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Thermal convection in a planetary mantle crystallizing from a magma ocean

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In a number of geophysical or planetological settings, including a silicate mantle crystallizing from a magma ocean, an ice shell surrounding a deep water ocean, or Earth's inner core, a convecting crystalline layer is in contact with a layer of its melt. Allowing for melting/freezing at one or both of the boundaries of the solid layer is likely to affect the pattern of convection in the layer. We study here the onset of thermal convection in a viscous spherical shell with dynamically induced melting/freezing at either or both of its boundaries. It is shown that the behavior of each interface depends on the value of a dimensionless number $\mathcal{P}$ (one for each boundary), which is the ratio of a melting/freezing timescale over a viscous relaxation timescale. A small value of $\mathcal{P}$ corresponds to permeable boundary conditions, while a large value of $\mathcal{P}$ corresponds to impermeable boundary conditions. The linear stability analysis predicts a significant effect of semi-permeable boundaries when the number $\mathcal{P}$ characterizing either of the boundary is small enough: allowing for melting/freezing at either of the boundaries results in the emergence of larger scale convective modes. In the case of a spherical shell with permeable inner and outer boundaries (*i.e.* a mantle starting to crystallize from an intermediate depth), the most unstable mode consists in a global translation of the solid shell, with no deformation. Numerical simulations above the convection onset show that allowing for melting/freezing at one boundary still promotes larger scale convective motions, and has also a strong influence on the heat flux and thermal structure.