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Climatological study in the Titan upper atmosphere for HCN, C_2H_2 and CH_4 gas concentration

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Abstract

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

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 upper atmosphere above 500 km the mean free path of the molecules is small enough that their emissions in non Local Thermal Equilibrium (non-LTE) can be observed. Around 3 μm the HCN, C_2H_2 and CH_4 gas molecules have strong energy level transitions and their non-LTE emissions can be used to retrieve the respective volume concentrations under daylight conditions. The Visible and Infrared Mapping Spectrometer (VIMS) is the only instrument aboard Cassini sounding that IR range of wavelengths.
In this work the latitudinal and seasonal variability of HCN, C_2H_2 and CH_4 molecule concentrations in thermosphere (500-1200 km) are investigated through their non-LTE emission spectral features.

2. Observations

A database of geo-located and time resolved vertical distributions of the gases in lower thermosphere has been developed from a selection of VIMS limb observations, reported in Table 1, for the 2004-2012 lapse time. The observations have been selected on the base of long integration times (≥600 ms) and phase angles lower than 90° [1,2].

3. non-LTE modelling

To calculate the HCN, C_2H_2 and CH_4 vibrational temperatures the Generic RAdiative traNsfer AnD non-LTE population Algorithm (GRANADA) non-LTE code [3] has been adapted to Titan's atmosphere [1,2].
That model was originally developed for the Earth's atmosphere and uses a generalized scheme for inclusion of radiative and collisional processes for calculating the populations of any specified molecule. The line-by-line radiative transfer calculations within GRANADA are performed with the Karlsruhe Optimized and Precise Radiative transfer Algorithm (KOPRA) [4].

Table 1: Cassini/VIMS observations for the 2004-2012 climatology

YEAR	FLYBY	Phase (°)	Ls (°)
2004	TA	13.3	297.2
2005	T4	57.0	303
2006	T15	60.6	319.8
	T17	63.0	322.3
2007	T34	60	333.7
	T35	26	335.2
2008	T41	66	341.4
	T44	95	344.8
		89	344.8
2009	T50	70	353.6
2010	T67	15	8.1
	T69	18	8.1
		31	10.1
2011	T74	31	18.7
	T75	16	20.6
2012	T80	58	29.1
	T81	22	30
		61	30.6

4. Measurements analysis and abundance retrieval.

Titan's limb atmospheric emission has been simulated in the retrieval with the Geofit Broad Band (GBB) radiative transfer code, adapted to Titan atmosphere, upgraded for VIMS instrumental characteristics and introducing the possibility to compute the limb radiance in non-LTE. This forward model has been included in a retrieval code that exploits the technical estimation technique [4] to retrieve the volume mixing ratios (vmr) from the VIMS limb radiances. More details on the used algorithms can be found in [2]. Starting from the retrieved single vmr profile, from each single spectra profile, a study on the latitudinal and seasonal variability of HCN, C_2H_2 and CH_4 molecules has been carried out, whose results are here shown.

5. Summary and Conclusions

Eight years of Cassini/VIMS observations have been analyzed to investigate the seasonal variability of HCN, C_2H_2 and CH_4 molecule concentrations in Titan's thermosphere (500-1200 km) through their non-LTE emission spectral features. Future developments foresee the extension of this study to CO and CH_3D molecules.

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