MULTI-INSTRUMENT DATA HANDLING FOR SUB-SURFACE ANALYSIS ON MARS. Melissa Mirino[1], Elliot Sefton-Nash [2], Olivier Witasse[2], Alessandro Frigeri[3], John W. Holt[4], Stefano Nerozzi[4]. [1] Open University, Milton Keynes, United Kingdom (melissa.mirino@open.ac.uk), [2] European Space Research and Technology Centre, European Space Agency, Noordwijk, The Netherlands, [3] Istituto di Astrofisica e Planetologia Spaziali, Istituto Nazionale di Astrofisica, Rome, Italy, [4] Institute for Geophysics, Jackson School of Geosciences, University of Texas, Austin, USA.

Introduction: The Martian polar caps have engendered substantial study due to their interesting spiral morphology and the seasonal variability in thickness of the uppermost H_2O and CO_2 ice layers (e.g. [1]). For this study we performed a multi-instrument study using data from NASA's MRO mission analyzing the exposed and buried layers deposits which composed the Planum Boreum, the ~1000 km diameter north polar plateau located in the center of Borealis Basin. We selected two opposite areas of the plateau; Chasma Boreale and Olympia Cavi, with the objective to characterize in multiple datasets each geologic unit identified in the north polar cap's stratigraphy (mapped by e.g. [7]). The combination of high resolution images, spectroscopy and radar datasets allowed us to attempt to correlate polar layering, made visible by dielectric interfaces between beds, with surface mineralogy and structures outcropping at specific stratigraphic levels.

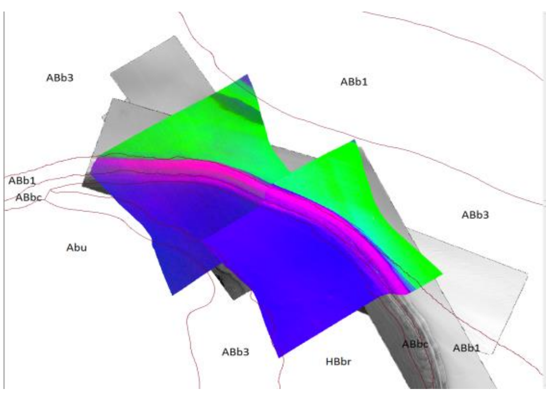

Figure 1: *Example of processed MTRDR CRISM data located in the Chasma Borealis using the spectral parameters to characterize the ice composition. The area indicated with the green color is characterized by H_2O ice, the area indicated with the pink color is composed by CO_2 ice with silica inclusions and the area indicated with the blue color indicated a composition made by CO_2 ice. In this figure is possible to see the correlation between the HiRISE images, the geologic units and the spectral data. To facilitate the analysis and interpretation the colors of geological map and other features were removed.*

Datasets: We performed analysis of high resolution images from HiRISE, which provide textural and morphological information about surface features larger than ~0.3m [3], with NIR hyperspectral data from CRISM, which allows study of surface mineralogy at a maximum resolution of 18 m/pixel [4]. Together with these surficial observations we interpret radargrams from SHARAD to obtain information about layered structures at a horizontal resolution between 0.3 and 3 kilometers and a free-space vertical resolution of 15 meters [5]. We used also data from MOLA, the laser altimeter which was on board of the MGS spacecraft which gave a precise topographic map of Mars [6]. A combination of MOLA data with images and radars allowed us to construct detailed geological profiles of the Planum Boreum.

Methods: We selected data of north polar scarps that exposed broad stratigraphic sections in two localities, to allow us to correlate spectral characteristics with visible stratigraphic horizons, topography, and radar reflectors. Through spatial-registration in ArcGIS, HiRISE images and the geological map realized by Tanaka et al 2008, were compared with MTRDR CRISM data products (id: frt00003509, frt00002f7f, frt0000aa7b, frt00002fa6, frt00003074, frt0000a176, frt0000a99d, frt0000b30d, frt0000a4a6,). Using the CRISM Analysis Tool and spectral summary parameters [8] we mapped the spectral characteristics of the two areas which show the sequence of the transient H_2O and permanent CO_2 ice cap layers, mixed with silicate spectral signatures (Fig.1). In order to constrain the cross section between the two selected localities we choose SHARAD radargrams, and the equivalent clutter simulations, that most closely align with the transect between the studied sites (176902 and 556202 tracks). Comparing radargrams and clutter simulations (e.g. Fig.3) we interpret sub-horizontal features to be due to dielectric interfaces involving the analysed deposits. Because the vertical radar signal is given in delay time, to produce a geological profile, we calculated the depth of each reflector using the following formulas:

$$D = v * dt$$

$$dt = \frac{t1}{t2} \qquad v = \frac{c}{\sqrt{\varepsilon}}$$

Where: D= depth, dt= delay time, v= wave velocity, t1= time of the surface reflection, t2 = time of the subsurface reflection, έ = permittivity.

Radar wave propagation speed is sensitive to changes in electrical properties, typically associated with changes in density and composition. Therefore, to calculate the reflection depth of a SHARAD signal we consider different compositions detected by CRISM, to provide an estimated constraint on the permittivity of the analyzed layers, considering that the wave velocity is proportional to $1/\sqrt{\varepsilon}$ (Fig. 2). This relationship may be used to assess the sensitivity of retrieved layer thickness to the inferred composition.

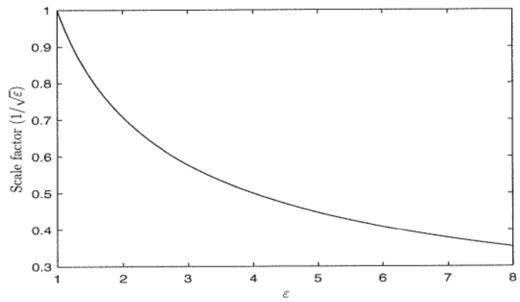

Figure 2: *Sensitivity of retrieved reflector distance to permittivity is described by the scale factor 1/√έ.*

We observed that for long distances the variation in depth of the radar signal is low even if we consider the έ range values with a bigger variation of depth. For this reason we simplified the model obtaining final geological profiles as showed in the Fig. 4.

Results: The correlation of surface and sub-surface datasets allowed us to obtain geological profiles of the north polar cap of Mars using the dielectric properties of the observed surface materials. Analyzing SHARAD radargrams of the Planum Boreum, we observed a main reflector corresponding to the boundary between NPLD and ABbc units (transition between CO_2 + H_2O ice and the more dust-rich cavi unit [2]).

may offer additional constraint on morphology of internal layering resulting from seasonal deposition/sublimation cycles over varying obliquity [9].

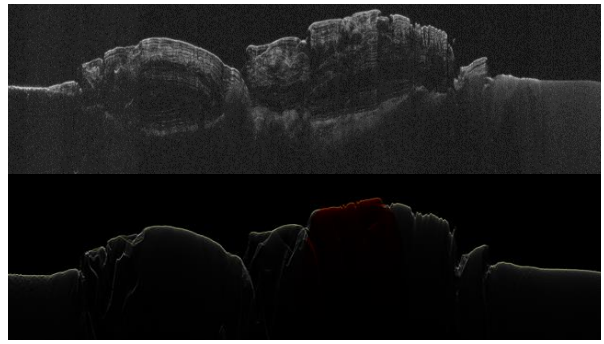

Figure 3: *Data used to perform the subsurface interpretation. Top: SHARAD radargram. Bottom: Clutter simulation.*

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References:

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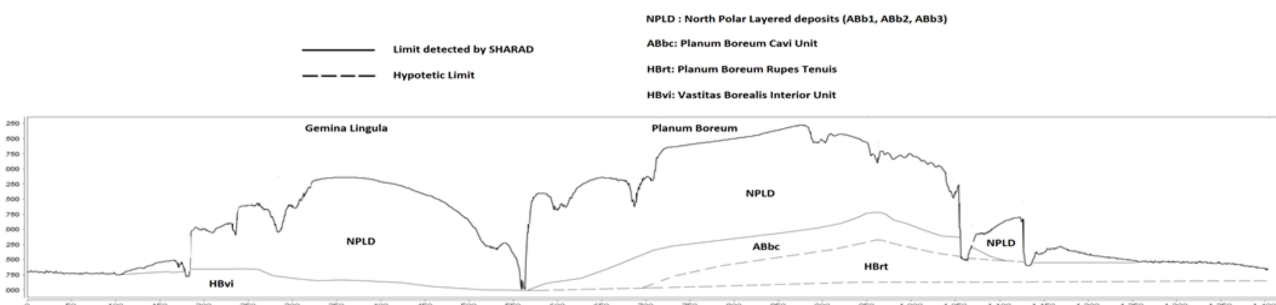

Figure 4: *The obtained final geological profile of Planum Boreum along our cross-section. In this profile the depth of the reflector was calculated using the permittivity of water ice έ* = 3.15.

Conclusions: The data handling of MRO mission data sets allowed us to obtain more information about the geological context of the area. Using this method we showed how to obtain information of the subsurface using the correlation between image, spectroscopic and radar remotely-sensed data. Our interpretation of radargrams in the context of compositional and structural constraints, from areas where pertinent beds outcrop, illustrates how joint analysis of surface and sub-surface data can benefit geological interpretation of planetary surfaces and sub-surfaces. We will apply this method using also MARSIS data to investigate deeper structures on the north polar cap. This technique applied to Mars' north polar layered deposits

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