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Titan's temporal evolution in stratospheric trace gases near the poles

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1. Context/Data

We analyze spectra acquired by the Cassini/Composite Infrared Spectrometer (CIRS) at high resolution from October 2010 until September 2014 in nadir mode. Up until mid 2012, Titan's Northern atmosphere exhibited the enriched chemical content found since the Voyager days (November 1980), with a peak around the Northern Spring Equinox (NSE) in 2009. Since then, we have observed the appearance at Titan's south pole of several trace species for the first time, such as HC_3N and C_6H_6, observed only at high northern latitudes before equinox. We investigate here latitudes poleward of 50°S and 50°N from 2010 (after the Southern Autumnal Equinox : SAE) until 2014.

2. Methodology

In this paper we extend previous work focusing on trace gases in Titan's stratosphere with emission signatures probing essentially the 100-400 km altitude range. We have been monitoring such emissions since the beginning of the Cassini mission in the focal plane 3 (FP3) of CIRS covering the spectral range from 600 to 1100 cm^{-1} (Coustenis et al., 2007, 2010, 2013; Bampasidis et al., 2012). Focal plane 4 (FP4) is used to extract the temperature profiles from the methane emission in the band centered at 1305 cm^{-1}. 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 warming in the North from February until September 2014 is about 6 K, whereas at about the same period of time, the South has become another 12-15 K colder in the stratosphere, totaling about a 40 K drop in temperature within 4 years since 2010. The temperature profiles at 70°S for the period in time from 2010 to 2012 are compatible with those found by Achterberg et al. (2008, 2011) and Vinatier et al. (2015) from limb-viewing observations in the stratospheric region that we probe here and show again a decrease in temperature by about 10 K (Fig. 1). Similarly, their mid-latitude southern and northern profiles, as well as the thermal profiles close to 70°N do not exhibit large variations, as also found here and with compatible trends.

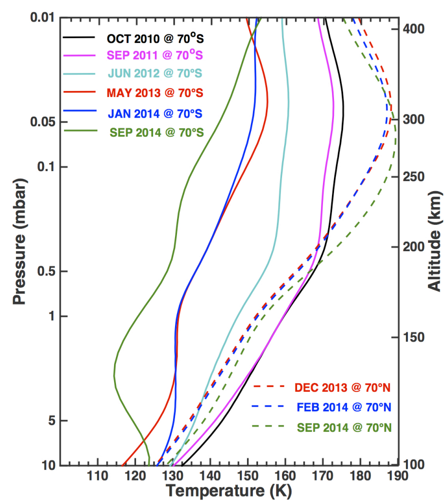

Figure 1: temperature variations in the South (From Coustenis et al., 2015)

For some of the most abundant and longest-lived hydrocarbons (C_2H_2, C_2H_6 and C_3H_8) and CO_2, the evolution in the past 4 years at a given latitude is not very significant within error bars especially until mid-2013. In more recent dates, these molecules show a trend for increase in the south. This trend is dramatically more pronounced for the other trace species, especially in 2013-2014, and at 70°S relative to 50°S. These two regions then demonstrate that they are subject to different dynamical processes in and out of the polar vortex region. For most species, we find higher abundances at 50°N compared to 50°S, with the exception of C_3H_8, CO_2, C_6H_6 and HC_3N, which arrive at similar mixing ratios after mid-2013.

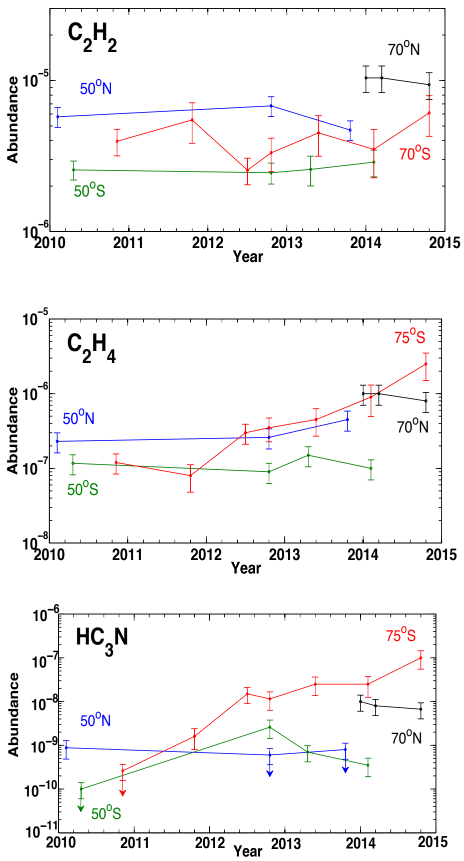

Figure 2: Examples of variations of the abundances of gases in Titan's stratosphere close to the south pole (adapted from Coustenis et al. 2015).

While the 70°N data show generally no change with a trend rather to a small decrease for most species within 2014, the 70°S results indicate a strong enhancement in trace stratospheric gases after 2012 (Fig. 2). The 663 cm^{-1} HC_3N and the C_6H_6 674 cm^{-1} emission bands appeared in late 2011/early 2012 in the south polar regions and have since then exhibited a dramatic increase in their abundances. At 70°S HC_3N, HCN and C_6H_6 have increased by 3 orders of magnitude over the past 3-4 years while other molecules, including C_2H_4, C_3H_4 and C_4H_2, have increased less sharply by 1-2 orders of magnitude). This is a strong indication of the rapid and sudden build-up of the gaseous inventory in the southern stratosphere during 2013-2014, as expected as the pole moves deeper into winter shadow. Subsidence gases that accumulate in the absence of ultraviolet sunlight, evidently increased quickly since 2012 and some of them may be responsible also for the reported haze decrease in the north and its appearance in the south at the same time (Jennings et al., 2012a,b).

The recent enhancement in gases and haze at the South Pole is probably the result of the seasonal reversal of atmospheric circulation (Teanby et al., 2012). While the situation at the equator seems stable, it needs monitoring at both poles.

Acknowledgements

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