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Dynamics of the global meridional ice flow of Europa's icy shell

Yosef Ashkenazy (1), Roiy Sayag (1) and Eli Tziperman (2)
(1) Solar Energy and Environmental Physics, Ben-Gurion University of the Negev, Israel (ashkena@bgu.ac.il), (2) Earth and Planetary Sciences and School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA

Abstract

Europa is one of the most probable places in the solar system to find extra-terrestrial life, motivating the study of its deep (~ 100 km) ocean and thick icy shell. The chaotic terrain patterns on Europa's surface have been associated with vertical convective motions within the ice. Horizontal gradients of ice thickness are expected due to the large equator-to-pole gradient of surface temperature and can drive a global horizontal ice flow, yet such a flow and its observable implications have not been studied. We present a global ice flow model for Europa composed of warm, soft ice flowing beneath a cold brittle rigid ice crust. The model is coupled to an underlying (diffusive) ocean and includes the effect of tidal heating and convection within the ice. We show that Europa's ice can flow meridionally due to pressure gradients associated with equator-to-pole ice thickness differences, which can be up to a few km and can be reduced both by ice flow and due to ocean heat transport. The ice thickness and meridional flow direction depend on whether the ice convects or not; multiple (convecting and non-convecting) equilibria are found. Measurements of the ice thickness and surface temperature from future Europa missions can be used with our model to deduce whether Europa's icy shell convects and to constrain the effectiveness of ocean heat transport.