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Thermal tides in Martian atmosphere from ACS/TIRVIM

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Thermal tides in Martian atmosphere from ACS/TIRVIM

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Abstract

Atmospheric thermal tides are planetary-scale temperature oscillations driven by diurnal solar forcing. They are characterized by temperature variations and winds throughout the thin atmosphere due to its low heat capacity. Given their long periods, which are typically equal or shorter than a Martian day, analyses of these tides require observations with high local time resolution. Observations from the TIRVIM Fourier-spectrometer, part of the Atmospheric Trace Gas Suite onboard ExoMars Trace Gas Orbiter (TGO), provide data meeting such requirements. Here we report independent temperature profiles of Martian atmosphere retrieved from TIRVIM nadir data. Amplitudes and phases of the tides are obtained, and their influence on the thermal structure of Martian atmosphere is estimated using the Mars Global Circulation Model (GCM).

Introduction

Diurnal thermal forcing by solar radiation excites temperature oscillations in Martian atmosphere through heat exchange with Mars surface (Gierasch & Goody 1968). Influenced by surface topography, the harmonic responses in the Martian atmosphere, thermal tides (Zurek 1976). Some modes of the tides occur at different altitudes with amplitudes growing exponentially with decreasing air density, which therefore influences the existence of such temperature and the related pressure variations has been observed by many Mars landers (e.g., 1977, Banfield et al. 2000, Lee et al. 2009, Kleinböhl et al. 2013, Forbes et al. 2020), but comprehensive studies as large spatial coverage and high temporal resolution are required to study s

Methodology and Results

We analyze the thermal tides using temperature structures retrieved from TIRVIM nadir data. TIRVIM spectrometer, as part of the ACS instrument onboard the ESA-Roscosmos mission ExoMars TGO (Koral 2020). TGO is on a non-solar-synchronous orbit with a period of 2 hours, so observations obtained cover a wide range of local time due to the short orbital period and orbit drifting (Capderou & Forgey 2018). The orbit cycle can be sampled between 74°N and 74°S within ~55 solar days (sols), which is equivalent to ~30 sols. Data within this range results in data covering most local time in a specific Martian month with TGO operated from April 2018 to December 2019, nearly one Martian year (MY) from MY34 Ls134° to MY35 Ls134°. We retrieved over 1 million thermal infrared nadir-viewing spectra with decent data quality. Despite some degeneracy, we extracted temperature profiles together with dust and water ice from these spectra (Guerlet et al. 2018). Each profile covers a vertical range from the surface to ~50-55km (~1-2Pa) with a vertical resolution of ~1 scale height (10km). Full coverage of local time on sub-seasonal scales (Figure 1), which makes it possible to evaluate thermal tides in Mars. We can resolve the harmonic aliasing introduced by solar-synchronous observations, e.g., observations at 3am local time. Climate Sounder (MCS, Lee et al. 2009).

A preliminary result of the thermal structure on the Martian southern hemisphere near MY35 spring is shown in Figure 2a. We binned the data between Ls 75° to 105° so that most of the local time is covered. No observations are shown during this period. The selected bin size of latitude is 3° and that of the local time is 1 hour. Temperature profiles and only migrating tides are shown. The diurnal temperature difference structure shows diurnal and semi-diurnal tides in the atmosphere, respectively, with "apparent" amplitudes of ~7K. Due to the degeneracy introduced by the response functions of TIRVIM thermal infrared spectra, the retrieved temperature profiles are vertically smoothed. Suggested by the LMD Mars GCM (Forget et al. 1999), amplitudes of these tides are 2-3 times larger than the observed ones. With the same response functions gives similar diurnal temperature difference structure (Figure 2c). A better retrieval makes a difference in extracting the diurnal temperature anomaly at low pressure level due to the smoothing kernels (Figure 2b and 2c), which requires further investigation with GCMs.

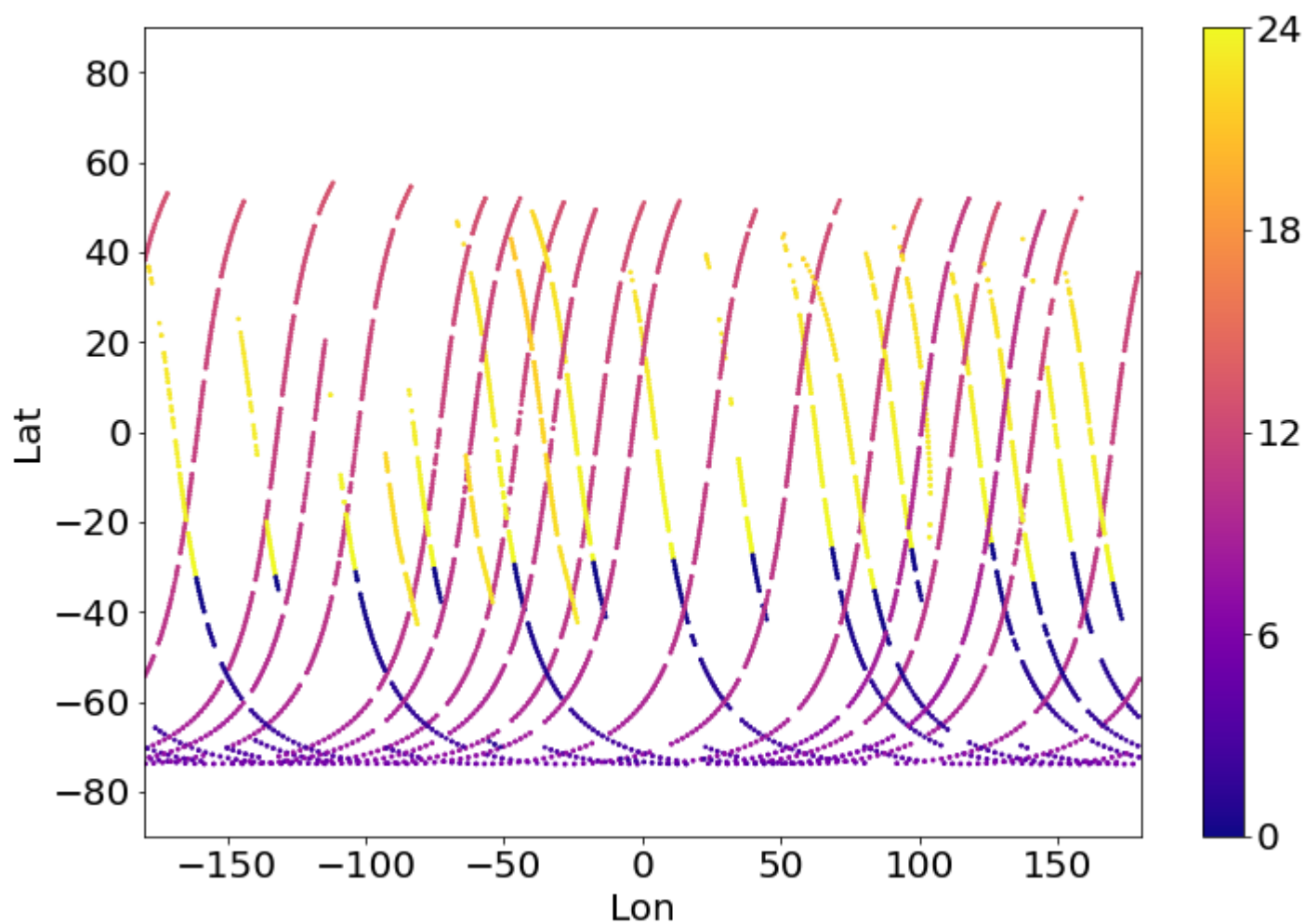
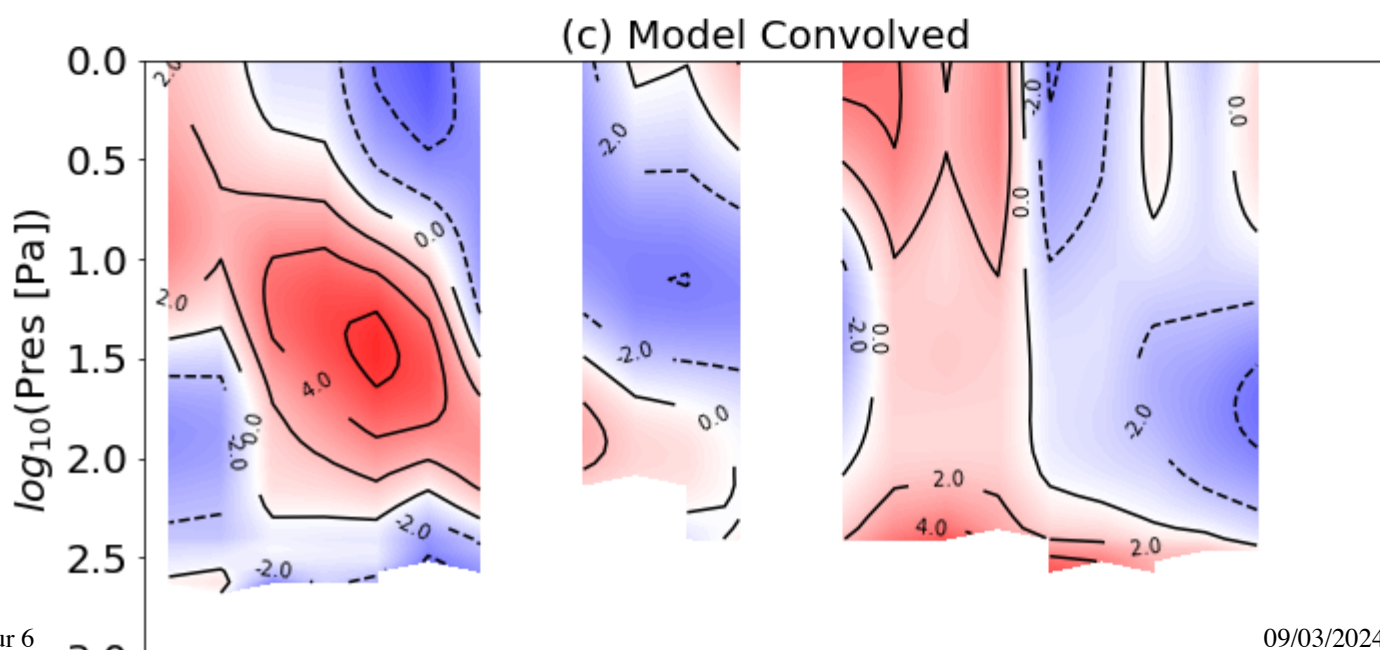
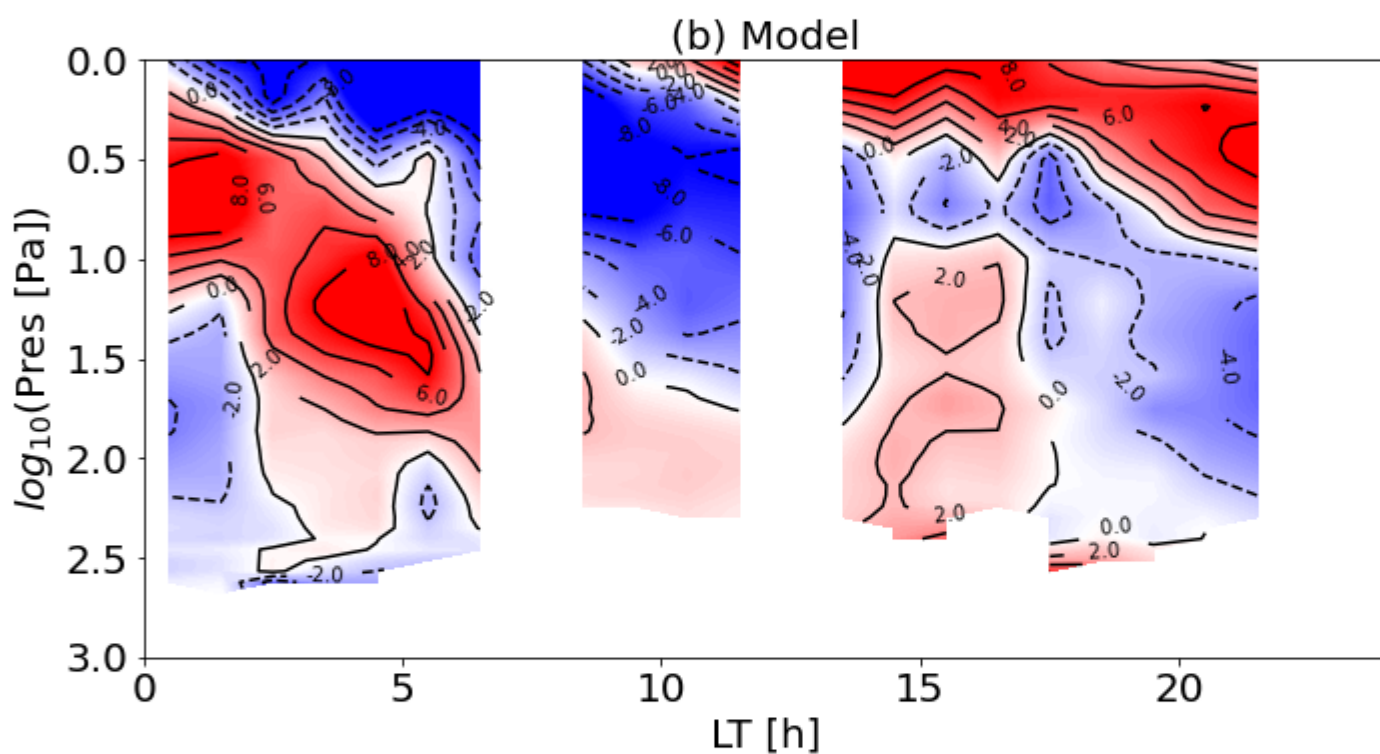
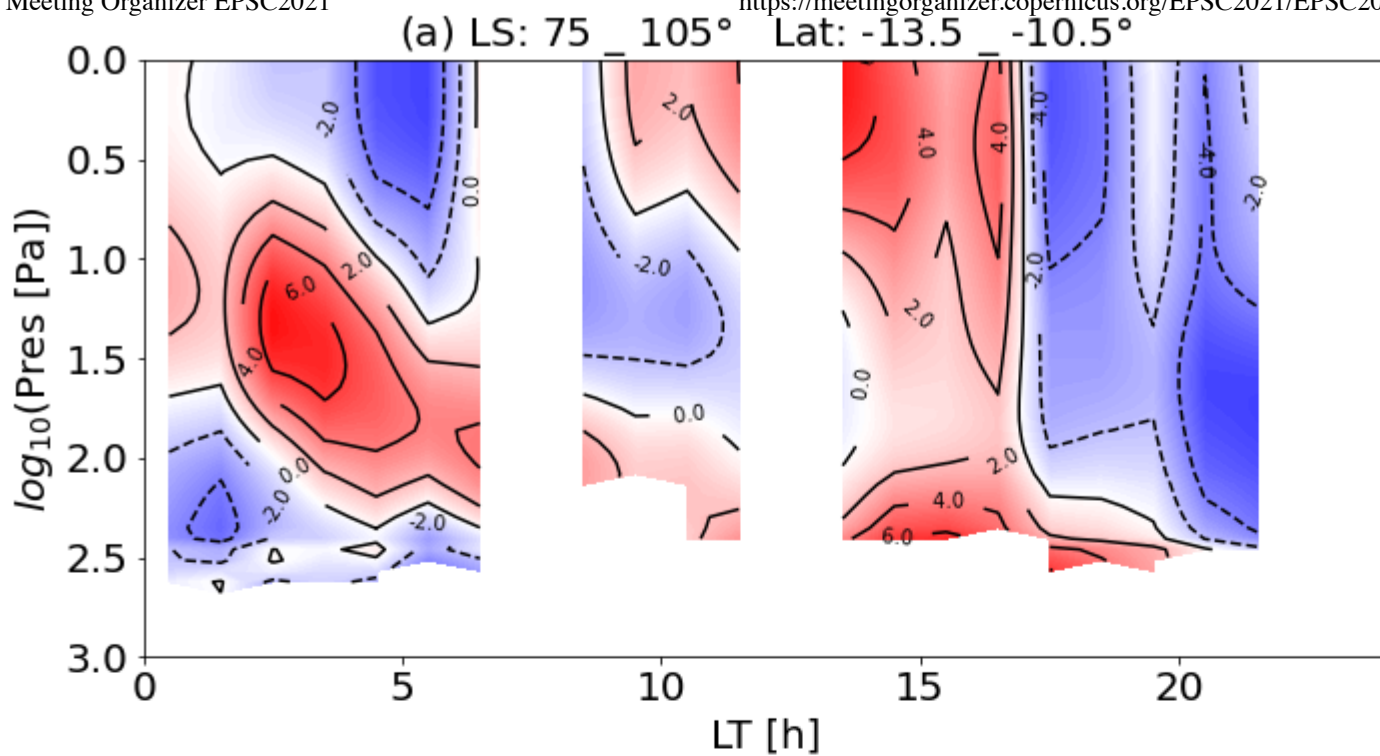


Figure 1. Spatial-temporal coverage of ACS/TIRVIM observations. Data from 20 orbits are shown for colors denoting the local time.



0

5

10

15

20

LT [h]

Figure 2. (a) Diurnal temperature anomaly derived using ACS/TIRVIM observations. The data is binned at 105°, and between 10.5°S and 13.5°S in latitude. (b) Result of the LMD Mars GCM. The model results are sampled with the same sampling weight as observations. (c) Same as (b), but vertically convolved with the averaging kernels used in the observations.

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