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A simulation of the OMEGA/Mars Express observations: Analysis of the atmospheric contribution

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Abstract

Spectral images of Mars obtained by the Mars Express/OMEGA experiment in the near infrared are the result of a complex combination of atmospheric, aerosol and ground features. Retrieving the atmospheric information from the data is important, not only to decorrelate mineralogical against atmospheric features, but also to retrieve the atmospheric variability. Once the illumination conditions have been taken into account, the main source of variation on the CO_2 absorption is due to the altitude of the surface, which governs atmospheric pressure variation by more than an order of magnitude between the summit of Olympus Mons down to the bottom of Valles Marineris. In this article we present a simplified atmospheric spectral model without scattering, specially developed for the OMEGA observations, which is used to retrieve the local topography through the analysis of the 2.0 μm CO_2 band. OMEGA atmospheric observations increase the horizontal resolution compared to MOLA altimetry measurements, and therefore complement the mineralogical studies from the same instrument. Finally, residual variations of the pressure can be related to atmospheric structure variation.

Keywords: Mars; Mars Express; OMEGA; Planetary atmosphere; Altimetry; Image-spectroscopy; Line-by-line; Topography

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1. Introduction

Mars Express is the first ESA planetary mission and it has successfully entered into an elliptical polar orbit around Mars in December 2003, with a pericenter of few hundred kilometers. OMEGA is one of the seven instruments on board the Mars Express mission (Chicarro, 2004). It consists of an imaging spectrometer devoted to the study of both the diffused solar light and the planetary thermal emission. OMEGA acquires a spectrum in 352 contiguous spectral channels from 0.35 to 5.1 μm, with a spectral sampling ranging from: 7 nm (VNIR, visible and near infrared) for the spectral range 0.4 1. μm; 13 nm (SWIR-C, short wavelength infrared and C stands for the french word "Court" meaning short) for the spectral range 1−2.7 μm; to 20 nm (SWIR-L, where L stands for the french word "Longue" meaning Long) for the spectral range 2.6−5.1 μm, with an instantaneous field of view of 1.2 mrad, for a spatial resolution that may attain ~400 m (Bibring and OMEGA Team, 2004).

A spectral analysis of the planet at this scale has never been done. Only the cameras have even overran this spatial resolution, attaining the resolution of few meters (Neukum and Jaumann, 2004), but providing only partial information on the composition. The complete spectral identification at this scale still remains to be done and it will be possible only through an image spectrometer. OMEGA is the first instrument to observe the planet in a continuous spectral range from the visible to the thermal infrared at a very small scale: for these reasons it is a suitable instrument to analyze meso-scale phenomena.

The spatial distribution of mineralogical and atmospheric features at this scale is a key factor for the study of the variety of the ground composition (Bibring et al., 2005); for instance, this will open the possibility of investigating the past aqueous activity of the planet (Gendrin et al., 2005); separating the atmospheric features (Drossart et al., 2005), allowing, among others, the detection and the study of pressure variations (Gendrin et al., 2003) and the dust distribution analysis (Fouchet et al., 2004).

The Infrared SpectroMeter/Phobos2 (ISM) (Bibring et al., 1989), which may be considered as a pre-OMEGA instrument, had already provided important information on the composition and on the spatial distribution of the mineralogical (Murchie et al., 1993, 2000; Erard and Calvin, 1997; Mustard et al., 1993, 1997; Mustard and Sunshine, 1995; Geissler et al., 1993) and atmospheric signatures (Chassefiere et al., 1995; Titov et al., 1994; Hunten, 1993; Combes et al., 1991). OMEGA improves over the ISM observations with a higher spatial and spectral resolution, larger bandwidth and higher spatial coverage.

In this work we present an atmospheric study of the OMEGA data with the main objective of an analysis of the ground pressure variation. This parameter is used for the altimetry retrieval and for the study of the atmospheric features at low scale, as the lee waves.

Recently the Mars Orbiter Laser Altimeter (MOLA) (Zuber et al., 1992) of the Mars Global Surveyor (MGS) mission has produced a complete topography of the planet with a vertical spatial resolution that may attain the scale of the meter (Soderblom and Kirk, 2003). Nevertheless, the horizontal spatial resolution may vary from region to region (best resolution is $1/128°$) and in particular situation OMEGA may observe altimetry variations not revealed at a local scale by MOLA.

In any case the knowledge of the MOLA data allows a detailed analysis of the atmospheric fluctuations; indeed, the ground pressure value depends mainly on two parameters, the altimetry and the atmosphere's dynamics. The MOLA data allow us to extract the contribution of the first parameter and help us focus the analysis on the second one. It is then possible to detect and analyze, with an image spectrometer, structures like the lee waves (Pirraglia, 1976; Pickersgill and Hunt, 1982), which are present at different scales on Mars. These structures have not been yet completely studied through a spectral analysis (Gendrin et al., 2003), but only under a geometrical point of view (Wood et al., 2003).

Moreover, the model that we present provides also a first approximation to the atmospheric contribution of the SWIR-C OMEGA detector spectrum 1−2.7 μm, allowing a better analysis of the ground spectroscopic features.

2. Simulation of the atmosphere

One of the most difficult tasks in the OMEGA/Mars Express data analysis is the separation of the contributions, the atmosphere from the spectral signature of the surface. As it is shown by the Sobolev (1975) equation which describes the reflectivity of a planet in the presence of an atmosphere and aerosols, these contributions are bounded together and depend on a large number of parameters (Table 1). Moreover, the "a priori" knowledge of some of

Table 1
List of the parameters needed to model the reflectivity of a planet

Orbital parameters	Ls (season)
	Sub solar longitude (local time)
	Position (lon−lat)
	Altitude (MOLA)
	Incident emergent angles (μ_0, μ_1)
Environmental parameters	Vertical temperature profile
	Vertical pressure profile
	Saturation profile
	Aerosol vertical density profile
Composition	Atmosphere (CO_2, H_2O, CO, ...)
	Aerosols
	Ground albedo