Arctic FW budget in the CCSM4 - a first look

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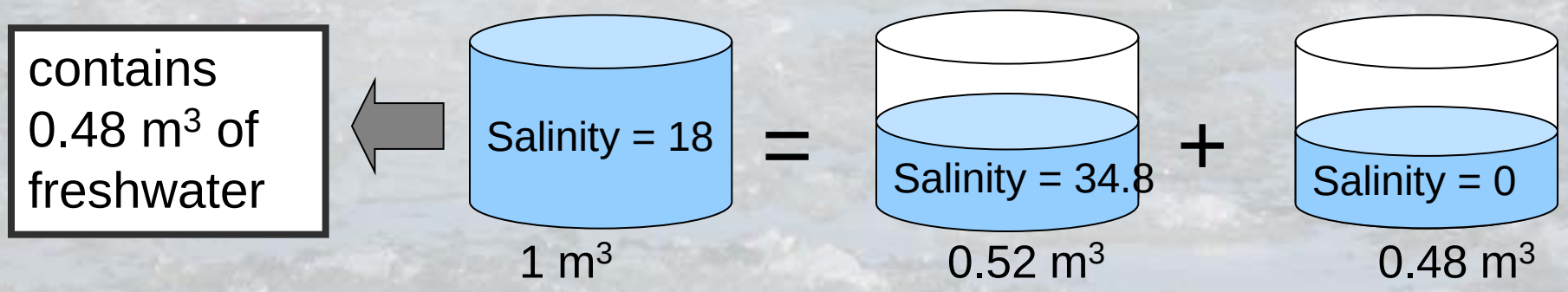
Definition of freshwater

- Freshwater (FW) in the Arctic is defined relative to S_{ref}=34.8 (Aagaard and Carmack, 1989)

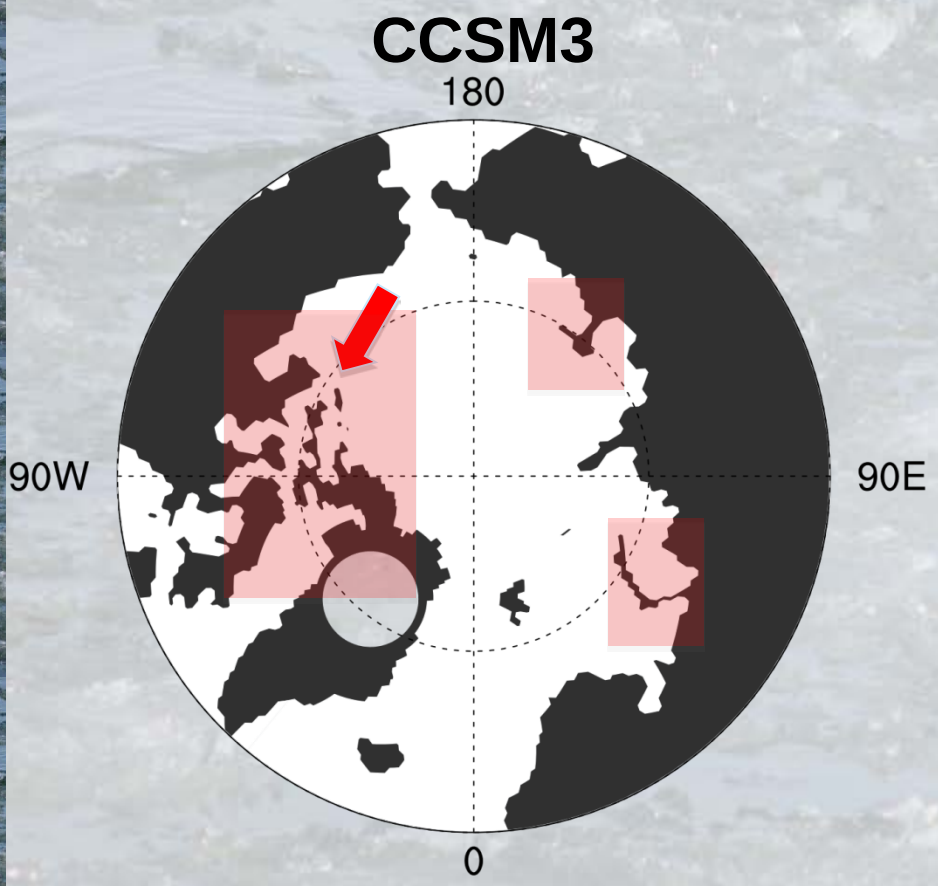
- Amount of FW in a volume of salt water:

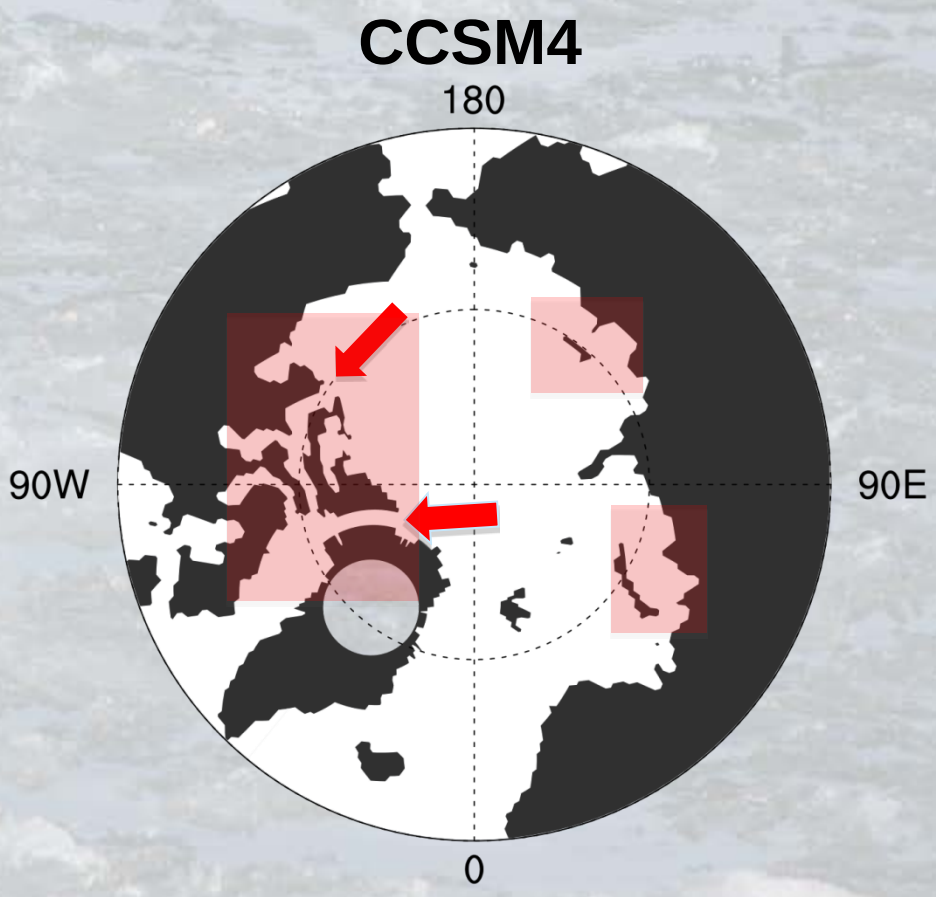


FW budget in CCSM4 versus CCSM3

- 30 years (1970-1999) from 20th century simulations
  - CCSM4: b40.20th.track1.1deg.005
  - CCSM3: b30.030b.ES01.

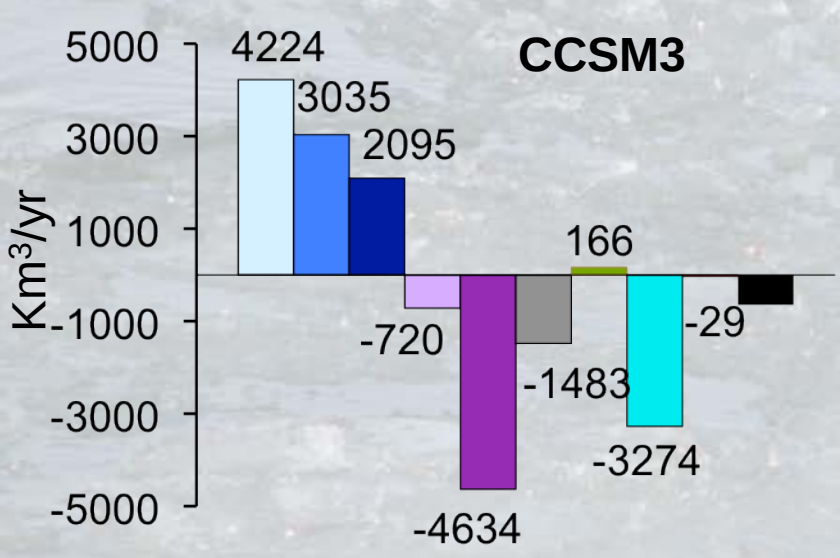
Land masks

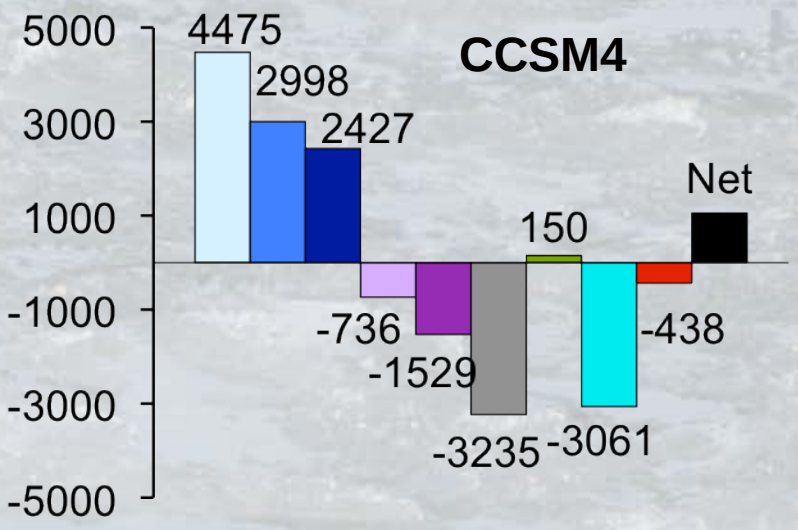




In the CCSM4, Nares Strait is open (140 m deep), and Kara and Sannikov Strait are also open (30-40 m deep)

Arctic FW budget

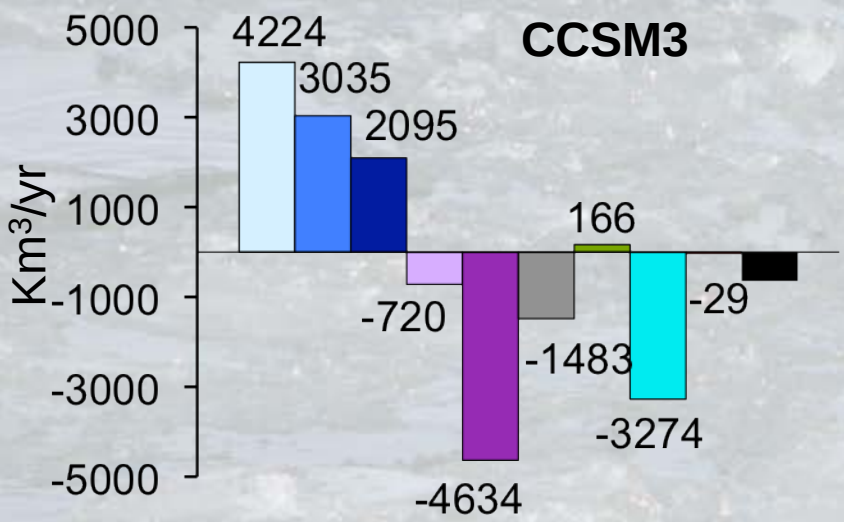


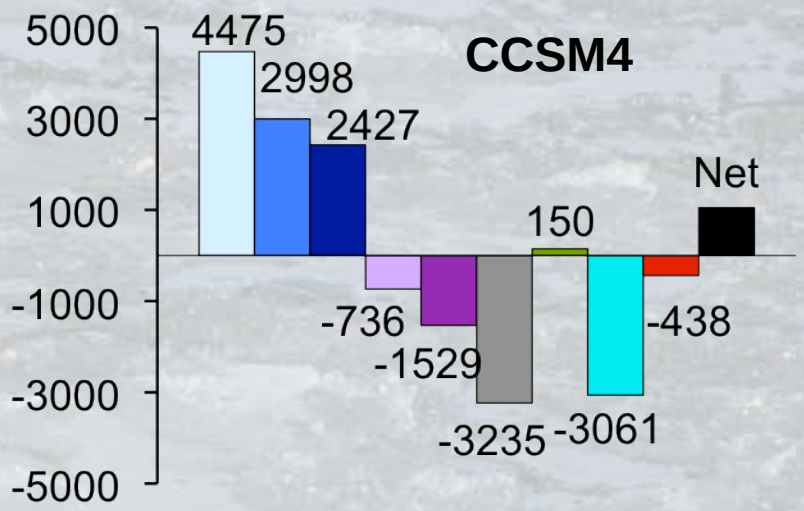


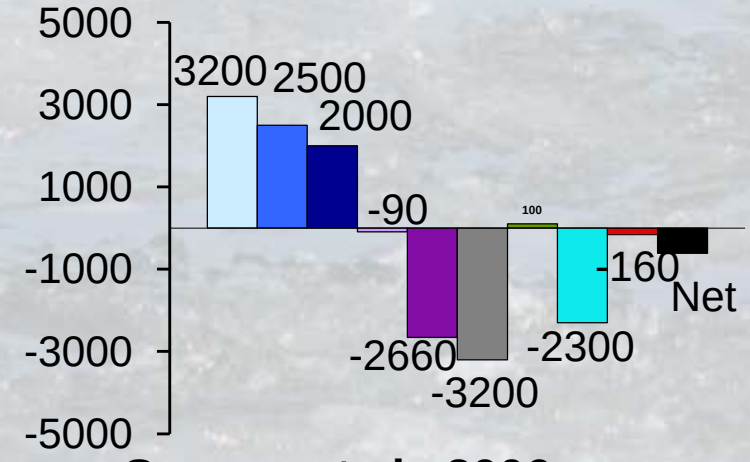
River Runoff
Bering Strait liquid
P-E
Barents Sea liquid
Fram Strait liquid
CAA liquid
Bering Strait Solid
Fram Strait solid
CAA solid

Largest changes in distribution of liquid FW between Fram Strait and the CAA, due to opening of Nares Strait

Arctic FW budget







Serreze et al., 2006,
Woodgate and Aagaard, 2005

- River Runoff
- Bering Strait liquid
- P-E
- Barents Sea liquid
- Fram Strait liquid
- CAA liquid
- Bering Strait solid
- Fram Strait solid
- CAA solid

Nares Strait versus Lancaster sound

Nares Strait

- In CCSM4, Nares Strait FW flux is -2323 km^3/yr, volume flux is -1.5 Sv (closed before)
- Observations suggest -0.57 +/- 0.09 Sv, 0.8 +/- 0.3 Sv as volume flux and -788 (Muenchow et al, 2006) to -978 km^3/yr (Melling et al., 2008) as FW flux

→ Nares Strait volume and FW flux is **too large** in model

Lancaster Sound

- In CCSM4, Lancaster Sound FW flux is -912 km^3/yr, volume flux is -0.26 SV.
- In CCSM3, the volume and FW flux was -0.36 Sv and -1482 km^3/yr
- Observations suggest volume flux of -0.75 Sv and FW flux of -1510 km^3/yr (Prinsenberg and Hamilton, 2005)

→ Lancaster Sound volume and FW flux is **too small** in the model

CAA FW flux

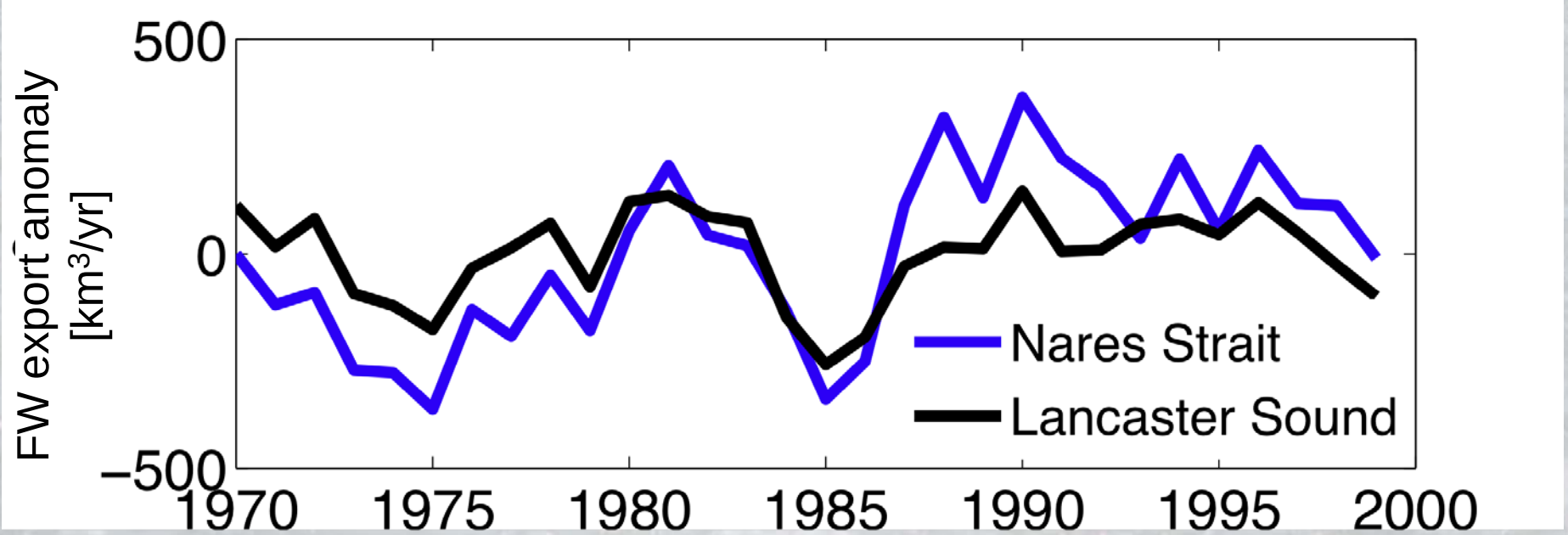
- In CCSM4, Lancaster Sound makes up 28% of total CAA FW flux, Nares Strait 72%
  - Other models suggest that Lancaster Sound transports makes up 40-50% of the CAA FW export (Kliem and Greenberg 2003, Maslowski, 2003)
  - Observations suggest than Nares Strait FW export makes up 39%, Lancaster Sound 61%.

  → Nares Strait export is likely too large, at the expense of Lancaster Sound
- Combined CCSM4 CAA FW flux (3235 km^3/yr) is in good agreement with observations (3200 +/- 320 km^3/yr).

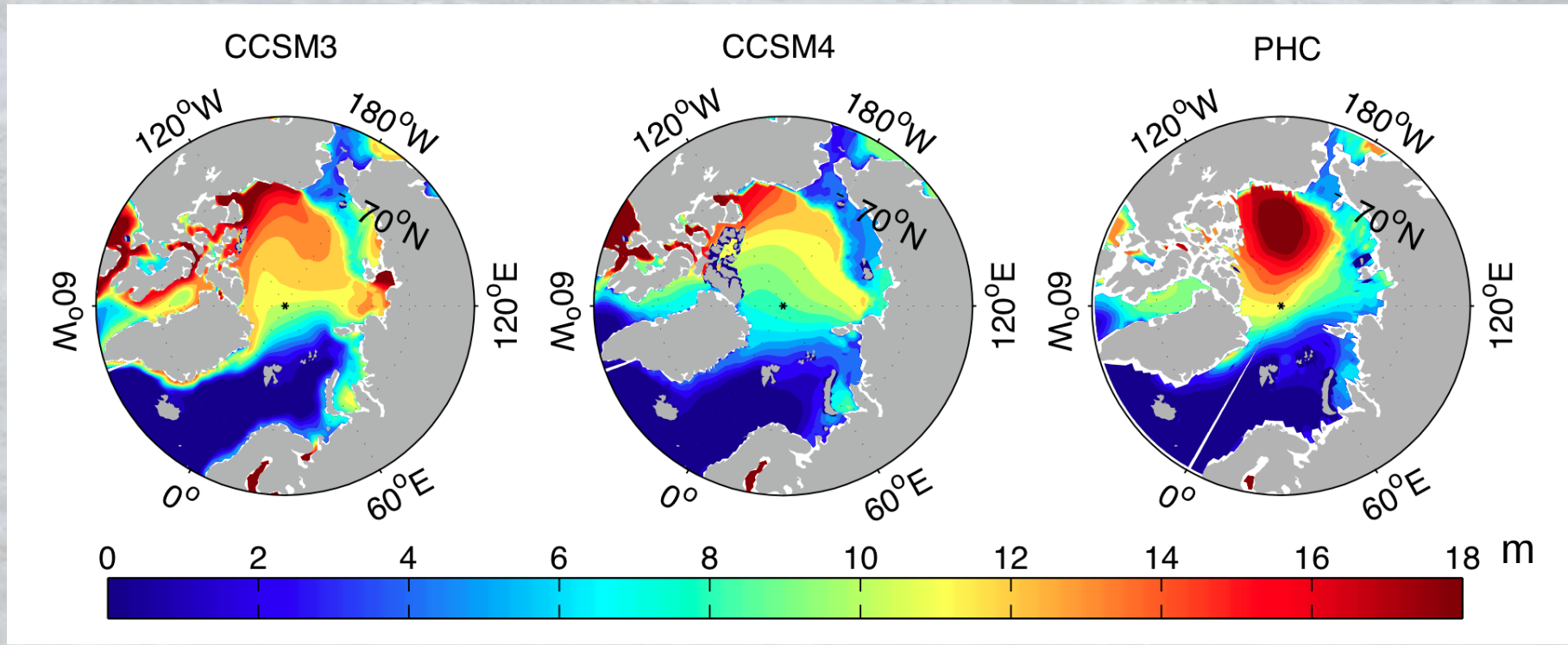
  → Overall, better agreement of FW fluxes with observations in CCSM4 than in CCSM3

Variability of export in Nares Strait and Lancaster sound

- FW export through the two straits are correlated with r=0.73
- Volume fluxes correlated with r=0.93, salinity anomalies with r=0.85



Liquid FW column



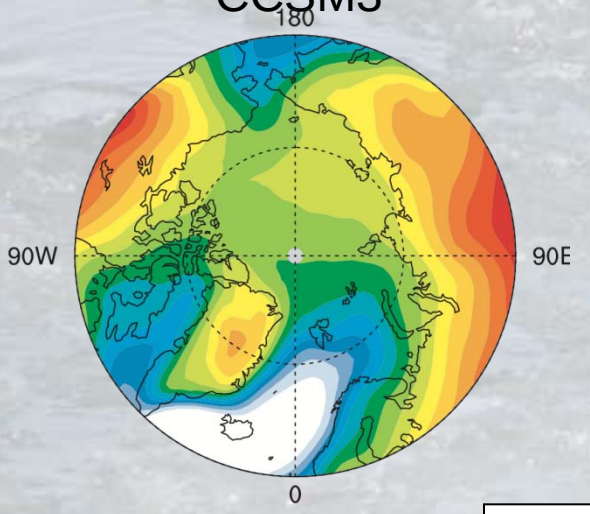
98,126 km^3 78,548 km^3 80,049 km^3

Arctic Ocean is saltier in CCSM4, and FW content is closer to observations (PHC data, Steele et al., 2001)
Beaufort Gyre in CCSM4 is not as large as in PHC data or CCSM3

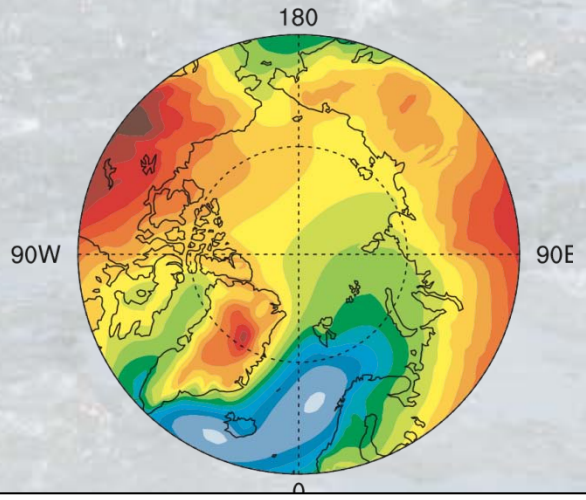
SLP field

Annual mean:

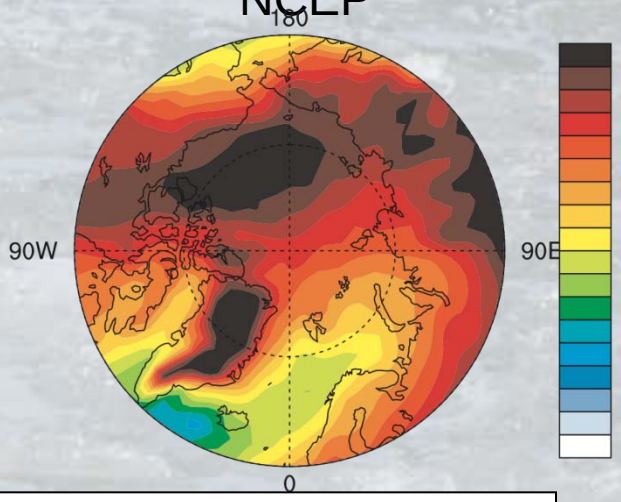
CCSM3



CCSM4

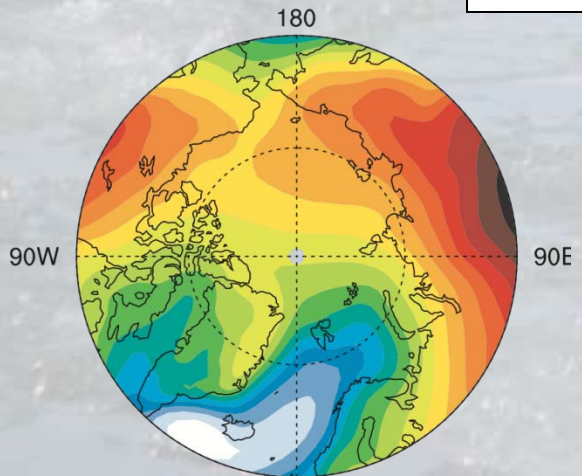


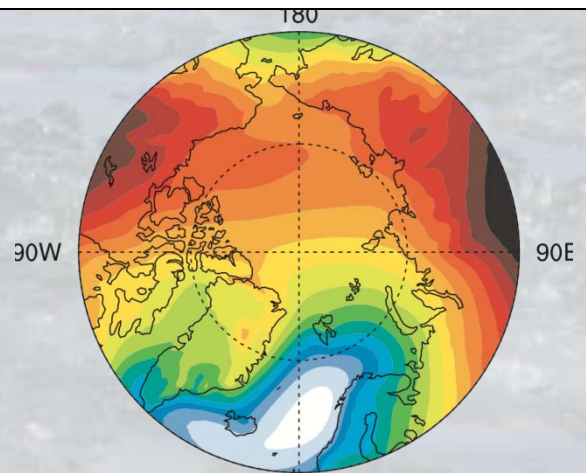
NCEP

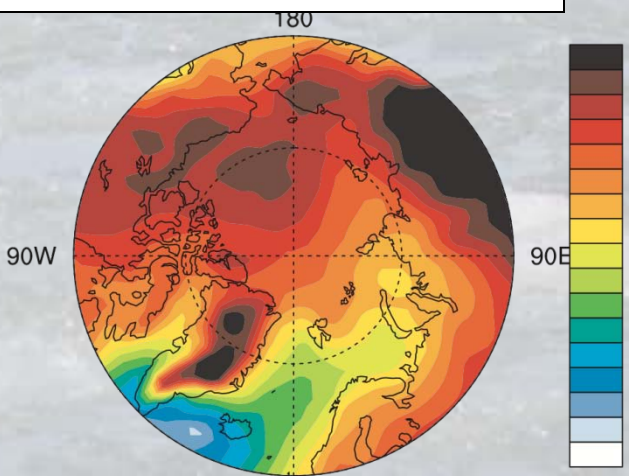


Stronger Arctic High in CCSM4 than CCSM3, but not as intense as shown in NCEP data

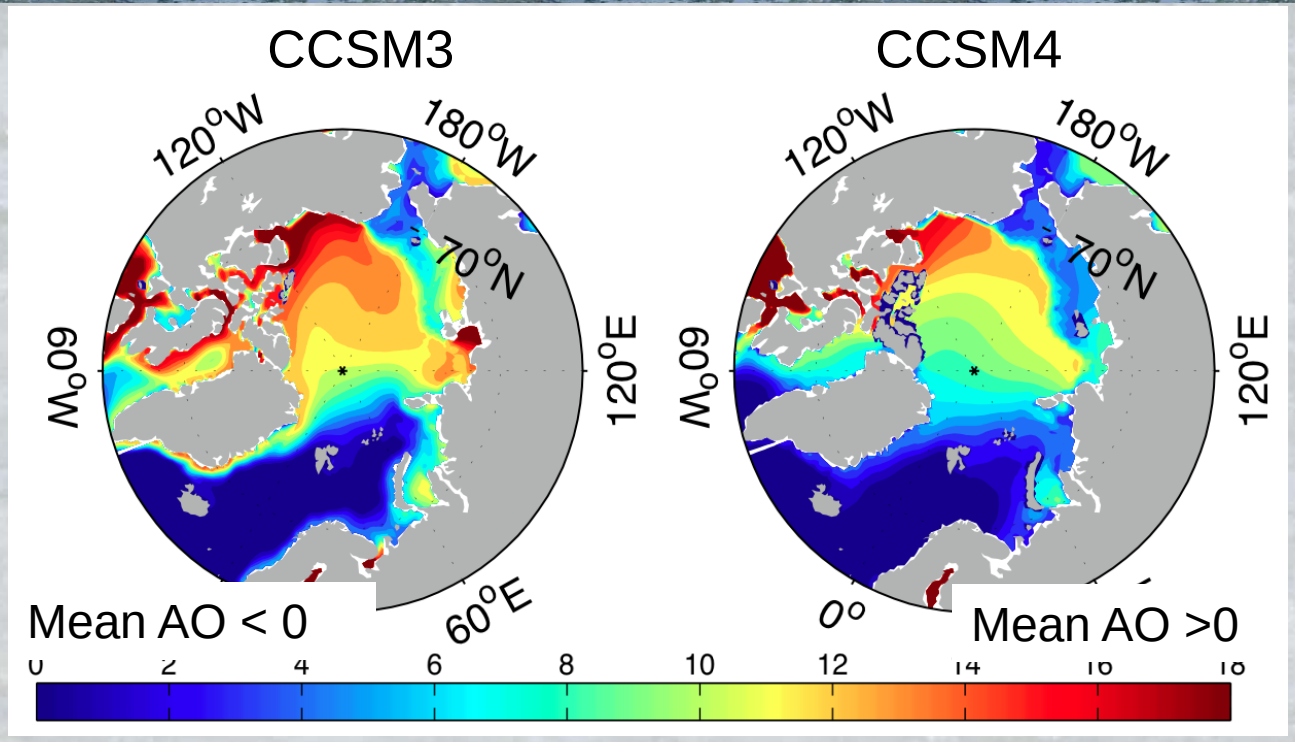
DJF mean



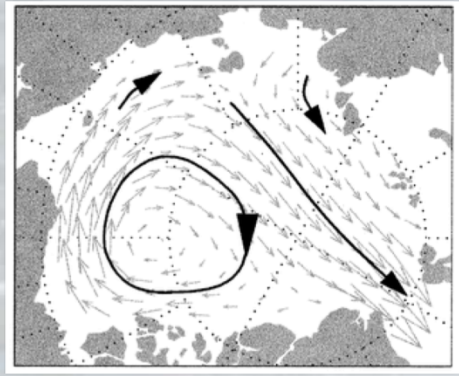




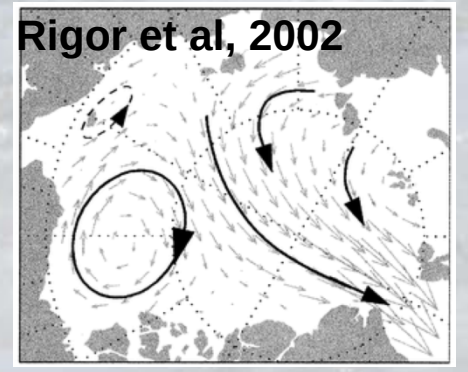
Phase of atmospheric forcing and possible effect on Beaufort Gyre shape



Anticyclonic regime



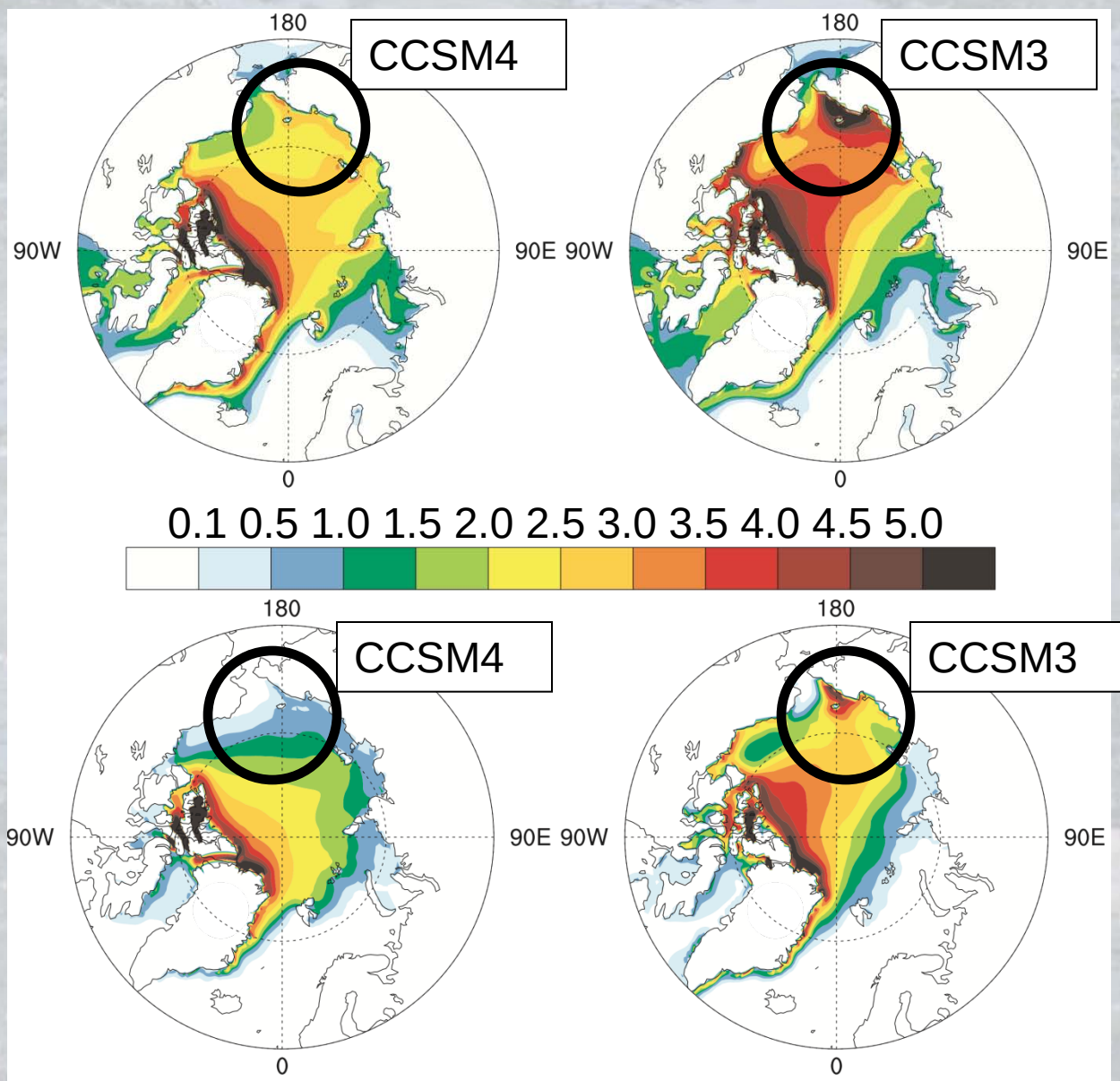
Cyclonic Regime



Sea ice thickness

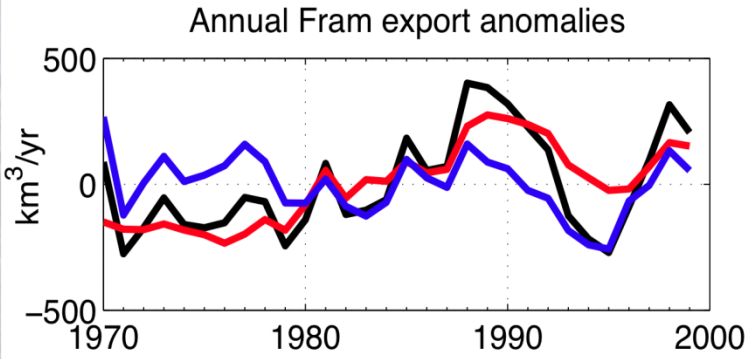
March

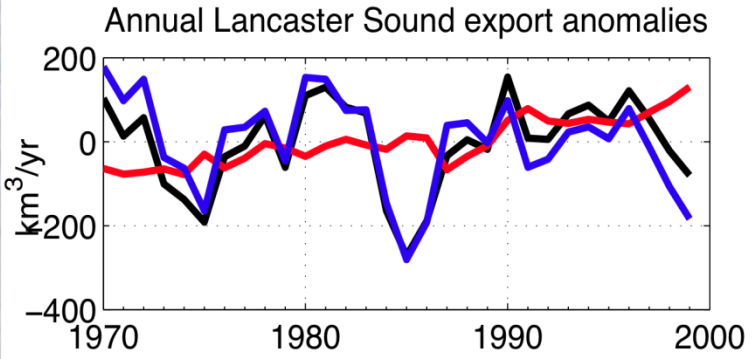
September

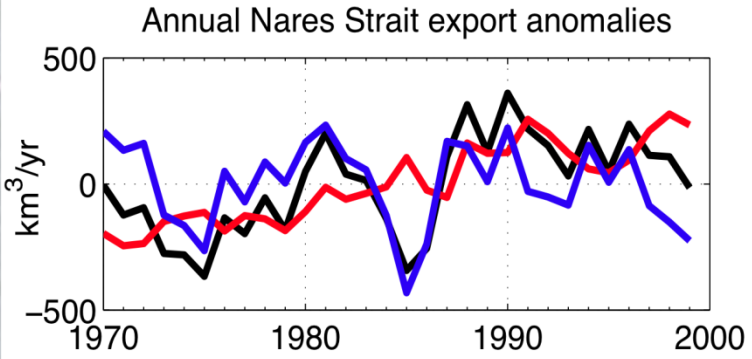


Salinity versus Volume flux anomalies?

CCSM4



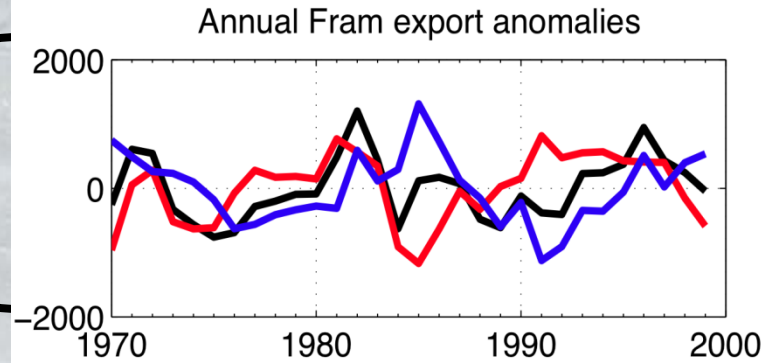


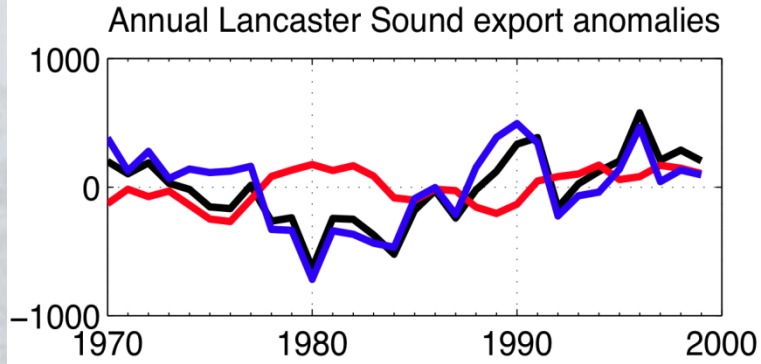


Affected by both salinity and volume flux anomalies

Dominated by volume flux anomalies

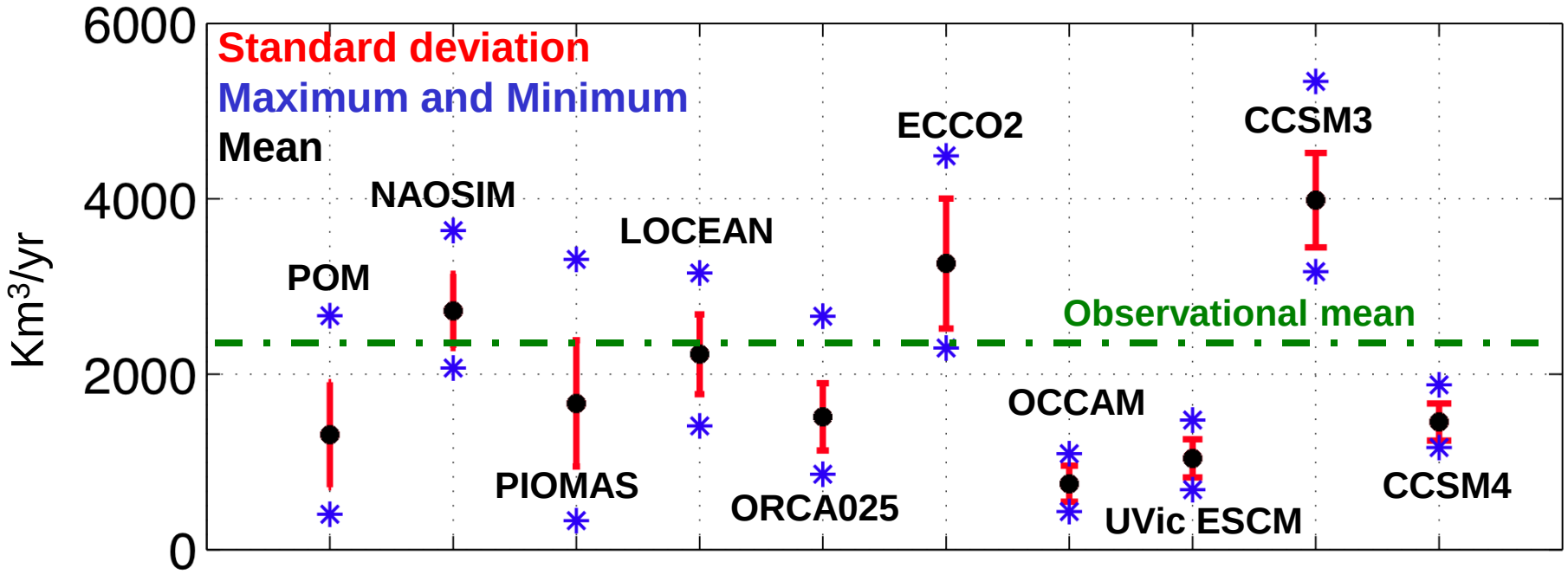
CCSM3





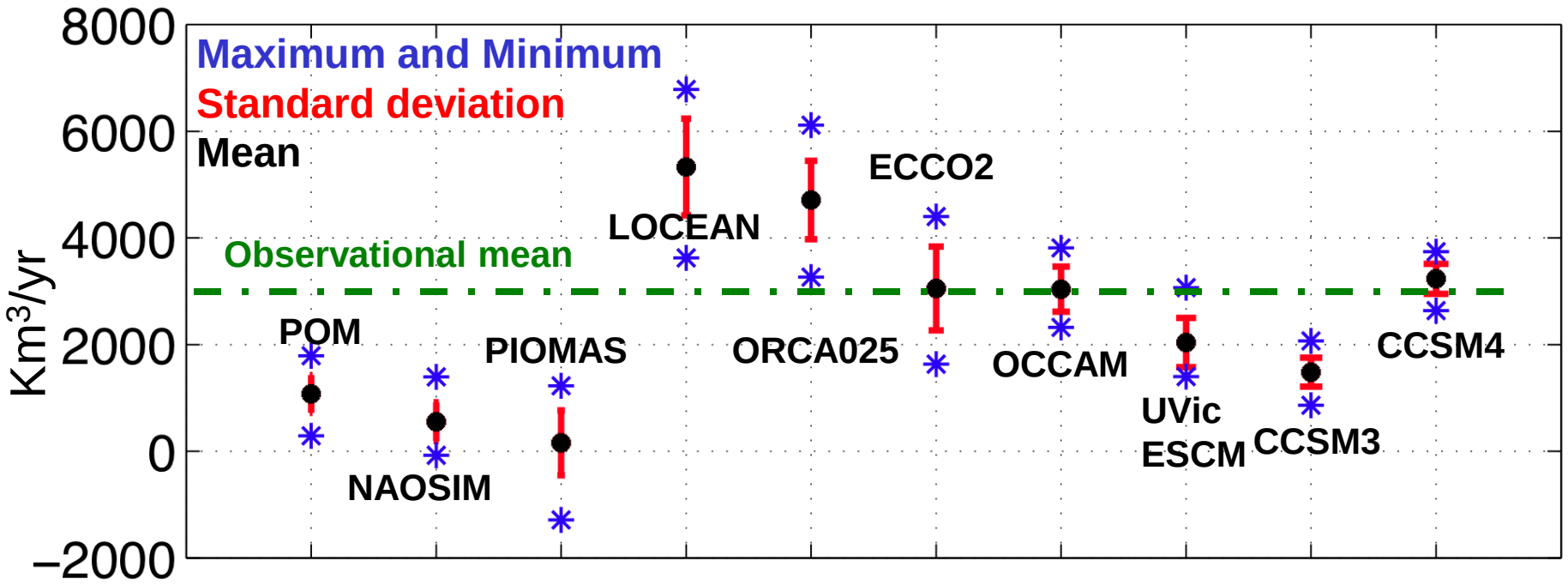
Total FW
Salinity driven
Volume flux driven

Variability of Fram Strait FW export



Variability is much smaller in CCSM4 than CCSM3, and smaller than in most regional models.

Variability of CAA FW export



Large disagreement between models on variability of the CAA FW export!

CCSM3 and CCSM4 have a similar standard deviation and range, but mean is in better agreement with observations in CCSM4

Summary

- As a result of the opened Nares Strait, the liquid FW export through Fram Strait is reduced, and more FW leaves through the CAA, which brings the budget into better agreement with observation
- Variability and mean of the Fram Strait FW export is now too small compared with observations and regional models
- Nares Strait export is too large, at the expense of the Lancaster Sound export. Observations and models suggest Lancaster Sound should have the larger FW export
- Export variability in Nares and Lancaster Sound is very similar, especially the volume flux variability. CAA export variability is within range of regional model results.
- In agreement with CCSM3, the Fram Strait FW export is due to salinity and volume flux changes, whereas in Lancaster Sound and in Nares Strait volume flux changes dominate the variability
- Beaufort Gyre occupies smaller area, possibly due to mean AO >0 in 30yr simulation with CCSM4. Generally, SLP field over Arctic is closer to NCEP data than in CCSM3

Future work

- Lots of more detailed analysis to be done, i.e.
  - How does simulation of future increase in liquid FW export change now that Nares Strait is open? Larger increase in CAA FW export, as seen in ECHAM5 results (Koenig et al., 2007)? Or still larger increase in Fram Strait liquid FW export, as in Holland et al. (2007)?
  - Water mass composition in Nares Strait in the model? And how does water mass composition change in Fram Strait, now that Nares is open?
  - How much does the Beaufort Gyre shape vary in CCSM4, and do we get a large Beaufport Gyre as in PHC during a different period?
  - How does better SLP simulation in CAM5 affect FW distribution in the Arctic?
  - How does opened Sannikov and Kara Strait affect distribution of runoff in the Arctic Ocean?

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