**GEOELECTRICAL MODEL OF THE MARTIAN NORTH POLAR LAYERED DEPOSITS**

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**Introduction:** During wintertime, the Martian polar caps are covered by a thin CO\(_2\)-ice layer which sublimes 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 water-ice deposited in the cap. Therefore, the North Polar Layered Deposits (NPLD) may preserve a record of the seasonal and climatic cycling of atmospheric CO\(_2\), H\(_2\)O and dust.  

High-resolution images of the northern polar caps are covered by a thin CO\(_2\)-ice layer which sublimes 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 water-ice deposited in the cap. Hence, the North Polar Layered Deposits (NPLD) may preserve a record of the seasonal and climatic cycling of atmospheric CO\(_2\), H\(_2\)O and dust.  

**Layered Deposits (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 a 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 $\tau$ 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 $\rho_i$ and $\rho_d$ are the densities of ice and dust respectively, $\Phi$ the porosity and $\varphi$ 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 $k_s - k_v$ 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. The calculation of thermal inertia given by this model for different temperatures, pore radius, porosities and dust weight fractions shows that $\Phi$ and $\tau$ 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 $\tau$ 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).

**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 a 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 $\tau$ 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 $\rho_i$ and $\rho_d$ are the densities of ice and dust respectively, $\Phi$ the porosity and $\varphi$ 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 $k_s - k_v$ 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. The calculation of thermal inertia given by this model for different temperatures, pore radius, porosities and dust weight fractions shows that $\Phi$ and $\tau$ 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 $\tau$ 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.

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.

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 3D model, the loss tangent and the penetration maps will be shown at the conference.