EPSC Abstracts
Vol. 11, EPSC2017-139, 2017
European Planetary Science Congress 2017

N_2 in Pluto's Northern Lowlands

L. A. Young (1), J. A. Stansberry (2), S. Protopapa (3), B. Schmitt (4) A. M. Earle (5), P. M. Schenck (6) A. D. Howard (7), and the New Horizons science team
(1) Southwest Research Institute, Colorado, USA (layoung@boulder.swri.edu), (2) Space Telescope Science Institute, Maryland, USA, (3) University of Maryland, Maryland, USA, (4) Université Grenoble Alpes, France, (5) MIT, Massachusetts, USA, (6) Lunar and Planetary Institute, Texas, USA, (7) University of Virginia, Virginia, USA.

Abstract

On Pluto, N_2-rich ice is seen at 35° to ~60° N latitude, with incursions up to 75° N [1]. The Northern incursions are mostly in smaller, flat-bottomed lowlands south of 70°. Both shadowing by canyon walls and the higher frost point at higher pressures favor N_2 accumulation in depressions. However, neither effect is sufficient to significantly redistribute N_2 ice over a single Pluto year, suggesting that the N_2 in the northern valleys is laid down over multiple Pluto seasons.

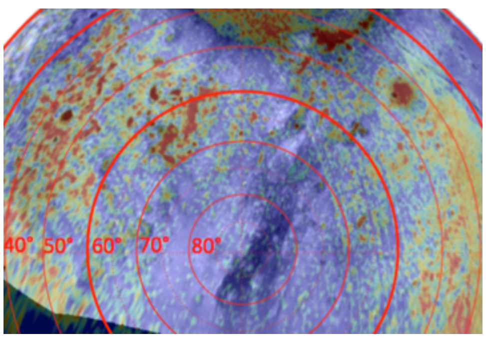

Figure 1. Shading denotes elevation (dark is deep, with the deepest canyons being ~2.5 km below the mean radius of Pluto). Color denotes N_2 band strength (red for more N_2 ice or larger grain size, blue for lack of detectable N_2). 180° longitude is up.

1. Introduction

Pre-encounter simulations of Pluto's seasons suggested that once sublimation of Northern N_2 begins post-perihelion (Northern summer), it should leave the Northern hemisphere bare on a timescale of only ~1 or 2 years [2], accompanied by a severe drop in the pressure. New Horizons found N_2 in northern mid latitudes, with scattered N_2 in the far north (Fig 1). The N_2 north of ~60° is confined to local depressions, with less N_2 in the far North, or in shallower or larger depressions (note the lack of N_2 in the low, wide feature straddling the North Pole). Thus we investigate N_2 stability vs. latitude, altitude, and shadowing by valley walls.

2. Method

The temperature of the N_2 ice on Pluto's surface will be at the "frost point," which depends on the globally averaged energy balance of the N_2 ice; the surface pressure then follows from vapor-pressure equilibrium [3]. The N_2 ice on depression floors will have higher surface pressures, higher surface temperature, and higher thermal emission. Absorbed insolation depends on season, latitude, albedo, and shadowing from canyon walls, so depression floors have potentially less insolation [4]. Local imbalances between emission and insolation are compensated by latent heat of sublimation, so higher frost points and lower insolation both lead to decreased sublimation (or increased deposition) *e.g.* on valley floors. Locally the net sublimation rate (R, cm/s) is found from:

$$(1-A)S(\lambda,\lambda_s,\alpha)-\sigma\varepsilon T(h)^4 = RL/\rho \quad (1)$$

A is the bolometric Bond albedo; as the observed reflectance varies little between lowlands and uplands, we adopted A = 0.8 [5]. S is the absorbed solar flux, which depends on the latitude, λ, the sub-solar latitude, λ_s, and the angle of the horizon, α. σ is the Stefan-Boltzmann constant, and ε is the emissivity, which we take to be unity. T is the temperature of the N_2 ice, which depends on the height h above the mean radius. L is the latent heat (2.5×10^9 erg/g), and ρ is the density of the N_2 ice (1.0 g/cm^3). An N_2-covered area can be a site of either condensation or sublimation. A bare area can be a condensation site if T is below the frost point and $R < 0$.

We use the N_2 pressure at h=0 as measured by New Horizons in 2015 [6] and extrapolated to the surface from ground-based stellar occultations 1988-2015 [7], then calculated $T(h=0)$ by vapor-pressure equilibrium. The wet adiabat (-0.1 K/km) defines the pressure and temperature of the N_2 ice on the valley floor, and the resulting difference in the thermal emission relative to ice at the frost point and h = 0 km. The resulting sublimation mass flux will deposit roughly 0.8 cm more N_2 at –2 km vs. 0 km altitude over the interval 1985-2015. Shadowing affects deposition rates by decreasing the solar insolation, especially for small depressions or near valley walls, adding ~3 to 4 cm more N_2 for a 15° vs 0° horizon over the same time span, depending on latitude. Shadowing also extends the duration of the "arctic night," during which a location receives no sunlight over a Pluto rotation, typically by ~30 years, yielding an additional tens of cm of N_2 ice per Pluto year in lowlands vs. highlands.

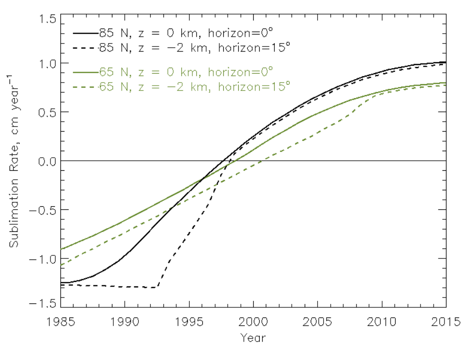

Figure 2: Sublimation Rate for N_2 at 65 N (green) and 85 N (black), on the uplands (solid) or in a depression (dashed). The small offset is due to a higher frost point at lower altitudes. The larger, variable offset is due to shadowing.

While N_2 favors lowlands, it is not a dramatic enough difference to operate over a single Pluto season. Roughly 1 m of N_2 condenses in the northern terrains over the arctic night. But many of the lowland N_2 floors are flat and visually smooth, with evidence of the same deep pitting seen in Sputnik Planitia, suggesting deeper deposits, perhaps built up over many seasons. Only a total of ~7-12 cm of N_2 has sublimed from the highlands this season. This could leave behind a CH_4 crust (~0.5 to 2 mm thick) sufficient to mask the underlying N_2. Alternatively, high thermal inertia may have kept the northern uplands too warm for condensation for most of the previous century. Thus, Pluto's northern N_2 may be perennially dichotomous, as suggested for Triton [8].

Acknowledgements

This work was supported by NASA ROSES NNX15AH35G and the New Horizons project.

References

[1] Protopapa, S, and 21 coauthors: Pluto's global surface composition through pixel-by-pixel Hapke modeling of New Horizons Ralph/LEISA data, Icarus, Vol. 287, pp. 218-228, 2017. Schmitt et al. 2017. Physical state and distribution of materials at the surface of Pluto from New Horizons LEISA spectrometer. Icarus 287, 229-260.

[2] Hansen, C. J. and D. A. Paige 1996. Seasonal nitrogen cycles on Pluto. Icarus 120, 247-265. Young, L. A. 2013. Pluto's seasons: New predictions for New Horizons. The Astrophysical Journal 766, L22. Olkin, C. B., and 23 colleagues 2015. Evidence that Pluto's atmosphere does not collapse from occultations including the 2013 May 04 event. Icarus 246, 220-225. Hansen, C. J., D. A. Paige, and L. A. Young 2015. Pluto's climate modeled with new observational constraints. Icarus 246, 183-191.

[3] Spencer, J. R., J. A. Stansberry, L. M. Trafton, E. F. Young, R. P. Binzel, and S. K. Croft 1997. Volatile Transport, Seasonal Cycles, and Atmospheric Dynamics on Pluto. Pluto and Charon 435.

[4] Trafton, L. M. and J. A. Stansberry 2015. On the departure from isothermality of Pluto's volatile Ice due to local insolation and topography. AAS/Division for Planetary Sciences Meeting Abstracts 47, 210.02.

[5] Buratti, B. J., and 16 colleagues 2017. Global albedos of Pluto and Charon from LORRI New Horizons observations. Icarus 287, 207-217.

[6] Hinson, D. P., and 15 colleagues 2017. Radio occultation measurements of Pluto's neutral atmosphere with New Horizons. Icarus 290, 96-111.

[7] Elliot, J. L., and 28 colleagues 2003. The recent expansion of Pluto's atmosphere. Nature 424, 165-168. Sicardy, B., and 67 colleagues 2016. Pluto's Atmosphere from the 2015 June 29 Ground-based stellar occultation at the time of the New Horizons flyby. The Astrophysical Journal 819, L38

[8] Moore, J. M. and J. R. Spencer 1990. Koyaanismuuyaw - The hypothesis of a perennially dichotomous Triton. Geophysical Research Letters 17, 1757-1760.