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NOMAD/TGO and PFS/MEx joint analysis for trace gases retrievals in the Martian atmosphere

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Abstract

Trace gases retrieval in the Martian atmosphere is one of the key goals of the NOMAD spectrometer suite onboard ESA's Trace Gas Orbiter (ExoMars/TGO). Planned and executed joint observations of NOMAD's IR high resolution channels and MEx/PFS spectrometer data will be analysed using both instruments in Nadir and Limb observational geometry. Synergies and complementarities between the two instruments will be exploited to increase accuracy and confidence on the retrievals of trace gases, such as water and carbon monoxide, and aerosols.

1. Introduction

Mars has always been a main target for Planetary Science, because of its peculiar characteristics of geological, physical, and astrobiological interest. Main issues involve the understanding of dynamics and chemistry evolution of Martian tenuous atmosphere, and in particular its volatile and trace gases composition. Despite the efforts and decades of spacecraft missions, a large number of open issues about its past and current climate and evolution remains unsolved. For this reason, in 2016 the European Space Agency sent the Trace Gas Orbiter for the ExoMars mission with the aim to study trace gases in the Martian atmosphere. The main aim of this work is to exploit simultaneous observations by PFS/MEx and NOMAD/TGO to retrieve trace gases abundances, with a particular interest for water vapour and carbon monoxide, and opacity of suspended aerosols. A number of synergies can be exploited. NOMAD IR channels work between 2.2 and 4.3 µm, with a relatively-high spectral resolution (~0.3-0.5 cm^{-1}), while PFS has a wider spectral range (1.2–5.5/5.5–45 µm) but a lower spectral resolution (~1.3 cm^{-1}). NOMAD can work both in Nadir or Limb (LNO) or in Solar Occultation (SO) geometry of observation, while PFS can observe in Nadir and in Limb geometry.

2. Methods

Any retrieval algorithm needs input parameters to describe the initial state of the atmosphere which includes an a-priori knowledge of the state parameters we want to retrieve. Typically, these parameters are extracted from General Circulation Models. A first basic way to exploit the joint observations could be therefore to use PFS well-established retrievals of atmospheric temperature profiles, surface temperatures, dust and water ice opacity, as well as water vapor and carbon monoxide abundance, as input parameters for NOMAD retrievals. An analysis of differences between retrievals using PFS and GCMs inputs will be carried out. The inversion method that will be used is a Levenberg-Marquardt fitting algorithm. Forward modelling will be pursued using available radiative transfer software such as ARS [1], a full multiple-scattering, plane-parallel RT code suitable for Nadir observations, and JACOSPAR [2], a Montecarlo RT code with spherical geometry, useful for Limb observations. The spectroscopic database used in the line-by-line computation of absorption coefficients is HITRAN 2016 [3], corrected for a CO_2 atmosphere.

3. Joint observations

Between 8th June 2018 and 10th of April 2019 (between Mars Express orbit 18267_A and 19318), 65 joint observations (nadir-nadir) have been executed, and more will be executed in the forthcoming months. Limb-limb joint observations will hopefully be planned and executed in the future. Two observations are considered "simultaneous" if their latitudinal and longitudinal distance is less than 5°, in a time-frame of ~5 minutes. Table 1 reports the MTP, MEx orbit and Date of the executed joint orbits.

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5. References

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[2] Iwabuchi (2006), Efficient Monte Carlo methods for radiative transfer modeling. J. Atmos. Sci., 63, 9, 2324–2339.

[3] LE. Gordon et al., (2017), The HITRAN2016 Molecular Spectroscopic database, J Quant Spectrosc Radiat Transfer 203, 3-69.

Table 1: executed joint NOMAD/PFS observations. MTP refers to "Mid-Term Planning" (one month) of PFS, Orbits are intended to be Mars Express' Orbits, Dates are terrestrial ones

MTP	Orbit	Date	MTP	Orbit	Date
183	18267_A	8/6/18 21.00		18862	28/11/18 22.10
	18269	9/6/18 10.33	**190**	18929_A	18/12/18 9.46
184	18344_A	1/7/18 3.33		18943	22/12/18 13.05
	18348	2/7/18 7.03	**191**	18968	29/12/18 20.04
	18355_A	4/7/18 7.56		18977	1/1/19 10.56
	18379_A	11/7/18 7.12		19002	8/1/19 17.48
185	18391	14/7/18 20.50		19011_B	11/1/19 8.40
	18423	24/7/18 5.45		19020_B	13/1/19 23.32
186	18580	7/9/18 20.38		19036	18/1/19 15.31
187	18589	10/9/18 11.34		19054	23/1/19 21.14
	18598	13/9/18 2.26		19056	24/1/19 10.59
	18607_A	15/9/18 17.18	**192**	19065	27/1/19 1.51
	18616	18/9/18 8.10		19072	29/1/19 2.58
	18625	20/9/18 23.02		19074	29/1/19 16.43
	18634	23/9/18 13.53		19083	1/2/19 7.35
	18652	28/9/18 19.37		19085	1/2/19 21.23
	18663	2/10/18 0.16		19092	3/2/19 22.27
	18674	5/10/18 4.55		19101	6/2/19 13.19
188	18685	8/10/18 9.34		19112	9/2/19 17.58
	18687	8/10/18 23.21		19114	10/2/19 7.45
	18695	11/10/18 6.27		19129	14/2/19 16.02
	18696	11/10/18 14.14		19140	17/2/19 20.43
	18704	13/10/18 21.19	**193**	19173	27/2/19 10.51
	18723	19/10/18 12.12		19202_A	7/3/19 21.25
189	18781	5/11/18 8.32		19211	10/3/19 12.21
	18790	8/11/18 22.27		19229	15/3/19 18.03
	18799	10/11/18 14.12		19238_A	18/3/19 8.54
	18817	15/11/18 19.54		19247	20/3/19 23.49
	18826	18/11/18 10.47	**194**	19309_A	7/4/19 22.47
	18835	21/11/18 1.20			
	18844_A	23/11/18 15.18			
	18853	26/11/18 7.55			
	18856	27/11/18 6.29			