CONVECTIVE HEAT TRANSFER IN EUROPA'S OCEAN AND THE FORMATION OF CHAOS TERRAIN. K. M. Soderlund[1] , B. E. Schmidt[1], and D. D. Blankenship[1], [1]University of Texas John A. and Katherine G. Jackson School of Geosciences, Institute for Geophysics (UTIG), J.J. Pickle Research Campus, Bldg. 196; 10100 Burnet Road (R2200), Austin TX 78758-4445, USA. (krista@ig.utexas.edu).

Introduction: Europa, Jupiter's innermost satellite, has long been considered to harbor significant astrobiology potential since it maintains a liquid water ocean beneath its icy outer shell [1-2]. Large bodies of liquid water have recently been hypothesized to exist in the shallow sub-surface as well [3]. Evidence of this water is given by the presence of chaos terrain, characterized by rafts of ice that protrude above matrix material, which covers at least one quarter of the satellite's surface and tends to be concentrated at low latitudes [4-9]. These structures may be the result of a thermal plume rising through the ice shell, consequent pressure-induced melting to form a liquid water lens, hydrofracture of the overlying ice, and refreezing of the lens and matrix [3]. This mechanism then requires the presence of an ascending plume.

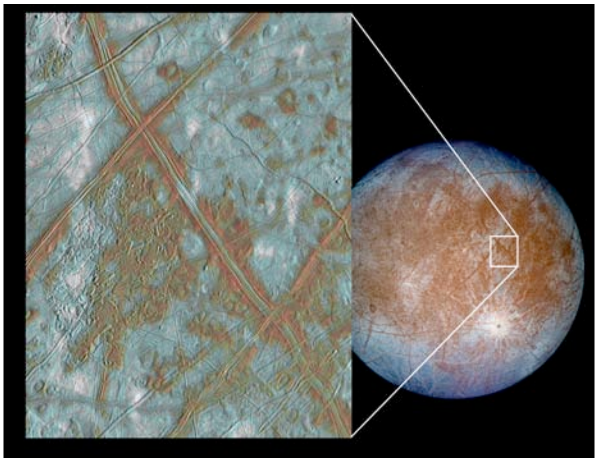

Figure 1: False-color image of Europa taken by the Galileo spacecraft. Blue indicates relatively pure ice, while brown indicates impurity-rich material. The left panel shows the Conamara Chaos region, exemplified by ice rafts surrounded by matrix material. The right panel shows that impurities tend to be concentrated at low latitudes. Image courtesy of NASA/JPL/University of Arizona.

The underlying ocean must be critical for generating the diapir required for this lens-collapse model [9-11]. Tidal dissipation and radiogenic heating are argued to be substantial enough to keep the ocean in liquid phase and to drive fluid motions [11]. In this study, we test the hypothesis that chaos terrain tends to occur in the equatorial region because convectively-driven ocean circulations preferentially emit heat near the equator. Such ocean-driven heat exchange from the interior of the moon to the base of the ice shell is important because it will increase the equatorial ocean temperature and influence the pattern of ice melt and accretion at the base of the shell. These factors may not only reduce the ice shell thickness at low latitudes through melting [13-14], but also enhance the likelihood that an ice diapir will be generated at the base of the ice shell depending on the stability and heterogeneity of the heat flux.

Convective Heat Transfer: Convection is able to efficiency redistribute heat in planetary bodies through fluid motions. Rotating convection experiments have shown that heat transfer patterns critically depend on the relative role of the Coriolis force compared against the inertial force [e.g., 15-16]. In rapidly-rotating systems, convection manifests as columnar vortices aligned with the rotation axis. These columns act to pump heat in the vertical (axial) direction, which causes heat transfer to peak near the poles with minima at the equator. In sharp contrast, convection in inertially-dominated systems is no longer constrained by the Coriolis force and the fluid motions are three-dimensional rather than quasi-2D. Here, heat transfer occurs via Hadley cells with peak flux near the equator and minimal flux near the poles.

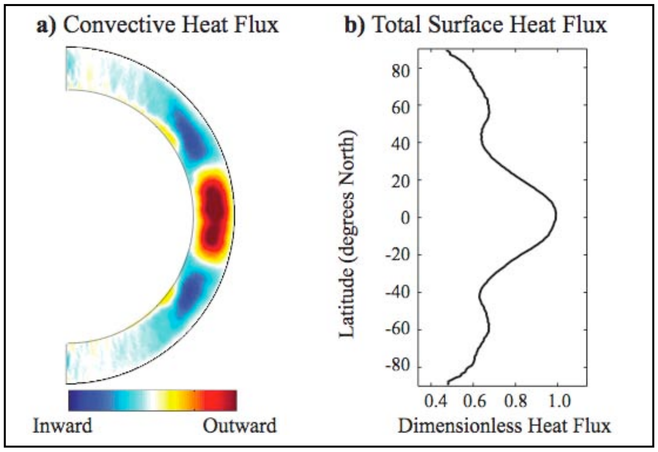

Figure 2: a) Time-averaged, axisymmetric convective heat flux, given by the product of radial velocity and temperature, in the inertially-dominated model. **b)** Total heat flux on the outer shell boundary as a function of latitude, normalized such that the peak flux is unity.

Extrapolating to Europa, simple scaling arguments based on [17-18] suggest that inertial effects exceed those of rotation. We present a simulation of inertially-dominated thermal convection in a thin rotating spherical shell. As shown in Figure 2, convective heat flux peaks at low latitudes, with minimal flux occurring near the poles, consistent with the distribution of chaos terrain.

Our current study considers only thermal convection. However, the simultaneous effects of both thermal and compositional gradients, ie. double-diffusive convection, may be important if significant salinity stratification exists. Furthermore, fluid motions in the ocean derived from changes in the orbital dynamics (e.g., libration) have also been neglected. Variations in heat flow from the interior resulting from local heat sources generated by tidal heating in the rocky core may influence the global heat flux pattern. Thus, we will also discuss the implications of spatially heterogeneous thermal boundary conditions and the potential that these variations influence the ice shell.

Implications: This work implies that thermal gradients along the bottom of the ice shell due to underlying ocean circulation are important to consider for the formation of chaos terrain, the evolution of Europa's ice shell, and the rates of mixing between the surface and subsurface.

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