

Popular Summary of:

Conference Summary: First International Conference on Global Warming and the Next Ice Age. 19-24 August 2001, Dalhousie University, Halifax, Nova Scotia, Canada by Peter J. Wetzell, Petr Chylek and Glen Lesins
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This paper presents a synthesis of the key ideas and issues emerging from the formal presentations and ample panel discussions that took place at the conference. The unusual and somewhat provocative title of the conference was designed to attract diverse views on global climate change, and it succeeded at this.

Among the most lively discussions were those debating a new theory that Cosmic Ray production of cloud droplet-forming nuclei may have played a major role in changing climate during the 20th century. The sun's output of particles (the solar wind) has more than doubled since the 1880's. The solar wind strongly affects how many cosmic rays enter the atmosphere. Cosmic rays are able to electrically charge certain gasses which makes them more easily clump together to form particles on which cloud droplets can form. The more cloud droplets there are in a volume of cloud, the more sunlight it can reflect, so the theory is that the highly variable solar wind could be indirectly affecting how much sunlight reaches the earth's surface.

Several other topics raised quite a bit of interest. Discussions about the ability of climate models to successfully project future climate demonstrated a polarization between model defenders and those who suggest that model parameterizations of clouds and other key climate sensitive processes are not yet good enough to trust. Conference attendees were united in their predictions that our present warm inter-glacial climate will last unusually long compared to any interglacial in the past million years. This is because of an unusual combination of Earth's orbital forcing parameters which are widely accepted as the primary drivers of climate change on 10,000 to 1,000,000 year time scales.

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1. INTRODUCTION

The First International Conference on Global Warming and the Next Ice Age was convened in Halifax, Nova Scotia, August 19-24, 2001. The conference program began each day with a 30 minute live classical music performances of truly international quality before the beginning business. Ample time for panel discussions was also scheduled. The general public was invited to attend and participate in a special evening panel session on the last day of the conference.

The unusual and somewhat provocative title of the conference was designed to attract diverse views on global climate change. This summary attempts to accurately reflect the tone and flavor of the lively discussions which resulted. Presentations ranged from factors forcing current climate to those in effect across the span of time from the Proterozoic “snowball Earth” epoch (Greg Jenkins [note: names of presenters appear herein as their contributions are mentioned]) to 50,000 years in the future. Although, as should be expected, attendees at the conference arrived with opinions on some of the controversial issues regarding climate change, and no-one openly admitted to a “conversion” from their initial point of view, the interdisciplinary nature of the formal presentations, poster discussions, panels, and abundant informal discourse helped to place the attendees’ personal perspectives into a broader, more diversified context.

2. MOTIVATION AND PURPOSE OF THE CONFERENCE

More than most scientific conferences, this conference kept a focus on the framework, or context within which the presentations of fact and the speculations about climate change are set. The intent of the conference was to provide a broad and diverse sampling of the differing human and scientific perspectives that make up that context. As in the fable of the six blind men attempting to describe an elephant, climate scientists immersed in their own familiar discipline may be more likely to reach skewed conclusions.

Broadening one's perspective, almost by definition, is enlightening. Consider, as a prime example, one of the central subjects of discussion: the global surface temperature trend and its time scale. If one examines the instrumental record, or subsets thereof, one set of conclusions might be drawn. Looking at successively longer records (from proxy information), several very different perspectives emerge.

Global climate has clearly warmed over the period of instrumental record, though there have been notable pauses in the trend, such as that in the 1940's and 1950's. Some regions of the world have not yet returned to the warmth of 1940 (Fred Singer), and other multi-decadal regional trends may not be statistically significant due to high natural variability and/or high autocorrelation (Betsy Weatherhead). The beginning of the instrumental record coincides with the end of the Maunder minimum in sun spots, and with a variety of major climate pattern changes. These include the lengthening of the time scale of the North Atlantic Oscillation (NAO, Victoria Slonosky), the apparent

"turning on" of the Pacific Decadal Oscillation (PDO, Ze'ev Gedalof), and a surprisingly abrupt, strong warming of the surface and bottom waters off Nova Scotia (Lloyd Keigwin). More generally, the beginning of the instrumental record coincides with the emergence from the "Little Ice Age". The latter is very evident in Canadian borehole temperature data (Hugo Beltrami) though not detectable in Tibetan glacier data (Lonnie Thompson). The influence of significant (presumably) natural change on the early measured temperature record leads to a potential risk of exaggerating the significance of the instrumental warming.

Moving to longer time scales, a widely discussed reconstruction of global temperature during the past millennium, the so called "hockey stick" (Mann et al.; 1998), received much attention at the conference (e.g. Dave Anderson). Framing climate in this particular temporal perspective suggests that there has been a highly anomalous temperature trend during the most recent century. Yet if one were to concede that the Mann et al. reconstruction is accurate, and that human influence caused all of the change seen in the past century, that change has still fallen short of returning Earth to the warmth of the climate optimum 5000 years ago (ya). And it is totally dwarfed by the natural warming since the Last Glacial Maximum (LGM) about 18,000ya. Further, the global surface temperature at the LGM was arguably the coldest the planet has seen in at least 100 million years (see for example Zachos et al., 2001). Which time scale is most relevant to the living Earth System is purely a matter of perspective.

Perspective, however, has many more dimensions. One question frequently raised at the conference was: Is global warming good or bad? Debate on the impact of recent warming on Nova Scotia found one camp arguing that local agriculture would significantly benefit from present trends. This was contrasted with the perspective from other parts of the world where change is likely to cause harm (such as low-lying Bangladesh), and with the argument that unnaturally rapid climate change could be traumatic for local natural ecosystems.

Such discussions evoked some over-riding questions: Are governments, which exist to protect their constituents from traumatic change and extremes, attempting to act to unnaturally preserve a static present climate to the long-term detriment of natural evolutionary/revolutionary change (raised by the authors in informal discussion)? And how important is climate change to humanity today compared to rapid socioeconomic change (raised in panel discussion)? Arguably the ice age cycles of the past million years, with frequent, rapid global temperature swings of up to 10K (often 5K during the span of a human lifetime) may have helped to accelerate the emergence of human intelligence. However, during the Holocene, climate swings have been relatively moderate, and extreme socioeconomic swings (exponential population growth, war, depression, the green revolution and the explosion in technology) have had a far greater impact on human quality of life than climate.

Deep in the individual human psyche, there exists is a readily demonstrated preference for the unusual over the mundane. This is the reason why a competent scientific report

predicting traumatic consequences of climate change attracts more attention than an equally competent report concluding that change will be minor, or will have little impact, or that the outcomes are substantially uncertain (Petr Chylek). This aspect of human perspective is as pertinent now as it was a quarter century ago when a National Research Council report (USC-GARP, 1975) predicted: "... a finite possibility that a serious worldwide cooling could befall the Earth within the next 100 years" (John Christy). It was the intent of this conference to provide an equal opportunity for exposure to all the diverse competent views on the contrasting issues of rapid human-induced global warming and the threat of sudden onset of a future ice age.

3. SYNTHESIS OF SOME SPECIFIC CONFERENCE HIGHLIGHTS

This section summarizes most of the specific discussions which took place in Halifax. The emphasis is more on a synthesis of ideas combining individual presentations and the panel discussions. An attempt is made to identify connections between research results that were not previously connected. We apologize in advance to any of the participants whose contribution may have been under-recognized herein. A complete conference preprint volume is available (see <http://www.mscs.dal.ca/HalifaxClimateConference/proceedings.html>).

This section is divided into a number of subsections headed by a deliberately provocative question.

1. Was solar forcing the primary driver of 20th century climate?

This hot current debate was represented by a number of talks on solar direct and indirect effects. In one, the possible solar influence was examined on a purely statistical basis using widely accepted global data sets for solar radiation and tropospheric temperature. The solar variability signal is required to produce a high ($R^2=0.92$) correlation between a four-variable multiple regression predictor and the observed temperature. Results showed a positive feedback mechanism must be invoked because the solar influence is roughly double that which direct irradiance changes would cause (David Douglas). A GCM modeling experiment using essentially the same four variables, which were sequentially added to a 20th century simulation, showed a 0.51K per century solar influence on surface temperature for the period 1900-1940 (Tony Broccoli). The GCM did not include any potential positive feedback mechanisms for the solar effect.

Of the three potential causal solar influences identified (direct, ultraviolet enhanced by ozone feedbacks, and solar wind variations) the latter sparked the greatest discussion. The strength of the solar wind is inversely proportional to the ability of the Earth's magnetic field to deflect cosmic rays. Cosmic rays ionize the upper atmosphere and, importantly, affect the isotope abundance of ^{14}C , which is preserved in tree rings, among other places (Paul Damon). Two circumstantial arguments for the importance of the cosmic ray effect on climate exist. First is the excellent correlation, being found in millennial scale proxies with annual resolution, between ^{14}C and the temperature proxy $\delta^{18}\text{O}$ (Hodell et al, 2001; Neff et al., 2001) (Paul Damon), although this could also

partially be the result of ozone/ultraviolet variations. The second is the high correlation between cosmic ray flux and satellite measured cloud amount (Svensmark and Friis-Christensen, 1997; Marsh and Svensmark, 2000). A notable result from these latter studies was that only low cloud amounts are responsible for the correlation (Wayne Evans, Pal Brekke).

The connection between cosmic ray flux and the formation of condensation nuclei in low cloud is the subject of considerable active study. A proposal has been submitted to use the CERN accelerator to study the processes.

Recent published modeling evidence (Yu and Turco, 2000, Yu 2002) hypothesizes that a process of ion-ion recombination can effectively form aerosols, especially at low altitudes. If further research confirms these results, then the much-discussed "first" aerosol indirect effect (pollution increases cloud albedo: Houghton et al., 2001) would then be the direct agent for the solar wind-induced cooling. Marine and Arctic stratocumuli, in particular, cover wide areas where middle and high cloud cover is often absent. Dust, pollution and other condensation nuclei are rarely abundant in these environments, as evidenced by the fact that ship tracks are readily apparent as bright tracks in marine stratocumulus, even in today's polluted world (Ulrike Lohman). The primary source of condensation nuclei are very large salt spray-derived particles which lead to few and large cloud droplets per unit of available condensate (Gerard Jennings). As a result, seeding with any further condensation nuclei presents a large potential to increase the albedo of these clouds.

Since temperature changes induced by an increase or decrease of low cloud affect only the layers near the surface, the cosmic ray seeding effect holds the potential for explaining the difference between observed surface warming trends and the much weaker trends in the middle and upper troposphere. Models which attribute the surface warming to greenhouse gas increases invariably also warm the middle and upper troposphere too much.

2. How might predicted future solar variations affect climate?

The consensus from the experts at the conference is that solar activity will diminish, driven by retreat of 80 and 200 year solar cycle periodicities from their current peaks, perhaps to another Maunder-like sunspot and solar wind minimum within the next century (Theodore Landscheidt, M. R. Morgan). If true, the divergence between greenhouse gas induced warming and solar-influenced cooling should provide a fortuitous test of their relative roles in climate in the near future.

By 1500 years in the future the indication is that solar cycles would return the climate to Holocene altithermal conditions. The purely solar cycle driven interglacial is predicted to last about 20,000 years (Charles Perry). This prediction reinforces the prediction of a long interglacial based on Earth's orbital parameters (see subsection 4 below).

3. Is the IPCC report fair to all competent science perspectives?

As would be expected, discussion often turned to the new IPCC Third Assessment Report (hereafter TAR; Houghton et al, 2001). The report was both derided and vigorously defended. It is clearly the seminal work on the topic of global warming, and should be read critically by all interested parties. However, the *de facto* "flagship" figure from the report, that depicting the direct radiative forcing impacts, was reviewed by several speakers. As the single most prominent image emerging from the technical results of IPCC, it was repeatedly concluded that this figure lacks the necessary breadth and generality.

The strict focus on *direct* radiative forcing can be quite misleading. The omission of radiative forcing caused by major feedbacks (water vapor and clouds) leaves an impression of certainty which belies the more detailed content of the report. The same can be said for the omission of selective forcings (though not all) which are poorly understood, notably the solar forcing from ultraviolet and its ozone feedback, the hypothesized solar wind/cosmic ray effects and the indirect land-use change effects (changes in vegetation due to temperature and precipitation changes).

4. Will we be able to prevent the onset of the next ice age?

The climate community has become quite united in its acceptance of orbital forcing (precession, obliquity and eccentricity) as a significant factor affecting global climate on time scales of 10,000 years and longer. At the conference, modeling evidence suggested that the NAO may be substantially responsive to orbital forcing – providing the kernel of a possible positive feedback mechanism driven by orbital changes (Amy Clement, Alex Hall). The frequency of El Niño events may also respond to orbital forcing according to model evidence. El Niño events correlate with high latitude autumn cooling in present day climate. Evidence from the end of the Eemian interglacial suggests that tropical warming coincided with the onset of high latitude glaciation (George Kukla). The warming of the tropics is hypothesized to increase high latitude snow accumulation.

However orbital changes over the next 130,000 years are very unusual, with some similarities to 400,000ya. Thus the consensus conclusion is that the onset of the next potential ice age is quite a long time away, most likely 30-40ky or more. Several presentations which touched upon this subject discussed the future orbital parameters which clearly show that we are at the conclusion of a 400kyr. eccentricity cycle. Every 400ky the eccentricity of Earth's orbit decreases to near zero. Since the precession signal is modulated by eccentricity, there will be no strong variations in summer high latitude insolation over the coming several ~19ky precession cycles. At the same time, for unrelated reasons, we are having a minimum in the amplitude of the obliquity cycle. This combination is exceedingly rare, having no counterpart in the past million years. The phasing of a strong eccentricity/precession-forced minimum with an obliquity minimum appears to be a prerequisite for glacial onset (i.e. nucleation of widespread North

American ice sheets). This was the circumstance 115kya at the end of the last interglacial (Dick Peltier).

Model simulations of the sensitivity of ice sheet nucleation to the concentration of carbon dioxide were also presented. It was reported that current ice caps would remain stable until CO₂ roughly tripled from pre-industrial values. At such high levels, the modelled Greenland ice cap melted and did not re-nucleate until after about 30ky into the future (Andre Berger).

5. How well-equipped are climate models to perform detection and attribution tests?

Speakers repeatedly criticized the model results which are the basis for the IPCC projections. Though outnumbered substantially, the modelers present provided evidence of substantial model successes, and gave an excellent and well-informed balance to these discussions (Tony Broccoli, Alex Hall, Reindert Haarsma). Models are, of course, the best laboratory available to produce detailed long period climate "data sets" (Robert Jacob), to examine complex process interactions (Ning Zeng), and to deduce cause and effect (Jim Hurrell). Model critics objected to the degree of faith that modelers place in their process parameterizations, particularly those related to cloud and precipitation. Other poorly modeled processes include dust generation (Glen Lesins), near surface inversion strength under very stable conditions (Pete Wetzel) and (possibly related) Arctic temperature and precipitation (Mark Serreze, Alexandre Gagnon).

The general impression emerging from the discussion is that, although models are clearly the best tool to evaluate cause and effect, much more work is required to remove remaining doubt. IPCC TAR reports that models which test additional sources of variability beyond the handful of relatively well understood forcings currently included in the detection and attribution tests, encounter the "degeneration" problem: that multiple combinations of different forcings can produce the observed temperature trends equally well. Until a single forcing combination can clearly emerge from these more robust and inclusive tests (some of which may have to be preliminary until physical mechanisms are better understood), the views of doubters and skeptics must continue to be given due consideration.

6. Are Greenland glaciers and the Arctic sea ice melting away?

Observations of Arctic sea ice extent show a statistically significant loss in extent from 1979 to 1997 (Mark Serreze). Monthly anomaly plots show the bulk of the loss occurring in late summer. Thus there has been a dramatic increase in warm season melt. Yet there has actually been a slight gain in ice extent in January. This remarkable cold season rebound in ice extent implies the need for an intensified cooling in autumn and early winter, and is consistent with observations of a stability-selective Arctic cooling mechanism which dominates fall and early winter weather patterns (Pete Wetzell). The underlying stability changes which actuate the cooling mechanism may be related to the intensification of El Niño cycles (see subsection 4 above).

An observational study recently published concludes that the Greenland ice cap is melting (see Krabill et al., 2000; also Thomas, 2001). Conference attendees noted that the two overflights of Greenland that produced this result, happened, by unfortunate circumstance, to immediately follow the Pinatubo eruption cooling (the first overflight: 1993-4) and the globally warmest year in the instrumental record (the second overflight: 1998-9). It would be expected that any trend based solely on these two samples would be highly unrepresentative of the general long term ice balance (Petr Chylek).

Along very similar lines, it was reported that by unfortunate circumstance, sea ice thickness measurements were made by submarines which cruised a pattern which seriously skewed the result. When the sampling biases are corrected, much less overall Arctic sea ice change is detected than has been reported (Greg Holloway).

7. Which comes first, CO₂ change or temperature change?

The consensus of this conference was that this question is unresolved. The carbon cycle is strongly linked to the water cycle which wields much more variability in mass exchange, which is a more important greenhouse gas, but which also exhibits a very strong dependence on temperature fluctuations (Bill Gray). On geologic time scales, Carbon and temperature seem less well linked than they are in the past million years or so (Jan Veizer).

8. Do clouds produce a negative feedback response to greenhouse warming?

Perhaps the holy grail of the climate change issue is the question of cloud feedbacks. Arguments were presented at the conference (Bill Gray) that increased surface warming strengthens convective overturning. Because convective updrafts are intense and localized, the subsidence branch of this overturning involves much more total horizontal area. Much of this area contains stratiform cloud "debris", primarily in convective anvil outflow. If the overturning is strengthened, there may be more anvil debris produced (assuming cloud microphysics responds neutrally to the change), but this debris would be subject to more rapid dissipation. Dissipation of layered middle and high clouds produces a weak positive feedback to solar warming of the surface, but a strong negative feedback involving more radiative heat loss to space. Counter-arguments were presented using observations in the tropical Pacific which suggest that the added water vapor due to a warmer surface appears to produce a weak but positive feedback to the net cloud radiation effects when all clouds are considered, not just the layered high clouds (Qiang Fu).

Convective updrafts have such small horizontal scales, and stratiform layer clouds have such narrow vertical scales that neither are adequately modeled, even in local scale numerical models. A considerable contingent at the conference felt that the cloud parameterizations used by GCM's may be inadequate to properly simulate these feedbacks. Few if any models are able to reproduce the difference between surface

warming trends and the relative lack of warming observed by satellites and radiosondes in the middle troposphere over the last 22 years (John Christy).

Observational and modeling evidence for the cause of the observed reduction of incident solar radiation at the surface in the USA contain a large residual which would require low cloud reflection to have increased during the period 1961-1990 (Beate Liepert). Since low cloud cools climate, this provides circumstantial evidence for a negative feedback response due to low clouds.

9. Will continued global warming cause sea level to fall?

Present evidence indicates that the cause of recent rise in sea level is a complex mix of thermal expansion, geostatic rebound from the last glacial, and an uncertain amount of glacial melt contribution. The mass balance of the Antarctic ice cap has been found to be positive, due to increased precipitation (Ellen Thompson). Although many mountain and low latitude glaciers are rapidly losing mass (Lonnie Thompson, Arthur Greene), and southern Greenland may possibly be losing mass as well, Antarctic snow is far from producing any snowmelt runoff at all, even at sea level (Hardy Granberg). The total mass balance loss involved in smaller glaciers may be dwarfed by Antarctica's gain.

10. Has global warming produced fewer extremes in weather?

One of the strongest conclusions about surface temperature trends is that the diurnal temperature range has decreased. There is little or no evidence to suggest precipitation extremes have increased, nor have tropical cyclone frequency or intensity. There is some evidence to suggest a decrease in intra-annual and intra-monthly temperature variability (Russell Vose). In the period 1946-1995, nearly all the observed positive temperature trends in the cold half-year occurred in areas dominated by anticyclones (Siberia and Western North America), wherein the minimum temperatures warmed about twice as much as the maxima (Pat Michaels). This moderation in the diurnal range during times of the coldest yearly temperatures is not likely to have a great effect on the ecosystem, which is virtually dormant during the cold half of the year.

11. Will climate warming trigger a sudden catastrophic cold climate shift?

It has been theorized that melting of Greenland glaciers combined with an intensified high latitude hydrologic cycle could freshen ocean surface waters enough to trigger a shut down in the North Atlantic thermohaline circulation, which sustains the moderate climate of Europe in particular. Climate model simulations have shown that this shift can occur almost at random, caused by surprisingly small natural variability in weather patterns (Alex Hall). Work with a coupled ocean-atmosphere model which simulated the last (Eemian) glacial onset demonstrated that a change in the thermohaline circulation is required to nucleate glaciers (Miriam Khodri). Northern European precipitation has

increased significantly during the 20th century (Raino Heino), however observational evidence from the oceans suggest that, although there has been considerable recent change in the detail of the North Atlantic ocean structure, there is just not enough observational evidence yet to indicate that a collapse is beginning (Allyn Clarke).

4. CONCLUSION

During the concluding panel discussion, two suggestions were proposed by the organizers. These are applicable to all inhabitants of the Earth, including the policy makers, and provide an agenda for current action, even in the face of remaining uncertainty in global change science:

First, regardless of what the main cause of current climate change may be, we all thrive on clean air and clean water. Therefore, we should invest in the development of renewable energy resources, and we should reduce wasteful consumption of energy and frivolous industrial products. We must preserve a clean environment and save natural resources for future generations. This we do because it is wise, because it is right, and because we are obligated to leave our descendants a habitable planet. It should not be necessary to resort to exaggerated predictions of apocalypse to motivate mankind to avoid soiling his own nest. Such predictions, if/when proven wrong could produce a counterproductive backlash.

Second, any reduction in the greenhouse gas emission by industrial nations will not by itself be an effective tool in producing a sustainable environment, unless it is coupled with the stabilization of the population and the raising of living standards of all developing countries. Because socio-economic change can amplify the effect of small climate shifts, or can occur independent of climate factors, and because it can be far more sudden and traumatic than most geophysical events affecting humanity, the wealth of industrialized nations would be well spent improving the quality of life for their underdeveloped neighbors.

Human nature causes us to gravitate to the unusual. The authors posit that two scientific reports, equally competent, one of which reports the possibility that a startling climate change is occurring, and one which reports that current climate change is unimportant, or that inconclusive results require further study, will not be given equal representation in the popular media. Since all known scientists are human, and are often consumers of popular media reports, their ability to retain impartiality on a subject which is as important as global warming, is severely tested daily.

The conference provided an excellent opportunity for exchange of diverse views and interpretations of current social and scientific issues within a framework of cutting edge science presentations. We hope this experience will be amplified when the Second International Conference on Global Warming and the Next Ice Age convenes. The second conference is now planned for August 2005 in Santa Fe, New Mexico.

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