Assessing the role of the Subtropical Front in regulating Agulhas Leakage at the Last Glacial Termination
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Paleoceanographic variability of Agulhas Leakage

Many paleoceanographic studies have found significant glacial-interglacial variability in the Agulhas Leakage, with cold glacial periods tending to have less leakage, and maximum leakage occurring during, or just prior to glacial terminations. One example is shown below.

Proposed mechanisms for reduced Agulhas Leakage during glacial periods:

1. Stronger Agulhas Current caused a more upstream (eastward) Retractofront, and less Leakage
An inverse relationship between Agulhas Current flux and Agulhas Leakage is supported by:
- Simple, idealized models (e.g. Ou and de Ruijter, 1986)
- Lagrangian drifter models (van Sebille et al. 2009)
- Modern observations (de Ruijter et al. 2004)

2. More northward Subtropical Front (STF) restricted the Agulhas Retractofront, causing less Leakage
A direct relationship between STF latitude and Agulhas Leakage is supported by various models (e.g. de Ruijter and Bouda, 1980, Makino, 1996)

Results from the Provenance and Flux of Terrigenous Sediments

Stromatolite isotopic ratios (31P/32P) of the terrigenous sediment deposited in the deep sea provide a good indicator of its provenance. In general, low 31P/32P indicate a relatively young continental source, while very high 31P/32P indicate that the provenance contains very old terrains, such as those exposed on the eastern coast of South Africa (Fig. 2). Terrigenous 31P/32P of modern sediments in the South Atlantic show a pattern resembling the surface ocean circulation, with sediments underlining the Agulhas Current and the Agulhas Return Current having significantly higher 31P/32P than surrounding sediments (Fig. 2). It is for this reason that we can use terrigenous 31P/32P as an Agulhas Current proxy.

Provenance Results

Provenance and flux data for sediments deposited in this region during the Last Glacial Maximum (LGM, ~20,000 years ago) are consistent with reduced Agulhas Leakage, but also indicate that the Agulhas Current was significantly weaker during the Holocene (recent 10,000 years) (Franzese et al. 2006).

Based on the relatively low LGM 31P/32P in cores northeast of the Agulhas Plateau (0.117), there is no compelling evidence that the Agulhas Retractofront was east of the Agulhas Plateau during the LGM (Fig. 3b). In addition, the homogeneity of LGM 31P/32P with water depth (Fig. 4) most likely reflects a surface water source that is common to all sites. This could only be true if during the LGM, the Agulhas Retractofront was positioned west of the Agulhas Plateau, close to its modern position.

Based on all available data, the most plausible scenario for the LGM circulation is no change from the modern flow path of the Agulhas Current or the location of Retractofront. The glacial pattern of 31P/32P is very similar to the modern, but the absolute values are generally lower than in the Holocene (Fig. 3g). This implies that during the LGM, the Agulhas Current flowed along its modern trajectory, but was depositing less material with very high 31P/32P. Since there is no evidence for a LGM to Holocene change in the end-member sediment composition (Franzese et al. 2006), this means that the Agulhas Current delivered less particles to these sediments during the LGM. We infer that the reason for this was a smaller Agulhas Current capacity, i.e. a weaker Agulhas Current flow.

Figure 2: Terrigenous 31P/32P for Holocene sediments for the region from 40°W-60°E and 20°S-60°S (Franzese et al. 2006).

Symbols marking core locations, 31P/32P contours and the ages of exposed land surfaces are color coded following the scales shown below.

Figure 3: Terrigenous 31P/32P for Holocene (a) and LGM (b) sediments for the Retractofront region from 17-14°E and 28-44°E. Sediment core data from this study are shown in circles and triangles; stars show the locations of the river mouth (Franzese et al. 2008)

In summary, the best paleoceanographic evidence suggests that during the LGM, the Agulhas Current was weaker and there was less Agulhas Leakage. This is inconsistent with hypothesis #1 above. In addition, the Agulhas Retractofront does not appear to have been displaced during the LGM, which is consistent with hypothesis #2 above. We therefore posed another hypothesis:

3. Stronger Agulhas Current may lead to more Leakage
A positive relationship between Agulhas Current flux and Agulhas Leakage is supported by a regional ocean model known as The Southern Africa Experiment (SAFEX), forced by the increased Agulhas Current strength due to recent global warming (Rouault et al. 2009).

Figure 4: Terrigenous 31P/32P for cores from the Agulhas Plateau with water depth (Franzese et al. 2009). The dashed line at 3.8 km to show the approximate interface between AABBW and CPRW.

Figure 5 (modified from Figure 3 of Beal et al. 2010). The major features of the Agulhas Current System (black arrows), the southern boundary of the modern STF (white line) and core locations for the proposed study (circles). Background color shows SST for 23 May 2009; SST data are from the NRT and K10 analysis with combined satellite infrared and microwave measurements, made available through the GHERST project (Denton et al. 2007). North-south migrations of the STF (red lines) related to wind changes and/or the interdecadal loop (related to varying Agulhas strength) can either open the "leakage gap" between Africa and the STF.

Figure 6: Mg/Ca (top) and 87Sr/86Sr (bottom) of G. bulloides from VM34-13B and VM34-105. Calibrated 14C ages of G. bulloides VM34-13B (red carrot) and VM34-155 (blue carrot) are also shown for reference.

Our project fills in a significant geographic gap in glacial reconstructions of the STF by using a meridional transect of cores from the western flanks of the Agulhas Plateau, between the latitudes of 38°S and 42°S. We are using paired measurements of planktonic Mg/Ca and δ18O as proxies for SST and SSS, to explicitly reconstruct the position of the STF over the past 25,000 years, covering the Last Glacial Terminations, and we plan to combine these with measurements of proxy tracers of particles and water mass. We will produce high-temporal resolution records of the SST and SSS gradients associated with the STF immediately south of the Agulhas Retractofront over the last 25,000 years. In the figures below, we present the initial results of our study, focusing on two of the southernmost cores in the transect, near the modern location of the STF.

Mg/Ca and 87Sr/86Sr both show clear glacial to interglacial gradients, indicating cooler, higher salinity waters during the LGM.

The latitudinal gradient in Mg/Ca appears to be larger than for δ18O, indicating that temperature, as opposed to salinity, dominates the signal.

More high-resolution down-core records and increased resolution records of these cores in the Agulhas Region are necessary to completely constrain the position(s) of the STF over the last deglaciation.

References


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