Numerical simulations of solid-state convection within Ganymede's ice shell in a 2-dimensional cylindrical geometry

Katherine Villavicencio Valero[1]

[1]International Research School of Planetary Sciences

November 22, 2022

Abstract

Solid state convection is expected to influence the evolution and the geological activity of Ganymede [1]. The spatial distribution of tidal dissipation could influence the temperature structure of the outer ice shell and, likely, the internal processes and the geological activity. We investigate the influence of the tidal dissipation on a convective ice shell of Ganymede. We use the finite-element code ASPECT [2] to solve the Boussinesq fluid equations of the conservation of continuity, momentum and energy to simulate solid-state convection within the ice shell of Ganymede. The numerical simulations are performed in a 2-dimensional cylindrical geometry. We adopt a temperature-dependent Newtonian viscosity for the water ice, assuming diffusion creep. The spatial distribution of the tidal dissipation rate is computed adopting a Maxwellian material model [3, 4]. Preliminary results show how the convective patterns, and the thermal plumes are influenced by the spatial distribution of the tidal dissipation. We also discuss how radar sounder investigations with RIME instrument [5] on board of the ESA's JUICE mission in combination with radio science measurements of the gravity field by 3GM experiment [6] could characterize the thermal structure of Ganymede's ice shell.

Numerical simulations of solid-state convection within Ganymede's ice shell in a 2-dimensional cylindrical geometry

Katherine Villavicencio[1,2], Giuseppe Mitri[1,2]

(1) International Research School of Planetary Sciences, Pescara, Italy

(2) Dipartimento di Ingegneria e Geologia, Università d'Annunzio, Pescara, Italy

*e-mail: katherine.villavicencio@unich.it

Solid state convection is expected to influence the evolution and the geological activity of Ganymede [1]. The spatial distribution of tidal dissipation could influence the temperature structure of the outer ice shell and, likely, the internal processes and the geological activity. We investigate the influence of the tidal dissipation on a convective ice shell of Ganymede. We use the finite-element code ASPECT [2] to solve the Boussinesq fluid equations of the conservation of continuity, momentum and energy to simulate solid-state convection within the ice shell of Ganymede. The numerical simulations are performed in a 2-dimensional cylindrical geometry. We adopt a temperature-dependent Newtonian viscosity for the water ice, assuming diffusion creep. The spatial distribution of the tidal dissipation rate is computed adopting a Maxwellian material model [3, 4]. Preliminary results show how the convective patterns, and the thermal plumes are influenced by the spatial distribution of the tidal dissipation. We also discuss how radar sounder investigations with RIME instrument [5] on board of the ESA's JUICE mission in combination with radio science measurements of the gravity field by 3GM experiment [6] could characterize the thermal structure of Ganymede's ice shell.

Acknowledgements

~~Katherine Villavicencio~~KV and ~~Giuseppe Mitri~~GM acknowledge support from the Italian Space Agency (contract ASI/2018-25-HH.0).

References

[1] Pappalardo et al., 2004. Geology of Ganymede. In Banegal et al. (Eds), Jupiter (pp- 363-369). Cambridge, UK: Cambridge University Press

[2] Bangerth et al., 2018. ASPECT v2.0.0 [software], doi: 10.5281/zenodo.1244587

[3] Mitri & Showman, 2008. A model for the temperature-dependence of tidal dissipation in convective plumes on icy satellites: Implications for Europa and Enceladus. Icarus 195, 758-764

[4] Han et al., 2012. The impact of a weak south pole on thermal convection in Enceladus' ice shell. Icarus 218, 320-330.

[5] Bruzzone et al., 2015. Jupiter ICY moon explorer (JUICE): Advances in the design of the radar for Icy Moons (RIME). International Geoscience and Remote Sensing Symposium (IGARSS), 7326002, 1257-1260.

[6] De Marchi et al. 2021. Observability of Ganymede's gravity anomalies related to surface features by the 3GM experiment onboard European Space Agency (ESA) JUpiter ICy moons Explorer (JUICE) mission. Icarus 354, 114003.