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Thermal convection regimes in asteroid (1) Ceres

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Abstract

Ceres is a "transition body" of the Main Asteroid Belt since it shows some features of the icy satellites of the outer solar system and other peculiarities of the rocky bodies of the inner region. Its surface exhibits evidences of ammoniated phyllosilicates [1] and of water ice [2], for example in craters as Oxo [4][5] or Occator [3]. Probably it formed in an outer (and icy) region of the solar system and then migrated in the current position. The value of the normalized moment of inertia, 0.37 [7], suggests that Ceres is partially differentiated: theoretical models (e.g.[9]) propose a structure made of a rocky core (of about 350 km) and an icy mantle of about 100 km, since the mean density is around 2000 kg m^{-3} [7]. The presence of a heavier crust than the mantle have been hypothesized by [6], in which it was studied the possible overturn of the crust, the energy released by this process and the consequent chemical reprocessing of the crust itself. The crust can also undergo thermal and mechanical stresses due to the presence of active convective cells in the interior layers, which can cause the break or the uplift of the crust. Ahuna mons could be, in this sense, a "product" of the thermal convection in deep interiors [8]. It is an isolated mountain, about 4.5 km high, localized at 10.4° S 316.2° E.

In this work, by using a 2D numerical code based on a finite element method (www.comsol.com) we solve the Navier-Stokes equation coupled with the thermal equation and varying the composition of the convective cell we can study the different thermal convection regimes and their physical consequences.

1. The Model

We numerically solve the Navier-Stokes equations coupled with the thermal equation with the assumption that the density variation is important only in the term of the buoyancy (*Boussinesq approximation*). Neglecting the inertial term, since the Prandtl number is very high in our context, we can write the Navier-Stokes equation as:

$$\rho\frac{\partial\vec{u}}{\partial t} = \vec{\nabla}\cdot\left[-p\vec{I} + \mu\left(\vec{\nabla}u + \left(\vec{\nabla}u\right)^{T}\right)\right] + F, \quad (1)$$

where F is the bouyancy term that represents the "link" with the heat equation:

$$\rho c_p\frac{\partial T}{\partial t} + \rho c_p\vec{u}\cdot\vec{\nabla}T + K\vec{\nabla}\cdot\vec{\nabla}T = 0. \quad (2)$$

In the above equations u is the convective velocity. We fixed temperature at the bottom (hot) and at the top (cold) of the mantle, with a drop in temperature of 200 K, based on the results of the models found in literature (e.g.[9]). The convective cell (the mantle) is assumed to be 100 km in size. No slip conditions is imposed on all boundaries: this condition requires that the velocity of the fluid tends to zero at wall-fluid interface. All the equations are in the dimensionless form. The mantle is supposed to be made of a mixture of ice and rock.

2 Discussion and Preliminary Results

In Fig.1 we report some preliminary results obtained with our numerical simulations. In the left panel (A) we report the results in the case of 90% of ice and 10% of rock, in the middle panel (B) it is shown a case of pure ice mantle and in the right one (C) the composition is 70% of rock and 30% of ice.

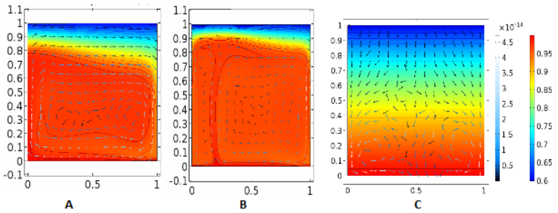

Figure 1: (A) 90% rock & 10% ice; (B) pure ice mantle; (C) 70% rock & 30% ice.

Case A is characterized by a Rayleigh number of the order of 10^7 that lead to a "classical" convective cell, with an isothermal profile and a viscous top layer, identifiable with the crust, of the order of few kilometers. This crust can undergo the thermal/mechanical effects of the convection and eventually break or bulge, depends on the assumed physical parameters. If the composition is pure ice (case B) the Rayleigh number increase of an order of magnitude and in this case we observe the formation of a channel in which material (ice?) from the inside can be expelled to the outside. In case of an important volume percentage of rock (30%), the Rayleigh number (10^5) is not sufficient to trigger the thermal convection.

Acknowledgments

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References

[1] De Sanctis, M.C., et al. 2015, Nature, 528, 241

[2] Schmidt, B.E.,et al. 2017, Nature Geoscience, 10, 338–343

[3] Nathues, A., et al. 2015, Nature 528, 237–240

[4] Raponi, A., et al. 2017, Lunar and Planetary Science XLVIII (2017)

[5] Combe, J.-P. et al. 2016, Science 353.

[6] Formisano, M., et al., 2016, MNRAS, 463, 1, 520-528

[7] Park, R.S. et al. 2016, Nature, 537, 515-517

[8] Sori, M.M., et al., 2017, Geophysical Research Letters, 44, 3, 1243-1250

[9] Neveu, M. and Desch, S.J., 2015, Geophysical Research Letters, 42, 23, 197–10