Review Response

I. REVIEWER 2

This is a good theoretical study explaining the fundamental dynamics of the Ferrel cell, which is largely driven by baroclinic eddies in the mid-latitudes. I expected that there might be a simple mathematical model capable of explaining the Hadley and Ferrel cells, including eddy fluxes, and this is one of a kind. I read this manuscript through an introduction from my friend, who often discussed it, and I wish to leave several comments.

We thank the reviewer for the careful reading of the manuscript and the useful comments.

This study successfully presents an idealized model for the eddy-driven Ferrel cell using simple parameterizations of eddy fluxes. I love this part, particularly Figs. 2 and 3. In addition, the analytical solutions are reasonable and could provide useful insights into understanding the behavior of Ferrel (even Hadley) cells. The derivation is also well supported by previous literature and is worth publishing as an academic asset, hopefully in a journal that appreciates fundamental theory.

We aim to strike a balance between realistic representation and simplicity to gain deeper theoretical insight. While theoretical research holds significant value, it often requires sacrificing a certain degree of realism. Thank you for your kind feedback.

I have also read the other scientist's comment. I agree a bit that the mathematical derivation is somewhat complex. The derivations until Eq. 11 are very clear and beautiful (may no become simpler than that). However, Section 2.4 (boundary layer) takes up too much energy in the paper, while it is not a main topic. What about first presenting the solution with w=0 boundary, and then updating it by simply adding the Ekman layer? In my opinion, the fundamental dynamics of the Ferrel cell still emerge even without the Ekman boundary.

In addition, readers could follow the paper better if Section 2.4. were moved to the Appendix. In the main text, authors may simply use the results for the analytic solution?

Response:
The key issue with imposing the boundary condition $w = 0$ at the surface is that it leads to vanishing surface westerlies. While the overall structure of the Ferrel cell is not significantly altered by this simplified boundary condition, the absence of surface westerlies is a nontrivial concern. Some researchers consider surface westerlies—analogous to surface easterlies in the tropics—as a fundamental component of the mid-latitude circulation. Therefore, we chose to incorporate the influence of the planetary boundary layer in the surface boundary condition. Without addressing this, solving the main PDE would be considerably simpler and more straightforward.

Changes in the text:
For improved clarity, we will present both cases in the revised manuscript for comparison and move parts of the original section 2.4 to an appendix.

For another comment, PV flux mostly gives a clear view for the eddy-mean interactions (I also love PV dynamics). However, for this topic, the heat/momentum fluxes-based argument could be much easier for readers, because the Ferrel cell is not explicitly shown in PV flux (and extended TEM) arguments. Particularly, the authors are likely considering a steady-state solution and non-acceleration condition, where PV flux is zero... The indirect circulation (Ferrel cell) balances with heat flux, but is not shown in PV flux (or EP-flux divergence) as it is canceled by momentum flux.

Thank you very much for your accurate and insightful interpretation of this research and its connection to the TEM formalism. Conducting this study also provided us with an opportunity to revisit and reevaluate the implications of the TEM framework and the potential vorticity (PV) flux perspective.

Is Boussinesq approximation too simple? It could be useful for education as it removes 1/H (but I think authors handle this part pretty well in the analytic solution)

This is an excellent suggestion for future work.

118 Rossby number reversed? $\sqrt{(gh)}/f$?

You are right. We will fix it in the revised manuscript.

These are just random thoughts. Hope this helps a bit.

Thanks for your insight and encouragement.