DIURNAL TEMPERATURE VARIATION AND THERMAL TIDES IN THE MARTIAN ATMOSPHERE OBSERVED BY EMM/EMIRS.

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Overview:

Due to the novelly designed high-altitude orbit, instruments onboard the Hope probe of the Emirates Mars Mission (EMM) have unprecedented temporal and spatial coverages, with all geographic locations and local times covered every 10 Martian days [1]. The Emirates Mars InfraRed Spectrometer (EMIRS) onboard the spacecraft observes surface temperature, temperature profile, dust content, water clouds, and water vapor in the Martian lower atmosphere [2]. It becomes possible for the first time to obtain the diurnal variations of these properties on a planetary scale without significant gaps in local time or interference from seasonal changes. In this paper, we present the investigation of diurnal temperature variations and thermal tides in Martian Year (MY) 36 and 37 using EMM/EMIRS observations. The results are compared to numerical simulations of the Mars Planetary Climate Model (PCM, Forget et al., 1999), providing valuable information on physical processes controlling the diurnal climate on Mars.

Introduction:

The Martian atmosphere experiences large diurnal variations due to its small thickness and low heat capacity. Driven by diurnal solar insolation and influenced by the topography and radiative drivers (clouds and dust), diurnal temperature changes propagate from lower atmosphere into higher altitudes as forms of atmospheric tides. These tides are coupled with clouds and dust, resulting in the difficulty of understanding the diurnal climate on Mars. Our current understanding of such diurnal variations is primarily limited by the observations, especially the ones covering the entire planet and all local times. Fortunately, the recent observations obtained by EMM/EMIRS can meet such a requirement due to the novel design of the orbit of the spacecraft, which is the subject of this work.

Observations:

Analysis in this work is based on the data obtained by EMIRS [2], a Fourier transform infrared spectrometer onboard the Hope Probe. As the spacecraft is in a high-altitude orbit, a full coverage of geographical locations and local times can be obtained every 10 Martian days (Figure 1). The data used in this work ranges from MY 36 L_S~50° to MY 37 L_S~140°, covering more than one Martian year.

Results:

Individual temperature profiles are first binned in solar longitude (L_S), longitude, latitude, and local time with grid sizes of 5°, 5°, 10°, and 1h, respectively. Daily temperature anomalies are then obtained across most of the latitudes by subtracting the zonal and diurnal means. Results of such diurnal temperature anomalies near the equatorial regions are shown in Figure 2. This is the first time that such variations are observed on a global scale without any significant gaps in local time or sampling bias in season.

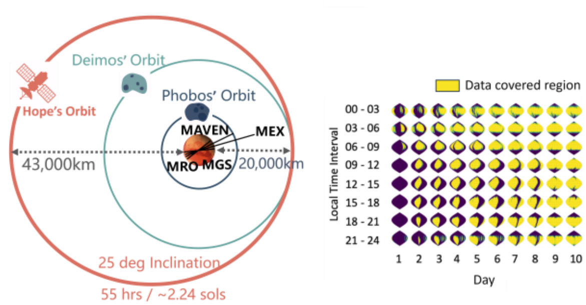

Figure 1. Orbit of Mars orbiters (left), and data coverage of EMM (right).

As shown in the bottom panels of Figure 2, the observed diurnal temperature variation is on the order of 4-8 K during the aphelion season (near northern summer solstice) at pressure levels between 500-5 Pa, corresponding to altitudes from near surface to ~40 km. Such an observed variation range is approximately half that of its real value, due to the vertical smoothing of temperature profiles rooted in the retrieval of near-nadir spectra [4, 5]. The daily temperature anomaly pattern is dominated by the diurnal thermal tide in this season, indicated by the downward propagation of diurnal temperature maxima and minima with a period of one Martian day. It suggests a downward phase velocity of the diurnal tide, and corresponds to upward group velocity according to the tidal theory, which agrees with the fact that the excitation sources of the tides are usually below these pressure levels. At some heights (e.g., ~30 Pa), there are two temperature maxima and minima, which are signs of semi-diurnal tides. This wave mode is usually the second largest during the aphelion season.

The diurnal temperature variation becomes stronger when Mars enters its dusty season. The amplitude of the temperature near the northern autumn equinox is twice that of the aphelion season, and the pattern dominated by the diurnal tide is broken near the northern winter solstice when the Martian atmosphere is very dusty. Instead, the semi-diurnal tide becomes the strongest, as the vertically extended dust content can damp the diurnal tide with short vertical wavelength and amplify that of the semi-diurnal tide. The typical pattern with dominant diurnal tide returns afterwards when Mars exits its perihelion season, moving away from the Sun.

As dust is one of the major drivers of the Martian atmosphere, the atmospheric thermal structure is different during regional dust storms, and so does its diurnal variation. Figure 2 also shows the results of daily temperature anomalies in the equatorial region during two major storms of MY 36, the A-storm and C-storm. Different from those during typical dusty seasons, the temperature anomaly shows signatures of upward propagation of thermal tides, which suggests tide excitation sources above the region, likely high-altitude water ice clouds elevated by the dust storms [6].

References:

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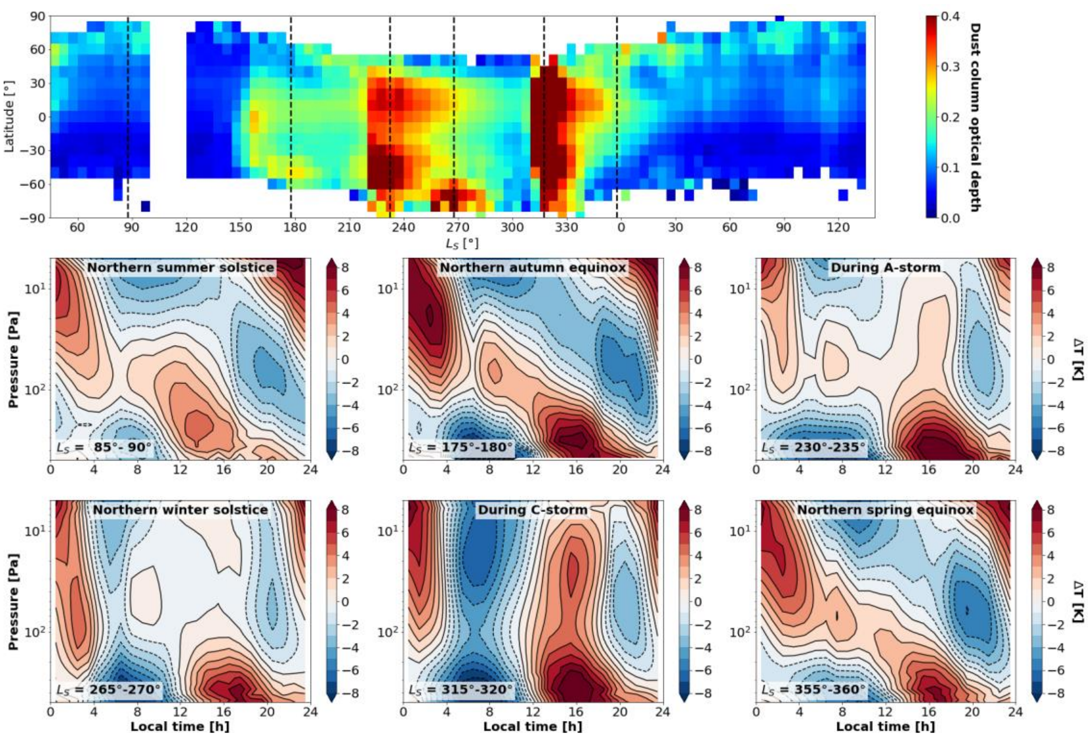

Figure 2. Dust column optical depth observed by EMM/EMIRS (top), and diurnal temperature anomalies in the equatorial region during different seasons of MY 36 (bottom). The dashed lines in the top panel denotes the corresponding seasons in the bottom panels.