Non-migrating tides connections with topography and surface properties

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Atmospheric densities derived from measured acceleration of several Mars orbiters reveal large amplitude Sun-synchronous longitudinal density variations at altitudes of about 100-160km (see Figure 1). These variations are associated with vertically-propagating non-migrating solar thermal tides that are excited near Mars' surface and propagate into the thermosphere. Excitation of these waves is associated with the zonally asymmetric component of the near-surface heating distribution, and is commonly attributed to topographic modulation of solar heating. However, there are other possible contributors to the excitation of non-migrating tides, including zonal variations in surface properties and wave-wave nonlinear interactions, whose relative contributions remain unexplored. In this study we use a general circulation model in combination with the Mars Global Surveyor accelerometer measurements to isolate the different waves responsible for the observed density structures.

We sought in this work to determine the specific origins of D0, DE1 and DE2, as well as other waves that make secondary contributions to the wave-1, -2, and -3 density structures. This was done by performing numerical experiments wherein we sequentially added different zonal wavenumber components to the specification of topography, and considered separately the effects of surface properties such as thermal inertia and albedo. The diurnal tides D0, DE1 and DE2 are found to be primarily generated by the interaction between the 24-hour harmonic of solar radiation interacting with the wave-1, -2, and -3 components of topography, which bear interesting similarities to the corresponding density structures in the thermosphere. Each of these interactions also produces a second wave, i.e., the westward-propagating diurnal tides DW2, DW3 and DW4. These waves have much shorter vertical wavelengths (i.e., < 30 km) than their eastward-propagating counterparts, are much more susceptible to dissipation as they propagate from the lower atmosphere into the thermosphere, and

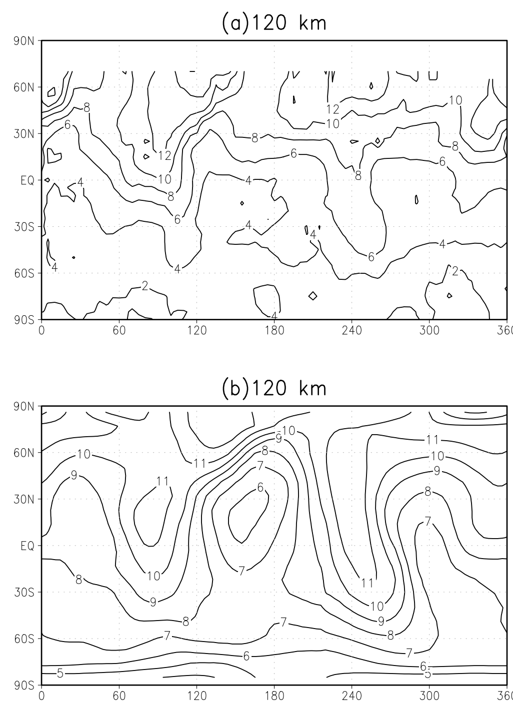

Figure 1: Density in kg/km^3, (a) measured by MGS and (b) simulated by GMMM at 120 km and 15 LST.

thus arrive there with much smaller amplitudes.

There are semidiurnal counterparts to the above process that produce waves of importance to the aerobraking density structures. For instance, interaction of the semidiurnal component of solar radiation with the topographic wave components 1, 2 and 3 produces the wave pairs (SW1, SW3), (S0, SW4), (SE1, SW5), all of which are found in the decomposition of model density structures at amplitudes of order 2-12%, and are likely produced by this mechanism. Contrary to the diurnal tides DW2, DW3, DW4, the semidiurnal analogs SW3, SW4, SW5 have longer vertical wavelengths ($>$ 60 km). This likely explains, at least in part, why their amplitudes relative to SW1, S0 and SE1 are larger than the amplitudes of DW2, DW3 and DW4 in comparison to D0, DE1 and DE2. In addition, we also found SE2 at significant amplitudes (up to 12%), likely originating from the presence of wave-4 topography.

Zonal variations in surface properties are found to have a much smaller effect on exciting waves relevant to the aerobraking density structures. We did find that their contribution to DE1 and D0 is non-negligible, and accounts for about one third of their total amplitudes, although the contributions from the two sources are not in phase. This process did not produce any semidiurnal tides of any significance.

Finally, there are some waves revealed in the simulations that may have been generated by wave-wave nonlinear interactions. For instance, SW1 and SW3 can be produced through nonlinear interaction between the migrating semidiurnal tide and the stationary planetary wave with $s = 1$ (SPW1). It is not possible to separate this source from the solar radiation/wave-1 interaction at the surface. Of particular note is SE3, which achieves amplitudes of order 2-6% in relative density amplitude. We suggest that this might result from the interaction between DE1 and DE2. Nonlinear interaction between waves is also a suitable explanation for the excitation of DE2 by wavenumber 2 in topography through interaction of DE1 and SPW1 (see Figure 2); it also provides, to some extent, an understanding of the origin of a wave-2 structure in the MGS data near the south pole as an interaction between D0 and SPW1.

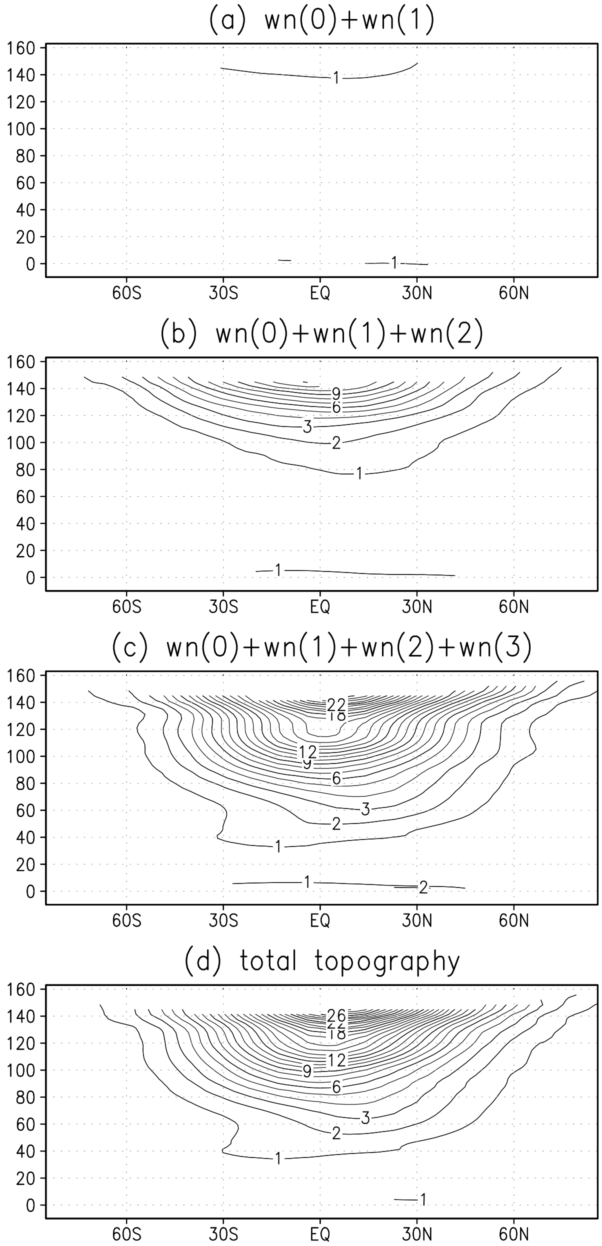

Figure 2: Latitude-altitude plot of the DE2 density amplitudes in percent of the zonal density average, simulated with different topography configurations. In the top panel the surface topography is set to the sum of wavenumber 0 (zonal average) and 1 (first harmonic). In the next panels higher degree harmonics are successively added. The amplitude is expressed in percent of the zonal average.

References

Moudden, Y., and J. M. Forbes, Topographic Connections with Density Waves in Mars' Aerobraking Regime, *J. Geophys. Res.*, doi:10.1029/2008JE003107, 2008.