EPSC Abstracts
Vol. 16, EPSC2022-922, 2022
https://doi.org/10.5194/epsc2022-922
Europlanet Science Congress 2022

Composition and size of Martian aerosols as seen in the IR from solar occultation measurements by NOMAD onboard TGO

aurélien stolzenbach[1], Miguel-Angel López Valverde[1], Adrian Brines[1], Ashimananda Modak[1], Bernd Funke[1], Francisco González-Galindo[1], Ian Thomas[2], Giuliano Liuzzi[3], Geronimo Villanueva[3], Mikhail Luginin[4], and Shohei Aoki[5]

[1]Instituto de Astrofísica de Andalucia, GAPT, Spain
[2]Belgian Royal Institute for Space Aeronomy, Brussels, Belgium
[3]NASA Goddard Space Flight Center, USA
[4]Space Research Institute (IKI), Moscow, Russia
[5]University of Tokyo, Kashiwa, Japan

Introduction

The nature, size and content of aerosols in the atmosphere affect the energy budget on all planets, hence the atmospheric dynamic of the planet. Mars exhibits three types of atmospheric aerosol. Mineral dust, water ice and carbon dioxide ice. Martian aerosols nature and size distribution were observed using many different methods and experiments, from rovers to satellites. Exhaustive review scan be found in [1] and in [2]. Usually, dust effective radius, r_{eff}, ranges from 1 to 2 µm and its effective variance, v_{eff}, from 0.2 to 0.4. H_2O ice r_{eff} ranges from 1 to 5 µm and its v_{eff} from 0.1 to 0.4. However, these two parameters and their variability are poorly constraint in the vertical to date. ExoMars TGO mission (ESA/Roscosmos) was primarily designed to study trace gases, thermal structure and aerosol content in Mars atmosphere with unprecedented vertical resolution [3].

NOMAD-SO Data processing

NOMAD (Nadir and Occultation for MArs Discovery) is suite of two infrared spectrometers onboard the ExoMars 2016 Trace Gas Orbiter (TGO) orbiter, covering the spectral range of 0.2 to 4.3 µm [4]. An Acousto-Optical Tunable Filter (AOTF) is used to select different spectral windows. The sampling of this channel is approximately of 1 second, allowing a vertical sampling about 1km. the SO channel is able to observe the atmosphere at a given altitude with 6 different diffraction orders. For this study, we selected a configuration of 5 diffraction orders (121,134,149,168,190) effectively spanning the overall spectral range of NOMAD.

In order to evaluate the local extinction due to aerosols, we use an inversion program called Retrieval Control Program (RCP). It is a multi-parameter non-linear least squares fitting of measured and modelled spectra [5]. Its forward model, KOPRA, was recently adapted to limb emissions on Mars [6] and for solar occultation data on Mars for the first time. RCP solves iteratively the inverse problem [7] and is described in details in [8]. The regularization matrix is build from Tikhonov-type terms of different orders which can be combined to obtain a custom-tailored regularization for any particular retrieval problem.

An example of the retrieved extinction profile is shown in Fig 1. The retrieved extinctions differs from previous work on aerosols using ACS data [9,10] using the Onion-peeling or Abel's transform method since this global fit is less affected by the large error propagation to low altitudes typical of those methods, and the lower Martian atmosphere is precisely where aerosols are particular relevant.

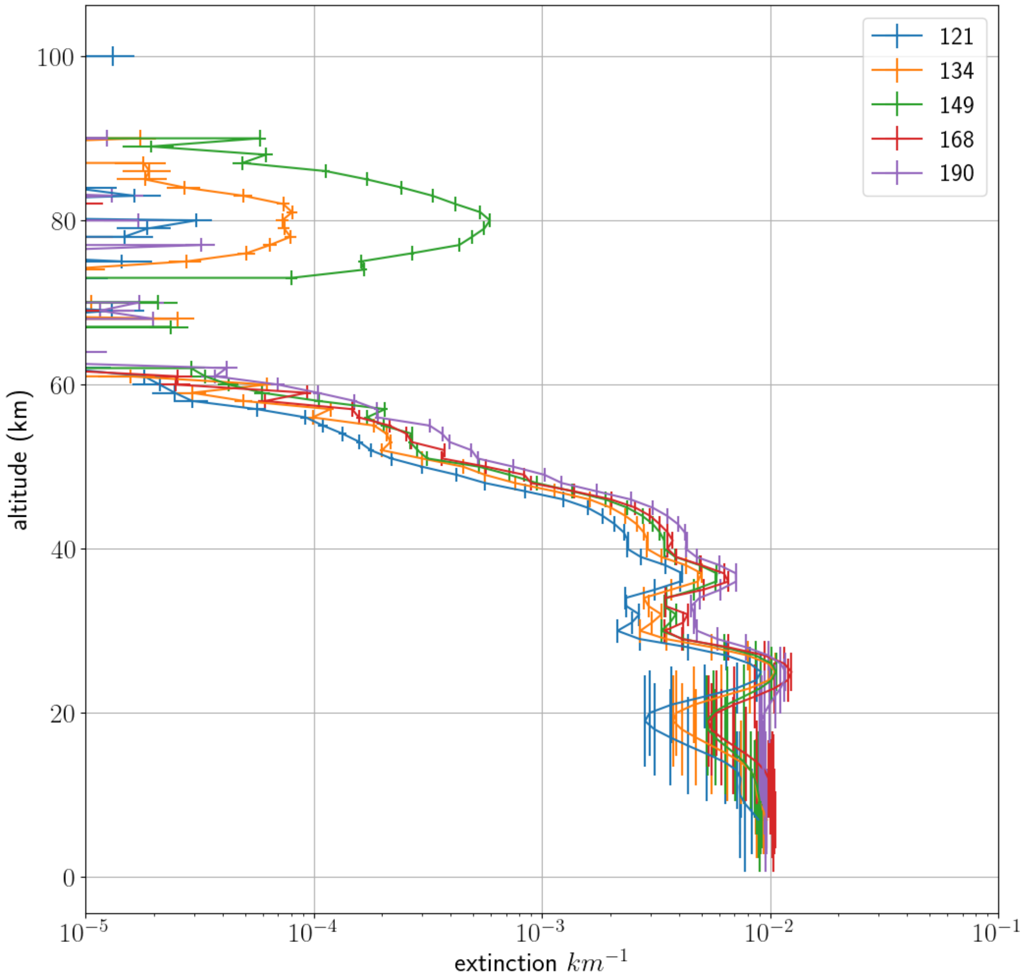

Fig 1.

Mean extinction cross-section ratio modelling

In order to model the optical behavior of the Martian aerosol we chose the log-normal distribution which is widely used in atmospheric sciences. It is a function of two parameters (r_g, σ_g). In optics, we change those parameters to more suitable ones, the effective radius, r_{eff} and its corresponding effective variance v_{eff}. For any aerosol size distribution, the extinction k is km^{-1} is $k(\lambda) = N \cdot \sigma_{ext} (\lambda r_{eff}, v_{eff})$. N is the aerosol number density and $\sigma_{ext} (\lambda, r_{eff}, v_{eff})$ is the mean average extinction cross-section at a wavelength λ, a specific aerosol distribution defined by (r_{eff},v_{eff}). We build a look-up table of dust and water ice σ_{ext} at the selected NOMAD order's wavelengths for different sets of (r_{eff},v_{eff}). The extinction are evaluated with a Lorenz-Mie code for polydisperse spherical particle from [11].

Aerosol composition and size distribution evaluation

We will detail the process of evaluating the aerosol composition and size distribution that consists of a mix of non-linear least square and brute force in order to evaluate the best set of parameters

(r_{eff},v_{eff} ,γ) where γ represent a mixture of dust and H_2O ice. The NLSQ algorithm is provided by the SciPy Python package [12]. To assess the robustness and limitations of our evaluation procedure, we will present results against synthetic extinction signal. We will discuss our main results, especially for the period covering the Global Dust Storm of MY34 (Fig 2.).

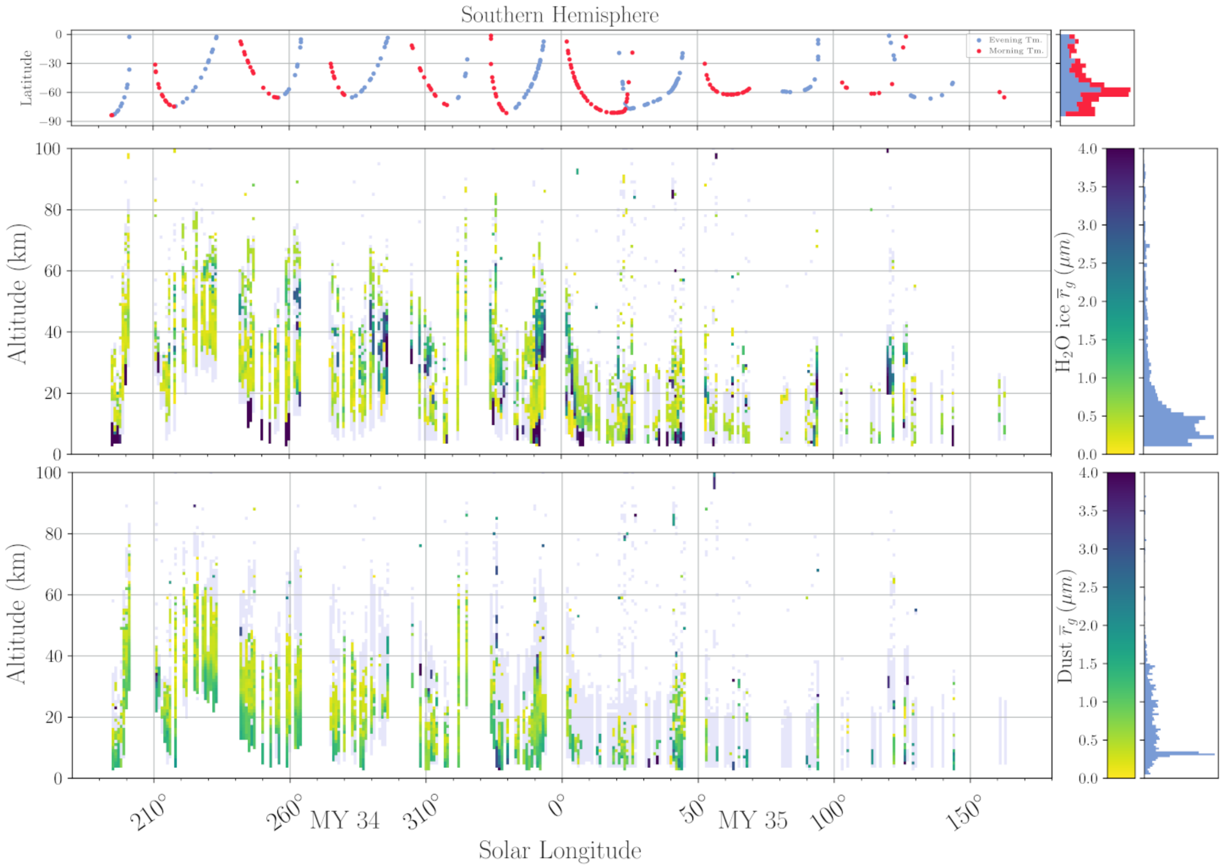

Fig 2.

Acknowledgments

The IAA/CSIC team acknowledges financial support from the State Agency for Research of the Spanish MCIU through the \emph{"Center of Excellence Severo Ochoa"} award for the Instituto de Astrofísica de Andalucía (SEV-2017-0709) and funding by grant PGC2018-101836-B-100 (MCIU/AEI/FEDER, EU). ExoMars is a space mission of the European Space Agency (ESA) and Roscosmos. The NOMAD experiment is led by the Royal Belgian Institute for Space Aeronomy (IASB-BIRA), assisted by Co-PI teams from Spain (IAA-CSIC), Italy (INAF-IAPS), and the United Kingdom (Open University).

References

[1] Robert M. Haberle et al., eds. The Atmosphere and Climate of Mars. Cambridge University Press, 2017.

[2] R. Todd Clancy et al. "The distribution, composition, and particle properties of Mars mesospheric aerosols: An analysis of CRISM visible/near-IR limb spectra with context from near-coincident MCS and MARCI observations". Icarus 328 (2019).

[3] J. Vago et al. "ESA ExoMars program: The next step in exploring Mars". SSR 49.7 (2015).

[4] A. C. Vandaele et al. "NOMAD, an Integrated Suite of Three Spectrometers for the ExoMarsTrace

Gas Mission: Technical Description, Science Objectives and Expected Performance”. SSR 214.5 (2018).

[5] T. von Clarmann et al. “Retrieval of temperature and tangent altitude pointing from limb emission spectra recorded from space by the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS)”. JGR: Atmospheres 108.D23 (2003).

[6] Sergio Jiménez-Monferrer et al. “CO2 retrievals in the Mars daylight thermosphere from its 4.3μm limb emission measured by OMEGA/MEx”. Icarus 353 (2021).

[7] Clive D Rodgers. Inverse Methods for Atmospheric Sounding. WORLD SCIENTIFIC, 2000.

[8] Jurado Navarro et al. Retrieval of CO2 and collisional parameters from the MIPAS spectra in the Earth atmosphere. Universidad de Granada, 2016.

[9] M. Luginin et al. “Properties of Water Ice and Dust Particles in the Atmosphere of Mars During the 2018 Global Dust Storm as Inferred From the Atmospheric Chemistry Suite”. JGR: Planets 125.11 (2020).

[10] A. Stcherbinine et al. “Martian Water Ice Clouds During the 2018 Global Dust Storm as Observed by the ACS-MIR Channel Onboard the Trace Gas Orbiter”. JGR: Planets 125.3 (2020).

[11] Michael I Mishchenko et al. Scattering, absorption, and emission of light by small particles. Cambridge university press, 2002.

[12] Pauli Virtanen et al. “SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python”. Nature Methods 17 (2020).