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Monitoring of the atmosphere of Mars with ACS TIRVIM nadir observations on ExoMars TGO.

Nikolay Ignatiev (1), Alexey Grigoriev (1), Alexey Shakun (1), Boris Moshkin (1), Dmitry Patsaev (1), Alexander Trokhimovskiy (1), Oleg Korablev (1), Davide Grassi (2), Pavel Vlasov (1,3), Ludmila Zasova (1), Sandrine Guerlet (4), François Forget (4), Franck Montmessin (5), Gabriele Arnold (6), Oleg Sazonov(1), Alexander Zharkov(1), Igor Maslov(1), Andrey Kungurov(1), Aleksandr Santos-Skripko(1), Viktor Shashkin(1), Fedor Martynovich(1), Igor Stupin(1), Dmitry Merzlyakov(1), Yury Nikolskiy(1), Dmitry Gorinov(1).

(1) Space Research Institute of Russian Academy of Scienses, Moscow, Russia, (2) Istituto di Astrofisica e Planetologia Spaziali – Istituto Nazionale di Astrofisica, Rome, Italy, (3) Moscow Institute of Physics and Technology, Dolgoprudny, Russia, (4) Laboratoire de Météorologie Dynamique (LMD), Paris, France, (5) LATMOS, Guyancourt, France, (6) German Aerospace Center (DLR), Berlin, Germany (ignatiev@iki.rssi.ru)

Abstract

The ExoMars Trace Gas Orbiter (TGO), a mission by ESA and Roscosmos started its operational scientific phase in March 2018. The Atmospheric Chemistry Suite (ACS) is a set of three spectrometers (NIR, MIR, and TIRVIM) designed to observe the Martian atmosphere in solar occultation, nadir and limb geometry [1]. The thermal infrared channel — TIRVIM is a Fourier-transform spectrometer encompassing the spectral range of 1.7–17 μm, with the best spectral resolution 0.13 cm^{-1}. In nadir operation mode, the primary goal of TIRVIM is the long-term monitoring of atmospheric temperature and aerosol (dust and ice clouds) state from the surface to approximately 60 km. We present the results of the first half year operation in orbit around Mars.

1. ACS TIRVIM Fourier transform spectrometer

TIRVIM is a 2-inch double pendulum Fourier-transform spectrometer with cryogenically-cooled HgCdTe detector, allowing both nadir and solar occultation observations. In nadir operation mode TIRVIM effective spectral range is limited to 5–17 μm (590–2000 cm^{-1}) with the apodized spectral resolution of 1.2 cm^{-1}. The capabilities of TIRVIM are similar to those of the previous experiments: IRIS/Mariner 9, TES/MGS and PFS/Mars Express, with advantages provided by the highest spectral resolution and better noise equivalent radiance (from 0.08 $mW/m^2/sr/cm^{-1}$) of the instrument, as well as the dense spatial coverage of the Martian surface due to TGO 400 km circular orbit. The altitude sensitivity range extends from the surface to 60 km with the vertical resolution from 3 km near the surface to 20 km at high altitudes. The best spatial resolution on the surface of 17 km is defined by the 2.5° field of view. In flight calibrations of TIRVIM are carried out with alternating observations of the deep space and the internal calibration black body.

2. Observations

First trial observations of TIRVIM were carried out from the equatorial capture orbit in November, 2016, and repeated from an intermediate orbit in February – March 2017. Routine operations started in March 2018. In nominal operation mode, 600 spectra are recorded from each orbit lasting 2 hours. The whole planet is covered with observations in just a couple of weeks. Examples of Martian spectra recorded by TIRVIM for a variety of locations and local times are shown in Figure 1.

3. First results

Inverse problem solution methods for the atmospheric thermal sounding are well known. We used both Bayesian approach, known also as statistical regularization, coupled with line-by-line radiative transfer for final result presentation with associated formal error, and a relaxation method coupled with convolved transmittance technique for fast evaluation of the temperature field. Vertical temperature profiles with the surface temperature in the bottom of each curve are presented in Fig. 2, while 2-D temperature field along the sub-spacecraft track on the surface is presented in Fig. 3. Half year of TGO operation should provide a unique opportunity to monitor a daily cycle of temperature field in addition to its seasonal variations.

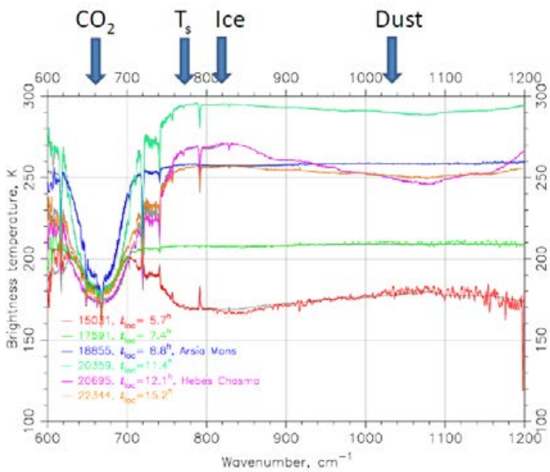

Figure 1: Examples of ACS TIRVIM measured and model spectra recorded at various locations and local times. Absorption bands of CO_2, dust and water ice, as well as the region with minimum opacity used for monitoring of the surface temperature are marked with arrows.

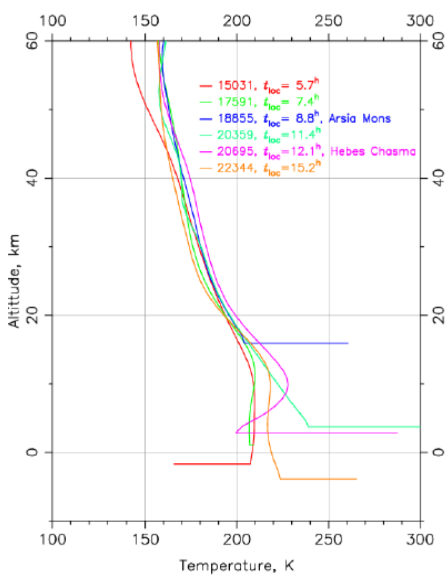

Figure 2: Temperature profiles retrieved for the spectra shown in Figure 1.

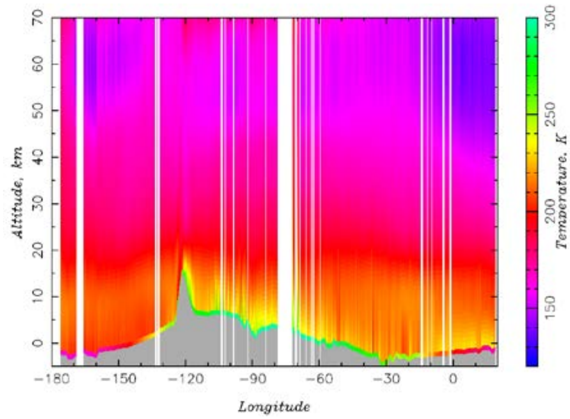

Figure 3: Temperature field along the sub-spacecraft track on the Martian surface measured from the equatorial capture orbit.

Acknowledgements

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References

[1] Korablev, O. et al.: The Atmospheric Chemistry Suite (ACS) of Three Spectrometers for the ExoMars 2016 Trace Gas Orbiter, Space Science Reviews, Vol. 214, Issue 1, 2018.