Effect of Bering Strait on Atlantic Meridional Overturning Circulation

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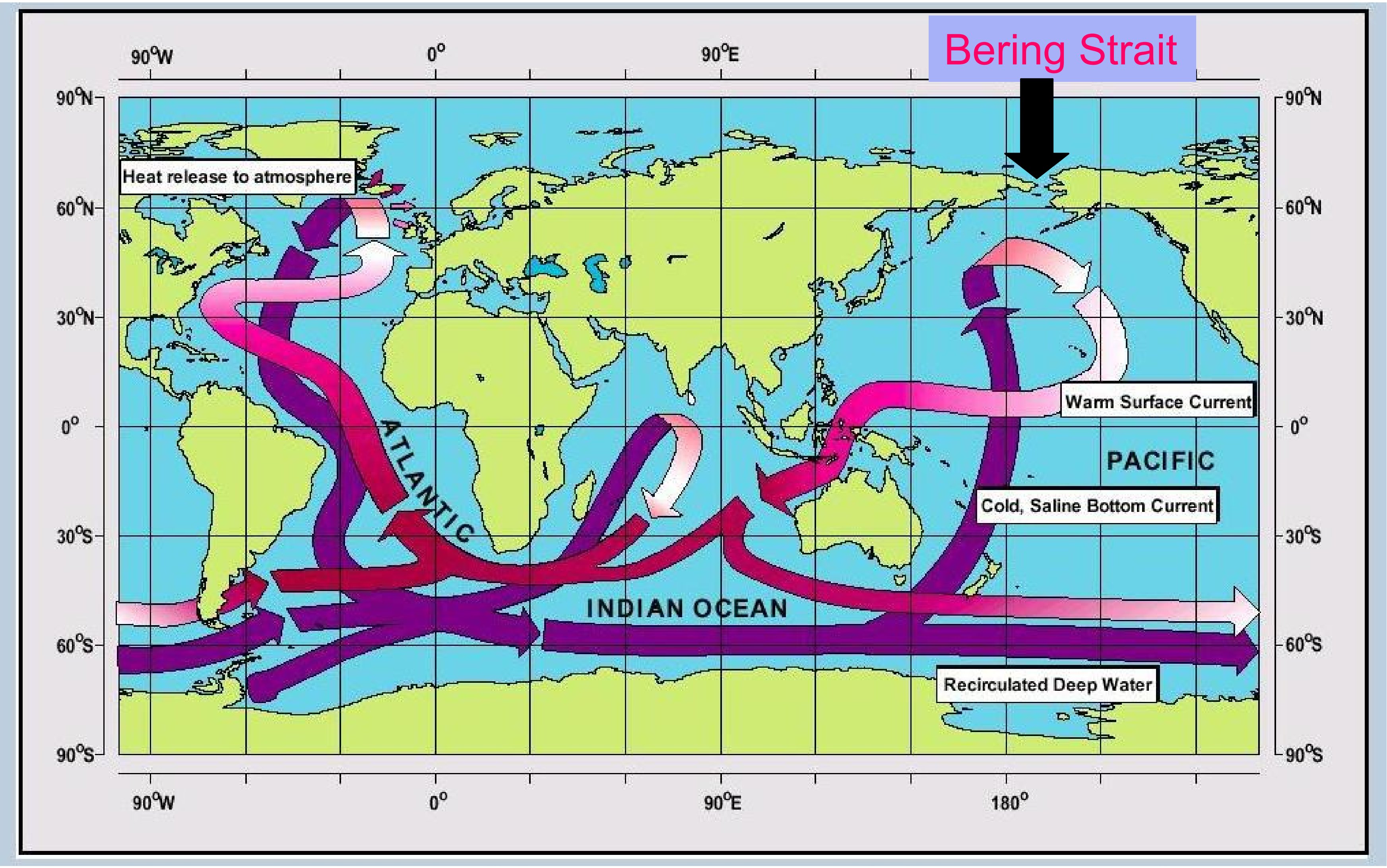
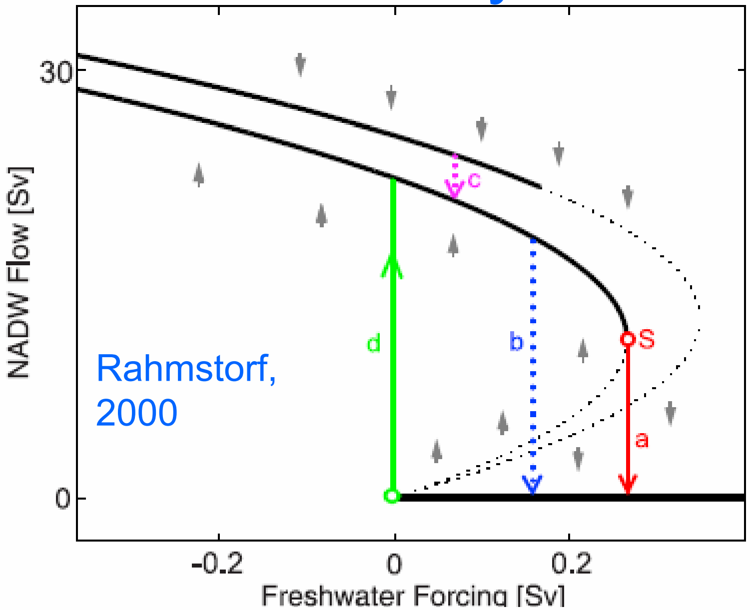
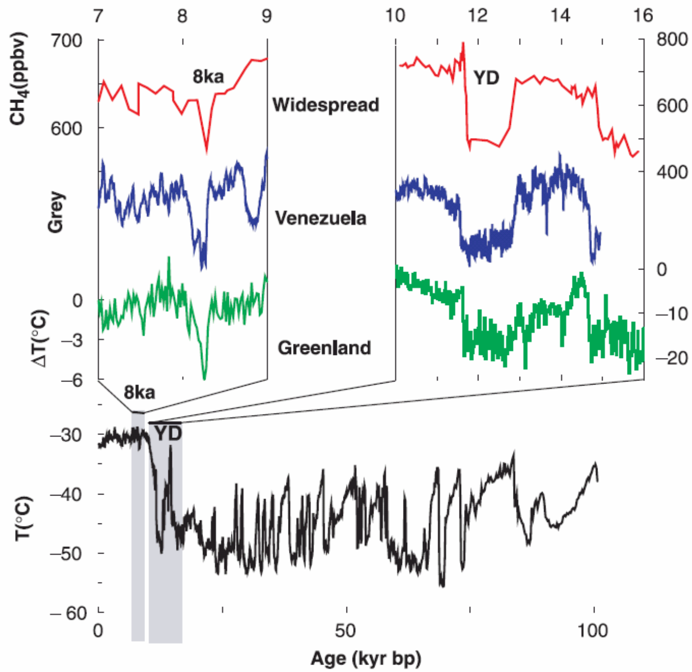
Introduction:



The thermohaline circulation is a global ocean circulation. It is driven by differences in the density of the sea water which is controlled by temperature (thermal) and salinity (haline).

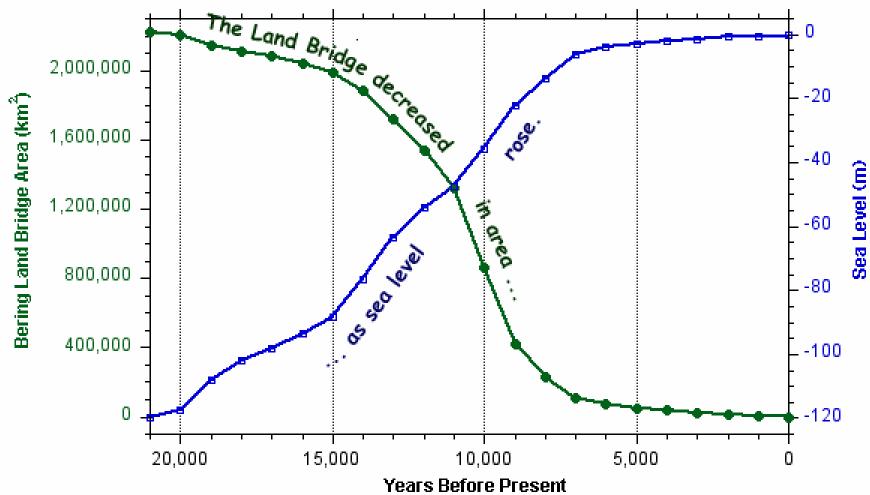
Schematic of hysteresis





Facts about Bering Strait:

Present:
~150 km wide;
~50 m deep;
0.8 Sv Flow;
0.08 Sv FW.



Sverdrup (Sv) ≡ $10^6\ m^3 s^{-1}$

Model and Experiments

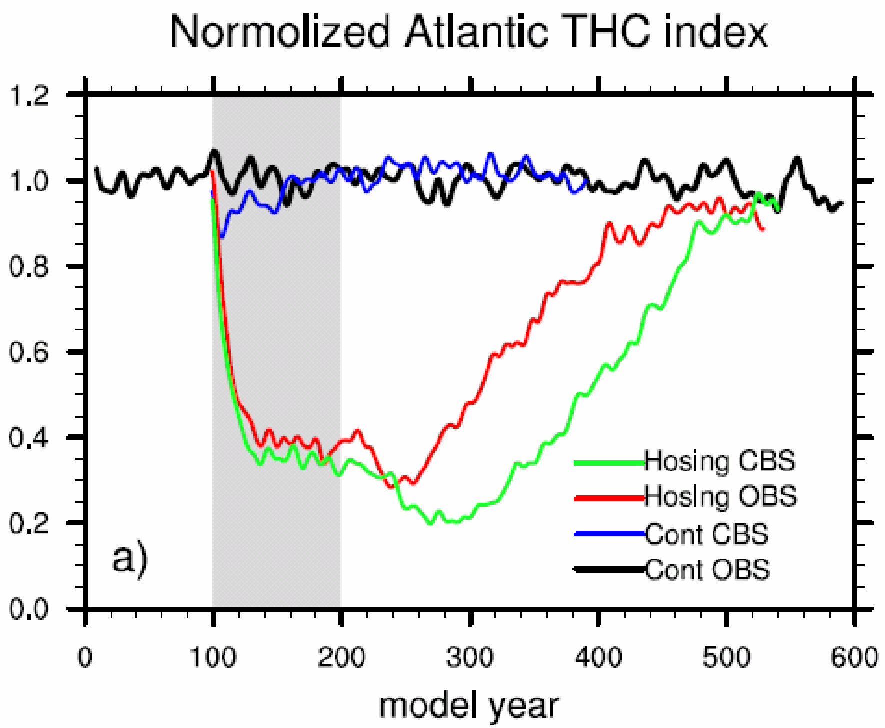
Community Climate System Model version 2:

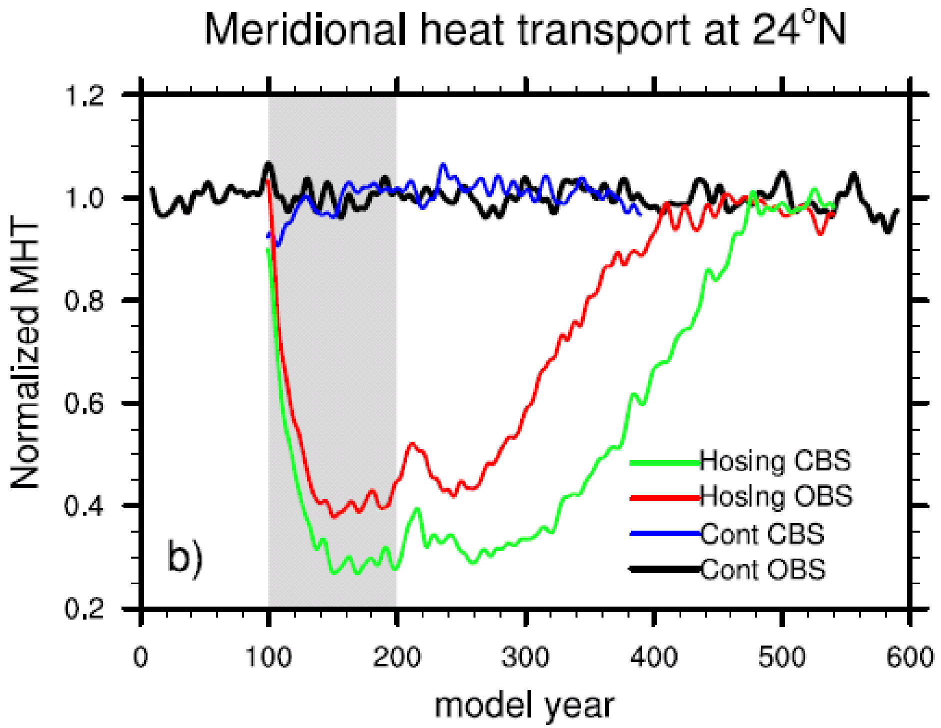
- CAM2 with T42 horizontally and 26 levels vertically
- POP with 1^o horizontally and 40 levels vertically
- CSIM4
- CLM2
- Present day (PD)

Kiehl and Gent (2004)

Experiments: 1. Two control runs with an open (OBS) and closed Bering Strait (CBS); 2. Two hosing runs with 1 Sv additional fresh water flux uniformly added into the northern North Atlantic between 50 and 70^oN for 100 years, then this flux is switched off.

Lowpass filtered THC and MHT index



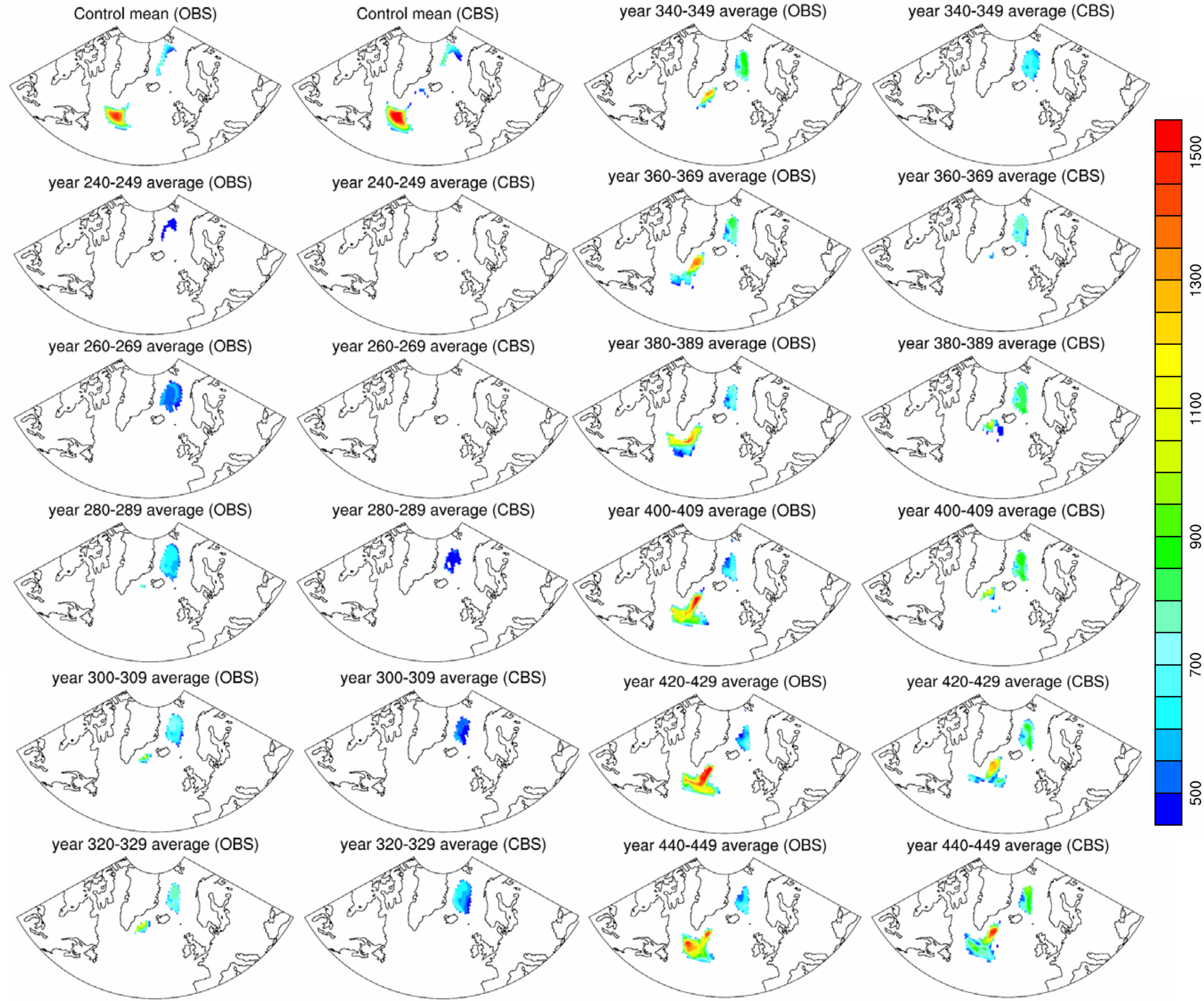


Control mean THC: 16 Sv OBS
18 Sv CBS
Control mean MHT: 0.82 PW OBS
0.95 PW CBS

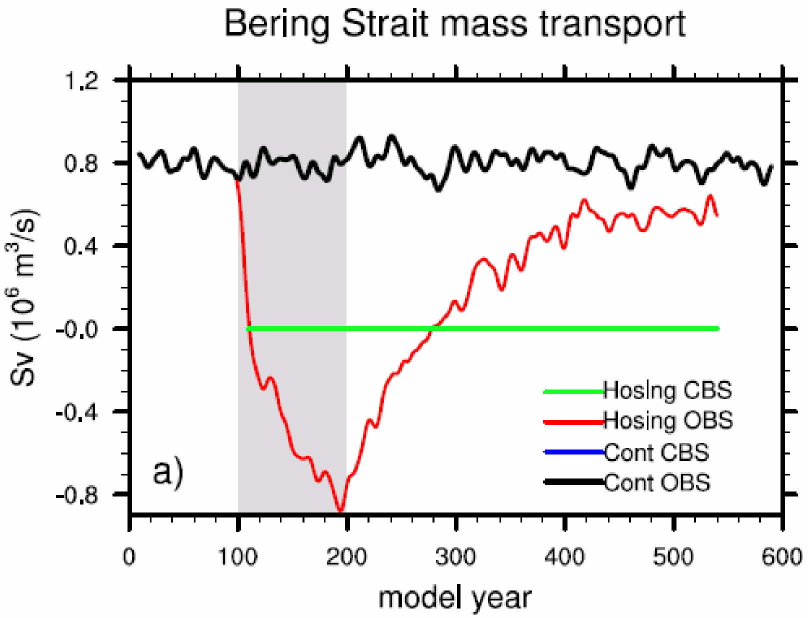
PW≡10^{15}W

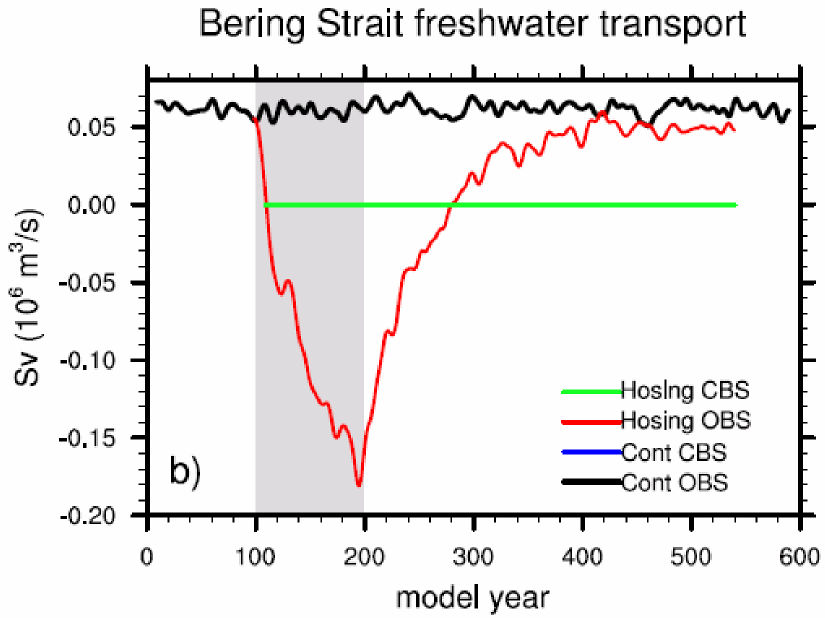
THC declines similarly during hosing and the first 50 years after that. However, the recovery of the THC is delayed by about a century in the CBS run than in the OBS run.

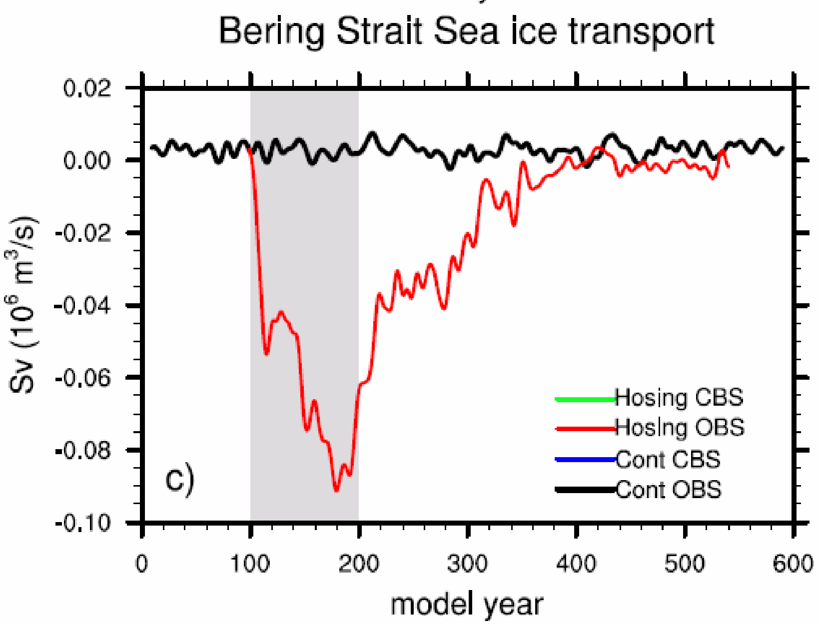
March Mixed Layer depth over 450 meter



Variations of the Bering Strait Transports

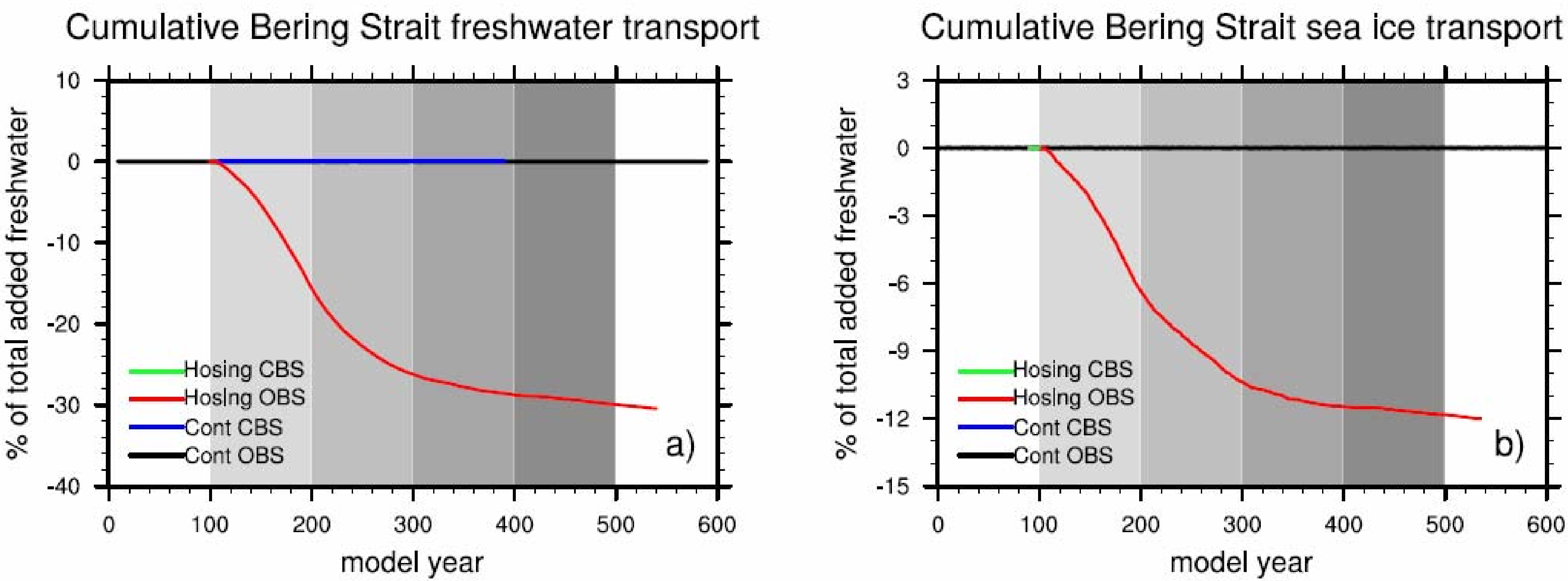






A decade after the hosing, the mass, freshwater and sea ice transports reverse their directions from an import into the Arctic to an export into the Pacific.

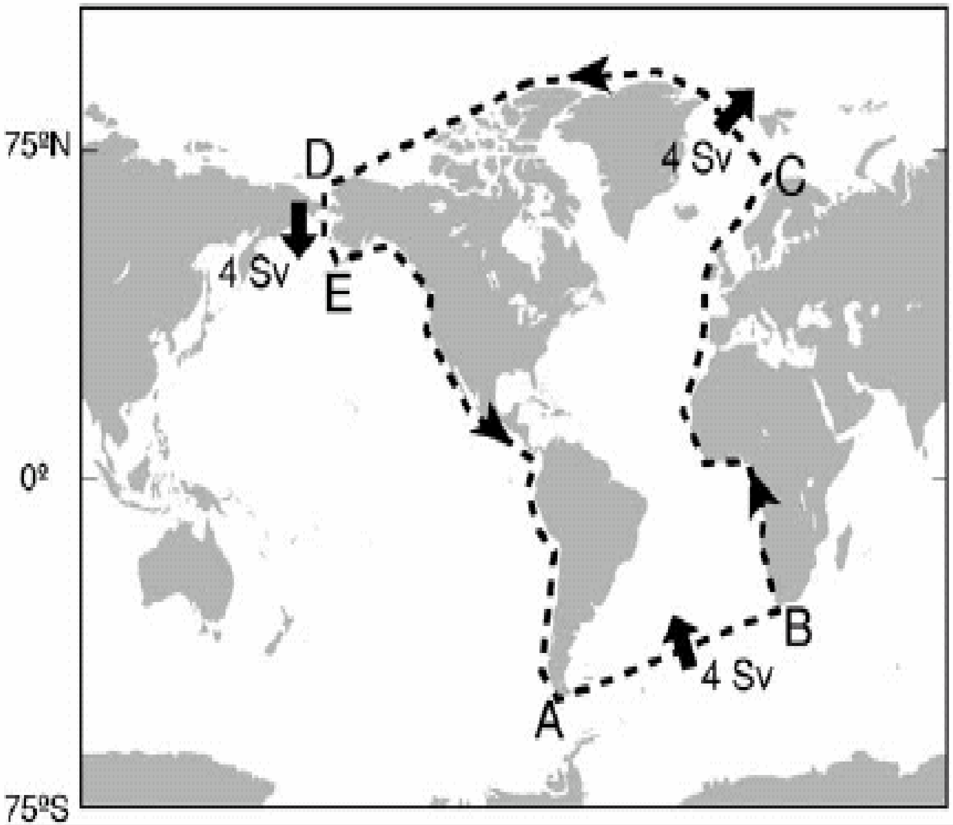
Cumulative freshwater and sea ice export

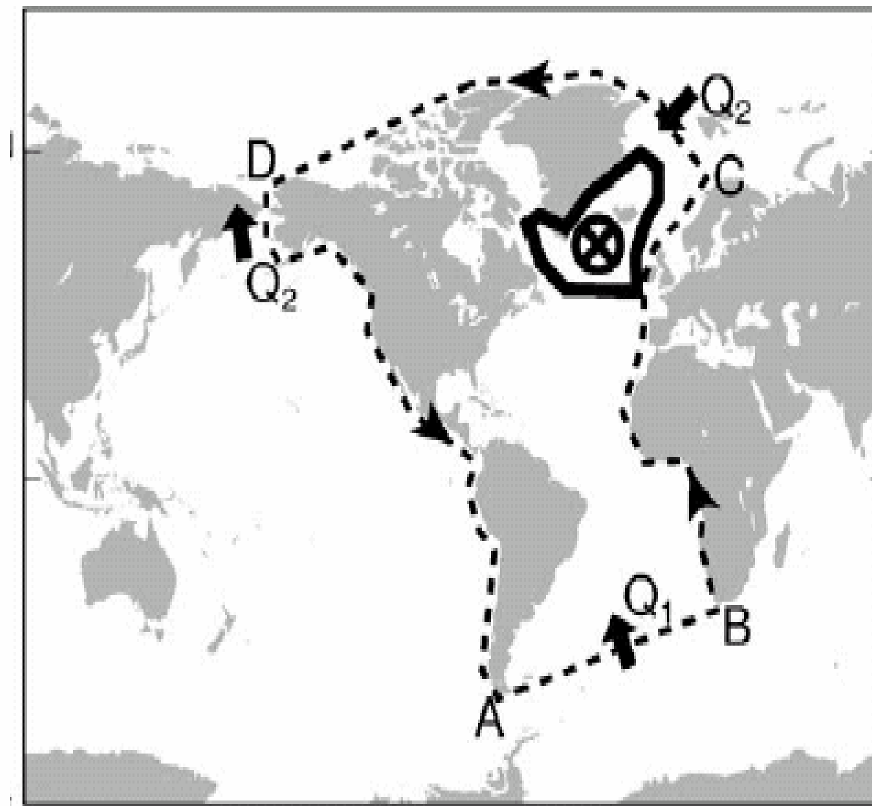


FW, ice transports normalized by total additional FW input

%	100-200 yr	100-300 yr	100-400 yr	100-500 yr	100-550 yr
FW trans	15.4	26.2	28.7	29.9	30.6
Sea Ice	6.3	10.4	11.5	11.8	12.1
total	21.7	36.6	40.2	41.7	42.7

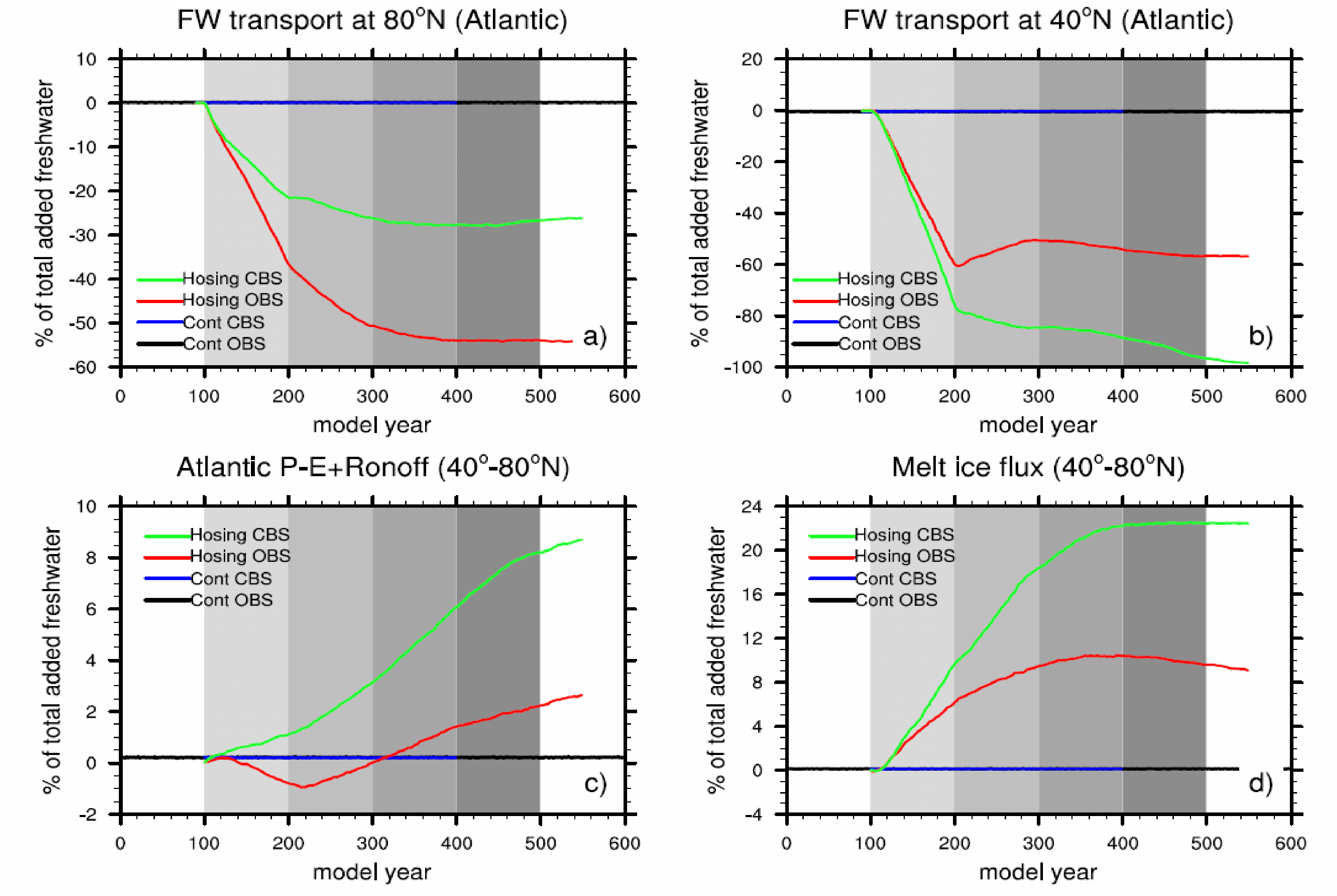
Theoretical Studies of the Bering Strait and THC



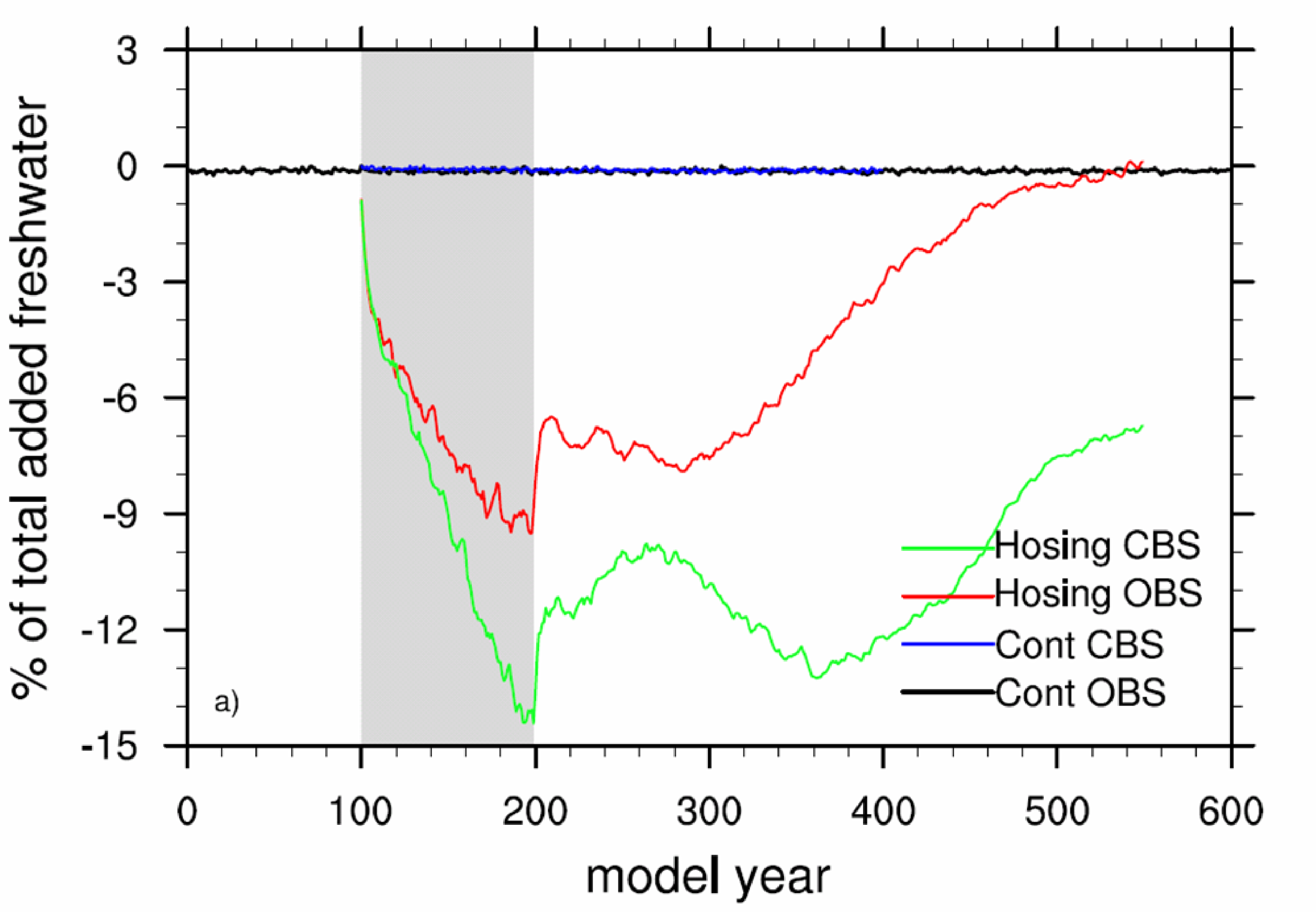


De Boer and Nof (2004a, b) indicate that without NADW formation, the 4 Sv of upper ocean water forced into the Atlantic by strong Southern Ocean winds will exit to the Pacific through the open Bering Strait, instead of returning to the Southern Oceans via the lower branch of the THC as NADW under present conditions. This implies that any strong freshwater flux into the North Atlantic would be quickly flushed out of there into the North Pacific by that 4 Sv upper Southern Ocean water. Consequently, the THC would be re-established fairly quickly.

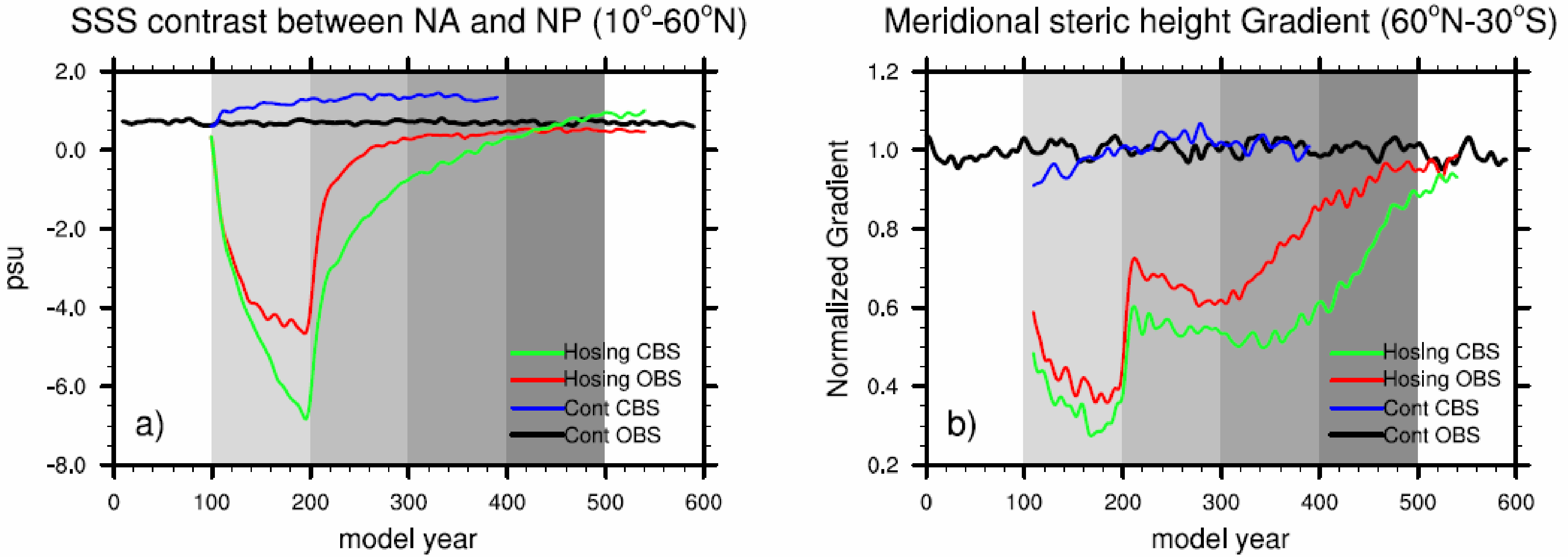
Cumulative freshwater transport and input



Freshwater residue in the Atlantic between 40 and 80^{o}N



Remote effect of the Bering Strait FW transport

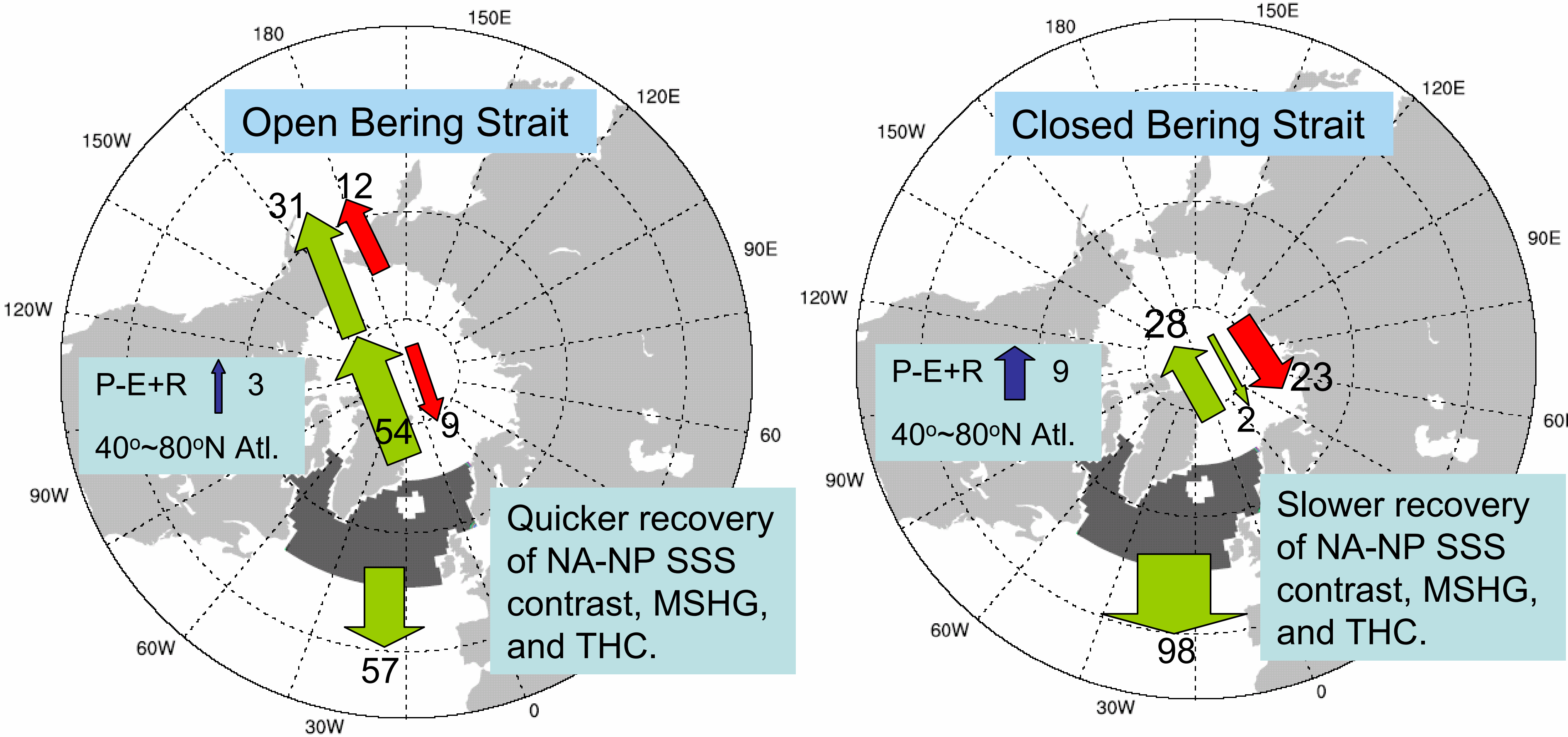


Seidov and Haupt (2003, 2005) proposed that the sea surface salinity contrast between North Atlantic and North Pacific (10°N~60°N) controls the THC strength under equilibrium state.

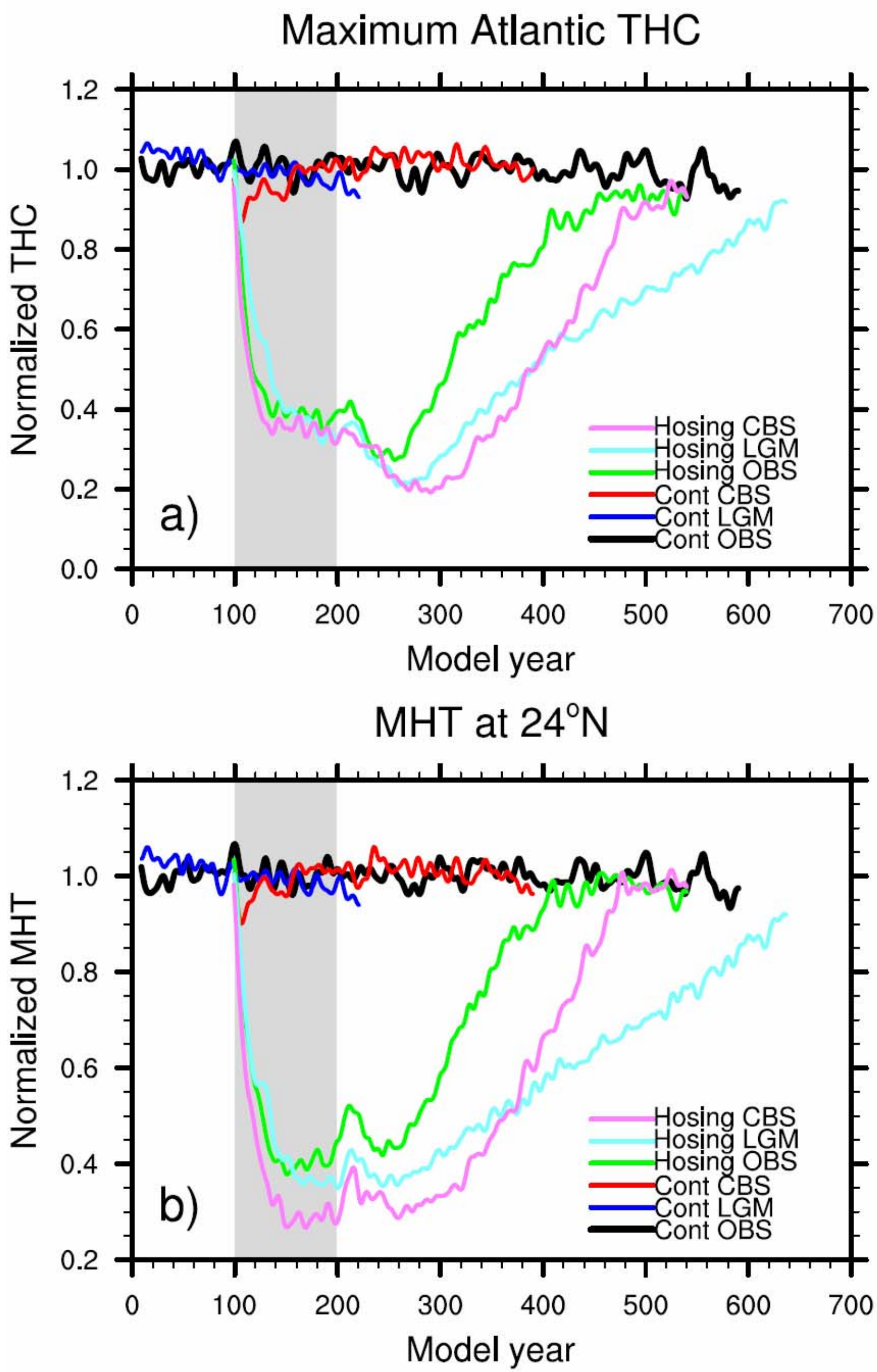
Meridional steric height has been proposed as a proxy measurement of the THC under equilibrium and transient states with a higher gradient related to a stronger THC (Hughes and Weaver, 1994; Thorpe et al., 2001).

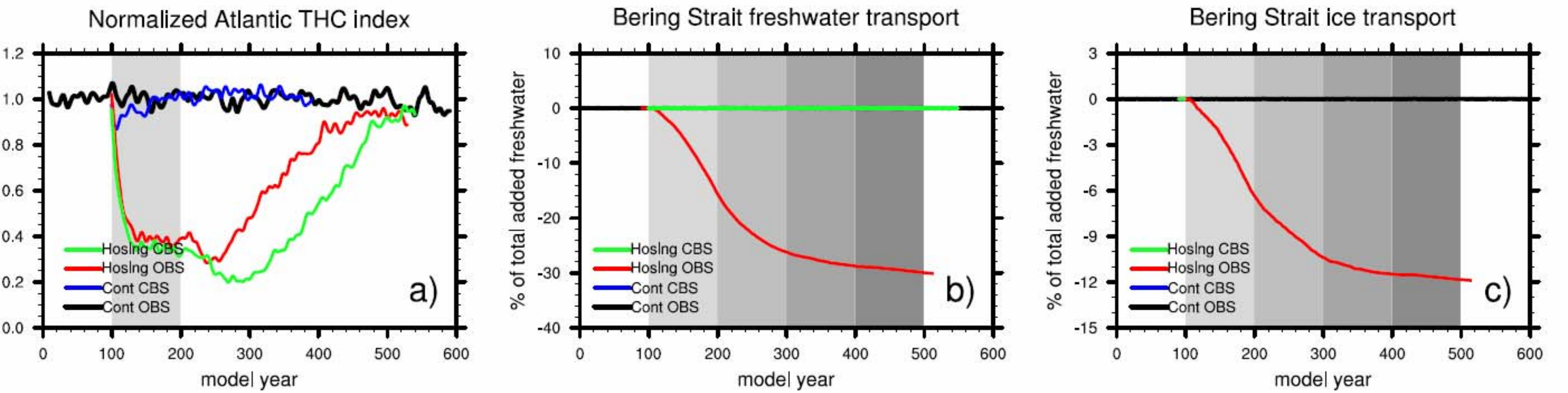
Conclusion

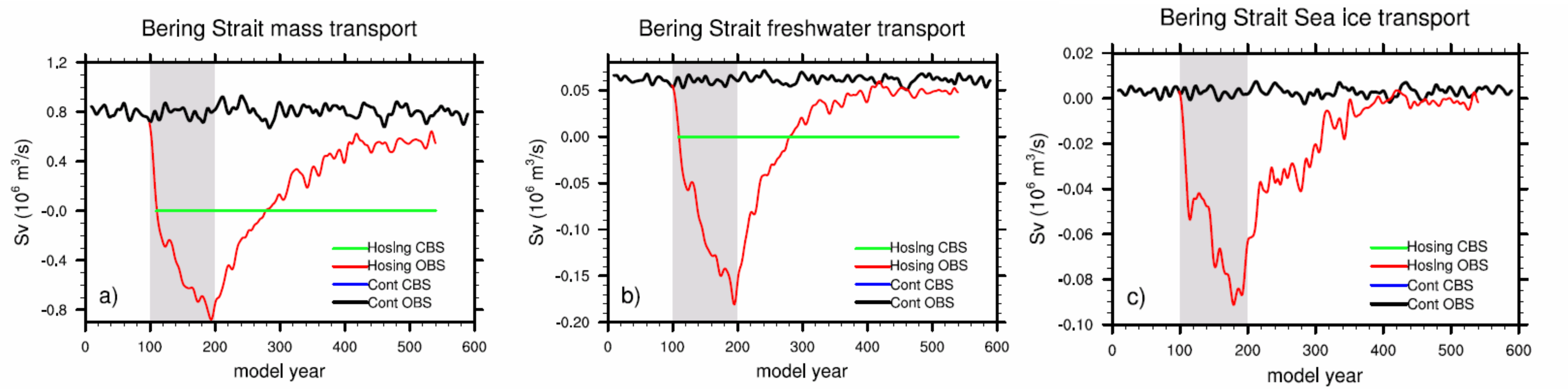
THC responses similarly during the hosing and the 50-yr right after that, then the THC recovers earlier in the OBS run than in the CBS run.



Arrows: Green, Oceanic freshwater transport; Blue: P-E+R; Red: Sea ice transport


Maximum Atlantic THC
Normalized THC
Model year
a)
Hosing CBS
Hosing LGM
Hosing OBS
Cont CBS
Cont LGM
Cont OBS
MHT at 24°N
Normalized MHT
Model year
b)
Hosing CBS
Hosing LGM
Hosing OBS
Cont CBS
Cont LGM
Cont OBS





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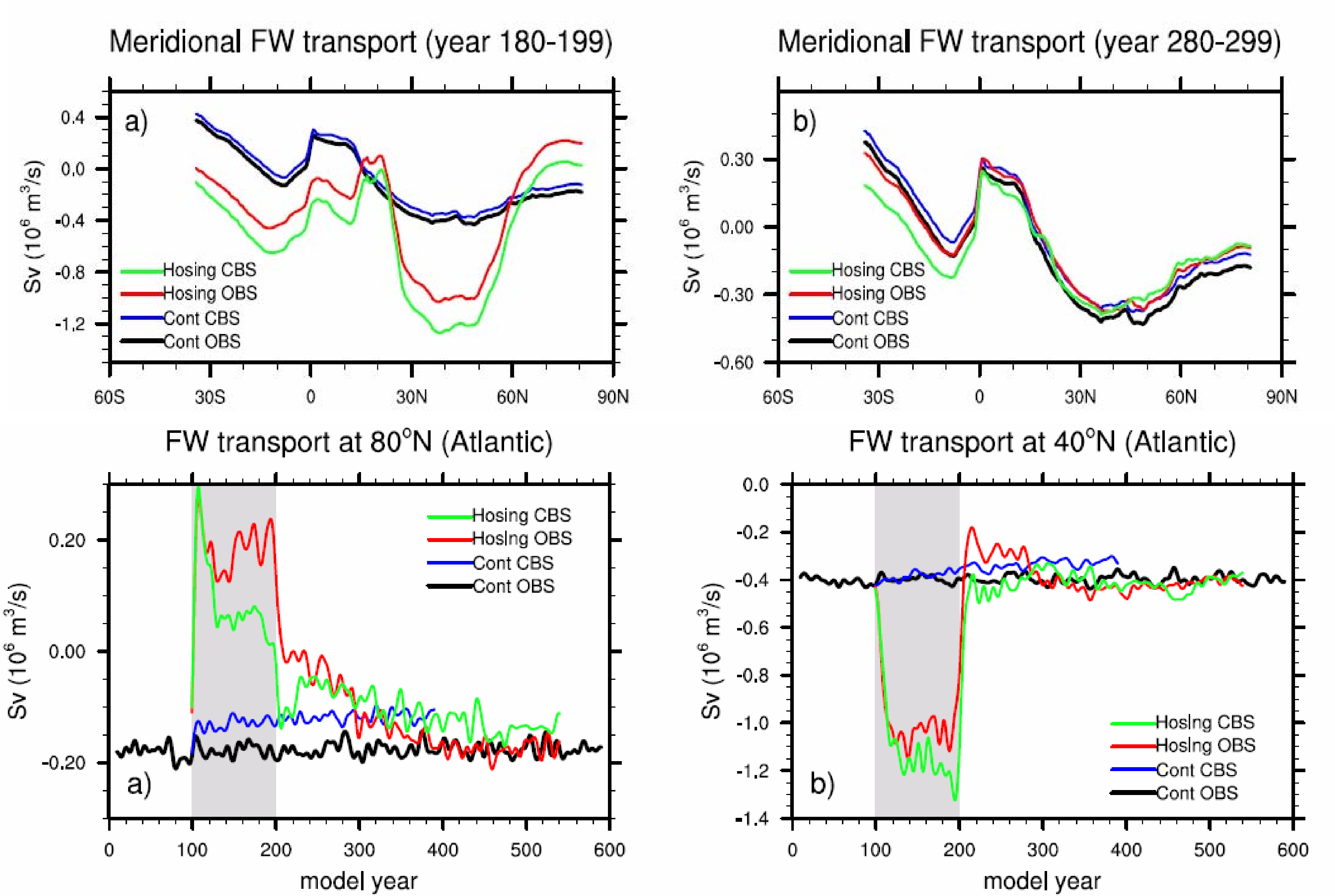
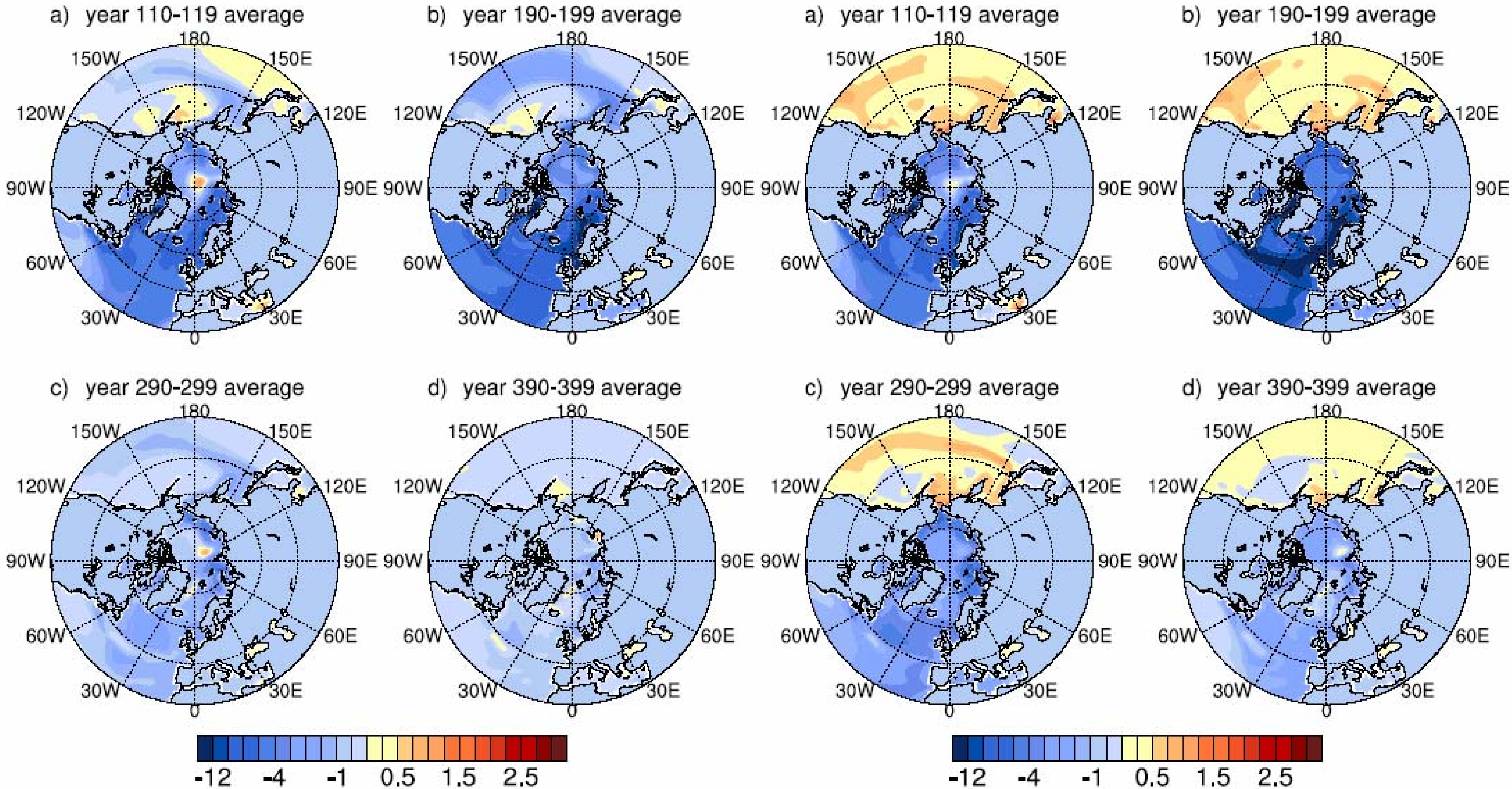
Oceanic meridional freshwater transport



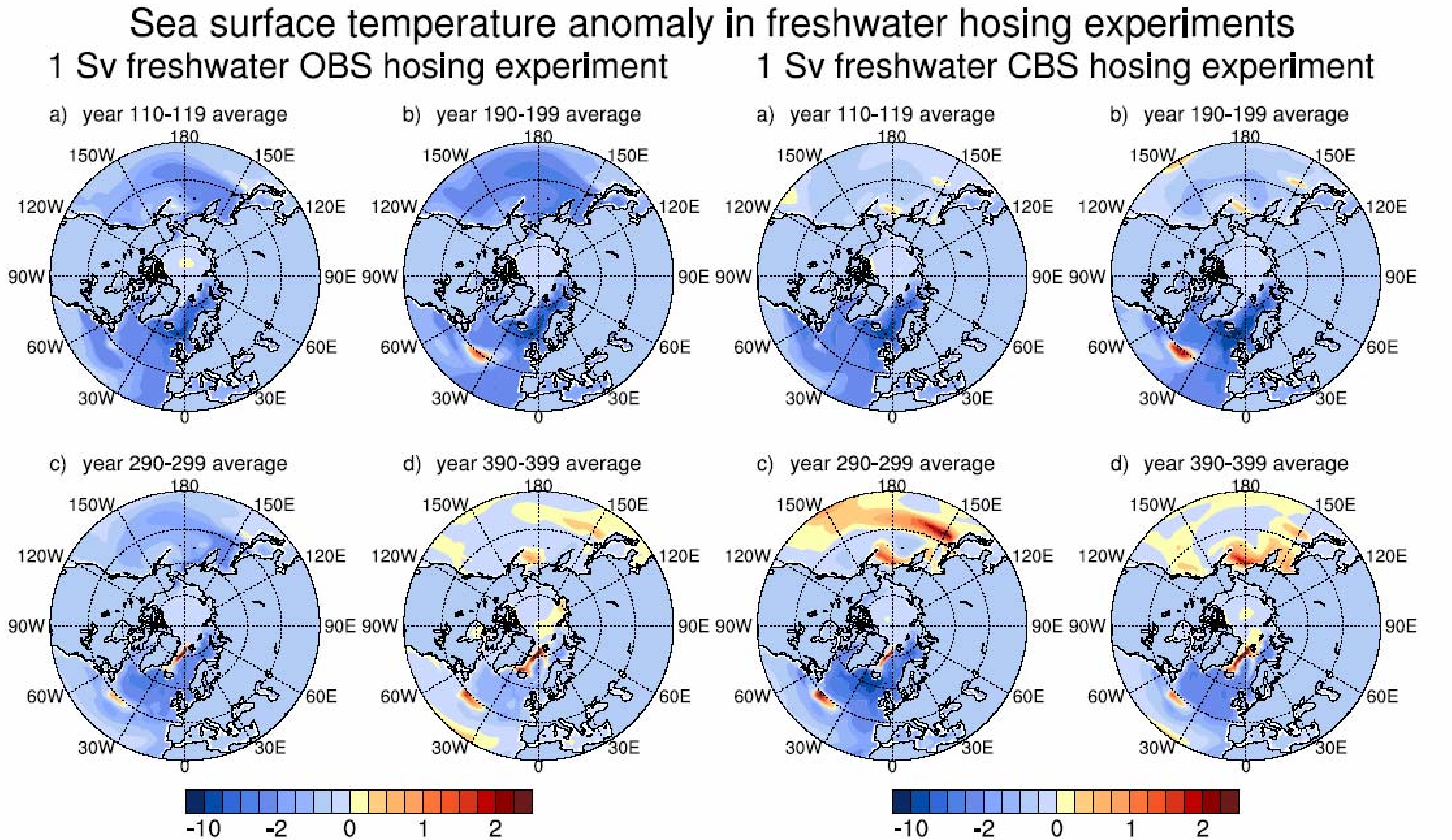
Sea surface salinity anomaly in freshwater hosing experiments

1 Sv freshwater OBS hosing experiment | 1 Sv freshwater CBS hosing experiment



In the OBS run, the Pacific surface water is fresher and the salinity anomaly in the Atlantic is weaker relative to the CBS run due to the export of FW at Bering Strait to Pacific.

In the CBS run, the Atlantic salinity anomaly is stronger and the Pacific is saltier due to reduced precipitation associated to the colder climate induced by a weaker THC.



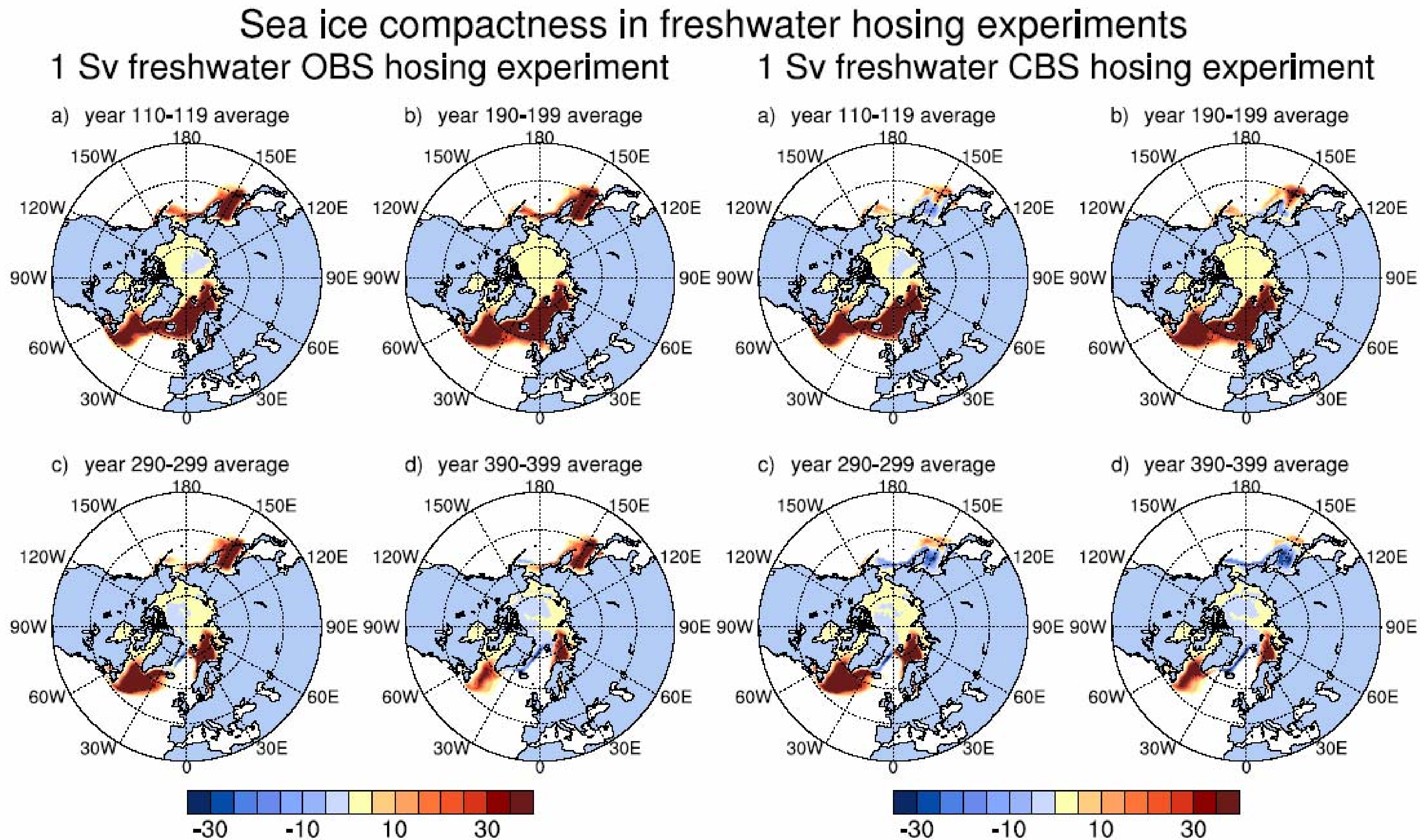
In the OBS run, the stronger cooling in the North Pacific is resulted from the export of the Arctic water and sea ice via Bering Strait. The decrease of the temperature anomaly in the North Atlantic is quicker in the OBS run than in the CBS run associated to the quicker recovery of the THC.

Atlantic Freshwater Budget (40^{o}N-80^{o}N)

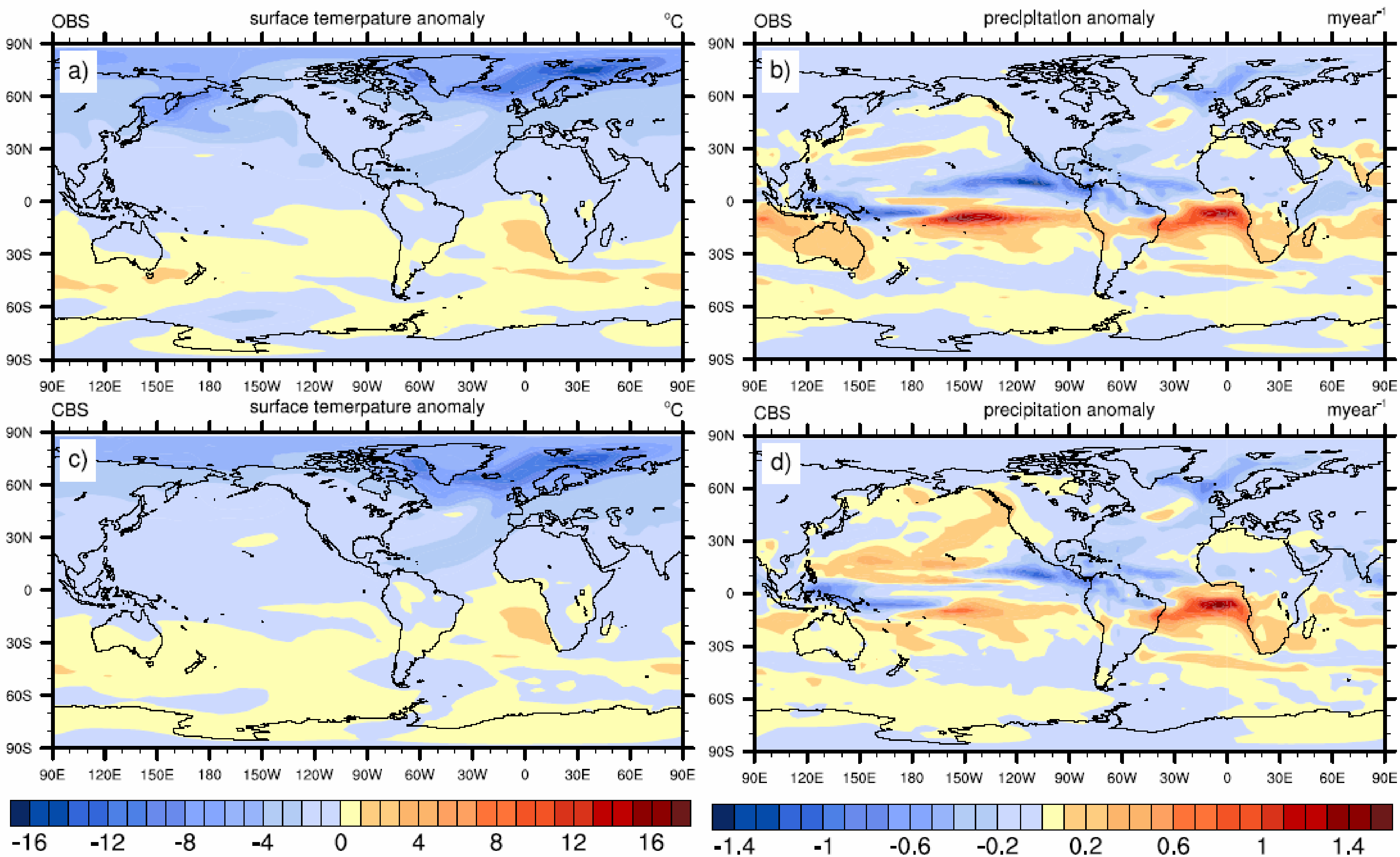
	OT 80^{o}N		OT 40^{o}N		P-E+R		Melt-ice		Budget	
	OBS	CBS	OBS	CBS	OBS	CBS	OBS	CBS	OBS	CBS
100-200y	-36.2	-21.3	-59.5	-74.9	-0.8	1.1	6.1	9.5	-90.4	-85.6
100-300y	-50.6	-26.1	-50.6	-84.6	0	3.1	9.4	18.4	-91.8	-89.2
100-550y	-54.3	-26.2	-56.8	-98.4	2.6	8.7	9.1	22.5	-99.4	-93.4

In the OBS run, most of the freshwater exported into the Arctic from the Atlantic is further transported into the Pacific via the Bering Strait as liquid water and sea ice, less than 20% is exported back to the Atlantic as sea ice.

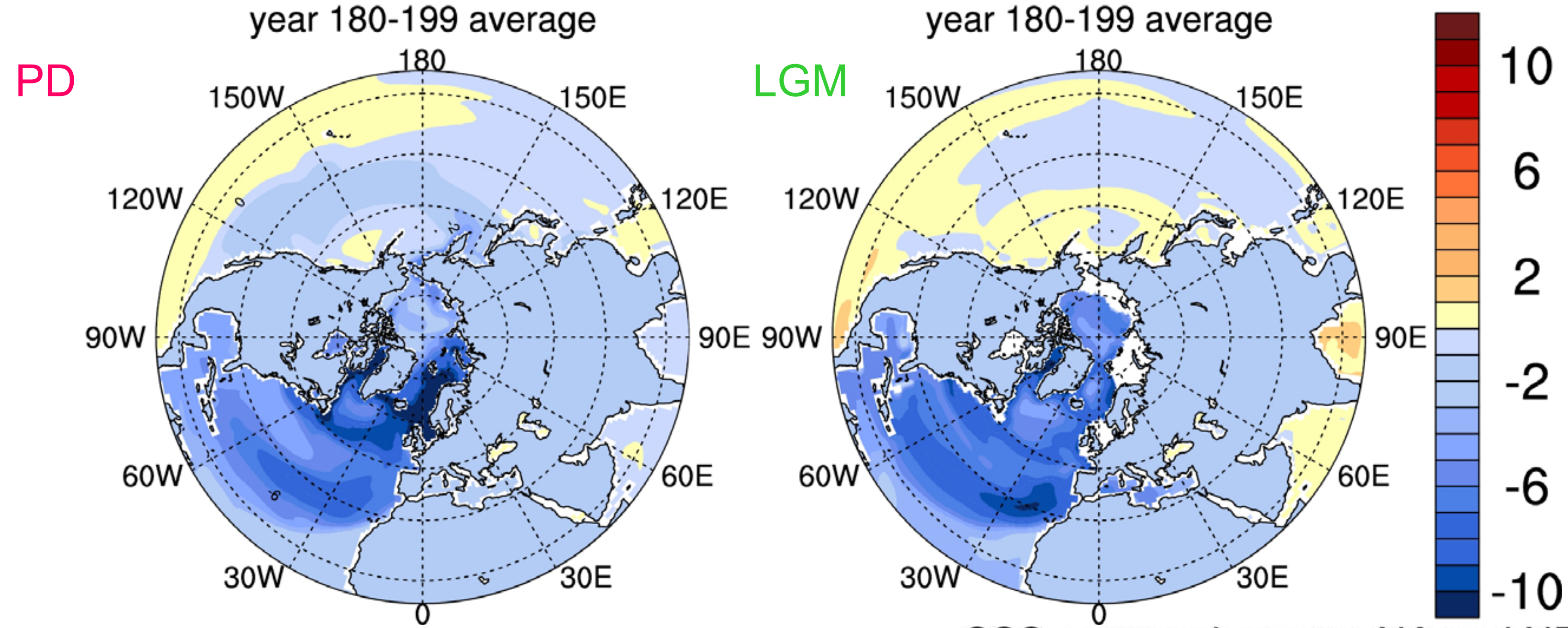
In the CBS run, since the Bering Strait is closed, most of the freshwater entering the Arctic is exported back to the Atlantic as sea ice. Along with the increase P-E+R, the surface freshwater input is much higher in the CBS run than in the OBS run, resulting in a delayed recovery of the deep convection and the THC.

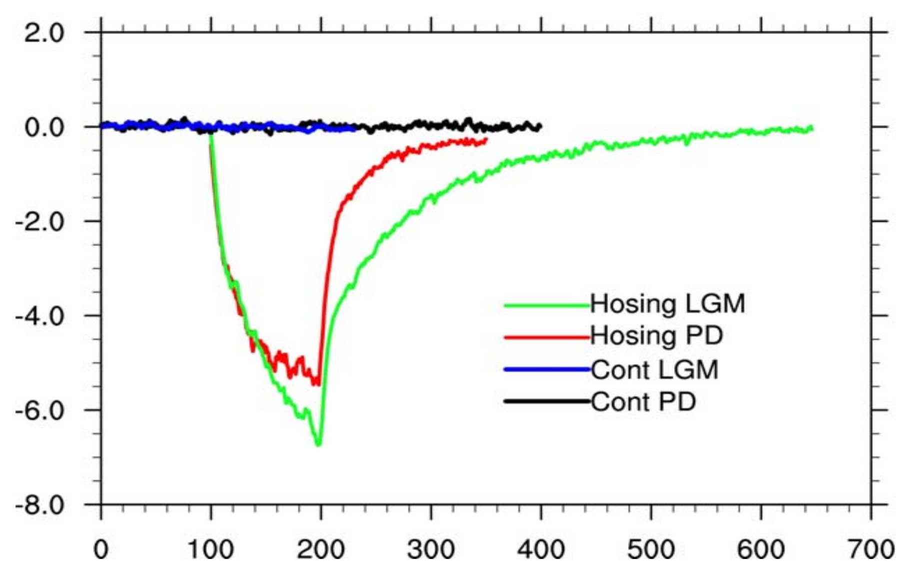

Sea ice compactness in freshwater hosing experiments
1 Sv freshwater OBS hosing experiment
1 Sv freshwater CBS hosing experiment
a) year 110-119 average
b) year 190-199 average
a) year 110-119 average
b) year 190-199 average
c) year 290-299 average
d) year 390-399 average
c) year 290-299 average
d) year 390-399 average
180
150W
150E
120W
120E
90W
90E
60W
60E
30W
30E
0
-30
-10
10
30
-30
-10
10
30

Surface temperature and precipitation anomaly



Sea surface salinity anomaly in 1 Sv hosing





Seidov and Haupt (2003, 2005) proposed that the sea surface salinity contrast between North Atlantic and North Pacific (10^{o}N~60^{o}N) controls the THC strength under equilibrium state.

Freshwater transport is defined as:

$$V_{fw} = \int\int v(1 - s/s_0)dxdz$$

where V_{fw} denotes the freshwater transport, v is the meridional velocity, s is the salinity, and s_0 is the reference salinity (34.7 psu), $dxdz$ denotes zonal and vertical integration.

Note: The cumulative freshwater transport discussed later is normalized by the total additional freshwater input in the North Atlantic during the hosing.