VERTICAL DISTRIBUTIONS OF WATER VAPOR AND AEROSOL IN THE MARTIAN ATMOSPHERE BY SPICAM-IR SPECTROMETER ON MARS-EXPRESS.

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Introduction: Solar occultations represent a sensitive method for detection of minor constitutes and aerosols in planetary atmospheres and retrieval of their vertical distribution including spatial and temporal variations at morning and evening terminators. The first approbation of occultation method on Mars was performed by Auguste experiment on PHOBOS 2 in 1989. Despite of short life of the mission (about 2 months) substantial new information was obtained: ozone vertical distribution [1], dust vertical distribution at L_s=30 [2, 3] and eddy diffusion coefficient; water vapor vertical profiles [4]. We report here a complete set of solar occultation study of the Martian atmosphere performed in Mars Express mission.

The instrument: An infrared AOTF spectrometer is a part of SPICAM experiment onboard Mars-Express mission [5]. It has solar occultation capability and operates in the range 1-1.7 µm with a spectral resolution of ~3.5 cm^{-1}. The FOV of the instrument when observing the sun is 4.2 arc min that corresponds to vertical resolution better than 3.5 km, provided the distance to limb is below 3000 km. During three Martian years (MY 27-29) about 500 successful infrared occultations have been carried out, with L_s varying from 50 to 344 and full range of latitudes and longitudes. We report results obtained in MY27-29 at L_s 50-80, 130-160, 180-200, 220-225, 250-300 from the middle southern to the high northern latitudes. For these orbits the atmospheric density from 1.43µm CO_2 band, water vapor mixing ratio based on 1.38µm absorption and aerosol opacities were retrieved simultaneously.

Retrieval: Aerosol vertical extinction profiles were obtained at 10 wavelengths (from 1 to 1.55 µm) (fig.2) in the altitude range from 10 to 60 km. The interpretation of these results using Mie scattering theory with adopted refractive indices of Martian dust and H_2O ice particles allows to retrieve particle size distribution and number density.

Vertical profiles of H_2O and CO_2 were obtained from 1.38 µm and 1.43 µm absorption bands respectively using HITRAN 2004 spectroscopic database [6] and Martian Climate Database v4.2[7].

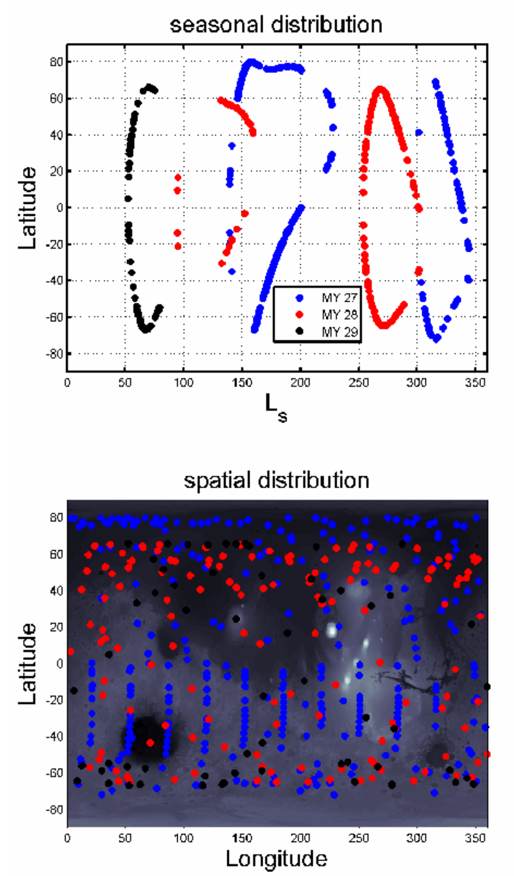

Figure 1. Seasonal and geographical distribution of solar occultation measurements of SPICAM IR for three Martian years.

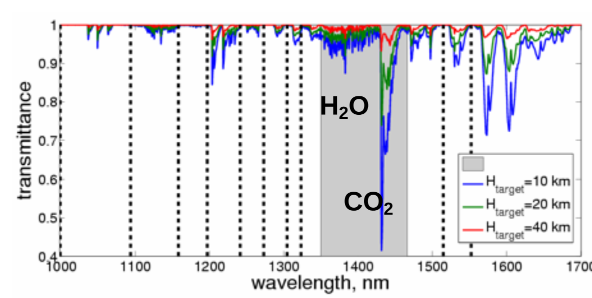

Figure 2. A synthetic model of transmittance in the Martian atmosphere for occultation geometry. H_2O mixing ratio is 100 ppm uniformly mixed. Spectra have been convolved with SPICAM IR instrument function. The positions of main gas features are indicated. Dashed lines mark the reference wavelength used to characterize aerosol.

Results: At L_s 130-160˚ (MY28) the aerosol number density is found to be of the order or below 1 cm^{-3} at the altitudes between 15 and 30 km, with the effective particle radius r_{eff} ~ 0.5-1 µm. The observed top of the haze is generally below 40 km. Extrapolated total optical depth is 0.33±0.23 (L_s =130-160˚) with increase of opacity from 0.23 at L_s=135° to 0.43 at L_s=155°. The results are in the large consistent with measurements performed on Viking Landers, Mars-Pathfinder and TES/Mars Global Surveyor. Exceptionally, in the range of 320°-50° of east longitude a number of high-altitude clouds were detected at 50-60 km (fig.3). Properties of these clouds are consistent with particles having r_{eff}=0.1-0.3 µm and variance ν_{eff}=0.1-0.2 µm, corresponding to number density N~10 cm^{-3}. The vertical optical depths of such clouds at 1.1 µm do not exceed 0.01, making them virtually undetectable for nadir or ground-based observations.

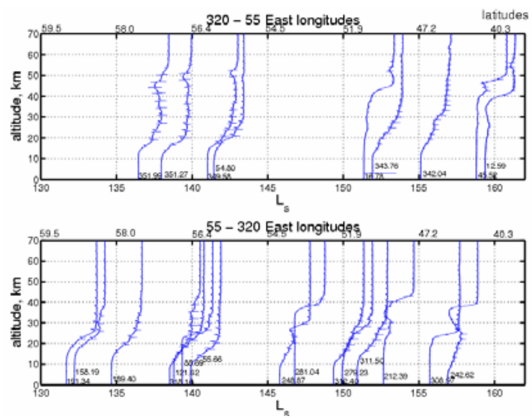

Figure 3. Vertical profiles of transmission obtained for L_s=130-160 (MY28)

The density of the atmosphere was retrieved from CO_2 band in the altitude range of 10-90 km, and H_2O mixing ratio was determined at the altitudes from 15 to 50 km (figure 4). Unless a severe supersaturation of water vapor occurs in the Martian atmosphere, the H_2O mixing ratio indicates by about 5K warmer atmosphere at altitudes from 25 to 45 km than predicted by most of GCM simulations [7].

Another example of the vertical distribution of H_2O mixing ratio and aerosol particle size is shown in figure 5. These observations have been performed near the North Pole in autumn in the northern hemisphere (L_s=200˚). The mixing ratio of H_2O does not exceed 1 ppm and aerosol particle size r_{eff} is 0.2-0.3 µm

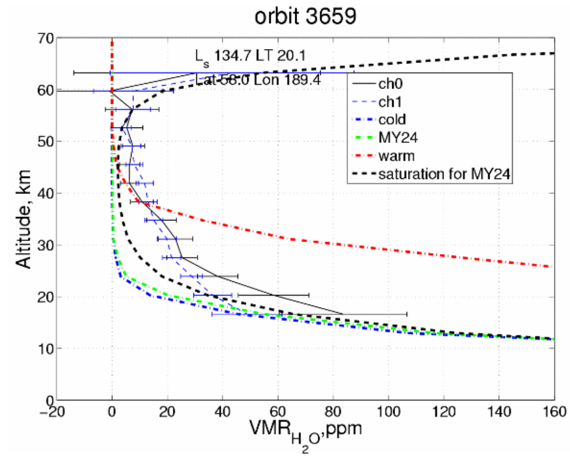

Figure 4. Comparison of H_2O mixing ratios measured by SPICAM IR with predictions of GCM: cold, MY24 and warm scenarios [7].

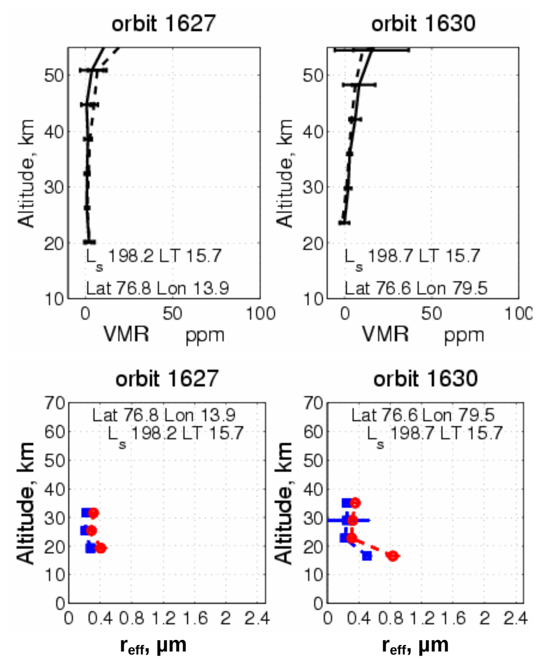

Figure 5. The H_2O mixing ratio and aerosol effective radius for observations of the North Pole at L_s 200˚. Dashed and solid lines for H_2O (top panels) indicate the results obtained for two detectors. Red and blue lines at bottom panels show the particle sizes under the assumption of H_2O and dust refractive indices, respectively.

The latest observation set performed in MY28 (summer 2007) allows to observe how the vertical distribution of dust evolves during the global dust storm, which began approximately at L_s 270˚ (figure 6) in the southern hemisphere.

The high altitude clouds (70-75km) spatially localized near longitudes of 200-260˚ have been detected in the northern hemisphere at Ls 265-272 before the beginning of the dust storm. The optical depths of these clouds are below 0.01.

The water shows a large abundance in the southern hemisphere as compared with the northern latitudes at Ls 255-270 before the beginning of the dust storm. Southern vertical profiles of H_2O show a close to uniform mixing ratio from 20 to 65 km with some variations. Obtained mixing ratio equals 100-200 ppm. The higher altitudes are already limited by the sensitivity of the spectrometer..

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References: [1] Blamont, J.E. and E. Chassefiere (1993), *Icarus 104*, 324-336. [2], Krasnopolsky, V.A. et al. (1989), *Nature 341*, 603-604. [3] Korablev, O.I. et al. (1993), *Icarus 102*, 76-87. [4] Rodin, A.V. *et al.* (1997), *Icarus 125*, 212-229. [5] Korablev, O. et al. (2006), *JGR 111*, doi:10.1029/2006JE002696. [6] Rothman, L.S. et al. (2005), *JQSRT, 96*, 139-204. [7] Forget, F. et al. (2007), LPICo1353.3098F

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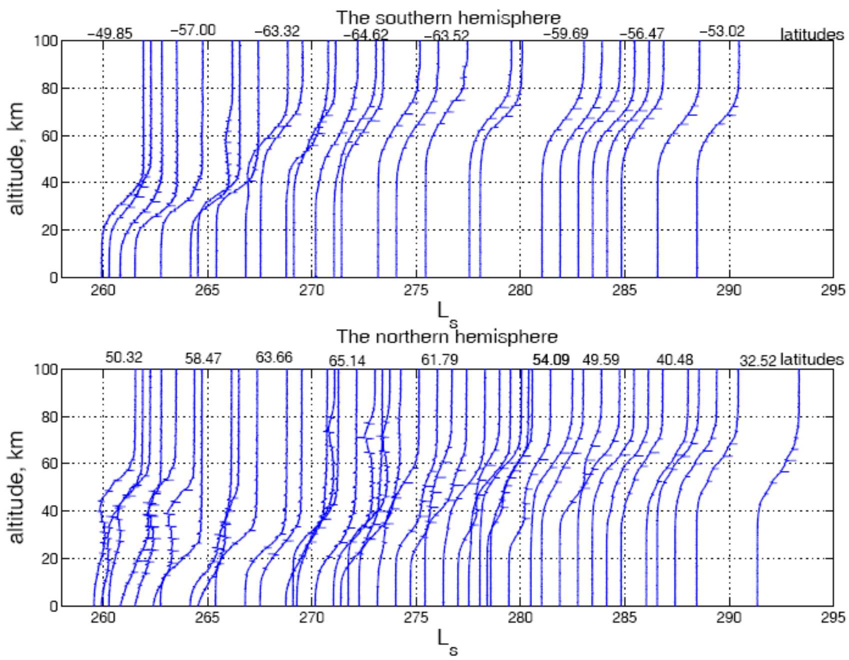

Figure 6. Vertical profiles of transmission obtained for L_s=260-295˚ (MY28)