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Interactive comment on "Temperature decadal trends, and their relation to diurnal variations in the lower thermosphere, stratosphere, and mesosphere, based on measurements from SABER on TIMED" *by* Frank T. Huang and Hans G. Mayr

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Authors' response to referee#1 concerning manuscript titled "Temperature decadal trends, and their relation to diurnal variations inthe lower thermosphere, stratosphere, and mesosphere, based on measurements from SABER on TIMED"

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Discussion paper

by Frank T. Huang and Hans G.Mayr

ANGEOD Interactivecomment Discussion paper Ann. Geophys. Discuss.,https://doi.org/10.5194/angeo-2020-63-RC1, 2020

Interactive comment on “Temperature decadaltrends, and their relation to diurnal variations inthe lower thermosphere, stratosphere, and mesosphere, based on measurements fromSABER on TIMED”

Anonymous Referee #1 Received and published: 6 November 2020

1) Refereee #1: This manuscript presents a study on the relationship between diurnal variations in the temperature and its decadal trends from the stratosphere to the lower mesosphere, based on SABER measurements on the TIMED satellite. This study is useful because it is important to understand the evolution of temperature in the middle and upper atmosphere in relation to global warming at the surface, but the analysis of satellite observations can be biased by their non-uniform local solar time. Most satellites are sun-synchronous, always measuring at two fixed local times for a given latitude. In addition, some of these satellites are affected by local time drifts during their lifetime. SABER is the only satellite providing temperature data at all local times in the mesosphere and the lower thermosphere, making it possible to separate the contribution of diurnal tides in temperature evolution. This study indicates that the estimation of temperature trends is not only biased by local time sampling but also by trends in the amplitude and phase of thermal tides. This is a new result that deserves to be published in Annales Geophysicae. However, I recommend to improve the content and the organization of the manuscript to make it more convincing as explained below.

2) Referee #1: The separation between diurnal variations and the long term evolution in temperature measurements by SABER is made using a least squares fit of a two dimensional Fourier series. This method is explained in details in Huang et al. (2010) and only very shortly described in the present paper. Such a detailed description is not

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needed in the present paper. However it would be useful for the readers to give a more complete synthesis of the method. In particular some parameters have to be fixed in the analysisas for instance the time length of the 2-D Fourier series, fixed to one year in Huang etal. (2010). Is it the same in the present study? It is important to know these parameters to understand the signification of decadal trends in mean temperature and in thermal tides.

Authors' response to 2):

We have added the following to Section 2.1 of the manuscript, as follows:

"Due to the orbital characteristics of TIMED, SABER measurements provide the potential to estimate the variations of temperature as a function of the 24 hours of local time that data from other satellites generally do not provide. The local times of the SABER measurements decrease by about 12 min from day to day, and it takes 60 days to sample over the 24 hours of local time, using both ascending and descending node data. Although this provides essential information over the range of local times, over 60 days, variations can be due to both local time and other variables, such as season. Diurnal and mean variations are embedded together in the data and need to be unraveled from each other to obtain more accurate estimates of each. Our algorithm is designed for this type of sampling in local time and provides estimates of both diurnal and mean (e.g., annual, semiannual, seasonal oscillations) variations together in a consistent manner. At a given latitude and altitude for zonal mean data over a period of a year, the algorithm performs a least squares estimate of a twoâĂŘdimensional Fourier series, where the independent variables are local solar time and day-of-year, and variations as a function of local time and day-of-year are generated. The fundamental Fourier period in day-of-year is 365 days, and that for local time is 24 hours. For subsequent months and years, the initial analysis serves as a sliding data window. To find subsequent monthly values, this window is advanced by one month, and the algorithm is applied again. Further details can be found in Huang et al.,[2010a]."

3): Referee #1: The analysis provides the characteristics of the tides and their evolution over time.There is a detailed discussion of comparisons of temperature trends inferred from SABER data with published results from terrestrial lidars and AMSU satellites for several fixed local hours. These comparisons are very interesting and show a good general agreement, but results on the decadal evolution of tidal parameters (amplitude and phase) are not presented, except for the example given in Figure 2. I don not know any published results on the evolution of tidal parameters in the middle atmosphere and this would be a very valuable result.

Authors' response to 3): We have added an Appendix to the manuscript, which contain additional plots of tidal trends, corresponding to Figure 2b of the manuscript. The Appendix is included below here also. The narrative of the Appendix is as follows: "We present additional figures, corresponding to Figure 2 (b), of temperature diurnal amplitudes and phases over more altitudes (20, 40, 60, 80, 90 km) and latitudes (0âĄř, 40âĄř). The left panels (a) of each figure show temperature tidal diurnal amplitudes and phases at various altitudes and the Equator, while the right panels (b) correspond to the left panels but at 40âĄřN latitude. In each panel, the left axis scale and black line denote tidal diurnal amplitudes (K), while the right axis scale and red line show the diurnal phases (hr of maximum value). The displayed trend values are obtained from a simple least squares straight line fit. The larger variations generally reflect modulation of the tides by the quasi biennial oscillation (QBO). This has been discussed in models (Mayr and Mengel, 2005) and other SABER data (Forbes et al., 2008). Although the figures may give additional insight to the nature of the trends, there are caveats to be considered. We note that the semidiurnal amplitudes and phases can also be significant. We have derived a total of five Fourier components, and our numerical results reflect all 5 Fourier terms. Because both amplitudes and phases exhibit trends, they need to be considered in parallel, in tandem, and this is difficult to discern, qualitatively. In addition, because the trends are generally small, it would be difficult to arrive at conclusions."

4): Referee #1: Concerning the organisation of the paper, it is rather unusual to give some conclusions in the introduction section as it is done in lines 81-89. This part should be moved to the summary and conclusion section.

4) Authors response: We have removed the paragraph.

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5) Appendix

Please see supplement file for figures.

We present additional figures, corresponding to Figure 2 (b), of temperature diurnal amplitudes and phases over more altitudes (20, 40, 60, 80, 90 km) and latitudes (0âĄř, 40âĄř). The left panels (a) of each Figure show temperature tidal diurnal amplitudes and phases at different altitudes and the Equator, while the right panels (b) correspond to the left panels but at 40âĄřN latitude. In each panel, the left axis scale and black line denote tidal diurnal amplitudes (K), while the right axis scale and red line show the diurnal phases (hr of maximum value). The displayed trend values are obtained from a simple least squares straight line fit. The larger variations generally reflect modulation of the tides by the quasi biennial oscillation (QBO). This has been discussed in models (Mayr and Mengel, 2005) and other SABER data (Forbes et al., 2008). Although the figures may give additional insight to the nature of the trends, there are caveats to be considered. We note that the semidiurnal amplitudes and phases can also be significant. We have derived a total of five Fourier components, and our numerical results reflect all 5 Fourier terms. Because both amplitudes and phases exhibit trends, they need to be considered in parallel, in tandem, and this is difficult to discern, qualitatively. In addition, because the trends are generally small, it would be difficult to arrive at conclusions.

Figure A1. Left panel (a): Temperature tidal diurnal amplitudes and phases at 20 km, equator; left axis scale: black line: tidal diurnal amplitude (K); right axis scale: red line: diurnal phase (hr of maximum value). Right panel (b): as in left panel but at 40âĄřN latitude.

Figure A2. Left panel (a): Temperature tidal diurnal amplitudes and phases at 40 km, equator; left axis scale: black line: tidal diurnal amplitude (K); right axis scale: red line: diurnal phase (hr of maximum value). Right panel (b): as in left panel but at 40âĄřN latitude.

Figure A3. Left panel (a): Temperature tidal diurnal amplitudes and phases at 60 km, equator; left axis scale: black line: tidal diurnal amplitude (K); right axis scale: red line: diurnal phase (hr of maximum value). Right panel (b): as in left panel but at 40âĄřN latitude.

Figure A4. Left panel (a): Temperature tidal diurnal amplitudes and phases at 80 km, equator; left axis scale: black line: tidal diurnal amplitude (K); right axis scale: red line: diurnal phase (hr of maximum value). Right panel (b): as in left panel but at 40âĄřN latitude.

Figure A5. Left panel (a): Temperature tidal diurnal amplitudes and phases at 90 km, equator; left axis scale: black line: tidal diurnal amplitude (K); right axis scale: red line: diurnal phase (hr of maximum value). Right panel (b): as in left panel but at 40âĄřN latitude.

Please also note the supplement to this comment:
https://angeo.copernicus.org/preprints/angeo-2020-63/angeo-2020-63-AC1-supplement.pdf

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