Statistical analysis of local dust storm using dust retrieved from 2.7 μm CO_2 band observed by OMEGA/MEx

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Dust constantly suspended in the Martian atmosphere heats the atmosphere through direct absorption of solar radiation. Local dust storms (LDS) occurring at scales below 1.6 x 10^6 km^2 have been suggested to develop into vertical dust transport movements that reach high altitudes, such as rocket dust storms (Spiga et al.,2013; Wang et al., 2017). LDSs can also coalesce and develop into regional dust storms (RDS) (Martin and Zurek, 1993, Cantor et al., 2001; Hinson and Wang, 2010; Wang and Richardson, 2015). Thus, various roles for LDSs have been suggested, and it is crucial in understanding the movement of dust in vertical and horizontal directions.
RDSs larger than 1.6×10^6 km^2 have been investigated by visible observations from orbiters (Cantor et al., 2001; Wang and Richardson, 2015; Battalio and Wang, 2020). However, spectroscopic observations of LDSs are limited, and no statistical studies have been conducted. We successfully retrieved dust optical depth and statistically detected LDSs using observation data from the Mars Express during Martian years (MY) 27-29, which was equipped with the high resolution Near-Infrared Spectrometer OMEGA. Utilizing these results, we conducted a statistical analysis of LDSs over three Martian years, including MY28 when global dust storms occurred, investigating their occurrence locations and frequencies.
In this analysis, we developed a new method to retrieve the dust optical depth using the 2.77 μm CO_2 absorption band. Typically, this band saturates during nadir-observations when surface pressures are greater than ~400 Pa, resulting in almost zero observed radiance under low dust conditions. However, when aerosol is lifted to atmosphere, reflected sunlight by aerosol can detected. We utilized this technique to retrieve dust optical depth in the atmosphere. Measurements at 2.77 μm used here were obtained by the L-channel of OMEGA. We identified a new artefact caused by a variable wavelength shift, that may be related to other known instrumental issues of the L-channel (Jouglet et al., 2009). We developed a method to correct this spectral calibration issue by comparing measured spectra with synthetic spectra. For the retrievals of the dust opacity, we employed a Look-up-table method (e.g., Forget et al., 2007) that calculates many synthetic spectra by DISORT radiative transfer code (Stamnes et al., 1988) at 2.77 μm. With this method, an instantaneous retrieval of dust optical depth is possible by comparing them with observed spectra.
The validity of this method was evaluated by comparing it with two previous studies: (1) retrieval of dust optical depth from the 2 μm CO_2 absorption band (Leseigneur and Vincendon, 2023) and (2) retrieval of dust optical depth from the slope of the continuum (Vincendon et al., 2008). In regions or seasons with high dust conditions (τ greater than 0.05), the dust optical depth by our method aligned within the error range with the other two studies. However, in regions or seasons with low dust conditions (τ less than 0.05), discrepancy was observed. Two hypotheses were considered: (1) saturation occurring in regions with high solar zenith angles, where the optical path length becomes long and saturates, and (2) dust mixing ratio is not uniform and concentrated at low altitudes. As we also observe discrepancies for low solar zenith angles (below 60°), we consider the latter to be the primary factor contributing to these discrepancies.

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We applied this method to the entire observational dataset of OMEGA during MY 27-29, comprising ~8300 orbits, to statistically detect LDSs. This analysis focused on observations at low solar zenith angles (below 60°) and in low and mid-latitude regions (±60°). Ice clouds, which cannot be distinguished from dust, were detected using the ratio of 3.4 μm to 3.5 μm, and data containing ice clouds were excluded (Langevin et al., 2007). The horizontal scale for detecting LDSs were defined at 1°×1° (~4000 km^2), 0.5°×0.5° (~1000 km^2), or 0.1°×0.1° (~50 km^2) and detection was determined if the dust concentration exceeded 1.5 times that of the background field.
In the analysis with a scale of ~50 km^2, LDSs were detected in 789 orbits out of ~4900 orbits. Focusing on seasonal variations, it revealed an increased occurrence of LDSs during specific seasons, during Ls=130°-200° and Ls=280°-330°. This finding is consistent with the season when RDSs are known to occur, as previous visible observations (Wang and Richardson, 2015). Interestingly, we found a smaller occurrence peak around Ls=0°-90°, a characteristic not typically observed in conventional visible observations. In this presentation, we will summarize the results of this statistical analysis.

Keywords: Mars, Radiation transfer, Meteorological , Spectroscopy

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