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Temperature, chemical species and wind distributions in the middle atmosphere of Titan from late northern spring to early summer

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We present a study of the seasonal evolution of Titan's thermal field and distributions of haze, C_2H_2, C_2H_4, C_2H_6, CH_3C_2H, C_3H_8, C_4H_2, C_6H_6, HCN and HC_3N from March 2015 (Ls = 66°) to September 2017 (Ls = 93°), i.e. from the last third of northern spring to early summer. We analyzed thermal emission of Titan's atmosphere acquired by the Cassini Composite Infrared Spectrometer (CIRS) with limb and nadir geometry to retrieve the stratospheric and mesospheric temperature and mixing ratios pole-to-pole meridional cross sections from 5 mbar to 50 μbar (120-650 km).

The southern stratopause varied in a complex way and showed a global temperature increase from 2015 to 2017 at high-southern latitudes. Stratospheric southern polar temperatures, which were observed to be as small as 120 K in early 2015 due to the polar night, showed a 30-K increase (at 0.5 mbar) from March 2015 to May 2017 due to adiabatic heating in the subsiding branch of the global overturning circulation. All photochemical compounds were enriched at the South Pole by this subsidence. Polar cross sections of these enhanced species, which are good tracers of the global dynamics, highlighted changes in the structure of the southern polar vortex. These high enhancements combined with the unusually low temperatures (<120 K) of the deep stratosphere resulted in condensation at the South Pole between 0.1 and 0.03 mbar (240-280 km) of HCN, HC_3N, C_6H_6 and possibly C_4H_2 in March 2015 (Ls = 66°). These molecules were observed to condense deeper further away from the South Pole.

At high-northern latitudes, stratospheric enrichments remaining from the winter were observed

below 300 km between 2015 and May 2017 (Ls = 90°) for all chemical compounds and up to September 2017 (Ls = 93°) for C_2H_2, C_2H_4, CH_3C_2H, C_3H_8, C_4H_2. In September 2017, these local enhancements were less pronounced than earlier for C_2H_2, C_4H_2, CH_3C_2H, HC_3N, HCN and no longer observed for C_2H_6 and C_6H_6, which suggests a change of the northern polar dynamics near the summer solstice. These enhancements observed during the entire spring may be due to confinement of this enriched air by a small remaining winter circulation cell that persisted in the low stratosphere up to the northern summer solstice, according to predictions of the Institut Pierre Simon Laplace Titan Global Climate Model (IPSL Titan GCM).

In the mesosphere, we derived a depleted layer in C_2H_2, HCN and C_2H_6 from the North Pole to mid-southern latitudes, while C_4H_2, C_3H_4, C_2H_4 and HC_3N seem to have been enriched in the same region. In the deep stratosphere, all molecules except C_2H_4 were depleted due to their condensation sink located deeper than 5 mbar outside the southern polar vortex. HCN, C_4H_2 and CH_3C_2H VMR cross section contours showed steep slopes near mid-latitudes or close to the equator, which can be explained by upwelling air in this region. Upwelling is also supported by the cross section of C_2H_4 (the only molecule not condensing among those studied here) volume mixing ratio observed in the northern hemisphere.

We derived the zonal wind velocity up to mesospheric levels from the retrieved thermal field. We show that zonal winds were faster and more confined around the South Pole in 2015 (Ls = 67 - 72°) than later. In 2016, the polar zonal wind speed decreased while the fastest winds had migrated toward low-southern latitudes.