The role of the North Atlantic winds in driving the Arctic Ocean sea level

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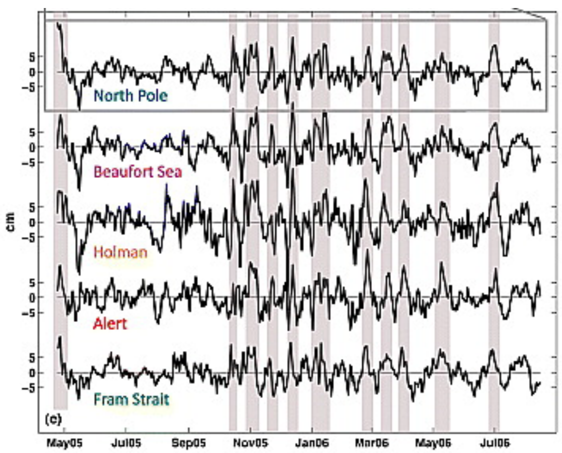
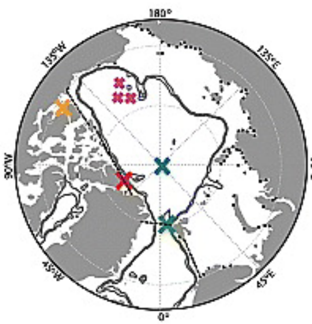
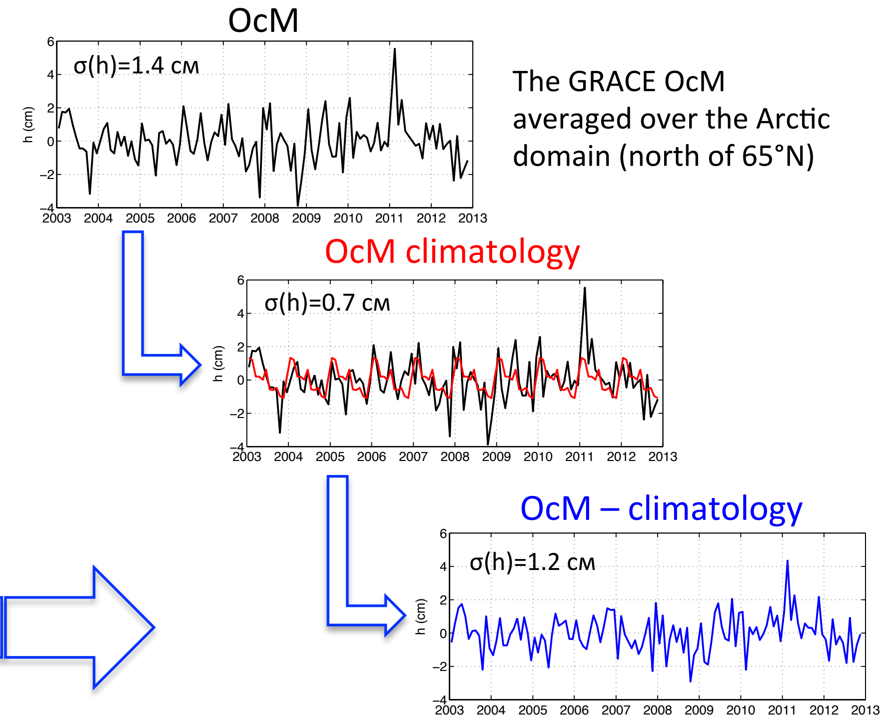
Introduction: research background and objective

- Good agreement between GRACE ocean mass (**OcM**) and bottom pressure recorders (BPRs) near the North Pole, in the Beaufort Sea, and in the Fram Strait (Morison et al., 2006; Chambers and Bonnin, 2012; Volkov et al., 2013)
- In situ measurements by BPRs manifest coherent fluctuations in different parts of the AO (Peralta-Ferriz et al., 2011)
- High-frequency (submonthly) oscillations of ocean bottom pressure have been related to meridional winds over the Norwegian and Greenland seas (Peralta-Ferriz et al., 2011)
- Annual cycle of OcM in the Arctic Ocean has been explained by fresh water fluxes (Peralta-Ferriz and Morison, 2010; Ponte et al., 2007)



Peralta-Ferriz et al., 2011



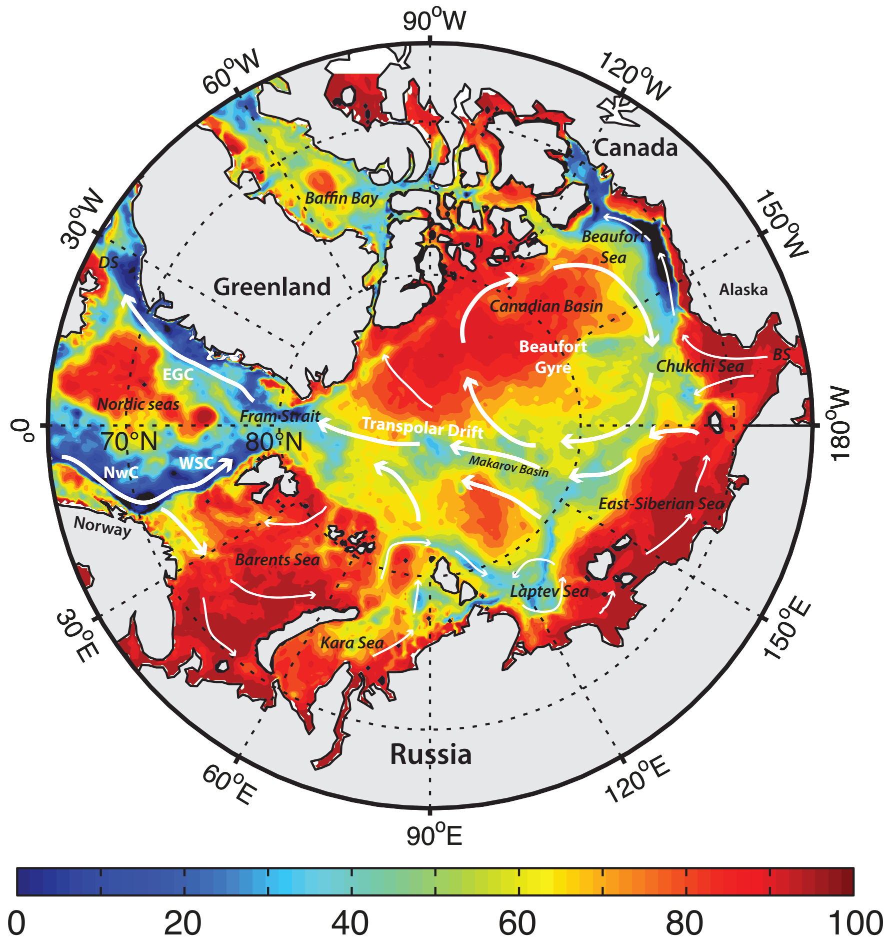


The GRACE OcM averaged over the Arctic domain (north of 65°N)

What drives the non-seasonal variability? (includes synoptic and interannual)

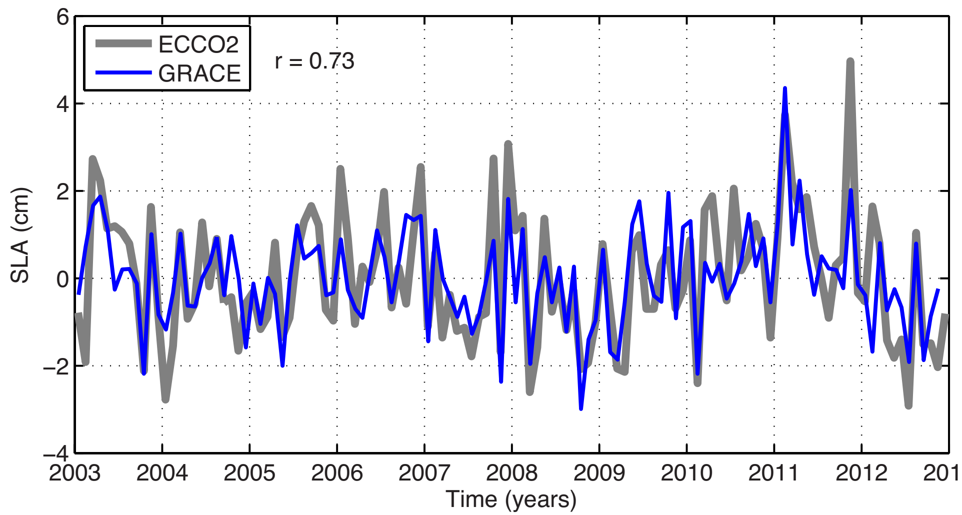
Nonseasonal variability of the Arctic Ocean mass: ECCO2 vs GRACE

Portion of the non-seasonal SLA variance (%) explained by the non-seasonal OcM in ECCO2 model



- The non-seasonal variability of SLA in the Arctic Ocean is mostly mass related
- Steric variability dominates along major currents

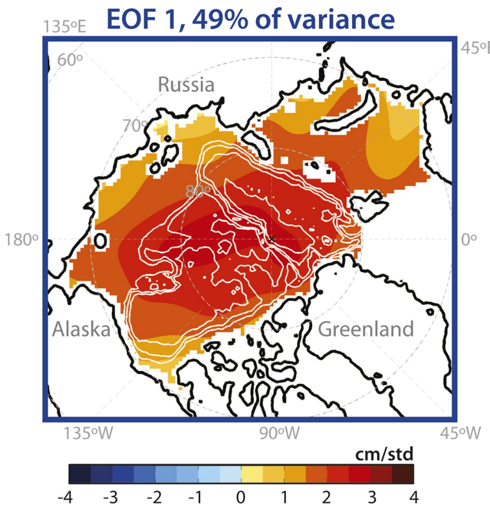
OcM measured by GRACE (blue) and simulated by ECCO2 (gray), averaged over the Arctic Ocean and adjacent seas (north of 65°N)

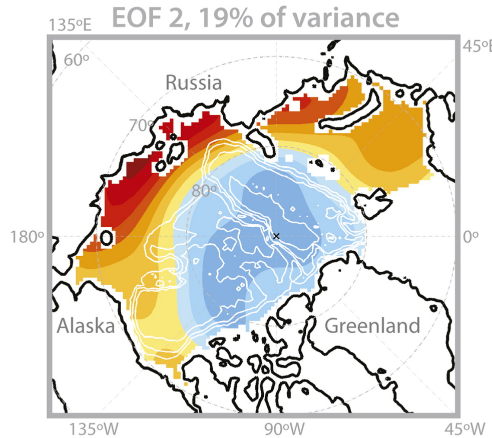


- ECCO2 compares with GRACE very well and, therefore, can be used to understand the mechanisms

Volkov and Landerer, JGR-Oceans, 2013

Statistical modes of the Arctic Ocean mass fluctuations observed by GRACE

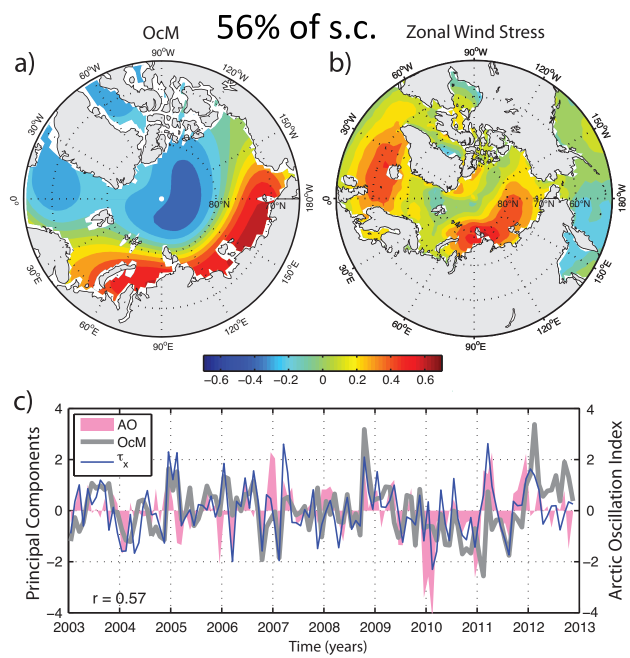


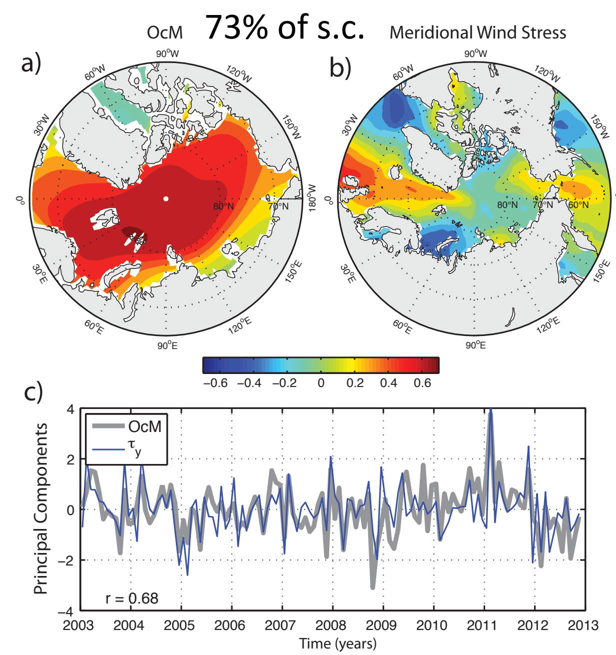


EOF of OcM: Peralta-Ferriz et al. (2014)

- The nonseasonal variability of OcM is dominated by basin-wide and di-pole modes (Peralta-Ferriz et al., 2014)
- The di-pole mode is correlated with zonal winds modulated by the Arctic Oscillation (Volkov and Landerer, 2013)
- The basin-wide mode is correlated with meridional winds over the Nordic and Bering seas (Volkov and Landerer, 2013)
- Relevance of Ekman dynamics

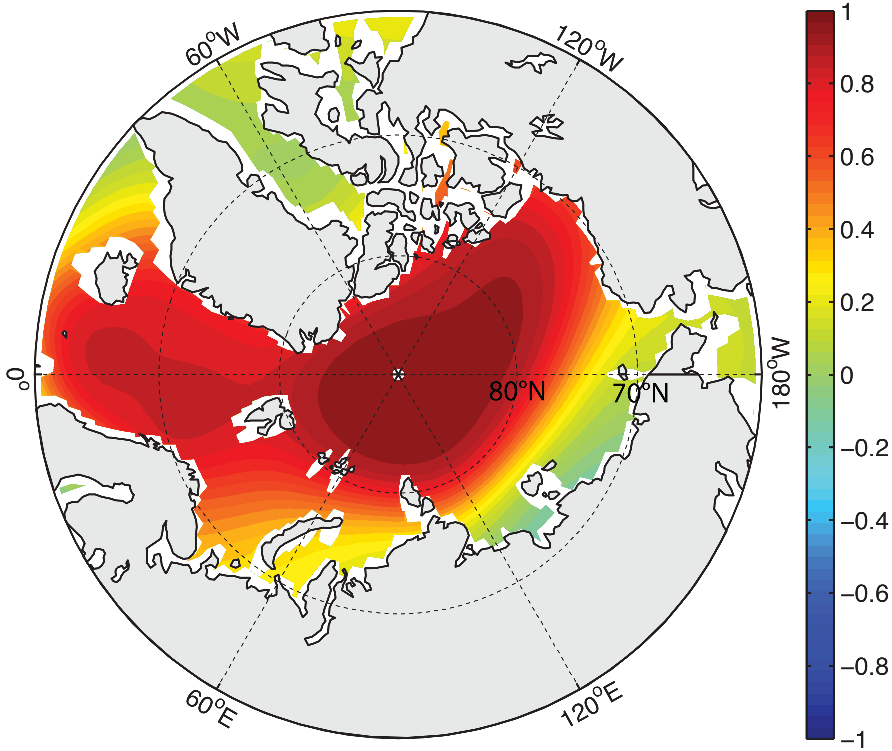
Coupled EOF-1:
OcM and wind stress
(Volkov and Landerer, 2013)

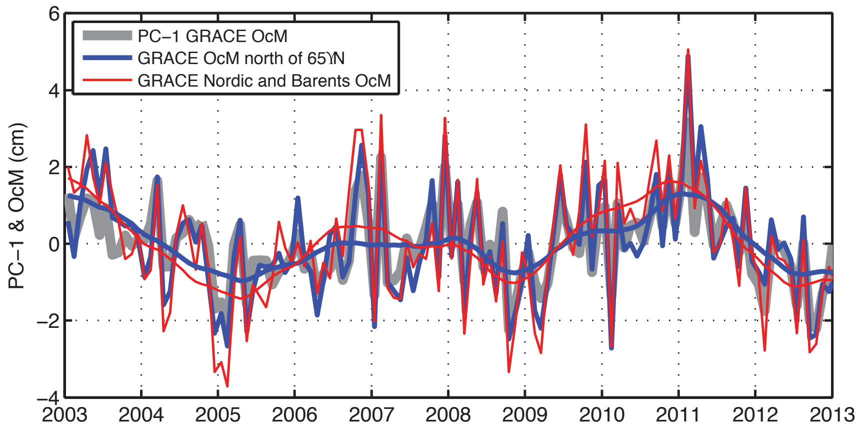




Basin-wide coherent fluctuations of the Arctic Ocean mass from GRACE

EOF-1 of the non-seasonal OcM (68.2% exp. var.)

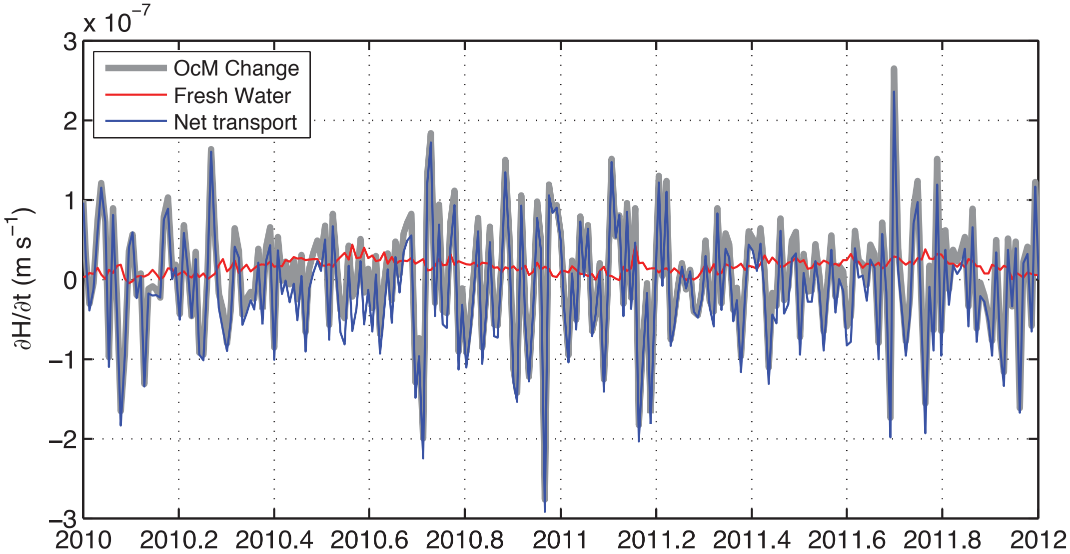


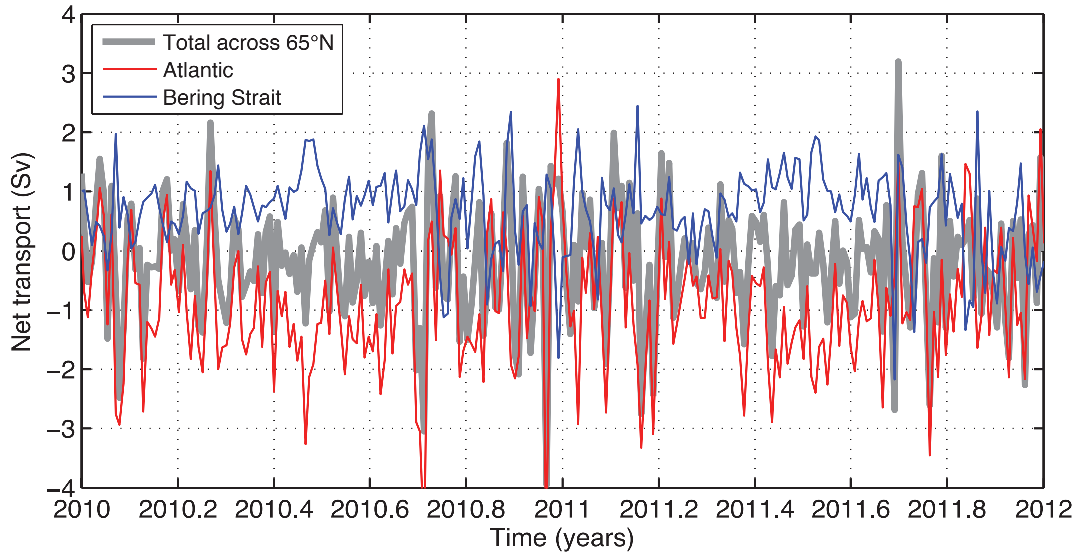


r	PC-1	Arctic	NGB
PC-1	1	0.91	0.89
Arctic	0.91	1	0.92
NGB	0.89	0.92	1

- The non-seasonal variability of OcM is nearly uniform all over the Arctic Ocean and the Nordic seas; **net transport across the domain boundaries is required!**
- Existing explanation that the non-seasonal variability of the Arctic Ocean mass is driven by winds over the Nordic seas is not complete (Peralta-Ferriz et al., 2013; Volkov and Landerer, 2013); **external forcing south of ~65°N should be relevant!**

Where does the water come from?





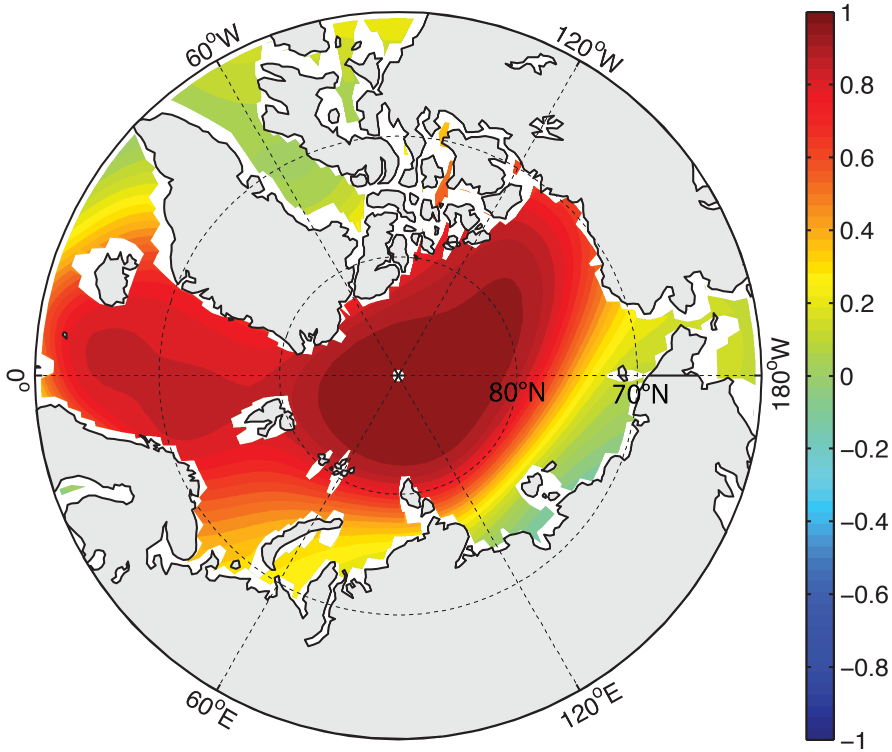
$$\frac{\partial OcM}{\partial t} = -\nabla uH + P + R - E$$

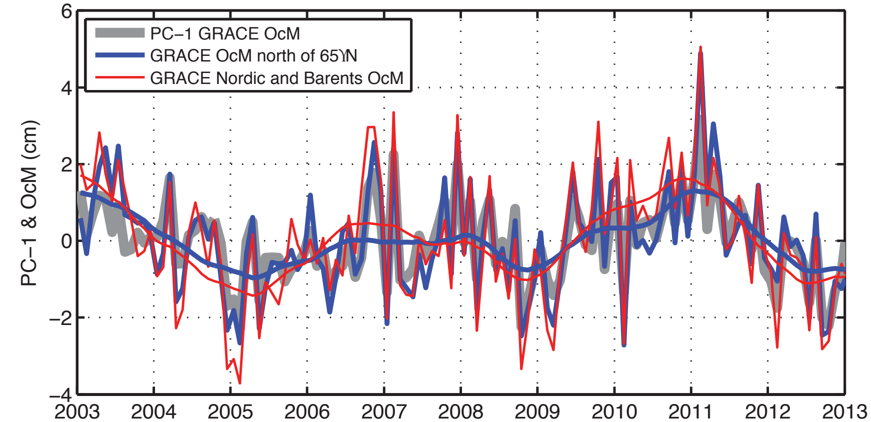
- Impact of **fresh water fluxes** on the non-seasonal variability of OcM is small
- The non-seasonal variability of OcM is mostly determined by the variability of the **net transport** across the basin boundaries
- The average transport across 65°N in the **Atlantic sector** = -0.9 Sv
- The average transport across the **Bering Strait** = 0.7 Sv
- The net transports across the **Atlantic sector** and **Bering Strait** partially compensate each other (r = -0.5)
- The variability of the total **net transport** is primarily determined by the variability of the **Atlantic sector** transport (r = 0.8)

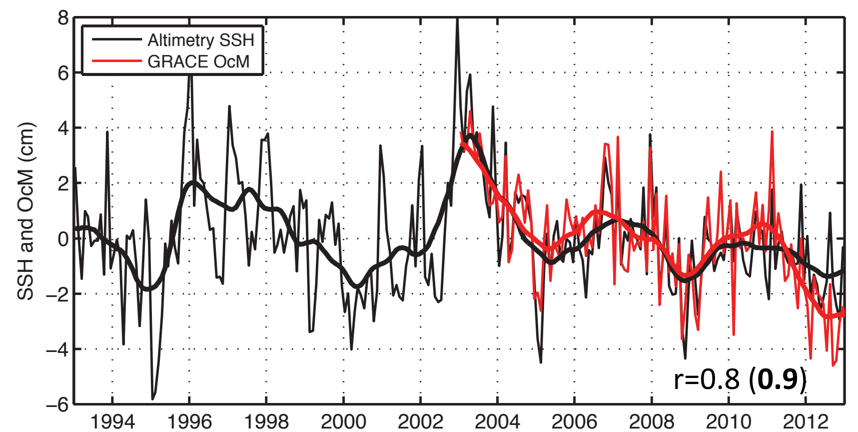
Volkov and Landerer, JGR-Oceans, 2013

Basin-wide coherent fluctuations of the Arctic Ocean mass and sea level

EOF-1 of the non-seasonal OcM (68.2% exp. var.)



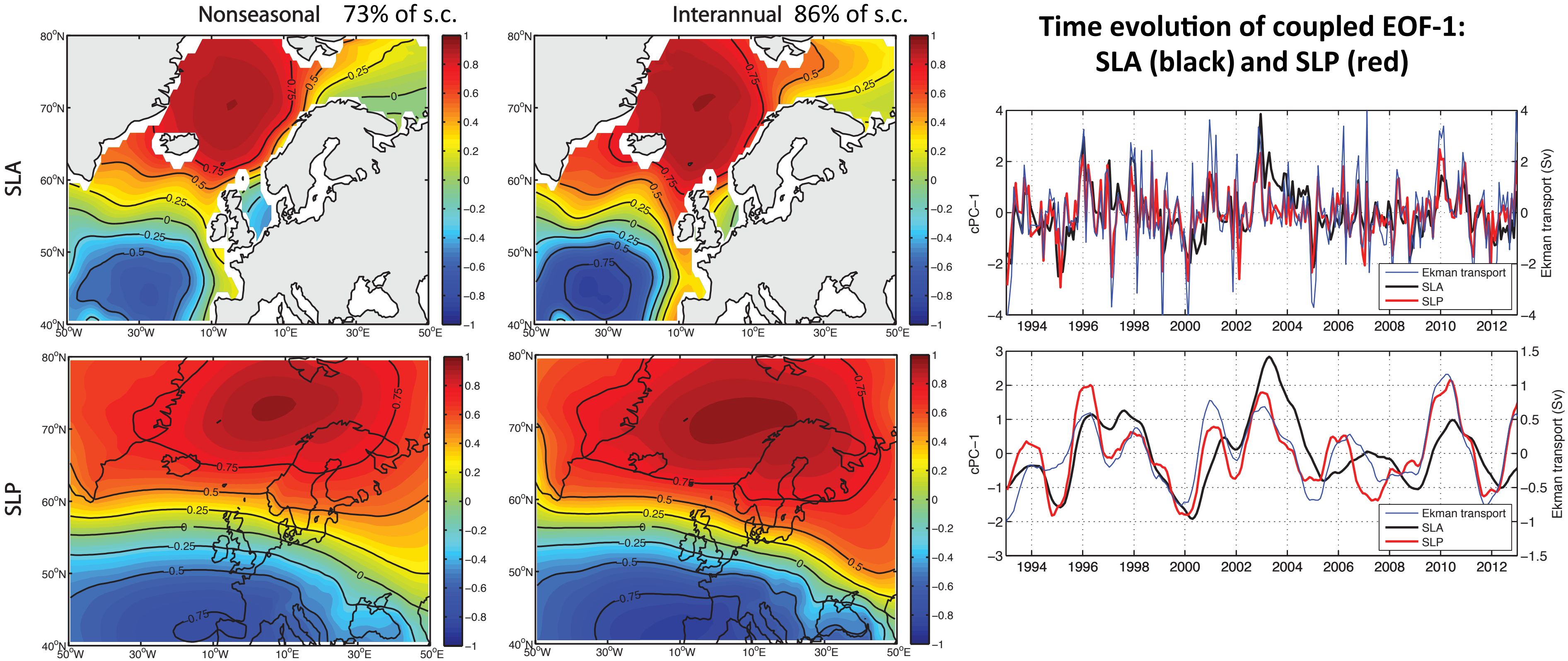




- The large-scale non-seasonal variability of SLA in the Nordic seas is mostly mass-related
- It is reasonable to assume that the non-seasonal variability of SLA in the Nordic Seas is representative for the entire Arctic Ocean; use longer altimetry records to couple with atmospheric forcing

Spatial patterns of coupled EOF-1: SLA and sea level pressure (SLP)

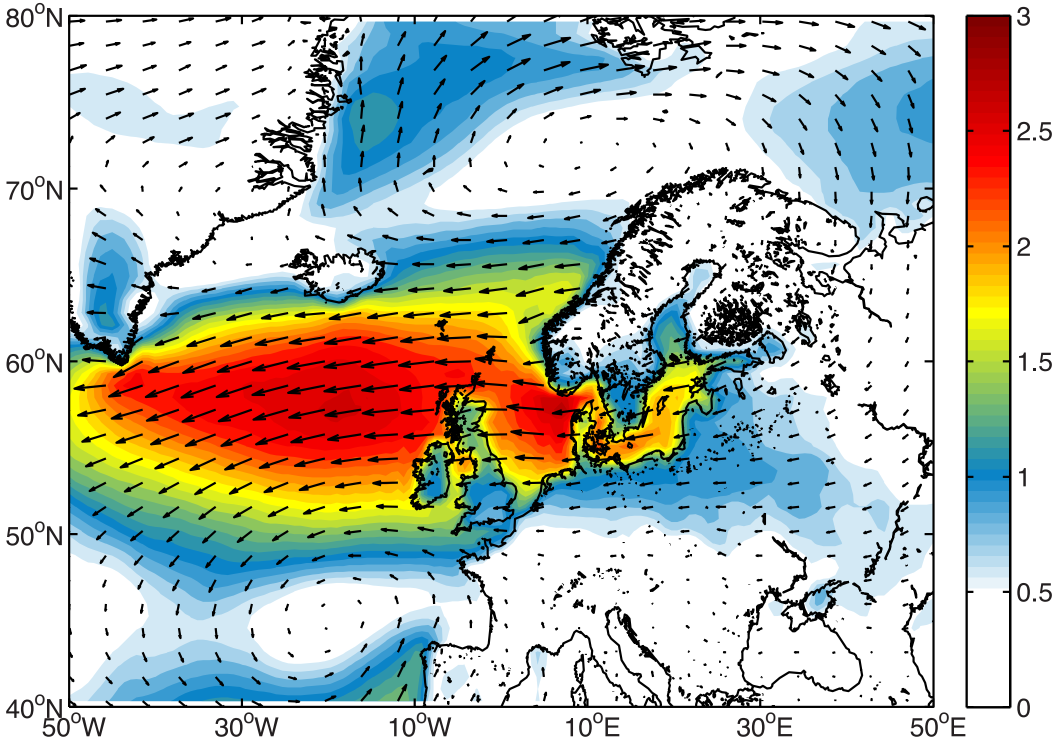
Time evolution of coupled EOF-1: SLA (black) and SLP (red)



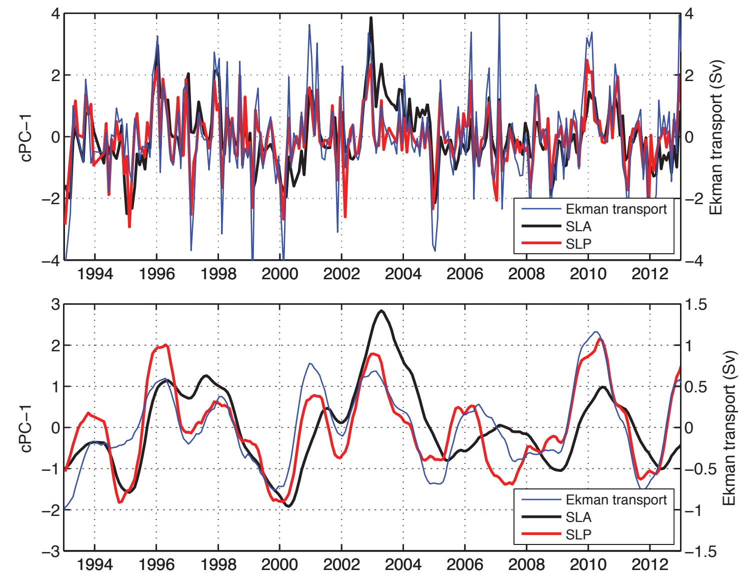
- The SLA and SLP fields are strongly coupled at synoptic and interannual time scales
- Positive/negative SLP anomalies over the Nordic seas are associated with positive/negative local SLA (convergence/divergence)

Statistical relationship between SLA and winds in the North Atlantic

Regression map of ERA-Interim winds projected on the nonseasonal cPC-1 of SLP (similar for interannual)



Time evolution of coupled EOF-1 (SLA & SLP) and meridional Ekman transport at 60°N



- The cEOF-1 pattern is associated with an anticyclonic wind anomaly over the Nordic seas and with much stronger zonal wind anomalies over the northeastern North Atlantic
- The zonal wind anomalies drive the **meridional Ekman transport** anomalies that can change SLA in the Nordic seas and possibly over the entire Arctic Ocean
- Correlation between cPC-1 of SLP (SLA) and the monthly NAO index is -0.62 (-0.38)

Summary and conclusions

- The nonseasonal variability of OcM in the Arctic Ocean is mainly driven by the net flow across the boundary between the Nordic Seas and the North Atlantic; it is not significantly affected by fresh water retained in the basin

- Satellite altimetry measurements over the Nordic and Barents seas are a good proxy for the non-seasonal variability of the Arctic Ocean mass

- The zonal winds over the northeastern North Atlantic (south of 65°N) drive the meridional Ekman transport that drives the nonseasonal variability of sea level in the Nordic and Barents seas, and over the entire Arctic Ocean

- The interannual variability may also be driven by the North Atlantic winds, which needs to be accounted for when interpreting the long-term changes of the Arctic Ocean sea level; this is the subject for future research (a relevant proposal has been submitted to NASA Physical Oceanography program)

References:

Volkov D.L., 2014: Do the North Atlantic winds drive the nonseasonal variability of the Arctic Ocean sea level? *Geophys. Res. Lett.*, 41, doi:10.1002/2013GL059065.

Volkov D.L., F.W. Landerer, 2013: Non-seasonal variability of the Arctic Ocean mass observed by the GRACE satellites, *J. Geophys. Res.*, 118, doi:10.1002/2013JC009341.