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Interactive comment on "Antarctic Circumpolar Transport and the Southern Mode: a model investigation of interannual to decadal time scales" *by* C. W. Hughes et al.

C. W. Hughes et al.

cwh@liv.ac.uk

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Reviewer's comments repeated, replies in bold.

p. 2086. lines 14–16. Abstract. The end of the abstract is not easily interpreted. I would recommend rewriting the sentence that says, "The role of density variations results in a sea-level signal, which, although reflecting transport changes at all time scales, has a ratio of sea level to transport which becomes larger at longer time scales." This may need to be split into two sentences in order to clarify the meaning for readers.

Sentence split up and changed to read: "Circumpolar sea level and transport are related at all investigated time scales. However, the role of density variations

results in a ratio of sea level change to transport which becomes larger at longer time scales."

p. 2086. line 21. In lieu of "errors", the text should probably say "uncertainties".

Changed "errors of between" to "an uncertainty lying between"

p. 2090. line 1. Clearer discussion of the definition differences between transport anomaly T' and depth-integrated transport anomaly ψ' would be helpful. On first reading, I had trouble deciphering whether this was a discussion of depth-integrated ψ' (with ψ' perhaps being equivalent to T') or whether ψ' itself was the depth-integrated transport anomaly.

We have changed T' to $T'(z)$ to make clear its depth dependence, and added an explicit definition of ψ' as the depth-integral of T' to clarify this.

p. 2090. lines 6–7. "…the current always flow at the same effective average value of f". This sentence should be rewritten for clarity. Most readers familiar with GFD are likely to be able to decipher this eventually, but the text appears to imply that f stands for "flow" rather than the latitude-dependent Coriolis parameter.

We have changed this sentence to read: "To be truly general, we should also note that this assumes that the Coriolis parameter, f, averaged over the latitudinal distribution of the current is constant in time"

p. 2090. lines 9–28. I think that if you were giving a seminar on this material, you would probably want to show a schematic diagram illustrating the differences in geostrophic currents for deep and shallow parts of the continental slope. Similarly, readers of this manuscript would probably benefit from a schematic meridional section showing where pressure is calculated.

We have added a new schematic figure (Figure 1) to illustrate how barotropic flows on the continental slope lead to a surface-intensified meridionally-integrated flow as described in this paragraph, and to highlight where p_S and

p_N are calculated.

p. 2090 line 24. “lower part of the slope” would be clearer as “deeper part of the slope”

Changed as suggested.

p. 2090 line 25. “upper part of the slope” would be clearer as “shallower part of the slope”.

Changed as suggested.

p. 2092. line 26. “which is as high as is possible with these correlation coefficients.” Please clarify the calculation needed to reach this conclusion.

For a given correlation coefficient, the largest fraction of variance which can be explained is given by the square of the correlation coefficient. This has now been noted.

Figure 2 (top panel). The numbers 85in the legend.

Description of the numbers in the figure has now been added in the caption. They refer to percentage of variance explained, and are consistent with the numbers in the text.

Figure 3. For power spectral density and phase, it would be good to show uncertainties. The calculation for the two gain estimates doesn’t seem to be explained. If one represents a regressed on b and the other represents b regressed on a, I would have thought they would have reciprocal relationships. Or have they been readjusted to have the same values?

Error estimates have been added to the figure as suggested (Fig. 2 below). Also, the caption has been changed to make it clear that what is plotted is a/b in both cases.

Figure 4. What are the statistical uncertainties in these regressions? I’m not sure of

the reason to show regression of p on transport as well as regression of transport on p. A more usual approach is to use weighted orthogonal regression, which is able to take into account the separate uncertainties of p and transport to produce a single robust estimate of the regression coefficients.

Performing a weighted orthogonal regression relies on knowing how much noise is associated with each time series, which we do not know. The two regressions we perform represent the most extreme possible versions of weighted orthogonal regression, with the noise all in one or all in the other time series. Any other weighting would produce results which lie between the two values we calculate.

We have experimented with a number of ways of displaying this information, and found that trying to include error estimates makes the plots far too cluttered to read. A good feel for the errors can be obtained by looking at the difference between the two fits plotted, which shows that the behaviour at depth is generally less well-constrained than that near the surface. A detailed quantification of the errors is not needed to justify the point which is being made by this figure.

Figure 6. What are the statistical uncertainties for these spectra? Do the different cases differ by more than their formal statistical uncertainties?

An error bar for the spectral estimates has been added (Figure 3 below). It is important to note though, that this is the error estimate applying to a single frequency. The errors will reduce on band averaging. Thus, although the pink curve in the bottom-right panel is not “significantly” below the blue curve at any one frequency, the fact that it lies below the blue curve over a wide frequency range is sufficient to ensure that the corresponding change in overall percentage of variance explained (from 84% to 90%) is significant.

Complete caption for Figure 1:

Schematic showing how two uniform, depth-independent eastward flows (shown as blue-shaded regions A and B) produce a surface-intensified flow when integrated meridionally across the currents. The left hand panel represents a meridional section, with Antarctica (black) on the right, and the three right hand panels show the meridional integrals of currents A, B, and $A+B$ as a function of depth. Cyan illustrates how pressure varies on any horizontal surface, and the green and red lines show where pressures p_N and p_S are measured.

Complete caption for Figure 2:

Spectra and cross-spectral analyses based on time series from the 1/4 degree model. Top left: power spectra for depth-averaged southern boundary pressure (blue), the analogous sea level (sub-surface pressure) time series (red), the difference sub-surface minus bottom pressure (pink), and Drake Passage transport divided by -3.69 Sv mbar^{-1}. Other panels show the squared coherence, gain, and phase lag between pairs of these time series as described in the legends. Orange lines are for guidance and show the offsets applied to the different curves, as well as the annual and semiannual frequencies and, in the case of squared coherence, the value representing significance at the 95% level. The phase plots include two sigma error bounds, and the power spectra plot includes a scale bar for the uncertainty (95% and 99%) to be applied at each individual frequency (band averages have smaller errors). Two versions of the gain are shown, representing ratios a/b derived from regressions of a on b, and from b on a, where a and b are the two time series. When both time series contain noise, the true relationship between them tends to lie between these two estimates.

Complete caption for Figure 3:

Power spectra associated with variations in transport through Drake Passage, south of Africa, and south of Australia, from the 1/4 degree model. The top left panel shows the spectrum of Drake Passage transport (red), that of the difference between Drake Passage transport and transport south of Africa (black), and that of the difference between transports south of Africa and Australia (blue). Other panels show the spectrum

of transport through each section (red), of the residual after subtracting the transport accounted for by southern boundary pressure (blue) and of the residual after subtracting the transport accounted for by southern boundary pressure and the corresponding northern boundary pressure (black). Pink curves are like the black curves but use a northern boundary pressure from a different section. Orange lines are for guidance only and show representative spectra separated by factors of ten, together with the annual and semiannual frequencies.The Drake residual plot includes a scale bar for the uncertainty (95% and 99%) to be applied at each individual frequency (band averages have smaller errors).

Interactive comment on Ocean Sci. Discuss., 10, 2085, 2013.

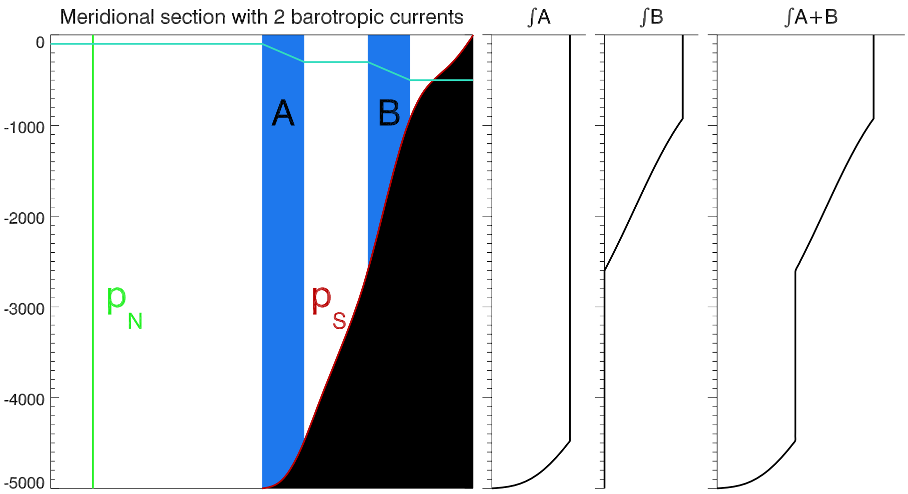

Fig. 1. Schematic showing how two uniform, depth-independent eastward flows (shown as blue-shaded regions A and B) produce a surface-intensified flow when integrated meridionally across the currents.

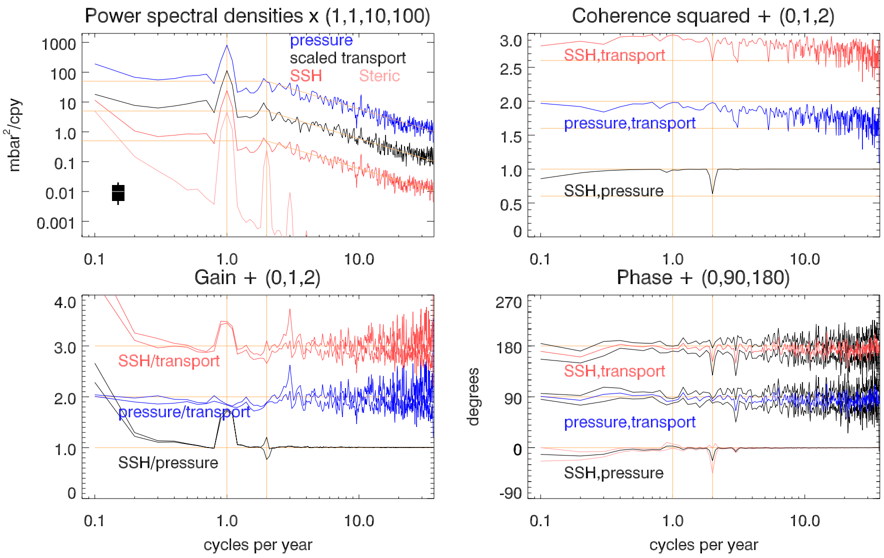

Fig. 2. Spectra and cross-spectral analyses based on time series from the 1/4 degree model.

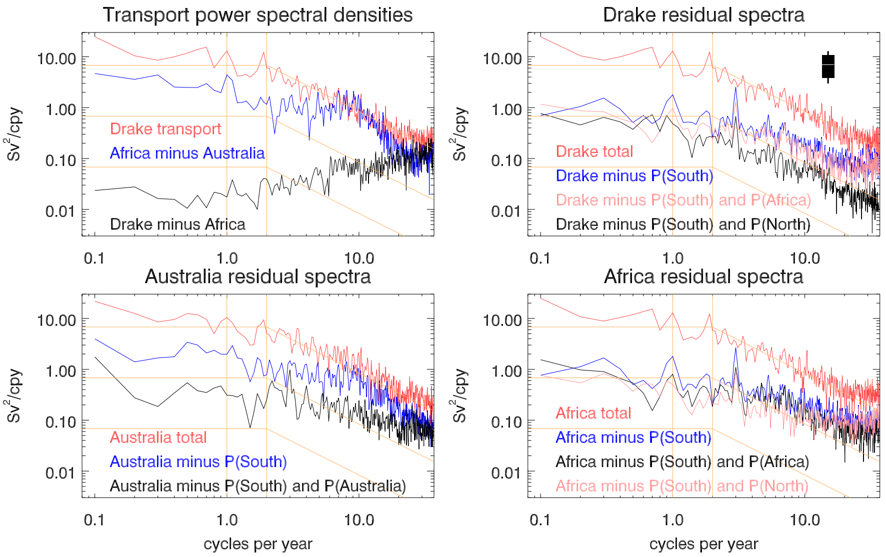

Fig. 3. Power spectra associated with variations in transport through Drake Passage, south of Africa, and south of Australia, from the 1/4 degree model.