Regional decadal trends in sealevel and implications for determining global mean sealevel change and its causes

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Summary

Estimates of regional patterns of sealevel change are obtained by combining the MIT general circulation model (1°x1°, 23 vertical levels, 80S-80N) and several hundred million ocean observations in a constrained optimization procedure for the period 1993-2004. The data include not only the available altimetry (TOPEX/Poseidon, Jason, GFO, ERS, Envisat), but most of the modern hydrography, ARGO float profiles, seasurface temperature and other observations. Adjustable parameters are initial temperature and salinity and NCEP-NCAR reanalysis forcing fluxes. Regional variations greatly exceed existing estimates of the mean rise in sealevel, including some regions with sealevel fall. Although thermal effects are largest, the contributions from salinity changes and mass redistribution within the oceans are both significant. Contributions below 1000m are also important, but not dominant. The inferred sealevel change is similar to other estimates derived strictly from data analyses, but there are quantitative differences. Given the complexity of the regional trends and the sparsity of the in situ hydrographic database, considerable uncertainty remains in the attribution of global mean sealevel change to thermal expansion or other effects. A major obstacle is the absence of atmospheric fluxes that are consistent in their conservation of freshwater and heat, and the lack of good regional uncertainty estimates for those fluxes.

Regional sealevel trends

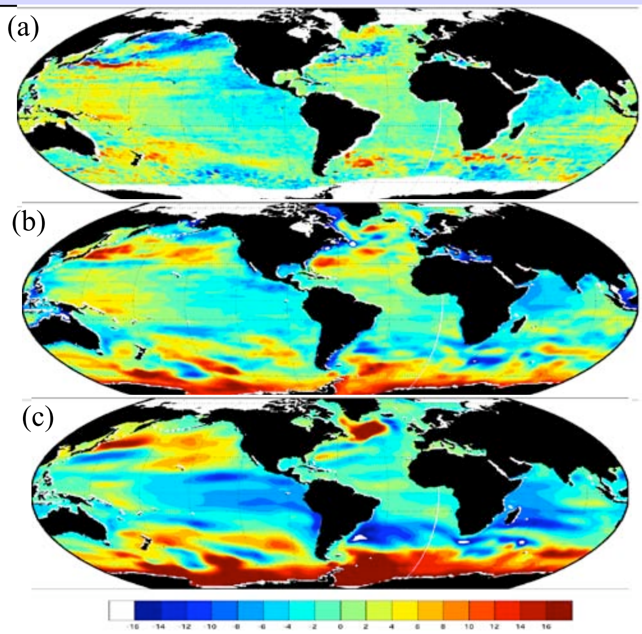

Figure 1. Sealevel trends based on *(a)* altimeter data (courtesy of S. Nerem), *(b)* optimized solution and *(c)* control run (no optimization). Units are mm/yr. Spatial means have been removed.

- Gross similarities between altimeter and optimized solution but noticeable differences as well, expected because altimeter data are not the only constraints used and their weights are spatially varying (see Fig. 3)
- Substantial changes in amplitude and sign of trends and in their regional patterns introduced by the optimization

Regional steric height trends

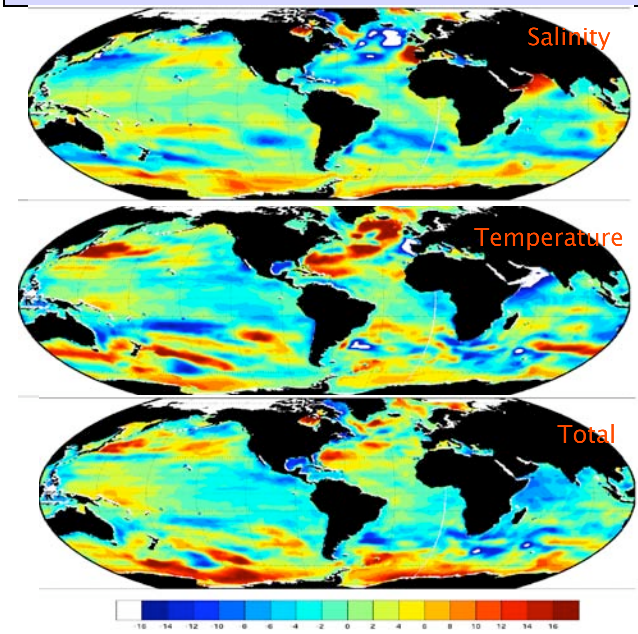

Figure 2. Steric height trends (mm/yr).

- Comparison with patterns in Fig. 1b indicate strong contributions from thermosteric effects to the sealevel trends
- Compensation of temperature and salinity effects implies smaller steric height signals than what can be inferred from temperature or salinity alone

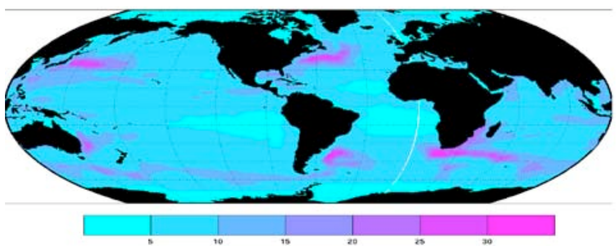

Figure 3. Estimated RMS error (cm) of the time-dependent altimeter observations, which is used to weight the data in the optimization.

Vertical dependence and abyssal contributions

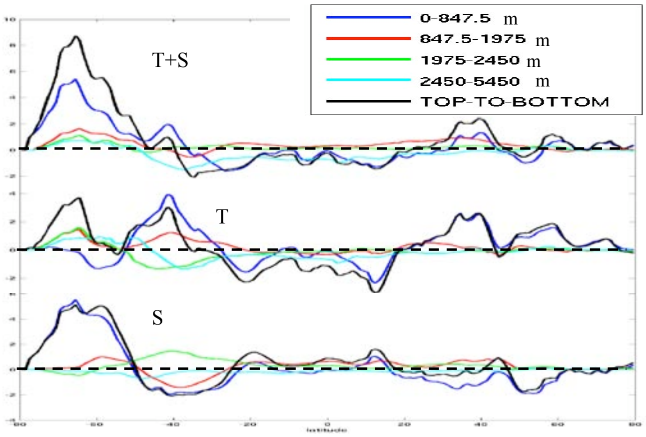

Figure 4. Zonal average of the steric height trends (mm/yr) over several depth ranges.

- Major contributions to sealevel trends from upper 800 m but measurable contributions from lower layers at many latitudes as well
- Omission of layers below main thermocline can lead to quantitative errors that would be expected to grow with time as surface signals penetrate the abyss

Potential sampling issues

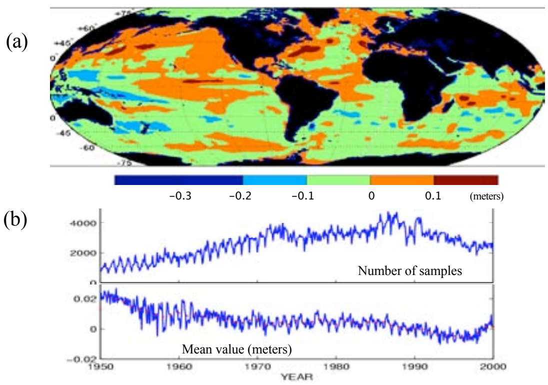

Figure 5. *(a)* Thermosteric height anomaly for an arbitrary month of the solution. Calculated mean of this pattern when sampled at data positions reported in the World Ocean Atlas since 1950 is shown in *(b)* together with total number of samples. The true area-weighted mean value is -10 mm.

- Deviations from true mean are pure artifact of imperfect spatial sampling and its changes with time

A few challenges ahead

- Can salinity data provide a sufficient constraint on the net freshwater flux?
- Can temperature data, particularly at depth, provide a sufficient constraint on the thermal expansion contribution to sealevel and net surface heat flux?
- Can constraints on surface forcing fluxes, initial conditions be improved for tighter estimates on regional and global sealevel trends?
- What model improvements (non-Boussinesq formulation, use of real freshwater flux, increased resolution,…) are most important for better sealevel estimates?
- What is the true accuracy of trends inferred from observed temperature and salinity alone, and what is the minimum statistically significant signal?