高分解能大気大循環モデルを用いた火星大気重力波の励起と伝播の評価
Assessment of the generation and propagation of the gravity waves in the Martian atmosphere using a high-resolution general circulation model

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Gravity waves (GWs) are small-scale atmospheric waves generated by various geophysical processes, such as topography, convection, and dynamical instability. On Mars, several observations and simulations have revealed that GWs strongly affect temperature and wind fields in the middle and upper atmosphere. Our previous study using the Max Planck Institute Mars General Circulation Model (MGCM) and the nonlinear spectral whole atmosphere parameterization of small-scale GWs by Yigit et al. [2008] have shown that the dynamical forcing of GWs significantly change the winds, reversing its direction above ~100 km [Medvedev et al., 2011]. We also have shown that the thermal effects induced by GWs can be the main source of cooling above ~120 km, reproducing the observed temperature structure on Mars [Medvedev and Yigit, 2012]. Similar physical importance of GWs has previously been demonstrated for the general circulation of Earth’s upper atmosphere using the whole atmosphere parameterization [Yigit et al., 2009; Yigit and Medvedev, 2009]. Despite numerous observations however, the global picture of GW activity is yet to be revealed both on Earth and Mars.
In order to investigate the global distribution of small-scale GWs in the Martian atmosphere, we have conducted the first simulations with a high-resolution MGCM, using the DRAMATIC (Dynamics, RAdiation, MAterial Transport and their mutual InteraCtions) MGCM [e.g., Kuroda et al., 2005, 2013]. The MGCM was run at the T106 spectral truncation, which corresponds approximately to a 1.1^{o} x 1.1^{o} (or ~60 km) horizontal resolution. In the vertical direction, the model domain extends from the surface to ~80–100 km and is represented by 49 sigma-levels. 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. We considered horizontal-scale fluctuations with a total wave number of larger than 60 (horizontal wavelengths of less than ~350 km) as GW-induced disturbances.
We investigated the spatial distributions of potential and kinetic energies associated with GW activity in the northern winter solstice. The simulated GW 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 investigations from the ratio of potential and kinetic energies show 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 waves 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} per Martian solar day (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 results of acceleration rates are comparable to those obtained from the application of the GW parameterization by Yigit et al. [2008], which considers only the vertical propagations of a broad spectrum of GWs.

The results represent a realistic surrogate for missing observations, which can be used to further constrain existing GW parameterizations and validate GCMs. Also the observational investigations of GW signatures in the thermosphere by the MAVEN mission would help better understand propagation and dissipation mechanisms of GWs.

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