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Evolution of the equatorial oscillation in Saturn's stratosphere

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Abstract

We present a new temperature map obtained from an analysis of Cassini/CIRS (Composite Infrared Spectrometer) spectra acquired in limb geometry in February 2010. We compare this map to that obtained from 2005 and 2006 data. We find a drastic cooling (21K) of the stratosphere around the 1-mbar level between the two dates that cannot be explained by a seasonal effect. We also show that the equatorial oscillation has moved downward by 1–1.5 scale height in 4.2 years.

1. Introduction

An equatorial oscillation has been recently discovered in Saturn's stratosphere from an analysis of 2005 and 2006 Cassini/CIRS limb data [1] and from long-term ground-based observations [3]. This oscillation is characterized by a succession of local minima and maxima of temperature in the vertical direction at the equator but also at 15-20° of latitude, where the extrema of temperature are anti-correlated with those at the equator. This oscillation in temperature is associated to a vertical oscillation in the zonal wind profile at the equator, where the wind regime alternates between westwards and eastwards jets. This structure is analogous to the Earth Quasi-Biennal Oscillation (QBO).

Here we present new results from an analysis of recent Cassini/CIRS limb data that allow us to study the temporal evolution of the vertical and meridional structure of this oscillation.

2. Observations and method

The CIRS instrument is an infrared spectrometer onboard the Cassini spacecraft, comprising three focal planes (FP1, FP3 and FP4). We use spectra acquired by FP3 and FP4 that cover the spectral region 600–1400 cm^{-1}. Both these focal planes consist of a linear array of 10 square detectors, with an individual field of view of 0.273 mrad. In limb geometry, these arrays are set perpendicular to the limb of the planet, so that each detector probes a different altitude with a vertical resolution of about 1.5 atmospheric scale height.

This extensive vertical information allows us to retrieve vertical profiles of the temperature. In order to do this, we use a line-by-line radiative transfer model coupled to a retrieval algorithm described in [2]. The ν_4 methane band centered at 1305 cm^{-1} provides information about the stratospheric temperature between 1 mbar and 1μbar, while the collision-induced continuum between 600 and 660 cm^{-1} is sensitive to the temperature between 20 and 1 mbar. These profiles are retrieved at 9 latitudes between 20°N and 20°S, every 5°, from a limb dataset acquired in Feb. 2010.

3. Results

The resulting temperature map is shown in figure 1.

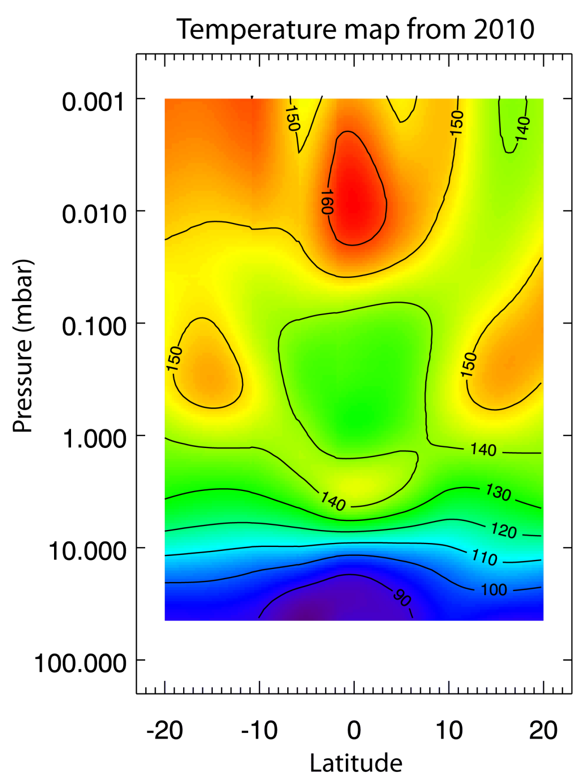

Figure 1: Temperature map obtained from an analysis of limb data acquired by Cassini/CIRS in February 2010.

The oscillation in temperature is clearly visible, with a minimal equatorial temperature of ∼130 K centered at 0.4 mbar located between two maxima of temperature at 3 mbar (145 K) and 0.01 mbar (165 K). The equatorial minimum of temperature is also surrounded by two local maxima centered at 15° of latitude (∼155 K).

To illustrate the temporal changes between 2005 and 2010, we compare in figure 2 the temperature profile obtained at 1°S (2010) to the profile we previously obtained at 2°N (2005). The temperature change is the strongest around 1 mbar, where the atmosphere has cooled down by 21K in 4.2 years. This large temporal change cannot be explained by a seasonal effect, as the solar insolation has not varied significantly between 2005 and 2010 in the equatorial region. In addition, if this cooling at 1 mbar was caused by a seasonal effect, the upper stratosphere in 2010 would also exhibit a lower temperature than in 2005, which is not observed. We thus attribute the largest changes in temperature to a dynamical effect linked to the evolution of the oscillation.

Finally, this figure also shows that the location of the extrema of temperature has moved down by 1 to 1.5 scale height between the two dates.

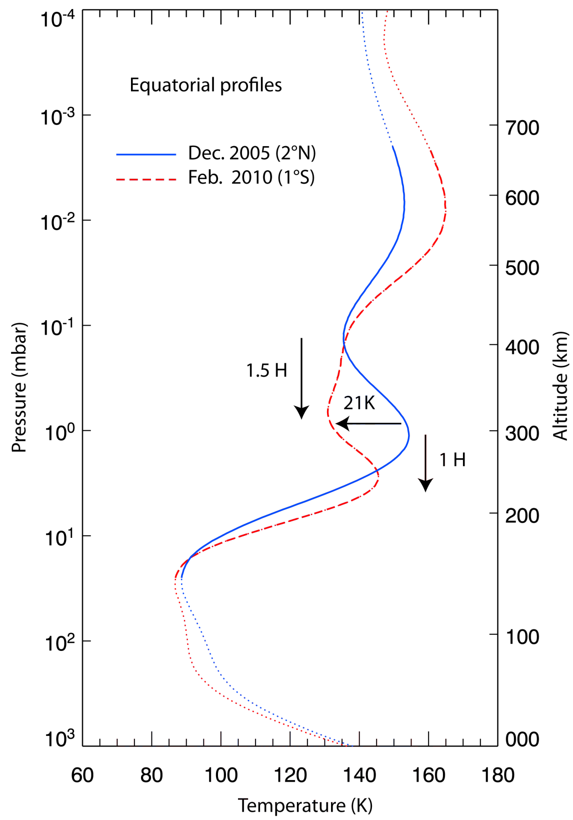

Figure 2: Two temperature profiles retrieved near the equator in 2005 (blue solid line) and 2010 (red dashed line).

4. Future work

To complete this study, we will present the map of the zonal wind obtained using the thermal-wind equation and we will compare it to the one derived from 2005–2006 data [1]. Temporal changes in the altitude of the zonal jets can provide additional constraints on the period of the oscillation, currently estimated to ∼15 years [3].

We will also present maps of the volume mixing ratio of ethane and acetylene, the main stratospheric hydrocarbons produced by methane photochemistry. Their abundances are not likely to change much between 2005 and 2010, so that any strong temporal changes in their distribution can be interpreted as a consequence of atmospheric dynamics taking place in the equatorial region.

References

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