# The roles of 3-dimensional propagating gravity waves and equatorial trapped waves on driving the Quasi-Biennial Oscillation

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A high-resolution atmospheric general circulation model (AGCM) has been developed to study various aspects of small-scale phenomena including gravity waves and their role on the large-scale fields in the middle atmosphere (Watanabe et al. 2008). Our spectral model has a T213 truncation in the horizontal (horizontal resolution of about 60 km) and 256 layers (L256) in the vertical from the surface to about 85 km with an interval of 300 m in the upper troposphere and above. No gravity wave parameterizations are included in our model and hence all gravity waves are spontaneously generated. The model simulates large-scale oscillations with realistic amplitudes in the equatorial atmosphere such as the quasi-biennial oscillation (QBO) and semi-annual oscillation (SAO), although the period of the QBO-like oscillation is shorter (about 1.5 years) than the real one.

Model outputs with a time interval of 1 hour are analyzed to elucidate relative importance of the internal gravity waves (IGWs) and equatorially-trapped waves (EQWs) to drive the QBO-like oscillation. It is shown that the zonal wavenumber versus frequency spectra of simulated precipitation and outgoing long wave radiation (OLR) represent realistic signals of convectively-coupled EQWs. The horizontal wind spectra reveals clear signals of equatorial Kelvin waves, Rossby-gravity waves, and n=0 eastward, n=1 and n=2 eastward/westward propagating gravity waves in the stratosphere. These wave signals are separately extracted for further examination following Wheeler and Kiladis (1999). The horizontal distribution of each EQW amplitude generally corresponds well to that of the activity of cumulus convection. On the other hand, it is seen that IGWs are strongly influenced by the vertical wind shear associated with the Walker circulation in the troposphere, which results in different distribution of IGW amplitudes between the eastern and western hemisphere. In the westerly shear phase of the QBO-like oscillation, IGWs contribute to 50-70% of the total eastward acceleration. The equatorial Kelvin waves contribute to the largest forcing among EQWs especially around the altitude with a zonal wind of 0 m/s, while the forcing due to n=0, 1, 2 eastward-propagating EQWs becomes comparable to that of Kelvin waves at higher altitudes. It is interesting that the distribution of the wave forcing is not zonally uniform and is different depending on the wave types.