Vasco-Cirene : a process study of air-sea interactions at interannual, intraseasonal and tropical cyclone timescales in the southwestern Indian Ocean

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The thermocline ridge of the Indian Ocean (TRIO) region

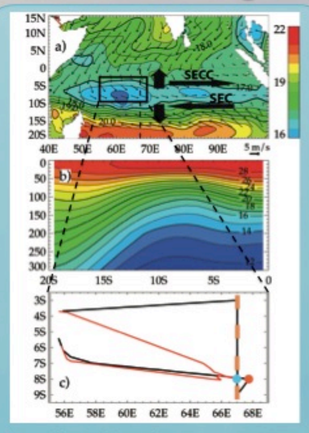


Fig1. a) Winds and average 0-300m temperature in winter in the Indian Ocean; b) meridional section of winter temperature along 67°E; c) Cirene cruise track (leg1 in black and leg2 in red)

Ekman pumping associated with the northern termination of the easterlies creates Ekman-pumping driven upwelling between the South Equatorial Current and South Equatorial Counter Current (Fig 1a). This lifts the thermocline between 5°S and 10°S (Fig 1a,b). In winter, the co-existence of a shallow thermocline and high (> 28°C) sea surface temperatures is conducive to strong air-sea interactions (e.g. Xie et al. 2002, Schott et al. 2009).

3 important timescales

Cyclones

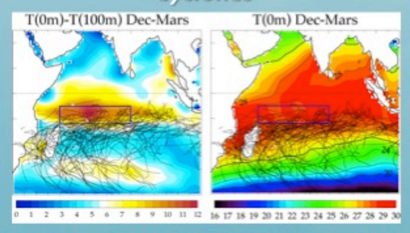


Fig 2. Trajectories of named tropical cyclones since 2000, overlaid on climatological temperature difference between surface and 100m (left) and surface temperature (right)

Intraseasonal

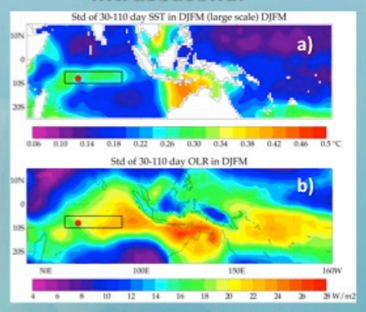


Fig 3. Standard deviation of 30-110 day filtered sea surface temperature (a) and outgoing long wave radiation (b)

Interannual

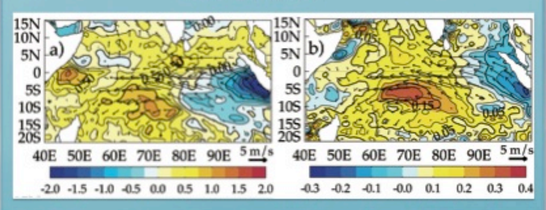


Fig 4. Sea surface temperature (left), sea level (right) and surface wind (both panels) anomalies in October 2006, during the peak of an Indian Ocean Dipole (IOD).

The TRIO region exhibits a clear climate variability at *3 timescales*. It is a key region of *cyclogenesis* for the south-western Indian Ocean (Fig 2). It exhibits a clear sea surface temperature *intraseasonal* variability (Fig 3a), as a signature of deep atmospheric convection variations (Fig 3b) associated with the *Madden-Julian Oscillation (MJO,* e.g. Zhang 2005*)*. The zonal wind anomalies associated with Indian Ocean Dipole (IOD) events (Fig 4) induce Ekman pumping-driven heat content anomalies in the central Indian Ocean (Fig 4b), which then travel to the TRIO region through planetary wave propagation (e.g. Schott et al. 2009).

The Vasco-Cirene goals

Scientific goals

- The Vasco-Cirene experiment aims at exploring air-sea interactions at the cyclones, intraseasonal (MJO) and interannual (IOD) timescales in the TRIO region.

The context

- TRIO region recognised as a key-region for Indian Ocean climate variability (Schott et al. 2010)
- Cruise endorsed by the CLIVAR Indian Ocean and Asian-Australian Monsoon panels (IOP & AAMP)
- Contribution to the IndOOS (Indian Ocean Observing System, Fig 5) concept through deployment of Argo profilers and of the 8°S, 67°E RAMA (Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction; McPhaden et al. 2009) mooring

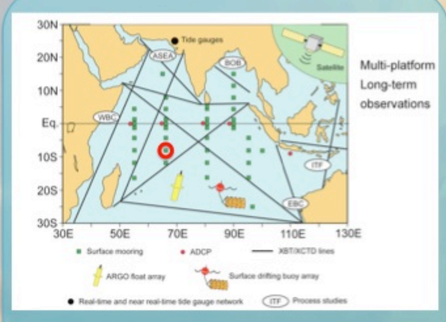


Fig5. The Indian Ocean Observing System (IndOOS). Planned RAMA mooring locations are indicated by green squares.

The Vasco-Cirene experiment

The Vasco-Cirene experiment took part in January-February 2007.

The Vasco experiment (Duvel et al. 2009) consisted of aeroclipper deployments. Aeroclippers (Fig 6) are experimental balloons flying ~50 m above the sea surface and measuring both oceanic surface and meteorological parameters.

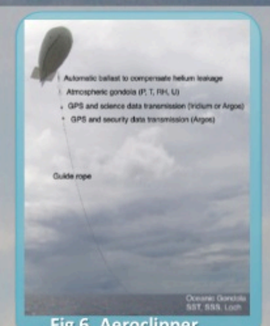


Fig 6. Aeroclipper

Fig 7. R/V Suroît during Cirene

The Cirene oceanographic cruise (Fig 1c, Vialard et al. 2009), on board R/V Suroît (Fig 7) allowed collecting oceanic, air-sea interface and atmospheric measurements in the TRIO region.

Interannual variability: the IOD

The 2006 IOD (Fig 4) resulted in a strong heat content anomaly in the TRIO region during the Cirene cruise. Cirene measurements (Fig 8) showed that the thermocline , normally at ~40m depth, was down at ~100m, and that there was a clear freshwater anomaly over the first 300 meters. Anomalous eastward currents were monitored down to 800 m. Biogeochemical properties were also affected (Wiggert et al. 2009) with a deeper than expected subsurface chlorophyll maximum.

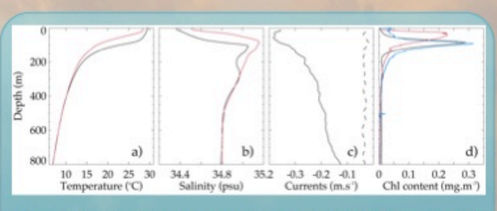


Fig 8. Climatological (red) and Cirene (black) profiles of a) temperature, b) salinity, c) currents and d) chlorophyll at 8°S, 67°E.

Intraseasonal variability : the response to the MJO

There was little MJO activity during the Cirene cruise itself. The deployment of the 8°S, 67°E RAMA mooring however allowed to monitor the MJO signature in the TRIO region during the following months.

There was a strong MJO event in late 2007 and early 2008, with clear SST signature (Fig 12, Left). The mooring at 8°S, 67°E allowed to diagnose that air-sea fluxes were responsible of most of the SST variations in the TRIO region (Vialard et al. 2008). A modelling study further suggested that air-sea fluxes contribute on average to ~70% of the SST variations in the TRIO region, but that oceanic processes can dominate the balance on some years (Jayakumar et al. 2011).

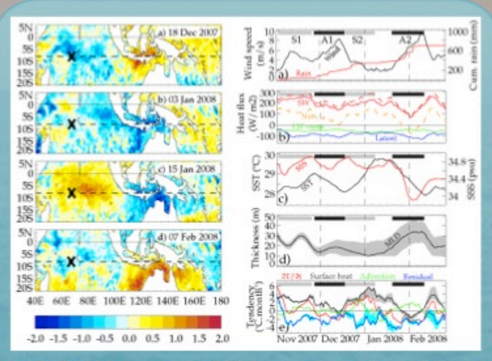


Fig 12. (Left) Intraseasonal SST anomalies in late 2007 and early 2008. (Right) Local conditions at the 8°S, 67°E RAMA mooring (a-d) and upper ocean heat budget (e).

Cyclones: the response to Dora

Into the eye of the cyclone. A tropical depression formed almost exactly above the Suroît and 8°S, 67°E mooring during the cruise, and later became the Dora tropical cyclone. Two aeroclippers were also sucked into the eye of Dora, and provided rare measurements of surface winds in the eyewall of a Tropical cyclone (Fig 9).

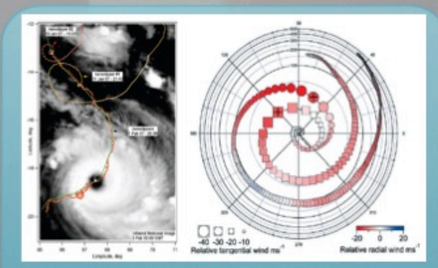


Fig 9. Trajectory of the aeroclippers that were caught into the eye of the Dora tropical cyclone (left) and associated surface wind measurements (right)

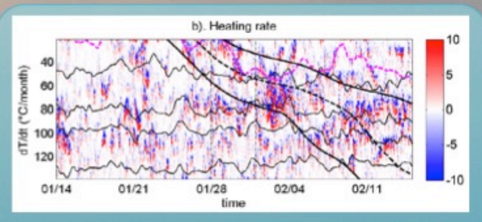
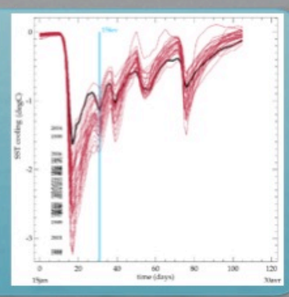


Fig 10. Heating rate due to vertical mixing (colors) and envelope of a near-inertial gravity wave packet (black lines) diagnosed from Cirene measurements

Energy into the thermocline. Measurements at the Suroît and RAMA sites allowed for identifying near-inertial gravity waves, that promoted downward mixing of heat along their track as they radiated downward through the thermocline (Fig 10, Cuyppers et al., in prep).

Scale interactions with the IOD. The deep thermocline during Cirene resulted in a moderate surface cooling in response to cyclone-induced mixing. Modelling experiments indeed suggest that the cooling could have been up to twice as large (Fig 11) if the same cyclone had occurred another year. This supports the Xie et al. (2002) hypothesis that heat content of the TRIO region could affect cyclones in the South-Western Indian Ocean.

Fig 11. Time-series of modelled surface cooling induced at 12°S by the Dora cyclone (black). Corresponding ocean cooling associated with ocean subsurface conditions corresponding to other years (red).



Further reading

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