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Seasonal changes in Saturn's stratosphere from Cassini/CIRS observations

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Abstract

In this study we present analysis of limb observations of Saturn's stratosphere acquired by Cassini/CIRS (Composite InfraRed Spectrometer) in 2010 and 2012. We measure the temperature and the abundances of ethane, acetylene and propane in the northern and the southern hemispheres. We also compare these results with those from previous observations performed between December 2005 and May 2007 in order to infer the evolution of Saturn's stratosphere from northern winter to spring.

1. Introduction

Seasonal variations of insolation are pronounced on Saturn because of its obliquity (26.7°) and of the shadows of its rings above the winter hemisphere. Hence, measurable changes are expected in Saturn's thermal structure, large scale dynamics and photochemistry.

The atmosphere of Saturn has been monitored since 2004 thanks to the Cassini spacecraft allowing to follow its thermal evolution through a season change. Fletcher et al. (2010) studied the seasonal change in the upper troposphere and the lower stratosphere between 2004 and 2009 (from northern winter to spring equinox) with Cassini/CIRS (Composite InfraRed Spectrometer) nadir observations and showed a warming of the northern stratosphere as it was emerging from the shadow of the rings and a cooling of southern mid-latitudes.

Measurements of hydrocarbons abundances such as ethane (C_2H_6) or acetylene (C_2H_2) can also give insights on seasonal variations. Limb observations performed in 2005 and 2006 with Cassini/CIRS (Guerlet et al., 2009) revealed that at 1 hPa, the meridional distribution of C_2H_6 was homogeneous whereas C_2H_2 was decreasing from equator to pole. This behaviour was not predicted by photochemical models such as Moses et al. (2005) and suggests a meridional transport affecting the distribution of C_2H_6.

In order to improve our knowledge of seasonal variations in Saturn's atmosphere, we analyse limb spectra acquired by Cassini/CIRS in 2010 ($L_s = 12°$) and 2012 ($L_s = 31°$) during spring in the north hemisphere to retrieve temperature and hydrocarbons abundances. We compare them to previous limb observations performed in 2005, 2006 and 2007 (from $L_s = 312°$ to $L_s = 331°$) during winter (Guerlet et al., 2009). We investigate the radiative contribution in the thermal seasonal evolution by the comparison between these results and our radiative-convective model (Guerlet et al., 2014, subm.). The retrieved hydrocarbons abundances are also compared to the photochemical model of Moses et al. (2005) to constrain large scale dynamics.

2 Observations and data analysis

In this study, we used two channels of the Cassini/CIRS spectrometer. The FP3 channel measures spectra from $9\,\mu m$ to $17\,\mu m$ and allows us to probe the abundances of C_2H_6, C_2H_2 and C_3H_8 and also the temperature in the lower stratosphere thanks to the H_2 collisions induced emission. The FP4 channel measures spectra from $7\,\mu m$ to $9\,\mu m$ and is sensitive to the ν_4 CH_4 emission band which probes temperature in the middle stratosphere. Our observations span latitudes from $70°S$ to $79°N$. Limb observations are sensitive to pressure levels from 30 hPa to 0.01 hPa with a vertical resolution of $\sim$ 1.5 times the scale height. Hence, they allow us to probe the vertical and meridional structure of Saturn's atmosphere.

The temperature and hydrocarbons abundances profiles are retrieved using a forward radiative transfer model coupled to a constrained and regularised linear inversion method. A detailed description of this algorithm is available in Guerlet et al. (2009).

3 Results

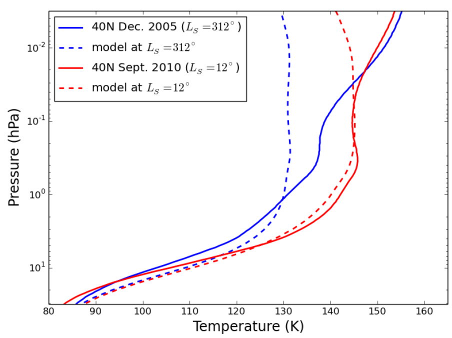

Figure 1: Temperature profiles at $40°N$ in December 2005 and September 2010. Solid lines represent the retrieved profiles from CIRS measurements whereas dashed lines represent the predicted profiles by our radiative-convective model (Guerlet et al., 2014, subm.). Blue is for winter and red for spring.

Figure 1 shows that from winter to spring, the stratospheric temperature has increased but not with the same amplitude at each altitude. The seasonal contrast is maximum at 1 hPa then it decreases with the altitude and even vanishes at 0.3 hPa. This behaviour is not predicted by our radiative-convective model. In the model, the temperature difference between winter and spring is quite stable between 0.4 hPa and 0.01 hPa. The stratosphere at $40°N$ is also warmer in winter than predicted by the model whereas the spring temperature is well reproduced until 0.2 hPa. Hence, simple radiative heating and cooling by atmospheric minor components is not sufficient to explain the seasonal evolution of temperature in winter.

On fig. 2, we can see that the C_2H_6 meridional distribution at 1 hPa has not changed from winter to spring. Its measured distribution is also quite homogeneous within errorbars whereas the predicted distribution shows a clear decrease from equator to pole. These measurements are consistent with those of Guerlet et al. (2009). Indeed at this altitude, the C_2H_6 abundance is not expected to evolve as the

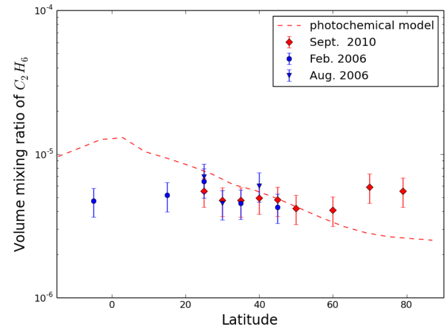

Figure 2: Meridional distribution of C_2H_6 at 1 hPa. CIRS measurements are represented by the red diamonds for spring and by the blue circles and triangles for winter. The dashed line is for the meridional distribution computed by the photochemical model of Moses et al. (2005). It is the same for the two observations times.

C_2H_6 photochemical timescale ($\simeq$ 600 years, Moses et al. (2005)) is much longer that a Saturn's year (29.5 years). These measurements strengthen the assumption of a meridional transport diverting the ethane distribution from a distribution following the yearly average insolation.

We will present the measurements of temperature and hydrocarbons abundances of 2010 and 2012 at all the latitudes between 1 hPa and 0.01 hPa and their comparison to the previous data of 2005 and 2006. This will give us a global point of view of the evolution of the meridional and vertical structure of Saturn's stratosphere. The comparison between the observations and the models will allow us to explore possible explanations of the behaviour of Saturn's atmosphere in response to the seasonal insolation variations.

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