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On the possibility of thermal convection in planetary ice sheets

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Abstract

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Thermal convection in the Antarctic ice sheets has been a speculation since a half-century ago. However, this type of flow did not attract much attention in glaciology. Using properties of ice and an updated creep law of polycrystalline ice, we revisited the possibility of occurrence of thermal convective in an ice sheet for both terrestrial and dwarf planets. Assuming non-linear ice rheology, a reasonable background flow, and a terrestrial type of heat flow the Rayleigh number is expected to be just about the critical value. For this regime we have done a systematic study of numerical simulations over a broad range of parameters.
We used a constitutive equation which is composed of four individual mechanisms of diffusion, dislocation, superplastic and basal slip creep regimes. In addition, the effects of rheological anisotropy of the polycrystalline ice is studied by a scalar anisotropic flow relation. As background flow compaction flow is examined and characterized by a Peclet number.
The analysis of a significant number of simulations reveals separate dynamical regimes that develop depending on the Peclet number and the Rayleigh number. Here we focus, where possible, on scalings with some theoretical basis. Furthermore, the parameter ranges in which different scaling applies will be quantified.