EPSC Abstracts
Vol. 11, EPSC2017-450, 2017
European Planetary Science Congress 2017

Saturn at Northern Summer Solstice: Thermal Structure during the Finale of the Cassini Mission

L.N Fletcher (1), S. Guerlet (2), G.S. Orton (3), J.A. Sinclair (3), T. Fouchet (4), P. Irwin (5), L. Li (6), F.M. Flasar (7)
(1) Department of Physics and Astronomy, University of Leicester, UK (leigh.fletcher@le.ac.uk; Tel: +44 116 252 3585); (2) Laboratoire de Meteorologie Dynamique, Paris, France; (3) Jet Propulsion Laboratory, Pasadena, USA; (4) LESIA, Observatoire de Paris, France; (5) Atmospheric, Oceanic and Planetary Physics, University of Oxford, UK; (6) Department of Physics, University of Houston, USA; (7) NASA Goddard Spaceflight Center, Maryland, USA.

Abstract

Cassini's orbital exploration of Saturn (2004-2017) has almost spanned from solstice to solstice, providing an unprecedented database of seasonal and non-seasonal atmospheric phenomena on the gas giant planet [1]. We report on the completion of our long-term campaign of thermal-infrared (7-1000 µm) observations from the Composite Infrared Spectrometer (CIRS), extending previous investigations of (i) the establishment of a large, warm polar stratospheric hood (75-90°N) in the northern summer hemisphere [2]; (ii) tracking of the equatorial stratospheric quasi-periodic oscillation (QPO) and the disappearance of the strong prograde jet in the equatorial stratosphere [3]; and (iii) the aftermath of the 2010-11 storm system and 'beacon' at mid-latitudes, both in a warm tropospheric band and residual wave activity in the stratosphere [4]. CIRS observations will be compared to ground-based 7-25 µm images from the Very Large Telescope (VLT) in 2015-2017, and to the record of IRTF observations from the previous northern summer solstice in 1987. Nadir CIRS spectra are inverted to determine zonal-mean variability in temperatures, para-hydrogen, ethane and acetylene. The resulting distributions trace large-scale circulation patterns at the equator and poles, and disruptions of these circulations by localised dynamic phenomena.

1. Introduction

With its 29.5-year orbital period and 26.7° axial tilt, Saturn's atmosphere is subjected to extremes of seasonal insolation that drive complex patterns of atmospheric circulation, chemistry, and cloud formation [1] that can be explored via thermal-infrared remote sounding. Cassini arrived at Saturn in July 2004 (Ls=293°), shortly after northern winter solstice (Ls=270° in 2002) when the north pole was shrouded in darkness. The longevity of Cassini has meant that our infrared records now span through spring equinox (Ls=0°, August 2009) and to northern summer solstice (Ls=90° on May 24, 2017), allowing us to explore processes over all four seasons on Saturn. We construct monthly-averaged zonal-mean CIRS spectra for inversion via an optimal-estimation retrieval algorithm, NEMESIS [5], Fig. 1. These are interpolated in time to reconstruct the temperature and composition variability over 13 years, and are used to explore processes in the following regions.

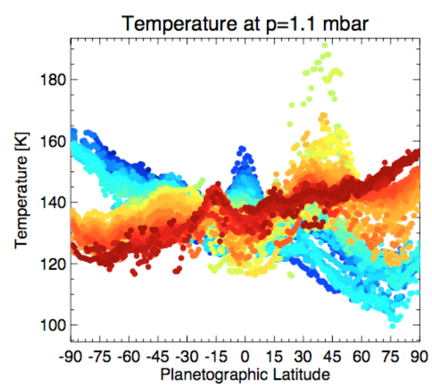

Figure 1 Example of 1-mbar temperatures from inversion of CIRS spectra early (blue) and late (red) in the mission, highlighting the shifting thermal asymmetries and equatorial oscillation.

2. Seasonal Polar Vortices

Saturn exhibits seasonally-independent warm polar cyclones in the troposphere at both poles [6], in addition to seasonally-dependent polar hoods in the stratosphere (within ~15° of the pole). Our previous study [2] tracked the evolution of these polar vortices to early 2014, showing the longevity of the polar cyclones; the disappearance of the southern summer polar hood; and the absence (at that time) of any comparable northern polar hood in spring (Ls=56°). Observations from northern summer in March 1989 (Ls=104°) by Gezari et al. [7] show the existence of the warm northern hood, suggesting that Cassini could see it by the end of the Grand Finale mission. Recent 7.8-µm observations from VLT (2016, Fig. 2) show that the north pole is certainly warming, but lacks the strong gradient and contrast that the southern summer hood exhibited in 2004, and which was evident in the 1989 images from Gezari et al. The evolution of these thermal gradients, and associated maxima in ethane and acetylene, will be presented using 2017 CIRS and VLT data.

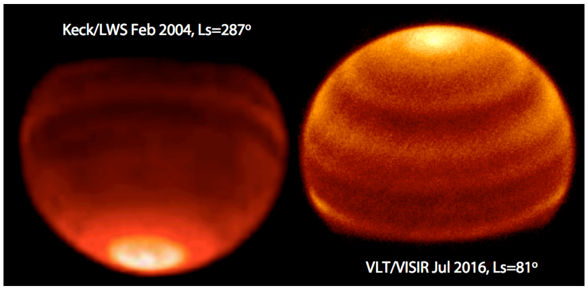

Figure 2 Comparing polar vortices in Saturn's 7.8-μm emission in southern summer (left) and late northern spring (right).

3. Equatorial Oscillations

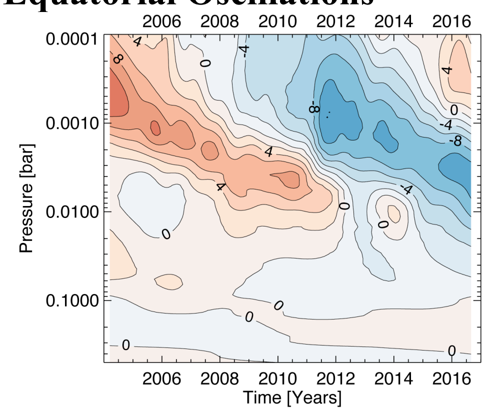

Figure 3 Equatorial temperature anomalies (compared to the mean over the full mission) showing the downward propagation of thermal anomalies.

Shortly after Cassini's arrival, Saturn's equatorial stratosphere was shown to exhibit vertical temperature/wind oscillations driven by wave-mean-flow interactions, analogous to Earth's Quasi-Biennial Oscillation [8]. Alternating regions of eastward/westward flow appear to move downward with a ~15-year period, as shown via temperature anomalies in Fig. 3. This evolution removed the strong prograde stratospheric jet observed early in the mission [9], and replaced the equatorial maximum with a cool airmass near 1-5 mbar in 2017 that can be seen in Fig. 2. There is evidence that the northern springtime storm (see below) disrupted the regular oscillation in 2011-2014 throughout the ±20^o latitude region [3], but that it has now re-established itself. Secondary circulation patterns modulate temperatures in the tropics (±15^o latitude), making inferences of Hadley-type circulations complicated.

4. Aftermath of the Storm

Saturn's northern mid-latitudes were spectacularly disrupted in 2010/11 by the eruption of a storm near 40^{o}N that encircled the entire latitude circle. The tropospheric storm generated a hot stratospheric vortex (the beacon) that was enhanced in hydrocarbons [10] due to chemistry and atmospheric subsidence. Our previous study [4] tracked the beacon through March 2012 – updated tracking in Fig. 4 shows the demise of the beacon in mid-2013, which will be compared to expectations of a radiative-climate model [11].

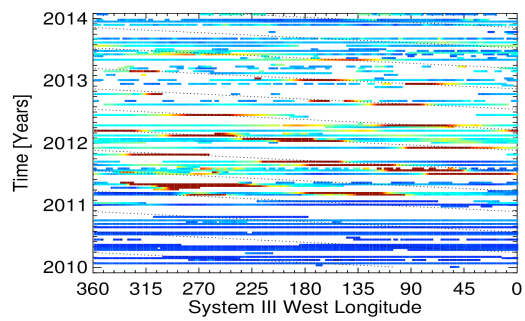

Figure 4 Tracking CH_4 emission from Saturn's beacon, showing the rapid westward motion (dotted lines) and disappearance after mid-2013.

Acknowledgements

LNF is supported by a Royal Society Research Fellowship and a European Research Council Consolidator Grant at the University of Leicester. We are indebted to the extraordinary efforts of the Cassini team in making these studies possible.

References

[1] Fletcher et al., 2015 (http://arxiv.org/abs/1510.05690)
[2] Fletcher et al., 2015 (doi:10.1016/j.icarus.2014.11.022)
[3] Fletcher et al., 2017, submitted.
[4] Fletcher et al., 2012 (doi:10.1016/j.icarus.2012.08.024)
[5] Irwin et al., 2008 (doi:10.1016/j.jqsrt.2007.11.006)
[6] Fletcher et al., 2008 (doi:10.1126/science.1149514)
[7] Gezari et al., 1989, (doi:10.1038/342777a0)
[8] Fouchet et al., 2008 (doi:10.1038/nature06912)
[9] Li et al., 2008 (doi:10.1029/2008GL035515)
[10] Moses et al., 2014 (doi:1 0.1016/j.icarus.2015.08.012)
[11] Guerlet et al., 2014 (doi:10.1016/j.icarus.2014.05.010)