An analysis on the momentum budget in the MLT region based on satellite and whole atmosphere model data

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In the middle atmosphere, gravity waves (GWs), tides (TWs) and Rossby waves (RWs) are dominant. By interacting with the mean flow, these waves maintain the thermal structure considerably different from that expected from a radiative balance. However, the momentum budget of the middle atmosphere has not thoroughly examined particularly for the mesosphere and lower thermosphere (MLT). In this study, the momentum budget in the MLT including piecewise contribution by each wave is examined by analyzing a satellite data and a whole atmosphere model data. An interplay of RWs and GWs is also focused on for the formation of barotropic (BT) /baroclinic (BC) instability. The analysis of the present study is mainly performed for climatology fields for each month in the zonal mean meridional cross-section. Used data are temperature and geopotential heights from Aura MLS observations as the satellite data (MLS data) and the neutral atmosphere data which was obtained by simulation using the GAIA model, which include a coupled neutral and ionized atmospheres from ground to lower thermosphere (LT) as the whole atmospheric model (GAIA data). The analyzed period is about 11 years from 8 August 2004-19 June 2015.
First, MLS data are analyzed. Magnitude of potential vorticity (PV) maximizes in low and middle (high) latitudes in the summer (winter) mesosphere. In the poleward side of these maxima, meridional gradient of PV (PVy) is negative, which is a necessary condition of BT/BC instability. EP flux (EPF) is strongly upward and EPF divergence (EPFD) is positive slightly poleward and above the PV maximum (PVM) in the summer mesosphere. Moreover the distribution of the occurrence frequency of positive EPFD accords well with that of negative PVy. These features suggest that RWs are radiated upward from the mesospheric PVM.
Second, the momentum budget is analyzed using GAIA data. EPF is divided into TW, RW and GW components. For the RW component, EPFD is significantly positive in the region where PVy is negative in the summer mesosphere. Strong upward EPF above the positive EPFD region is extended up to 0.0001 hPa in the LT. From a spectral analysis in this upward EPF region, it is seen that westward propagating waves having a 1.8 day period and s = 2-4 are dominant. This feature is similar to that of quasi-two day waves detected by previous observations. Moreover the feature that strong upward and equatorward EPF is observed above the negative PVy region suggests that these waves are generated through BT/BC instability. Next, the GW component is examined. GW EPFD is generally positive (negative) in summer hemisphere (SH) (winter hemisphere (WH)) in the MLT. It is seen from the direction of EPF that eastward (westward) waves are dominant in the SH (WH). The downward EPF (i.e. dominance of eastward waves) is particularly strong above the negative PVy region in the SH MLT, suggesting that GWs are generation there. The Richardson number in this region is frequently lower than 1/4, suggesting that the eastward GWs are generated by shear instability. EPFD due to all wave components is mainly positive (negative) in SH (WH) in the MLT. Among these, the GW component is most dominant. The forcing of subgrid-scale GWs (GWFP) is parameterized in the GAIA model. The GWFP maximizes around ~90 km in the upper mesosphere of the both hemispheres. The GWFP is comparable to the EPFD due to all resolved waves although the vertical distribution is different.
Last, the relation between GWFP distribution and negative PVy region is examined. GWFP is positive (negative) in low and high latitudes (all latitudes) of the SH (WH) mesosphere, and these maxima correspond to the location of the PVM. It is shown that the PVM is mainly contributed to by N2 in

WH and by both N2 and relative vorticity in SH. In addition, the rate of change of PV due to GWFP is directly estimated. The result indicates that the GWFP is likely responsible for the formation of PVM.

Keywords: Middle atmosphere, Rossby wave, Gravity wave, Barotropic / baroclinic instability, Momentum budget

