Modeling sensitivity of the ocean circulation to freshwater impacts during Eocene-Oligocene cooling climate trend

Bernd J. Haupt bjhaupt@psu.edu http://www.personal.psu.edu/bjh18
Dan Seidov dseidov@psu.edu http://www.personal.psu.edu/dxs60

PENNSTATE
Earth and Environment Systems Institute

Introduction

The sensitivity of the past ocean circulation to meltwater impacts may have been different from the present-day. It is important to understand what are these differences and what causes them. One obvious candidate for altering the character of the ocean and climate response to similar to present-day impacts is different land-ocean distribution. Since freshwater impacts in past geologic eras having different basins configurations may have been different from the present-day pattern, the sensitivity of the ocean circulation to sea surface density impacts and climate change could have been different as well.

To address this issue, we use the Eocene-Oligocene geometry and sea surface climatology to address the past ocean sensitivity to freshwater variability.

The Eocene epoch is crucial as a transition from the warm Cretaceous ocean to cooler oceans that may have been subject to bi-polar millennial-scale oscillations of the deep ocean circulation caused by freshwater pulses of the developing southern cryosphere. In a series of numerical experiments, sea ice melting and sea water freezing around Antarctica were simulated by superimposing freshwater layers over zonally-averaged sea surface salinity. Eocene sea surface temperature and sea surface salinity are specified based on the paleoclimatic record and modeling. In our simulations, the Eocene ocean circulation is shown to be very sensitive to freshwater impacts in the Southern Hemisphere. There are also noticeable sea level changes caused by the restructuring of the deep ocean thermal and haline fields linked to the changes in deep ocean circulation.

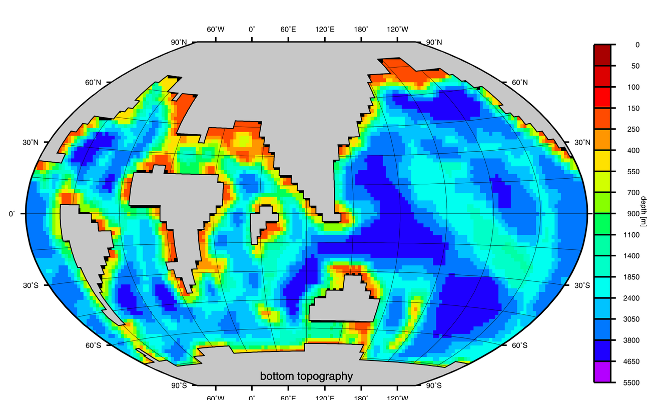

Figure1: Eocene bottom topography

Table 1: Amplitudes of sea surface salinity anomalies (in psu) in Southern Hemisphere

Experiment:	Cntrl (#1)	#2	#3	#4	#5	#6	#7	#8
Anomaly: in psu	0	-0.5	-1.0	-1.5	-2.0	0.5	1.0	2.0

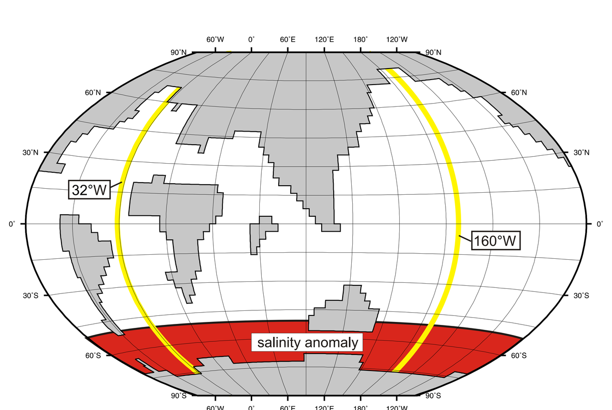

Figure 2: Sea surface salinity anomaly (in psu)

Ocean bi-polar seesaw: Southern meltwater events

Model simulations demonstrate that meltwater impacts in one hemisphere may lead to strengthening of the thermohaline conveyor driven by the source in the opposite hemisphere. This leads to significant changes in poleward heat transport and to either deepsea warming or cooling, which may in return lead to sea level changes.

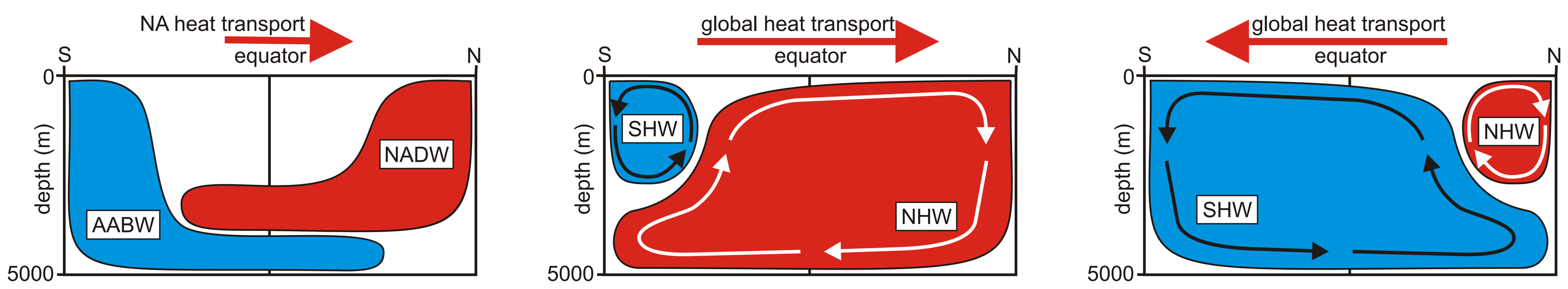

Figure 3: Sketch of bipolarity of deep-ocean dynamics. A:Present-day ocean; NADW— North Atlantic Deep Water, AABW—Antarctic Bottom Water. (b) Sea ice melting in Southern Hemisphere (SH); NHW—Northern Hemisphere water, SHW—Southern Hemisphere water. (c) Sea water freezing in SH. Note that NA present-day overturning is shown, whereas (b, c) global overturning can be only estimated. Arrowed lines show schemes of global meridional overturning. Direction of cross–equatorial oceanic heat transport is shown by arrows above each scheme.

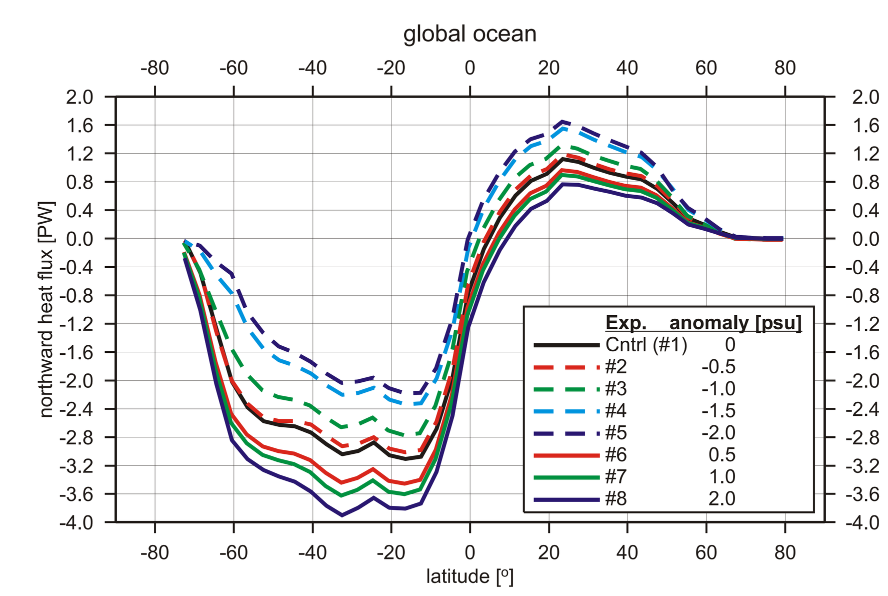

Figure 10: Northward heat transport (in PW; 1 PW = 10^{15}W) in the Global Ocean

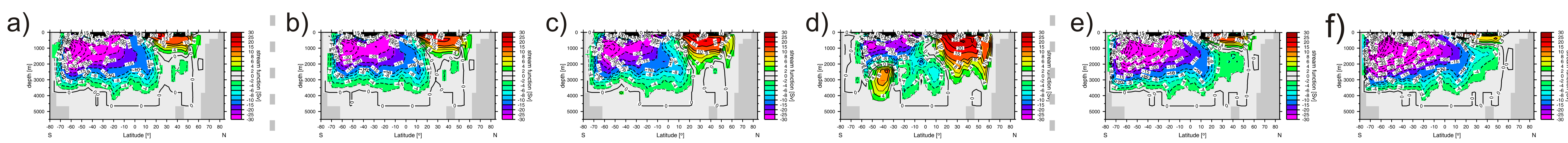

Figure 4: Meridional overturning in the World Ocean: (a) Cntrl (#1); (b) #2; (c) #3; (d) #5; (e) #6; (f) #8 (see Table 1). Streamfunction is shown in Sv (1 Sv=$10^6 m^3/s$)

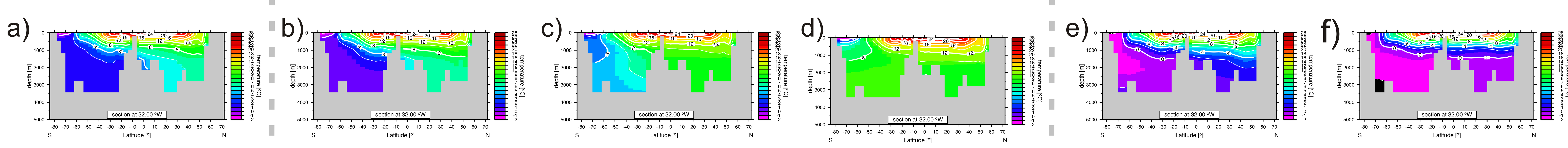

Figure 5: Temperature sections in the Atlantic Ocean at 32ºW: (a) Cntrl (#1); (b) #2; (c) #3; (d) #5; (e) #6; (f) #8 (see Table 1).

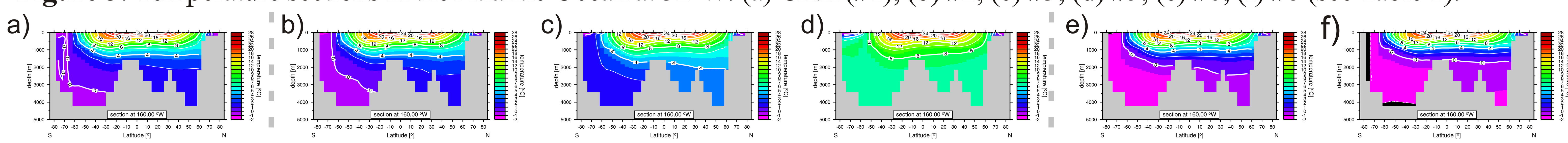

Figure 6: As in Figure 5 for the Pacific Ocean at 170ºW.

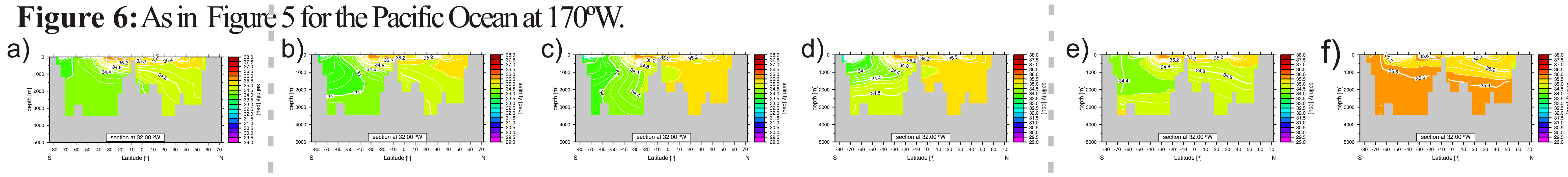

Figure 7: Salinity sections in the Atlantic Ocean at 32ºW: (a) Cntrl (#1); (b) #2; (c) #3; (d) #5; (e) #6; (f) #8 (see Table 1).

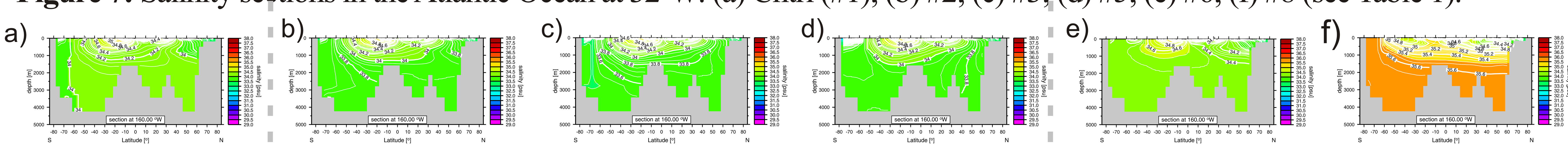

Figure 8: As in Figure 7 for the Pacific Ocean at 170ºW.

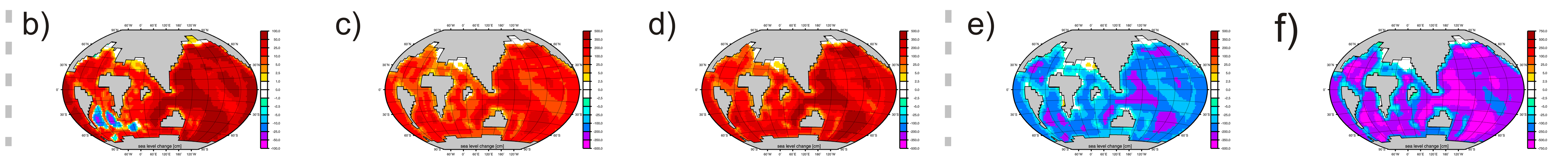

Figure 9: Sea level change realtive to control experiment Cntrl (#1): (b) #2-#1; (c) #3-#1; (d) #5-#1; (e) #6-#1; (f) #8-#1 (see Table 1)