HIGH-RESOLUTION PIXEL-SCALE TOPOGRAPHY OF PLUTO AND CHARON. R.A. Beyer[1,2], P. Schenk[3], J.M. Moore[2], C. Beddingfield[1,2], O. White[1,2], W.B. McKinnon[4], J.R. Spencer[5], S.A. Stern[5], L.A. Young[5], C.B. Olkin[5], K. Ennico[2], H.A. Weaver[6], and the New Horizons Science Team. [1]SETI Institute (rbeyer@seti.org), [2]NASA Ames Research Center, CA [3]Lunar & Planetary Institute/USRA, TX (schenk@lpi.usra.edu); [4]Washington U. in St. Louis, MO; [5]Southwest Research Institute, CO; [6]Johns Hopkins University, Applied Physics Lab., MD.

Introduction: The geology of the Pluto system as revealed by *New Horizons* in July 2015 proved to be surprisingly diverse [1]. A prime objective of the mission was to acquire topographic maps of Pluto and Charon to provide physical constraints on the formation of these geologic features. Multiple observations permit topographic mapping at a variety of scales, and initial analyses focused on global and regional scale mapping to survey as much territory and terrain types as possible. Preliminary results were described [1,2], and full reports on these data sets have now been published [3,4]. These global data products (Fig. 1) have also been archived to the PDS. Here we report on high-resolution topographic data products for the Pluto system that address the origins of specific features on both the planetary and local scales.

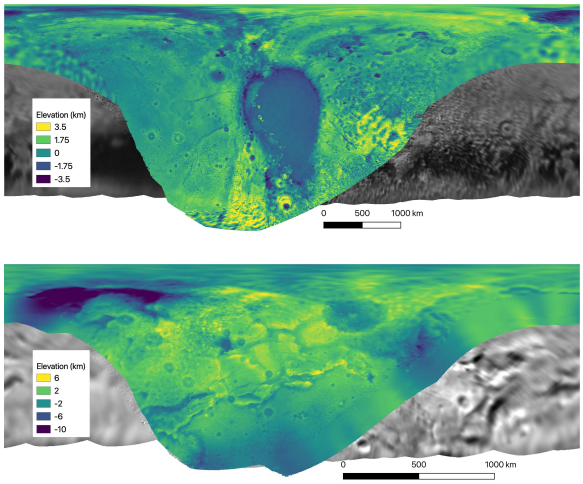

Figure 1. Topographic maps [3, 4] of Pluto (top) and Charon (bottom). Color-coding indicates vertical elevation.

Sputnik Planitia Topography: Most of the high-resolution topography of Pluto is centered on Sputnik Planitia (SP). Key questions remain unresolved in the global product regarding the topography of the SP N_2 ice sheet: How deep is it? How flat is it? These questions arise because the global-scale digital terrain model (DTM, Fig. 1) relies on MVIC line-scan data and ambiguities remain regarding pointing knowledge and hence reliability of long-wavelength components. To address this, we use geometrically controlled LORRI-only framing camera stereo data, which give us an undistorted topographic swath of ~1/4th of the basin (Fig. 2) from NW to SE.

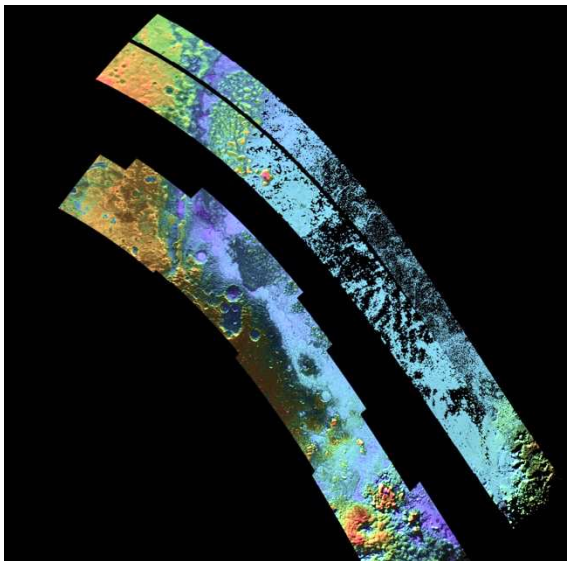

Figure 2. High-resolution mosaics across Sputnik Planitia basin on Pluto, color-coded for topography. Relief shown is 6 km (red is high, blue is low).

LORRI stereo data for SP reveal that the basin is ~2.5 to 3 km deep relative to the rim region sampled by the DTMs (a backup stereo sequence that includes surrounding terrains is in production). Further, the data reveal that the surface of the SP ice sheet is flat (Fig. 2) with respect to the global spheroid and to the limit of the data set's ~100-150 m stereo height accuracy). The only significant large-scale relief within the ice sheet is the along the outer 30-40 km perimeter which forms a moat several hundred meters deep to the north and a rampart rising several hundred meters to the southeast (where it meets glaciated deposits [2, 3]. These data place important constraints on the formation and dynamics of the ice sheet.

Sputnik Planitia Features: The ice sheet also features smaller scale features [1], notably the 20-50 km scale ovoid cells, and the multitude of km-scale pits scattered across the surface, each of which represent different physical processes.

Shading patterns in *New Horizons* images suggest that the cells within the SP ice sheet are domical. A few of these cells are marginally resolved in the global stereo DTM but with relief on the order of the vertical precision of the data. To supplement these

products we use shape-from-shading (photoclinometry, PC) toolkits developed at LPI to improve DTM resolution. PC can be used on all data products with low-Sun shading and at resolutions of 315 to 70 m/pixel scales. These data (Fig. 3) confirm that cells are elevated in the central portions by 100-150 m, consistent with convective overturn [5].

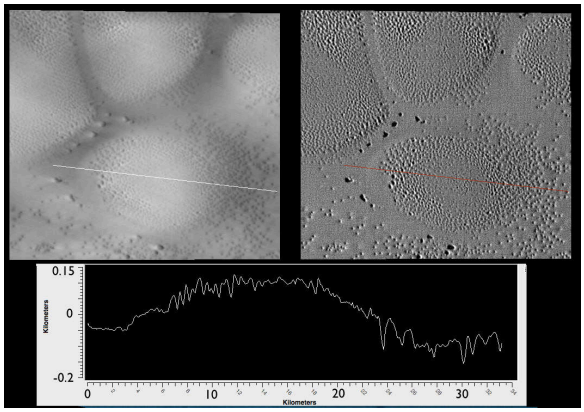

Figure 3. Preliminary PC-DTM and profile across ovoid cells within Sputnik Planitia, Pluto. Spatial resolution ~80 m, stereo height accuracy <100 m. Data not yet integrated with stereo data in Figure 2.

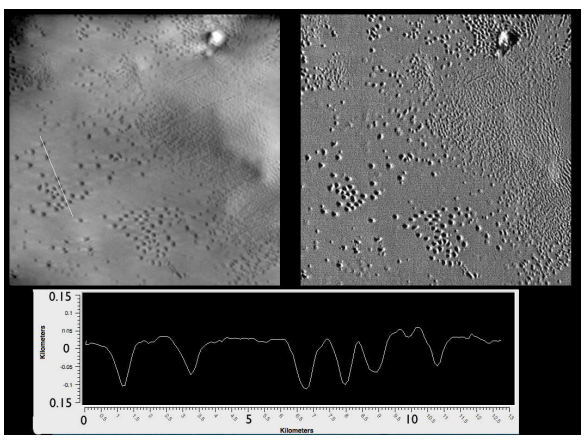

Figure 4. Preliminary PC-DTM and profile across km-scale pits within Sputnik Planum. Spatial resolution ~70 m, stereo height accuracy <100 m.

Kilometer-scale pitting across SP (Fig. 4) is not resolved in stereo DTMs, and can only be resolved in PC-DTMs. Preliminary PC tests (which depend on knowledge of photometric parameters as a function of phase angle) indicate depths of 100 m or so. The data are robust enough to indicate that reliable statistics on the depths of the pits, and hence any layers they may be exposing, can be derived.

Charon: The highest-resolution LORRI mosaic across the Charon disk at ~150 m/pixel reveals small-scale linear troughs and pitting across the surface of the volcanic plain informally named Vulcan Planitia [1]. A merged PC- and stereo-DTM product reveals the troughs to have relief of ~200-650 m and the pitting ~100-150 m (Fig. 5).

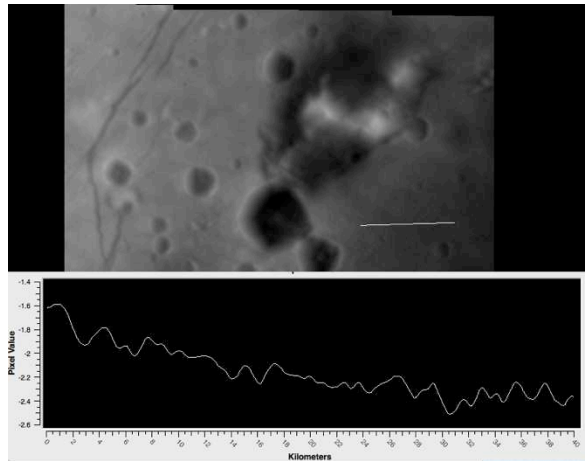

Figure 5. Stereo/PC-DTM of portion of Vulcan Planitia, Charon, showing pitting on surface of plain.

Conclusions: Pluto's topography is complex and reflects a diversity of geologic processes throughout its history [e.g., 1,2]. Supplemental topographic data now in production increase our knowledge and understanding of processes occurring on Pluto and Kuiper Belt objects generally. The SP ice sheet appears to be remarkably level within the limits of measurement (~125 m). The outer 20-40-km of the ice sheet can be either depressed or raised several hundred meters, with the depressed moat forming north of ~30° latitude or so, the raised portions forming south and corresponding to areas where glacier-like flow of material from the elevated rim regions meets the ice sheet [2]. A relative SP depth of 2.5 to 3 km implies a possible maximum thickness of the observed ice sheet of ~6 km, depending on assumptions about the preexisting surface. The ice sheet is also characterized by polygonal and ovoid 'cells' diagnostic of convection, which can be elevated at their centers 100-150 m. The ice surface is also extensively pitted at smaller scales, and pit depths of 100-200 m suggest there may be an eroding surface layer of equivalent depth on a more resilient subsurface ice sheet.

References: [1] Moore, J., et al., (2015), Science, 351, 1284-1293. [2] Howard, A., et al. (2017) Icarus, 287, 287-300. [3] Schenk, P., et al. (2018a) Icarus, 314, 400-433. [4] Schenk, P., et al. (2018b) Icarus, 314, 124-145. [5] McKinnon, W., et al., (2016) Nature, 534, 82-85.