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Wadati Conference on Global Change and the Polar Climate, 7–10 November 1995, Tsukuba, Japan

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meeting summary

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1. Introduction

The Wadati Conference on Global Change and the Polar Climate was held in Tsukuba, Japan, on 7–10 November 1995. The conference brought together approximately 60 scientists from North America, Europe, Japan, and Australia to review and assess recent polar climate variations in the context of global change. The conference consisted of oral presentations, a poster session, and a plenary discussion session in which an attempt was made to synthesize the results of polar climate research into a consistent picture of recent changes.

The need for the current assessment of polar climate in the global context arises, in part, from several generations of global climate model experiments indicating that the strongest greenhouse effects might occur in the polar regions. The recent (1995) assessment of the Intergovernmental Panel on Climate Change indeed cites the polar amplification of near-surface warming, at least in the Arctic, as a characteristic of greenhouse experiments with global models. Feedbacks involving sea ice, snow cover, polar clouds, the hydrologic cycle, and the stratification of the polar oceans have been proposed as mechanisms by which the polar regions might amplify global change. However, these feedbacks are poorly understood, and their treatments in global models are largely unexplored. The uncertainties surrounding polar climate change have served as scientific stimuli for the recent surge of polar climate research. At the same time, technology has provided an unprecedented array of new research opportunities through advances in satellite measurements, ice-coring capabilities, automated measurement techniques, and more powerful computers. The results of recent research on polar climate have accumulated at an increasingly rapid rate in disciplinary as well as interdisciplinary outlets, creating a need for the synthesis and assessment that were the objectives of this conference.

In order to achieve the goal of a synthesis and assessment of information on recent polar climate variations, the Wadati Conference's Organizing Committee brought together an international group of experts to address four topics that are central to the role of polar climate in global change. The conference's four sessions were devoted to these topics. Session 1 addressed the observational evidence of climate change. The emphasis of this session was on instrumental measurements, thereby creating a focus on changes over the past century or two. The presentations in session 2 addressed the processes underlying the interactions and feedbacks within the polar climate system. These feedbacks include the albedo–temperature feedback, ocean–atmosphere exchanges, cloud–radiative interactions, and other polar processes contributing to global change. Session 3 dealt with the longer timescales, over which paleoclimatic reconstructions provide a window on climate variations. The polar climate reconstructions draw heavily upon ice cores. Finally, the increasing use of models to examine polar climate variability was the subject of session 4. Papers in this session spanned the range of regional and global models, including the coupled ocean–atmosphere global models of several major modeling centers. The plenary discussion session represented an attempt to reconcile the model results with the observational and process-based studies of the first three sessions.

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2. Evidence of climate change

Session 1 began with an overview by J. Walsh of global climate model simulations of greenhouse changes in the Arctic, with an emphasis on the seasonality and regionality of the changes. The largest greenhouse warming projected by the models is in the central Arctic Ocean during autumn and early winter; this warming is largely a response to a thinning and/or disappearance of sea ice during the summer and early autumn. While the Arctic warming is generally diminished somewhat when the models include sulfate aerosol effects and coupling to a deep ocean, a polar amplification is a characteristic feature of the model-projected greenhouse warming in the Northern Hemisphere. In contrast to the model projections of a maximum warming over the Arctic Ocean, observational data for the past 30–40 years show a warming that appears to be strongest over the northern land areas and during spring and winter, although there has not yet been a systematic integration of estimates of recent temperature changes over arctic sea ice and land areas.

As noted by C. Folland, much of the wintertime warming over northern Eurasia is due to an increase of westerly airflow. Moreover, the signal-to-noise ratio of the greenhouse warming in GCM simulations is smaller in polar regions than in tropical latitudes. P. Jones showed that the spatial scale of summer temperature anomalies is much smaller in the northern polar regions than in lower latitudes. Jones also showed that interannual variations of temperature over Antarctica are divorced from those of the rest of the Southern Hemisphere during the period of instrumental data. More comprehensive integrated assessments of ocean surface temperature and sea ice margin variations are now becoming possible with the newly available Global Ice and Sea Surface Temperature (GISST) dataset, version 2.2, compiled at the Hadley Centre of the U.K. Meteorological Office (UKMO) by Folland and colleagues. A cooling of the subpolar North Atlantic over the past several decades is a consistent result of temperature trend analyses based on sea surface temperatures as well as land station data.

In the stratosphere, temperature trends reported by K. Labitzke show a negative trend of approximately −0.6°C per decade at 50 mb over the central Arctic over the past several decades. A link to the solar cycle is present in the upper stratosphere, and the link also appears to be present in the lower troposphere. T. Yasunari showed that subarctic features of the recent (1964–93) temperature changes extend from the surface to 500 mb. Yasunari's EOF analysis revealed two leading modes of Northern Hemisphere temperature variability, one with a time series corresponding to hemispheric snow cover and having an amplitude maximum near the surface, and the other with a time series corresponding to equatorial SST and having a maximum amplitude at 500 mb. Yasunari also showed that wintertime soil temperatures (120 cm) at Yakutsk in Siberia have increased since 1973. H. Tanaka presented evidence of several jumps in climate variables, in particular in Alaskan temperatures in 1989 and in vorticity over the Arctic Ocean in 1988–89. Tanaka argued that these and other more transient shifts may be triggered by abnormal persistent blocking.

Several speakers in session 1 also addressed recent variations of sea ice. R. Barry discussed the importance of monitoring changes in cryospheric variables (particularly snow cover, sea ice, glaciers). Remote sensing of spatial characteristics complemented by surface measurements of snow water equivalent, sea ice thickness, and glacier mass balance, in particular, is required. J. Zwally noted that the passive microwave database points to an absence of trends in Antarctic sea ice and a very small (> 1% per decade) decrease of Arctic sea ice. This decrease is concentrated in the eastern Siberian sector and is associated with strong low pressure systems in 1990 and 1993, according to Barry. Zwally also stressed the importance of consistent observations over long intervals; the use of different passive microwave sensors for 1978–87 and 1987–94 has created uncertainty over a recently reported decrease of Arctic ice area in summer. N. Ono showed that there is considerable interannual variability in sea ice extent as well as glacier mass balances, while P. Wadhams showed that submarine measurements of ice draft (thickness) may be useful in trend detection if sampling errors are estimated from a series of short (~50 km) transects obtained in a particular area and time.

3. Processes, interactions, and feedbacks

Session 2 included a report by K. Aagaard on recent Arctic/subarctic ocean variations obtained from ship cruises. In the Arctic Ocean, a warming of the upper part of the water column is approaching 1°C; in the vicinity of the Lomonosov Ridge, signs of warming extend down to 1–2 km. In the Greenland

Sea, 1994 was the warmest of the past 30 years, probably because the cooling from deep convection has been weak during much of this period. Aagaard concluded that "we are beginning to accumulate evidence of a change in ocean properties in the Arctic Ocean and the Greenland Sea."

E. Augstein reported on aircraft measurements made over Fram Strait, where the greatest water mass and heat exchanges between the Arctic and Atlantic Oceans appear to occur. The measurements showed that the net vertical radiative flux at the ice-covered air–sea interface significantly exceeds the turbulent sensible heat flux but that the latter is up to 10 times larger than the net radiative flux over open water, particularly in an off-the-ice cold air flow. Exchange coefficients for the surface momentum and heat fluxes in the marginal ice zone have been derived from the aircraft observations; they are essential for the flux computation in ocean and sea ice models.

T. Yamanouchi, describing a study of the role of polar regions in the earth radiation budget, reported that the effect of clouds on the earth–atmosphere energy budget is reduced over sea ice; conversely, the effect of sea ice is reduced when clouds are present. K. Yamazaki described a study of the atmospheric water budgets of the two hemispheres, showing that the poleward moisture flux convergence is larger in the Northern Hemisphere poleward of 70° and in the Southern Hemisphere equatorward of 70°. A. Ohmura showed that a state-of-the-art global circulation model (ECHAM3) is able to reproduce quite accurately the precipitation fields over Greenland and Antarctica, provided that the model is run at high (T106) resolution. When run in a greenhouse ($2 \times CO_2$) mode, the same model predicts that the increase of sea level resulting from increased melt over Greenland will be largely offset by increased accumulation over Antarctica.

4. Paleoclimatic reconstructions

Session 3 emphasized the recent information deduced from ice cores. The Antarctic ice core records surveyed by E. Mosley-Thompson suggest a recent warming over most of Antarctica, including a strong warming over the Antarctic Peninsula consistent with recent station data. However, parts of the East Antarctic region appear to have experienced a recent cooling, as shown by both Jones and Mosley-Thompson, and thus are somewhat anomalous with respect to the aggregate of ice-core evidence from around the world. Evidence of the Little Ice Age is spotty, as the cooling of that period is not detectable in ice cores from West Antarctica, confirming Jones's finding from instrumental temperature records that Antarctica is divorced from the rest of the Southern Hemisphere. On longer timescales, a cooling over the past 4000 years, particularly around 2000 BP, has been inferred from $\delta^{18}O$ measurements of ice from the Antarctic Plateau. The $\delta^{18}O$ data are ambiguous and may be indicative of temperature changes or of changes in the source region of precipitation. The ice-core data also indicate that precipitation has been increasing over all parts of Antarctica. The increase is especially large over the Antarctic Peninsula and the plateau/South Pole region, where there has been a 20% increase in accumulation since 1954. The percentage increase is even greater over some Antarctic regions if longer time periods are considered.

R. Koerner reviewed evidence obtained from ice cores in the Northern Hemisphere. The complete disappearance of the Laurentide ice sheet did not occur until about 6000 BP, which is shortly after the time when a long cooling began. This cooling is apparent in circumpolar cores but not in the Greenland summit cores. The long cooling was ended only by the recent warming, which may be related to anthropogenic factors. The Northern Hemisphere ice-core records also suggest a large release of freshwater around 8500 BP, which may represent the last of the Dansgaard–Oeschger events. M. Nakawo addressed the evolution of the Shirase drainage basin of the East Antarctic ice sheet. A rapid lowering of the surface elevation has been observed recently in this region. A dynamical response to an event in the past few thousand years is suggested.

J. Svoboda addressed the susceptibility of the eastern Canada–Greenland region to glaciation under present conditions, even if the near-term scenario includes global warming. Much of the vegetation presently found in the high Arctic is not older than 150 years, implying a rapidly varying ecology in this region. The underlying deep and cold permafrost represents a concealed glaciation, which could be ready to support new glaciation if increased precipitation is delivered. Interestingly, the onset of the last ice age occurred when the temperature and CO_2 concentration were high. The recent pattern of global "warming" shows a cooling over northeastern Canada. The possible abruptness of a future onset of glaciation in this region remains an open question.

5. Climate modeling

Session 4 included a summary by A. Lynch of results from a regional Arctic climate system model. The model, which includes interactive atmosphere, sea ice, and land/vegetation components, reproduces observed summer air temperatures over northern Alaska, although the agreement is weaker during winter. Results from global atmosphere–ocean coupled models were presented by representatives of three major modeling centers [Meteorological Research Institute (MRI)-Japan, the UKMO, and the Geophysical Fluid Dynamics Laboratory (GFDL)]. T. Motoi showed that the MRI coupled model undersimulates Antarctic sea ice and oversimulates Arctic sea ice in the present climate, suggesting that the formulations of polar clouds and albedo require closer investigation. A. Noda described the results of a transient CO_2 simulation with the same model. The response in the polar regions was found to be strongly shaped by the inclusion of leads, which eliminated the polar amplification in the Antarctic and reduced polar amplification by 50% (relative to GFDL) in the Arctic.

By contrast, H. Cattle showed that the UKMO Hadley Centre's "unified model" produced a strong (5°–10°C) warming over the Southern Ocean during winter when CO_2 was slowly increased. Perhaps more importantly, the inclusion of sulfate aerosol reduced the Arctic warming by some 20% and eliminated the decrease of Arctic sea ice in the period corresponding to 1979–95 (when Zwally had argued earlier in the meeting that the observed decrease has been small or nonexistent). At the time of doubling of greenhouse gas concentrations, changes of ice concentration and thickness were found to correlate better with areas of maximum warming than did ice extent, suggesting that the latter may not be the optimum choice of a variable for greenhouse monitoring. In the ocean component of the unified model, the increase of CO_2 was accompanied by a warmer core of the North Atlantic inflow to the Arctic, although the model's Arctic Ocean density structure remained stable.

S. Manabe described the use of the GFDL coupled ocean–atmosphere model to examine the role of the thermohaline circulation in abrupt climate change. When the surface of the North Atlantic Ocean (50°–70°N) was artificially freshened by surface water input, the model's thermohaline circulation rapidly weakened and became more shallow. In addition, it was shown that the disproportionate increase of precipitation in high latitudes induced by greenhouse warming also led to a more drastic weakening of the thermohaline circulation. These model results suggest that the monitoring of the global ocean must be a high priority in the greenhouse-detection strategy.

While the North Atlantic exerts a strong control over the thermohaline circulation, 60% of the ocean water is colder than 2°C, implying a source in the Antarctic subpolar ocean. Thus, heat fluxes and watermass formation processes in the Southern Ocean must be modeled realistically if global ocean simulations are to be successful. A. Gordon presented recent estimates of the heat fluxes to the mixed layer from the Weddell Deep Water. These fluxes are much larger (40 W m^{-2} during winter) than in the Arctic Ocean, effectively limiting Antarctic sea ice thickness to about 0.5 m in this area. Based on the history of the Weddell Polynya, the Weddell Sea appears to be delicately poised with respect to deep convection.

B. Saltzman described the modeling of global ice variations over the past 5 Myr. When driven by GCM-derived estimates of global ice parameters, this model indicates that the 100 kyr oscillation of global ice mass is internal rather than driven by Milankovitch cycles. The model also indicates that ice-age cycles will not continue into the next 100 kyr if CO_2 concentrations are maintained near 350 ppm. A. Abe-Ouchi also described an ice model, which when applied to the Greenland ice sheet, predicts ice-sheet disintegration for a warming of only 3°–4°C.

Finally, M. Sugi described experiments addressing Eurasian snow–monsoon relationships in the global model of the Japan Meteorological Agency. The link between the monsoon's direct forcing (land surface temperature) and the late-winter snow fades away by June or July, leading to an insignificant correlation between snow and the monsoon index. These results imply that the more important factor(s) are the internal dynamics of the monsoon or influences from outside the monsoon region.

6. Plenary discussions

The plenary discussion of the detection of the greenhouse signal in polar regions revolved around two questions. 1) Are we now seeing the greenhouse signal in polar regions? 2) If not, how and when will the signal manifest itself? In response to 1), the conference papers and discussion led to Table 1, summarizing the observational evidence from the past few decades. A view that emerged on several occasions is that the "traditional" emphasis on sea ice extent and Arctic Ocean air temperatures as early indicators may yield to the search for a broader fingerprint involving information from ice cores, sea ice concentration and thickness, subpolar sea surface temperatures, subsurface polar ocean temperatures, and high-latitude precipitation. The latter set of variables shows some evidence of recent changes that are consistent with those anticipated from anthropogenic influences. However, records are long for only surface air temperatures, and even these are not long enough to distinguish unambiguously the natural and anthropogenic influences.

A recurring theme of the presentations and discussion was the possibility of an abrupt and surprising climate change involving the high latitudes. In addition to the "thermohaline catastrophe" in which deep convection in subpolar oceans is the key process, the onset of glaciation is a terrestrial process with its roots in the subpolar North Atlantic sector. This sector has indeed cooled in recent decades despite the "global" warming during this period. Given the concomitant increase of precipitation in high latitudes, it is quite possible that the polar land areas as well as the subpolar oceans are delicately poised with respect to rapid climate reversals.

TABLE 1. Summary of changes observed in the high latitudes over the last few decades of the twentieth century.

Parameter	Arctic	Antarctic
Surface temperature	Generally warmer (on land, in winter/spring, but some cooling; unclear over sea ice)	Slightly warmer, but much warmer over Antarctic Peninsula
Tropospheric temperatures	Warmer (lowest layers)	Not yet assessed
Stratospheric temperatures	Colder (summer only)	Colder
Precipitation	Wetter over land, unknown over sea ice	Not certain (wetter in East Antarctica)
Extreme weather	Not yet assessed	Not yet assessed
Ocean temperatures	Warmer (central Arctic)	Weak warming
Snow cover extent	Reduced (Eurasia, spring; also in Canada/Alaska)	
Sea ice extent	Slightly reduced (East Siberian Sea)	No trend
Sea ice thickness	Thinner in some regions (short-term record only)	Not yet assessed
Ice-sheet elevation	Higher (South Greenland, no change in Canada)	Higher (East Dronning Maud Land)
Ice-sheet surface melting	Increased (South Greenland)	Decreased (Queen Maud Land)
Ice-shelf extent	Reduced (Canada)	Reduced (peninsula)
Permafrost extent	Reduced (Alaska, Canada, Siberia)	—

Regardless of whether such changes occur in the subpolar ocean and land components of the climate system, the results of state-of-the-art GCMs such as the U.K. unified model and the Goddard Institute of Space Sciences model, both of which have been run with sulfate aerosol effects, suggest that the enhanced greenhouse effect should be detectable in the polar regions and elsewhere in the next decade or two. The Wadati Conference has highlighted the possible early indications of anthropogenic changes and has called attention to the need to monitor the polar climate system carefully for rapid, complex, and perhaps surprising changes in the near future.

A preprint volume of the papers presented at the conference is available from H. L. Tanaka, Institute of Geoscience, University of Tsukuba, Tsukuba 305, Japan.

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