Sea level rise in the Indian Ocean

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Sea levels are rising worldwide and along much of the South Asian coast. (IPCC, 2007). Tide gauge measurements and satellite altimetry suggest that sea level has risen worldwide approximately 4.8-8.8 inches (12-22 cm) during the last century (IPCC, 2007). A significant amount of sea level rise has likely resulted from the observed warming of the atmosphere and the oceans.

**Reconstructed Sea level (red)**
**TG Measured**
**Since 1950 (blue)**
**Altimetry (black)**
(Church and White)

![Graph of Annual Averages of Global Mean Sea Level](image)
Global mean sea level from Topex/Poseidon altimetry

Observed rate of sea level rise:

1950-2000: 1.8 +/- 0.3 mm/yr
1993-2005: 3.3 +/- 0.4 mm/yr
Rise in mean sea level: Global and in Indian Ocean

Global Sea level was rising steadily till 2003 but since 2004 the rise is slower. But in the Indian Ocean the period 2004-2009 shows higher sea level rise.

M. Ravichandran (personal communication)
What causes the changes in Sea level?

Change in Volume
- Sea water density (Steric)
  - Temperature (thermosteric)
- Change in Mass (Eustatic)
  - Salinity (halosteric)

Shape of the Ocean Basin
- Vertical displacement of land (tectonic)
Rise in mean sea level: New observations in 21st century

Active Argo floats – Indian 71; other countries 680

GRACE (Gravity Recovery And Climate Experiment), twin satellites launched in March 2002, are making detailed measurements of Earth's gravity field. A NASA-DLR mission
Rise in mean sea level in Indian Ocean

- Contribution from **Steric (density change)** to IO total Sea level rise during 2004-2009 is **48%**.

- For **Global**, Steric contribution during 2004-2009 is almost negligible (~ 6%)

- Contribution from **water mass** to IO sea level rise during 2004-2009 is **47% only**.

- For **Global**, water mass contribution during 2004-2009 is high, ~ **90%**.

M. Ravichandran (personal communication)
Mean sea level trend - Spatial

M. Ravichandran (personal communication)
Sea level trend from altimeter and tide gauge locations

M. Ravichandran (personal communication)
Sea level from tide gauges and altimeter

M. Ravichandran (personal communication)
Mean-sea-level-rise trends along the north Indian Ocean coasts from past tide-gauge records

Estimated trends vary from 1.06 to 1.75 mm/year for individual records (an average of 1.30 mm/year)

Unnikrishnan and Shankar (2007)

<table>
<thead>
<tr>
<th>Station</th>
<th>No of years</th>
<th>Trends (mm/yr)</th>
<th>GIA (mm/yr)</th>
<th>Net sea level rise (mm/yr)</th>
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</thead>
<tbody>
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<td>Aden</td>
<td>58</td>
<td>1.21</td>
<td>-0.16</td>
<td>1.37</td>
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<td>Karachi</td>
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<tr>
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<td>-0.39</td>
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<td>Diamond Harbour</td>
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<td>5.22</td>
<td>-0.52</td>
<td>5.74</td>
</tr>
</tbody>
</table>
Sea level has decreased substantially in the south tropical Indian ocean and has increased elsewhere. This pattern is driven by changing surface winds.

Han et al., July 2010, Nature Geoscience
Changing atmospheric circulation causes the patterns in sea levels.
Net heat flux

M. Ravichandran (personal communication)
Decadal warming – Connections with Pacific

Feng et al, GRL, 2010
Concluding remarks

During the year 2004-2009

- The rate of Sea level rise in the Indian Ocean is much larger than the global average.
- Total mean sea level rise in the Indian Ocean is contributed from both steric and water mass changes.
- The changing atmospheric circulation could be a cause for the spatial patterns.
- In the Northern Indian Ocean the trends are mostly due to the trends in net heat gain.
- In the Southern Ocean, the decadal oscillations contribute to the observed trends in sea level.
Thank You