SF2A 2006
D. Barret, F. Casoli, T. Contini, G. Lagache, A. Lecavelier, and L. Pagani (eds)

COMPARISON OF TEMPERATURE AND ABUNDANCE VERTICAL PROFILES OF TITAN BETWEEN THE EQUATOR AND THE NORTH POLE AS RETRIEVED FROM CASSINI/CIRS LIMB SPECTRA

S. Vinatier[1], B. Bézard[1] and The CIRS Investigation Team

Abstract. We present an analysis of two sets of Titan limb spectra recorded by the Composite Infrared Spectrometer (CIRS) aboard Cassini between 100 and 1400 cm^{-1}. The first set of spectra was recorded near the equator (15°S) and the second set near the north pole (80°N). The geometry of limb observations allows the retrieval of vertically-resolved information on temperature and abundance of compounds displaying a good signal-to-noise ratio such as C_2H_2, C_2H_6, C_4H_2, CH_3C_2H, C_3H_8, C_2H_4, C_6H_6, HCN, HC_3N and CO_2. At 15°S, the limb spectra probe the 250-460 km range, and by using a set of nadir spectra acquired at 10°S, we were able to retrieve profiles at lower levels in the range 150-250 km. At 80°N, vertical profiles were retrieved between 170 and 500 km using limb spectra only.

Emission intensities of molecular bands depend on both temperature and abundance profiles. Temperature was deduced from the emission of the ν_4 methane band centered at 1305 cm^{-1} (7.7 μm), using an inversion algorithm of the radiative transfer equation combining both nadir and limb spectra. The retrieved thermal profiles were then used to model the observed spectra in the range 600-1000 cm^{-1}. An inversion algorithm combining both nadir and limb spectra permits the retrieval of the vertical mixing ratio profile of molecules mentioned above. We present here the temperature profiles and the mixing ratio profiles obtained at the two latitudes and discuss the observed differences.

1 Introduction

The instrument CIRS (Composite InfraRed Spectrometer) aboard Cassini records spectra of Titan in the 10-1400 cm^{-1} range (7μm-1mm) with a spectral resolution as high as 0.5 cm^{-1}. This spectral range displays a lot of emission bands of hydrocarbons, nitriles and oxygen compounds created by the complex chemistry of Titan.

CIRS includes 3 focal planes (FP1, FP3 and FP4). FP1, composed of one detector, acquires spectra in the range 10-600 cm^{-1}, with a field of view of 3.9 mrad. FP3 and FP4 are each composed of a linear array of 10 detectors (0.273-mrad field of view each) and cover the ranges 600-1100 cm^{-1} and 1100-1400 cm^{-1} respectively. In a limb geometry observation, each detector of FP3 and FP4 probes a particular level in Titan's atmosphere.

This work is based on the study of limb spectra acquired by FP3 and FP4 at 15°S during the Tb flyby (December 2004) and 80°N during the T3 flyby (February 2005), with a spectral resolution of 0.5 cm^{-1}. We also use nadir observations at 10°S in order to probe lower levels than those probed by limb measurements.

2 Vertical temperature profile retrievals

Emission band intensity depends on both temperature and molecular abundances. The determination of the vertical abundance profile requires the knowledge of the temperature profile. This latter is determined by using the intensity of the ν_4 methane (CH_4) emission band at 1305 cm^{-1} (7.7 μm) at several altitudes, and by assuming that the CH_4 abundance is constant in the whole stratosphere and equal to 1.6 %, as inferred from the CIRS data (Flasar et al. 2005). An inversion algorithm of the radiative transfer equation combining both nadir and limb spectra is used to retrieve the vertical temperature profile.

Figure 1 shows some examples of the modeling of limb spectra in the ν_4 CH_4 band (left panel), the retrieved temperature profiles (right panel) at 13°S (solid line) and 80°N (dot-dashed line).

[1] LESIA, Observatoire de Paris-Meudon

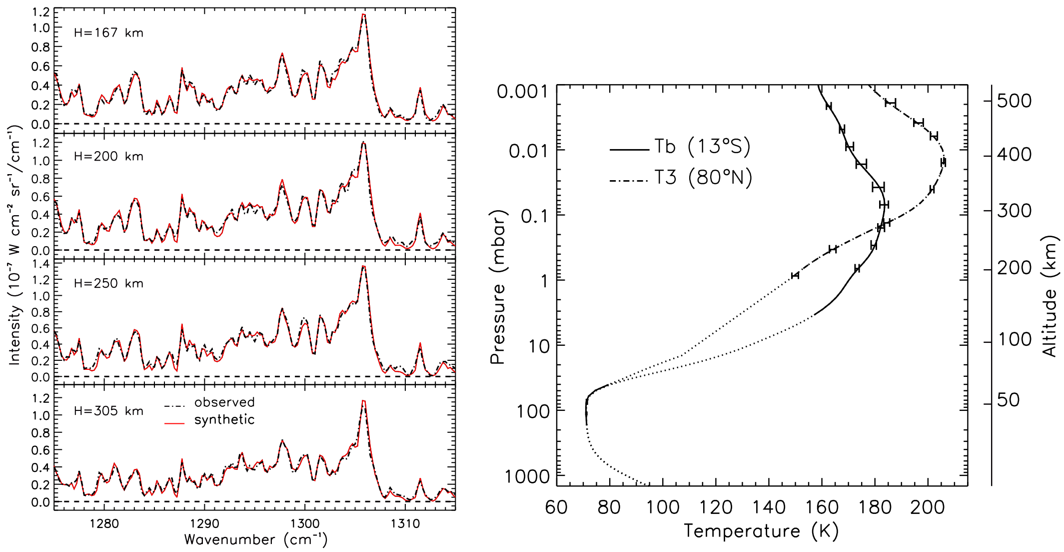

Fig. 1. Left: Fit of the ν_4 CH_4 band at 80°N for 4 limb spectra at 167, 200, 250 and 305 km. Right: Temperature profiles retrieved at 13°S (solid line) and 80°N (dot-dashed line). Parts of the profiles in dotted lines are equal to the initial temperature profiles given as inputs of the inversion algorithm.

3 Mixing ratio profile retrievals

The retrieved thermal profile is then used to model observed spectra in the range 600-1000 cm^{-1}. An inversion algorithm combining both nadir and limb spectra is used to retrieve the vertical mixing ratio profiles of the molecules we consider. Figure 2 displays examples of fits of observed spectra in the range 705-850 cm^{-1}, in which the bands of HCN, C_2H_2, C_3H_8 and C_2H_6 are detectable.

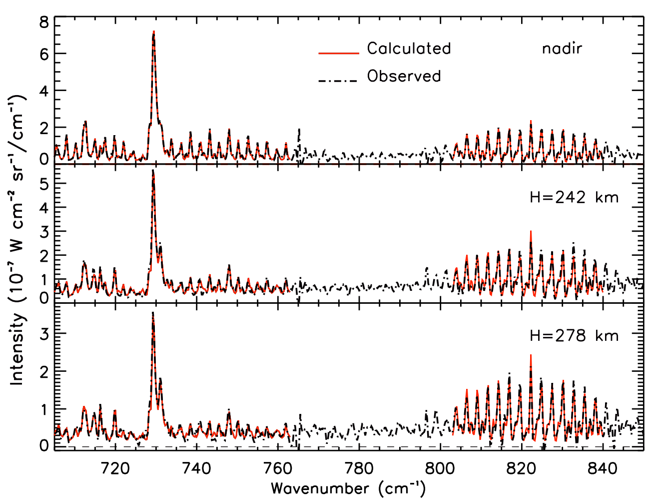

Fig. 2. Examples of fits of observed spectra at 15°S for the nadir and 2 limb spectra at 242 et 278 km. This spectral range displays emission bands of HCN (713 cm^{-1}), C_2H_2 (729 cm^{-1}), C_3H_8 (748 cm^{-1}) and C_2H_6 (822 cm^{-1}).

4 Retrieved mixing ratio profiles

Retrieved mixing ratio profiles of C_2H_2, HCN, C_3H_8 and C_2H_6 are plotted in Fig. 3. Figure 4 displays vertical profiles of C_4H_2, CH_3C_2H and C_2H_4, while in Fig. 5 are plotted the profiles of CO_2, HC_3N and C_6H_6. For all these figures, the left panel corresponds to the latitude 15°S and the right panel to 80°N.

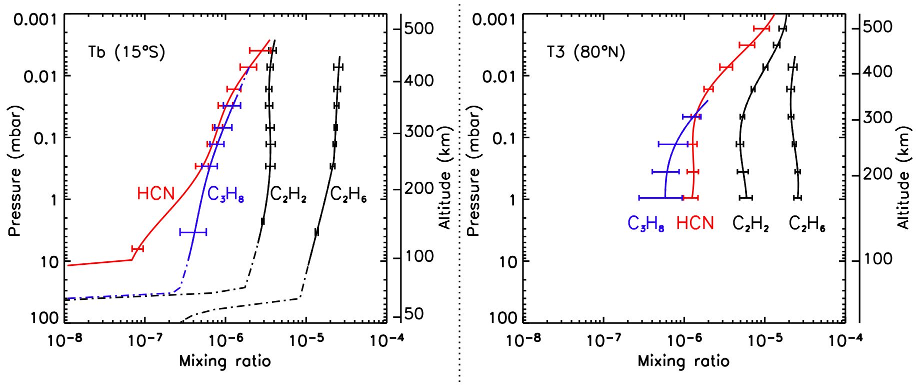

Fig. 3. Abundance profiles of HCN, C_2H_2, C_3H_8 et C_2H_6 at 15°S (left) and 80°N (right). These molecules are enriched at 80°N.

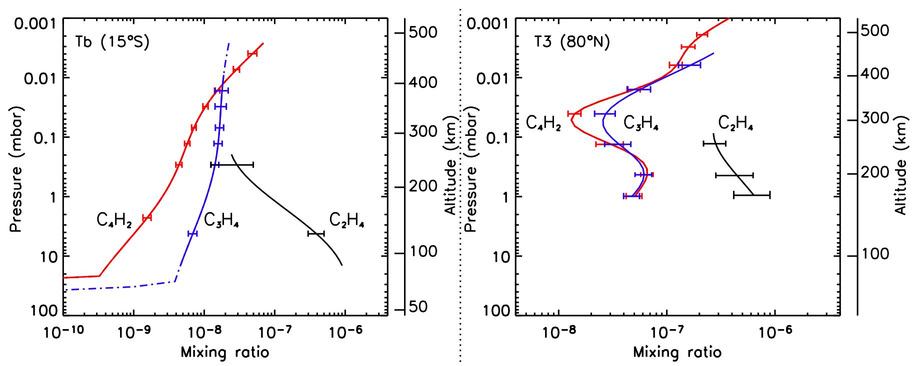

Fig. 4. Abundance profiles of C_4H_2, CH_3C_2H et C_2H_4 at 15°S (left) and 80°N (right). The decreasing-with-height profile of C_2H_4 at 15°S and the abundance minima around 0.07 mbar (300 km) observed for the three molecules at 80°N are not predicted by photochemical models.

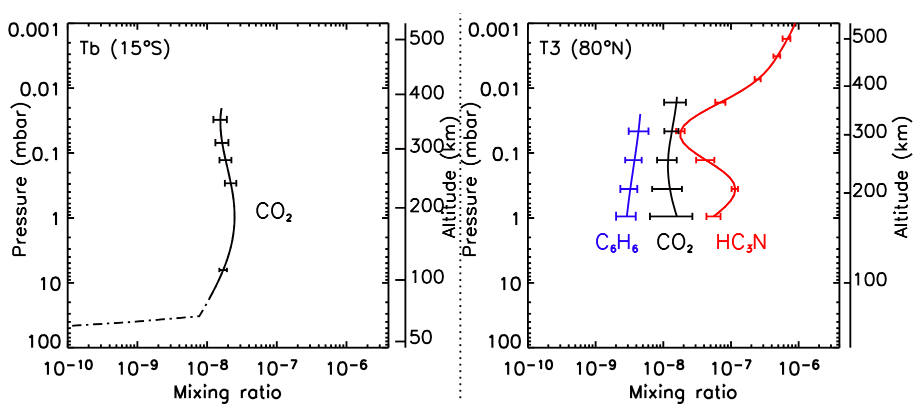

Fig. 5. Abundance profiles of CO_2 at 15°S (left) and C_6H_6, HC_3N and CO_2 at 80°N (right). HC_3N shows also a mixing ratio minimum at 80°N around 0.07 mbar.

5 Conclusions

5.1 Temperature profiles

At 80°N, stratopause is situated at 383 km with a temperature of 207 K, and at 15°S, it is located at 312 km with a temperature of 183 K (Fig. 1, right panel). The north pole of Titan is currently situated in the polar night, which explains the low temperatures in the stratosphere. The mesosphere at 80°N is probably warmed by adiabatic compression of air parcels that results from the subsidence of air predicted at the winter pole by General Circulation Models (e.g. Lebonnois et al. 2001)

5.2 Abundance profiles

Abundances of HCN, C_2H_2, C_2H_6 and C_3H_8 (Fig. 3) increase with altitude at 15°S and 80°N because of their formation in the upper atmosphere of Titan, as predicted by photochemical models. At 15°S, HCN displays a stronger vertical gradient than C_2H_6 (these two molecules are a priori chemically stable in the stratosphere), which suggests the existence of a stratospheric sink for HCN that is not predicted by models (Vinatier et al. 2006) and that could be connected to haze formation (Lara et al. 1999).

The C_2H_4 mixing ratio decreases with altitude at 15°S and shows a minimum of its abundance at 80°N around 0.07 mbar (Fig. 4). This minimum is also observed for C_4H_2, CH_3C_2H and HC_3N. This pattern is probably not connected to dynamics because it would affect all molecules at 80°N. Moreover, the molecules that exhibit these mixing ratio minima have chemical lifetimes much shorter than those of other molecules studied here (except C_6H_6) (Wilson and Atreya 2004), which suggests that the origin of these abundance minima are related to chemistry.

5.3 South-North enrichment

The south-to-north enrichment is more or less pronounced for the different molecules. It is in agreement with predictions of General Circulation Models that indicate downwelling at the winter pole (the north pole here), which brings air enriched in photochemical compounds from the upper layers of the atmosphere where they are formed to the stratosphere.

References

Flasar, et al. 2005, Science, 308, 975

Lara, et al. 1999, A&A, 341, 312

Lebonnois, et al. 2001, Icarus 152, 384

Vinatier, et al. 2006, Icarus, in press

Wilson, & Atreya 2004, JGR, 109, E06002