Northern spring in Titan's stratosphere observed with Cassini/CIRS

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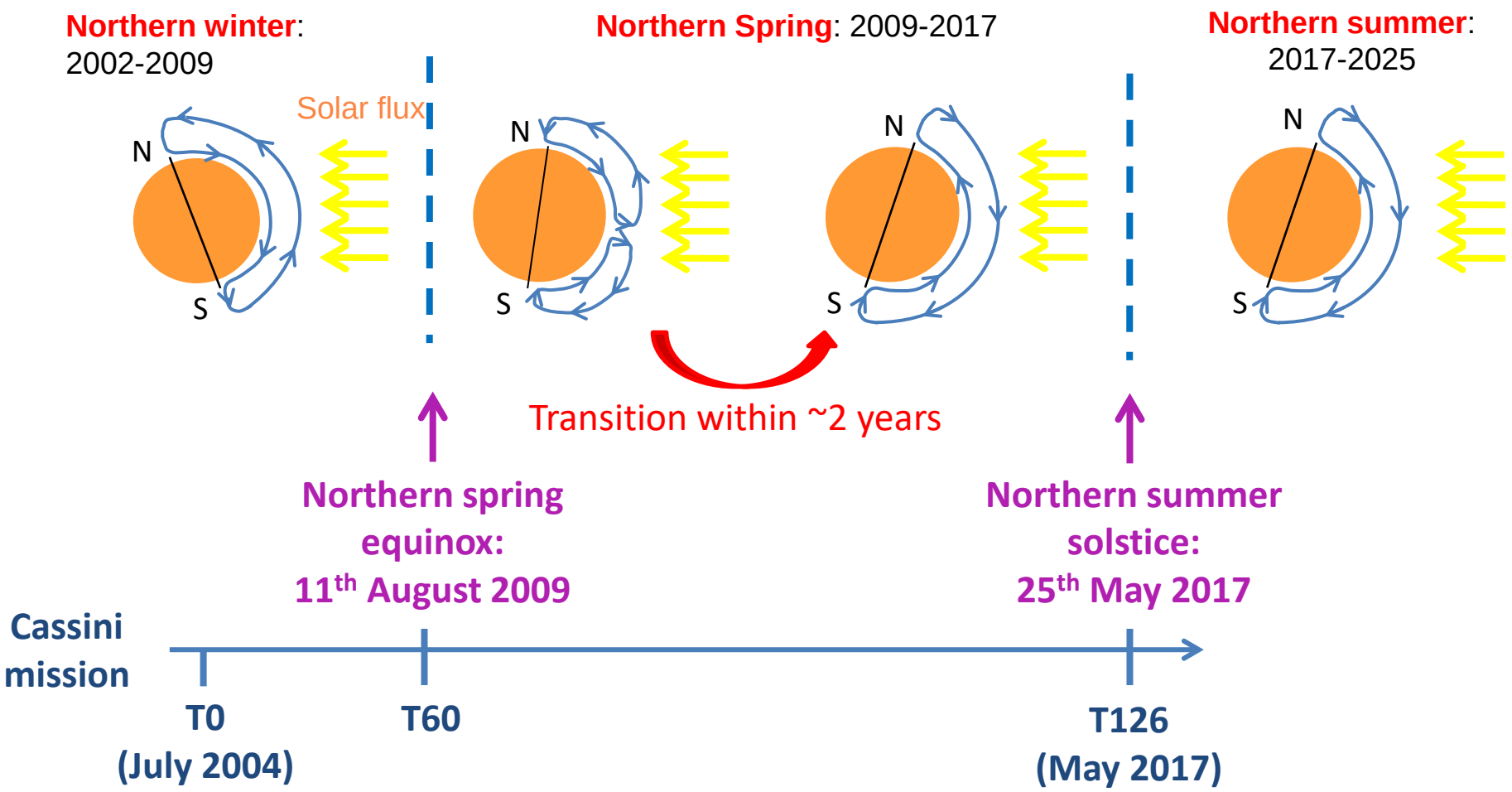
[(3)] LMD, Université Paris 6, France
[(4)] IPAG, Grenoble, France
[(6)] NASA/GSFC, USA

Predicted seasonal variations of the stratospheric dynamics

General Circulation Models predict a global reversal of the dynamics within 2 years after the equinox .



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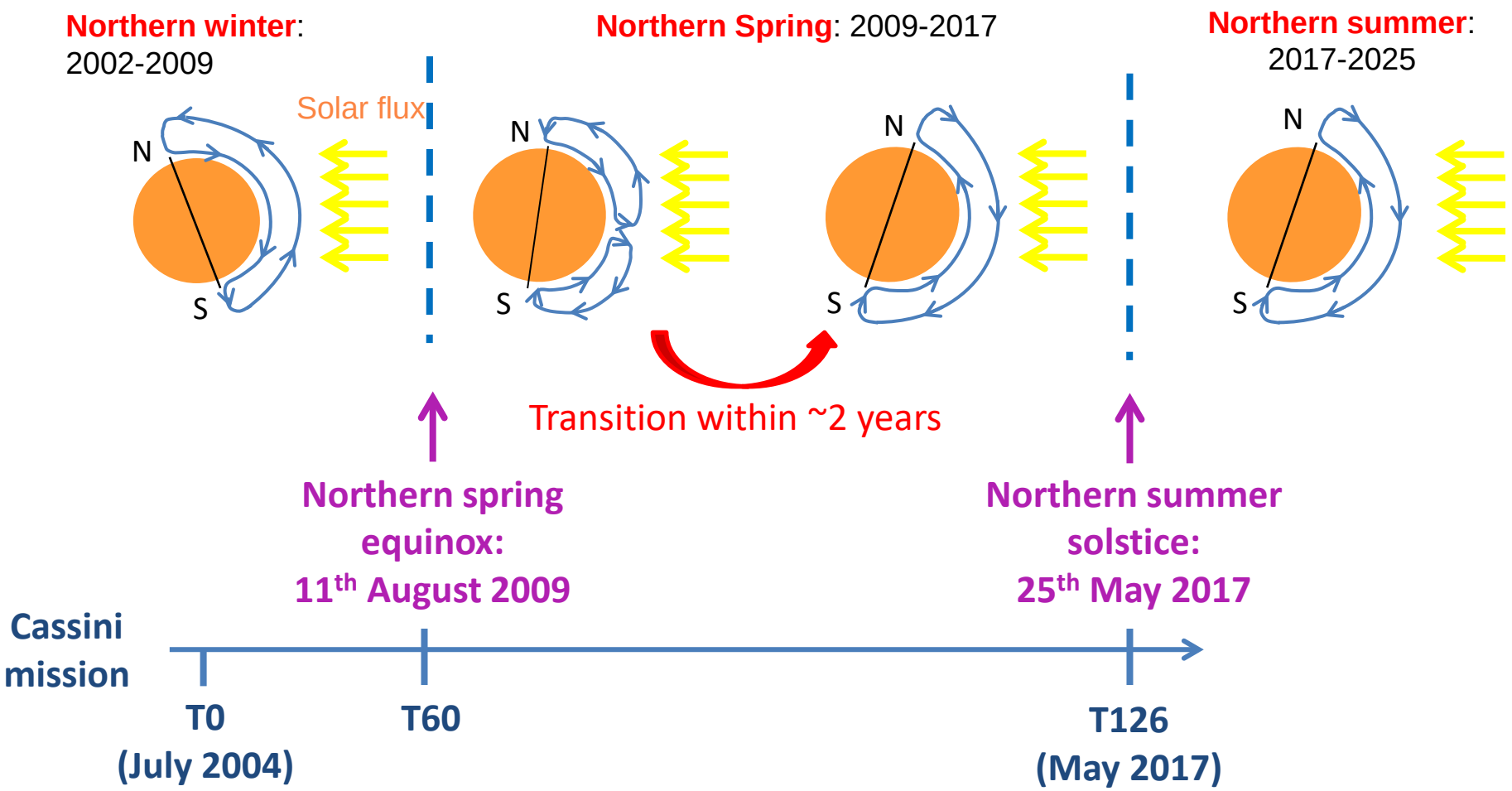
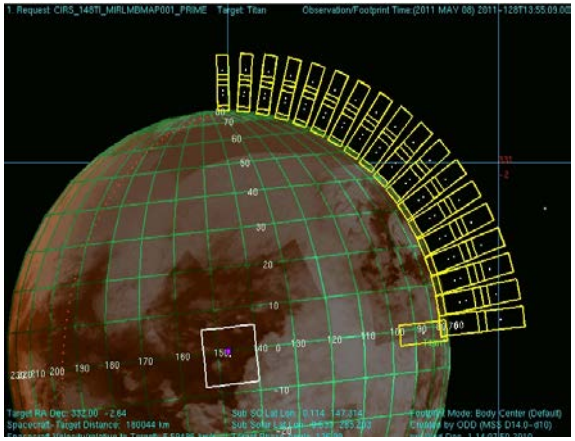


Characterization of the dynamic seasonal changes through T, molecular abundances and aerosol spatial distributions -> use of Cassini/CIRS data.

Cassini/Composite Infrared Spectrometer Observations

CIRS mid IR limb map observations (600 – 1500 cm^{-1})

- global latitude/altitude maps from limb observation:
  from 120 to 500-600 km with a 30 km-vertical resolution



- 15.5 cm^{-1} resolution $\Rightarrow$ T, C_2H_2, C_2H_6, C_2H_4, CH_3C_2H, C_3H_8, C_4H_2, HCN, HC_3N, C_6H_6, haze

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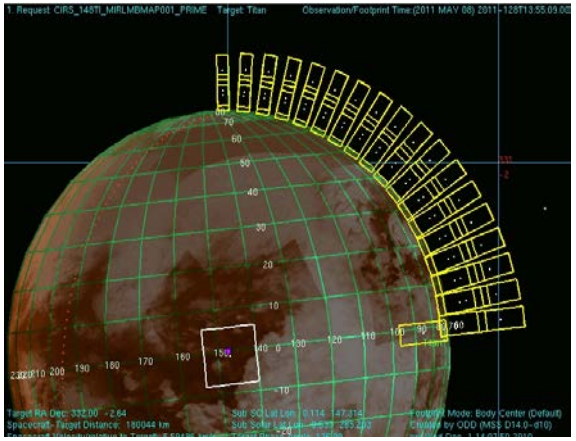
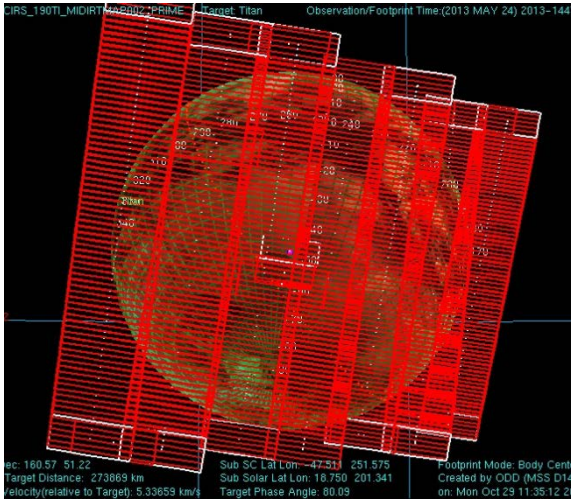


- Use of nadir data to complete the latitude/altitude maps
  3 cm^{-1} resolution
  probe the 100 to ~300 km (no vertical resolution)



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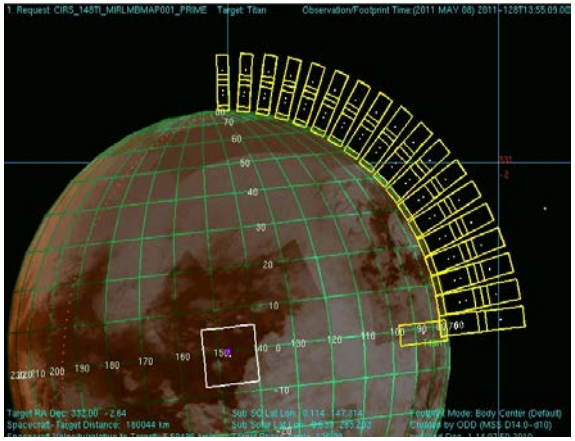

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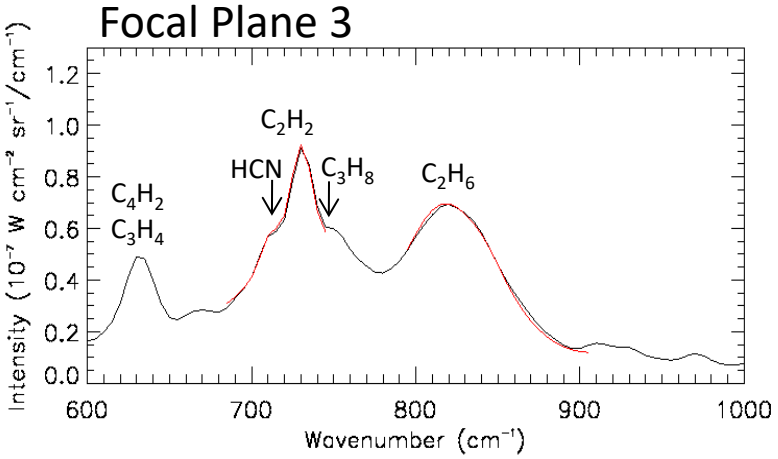
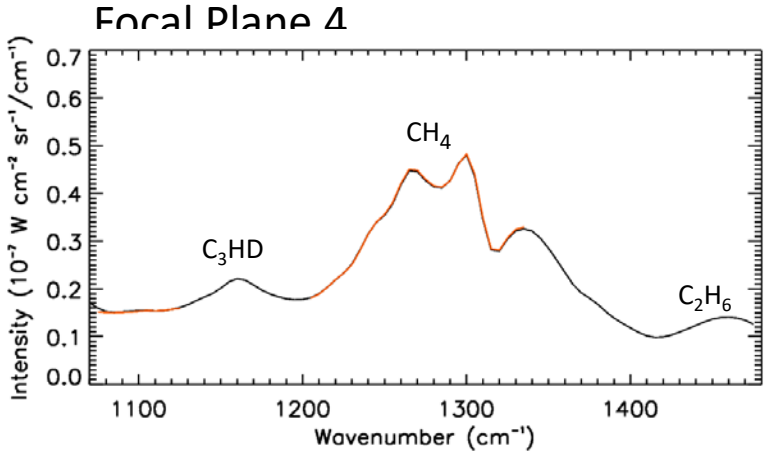




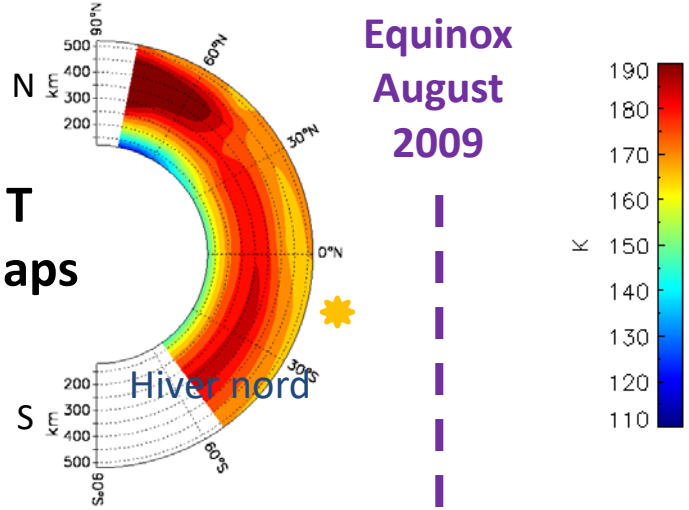
Use of inversion algorithm and radiative transfer code to derive temperature and minor species mixing ratio maps.

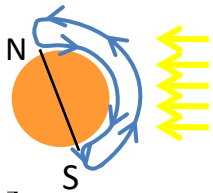
Reversal of the global dynamics from T and HCN maps

Northern winter

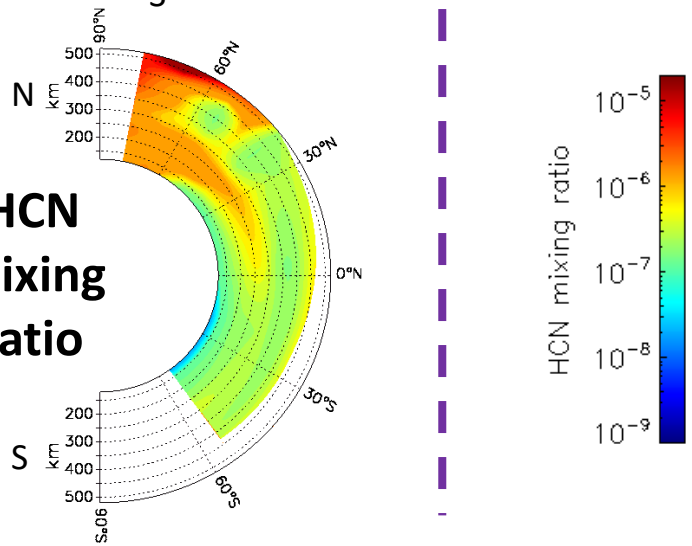
Equinox August 2009

T maps





HCN mixing ratio



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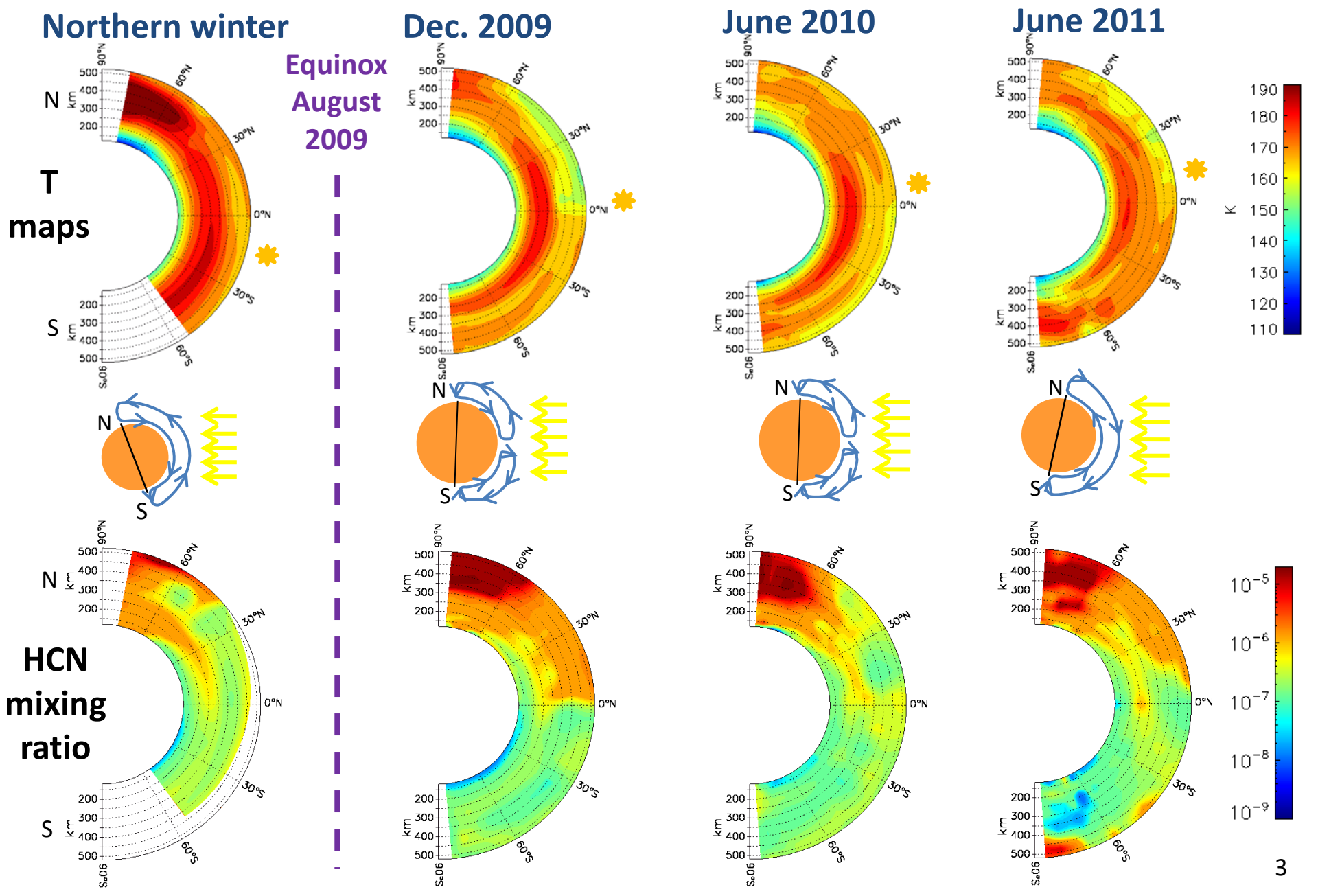
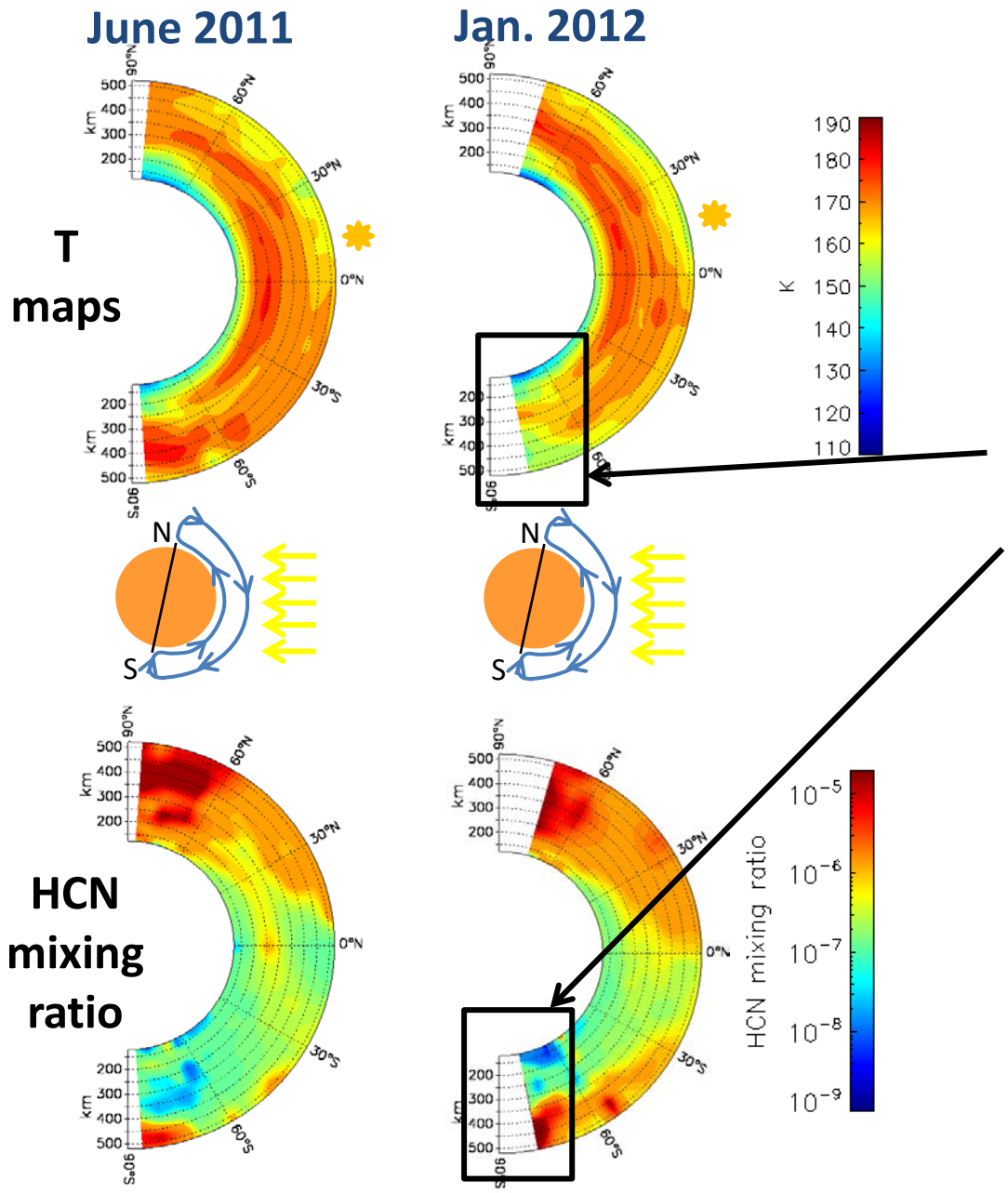


Unexpected cooling of the Southern polar region in 2012



Unexpected cooling at the S pole

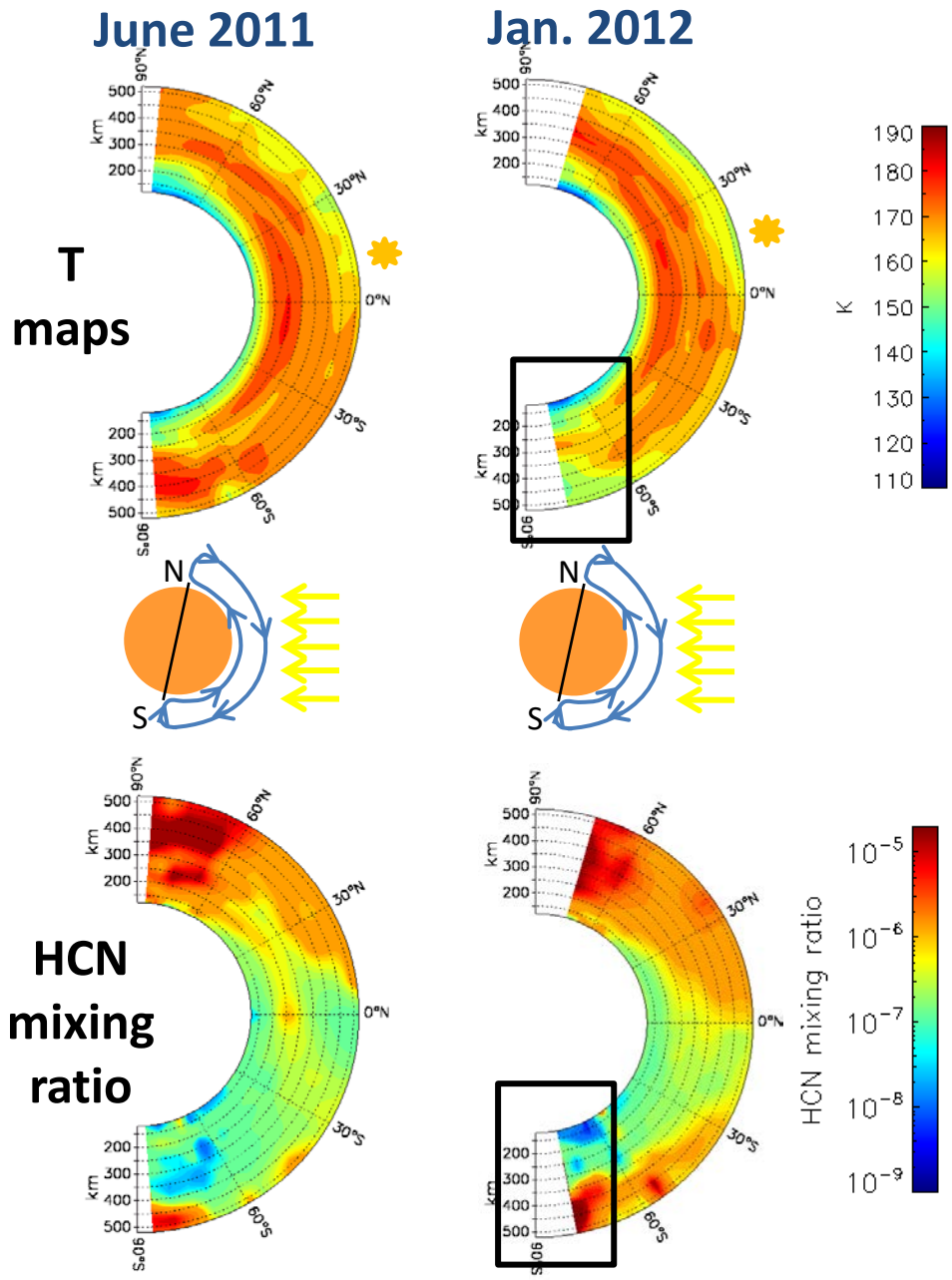
+

Strong enrichment at the S pole

⇒ Radiative cooling by molecules and aerosols compensate the adiabatic heating from the descending branch

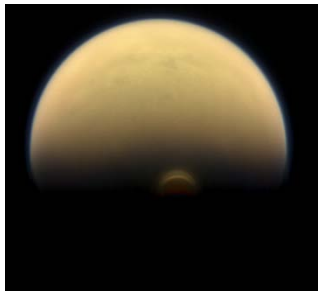
Vinatier et al. (2015)
Teanby et al. (2017)

Cooling of the S pole + stratospheric cloud observations



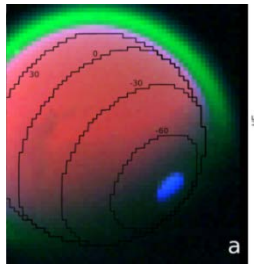
- Cold S polar T => **southern stratospheric polar cloud** observed since mid-2012 at 300 km

Cassini/ISS



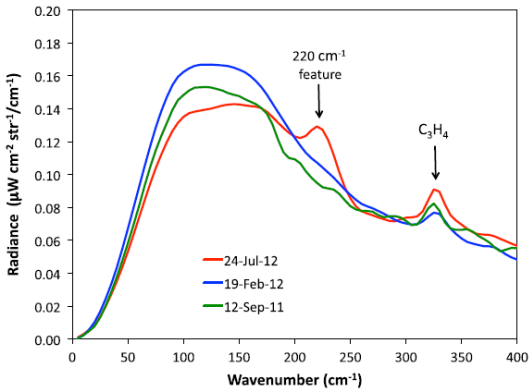
West et al. (2016)

HCN ice detected with VIMS



de Kok et al. (2014)
Le Mouélic et al. (2018)

Condensate signatures detected with CIRS in far-IR



Jennings et al. (2012)

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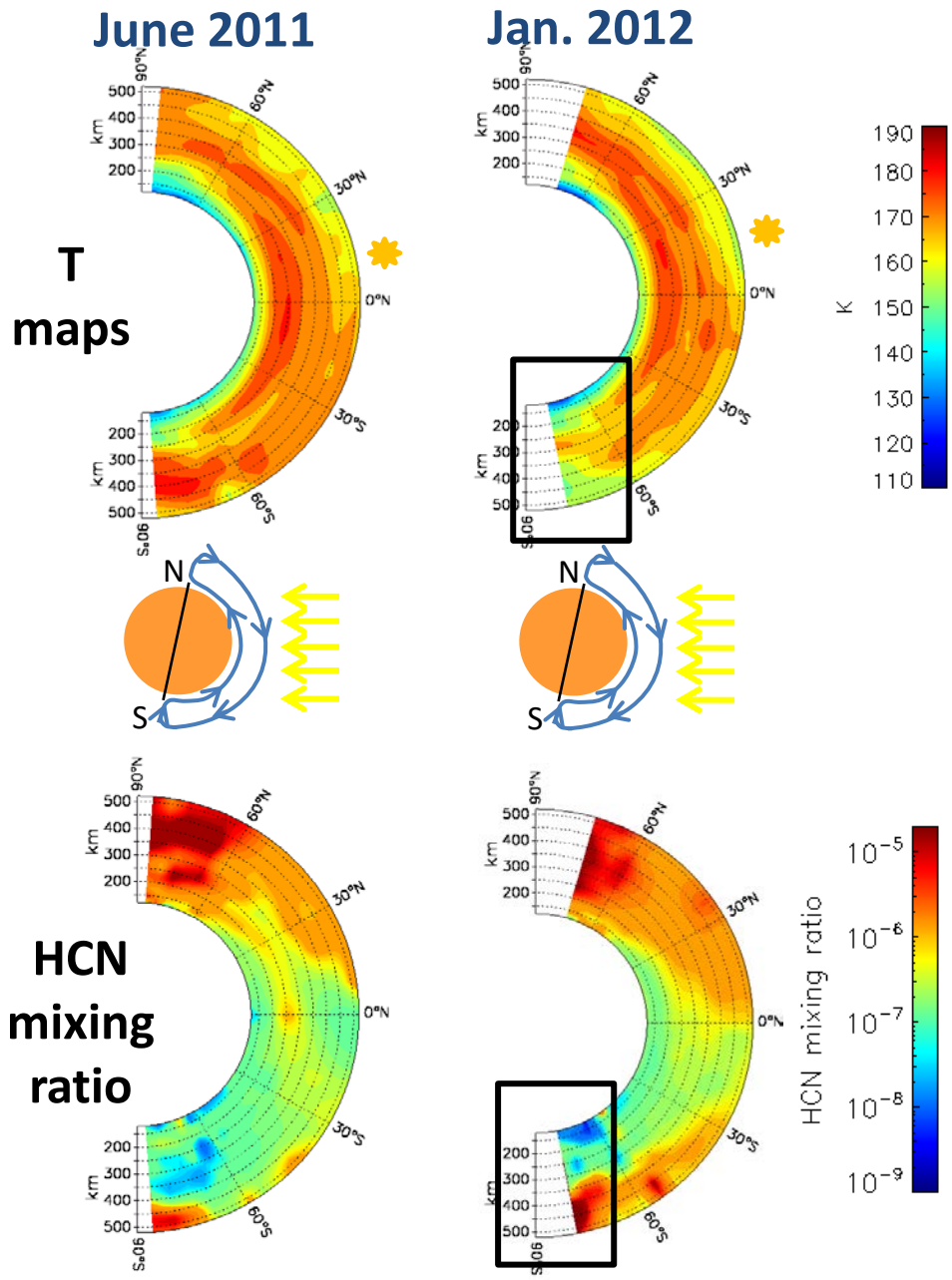

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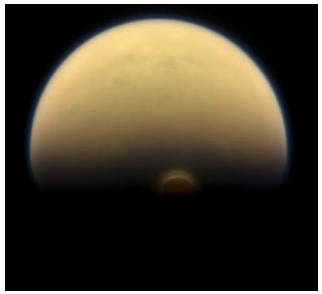

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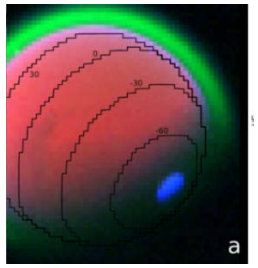

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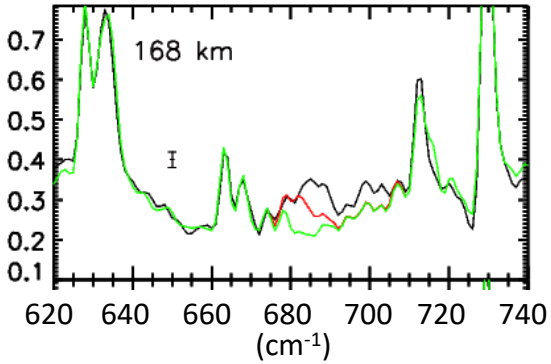
Condensate signatures + **C_6H_6 ice** detected with CIRS in mid-IR



Vinatier et al. (2018)

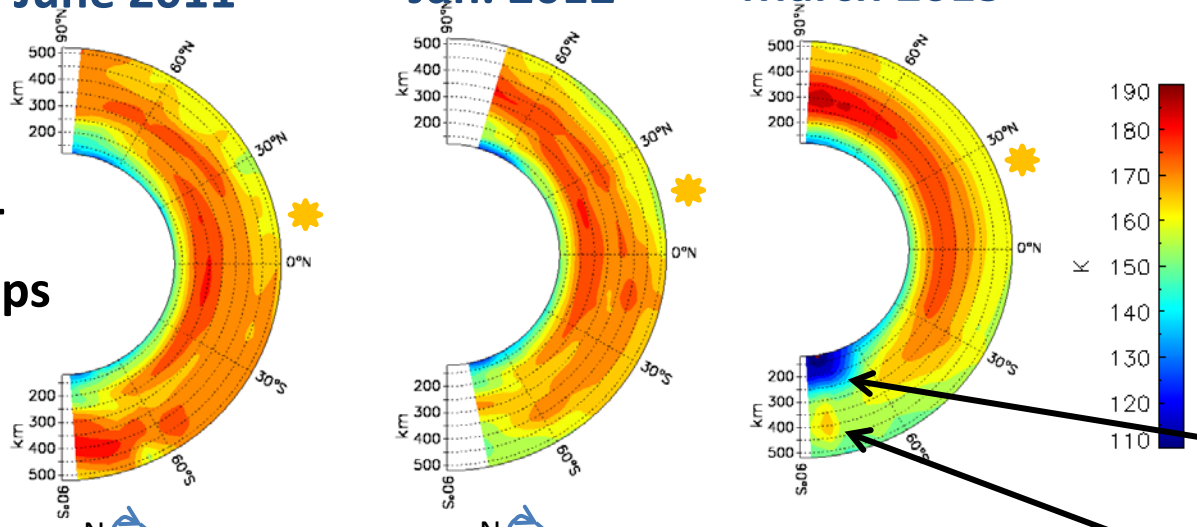
Seasonal variations since mid-spring

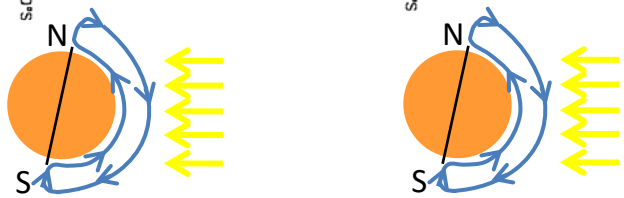
June 2011

Jan. 2012

March 2015

T maps

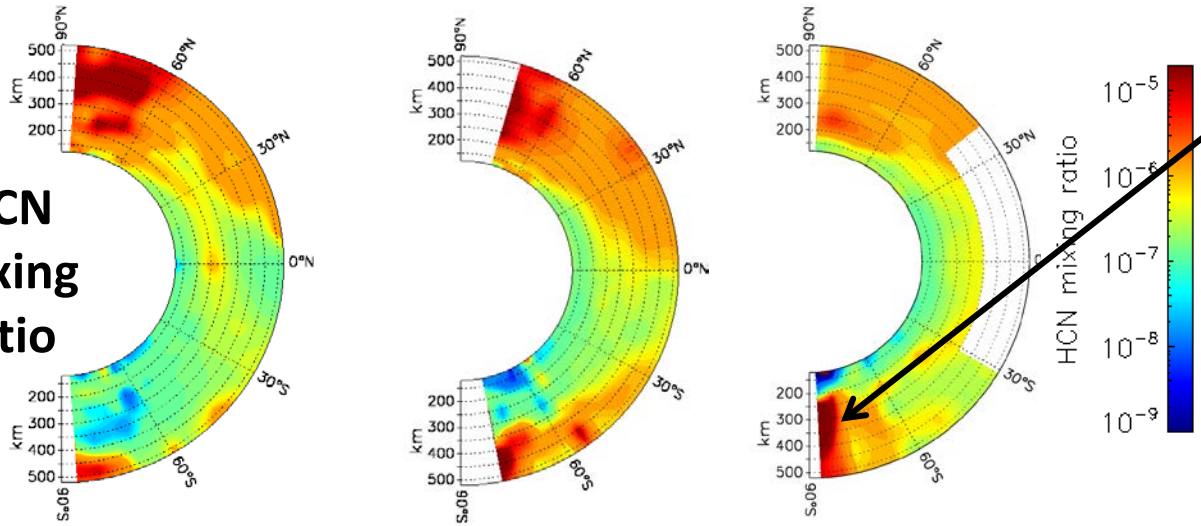




Strong cooling at the S pole: polar night

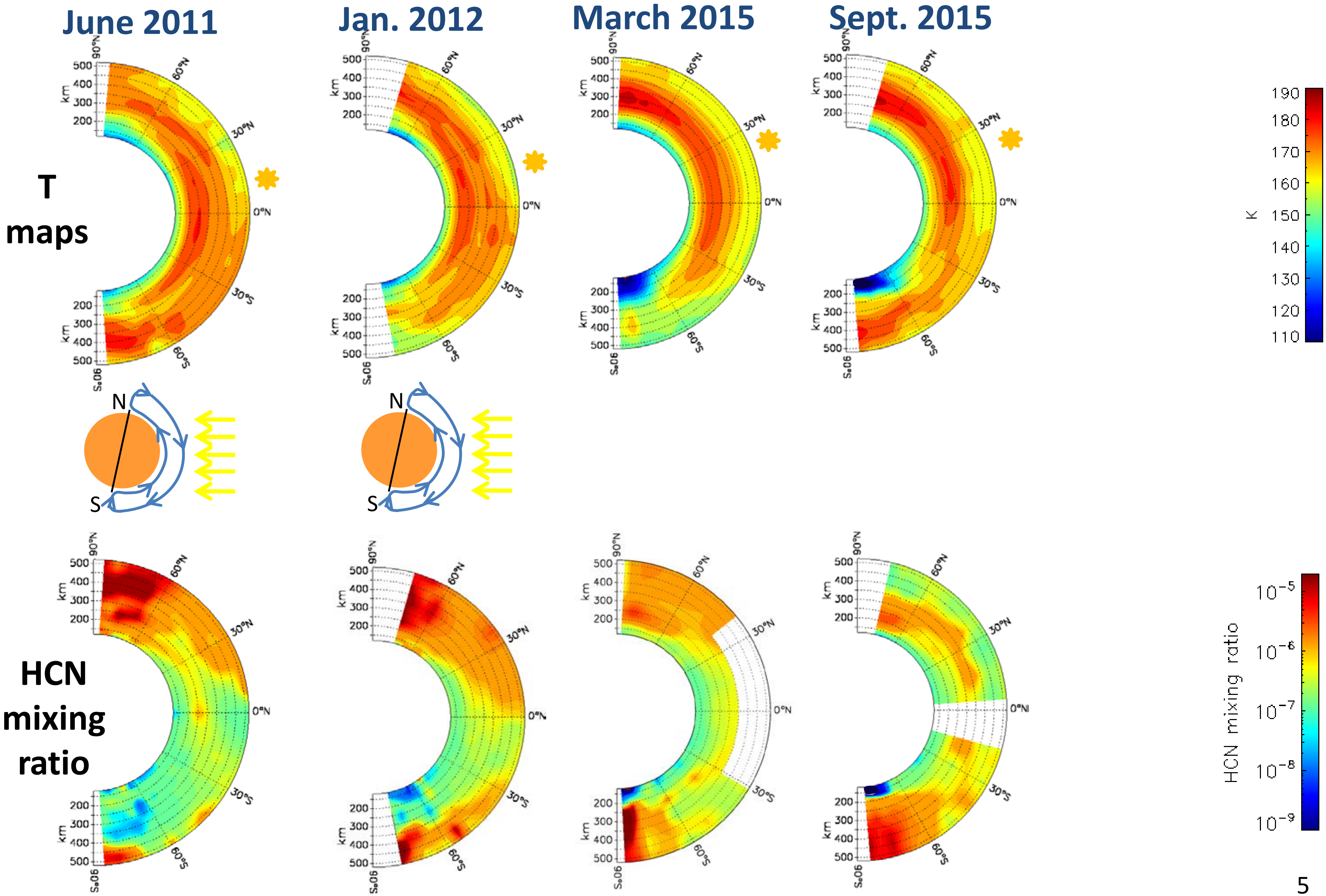
Adiabatic heating

HCN mixing ratio



Very strong molecular enhencement confined at latitudes higher than 80°S

Seasonal variations since mid-spring



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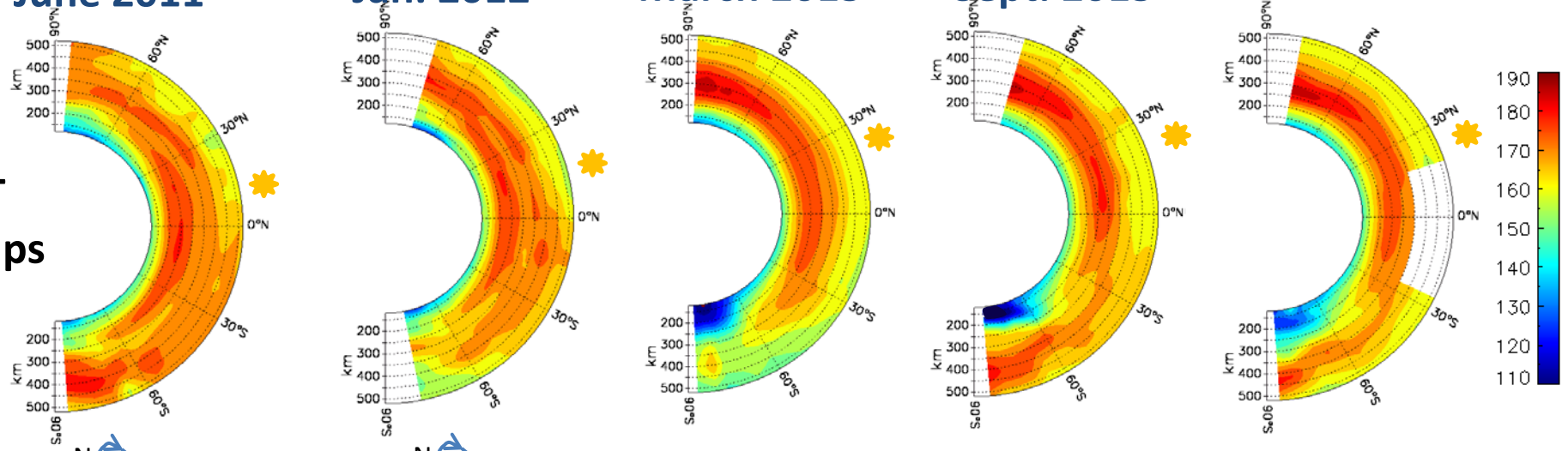
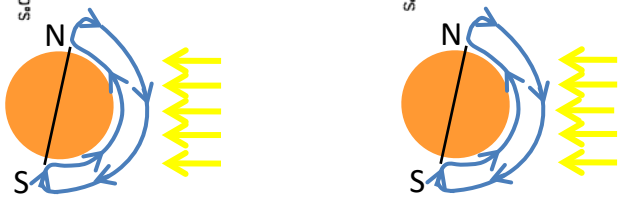
T maps





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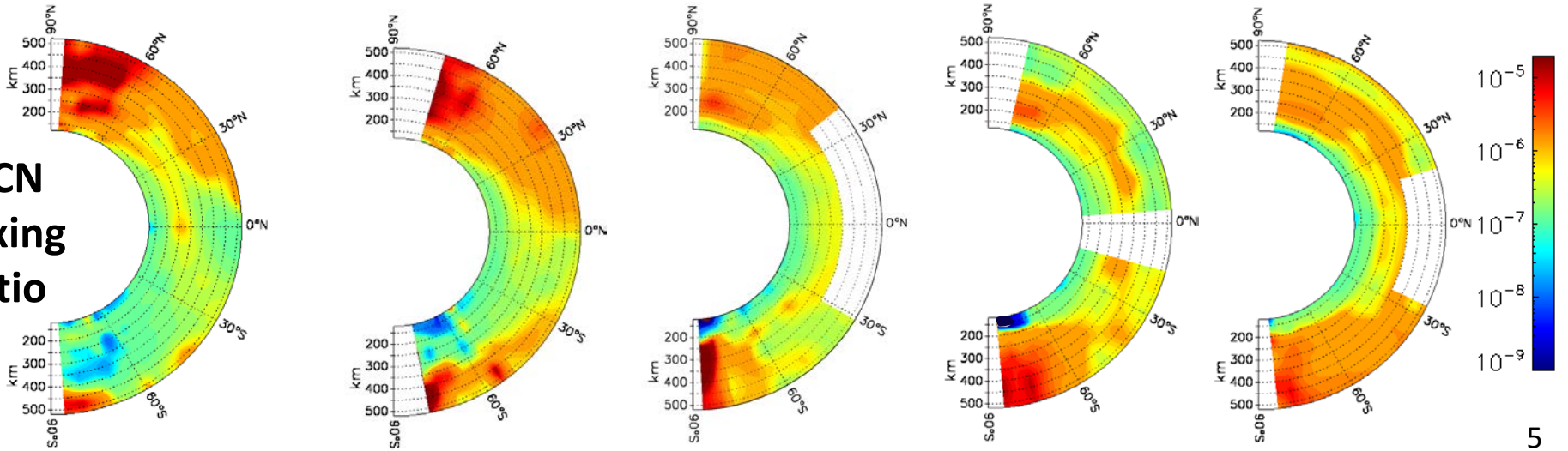
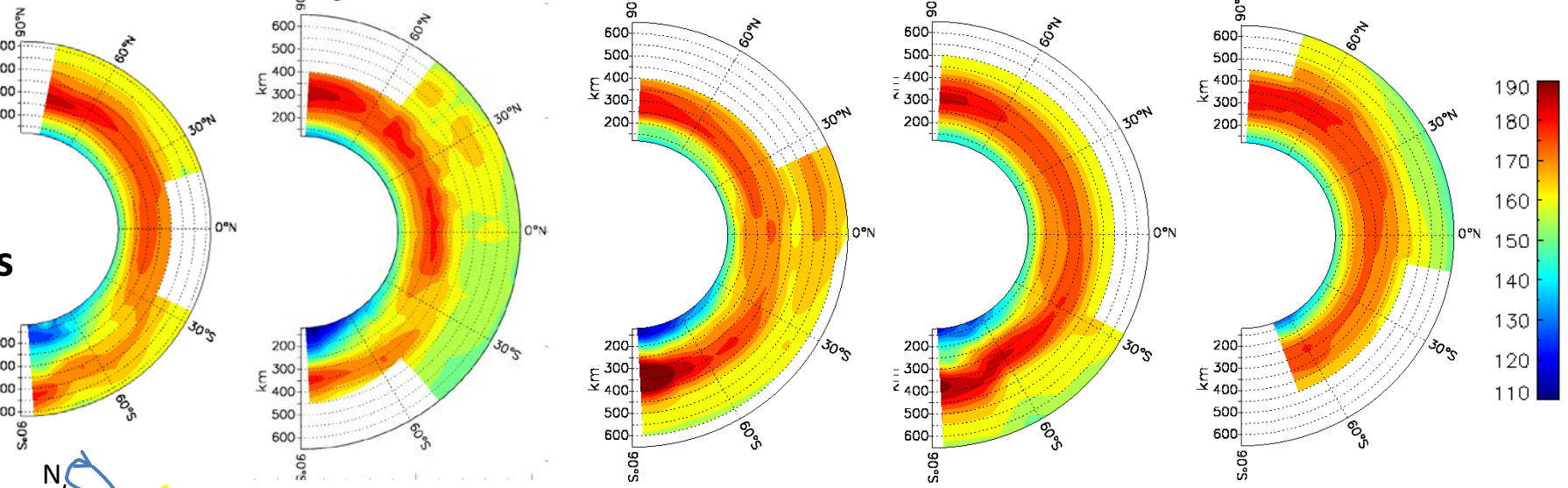
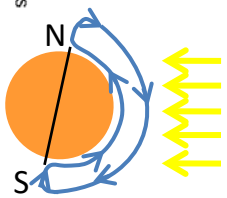


Seasonal variations before the northern summer

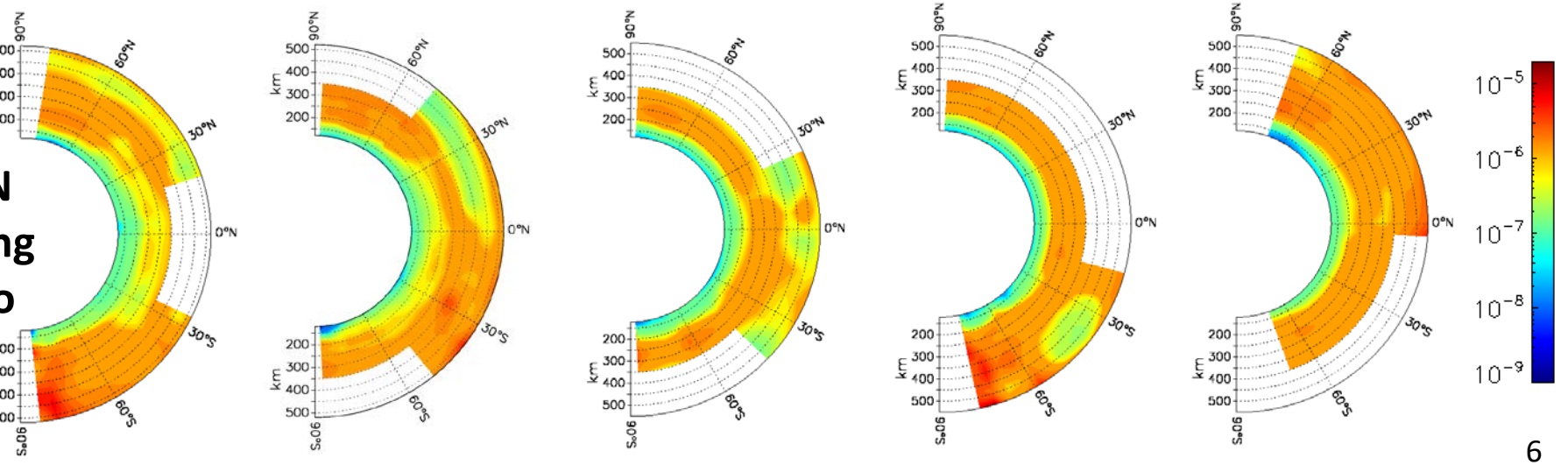
Jan. 2016 | May 2016 | Feb. 2017 | May 2017 | Sept 2017

T maps

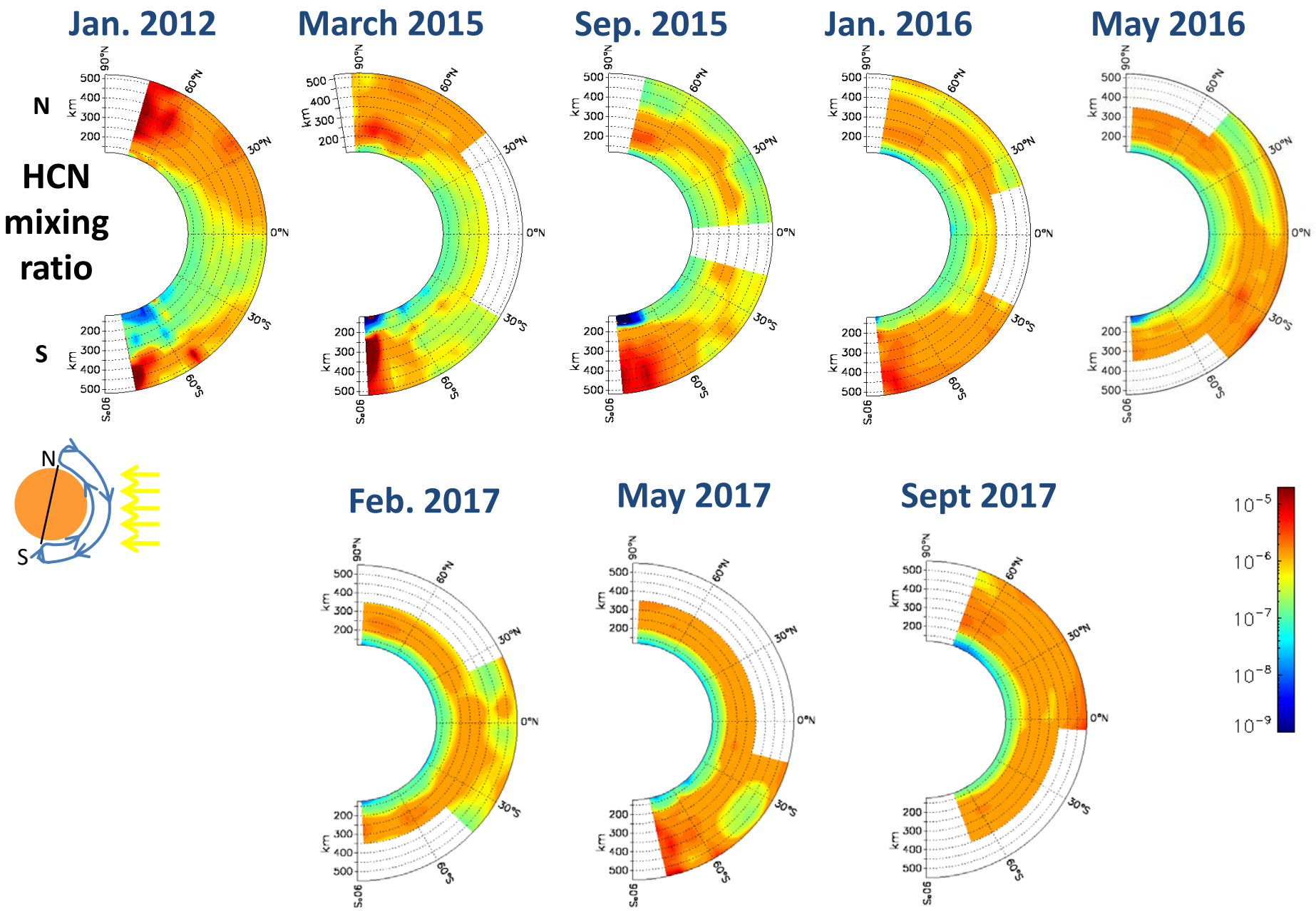




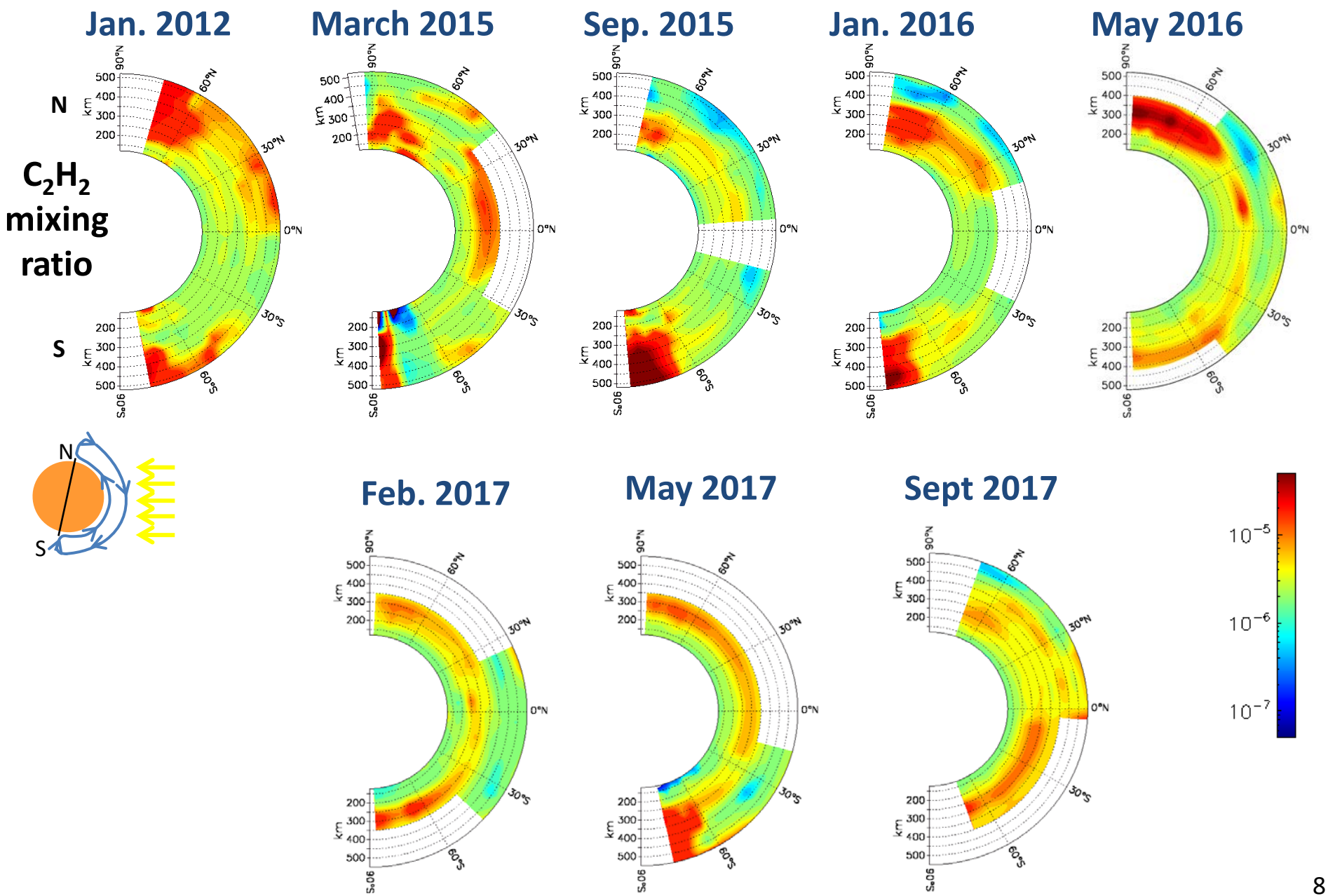
HCN mixing ratio



HCN mixing ratio from mid-N spring to summer



C_2H_2 mixing ratio from mid-N spring to summer



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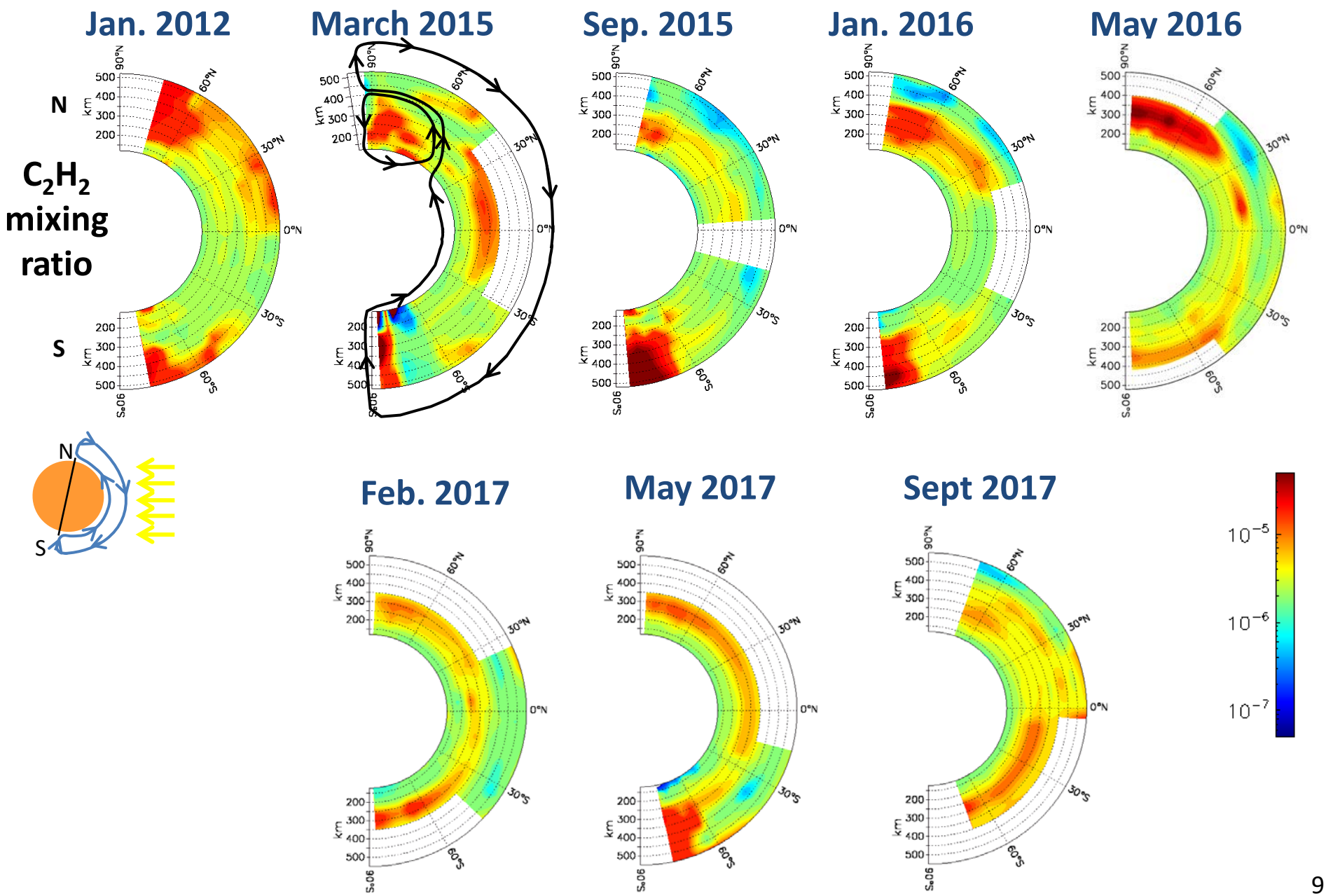
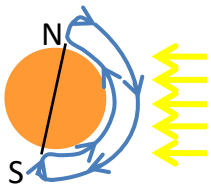
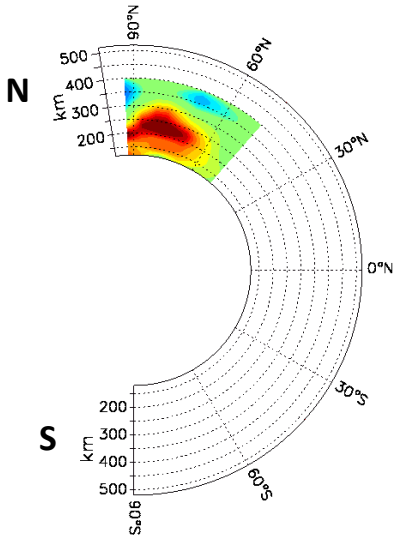


CH_3C_2H mixing ratio from 2015 to 2017

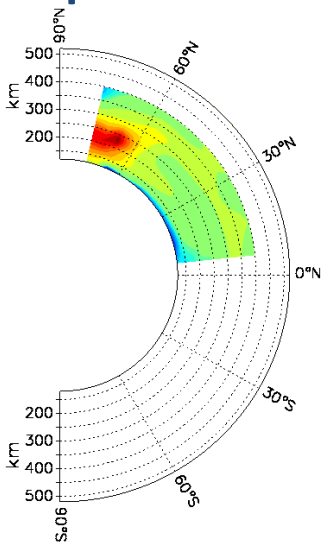
CH_3C_2H mixing ratio



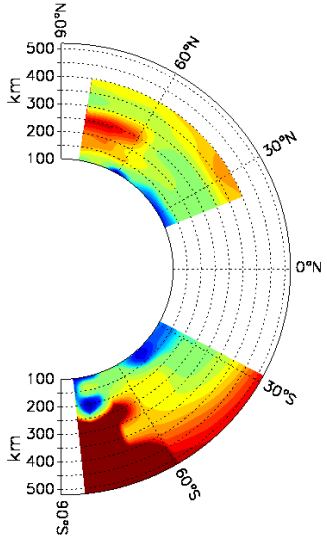
March 2015



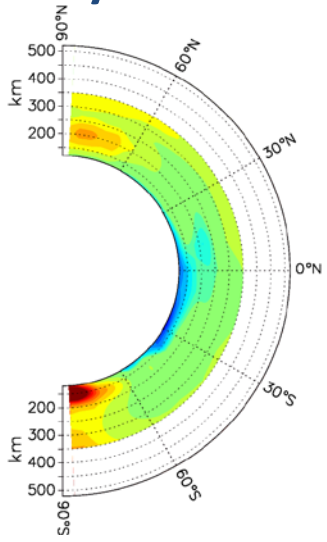
Sep. 2015



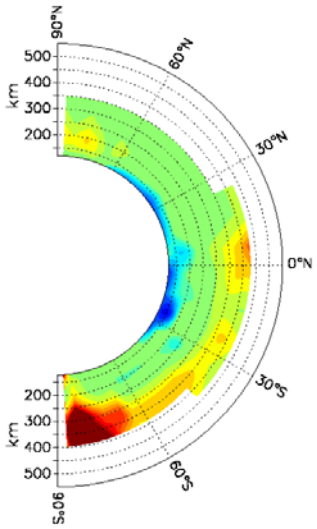
Jan. 2016



May 2016



Feb. 2017



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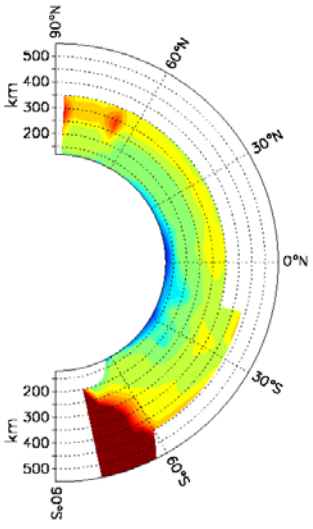

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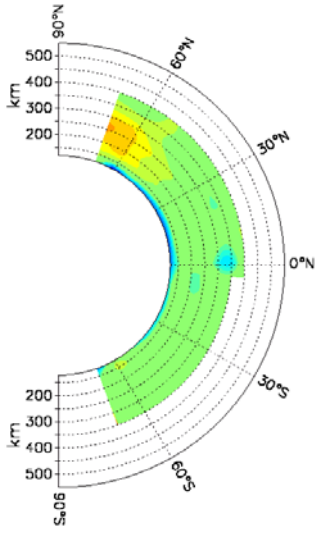
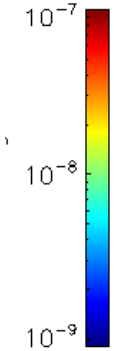
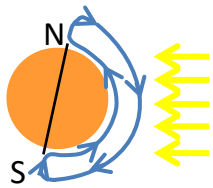




C_4H_2 mixing ratios from 2015 to 2017

C_4H_2 mixing ratio



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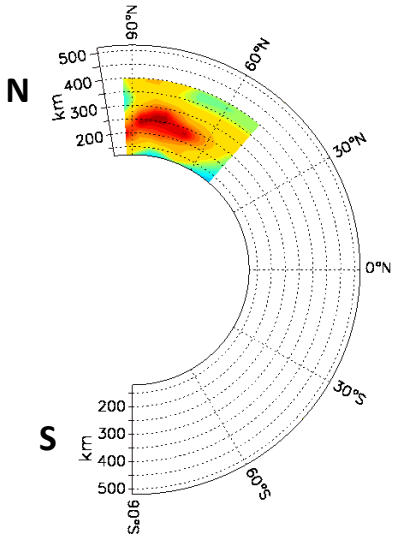

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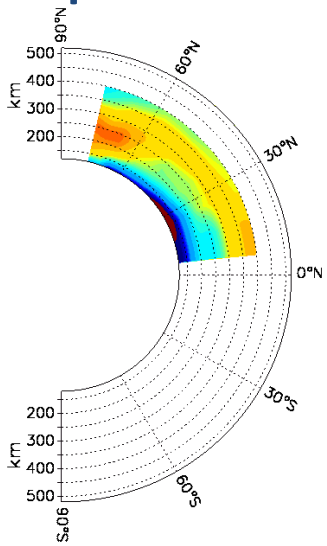
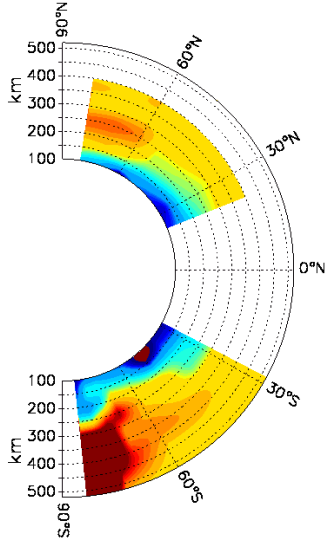


Jan. 2016



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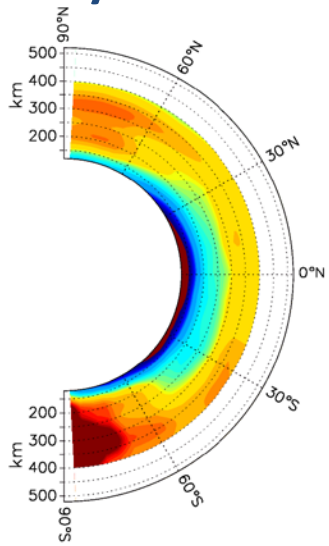

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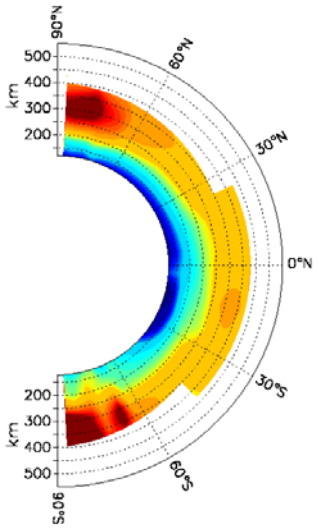

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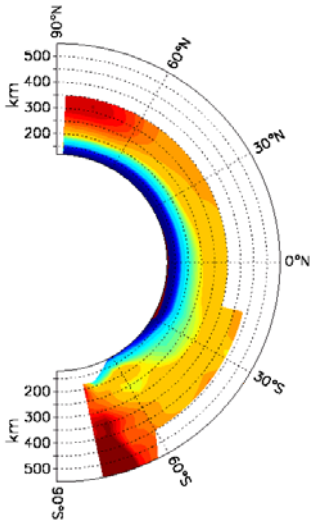

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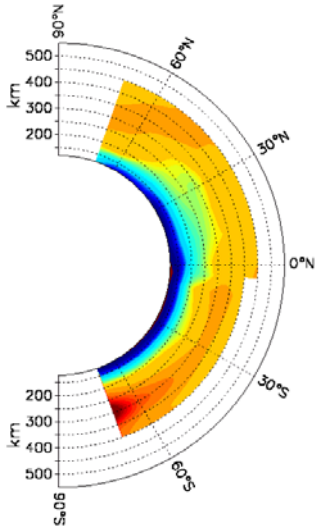
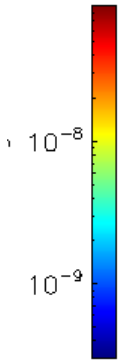
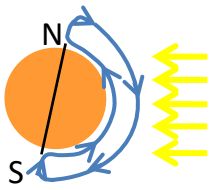




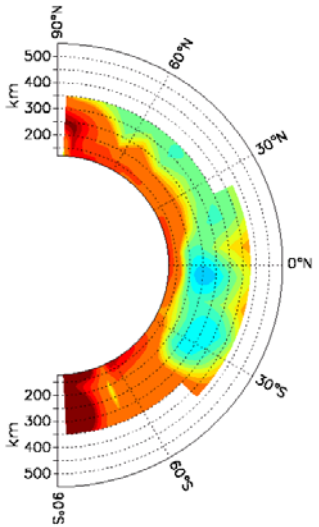
C_2H_4 mixing ratios in 2017

- C_2H_4 does not condense
- Below 500 km: photodissociation + reaction with H to form C_2H_5
- Transport by global dynamics

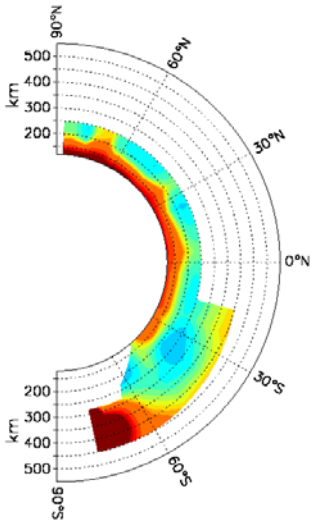
} Enrichment in the deep stratosphere



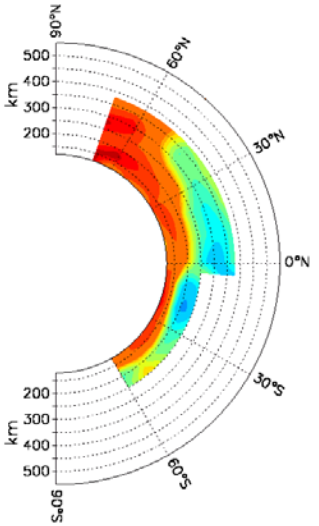
Feb. 2017

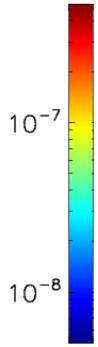


May 2017



Sept 2017



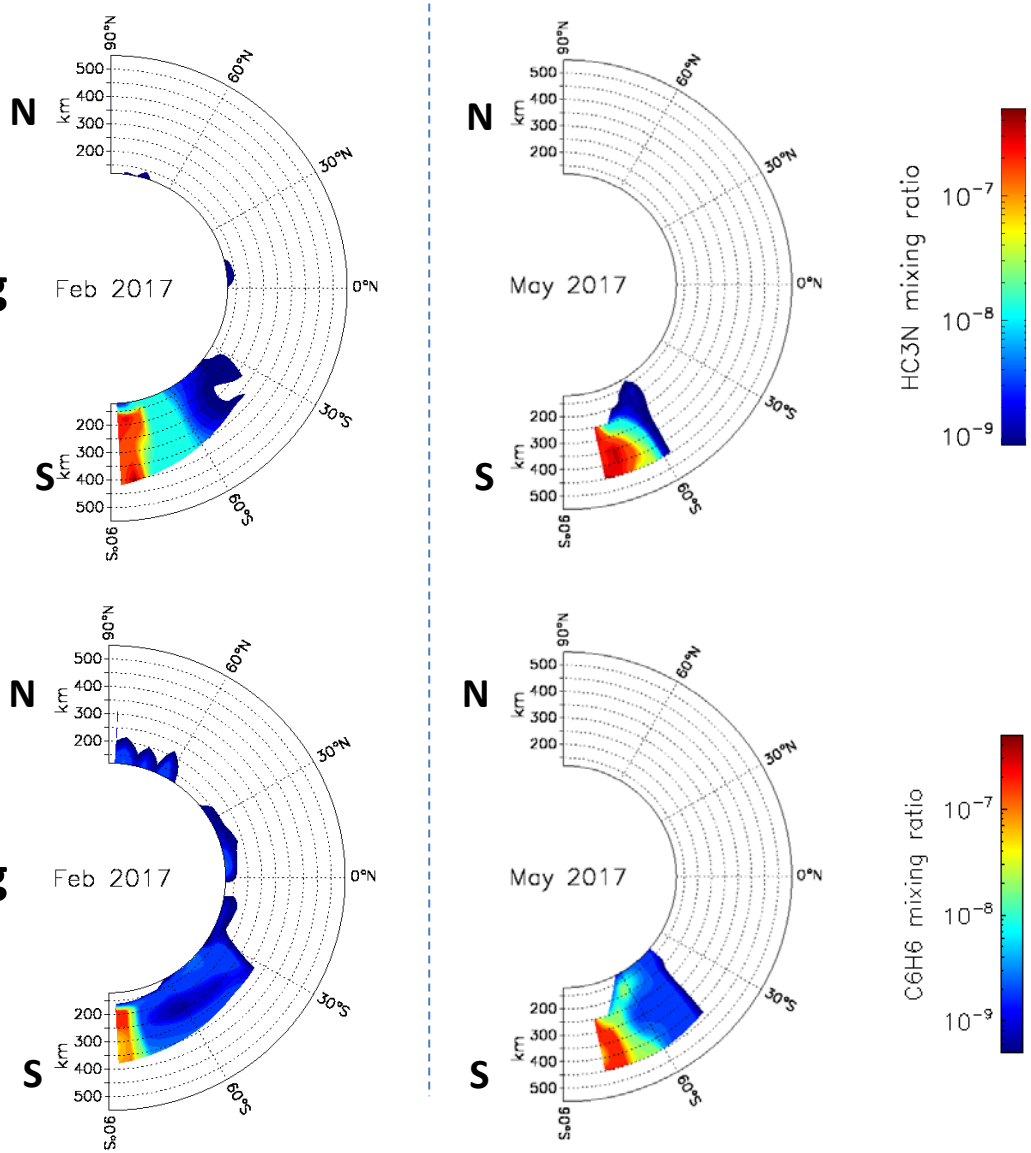


HC_3N and C_6H_6 mixing ratios in 2017

Feb. 2017 (nadir)

May 2017 (limb)

HC_3N mixing ratio



C_6H_6 mixing ratio

HC_3N and C_6H_6 are observed only at high southern latitude
-> enrichment due to the descending branch.

Very sharp latitudinal gradient from 70°S to 80°S
-> boundary of the polar vortex

Increase of the polar vortex size between Feb and May 2017.

Summary

- **Reversal of the global circulation** within 2 years after the northern spring equinox
- **Strong molecular enrichments at the S pole after the equinox + cold stratospheric temperatures** => condensation of several species
  -> observation of the South polar cloud since May 2012
- **Persisting molecular enrichment at the north pole during the Spring**
  -> persistence of the northern winter cell during the spring in the lower stratosphere (as predicted by GCM)
- **Layer structure seen in the upper stratosphere mixing ratio maps since 2015**
  -> dynamical effect
- All profiles will be available in the European planetary science VO portal **http://vespa.obspm.fr** (currently includes profiles from Vinatier et al. 2015).
- See also **Christophe Mathe's poster (WS26)** for seasonal variations from 2004 to 2017 from other CIRS limb spectra