How Well Can We Simulate Sea Level Anomalies?

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1. Introduction

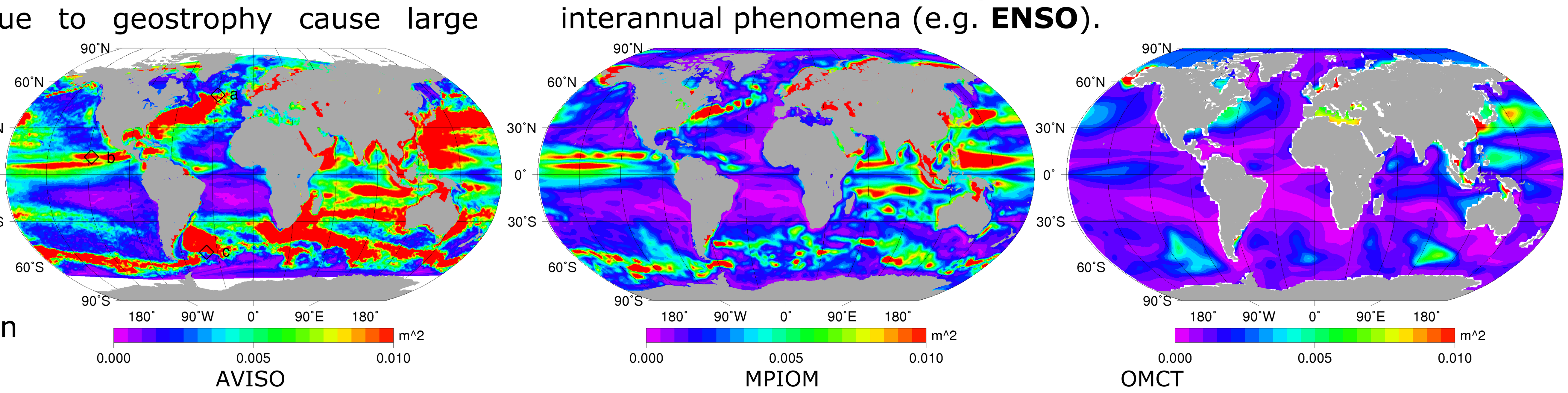
Sea level is a crucial variable in oceanography and climate science both in itself (consider coastal populations and ecosystems) and as an easy-to-measure proxy for subsurface processes (variations in currents, temperature, and salinity distributions).
Global mean sea level has risen at a rate of around **3.3 mm/yr** between 1993 and 2009 (Nicholls & Cazenave, 2010). Yet **regional differences** are often larger than this global trend, and variations on all timescales – from storm surges to postglacial rebound – are superimposed on the mean signal.
The **comparison** of long timeseries of **satellite altimetry data,** starting in 1992, with output from **ocean models** driven by reanalysis data for atmospheric forcing will help to identify the processes that state-of-the-art ocean models are able to resolve and those that they are currently missing.

2. Data and Models

AVISO: Multi-satellite altimetry data product covering 1992-today, providing global maps on weekly intervals (provided by CNES&CLS, *www.aviso.oceanobs.com*).
Jason, TOPEX: Incomplete 1°x1° grids for individual altimetry satellites, daily resolution (provided by S. Esselborn, GFZ).
MPIOM: Max Planck Institute Ocean Model (Marsland et al., 2003) on a curvilinear grid ~1°x1°, 40 vertical layers, driven with ERA Interim reanalysis atmospheric forcing.
OMCT: Ocean Model for Circulation and Tides (Thomas, 2002) on a regular grid 1.875°x1.875°, 13 vertical layers, driven with ERA Interim reanalysis atmospheric forcing.
Neither model can realistically simulate long-term sea level trends in its current configuration: The effect of land ice is not included, and MPIOM in particular conserves volume on a daily basis.

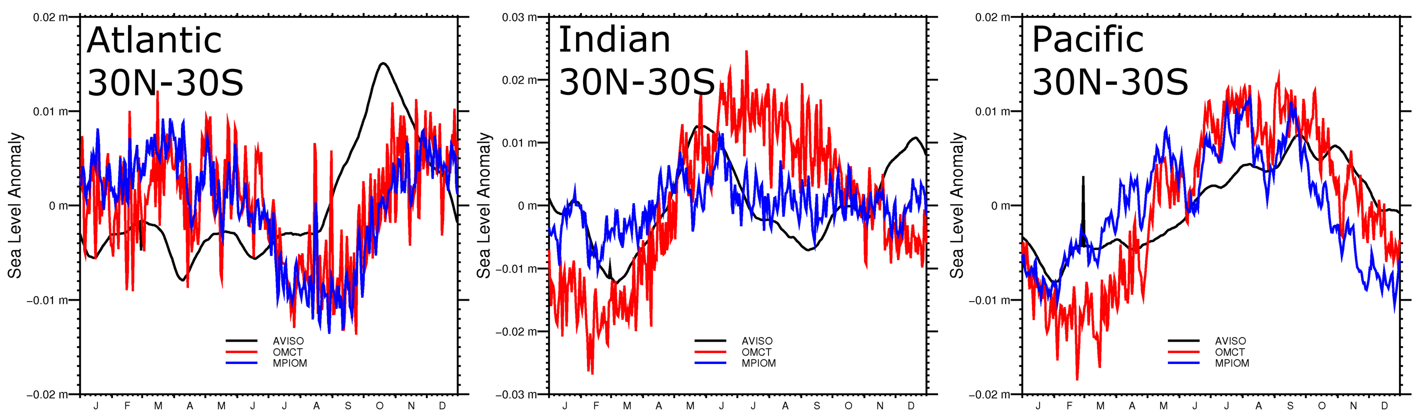
3. Weekly to Interannual Variability

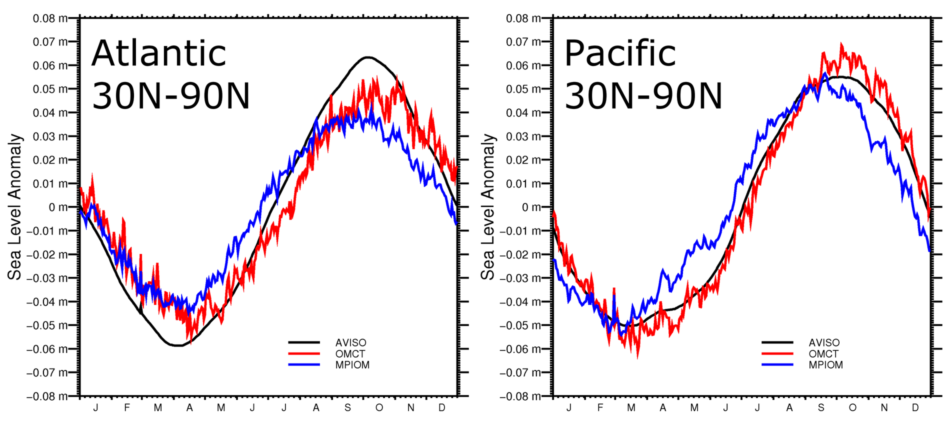
The variance of local sea level for weekly data in the 2001-2008 period shows marked regional differences: Areas of strong **ocean currents** (e.g. Gulf Stream, Kuroshio, ACC) associated with steep cross-current sea level slopes due to geostrophy cause large variabilities when flow paths vary slightly. Observed **variances reach 0.01 m²** in large parts of the ocean. Modelled variances show similar geographical patterns, although **variances are generally too low in both models**.
OMCT underestimates them more than MPIOM does, most notably so in the ACC. Variability occurs on several timescales in all ocean basins: Short term changes caused by eddies (e.g. in the **ACC**), seasonal changes due to temperature, wind and precipitation (e.g. **Indian Summer Monsoon**), and interannual phenomena (e.g. **ENSO**).

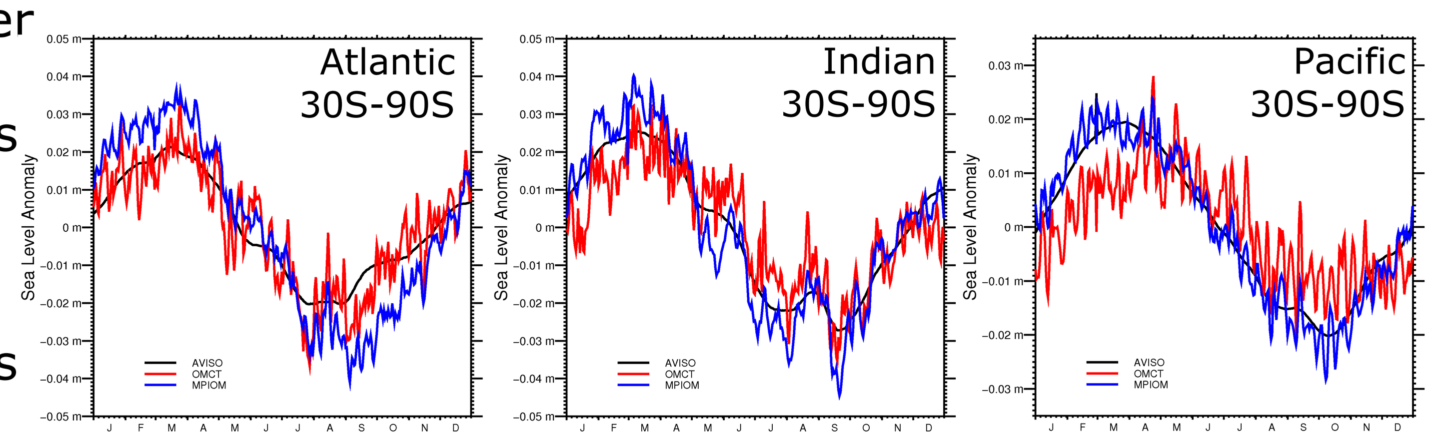


4. Seasonal Cycle

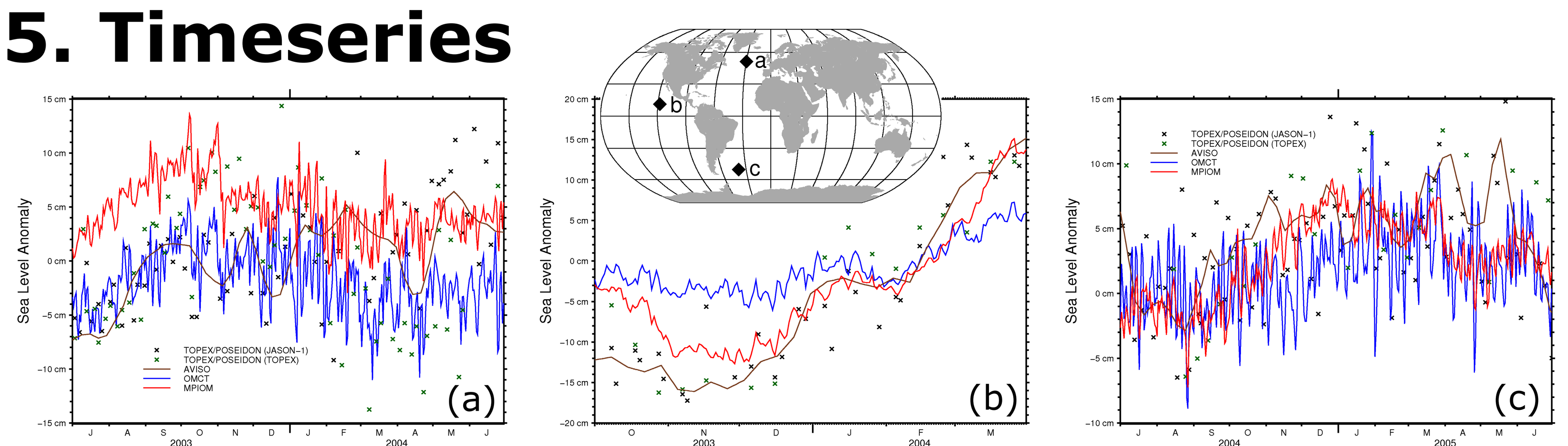
Sea level, especially in high latitudes, shows a strong seasonal cycle due to **thermal uptake and fresh-water fluxes**. While the amplitudes in the high latitudes reach values of **around 10 cm**, seasonal signals in the tropics are considerably weaker. The southern hemisphere seasonal cycle is shifted by 6 months compared to its northern hemisphere counterpart. Both MPIOM and OMCT succeed in reproducing the amplitudes and phase shifts measured by AVISO in the extratropics. Note that the higher level of noise in the model output is due to the daily resolution which is not included in the weekly AVISO data. The reproduction of the smaller amplitude **tropical seasonal cycle poses a problem** to both models: Neither of them shows the two-peak structure measured in the tropical Indian Ocean; in the topical Atlantic, both models agree well, but are far from the observations; in the tropical Pacific, the models obtain a seasonal cycle of the right shape, but a 3-month phase shift is evident. Those deficits may be grounded in inaccurate implementation of freshwater fluxes or erroneous cloud cover in the reanalysis data.







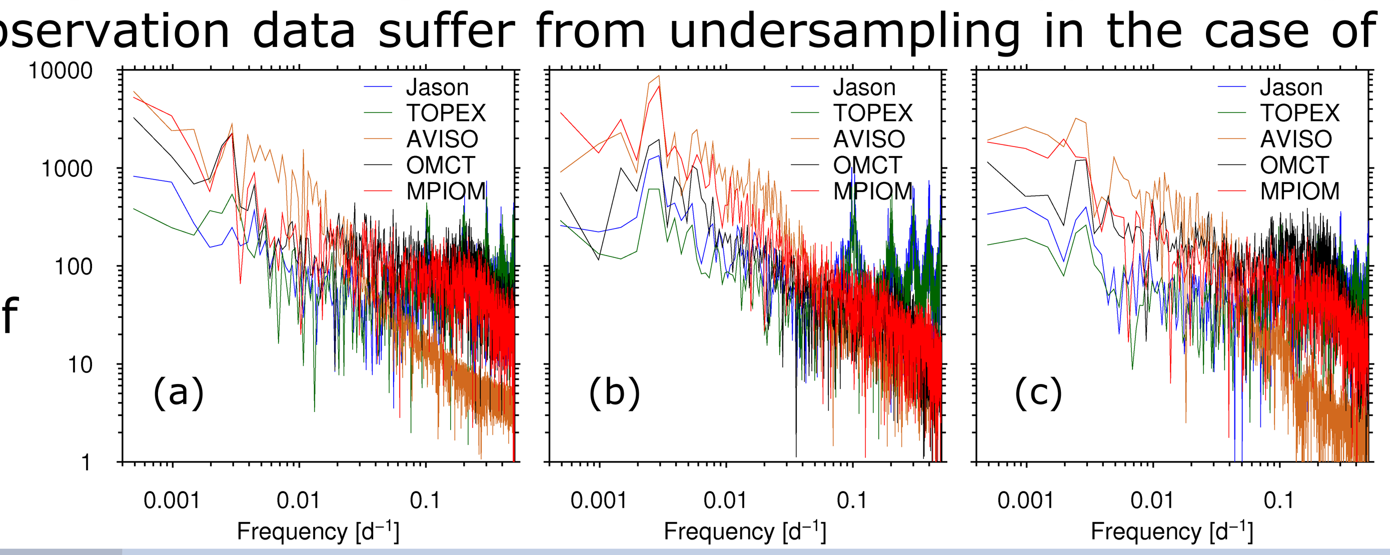
5. Timeseries



If mismatches between model output and the AVISO data originate from undersampling and interpolation issues, along-track altimetry data should correspond more exactly to modelled sea levels. **Correlations of daily data** in selected 1°x1° boxes are, however, **rather low**. Possible reasons are the lack of surface pressure forcing or effects of loading and self attraction. Long-term variability, such as ENSO signals (see Fig. (b)), is reproduced far more accurately.

6. Spectra

While pointwise correlation may be too ambitious a goal, a realistic simulation of the dominant physical processes should produce signals in the right frequency bands. The strong seasonal signal is always well reproduced, whereas the **models underestimate variability on the weekly to monthly timescales**. In this approach, high frequency observation data suffer from undersampling in the case of individual satellites and from interpolation in the case of AVISO.



7. Conclusions

- Regional patterns of variabilty well reproduced in both MPIOM and OMCT.
- Weekly to interannual variability generally underestimated by models.
- Seasonal cycles in the extratropics well reproduced, but problems with tropical seasonal cycles: Sensitivity studies needed to identify error sources (freshwater uptake / cloud cover?)
- Short-term variability not exactly reproduced in either model: Impacts of surface pressure forcing or loading and self attraction effects?

References:

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