Thermophysics of Airless Icy Surfaces to Probe Their Vertical Structure

C. Ferrari and A. Lucas

Institut de Physique du Globe de Paris - Sorbonne Paris Cité, Université Paris Diderot, UMR CNRS, Paris, France
E-mail: ferrari@ipgp.fr

The thermophysics of icy planetary surfaces has regained lot of interest in the last 20 years with the collection of a huge amount of new thermal data. As the absorption of water ice changes from near-infrared wavelengths to microwaves and icy bodies rotate at different rates, various depths can be probed with multi-modal observations of their thermal cycles. The order of magnitude of their thermal inertia depends on the thermal conductivity, both by conduction or radiation, on the ice phase, the grain sizes or on the porosity of the icy regolith. Put together, new measurements on thermal inertias and thermal models can provide new insights into the properties of icy surfaces and the thermal processes at play.

Recently, [1] have proposed a thermophysical model for icy regoliths which estimates the thermal inertia from their microstructural properties such as grain size, porosity, ice phase (crystalline/amorphous), Bond albedo or the quality of contacts, either tight for elastic smooth spheres or loose for rough grains. They introduced in the heat transfer a radiative component, which had been often neglected because of low temperatures beyond Jupiter. But for grains larger than a mm or so, the radiative conductivity can be comparable or larger than the conduction through the solid phase. This is all the truer if contacts between grains are loose or if the ice is in its amorphous phase.

As reviewed by [2], new thermal maps, diurnal thermal cycles, eclipse events, or the thermal anomalies which have been observed on icy regoliths in the solar system provide new insights in understanding surfaces processes competing in various planetary environments. Thermal inertias are very small. These low values are usually interpreted as due to highly porous unconsolidated regoliths. [1] demonstrated that the decrease of thermal inertias with heliocentric distance can easily be reproduced if contacts between grains of crystalline ice are loose and grain size greater than 1 mm or if the ice is amorphous. The heliocentric decrease of thermal inertia is in this case easily reproduced for any porosity between 30 and 80 % or Bond albedo. A large porosity is no more needed. The low thermal inertias measured might therefore originate from the presence of amorphous ice in the near-subsurface.

Figure 1 shows how the observed thermal inertias of airless icy regoliths vary with thermal skin depth. Assuming this curve is representative of water ice regoliths in the solar system, we investigate with our model ([1]), its dependency to the vertical profile of porosity $p(z)=p_{min}+(p_{max}-p_{min})e^{-z/d_p}$, the grain size r_0, the ice phase (crystalline or amorphous) or the type of contacts (tight or loose). Sensitivity analysis shows that this vertical profile is mainly sensitive to r_0, and minimum and maximum porosities at depth and surface, p_{min} and p_{max} respectively, given Bond albedos, heliocentric distances and physical constants of the targetted celestial bodies. The relative importance of the parameters varies slightly with the phase of ice and much less on the type of contacts and the model used to model the radiative conductivity. Results of a bayesian inversion will be performed to tentatively derive average properties of icy regoliths and will be presented.

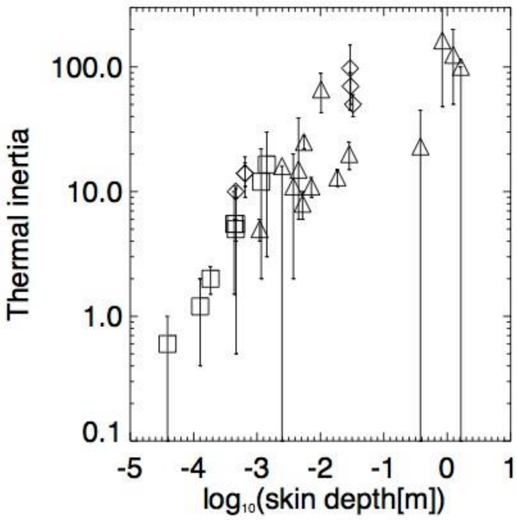

Figure 1- Thermal inertias vs thermal skin depth for water icy regoliths. (◊) Galilean satellites, (△) Saturn moons, (□) Centaurs and TNOs. The unit of thermal inertia is $J/K/m^2/s^{1/2}$.

References:

[1] Ferrari, C. and A. Lucas (2016) *A&A*, **588**, A133.
[2] Ferrari, C. (2018) *Space Science Rev.*, **214**, 111.