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Impact of tidal heating on the onset of convection in Enceladus' ice shell

Marie Behounkova (1), Gabriel Tobie (2,3), Gael Choblet (2,3), and Ondrej Cadek (1)

(1) Charles University, Department of Geophysics, Prague, Czech Republic (behounek@karel.troja.mff.cuni.cz), (2) Universite de Nantes, LPGNantes, UMR 6112, F-44322 Nantes, France, (3) CNRS, LPGNantes, UMR 6112, F-44322 Nantes, France

Observations of Enceladus by the Cassini spacecraft indicated that its south pole is very active, with jets of water vapor and ice emanating from warm tectonic ridges. Convective processes in the ice shell are commonly advocated to explain the enhanced activity at the south pole. The conditions under which convection may occur on Enceladus are, however, still puzzling. According to the estimation of Barr and McKinnon (2007) based on scaling laws, convection may initiate in Enceladus' ice shell only for grain size smaller than 0.3 mm, which is very small compared to the grain size observed on Earth in polar ice sheets for similar temperature and stress conditions (2-4mm). Moreover, Běhounková et al. (2012) showed that such enhanced activity periods associated with thermal convection and internal melting should be brief ($\sim 1-10\mathrm{Myrs}$) and should be followed by relatively long periods of inactivity ($\sim 100\mathrm{Myrs}$), with a probable cessation of thermal convection. In order to constrain the likelihood and periodicity of enhanced activity periods, the conditions under which thermal convection may restart are needed to be investigated. In particular, the goal is to understand how tidal heating, especially during periods of elevated eccentricity, may influence the onset of convection. To answer this question, 3D simulations of thermal convection including a self-consistent computation of tidal dissipation using the code Antigone (Běhounková et al., 2010, 2012) were performed, a composite non-Newtonian rheology (Goldsby and Kohlstedt, 2001) and Maxwell-like rheology mimicking Andrade model were considered. Our simulations show that the onset of convection may occur in Enceladus' ice shell only for ice grain size smaller or equal than 0.5 mm in absence of tidal heating. Tidal dissipation shifts the critical grain size for convection up to values of 1-1.5 mm. The convection is initiated in the polar region due to enhanced tidal dissipation in this area and remains in the southern hemisphere as long as the ocean width is smaller than $\Delta < 240^{\circ}$. Furthermore, we show that the onset of convection is associated with internal melting for tidal heating rate larger than $\sim 0.5-1\cdot 10^{-6}\mathrm{Wm}^{-3}$ and that increasing the heating rate above $10^{-6}\mathrm{Wm}^{-3}$ does not influence anymore the critical grain size for the initiation of convection.