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Seasonal evolution of tropospheric H_2 on Titan from the Cassini CIRS investigation

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Abstract

Far-infrared Titan spectra obtained with the Composite Infra-Red Spectrometer on the Cassini spacecraft have been analyzed to study the latitude distribution of H_2 in the troposphere, as well as its temporal evolution over the period from March 2007 to August 2014. This analysis shows that the previously observed distribution, characterized by a 30%-70% enhancement at high Northern latitudes, has become more symmetrical since Equinox. Hence, the reversed pole-to-pole Hadley cell circulation established shortly after Equinox has been effective in equilibrating the H_2 mole fraction in both polar regions, although not effective enough to produce a reversal of the polar enhancements probably because of a long time constant for the transport of air masses from the stratosphere to the troposhere.

1. Introduction

Earlier in the Cassini orbital mission, measurements obtained between March 2006 and February 2007 with the CIRS instrument on Cassini revealed that the tropospheric H_2 mole fraction was enhanced by 30%-70% at high Northern latitudes compared to the global mean value of 0.1% [1]. Based on the vertical profile of H_2 inferred from the tropospheric and thermospheric mole fractions [2] and the dynamics associated with the Titan atmospheric circulation [3, 4], it was concluded that the North polar enhancement was the result of transport of H_2-rich stratospheric air masses down to the tropospheric levels by the descending branch of the pole-to-pole Hadley cell located over the North pole during Northern winter.

Additional CIRS measurements acquired from March 2007 until August 2014 have been analyzed to study the evolution of that previously-observed latitude distribution across the Equinox epoch, when a reversal of the pole-to-pole Hadley cell circulation was expected, and indeed observed.

2. The CIRS data set in 2007-2014

We have selected a total of 43,640 CIRS spectra measured at a resolution of 2.5 cm^{-1} with the FP1 focal plane operating in the 10-600 cm^{-1} range. These data were separated into three periods: P1 from March 2007 to June 2009 (21,638); P2 from July 2009 to Feb. 2011 (5297); and P3 from Dec. 2011 to Aug. 2014 (16,705), corresponding to the Titan targeted encounters T25-to-T57, T58-to-T74, and T78-to-T104, respectively. Furthermore, the data were binned into appropriate latitude bins: 8 bins for P1; 4 bins for P2, and 10 bins for P3.

3. Results

From each selection of spectra, the H_2 mole fraction was determined by fitting the observed contrast of the H_2-N_2 dimer feature S(0) centred at 355 cm^{-1}. In a first step, a global mean was derived for each time period for the sake of comparison with that determined earlier in the mission. These values are respectively $(0.96 \pm 0.14) \times 10^{-3}$ (P1), $(0.87 \pm 0.30) \times 10^{-3}$ (P2), and $(1.14 \pm 0.25) \times 10^{-3}$ (P3), in good agreement with the earlier value of $(0.96 \pm 0.24) \times 10^{-3}$ [1].

The latitude distributions of H_2 derived for the three time periods, and that derived earlier in the mission (P0) are shown in Figure 1.

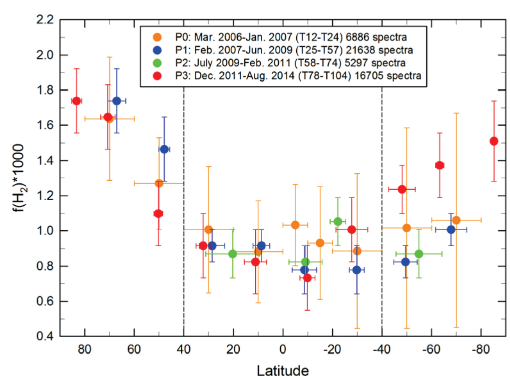

Figure 1: Latitude distribution of H_2 in four different periods extending from March 2006 to August 2014.

Only the data selections obtained in periods P0, P1, and P3 contain spectra measured at high latitudes. However, the results of Figure 1 reveal that the previously-observed enhancement over the North polar latitudes has not evolved significantly, whereas a similar enhancement has appeared over the South polar regions, making the overall latitude distribution more symmetrical with respect to the equator.

Hence, the reversed pole-to-pole Hadley cell circulation established shortly after Equinox has been somewhat effective in equilibrating the H_2 mole fraction in both polar regions. But contrary to what is observed in the case of several minor species, notably hydrocarbons and nitriles, the magnitude of the H_2 enhancement in the South is all but dramatic. This is probably due to the long time it takes to transport upper stratospheric H_2-rich air masses to tropospheric levels where the CIRS measurements are relevant, i.e. in the 0-30 km altitude range.

4. Summary and Conclusions

Titan far-infrared spectra obtained with the CIRS instrument between March 2006 and August 2014 show that the latitude distribution of tropospheric H_2 has evolved from a pre-Equinox situation characterized by a North polar enhancement to a more symmetrical one with enhancements in both polar regions, whereas the low- and mid-latitude regions do not show any significant variation.

These results tend to confirm the influence of the pole-to-pole Hadley cell circulation that affects the latitude distributions of most minor species on Titan. The reversal of that circulation shortly after Equinox is the most probable cause of the more symmetrical pattern observed for H_2, although the more subdued increase now observed in the South would imply longer time constants than for hydrocarbons and nitriles. Over the long term, such a characterization of the seasonal evolution of all minor species will certainly bring more insights into the temporal aspects of the atmospheric dynamics on Titan.

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