Retro-fiction - a reappraisal of the fate of the East Madagascar Current

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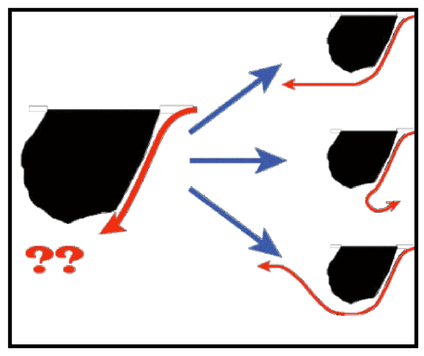
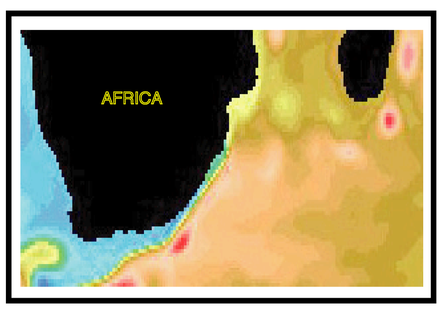
INTRODUCTION

The East Madagascar Current (EMC) flows south along the Madagascar coast (see schematic to right) but its fate thereafter is uncertain. Does it flow west to feed the Agulhas Current? Does it retroflect, in a similar manner to the Agulhas? Does it round Madagascar and flow into the Mozambique Channel?



Numerical models, such as OCCAM, suggest that anticyclonic eddies track south along the east coast of Madagascar, and then move southwestwards towards the Agulhas.

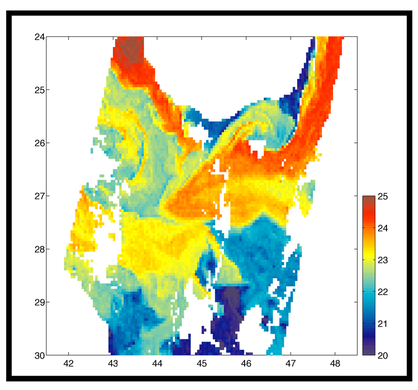
A snapshot of sea surface height from OCCAM. Anticyclones (highs) in pink; cyclones (lows) in yellow. Output courtesy of the OCCAM team at SOC.



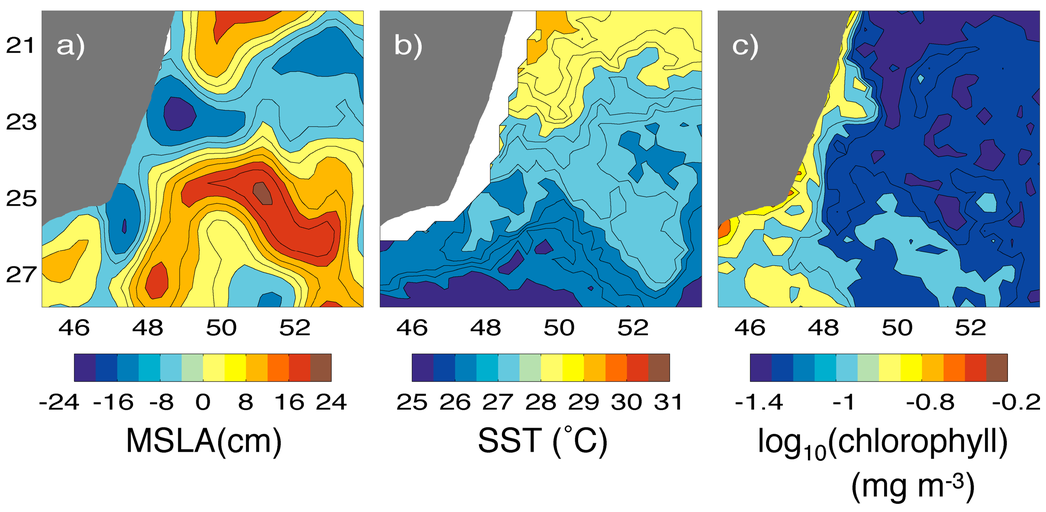
It has been conjectured that the EMC exhibits a retroflection south of Madagascar. This idea is based on "snapshot" images of sea surface temperature (SST) or ocean colour. Here we examine this hypothesis using time series of composites from three different datasets:

- altimeter mean sea level anomaly (MSLA) - provided by CLS
- SST - from TMI provided by Remote Sensing Systems
- chlorophyll concentration - from SeaWiFS provided by NASA/GSFC

SST data from the ATSR-2 on ERS-2 showing an apparent retroflection of the EMC south of Madagascar (16 July 2000). Data courtesy of RAL.

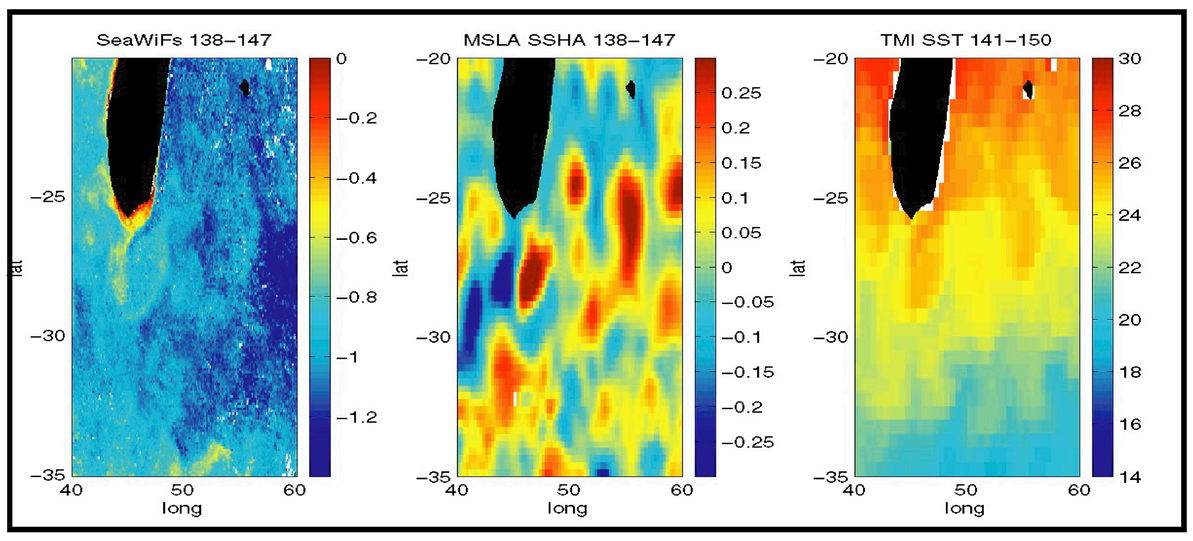


CYCLONIC EDDIES



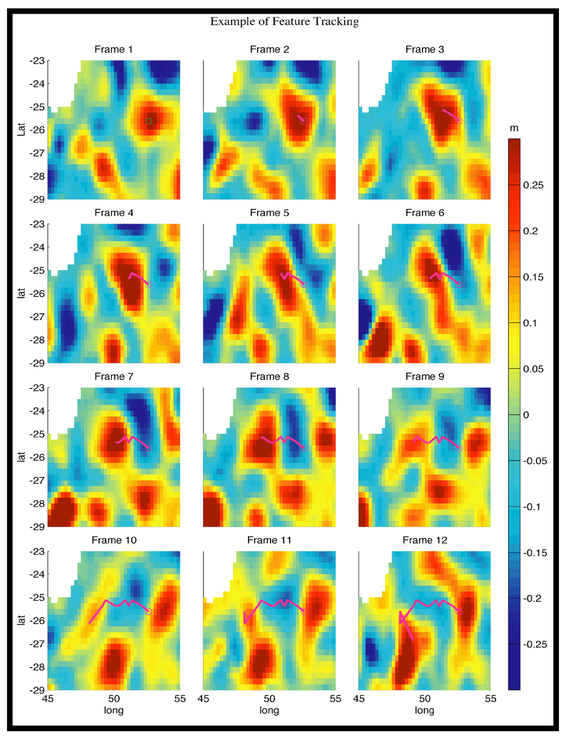
In addition to the anticyclonic features that approach the coast of Madagascar we have found that on occasion cyclonic features can interact with the EMC. An example is given above using 10 day composites for a period in April 2001. The EMC is low in chlorophyll and shows a sharp contrast with the chlorophyll-rich coastly-upwelled waters along the eastern edge of Madagascar. This boundary lies close to the coast unless it is disturbed by an eddy, as in the example above. The presence of the eddy disturbs the SST and chlorophyll fields and transports coastal waters offshore. Ocean circulation models do not exhibit cyclonic features interacting with the EMC, only anticyclonic ones (as shown in the OCCAM snapshot in the panel above).

ANTICYCLONIC EDDIES AND FEATURE TRACKING



Ten day composites (2001) showing apparent retroflection in colour and SST.

SeaWiFS and TMI data show that the appearance of a retroflection corresponds to an anticyclone (high in MSLA), especially when there is also a low to the west of it. The appearance of a retroflection occurs about 3 times a year. To examine the origin of these anticyclones we carried out a feature tracking analysis.

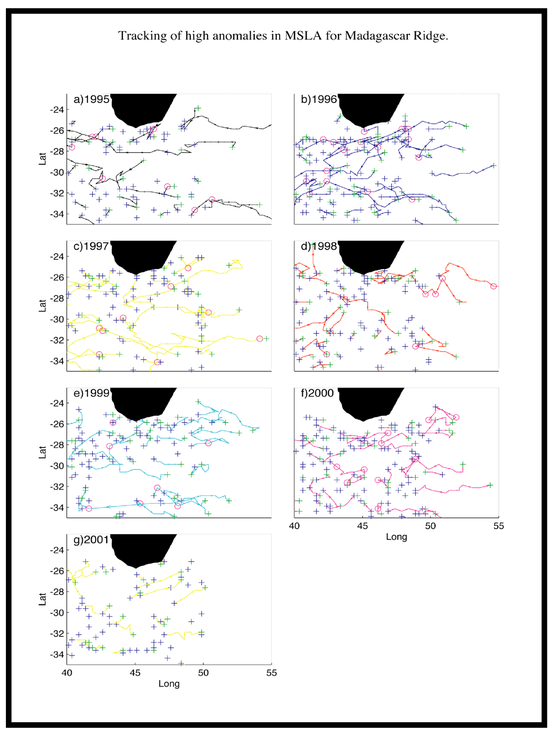


The feature tracking was carried out on the altimeter MSLA (cm). The technique was based on that of Isern-Fontanet et al. (2003) using Q>0

$$Q = -\left(\frac{\partial u}{\partial x}\right)^2 - \left(\frac{\partial v}{\partial x}\right)\left(\frac{\partial u}{\partial y}\right)$$

to identify eddies, together with the MSLA exceeding a threshold. Trial and error led to a choice of ±12.5cm for the threshold. The centre of an eddy was taken as the mean latitude / longitude of all the points in the eddy.

The "frames" are at 10 day intervals, and the start of the eddy track is marked by a circle. Using this tracking approach it is possible to examine the movement of both cyclonic and anticyclonic eddies.



The tracking of anticyclonic eddies shows that, on average, about three to four such features pass by the southern tip of Madagascar each year. Some of these appear to split on encountering the sharp bathymetric change due to the Madagascar Ridge. All these features originate from further east, in the band 25˚-28˚S. Animations show some anticyclones moving south in the EMC, but these have a weaker height signature and are more difficult to track. In contrast, OCCAM shows greater height variability along the east coast of Madagascar.

CONCLUSIONS

- On the basis of the above analysis it is clear that there is no evidence for the existence of a retroflection of the EMC. The apparent retroflection seen in SST and ocean colour images is an artefact of the interaction of anticyclonic eddies with the EMC leading to a wrapping round of wamer water or water with higher chlorophyll concentration, giving the illusion of a retroflection.

- Additionally, we find that cyclonic eddies occasionally interact with the EMC and that these interactions are not found in the ocean model results for the area. The interaction leads to the transport of coastal waters offshore.

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