A study of gravity waves in the middle and high latitudes regions of the Southern Hemisphere using a high-resolution GCM

Satoshi Tateno[1]; Kaoru Sato[2]; Shingo Watanabe[3]; Yoshio Kawatani[3]; Yoshihiro Tomikawa[4]; Kazuyuki Miyazaki[3]; Masaaki Takahashi[5]

[1] Earth and Planetary Science, Univ. of Tokyo; [2] U. Tokyo; [3] FRCGC/JAMSTEC; [4] NIPR; [5] CCSR, Univ. of Tokyo

A climatology of gravity wave (GW) activities as well as GW sources and characteristics in the middle atmosphere are examined using data from a high-resolution general circulation model (GCM) over three model years. Particularly, GWs in the middle and high latitude regions of the Southern Hemisphere are investigated. The GCM can explicitly resolve GWs in a height region from surface to the upper mesosphere. The horizontal model resolution is T213 (corresponding to about 62 km), 256 vertical levels are used at a fine interval of about 300 m in the stratosphere and mesosphere. The sampling time intervals of the GCM data are 1 h.

Fluctuations whose horizontal wavenumbers are more than 22 (shorter than a horizontal wavelength of about 1819 km) are extracted and analyzed as the GWs. It is found that the GW climatology made using the GCM data agrees well with observations reported by previous works. Additionally, meanings of seasonal variations observed at limited stations in the global GW climatology are revealed. For example, it is shown that the positive vertical flux of zonal momentum associated with GWs in summer in the lower stratosphere as reported using the MU radar in Shigaraki by Sato (1994) is maximized around the subtropical region. Semiannual variation of GW activities in the mesosphere at middle latitudes of both hemispheres as reported by Tsuda et al. (1994) and Vincent and Fritts (1987) are due to two peaks around the mesospheric westerly jet axis and around the low-latitude side of the mesospheric easterly jet.

Further analysis is performed for GWs in the middle and high latitude regions of the Southern Hemisphere. In the winter stratosphere, significant enhancements of GW energy originated from the Andes and the Antarctic peninsula are observed. This enhancement region extends over more than a half of the latitude circle along the polar night jet (PNJ). Intermittencies of GW activities in this region are higher than those in the other regions where GW activities are weak. The phase structures indicate that the orientations of the horizontal wavenumber vectors (K) of GWs originated from the Andes and from the Antarctic peninsula are roughly south-westward and north-westward, respectively. The distribution of the vertical flux of the meridional momentum associated with the GWs indicates that both GWs focus on to the PNJ axis.

In order to investigate propagation characteristics of the orographic GWs generated by the Andes and the Antarctic peninsula, a simple ray tracing analysis is made. To focus on to the PNJ axis, these GWs need to have non zero meridional components of K. The orientation of K is decided by the alignment of the mountains. Increase of meridional components of K due to meridional wind shear is also important. The GWs are drifted to east because the westward intrinsic group velocity are weaker than the background westerly wind. However, the ray tracing analysis suggests that the longitudinal range which GWs can reach is only about 70^o at the maximum. This fact implies that the other sources contribute for the formation of the enhancement region extending for a longitudinal range of more than 180^o.

It is known that GWs propagating energy downward exist in the Antarctic lower stratosphere. In our model, GWs propagating energy downward are dominant in the southern edge of the energy enhancement region observed to the southeast of the Andes. Two mechanisms are considered as generation mechanisms. One is the secondary emission of GWs from the convergence region of the vertical momentum flux associated with the primary waves near the enhancement region. Another is the partial reflection of the GW due to the large vertical gradient of the buoyancy frequency in the middle stratosphere in winter.