

American Meteorological Society's Environmental Science Seminar Series

Changes in Cold Places: A Look at the Greenland Ice Sheet, Arctic Sea Ice and the Antarctic Ice Sheet

Are parts or all of the Greenland and Antarctic Ice Sheets undergoing a net melting? What is the nature of the observational evidence of melting? How far back in time do these observations extend? Are the melting and rates of melting consistent with model simulations and projections of melting? What are the factors deemed responsible for the melting? Is Arctic Sea Ice thinning? If so, by how much and over what period of time? What is the nature of the observational evidence for this thinning? Are the thinning and rates of thinning consistent with model simulations and projections of thinning? What factors are deemed responsible for the thinning of Arctic Sea Ice? Are there implications with respect to sea level rise? Is there any evidence of a fundamental change in the rate at which the Greenland ice sheet is changing and the manifestation of those changes? If so, why? How well do model simulations capture the dynamics of ice sheets and sea ice relative to observations? How well are these ice sheet models poised to project future changes in ice sheets, sea ice and sea level?

Public Invited

(No Pre-Registration Necessary)

Please provide us with a business card if you would like to be on our future mailing list

Date and Time:

Wednesday, May 3, 2006,

12:00 Noon - 2:00 pm

Location: Russell Senate Office Building, Room 428

Washington, DC

Reception Following

Moderator:

Dr. Anthony Socci, Senior Fellow, American Meteorological Society

Speakers:

Dr. H. Jay Zwally, ICESat Project Scientist, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD

Dr. Wieslaw Maslowski, Research Associate Professor, Department of Oceanography, Graduate School of Engineering and Applied Sciences, Naval Postgraduate School, Monterey, CA

Dr. Richard B. Alley, Evan Pugh Professor of Geosciences and Associate of the Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA

Introductory Perspective on Current Climate Changes

Over the last 30 years, the scientific understanding of the causes of the Earth's natural climate variability and the climatic impacts of human activity has advanced dramatically. In the early 1900's, global average temperatures increased from the predominately cooler temperatures of the previous several centuries, declined a little from 1940 to 1975, and then began to rise significantly. The climate warming of the early 1900's is now largely attributed to recovery from a period with more volcanic activity and consequent cooling. The small subsequent cooling in the mid-1900's is attributed mainly to increasing tropospheric aerosols from emission of sulfate pollutants, and the subsequent warming is attributed to increasing greenhouse gas (GHG) concentrations, the effect of which now overrides the aerosol cooling. About 0.6° C of the recent warming is attributed to the effect of GHG, which have been increasing exponentially (0.5%/year). Model projections of warming during the coming century range from about 1.5° C to 6° C depending on the GHG emission scenario. The models have also consistently projected that the warming will be greatest in the Arctic. During this century, we may be reaching or surpassing temperatures not seen since the last major warm period between ice ages 125-thousand years ago, when much of the Greenland ice sheet melted. Already, some of the largest effects of the global warming are becoming apparent in the Greenland ice sheet and the Arctic sea ice.

Observed Changes in Polar Ice Sheets and Sea Ice: Responses to Climate Warming

Until recently, we did not know whether the Greenland and Antarctic ice sheets were growing or shrinking, but significant climate-induced changes are now being detected. Satellites are detecting changes in ice sheet mass by measuring changes in ice surface elevations and changes in the sub-satellite gravity fields. Changes in ice velocity and ice area are being determined from imaging radar and other high-resolution imagery. The area and timing of surface melting are measured by satellites, ice acceleration is measured by surface GPS, and surface temperatures and other meteorological parameters are measured by automatic weather stations on the ice. We now know that during 1992 to 2002 the Greenland ice sheet was thinning at the margins and growing inland, probably with a small overall mass gain. Thinning at the margins from increased melting and inland growth from increasing precipitation are the expected responses to climate warming. The area of surface melting during summer continues to increase, and the acceleration of the ice flow (caused by the increased melting) has also been increasing, since it was first detected in 1997. In the last 5 to 10 years, some of the outlet glaciers in Southern Greenland have been accelerating and the number of associated ice-quakes has been increasing. New satellite-gravity measurements indicate the mass balance has now changed to a net loss, which suggests that the effects of melting are becoming dominant over increasing precipitation, and that the newly-discovered ice accelerations are very important.

During the 1990's, the ice sheet in West Antarctica was losing mass and the ice sheet in East Antarctica had a small mass gain. The ice loss in West Antarctica is probably an ice-dynamic response to long-term climate change and perhaps past removal of adjacent ice shelves. The ice growth in the Antarctic Peninsula and parts of East Antarctica may be due to increasing precipitation. The floating ice shelves of the Antarctic had a corresponding mass loss in the West and a gain in the East. Continued ice shelf thinning from regional climate warming in West Antarctica may be a precursor to more loss of grounded ice. The recent contribution of the ice sheets to sea level rise has been a small part of the current rate of 3 mm/year (1 foot/century), but the ice sheets are likely to lose mass faster with additional warming.

The most significant change in sea ice has been a 9%/decade decline in the area of sea ice surviving the summer melting on the Arctic Ocean. Now, for the first time the laser altimeter on NASA's ICESat is making comprehensive measurements of sea-ice freeboards, from which ice thickness maps are being derived. These new results show a fundamental change in the character of the sea-ice thickness distribution in the Arctic, indicating a loss of the thicker ice that was characteristic of earlier decades.

Causes of Changes in Arctic Sea Ice

The Arctic Ocean has been warming in recent decades and that warming appears to have accelerated during the last several years as observed by satellites and *in situ* measurements and as projected by models. The main manifestation of such a trend has been melting of the Arctic ice pack and the dramatic reduction of summer sea ice cover. Satellite records of the Arctic sea ice cover show a decreasing trend in ice concentration since 1979, with large seasonal and interannual variability. This trend has been coincident, in part, with the high-index polarity of the Northern Hemisphere Annular Mode or NAM (a.k.a., the North Atlantic Oscillation or NAO, or the Arctic Oscillation or AO) represented by a reduced winter weather regime over mid- to high-latitude continental regions of the Northern Hemisphere. However, some of the recent variability clearly points to other modes of large scale climate forcing as well. Especially overlooked appears to be the oceanic thermodynamic control of sea ice through the under-ice ablation and lateral melt along marginal ice zones. Those ice-ocean interactions may act to accelerate summer melt and significantly reduce the correlation between sea ice cover change and AO/NAO forcing.

Some global climate models project up to a 50% reduction of summer sea ice cover in the Arctic Ocean by 2100, as a result of an amplified response to global warming. Unfortunately, the majority of such models can not adequately reproduce past and present variability in the Arctic sea ice and ocean circulation, which diminishes their accuracy of future climate prediction. An arguably more realistic representation of the Arctic Ocean and its sea ice, using regional high resolution simulations over the past decades, implies that during the last decade sea ice thickness and volume might be shrinking at a much higher rate than predicted by climate models or determined from the satellite-derived trend of sea ice extent. Positive ice-albedo feedback and increased oceanic advection of heat via Pacific and Atlantic Water may in reality lead to an accelerated reduction or even to the complete removal of summer Arctic sea ice within a few decades. Such a change may result in additional significant changes to the global ocean thermohaline circulation and climate, especially over northern Europe. In addition, the warming trend, if it continues along its present trajectory, will likely not only significantly affect global climate but is also likely to change the strategic and economic importance of the Arctic Ocean through its use for commercial shipping routes and increased exploration of natural resources.

Model Estimates of Ice-Sheet Thinning

Ice-sheet thinning in response to warming probably is contributing to sea-level rise a century earlier than indicated by previous model estimates, suggesting that future sea-level rise may be faster than formerly projected.

Earth-system models are increasingly skillful at simulating the atmospheric and oceanic changes that have occurred over recent decades, and projections from earlier earth-system models are proving to have been fairly accurate. However, the 2001 IPCC assessment indicated that the most-likely response of the Greenland and Antarctic ice sheets to warming through the year 2100 would be to remove water from the oceans, with snowfall increasing more than melting and with little change in ice flow, although assessed uncertainty was large and included the possibility of

ice-sheet mass loss. Just five years later, best estimates from numerous recent studies indicate that the ice sheets are losing mass in response to warming, although again with some uncertainty.

Numerous barriers exist to accurate projection of ice-sheet changes in response to specified climate changes. The ice-sheet thickness is not even known everywhere, nor is the depth of ocean water beneath floating extensions called ice shelves that expose ice to potentially rapid melting from below. Basal thawing of ice on land allows faster ice flow, especially if the ice rests on smooth rocks or soft muds, but the distribution of these substrates is not well-mapped. Most earlier ice-flow models simplified the representation of ice flow for computational efficiency, but the recent data show that the simplifications omitted important processes that can contribute to rapid ice-sheet changes. Coupled ocean-atmosphere models do not resolve the processes and heat fluxes very near the ice sheets well, complicated by difficulties in representing sea ice that often occurs near ice sheets.

Consideration of history over many time scales shows that warming generally melts ice and raises sea level. The recent ice-sheet changes point in the same direction. Model improvements and additional data will be required to learn how rapidly this might occur in the future.

Biographies

Dr. H. Jay Zwally has held several senior science research positions (Physical Scientist, Oceanographer, Supervisory Physical Scientist, Research Scientist) since he joined NASA's Goddard Space Flight Center in 1974. Currently, he is ICESat Project Scientist and a member of the Mars Orbiting Laser Altimeter (MOLA) and Geoscience Laser Altimeter Team (GLAS) science teams. His recent research includes leading a comprehensive analysis of the mass balance of the Greenland and Antarctic ice sheets and ice shelves, the discovery of the melt-acceleration effect on the flow of the Greenland ice sheet, and the first comprehensive mapping of sea ice freeboard and thickness distributions. He was instrumental in promoting a laser altimeter satellite for ice sheet mass balance and multi-disciplinary science, leading to the Ice Cloud and Land Elevation Satellite (ICESat) launched in 2003. Dr. Zwally was also a lead scientist on the Environmental Task Force/Medea committee advising the CIA and other agencies on the use of classified assets for environmental protection and security.

Prior to his arrival at NASA, Dr. Zwally served in the National Science Foundation's Division of Polar Programs, where he managed the initiation of the interdisciplinary Ross Ice Shelf Project, the Greenland Ice Sheet Project, improved airborne radar mapping of ice sheet thickness, and planned for West Antarctic ice sheet projects.

For his considerable efforts and skill, Dr. Zwally has been the recipient of the following Awards: Goddard Award of Merit for Outstanding Contributions and Scientific Leadership, Laboratory Peer Award for Outstanding Publication, NASA Outstanding Scientific Achievement Award, NASA Group Achievement Award to Authors of Antarctic Sea Ice Atlas, and the Goddard Exceptional Performance Award for leadership in establishing a recognized cryospheric research program. In addition, Dr. Zwally has authored over 100 peer-reviewed scientific publications in glaciology, polar research, climate science, and physics.

Dr. Zwally received a B.S. degree in Mechanical/Aeronautical Engineering from Drexel University, PA, and a Ph.D. degree in Physics and Mathematics from the University of Maryland.

Dr. Wieslaw Maslowski is an associate research professor of the Oceanography Department at the Naval Postgraduate School, Monterey, CA, USA. His research interests include polar and physical oceanography, high resolution numerical ocean and sea-ice modeling, ice-ocean-atmosphere interactions, ocean circulation, sea ice, and climate variability in the Arctic Ocean and their effects on global ocean thermohaline circulation and climate. Dr. Maslowski's recent research has focused specifically, on documenting and modeling changes in the multi-year sea ice cover in the Arctic Ocean in the late 1990s and 2000s. While still relatively young in his career, he has authored or co-authored around 30 peer-reviewed scientific publications.

Dr. Maslowski earned his Ph.D. in physical oceanography from the University of Alaska in 1994, and M.S. degree in physical oceanography from the University of Gdansk, Poland in 1987. He is a recipient of the Naval Postgraduate School Special Act Award, NOAA Global and Climate Change Postdoctoral Fellowship, and NASA Global Change Graduate Fellowship. He has served on the National Academies of Science / National Research Council Committee on A Science Plan for the North Pacific Research Board, the National Science Foundation's Committee for the Bering Sea Initiative and the Shelf Basin Interaction Program, the Arctic Region Supercomputing Center Technology Panel, Board of Directors of the Arctic Research Consortium of the US, and most recently on several working groups of the Second International Conference on Arctic Research Planning.

Dr. Richard B. Alley is the Evan Pugh Professor of Geosciences and Associate of the Earth and Environmental Systems Institute at The Pennsylvania State University, University Park, PA, USA. There he teaches and conducts research on the paleoclimatic records, dynamics, and sedimentary deposits of large ice sheets, as a means of understanding the climate system and its history, and projecting future changes in climate and sea level. Dr. Alley has spent three field seasons in Antarctica, eight in Greenland, and three in Alaska. He is a Fellow of the American Geophysical Union, and has been awarded a Packard Fellowship, a Presidential Young Investigator Award, the Horton Award of the American Geophysical Union, the Easterbrook Award of the Geological Society of America, the Agassiz Medal of the European Geosciences Union, the Wilson Teaching Award and the Mitchell Innovative Teaching Award of the College of Earth and Mineral Sciences, and the Faculty Scholar Medal of the Pennsylvania State University. His book on abrupt climate change, *The Two-Mile Time Machine*, was the national Phi Beta Kappa Science Award winner for 2001.

Dr. Alley served as Chairperson on the recent U.S. National Academy of Sciences study on Abrupt Climate Change, and serves, or has served, on many other advisory panels and steering committees including the Intergovernmental Panel on Climate Change. He has been invited to the White House to discuss climate change, and has testified on climate change before a U.S. Senate Committee. He has authored or coauthored more than 170 peer-reviewed scientific publications.

Dr. Alley is happily married with two children, two cats, one ranch house, a minivan, and two bicycles, and resides in State College, PA, USA, where he coaches recreational soccer and occasionally plays some. He received his Ph.D. in Geology, with a minor in Materials Science, from the University of Wisconsin-Madison in 1987, and earned an MSc degree (1983) and BSc degree (1980) in Geology from the Ohio State University.

**This seminar series is open to the public and does not require a reservation.
Please feel free to forward this notice**

The **Next Seminar** is tentatively scheduled for the week of May 22nd, Topic: Impacts of Air Pollution in the Arctic

Please see our web site for seminar summaries, presentations and future events:
<http://www.ametsoc.org/atmospolicy>

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