Getting Ready for Mars: WISDOM/ExoMars 2020 Data Processing Pipeline and Field Tests. A. Le Gall[1], V. Ciarletti[1], Y. Hervé[1], N. Oudart[1], C. Corbel[1], D. Plettemeier[2], V. Tranier[1], W-S. Benedix[2], S. Hegler[2], A-J. Vieau[1], (1) LATMOS/IPSL, UVSQ (Université Paris-Saclay), UPMC (Sorbonne Univ.), Guyancourt, France, (alice.legall@latmos.ipsl.fr), (2) Technische Universität Dresden, Dresden, Germany.

Within one year the second ExoMars mission will be launched to land on Oxia Planum, an ancient terrain on Mars, and search for evidence of past and/or present life. If such evidence is to be found, it will most likely be in the subsurface, where organic molecules are shielded from the destructive effects of radiation and oxidation. That is the reason why the ExoMars Rover will be equipped with a drill able to sample material at depth down to 2 m. In order to reveal the subsurface stratigraphy and to help planning drilling operations, the ExoMars Rover's payload also includes a Ground Penetrating Radar (GPR): WISDOM. In this paper we describe the data processing pipeline we have developed in order to analyze WISDOM electromagnetic soundings and the results and lessons learnt from a recent simulation operation field campaign in Chile (ExoFit 2019, Feb-March 2019).

WISDOM: WISDOM (Water Ice and Subsurface Deposit Observations on Mars) is a polarimetric step-frequency GPR operating between 500 MHz and 3 GHz. Its main objective is to characterize the subsurface below the ExoMars Rover by non-destructive electromagnetic soundings [1] [2]. WISDOM will provide high-resolution (a few cm) observations of the subsurface structure and stratigraphy down to a few meters' depth. It will also help selecting optimal sites for drilling and ensuring the drilling operations safety by identifying potential buried hazards.

On Mars, WISDOM will perform subsurface soundings at various locations along the Rover track, typically every 50 cm along a several meter-long transverse. A sounding consists in transmitting electromagnetic waves into the subsurface and measuring the signal that returns to the radar. WISDOM main products will be radargrams (see Fig. 1B) i.e., images showing the amplitude of the signals reflected by permittivity contrasts in the sounded volume as a function of the propagation delay (ultimately converted into depth from the measured delay and the knowledge of the mean subsurface permittivity value) on the vertical axis and the sounding location on the horizontal axis. WISDOM radargrams will open the third dimension of Mars shedding light on the geological structures buried in its shallow subsurface.

WISDOM data processing pipeline: One of the objectives of WISDOM is to detect potential buried hazards that might jeopardize drilling activities. The greatest concern is the presence of buried rocks that could damage the drill. After each sounding sequence on Mars, the WISDOM team will have a limited time (less than one hour) to analyze the subsurface configuration, and detect and localize potential buried scatterers which signature on radargrams are hyperboles. The data processing pipeline has to be fast and reliable to meet the strict time constraints imposed by ESA. We have therefore focused our effort on the development of algorithms as automatic as possible. In particular, we have developed automatic tools for the detection of hyperbolic signatures in the radargram and the derivation of the ground permittivity from the amplitude of the surface echo. This later must indeed be known in order to convert times of arrival of echoes into distances and thus to estimate the depth of the detected buried structures. The data processing pipeline also includes corrections aiming at removing the parasitic signals of various origins (temperature variations, electronic coupling, antenna crosstalk, multiple surface echoes, ect.) that affect the interpretation of WISDOM radargrams. These corrections rely on a careful and accurate characterization of the different versions of the instrument (prototype, spare model, flight model) that will be described in [3].

The ExoFit 2019 field campaign in Chile: Once validated on synthetic data, WISDOM signal processing pipeline is tested on experimental data acquired either in a semi-controlled environment (e.g., a "Mars yard" built at LATMOS, Guyancourt) or during field surveys on potential Martian analogs. In particular, WISDOM took part in 3 operation simulation campaigns during which several instruments of the ExoMars Rover were operated from a remote control center to test and improve the efficiency of the data processing pipeline, decision-making process and operation planning under conditions similar to those expected during the ExoMars mission [4] [5] [2]. During the latest of these simulation operation field trials, ExoFit 2019 [6], a flight-like version fully representative of the WISDOM flight model was mounted on a rover in the Atacama Desert in Chile (Fig. 1A) and controlled from the European Centre for

Space Applications and Telecommunications (ECSAT) in Harwell, UK. Several WISDOM profiles with various configurations were then acquired. Fig. 1B shows an example of radargram acquired along a 8m-long profile with 10 cm-spaced soundings during ExoFit 2019. This radargram displays small structures having horizontal extension around 1 meter (in green) and reveals the presence of numerous small (~10 cm) rocks easily recognized by their hyperbolic signatures (a few are highlighted in red). However, no clear interface is visible. Fig. 1C shows (bottom) the permittivity values retrieved from the surface echo amplitude for each sounding location for the 2 co-polarizations (00 and 11) and (top) the two corresponding histograms. The retrieved values are around 3, which is the order of magnitude of what is expected for dry sand. Considering, as a first estimate, that the permittivity is uniform in the subsurface, its value can be used to convert the measured delays into depth as done in Fig. 1B. Other results from the ExoFit 2019 campaign will be shown and commented in terms of lessons learnt in order to optimize the scientific return of the WISDOM experiment on Mars.

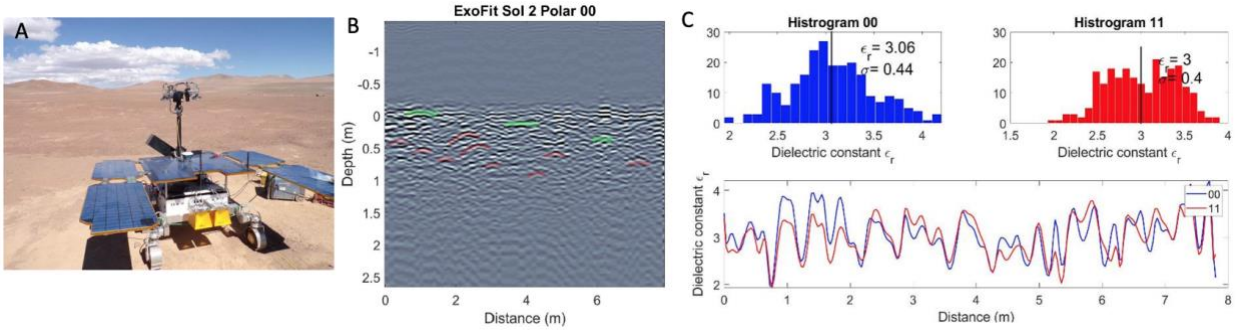

Figure 1: A) Charlie Rover (a replica of the ExoMars Rover) in the Atacama desert (Chile) during the ExoFit 2019 simulation operation campaign (Feb.-March 2019). The antennas of WISDOM are yellow in the first plan. **B)** Radargram showing the data acquired during Sol 2 of the ExoFit 2019 campaign in polarization 00. **C)** Permittivity values estimated from the surface echo amplitude along the Sol 2 traverse both in polarizations 00 and 11.

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Acknowledgment: The WISDOM development has been supported by the CNES French agency and DLR German agency.