Reconstructing Arctic climate variability over the last 150 years from in-situ and paleo archives

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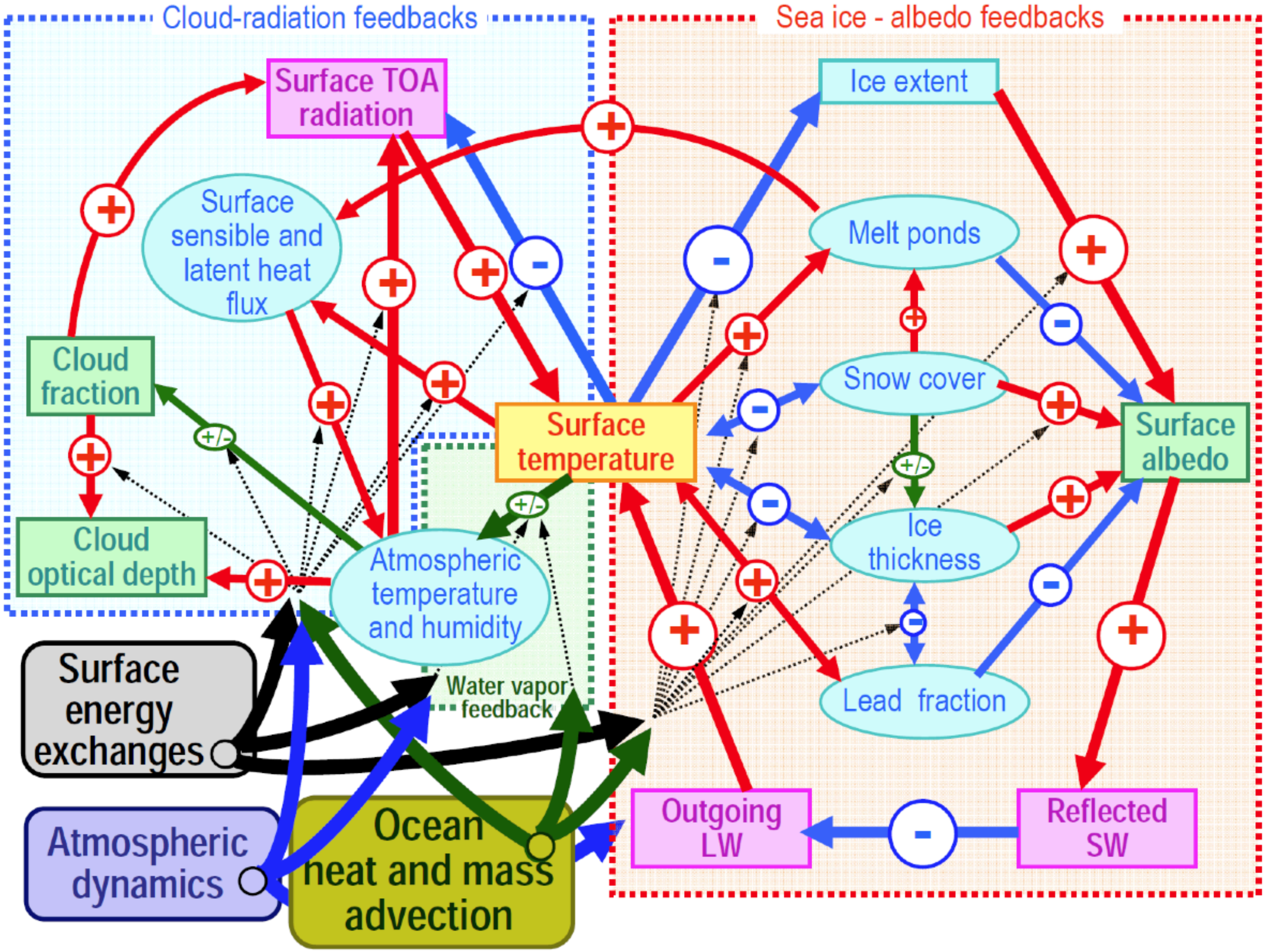
Main goal of the project

(i) **The main goal of the project is the reconstruction of the Arctic climate variability during the last 150-180 years on the basis on instrumental observations and paleo archives.** For the first time this will allow for the comparison with climate models and assessment of the their reliability in the long term prediction if the Arctic climate.

(i) creation of the unified archive
(ii) development of the new approaches for the data analysis:quality control methods and statistical data analysis methods
(iii) comparison with climate models

Why is it important



Various feedbacks in the Arctic climate system “sea ice-albedo”, “clouds - radiation”, “water vapour”. Surface interactions, atmospheric dynamics and heat and fresh water advection in the ocean affect almost all feedbacks.

Why it is important

All these feedbacks are poorly resolved:

- on the basis of observational data
- on the time scales longer than 40 yrs (observational period of reanalyses)

Climate models for the prediction of the Arctic climate are based on a simplified feedback:

Sea ice is thermally isolating ocean from the atmosphere, sea ice decline potentially activate air-sea interaction processes

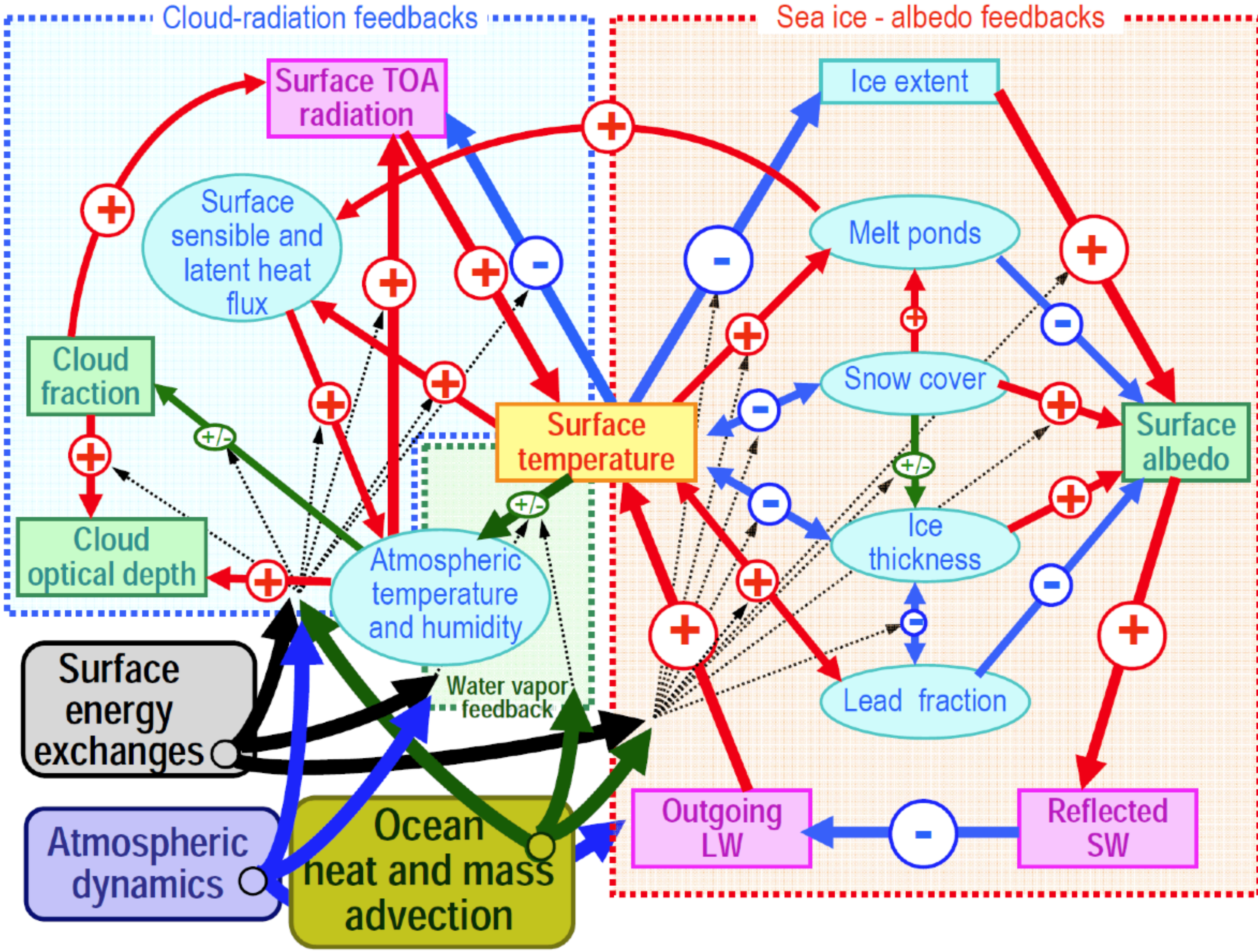
Arctic amplification →

Diabatic heating of the atmosphere, further amplification under the climate change scenarios

CMIP5 models tend to reproduce this effect and currently can not be verified with observational datasets of (!)

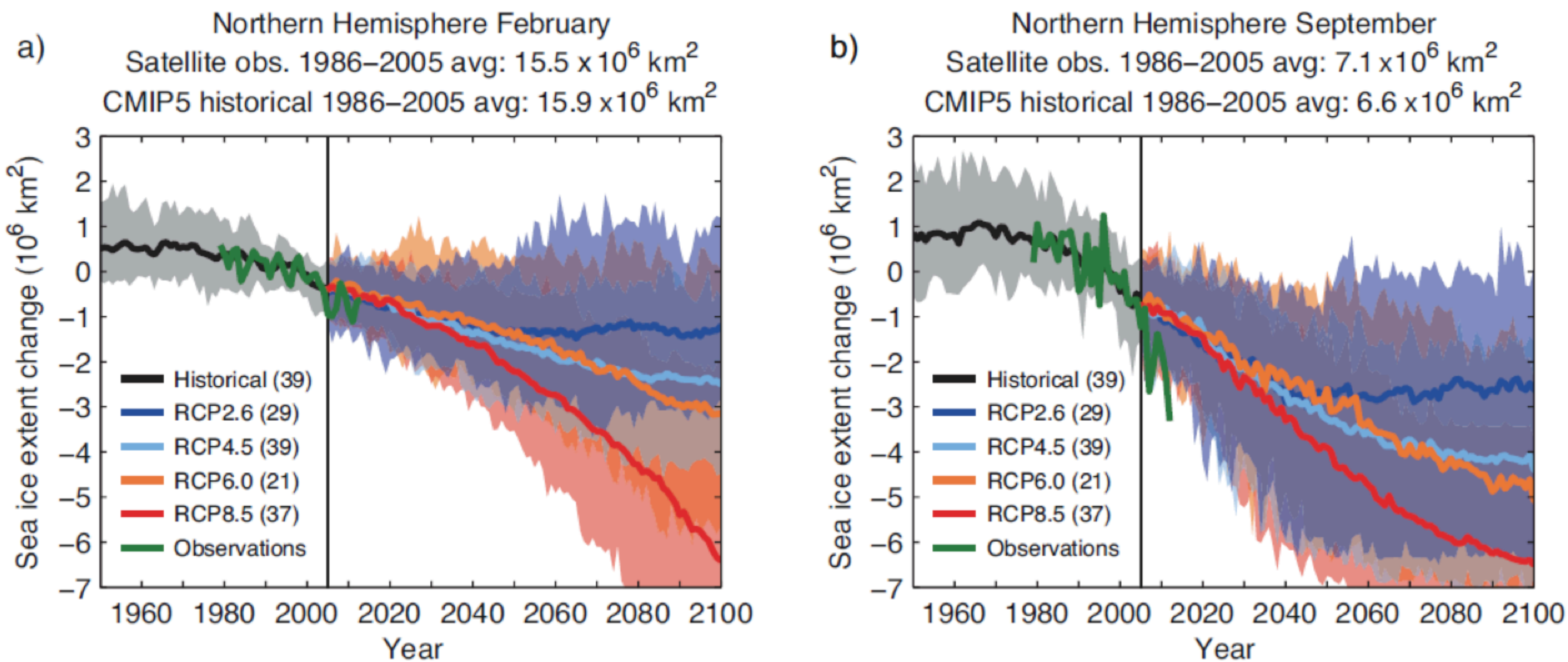
- ocean state
- atmospheric moisture transport
- snow cover and its influence on earth albedo

Why it is important



Various feedbacks in the Arctic climate system “sea ice-albedo”, “clouds - radiation”, “water vapour”. Surface interactions, atmospheric dynamics and heat and fresh water advection in the ocean affect almost all feedbacks.

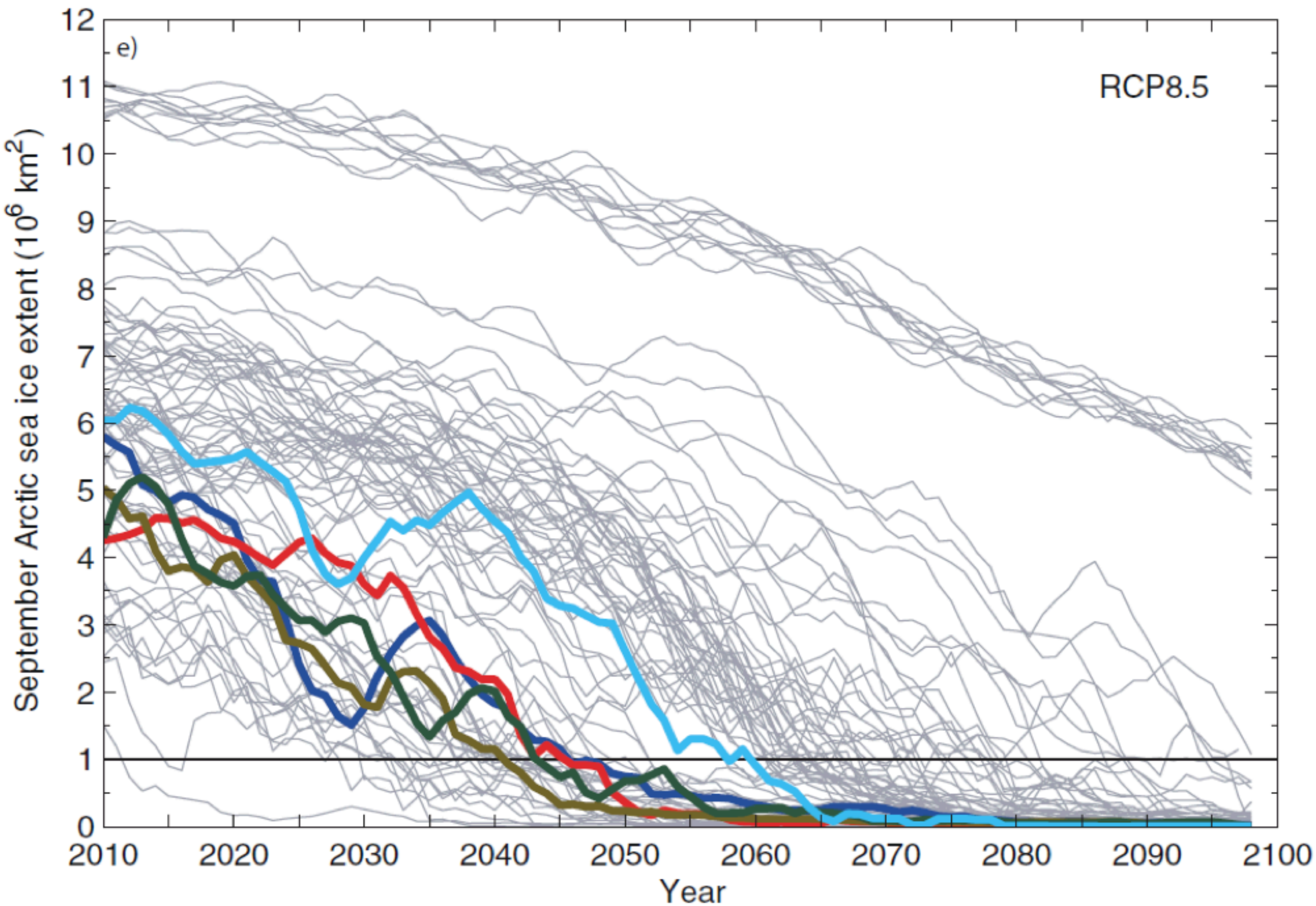
As a result, the forecast for the Artic climate projections is highly uncertain (temperature, moisture, ice conditions).



Sea ice cover change in CMIP5 models according to difference warming scenarios for the Northern Hemisphere in February and September

Collins et al. 2013

This uncertainty increase for the projection of the navigational potential of the Arctic. The most reliable models are not in agreement in prediction ice free-ocean date.

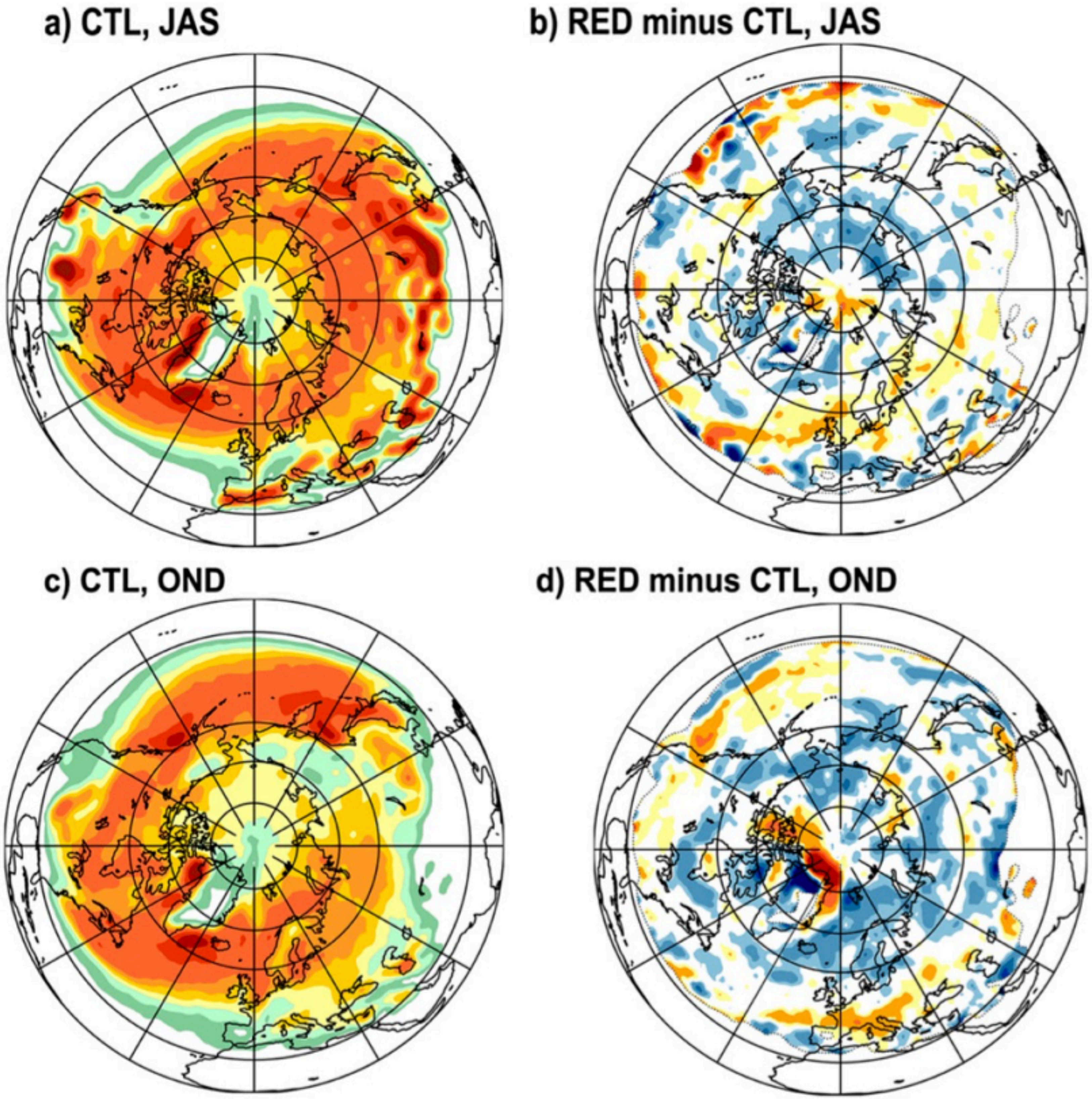


Time series of the Artic sea ice cover area in September as predicted by the ensemble of the CMIP5 models for the 21st century. In colours are the most reliable models.

Massonnet et al. 2012

Why forecasts for the Arctic are so uncertain and models, that adequately resolve sea ice decline are not capable for quantitative estimates?

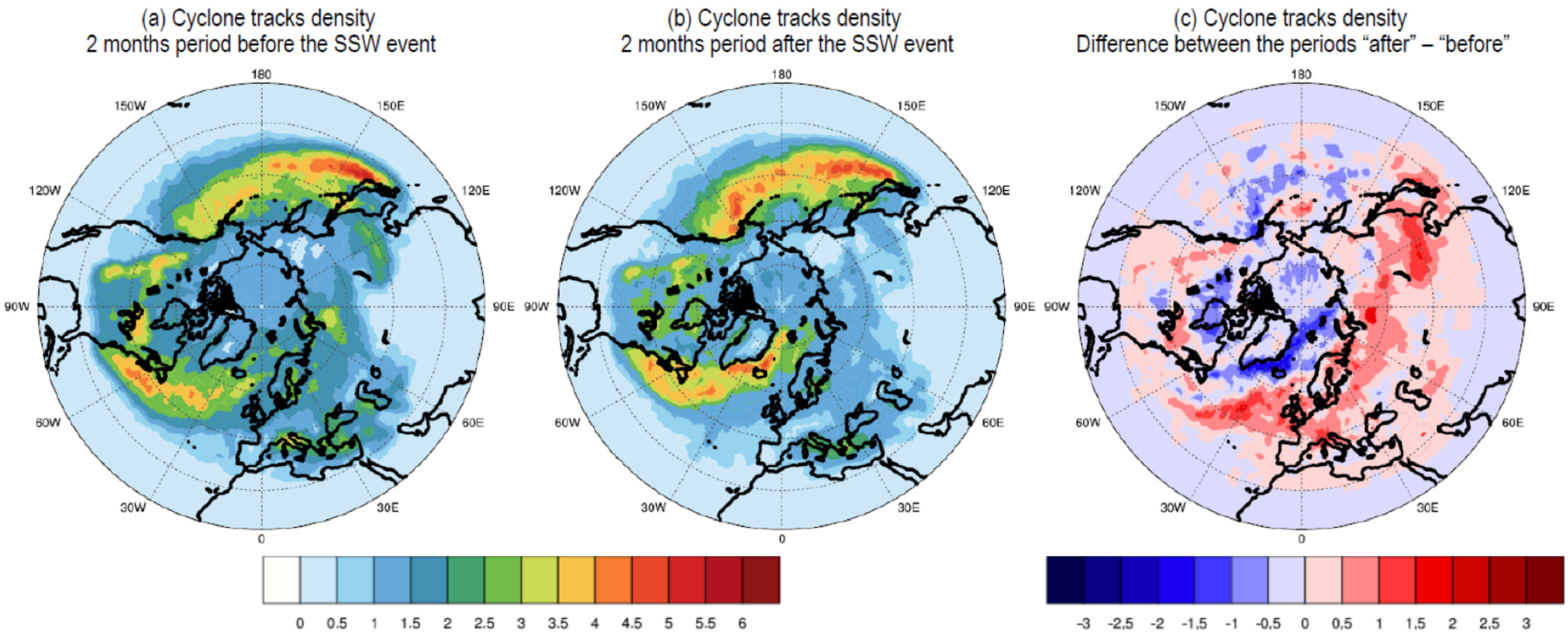
Another example of non linear feedback in the Arctic climate system:



Response of the cyclones in the NH to the sea ice decline by 80% in summer and autumn

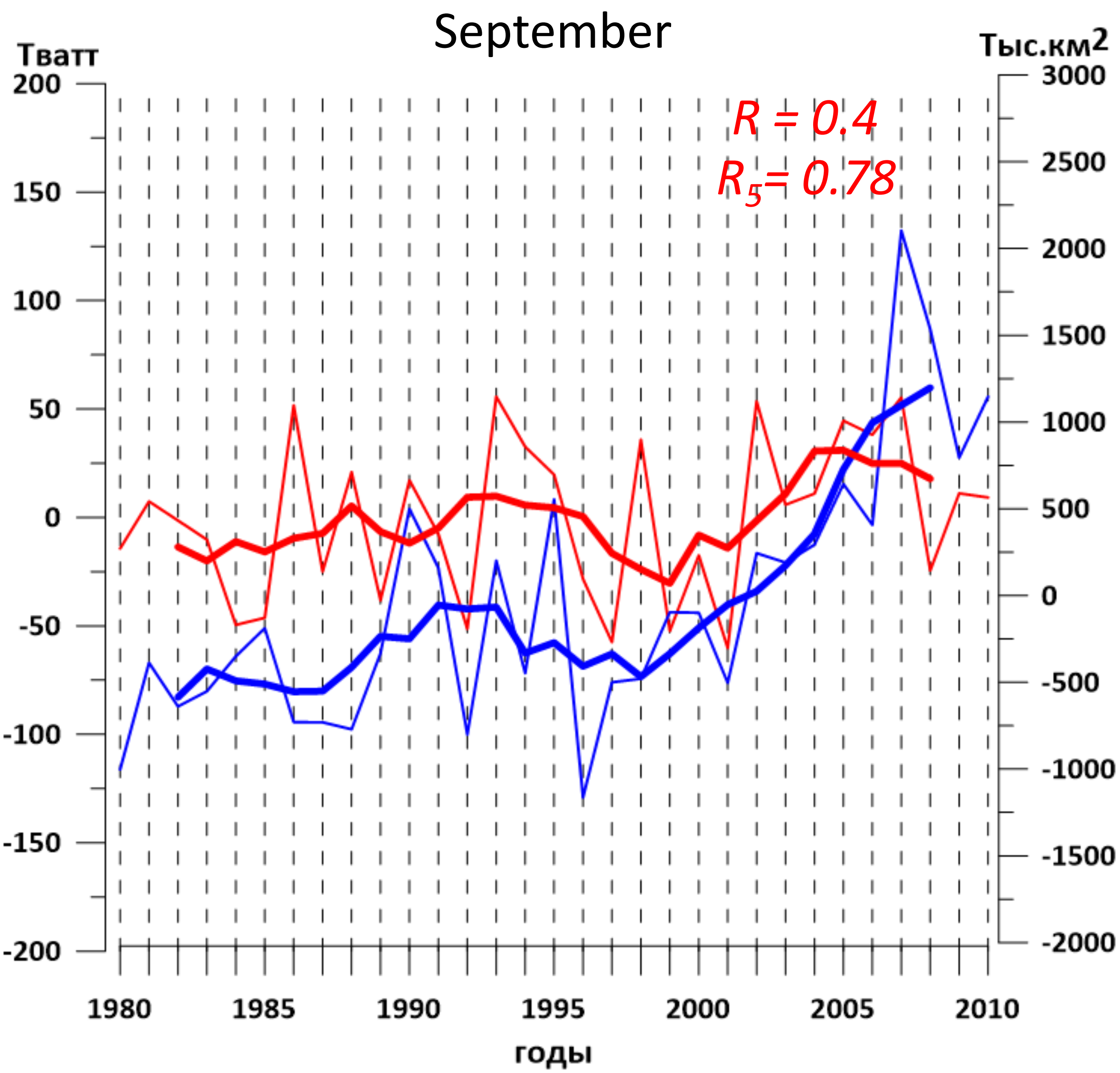
Semmler et al.,2016

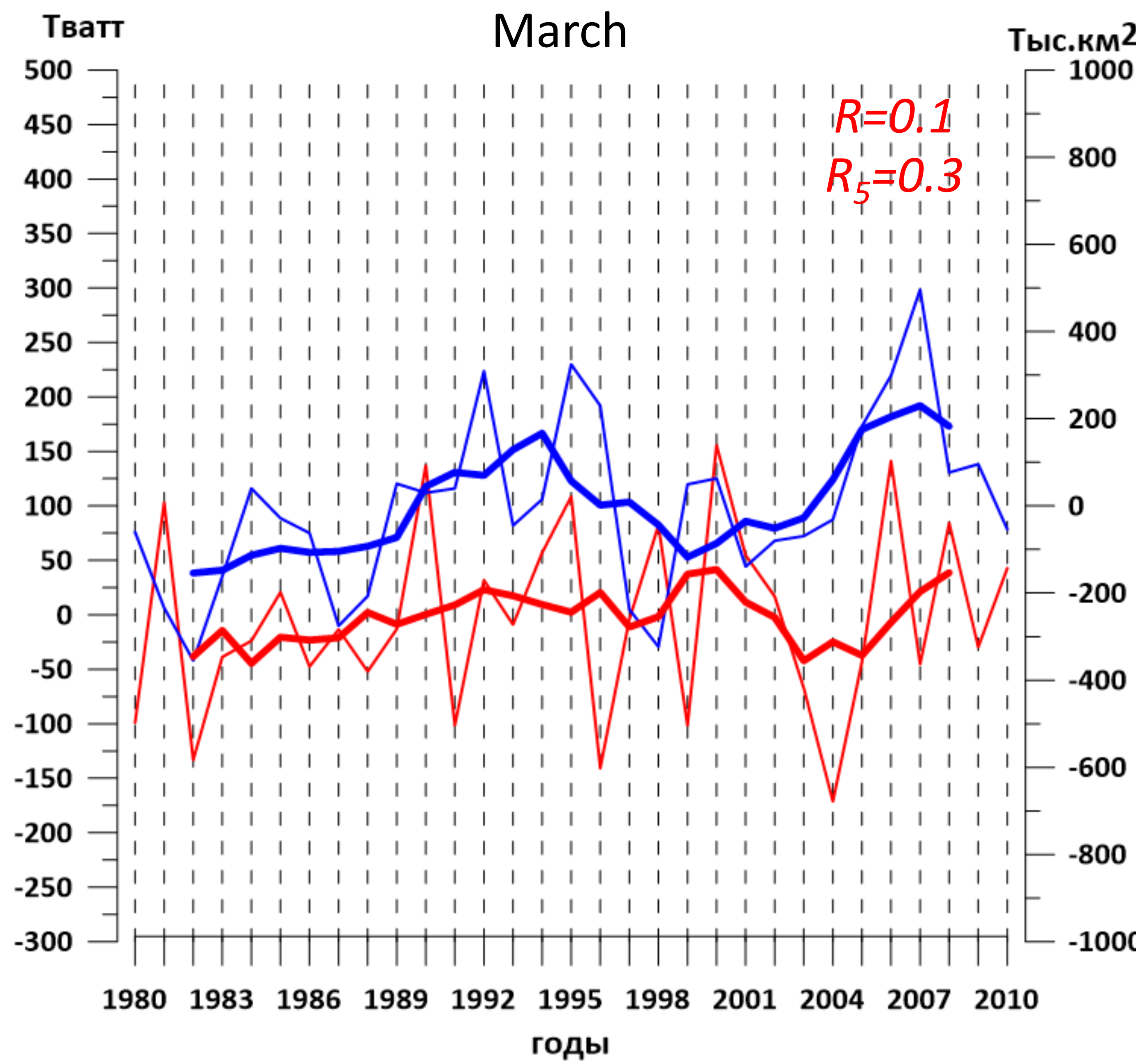
Response of the storm track to the Sudden Stratospheric Warming events



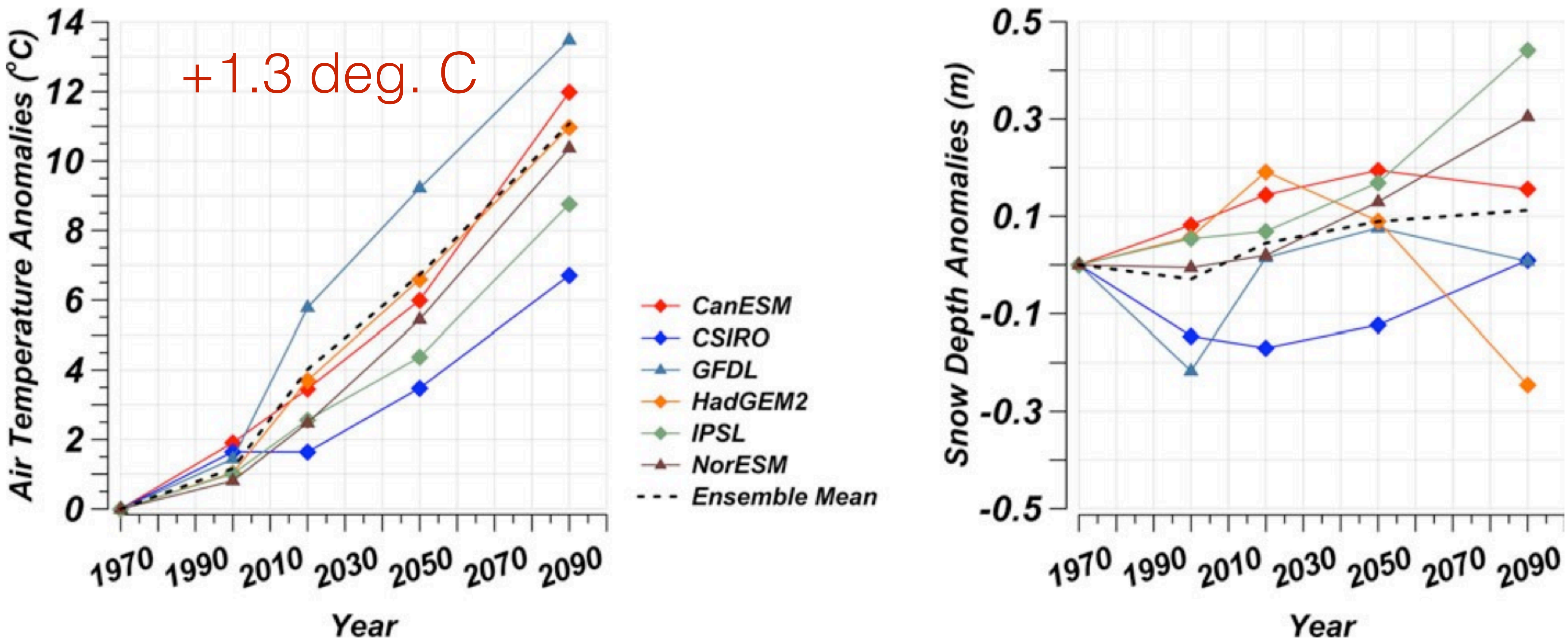
Another example of non linear feedback in the Arctic climate system:

Time series of the ice-free area (blue) and integrated over the ice free area turbulent heat fluxes (red)





Selivanova et al., 2019
on the basis of NCEP CFSR data

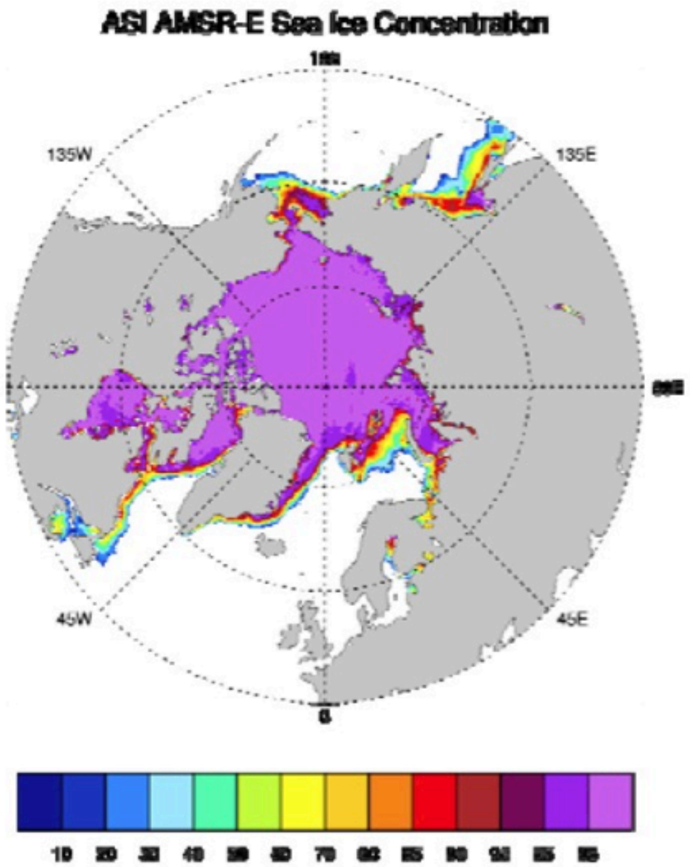


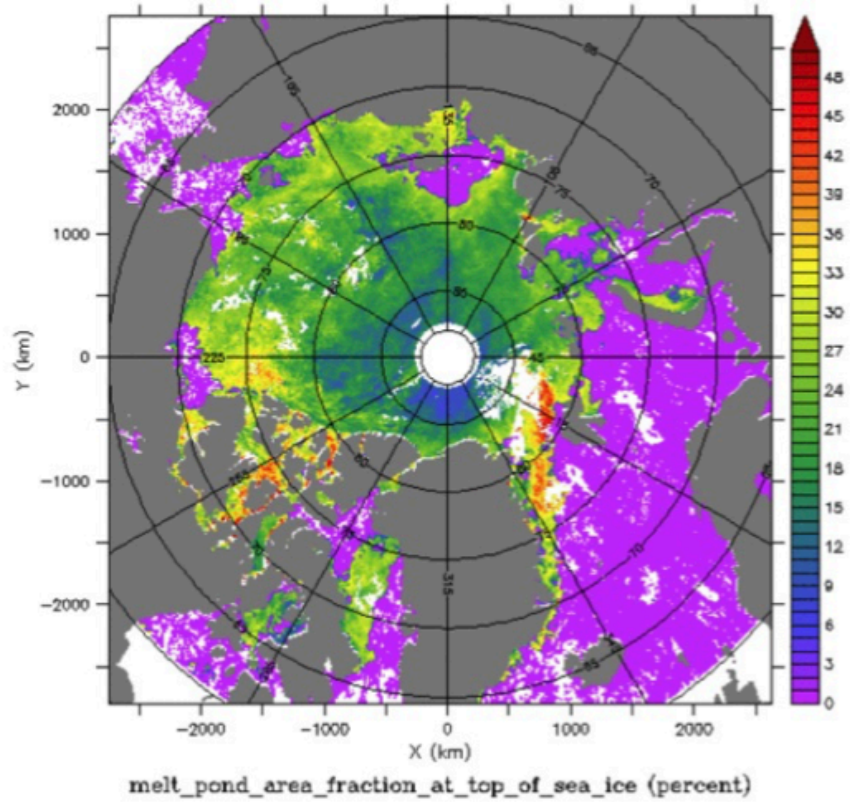
Projected changes of the average temperature (left) and snow cover thickness (right) in different CMIP5 (RCP8.5) models relative to the basis period 1965-1970 for the Arctic Siberia (north of 65N)

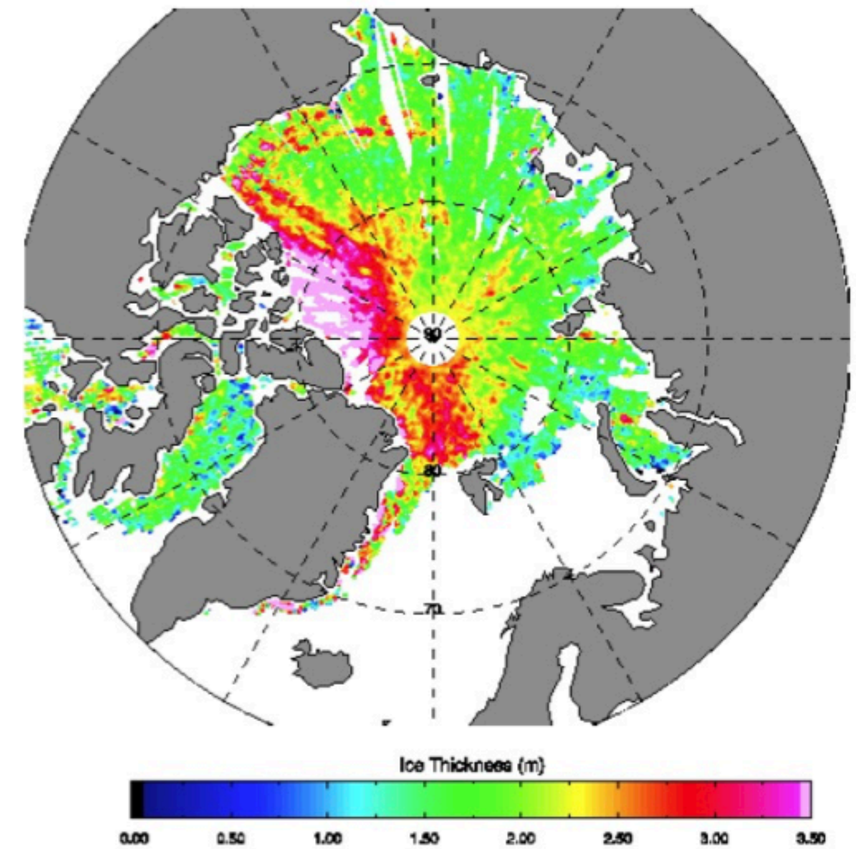
Understanding the sources of these uncertainties is only possible by long term studies of the processes in the Arctic on the basis of observational data: results of the expeditions, paleo archives, VOS, etc.

For the first time we will be complexly using datasets with different accuracy and quality for the long term Arctic climate reconstruction.

Satellite datasets



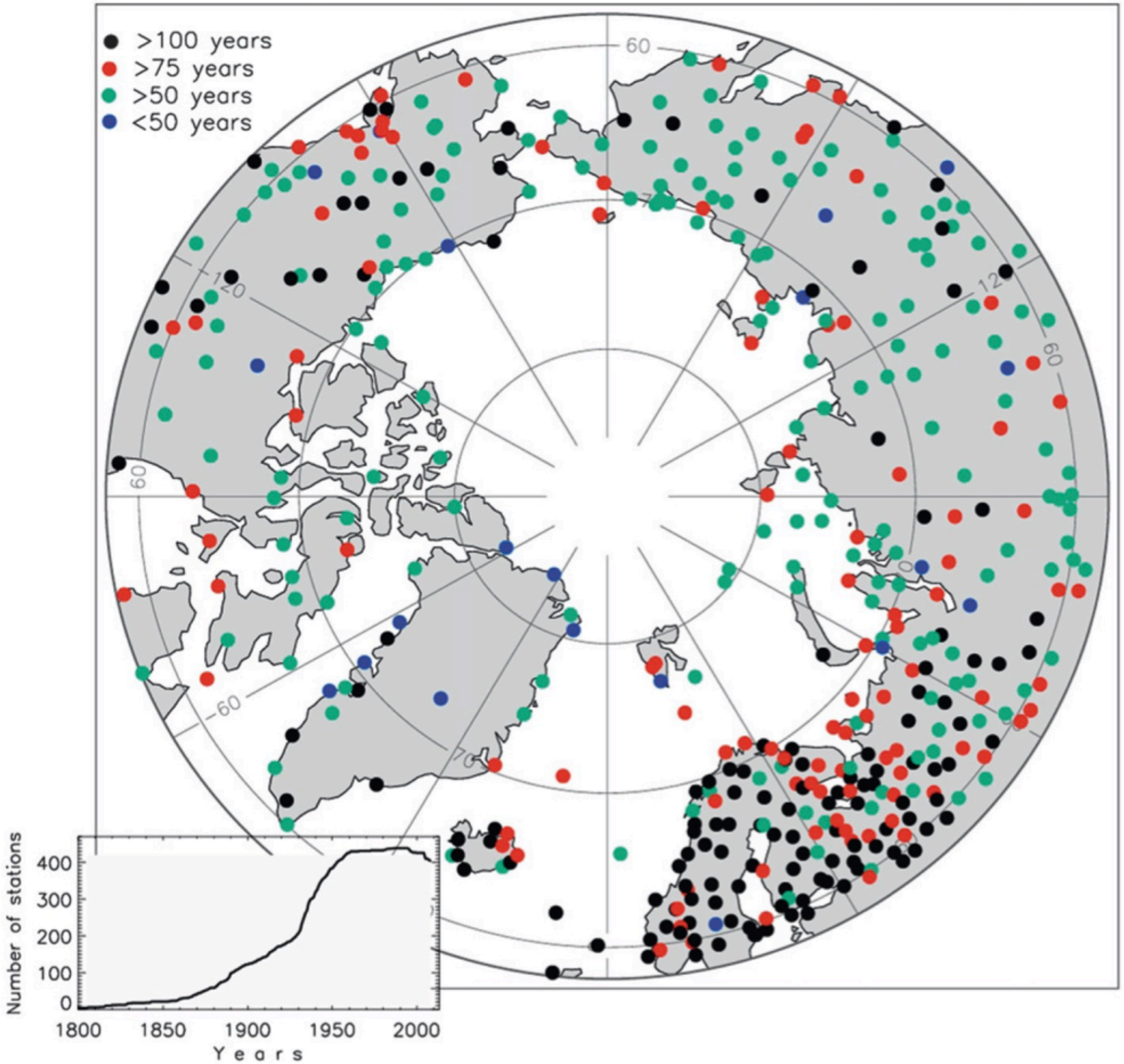




Examples of the high resolution sea ice data:

left - ice concentration on the basis of the ASI-SSMI
center - ice fraction with melt ponds
right - ice thickness

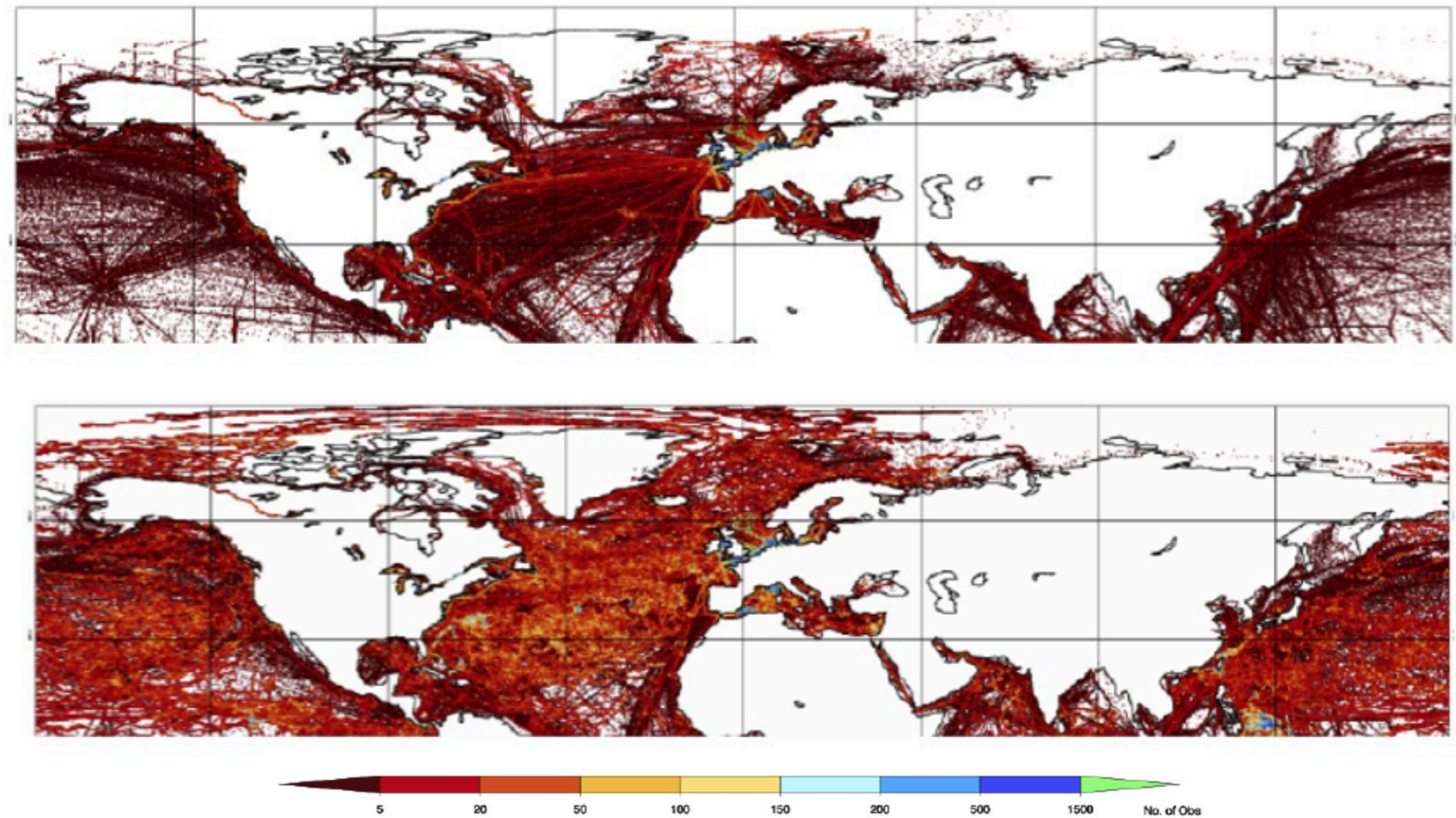
Meteorological stations



Arctic meteorological stations with the length of the observational period and total number of station since 1800.

Bekryaev et al., 2010

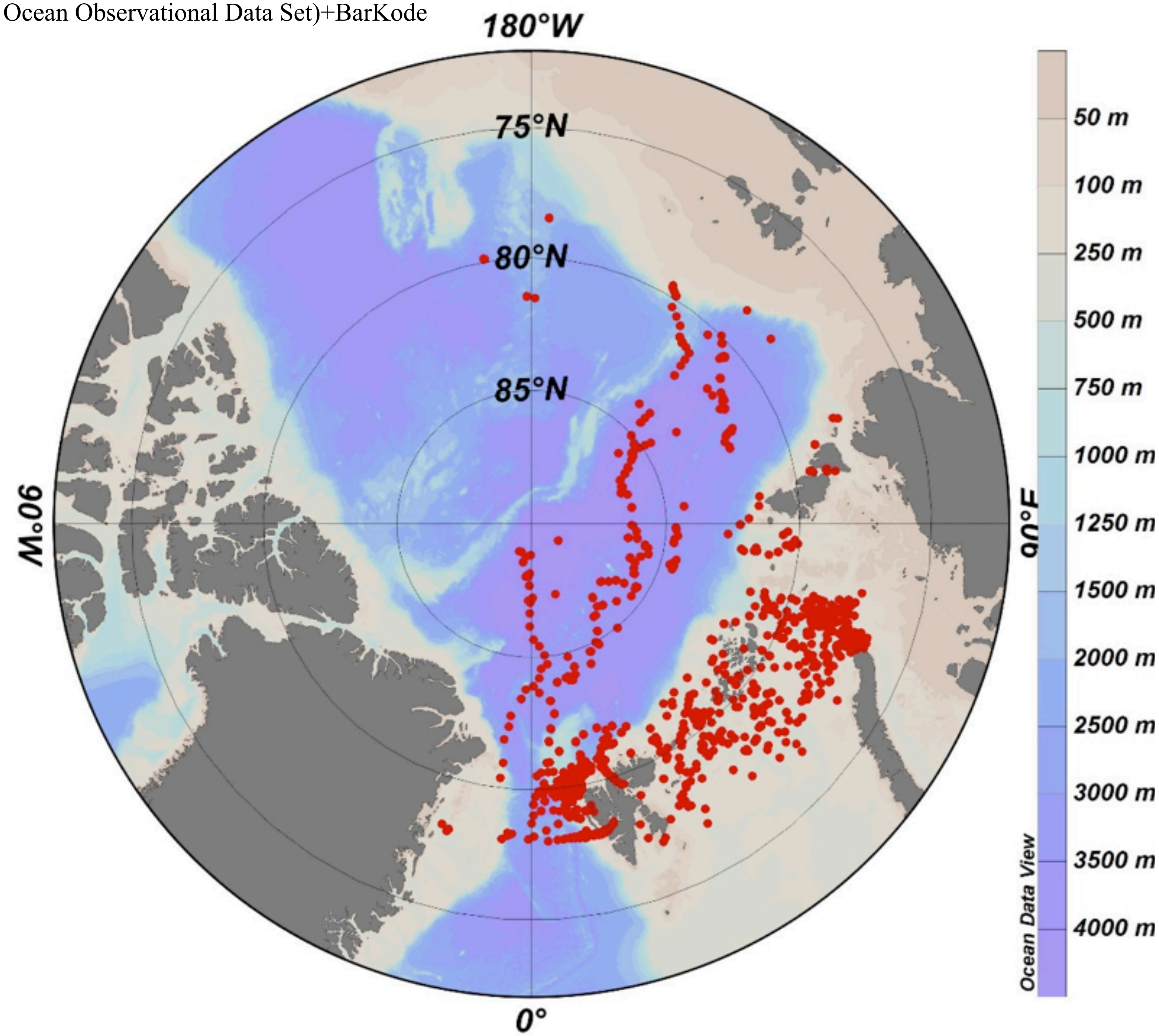
Voluntary Observing Ships



Number of ship observations on 2 degree boxes during 1850 - 1900.Top - in ICOADS, bottom - DWD archive.

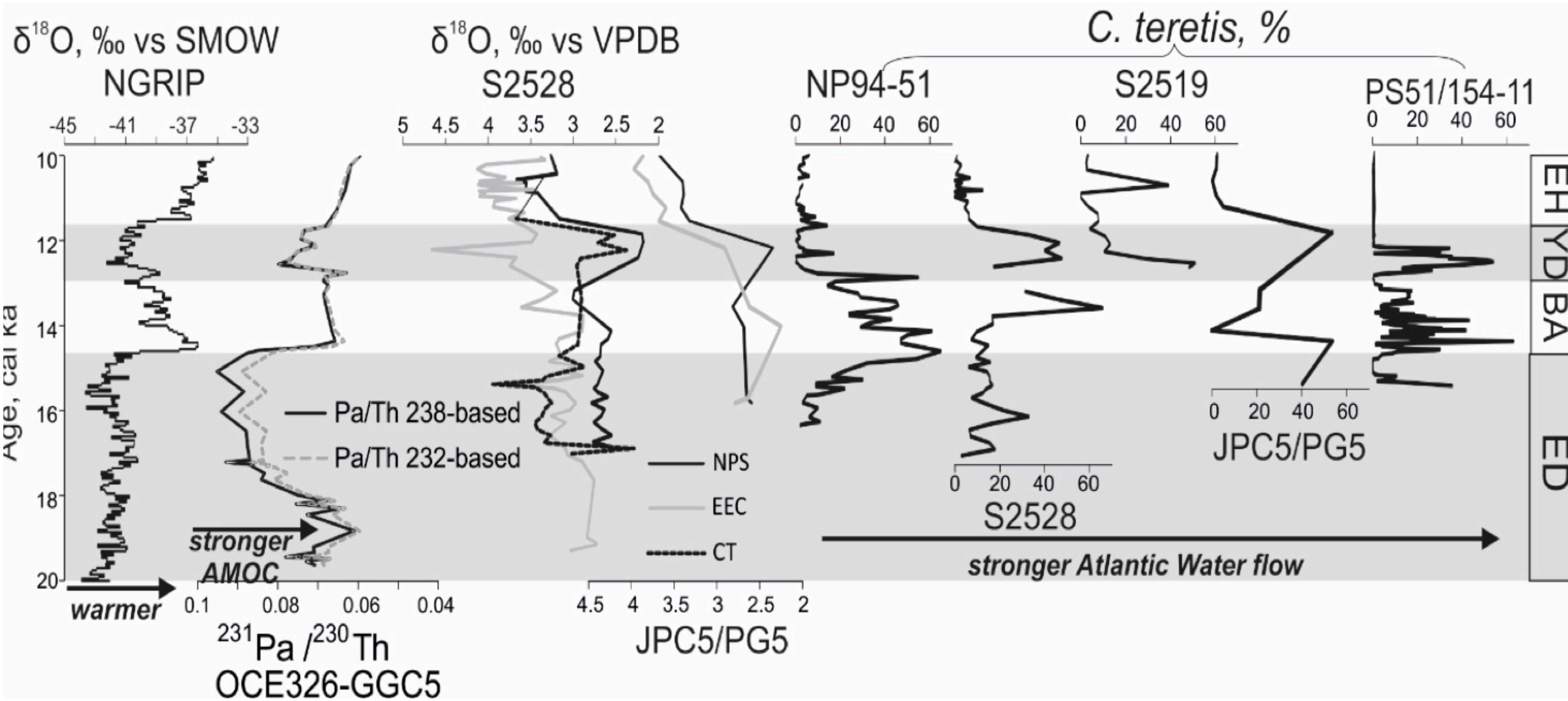
Hydrological measurements in Arctic

USA (WOD NODC)+MOODS (Master Ocean Observational Data Set)+BarKode



Location of the 1010 oceanographic stations, made in the Arctic during the 1900-1950 and available in **Shirshov Institute of oceanology** as a results of the archives digitisation

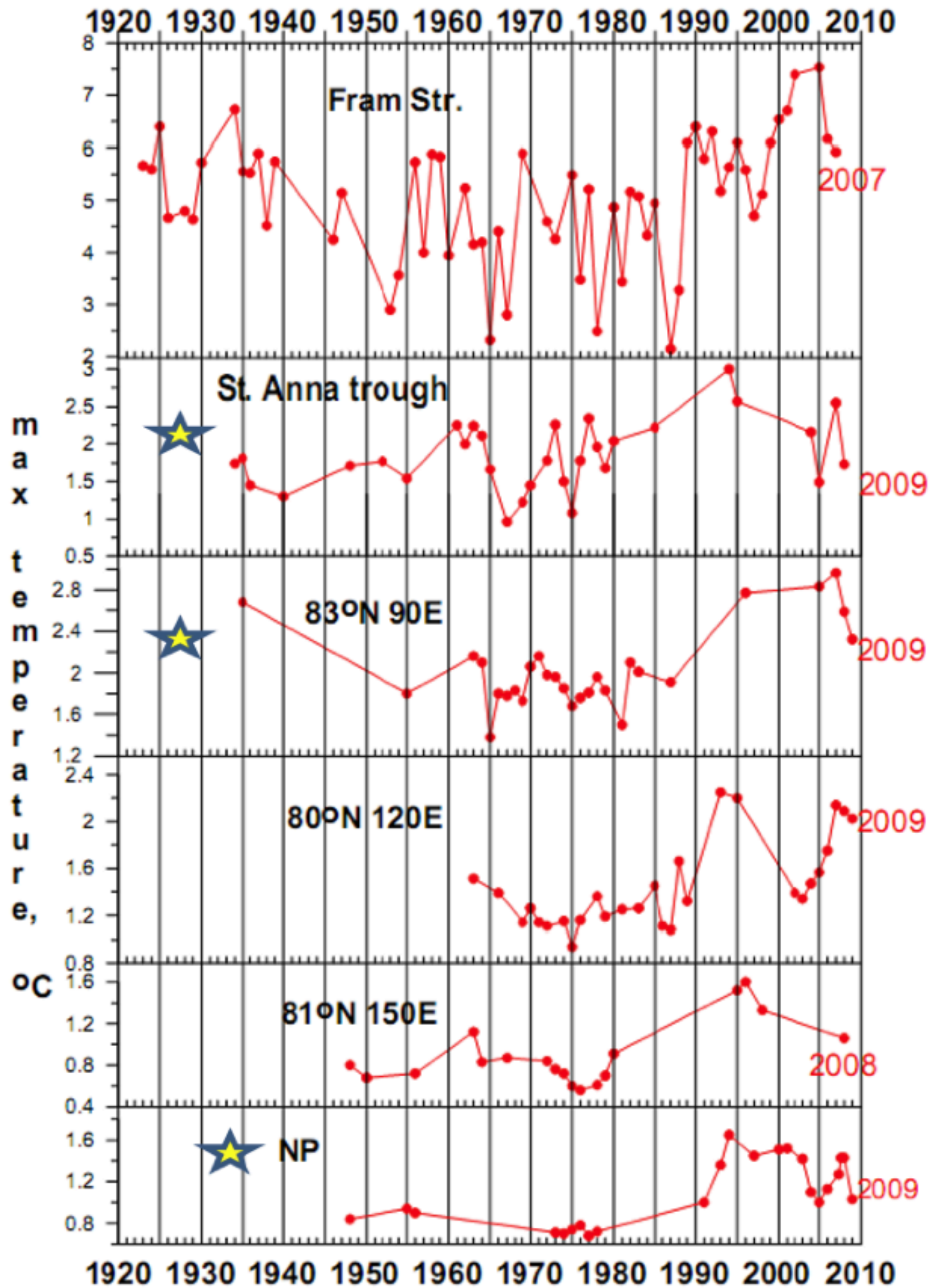
Paleo archives (more than 13 000 years)



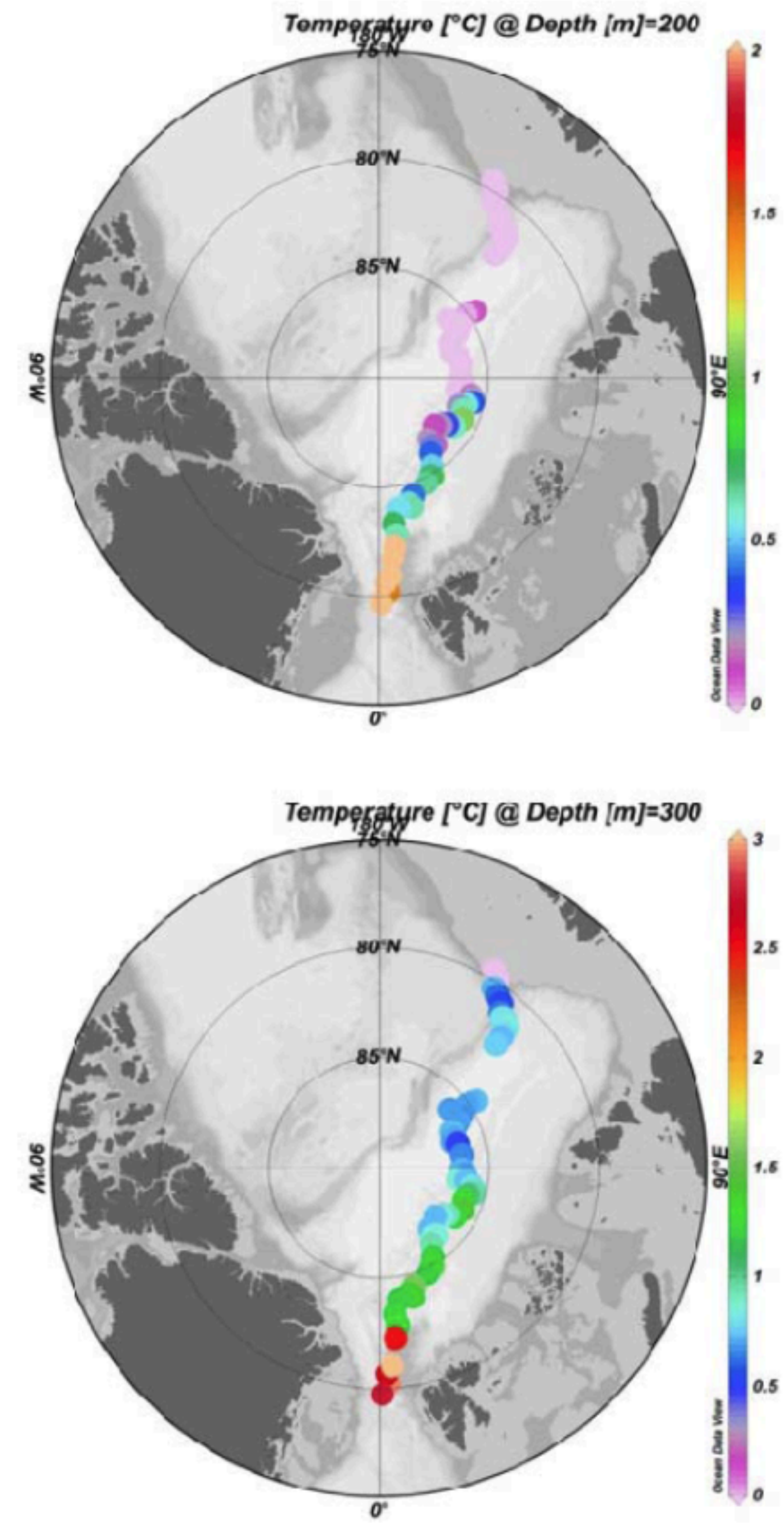
Correlation of the time series of the paleo parameters for the last glacial termination:

- oxygen isotopes of the Greenland core (North Greenland Ice Core Project members 2004)
- Pa/Th reaction in the bottom sediments OCE326-GGC5 (McManus et al. 2004) in the North Atlantic
- oxygen isotopes of the plankton in cores S2528 and JPC5/PG5 (Lubinski et al. 2001)
- bentos indicator *Cassidulina teretis*, determining intensity of the North Atlantic water mass penetration to the Arctic

Murdmaa and Ivanova, 2017



Interannual variability of the max temperature of the North Atlantic water mass in the Arctic on the basis of the station data (★ - on the basis of the newly digitised datasets in the Shirshov Institute of oceanology)



North Atlantic water mass temperature (200 and 300 m depth) on the basis of the data not yet included into international datasets, but available in the Shirshov Institute of oceanology (e.g. Nansen expesition in the Fram Strain in 1893-1896; Sedov expedition in 1927-1940; Tara research cruise in 2006-2008)

Main expected results

(i) New novel long term (>100 years) dataset for the Arctic climate studies, such as

- (i) wind waves
- (ii) hydrological characteristics
- (iii) quality control algorithms

(ii) New methodologies and algorithms for statistical modelling of observations (re-sampling), that would allow for the equal observational density. All algorithms will be shaped as software packages for different operational systems

(iii) Results of the analysis of extra long term variability of the Arctic climate - ice conditions, temperature, ocean state on the basis of paleo archives - both gridded for the Arctic and as temporal sequences for selected regions

(iv) Estimates of the trends and oscillational components of the Arctic climate variability on the basis of reconstructed data

(v) Phenomenological and conceptual models of the main regional mechanisms of the climate variability over the high latitudes

- (i) wind waves interaction with ice cover
- (ii) turbulent heat fluxes response to the ice cover variability
- (iii) radiative fluxes and cloudiness over the Arctic
- (iv) cyclones' response to the observed anomalies of the ice cover

(vi) Estimates of the predictability of the Arctic climate on the basis of the newly observed mechanisms in the set of experiments with climate models - experiments will cover the preindustrial period back to the Maunder minima. This will allow for the critical assessment of the forecasted Arctic climate change in the 21st century

(vii) Publications in internationally recognised scientific journals

(viii) Datasets available for the community

Для выполнения проекта коллектив располагает также мощным компьютерным LINUX-кластером на основе 48 процессоров SUN, оперативной памятью 256 GB и массивом RAID-диском объемом 48 Терабайт. В настоящее время кластер также дополнен мощной вычислительной векторной платформой CRAY CX1 - Xeon X5670. Кроме того, в распоряжении коллектива имеются мощная многопроцессорная LINUX - платформа среднего класса с 4-х и 8-ми ядерными процессорами и оперативной памятью 32 Gb.
В настоящее время коллектив, помимо массива RAID-дисков на 400 Терабайт располагает общим объемом SCSI устройств в 280 TB на LINUX платформах и более 80 TB на Windows – платформах. Коллектив также располагает девятью мощными Windows – платформами, объединенных с LINUX-кластером в локальную сеть. Коллектив в настоящее время имеет в оперативном распоряжении все коды используемых в проекте моделей и диагностик.

Statistical characteristics of the relative (in %) changes in the soil bearing capacity relative to the 1965-1975 and 1995-2005 periods