An assessment of Arctic Ocean freshwater content changes from the 1990s to the 2006-2008 period and beyond

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Bundesministerium für Bildung und Forschung

Why?

- 10% of worldwide river runoff goes into the Arctic Ocean, and a similar amount of freshwater from the Pacific.
- Liquid freshwater (LFW) determines upper ocean stratification and plays a major role in Arctic Ocean dynamics and the formation of water masses and sea ice.
- Influence reaches to lower latitudes through export of LFW and modified deeper water masses, with implications for climate and ocean circulation in the Atlantic and Nordic Seas.
- Simulations indicate a draining of LFW in the Arctic Ocean from the 1970s to the mid-1990s and subsequent accumulation.
- Variability in LFW storage can help to understand changes in circulation and export

How?

1) Liquid freshwater (LFW) from salinity profiles
   → LFW inventories
2) Outlier elimination
3) Objective mapping (*Bretherton et al., Böhme et al.*)
4) → Map of LFW inventories for specified time periods
5) (Differences between maps / time periods)
6) Area integral → LFW content

$$h_{fw} = \int_{z=0\mathrm{m}}^{h} \frac{S_{ref} - S}{S_{ref}}\, dz$$

h_{fw} – LFW inventory
S – observed salinity
S_{ref}=35 – reference salinity
h – depth of 34 isohaline
z – depth in profile (pos. downwards)

Summary

- Observed increase in liquid freshwater (LFW) reservoir by 20% (+8400±2000 km³), equivalent to annual freshwater export (liquid and ice) from the Arctic.
- Increase in LFW of 6120 km³ in NAOSIM simulation.
- Preliminary analysis of observations indicates some decrease and levelling of LFW content from 2008 to 2011.
- Observed LFW changes primarily due to changes in the mean salinity, and only ¼ layer thickness (Ekman pumping).
- Mean salinity changes associated with temporary change in Eurasian river water pathways during 1990s.

Layer depth / Ekman pumping changes likely regular (c.f. large-scale wind field, Arctic Oscillation), not temporary.

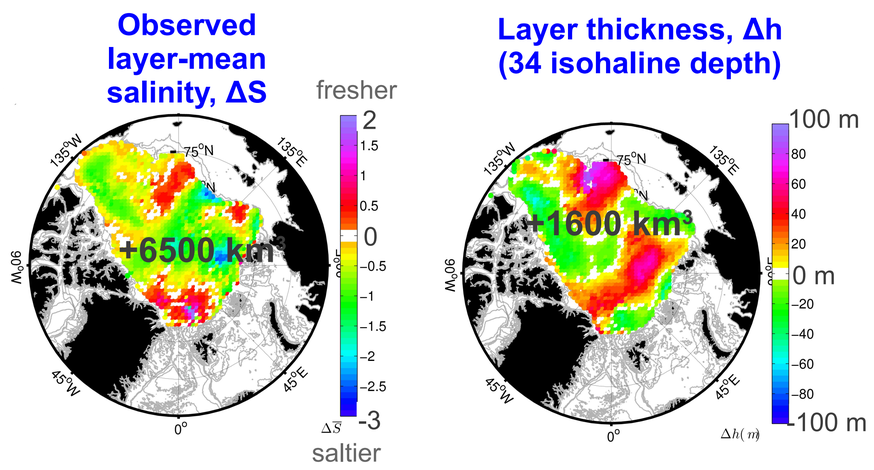
Simulated regional mean wind-/ice-induced ocean surface stress regional driver of isohaline depth changes.

- Significant ice melt only north of the Bering Strait and on Siberian shelves in simulation.
- Shelves are not important for liquid freshwater storage variability in simulation.
- Changes in freshwater induce regional changes in sea surface dynamic height.

Challenges

- Bias in observational mapping toward end 2000s ?
- Influence on ocean circulation in recent two decades ?

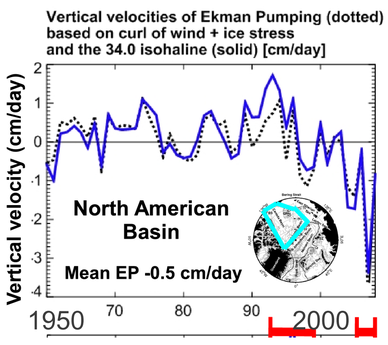
Contributors to Changes



Changes between 1992-1999 and 2006-2008: observed JAS mean salinity between the surface and the 34 isohaline (top, left) and the depth of this isohaline (top, right); all-year net thermodynamic ice melt in the simulation (bottom, right) and timeseries of vertical velocity due to Ekman pumping (bottom, left; dotted line) and the displacement of the 34 isohaline (solid line) in the simulation.

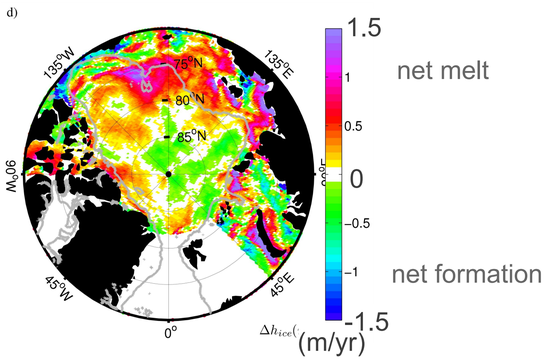
Ekman Pumping (EP)

Annual and regional means

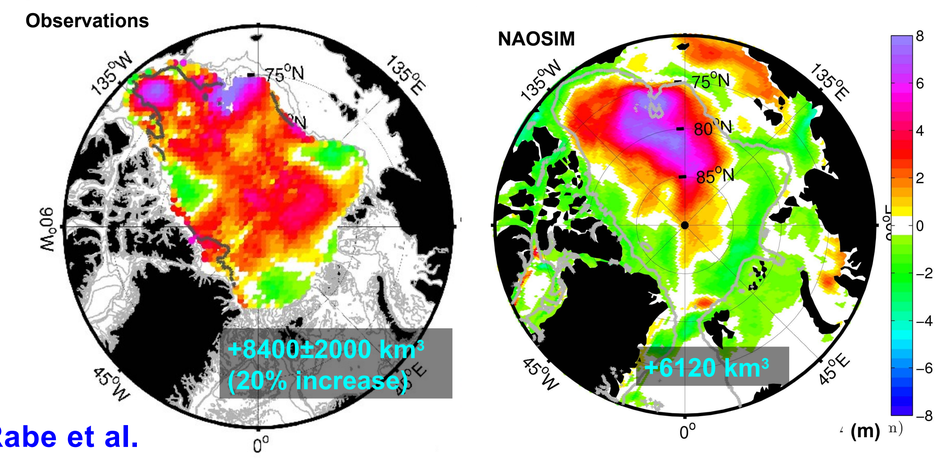


NAOSIM net ice melt

(whole year)



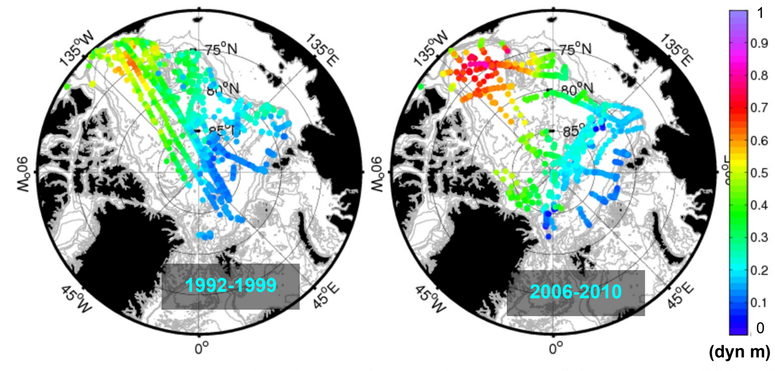
Liquid Freshwater Changes upper Arctic Ocean Basins 92-99 to 06-08 (JAS)



Rabe et al. (2011; DSR-I)

Changes in liquid freshwater inventories of the upper Arctic Ocean basins between JAS 1992-1999 and 2006-2008 (positive=increase) from observations (left) and ice-ocean model simulations (right). Liquid freshwater is relative to a salinity of 35. The integral over the regio,n covered by the grid in the left-hand plot, is given in bold cyan (water depth more than 500 m and near the prime meridian north of 82°N.

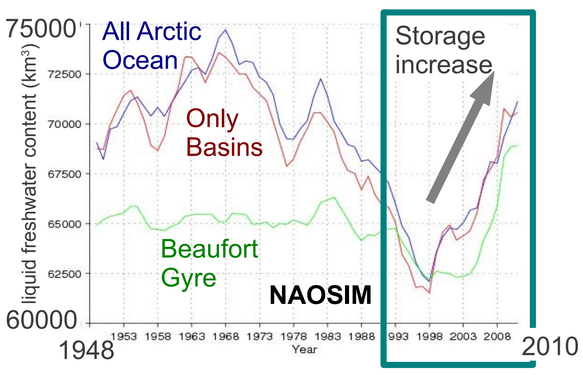
Freshwater-induced Changes in Ocean Circulation?

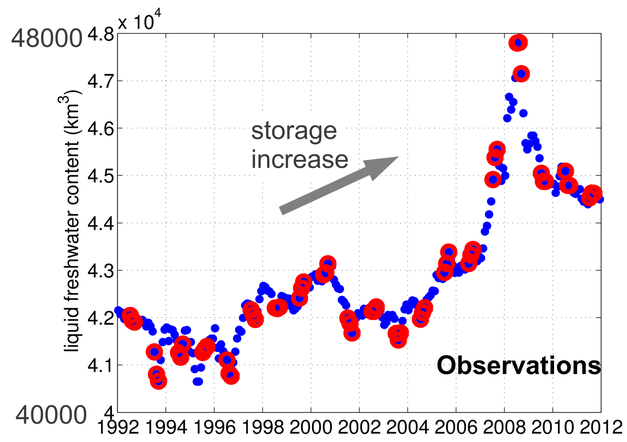


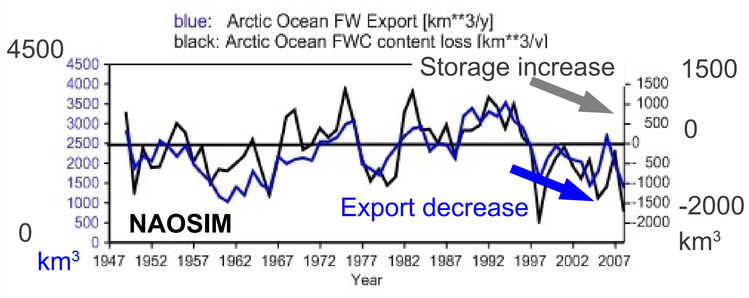
Sea surface dynamic height between the surface and 400 dbar for 1992-1999 and 2006-2008. A mapping procedure for obtaining this quantity and geostrophic velocity in the upper Arctic Ocean is in progress.

Preliminary results up to 2011

Liquid Freshwater Variability

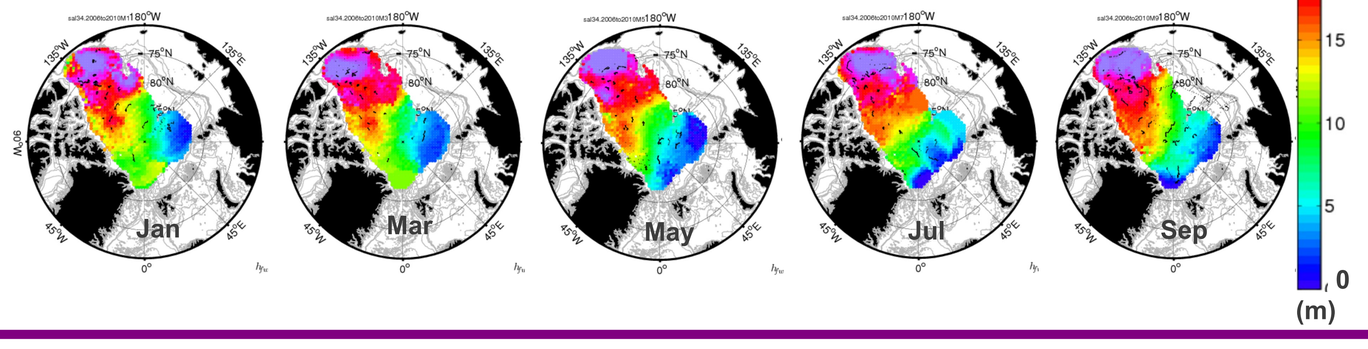






Variability of Arctic Ocean basins liquid freshwater content above 34 isohaline: observed monthly mean (blue dots, top right), with JAS marked in by red circles, and simulated annual mean (top left), where the red and green curves are offset by +23000 km³ and +50000 km³. The simulated full-depth annual mean storage change and export are shown at the bottom left.

Mean Seasonal Cycle of Liquid Freshwater in the Upper Arctic Ocean



References

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Bretherton, F.P., R.E. Davis and C.B. Fandry (1976), A technique for objective analysis and design of oceanographic experiments applied to MODE-73. Deep-Sea Res. I 23, 559–582.

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