Some results of the use of the numerical model in the Arctic Ocean climate simulation

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GOALS

To study of the Arctic Ocean climatic changes during the last half of the XX century and possible variations in the first half of the XXI century under the atmospheric forcing. For these goals two experiments were made:

RUN 1
Period 1948 – 2010
Atmospheric forcing from the reanalysis NCEP/NCAR

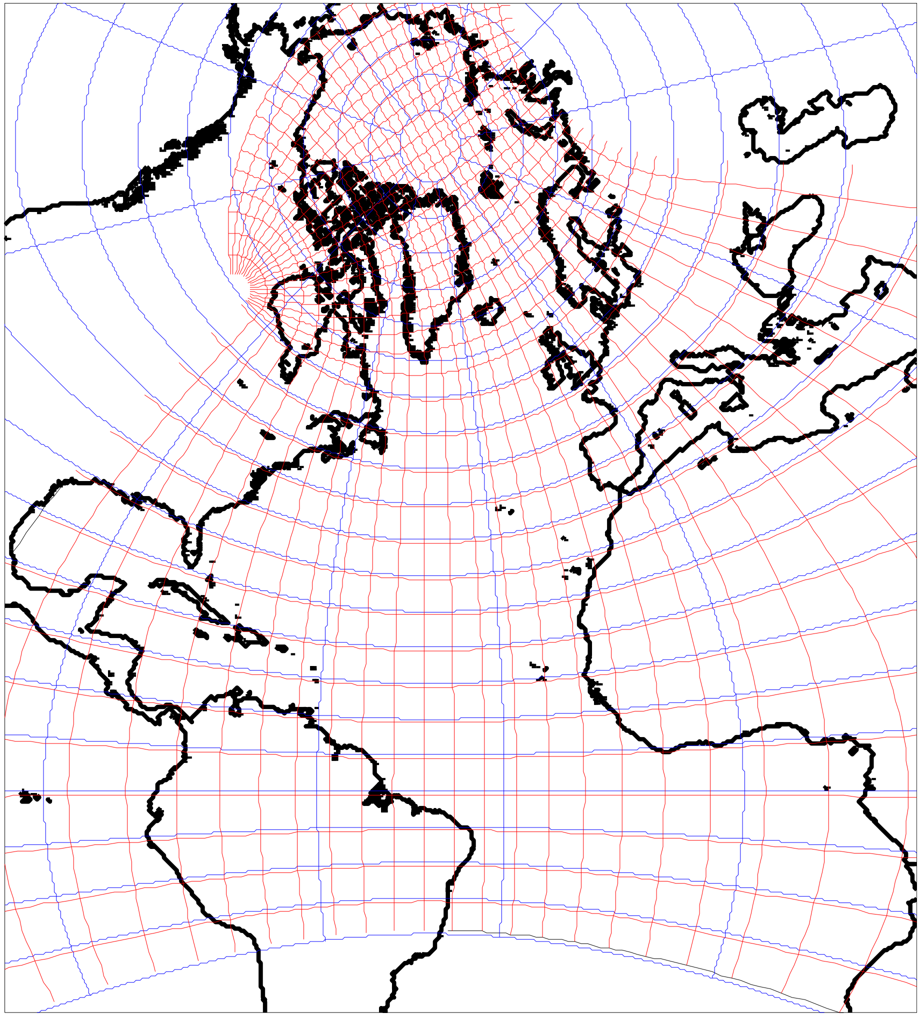
RUN 2
Period 2006 – 2050
Atmospheric forcing from the model CNRM/CERFACS, Experiment RC8.5 (IPCC scenario)

Coupled Ice-Ocean Model

3D Ocean Circulation Model of ICM&MG

Technique: combination of reprojective greed in Arctic and spherical greed in Atlantic, splitting method and finite element approach

Resolution: 0.5 deg in Atlantic, 20 km. In Arctic with 12 km. in straits



(Kuzin [1984], Golubeva at al.,[1992], Golubeva [2001], Golubeva and Platov [2007], Kuzin et al. [2012])

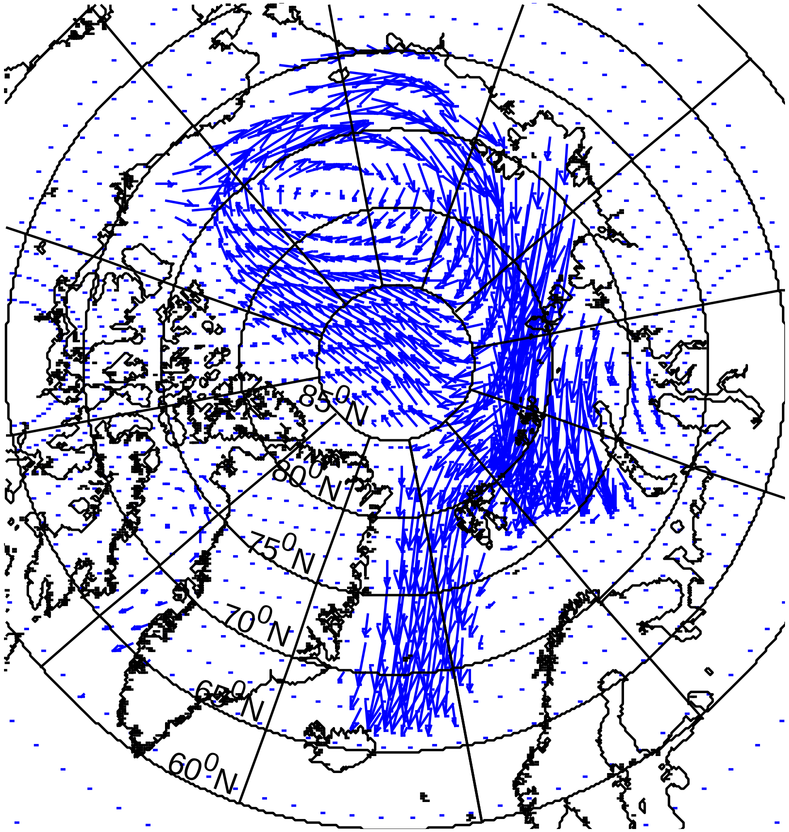
Princeton ice model-CICE 3.14 (elastic-viscous-plastic)

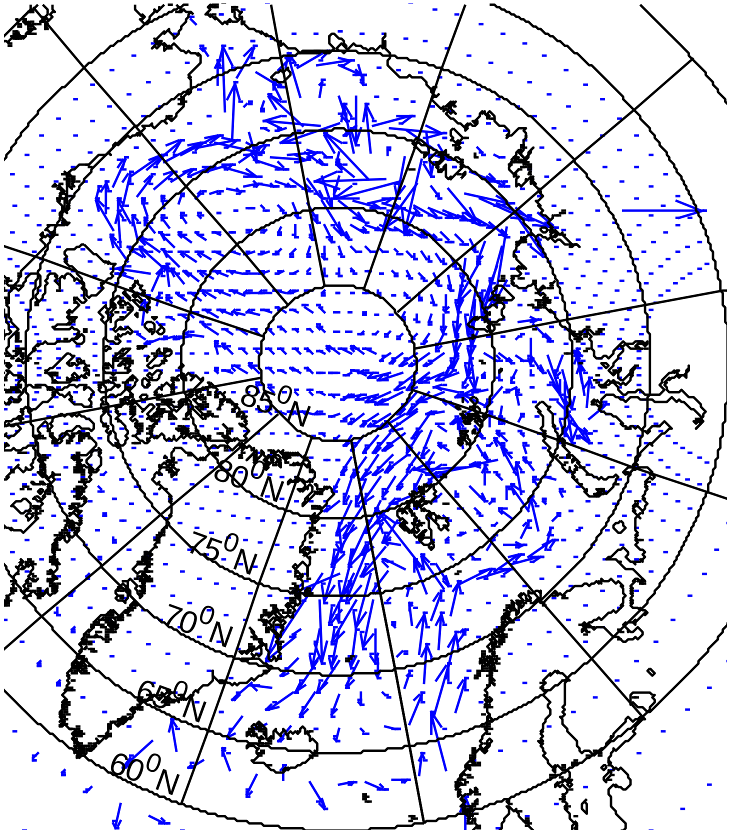
W.D.Hibler [1979],
E.C.Hunke, J.K.Dukowicz [1997],
G.A.Maykut [1971],
C.M.Bitz, W.H.Lipscomb [1999],
J.K.Dukowicz, J.R.Baumgardner [2000],
W.H.Lipscomb, E.C.Hunke [2004]

RUN 1

Period 1948 – 2010
Atmospheric forcing from the reanalysis NCEP/NCAR

Model Circulation



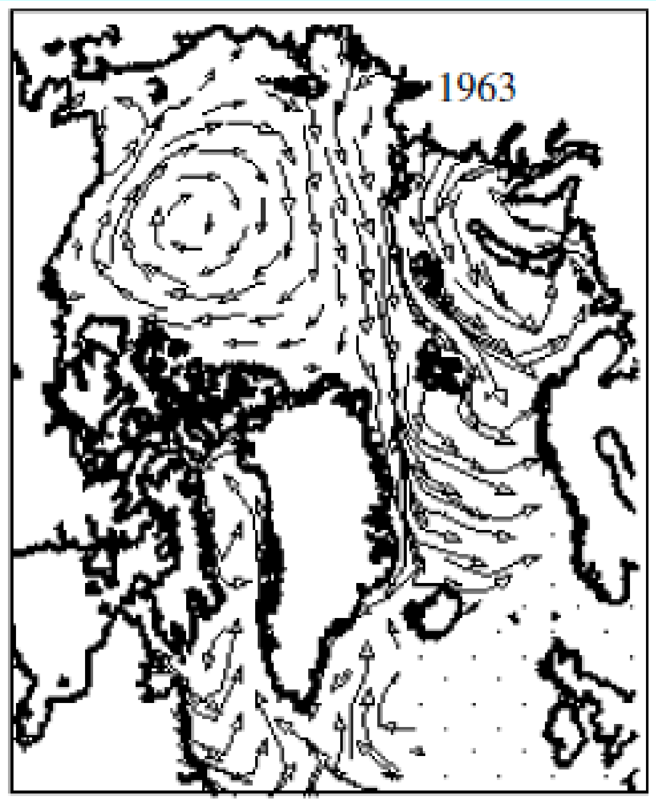


Ice

Water

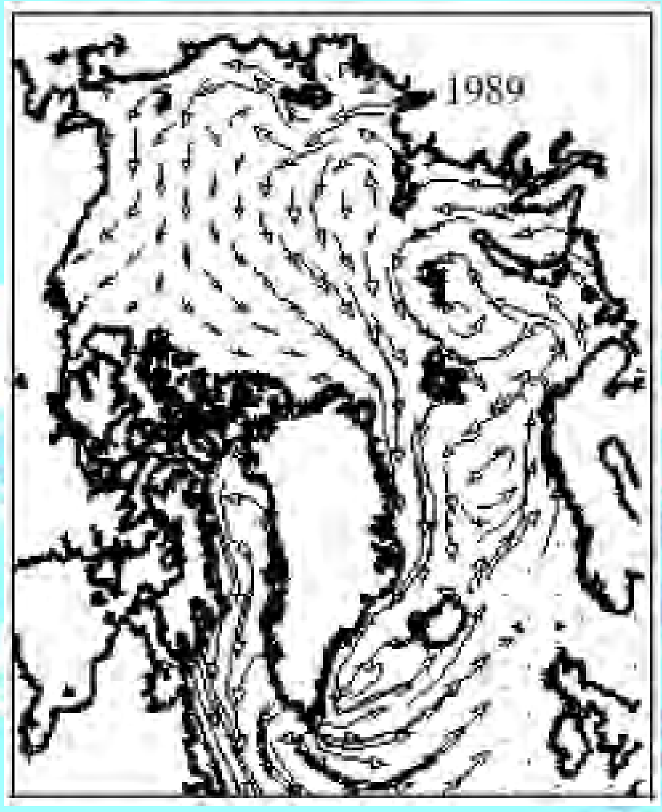
Two main modes of the Arctic Ocean circulation as the response to the NAO index variations

Negative NAO index –
anticyclonic mode



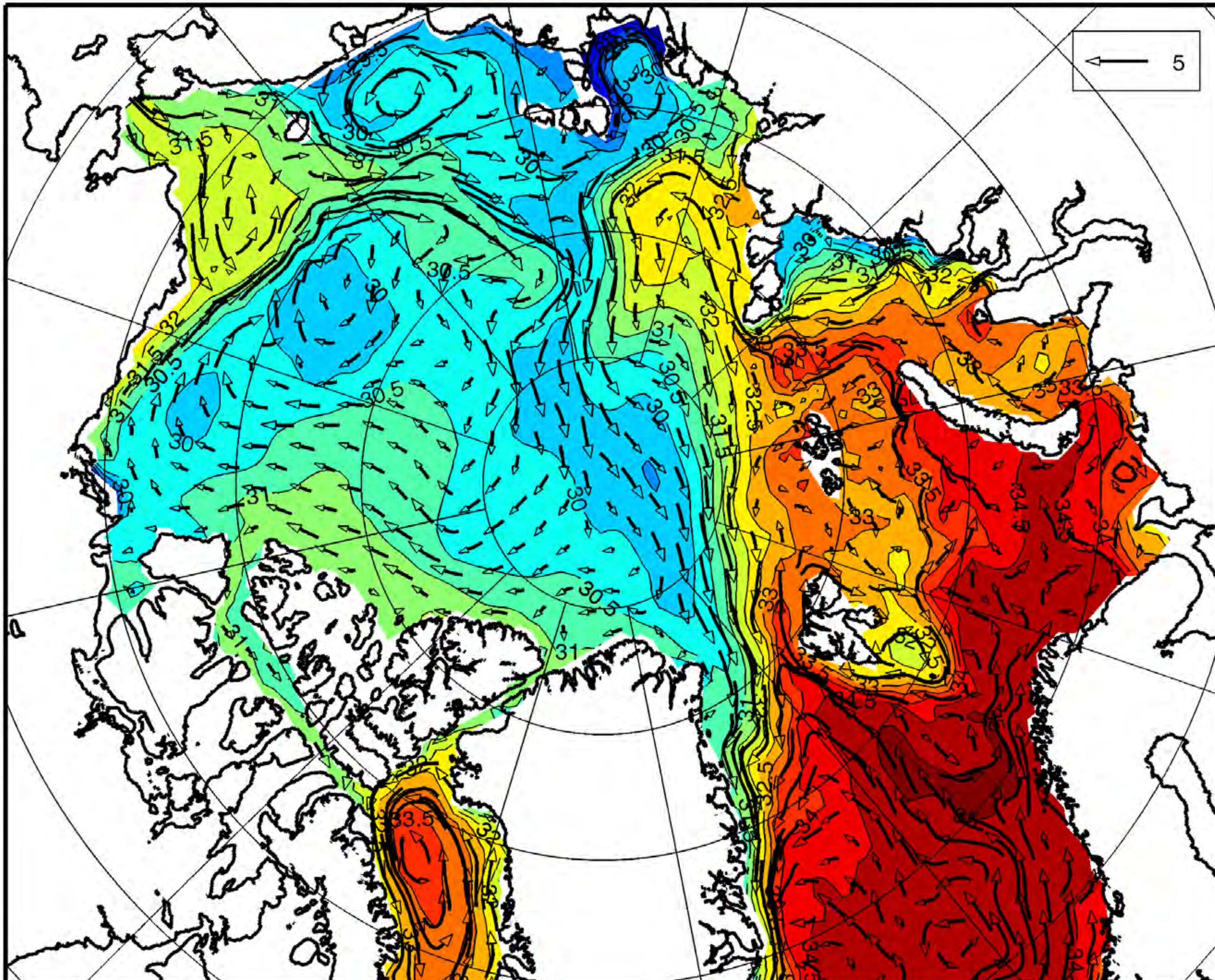
1960, 1961, 1963,1965,1966,1969, 1970-1973, 1977-1980,1982-1983, 1985-1986, 1988, 1992,1994, 1996, 1998, 2001

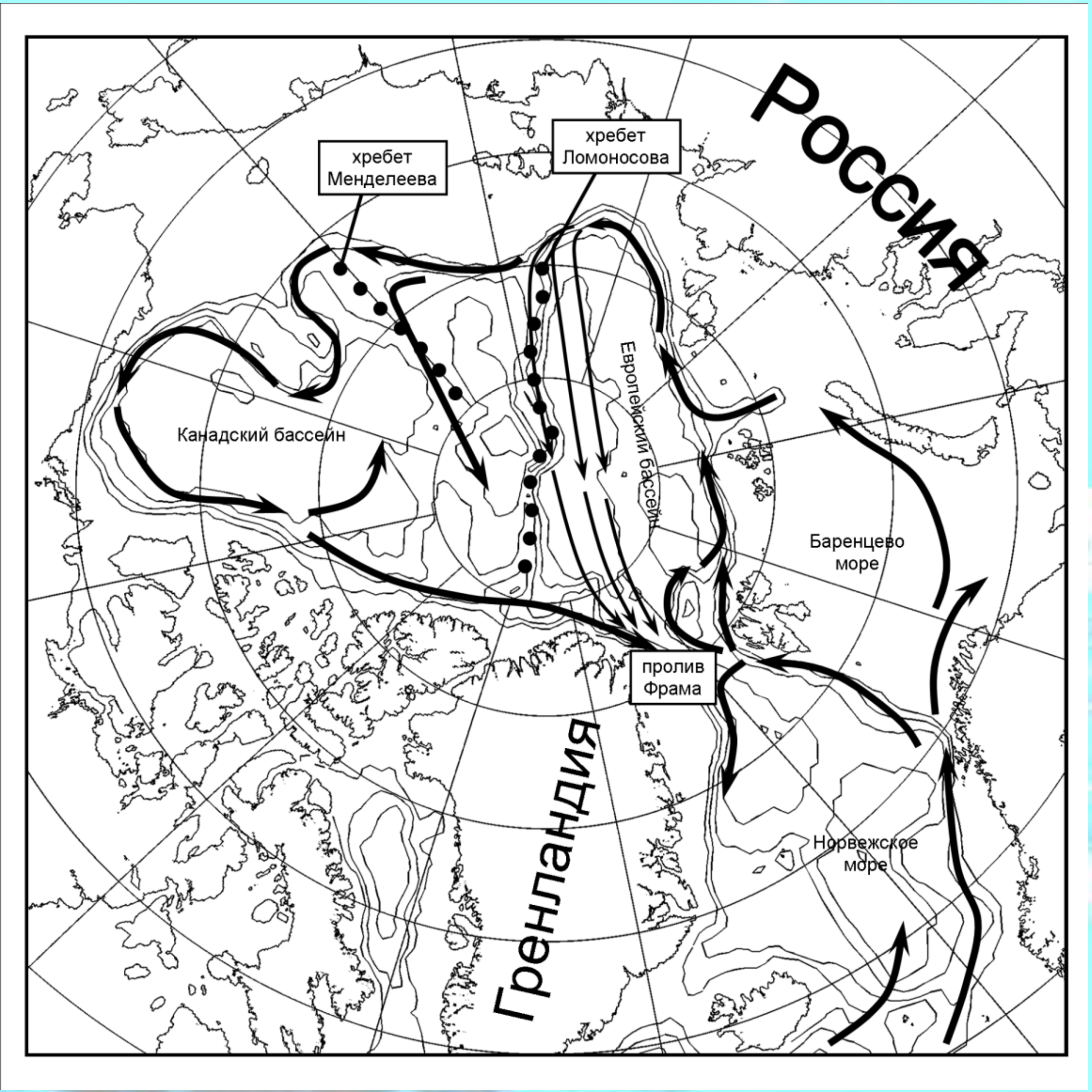
Positive NAO index –
cyclonic mode



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

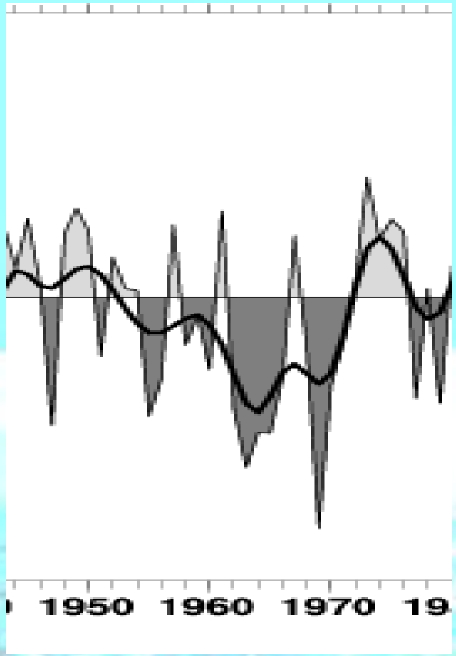
Salinity (psu) and Velocity Vectors (cm/s) (0-50m averaged) 1961



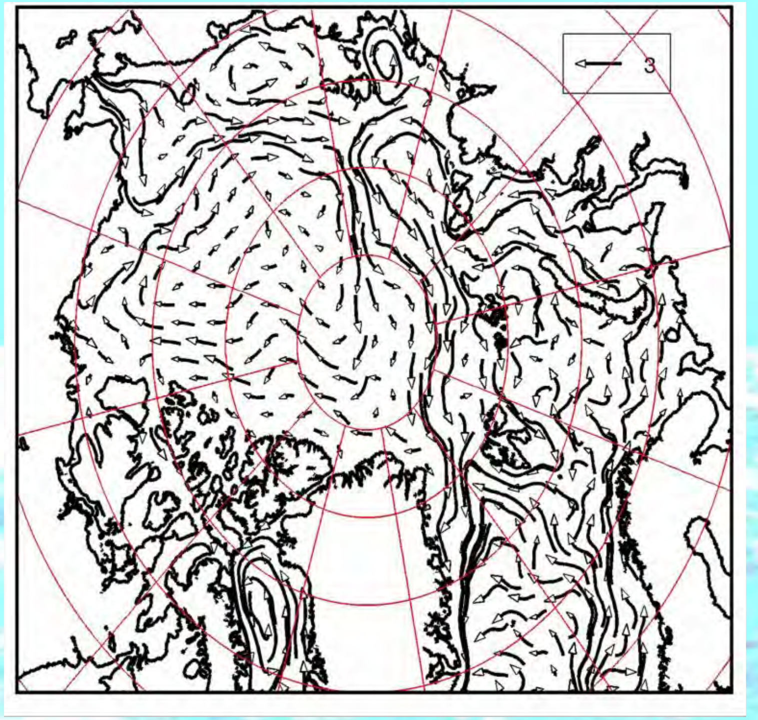


One of the prominent features of the Arctic Ocean circulation is a warm (with the temperature exceeding zero) and a salty flow of Atlantic Water (AW) entering the Arctic via Fram Strait and the Barents Sea from the Norwegian Sea. The Eastern branch of the AW is passing through the Barents Sea. Being originally warm, it loses its heat because of intensive air-sea exchanges in the area, provided that the Barents Sea has in the average, a shallow basin. Another branch, the West Spitsbergen Current, being mixed with a colder and fresher Arctic surface water, sinks to the intermediate level and flows farther into the Arctic Ocean along the continental shelf break isobaths. It serves as a major heat source associated with the AW transport. Following the isobaths along the slopes and ridges it forms a circulation cell in each topographic basin in the Arctic Ocean [Rudels et al., 1994].

NAO index



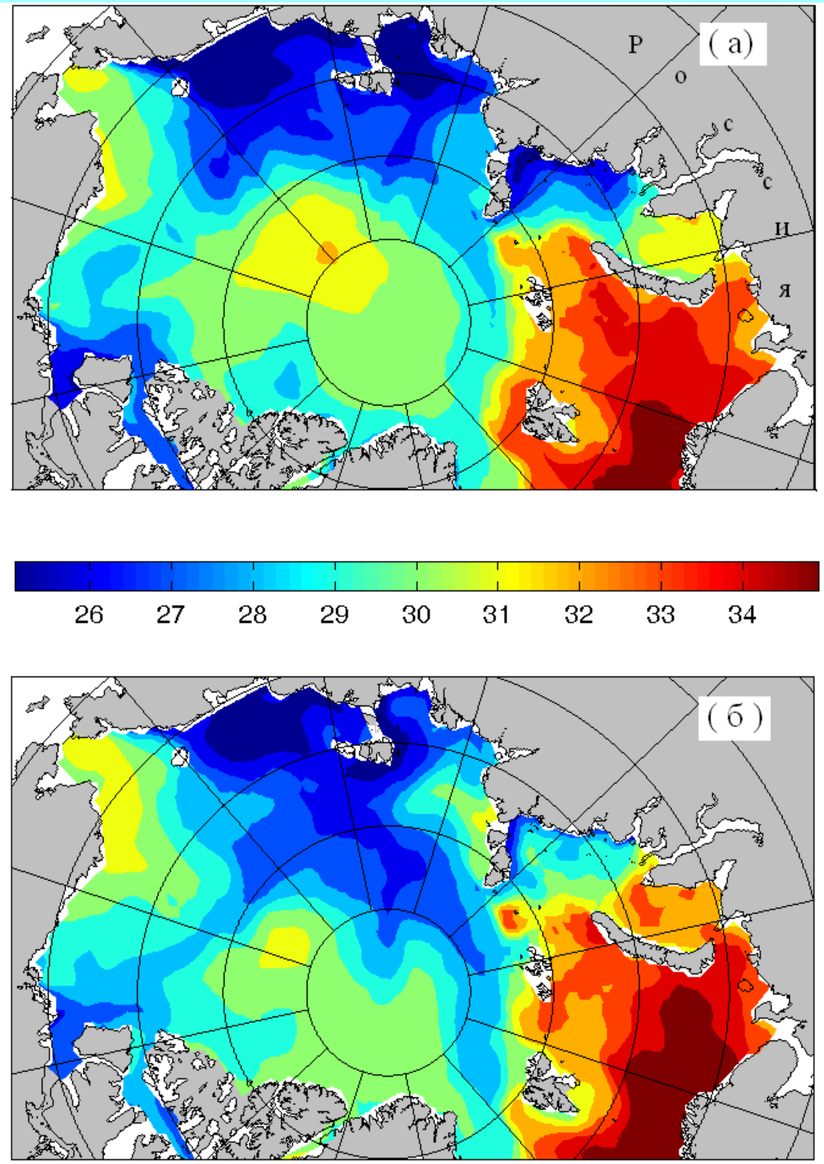
Surface currents



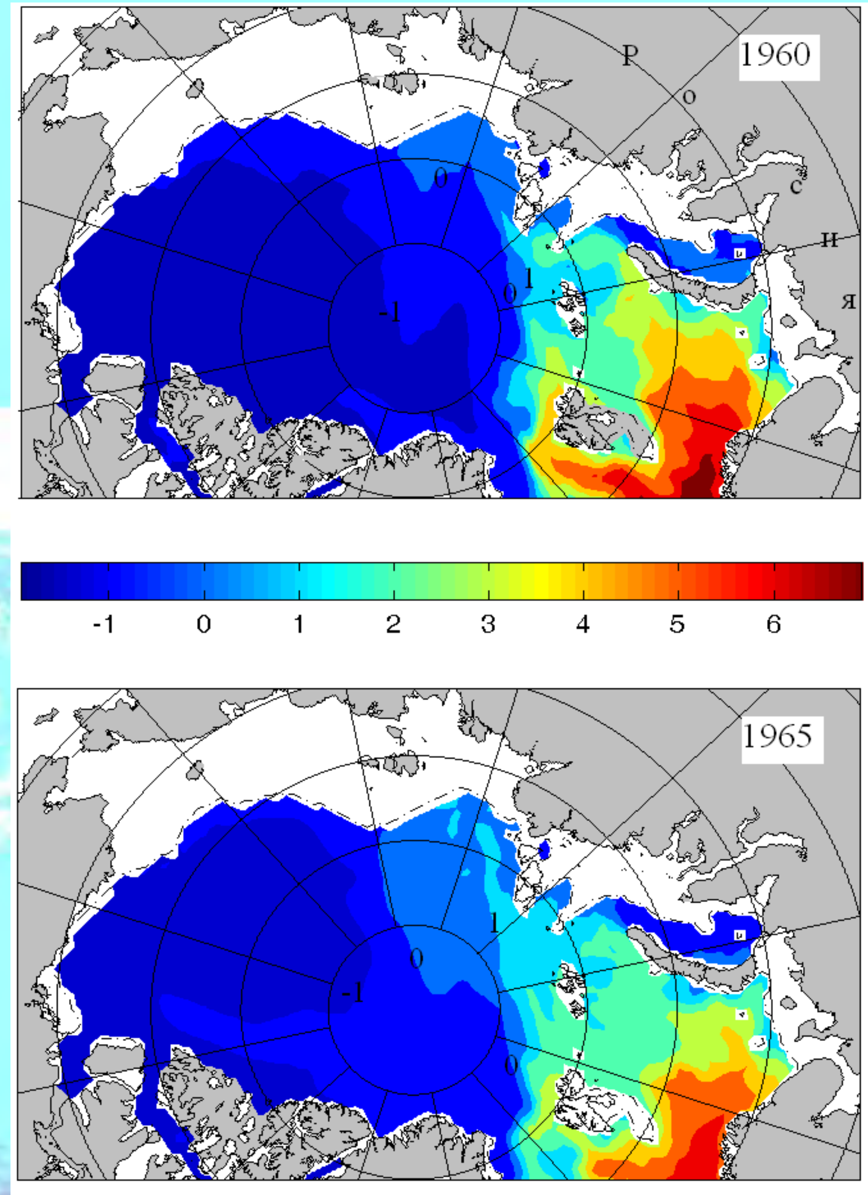
Warm period occurs during the negative NAO phase. According to the circulation pattern fresh water spreads anticyclonically in the surface layer in the region of the AW path. It strengthens stratification and reserves heat in the Atlantic layer.

Warm period (1963-1969)

Surface salinity

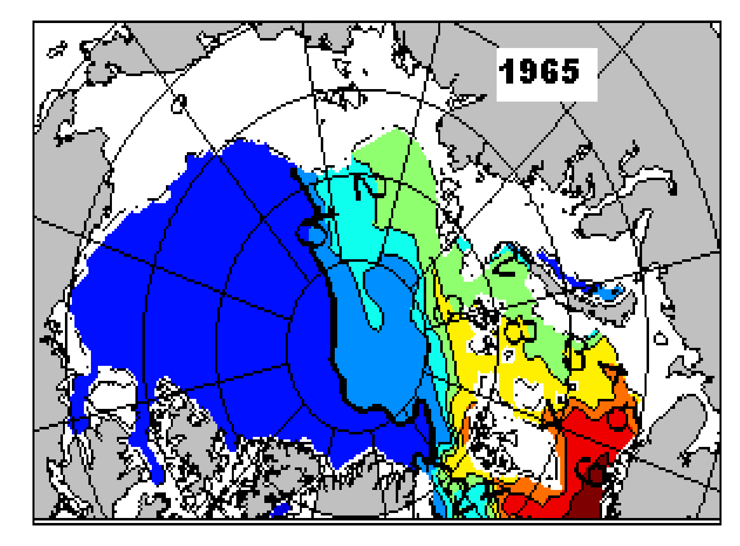


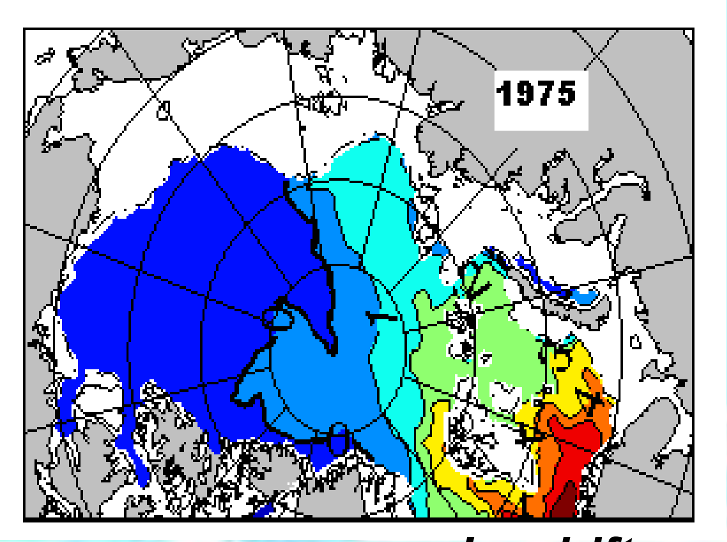
Temperature (200m)



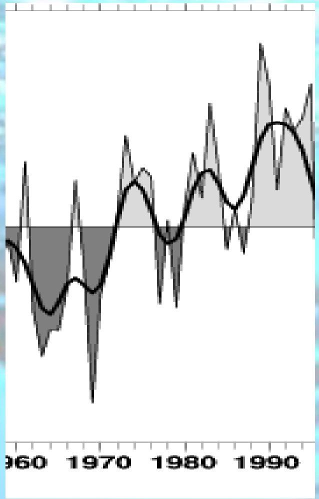
Cold period (1974—1982)

Temperature (200m)



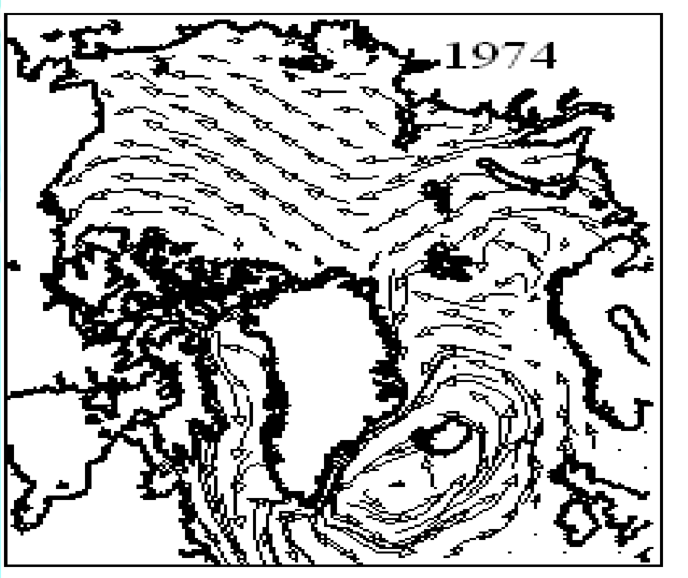


NAO index



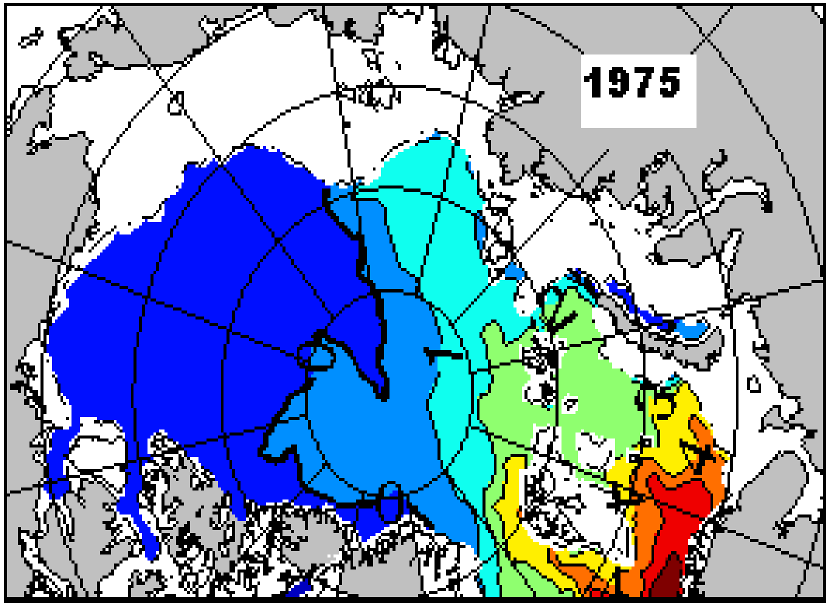
Enhanced cooling of the Atlantic layer in the middle of 70-s is the result of ice and cold waters propagation into the Nansen basin from the Barents and Kara seas

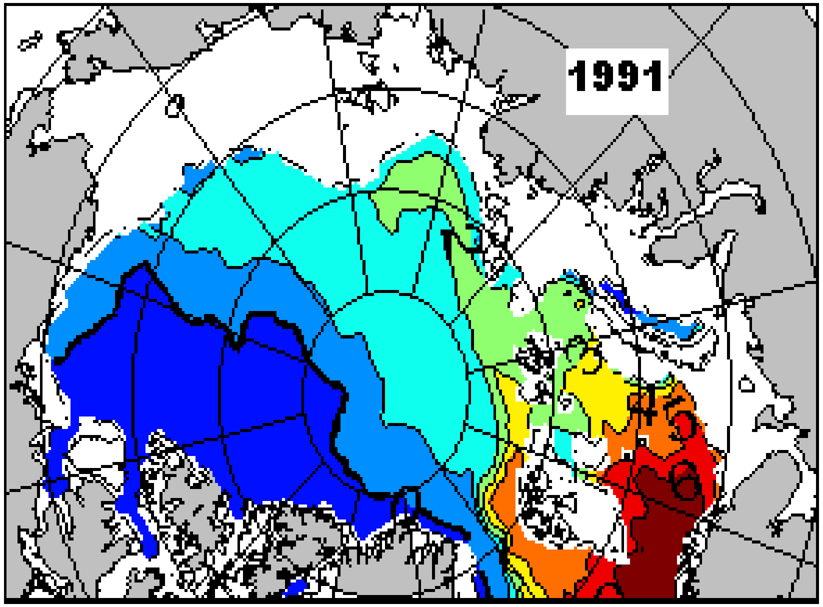
Ice drift

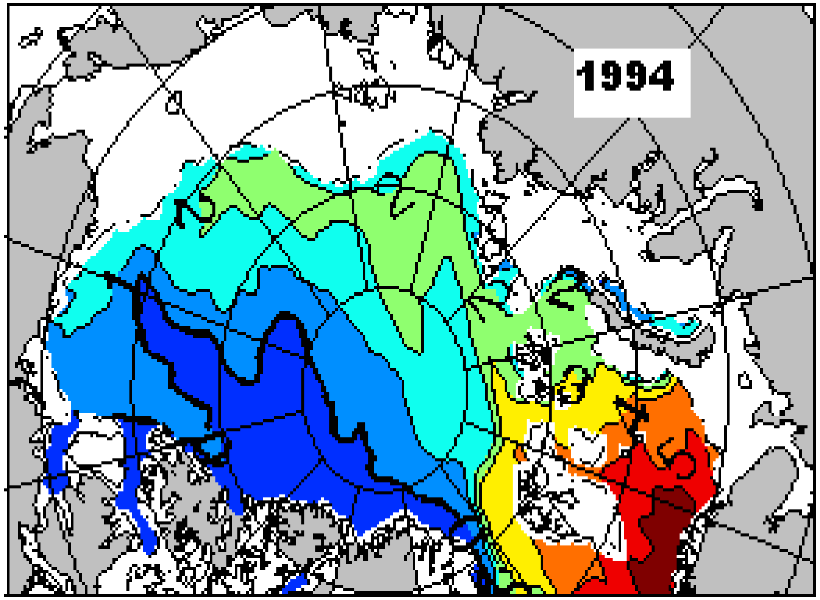


Warm period (1989-1995)

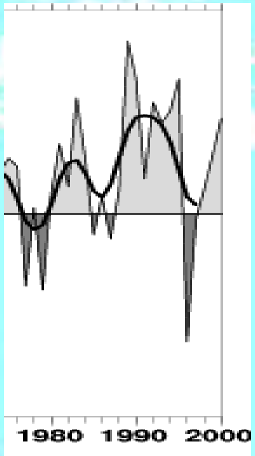
Temperature (200m)



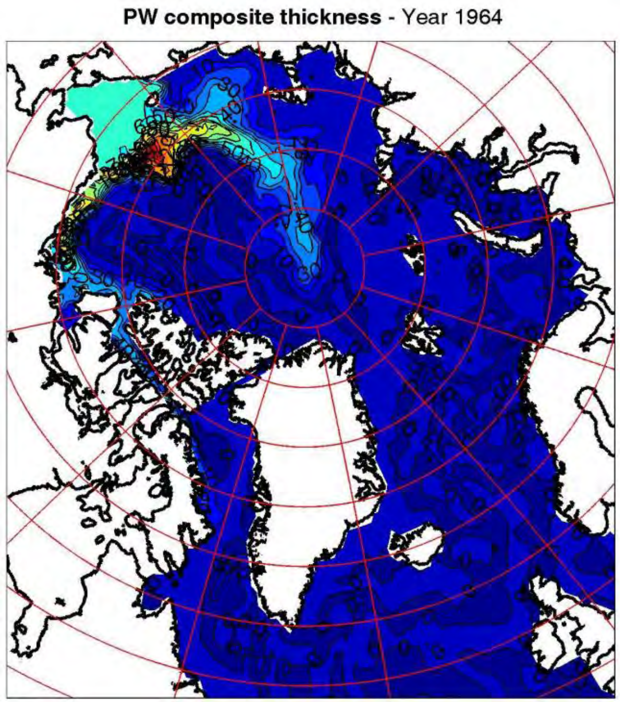


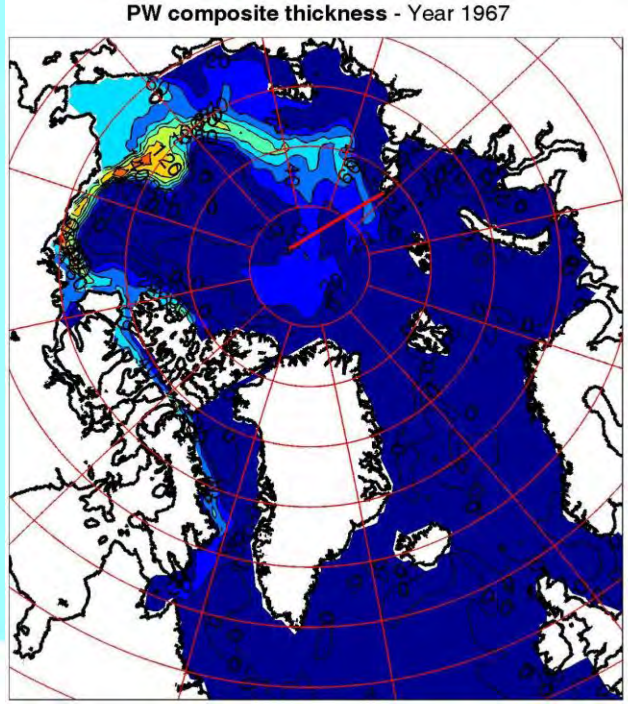


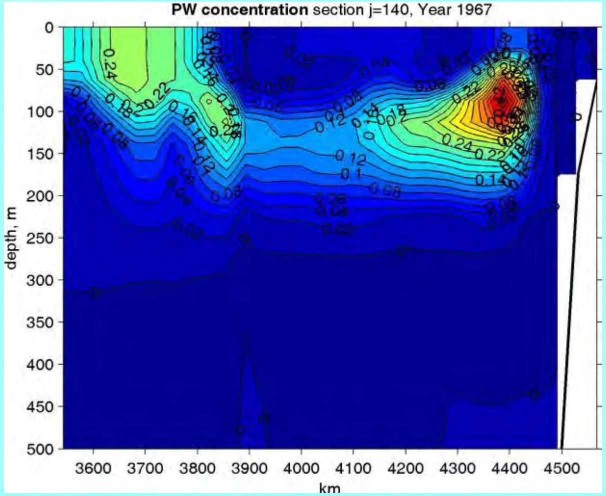
NAO index

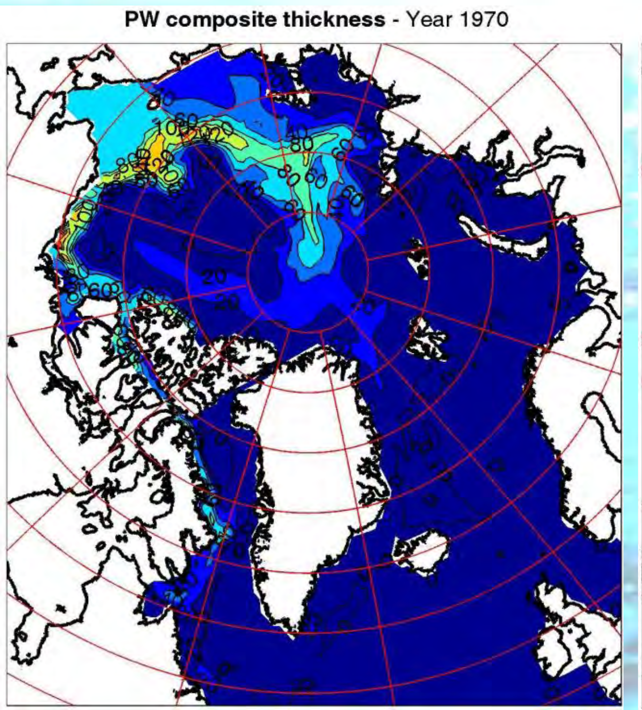


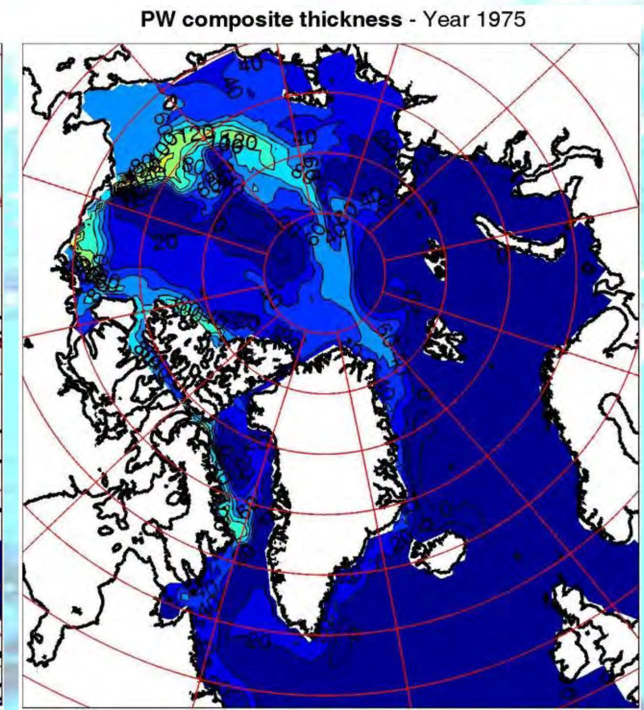
In the early 1990s warm water from the Fram Strait is transported by the boundary current along the continental slope. Near the Lomonosov Ridge the warm signal splits into two branches following the circulation pattern.







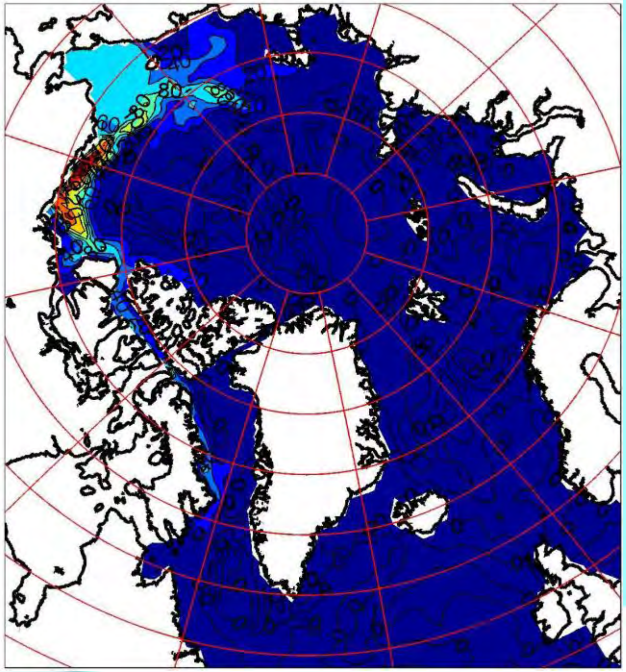




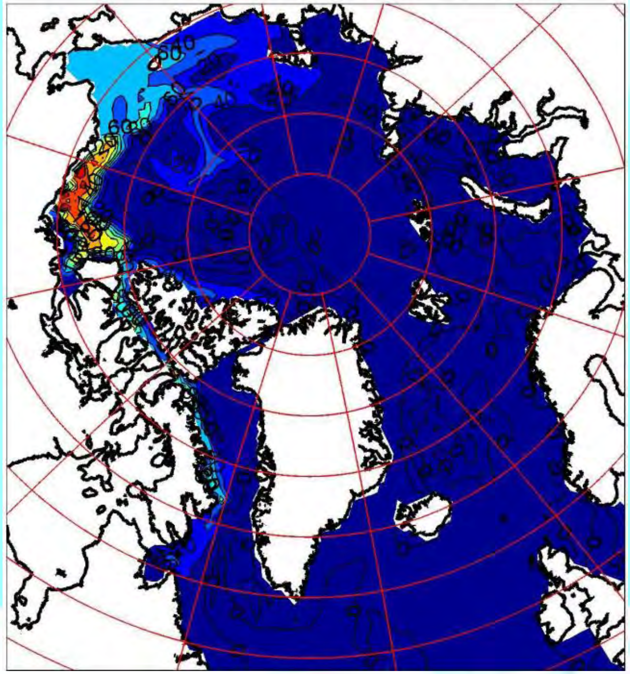
<u>PW circulation features in 1960's</u>

- 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

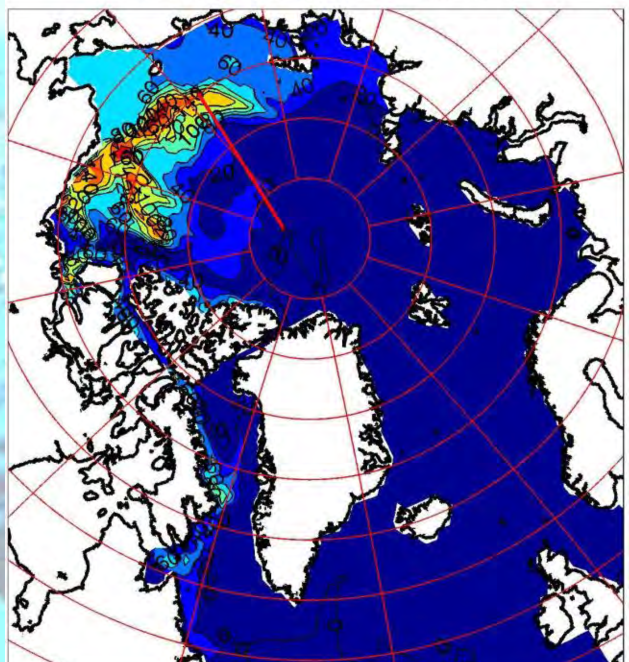
PW composite thickness - Year 1991

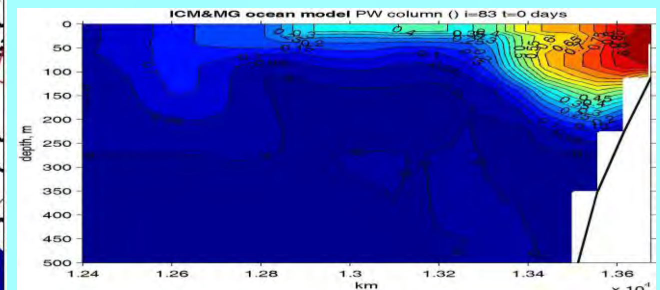


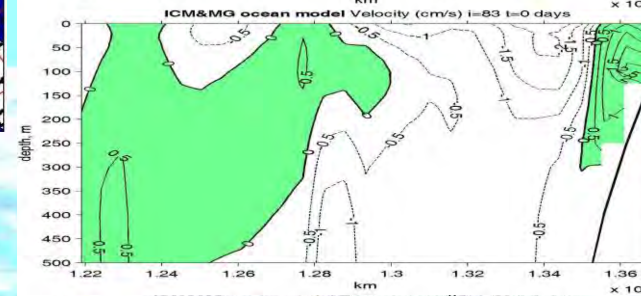
PW composite thickness - Year 1993

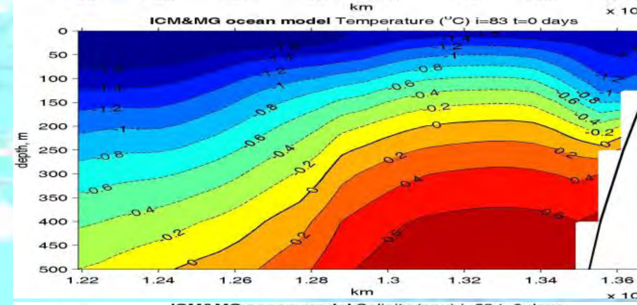


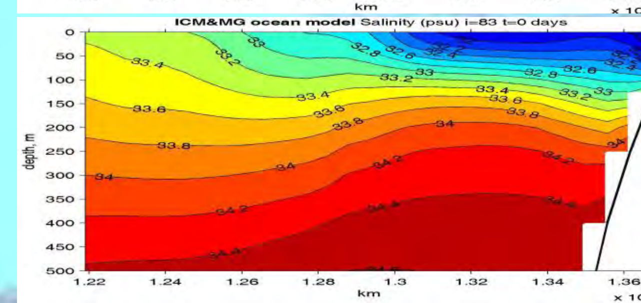
PW composite thickness - Year 1999



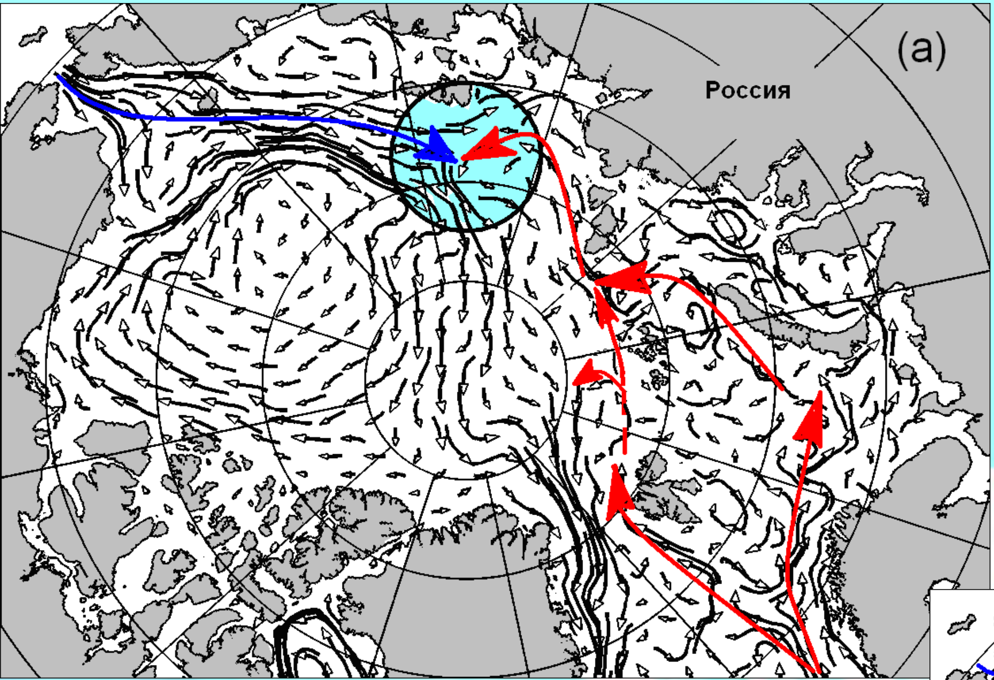






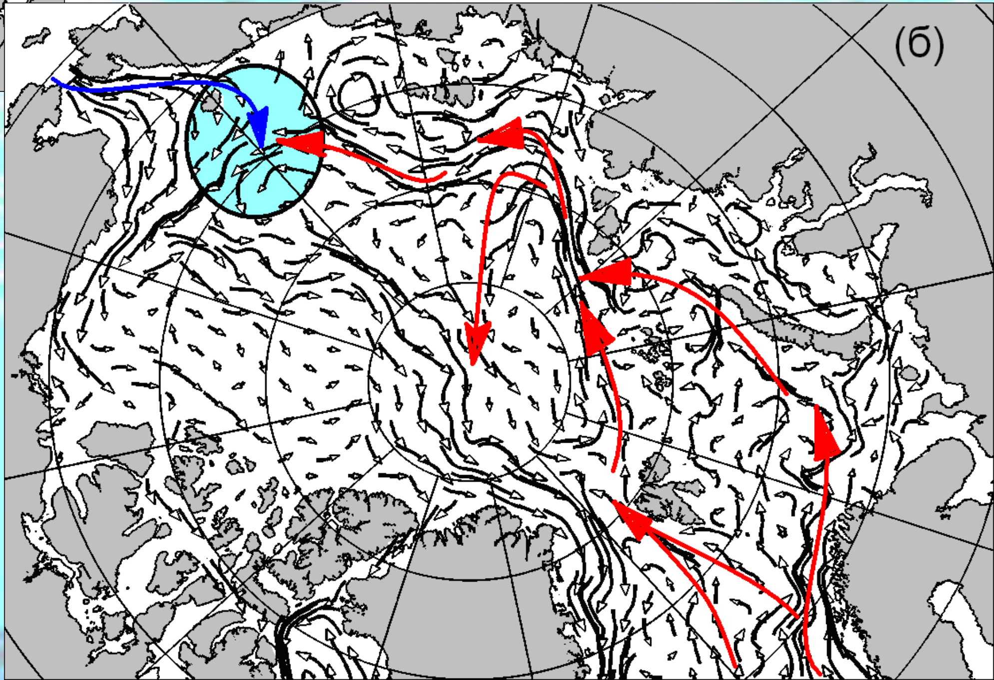


Shift of the zones of the penetration of the Atlantic and the Pacific waters (velocities at the depth 50 m)



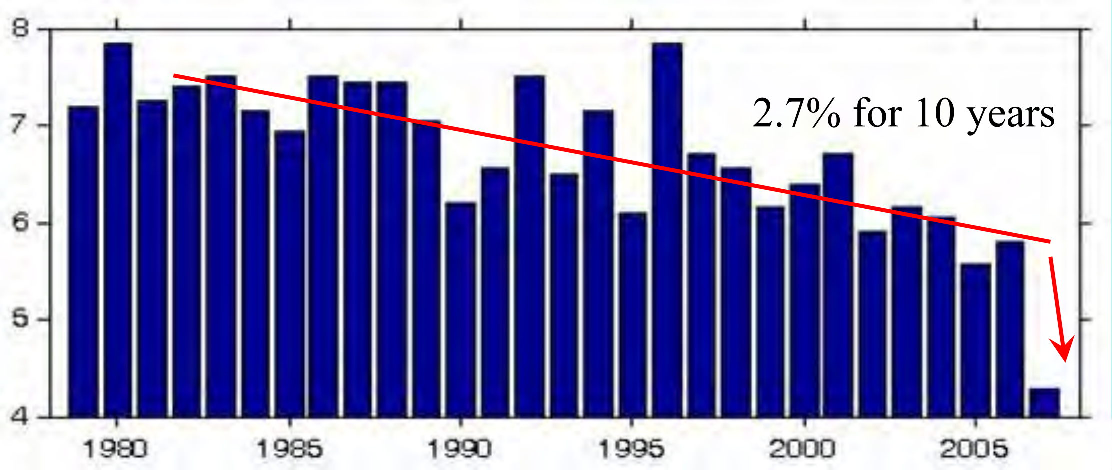
(a) – 1970,
(b) – 1990.
Rounds on the pictures show the zones of the penetrations of the Atlantic and the Pacific waters as the response to the atmospheric forcing

The strong inflow of warm Atlantic water coming from the Fram Strait. PW turns 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 1990s



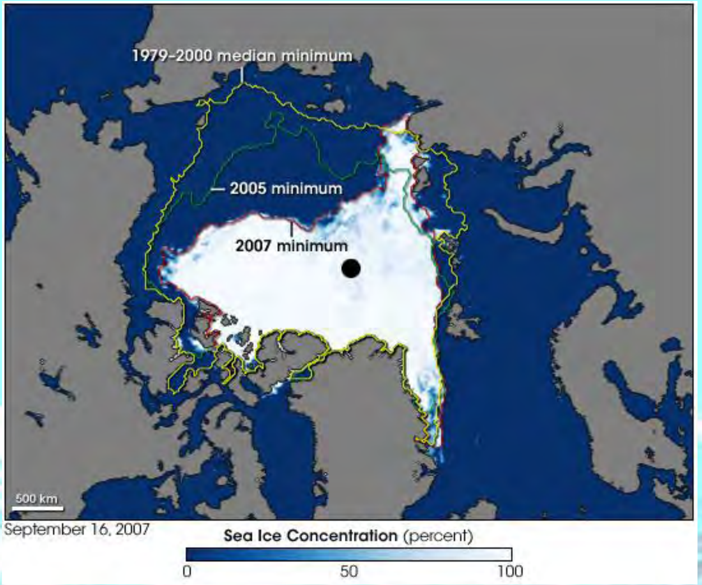
Ice cover variationsfor the period 1948 – 2007 гг.

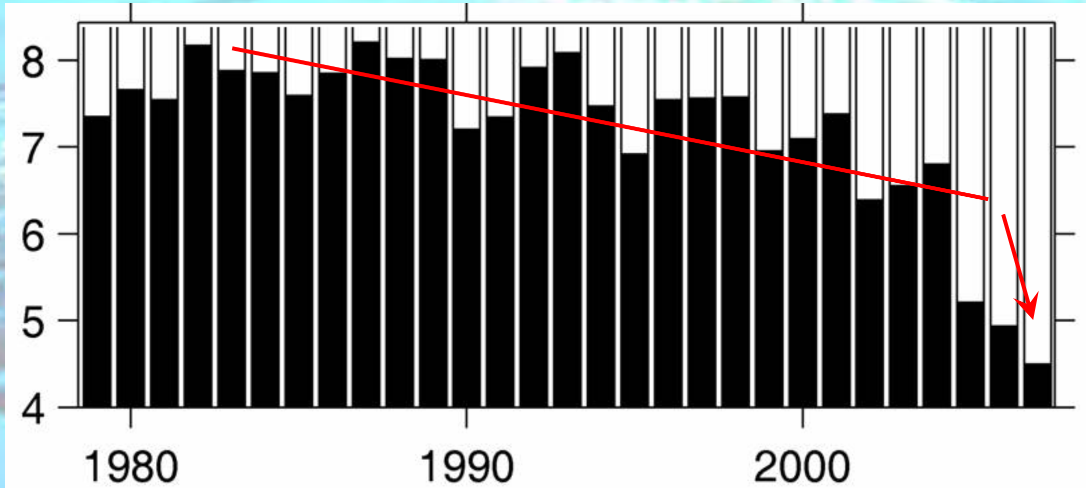
Arctic ice decreasing (mln. km2)



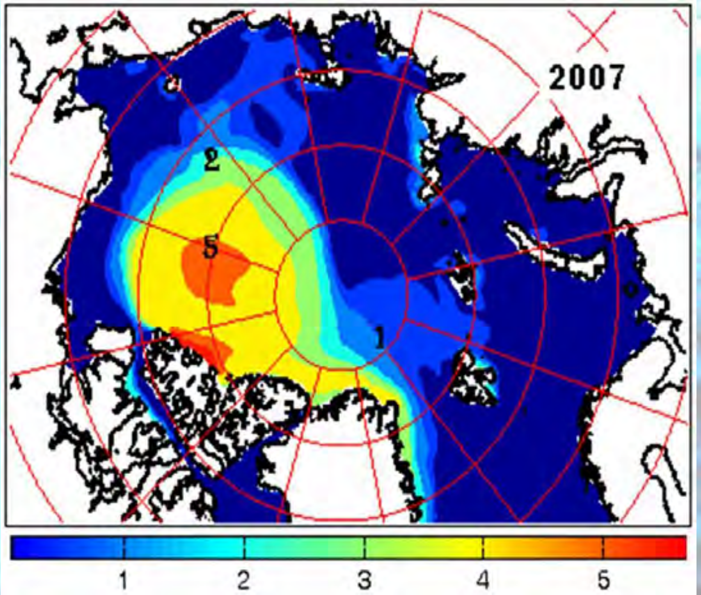
Data

2007. Ice cover minimum

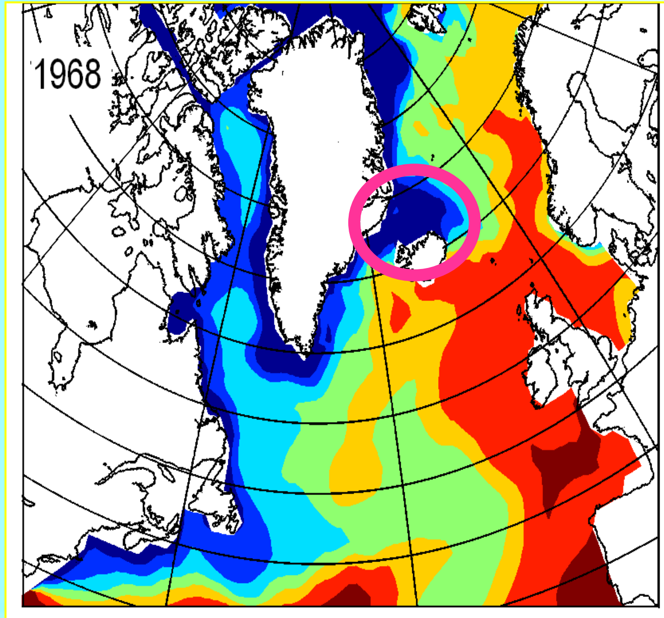


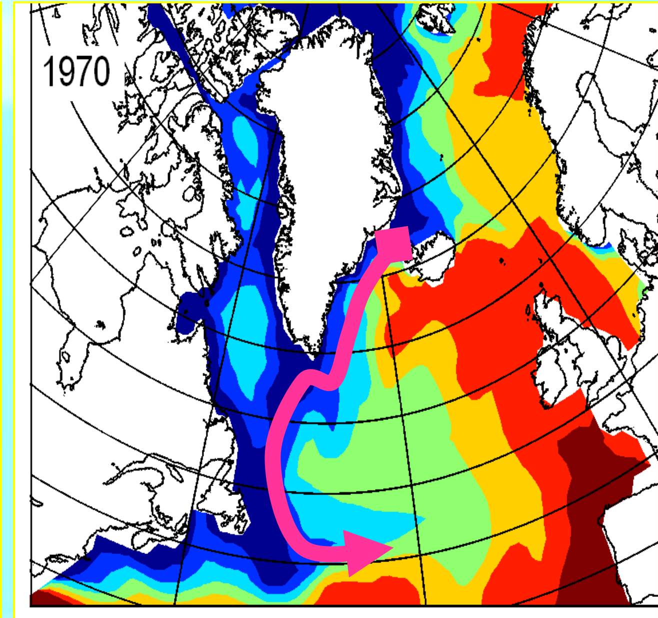


Model ICM&MG

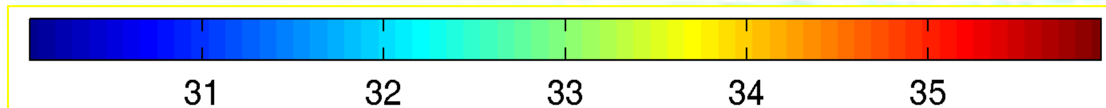


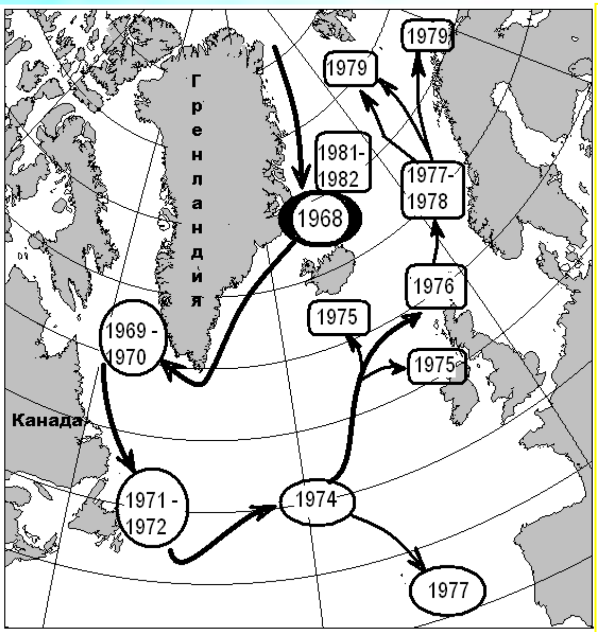
The pathway of the Great Salinity Anomaly in 1968-1979 according to model results

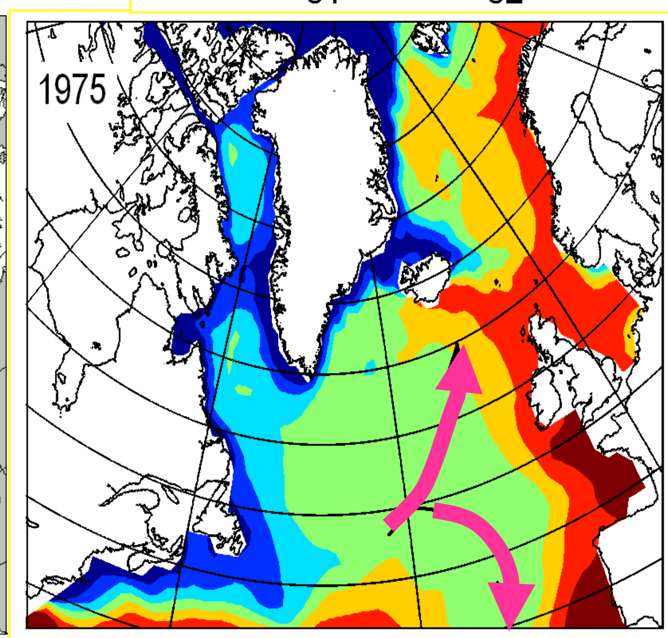


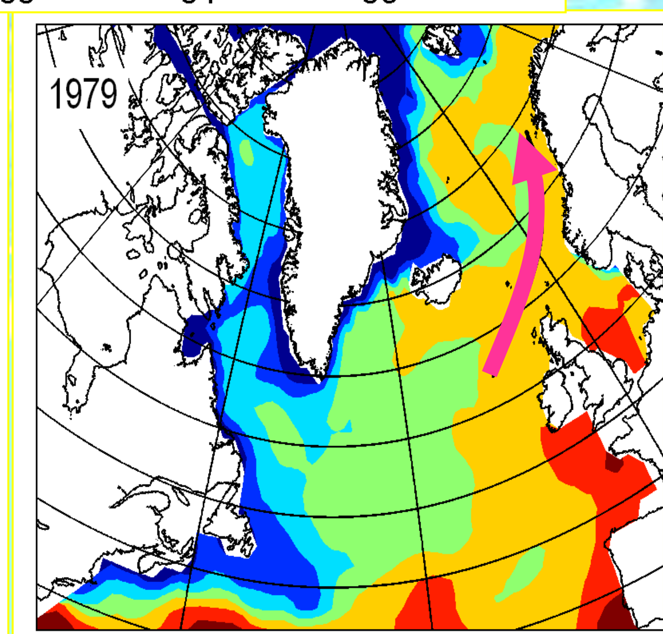


The pathway of the Great Salinity Anomaly in 1968-1982 according to Raymond W. Schmitt *(http://www.whoi.edu/oceanus)*

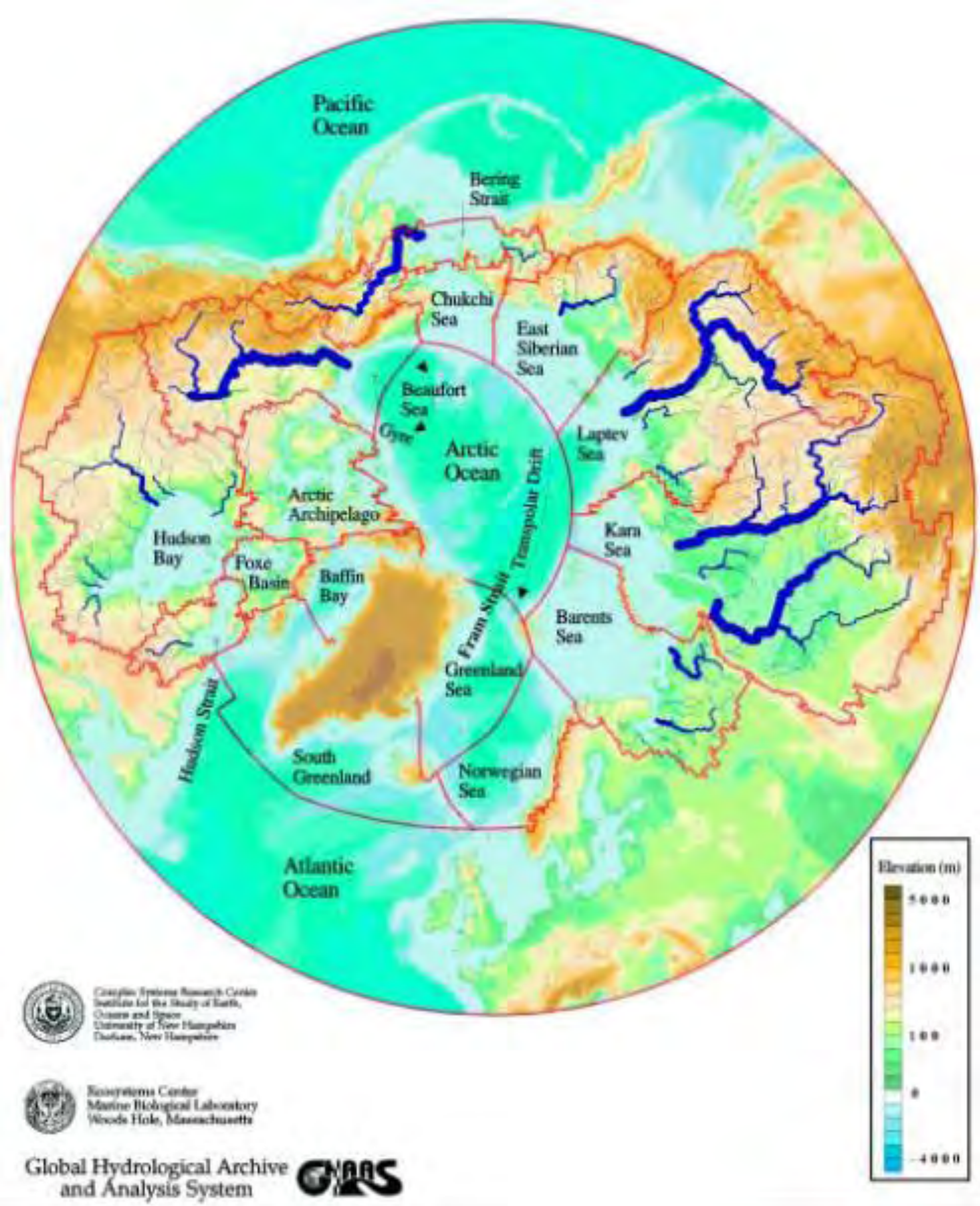








Arctic basin and the main rivers

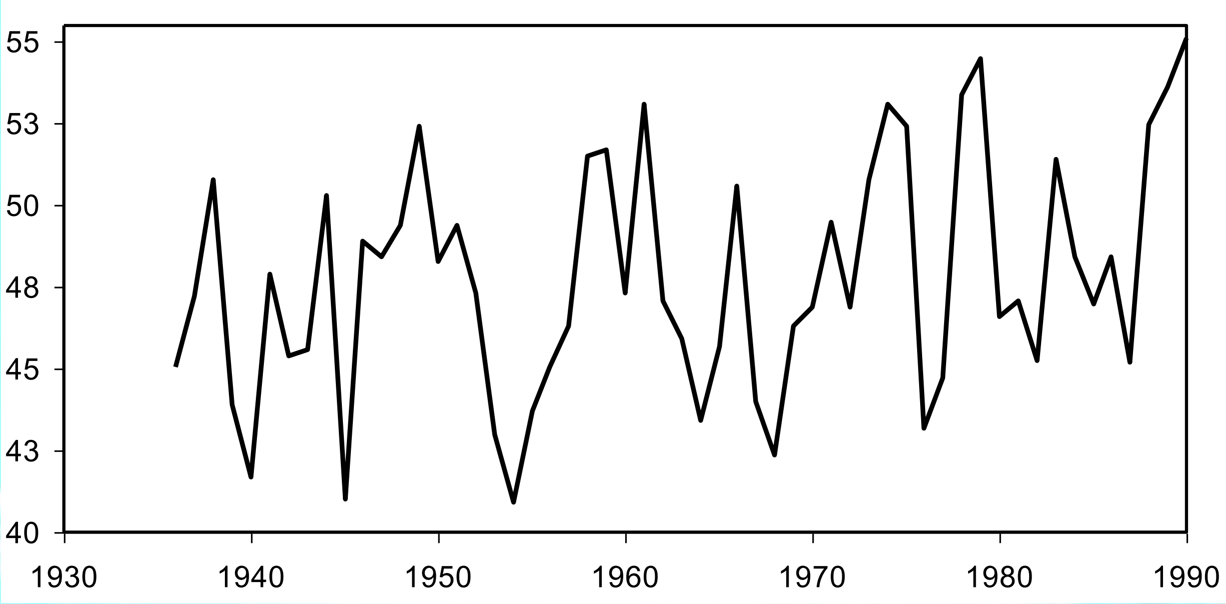


Arctic ocean form 5% of total area of the World ocean (14.4 mln km^2, Ivanov, 1976) and 1% of its volume. However it gives input 11% of total rivers water into the World Ocean (Kalinin, Shiklomanov, 1972).

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 km^3/y (Agaard, Karmak, 1989, Sereze et al, 2006, Woodgate et al, 2006, Shiklomanov, 2010).

NUMERICAL EXPERIMENTS WITH RIVER RUNOFF VARIABILITY

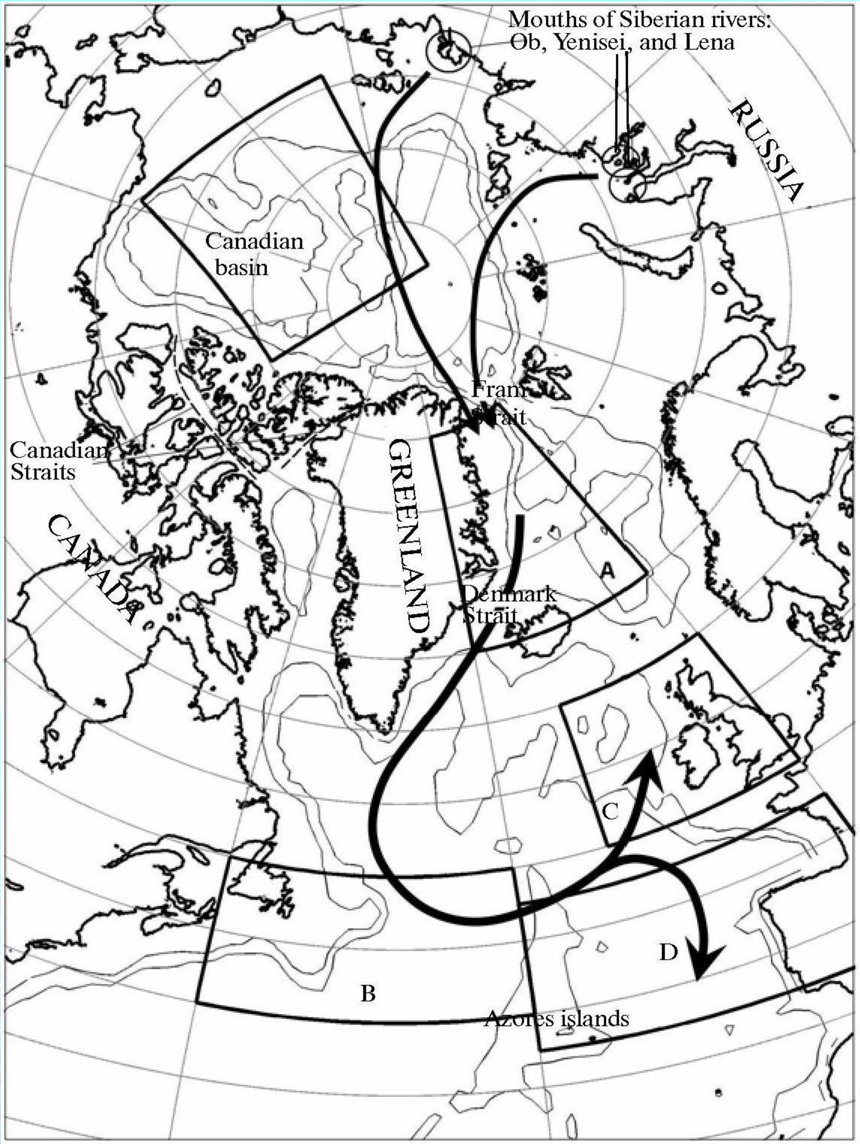


Total volume transport of Yenisei +Lena +Ob Rivers (th. cubic m/s)

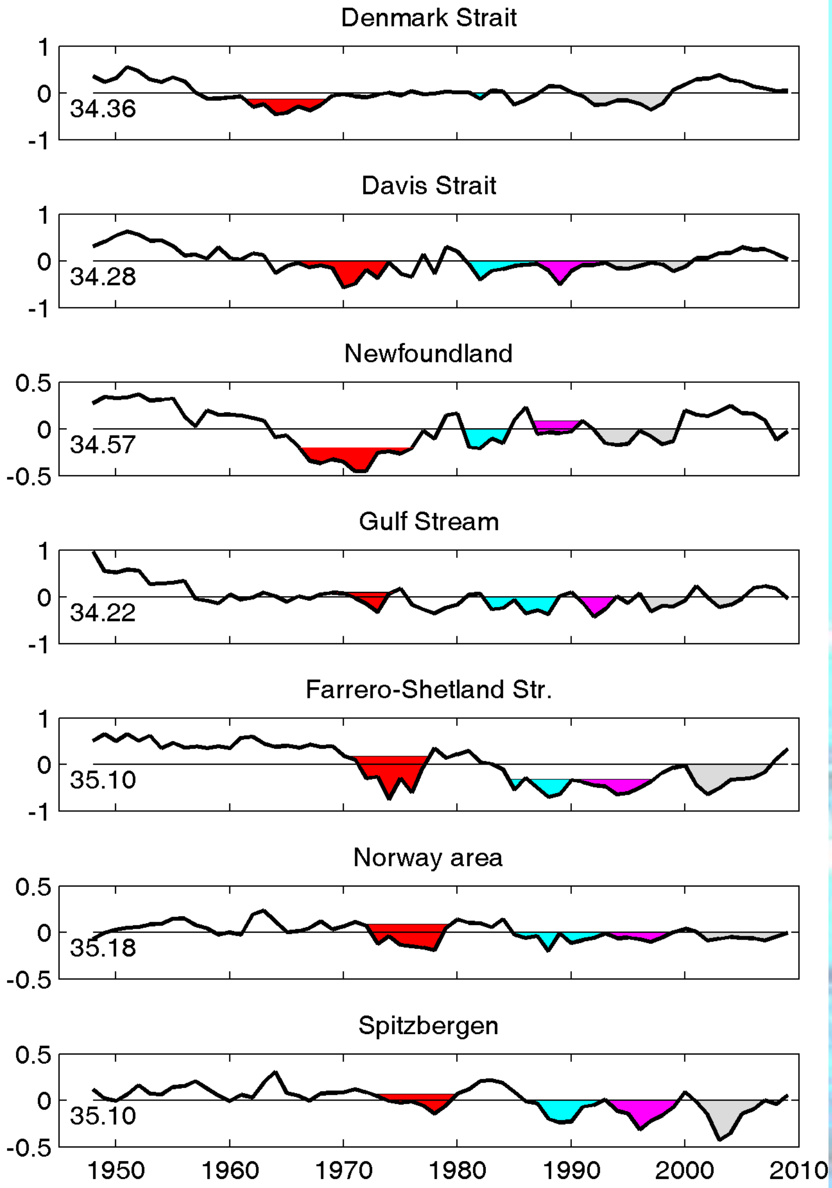
Straits	Freshwater discharge
Fram Strait	-0,75
Canadian Archipelago	0,71
Barents Sea	0,40

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 losses of freshwater though these straits.



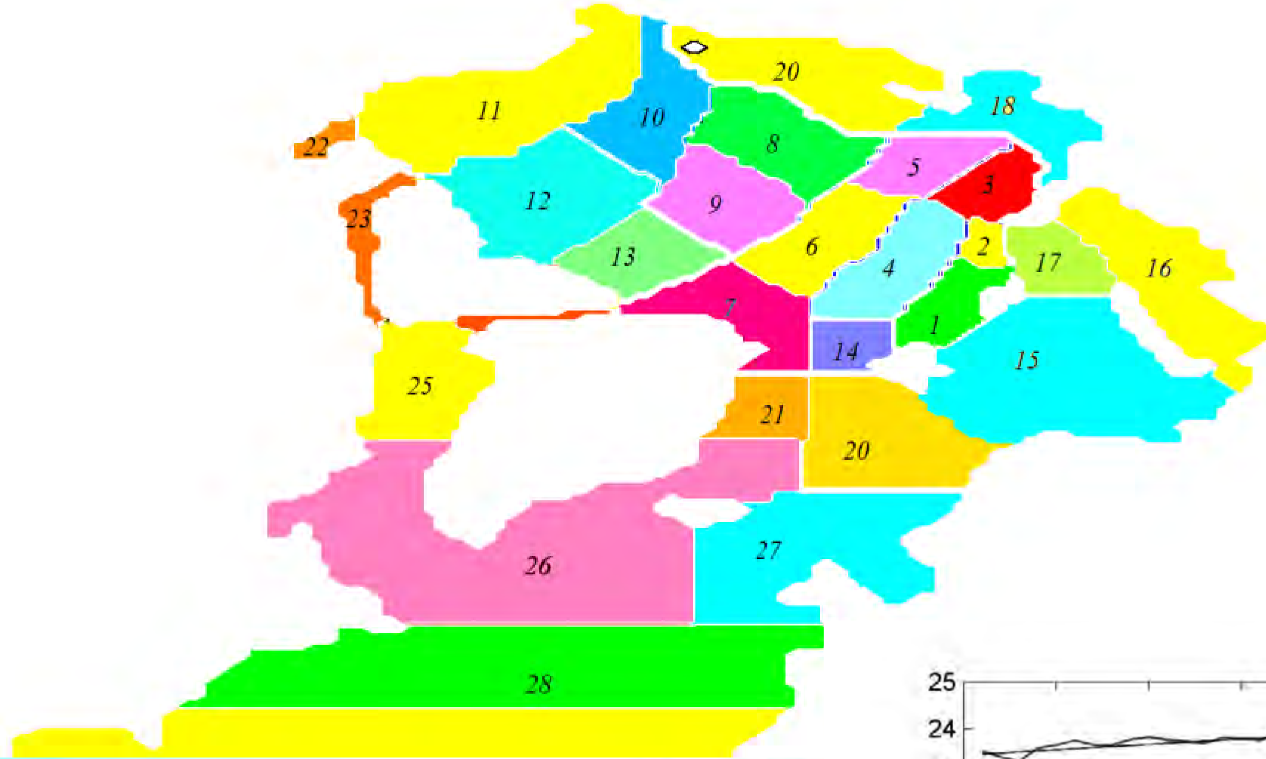
Arrows in the Arctic Ocean schematically snow the trajectory of the river discharge anomaly in 1958-1962; this anomaly arose due to the difference between the observed and climatic river discharges. Bold arrows in the North Atlantic show the approximate pathway of the GSA.



Salinity anomalies propagation through the straits

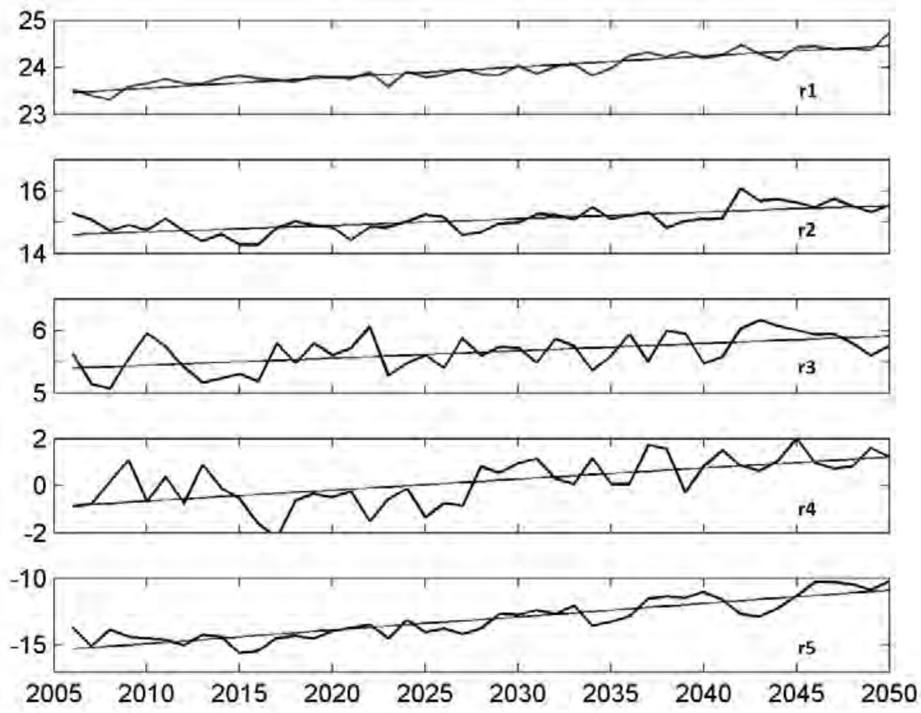
RUN 2

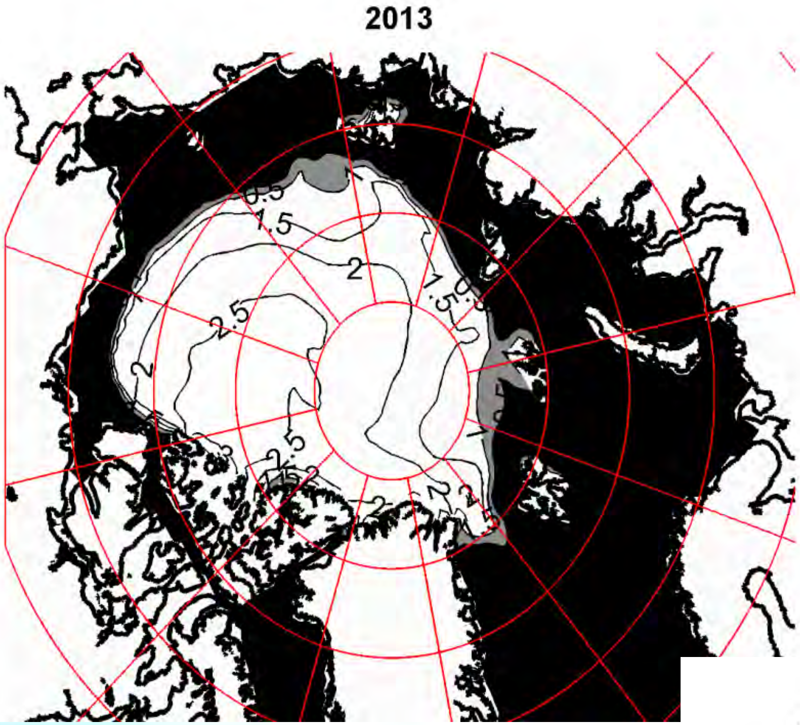
Period 2006 – 2050
Atmospheric forcing from the model CNRM/CERFACS, Experiment RC8.5 (IPCC scenario)



Regions separated in the modeling domain

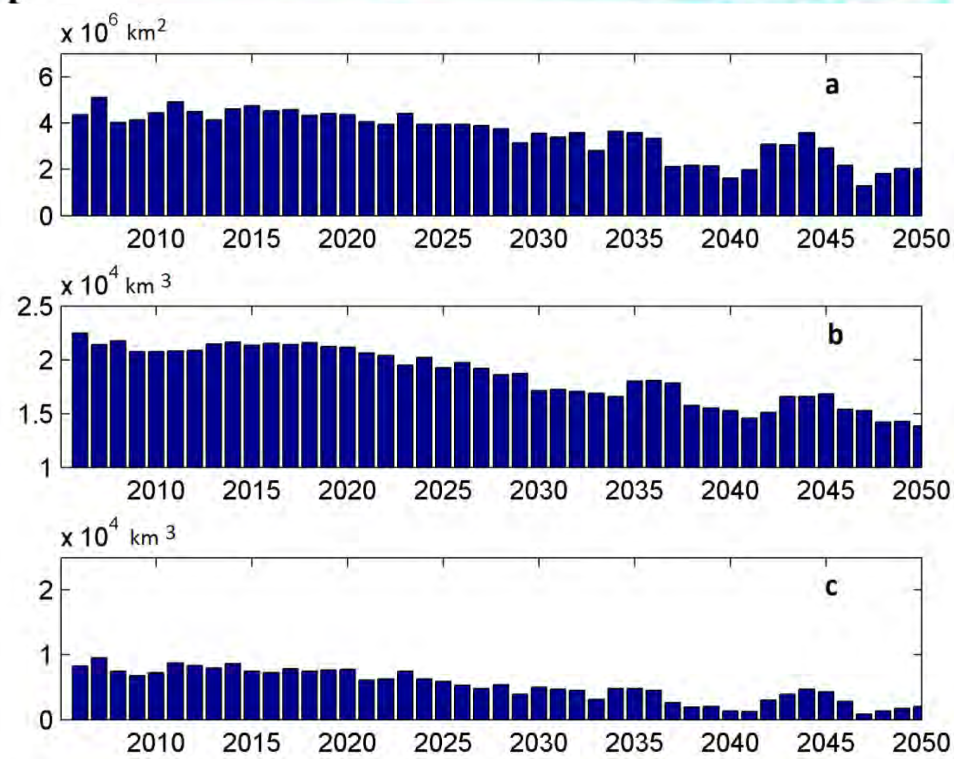
Annual mean air temperature averaged by the regions, represented above:
r1-region 29,
r2 -region 28,
r3 – regions 26, 27,
r4 –sectors 20, 21,
r5 – sectors from1 to 14.
Linear trend is more intensive in Arctic (appr. 0.1 grad.C/y).



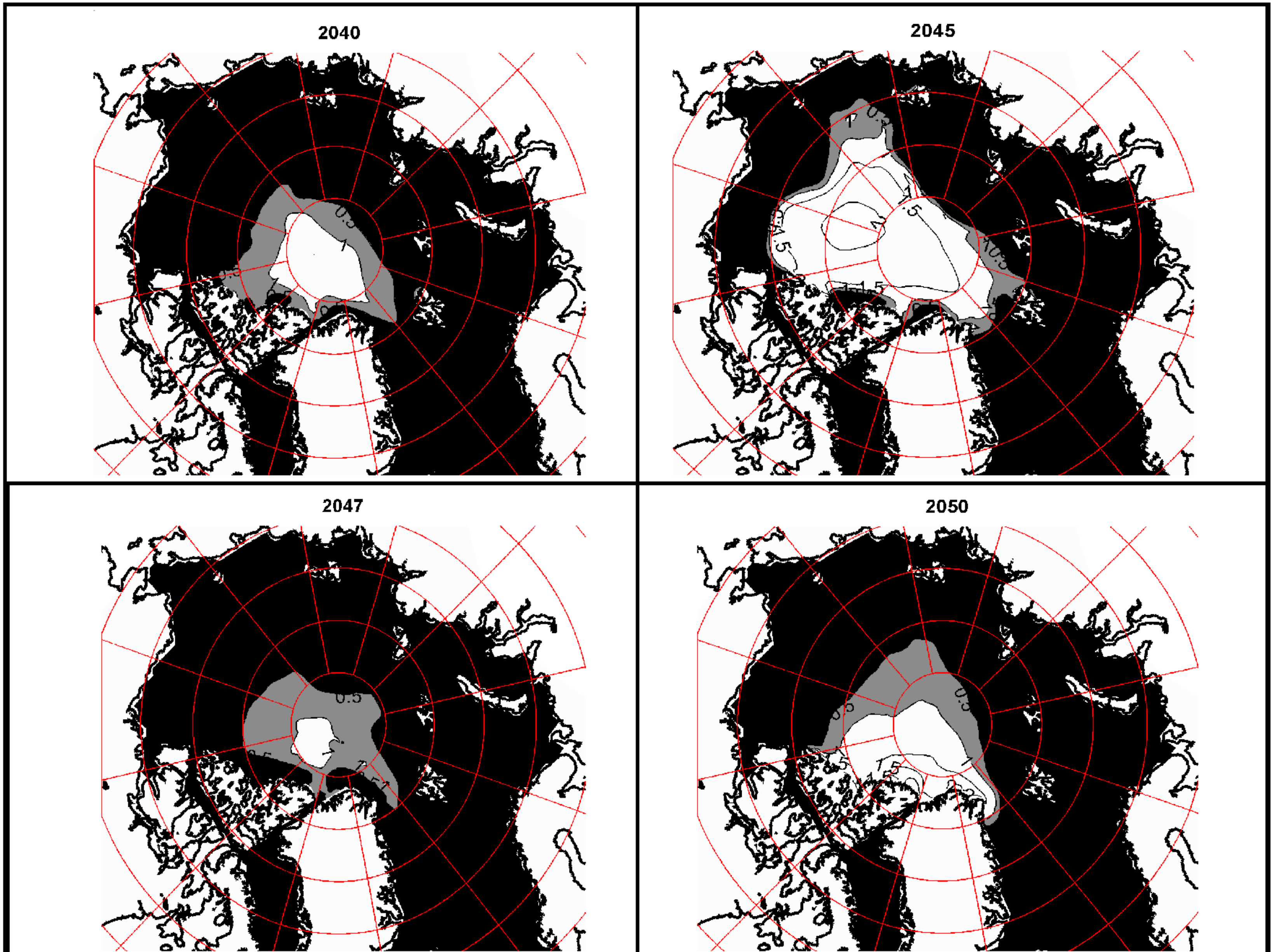


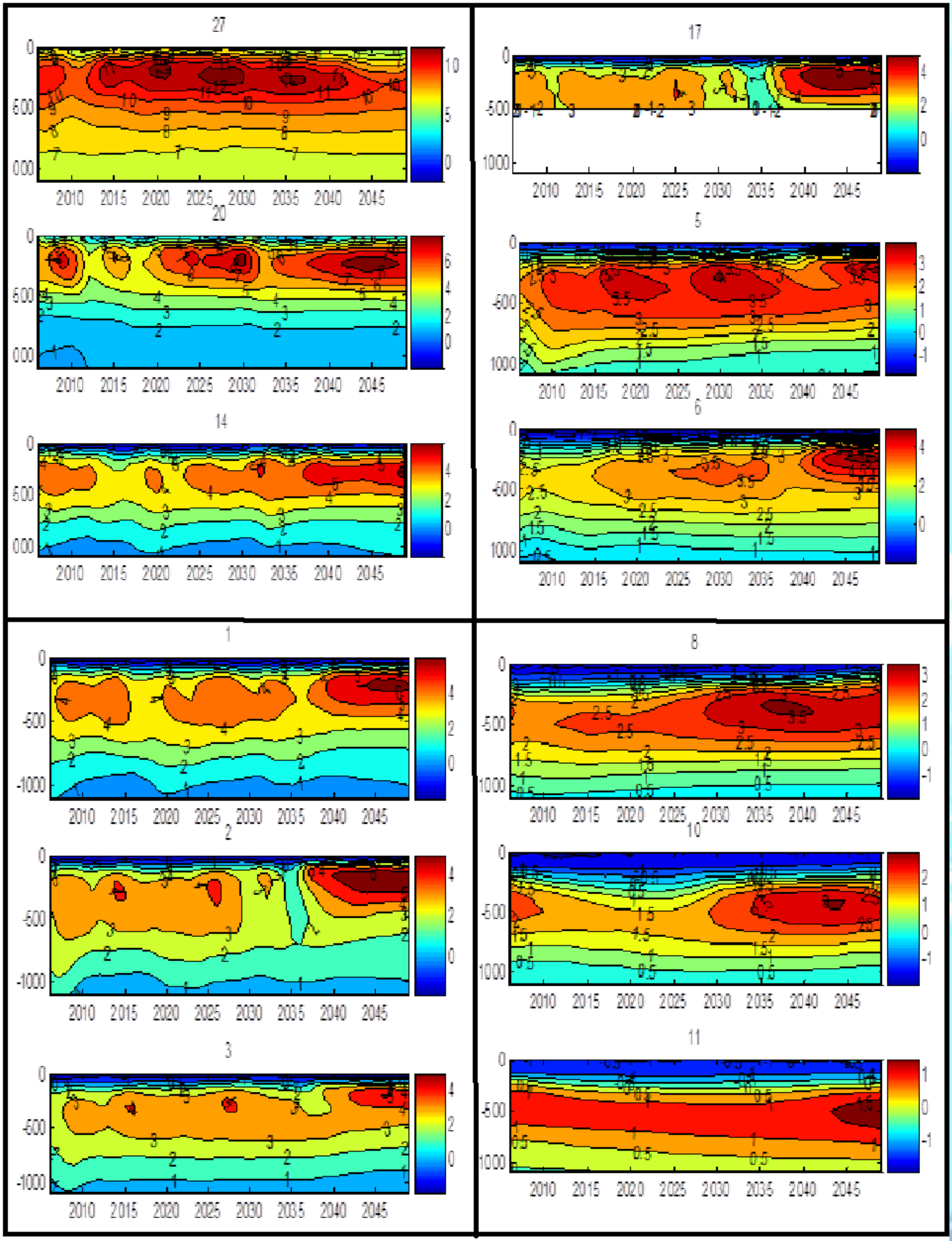
Spatial distribution of the ice thickness for the September in meters for 2013

Temporary distribution of the ice in the Arctic Ocean:
a) Total minimal ice square;
b) maximal volume of the ice;
c) minimal volume of the ice.



Spatial distribution of the minimal (September) ice cover in the last decade





Temporal variability of the temperature vertical profile averaged by the regions presented above

Velocity at the depth 200 m for the different periods

Conclusion

- A numerical simulation with a coupled sea-ice model of the Arctic and North Atlantic oceans is used to study the Arctic Ocean behavior of the hydro-physical characteristic in the last half of XX century and the first half of the XXI century.
- The numerical experiments with the reanalysis data forcing confirm the existence of two regimes of ice drift and water circulation which leads to the redistribution of the Atlantic and the Pacific water propagations.
- The model ice cover is characterized by the decreasing of the ice square with the speed of 2.8% per decade with more intensive degradation in the last decade.
- 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 the World ocean what control the thermohaline circulation and hydrological cycle.
- The projection for the future century shows that the conditions of the ice cover and water masses are characterized by essential variability.
- The ice cover in accordance with the atmospheric air and Atlantic water temperature increasing decrease during this period with some variations. However, until 2050 Arctic ocean partially is covered by ice with depth less 2 meters.
- The temperature field show the series of the temperature signals which comes from Atlantic and moving along the bottom slope and influence to the thermohiline structure in Arctic Ocean.

Thanks for attention!