Modeling the Arctic hydrologic cycle: About the influence of atmospheric modes on the variability

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1. Motivation

The large amount of freshwater contained in the upper Arctic ocean is exported in ice and liquid form through Fram Strait and through the Canadian Arctic archipelago. By influencing the stratification of the water column in the regions of deepwater formation it strongly affects the strength of the meridional overturning circulation.

The main problem of global general circulation models calculating the freshwater (FW) cycle of the Arctic is the resolution, which is too coarse to adequately resolve small scale processes and complex topography. To overcome this difficulty we use a high resolution regional coupled climate model to simulate the Arctic hydrologic cycle.

We want to understand the mechanisms leading to the variability in the liquid and ice components of the FW cycle in the Arctic.

2. Model set-up

The ocean/sea ice model MPIOM with high resolution in the Arctic is coupled to the regional atmosphere model REMO (see Aldrian et al., Mikolajewicz et al.). The domain of the atmosphere model covers the full catchment areas of the Arctic rivers. Furthermore, we include a discharge model providing lateral terrestrial waterflows. The model is run for the years 1960 - 1999 with 4 ensemble members and is forced with output from a 20th century run with ECHAM5/MPIOM that was performed for the IPCC AR4.

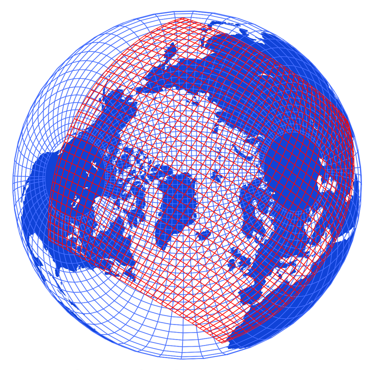

Fig. 1: Computational grids from MPIOM (blue) and REMO (red). Not every line is shown.

3. Climatological freshwater (FW) budget of the Arctic

The model represents well the mean of the Arctic FW sinks and sources. Compared to observations (Fig. 2) precipitation is slightly overestimated. The transport through the Canadian Arctic archipelago (CAA) and through Bering Strait is improved compared to the global model.

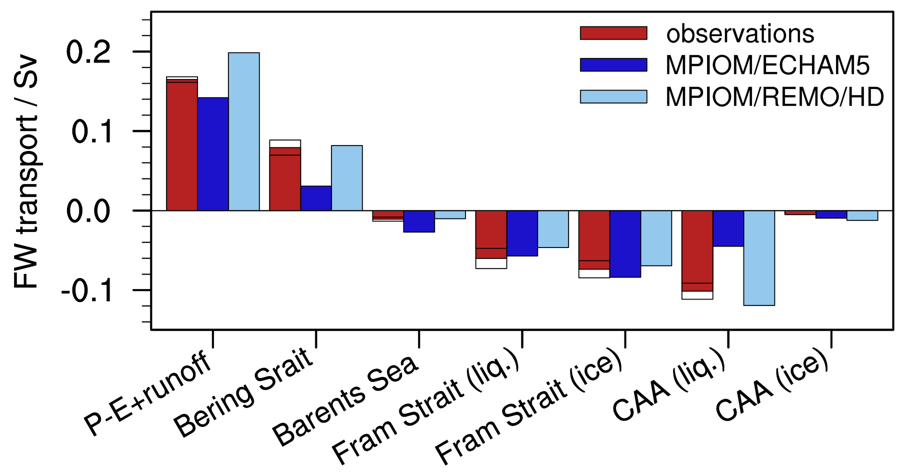

Fig. 2: Comparison from model results (blue) with observational estimates from Serreze et al. (red). Freshwater is defined relative to a salinity of 34.8.

4. Composite analysis

We compare years where a defined MSLP index exceeds $\pm 1\sigma$, with $\sigma =$ standard deviation.

4.1 Principal component of the leading empirical orthogonal function (EOF1)

A strengthening of the Arctic low with shift to Barents Sea in positive years and a weaker Icelandic low combined with a stronger Siberian high in negative years, see Fig. 3, lead to

- an increase of ice export through Fram Strait in pos. years (due to a strong transpolar drift), a decrease in neg. years (due to a Beaufort gyre circulation), see Fig. 4 (correlation $r = 0.57$).
- a strenghtening of the liquid FW transport through CAA in pos. years, a weakening in negative years, see Fig. 5. As indicated this is caused by changes in the volume transport, driven by changes in the sea surface height gradient.

4.2 Principal component of the second empirical orthogonal function (EOF2)

A high pressure system over Europe in positive years and a relatively strong Siberian high in negative years, see Fig. 6, lead to

- higher/lower temperatures in Scandinavia in pos./neg. years (not shown).
- an increase/a decrease of sea ice volume at the Canadian coast in pos./neg. years, see Fig. 7.
- a decrease of liquid FW export through CAA in neg. years, see Fig. 8, mainly driven by changes in the FW flux due to advection of the mean salinity by volume flux anomaly.

4.3 Siberian high (SH) index

We use a MSLP area mean anomaly located over Siberia normalized with its standard deviation as the SH index. High pressure over Europe in positive years and a weaker pressure system over Eurasia in negative years, see Fig. 9, lead to

- a strengthening of moisture (and heat) tranport into Siberia in pos. years, a weakening in precipitation (and temperature) in neg. years. For precipitation anomalies see Fig. 10.
- a decrease of liquid freshwater transport through CAA in pos. years, see Fig. 11. This is the opposite behaviour compared to EOF composites.

EOF 1

Sea level pressure

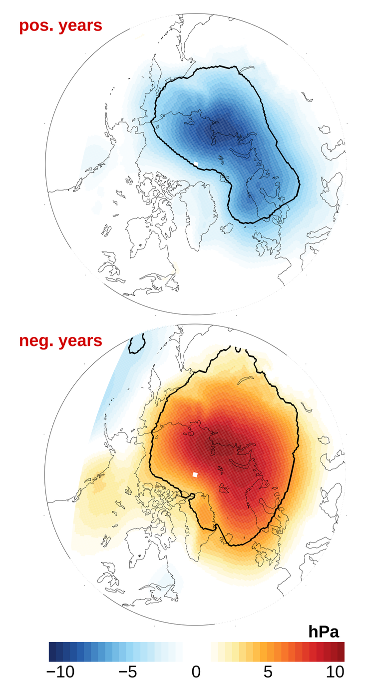

Fig. 3: Winter mean sea level pressure (MSLP) anomalies.

Sea ice velocity

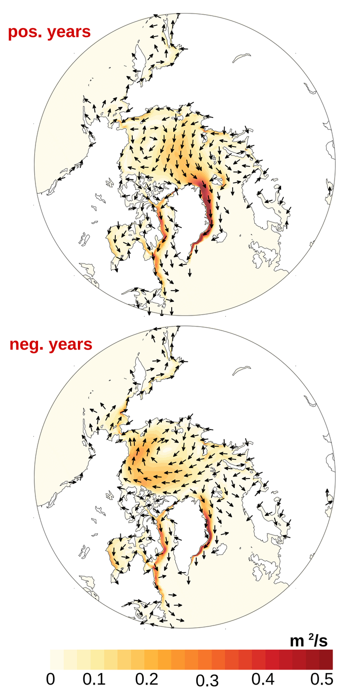

Fig. 4: Winter sea ice velocities.

Liquid FW transport F_{FW}

It is

$$F_{FW} = \int_A \langle S\rangle\langle v_\perp\rangle + \int_A v'_\perp \langle S\rangle + \int_A S'\langle v_\perp\rangle + \int_A S' v'_\perp,$$

with the normalized salinity anomaly $S = \frac{S - S_{ref}}{S_{ref}}$, $S_{ref} = 34.8$, $v_\perp$ velocity through A, $\langle\cdot\rangle$ time mean, $\cdot'$ time varying anomaly values.

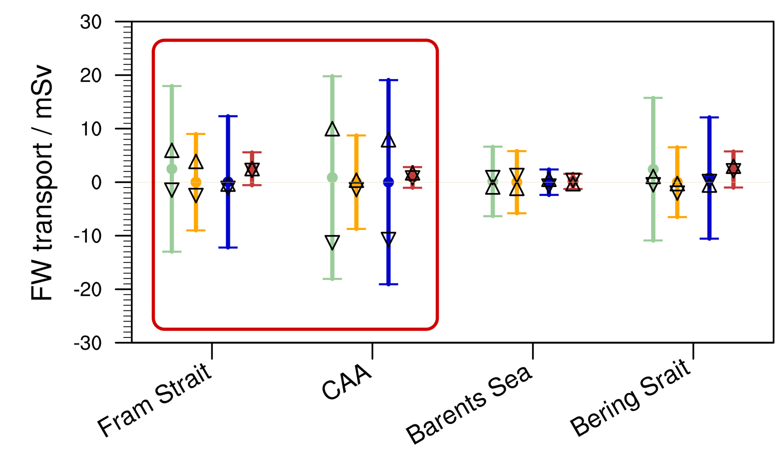

Fig. 5: Liquid FW transport components. Bars indicate $\pm\sigma$, triangles the mean of pos.(△) and neg.(▽) EOF 1 years.

EOF 2

Sea level pressure

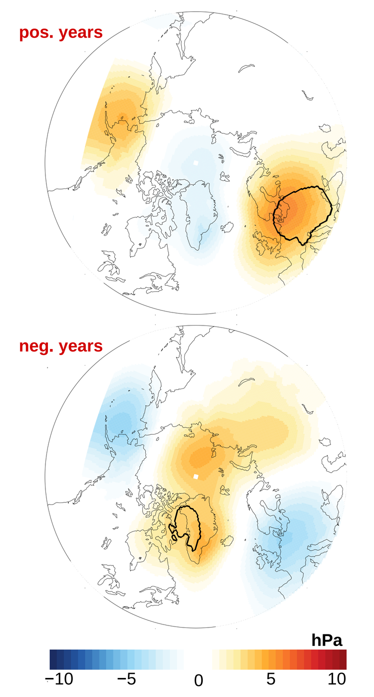

Fig. 6: Winter MSLP anomalies.

Sea ice thickness

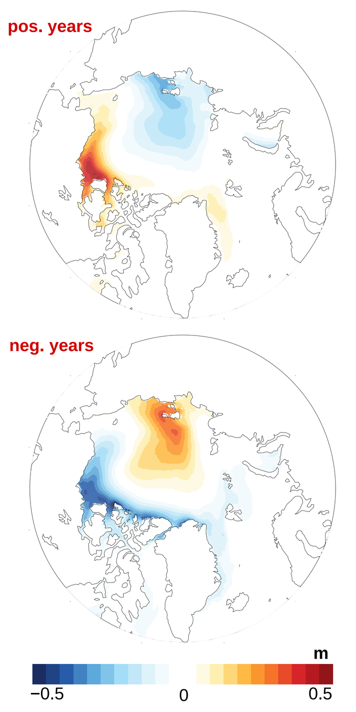

Fig. 7: Mean sea ice thickness anomaly.

Liquid FW transport F_{FW}

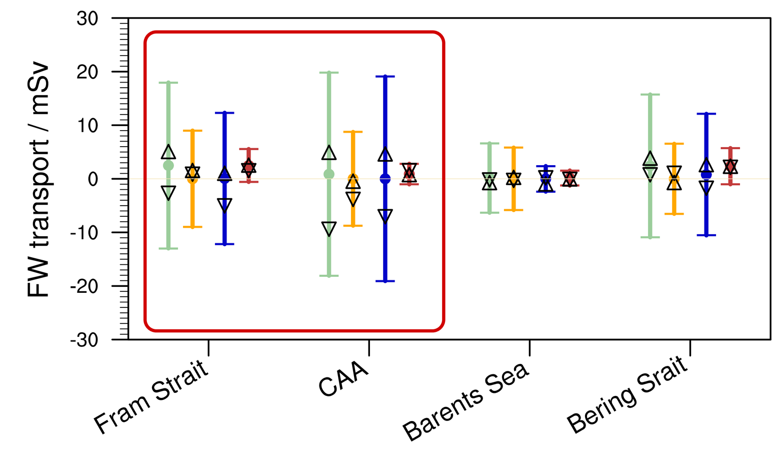

Fig. 8: Liquid FW transport components. Bars indicate $\pm\sigma$, triangles means of pos.(△) and neg.(▽) EOF 1 years. For color coding of the different FW components see above.

SH

Sea level pressure

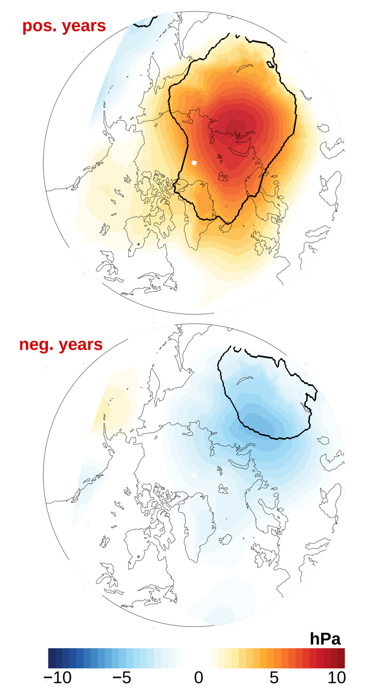

Fig. 9: Winter MSLP anomalies.

Precipitation

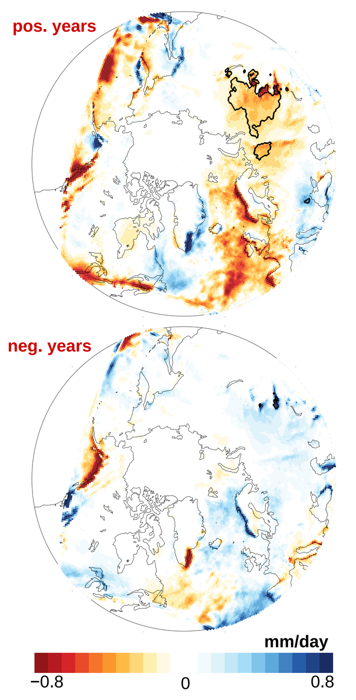

Fig. 10: Winter precipitation anomaly.

Liquid FW transport F_{FW}

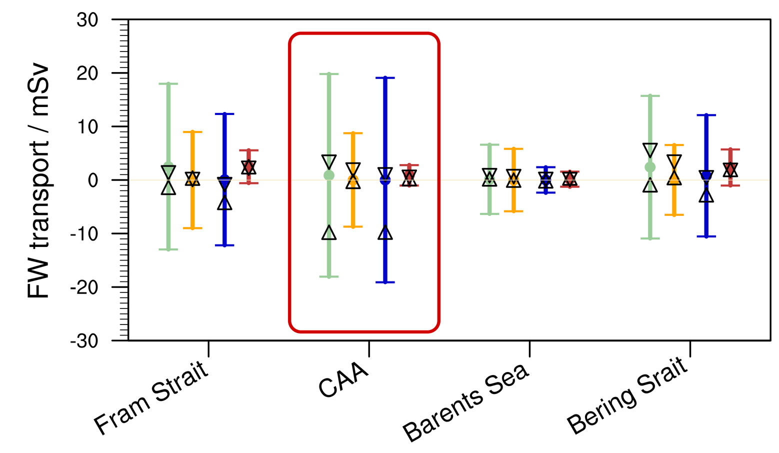

Fig. 11: Liquid FW transport components. Bars indicate $\pm\sigma$, triangles means of pos.(△) and neg. (▽) EOF 1 years. For color coding of the different FW components see above.

References

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