HOW SENSITIVE IS GENERALISED LINEAR ROSSBY WAVE THEORY TO UNCERTAINTIES IN THE DETERMINATION OF THE BACKGROUND MEAN FLOW?

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1.BACKGROUND

- Bathymetry and mean flow significantly affect Rossby wave propagation
- Testing extended Rossby wave theories is challenging due to difficulties with estimating the background mean flow.
- Previous tests have only considered the effect of the baroclinic component of the mean flow, using climatological observations of T and S.
- The barotropic part of the mean flow is critical to explain Rossby wave propagation at high wavenumbers (Tailleux 2012).
- The exclusion of a non-linear term in the Killworth and Blundell (2004) theory which formed the basis for observations/theory comparisons in Maharaj et al. (2007) potentially affects the latter's results at high wavenumbers.
- We seek here to test the sensitivity of the extended theory with high resolution data and compare the results from Maharaj et al. (2007) with the correction to theory proposed by Tailleux (2012)

2. METHOD AND CASE STUDIES

Maharaj et al (2007) examined 8 case studies in the South Pacific of 20 degree longitude length centered on locations a-h which are revisited here. Locations i-k are additional case studies identified as eddy rich regions in recent literature. The sensitivity of the predictions of the extended theory were investigated at these locations using 20 years of ECCO2 data from 1992 to 2012. Temporal and spatial variability were examined.

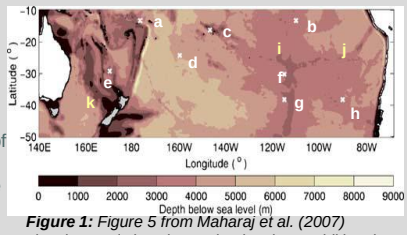

Figure 1: *Figure 5 from Maharaj et al. (2007) showing study locations a-h, plus three additional case studies i-k, superimposed on Smith and Sandwell (1997) bathymetry.*

3a. TEMPORAL VARIABILITY FROM ECCO2

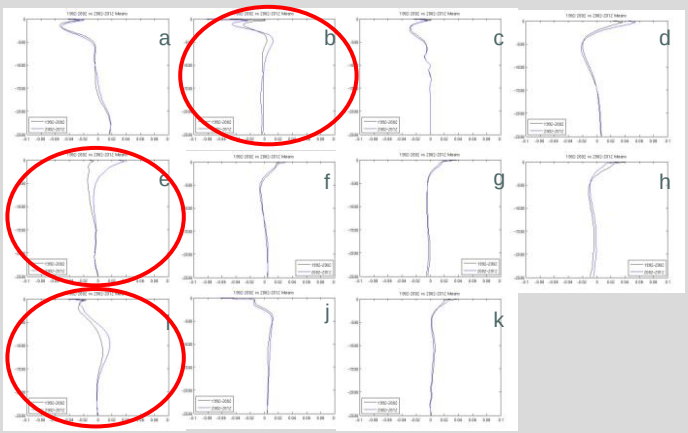

Figure 2: *Panels above illustrate the differences between the time mean zonal velocity (ms^{-1}) between the two decades 1992-2002 versus 2002-2012 in the latitude band centred around each case study. A few examples where temporal differences are evident are highlighted with a red circle.*

5. FURTHER WORK

- Confirm ECCO2 ability to reproduce ocean variability in this region correctly
- Test whether the regions considered are special cases, and whether there may be other instances of mean flows for which the dispersion relations are much more sensitive to errors or variations in the mean flow.
- Advancement of theoretical work on identifying what is the `optimal perturbation' maximising the sensitivity of the phase speeds for a given background mean flow.

3b. SPATIAL VARIABILITY FROM ECCO2

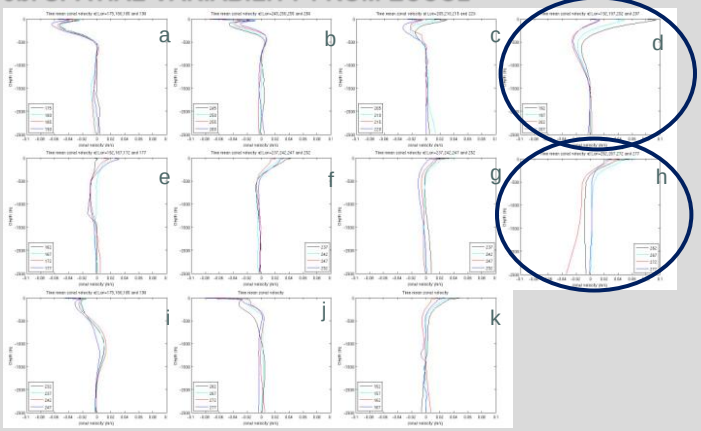

Figure 3: *Vertical profiles of longitudinal variations in zonal mean velocities (ms^{-1}) averaged over the full 20 years at 4 different longitudes, in the latitude band centred around each case study. A few examples where spatial differences are evident are highlighted with a blue circle.*

3c. COMPARISON OF DISPERSION RELATIONS AND W-K SPECTRA

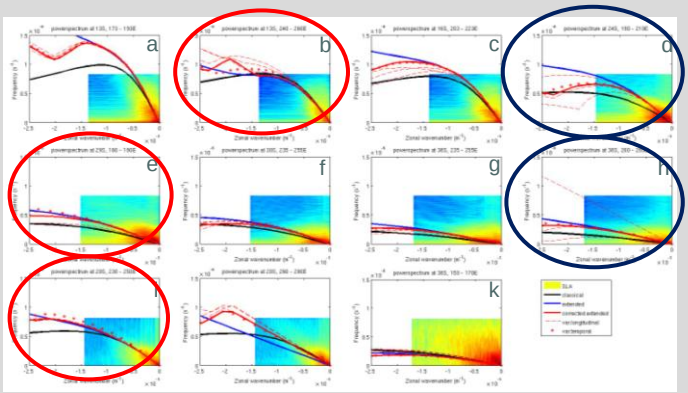

Figure 4: *Representations of the first baroclinic mode projected against w-k spectra from ¼° merged AVISO SSH from 1992-2013. Red and blue circles correspond to Figures 2 and 3.*

4. CONCLUSIONS

The results confirm that the error in Killworth and Blundell (2003) theory identified in Tailleux (2013) dramatically affects the nature of the theoretical dispersion relation at high wavenumbers, but on the cases considered, the differences occur in a part of the wavenumber space that is not observable. In the case studies considered, generally neither the time nor the longitudinal variations of the zonal mean velocity appear to affect inferences based on the temporal mean at the central longitude of the domain considered. **This study confirms that for wavelengths below the Rossby radius, theoretical dispersion relations appear to be relatively insensitive to variations in the mean flow.**

Where the variability seems to become important (i.e. at high wavenumbers) linear assumptions may not apply. Additionally, the standard deviation in the region considered (not shown) appears to be very large compared to the mean zonal velocity, raising the question of the validity of the linear approximation. In regions dominated by westward propagating eddies, (e.g., locations i-k) the eddies can also contribute to the definition of the zonal mean velocity, raising the question of the correct theoretical approach to studying linear Rossby waves.

References:
1.Chelton, D.B., and M.G. Schlax (1996) Global observations of oceanic Rossby Waves. *Science*, 272, 234-238.
2. Chelton, D.B., M.G. Schlax, R.M. Samelson, and R.A.deSzoeke (2007) Global observations of large oceanic eddies. *Geophys. Res. Lett.*, 34, doi:1029/2007GL03812
3. Chelton D. B.,M.G. Schlax, and R. M. Samelson (2011) Global observations of nonlinear mesoscale eddies, *Progr. in Oceanogr.*,91 (2), 167–216
4. Killworth, P.D., and J.R. Blundell (2004) The dispersion relation for planetary waves in the presence of mean flow and topography. Part I: Analytical theory and one-dimensional examples. *J. Phys. Oceanogr.*, 34, 2692-2711.
5. Killworth PD, Blundell JR (2005) The dispersion relation for planetary waves in the presence of mean flow and topography. Part II: two-dimensional examples and global results. *J. Phys. Oceanogr.* 35, 2110–2133.
6. Maharaj, A.M et al. (2007) An evaluation of the classical and extended Rossby wave theories in explaining spectral estimates of the first few baroclinic modes in the Southern Pacific ocean. *Ocean Dyn.*, doi 10.1007/s10236-006-0099-5
7. Smith WHF, Sandwell DT (1997) Global sea floor topography from satellite altimetry and ship depth soundings. *Science,* 277 (26):1956–1962
8. Tailleux, R. (2012): On the generalized eigenvalue problem for the Rossby wave vertical velocity in the presence of mean flow and topography. *J. Phys. Oceanogr.*, 42, 1045-1050.

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