DETERMINING HEAT FLUXES OF SMALL ICY BODIES USING 2D NUMERICAL MODELS. D. Allu Peddinti[1] and S. J. Desch[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287.

Introduction: Small icy bodies such as Ceres and Charon exhibit morphological and chemical signatures suggestive of prior cryovolcanic activity. Discerning their thermal evolution can refine the timing and origin of cryovolcanism on these bodies. Heat flow through these bodies has profound implications for the existence and transport of liquid water, leading to cryovolcanism on their surfaces [1], [2]. This cryovolcanic activity is expected to last the first few billions years of their evolution [2], [4]. Several models [2], [3], [4], [5] examined the thermal evolution and differentiation of the small icy bodies beginning from a homogenous mixture of rock and ice.

Desch and group developed models [2], [5] that considered, in a time-dependent manner, the effect of presence of antifreeze such as ammonia, heating due to radiogenic decay and the loss of heat by convection and conduction. These 1D spherically symmetric models use thermal conductivity to compute heat fluxes across the layer. These models assume a nearly isothermal profile across the ice-layer and do not explicitly model convection in the stagnant lid regime. They show that the crude treatment of ice-convection results in only small differences in freezing times of the layers.

In this work, we propose to assess the effects of modeling the stagnant-lid convection using 2-dimensional numerical models that consider the relevant ice rheology, on the surface heat flux. The results of these numerical experiments can then be compared to the 1-D parameterized models to determine if there is substantial difference in heat flux, and examine the implications for the extent of cryovolcanic processes on these small bodies. It is evident, for example for Charon, that despite its ~ 4 Gyr old surface, it experienced resurfacing in early stages. While it is predicted that it may have sustained cryovolcanism until about 1 Gyr ago, it would be useful to estimate this time based on heat flux calculations from dynamical models as well.

Methods: For the numerical modeling, the thermochemical version [6], [7] of the Citcom 2D mantle convection code is modified. This code solves the incompressible equations for conservation of mass, momentum and energy under the Boussinesq approximation.

Model Setup. The 2-D models consider similar material parameters and boundary conditions as used in [2]. Therefore, the model is capped off by a cold surface temperature of ~ 40 K at the top with a temperature drop of ~ 176 K across the layer, consistent with water-NH_3 eutectic. A Newtonian viscosity law [8] is used for the ice, similar to the one used in [2]. Radiogenic heating is considered for the heat source.

The surface heat fluxes for various input parameters (such as temperature-dependence of viscosity, thickness, internal heating etc.) are computed over time.

Discussion: The 2D convection codes are widely used to model ice mantles of ice-satellites [7], [8] to understand the geophysical evolution of ice-shell thickness over time. Convection models have been used to derive scaling laws to develop parameterized models for computation of heat flux with potential implications for thermal evolution of the body (e.g. [9], [10]). In study of thermal budget of Earth's mantle, numerous studies [11], [12], [13], [14], [15] have compared parameterized models to 2-dimensional convection models. It has been recognized in these studies that since the surface heat flux is sensitive to both cooling rate and rheology, it might be more accurate to consider dynamical convection models with appropriate viscosity laws and boundary conditions. This might be particularly significant for convection under the stagnant lid regime, possibly affecting the timescale of cryovolcanic activity.

Dynamical convective heat flow computation for colder and smaller icy bodies might not differ significantly from the predictions of existing thermal evolution models. However, it would be educational to validate the heat flow values for these smaller bodies, particularly during the early stages of their evolution (with high internal and radiogenic heating), to refine their potential for cryovolcanism and the time of retention of the subsurface liquid layer.

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