STUDIES OF THE LOCAL CIRCULATION IN THE MARTIAN ATMOSPHERE FROM PFS DATA

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Introduction:

The Planetary Fourier Spectrometer (PFS) is a wide range (300-8000 cm^{-1}), high resolution (2 cm^{-1}), spectrometer included in the payload of the Mars Express (MeX) mission [1]. The data acquired by the instrument in the thermal range, once properly calibrated, can be used for the self-consistent retrievals of the vertical air temperature profile (in the indicative range 5-45 km above the surface), ground temperature and integrated contents of silicate dust and water ice suspended in the atmosphere [2]. More specifically, the high spectral resolution of the instrument allows a vertical resolution in the retrieved T(p) profile in the order of 15km @30km altitude. These performances make PFS a suitable tool to study the details of atmospheric circulation in the locations of specific atmospheric behavior, such as topographic discontinuities or polar caps. The former class of studies is reviewed and extended in this paper, while a synopsis of polar investigations is given in the companion work by Giuranna et al.

Analysis method:

The orbital evolution of MeX satellite has imposed a strong correlation between local time, season, latitude and spatial resolution in nadir measurement. Consequently, the direct comparison of experimental retrievals derived from very different observative conditions may become puzzling. PFS-derived state vector characteristics are often better understood by comparison against the expectations of a global circulation model (GCM). For this purpose, we adopted EMCD 4.0 [3], the pre-computed version of LMD-AOPP-IAA GCM [4]. This approach must however be exercised cautiously because of the moderate grid resolution (5°x5°) adopted during GCM runs.

PFS study cases:

Three specific cases are considered here to demonstrate the potentialities of PFS data.

Atmosphere in the region of volcanic reliefs. The surroundings of high volcanic domes are well-known locations of mesoscale phenomena [5]. We reported in [6] a first direct observation of anomalous air temperature fields on the summits of Olympus and Ascreus montes during the early phases of MeX mission. Namely, in fig. 1 and 2. strong coolings can be appreciated at high altitudes as well as very different vertical gradients on the two sides of the domes. Interpretation of this behavior is not straightforward without the support of a mesoscale circulation model, but preferential air heating due to slope or gravity waves triggered by the global circulation may both play a role. In progress studies (fig. 3-4) demonstrate that a similar behavior occurs even in other seasons and is somehow related to the position of the subsolar point. Noteworthy, similar trends are documented for other Tharsis domes, exception made for the broad and moderate relief of Alba Patera.

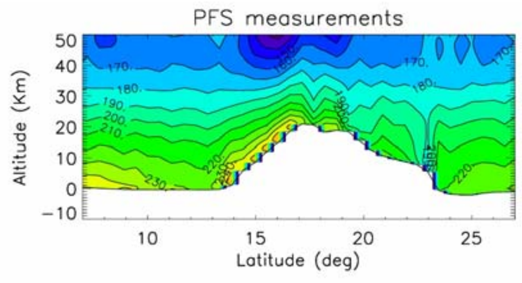

Fig. 1 Orbit 37, Olympus Mons. L_s=337, Lt=13.8

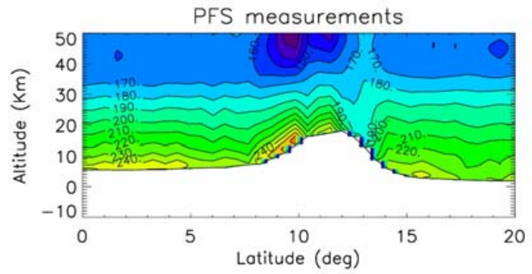

Fig. 2 Orbit 68, Ascreus Mons. L_s=342, Lt=13.1

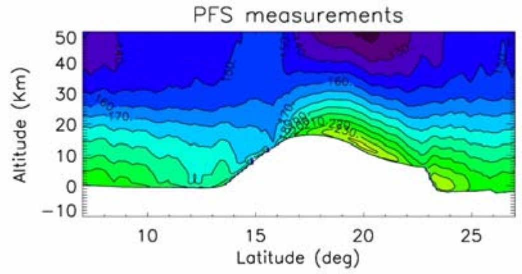

Fig. 3 Orbit 501, Olympus Mons. L_s=46, Lt=9.0

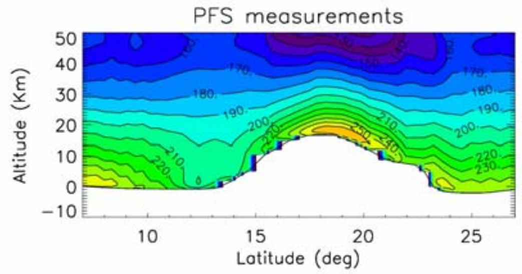

Fig. 4 Orbit 1437, Olympus Mons. L_s=168, Lt=11.0

Hellas basin. The location has been identified since a long time as the site of peculiar atmospheric phenomena [e.g.:7], mainly related to aerosol. Namely, several authors [e.g.:8] pointed out a possible role of slope winds in the rising of dust at the rim of the basin. The relatively smooth topography of the basis allows in this case an effective comparison of PFS measurements against EMCD expectations (fig. 5) [9].

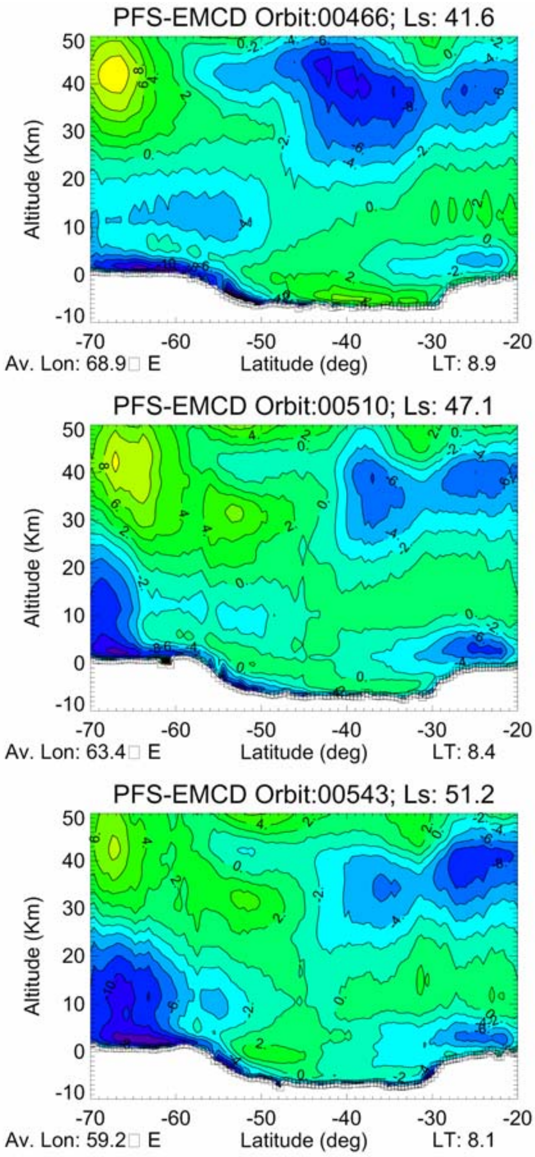

Fig. 5 Differences between the air temperature fields derived from PFS data and corresponding EMCD 4.0 expectations.

Data highlight the constant occurrence of temperature deficiencies at the northern rim and at the center of the crater for intermediate altitudes. Assuming that the structures do not vary with local time and season on the limited ranges considered here, it is possible to build a 3D reconstruction of temperature differences (fig. 6) which makes evident the correlation with topography.

Once again, a physical interpretation of the observed phenomenology suffers from the lack of a mesoscale circulation models. A very simplistic interpretation is given by the adiabatic expansion of the air masses moving southward in the context of the global circulation.

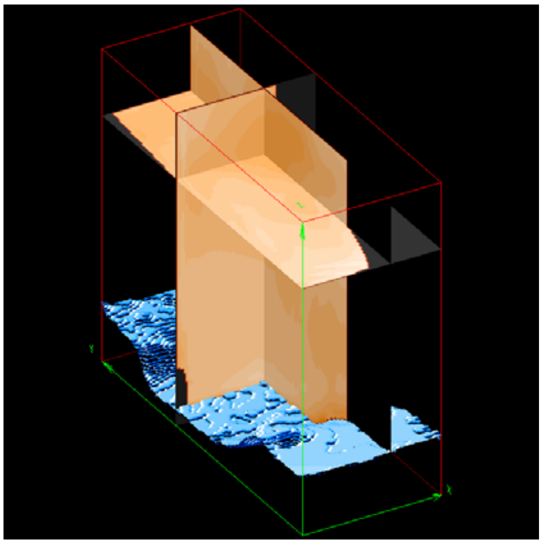

Fig. 6 3D reconstruction of temperatures anomalies observed in the Hellas basin around L_s=50°. Z axis = altitude [-10, 50] km, x axis = longitude [58, 78] deg E, y axis = latitude [70, 20] deg S. Color code spans from –10K (dark orange) to +10K (white).

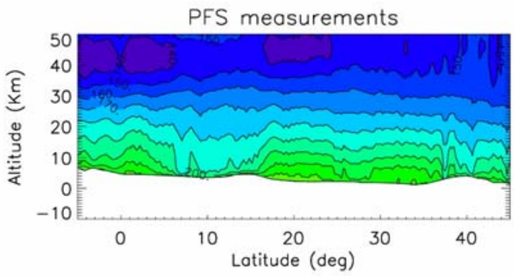

Fig. 7. Orbit 331, av. lon.=260°E, L_s=23.6, Lt=10.5

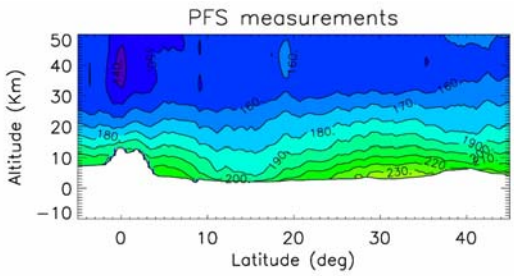

Fig. 8. Orbit 891, av. lon.=246°E. L_s=93.9, Lt=16.7

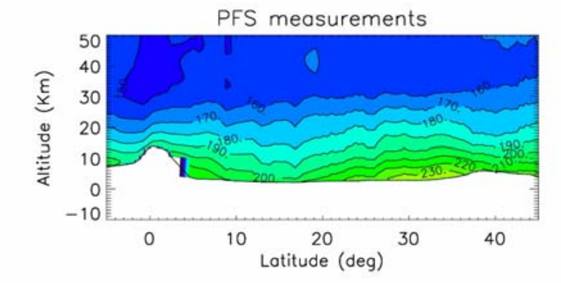

Fig. 9. Orbit 902, av. lon.=247°E, L_s=95.3, Lt=16.6

Tharsis plateau, south of Alba Patera. PFS detected here a region of cold air (with respect to surrounding areas and EMCD expectations) at low altitudes, constantly located at the center of the topographic minima around 15N (fig. 7-9), roughly defined by Pavonis Mons, Ascreus Mons and Alba Patera,. Noteworthy, this thermal structure seems to be persistent over different seasons. Moreover, the observations from orbit 331, obtained at 10.5 Lt (to be compared to the afternoon time of other cases) might also indicate for this area constant patterns of local circulation on daily time scale. Both aspects make the observed behaviour very difficult to justify heuristically.

Conclusions:

The PFS dataset is demonstrating as a potential key tool in the understanding of the local phenomena of Martian atmosphere. The full exploitation of its potential requires however a much closer comparison with mesoscale circulation models coupled with the boundary conditions provided by GCMs. Until that, the mere phenomenological approach can provide only very limited understanding of the ongoing processes.

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References: [1] Formisano et al., P&SS, 53, 10, p. 963-974, 2005 [2] Grassi et al., P&SS, 53, 10, p. 963-974, 2005 [3] Lewis et al., JGRE, DOI 10.1029/1999JE001024, 1999 [4] Forget et al., JGRE, DOI 10.1029/1999JE001025, 1999 [5] Rafkin et al., Nature, 419, 6908, p. 697–699, 2002 [6] Grassi et al., P&SS, 53, 10, p. 1053-1064, 2005 [7] Leikin and Zabalueva, PAZh, 1, p. 36-38. in Russian., 1975. [8] Joshi et al., JGRE, DOI 10.1029/96JE03765, 1997 [9] Grassi et al., abstract # 33.11, 37th DPS meeting, 2005