EOS

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 91 NUMBER 12

23 MARCH 2010

PAGES 109–116

Investigating the Global Impacts of the Agulhas Current

PAGES 109–110

The Agulhas Current is the major western boundary current of the Southern Hemisphere [*Lutjeharms,* 2006] and a key component of the global ocean "conveyor" circulation controlling the return flow to the Atlantic Ocean [*Gordon,* 1986]. As such, it is increasingly recognized as a key player in ocean thermohaline circulation, with importance for the meridional overturning circulation (MOC) of the Atlantic Ocean.

Unusual dynamics pervade the motion of this warm-water current—as it moves west around the southern tip of Africa, it is retroflected back east by the Antarctic Circumpolar Current. Not all waters are captured by this sudden diversion of course—parts of the Agulhas Current leak away into the South Atlantic Ocean (Figure 1).

New research is giving tantalizing suggestions that variations of the Agulhas leakage south of Africa are key players in global climate developments, and hence understanding their operation is important to climate projections. To examine the possible relationships between the Agulhas system and climate, two investigative avenues are open: modeling and paleoceanographic reconstructions. A new international initiative, called Multi-Level Assessment of Ocean-Climate Dynamics: A Gateway to Interdisciplinary Training and Analysis (GATEWAYS), addresses both.

The Agulhas System and Impacts

The Agulhas Current has a volume flux of about 70 sverdrups (1 sverdrup = 10^6 cubic meters per second), a dimension similar to the Gulf Stream and the North Atlantic Current. South of Africa the current retroflects back into the South Indian Ocean. Before reaching this retroflection, meanders—triggered by anticyclonic eddies deriving from the Mozambique Channel—propagate downstream with the current. On reaching the area of retroflection, these eddies, called "Agulhas rings," spin off into the South Atlantic (Figure 1). This mechanism, and the volume of the Agulhas Current itself at any given time, constitute the primary factors that define the leakage.

The Agulhas Current influences climate in two ways. First, the warm tropical waters carried by the current stimulate convection of the overlying atmosphere with direct consequences for regional weather systems [*Reason and Jagadheesha,* 2005]. Second, the shedding of Agulhas rings south of Africa causes buoyancy anomalies in the South Atlantic that stimulate dynamical responses with potential consequences for the Atlantic MOC [*Biastoch et al.,* 2009; *Knorr and Lohmann,* 2003]. While the significance of these mechanisms is increasingly recognized, their dynamics and sensitivity are not well understood. The key questions that arise are as follows: (1) How does the Agulhas Current react to shifts in wind fields and regional ocean fronts? (2) How do such changes affect the Agulhas leakage into the Atlantic? (3) Does the leakage indeed perturb the Atlantic MOC? To answer these questions, paleoceanographic reconstructions and numerical modeling are essential tools.

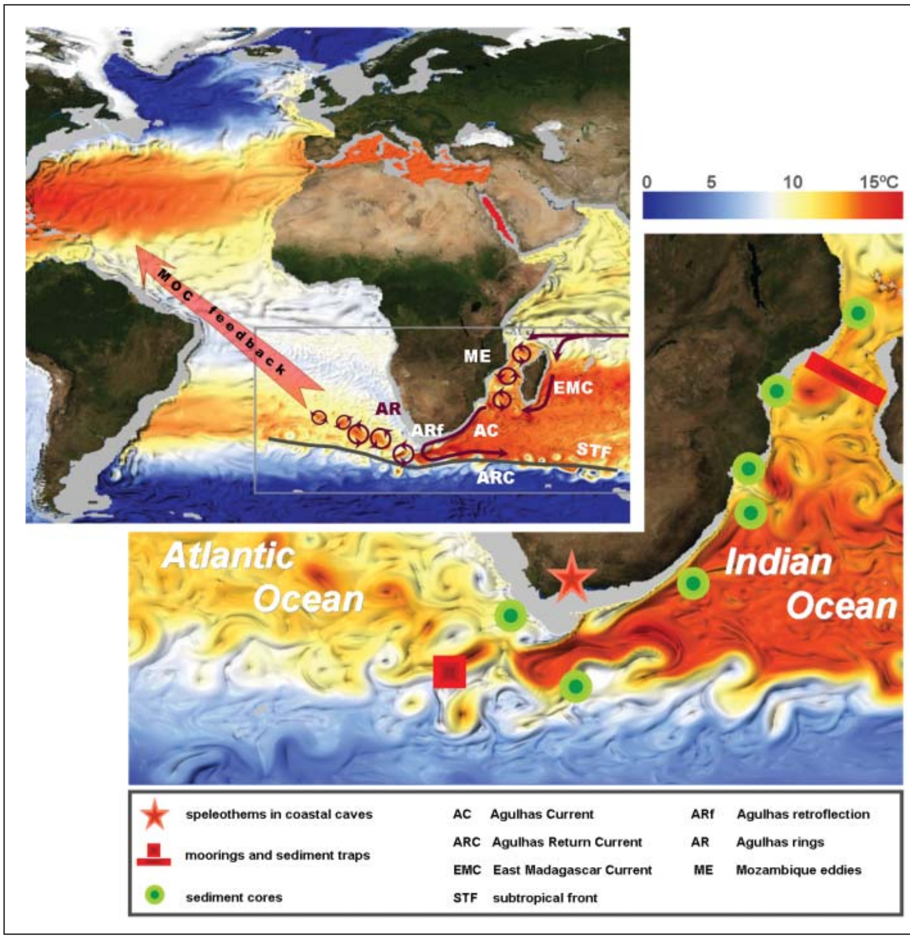

*Fig. 1. The Agulhas Current and Indian-Atlantic water exchange. The snapshot is taken from a high-resolution Agulhas model (box outlined in gray) nested in a global ocean/sea ice model [*Biastoch et al., *2009]. Colors and shading indicate temperature and magnitude of currents. Symbols mark locations and sample materials used to reconstruct past variation of the current. The data will be fed into models to assess the dynamics of the current and interocean water transports, including the Atlantic meridional overturning circulation (MOC), under contrasting past climates.*

Documenting Past Changes Through Paleoreconstruction

Paleoceanographic records spanning the past several hundred thousand years have helped to demonstrate the Agulhas Current's sensitivity to variable wind fields over the South Indian Ocean and the migration of ocean fronts south of Africa. Paleoevidence provides qualitative indications of past variations of the Agulhas Current and adjacent ocean fronts [*Bard and Rickaby,* 2009; *Peeters et al.,* 2004; G. Martínez-Méndez et al., A 345,000 year record of heat and salt transports in the Agulhas corridor south of Africa, submitted to *Paleoceanography,* 2009;] that suggest shifted wind fields and, potentially, changes to the circulation in the Agulhas corridor and the leakage. Radiogenic isotope signals point to past changes in Agulhas Current strength, while the position of the retroflection appeared reasonably stable according to these data [*Franzese et al.,* 2009]. The consequences of such scenarios for the Agulhas leakage have yet to be tested.

New sediment cores have been collected from three sectors of the Agulhas regime (Figure 1). These sectors are the southeast African margin, to reconstruct the current's variability as it forms the South Indian Ocean western boundary current; the Agulhas corridor south of Africa, to reconstruct the Indian-to-Atlantic water transports; and the Agulhas plateau, to capture migrations of the ocean subtropical front and their impact on the gateway circulation. Analysis of the sediment cores will be complemented by studies of data and materials from sediment traps and moorings. Ongoing work on some of these materials and cores already highlights the quality of the paleoprofiles obtainable from this region.

Facing the Challenge

Integrating paleoceanographic reconstructions and numerical ocean modeling is the only way to fully understand the sensitivity of the Agulhas Current and the significance of the interocean salt transports for the Atlantic MOC. Further, embedding high-resolution Agulhas modules into global models (as seen in Figure 1) in conjunction with atmosphere-ocean simulations will allow for the assessment of impacts of the Agulhas regime on global oceanic and atmospheric circulation [*Biastoch et al.,* 2009; *Park and Latif,* 2008]. This has important implications for climate studies, and Earth system models of intermediate complexity (EMICs) [*Knorr and Lohmann,* 2003] are valuable tools for studying the relationships between different climate components and for validating paleoceanographic data.

The new GATEWAYS project, sponsored by the 7th Framework Programme of the European Community, takes up these challenges through fostering collaborations among scientists from Spain, Germany, Israel, Netherlands, United Kingdom, and South Africa in an interdisciplinary partnership of physical oceanography, ocean and atmospheric numerical modeling, and paleoceanography and paleoclimatology. Collaboration between these disciplines enables scientists to (1) test the sensitivity of the Agulhas Current to changing climates of the past, (2) assess the impact of the current on climates in southeastern Africa, and (3) examine the sensitivity of the Atlantic MOC to Agulhas leakage.

GATEWAYS also offers training to young researchers in paleoceanographic reconstructions and ocean and atmosphere modeling. The interdisciplinary transfer of knowledge is pivotal to gaining fuller understanding of the Agulhas Current as one of the most vigorous and complex current systems in the world ocean.

More information about GATEWAYS can be found in the electronic supplement to this *Eos* issue (http://www.agu.org/eos_elec/).

Acknowledgments

GATEWAYS is sponsored by the 7th Framework Programme of the European Community. Acquisition of materials is supported by the International Marine Global Change Study (IMAGES); Deutsche Forschungsgemeinschaft, Germany; Natural Environmental Research Council, United Kingdom; Ministerio de Ciencia e Innovación, Spain; Institut Polaire Français Paul Émile Victor, France; European Commission Access to Research Infrastructures (ARI, grant HPRI-CT-2001-00120); and the Netherlands Organization for Scientific Research. Efforts of chief scientists, masters, and crews of the RRS *Charles Darwin*, R/V *Marion Dufresne*, R/V *Meteor*, R/V *Pelagia*, and R/V *SA Agulhas* are gratefully acknowledged.

References

Bard, E., and R. Rickaby (2009), Migration of the Subtropical Front as a modulator of glacial climate, *Nature, 460,* 380–383.

Biastoch, A., et al. (2009), Increase in Agulhas leakage due to poleward shift of Southern Hemisphere westerlies, *Nature, 462,* 495–499.

Franzese, A. M., S. R. Hemming, and S. L. Goldstein (2009), Use of strontium isotopes in detrital sediments to constrain the glacial position of the Agulhas Retroflection, *Paleoceanography, 24,* PA2217, doi:10.1029/2008PA001706.

Gordon, A. L. (1986), Interocean exchange of thermocline water, *J. Geophys. Res., 91,* 5037–5046.

Knorr, G., and G. Lohmann (2003), Southern Ocean origin for the resumption of Atlantic thermohaline circulation during deglaciation, *Nature, 424,* 532–536.

Lutjeharms, J. (2006), *The Agulhas Current,* 329 pp., Springer, Berlin.

Park, W., and M. Latif (2008), Multidecadal and multicentennial variability of the meridional overturning circulation, *Geophys. Res. Lett., 35,* L22703, doi:10.1029/2008GL035779.

Peeters, F. J. C., et al. (2004), Vigorous exchange between the Indian and Atlantic oceans at the end of the past five glacial periods, *Nature, 438,* 661–665.

Reason, C. J. C., and D. Jagadheesha (2005), Relationships between South Atlantic SST variability and atmospheric circulation over the South African region during austral winter, *J. Clim., 18,* 3339–3355.

—Rainer Zahn, Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain; and Institut de Ciència i Tecnologia Ambientals, Departament de Geología, Universitat Autònoma de Barcelona, Bellaterra, Spain; E-mail: rainer.zahn@uab.cat; Johann Lutjeharms, Department of Oceanography, University of Cape Town, Rondebosch, South Africa; Arne Biastoch, Leibniz-Institut für Meereswissenschaften (IFM-GEOMAR), Kiel, Germany; Ian Hall, School of Earth and Ocean Sciences, Cardiff University, Cardiff, UK; Gregor Knorr, Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany; Wonsun Park, IFM-GEOMAR; and Chris Reason, Department of Oceanography, University of Cape Town