The impact of climate change on large scale coastal currents of South Africa

A MEYER
CSIR Natural Resources and the Environment, PO Box 395, Pretoria, 0001, South Africa
Email: ameyer@csir.co.za – www.csir.co.za

SCIENTIFIC BACKGROUND

The increase in equatorial temperatures and the presence of an ozone hole over Antarctica have caused an increase in the pole-to-equator pressure gradient with a concomitant intensification of the high-latitude westerlies (Cai *et al.*, 2006). The transfer of momentum from the westerlies to the underlying Antarctic Circumpolar Current (ACC) (**Figure 1**) has lead to a steady increase in ACC velocity. Since this current is in contact with the southern boundaries of the Southern Hemisphere subtropical gyre systems, a spinning up and southward shift of these basin scale gyres have been observed.

Climate models (Saenko *et al.*, 2005) based on the Intergovernmental Panel for Climate Change (IPCC) estimates of a 1% increase in CO_2 per year, show that this trend will continue into the 21st century, that is:

1) A further intensification and southward shift of the mid-latitude westerlies with an affiliated increase in the Antarctic circumpolar current transport;
2) A southwards migration and intensification of the Southern Hemisphere sub-tropical gyre circulations; and
3) Stronger western boundary currents, that is, stronger Agulhas Current (along the east coast of South Africa), and stronger Brazil and East Australian Current.

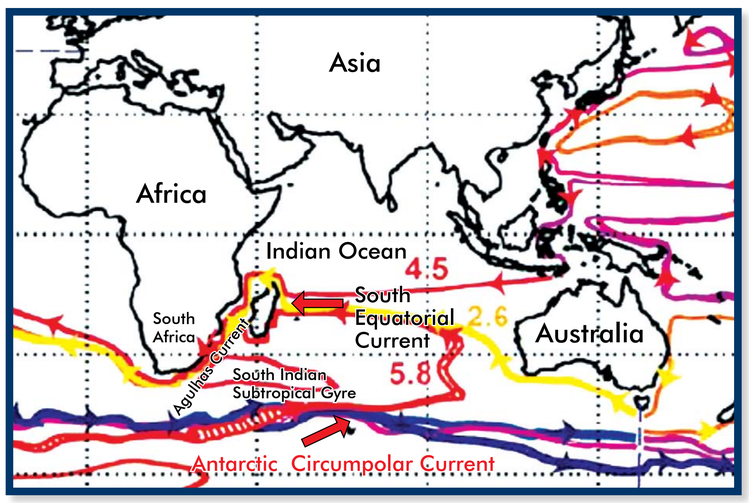
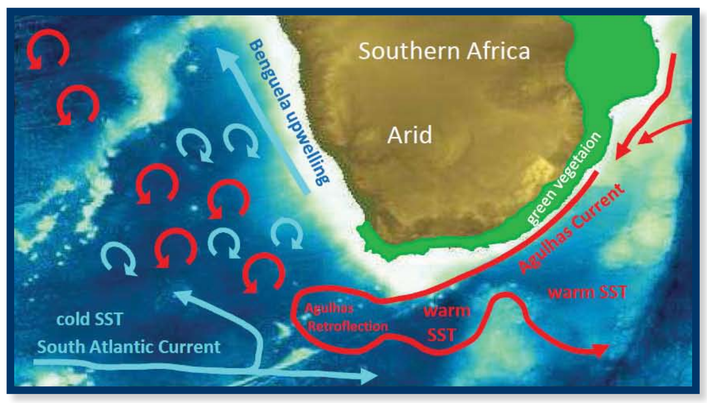


Figure 1: Map showing the model outputs of volume transport of oceanic currents of the Indian Ocean sector (after Speich *et al.*, 2007). The major current systems are indicated, with values denoting volume transport in 106 m^3/s

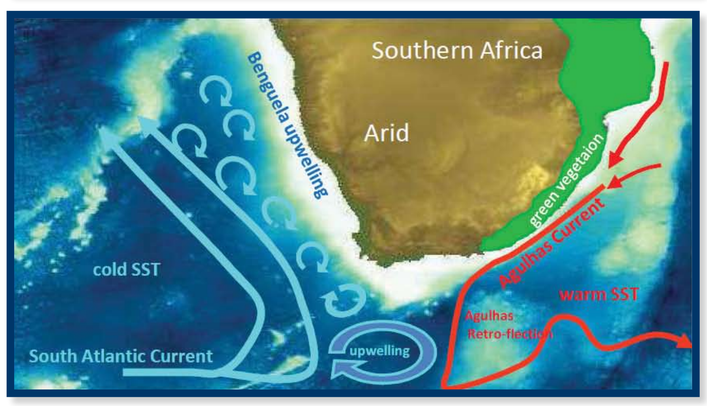
The impact of a stronger Agulhas Current on the retroflection (**Figure 2**) is still unclear. Currently the Agulhas Current is known to terminate in two distinct modes, a) normal or downstream mode (**Figure 2a**) and an upstream mode (**Figure 2b**).

The models study of Cai *et al.* (2007) and Rouault *et al.* (2009) indicates that the increase of Agulhas Current transport will lead to an on average downstream retroflection, with more warm Indian Ocean water passing the southern and western coasts of South Africa. The model study of Van Sebille *et al.* (2009) clearly shows the opposite – that an increase in Agulhas Current transport will lead to a higher frequency upstream retroflection, with a reduction of Indian Ocean water leaking into the Atlantic Ocean.

a



b



Figures 2a & b: Position of the normal or downstream Agulhas retroflection, and b) upstream Agulhas retroflection

Before the publication of the data in **Figure 3a** (Lutjeharms & Van Ballegooyen, 1988), the phenomena of an upstream retroflection was unknown. This is mainly due to the fact that such large-scale oceanic events can only be captured using ocean observation satellites. The only other clear observation was presented by De Ruijter *et al.* (2004), where they show that the triggering of the upstream retroflection was induced by a stronger South Equatorial Current (**Figure 1**) due to *La Nina* (the counter part of *El Nino*) which forces increased amounts of water through the Indonesian passages.

In this paper, the third such observation of an upstream retroflection and its dramatic impact on the commercially-important nursery and fishing grounds of the Agulhas Bank is presented (**Figures 3b and c**). These satellite images from the MODIS instrument on NASA's Aqua Satellite clearly show the retroflection just south of Port Elizabeth, further upstream from its normal position, forcing large quantities of nutrient-, phytoplankton- and fish-rich waters off the Agulhas Bank into the deep ocean. The duration of this upstream retroflection was one month, compared to the six months' duration of the one De Ruiter *et al.* (2004) observed. An important fact is that the new observations presented here were also captured during a *La Nina*-event.

This paper presents the first satellite observation of the upstream retroflection of the Agulhas Current and its dramatic impact on the commercially-important nursery and fishing grounds of the Agulhas Bank.

a

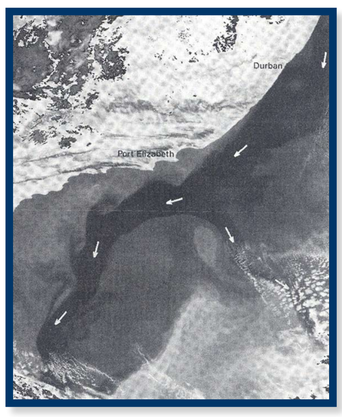
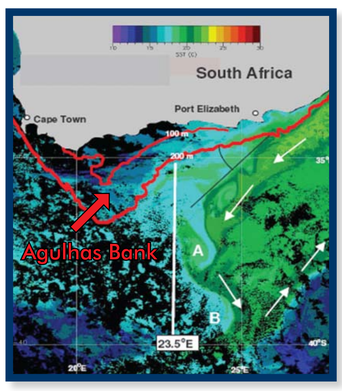


Figure 3a: The fist satellite observation of the upstream retroflection of the Agulhas Current by Lutjeharms and van Ballegooyen (1988). Figure 3b reflects the Sea Surface Temperature data from MODIS Aqua showing the upstream retroflection of the Agulhas Current just south of Port Elizabeth, and Figure 3c depicts Ocean Colour data (proxy for phytoplankton biomass) showing the off-shelf transport of Agulhas Bank water on the western edge of the retroflection current

b



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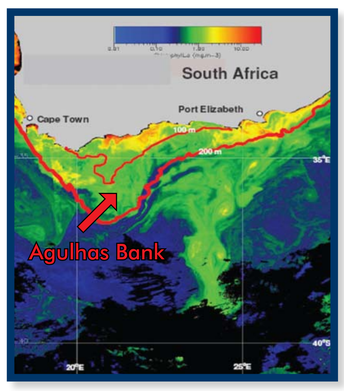

CONCLUSION

It is predicted that as the temperature of the planet warms up, more warm water will be forced into the Agulhas Current system, which can be compared to *La Nina* years when most water of the South Equatorial Current is forced south of Madagascar into the Agulhas Current. Both De Ruiter *et al.* (2004) and the data presented here clearly show that during these events the probability increases for upstream retroflections to occur.

We can thus come to the preliminary conclusion that we would expect, on average, more upstream retroflection with a warming planet, with an on average increase in off-shelf transport of carbon-rich Agulhas Bank waters. The impact of continued upstream retroflections will thus impact significantly on the future fish stock of South Africa's fishing industry, which in turn supports the livelihood of many families.

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A warming planet could, on average, lead to more upstream retroflections of the Agulhas current, with an on average increase in off-shelf transport of carbon-rich Agulhas Bank waters. The impact of continued upstream retroflections may impact significantly on the future fish stock of South Africa's fishing industry.