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Large north/south differences in Saturn's polar cloud structure revealed by Cassini/VIMS near-IR spectra

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Abstract

Using VIMS near-IR spectra of both of Saturn's polar regions, we constrained a four layer cloud model of the band structures within 3° of the poles, finding small optical depths generally, and small step changes in optical depth as the south pole is approached, but dramatic changes as the north pole is approached. We found no evidence of optically thick eyewall clouds surrounding either pole.

1. Introduction

The polar regions of Saturn are characterized by strong cyclonic circulations, with the south containing shadow-casting cloud bands [2] suggestive of deep convective eyewalls. However, radiative transfer analysis applied to the south polar bands [4] found low optical depths, indicating a lack of deep convection. Initial analysis of the high spatial resolution Grand Finale VIMS observations of the north region [1] found evidence for local convection associated with discrete ammonia clouds. Here we focus on the structure of the background cloud bands and how they compare with similar bands near the eye of the south polar vortex. We constrain models of their vertical structures using 0.9-5.12 μm VIMS spectra.

2. Observations

The most detailed Cassini/VIMS observations of Saturn's polar eyes were obtained in 2006 for the south and in 2017 for the north, the latter during the Grand Finale. Polar projections at key wavelengths are shown out to a radius of 3° from the poles in Fig. 1. Discrete clouds with ammonia ice content, which have absorption near 3 μm, appear as magenta in the left column and cyan in the right column. Regions of thermal emission escaping from the 3-4 bar level appear as orange to red in the right hand column.

3. Radiative transfer modeling

We modeled cloud structure as a stack of four sheet clouds. On top is a stratospheric haze, of generally

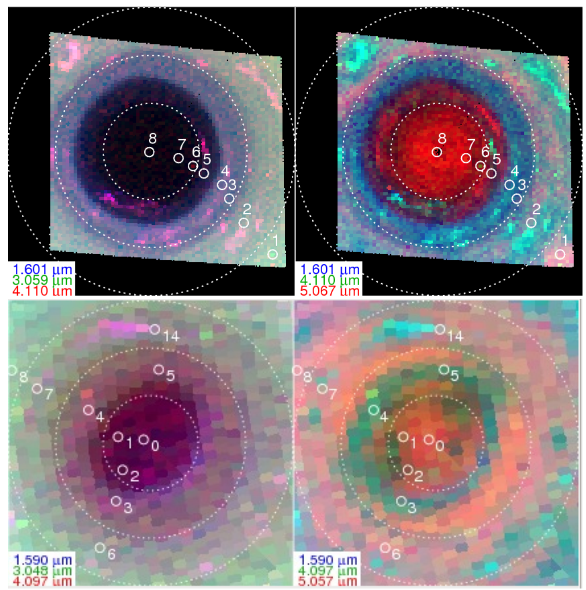

Figure 1: Color composite polar projections for north (top) and south (bottom) polar regions with dotted latitude circles shown at 1, 2, and 3° from the poles. Numbered circles locate spectral samples that were analyzed to obtain results in Figs. 2 and 3.

low optical depth and small particle size, which we assumed to be conservative over the near-IR region, with a refractive index of 1.4. The next layer, which is generally the main visible cloud layer on Saturn, has an unknown composition, possibly diphosphine (P_2H_4) or some phosphorus compound (possibly P_4). For this layer we assumed a real index of 1.82, and an imaginary index with the λ dependence of the phosphorus compound produced by [3], but only 10% the magnitude. We assumed the third layer to be ammonia ice, and for the deep layer, we assumed an index of 2+0.03i, following [4] as a rough simulation of an unknown mixture of NH_4SH and water ice. The λ dependence of optical depth and scattering phase functions of all particles were parameterized as Mie scatterers (spheres). Thermal emission and multiple scattering were both included to constrain key variable gases as well as aerosols. We assumed a fixed profile for NH_3 ,

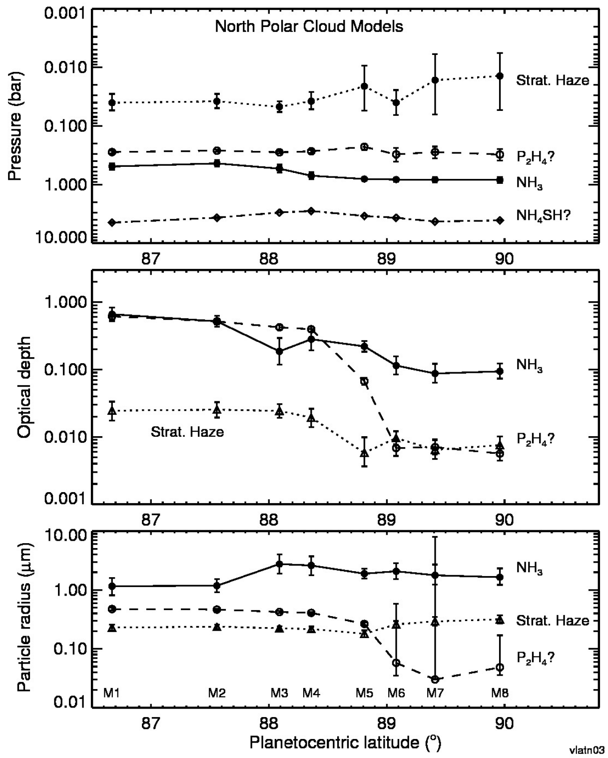

Figure 2: Fit results for the north polar region.

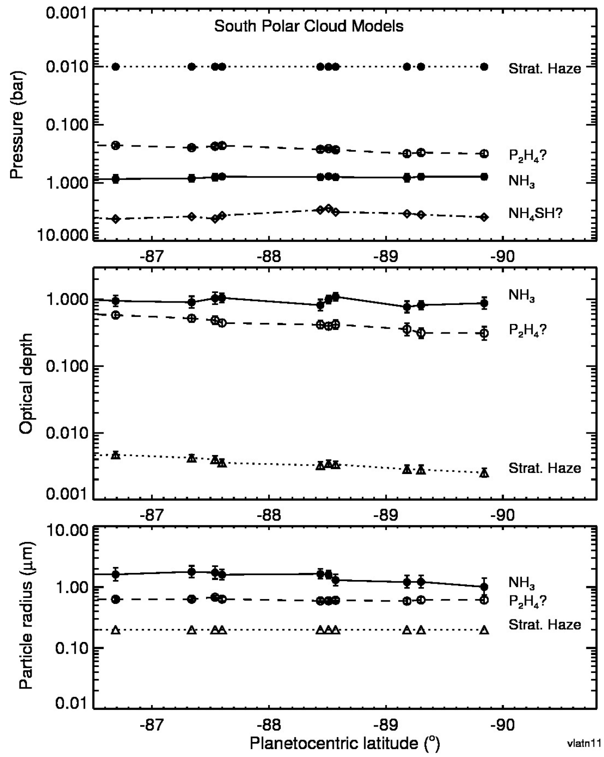

Figure 3: Fit results for south polar regions from [4].

and adjusted PH_3 and AsH_3, as well as particle radius, pressure, and optical depth for each layer to optimize the spectral fits.

4. Comparison of fit results

Results from fitting models to north polar spectra are shown in Fig. 2. The pressure levels of the various layers are relatively stable compared to other parameters. The optical depth (at 2 μm) of the putative diphosphine layer declines by a dramatic factor of 60, from 0.4 near 88° to 0.0068 near 89°. The stratospheric haze optical depth also declines, but over a smaller latitude range, and by only a factor of 4. The ammonia layer optical depth declines by a similar factor, but its transition is not as sharply defined. Particle radii (bottom panel) hardly change for the stratospheric haze, remaining near 0.2 μm. The putative diphosphine particle radii become lower and very uncertain where the layer optical depth becomes very small. On the other hand, south polar cloud changes (Fig. 3) are tiny by comparison, showing mainly slight declines in the optical depths of the diphosphine and stratospheric haze layers. Yet these small optical depth transitions create more prominent shadows than seen in the north polar region. The different structures seem unlikely to be seasonal effects as the north pole was observed very close to northern solstice and the south pole just a few years after southern solstice.

Acknowledgments

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