Latitudinal and longitudinal basin-scale surface salinity contrasts and freshwater transport by ocean thermohaline circulation

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Introduction

The role of sea surface salinity (SSS) contrasts in maintaining vigorous global ocean thermohaline circulation (THC) is revisited. Relative importance of different generalizations of sea surface conditions in climate studies is explored. In numerical experiments using an ocean general circulation model, we have aggregated the observed sea surface temperature (SST) and SSS in several different ways: we used observed unchanged SST with SSS taken as constant (34.25 psu) everywhere; SST unchanged, and SSS zonally averaged globally, i.e., in the whole World Ocean; SST averaged globally, and SSS unchanged; SST zonally averaged globally and SSS zonally averaged basin-wide in individual basins, i.e., in the Atlantic, Indian, Pacific, and Southern Oceans separately; and, finally, both SST and SSS zonally averaged in individual basins. Global zonal averaging removes all longitudinal differences in sea surface climatology among ocean basins. However, latitudinal profiles of zonally averaged parameters preserve the main character of large-scale equator-to-pole sea surface variability. Basin-wide zonal averaging does an even better job of preserving latitudinal distributions within each basin.

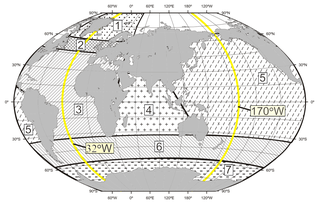

Figure 1. Areas of the World Ocean selected for the experiments, with area-averaged sea surface parameters.

Table 1. Experiments with globally averaged sea surface conditions

Exp	SST	SSS	TAU	$\overline{SST}$	$\overline{SSS}$	$\overline{TAU}$
1	x	x	x			
2		x	x	x		
3	x		x		x	
4	x	x				x
5			x	x	x	
6		x		x		x
7				x	x	x

Exp. 1 is the "control run" with annually mean ocean surface climatology; SST and SSS are from [*Levitus and Boyer*, 1994; *Levitus et al.*, 1994], and wind stress TAU is from [*Hellerman and Rosenstein*, 1983]. SST means globally zonally averaged SST; the same notation is used for SSS and TAU. The small crosses show what fields are used in each experiment.

Table 2. Experiments with sea surface conditions averaged zonally over each basin.

Exp	SST	SSS	TAU	[SST]	[SSS]	[TAU]
8		x	x	x		
9	x		x		x	
10	x	x				x
11			x	x	x	
12		x		x		x
13				x	x	x

Table 3. Experiments with area-averaged sea surface conditions.

Exp	SST	SSS	TAU	{SST}	{SSS}	{TAU}
14		x	x	x		
15	x		x		x	
16	x	x				x
17			x	x	x	
18		x		x		x
19				x	x	x

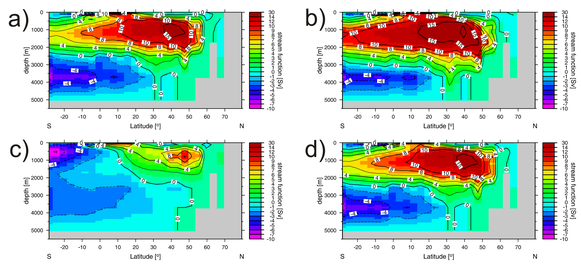

Figure 2. Meridional overturning in the Atlantic Ocean in the experiments shown in Table 1; (a) present-day; (b) Exp. 2; (c) Exp. 3; (d) Exp. 4. Streamfunction is shown in Sv (1 Sv = 10^6 m^3/s). Areas with negative values are shaded.

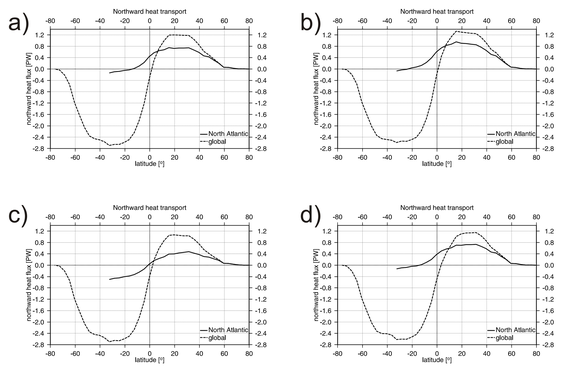

Figure 3. Northward heat transport (in PW; 1 PW = 10^{15} W) in the Atlantic Ocean (solid line) and global (dotted line): (a) present-day; (b) Exp. 2; (c) Exp. 3; (d) Exp. 4; see Table 1.

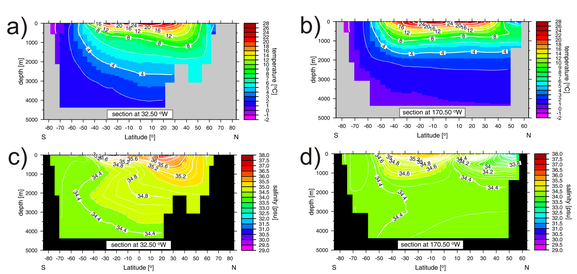

Figure 4. Temperature and salinity sections in the Atlantic Ocean at 32°W (left panel) and in the Pacific Ocean at 170°W (right panel) in the control case (Exp. 1; see Table 1): (a)-(b) temperature; (c)-(d) salinity.

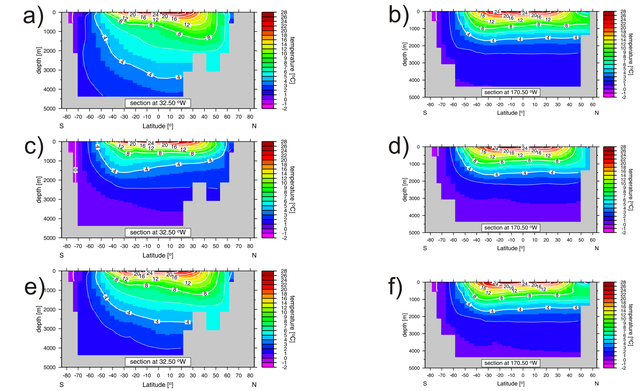

Figure 5. Temperature sections in the Atlantic Ocean at 32ºW (left panel) and in the Pacific Ocean at 170ºW (right panel) in Exp. 2-4: (a)-(b) Exp. 2; (c)-(d) Exp. 3; (e)-(f) Exp. 4; see Table 1.

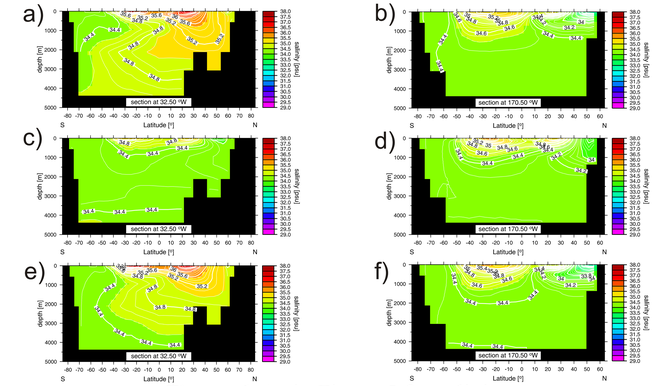

Figure 6. As in Figure 5 for salinity.

The results of the experiments could hardly be anticipated a priory. Surprisingly, SST could be used as a 2-D field, or as a zonally-averaged field without much difference in the THC dynamics. Moreover, SST could be averaged either globally, or basin-wide, and it also did not change the overall character of THC. At the same time, THC responded vigorously to how the SSS has been changed. It appeared that the THC structure with the globally averaged SST and basin-wide averaged SSS was very close to the one obtained in the control run (control run operates with 2-D observed SST and SSS).

Our main conclusion is that ocean-wide inter-basin sea surface salinity contrasts serve as the major controlling element in global thermohaline circulation. Thermal inter-basin contrasts, as well as longitudinal variation in SSS, are less important than latitudinal thermal gradients and inter-basin salinity contrasts. Details of SSS also decrease in importance as soon as its inter-basin contrasts are retained. This is especially important for paleoclimate and future climate simulations, as only the large-scale inter-basin contrasts of the sea surface conditions really matter.