SUBLIMATION PIT DISTRIBUTION INDICATES CONVECTION CELL SURFACE VELOCITY OF ~10 CENTIMETERS PER YEAR IN SPUTNIK PLANITIA, PLUTO. P. B. Buhler[1] and A. P. Ingersoll[1], [1]California Institute of Technology, Department of Geological and Planetary Science, MC 170-25, Pasadena, CA, 91126, bpeter@caltech.edu.

Introduction: Sputnik Planitia (SP), Pluto is thought to be the upper surface of a vast basin filled with N_2 ice [1]. Cellular patterns in SP are thought to be the surface manifestation of convection within the ice [2,3]. The convection rate has been modeled to renew the surface on a timescale of ~500 kyr [2]. However, there are no observable impact craters in SP [4], necessitating an alternative method for independently dating the surface in order to determine the surface velocity of the convection cells.

We utilize the distribution of sublimation pits on the convection cells to date the cell surface. Cells in SP typically have smaller pits toward their centers and larger pits toward their edges (Fig. 1). This suggests that pits grow larger by sublimation during transport from the centers to the edges of convection cells. This motivates us to calculate the rate at which pit radii enlarge in order to use the spatial distribution of pit sizes to determine the surface velocity of the convection cells.

Methods: We map pits in published 100 m/px Long Range Reconnaissance Imager (LORRI) data [2,5], with an estimated Gaussian uncertainty of 1 px in each pit diameter. We then performed both a Markov Chain Monte Carlo (MCMC) and a least-squares regression in order to determine the distribution of the pit radii as a function of distance from the center of the pit.

In order to convert the radius vs. distance distribution to that of age vs. distance, we calculated the rate at which the radii of pits enlarge due to sublimation using an analytic radiative transfer model [see 6]. The model provides a closed-form expression for the total energy absorbed by the walls of a pit due to incident and reflected sunlight under the assumption that the pit is a spherical cap. We then calculate how rapidly the pit walls erode from the density and latent heat of N_2 ice.

Results: We determine that the radius vs. distance distribution of pits is $3.6^{+0.8}_{-0.4} \times 10^{-3}$ m m^{-1}, with 68% confidence (Fig. 2). The analytic sublimation model yields a growth rate of 3–6 × 10^{-4} m yr^{-1}, indicating that the convection surface velocity is $13.8^{+3.8}_{-4.8}$ cm yr^{-1} (Fig. 3, 68% confidence), implying a surface age of $1.8^{+0.9}_{-0.4} \times 10^5$ yr. The surface velocity we obtain is similar to the ~6 cm yr^{-1} rate calculated from convection modeling [2]. The surface velocity we obtain refines constraints on the surface of SP of < 1 × 10^7 yr based on a lack of craters [7] and of ~5 × 10^5 yr from convection modeling [2], and provides error bars on the age estimate.

Discussion: We hypothesize that pits form due to surface deformation from convective stress near the centers of cells. This proposed deformation would create deviations from a perfectly smooth surface, leading to a surface that scatters light back onto itself. This extra power from scattered light then causes surface imperfections to further enlarge. The ~100 meter-scale linearly organized pits (or troughs) in the centers of some cells (Fig. 1) support this hypothesis. Feedback from a rough surface scattering back onto itself is also thought to be how pits initially form in CO_2 ice at the martian south pole, and even cavities that do not initially have radial symmetry (such as linear fractures) can develop into quasi-circular pits [8]. A tectonic role in enhancing pit formation also naturally explains the higher density of pits on the (dynamic) surface of cells as compared to the (static) surface of non-cellular terrain (Fig. 1).

The fact that 100-m-scale pits in SP are stable over geologic time allows an estimation of the viscosity of the surface N_2 ice. Specifically, the sublimation rate of the pit should either equal or outpace the viscous relaxation. Otherwise, the pits would have relaxed to a shallower depth. Based on this argument, we estimate that the viscosity is $10^{16} – 10^{17}$ Pa s. This value is consistent with the N_2 ice viscosity from lab measurements [9] extrapolated to the temperature, stress, and measured grain sizes [10] in SP.

References: [1] Stern S. A. et al. (2015) *Science*, *350*, 6258. [2] McKinnon W. B. et al. (2016) *Nature*, *534*, 82-85. [3] Trowbridge A. J. et al. (2016) *Nature*, *534*, 79-81. [4] Greenstreet S. et al. (2015) *Icarus*, *258*, 267-288. [5] Weaver H. A. et al. (2008) *Space Sci. Rev.*, *140*, 75-91. [6] Ingersoll A. P. et al. (1992) *Icarus*, *120*, 40-47. [7] Moore J. M. et al. (2016) *Science*, *351*, 1284-1293. [8] Byrne S. et al. (2008) *LPSC 39*, *#2252*. [9] Yamashita et al. (2010) *Icarus*, *207*, 972-977. [10] Protopapa et al. *arXiv preprint 1604.08468*.

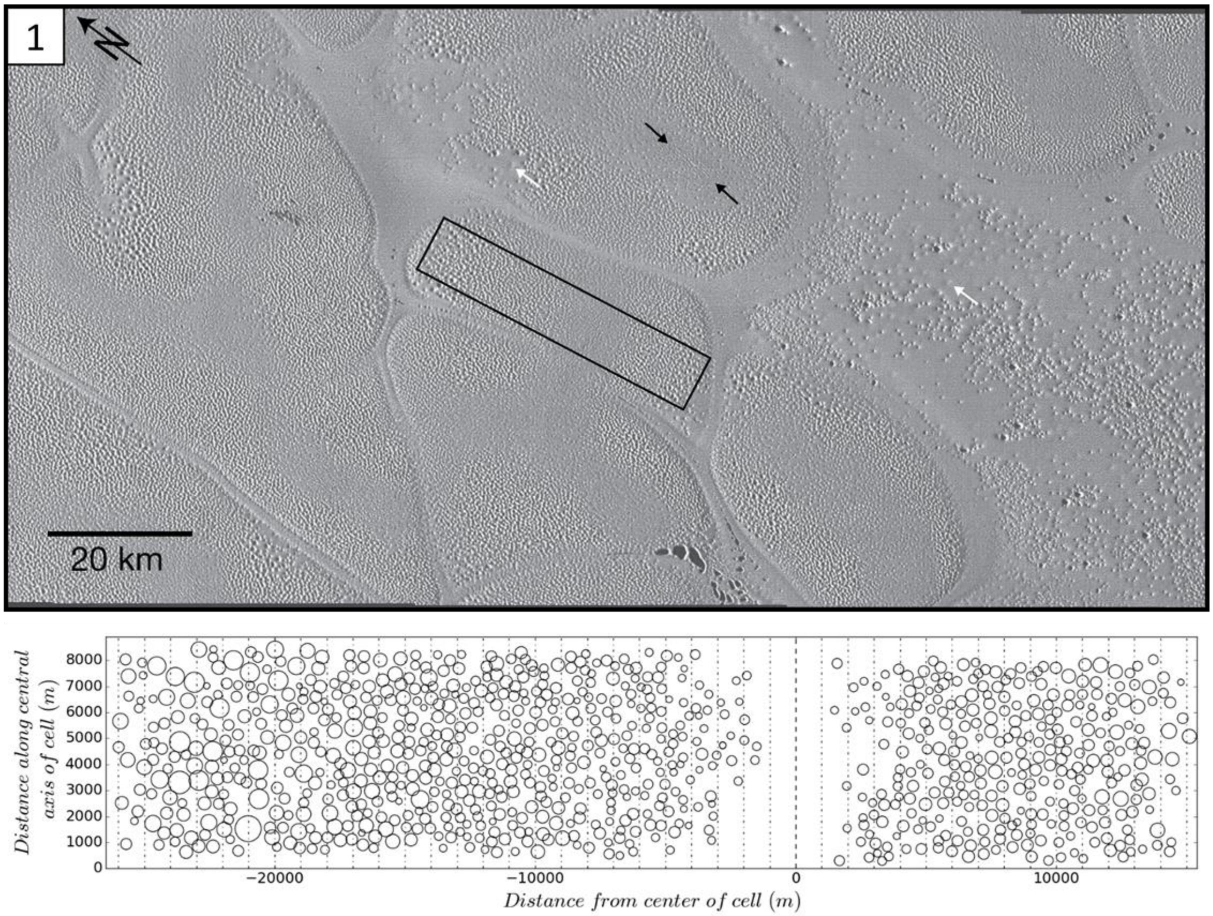

Fig 1. Top. Cellular terrain in Sputnik Planitia. The average sublimation pit size increases toward the edge of the cells. Note the region on the right side of the figure is devoid of cells, and pits are not organized by size. Rectangle indicates the area in which pits were mapped (Fig. 1B). Black arrows indicate parallel, linear troughs or aligned rows of pits near the center of a cell. White arrows indicate representative shallow pits in the non-cellular terrain and a smooth region on a cell edge.

Fig. 1. Bottom. Map of pits from the region indicated in top panel. The centerline (dashed line) is halfway between the most central pit of the Left-hand side (LHS) and Right-hand side (RHS) groups. Image in A is the LORRI portion of P_MVIC_LORRI_CA (100 m/px) taken from figure 2b of McKinnon et al. (2016) [2].

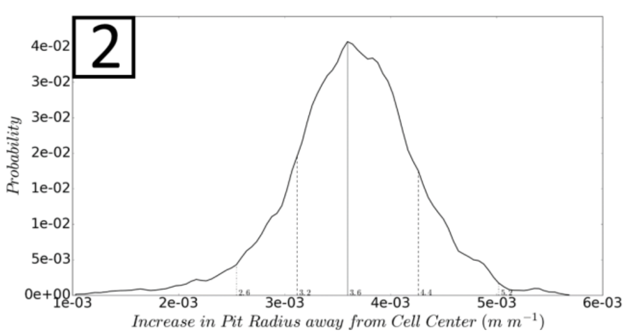

Fig 2. Results of the joint fit MCMC run for the radius vs. distance distribution of pits, with the best fit (solid), 68% confidence (dash), and 95% confidence (dash-dot) intervals indicated.

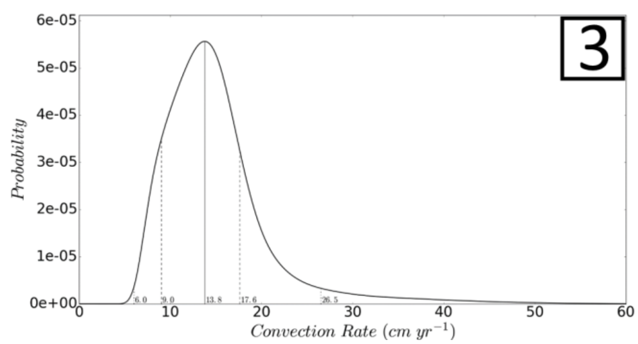

Fig 3. Likelihood curve for the surface velocity, with the best fit (solid), 68% confidence (dash), and 95% confidence (dash-dot) intervals indicated.