AUTOMATIC DETECTION OF H_2O AND CO_2 ICES IN OMEGA/MEX IMAGES FOR THE MONITORING OF THE SOUTH POLAR CAP RECESSION.

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ABSTRACT

The high latitudes of Mars are covered by a seasonal CO_2 ice deposit. The time and space evolutions of this cover is a major annual climatic signal both at the global and the regional scales. In particular the measurement of the temporal and spatial distributions of CO_2 constrains many atmospheric and surface processes involving the latter compound but also H_2O and dust. The hyperspectral imaging spectrometer OMEGA on board Mars Express has been scrutizing the seasonal changes at the surface of Mars in the near infrared in both hemispheres since it began its operation in early January 2004. OMEGA produces hundreds to thousand images a year, each one made up of thousand to million spectra. Such huge hyperspectral datasets must be analysed by efficient yet accurate algorithms. Thus we propose to use *wavanglet*, an algorithm particularly suitable for the automatic detection of the spectral signatures characteristics of H_2O and/or CO_2 ices. This paper presents results obtained by applying *wavanglet* on a temporal series of images covering the southern hemisphere during the martian spring and summer of 2005 (between Ls=242^0 and Ls=282^0). In particular, the detection masks built by the algorithm for each image allows us to draw automatically, as a function of time, the defrost line - the line that separates the regions still mantled by frost from those that have lost their icy cover.

INTRODUCTION

In order to understand Mars' current climate it is necessary to detect, characterise and monitor CO_2 and H_2O at its surface (permanent and seasonal icy deposits) and in its atmosphere (vapor, clouds). The series of images acquired above the medium latitudes and the poles by the OMEGA [1] imaging spectrometer on board Mars Express mission (ESA) represent an unique opportunity to achieve these objectives. At present time, the OMEGA database contains more than a hundred visible (VIS) and near infrared (NIR) hyperspectral images recorded at different seasons above the north and south polar regions with usually $\sim$ 100 000 spectra per image. Their spatial resolution varies from 350 meters up to 4 kilometres depending on the observation altitude. The instrument has three distinct spectral channels labelled V, C and L. Unlike the V channel, the C and L channels are particularly relevant for our studies since they sample numerous absorption bands distinctive of CO_2 and H_2O in their solid state. The C channel has a spectral range from 0.93 to 2.73 μm with a spectral resolution of 0.013 μm (128 spectels). The L channel has a spectral range from 2.55 to 5.1 μm with a spectral resolution of 0.020 μm (128 spectels). After calibration, the dimensionless physical unit used to express the spectra is the reflectance : the irradiance leaving each pixel toward the sensor divided by the solar irradiance at the ground.

We aim to :

1. evaluate the relevance of each image of the database for volatile molecule studies in terms of fractions covered by CO_2 and H_2O ices.
2. generate CO_2 and H_2O ice distribution maps.
3. automatically determine the seasonal condensation and defrost lines and their temporal evolutions.

Because of the huge volume of data, we need an automatic and efficient algorithm to achieve these goals in a reasonable calculation time.

METHOD

We propose a supervised automatic classification method, called *wavanglet*, that identifies spectral features and classifies the image in spectrally homogeneous units [2]. It follows four steps : A. Selection of a library composed of reference spectra representative of all types of terrains present in the images ; B. Application of a Daubechies wavelet transform to all referenced spectra. Determination of the wavelet subspace which best separates all referenced spectra ; C. In this selected subspace, determination of the best threshold on the spectral angle (i.e. modified correlation coefficient) to produce detection masks ; D. automatic generation of positive detection masks for the whole dataset.

This method was previously calibrated and tested on synthetic as well as on real OMEGA data [3]. We demonstrated that the *wavanglet* method is able to discriminate between different spectral patterns that sometimes do not differ greatly and strongly overlap. We also evaluated the sensitivity of *wavanglet* for the detection of CO_2 and H_2O ices as a function of certain physical (e.g. grain sizes) as well as geometrical parameters (e.g. solar incident angle) using synthetic data. Thanks to the selection of small scale wavelets, the sensitivity of *wavanglet* is not hampered by photometric variations due to the incidence and emergence angles. Furthermore, the presence of atmospheric CO_2 bands has a minor influence on the detection. These two properties bring *wavanglet* an advantage over the widely used ratio method. On the contrary, the non linear effect of grain size variability on the spectral signatures is difficult to handle with only one reference spectrum per material. We assume that the grain sizes of both CO_2 and H_2O ices vary in a limited range of values in order to neglect these non linear effects. The physical analysis of OMEGA spectra by inversion of a radiative transfer model shows that the grain size is quite homogeneous for the permanent south polar cap for CO_2 and H_2O ices alike [4].

PRELIMINARY RESULTS

We operate the *wavanglet* algorithm to monitor the seasonal South Polar Cap recession during the martian spring and summer of 2005 (between Ls=242^0 and Ls=282^0). Figure 1 shows a mosaic of detection masks superimposed on a MOLA

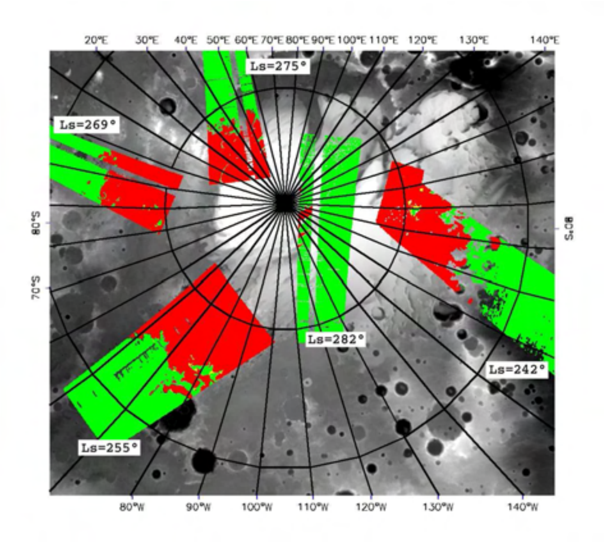

Figure 1: Mosaic of detection masks superimposed on a MOLA topographic background. Here the regression of the seasonal South Polar cap is followed from late spring (Ls = 242^0) to early summer (Ls = 282^0). Positive detection of : CO_2 ice (red), dust (green), both CO_2 and dust (yellow). The inner and outer black circles correspond respectively to the latitudes 80^0 and 70^0S .

topographic background. The defrost line separates the CO_2 mantled (red) regions from the ice free (green) regions. It departs from a simple circular arc because, in these highly cratered areas, the local slope distribution induces a complex spatial pattern of absorbed solar energy and thus of CO_2 sublimation. Nevertheless one can estimate from this kind of mosaic the approximate position of the defrost line according to longitude and time (Ls). Furthermore, the behaviour of the recession in the south seems to be different than in the north [5] because no H_2O ice lag is detected in area where CO_2 ice just sublimed.

Conclusion

Our detection algorithm *wavanglet* has been applied on a temporal series of OMEGA/MEX images covering the retreat of the seasonal southern polar cap in 2005 (between Ls=242^0 and Ls=282^0. It allows an automatic and accurate determination of the defrost line as a function of longitude and time (Ls).

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References

[1] Bibring, J.P., et al., 2004, *OMEGA: Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité*, ESA SP-1240: Mars Express: the Scientific Payload, 37–49.

[2] Schmidt, F., et al., *IEEE Transactions on Geoscience and Remote Sensing, submitted*.

[3] Schmidt, F., et al., *IEEE Transactions on Geoscience and Remote Sensing, submitted*.

[4] Douté, S., et al., *Planetary and Space Sience, submitted*.

[5] Schmitt, B., et al., 2005, in *36th Annual Lunar and Planetary Science Conference*, 2326–+.