MARS ATMOSPHERE AND CLIMALOGY WITH MARS-EXPRESS: MAIN RESULTS OF EXPERIMENTS WITH RUSSIAN PARTICIPATION.

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Introduction: More than one and half year passed since insertion of Mars-Express into Martian orbit on 25 December 2003. The spacecraft carries instruments HRSC, OMEGA, PFS, ASPERA and SPICAM [1,2,3] which are heritage from unsuccessful Mars-96 mission. This paper highlights main results on the Martian atmosphere and climate obtained by three instruments, PFS, SPICAM and OMEGA, and with Russian participation. Temperature field, concentration of minor constitutes like water vapor, ozone, methane and CO, H_2O and CO_2 ice clouds, opacity, aerosol content and vertical distribution, were observed during almost one Martian year. These data are critical in understanding the dynamics, photochemical processes and history of Martian atmosphere, challenging new theoretical studies with general circulation models.

Temperature field: Temperature profiles from the surface to 60 km altitude, and their variations versus season and local time, are retrieved at each orbit on the basis of thermal emission in the vicinity of 15-μm CO_2 band.

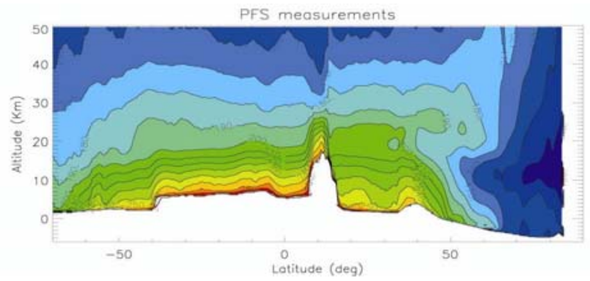

Figure 1: Temperature field (isolines) vs. altitude and latitude along orbit 68, which passes across Tharsis (jo401S), Ascraeus Mons (101N) and marginal area of Alba Patera (401N). [4]

Due to high spectral resolution, a fine structure of temperature inversion in the polar region, related to descending branch of Hadley cell (L_s=342°) was observed as low as at 10-20 km. The winter temperature inversion is caused by downdraft of the air mass advected from the summer hemisphere by the main Hadley cell branch, and subsequent adiabatic heating. As the heating occurs at relatively high altitude (30-60 km), lower atmosphere controlled by radiative transfer processes appears colder, which renders as sharp temperature inversion.

Water vapor: The water vapor was observed by PFS, SPICAM and OMEGA instruments. Seasonal and spatial distribution of H_2O was obtained by SPICAM (in 1.38 μm band) and PFS (2.56 and 20-40 μm). Figure 2 shows seasonal distribution of H_2O from SPICAM IR channel and special distribution from PFS 20-40 micron band.

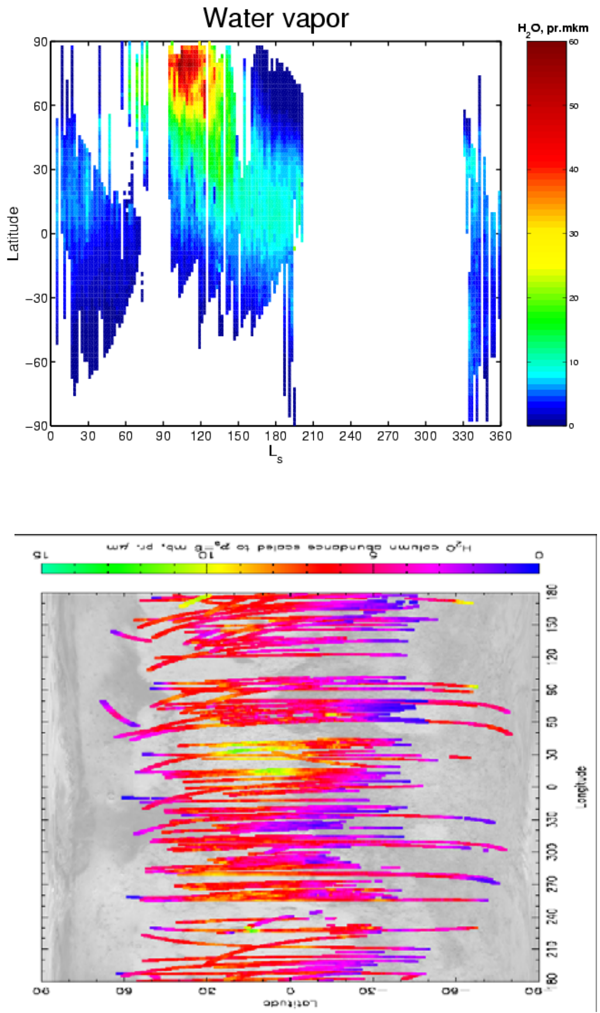

Fig. 2 Seasonal distribution of water vapour measured by SPICAM IR (orbits 8-1640), and areographical distribution of water in Northern spring by PFS (L_S=330°-60°). Apparent zonal structure revealing a strong equatorial maximum at 10°-45°E and a weaker maximum at 200°-240° suggests contribution from stationary planetary waves to the global water cycle on Mars.

O_2 airglow at 1.27 micron in nadir viewing: Mars-Express implements 4 methods of ozone detection: UV stellar occultations; UV solar occultations; UV nadir viewing (ozone total column density); O2(1Δ) emission at 1.27 μm (high altitudes). The latter approach gives an access to ozone density above 20 km. Measurement of ozone in the NIR range are also possible for SPICAM and OMEGA.

A singlet oxygen O_2 ($^1\Delta_g$) dayglow at 1.27 µm was predicted just after the discovery of ozone on Mars by Mariner 9 [5]. On Mars the situation is similar to Earth, where a strong airglow arises from O_2 ($^1\Delta_g$) produced by ozone photolysis. For the first time this emission was observed from the ground at high resolution by Noxon et al.[6]. The mapping of this emission was reported by Krasnopolsky and Bjoracker [7]. Krasnopolsky [8] argues that the O_2 emission provides even better insight to photochemistry than ozone, since it is more sensitive to the variations of the water vapour saturation level (10-35 km) than total ozone, which remains nearly constant.

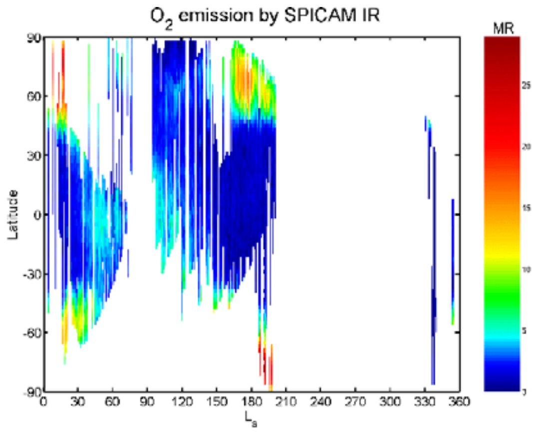

Fig. 3. Seasonal distribution of $O_2(^1\Delta_g)$ emission in Mars atmosphere (SPICAM). Colour code is in MR.

Ozone quantity is controlled by the abundance in odd hydrogen species (HOx). HOx are produced by the photolysis of water vapor. Expected anti-correlation between ozone and water vapor are well seen by OMEGA and SPICAM (fig.4).

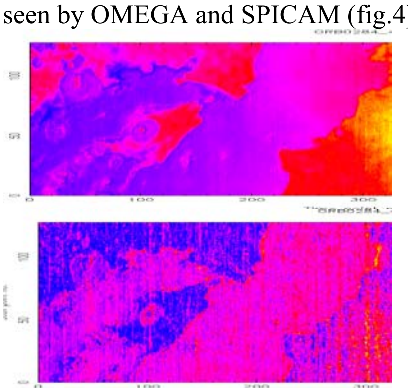

Fig.4 Autocorrelation of O3 and H_2O (OMEGA – orbit). Top: 1.38 micron H_2O band, bottom: Intensity of the 1.27 µm O2 emission.

Vertical distribution of aerosol: All spectrometers are capable of studying the distribution and composition of Martian aerosols. Observations of water ice clouds, insight into their microphysics and the discovery of fine fraction of submicron particles extending high up in atmosphere are among the important results of Mars-Express. In particular, vertical profiles of aerosols were observed by SPICAM IR channel in solar occultation mode (fig.5).

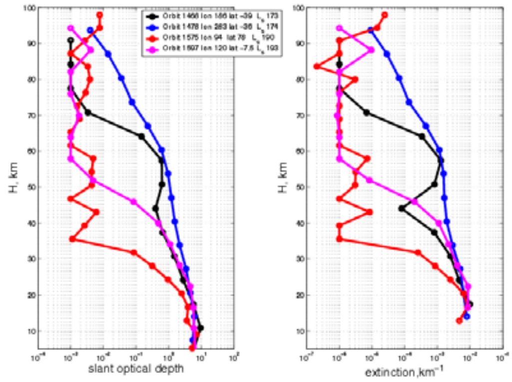

Fig.5. Slant optical depth and extinction profiles are obtained by SPICAM IR channel in range 1274 micron. Lower north polar profile contrasts with high extended south middle latitude extinctions.

We believe that the specific features of the vertical distribution of high-altitude aerosols, including evident depression near the poles and subtle inversions in midlatitudes, have dynamical origin. This conclusion is based on the numerical experiments with the GFDL's Mars GCM including interactive transport and coupled with ab initio microphysical description of water ice clouds. In the equinox season, Hadley cell circulation lifts dust and cloud particles in the equatorial latitudes up to 35-50 km and then advects them out of the equator in the two symmetric branches. In midlatitudes (approximately at 45-60^o) the advective poleward flow fades. Larger particles settle out, while smaller ones are accumulated in the convergent areas of the circulation pattern. It is this location where SPICAM solar occultation data suggest inversion of the vertical dust profile. Upper polar latitudes are characterized by very weak circulation with dominating downdraft vertical air motion. Therefore those particles trapped in the polar atmosphere are transported downwards until they either precipitate at the surface or advected back to low latitudes within the low-altitude closing flow of the Hadley cell. These causes substantially lower, relative to midlatitudes, vertical extension of the aerosol layer.

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