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Variability of Martian water ice and dust vertical profiles with TGO/NOMAD

Giuliano Liuzzi (1,2), Geronimo L. Villanueva (1), Matteo M. J. Crismani (1), Michael D. Smith (1), Michael J. Mumma (1). Ann Carine Vandaele (3), Shohei Aoki (3), Frank Daerden (3), Ian R. Thomas (3), Miguel Angel Lopez-Valverde (4) Bojan Ristic (3), Cédric Depiesse (3), Yannick Williame (3), James A. Holmes (5), Stephen Lewis (5), Fabrizio Oliva (6), Will Hewson (5), Manish R. Patel (5), Giancarlo Bellucci (6), Jose Juan Lopez-Moreno (4) and the NOMAD Science team

(1) NASA Goddard Space Flight Center, USA (giuliano.liuzzi@nasa.gov), (2) Department of Physics, American University, USA, (3) Royal Belgian Institute for Space Aeronomy, Belgium, (4) Instituto de Astrofísica de Andalucía, Spain, (5) The Open University, UK, (6) Istituto di Astrofisica e Planetologia, Italy.

Abstract

We present the first results of water ice and dust microphysical properties derived from the Nadir and Occultation for Mars Discovery (NOMAD) instrument, onboard ExoMars Trace Gas Orbiter (TGO). These retrievals are derived from vertical profiles that span the entire science phase so far, which began April 21st, 2018.

1. NOMAD instrument

The NOMAD spectrometer onboard ExoMars TGO operates in the wavelength range between 0.2-4.3 μm [1]. This instrument suite has three spectral channels: a solar occultation channel (SO – Solar Occultation; 2.3-4.3 μm), a second infrared channel capable of nadir, solar occultation, and limb sounding (LNO – Limb Nadir and solar Occultation; 2.3-3.8 μm), and an ultraviolet/visible channel (UVIS – UV visible, 200-650 nm). The infrared channels (SO and LNO) have high resolving power (λ/dλ~10,000-20,000) provided by an echelle grating in combination with an Acousto Optic Tunable Filter (AOTF), which restricts the bandpass width and selects the observed diffraction order [2]. The infrared channels were derived from the Solar Occultation in the IR (SOIR) instrument [3] onboard Venus Express. The high sampling rate (1 second) of SO measurements provides unprecedented vertical resolution (~ 1 km), which span altitudes from the surface to ~200 km. Moreover, the instantaneous change of the observed diffraction orders, made possible by the AOTF, enables the SO channel to measure five or six different diffraction orders per second.

In this study, we combine broadband (2700 to 4300 cm^{-1}) information in single occultations to infer the vertical structure of dust and water ice profiles. The sensitivity and accuracy of this kind of analysis is maximized when the diffraction orders observed are not heavily affected by molecular extinction due to CO_2. The characterization of the sensitivity of each diffraction order to dust and water ice is performed as a preliminary step to the retrievals, according to the calibration scheme developed for the NOMAD instrument [4]. The combined broadband transmittance (I/F) has been used to infer the dust and water ice concentrations and their particle size, for each altitude from 0 to 100 km in each occultation. Data have been analyzed with the Planetary Spectrum Generator (PSG [6]) developed at NASA GSFC, which embodies a full retrieval package based on a state-of-art implementation of Optimal Estimation [7].

2. Water ice vertical profiles

Using the data acquired by NOMAD from April 2018 to April 2019, we have analyzed the vertical distribution of water ice from the surface up to 110 km, as well as the vertical variation of particle size. The measurements acquired between June and September 2018, coincide with a Planet Encircling Dust Event (PEDE). The effect of this storm on the properties and localization of water ice clouds is presented and discussed in depth. We find that high altitude (mesospheric) water ice clouds are detected frequently and that their microphysical characteristics differ from low-altitude clouds. Their altitude has also been observed to abruptly increase as the PEDE starts, and the velocity at which this happens (of the order of a Martian day) can provide feedback about the dynamics behind high altitude cloud formation. We have also characterized the latitudinal distributions of water ice clouds, and we elaborate on the implications of these observations to the advance of the current knowledge of the water cycle on Mars [5].

3. Dust vertical profiles

We have simultaneously retrieved dust vertical profiles of concentration and average particle sizes for this same dataset. We discuss the temporal evolution and morphology of dust profiles, with particular attention to the PEDE and a second, less intense dust storm in January-February 2019. This provides evidence for the thermal effects of dust on the atmosphere, and its role in cloud formation processes. In particular, we have found that dust can lift up in the atmosphere to altitudes ~60 km during dust storms, forming suspended layers with complex vertical structures.

Figure

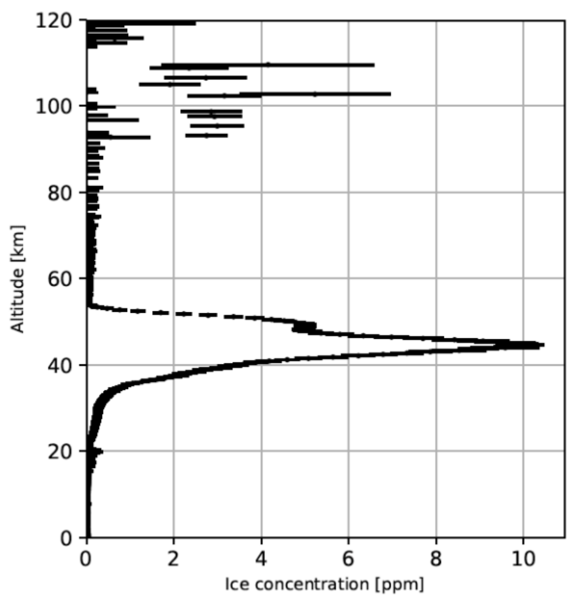

Figure 1: Example of water ice vertical profile retrieved from the NOMAD-SO data before the global dust storm in 2018 (L_S = 171.45° and latitude 43° N–68° N) [5].

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The NOMAD Science Team

Ann Carine Vandaele, Jose-Juan López-Moreno, Giancarlo Bellucci, Manish R. Patel, Gustavo Alonso-Rodrigo, Shohei Aoki, Francesca Altieri, Sophie Bauduin, David Bolsée, Giacomo Carrozzo, R. Todd Clancy, Edward Cloutis, Matteo Crismani, Frank Daerden, Fabiana Da Pieve, Emiliano D'Aversa, Cédric Depiesse, Justin T. Erwin, Giuseppe Etiope, Anna A. Fedorova, Bernd Funke, Didier Fussen, Maia Garcia-Comas, Anna Geminale, Jean-Claude Gérard, Marco Giuranna, Leo Gkouvelis, Francisco Gonzalez-Galindo, James Holmes, Benoît Hubert, Nicolay I. Ignatiev, Jacek Kaminski, Ozgur Karatekin, Yasumasa Kasaba, David Kass, Armin Kleinböhl, Orietta Lanciano, Franck Lefèvre, Stephen Lewis, Giuliano Liuzzi, Manuel López-Puertas, Miguel López-Valverde, Arnaud Mahieux, Jon Mason, Michael J. Mumma, Hiromu Nakagawa, Lori Neary, Eddy Neefs, Robert E. Novak, Fabrizio Oliva, Arianna Piccialli, Etienne Renotte, Birgit Ritter, Séverine Robert, Frédéric Schmidt, Nick Schneider, Giuseppe Sindoni, Michael D. Smith, Nicholas A. Teanby, Ed Thiemann, Ian R. Thomas, Alexander Trokhimovskiy, Loïc Trompet, Jean Vander Auwera, Geronimo L. Villanueva, Sébastien Viscardy, James Whiteway, Valerie Wilquet, Yannick Willame, Michael J. Wolff, Paulina Wolkenberg, Roger Yelle.