NUMERICAL SIMULATIONS OF THE SURFACE AND SUBSURFACE TEMPERATURES OF OXIA PLANUM, LANDING SITE OF EXOMARS 2022 MISSION

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Abstract: In this work we performed numerical simulations in order to investigate the surface and shallow subsurface temperature of Oxia Planum, the landing site of the mission ExoMars 2022 [1]. In particular we explored: I) the dependence of the temperature on the thermal inertia of the landing site; II) the contribution of the heat released by the drilling operations; III) the lifetime of the subsurface ices.

Introduction: Oxia Planum, the landing site selected for the mission ExoMars 2022, has a high potential for past habitability and exhibits evidence of sub aqueous episodes [2, 3, 4]. ExoMars rover is equipped with a drill able to investigate the shallow subsurface up two meters while the Mars Multispectral Imager for Subsurface (Ma_Miss) embedded in the drill system will analyze the borehole generated by the drill, providing information about the mineralogy, oxidation state and hydration state of the sample before the extraction [5, 6]. Numerical simulations carried out in this work will support the characterization and mapping of volatiles likely present in the subsurface of Oxia Planum.

Numerical method: We developed a numerical code [7] based on the models described e.g. in [8, 9]. The numerical technique is the finite element method (FEM): the code solves the classical heat equation in a small domain representing a portion of Oxia Planum (see Fig.1), compatible with the hole produced by the drilling operations. The top of the domain, representing the Martian surface, is modeled as a Gaussian random surface in order to take into account the roughness of the surface. A radiation boundary condition is imposed at the surface, while on the other sides, a zero heat flux is imposed as boundary condition. The initial temperature is set at 200 K, compatible with the surface equilibrium temperature (see [7] for the others thermophysical parameters adopted in these simulations).

I) We developed three different scenarios, characterized by different thermal inertia (see Tab.1). We explored the aphelion case, since the landing time is currently planned for June 2023, when Mars is very close to its aphelion.

II) The heat released by the drilling operations is evaluated by considering a constant flux on the sides of the borehole in contact with the subsurface. This flux depends in particular on the frictional coefficient, on the

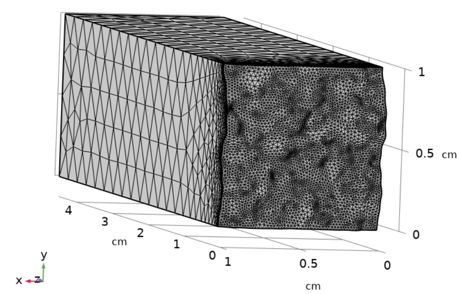

Figure 1: Domain of integration for the part I) of this work: zoom of the first 5 cm from the Oxia Planum surface. A radiation boundary condition is imposed at the top (x-y plane) while zero flux is applied on the other sides. Figure from [7].

Model A (I = 160 TIU)		
Density	1700 kgm^{-3}	[10]
Thermal Conductivity	0.018 $Wm^{-1}K^{-1}$	[11]
Model B (I = 255 TIU)		
Density	1700 kgm^{-3}	[10]
Thermal Conductivity	0.048 $Wm^{-1}K^{-1}$	[11]
Model C (I = 650 TIU)		
Density	2700 kgm^{-3}	[12]
Thermal Conductivity	0.2 $Wm^{-1}K^{-1}$	[7]

Table 1: Model A and B are characterized by a composition similar to high porous sedimentary rocks, while Model C is compatible with a composition clay dominant (e.g. vermiculite). Table adapted from Formisano et al. [7].

rotational velocity of the drill and on the vertical thrust. We explored two different frictional coefficient (0.3 and 0.9) and two rotation for minutes (rpm): 30 and 60. The drilling window adopted in this work is characterized by the first 30 minutes in ”on mode”, followed by 30 minutes in ”off mode” and finally other 30 minutes in ”on mode”. III) Lifetime of the subsurface ices is computed by the classical formula [13] which links the rate of sublimation of ice with the temperature and saturation pressure.

Summary and Conclusions: In Fig.2 we report an example of results in the case of Model A: the surface temperature ranges between 175 K and 265 K. At depths greater than 20 cm the solar input becomes negligible [7]. Our simulations also suggest that the thermal environment of Oxia Planum can be strongly influenced by the drilling operations with possibly losses of volatile species. In fact, the increase in temperature could be (in the hottest case explored, i.e. rpm = 60 and friction coefficient close to 1) up to 120 K. Since some assumptions are made (i.e. instantaneous drilling, constant flux applied along the borehole and constant thrust and rotational velocity) our results can be considered as an "upper limit scenario". In the case of the presence of a icy spherical deposit, with a radius compatible with the radius of the borehole, the model indicates that only in the coldest case explored (rpm = 30 and friction coefficient = 0.3) a significant quantity of ice (about 60%) is maintained.

In Fig.3 we report the sublimation rate calculated through the top of the cylinder representing the borehole.

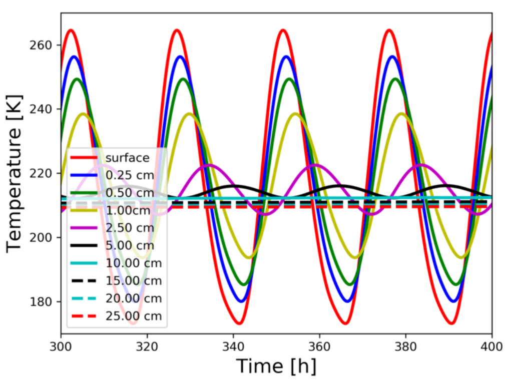

Figure 2: Model A: Temperature profiles at different depths from the surface. Figure taken from [7].

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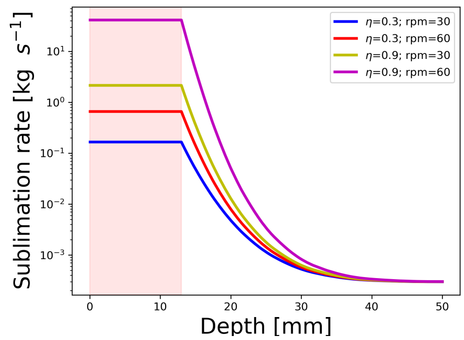

Figure 3: Sublimation rate calculated through one basis of the cylinder representing the borehole. Figure taken from [7].

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