National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

THE MADAGASCAR BLOOM - A SERENDIPITOUS STUDY

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INTRODUCTION

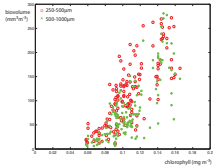
The late austral summer (February-April) phytoplankton bloom that occurs east of Madagascar exhibits significant interannual variability and at its largest extent covers ~1% of the world's ocean surface area. The bloom raises many intriguing questions about how it begins, is sustained, propagates to the east, exports carbon and ends. It has been observed and studied using satellite ocean color observations, but the lack of *in situ* data makes it difficult to address these questions. Here we describe observations that were made serendipitously on the MadEx cruise in February 2005. The MadEx cruise was aimed at studying the East Madagascar Current and its interaction with the eddies to the south of Madagascar but, due to a medical emergency, it was necessary to divert *RRS Discovery* to the island of Réunion. This allowed the 2005 bloom to be sampled on the return journey (see full purple line marked on (e) and (f) of centre panel SeaWiFS).

In situ observations

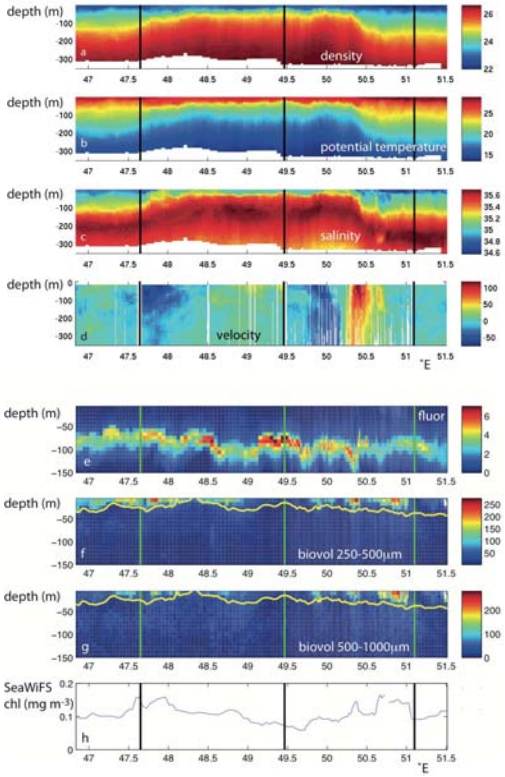
SeaSoar is a towed undulator and carries standard CTD sensors for temperature and salinity, a fluorimeter for chlorophyll fluorescence, and an optical plankton counter (OPC) giving data on the abundance (no. m^{-3}) and biovolume ($mm3\ m^{-3}$) of particles in the size range 250-2000 µm.

SeaSoar sections through bloom plotted against longitude (to right):
a) density (kg m^{-3}), b) temperature (˚C), c) salinity, d) cross-track currents from 75 kHZ ADCP (positive to left of track as ship travels southwest, cm s^{-1}). Note that hull-mounted ADCP does not make measurements in the top few meters, e) uncalibrated chlorophyll fluorescence (mg m^{-3}), f) OPC biovolume in size class 250-500, g) 500-1000 µm ($mm3\ m^{-3}$), h) SeaWiFS surface chlorophyll (mg m^{-3}). Vertical lines mark where the ship changes course (see Effect of eddies - far right). The yellow contour in f & g is that for potential temperature equal to 26.5˚C delineating optimum conditions for diazotroph (nitrogen fixer) growth. Note that chlorophyll fluorescence and OPC biovolume data are only shown for top 150 m.

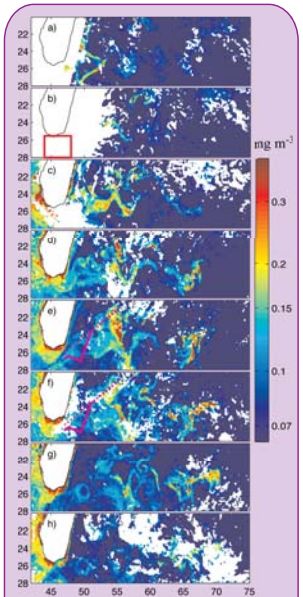
The points to note are:
- the simulatneous existence of a deep chlorophyll maximum (DCM; seen by SeaSoar) and the surface bloom (seen by SeaWifS)
- DCM too deep to be observed by SeaWIFS
- DCM does not appear to be strongly modulated by eddies
- the high level of biovolume confined to the shallow mixed layer seen by OPC. This is unlikley to be mesozooplankton, more likely to be colonies of *Trichodesmium* or diazotrophic diatom assemblages (DDAs), as suggested by strong correlation between SeaWiFS cholorophyll and biovolume (below and also to right Phytoplankton and nutrients).



SeaSoar and ADCP

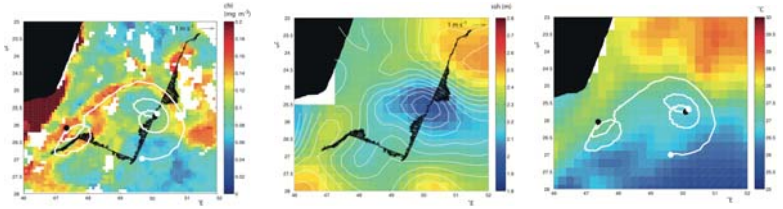


SeaWiFS



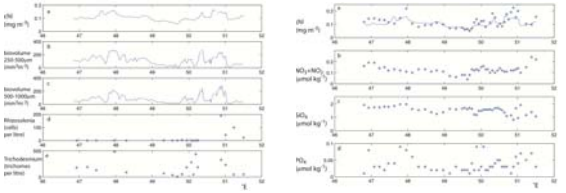
Sequence of SeaWiFS ocean color images (chlorophyll in mg m^{-3}) showing development of the bloom in 2005 – seven day composites, with a 3 x 3 median spatial filter applied: a) 12-18 Jan; b) 19-25 Jan; c) 26 Jan – 1 Feb; d) 2-8 Feb; e) 9-15 Feb; f) 16-22 Feb; g) 23 Feb -1 Mar; h) 2-8 Mar. White areas are persistent cloud cover. Red box in panel (b) shows the intended MadEx study region. On panels (e) and (f) the purple dotted line shows the diversion to Réunion and full purple line the track during SeaSoar deployment on return. The modulation of the bloom by the underlying mesoscale eddy field is clearly visible in the SeaWiFS data.

Effect of eddies



Left: Ocean color composite image for 14 to 17 February 2005. The track of the *RRS Discovery* is overlaid, with its 75 kHz ADCP surface currents, plus the trajectories of two satellite-tracked surface drifters (drogued at 15 m) deployed during the cruise. The track of the buoy deployed in the cyclonic eddy is for 20 days after deployment from the ship, while the track for the buoy in the anticyclonic eddy (deployed earlier in the cruise) is from 10 days prior to ship's passage to 20 days afterwards. Black dots mark the start of drifter tracks, white dots the end. Centre: Absolute dynamic height from altimetry, with height contours superimposed (every 5cm), for the week centered on the 16th February 2005. 75 kHz ADCP surface currents overlaid. Right: Sea surface temperature (SST) for 15th February 2005 - 0.25˚ product from NCDC based on optimal interpolation of AVHRR. Overlaid are the trajectories of two satellite-tracked surface drifters (as left).

Phytoplankton and nutrients



Underway measurements from non-toxic water supply (inlet at 5m depth):
Left: Surface values along SeaSoar transect of (top to bottom): a) SeaWiFS chlorophyll (mg m^{-3}), b) OPC biovolume in size class 250-500 µm ($mm^3\ m^{-3}$), c) OPC biovolume in size class 500-1000 µm ($mm^3\ m^{-3}$), d) *Rhizosolenia clevei* (and symbiont *Richelia intracellularis*) abundance (cells per liter), e) *Trichodesmium* abundance (trichomes per liter).
Right: Surface values along SeaSoar transect of (top to bottom): a) SeaWiFS chlorophyll (mg m^{-3}) with *in situ* chlorophyll (*; mg m^{-3}), b) nitrate + nitrite (µmol kg^{-1}), c) silicate (µmol kg^{-1}), d) phosphate (µmol kg^{-1}).

CONCLUSIONS

The data that were obtained serendipitously on the MadEx cruise allow the following new insights into the bloom:
- a deep chlorophyll maximum and a surface chlorophyll bloom are found to exists simultaneously.
- the surface biological signature is modulated by the eddy field, but the deep chlorophyll maximum does not seem to be.
- the surface bloom seen in ocean color data is confined to the shallow (~30 m) mixed layer.
- nitrogen fixers play a key role in the Madagascar blooms visible in satellite ocean color data. *Trichodesmium* dominates near to Madagascar, while *Rhizosolenia/Richelia* dominates further to the east.

These observations further our understanding of the bloom but we conclude that definitive determination of thenature of the bloom will require further and more comprehensive *in situ* sampling to be carried

References

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