THERMOPHYSICAL MODELING OF OXIA PLANUM, LANDING SITE OF EXOMARS 2022

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Abstract: Oxia planum is the site (18°N) selected for the landing of the ExoMars 2022 rover [1]. This site exhibits signatures of a past existence of liquid water [1] and in this regard it is useful to characterize the site from a thermophysical point of view, evaluating for example the lifetime of possible species. The numerical simulations that we carried out concern: I) the influence of the thermal inertia on the (sub)surface temperature; II) the heat released in the subsurface by the drill installed on the ExoMars rover.

Introduction: We applied a numerical model (e.g. [2, 3]) in order to characterize from a thermophysical point of view the surface/subsurface of the landing site of the mission ExoMars 2022. ExoMars 2022 rover is equipped with a drill able to excavate up two meters in the subsurface of Mars. The spectrometer Ma_MISS (Mars Multispectral Imager for Subsurface) [4] will investigate the lateral wall of the borehole generated by the drill, providing hyperspectral images. The characterization and the mapping of volatiles is one of the scientific aims of Ma_MISS and in this regard a numerical modeling of the (sub)surface is required to establish if the temperatures are such to preserve volatiles, especially after the heating provided by the drilling activity.

Numerical method: We applied a 3-D numerical model (e.g. [2, 3]) based on the technique of the finite element method (FEM), which solves the classical heat equation in a parallelpipedal domain representing a small portion of Oxia Planum compatible with the hole produced by the drilling activity. The size of the domain is 1cmx1cmx5cm: the depth (5 cm) is compatible with the skin depth. The top of the domain is modeled as a Gaussian random surface in order to take into account the roughness of the surface. At the top of this domain we imposed a radiation boundary condition while on the other sides a zero heat flux is imposed. The starting temperature of our domain is set at 200 K, a value compatible with the surface equilibrium temperature of Mars at the latitude of Oxia Planum. The numerical model takes into account also the so-called self-heating, i.e. the indirect light between the facets of the domain (e.g.[5]). We investigated: I) the thermal response of the (sub)surface to different thermal inertia values; II) the heat released by the drill in the subsurface. In particular, for point II, we assume that thrust and rotational velocity are constant and that the drilling is instantaneous. We assume that drill operates in the following way: "on" in the first 30 minutes of simulations, followed by 30 minutes in "off" mode and after all other 30 minutes in "on" mode. The heat released by the drill is taken into account by applying an heat flux on the sides in contact with the drill: this flux depends on the thrust, angular velocity and coefficient of friction (η). This boundary condition overrides the zero heat flux condition assumed for the point I.

Summary and Conclusions: We report in Fig.1 an example of results obtained with our numerical modeling. In Fig.1 we report the temperature vs time profile, at different depths, in case of (A) thermal conductivity (K) equal to 0.045 W m^{-1} K^{-1} (compatible with the Insight estimation Spohn et al. [6]) and (B) thermal conductivity an order of magnitude smaller than case (A). Case (A) is characterized by a thermal inertia of 270 TIU (Thermal Inertia Units) and a skin depth of 3 cm, while case (B) by a thermal inertia of 85 TIU and a skin depth $<$ 1 cm. Our numerical results suggest that in case of "high" thermal inertia (A), the temperature ranges from 180 K to 270 K, while in case of "low" thermal inertia (B), the surface temperature ranges from 140 K to 280 K. Self-heating can increase surface temperature of about 10 K.

Regarding the heat released by the drill, we show some results in Fig.2. In Fig.2 we show the increase in temperature due to the heat released by the drill: in the x-axis is plotted the distance from the hole in the direction perpendicular to the drilling direction. We analyzed four cases: rpm (rotation per minute) equal to 30 and 60 and coefficient of friction equal to 0.5 and 0.9. We observe that the heat provided by the drilling activity can produce an increase in temperature at most of 100 K. The results obtained by this numerical modeling offer a complete picture of the (sub)surface of the Oxia Planum: future simulations with different physical parameters will be carried out.

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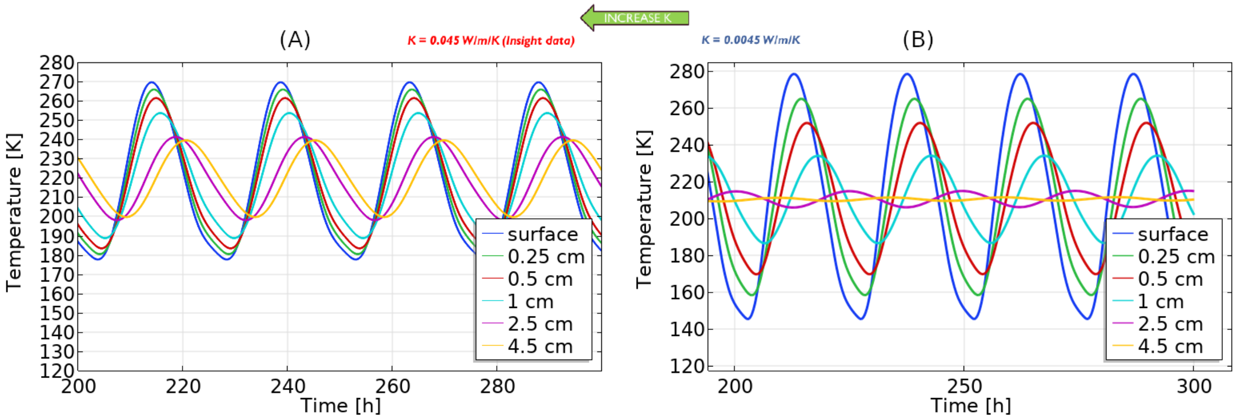

Figure 1: Temperature profile vs time at different depths: case (A) with K = 0.045 W m^{-1} K^{-1}; case (B) with K = 0.0045 W m^{-1} K^{-1}.

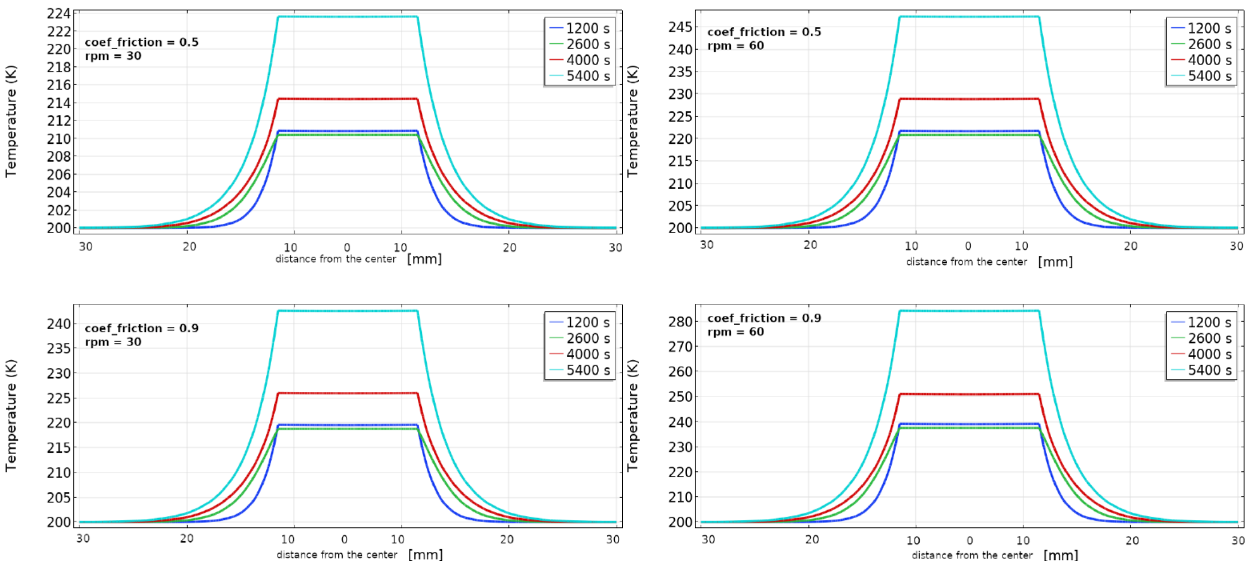

Figure 2: From top left to bottom right: rpm=30 and η=0.5; rpm=60 and $\eta = 0.5$; rpm=60 and $\eta = 0.9$; rpm=60 and $\eta = 0.9$.

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