



Climate Change Denial in the Classroom

A report on the course "Climate Change: An Earth Sciences Perspective" (ERTH2402) at Carleton University

Dr Christopher Hassall, Ms Carley Centen, Dr Cliff Beninger, and Dr Chris Hebbern

28th February 2012

This report details an audit of a course taught at Carleton University in the 2010/11 academic year. The course, "Climate Change: An Earth Sciences Perspective" (ERTH 2402) provides an unbalanced and, in many cases, factually inaccurate view of anthropogenic global warming which detracts from the high quality of teaching at Carleton University. We highlight 142 incorrect or equivocal claims and cite the relevant scientific literature to correct those statements. While the principle of academic freedom remains paramount, it is nonetheless imperative that university students be presented with accurate scientific information.

Table of Contents

Executive Summary	3
Background to the Study	4
Summary of Findings	8
Student Feedback	10
The Climate Change Debate and Academic Freedom.....	11
The Response from Carleton University	Error! Bookmark not defined.
Conclusion	14
Appendix A – Details of claims and evidence	15
Lecture 1: Course Introduction	15
Lecture 2: Man’s Awareness of Climate Change.....	23
Lecture 3: Comparative Planetology/Climates of the Solar System	31
Lecture 4: Geology	33
Lecture 5: Glaciations and “The Ice Age”	45
Lecture 6: Glaciations and the Ice Age Part 2.....	52
Lecture 7: Causes of Climate Change Pt 1	56
Lecture 8: Causes of Climate Change Pt 2 – Greenhouse Gases	60
Lecture 9: Causes of Climate Change Pt 3 – Celestial.....	69
Lecture 10: Atmosphere and Ocean Circulation.....	72
Lecture 11: Climate Change Politics and Tsunamis & Ocean Surges.....	74
Lecture 12: Summation.....	78
Appendix B – In Anticipation of Criticism.....	88
References	90

Executive Summary

1. Climate change represents a challenge to current and future civilisation. Warming of the climate system is unequivocal, and most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. Schools and universities have a responsibility to ensure students understand the scientific basis for climate change.
2. We describe a case in which noted climate change deniers have gained access to the Canadian higher education system through a course taught at Carleton University – *Climate Change: An Earth Sciences Perspective* (ERTH2402). These academics are closely associated with a number of organisations that have involvement with the energy industry.
3. Carleton University teaches a range of courses on various aspects of climate change and the vast majority adhere to the highest academic standards. However, the content of *this particular* course is heavily biased against the scientific consensus concerning the anthropogenic causes of dangerous climate change. Through an extensive audit of the course material, we identify 142 claims made during the lectures by the instructor, Mr Tom Harris, and various guest lecturers, that run counter to established scientific opinion. We review these claims and provide corrections, citing peer-reviewed scientific publications where appropriate.
4. This course is taught with little reference to the primary literature and is largely presented to non-science majors. We note that other courses at Carleton University teach the established science on climate change, with instructors who have been involved with the IPCC and sharing in the Nobel Peace Prize that that organisation was awarded.
5. We acknowledge the need for academic freedom and the promotion of multiple viewpoints on course material – particularly in such an important area as climate change. However, it is important to note that the unbalanced nature of the course, the lack of peer-reviewed literature cited, and the non-science audience mean that the course fails to constitute “promotion of debate” and instead merely presents a biased and inaccurate portrayal of contemporary climate science.
6. We present our report to highlight how one extreme of the climate change debate is being taught in higher education and where that teaching diverges from the contemporary scientific consensus.

Background to the Study

Carleton University, based in Ottawa, Canada, is consistently ranked in the top 10 of Canada's comprehensive universities, employing over 2,000 faculty members to provide top quality higher education to 25,000 students. It is not our intention to disparage this institution, but to provide a critique of a single course among many hundreds that are offered by the university. The university's policy on public accountability states that "Carleton University is committed to being a leader in public accountability among Canadian universities", and we hope that our report will contribute toward that goal.

The public conversation on climate change has been steered by various organisations with differing agendas. Scientific opinion on climate change is expressed through peer reviewed publication, synthesis reports and scientific bodies such as the Royal Society of Canada, but perhaps most importantly by The Intergovernmental Panel on Climate Change (IPCC). The IPCC exists to assess scientific research relevant to human induced climate change, its impacts, and the options for adaption and mitigation, and to disseminate these assessments to policymakers and the public. The IPCC Fourth Assessment Report (summary for policymakers) found that "warming of the climate system is unequivocal", and that "...most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations".

In conflict with the IPCC are a number of smaller organisations that rely not on scientific evidence but on rhetoric and PR tactics. These organisations include Friends of Science (FoS), the Natural Resources Stewardship Project (NRSP) and the International Climate Science Coalition (ICSC). These organisations have sought to discredit the widely held scientific assessments of the IPCC and other prestigious scientific organizations regarding human induced climate change. A member of all three of these organisations, Professor Tim Patterson, of Carleton University's Department of Earth Sciences, formerly taught a course entitled "Climate Change: An Earth Sciences Perspective" (ERTH 2402) to second year undergraduate students.

Tim Patterson is a trained scientist with an extensive publication record and numerous large research grants. We do not have access to Prof. Patterson's course materials. However, he ceased teaching the course in 2009, when it was taken over by Tom Harris, the Executive Director of the ICSC, former Executive Director of the NRSP, an expert at the Heartland Institute, and former lobbyist at the communications firm APCO Worldwide, where he conducted media and public relations campaigns on behalf of the oil and energy industry. Note also that three guest lecturers in the course (Prof. Ian Clark, Prof. Tad Murty and Prof. Bob

Carter) were all members of the NRSP and are all members of the ICSC. Harris, Patterson, Clark and Carter are also listed as experts at the Heartland Institute.

Given the strong associations between these four organisations and the teaching of the course, it is worth probing a little bit deeper into their histories:

- **Friends of Science (FoS)** – FoS was established in 2002 and believes that "the Sun is the main direct and indirect driver of climate change". This group produced a number of publications disputing the science and politics of climate change. FoS claimed not to be funded by corporations. However, an investigation by the Globe and Mail in 2006 demonstrated that undisclosed sums were solicited by the Calgary Foundation (which has as a policy the non-disclosure of donors' details), which then passed this money on to the "Science Education Fund", a grant held by Professor Barry Cooper at the University of Calgary. The SEF then gave the money to FoS. A University of Calgary audit found Cooper guilty of breaking UofC rules by employing his wife and daughter, and dispersing huge sums (up to \$100,000) to lobbyists, including Tom Harris' former employer, APCO Worldwide. As an employee of APCO Worldwide, Tom Harris produced the FoS documentary "Climate Catastrophe Cancelled" in 2005 which was funded by Talisman Energy, an "independent oil and gas exploration and production company". Other APCO campaigns include "The Advancement of Sound Science Coalition", which was created by APCO with money from the tobacco industry to dispute scientific findings of a link between secondhand smoke and cancer. There were also extensive investigations by Elections Canada, as money supplied to FoS by Cooper's fund was used in political advocacy without being declared as such (any person or organisation spending more than \$500 must register with Elections Canada). FoS boasted of running advertisements in swing Ontario ridings which contributed to the minority victory in 2006 of now Prime Minister Stephen Harper.
- **Natural Resources Stewardship Project (NRSP)** – The NRSP was set up in October 2005 to provide "a proactive grassroots campaign to counter the Kyoto Protocol and other greenhouse gas reduction schemes while promoting sensible climate change policy". The group was established by the High Park Advocacy Group, a Toronto-based organisation which actively lobbied on behalf of the energy industry. The three directors were all current or former HPG employees, including Mr Harris (who was Director of Operations in Ottawa for the HPG), Timothy Egan (a registered lobbyist for the Canadian Gas Association and the Canadian Electricity Association), and Julio Legos whose work at HPG "...focused on federal and provincial energy and environmental law and policy, particularly as they affect Canadian industry." The NRSP office was situated in the same building as the HPG. The group did not reveal its funding sources, but some press articles

have linked the group to the energy industry and the group has received money from the Heartland Institute (see below).

- **International Climate Science Coalition (ICSC)** – The ICSC was founded in 2007, and claims to be "an association of scientists, economists, and energy and policy experts working to promote better public understanding of climate change science and policy. ICSC is committed to providing a highly credible alternative to the United Nations Intergovernmental Panel on Climate Change and helping foster a more rational, open discussion about climate issues. Two panels of distinguished scientists and policy experts from more than a dozen countries oversee the ICSC's research and educational efforts." In 2007, the ICSC received \$45,000 from the Heartland Institute.
- **Heartland Institute** – In a recent (February 2012) leak of key strategy documents it was revealed that the Heartland Institute allocated \$100,000 for the development of a "[K-12 school] curriculum that shows that the topic of climate change is controversial and uncertain - two key points that are effective at dissuading teachers from teaching science" (to be developed by Dr. David E. Wojick, a coal-industry consultant). Furthermore, Heartland directly paid salaries to a number of "high-profile individuals who regularly and publicly counter the alarmist AGW message", including Prof Robert Carter (\$1,667 per month) who appears in a video during the EARTH2402 course. The climate denial projects run by Heartland appear to be funded largely by one anonymous donor who gave \$700,000 in 2011 and a combined total of \$14.3 million between 2006 and 2011. The Heartland Institute has received large donations from the energy industry (including at least \$676,500 from ExxonMobil from 1998-2006) and has given money to both the ICSC and the NRSP. Heartland funds an ongoing series of conferences on climate change denial ("International Conference on Climate Change") that bring together leading deniers. Six such conferences have taken place since 2008.

These four organisations are intimately involved with one another, with the energy industry, and with the instructors on the Climate Change course at Carleton. The following table demonstrates the involvement that the various speakers or sources have with the groups outlined above:

<i>Name</i>	<i>Affiliation</i>	<i>FoS</i>	<i>NRSP</i>	<i>ICSC</i>	<i>Heartland</i>
Tom Harris	ICSC, Carleton University		Yes	Yes	Yes
Prof Tim Patterson	Carleton University	Yes	Yes	Yes	Yes
Prof Tad Murty	University of Ottawa	Yes	Yes	Yes	
Prof Ian Clark	University of Ottawa		Yes	Yes	Yes
Prof Tim Ball	University of Winnipeg (retired)	Yes	Yes	Yes	Yes
Prof Bob Carter	James Cook University, University of Adelaide		Yes	Yes	Yes

While we accept that teaching climate change from a long-term geological perspective within the Department of Earth Sciences is quite justifiable, such a preponderance of individuals representing views on present-day climate change that are contrary to those held by the vast majority of climate scientists, and with no scientist speaking to the generally accepted consensus view, suggests that the course may lack balance. These observations alone do not necessarily justify taking any action, although the appointment of an individual who is active in groups that oppose the findings of climate science to a teaching position in a prominent Canadian university raises obvious concerns. It is therefore of interest to know how the teaching of science in this course compares to the general body of literature on the subject of climate change.

We would like to begin at the outset by stating that it is not our intention to foist censorship or exert control over teaching at a university. In higher education, at least, it is among the rights of a teacher to teach whatever they like (for a broader discussion of academic freedom, see below). Academic freedom aids in the progress of teaching and learning through the development and promotion of debate. That said, the content of courses should still stand up to scrutiny and peer-review like any other academic enterprise. Such scrutiny is the subject of this study.

The video recordings of the 12 lectures (totalling 27 hours of teaching) that comprised the course in the 2010/11 academic year were surveyed in detail and notes made of statements that could be considered unsupported by the scientific literature. 142 such claims (with some duplication where similar claims were made multiple times) were recorded as direct quotes from Mr Harris during the lectures and then checked against the scientific literature. The results are shown in Appendix A. The nature of the course (a "review course" provided for non-science majors) means that there is relatively little citation of the primary literature. As a result, when Harris makes an assertion it can be difficult to verify exactly what study that assertion is based upon. Where possible we have provided the likely study, along with a discussion of its findings.

Summary of Findings

While the full text of our analysis covers 73 pages, we summarise the key findings here.

First we note the lack of scientific evidence that is actually cited in the course. Rather than present the peer reviewed literature for his students, Harris frequently claims to have spoken to or emailed scientists to ask them for their opinions on particular issues. As a result, many of Harris' arguments do not appear to be based on peer reviewed published research. Harris does not introduce students to the primary scientific literature, instead requiring them to read books and watch films (i.e. not peer-reviewed material) for the exam. While we understand that asking students to read technical scientific papers may be inappropriate for this level of study, there is nevertheless a requirement to present the complete range of scientific findings and in an accessible form.

The second issue is the use of particular pedagogical tools throughout the course. Harris institutes a "bloopers of the week" where students are encouraged to find a claim made in the mainstream media and then rebut it using arguments that Harris provided. By way of example, in response to seeing a quote from Ban Ki Moon saying: "climate change will continue unless drastic measures are taken to stop it" the winning student from one week wrote "the climate is always changing, so this cannot be stopped as we do not have such control over the sun and other cosmic forces that greatly correlate to the warming and cooling of Earth. We cannot change climate just as we cannot change the seasons from winter to summer." Without knowledge of the scientific evidence against Harris' arguments, the students are unable to evaluate them and are simply encouraged to parrot climate denial rhetoric.

Like much of the climate change denial movement, Harris' course is structured around concentric sets of arguments. The first line of defence is to claim that climate change (more specifically, global warming) is not happening. This makes the title of our report accurate: as well as a role for humans in contemporary climate change, Harris disputes even the existence of and our ability to detect warming in global temperatures in the face of substantial scientific evidence and, therefore, qualifies as a climate change denier. Harris makes a variety of statements to support this, hinging on a combination of claims of a lack of scientific consensus, inference of fraud and dishonesty, and inaccurate critiques of established science (see Appendix A for detailed criticism). The following statements illustrate this:

- *"The climate problem is so difficult that we might never solve it."* (Tom Harris - TH)
- *"The bottom line is we don't know what the consensus is of world scientists is [sic]. We know there's a lot of dissent, and it's dissent among some of the absolute leaders in the field."* (TH)

- "...we keep seeing things like this: 'Few still debate the primary cause of climate change.' Except 90% of the scientists in the field." (TH)
- "The sea level has been significantly higher, to about a meter higher, in the Maldives seven times in the last 4000 years and it's not particularly high right now and it's not showing any trend of doing so. So I'm afraid the scare is in fact completely fabricated." (TH)
- "There hasn't been an acceleration in glacier retreat worldwide" (TH)
- "When you look at most rural datasets, you don't see global warming." (TH)
- "One of the things I find astounding about this whole climate debate is that some of the most basic tenets – you know, the idea that CO₂ rise is mainly caused by humans, the idea that temperature rise is definite, its occurring, - many of these things are either not true or are simply unknown, or highly debatable." (TH)
- "You know, we haven't had any warming since 2003 and CO₂ is still rising. I know that's not climate, but still it just doesn't really make a lot of sense." (TH)

Given the overwhelming observational evidence for a positive trend in global warming that is outside the range of normal climate variability, Harris' case that it is not happening is untenable. Harris now falls back on the second line of defence, which is to claim that the causes of global warming are not anthropogenic:

- "We would be arrogant to think that we understand and we control the climate of the earth" (TH)
- "The only constant about climate is change." (TH)

However, there is now strong and growing evidence that the contemporary phase of environmental warming (since the 1950s) cannot be explained without the inclusion of anthropogenic forcings, specifically the increase of greenhouse gas concentrations in the atmosphere as a result of the burning of fossil fuels. Natural climate variability and forcing due to solar variability and volcanic activity are insufficient to account for climate change. In response to this and in apparent contradiction to his earlier stated beliefs, Harris states that the global warming that we are causing is not bad, and may in fact be a good thing.

- "Carbon dioxide is not a pollutant" (TH)
- "Today, we're having extinction rates that are somewhat higher in certain species, but nothing like what we had in the geologic past". (TH)
- "Every day in the newspaper I read about another idiot biologist who says that the world's biota is going to be destroyed by another temperature rise of a degree or two. It is complete nonsense." (Bob Carter, during a recorded lecture entitled "An Analysis of the Facts of Climate Change in a Balanced Context" which was shown during the class)

- *"Many people say that those who are on the climate deniers side of the debate they say that humans are not causing climate change. But no they're not saying that, what they're saying is that they're not causing dangerous climate change."* (TH)
- *"Rather than a dangerous pollutant, carbon dioxide could be called a miracle gas that acts as a free fertilizer to help alleviate famines in regions of the world that have frequent droughts and famines, all without causing harm to the environment or people."* (Kristie Pelletier, in the video "Global Warming: Emerging Science and Understanding" which was shown during the class)
- *"...that's what the scientists in many cases are saying, that in fact the CO₂ levels are not something that we should be in any way worried about."* (TH)
- *"Basically carbon dioxide is an aerial fertilization.... So the bottom line is that if CO₂ enrichment continues, we'll have an easier time feeding the world's population. With population probably peaking around 9 billion, maybe we want to purposely increase CO₂. I'm sure a lot of agricultural scientists would say that. [Carbon dioxide] is not a pollutant and it's probably a benefit."* (TH)

Perhaps the best summary of the questionable arguments used in the course is given by Harris in the final lecture, where he provides take-away slogans for the students:

- *"The only constant about climate is change."* (TH)
- *"Carbon dioxide is plant food."* (TH)
- *"There is no scientific consensus about climate change causes."* (TH)
- *"Prepare for global cooling."* (TH)
- *"Climate science is changing quickly."* (TH)

Student Feedback

While official module evaluations are not publicly available, the website "Rate My Professor"¹ offers some insights into the mixed reception that the course received from the students. Below is a summary of some selected comments (not edited in any way, so mistakes are from the originals):

- *"I am so glad I have taken this class. I am now passionate about the environment in a different way. Best class at Carleton by far."*
- *"The prof is well informed and intent on informing the students, I appreciate his sincerity and his research."*
- *"I was and remain an environmentalist but this class has opened my eyes to REALITY. A real scientific view of climate change. Lets focus our attention and expenses on issues that are of real concern to this planet and on issues that we actually can influence. Very interesting course."*

¹ <http://www.ratemyp Professors.com/ShowRatings.jsp?tid=1274233&all=true>

- *"Great prof, awesome course with alternative views on global warming. I managed an A+ and I am doing an arts degree, not science.. I find it hard to believe any science students had a hard time with it. Great to hear a prof going against the grain, presenting us with information to make up our own minds on such an important topic!"*
- *"Professor Thomas Harris is an excellent Earth Science reference and knows his subject well. His output is refreshing and he compares his perspective extremely well. This course was amazing, I am very happy I took it."*
- *"Interesting course offering an alternative perspective on climate change. Not extremely difficult, but not very easy either. Well put together and presented. I recommend taking this class."*
- *"one of the few profs ive encountered who goes against the grain. although he is biased its nice to hear some alternative theories about global warming, mostly created by Dr. Patterson."*
- *"Great to hear alternative perspectives on climate change and to get away from the global warming dogma for a bit. Not sure if a believe it or not but very interesting all the same. Keep the debate alive! and always question the church of science."*
- *"Interesting course. Nice to have some fresh perspectives on global warming rather than the dramatized fear mongering versions. Harris really loves to indulge in the facts and presents some pretty compelling evidence."*
- *"Prof Hariss seems to have tried very hard in creating this course and making it interesting. He is a fairly good speaker and makes it fairly interesting. However, like others have mentioned the course is based on his opinion essentially. There are interesting points are brings out, and certainly he's not always lying, but its not a fullyhonest course."*

Clearly the students have a positive view of the course. Having watched Harris' lectures, it is clear that he is a more-than-competent teacher. However, what is also clear is that there are a number of students who have been influenced by the course such that they now consider the mainstream scientific opinion on climate change to be incorrect. Other students clearly see that the course is unrepresentative of the scientific consensus, but without balance and knowledge of alternative arguments it is difficult for them to critically evaluate the material.

The Climate Change Debate and Academic Freedom

The Carleton University Academic Staff Association (CUASA, the representative body for Faculty at Carleton University) has within its Collective Agreement² (within Article 4) the following statements:

² <http://www.cuasa.ca/agreement/agreement/s1.html>

The common good of society depends upon the search for truth and its free exposition. Universities with academic freedom are essential to these purposes both in teaching and scholarship/research. Employees are entitled, therefore, to:

- (a) freedom in carrying out research and in publishing the results thereof,**
- (b) freedom in carrying out teaching and in discussing his/her subject and,**
- (c) freedom from institutional censorship.**

Academic freedom carries with it the duty to use that freedom in a manner consistent with the scholarly obligation to base research and teaching on an honest search for truth.

Similarly, the Canadian Union of Public Employees (CUPE) 4600 branch, which represents contract instructors such as Mr Harris, has within its Collective Agreement³ (within Article 10) a more extensive consideration of academic freedom including the following passage:

Academic freedom is the right of reasonable exercise of civil liberties and responsibilities in an academic setting. *As such it protects each member's freedom to disseminate her/his opinion both inside and outside the classroom, to practice her/his profession as teacher and scholar, to carry out such scholarly and teaching activities as she/he believes will contribute to and disseminate knowledge, and to express and disseminate the results of her/his scholarly activities in a reasonable manner, to select, acquire, disseminate and use documents in the exercise of her/his professional responsibilities, without interference from the Employer, its agents, or any outside bodies. All the abovementioned activities are to be conducted with due and proper regard for the academic freedom of others and without contravening the provisions of this agreement. Academic freedom does not require neutrality on the part of the member, but rather makes commitment possible. However, academic freedom does not confer legal immunity, nor does it diminish the obligations of members to meet their duties and responsibilities.*
[emphasis added]

Clearly these Collective Agreements shelter the teaching of non-mainstream opinions given by contract instructors and faculty.

³ http://4600.cupe.ca/updir/4600/CUPE_4600_Contract_Instructors_Agreement_Exp_2013_-0.pdf

The course "Climate Change: An Earth Sciences Perspective" contradicts material taught in other courses at the same university (instructors of other courses on climate change at Carleton University include at least two individuals who shared the Nobel Peace Prize for their contributions to the IPCC), which leads to confusion on the part of students. There was no free exchange of ideas, but the one-sided presentation of a biased viewpoint that contradicts much established research. Indeed, not only were alternative views not given time, but students were actively encouraged to ridicule those individuals who espoused views considered "alarmist" by the instructor (see our comment concerning "bloopers of the week" above). Finally, as we demonstrate extensively in our analysis, the material presented was not an adequate representation of the current state of the field of climate science. The teaching of critical thinking and skepticism is healthy in a university setting where students are expected to move beyond the confines of rote learning. Indeed, our organisation (Centre for Inquiry) is dedicated to the promotion of such. However, it is unlikely that healthy scientific skepticism will win-out when only one point of view is offered. Furthermore, the scarcity of primary literature in the course makes it difficult for students to understand the processes by which information is gathered and, therefore, to adequately evaluate that information.

We have documented a large number of examples where the science that is taught is at least incomplete if not incorrect (see Appendix A). There are a number of examples where Harris cites studies that were later rebutted (for example, the publication and subsequent revision of Stephen Schwartz's estimates of climate sensitivity, George Chilingar's work on CO₂-mediated cooling, and criticism of Vermeer and Rahmstorf's work on sea level rise), and still more where he appears to have missed key publications (for example, again in his discussion of sea level rise and elsewhere while discussing the urban heat island effect) and this may indicate that he is unaware of the current scientific literature and prevailing scientific opinion. We hope that our report can be of some use in subsequent updating of the material if the course is to be given again in the future.

Irrespective of the inaccurate information in the course, there may be a place for a controversial view of climate change in a post-secondary education but it is absolutely essential that this be based on peer-reviewed science. Where students are less familiar with, and have less access to, the primary literature, the teaching provided must be accurate and balanced. While some of the issues raised by Mr. Harris could be discussed among graduate students enrolled in a climate science program, we question whether the one-sided nature of the arguments used in this course is appropriate for a class of non-scientists with limited knowledge of the field as a whole. A more productive may be to tie or splice existing courses together, such that the debate is laid bare on both sides.

Conclusion

We have demonstrated that the Earth Sciences Department at Carleton University has until recently run a course which down-plays and contradicts the overwhelming scientific consensus on dangerous, man-made climate change. This course was run by an instructor who has been actively involved in climate change denial for many years. The issue of academic freedom allows the instructor to express his opinion and we do not wish to contravene that principle, however, students also deserve to know where what they are taught falls within the broader context of the debate. We hope that our review provides useful feedback on the course in preparation for its next delivery under Prof Patterson. Since climate change presents a substantial threat to our society, it is imperative that people are as well-informed as possible. We hope that our report will contribute in some small way to an improvement in the education of future Carleton University students in this important field.

Appendix A – Details of claims and evidence

Lecture 1: Course Introduction

[Tom Harris introduces himself as the director of the International Climate Science Coalition, a “non-partisan – we’re not left or right wing – group of scientists, economists, policy experts, and engineers trying to establish a realist view of climate change.” “We’re not climate change deniers – of course, climate always changes – and we’re not saying there’s going to be a catastrophe necessarily either. We’re really in the middle.”]

Claim 1. “That’s indeed the kind of position that most scientists are, in the climate change field. If you talk to them behind closed doors, and you say to them: ‘what’s the climate going to be like in 10 years?’ the typical answer is ‘ask me in 10 years.’ because the vast majority of scientists, as you’ll see as we go through the course, are somewhere in the middle – somewhere between climate change deniers and climate change alarmists.”

RESPONSE: Harris vastly overstates the extent of the disagreement. There are no scientific organisations (i.e. organisations representing scientists and institutions) that maintain a dissenting opinion over the anthropogenic global warming hypothesis (see [Wikipedia’s list](#)). Also, surveys of scientists indicate that the closer an individual is to the research, the more likely they are to believe that human activity is linked to climate change, with an overwhelming majority of climate scientists agreeing with an anthropogenic influence on climate [1–3]. The published literature is similarly conclusive, with no papers published between 1993 and 2003 rejecting the consensus opinion of anthropogenic global warming [4]. Finally, the IPCC’s most recent (2007) report stated that “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level” [5]. To claim that there is no consensus is simply false.

Claim 2. “We think that natural variations play a big role in climate change.”

RESPONSE: Climate scientists accept that natural variations at all temporal scales play some role in climate change. However, contemporary climate change is predominantly affected by

anthropogenic forcings such as greenhouse gases and land use change [6], and natural variations alone cannot account for the rate of warming seen in the second half of the 20th Century [7–9].

Claim 3. “The field of climate science is just in its infancy. We are learning, as the years go by, how much we don’t know.” Example: “Clouds are at least 10 times more influential on global climate than all human activities combined.... It turns out that the influence of clouds was at first believed to be a warming agent because clouds contain water vapour and water vapour is, of course, a greenhouse gas... You can see that later models... actually show that it’s a negative agent.... In other words, the more clouds there are, the cooler it gets.” “Clouds are now believed to be a net cooling agent.”

RESPONSE: Harris points to examples of advances in climate science as though this is a bad thing. He is correct to point out that the modelling of clouds is an obstacle in accurate forecasting of future climate, but this problem is being addressed using, *inter alia*, global cloud resolving models (GCRMs) with some success [10]. However, he is incorrect in stating that they are likely to be a negative force. New modelling approaches using more detailed, regional cloud models have suggested positive feedback of clouds on regional temperature over the Pacific Ocean [11], [12]. Over the past 22 years, four IPCC reports have been published, summarising the contemporary research on climate change, each increasingly confirming the role that humans are playing in modifying the world’s climate.

Claim 4. “The Earth is by far more complicated than any other planet by far. We would be arrogant to think that we understand and we control the climate of the earth... We can’t even forecast how these clouds are going to move in the next week. Our understanding of the physics is so bad that we can’t even do that. So to think that we could do a whole planet for 50 years in the future...”

RESPONSE: Many studies have used models to “hindcast”, i.e. project backwards to explain past climate using the forcings that were present at that time [8]. Furthermore, the earliest global climate models (GCMs) have been demonstrated to match observed patterns of warming between 1988 and 2006 [13]. The incorporation of the details of clouds into these models will only enhance their predictive power. It is also worth mentioning that Harris makes the mistake of equating weather and climate. “Weather” involves extremely fine details which are difficult to predict but that are irrelevant to the long-term averages that make up “climate”. Our inability to predict weather beyond a couple of weeks does not impinge on our ability to predict

climate. Furthermore, Harris` use of the word “control” is not really apt for the situation of anthropogenic global warming – we can *influence* climate but not control it.

See also “[How reliable are climate models?](#)”, “[Chaos theory and global warming: can climate be predicted?](#)” and “[The difference between weather and climate](#)” on Skeptical Science.

Claim 5. “There’s a lot of variation in the system, but you can’t draw conclusions with regards to climate until you have at least 30 years of data. So, somebody says to me is it warming or cooling in the 21st century and I say, well let’s wait until 2030 and I can tell you.”

RESPONSE: Harris ignores the fact that we have long temperature series recorded using instruments for most of the 20th century. Furthermore, we have a number of proxies that we can use to extend that time series even further. These have been accurately reproduced using models [8]. Also, James Hansen’s earliest predictions were made in 1988, 24 years ago, and as mentioned above these have been borne out by observations [13]. The science of climate goes back more than 100 years to the proposition by Arrhenius that changes in CO₂ could influence climate [14]. To claim that we cannot know something now about how climate changes is demonstrably false.

Claim 6. “Dr. Ball makes a joke, he says, ‘Ok, there’s something wrong with my car and I’m trying to figure out what it is and I’m going to ignore the engine, I’m going to ignore the transmission, and I’m going to look at one nut on the rear wheel to see if maybe it’s loose.’ Well, I think greenhouse gases have more impact than that, but you can see it is just one of many many factors. So when we hear people say ‘stop greenhouse gases and we’ll stop climate change,’ well they’re kind of ignoring a few things.”

RESPONSE: Actually, a combination of the forcings that greenhouse gases represent [6] and the attribution of contemporary climate change to principally anthropogenic impacts such as increased greenhouse gases [7–9] mean that this is a very valid opinion to hold.

Claim 7. “In cases in Vancouver there are temperature changes of 6 degrees Celsius within just a few blocks.” “Urban heat island can have a very big affect on local climate, no question about it.”

RESPONSE: It is true that the urban heat island effect can make cities warmer than surrounding rural areas. However, 42% of city sites are actually *cooler* than their nearby country sites, showing that the trend can go both ways [15]. Scientists understand that the UHI effect exists and they control for it by comparing urban sites to rural, remote sites [15]. Studies comparing urban and rural sites have shown that there is no consistent difference in temperature trends between urban and rural sites [16] and that the trends in all locations are similar (i.e. an increase in temperature during the latter part of the 20th Century) [17]. Finally, and most comprehensively, the Berkeley Earth Surface Temperature Project found that "...urban warming does not unduly bias estimates of recent global temperature change" [18].

See also "[Does the urban heat island effect exaggerate global warming trends?](#)" on Skeptical science.

Claim 8. "Despite the fact that there are so many factors driving climate and we really don't understand much about very many of them, we keep seeing things like this... 'Few still debate the primary cause of climate change.' Except 90% of the scientists in the field."

RESPONSE: Again, Harris attempts to undermine the consensus that exists within the scientific community. See [1–3] for the climate scientists' personal opinions and [4] for a review of the peer-reviewed literature which both emphasise a high degree of consensus.

Claim 9. "[Carbon] is shorthand, but it's a sloppy shorthand because they could be talking about carbon pollution, which is soot. Carbon pollution is not carbon dioxide. Carbon dioxide is invisible, or you'd be seeing smoke all around me as I talk. It's benign, it's plant food of course. The debate of course is not whether it's a pollutant – because it's not a pollutant. Carbon footprint is not a pollution – the debate is how much does it drive climate change."

RESPONSE: Carbon dioxide is a pollutant as it causes acidification of the oceans, disrupting the formation of biological structures in those environments. Its major role is in the greenhouse effect where increasing concentrations warm the earth, which matches the definition of a pollutant given by the US EPA: "'emissions of which... cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare" [19]. In any case, this is pure semantics.

See also "[Is CO₂ a pollutant?](#)" on Skeptical Science.

Claim 10. "I don't think humans control climate change. We have a certain amount of influence and we've got to figure out what that is. And of course we should reduce our energy consumption to reduce pollution and to conserve energy. But no, we don't control climate change, at least not to that degree."

RESPONSE: While Harris is welcome to his opinion, that opinion is simply not in line with current climate science. Anthropogenic factors are causing contemporary warming, as demonstrated by the necessity of their inclusion in climate models predicting past warming [7–9] and those anthropogenic factors far outweigh natural variations [6].

Claim 11. "In 1998 there was a fairly big change that did occur very quickly, but the system recovered. There's a lot of buffers in the system."

RESPONSE: 1998 was a peak of an El Nino cycle in which there were large changes in the distribution of ocean heat which affected the climate. El Nino/La Nina is a natural part of the climate's variability – it occurs every 4-7 years. This is not a buffer. The total heat content of ocean, land and atmosphere is still steadily increasing [20].

See also "[What has global warming done since 1998?](#)" on Skeptical Science.

Claim 12. "Now I predict – and many people are also predicting – that we're going to see a bit more cooling before we see, perhaps, who knows?"

RESPONSE: Again, Harris is welcome to his opinion, and again he is likely to be wrong. Given that (A) we have observed and are observing steadily increasing surface temperatures, and (B) we have strong support for an anthropogenic cause of that warming, there is no reason to suspect that the climate will cool significantly without a reduction in one or more forcings. Of course, Harris doesn't propose a mechanism by which the climate might cool, so it is difficult to speculate as to what he is thinking about.

See also "[Are we headed into global cooling?](#)" on Skeptical Science.

Claim 13. [Land surface records go back to 1880 and global data from NASA show] "fairly substantial rises, we're talking about perhaps almost a degree from the zero line up here. Now, if these measurements were real – and that's a big if, we'll talk about it later – you would expect this kind of warming to be visible, in let's say, the United States.... it has by far the best temperature record of anywhere in the world.... You would expect

to see that if there was global warming, that there should be some indication of warming in the United States. Well what you see is... there is a very slight overall warming in the United States, but in the 1920s and 30s we were just about as warm as we are today."

RESPONSE: Harris has correctly identified the reason why "global warming" is so named. The warming of the global climate is based on planetary averages, which incorporate geographical variation in the rates of warming. Examples of regional cooling are well-documented [21] but do not detract from the observation of warming on a global scale. His statement that "you would expect to see...some indication of warming in the United States" is clearly incorrect - you could see significant cooling in the US but still global warming if the rest of the world compensated to the appropriate degree. One of the most recent examples of a historical temperature reconstruction is the Berkeley Earth Surface Temperature (BEST) project which shows 0.911 degrees Centigrade of land warming (+/- 0.042 C) since the 1950s [22], thus confirming the current data on global warming. Their animated time series of temperature increases also demonstrates the regional variability over time, and is available online at <http://berkeleyearth.org/movies.php>.

Claim 14. "You'll find that on average, quite a few of the early century temperatures have been adjusted down. While the late century temperatures have been adjusted up." "A lot of people say there is something funny going on." "One of the scientists I was corresponding with said 'Well, what they're trying to do is they're trying to account for increasing urbanisation around temperature sensors'" "It is coincidental that all the shifts show increasing warming. You know, that does sound kind of coincidental..."

RESPONSE: Harris questions the reliability of the temperature record from a number of different angles. Here, he briefly discusses the nature of the adjustments made to NASA's Global Historical Climatology Network (GHCN) monitoring data but does not go into sufficient detail to explain why the adjustments are made or how. He simply points to a pattern that he suggests might be suspicious. A paper was published in 2010 which deals with an update to the methods used in record adjustment [23]. This used to be done by comparing sites with high human population densities ("urban" sites) and sites with very low human population densities ("remote" sites). A correction was applied to account for the deviation produced by the urban location. However, recently the adjustment has been calculated by flying over an area at night and assigning the urban/remote status according to the amount of light emanating from the land. The assumption is that urban areas give off more light pollution. This is an objective system that does not allow any interference from the scientists involved [23].

Claim 15. "Current resurvey of 1221 US Historical Climatological Network found 70% of stations severely compromised. Only 4% at proper standards."

RESPONSE: Some existing climatological network stations do need to be brought in line with current standards. However, NOAA is aware of these kinds of problems and responded by comparing the best 70 stations with the full 1218 station dataset, and found almost identical trends [24]. A recent, comprehensive, analysis of station quality further indicated that station quality did not alter the warming trends in temperature data [25].

See also "[Is the US surface temperature record reliable?](#)" and "[Are surface temperature records reliable?](#)" at Skeptical Science.

Claim 16. "The only constant about climate is change."

RESPONSE: The fact that climate has changed dramatically in the past only goes to demonstrate the sensitivity that the climate system exhibits. This makes it more reasonable to assume that humans are capable of perturbing that system. In fact, models suggest that only with the inclusion of anthropological factors can we adequately account for the causes of the contemporary phase of climate change [7–9].

See also "[What does past climate change tell us about global warming?](#)" at Skeptical Science.

Claim 17. "There's no question that there has been global warming since the little ice age, and thank god there has been."

RESPONSE: In comparison to the warming we have seen recently the cooling during the Little Ice Age was mostly in the Northern Hemisphere and was likely caused by a decline in the activity of the sun [26]. We understand this relatively well. However, these factors cannot account for the warming that occurred beyond the 1950s [27].

See also "[What ended the Little Ice Age?](#)" on Skeptical Science.

Claim 18. "Greenlanders, a lot of them, are looking forward to any warming that might happen, the only thing is the fact is we simply don't know. If warming happened, more of Greenland would be habitable, but we simply don't know."

RESPONSE: The positive and negative results of climate change will not be evenly distributed. Greenland may warm and become more hospitable to human habitation, but other areas are likely to become inhospitable. Africa is thought to be particularly vulnerable to a number of climate change impacts: for an extensive list see Table 19.1 in [28]. Furthermore, it is difficult to see how an increase in growing seasons at extreme latitudes and a reduction in deaths due to winter cold could compensate for drought, loss of farmland, sea level rise, ocean acidification, widespread species extinction, the spread of vector-borne diseases, and increases in summer heat deaths.

See also "[It's not bad](#)" at Skeptical Science.

Claim 19. "Right now, we're actually in a colder period than usual in the long term record."

RESPONSE: Obviously contemporary temperatures will be either higher or lower than the past depending on which past period you compare them to.

[At this point in the lecture, Harris shows the film "[The Great Global Warming Swindle](#)."]]

RESPONSE: A variety of sources have taken this film to task over factual inaccuracies and misrepresentations:

- [Sir John Houghton](#) (Sir John was the co-chair of the IPCC and provides a series of responses to claims made in the film)
- [RealClimate](#) (a review of several of the scientific claims made in the GGWS)
- [DeSmogBlog](#) (a review of some of the GGWS's arguments along with more details on the contributors)
- [Scienceblogs](#) has two posts: [one](#) discussing the main points, and a [second](#) discussing the link between solar activity and temperature.
- [Fermi Paradox](#) (also covers solar vs. temperature)
- [Climate Denial](#) (covers some of the background to the documentary and provides links to RESPONSEs)
- [Monbiot.com](#) (George Monbiot covers the questionable past of the documentary's maker)

Lecture 2: Man's Awareness of Climate Change

Claim 20. "The warmest period in the current interglacial that we're in, which is called the Holocene, is in fact this period here, called the Holocene optimum and that's when warming was considered good."...and..."In general, a warmer world is a more tranquil world."...and..."You can say that globally, warmer leads to more tranquil weather, with of course some exceptions in some regions."

RESPONSE: Harris claims repeatedly that, while climate change might be happening, it is not a dangerous thing. The vast array of projected impacts that have been proposed highlight the extent and detrimental nature of climate change, see Table 19.1 [28].

Claim 21. "This is something we'll see generally speaking throughout history, is that we ended up in periods of drought and extreme weather at times when it was cold. A lot of the forecasts of the future from the IPCC talk about extreme weather events increasing when it gets warmer, but in fact in general that's not the case. And it was explained in the Great Global Warming Swindle, where in fact, in general, weather is driven by the difference in temperature – actually difference in pressure, but that causes temperature – between the poles and the tropics. And in a warmer world, as forecast by David Suzuki and the IPCC, the difference in temperature between polar and tropics reduces. And yet it's that that drives extreme weather."

RESPONSE: Harris claims that "extreme weather" is not increasing when temperatures increase. We need to define "extreme weather" before we can evaluate the claim. It should be immediately apparent that the frequency of extreme temperatures will increase as temperatures increase. With a positive linear trend with constant noise, the outliers on that trend will continue to increase over time. If we take a more complex phenomenon such as wind speed then we see that the implications for warming are also more complex. There is evidence that increasing temperatures could inhibit the formation of tropical storms (by enhancing vertical wind shear), which may act to decrease the frequency of hurricanes [29]. However, studies of trends in the wind speed of hurricanes that do form suggests that there has been an increase in the intensity of tropical storms over the period of recent warming, and that that pattern is present wherever hurricanes are found [30], [31].

See "[Extreme events increase with global warming](#)" and "[What is the link between hurricanes and global warming?](#)" on Skeptical Science.

Claim 22. "Since the Holocene optimum about 5000 years ago, we've seen a gradual ramping down. And some geologists believe that this is a harbinger of the next glacial period about to begin. When it begins is very hard to say. It could be starting now." "There's no question that in the next 5000 years, we're headed into the next glacial."

RESPONSE: If glacial cycles were to continue, we might expect cooling at some stage in the next 5,000 years. However, that is assuming that all other factors remain constant. Even if this is not the case, the projected warming of 1.8-4.0 °C by the end of the 21st Century, depending on SRES scenarios (predictions of future political and technological development which may influence emissions of greenhouse gases) [5], would be more than enough to cause serious global problems well before the next glaciation.

See also "[Are we headed into global cooling?](#)" on Skeptical Science.

Claim 23. "Here's what the sea level rise looks like since the end of the last glacial. And as you can see, at times it was going up 10 times faster per year as it is now.... the forecast for sea level rise by around the year 2100 according to the American Environmental Protection Agency is around 20 cm between now and then. And typically, that's the rise we've seen. As Tim Patterson says in the video I'll be showing you later, there's no indication of an acceleration of sea level rise."

RESPONSE: Harris is incorrect here. There have been a number of papers over the past few years which may have led to his confusion. First of all, he is correct that sea levels rise during interglacials – temperatures warm, ice melts and water expands as it heats leading to higher sea water levels around the world (although the amount of rise varies between regions). In 2006, a reconstruction of sea level rises from 1870 to 2004 was published, showing acceleration in the rate of rise that would be expected if global warming were influencing sea levels [32]. A subsequent paper demonstrated that global temperature could be used to predict very accurately the amount of sea-level rise [33], including the acceleration observed by [32]. A paper published in 2011 disputed these two studies, based on an analysis of US tide-gauge data from 1930 to 2007, and found no evidence of acceleration in sea level rise [34]. However, a subsequent response from the authors of [33] demonstrated that the results of [34] were largely due to their choosing 1930 (a time of global plateau in temperatures) and regional effects in the US [35].

Claim 24. "What you think is sea level rise might not in fact be sea level rise at all. It might in fact be ground level drop. In fact, in Halifax, the sea level rise that they're seeing is half because of sea level rise and half because the land is falling."

RESPONSE: In general, subsidence is taken into consideration where it is present, and we have good evidence of sea level rise at tectonically stable sites [36]. There is evidence to suggest that this rate of increase is accelerating towards the end of the 20th Century and the beginning of the 21st Century [32]. Sea level rise during the 20th Century at Halifax (32cm [37]) is far higher than the global average (10-20cm [8]). The greater sea level rise at Halifax since 1920 is a combination of regional subsidence (1.6 ± 0.3 mm/yr, or 16 ± 3 cm per century) and a rate of local sea level rise that is consistent with the global average (~ 1.6 mm/yr, or 16cm per century) [38]. As such, Halifax is representative of the global trend in sea level rise, irrespective of the degree of subsidence that is occurring in that location.

Claim 25. [citing Nils Axel-Morner] "The sea level has been significantly higher, to about a meter higher, in the Maldives seven times in the last 4000 years and it's not particularly high right now and it's not showing any trend of doing so. So I'm afraid the scare is in fact completely fabricated."

RESPONSE: Harris is correct in saying that sea level has been higher in the past, even during the present interglacial. This period is known as the "mid-Holocene hydro-isostatic highstand", and occurred in the Pacific around 2,000-4,000 years ago, producing a large number of atolls which developed into islands as sea level later dropped over the next couple of millennia as a result of "ocean siphoning" [39], [40]. Late Holocene sea level rise is on the order of 120m but peaked at the highstand in the equatorial oceans and gave the modern atolls their height. However, Harris is incorrect with regard to current trends in sea level rise which in fact suggest that the highstand (and all the atolls that act as homes for human populations) will be reached once again by the end of the 21st century [33]. Based on the various heights of the atolls, it is even possible to predict when each island will be inundated [41]. See also "[Coral atolls grow as sea levels rise](#)" on Skeptical Science.

Claim 26. "In many cases [coral] is quite able to keep up with future sea level rise."

RESPONSE: Harris provides no support for this claim, so it is difficult to tell on what it is based. The history of atoll and reef formation is a stop-start affair, with coral reefs being, in turn, submerged and exposed during glacial and interglacial's [42]. Reef formation continues

whenever the water depth is appropriate but reefs are frequently inundated and drowned. The highly mobile larvae of these organisms allow them to colonise new sites when this occurs. It is also worth noting that coral is sensitive not only to sea level but also ocean acidification and temperature increases [43] – both of which are enhanced by climate change.

See also “[Coral atolls grow as sea levels rise](#)” on Skeptical Science.

Claim 27. “They often attribute statements to the IPCC as if it’s some sort of an authoritative body of thousands of scientists who all agree on, let’s say that [points to chart of rising sea level]. But what you’ve got to remember is that each scientist has their own specialty. And in the thousands of pages that are written in the IPCC reports, they may only comment on one page because they typically compress a lot of science into just a few pages. So many of the scientists don’t even see the results – many of the IPCC scientists – most of them in fact don’t even see the results of things outside of their specialty until the IPCC reports are published. So yes, a small group of scientists who worked on sea level work, they’re forecasting this kind of sea level rise in the future and that may, in fact, swamp small islands. But this is based on computer models. If you actually look at the current data... taken by satellite, you can see there hasn’t been any acceleration for about 60 years. So there’s nothing in the current evidence that suggests that future sea level rise globally is going to be catastrophe. It’s based on future projections of models.”

RESPONSE: Harris makes two points here. The first is that the results of the IPCC are only based on a small number of experts working on different aspects. It may be true that a small number of scientists work on their specific areas of expertise, but many scientists will be sufficiently familiar with the literature to be able to verify the findings of those smaller groups. The second point is his incorrect restatement that there is no acceleration in sea level rise. Sea level rise is accelerating [32], [33], [35]. As a follow up, Harris criticises the use of models, despite the fact that the models that have been used to hindcast (predict into the past) have been shown to fit extremely well with observations of sea level over the past 140 years [35]. In fact, IPCC projections of sea level rise have been shown to be too conservative by data collected since the last IPCC report was published [44].

Claim 28. “By 4000 AD we could very well be into the next glacial and sea level would be dropping, because more and more of the water would be going into ice. So, unless we see an acceleration in sea level rise there isn’t really any observational data to be backing up some of these extreme forecasts.”

RESPONSE: We have seen an acceleration in sea level rise [32], [33], [35] so we can assume that Harris will consider the projections of sea level rise to be valid. Again, Harris claims that the situation will reverse in 4,000 years. However, this will not reassure the island-dwellers whose homes will be inundated in the next 200 years [41].

Claim 29. “Generally speaking, we’re at about the same temperature as the medieval warm period.”

RESPONSE: This is not strictly true. The Medieval Warm Period was only warm in some regions of the planet. Globally we are now far warmer than that period [45].

Claim 30. [Referring to a graph comparing CO₂ and temperature over the past 1000 years] “You can see CO₂ just did what it did and gradually rose and temperature just seems to go all over the place. So, there doesn’t seem to be a very good correlation here.”

RESPONSE: As mentioned above, the Medieval Warm Period was only warm in some regions [45], while the overall trend was relatively stable with a sharp increase in the past century [46]. We know that the MWP was caused by variation in solar activity [26], [45]. When we look over longer time periods (e.g. over glacial cycles) we can see a very clear correlation between CO₂ and temperature [47].

Claim 31. “And this is when climate is more variable: during cold periods. You’ll see throughout the course, that when we talk about warm periods, climate change is more – I should say weather change – is more tranquil. Ok, it’s cold periods where you see the extreme storms. It was during the little ice age... that complete cities were washed away by storms from the ocean.”

RESPONSE: Once again, Harris asserts that warmer is better. See Table 19.1 in [28] for an extensive list of why this is not necessarily the case.

Claim 32. “They forecast that the next cycle, going into the 2030s, cycle number 25, will actually be as weak as when Napoleon went to Russia. And so the concern is, that what

we might see actually is a return to conditions that existing in the Dalton Minimum.... Depends on which scientist you talk about, whether or not the solar effect is the greater effect or greenhouse gases or whatever. But if solar is driving our climate, and it does seem more and more like that's the case, then we're in for some real cooling come around 2030 because we're going back to the conditions that existed at the time of Napoleon. So cold weather is coming."

RESPONSE: While the sun is a major driver of global temperature, there is increasing evidence that the contemporary phase of warming has been going on independent of solar activity. There are two related pieces of evidence for this: first, models of contemporary climate cannot account for contemporary warming using only natural phenomena (including sun spots) [7–9]. The second is that solar activity has been declining over the past 30 years while temperature has continued to rise [48].

See also "[Solar activity and climate: is the sun causing global warming?](#)" on Skeptical Science.

Claim 33. "The rate of retreat of glaciers has stayed about the same since around 1850... There hasn't been an acceleration in glacier retreat worldwide." ...and... "Glacier retreat does not always correspond with a warming temperature."

RESPONSE: There has been an acceleration in the loss of global glacier volume. After remaining relatively constant between 1850 and 1900, global glacier volume declined slowly between 1900 and 1950, increased to 1970, and then decreased at an accelerating rate to the present day [49]. While increasing temperature can increase precipitation which causes growth in glaciers, the warming-induced melt remains the dominant force affecting glacial mass [50]. Finally, the World Glacier Monitoring Network report has shown that the majority of glaciers that are being monitored are receding and that that rate of glacier recession is increasing [51].

See also "[An overview of glacier trends](#)" and "[What's happening to glaciers globally?](#)" on Skeptical Science.

Claim 34. "It may be more than a coincidence that the 18th century, which was getting slightly warmer... than previously, they saw a more cheerful social and political mood."

RESPONSE: See Table 19.1 in [28] for a list of projected impacts associated with climate change.

Claim 35. "You can have big changes in temperature, but not necessarily see it reflected in glaciers. These are glacial fluctuations and if you compare, for example, 1700-1850... You can see the glaciers didn't really change very much, over Europe at least, even though the temperature was changing quite a lot. It was only quite a lot later, like coming into the 1900s, up here, when it really got warm and stayed warm that we saw a big retreat in the glaciers. But you know, glaciers retreat, as I say, for a number of reasons. One reason is because of more snowfall at the top, in the mountains, it pushes forward. But there can be other reasons, too, that have nothing to do with temperature. For example, if you have a coal station, or some sort of source of particulate matter that's near the glacier, it can build up a black, sooty sort of layer on the glacier, and as you know black absorbs sunlight more easily than light colours, so the kind of pollution produced in a lot of these coal firing stations, if it's not taken out at the source, can actually reduce ice and glacier cover nearby."

RESPONSE: There has been a reduction in the quantity of soot emitted from power stations over the past century [52] – Harris provides no evidence for local black carbon emissions. Nevertheless, glaciers have consistently shown a retreat [51].

See also "[An overview of glacier trends](#)" and "[What's happening to glaciers globally?](#)" on Skeptical Science.

Claim 36. "The dirty thirties, of course, was a period when indeed we saw higher arctic temperatures than we even see today.... you go back to the satellite records, you see that since 1979 the arctic is getting a lot warmer and ice is shrinking. Well, if you go back to the '30s, you see that in fact it was warmer in the arctic than it is today. Now we don't know what the ice conditions were because we didn't have satellites, but very likely they were similar to today."

RESPONSE: Harris is correct in that we do not know about ice cover before 1953. However, all data from 1953 suggest that the arctic sea ice has shown an accelerating decline in extent and thickness [53]. The period of high arctic temperatures in the 1930s showed a different pattern to contemporary warming. In the 1930s, the warming was regional and resulted from the Atlantic Multidecadal Oscillation [54]. In contrast, the current phase of warming is global and studies suggest that anthropological forcings predominate [6], [7], [9].

See also "[Arctic icemelt is a natural cycle](#)" on Skeptical Science.

Claim 37. “And just based on this one paper [referring to the Mann et al. “hockey stick graph”], and their research, the UN did a complete u-turn... they had decades of reports and scientific papers that showed there was a little ice age, there was a medieval warm period, they could see it in the historical climatology, they could see it in the paintings that were done at that time, things like height of people, all sorts of evidence. But this particular graph threw that all away. And this was considered the smoking gun of human impact on climate.”

RESPONSE: Michael Mann and colleagues published the “hockey stick” paper in 1998 [55], which aggregated Northern Hemisphere historical temperature reconstructions. This presentation revealed a distinct uptick in global temperatures, in multiple data sets, in the second half of the 20th Century. Rather than a u-turn, the graph further supported mainstream climate science opinion that recent temperature increases were unusual. In other words, Mann et al. focused on climate change detection, not attribution as Harris suggests. The Medieval Warm Period was only warm in some regions. The cooling during the Little Ice Age was caused by a combination of volcanic activity [56] and a decline in the activity of the sun [26]. We understand this relatively well. However, these two factors cannot account for the warming that occurred beyond the 1950s [27]. Globally we are now far warmer than that period [45].

Claim 38. [Discussing tree ring proxies stop in 1975-80] “I’m not trying to ascribe nefarious motive to them, but if you actually did take those proxies, especially tree rings, right up to the present, you would find they would drop.” ...and... “[Tree rings are] not really a good proxy for temperature – it’s only a proxy for good or bad growing conditions.”

RESPONSE: This decoupling of temperature and tree-ring records is known as the “Divergence Problem” and has been recognised in the literature since 1995. It is thought to be unique to the latter part of the 20th Century so it would not affect the use of tree-ring proxies before that date. The cause is thought to be a reduction in solar activity [57].

Lecture 3: Comparative Planetology/Climates of the Solar System

Claim 39. "We could talk about lots more. Jupiter, for example, and the fact that it's going through global cooling, and what impact that has on the atmosphere." ...and.. "They [outer zone planets] are indeed, in the case of Jupiter, undergoing global warming right now. Not that that means a great deal, but we'll talk about the implications of that later."

RESPONSE: Harris makes two contradictory claims here, one of which is presumably a slip of the tongue and both of which are unsupported by science. We currently understand relatively little about what drives the climate on other planets, including Jupiter. However, we do know that Jupiter's temperature is relatively equal over its entire surface due either to chaotic mixing by vortices of gas or a "thermostat" effect of the warm core which distributes heat evenly across the surface [58]. It is also well-established that the planet emits more heat than it absorbs from the sun [59]. However, there has been a prediction that an alignment of such vortices may merge in the future, creating a larger vortex system which could prevent this mixing. If this occurred, the poles could cool and the equatorial regions could warm [60]. So not only is Jupiter not warming, it is extremely unlikely that any Jovian climatological changes could be used to inform the study of Earth's climate. Also, note that Harris expresses no doubt that global warming is occurring on other planets (for which we have very little evidence), yet equivocates as to whether it is occurring right here on Earth (where we have overwhelming evidence).

Claim 40. "And what [the Greenhouse Effect] does – and this is still under debate. A lot of people act as if this is completely settled. A new book was just published with Dr. Ball and a group of other scientists called Slaying the Sky Dragon. And they actually talk about the fact that the greenhouse effect may not work at all like this. It may actually be quite different.

RESPONSE: Tim Ball's book has not been reviewed in any scientific journals, nor has the claims made within it been published in those journals. If their mathematics and science were sound then we would expect publications demonstrating this. In the meantime, the existing science on the mechanisms by which greenhouse gases heat the earth's lower atmosphere are still more than valid. Without Harris being more specific (and citing scientific studies) it is difficult to know what phrases like "it may actually be quite different" mean.

Claim 41. There's even a scientist at the University of Southern California – or sorry, UCLA, and he works with USC scientists – and this is George Chilingar, and you know what he says? He says that when the air molecules, the greenhouse gas molecules, absorb energy, there is a brief time in which they are more energetic than the surrounding air mass, and so they rise into the atmosphere. And then cooler air comes in from above, to fill in their place. And so, he's saying, that in fact the atmosphere may actually cool due to greenhouse gases. Now I don't entirely believe that..."

RESPONSE: It is difficult to verify what Chilingar has said without reference to his work. Briefly, he has published a series of modelling papers in which he seeks to redefine the greenhouse effect [61], [62]. That second paper has been rebutted [63], with the author of the rebuttal stating *"It is astonishing that the paper of Khilyuk and Chilingar (2006) (as well as Khilyuk and Chilingar 2004, for that matter) could pass the review process of a seemingly serious journal such as Environmental Geology. Such failures of this process, which is supposed to guarantee the quality of published literature, are likely to damage the reputation of this journal."* The response that Chilingar sent in to the journal [64] turned out to be a paper that was identical to a paper in a different journal [65]. This is gross malpractice in academic publishing. The response to rebuttal and the identical paper both eliminate the greenhouse effect from their models before claiming that the greenhouse effect does not occur [66]. Their later paper [64] and, by virtue of being identical, [65] appears to hinge on the incorrect premise that *"The proponents of [greenhouse gas] theory take into consideration only one component of heat transfer in atmosphere, i.e., radiation. Yet, in the dense Earth's troposphere...the heat from the Earth's surface is mostly transferred by convection"*. It is simply not correct to state that climate scientists ignore convection. Of course, since Harris does not even cite these studies, the students (who are not even science majors) cannot check for themselves.

Lecture 4: Geology

[In this lecture, we will respond to some comments made by Prof Bob Carter during a YouTube video that Harris shows. We will try to be clear who makes each claim]

Claim 42. [HARRIS]: "A geologist was telling me the other day, he said did you know that – this is Tim Patterson, actually – he was saying that did you know that coming out of the last glacial period there was a time period about 10,400 years ago where the temperature rose almost 100 times faster, in other words the rate of change was almost 100 times faster than what we've seen in the last century".

RESPONSE: Patterson is presumably referring to the end of the Younger Dryas at the beginning of the Holocene, 10,400 years ago. The Younger Dryas was a period of intense cooling seen across Western Europe and Greenland, with similar phenomena possibly seen in other parts of the globe [67]. It is currently thought to have arisen due to the slowing or stopping of the North Atlantic "Conveyor" (the thermohaline circulation commonly referred to as the "Gulf Stream"), possibly due to an influx of freshwater into the Atlantic from the North American ice sheet [67]. At the end of the Younger Dryas, temperatures rose around 7 degrees in around 50 years. Prior to the Younger Dryas, there were a series of so-called "Heinrich events" [68] which were accompanied by (geologically) rapid changes in temperature. These events involved the breaking-off of large portions of ice shelves in the Northern Hemisphere six times over the past 60,000 years and the release of huge quantities of sea ice and icebergs; for a review see [69]. However, the resolution of the data prior to the Holocene would make it difficult to determine the rate of change over a period as short as 100 years. Furthermore, we think we understand these events as well – they result from freshwater impulses into the North Atlantic which altered the ocean circulation. What is at issue in both of these examples is not the rate of increase in temperature but the principal forcings behind that increase. It is worth noting in Harris' comparison of that climate transition to contemporary warming, that we do not observe any such dramatic changes in ocean circulations today. Contemporary warming cannot be explained without reference to anthropological forcings [7–9]. This warming will eventually reach dangerous levels, irrespective of how quickly it gets there.

Claim 43. [HARRIS]: "Today, we're having extinction rates that are somewhat higher in certain species, but nothing like what we had in the geologic past".

RESPONSE: Extinction rates in the past are estimated to be on the order of 1 extinction per million species years (1 E/MSY). Much higher rates are only seen during mass extinctions, of which there have been five since the beginning of the Phanerozoic. Contemporary extinction rate estimates are an order of magnitude greater, depending on the taxon, and these will increase dramatically if threatened or endangered species are lost [70]. Bird species are currently thought to be going extinct at 85 E/MSY [71]. While we are not at the level of extinctions that would classify this as a “mass extinction”, rates of extinctions across taxa are vastly higher than background rates [72].

[HARRIS, in reference to the video by Bob Carter that he is about to show]: “I’m actually going to pause the video in a number of places because he makes what I wouldn’t consider mistakes exactly, but they are things that other scientists would disagree with.”

Claim 44. [HARRIS]: “Many people say that those who are on the climate deniers side of the debate they say that humans are not causing climate change. But no they’re not saying that, what they’re saying is that they’re not causing dangerous climate change. Very few scientists debate whether human greenhouse emissions are causing global warming. The question is whether it is significant enough to be dangerous. That’s the real question. Because, I mean, think about it: if it’s not dangerous then while it’s an interesting scientific question, it’s not really a policy question. It’s only when it becomes dangerous that it becomes a policy question. So that’s the real key to remember in all of these debates, yeah of course greenhouse gases cause warming, but is it dangerous, the amount that we’re causing, and that’s the key – that’s what we really have to focus on.” [emphasis in original]

RESPONSE: The dangerous implications of climate change have been extensively documented [28]. It is interesting how the deniers continually change their tune – now it is not that the climate is not changing (which some still defend) but that the changes are not dangerous. Of course, dangerous cannot be defined by science alone; it depends on what we value. It is also worth noting Harris’ acceptance of the greenhouse effect. Contrary to this statement, Harris later questions the existence of contemporary warming (see CLAIMS 87-90), and whether humans are the cause (highlighting potential roles for the sun, clouds, and galactic cosmic rays).

Claim 45. [CARTER]: “Carbon dioxide is not a pollutant”

RESPONSE: Carbon dioxide is a pollutant as it causes acidification of the oceans, disrupting the formation of biological structures in those environments. There is no denying that its major role is in the greenhouse effect where increasing concentrations warm the earth. However, this matches the definition of a pollutant given by the US EPA: "emissions of which... cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare" [19]. Furthermore, CO₂ causes acidification of the oceans with complex and extensive biological and chemical impacts [73]. In any case, this is pure semantics. See also "[Is CO₂ a pollutant?](#)" on Skeptical Science.

Claim 46. [CARTER]: "Is it warming or not? And I look at them and I say "It depends"" [demonstrates that the time range over which temperature series are plotted affects the trend]...and... " There are lots of places where temperature is increasing like this, here and here and here. This is absolutely not unusual." [emphasis in original]

RESPONSE: Carter correctly states that you can obtain positive or negative trends depending on where you begin the trend. There are times and places where the temperature rise is faster than the global average and times and places where it is slower. However, the overall picture is unambiguously one of warming. The Arctic is warming at least twice as fast as the global average [74].

Claim 47. [CARTER]: "There's nothing unusual about the late 20th century warm period".

RESPONSE: The unique aspect of late 20th century warming is that it can only be explained with the inclusion of anthropological factors [6], [7], [9].

Claim 48. [CARTER]: 45m36s "Solar physicists right now are predicting that there is a good chance that we are heading into another little ice age in the next 25 to 30 years."

RESPONSE: Models of contemporary climate cannot account for contemporary warming using only natural phenomena (including sun spots) [6], [7], [9]. Besides, solar activity has been declining over the past 30 years while temperature has continued to rise [48], suggesting that the past link between solar activity and global temperature no longer holds. See also "[Solar activity and climate: is the sun causing global warming?](#)" on Skeptical Science.

Claim 49. [CARTER]: "It's not going to get warmer next, it's going to get colder. It's not a matter of if, it's a matter of when."

RESPONSE: This is an assertion by Carter without evidence or even a reasonable argument. We have addressed the issue of solar activity, which we assume is the basis for his assertion, above.

Claim 50. [CARTER]: "Everyday in the newspaper I read about another idiot biologist who says that the world's biota is going to be destroyed by another temperature rise of a degree or two. It is complete nonsense."

RESPONSE: A series of studies have demonstrated coherent, global effects of climate change on biota [75] and predictive models have suggested that large numbers of species could be at risk of extinction [76]. We have already lost some species to climate change [77]. The fact is that the ecological and evolutionary implications of climate change are not yet understood. However, we can be pretty sure that they will be significant [78].

Claim 51. [CARTER]: "The planet biota that we have today grew up with and is adapted firstly in its genetic inheritance firstly to temperatures that are on average warmer than today, secondly by God you'd better believe that they're adapted to climate change because look what they've just been through [points at 8myr graph]. They can cope with rapid climate change. And thirdly, they're adapted to a world that is, on average, three degrees warmer than today"

RESPONSE: Carter's argument is flawed for a number of reasons. First, adaptations can be lost as well as gained so his argument that experience of a given climate in the past equips a species for the same effects in the future is not necessarily correct. Secondly, and more importantly, the world that the species are adapted to is not the same world that humans have created over the past few thousand years. We have seen extinctions due to climate change already [77]. In addition, climate change combines with other factors such as habitat destruction and pollution to create synergism between these extinction pressures [79]. Finally, rapid phases of climate change are almost always a contributing factor to the mass extinctions and mass depletions of the past few hundred million years [72].

Claim 52. [CARTER]: "Here is the satellite graph from 1979 through to 2005 and yes, if we wish we can fit a line. And lo and behold the line says on average it's warming at about

1.5 degrees per century, is that unusual? No. It's right within the geological envelope of change and it just happens to be warming – it could just as easily have been cooling."

RESPONSE: The current phase of warming fits extremely closely to the combination of natural and anthropogenic forcings over the past century [6], [7], [9]. This is not a random fluctuation as part of natural variation. It is also worth noting that Carter has been fitting straight lines to trends that are clearly non-linear, in contravention of good statistical practice.

Claim 53. [CARTER]: "There is no empirical data for the greenhouse hypothesis being true – the dangerous one – and if you test it against the kind of data that I have just given you [previous temperature records], it fails that test."

RESPONSE: The current phase of warming fits extremely closely to the combination of natural and anthropogenic forcings over the past century [6], [7], [9]. This is not a random fluctuation as part of natural variation. That there will be a range of dangerous consequences is extremely likely [28].

Claim 54. [CARTER]: "Three sovereign houses of parliament in three sophisticated scientific nations, western nations, have concluded that the alarmist case does not stack up. You'd think this would be greeted with clapping hands and 'well done them's. You'd be joking. This I might say is the first torpedo."

RESPONSE: The scientific consensus on AGW is all but settled [1–3]. Whether politicians agree or not does not influence that fact. It is worth noting that the governments of almost all nations are now seeking not for more evidence on whether climate change is occurring, but for options to limit and mitigate the climate change that is almost certainly occurring due to human intervention.

Claim 55. [CARTER]: "This [the iris effect] is an enormous torpedo because if this same mechanism occurs on an annual-decadal scale, it would account for 75% of the warming that is predicted to occur by the alarmist computer models. Now whether you believe those models or not is not important. Even if those predictions are right they don't take into account this mechanism"

RESPONSE: The iris effect [80] predicts a strong negative feedback role for clouds. This has been shown not to be the case [81–84]. Cloud feedbacks are at most too weakly negative to provide the effect that Lindzen proposes, and are potentially positive.

Claim 56. [CARTER]: “Now they get to that [the IPCC projections of between 1.5 and 4 degrees of warming] from one degree by considering the positive feedbacks which is the water vapour, as Chris has already explained, you get a little bit warmer because of the carbon dioxide warming then you evaporate more water that’s the more powerful greenhouse gas so you get warmer still. That’s true – in theory – but in the real world other processes come into play and they’re mostly negative. Particularly clouds – more water vapour more clouds, they bounce the light back to space, the low clouds, so you get cooling. And the climate system is highly homeostatic – it is self-regulating in this sense – take it away from its more or less stable up-and-down jiggling everyday... and it will always tend to return.”

RESPONSE: Regional cloud models have suggested positive feedback of clouds on regional temperature over the Pacific Ocean [11], [12]. The claim that the climate is homeostatic runs counter to the claim of common arguments of “constant change” and “it was warmer in the past”. The climate is sensitive to perturbation, sometimes over relatively short time scales, as shown by the effects of relatively small volcanic eruptions over the past few decades [85]. Even if we ignore the possibility that anthropological forcings on climate might negate climatological homeostasis, the question is not “will climate return to equilibrium?”, but “how severe will future climate change be before it returns to equilibrium?”

Claim 57. [CARTER]: “OK, so against that background you get the alarmist figures by invoking positive feedbacks and ignoring negative feedbacks, Stephen Schwartz, a very well respected climatologist published a new paper where he’s analysed, using empirical data, the amount of warming that we should get for a doubling of carbon dioxide and here’s his conclusion. He looks at the relationship between surface air temperature and ocean heat content and he concludes that for a CO₂ doubling you will get a degree of warming, which is right on the line of what that theoretical curve showed in the first place. IN other words, the positive and negative feedbacks cancel each other out. Here I’ve plotted that and you’ll see that even the error bars that only just overlaps with the error bars of the alarmist IPCC estimates so torpedo number 3 is another devastating torpedo. There’s no answer for this at the moment, this is good, sound, empirical science. It’s not arm-waving, it’s not a computer model, it’s empirical science.”

RESPONSE: Stephen Schwartz did publish a paper in 2007, and that paper did suggest a climate that was less sensitive to doubling in carbon dioxide than the IPCC reports had suggested [86]. However, this paper was roundly criticised by a number of researchers [87–89] on the basis of Schwartz’s modelling of autocorrelation of temperature through time. These criticisms led Schwartz to revise his own estimate of the effect of climate sensitivity from 1.1 ± 0.5 K to 1.9 ± 1.0 K [90]. This may not seem like a big deal, but his estimate is now within the error margin for the IPCC estimate (3 degrees [91]), suggesting yet more consensus on climate sensitivity. Neither Carter nor Harris mention Schwartz’s revised estimate (published in 2008).

Claim 58. [CARTER]: “It happens that there’s just been another paper published, a very important paper by Camp and Tung (2007) where they show that the relationship here, the two variables are the total solar irradiance the energy from the sun coming in at the top of the atmosphere, and the surface temperature near earth, and it turns out that there’s a bit of amplification and that we get this pattern here where on these are 11 year sun spot cycles that they’re tracking here and his scale, so we’re going from about -0.2 to +0.2, so we’ve got about a +0.4 degree being driven by solar variability for change in temperature. That’s not in this model – there it is plotted on the model. I mean how can you take these people seriously, let alone how can they get their papers published in Science and Nature? This is not science!”

RESPONSE: First, contrary to what Carter claims, patterns of solar activity are incorporated into models [6], [7], [9]. Secondly, the study by Camp and Tung that Carter cites supports a climate sensitivity of between 2.3 and 4.1°C [92], in line with IPCC estimates despite being derived independently of those other models.

See also, “[Do solar cycles cause global warming?](#)” on Skeptical Science.

Claim 59. [CARTER]: “Well there’s a gentleman who deserves a Nobel Prize, or a prize of some sort, called Anthony Watts who is an amateur – well he’s not amateur – he’s a weather forecaster in the States... [cites Watts] “Urbanisation has placed many sites in unsuitable locations – on hot black asphalt, next to trash burn barrels, beside heat exhaust vents, even attached to hot chimneys and above outdoor grills!”

RESPONSE: Some measurement sites do have shortcomings with respect to location. However, NOAA is aware of these kinds of problems and has responded by comparing the best 70

stations with the full 1218 station dataset and found almost identical trends [24]. Also, the BEST project found no evidence of an effect of the urban heat island effect on temperature trends [18]. See also [“Is the US surface temperature record reliable?”](#) and [“Are surface temperature records reliable?”](#) at Skeptical Science.

Claim 60. [CARTER] “Analysis of the warming showed that most of the warming was in winter, this step here, and the air conditioners weren’t turned on. That’s a big problem. A giant problem. So when you have a giant problem, you call in a giant to deal with them. Here he is, his name’s Steve McIntyre. He’s the dragon slayer of this nonsensical piece of propaganda called the “hockey stick”. Most people, having slain that giant and absorbed the amount of abuse he did over that would have retired. Not Steve McIntyre. He had a think about that...and he went back and looked at the data which is always a good thing to do and he discovered that at that time, because of preparation for the year 2000 computer scare, NASA, just by mistake it wasn’t sinister, restored after they’d corrected their software for Y2K they restored the wrong data stream, the raw data stream rather than the processed data stream, not only for this station but for a number of other stations in the US network. Torpedo number 6, and it’s a big one, here was the previous reconstruction of the US temperatures and five out of the top 10 temperatures in the last 100 years fell up here with this one, 1995, being the warmest ever. When you correct for these mistakes, which NASA now does, you take 0.15 degrees centigrade off most of this part of the graph, it reduces down here and now the cluster of hot years is in the 1930s, not at the end of the 20th century at all.”

RESPONSE: There are a series of related claims here. First, we can be fairly sure that the US temperature record is accurate, irrespective of station quality [24], [25]. Second, there was indeed a problem with a correction that NASA applied to data from the years 2000-2006 for the USA. James Hansen and colleagues had proposed mathematical adjustments to the US temperature network to account for (i) variations in times at which temperatures were taken, (ii) a more accurate evaluation of how urban/rural each site was, and (iii) a more flexible incorporation of this urban/rural effect [15]. However, it appears that these corrections were not applied and, when someone noticed in 2007, the correction was made. James Hansen responded personally (though not in the peer-reviewed literature) to set the record straight [93]. A reanalysis of the data with the correct correction demonstrated that there was little change to the temperature series. There were indeed a cluster of hot years in the 1930s, but this was a regional phenomenon restricted to the US. Globally, the correction had no noticeable effect whatsoever and 13 of the warmest years on record still fall in the 15 years since 1997 [94].

See also "[Is the US surface temperature record reliable?](#)" and "[Are surface temperature records reliable?](#)" at Skeptical Science.

Claim 61. [HARRIS] You're probably getting quite confused about which of these graphs are right, because I showed you the various updates that were done in the last few years, he's showing you different ones. I've asked a number of scientists over the past week, which of these graphs you believe. Because some show the most recent temperatures as slightly warmer than the 20s, some show that they're colder, and the general answer is that we don't believe any of them, so I don't honestly think that, when you're talking about 100ths of a degree change when the different versions of the same data are bigger in difference by far than the kinds of temperature change that you're talking about, I think that the whole system has to be re-evaluated, basically, because I don't think we really know how much it has warmed or cooled over the last 20 years. I think that it's really just a guess. And it's interesting because Phil Jones, the fellow who was the Climategate suspect, so to speak, and we'll talk a little about Climategate when we get to the political part of the course, he has still not revealed most of the locations of a lot of the world's historic data or how the urban heat island corrections were made. He still hasn't revealed that. New Scientist had an interesting article talking about a lot of the background of Climategate and Phil Jones and that and other sources have revealed that they've actually lost a lot of the original data and calculation methods, so I honestly don't think that any of these surface data measurements are to be trusted. Again, the temperature changes are so minute in the last 10 years, they're probably not significant anyways. I think you can say overall that it has warmed since the early 1900s, but quite frankly that's about all I think you can say."

RESPONSE: A recent reassessment of global temperature trends has concluded that there is a substantial warming signature of 0.911 ± 0.042 °C since the 1950s (95% confidence for statistical and spatial uncertainties) [22]. If climate were to stop changing now then we might not notice the difference, but there is no indication that it will stop changing any time soon.

Claim 62. [CARTER]: "Here's our temperature curve again, warming to 1940, cooling and warming. And the question is: is this warming in here largely due to the urban heat island effect that I've just shown you examples of? And virtually all experienced climatologists would say "yes", it's just a degree of how much. But studies were done which claimed to show that this curve has been corrected for the urban heat island

effect. Two of the keys studies were by Jones, who is British at a climate research centre in Britain, and his co-author Wang, a Chinese gentleman who published another paper in the same year in Geophysical Research Letters. These two papers said, and they are still relied upon today by the IPCC, the stations were selected on the basis of history, we chose those with few if any changes in instrumentation, location or observation times. Well they looked at 84 stations, for 49 of those, more than half, there is no historical record whatsoever. Nobody has the faintest idea of whether they've been moved or not, and most of them probably have. So the other 35 stations, more than half of those have been moved two or three times, one of them has been moved five times. There is no possible way that the statement I read you just now, that they selected the stations which had the best history of not being mucked-about to get their data from, could be true. Doug Keenan a British statistician has therefore recently the essential point here is the quoted statement cannot be true, they could not be in error by accident, the statements are fabricated. In other words, he is saying that this is fraudulent research. This research underpins the whole IPCC case that urban heat island effect does not affect that graph."

RESPONSE: It is worth filling in the studies that Carter cites, for completeness' sake: The two papers [95], [96] that used data from weather stations were both published by Wei-Chyung Wang, a senior researcher at the University at Albany, New York. Keenan made the allegation of research fraud in 2007 [97]. Specifically, Keenan alleged that Wang had knowingly misled the scientific community in thinking that the weather stations used in the analyses conducted in the first two papers had reliable histories which indicated a lack of disturbance. If such histories do exist, they have not been presented for scrutiny, despite the fact that it would clear Wang's name if they were. The lack of transparency in the way that the University at Albany dealt with the investigation left a lot of people on both sides of the climate debate unsatisfied. Of course, it is worth noting that, while this suggests questionable ethical judgement on the part of Wang, the science is still sound. The BEST project demonstrated that neither station quality [25] nor the urban heat island effect [18] have a significant effect on climate trends.

Claim 63. [HARRIS]: "It's very unfortunate, they're [earth scientists] very rarely included in the climate science meeting. If you look at the climate science meetings, you see meteorologists, and climatologists and lots of computer modellers, because they're doing a great deal of modelling, I mean that's basically what the whole scare is based on, it's based on models of the future, because nothing that we're seeing, very little of what we're seeing up to the present is indicative of unusual change, whether you are talking about glacier rate of melt or whatever, none of these things are particularly

unusual when you look at the actual observational data, and certainly the long historical data too. It's forecast to the future, and that's why we're going to dedicate pretty much a whole lecture to computer models. Because if that is the foundation of the scare then we'd better have a good look at them and see if they make any sense."

RESPONSE: Once again Harris states that the current phase of climate change is not unusual. However, he fails to inform the students that, while we understand past phases of climate change to be natural in origin, the contemporary phase of warming is largely due to anthropological forcings which will continue to influence climate into the future [6], [7], [9]. The earth scientists may not be "included in the climate science meeting" (it is unclear whether this is true) but they have every opportunity to make their case in the scientific literature.

Claim 64. [HARRIS]: "Now I wanted to talk a little bit about some of the problems here [with tree ring proxies]. Some people use tree rings as a proxy for temperature. And they just assume that it's a good temperature proxy. And in the Mann Hockey Stick that's exactly what they did for most of the last 1000 years. They took a range of proxies, tree rings being the most prominent one, and they said "OK, here's what it's showing for 900 years, and then it starts to go up" and then they stopped and what they did is they taped on, basically, the temperature record up to the present. Now some people said "well why did you stop, I mean trees are growing right up to the present. It's not like they stopped in 1900 when the thermometer record started. Why don't you keep going with your temperature proxy which they're using the tree rings as a proxy. Why don't you keep going to the present and see what it does. Here's what they found that it did: it went down.

This is really interesting, because we know that the real temperature actually went up because we have surface temperature measurements. But if you actually use the proxies that they were using over the past 900 years, tree rings in particular, what you find is that they go down as the temperature rises. Now how do you know that that didn't happen at other times in the past when there was not a correlation between temperature and tree ring width? They call that the "divergence problem" and if you're trying to use tree rings as a reliable proxy for this period, indeed that is quite a problem, isn't it? Because it totally diverges from the real temperature record. That's the point. They call this the divergence problem, and we actually have a paper on WebCT, it's not examinable, but it's on there for you to look at, it's very easy to read. It talks about the divergence problem. It also talks about another problem The tree rings are not always related to temperature in a linear sense In other words, as temperature rises, let's say

this is temperature, as it rises, a lot of trees show an increase in width of the tree ring but they get to a maximum and then they drop off. So let's say this is the tree ring width [indicates y-axis] let's say you measure a width right there, how do you know which side of the maximum you are on? So this is another real problem so some trees respond like this to increasing temperature. They rise to a certain point but then they drop off when the temperature gets too hot to be a good growing condition for that tree, it starts to drop off. You can't really use tree rings reliably for both those reasons."

RESPONSE: This decoupling of temperature and tree-ring records is known as the "Divergence Problem" and has been recognised in the literature since 1995. It is thought to be unique to the latter part of the 20th Century so it would not affect the use of tree-ring proxies before that date. The cause is thought to be a reduction in solar activity [57]. Tree rings are only one of a range of proxies, they are understood to have strengths and limitations, and are used accordingly [98].

Lecture 5: Glaciations and “The Ice Age”

[This lecture contains a guest lecture from Professor Ian Clark of the University of Ottawa. We shall make clear which claims are attributed to Prof. Clark and which to Mr Harris]

Claim 65. [HARRIS]: “So, the interesting question is, is the overall ice cover of the earth going down, and the answers I get from scientists is, probably not, OK.”

RESPONSE: Without more details, it isn’t possible to establish who these “scientists” are that are giving Harris his facts. We know that in Greenland ice is being lost and the loss is accelerating [99], most glaciers worldwide are losing mass and thickness and the loss is accelerating [100], and Arctic sea ice loss is accelerating and is faster than was forecast [101]. Harris is likely referring to the fact that only in Antarctica the sea ice level is actually increasing and has been doing so since the beginning of records in the 1970s [102]. This is thought to result from warmer oceanic water being trapped at lower depths due to weak stratification of the Southern Ocean which means that ice can continue to grow.

Claim 66. [HARRIS]: “You know, one of the things that people don’t realize when they read these articles in the newspaper about it being super warm in the arctic in comparison with past years, they have to ask in the global historic network how many data points, does anybody know this, how many data points are there for all of northern Canada, that’s used for the Global Historic Climate Network to determine whether the earth is warming or cooling? You know how many data points there are? One. They’re using one data point for the whole of northern Canada in the whole global historic surface, uh, temperature measurement and that data point happens to be at Eureka, OK, very far north. Eureka however, is what’s called a refugia. It’s an unusual region that is much warmer than most of the surrounding area and it’s called a refugia because in wintertime that’s where a lot of the animals go, OK, because it’s much easier to survive there. So when it comes to, um, global historic records, all of Canada being represented by one data point, and it’s an anomalous location, you know it’s really sad, because it certainly does make you question the global record.”

RESPONSE: Harris claims that there is only one weather station in the Canadian Arctic that can provide information about warming trends. This is incorrect. First, there are multiple weather stations in the Canadian Arctic. There are 42 weather stations that are part of the GHCN network in Canada above a latitude of 66.5 degrees and a further 7 that are located in the Arctic

portion of the USA [Data from the station inventory data for GHCN v.3, available at <ftp://ftp.ncdc.noaa.gov/pub/data/ghcn/v3/>]. Second, these form only a part of the 111 stations that are currently recording temperatures in the Arctic.

Claim 67. [HARRIS, displays graph with increasingly short geologic time periods]: "...and when you start looking at the temperature changes that people are getting excited about now, you know, a tenth of a degree, it does seem rather trivial when you look up here at five degrees and fifteen degrees of changes, uh, it sort of helps put things in perspective. But it also lets you see how [referencing a video shown in the previous lecture] Bob Carter was able to say, is it warming or is it cooling, you know? It depends. It depends what graph you're looking at, over what time frame, etc. OK."

RESPONSE: Carter correctly states that you can obtain positive or negative trends depending on where you begin the trend. However, even when taking natural forcings that have caused past climate change into account, contemporary warming can only be explained with the inclusion of anthropological factors [6], [7], [9]. Furthermore, we are not talking about a tenth of a degree – contemporary climate has warmed by 0.8 degrees globally and by twice that amount in the Arctic.

Claim 68. [HARRIS]: "When the next glacial starts is a good question. Certainly within 5,000 years Canada will be uninhabitable. I mean with the exception of some small regions in the Yukon that weren't covered with glacier, all of Canada will be covered with ice again, uh, within 5,000 years. But it could be 1,000, I mean it could be 500. We really don't know. The end of an interglacial is somewhat, well, you can see it varies all over the place. But certainly within 5,000 years from now, um, this isn't going to be a place to live."

RESPONSE: Harris is looking a little bit too far ahead. The glacial cycles may continue in the long-term, but we are more concerned with the rapid and unabating rise in global temperatures in the short- to medium-term. These are predicted to increase [9] to a level which could bring widespread hardship to our species, see Table 19.1 of [28].

Claim 69. [HARRIS, in reference to the fact that a student once said to him that some groups would have good reason to protest global warming because it would negatively affect them]: "But seriously, if um. There are very few examples in history where

warming has been bad for civilization, or for nature. OK. There are some and I put this out as a challenge to the class OK. In my very first year of teaching the course there are virtually no examples. Well there are some...If you could bring to, send to me by email, where warming has hurt society and has hurt civilization and hurt, uh, nature, I'll be glad to show people. But as we're seeing through the course, it's usually cold periods that are much tougher to get through, and I mean that for everything. You can be sure a polar bear, uh, is not too concerned if it's minus thirty instead of minus thirty five."

RESPONSE: There are a great many potential problems with warming, see Table 19.1 in [28].

Claim 70. [HARRIS]: "By the way, I don't know if you noticed, but Al Gore is now saying that the blizzard and the bad weather that we're now having right now in North America is caused by global warming. Um, so I, it's uh, it might be a future blooper topic, but I thought I'd ask some of the scientists, you know, what do you think about this, and uh, the answers I'm getting are right out of the swindle movie. You know, you have to realize that as things warm, the pressure differential, sorry, the temperature differential, and therefore the pressure differential, between the polar regions and the tropics, it actually reduces, OK. So, in a warmer world, there's less force driving extreme weather."

RESPONSE: It is clear that a warmer world will have more extreme higher temperatures with greater heat-related morbidity and mortality [103], a factor that Harris neglects to mention. In addition, while there is evidence that increasing temperatures could inhibit the formation of tropical storms (by enhancing vertical wind shear), which may act to decrease the frequency of hurricanes [29], studies of trends in the wind speed of hurricanes that do form suggests that there has been an increase in the intensity of tropical storms over the period of recent warming, and that that pattern is present wherever hurricanes are found [30].

See "[Extreme events increase with global warming](#)" and "[What is the link between hurricanes and global warming?](#)" on Skeptical Science.

Claim 71. [HARRIS]: "The Antarctic ice shelves they are actually growing in size. OK. Which is quite, sort of counterintuitive to what you would think when you read the media reports."

RESPONSE: We know that in Greenland ice is being lost and the loss is accelerating [99], glaciers are losing mass and thickness and the loss is accelerating [100], and Arctic sea ice loss is

accelerating and is faster than was forecast [101]. Harris is correct in stating that Antarctic sea ice seems to be increasing and has been doing so since the beginning of records in the 1970s [102]. This is thought to result from warmer oceanic water being trapped at lower depths due to weak stratification of the Southern Ocean. This means that ice can continue to grow.

Claim 72. [CLARK]: "...and where we have subsidence we have apparent sea level rise. So we're looking at some tide gauge stations which show sea level's coming up – oh, stop, sell your SUV. We're warming the climate and sea level's rising. No! It's rising as a residual effect of, um, the uh, the weight of ice that we had during the Pleistocene."

RESPONSE: Clark is wrong to say that the sea level rise observed in Canada is purely the result of subsidence. In general, subsidence is taken into consideration where it is present, and we have good evidence of sea level rise at tectonically stable sites [36]. There is evidence to suggest that this rate of increase is accelerating towards the end of the 20th Century and the beginning of the 21st Century [32].

Claim 73. [HARRIS]: "I heard that half of all the sea level, apparent sea level rise, in Halifax is due to the land actually falling. Is that the case?" Clark responds: "Yes. Ya, in fact Halifax is one of those stations where the land is subsiding."

Sea level rise during the 20th Century at Halifax (32cm [37]) is far higher than the global average (10-20cm [8]). The greater sea level rise at Halifax since 1920 is a combination of regional subsidence (1.6 ± 0.3 mm/yr, or 16 ± 3 cm per century) and a rate of local sea level rise that is consistent with the global average (~ 1.6 mm/yr, or 16cm per century) [38]. As such, Halifax is representative of the global trend in sea level rise, irrespective of the degree of subsidence that is occurring in that location.

Claim 74. [CLARK]: "My goodness, this ice sheet is melting. Sea level is gonna rise. You worried? You gonna lose your landscape. No! There's a very interesting effect. The ice that covers Greenland is a huge gravitational mass. It's pulling sea level up. So there's a distortion of sea level because of the ice. We melt that ice away, it goes into the ocean – sea level goes down."

RESPONSE: Global measurements and models of sea level rise have been shown to be accelerating [32], [33], [35] and continued glacial melt will only add to this. Clark is referring to

regional variation in sea level which modulates around the global average and this is, indeed, driven partly by isostatic rebound and other gravitational phenomena [104]. For a review see [105].

Claim 75. [CLARK]: "So, [referring to graph] so we're coming to the end of a 400 year [he means 400,000 year] cycle that was characterized by these sharp interglacials, and now the Holocene, and we'll look at, uh, Vostok has that long interglacial. And that's very close to what we had back here (referring to interglacial 400,000 years ago on graph) so if we go back through the Milankovitch cycles to a time similar to what we're entering into now and we see that maybe this interglacial [referring to interglacial 400,000 years ago on graph] characterizes the Holocene a little bit better than the Sangemon. So..." Harris interjects: "So it may be 5,000 years more. Ya." Clark responds: "Keep driving those SUVs."

RESPONSE: Milankovitch cycles result from changes in the location and orientation of the earth relative to the sun. These cycles have a weak effect that is thought to work in combination with albedo and greenhouse gases to drive long-term cycling of the climate. Harris and Clark are arguing that we will, in the next 5,000 years, be entering the next glaciation. However, the current phase of the Milankovitch cycle suggests that we should be cooling now during the winter [106] when in fact temperatures are increasing [22]. This, combined with the large forcings from anthropogenic factors relative to astronomical factors [6], [7], [9] suggests that we may be able to override astronomical forcings in global climate oscillation.

Claim 76. [HARRIS]: "Is it possible our CO₂ emissions could delay the onset of the next glacial, or is it that significant?" Clark responds: "Uh, you probably know better than me. My understanding is that CO₂ contributes in a very minor way. So, uh, a doubling of CO₂ might warm the planet, by uh, if we attribute full radiative, uh, full radiative of uh, energy, or the amount of radiative response to CO₂, that, that is possible it would raise temperatures by about one degree. Is that what you sort of read [asks Harris]?"

RESPONSE: Clark cites Stephen Schwartz's estimate of climate sensitivity [86] which was demonstrated to be wrong [87–89] and later revised upward by Schwartz himself to bring it in line with IPCC projections [90].

[There follows a series of related claims that we will take as one].

Claim 77. [CLARK, referring to graph]: “And so when we look at this we get concerned that it seems to be that changing CO₂ could be driving climate, and uh, on a cynical note I’ll say that if you read what Al Gore writes then that’s what you would believe, because he has been telling us that CO₂ has been driving climate over the ice age. Nothing could be further from the truth. CO₂ is changing with, with temperature because CO₂ is exchanging with the oceans. The colder we make our oceans the more CO₂ its, their gonna absorb. So, they suck up CO₂. So during glaciations atmospheric CO₂ goes down because its more soluble in the cold oceans.”

“We also get expanded carbon cycling in higher CO₂ during the interglacials, not only do the oceans de-gas, but the uh, the creation of biomass and respiration under warmer climate puts more CO₂ into the air. So CO₂ is being driven by temperature, and we can actually see that in the ice cores, and I’ll say right away that this is not an easy thing to do. When we were on Devon island icecap we were trying to look at that offset between the age of an entrapped atmosphere and the age of the ice, ‘cause we could date the ice but how do you know the air that you find in that ice, the ice gives us a temperature record, the 18O record, now we’ve got the CO₂ out of that same ice sample, but it doesn’t have the same age so we can’t correlate it. We have to correct it.”

[CLARK referring to Caillon et al.’s graph of mismatching CO₂ and temperature:] “And here’s what these guys found. There’s an offset of 800 years between the maximum temperature, when the temperatures are changing, and CO₂. So CO₂ is lagging, CO₂ only came up 800 years after, CO₂ is not driving temperature.”

[HARRIS] “So temperature goes up and CO₂ follows.” Clark responds: “Temperature goes up, CO₂ goes up, that’s been demonstrated in other cores since, but there’s always an increase in temperatures followed by increase in CO₂. And that makes sense, I mean it makes perfect sense. Why are we going to increase CO₂, how are we going to increase CO₂ concentrations. It has to be driven by temperature. If we warm up the planet, ice starts to melt, the oceans warm, they degas CO₂ so atmospheric CO₂, uh, comes up.”

RESPONSE: Clark is correct that on a geological time scale CO₂ is influenced by temperature. As the world warms and the planet moves into an interglacial, as a result of astronomical forcings (Milankovitch cycles), the amount of CO₂ increases and amplifies that warming. As the astronomical forcing wanes, the CO₂ levels drop and temperature also drops. However, there is a big difference between CO₂ *amplifying* global warming and CO₂ *initiating* global warming. Clark and Harris equivocate the two, thereby calling into question the role for CO₂ in driving global climate. In actual fact, it has been predicted [107] and well-described [47] that CO₂ lags

temperature rises in the past. The lag is thought to be caused by the slow vertical mixing that occurs between the decrease in the solubility of CO₂ in the Southern Ocean as temperatures increase [108] and subsequent out-gassing of the oceans [109].

In the case of anthropogenic global warming, rather than astronomical forces causing a release of greenhouse gases we have done it ourselves. This puts a different interpretation on the talk of “cycles”: previous cycles came and went with astronomical forcings via Milankovitch cycles. The earth’s tilt and distance from the sun resulted in small temperature changes which caused the release of greenhouse gases which then exaggerated those changes. Eventually the astronomical forcings declined, slightly cooling the earth and beginning the decline in greenhouse gases which eventually faded as the earth subsequently cooled. In the case of the present day, the peak of the Milankovitch cycle, the process by which we would usually expect temperatures to drop once more, has passed. Our artificial augmentation of greenhouse gas concentrations has perpetuated the warming that the natural cycles began.

Lecture 6: Glaciations and the Ice Age Part 2

Claim 78. "This is really important to understand when you're discussing with your other professors who may disagree with me, or with your fellow friends, or enemies or whatever. Logical fallacies permeate this debate..." "They're saying that you know, these oil companies and other, they're against it you know, they're denying climate change. Well of course, they have a responsibility to their stockholders to actually, you know, make their company prosper. And so if they don't know anything about the science their default position, that they're going to fall back on, of course, is that they don't believe it ,OK. Now that doesn't mean they're wrong though, OK, you have to actually listen to what's being said and make up your own mind."

RESPONSE: While the appeal to motive is a form of a logical fallacy, it is difficult to argue that the oil industry's lack of impartiality on climate change is not in some way morally questionable. Studies have highlighted the questionable rhetoric of the oil industry [110], [111] and variations between companies in their adherence to their environmental rhetoric [112]. Outside of the peer-reviewed literature, there has been a large amount of interest in leaked memos from within the oil industry. One, dated 1998, details an attempt to "develop and implement a national media relations program to inform the media about uncertainties in climate science; to generate national, regional and local media coverage on the scientific uncertainties," from the American Petroleum Institute [113]. This was to be run by Stephen Milloy, who has run similar campaigns focusing on muddying the waters concerning the harm caused by tobacco. Another, from the Intermountain Rural Electric Association (IREA) in 2006, detailed the potential costs of carbon taxes to the company and how they planned to fund a climate change denier to combat the problem [114]. More recently, another API memo detailed plans to create an astro-turfing campaign to attack climate legislation (for more details see Desmogblog, <http://desmogblog.com/oil-lobbys-%E2%80%98energy-citizens%E2%80%99-astroturf-campaign-exposed-launch>). This would involve bussing in company members to events stage-managed by a large-scale events company. In summary, the motive does not make them wrong, but it does appear to have made them adopt questionable PR practices.

Claim 79. "But most of the world was drier (during last glaciation?) , because you remember that we were talking about how when the earth gets colder the whole hydrological cycle, the evaporation, the raining and snowing, the whole thing slows down, OK. So you generally have less precipitation in a colder world, you have more precipitation in a warmer world. Now that's actually quite the opposite from what you

hear from many of the politicians, and many of the activists, they say, oh we're going to have warming, it's going to be drought. Well it is true that weather patterns will change and some regions that are not drought now, they'll become drought in a warmer world, but overall, if you average the world what you'll find is that there is lower precipitation, um, globally, OK. And that's, sorry... there's higher precipitation when things get warmer... "

RESPONSE: Global models predict that there will be slightly less frequent but longer spells of drought, and that (as Harris says) while some regions will become wetter and others drier, there will be a net drying. Furthermore, the proportion of the earth's terrestrial surface that will be subject to extreme drought conditions is projected to increase from 1% to 30% by the end of the 20th Century [115]. There is strong evidence that this will occur soon if it has not already begun [116].

Claim 80. "The Amazon jungle is a fairly new phenomenon, OK. There wasn't an Amazon jungle not too many millennia ago."

RESPONSE: This is untrue. The Amazon Rainforest has been geographically coherent for around 55 million years [117].

Claim 81. "When's the next glacial gonna occur? It's very, I mean, it could be starting now OK. We're at a time period where we're due for a glacial, based on previous interglacials, so it could be starting in the next century, it could start in 3,000 years, we really don't know."

RESPONSE: Orbital factors that contribute to Milankovitch cycles suggest that we should be cooling now, but anthropogenic forcings have reversed that trend and are continuing to warm the environment [9], [74].

Claim 82. "Global warming, if actually occurring, may present only temporary reprieve from glaciation."

RESPONSE: First, global warming *is* occurring [22]. Second, the temperature decline that would lead to the next glaciation appears to have been reversed by anthropogenic forcings [74].

Claim 83. "...right now we've accomplished, you know, with the rise in, uh, carbon dioxide, there's been about two thirds of all the warming that could occur due to a doubling of CO₂ from pre-industrial levels ...the bottom line is when you add a little CO₂ when the CO₂ level is low you get a big temperature change OK. When you go from 0 to say 10 ppm, but when you're up where we are now you're not getting much additional temperature change as a result of greenhouse gas rise."

RESPONSE: A review of two satellite measurements of outgoing radiation (i.e. the radiation that is not trapped in the "greenhouse") showed a decline between 1970 and 1997 [118]. This is empirical evidence for an increase in the magnitude of the greenhouse effect, not a decline as Harris suggests.

See also, "[Is the CO₂ effect saturated?](#)" on Skeptical Science.

Claim 84. [Referring to bills before the US senate] "They're always calling it CO₂ pollution. Global warming pollution. Well, it's not OK. And that's why it's so important for us to understand, is carbon dioxide from humans really causing a climate crisis, 'cause if it isn't then we can just forget it, OK? Because the bottom line is CO₂ is not a pollutant."

RESPONSE: Carbon dioxide is a pollutant as it causes acidification of the oceans, disrupting the formation of biological structures in those environments. There is no denying that its major role is in the greenhouse effect where increasing concentrations warm the earth. However, this matches the definition of a pollutant given by the US EPA: "'emissions of which... cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare" [19]. Furthermore, the acidification of the oceans by increasing atmospheric carbon dioxide certainly constitutes pollution [73]. In any case, this is pure semantics.

See also "[Is CO₂ a pollutant?](#)" on Skeptical Science.

Claim 85. "So, personally if we see an increase of CO₂ to, you know, to 450 then, I mean, I don't really care quite frankly."

RESPONSE: The 450ppm CO₂ level corresponds to the IPCC estimate of the level to which CO₂ would have to be limited in order to restrict warming below 2.1 degrees C. Harris might not care, but there are going to be a lot of people suffering if this kind of warming occurs; see Table 19.1 in [28]. Governments having looked at the evidence have made a "political" commitment to avoid more than a 2 degree rise in temperatures (above pre-industrial levels) in order to

avoid dangerous interference with the climate. Science has played a part in this determination but in the end it has to be based on what we value. A 2 degree increase does equate to rough doubling of CO₂ concentrations but it depends on the climate's sensitivity. Anyway, with 0.8 degrees in the last century and a further 1 degree in the pipeline we have little flexibility left.

Lecture 7: Causes of Climate Change Pt 1

[Because this discussion of galactic cosmic rays is all linked to the same concept, it is worth considering them as a single entity]

Claim 86.

- *“When a supernova goes off, it bathes the surrounding area with galactic cosmic rays. And in fact they go throughout the whole galaxy. They tend to be deflected at the end of the galaxy by the galactic field, magnetic field, so they can have a tendency to whip around the galaxy many times. Now, eventually they may actually hit an object. Not very often, of course, but sometimes they do. And they can cause changes to climate on the Earth when they hit the Earth.”*
- *“These galactic cosmic rays increase when we enter a galactic arm because when we enter an arm there are more stars.”*
- *[Cites study of iron meteorites by astrophysicist [Nir Shaviv](#) that] “...found regular, periodic variation in galactic cosmic ray flux over the last half billion years.”*
- *[Cites study by [Jan Veizer](#) who] “...found similar periodic relationship between temperature and time over the same time period.”*
- *“Every time the galactic cosmic rays are high and we are in a galaxy arm, temperatures are low.” [Notes correlation is not perfect, but] “...awfully coincidental that over such long time frames there would be such a good correlation.”*
- *“When the galactic cosmic ray changes, we have a change in low cloud cover. Theoretically it’s been forecast, they’ve actually produced it in cloud chambers and they can actually observe it in nature. So the way it works, they think, is this: We move into a galactic arm, we get more galactic cosmic rays, we get more clouds, and remember what clouds do. Nowadays we believe that clouds are a net cooling agent, so the earth gets colder.”*
- *“This appears to be the dominant [climate change] affect in this time frame.”*
- *“What this shows us is that over the last ½ billion years... we can say that there is a very good correlation between our position in the galaxy and temperature and we believe the connecting factor is clouds.”*

RESPONSE: Svensmark first proposed that galactic cosmic rays (GCRs) could alter climate [119]. The theory is that the magnetic field generated by the sun that surrounds the solar system (the “heliosphere”) reflects GCRs, so a weakening of the solar magnetic field will increase GCRs striking the earth. The strength of the magnetic field is correlated with other aspects of solar activity. These GCRs that strike earth seed low-level clouds which reflect solar

radiation, cooling the earth. Thus an increase in solar magnetic field strength decreases cloud seeding by GCRs and, therefore, decreases planetary albedo and increases planetary temperature. There are a number of problems with using this forcing to explain contemporary climate change:

1. Solar magnetic field strength has not increased over the past few decades [120].
2. GCR flux has diverged from global temperature trends since 1990 [121], showing the same pattern as solar activity [48].
3. There is evidence from models that GCRs cannot provide sufficient cloud condensation nuclei (points around which clouds form) to play a significant role in climate change [122].
4. A number of studies have disputed the size of the effect of GCRs and their ability to explain variation in clouds [123–126].
5. The link between GCRs and clouds was strong until 1990 and then diverged markedly [127].

In summary, then, GCRs may induce the formation of aerosols, but these aerosols do not have sufficient effect on cloud formation to affect climate. GCR flux shows no relationship with temperature or cloud activity over the past 20 years and can therefore be discounted as a primary driver of contemporary climate change.

See also, "[What's the link between cosmic rays and climate change?](#)" on Skeptical Science.

Claim 87. [Referring to chart showing 10 hottest year records and points out that recent years have been shifted up and previous years have been shifted down] "What exactly happened to make all the recent temperatures rise and the previous ones lower? I found out. The reason is, in the most recent data, that was displayed in that graph from lecture 1, they have completely removed any urban heat island effect. Now that, according to most scientists, is a big mistake. And naturally, if you take out the urban heat island effect and you assume the temperatures in cities are just about the same as the country and indicative of global warming, well then you're going to see the graph shift up. And that's what has happened."

RESPONSE: Harris is incorrect. It is true that the urban heat island effect can make cities warmer than surrounding rural areas. However, 42% of city sites are actually *cooler* than their nearby country sites, showing that the trend can go both ways. Scientists understand that the UHI effect exists and they control for it by comparing urban sites to rural, remote sites [15]. Studies comparing urban and rural sites have shown that there is no consistent difference in temperatures between urban and rural sites [16] and that the trends in all locations are similar (i.e. an increase in temperature during the latter part of the 20th Century) [17]. Finally, and most

comprehensively, the Berkeley Earth Surface Temperature Project found that “...urban warming does not unduly bias estimates of recent global temperature change” [18].

See also “[Does the urban heat island effect exaggerate global warming trends?](#)” on Skeptical science.

Claim 88. “When you look at most rural datasets, you don’t see global warming.”

RESPONSE: This is simply incorrect. Studies comparing rural and urban weather stations find negligible difference between the two and both show warming [16], [18].

Claim 89. “Almost perfect correlation between when global warming started to become serious and when they closed most of the country data stations.”...and...“I don’t know for a fact that that’s the cause, but a lot of scientists are now starting to say that the recent global warming since 1980 is not real – that in fact it’s an artefact of closing down so much or not using so much of the data from the rural, cold data stations.”

RESPONSE: It is unclear which “lot of scientists” are making this claim. There has been a graph circulating that was produced by Joseph D’Aleo and promoted by Ross McKittrick that demonstrated a decline in station numbers that occurred alongside an increase in average temperature [McKittrick’s graph is available at <http://www.uoguelph.ca/~rmckitri/research/nvst.html>]. However, that graph was never supported by an analysis of the differences between dropped and retained weather stations. These analyses have now been conducted and show that stations that have been dropped by NASA actually report a *greater* warming trend than those that were left in the dataset [For details of four separate analyses, see “[Why are there fewer weather stations and what is the effect?](#)” at Skeptical Science]. This is likely because the rate of global warming is greatest at higher latitudes where many of the dropped stations were located (cold but rapidly warming locations). Harris also fails to mention the satellite data that corroborates terrestrials measurements.

Claim 90. “If the global warming shape that we see here was true, you’d expect to see at least the general shape reflected in the United States. But you don’t. [Points out that it was just as warm in 20-40s as it is now]”

RESPONSE: This is an obvious non-sequitur. Global climate signals do not have to manifest in the United States. The US could be cooling, but the global warming signal could still be

increasing. In fact, the warm period in the 1930s in the US was a regional phenomenon caused by anomalous ocean temperatures and a slowing of the jet stream [128] – this is an example of cherry-picking the data.

Lecture 8: Causes of Climate Change Pt 2 – Greenhouse Gases

[Harris shows the class the video "Global Warming: Emerging Science and Understanding", which contains comments from a number of different individuals. Where we cite them, we will attempt to make clear who is speaking]

Claim 91. "There is no such thing as average temperature."

RESPONSE: This was stated in a paper published in 2007 [129]. The authors argue that (i) there are many ways to calculate an average and that some methods lead to negative trends while others lead to positive trends, and (ii) a "global" temperature is not physically meaningful because the earth is not in equilibrium. The first misconception of this paper is that the global average temperature series is actually calculated as temperature *anomalies* and not absolute temperatures. Second, it is reasonable to calculate regional temperature in local thermal equilibria (with some limiting assumptions), so regional temperature change can be documented. Third, the authors repeatedly make the mistake of using Celsius instead of Kelvin in thermodynamic calculations, leading to erroneous results. While the calculation of a global temperature is not straightforward, it is not as problematic as those authors make out and it is still informative in terms of indicating the Earth's overall energy balance.

For more details, see a series of (slightly irreverent) blog posts at [Rabett Run](#).

Claim 92. "It is low, cooling clouds that galactic cosmic rays help to cause... The cooling clouds actually dominate, so overall what you have is a cooling effect of clouds."

RESPONSE: First, there is no evidence that GCRs can cause cloud formation, or if they can then the scale at which they form is too small to have a significant impact [123–126]. Second, there is evidence that clouds will have a net positive effect on temperature, not a cooling effect [11], [12].

Claim 93. "Anthropogenic (human caused) sources may result in an increasing greenhouse effect and warming Earth."...and..."No question that there is some impact."

RESPONSE: This is one of the few occasions on which Harris admits to anthropogenic impacts on climate.

Claim 94. "In talking about greenhouse warming in general, it could heat up the Earth, generally speaking, a little bit more for several hundred years. Left on its own, however, the Earth would cool as we enter the next glacial stage, sometime in the next few thousand years. So even if the greenhouse theory of extreme warming was right, in the long run – and I'm not talking about the next century, but in the very long run – it could delay the next glacial onset. But that's not a good reason to perhaps cause problems in the short term."

RESPONSE: Temperature cycles on geological timescales are not really at issue when we are talking about the future of the human civilisation over the next hundred years. Besides, the current phase of the Milankovitch cycles that drive glaciations indicate that we should be cooling [106] when we are in fact warming [22]. This suggests that the "natural cycles" that Harris continually refers to have been overridden by the additional climate forcing provided by anthropogenic greenhouse gas emissions [9]. Not only will we not enter a new ice-age anytime soon but because of the inertia of the climate system we are likely to see changes (in temperature for example) which will be essentially irreversible on human time-scales. This is due to the long life-time of CO₂ in the atmosphere and the heat stored in the oceans.

Claim 95. "Until we understand natural cycles of climate without humans, it's very very tough to tease out what affect humans are having because it's much smaller. It's not the big carrier wave that nature is doing anyways, it's a smaller affect on top of that."

RESPONSE: We know the relative contributions of forcings to climate and we can only model contemporary climate change when we include anthropogenic factors [6], [7], [9].

Claim 96. "The climate problem is so difficult that we might never solve it."

RESPONSE: While climate is complex, we have nevertheless demonstrated our ability to model the climate system with a fair degree of accuracy. For example, many studies have used models to "hindcast", i.e. project backwards to explain past climate using the forcings that were present at that time [8]. Furthermore, the earliest global climate models (GCMs) have been demonstrated to match observed patterns of warming between 1988 and 2006 [130]. The incorporation of the details of clouds into these models will only enhance their predictive power, e.g. [11], [12]. Studies suggest that we can accomplish a restriction of carbon dioxide levels below 450ppm using current technology [131] and that this can be done at relatively little economic cost [132]. Indeed, the collateral benefits of reducing consumption and increasing

efficiency in terms of health, energy independence, air and water quality, and sustainability suggest that we should be carrying out most of these actions regardless. But we know from the increase in the concentrations of GHG in the atmosphere and the well-tested Greenhouse Effect (basic physics) that the climate will change, thus posing a threat.

Claim 97. "Anthropogenic production of N₂O, that's nitrous oxide, in contrast to NO₂. A very big difference. NO₂ is actually a pollutant, no question about it, Nitric Oxide is something we have to control. N₂O is not serious. Some people say that it's actually impacting the ozone layer, but the very fact that people have parties with this and actually make themselves high tells you it's not a particularly serious short term pollutant."

RESPONSE: Nitrous oxide has a greater forcing than solar variation and contributes to global warming as a greenhouse gas [91]. Harris claims that "some people say" that it has an effect on the ozone layer. This is a vast understatement. A paper published in the journal Science in 2009 described N₂O as "the dominant ozone-depleting substance emitted in the 21st century" [133]. This is clearly an important and serious pollutant.

Claim 98. "[Nitrous oxide] converts carbon monoxide to carbon dioxide, which of course is not a pollutant."

RESPONSE: Carbon dioxide is a pollutant as it causes acidification of the oceans, disrupting the formation of biological structures in those environments. There is no denying that its major role is in the greenhouse effect where increasing concentrations warm the earth. However, this matches the definition of a pollutant given by the US EPA: "'emissions of which... cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare" [19]. Furthermore, carbon dioxide causes ocean acidification, and therefore certainly deserves classification as a pollutant [73]. In any case, this is pure semantics.

Claim 99. "Nitrous oxide is an important greenhouse gas, but it's not really a pollutant, nothing in the realm of real pollutants."

RESPONSE: Again, this is an issue of semantics: the effects of N₂O match the definition of a pollutant given by the US EPA: "emissions of which... cause or contribute to air pollution which

may reasonably be anticipated to endanger public health or welfare" [19] through its greenhouse efficacy [133]. In any case, this is pure semantics.

Claim 100. "Most important greenhouse gas is water vapour."

RESPONSE: It is important to note that water vapour is the most dominant greenhouse gas. However its lifetime in the atmosphere is measured in days as opposed to that of CO₂ which is measured in millennia. Also, we have done nothing to increase water vapour concentrations. Indirectly they increase because a warmer atmosphere can hold more water vapour. This is a common red herring in the climate change debate. For the contemporary phase of warming, CO₂ is more important as it is this gas that is creating the positive feedback within which water vapour acts.

Claim 101. "Carbon dioxide of course is a greenhouse gas, but it is not a pollutant. it's invisible, odourless, it's essential to plant photosynthesis."

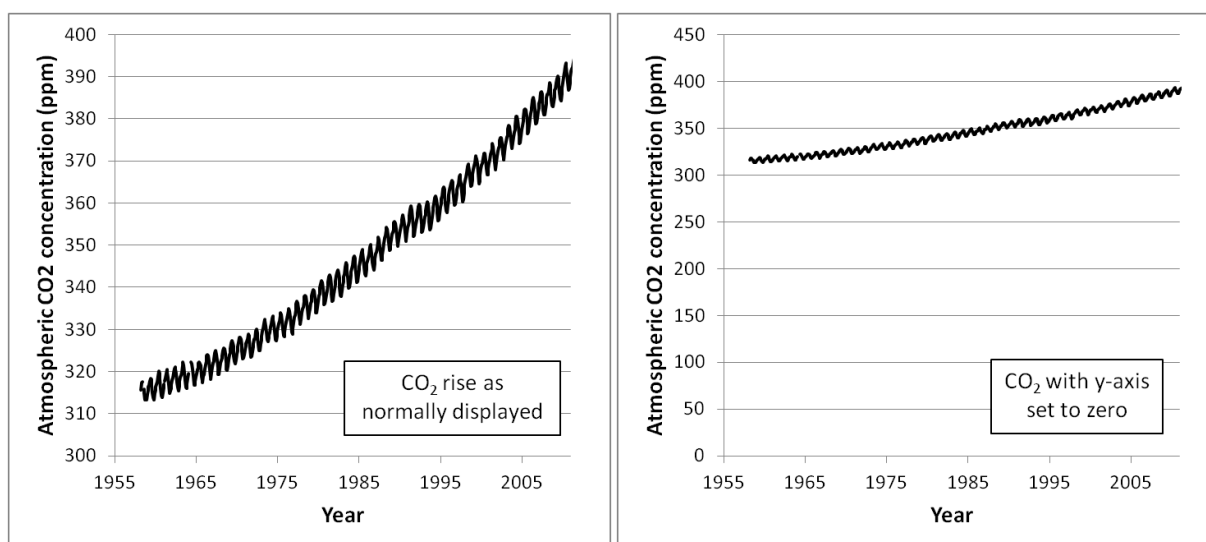
RESPONSE: Carbon dioxide is a pollutant as it causes acidification of the oceans, disrupting the formation of biological structures in those environments. There is no denying that its major role is in the greenhouse effect where increasing concentrations warm the earth. However, this matches the definition of a pollutant given by the US EPA: "'emissions of which... cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare" [19]. The effects of carbon dioxide on ocean acidification certainly qualifies carbon dioxide as a pollutant [73]. In addition, the argument that it is "plant food" (as one American senator once remarked) is somewhat misleading. Under certain conditions, increased CO₂ will increase plant growth. However, if CO₂ increases globally, the accompanying changes in precipitation and evapotranspiration will not necessarily benefit plants [134].

Claim 102. "Basically carbon dioxide is an aerial fertilization and you can see very clearly that not only plants growing in good conditions have an increase in yield, but plants growing in very dry conditions like in the desert actually grow better when there's more CO₂. So the bottom line is that if CO₂ enrichment continues, we'll have an easier time feeding the world's population. With population probably peaking around 9 billion, maybe we want to purposely increase CO₂. I'm sure a lot of agricultural scientists would say that. So it's really an important question: is it really going to cause serious

global warming? Because if it isn't, then let's just completely forget it. It's not a pollutant and it's probably a benefit."

RESPONSE: This is incorrect. The complex association of factors that come with climate change make it almost impossible to evaluate the effects of increased carbon dioxide on agricultural yields [134]. These factors include sea level rise, temperature, plant physiology, responses of pests and pathogens, regional variation in precipitation, and availability of other sources of water (e.g. glaciers). Irrespective of this, there is still the extremely serious issue of ocean acidification which is caused by elevated carbon dioxide [73].

Claim 103. Harris contrasts how CO₂ is "normally displayed" with rescaled y-axis to demonstrate the absolute extent of the increase in atmospheric CO₂ concentration [we cannot reproduce those plots for copyright reasons, but have redrawn them below]:



RESPONSE: Axes can be rescaled in whatever way an author chooses; this is just a graphical description of the data which does not alter the fact that the CO₂ time series is showing a strong and accelerating increase over time.

Claim 104. "Most of the recent increase is due to fossil fuel burning or deforestation – or maybe not. Because once again there's a big debate. A lot of people are saying well you know, as the ocean warms, it releases more CO₂. So there's other sources of CO₂. How much of this 35% rise is really due to humans? Now I always assumed, until a few days ago that most of it was. In fact, some people say all of it. Well in fact, I'm getting

emails now from scientists, one in particular from Poland, who just authored a paper with a guy from Norway, very leading scientists on CO₂ studies, who say that they've shown in fact the majority of the rise of CO₂ has nothing to do with humans."

RESPONSE: Harris relates conversations with scientists rather than referring to prevailing scientific knowledge, so it is difficult to evaluate his statements. CO₂ levels are the highest they have been for at least the last million years [135]. Analyses of isotopes of carbon in the atmosphere have proven that anthropogenic sources of atmospheric carbon are increasing [136]. Trends in the release of carbon from fossil fuels corresponds closely to the trend in overall increase in carbon release [91], while carbon emissions from land use change (principally deforestation) have remained significant but stable over the past few decades [137].

Claim 105. "One of the things I find astounding about this whole climate debate is that some of the most basic tenets – you know, the idea that CO₂ rise is mainly caused by humans, the idea that temperature rise is definite, its occurring, - many of these things are either not true or are simply unknown, or highly debatable."

RESPONSE: Harris is overstating the extent of the uncertainty associated with the debate. Temperature rise is occurring [22], and rising human contributions to increasing CO₂ explain the rising atmospheric trends in CO₂ [91], [136]. To quote the IPCC, "warming of the climate system is unequivocal", and "...most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations" [5].

Claim 106. "There isn't a good correlation between temperatures and CO₂ over the record. But right now, seen in a geologic sense, we're at one of the lowest levels of CO₂ in the whole geologic record."

RESPONSE: It is unclear how the first part of this claim can be reconciled with Harris' earlier conversation with Ian Clark where they discuss the association between CO₂ and temperature, noting that CO₂ lags behind temperature [47], [107]. We are at the highest level of CO₂ concentrations in the past one million years, which is certainly a reasonable length of time even "in a geological sense" [135].

Claim 107. "When CO₂ levels were at their highest level in the last ½ billion years, we had the coldest time in the last ½ billion years."

RESPONSE: The simple response to this is that on geological time scales CO₂ is not the only contributor to climate change. Tracing back through the Phanerozoic Era (to the base of the Cambrian), CO₂ did show far higher concentrations (possibly up to 5,000ppm compared to 280ppm in pre-industrial conditions) [138]. However, this is thought to be due to a very active period of volcanic activity as the Earth was being formed. When we look closer to the present, around 3 million years ago, we find similar level of carbon dioxide (365 - 410ppm) to current conditions which prevailed for thousands of years. The result was Arctic temperatures 11-16 °C warmer than present [139] and sea levels 25m higher than present [140].

Claim 108. [KRISTIE PELLETIER, in the video "Global Warming: Emerging Science and Understanding" which was shown during the class]: "Rather than a dangerous pollutant, carbon dioxide could be called a miracle gas that acts as a free fertilizer to help alleviate famines in regions of the world that have frequent droughts and famines, all without causing harm to the environment or people."

RESPONSE: Carbon dioxide is a pollutant using the definition in [19], particularly in the context of ocean acidification [73]. Claims that carbon dioxide will solve world hunger are clearly spurious, given the complexities associated with predicting the effects of climate change as a whole on plant productivity [134].

Claim 109. [PATRICK MICHAELS]: "The evidence that increasing carbon dioxide in the atmosphere is going to cause a disaster is somewhere between slim and none. However, the evidence that it's doing a good thing by lengthening the growing season and making plants grow better is somewhere between large and overwhelming." Harris, referencing the Michaels quote, says that it is not a politically correct thing to say, "but nevertheless that's what the scientists in many cases are saying, that in fact the CO₂ levels are not something that we should be in any way worried about."

RESPONSE: Once more, carbon dioxide is a pollutant using the definition in [19], particularly in the context of ocean acidification [73]. Claims that carbon dioxide will solve world hunger are clearly spurious, given the complexities associated with predicting the effects of climate change as a whole on plant productivity [134]. Harris needs to cite studies and not the personal communications from scientists in order for us – and his students - to properly verify his claims.

*Claim 110. "CO₂ from fossil fuels is by far the leader of CO₂ production of humans for now."
"No question there has been a rise, but as you just saw in the video, that rise is probably not a significant problem." Slide text reads: "Human CO₂ production comparatively small."*

RESPONSE: CO₂ levels are the highest they have been for the last million years [135]. The reason for this recent increase is that anthropogenic carbon sources are modifying the natural flow (the carbon cycle) in which natural emissions were balanced by natural absorption. Analyses of isotopes of carbon in the atmosphere has demonstrated that anthropogenic sources of atmospheric carbon are increasing [136]. Trends in the release of carbon from fossil fuels corresponds closely to the trend in overall increase in carbon release [91].

Claim 111. "If you actually start at 0 and you add a little bit, say 20 parts per million of carbon dioxide, you get a big temperature rise. But as you add more and more carbon dioxide the amount of additional temperature rise you get gets increasingly smaller."

RESPONSE: A review of two satellite measurements of outgoing radiation (i.e. the radiation that is not trapped in the "greenhouse") showed a decline between 1970 and 1997 [118]. This is empirical evidence for an increase in the magnitude of the greenhouse effect, not a decline as Harris claims.

See also, "[Is the CO₂ effect saturated?](#)" on Skeptical Science.

Claim 112. "The debate centres around what are called feedbacks. What they're saying on the side of the IPCC and the side of Al Gore, is they're saying, as the earth gets warmer, slightly warmer as a result of CO₂ rise, that causes increased evaporation, that makes more clouds, and more water vapour in the atmosphere and so that actually warms the Earth a bit more because clouds and water vapour are a greenhouse gas." "They say that's a positive feedback. That is why the models actually show significant rise in temperature with increasing CO₂. It's not this direct effect, it's the positive feedback of more and more water vapour causing more and more greenhouse gas, and more and more warming. However, as I showed you earlier, the net effect of clouds is actually shown to be negative." "The feedback overall from increasing water vapour is negative"

RESPONSE: Harris is correct in stating that CO₂ is linked to climate largely through its amplifying effects on the forcings due to water vapour. However, the feedback from clouds is actually thought to be slightly positive, if anything [11], [12].

Claim 113. "The plants are water starved right now. They can't actually process photosynthesis as fast as they could if there was more water in the atmosphere. So the global terrestrial ecosystem is in currently a state of water deficiency. So what would happen, is if it got warmer, there was more water in the atmosphere, then plants would in fact accelerate in plant photosynthesis and so what you would end up with is more CO₂ would be pulled out of the air and that again is a negative feedback."

RESPONSE: This claim comes from a 2003 paper which suggests that plants could constitute an increasingly effective carbon sink [141]. However, this mechanism, even if it could be demonstrated beyond theory, would not necessarily hold under the complex changes that would be brought about by climate change [134].

Lecture 9: Causes of Climate Change Pt 3 – Celestial

[This lecture contains a video of a lecture by Professor Tim Patterson of Carleton University. We shall make clear which claims are made by Harris and which are made by Patterson]

[As with the previous claim regarding GCRs, there are a series of statements leading up to the claim which are relevant - we shall consider them as a unit]

Claim 114. [PATTERSON]: "The sun's energy is known to fluctuate periodically" and "quite considerably." "How can we reconcile, then, only a 0.1% variation in energy, which is allegedly insufficient to cause any of the temperature record changes that we see, with what we actually see? So obviously something is in there, and what we had to have was an amplifier. It was just by luck about the time that our fisheries results were starting to come out, new papers began to appear which suggested about how we could have an amplification of that slight variation across the sunspot cycle and how that could influence climate."

"There is a 15% variation in cosmic ray flux penetration between a solar maximum and a solar minimum and this is a correlation also with clouds." 1.7% variation in low clouds. "That 1.7% variation in clouds across the sunspot cycle is equal to 1.3 watts per square meter, which is the equivalent of about 85% of what the International Panel on Climate Change estimate for the effect of all, the total effect of carbon dioxide since the beginning of the industrial revolution... so across one sunspot cycle that's quite a variation."

"We've talked about going across the sunspot cycle and we have a very slight variation in energy, a 1.4 watts/sq metre. We've also told you we have a variation in cosmic ray flux, which mysteriously also correlates with the sun spot cycle. We also have a variation in cloud formation, which also varies with the sunspot cycle, so what gives? How are they all related? It can't be coincidental.... Something has to be interacting here."

"We have galactic cosmic rays are whacking us all the time. As you sit, you are being hit with galactic cosmic rays in your seat right now. And that, coming in here, they influence cloud formation." Add to this the sunspot cycle. "As you move from a trough, more flares, slightly more energy production. What that does is basically, the sun is hitting the earth, it begins to have an influence upon our cosmic rays. It begins to divert

some of those cosmic rays away from the earth and basically if you divert cosmic rays away from the earth what's going to happen to cloud formation? Less. And that is what the correlation is. This is the amplifier that we've been talking about."

RESPONSE: Svensmark first proposed that galactic cosmic rays (GCRs) could alter climate [119] and a correlation has been proposed between climate and GCRs [142], although this correlation has been disputed a number of times [143–146]. The theory is that the magnetic field generated by the sun that surrounds the solar system (the “heliosphere”) reflects GCRs, so a weakening of the solar magnetic field will increase GCRs striking the earth. The strength of the magnetic field is correlated with other aspects of solar activity. These GCRs that strike earth seed low-level clouds which reflect solar radiation, cooling the earth. Thus an increase in solar magnetic field strength decreases cloud seeding by GCRs and, therefore, decreases planetary albedo and increases planetary temperature. There are a number of problems with using this forcing to explain contemporary climate change:

- Solar magnetic field strength has not increased over the past few decades [120].
- GCR flux has diverged from global temperature trends since 1990 [121], [147], showing the same pattern as solar activity [48].
- There is evidence from models that GCRs cannot provide sufficient cloud condensation nuclei (points around which clouds form) to play a significant role in climate change [122].
- A number of studies have disputed the size of the effect of GCRs and their ability to explain variation in clouds [123–126]. Recent results from CERN [148] and from modelling studies [149] seem to support this relatively small effect, if it exists at all.
- The link between GCRs and clouds was strong until 1990 and then diverged markedly [127].

In summary, then, GCRs do induce the formation of aerosols, but recent studies suggest that these aerosols do not have sufficient effect on cloud formation to affect climate. GCR flux shows no relationship with temperature or cloud activity over the past 20 years and can therefore largely be discounted as a primary driver of contemporary climate change.

See also, “[What’s the link between cosmic rays and climate change?](#)” on Skeptical Science.

Claim 115. “They’re predicting that the next sunspot cycle is going to be a really really weak one. I know at the present time the current consensus is that we’re moving into intervals of unprecedented warming. But all I have to do to talk about consensus is: anybody remember back to Y2K? And the great consensus the night before of what was going to go on with Y2K and what happened the next day. Well the global warming scare now, no matter what happens the next day, there’s never a next day, you can’t just have it

turn off like Y2K. But anyway. In addition to worrying about warming, I think that you need to think about what would happen if things got colder. And if you look at the solar record we have, it could be serious times as we move forward."

RESPONSE: Models suggest that only with the inclusion of anthropological factors can we adequately account for the causes of the contemporary phase of climate change [6], [7], [9]. In other words, patterns of solar activity simply are not the principle forcings behind contemporary climate change. We took enormous steps to ensure that Y2K would not cause disruptions. We saw the threat and we acted. It is the same with climate change. The longer we delay taking action the riskier and costlier it will be to fix.

See also "[What does past climate change tell us about global warming?](#)" at Skeptical Science.

Lecture 10: Atmosphere and Ocean Circulation

[Harris shows a video featuring Tad Murty from the University of Ottawa. We shall make clear which comments are by Harris and which are by Murty]

Claim 116. [MURTY]: "All the importance is given to the atmosphere, and very little to the ocean. When really it should be the opposite." Harris interjects: [Slide shows ocean temps going down over time at each depth] "Overall, we've seen, certainly, in the biggest heat reservoir on the earth, we've seen steady cooling over many millions of years. It's too bad you don't hear that more often when the media report on overall climate trends on the earth. This is the biggest heat reservoir and it's been getting steadily colder."

RESPONSE: It is incorrect to say that scientists do not consider the ocean and also incorrect to assert that it is cooling. Harris may be referring to a study of 4.5 years of data which showed cooling in the upper 700m of ocean [150]. However, this is the opposite of what was found in a study of variation between 1955 and 2008 of the upper 700m of ocean which demonstrated an approximately linear warming trend [151] (also seen in estimates of ocean heat content [152]). What Loehle observed was a short term cooling event which was part of longer term warming - this short term event arises because the warming trend is not monotonic. In addition, other studies which have attempted to replicate Loehle's work have found different results [153], which may have resulted from issues with data collection from the monitoring system (ARGO floats, not fully rolled-out until 2007).

Claim 117. [HARRIS]: "Some people think it [the North Atlantic Oscillation] is the cause of a lot of the arctic ice melt that we've seen over the last 15 years." ...and..."some people believe that this influx of warm water to the north is one of the reasons that we're seeing more ice melt. If you actually look at a graph, what you'll find is that there's been an abnormally - a long period of time where the north Atlantic oscillation has been in a positive phase, ever since about 1975. We don't know why that's happened but indeed it has and some people have said that has pulled more hot water into some of the arctic regions. Because the pressure gradient has become greater here. That's one of the possible effects. We don't know how much it affects arctic sea ice. I sent around a number of emails to people and they say yes, we think it does, but they don't know how much."

RESPONSE: Trends in sea ice extent have only been monitored since 1978 so looking at the influence of irregular climate oscillations like the NAO has been difficult. A study in 1999 stated that “20 years are inadequate to establish that this is a long-term trend rather than reflecting decadal-scale atmosphere-ocean variability such as the North Atlantic Oscillation” [154]. However, a later study using a longer dataset concluded that “the fact that over the past few years, sea ice coverage has continued, overall, to decline despite changes in the modes of the AO and NAO and in the predominant wind patterns suggests that at this point the warming conditions may be overriding the oscillations” [155].

Lecture 11: Climate Change Politics and Tsunamis & Ocean Surges

[This lecture contains comments from Professor Tad Murty of the University of Ottawa, we shall make clear which comments relate to Harris and which to Murty]

Claim 118. [HARRIS]: "Next week we'll be actually analyzing how many of the scientists in the IPCC actually agree with, are known to agree with, the principle statements that humans are causing most of the climate change. And I think you'll be astounded to see. It's not like half, or a quarter or a tenth. It's way lower than that and I won't give it away. It's a very small number of people who actually study what are called attribution. In other words, yeah, we're seeing this climate change, but why is it happening? Very small number... And I'll give it away. 2.5%. About two and a half percent of the 2500 scientists who are supposedly agreeing with the IPCC statements – only about 2.5% even commented on that section of the report."

RESPONSE: It is, indeed, incorrect to state on the basis of the IPCC report that "2,500 scientists agree that humans are causing climate change". However, it is also incorrect to imply that "because only a few dozen scientists worked on the attribution section of the IPCC report, there is no consensus on attribution within the climate change community". There are a number of points to be made here. First, 2.5% of 2500 scientists is still 63 of the world's leading climate scientists (for comparison, most scientific publications are only reviewed by 2 or 3 scientists). Second, a survey of climate scientists' personal opinions [1–3] and a review of the peer-reviewed literature [4] both emphasise a high degree of consensus. Third, the dichotomy between "agrees with" and "disagrees with" is clearly false. There are a range of potential stances to take on the basis of the different aspects (mitigation, attribution, adaptation, impacts) of the IPCC's report. In addition, more recent surveys of scientists have suggested that some dissent from the IPCC's findings because those findings are too *conservative*, particularly in the case of sea level rise and Arctic sea ice melt [2].

Claim 119. [HARRIS]: "The IPCC's Second Assessment Report asserted that the "balance of the evidence" – not all of it, but the balance of it – "suggests" – doesn't prove – "a discernable human influence on global climate." Now, doesn't say that it's going to be catastrophic, doesn't say that we're the major driver or that we could have any chance at stopping it. But I just find it funny that when you read these documents and you see four conditional statements in one little statement."

RESPONSE: The IPCC was stating a conservative finding within the bounds of statistical probability. To state anything with certainty is not the domain of science. In contrast, the Fourth Assessment Report states “Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations” [91]. That “very likely” is a carefully calibrated assessment which means there is at least a 90% level of confidence. Furthermore, Harris’ reference to the Second Assessment Report rather than the Fourth leaves students unaware as to the level of confidence in the climate science community regarding anthropogenic global warming. The SAR was released in 1996, while the most recent was published in 2007. Much has changed in 11 years, as the contrasting statements show.

Claim 120. [HARRIS]: “The governments had produced the summary for policy makers and it had already made announcements that were quite different to this. So the scientist, Benjamin Santer was told, ‘go back and change the science.’” [See slide for quote change.] “That’s the beginning of when the IPCC started to become a somewhat suspect organization in the eyes of those people understood it properly.” [Harris shows two versions of the conclusion, first “the original draft submitted by Dr Benjamin Santer”:

“Finally we have come to the most difficult question of all: ‘When will the detection and unambiguous attribution of human-induced climate change occur?’ In the light of the very large signal and noise uncertainties discussed in the Chapter, it is not surprising that the best answer to this question is, ‘We do not know’”

...and then the version “changed by Santer to accommodate the SPM [summary for policymakers]”:

“The body of statistical evidence in Chapter 8, when examined in the context of our physical understanding of the climate system, now points toward a discernible human influence on global climate.”]

RESPONSE: The “Chapter 8 Controversy” was a storm in a teacup but a storm that, nevertheless, rages on 17 years later. The issue is the summary for policymakers (SPM) which condenses the 2000 pages of dense, technical literature review into a more-digestible 4 ½ pages (three SPMs, one for each working group). Days after the formal release of the Second Assessment Report (SAR), Frederick Seitz, without consulting IPCC authors (of which he was not one) and without being present at any IPCC meetings, published an op-ed in the Wall Street Journal declaring that the report constituted “A Major Deception on Global Warming”. This hinged on the changed passage above and whether or not it had violated the IPCC procedures for modification. Ben Santer responded immediately in a letter co-signed by 40 other IPCC

authors stating that the changes were made *at the behest of* and not *in contravention of* peer review procedures in the IPCC. The decision to change the passage was a standard edit, like many others during the writing process, designed to properly reflect the tone of the SAR. Anyone who is worried about covering up the consideration of uncertainties only need read the SAR and the SPM to see the lengths to which the authors outline the various areas of imprecision and doubt. However, the bottom-line of a “discernible human influence” remains. For a further discussion of the details of the case, see [156], and for Ben Santer’s version of events, see a talk posted at http://cyperusmedia.com/pages/shs_memorial1/symposium27.html#vid4.

Claim 121. [MURTY]: “The global activity of tropical cyclones and hurricanes. Now it is at a 30 year low. What you see in the media or with the politicians – the whole thing is complete hogwash. The truth is that hurricanes are at a 40 year low.” “If you take the US alone, it is at a 100 year low. So don’t believe what you see on TV or newspapers or radio or media, what the politicians or environmentalists are telling you. The reality is hurricane activity is practically dead. Is it going to be dead all the time? No, of course not. A time will come when we’ll have a lot of hurricanes again. But this will happen due to natural causes. Humans have nothing to do with it.”

RESPONSE: It is extremely difficult to determine past trends or predict future patterns in hurricane or tropical storm frequency or severity. This is because we have only had satellite records for the past 40 years. Furthermore, patterns that are observed tend to be regional. For example, there is some evidence of an increase in the number of tropical cyclones in the Atlantic [157], but there is no consistent global pattern. This is unsurprising, given the fact that increased temperatures may actually reduce the incidence of hurricanes through increasing vertical wind shear and the effect that this has on disrupting hurricane formation [29]. However, there is evidence for an increase in the energy dissipation of hurricanes, which is a product of greater wind strength and longer duration [30]. This pattern of decreased frequency and increased severity is projected (tentatively) to continue [31], although there remain uncertainties as to the response of tropical storms to temperature which will determine whether or not anthropogenic global warming has any influence [158]. Stating that we are currently at a 30 year low globally or a 100 year low in America is unwise, given the uncertainties outlined above. In fact, there is some evidence that number of tropical storms globally and the number of landfalling American tropical storms from the Atlantic were both higher in the 21st century than during the 20th century [31]. See section 10.3.6.3 in [91] for a discussion. See “[Extreme events increase with global warming](#)” and “[What is the link between hurricanes and global warming?](#)” on Skeptical Science.

Claim 122. [MURTY]: "I won't go into details on climate change because you have a whole course. The only thing I want to say is this: the media and the politicians and the environmental groups make you sort of feel that climate change is something that is recent. That's nonsense. Climate change has been happening continuously, non-stop for 280 million years. That is when our atmosphere first came into existence."

RESPONSE: Murty states that the only thing constant about climate is change. The fact that climate has changed dramatically in the past only goes to demonstrate the sensitivity that the climate system exhibits. This makes it more reasonable to assume that humans are capable of perturbing that system. In fact, models suggest that only with the inclusion of anthropological factors can we adequately account for the causes of the contemporary phase of climate change [6], [7], [9].

See also "[What does past climate change tell us about global warming?](#)" at Skeptical Science.

Lecture 12: Summation

[There are a number of claims here which all hinge on one point so we shall deal with them together]

Claim 123. [referring to Canada's "Clean Air Agenda"] "Let's look at this and see how much of this is trickery and how much of this is real." "When they get to the first words they use the wrong words. Greenhouse gas emissions has nothing to do with clean air because as you know 85% of our emissions aside from water vapour are carbon dioxide, which is not going to make it unclean. So that's wrong. We'll just continue here and see if there are any other mistakes. There just might be. 'Air pollutions are harmful to Canadian's health, degrade the environment and' – nope, they don't contribute to climate change , except for soot, which may cool it a little bit – 'the government is renewing funding for the Clean Air Agenda with an increased focus on regulatory actions as the cornerstone of Canada's approach to climate change and clean air.' – whoa, no. Shouldn't be there. It's clean air, remember? We're not talking about climate change. Like they should have two different parts to the budget. One that deals with climate change that we can agree or disagree with and one that deals with clean air. See, the trouble is they mix them all up. So then people say, oh are you against clean air? Well of course not. So by mixing it up it kind of diffuses a lot of their opponents."

"That number, \$252 million, is for two things: climate change and air quality, and they're not the same. The next one of course shouldn't be under this category at all. A program helping people adapting to climate change. That's great, but it shouldn't be in this particular bill at all. It should be somewhere else. It doesn't have anything to do with clean air. And of course this one here, \$25 million over 2 years to advance Canada's international engagement on climate change has nothing to do with clean air."

"It's sort of the politically correct thing to do – to combine climate change and clean air so you can slip it through and people won't object."

"So that's our financial budget. I'm not too impressed because they've just simply bought into a lot of the language of the debate without actually tell us what they're really going to do with respect to pollution versus the fictitious climate scare. And I call it fictitious because of course while adaptation is important, it should be in another part of the budget, it shouldn't be in the clean air agenda."

RESPONSE: This argument seems to hinge on the “carbon dioxide is not a pollutant” argument. However, it is a pollutant under the US EPA’s definitions [19] and its contribution to ocean acidification certainly make it a pollutant under still broader definitions [73].

Claim 124. “You know, we haven’t had any warming since 2003 and CO₂ is still rising. I know that’s not climate, but still it just doesn’t really make a lot of sense.”

RESPONSE: Harris makes an assertion that isn’t valid even within his own reasoning. His assertion is correct in the sense that there has been little warming since 2003. However, we understand that this is the result of a combination of natural climate variability mostly related to ocean heat uptake, reduced solar activity and a strong La Nina phase. When these effects are accounted for, the warming trend continues [159]. This is more concerning, because when those mitigating factors cease, we should see a stronger upward trend in warming. Recall also that in an earlier lecture he claimed there was no such thing as a global average temperature; if he really believes that to be true, it is not possible to draw any conclusions about temperature trends since 2003. Most importantly, it is not meaningful to discuss climate on such short timescales. Choosing 2003 as the start date is an obvious example of cherry picking; in fact, the last decade is one of the warmest on record.

Claim 125. “We’re going to ask ourselves: is the IPCC a meaningful indicator of world scientific opinion on the causes of, or future of, climate change? Well, it turns out it isn’t. It’s accepted as the Bible for many people as the absolute most authoritative body on climate change. It’s certainly the most authoritative. But it’s also in many cases is the most wrong. But regardless, most climate scientists are not in the IPCC.” “It’s not a consensus of world scientists because the vast majority of scientists are not in it.” [Cites Paul Reiter as being listed as agreeing when he didn’t agree] “and there’s lots of people like him.”

RESPONSE: A survey of climate scientists’ personal opinions [1–3] and a review of the peer-reviewed literature [4] both emphasise a high degree of consensus. The dichotomy between “agrees with” and “disagrees with” is clearly false. There are a range of potential stances to take on the basis of the different aspects (mitigation, attribution, adaptation, impacts) of the IPCC’s report. In addition, more recent surveys of scientists have suggested that some dissent from the IPCC’s findings because those findings are too *conservative*, particularly in the case of sea level rise and Arctic sea ice melt [2]. Harris produces quotes (not scientific articles) from a

series of scientists who disagree with IPCC conclusions; while a small percentage of scientists may disagree in public with the IPCC's main findings, they have not made a convincing case in the peer reviewed scientific literature.

Claim 126. "Greenhouse gas forcing has very likely caused most of the observed global warming over the last 50 years.' That's the statement that's supposedly agreed to by 2,500 scientists. Or, at least so says the media and the politicians." "Most of them of course would comment on their area of expertise, which might be totally independent of the most important statement of the whole document." "Only five, actually, who commented on the whole report." "It turns out that only 62 reviewers of the whole 2500, 8 of whom are designated as "Government of XYZ", OK, in other words they are official – they will basically say whatever the government tells them to – that only 62 reviewers gave any comments at all on the whole chapter, let alone that most important statement that 2500 scientists supposedly agree to. And look at this: of the remaining 54 individuals, 47 of them had serious potential vested interests in that they were authors or editors of the report – OK, so you're reviewing your own stuff, you're probably not going to disagree – or authors of papers referenced to support it, or they worked for establishments that likely received funding etc to actually find a human connection. So you use a bit of arithmetic here and you don't find too many left over who are independent – who aren't just reviewing their own work. And here's the big breakdown question: of the 62 – 2.5% - who actually commented on Chapter 9 (and some of them didn't agree, OK), how many explicitly endorsed Chapter 9? I need a drum roll here, you know? Of the 2500... 1!! The consensus of 1 world scientist who could be said to be free of vested interest, explicitly endorsed this, the most significant statement of the entire chapter, indeed the entire report, and in fact probably the most important statement in the world on the whole climate change issue, and his generalised support was his only comment on the entire 11 chapter document. So our 2500 number, if you want to take out those who have obvious conflicts of interest because they're commenting on their own report and other factors like I mentioned, you're only really left with one independent scientist. Now that doesn't mean the others are all wrong - they could very well be right – but we better be clear, there's only one independent assessor."

RESPONSE: Harris is correct to say that 2500 scientists did not signal their agreement with all aspects of the IPCC by simply being authors. However, subsequent analysis has suggested a high degree of agreement [2]. "Only 62" reviewers gave comments on Chapter 9 - that's a

pretty intensive peer-review! Harris also dismisses some of those reviewers because they had authored papers that were referenced in the report. Surely those are the people you want to be reviewing the study? You cannot discount reviewers because they are involved with the actual scientific research.

Claim 127. "One of the scientists told me, he said 'you realize that once government gets involved things start to really change. They have what are called green runners, who run back and forth between the various meetings where the scientists are meeting and they basically look over their shoulders. And they tell them how they want things changed, 'oh that doesn't match the summary for policy makers' and so the scientists are expected to basically display their green credentials to these government people who are running around looking over their shoulder while they are preparing the third draft. So if you really want to see what the scientists prepared without government interference, you've got to go back to the second draft."

RESPONSE: Harris seems to be relating hearsay to dispute the credibility of a major organisation. Governments have a role in ensuring the SPM is accessible, balanced and based on the underlying chapters. Nothing is approved unless the authors agree that it agrees with the science. When it is approved it is owned by both the scientists and governments. The fact that all governments present during an IPCC Plenary agree with the final SPM is a strong indicator of the breadth of consensus.

Claim 128. Harris cites (i) the Oregon Institute of Science and Medicine petition project, (ii) the Bali open letter, (iii) the ICSC Manhattan declaration on climate change, and (iv) the Climate scientists register: "this is a very very very simple, non political document. We're trying to strip the politics out of it." "The bottom line is we don't know what the consensus is of world scientists is. We know there's a lot of dissent, and it's dissent among some of the absolute leaders in the field."

RESPONSE: This is untrue. Time and again, surveys of climate scientists and the scientific literature have demonstrated overwhelming consensus [1–4].

Claim 129. "[Models] are not terribly meaningful as indicators of climate change."

RESPONSE: It is worth beginning with a discussion of the role of climate models in the climate change field, and there are a number of important points to consider in this context. First, there is little doubt that anthropogenic forcings are causing the contemporary phase of warming [6], [7], [9]. This finding comes not from the models but from explaining the past and so the accuracy of models or lack thereof in predicting future climate is of little consequence. Second, it is often said that models by their very nature are always wrong, but sometimes useful. A model will never completely represent the way the world is because they contain, by design, a systematic simplification of the world in order to make calculations feasible. Third, the role of climate models is to project what we do know (based on observations and theory) into the future to illustrate the types of responses that the climate might show under various scenarios: different concentrations of atmospheric gases, changes in land use, different understandings of climatic phenomena... Fourth, the climate models never make precise predictions. Those scientists responsible for constructing and running climate models will spend as much time (if not more) calculating the sensitivity of the model (i.e. how much effect changes in assumptions or equations have on the results) and the errors associated with that sensitivity. These factors taken together show that models cannot be used to answer all questions. For example, they may provide unreliable answers to questions such as “What will the global temperature be in 50 years?” (time will tell). However, they are useful in more limited contexts to answer questions such as “Why is the planet warming?” and “Will the planet continue to warm?”.

Claim 130. “Until we have much faster computers we can’t get our grid size small enough to incorporate some very very major and important phenomena. And that’s one of the reasons, of course, why we saw earlier the projections of computer models are not matching the data.”

RESPONSE: As noted above, all models will be incorrect in some aspects. Models are used to test hypotheses through making predictions and comparing them to observations. It is up to those who question the models to specify a level of “goodness-of-fit” that will satisfy them. It is always possible to argue that we could be more specific, that models need more details, and that computers aren’t powerful enough. However, there comes a point when models are useful enough that we do not need to improve them too much further in order to answer important questions. For example, models have demonstrated that it isn’t possible to explain recent warming without incorporating anthropogenic emissions of CO₂ [6], [7], [9], suggesting that the current phase of warming is anthropogenic in origin. Projections made in 1988 [160] have largely been borne-out over the past 24 years [13]. Furthermore a large number of models that are combined in the IPCC projections suggest a consensus of future warming (although the precise amount of warming will depend on a wide range of future variables). A better

understanding of some phenomena, such as the role of clouds or aerosols, for example, would improve the models, but would be unlikely to overturn our current understanding that CO₂ is the more important forcing [12]. It is also worth discussing the range of climate-related projections that have been made aside from global temperature patterns. For example, predictions of sea ice loss and sea level rise are in line with IPCC projections [44], if not slightly more rapid than expected. Observations of increased ocean heat content are also consistent with predictions based on models of heat retention by the increased greenhouse gases in the atmosphere [161]. On a finer scale, these models can even respond to smaller forcings such as volcanic eruption [85]

Claim 131. "IPCC models, for example don't include things like we were talking about – the amplifier of solar radiation due to the formation of clouds for galactic rays... if you're not including many of the physical parameters, then you know your models might by coincidence match what's happening, but you haven't really got a solid model for a future forecast."

RESPONSE: As previously discussed, it is extremely unlikely that GCRs actually influence cloud formation in any meaningful way, for the following reasons: (i) solar magnetic field strength has not increased over the past few decades [120], (ii) GCR flux has diverged from global temperature trends since 1990 [121], showing the same pattern as solar activity [48], (iii) there is evidence from models that GCRs cannot provide sufficient cloud condensation nuclei (points around which clouds form) to play a significant role in climate change [122], (iv) a number of studies have disputed the size of the effect of GCRs and their ability to explain variation in clouds [123–126], and (v) the link between GCRs and clouds was strong until 1990 and then diverged markedly [127]. Harris is speculating as to which factors may or may not be important, but climate modellers understand broadly what is missing. As mentioned above, all models will be wrong irrespective of how many factors you enter, as they will always be simplified representations of the environment. Regardless, the current crop of models do perform well when hindcasting [6], [7], [9] and the older models on which they are based have performed well in forecasting [13], [160].

Claim 132. "All the greenhouse gas models, they forecast that there should be a hot spot and there isn't. Really we have to say we have a long long way to go in the models."

RESPONSE: A hotspot in tropospheric warming is predicted by the IPCC models [91]. Satellite measurements vary in whether or not that hot spot is detected as a long-term trend, which is

thought to be the result of measurement error [162], [163]. However, recent data from weather balloons [164–166] and measurement of thermal winds [167] suggests that the troposphere is warming.

See also [“There’s no tropospheric hot spot”](#) on Skeptical Science.

Claim 133. [Cites “expert forecasters” who question IPCC on 72 grounds of good forecasts, comparing a ‘naive model’ with best models of IPCC] “The naive model gave results that were seven times better than the IPCC’s best models.”

RESPONSE: First, it is important to differentiate “forecasting” from “projections”. Forecasting takes present circumstances and predicts the future. Projections, which are the model outputs used by the IPCC, are a series of “what-if” scenarios based on unknown future changes in technological advancement and societal attitudes. These climate projections are based on models that are extensively validated, see Chapter 8 of [91] for a thorough discussion.

Second, did a naïve model give better results than the IPCC models? Green and Armstrong published a paper in 2007 in *Energy and Environment* [168], a journal whose editor has admitted to publishing articles with a political agenda [169], [170]. In their paper they claim to have: “...audited the forecasting processes described in Chapter 8 of the IPCC’s WG1 Report to assess the extent to which they complied with forecasting principles. We found enough information to make judgments on 89 out of a total of 140 forecasting principles. The forecasting procedures that were described violated 72 principles. Many of the violations were, by themselves, critical.” These “principles of forecasting” were created by G&A, themselves. They concluded: “The forecasts in the Report were not the outcome of scientific procedures. In effect, they were the opinions of scientists transformed by mathematics and obscured by complex writing. Research on forecasting has shown that experts’ predictions are not useful in situations involving uncertainty and complexity. We have been unable to identify any scientific forecasts of global warming. Claims that the Earth will get warmer have no more credence than saying that it will get colder.” The reference to Green and Armstrong draws on a semantic argument, that according to a certain set of criteria, the forecasts in the IPCC report were not ‘scientific’ and should therefore be ignored. On the contrary, climate models can successfully hindcast [6], [7], [9] and successfully project future climate conditions [13], making them scientifically sound and relevant.

See also [“Green and Armstrong’s scientific forecast”](#) on RealClimate.

Claim 134. "Climate models have so far not been validated. Models have not been successful in simulating the past – consequently, they do not offer a reliable basis for predicting the future."

RESPONSE: This is not true. Climate models are validated using hindcasting, an essential and important process in model development and a concept to which these students should be introduced. In fact, models have been very successful in predicting the past, and are unable to predict recent warming without considering increasing CO₂ levels [6], [7], [9]. Climate change deniers have yet to produce a GCM that can explain warming over the past century that does not include CO₂ forcing. Models have also been able to predict future temperature trends; predictions made by Hansen in 1988 [160] showed good agreement with real world observations [13].

Claim 135. "The role of the sun has been underestimated."

RESPONSE: Solar activity has been declining over the past 30 years while temperature has continued to rise [48]. Furthermore, solar forcings, while significant in climate models, are overridden in long-term trends by anthropogenic forcings [6], [7], [9]. See also "[Solar activity and climate: is the sun causing global warming?](#)" on Skeptical Science.

Claim 136. "Insufficient account has been taken of the progressive uptake of CO₂ by plants and the equally progressive growth of vegetation."...and..."Consequently, the CO₂ concentration will increase less than expected."...and..."Growth of vegetation as such is very valuable for mankind."

RESPONSE: A recent study has demonstrated that the negative feedback provided by plant growth in response to increased CO₂ could reduce global temperatures by as much as -0.3 degrees Celsius [171]. However, the contribution by plants is not the uptake of CO₂ but the increased efficiency of photosynthesis at higher levels of CO₂, leading to greater evapotranspiration (loss of water). Of course, the productivity of plants in the future is not solely dependent upon temperature and CO₂, so these findings are not unequivocal [134]. In the best case, this would only reduce the warming by around 15%, not alleviate the trend. The alternative mode of action is to consider plants as a carbon sink, which is already incorporated into models.

Claim 137. “Why do we think we can do better with climate predication than we can do with weather?”

RESPONSE: Weather forecasting is an “initial value” problem – it depends on today’s weather. Over the period of a forecast the GHG forcing is constant. Climate projections are a “boundary value” problem – they depend on the forcing of the climate. Over the period of a climate experiment the GHG forcing changes – that is the whole point of the exercise. Understanding the distinction between weather and climate is critically important and a fundamental concept for students studying climate change. It is astonishing that Harris, the course lecturer, does not appear to grasp the difference nor seek to explain it. Climate and weather are two different concepts. Weather is a short-term phenomenon with complex, chaotic forces that make prediction almost impossible beyond a certain time window. Climate is averaged over a longer period with substantial inertia and, as such, has much of that chaos “ironed-out”. This makes climate more amenable to study and predictions. Also, climate models have been shown to be accurate in hindcasting [6], [7], [9] and forecasting [13].

See also “[The difference between weather and climate](#)” at Skeptical Science.

[Harris provides the following take-away slogans for his students to close the course]

Claim 138. “The only constant about climate is change.”

RESPONSE: Climate has always changed in the past and is changing now. However, the current phase of climate change, characterised by a 50-year phase of warming, coincides with (and cannot be accounted-for without reference to) anthropogenic change, particularly increases in atmospheric concentrations of CO₂ [6], [7], [9].

Claim 139. “Carbon dioxide is plant food.”

RESPONSE: Plants need CO₂ to survive. However, CO₂ has a hugely negative effect on the world’s oceans by causing acidification [73]. Aside from that, the substantial role that CO₂ plays in the greenhouse effect and the resultant global warming will have substantial negative effects on human populations, see Table 19.1 in [28]. Finally, there is uncertainty over the extent to which plants will be able to use this extra CO₂ in the event of climate change, as there will be a range of other changes to the environment including patterns of precipitation, distributions of plant pests and changes in human activity [134].

Claim 140. "There is no scientific consensus about climate change causes."

RESPONSE: There is a very strong consensus that the current phase of climate change is caused predominantly by anthropogenic forcings, both among climate scientists [1–3] and in the peer-reviewed literature [4].

Claim 141. "Prepare for global cooling."

RESPONSE: There is no evidence that we are going to enter a phase of global cooling any time soon. Solar activity and orbital forcings, which are primary drivers of the glacial cycle, are fading already, indicating that we should be entering a phase of cooling [106], [121]. Instead, the continued strengthening of anthropogenic forcings, which are the primary drivers of contemporary warming [6], [7], [9], are expected to produce substantial future warming [91].

Claim 142. "Climate science is changing quickly."

RESPONSE: Harris paints a picture of an academic field in the throes of a revolution. However, the field is actually undergoing *refinement*. Previous predictions have been shown to be correct [130], new discoveries are producing refinements of models [11], [12], [171], and there is consistent and corroborative evidence from multiple studies that anthropogenic forcings are and will continue to be the primary cause of climate change for the next century [6], [7], [9].

Appendix B – Additional Background

We anticipate that some questions will be asked of this report and we provide details of what we consider to be relevant here:

Competing interests

None of the authors have any competing interests, nor have any of the authors benefitted financially from the publication of this report. All authors volunteered their time toward the production of this report.

Backgrounds to the authors

Christopher Hassall is a postdoctoral fellow at Carleton University, holding a BSc in Zoology and a PhD in environmental entomology both from the University of Liverpool. His academic research involves the ecology and evolution of insects, including their responses to climate change. He is the author of 19 peer-reviewed scientific publications in journals including *Nature* and *Ecology Letters*. He is also a contract instructor at Carleton University, where he teaches Conservation Biology. He is co-organiser of the Ottawa Skeptics and a member of the Committee for the Advancement of Scientific Skepticism (CASS).

Carley Centen is a writer and communications professional. She recently completed an MA in Socio-Legal studies, an interdisciplinary field of study that focuses on a critical analysis of the role of law and regulation in society. Her research focused on the regulation of protest and dissent in Canada, allowing her to explore one of her primary interests: freedom of expression and inquiry. Carley presently works as an Account Manager for a small digital media firm specializing in services for nonprofits in Ottawa. Her writing on everything from science to education and business has been published by a variety of print sources, including Metro News and the Canadian University Press, and in online blogs and magazines. She is a member of CASS.

Cliff Beninger completed a HBSc and MSc in biology at Carleton University and in 1990 began his Ph.D. at the University of Ottawa, but conducted the research at the Canadian Forestry Service natural products lab in Sault Ste Marie Ontario. Since completion of his Ph.D. he has worked for the USDA and University of Guelph on a variety of research projects. He has 31 publications in peer-reviewed journals such as *Chemical Ecology*, *Biochemical Systematics and Ecology* and *Journal of Agricultural and Food Chemistry* (PDFs of his publications are available on request at his website: <http://beninger-consulting.com>). He is a member of CASS.

Chris Hebborn obtained his PhD in plant sciences from the University of Copenhagen. His current research involves the health effects of climate change in Canadian cities. He is co-organiser of the Ottawa Skeptics and a member of CASS.

Access to lecture material

In the case of this report, Christopher Hassall (CH) requested access to the video recordings of lectures given as part of the EARTH2402 course in Winter 2010/11 in an email (dated Friday 10th September 2010) to the email account vod@carleton.ca ("VOD" stands for "Video on Demand" which is the group that administers videos of lectures) which read:

"I am a member of staff at Carleton and am interested in gaining access to the course materials for EARTH 2402. Is this possible for non-students? If not, how would I go about it?"

CH received the following response (13th September 2010) from the VOD:

"Chris, Please go back to Carleton Central and add the following CRN [redacted] for EARTH 2402 (winter term). You have 'til Jan 14 to subscribe to this service. Also if you are a staff, once you've subscribed, get back to me with your CUNET account login name and I can verify if you are able to access the lectures."

CH responded (13th September 2010):

"I do not have an option to add courses to my Carleton Central account. I don't suppose the lectures from last year are still available on DVD? I am not interested in taking the course, but simply desire some background information on the lectures."

...and received the following reply (14th September 2010):

"Hello Chris, I can give you access to the VOD lectures, complimentary; what's your employee number? Thanks."

We hope that this demonstrates comprehensively that there was no deception on our part in the acquisition of lecture materials.

References

- [1] P. T. Doran and M. K. Zimmerman, "Examining the scientific consensus on climate change," *Eos, Transactions American Geophysical Union*, vol. 90, no. 3, p. 22, 2009.
- [2] D. Bray, "The scientific consensus of climate change revisited," *Environmental Science & Policy*, vol. 13, no. 5, pp. 340-350, Aug. 2010.
- [3] W. R. L. Anderegg, J. W. Prall, J. Harold, and S. H. Schneider, "Expert credibility in climate change," *Proceedings of the National Academy of Sciences*, vol. 107, pp. 12107-12109, 2010.
- [4] N. Oreskes, "Beyond the ivory tower. The scientific consensus on climate change.," *Science (New York, N.Y.)*, vol. 306, no. 5702, p. 1686, Dec. 2004.
- [5] IPCC, "Summary for Policymakers," in *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 et al., Eds. Cambridge: Cambridge University Press, 2007.
- [6] J. Hansen, "Efficacy of climate forcings," *Journal of Geophysical Research*, vol. 110, no. 18, p. D18104, Sep. 2005.
- [7] P. A. Stott, "External control of 20th Century temperature by natural and anthropogenic forcings," *Science*, vol. 290, no. 5499, pp. 2133-2137, Dec. 2000.
- [8] IPCC, *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 2001.
- [9] M. Huber and R. Knutti, "Anthropogenic and natural warming inferred from changes in Earth's energy balance," *Nature Geoscience*, vol. 5, pp. 31-36, 2012.
- [10] H. Miura, M. Satoh, T. Nasuno, A. T. Noda, and K. Oouchi, "A Madden-Julian oscillation event realistically simulated by a global cloud-resolving model.," *Science (New York, N.Y.)*, vol. 318, no. 5857, pp. 1763-5, Dec. 2007.
- [11] A. Lauer, K. Hamilton, Y. Wang, V. T. J. Phillips, and R. Bennartz, "The impact of global warming on marine boundary layer clouds over the Eastern Pacific — a regional model study," *Journal of Climate*, vol. 23, no. 21, pp. 5844-5863, Nov. 2010.
- [12] A. C. Clement, R. Burgman, and J. R. Norris, "Observational and model evidence for positive low-level cloud feedback.," *Science*, vol. 325, no. 5939, pp. 460-464, Jul. 2009.
- [13] J. Hansen, M. Sato, R. Ruedy, K. Lo, D. W. Lea, and M. Medina-Elizade, "Global temperature change," *Proceedings of the National Academy of Sciences*, vol. 103, no. 39, pp. 14288-14293, 2006.
- [14] S. Arrhenius, "On the influence of carbonic acid in the air upon the temperature on the ground," *Philosophical Magazine and Journal of Science*, vol. 41, no. 251, pp. 173-276, 1896.
- [15] J. Hansen et al., "A closer look at United States and global surface temperature change," *Journal of Geophysical Research*, vol. 106, no. 20, pp. 23947-23963, 2001.
- [16] T. C. Peterson, "Assessment of urban versus rural in situ surface temperatures in the contiguous United States: no difference found," *Journal of Climate*, vol. 16, no. 18, pp. 2941-2959, 2003.
- [17] P. D. Jones, D. H. Lister, and Q. Li, "Urbanization effects in large-scale temperature records, with an emphasis on China," *Journal of Geophysical Research*, vol. 113, no. 16, pp. 1-12, 2008.
- [18] C. Wickham et al., "Influence of urban heating on the global temperature land average using rural sites identified from MODIS classifications," *available online as a preprint*.
- [19] US EPA, "Air quality criteria and control techniques." .
- [20] D. M. Murphy, S. Solomon, R. W. Portmann, K. H. Rosenlof, P. M. Forster, and T. Wong, "An observationally based energy balance for the Earth since 1950," *Journal of Geophysical Research*, vol. 114, no. 17, pp. 1-14, 2009.

- [21] M. Falvey and R. D. Garreaud, "Regional cooling in a warming world: Recent temperature trends in the southeast Pacific and along the west coast of subtropical South America (1979–2006)," *Journal of Geophysical Research*, vol. 114, no. 4, pp. 1-16, 2009.
- [22] R. Rohde et al., "Berkeley earth temperature averaging process," *available online as a preprint*.
- [23] J. Hansen, R. Ruedy, M. Sato, and K. Lo, "Global surface temperature change," *Reviews of Geophysics*, vol. 48, no. 4, pp. 1-29, 2010.
- [24] NOAA, *Talking points related to concerns about whether the US temperature record is reliable*. Washington DC: NOAA, 2009.
- [25] R. A. Muller et al., "Earth atmospheric land surface temperature and station quality in the United States," *available online as a preprint*.
- [26] J. A. Eddy, "The maunder minimum.," *Science*, vol. 192, no. 4245, pp. 1189-1202, 1976.
- [27] G. A. Meehl, W. M. Washington, C. M. Ammann, J. M. Arblaster, T. M. L. Wigley, and C. Tebaldi, "Combinations of natural and anthropogenic forcings in Twentieth-Century climate," *Journal of Climate*, vol. 17, no. 19, pp. 3721-3727, 2004.
- [28] IPCC, *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007*. Cambridge: Cambridge University Press, 2007.
- [29] G. A. Vecchi and B. J. Soden, "Increased tropical Atlantic wind shear in model projections of global warming," *Geophysical Research Letters*, vol. 34, no. 8, p. L08702, 2007.
- [30] J. B. Elsner, J. P. Kossin, and T. H. Jagger, "The increasing intensity of the strongest tropical cyclones.," *Nature*, vol. 455, no. 7209, pp. 92-95, 2008.
- [31] T. R. Knutson et al., "Tropical cyclones and climate change," *Nature Geoscience*, vol. 3, no. 3, pp. 157-163, Feb. 2010.
- [32] J. A. Church and N. J. White, "A 20th century acceleration in global sea-level rise," *Geophysical Research Letters*, vol. 33, no. 1, pp. 94-97, 2006.
- [33] M. Vermeer and S. Rahmstorf, "Global sea level linked to global temperature.," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 106, no. 51, pp. 21527-21532, 2009.
- [34] J. R. Houston and R. G. Dean, "Sea-level acceleration based on U.S. tide gauges and extensions of previous global-gauge analyses," *Journal of Coastal Research*, vol. 27, no. 3, pp. 409-417, 2011.
- [35] S. Rahmstorf and M. Vermeer, "Discussion of: Houston, J.R. and Dean, R.G., 2011. Sea-level acceleration based on U.S. tide gauges and extensions of previous global-gauge analyses. *Journal of Coastal Research*, 27(3), 409–417," *Journal of Coastal Research*, vol. 274, no. 3, pp. 784-787, 2011.
- [36] M. D. Blum and H. H. Roberts, "Drowning of the Mississippi Delta due to insufficient sediment supply and global sea-level rise," *Nature Geoscience*, vol. 2, no. 7, pp. 488-491, 2009.
- [37] CBCL Limited, *The 2009 State of Nova Scotia's Coast Technical Report*. Province of Nova Scotia: Crown copyright, 2009.
- [38] D. L. Forbes, G. K. Manson, J. Charles, K. R. Thompson, and R. B. Taylor, "Halifax Harbour extreme water levels in the context of climate change: scenarios for a 100-year planning horizon," *Geological Survey of Canada*, vol. Open File, p. iv+22, 2009.
- [39] W. R. Dickinson, "Impact of Mid-Holocene hydro-isostatic highstand in regional sea level on habitability of islands in Pacific Oceania," *Journal of Coastal Research*, vol. 19, no. 3, pp. 489-502, 2003.
- [40] J. X. Mitrovica and G. A. Milne, "On the origin of late Holocene sea-level highstands within equatorial ocean basins," *Quaternary Science Reviews*, vol. 21, no. 20-22, pp. 2179-2190, 2002.
- [41] W. R. Dickinson, "Pacific atoll living: how long already and until when?," *GSA Today*, vol. 19, no. 3, pp. 4-10, 2009.
- [42] E. G. Purdy, "Reef configurations: Cause and effect," in *Reefs in Time and Space*, vol. 18, L. F. Laporte, Ed. SEPM Special Publication No. 18, 1974, pp. 9-76.

- [43] O. Hoegh-Guldberg et al., "Coral reefs under rapid climate change and ocean acidification," *Science*, vol. 318, no. 5857, pp. 1737-1742, 2007.
- [44] I. Allison et al., *The Copenhagen Diagnosis, 2009: Updating the world on the Latest Climate Science*, 2nd ed. Sydney, Australia: The University of New South Wales Climate Change Research Centre (CCRC), 2009, p. 60.
- [45] M. E. Mann et al., "Global signatures and dynamical origins of the Little Ice Age and Medieval Climate Anomaly.," *Science*, vol. 326, no. 5957, pp. 1256-1260, 2009.
- [46] P. D. Jones, T. J. Osborn, and K. R. Briffa, "The evolution of climate over the last millennium," *Science*, vol. 292, no. 5517, pp. 662-667, 2001.
- [47] N. Caillon, J. P. Severinghaus, J. Jouzel, J.-M. Barnola, J. Kang, and V. Y. Lipenkov, "Timing of atmospheric CO₂ and Antarctic temperature changes across Termination III," *Science*, vol. 299, no. 5613, pp. 1728-31, 2003.
- [48] A. D. Erlykin, T. Sloan, and A. W. Wolfendale, "Solar activity and the mean global temperature," *Environmental Research Letters*, vol. 4, no. 1, p. 014006, 2009.
- [49] J. G. Cogley, "Geodetic and direct mass-balance measurements: comparison and joint analysis," *Annals Of Glaciology*, vol. 50, no. 50, pp. 96-100, 2009.
- [50] A. M. Greene, "A time constant for hemispheric glacier mass balance," *Journal Of Glaciology*, vol. 51, no. 174, pp. 353-362, 2005.
- [51] WGMS, "Global Glacier Changes: Facts and Figures," *Human Development*, p. 88, 2008.
- [52] J. R. McConnell et al., "20th-century industrial black carbon emissions altered Arctic climate forcing.," *Science*, vol. 317, no. 5843, pp. 1381-1384, 2007.
- [53] NSIDC, *State of the Cryosphere*. 2011.
- [54] R. A. Kerr, "A north atlantic climate pacemaker for the centuries.," *Science*, vol. 288, no. 5473, pp. 1984-1985, 2000.
- [55] M. E. Mann, R. S. Bradley, and M. K. Hughes, "Global-scale temperature patterns and climate forcing over the past six centuries," *Nature*, vol. 392, no. 6678, pp. 779-787, 1998.
- [56] T. J. Crowley, "Causes of climate change over the past 1000 years," *Science*, vol. 289, no. 5477, pp. 270-277, 2000.
- [57] R. D'Arrigo, R. Wilson, B. Liepert, and P. Cherubini, "On the 'Divergence Problem' in Northern Forests: A review of the tree-ring evidence and possible causes," *Global and Planetary Change*, vol. 60, no. 3-4, pp. 289-305, 2008.
- [58] A. P. Ingersoll et al., "Dynamics of Jupiter's Atmosphere," in *Jupiter The Planet Satellites and Magnetosphere*, vol. 1, F. Bagenal, T. E. Dowling, and W. B. McKinnon, Eds. Cambridge Univ. Press. Cambridge, UK, 2004, pp. 105-128.
- [59] F. J. Low, "Observations of Venus, Jupiter, and Saturn at $\lambda 20 \mu$," *Astronomical Journal*, vol. 71, p. 39, 1966.
- [60] P. Marcus et al., "Velocities and temperatures of Jupiter's Great Red Spot and the New Red Oval and their implications for global climate change," *Bulletin of the American Astronomical Society*, vol. 38, p. 554, 2006.
- [61] L. F. Khilyuk and G. V. Chilingar, "Global warming and long-term climatic changes: a progress report," *Environmental Geology*, vol. 46, no. 6-7, pp. 970-979, 2004.
- [62] L. F. Khilyuk and G. V. Chilingar, "On global forces of nature driving the Earth's climate. Are humans involved?," *Environmental Geology*, vol. 50, no. 6, pp. 899-910, 2006.
- [63] W. Aeschbach-Hertig, "Rebuttal of 'On global forces of nature driving the Earth's climate. Are humans involved?' by L. F. Khilyuk and G. V. Chilingar," *Environmental Geology*, vol. 52, no. 5, pp. 1007-1009, 2006.

- [64] G. V. Chilingar, O. G. Sorokhtin, and L. F. Khilyuk, "Response to W. Aeschbach-Hertig rebuttal of "On global forces of nature driving the Earth's climate. Are humans involved?" by L. F. Khilyuk and G. V. Chilingar," *Environmental Geology*, pp. 1567-1572, 2008.
- [65] G. V. Chilingar, L. F. Khilyuk, and O. G. Sorokhtin, "Cooling of atmosphere due to CO₂ emission," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, vol. 30, no. 1, pp. 1-9, Nov. 2007.
- [66] T. Lambert, "Chilinger: if you assume that CO₂ isn't a greenhouse gas then increasing it doesn't warm the Earth." Deltoid, 2008.
- [67] R. B. Alley, "The Younger Dryas cold interval as viewed from central Greenland," *Quaternary Science Reviews*, vol. 19, no. 1-5, pp. 213-226, Jan. 2000.
- [68] H. Heinrich, "Origin and consequences of cyclic ice rafting in the Northeast Atlantic Ocean during the past 130,000 years," *Quaternary Research*, vol. 29, no. 2, pp. 142-152, Mar. 1988.
- [69] S. R. Hemming, "Heinrich events: Massive late Pleistocene detritus layers of the North Atlantic and their global climate imprint," *Reviews of Geophysics*, vol. 42, no. 1, p. RG1005, Mar. 2004.
- [70] S. L. Pimm, G. J. Russell, J. L. Gittleman, and T. M. Brooks, "The Future of Biodiversity," *Science*, vol. 269, no. 5222, pp. 347-350, 1995.
- [71] S. L. Pimm and C. N. Jenkins, "Extinctions and the practice of preventing them," in *Conservation Biology for All*, vol. 1, no. 9, N. S. Sodhi and P. Ehrlich, Eds. Oxford: Oxford University Press, 2010, pp. 181-198.
- [72] A. D. Barnosky et al., "Has the Earth's sixth mass extinction already arrived?," *Nature*, vol. 471, no. 7336, pp. 51-7, Mar. 2011.
- [73] J. Raven et al., *Ocean acidification due to increasing atmospheric carbon dioxide*, vol. 12, no. June. Policy document 12/05: The Royal Society, 2005, p. 68.
- [74] D. S. Kaufman et al., "Recent warming reverses long-term arctic cooling," *Science*, vol. 325, no. 5945, pp. 1236-1239, 2009.
- [75] C. Parmesan and G. Yohe, "A globally coherent fingerprint of climate change impacts across natural systems," *Nature*, vol. 421, no. 6918, pp. 37-42, 2003.
- [76] C. D. Thomas et al., "Extinction risk from climate change," *Nature*, vol. 427, no. 6970, pp. 145-148, 2004.
- [77] J. A. Pounds et al., "Widespread amphibian extinctions from epidemic disease driven by global warming," *Nature*, vol. 439, no. 7073, pp. 161-167, 2006.
- [78] C. Parmesan, "Ecological and evolutionary responses to recent climate change," *Annual Review of Ecology, Evolution and Systematics*, vol. 37, pp. 637-669, 2006.
- [79] J. M. J. Travis, "Climate change and habitat destruction: a deadly anthropogenic cocktail," *Proceedings of the Royal Society: Series B (Biological Sciences)*, vol. 270, pp. 467-473, 2003.
- [80] R. S. Lindzen, M.-D. Chou, and A. Y. Hou, "Does the Earth have an adaptive infrared iris?," *Bulletin of the American Meteorological Society*, vol. 82, no. 3, pp. 417-432, 2001.
- [81] B. Lin, B. A. Wielicki, L. H. Chambers, Y. Hu, and K.-M. Xu, "The Iris Hypothesis: a negative or positive cloud feedback?," *Journal of Climate*, vol. 15, no. 1, pp. 3-7, 2002.
- [82] D. L. Hartmann and M. L. Michelsen, "No evidence for iris," *Bulletin of the American Meteorological Society*, vol. 83, no. 2, p. 249, 2002.
- [83] Q. Fu, M. Baker, and D. L. Hartmann, "Tropical cirrus and water vapor: an effective Earth infrared iris feedback?," *Atmospheric Chemistry and Physics*, vol. 2, no. 1, pp. 31-37, 2002.
- [84] A. E. Dessler, "A determination of the cloud feedback from climate variations over the past decade," *Science*, vol. 330, no. 6010, pp. 1523-1527, 2010.
- [85] J. Hansen et al., "Climate simulations for 1880-2003 with GISS modelE," *Climate Dynamics*, vol. 29, no. 7, pp. 661-696, 2007.

- [86] S. E. Schwartz, "Heat capacity, time constant, and sensitivity of Earth's climate system," *Journal of Geophysical Research*, vol. 112, no. 24, pp. 1-12, 2007.
- [87] G. Foster, J. D. Annan, G. A. Schmidt, and M. E. Mann, "Comment on 'Heat capacity, time constant, and sensitivity of Earth's climate system' by S. E. Schwartz," *Journal of Geophysical Research*, vol. 113, no. 15, p. D15102, Aug. 2008.
- [88] R. Knutti, S. Krähenmann, D. J. Frame, and M. R. Allen, "Comment on 'Heat capacity, time constant, and sensitivity of Earth's climate system' by S. E. Schwartz," *Journal of Geophysical Research*, vol. 113, no. 15, pp. 0-3, 2008.
- [89] N. Scafetta, "Comment on Heat capacity, time constant, and sensitivity of Earth's climate system by S.E.Schwartz," *Journal of Geophysical Research*, vol. 113, p. D15102, 2008.
- [90] S. E. Schwartz, "Reply to comments by G.Foster et al., R.Knutti et al., and N.Scafetta on Heat capacity, time constant, and sensitivity of Earth's climate system," *Journal of Geophysical Research*, vol. 113, p. D15105, 2008.
- [91] IPCC, "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge, UK and New York, USA, p. 996, 2007.
- [92] C. D. Camp and K. K. Tung, "Surface warming by the solar cycle as revealed by the composite mean difference projection," *Geophysical Research Letters*, vol. 34, no. 14, pp. 1-5, 2007.
- [93] J. Hansen, "A light on upstairs." 2007.
- [94] WMO, "2011: world's 10th warmest year, warmest year with La Niña on record, second-lowest Arctic sea ice extent," *Provisional Statement on the Status of the Global Climate*, 2011.
- [95] P. D. Jones, P. Y. Groisman, M. Coughlan, N. Plummer, W.-C. Wang, and T. R. Karl, "Assessment of urbanization effects in time series of surface air temperature over land," *Nature*, vol. 347, pp. 169-172, 1990.
- [96] W. C. Wang, Z. Zeng, and Karl T.R., "Urban heat islands in China," *Geophysical Research Letters*, vol. 17, pp. 2377-2380, 1990.
- [97] D. J. Keenan, "The fraud allegation against some climatic research of Wei-Chyung Wang," *Energy Environment*, vol. 18, no. 7, pp. 985-995, 2007.
- [98] M. E. Mann, "The value of multiple proxies," *Science*, vol. 297, no. 5586, pp. 1481-1482, 2002.
- [99] I. Velicogna, "Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE," *Geophysical Research Letters*, vol. 36, no. 19, pp. 5-8, 2009.
- [100] A. A. Arendt, K. A. Echelmeyer, W. D. Harrison, C. S. Lingle, and V. B. Valentine, "Rapid wastage of Alaska glaciers and their contribution to rising sea level.," *Science*, vol. 297, no. 5580, pp. 382-386, 2002.
- [101] J. Stroeve, M. M. Holland, W. Meier, T. Scambos, and M. Serreze, "Arctic sea ice decline: faster than forecast," *Geophysical Research Letters*, vol. 34, no. 9, pp. 1-5, 2007.
- [102] J. Zhang, "Increasing Antarctic sea ice under warming atmospheric and oceanic conditions," *Journal of Climate*, vol. 20, no. 11, pp. 2515-2529, 2007.
- [103] R. D. Peng, J. F. Bobb, C. Tebaldi, L. McDaniel, M. L. Bell, and F. Dominici, "Toward a quantitative estimate of future heat wave mortality under global climate change," *Environmental Health Perspectives*, vol. 119, no. 5, pp. 701-706, 2011.
- [104] J. X. Mitrovica, M. E. Tamisiea, J. L. Davis, and G. A. Milne, "Recent mass balance of polar ice sheets inferred from patterns of global sea-level change.," *Nature*, vol. 409, no. 6823, pp. 1026-9, Feb. 2001.
- [105] M. E. Tamisiea and J. X. Mitrovica, "The moving boundaries of sea level change: understanding the origins of geographic variability," *Oceanography*, vol. 24, no. 2, pp. 24-39, 2011.
- [106] J. Hansen and M. Sato, "Paleoclimate implications for human-made climate change," *New York*, p. 32, 2011.

- [107] C. Lorius, D. Raynaud, J. Jouzel, J. Hansen, and H. Le Treut, "The ice-core record - Climate sensitivity and future greenhouse warming," *Nature*, vol. 347, no. 6289, pp. 139-145, 1990.
- [108] P. Martin, D. Archer, and D. W. Lea, "Role of deep sea temperature in the carbon cycle during the last glacial," *Paleoceanography*, vol. 20, no. 2, pp. 1-10, 2005.
- [109] J. R. Toggweiler, "Variation of atmospheric CO₂ by ventilation of the ocean's deepest water," *Paleoceanography*, vol. 14, no. 5, pp. 571-588, 1999.
- [110] Ø. Ihlen, "The oxymoron of 'sustainable oil production': the case of the Norwegian oil industry," *Business Strategy and the Environment*, vol. 63, no. 2006, pp. 53-63, 2009.
- [111] S. Van Den Hove, M. Le Menestrel, and H.-C. De Bettignies, "The oil industry and climate change: strategies and ethical dilemmas," *Climate Policy*, vol. 2, no. 1, pp. 3-18, 2002.
- [112] I. A. Sæverud and J. B. Skjærseth, "Oil companies and climate change: inconsistencies between strategy formulation and implementation?," *Global Environmental Politics*, vol. 7, no. 3, pp. 42-62, 2007.
- [113] J. Walker, "Draft Global Climate Science Communications Action Plan." American Petroleum Institute, 1998.
- [114] S. R. Lewandowski, "IREA memo." Intermountain Rural Electric Association, 2006.
- [115] E. J. Burke, S. J. Brown, and N. Christidis, "Modeling the recent evolution of global drought and projections for the Twenty-First Century with the Hadley Centre Climate Model," *Journal of Hydrometeorology*, vol. 7, no. 5, pp. 1113-1125, 2006.
- [116] R. Seager et al., "Model projections of an imminent transition to a more arid climate in southwestern North America.," *Science*, vol. 316, no. 5828, pp. 1181-1184, 2007.
- [117] M. Maslin, Y. Malhi, O. Phillips, and S. Cowling, "New views on an old forest: assessing the longevity, resilience and future of the Amazon rainforest," *Transactions of the Institute of British Geographers*, vol. 30, no. 4, pp. 477-499, 2005.
- [118] J. E. Harries, H. E. Brindley, P. J. Sagoo, and R. J. Bantges, "Increases in greenhouse forcing inferred from the outgoing longwave radiation spectra of the Earth in 1970 and 1997," *Nature*, vol. 410, no. 6826, pp. 355-357, 2001.
- [119] H. Svensmark, "Influence of cosmic rays on Earth's climate," *Physical Review Letters*, vol. 81, no. 22, pp. 5027-5030, 1998.
- [120] M. Lockwood, "Long-term variations in the magnetic fields of the Sun and the heliosphere: their origin, effects and implications," *Journal of Geophysical Research*, vol. 106, no. 8, pp. 16021-16038, 2001.
- [121] M. Lockwood and C. Frohlich, "Recent oppositely directed trends in solar climate forcings and the global mean surface air temperature," *Proceedings of the Royal Society A*, vol. 464, pp. 1367-1385, 2007.
- [122] J. R. Pierce and P. J. Adams, "Can cosmic rays affect cloud condensation nuclei by altering new particle formation rates?," *Geophysical Research Letters*, vol. 36, no. 9, pp. 1-6, 2009.
- [123] J. Kazil, E. R. Lovejoy, M. C. Barth, and K. O'Brien, "Aerosol nucleation over oceans and the role of galactic cosmic rays," *Atmospheric Chemistry and Physics*, vol. 6, no. 12, pp. 4905-4924, 2006.
- [124] T. Sloan and A. W. Wolfendale, "Testing the proposed causal link between cosmic rays and cloud cover," *Environmental Research Letters*, vol. 3, no. 2, p. 024001, 2008.
- [125] J. E. Kristjánsson, C. W. Stjern, F. Stordal, A. M. Fjæraa, G. Myhre, and K. Jónasson, "Cosmic rays, cloud condensation nuclei and clouds – a reassessment using MODIS data," *Atmospheric Chemistry and Physics*, vol. 8, no. 24, pp. 7373-7387, 2008.
- [126] M. Kulmala et al., "Atmospheric data over a solar cycle: no connection between galactic cosmic rays and new particle formation," *Atmospheric Chemistry and Physics*, vol. 10, no. 4, pp. 1885-1898, 2010.

- [127] P. Laut, "Solar activity and terrestrial climate: an analysis of some purported correlations," *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 65, no. 7, pp. 801-812, 2003.
- [128] S. D. Schubert, M. J. Suarez, P. J. Pegion, R. D. Koster, and J. T. Bacmeister, "On the cause of the 1930s Dust Bowl," *Science*, vol. 303, no. 5665, pp. 1855-9, Mar. 2004.
- [129] C. Essex, R. McKittrick, and B. Andresen, "Does a global temperature exist?," *Journal of Non-Equilibrium Thermodynamics*, vol. 32, pp. 1-27, 2007.
- [130] J. Hansen, M. Sato, R. Ruedy, K. Lo, D. W. Lea, and M. Medina-Elizade, "Global temperature change.," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 103, no. 39, pp. 14288-93, Sep. 2006.
- [131] S. Pacala and R. Socolow, "Stabilisation wedges: solving the climate problem for the next 50 years with current technologies," *Science*, vol. 305, pp. 968-972, 2004.
- [132] IPCC, "Summary for Policymakers," in *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, and L. A. Meyer, Eds. Cambridge: Cambridge University Press, 2007.
- [133] A. R. Ravishankara, J. S. Daniel, and R. W. Portmann, "Nitrous oxide (N₂O): the dominant ozone-depleting substance emitted in the 21st century," *Science*, vol. 326, pp. 123-125, 2009.
- [134] J. Gornall et al., "Implications of climate change for agricultural productivity in the early twenty-first century.," *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, vol. 365, no. 1554, pp. 2973-89, Sep. 2010.
- [135] A. K. Tripathi, C. D. Roberts, and R. A. Eagle, "Coupling of CO₂ and Ice Sheet Stability Over Major Climate Transitions of the Last 20 Million Years," *Science*, vol. 326, no. 5958, pp. 1394-1397, 2009.
- [136] P. Ghosh and W. A. Brand, "Stable isotope ratio mass spectrometry in global climate change research," *International Journal of Mass Spectrometry*, vol. 228, pp. 1-33, 2003.
- [137] J. G. Canadell et al., "Contributions to accelerating atmospheric CO₂ growth from economic activity, carbon intensity, and efficiency of natural sinks.," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 104, no. 47, pp. 18866-70, Nov. 2007.
- [138] D. L. Royer, "CO₂-forced climate thresholds during the Phanerozoic," *Geochimica et Cosmochimica Acta*, vol. 70, pp. 5665-5675, 2006.
- [139] A. Z. Csank et al., "Accurate estimates of Arctic land surface temperatures during the Early Pliocene from two novel proxies," *Earth and Planetary Science Letters*.
- [140] G. S. Dwyer and M. A. Chandler, "Mid-Pliocene sea level and continental ice volume based on coupled benthic Mg/Ca palaeotemperatures and oxygen isotopes.," *Philosophical Transactions of the Royal Society - Series A: Mathematical, Physical and Engineering Sciences*, vol. 367, no. 1886, pp. 157-168, 2009.
- [141] D. Lee and J. Veizer, "Water and carbon cycles in the Mississippi River basin: Potential implications for the Northern Hemisphere residual terrestrial sink," *Global Biogeochemical Cycles*, vol. 17, no. 2, p. 1037, Apr. 2003.
- [142] N. J. Shaviv and J. Veizer, "Celestial driver of Phanerozoic climate?," *GSA Today*, vol. 13, no. 7, p. 4, 2003.
- [143] S. Rahmstorf, "Cosmic Rays, Carbon Dioxide, and Climate," *Eos Transactions American Geophysical Union*, vol. 85, no. 4, pp. 2003-2005, 2004.
- [144] D. L. Royer, R. A. Berner, I. P. Montañez, N. J. Tabor, and D. J. Beerling, "CO₂ as a primary driver of Phanerozoic climate," *GSA Today*, vol. 14, no. 3, pp. 4-10, 2004.
- [145] R. Muscheler, J. Beer, P. W. Kubik, and H.-A. Synal, "Geomagnetic field intensity during the last 60,000 years based on ¹⁰Be and ³⁶Cl from the Summit ice cores and ¹⁴C," *Quaternary Science Reviews*, vol. 24, no. 16-17, pp. 1849-1860, Sep. 2005.

- [146] A. C. Overholt, A. L. Melott, and M. Pohl, "Testing the link between terrestrial climate change and galactic spiral arm transit," *The Astrophysical Journal*, vol. 705, no. 2, p. L101-L103, Nov. 2009.
- [147] M. Lockwood and C. Fröhlich, "Recent oppositely directed trends in solar climate forcings and the global mean surface air temperature. II. Different reconstructions of the total solar irradiance variation and dependence on response time scale," *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, vol. 464, no. 2094, pp. 1367-1385, Jun. 2008.
- [148] J. Kirkby et al., "Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation," *Nature*, vol. 476, no. 7361, pp. 429-433, Aug. 2011.
- [149] E. J. Snow-Kropla, J. R. Pierce, D. M. Westervelt, and W. Trivittayanurak, "Cosmic rays, aerosol formation and cloud-condensation nuclei: sensitivities to model uncertainties," *Atmospheric Chemistry and Physics*, vol. 11, pp. 4001-4013, 2011.
- [150] C. Loehle, "Cooling of the global ocean since 2003," *Energy Environment*, vol. 20, no. 1-2, pp. 101-104, 2003.
- [151] S. Levitus, J. I. Antonov, T. P. Boyer, R. A. Locarnini, H. E. Garcia, and A. V. Mishonov, "Global ocean heat content 1955–2008 in light of recently revealed instrumentation problems," *Geophysical Research Letters*, vol. 36, no. 7, pp. 1-5, 2009.
- [152] J. A. Church et al., "Revisiting the Earth's sea-level and energy budgets from 1961 to 2008," *Geophys. Res. Lett.*, vol. 38, no. 18, p. L18601, 2011.
- [153] E. W. Leuliette and L. Miller, "Closing the sea level rise budget with altimetry, Argo, and GRACE," *Geophysical Research Letters*, vol. 36, no. 4, pp. 1-5, 2009.
- [154] O. M. Johannessen, E. V. Shalina, and M. W. Miles, "Satellite Evidence for an Arctic Sea Ice Cover in Transformation," *Science*, vol. 286, no. 5446, pp. 1937-1939, 1999.
- [155] J. C. Comiso, C. L. Parkinson, R. Gersten, and L. Stock, "Accelerated decline in the Arctic sea ice cover," *Geophysical Research Letters*, vol. 35, no. 1, pp. 1-6, 2008.
- [156] P. N. Edwards and S. H. Schneider, "The 1995 IPCC Report: Broad Consensus or 'Scientific Cleansing'?" *Ecoscience*, vol. 1, pp. 3-9, 1997.
- [157] M. E. Mann and K. A. Emanuel, "Atlantic hurricane trends linked to climate change," *Eos*, vol. 87, pp. 233-244, 2006.
- [158] G. A. Vecchi, K. L. Swanson, and B. J. Soden, "Whither hurricane activity?," *Science*, vol. 322, pp. 687-689, 2008.
- [159] G. Foster and S. Rahmstorf, "Global temperature evolution 1979–2010," *Environmental Research Letters*, vol. 6, no. 4, 2011.
- [160] J. Hansen et al., "Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model," *Journal of Geophysical Research*, vol. 93, no. 8, pp. 9341-9364, 1988.
- [161] J. Hansen et al., "Earth's energy imbalance: confirmation and implications," *Science (New York, N.Y.)*, vol. 308, no. 5727, pp. 1431-5, Jun. 2005.
- [162] B. D. Santer et al., "Amplification of surface temperature trends and variability in the tropical atmosphere," *Science*, vol. 309, no. 5740, pp. 1551-6, Sep. 2005.
- [163] T. R. Karl, S. J. Hassol, C. D. Miller, and W. L. Murray, "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences, A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research," Washington D.C., 2006.
- [164] H. A. Titchner, P. W. Thorne, M. P. McCarthy, S. F. B. Tett, L. Haimberger, and D. E. Parker, "Critically Reassessing Tropospheric Temperature Trends from Radiosondes Using Realistic Validation Experiments," *Journal of Climate*, vol. 22, no. 3, pp. 465-485, Feb. 2009.
- [165] S. C. Sherwood, C. L. Meyer, R. J. Allen, and H. A. Titchner, "Robust Tropospheric Warming Revealed by Iteratively Homogenized Radiosonde Data," *Journal of Climate*, vol. 21, no. 20, pp. 5336-5352, Oct. 2008.

- [166] L. Haimberger, C. Tavalato, and S. Sperka, "Toward Elimination of the Warm Bias in Historic Radiosonde Temperature Records—Some New Results from a Comprehensive Intercomparison of Upper-Air Data," *Journal of Climate*, vol. 21, no. 18, pp. 4587-4606, Sep. 2008.
- [167] R. J. Allen and S. C. Sherwood, "Warming maximum in the tropical upper troposphere deduced from thermal winds," *Nature Geoscience*, vol. 1, no. 6, pp. 399-403, May 2008.
- [168] K. C. Green and J. S. Armstrong, "Global Warming: Forecasts by Scientists Versus Scientific Forecasts," *Energy Environment*, vol. 18, no. 7, pp. 997-1021, 2007.
- [169] R. Monastersky, "Storm Brews Over Global Warming (September 5, 2003)," *Chronicle of Higher Education*, p. 16, 2003.
- [170] C. Hunt, "Energy and Environment – 'journal of choice for climate skeptics' Analysing the 900+ skeptic papers part III," *The Carbon Brief*, 2011. [Online]. Available: <http://www.carbonbrief.org/blog/2011/04/energy-and-environment-900-papers>. [Accessed: 29-Jan-2012].
- [171] L. Bounoua et al., "Quantifying the negative feedback of vegetation to greenhouse warming: A modeling approach," *Geophysical Research Letters*, vol. 37, no. 23, p. L23701, Dec. 2010.