Comments on "Analysis of Migrating and Non-Migrating Tides of the Extended Unified Model in the Mesosphere and Lower Thermosphere" by Griffith and Mitchell (Manuscript # angeo-2021-21)

This modeling study analyzes and validates the amplitude of diurnal and semidiurnal atmospheric tidal perturbations in the Extended Unified Model (ExUM). The authors find that the temporal and spatial distribution of diurnal and semidiurnal migrating and non-migrating tidal amplitudes in the ExUM compare favorably to other whole atmosphere and upper atmosphere models, as well as satellite observations on seasonal time scales. This paper also examines day-to-day variations in tidal amplitudes and finds that they can be of the same magnitude as the seasonally-derived amplitudes. The manuscript is well-written, well-organized, and suitable for publication after a few remaining points are addressed.

Original Reviewer Comment: *There is very little discussion throughout the manuscript about the phases of the different tidal components produced in the model. The manuscript would be greatly enhanced if there were some phase comparisons between the tidal phases produced in ExUM and other models, as well as observations.*

> **Response:** *We agree that phases are an important consideration. However, we feel that this would make the paper too long, adding many more figures. This is an interesting topic that will be addressed in future studies of the ExUM. We have added a footnote to this effect in the paper (Page 5).*
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> Text added to manuscript: "Note that the tidal phases are also an important consideration. However, these will not be presented here to keep the paper at a reasonable length. This is an interesting topic that will be addressed in future studies of the ExUM.

New Reviewer Comment: I agree that keeping the paper at a reasonable length is important. However, I must push back on this boilerplate response. In my opinion, there must be some discussion about the tidal phases, especially given the lack of dissipative mechanisms (i.e., lack of eddy and molecular diffusion) in the MLT region in this version of ExUM. It is extremely important to know where the tides are no longer vertically-propagatinedg and or dissipat versus generated in-situ. I strongly suggest the authors' provide at the very least some comments and additional text on the most notable tidal components, e.g., DW1, DE3, SW2, SE3, etc phases. Simply not looking and or reporting on the tidal phases is neglecting one of the two characteristics that make a wave, a wave.

Original Reviewer Comment: *While the authors discuss how one major source of tidal dissipation is handled (ion drag, which is not included since the model top is at 120 km), there is little to no discussion about how the other major tidal dissipation processes including eddy and molecular diffusion are handled in the model. Were these discussed in previous papers? If so, one or two sentences of how these types are handled would suffice. If not there needs to be some discussion about how these things are handled, parameterized, in the dynamical core in the ExUM. A follow onto this question would be how are the specific heats handled in ExUM? Are they height varying? Please elaborate on this as well.*

Response: *We agree that additional clarification is required here, and it has been added to the text (L153 - L155). Eddy and molecular diffusion are not used in the MLT in this version of the ExUM (the paper by Griffin et al. (2018) (below) suggests this has its most dominant effect above 150 km). The specific heats are also not height varying and are just the standard values for air. This is a reasonable assumption up to the turbopause which is the primary region of interest in this paper. These are all additions which can be made to improve the model in later versions, but this paper represents a first look at tidal components from the newly extended Unified Model.*

Text added to manuscript: Other tidal dissipation processes such as eddy and molecular diffusion are not included in the MLT in this version of the ExUM (Griffin and Thuburn (2018) suggest that these effects become important at around 150 km). Furthermore, the specific heats are not height varying, which is a reasonable assumption up to the turbopause which is the primary region of interest in this study.

New Reviewer Comment: Eddy and molecular diffusion are certainly important below 150 km, especially eddy diffusion, which is dominant between 90-105 km. Specifically the turbopause is defined as where the time scale of molecular diffusion becomes shorter than that of eddy diffusion (Schunk and Nagy, 2009). This has been known and shown for some time in the MLT and thermospheric communities. If you say molecular diffusion does not become dominant up until about 150 km, that would be more correct, although I think a more accurate altitude would be between 110-120 km. Below I have provided just a few references for the authors' so that these statements can be revised. Stating they are not included in the model is fine, but then one wonders how are the tides dissipated in ExUM. Stating they are not important until 150 km is not what is generally accepted in the MLT and thermospheric communities. Please revise these statements with appropriate referencing to be more accurate and completely describe how the tides are dissipated in ExUM.

Eddy and Molecular Diffusion/Tidal Dissipation Reference(s) (and references therein):

Jeffrey M. Forbes, Maura E. Hagan,
Diurnal propagating tide in the presence of mean winds and dissipation : a numerical investigation,
Planetary and Space Science,
Volume 36, Issue 6,
1988,
Pages 579-590,
ISSN 0032-0633,
https://doi.org/10.1016/0032-0633(88)90027-X.
(https://www.sciencedirect.com/science/article/pii/003206338890027X)

Qian, L., Solomon, S. C., & Kane, T. J. (2009). Seasonal variation of thermospheric density and composition. Journal Of Geophysical Research-Space Physics, 114, 15 pp. doi:10.1029/2008JA013643

Forbes, J. M., Zhang, X., Maute, A., & Hagan, M. E. (2018). Zonally symmetric oscillations of the thermosphere at planetary wave periods. Journal Of Geophysical Research: Space Physics, 123, 4110-4128. doi:10.1002/2018JA025258

Forbes, J. M. and R. A. Vincent, 1989: Effects of mean winds and dissipation on the diurnal propagating tide: An analytical approach. Planet. Space Sci., 37, 197–209.

Schunk, R., & Nagy, A. (2009). *Ionospheres: Physics, Plasma Physics, and Chemistry*. Cambridge: Cambridge University Press. Doi: 10.1017/CBO9780511635342

Turbopause Reference(s):

Zhao, X. R., Sheng, Z., Li, J. W., Yu, H., & Wei, K. J. (2019). Determination of the "wave turbopause" using a numerical differentiation method. *Journal of Geophysical Research: Atmospheres*, 124, 10592– 10607. https://doi.org/10.1029/2019JD030754.