SEASONAL CHANGE AT TITAN'S POLES N. A. Teanby[1], P. G. J. Irwin[2], C. A. Nixon[3], and R. de Kok[4], [1]School of Earth Sciences, University of Bristol, UK (n.teanby@bristol.ac.uk). [2]Atmospheric, Oceanic, and Planetary Physics, University of Oxford, UK. [3]Department of Astronomy, University of Maryland, USA. [4]SRON, Utrecht, Netherlands.

Introduction: Titan's obliquity of 26.7° causes large seasonal variations in solar illumination during its 29.5 year orbit around the sun. This leads to dramatic atmospheric changes - including changing circulation patterns in the stratosphere and mesosphere, which can be indirectly observed using minor gases as tracers.

The Cassini spacecraft has been in orbit around Saturn since July 2004 and has been returning data ever since. Cassini thus provides an ideal platform from which to observe the detailed pattern of seasonal changes in Titan's atmosphere for the first time.

Since Cassini arrived in the Saturnian system, Titan's season has progressed from northern winter to northern spring, passing through northern spring equinox in August 2009. Measurements taken before the equinox show an intense stratospheric polar vortex highly enriched in trace gases, and a single south-to-north circulation cell [1-3].

Following equinox, dramatic changes in atmospheric temperature and composition are expected. Over Cassini's entire mission (2004-2017) atmospheric models predict first a single south-to-north cell with north polar subsidence and southern upwelling, second a short-lived transitional two-cell phase with equatorial upwelling and subsidence at both poles, and finally a full reversal of the initial circulation into a north-to-south cell [4,5].

Here we use an eight year dataset (2004-2012) of mid-infrared spectra measured by Cassini's Composite InfraRed Spectrometer (CIRS) to document changes in Titan's polar atmosphere since the equinox. This extends our recent 2010 study [6] well into the post-equinox period, capturing circulation changes during Titan's most changeable time of year.

Probing Atmospheric Circulation: Titan's atmosphere mainly comprises N_2 (98%) and CH_4 (2%), but includes many minor species formed by photochemical processes [7]. These species are mixed from their upper atmosphere source regions into the lower atmosphere where they are destroyed by photolysis and eventually lost due to condensation near the tropopause. This production and loss mechanism gives rise to vertical gradients, with trace gas relative abundances increasing with altitude under equilibrium conditions. Vertical motion of the atmosphere can advect these equilibrium profiles and cause local increases or decreases in abundance at a particular atmospheric level – subsidence leads to enrichment and upwelling leads to depletion. Therefore, abundances of minor gases can be measured using mid-IR spectral emission features and used as tracers of vertical advection [3].

Observations: Cassini's Composite InfraRed Spectrometer (CIRS) is a Fourier transform spectrometer covering the spectral range 10-1500 cm^{-1}, with an adjustable spectral resolution of 0.5-15 cm^{-1}. CIRS is fully described by [8]. Here we use nadir and limb data taken with CIRS' mid-IR focal planes (FP3 and FP4) in the 600-1400 cm^{-1} region.

Nadir (downward looking) data has a spectral resolution of 0.5 cm^{-1} or 2.5 cm^{-1}, which allows individual gas emission peaks to be resolved and latitudinal gas distributions to be mapped. These data provide the most complete latitude and time coverage over the entire eight year mission so far. However, polar coverage of nadir data is limited in the post-equinox period due to Cassini's orbital geometry.

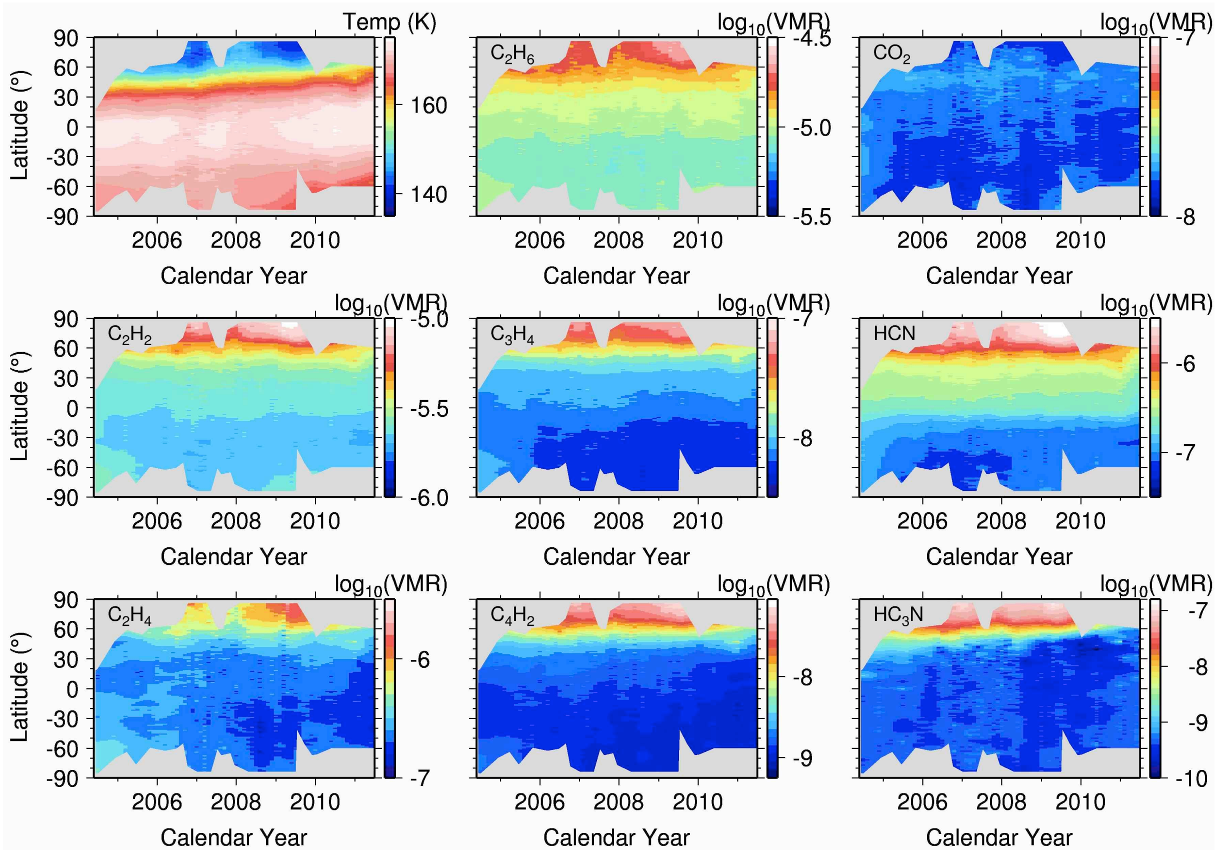
Limb (horizontal viewing) data has a spectral resolution of 0.5 cm^{-1} or 13.5 cm^{-1}, and gives the best vertical resolution of gas profiles. Latitude and temporal coverage is generally much more limited than the nadir data, but importantly the limb data has coverage of the polar regions in the post-equinox period.

By combining both datasets the seasonal evolution of Titan's atmospheric temperature and composition can be studied.

Methods: Atmospheric temperature and composition were retrieved using NEMESIS [9] - a non-linear optimal estimation technique using the correlated-k approximation. Temperature and abundances profiles of C_4H_2, C_3H_4, CO_2, HC_3N, HCN, C_2H_2, C_2H_6 and C_2H_4 were determined. These determinations are sensitive to the stratosphere and mesosphere and can be used to probe the circulation there.

Results: The figure shows variations of temperature and composition with latitude and time at the 0.7mbar pressure level derived from the nadir data, covering northern winter to northern spring, and indicates a large number of atmospheric changes.

Temperature: Both north and south poles exhibit cooling at 0.7mbar as the season progresses; and the region of maximum temperature gradient (around the vortex boundary at 30-50°) has moved northwards by about 15°.



Composition: Spatially, trace gases have relatively uniform abundances at southern and equatorial latitudes, with significant subsidence-induced enrichment at northern latitudes [3]. CO_2 does not vary significantly with latitude due to its long photochemical lifetime.

Equatorial and low latitude abundances remain relatively stable with time; although an initial enriched cap of gas over the south pole (most visible in C_2H_2, C_2H_4, and HCN) has dissipated. South polar HCN increases somewhat during 2008-2011 and HC_3N appears to be confined to more northerly latitudes as the season progresses. North polar abundances of most trace species increase dramatically post-2009 relative to their 2004-2008 values.

The north polar increase is most pronounced for HCN and C_2H_2 and least pronounced for HC_3N and C_4H_2. The south polar HCN increase is a more subtle effect, and may suggest the onset of southern winter is close. This will be studied in more detail using recent limb data.

Discussion: Our preferred explanation for the observed temperature decrease and trace gas increase within the northern vortex is a weakening meridional circulation cell, combined with a shrinking polar vortex wall, and reduced trace gas loss by horizontal mixing across the vortex boundary. These changes suggest the atmosphere may be close to the transitional circulation period.

The first sign of this new regime is the recent increase in south polar HCN abundance - indicating weakening southern uplift. As subsidence in the southern circulation cell develops we eventually expect abundance increases for other trace gases coupled with temperature increases caused by adiabatic heating in the upper stratosphere.

This will be studied further using 2010-2012 limb measurements and monitored during Cassini's Solstice Mission, which is due to run until 2017. The 13 year mission length will eventually give coverage of almost half a Titan year and provide even more stringent constraints on Titan's seasonal variability.

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