Outline

• What is the observed ISO thermocline variability in the Bay of Bengal
• What is the causative mechanism for the same
• What is the impact / role of thermocline variability
  – Barrier layer and associated thermal inversion
  – Chlorophyll-a productivity & Oxycline
  – Cyclone genesis
Observed thermocline variability in the Bay

Girishkumar, M. S., M. Ravichandran and W. Han, J. Geophys. Res., 2013
Intra-seasonal (30-120 days) band-pass filtered vertical temperature profiles and its standard deviation (°C) at buoy locations in the BoB.
The Fourier amplitude spectra of RAMA buoy temperature (°C) in the BoB

**Dominant peaks**
- 30-70 days
- 90 days
- 120 days
Local or Remote forcing

- Ekman pumping velocity
- Equatorial forcing
Time series of band pass filtered (30-70 day) Ekman pumping velocity (m day$^{-1}$) (blue), rate of change of D23 (m day$^{-1}$) (black) at RAMA buoy locations in the BoB.

Shoaling $\rightarrow$ +Ve (Upwelling)
Deepening $\rightarrow$ – Ve (Downwelling)

Local Ekman pumping is not the dominant cause of the D23 at all ISO timescales
Time series of QuikSCAT surface wind stress (N/m²) (black line) averaged over the box bounded by 70° - 90°E, 1°N - 1°S (black box), SSHA (cm) (red line) averaged over the box bounded by 94° - 100°E, 1°N - 1°S, (red box) and D23 (m) from moored buoy located at 1.5°S, 90°E (green dot)
D23 and SSHA variability in Equatorial Indian Ocean and BoB

Whether SSHA can be used as a proxy for D23?

D23 and SSHA variability in Equatorial Indian Ocean and BoB
(a) Depth-time section of salinity at the buoy location [15°N, 90°E].

Note the drop in salinity whenever SSHA and D23 match is poor
Equatorial Winds
Equatorial winds and Sea Level
D23 Vs local forcing

**Table 2.** Standard Deviation of Band-Pass-Filtered Rate of Change of RAMA D23 (D23-R) and Ekman Pumping (Ek) at the Three Buoy Locations for the 30–70 day, near 90 day (80–100 day), and 120 day (110–130 day) periods\(^a\)

<table>
<thead>
<tr>
<th>Location</th>
<th>30–70 Days</th>
<th>80–100 Days</th>
<th>110–130 Days</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>D23-R</td>
<td>Ek</td>
<td>D23-R</td>
</tr>
<tr>
<td>15°N</td>
<td>0.30</td>
<td>0.15</td>
<td>0.21</td>
</tr>
<tr>
<td>12°N</td>
<td>0.40</td>
<td>0.18</td>
<td>0.24</td>
</tr>
<tr>
<td>8°N</td>
<td>0.62</td>
<td>0.27</td>
<td>0.30</td>
</tr>
</tbody>
</table>

\(^a\)Units: m day\(^{-1}\).
Temporal evolution of 30-70 day filtered (Inverse Fourier transform)

Downwelling RW exists only at 8 N (Critical latitude)

Importance of Local ekman pumping

Possible role of alongshore winds in affecting the 30–70 day variability in the region
90-Day oscillations

Ekman Pumping + Remote forcing
120-day oscillations

Ekman Pumping + Remote forcing
Thermocline variability in the Bay of Bengal

• Pronounced persistent intraseasonal variability in the thermocline region with dominant periods in the range of 30–120 (30-70, 90, 120) days

• ISO variability of D23 in the BoB cannot be explained by local Ekman pumping velocity alone. Remote forcing by winds from the EIO plays an important role.

• 30-70 days: North and Central: Ekman (local)
  South: Remote forcing + alongshore winds in the eastern BoB

• 90 and 120 days: strongly affected by Rossby waves driven by the equatorial zonal winds. The Ekman pumping velocity in the interior BoB has significant contributions to the westward enhancement of these signals (particularly northern Bay)
1. Barrier layer changes due to thermocline

Temporal evolution of winds, temperature, salinity and BLT
Correlation between BLT and MLD & ILD

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Total time period</strong></td>
<td></td>
</tr>
<tr>
<td>BLT Vs MLD</td>
<td>-0.39</td>
</tr>
<tr>
<td>BLT Vs ILD</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>During (Sep to May)</strong></td>
<td></td>
</tr>
<tr>
<td>BLT Vs MLD</td>
<td>-0.35</td>
</tr>
<tr>
<td>BLT Vs ILD</td>
<td>0.83</td>
</tr>
</tbody>
</table>
Daily evolution of Ekman pumping velocity (m/day) and rate of change of ILD (m/day) at the buoy location.

Local Ekman pumping plays a minor role in modulating ILD.
40-100 days band pass filtered
(a) zonal wind along the equator,
(b) SSHA at equator and off Sumatra coast
(c) SSHA along 8N in the southern Bay of Bengal and
(d) time series of ILD (unfiltered) at the buoy location
(e) Time series of ILD and SSHA (filtered) at the buoy location

Girishkumar et al., JGR, 2011
Role of ILD in BL

Shallow salt stratified MLD

Thick BL

Thin BL

Shallowing of ILD due to upwelling Rossby wave

Deepening of ILD due to downwelling Rossby wave

Time
2. Observed intra-seasonal variability of temperature inversion in the south central BoB
Temperature inversion
Temperature inversions are large when the barrier layer is thick, not all thick barrier layers exhibit temperature inversions.
Much of the variability in upper ocean thermal structure and hence the upper ocean heat budget in the BoB is forced remotely by winds in the EIO on intraseasonal to interannual time scales.

Thus, understanding the controls on BoB SST is ultimately a problem that requires a basin scale perspective on wind, heat flux and fresh water forcing.

3. Oxycline depth from Altimeter based SLA?

4. Easterly winds, Upwelling Rossby waves, increase in Chl and reduction in SST

Temp @ 8 N/ 90 E

Chl-a

WOA

SSHA

5. Westerly winds, Downwelling Rossby wave, increase in HC and SST

Conclusion

- Pronounced persistent intraseasonal variability in the thermocline region with dominant periods in the range of 30–120 (30-70, 90, 120) days with maximum variation in the southern BoB.
- It is due to both local and remote forcing
- Westerly winds in Equ (DW KW) → SL and D23 increases (EEIO) → DW RW and Coastal KW → HC, BL and TI increases → (Cyclone genesis, low chlorophyll-a, deep oxycline)
  - Easterly winds in Equ (UW KW) → SL and D23 decreases (EEIO) → UW RW and Coastal KW → HC, BL and TI decreases → Cyclone genesis, high chl-a, shallow oxycline)
- Understanding the controls on BoB SST is ultimately a problem that requires a basin scale perspective on wind, heat flux and fresh water forcing.
Thank you for your attention

References


