Reanalysis of Titan INMS mass spectra

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Titan's ionosphere was sampled by the mass spectrometer of the *Cassini* spacecraft many times during the course of the mission. Mass spectrometer analysis can be complicated, and identifying in which way a specie contribute to a mass peak is challenging. It is easier to fit the most abundant species, and trace species are often left unanalysed. Here we focus our work for now on 3 major species (N_2,CH_4, H_2) and 1 trace specie (Ar).

Method and data treatment

- **Calibration of INMS data** using recommendations from previous works[1,2,3,4,5]
- MS deconvolution code[6]

→ **Randomisation of the species fragmentation patterns** between the allowed incertitudes

→ **Monte-Carlo simulation**. The code then try to fit at once all m/q peaks using the species in our database.

→ **100000 simulations**

→ **Allowed incertitude of 5%** for the **major species**, and **30%** for **Argon**.

→ **Mean of the 5% best simulations.**

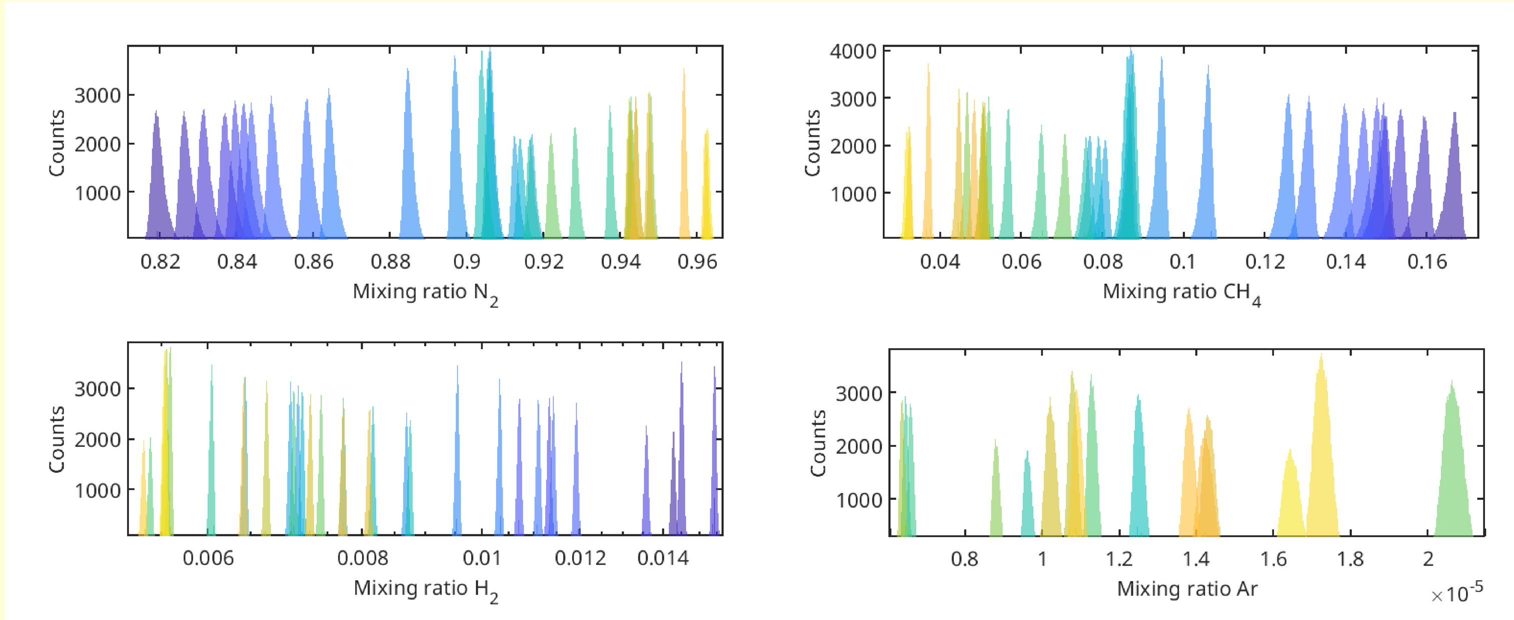

Figure 1: 100000 simulations of gases mixing ratio results for flyby T126 at each altitude (low to high altitudes represented as a colour variation from yellow to blue).

Results

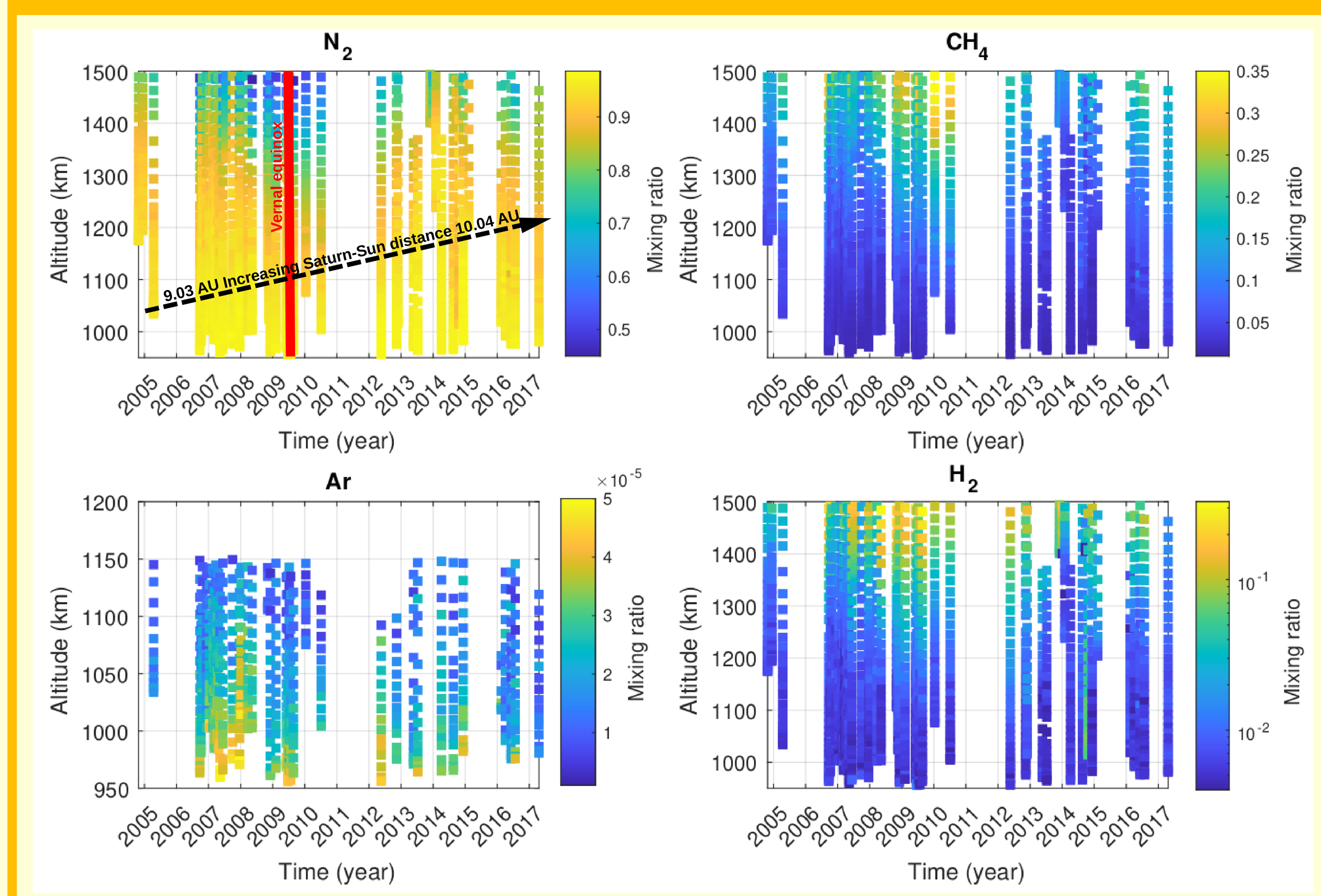

Figure 2: Mixing ratios of Nitrogen, Methane, Argon and Hydrogen as a function of time and altitude.

N_2
→ Isotope ratio $^{14}N/^{15}N = 197 \pm 1.3$ constant over the years.
→ Mixing ratio decreases when altitude increase.
→ molecular density changes with time.

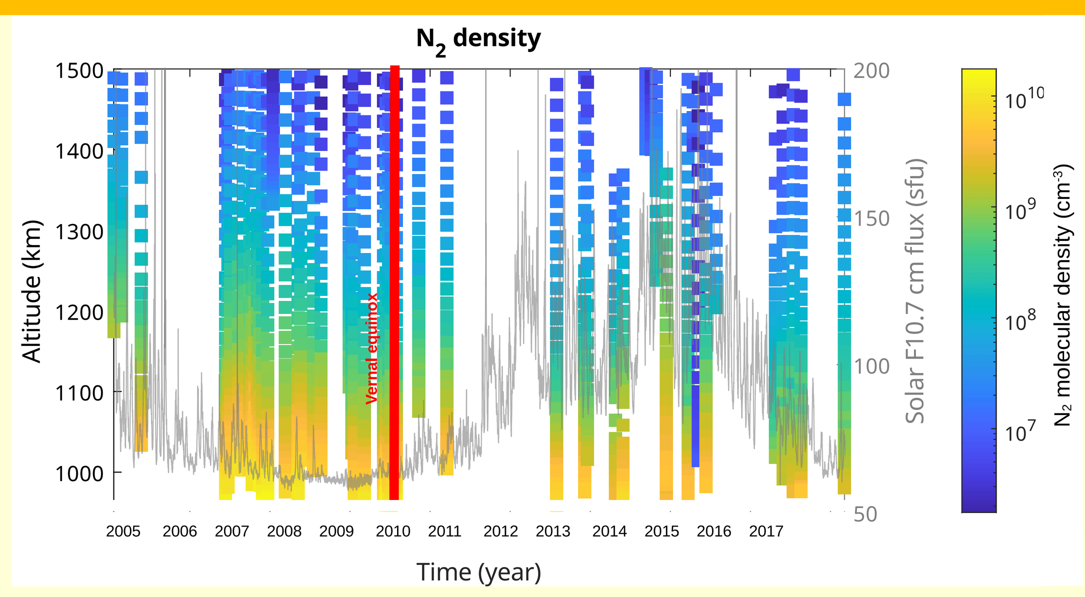

Figure 3: Nitrogen density (cm^{-3}) as a function of altitude and time. The gray line is the solar F10.7 cm flux in solar flux units.

CH_4
→ Mixing ratio increases with altitude

Argon
→ Not found above 1150 km of altitude
→ Like N_2, Ar mixing ratio decreases when altitude increases

H_2
→ Mixing ratio increases with altitude

Global scale temporal variation clearly visible

→ Steady decrease of N_2 mixing ratio and density until the vernal equinox. It increases until 2014 then decreases again.
→ Nightside/Dayside and Latitude/Longitude effects on the global scale variation are minor.

Influence of the solar flux

→ N_2 **mixing ratio** and **density** increase with periods of intense solar flux.
→ CH4 density increases with periods of intense solar flux, but proportionally less than N_2.

Influence of Saturn-Sun distance

→Solar flux influence more important when Titan is closer to the sun (Fig. 2 and 3) : lesser solar flux needed to increases N_2 density.

Evidence of a homopause

→Ar decreases 10 times faster with the altitude than N_2→segregation depending on the molecular weight.
→ Changes of slopes in mixing ratios with altitude.

About the homopause

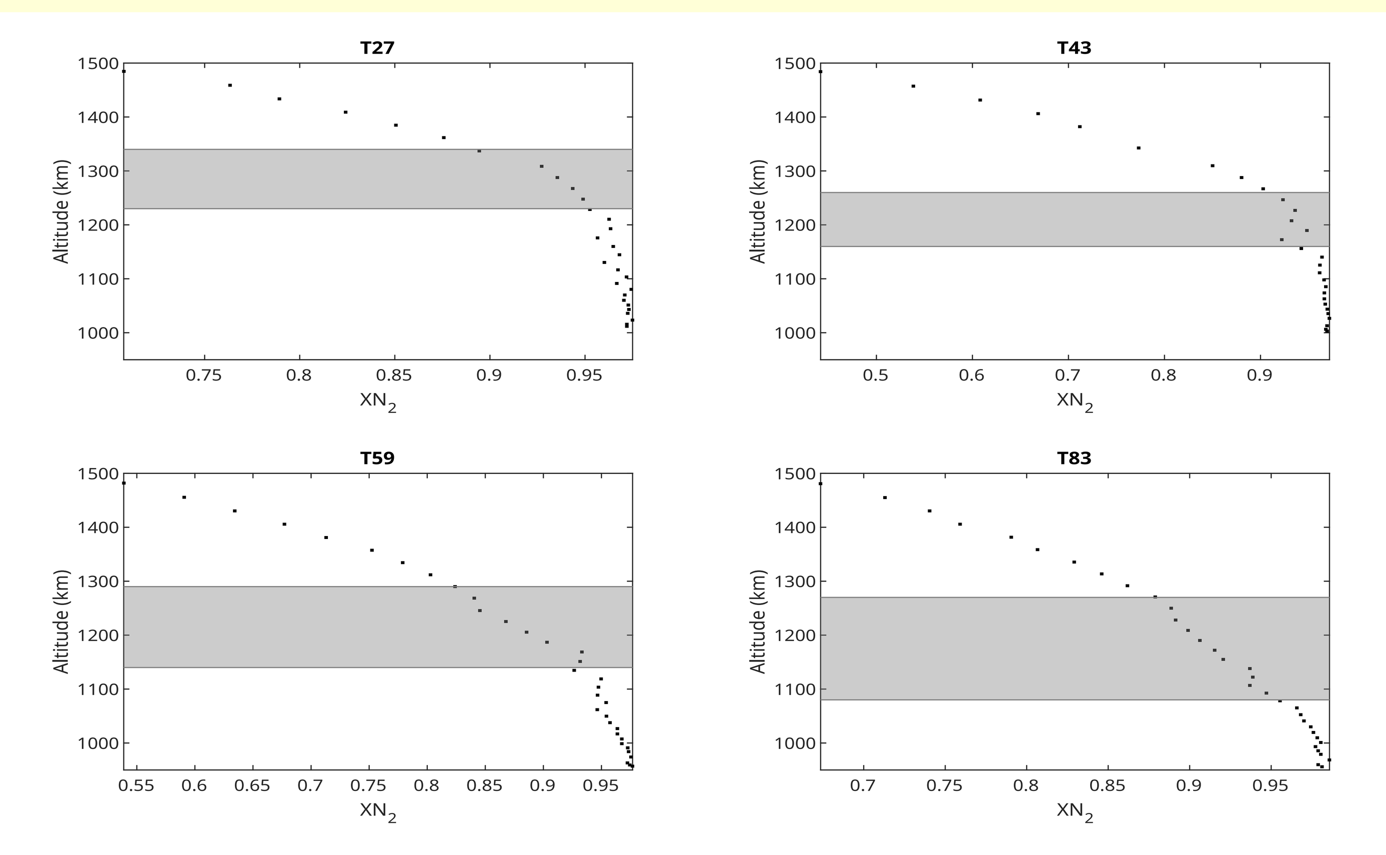

Figure 4: Mixing ratios of Nitrogen for flyby T27, T43, T59, and T83 used in our analysis. The gray area represents the altitude of the homopause graphically determined.

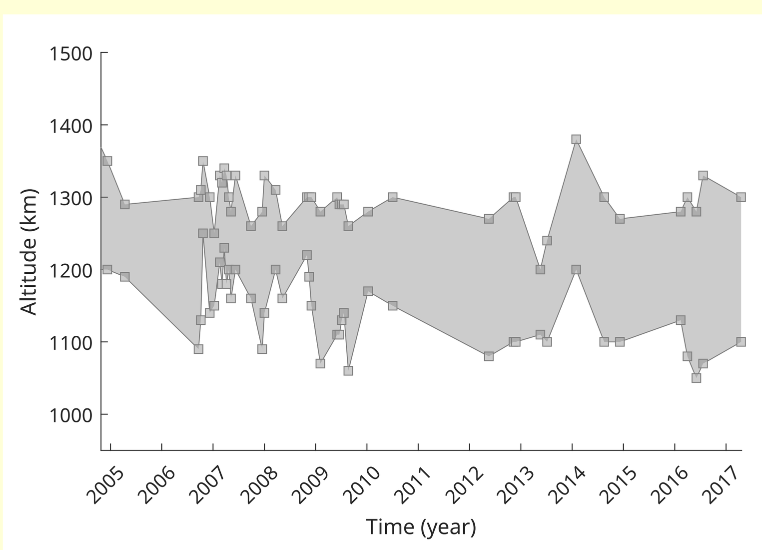

Figure 5: Homopause altitude as a function of time.

How to determine it ?

1: Above the homopause the molecular density of N2 can be written as :

$$n_{N_2} = n_{0N_2} e^{\frac{-z}{H}}$$

With $H = \frac{RT}{M_{N_2} g}$

R: gas contant
T: temperature
M: molar mass
g: acceleration of gravity
z: altitude

When we can't fit the data anymore using these parameters, we can place the upper boundary of the homopause.
→ We can extract the temperature when fitting the exponential at high altitude : 250 to 450 K.

2: Localising the change of slope in N_2 mixing ratio with the altitude using tangents graphically determined, or using the derivative of the power law fitting the data.

Risk: Confusing the change of slope due to the separation of the gases according to their molecular weight, and a change of slope due to (photo)chemical reactions changing the mixing ratios.

→**Hommopause altitude globally decreases over the years.**

→ **The altitude variations of the homopause follow the mixing ratio variations between each flyby.**

Consequences and prospectives

Consequences:
The season and solar cycle can change the column density of the upper part of the atmosphere atmosphere by a factor of 10 → Impacts future missions landing on Titan that need to be slowed down significantly in the upper part of the atmosphere.

The changes in N_2-CH_4 mixing ratio can influence the altitude of synthesis and composition of Titan's aerosols.

Future work:

Analysis of traces species (HCN, C_2H_2, C2H6…)
Storing the results in a public database

References

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