Simulation of river runoff in the Eastern Siberia and the propagation of the river freshwater in the Arctic

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GOALS

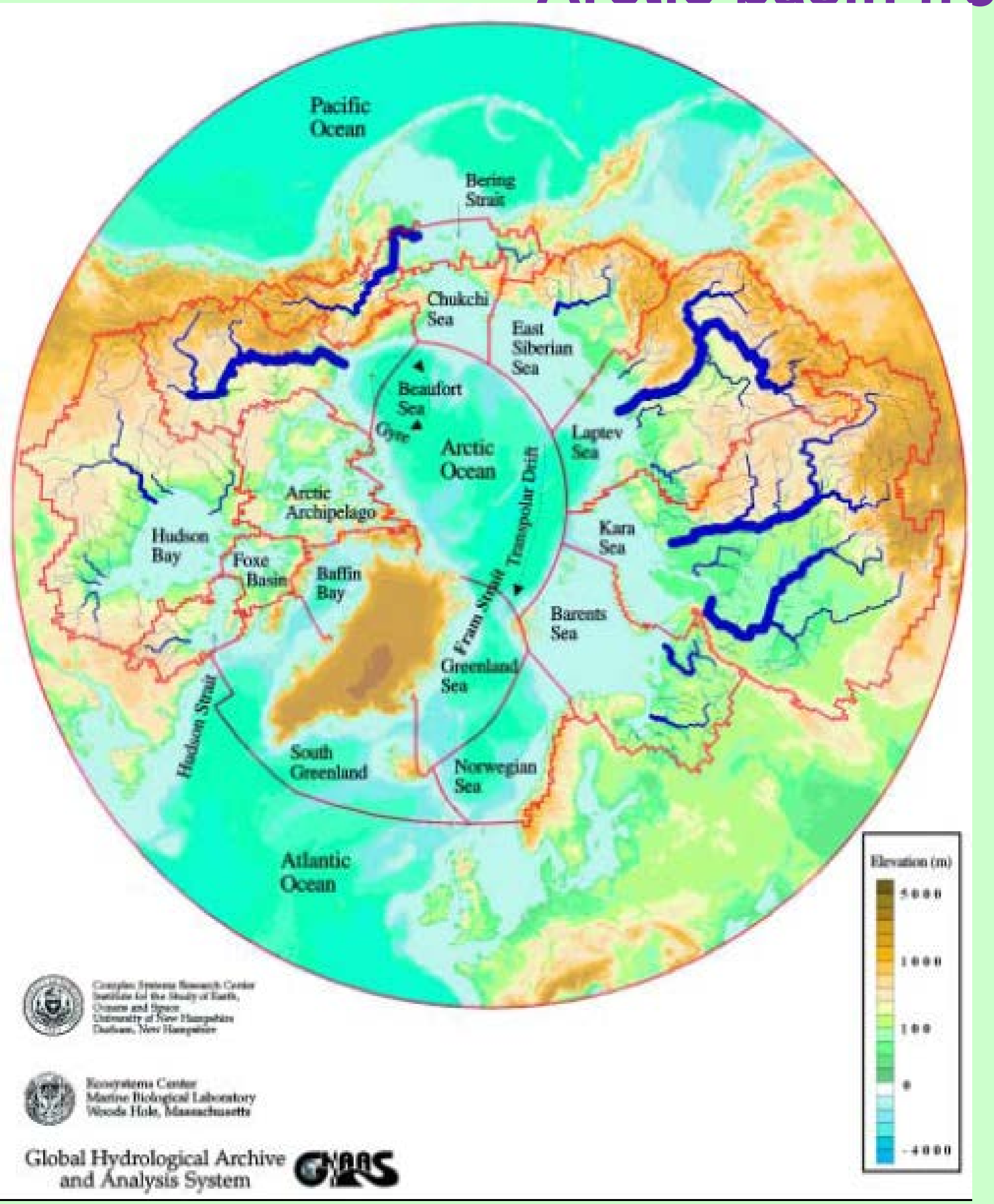
- To estimate the variations of the river runoff in Eastern Siberia which possible may be erased in the XXI century in comparison with that what it was in XX century

- To make the estimation of the fresh water propagation in Arctic Ocean during climatic changes in the XXI century by the 3D Arctic Ocean circulation numerical model.

Content

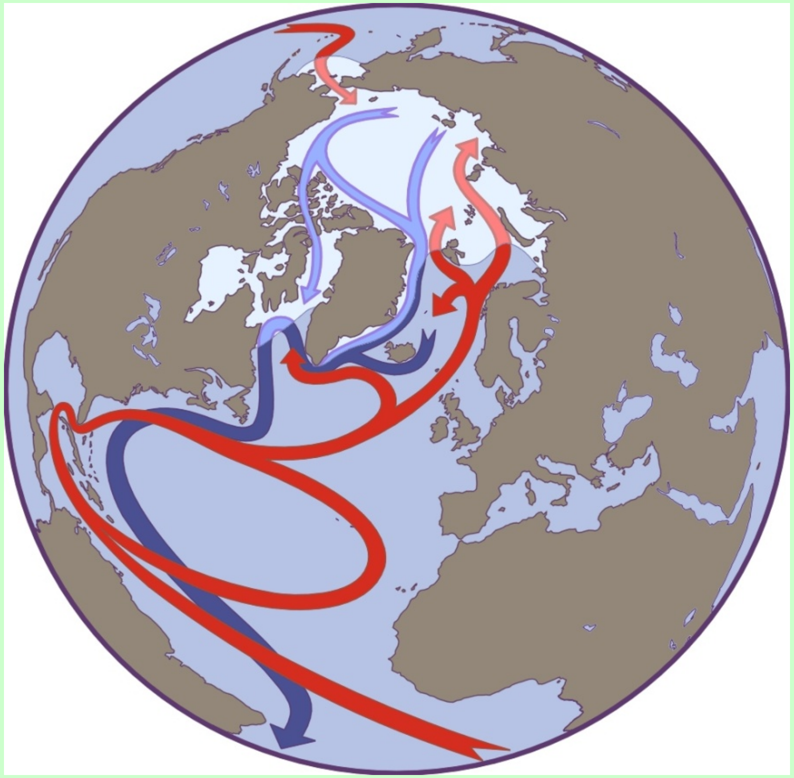
- Motivation for the study of the Siberian rivers runoff and Arctic basin fresh water balance
- Simulation of the river runoff
- The Arctic ocean circulation in XX century
- Simulation of the fresh water content in XXI century
- Propagation of the fresh water deviations in the Arctic ocean
- Summary

Motivation for the study of the Siberian rivers runoff and Arctic basin fresh water balance



Arctic ocean form about 1% of the World Ocean volume . However it gives input 11% of total fresh water into the World Ocean (Kalinin, Shiklomanov, 1972). Siberian rivers gives about 55% of the total volume, McKenzy - 5 %, the Bering strait gives about 40% with variability 25-30% (Agaard, Karmak, 1989, Sereze et al, 2006, Woodgate et al, 2006,).

So, there arise a question how that input may be changed in XXI century.



A schematic drawing of North Atlantic and Arctic Ocean circulation.
Red arrows represent relatively warm water from lower latitudes entering the Arctic, while blue arrows represent the export of colder water from the Arctic. Shaded white shows the average area covered by sea ice. (Figure courtesy of G. Holloway, Institute of Ocean Sciences, Sidney, British Columbia).

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"CONVEUOR" BELT IN THE WORLD OCEAN

In is evident now that the Great Salinity Anomaly in 70-th decreased the deep water formation in the North Atlantic As the result, the meridional thermohaline circulation in the World Ocean was depressed. And exchange of the water masses between the low and high latitudes was destroyed what shifted the global hydrological cycle.

•Simulation of the river fresh water in the Arctic Ocean

Models:

Hydrological discharge model (ICM& MG)

3D Arctic –North Atlantic circulation model (ICM&MG, Russia)

Data:

The experiment for XX century:

reanalysis ERA40 and GMAO MERRA

The experiments for XXI century:

Data from model projection by the scenario RCP8.5 of IPCC calculated by two models:

model INM (Russia)

model CRNM (France)

Experiments

River runoff simulation

1) Preliminary experiment for the simulation of the river runoff for the XX century for the verification of the model;

2) Experiments for simulation of the river runoff for the XXI century on the basis of the data CRNM and INM models;

Experiments with 3D Arctic Ocean circulation model:

Run1: CRNM forcing & climatic river runoff (CRNM_1);

Run2: CRNM forcing & modeled Siberian rivers runoff (CRNM_3);

Run3 : INM forcing & climatic river runoff (INM_1);

Run4: INM forcing & modeled the Siberian rivers runoff (INM_5)

SIMULATION OF THE RIVER RUNOFF

Main features of then Hydrological Discharge Model

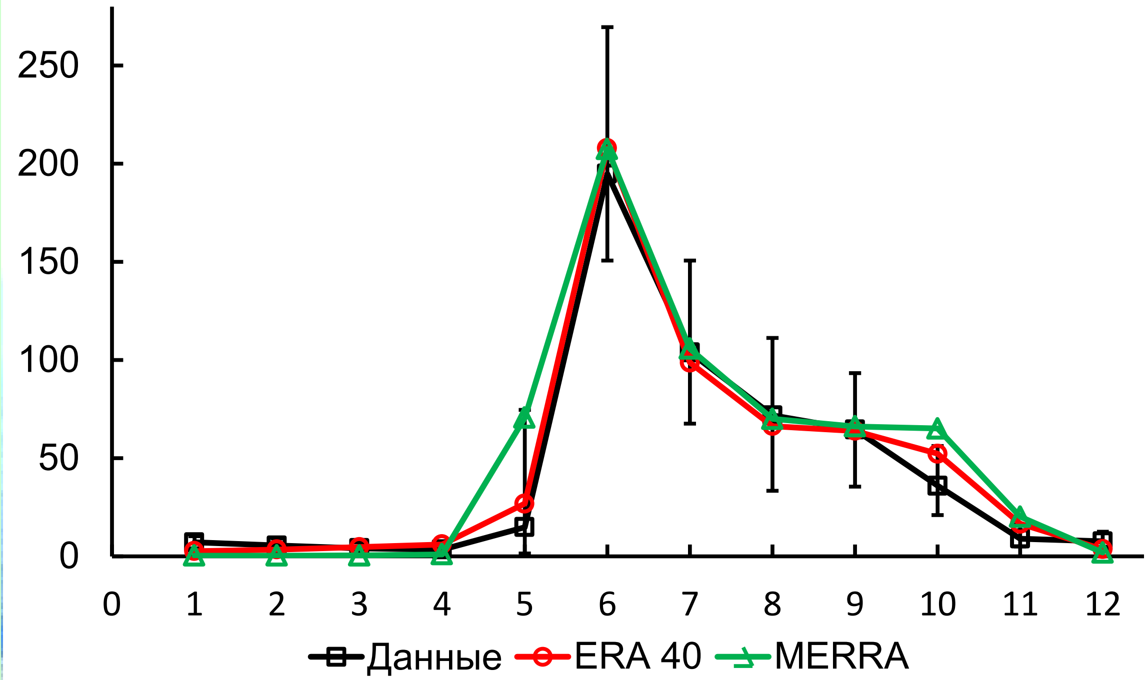
<u>Model is constructed from linear reservoirs in the grid boxes</u>:

- Velocity of the outflow is found on the basis of the solution of the ordinary differential equations

<u>The lateral water flow separates into three flow processes:</u>

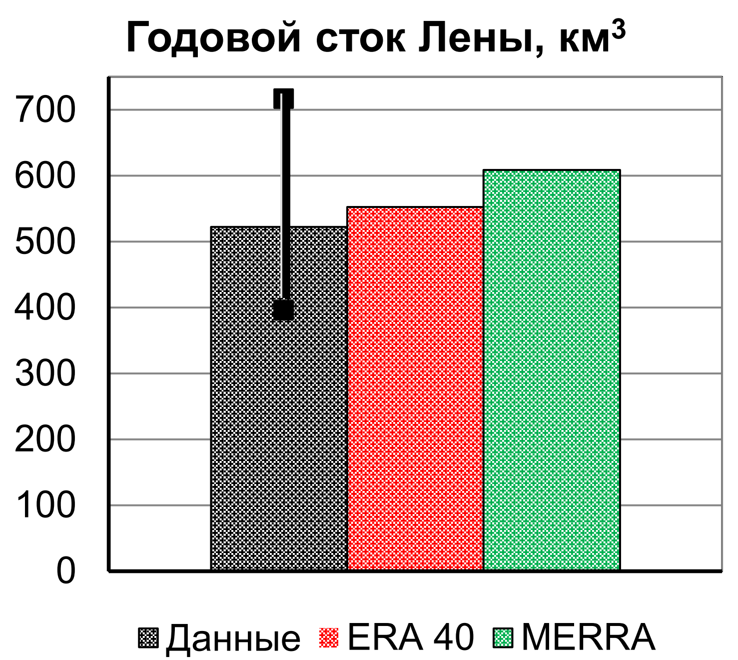
- Overland flow
- Base flow
- River flow

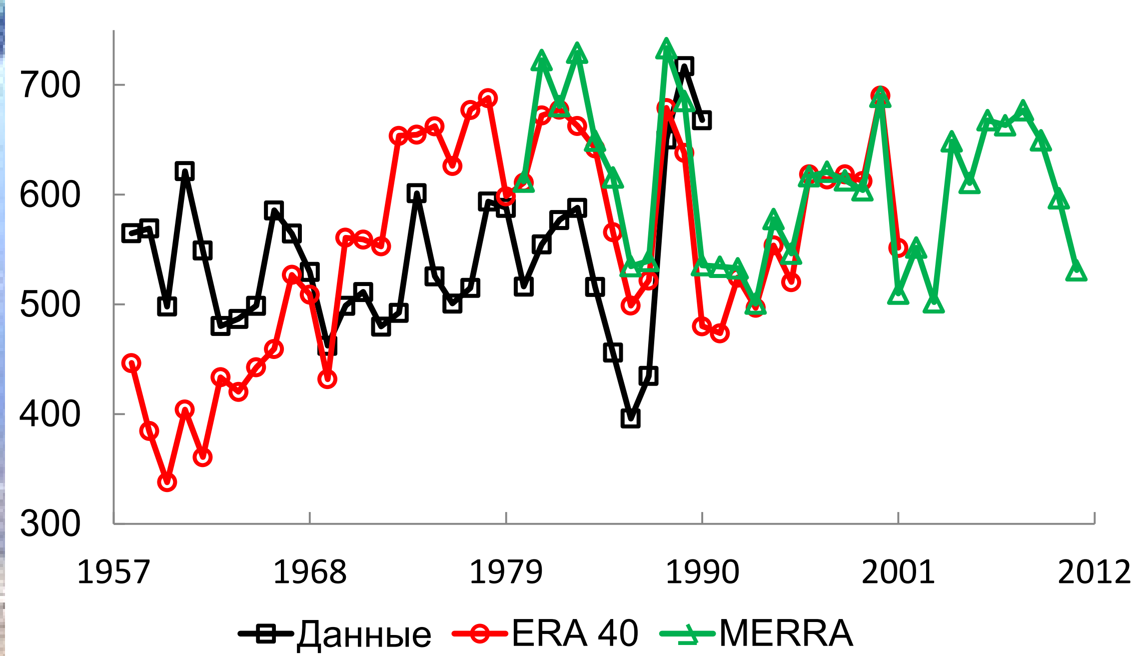
The climatic hydrograph of Lena River(км^3) for XX cent.

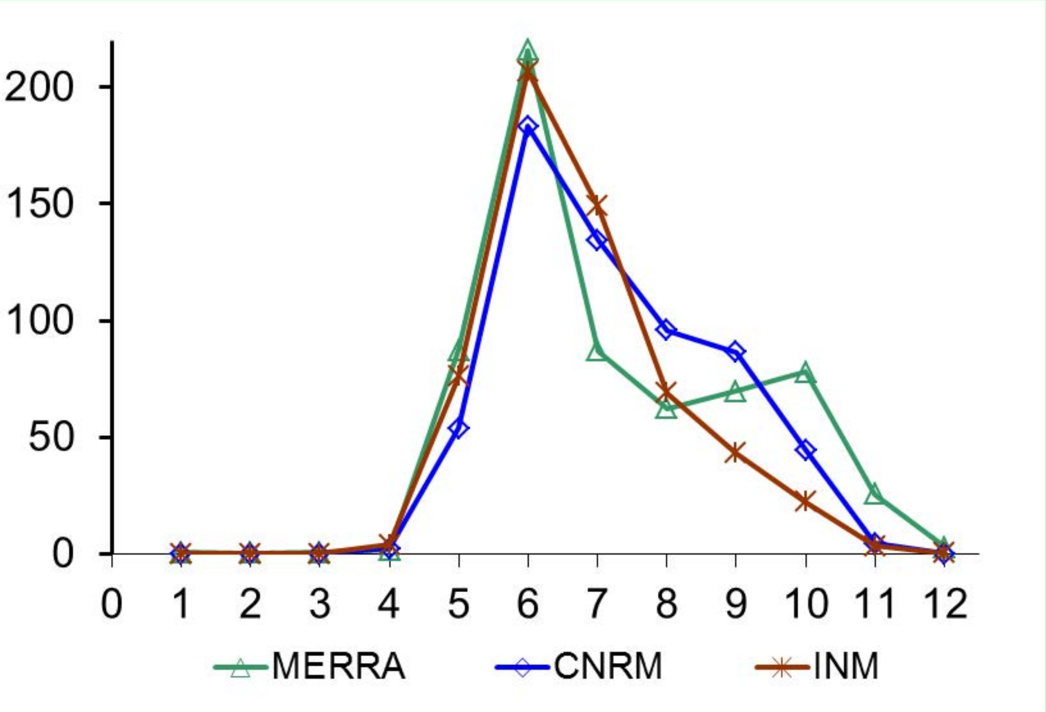


Reanalysis	ERA 40	MERRA
Max amplitude, %	6,7	6,4
Total runoff, %	5,8	10,4

CORRELATION:	
DATA- ERA40	0,39
DATA - MERRA	0,51
ERA40 - MERRA	0,93

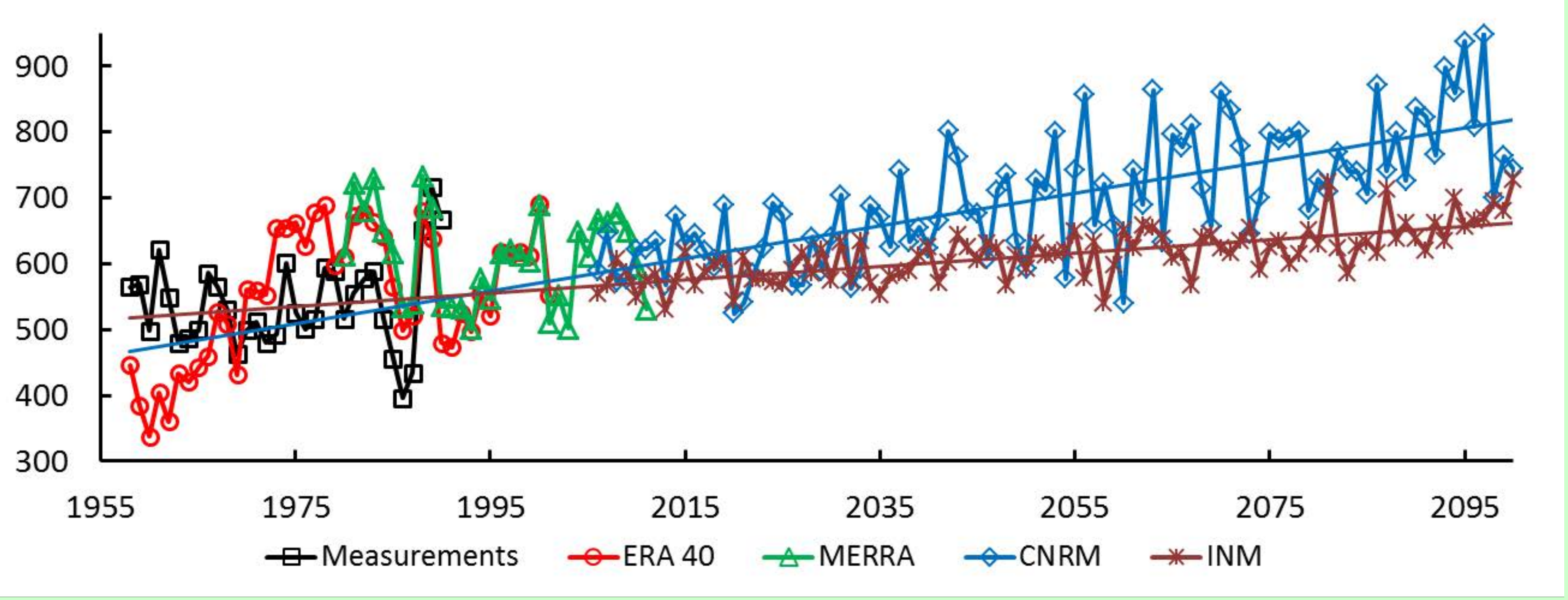


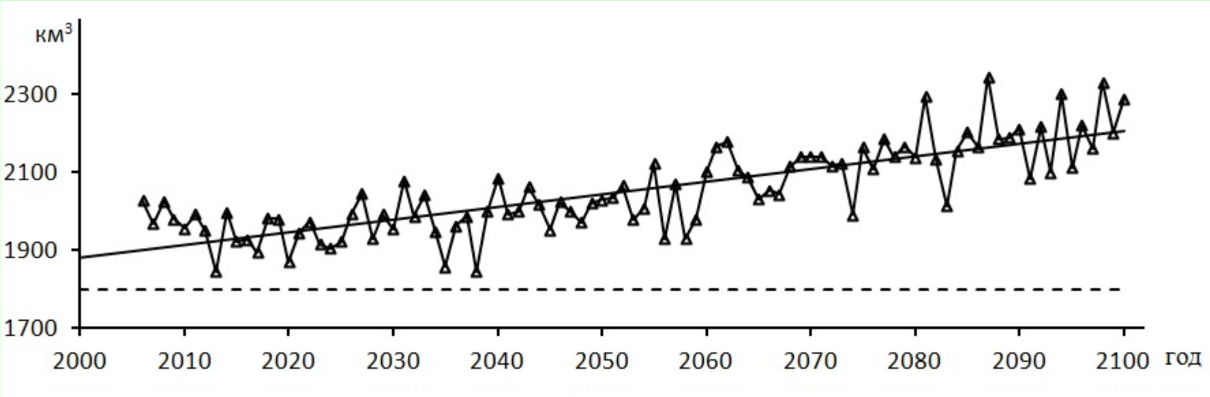




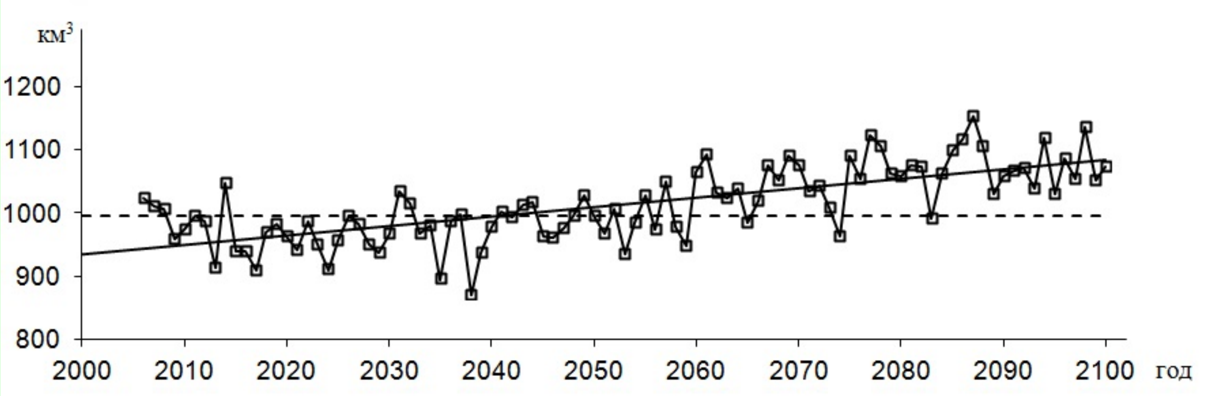
The climatic hydrograph (км³) for the Lena River for the XXI cent. Trends are excluded.
(Comparison with MERRA 2006-2011 yrs).

Correlation:	
ERA40 - MERRA	0,93
CNRM - INM	0,39

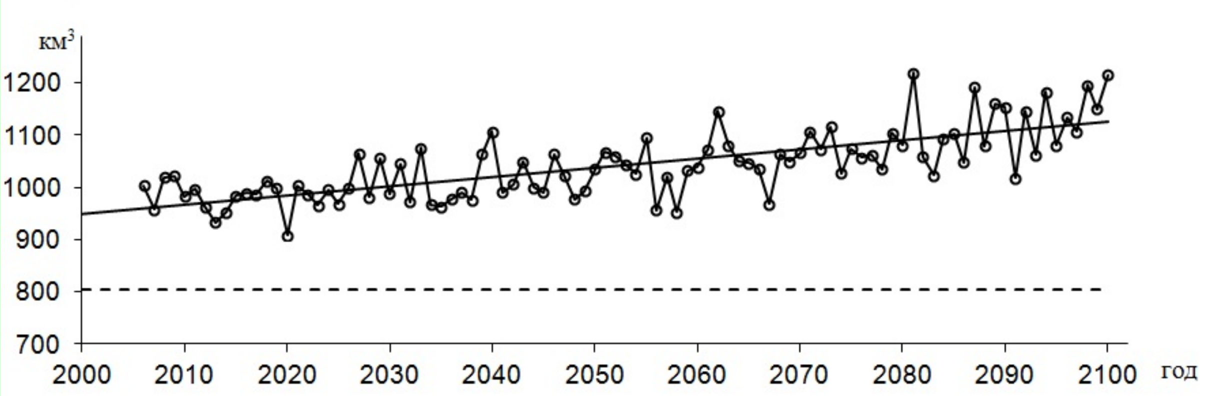




Interannual variability of the total Siberian rivers runoff to the Arctic Ocean



The sum of runoff of the Ob and Yenisei rivers to the Kara Sea

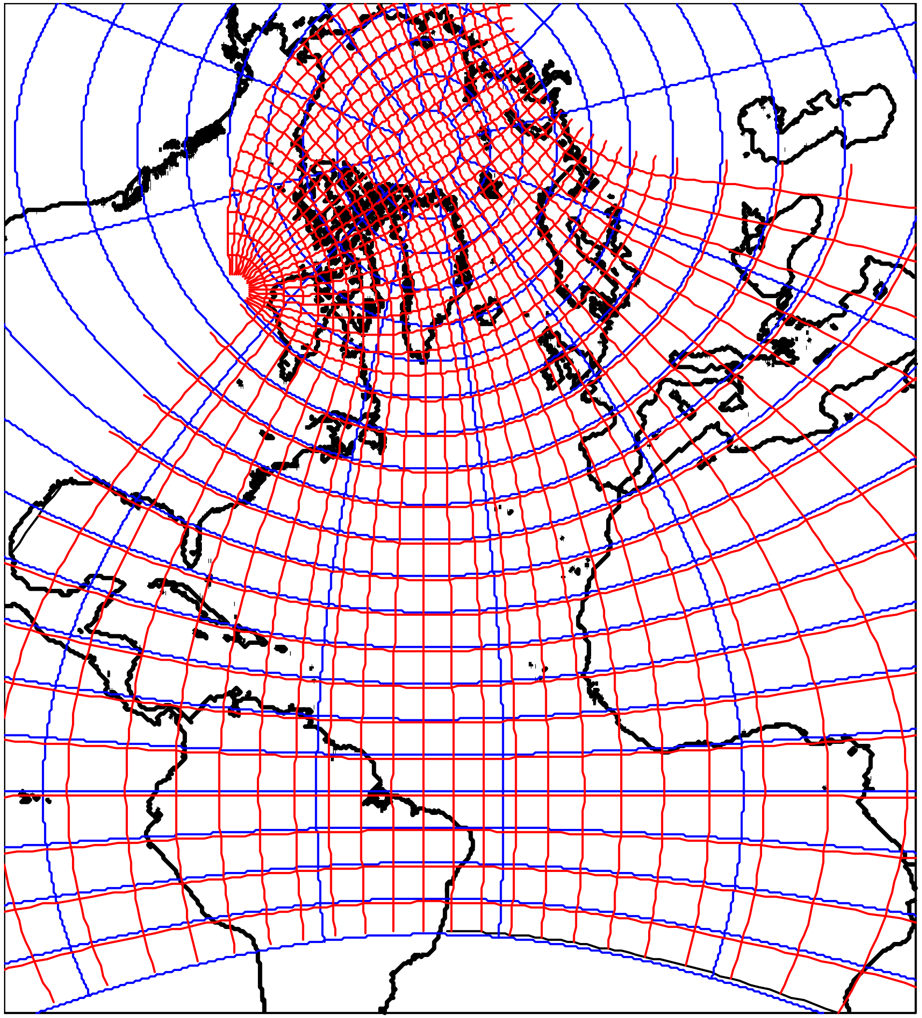


The sum of runoff to the Laptev Sea and Eastern-Siberian Sea

THE ARCTIC OCEAN CIRCULATION IN XX CENTURY

Coupled Ice-Ocean Model

3D Ocean Circulation Model of ICM&MG
(based on splitting method with finite element approach)

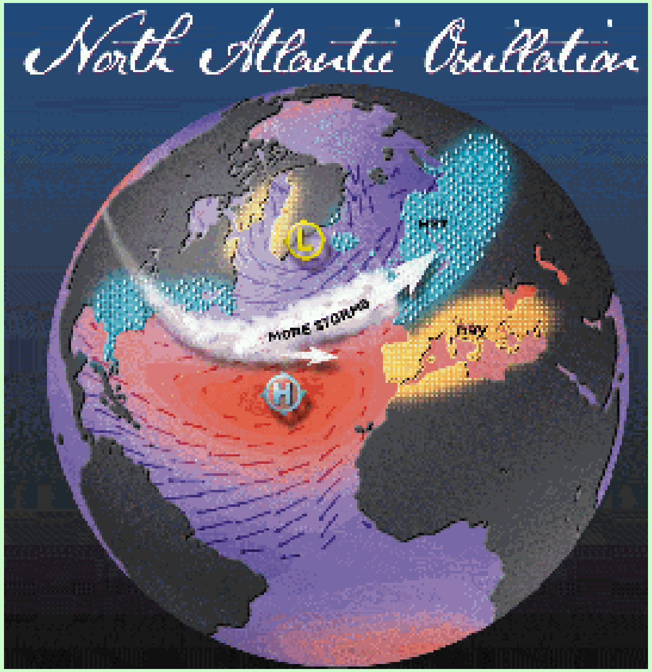


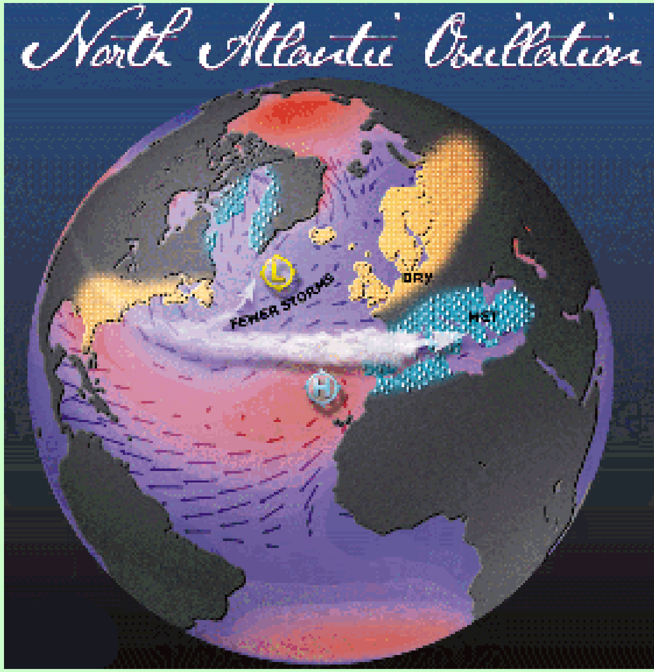
(Kuzin [1982], Golubeva at al.,[1992], Golubeva [2001], Golubeva and Platov [2007])

Princeton ice model-CICE 3.14 (elastic-viscous-plastic)

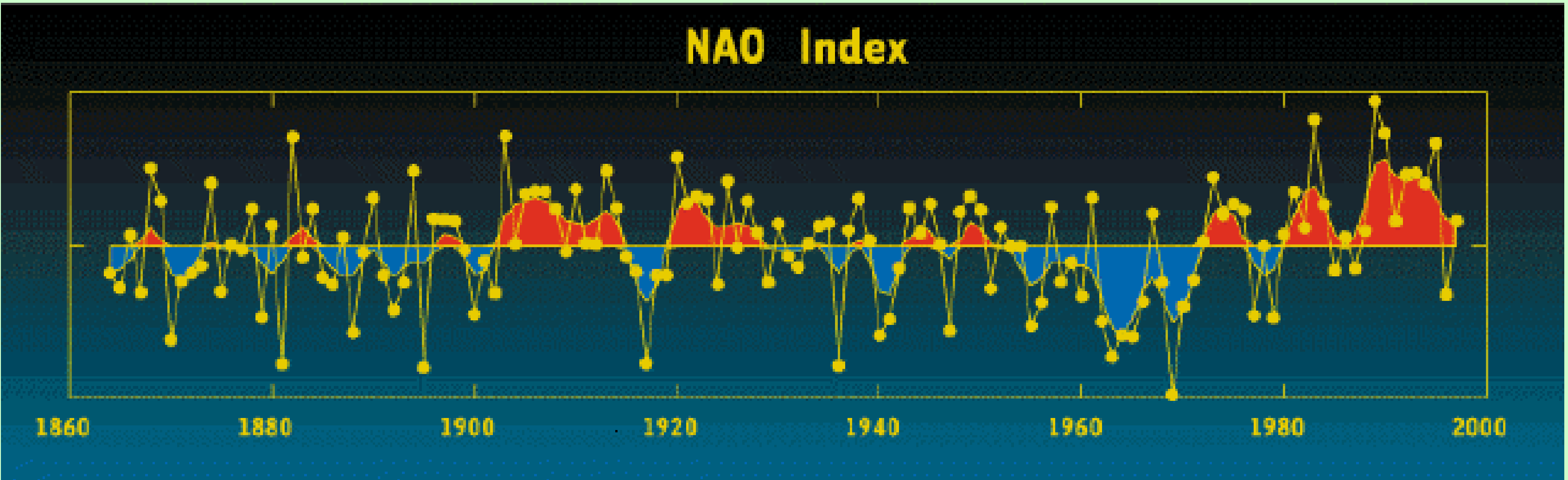
W.D.Hibler [1979],
E.C.Hunke, J.K.Dukowicz [1997],
G.A.Maykut [1971],
C.M.Bitz, W.H.Lipscomb [1999],
J.K.Dukowicz, J.R.Baumgardner [2000],
W.H.Lipscomb, E.C.Hunke [2004]

The North Atlantic Oscillation (NAO) is the regional manifestation of Arctic Oscillation (AO), a hemispheric mode of variability defined by expansion and contraction of the polar vortex [Thompson and Wallace, 1998; Hurrell, 1995; Ting et al., 1996



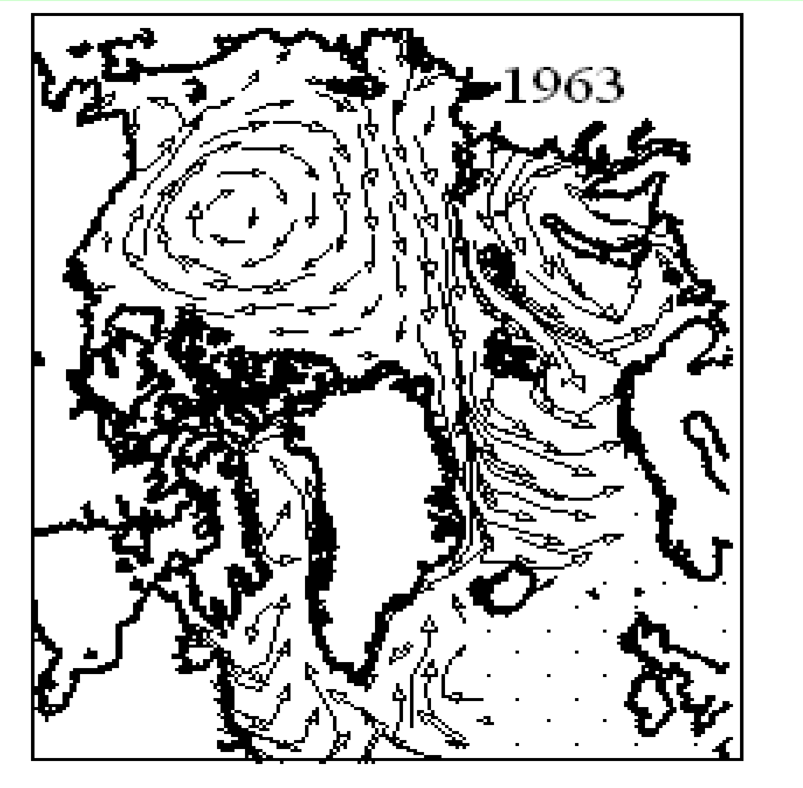


The positive/negative NAO phases are associated with enhanced/diminished Icelandic Low and Azores High.



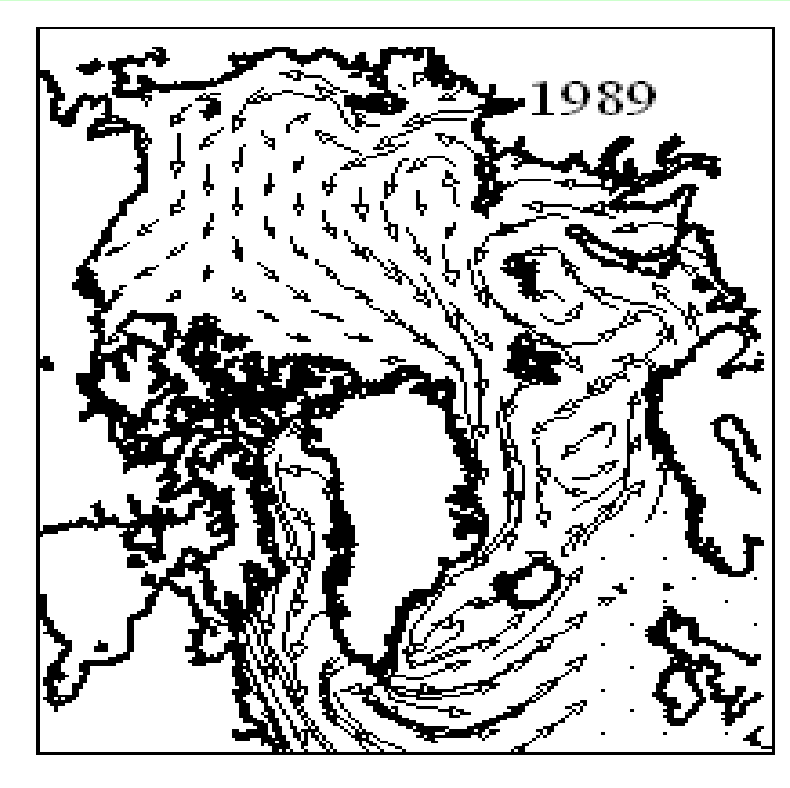
Two main modes of the Arctic Ocean circulation as the response to the NAO index variations

Negative NAO index –
anticyclonic mode



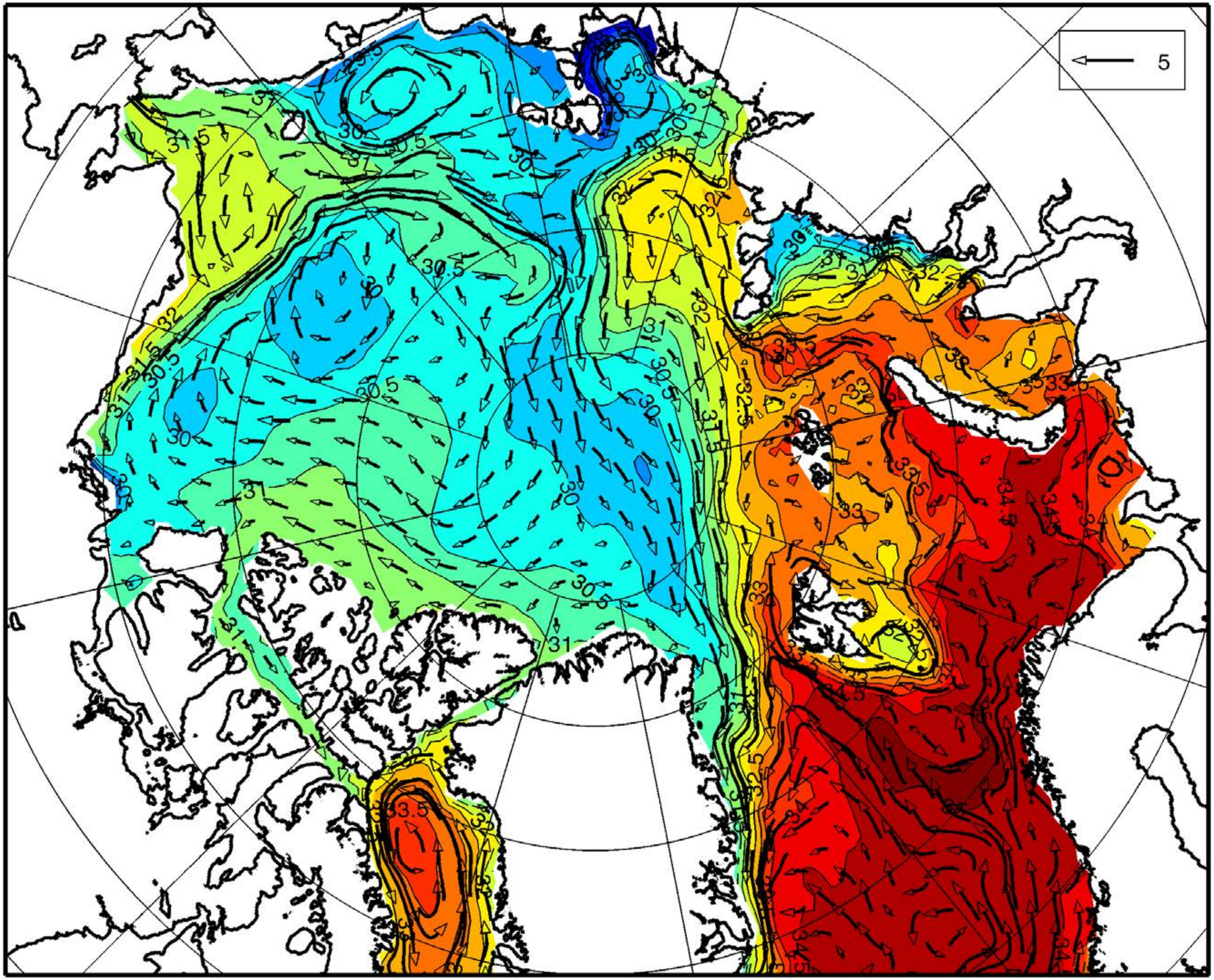
1960, 1961, 1963,1965,1966,1969,
1970-1973, 1977-1980,1982-1983,
1985-1986, 1988, 1992,1994, 1996,
1998, 2001

Positive NAO index –
cyclonic mode

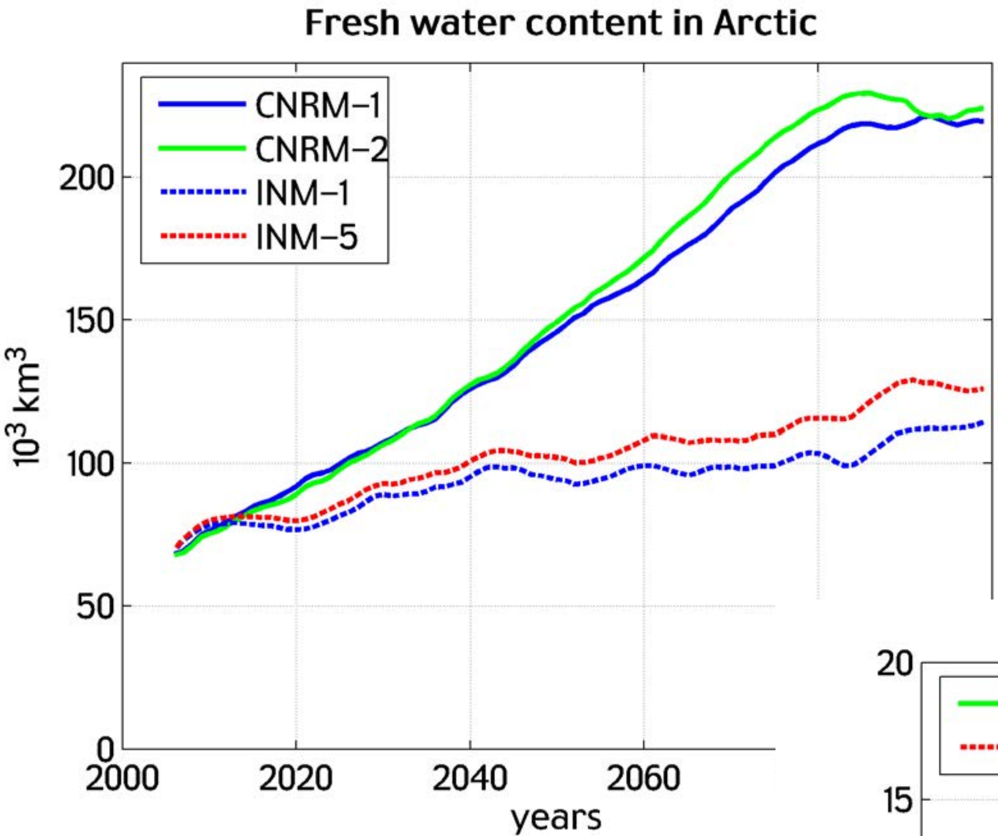


1967,1968,1981,1984,1989,1993,
1995,1997,1999, 2000, 2002, 2003

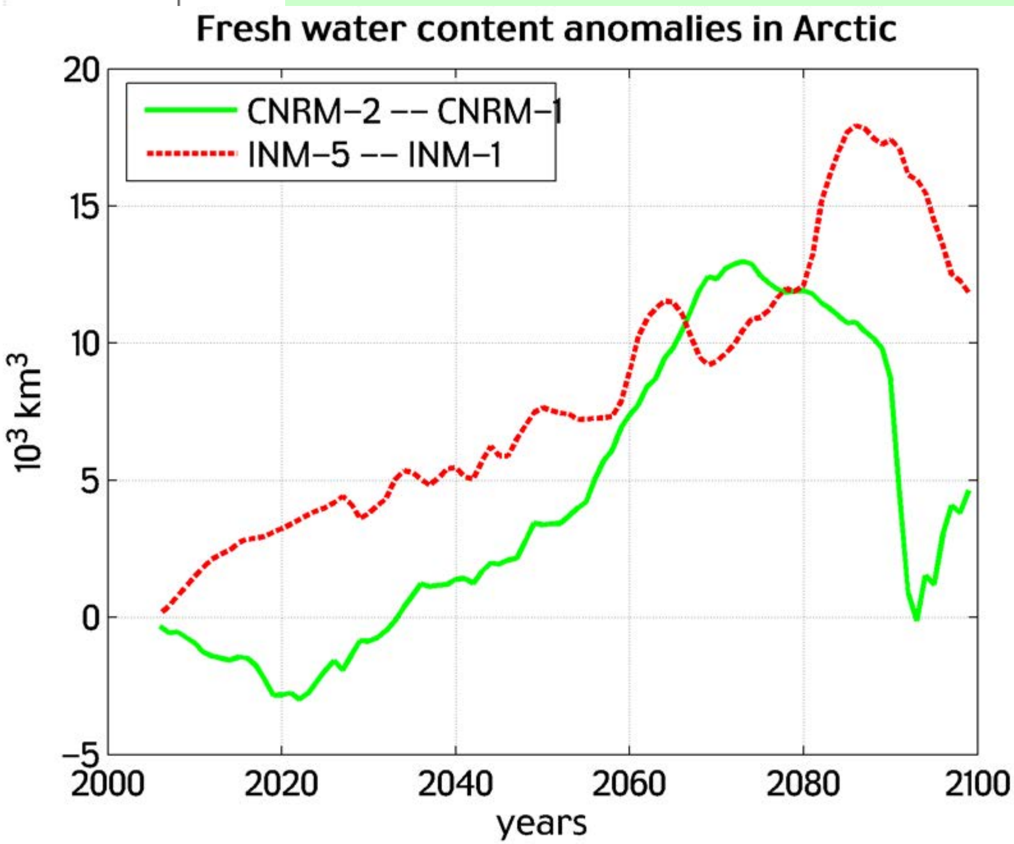
Salinity (psu) and Velocity Vectors (cm/s) (0-50m averaged) 1961



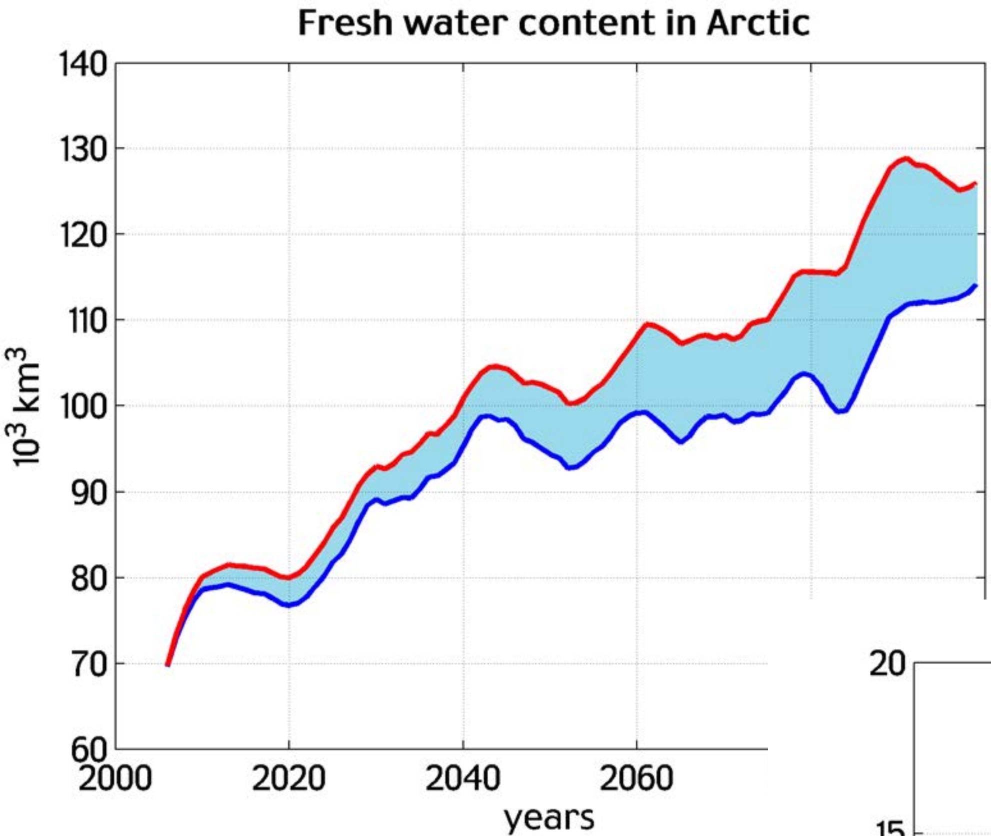
SIMULATION OF THE FRESH WATER CONTENT IN XXI CENTURY



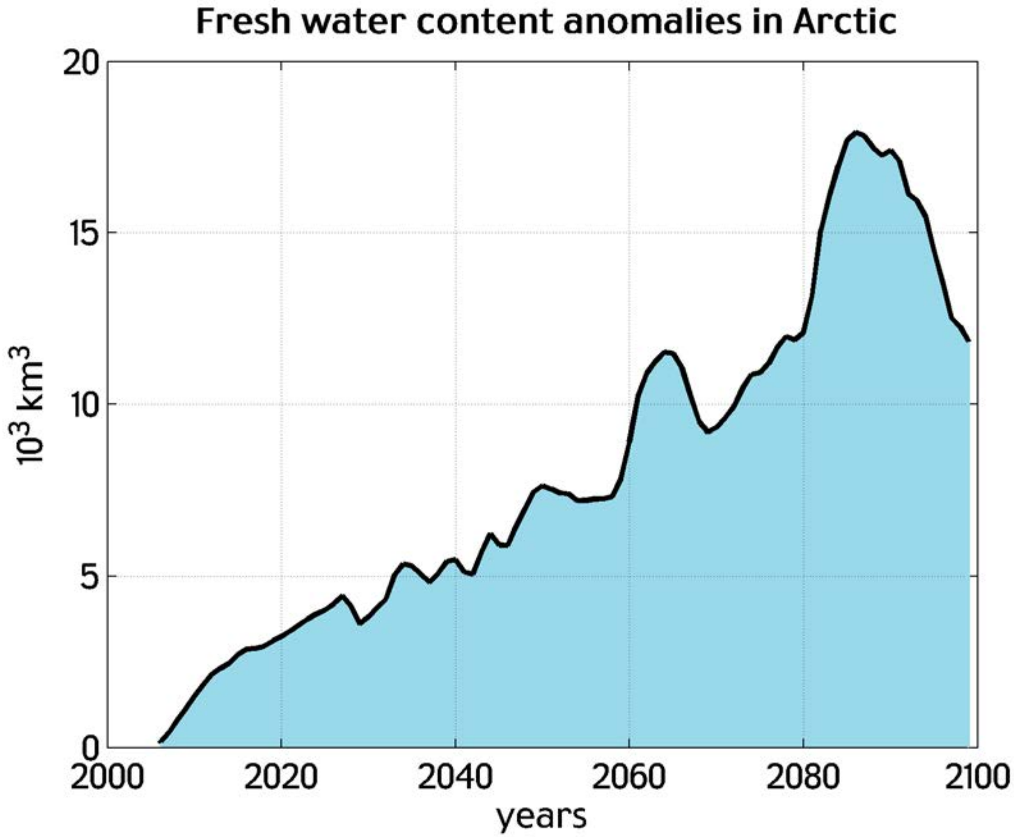
Fresh water content and anomalies in Arctic for two different models input and two different experiments



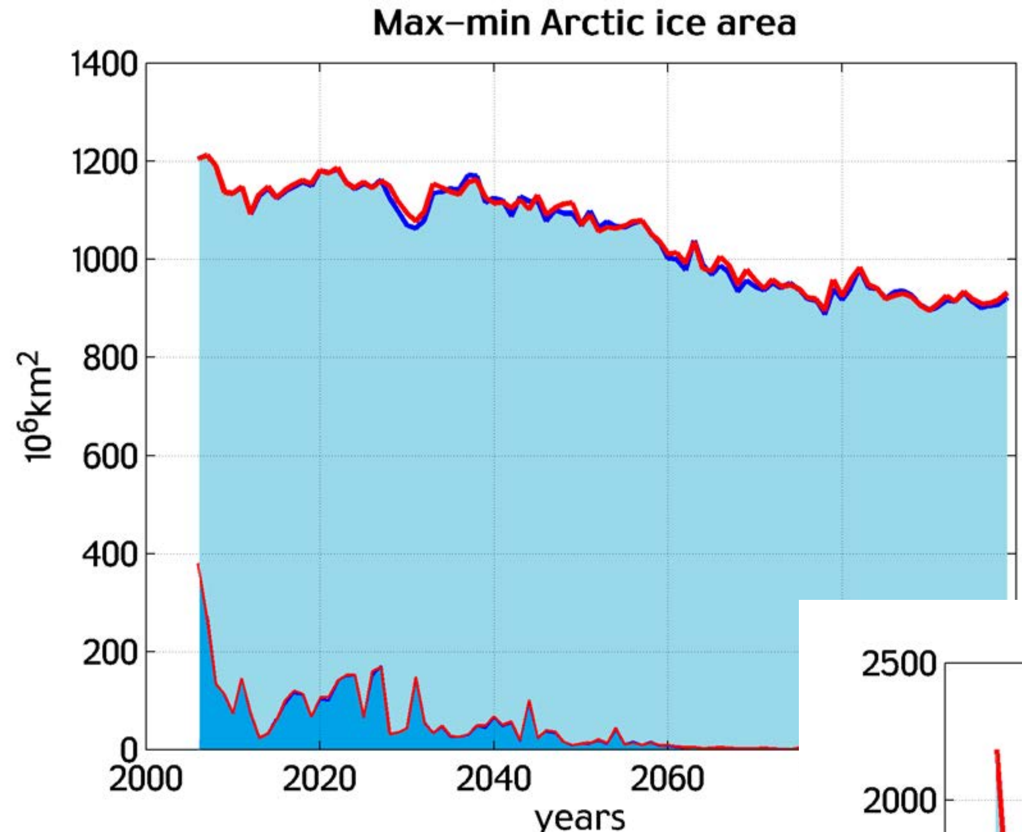
The CRNM model has more high fresh water amount then INM model. However, the anomalies more high for the INM model



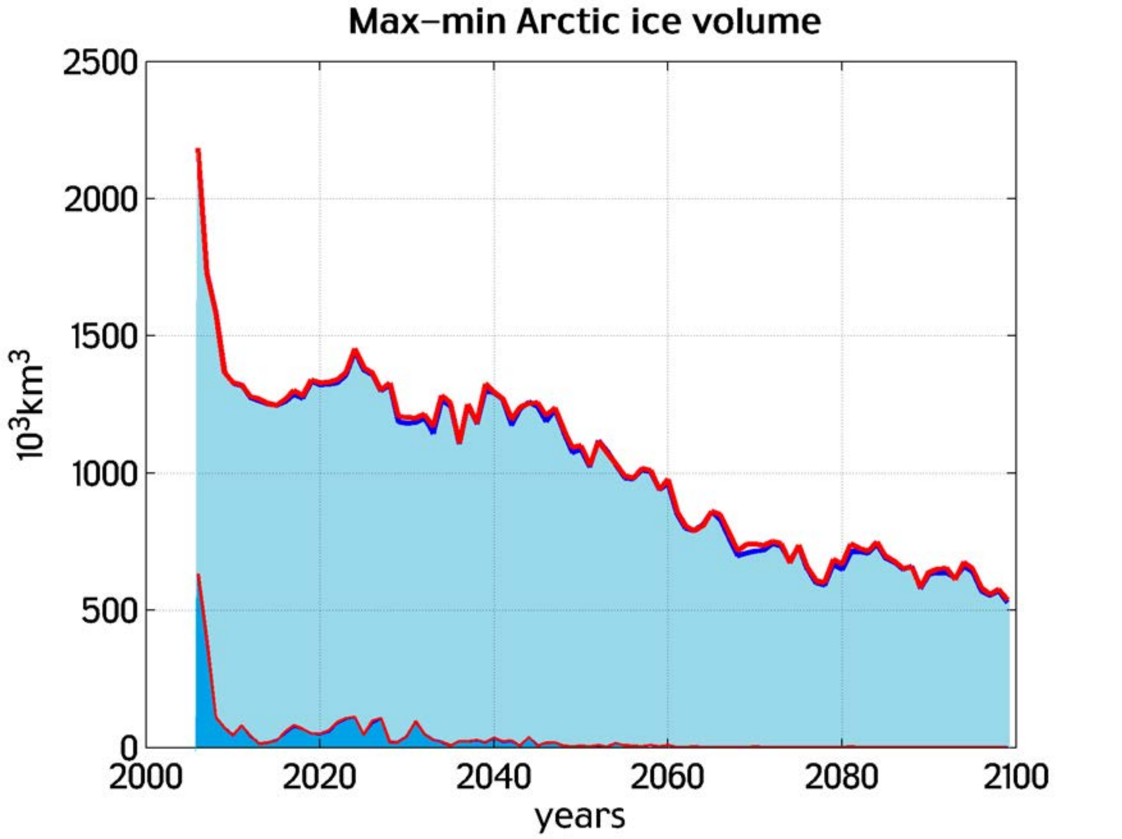
Fresh water content and the anomalies in Arctic for two river runoff (blue – climatic, red – modeled by the INM data)



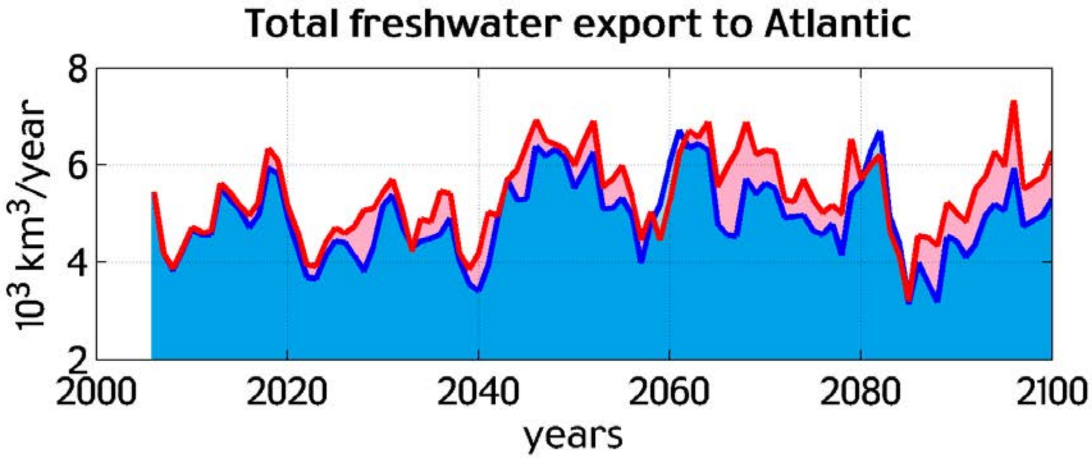
Modeled runoff gives more high values of the fresh water content then climatic

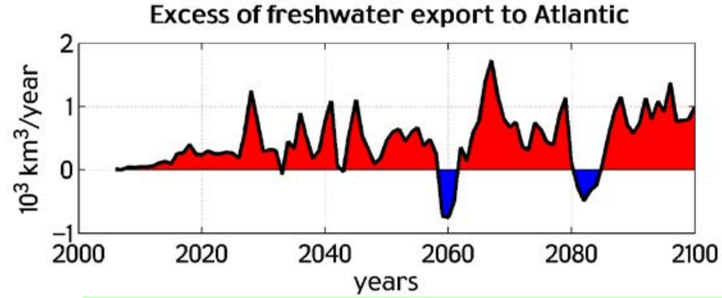


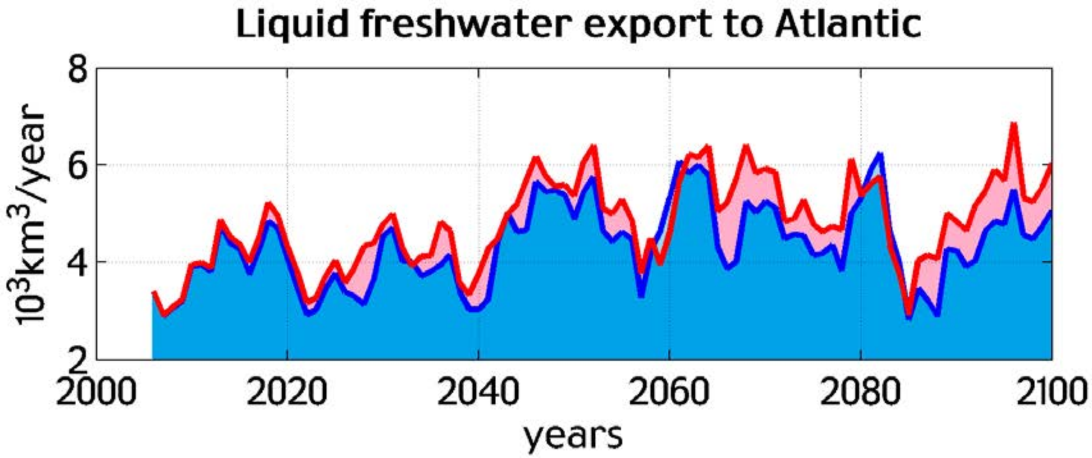
Minimal and maximal ice area, minimal and maximal ice volume (minimal – September, Maximal – Marsh)

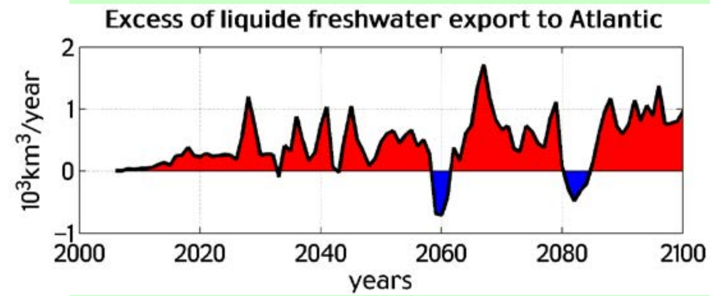


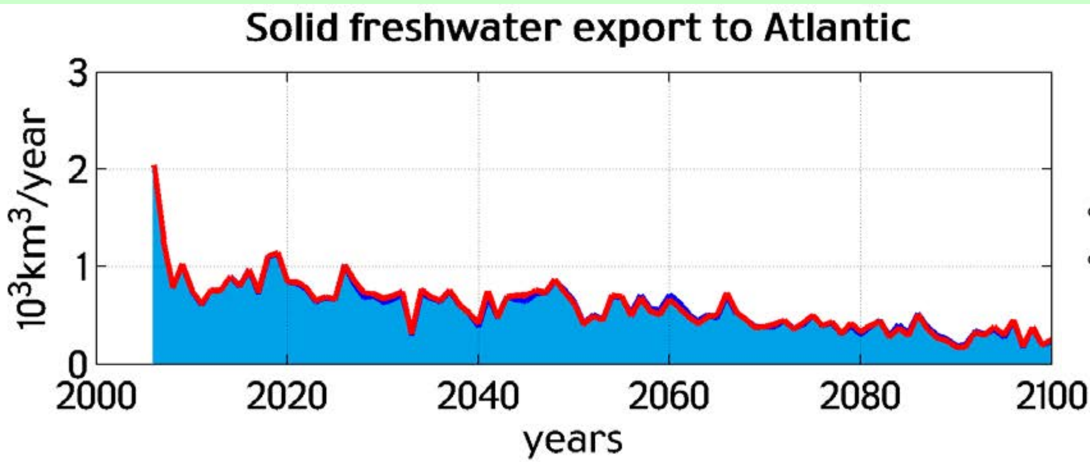
There are no significant changes between two version of runoff

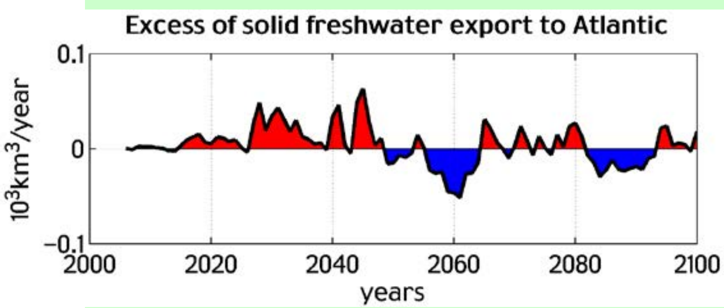

Total freshwater export to Atlantic
10^3 km^3/year
8
6
4
2
2000
2020
2040
2060
2080
2100
years


Excess of freshwater export to Atlantic
10^3 km^3/year
2
1
0
−1
2000
2020
2040
2060
2080
2100
years


Liquid freshwater export to Atlantic
10^3km^3/year
8
6
4
2
2000
2020
2040
2060
2080
2100
years

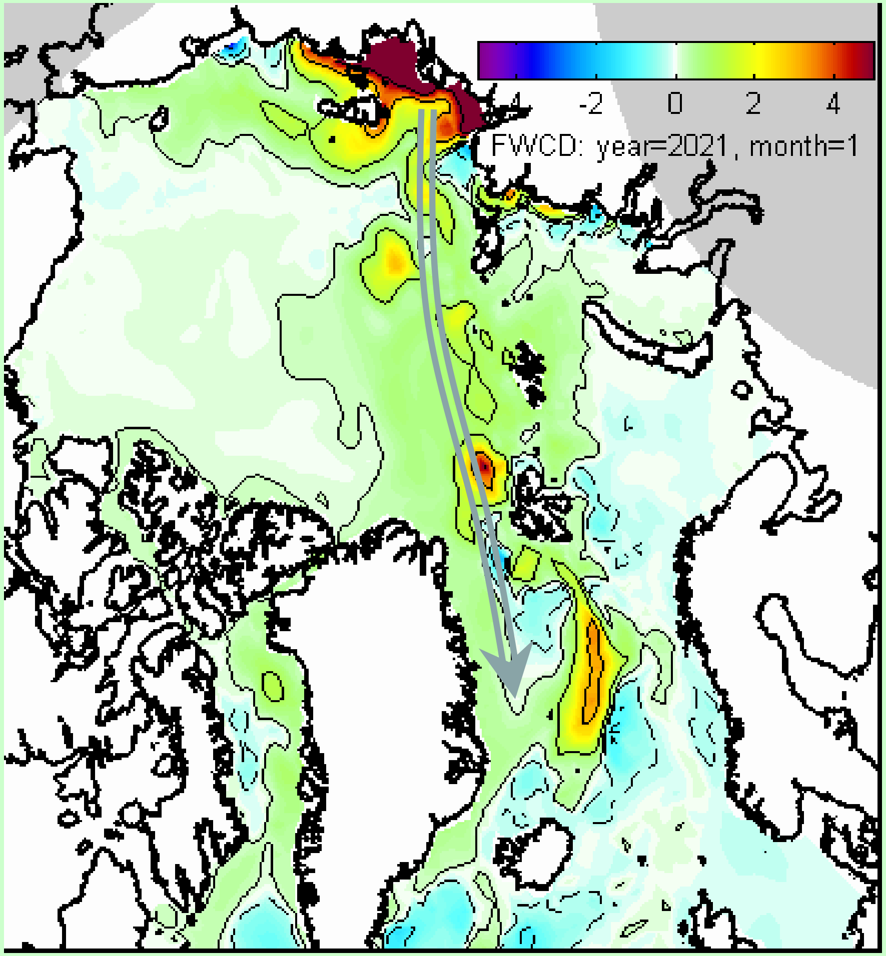

Excess of liquide freshwater export to Atlantic
10^3km^3/year
2
1
0
−1
2000
2020
2040
2060
2080
2100
years


Solid freshwater export to Atlantic
10^3km^3/year
3
2
1
0
2000
2020
2040
2060
2080
2100
years

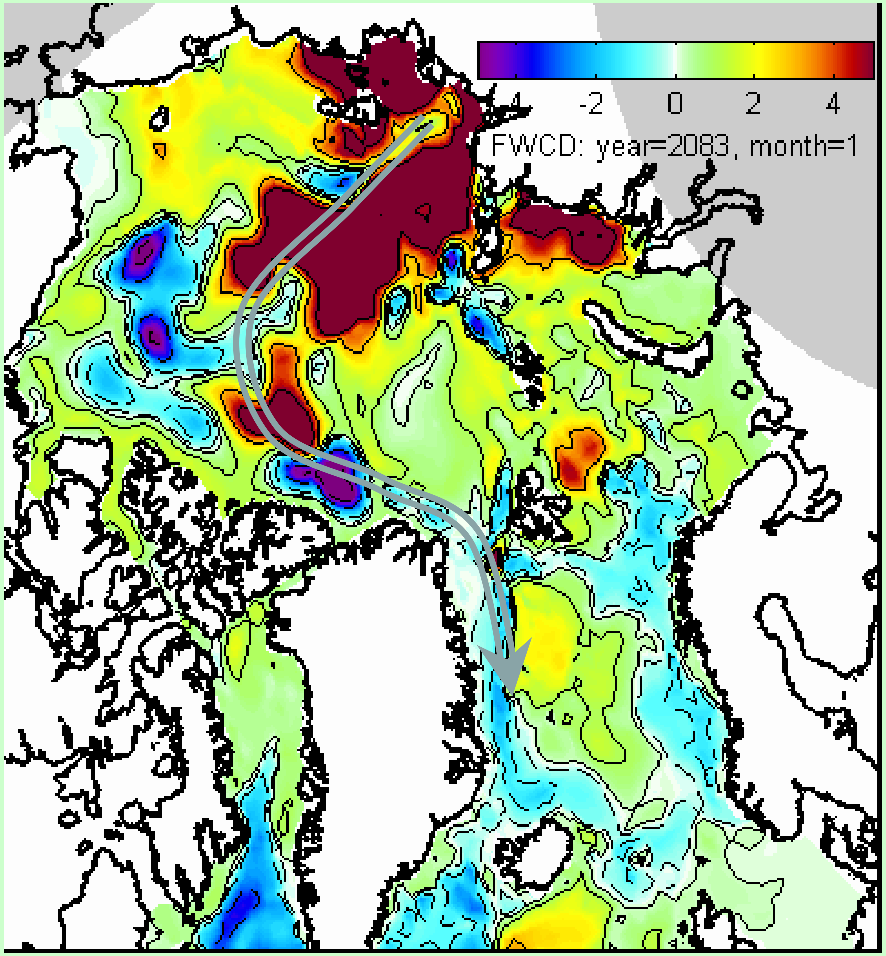

Excess of solid freshwater export to Atlantic
10^3km^3/year
0.1
0
−0.1
2000
2020
2040
2060
2080
2100
years

THE FRESH WATER EXCESS PROPAGATION IN THE ARCTIC OCEAN (2021 -2023, 2083 -2087)

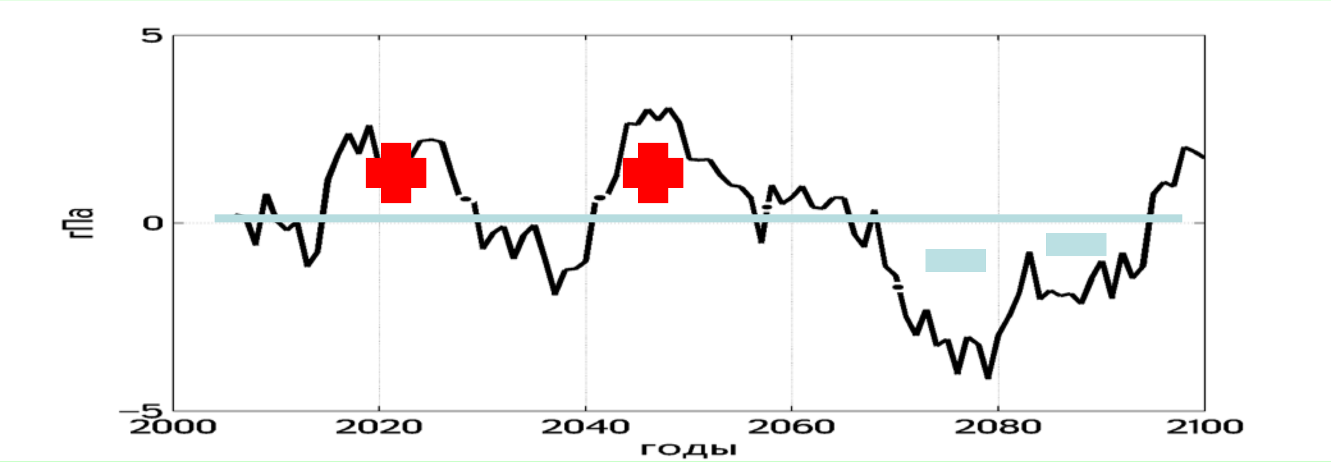
Fresh water excess propagation 2021 - 2025

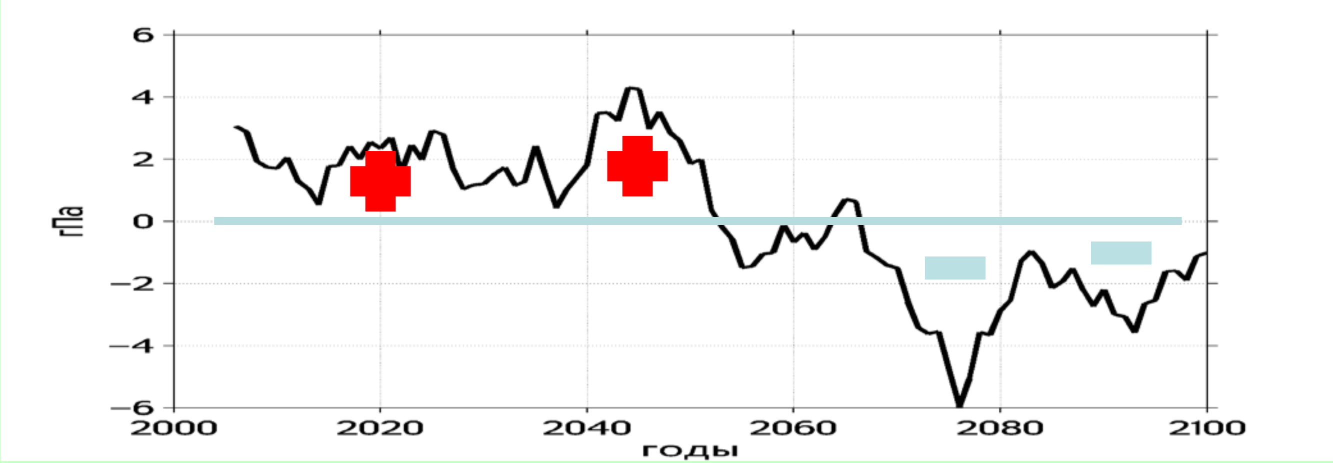


Fresh water excess propagation 2083 - 2087



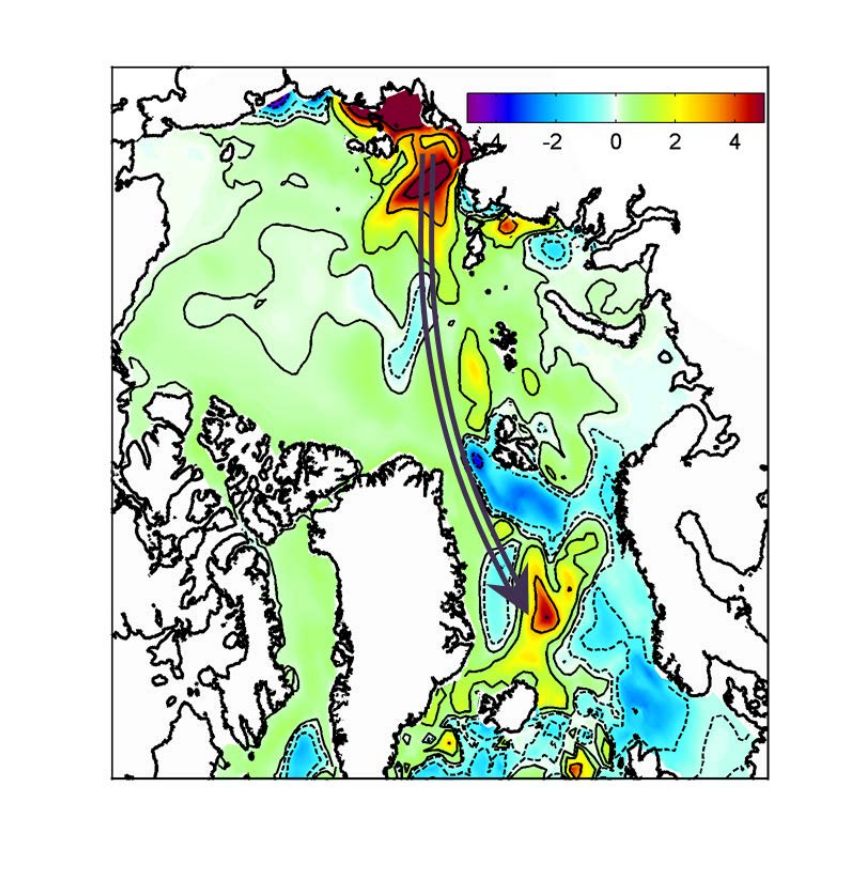
NAO и AO Indices

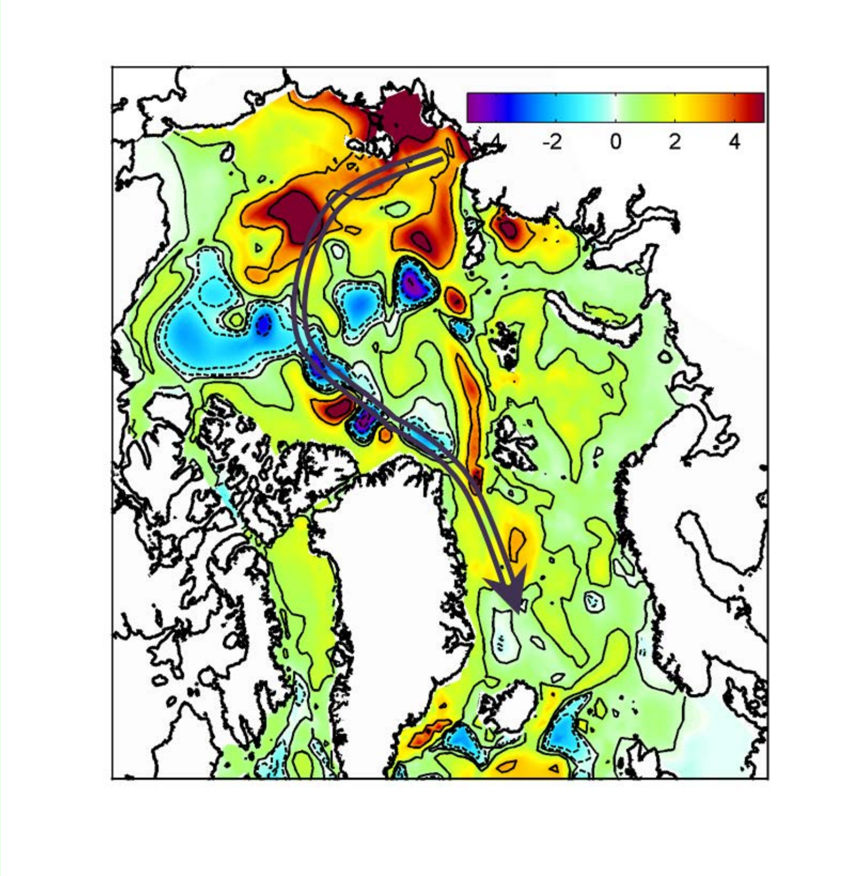




Two types of excess propagation

Positive NAO index (left) Negative NAO index (right)





Summary

- The role of the Siberian rivers in the global hydrological cycle is very important because of the essential fresh water input through the Arctic ocean to North Atlantic what control the thermohaline circulation in the World ocean.
- For estimation of the variations of the fresh water balance in the Arctic Ocean in the XXI century the hydrological discharge model and 3D Arctic - North Atlantic circulation model were used.
- Numerical simulation with the hydrological discharge model gives the positive trend of the Siberian rivers runoff for the XXI century in comparison with XX century
- Numerical simulation with a model of the Arctic Ocean shows:
- the use of the simulated Siberian rivers runoff gives more high fresh water content in the Arctic in comparison with the climatic runoff
- the different models may give quite different results of fresh water content in Arctic. So, it may be reasonable to use the ensemble approach with the use of the results of the series different models.
- the intensification of either cyclonic or anticyclonic components of motion of the nearsurface Arctic Ocean waters is determined by the signs of the NAO index. This leads to different pathways of the fresh water propagation in the Arctic what may induce the different condition of the Saline Anomalies formation in the North Atlantic.

Thanks for attention!