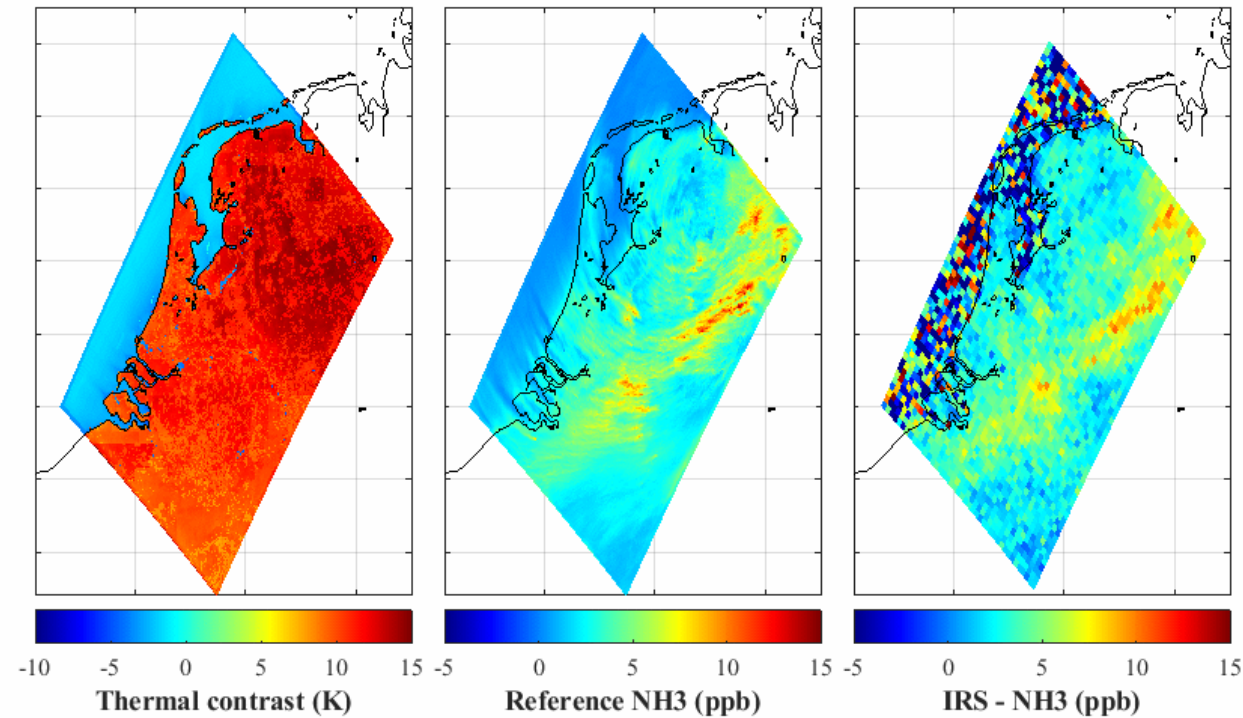


Atmospheric Composition with IRS on MTG-S



P. Coheur • ULB SQUARES • December 2025

About MTG-S and IRS

Imager

MTG-I

- 1 *FCI (Flexible Combined Imager)*
- 2 *LI (Lightning Imager)*
- 3 *DCS (Data Collection System)*
- GEOSAR (Search and Rescue)*

Launched 13 December 2022

Sounder

MTG-S

- 1 *IRS (Infrared Sounder)*
- 2 *COPERNICUS SENTINEL-4*
(Ultra-violet, Visible and Near-Infrared Sounder)

Launched 1 July 2025

About MTG-S and IRS Atmospheric composition?

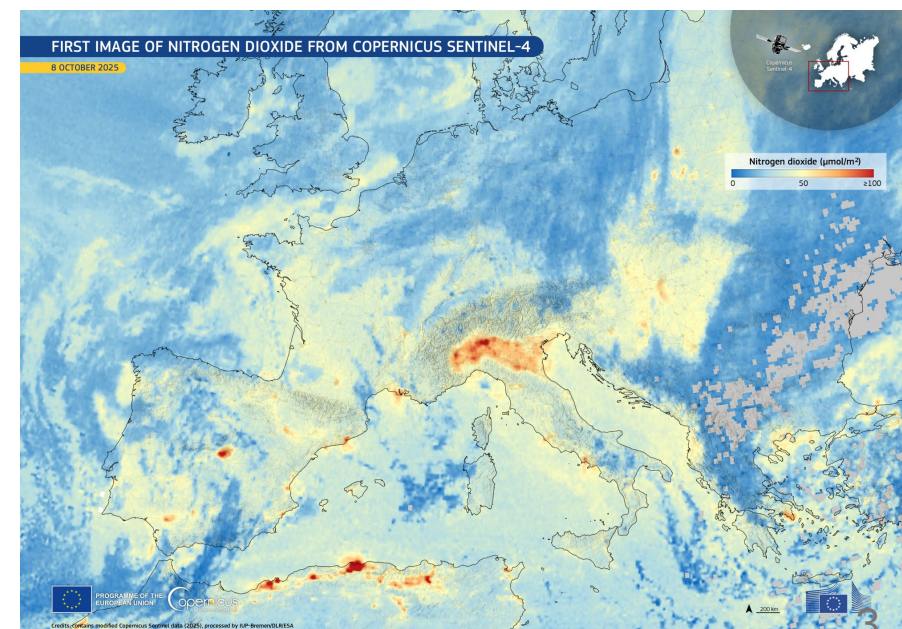
Let's ask AI....

Me

Can you please let me know -in just 2 or 3 sentences - how the MTG satellite will contribute to atmospheric composition; highlighting the instrument involved?

AI

The Meteosat Third Generation (MTG-S) satellites will improve monitoring of atmospheric composition by hosting the **Sentinel-4 UVN instrument**, which provides high-resolution measurements of key air-quality gases such as NO_2 , O_3 , and SO_2 . Together with the MTG **Infrared Sounder (IRS)** for temperature and humidity profiles, MTG will offer more accurate, frequent data on atmospheric chemistry over Europe.



About MTG-S and IRS Atmospheric composition?

Let's ask AI....

Me

Hmmm.... will IRS not provide useful measurements for atmospheric composition?

AI

Good question. Yes — the InfraRed Sounder (IRS) aboard Meteosat Third Generation *will* indeed contribute to atmospheric-composition monitoring, not just temperature and humidity.

European Space ... +2

Specifically, IRS's hyperspectral infrared measurements are sensitive to trace gases (like ozone and carbon monoxide) as well as moisture and temperature, enabling "4-D" (altitude + space + time) views of atmospheric composition and structure.

European Space ... +2

Me

No application for other air quality species -specifically short-lived ones?

AI

IRS does **not** provide operational products for short-lived air-quality species. Short-lived pollutants will instead come almost entirely from **Sentinel-4 UVN** on MTG-S, which is explicitly designed for high-resolution air-quality monitoring.

Atmospheric Composition with IRS on MTG-S

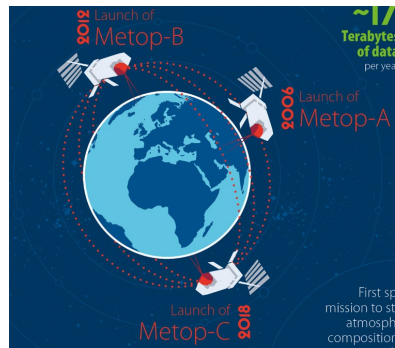
IRS in commissioning
no public data yet

1. Atmospheric composition with (hyperspectral) IR sounders – **IASI heritage**
2. Expected contribution from IRS
 - What will IRS bring ?
 - Improving mapping with over- or supersampling

Atmospheric Composition with IRS on MTG-S

- 1. Atmospheric composition with (hyperspectral) IR sounders – IASI heritage**
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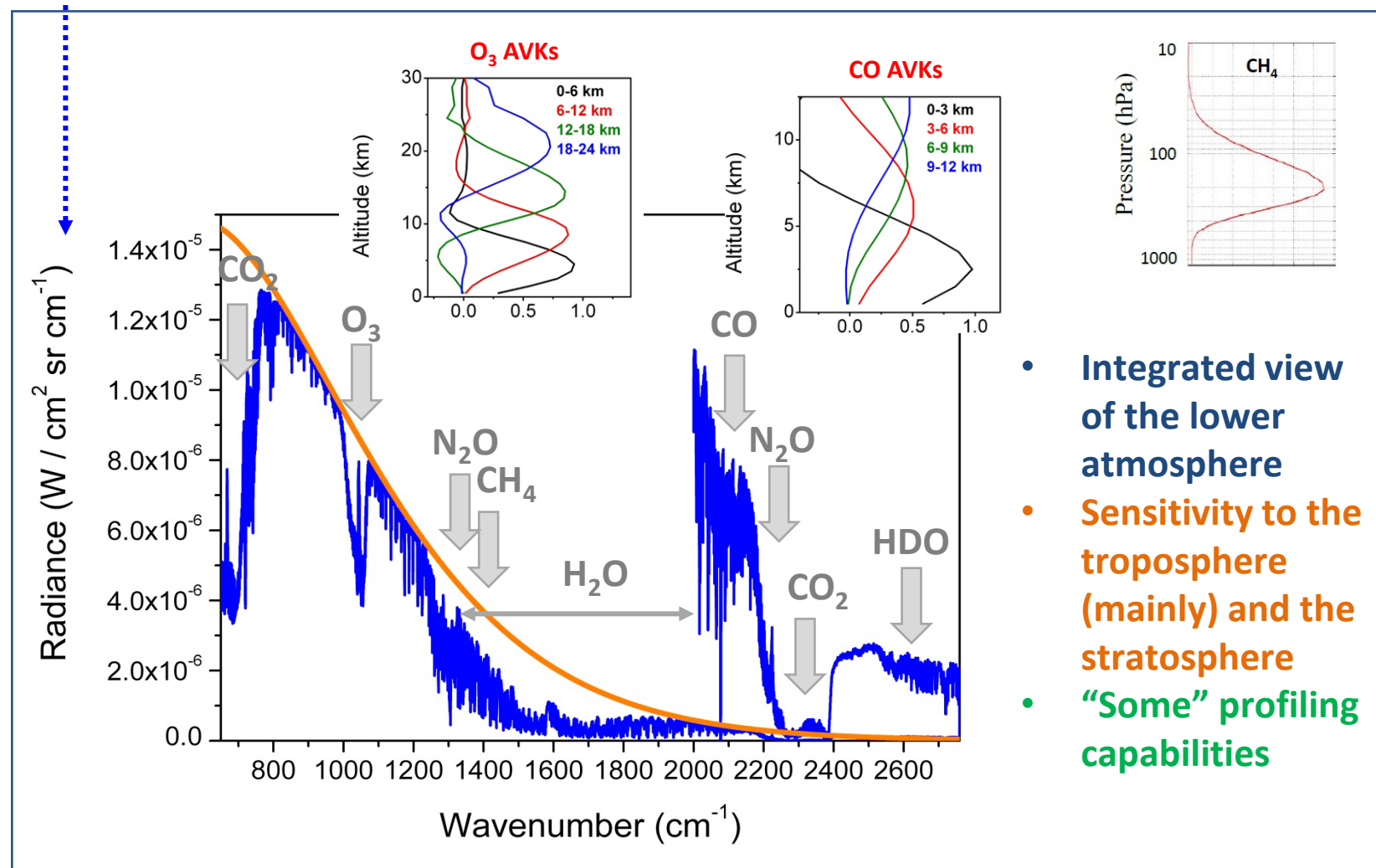
Atmospheric composition: what information do hyperspectral IR measurements carry ?



Infrared
Atmospheric
Sounding
Interferometer

on Metop –A, – B, – C

IASI Level 1C radiances ($\text{W} / \text{cm}^2 \text{sr cm}^{-1}$)



- Integrated view of the lower atmosphere
- Sensitivity to the troposphere (mainly) and the stratosphere
- “Some” profiling capabilities

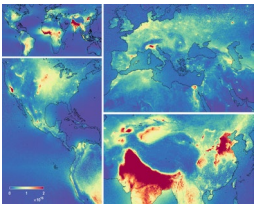
Key features for atmospheric composition

- Extended spectral range without gaps (3.6-15.5 μm ; 645-2760 cm^{-1})
- High spectral and radiometric performances



⇒ Large number of trace gases measured simultaneously with some vertical profiling capability

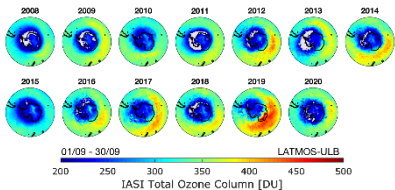
- Near-global coverage twice daily (9:30 and 21:30)
- Medium spatial resolution (12 km on-ground)



⇒ Global pollution mapping (and forecast)
⇒ Monitoring fires and volcanoes
⇒ Detection, quantification of emission sources

Somewhat
less relevant for IRS

- Towards > 25 years of global measurements
- Exceptional stability and coherence between instruments

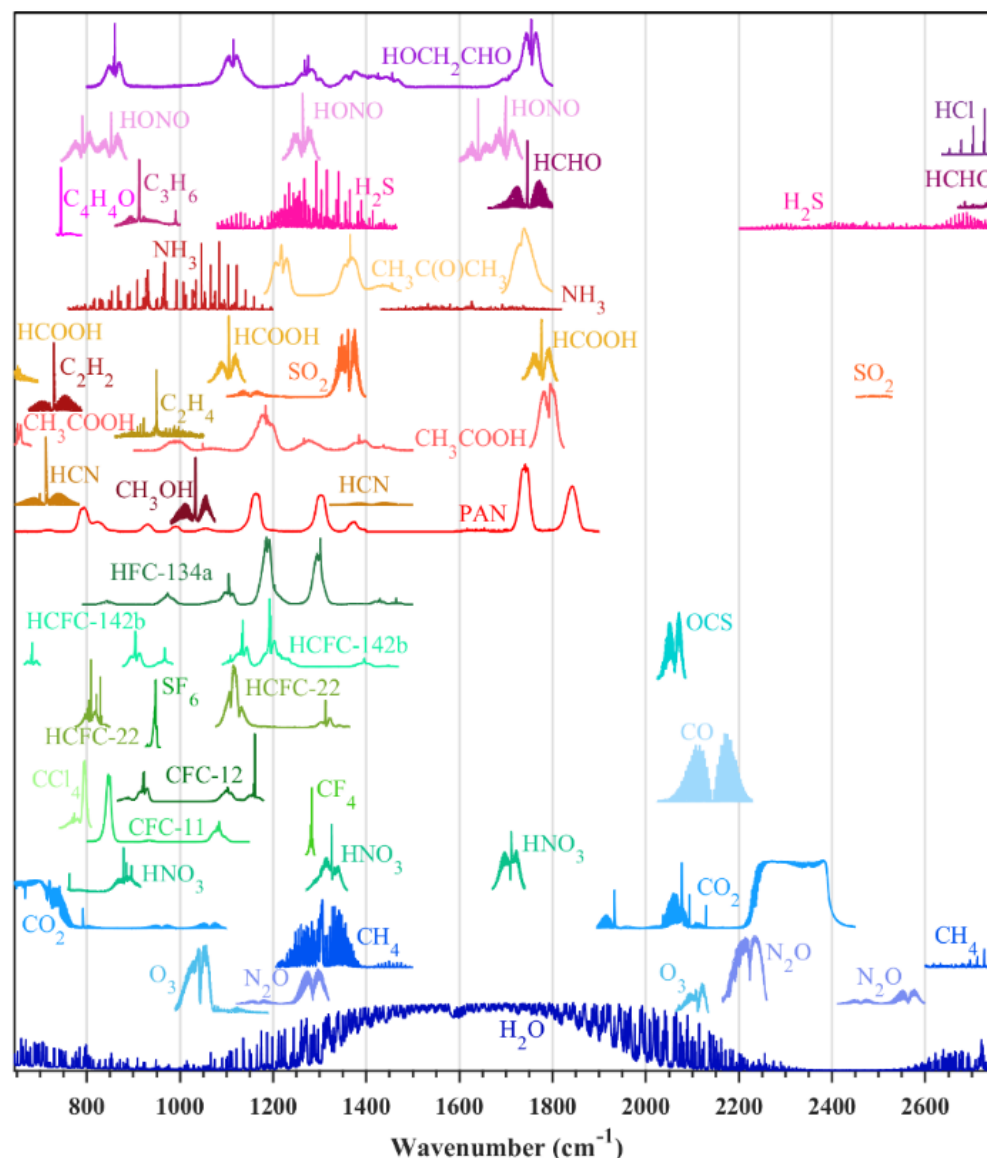


⇒ Long-term evolution, trends and protocol monitoring

Atmospheric composition: what information do hyperspectral IR measurements carry ?

Trace gases

> 30 species



Water: H_2O and HDO

Long-lived climate gases: CO_2 N_2O CH_4

O_3

Reactive nitrogen: HNO_3 NH_3 PAN HCN HONO

CO

VOCS: CH_3OH C_2H_2 HCOOH C_2H_4 C_3H_6 $\text{C}_4\text{H}_4\text{O}$ CH_3COOH CH_3CHO

Sulfur species: SO_2 OCS H_2S

CFCs: CFC-11 CFC-12

- With global distributions daily
- In concentrated plumes (fires, volcanoes)
- Exceptional
- With sensitivity in the stratosphere

F. Hilton et al., 2012

L. Clarisse et al., GRL 2011

H. De Longueville et al., 2021

○ Atmospheric composition: what information do hyperspectral IR measurements carry ?

Aerosols (coarse mode)

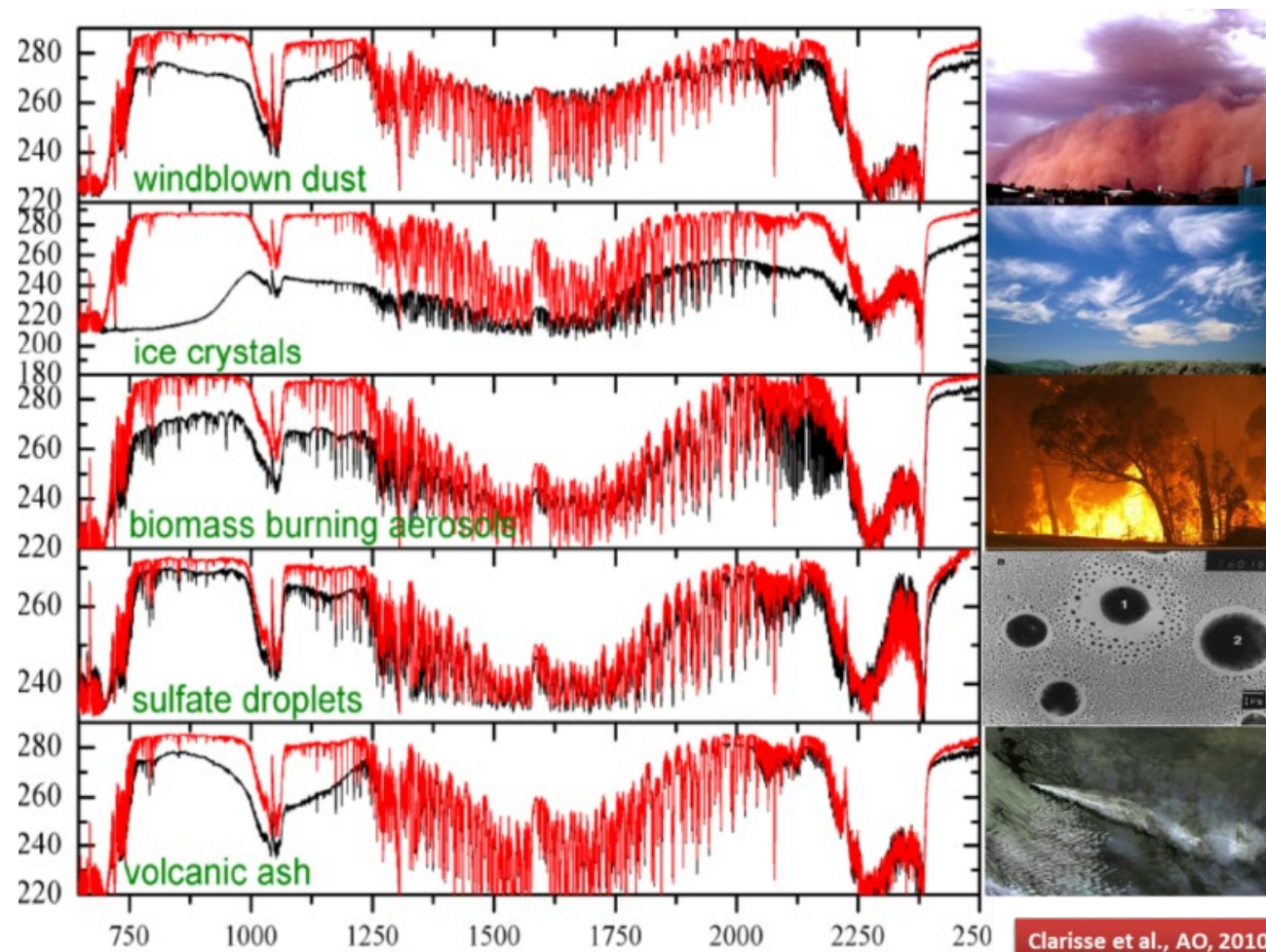
> Type differentiation based on their IR signature!

Dust

volcanic ash (different types)

Sulfates

Polar stratospheric clouds



⇒ Global pollution mapping and forecast; global tropospheric chemistry

☐ Emissions

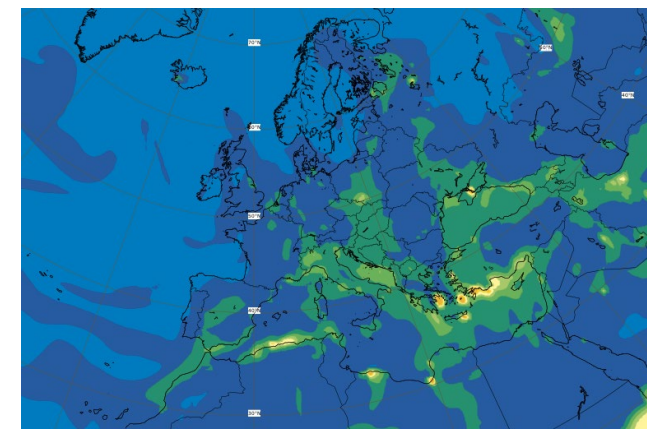
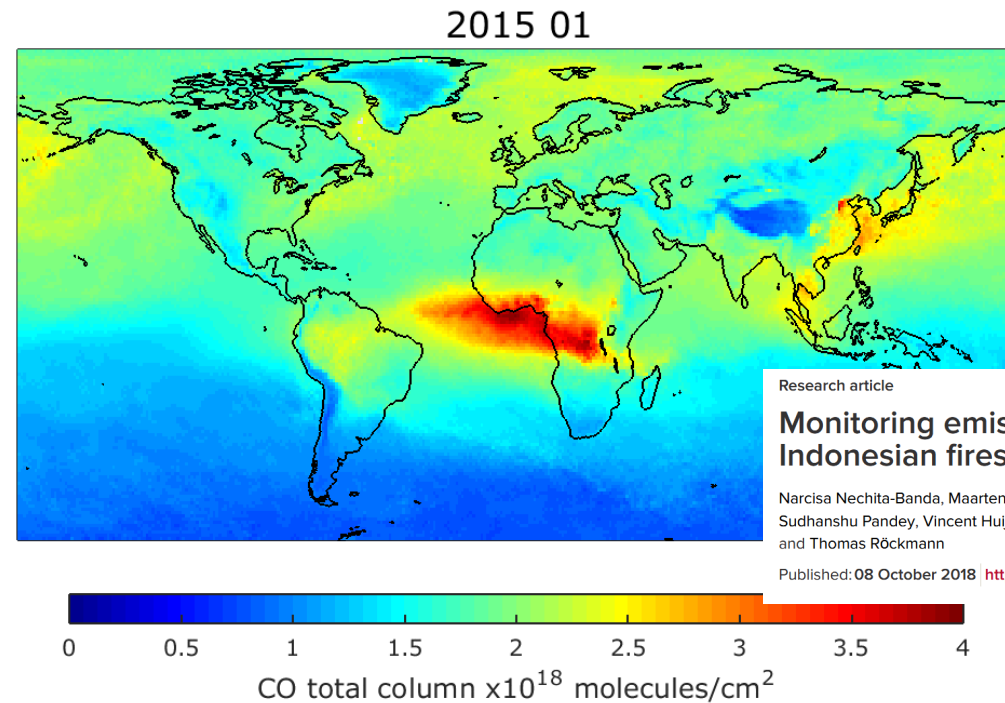
- Anthropogenic
- Fires

☐ Photochemistry

☐ Long-range transport of pollution

☐ Air Quality forecast

IASI data assimilated in CAMS



⇒ Hazard monitoring: volcanoes, fires, dust outbreaks, accidental industrial “releases”

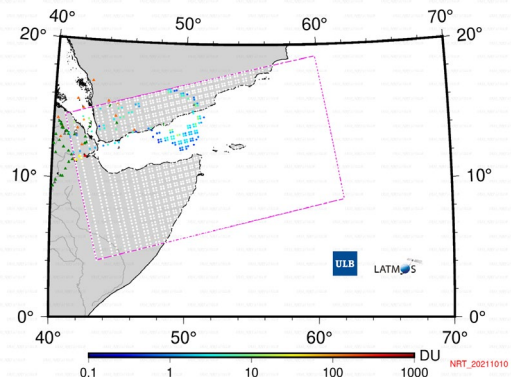
☐ Volcanic plumes: SO₂ and ash ; SO₂ altitude; + NRT alerts
SO₂ columns

Ash index

Plume altitude

Hayli Gubbi eruption 23.11.2025

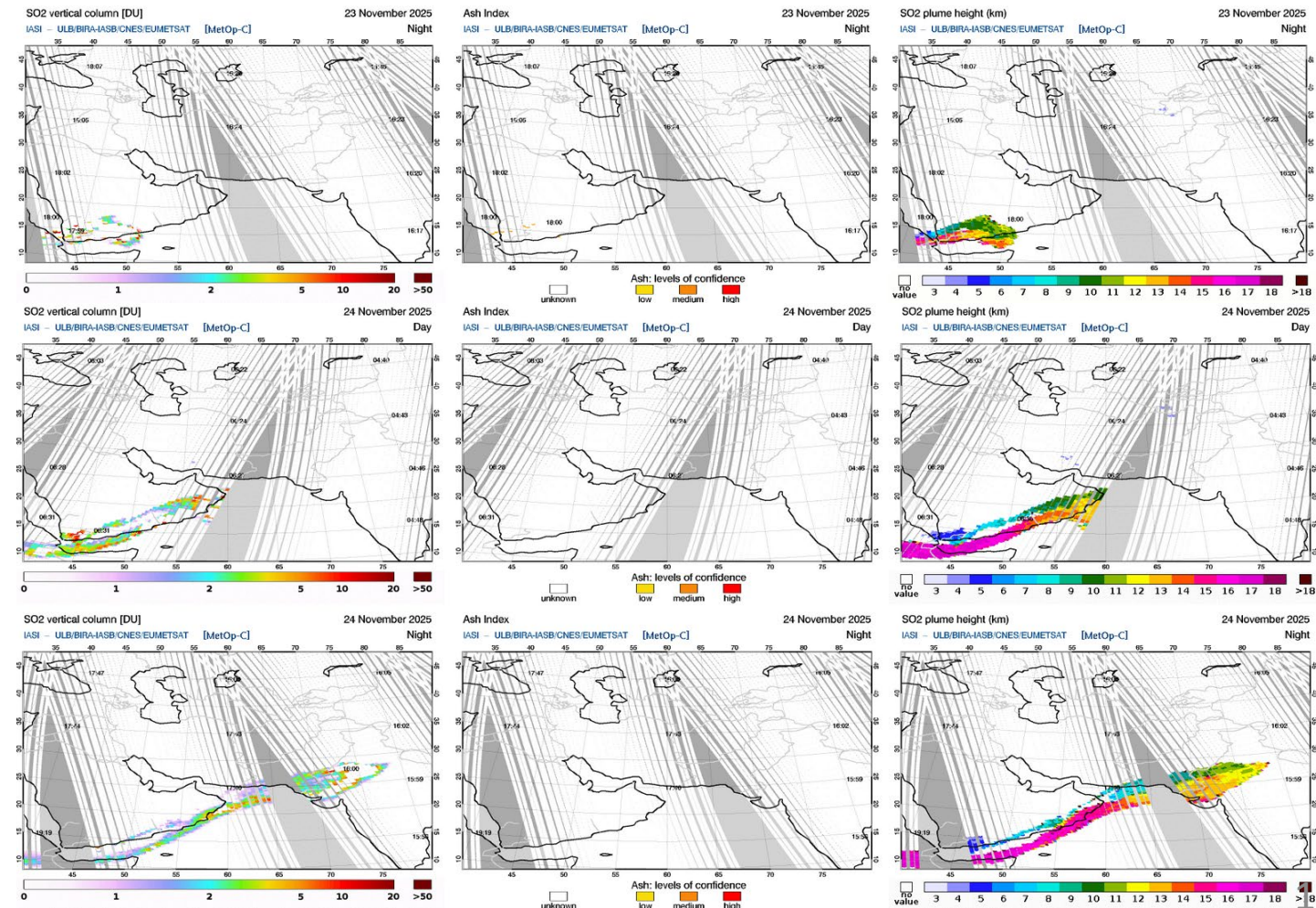
SO₂ Alert 20251123.175655 (c 36565) PC



23.11 PM

24.11 AM

24.11 PM



- <http://cpm-ws4.ulb.ac.be/Alerts/>
- <http://sacs.aeronomie.be>

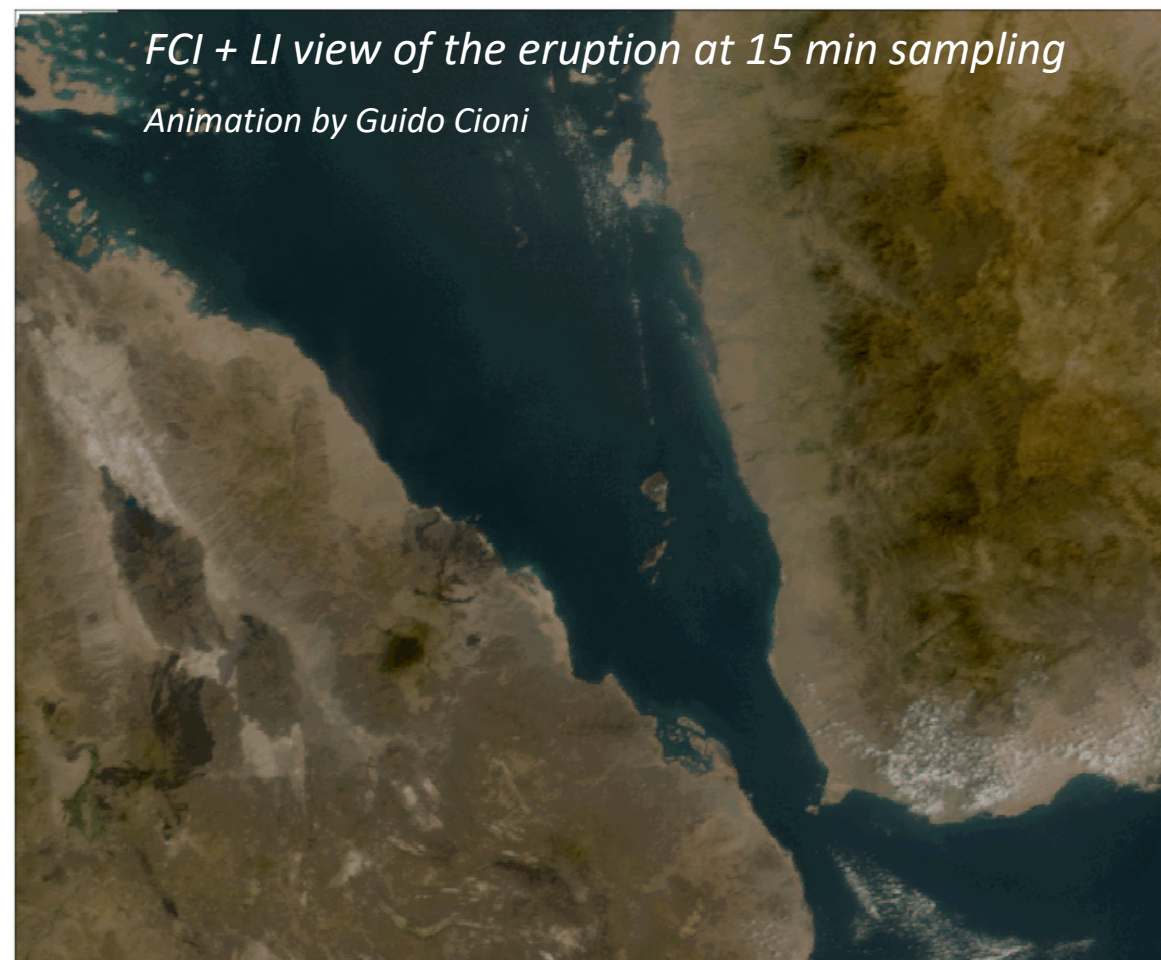
⇒ Hazard monitoring: volcanoes, fires, dust outbreaks, accidental industrial “releases”

□ Volcanic plumes: SO₂ and ash ; SO₂ altitude; + NRT alerts

Hayli Gubbi eruption
23.11.2025

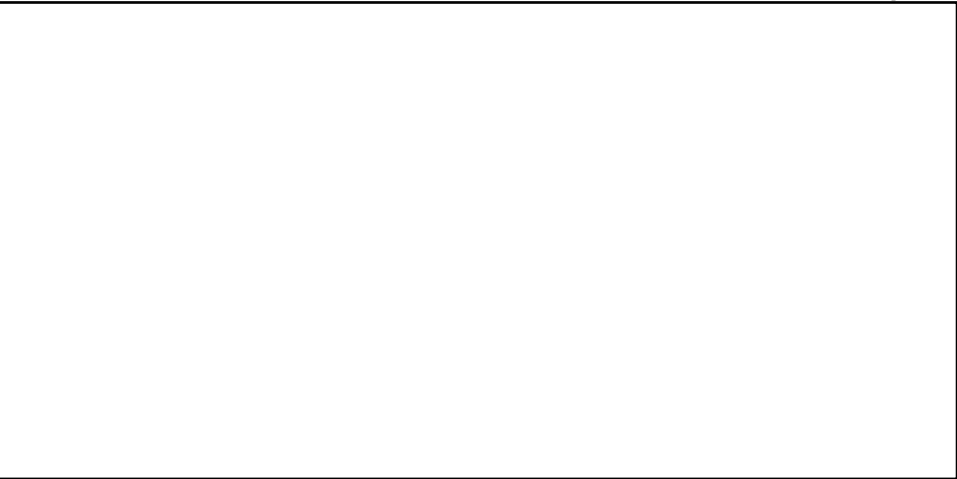
Now imagine with IRS....

- 1h resolution for Africa !
- Unfortunately IRS does not have the most sensitive SO₂ channels....



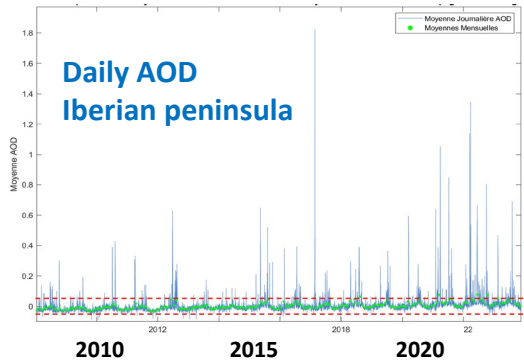
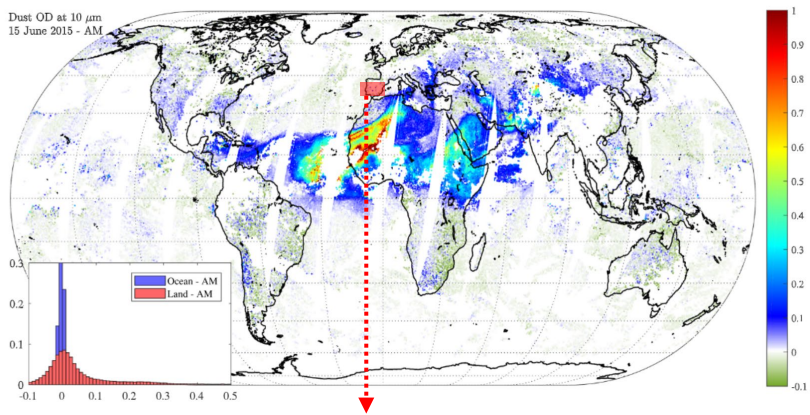
⇒ Hazard monitoring: volcanoes, fires, dust outbreaks, accidental industrial “releases”

☐ Fires: CO, NH₃ and other tracers



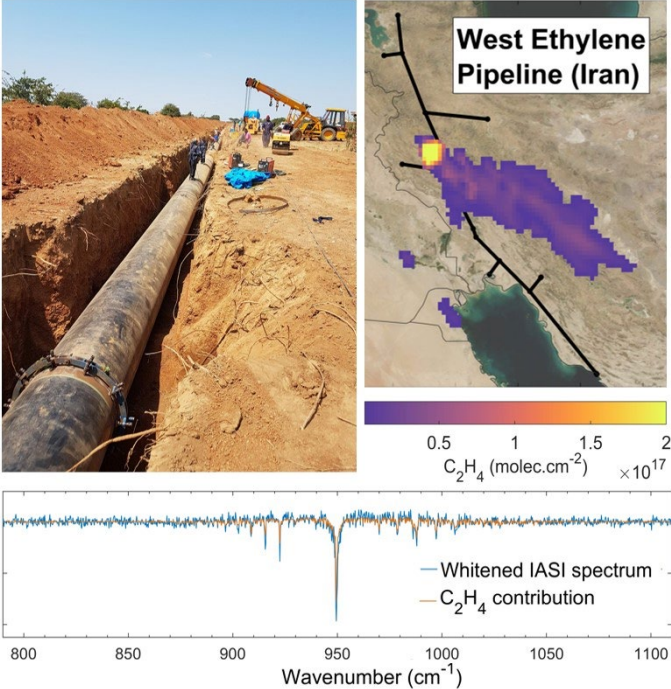
Excess CO – Animation by M. George

☐ Dust outbreaks



Clarisse et al. JGR 2019
Figures by L. Clarisse and G. Dewever

☐ industrial “releases”

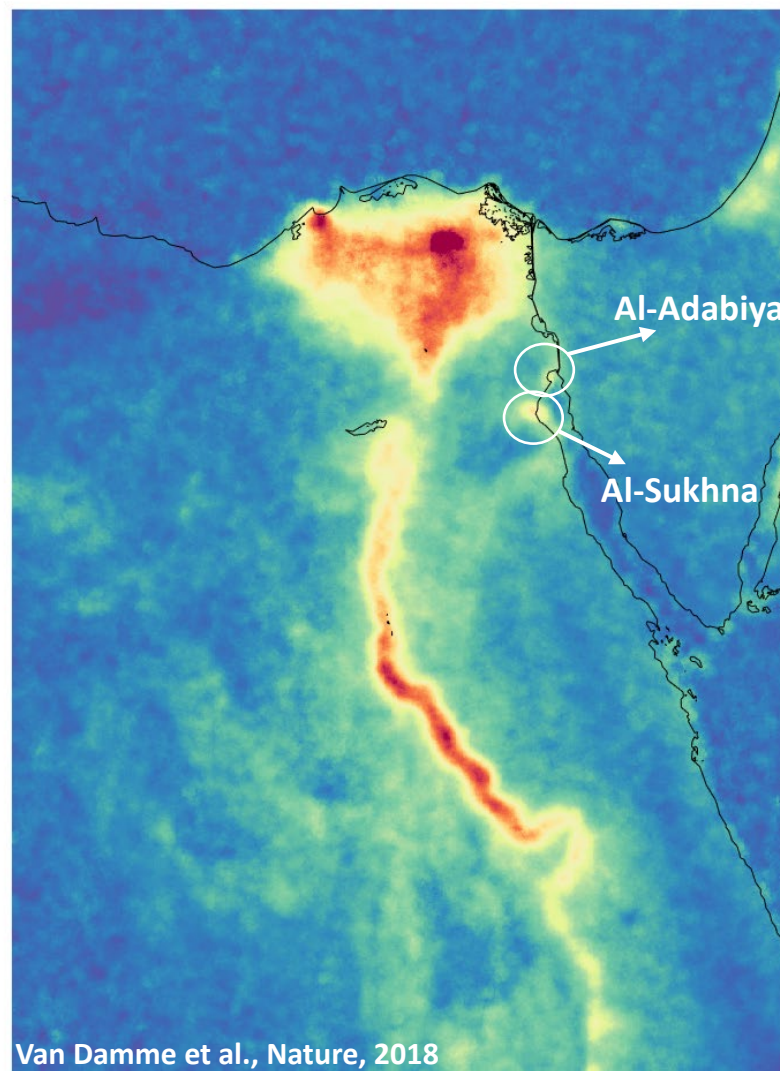


Figures by H. Massager. Paper in preparation

⇒ Detection, quantification of single anthropogenic pollution sources

Ammonia point sources and hotspots from 10-year; **regular oversampled** average

! Implies large temporal averages



ENVIRONMENTAL SCIENCE

Ammonia maps make history

Ammonia emissions harm humans and the environment. An analysis shows that satellites can locate sources precisely, and could thus help to monitor compliance with international agreements to limit such emissions. [SEE LETTER P.99](#)

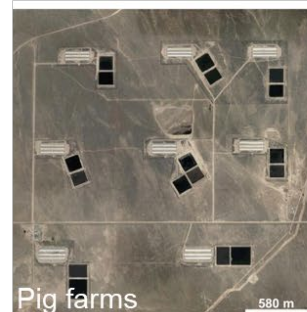
10 years

Figures by M. Van Damme (ULB)

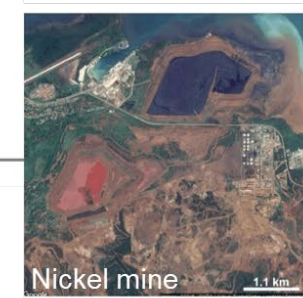
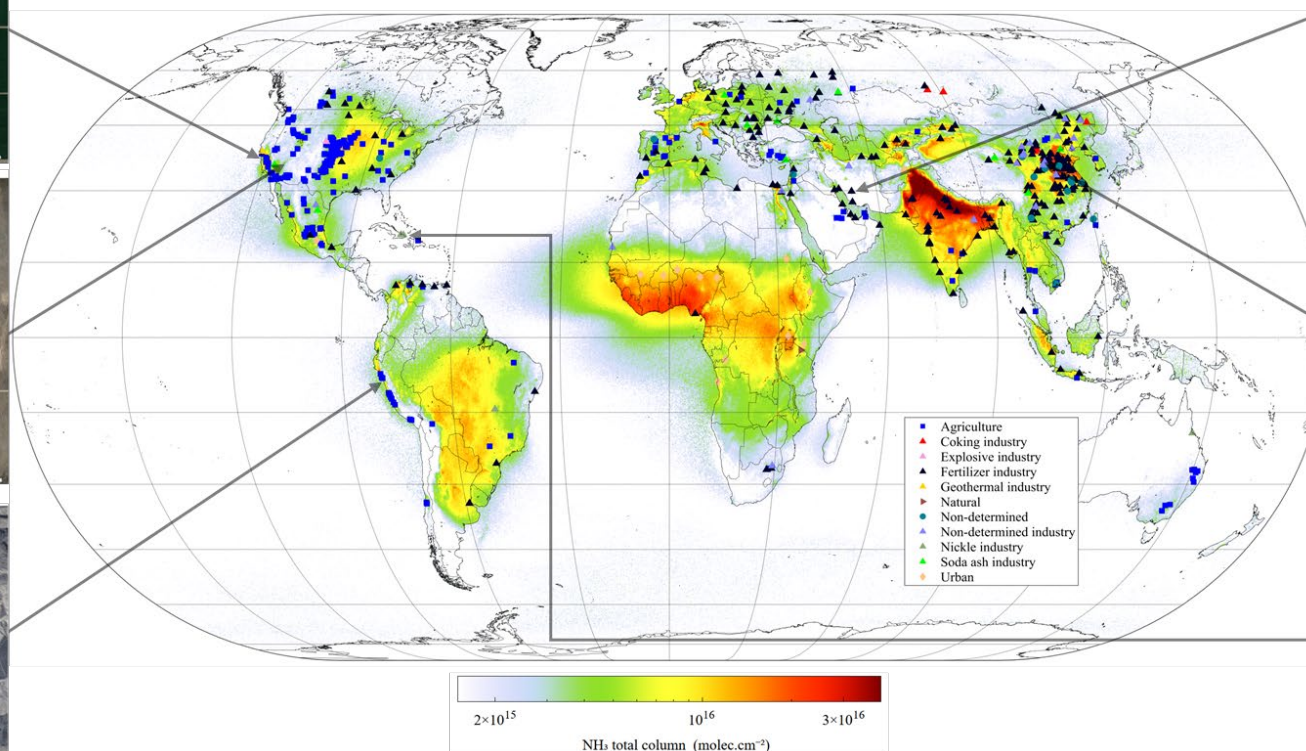
⇒ Detection, quantification of single anthropogenic pollution sources

Ammonia point sources and hotspots from 10-year; **regular oversampled** average

! Implies large temporal averages



>600 NH₃ point sources identified, categorized and quantified!



(Van Damme et al., Nature 2018; Clarisse et al., AMT 2019; Clarisse et al., AMT 2023)

See <https://squares.ulb.be/NH3-IASI.html>

Atmospheric Composition with IRS on MTG-S

1. Atmospheric composition with (hyperspectral) IR sounders – IASI heritage

2. Expected contribution from IRS

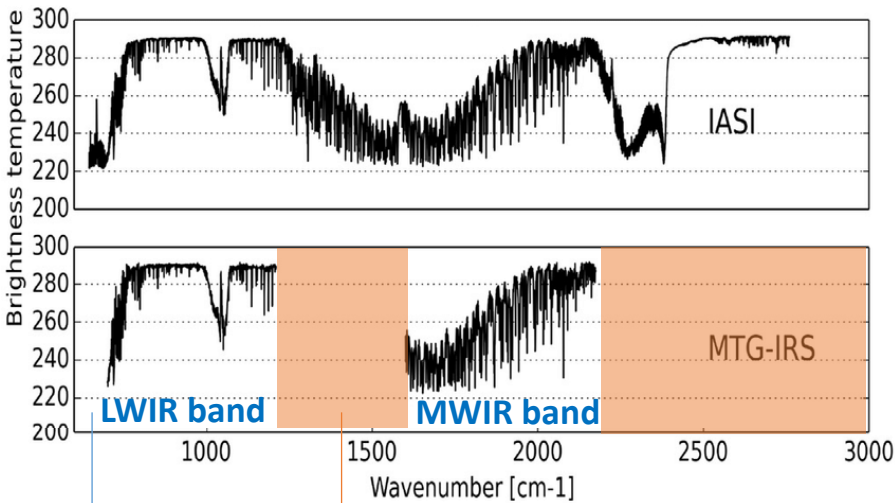
- What will IRS bring ?
- Improving mapping with over- or supersampling

What will IRS bring ?

Figures and animations by L. Clarisse

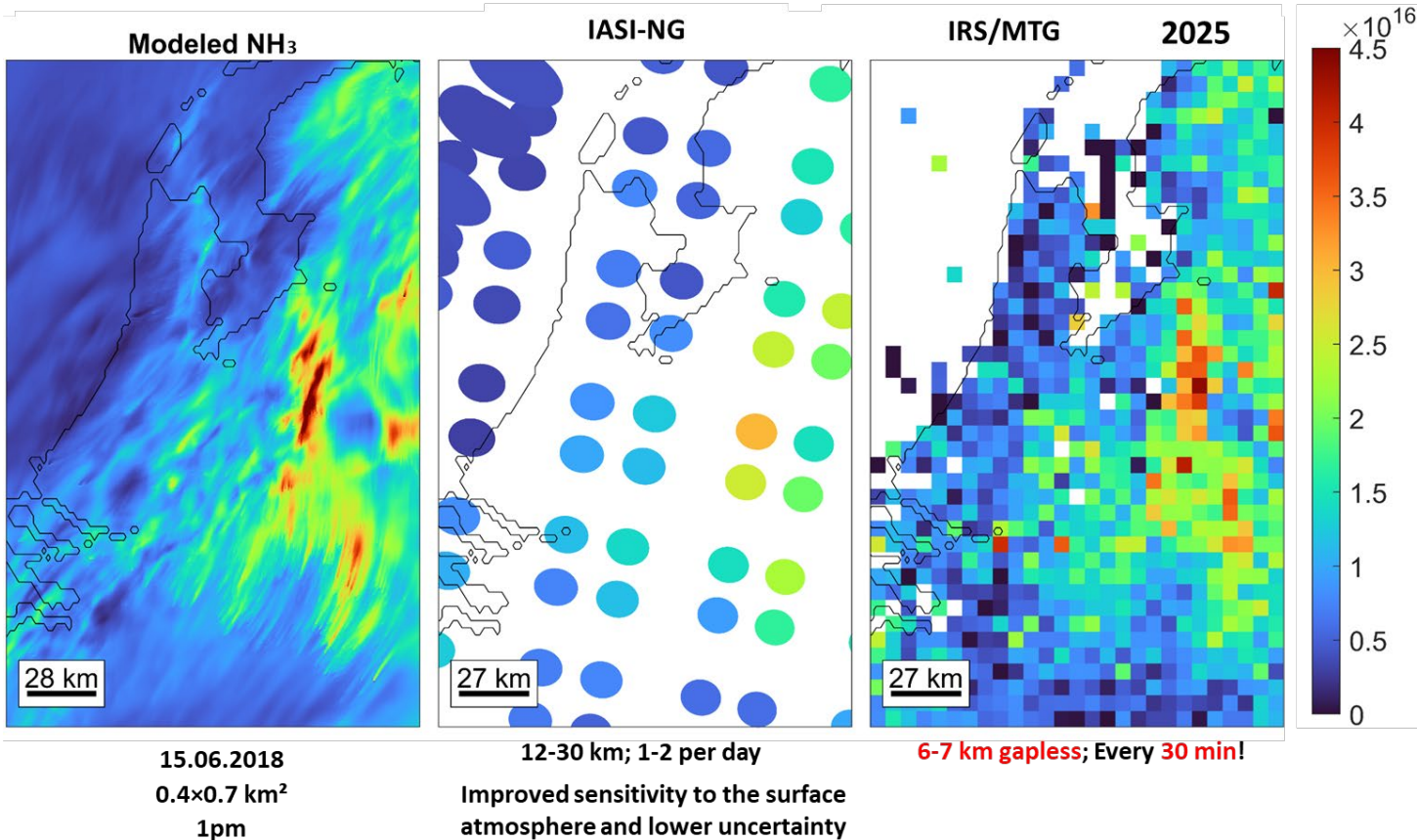
IRS

- Continuous coverage of the Earth surface ⇒ Better mapping opportunities
- Higher spatial resolution (~7 km on-ground pixel size at mid-latitudes) ⇒ improved resolution of sources

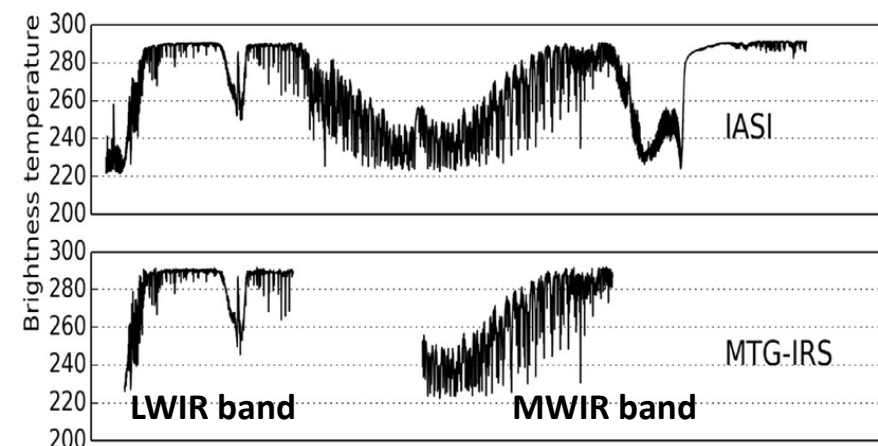


Coarser resolution (0.6 cm⁻¹ sampling) over IASI
Larger noise

Missing range for
• SO₂ • CH₄ • N₂O



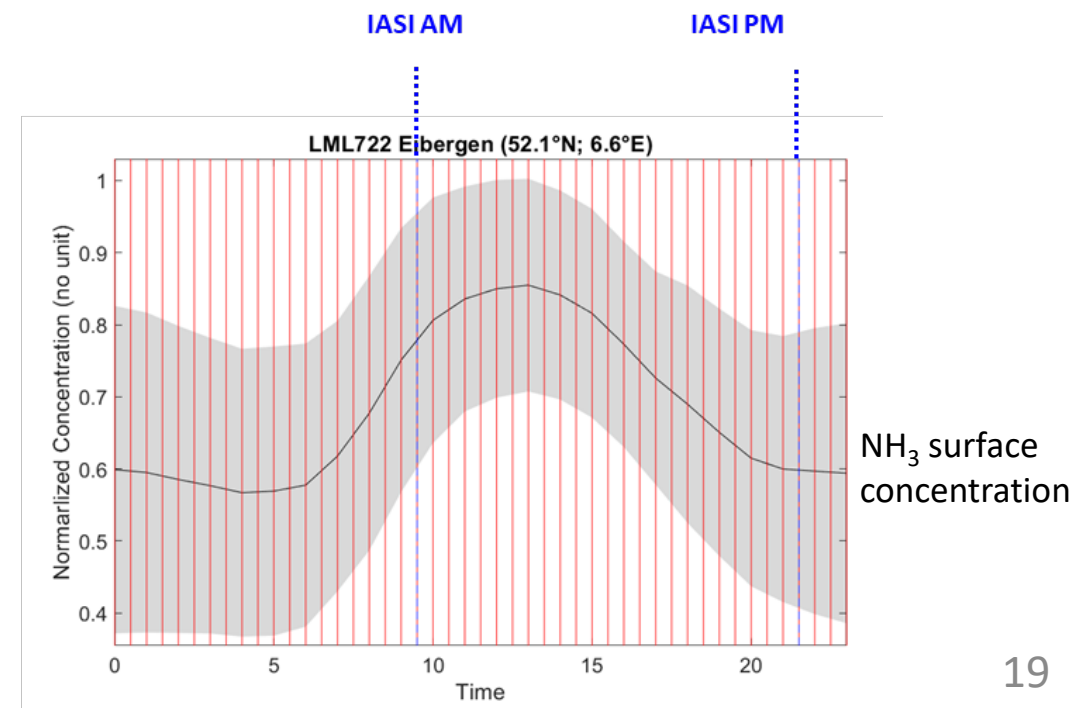
What will IRS bring ?



IRS

- Continuous coverage of the Earth surface ⇒ Better mapping opportunities
- Higher spatial resolution (~7 km on-ground pixel size at mid-latitudes)
⇒ improved resolution of sources
- High temporal sampling ⇒ Diurnal sampling; rapidly changing chemistry

30 minutes revisit above Europe
1 h revisit above Africa



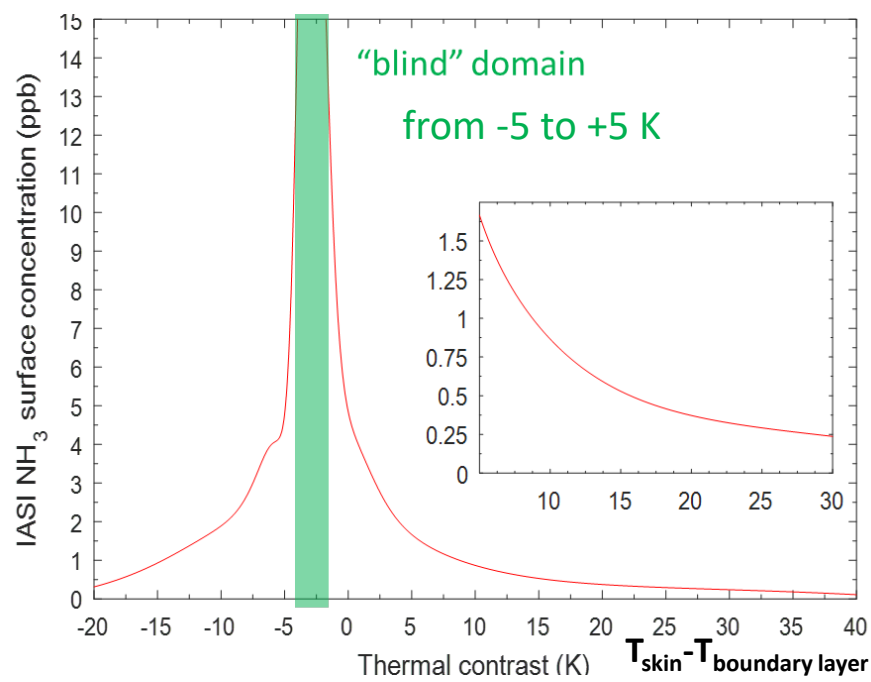
What will IRS bring ?

⚠ Additional consideration for Air Quality and source monitoring:

Highly variable sensitivity of IRS to the boundary layer as a function of the local **thermal contrast**

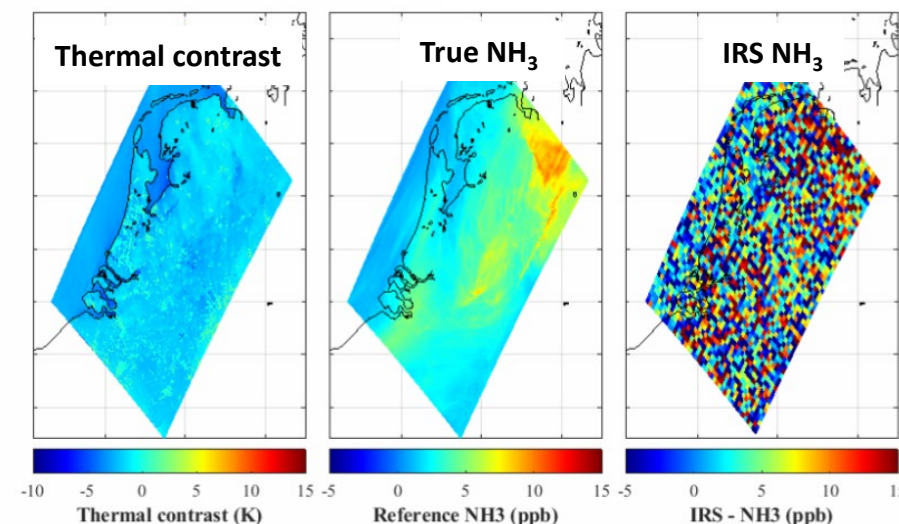
- ⇒ variable sensitivity throughout the day!
- ⇒ Measurements will not be equally usable *with blind spots in the diurnal cycle*

NH₃ retrieval accuracy vs. thermal contrast for IASI

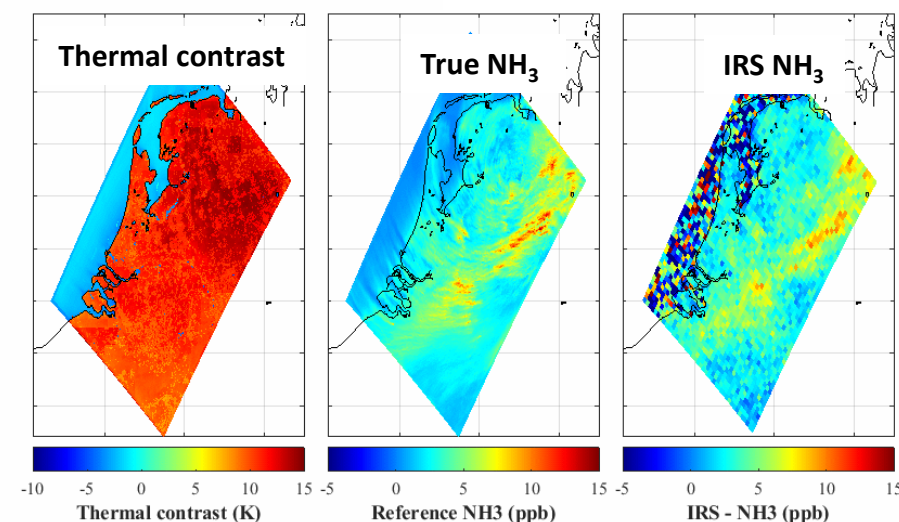


Figures and animations by L. Clarisse

Local time: 22:00



Local time: 09:30



What will IRS bring ?

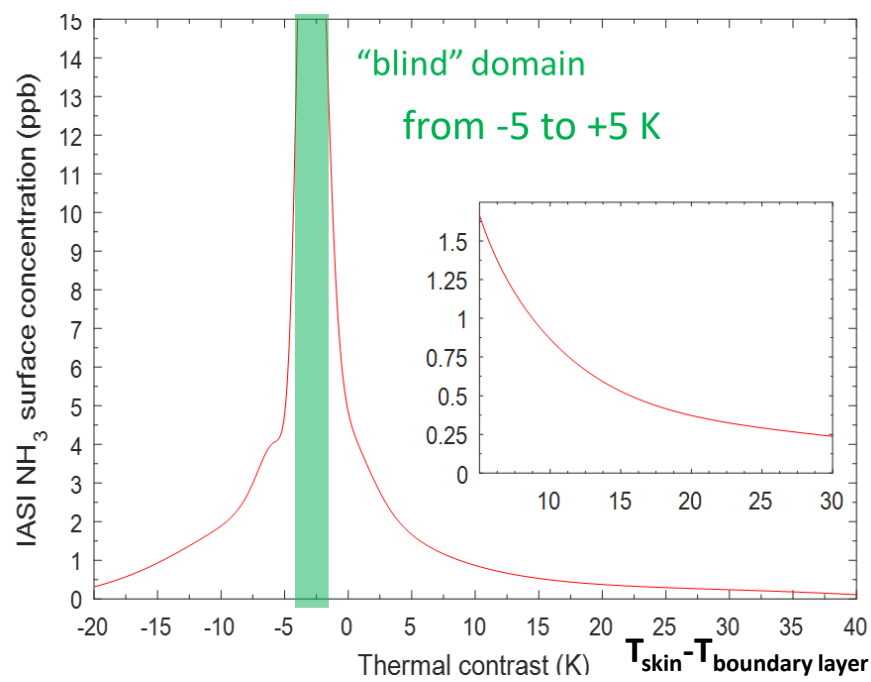
Figures and animations by L. Clarisse

! Additional consideration for Air Quality and source monitoring:

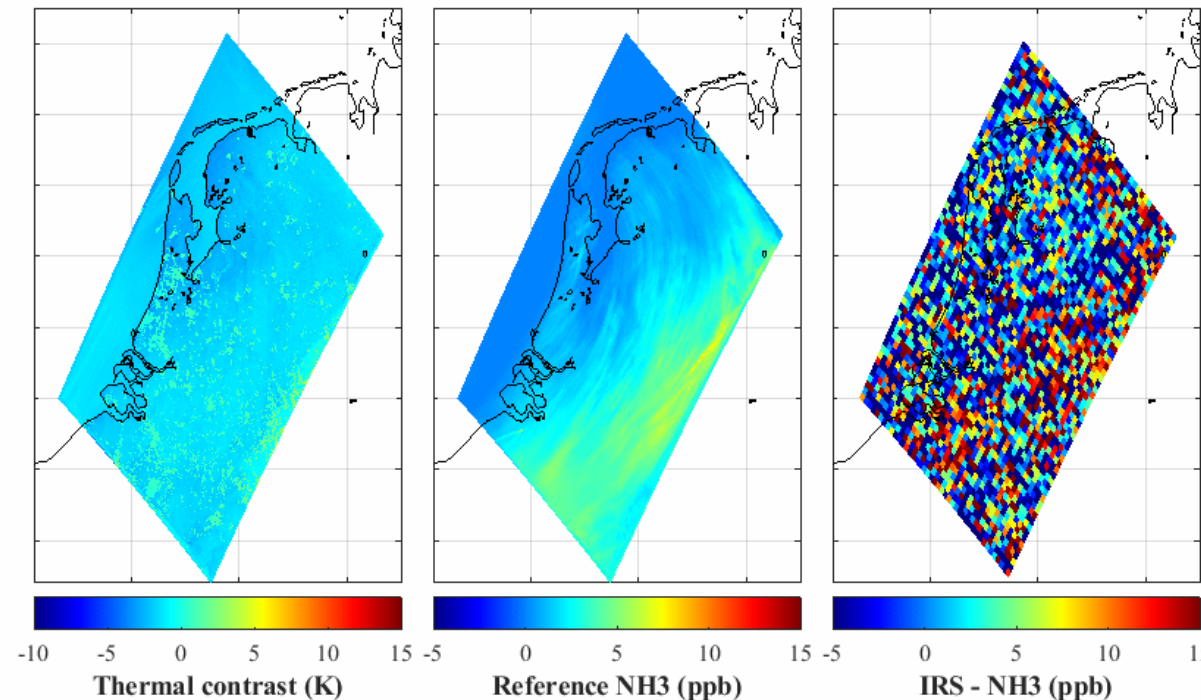
Highly variable sensitivity of IRS to the boundary layer ^{Thermal contrast}
as a function of the local **thermal contrast**

- ⇒ variable sensitivity throughout the day!
- ⇒ Measurements will not be equally usable
with blind spots in the diurnal cycle

NH₃ retrieval accuracy vs. thermal contrast for IASI



Local Time: 00:00



What will IRS bring ?

The large number of gapless images will largely improve over / supersampling possibilities

⇒ Improved spatial mapping and better identification of single emitters

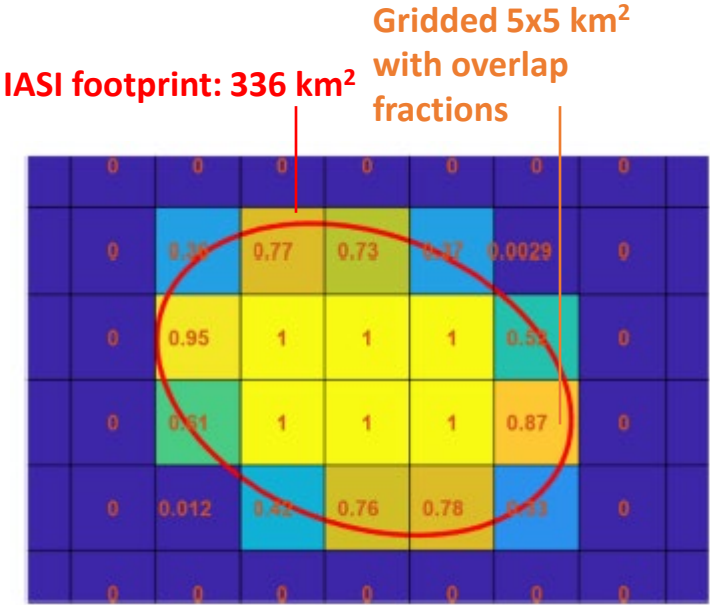
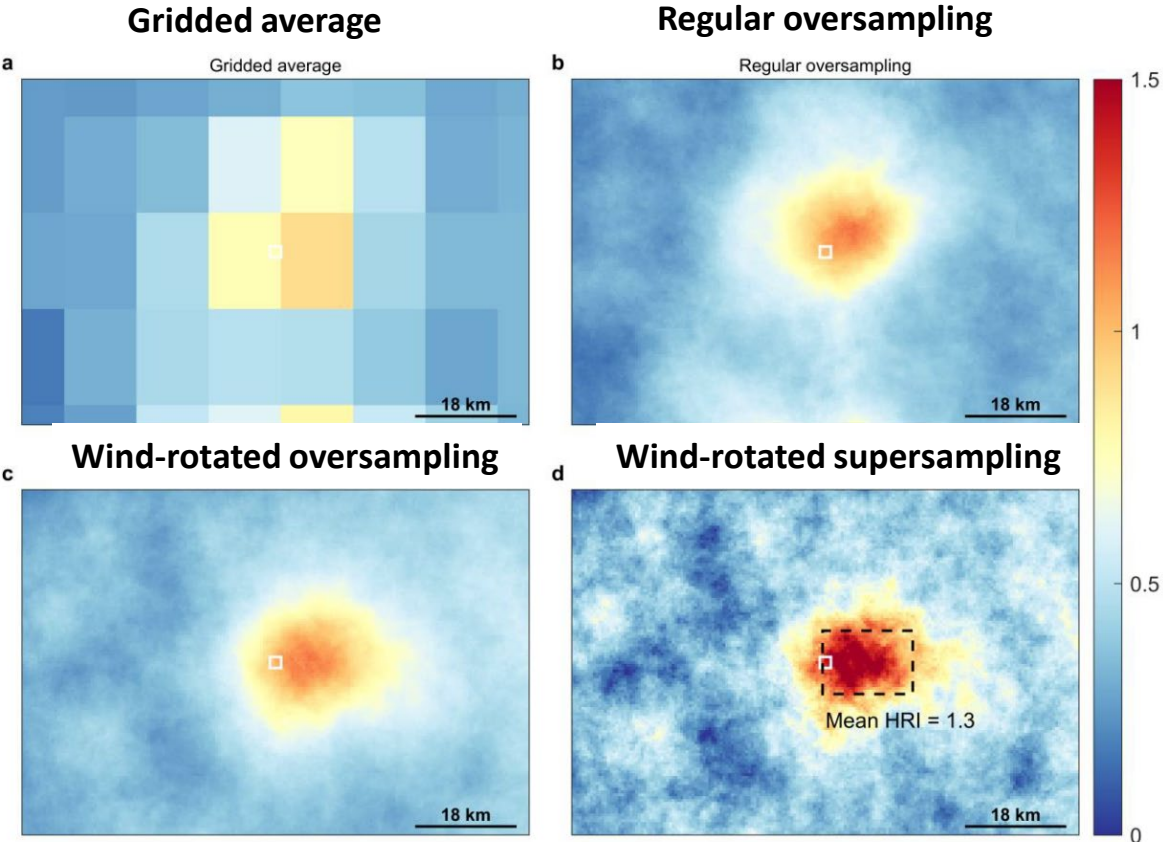


Figure 1. Illustration of IASI footprint (in red) and overlap fractions with target grid cells for an oversampling approach (numbers in red and color-coded from yellow for 1 to blue for 0). The figure is reproduced from (Sun et al., 2018). In this example, the IASI pixel area is 336 km² and the grid resolution is 5 x 5 km.

Example on IASI-NH₃ distributions

Distance to source typically determined within <2km!

Figures by L. Clarisse and A. Honet



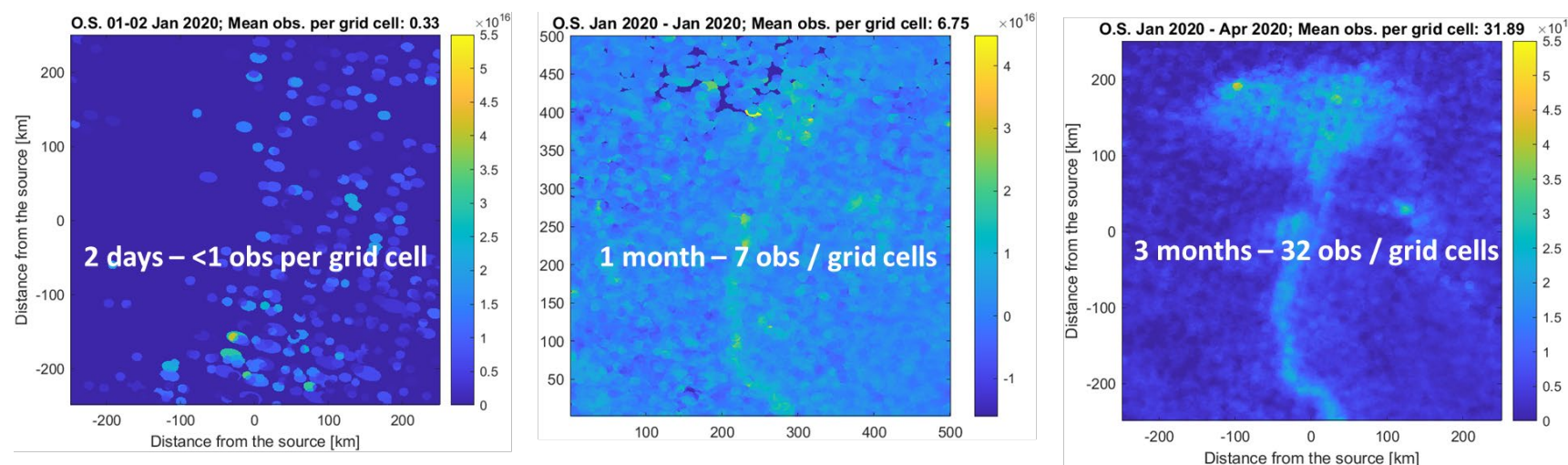
What will IRS bring ?

The large number of gapless images will largely improve opver / supersampling possibilities

⇒ Improved spatial mapping and better identification of single emitters

Back of the envelope calculation:

With IASI, around **30 measurements per grid cells** are typically needed for source identification. Only daytime cloud-free measurements are used ⇒ **oversampled images each 3-4 months**



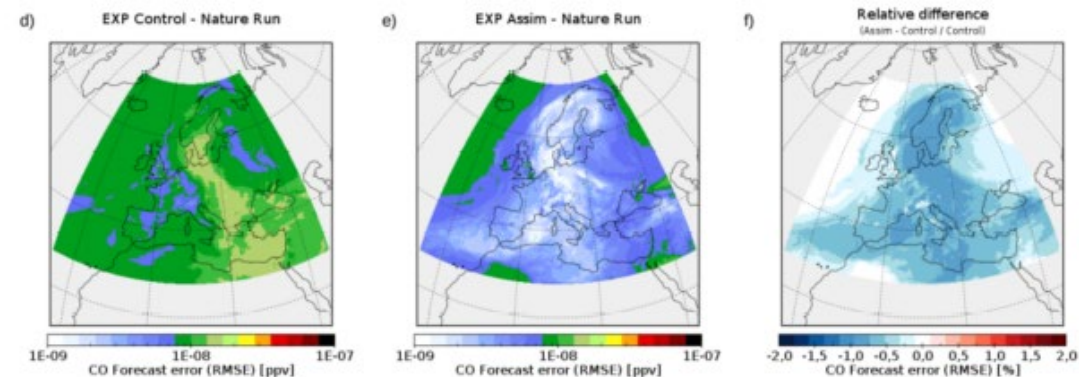
Figures by A. Honet

With IRS one can expect in “typical” summer conditions to measure surface NH_3 between 7 and 19h
For Europe (LAC 4) that would mean around **25 measurements** ⇒ **daily oversampled images!**



A lot to be expected from IRS for atmospheric composition on top of Sentinel-4

- Mapping of pollution at half-hourly (Europe) to hourly (Africa) resolution
- Improved detection of single emitters (NH_3 , C_2H_4 , VOCs, maybe GHGs)
- Hazard and post hazard monitoring (fires, volcanoes...)
- AQ forecast via assimilation



Coopmann et al.; QJRMMS -in review-

To know more: **MTG-IRS Science Plan** (July 2025)

[https://user.eumetsat.int/s3/ope-eup-strapi-media/MTG S IRS Science Plan 47145497b0.pdf](https://user.eumetsat.int/s3/ope-eup-strapi-media/MTG_S_IRS_Science_Plan_47145497b0.pdf)