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Seasonal and long-term variations in Titan's stratospheric chemical composition

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1. Context/Data

Ten years after Cassini's Saturn orbit insertion, we look at the evolution of the thermal and chemical composition of Titan's atmosphere by analyzing Cassini CIRS spectra. In particular, we use CIRS data from 2004-2013 to derive the temperature structure [1,2,7] and the neutral chemistry at latitudes between 50°S and 50°N [2]. A peak in abundance in the North was observed around the northern spring equinox (NSE), with a rapid decrease after mid-2009, indicating that the vortex has shrunk. The fulfillment of one Titanian year of space and ground-based observations in 2010 provided us for the first time with the opportunity to evaluate the relative role of different physical processes in the long-term evolution of this complex environment [2-7], as also reported by other studies [10, 11].

2. Methodology

We use a radiative transfer code (ARTT) that we apply to CIRS spectral averages corresponding to data from flybys of Titan until 2013, binned over 10° in latitude for both medium (2.5 cm^{-1}) and higher (0.5 cm^{-1}) resolutions mostly from nadir observations. In analyzing the spectra, we search for variations in temperature and composition at northern (around 50°N), equatorial and southern (around 50°S) latitudes. Our code uses the most recent spectroscopic databases.

3. Results

The haze and gaseous content in Titan's atmosphere has shown some significant and rapid evolution in the past couple of years as Titan has moved from Northern winter through Northern Spring Equinox (NSE, in mid-2009) to summer. The reverse is true for the Southern hemisphere. The gaseous and haze content of the atmosphere has exhibited new features marking these seasonal passes [8,9]. After inferring the haze component by adjusting the aerosol description for each latitudinal bin, we have been monitoring the molecules appearing in CIRS/FP3 looking for recent seasonal variations as the south polar region is now moving into winter.

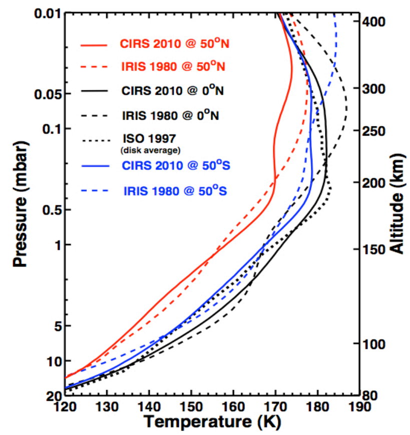

Figure 1. Retrieved thermal profiles from CIRS and V1/IRIS data (in full and dashed lines respectively) at 50°S, 50°N and equator for the 2010 nadir data and IRIS 1980 data. The CIRS temperature profiles correspond to April, July and January 2010 at 50°S, equator and 51°N respectively. The temperature profile corresponding to the ISO disk-averaged SWS data of 1997 is also shown in dotted black lines. From Coustenis et al. (2013).

We find significant changes for all the molecules included in the 600-720 cm^{-1} range (C_4H_2, C_3H_4, HC_3N, CO_2, C_6H_6, and HCN), as well as from the R-wing lines of the HCN and C_2H_2 bands. Within a 2-3 yr period in the South, strong factors of increase for C_4H_2 and C_3H_4 are observed, whereas 30-40% decreases are found for HCN and for CO_2. A rather stable situation with its "summer" abundance is observed for C_2H_2 and C_2H_6.

Most importantly, we witness the dramatic advent of HC_3N and C_6H_6, among the most short-lived and least abundant species after late 2011 and early 2012.

The HC3N disappearance in the North has happened some time between 2009 and 2010. Its appearance in the South is more recent, sometime in 2012, just as for the 220 cm-1 haze feature. All in all the HC3N distribution between North and South seems to have changed by 2 orders of magnitude in 2 years time. In addition, by fitting the continuum in FP3 and FP4 we show that the haze content does indeed decrease in the North while it increases in the South, remaining stable in the equatorial region.

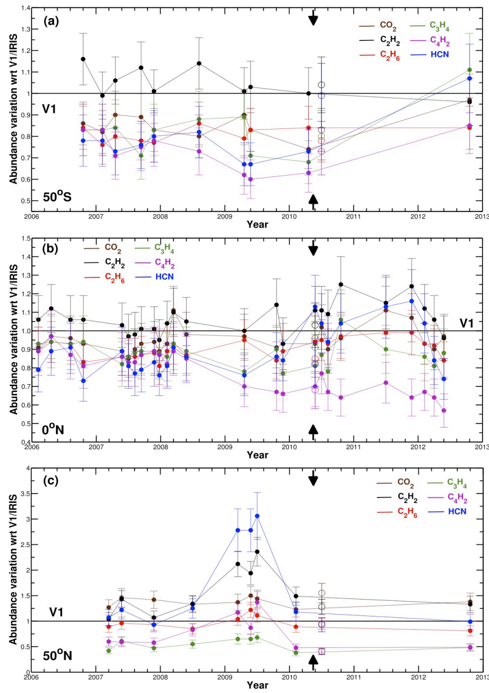

Figure 2: a) variations of the abundances of gases in Titan's stratosphere with respect to the V1/IRIS values at 50°S (normalized as 1) for: C2H2 (black), C2H6 (red), CO2 (brown), HCN (blue), C3H4 (green), C4H2 (magenta). The arrows indicate the date of the 1980 V1 encounter. Larger open circles correspond to medium-resolution (2.5 cm^{-1}) data that we have in 2010. b) : same as a) but for the equator. c) : same as a) but for 50°N. (adapted from Coustenis et al. 2013).

The recent enhancement in gases and haze at the South Pole is probably the result of the seasonal reversal of atmospheric circulation. While the situation at the equator seems stable, it needs monitoring at both poles.

Acknowledgements

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