Review of the paper entitled "Interannual variability of winds in the Antarctic mesosphere and lower thermosphere over Rothera (67°S, 68°W) in radar observations and WACCM-X" by Noble et al.

The authors present the long-term interannual variability of zonal and meridional winds in the mesosphere and lower thermosphere (MLT) mainly from meteor wind radar observations during 2005-2020 over an Antarctic station, Rothera (67°S, 68°W). They also compare the observed MLT winds with the NCAR's extended version of the Whole Atmosphere Community Climate Model, WACCM-X simulations during 2005-2017. Further, the monthly/seasonal variations in MLT horizontal winds in response to solar forcing, Quasi-Biennial Oscillation (QBO 10 hPa and 30 hPa), El Niño Southern Oscillation (ENSO) and Southern Annual Mode (SAM) are compared from radar observations with the model simulations during 2005-2015. Significant biases were found between observed and model climatological monthly winds. The authors propose these biases are due to the lack of gravity wave forcing in the model simulations. I have major concerns in the present form of this work. The authors did not explain any strong reason why they considered only the above mentioned forcings in their regression analysis? As the winds are related to temperature gradients and they are in close agreement with the thermal wind balance, the climate index for temperature variability or its driving factor like CO_2 or O_3 has not been considered. The gravity wave tendencies are discussed but not the tides as they are also the key drivers of the horizontal winds in the MLT region. The wind anomalies (mean removed) are used in the regression analysis, however it is not clearly stated whether the climate indices are used as their anomalies (mean removed). If not done so, the mean removed anomalies of the predictors must be used in the regression analysis. Please avoid explaining/focusing statistically insignificant regions of the results obtained from linear regression analysis.

Below are my specific comments (major & minor).

Line #4: Replace 'test' with other wordings like 'validate' or 'evaluate'.

Line #7: Here and anywhere else in the paper, the authors used the monthly median winds. How the monthly medians vary from monthly mean in the regression analysis? It will be more comfortable if elaborated the difference between them.

Lines #8-9: For which year (s) you are referring to?

Line #11: why only the secondary gravity waves?

Lines #17-18: Here and wherever applicable, what is meant by 'correlations' between predictand and predictors? Do you mean 'responses'?

Line #29-30: Include 'after they break' between 'their momentum' and 'and thus driving..'

Line #61 and 69: Do these both studies are represent 'first' results of this radar? Both can't be the 'first'.

Section 2.1: Include more technical details of the SKiYMET radar.

Line #98: Why only 20 meteors considered here as a minimum threshold? How this will impact the accuracy of wind retrievals…should explain.

Line #112: I didn't find the model winds shown for the period of 1980-2017. Is it for 2005-2017…correct it.

Section 2.3: Definitions of all the climate indices must be included.

Panel (b) of Figure 2: It seems the ENSO values (on y-axis) are in ^{o}C and not in K….correct it. Perform the regression analysis again with the corrected values.

Section 3.1:

(i)   How many runs/realizations of the model have been used in this study? More runs/realizations enhance the statistical reliability.

(ii)   It is very important to use the anomalies of the climate indices in the regression model. If not done so, the anomalies must be used to repeat the regression analysis.

(iii)   In equation (1), what are β_1, β_2…..β_5 represent? Also U' stand for zonal or meridional wind anomalies? In general, U is the symbol to represent the zonal wind. As mentioned above, define all the climate indices used in the regression analysis.

Line #156: What are those 'other causes'….please include?

Section 3.1.1:

(i)   I am not sure why the VIFs are needed and calculated? The correlation coefficients (R) between the predictors must be included. As I see from Figure 2, no two predictors are correlated….verify it with the R values by including them.

(ii)   Line #172-175: The references for the values must be included.

(iii)   What are the VIF values for individual index? This helps for complete diagnosis.

Line #182: Include more details of DW test instead simply adding a reference.

Line #183-185: It is very important to include the reference for the values mentioned here.

Section 3.1.3:

(i)   What is the purpose of this section as the 'time' or 'trend' term is not included in the regression equation as there is no β_6 x t in equation (1). However the

2

multicollinearity between $F_{10.7}$ and time should be evidenced by a figure or values. Otherwise, it is difficult to understand for the readers.

(ii)   Line #200-201: What about the VIF values of other indices in the regression equation in this experiment? i.e. whether they are increasing or decreasing when one of the two correlated solar or time terms removed.

Line #211: Here and wherever applicable, does the 'average year' represent 'composite mean' of all the years? It should be replaced.

After line#228: Also the stronger winds occur in different months, in February from radar and in Dec-Jan in WACCM-X.

Section 4.1, Figure 3: Panels (a) & (b) – the radar zonal winds are averaged for 2005-2020 with gaps during 2016-2018 and, parts for 2009-2010. The model zonal winds are averaged for 2005-2020 with data gaps during 2018-2020. How accurate the composite zonal wind comparisons between radar observations and model simulations with these data gaps? This is misleading completely in making the conclusions of biases between observed and modelled winds. Moreover the regression analysis has been performed for the winds during 2005-2015 only. Please use the datasets for the same duration to avoid misperceptions.

Line #231-232: Replace 'to be' with 'are' & 'predicted' with 'simulated' (wherever applicable in the paper). Remove 'are' after 'eastwards but'.

Section 4.2, Figure 4: Refer to the above comment for Figure 3. The composite monthly means with the data gaps impose inaccuracies in drawing the important conclusions particularly comparing two datasets of observations and model.

Line #235, 237 & 260: Here and wherever applicable, are the 'upper branch of the Brewer-Dobson circulation' and the 'mesospheric meridional circulation' same or related to each other? I am confused with this terminology and their different driving mechanisms: former is accompanied by the planetary wave (equator-to-pole) and the latter is due to gravity wave driven circulation (pole-to-pole).

Line #250: Replace 'beyond' with 'up to'. Does this line represent 'model' or 'observation'?

Line #257: Replace 'over' with 'in'. The wind reversal is evident in WACCM only but not in the radar observations. But still why the interdecile range is maximum (above 90 km) in summer from radar observations also (Figure 5a)?

Line #259: The interdecile range of meridional winds doesn't peak in the winter from WACCM-X simulations…..why?

Section 5.1: Why the authors considered the solar response per 70 sfu? The normal practice to retrieve the solar response is per 100 sfu.

Line 269: Here and wherever applicable, why the statistical significance is not considered for 95% or 99% level? This is maybe more helpful than the 90% level.

Line #270: Why do you need to use three-month window instead monthly means?

Line #276: Do you mean the 'Solar maximum' refers to 'solar cycle maximum' or 'solar irradiance maximum'? What could be the physics behind why the solar maximum weakens the summertime westward wind reversal and strengthens the eastward winds?

Line #286: Do you mean 'positive response' at 'positive correlation'?

Sections 5.2, 5.3: Avoid explaining/focusing the regions which are not statistically significant.

Line #293 & 303: what is meant by 'index is large'? Does this have any significance?

Line #294-295: I could see significant positive and negative responses in model zonal winds in April and Dec-Jan respectively.

Line #301: I could see no agreement from radar and model.

Line #306: Replace 'over' with 'in'.

Lines #304-306: From figures 6e & 6f, I am wondering why the radar and model exhibit the opposite responses to QBO10 particularly in summer. Because both show the same westward winds below 90 km during this season (figure 3a & 3b) and thus we can expect both the responses should be same.

Line #308 & 337: In general, we see eastward and westward wind regimes in the QBO. But what does it meant by 'index is higher' or 'large' here?

Line #312-313: From figures 7g & 7h, why the meridional wind response to QBO30 is negative during Dec-Mar only in the model and not in the radar observations? Because the winds are northward from figure 4a & 4b, we can expect the similar responses in both radar observations and model simulations during this season.

Line #320: Is it more 'negative'? Please check. Does it mean more 'westwards'?

Section 6, figure 8: I am confused how the gravity wave tendencies are estimated? Also how these tendencies could explain the wind responses in WACCM-X (not sure why they are not shown for rocket observations).

Line #326: Not sure why the 'zonal mean' and not localised? This could lead to de risory comparisons. 'In panel (a) we present the average year' of what?

Line #333: Panel (e) represents QBO30 and not QBO10.

Section 7.1: I am not sure why the winds from two different techniques (meteor and MF radar) and during different observational periods are compared here. Also how these comparisons are scientifically useful as the changes in several dynamical/chemical processes in the atmosphere over time could lead to different results. Obviously it is not expected the winds measured during 2005-2015 (in this study) are comparable to those observed during 1994-2005, 1999-2003 and 1985-2004.

Line #371: Not sure whether the MF radar winds go below 80 km (or 78 km)? Any references?

Line #459: Remove 'observations'.

Line #462: It is WACCM6 and not WACCM-X.

Line #468: Replace 'similar' with 'nearly similar'.