Gravity wave drag in the mesosphere of Mars

Alexander Medvedev, Erdal Yiğit[2], Paul Hartogh[1]

[1]*Max Planck Institute for Solar System Research, Germany*

[2]*University of Michigan, Department of Atmospheric Oceanic and Space Sciences, USA*

Summary

Observations and theoretical considerations point to a much stronger than on Earth generation of gravity waves (GWs) in the troposphere of Mars due to instabilities of weather systems, volatile convection, and flow over the rugged topography. Disturbances attributed to GWs have amplitudes several times larger than on Earth in both Martian lower and upper atmospheres. However, unlike on Earth, the significance of these vertically propagating waves is not yet established. GCMs are apparently able to reproduce the observed circulation patterns without parameterized GWs, at least up to 80-100 km. We address a fundamental gap in the knowledge of momentum budget in the Martian atmosphere. Using a GCM and our recently developed GW scheme suitable for thermospheres, we quantify for the first time the GW momentum deposition at thermospheric heights. This is the first application of a broad spectrum GW parameterization to the atmosphere of Mars. It is shown that GW drag plays a role similar to the one in the terrestrial lower thermosphere but somewhat higher, at 110-130 km, at altitudes where the recently observed temperatures deviate significantly from model simulations.

Spectral GW parameterization:

$$\frac{d\overline{u'w'}}{dz} = \left(\frac{1}{H} + \frac{m_z}{m} - \beta_{break} - \beta_{mol} - \beta_{ion} - \beta_{Newt} - \beta_{eddy}\right)\overline{u'w'}$$

Thermospheric dissipation

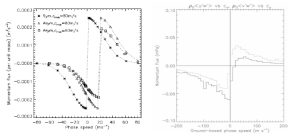

Figure 1. GW fluxes at the source level (~8 km)

Martian GCM

- Spectral model from the surface to 1.5x10^{-5} Pa
- T21 horizontal truncation, 63 vertical eta-levels
- Realistic topography and surface parameters: albedo and thermal inertia
- All relevant parameterizations (except UV heating)

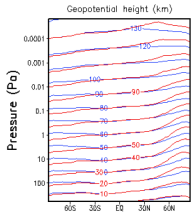

Figure 2. Simulated mean geopotential height at equinoxes (L_s=180) and solstices (L_s=270^0)

Results

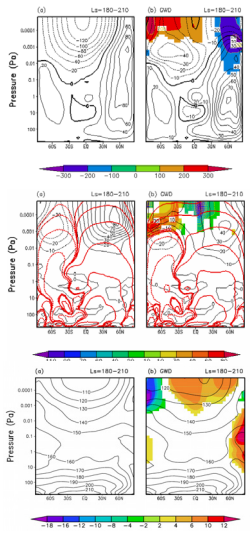

Figure 3. Equinoctial zonal and meridional wind, and temperature (contour lines) simulated without (left) and with GW scheme (right). Shaded are GW momentum deposition in m s^{-1} sol^{-1} , and temperature difference in K (lower panel).

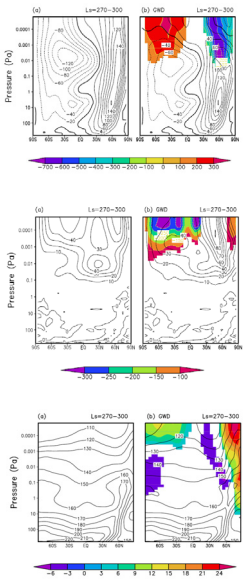

Figure 4. Same as Figure 3, but for the Northern winter solstice.

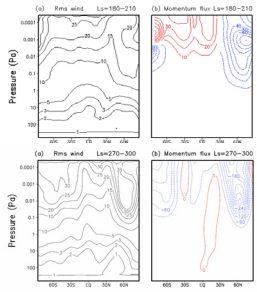

Figure 5. GW-induced rms horizontal wind variations (left) and momentum fluxes (right) simulated at the equinox and solstice.

Conclusions

- Gravity wave drag is not negligible on Mars, but strong (hundreds m s^{-1} sol^{-1}) in the upper mesosphere (110-130 km) and possibly higher.
- It closes zonal jets and even produces wind reversals. Associated temperature changes exceed tens of K.
- GW momentum deposition in the mesosphere exceeds those by large scale eddies (including tides)
- Wind measurements in the mesosphere are required to confirm or disprove this prediction

References

Medvedev, A. S., E. Yiğit, and P. Hartogh (2011), Estimates of gravity wave drag on Mars: Indication of a possible lower thermospheric wind reversal, *Icarus,* 211, 909-912, doi:10.101016/j.icarus.2010.10.013.

Yiğit, E., A. D. Aylward, and A. S. Medvedev (2008), Parameterization of the effects of vertically propagating gravity waves for thermosphere general circulation models: Sensitivity study, *J. Geophys. Res.*, 113, D19106, doi:10.1029/2008JD010135.

Yiğit, E., A. S. Medvedev, A. D. Aylward, P. Hartogh, and M. J. Harris (2009), Modeling the effects of gravity wave momentum deposition on the general circulation above the turbopause, *J. Geophys. Res.*, 114, D07101, doi:10.1029/2008JD011132.

Yiğit, E., and A. S. Medvedev (2009), Heating and cooling of the thermosphere by internal gravity waves, *Gephys. Res. Lett.*., 36, L14807, doi:10.1029/2009GL038507.

Yiğit, E., and A. S. Medvedev (2010), Internal gravity waves in the thermosphere during low and high solar activity: Simulation study, *J. Geophys. Res.*, 115, A00G02, doi:10.1029/2009JA015106.

For further information

Please contact *medvedev@mps.mpg.de*.