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Bio-physical coupling in the equatorial Indian Ocean over short time scale from MISMO time-series

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Equatorial Indian Ocean (EIO) is very different from the other equatorial regions of the World Ocean

- **Very Strong seasonal signal compared to inter-annual variability**
- **No equatorial upwelling**
- **No permanent EUC**
- **Occurrence of IOD**
- **Very low biological productivity compared to the rest of the IO**

In spite of the above IO still remains as one of the under sampled regions

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Outline of the presentation

- **Seasonal cycle in the MISMO Box (70-85ºE, 5ºN-5ºS) - climatology, 2005 & 2006**
- **MISMO Time-Series October-November 2006 Onboard RV *Mirai***
- **Trans-equatorial section along 83E August 2006 collected onboard ORV *Sagar Kanya***

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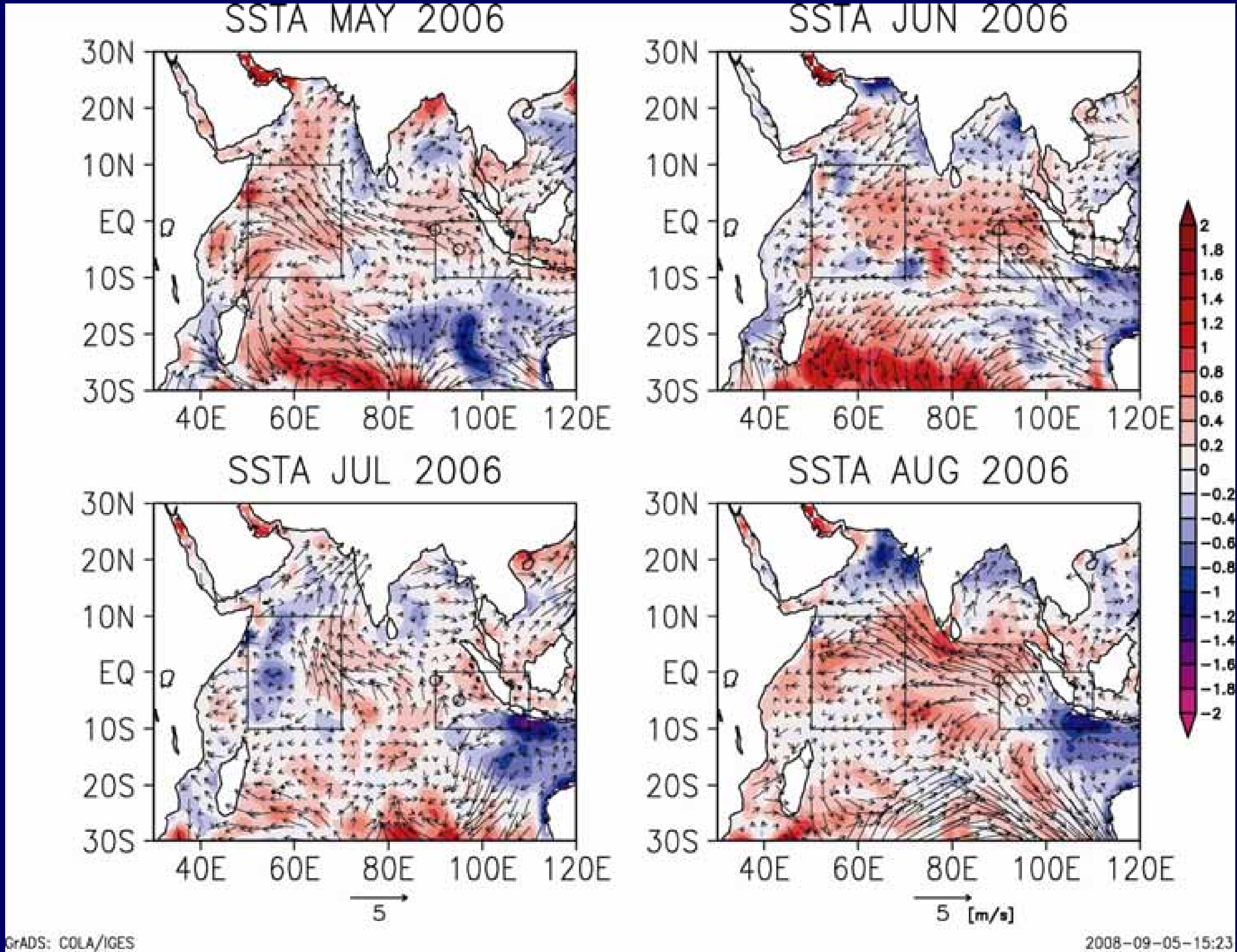
Time evolution of 2006 IOD (courtesy Horii-san)

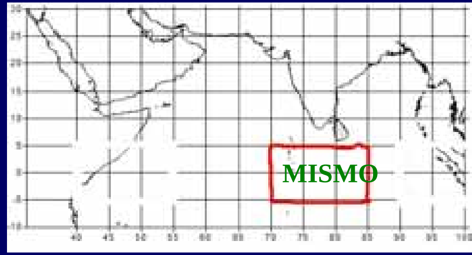


3rd largest IOD After 1997 & 1994

See Horii et al. 2006 GRL , Masumoto et al. 2008 GRL for details

To set the stage………

Seasonal cycle Climatology vs 2005 & 2006



TMI SST

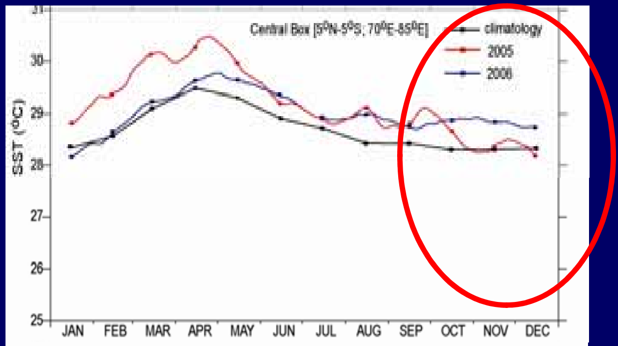


Fig. The area-averaged 30-day running mean sea surface temperature (SST) during 2005 (red) and 2006 (blue), and monthly mean climatology of SST (balck) in the western (top), central (middle), and the eastern box (bottom). The SST during 2005 & 2006 is from dailyTMI data (ftp://ftp.misst.org/L4/tmi/nc/) while monthly mean climatology is from the National Oceanic and Atmospheric Administration Optimum Interpolation dataset (http://www.cdc.noaa.gov/cdc/data.noaa.oisst.v2.html).

Signature of IOD is clearly seen in all the parameters in the year 2006 (Blue)

Warmer SST
High SSH anomaly

Westerly zonal winds
Eastward zonal current

SSHA

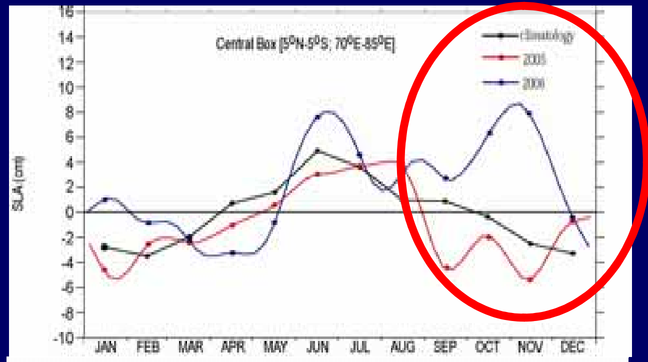


Fig. The area-averaged 30-day running mean sea surface height anomalies (SSHA) during 2005 (red) and 2006 (blue), and monthly mean climatology of SSHA (balck) in the western (top), central (middle), and the eastern box (bottom). The SSHA is from AVISO altimeter products and the monthly mean climatology is based on the data from 1993 to 2007.

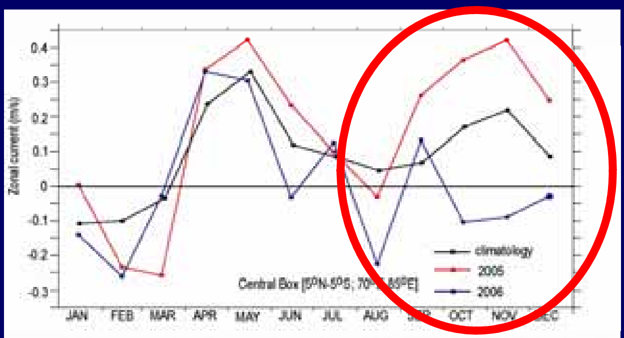


Fig. The area-averaged monthly mean surface zonal current during 2005 (red) and 2006 (blue), and monthly mean climatology (balck) in the western (top), central (middle), and the eastern box (bottom). The current data is taken from OSCAR (http://www.oscar.noaa.gov/datadisplay/datadownload-nj.htm). Climatology is based on the data from 1993 to 2007. Eastward currents are positive.

Zonal Currents - OSCAR

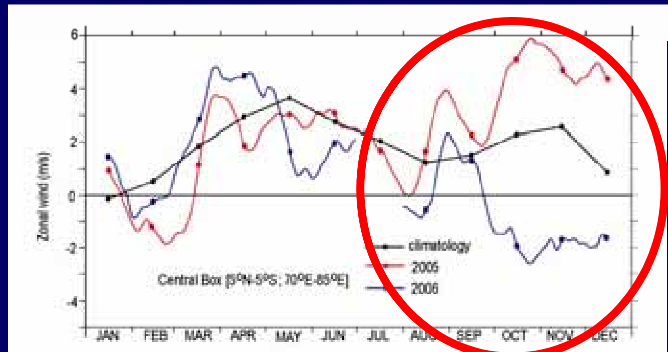


Fig. The area-averaged 30-day running mean zonal wind during 2005 (red) and 2006 (blue), and monthly mean climatology of zonal wind (balck) in the western (top), central (middle), and the eastern box (bottom). The wind data is taken from QuikSCAT. Climatology is based on the data from 1999 to 2005. Westerlies are positive.

Zonal Wind - QuikSCAT

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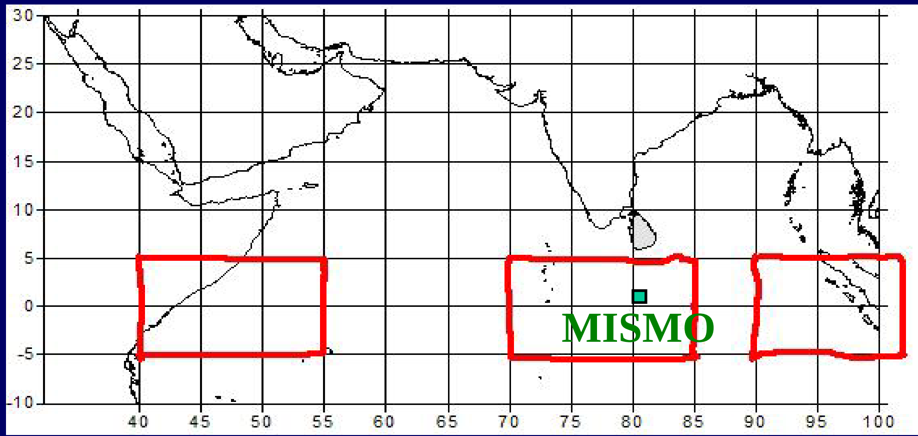
MISMO Time Series

(Mirai Indian Ocean cruise for the Study of the MJO-convection Onset)



Location of Time series Equator, 80.5ºE

Duration of Time series 28 October 21 November 2006

Frequency of CTD 4 hourly later 6 hourly

Frequency of Chl & NO_3 6 hourly

Temperature

5-60mm/day

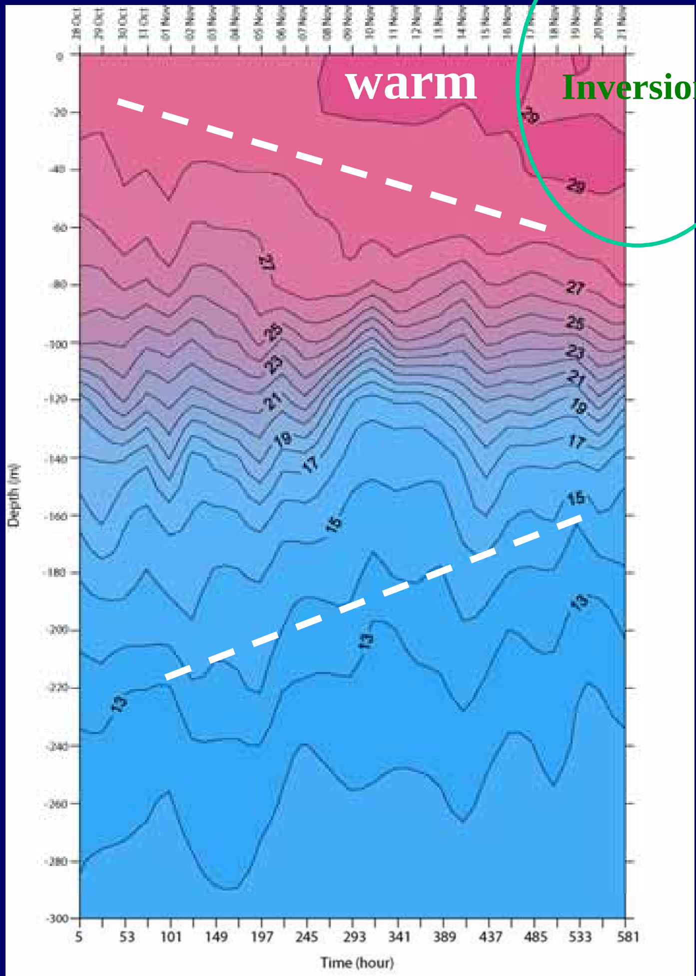


Fig.3 Time evolution of thermal structure in the upper 300 m of the water column during 28 October to 21 November 2006 at location in the equator and 80.5°E

Salinity

20-80mm/day

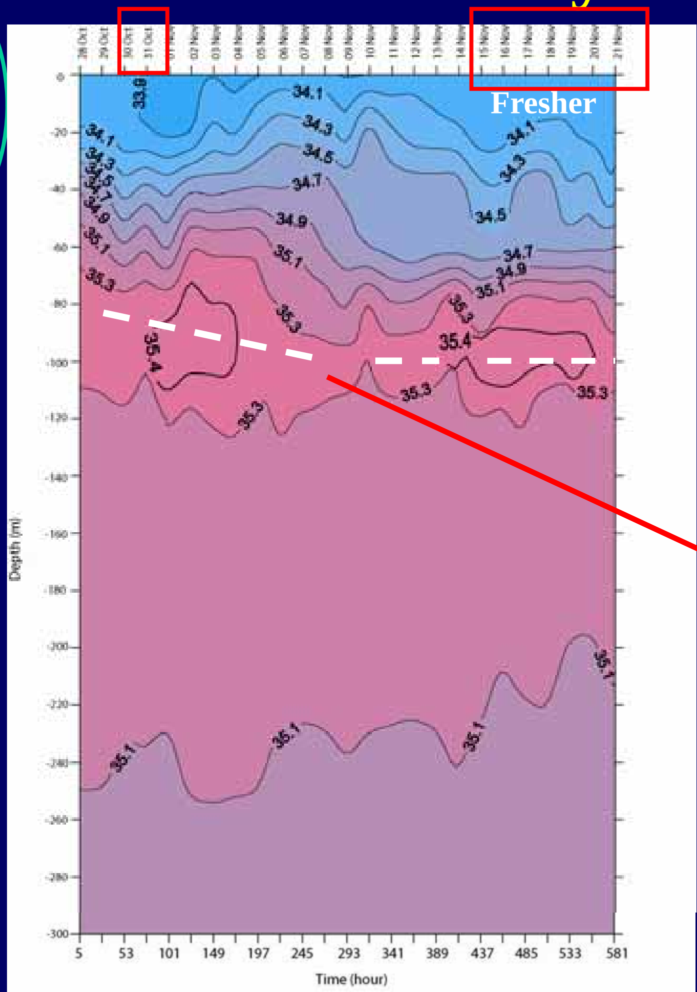


Fig.4 Time evolution of salinity structure in the upper 300 m of the water column during 28 October to 21 November 2006 at location in the equator and 80.5°E

High frequency thermocline oscillation Thickness of

High salinity water mass showed large temporal variation

Thermal structure – Deepening of surface layer and shoaling of subsurface layer

Salinity structure – Two rain events leading to freshening and subsurface high salinity core

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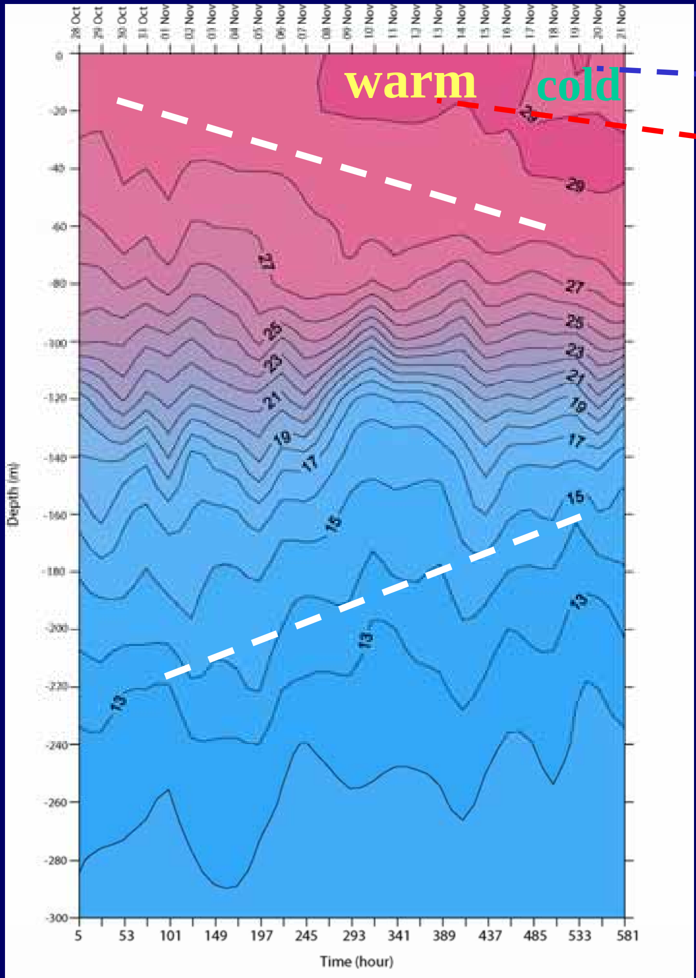

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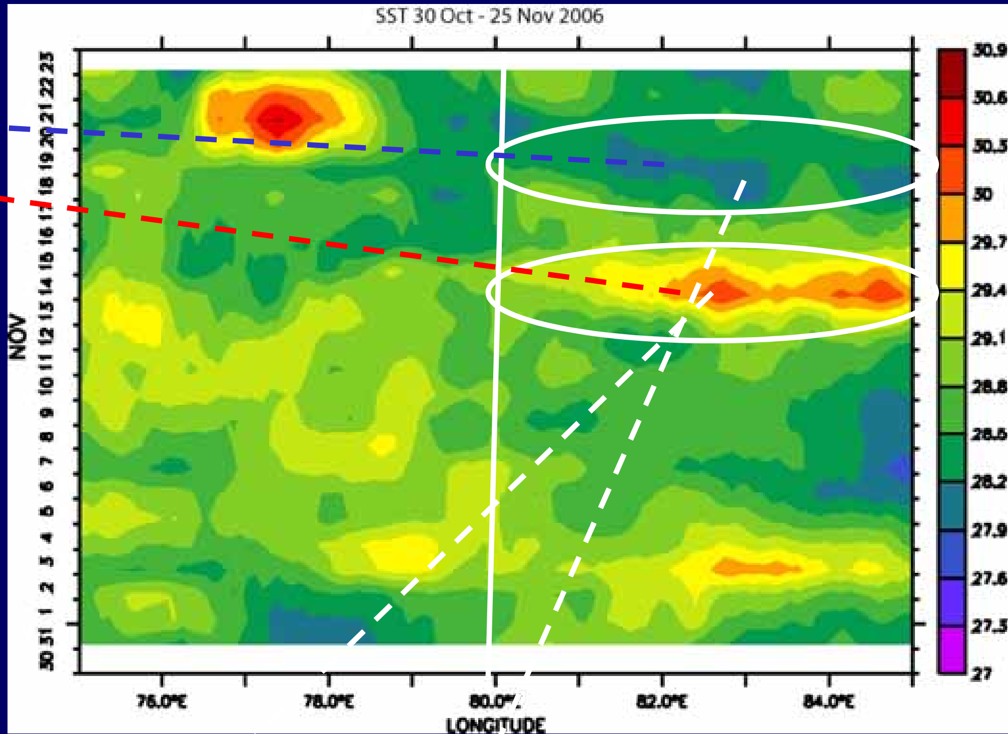

Warming/cooling caused by local heat flux as well as advection of warm/cool waters

Deepening of the upper layer was driven by the curl of the wind stress

Strong upwelling signature ………*Masumoto et al* 2008
Meridional divergence and Northward current……..*Horii et al* 2009

Chlorophyll (mg/m³)

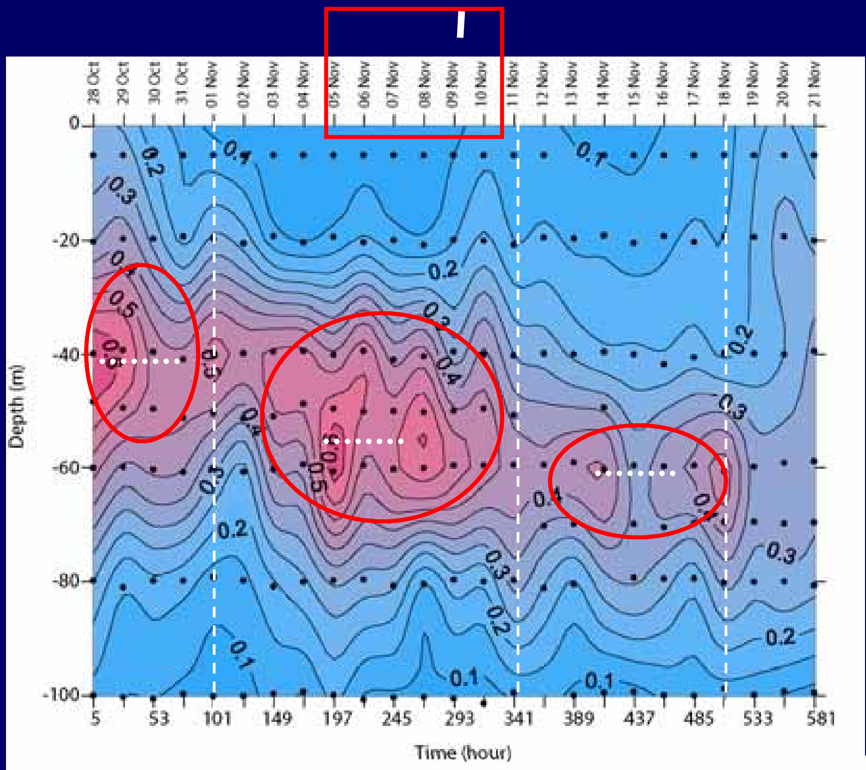

Fig.1 Time evolution of chlorophyll a distribution in the upper 100 m of the water column during 28 October to 21 November 2006 at location in the equator and 80.5°E. The filled black circles represents the sample location.

Nitrate (micro mole/kg)

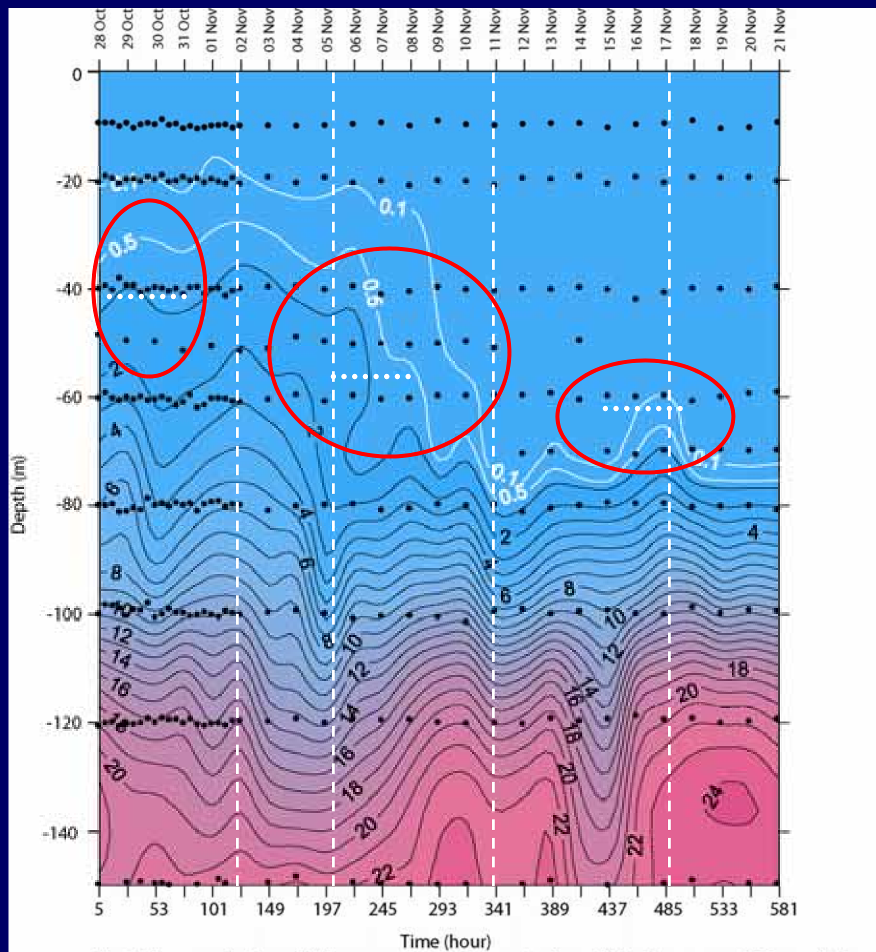

Fig.2 Time evolution of Nitrate concentrations (micro M) in the upper 150 m of the water column during 28 October to 21 November 2006 at location in the equator and 80.5°E. The filled black circles represent thesample location.

Deepening and thickening of SCM
Deepening of nitracline

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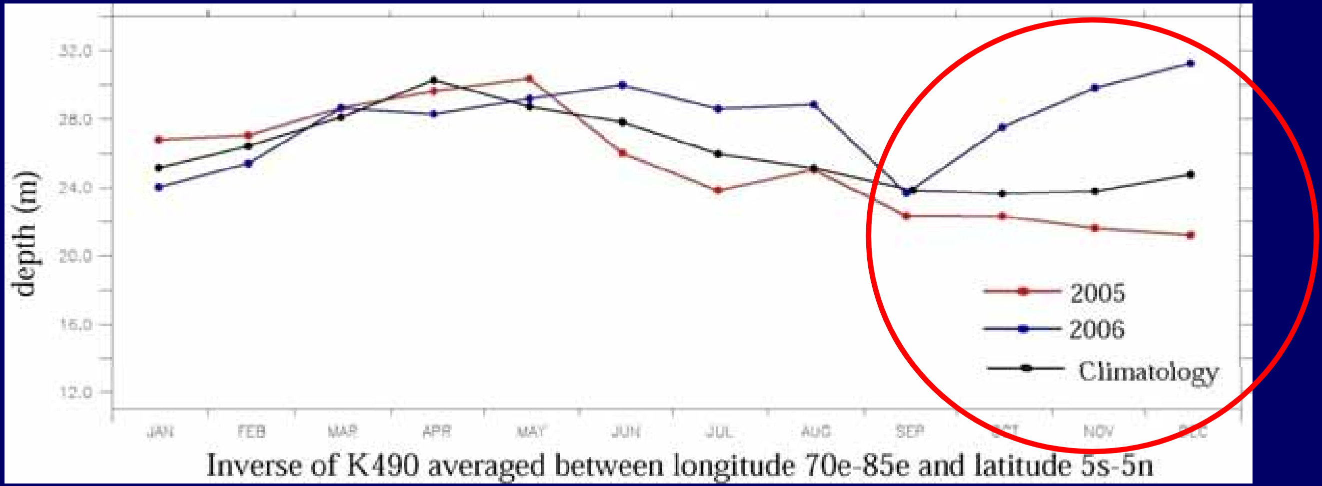
Light penetration depth (Inverse Kd490 -attenuation Coefficient)



Thus the observed deepening of the SCM is driven by anticyclonic wind stress curl and the enhanced chl concentrations within the SCM is due to the increase in the depth of light penetration and supply of additional nutrients by the subsurface upwelling

1. Is it the typical chlorophyll structure of the EIO?

Subsurface Chlorophyll Maxima (SCM)

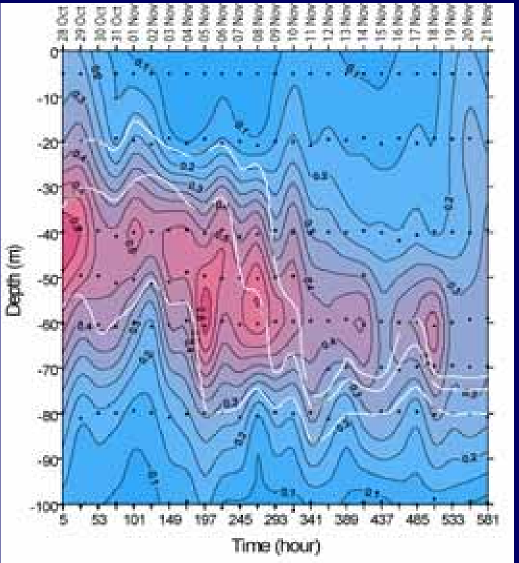


Fig. Time evolution of chlorophyll concentrations (mg/m^3) in the upper 100 m of the water column during 28 October to 21 November 2006 at a location in the equator and 80.5°E. The white contour represents the 0.1, 0.5 and 2 micro mol nitrate isopleths during the time-series observation and filled circles represent the sample location.

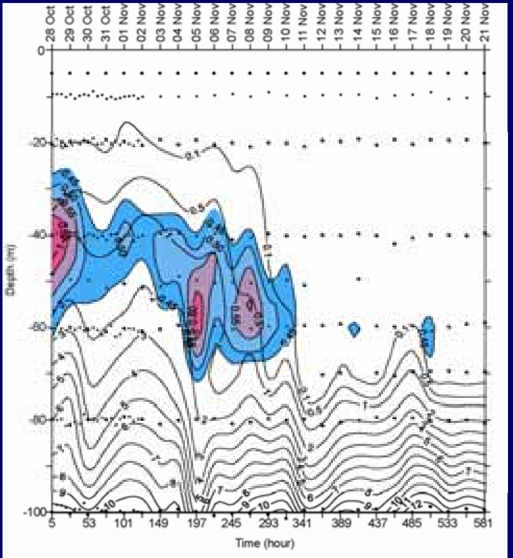


Fig. Time evolution of Nitrate concentrations (micromol per Kg) in the upper 100 m of the water column during 28 October to 21 November 2006 at a location in the equator and 80.5°E. The colour shading represents the location of the subsurface chlorophyll maxima (defined by biomass greater than 0.45 mg/m^3) during the time-series observation and filled circles represent the sample location.

2. What controls the chlorophyll variability?

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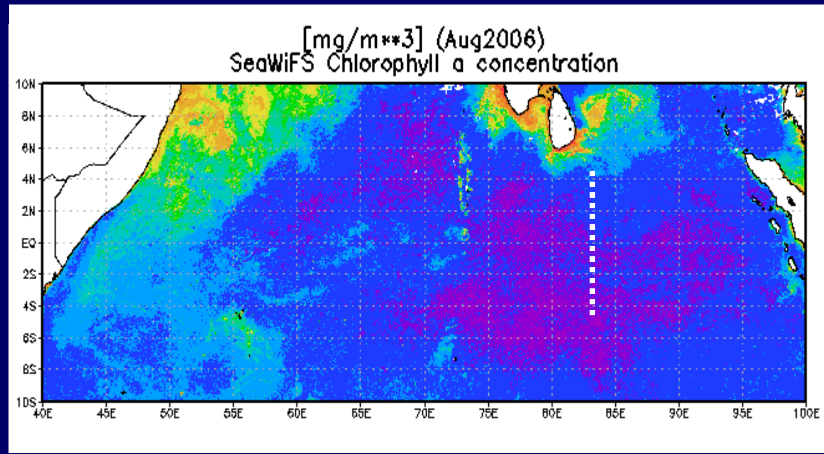
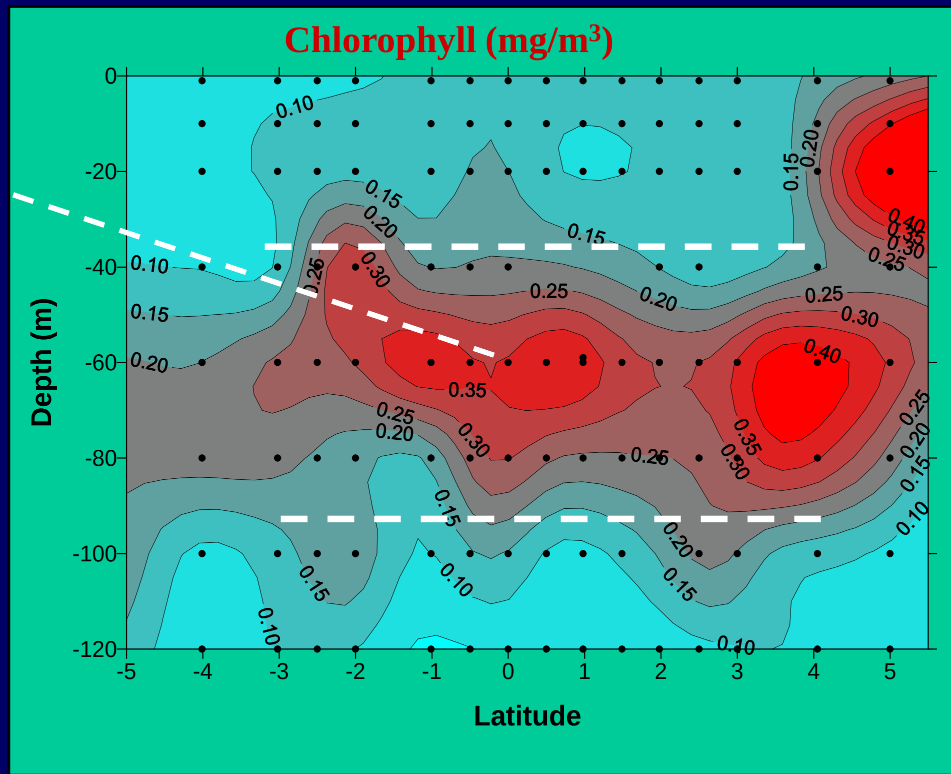
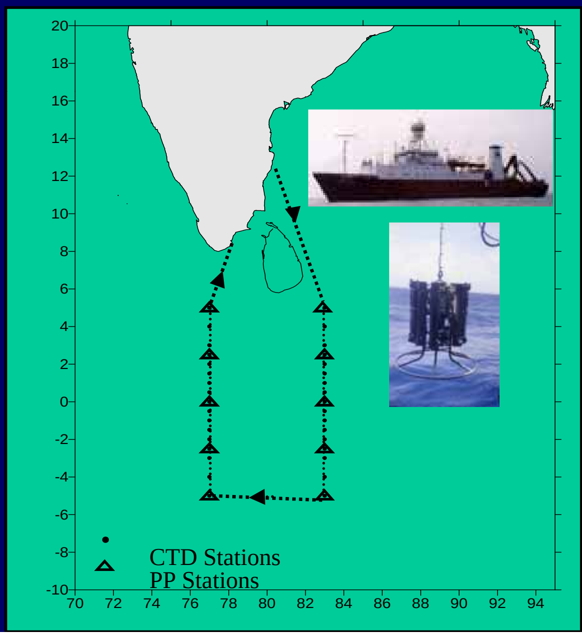
1. Is this the typical chlorophyll structure of the EIO?

For this we will look at data collected onboard ORV Sagar Kanya during 1-29 August 2006 along 83°E from 5°N to 5°S



SCM is the characteristics of the vertical *chl* structure in the EIO





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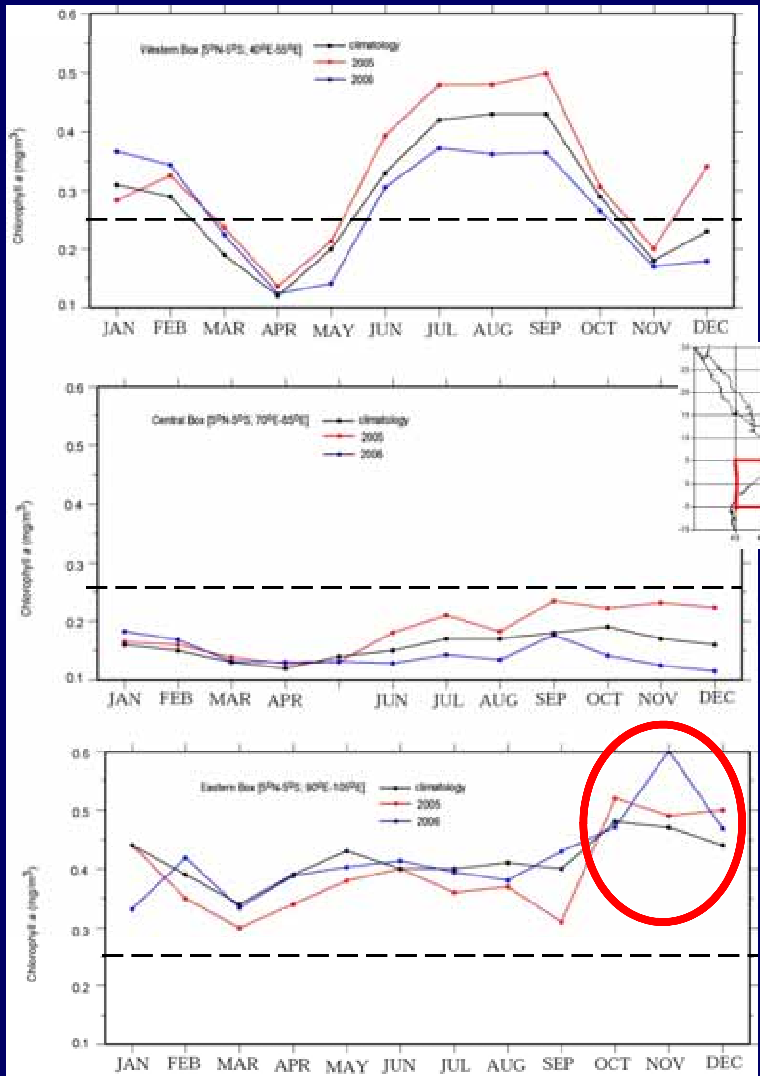
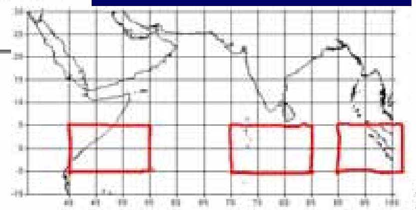
What controls chlorophyll structure is the Availability of Nutrients

Climatology

Chlorprphyll - SeaWiFS





Nitrate – WO5

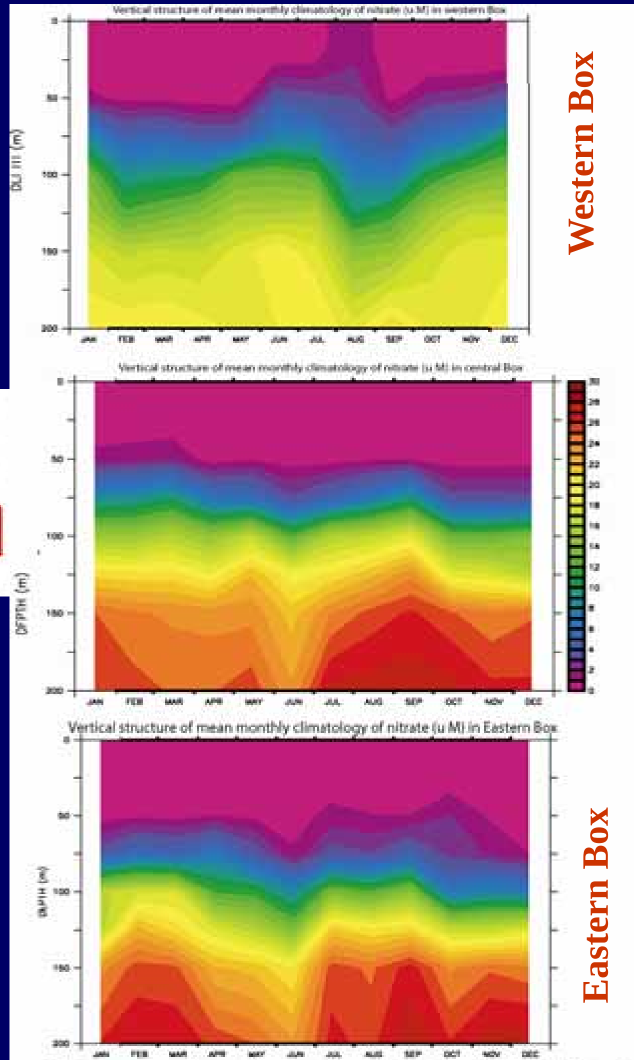


Fig. Area-averaged monthly mean climatology of vertical distribution of NO3 in the western (top), central (middle) and easter (bottom) boxes. Data from WO5.

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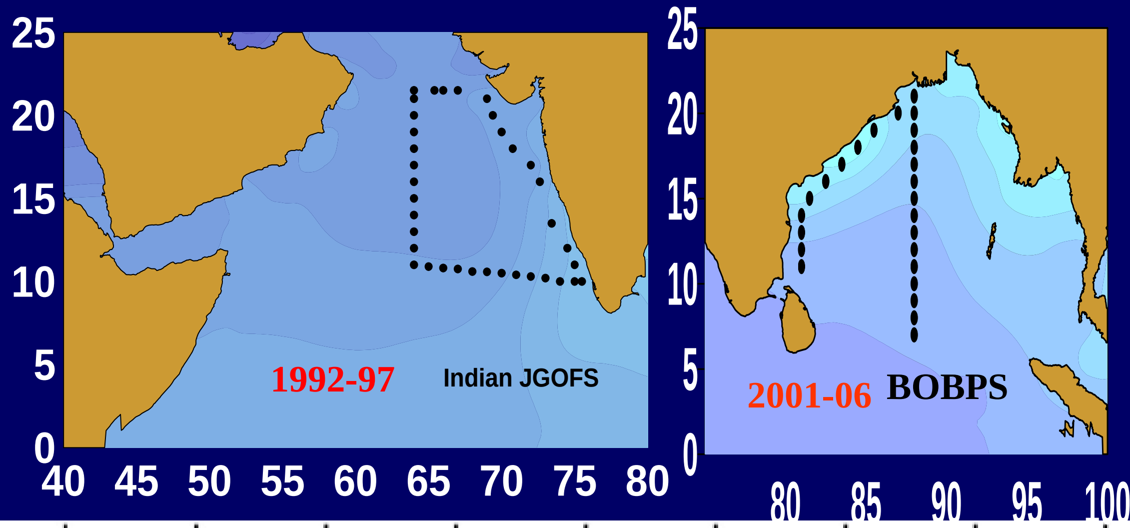
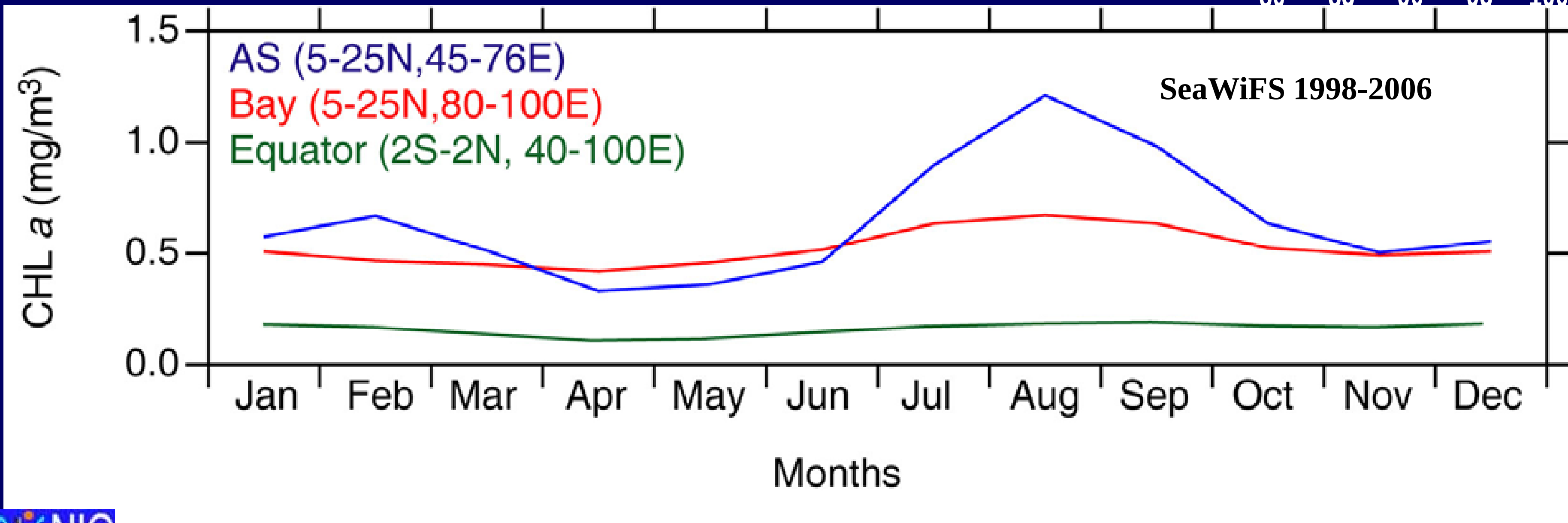
Un like the other parts of the Indian Ocean nutrients in the EIO are always below ~40m





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Summary

- MISMO time-series provided an unprecedented opportunity to understand the bio-physical coupling over very-short time-scale in the EIO

- The local net heat flux combined with advection of warm/cold waters into the MISMO time-series location controlled the warming/cooling of SST.

- The deepening of upper layer was and the SCM was driven by the anticyclonic wind stress curl.

- The increased chlorophyll concentrations within the SCM was due to an increase in the penetration depth of light in combination with the additional pumping of nutrients due to subsurface upwelling

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