On the freshwater content modeling in the Arctic basin: a sensitivity study

Gennady Platov

Institute of Computational Mathematics and Mathematical Geophysics, Novosibirsk, Russia, Platov.G@Gmail.ru

Model and Data uncertainties that change FW balance in numerical experiments

1. **Precipitation rate** (in summer (10%) and in winter (80-120%), Yang et al 2005)
2. **River runoff** (ungauged volume is 30%, increasing trend of 2.9 ± 0.4 $km^3 a^{-1}$ Shiklomanov 2010)
3. **Pacific waters** (since 2001 Bering Strait freshwater variability is ~ 25% of the total annual Arctic river run-off (Woodgate et al 2006))
4. **Ice model** (Radiation and Cloudiness)
5. **Evap+Rivers-Precipit. balance**
6. **Vertical and horizontal diffusion**

Coupled Ice-Ocean Model

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

(Kuzin1982, Golubeva at al.,1992, Golubeva,[2001], Golubeva and Platov,[2007])

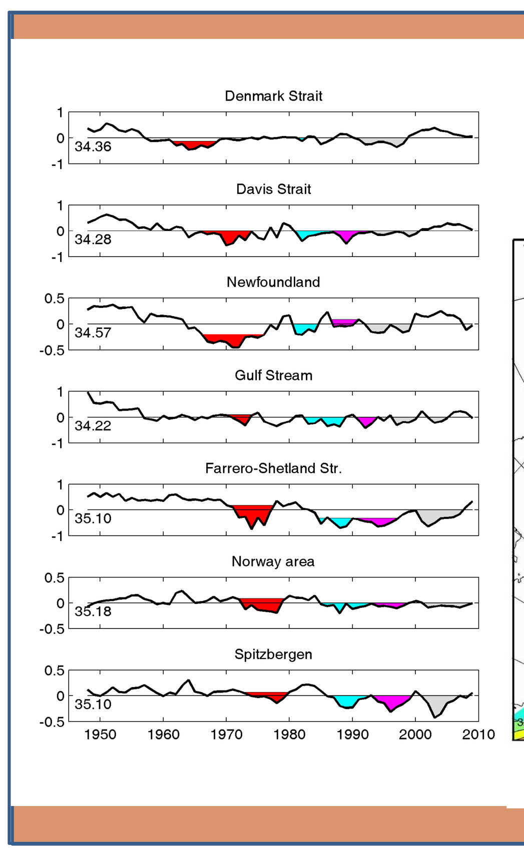
Ice model-CICE 3.14 (elastic-viscous-plastic)

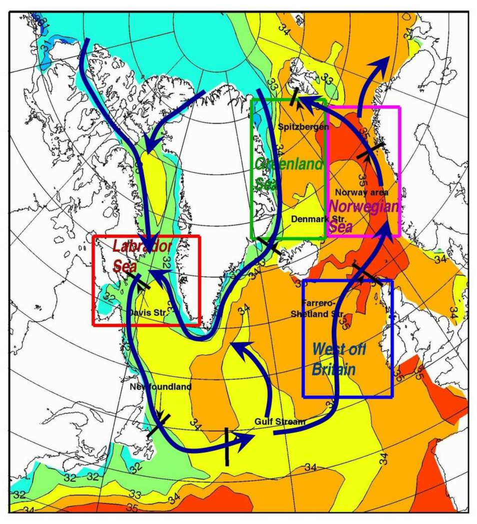
W.D.Hibler ,1979, E.C.Hunke, J.K.Dukowicz,1997, G.A.Maykut 1971

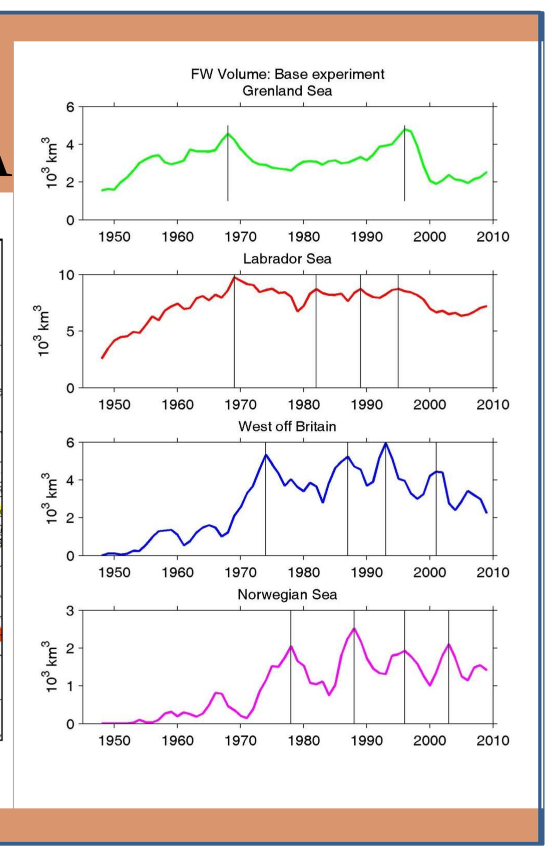
C.M.Bitz, W.H.Lipscomb 1999,J.K.Dukowicz, J.R.Baumgardner 2000, W.H.Lipscomb, E.C.Hunke 2004

A set of the model parameters were chosen to conduct numerical experiment which we called "Base experiment". By variation of "uncertain values" we planed to examine their roles in FW balance. But first we have to be sure that our Base experiment shows a reasonable result. The important part of the FW balance is the reproduction of Great Salinity Anomalies. Next plot represents the timeseries of GSA at different locations in terms of salinity in upper 100 m. Red shading color corresponds to the GSA'70, cyan – to GSA"80, and pink – to GSA"90. Also grey color represents the anomaly, which propagates in North Atlantic in 2000s. The same GSAs could be traced in terms of FW volumes of presented four areas.

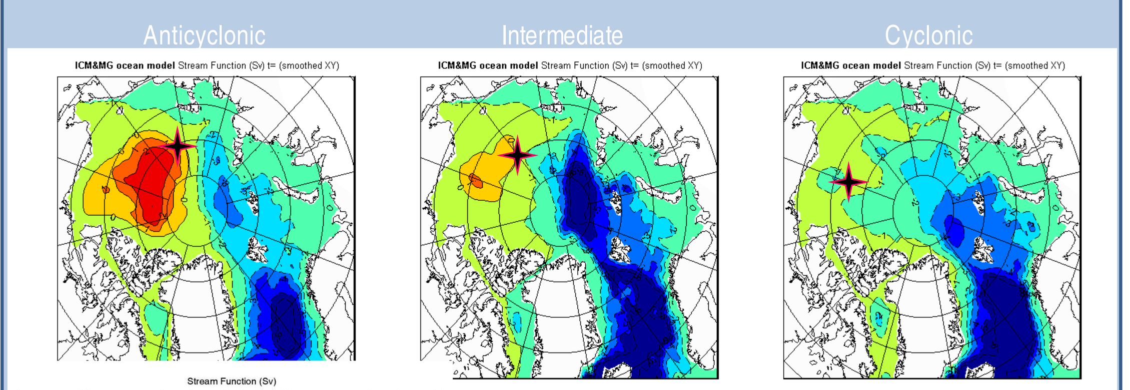
Base model experiment: GSA

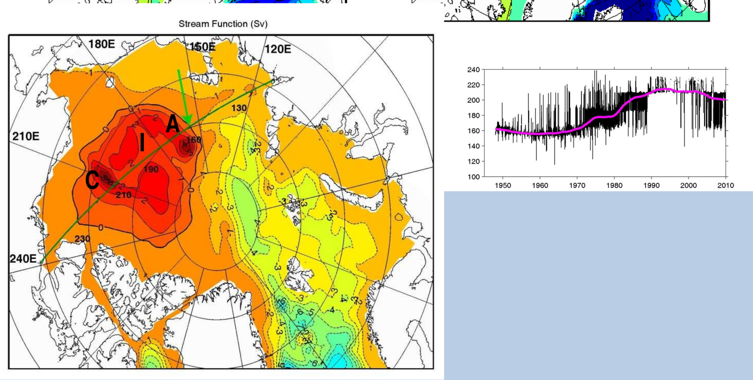




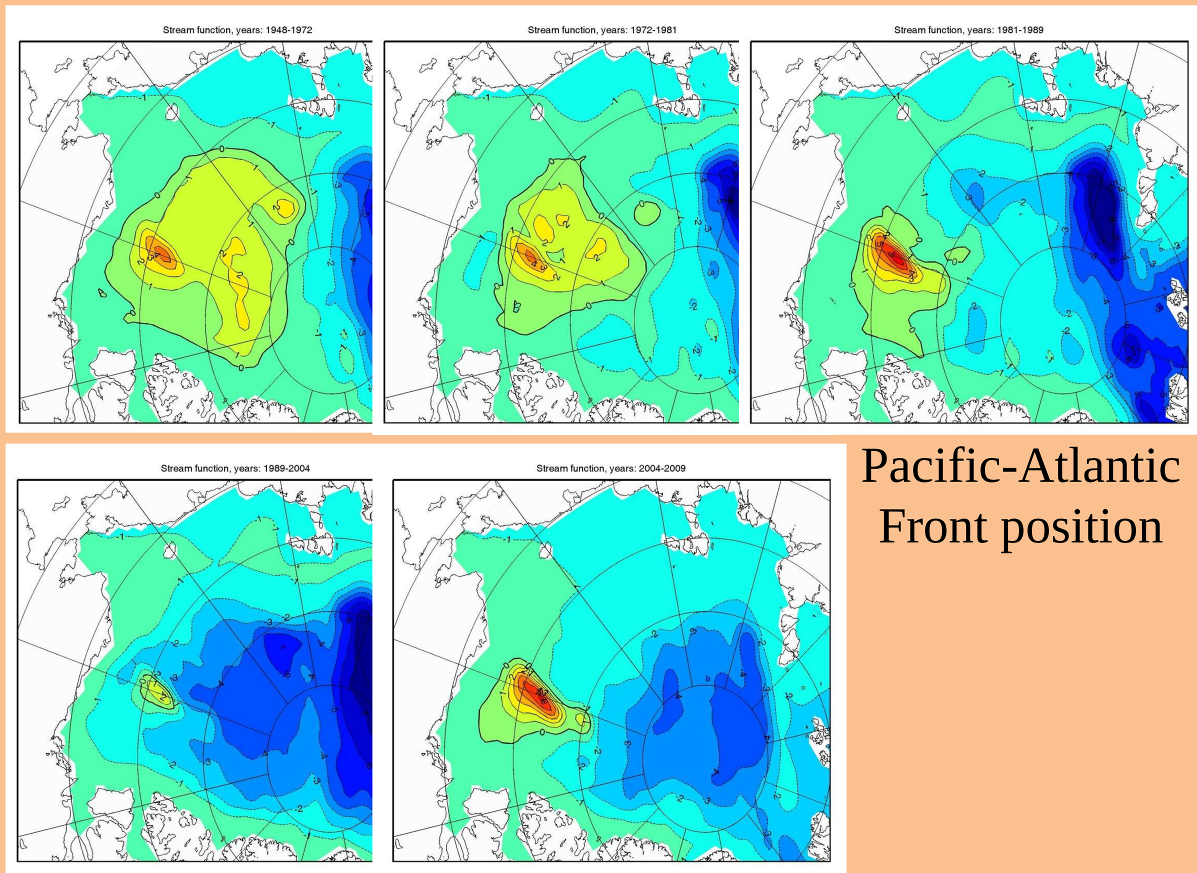


Arctic Circulation Modes

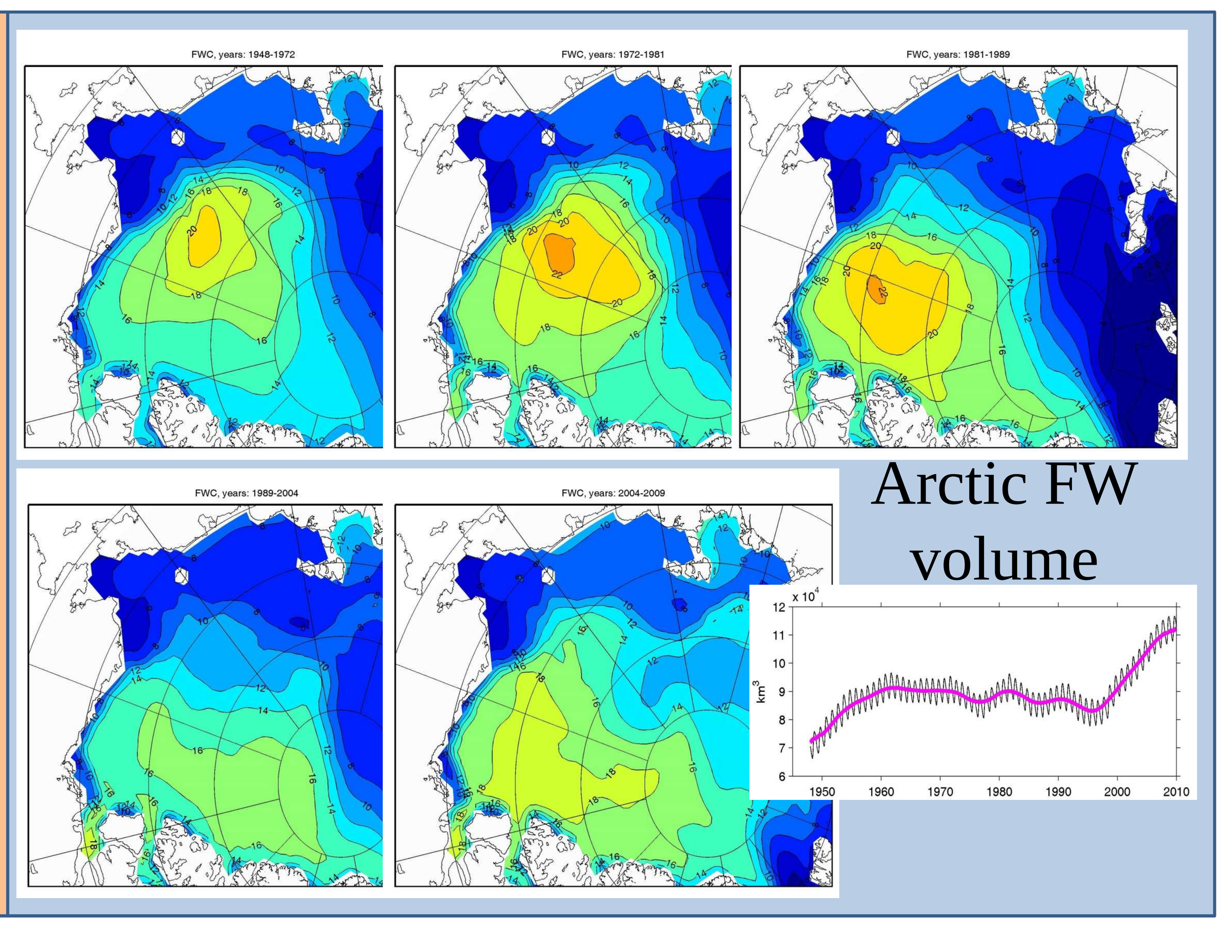




The Beaufort Gyre circulation cell is a storage place of FW in Arctic and its extention is constrained by Pacific-Atlantic water front. We considered its position as the east longitude of a point lying on the specified line, where the zero isoline of the stream function crosses it. The timeseries of this value showed that Pacific-Atlantic front was more or less stable in 1950-1970, but after that it started shifting toward Beaufort Sea. In 1990s the Beaufort Gyre was almost disappeared, but in 2000s it started a slow recovering.

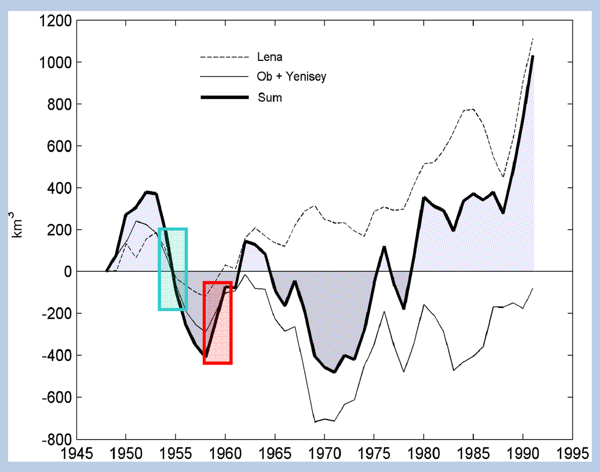


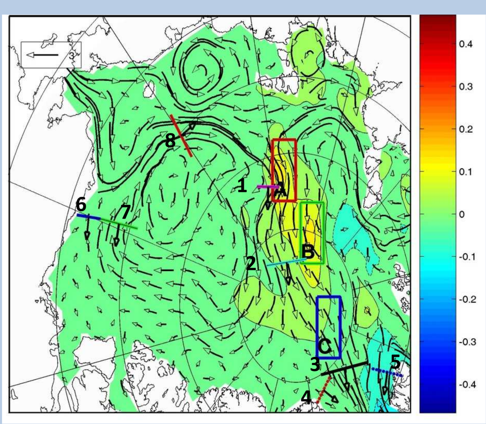
Pacific-Atlantic Front position



Arctic FW volume

Interannual variability of river discharge

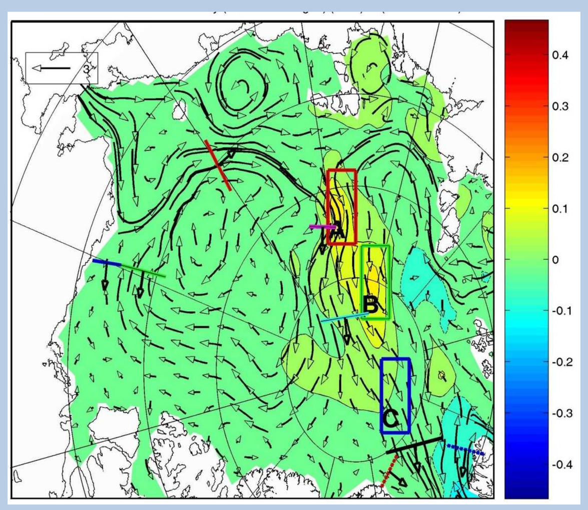


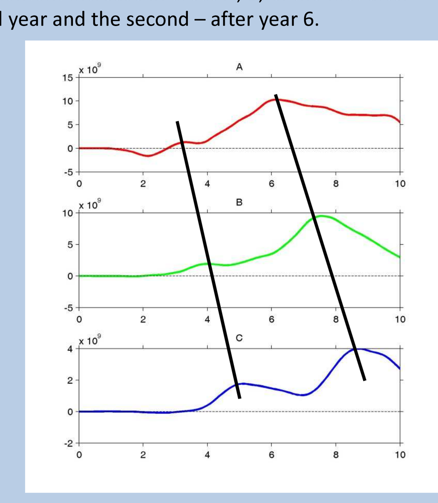


The first parameter to be varied in our numerical tests was the river runoff. If we look at the timeseries of accumulated Siberian river discharge, we notice that there were several periods of its growth and decrease. We chose 1953 as sample year of negative change and 1958 as one of positive change, and performed two experiments in which seasonal river runoff variation was climatic, but first test had a negative anomaly in Siberian discharge in 1953 and second – a positive anomaly in 1958. The resulting anomaly of FW content will be traced in areas A, B, and C along the Transpolar Drift Current and the dynamics changes will be traced in terms of transport changes through the specified sections: 1-3 – Transpolar Drift Current, TDC-1, TDC-2, TDC-3, 4-5 – Fram Strait (Greenland) and Fram Strait (Spitzbergen), 6 – Current Along Alaska, 7 – Beaufort Gyre, 8 – Beaufort Gyre plus Pacific Inflow

Positive anomaly in 1958

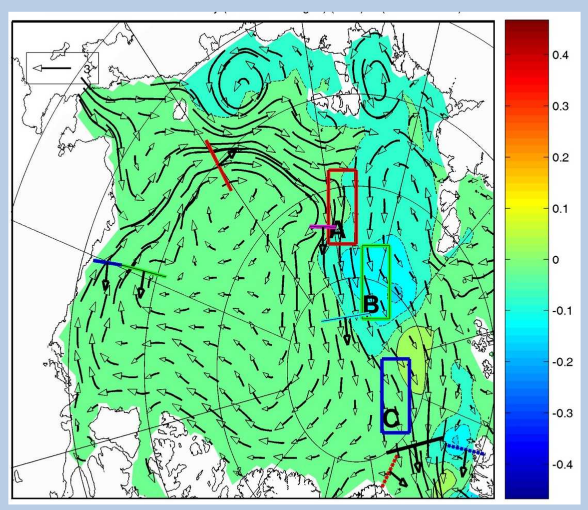
The positive anomaly of 1958 produces two waves of FW content increase in areas A, B, C: the first after third year and the second – after year 6.

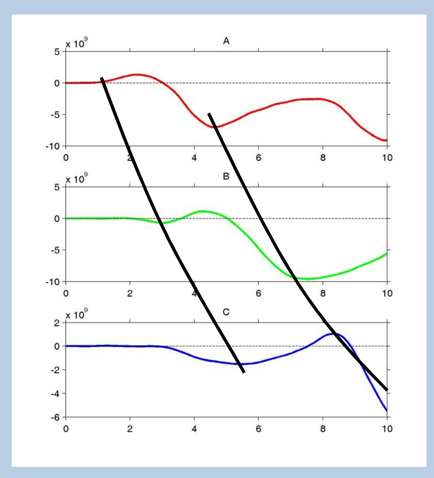




Negative anomaly in 1953

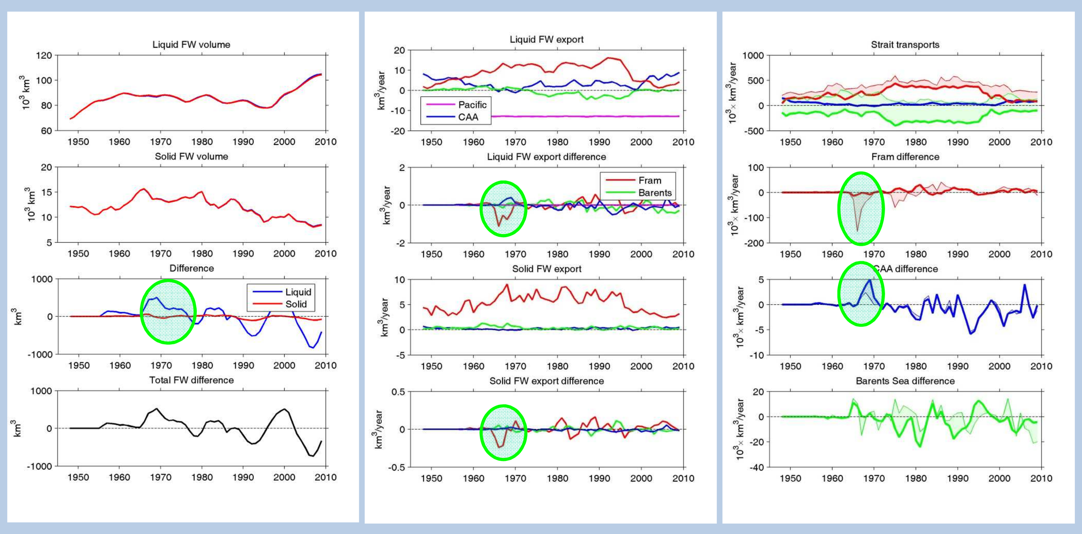
Negative anomaly features are mostly similar but of opposite sign.





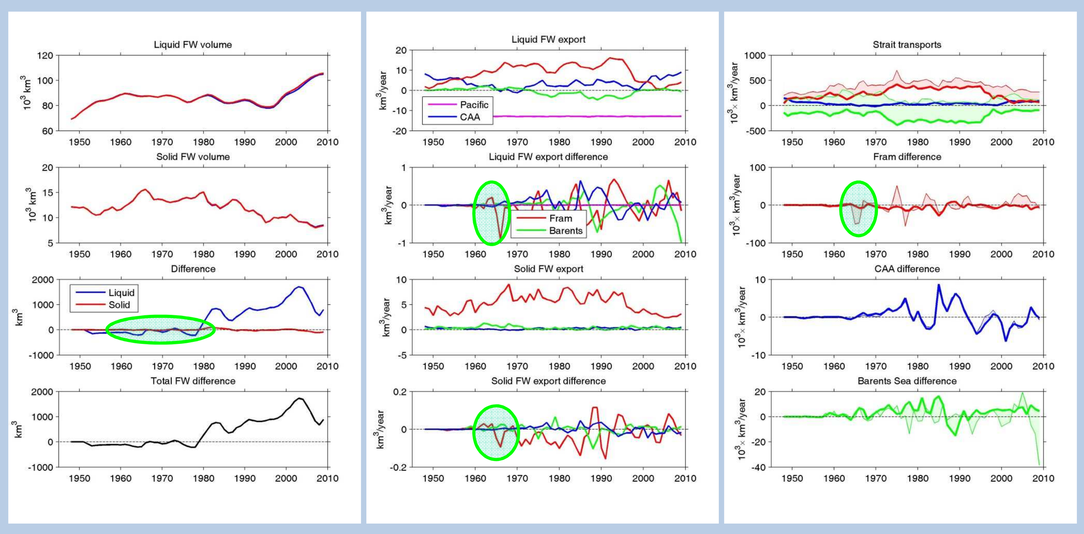
GSA reduction: positive anomaly

In 1968 the first known GSA was formed in Greenland Sea. During this period the difference between FW volumes reached its maximum. The export of FW into the Atlantic reduced, so the GSA became a bit weaker. We also can notice that outflow through the Fram Strait is decreased but an opposite decrease of Atlantic water inflow completely compensated it. Also the transport through the Canadian Arctic Archipelago increased.



GSA reduction: negative anomaly

Because 1953 is much earlier than GSA formation, its role is different. We see just a small changes in Arctic FW volume. Liquid and solid exports first increased for a short time but then decreased more remarkably. The outflow through the Fram Strait also lowered.



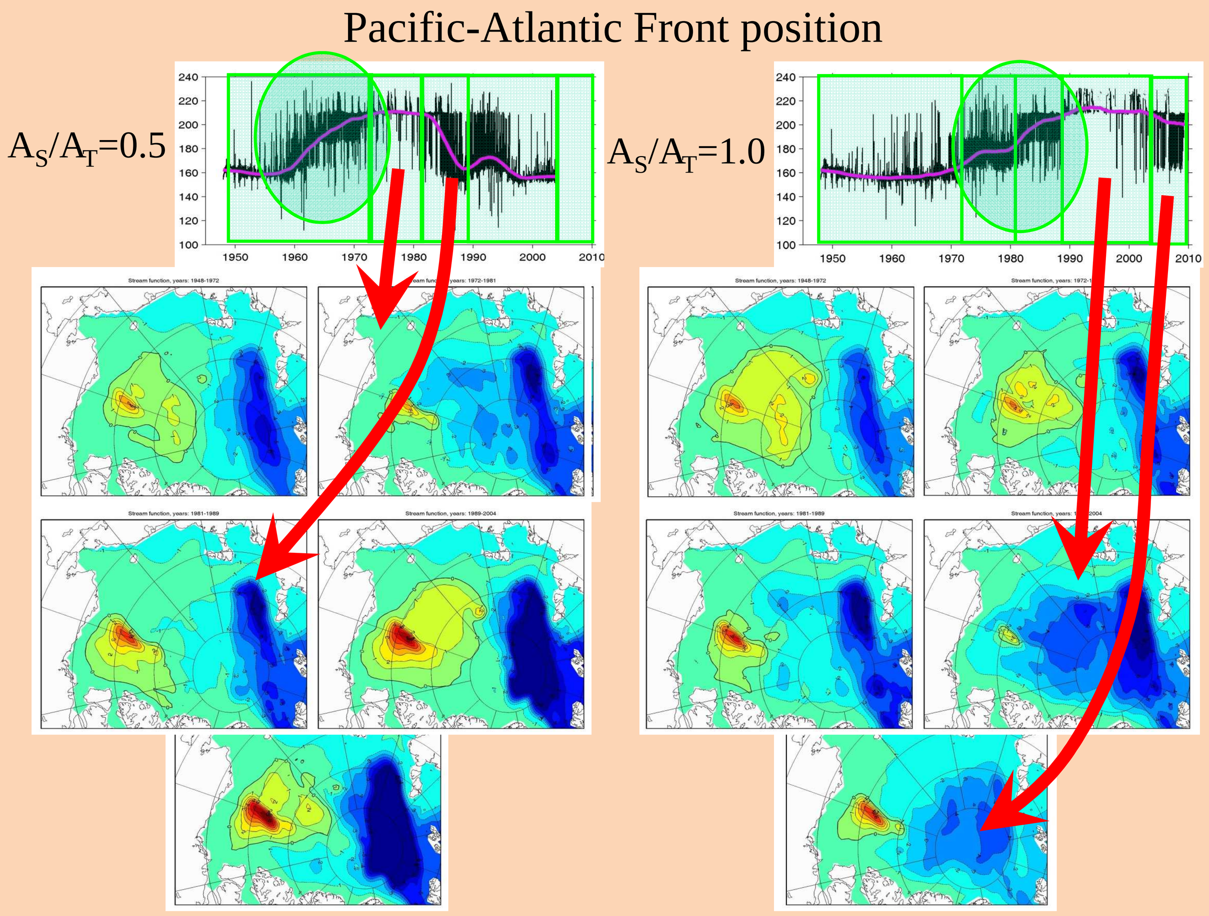
Vertical Diffusion

- Model "uncertainty"
  - Constrained by numerical stability
  - Regulate surface salinity minimum, formed by precipitation, river runoff and melted ice water
  - Regulate the Atlantic and Pacific water layer thicknesses, their interaction and their involvement into the surface layer processes

Different salinity and temperature vertical diffusion

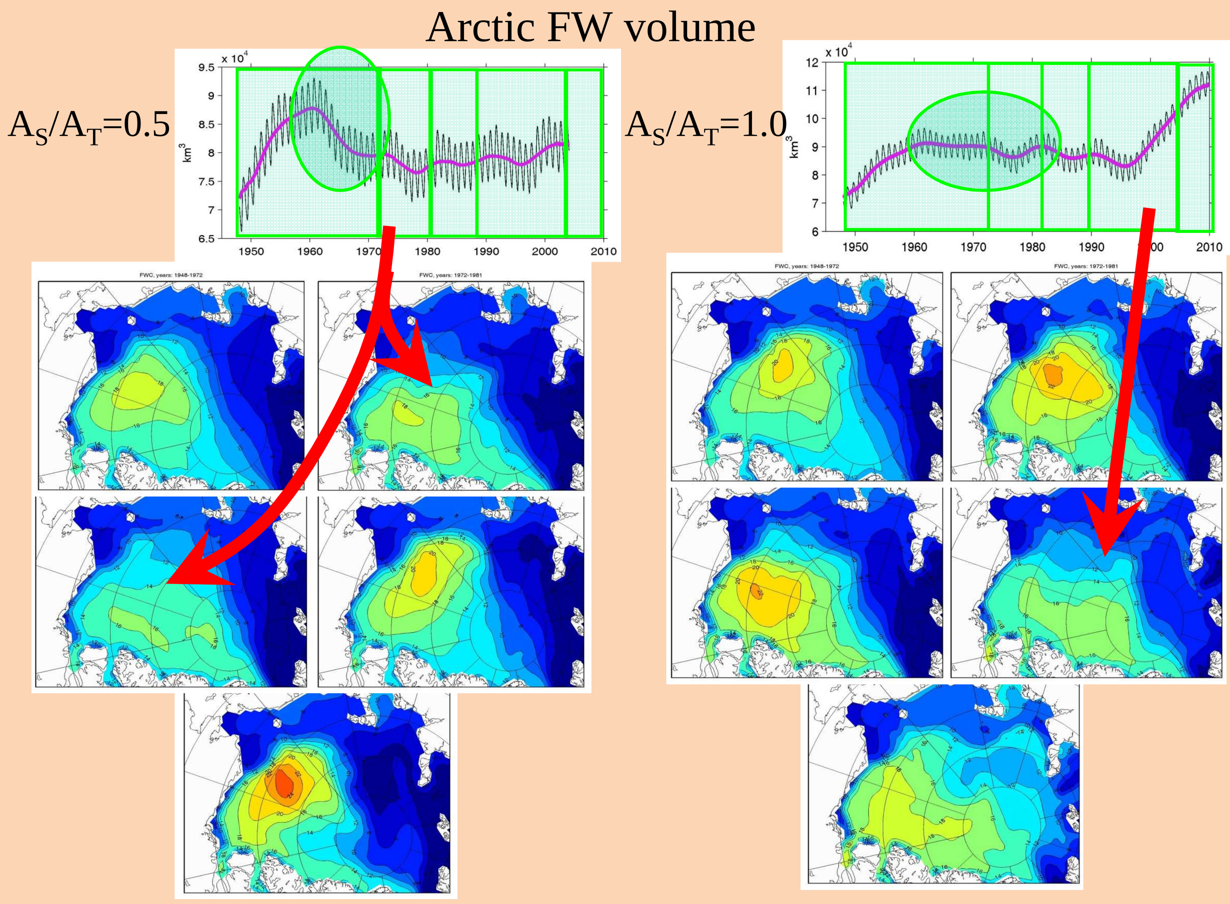
- Lower A_S/A_T ratio causes water to change its temperature faster than its salinity.
  - Salty and warm Atlantic waters in Arctic become colder faster than fresher, therefore their density increases and their position deepens
  - Cold and fresher Arctic waters in Atlantic become warmer faster than saltier, therefore their density decreases and they tend to get upper position.

Pacific-Atlantic Front position



The experiment with the ratio A_S/A_T set to 0.5 showed that BG reduction took place much earlier in 60s, but also it recovered more rapidly. But even so, in its minimum phase the BG looked stronger than in Base experiment minimum. And its recovery is faster in following years.

Arctic FW volume



As in Base experiment, FW volume reached the 90 thousand km^3 level in 1960, but soon after that it moved down to 80 thousand km^3. The minimum values were in 70s and 80s while in Base experiment just in 90s. Also we see, that FW is more concentrated in the BG core region in 2000s than in Base experiment