Thermal convection as a mechanism at the origin of Sputnik Planum polygonal patterns on Pluto

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High resolution pictures of Pluto’ s surface obtained by the New Horizons spacecraft revealed a large nitrogen ice glacier informally named Sputnik Planum. The surface of this glacier is separated into a network of polygonal cells with a wavelength of 20–40 km. This network is similar to the convective patterns obtained under certain conditions by numerical and experimental simulations, suggesting that it is the surface expression of thermal convection within Sputnik Planum glacier. Here, we investigate the surface planform (sub-surface temperature and dynamic topography) obtained for different convective systems in 3D-Cartesian geometry with different modes of heating and rheologies. We find that bottom heated systems do not produce surface planforms consistent with those observed at the surface of Sputnik Planum, even when temperature dependent viscosity are taken into account. Alternatively, for a certain range of Rayleigh-Roberts number, Ra_H, a volumetrically heated system produces a surface planform very similar to the one found on Sputnik Planum. Combining scaling laws published in earlier studies with values of Ra_H within its possible range, we then establish relationships between the critical parameters of Sputnik Planum. In particular, for reasonable vertical temperature jump across the glacier (5–25 K) and nitrogen ice viscosities (10^{14}–10^{15} Pa s), our calculations indicate that the glacier thickness and the surface heat flux are in the ranges 2–10 km and 0.1–10 mW/m^2, respectively. However, if volumetrically heated convection operates within Sputnik Planum, a diffculty is to identify a proper source of internal heating. The most likely source may be induced by the cooling of Sputnik Planum, but it remains uncertain. Additional studies are thus required to determine a possible source of volumetric heating, or another mechanism than thermal convection to explain Sputnik Planum polygonal patterns.

Keywords: Pluto, Sputnik Planum, Thermal convection

