Sea Level variability in the Argentine Basin

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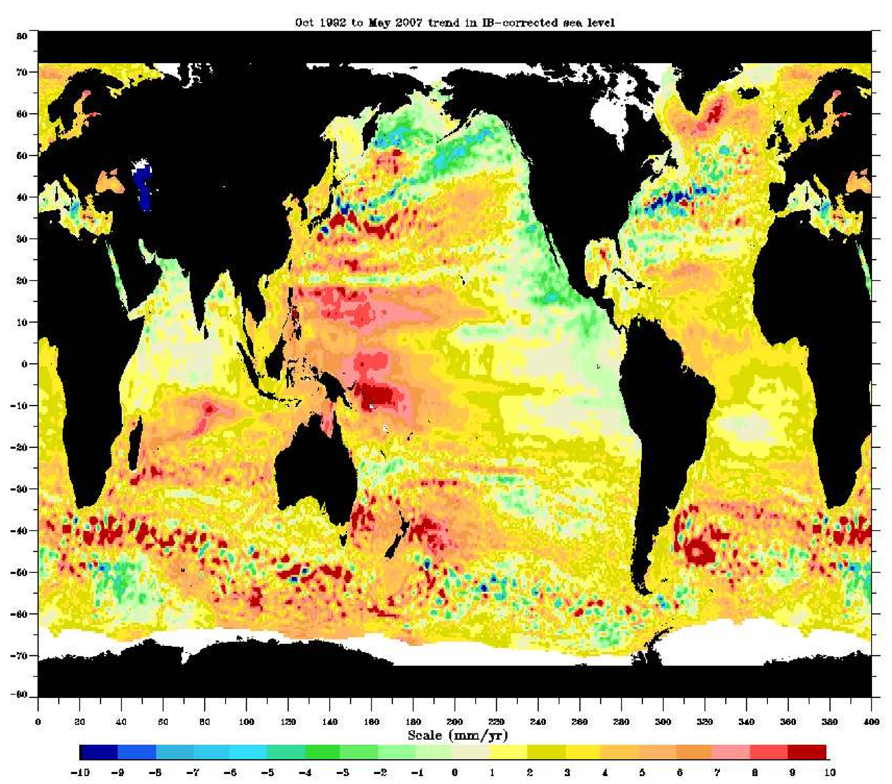
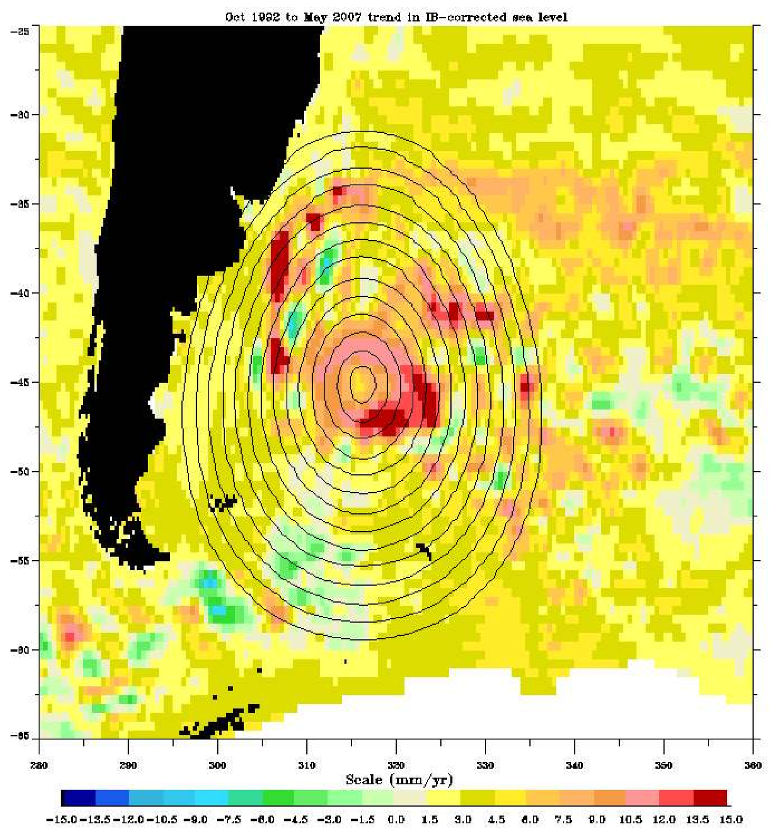
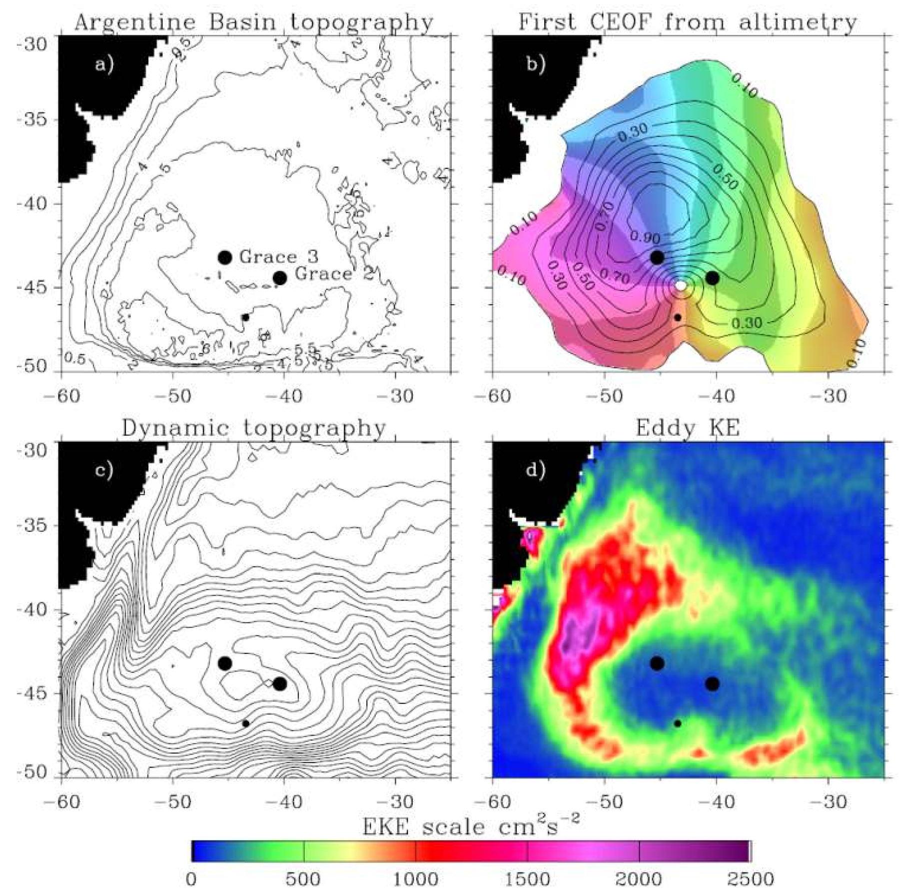


To the left is shown a the rate of sea level rise over 14.5 years, found by fitting a linear trend together with annual and semiannual cycles to the joint (Topex or Jason) and (ERS or Envisat) reference altimeter timeseries provided as a gridded dataset by AVISO.

The Argentine Basin stands out as a region particularly strong sea level rise. To the right we zoom in, and define a set of 15 circular strips centred on the sea level anomaly. This are strictly circular (although distorted by the projection) and at intervals of one great circle degree away from the centre.

The question is, can this strong sea level signal be explained by the changing action of eddies? I first give some background explaining why this might be a reasonable expectation, and then present results showing that eddy effects may plausible account for a significant part of the observed signal.

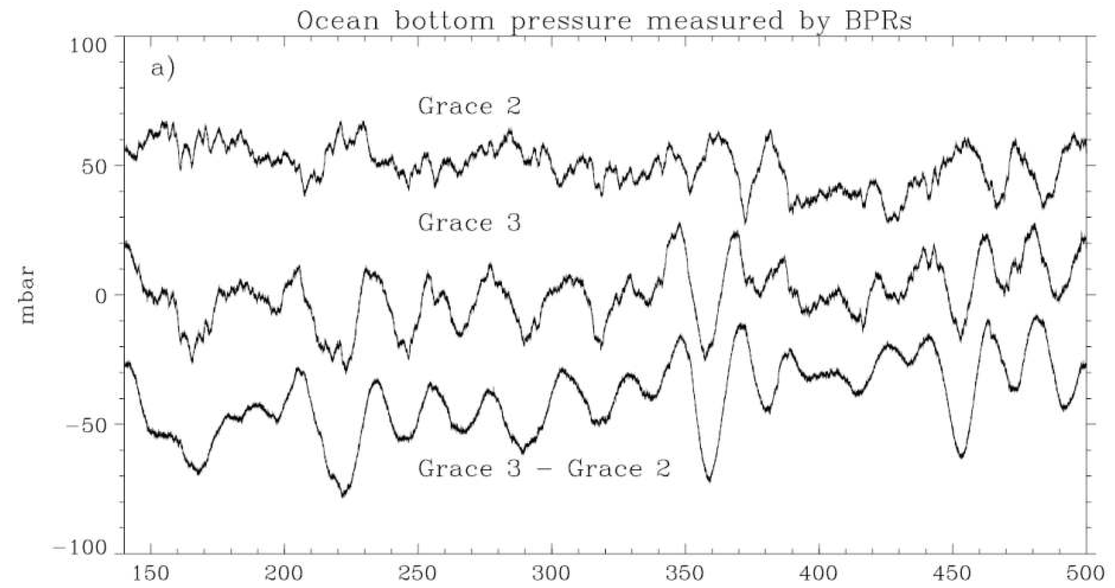




The Argentine Basin is a strange region of the ocean. North of the Falklands and east of Argentina, most of the basin is more than 5 km deep, and it is bounded to the south by a very steep continental slope. Near the middle of the basin is a small rise, the Zapiola Rise, which is covered in ‘mud waves’: giant ripples with heights of tens of metres and typical wavelengths of about 5 km, indicative of large currents. A large anticyclonic current (the Zapiola Anticyclone) flows around the rise, with transport thought to be about 100 Sv (seen here in panel c).

Model experiments have shown that the anticyclone is driven by eddies, (de Miranda et al., 1999), and that great care has to be taken in the representation of both eddies and topography (Barnier et al., 2006) to model both the anticyclone and the characteristic C-shaped region of high eddy energy (panel d).

Altimetry in the region (Fu et al., 2001) has also identified an energetic mode (panel b) in the region consisting of a dipole in sea level, rotating around the Zapiola Rise with a period of about 25 days. The existence, strength and depth-independence of this mode has been confirmed by a POL project (Hughes et al., 2007). We deployed 3 bottom pressure recorders (black dots above) for a year starting 16 May 2002. One (Grace 1) was lost, but the others (Grace 2 and Grace 3) produced good records.



The change in pressure difference near to day 360 of almost 60 mbar corresponds to a **change in transport of almost 300 Sv over 12 days.**

A further link in the chain has been added recently. Fu (2007) has shown that the amplitude of the 25-day waves is inversely correlated with the amplitude of mesoscale energy in the north-west of the C-shaped eddy region.

Put together, the results so far suggest that:

1) The Zapiola anticyclone is eddy-driven, as first suggested by Dewar (1998)

2) Eddies also excite the 20-25 day wave modes in the middle of the basin

3) Models must reproduce the C-shaped eddy distribution in order to capture these features.

Accordingly, as the large sea level signal appears to represent a strengthening of the Zapiola anticyclone, we might expect that this relates to a change in the strength of the eddies in the region. To test this, I calculated the following:

1) Sea level anomaly, averaged over each of the rings centred on the large sea level signal.

2) Eddy kinetic energy, averaged over each of these rings.

3) Rotational eddy force, integrated over the areas enclosed by each of these rings. This is defined as the area integral of the curl of the divergence of the eddy Reynolds stresses, with eddies defined as variations at periods less than 6 months. Assuming no other vorticity sources are present, this should be proportional to the acceleration of the tangential velocity at that radius.

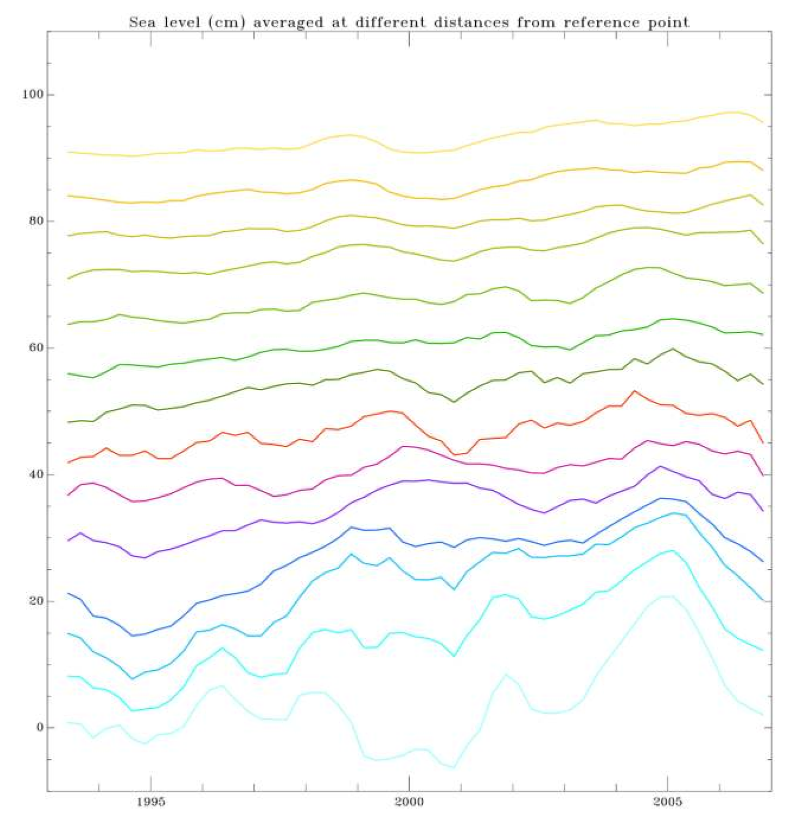
Each of these is smoothed with a running annual mean, to focus on interannual variations.

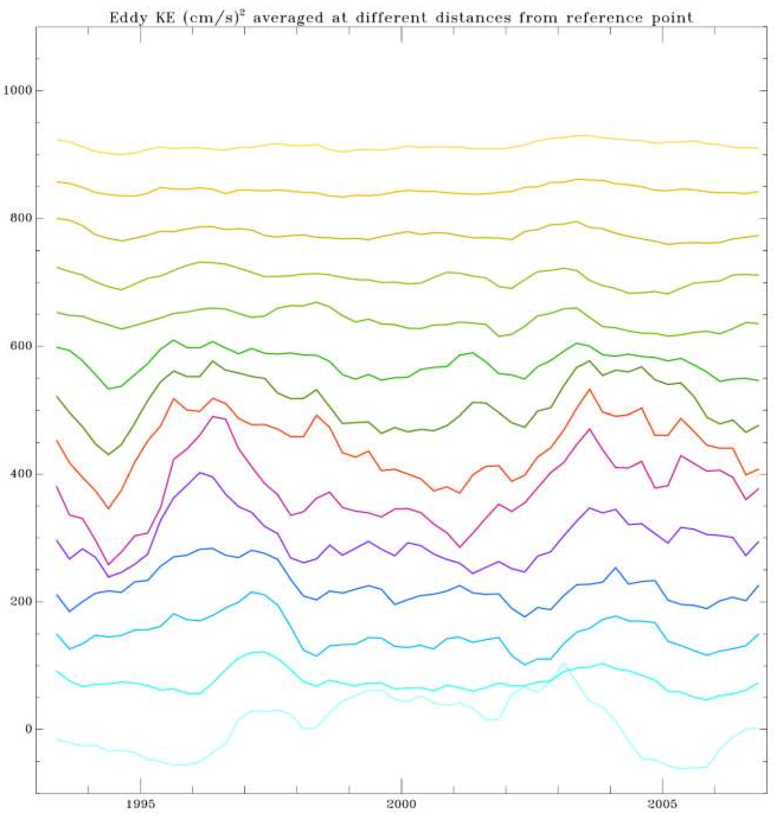
Results

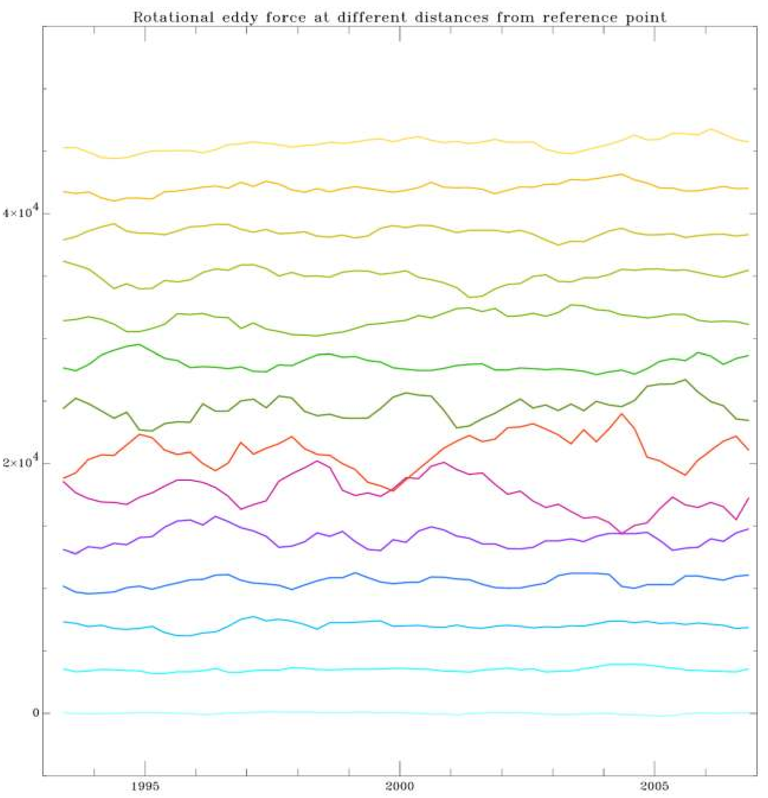
We see that there is significant interannual variation in the sea level signal, and a fair degree of coherence as a function of radius. On top of the increasing trend, there are peaks at about 1999-2000 and 2004-2005.

There are also 2 peaks in the energetic eddy region (radii 5-8 degrees), occuring somewhat before the sea level peaks, in 1996 and 2003).

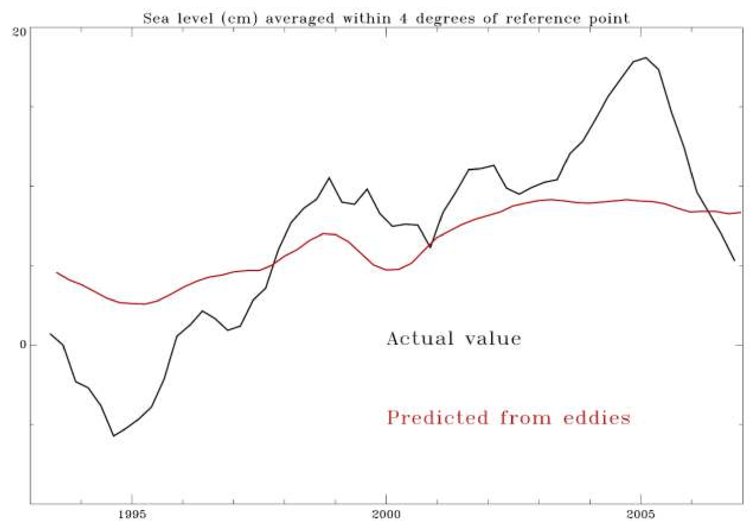
The two peaks can be seen, somewhat more noisily, in the rotational eddy force plot, particularly at a radius of 7 degrees. This suggests that it may be worth making a direct comparison between the eddy forcing and the observed sea level signal.







Results 2. The effect of the eddies on sea level is of the right size, and has the right timing, to account for a significant fraction of the interannual sea level variability.



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