Thermal stability of water ice on Ceres' surface: the Juling case.

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Introduction

Significant amounts of water ice have recently discovered on the dwarf planet Ceres at the local scale by the Visible Infrared mapping spectrometer (VIR) onboard Dawn, e.g. in Oxo and Juling craters [6,7,11]. These craters are located at about 40°-N and 36°-S, respectively.

The evaluation of the ice stability on the surface of Ceres is crucial to establish the mechanism that exposes the ice as well as putting constrains on the physical mechanisms of its emission. In literature, we can find several suggestions for the observed OH and H_2O fluxes come from Ceres [9]: cryovolcanism [10], cometary-type emission [1], impacts with other bodies. In particular, the stability of ice (with a rough topography) was already addressed by [5]. In this work, however, we adopt the real topography, based on the shape model of asteroid Ceres [12].

For this purpose, we developed numerical model, combining the heat and the water ice diffusion equations.

We performed several numerical simulations in order to study the effects of the thermal inertia and albedo on surface temperature and on the ice sublimation rate. Here we present some preliminary results obtained on crater Juling.

Numerical Model

Our numerical model is based on a 3D finite element method (FEM). We solve the classical heat equation with the source term represented by the solar input (see for example [2,3,4] and also Fig. 1). Self-heating is also included.

Ice diffusion is treated by using a mass conservation equation, where the diffusion coefficient is calculated according to the kinetic theory of gases.

We assume that the water vapor acts as a perfect gas and the local thermodynamic equilibrium is valid.

We use a shape model based on the images acquired by the Framing Camera in the Survey mission phase [12].

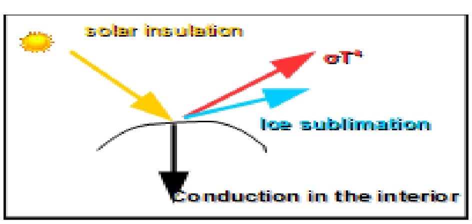

Figure 1. How solar energy "is used" by the surface of the crater.

On the surface, a radiation boundary condition is imposed. Thermal insulation is also imposed on each sides of the 3D object, representing the Juling crater, we modeled (see Fig.2). The initial temperature is fixed to 163 K, i.e. the equilibrium surface temperature (assuming a solar constant of 1330 W m^{-2} and an emissivity of 0.9). We analyzed only the surface and sub-surface region, since the skin depth is of the order of the cm.

The surface is characterized by a icy region of about 25 km^2 on the northern wall of the crater. In our simulations, we set the percentage of ice in such region at 1

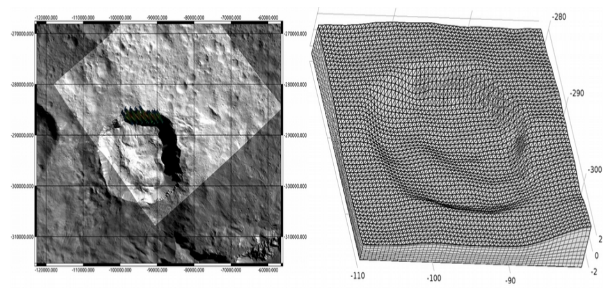

Figure 2. Juling map (on the left) and its 3D reconstruction (on the right).

vol.%. The composition of the remaining part of the crater is simulated with the typical thermal parameters of the regolith [8].

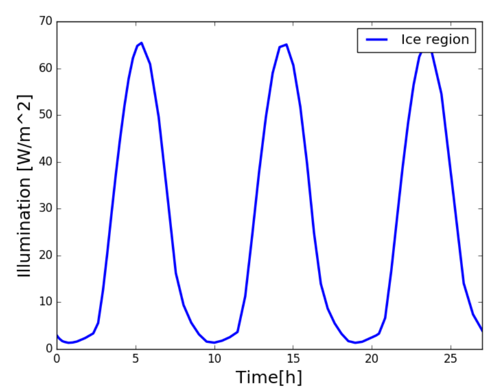

Figure 3. Illumination of the icy region.

To explore how the temperature, and consequently the ice sublimation rate, are affected by the the solar input, we tested different heliocentric distance: 2.98 AU (aphelion), 2.56 AU (perihelion) and 2.90 AU. We also tested different values of thermal inertia. In Fig. 3 we show a typical profile of diurnal insulation at perihelion.

Preliminary Results:
Our results show that the thermal inertia is the major parameter driving the lifetime of the ice. At perihelion, values of thermal inertia of about 50 in SI units provide to an ice loss of a fraction of mm (about 0.5) per orbit (4.6 Earth year) and to a mean temperature in the icy region of about 150 K. At aphelion, the rate is of about 0.1 mm per orbit, while the mean temperature (in icy region) is about 10 K lower than the value at perihelion distance. In Fig.4 we display a typical profile of the surface temperature as a function of local solar time in the ice-rich region.

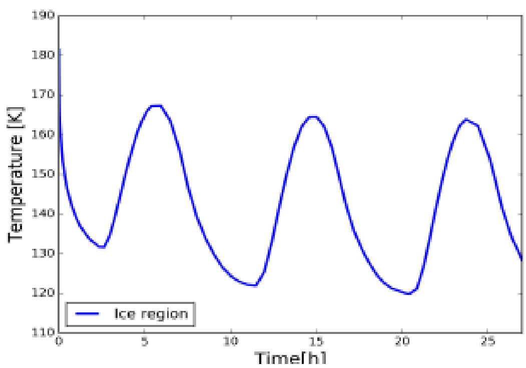

Figure 4. Surface temperature vs time, in the icy region, for thermal inertia of 50 [SI] at perihelion.

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