EPSC Abstracts
Vol. 13, EPSC-DPS2019-258-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Titan's stratospheric seasonal variations up to the end of the Cassini mission

A. Coustenis(1), D. E. Jennings(2), R. K. Achterberg(2,3), P. Lavvas(4), G. Bampasidis(5), C. A. Nixon(2), F. M. Flasar(2)
(1) Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique (LESIA), Observatoire de Paris, CNRS, UPMC Univ. Paris 06, Univ. Paris-Diderot, 5, place Jules Janssen, 92195 Meudon Cedex, France, (2) Planetary Systems Laboratory, Goddard Space Flight Center, Greenbelt, MD 20771, USA, (3) Department of Astronomy, University of Maryland, College Park, MD 20742, USA, (4) GSMA, Reims Champagne-Ardenne, 51687 Reims, France, (5)Faculty of Physics, National and Kapodistrian University of Athens, 15783 Zographos, Athens, Greece (athena.coustenis@obspm.fr,)

Abstract

We have monitored the seasonal evolution near Titan's poles and equator from 2012 until the last flyby of Titan in 2017. The 2017 data we have acquired and processed here are very important as they also show that the Southern pole is finally showing a significant decrease in abundance. Indeed, in the Titan south pole stratosphere some molecules had preserved their enhancement until end of 2016, before suffering a sudden and large drop in abundance in 2017. This is indicative of a non-symmetrical response to the seasons in Titan's stratosphere that can set constraints on photochemical and GCM models.

1. Introduction

In previous papers (Coustenis et al. 2016; 2018 and references therein) we reported on the strong temperature decrease and onset of a strong enhancement of several trace species such as complex hydrocarbons and nitriles (HC_3N and C_6H_6 in particular) observed at Titan's south pole, while previously found only at high northern latitudes. This is due to the transition of Titan's seasons from northern winter in 2002 to summer in 2017 and, at the same time, the advent of winter in the south pole. An opposite effect was expected in the north, but observed with certainty only after 2015. We present here a complementary analysis of nadir spectra acquired by Cassini/CIRS (Jennings et al., 2017) at high resolution in the past years and until the last Titan flyby in 2017 and describe the temperature and composition variations near Titan's poles. From 2013 until 2016, the northern polar region has shown a temperature increase of 10 K, while the south has shown a more significant decrease (up to 25 K) in a similar period of time. While the south polar region is continuously enhanced since about 2012, the chemical content in the north is showing a clear depletion for all molecules only since 2015 (Coustenis et al., 2018, and in preparation).

2. Observations and analysis

The data analyzed here were taken in 2017 by CIRS at high spectral resolution (0.5 cm^{-1}) in the surface-intercepting nadir mode (Jennings et al., 2017; Nixon et al., 2019). Here, we use the spectra acquired in the far-infrared focal planes (FP3 and FP4) that cover the 600-1500 cm^{-1} range.

In particular, since we require high-resolution nadir spectra of Titan's stratosphere near the poles (from 65° to 90°), our dataset suffers from gaps in the observations for high latitudes, caused by Cassini's orbital geometry. Indeed, the north pole was not observed before mid-2013 and between fall 2014 and May 2016. For the south pole we did not have enough high-resolution (0.5 cm^{-1}) available spectra from fall of 2014 onwards and until 2017. The 2017 data that we present here are then very important because they give us for the first time an indication to what happened in the south polar stratosphere after 2014 and because they increase the observations we can analyze in the northern pole region.

As in previous papers, we use a monochromatic radiative transfer code adapted to Titan's stratosphere (ARTT: Coustenis et al. 2010; Bampasidis et al. 2012) and we infer the temperature profile from the best fit of the 7.7-micron methane band in FP4 (following the method described in e.g. Achterberg et al. 2008). We then inject the temperature profile in our ARTT radiative transfer code and solve for the opacity in the rest of the spectrum retrieving the abundances of trace gases and their isotopes in the FP3 region of the CIRS spectra. Figure 2 shows two of our fits in the 600-900 cm^{-1} range, where we observe the emission of several gaseous bands of hydrocarbons, nitriles and oxygen compounds (e.g. HCN, C_2H_2, C_3H_8, C_2H_6, CO_2).

3. Results and discussion

3.1 Temperature variations

In our previous papers, as well as in those of other investigators, it has been discussed how as the southern hemisphere moved into winter after the mid-2009 equinox, large temperature variations were observed near the south pole (beyond 60°S) in the stratosphere (essentially from 0.1 down to 1 mbar). Indeed, while a moderate warming was observed in the summer-entering north for the mid and high northern latitudes, a spectacular drop in temperature by as much as 25 K at 70°S was measured from 2012 to 2014. Since 2014, we had no high-resolution data to exploit for temperature and composition, which now is feasible with the 2017 measurements. The previous temperature variations were accompanied by a strong enhancement of chemical compounds in the south polar region, while the north failed to show the opposite effect in a similar magnitude, which indicated a non-symmetrical reaction to the seasonal influence for each pole. In our 2018 paper, we showed how the north polar stratosphere only responded with a decrease of the chemical content after 2015, a three-year delay with respect to the increasing south.

The stratosphere over the south pole of Titan shows dramatic increase in temperature in 2017 since 2014, by 10-50 K in the 0.5 mbar-0.05 mbar pressure range, the larger 2017 temperatures observed in the higher atmospheric levels around 0.05 mbar. Moderate changes were found above the northern polar region since 2016 and a temperature profile for the equator is more homogeneous with altitude and similar in shape to the earlier southern profiles.

3.2 Compositional variations

We find here that the strong increase in temperature over the south pole in 2017 with respect to 2014 is associated with a significant and rapid drop in chemical content near the south pole. We thus witness in Titan's south pole, where we had no data since 2014, and following the dramatic enhancement of the chemical species (e.g. as described in Coustenis et al., 2016; 2018), a negative evolution or even disappearance of several trace species, such as HC3N and C6H6, previously observed clearly at high southern latitudes. All the molecules (except for CO2) have dropped with respect to the end-of-2014 peak at latitudes near 70°S and are now at abundance levels close to the ones witnessed in 2013. This is due to the seasonal change on Titan, moving from northern winter in 2004 to advanced northern spring in 2012 and towards summer solstice in mid-2017, with the opposite effect in the south pole as it moves into winter. During that time, Titan's main atmospheric circulation cell is expected to reverse and models predict that newly produced photochemical species are channeled from mid latitudes towards the south pole (e.g. Teanby et al. 2012).

Looking at the Titan north polar area, we find that all trace gases have decreased from September 2013 to August 2017, except for CO2 which remains constant within error bars and is not shown on this plot. Propane (C3H8) has shown a trend for decrease until 2016, but from more recent data and within error bars we see no additional drop in its abundance in 2017, where it remains at around 1.5x10-6. In this 4-year period, we find the decrease we had announced in Coustenis et al. (2018) near the northern polar region to be confirmed and prolonged. In total, from the abundances around the beginning of 2014, when the north polar stratosphere was stable with enhanced species, until September 2017 (about 3 years), we find that the north polar region has thus continued to become rarified in most of the stratospheric gases (exceptions are CO2 and C3H8), with the hydrocarbons somewhat less affected than the nitriles HCN and HC3N, who are reduced by more than an order of magnitude. The decrease in chemical species is affecting first lower latitudes before reaching the pole. The processes responsible for these observations need to be evaluated in future studies and our retrievals provide sufficient constraints for their validation.

References

[1] Coustenis, A., Jennings, D. E., Achterberg, R. K., et al. 2016, Icarus 270, 409.

[2] Coustenis, A., Jennings, D. E., Achterberg, R. K., et al. 2018, Astroph. J. Lett., 854, no2

[3] Jennings, D. E., Flasar, F. M., Kunde, V. G., et al. 2017, Ap. Opt, 56, 5274

[4] Nixon, C.A., Ansty, T. M., Lombardo, N. A., et al. 2019, submitted.

[5] Teanby, N. A., Irwin, P. G. J., Nixon, C. A., et al. 2012, Nature 491, 732