Decadal variations of wind and currents of the Indian Ocean inferred from satellite observations and ECCO assimilation

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Motivation:

- Observations for decadal changes of ocean currents & relations to climate variability have been reported for the Pacific (e.g., McPhaden & Zhang 2002) and Atlantic (e.g., Hakkinen & Rhines 2004), but not for the Indian Ocean.
- Why is decadal & longer variability of heat content (Levitus et a. 2000) in the upper South Indian Ocean (SIO) much larger than that in upper North Indian Ocean (NIO)?
- Indian-Ocean SST has an increasing trend for the past two decades (Fig.1a), yet net surface heat gain by this ocean estimated from NCEP reanalysis is decreasing (Fig.1b), suggesting a potential role of ocean circulation in warming this ocean.

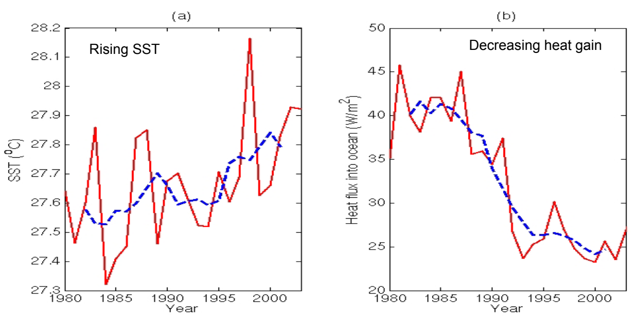

Fig.1 Indian-Ocean basin-averaged (a) SST & (b) surface heat gain.

How do mean currents regulate upper Indian-Ocean heat content?

- Meridional overturning cells (Fig.2) carry warm surface water southward & colder thermocline water northward; upwelling counteracts net surface heat gain (e.g., Lee & Marotzke 1997).
- Indonesian throughflow introduces warmer water from Pacific to Indian Ocean - not addressed in this study.

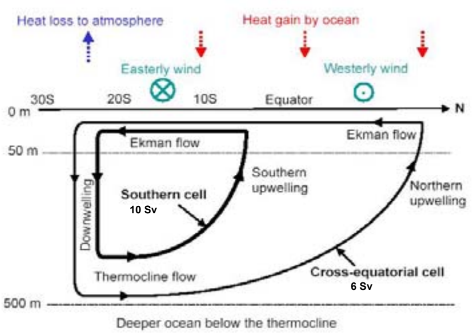

Fig.2 Schematics of the shallow meridional circulation of the Indian Ocean that consists of a southern & a cross-equatorial overturning cell.

Here we examine decadal changes of the wind & overturning cells in the 1990s: evidence for (1) weakening of wind over the SIO & a slowdown of the southern cell, and (2) lack of decadal changes of NIO wind & the cross-equatorial cell.

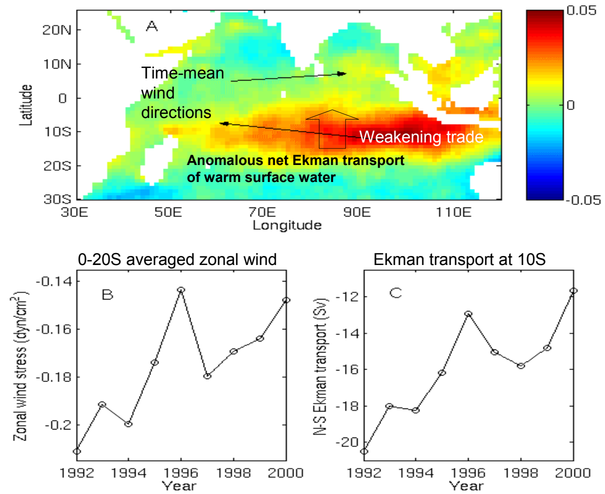

Fig.3 Weakened easterly trade wind over the SIO inferred from ERS-2 wind data. (a) 1992-2000 trend of zonal wind stress in dyn/cm²/yr; (b) 0-20S averaged zonal wind stress; (c) meridional Ekman transport at 10S (center latitude of overturning cells). The linear reduction of 10S Ekman transport is about 7Sv. Since little change occurs in the NIO, the cross-equatorial cell must have been relatively steady. Thus, the 7-Sv reduction of southward Ekman transport of warm surface water reflects a slowdown of the southern cell, up to 70% of its mean strength.

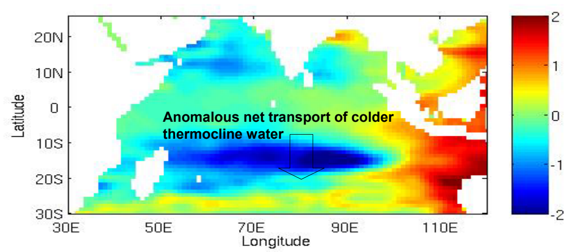

Fig.4 Linear trend of sea level estimated from T/P altimeter data over 1993-2000 in cm/yr. The increasing east-west sea level difference across the SIO indicates a decreasing net northward transport of colder thermocline water. Smaller changes in the NIO again indicate a relatively steady cross-equatorial cell. Also evident is a slowdown of the subtropical gyre (see Lee 2004).

ECCO assimilation products are being evaluated for the observed changes & impacts on upper-ocean heat budget.

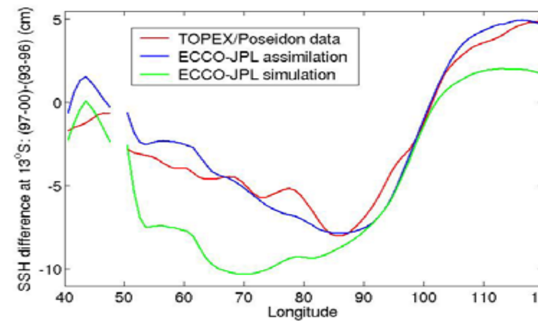

Fig.5 Difference in zonal distribution of SSH at 13S between 1997-2000 & 1993-1996. The assimilation out-performs the simulation in reproducing the observed increase of east-west tilt in SSH (indicative of a slower southern cell) & the bowl shape (indicative of a slower subtropical gyre). The physical consistency of ECCO assimilation allows one to quantify the impacts of changing forcing and currents on heat content.

Summary:

- ERS data reveal a weakened southeasterly trade wind over the SIO (92-00), indicating less southward export of warm surface water.
- T/P data observe an increasing E-W sea level difference across the SIO (93-00), suggesting less import of colder subsurface water.
- These data suggest a near-decadal slowdown of the southern overturning cell (up to 70% of mean strength), but not the cross-equatorial cell.
- ECCO assimilation reproduces the observed changes, & is being used to quantify impacts on upper-ocean heat content.
- Slower overturning tends to increase upper-ocean heat content.
- Larger changes of wind and currents in the SIO than the NIO, possible manifestation of decadal & longer climate variability, may explain the larger heat content variability in the SIO as observed by Levitus et al. (2000).
- Potential impacts on ecosystem and air-sea flux of CO_2.

References:

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