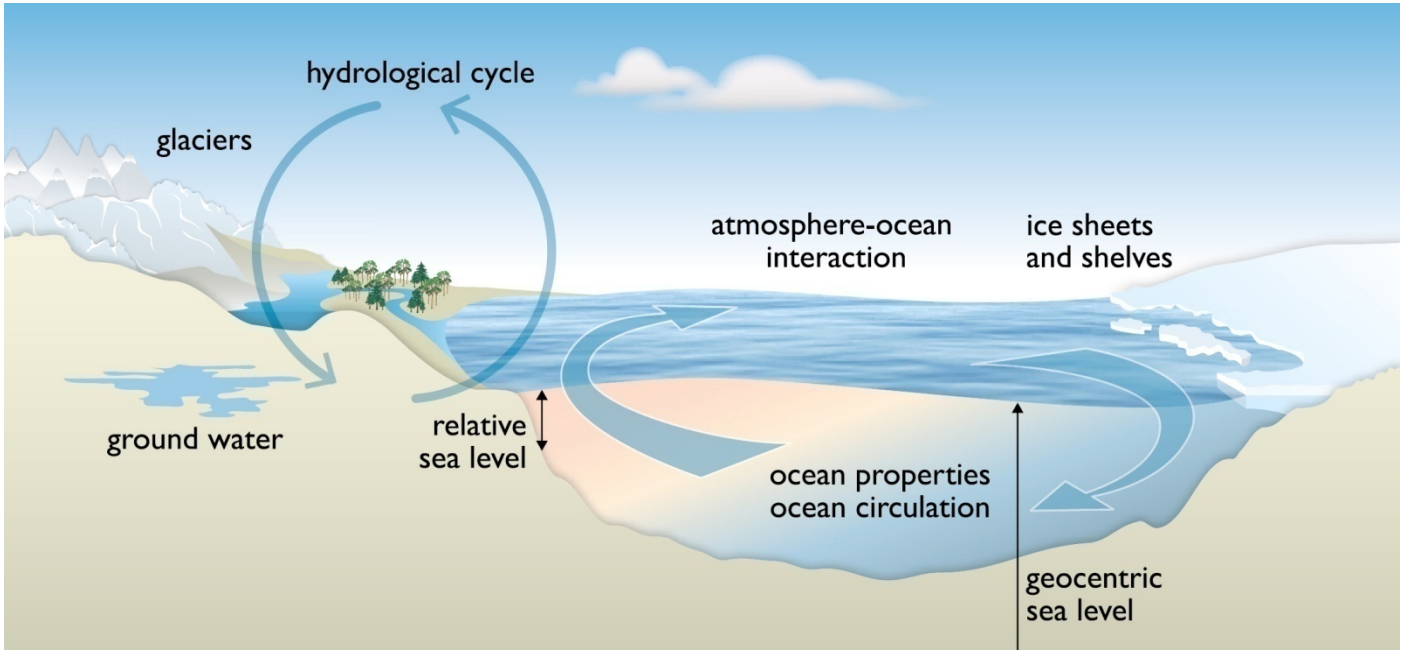
Sea level rise and extreme sea level changes in the north Indian Ocean

A.S. Unnikrishnan

CSIR- National Institute of Oceanography, Goa

Processes of sea-level changes



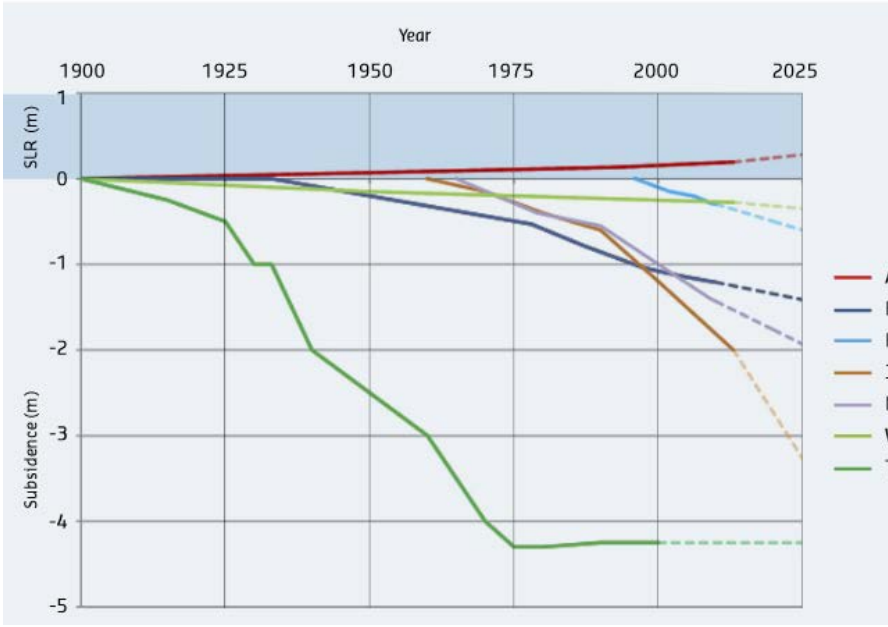
- Relative sea level is also affected by land movements, changes in ocean density, circulation and distribution of mass on the earth

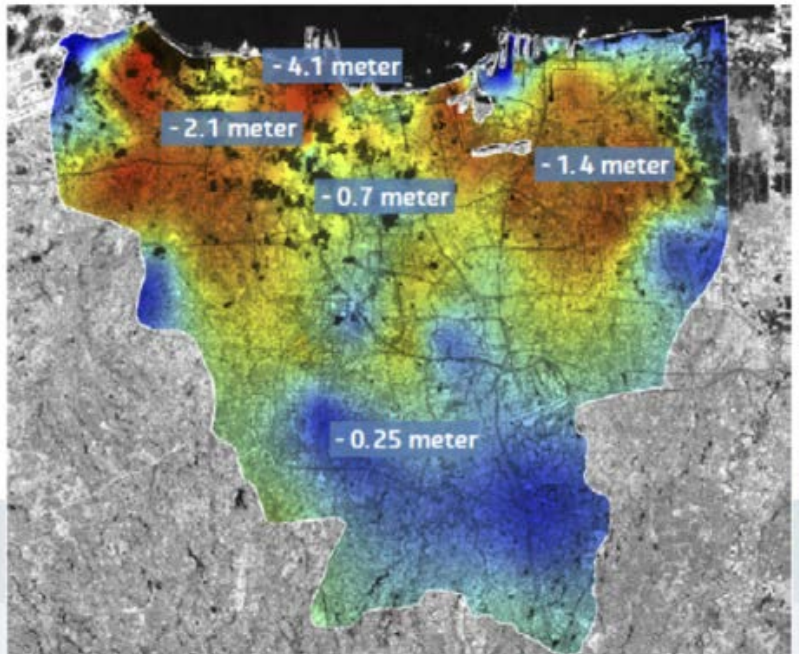
Regional Sea level changes

Climate variability

Long-term trends in MSL

Land movements (subsidence, glacial isostatic adjustment, local tectonic activity)



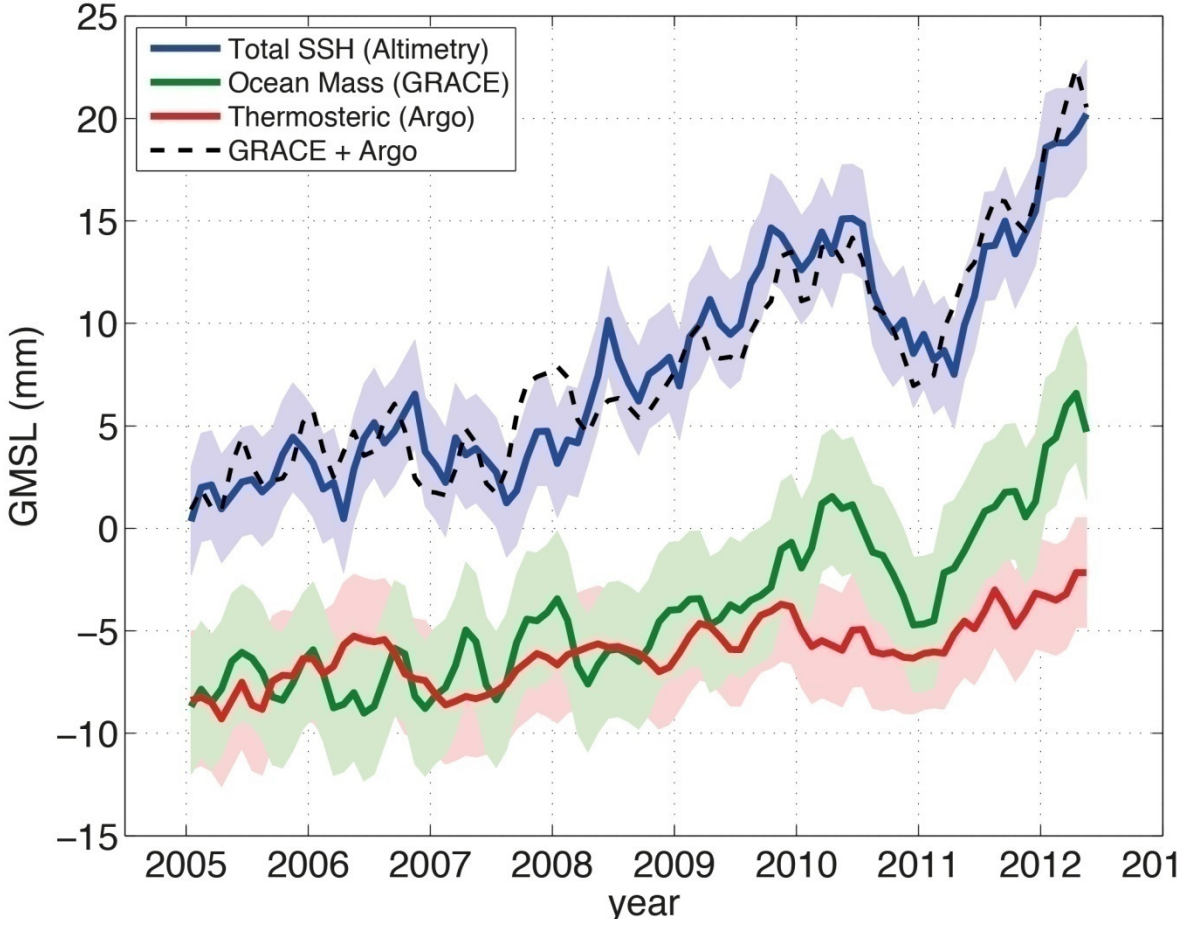


Observational evidences for sea-level rise

- Increase in the observational evidences for sea-level rise
- Tide gauge records
- Satellites, TOPEX/Poseidon (since 1992), Jason-1 & 2 and the Indo-French satellite, SARAL/Altika, which is currently in orbit since 2013, measures sea level using altimeters
- GRACE satellite (since 2004) measures minute changes in gravity making it possible to estimate ice sheet melting (Greenland, Antarctica)
- ARGO measurements of temperature and salinity in oceans

Global sea level- Contributions from glacier melt and thermal expansion

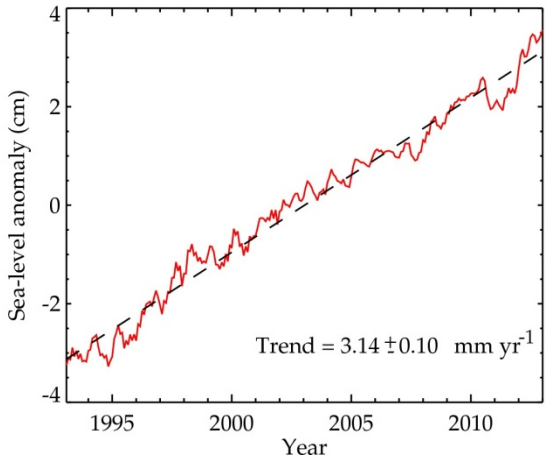
Ocean thermal Expansion and mass added from Glacier melt together account for the Most of observed SLR (Church et al., 2013)



Observations since 1971 indicate that thermal expansion and glaciers (excluding the glaciers in Antarctica) explain 75% of the observed rise (*high confidence*).

Global sea-level rise during altimeter period

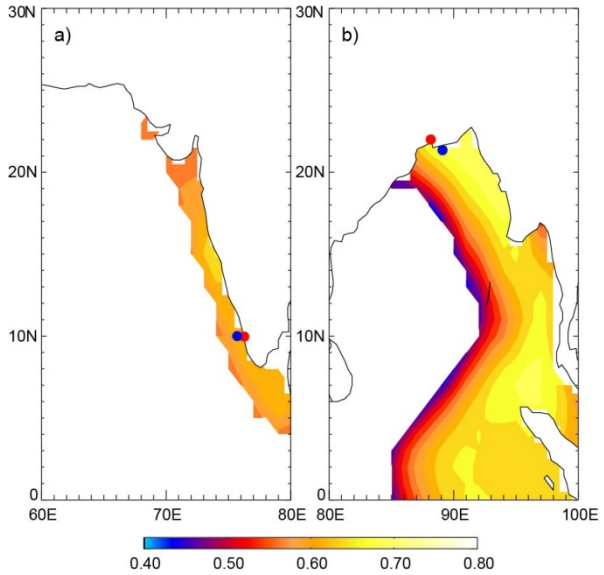
- Global sea-level rise is relatively well understood; however, regional sea level rise is less studied

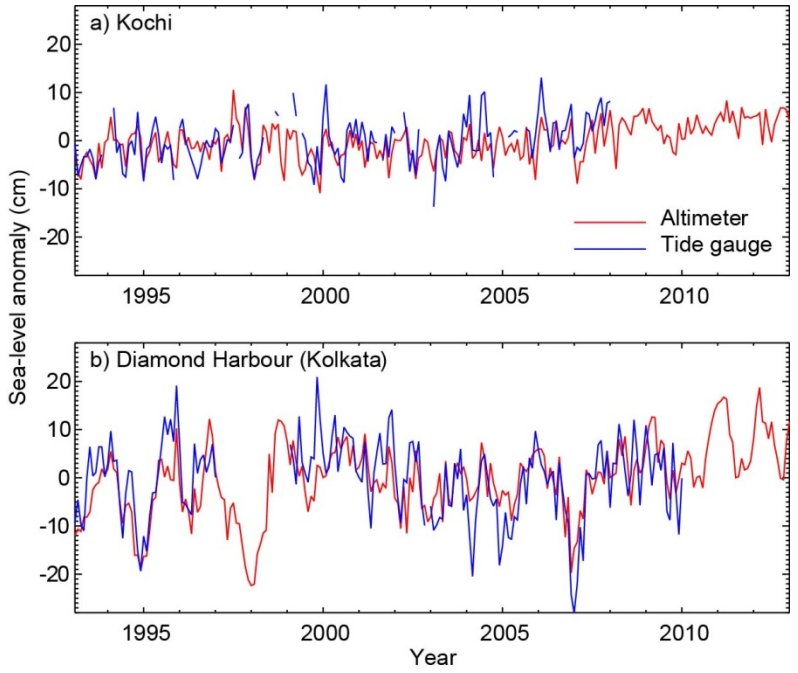


Global average trend is 3.12 mm yr^{-1}
for the period 1993-2012 (Masters et al., 2012)

- Global sea-level rise had been 1.7 mm yr^{-1} 1901-2010 (Church et al., 2013) and at the rate of 3.12 mm yr^{-1} during the last two decades (1993-2012).

Comparison between satellite altimeter data and tide-gauge data in selected stations





- Blue (red) dots show tide-gauge (altimeter)locations

Linear correlation coefficient 0.63 for Kochi 0.69 for D Harbour

Spatial distribution of sea-level-rise trends in the north Indian Ocean from satellite altimetry

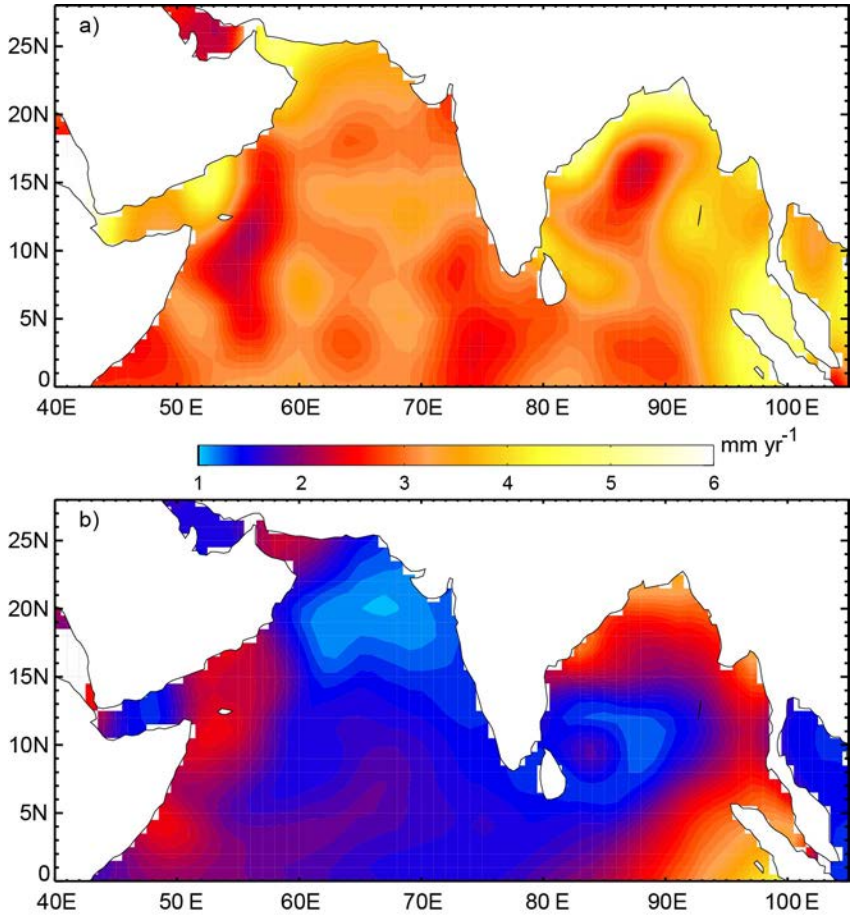
Trends are larger (3.28 mm Yr^{-1} basin average) in the past two decades, compared to those in 20th century

Large trends and uncertainties in the eastern Bay of Bengal

Regions of low uncertainties are Associated with regions of low inter-annual variability (as described In previous studies, Shankar et al., Aparna et al.)

Unnikrishnan et al.,
(Current Science, 2015)

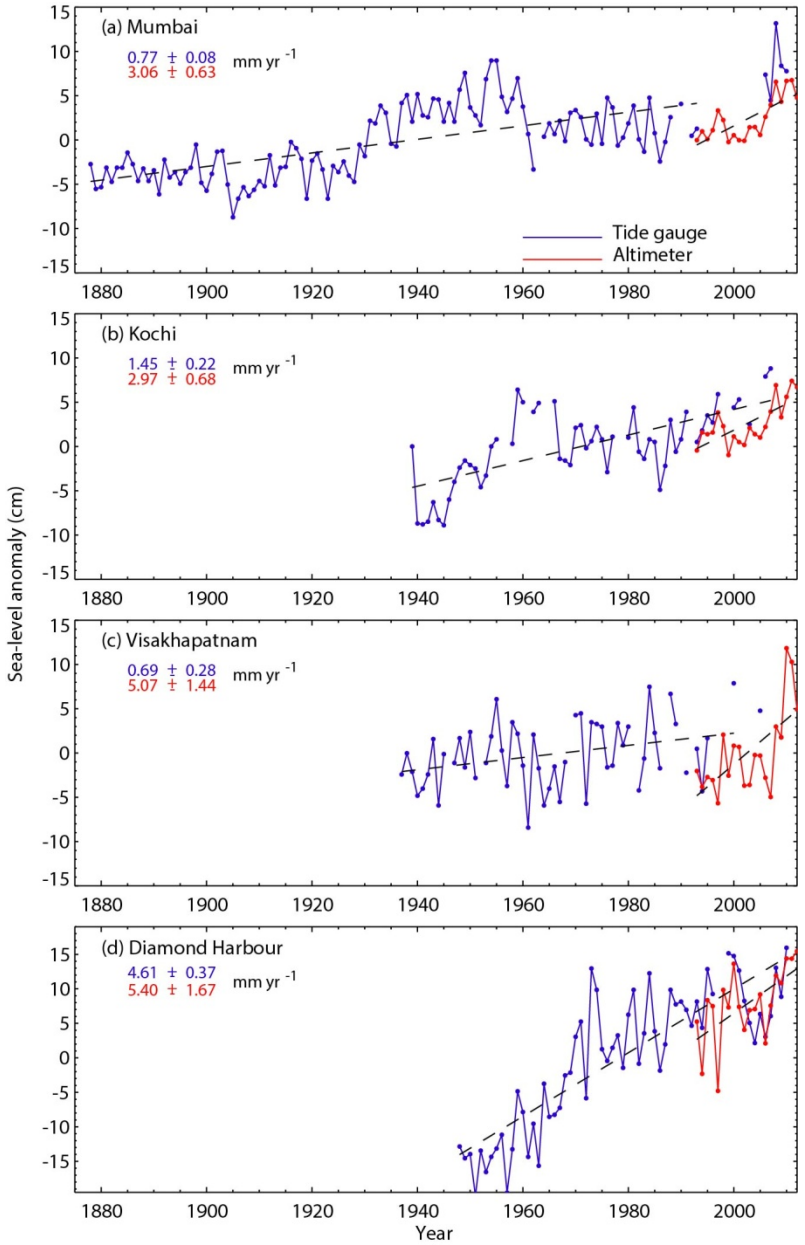
Sea-level-rise trends(1993-2012) and related uncertainties



Sea-level-rise trends along the Indian coasts

- Gaps in some tide gauge-records during altimeter period

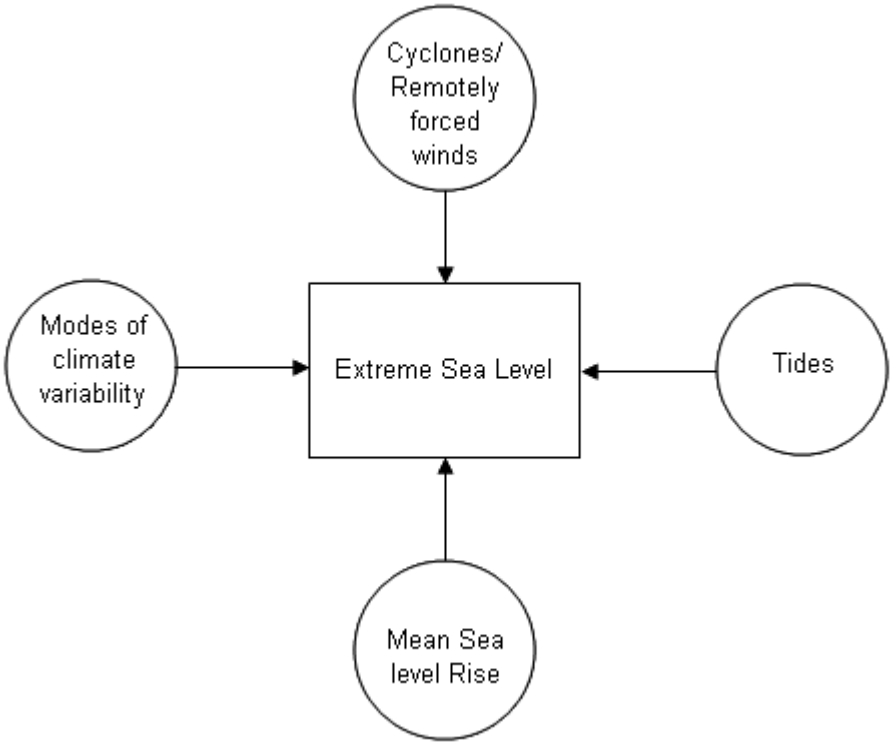
Large trends in the deltaic regions (Diamond Harbour) are partly attributed to subsidence

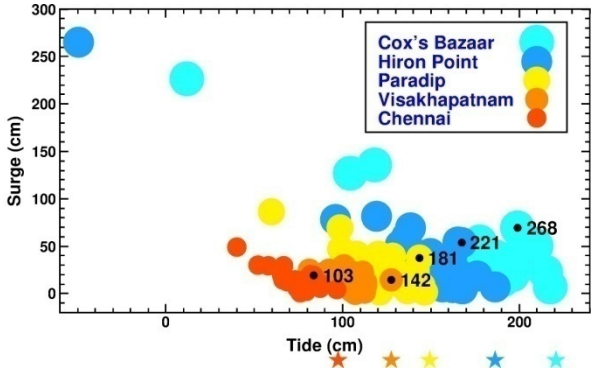


Current issues

- Data rescue of tide-gauge records(digitisation of old records)
- Data gaps, filling up with adjacent records
- Measurement of land movements (GNSS)

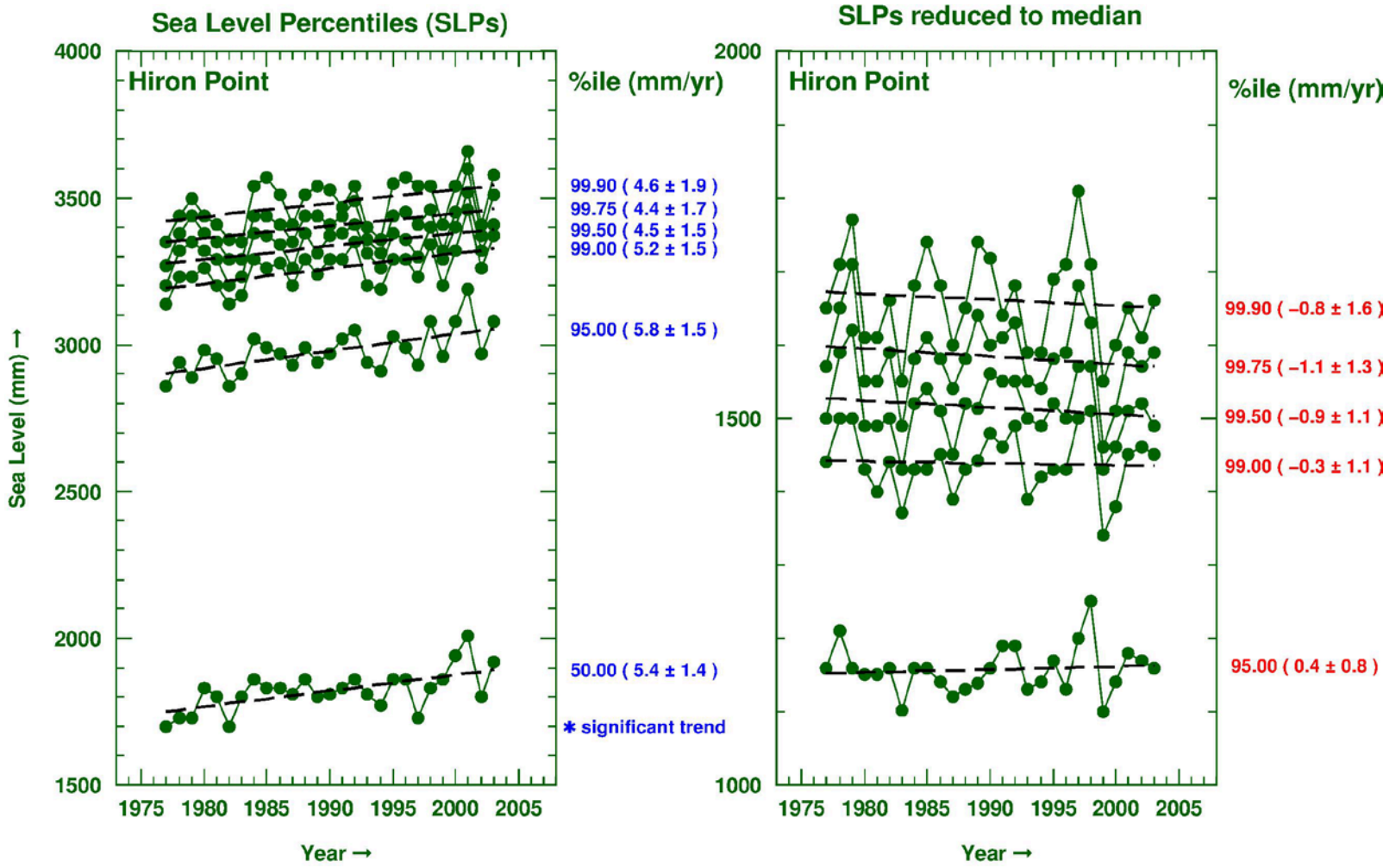
Extreme high waters in the Bay of Bengal



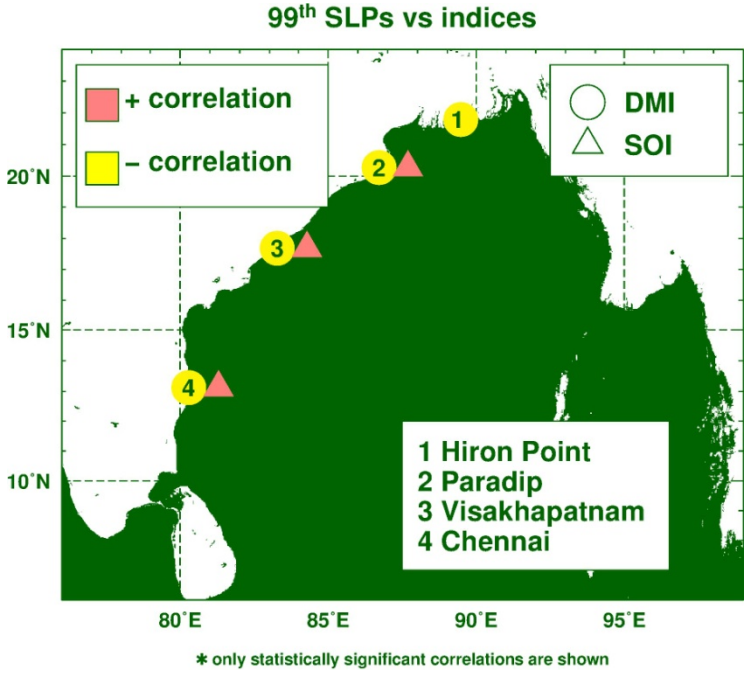


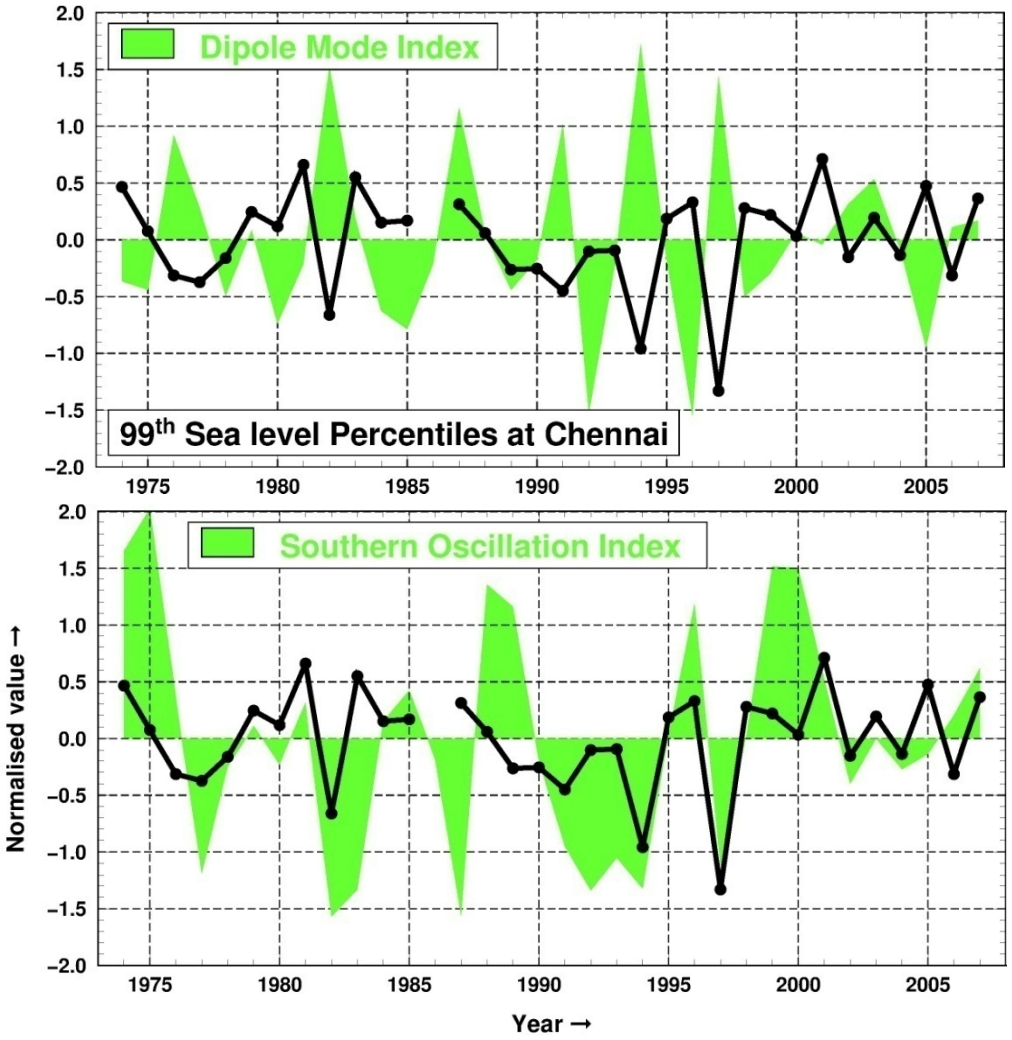
Extreme high waters in the Bay of Bengal

Charls et al. revision



Inter-annual variations



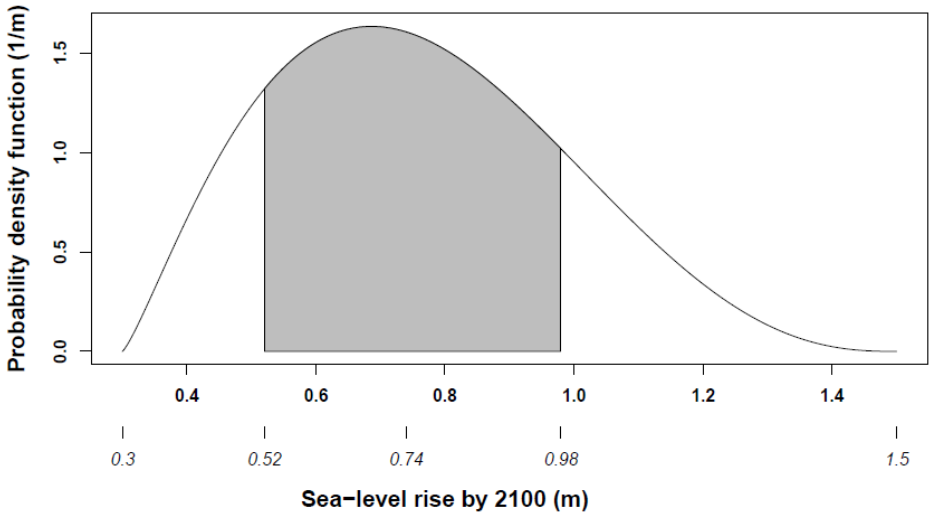


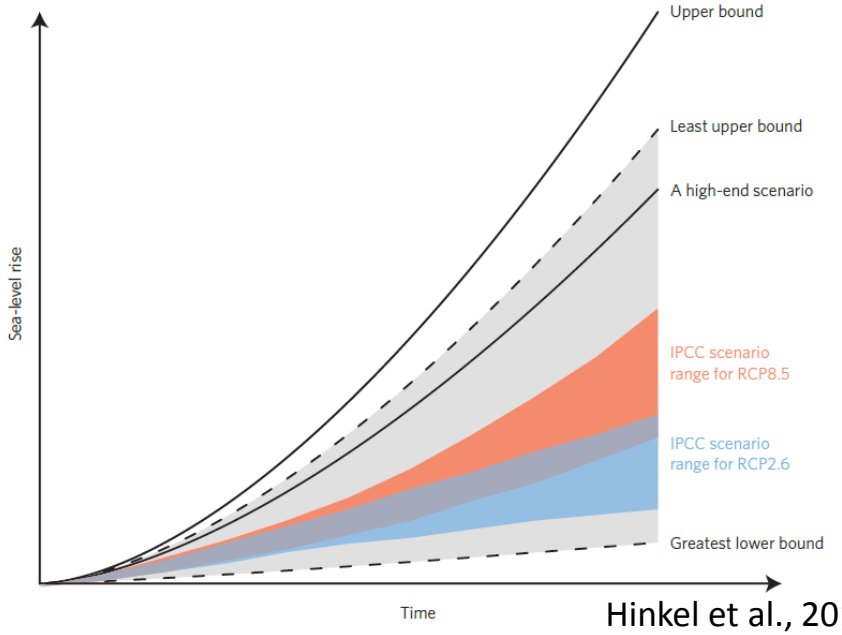
Impacts, Adaptation

- Sea-level rise adds to the occurrence of extremes, even if the occurrence of storms/cyclones do not indicate a clear change
- Adaptation needs sea-level projections information
- Infrastructure development at the coast

Challenges that need to be addressed:

- From the Science and Implementation plan:
  - **Sea level information useful for coastal management**, e.g. end-tail of SLR distributions, uncertainties
  - **Downscaling sea level variability and uncertainties** from regional to local coastal scale,
  - *Sea level rise vs **relative sea level rise** (land subsidence in coastal mega-cities and deltas can be up to one order of magnitude larger than sea level change)*
  - **Probabilistic information and return-period** from combined effects of sea level rise and changes in extremes (e.g., storm surges), in order to define *sea-level allowances* (needs for coastal defense raising to keep extreme marine submersions unchanged)
  - **Pilot studies** for mega city, delta, island state, etc. using accurate sea level products from working groups 1-4. => definition of these pilot studies (Indo-Gangetic delta….)





Hinkel et al., 2015

Conclusions

- At regional scale, considerable inter-annual/decadal variability (previous studies) can aliase the trends in short records, as found in the eastern Bay of Bengal (Large uncertainties present)
- Except for the northern and eastern BB, the trends in the north Indian Ocean during last two decades are consistent with global trends
- Increase sea level rise trends could be due to an acceleration resulting from global warming or partly caused by aliasing by natural variability

Statement: key needs from coastal users (From the science and implementation workplan)

- WP Objectives: to maximize the impacts of sea-level rise research for impact, adaptation and planning assessments in coastal communities
- Key need: more applied coastal information
  - probabilistic and high-end scenarios of future relative sea level rise tuned to coastal manager's needs
  - Future return-periods of extreme waves and water levels
  - Information on how sea level variability on different time and space scales combine to produce local extremes (e.g. for SLR allowance)
- Considering the impacts of climate change on winds, waves and storm surges to develop future projections of wave and wind-driven coastal currents
- Considering the relevant interactions between processes: tides and sea level rise; river water discharge. coastal hydrodynamic processes, natural (i.e., unmanageable) and anthropogenic (i.e., manageable and even preventable) land subsidence
- **Communities involved:** geodesy, geophysics, geologist, geomorphologists, coastal oceanography, social, environments and economic sciences, coastal engineers, atmospheric scientists.
- **Linkages** with EUCC, GEOSS Coastal Community of Practice, COWCLIP……