Response to reviewer 2

We thank the referee for their useful feedback on the manuscript “Nonlinear dynamics of time-variable slope circulation”, helping us to improve the manuscript. Below, we respond point-by-point to the individual comments.

Comment:
-Although the main motivation are the Nordic Seas and the Arctic, the results are broadly applicable to any closed f/h basin. I Think this is worth mentioning.

Response:
We agree that this is worth mentioning. We will add this point to the introduction and conclusion.

Comment:
-What happens beyond at larger Rossby numbers, i.e., can the two perspectives be shown to always be equivalent, or does this just happen in the QG regime? What does that mean for more ageostrophic flows such as those in steeper canyons? Worth discussing.

Response:
The reviewer is right. The similarities of the two perspectives are only strictly valid in the limit of small Rossby numbers and small topographic deviations. In the revised manuscript we stress this point both where the concept is introduced in the theory section and where it is examined in the results section. Essentially, what we find is that the QGPV flux perspective is useful and that the approximations made are good except, perhaps, over the steepest parts of the slope.

Comment:
Line 162: Would be good to reference the animations here too.

Response:
Agreed. A reference to the supplementary material will de added.

Comment:
Figure 4b, line 317: Is the nonlinear constant prograde offset in Figure 4b sensitive to t = 0 being at the beginning of a prograde forcing period instead?

Response:
The analytical estimates are integrated from the beginning of the spin-up. After some time, approximately given by H/R, the estimates lose memory of the initial state. After that, the analytical estimates are identical cycle to cycle, and we plot the last 128 days of the simulations. We then shift t=0 to be at the beginning of a prograde forcing period for convenience of presentation.
So setting t=0 at the beginning of a retrograde forcing period does not affect the offset. We will update the manuscript text to clarify that both the numerical and analytical solutions are analysed after the initial spin-up and that the results are insensitive to the choice of t=0.

Comment:
Line 344, Figures 5-7's y-labels and elsewhere: Maybe use "isobath" or "local depth" instead of "depth".

Response:
We agree that the y-labels can be more precise. On the basis of other review comments as well, we have chosen to use “y” as the y-labels, and then specify in the caption that this y is the mean y-position for each isobath.

Comment:
Lines 375-376: Does the time of maximum circulation at different isobaths scale with the frictional timescale H/R?

Response:
To test this, we added a line showing H/R in Figure 5. The time of maximum circulation scales well with H/R for the long forcing period, where the forcing period is much longer than the frictional damping timescale. However, we see that this is not the case at depth for the short forcing period, where the damping time scale is longer than the forcing period. We will include the updated figure in the manuscript, and update the text to reflect this behaviour.

Comment:
Line 448-449: Worth discussing why in 1-2 sentences. Also, why is there a preference for modes 2 and 3 instead of mode 1? Is this sensitive to the geometry? The comment involving Zhang and Lentz (2017) in the section's last paragraph seems to be a possible explanation, you could move that statement here.

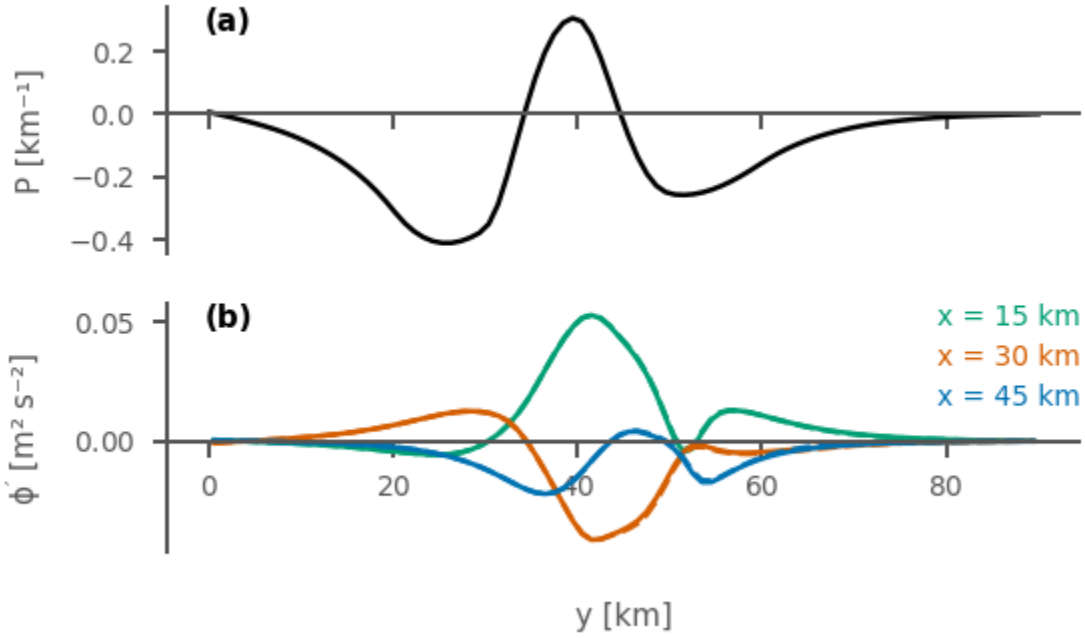
Response:
This is a good point. We will move the comment involving Zhang and Lents (2017) up, and included it in the discussion.

Comment:
Line 458-459: You might also get some insight by looking at phase averaged composites (i.e., averaged in phase bins).

Response:
Thank you for the helpful suggestion. We have now computed phase-averaged composites by averaging the fields at the same relative time within each forcing cycle across multiple cycles. The resulting patterns are almost identical to those obtained from our original single-cycle analysis, reflecting the highly repeatable, idealized nature of the experiments. Because this additional analysis does not change the results, discussion, or conclusions, we have retained the original figure and description in the manuscript.

For reference, we include a figure showing the results of both approaches below. The solid lines correspond to the original method, while the dashed lines show the phase-averaged

composites:



Comments:

Minor edit suggestions/typos

Line 63: i.e. -> e.g.

Line 79: he -> Holloway (1987)

Line 336: fluxes -> flux

Line 347: momentum term signify -> momentum terms signifies

Line 487: does -> do

Line 503: generates -> generate

Line 503: alter -> alters

Line 551: is -> be

Line 604: Figure A1 show -> Figure A1 shows

Response:
Thanks. All are fixed.