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From Voyager 1/IRIS to Cassini/CIRS : how the neutral atmospheric chemistry has changed within a Titan year

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Abstract

Seven years after the Cassini's Saturnian orbit insertion, we are able to view Titan's stratospheric budget in the context of changing chemical composition. Indeed, by combining (a) Voyager/IRIS measurements from 1980, (b) Cassini/CIRS continuous recordings from 2004 to 2010 and (c) the intervening ground- and space- based observations, we have in hand almost a complete picture of the stratospheric evolution within a Titan year.

1. Introduction/context

We have probed Titan's stratosphere using the Cassini Composite Infrared Spectrometer (CIRS) to take nadir and limb spectra taken during the past 7 years, looking for temporal variations in temperature and composition, within the duration of the Cassini mission and with respect to the remote infrared measurements acquired during the Voyager encounter in 1980, exactly a Titan year ago today. Indeed, the Ls of about 9° corresponding to the V1 encounter is reached again in 2010.

2. Observations and analysis

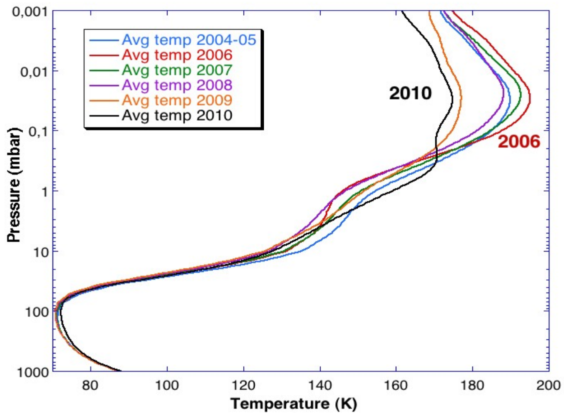
We have re-analyzed all the Voyager 1 /IRIS data from 1980 with the most recent spectroscopic data and using the radiative transfer code that was applied to the first V1 retrievals [2] and ISO inferences [3] as well as more recent Cassini spectra analyses [4,5]. The re-analysis shows that the V1 retrievals in 1995 were correct for all molecules and latitudes except for the species where the spectroscopic parameters have significantly changed (C_2H_4 and C_2H_6 in particular) recently.

Our method consists in applying this radiative transfer code to spectral averages binned over 10° in latitude for both medium (2.5 cm^{-1}) and higher (0.5 cm^{-1}) resolutions. Latitudinal variations were previously inferred in a number of works [4 - 9]. We look here for variations in temperature and composition as the season on Titan progresses.

We have thus formed one or more spectral selections within a given year in the FP3 and FP4 CIRS focal planes at northern, mid and southern latitudes. Where enough spectra were available we have extracted variations within a given month. In analyzing the spectra, we search for variations in temperature and composition at northern (around 50°N), equatorial and southern (around 50°S) latitudes.

3. Results

The temperature profiles are extracted from the best fit of the nu4 CH_4 emission band at 7.7 micron [1]. The different profiles are shown in Figure 1. In the northern hemisphere, in the stratosphere, we find a rather confused situation with, however, a trend for a decrease in temperature between earlier and recent years. The north polar region initially warmed up by ~4K throughout 2007, then began cooling. In the mesosphere, above 0.1 mbar, more sensitive to the seasonal insolation variations, the temperature shows a 20-25K decrease within the past few years from 2005 to 2010. North polar temperature changes suggest weakening of descending branch of meridional circulation. Subsidence at northern latitudes (descending branch of middle-atmosphere Hadley circulation) is weakening [1]. At mid and southern latitudes the stratospheric temperature variations are significantly smaller and the excursions are constrained within a few degrees.



The results show that the gases generally increase in abundance from 2004 to 2010 in the northern hemisphere and decrease or remain stable in the southern and mid-latitudes in agreement with some previous inferences [7]. We witness, however a very strong increase in the couple of past years, which will allow the enhancement in the north pole at the present time to reach the level observed at the Voyager time, at least for some molecules (Coustenis et al., 2011, in preparation).

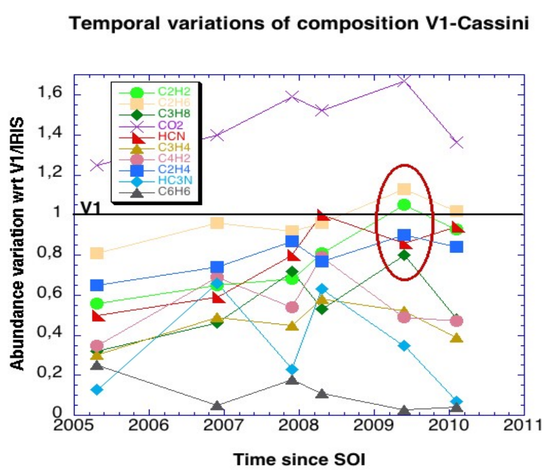


Figure 2 shows the variation with respect to the V1/IRIS abundances at 50°N. The calibration with respect to the 1980 data, indicates that since the beginning of the Cassini mission the abundances have increased for C2H6, C2H2, C2H4, C3H8, CO2 and HCN steadily up until 2009, reaching very close to the 1980 values. It would seem that in early 2010 we are witnessing a slight decrease in abundance with respect to Voyager for these species, but more data at later dates are needed to confirm such a tendency.

Other species, such as the complex hydrocarbons C3H4 and C4H2 present an abundance also increasing in time since SOI but falling short of the V1 values by about 60%. The weakest species like HC3N and C6H6 determinations show that they will not reach (by far) the values attained in 1980.

We will also be looking at limb CIRS data for variations during a Titan year and seek the chemical and dynamical interpretations that are more suitable to explain the data.

4. Comparison with ground-based and other abundance data

We also compare with the disk-average results from ISO (1997) and with ground-based data taken from Earth-based telescopes. This is work in progress and it will allow us to have a more precise and detailed description of the temporal variations within a Titan year.

5. Conclusion

With this study we seek to set constraints on seasonal, photochemical and circulation models and to make predictions as to the spatial variations of the chemical composition on Titan at a time when the season has finally become exactly the one of the Voyager encounter in 1980 and then move towards summer solstice in the north during the Cassini extended Solstice mission. Temporal changes of Titan's stratosphere will give us the ability to understand the significance of its atmospheric contribution to the function of the moon's system as a whole.

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