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Trace Species Identified in Saturn's Northern Storm Region

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Abstract

The massive storm at 40°N on Saturn that began in December 2010 has produced significant and lasting effects in the northern hemisphere on temperature and species abundances [1]. The northern storm region was observed at 0.5 cm^{-1} spectral resolution in March 2011 by Cassini's Composite Infrared Spectrometer (CIRS). Temperatures in the stratosphere as high as 190 K were derived from CIRS spectra in warm regions referred to as "beacons". Other longitudes exhibit cold temperatures in the upper troposphere. These unusual conditions allow us to identify rare species such as C_4H_2, C_3H_4, and CO_2 in the stratosphere, as well as to measure changes in the abundance of phosphine (PH_3) in the troposphere. Phosphine is a disequilibrium species whose abundance is a tracer of upwelling from the deep atmosphere.

1. Introduction

In December 2010 a major storm was observed on Saturn near 40°N (planetographic latitude). It quickly spread over all longitudes and perturbed the temperature and gas composition of both the upper troposphere and stratosphere [1]. Storms of this size and longevity are very rare, with the last such storm occurring in 1990 near the Equator. Cassini/CIRS observations of mid-northern latitudes in March 2011 were designed and scheduled prior to the outbreak of the storm in order to study seasonal change on Saturn. As a serendipitous result we have an impressive dataset of thermal infrared spectra to characterize the response of Saturn's atmosphere to this major storm.

Prior to Cassini the best dataset for the composition of trace species in Saturn's stratosphere was obtained using the Infrared Space Observatory (ISO). Sensitive detectors and high spectral resolution led to the detection of C_4H_2, C_3H_4, and CO_2 in the stratosphere [2]. However, the beam size of ISO was larger than Saturn, so the spatial distribution of these species remained unknown. Prior to the northern storm, CIRS was able to detect these species only near the South Pole shortly after summer solstice. Elsewhere, the stratosphere remained too cold for CIRS to map these species. The generation of warm beacon regions in Saturn's stratosphere in response to the upwelling and subsequent fallback of material from the storm [1] has resulted in the identification of C_4H_2, C_3H_4, and CO_2 at mid-northern latitudes in the CIRS spectra. In addition, at certain longitudes the upper troposphere is up to 8 K colder than in an average away from this "cold spot". The abundance of PH_3 is enhanced in this region, qualitatively consistent with the results of Fletcher et al. [1] obtained using a CIRS dataset obtained in January 2011 near 50°N.

2. Observations

The Cassini/CIRS instrument in orbit around Saturn is a dual Fourier transform spectrometer covering the thermal infrared with three focal planes: FP1 which is a single detector covering 10-600 cm^{-1}, FP3 an array of 10 detectors covering 600-1100 cm^{-1}, and FP4 an array of 10 detectors covering 1100-1500 cm^{-1} [3]. The CIRS observations were performed in March 2011 while the spacecraft was targeted at 30°N and 35°N planetographic latitude. Observations known as COMPSITs target one latitude at a spectral resolution of 0.5 cm^{-1}, letting the planet rotate to cover all longitudes, and operating in a paired mode to return, for example, one far-infrared dataset centered at 35°N and 5 mid-infrared spectral datasets at 31, 33, 35, 37, and 39°N latitude.

3. Results

The March 2011 CIRS data show temperatures as high as 190 K in the beacons in the stratosphere, significantly warmer than observed in January 2011 [1], but less than observed in May 2011 (220 K). The spectra resulting from the CIRS observations of the northern storm region from March 12-14, 2011 are shown in

Figs. 1 and 2.

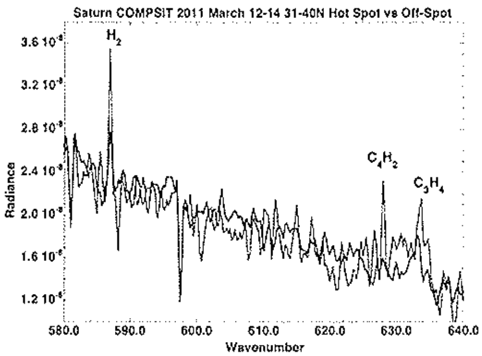

Figure 1: Emission due to H_2, C_4H_2, and C_3H_4 is clearly enhanced in a stratospheric hot spot or "beacon". Elsewhere, emission from trace hydrocarbons is near the noise level.

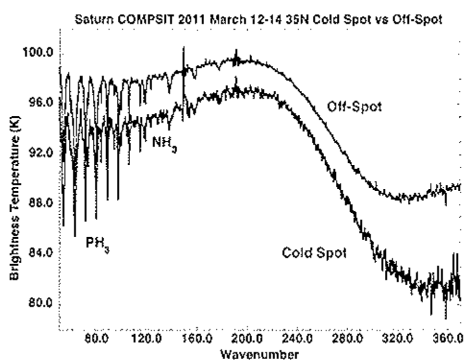

Figure 2: CIRS far-IR spectra indicate significantly colder temperatures in the upper troposphere and higher abundances of PH_3 in regions due to upwelling from the massive storm system near 35°N.

The next step of our analysis will be to retrieve abundances of C_4H_2, C_3H_4, and CO_2 in the stratosphere and compare them with values obtained near the South Pole. The abundance of both PH_3 and NH_3 will be derived inside and outside of the tropospheric cold spot and compared with pre-storm observations to assess the magnitude of upwelling from Saturn's deep interior.

Acknowledgements

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References

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