TEMPERATURES AND WINDS IN THE MARTIAN MESOSPHERE FROM CO2 CLOUDS OBSERVATIONS AND GCM SIMULATIONS.

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Introduction

The presence of mesospheric CO_2 clouds in the Martian mesosphere has been recently revealed by different instruments: TES and MOC on board Mars Global Surveyor (Clancy et al., 2004, 2007), SPICAM (Montmessin et al., 2006), OMEGA (Montmessin et al., 2007; Määttänen et al., 2010) and HRSC (Scholten et al., 2010) on board Mars Express, and THEMIS (McConnochie et al., 2010), on board Mars Odyssey. These observations have unveiled two different populations of clouds: equatorial clouds around the aphelion season and mid-latitude clouds during autumn, mainly in the Northern hemisphere. In general, clouds tend to appear in restricted latitudinal and longitudinal corridors, and they have been observed at higher altitudes during the night (around 100 km from the surface) than during the day (between 60 and 80 km of altitude). Given that a necessary condition for the formation of these clouds is that temperatures have to be below the condensation temperature of CO2, the presence of these clouds is an indicator of low temperatures in the Martian mesosphere, and as a consequence the distribution of mesospheric clouds can be seen as a distribution of cold mesospheric areas. In addition, some of the observations of the clouds have allowed for the determination of their zonal speed, that should be similar to the zonal wind speed. So, these clouds offer very valuable information about an atmospheric region characterized by the scarcity of observational data.

In this work we use a ground-to-exosphere General Circulation Model, the LMD-MGCM (Forget et al., 1999; González-Galindo et al., 2009), to study the temperatures and winds in the Martian mesosphere and compare with the information provided by the observations of mesospheric clouds. This will allow to validate the behavior of the model in the mesosphere and, more important, to gain insight into the physical processes that are behind the distribution of these clouds.

Mesospheric temperatures

Fig. 1 shows the distribution of the areas of cold mesospheric temperatures predicted by the LMD-MGCM during daytime as a function of season and latitude. Minimum temperatures are predicted by the model close to the equator before and after aphelion and in mid-latitudes of both hemispheres during autumn, in reasonably good agreement with the observed distribution of the clouds. However, the model only predicts temperatures below condensation in the mid-latitudes during autumn. We think that small scale processes not included in the GCM, such as the propagation of gravity waves to the upper atmosphere, can produce perturbations and produce excursions below condensation, if the average temperatures predicted by the GCM are just few Kelvins above condensation. During the nighttime (figure not shown) the model predicts temperature below condensation at almost all latitudes and seasons, while only relatively few nighttime clouds have been observed.

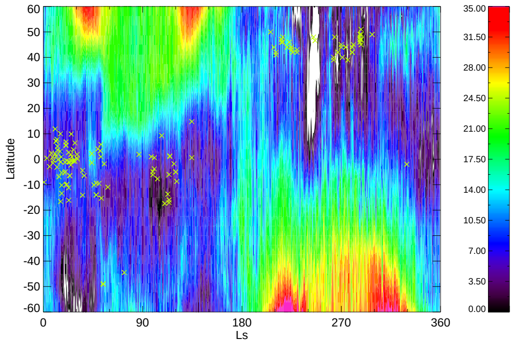

Figure 1: Difference between the minimum mesospheric temperature predicted by the LMD-MGCM and the condensation temperature of CO_2, as a function of latitude and season. The location of the observed mesospheric clouds is indicated by the green crosses

We have found that the model predicts correctly the altitude, latitude, longitude and local time of the equatorial clouds. Minimum temperatures are predicted by the model at about 80 km during the day and 100 km during the night, in good agreement with the observations (fig. 2). This altitude variation is due to the vertical propagation of the diurnal thermal tide. The intensity of the diurnal thermal tide is the strongest at these seasons around the equator, producing the latitudinal confinement of the equatorial clouds. The areas of minimum temperature are predicted at two longitudinal regions between 150W and 40W and between 20W and 20E, which corresponds with the longitudes where mesospheric clouds have been

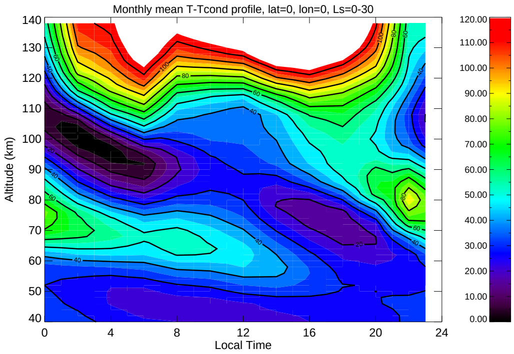

Figure 2: Difference between the predicted atmospheric temperature and the condensation temperature of CO_2 as a function of altitude and local time. Average over Ls=0-30 seasons, lat=0

observed. We think this longitudinal confinement is due to the effects of non-migrating tides, created by the interaction of the solar illumination with the topography, and that propagate up to the upper atmosphere.

For the mid-latitude clouds, their latitudinal and longitudinal location are also well predicted by the model. However, minimum temperatures are predicted at altitudes of about 90 km and at the beginning of the morning, while the clouds have been observed at altitudes between 45 and 70 km and in the afternoon. It has to be noted, though, that the model predicts a secondary minimum of temperature at the altitude and local time where the clouds have been observed, although that secondary minimum is not strong enough to allow for CO2 condensation. These differences might be due to an incorrect prediction of the structure of the diurnal thermal tide at this particular time of the year.

Mesospheric winds

Given the scarcity of measurements of winds in the Martian mesosphere, this dataset is very useful to constrain the dynamics predicted by General Circulation Models. Määttänen et al. (2010) showed that the mesospheric zonal winds predicted by the LMD-MGCM for the Ls=0-30 season were in good agreement with the observations. We extend here that study to other seasons. In general, we find that the model predicts correctly the wind magnitude for the different seasons. Predicted winds are eastward for the Ls=210-240 and the Ls=270-300 seasons, and westward for the Ls=30-60 and Ls=90-120 season, as observed, and the magnitude of the winds is generally in rather good agreement with the observations. The model predicts a strong day-to-day variability of wind profiles inside each season, although in some cases this variability is not enough to explain the differences between wind intensities measured by different instruments, in particular for the Ls=30-60 season. The longitudinal variability of the wind seems to be also correctly predicted by the model.

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