RADAR STRATIGRAPHY OF THE GREENLAND ICE CAP AND IMPLICATIONS FOR THE MARS PLDs INVESTIGATION.

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Introduction: The aim of this work is to understand how the ice structure (both in terms of microscopic and macroscopic features) may affects the return of radar signals, in order to correctly interpret the data of martian ice-caps subsurface acquired with the SHAllow Radar (SHARAD) instrument [7]. Ice penetrating radar measurements of the Greenland ice sheet were acquired by CReSIS using an airborne radar [8], and show internal reflections that highlight changes of the ice compostition and internal structure.We performed a lito-stratigraphic study (radar facies analysis) and geophysical modelling to identify the main features that influence the different electrical properties of ice and potential implication for Mars.

Methods: Greenland radar data were acquired by CReSIS using an airborne radar [8] (Figure 1). The radar parameters are: frequency range of 140-160 MHz; nominal aircraft altitude of 500 m; bandwidth of 20 MHz; pulse duration of 3 to 10 microseconds linear FM up-chirp and vertical resolution (in ice) of 4.2 m.

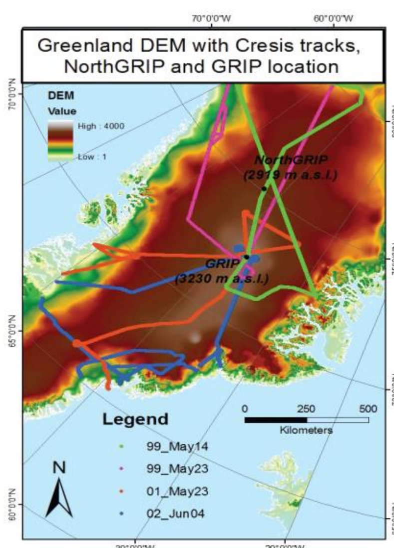
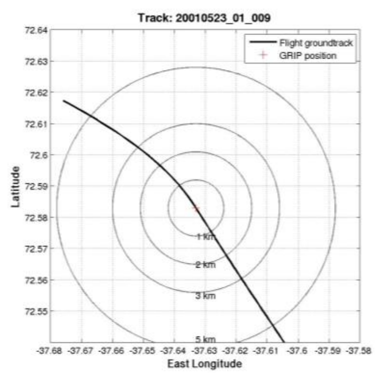


Figure 1. Map with the Greenland airborne radar tracks passing through the ice cores GRIP and NGRIP.

As discussed by several authors [1,2,3], the Greenland ice layers can include material of different origin. Dust and volatiles of unambiguous volcanic origin has been clearly identified and related to specific volcanic event. The concentration of these materials in the ice sheet and their composition varies along the sequence, causing changes in the internal permittivity [4,5,6].

Ice radar stratigraphy: Ice penetrating radar measurements of the Greenland ice sheet show internal reflections that highlight changes in ice composition (Figure 2). The Greenland ice layers can include wind-transported materials of different origin. The composition of impurities has effects on the permittivity and conductivity of ice, thus determining different Power Reflection Coefficients and in turn different internal reflections. We used the radar dataset acquired by CReSIS (Center of Remote Sensing of Ice Sheets, University of Kansas) and macro and micro-analysis of ice sheet cores provided by NSIDC (National Snow and Ice Data Center, University of Colorado).



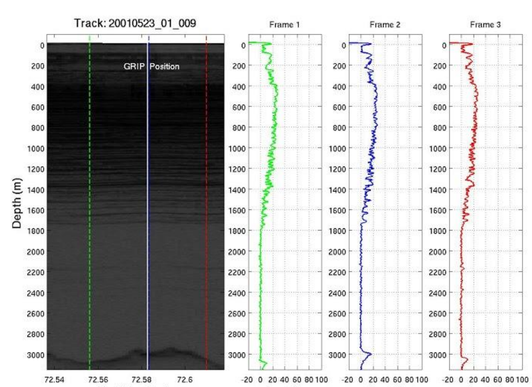


Figure 2. The 20010523 track intersects the GRIP ice core location and other two radar tracks nearby showing the continuity of the radar layers.

We recognized four different radar facies (Figure 3): Unit A sits on the rocky bedrock and is characterised by a few reflectors; Unit B reflectors become thinner and closer upward with cyclic pattern; Unit C is probably an artifact, resulting from the algorithm used for correction of the radar signal; Unit D has a weakly defined stratification and is mainly formed by fresh snow.

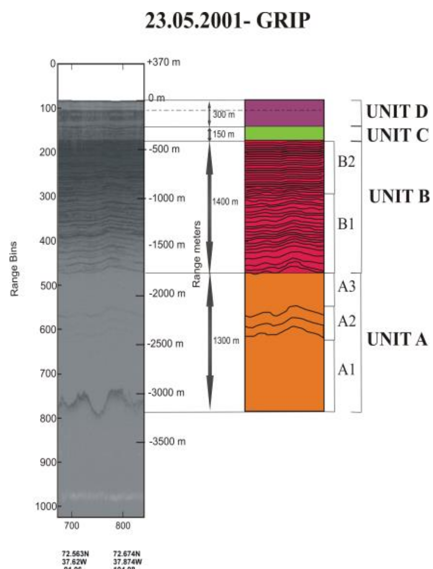


Figure 3. The 20010523 radar track passing through the GRIP ice core with the radar facies identified.

Geophysical model: The response of a surface-penetrating radar is highly dependent on the stratigraphy and lithology of the subsurface layers, and, since the electrical properties of these layers on Mars are unknown a comparison with the terrestrial data is very usefull. The electrical properties of internal reflection can be estimated as a function of acid concentration, frequency and temperature. The conductivity (ECM) is related to the acidic impurities embedded in the ice during volcanic eruptions. The conductivity change abruptly most likely because of variations in impurity content. Moreover the conductivity changes, also because of the alternating alkaline (cold period) and acidic (warm period) nature of the ice. To determine their contribution, we use the calibrated dielectric profile (DEP) from the ice cores. The DEP derived conductivity is, infact, sensitive to the impurities concentrations, that contribute significantly to the ice permittivity. We developed a simulator to reproduce the radar response based on the detailed ice information measured in the Greenland cores. As shown in Figure 4, we were able to simulate a realistic radar response which is mostly correlated with the ECM (ions content) rather than the layer geometry and stratigraphy.

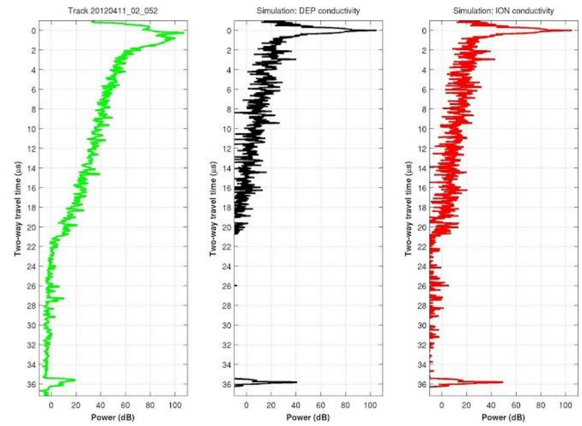


Figure 4. Comparison between a real radar track (green), the simulation using the Dielectric Profile plus the dust content (black) and the simulation using the ION conductivity (red).

Conclusions: We were able to reproduce the radar profiles acquired on terrestrial ice sheets using a direct inversion model based on the ice dielectric properties measured at Greenland ice cores. we could verify the the radar response is mostly influenced by the presence of ionic species in the ice rather than the dust content. As the model demonstrates its robustness with the comparison of real radargrams, we are going to adapt it to obtain a more realistic interpretation of the radar profiles acquired on Martian PLDs.

References: The authors acknowledge Center for Remote Sensing of Ice Sheet (CReSIS) and National Snow and Ice Data Center (NSIDC) for providing the data. [1] Paren J. G . and Robin G. de Q. (1975) Journal of Glaciology, 14, 71, 251-259. [2] Fujita S. and Mae S. (1994) Annals of Glaciology, 20, 80-86. [3] Harrison C.H. (1973) Journal of Glaciology, 12, 65, 383-397. [4] Moore and Fujita, (1993) Journal of Geophysical Research, 98, B6, 9769-9780. [5] Steffensen, (1997) Journal of Geophysical Research, 102, C12, 26755-26763. [6] Taylor (1997) Journal of Geophysical Research, 102, C12, 26511-26517. [7] Seu, R., et al., 2007. Science, 317, 1715-1717. [8] Gogineni S., Allen C, Stiles J. M. (2000) Radar Systems and Remote Sensing Laboratory Technical Report 13720-11. [9] Svensson et al. (2005) Journal of Geophysical Research, 110, D02108. [10] Thorsteinsson et al. (1997) Journal of Geophysical Research, 102, C12, 26583-26599. [11] J. W. Clough (1977) Journal of Glaciology, 18, 3-14 [12] Eisen et al. (2007) The Cryosphere, 1, 1-10.