STUDY OF GRAVITY WAVES DISTRIBUTION AND PROPAGATION IN THE THERMOSPHERE OF MARS BASED ON MGS, ODY, MRO AND MAVEN DENSITY MEASUREMENTS.

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Introduction

The properties of gravity waves (GW) were particularly observed in the martian atmosphere by Mars Global Surveyor (MGS), Mars Odyssey (ODY) and Mars Reconnaissance Orbiter (MRO) during aerobraking operations, when the spacecraft went down inside the upper Mars atmosphere to benefit from the atmospheric drag to change its orbit. Regular density perturbations were observed near to the periapsis of the spacecraft's trajectories, revealing the presence of gravity waves.

More recently, NASA's Neutral Gas Ion Mass Spectrometer (NGIMS) instrument aboard the Mars Atmosphere and Volatile EvolutioN (MAVEN) satellite also retrieved many cases of GW-induced CO_2 density perturbations in the Mars atmosphere.

Although some correlation with topography and modulation by season have been already reported for example by Creasey et al. [2006a,b] with the data then available, the source and propagation of observed gravity waves are not yet well understood and fail to be properly modelled.

The combined datasets from the different instruments are together covering wide ranges of latitudes, longitudes and seasons within the Mars thermosphere between 90 and 190km altitude (see Figures 2 and 3). They allow to further explore the GW mechanisms and improve their modeling. Based on this large data amount, it is proposed to study the gravity waves filtering and propagation.

Data processing

MGS, ODY and MRO respectively gathered 850, 320, and 430 passes covering latitude ranges from 60°N to 90°S, 30°N to 90°N, and 0° to 90°S. Periapsis altitudes varied from around 95 to 150km. In addition, the CO_2 density variations from 1451 orbits were retrieved from available NGIMS/MAVEN data. MAVEN covered higher periapsis altitude between around 120 and 190km.

For each orbit, the wandered longitude, latitude, solar longitude, local time, altitude, CO_2 density, as well as the distance from the periapsis were extracted. The density perturbation is calculated by subtracting the instantaneous density to the mean density, taken here to be the 40-second sliding averaged density. The perturbations are then normalized to this same mean density over 40-second to provide an estimate of the relative density perturbation (see example of orbit 266 Figure 1). The root mean square (RMS) of this relative density is calculated for every orbit to attest of the GW intensity per orbit. The reported RMS extends from ˜2 to ˜33% for MAVEN, from ˜1 to 20% for MGS, from ˜3 to 28% for ODY and from ˜1 to 17% for MRO. Its calculation was limited to the frame of -700 to 700km from the periapsis, in order to focus on the lowest entrance in the atmosphere and discard the observed noise effects. On the same principle the variance was also calculated and extends respectively from ˜0.03 to ˜11%, from ˜0.01 to ˜4%, from ˜0.1 to ˜8%, from ˜0.02 to ˜3%. It is expected that the amplitude of gravity waves increases with altitude, which can attest for the higher percentages obtained for MAVEN exploring higher ranges of altitude (see Figure 4).

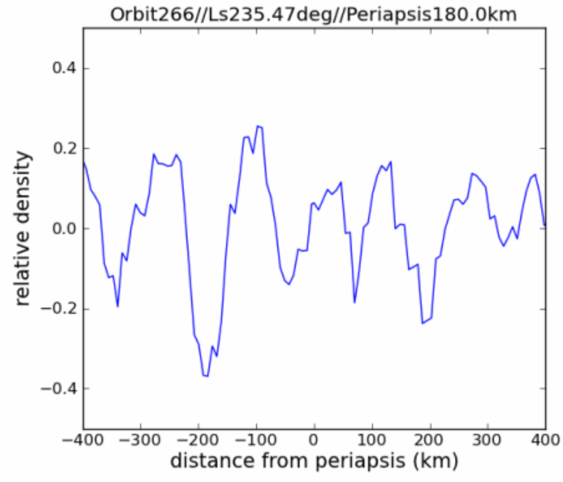

Figure 1: Relative density in function of the distance from periapsis in kilometers for the MAVEN's orbit 266 with Ls (Solar Longitude) = 235.47°, periapsis altitude and latitude (not given in the title) of respectively 180km and 62.54°

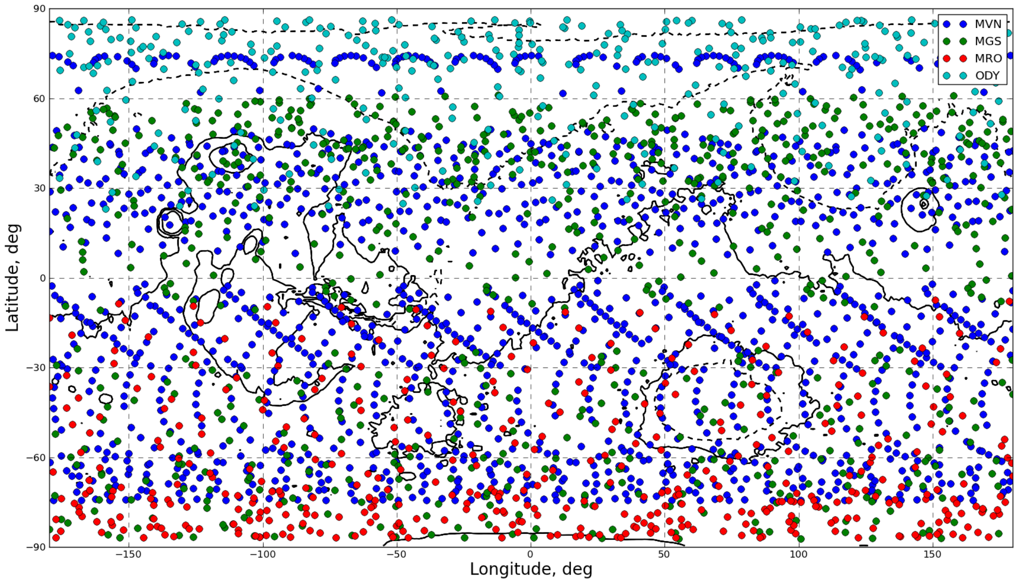

Figure 2: Latitude/longitude map of the martian topography covered by MGS, ODY, MRO and MAVEN (MVN) orbits periapsis locations

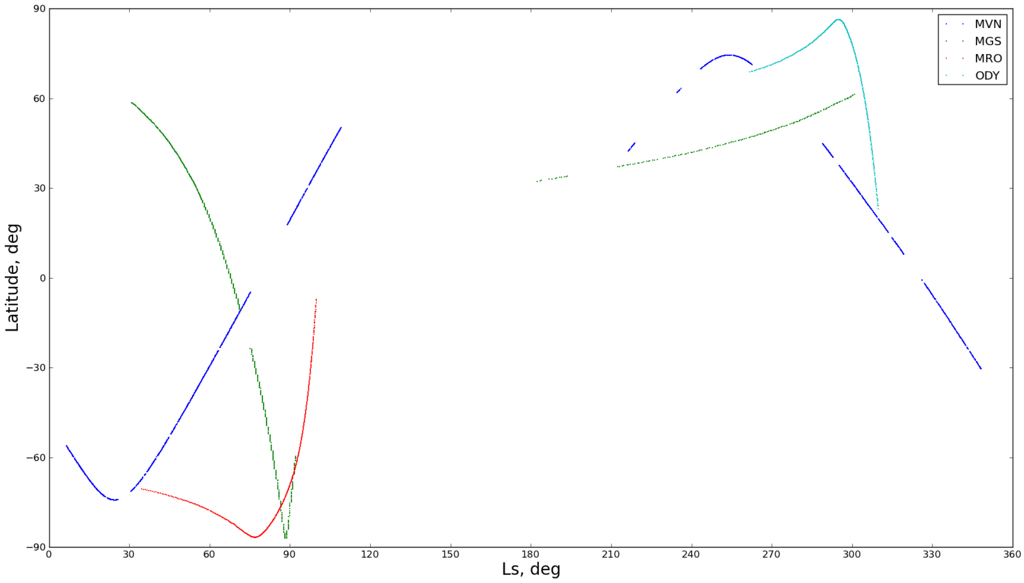

Figure 3: Latitude/Solar longitude distribution covered by MGS, ODY, MRO and MAVEN (MVN) orbits

Preliminary conclusions

As a first result from the analysis of the complete set of data, a strong correlation of the GW distribution with latitude and season ranges is observed. RMS greater

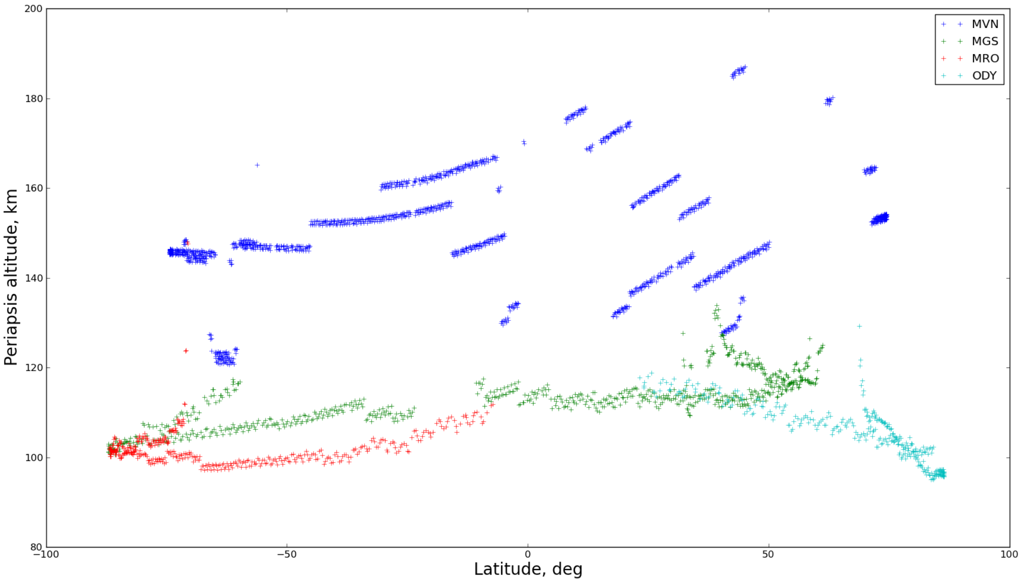

Figure 4: Altitude/latitude distribution covered by MGS, ODY, MRO and MAVEN (MVN) orbits

than 20% (essentially obtained for MAVEN orbits) are mainly observed during the Northern Hemisphere Winter over 50°N latitude, and secondly during Southern Hemisphere Winter under 50°S latitude. The minimal RMS, under 5%, are concentrated in the tropics during Spring and Autumn. These observations are in accordance with what was reported by Creasey et al. [2006b] focusing on Mars' thermosphere.

GW propagation and filtering

The amplitude of gravity waves is a priori controlled by both filtering and propagation parameters.
Regarding filtering, Spiga et al. [2012] stated that significant mesospheric GW activity is expected at locations, local times and seasons with high $|\langle u \rangle - c|$, where c is the GW phase speed and $\langle u \rangle$ the background wind. The observations of high RMS could thus be easily related to the apparition of the seasonal jet stream for both hemispheres. Spiga et al. [2012] also indicates the possibility of estimating to first order a saturation index for the gravity wave:

$$S = \frac{T'}{T'_m} = \sqrt{\frac{\alpha N}{\langle \rho \rangle |\langle u \rangle - c|^3}} \text{ with } \alpha = \frac{F_0 \lambda_H}{2\pi} \qquad (1)$$

where $\langle \rho \rangle$ is the background density, $T'(T'_m)$ the (maximum) GW perturbation before wave breaking, λ_H the GW horizontal wavelength and $F_0 = \rho \langle u'w' \rangle$ the GW vertical momentum flux conserved for non-dissipating GWs. N refers to the static stability with $N^2 = \frac{g}{\langle T \rangle}[\frac{d\langle T \rangle}{dz} + \frac{g}{C_p}]$, where $\langle T \rangle$ is large-scale temperature, g acceleration of gravity and C_p specific heat capacity. The closest S is to 1 (or greater values), the more likely upward-propagating GWs from tropospheric sources are to break through criticality or saturation.
Regarding propagation, sources generating gravity waves have to be considered. It is known that they include topography, near-surface thermal contrasts, wind shear instability, frontal processes and convection. However the implementation of all these forcings in models remains very complex. The LMD's (Laboratoire de Météorologie Dynamique) general circulation model (GCM) for Mars Forget et al. [1999] uses for example gravity wave forcing scheme based on the surface stress, taking orographic sources into account. Non-orographic gravity waves are currently parameterized (see Gilli et al., this issue).

Objectives

In the frame of the conference it is proposed to calculate the gravity wave saturation index, for which meteorological fields can be locally extracted from the Mars Climate Database (MCD), for all gathered orbit data, and to display potential correlations of this saturation ratio with the data characteristics like the orbit's associated RMS. Some GCM simulations results, obtained with the LMD's GCM and based on the orbit data, will also be presented with focus on the prospective connection between the wave intensity and GCM implemented sources for gravity waves.

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