

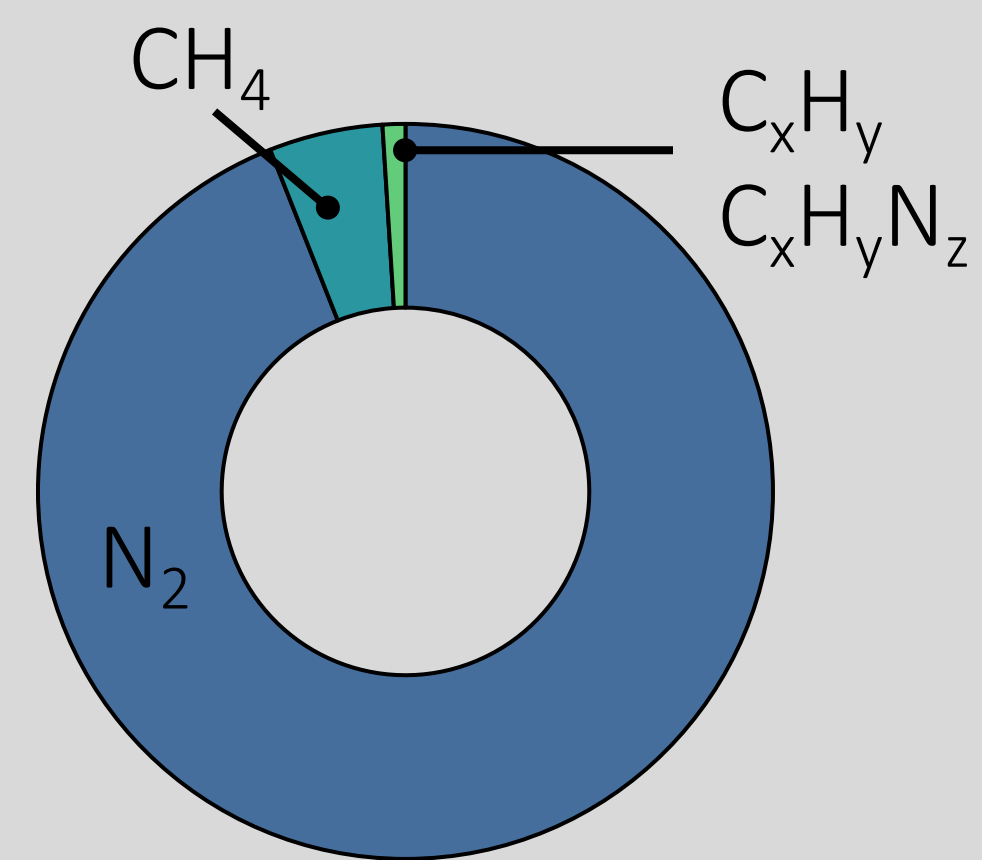
Evolution of Titan's Stratospheric HCN in High Spatial Resolution

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TITAN

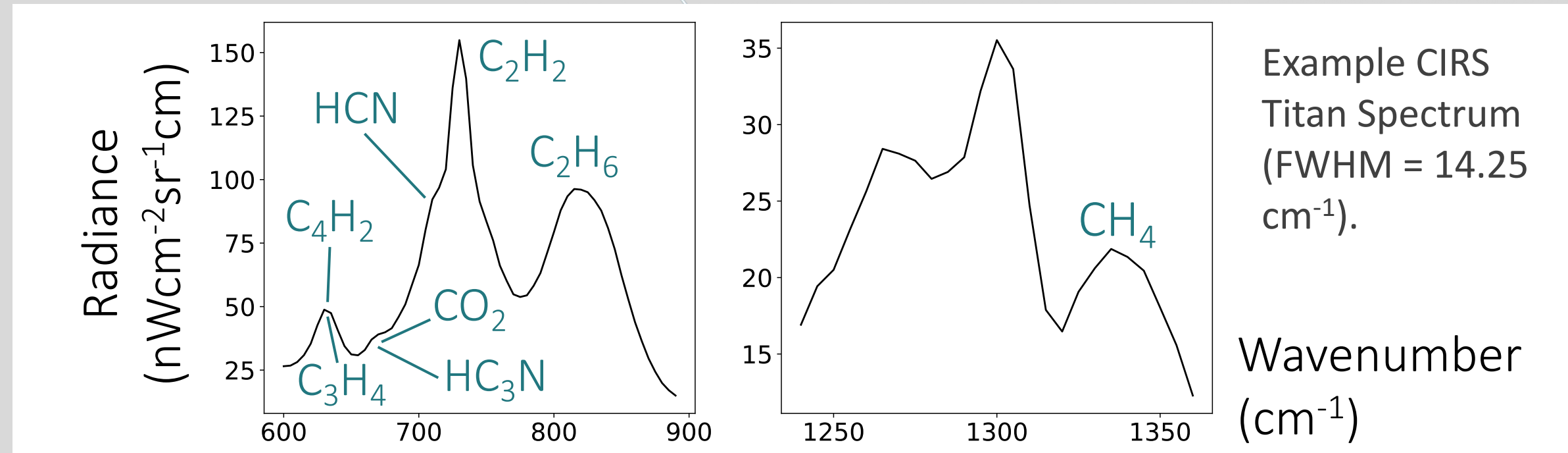


Saturn's largest moon, Titan, is the only moon in our solar system with a substantial atmosphere. Titan's atmosphere comprises mostly Nitrogen and is also host to many hydrocarbon and nitrile species, produced by a **complex photochemistry**¹ in Titan's upper atmosphere.

GCMs predict that the **meridional circulation** in the middle atmosphere (stratosphere and mesosphere) is dominated by a **single pole-to-pole Hadley cell**, with potentially a second small cell at the winter pole^{2,3}. This model suggests free mixing across the equator.

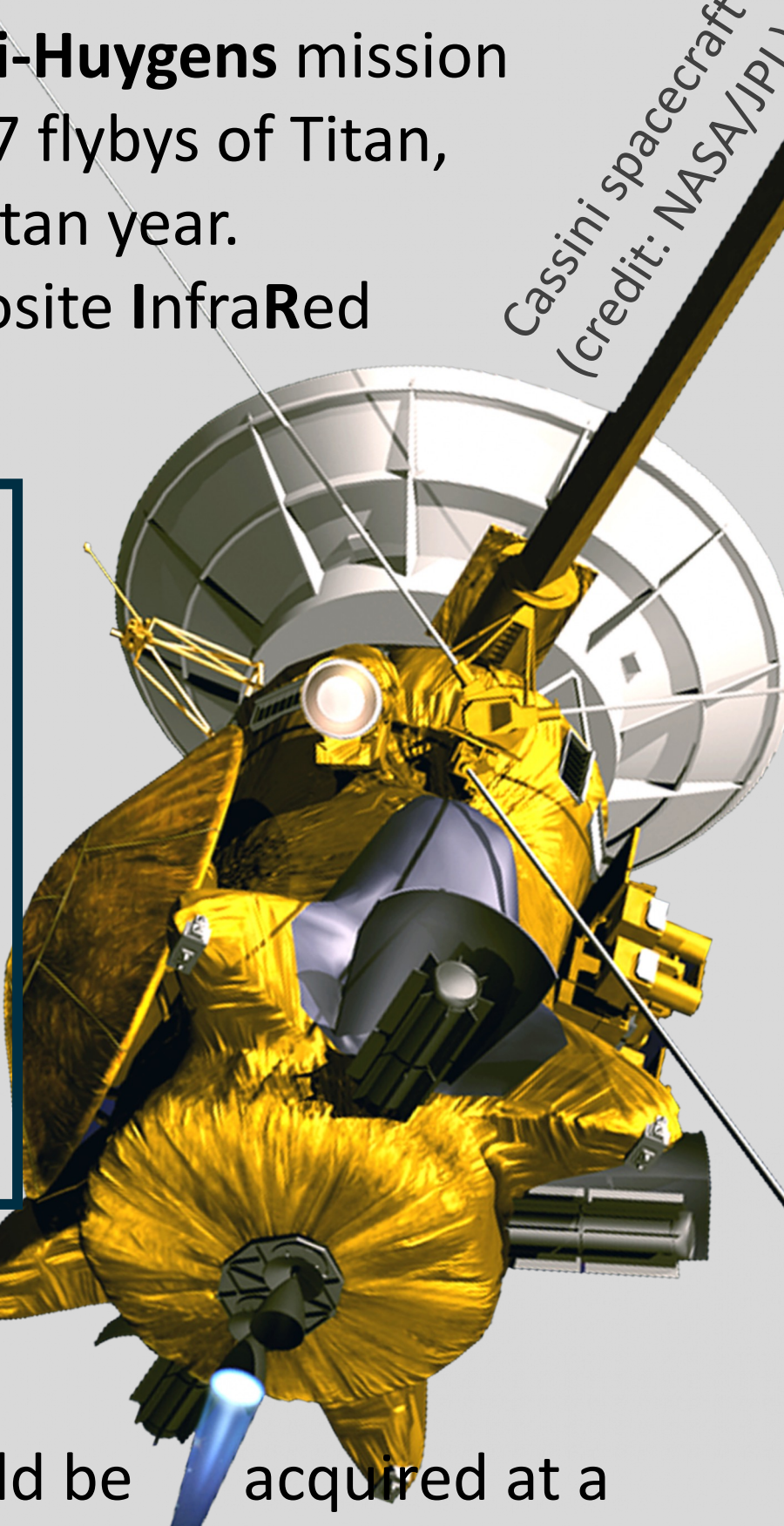


SPACECRAFT DATA



- From 2004 – 2017, the **NASA/ESA/ASI Cassini-Huygens** mission explored the Saturn system. **Cassini** made 127 flybys of Titan, observing Titan for 13 years – almost half a Titan year.
- We use infrared spectra from Cassini's **Composite InfraRed Spectrometer (CIRS)** instrument^{4,5,6}.

Cassini/CIRS	Comprised two interferometer spectrometers	Adjustable spectral resolution (FWHM 0.5 – 15.5 cm ⁻¹)
	Sensitive to the mid to far-infrared (10 – 1500 cm ⁻¹)	Collected 8 million Titan spectra

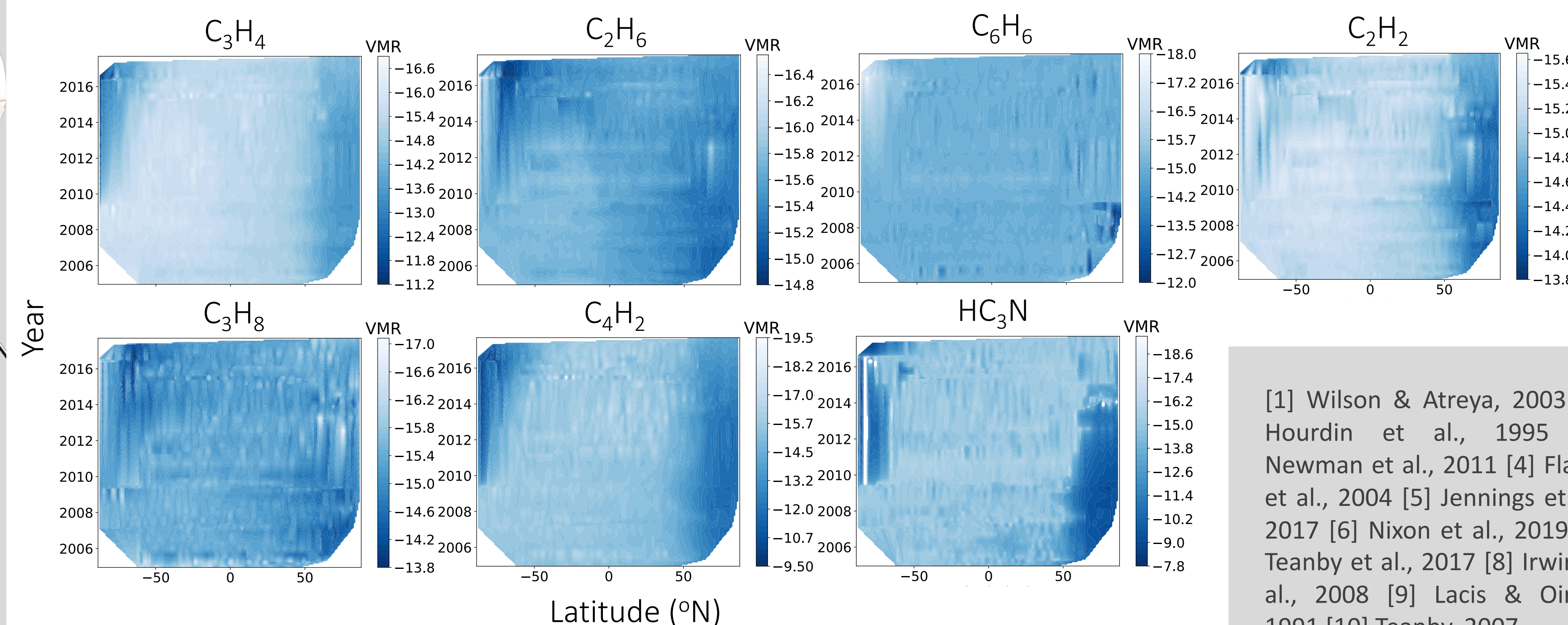
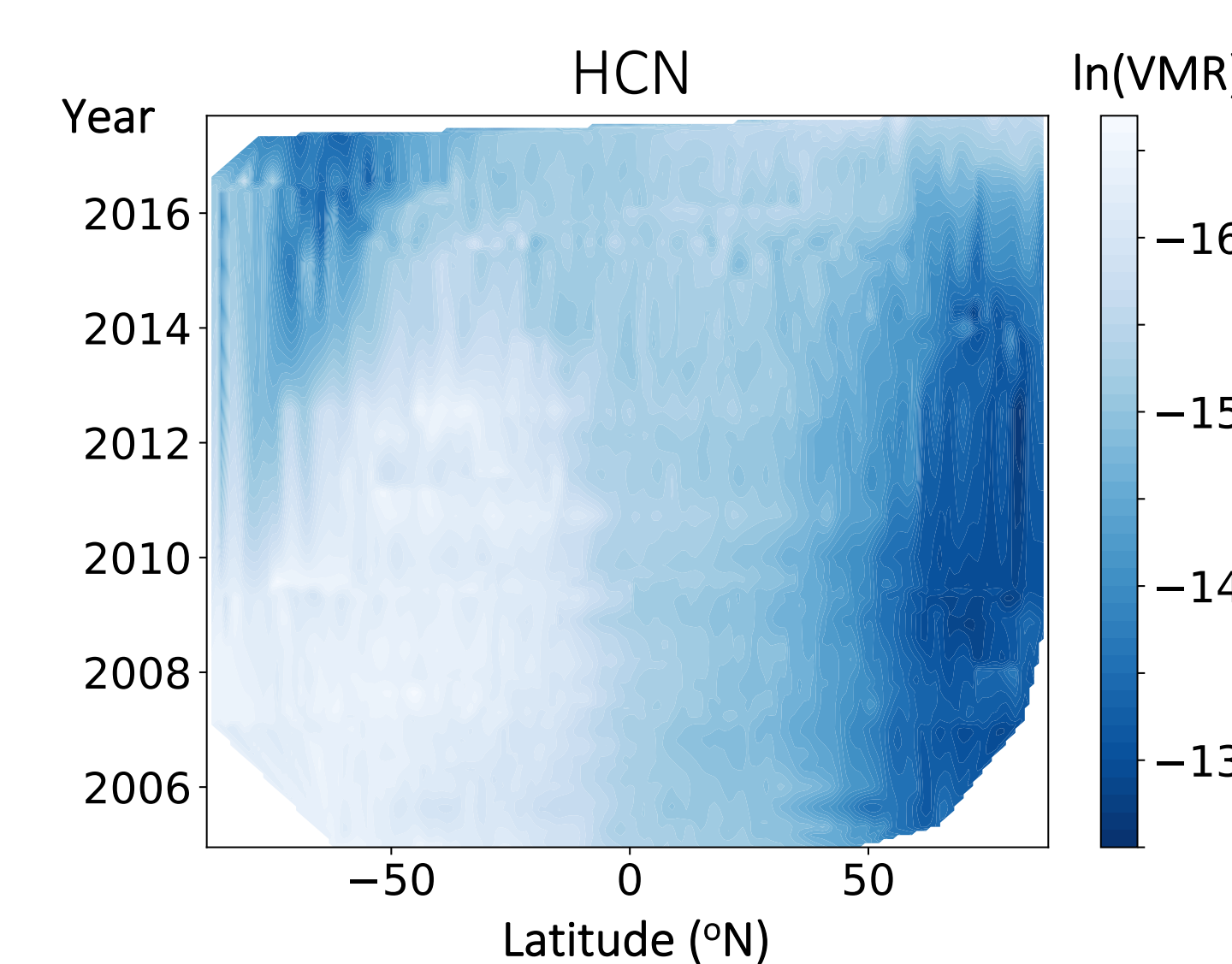
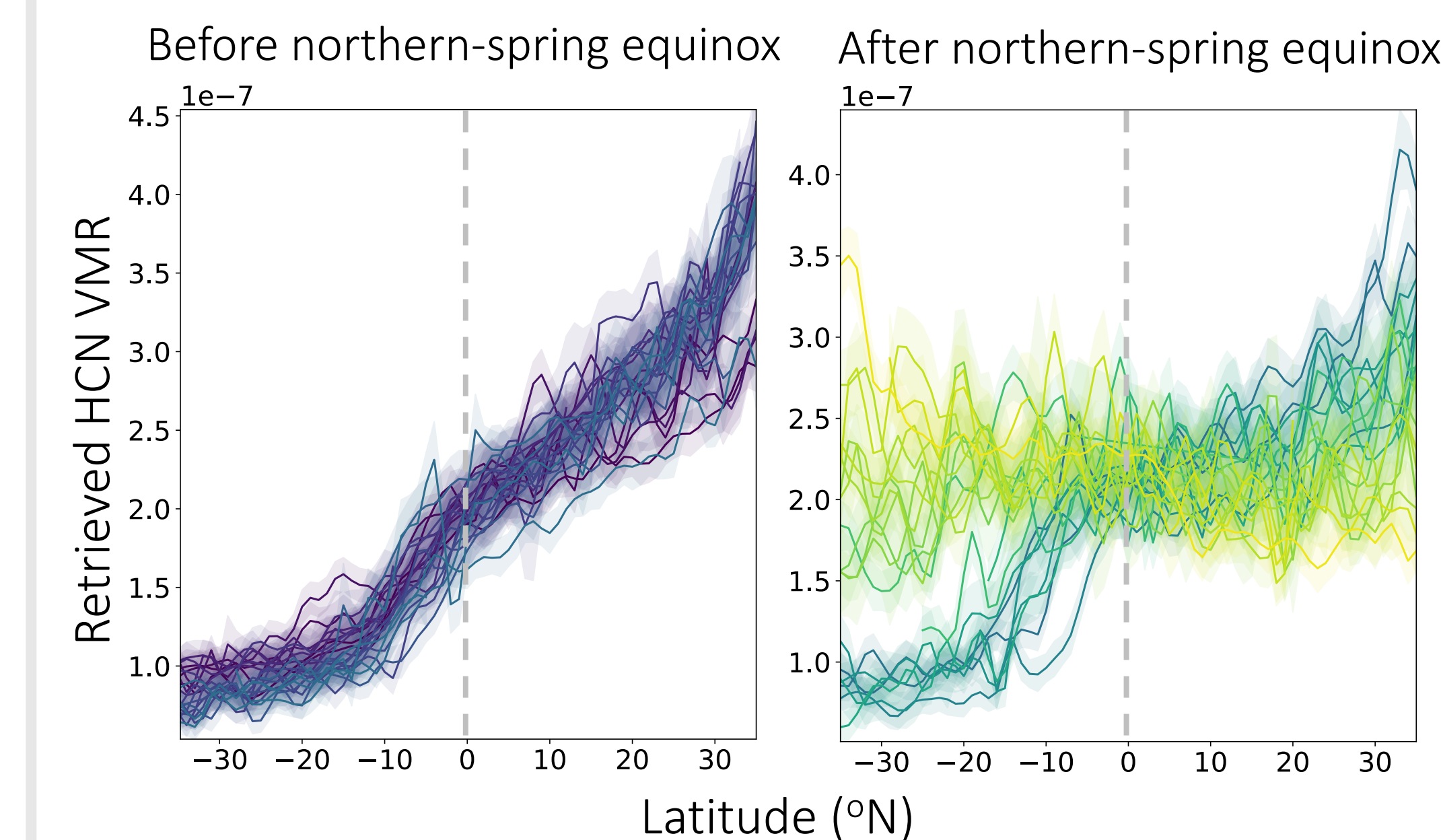
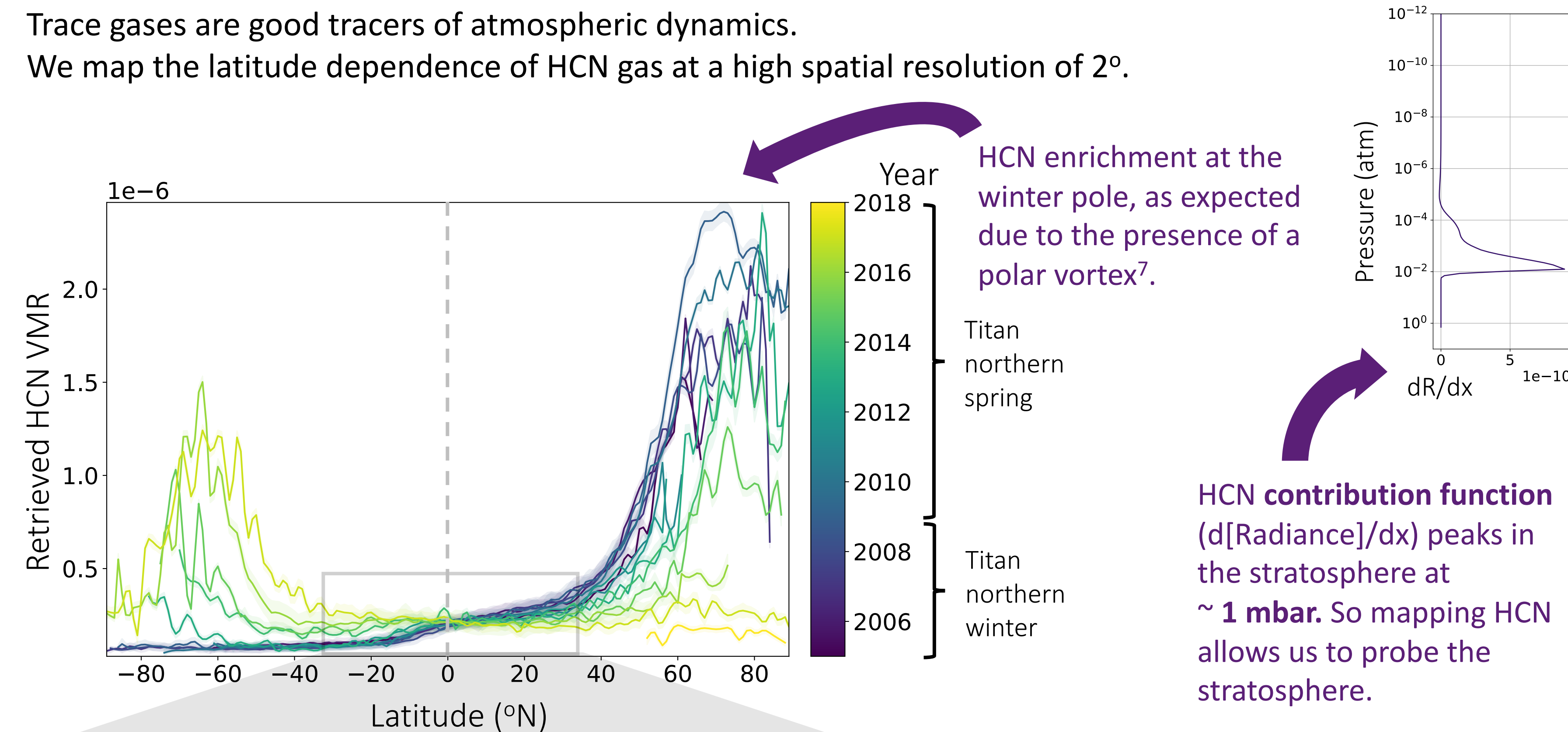


We analyse **low spectral resolution** observations (av. FWHM = 14.25 cm⁻¹), because:

- ✓ Observations of a low spectral resolution could be acquired at a closer approach distance to Titan, so have a **high spatial resolution**.
- ✓ Low-spectral resolution observations have **good temporal and latitudinal coverage** throughout the Cassini mission.

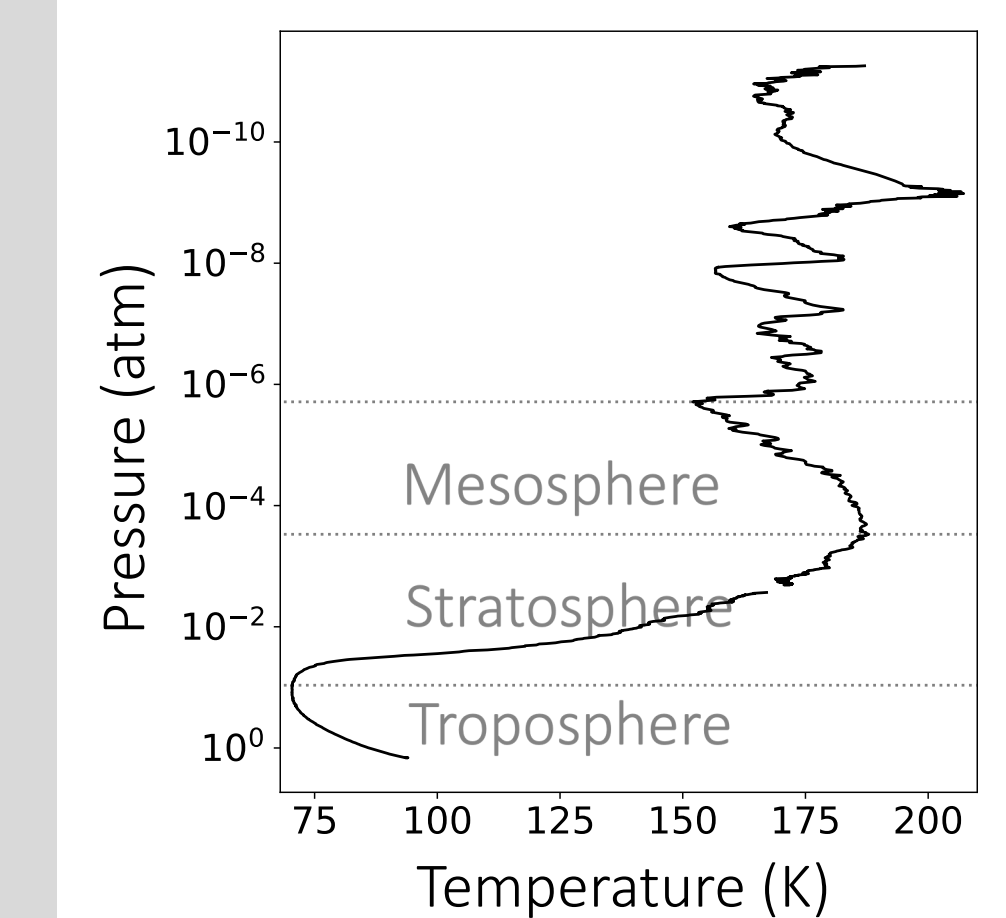
RESULTS

- Trace gases are good tracers of atmospheric dynamics.
- We map the latitude dependence of HCN gas at a high spatial resolution of 2°.



[1] Wilson & Atreya, 2003 [2] Hourdin et al., 1995 [3] Newman et al., 2011 [4] Flasar et al., 2004 [5] Jennings et al., 2017 [6] Nixon et al., 2019 [7] Teanby et al., 2017 [8] Irwin et al., 2008 [9] Lacis & Oinas, 1991 [10] Teanby, 2007.

IN-SITU DATA



Titan temperature profile measured by the Huygens/HASI instrument.



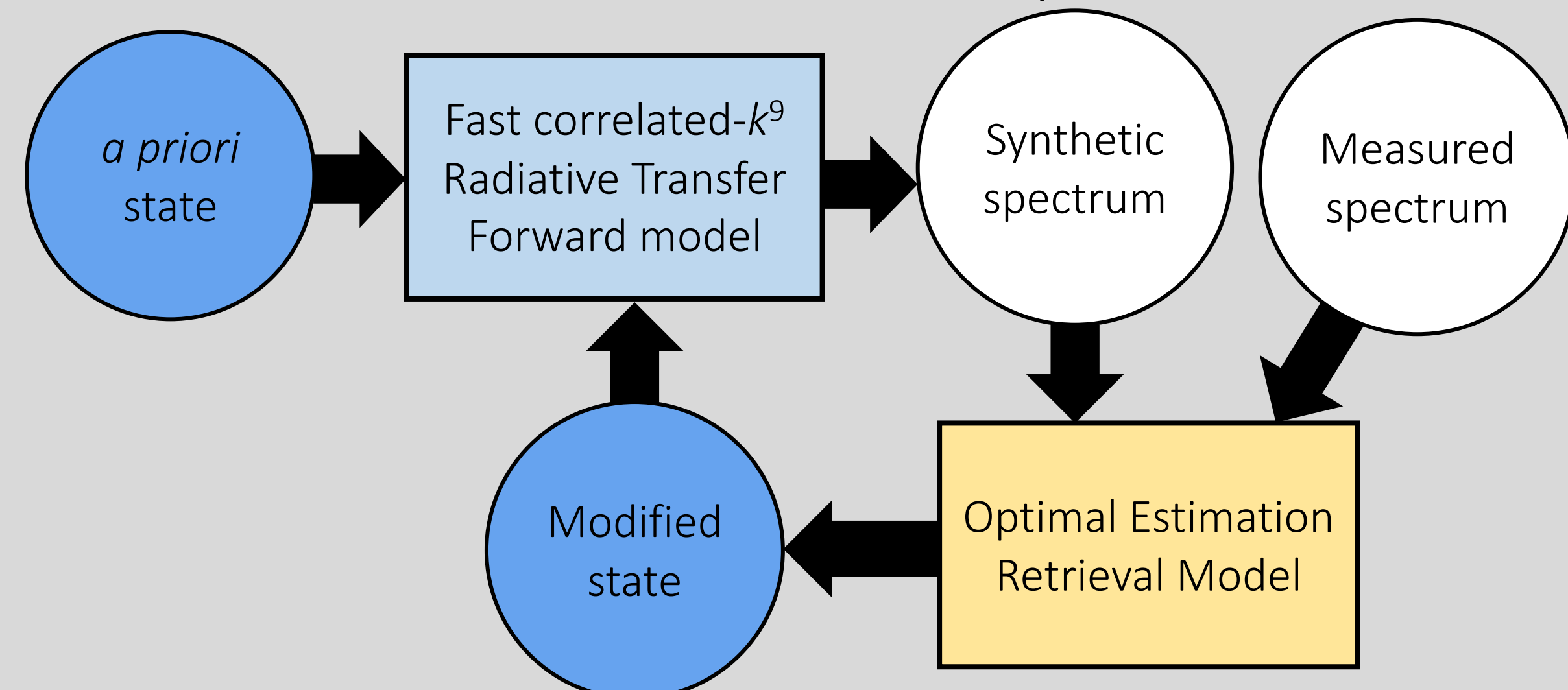
Artist's impression of the Huygens probe descent and landing on Titan (credit: NASA/JPL, ESA).

- On its 3rd flyby of Titan, the Cassini spacecraft released the **Huygens** probe. **Huygens** took measurements on descent through Titan's atmosphere and on landing at Titan's surface.
- We use *in-situ* temperature and methane abundance measurements to constrain our atmospheric retrievals.

METHOD

NEMESIS

- We use the **Non-linear optimal Estimator for Multivariate spectral analysis (NEMESIS)**⁸ radiative transfer and retrieval code. This couples a radiative transfer forward model with an optimal estimation retrieval:



- Gas VMRs as functions of latitude are smoothed by fitting splines¹⁰.

CONCLUSIONS

We observe a sharp change in the gradient in HCN over the equator

This gradient changes seasonally

This hints at a potential mixing barrier near the stratospheric equator. However, the predicted meridional circulation in Titan's stratosphere suggests that species should be freely mixed over the equator.