GEOELECTRICAL MODEL OF THE MARTIAN NORTH POLAR LAYERED DEPOSITS

E. Heggy[1,2], S. M. Clifford[1], J. Cosmidis[3], A. Humeau[4], J. Boisson[1], R.V. Morris[5] [1]Lunar and Planetary Institute, Houston, 77058 TX, USA; [2]Institut de Physique du Globe de Paris, St Maur des Fosses, France; [3]Ecole Normale Superieure, Lyon, France; [4]Universite de Bordeaux I, Pessac, France; [5]NASA Johnson Space Center, Houston, TX, USA.

Introduction: During wintertime, the Martian polar caps are covered by a thin CO_2-ice layer which sublimates away by the end of spring. In the North, the dissipation of the seasonal CO_2 frost reveals a much smaller residual cap composed of water-ice and dust. High-resolution images of the spiral scarps that run through the cap have revealed the presence of finely layered deposits. The variations in thickness and albedo of the layers are thought to reflect temporal variations in the relative abundance of dust and water-ice deposited in the cap. Thus, the North Polar Layered Deposits (NPLD) may preserve a record of the seasonal and climatic cycling of atmospheric CO_2, H_2O and dust over the past ~10^5-10^8 years – potentially serving as a Rosetta Stone for understanding the geological and climatic history of the planet [1]. The orbital radar sounders SHARAD (SHAllow RADar) and MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) have the ability to probe the Martian subsurface to kilometers depth, providing a three-dimensional view of the polar caps. The radar observations can be interpreted in terms of internal geometry and thickness of the deposits, the basal topography, and perhaps presence of basal melt water [1]. However, the accuracy of these interpretations depends on our ability to constrain the dielectric properties of the polar ices. Indeed, the variation of the dielectric constant of ice as a function of the concentration and composition of dust controls the way the electromagnetic wave interacts with the subsurface materials and is essential to understanding the dust concentration in the NPLD. In order to constrain these ambiguities we have constructed first order maps of the surface dielectric properties of the NPLD based on the observed thermal properties of the surface and laboratory measurements of the electromagnetic properties of ice-dust mixtures. We first use Mars Global Surveyor (MGS) Thermal Emission Spectrometer (TES) thermal inertia observations [2] in order to asses the geographical distribution of the dust mass fraction in the ice at the top of the permanent cap. We then combine these with laboratory measurements of the dielectric properties of polar ice-dust analogs as a function of composition, temperature (-100 to -30 C°), radar frequency (1 MHz to 1 GHz) and dust mass fractions (0 to 100%) in order to obtain the parametric dielectric maps.

TES Modeled dust map of the surface of the NPLD: **Here** we describe the thermophysical model we developed to obtain a theoretical relation between thermal inertia and the dust weight fraction of an ice-dust mixture at given temperature, porosity and pore size of the ice. We have calculated the bulk specific heat capacity as $C = \tau C_d + (1-\tau)C_i$ where τ is the weight fraction of dust and C_i and C_d are the specific heat capacities of ice and dust respectively. Assuming a low dust contamination, the bulk density is: $\rho = (1-\Phi)[(1-\varphi)\rho_i + \varphi\rho_d]$ where ρ_i and ρ_d are the densities of ice and dust respectively, Φ the porosity and φ the dust content by volume. In order to take into account both the effect of heat conduction within the solid particles and across interparticle contacts and the effect of heat conduction by the vapor present in the void space between the particles, the bulk thermal conductivity is calculated as $k = k_s + \Phi k_v$ where k_s and k_v are the thermal conductivities of the icy matrix and the pores respectively. We use k_s~k_i the thermal conductivity of ice and k_v as a complex function of the ice physical and geometrical parameters obtained by thermal modeling of the vapor flux in the pores [3]. The calculation of thermal inertia given by this model for different temperatures, pore radius, porosities and dust weight fractions shows that Φ and τ are the main parameters controlling the variations thermal inertia. In particular, low porosities and dust content of the ice increase thermal inertia. Our study demonstrates a simple polynomial relation between τ and I for a constant porosity and for low dust concentrations. Thermal inertia maps have been derived from recent TES observations of the surface temperatures of Mars taken over three Mars-years from orbit 1583 to 24346 [2]. We use these data to derive the map of the dust contamination of the ice at the surface of the NPLD (Fig.1).

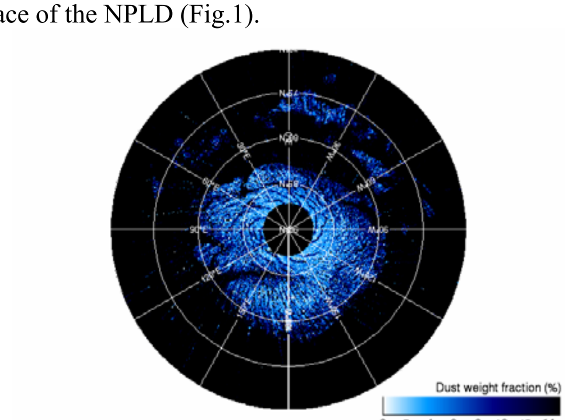

Figure 1: Surface dust contamination map of the NPLD, assuming an upper limit to dust weight fraction in the ice of 15%.

It is necessary to assume a maximum dust content to produce a map consistent with the TES results. Langevin *et al* (2005) suggest an upper limit to dust content by volume of 6%

which corresponds to a dust weight fraction of ~15%. Though, much smaller upper limit values are possible [4].

Relation between dust weight fraction and the dielectric parameters of ice-dust mixtures: We have conducted laboratory measurements of the dielectric properties of ice-dust mixtures with various concentrations of an analog basaltic soil as a function of density, temperature and radar frequency range. The results show an increase in the dielectric constant as a function of dust content. The measurements indicate that the influence of temperature on the real and complex parts of the dielectric constant is increases as the dust fraction gets larger. The dielectric properties of the ice-dust mixtures appear to have a very low frequency-dependence in the 1 -100 MHz range. Fig. 2 presents the empirical relation derived from measurements of the real part of the dielectric constant and the loss tangent as function of the dust weight fraction for a mixture of water ice and fine basaltic powder.

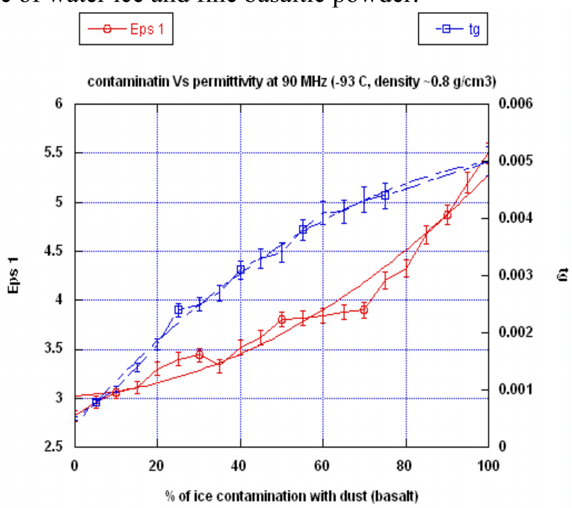

Figure 2: Real part of the dielectric constant and loss tangent of ice-basaltic dust mixtures as functions of the dust weight fraction for a constant temperature of -93 C and a frequency of 20MHz.

Parametric dielectric maps: We have integrated the laboratory measured dielectric properties and the dust contamination map derived from TES thermal inertia data into a comprehensive first order model of the surface dielectric properties of the PLD. We have obtained maps of the real part of the dielectric constant (shown in Fig. 3) and of the loss tangent for a given surface temperature, ice porosity, dust composition and radar frequency.

The equation giving the penetration depth as a function of the real and imaginary parts of the dielectric constant can be found in Heggy (2006) [5]. We have produced theoretical penetration depth maps at appropriate MARSIS and SHARAD frequencies (2 and 20MHz respectively), assuming that the dielectric properties observed at the surface don't vary significantly in depth. These maps show maximal values since their calculation don't take into account the layering inside the cap which causes energy losses and reduces the penetration depth.

The calculated penetration depth for MARSIS and SHARAD radar waves assuming propagation dielectric losses only suggests maximum penetration depths that allow both instruments to map the basal topography of the NPLD.

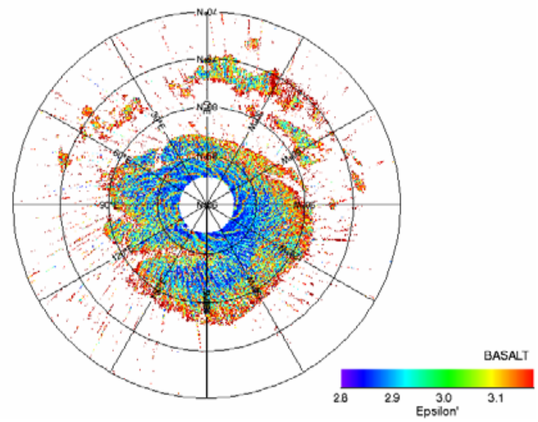

Figure 3: Real part of the dielectric constant at the surface of the NPLD at 90 MHz, assuming a basaltic composition of the dust and homogeneous surface temperature and porosity.

The thickness of the NPLD is approximately equal to their elevation above the surrounding plains. Hence, their maximum thickness is just over 3km at the pole and decreases equatorward. Our model demonstrates that both MARSIS and SHARAD should have the capability to detect the interface between the ice-dust material constituting the layered deposits and the underlying basaltic bedrock unit if the ice dust concentration is lower then ~ 20%. Radargrams of the NPLD from MARSIS [6] and SHARAD [7] have shown basal reflectors at depths estimated of up to several kilometers (1-3.5 km), which seems to confirm the validity of the current geoelectrical analysis.

Conclusion: The first-order geoelectrical model of the NPLD presented here yields estimates of dielectric properties that are consistent with recent radar observations from MARSIS and SHARAD, which indicate that the dust content in the NPLD is low.

Thermal observations of the layers visible in the polar troughs, coupled with MOLA (Mars Orbiting Laser Altimeter) topographic data, will allow us to create a three-dimensional model of the dielectric properties of the NPLD materials and improve the precision of the interpretation of radargrams from present and future Mars radar investigations. The 3 D model, the loss tangent and the penetration maps will be shown at the conference.

References: [1] Clifford, S. M. (2000), *Icarus* 144, 210-242 [2] Putzig, N. E., (2007) *Icarus*, in press [3] Clifford, S. M., (1993), *JGR* 98, 10,973-11,016 [4] Langevin, Y. (2005), *Science* 307, 1581-1584 [5] Heggy, E. (2006), JGR 111 [6] Picardi, G. (2005), *Science* 310, 1925-1928 [7] Phillips, R. J. (2007), *LPSC 38.*