Arctic Ocean simulation in the CCSM4

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Objective and Method

Objective:

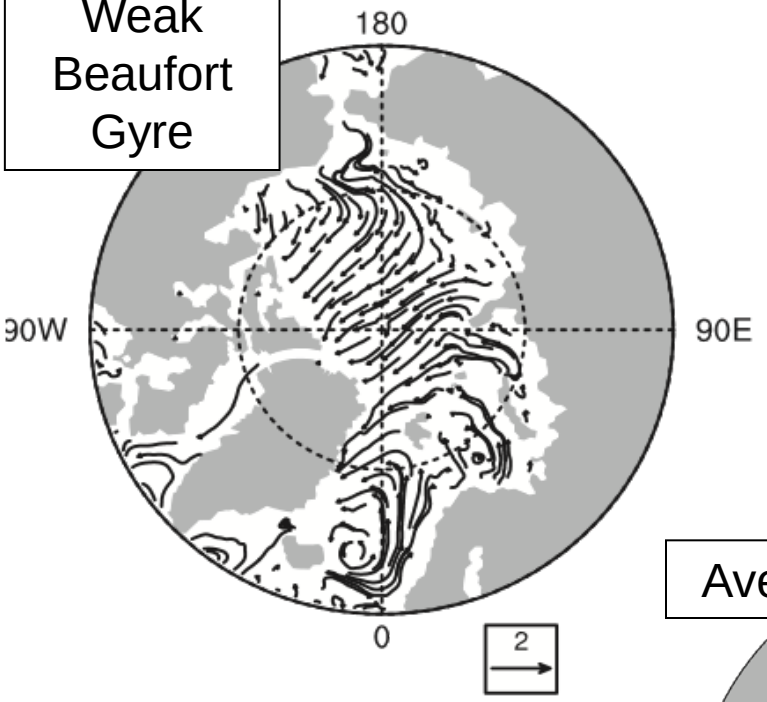
- 1) Establish how well the CCSM4 simulates the late 20th century Arctic Ocean properties
- 2) Investigate how the key parameters of the Arctic Ocean change in the 21st century

Method:

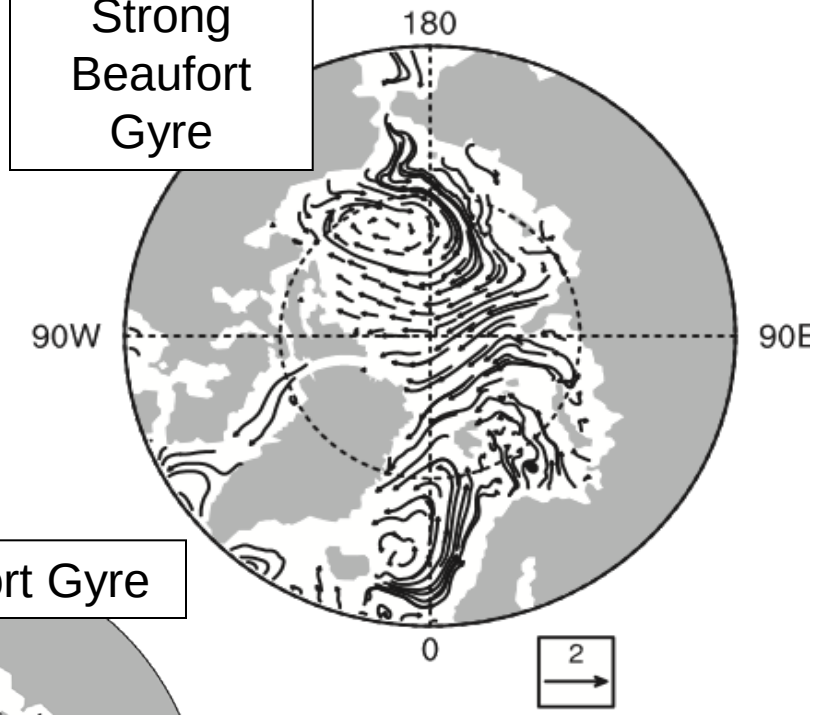
- Use the six available CCSM4 ensemble simulation for 1981-2005 and the 21st century, and available observations

Beaufort Gyre in CCSM4

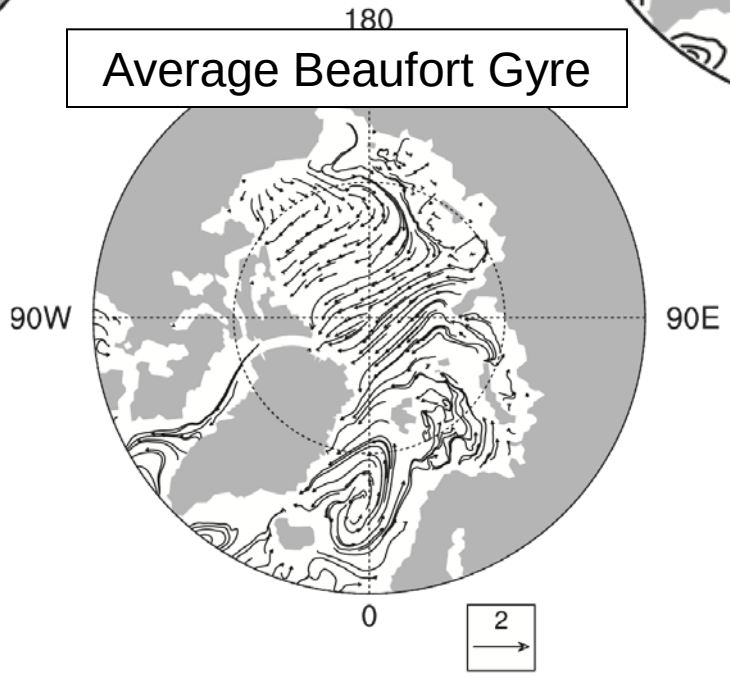
Weak Beaufort Gyre



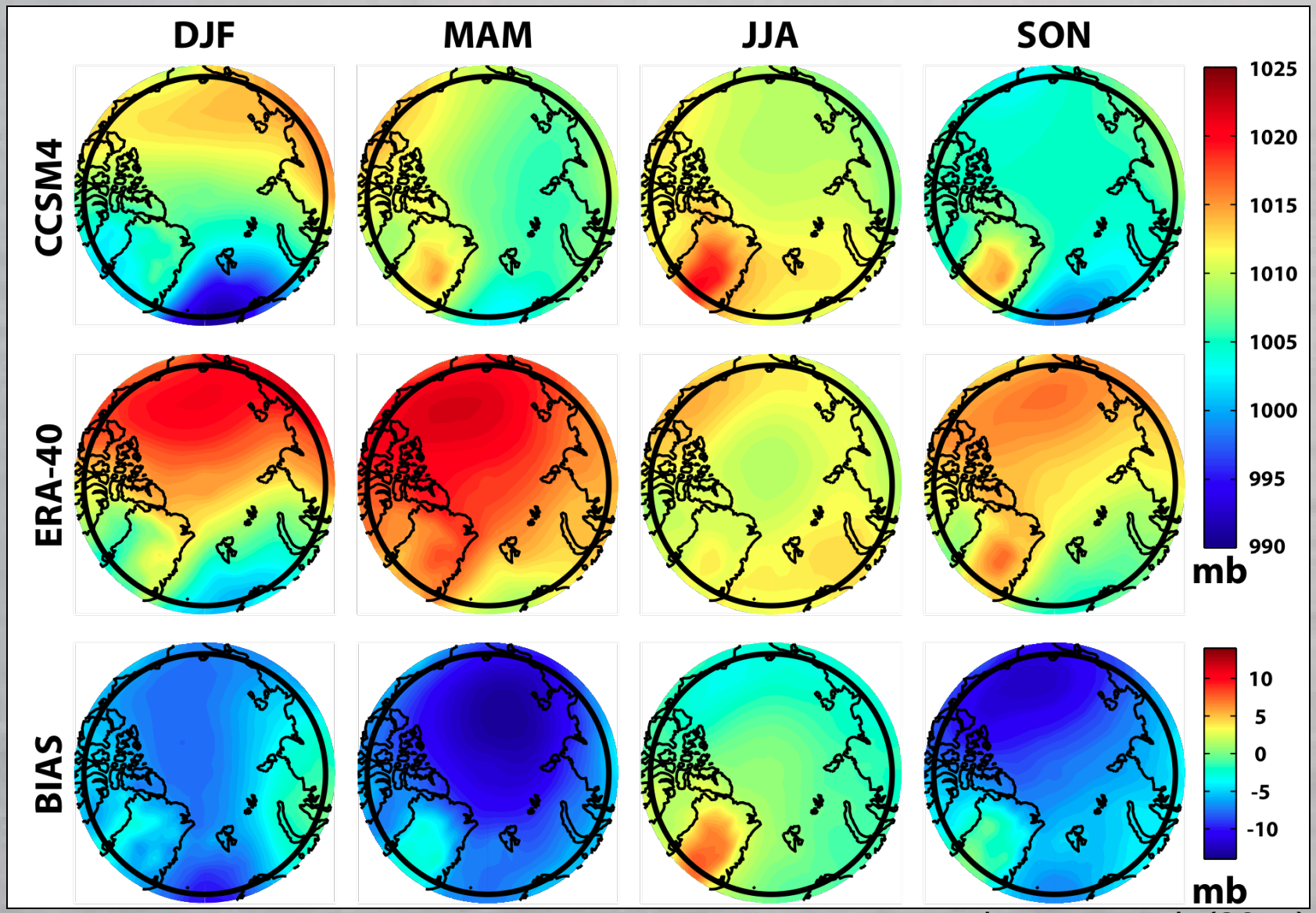
Strong Beaufort Gyre



Average Beaufort Gyre

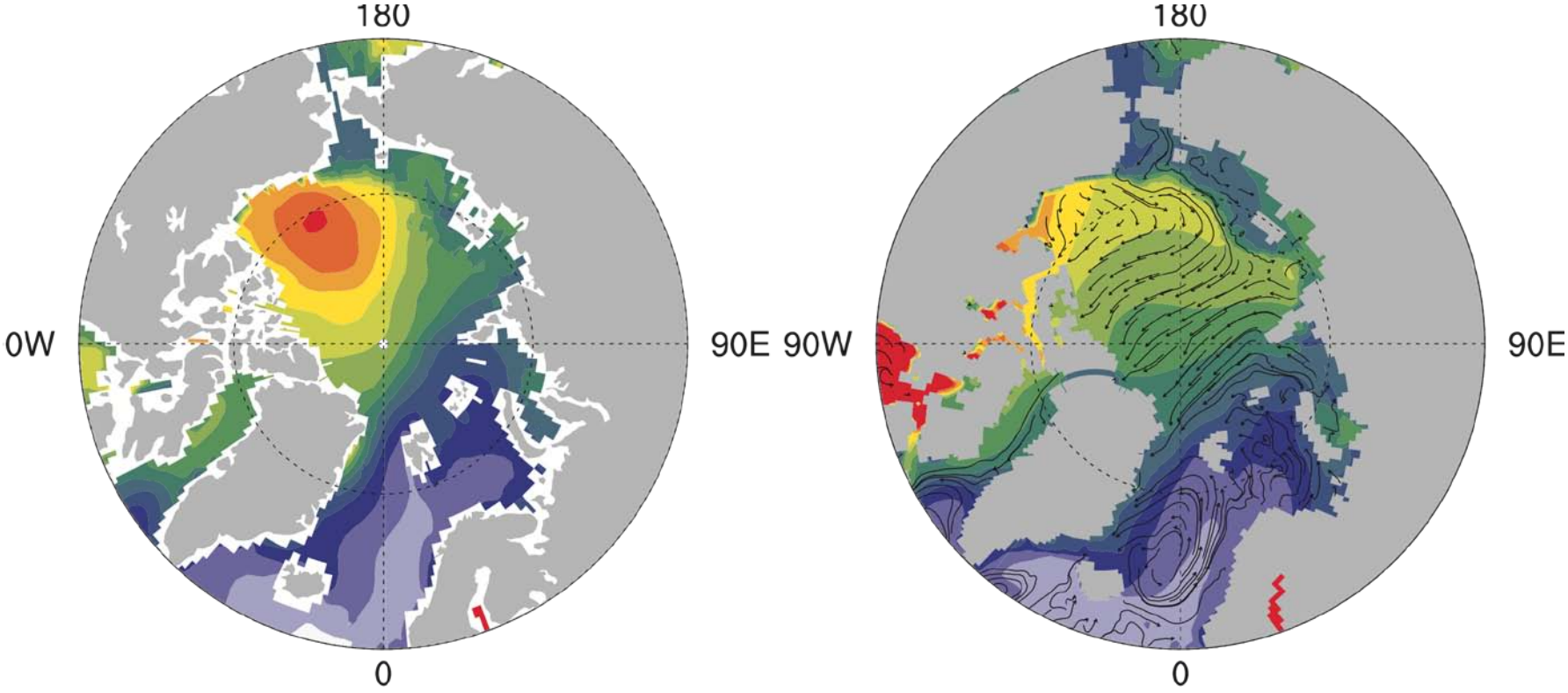


SLP bias



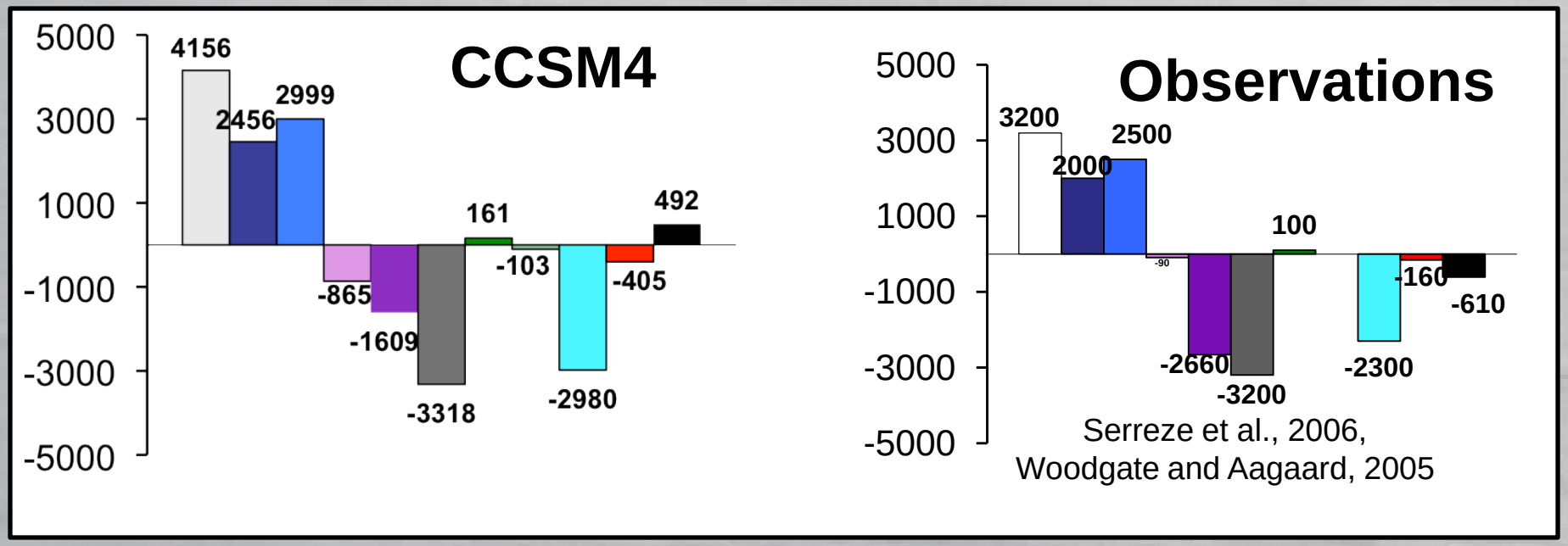
de Boer et al. (2011)

Arctic FW column [m]



Jahn et al., 2011

Arctic FW budget



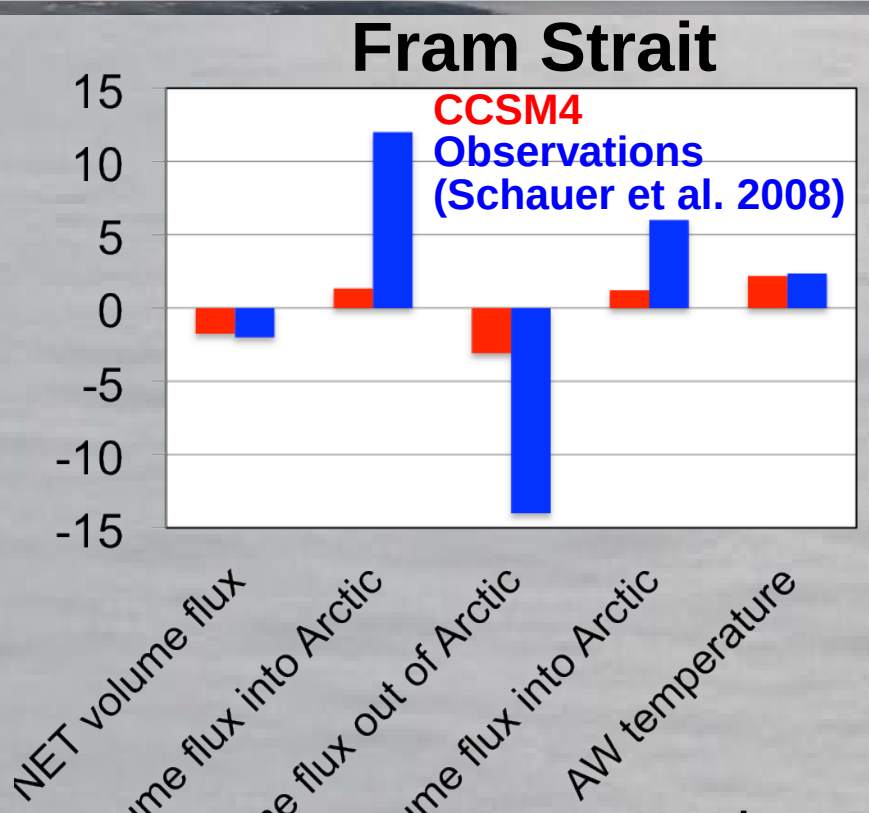
- River Runoff
- P-E
- Bering Strait liquid
- Barents Sea liquid
- Fram Strait liquid
- CAA liquid
- Bering Strait solid
- Barents Sea solid
- Fram Strait solid
- CAA solid
- Net

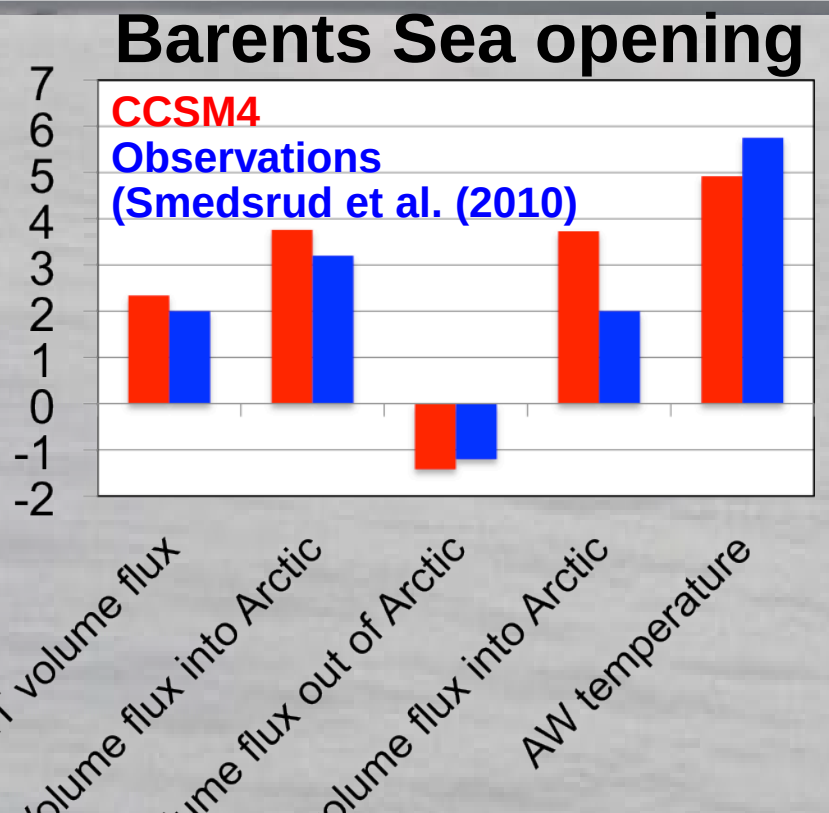
Overall good agreement.
Main biases:

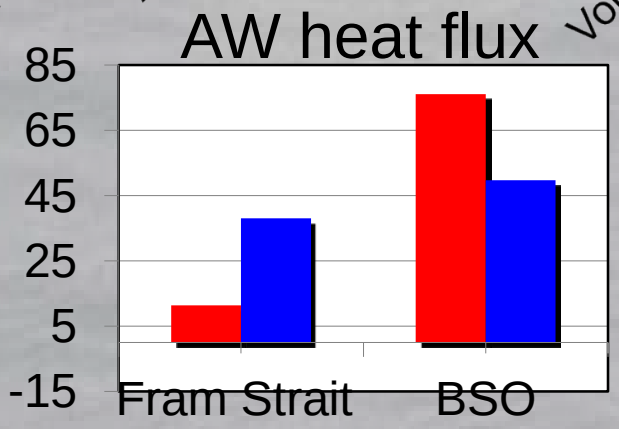
- Too much FW input
- FW export east of Greenland split between Fram Strait and Barents Sea

Jahn et al., 2011

Volume and AW heat fluxes: Fram Strait



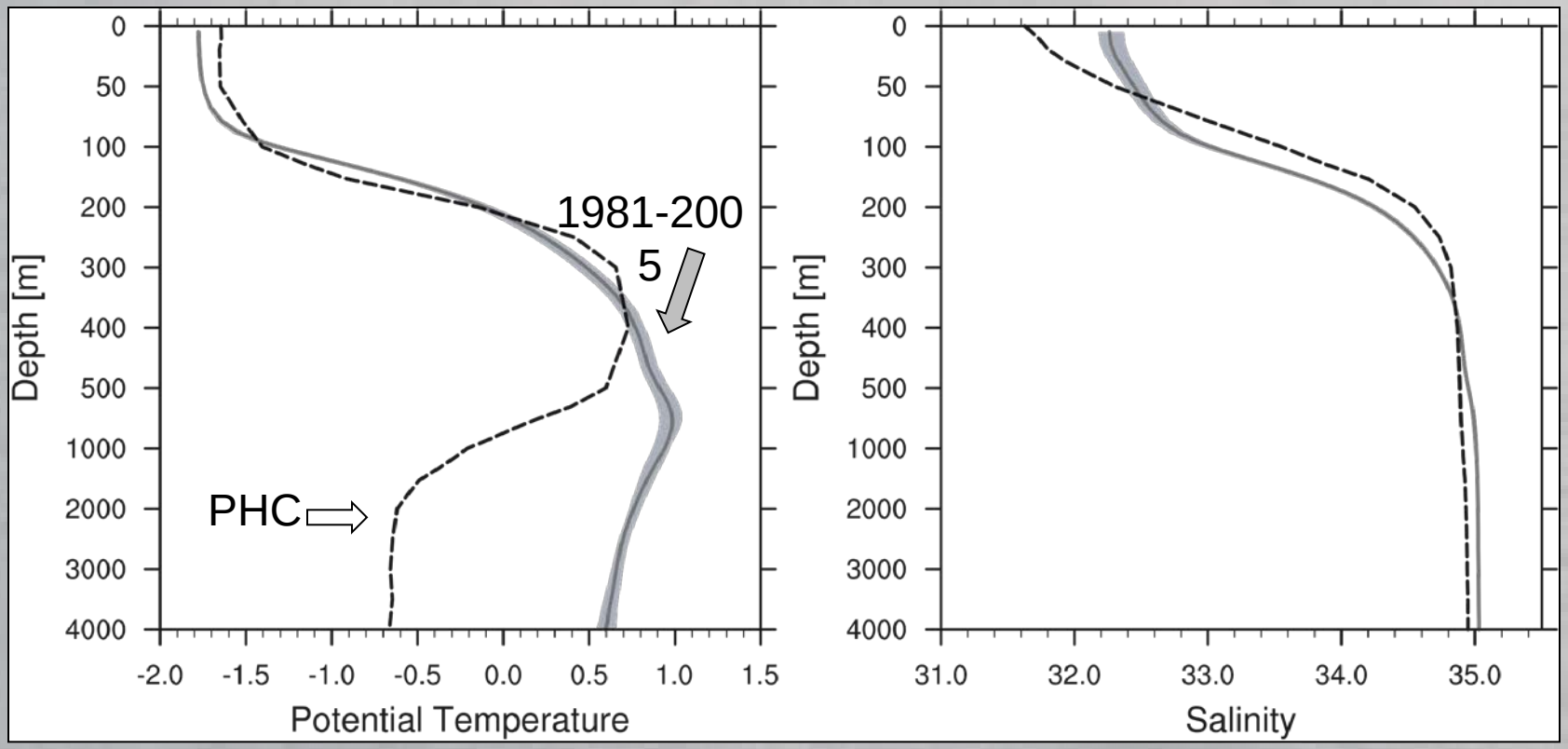




Net heat flux into Arctic Ocean about right, but too much enters through the BSO

Jahn et al., 2011

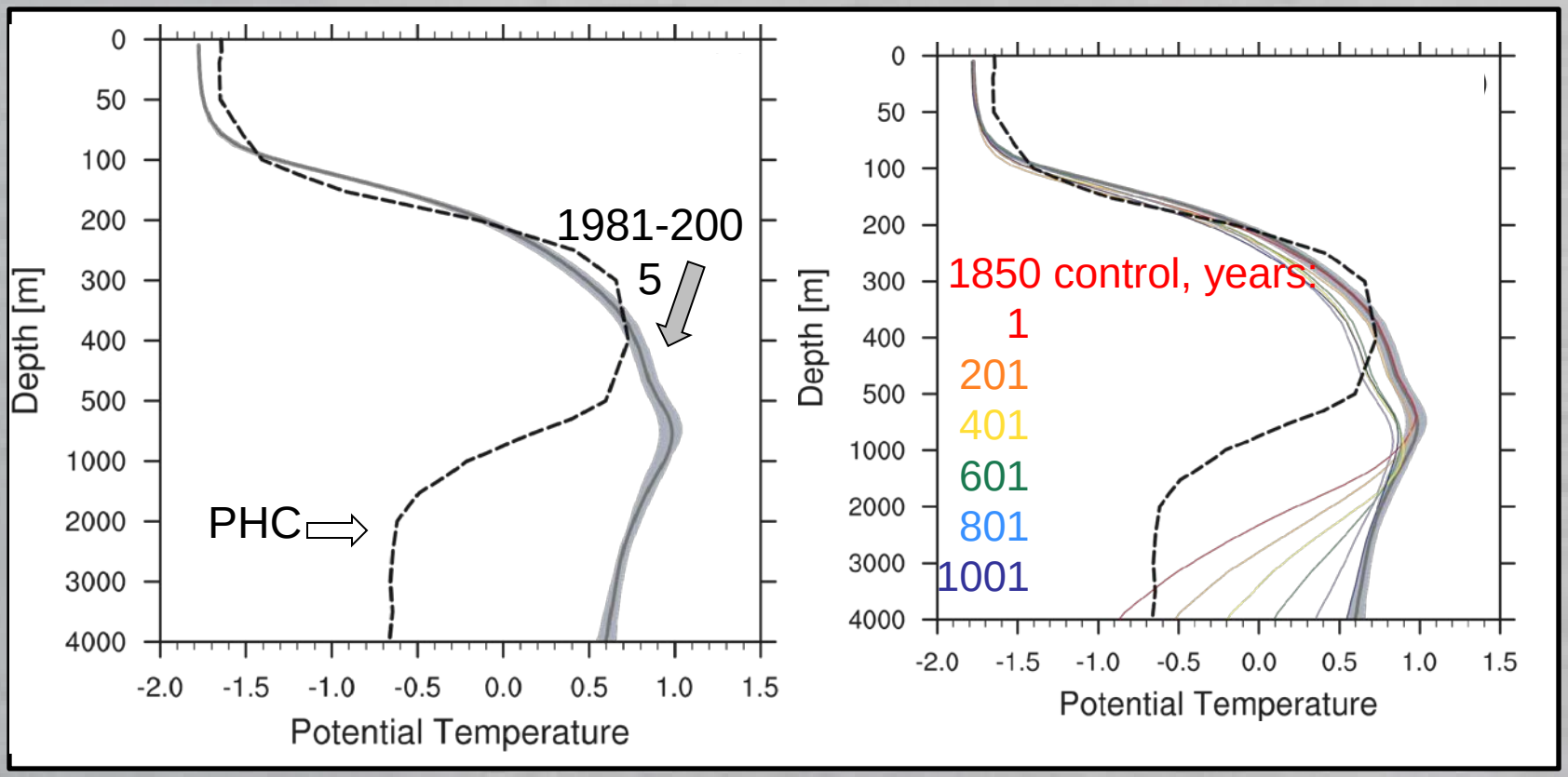
Vertical Temperature and Salinity



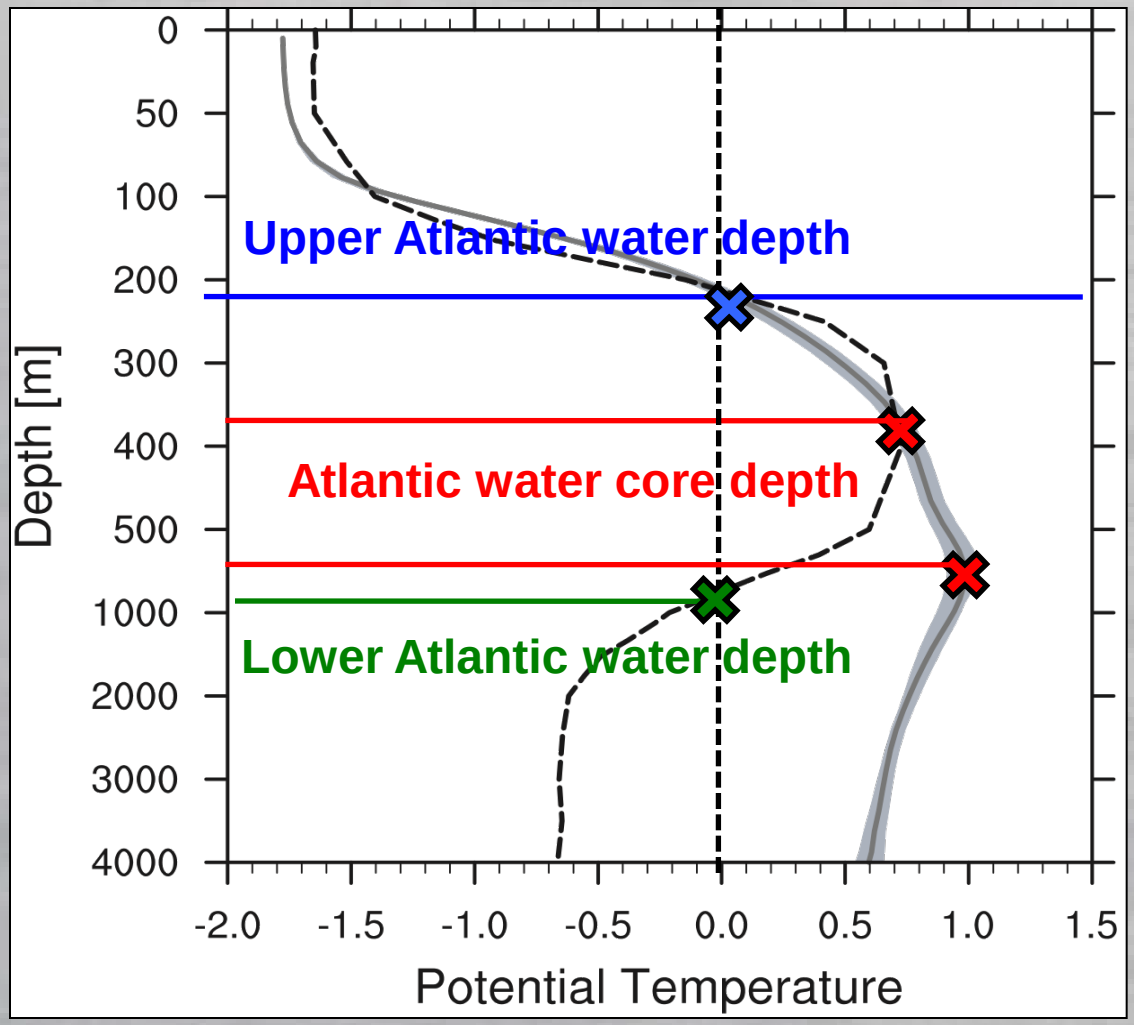
Too deep and warm AW temperature maximum
Not enough cooling below 500m
Surface waters too salty

Jahn et al., 2011

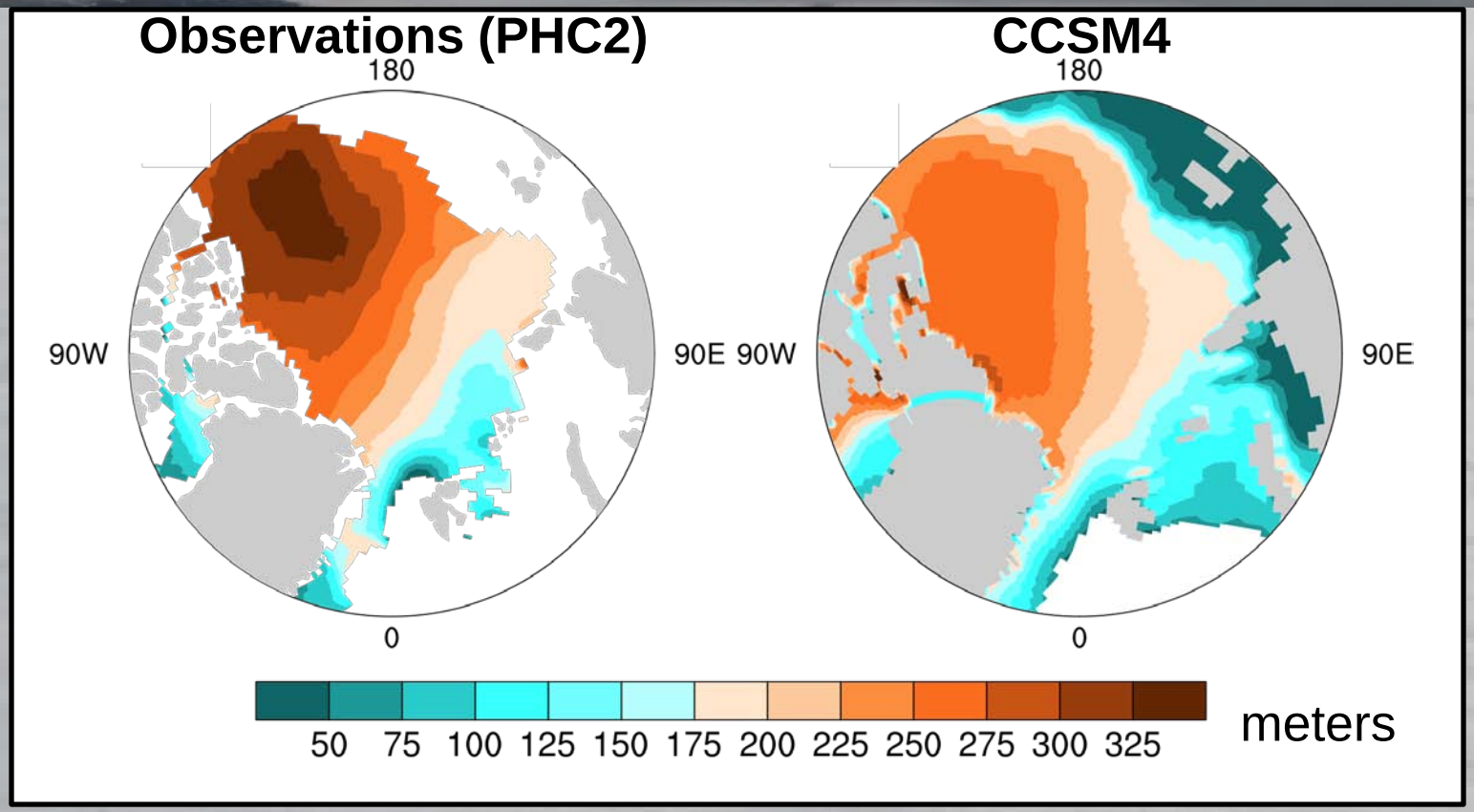
Why is the deep Arctic Ocean so warm?

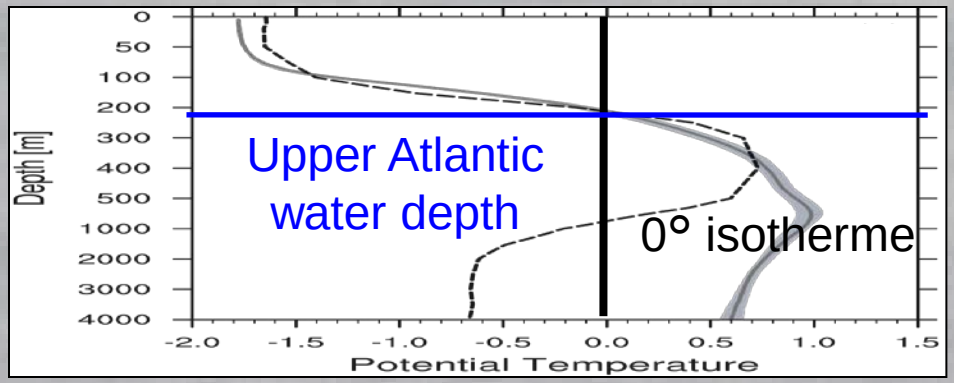


Atlantic water



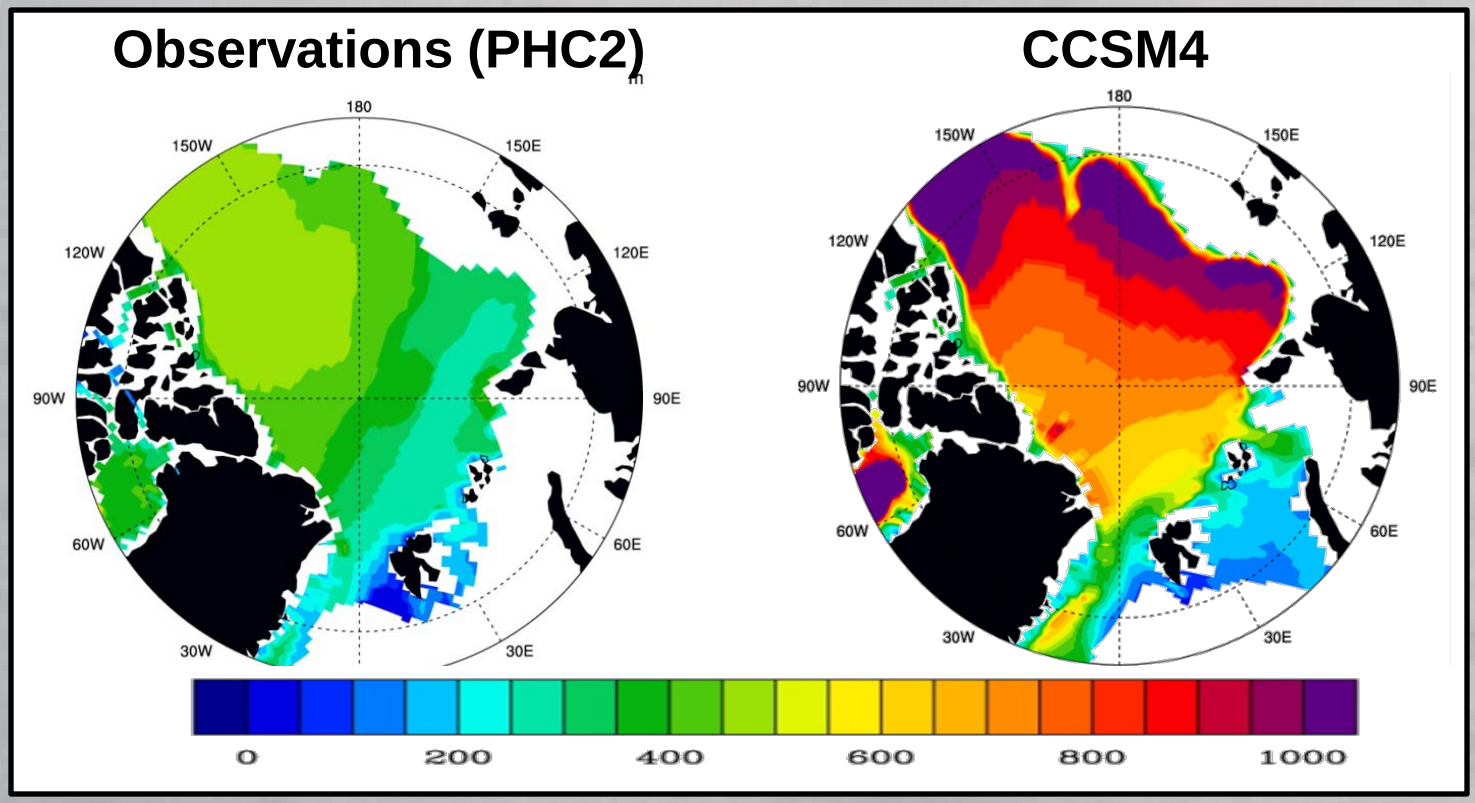
Upper Atlantic water depth

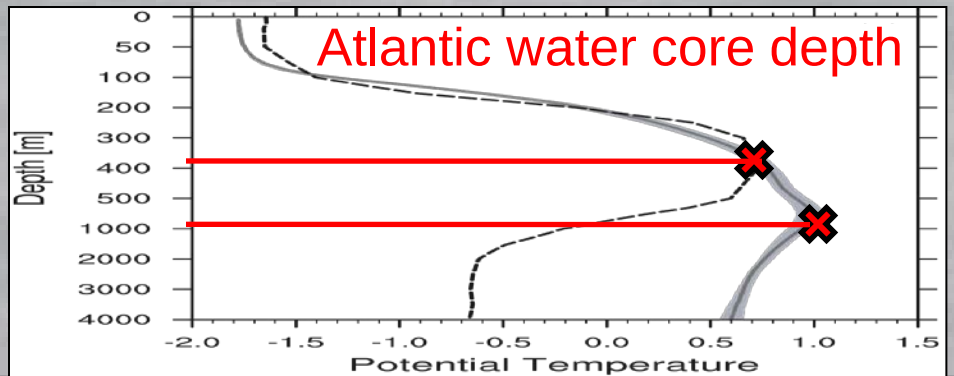




Jahn et al., 2011

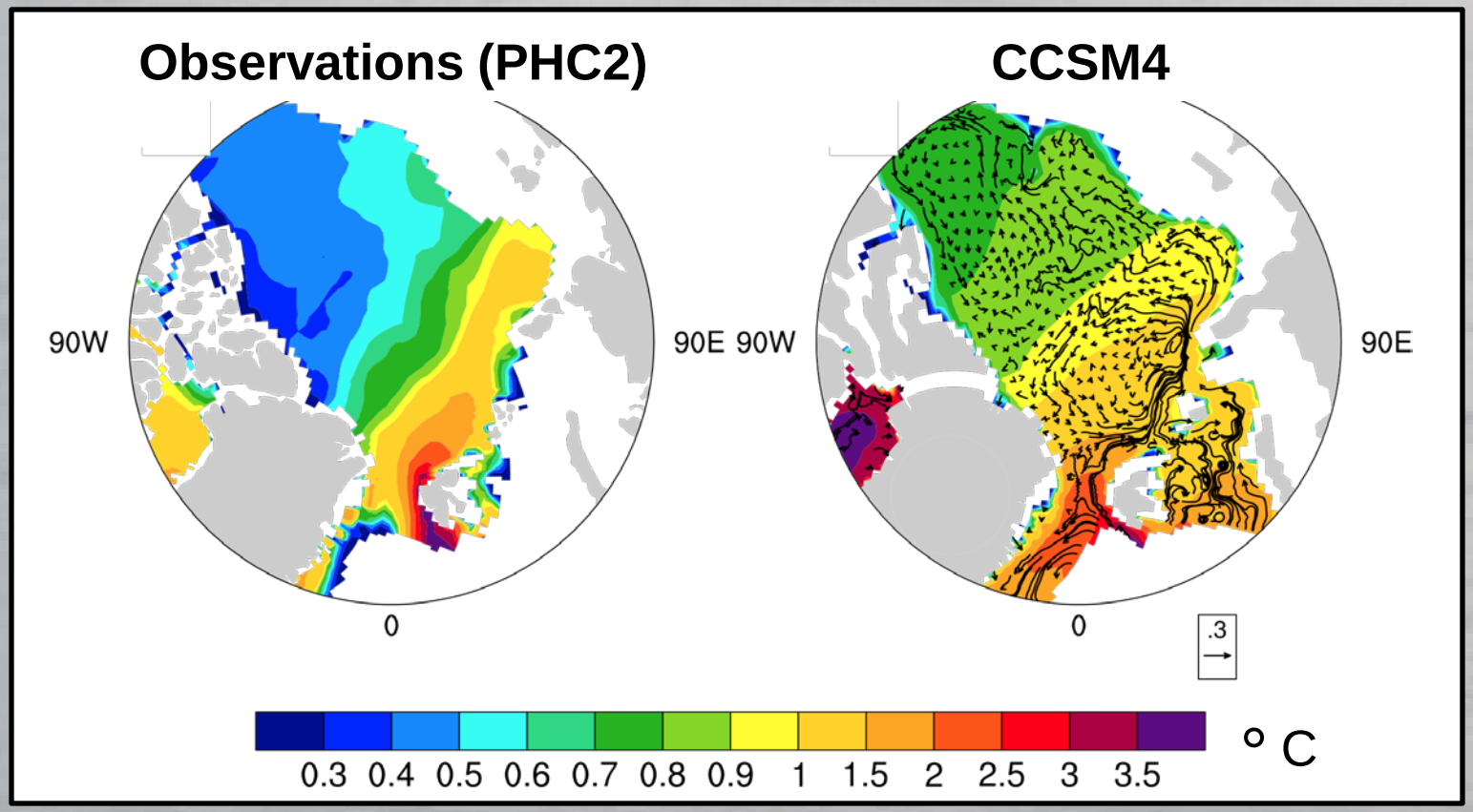
Atlantic water core depth





Jahn et al., 2011

Temperature at Atlantic water core depth

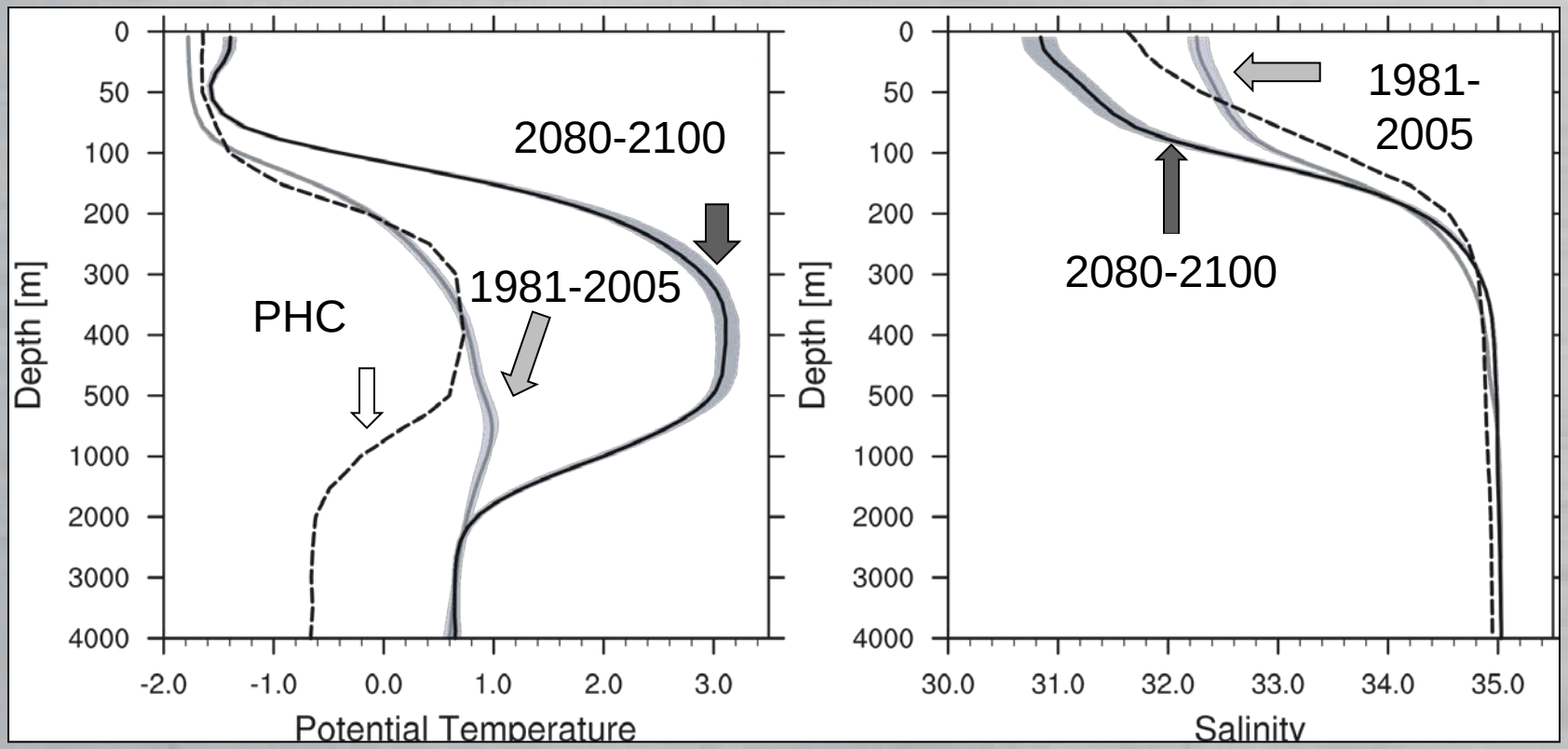


- AW core temperature too warm (by ~0.5°C)
- AW circulation shows many of the observed features

Jahn et al., 2011

21st Century

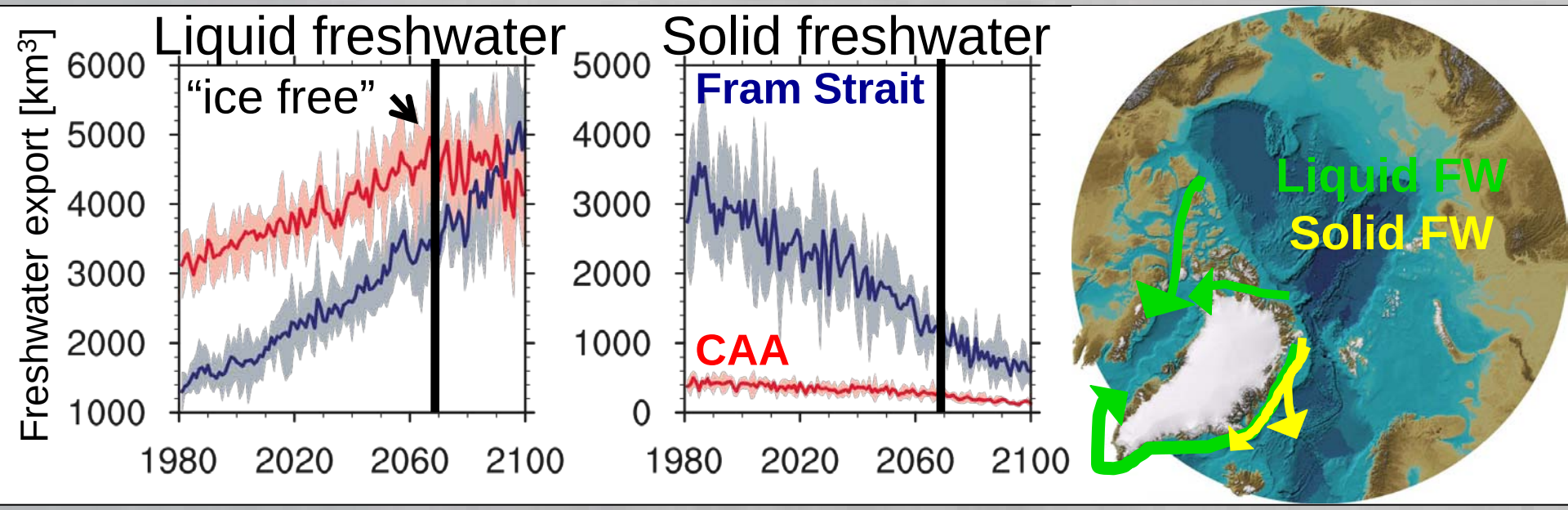
Vertical Temperature and Salinity



- Warming of AW layer is due to increased temperature of inflowing AW
- Surface freshening is due to increased FW input by rivers and more sea-ice melt within the Arctic Ocean

Vavrus et al., 2011

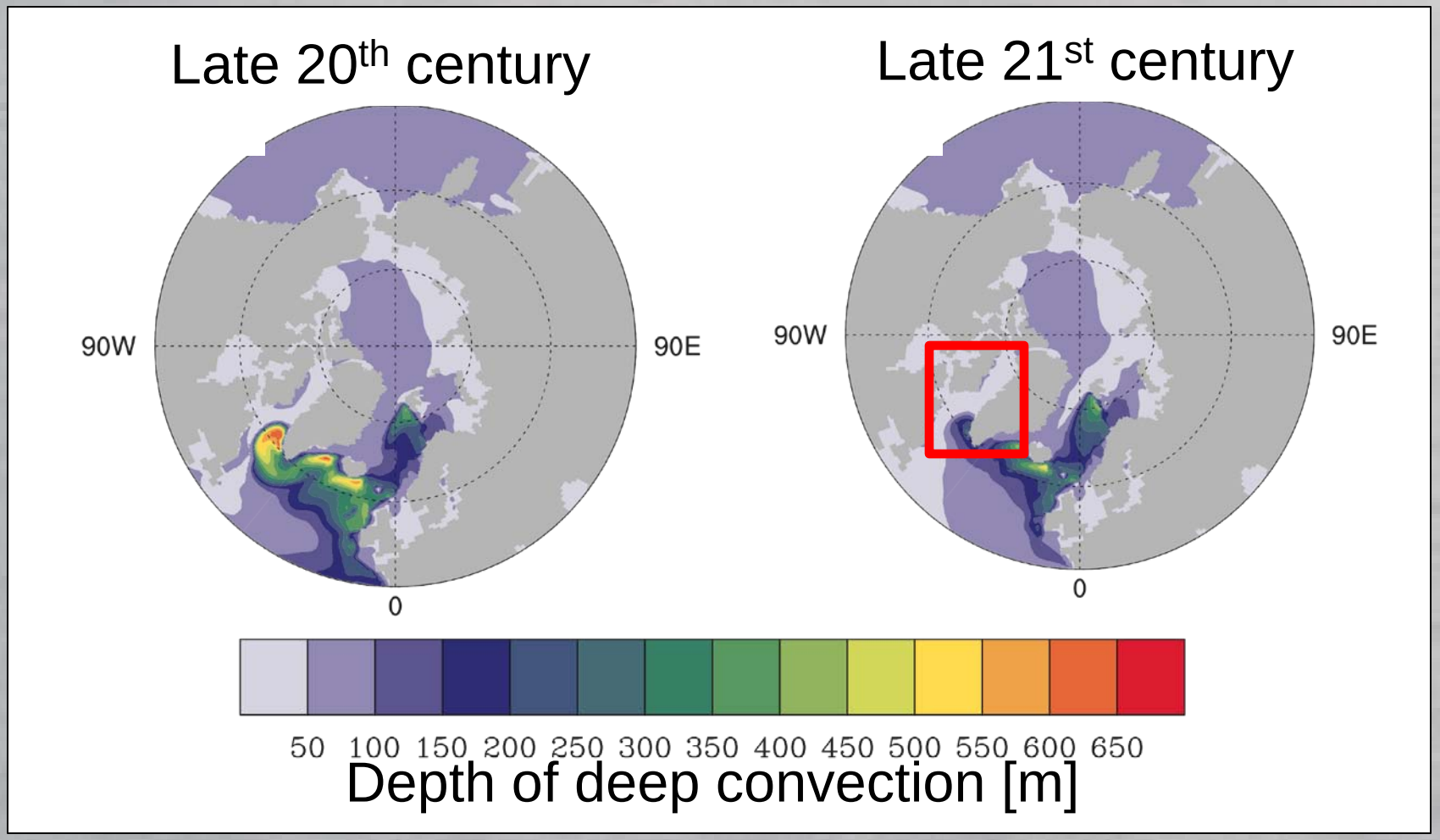
Freshwater export over the 21st century



Increasing freshwater export increases over the 21st century, with a shift from solid to liquid freshwater export

Vavrus et al., 2011

Impact on deep convection?



Vavrus et al., 2011

Summary: 20th century

20th century:

- The Beaufort Gyre is too weak due to a large SLP bias in all seasons
- Arctic FW budget is in overall good agreement with observations
- Net heat flux into Arctic Ocean about right, but too much enters through the BSO
- The upper Atlantic water depth (defined as the 0° C isotherm) is well simulated compared to the PHC2 temperature data, except in the Beaufort Gyre region where it is too shallow by 25-100 m compared to PHC2
- The Atlantic water core depth is too deep compared to PHC2 (by about 500m) and AW fills the entire deep Arctic Ocean
- Temperatures at the Atlantic water core depth are overall to warm, but the circulation pattern agrees with observations

Summary: 21st century

21st century:

- The AW layer warms due to increased temperatures of the inflowing water
- The surface freshens due to more runoff and more sea-ice melt in the Arctic Ocean
- The FW export from the Arctic shifts to predominantly liquid FW, which contributes to a decrease of the deep convection in the Labrador Sea at the end of the 21st century


Questions?
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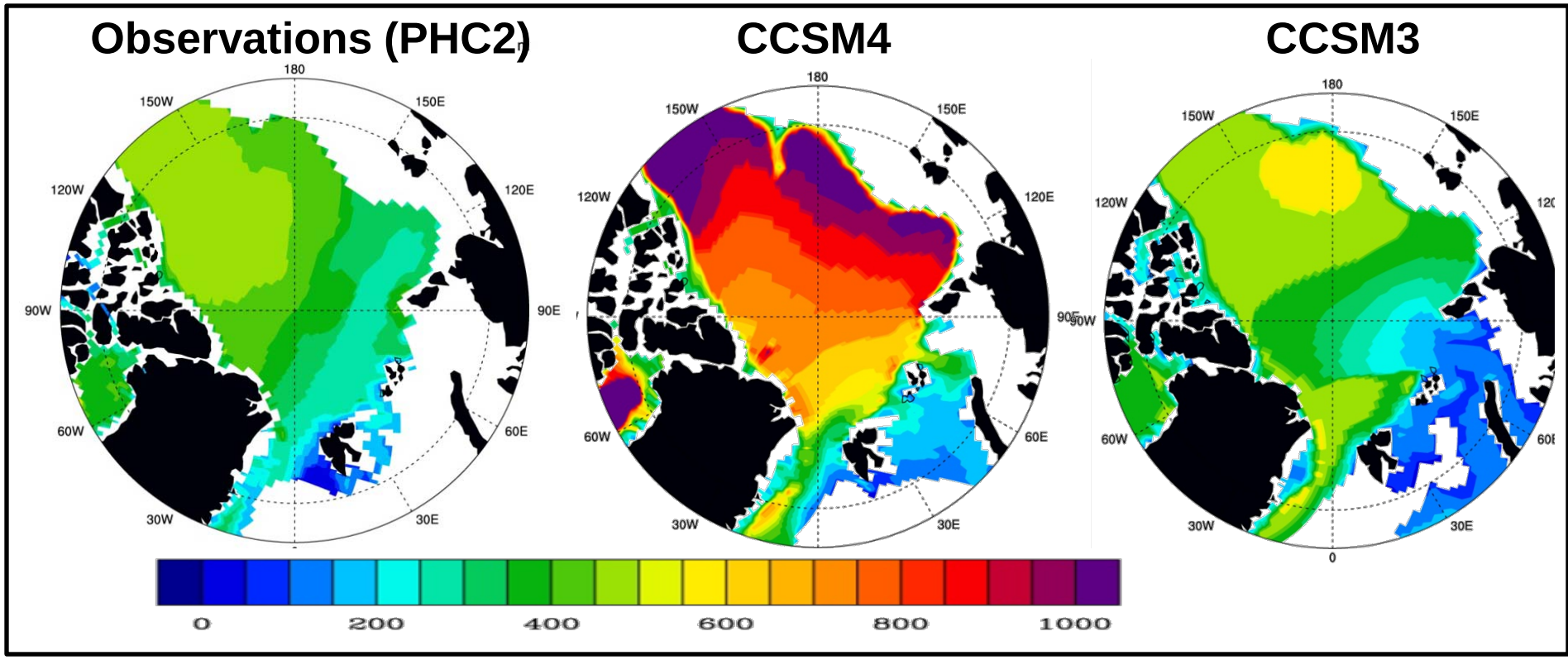
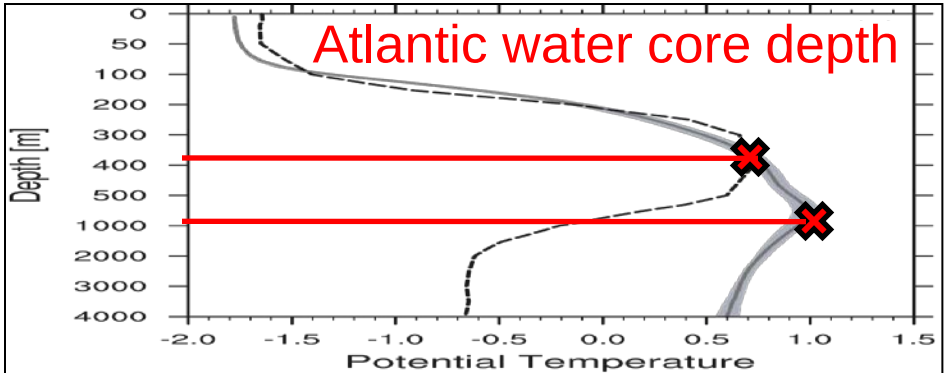
Atlantic water core depth





Impact on deep convection?

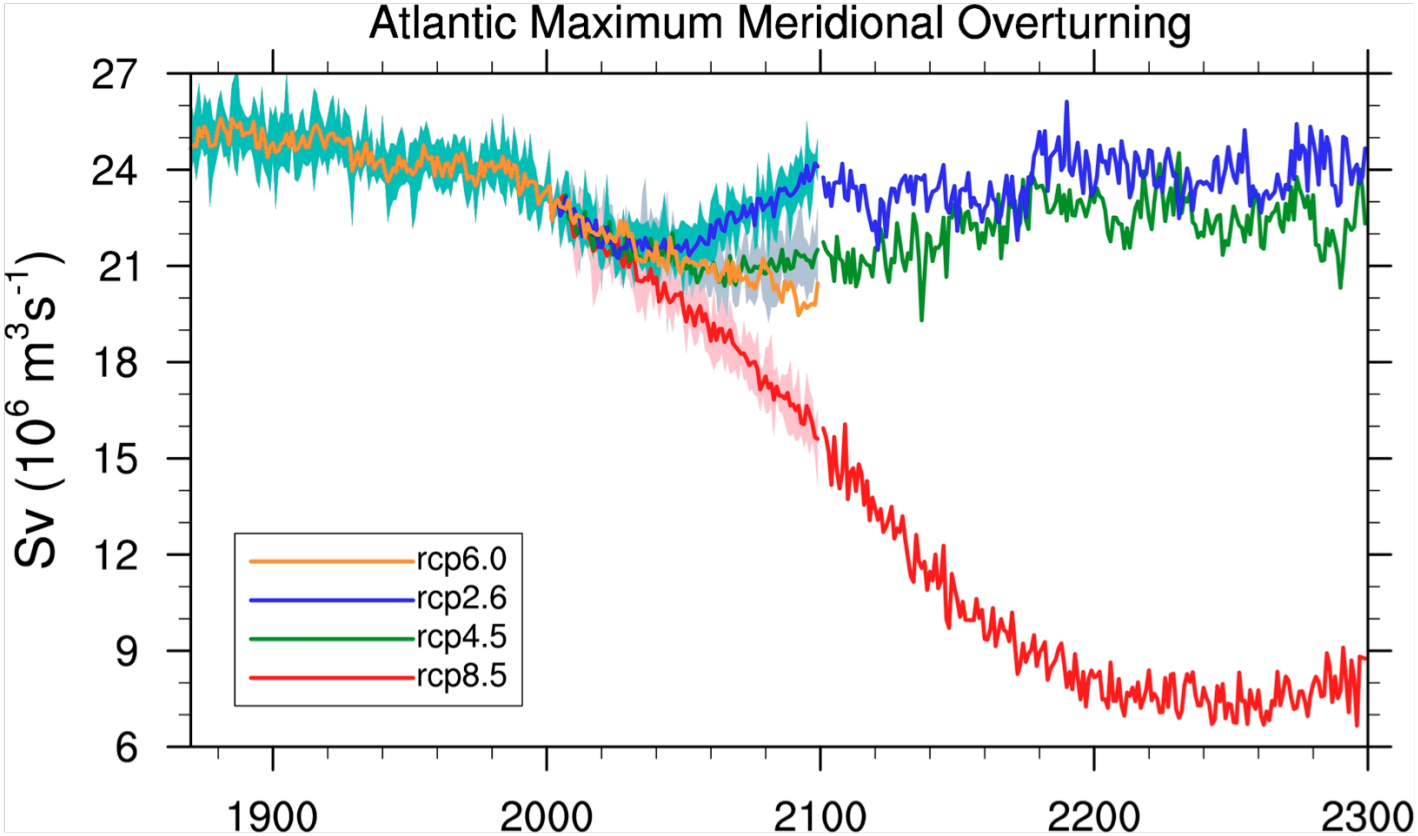


Fig. 15: Index of meridional overturning circulation (MOC) in the Atlantic taken as the largest value of meridional overturning streamfunction below 500 m depth in Sverdrups ($10^6 m^3 s^{-1}$). Solid lines are ensemble averages for 20th and 21st centuries with shading indicating the range of the ensemble. After 2100, solid lines indicate single members.

Meehl et al., 2011