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From Voyager-IRIS to Cassini-CIRS: Interannual Variability in Saturn's Stratosphere

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Abstract

We present an intercomparison of Saturn's atmosphere from Voyager-IRIS observations in 1980 with Cassini-CIRS observations in 2009/2010. Over a Saturn year (∼29.5 years) has now passed since the Voyager flyby of Saturn in 1980/1981. Cassini observations in 2009/2010 and those from Voyager therefore capture Saturn in the same season (at approximately the vernal equinox, solar longitude, $L_s \sim 0°$). Any differences in Saturn's stratospheric properties implied by a comparison of these two datasets will therefore highlight interannual variability. We retrieve temperature and stratospheric acetylene and ethane concentrations from Voyager 1-IRIS (FWHM = 4.3 cm^{-1}) in 1980 and Cassini-CIRS 'FIRMAP' (FWHM = 15.5 cm^{-1}) observations in 2009/2010. Preliminary results show the equator to be warmer by 7.3 ± 1.6 K at ∼2.1 mbar in 2009 than in 1980 implying a differing phase of the SSAO (Saturn's semi-annual oscillation). Ethane's meridional distribution at 2.1 mbar appears consistent between 1980 and 2009/2010. However, the concentrations of acetylene at the same altitude appear enhanced at ∼25°S and ∼25°N in 1980 when compared to 2009/2010. A global-circulation model shows cells of downwelling at these latitudes [3]: the richer concentrations of acetylene at these latitudes in 1980 suggests that there was stronger downwelling at this time than in 2009.

1. Introduction

The Voyager mission has provided a wealth of knowledge of the properties of our solar system. The mission refers to two identical spacecraft, Voyager 1 and Voyager 2, which were launched from Earth in 1977, explored the outer planet systems and have recently crossed the solar system's termination shock. Both spacecraft feature the IRIS (Infrared Spectrometer) instrument which provides observations from 180 cm^{-1} to 2500 cm^{-1} at a spectral resolution of 4.3 cm^{-1} [4].

Over three decades have now passed since the Voyager flybys of the Jovian planets and IRIS observations continue to be used in more recent studies. Globally-averaged abundances of acetylene and ethane on Saturn derived from Voyager-IRIS observations in 1980 and Celeste (a cryogenic grating spectrometer, [7]) observations in 1994 were compared in [9]. Voyager observations of Jupiter have been compared with those from Cassini during the latter's 2000/2001 flyby [10]. Most recently, the evolution of Titan's thermal structure and chemical species from Cassini-CIRS observations have been compared with results from the Voyager flyby of Titan [1]. However, an intercomparison of Voyager and Cassini observations corresponding to the same season on Saturn remains to be conducted. In this study, we retrieve stratospheric properties from Voyager-IRIS observations in 1980 and Cassini-CIRS in 2009/2010 and compare the results.

2. Observations

Voyager-IRIS: IRIS observations of Saturn were obtained from both Voyager spacecraft though the interferometer of IRIS on Voyager 2 was misaligned during its Saturn flyby [5]. We have therefore omitted Voyager 2-IRIS observations from this study. Voyager 1-IRIS observations were sorted into 10° (planetographic) latitude bins, with a Nyquist overlap of 5° and the spectra were coadded together.

Cassini-CIRS: The November 2009 (50°S to 82°N) and December 2010 (82°S to 9°N) FIRMAP observations were chosen for comparison. Although FIRMAP observations represent the lowest spectral resolution offered by the Cassini-CIRS instrument ($\Delta\tilde{\nu}$ = 15.5 cm^{-1}), Voyager-IRIS and FIRMAP observations from Cassini-CIRS map the planet in a similar way and so latitudinal sampling and emission angles are comparable which is ideal. FIRMAPs were coadded into 10° latitude bins as described above for Voyager-IRIS observations.

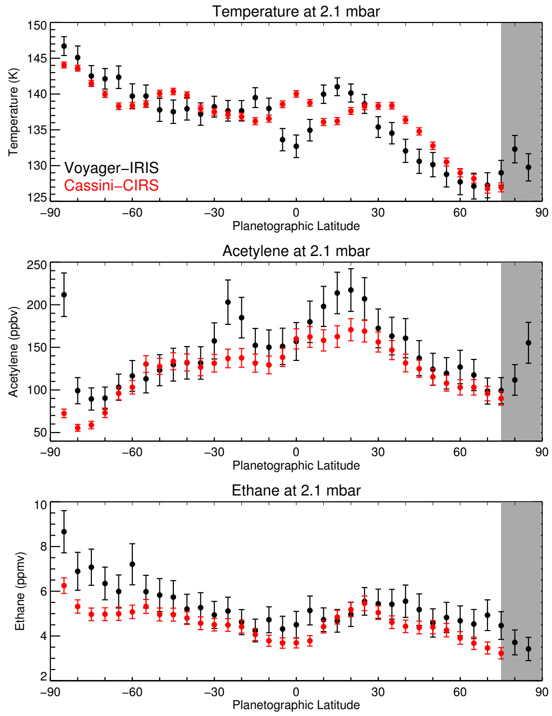

Figure 1: Preliminary retrieved results of temperature (top) and the concentrations of acetylene (middle) and ethane (bottom) at 2.1 mbar as a function of planetographic latitude from Voyager-IRIS observations in 1980 (black) and Cassini-CIRS observations in 2009/2010 (red). The shaded regions at high-northern latitudes indicate little confidence in these results due to low signal-to-noise.

3. Analysis

Atmospheric properties were retrieved using the NEMESIS radiative transfer and retrieval algorithm [6]. The vertical temperature profile was initially retrieved from the collision-induced spectrum of hydrogen (600 cm^{-1} to 680 cm^{-1}) and the methane ν_4 band 1230 cm^{-1} to 1380 cm^{-1} providing sensitivity to tropospheric and stratospheric temperatures, respectively. Adopting this temperature retrieval as the temperature profile, the concentrations of acetylene and ethane were then retrieved from their emission features at $\sim$730 cm^{-1} and $\sim$ 820 cm^{-1} respectively.

4. Preliminary Results

Figure 1 shows preliminary retrieved results of temperature and the concentrations of acetylene and ethane at $\sim$2 mbar where there is sensitivity in both sets of data. As shown, there are differences in temperature from 15°S to 15°N which represents the range of latitudes occupied by the SSAO [2]. The differences in temperature are puzzling since, by definition, the SSAO cycle should repeat every half year and so the same phase would be expected after one Saturn year. With the exception of high-southern latitudes, ethane's meridional distribution appears consistent between 1980 and 2009/2010. Acetylene exhibits higher concentrations at $\sim$25°S and $\sim$25°N in 1980 than in 2009. These latitudes mark the position of downwelling as a result of seasonally-varying Hadley circulation [3]. The richer concentrations of acetylene in 1980 imply that the downwelling was stronger at this time. Ethane does not exhibit a similar response which is perhaps because its vertical gradient in concentration is less than that of acetylene and thus is less sensitive to vertical motion [8].

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