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PLUTO’S MINIMUM SURFACE PRESSURE AND IMPLICATIONS FOR HAZE PRODUCTION

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Abstract

Pluto’s surface is heterogeneous despite uniform deposition of haze particles onto it. We use the VT3D energy balance model to investigate if the atmosphere ever becomes sufficiently thin to disrupt haze production, explaining this heterogeneity. If a bare southern hemisphere is assumed, the pressure remains high enough throughout the orbit to maintain haze production. The addition of southern N_2 allows for more thermal emission which could lead to atmospheric collapse and haze interruption.

1. Introduction

Pluto’s surface exhibits extreme contrasts in color, albedo, and composition [11]. Pluto’s atmosphere is globally hazy, and haze particles should be deposited onto the surface at a rate of ~1 micron/Pluto year [1, 5]. This deposition should form a uniform, optically thick layer quickly, which is in contradiction with the observed surface heterogeneity.

If the atmospheric pressure at the surface gets low enough, haze production may be altered, suppressed or stopped completely. In Pluto's current atmosphere, haze aggregation occurs at pressures higher than 0.5 μbar; therefore if the surface pressure drops below this level, monomer haze particles may be deposited instead of aggregates, potentially changing the appearance on the surface [1]. Additionally, if the surface pressure drops below 10^{-3}-10^{-4} μbar, the atmosphere would be transparent to UV [4], which would shut off the photolysis of N_2 and CH_4, suppressing haze production at its source and allowing direct photolysis of surface ices [10]. For surface pressures under 0.06 μbar, Pluto cannot support a global atmosphere [10], and instead the atmosphere becomes local, or “patchy”, restricting the region in which haze particles are deposited.

2. Climate Model

As described in [13, 14], the 3-Dimensional Volatile Transport (VT3D) model imposes local energy balance (insolation, thermal emission, conduction, and latent heat of sublimation) and global mass balance for volatile-covered bodies with efficient transport of volatiles. As used here, VT3D has three free parameters: Bond albedo A, thermal inertia Γ, and emissivity ε of the volatiles. For each pair of A and Γ, there exists a unique ε such that the model-predicted pressure in 2015 matches the 11 μbar surface pressure observed at the New Horizons flyby. We constrain our grid search of the (A, Γ, ε) parameter space by two criteria: (i) that the emissivity is less than one and greater than some minimum physical value (0.3 in the work below), and (ii) that the modeled pressure increase between 1988 and 2015 matches the measured pressure increase from occultations [2, 6]. If either of these conditions are violated, the (A, Γ, ε) triplet will be eliminated.

3. Nitrogen Distributions

Fig. 1 shows the northern N_2 spatial distributions used here. The red outline encloses Sputnik Planitia (SP), as defined in [12]. For our first distribution, we assume everything enclosed by this outline is filled with N_2 ice of uniform A, Γ, and ε, and that no N_2 ice is present elsewhere on the surface. This is not a realistic situation, but serves as a lower limit. For our second (more realistic) distribution, we use the N_2 map created by [7]. This map combines spectral data from observations and Hapke modeling on the encounter hemisphere of Pluto [8, 9]. [7] extends the observed/modeled fractional coverage of N_2 ice to the non-encounter hemisphere, by assuming the fractional coverage is constant within a zonal band.

There are no detailed observational constraints on the distribution of N_2 in the southern hemisphere south of

-35°. For our modeling so far, we have assumed no southern N_2. We will explore alternative models for the southern N_2, for example, full N_2 coverage in the polar night region of the planet or permanent polar caps extending to specified latitudes.

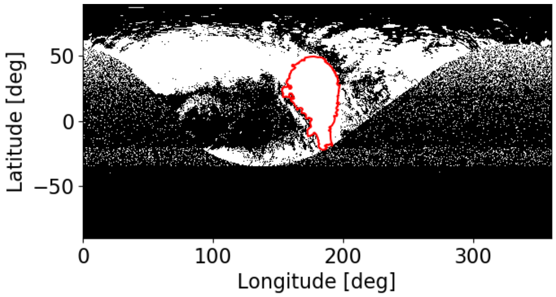

Figure 1: Northern N_2 distributions, as described in [7]. White indicates N_2 ice, black is bare. The red outline shows the border of SP, as defined in [12]. Southern N_2 distributions are discussed in the text.

4. Climate Modeling Results

Preliminary modeling with a bare southern hemisphere indicates that the pressure likely does not get low enough to disrupt haze production. For a short period of time near northern winter solstice the pressure drops below the 0.5 μbar haze-aggregation limit, but only for select cases of A, Γ, and ε. The addition of southern N_2 increases the surface area undergoing thermal emission, allowing the volatiles to be colder and perhaps for the atmospheric pressure to drop low enough to interrupt haze.

5. Conclusions

Based on a northern-only N_2 distribution, haze production is not likely to be significantly disrupted by reductions in atmospheric pressure. The addition of unseen N_2 in the southern hemisphere might be sufficient to cool the atmosphere and affect haze production. The haze particle sedimentation may occur at a faster rate during the low-pressure period near northern winter solstice, although more work is needed before conclusions can be drawn about how this would affect the surface heterogeneity.

Acknowledgments

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