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A climatological study of the composition of Titan upper atmosphere from VIMS-IR soundings in limb geometry has been carried out for HCN, C_2H_2 and CH_4

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Abstract. A climatological study of the composition of Titan upper atmosphere from VIMS-IR soundings in limb geometry has been carried out for HCN, C_2H_2 and CH_4. The results of this study are here presented for the 2004-2012 period.

Key words. Titan climatology – non-LTE emission – Radiative transfer

1. Introduction

Ten years ago, on June 2004, NASA's Cassini spacecraft made its Saturn Orbit Insertion (SOI) for an initially scheduled four-year tour of the Saturnian system. At the end of the very successful prime mission all instruments and major spacecraft systems were healthy and NASA Headquarters allocated funding to extend Cassini mission initially for a 2-year period and successively until 2017. The unusually long extent of the Cassini mission has given to all the instrument teams the opportunity to extend their studies to cover an half season of the Saturnian system: short after the winter (SOI) until the summer solstice (end of mission).

In the Titan atmosphere above 500 km the mean free path of the molecules is small enough that their emissions due to non-Local Thermal Equilibrium (non-LTE) can be observed. Around 3 μm the HCN, C_2H_2 and CH_4 have strong transitions. Their non-LTE emissions can be used to retrieve the respective concentrations under daylight conditions. PAH (Polycyclic Aromatic Hydrocarbons) molecules, also emitting under the CH_4 R branch [5,6], resulted affected by a too much pronounced uncertainty to permit a possible estimation of their concentration variability with the time.

That IR range of wavelengths is sounded only by VIMS (Visible and Infrared Mapping Spectrometer) among the onboard Cassini instruments. VIMS observations in limb viewing have been used to study possible altitude and latitude variability of those molecules in thermosphere (500-1200 km) by their non-LTE emissions, possibly associated to the season changes.

2. Data management

A database of geo-located vertical distributions of radiances has been developed from a selection of VIMS limb observations for the 2004-2012 time period. The observations have been selected on the base of long integration times ($\geq$ 600 ms) and Solar Zenith Angle (SZA) lower than 90° [1,2]. Long integration times are a necessary condition to have large enough signal to noise (S/N) ratios and low SZA angle values help to prevent stray-light effects able to change the original spectral signal. In this sense, we have chosen only those observations with a high degree of saturation at the Titan's surface, a proxy for long exposure time. In Figure 1 the coverage for year and latitude of the constrained data is illustrated.

As can be seen from Figure 1, there have been many time periods and zonal regions without the favorable conditions of observations inside the constraint limits. This issue will influence the study conclusions.

3. Modeling

To evaluate the HCN, C_2H_2, CH_4 and PAH concentrations for each sounded altitude, the vibrational temperatures of that molecules have to be calculated and inserted in a radiative transfer (RT) model of the Titan atmosphere. By the RT inversion the required concentrations can be obtained from the measured spectral signals. The vibrational temperatures are computed by the Generic RAdiative traNsfer AnD non-LTE population Algorithm (GRANADA) non-LTE code [4], originally developed for the Earth's atmosphere, and adapted to the Titan's atmosphere [1,2]. The Titan's limb atmospheric emissions have been inverted with the Geofit Broad Band (GBB) radiative transfer code, originally designed for the Earths atmosphere. This code is the self-standing version of the forward model inside the Geofit Multi-Target Retrieval (GMTR) code [3], updated to perform simulations over broad frequency intervals using a line-by-line cross sections computation. Also GBB has been adapted to the Titan atmosphere, and upgraded for the VIMS instrumental characteristics and for the non-LTE formalism.

4. Results

The concentration profiles of HCN, C_2H_2 and CH_4 molecules have been calculated for each observation plotted in Figure 1, for altitude layers of 100 km starting from 500 km up to 1100 km. PAH molecule concentration is resulted to be affected by a too much pronounced uncertainty for evaluating its variability with the time. The other three molecules give some opportunity to examine the existence of a climatology. The single concentration profiles then have been elaborated by using different strategies pointing to emphasize possible relationships between concentration variability and season's time. In Figure 2 the volume mixing ratio (vmr) profiles for HCN, C_2H_2 and CH_4 molecules both for the pre-equinox (purple) and for the post-equinox (green) period are shown. Mean (triangle) and median (dot) values have been calculated to protect the statistical robustness of the result. Only median values are connected along the profile, and the error bars represent the esd of the average. This statistic has been computed for five latitude zones in the two hemispheres, covering high and middle latitudes in addition to the equatorial region.

As a general remark, we can say that extreme caution have to be used to interpret these results due to the large esd of the data in the majority of cases. Only HCN and CH_4 vmr at the lower altitude of the South Pole (SP) and North Pole (NP) regions, respectively, seem to show a sensible difference, not contaminated by uncertainties, between pre and post-equinox time: CH_4 appears to decrease at north while HCN to increase at south. In Figure 3 the data relative to the CH_4 and HCN vmr at NP and SP respectively are plotted year by year. There the molecule vmr are mapped for each year and for the same altitude layers of

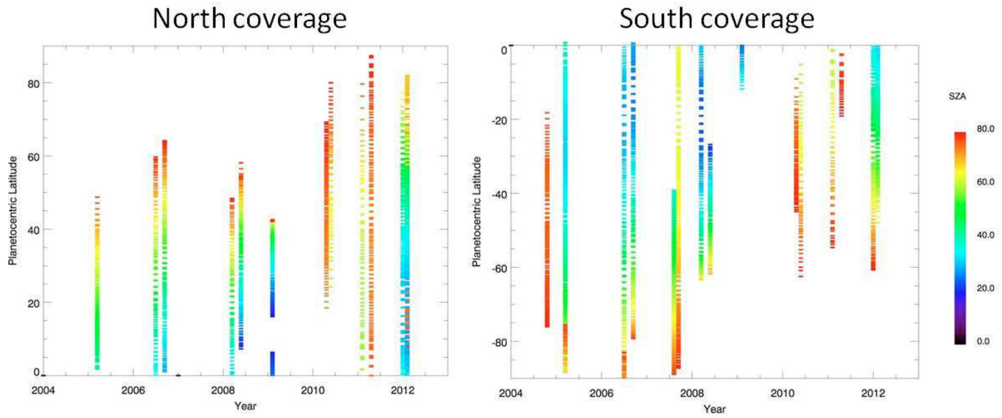

Fig. 1. The two above panels show the distribution in time and latitude - north at left, south at right - of the spectral pixels archived in the dataset setup to study the seasonal variability of the Titan upper atmosphere. All the pixels have been observed in limb geometry and their SZA dependence is expressed in the color scale at right of the plots.

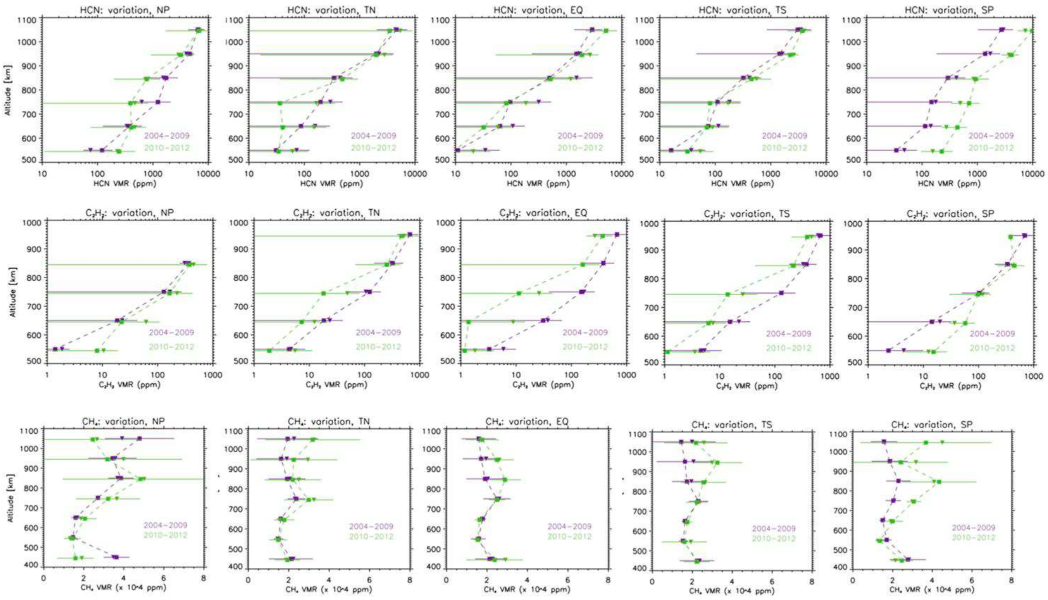

Fig. 2. In this figure the vmr profiles for HCN, C_2H_2 and CH_4 molecules are plotted for the pre-equinox (purple) and post-equinox (green) periods. The vmr profiles have been calculated for five latitude zones: 90-60N (NP), 60-20N (TN), 20N-20S (EQ), 60-20S (TS) and 90-60S (SP). The triangles and dots represent the time average and median values respectively, calculated on the 2004-2009 and 2010-2012 datasets. Horizontal error bars represent the esd of the time averages. Vmr profiles (dashed line) connect the median values, that generally are coincident with the time averages testifying the statistical robustness of the results.

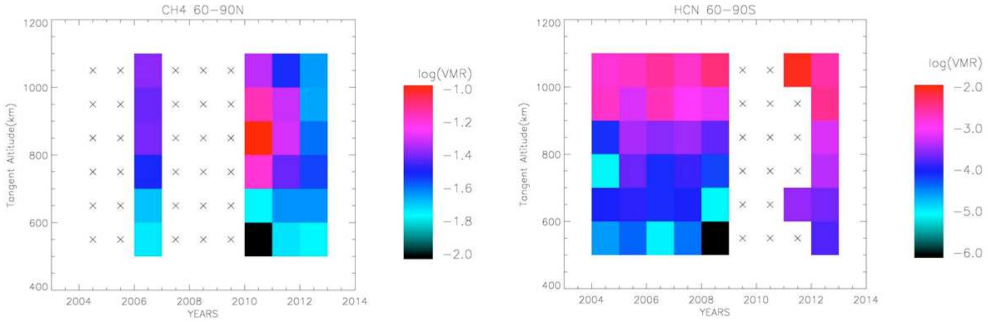

Fig. 3. In the above panels the altitude vs time maps of CH_4 at NP (left) and HCN at SP (right) are reported. The vmr yearly averaged are mapped in a colour logarithmic scale and the crosses indicate missing observations or uncertain retrieval result. The CH_4 map points out a sudden increasing and a drop at the middle and lower altitudes of the vmr after the equinox. But the scarcity of data discourages any interpretation. The HCN map shows a quite regular distribution of the vmr increasing with altitude before the equinox, but for the lower layer where irregular values succeed until a drop to equinox. After a series of missing observations, a new regular HCN distribution looks to begin with vmr values greater than one order of magnitude respect to the pre-equinox period.

Figure 2. The vmr yearly averages are mapped in a colour logarithmic scale and the crosses indicate missing observations or uncertain retrieval result. This second kind of visual model points out that the CH_4 decreasing at NP is a false positive due to the insufficiency of measurements, but the HCN increasing at SP is confirmed. It should be remembered that the lower altitude sounded by VIMS roughly corresponds to the interface with the lower atmosphere, where general Titan circulation develops. Seasonal variations could be there induced by a coupling with the seasonal circulation or the chemical reactions associated to the insolation change. Really HCN increasing at SP agrees with CIRS findings for the same altitude [7].

5. Conclusions

The preliminary results of the study on the HCN, C_2H_2 and CH_4 seasonal variations in Titan upper atmosphere for the 2004-2012 period do not give indications of a seasonal impact for altitudes greater than 600 km. Episodic variations at higher altitudes between pre and post equinox time are not completely reliable due to the large uncertainties linked to the scarcity of observations or insufficient information for the retrieval procedure. Some possible seasonal impact can be found for the HCN concentration at SP in the 500-600 km layer, where our results are consistent with the nitriles enriching inside the polar vortex revealed by the CIRS measurements [7]. Further work is necessary to widen the present dataset and to increase the data reliability. Moreover the last years' VIMS acquisitions have to be still analyzed.

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