Climate Change: Consequences for the Arctic Physical Environment

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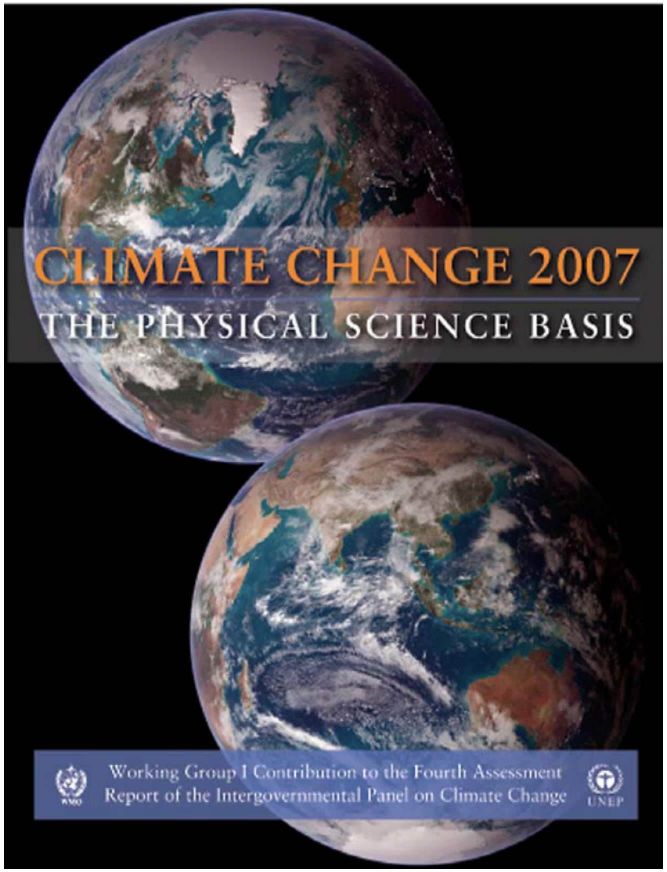
IPCC AR4 Working Group I: Summary of projections of change in the Arctic



The Arctic is very likely to warm during this century more than the global mean. Warming is projected to be largest in winter and smallest in summer.

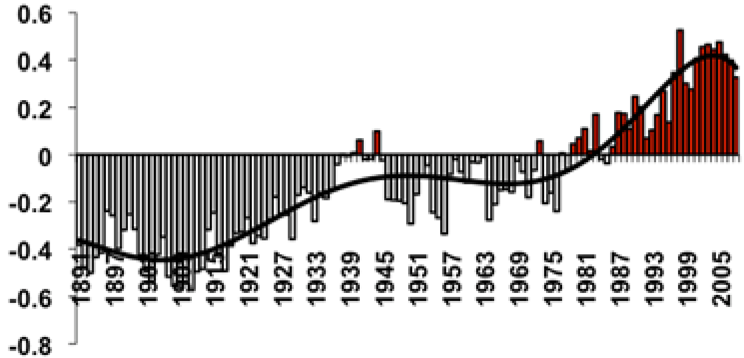
Annual arctic precipitation is very likely to increase. It is very likely that the relative precipitation increase will be largest in winter and smallest in summer.

Arctic sea ice is very likely to decrease in its extent and thickness.

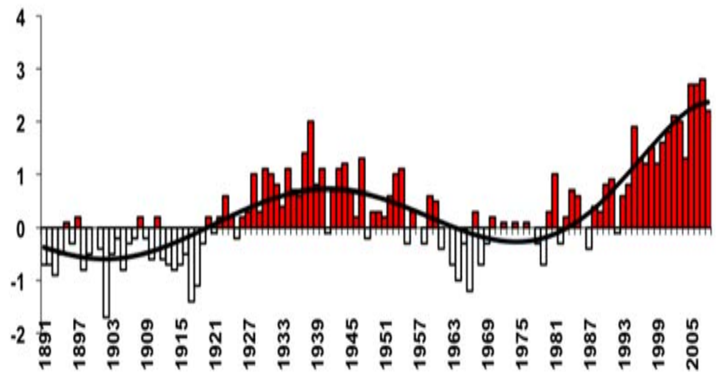
It is uncertain how the Arctic Ocean circulation will change.

It is uncertain to what extent the frequency of extreme temperature and precipitation events will change in the polar regions.

Surface Air Temperature Anomalies



Annual global surface air temperature anomaly (WMO)



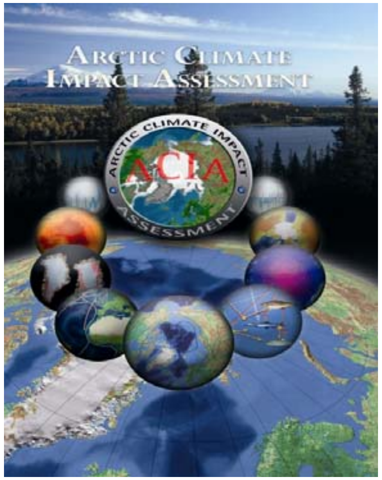
Annual surface air temperature anomaly in the Arctic (Hydrometcentre of Russia)

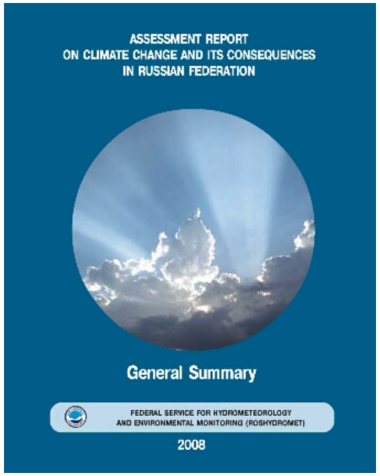
Average air temperature over the globe in the year 2008 took 10th place in top 100 warm year's list. In the year of 1988 air temperature reached its highest point and became more or less fixed experiencing insignificant decrease since then.

Average surface temperature in the Arctic appears to have increased during most of the 20th century.

It is very probable that Arctic air is warming faster than in any other region on planet since 1966 and beats temperature increase in 30th and 40th.

Consequences for the Arctic physical environment (ACIA,2005;FRA,2008)





Along the Northern Sea Route at the end of the warm season its condition became substantially more favorable for navigation in high latitudes

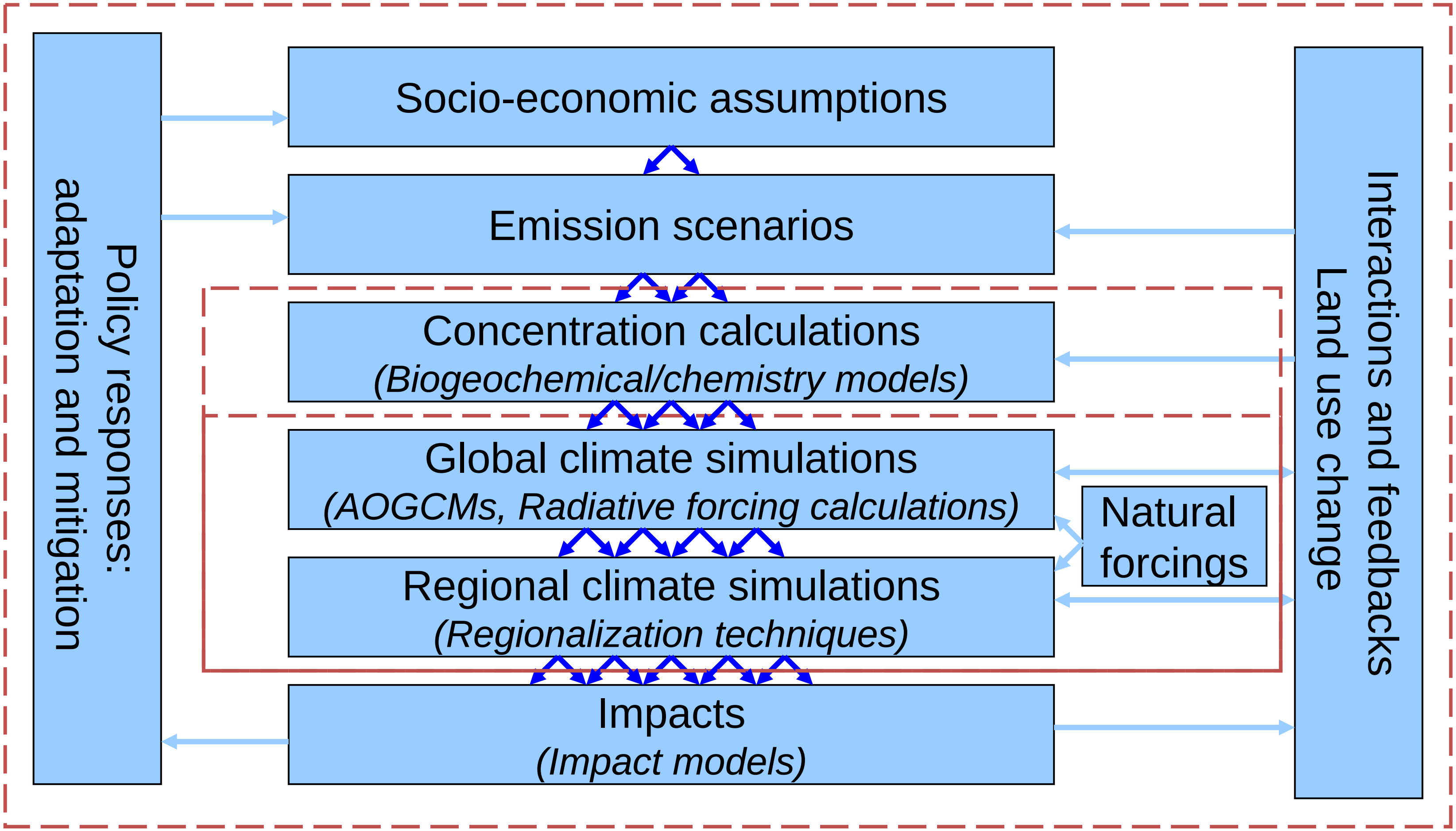
Climate change have negatively affect coasts of the northern seas (erosion intensification) and their infrastructure.

Enhancement of seasonal thawing of permafrost, especially nearby its southern boundary, poses a threat to infrastructure installations (houses and engineering blocks, communication lines, including oil and gas pipelines).

The risk of dangerous floods on rivers in the season of snow melt will grow in those regions where ice jams accompany runoff peaks.

UV radiation has a variety of harmful impacts on humans, flora and fauna. It certainly influences inanimate objects.

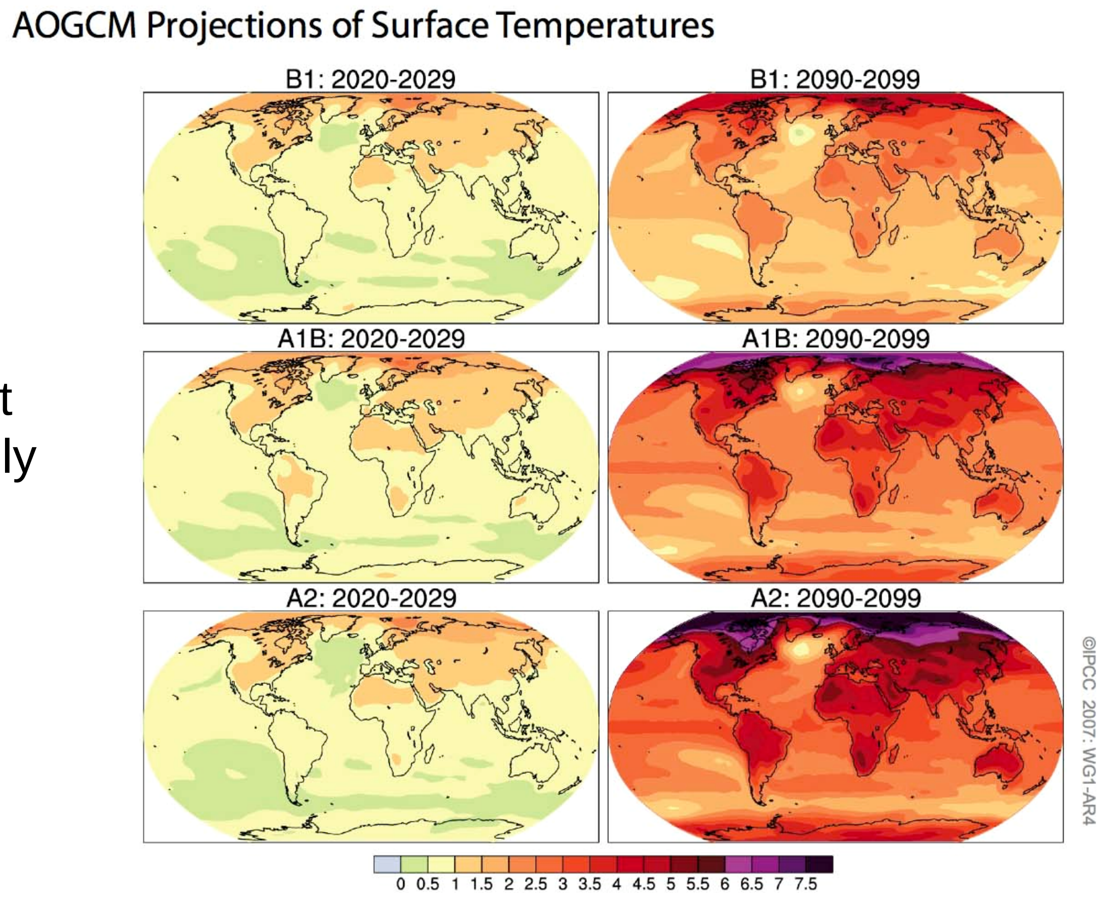
Projection uncertainty cascade



Courtesy Giorgi, 2005

Surface air temperature change

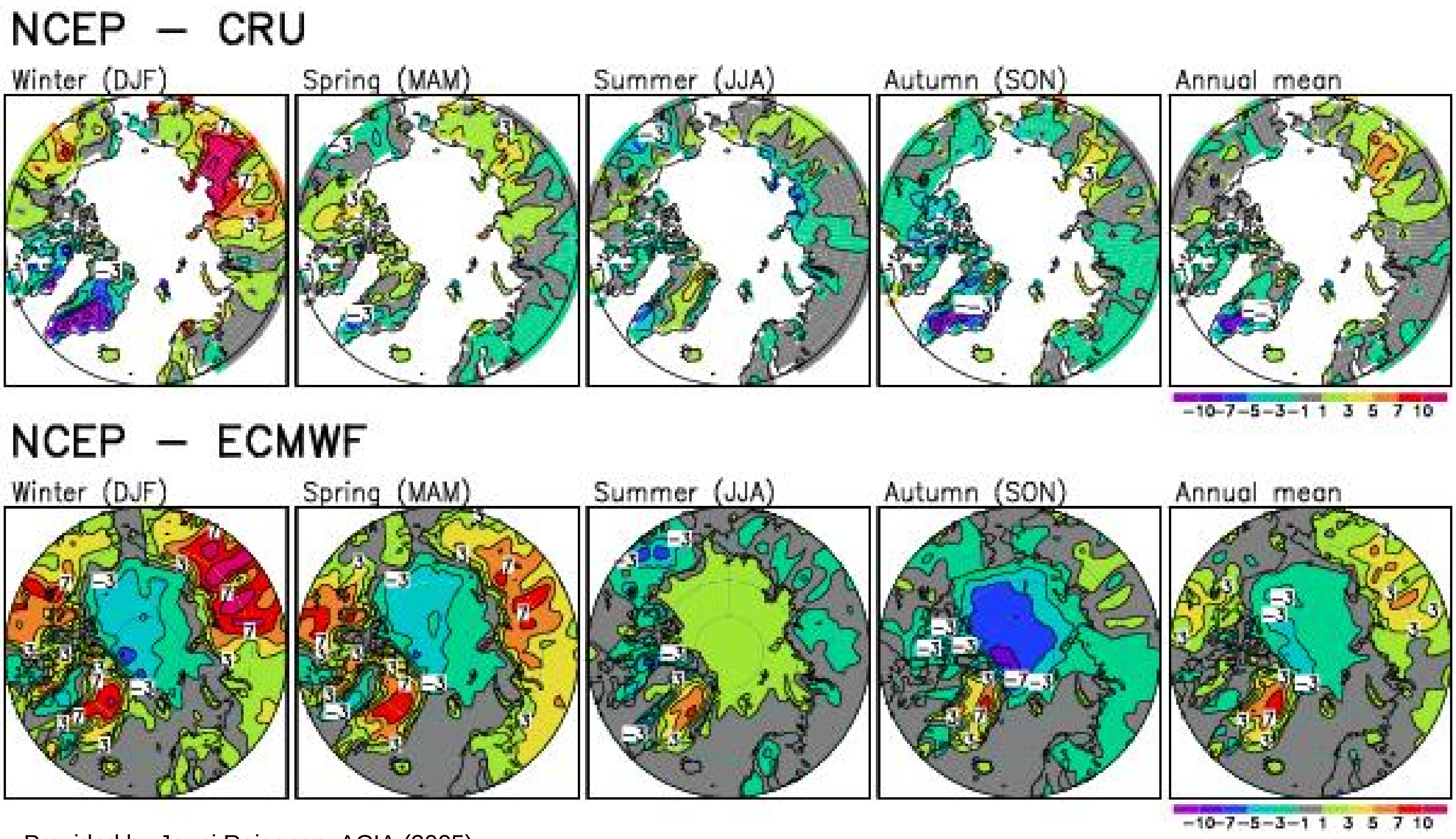
This pattern has not changed qualitatively since 1970s



Then, what has changed?..

- Data availability?
- Models?
- Computational strategies?
- Methods of model evaluation?
- Understanding?
- Credibility of projections?

Intercomparison of surface air temperature climatologies in the Arctic



Provided by Jouni Raisanen, ACIA (2005)

Observations needed to improve reanalyses.

ASR (Arctic System Reanalysis) is underway:

- comprehensive, homogeneous, long-period data sets;
- filling gaps in observations;
- insufficient quality in high lats (inter-reanalyses scatter)

Satellites:

- coverage OK;
- accuracy and number of characteristics – should be improved

In situ (surface, aircrafts and balloons):

- accuracy is an advantage, but not the coverage

IPY legacy - major observing initiatives

Sustaining Arctic Observing Networks (SAON)

Purpose: To develop a set of recommendations on how to achieve long-term Arctic-wide observing activities that will provide free, open and timely access to high quality data that make it possible to realize pan-Arctic and global value-added services with high societal benefits.

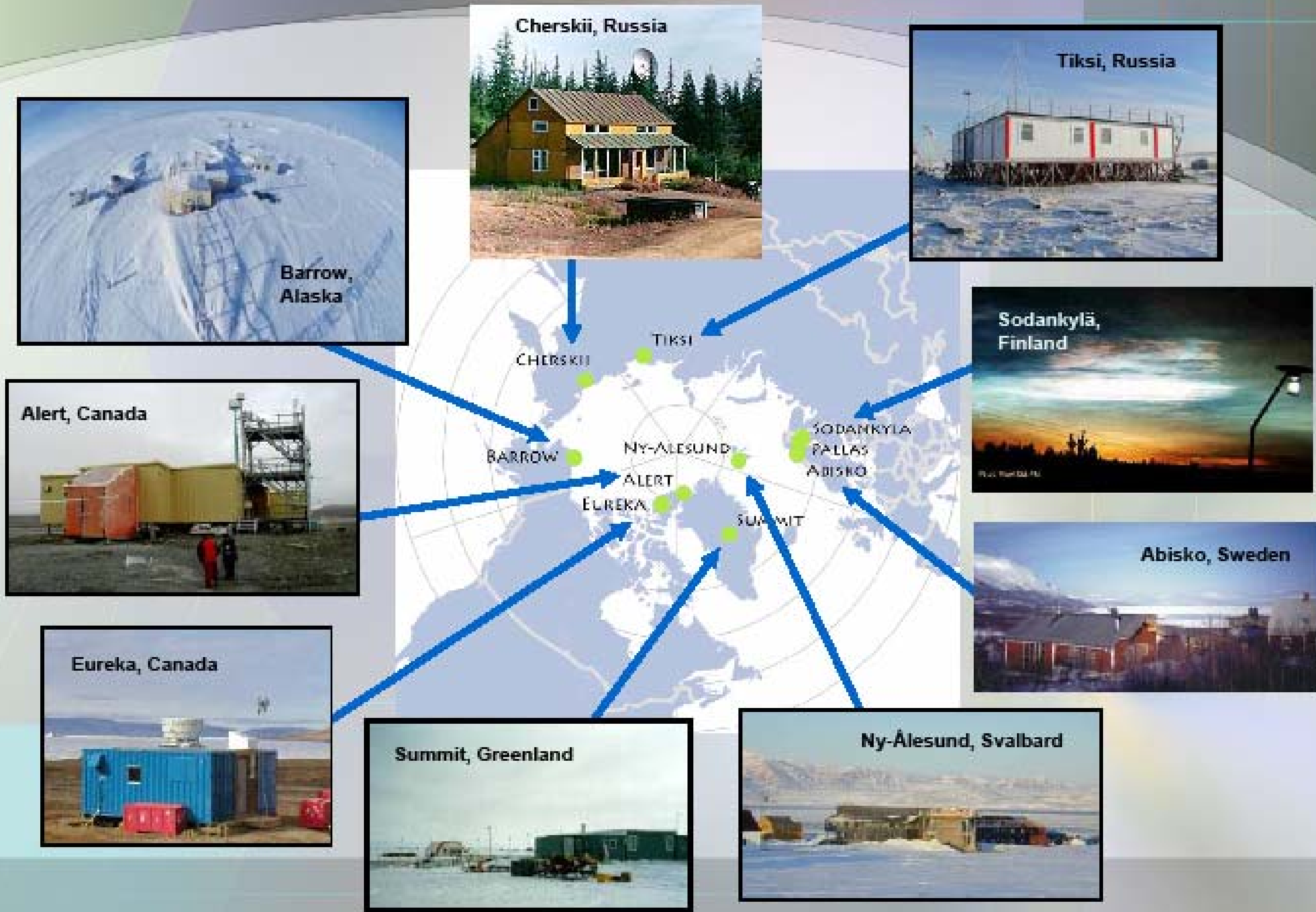
Global Cryosphere Watch (GCW)

Purpose: Explore the possibility of creating a Global Cryosphere Watch as important contribution to the IPY legacy and to prepare recommendations for its development.

Establishing an IPY Satellite Data Legacy Initiative

Purpose: To leave a legacy data set compiled from multiple space agency satellite data portfolios comprising a broad range of a “polar snapshot” products and propose a cooperation arrangement between major satellite agencies ensuring coordination of their polar observations beyond IPY.

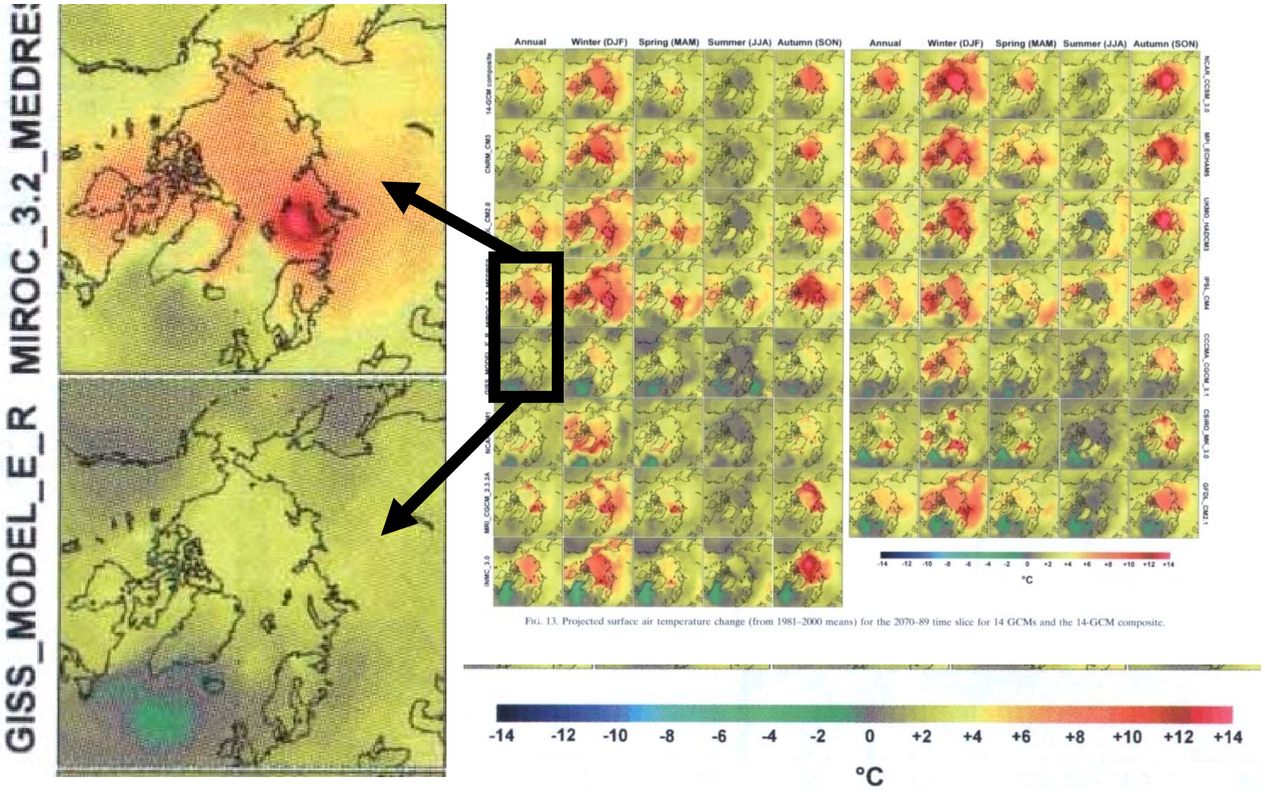
Atmospheric Arctic Observing Sites



РОСГИДРОМЕТ
ROSHYDROMET
Federal Service for Hydrometeorology and Environmental Monitoring
РОСКОСМОС
Russian Federal Space Agency
High-elliptical Orbits Satellite System "Arctica"
State Centre on Space Hydrometeorology "Planeta"
Lavochkin Association

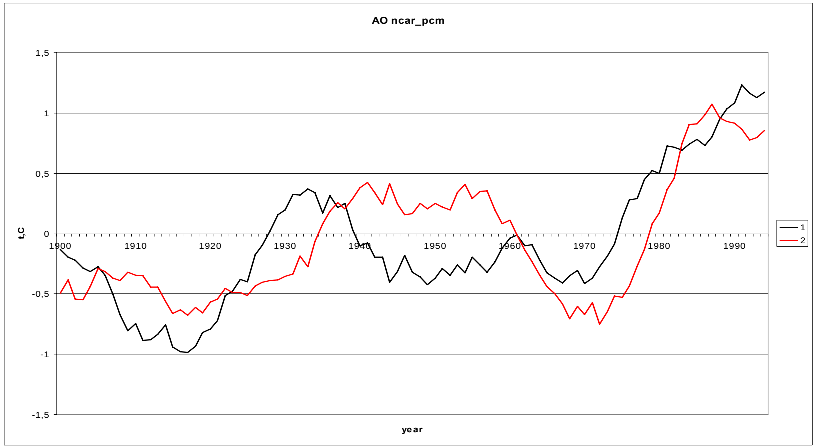
Uncertainties due to model differences

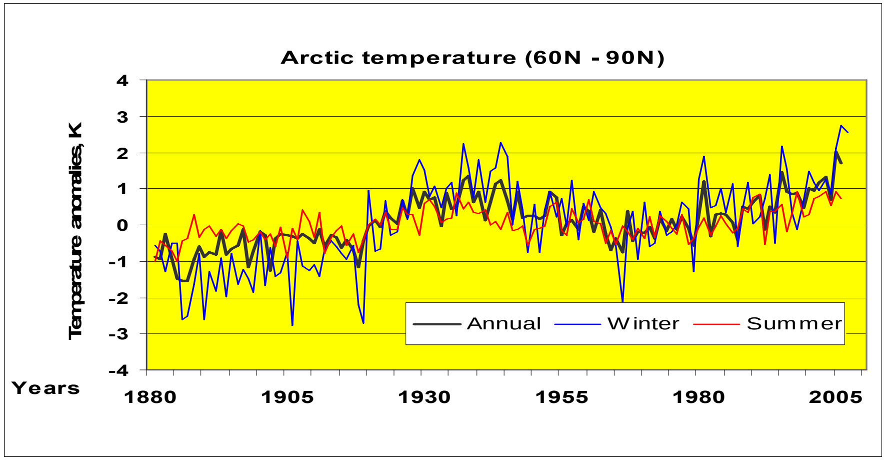
Annual mean temperature change by 2070-89 (A1B)

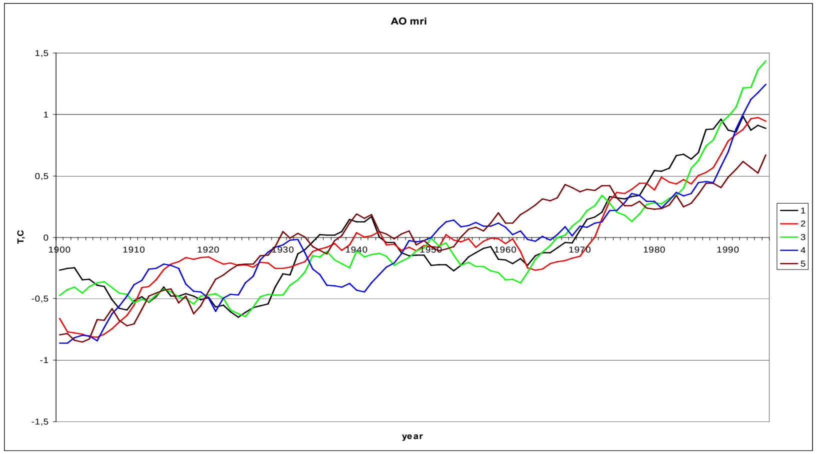


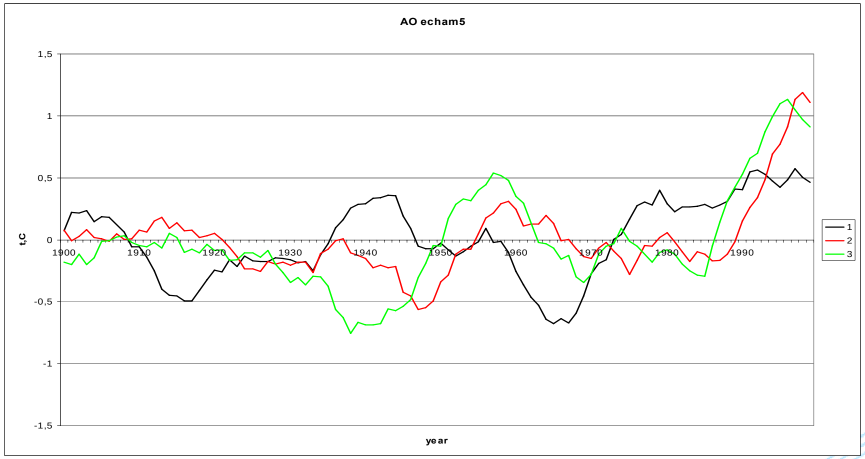
Models have been improving, but…
Inadequate knowledge of important physical processes and feedbacks results in systematic biases and differences between model responses to the same forcing.

Variability: the two warming events









Climate models "Arctic" problems: numerics

- The "pole" problem (converging meridians in spherical coordinates);
- Poor spectral representation of some variables (e.g. water vapour);
- Insufficient resolution (ABL, ocean shelves and straits, orographic gradients);

Climate models "Arctic" problems: physics

- Stable stratification in the lower troposphere;
- Low water vapour content in the atmosphere;
- Multi-layer clouds;
- Specific features of the ocean TH structure;
- Sea ice (dynamics & thermodynamics);
- Terrestrial cryosphere;
- Specific interactions (e.g. snow-vegetation);
- Unforced variability.

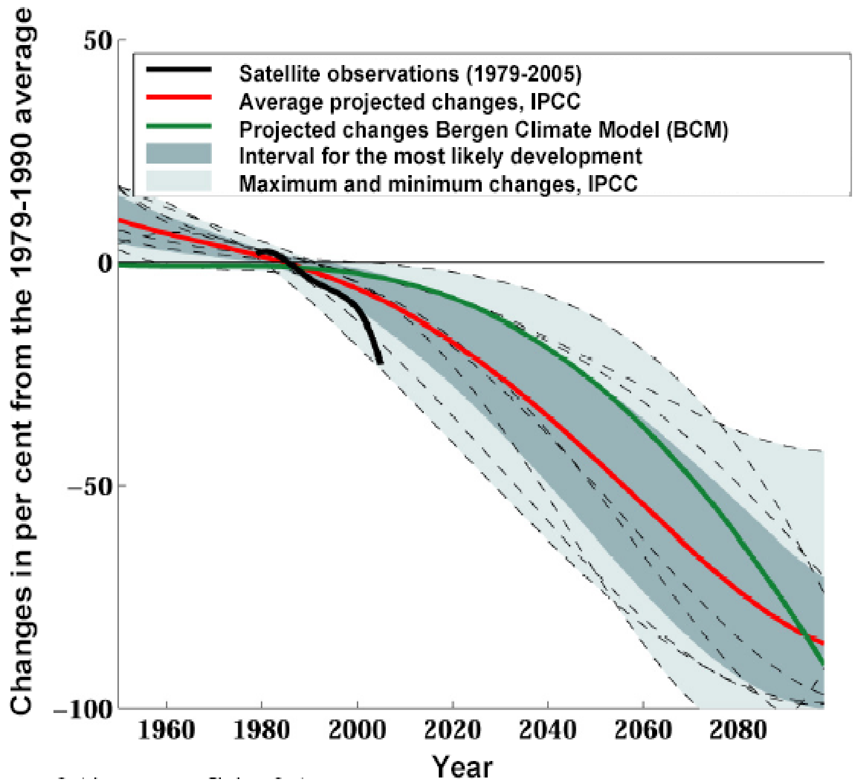
Climate models “Arctic” problems: feedbacks and forcing

We need better understanding of:

- Climate feedbacks related to clouds, carbon cycle & biosphere, mass balance of ice sheets, ocean circulation;
- Climate forcings (e.g. from all aerosol sources, land use change) & couplings of forcings to changes other than global mean temperature (e.g. circulation changes).

Arctic sea ice

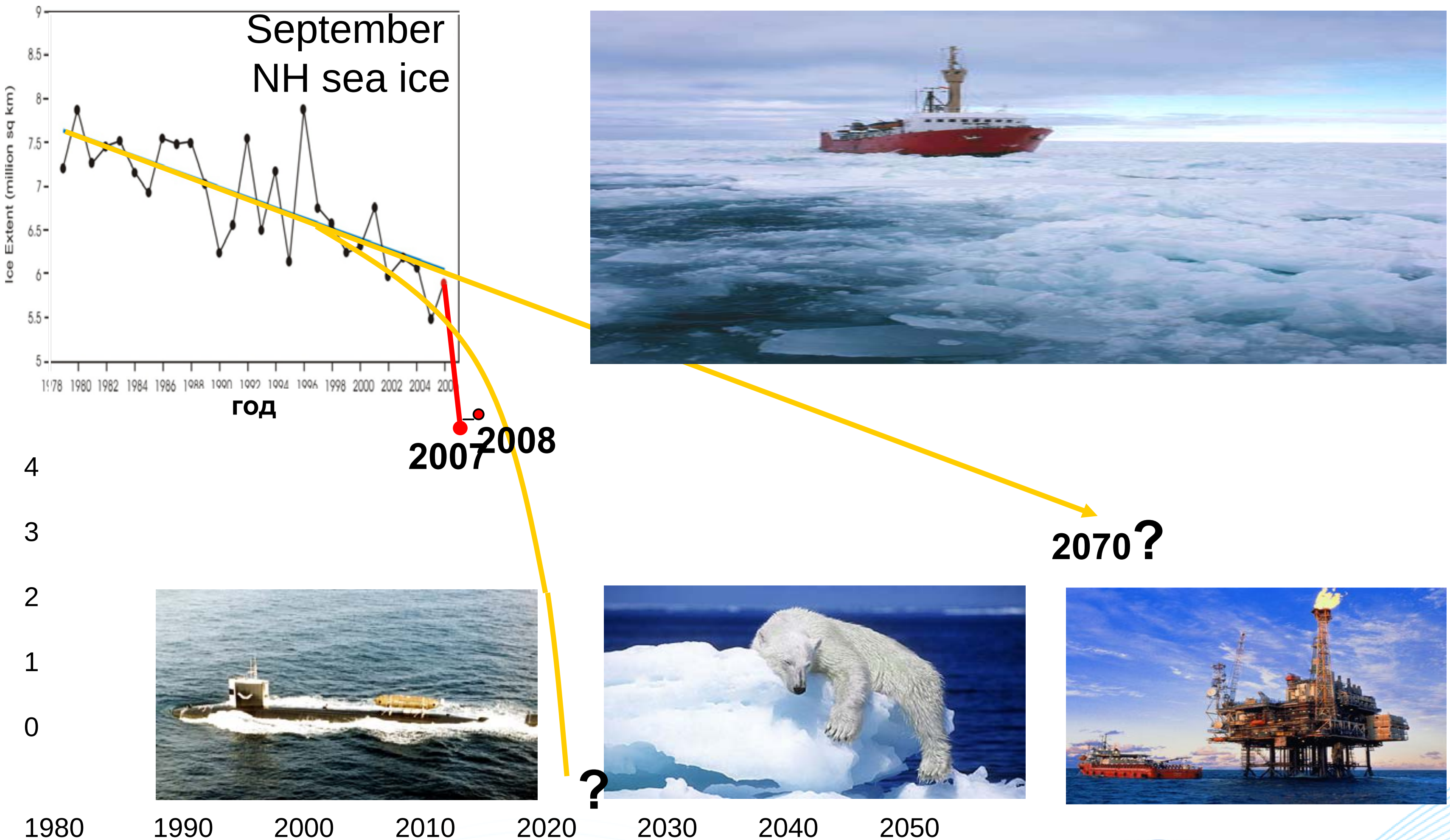
Projected and actual reduction in the summer sea ice in the Arctic (20C3M+A2)



Courtesy Prestrud, 2007

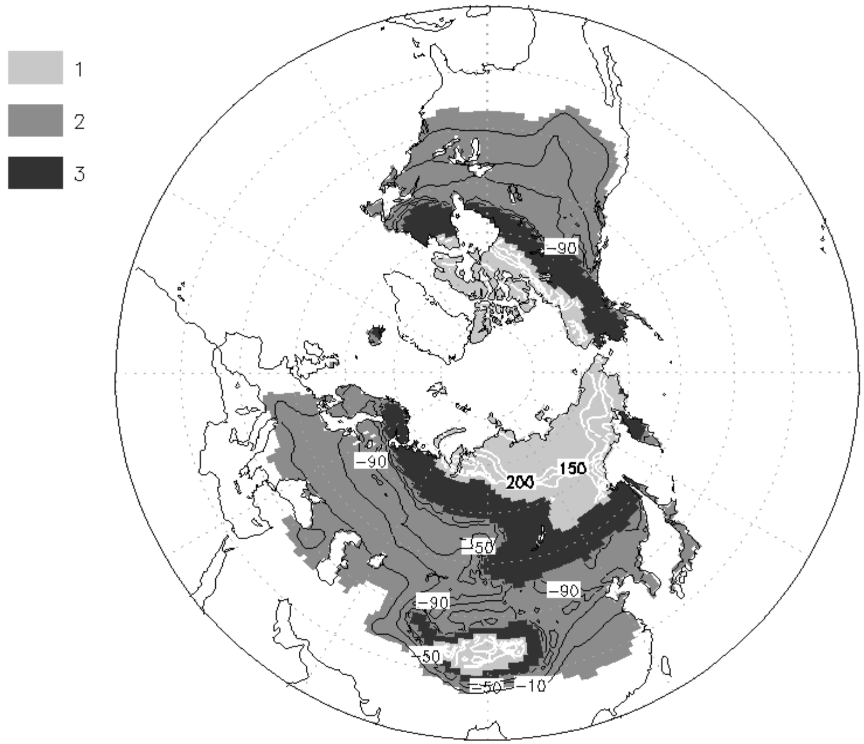
Does sea ice disappear in the real world faster than the models project?

A different Arctic



Overland et al., 2008

Permafrost



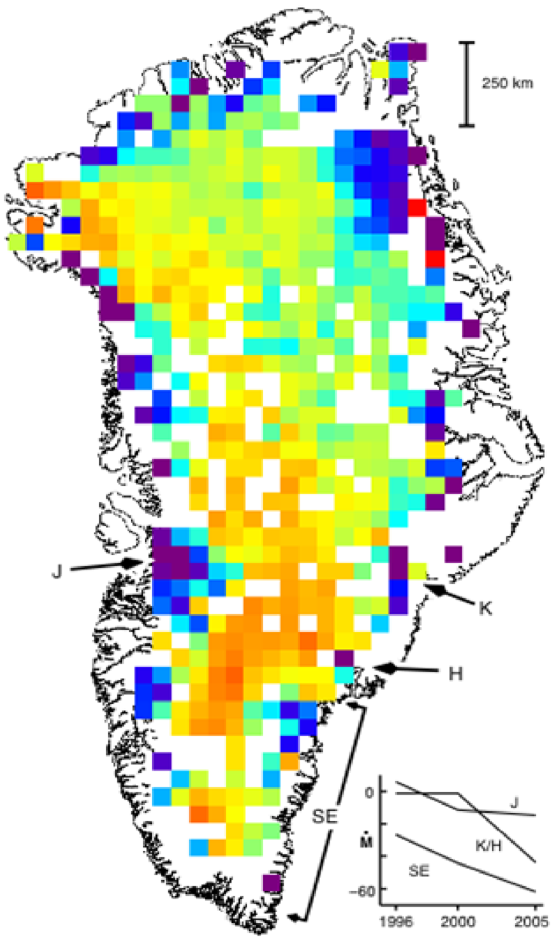
Depth changes of seasonally thawing layer (gray lines, cm) and seasonally frozen layer (black lines, cm) in 2080-2099 (A2) relative to 1980-1999.

1) region of seasonal thawing retained by the end of the 21st century,
2) same but for seasonal freezing,
3) region where seasonal thawing is replaced by seasonal freezing in the upper 3 m layer.

Does expected increase in emissions of methane from wetlands of Arctic permafrost regions will not have remarkable influence on the global climate?

Courtesy Pavlova et al., 2007

Sea level rise and ice sheets



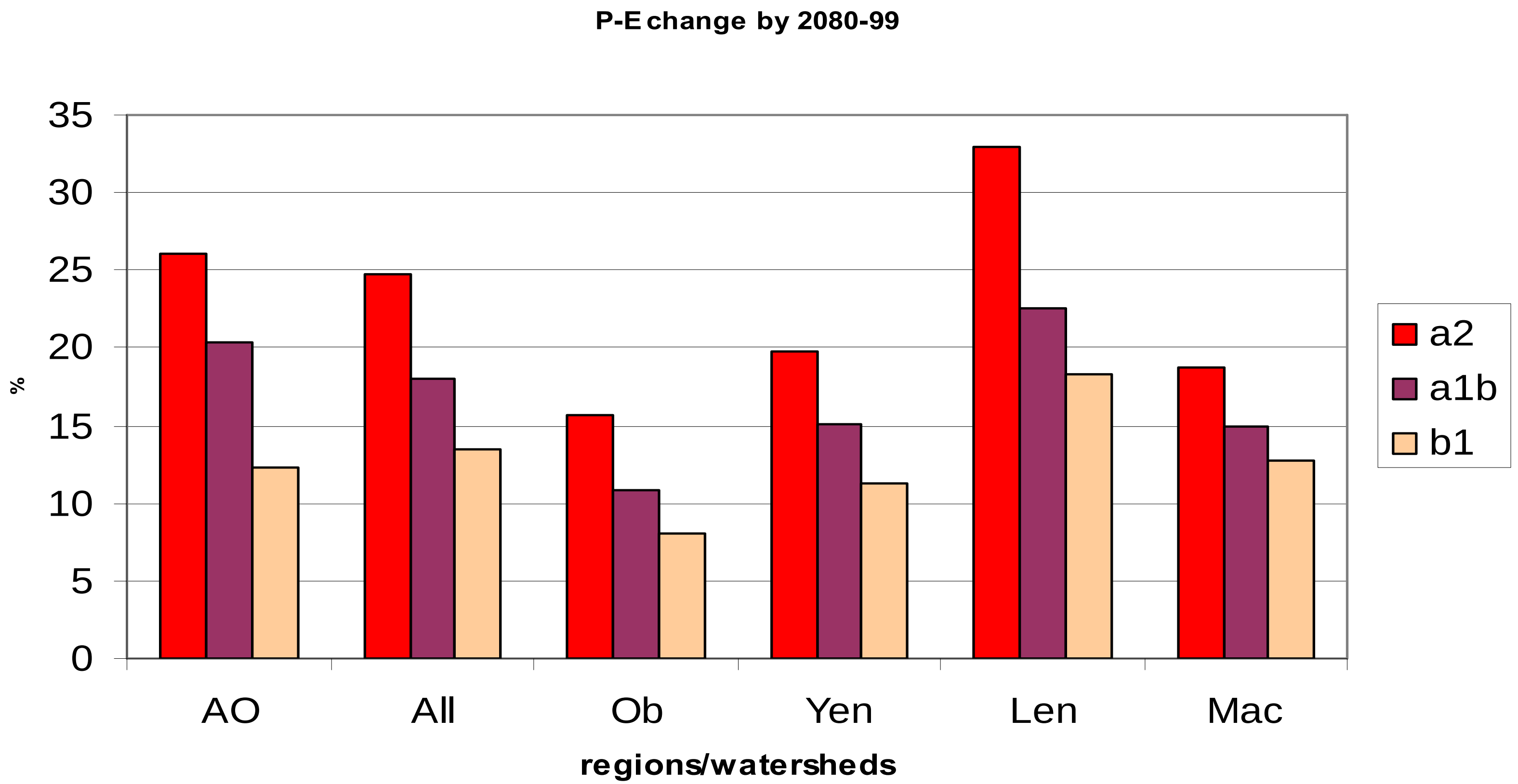
7m of SL equivalent is on Greenland. This is expected to melt slowly, and raise SL on a time scale of millennia, for warming >2-5°C.

The last time polar regions were significantly warmer (by 3-5°C) than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of SLR.

Could SLR be much faster than thought?

Some studies suggest this is transient and will stop. Others suggest it may increase.

P-E changes (%) in A2, A1B, and B1 over the Arctic Ocean and its watersheds by 2080-99 from 1980-99



Courtesy Kattsov et al., 2007

Eurasian Arctic River Discharge to the Arctic Ocean and Maximum Sea Ice Extent in the Arctic Ocean

Rivers: Ob', Yenisey, Lena, Severnaya Dvina, Pechora, Kolyma

The annual runoff of Arctic rivers rose by 20–30% since 1978 relative to 1946–1977 basically due to winter flow increase.

Freshening of the Arctic Ocean by increased precipitation and runoffs is likely to reduce the formation of cold deep water, thereby slowing the meridional overturn circulation.

Is it likely that meridional circulation slowdown would lead to chilling influence on the Arctic as Gulf Stream heat transport is reduced?

Arctic climate projections: Uncertainties/Opportunities

Uncertainties	Opportunities
SLR: Greenland melt dynamic mechanisms?	Enhanced physics /Longer runs
Feedbacks (rate of warming): Permafrost/vegetation carbon? Ice-free Arctic? MOC slowdown?	More components/Enhanced physics/ Longer runs
Near-term predictions (up to a decade): Decadal scale variability or anthropogenic signal?	Larger ensembles
Spatial scale: Adaptation and mitigation options	Higher resolution/Larger ensembles
	MORE COMPUTING RESOURCES!!!

Conclusions and suggestions

1

Observational database for the Arctic is quite limited, with few long-term stations, making it difficult to distinguish with confidence between the signals of climate variability and change.

The Sustained Arctic Observing Networks (SAON) is seen as a means of addressing several of these problems, and improving the situation through involving all relevant partners (see **http://www.arcticobserving.org** for details).

UNESCO could significantly contribute to SAON, specifically, in framework establishment for the development of a portal for archiving data and metadata, publishing of dataset and derived products.

Conclusions and suggestions

2

It is evident that further research is needed. For example, models differ considerably in their estimates of the strength of different feedbacks in the climate system, particularly cloud feedbacks, oceanic heat uptake and carbon cycle feedbacks.

UNESCO could further encourage scientific research of Arctic climate in the framework of the World Climate Research Programme and IHP, IOC and MAB.

Conclusions and suggestions

3

Further evaluation of adaptation potential is required for the whole Arctic and its individual regions. Adaptation can reduce vulnerability, both in the short and the long term. Special attention should also be given to the development of models and techniques for prediction of extreme events leading to serious negative socio-economical and ecological consequences.

For adaptation studies, improved understanding of key aspects of climate system down to regional scale, -e.g. precipitation, circulation, sea level, extreme events etc.

Thank You