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Monitoring Atmospheric Dust Spring Activity at High Southern Latitudes on Mars using OMEGA

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Abstract

This paper presents a monitoring of the atmospheric dust in the south polar region during spring of martian year 27 based on a comprehensive set of hyperspectral observations acquired in the near-infrared (0.93-5.1 microns) by OMEGA on board Mars Express. Through the mapping of the aerosol optical depth, our goal is to contribute to identifying the source regions and to understanding lifting as well as transport mechanisms in relation with the seasonal ice regression and the dynamics of the atmosphere. This is of paramount importance since local dust storms generated in this region sometimes grow to global proportions.

1. Methods for retrieving the optical depth

The first method [1] 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 [2] 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

We have processed 284 OMEGA images taken from L_S=220° to 280° by using the two complementary methods. As a result a series of maps is obtained depicting the distribution of aerosol optical depth (AOD) at a reference wavelength of one micron. These maps are de-trended in order to correct for changes due solely to varying atmospheric column because of topography. Then they are independently integrated onto a common geographical grid generated from the Hierarchical Equal Area isoLatitude Pixelization (Healpix, http://healpix.jpl.nasa.gov) of Mars southern hemisphere. When binned at a spatial resolution of $1.0°.\text{pixel}^{-1}$ the AOD is sampled with a mean period ranging from less than two sols for latitudes higher than 80°S to approximately six sols at latitudes [65-75°S]. First the Healpix integration allows to build the time evolution of the AOD for each spatial bin of the partition. Two contributions are separated with an adapted method: a mean trend of AOD versus time, i.e. the baseline, and a highly variable component, i.e. the day-to-day variability around the baseline. A data processing is also implemented to isolate any dependencies to the local time (diurnal cycle) of a given bin. Second the Healpix integration allows to generate time series of orthographic mosaics depicting the seasonal dust loading (Fig. 1) as well as the day-to-day variability and local time dependence of the AOD according to solar longitude. Although the modelling of the AOD time evolution is performed in a pixel-wise manner, the seasonal baselines can be gathered, based on similar shapes, into a limited number of classes. The latter correspond to four spatially coherent units.

3. Results

Following the complete analysis of the data, a synthetic view of dust activity in the south polar atmosphere in mid spring to early summer is established. From this compilation of observations we propose an interpretation of the behaviour of the four spatio-temporal units. Two mechanisms play a major role for lifting and transporting efficiently mineral particles and create dust events or storms: (i) nighttime katabatic winds at locations where a favourable com-

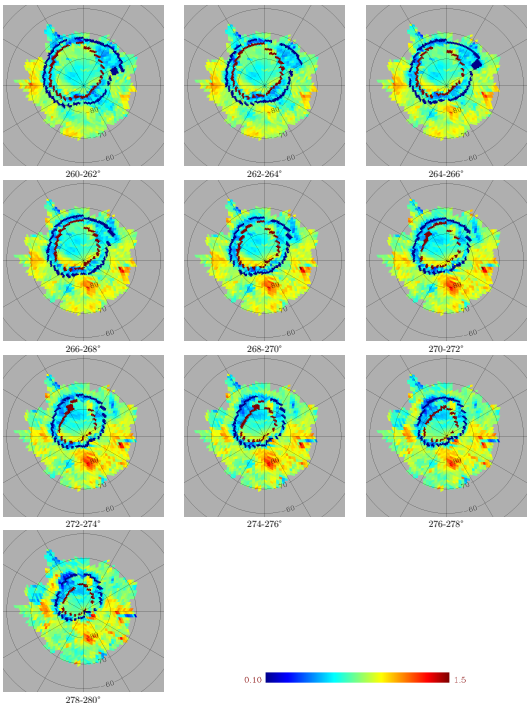

Figure 1: Time series of orthographic mosaics depicting from L_S=260° to L_S=280° the spatial distribution of seasonal mean values for the aerosol optical depth at 1 μm. The inner (respectively outer) crocus line of the South Seasonal Polar Cap is coloured in red (respectively in blue).

bination of frozen terrains and topography exists (e.g. unit1, 220°$\lesssim L_S \lesssim$255°) (ii) daytime mesoscale thermal winds at the edge of the cap when the defrosting area (transition zone) is sufficiently narrow (e.g. unit2, 240°$\lesssim L_S \lesssim$260°). Indeed this kind of breezes could be inhibited, should the width of the transition zone be broad, i.e. in the absence of a sharp thermal boundary of regional proportions (e.g. unit4, $L_S \gtrsim$260°). Thermal gusts due to the high thermal contrasts associated to segregated terrains in the transition zone exist and could also pick up some dust but likely leads to limited vertical and horizontal transport (e.g. unit3, 250°$\lesssim L_S \lesssim$270°). Far from the seasonal cap, gusts and vortexes associated with the convection of the boundary layer over ice-free terrains is not an efficient mechanism to inject large amount of dust in the atmosphere explaining the clear decline of the AOD after $L_S \approx$ 270° for the whole south polar region. Inside the seasonal cap, advection of dust at high altitude from the lower active latitudes is the main origin of the increase of the seasonal atmospheric opacity around $L_S \approx$ 235°, then $L_S \approx$ 275°. Such fluxes may correspond to the return branch of a synoptic convection cell that is established between the cold cap and the surrounding warming ice free terrains. Due to orographic differences or due to the different extension of the transition zone, this synoptic feature could be more strongly established at the longitudes of unit 2 than at those of unit 1. As regards to the production of atmospheric dust in the defrosting area, the most productive sector spans longitudes 180-300°E (unit 2) around $L_S \approx$ 250°. Later ($L_S \approx$ 267°) the situation has changed drastically and the cryptic sector becomes the most productive while the longitude sector 300-60°E (unit 4 and 3) remain moderately dust-generative.

4. Conclusion

Our work contributes to understanding the sequence of phenomena that control dust activity in the south polar atmosphere and suggests complex interaction between them. It calls for new simulations of the martian surface-atmosphere dynamics at mesoscales (between 1000 km and 1 km) considering topographical effects to reproduce the observations and to confirm the interpretations. In particular taking into account the gradual defrosting between the inner and outer crocus lines instead of considering a neat cap edge is of primordial importance.

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