重力波解像大気大循環モデルを用いた中間圏の順圧・傾圧不安定の研究

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A Study on the Structure of Barotropic/Baroclinic Instability in the Mesosphere Using a Gravity-wave Resolving General Circulation Model

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In general, atmospheric motions are categorized into two: One is the quasi-geostrophic (QG) flows including planetary waves (PWs), and the other is gravity waves (GWs). The GWs are largely affected by the QG flows in their generation, propagation, and dissipation, but GWs can modify the QG flows such as the weak wind layer in the upper mesosphere by their ability of momentum transport. In the winter mesosphere, a necessary condition of barotropic and/or baroclinic instability for the QG flow, i.e., negative latitudinal gradient of potential vorticity (PV), is often satisfied. This study examines dynamical mechanism of the formation of such instability condition in boreal winter and discusses the significant role of the GW forcing. We used simulation data from a GW-resolving general circulation model (GCM). As this GCM does not include any GW parameterizations, all waves including GWs are resolved, which allows us to analyze the role of GWs in the momentum budget in the middle atmosphere explicitly.

First, a two-dimensional (2-d) analysis using the transformed Eulerian-mean equations was made. It is seen that the negative PV gradient is regarded as an enhanced PV maximum. This maximum is due to the poleward shift of the westerly jet in association with strong EP-flux divergence caused by PWs from the troposphere. Strong GW drag slightly above the westerly jet shifts poleward as well, which can be understood by a selective GW-filtering mechanism. It seems that this GW-drag shift induces strong upwelling in the middle latitudes and adiabatically cools the middle mesosphere. Resultant enhanced static stability is the main cause of the PV maximum in the upper mesosphere. Because of the dominance of PWs during this event, this process may not be zonally uniform.

Thus, second, a 3-d analysis was made using a recently derived 3-d transformed Eulerian-mean theory. As expected, the GW drag is distributed depending on the longitude. The zonal structure of PV maximum is consistent with the GW drag distribution. An interesting fact is that the spatial distribution of GW drag is not largely correlated with that of the zonal wind at the same level but highly correlated with that in the stratosphere where PWs are dominant. This result indicates significant coupling between the stratosphere and mesosphere via the selective GW filtering.