Regional sea level trends in the Bay of Bengal: preliminary results from a GRACE and Jason-1/-2 joint inversion

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Abstract

Sea level rise is not uniform, but it exhibits considerable regional variations. In Bangladesh, sea level rise in combination with land subsidence resulting from groundwater pumping, sediment load and/or tectonic motion, poses a major threat to the coastal regions. As part of the Belmont-project "BanD-AID", a joint inversion method is employed to estimate the different contributors to the total sea level rise, such as melting of mountain glaciers/ice caps and Greenland and Antarctica ice-sheets, hydrology, glacial isostatic adjustment, and steric sea level changes. Spatial patterns (fingerprints) are forward computed for each of the contributors. Temporal GRACE gravity data and along-track Jason-1 and -2 sea level anomaly data is combined to estimate the time variable amplitudes of these individual fingerprints, which allow the computation of individual sea level trends. In this work, we provide preliminary results from a global solution of the inversion which are compared to local measurements for offshore Bangladesh.

Joint Inversion

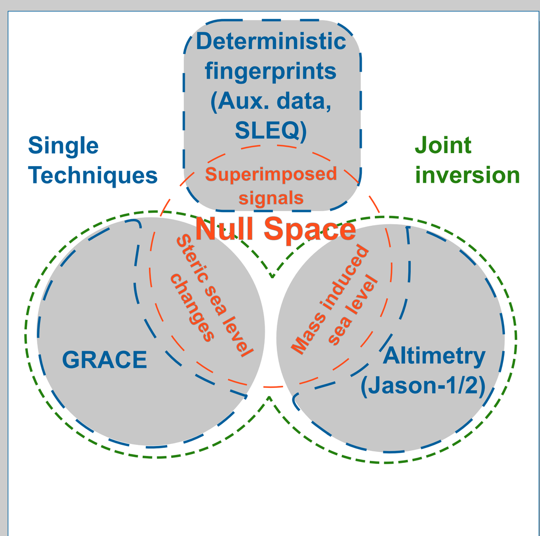

Fig. 1 Advantages of a joint inversion compared to the individual techniques.

Usual approach: GRACE minus altimetry
Problems arise from:

- Corrections
- Filtering of GRACE data
- Reference system
- Separation of the different contributions (mass, steric) to the total sea level

- The joint inversion combines GRACE and altimetry data in a (constrained) Least Squares solution.
- It is based on an 1D elastic response Earth model and includes a consistent reference frame treatment (incl. degree 1 coefficients)

Data

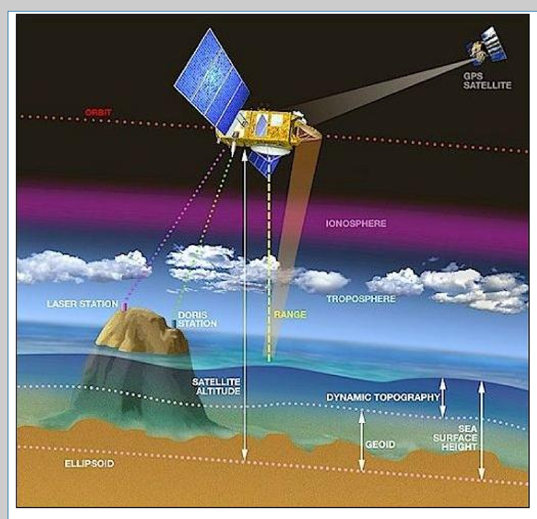

Fig. 2 Measurement principle of altimetry. (Image credit: AVISO)

Jason-1/-2 Altimetry

- Geometric (geocentric) measurement of sea surface height
- Groundtrack coverage limited to +/- 66° latitude
- Sensitive to ocean floor deformation
- Data from OpenADB

Gravity Recovery And Climate Experiment (GRACE)

- Monthly **unfiltered** RL5 GFZ normal equations
- Time series since 2002
- No detection of geocenter motion

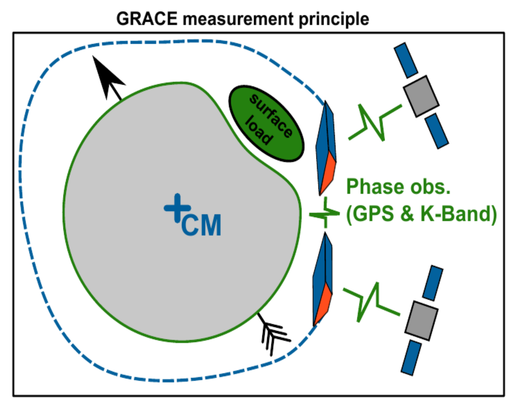

Fig. 3 GRACE measurement principle.

Global Results

Contribution [mm/yr]	Inversion (2003-2011)	IPCC AR5 (1993-2010)	Church, 2011 (1993-2008)	Jacob, 2012 (2003-2011)
Antarctica	0.40 ± 0.03	0.27 ± 0.11	0.43 ± 0.20	0.45 ± 0.19
Greenland	0.66 ± 0.01	0.43 ± 0.08	0.31 ± 0.17	0.60 ± 0.02
Glaciers	0.43 ± 0.02	0.76 ± 0.37	0.99 ± 0.04	0.41 ± 0.08
Hydrology	-0.20 ± 0.09	0.38 ± 0.11	-0.08 ± 0.19	
Steric	1.20 ± 0.14	1.10 ± 0.30	0.88 ± 0.33	
Total	2.50 ± 0.11	2.80 ± 0.50	2.54 ± 0.46	

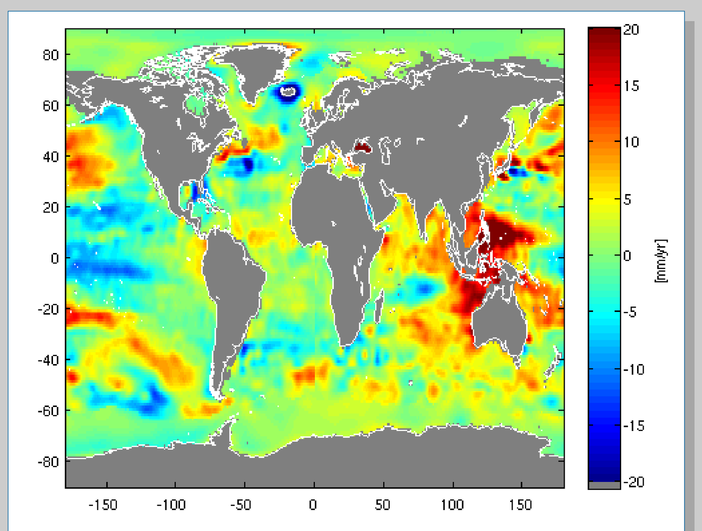

Fig. 7 Global sea level rise obtained from the inversion results

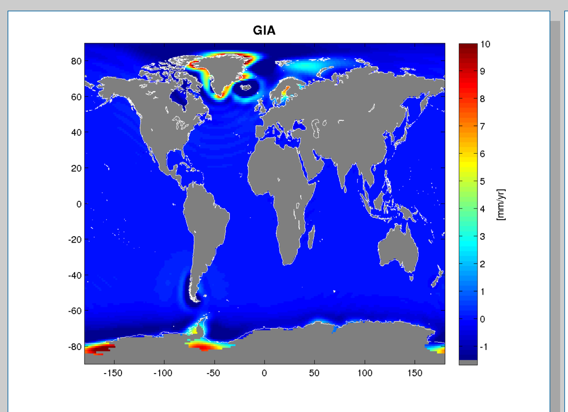

Fig. 8 Combined sea level trends from Glacial Isostatic Adjustment

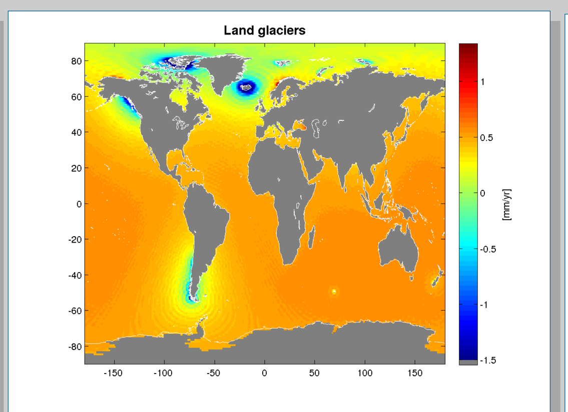

Fig. 9 Combined sea level trends from ablation of glaciers

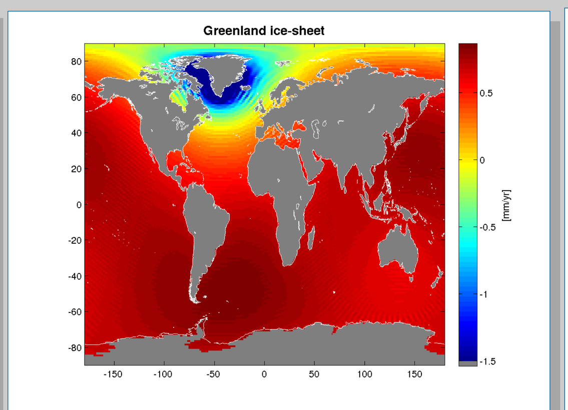

Fig. 10 Combined sea level trends from the Greenland basins

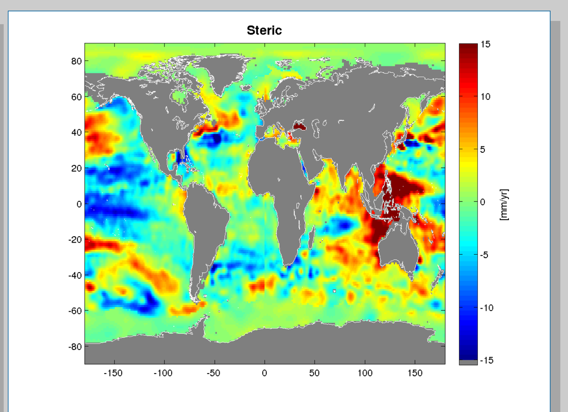

Fig. 11 Combined sea level trends from steric changes

Bay of Bengal: Altimetry, Tide Gauges

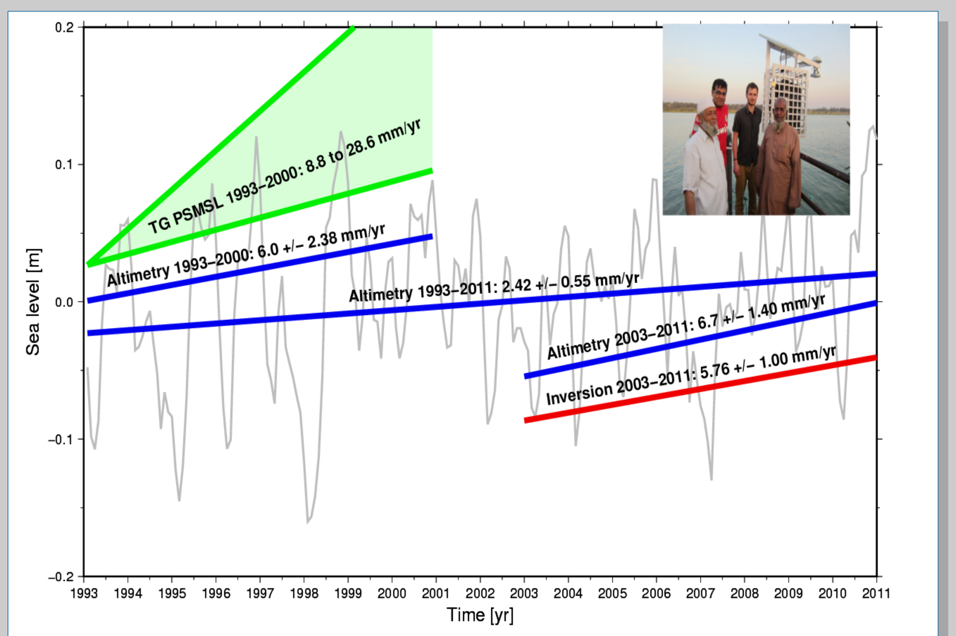

Fig. 12 Sea level trends in the Bay of Bengal (Lon: 80°-95.5°, Lat: 16°-23°). Grey line: The change in water height, as observed by altimetry. Note that the individual trends are shifted in height for visual reasons.

- Tide gauges are influenced by tectonic motion of about 4-18 mm/yr (e.g., Singh, 2002)
- Modernization of TGs as part of the BanD-AID project

Bay of Bengal: Steric Sea Level

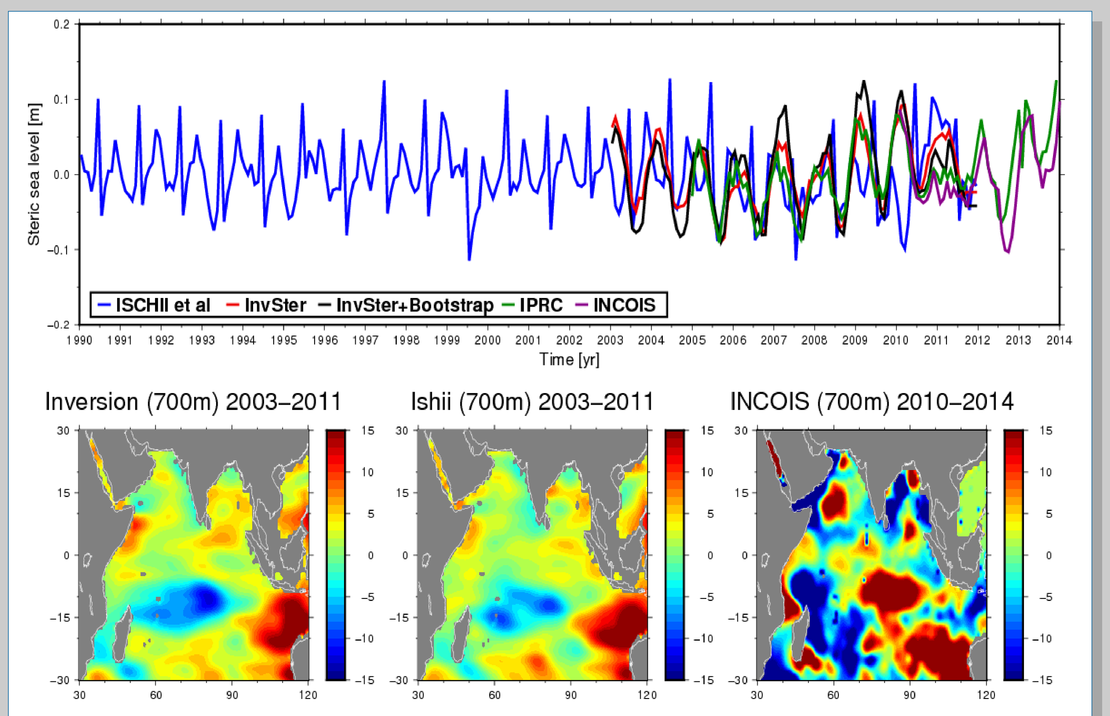

Fig. 13 Steric sea level trends in the Bay of Bengal (Lon: 80°-95.5°, Lat: 16°-23°). Trends from short time periods are heavily influenced by interannual phenomena.

Conclusions and Outlook

- Sea level rise in the Bay of Bengal of about $6\,\frac{\text{mm}}{\text{yr}}$ is significantly larger compared to the global mean sea level rise of $3.1\,\frac{\text{mm}}{\text{yr}}$
- The increased sea level rise in combination with land subsidence poses a serious threat to the coastal regions in Bangladesh
- Our fingerprint inversion allows the separation of the total change in sea level into its individual contributors, where influences from hydrology and steric changes are the most variable over time.
- In the future, we will increase the resolution of the inversion and incorporate local measurements to enhance the quality on a regional scale

Fingerprints

Mass fingerprints are computed utilizing the Sea Level Equation and steric fingerprints are derived from Principal Component Analysis. The fingerprints are time invariant.

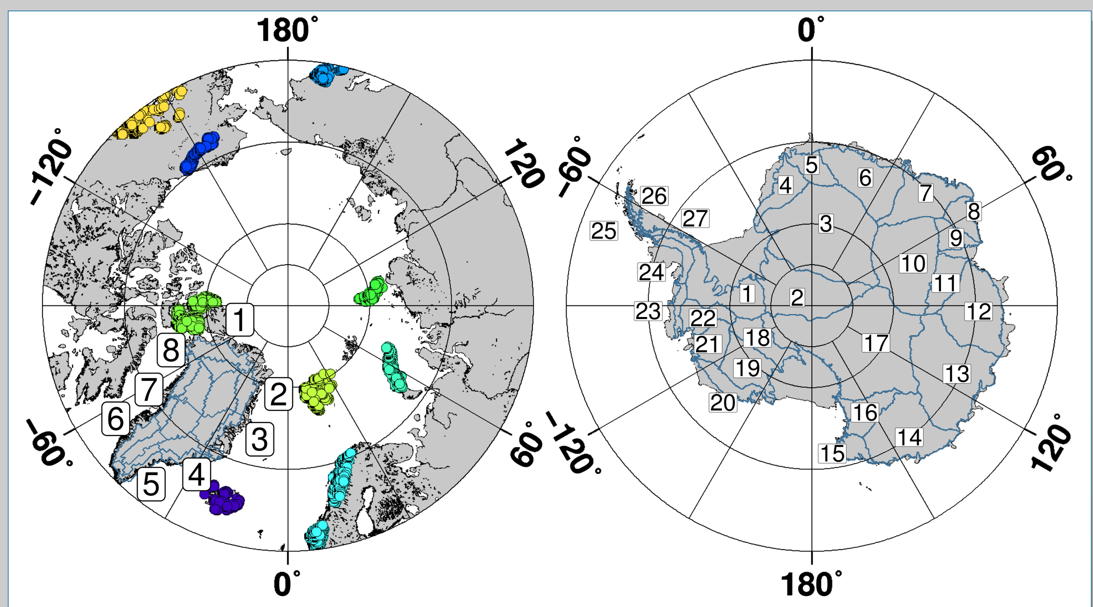

Fig. 4 **Left:** Individual glacial clusters and Greenland basins. **Right:** Individual basins in Antarctica.

Mass fingerprints (Fig. 4)
Derived for different basins. Reconstructions for each individual basin are possible.

- Greenland basins (16)
- Antarctic basins (27)
- Glacier clusters (16)
- Hydrology (60 EOF's derived from WGHM)
- Glacial isostatic adjustment (5) from Klemann, 2009

Steric fingerprints (Fig. 6)

- Volume change from temperature and salinity in the upper 700m (Ishii et al., 2009)
- Additional "deep" patterns from altimeter residuals
- 100 shallow EOFs + 100 "deep" ocean EOFs

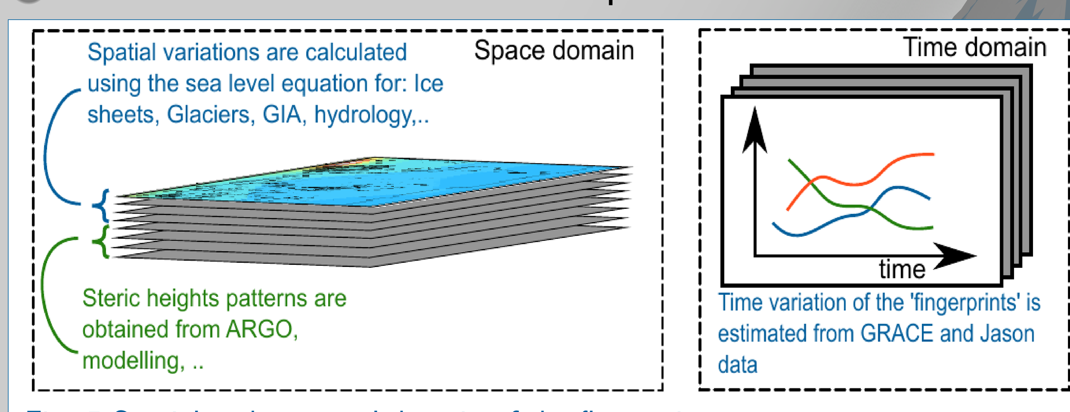

Fig. 5 Spatial and temporal domain of the fingerprints

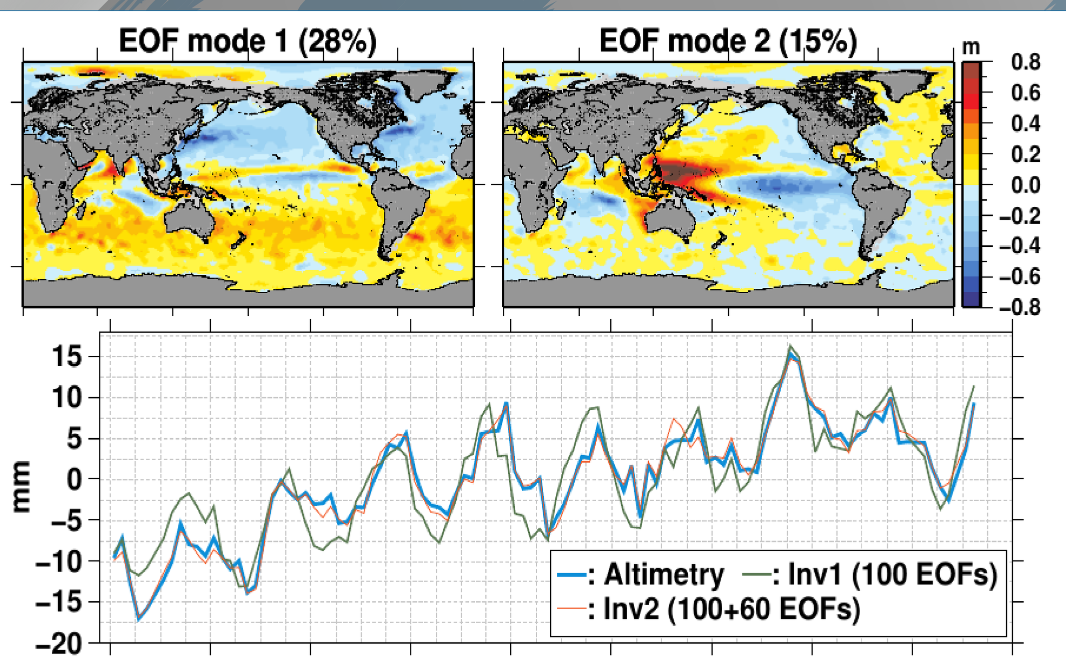

Fig. 6 **Top:** First two modes (steric fingerprints) from PCA. **Bottom:** Comparison to altimetry data.

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