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Seasonal temperature variations in Saturn's stratosphere

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Abstract

Here, we present limb observations of Saturn's atmosphere acquired by Cassini/CIRS (Composite InfraRed Spectrometer) in 2010. The analysis of these data allows us to investigate the thermal structure of the stratosphere of this planet. We also compare these latest results with those from previous observations to infer the seasonal variations of temperature in this planet, between March 2005 (winter in northern hemisphere) and September 2010 (spring in the same hemisphere).

1. Introduction

Due to the tilt of its rotational axis (26.7°), Saturn undergoes large seasonal variations in solar energy deposition during its orbit. These variations lead to measurable changes in Saturn's atmospheric heating and large scale dynamics.

The observations performed with the Cassini spacecraft since 2004 allowed us to study more precisely Saturn's atmosphere and to reveal some phenomena which were not foreseen by the radiative models. Indeed, in [1], the authors observed a temperature and zonal wind equatorial oscillation in 2005 and 2006. This structure, confined between $20°N$ and $20°S$ and composed of alternating temperature anomalies and alternating eastward/westward winds, propagates downward with a period of 14.7 ± 0.9 terrestrial years and is very similar to Earth's quasi-biennal oscillations (QBO) or to Jupiter's quasi-quadriennal oscillations (QQO). On those two planets, these oscillations are triggered by interactions between the mean zonal flow and upwardly propagating waves. Hence this suggests that the Saturn's equatorial oscillation has a dynamical origin. In the same article, the authors determined a similar cooling rate of $0.2\,K/day$ in both hemispheres whereas the winter hemisphere was under the shadow of the rings. This requires a season independant heat source (unlikely) or a meridional heat redistribution.

In order to extend our knowledge of seasonal variations in Saturn's atmosphere, we analysed limb spectra acquired by the Cassini/CIRS (Composite InfraRed Spectrometer) in September 2010, a few months after the spring equinox in the northern hemisphere ($L_S = 12°$), between the latitudes $24°N$ and $80°N$. We compared them to previous limb observations between March 2005 and August 2006 ($L_s = 300°$ to $L_s = 319°$) during the winter in northern hemisphere, analysed in [2].

2. 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 is sensitive to the emission induced by the collisions between H_2 and He which probes temperature in the lower stratosphere. The FP4 channel measures spectra from $7\,\mu m$ to $9\,\mu m$ and is sensitive to a CH_4 emission band which probes temperature in the middle stratosphere. For each latitude observed, we have spectra measured at different altitudes. This kind of observations is a good way to investigate the vertical structure of the atmosphere as we can get a vertical resolution of ~ 1.5 times the scale height and probe the atmosphere from $2 \times 10^{-2}\,bar$ to $10^{-6}\,bar$.

To retrieve the temperature profiles at the different observed latitudes, we use a forward radiative transfer model to compute synthetic spectra from an *a priori* temperature profile. This provides a fit of the data. The adjustement of the data by the forward model is obtained using a constrained and regularised linear inversion method until the variation of χ^2 between two iterations reaches less than 1%. A detailed description of this algorithm is avalaible in [2].

3. Results

Figure 1 shows the temperature profile retrieved at $30°N$ from the observations in September 2010 (in

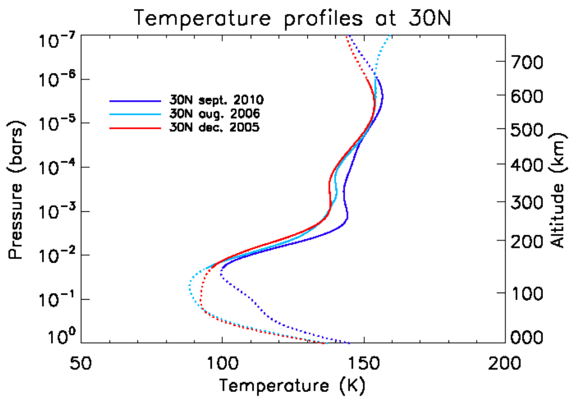

Figure 1: Temperature profiles at $30° N$ from December 2005 to September 2010 - The solid lines represent the parts of the profiles where the atmosphere is probed whereas the dotted lines are the parts of the profiles which are not constrained by the observations.

blue) compared to temperature profiles from previous observations in August 2006 (in light blue) and December 2005 (in red). We can see a global warming of the atmosphere as the blue profile was measured in spring whereas the other ones were measured during winter. Nevertheless, the amplitude of this warming increases with altitude in the low stratosphere and then decreases in the middle and high stratosphere. Just above the tropopause, at $10^{-2}\,bar$ there is a difference of $6\,K$ between the profiles of December 2005 and September 2010. The difference between those profiles is maximal at $1.5 \times 10^{-3}\,bar$ where it is equal to $12\,K$. Then this difference decreases and even vanishes at $10^{-5}\,bar$. This behaviour is quite unexpected. Indeed, as the thermal inertia of the atmosphere decreases with height, the warming amplitude should increase with height. It seems that radiative processes are not sufficient to explain this phenomenon.

We will present all the temperature profiles retrieved from the observations of September 2010 and compare them to the previous observations. This will provide us a global point of view of the evolution from winter to spring of Saturn's atmosphere in the northern hemisphere and allow us to deal with this analysis in depth. In order to better interpret the Cassini/CIRS observations, our team is currently developping a GCM (Global Climate Model) for Saturn. Our goal is to compare our observations to this model and to look for an explanation of the behaviour of Saturn's atmosphere in response to the seasonal insolation variations (*Spiga et al.*, this issue).

References

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