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Cassini Returns to Saturn's Poles: Seasonal Change in the Polar Vortices

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Abstract

High inclination orbits during Cassini's solstice mission (2012-2013) are providing us with our first observations of Saturn's high latitudes since the previous high inclination phase in 2007 (during the prime mission). Since that time, the northern spring pole has emerged into sunlight and the southern autumn pole has disappeared into winter darkness, allowing us to study the seasonal changes occurring within the polar vortices in response to these dramatic insolation changes. Observations from the Cassini Composite Infrared Spectrometer [1] have revealed (i) the continued presence of small, cyclonic polar hotspots at both spring and autumn poles [2]; and (ii) the emergence of an infrared-bright polar vortex at the north pole, consistent with the historical record of Saturn observations from the 1980s (previous northern spring, [3]).

1. Introduction

Saturn's polar atmosphere provides an extreme test of our understanding of atmospheric chemistry and dynamics, being the apex of a planet-wide circulation system and the site of a unique connection between the atmosphere and the wider charged-particle planetary environment. Furthermore, Saturn's 26-degree axial tilt subjects these poles to substantial changes in solar illumination, such that the thermal structure and composition of the polar vortices varies over the course of a Saturnian year. Infrared remote sensing during Cassini's first high-inclination orbital phase in 2007 revealed Saturn's north pole under the shroud of winter darkness. In the troposphere, a small hot cyclonic vortex [2] was found to be co-located with a 'polar-eye' structure [4], a near mirror image of that found at the southern summer pole in reflected sunlight images. The continued presence of vortices at both poles suggests that these hot polar cyclones, coupled with strong peripheral jets, are common features of Saturn's atmospheric circulation irrespective of season.

The polar stratospheres differed substantially, with the south pole exhibiting a broad warm 'polar hood' (70-90°S) surrounding a small cyclonic vortex, whereas no such polar hood was visible in northern winter [2]. Nevertheless, historical observations from ground-based telescopes [3] suggested that a warm north polar stratosphere should have become visible during northern springtime conditions, before a heliocentric longitude of L_s=60 degrees (September 2014). The Cassini solstice mission has recently provided the opportunity to observe the onset of this stratospheric hood and to pinpoint its emergence (L_s=42°).

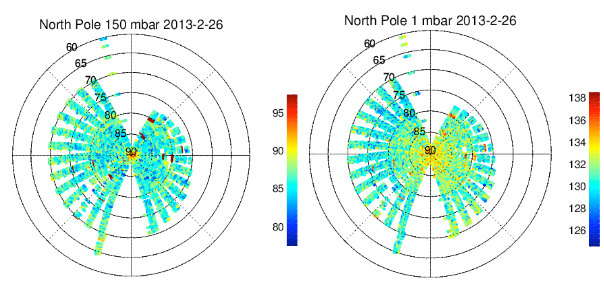

Fig.1. Raw brightness temperatures averaged over the 600-620 cm^{-1} region of H_2 emission (sensitive to 150-mbar temperatures, left) showing the compact polar cyclone at the north pole; and the 1290-1310 cm^{-1} region of CH_4 emission (sensitive to 1-mbar temperatures, right) indicating the warmer north polar stratosphere.

2. Temperature and Composition

We report on the latest Cassini/CIRS infrared remote sensing of Saturn's polar atmosphere during the current inclined orbital phase, confirming (i) the seasonal cooling of the south polar stratospheric hood; (ii) the continued presence of the warm cyclonic vortex at both north and south poles; (iii) hydrocarbon enhancements (ethane and acetylene) within these small polar vortices; and (iv) the warming of the north polar hood.

These observations coincide with the first reflected-light images of the north pole from Cassini. Spectra at a resolution of 2.5 cm^{-1} between October 2012 and March 2013 were analysed via an optimal estimation retrieval algorithm (NEMESIS, [5]) to determine the three dimensional temperature field (0.5-5 mbar in the stratosphere; 70-400 mbar in the troposphere) at Saturn's high latitudes (Fig. 2); and the two-dimensional distributions of phosphine (a tracer of tropospheric vertical mixing); ethane and acetylene (hydrocarbon tracers of the stratospheric circulation). The spatial distributions of these species are reported at the peaks of their transmission weighting functions (Fig. 3), showing poleward enhancements but different chemical gradients in each hemisphere.

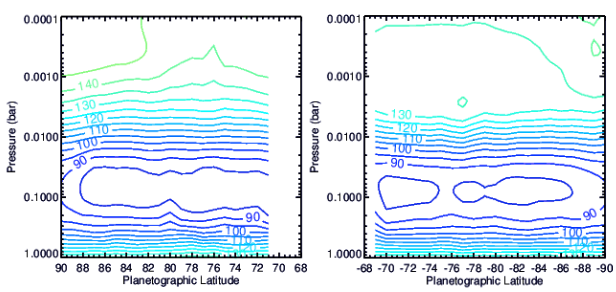

Fig. 2. Two-dimensional temperature retrievals at the high polar latitudes for January 4th 2013 (right) and February 26th 2013 (left).

The implications of this polar variability on Saturn's atmospheric circulation will be discussed, and compared to the historical record (i) from previous Cassini studies of the pole [2] and (ii) ground-based infrared observations from the previous Saturnian year [3].

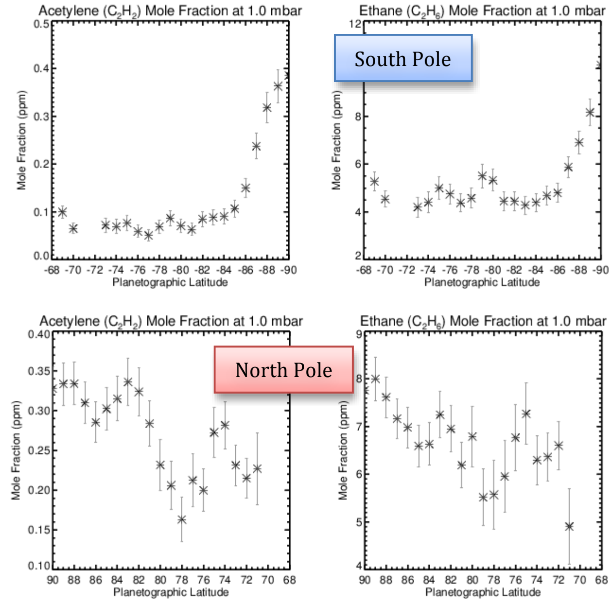

Fig. 3. Scaling the photochemical profiles [6] of acetylene (left) and ethane (right) to reproduce the observed CIRS zonally-averaged spectra, showing elevated abundances towards both poles but different latitudinal gradients in the spring versus the autumn. These will be compared to a reanalysis of the 2007 high inclination datasets presented by [2].

Acknowledgements

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