NEAR-INFRARED SPECTRAL SLOPE AS A CLUE TO AEROSOL VERTICAL DISTRIBUTION ON MARS. S. Erard, P. Drossart, J-P. Bibring, J. Rosenqvist and E. Chassefière.

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Introduction: The imaging spectrometer ISM flew aboard the Phobos-2 spacecraft which orbited Mars from January to March, 1989. About 40,000 spectra were acquired between 0.76 to 3.16 μm, with a spatial resolution of 25 km and a signal-to-noise ratio ranging up to 1000, under various incidence and emergence angles [1] [2] [3]. The observed spectra all exhibit a strong negative slope. Previous studies of photometric variations of reflectance showed that this slope is mainly due to scattering by aerosols — although surface properties also have an influence on it — and made it possible to retrieve the spectrum of the scattered contribution [4] [5].

Spectral slope evaluation: The slope, computed as the difference Δr of reflectances measured at 1.8 and 2.4 μm, is the sum of a contribution Δr\text{surf} reflected by the surface and a contribution Δr\text{aer} scattered by aerosols. The latter is much stronger and proportional to the line of sight between the surface and the instrument, so the overall spectral slope can be written as:

\[ Δr = Δr_{\text{aer}} = \frac{1}{4μ} Δ[τ_a w_a f(φ)] \]

letting μ be the cosine of the emergence angle, τ_a the vertical opacity of aerosols, and w_a f(φ) the single-scattering albedo in the direction φ [5]. This expression is valid in the martian atmosphere for small phase angles φ when the opacity is small. Upon uniform terrains, spatial variations of μΔr are proportional to the column density of aerosols; along the volcanos flanks, the altitude excursion allows to study their vertical profile.

Comparison with CO₂ profile: At a given time, the vertical airmass depends only on the altitude of the surface. The CO₂ optical depth τ_{\text{atm}} was evaluated from the depth of the CO₂ band at 2 μm, and was found to be a very good (non-linear) estimate of altimetry [1] [2]. The variations of the ratio μ Δr/τ_{\text{atm}} were studied in the region of Olympus Mons as a function of τ_{\text{atm}}, i.e. altimetry (Fig. 1). The basal scarp (4 km above the datum) corresponds to τ_{\text{atm}} = 0.16 and the summit (25 km) to τ_{\text{atm}} = 0.10. On lower terrains this ratio is constant, save for small variations that may be due to the surface or to thin dust clouds. On the volcano itself, the ratio increases with altitude; we checked that photometric effects or changes in the spectral slopes of surface materials can’t result in such a behavior, which therefore must be attributed to an increasing mixing ratio.
Interpretation: Fig. 1 shows that the ratio of column densities of aerosols and CO$_2$ increases by a factor of 2 to 3 between 4 and 25 km upon Olympus Mons and remains constant at lower altitudes. A recent analysis of IRTM data [6] showed the same behavior on this region at a different time of the year ($L_s = 226^\circ$), and the authors suggested that it could result from a local and seasonal wind pattern. The ISM data were acquired at $L_s = 12^\circ$, and a similar phenomenon is observed for several image-cubes on the Tharsis plateau (Fig. 2). It is thus not specific of this single region and not seasonal, but could be a permanent feature of the vertical profile of aerosols in the Martian atmosphere. This might be connected to the density variations of CO measured by ISM [7], as the suspended dust is probably an important actor of the photo-chemistry of minor constituents of the atmosphere.

![Graph](image1.png)

Fig. 1: Proportional estimates of CO$_2$ opacity and aerosol column density on Olympus Mons and Amazonia, as defined in the text. The basal scarp of the volcano (4 km) corresponds to a CO$_2$ opacity of 0.16.

![Graph](image2.png)

Fig. 2: Same as Fig. 1 on the Tharsis plateau. The bottom of Pavonis Mons (10 km) corresponds to a CO$_2$ opacity of 0.16, while the chasmata terrains (below 7 km) correspond to opacities greater than 0.22.