

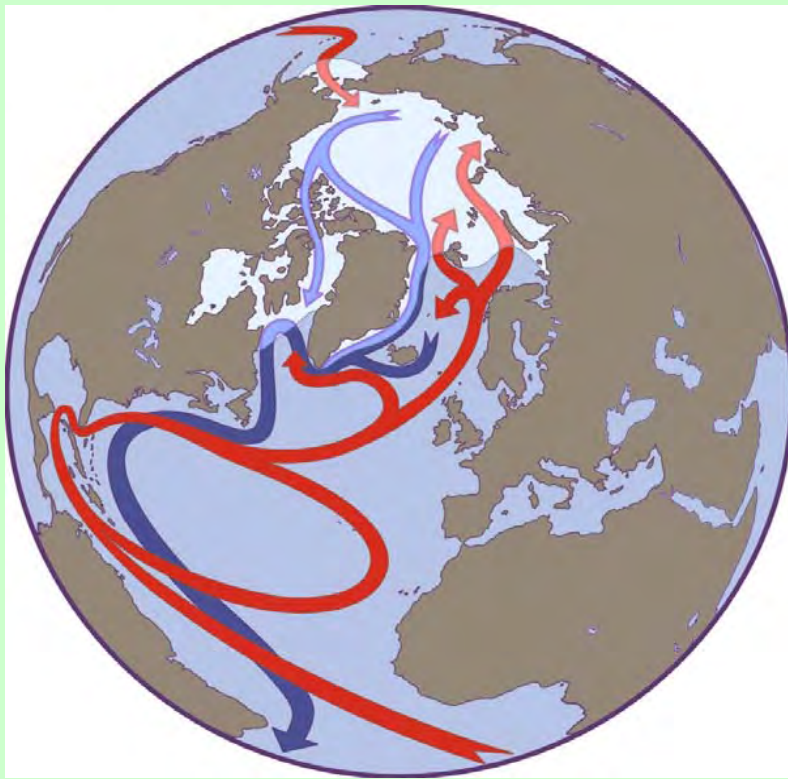


Influence of the Interannual Variations in Siberian Rivers Discharge on Redistribution of Freshwater in Arctic Ocean

Viktor Kuzin
Gennady Platov
Elena Golubeva

Institute of Computational Mathematics & Mathematical Geophysics,
RAS, Novosibirsk, Russian Federation

Email: kuzin@sscc.ru



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).

GOALS

- To reproduce basic pathways of the Siberian Rivers waters.
- To investigate the role of nonstationary Siberian Rivers discharge in controlling the fresh water distribution in the Arctic and North Atlantic

“CONVEUOR” BELT IN THE WORLD OCEAN

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

Arctic basin and the main rivers

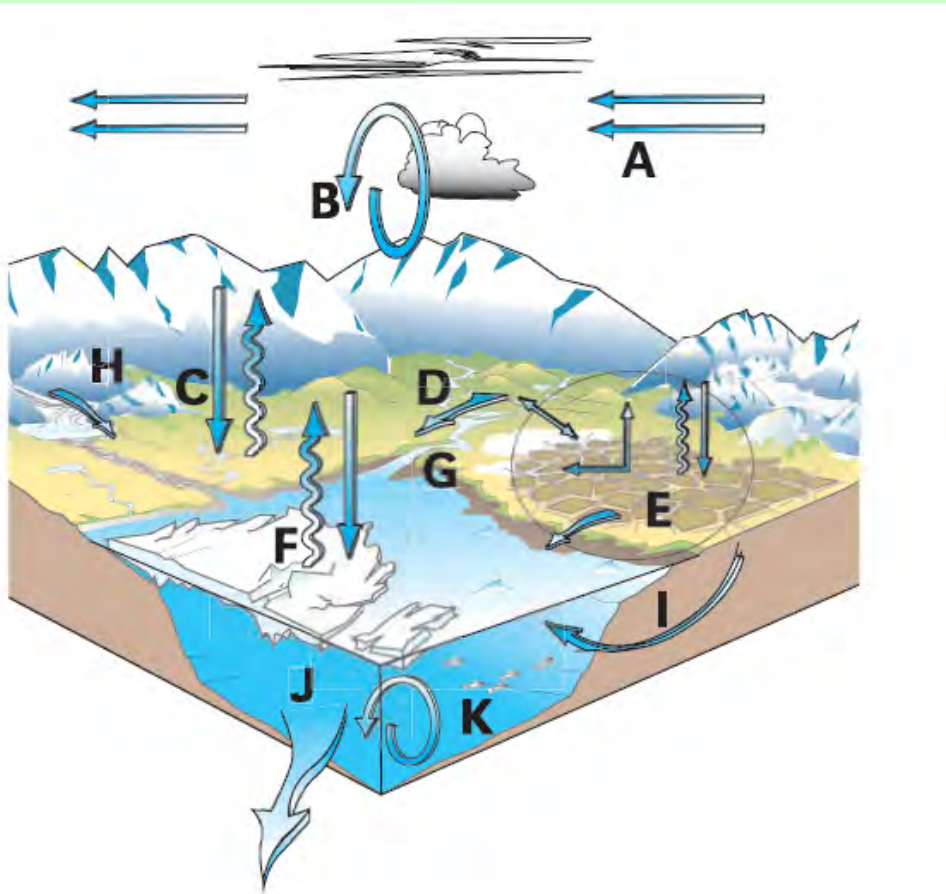


Arctic ocean forms 5% of total area of the World Ocean (14.4 mln. km², Ivanov, 1976) and 1% of its volume. However, it gives input 11% of total rivers water into the World Ocean (Kalinin, Shiklomanov, 1972).

Siberian rivers gives about 55% of the total volume, McKenzie - 5 %, the Bering strait gives about 40% with variability 25-30%.

Increasing trend $2.9+0.4$ km³/y (Agaard, Karmak, 1989, Sereze et al, 2006, Woodgate et al, 2006, Shiklomanov, 2010).

Conceptual model of the Arctic hydrological cycle, with key linkages among land, ocean, and atmosphere (Water System Analysis Group, Univ. of New Hampshire)



A = atmospheric boundary fluxes

B = atmospheric dynamics

C = land-surface atmosphere exchanges (with vegetation and permafrost dynamics)

D = discharge through well-defined flow networks (with groundwater and river channel flow)

E = runoff from poorly organized lowland flow systems

F = sea ice mass balance and dynamics

G = estuarine controls on terrestrial/shelf interactions

H = changes in glacial mass balance and associated runoff

I = direct groundwater discharge to ocean

J = Arctic Ocean dynamics and deep water formation

K = biological dynamics and oceanic food chains

The Fresh Water balance, variations and data uncertainties.

Total content about 80 th. km³

Input

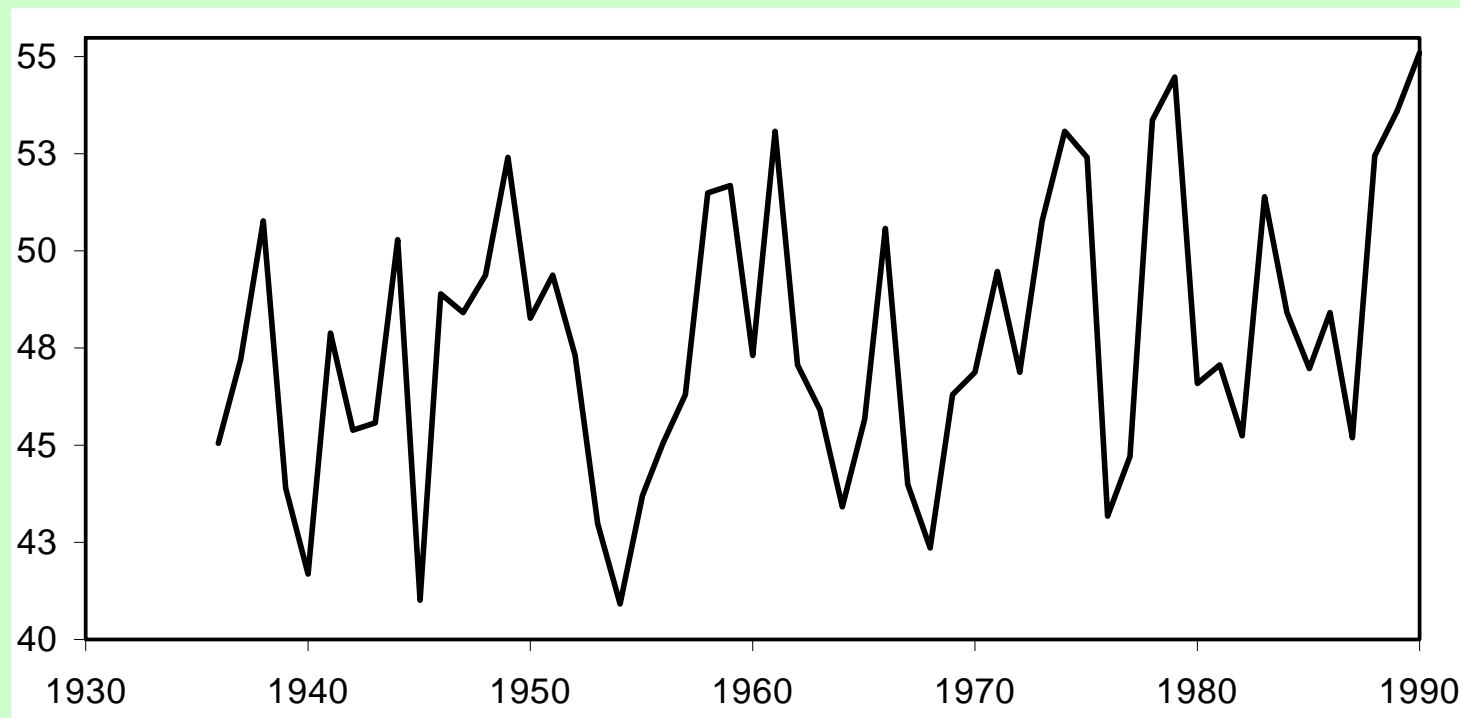
- **Precipitation - Evaporation - 900 km³/y** (uncet. in summer (10%) and in winter (80-120%), Yang et al 2005)
- **River runoff 3300 km³/y** (variations about 35%, increasing trend of $2.9 \pm 0.4 \text{ km}^3 \text{ a}^{-1}$ Shiklomanov, 2010)
- **Pacific waters - 1670 km³/y** (Bering Strait freshwater variability is ~ 25% of the total annual Arctic river run-off (Woodgate et al 2006))
- **Ice content appr. - 17300 km³/y** (variations not estimated).
- **Direct ground water discharge** – (not estimated)

Output

Though the Fram strait and the Canadian Archipelago - 2790 km³/y (variations not estimated)

MOTIVATION OF THE NUMERICAL EXPERIMENTS WITH INTERANNUAL RIVER RUNOFF VARIABILITY

The interannual variability of the runoff of the most significant Siberian rivers (Ob, Yenisei, and Lena) reaches 35%. In numerical experiments we compared simulations with the use of observational data against the results of climatic seasonal variations of their discharges.

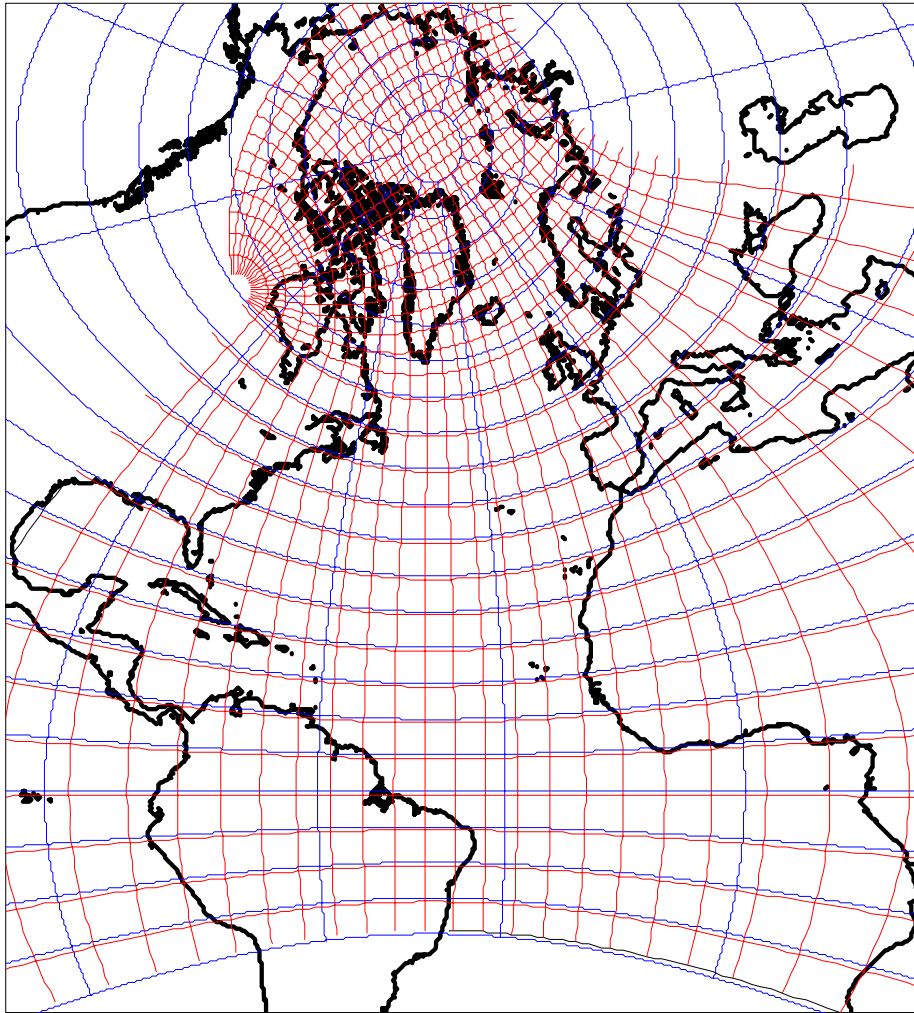


Total volume transport of Yenisei +Lena +Ob Rivers (th. cubic m/s)

Coupled Ice-Ocean Model

3D Ocean Circulation Model of ICM&MG

(based on splitting method with finite element approach)



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

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

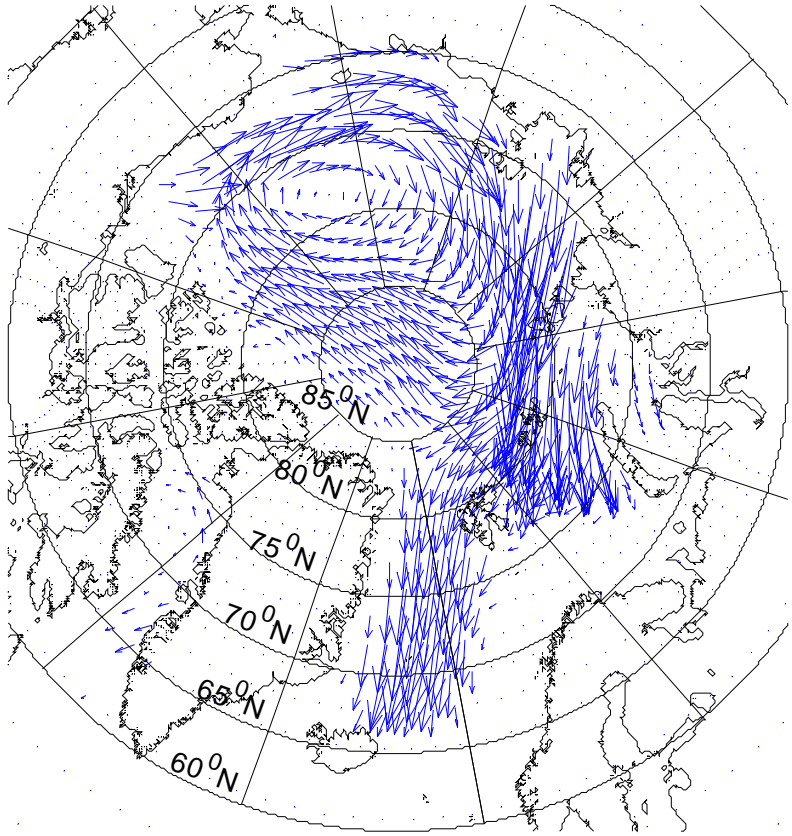
*W.D.Hibler [1979],
E.C.Hunke, J.K.Dukowicz [1997],
G.A.Maykut [1971],
C.M.Bitiz, W.H.Lipscomb [1999],
J.K.Dukowicz, J.R.Baumgardner [2000],
W.H.Lipscomb, E.C.Hunke [2004]*

Data

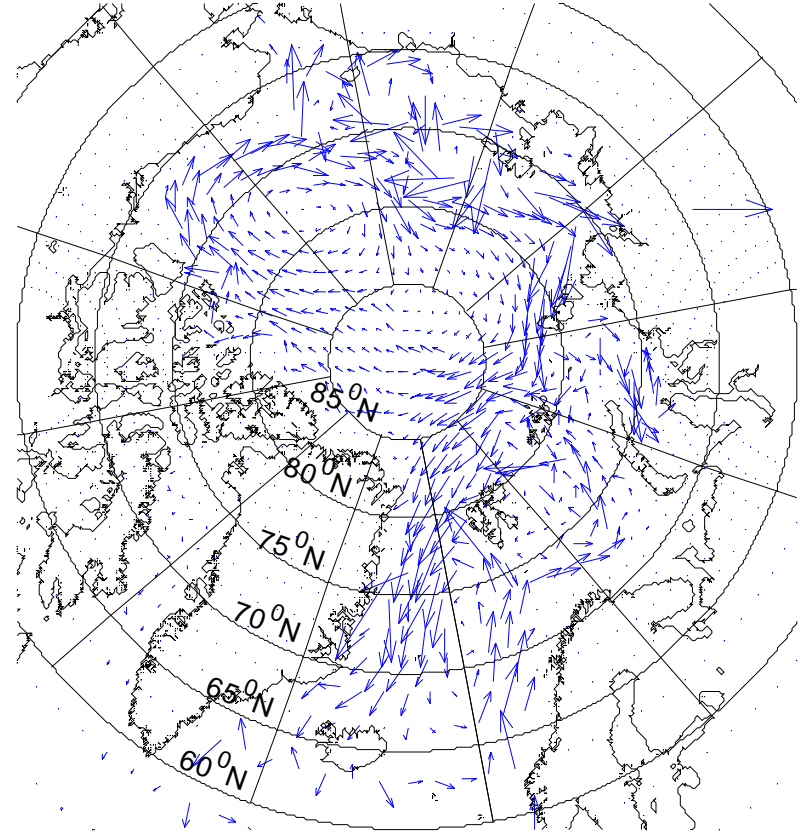
NSEP/NCAR reanalysis

Climatological and measured river
runoff

Arctic Ocean Model Circulation

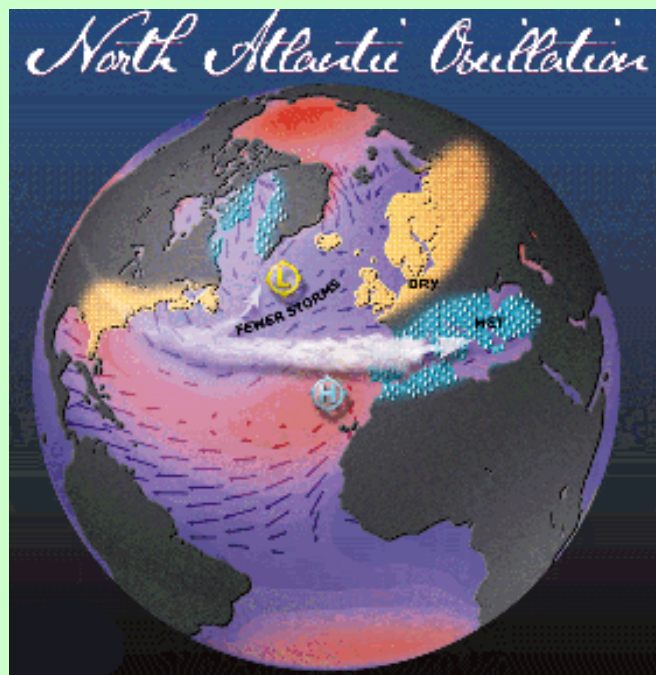
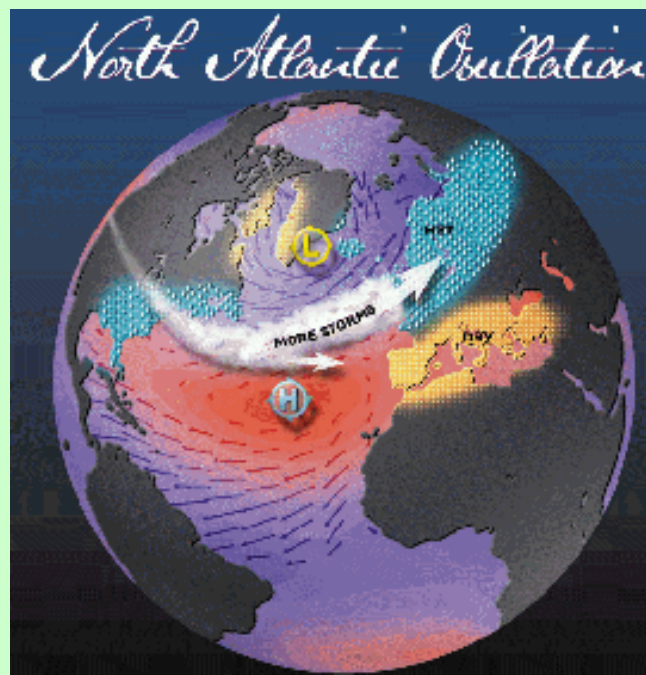


Ice

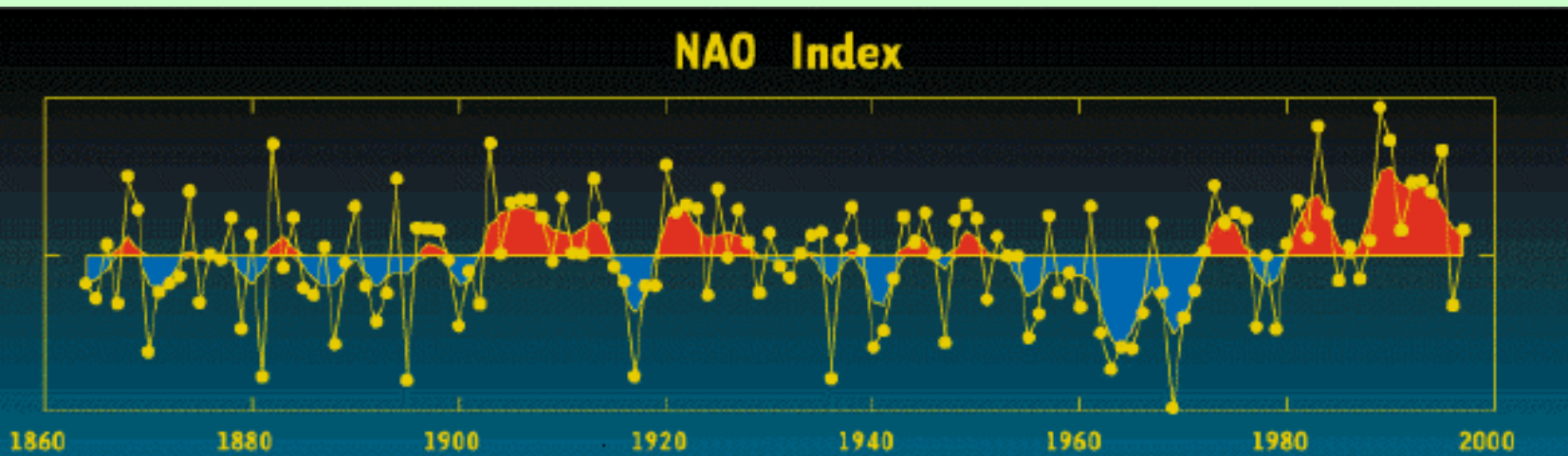


Water

The North Atlantic Oscillation (NAO) is the regional manifestation of the 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

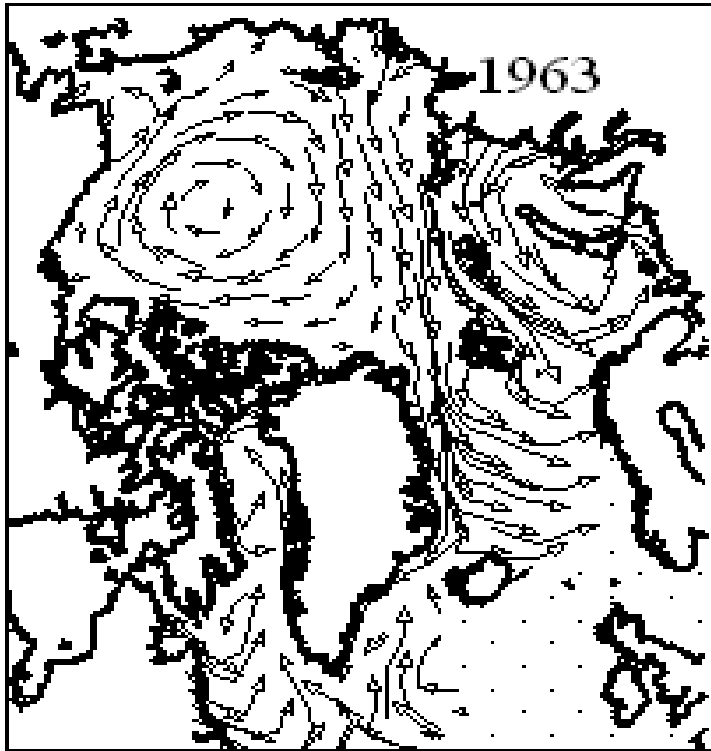


The positive/negative NAO phases are associated with enhanced/diminished Icelandic Low and Azores High.

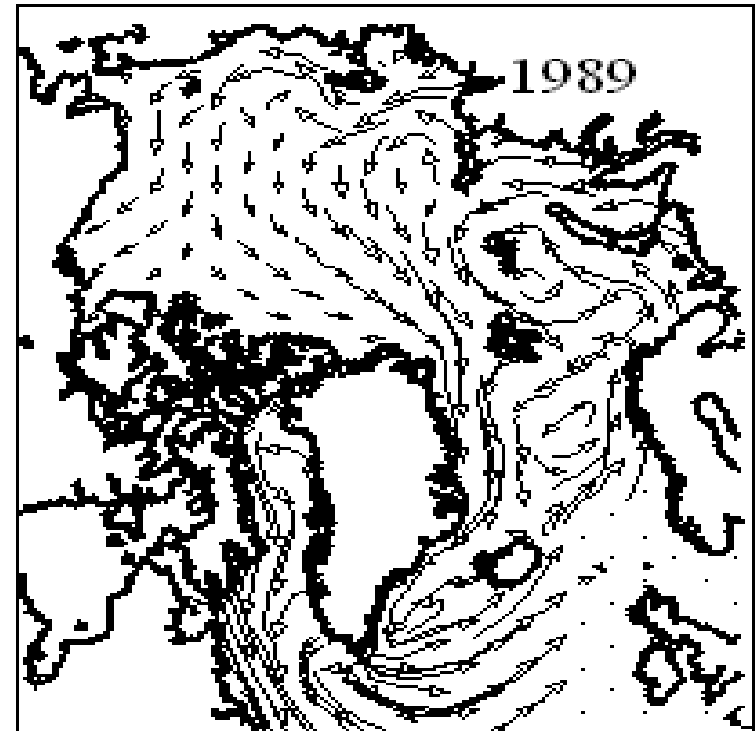


Two main modes of the Arctic Ocean circulation as the response to the NAO index variations

Negative NAO index –
anticyclonic mode



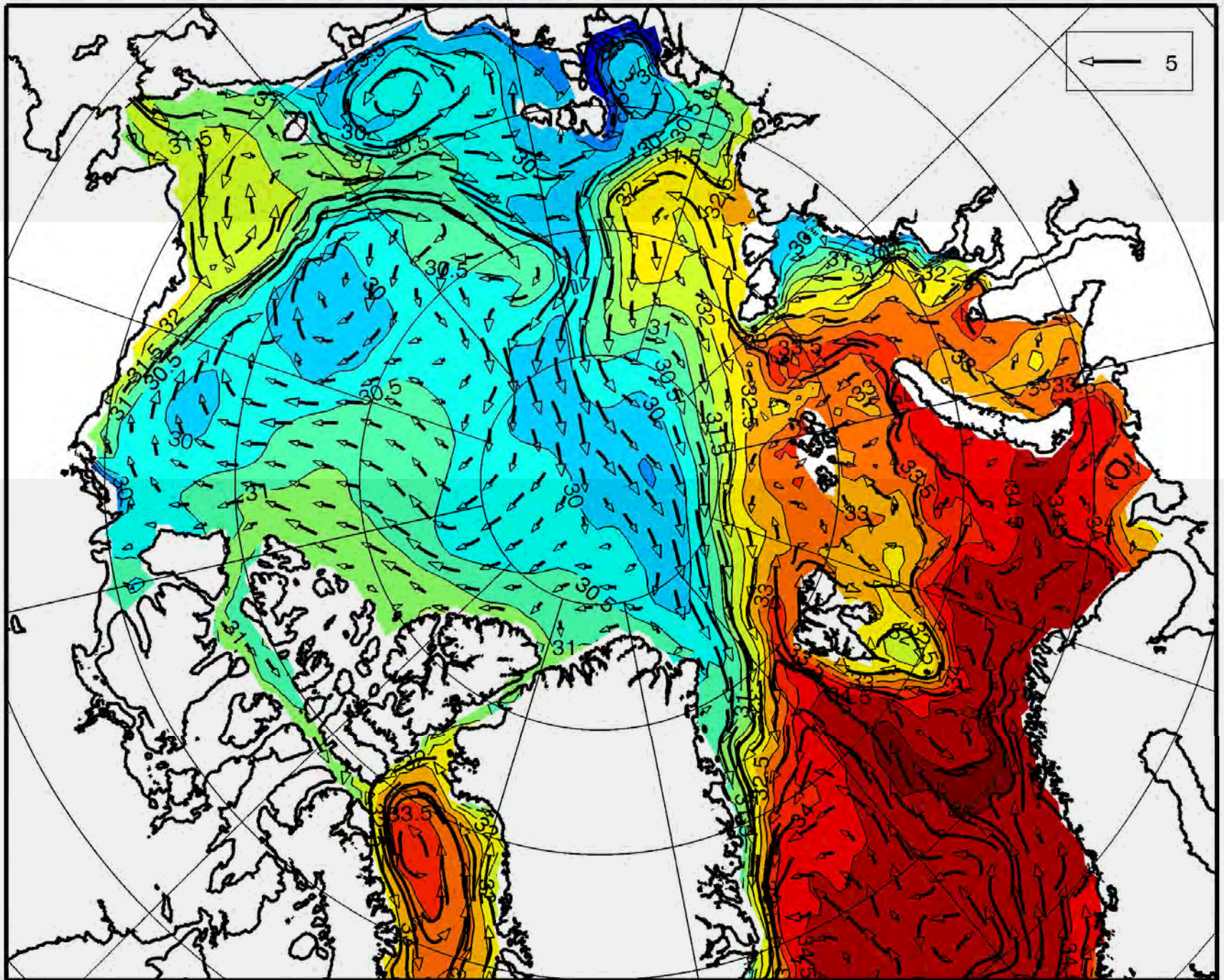
Positive NAO index –
cyclonic mode



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

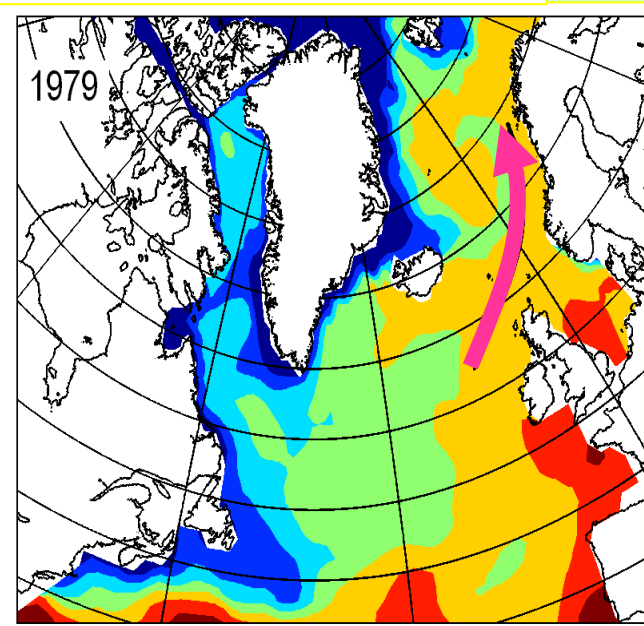
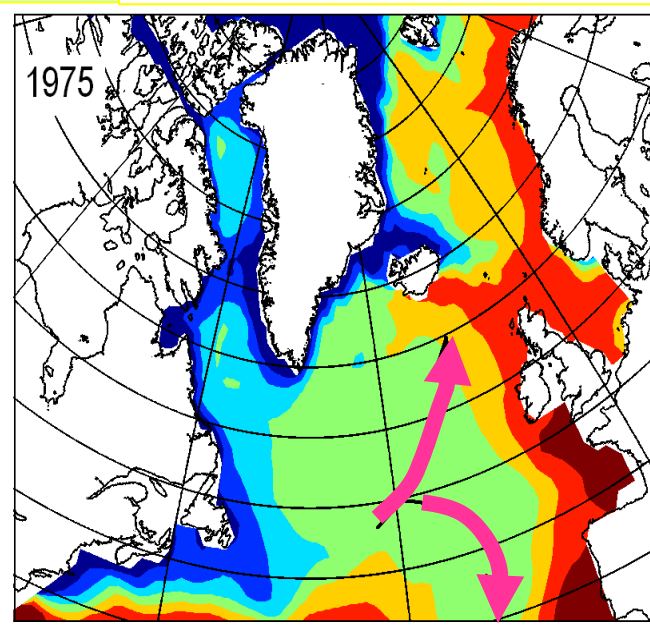
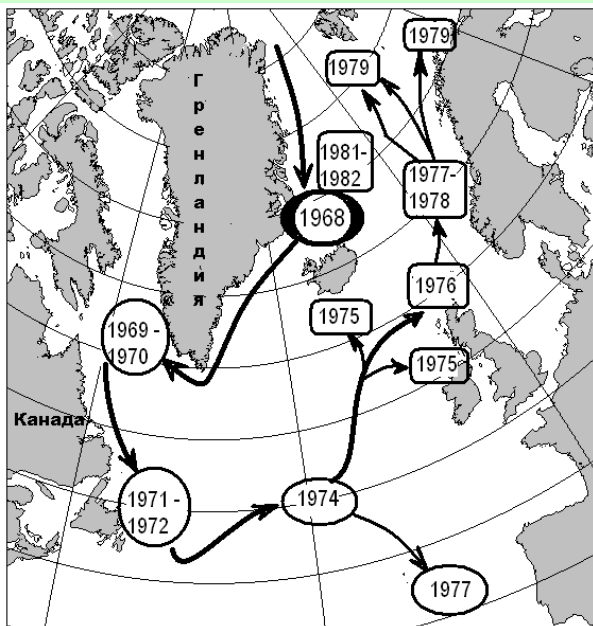
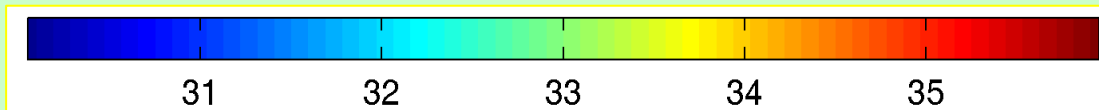
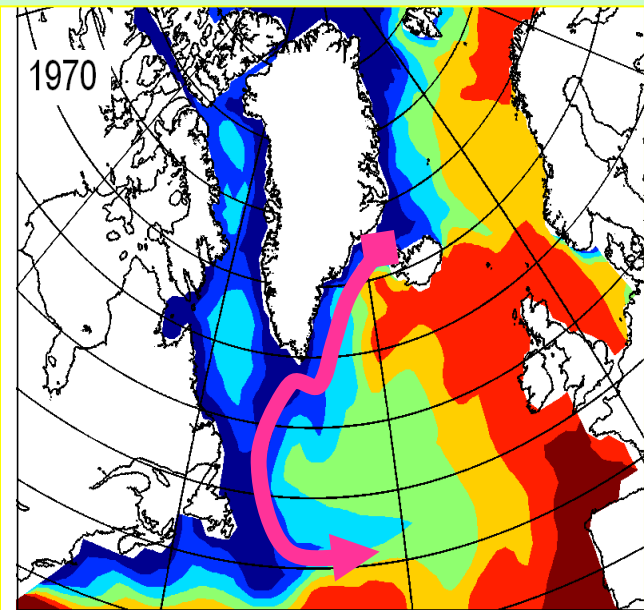
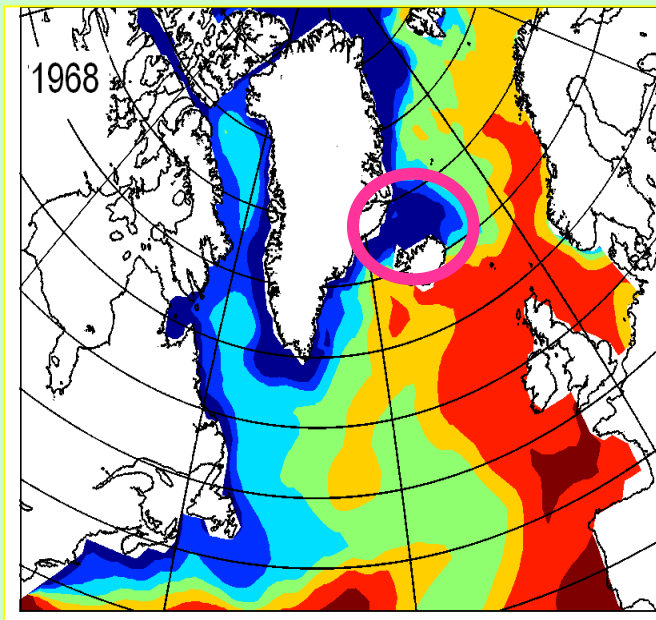
1967, 1968, 1981, 1984, 1989, 1993,
1995, 1997, 1999, 2000, 2002, 2003

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

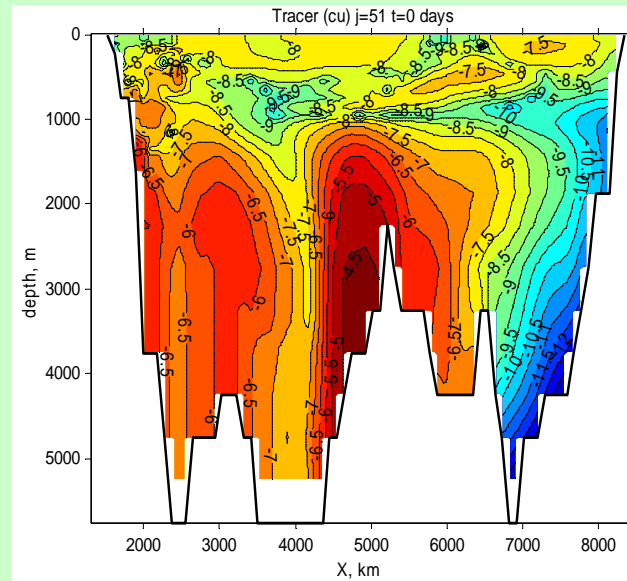
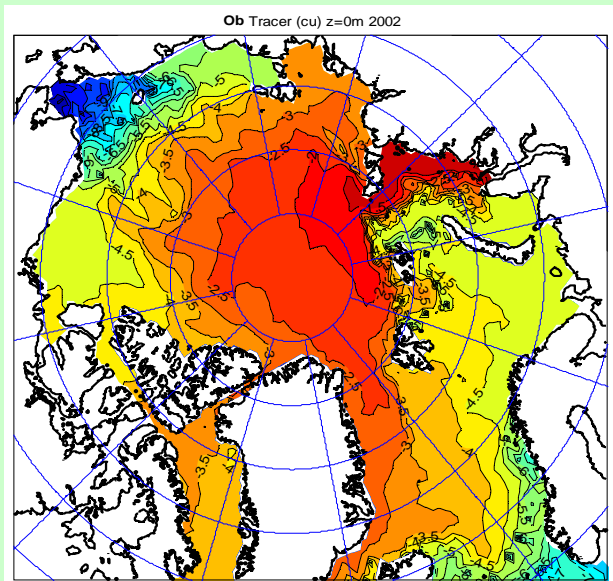
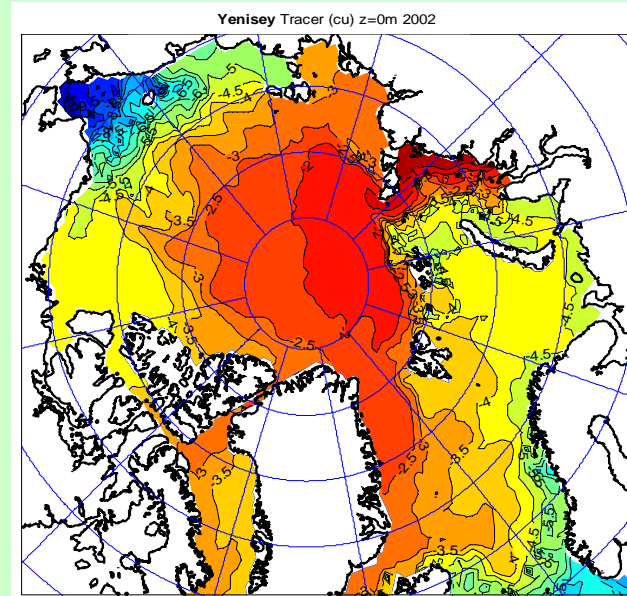
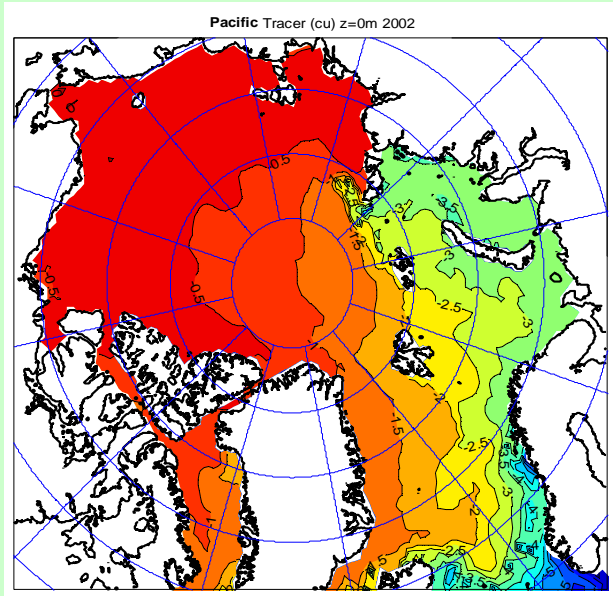


The pathway of the Great Salinity Anomaly in 1968-1979 according to model results

The pathway of the Great Salinity Anomaly in 1968-1982 according to Raymond W. Schmitt (<http://www.whoi.edu/oceanus>)



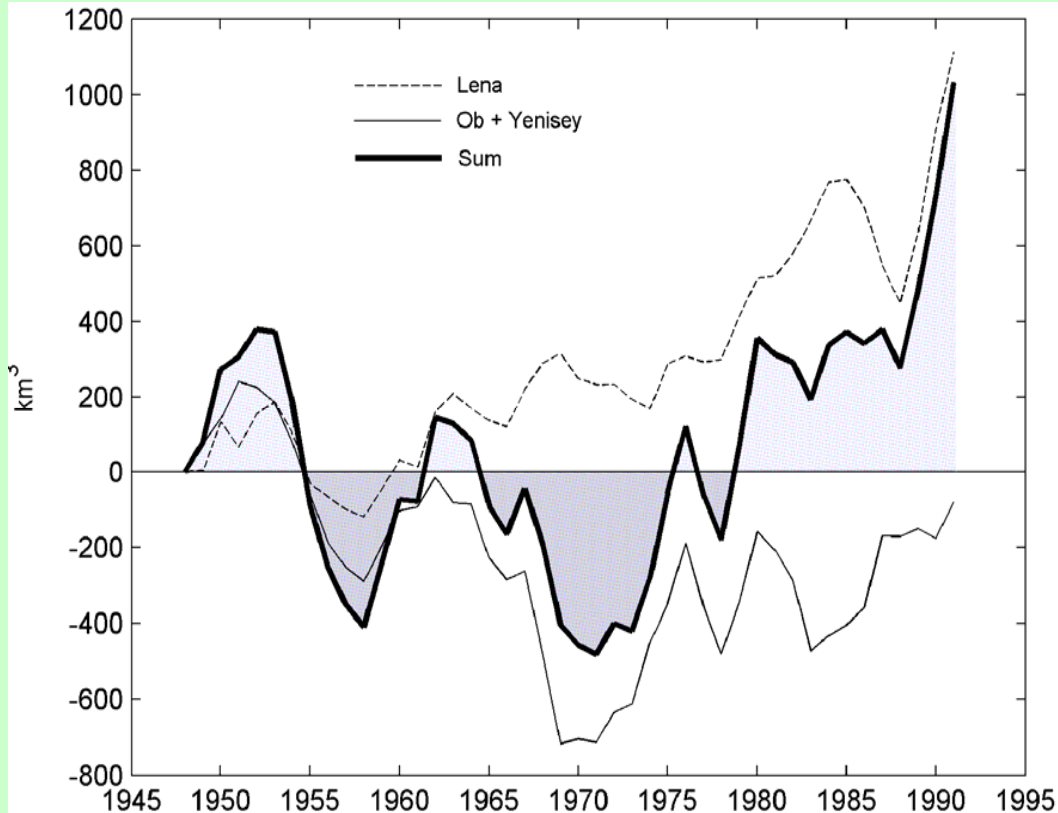
Transport of the freshwater after 37 years of the emission beginning (1966) :



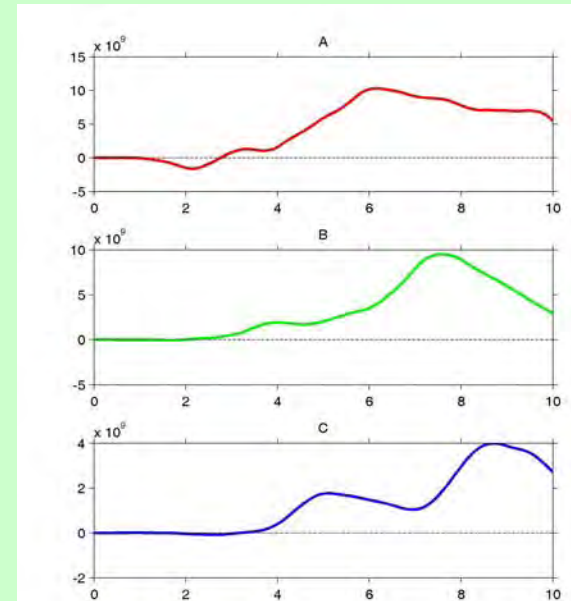
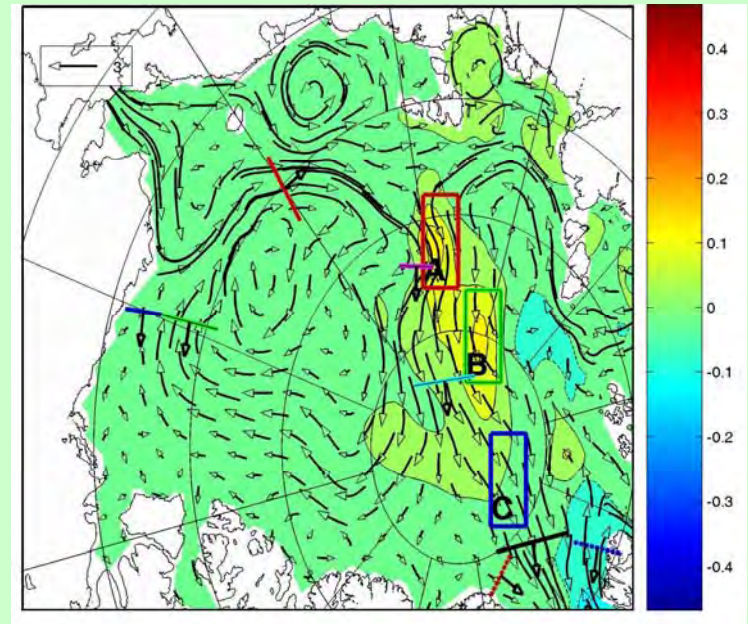
Pacific water from Bering strait (upper left);
Yenisei river water (upper right);
Ob river water (low left);

The vertical cross-section of the concentration of the Ob river freshwater through the latitude 30 N (low right) (the West is in the right)

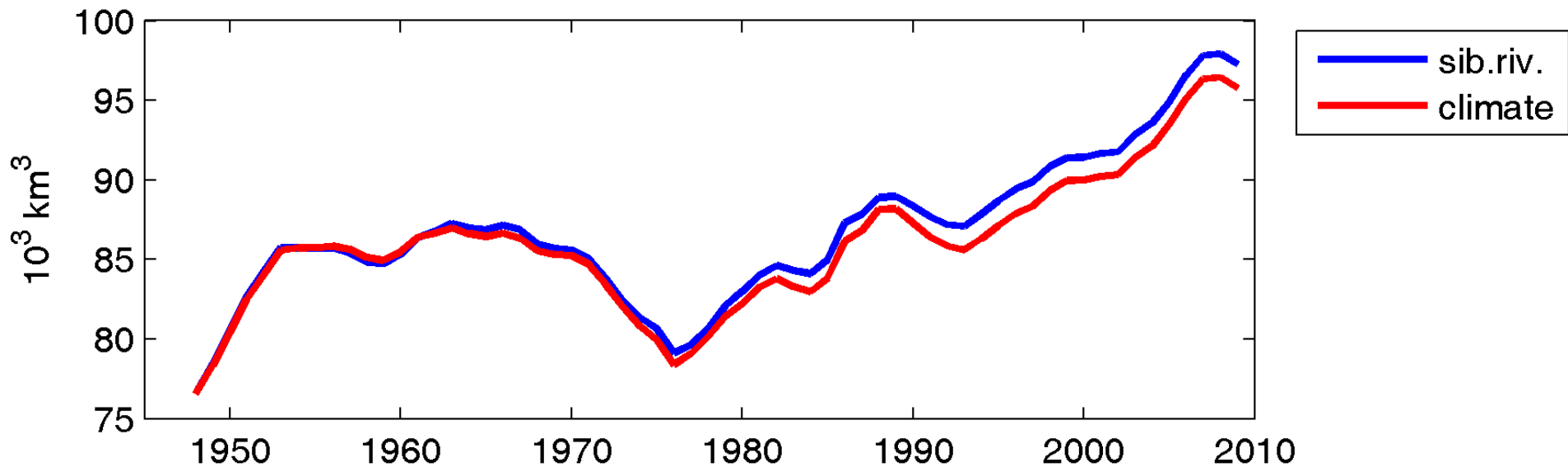
Interannual variability of the Siberian rivers discharge. Difference in the volumes between the observed and climatic discharges of Siberian rivers accumulated since 1948.



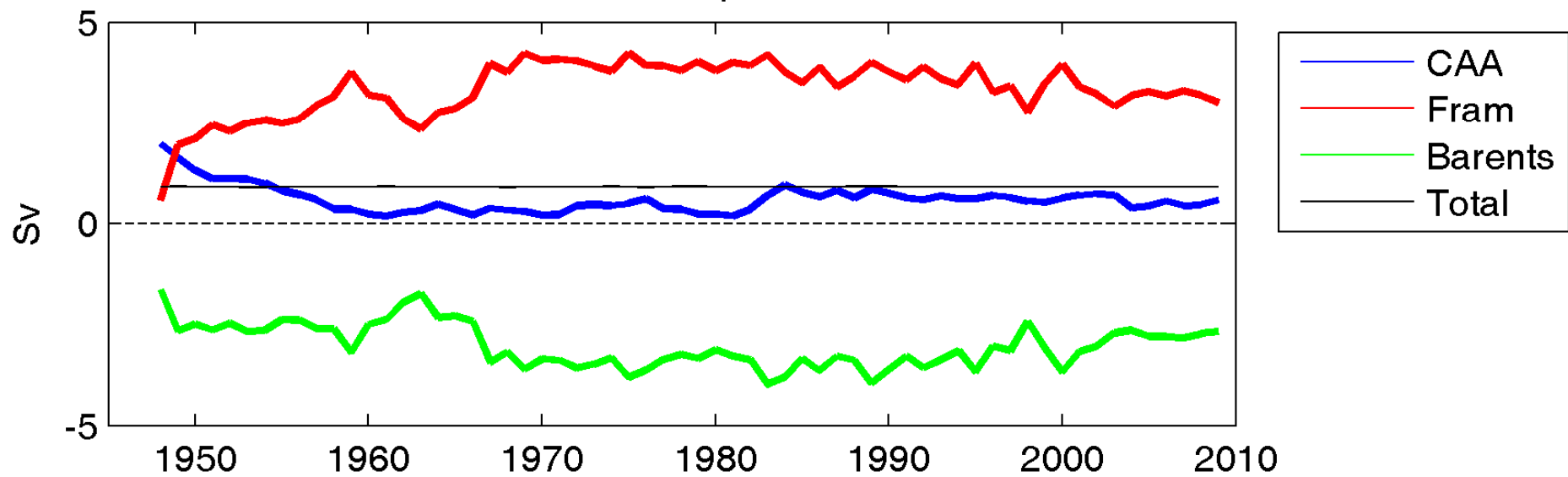
Movement of the positive anomaly of the fresh water since 1958.

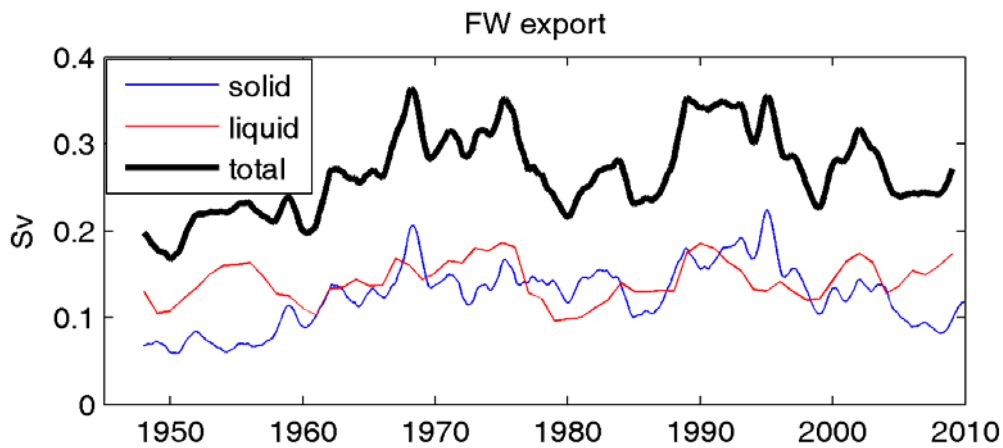


Arctic FW volume

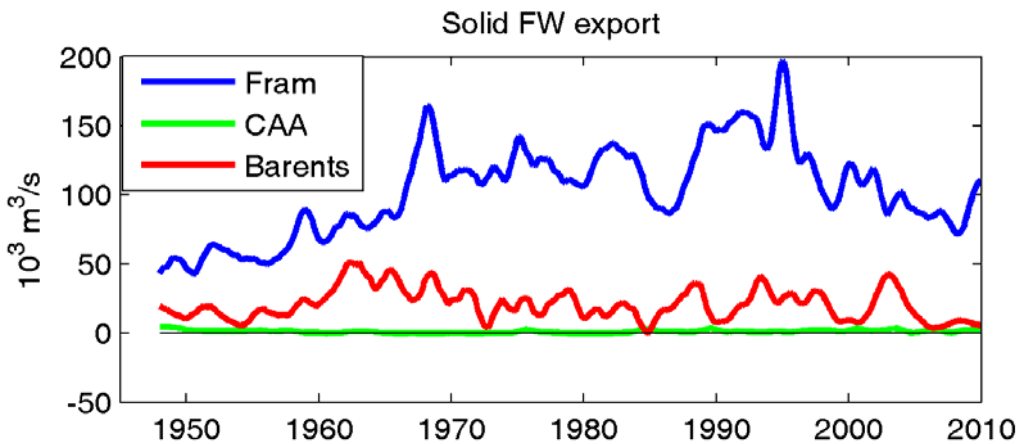


Strait transports

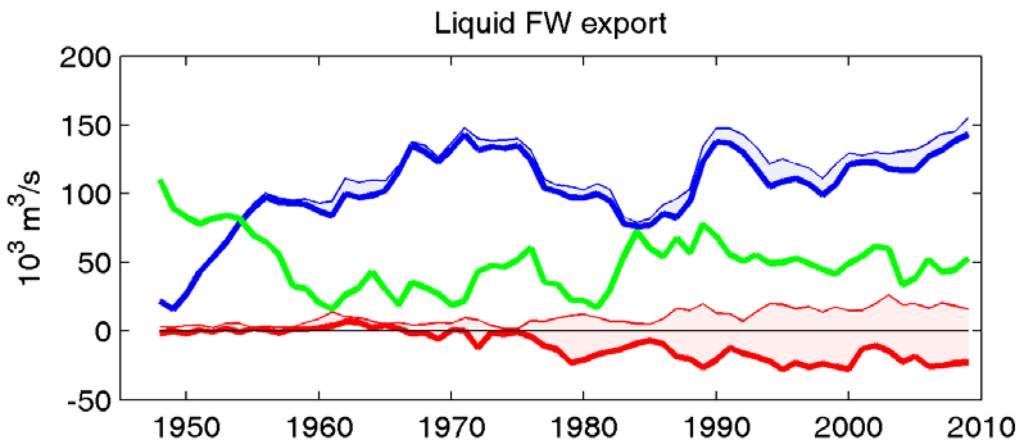




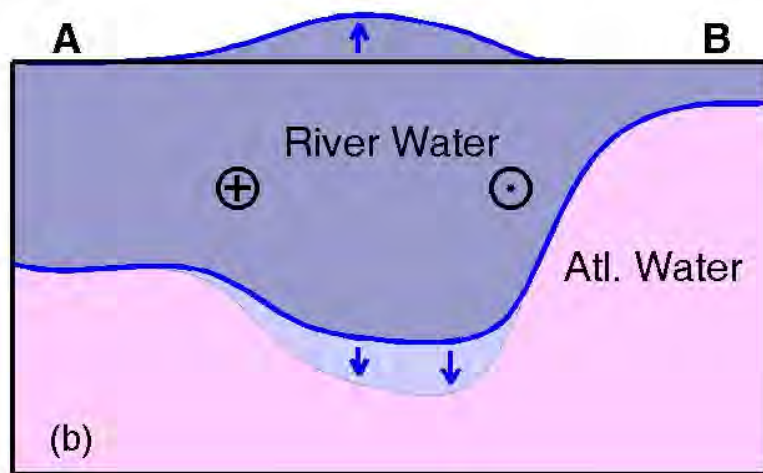
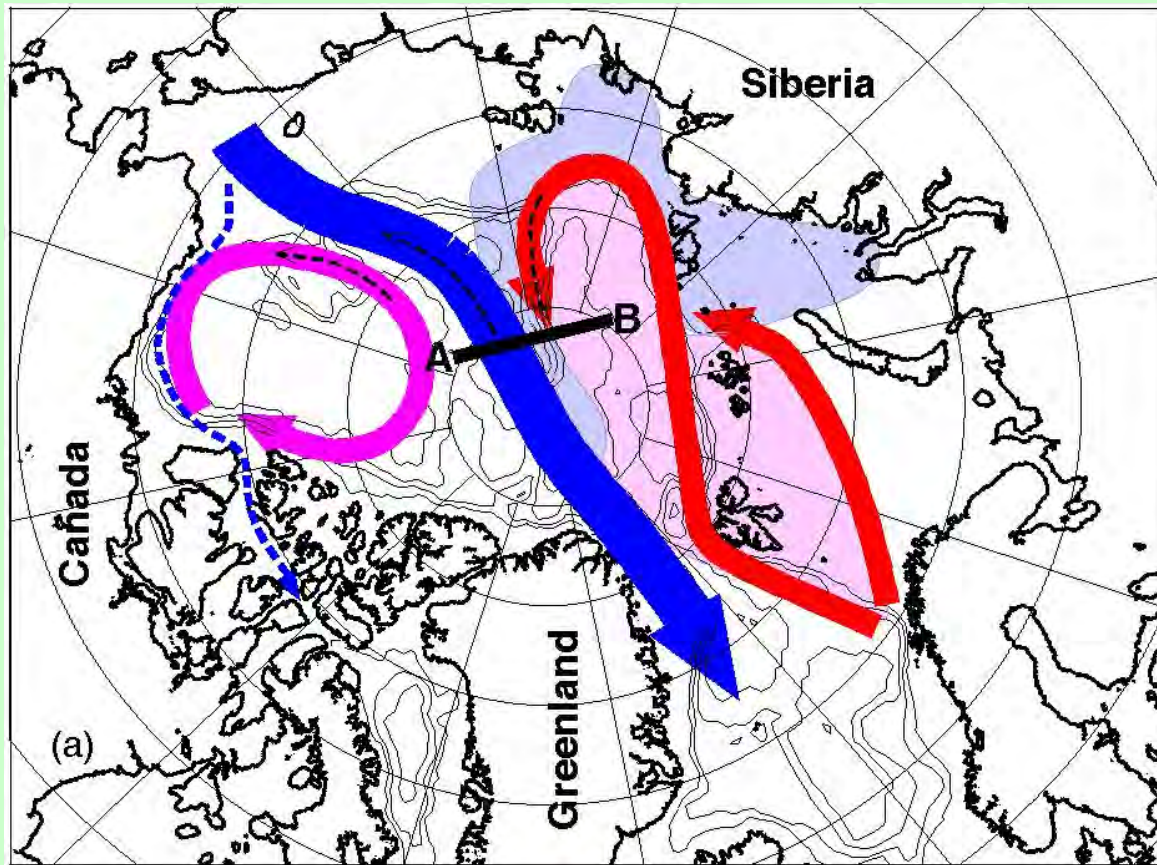
(a) Arctic freshwater transport to North Atlantic: red line - liquid FW export, blue line – FW export in solid state, bold line - total;



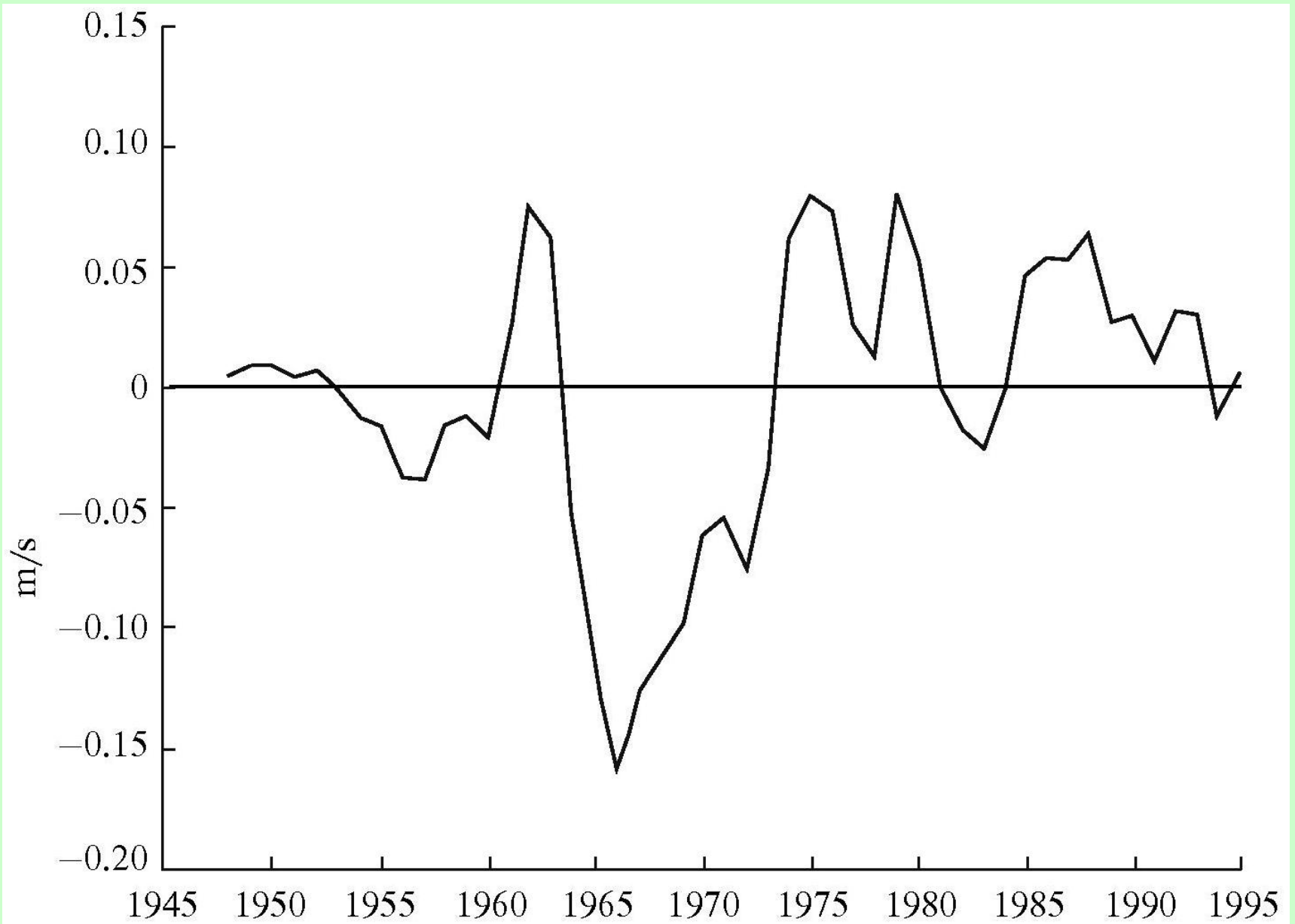
(b) export of freshwater in solid state through the straits;



(c) transport of liquid Arctic freshwater through the straits.



Scheme of regional subsurface circulation and changes made by fresh river waters. (a): Wide arrow line across the basin is Transpolar Drift Current (TDC), on its right - Atlantic water current, on its left - Beaufort Gyre. Line AB shows the section position presented on (b): vertical section across TDC. When FW volume grows, pressure gradient in subsurface layer increases also and makes the additional anticyclonic circulation (thin dashed arrows on (a)), thus the Atlantic water current and TDC weaken in subsurface layer and the water fluxes redistributed from the Fram strait to the Canadian Archipelago straits.

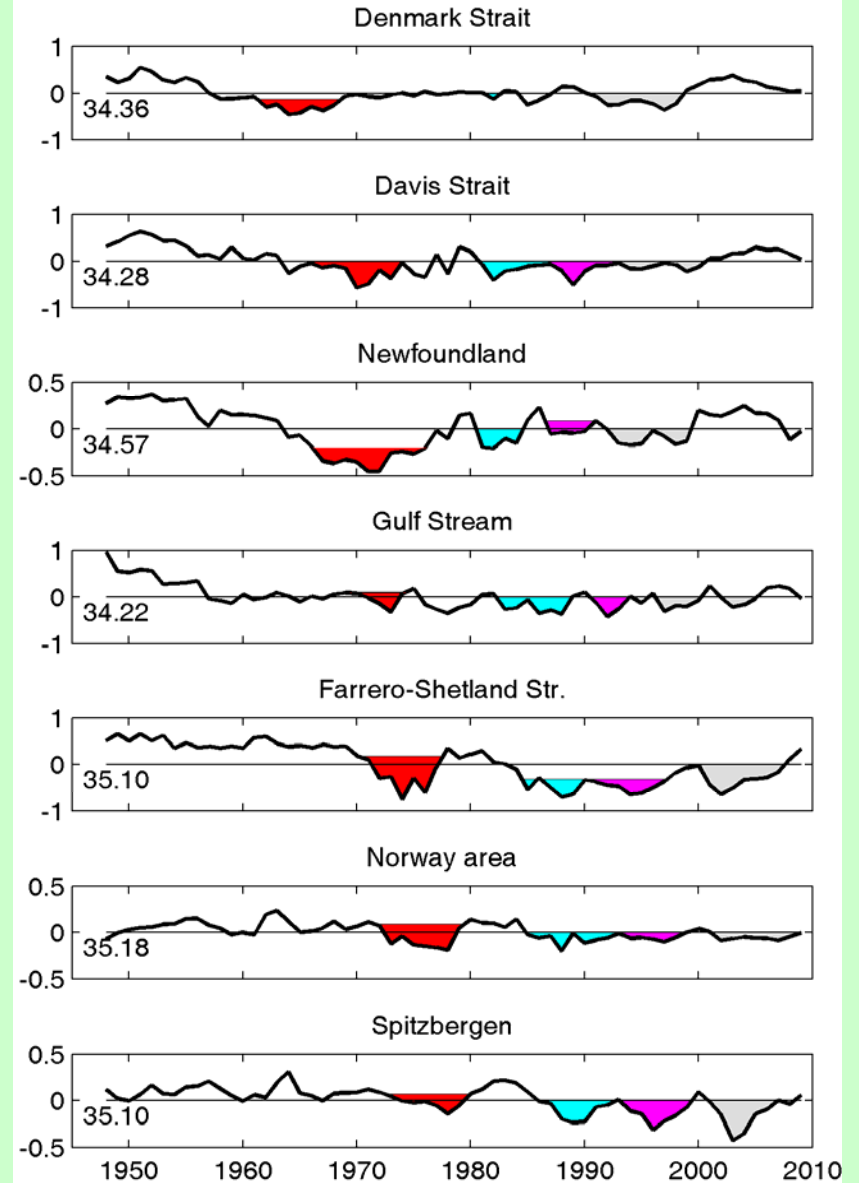
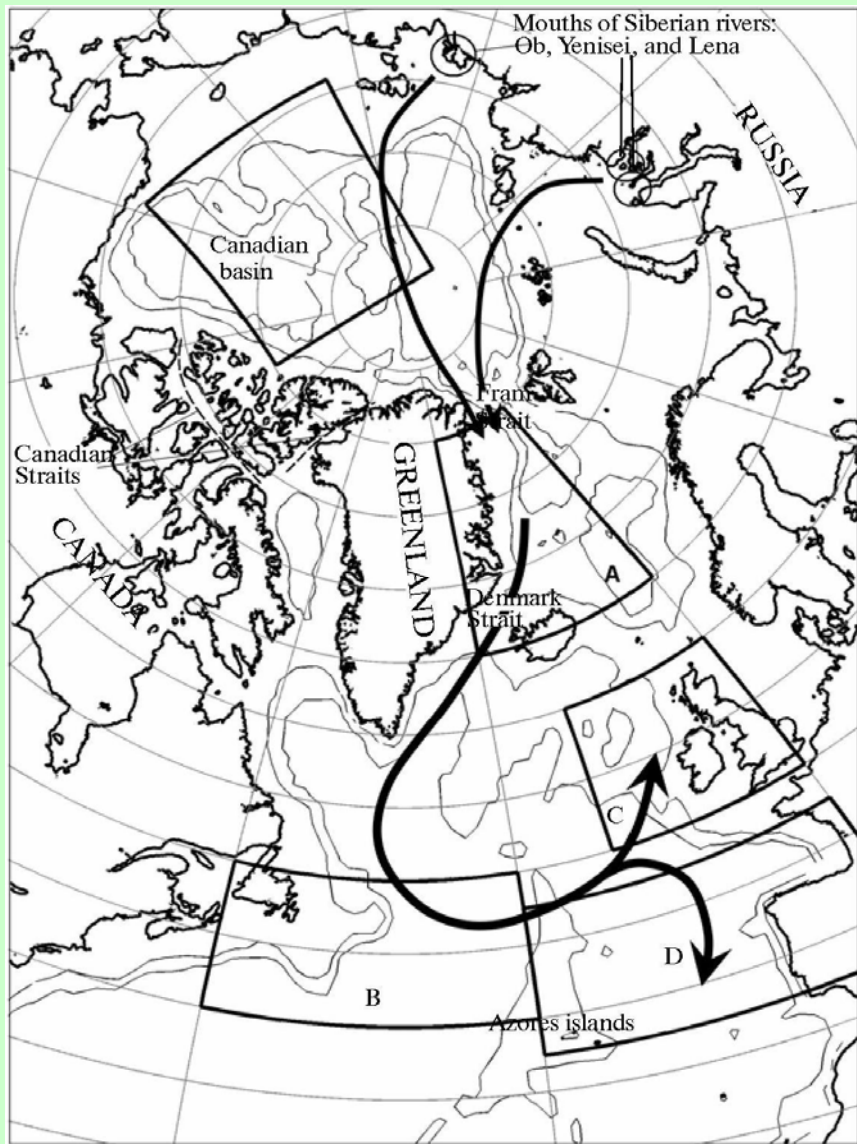


Difference in the circulation of the velocity current at a depth of 100 m between two experiments around the Canadian basin, represented in terms of the average velocity directed along the contour counterclockwise.

Redistribution of the water fluxes in consequence of FW content

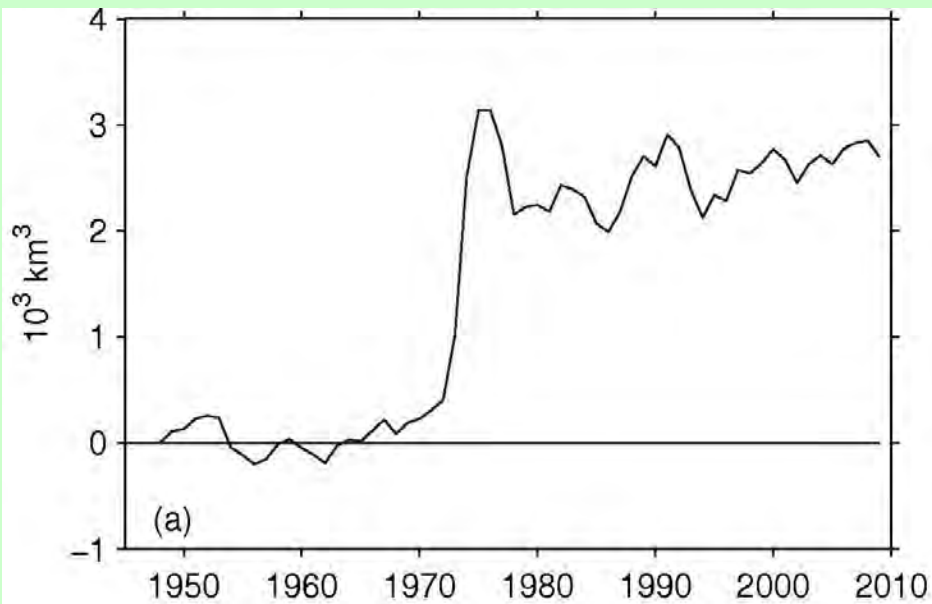
Coefficients of correlation of accumulated river discharge with the total loss through the main straits, as well as loss of freshwater through these straits. (1) - correlation coefficient at the maximum level with respect to the significance level, (2) – time lag prior to the maximum response (in years) to the river discharge anomaly.

Straits	1	2
Total loss through the straits		
Fram Strait	-0,78	4
Canadian Archipelago	0,59 (0,71)	0 (12)
Barents Sea	0,74	4
Freshwater discharge		
Fram Strait	-0,75	6
Canadian Archipelago	0,57 (0,71)	0 (12)
Barents Sea	0,40	7

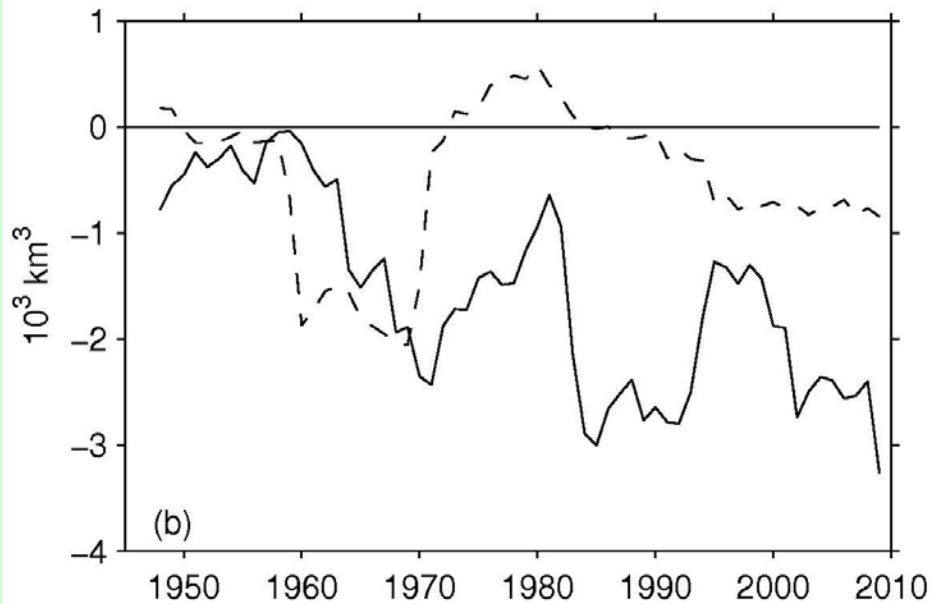


Arrows in the Arctic Ocean schematically show the trajectory of the positive anomaly of the river discharge in 1958-1965. Bold arrows in the North Atlantic show the approximate pathway of the GSA 1968-1979. The anomaly increases due to the variability of the observed river discharges.

Salinity anomalies propagation through the straits



(a) Difference between FWC volumes calculated for the entire simulation domain including Arctic and north of 20° S Atlantic;



(b) Volume of water annually involved into vertical mixing due to stratification or dynamic instability for FWC anomalies in 1965 in Greenland Sea (dashed line) and in 1975 near the Azores Islands (solid line).

SUMMARY

Arctic Ocean play the key role in the global hydrological cycle as well as in the formation of the thermohaline conditions of the World Ocean.

A numerical simulation with a coupled sea-ice model is used to study the influence of the fresh water distribution from the Siberian rivers on the propagation of fresh water in this region.

The interannual variations of the main Siberian rivers discharge may have significant consequences.

These consequences include:

(1) the intensification of either cyclonic or anticyclonic components of motion of the nearsurface Arctic Ocean waters and, as a result, the redistribution of freshwater fluxes from Arctic region between the Fram Strait and the Canadian Archipelago straits.

(2) changes in the Siberian rivers freshwater input to the Arctic Ocean influence to the process of their motion in the North Atlantic.

Thanks for attention!

