PHYSICAL CHARACTERIZATION OF THE SOUTH SEASONAL CAP OF MARS DURING RECESSION FROM OMEGA OBSERVATIONS. Sylvain Douté[1], Frédéric Schmidt[1,2], Bernard Schmitt[1], Yves Langevin[3], Mathieu Vincendon[3], Jean-Pierre Bibring[3], [1]*Laboratoire de Planétologie de Grenoble Bât D de Physique B.P. 53 Grenoble Cedex 09 France sylvain.doute@obs.ujf-grenoble.fr*, [2]*European Space Astronomy Centre (ESAC), P.O. Box - Apdo. de correos 78, 28691 Villanueva de la Canada, Madrid, Spain*, [3]*Institut d'Astrophysique Spatiale, CNRS / Université Paris XI, Orsay Campus, 91405, France*.

Introduction The time and space evolution of the South Seasonal Polar Cap (SSPC) is a major annual climatic signal. The composition, physical state and texture of the SSPC give clues about the exchange of CO2, H2O and dust with the atmosphere. The imaging spectrometer OMEGA on board Mars Express has acquired the most comprehensive set of observations to date in the near-infrared (0.93-5.1 microns) on the SSPC from mid-winter solstice (Ls=110^o, December 2004) to the end of the recession at Ls=320^o (November 2005) [1]. The time resolution is 3 days to one month and the spatial resolution ranges from 700m to 10 km/pixel. The spectral range covered by OMEGA is particularly relevant for our studies since it samples numerous absorption bands distinctive of CO2 and H2O in their solid state. [1] showed that, during southern spring and summer, there is a very complex evolution in terms of effective grain size of CO2 ice and contamination by dust or H2O ice. H2O ice does not play a significant role except close to the end of the recession. Here we analyze with statistical techniques and physical models a collection of OMEGA spectral images covering the SSPC at Ls ≈220-254^o, i.e. close to the maximum development of the cryptic region. Our goals are to (i) systematically segment the South Seasonal Polar Cap into different spectral units. The latter may correspond to well differentiated terrains on the basis of material composition, physical state and organization (ii) test diverse surface representations by the modeling of spectral end-members and average unit spectra (iii) map the spatial variations of the terrain physical properties : dust abundance, granularity, icy layer thickness, etc. by a systematic inversion of the dataset.

Observations We use a supervised automatic classification method, called "wavanglet", that identifies spectral features in wavelet sub-spaces to detect reference compounds (CO2, H2O, and dust) [2]. From Ls=110° to Ls =320° of martian year 27 (early 2005 to mid 2006) we select a total of 605 OMEGA/MEX observations with a positive detection of CO2 ice at high southern latitudes. Detection statistics allowed us to monitor the position and structure of the SSPC edge [3, 4]. A prior task of the present work consists in sorting the observations by irregular intervals of Ls (≈ 10 images per time bin) so that the coverage of the SSPC is approximately complete while reducing the effects of temporal evolution. Products derived from the separate analysis of each image falling into the same time bin are usually merged into a single mosaic. The geographical projection we use is south polar stereographic with east longitude 0^o at the top.

Analysis ***Statistical methods*** We perform the systematic classification of the SSPC into spectral units and extract end-members by first reducing the spectral dimension of the observations. For that purpose we carry out a PCA for each set of images falling into the same time bin. We calculate incrementally the covariance matrix of the whole population of spectra belonging to these images and find the eigenvalues and eigenvectors of the matrix. Such a operation allows obtaining a common set of axis for a coherent reduced representation. First we can map the highest 3 PCA components of a spectrum into the RGB color space. Mosaics (one for each time bin) are thus built where false color variations reveal spectral units (Fig. 1). Second we select the most spectrally pure spectra (that appear as white dots in Fig. 1) by performing a pixel purity index operation (PPI) on the basis of the first 7 PCA components. We typically retain at least 200 individuals that we visualize as a n-dimensional (n=7) cloud of points with various projections and perspectives to manually locate and identify clusters. Each of them is unambiguously related to a spectral unit which purest and representative pixels are thus extracted. We recognize ten main spectral units that occur at least once for Ls ≈220-254^o. In figure 2 we reproduce, for four of them, the average of their purest spectra according to the time interval of occurrence.

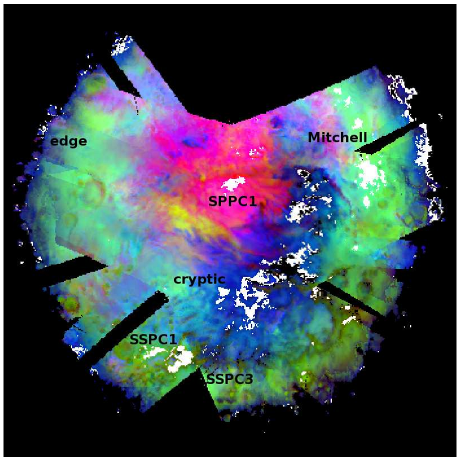

FIG. 1 – Segmentation of the south seasonal polar cap (SSPC) into distinct spectral units. The white area indicate the location of the most representative spectra.

Physical characterisation We model the representative spectra of the spectral units to get insights about the physical state and properties. The removal of the spectral effects due to aerosols and atmospheric gases is respectively performed using fast algorithms for the multiple scattering and a line-by-line radiative transfer model fed by the vertical compositional and thermal profiles predicted by the European Mars Climate Database (EMCD) for gaseous absorption [5]. The modelling

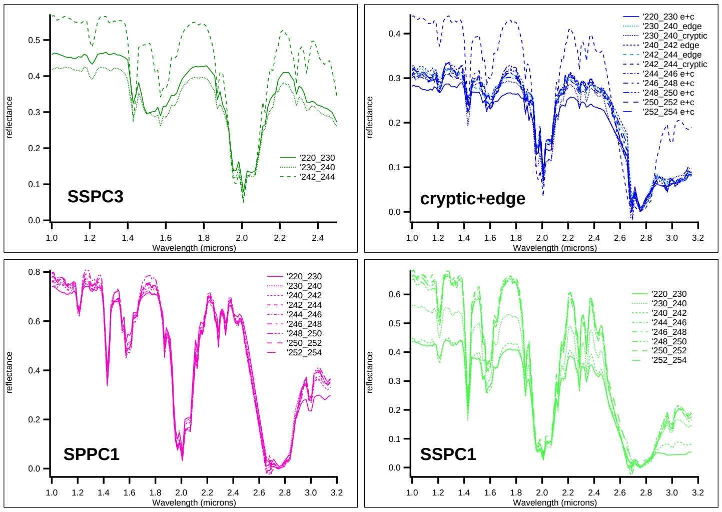

FIG. 2 – Temporal evolution (by intervals of Ls) of the average spectrum of four selected spectral units making most of the SSPC between Ls ≈220-254^o.

of the spectra after atmospheric correction is performed with a radiative transfer algorithm that calculates the spectral reflectance of layered, icy, and dense materials taking into account shadowing effects due to macroscopic roughness [6, 5]. Each layer can have a granular or a compact (icy matrix with inclusions) texture.

Discussion The classification of the OMEGA spectra for Ls = 220 - 254^o distinguishes ten major spectral units for the regressing seasonal polar cap. Three of them are ubiquitous, cover large area, and are characterized by the following basic spectral properties : (i) SPPC1 with a very high albedo in the continuum and strong CO2 ice absorption bands. The SPPC1 spectra are remarkably stable. (ii) SSPC1 with a moderate to high albedo and extremely deep, sometimes saturated (at 2 μm) CO2 ice absorption bands. This unit displays a more important spatial and/or temporal variability. (iii) the cryptic region and the edge of the polar cap with a low albedo and weak absorption bands. The representative spectra of units SPPC1 and SSPC1 can be satisfactorily reproduced with the following model (model 1) : a clear slab of CO2 ice ≈ 1-10 cm thick with a upper limit of 0.02 % in volume for the dust and H2O ice inclusions content (size range of 10 µm - 100 µm). The slab lies on a optically thick layer of fine-grained CO2 ice that gives the high reflectance factor in the spectrum continuum (at $\approx 1\mu m$). This factor highly depends on the acquisition geometry and on surface roughness. At contrary a simple model (model 2) with a single optically thick layer of granular CO2 ice with a small fraction of dust (0.-0.2 wt%) and a mean grain size between 1mm and 6 cm cannot reproduce at the same time the continuum and the strength of the 1.43, 1.57,2.0, 2.29 and 2.43 μm CO2 bands. Nor a model (model 3) similar to model 1 but with the slab and the CO2 granular layer reversed. We conducted similar tests with models to study the spectral and thus the physical evolution of the cryptic region. The results can be found in [7].

Conclusion Modeling the representative spectra of the main spectral units of the south seasonal polar cap during recession (Ls ≈220-254^o) shows that the presence of a very pure CO2 slab of ice is mandatory to reproduce all the spectral features in any case. This confirms the work of [8]. For the SPPC1 and SSPC1 units, the slab lies on an optically thick layer of fine-grained CO2 ice. Variations of the slab thickness and roughness as well as variations of the dust content and granularity for the underlying layer likely explain the spectral differences between SPPC1 and SSPC1 and their intrinsic variability. For the cryptic region, the slab extends down to the mineral substratum. It is superficially contaminated by a variable amount of dust. At the edge of the polar cap, these icy terrains coexist geographically with ice free terrains in a transition zone before complete disappearance.

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