Simulation of the Pacific and Siberian Rivers waters propagation to the Arctic-North Atlantic

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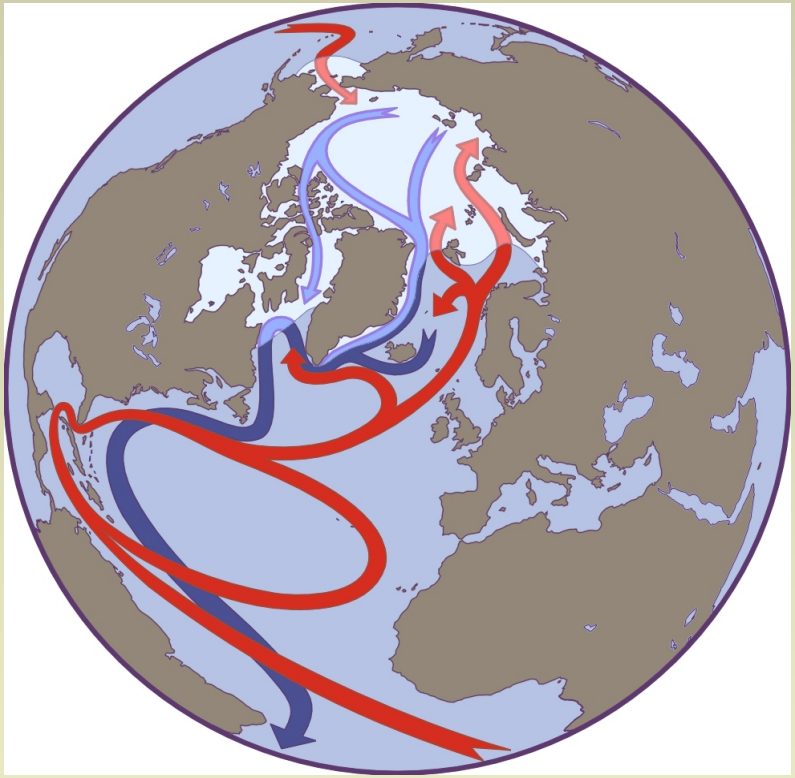
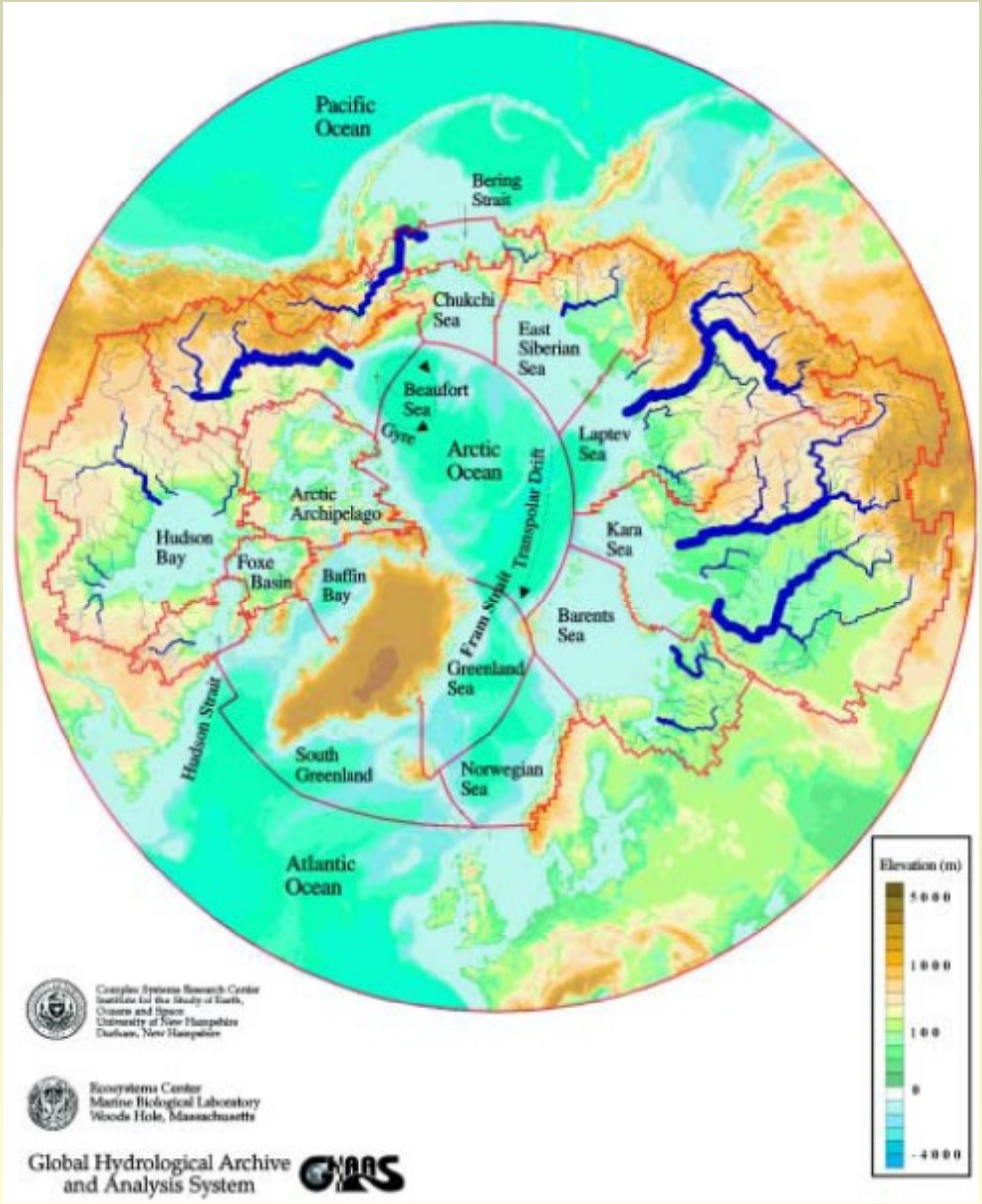


A schematic drawing of North Atlantic and Arctic Ocean circulation.
Red arrows represent relatively warm water from lower latitudes entering the Arctic, while blue arrows represent the export of colder water from the Arctic. Shaded white shows the average area covered by sea ice.
(Figure courtesy of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

GOALS

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

Arctic basin and the main rivers



Arctic ocean form 5% of total area of the World ocean and 1.5% of its volume. However it gives input 10% of total fresh water into the World Ocean. Siberian rivers gives about 55% of the total volume, McKenzy - 5 %, the Bering strait gives about 40%.

Coupled Ice-Ocean Model
3D Ocean Circulation Model of ICMMG based on z-level vertical coordinate approach

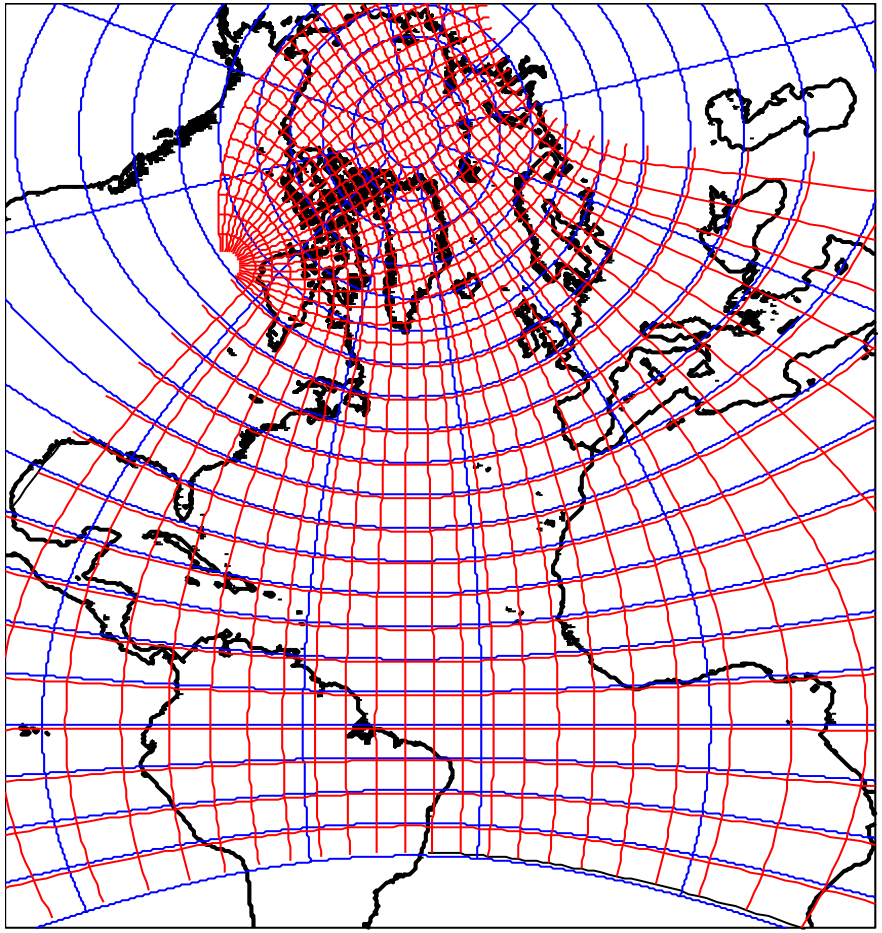
(Kuzin [1985], Golubeva at al.,[1992], Golubeva,[2008], Golubeva and Platov,[2007])

- Conservation laws for heat, salt and momentum with Boussinesq, hydrostatic and 'rigid lid' approximations
- Separation of the external and internal mode in momentum equations
- Barotropic momentum equations are expressed in term of stream function
- QUICKEST (Leonard,[1992]) is used in the latest model version for the T-S advection.
- Two versions of mixed layer parameterization:
  - Vertical adjustment based on the Richardson number
  - Vertical diffusion coefficient based on the stable solution of turbulent energy equation

Ice model-CICE 3.14 (elastic-viscous-plastic)

W.D.Hibler ,1979, E.C.Hunke, J.K.Dukowicz,1997, C.M.Bitz, W.H.Lipscomb 1999, W.H.Lipscomb, E.C.Hunke 2004

Arctic – North Atlantic model domain



The model configuration.

Grid has 1x1 degree resolution in the North Atlantic. At 65N, the North Atlantic spherical coordinate grid is merged with the polar reprojective grid (*Murray, [1996]*).

The horizontal spacing in the polar grid varies from 50 to 34 km.

Vertically, the grid has 33 constant layers, with a higher resolution near the surface.

The minimum shelf depth is 50 m.

Fresh water income

In the Bering Strait, an open boundary is introduced with a prescribed transport of 0.8 Sv, or alternatively according to Woodgate et al [2000].

The river run-off transport is prescribed for Ob, Yenisei and Lena rivers from the observations 1936-1990.

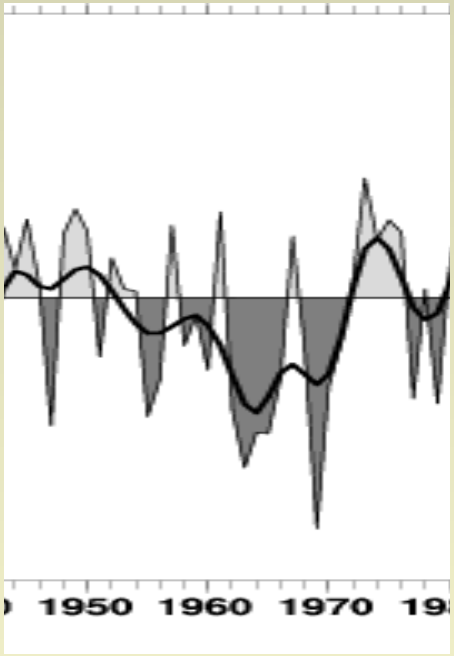
T,S data are used for all incoming flows and free-following condition for outcoming flow.

Data sources

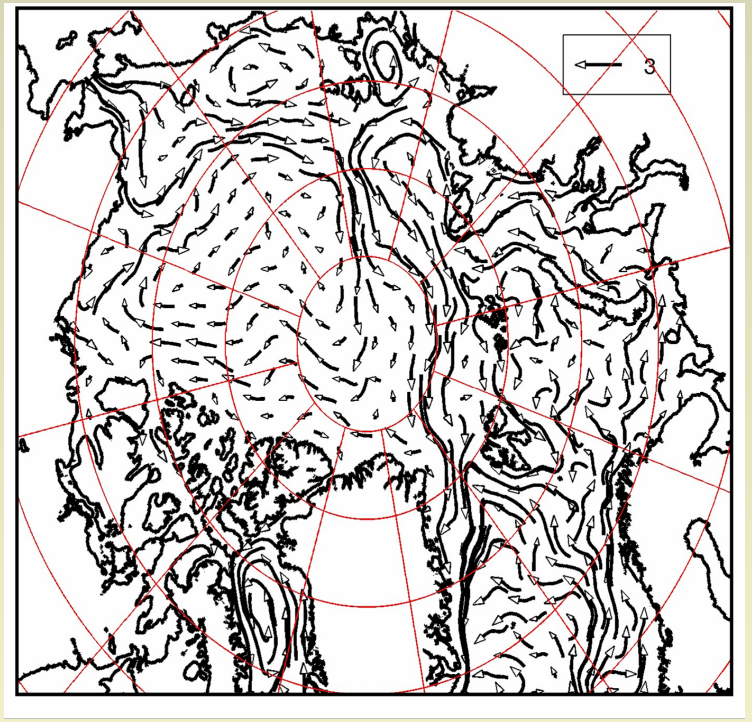
- Reanalysis NCEP/NCAR data for the Arctic region
- The data of Trenberth et al. for the North Atlantic
- Ob, Yenisei, Lena monthly river runoff from the measurements 1936-1990.
- Climatic inflow through the Bering strait and the Siberian rivers from AOMIP data

Pacific Water in the Arctic Ocean

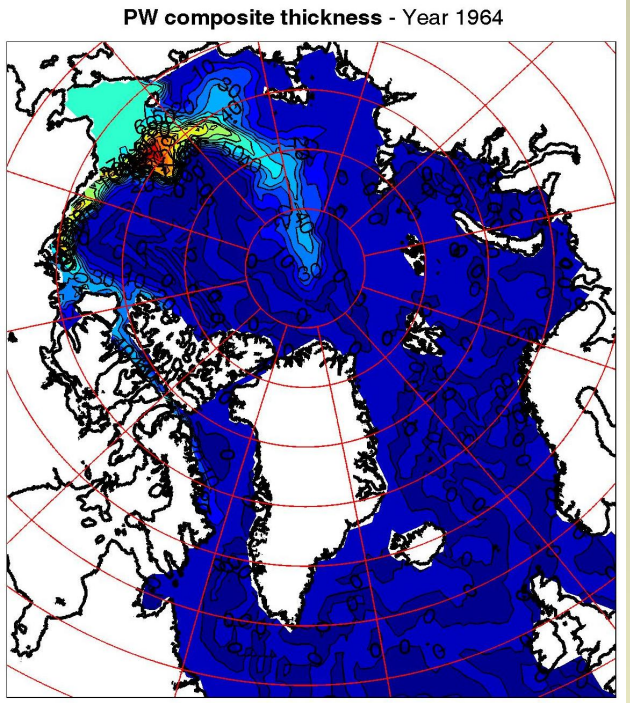
NAO index

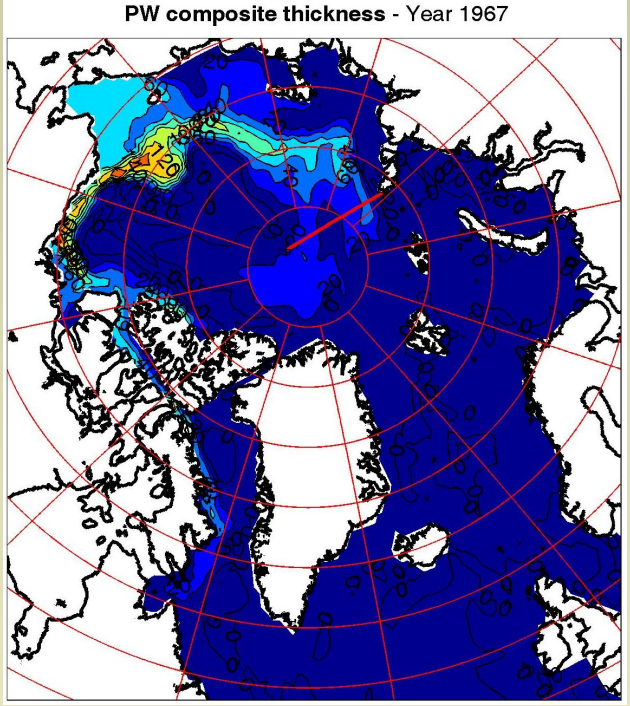


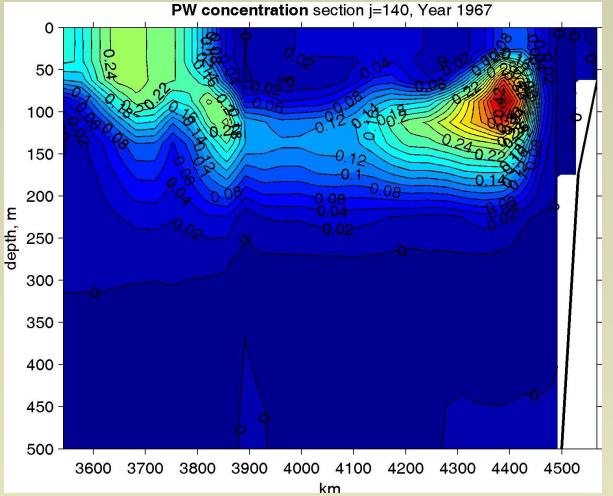
Surface currents

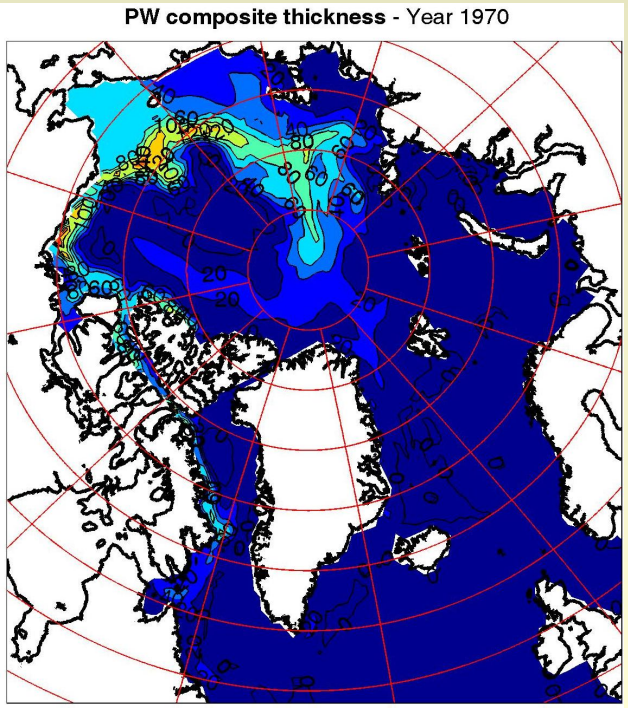


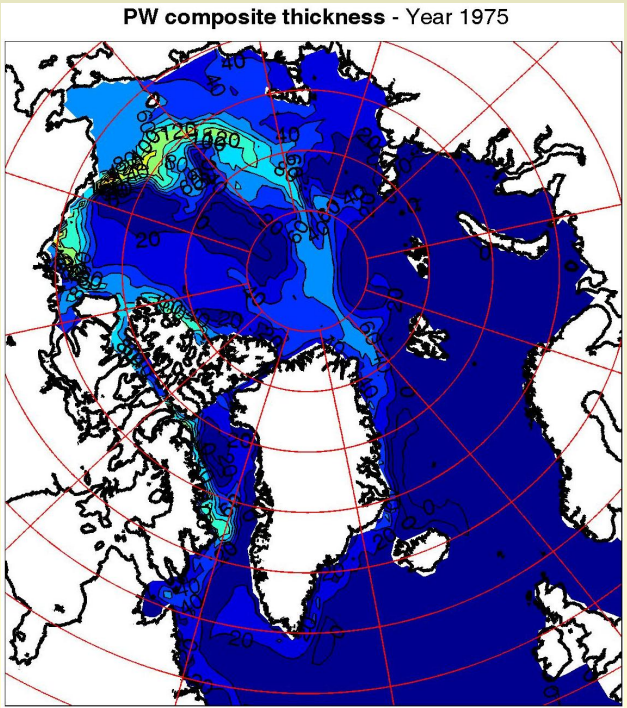
Warm period occurs during the negative NAO phase. According to the circulation pattern fresh water spreads anticyclonically in the surface layer in the region of the AW path. It strengthens stratification and reserves heat in the Atlantic layer.







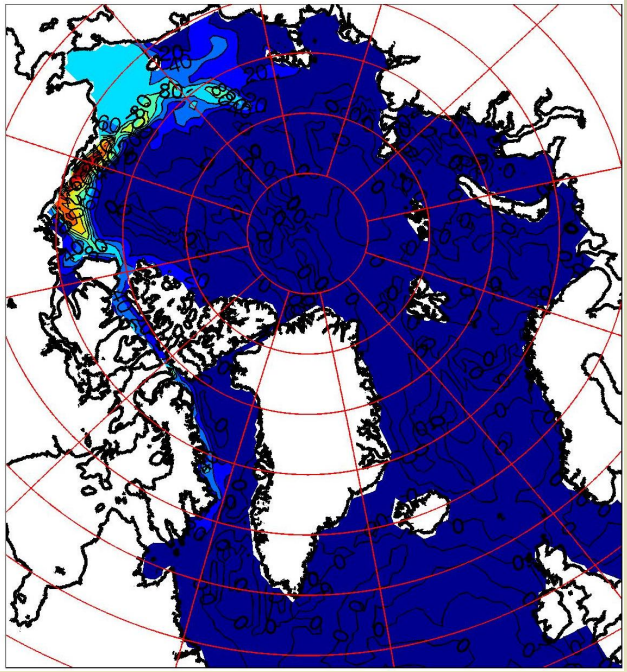




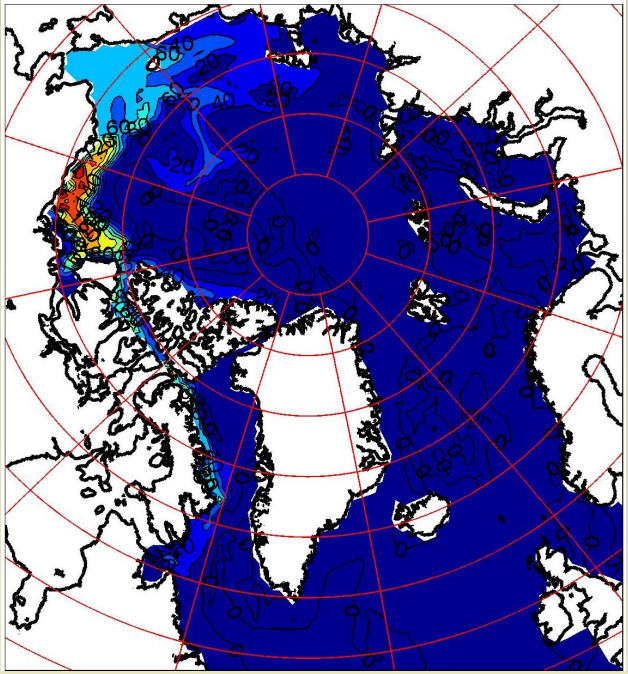
PW circulation features in 1960's

- An anticyclonic circulation over most of the Canadian basin
- A weak branch flowing through the Archipelago
- An appearance of anticyclonic feature in the Amundsen basin in 1967 and its further degradation
- An outflow of an essential part of PW through the Fram Strait

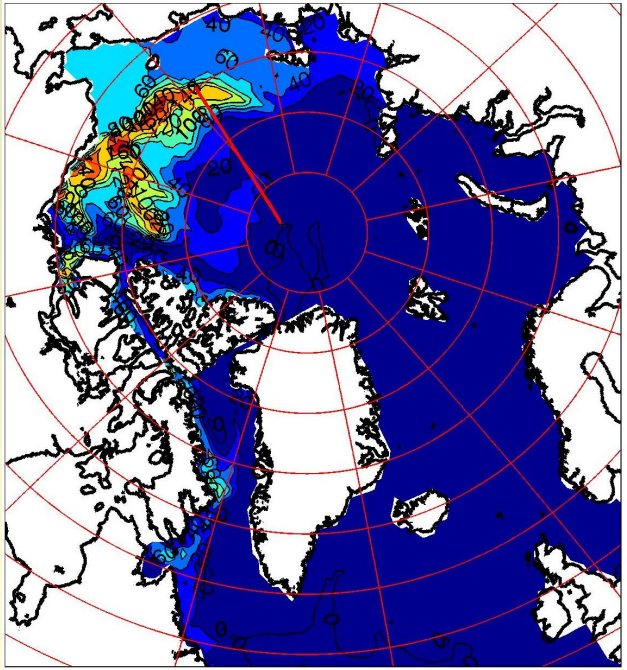
PW composite thickness - Year 1991

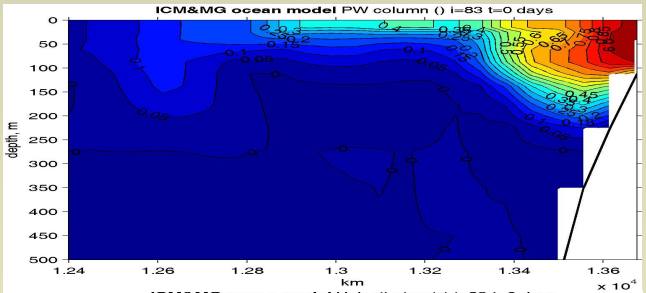


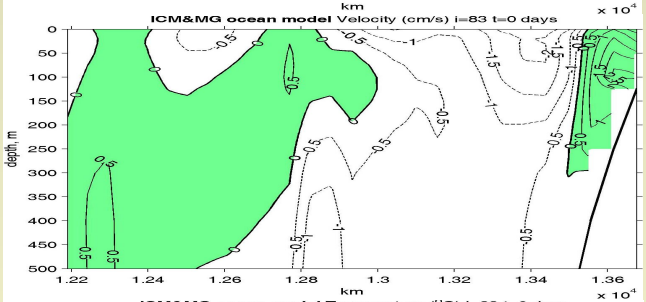
PW composite thickness - Year 1993

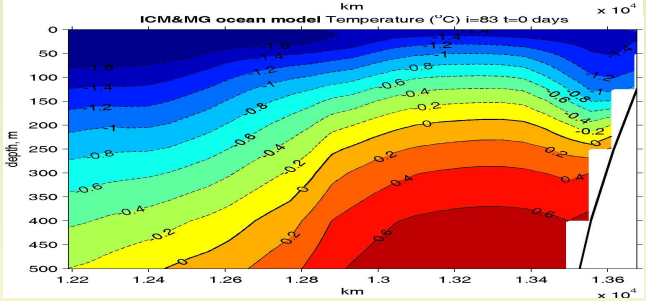


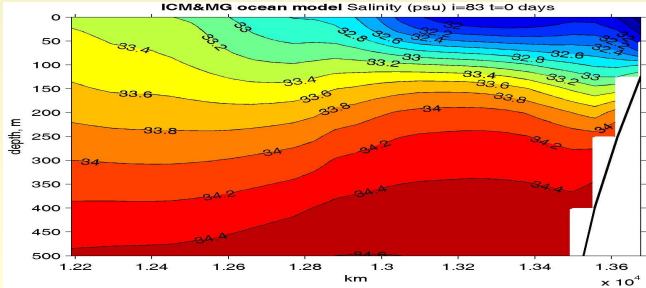
PW composite thickness - Year 1999



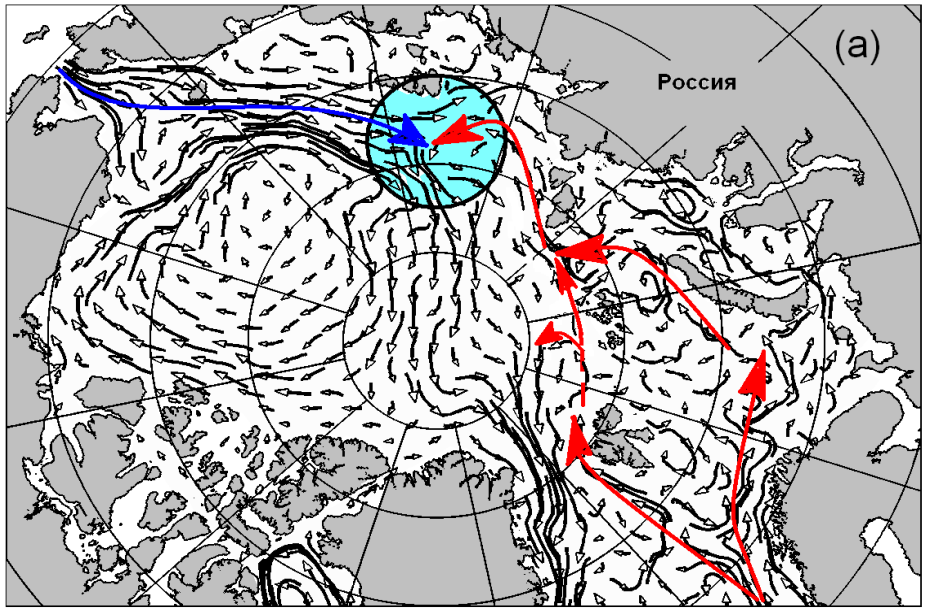


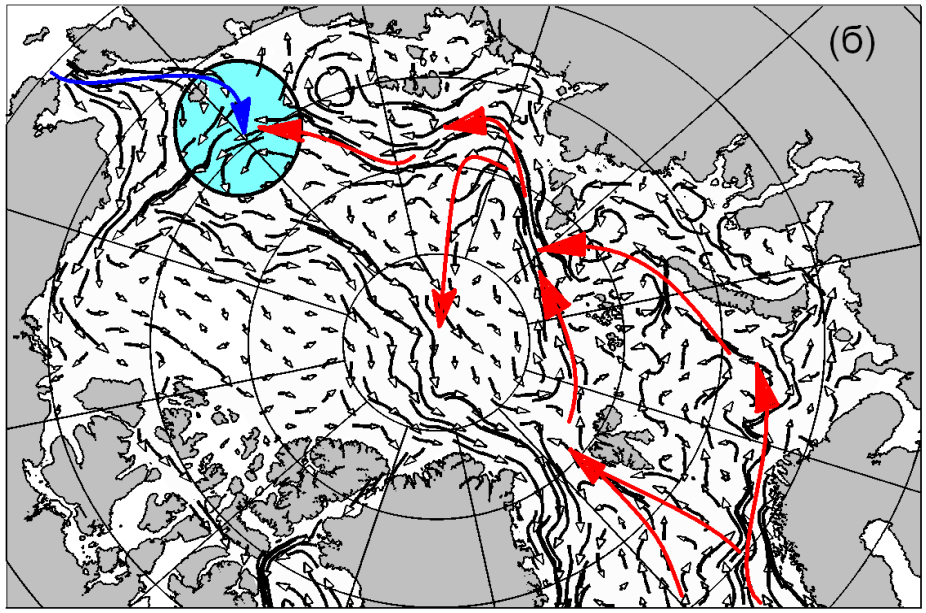




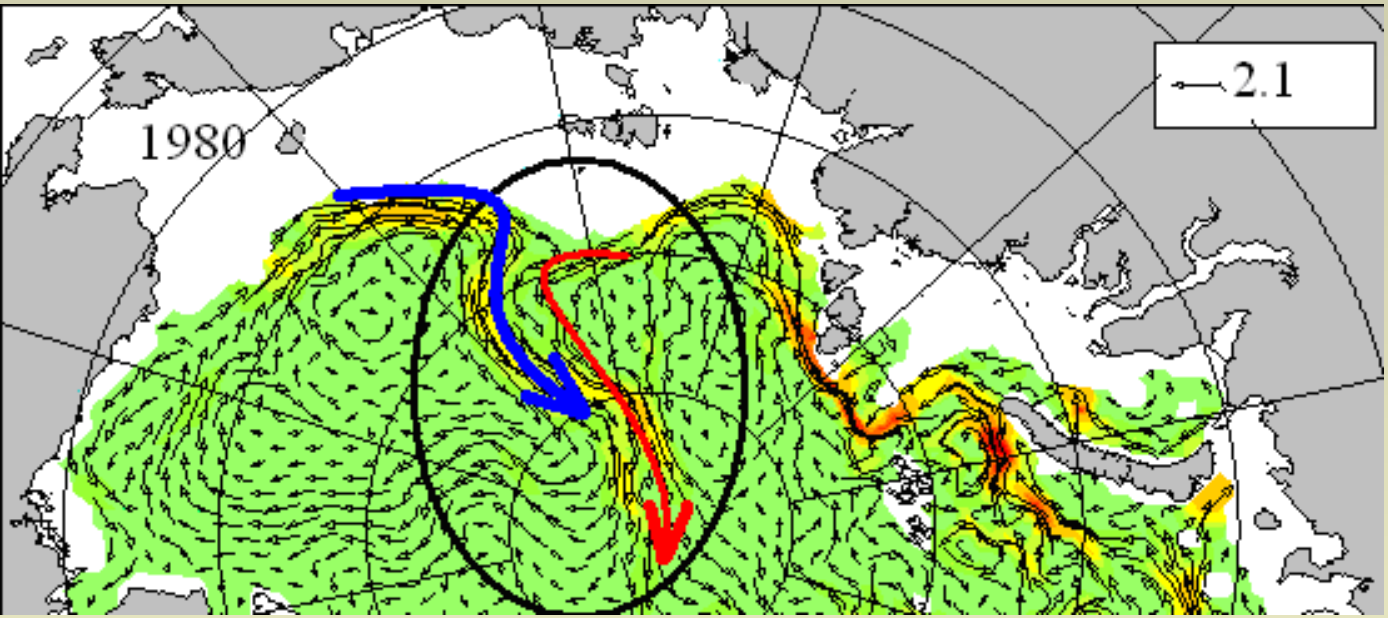


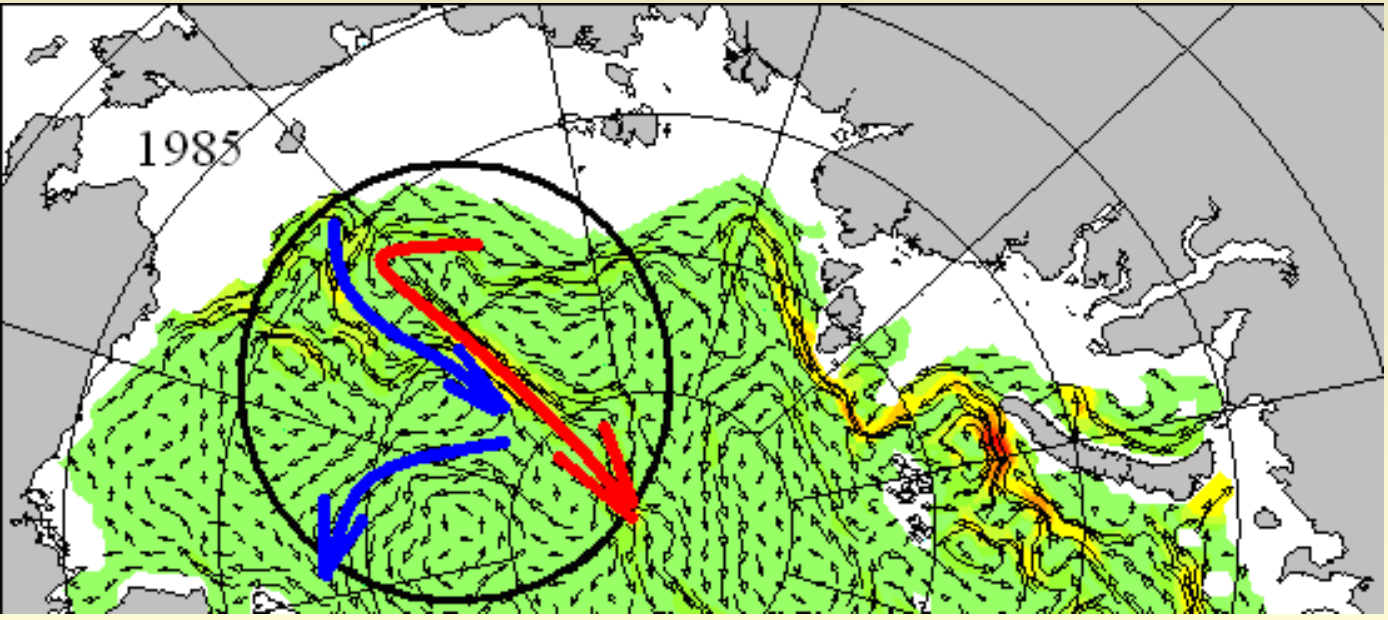
Current velocity at 50 m



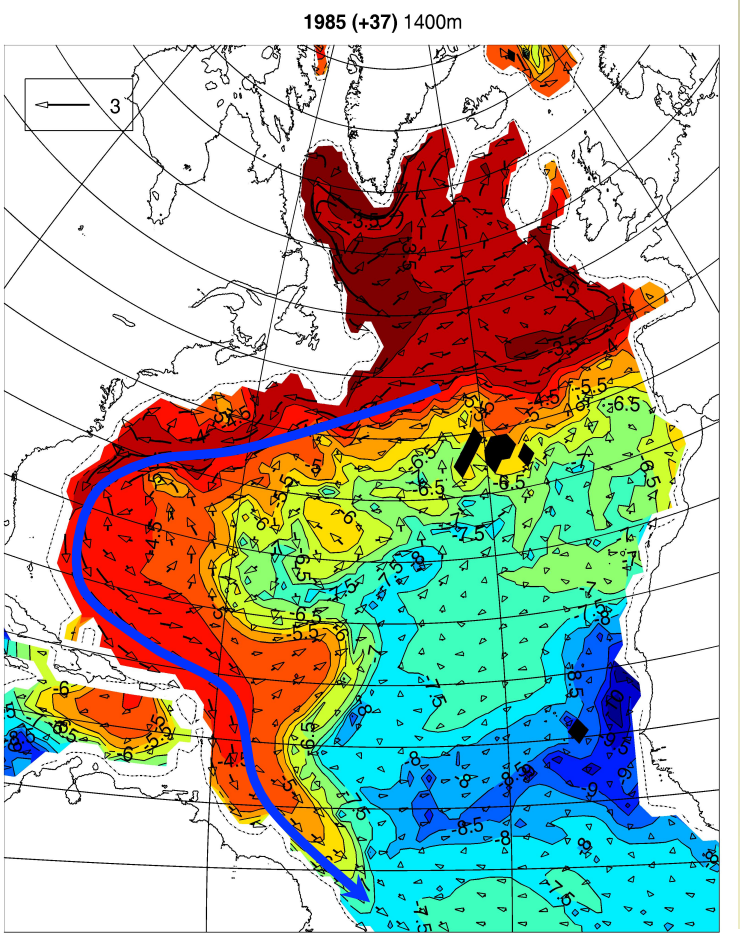


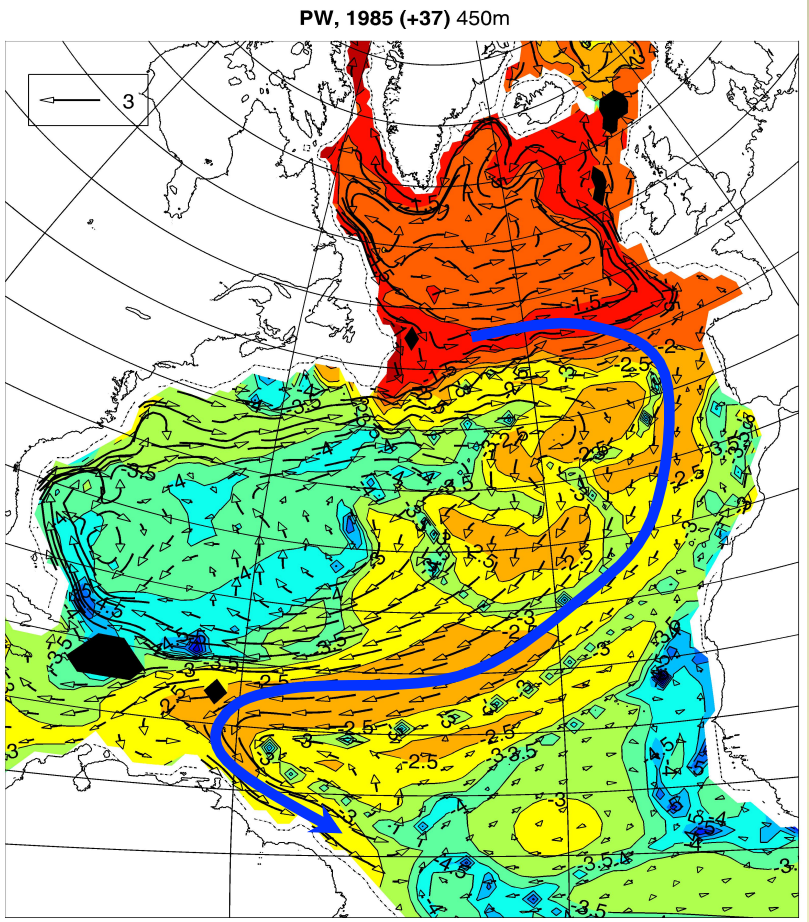
The strong inflow of warm Atlantic water coming from the Fram Strait pushes PW toward the North American coast producing the cyclonic circulation over the most of the Arctic. Only the small area in the Canadian basin remains anticyclonic. Atlantic water branch dominates in the end of 1990's.

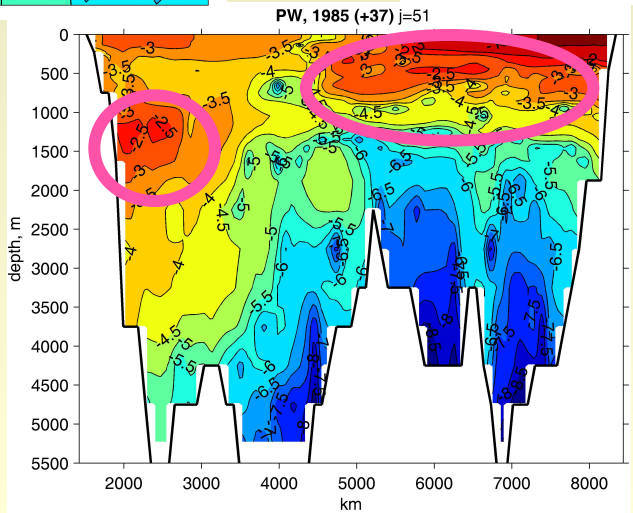




The velocity fields at the depth 100 m. Blue arrays indicate the Pacific water Red arrays indicate the Atlantic water The shift of the Pacific and the Atlantic waters distributions obtained in the model for these periods is in agreement with the EWG data [Swift et al., 2007]

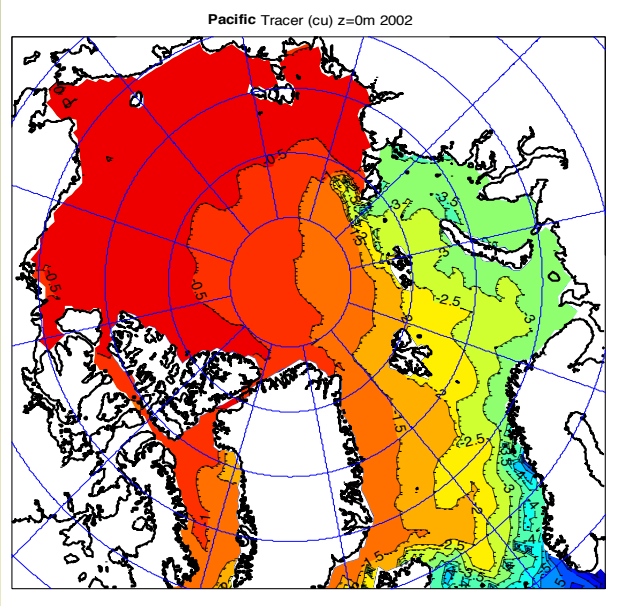

1985 (+37) 1400m
3

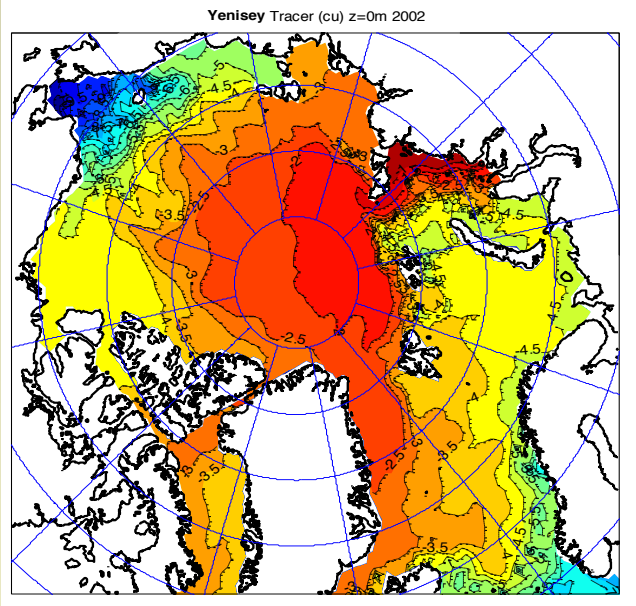

PW, 1985 (+37) 450m
3


PW, 1985 (+37) j=51
depth, m
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
2000
3000
4000
5000
6000
7000
8000
km

Siberin Rivers Water in the Arctic and the North Atlantic

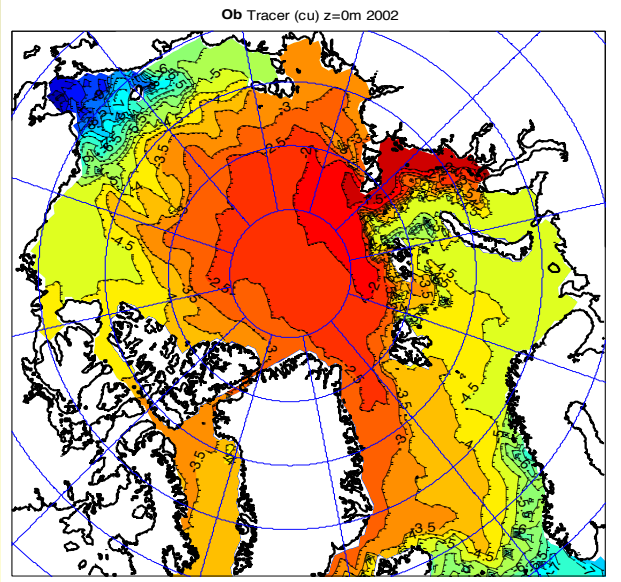
Transport of the freshwater after 37 years of the emission beginning (1966) :

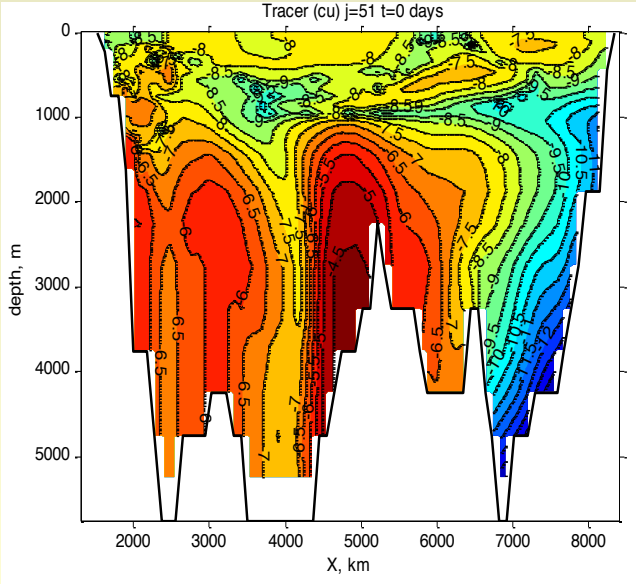




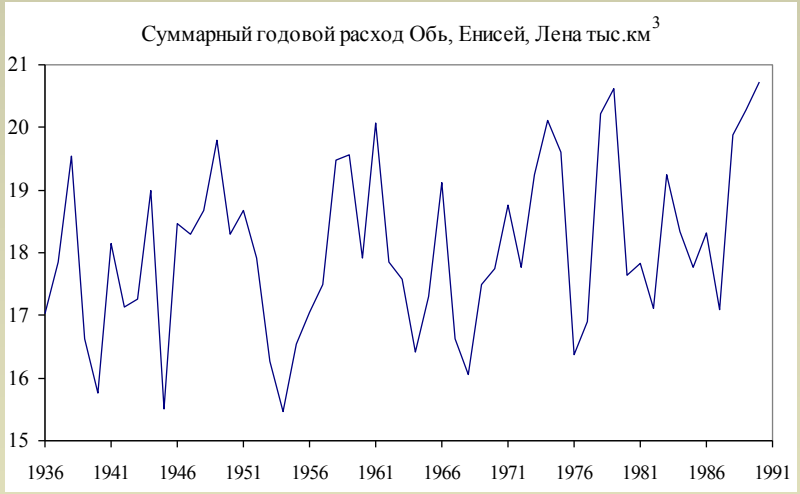
Pacific water from Bering strait (upper left);
Yenisei river water (upper right);

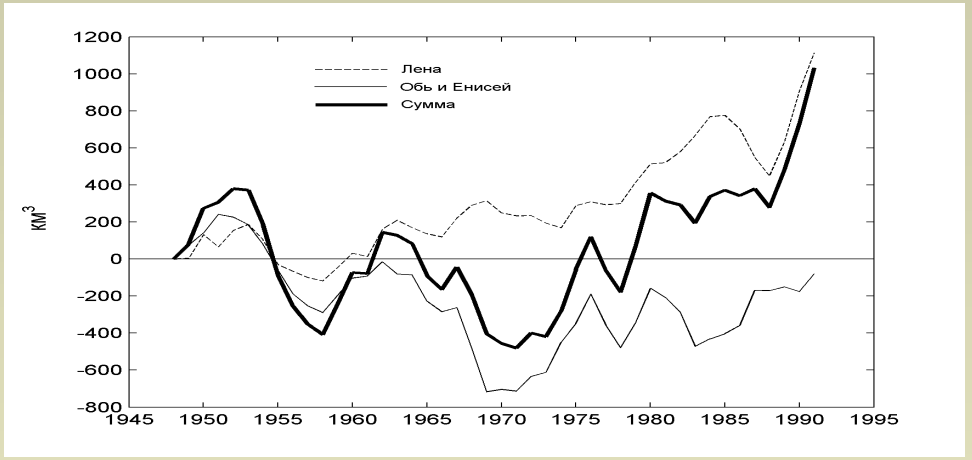
Ob river water (low left);

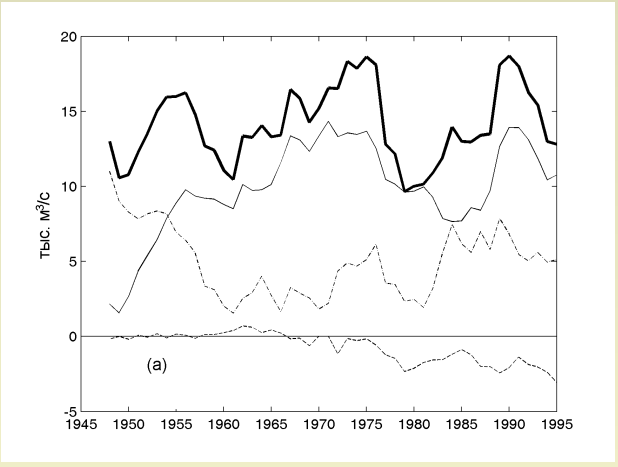


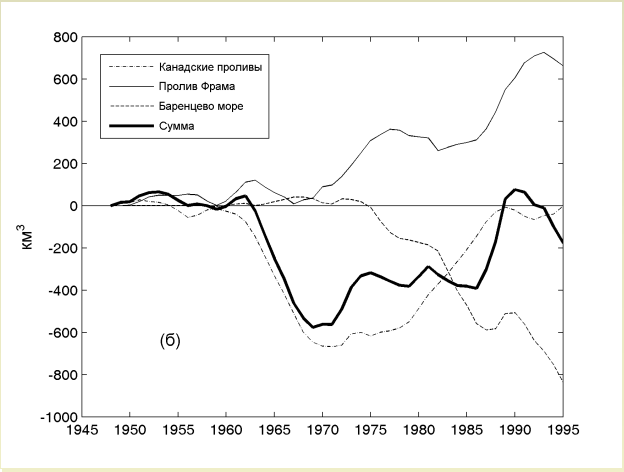


The vertical cross-section of the concentration of the Ob river freshwater through the latitude 30 N (low right) (the West is in the right)

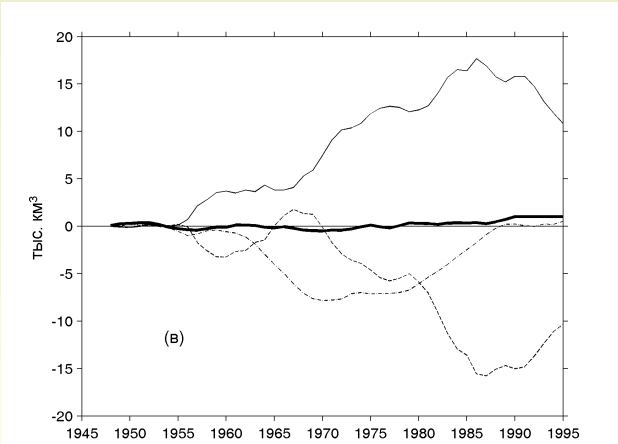








Difference of the volumes of observed (run 2) and climatic (run 1) of the Ob, Yenisei, Lena Rivers runoff summarizing from 1948.



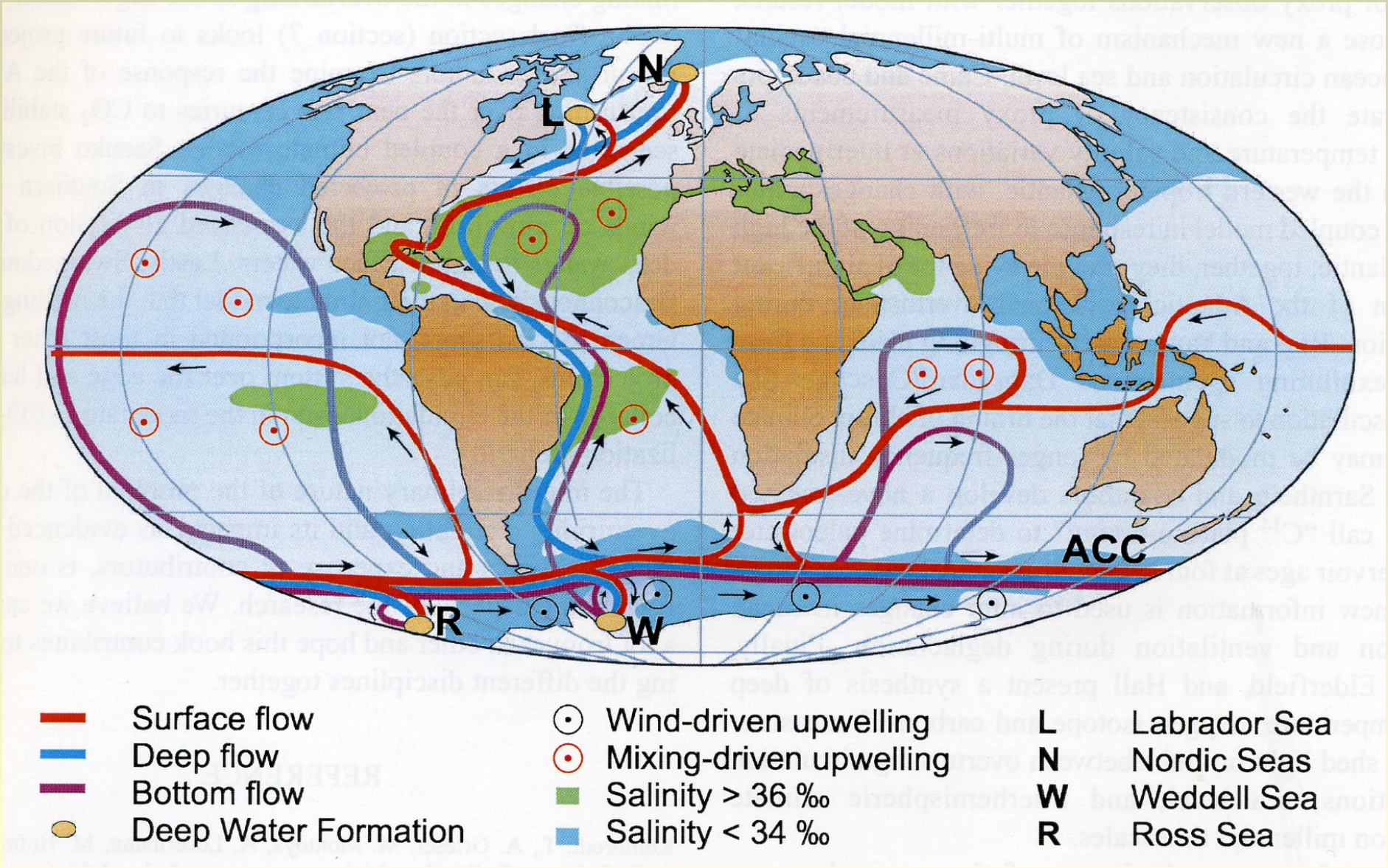
The inflow through the main straits:

(А) the inflow of fresh water relatively averaged salinity 34.8‰ (positive values correspond to the inflow from the Arctic to the North Atlantic),

(Б) the difference of the summarized amount of the fresh water volume in the run 2 relatively to the run 1, transported from Arctic to the North Atlantic summarized from 1948,

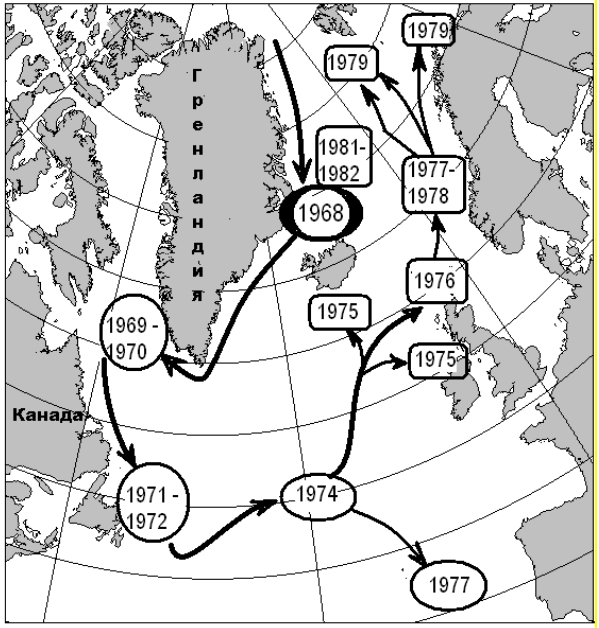
(В) the difference of the fresh water amount between the run 2 and run 1, transported from Arctic to the North Atlantic summarized from 1948.

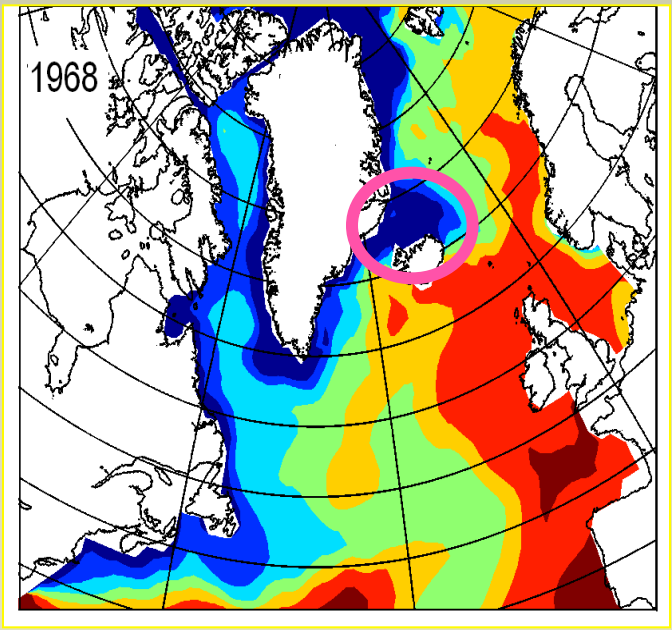
A schematic drawing of World Ocean circulation

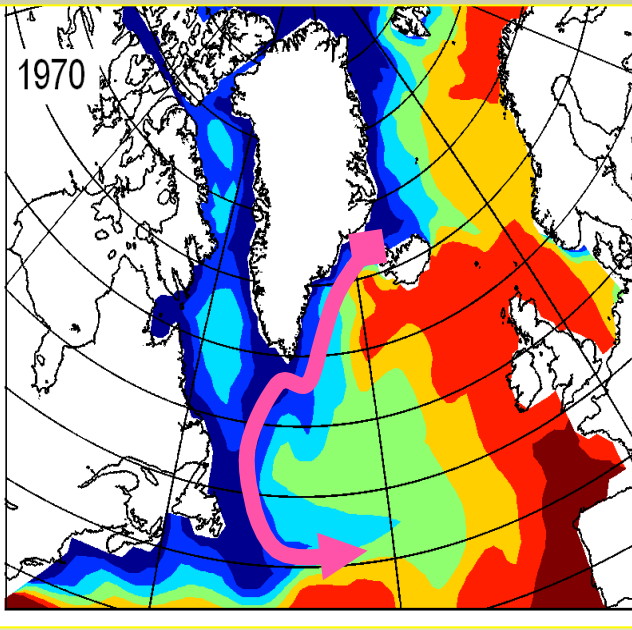


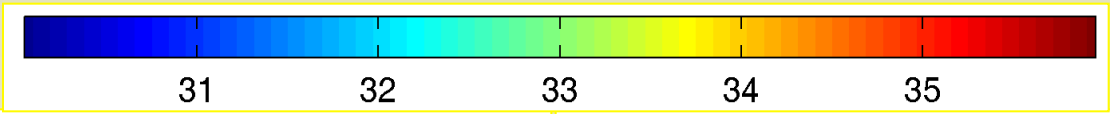
The pathway of the Great Salinity Anomaly in 1968-1979 according to model results

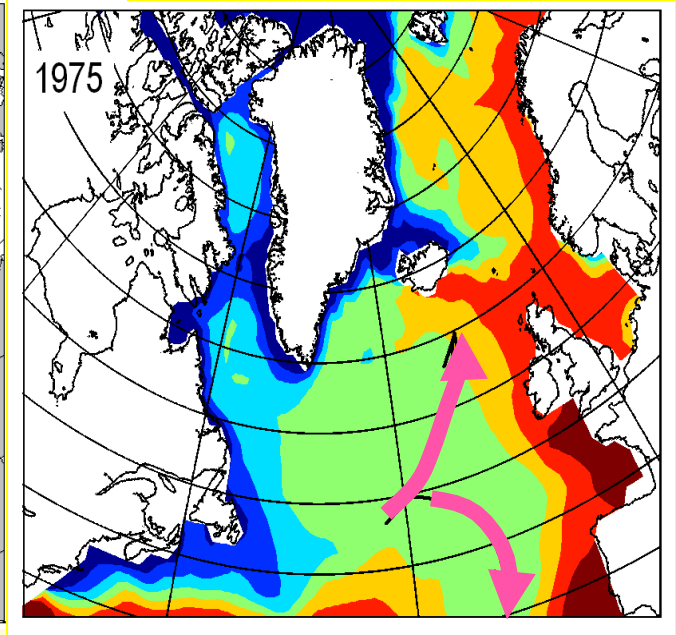
The pathway of the Great Salinity Anomaly in 1968-1982 according to Raymond W. Schmitt *(http://www.whoi.edu/oceanus)*

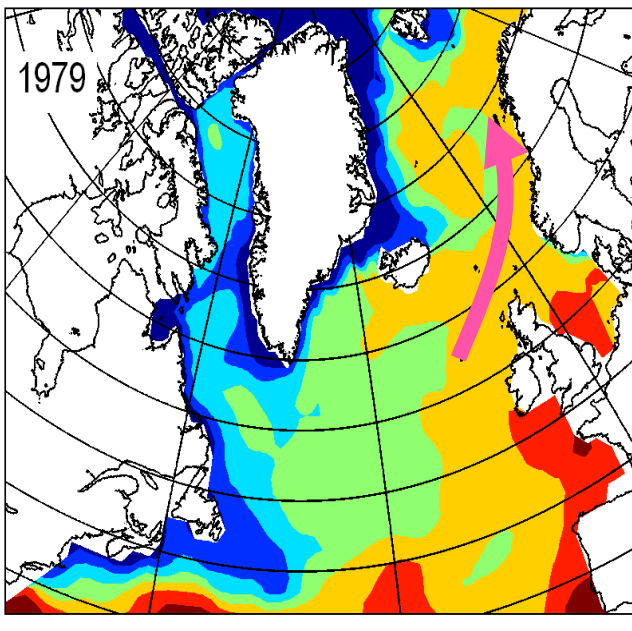


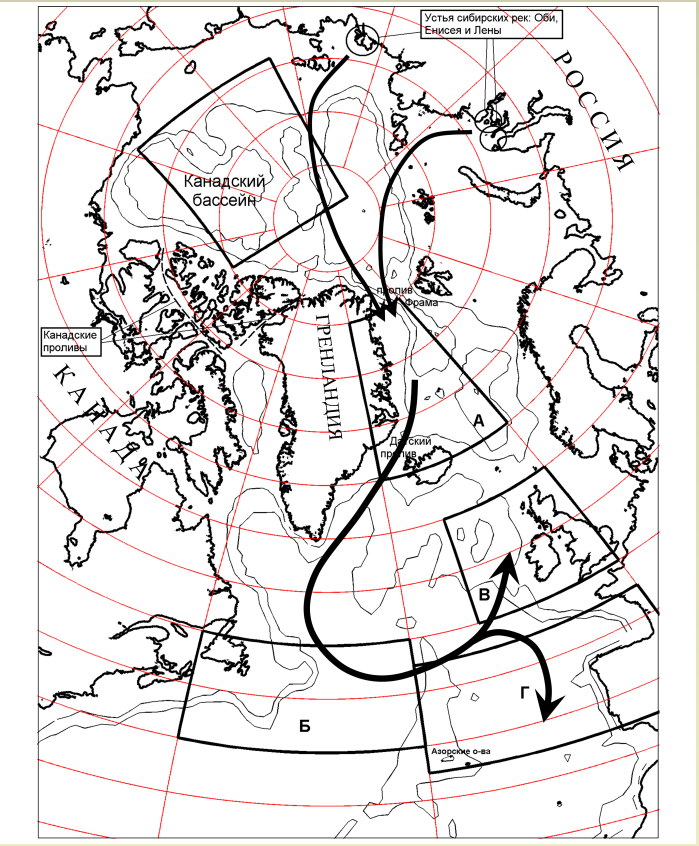


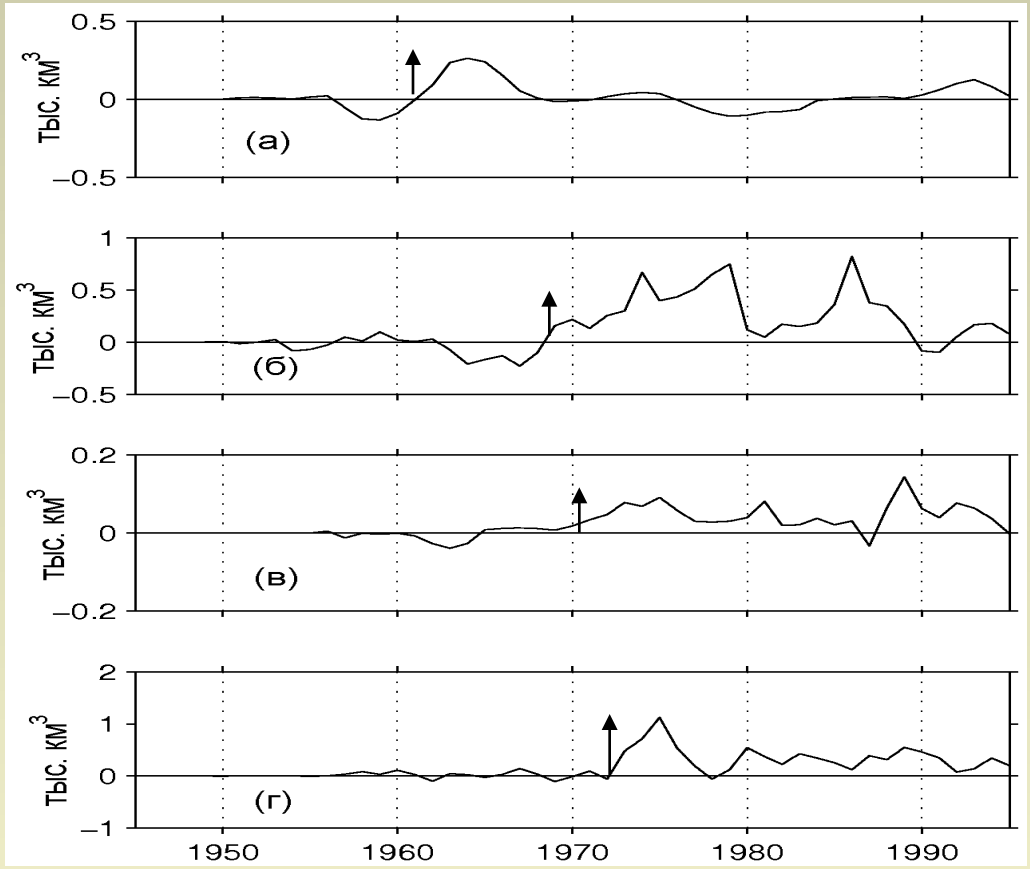






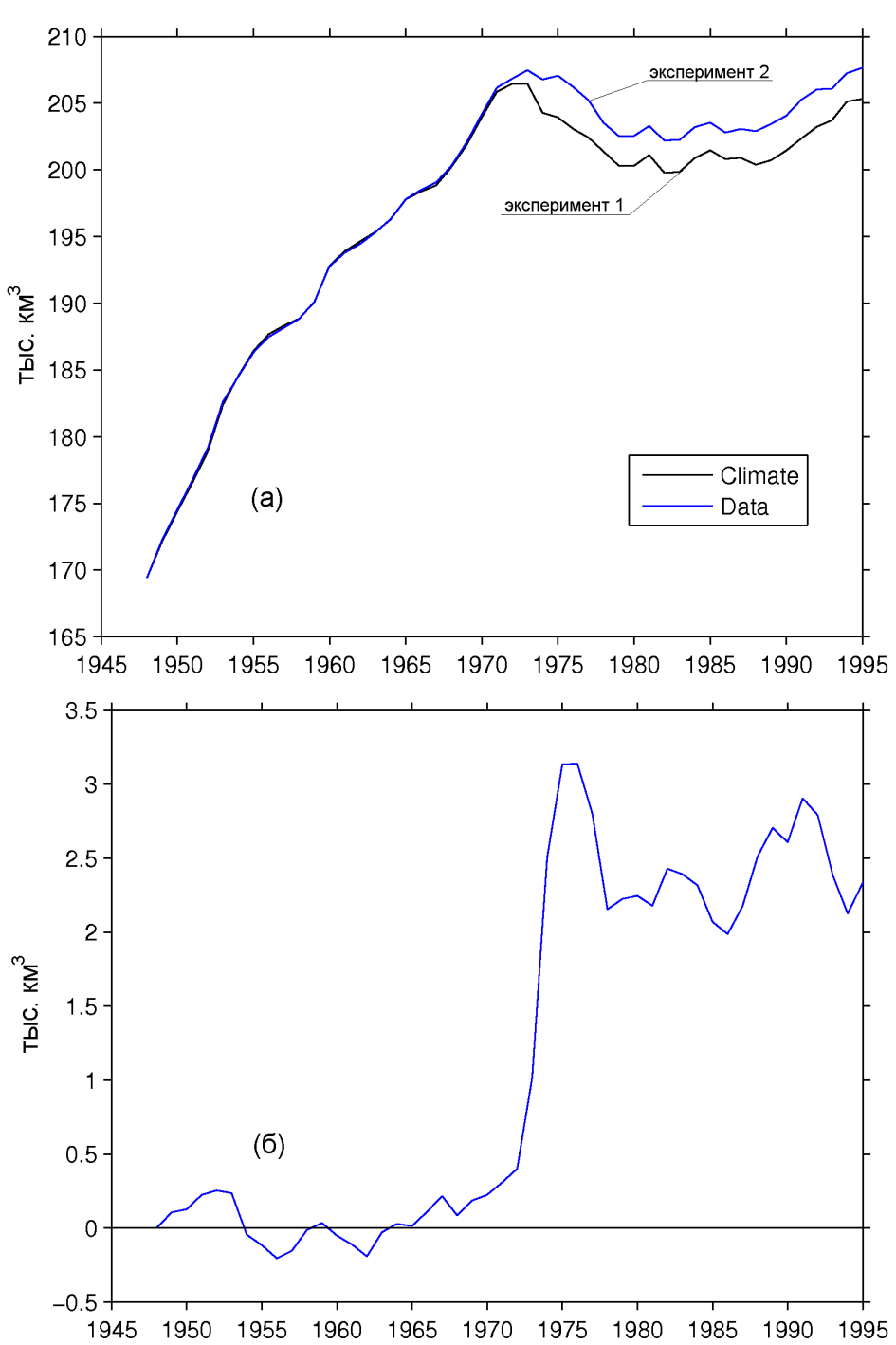






Geographical position of the zones where fresh water anomaly propagates. Arrows show the pathway of the river fresh water anomaly in 1958-1962.
The anomaly shows the difference between the climatic and observed runoff (runs 1 and 2 accordingly).

Temporary behavior of the difference of the fresh water volumes between the runs 2 and 1in the different zones of North Atlantic alone the pathway of the “Great Saline Anomaly”:
Zone (А) to the East of Greenland,
Zone (Б) to the East of the Newfoundland,
zone (В) to the West of Great Britain,
Zone (Г) to the West of Spain in the region of the Azores Islands.



Change of the content of the fresh water in the Arctic and North Atlantic Oceans relatively averaged salinity of the Arctic 34.8‰:

(upper panel)
The changes of the total amount of the fresh water in the runs 1 and 2,

(lower panel)
The difference of the amounts of fresh water between the runs 2 and 1 (the positive values indicate that the fresh water amount in run 2 exceeds relatively run 1).

Conclusion

• The freshwater exchange between the polar and the subpolar oceans is the main mechanism of the thermohaline circulation of the World ocean and the global hydrological cycle.

• The Bering throw flow play an important role not only in the regional sense for the Chukchi Sea and Arctic Ocean, but globally in the Atlantic deep water formation and global water cycle.

• The comparison of the water spreading from the Bering strait and the Siberian rivers have some common features, but there exist some differences in the water masses distribution as well as in Arctic as in North Atlantic.

• The use of the seasonal and internal variability of the Siberian rivers runoff leads to the variations in the fresh water content in the Arctic basin as well as to the variations in the behavior of the “Great Saline Anomaly” in the North Atlantic because of the decrease of the convection.

Thanks for attention!