A GLOBAL STUDY OF MARTIAN ATMOSPHERIC DUST WITH THE NEAR-INFRARED IMAGING SPECTROMETER OMEGA/MARS EXPRESS.

Y. Leseigneur and M. Vincendon, *Institut d'Astrophysique Spatiale, Université Paris-Saclay, CNRS, Orsay, France (yann.leseigneur@ias.u-psud.fr.*

Introduction:

Dust, composed of micrometer-sized particles, is an important component of both the atmosphere and the surface of Mars. This high albedo material modifies heat balance while being highly mobile: it is thus a major contributor to current Mars atmosphere and surface dynamics. Numerous studies realized from the Martian orbit or from the ground already provided information on dust spatial and time distribution (e.g., [1], [2], [3]). However, some characteristics of the dust cycle remain uncertain. This is notably related to the fact that dust movements occur over a large range of spatial scale, from Recurring Slope Lineae (RSL) to Global Dust Storm (GDS), and with important interannual variability ([4], [5]). Further global monitoring of dust movements with high spatial sampling and over several years may help improving our knowledge about Martian dust. Here we present a new method used to derived atmospheric dust optical depth using OMEGA observations acquired between 2004 and 2010, i.e. over three Martian Years (MY).

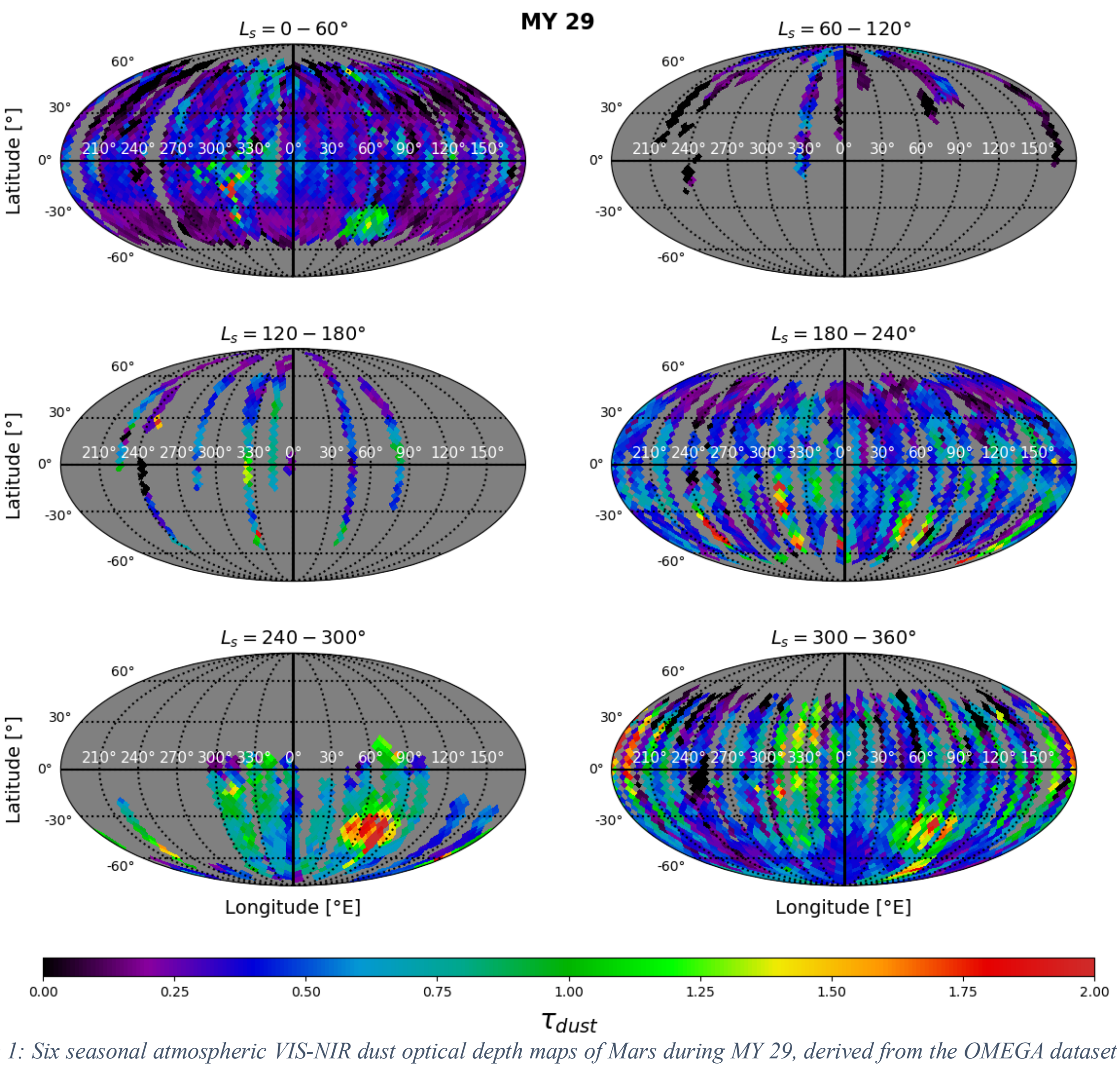

Figure 1: Six seasonal atmospheric VIS-NIR dust optical depth maps of Mars during MY 29, derived from the OMEGA dataset (see text for details).

Data and method:

The near-infrared imaging spectrometer OMEGA [6] onboard Mars Express collected about 8300 observations over that time range, with a spatial sampling typically close to 1 km.

First, we analyze the prominent 2 µm atmospheric CO_2 absorption band to detect dust, as airborne dust reduces atmospheric optical paths. We have developed a model to predict the CO_2 optical depth τ_{CO_2} under clear atmospheric conditions: observed CO_2 optical depths are compared to these predictions to derive the difference "$\Delta\tau_{CO_2}$", an index sensitive to dust. More details about this first part of the method can be found in [7].

Then, we calibrate this $\Delta\tau_{CO_2}$ using the visible (VIS) dust optical depth (from 880 nm images) measured by the Mars Exploration Rovers (MER: Spirit and Opportunity) [2], which operated during the same period as OMEGA. Concomitant MER/OMEGA observations are used to characterize the relation between $\Delta\tau_{CO_2}$ (OMEGA) and the ground optical depth (MER), which notably depends on solar incidence angle and albedo. This relation is then extrapolated to the whole OMEGA dataset to calculate a VIS-NIR dust optical depth (τ_{dust}).

Results and discussion:

The OMEGA dataset allows to produce global seasonal maps of dust optical depth with a spatial coverage typically greater than 50% for most 60° wide intervals in solar longitude (L_s). We provide the six seasonal maps of the MY 29 in Figure 1. Firstly, we observe the well-known seasonality of dust: overall higher values of dust optical depth during the "dusty season" ($L_s = 180 - 300°$) than during the "clear atmosphere season" ($L_s = 0 - 120°$). Some localized higher values are also observed in all maps, such as in the $L_s = 0 - 60°$ map (top left panel of Figure 1) near 315°E and 20°S, that can be associated to dust storms. Then, some main dust storm travel routes [8] (from the northern hemisphere to the southern one) can be identified, in particular in the $L_s = 300 - 360°$ map, the Acidalia-Chryse-Margaritifer route which correspond to moderate and high values of dust optical depth. This area is also known by the observation of Recurring Slope Lineae (RSL), which are active in this $L_s = 300 - 360°$ period [9]. This indicates that large-scale atmospheric dust events may be connected to local surface dust movements occurring at RSL location.

We are also able to plot latitude/solar longitude diagrams with the OMEGA dataset, such as for MY 27 in Figure 2, that provides information on the time evolution of the dust optical depth. We observed characteristics of the well-known dust cycle, in particular the late storms called "C-storms" between $L_s = 310°$ and 330° (as defined in [10]). Other main dust optical depth investigations were made with thermal infrared data [3], where results are preferential represented in this type of diagrams. We can notice an overall good agreement between our study in VIS-NIR and in thermal studies (see Fig. 16 of [3]).

But there are still differences that can be studied by computing the ratio between our VIS-NIR OMEGA values derived at 2 µm (and converted to 880 nm using MER) and the thermal ones at 9 µm. We show the histogram of this ratio in Figure 3. The maximum is reached for a ratio of 2.4, which is in agreement with the value of 2.6 considered in [3] and also the values found locally with the MER (see Fig. 10 of [2]). We can also notice that the distribution is very large, with a 2.0 equivalent standard deviation, which may be related to variations of the mean dust particle size according to [2].

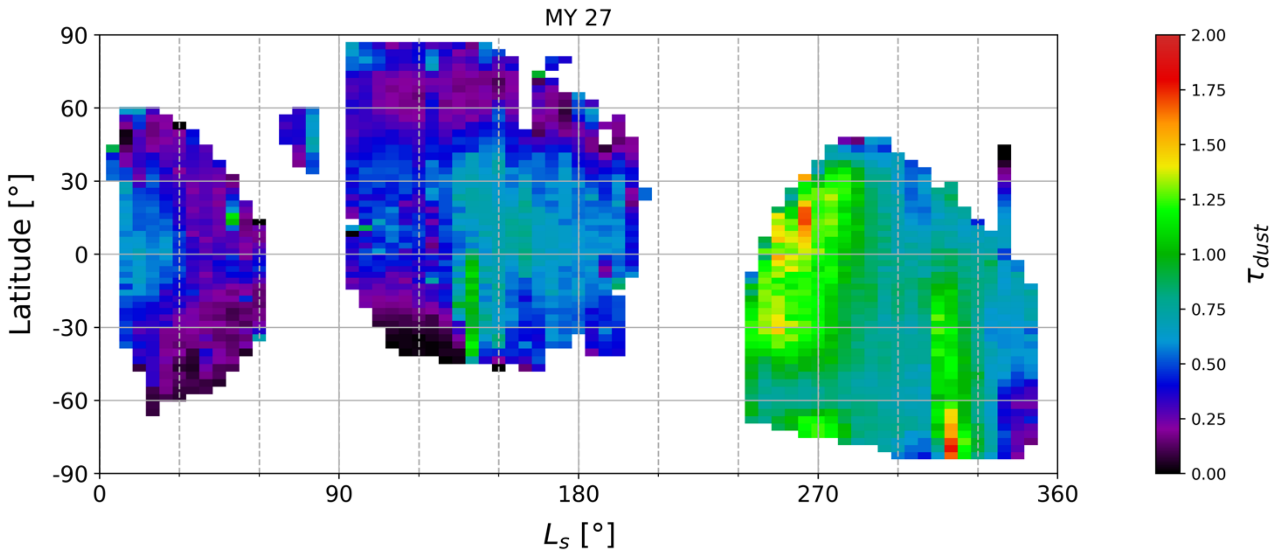

Figure 2: OMEGA VIS-NIR dust optical depth as a function of solar longitude (L_s) and latitude for MY 27. For each L_s and latitude, we average τ_{dust} obtained at various longitudes. Each pixel of the diagram is 5° wide in L_s and in latitude. The sampling in longitude is variable (see examples of maps for another MY in Figure 1).

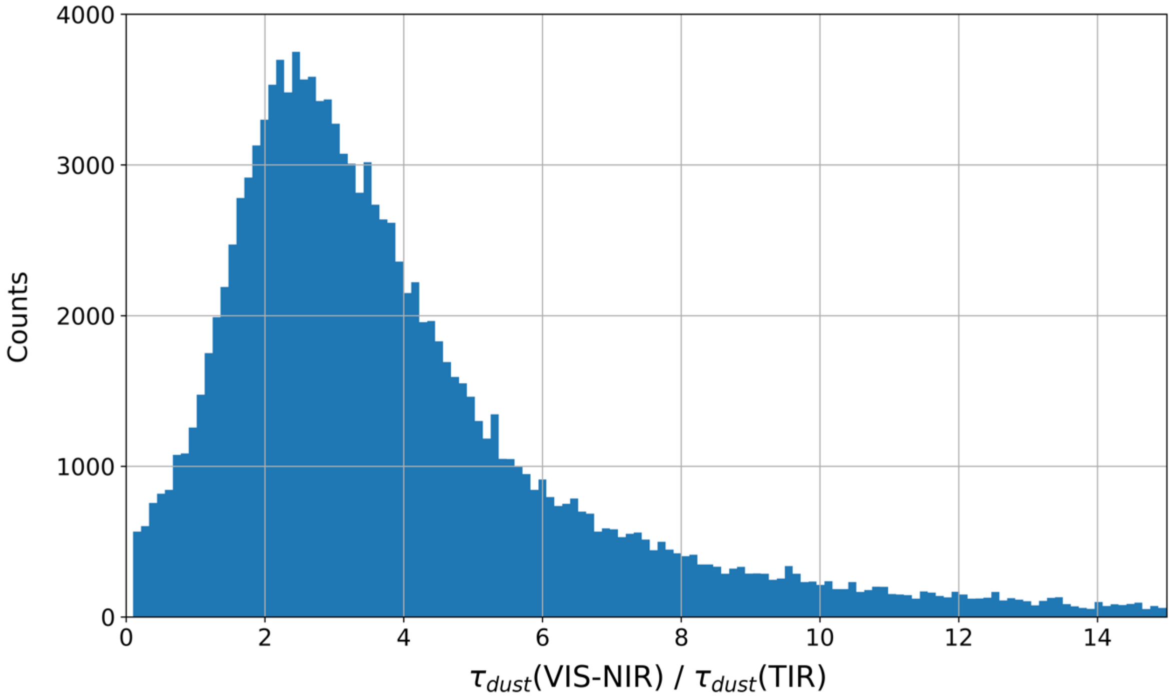

Figure 3: Global histogram of the ratio between OMEGA VIS-NIR dust optical depth (computed at 2 µm and converted to match the 880 nm MER reference) and thermal-infrared (TIR) optical depth (9 µm) presented in [3].

Conclusion:

We have developed a new method to detect atmospheric dust using near-infrared spectrometer data. The method relies on CO_2 absorption band at 2 µm and is applied to OMEGA data. We also implemented a calibration procedure based on MER ground measurements to compute a VIS-NIR dust optical depth. We constructed seasonal global maps (Figure 1) and latitude/solar longitude diagrams (Figure 2). Overall, results are in good agreements with previous studies based on thermal-infrared observations, but with some differences noticed by a particular distribution of the dust optical depth ratio between VIS-NIR and thermal-infrared (Figure 3), with a maximum occurrence value of 2.4. This OMEGA dataset may also be used to connect dust activity over several spatial scales. For example, preliminary results indicate that large scale atmospheric dust events may be related to local RSL activity occurring in the Chryse-Acidalia area.

Acknowledgments:

The OMEGA/Mex data are freely available on the ESA PSA at https://archives.esac.esa.int/psa/#!Table%20View/OMEGA=instrument.

References:

[1] Smith M. D. (2004) *Icarus, 167,* 148-165. [2] Lemmon M. T. et al. (2015) *Icarus, 251,* 96-111. [3] Montabone L. et al. (2015) *Icarus*, *251*, 65-95. [4] Szwast M. A. et al. (2006) *JGR*, *111*, E11008. [5] Vincendon M. et al. (2019) *Icarus, 325,* 115-127. [6] Bibring J-P. et al. (2004) *ESA Publication Division*, 1240, 37-49. [7] Leseigneur Y. et al. (2021), *52nd LPSC*, LPI contribution No. 2548, id. 1741. [8] Wang H. et al. (2015) *Icarus, 251,* 112-127. [9] Stillman D. E. and Grimm R. E. (2018) *Icarus, 302,* 126-133. [10] Kass D. M. et al. (2016) *Geophys. Res. Lett.*, *43*, 6111-6118.