Study of the gravity waves on Martian atmosphere using a high-resolution Mars General Circulation Model

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Gravity waves (GWs) are the small-scale atmospheric waves generated by the topography, convection, dynamical instability, and so on. On Mars, several observations and simulations have revealed that the GWs strongly affect temperature and wind fields in the middle and upper atmosphere. Especially, our previous study using the Max Planck Institute- Mars general circulation model (MGCM) and a nonlinear spectral parameterization of small-scale GWs [Yiğit et al., 2008] have shown that the GWs significantly change the wind speed and even reverse the wind direction above ~100km altitude, and also can be the main source of cooling above ~120km [Medvedev et al., 2011; Medvedev and Yiğit, 2012]. However, the global picture of GWs is not clear even on Earth with numerous observations, and far less on Mars.

For more realistic investigations of GWs on Mars, we did the first simulations with a high-resolution MGCM to present the global distributions of small-scale GWs in the Martian atmosphere. Here we used the DRAMATIC (Dynamics, RAdiation, MAterial Transport and their mutual InteraCtions) MGCM [Kuroda et al., 2005, 2013] with the horizontal resolution of ~1.1° × ~1.1° (or ~60 km) and 49 σ-levels in vertical from surface up to ~80–100 km. Such setup allows for realistically capturing generation and propagation of GWs with horizontal wavelengths of ~180 km and longer and, to some extent, their vertical attenuation due to nonlinear processes. Here we assumed the horizontal-scale fluctuations with the total wave number of larger than 60 (horizontal wavelengths of less than ~350 km) as GW-induced disturbances.

We investigated the spatial distributions of GW-induced potential and kinetic energies in the northern winter solstice (Ls=270°). The simulated GW-induced potential energy distribution is in a good agreement with available radio occultation data [Creasey et al., 2006] in the lower atmosphere between 10 and 30 km. The model reveals a latitudinal asymmetry with stronger wave generation in the winter hemisphere, and the ratio of potential and kinetic energies shows that there are two distinctive sources of GWs: mountainous regions and the meandering winter polar jet. Orographic GWs are filtered upon propagating upward, and the mesosphere is primarily dominated by harmonics with faster horizontal phase velocities. Wave fluxes are directed mainly against the local wind, with a clear relation between wave dissipation and wind acceleration. GW dissipation in the upper mesosphere generates a body force per unit mass of tens of m s^{-1} sol^{-1}, which tends to close the simulated jets. Effects of horizontal propagation of GWs on the acceleration are much smaller than those of vertical propagation, and the acceleration rates are comparable to the those obtained from the parameterization by Yiğit et al. [2008] which considers only the vertical propagations.

The results represent a realistic surrogate for missing observations, which can be used for further constraint of GW parameterizations and validating GCMs. Also the observational investigations of the thermospheric GW features by the MAVEN mission would help the understandings of the propagation and dissipation mechanisms of GWs.