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Gravity waves and the exotic meteorology of Mars

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As is the case on Earth, atmospheric gravity waves are ubiquitous and play a key role on Mars. We recently obtained new results on Martian gravity waves by combining the latest remote sensing observations with Martian mesoscale modeling.

Many independent measurements have shown that extremely low temperatures ("cold pockets") are found in the Martian mesosphere. Recent observational achievements also hint at such cold pockets by revealing mesospheric clouds formed through the condensation of CO_2, the major component of the Martian atmosphere. We show that, in combination with large-scale thermal tides, mesoscale gravity waves are crucial for creating mesospheric cold pockets propitious to CO_2 condensation. Most of regions/seasons featuring mesospheric CO_2 clouds are characterized by atmospheric conditions favorable to the upward propagation of gravity waves from tropospheric sources. How gravity waves contribute to form CO_2 clouds is reminiscent of their role in the formation of polar stratospheric clouds with relatively high optical depths on Earth.

We also report how airglow imagery is a powerful method to detect and study the propagation of Martian gravity waves. This technique has already proved powerful in the case of terrestrial gravity waves. Wave patterns in the southern polar region of Mars were found in O_2 dayglow maps obtained at 1.27 μm with the imaging spectrometer OMEGA on board Mars Express. We show through mesoscale modeling that the propagation of gravity waves in the Martian troposphere could explain these patterns. Model predictions match the intensity and spatial variability of dayglow fluctuations observed in the OMEGA maps.

We finally propose to make gravity wave activity a plausible explanation for the "cloud trails" recently discovered by the high-resolution color imager MARCI on board Mars Reconnaissance Orbiter. The name of those clouds reflect their extended longitudinal dimensions, which develop within less than two hours. Cloud trails appear at altitudes $40 - 50$ km, only above very specific regions, at the warmest season (perihelion) and local time (early afternoon). Those characteristics appear paradoxical, given atmospheric temperatures at which Martian water ice clouds usually form. We show however that a possible explanation involves gravity waves emitted by turbulent convection in the highly unstable Martian boundary layer which vertical extent could reach one atmospheric scale height.

Further studies are needed on convectively-generated gravity waves on Mars, to complement existing work on the orographic source. In addition to boundary layer convection, recent modeling shows indeed that dust-induced deep convection within Martian dust storms could trigger gravity waves.