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Interactive comment on “On the role of domain aspect ratio in the westward intensification of wind-driven surface ocean circulation” *by* Kaushal Gianchandani et al.

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This manuscript revisits the classical wind-driven gyre models of Stommel (1948) and Munk (1950). After non-dimensionalising the underlying equations and writing down the analytic solutions, the authors derive estimates of the frictional boundary current transports. They conclude that the transport scales with the linear drag coefficient in the Stommel model, but not with the lateral viscosity ("damping factor") in the Munk model. They also comment on the scaling of the boundary current transports with the domain aspect ratio.

While it was an enjoyable exercise to revisit the general solutions of these classical

models, I'm afraid that I am unable to recommend the manuscript for publication as I believe the results are misleading, at least in the parts of parameter space of most relevance to the ocean (and it is debatable that these models are of any quantitative relevance beyond their substantial conceptual value).

Major comment:

The solution (3) to the Stommel model is indeed the most general, but this form rather obscures the essential physics in the physically-relevant limit of small α (i.e., the boundary current width is much smaller than the basin width). The authors erroneously state that in this limit, the solution becomes linear in x and can satisfy just one boundary condition. However, a more careful expansion of the exponential terms leads to a more complete solution.

I prefer to see this by assuming α is small and hence $\partial^2/\partial x^2 \gg \partial^2/\partial y^2$. Thus (1) is well approximated by

$$\alpha \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial \psi}{\partial x} \approx \sin(\pi y),$$

the solution to which is

$$\psi \approx \left(x - 1 + e^{-\alpha x}\right) \sin(\pi y).$$

This solution consists of the Sverdrup (1947) solution in the basin interior – the first two terms in brackets on the right-hand side – and a Stommel (1948) western boundary current correction – the third tern in brackets on the right-hand side.

Mathematically, the dropping of the $\alpha \partial^2\psi/\partial y^2$ term in (1) means that the particular integral is instead formed by balancing $\partial\psi/\partial x$ against the wind stress curl on the right-hand side. However, the same result can be obtained through a careful treatment of the limit of small α in the two exponential terms in the more general solution.

The implications are that the western boundary current transport is:

- approximately equal (and opposite) to the Sverdrup gyre transport;

- independent of the linear drag coefficient, α;
- independent of the basin aspect ratio, δ.

These conclusions are at odds with those stated in the manuscript.

I do accept that in the case that α becomes larger, the boundary current transport, and indeed the entire nature of the solution changes, but it is hard to see what relevance this has to a large-scale ocean basin.

Minor comments:

1. I don't understand why the authors estimate the boundary current transport rather than simply calculate the maximum value of the streamfunction which gives the actual western boundary transports. If I follow correctly, the authors also invoke the Stommel scaling for the boundary layer width, but that only holds in the low α limit.

2. It might be helpful to many readers to state the original equations, before non-dimensionalising.

3. γ is the non-dimensional magnitude of the wind stress curl, not the wind stress.

4. In figure 1(d), why is the eastern boundary condition not satisfied?

5. I'm really struggling with the numerical and theoretical boundary current transport scalings in figure 3, especially the upper panel for the Stommel gyre. I understand that the authors will state that these results support their conclusions, but they are at odds with the basic dynamics of the low α limit (see major comment above). The explanation in lines 194-189 of what has been done to obtain the theoretical scalings, and why, is confusing (to me at least).

6. Regarding figure 4, are you seriously suggesting that $\alpha = 0.5$ is an appropriate value for the East Australian Current? This would imply the failure of geostrophy, for example.

7. Following on from point 6, there are numerous other processes that are likely in influence the width of real world western boundary currents ahead of linear bottom drag and lateral friction. These include relative vorticity (Fofonoff, 1954; Charney, 1955), stratification (the deformation radius emerges as a natural length scale), bottom topography (e.g., Hughes and de Cuevas, 2001), eddy fluxes (e.g., Eden and Olbers, 2010).

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