Thermohaline Changes Throughout the Greater Agulhas System in Response to Northern Hemisphere Ocean Freshening

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Summary

It has been proposed that the influence of the Indian-Atlantic warm water exchange route on the Atlantic Meridional Overturning Circulation has been subject to change in the past. In particular, changes in Agulhas Leakage may have acted to modulate glacial-interglacial and interstadial interstadial transitions. In order to analyze thermohaline changes throughout the greater Agulhas System in response to North Atlantic freshwater forcing, designed as a surrogate for cold stadial conditions, a 0.2 Sv hosing experiment is conducted using the comprehensive climate model COSMOS (MPIOM-ECHAM-JSBBACH).

Throughout the Agulhas region an upper layer salinity and temperature increase is simulated in response to the freshwater perturbation. Contemporaneously, upper layer velocity suggest a reduction of the volumetric flow rates in the Agulhas Current and Agulhas Return Current, as well as the Atlantic & Indian Ocean subs-tropical gyre systems. We propose that salinity and temperature increases occur in response to the slowdown of these gyre systems, acting to trap salt in the region, and the thermal bi-polar sea-saw, respectively. Upon resumption of the AMOC, salt released into the Atlantic Basin from the Agulhas region provides an important salinity advection feedback on the recovery of the AMOC, modulating the dynamics towards interstadial conditions. Our simulated salinity and temperature data is corroborated by high resolution proxies from the Agulhas region (Marino et al. unpublished results).

Conclusions

- An upper layer salinity and temperature increase is simulated throughout the Agulhas region in response to North Atlantic freshwater perturbation.
- Contemporaneously, a slowdown of the Agulhas Current, Agulhas Return Current, and Atlantic & Indian Ocean STG systems is simulated.
- The Agulhas system responds passively to North Atlantic hosing – leakage is curtailed.
- The Agulhas system provides an active salinity advection feedback upon the AMOC during recovery towards interstadial conditions (over a period of 500 years).

The Agulhas System

The Agulhas system comprises a complex non-linear network of currents and eddies located around the southern tip of the African continent. The ocean region encompassed the primary route whereby warm saline thermocline waters enter the Atlantic basin from the Indian ocean, in what is termed Agulhas Leakage (Beal et al. 2011).

The COSMOS Earth System Model

The fully comprehensive COSMOS Earth System Model incorporates the Earth’s various components in order to simulate global climates. This research utilizes the MPIOM ocean model interacting with the ECHAM5 and JSBBACH atmospheric and dynamic land-vegetation components. By varying the models boundary parameters we can simulate present, past and future climates.

In order to investigate the response of Agulhas gateway to North Atlantic freshwater forcing, a reconfigured MPIOM ocean grid with the south pole positioned over South Africa has been configured. With the North Pole positioned over Greenland, this setup ensures that the North Atlantic deepwater formation zones as well as the Agulhas region are located within the most highly resolved regions. This configuration allows a better representation of the non-linear dynamical behavior which is typical of the Agulhas region. Via this method we aim to accurately simulate the transfer of warm saline Indian Ocean waters into the Atlantic basin over present and paleo timescales. The research outlined on this poster utilizes a pre-industrial state as the basis for experimentation.

Simulated dynamics of the Agulhas System and AMOC.

Figure (a) and (b), velocities at the surface and 1000m depth, respectively, throughout the Agulhas region. Streamlines indicate the actual movement of water. Salinity, measured in psu, indicates the higher rate of Indian-Atlantic water mass transfer (Agulhas Leakage) at the surface.

Figure (c), barotropic streamfunction throughout the Agulhas region and Atlantic Basin, measured in Sv. The Indian Ocean gyre rotates at a maximum rate of 50-60 Sv. The South Atlantic sub-tropical gyre rotates at a maximum rate of 30-60 Sv.

Figure (d), anomaly plots of AMOC from 30S to 90N, measured in Sv. The maximum overturning of ~15Sv is simulated at 30N at a depth of 1000m, consistent with observations.

Pre-Industrial Simulation

Anomaly plots between the initial state (after 250 years of hosing) and the pre-industrial state, for (a) upper 500m averaged salinity, measured in psu, (b) upper 500m averaged velocity, measured in m/s, and (c) surface height, measured in metres.

Time series of the freshwater experiment. Years 0-100 display the pre-industrial control state, years 100-300 show the system evolution during hosing, and years 300-750 the recovery period after North Atlantic freshwater is removed. (d) illustrates the evolution of the AMOC throughout the experiment, with maximum overturning measured at 50N. (e) indicates the salinity anomaly at all depths at a transect 10E between 30S and 40S, a system sensitive to diapycnic salt changes in the Agulhas region.

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