Spatiotemporal variability of ammonia (NH_3) derived from the future IRS geostationary satellite and IASI observations

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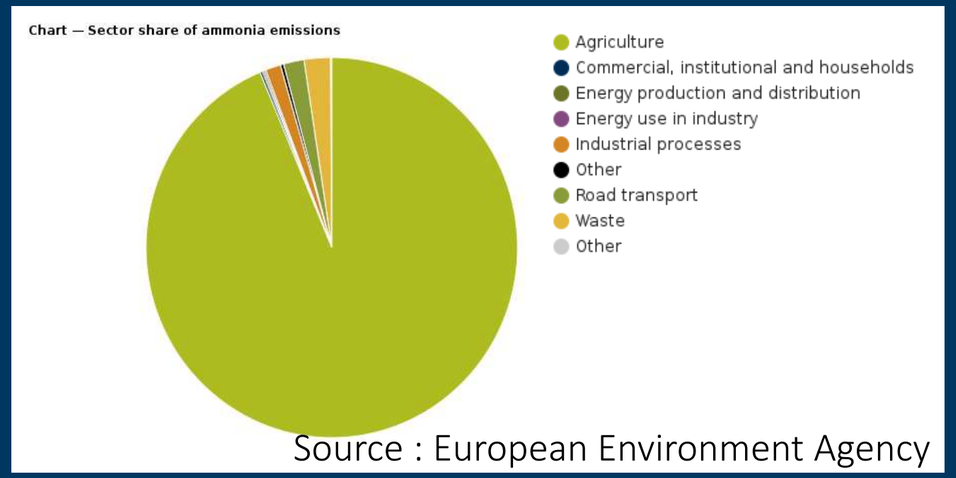
Introduction

- Ammonia is an atmospheric pollutant mainly emitted by **agricultural** activities (accounts for 94% of total NH_3 emissions)

- Ammonia has an impact on the **environment** *[Hernández et al., 2016; Rockström et al., 2009]* and **human health** *[Pope et al., 2002; Myhre et al., 2013]*

- However measuring ammonia is very difficult, with lack of **diurnal variability** and local scales observations *[Von Bobrutzki et al., 2010; Twigg et al., 2022]*

- Hopefully, **IRS**, an European geostationary satellite will be launched next year to fulfill this gap



Source : European Environment Agency

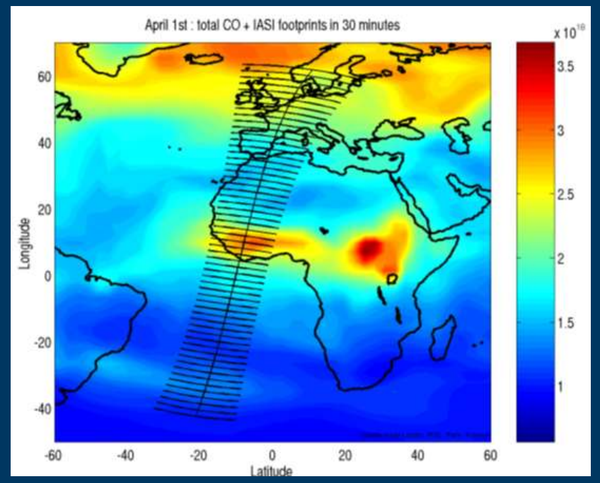
Source : Agence Régionale Santé Bretagne

Objective : prepare IRS observations to study spatio-temporal variability of NH_3 at regional and local scales

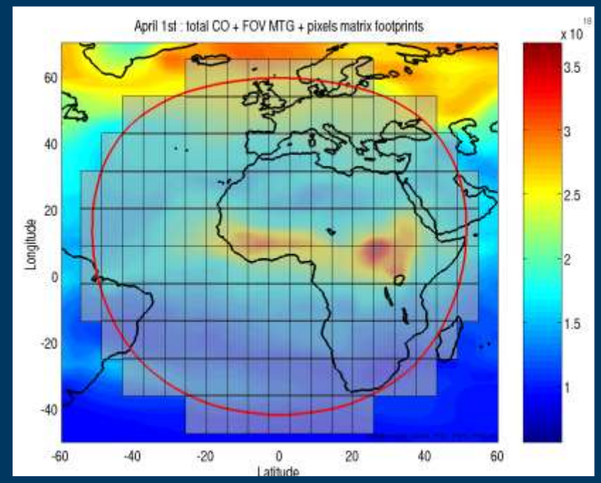
Instrumental characteristics of IASI and IRS

	IASI	IRS
Spatial resolution (nadir)	12 km	4 km X 4 km
Temporal resolution	Twice a day 9:30 AM - 9:30 PM	Every 30 minutes (Europe)
Spectral resolution (after apodisation)	0.5 cm^{-1}	0.754 cm^{-1}
Spectral bands	645cm^{-1} – 2760cm^{-1}	700cm^{-1} - 1210cm^{-1} and 1600cm^{-1} -2175cm^{-1}

IASI

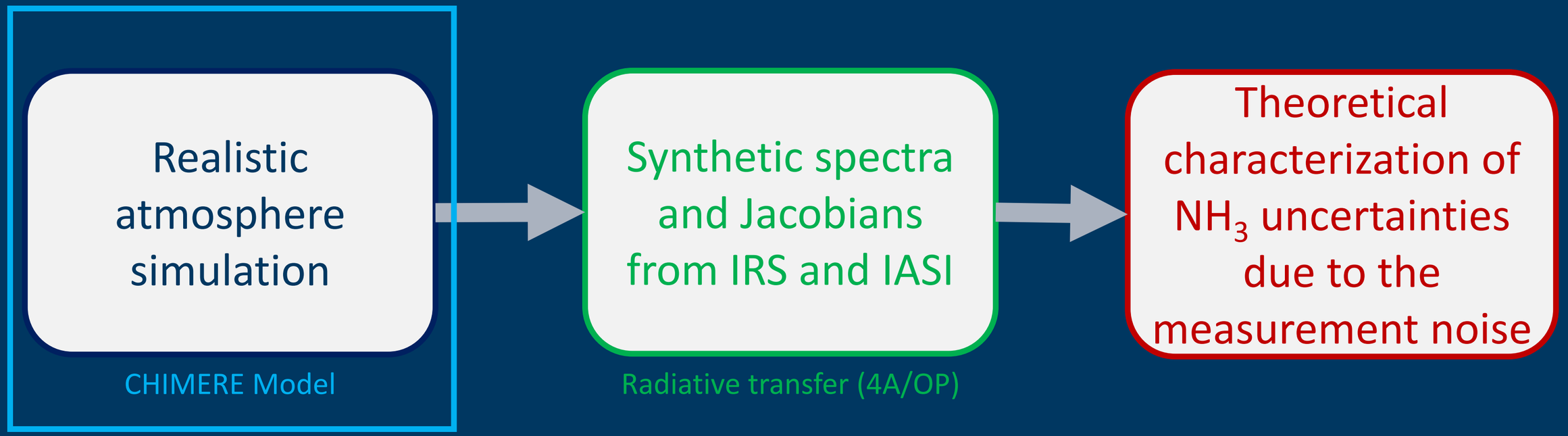


IRS



➔ quantify the **IRS integrated uncertainties of ammonia concentrations** due to the measurement noise and compare them to the IASI ones

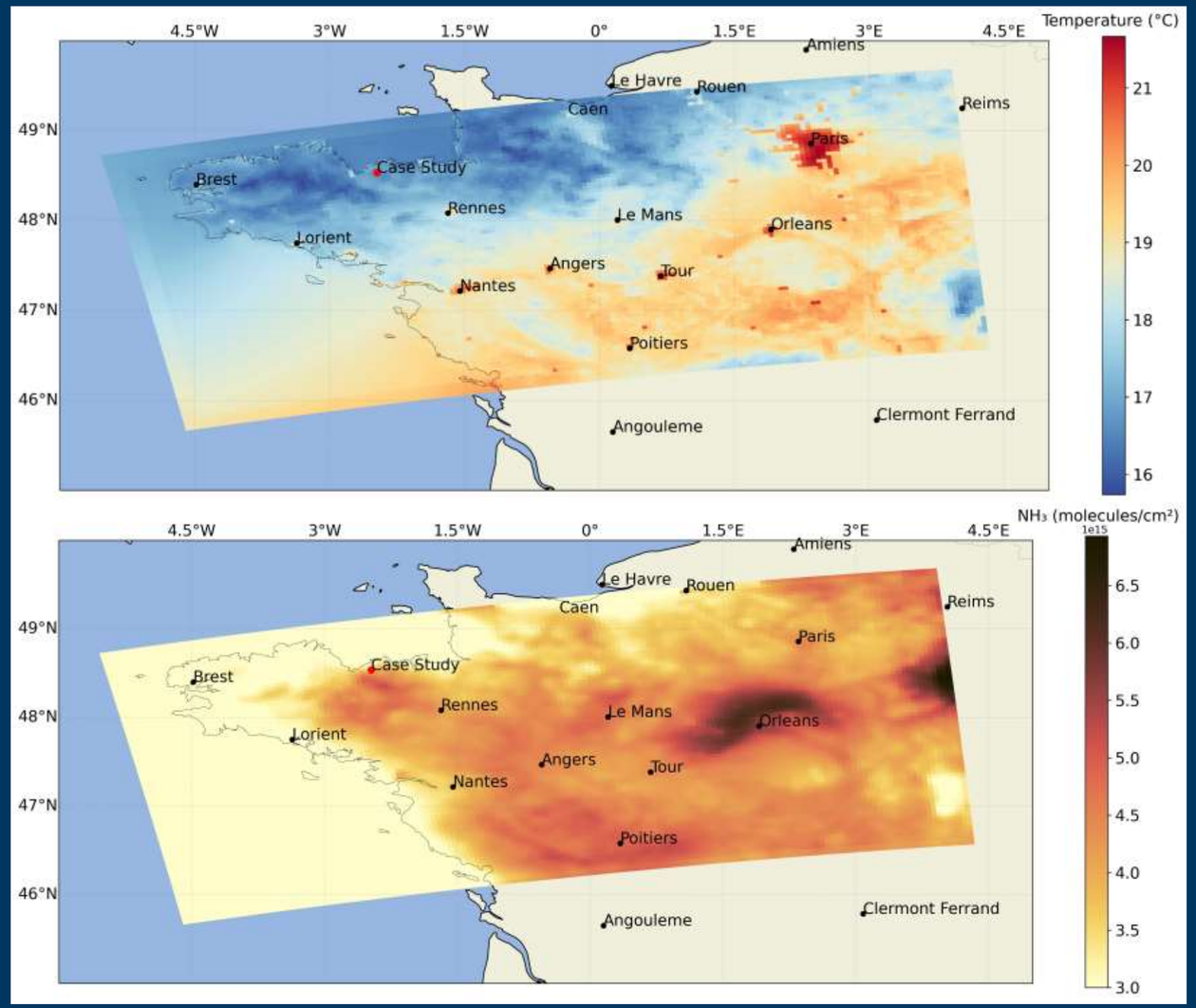
Methodology



This study is made over the first NH_3 emitted region of France: Brittany

Chimere

Realistic atmosphere simulation

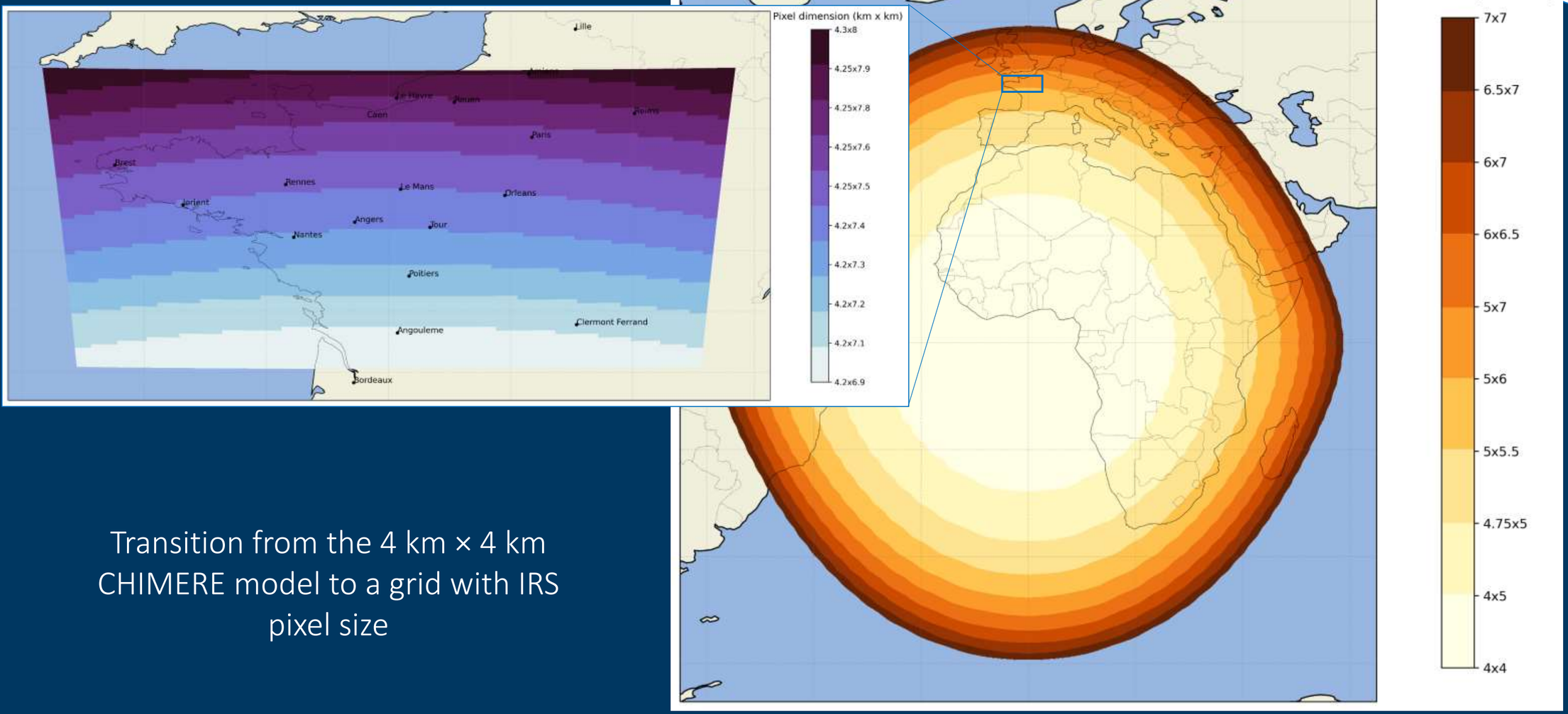


CHIMERE simulation for July 2016

- **Hourly simulation** with a spatial resolution of **4 km × 4 km** for July 2016
- Urban Heat Islands (UHI) around major cities on the **2-meter temperature** map
- High total column of NH_3 around Orléans
- Orléans is an agricultural region (25,000 farms), similar to Brittany (27,000 farms)

Pixel size for IRS-MTG

Realistic atmosphere simulation

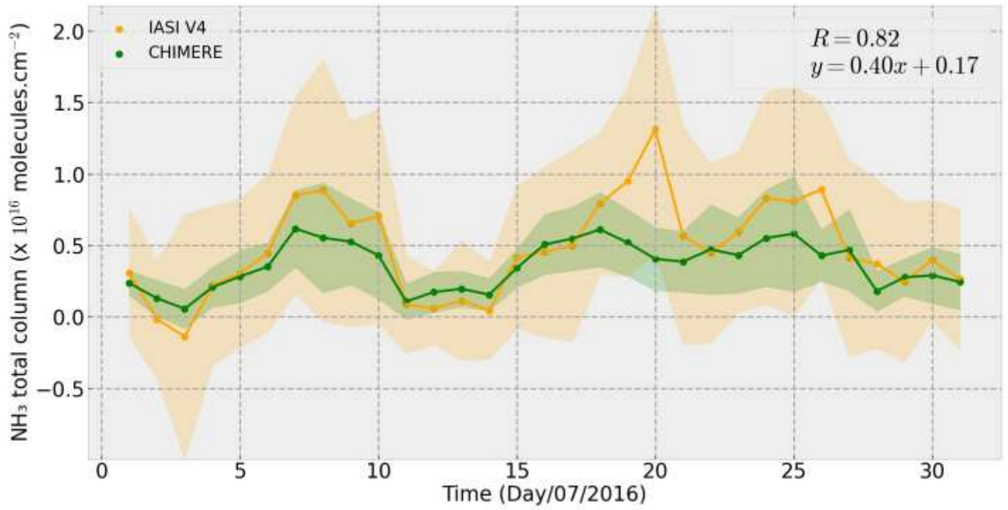


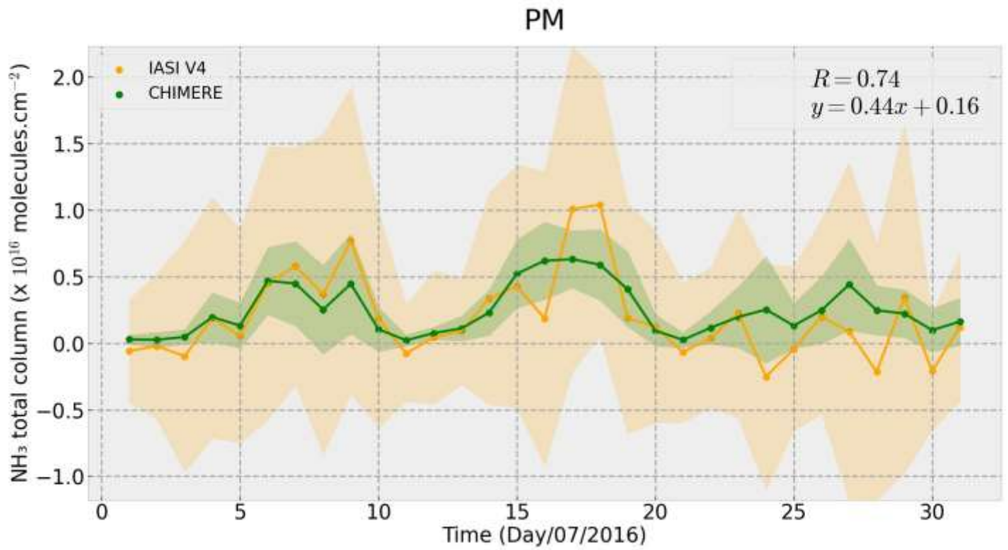
Transition from the 4 km × 4 km CHIMERE model to a grid with IRS pixel size

Pixel size for IRS-MTG

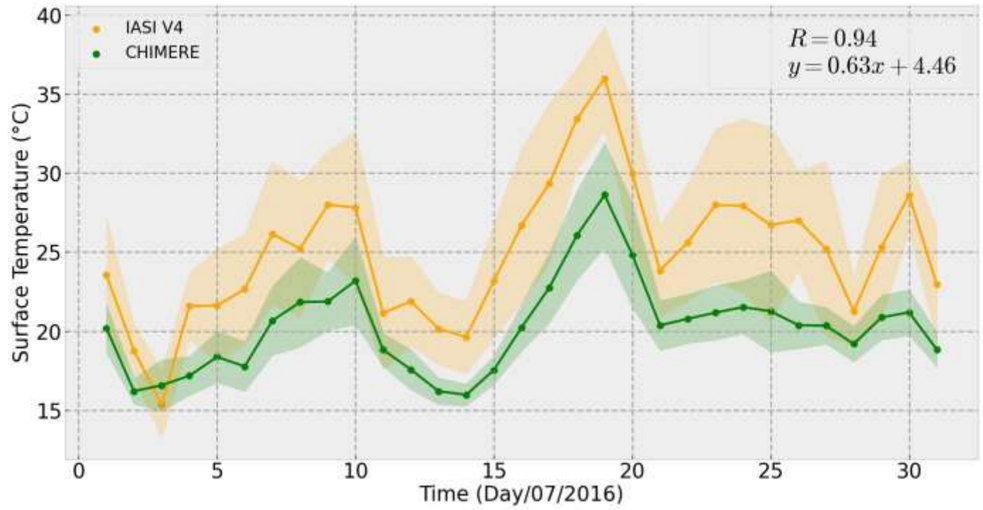
CHIMERE : A realistic atmosphere?

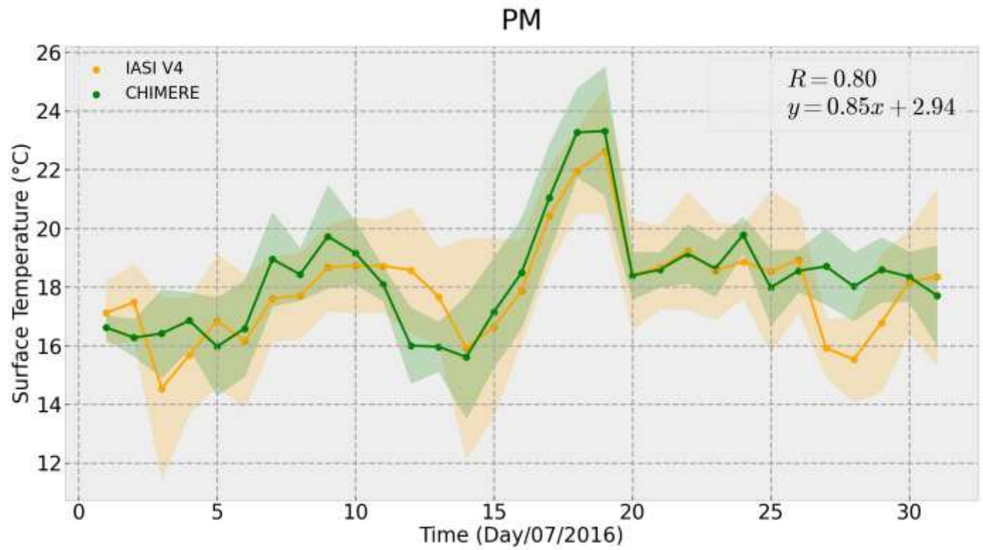
NH_3



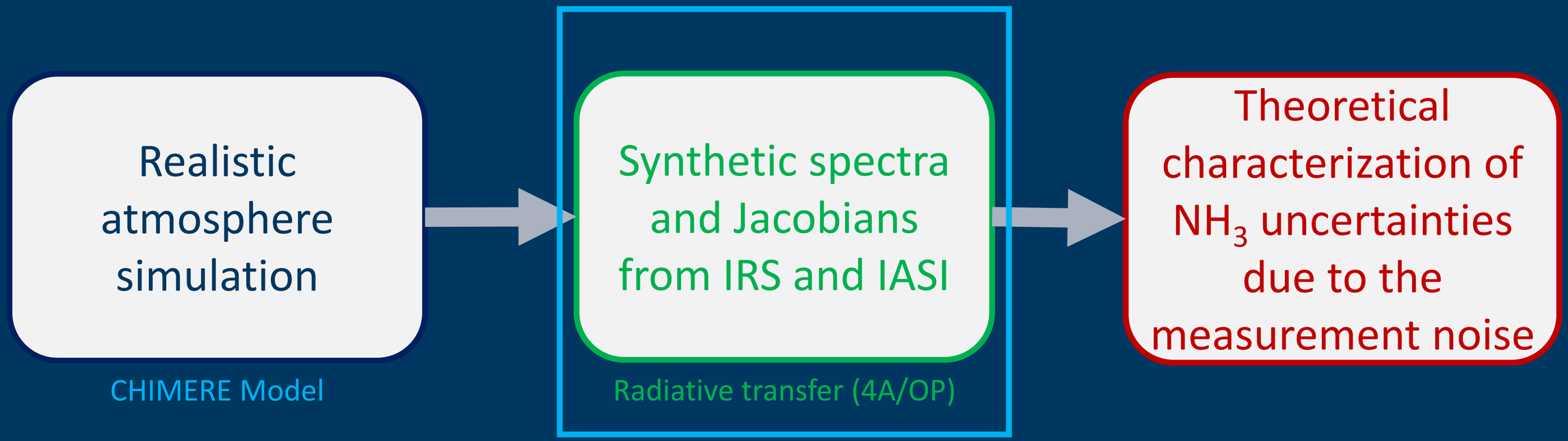


T_{surf}



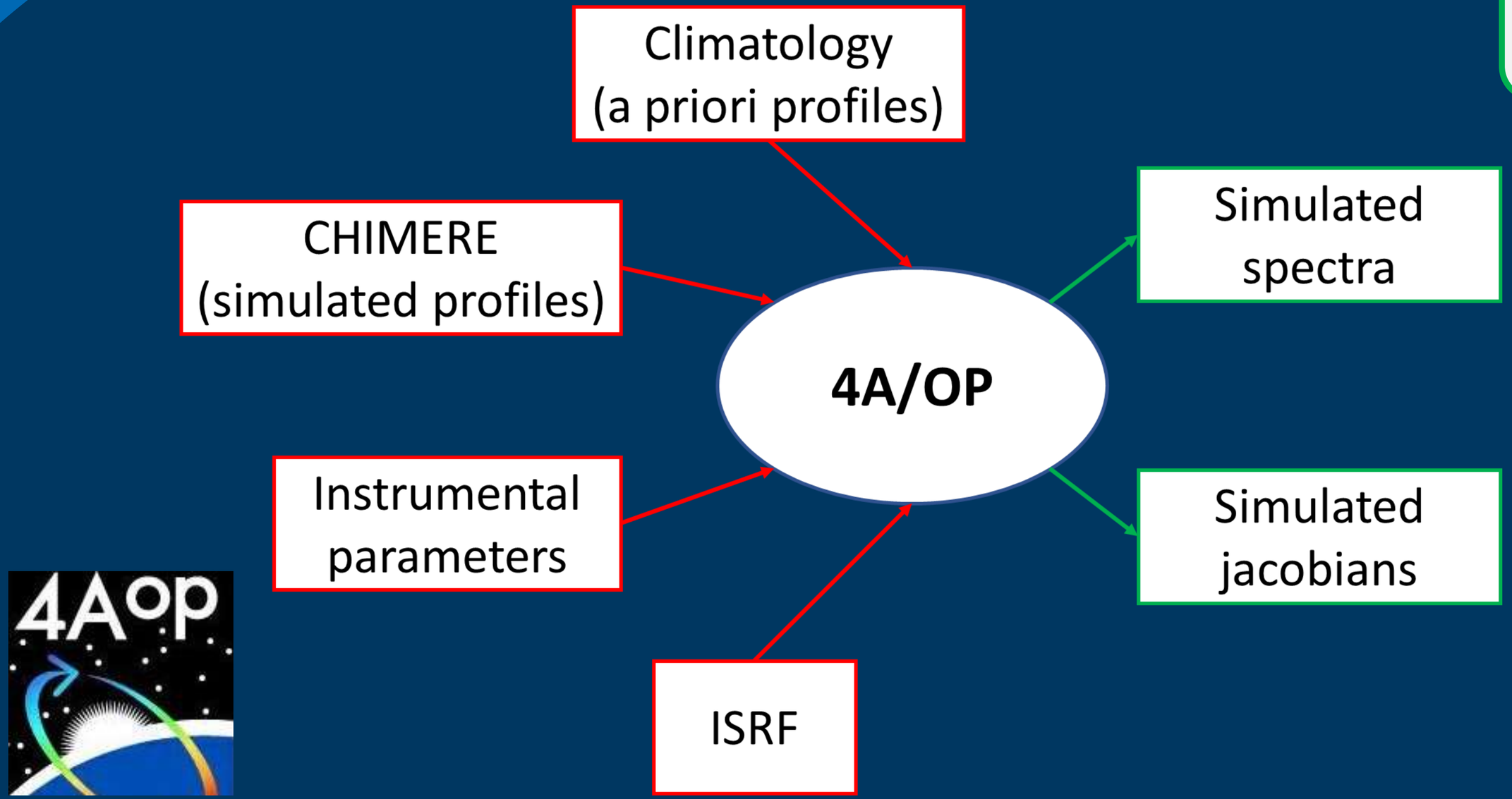


Methodology

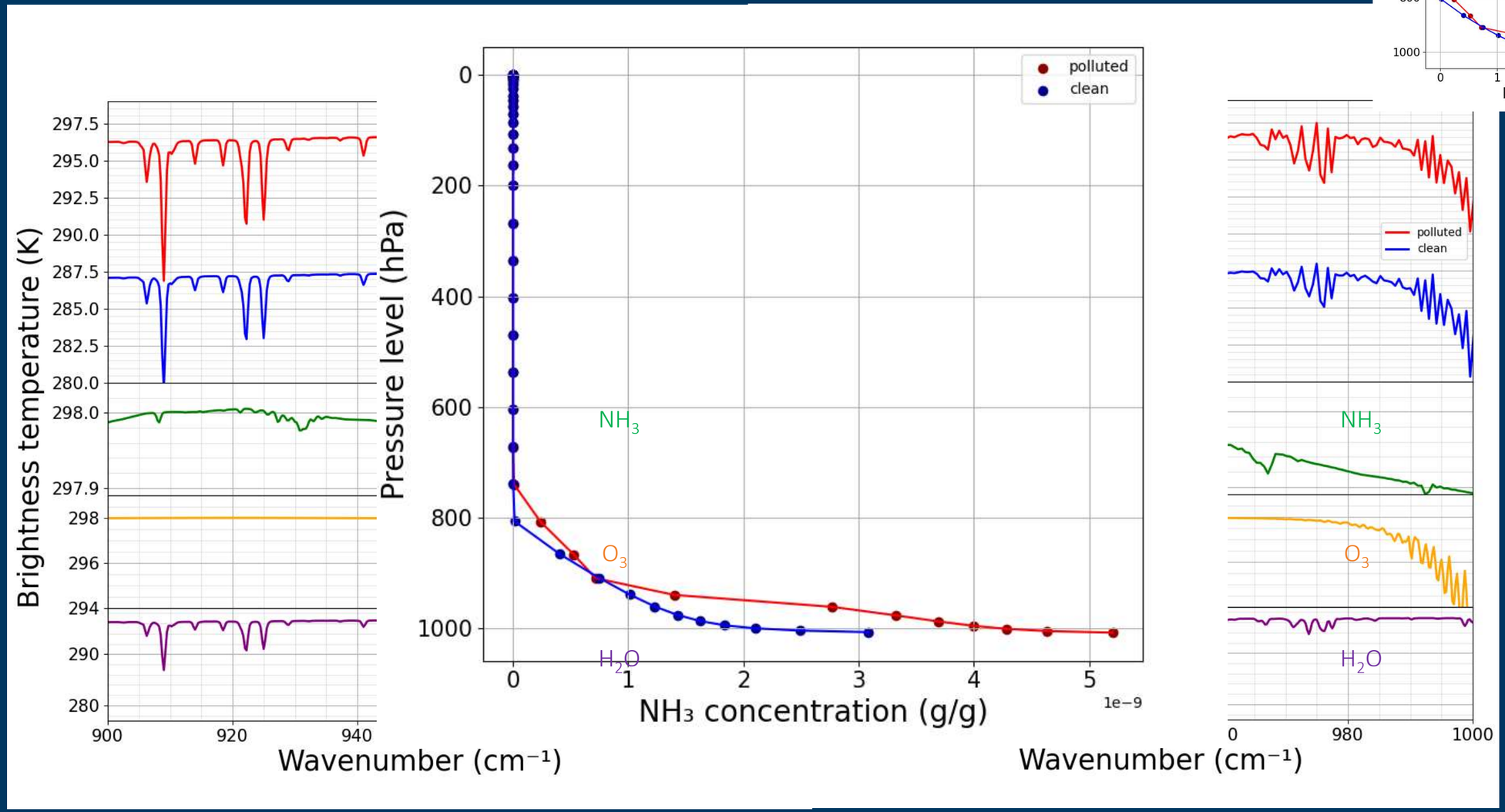


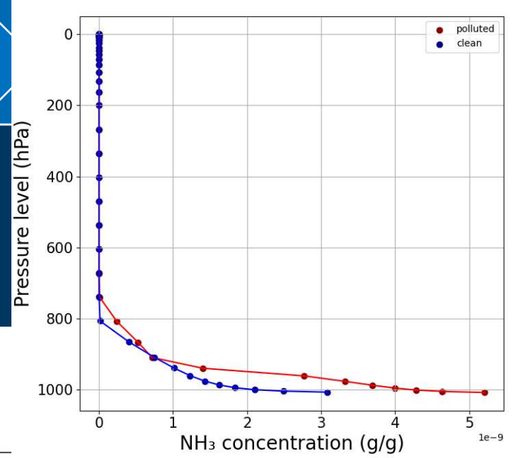
Radiative transfer code : 4A/OP

Synthetic spectra and Jacobians from IRS and IASI



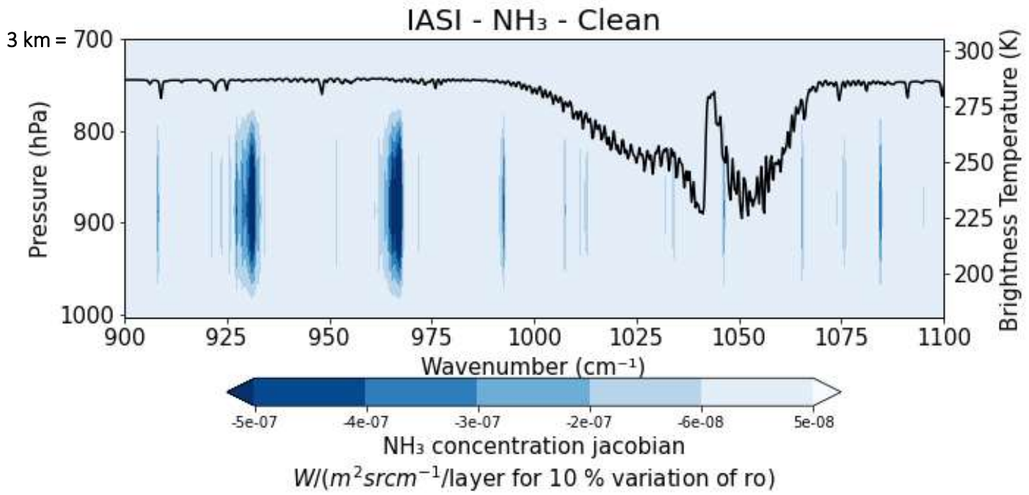
Simulated spectra for IASI and IRS

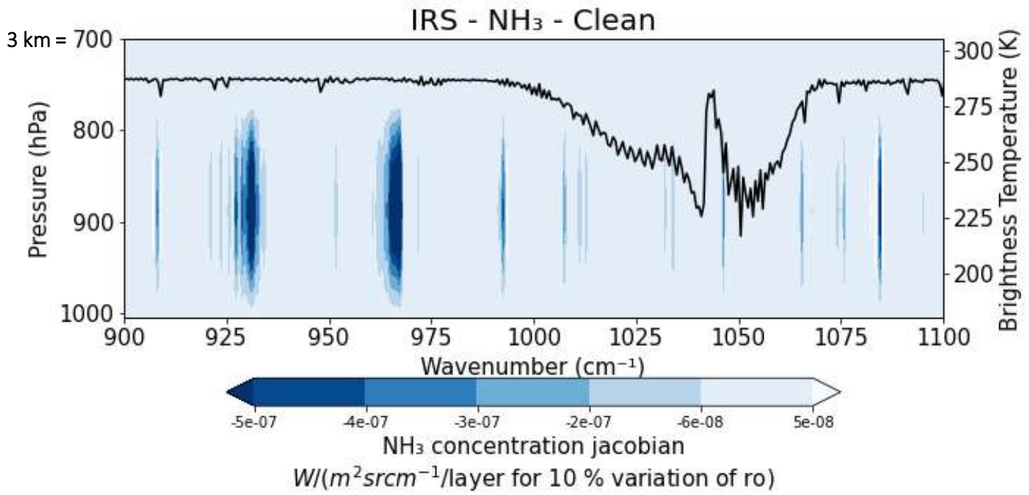


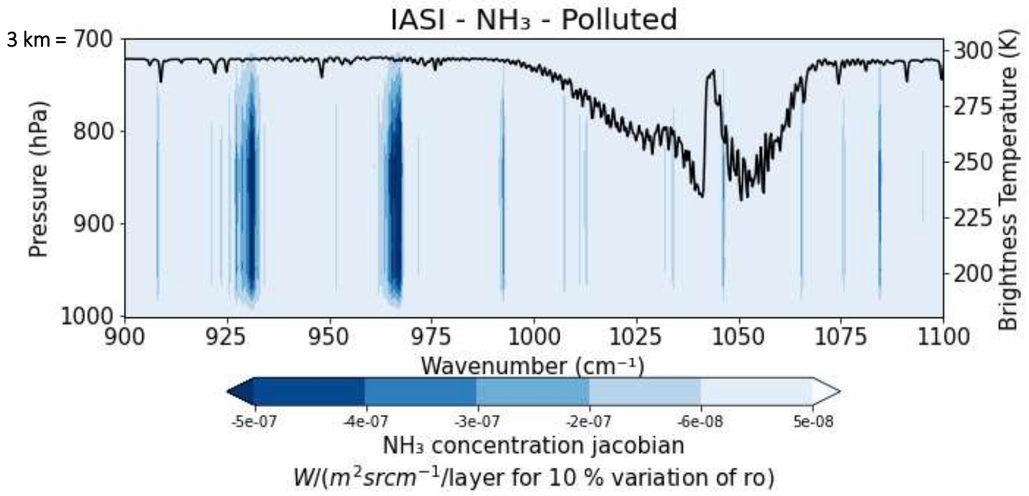


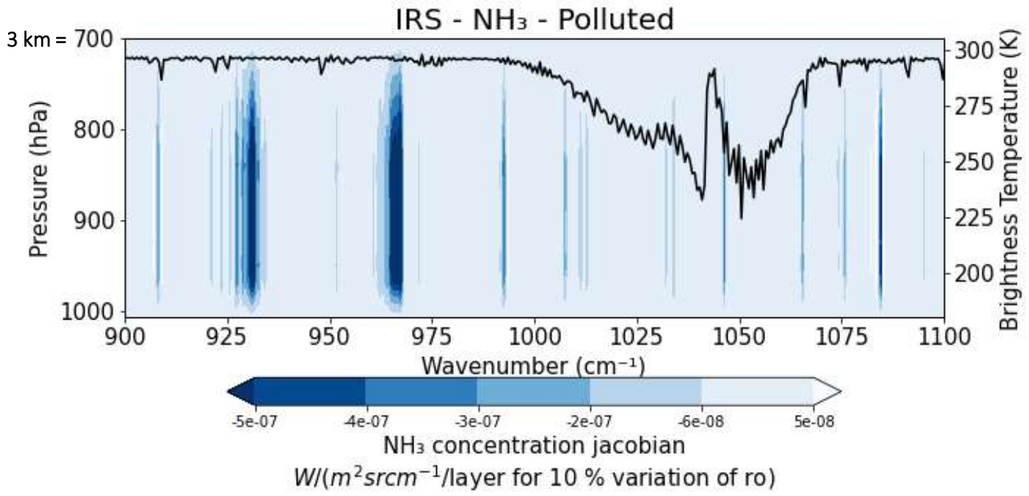
Simulated NH_3 Jacobian for IASI and IRS

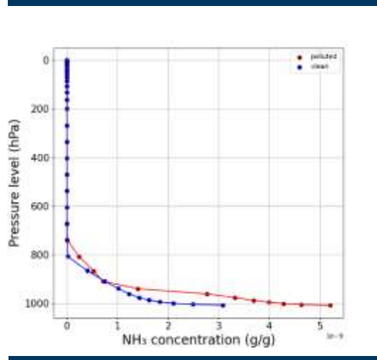
Synthetic spectra and Jacobians from IRS and IASI











Methodology

Integrated components of NH_3 uncertainty

Theoretical characterization of NH_3 uncertainties due to the measurement noise

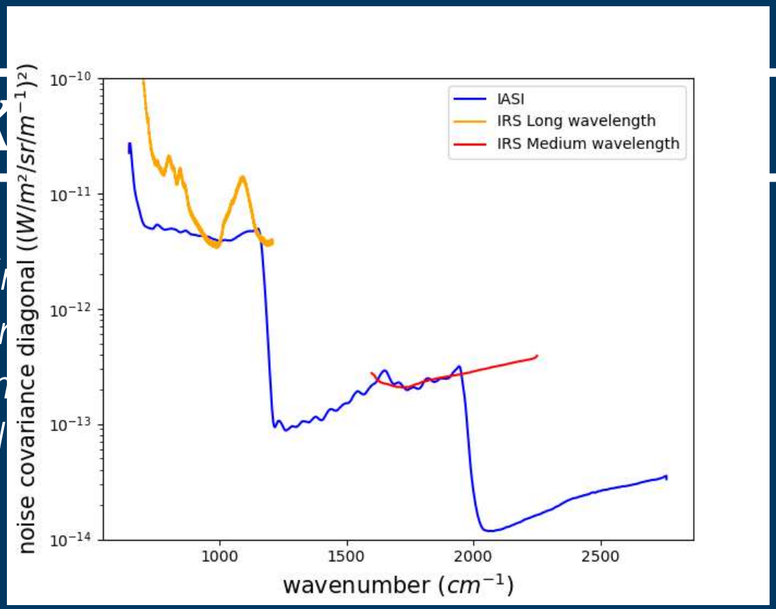
Estimation of the integrated NH_3 concentrations uncertainties due to the measurement noise from the Jacobians (K) and the noise covariance matrix *[Rodgers (2000)]*

$$\sigma^2_{instrument} = S = (K^T S_\varepsilon^{-1} K)^{-1}$$

- *K : NH_3 Jacobian (W/(m².sr.cm^{-1})/(molecules/cm²))*
- *Sε : Full Instrumental Noise Covariance Matrix(W/(m².sr.cm^{-1}))²*
- *S : Measurement Uncertainty Matrix (molecules/cm²)²*

$$K = \frac{L(X + dX) - L(X)}{dX}$$

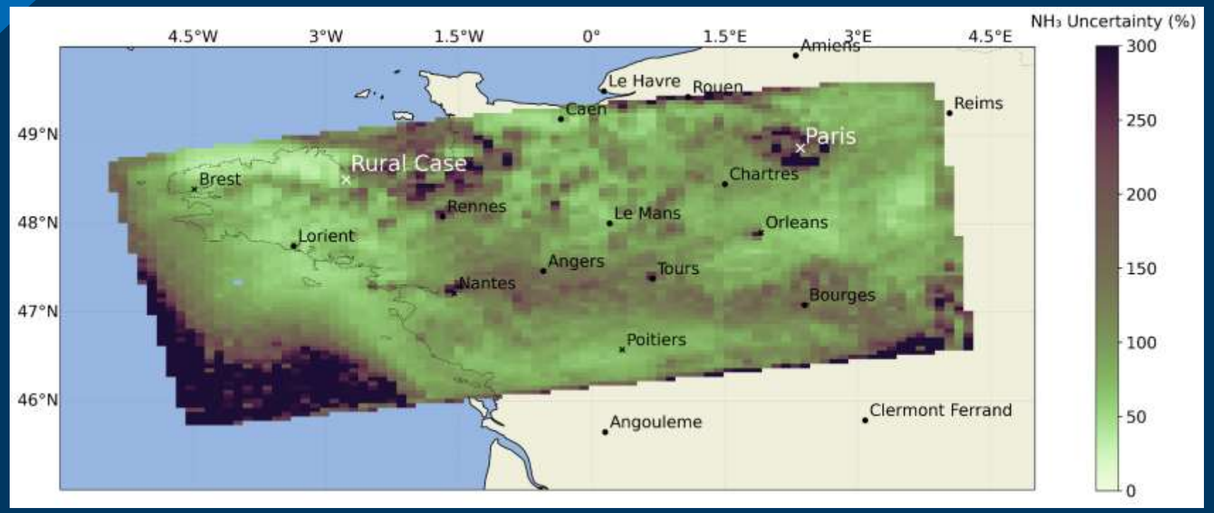
- *K : NH_3 total column Jacobian (W/(*
- *L(X) : Radiance spectra (W/(m².sr.cr*
- *X : NH_3 total column (molecules/cm*
- *dX : 0.1% increment of the total col*



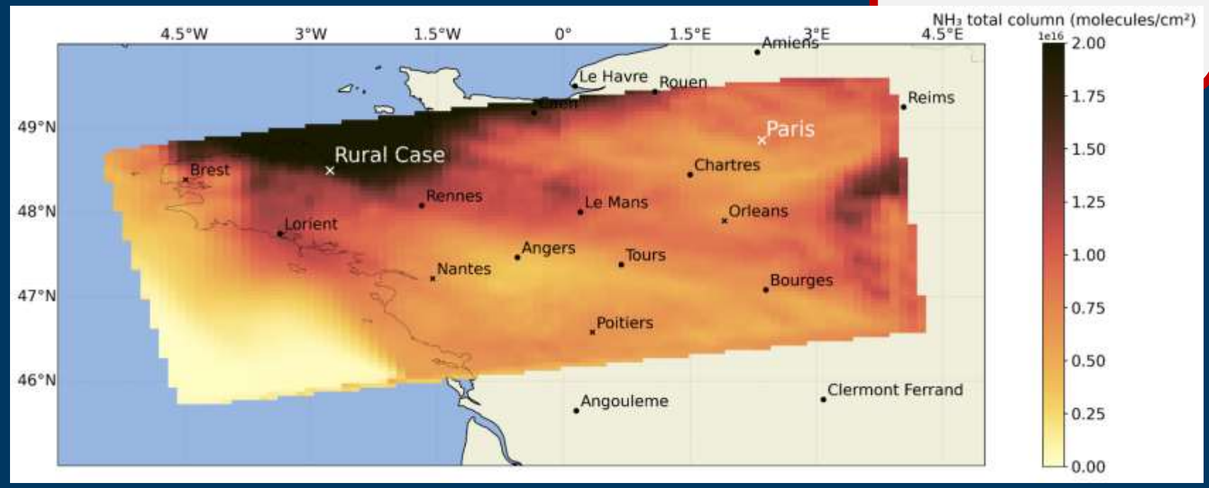
Example for the 19th of July 2016 at 1AM

Theoretical characterization of NH_3 uncertainties due to the

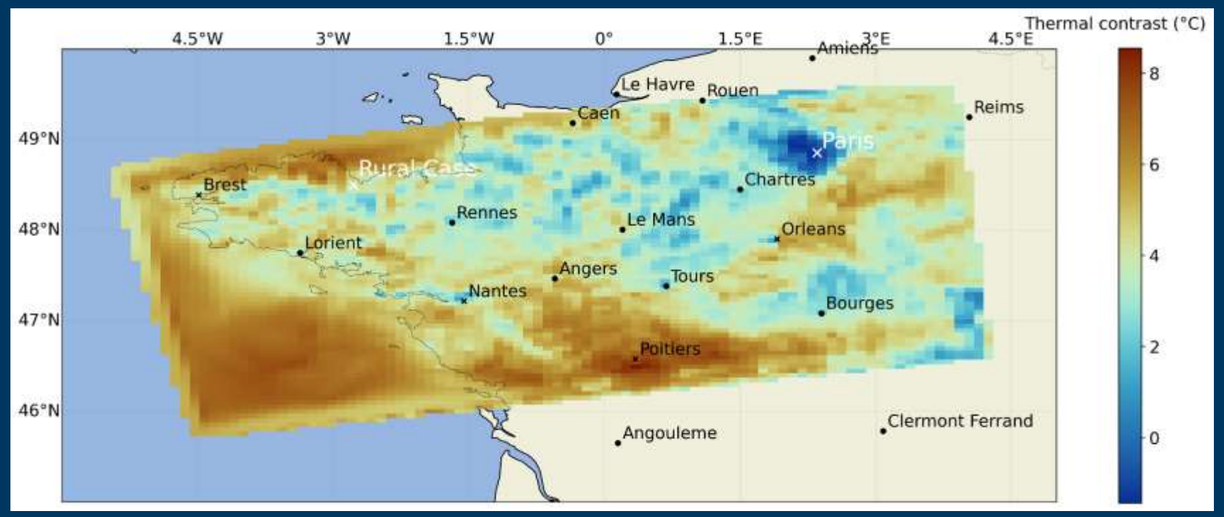
NH_3 uncertainties due to IRS measurement noise



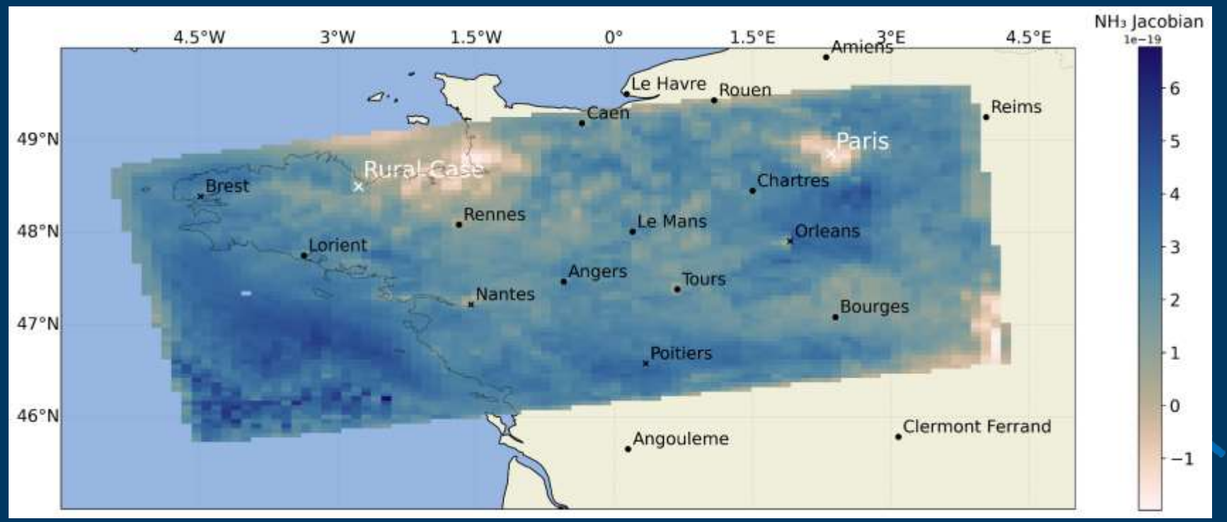
NH_3 total column



$TC = T_{skin} - T_{600m}$

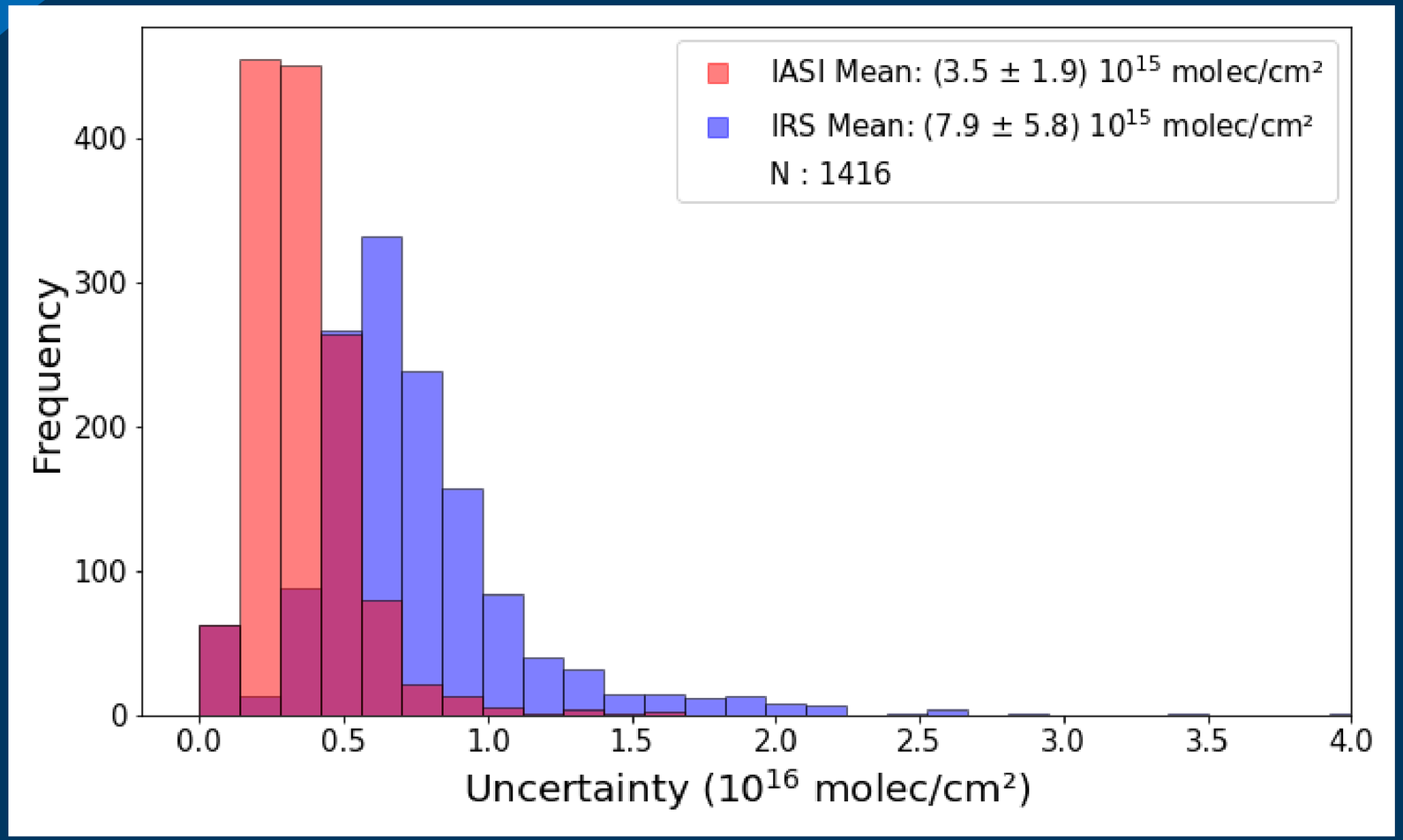


NH_3 Jacobian



Distribution of integrated ammonia uncertainty

Theoretical characterization of NH_3 uncertainties due to the measurement noise



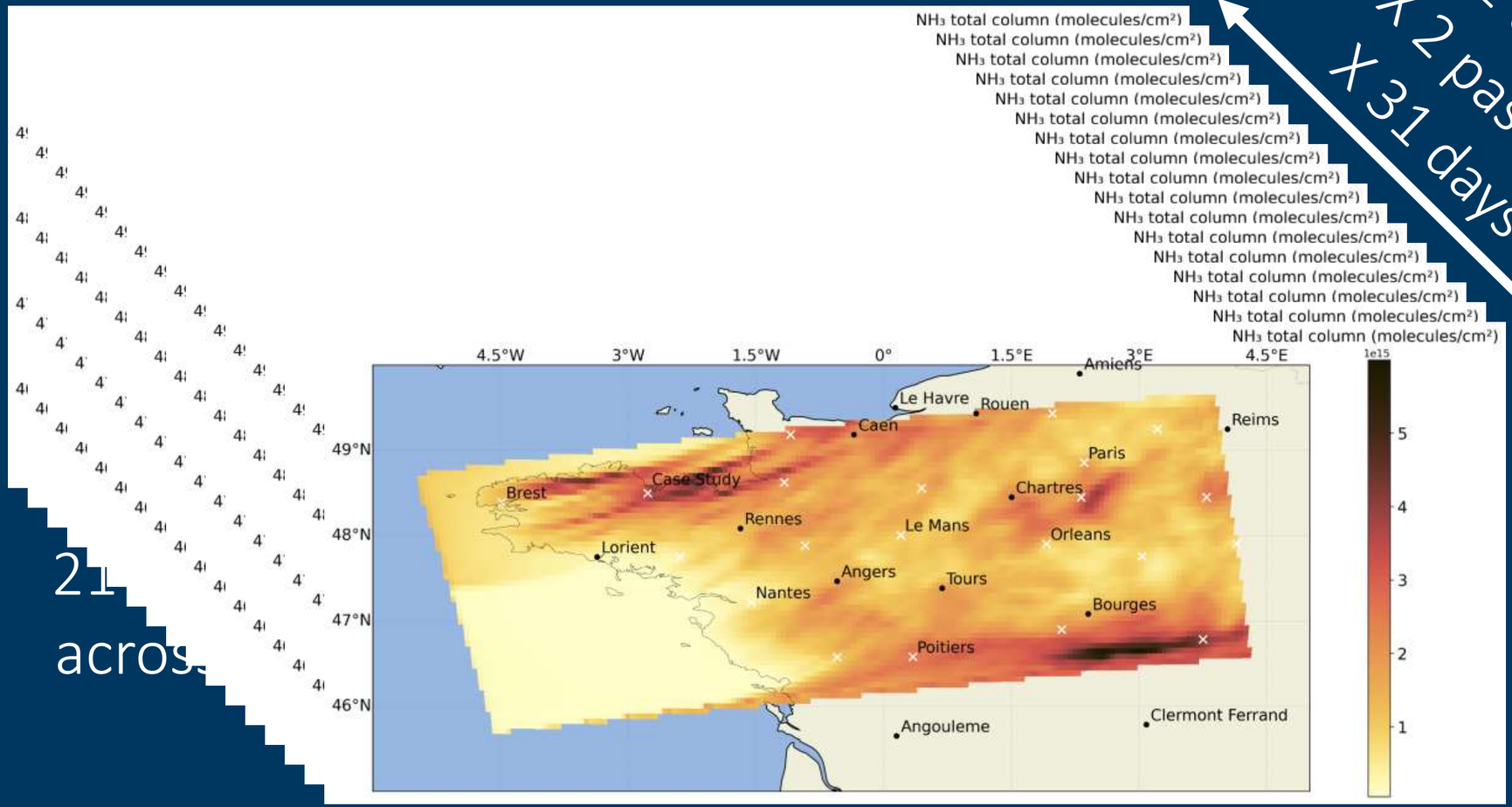
average NH_3 incertainties due to IRS measurement noise is **more than twice higher** than the IASI ones when considering coincident observations in space and time

How to reduce NH_3 uncertainties due to IRS measurement noise?

Reduction of NH_3 uncertainties due to the measurement noise through temporal averaging

Theoretical characterization of NH_3 uncertainties due to the measurement noise

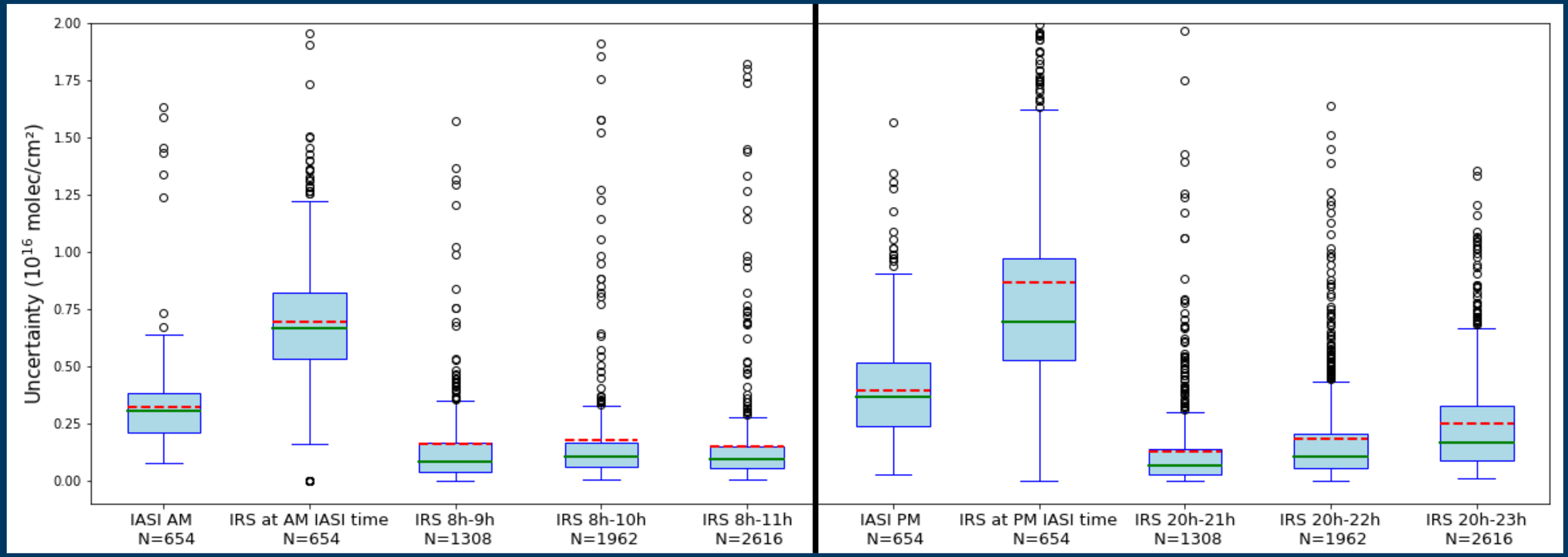
21 cases
x 2 passes
x 31 days



21
across

Reduction of NH_3 uncertainties due to the measurement noise through temporal averaging

Theoretical characterization of NH_3 uncertainties due to the measurement noise



By averaging the IRS uncertainties between 8 AM and 9 AM, IRS uncertainties are **3.7 times lower** than those of IASI for the AM overpass (5.8 times lower for the PM overpass)

[Guendouz et.al., in prep 2025]

Reduction of NH_3 uncertainties due to the measurement noise through spatial averaging

Theoretical characterization of NH_3 uncertainties due to the measurement noise

Case study IRS pixel

8	1	2
7		3
6	5	4

IRS 2 pixels

8	1	2
7		3
6	5	4

IRS IASI shape

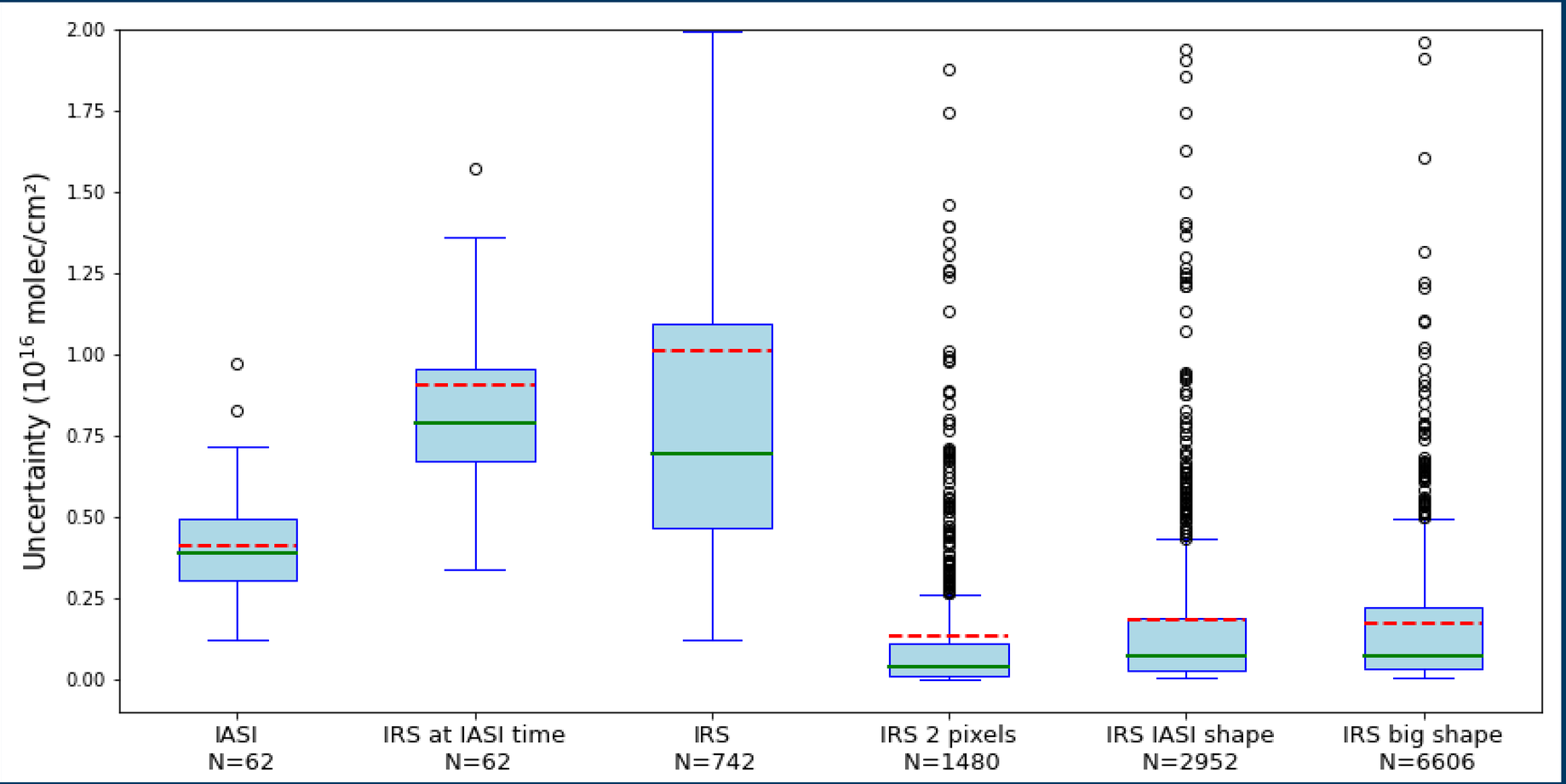
8	1	2
7		3
6	5	4

IRS big shape

8	1	2
7		3
6	5	4

Reduction of NH_3 uncertainties due to the measurement noise through temporal averaging

Theoretical characterization of NH_3 uncertainties due to the measurement noise



By averaging the IRS observations over 2 pixels, the NH_3 uncertainties related to the measurement noise of IRS are **5.6 times lower** than those of IASI *[Guendouz et.al., in prep 2025]*

Conclusion

- This study aims to prepare the IRS mission in terms of NH_3 observations by quantifying the integrated uncertainties due to the measurement noise and compare them to the IASI ones.
- For this, the CHIMERE model and 4A/OP radiative transfer code have been used and adapted to best reproduce the future IRS observations over the first NH_3 emitted region of France: Brittany.
- We found that NH_3 uncertainties due to IRS measurement noise are 2 times higher than the IASI ones when considering the same overpass time (9 AM and PM).
- These uncertainties are significantly reduced (by at least a factor of 4) when averaging 2 hours or 2 pixels of IRS measurements, which will be useful to study NH_3 diurnal variabilities or local sources.
- This shows the potential of the future IRS mission to monitor NH_3 spatial-variabilities.

Thank you for your attention !

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