SPICAM AEROSOL VERTICAL DISTRIBUTION CLIMATOLOGY FROM UV OCCULTATIONS.
A. Määttänen[1], C. Listowski[1], F. Montmessin[1], L. Maltagliati[2,*], L. Joly[3], A. Reberac[1], J.-L. Bertaux[1], [1]Université Versailles St-Quentin; Sorbonne Universités, UPMC Univ. Paris 06; CNRS/INSU, LATMOS-IPSL, 11 boulevard d'Alembert, 78280 Guyancourt, France, anni.maattanen@latmos.ipsl.fr. [2]LESIA, Observatoire de Paris, Meudon, France. [3]Groupe de Spectrométrie Moléculaire et Atmosphérique GSMA, Université de Reims, Reims, France. [*]Presently at : AIM, CEA/DSM-CNRS-Université Paris Diderot, Service d'Astrophysique, Centre de Saclay, Orme des Merisiers, 91191 Gif sur Yvette.

Introduction: We present observations of aerosol profiles analysed from MEx/SPICAM solar occultations in the ultraviolet ([1]), recently completed with UV stellar occultations. This dataset allows [2] the retrieval of vertical profiles of the abundance of gaseous species (CO_2 , O_3), aerosol optical depth in the UV, and the Ångström coefficient. We have analysed all (several hundred) solar occultations of adequate quality between orbit numbers 0-10000 (Martian Years 27-30) spanning 4 Martian Years (MY) with a good seasonal and spatial coverage. The results reveal the dust haze near the surface, and detached layers (possibly clouds) at high altitudes. We will present a global overview of the results and some specific cases of interest and complete the solar occultation dataset with a comparison to the UV stellar occultations. The solar occultation results have been published in [1].

SPICAM data: SPICAM (SPectroscopie pour l'Investigation des Caractéristiques Atmosphériques de Mars) observes Mars in the ultraviolet (118–320 nm) and in the near infrared (1–1.7 μm) ranges [4]. We are focusing here on the UV solar occultation dataset of about 650 profiles, and we have also included over 800 UV stellar occultations mainly from MY27-28 (with some observations in MY29-30) to achieve a better overall coverage in latitude and L_s. The transmission spectra are fitted with the Beer-Lambert law and aerosol extinction is modeled with the so- called α-model, giving access to the Ångström coefficient, which depends on the size of the aerosols.

Hazetops: The so-called hazetop (the altitude where the slant optical depth drops to τ=1 from the higher near-surface values) correlates with the vertical extent of the low-lying, well-mixed continuum of aerosols (haze) near the surface of Mars. Outside the polar regions, where the polar hoods are formed of fairly low-lying clouds, the haze should be composed of dust. The dust haze is formed by dust particles lifted from the surface and mixed higher in the atmosphere by convection. The hazetop can thus give some information on how active the atmosphere is.

In SPICAM data, generally the higher hazetop values are observed at warm seasons and regions, i.e., near the equator and in the southern hemisphere during southern spring and summer (Ls = 180–360°), where convection acts more efficiently and the general circulation is stronger, as is often the case around the perihelion (Ls = 220– 300°) where dust storms are frequent ([5]). Seasonal changes in atmospheric temperatures modulate the cloud formation level as well, which regulates the dust haze extent through scavenging of dust particles and sedimentation to the lower atmosphere.

Detached layers: In almost half (48%) of the analyzed solar occultation profiles, and in more than two thirds (70%) of the stellar occultation profiles, the slant optical depth has a clear local maximum that we can identify as an aerosol layer. We performed a systematic investigation on the dataset to detect these atmospheric structures. A detached layer may be an ice cloud or a dust plume, but in the occultation mode we cannot spectrally determine the composition. In contrary to what [2] found, these layers are not limited to mid-southern latitudes in our data, but are observed at all latitudes and seasons in the analysed dataset. They are in most cases found above the near-surface haze, but clear layer structures are also found within it. We concentrate here mainly on the more frequent cases of layers above the haze (i.e., high-altitude detached layers).

Seasonal behavior of the vertical profiles: A large-scale examination of the seasonal evolution of the hazetop and the detached layers revealed some interesting phenomena.

Around the northern autumn equinox in MY27, as sudden change in the hazetop altitudes happens nearly simultaneously, but in the opposite directions, in the two hemispheres. In the north, the haze that was previously more active remains strongly confined below 40 km after the change. The northern occultations scan the polar regions, showing most probably the development of the polar hood where the slant opacities are quite high in the lower atmosphere, and the transition from aerosol-loaded to aerosol-free atmosphere is very sharp. In contrast, in the south after the change the hazetop altitude increases and high-altitude detached layers are observed very frequently, which might be the first indications of the starting dust storm season.

Observations at the southern spring/summer (Ls=200–290°) were acquired during two campaigns on two different years (MY28 and MY29). They include the global dust storm of MY28, and we also should observe the early ("pre-season") dust activity in MY29 observations, pointed out by [6]. The hazetops in the southern summer through the southern hemisphere parts of the campaigns (Ls = 170–270°) reveal an increase in hazetop altitudes in the southern midlatitudes. This is related to the advancing local spring and the circulation becoming more vigorous on average. There is an abrupt increase in the hazetop altitude at around Ls = 240°, which can also be seen in the detached layers. High-altitude layers are clearly more frequent at this season, and the highest layers of our whole dataset are observed during the MY28 dust storm.

An interesting, isolated phenomenon was observed in the early winter in the southern hemisphere. Only in occultations made directly south of the Hellas basin (70–72°S), we observed a thin but distinct, quite constant aerosol layer at around 40 km with $\tau< 0.1$ in about 10 consequent profiles (Ls = 43–53°). These observations stand out from the data since most of the detached layers of this season were detected in the northern leg of the campaign, and because of the very constant shape and altitude of the detached layer. The Ångström coefficient in the layer is always greater than 2.6, which means that only ice crystals fit the wavelength dependence of the optical depth. The deduced effective radii of the crystals in the layer are very small, below or of the order of 100 nm (smallest ones at 50nm). We think this cloud is related to the forming south polar hood.

Interannual variations: Two solar occultation observation campaigns were acquired at mid-southern latitudes during the same season (Ls =34–110°), but for MY27 and MY29. They show remarkably similar average hazetop values (26.4 and 23.3 km) in this region and season. Also the MY27 stellar occultations at the same region and season show similar values. We conclude that the hazetop follows a quite undisturbed seasonal cycle at this period at mid to high southern latitudes since we observe almost the same hazetop altitudes two MY apart, and with a global dust storm in between.

For the same solar occultation campaigns, the mean altitude of the detached layers in the southern hemisphere shows a very small 4 km difference, but the layers in MY29 are almost twice as thick (in vertical extent, 11 km) as those of MY27 (6 km), and are more opaque with respect to the background. This might be caused by the global dust storm of MY28 that has increased the amount of condensation nuclei, which have a long-term effect on the microphysical properties of clouds without necessarily changing their formation altitude.

Naturally, the global dust storm of MY28 is the most significant source of interannual variability. Two solar occultation campaigns observed the southern spring/summer season on MY27 and 28. The mean hazetop altitude in MY28 is 23 km higher in the southern and 14 km higher in the northern hemisphere than that observed slightly earlier in the season on MY27. In addition, the average altitudes of the detached layers of MY27 are clearly lower (59–61 km) compared to MY28 (77–81 km).

Ångström coefficients: The α-model used to fit the wavelength dependence of the aerosol extinction gives, through certain hypotheses, access to the particle size. Because of the difficulty to draw certain conclusions, we have mainly investigated the vertical variation of the coefficient. We have looked for vertical trends in correlation with the optical depth profiles in the solar occultation data. We could expect that in the dust haze the Ångström coefficient increases (and the particle radii decrease) with increasing altitude with a similar trend in optical depth. If the detached layers are ice clouds, we might expect the Ångström coefficients to be smaller (and the radii to be larger) than in the surroundings, since the ice crystals form on dust particles. The solar occultation data, contrary to the conclusions of [2] on the stelar occultations, does not always show this "expected" behavior. Consequently, we are not able to draw definite conclusions on the behavior of the effective radii in the haze and on the composition of the detached layers. In only one exceptional case of the detached layer near Hellas mentioned before, the particles were identified as ice crystals thanks to their large Ångström coefficients.

Conclusion: The four Martian years of data of SPICAM occultations show that the seasonal behavior of the hazetop follows closely the seasonal temperature variations. Observations during the MY28 dust storm reveal very high hazetops and detached layers. The high northern latitudes in the autumn give the opposite example of very calm vertical distribution with a low hazetop. These data show that the martian dust vertical distribution is very variable. We observed detached layers in more than half of the analyzed dataset of solar and stellar occultations. The highest detached layers were observed during the global dust storm of MY28, and single and multiple layers are observed also during other seasons and at all latitudes. The solar occultation dataset can be accessed through the Supplementary Material of the article [1] and through the Europlanet IDIS atmospheres node at http://bdap.ipsl.fr/idis/.

References:

[1] Määttänen, A. et al. (2013) *Icarus 223*, 892–941. [2] Montmessin, F. et al. (2006) *J. Geophys. Res. 111*, E09S09. [3] Listowski, C et al. (2011) *In: Forget, F., Millour, E. (Eds.), Mars Atmosphere: Modelling and observation.* pp. 191–194. [4] Bertaux, J.L. et al. (2006) *J. Geophys. Res. 111* (E10), 10. [5] Smith, M. D., (2004) *Icarus 167*, 148–165. [6] Smith, M. D., (2009) *Icarus 202*, 444–452.