TEMPERATURES OF MARTIAN ATMOSPHERE IN THE ALTITUDE REGION 60-100 KM RETRIEVED FROM THE MGS/TES BOLOMETER INFRARED LIMB RADIANCES.

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Introduction: The Thermal Emission Spectrometer (TES) on-board the Mars Global Surveyor (MGS) consists of a thermal infrared spectrometer (6–50 μm), with either 6 or 12 cm^{-1} spectral resolution) as well as of two broadband bolometers covering the solar band (0.3–3.0 μm) and thermal band (5.5–100.0 μm) [1]. The limb observations of the Mars atmosphere have been included roughly every 10 degrees of latitude throughout the orbit (both day and night) throughout the mission. The 8.3 mrad single detector field-of-view had a projected size of about 13 km at the limb, allowing vertical resolution of just over a scale height. However, the 3x2 array of TES detectors (both spectrometer and bolometer) were scanned in overlapping steps from below the surface to about 120 km tangent height above the surface providing vertical step varying from about 1 to 5 km. About 750,000 limb geometry sequences have been obtained covering a span of four Martian years. While the noise level of the TES limb-geometry spectrometer data limits retrieved temperature profiles to a maximum height of about 60–65 km above the surface [2], significant signal above the noise level is still observed in the thermal band bolometer to at least 90–95 km above the surface.
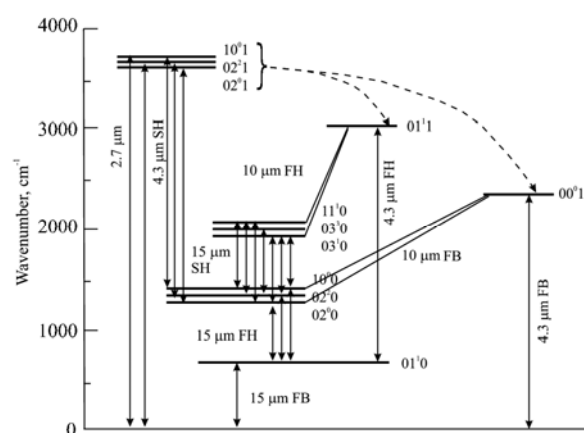

Figure 1. The diagram of lower CO_2 vibrational levels and main transitions.

Non-LTE model of TES/MGS bolometer signal. In the altitude region 60–100 km the non-LTE emissions of the infrared CO_2 bands around 15 and 10 μm form the limb-geometry TES bolometer radiances. The diagram of lower CO_2 vibrational levels and main transitions is shown on Fig.1. At nighttime the levels of the vibrational bending mode of the CO_2 molecules responsible for the 15 μm emission are populated due to the absorption of upwelling atmospheric radiation and inelastic collisions (vibration-translational, or V-T processes). Levels of various isotopes of different excitation degrees are also involved in intensive exchange of vibrational energy (V-V processes) by molecular collisions. In addition to this at daytime the absorption of near infrared Solar radiation by the CO_2 bands in the spectral region 1–4.3 μm provides strong pumping of higher combination levels which causes complex chain of radiative, V-T, and V-V energy transfer processes. This leads to populating combination levels responsible for daytime 10 μm transitions and to increasing the populations of bending mode levels and 15 μm daytime emission (see Fig.2 for contributions to bolometer signal). We applied for daytime calculations and retrievals presented below the model that includes about 120 vibrational levels of 7 CO_2 isotopes and about 400 bands with 60000 spectral lines available in HITRAN/HITEMP database.
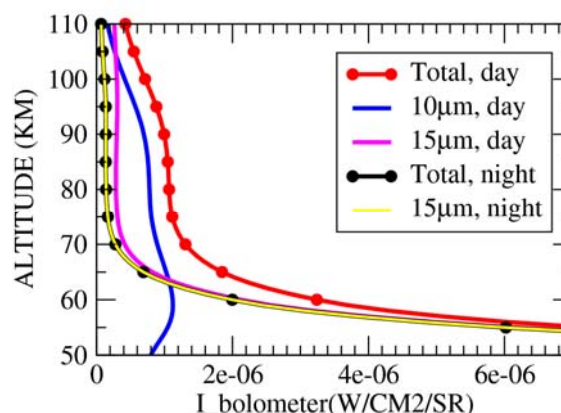

Figure 2. Contributions to bolometer signal for Mars Pathfinder entry temperature profile.

For nighttime the model was reduced to 60 vibrational levels of 5 isotopes (about 150 bands with 20000 lines). We utilize the ALI-ARMS (for Accelerated Lambda Iterations for Atmospheric Radiation and Molecular Spectra) code package [3,4] developed for the solution of the non-LTE problem and limb radiance calculations. We use an extended and revised kinetic model for V-T and V-V interactions described in [5] supplemented with the processes of the CO_2-CO_2 collisions in the Martian atmosphere ac-

quired from [6,7]. The CO_2 and $O(^3P)$ volume mixing ratios have been taken from [8].

Forward-fit temperature retrievals from the TES bolometer limb signal. Fig.3a shows numerical simulation of retrieval from the TES bolometer limb signal. The Mars Pathfinder profile from July 4, 1997 (http://starbase.jpl.nasa.gov/archive/mpfl-m-asimet-2-edr-surf-v1.0/mpam_0001/document/edlddrds.htm) was used for simulating the bolometer signal with the accounting for the bolometer bandpass and the detector field-of-view. It was used as a replacement of measured signal in the retrieval forward fitting algorithm. T(z)=const=200 K was used as an initial temperature guess for the iterative fitting shown here. The upper limit was determined by the bolometer signal-to-noise ratio. T(z) profiles for a number of iterations as well as the converged profile are shown.
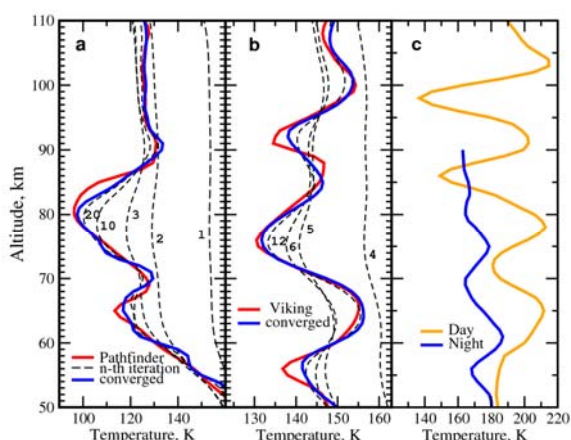

Figure 3. a) Self-consistency test with Pathfinder T profile; b) Same test with Viking1 T profile; c) Retrievals from real TES bolometer signals.

In Fig.3b the process of fitting the Viking 1 temperature profile is presented. The retrieved temperature profiles did not depend on the initial guesses. The converged profiles reproduce well the wave patterns of profiles used for initial signal modeling. The temperature differences between initial and converged profiles reach 8 K at the altitude of 84 km for the Pathfinder profile. The study showed they are caused mostly by the averaging effect of the broad detector field-of-view combined with low temperatures in this region. The nighttime retrieval from a real TES bolometric limb signal is shown on Fig.3c in the altitude region 50–85 km (the upper limit defined by the nighttime signal-to-noise ratio) for 20 December 2005 (Mars Year 27, Ls=343°, latitude = -7°, zonal averaged within longitude = 5°). The daytime retrieval in Fig.3c has been performed for the same day and latitude in the altitude region 60–110 km. The upper limit for this retrieval

has been extended up to 110 km because of better daytime signal-to-noise ratio. For both day- and nighttime retrievals the bolometer limb signal profiles were interpolated from the variable vertical grid to the regular one with 1 km step, on which the iterative fitting was performed. The iterations were stopped when the overall r.m.s. value of the signal residual in the altitude range of our retrieval reached the plateau (usually it happened after about 20 iterations). In this case the signal residuals were less than 10 % and two sequential corrected temperature profiles differ by less than 1 K. Further iterations lead to a quick destabilization of the relaxation process and loss of "physical solution". The converged profile also did not depend on the initial temperature guess. The retrieved profiles demonstrate strong wave pattern with the wavelengths of ≈15–20 km and ≈10–15 K amplitudes. Structures similar to these were observed during Viking, Spirit, Opportunity and Pathfinder entries (see [9-11]), and are also obtained in the models [12].

Conclusion. We demonstrate the possibility of retrieving the Martian middle and upper atmospheric temperatures from the broadband TES/MGS infrared bolometer limb radiance measurements. This feasibility study was performed for the proposal "Retrieval of temperatures of Martian atmosphere in the altitude region 60–100 km from the MGS/TES bolometer infrared limb radiances" submitted in response to the NASA Research Announcement NNH07ZDA001N-MDAP (C.12 Mars Data Analysis). The temperatures obtained between 60 and 100 km from the TES limb bolometer data for all available latitudes and seasons will be linked to those already retrieved below 65-70 km from the TES spectrometer data providing new extended database of the thermal structure of the Martian atmosphere.

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