia and the globe have been influenced by increasing greenhouse gases and the enhanced greenhouse effect.

KEY QUOTES

- "Nationally, Australian temperatures have warmed approximately 1 °C since 1950, consistent with global climate trends. Globally, each of the past 13 years (2001 to 2013) have ranked among the 14th warmest on record." (Bureau of Meteorology Media Release dated 3 January 2014, at **Attachment A**)
  http://www.bom.gov.au/announcements/media_releases/ho/20140103.shtml
- "University of New South Wales climate expert Dr Sarah Perkins says last year shows the effects of global warming are taking hold. 'It's here and now. We're actually starting to feel the effects, and even though the global temperature hasn't risen more than a degree at the moment, that's already had impacts on extreme temperatures and that's consistent with what we've been seeing for quite a while'." (ABC News Online, 3 January 2014, at **Attachment B**)

  http://www.abc.net.au/news/2014-01-03/2013-was-the-hottest-year-on-record-for-australia/5183040

BACKGROUND

- 2013 was most notable for its lack of cold weather, as well as a series of heatwaves or periods of winter warmth.

[redacted]

ATTACHMENTS

A: Bureau of Meteorology media release, dated 3 January 2014

B: ABC News Online article, dated 3 January 2014

Attachments A and B not included (published material - out of scope).

24 RECENT RECORD WARM TEMPERATURES AND BLUE MOUNTAINS FIRES

SUMMARY OF ISSUE – Australia experienced its warmest September on record in 2013, continuing a period of record warm temperatures stretching back more than 12 months. The warmth has exacerbated fire danger in many parts of Australia by contributing to early fuel curing and more severe early season fire weather.

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. Will 2013 be Australia's hottest year on record and is this due to global warming?

A. It is now very likely that 2013 will be Australia's hottest year on record, breaking the previous record of +1.03 °C set in 2005. At the end of October the 2013 year to date temperature anomaly was +1.3°C.

Our preliminary analysis of the temperature data over the past 12 months suggests that the record high temperatures are largely due to climate change (global warming). The likelihood of national temperature anomalies this large occurring through natural variability is assessed as extremely low.

Q. Were the Blue Mountains Bushfires unusual and were they caused by global warming?

A. Severe and early onset bushfires such as these are rare but not unprecedented. Comparable fires occurred in the Blue Mountains in 1926 and 1968.

Fires are a combined consequence of a complex set of interacting factors. These include antecedent climate conditions, the extant weather conditions, the ignition circumstances, fuel load management and the management of the fire itself.

While it is not possible to attribute any single event to climate change without a more detailed study, there is evidence that climate change experienced to date has increased the odds of severe weather conducive to severe bushfires occurring.

Climate projections show that the frequency and intensity of heatwaves and bushfire threat can be expected to increase in southern Australia in the future. This is due to expected higher temperatures, higher evaporation, lower rainfall and, for the south east, the potential for summer-time weather systems that are associated with the most extreme and damaging bushfire activity.

Written by: Neil Plummer Mobile: [redacted]
Cleared by: Graham Hawke
Date Updated: 12 November 2013

26 CLIMATE CHANGE AND VARIABILITY

SUMMARY OF ISSUE – Recent climate observations and how these relate to longer-term trends and variations in Australia and with reference to the global context.

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. Has Australia experienced unusual climatic conditions in the past year?

A. The last year has seen unprecedented hot conditions affect the Australian continent in most states and territories. Australia is tracking towards 2013 being the warmest year on record.

The number of heat records that have been broken throughout 2013 has been exceptional. During this period Australia has seen its hottest day, week, month, season, 12 months and start to a year (January to October) on record. The unusual warmth is consistent global trends, dry conditions and with elevated sea surface temperatures around southern Australia.

KEY POINTS

- Australia's record for the warmest 12-month period has been broken for a third consecutive month in October 2013.
- This continues a remarkable sequence of warmer-than-average months for Australia since June 2012. The mean temperature for Australia, averaged over the 12 months from November 2012 to October 2013, was 1.3 °C above the long-term (1961–1990) average. This was also 0.2 °C warmer than any 12-month period prior to 2013.
- Temperatures for the 2013 calendar year to date (January to October) have also been the warmest on record, at 1.3 °C above the long-term average, well above the previous record set for January to October 2005 (+1.08 °C).
- The unusual warmth over Australia is consistent with global trends, dry conditions and with elevated sea surface temperatures around southern Australia.
- At a global scale 2013 has seen neutral conditions in the Pacific Ocean (i.e. neither El Niño nor La Niña) meaning that natural large scale drivers have not been present. This means that the recent conditions over Australia cannot be explained by natural drivers.

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Date Updated: 12 November 2013

28 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – FIFTH ASSESSMENT REPORT HIGHLIGHTS

SUMMARY OF ISSUE – The Intergovernmental Panel on Climate Change (IPCC) released the full Working Group I contribution to the Fifth Assessment Report on 27 September 2013. This report provides an update of knowledge on the scientific aspects of climate change.

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. Have global temperatures stopped rising in recent years (the so-called 'hiatus')?

A. Global temperatures continue to rise, however observations show that air temperature is currently rising at a lower rate than the average since 1950. Observations show that global average air temperature increased by around 0.85°C since 1880, with 2001–2010 being the hottest decade on record.

Short-term fluctuations are superimposed on long-term trends for all climate indicators. This is because multiple forces, including increasing greenhouse gases, increased aerosol pollution, changes in solar radiation and volcanic eruptions, act upon the climate system. Some of those influences, notably volcanic eruptions and reductions in solar radiation, act to cool the climate system temporarily.

The climate system also displays natural variability. This variability does not cool or warm the entire climate, but it can exchange heat through different parts of the climate system. Decadal changes in global-mean temperature are mostly due to decadal oscillations in the exchange of heat between the atmosphere and oceans.

The lower rate of warming during the past decade, compared with the previous decade, is likely due in large part to increased ocean heat uptake. The lower rate of warming has also occurred during a period of reduced solar radiation, corresponding to a downward phase in the 11-year solar cycle. Decadal natural variability is not unusual, and is observed over the entire 20th century. Further, global-mean temperature is just one metric of warmth accumulated in the climate system. When looking across multiple indicators, including deep ocean heat content, loss of northern

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Date Update: 12 November 2013

hemisphere sea-ice, loss of ice mass at the poles, a consistent picture of continued warming of the climate system is clear.

Q. Has the warming been caused by changes in the radiation output from the sun related to the solar cycle?

A. The Working Group report findings make it clear that neither changes in the sun's output over the last 100 years nor cosmic rays have contributed to the observed warming of the climate system.

Q. Have the recent fires been caused by global warming?

A. Individual weather events cannot be attributed to being caused by climate change. However, climate projections show that heat events (and associated bushfire risk) are expected to occur more often and with greater intensity in the future. There is a clear trend towards increasing temperature extremes that increase the probability of fire weather. Other factors include fuel load and dryness.

KEY POINTS

- The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for assessing the most recent scientific research on climate change, under the auspices of the United Nations. It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research, nor does it monitor climate related data or parameters.
- The IPCC is acknowledged by governments around the world as the most reliable source of advice on climate change. The scientific and consensus nature of IPCC assessments mean they provide a vital reference and evidence base.
- The main activity of the IPCC is to provide, at regular intervals, Assessment Reports of the state of knowledge on climate change. The last was Climate Change 2007, the IPCC Fourth Assessment Report. The IPCC is currently preparing its Fifth Assessment Report, which will be released in phases that began in September 2013 and will continue to October 2014. The report of Working Group I, the Physical Science Basis of Climate Change, was released on 27 September 2013. The Working Group II, Impacts, Adaptation and Vulnerability report, will be released on 30 March 2014.

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Date Update: 12 November 2013

- Significant investment by many scientific organisations, including the Bureau and CSIRO, has supported critical research contributing to the IPCC's Fifth Assessment Report. This includes contributions of climate model data as well as involvement from key Bureau staff in the report writing and review.
- There was considerable international media interest in the lead up to, and following the release of, the Working Group I report.
- The main findings of the Working Group I report are that:
    - there is robust evidence that multiple components of the Earth's climate system are changing;
    - scientists are more certain than ever that most of the warming since 1950 has been caused by human activities;
    - for the first time the IPCC provides an estimate of the total allowable global emissions in order to limit temperature rise to 2 C above pre-industrial levels;
    - we are already observing the consequences of a changing climate in Australia and elsewhere around the world; and scientific understanding of sea level rise is stronger and projections of global average sea level rise are higher than in previous IPCC reports.

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Date Update: 12 November 2013

DOC 12

IRRELEVANT INFORMATION REMOVED FROM THIS DOCUMENT -s22.

30 AUSTRALIAN ANNUAL CLIMATE STATEMENT 2013

SUMMARY OF ISSUE – The Bureau of Meteorology released its annual climate statement on 3 January 2014, detailing a record warm year with average rainfall. There was significant public and media interest in the statement.

FAST FACTS

- The past year was characterised by persistent and widespread warmth.
- The Australian area-averaged mean temperature for 2013 was +1.20 °C above the 1961–1990 average, and +0.17 °C above the previous record set in 2005 (+1.03 °C). Maximum temperatures were +1.45 °C above average, and minimum temperatures +0.94 °C above average.
- This continues a remarkable sequence of warmer-than-average months for Australia since June 2012. The unconstrained 12-month record for Australian mean temperature was broken three times during 2013.
- Sea surface temperatures (SSTs) around Australia were unusually warm throughout the year, with the monthly anomalies for January and February 2014 the highest on record and that for November 2013 the second-highest on record. This extends a period of sustained record-high SSTs in the Australian region since 2010.

[redacted]

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. How does 2013 compare to the temperature during the exceptionally hot years in the early 1900s – for which there are ACORN-SAT measurement sites fitted with Stevenson screens to enable accurate comparisons?

A. Because of the lack of metadata prior to 1910, it is difficult to compare temperatures from that period to those after 1910. However, a recently completed joint project between the University of Melbourne and the Bureau of Meteorology shows that there were no years prior to 1910 across southeastern Australia (area-averaged) that were warmer than recent years. There is no evidence that the early 1900s were exceptionally hot across this region in comparison with modern temperatures. Rather, temperatures were likely around a degree cooler. The southeast is the most suitable region for extending the climate record since it has the most available pre-1910 data, with a significant lack of data in other regions.

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Date Updated: 30 January 2014

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Q. Isn't this 'hottest year' just climate variability, given that we had a cool year a couple of years ago?

A. The warming trend, both globally and in Australia, has been attributed to increasing greenhouse gases in the scientific literature. Australia has experienced just one cooler-than-average year (2011) in the last decade. The 10-year mean temperature for 2004 – 2013 was 0.50 °C above average, the equal-highest on record. Recent studies have attributed the record hot summer of 2012-2013 to increasing greenhouse gases. Similar studies around the world have shown that recent extreme heat is very unlikely to have occurred due to natural variability alone, while being consistent with the enhanced greenhouse effect.

Q. What do you say to claims that the Bureau has overestimated the average Australian temperature by about 4 degrees?

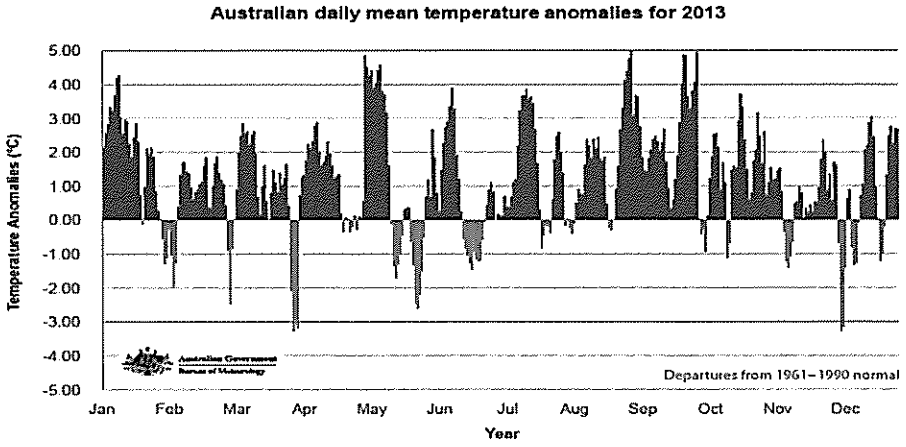
A. These claims are not correct and are certainly not supported by analysis conducted at the Bureau of Meteorology, or other organisations including CSIRO, Australian universities or international research centres such as NASA, the US National Climatic Data Center (NCDC) or the UK Hadley Centre.

Q. To what extent does solar activity explain the observed warming, given a steady increase?

A. Climate change attribution studies published since the mid-1990s have firmly attributed observed warming to increasing greenhouse gases. Changes in solar radiation are very unlikely to have been responsible for warming seen since the mid-20th century. In particular, the vertical profile of temperature changes in the atmosphere, with warming at the surface and cooling in the stratosphere, is associated with greenhouse gas increases and not solar radiation increases.

FURTHER BACKGROUND INFORMATION

- 2013 was most notable for its lack of cold weather, as well as a series of heatwaves or periods of winter warmth. The graph below shows daily temperature anomalies (departures from the long-term average) for 2103 for Australian averaged temperature, showing the remarkable absence of cold weather.



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Date Updated: 30 January 2014
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DOC 13

32 CLIMATE CHANGE AND VARIABILITY

SUMMARY OF ISSUE – Recent weather and climate extremes over Australia and the globe are being frequently queried in terms of their consistency with longer-term trends and as evidence of global warming.

FAST FACTS

- Australia's climate is highly variable from year to year, largely due to the influence of the El Niño Southern Oscillation phenomenon.
- Overlaid on the high year to year variability are several trends in Australian climate, including more frequent hot extremes compared to cold extremes, which are a result of increasing greenhouse gases.
- Australia has experienced just one cooler-than-average year (2011) in the last decade. The 10-year mean temperature for 2004–2013 was 0.50 °C above average, the equal-highest on record.
- The unusual warmth over Australia in 2013 is consistent with global trends, dry conditions and with elevated sea surface temperatures around Australia.
- 2013 has seen neutral conditions in the Pacific Ocean, i.e. neither El Niño nor La Niña, meaning that natural large scale climate drivers have not been present. Hence, the recent conditions over Australia cannot be explained by natural drivers.
- According to the latest data from the US NOAA, the year 2013 ties with 2003 as the fourth warmest year globally since records began in 1880. The annual global combined land and ocean surface temperature was 0.62 °C above the 20th century average of 13.9 °C. This marks the 37th consecutive year (since 1976) that the yearly global temperature was above average. Currently, the warmest year on record is 2010, which was 0.66 °C above average.

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. Wouldn't we expect fewer extreme 'cold waves', as seen in US and Europe if global warming was true?

A: While extreme cold weather continues to occur, the latest IPCC report states that "It is very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale". The recent 'cold wave' in the US broke few significant climate records and, during this period, Northern Hemisphere and global temperatures remained well above average. A range of climate indicators in the atmosphere, oceans and cryosphere show that the world continues to warm.

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Q. There has been an increase in sunspots. Does this suggest solar activity is causing the world to get warmer?

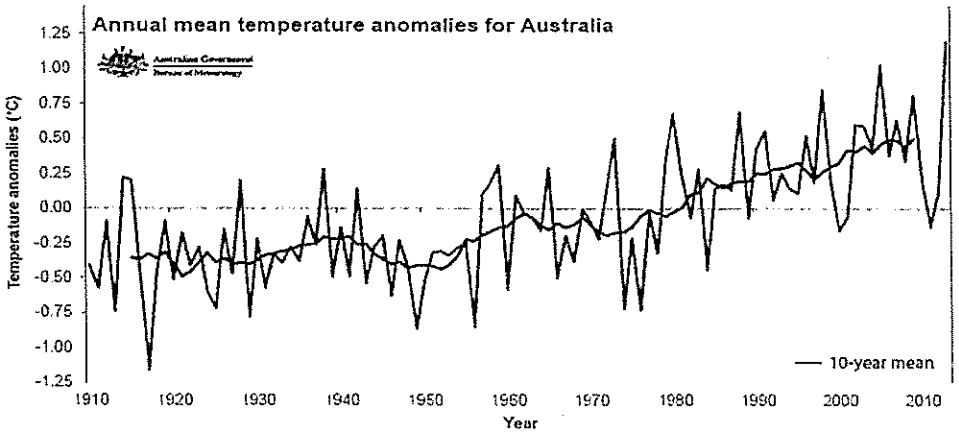
A: Climate change attribution studies published since the mid-1990s have firmly attributed observed warming to increasing greenhouse gases. The effect of solar forcing on global temperature trends has been found to be small, with less than 0.1 °C warming attributable to combined solar and volcanic forcing over the 1951–2010 period. Furthermore, the vertical profile of temperature changes in the atmosphere, with warming at the surface and cooling in the stratosphere, is associated with greenhouse gas increases and not solar radiation increases. It is possible that the downward phase of the 11 year solar cycle has had a small, relative cooling influence on global temperatures since 1998, which may have contributed to a lower rate of warming in the past decade compared to the 1990s.

Q. How does the Bureau construct areal averaged temperatures?

A: The Australian annual temperature is constructed through a process of averaging. The first step is to create monthly mean temperatures at the stations which are part of the (homogeneous) ACORN-SAT. The second step is forming spatial averages of these data, using spatial interpolation. This involves calculating temperatures on a uniform grid across Australia through a data weighting process that, for any given gridpoint, gives more influence to station temperatures that are closer to it.

FURTHER BACKGROUND INFORMATION

- Information on changes in the Australian climate is publicly available on the Bureau's website on its Australian Climate Change Tracker pages.
- The graph below shows the annual mean Australian temperature illustrating the recent record warmth.



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Date Updated: 30 January 2014

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DOC 14

35 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – FIFTH ASSESSMENT REPORT

IRRELEVANT INFORMATION REMOVED FROM THIS DOCUMENT - s22.

SUMMARY OF ISSUE – The Intergovernmental Panel on Climate Change (IPCC) released the full Working Group I contribution to the Fifth Assessment Report on 27 September 2013. This report provides a comprehensive update of knowledge on the science of climate change.

FAST FACTS

- The IPCC, under the United Nations, assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to climate change.
- The IPCC does not conduct any research, nor monitor climate related data or parameters.
- The IPCC is preparing its Fifth Assessment Report (AR5), which will be released in phases that will continue to October 2014.
- The report of Working Group I, the *Physical Science Basis of Climate Change*, was released on 27 September 2013. The Working Group II Report, *Impacts, Adaptation and Vulnerability*, is expected to be released on 31 March 2014.
- The Bureau and CSIRO have supported critical research contributing to the IPCC AR5; by providing climate model data and key staff writing and reviewing reports.
- The main findings of the Working Group I report are that:
  - Warming of the climate system is unequivocal. There is robust evidence that multiple components of the Earth's climate system are changing;
  - Humans have influenced warming of the atmosphere and ocean, global sea level rise and changes in some climate extremes. Scientists are more certain than ever that most of the warming since 1950 has been caused by human activities;
  - For the first time the IPCC provides an estimate of the total allowable global emissions in order to limit temperature rise to 2 °C above global temperature relative to 1861—1880;
  - We are already observing the consequences of a changing climate; and scientific understanding of sea level rise is stronger, and projections of global average sea level rise are higher than in previous IPCC reports.

Written by: Peter May
Cleared by: Graham Hawke
Date Update: 16 February 2014
Mobile: [redacted]

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. Have global temperatures stopped rising in recent years (the 'hiatus')?

A. Global temperatures continue to rise, however observations show that air temperature rose at a lower rate since 1998 than the average rate since 1950. Observations show that global average air temperature increased by around 0.85 °C since 1880, with 2001–2010 being the hottest decade on record.

Year-to-year and decade-to-decade fluctuations are superimposed on long-term trends driven by increasing greenhouse gases. Naturally occurring contributions to reduced decadal warming rates in global-mean temperature can occur from changes in volcanic activity, and from natural variability including the Interdecadal Pacific Oscillation.

There are many difficulties in drawing conclusions about short term temperature variations, such as that since 1998. The most rapid global warming is currently occurring in regions which are very difficult to monitor accurately, including the Arctic and Antarctic and the continental interiors of Africa and Asia.

The process of selecting a particular year (1998) for the start of trends is also a statistically problematic approach.

The lower rate of warming during the past decade compared with the previous decade is likely due in large part to increased ocean heat uptake. The lower rate of warming has also occurred during a period of reduced solar radiation, corresponding to a downward phase in the 11 year solar cycle.

Natural decadal variability is not unusual, and is observed over the entire 20th century. Further, global-mean temperature is just one metric of warmth accumulated in the climate system. When looking across multiple indicators, including deep ocean heat content, loss of northern hemisphere sea-ice and loss of ice mass at the poles, a consistent picture of continued warming of the climate system is clear.

Q. Could the warming have been caused by changes in the radiation output from the sun related to the solar cycle?

A. The Working Group report findings make it clear that neither changes in the sun's output over the last 100 years nor cosmic rays have contributed to the observed warming of the climate system.

The effect of solar forcing on global temperature trends has been found to be small, with less than 0.1 °C warming attributable to combined solar and volcanic forcing over the 1951–2010 period.

Written by: Peter May
Cleared by: Graham Hawke
Date Update: 16 February 2014
Mobile: [redacted]

Q. Have recent fires such as the October fires in the Blue Mountains been caused by global warming?

A. Individual weather events cannot be attributed to climate change without detailed attribution studies. We are not aware of any such studies having been published for the October 2013 events. However, we have observed that fire season severity is increasing across much of Australia as a result of rising temperatures and cool season rainfall declines. Climate change projections indicate that this trend will continue, suggesting that serious fires are more likely to occur in the future.

Q. Were the recent heat waves in Australian caused by global warming?

A. Australia's climate has warmed by around 1 °C since national records began in 1910, making high temperature extremes more frequent. The duration, severity and frequency of heatwaves have increased across many parts of Australia. Attribution of extremes is in its infancy and formal attribution studies have not yet been done on these particular events. However one study (Lewis and Karoly, 2013) found a 2.5 to 5 times increase in the likelihood of the hot summer record in 2012—13 due to human influences.

Q. 'Climate sensitivity' has been decreased in the latest IPCC report, does this mean expected warming is not as great?

A. No. Although the IPCC noted a small reduction in the lower end estimate of climate sensitivity compared with the Fourth Assessment report, the range is exactly the same as in the First, Second and Third Reports, showing remarkable consistency over 20 years of assessment.

'Climate sensitivity' is a measure of the response of the climate to a doubling in CO_2 concentrations once the land and oceans have responded fully, which might take centuries as the oceans are slow to warm.

IPCC found climate sensitivity to be 'likely' in the range 1.5 to 4.5 °C in four of the five Assessment reports from 1990 to 2013. There was a slightly different lower end value in the Fourth report in 2007 of 2 to 4.5 °C.

Q. Don't the record cold temperatures in North America clash with the orthodoxy of climate change science?

A. While the cold weather in the northeast of the United States has attracted significant media interest, the events have not set many records. In contrast, this period was actually notable for record high temperatures broken across the western US, Alaska and western parts of Canada. In fact, global and Northern Hemisphere temperatures have continued to be much warmer than average.

In a warming climate we still expect to see extreme (including record) cold temperatures to occur from time to time. Global warming implies an increase in the likelihood of extreme high temperatures and a decrease in the likelihood of extremely low temperatures. It does not exclude the occurrence of severe cold weather.

Written by: Peter May
Cleared by: Graham Hawke
Date Update: 16 February 2014
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Over the past decade, the number of extreme heat records in Australia outnumbered extreme cold records by almost 3 to 1 for daytime maximum temperatures and 5 to 1 for overnight minimum temperatures.

Written by: Peter May
Cleared by: Graham Hawke
Date Update: 16 February 2014

Mobile: [redacted]

DOC 15

IRRELEVANT INFORMATION REMOVED
FROM THIS DOCUMENT - s22.

36 SEA ICE COVER

SUMMARY OF ISSUE – In contrast to the clearly diminishing sea ice cover in the Arctic, there has been a small net increase in total Antarctic sea ice extent over the past 30 years. This has received significant media attention.

FAST FACTS

- Sea ice around Antarctica has a minimum summer extent (in February) of about 3 million km^2, and a maximum extent (in September-October) of about 19 million km^2 – more than 2.5 times the size of Australia. By comparison, the continental ice in Antarctica is about 14 million km^2 or twice the size of Australia.
- In the Arctic, mean monthly sea ice extents range from a minimum of about 7 million km^2 (in September) to a maximum of about 15 million km^2 (in March).
- Although there are large fluctuations in Antarctic sea ice extent from year to year, a small but statistically-significant increase in total Antarctic sea ice extent of 1.2 to 1.8% per decade has occurred between 1979 and 2012.
- This increasing trend in Antarctic sea ice extent is in contrast to the loss of Arctic sea ice (at a rate of 3.5 to 4.1% per decade for 1979-2012).
- It is theorised that sea ice extent is increasing in Antarctic waters due to (1) strengthening circumpolar winds that push the ice northwards due to the coriolois effect, and (2) freshening of sea surface waters owing to increased precipitation and continental ice melt.
- It has been shown that Arctic sea ice is also thinning, though insufficient data is available to assess thickness changes for Antarctic sea ice.
- The small increasing trend in total Antarctic sea ice extent masks major contrasting regional changes in both sea ice extent and the length of the annual ice season (the period of the year over which ice is present).
    - In the West Antarctic Peninsula region, the length of the annual sea ice season is more than 3 months shorter now than in 1979, but in the adjacent Ross Sea, the length of the ice season is approximately 2.5 months longer.
- These contrasting regional changes have been linked to changes in large-scale atmospheric circulation patterns, which in turn have been attributed to increased atmospheric greenhouse gas concentrations and ozone depletion in the stratosphere.
- Climate models predict an overall reduction in Antarctic sea ice over the coming decades as seasonal influences of stratospheric ozone loss decline (during recovery of the Antarctic Ozone Hole) and the effects of greenhouse gas increases become more significant.

Written by: Phil Reid
Cleared by: Graham Hawke
Date Updated: 5 February 2014

Mobile: [redacted]

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. How can we have melting of the Antarctic continental ice given it is generally always below freezing?

A. There is sufficient direct energy from solar radiation to cause melting, despite surface temperatures being below freezing. The Antarctic ice sheet mainly loses ice mass through a combination of:

- iceberg calving (via glacial ice shelves),
- runoff of surface melt water, and
- basal melting beneath the floating ice shelves which fringe much of Antarctica, due to warming of the oceans.

Recent studies have also suggested that periodic drainage of sub-glacial lakes (water flowing beneath the ice sheet) could also be a factor in the loss of ice from ice sheets.

Q. The extent of Antarctic sea ice has been increasing. Doesn't this disprove the claim that the Southern Ocean is warming?

A. Regional changes in Antarctic sea ice are made up of a combination of large-scale interactions between sea ice, the ocean and atmosphere associated with decadal shifts in dominant modes of atmospheric circulation (large-scale wind patterns), e.g., the Southern Annual Mode (SAM) and the high-latitude response to El Niño-Southern Oscillation (ENSO). Recent studies also suggest that warming of the ocean under the ice shelves may cause basal ice melting, leading to upper-ocean freshening that enhances ice growth regionally.

Q. How do you explain the increase in the extent of sea ice in the Antarctic, with a decrease in the Arctic? Doesn't this suggest this suggest we're only observing variability?

A. The observed differences between the sea ice covers of the Antarctic versus the Arctic stem from differences in their geographical settings, sea ice growth and decay processes, large-scale climate interactions, and ice-ocean interactions and feedbacks.

The IPCC Fifth Assessment Report assessed that both the annual average and the minimum summer extent of Arctic sea ice had decreased over the period 1979 to 2012, consistent with the observed warming in the region.

While the net change in total Antarctic sea ice extent since 1979 is slightly positive (+1.2% to 1.8% per decade), there have been considerable yet contrasting changes in some regions.

Although the observed changes in *overall* Antarctic sea ice extent are within the range of natural climate variability, the regional changes are much larger in terms of percentage change. In the case of the Antarctic Peninsula region, they coincide with the zone of largest ice mass losses from the West Antarctic Ice Sheet and recent rapid disintegration of the Larsen and Wilkins ice shelves.

The reduction in sea ice around the Antarctic Peninsula region is coincident with an increase in mean air temperature of approximately 0.5 °C per decade over

the past 50 years for that region. This warming trend has been attributed to anthropogenic climate change and is much larger than the global trend.

Q. Doesn't the recent events with ships being stuck in the ice show that the impacts of climate change are being exaggerated?

A. There has been an overall increase in Antarctic sea ice extent over the past decades. Strong winds cause the sea ice to drift and this sometimes traps ships. It is not at all unusual for vessels to be stuck in the Antarctic sea ice – this happens most years.

FURTHER BACKGROUND INFORMATION

Sea ice is ice formed by the freezing of seawater, and long-term (decadal-scale) trends in its distribution (areal extent) and seasonality (length of annual sea ice season) are sensitive indicators of climate change and variability. Sea ice is also a crucial element of the global climate system and high-latitude marine ecosystems.

The areal extent of sea ice coverage in the Arctic and Antarctic are observed routinely from satellites, which have provided daily snapshots of global sea ice distribution since October 1979.

Sea ice forms a thin yet highly variable veneer on the ocean surface, affecting exchanges of heat, momentum and gases between the ocean and atmosphere, and influencing marine ecosystems. Sea ice is typically a few tens of centimetres to a few metres thick, although heavily-deformed ice can be ten or more metres thick. Sea ice is moved on the ocean surface by wind and ocean currents, and is modified by accumulation of a snow cover.

Changes in sea ice do not directly affect sea level, but changes in the grounded Antarctic Ice Sheet do influence sea level.

Sea ice around Antarctica has a minimum summer extent (in February) of about 3 million square km, and a maximum extent (in September-October) of about 19 million sq km – more than 2.5 times the size of Australia. This seasonal waxing and waning represents one of the greatest seasonal changes in surface conditions on Earth, and has a big impact on the Earth's climate.

In the Arctic, mean monthly sea ice extents range from a minimum of about 7 million sq km (in September) to a maximum of about 15 million sq km (in March). The Arctic sea ice cover has been less variable from season to season because it is largely land-locked, therefore less ice tends to drift to warmer waters and melt. This situation is changing, however, as less Arctic sea ice survives the summer melt season.

The Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5, 2013) assessed that both the annual average and the minimum summer extent of Arctic sea ice had decreased over the period 1979 to 2012. It has decreased further since then. The mean annual Arctic sea ice extent declined at a rate that was very likely in the range of 3.5 to 4.1% per decade, and very likely in the range of 9.4 to 13.6% per decade for the summer sea ice minimum (September). These decreases in Arctic sea ice are consistent with the observed warming in the region.

While the net change in total Antarctic sea ice extent since 1979 is slightly positive (at a rate of +1.2% to 1.8% per decade), there have been considerable yet contrasting changes in some regions. A major decline has occurred in the Bellingshausen and Amundsen Seas (west of the Antarctic Peninsula), coincident with a significant decrease in the length of the annual ice

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season (by approximately 3 months). In the Ross Sea region, on the other hand, there has been an increase in both ice extent and ice-season length (the latter by approximately 2 months), while the East Antarctic region (where Australia's bases are) and the Weddell Sea to the east of the Antarctic Peninsula have shown mixed signals.

It is quite possible that the observed changes in overall Antarctic sea ice extent are within the range of natural climate variability. However, the regional changes are much larger in terms of percentage change, and in the case of the Antarctic Peninsula region, coincide with the zone of largest ice mass losses from the (West) Antarctic Ice Sheet and recent rapid disintegration of ice shelves (Larsen and Wilkins).

The reduction in sea ice around the Antarctic Peninsula region is also coincident with an increase in mean air temperature of approximately 0.5° C per decade over the past 50 years for that region. This warming trend has been attributed to anthropogenic climate change and is much larger than the global trend.

Regional changes in Antarctic sea ice are associated with decadal shifts in dominant modes of atmospheric circulation (large-scale wind patterns) e.g. the Southern Annual Mode (SAM) and the high-latitude response to El Niño-Southern Oscillation (ENSO).

Conclusions about long-term trends in Southern Hemisphere sea ice extent cannot be drawn from single (isolated) monthly or seasonal observations, as there are large fluctuations from year to year.

Climate projections for the rest of this century suggest a large (~30%) decrease in Antarctic sea ice by 2100 extent as stratospheric ozone levels recover but greenhouse gas concentrations continue to rise.

An increase in sea ice extent does not translate directly to an increase in the total amount of sea ice. The total volume is also determined by the thickness of the ice. Whether Antarctic sea ice thickness is changing, as it is in the Arctic, is currently a major unknown, as insufficient data are available to routinely monitor this key variable.

An exciting development in respect of measuring and monitoring Antarctic sea ice thickness was the launch (in 2010) of the European Space Agency's CryoSat II satellite. This is dedicated to Earth ice and snow measurements, including monitoring of sea ice thickness. The Australian Antarctic Program is playing a crucial role in providing ground-truth data for calibration and validation of the satellite data.

There is much yet to be learned about changes in the Antarctic atmosphere-ice-ocean system and the complex feedbacks involved, and research efforts continue around the world. In Australia, the Antarctic Climate and Ecosystems Cooperative Research Centre (whose partners include the Australian Antarctic Division, CSIRO Division of Marine and Atmospheric Research and the University of Tasmania) is a key centre for such research.

The information in this Senate Estimates Brief is derived from the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) and literature published in peer-reviewed scientific journals.

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DOC 16

IRRELEVANT INFORMATION REMOVED
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29 STATE OF THE CLIMATE 2014

SUMMARY OF ISSUE – The Bureau of Meteorology and CSIRO released the third biennial *State of the Climate 2014* on 4 March 2014. There was significant public and media interest in the report.

FAST FACTS

- The *State of the Climate 2014* report focuses primarily on climate observations and monitoring carried out by the Bureau and CSIRO in the Australian region, as well as on future climate scenarios.
- The report paints a clear picture of change already occurring against a background of high climate variability.
- Key points of the report:
  - **Air and ocean temperatures** across Australia are now, on average, almost a degree Celsius warmer than they were in 1910. This warming has seen Australia experiencing more warm weather and extreme heat, and fewer cool extremes.
  - **Rainfall** averaged across all of Australia has slightly increased since 1900. Since 1970, there have been large increases of annual rainfall in the northwest and decreases in the southwest. Autumn and early winter rainfall has mostly been below average in the southeast since 1990.
  - Atmospheric **greenhouse gas concentrations** continue to rise and continued emissions are projected to cause further warming over this century.

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. How does the Bureau analyse Australian temperature trends?

A. Through the Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT) dataset.

The dataset employs the latest analysis techniques and takes advantage of newly digitised observational data to provide a daily temperature record from 1910.

The dataset and the techniques used in developing it have been internationally peer reviewed.

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Q. How can you be confident that human-induced greenhouse gases are responsible for changes in the climate?

A. The State of the Climate 2014 report notes that multiple lines of evidence indicate that it is extremely likely that the dominant cause of recent warming is human-induced greenhouse gas emissions and not natural climate variability. The evidence is comprehensively laid out in the Intergovernmental Panel on Climate Change Fifth Assessment Working Group 1 Report.

Atmospheric greenhouse gas concentrations continue to increase, with global mean CO_2 levels reaching 395 ppm in 2013.

The origin of CO_2 in the atmosphere can be determined by examining the different types (isotopes) of carbon in air samples. This identifies the additional CO_2 as coming from human activities, mainly the burning of fossil fuel.

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DOC 17

IRRELEVANT INFORMATION REMOVED FROM THIS DOCUMENT - s22.

31 CLIMATE CHANGE AND VARIABILITY

SUMMARY OF ISSUE – Recent weather and climate extremes over Australia and the globe are being frequently queried in terms of their consistency with longer-term trends and as evidence of global warming.

FAST FACTS

[redacted]

- Several trends have been observed in the Australian climate, overlaid on the high year to year variability, including more frequent hot extremes compared to cold extremes, which are a result of increasing greenhouse gases.
- In Australia, the 10-year mean temperature for 2004–2013 was 0.50 °C above average, the equal-highest on record.
- Australia has experienced just one cooler-than-average year (2011) in the last decade.
- Global warming has played a significant role in recent temperature anomalies, raising the background mean temperature against which natural variability occurs.
- 2013 was Australia's warmest year on record, being 1.2°C above average. Global temperature in 2013 was 0.5 °C above average.
- The unusual warmth over Australia in the past year is consistent with dry conditions and elevated sea surface temperatures around Australia.

[redacted]

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. Wouldn't we expect fewer extreme 'cold waves', as seen in US and Europe if global warming was true?

A The recent 'cold wave' in the US broke few significant climate records and, during this period, Northern Hemisphere and global temperatures remained well above average.

A range of climate indicators in the atmosphere, oceans and cryosphere show that the world continues to warm.

While extreme cold weather continues to occur, the latest IPCC report states that "It is very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale".

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Q. There has been an increase in sunspots. Does this suggest solar activity is causing the world to get warmer?

A No.

- Climate change attribution studies published since the mid-1990s have firmly attributed observed warming to increasing greenhouse gases.
- The effect of changing solar activity on global temperature trends has been found to be small, with less than 0.1 °C warming attributable to combined solar and volcanic forcing over the 1951–2010 period.
- The vertical profile of temperature changes in the atmosphere, with warming at the surface and cooling in the stratosphere, is associated with greenhouse gas increases and not solar radiation increases.

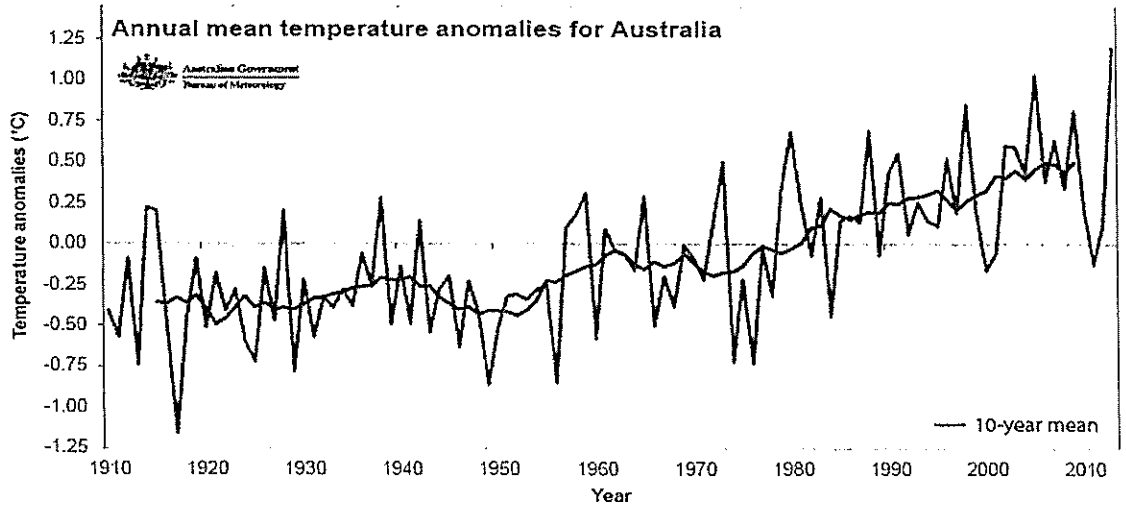
However, it is possible that the downward phase of the 11 year solar cycle has had a small, relative cooling influence on global temperatures since 1998, which may have contributed to a lower rate of warming in the past decade compared to the 1990s.

[redacted]

FURTHER BACKGROUND INFORMATION

- Information on changes in the Australian climate is publicly available on the Bureau's website on its Australian Climate Change Tracker pages.

Graph showing annual mean temperature anomalies for Australia illustrating the recent record warmth.



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34 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – FIFTH ASSESSMENT REPORT

SUMMARY OF ISSUE – The Intergovernmental Panel on Climate Change (IPCC) released the full Working Group II contribution to the Fifth Assessment Report on 31 March 2014. This report provides a comprehensive update of knowledge on Climate Change: Impacts, Adaptation and Vulnerability.

FAST FACTS

- The IPCC, under the United Nations, assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to climate change.
- The IPCC does not conduct any research, nor monitor climate related data or parameters.
- The IPCC is preparing its Fifth Assessment Report (AR5), which will be released in phases that will continue to October 2014.
- The report of Working Group II, the *Climate Change: Impacts, Adaptation and Vulnerability*, was released on 31 March 2014.
- The Bureau and CSIRO have supported critical research contributing to the IPCC AR5; by providing climate model data and key staff writing and reviewing reports.
- Most Bureau input has focussed on Working Group I, which is more closely aligned with Bureau core activities and expertise Bureau direct input into Working Group II has been limited, and detailed queries on WGII issues should be directed to other agencies.
- CSIRO has a number of Lead Authors and Contributing Authors in the IPCC WGII report.
- The main findings of the Working Group II report are that:
    - In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans;
    - Differences in vulnerability and exposure arise from non-climatic factors;
    - Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability
    - Although human ill-health from climate change is relatively small, climate-related hazards exacerbate other stressors, often with negative outcomes for livelihoods and increased exposure to climate related extremes, including crop yields and water quality and quantity. This is especially impactful for people living in poverty or impacted by violent conflict;
    - Adaptation and mitigation choices in the near-term will affect the many risks of climate change throughout the 21st century. Responding to climate-related risks involves decision-making in a changing world, with continuing

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uncertainty about the severity and timing of climate-change impacts and with limits to the effectiveness of adaptation.

POSSIBLE QUESTIONS & SUGGESTED RESPONSES/ANSWERS

Q. Have global temperatures stopped rising in recent years (the so-called 'hiatus')?

A. It is too simplistic to assert that global temperatures have stopped rising in recent years.

There are a set of climate variables that would indicate either warming or cooling of the climate system. These include global-mean surface temperature, ocean heat content, global-mean sea level and changes in ice sheets and sea-ice. When considering these variables collectively, it is clear that the climate system has continued to accumulate heat in recent years.

Warming on the oceans has accounted for over 90% of the additional energy from the enhanced greenhouse effect since the mid to late 20th century. Observations of ocean heat content and se-level rise indicate continued warming during over the past decade.

One variable, global-mean surface temperature, has experienced relatively less warming in the past decade than the preceding decade. These observations are consistent with decade-to-decade natural variability in surface temperature which is mostly driven by the El Niño-Southern Oscillation. It is not possible to infer that warming has stopped from this observation.

Q. Could the warming have been caused by changes in the radiation output from the sun related to the solar cycle?

A. There is no evidence that changes in solar radiation have been the dominant cause of warming over the past century. There is a wealth of evidence that the warming has been caused by increasing greenhouse gases. In recent years, changes in solar energy are of the wrong sign to be associated with warming, and are more likely to have caused relative cooling of the climate system.

A key piece of evidence against a role for solar radiation is the cooling that has been observed in the stratosphere (high atmosphere). Cooling of the stratosphere and warming of the troposphere (lower atmosphere) is a specific fingerprint of the enhanced greenhouse effect, and matches the observed pattern of warming over the past 60 years.

Q. Were the recent heat waves in Australian caused by global warming?

A. Individual extreme weather events are caused by proximate, antecedent climate and weather conditions. However the frequency of extreme weather events, and trends in the magnitude of extreme weather, have been related to global warming in the scientific literature.

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In this context, there has been a large shift toward more frequent extreme heat in Australia; and a trend for longer, more frequent and hotter heatwaves over many parts of the continent. This is consistent with the enhanced greenhouse effect. Individual studies have shown that climate change likely plays a role in the magnitude of extreme heat events experienced in Australia and globally this century.

Q. 'Climate sensitivity' has been decreased in the latest IPCC report, does this mean expected warming is not as great?

A. IPCC reports in 1990, 1992, 1995, 2001, and the recent report in 2013, all estimated a likely range of equilibrium climate sensitivity of 1.5C to 4.5C (although the 2007 report modified it slightly to 2.0C to 4.5C). This shows a remarkable consistency over more than 20 years.

The equilibrium climate sensitivity is not the same as a climate change projection. The equilibrium sensitivity describes the response of the climate system to a 1% per annum increase in atmospheric carbon dioxide concentrations over 70 years. This is calculated as a standard comparison of climate sensitivity between climate models.

Actual climate projections use emissions scenarios. For a high emission scenario, CO2 levels increase to more than 900 parts per million by 2100, compared with pre-industrial levels of 280 parts per million. For this scenario, models project end of century warming of 3.2C to 5.4C above an 1850 – 1900 baseline. For a low emission scenario, for which CO2 levels peak then decline to 420 parts per million, models project warming of 0.9C to 2.3C by 2100.

Q. Don't the record cold temperatures in North America clash with the orthodoxy of climate change science?

A. Cold weather still occurs in a world with a 40% increase in carbon dioxide levels. However that cold weather happens less frequently than in the past, especially relative to the frequency of warm weather. Globally, there is a clear trend of reductions in cold weather and increases in warm weather.

While individual regions may have experienced cold weather, the global and hemispheric averages have been consistently warmer than the 20th century average since 1985. This indicates that fewer regions have experienced cold weather than warm weather for the past 30 years.

In the specific instance of recent cold weather in North America, a number of regions in the US experienced a January to March average temperature that was in the bottom 10th percentile, however no state observed temperatures that were the coldest on record for that period.

Very warm conditions concurrently prevailed in the west of the US and Alaska.

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Q. Is a 5% reduction in emissions by 2020 'enough' to avoid dangerous climate change?

A. Two degrees centigrade of warming from pre-industrial levels has been identified as a realistic objective for avoiding the most dangerous impacts of climate change.

The IPCC Fifth Assessment Report found that for global temperatures to be likely to stay below two degrees (with a >66% probability), the total amount of all carbon dioxide emitted since the late 19th Century should be no more than 790 billion tonnes (790 Gigatonnes of carbon). By 2011 we had already emitted 515 Gigatonnes of carbon. This is about two-thirds of the total emissions allowed to stabilise temperatures below 2 degrees.

This leaves only another 275 Gigatonnes of carbon for future use. With the current rate of carbon dioxide emissions at about 10 Gigatonnes of carbon per year - and assuming an annual growth rate of 3%, as seen over the last decade - the remaining carbon budget will be used up in less than 25 years.

Q. Is the Australasian regional climate changing?

A. The region continues to demonstrate long term trends toward higher surface air and sea-surface temperatures, more hot extremes and fewer cold extremes, and changed rainfall patterns. Over the past 50 years, increasing greenhouse gas concentrations have contributed to rising average temperature in Australia and New Zealand and decreasing rainfall in southwestern Australia.

High sea surface temperatures have repeatedly bleached coral reefs in north-eastern Australia (since the late 1970s) and more recently in western Australia.

Warming is expected to be associated with rising snow lines, more frequent hot extremes, less frequent cold extremes, and increasing extreme rainfall related to flood risk in many locations.

Annual average rainfall is expected to decrease in south-western Australia and elsewhere in most of far southern Australia during the cool season. and the north-east South Island and northern and eastern North Island of New Zealand, and to increase in other parts of New Zealand.

Tropical cyclones are projected to increase in intensity but remain similar or decrease in numbers, and fire weather is projected to increase in most of southern Australia and many parts of New Zealand. Regional sea level rise will very likely exceed the historical rate (1971-2010), consistent with global mean trends.

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Q. Will the Australasian climate continue to change without adaptation and mitigation?

A. Without mitigation and adaptation, further changes in climate, atmospheric CO2 and ocean acidity are projected to have substantial impacts on water resources, coastal ecosystems, infrastructure, health, agriculture and biodiversity.

Freshwater resources are projected to decline in far south-west and far south-east mainland Australia and for rivers originating in the north-east of the South Island and east and north of the North Island of New Zealand.

Rising sea levels and increasing heavy rainfall are projected to increase erosion and inundation, with consequent damages to many low-lying ecosystems, infrastructure and housing; increasing heat waves will increase risks to human health; rainfall changes and rising temperatures will shift agricultural production zones; and many native species will suffer from range contractions and some may face local or even global extinction.

Q. What risks do we face if we do not pursue adaptation and mitigation?

A. There are eight regional key risks during the 21st century based on the severity of potential impacts for different levels of warming, uniqueness of the systems affected, and adaptation options:

- Significant change in community composition and structure of coral reef systems in Australia;
- Loss of montane (alpine) ecosystems and some native species in Australia;
- Increased frequency and intensity of flood damage to settlements and infrastructure in Australia and New Zealand;
- Constraints on water resources in southern Australia;
- Increased morbidity, mortality and infrastructure damages during heat waves in Australia;
- Increased damages to ecosystems and settlements, economic losses and risks to human life from wildfires in most of southern Australia and many parts of New Zealand;
- Increasing risks to coastal infrastructure and low-lying ecosystems in Australia and New Zealand from continuing sea level rise, with widespread damages towards the upper end of projected changes; and
- Significant reduction in agricultural production in the Murray-Darling Basin and far south-eastern and south-western Australia if scenarios of severe drying are realised.

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