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Convection in Sputnik Planitia, Pluto: Depth of the N2-CH4 ice layer and possible presence of basal melts

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Pluto's Sputnik Planitia basin displays regular cellular patterns strongly suggesting that solid-state convection is occurring in a several-kilometers-deep nitrogen-plus-dissolved-methane-ice layer (e.g., McKinnon et al. 2016). We perform convection calculations to constrain the depth of this ice sheet and thus the depth of the Sputnik impact basin and related properties and conditions. For a plausible range of Rayleigh numbers and viscosity contrasts for solid nitrogen-methane mixtures, convection can occur in all possible regimes: sluggish lid, transitional, or stagnant lid, or the layer could be purely conducting. Convective dynamics are complicated at the vicinity of regime transitions, thus we conduct a systematic analysis of convection regimes using 2-D convection simulations. Moreover the conditions at the base of the nitrogen-methane ice layer are uncertain. It may be directly in touch with the water ice bedrock, or nitrogen-methane melts may be present if the base reaches the melting temperature of beta-nitrogen. This bottom boundary condition affects the dynamics of the convection system and thus the surface manifestation, which is more prominent in 3-D models. We suggest that with the average separation of plumes 20-40 km apart ($\sim$1000 km2), the depth of the layer can be a 3-10 km. The largest cells, which can be $\sim$10000 km2, are longitudinally extended N-S, apparently by bulk toward the south.