Glacial climate stability and the oceanic pathway in the North Pacific

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Bering Strait: the Northern Oceanic Pathway between Pacific and Atlantic

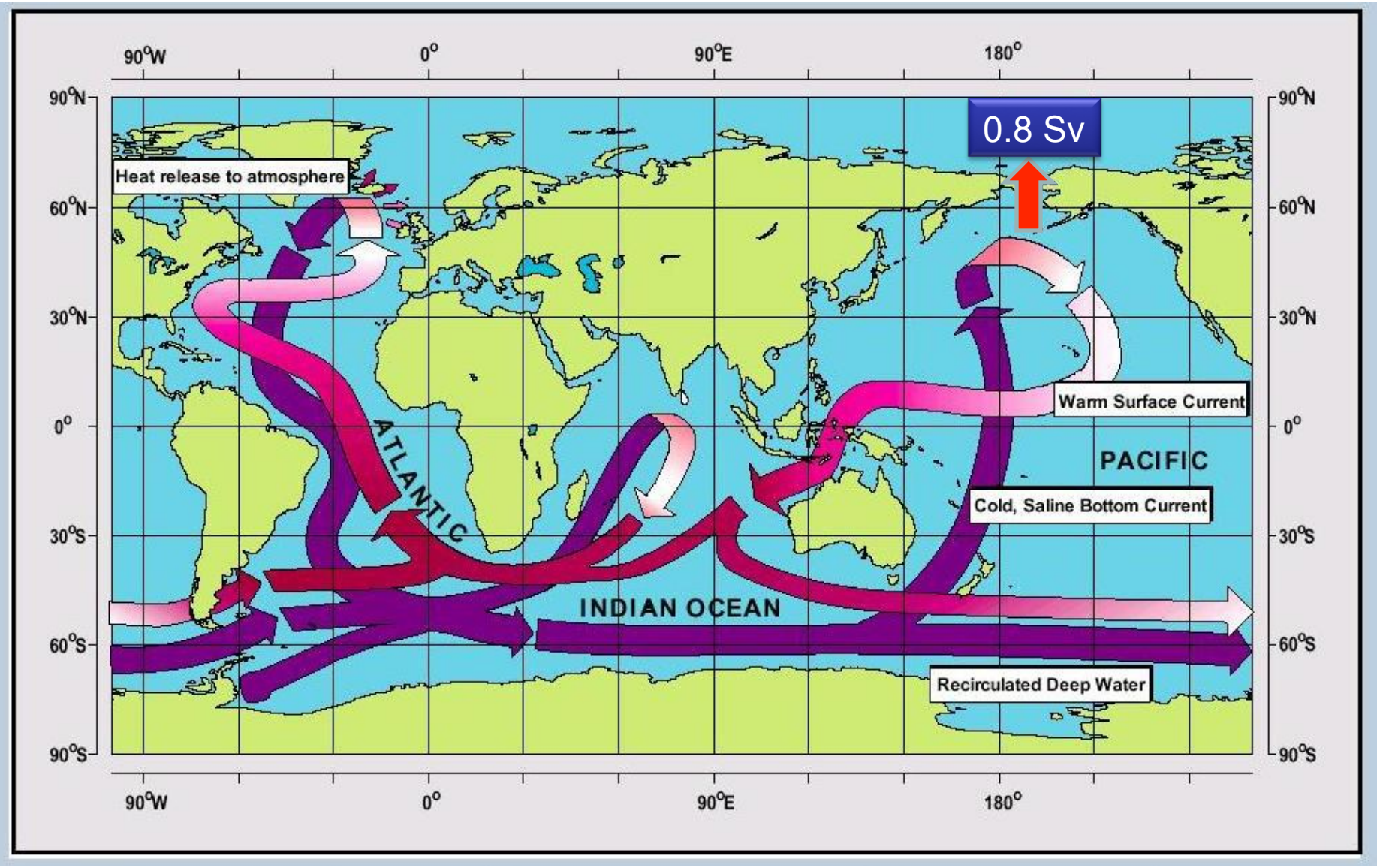
Facts about Bering Strait:

Present: Bering Strait is a narrow (~150 km) and shallow (~50 m) pathway connecting the Pacific and the Arctic between Alaska and Siberia.

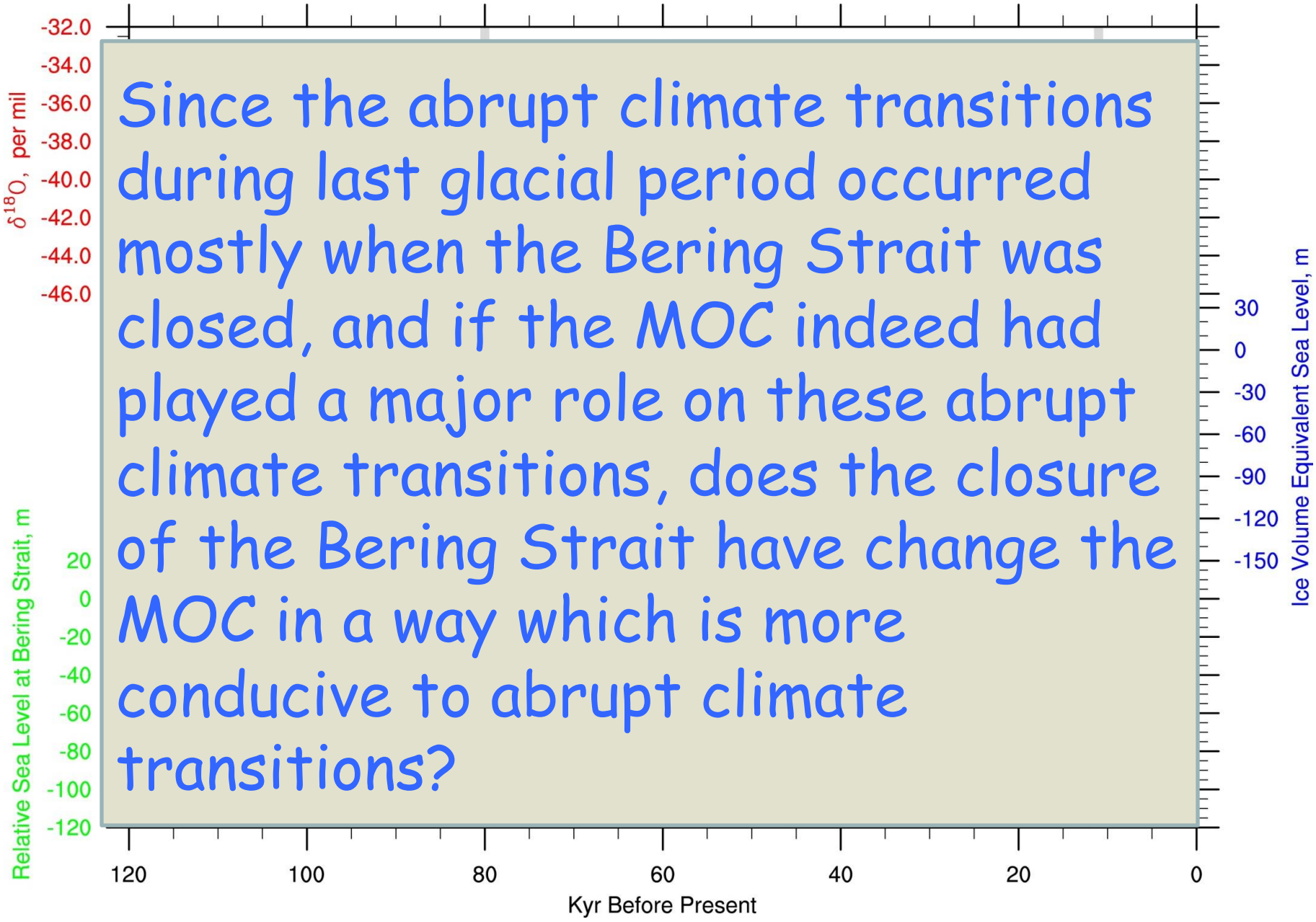
On average, about 0.8 Sv fresher North Pacific water flows through this strait into the Arctic, subsequently into the North Atlantic.

Sverdrup (Sv) $\equiv 10^6\ m^3 s^{-1}$ or 1 million cubic meters per second

What is Meridional Overturning Circulation (MOC) or Thermohaline Circulation (THC)?



Past abrupt climate transitions and the possible relation with Bering Strait



Model and Experiments:

Here we use the National Center for Atmospheric Research Community Climate System Model version 3.

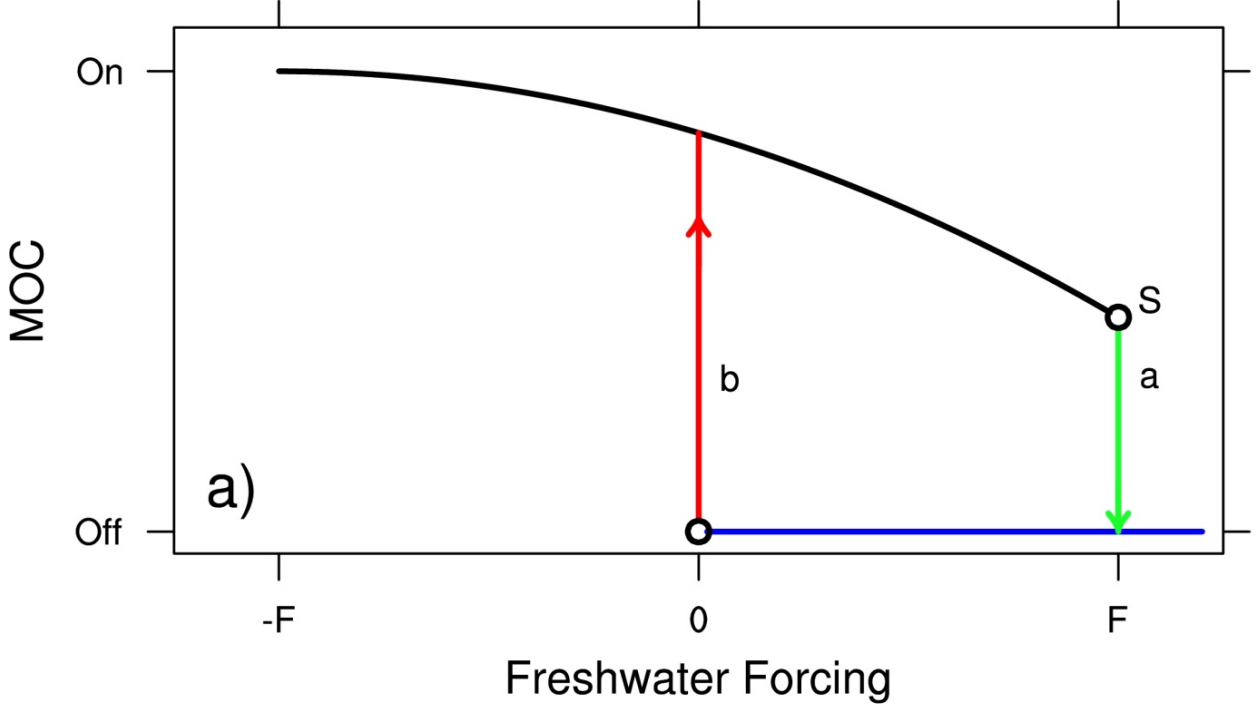
Atmospheric model (CAM3): T42 (2.8 degree), 26 hybrid levels
Land model (CLM3): T42
Ocean model (POP): 1 degree, 40 levels
Sea ice model (CSIM5): 1 degree

Climate boundary condition: present day

Hysteresis Experiments:
Two experiments are carried out with everything identical, except one with an open Bering Strait (OBS) and the other with a closed one (CBS). Following Rahmstorf et al. (2005), the freshwater forcing is added uniformly in the Atlantic between 20 and 50°N at an initial rate of 0.0002 Sv (200m^3/s), with a linear annual increment of 0.0002 Sv. Note: it takes 500 model years for the freshwater forcing to increase by 0.1 Sv. Each of the model simulations shown here run for 4400 years.

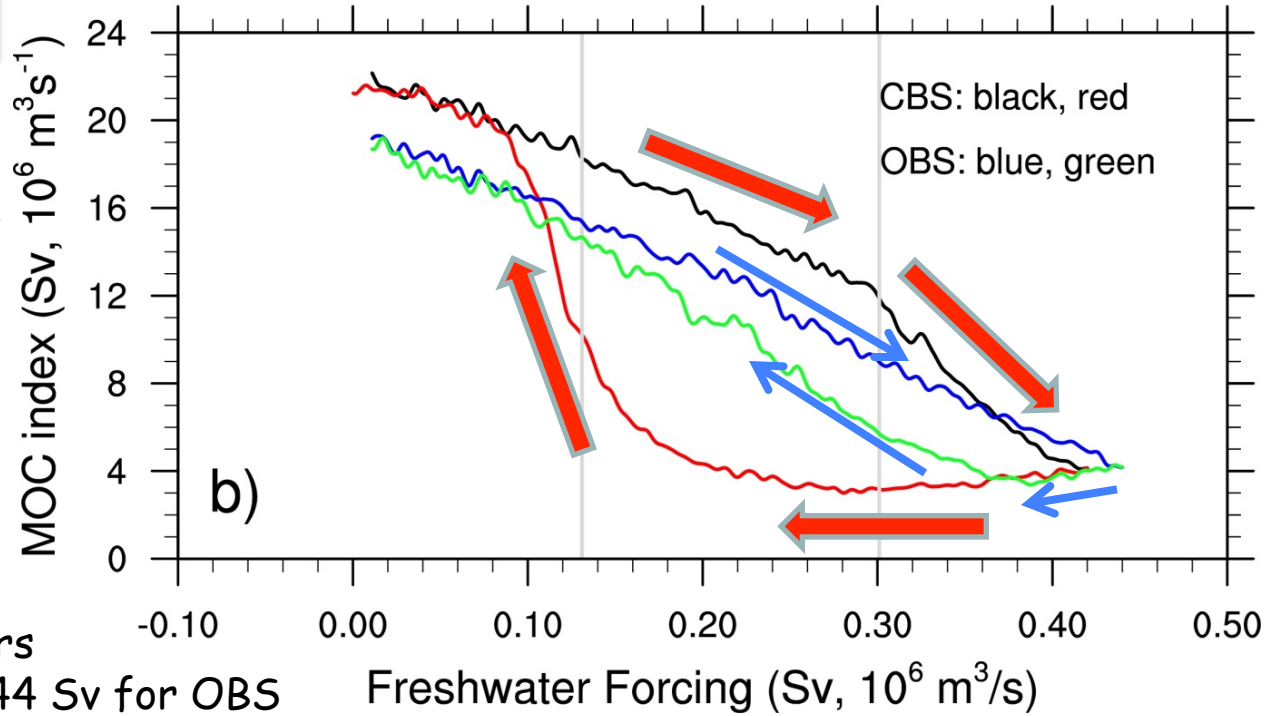
Results:

Theoretical MOC hysteresis diagram



When the Bering Strait is closed, MOC's hysteresis behavior is much clear. When the Bering Strait is open, MOC's hysteresis behavior is much weaker.

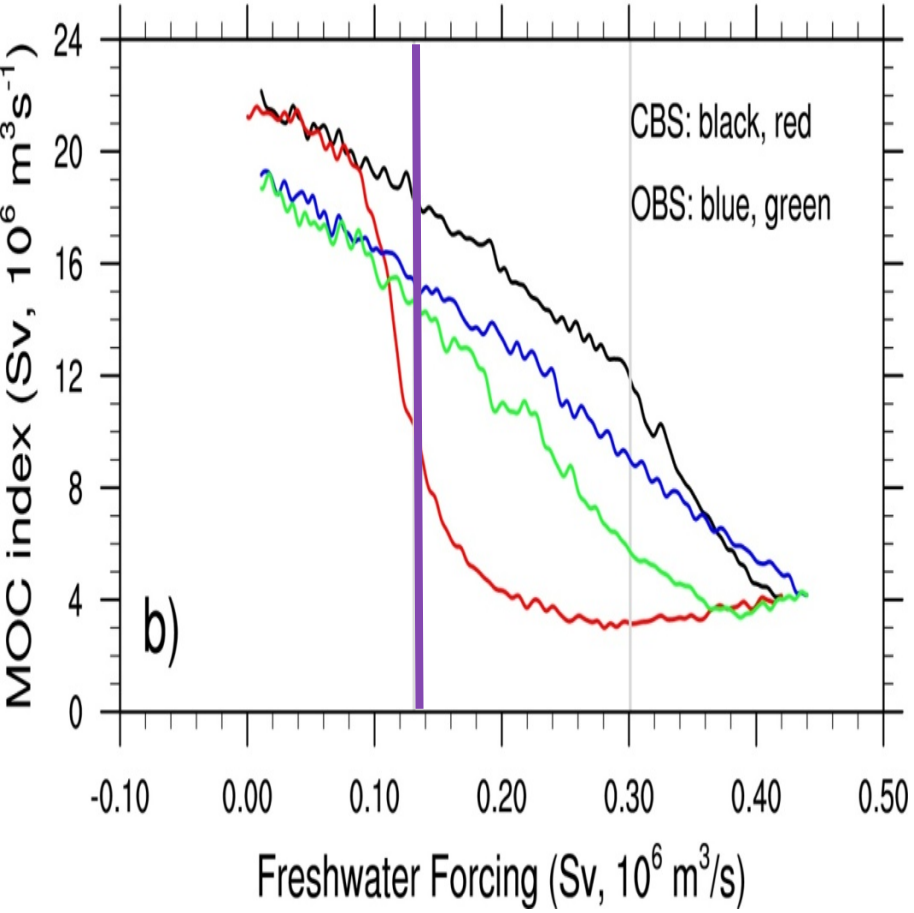
MOC hysteresis diagram in CCSM3



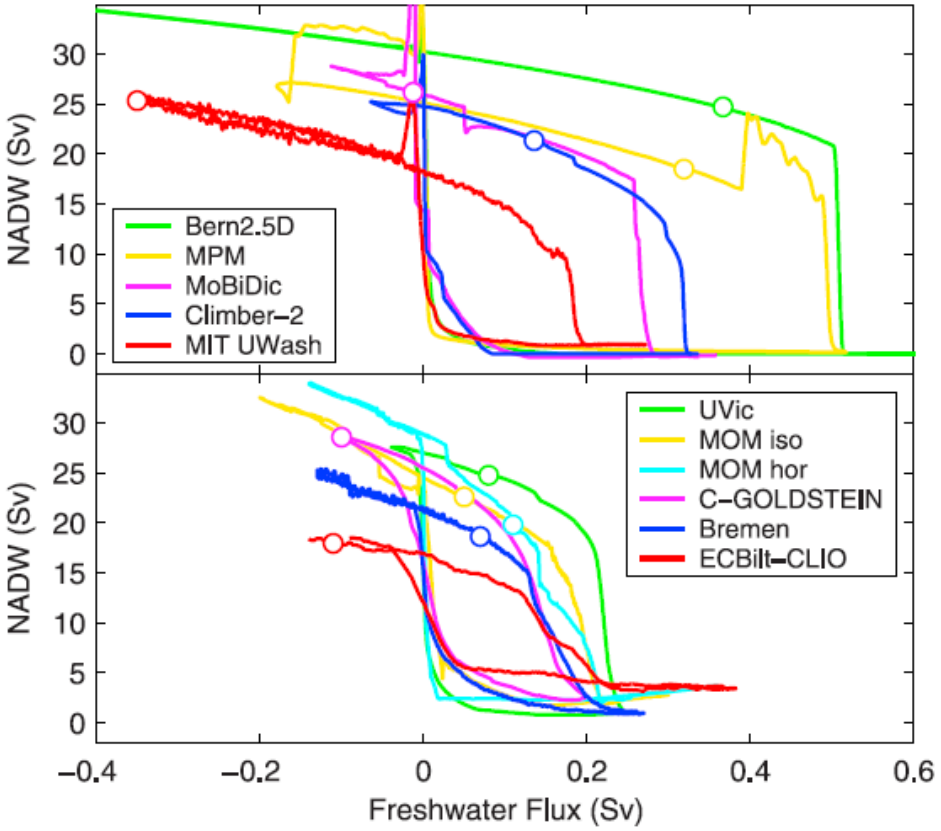
A 0.1 Sv FW change = 500 years
Max FW = 0.42 Sv CBS and 0.44 Sv for OBS

A comparison of the MOC hysteresis

Fully Coupled Climate Model (CCSM3)



Earth System Model of Intermediate Complexity



Rahmstorf et al., GRL, 2005

Greenland surface
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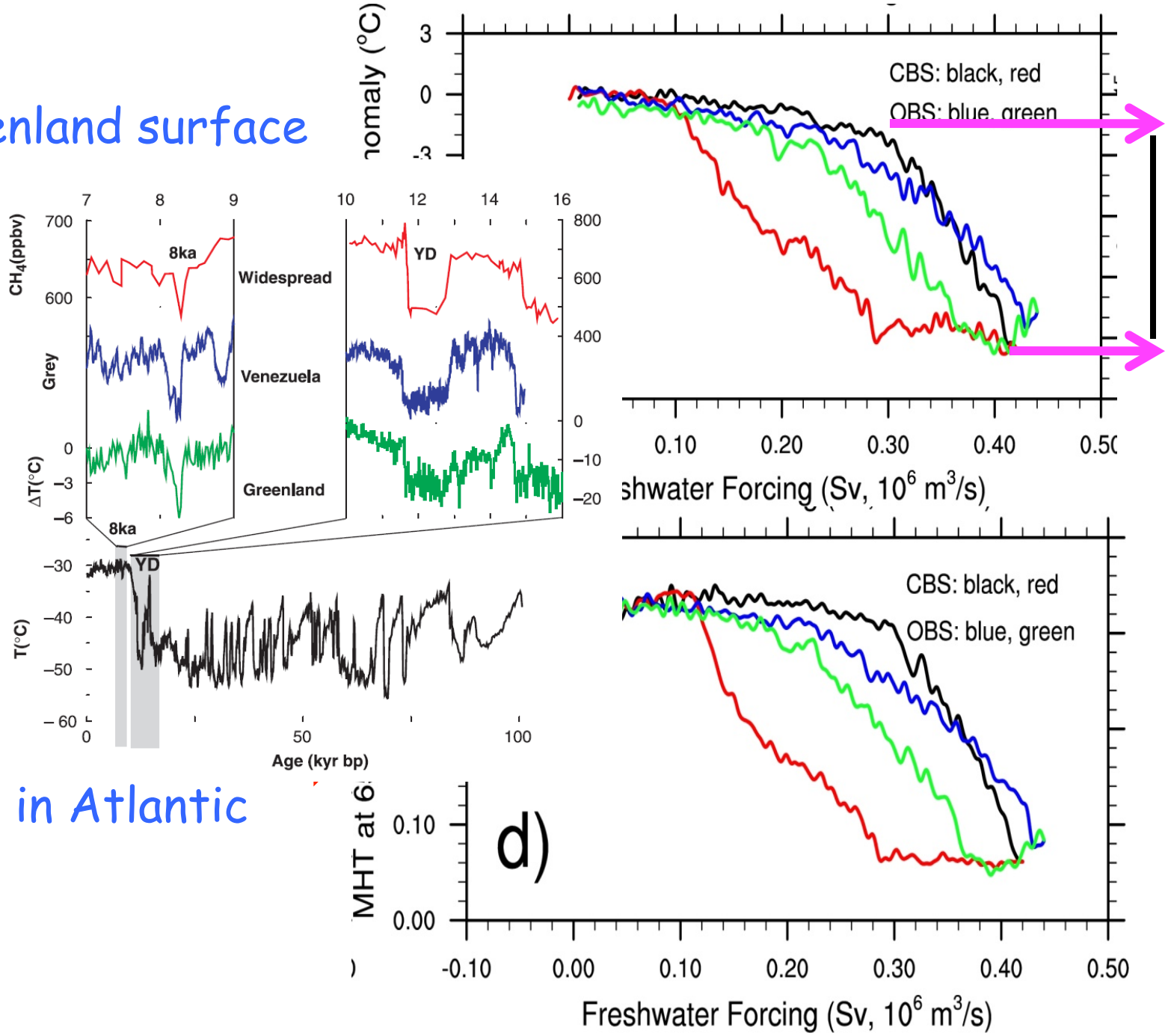
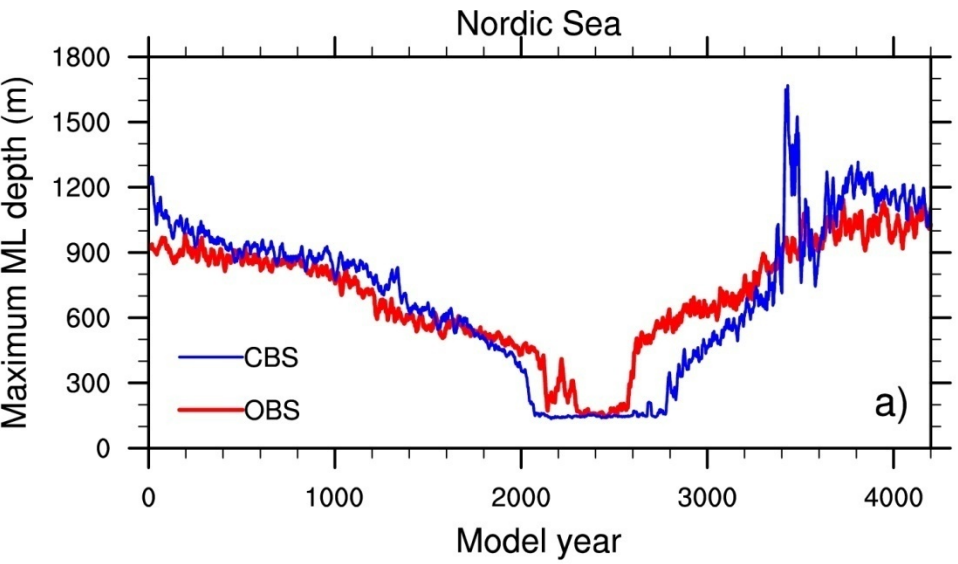
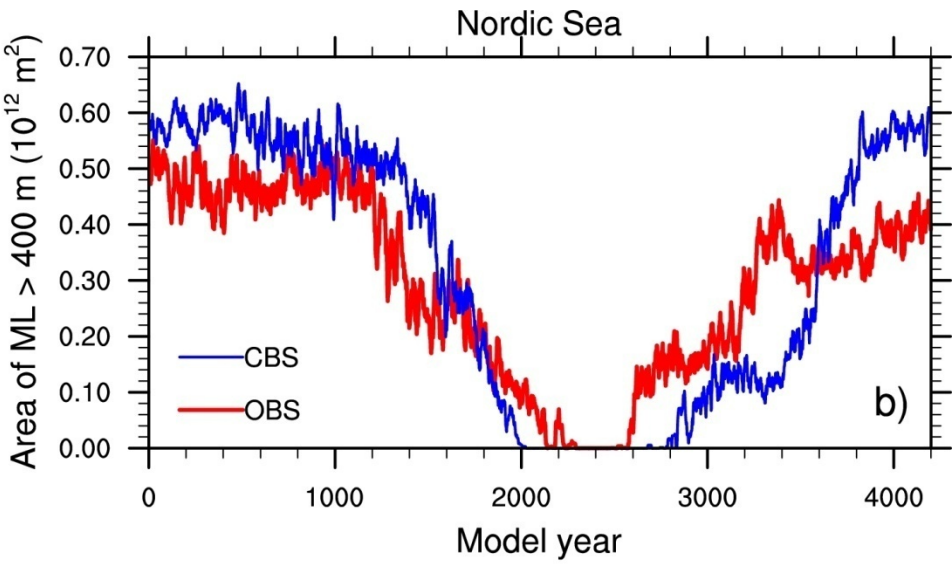
65°N in Atlantic

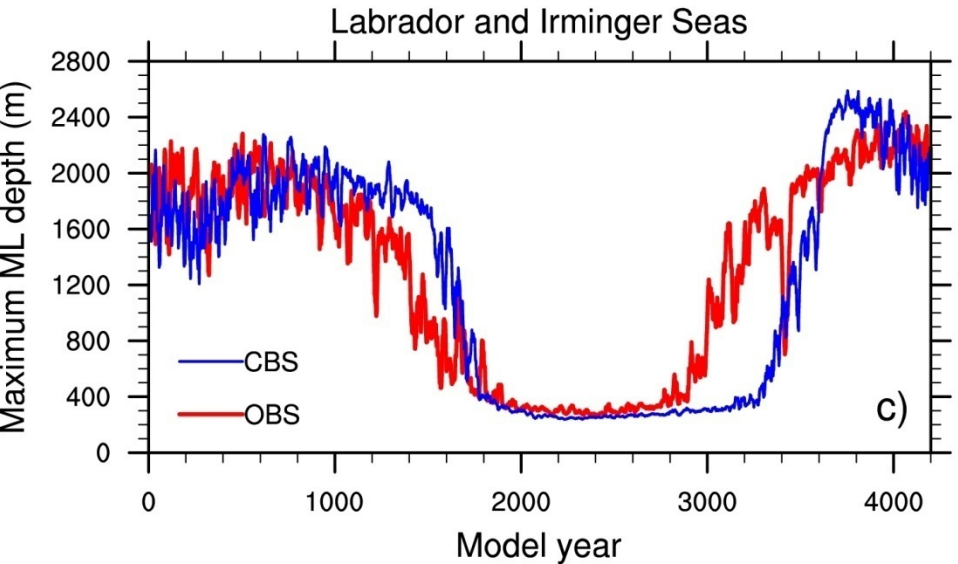


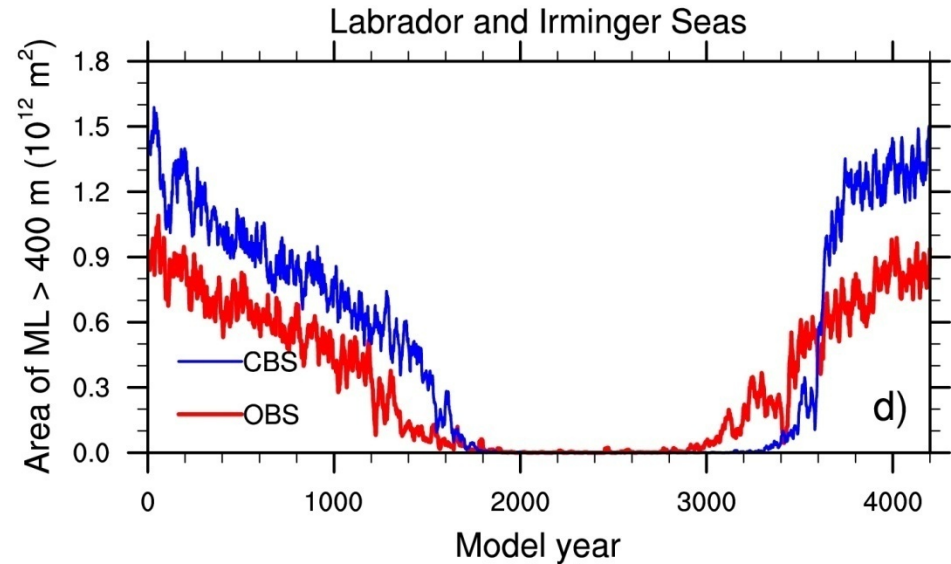
March mean maximum mixed layer depth

Area of the March mean mixed layer deeper than 400 meters

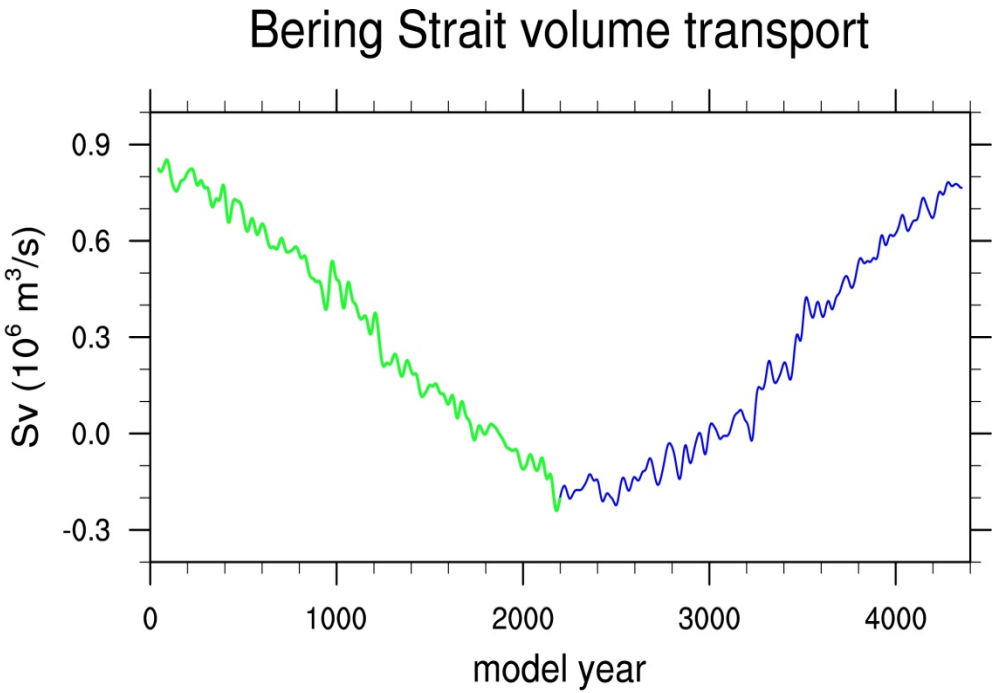


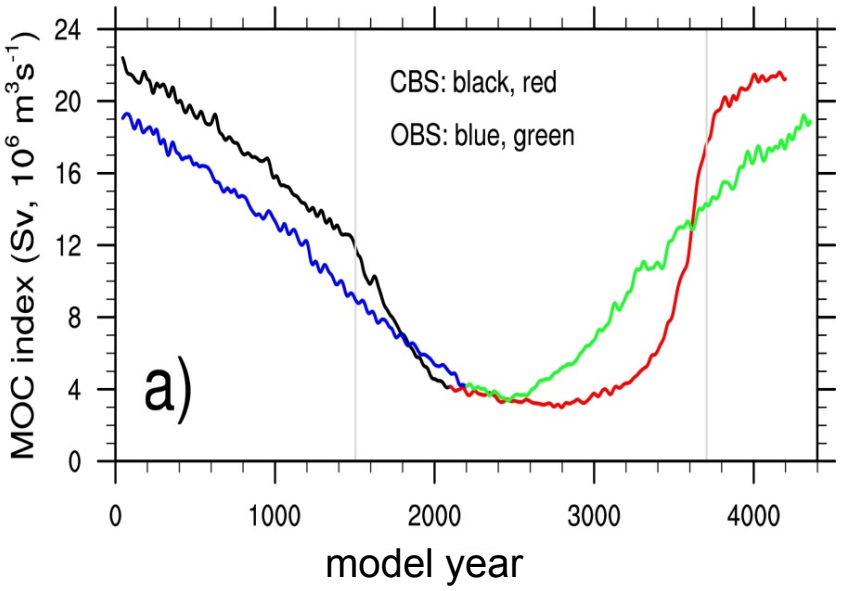


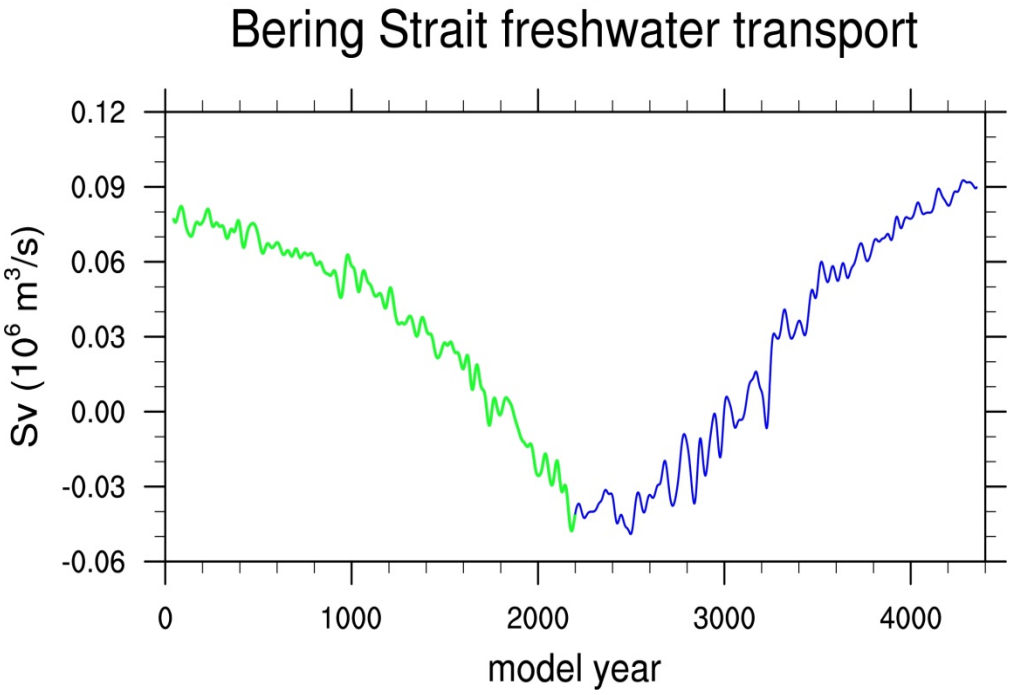




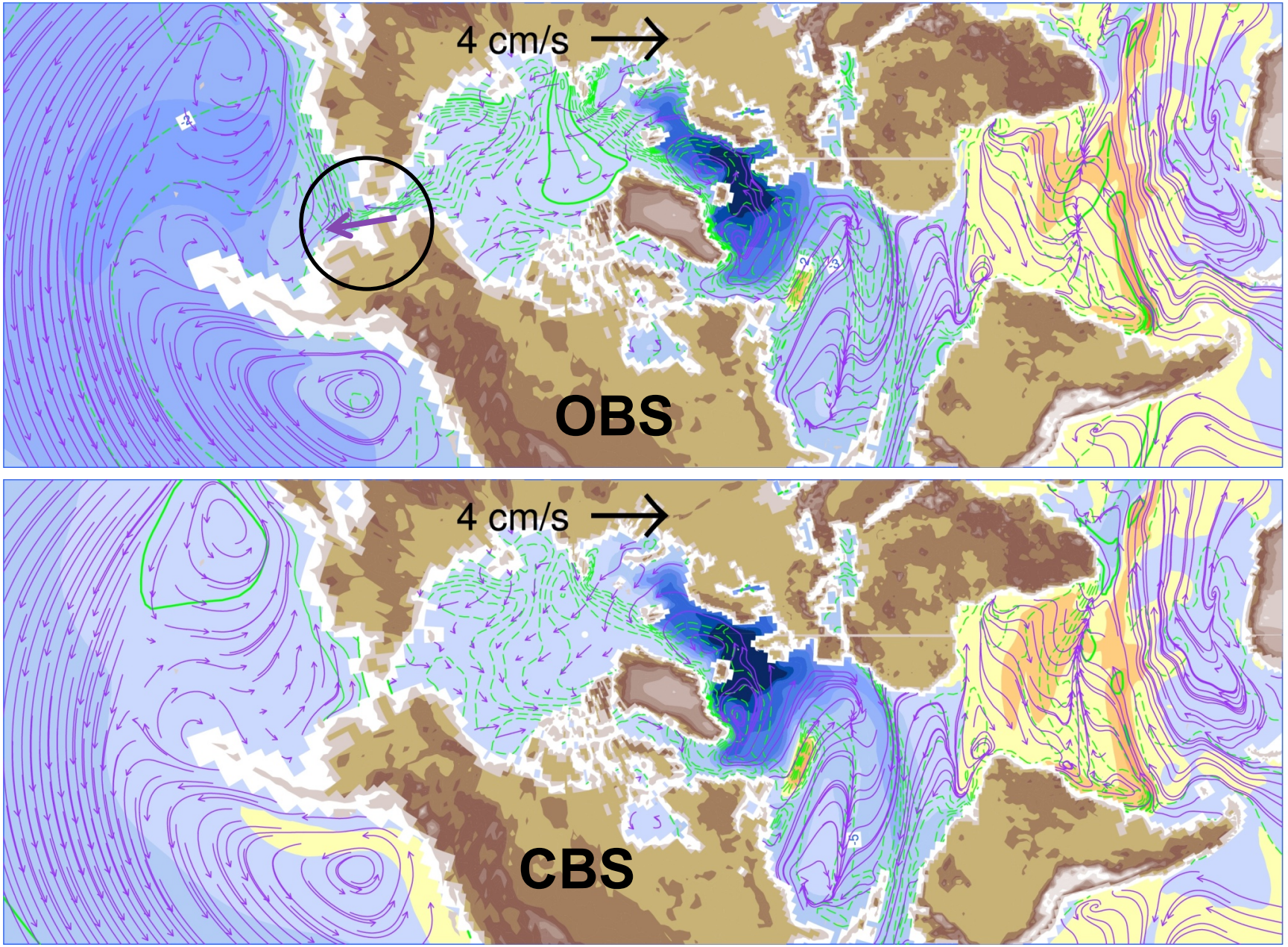
Changes of the Bering Strait mass and freshwater transport as the MOC weakens/strengthens in the open Bering Strait simulation





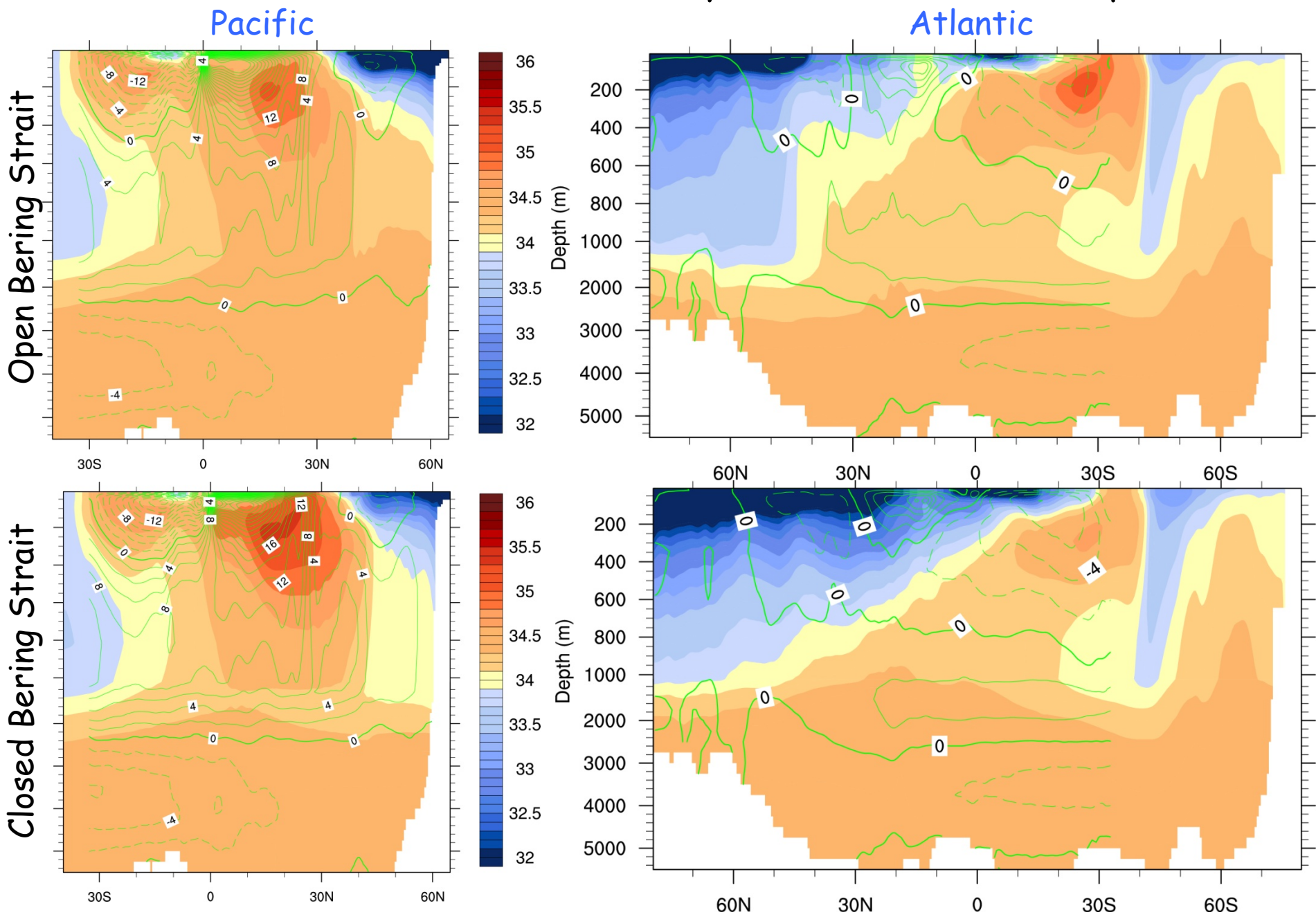


Surface property changes in open/closed Bering Strait simulations



Arrows: surface currents (cm/s); shading: SST anomaly (°C); contours: SSS anomaly (psu)

Pacific and Atlantic zonal mean salinity and MSF with a collapsed MOC



Summary

Our results suggest that the opening/closure of this North Pacific pathway -- the Bering Strait, may have played an important role in modulating the MOC and ice age climate, e.g.

i. A Bering Strait closure may have changed the characteristics of the ocean circulation to a state, such as the existence of the MOC hysteresis, which is in favour of abrupt climate transitions.

ii. Since an open Bering Strait can transport water mass in both directions depending on the MOC's strength, it leads to the absence of the MOC hysteresis, thus preventing abrupt climate transitions during the Holocene. Therefore, we propose that abrupt climate transitions due to a sudden collapse of the MOC would be unlikely to occur in the future warm climate.

Thank You

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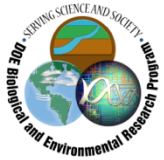

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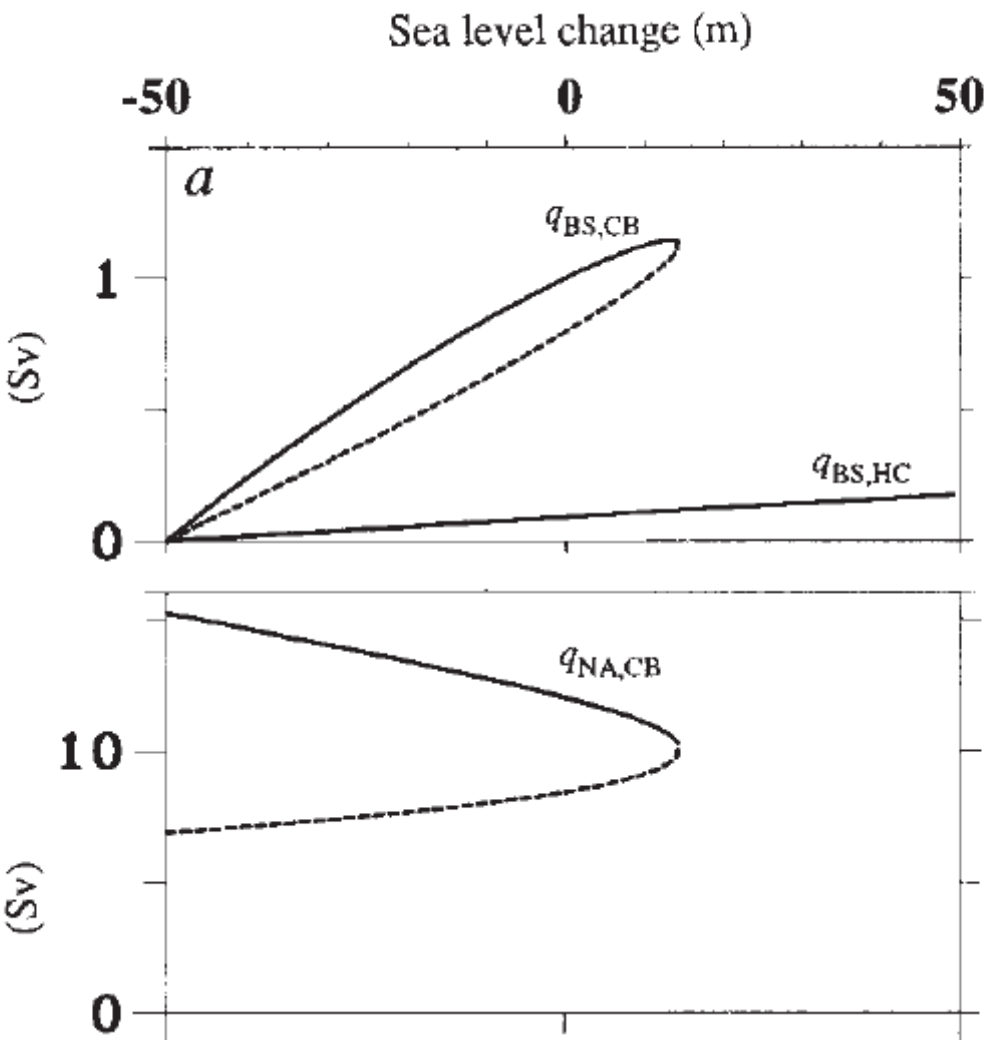
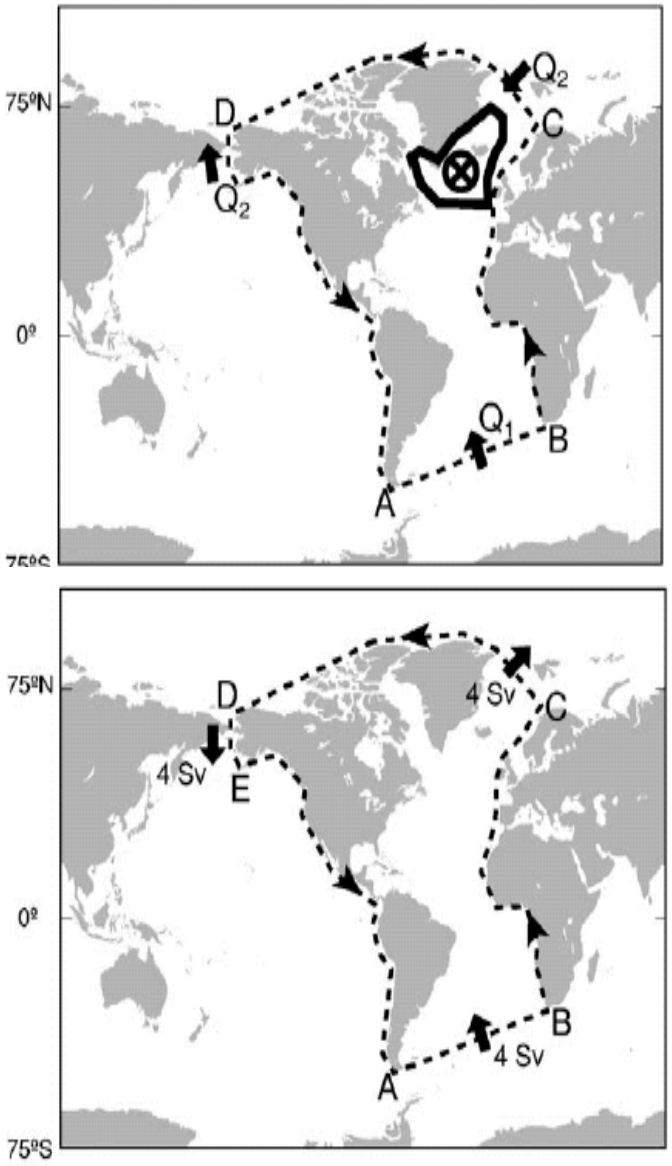
Why is this pathway important?

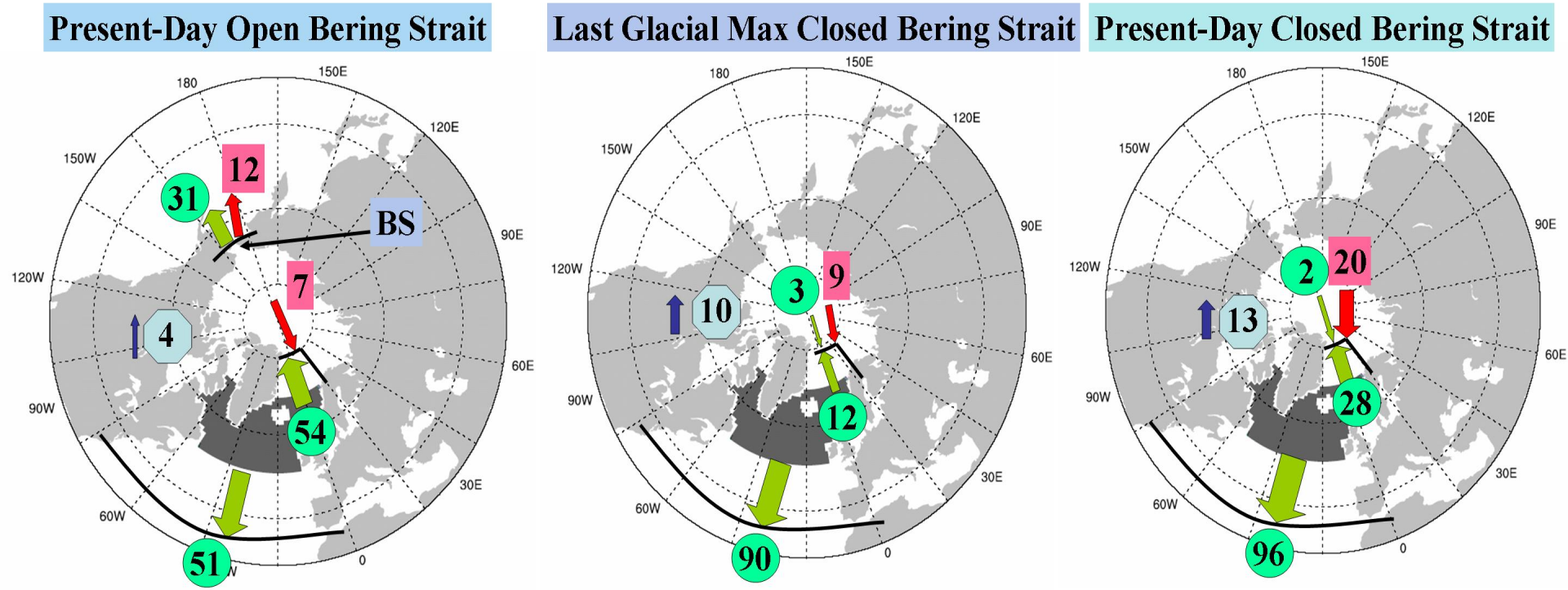


Shaffer and Bendtsen, 1994



De Boer and Nof, 2004a,b

A summary of the comparison of the present day open Bering Strait, closed Bering Strait to LGM closed Bering Strait simulation



Arrows: Green, Oceanic freshwater transport; Blue: P-E+R (Atlantic 35°N~80°N); Red: Sea ice transport

Shape: Circle, liquid freshwater transport; Hexagon, P-E+R (Atlantic 35°N~80°N); Square, sea ice transport

Numbers shown in this figure are the percentage of the total freshwater added into the subpolar North Atlantic during hosing

Hu et al., J. Climate, 2008