MAPPING CLOUDS MICROPHYSICS WITH OMEGA/MEX.

J.-B. Madeleine1,2, J.-P. Birbig1, B. Gondet1, F. Forget1, F. Montmessin1, A. Spiga2, D. Jouget1, M. Vincendon1, Y. Langevin1, F. Poulet1, B. Schmitt1.

1IAS, Orsay, France. 2Laboratoire de Meteorologie Dynamique, Institut Pierre Simon Laplace, Paris, France. 3Service d’Aeronomie, Institut Pierre Simon Laplace, Paris, France. 4Laboratoire de Planetologie de Grenoble, France. jbmld@lmd.jussieu.fr

1. Introduction

Near-IR hyper-spectral imaging of clouds is currently used on Earth as a powerful meteorological tool, and this technique is made possible on Mars by the OMEGA (Observatoire pour la Minéralogie, l’Eau, les Glaces et l’Activité; instrument [1]) imaging spectrometer. Past analysis of clouds has been done in the visible range with Mariner 9 and Viking Orbiters [3], and more recently in the visible (MODIS) images [4] and thermal infrared (TIRS) 6 to 50 μm [56] with Mars Global Surveyor.

Bridging the gap, OMEGA data are spectral image cubes (3x3) of the atmosphere and the surface both in the visible and near infrared, spanning 0.35 to 5.1 μm with a spectral sampling of 0.015-0.020 μm and kilometer-scale spatial resolution. Water vapor, methane, and carbon dioxide absorptions at 1.25, 1.5, 2 and 3 μm that can be used to detect water-ice clouds and derive their microphysical properties.

Analyzing the kilometer-scale microphysics of clouds on Mars is key to understanding their formation, their role in the water cycle and radiative transfer of the planet, their interaction with the dust cycle, and can provide major insights into the fundamental physics of nucleation.

2. Cloud cover mapping

To first detect and map the cloud cover, 1.5 and 3 μm water ice absorption bands are visualized using RGB composition:
- The red is proportional to the slope at the edge of the 3 μm H2O vibrational band (3.4-3.525 μm criterion defined in [2]);
- The green is proportional to the depth of the 1.5 μm water absorption band (used in [7]);
- The blue is held constant.

Correlated increase of the 1.5 μm absorption depth and 3.4 μm slope reveals the formation of water ice clouds, and appears in blue. On the contrary, large 1.5 μm absorption depth and drop of the 3.4 μm slope are typical of surface grains larger than 10 μm which appear in magenta, allowing us to distinguish between surface ice and clouds (see image a).

3. Cloud microphysical properties

Cloud optical depth and particle size can be retrieved at a given point using an inversion method presented on figure 2. The model minimizes the difference between a simulated reflectance and the observed cloud reflectance by using a downhill simplex method and a least-squares criterion. The free parameters are the optical depth of the cloud at 3.2 μm τc and the water ice crystal effective radius r.

These two parameters are fitted during the inversion by calculating the radiative transfer through a single-layer atmosphere using the Spherical Harmonics Discrete Ordinate Method [8]. Scattering parameters are given by a Lorentz-Mie code which uses the recent ice optical constants at 100K of Grundy & Schmitt [9], and assumes that the ice particles are spherical and follow a unimodal log-normal distribution (effective variance of 0.2). A spectrum of the same region, free of any clouds, must be used as a surface boundary condition of the model. This spectrum must be carefully chosen through a “man-in-the-loop” method, in order to make sure that the surface geology, the atmospheric dust opacity and the viewing geometry are similar to what is found for the analyzed cloudy pixels.

In the actual radiative transfer model can also reproduce the behavior of the 1.5 μm absorption band and 3.4 μm slope to generate a framework given in figure 1. This framework is a first guiding tool for reading RGB compositions and assessing cloud particle size and opacity. Indeed, automatic inversion of the two microphysical parameters (τc,r) over an entire orbit is still a challenge that has to be addressed.

4. Ongoing improvements and analyses

Improvements of the inversion model are underway to take into account the retrieval uncertainties, the radiative effect of atmospheric dust [10] and ice nucleation on mineral dust cores, the contribution of the 3 μm hydration band of surface dust [11], and to quantitatively map the microphysical properties over an entire orbit.

Final results from the inversion model will be compared to the water cycle simulated by the LMD/GCM (see [12] and poster [13]), and regional cloud structures will be interpreted with the help of the new LMD mesoscale model (poster [14]).

References