The Effect of Bathymetry Changes on Meridional Overturning Currents

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Abstract

1 Introduction

The geometry and resulting bathymetry of our planet is an ever changing phenomenon. In the last 120 Ma the earth moved from having one major oceanic system in the Pacific with a single large continent to the current 3 ocean system (Besse and Courtillot 2002). The Bathymetry changes that occurred in this time period are characterized by the opening and closing of certain passages through which exchange of water between the oceanic basins is observed. The exact timing of passage openings is a topic of rigorous debate in literature (Scher and Martin 2006, Schmidt 2007).

One of the changes on which there is general consensus, is the inception and expansion of the Atlantic ocean and the resulting decrease in size of the Pacific basin. The creation of the Atlantic basin has had major effects on the earth's climate, especially resulting in massive localized changes such as the temperate European climate, due to the north Atlantic meridional overturning current (AMOC). This creates the current Northern sinking oceanic throughflow in the Atlantic. However it is unknown when exactly this northern sinking started. With the past non-existance of the Atlantic it must have started some time in the last 40Ma with the advent of a larger Atlantic (Abelson and Erez 2017).

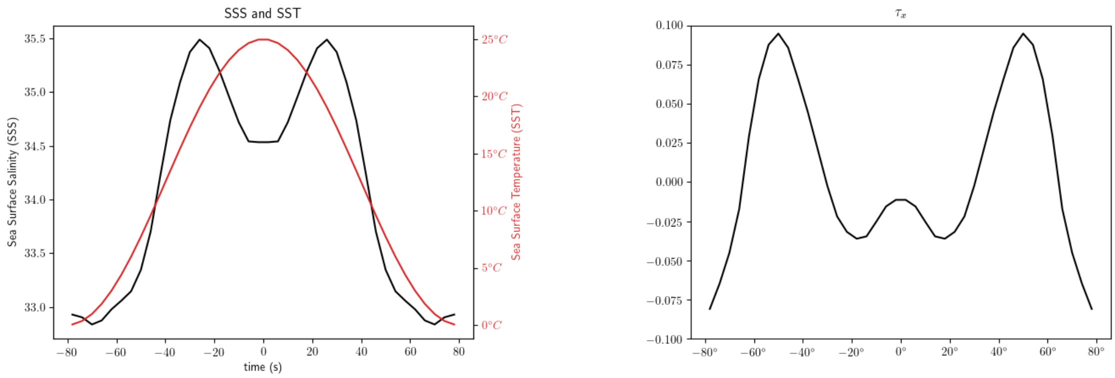
The result of these bathymetry changes on the oceanic stream function and the resulting overturning currents is something that has been previously studied by Mulder et al. 2017. They however found that using a Jacobian matrix for continuation in each of the model years fails to simulate the onset of the Northern sinking AMOC that is physically observed. Here we instead propose to use a general circulation ocean model with only a changing bathymetry keeping the same initial forcing for each time step. This eliminates the need for a continuation using the Jacobian matrix method proposed in Mulder et al. 2017.

This paper will focus solely on changes in bathymetry using simplified zonally averaged global forcings. The results of the model will be used to estimate global changes in oceanic through flow at the critical passages. Furthermore the strength of the meridional overturning currents (MOC) will be studied.

2 Methods

2.1 Simplified Forcings

The domain chosen is bounded by longitudes $\phi_E = -180°$ and $\phi_W = -180°$ and latitudes $\theta_N = 80°$ and $\theta_S = -80°$ with periodic boundary conditions in the zonal direction. Furthermore the model uses restoring boundary conditions first proposed by Haney 1971. Restoring the boundary at the surface of the oceanic basin to be a certain value based of a forcing field for Sea Surface Temperature (SST), Sea Surface Salinity (SSS), and wind stresses (τ). The depth profile has 15 layers with grid stretching. There are 90×40 grid points to make a $4° \times 4°$ resolution model. The forcings are prescribed as in Mulder et al. 2017 by highly idealized zonally averaged forcings using current day values. The SST and Zonal wind stress are chosen as the analytical model in Bryan 1987. While SSS is chosen as a zonal average of current day values (from ECMWF but not sure how to cite). The meridional wind stress is set to zero. The maximum ocean depth is 5000m. The model also requires initial conditions for salinity and temperature, for this zonally averaged present day values are again used.



(a) SSS and SST

(b) Zonal wind stress (τ_x) profile

Figure 1: Idealized forcing profiles

2.2 Creating Bathymetries

(Section on how I created the geometries for veros) 90/100 done

2.3 Model running

(Section on how the model was run (script making sure it is as fast as possible etc.)) 80/100 done

3 Results

3.1 Stabilizing of the models

(Section on when the integration was stopped. How good it is etc.) 60/100 done

3.2 Passage throughflow

(Section on throughflow for each passage) 50/100 done

3.3 Stream function

(Section on the Long-Lat stream function and vertical zonnally integrated streamfunction) 60/100 done

4 Summary

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5 Discussion

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