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Monitoring Atmospheric Dust Opacity at High Latitudes on Mars with OMEGA

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Abstract

On Mars monitoring atmospheric dust as well as identifying its sources and sinks in relation with surface activity is of paramount importance especially at high latitudes. The imaging spectrometer OMEGA on board Mars Express has acquired the most comprehensive set of observations to date in the near-infrared (0.93-5.1 microns) of the southern high latitudes of Mars from mid-winter solstice (Ls=110°, December 2004) to the end of the recession at Ls=320° (November 2005) [1]. The time resolution is 3 days to one month and the spatial resolution ranges from 700m to 10 km/pixel. We use two complementary methods in order to retrieve the optical depth τ_{aer} of the atmospheric dust at a reference wavelength of one micron. After cross-validation, we apply both methods on a time series of OMEGA images for global coverage of the high latitudes for martian year MY=27 between L_S=220° and L_S=264°. Global as well as regional investigations about atmospheric dust in relation with surface activity are made possible.

1. Methods for retrieving the optical depth

The first method [2] is based on a parametrization of the radiative coupling between particles and gas that determines, with local altimetry and the meteorological situation, the absorption band depth of gaseous CO_2. This approach specifically treats pixels occupied by purely mineral surfaces or icy deposits contaminated by a large amount of dust while being observed at one geometry. The second method by [3] is complementary since it is restricted to area where CO_2 deposits are not contaminated by dust and water, i.e. above most places of the seasonal cap except the cryptic sector. The mapping is based on the assumption that the reflectance in the 2.64 μm saturated absorption band of the surface CO_2 ice is mainly due to the light scattered by aerosols. In this case one geometry is also sufficient.

2. Analysis of a time series of OMEGA observations

By applying the two methods, we obtained a series of τ_{aer} maps that were de-trended in order to correct for changes due solely to varying atmospheric height because of topography. These maps were independently integrated on a common grid generated from the Hierarchical Equal Area isoLatitude Pixelization (http://healpix.jpl.nasa.gov) of Mars southern hemisphere at different spatial resolutions. Such an integration, possibly followed by averaging over time or latitude bins, makes it easy to create mosaics or to build space-time evolution curves.

The global mosaics, sampled at 128 points per degree clearly show the details of dust activity within and around the area covered by the CO_2 seasonal deposits. Around the seasonal cap we note an intense activity, high temporal variability, and a heterogeneous spatial distribution of atmospheric dust with localized enhancement of the optical depth (values up to 1.5). The enhancement takes regional proportions first during the interval L_S=230-240° and then after $L_S \approx$ 252°. Within the seasonal cap, we note lower values than at the outskirts, a more homogeneous spatial distribution and a lower temporal variability even if occasional incursions of dusty clouds from outside the cap can occur. Figure 1 shows the atmospheric dust activity for two broad longitude sectors, the "cryptic" sector between longitudes 30 and 150°E and the opposite sector named "anti-cryptic" both further divided into three different bands of latitude. Their temporal behaviors are substantially different. For the "cryptic" sector all the distinguished latitude bins display a rather similar temporal signal τ_{aer} for the covered time period. A noticeable difference only occurs at $L_S \approx$252° with a sudden increase of the dispersion for τ_{aer} around the mean curve for latitudinal bands 55-60° and 65-70°S. Note that these regions are entirely defrosted since $L_S \approx$ 180° and 240° respectively. For the "anti-cryptic" sector, the mean level of atmospheric opacity of the same two latitudinal bands is higher than above the permanent cap as early as $L_S \approx$235° for the first band and $L_S \approx$248° for the second. The dispersion around the mean curve is also more pronounced, i.e. the activity is more erratic. One can note that the bin of lowest latitudes is already defrosted at the beginning of the covered period while the bin of intermediate latitudes is free of seasonal deposits at $L_S \approx$ 248°. In addition the dust optical depth above the "cryptic" region is comparable sometimes lower than above the cap except for the period L_S=245-252°.

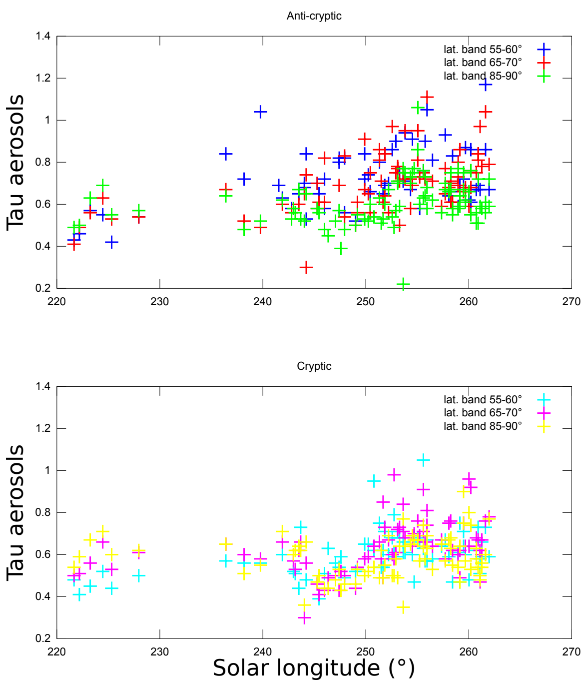

Figure 1: Time evolution of the atmospheric opacity at 1 micron for three different bands of latitude. Up : anti-cryptic sector. Bottom cryptic sector.

3. Discussion

As soon as the surface is defrosted it undergoes a sharp increase of temperature. The marked thermal contrast between the ice free terrains and the regressing seasonal icy deposits leads to an intensification of the mesoscale winds such as thermal breezes or katabatic winds, flows that are likely turbulent. In addition, since the defrosted terrains warm up faster than the overlying atmosphere in altitude, the vertical instability and convection increase. In such conditions, the uplifting, the vertical transport, and the mixing of dust are very efficient. Consequently the atmospheric opacity increases on average according to time. The observed high temporal variability reflects the fluctuating nature of the previous phenomena, the migration of the dusty clouds but also the fact that the atmospheric conditions may change with the local time of observation. The dust injected in the atmosphere must also migrates towards the highest latitudes thanks to the return branch of the thermal breezes. So even the optical depth of the aerosols above the permanent cap increases substantially with time. The most surprising result of our investigation is the different situations that prevail for the "cryptic" and "anti-cryptic" sectors. The atmosphere seems to be more stable in the first case than in the second one. However, very early in spring, a gas sublimation-driven activity of dusty jets emanating from the CO_2 deposits is observed in the "cryptic" region. The atmospheric dust to which our method is sensitive is minimum when the superficial contamination of the ice by dust is maximum. As a result the jets cannot inject dust more than one kilometer in altitude and the very stable vertical thermal profile of the atmosphere does not allow mixing of this dust over the atmospheric scale height.

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