Report on the Workshop on 'Recent High Latitude Climate Change', Fairbanks, Alaska, 6-8 December 2004

This workshop was held to gain insight into the nature of, and mechanisms behind, the major increases that have been observed in near-surface air temperature in some parts of the high latitude areas over the last 50 years. The meeting was sponsored by the Scientific Committee on Antarctic Research (SCAR), the WCRP Climate and Cryosphere Project and the International Commission on Polar Meteorology. The workshop was held at the International Arctic Research Center (IARC) (University of Alaska), which provided excellent facilities for the workshop.

The meeting opened with welcome addresses by Dr Akasofu (Director of IARC) and Dr John Walsh. Following these, the meeting consisted of lectures during the mornings and working sessions during the afternoons, plus a final series of presentations by the rapporteurs and a wrap-up session. It was broken up into three sessions dealing with a) The observed changes, b) Climate change mechanisms and c) Modelling climate variability and change.

The observed changes

The first papers considered the changes that have been observed over the last 50 years in the primary meteorological observations and atmospheric circulation of the polar regions. Jim Overland reviewed our knowledge of broadscale Arctic change. The record of air temperatures extends back to the start of the Twentieth Century and the mean November-March value for the region has increased over this period. However, following a maximum in the 1930s and 1940s, temperatures decreased until about 1970, with a marked warming since that time. Most of the warming has occurred in the winter and spring, and has taken place over Siberia and Arctic North America. Much of the observed change in the Arctic can be explained by changes in the advection of air masses into the region. Over recent decades the Arctic Oscillation (AO) has been in its positive phase, giving stronger westerlies, which can explain a lot of the temperature increase in Siberia. But over the last few years the AO has become neutral, while Arctic sea ice has continued to decrease. This suggests that the Arctic climate system has a 'memory'.

Gerd Wendler reviewed the changes that have taken place across Alaska over the last 50 years. These high quality records show the greatest temperature increases in the winter and spring, with a minimum of change in the autumn. There is a strong link between changes in this area and the Pacific Decadal Oscillation (PDO), suggesting a link with tropical conditions. The temperature record suggests a jump around 1976; at the same time as there was a phase shift in the PDO. Since 1977 no temperature increase has been observed, with the exception of the Arctic (1.5°C). There has been an increase in precipitation across much of the state over the last 50 years. There has been greater storm activity in recent years, which is in agreement with lower surface pressures.

Igor Semiletov summarised the changes in Siberia in relation to the temperature variability, snow cover and ocean conditions. Over the last few decades there has been a significant increase in the discharge of the major Siberian river systems as a result of atmospheric circulation changes and higher near-surface temperatures. This could have a serious impact on the ocean's thermohaline circulation because of this fresh water discharge into the Arctic Ocean. The degradation of Siberian permafrost may have contributed to the increased river run off. The conditions in Siberia are strongly influenced by the Siberian High. During the last 3 decades enhancement of the Siberian High and the increase in its area has caused more precipitation over the Ob and Yenisey watersheds north of 60N and to the west of 110E in comparison the earlier period. Precipitation over the East Siberia has decreased during the same period.

Gareth Marshall considered the changes that have taken place in the Antarctic over the last 50 years. The Antarctic Peninsula is clearly an exceptional area where temperatures have increased markedly, while the trends around the rest of the continent have been very small and generally not statistically significant. It is now believed that there are two major changes taking place in the Peninsula. Firstly, a winter season warming that is most apparent on the western side. This seems to be associated with a decrease in sea ice over the Bellingshausen Sea, although it is not clear why this has taken place. Some data suggest higher surface pressure over the Bellingshausen Sea in the 1950s and 1960s, but there is no in-situ data to support this. The summer warming is most apparent on the eastern side of the Peninsula and seems to be a result of the changes in the Southern Hemisphere Annular Mode (SAM) into its positive phase in recent decades, giving stronger westerlies. These could have given higher temperatures on the eastern side because of the Foehn wind effect, coupled with greater cyclogenesis over the western Weddell Sea. There is evidence that recent changes in the SAM are, at least in part, a result of increasing greenhouse gases. Tropospheric warming at Bellingshausen is greater than at stations further south, particularly in summer, due to the influence of a positive SAM. The annual warming between 850-300 hPa (1.4ºC) is more than three times the global average.

Joey Comiso summarised the changes observed in the polar regions via the valuable data set of satellite Advanced Very High Resolution Radiometry (AVHRR) imagery that extends back to the early 1980s. Over this period the largest warming has been seen in the Arctic during the spring and autumn, which is in contrast to the 50 year trends from in-situ data, which show the greatest change in the winter and spring. Regionally the greatest warming has been over the western Arctic and northern Canada. Some cooling is apparent in the Eastern Arctic. The first 4 years of the sea ice extent record versus the last 4 years of the satellite record shows a substantial decline. Over the period 1982-2003 the record of surface temperature changes across the Antarctic shows few areas of statistically significant change. Over this period sea ice extent has increased (decreased) in the Ross (Bellingshausen Sea).

Ron Kwok considered our understanding of sea ice changes from satellite data. The two polar regions present very different pictures of sea ice change over the last two decades. Since 1979 Arctic sea ice extent has decreased by 2.3%/decade and ice area by 3.2%/decade. The only area of positive trend has been the Bering Sea. Perennial ice area has decreased by 8.9% per decade. Around the Antarctic there has been small positive trends in ice area and extent over the last 20 years.

Christophe Genthon described Antarctic climate variability and trends from satellite and model data. Satellite microwave data allows the number of melting days per year to be estimated, with the largest number of days being found in the Antarctic Peninsula region. Here the trend is positive, although the whole Antarctic shows a negative trend. An EOF analysis of the 500 hPa height fields from the re-analysis data indicates that EOF 1 is related to the SAM, and EOF 2 to tropical forcing via ENSO (El Nino-Southern Oscillation). The Amundsen Sea low plays an important role, with the location and intensity of this feature affecting the atmospheric circulation from the Antarctic Peninsula to the Ross Sea. Firn cores from West Antarctic are a powerful tool for investigating links between precipitation and the Southern Oscillation Index (SOI). However, there is no significant correlation over the longest time span available for 6 records covering 1890-2000. In addition, there is no significant correlation over 1958-2000. This could be a result of noise in the ice core data.

Igor Polyakov considered oceanic changes in the Arctic. The Arctic Ocean is closely coupled to the rest of the climate system via the thermohaline circulation, the atmospheric circulation, the sea ice and high latitude precipitation. Our knowledge of the ocean circulation has increased in recent years, but we still need more long-term Arctic Ocean records to determine trends and variability in the system. The variability of key Arctic climatic parameters is dominated by multidecadal fluctuations with timescale of 50-80 years. The Arctic air-ocean system and the North Atlantic sea surface temperatures (SSTs) display coherent low-frequency fluctuations. Elucidating the mechanisms behind this relationship will be critical to our understanding of the complex nature of low-frequency variability. We need a permanent observational monitoring system for the Arctic Ocean.

Changes in permafrost across Siberia and Alaska were discussed by Vladimir Romanovsky. Permafrost is very sensitive to changes in climate (most importantly, are changes in air temperature, wind, and precipitation, especially snow), as well as changes in land cover/land use (both naturally occurring and as a result of human activities). Permafrost covers 10-30% of East Siberia and Alaska. The loss of permafrost in recent years is evident in Alaska and Siberia in terms of damage to pipelines, buckling of roads and damage to buildings.

Climate change mechanisms

David Thompson discussed the impact of the stratosphere on climate change at the Earth's surface. He considered the response to anomalous momentum forcing in the stratosphere and the possible impact at the surface. He felt that the mechanism must play a role, although the amplitude was still being debated. Over the period 1979-2000 Southern Hemisphere 500 hPa heights had dropped over the Antarctic and risen in mid-latitudes. The surface temperature decreases observed over much of the Antarctic in summer and autumn are to a large extent congruent with changes in the SAM, as is at least a portion of the observed temperature increases observed over the Peninsula. Observational and numerical results suggest that stratospheric ozone losses have played a key role in driving recent climate change at the Earth's surface in the Southern Hemisphere. But the underlying physical mechanisms are still under investigation. The annular modes appear to be susceptible to a range of forcings. It is unclear what the response to increasing greenhouse gases will be.

Mark Serreze examined recent atmospheric circulation changes in the Arctic. The North Atlantic Oscillation (NAO), which is a large-scale mode of atmospheric variability that describes a correlation between the strength of the Icelandic Low and the Azores High, is a key player in recent Arctic change. Since about 1970, the NAO has gone into a primarily positive mode (strong Icelandic Low), largely consistent with the pattern of recent surface air temperature change in the Northern Hemisphere. There is still controversy over whether the Arctic Oscillation and the NAO are really separate modes. There are arguments for and against based on statistical and physical grounds. A major question is whether the recent observed climate change is unusual and what is driving it? Some 1000 year simulations indicate recent change is within the "envelope" of natural variability. A number of studies provide convincing evidence of links between the recent AO trend and changes the stratosphere. Increasing greenhouse gas concentrations or reductions in ozone act to “spin up” the polar stratospheric vortex, with the effects propagating downwards. For example, part of the AO trend is linearly related to trends in total ozone concentration. Recent modelling work suggests that the NAO trend is at least partly driven by increasing sea surface temperatures (SSTs) in the tropical Indian Ocean and that the SST changes involve a non-linear response to greenhouse gas loading. Over the past five years or so, the NAO/AO has regressed to a more neutral state, but the Arctic is still warming. And sea ice is still retreating. The past three Septembers have seen record or near record minima.

We then switched to the Antarctic when Michiel van den Broeke talked on attribution of near surface climate change in Antarctica: the role of circulation variability. Local, near surface climate change in Antarctica is driven by a multitude of processes (advection, turbulent mixing, radiation) that obscure a possible anthropogenic signal. Large scale circulation variability is transferred to the surface in various ways, such as the semi-annual oscillation (SAO), which is important in coastal Antarctica via advection. The SAM is also very important as a near surface climate forcer through advection changes and turbulent mixing. The SAO is driven by latitudinal radiation gradients, could also act on much longer timescales. The radiation balance is also important: ice shelves in the rain/snow shadow of the Peninsula are more sensitive to warming through albedo feedback. Automated weather stations (AWSs) have revealed a strong negative cloud-albedo feedback over dry snow.

Jia Wang considered the search for causes and drivers of Arctic climate variability and asked the question ‘is the AO the only dominant mode interacting with the Arctic climate system’? He concluded that the AO is the northern hemisphere (NH) leading mode with its centre in the Arctic. Its thermodynamic impact (warming) in the last 3-4 decades played an important role in the Arctic. However, the wind anomalies induced by the AO are not statistically significant in the central Arctic, although the SLP change since 1989 was significant. Its dynamic impact is through the North Atlantic water intrusion. A new atmospheric dipole anomaly (DA) is the second dominant mode in the central Arctic (local). Its dynamic impact is more important than the AO, while the local thermodynamic effect is also important, reflecting the feedback of the local ice anomaly to the atmosphere. The mechanism maintaining the DA is due to the Arctic atmospheric wave flux (energy propagation). Using a coupled ice-ocean model, it has been confirmed that the critical atmospheric regime to influence the Arctic Ocean is dipole forcing (EOF 2) rather than the AO (EOF 1), particularly, the dipole forcing’s influence on sea ice export out of the Arctic Basin via the Fram Strait and the northern Barents Sea. This leads to thinning of the Arctic Basin ice. Using the model, it was found that the AO was related to North Atlantic Water intrusion driven by sub-Arctic anomalous wind stress (v), causing the subsurface seesaw between the Barents Sea and the Labrador Sea. Mechanisms are oceanic advection (primary) and local cooling, similar to the SAT seesaw and sea-ice seesaw

John Klinck considered the role of the ocean in high latitude climate change. The thermohaline circulation plays a major role in modulating the high latitude climate. Processes that can possibly play a role in climate change include surface heat flux changes via solar radiation, clouds, air temperature and the wind field. Surface fresh water changes through precipitation - evaporation, ice transport and glacial melt. Wind strength changes via mixing, upwelling, ice transport and shifting polar troughs. And circum-polar deep water (CDW) changes (flux or properties) through current shift, current stability, NH convection. Smaller scales are important at high latitude. Fundamental changes to water properties and circulation are possible in response to atmospheric changes. Ocean heat content and redistribution are important, but not well understood. Continental shelves are important, but not well represented in OGCMs.

Roger Barry discussed Arctic climate feedbacks through changes in snow cover and sea ice. Feedbacks can occur through many processes, such as clouds, troposphere/stratosphere interactions, the surface albedo and the Arctic boundary layer. The cryosphere can play a role through albedo feedbacks, modification of the atmospheric thickness, insulation of the land or ocean, time delay through water storage in snow, sea ice formation/decay or seasonally frozen ground effects. There can also be synoptic-scale interactions via storm track changes and snow cover. On larger scales there can be planetary-scale interactions, such as the Eurasian snow cover affecting the Arctic sea ice.

Uma Bhatt looked at the influence of sea-ice on the atmosphere. There has been a large sea ice extent decline during the summer of 4% per decade. Uma described modelling experiments where the model was forced with realistic sea ice conditions. There is evidence for ice feeding back onto the atmosphere during summer. Response to enhanced summer ice area yields more large scale response than reduced ice response. Significant remote response in North Pacific to reduced summer sea ice in Siberian Seas In contrast to winter, response in ice concentration experiments not very different than in the extent experiments.

Modelling the changes

John Turner presented an assessment of the performance of the Hadley Centre Climate Models (atmosphere-only and coupled ocean-atmosphere) in the Antarctic. The models generally performed well in the Antarctic, but it's unfortunate that the largest errors occur in the Peninsula sector. However, this is a difficult region to represent because of the steep orography. The largest error was overly deep surface pressure over the Bellingshausen Sea, which resulted in excessively strong northerly winds to the west of the Peninsula, giving too little sea ice. This error has been traced to a lack of marine stratocumulus cloud over the eastern sides of the tropical oceans. The poor representation of current conditions in this area must caste doubt on the predictions for the next 100 years. It's particularly unfortunate that the early HadGEM (the next version of the Hadley Centre model) runs also have this tropical cloud problem.

John Walsh discussed Arctic change from models. The Arctic Climate Impact Assessment considered projections of 21st-century greenhouse change using five models. The strongest warming is projected for the Arctic but the projected warming is strongest for autumn, not winter/spring (vs. obs) threshold exceedences are most significant outside of the Arctic. Arctic sea level pressures are projected to decrease, consistent with warming. Arctic precipitation is projected to increase: the pattern is highly seasonal (inland areas wetter in summer). Present-day high thresholds projected to be exceeded most in high latitudes. Sea ice and snow cover show retreats in models; as do permafrost and glaciers (off-line).

John Fyfe considered the potential impacts of Southern Hemisphere (SH) circulation change on the 1) position, number and intensity of SH cyclones and 2) the position and intensity of the Antarctic Circumpolar Current (ACC). 1) In concert with a poleward shift in baroclinicity the synoptic environment south of 40 deg S appears to have changed significantly over recent decades. South of 40 deg S and north of the Antarctic Ocean the number of cyclones has dramatically decreased, whilst over the Antarctic Ocean a modest increase has occurred. A global climate model (GCM) produces similar historical changes, and under a "business-as-usual" emissions scenario predicts that the number of sub-Antarctic ocean cyclones will drop by over 30% between now and century's end. 2) GCMs indicate that the poleward shift of the ACC observed over recent decades may have been significantly human-induced. The poleward shift, along with a significant increase in the transport of water around Antarctica, is predicted to continue into the future.

David Reusch considered recent high-latitude climate variability from a “nonlinear” perspective. He discussed Self-Organizing Maps (SOMs), which are a tool for extracting generalized patterns of variability from multivariate data. The technique has already been applied to the North Atlantic atmosphere, Antarctic sea ice edge and Antarctic Peninsula-centric atmosphere. It is early days in the use of the tool but the technique does hold definite promise both on its own and when used with other analysis/diagnostic techniques.

The final talk was on polar amplification of surface warming in climate models without ice-albedo feedbacks by Vladimir A. Alexeev. His conclusions were that the reasons for the polar amplification were two-fold. Firstly, larger sensitivity of tropical surface budget to SST changes. Secondly, warming and moistening of the extra-tropical atmosphere due to warming of the tropics (non-local heat transport effects). He also found that in version 3 of the Community Climate Model (CCM3) that the clouds make a considerable contribution to the amplification.

During the afternoons four working groups met and their conclusions are summarized below:

<u>Group 1 – Data voids and future data requirements</u>

The following areas were discussed – satellites, making use of past data sets, ocean, sea ice, glaciers, permafrost, watersheds, ice shelves, snow and radiation

The major recommendations were:

- We need to make best use of available data
- Recommend data rescue, digitization and archival.
- Observations vital for satellite cal/val.
- Need for longer time series, due to higher variability in polar regions.
- Desire for general release of data (even with Antarctic Treaty this is not happening)
- There are data gaps: e.g. Bellingshausen Sea
- This group endorses GCOS-82 recommendations on data archival and rescue.

Satellite challenges:

- The EOS era is coming to an end
- Uncertainty of continuation of data streams.
- Long term archiving and Climate Data Records (CDRs) – NOAA.

- We should take a critical look at NOAA proposed CDRs and NRC committee report on CDRs from operational satellites (2004).

Sea ice and sea ice thickness

- The importance of observations of sea ice thickness was raised.
- Current NPOESS EDR is ice age, not directly extent of concentration. Ability to do this from optical sensors is doubtful.
- Altimetry methods for measuring freeboard need better precision for the Antarctic.
- Issues for ULS in the Antarctic (icebergs)
- EM-induction method looks promising, but spatial-temporal coverage is not adequate for climate monitoring.
- Need for timely release of ULS Data. Need for further moorings (Siberian Seas).
- Release of all available submarine data highly desirable.
- Russian North Pole data from NP 32/33 must be archived and distributed.

Feedbacks

- We endorse recommendations of Perovich + Wadhams (2004 NPI report 124 "Arctic climate feedback mechanisms", S Gerland and B Nj). See table. Identify key sea ice parameters and suggest action items to acquire necessary observations.
- Planned workshops (SIMBA, passive microwave) will contribute to more detailed specifications and strategies for integrated feedback studies.
- Continue SCICEX data collection
- More moored ULS and fixed data sets: Pole, E-W variability, Siberian Shelf
- Polar installation of Argo buoys could be an IPY project.

Archiving data

- Difficulty obtaining data in general:
- Archiving issues: ULS
- Data Rescue: Russian data sets, translation and digitization. Small cost.
- Updating: Maintain data bases and update to 2005 (across the board)
- Metadata: Priority
- List data availability and status in central location.e.g. for all met stations, soil obs etc.
- Data void in Siberia … data are available but requires initiative to obtain and archive.
- This may address questions of change in Siberia.
- Recommend the promotion of Metadata.
- Distribute through SCAR (CliC and NSIDC)

Key data sets to digitize

- Heat balance components
- Fresh water balance components, including soil moisture and temperature.

Radiation data

- Data gaps in Alaska and Russian Arctic
- NOAA initiative to measure, not universities

The oceans

- Repeat WOCE sections in the Southern Ocean.
- Continue support for Argo buoys and expand programme into Polar Oceans.
- Repeat lines very useful.

Snow

- Obtain Russian data
- Are temperature, snow cover and river flow data consistent?
- Need more N. American sites recording snow depth and density
- Need records extending into mountains
- More hydrographic measurements from Antarctic stations.
- Need to maintain hydrographic programme. (To monitor high interannual variability)

New nations in Antarctica

- Provide advice on observation programmes:
- Hydrography
- Fast ice thickness
- Snow depth

Permafrost

- Network sparse
- Need to obtain Russian data, and continue data collection 1990s onwards
- Circumpolar Arctic Permafrost System CAPS: _ stations no longer active in 2002, need resources to address this
- Need for daily data
- Need to strengthen Antarctic and sub-Antarctic measurements
- Need measurements under ice shelves

Ice shelves

- Deploy autosub under ice shelves before they disintegrate!

Glaciology

- Big need to inventory and map glacial exchange and changes in high latitude areas.
- Support GLIMS in this.
- Uncertainty in Digital elevation maps. Need improved accuracy.
- Need high-resolution coastline maps for all areas with floating ice tongues.
- Need time series of high resolution maps to show change.

Water sheds

- Fresh water records needed from Finland and Russia.
- Ice covered lakes in dry valleys

Ice cores

- ITASE shallow cores: endorse and encourage rapid archiving.
- Recommend that the King+Comiso study for Antarctica (on where to collect cores) should be repeated for the Arctic.
- Need to look at spatial variability around cores.
- Run blowing snow model for 2 IPY years.
- Need surface winds, high res orography etc.

Antarctic seas

- Comprehensive Review of what data is available from expeditions, whalers etc.

Recommendations

- Maintain international in-situ and satellite observation networks.
- Improve and centralize metadata archive.
- Encourage digitization, calibration and analysis of old records.
- Establish bulletin board of ongoing data rescue projects.
- Ensure key data sets for GCOS essential climate variables, are updated at least annually.
- Coordinate recommendations with the IGOS-Cryosphere project, CliC and SCAR
- Also transmit to WCRP COPES.

<u>Group 2 – The re-analysis data sets</u>

The problems considered were:

- Would regional polar re-analysis products be useful enough to the community to be worth effort? Polar opt global hard sell
- If so, is it worth analysis of pre-satellite era (-1979) fields?
- What are specific improvements that need to made to re-analysis product, whether regional or global, to enhance performance in polar regions?

The planned development of Global Products was noted as:

- NCEP 1979+ (work starting 07-08)
- New GNEA 1979+ (GEOS-5)
- CDC Historical Re-analysis 1880's+

Issues

- Limitations of global products: analysis optimized for mid-lats, missing physics important to polar simulation
- Why do reanalysis if convenient access (NC) is made to raw data? Necessary quantity for solution constraint?
- Current re-analysis products good for large scale study of polar hydrologic cycle/moisture budget, but not to be trusted for small regions
- Warnings on pre-79 products? Level?

List of problems:

- Access to assimilation observation statistics (available/used)
- Model improvements
  - Sea ice, ice shelves
  - Albedo
  - Precipitation spin-up
  - Hydrologic cycle

<u>Group 3 – The mechanisms of rapid recent regional warming</u>

Key points raised in discussion:

- Antarctic Peninsula warming in winter is associated with a decrease in sea ice; Summer warming may have a greater anthropogenic component
- Changes in Alaska, at least during winter and spring, are largely advection-driven; key circulation features are in the North Pacific
- Siberian winter warming also appears to be largely advection-driven, although absence of a stronger European signature needs to be explained
- Papers in literature point to snow cover retreat over the past 30 years being responsible for ~33% of the warming in spring over northern land areas
- Is there convincing evidence that the greenhouse-gas increases can cause changes in the Arctic Oscillation? Arguments were made that the answer is "no", especially in view of the AO's return to a near-neutral state over the past 5-9 years.
- Do we understand the mechanisms linking increased greenhouse forcing to changes in the AO? Answer seemed to be "no" -- could rationalize AO changes of either sign. [Challenge Project indicates no CO2-AO link; points to tropical forcing of AO].
- IPCC report (2001) highlights conclusion that anthropogenic contributions are present in recent changes. Tone of discussion here seems to be "not so fast".
- One issue that needs to be reckoned with is that the more recent changes in tundra and sea ice seem to be extreme (if not unique) in the records of past 200 years or so.
- Why is Antarctic sea ice so different from Arctic sea ice in recent changes? Can reason in terms of katabatic winds, enhanced westerlies, oceanographic conditions, and Ekman drift…

<u>Group 4 – Improvements required to models</u>

Problems:

- What is the best way to prioritize the allocation of existing or additional computational resources among climate model components in order to maximize Arctic region simulation utility to user community?
- Two routes:
  - Increased resolution
  - Representation of additional physics, either via explicit simulation of parameterization

Specific issues

- Boundary Layer Processes
- Resolution of boundary layer: gradients
- Inversions properly parameterized
- Many problems thermodynamic rather than dynamic
- Cryosphere: ice shelves, permafrost, snow trapping/resuspension, snow thickness on sea ice, improved sea ice rheological parameterization
- Sea ice sensitive to errors in surface winds
- Clouds over sea ice regions
- Radiation schemes
  - Especially w/r to water vapor
  - Insolation in mixed layer important for ice-albedo feedback

Assessment

- Experiment design to assess utility of 'packages' of improvements to specific climate problems of interest

<u>Conclusions</u>

1. Although climate model experiments with increasing greenhouse gases predict that the greatest changes will be observed in the polar regions (primarily as a result of a decrease in sea ice), the pattern of temperature change over the last 50 years presents a complex picture that does not map directly onto the model predictions.
2. While the Arctic has experienced some of the largest temperature increases on Earth, the greatest changes have been over the continents rather than the ocean areas, with evidence suggesting that the temperatures have risen because of greater *advection* of warm air masses into these areas.
3. Large differences are seen in the Arctic temperature trends depending on the season and time period considered.
4. Changes in the Arctic Oscillation into its positive phase over the last few decades (giving stronger westerlies) can explain some of the temperature increases in Siberia, but over the last few years the AO has become neutral, while Arctic sea ice has reached record low amounts. This suggests some 'memory' in the system.
5. The increase in the extent of the Antarctic sea ice over the last two years is at odds with the model predictions. The increase may be a result of oceanographic changes, but there are insufficient observations to confirm this.

6. There is evidence that the summer temperature increases in the Antarctic Peninsula region may be, at least in part, a result of anthropogenic activity.
7. It was felt that some of the ‘sound bite’ statements coming out of the Arctic Climate Impact Assessment report were not sufficiently based on the available evidence e.g. ‘The polar regions over the last 25 years have experienced what the rest of the world will experience over the next 25’.

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John Turner
13 January 2004

Annex 1 – Participants

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Annex 2 ACRONYMS

ACC	Antarctic Cicumpolar Current
AO	Arctic Oscillation
AVHRR	Advanced Very High Resolution Radiometer
AWS	Automated Weather Station
CAPS	Circumpolar Arctic Permafrost System
CCM	Community Climate Model
CDR	Climate Data Records
CDW	Circum-polar Deep Water
CliC	Climate and Cryosphere programme (of WCRP and SCAR)
COPES	Coordinated Observation and Prediction of the Earth System
DA	Dipole Anomaly
EM	Electromagentic
ENSO	El Nino-Southern Oscillation
EOS	Earth Observing Satellite
GCM	Global Climate Model
GCOS	Global Climate Observing System
GLIMS	Global Land Ice Measurements from Space
IARC	International Arctic Research Council
IGOS	Integrated Global Observing Strategy
IPCC	Intergovernmental Panel for Climate Change
IPY	International Polar Year
ITASE	International Trans-Antarctic Scientific Expedition
JPL	Jet Propulsion Laboratory
NAO	North Atlantic Oscillation
NASA	National Aeronautic and Space Administration
NCEP	National Centres for Environmental Prediction (USA)
NH	Northern Hemisphere
NOAA	National Oceanic and Atmospheric Administration (USA)
NPOESS	National Polar Orbiting Environmental Satellite System (USA)
NRC	National Research Council (USA)
NSIDC	National Snow and Ice Data Centre (USA)
PDO	Pacific Decadal Oscillation
SAM	Southern hemisphere Annular Mode
SAO	Semi Annual Oscillation (around Antarctica)
SCAR	Scientific Committee on Antarctic Research
SCICEX	Scientific Ice Expeditions (by US submarine under Arctic ice)
SH	Southern Hemisphere
SOI	Southern Oscillation index
SOM	Self-Organising Maps
SST	Sea Surface Temperature
UAF	University of Alaska, Fairbanks
WOCE	World Ocean Circulation Experiment
WRCP	World Climate Research Programme

To be added

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