Geophysical Research Abstracts
Vol. 17, EGU2015-8484, 2015
EGU General Assembly 2015

Constraints on the thermal state of Io from electromagnetic induction

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Theoretical models of tidal dissipation in Io's interior have provided support for a global melt layer in the interior of Io. The extremely high temperature of the lava erupting on Io's surface also hint at an extremely hot interior consistent with an internal magma ocean.

Using Jupiter's rotating magnetic field as a sounding signal, Khurana et al. (2011) provided evidence of a strong dipolar electromagnetic induction signature in Galileo's magnetometer data from four different flybys. They further showed that the signal is consistent with electromagnetic induction from large amounts of rock-melts in the asthenosphere of Io. Modeling of this signature showed that the induction response from a completely solid mantle model is inadequate to explain the magnetometer observations. However, they found that a layer of asthenosphere > 50 km in thickness with a rock melt fraction $\geq 20\%$ is adequate to accurately model the observed magnetic field.

In this presentation, we will provide a progress report on our effort to further enhance the understanding of Io's interior, especially its magma ocean, and internal temperature profile by marrying the principles of thermodynamics with those of electromagnetism. In particular, we are obtaining guidance on stable mineral phases and their physical properties (such as density, melt state and electrical conductivity) from thermodynamic principles whereas how the resulting internal conductivity profile affects the magnetic environment around Io is being determined from electromagnetism. The constraints on the mineralogy, temperature and melt state of Io are being obtained from MELTS a modeling program that utilizes thermodynamic principles to calculate the chemical variations in the assemblages of minerals and melts as a function of pressure, temperature and oxygen fugacity. By using appropriate mixing laws, we plan to compute conductivity profiles of these mineral and melt assemblages by utilizing conductivity data for olivines and orthopyroxenes. Electromagnetic induction responses is calculated by solving the induction equation numerically for several different models of the interior and tested for their agreement with the Galileo magnetometer data. The magnetic field perturbation resulting from Io's interaction with Jupiter's magnetosphere will be estimated using fully self-consistent 3-d MHD simulations.