WISDOM GPR INVESTIGATIONS OF ICE THICKNESS, STRATIGRAPHY, STRUCTURE, AND BASAL TOPOGRAPHY IN AN ALPINE ICE CAVE IN DACHSTEIN, AUSTRIA. V. Ciarletti[1] (valerie.ciarletti@latmos.ipsl.fr), S. M Clifford[2] (clifford@lpi.usra.edu), D. Plettemeier[3], S. Dorizon[1], C. Statz[3], B. Lustrement[1], O. Humeau[1], R. Hassen-Khodja[1], A. Galic[1]. [1]LATMOS-IPSL; UVSQ; CNRS/INSU, France, [2]Lunar and Planetary Institute/USRA, Houston, TX, USA, [3]Technische Universität Dresden, Germany.

Introduction: The WISDOM (Water Ice Subsurface Deposit Observations on Mars) Ground Penetrating Radar (GPR) is among the instruments selected as part of ESA's 2018 ExoMars Rover mission, whose scientific objectives are

- To search for signs of past and present life;
- To characterize the geologic environment and distribution of water as a function of depth in the shallow subsurface;
- To study the surface environment and identify hazards to future human missions;
- To investigate the planet's subsurface to better understand the evolution and habitability of Mars.

WISDOM, in combination with the Rover's Panoramic Camera will be used to perform large-scale scientific investigations of the area. WISDOM will provide high resolution observations of the structure of the shallow subsurface and assist in the identification and location of sedimentary layers, potential massive ice deposits, and other geologic environments where organic molecules are the most likely to be found and well-preserved

WISDOM's observations will be crucial to the identification of optimal drilling sites and the successful retrieval of subsurface samples – providing a valuable tool for determining the nature, location and extent of potential targets and helping to ensure the safety of drilling operations by indentifying potential hazards .

The resulting ExoMars data sets will characterize a domain that, until now, has remained relatively unexplored – providing important information on the nature of the shallow subsurface that is essential to understanding the processes and environmental conditions responsible for its formation, as well as its past and present habitability.

The instrument: The electromagnetic waves transmitted by the radar antennas are reflected by the electrical parameters inhomogeneities of the soil, (permittivity and/or conductivity) which are linked to the pre sence of interfaces between stratigraphic layers with different electromagnetic characteristics or units buried under the surface -- such as boulders and rocks or massive ice units

WISDOM operates over a frequency range of 0.5 - 3 GHz. Due to this wide frequency range, a vertical resolution of a few centimetres is expected over a few meters depth commensurate with the expected range of the drilling unit [1], [2] .

WISDOM's ability to make polarimetric measurements of the returning echoes will improve the radar's capability to retrieve the geometrical properties of the reflecting structures buried in the soil, the location of the off-track reflectors and to determine the geometry and roughness of the inter-layer interfaces.

Detection of ice: From a geoelectrical point of view, massive ice containing a small amount of impurities can be approximate as a rather homogeneous medium having a relative permittivity real part ε'_r around 3.2 (for a temperature around -10°c) and a imaginary part ε''_r typically of the order of magnitude of 10^{-3} .

Homogeneous unit: little backscattered signal (except when the ice is highly fractured with embedded air). A massive ice unit will appear on a radargram as an area with no noticeable signal return

Low conductivity value: deep penetration is possible through the ice. Deep and strong reflections can be observed from single scattered embedded in the ice or from interfaces below the ice unit.

Real permittivity value ε'_r around 3.2: The wave velocity and thus the permittivity value can be retrieved using individual reflectors' signature (hyperbolic shape). In case of a flat and smooth interface between a known material (air for example) and ice, the estimated reflection coefficient provides an estimate of the ice real permittivity value.

The presence of water ice into the subsurface can also be detected through dielectric changes associated with melting due to temperature changes.

Field tests: WISDOM prototypes, representative of the final flight model, are currently being field tested in various Mars analogue and cold-climate environments. In April 2012, members of the WISDOM team brought two development prototypes to an Alpine ice cave in Dachstein, Austria, to field test the instrument and participate in the Mars Simulation organized by the Austrian Space Forum.

The WISDOM GPR was tested on 3 different platforms (see figure 1): (Top) the radio-controlled "Magma White" Rover from ABM Space Education in Poland; (Middle) the WISDOM wheeled cart; and (Bottom) a 'Cliffbot' developed by the French Planète Mars Association. Radar investigations were conducted in four different cave environments, measuring ice thickness, stratigraphy, fracture geometry, and basal topog-

raphy (Figure 2). Because of variations in fracture width, density and orientation, determining fracture geometry proved to be the most challenging of these four tasks. Radar-derived 2- and 3-D reconstructions of the internal characteristics of the ice deposits and cave floor were in agreement with those determined by direct observation and previously obtained with commercial GPRs.

Summary: The unambiguous detection of ice units needs quantitative estimations of losses and reflection coefficients; thus, an accurate measurement of the amplitudes of the returned echoes in addition to the usual measurement of propagation delays. This can only be achieved through a precise calibration of the instrument that includes the electronic units, the cables and the antennas system.

The frequency range of WISDOM together with its small size allow it to be tested in anechoic chamber on targets which dimensions remain within reasonable size.

Additional field investigations, conducted in a wide variety of simulated [3] and natural cold environments, are planned to build a database of well-characterized ice-rich terrestrial environments and improve our ability to characterize them. A more detailed discussion of these field results is currently in preparation.

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References: [1] Ciarletti V et al. : WISDOM a GPR designed for shallow and high resolution sounding of the Martian subsurface, 0023-SIP-2010-PIEEE, 2010. [2] Plettemeier D et al, Full Polarimetric GPR Antenna System Aboard the ExoMars Rover, IEEE Radar Conference - 2009, 2009, Wisdom GPR measurements in a cold artificial and controlled environment. [3] Dechambre M., et al. IEEE International Geoscience and Remote Sensing Symposium (IGARSS), (2012)

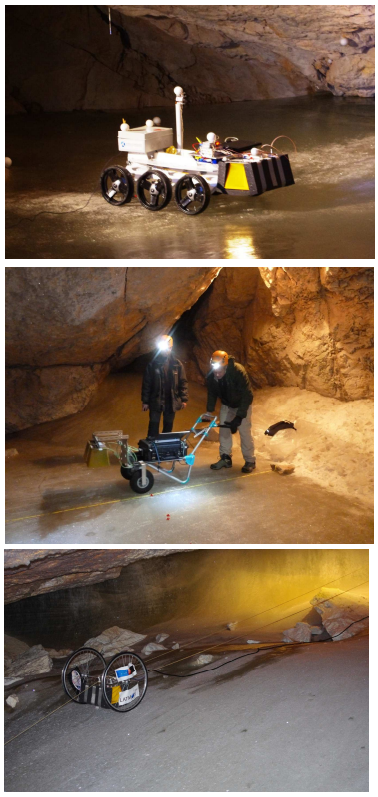

Figure 1 : The three different platforms used during the Ice caves field test in Dachstein.The WISDOM yellow antennas are noticeable.

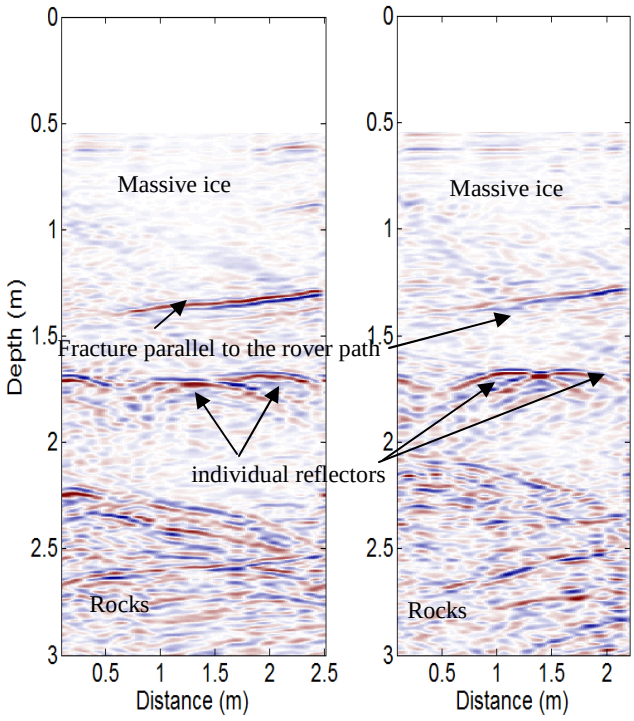

Figure 2 : Radargrams showing two parallel profiles acquired in the ice caves.