# Initial estimates of ocean steric sea-level rise from sparse ocean data sets


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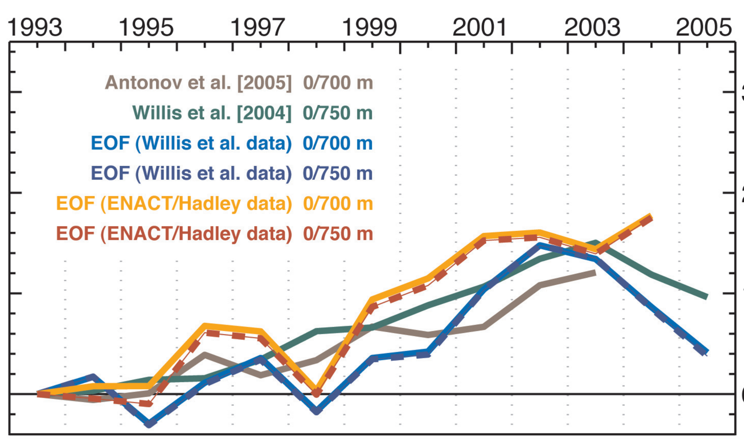
## Introduction

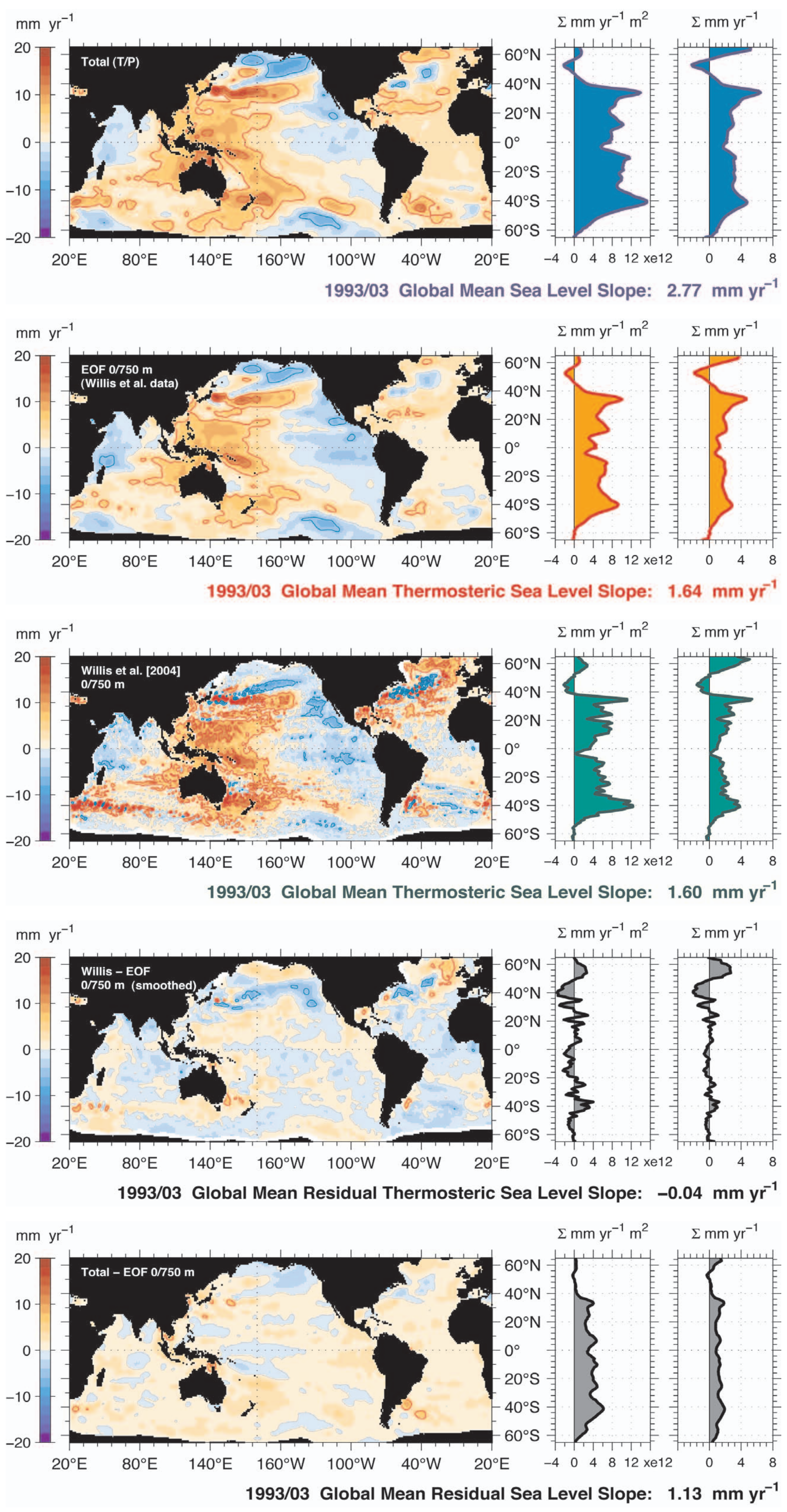
Estimating historical rates of ocean thermal expansion is difficult because of substantial data gaps, particularly in the southern hemisphere. A number of previous estimates are likely to be biased low because they essentially assume no change in data-void regions (Gregory *et al.*, 2004). Here, we use reduced space optimal interpolation in an attempt to overcome these biases.

## Approach

Steric sea-surface height anomalies (seasonal signal removed) are calculated from the ENACT (Ingleby and Huddlestone, 2006) data and from an update of the Willis *et al.* (2004) data. EOFs are calculated from satellite altimeter data for the period 1993 to 2004 (inclusive). The amplitude of a limited number of EOFs and a spatially constant field are then determined for each month by minimising the difference between the sum of these fields and the observed steric heights (Kaplan *et al.*, 2000).

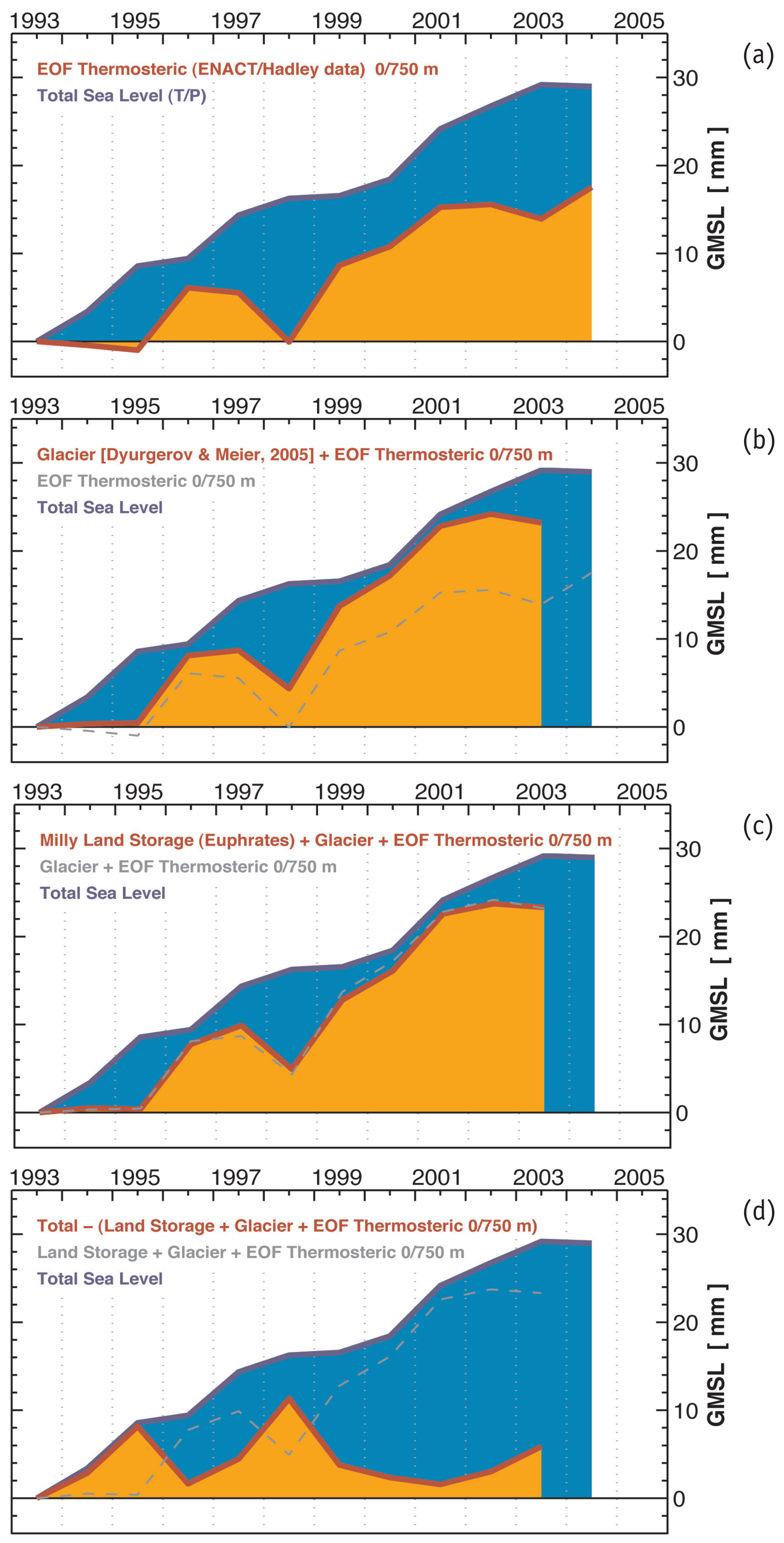



Over the period 1993 to 2003, we estimate a rate of global averaged steric rise of 1.6 mm/yr in the upper 750 m. For the last two years the two data sets give somewhat different results – the estimate using the ENACT data continues to rise whereas the estimate using the Willis *et al.* (2004) data falls.



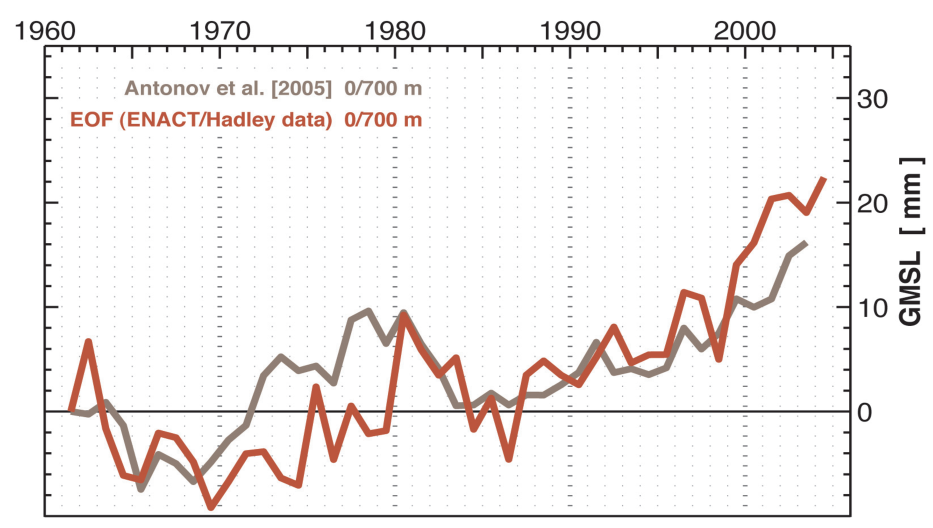

The estimates of regional sea-level rise for the upper 750 m from our analysis are similar to those of Willis *et al.* The difference between the observed sea-level rise from satellite altimeter data and the estimates of thermal expansion in the upper 750 m indicates the contribution from deep ocean warming and from increases in mass of the ocean from glaciers, ice sheets and other terrestrial storage sources.

## 1993 to 2004

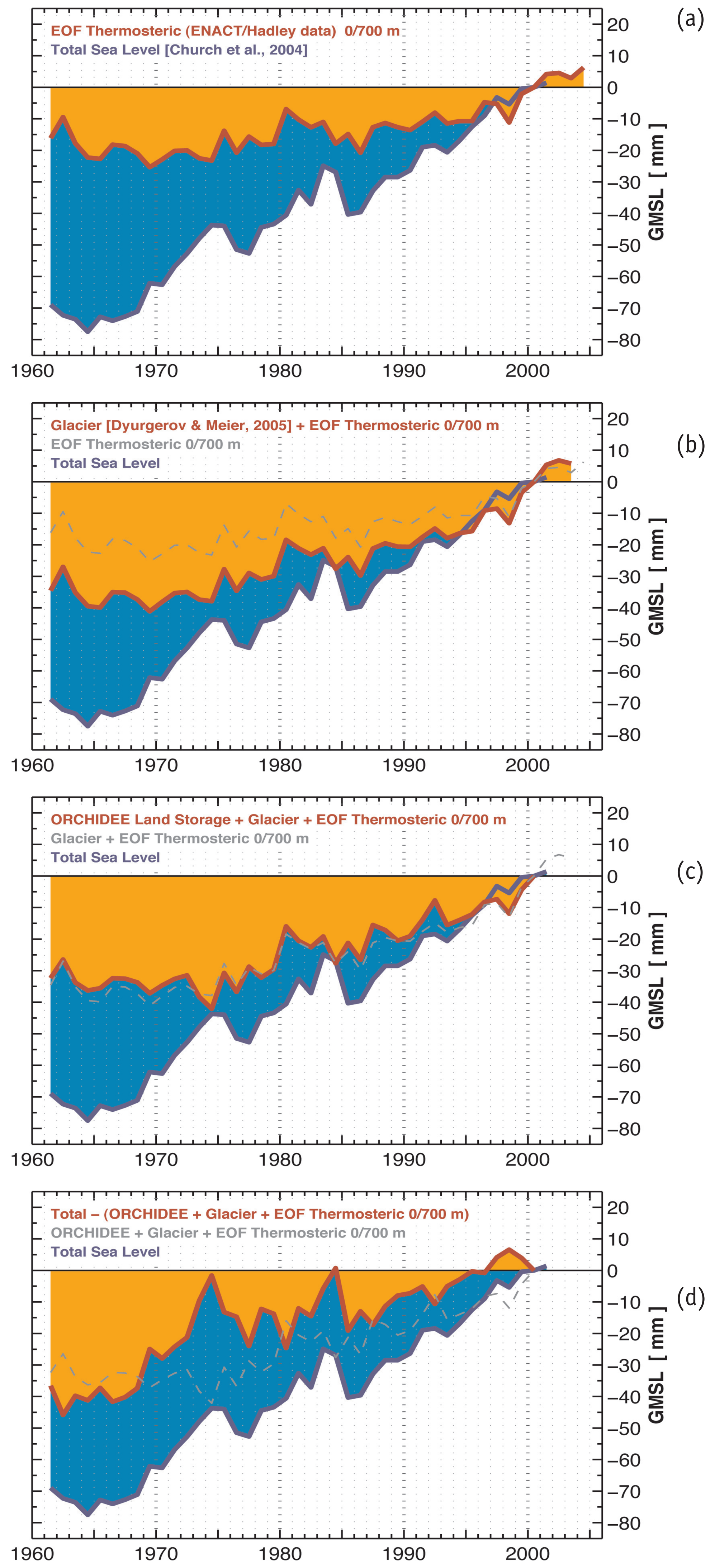



The time series of total sea level (from satellite altimeters) is shown, together with (a) thermosteric sea level, (b) thermosteric + glacier, (c) thermosteric + glacier + terrestrial storage (Milly *et al.*, 2003), and (d) the residual sea level.

## 1961 to 2000




Estimates of the thermosteric component of sea level from our technique (using ENACT data) and from the Levitus data set (Antonov *et al.*, 2005).




Our estimates of thermal expansion over the period 1961 to 2000 are somewhat larger than earlier estimates of thermal expansion. The four panels show estimated (total) GMSL for 1961 to 2000+. As in figure 3, the cumulative contributions are shown. Terrestrial storage is from the ORCHIDEE model (Ngo-Duc *et al.*, 2005). Note that the residual (d) is more-or-less constant from ~1974 (slope ~0.5 mm/yr), suggesting that one of the components (possibly the thermosteric component – note the dip in the late 1960s) is of poorer quality before this.

## Conclusion

For recent (post mid 1970s) times, the separate components of sea level add up to the total reasonably well. Before this there are problems with one or more of the data sets. More effort in closing the budget over the whole period is warranted.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