Exploring Martian Dust Vertical Profiles Using Multiple CO_2 Absorption Bands at 2.01 and 2.77 μm in OMEGA Nadir Observations

Dust plays a central role in Martian atmospheric processes, influencing circulation, thermal structure, and meteorological phenomena through horizontal and vertical transport. While previous orbital observations from ultraviolet to infrared wavelengths have provided substantial information on the horizontal distribution of dust (e.g., Smith et al., 2001; Montabone et al., 2015; Battalio and Wang, 2021; Leseigneur and Vincendon, 2023), knowledge of its vertical structure remains limited. Traditional limb and solar occultation measurements have directly constrained dust altitudes but suffer from sparse spatial and temporal sampling.

To address this limitation, we investigate the feasibility of retrieving vertical information on Martian dust from nadir-viewing observations using a multi-wavelength approach. The spectral synergy method estimates the altitude of atmospheric constituents by leveraging differences in absorption characteristics at multiple wavelengths (Pan et al., 1995; Pan et al., 1998; Edwards et al., 2009). This method applied in Earth remote sensing for retrieving the vertical distributions of CO_2 (Christi & Stephens, 2004), O_3 (Landgraf & Hasekamp, 2007), and CH_4 (Razavi et al., 2009) and it was recently used to analyze water vapor in the Martian atmosphere (Knutsen et al., 2022). However, no studies have applied this approach to Martian dust yet.

Specifically, we explore the synergy between two dust optical depths (DOP) retrieved from two near-infrared CO_2 absorption bands at 2.01 μm (Leseigneur and Vincendon, 2023) and 2.77 μm (Kazama et al., under review) observed by the OMEGA spectrometer onboard Mars Express. The 2.77 μm band is strongly saturated and preferentially senses high-altitude dust (~20–30 km), while the 2.01 μm band remains sensitive to dust in the lower atmosphere (~10–20 km). We derive a diagnostic ratio that reflects the dust vertical distribution by comparing these dust optical depths.

Our analysis covers about 4,000 nadir observations acquired between Martian Years 27 and 29, encompassing both calm and active periods, including the global dust storm of MY28. Preliminary results indicate seasonal shifts in DOD ratio values between: (1) clear atmosphere seasons (Ls = 0°–180°) for which the values are in high agreement with the presence of elevated or detached dust layers, and (2) active dusty seasons (Ls = 180°–360°), suggesting of a well-mixed vertical structure.

Although challenges remain in constraining absolute dust altitudes due to retrieval uncertainties, this technique offers a promising complementary perspective. We will present the methodology, interpret the retrieved patterns in the context of Martian dust dynamics, and discuss implications for understanding atmospheric transport and climate.