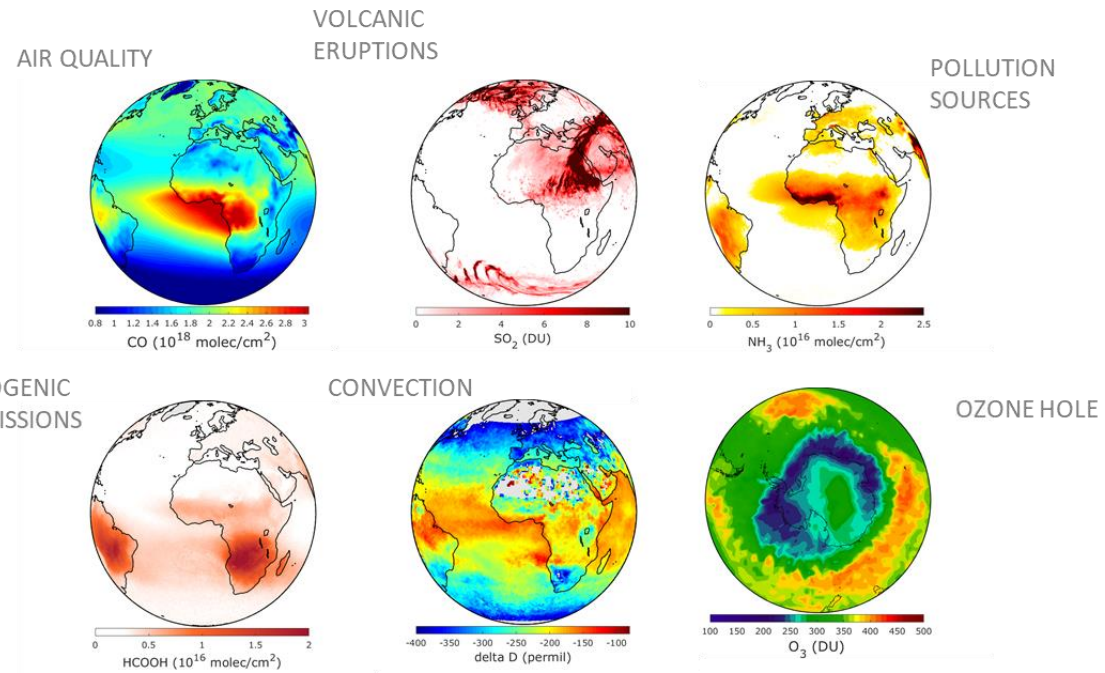
# Sondage de la composition de l'air dans l'infrarouge

## Principaux succès de la mission IASI

### Vers les futurs sondeurs hyperspectraux IR

P. Coheur • GTEO Air-Atmosphère • Nov. 2020

UNIVERSITÉ LIBRE DE BRUXELLES



# Sondage de la composition de l'air dans l'infrarouge

## Principaux succès de la mission IASI (sondage hyperspectral)

### La mission IASI

- Objectifs, principe de mesure et produits de composition atmosphérique
- Applications
  - Du local au global – *l'exemple du monoxide de carbone (CO)* –
  - Identification et monitoring des sources ponctuelles – *l'exemple de l'ammoniac ($NH_3$)*–
  - Suivi des événements soudains: feux et éruptions volcaniques
  - Suivi climatique et la surveillance des protocoles

### Sondeurs hyperspectraux IR de nouvelle génération

- Les missions opérationnelles Copernicus: IASI-NG (Metop-SG) et IRS (MTG)
- Les missions Earth Explorer: FORUM (EE9) et Nitrosat (candidate EE11)

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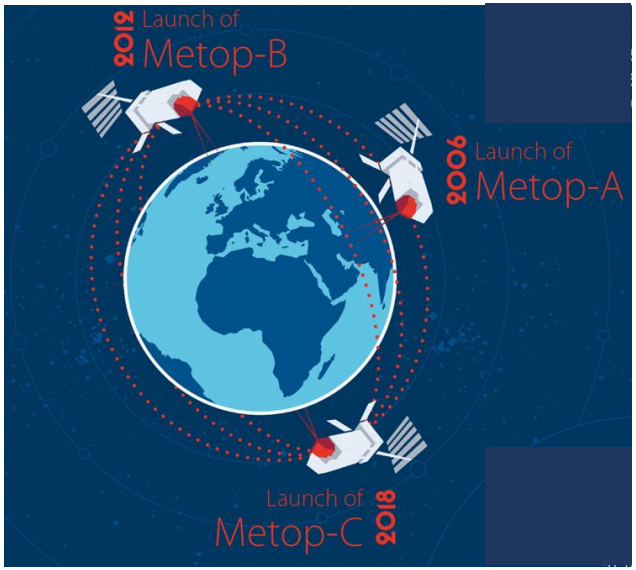
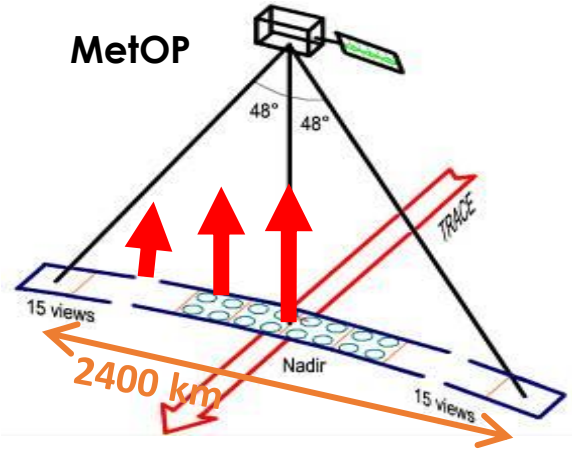
# A success mission for the monitoring of the atmosphere



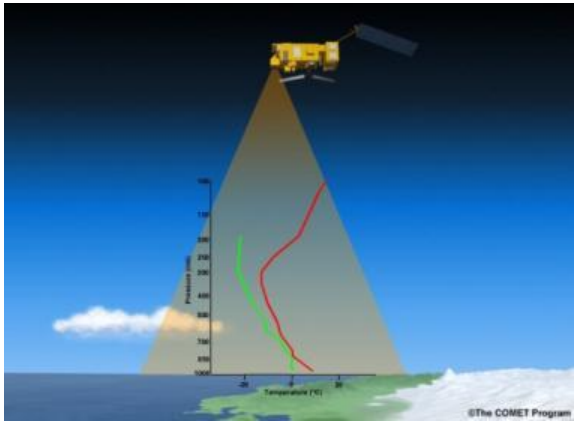




**I**nfrared
**A**tmospheric
**S**ounding
**I**nterferometer

## Key points for atmospheric composition

- Near-global coverage twice daily (9:30 and 21:30)
  *>1 million observations daily per IASI*
- Medium spatial resolution (12 km on-ground)
- High spectral and radiometric performances
- Towards 18 years of global measurements
- Exceptional stability

## A success mission for the monitoring of the atmosphere

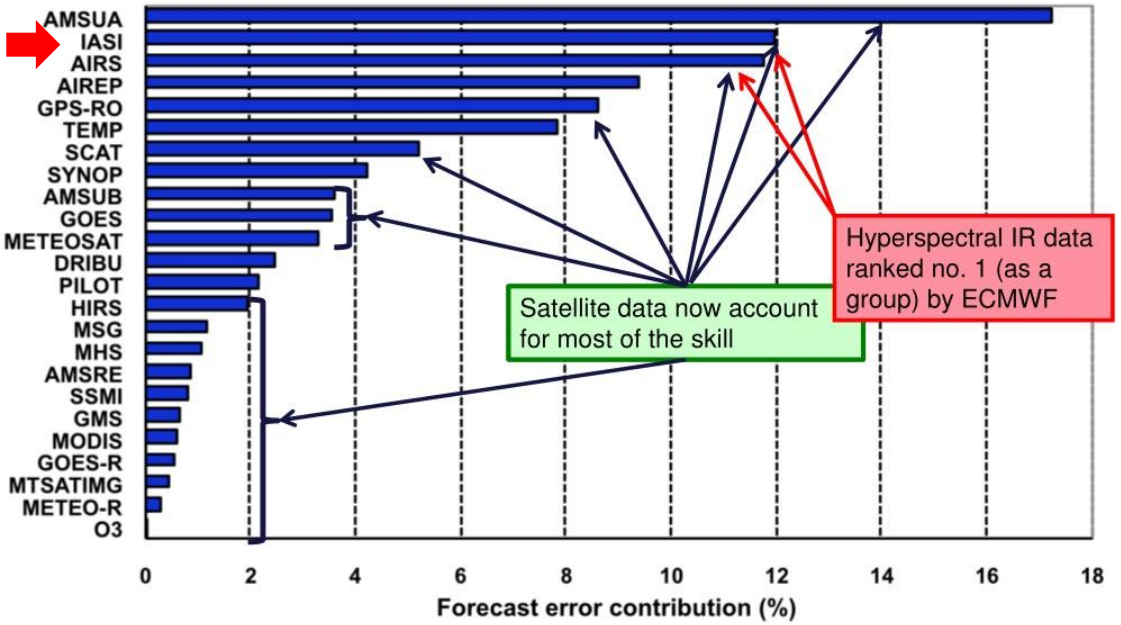




Vertical profiles of temperature and humidity with unprecedented accuracy and resolution

⇨ Weather forecast

Impact of GOS components on 24-h ECMWF Global Forecast skill

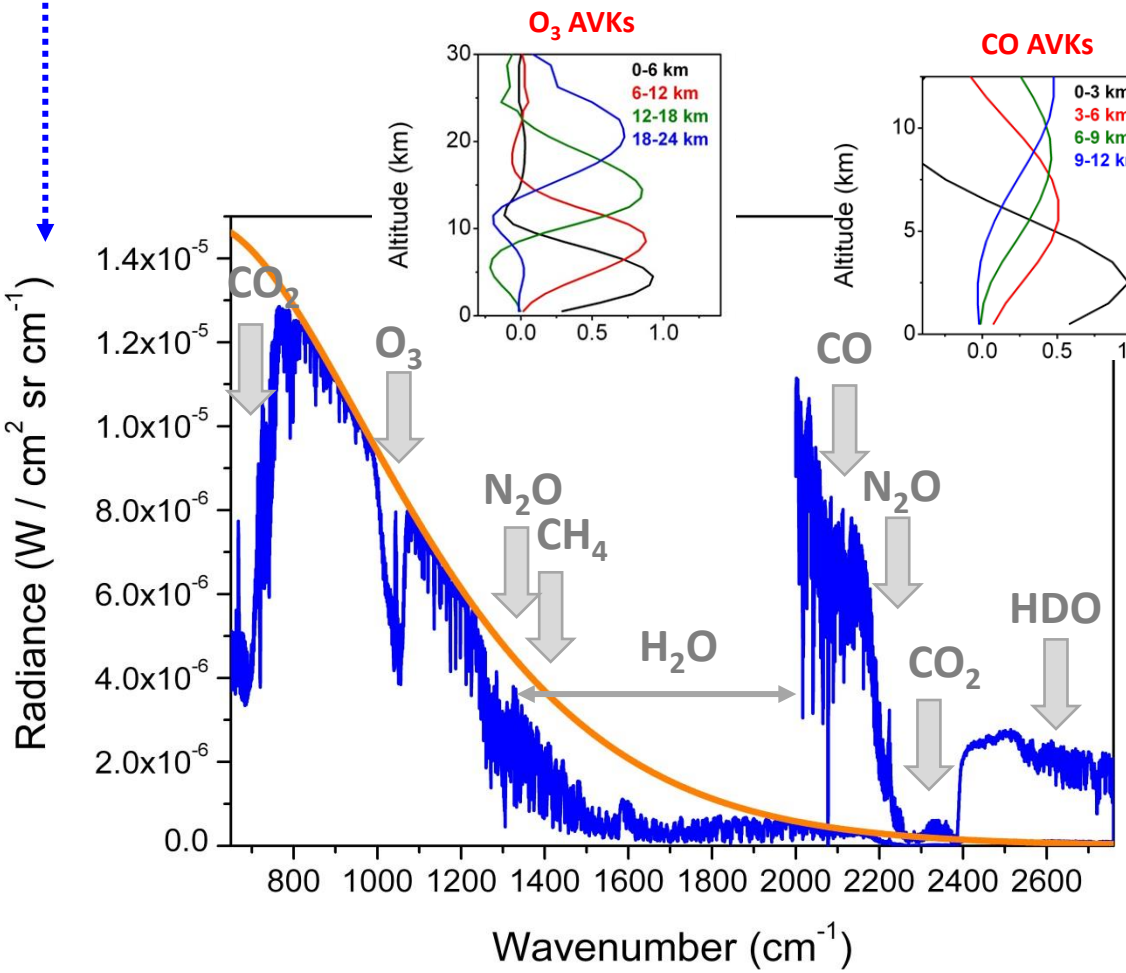
*(courtesy of Erik Andersson, ECMWF)*



# A success mission for the monitoring of the atmosphere

# What information do hyperspectral IR measurements carry ?

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




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

# What information do hyperspectral IR measurements carry ?

**> 30 species detected by IASI**

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 $C_2H_4$ $C_3H_6$ $C_4H_4O$ $CH_3COOH$ $CH_3CHO$
Sulfur species: $SO_2$ OCS $H_2S$
CFCs: CFC-11 CFC-12

**With global distributions daily**

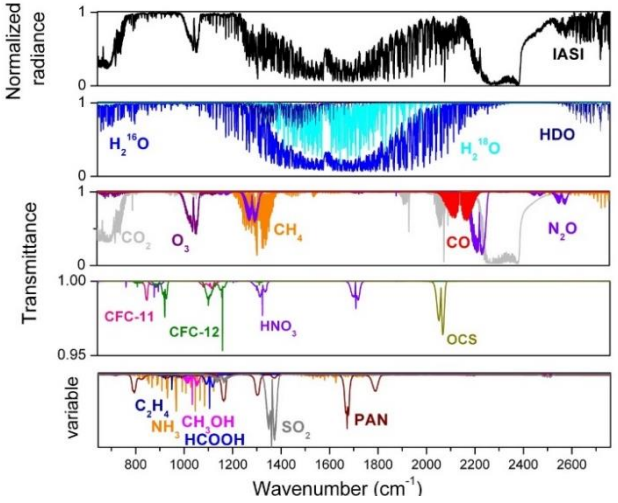
**In concentrated plumes (fires, volcanoes)**

**Exceptional**

**With sensitivity in the stratosphere**

33 Gases

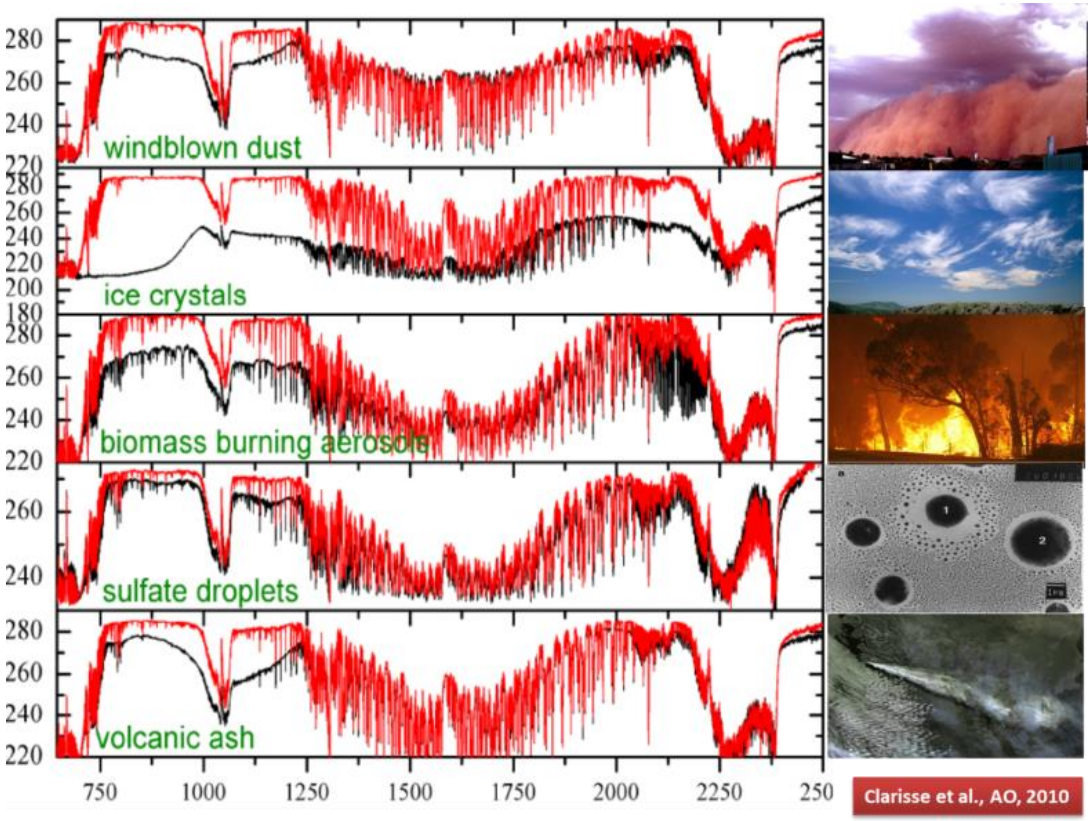
4 times more than anticipated

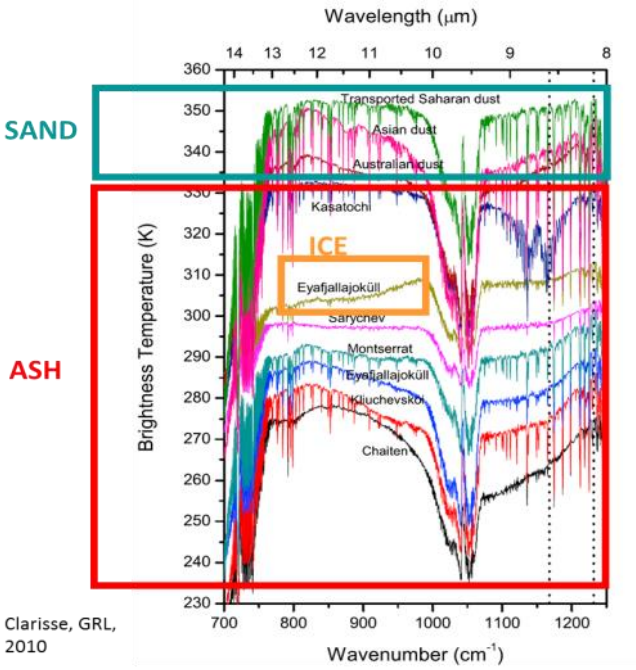



F. Hilton et al., 2012
L. Clarisse et al., GRL 2011
…

# What information do hyperspectral IR measurements carry ?

**+ Aerosols** Aerosol of various sources (coarse mode), including
**Dust**
**volcanic ash** (different types)
**sulfates**



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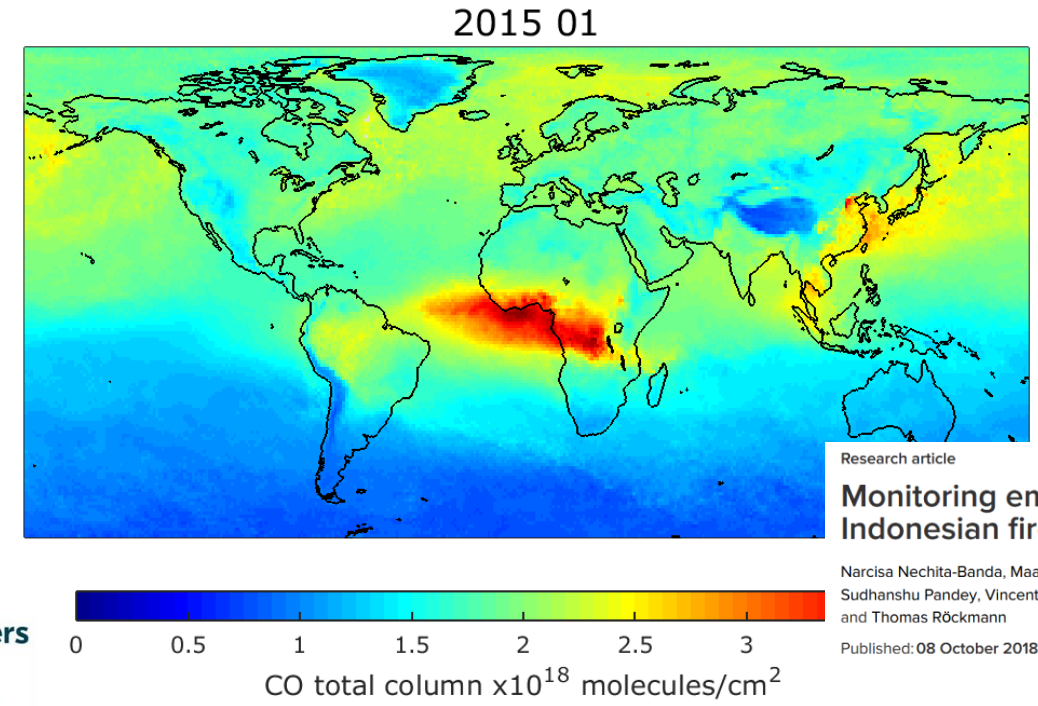
## ○ Applications

### 1. GLOBAL MAPPING: SOURCES, CHEMISTRY AND TRANSPORT

# Carbon monoxide

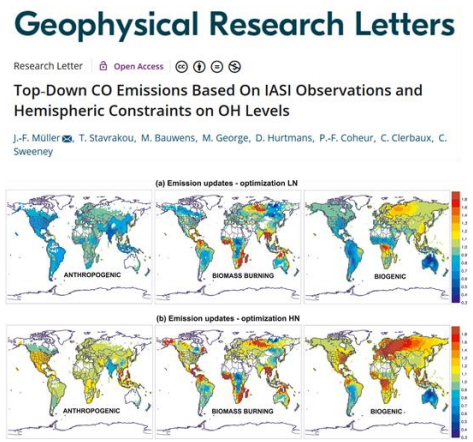



Animation from M. George

LATMOS

**Emissions**

- Anthropogenic
- Fires




Research article

**Monitoring emissions from the 2015 Indonesian fires using CO satellite data**

Narcisa Nechita-Banda, Maarten Krol, Guido R. van der Werf, Johannes W. Kaiser, Sudhanshu Pandey, Vincent Huijnen, Cathy Clerbaux, Pierre Coheur, Merritt N. Deeter and Thomas Röckmann

Published: 08 October 2018 | https://doi.org/10.1098/rstb.2017.0307

- **Photochemistry**
- **Long-range transport of pollution**

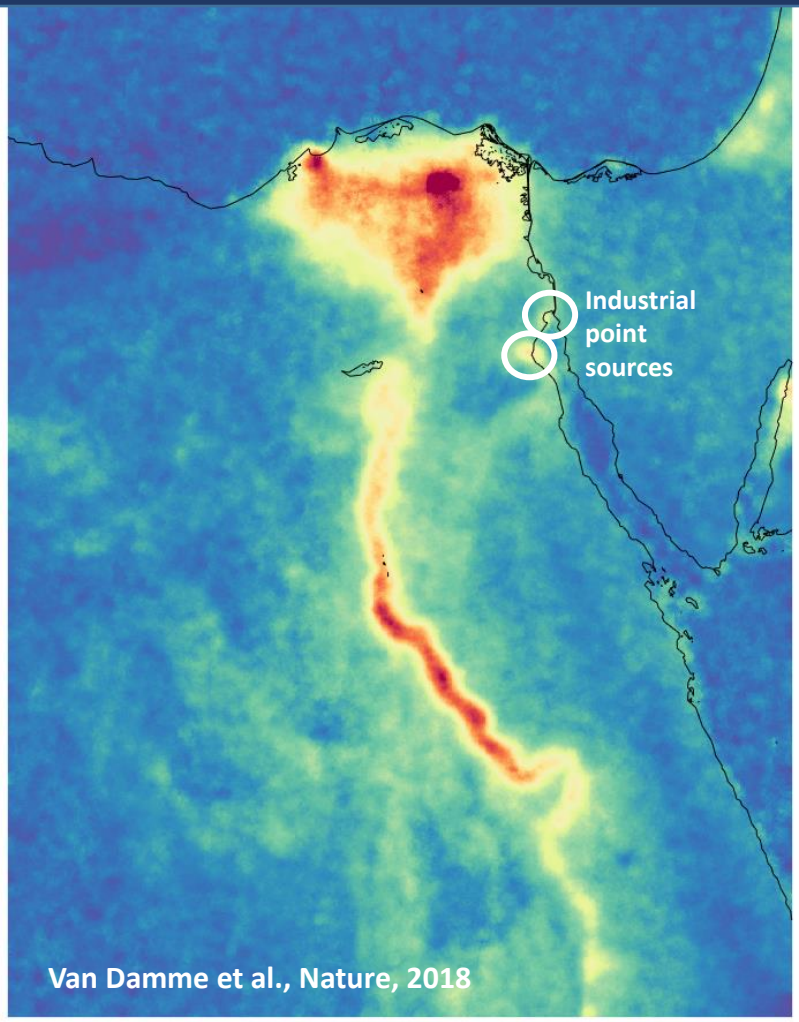
IASI-CO is assimilated by CAMS

## ○ Applications

### 2. TRACKING DOWN EMISSION SOURCES

# Ammonia

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



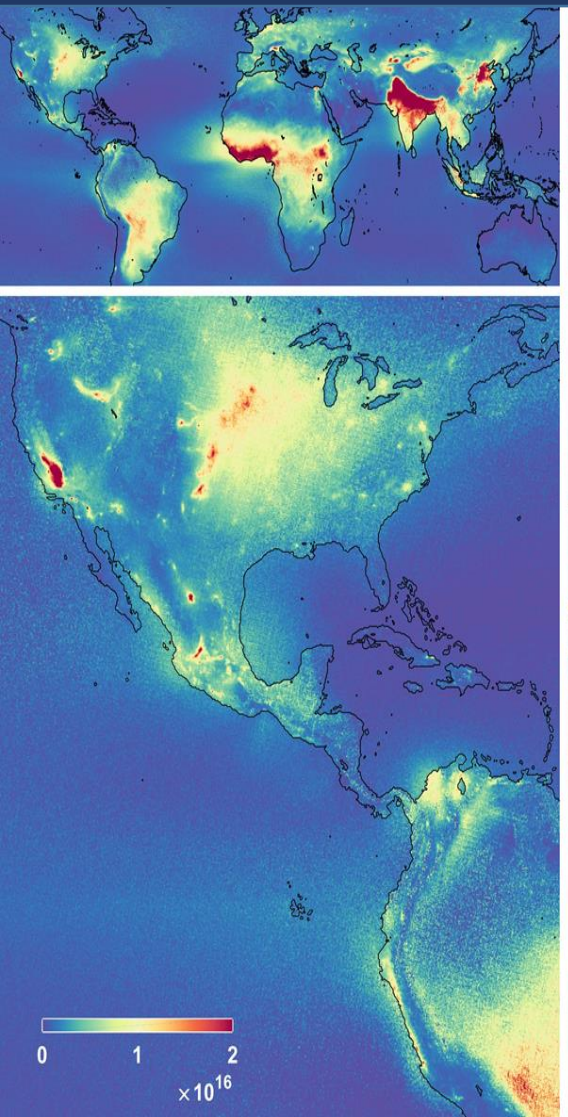

10 years

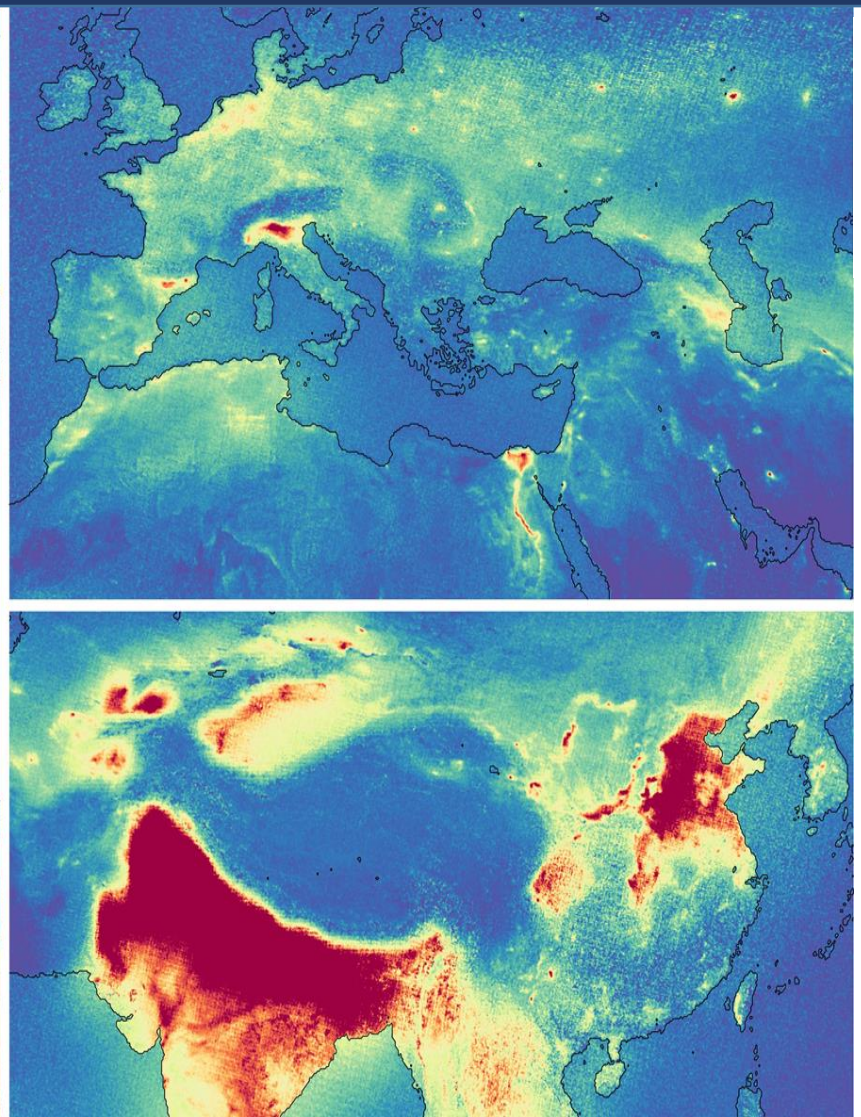
Van Damme et al., 2014
Van Damme et al., 2018
Sun et al., 2018

- Applications

## 2. Tracking down emission sources

# Ammonia



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

MARK A. SUTTON & CLARE M. HOWARD

consequences that increase greenhouse-gas

- Large source regions
- **> 500 point sources**
  *<50 km across*
  - **Agricultural**
  - **Industrial**
  - **Developing megacities**
  - **Natural**

○ Applications

## 2. Tracking down emission sources

# Ammonia

⇨ **Agricultural** point sources

○ Applications

## 2. TRACKING DOWN EMISSION SOURCES

# Ammonia

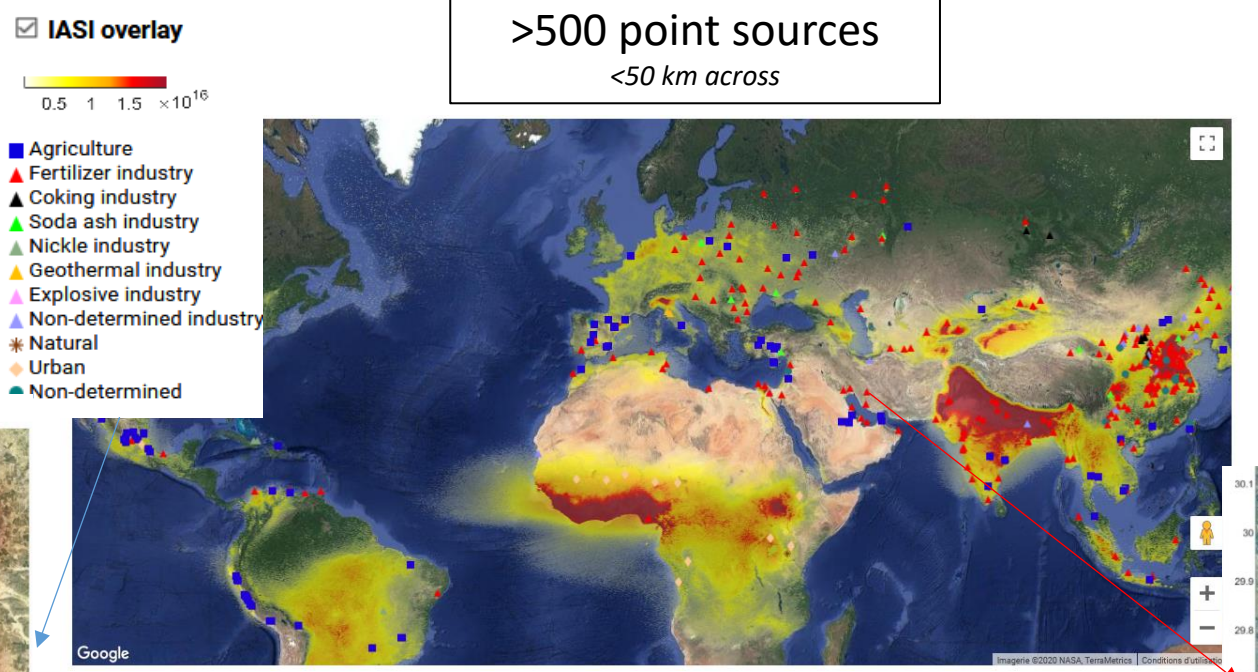
⇨ **Industrial** point sources

## ○ Applications

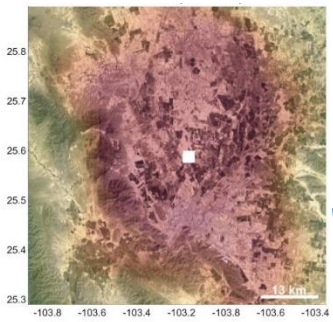
## 2. TRACKING DOWN EMISSION SOURCES

# Ammonia

>500 point sources
*<50 km across*

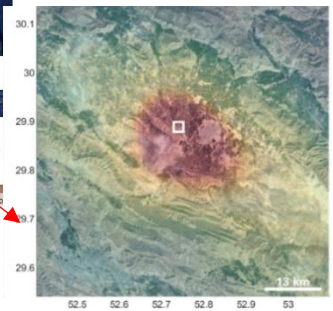



**Torreon (Mexico)**




*cattle feedlot*

**Marvdasht**




⇨https://www.ulb.ac.be/cpm/NH3-IASI.html

Missing or large underestimation of emissions in inventories

## ○ Applications

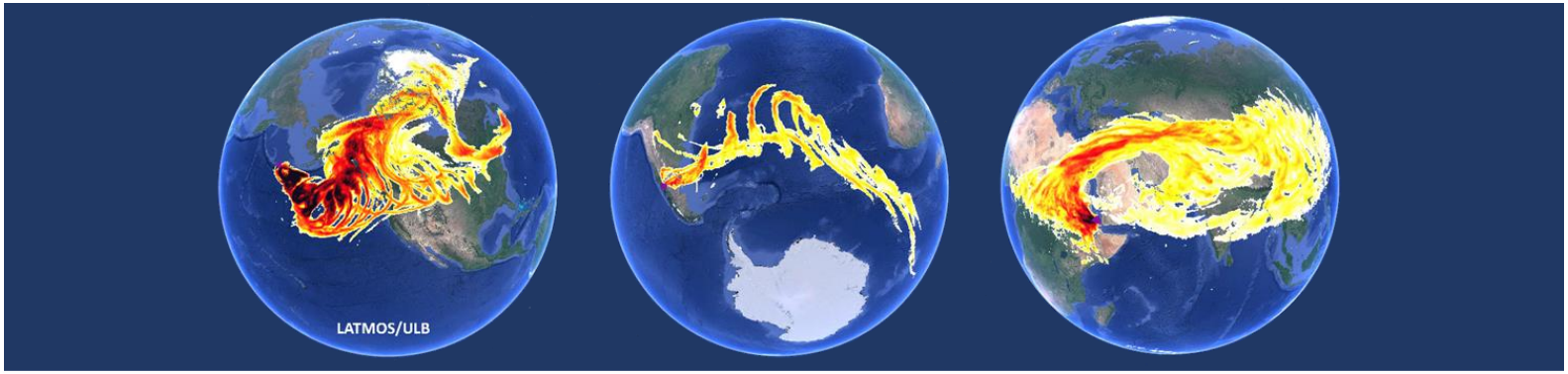
### 3. MONITORING UNPREDICTABLE EVENTS

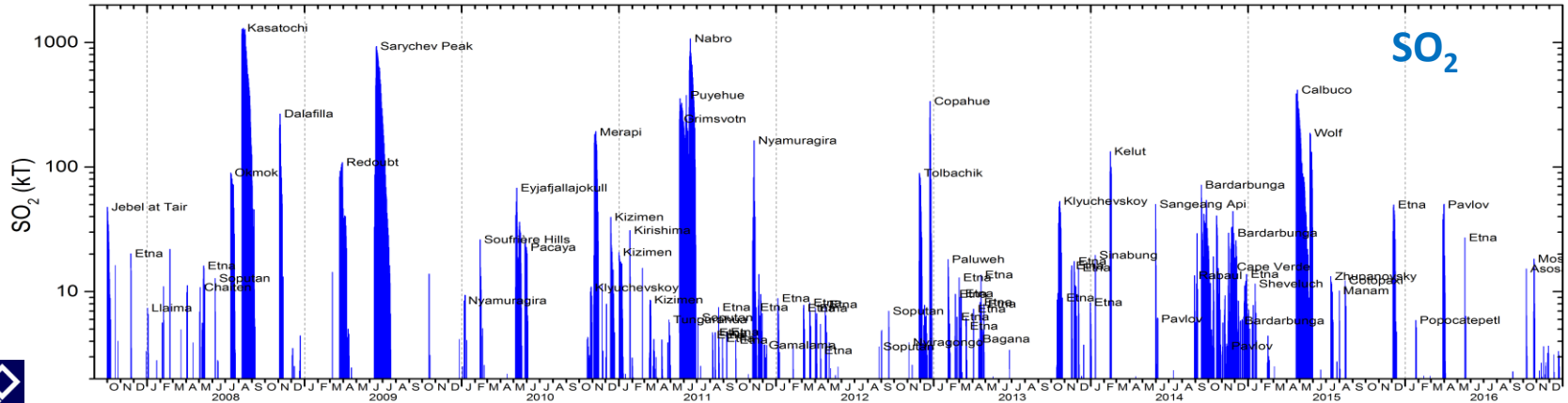
Detection of volcanic plumes, large fires, pollution peaks, etc.

# Volcanic plumes – $SO_2$ and ash

All major eruptions captured and tracked;

⇨ contribution to an operational alert system for aerial safety




Figures from L. Clarisse

## ○ Applications

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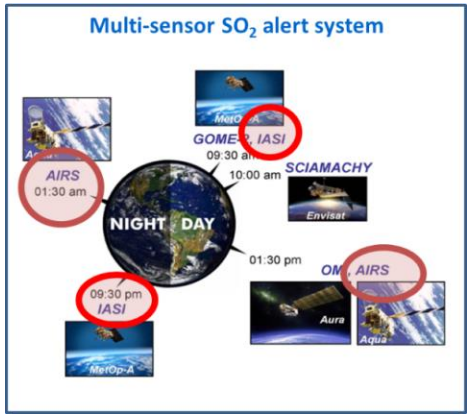
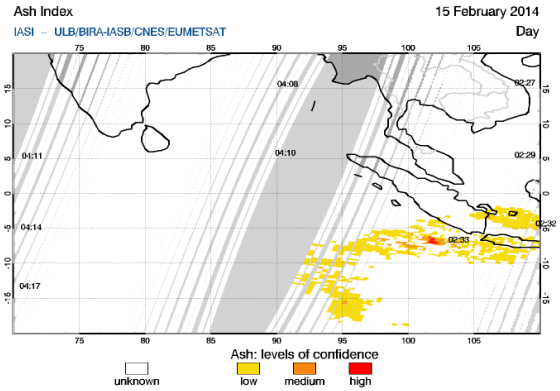
Existing NRT service for volcanic plumes
http://sacs.aeronomie.be

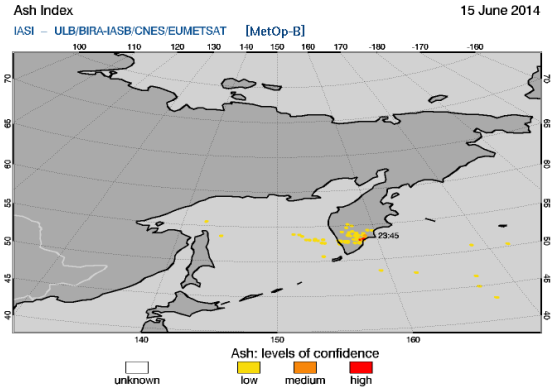



Large user base; main users being the VAACs (Volcanic Ash Advisory Centers)

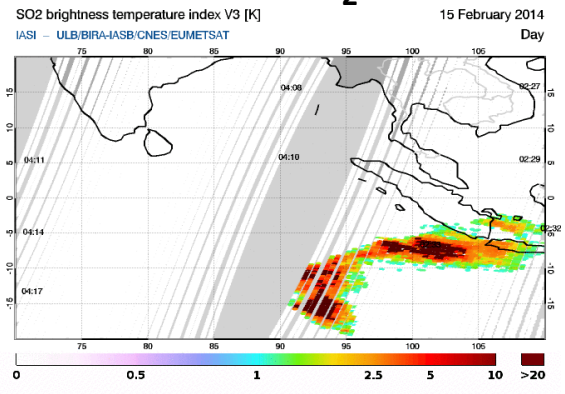
**Kelut**
February 2014

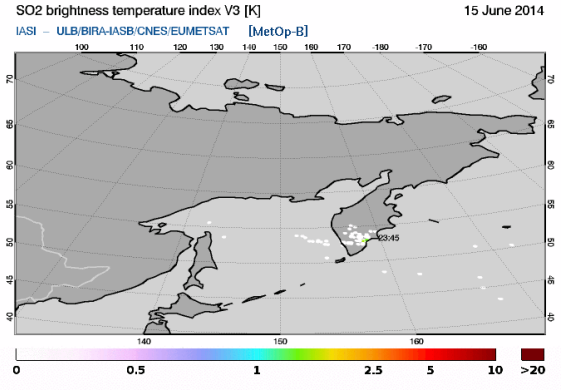
**Ash**



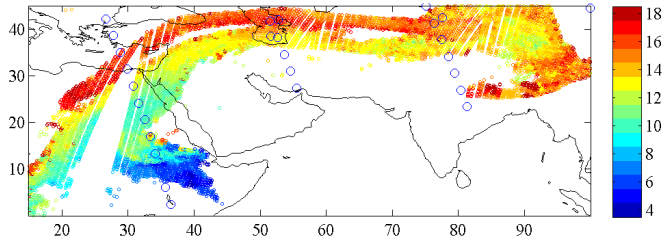

**$SO_2$**




**Zhupanovsky**
June 2014

+ plume altitude



## ○ Applications

## 3. MONITORING UNPREDICTABLE EVENTS

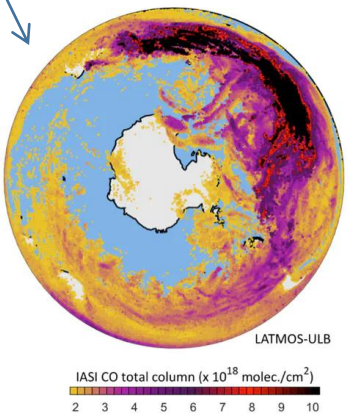
Detection of volcanic plumes, large fires, pollution peaks, etc.

# Fires

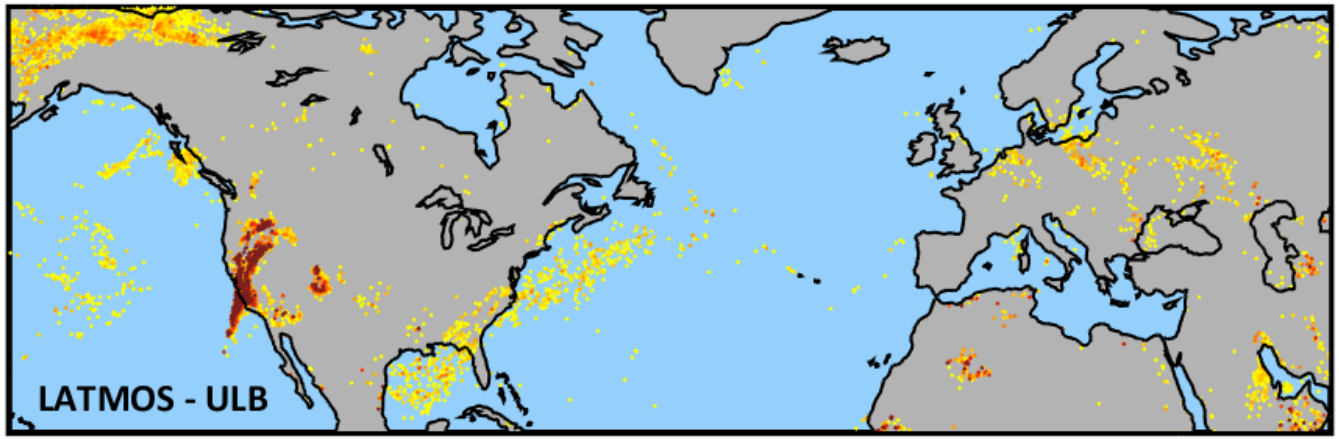
Animation from M. George

LATMOS

2019-2020 fire years
Siberia
Amazonia
Australia
California




2020 08 19




IASI CO total column (x $10^{18}$ molec./$cm^2$)

3 3.5 4 4.5 5 5.5

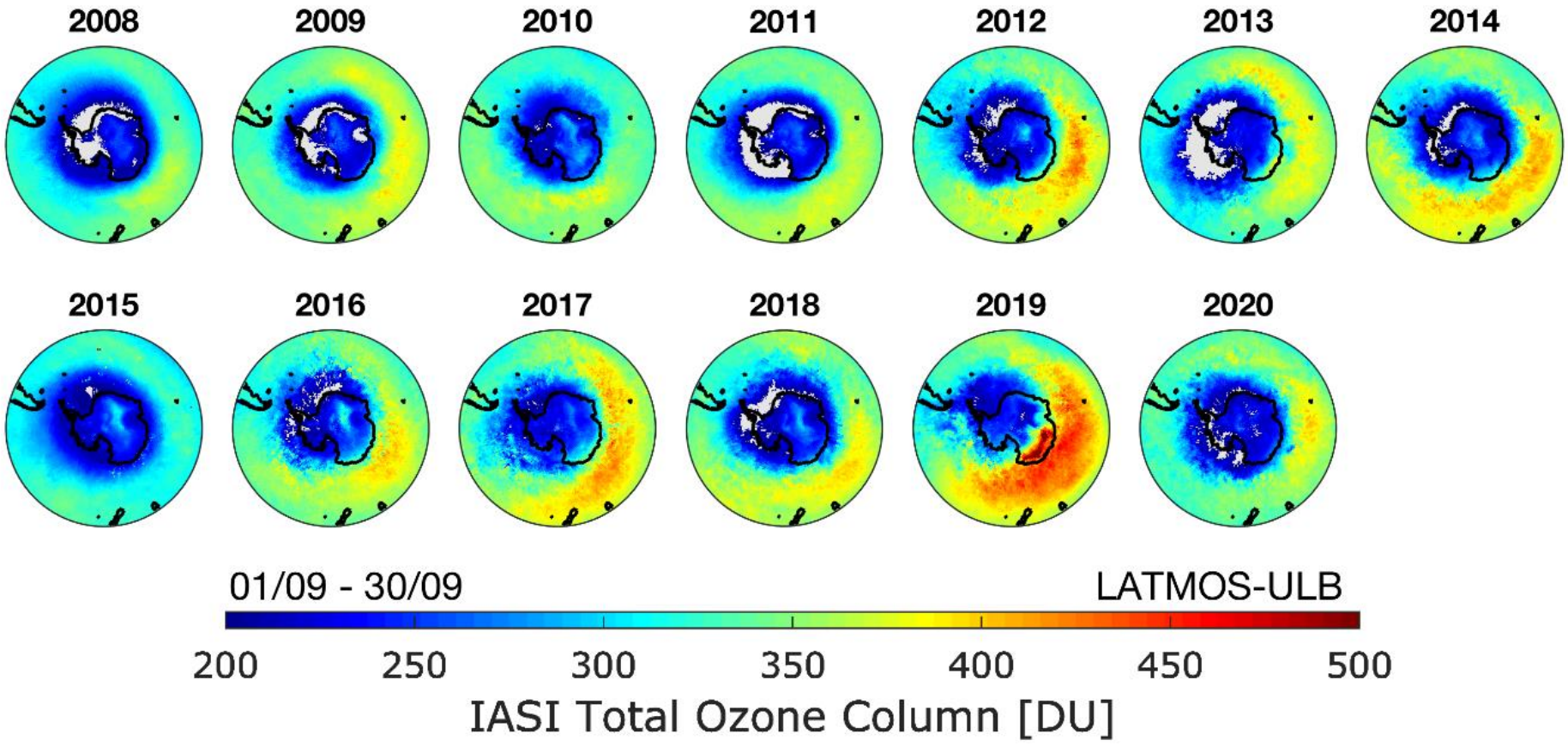
- Applications

## 4. Long-term assessment and protocol monitoring

First space mission to study atmospheric composition for at least 18 years

# Ozone

## Stratospheric Ozone



- Applications

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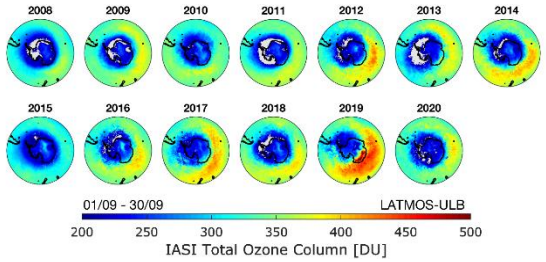
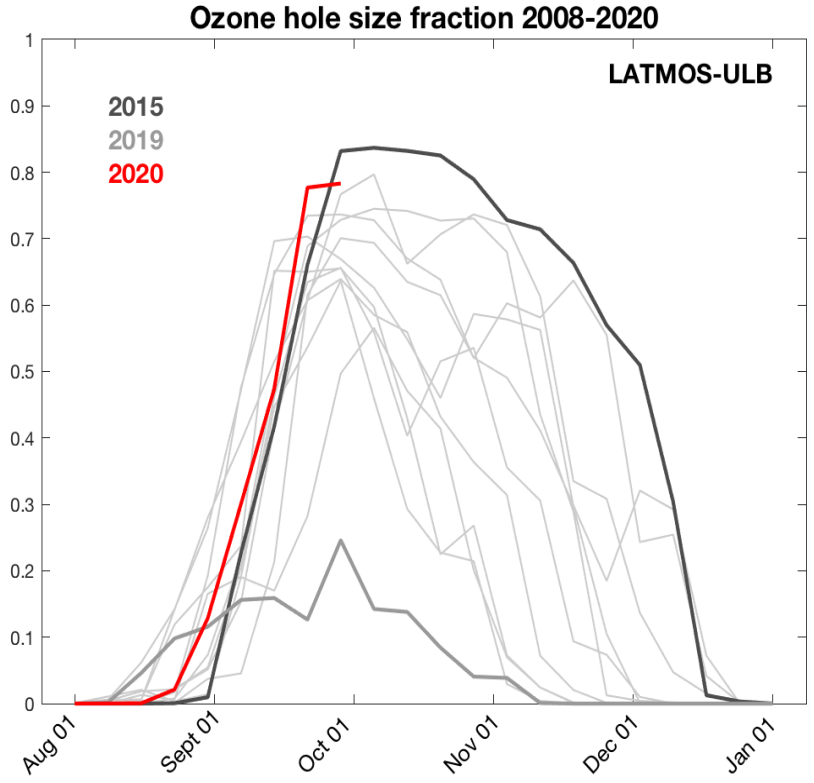
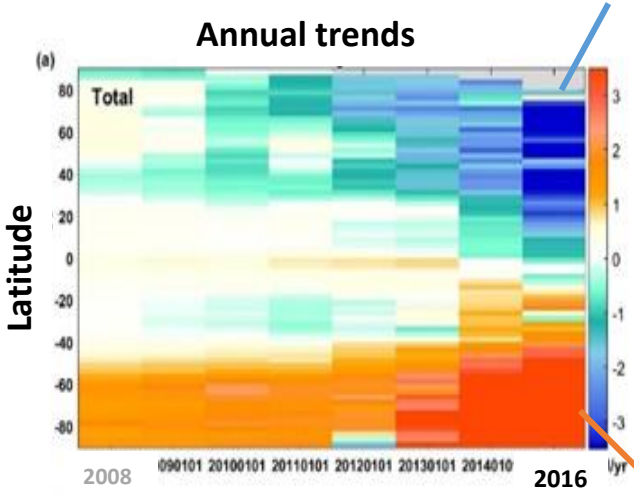



Decreasing trend in the NH !




C. Wespes et al., 2020

Increasing trend (recovery of the ozone layer) in the SH

- Applications

## 4. LONG-TERM ASSESSMENT AND PROTOCOL MONITORING

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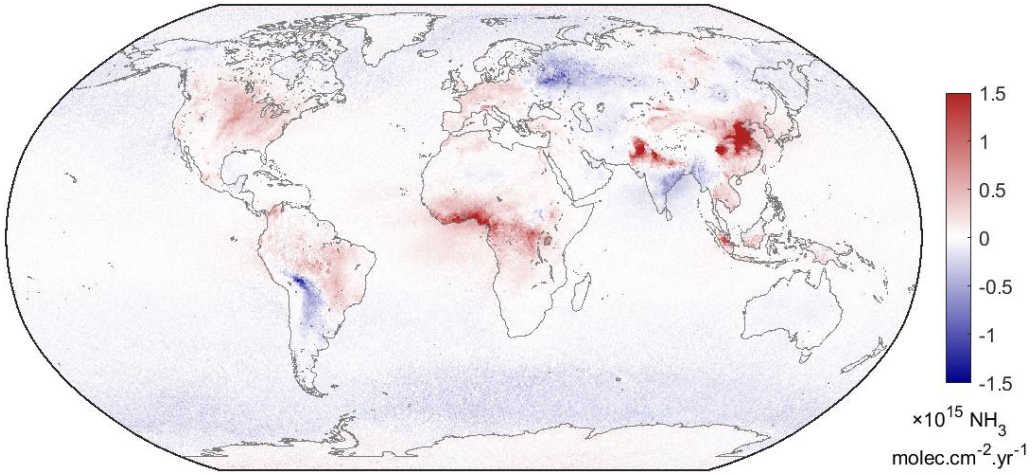
# ammonia

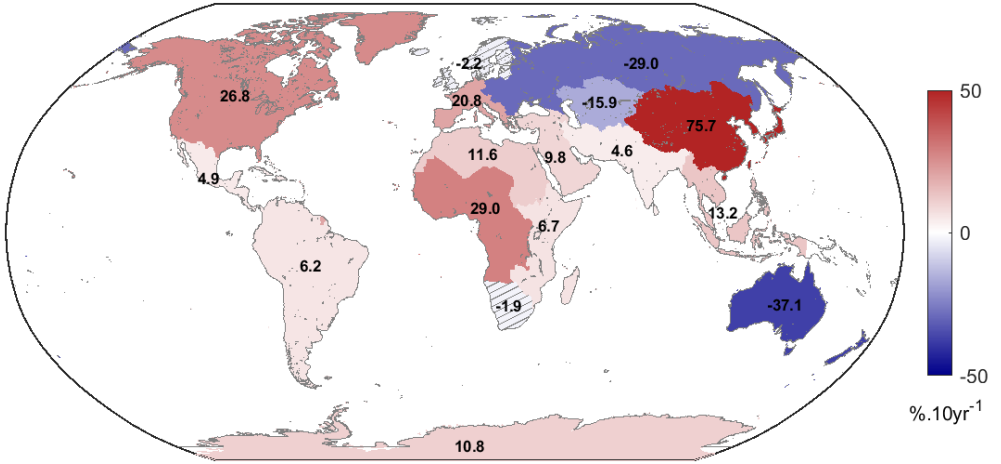
Despite national regulations large increases of $NH_3$ in several regions over the last decade:

- 75.7 ± 6.3 % in east Asia
- 29 ± 2.3 % in central Africa
- 26.8 ± 4.5 % in North America
- 20.8 ± 4.3 % in western and southern Europe




State of the European environment 2020

While sulphur dioxide emissions declined by 62 % since 2000, ammonia emissions decreased by only 4 % in the EEA member countries.




⇨IASI sees 3 % increase per year

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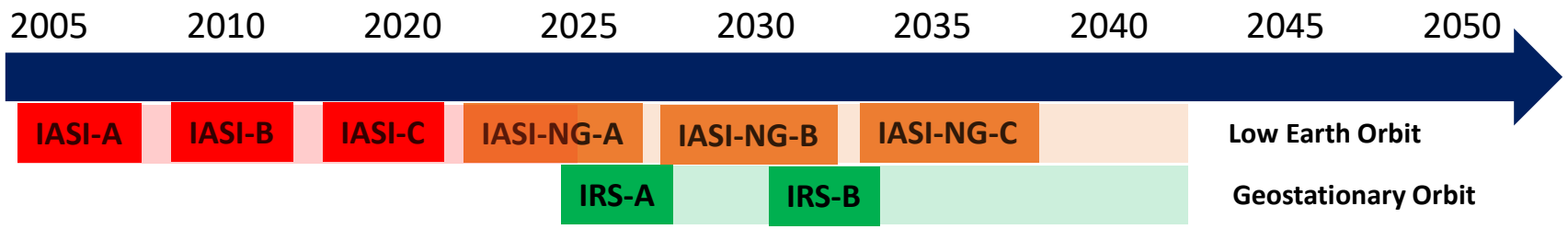
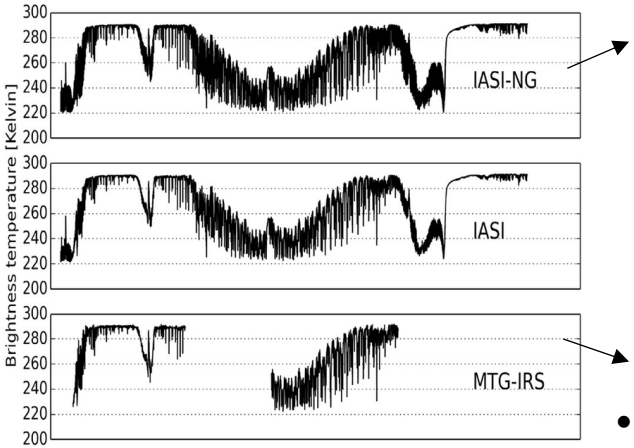
IASI-NG

IRS




**IASI-NG = IASI** with

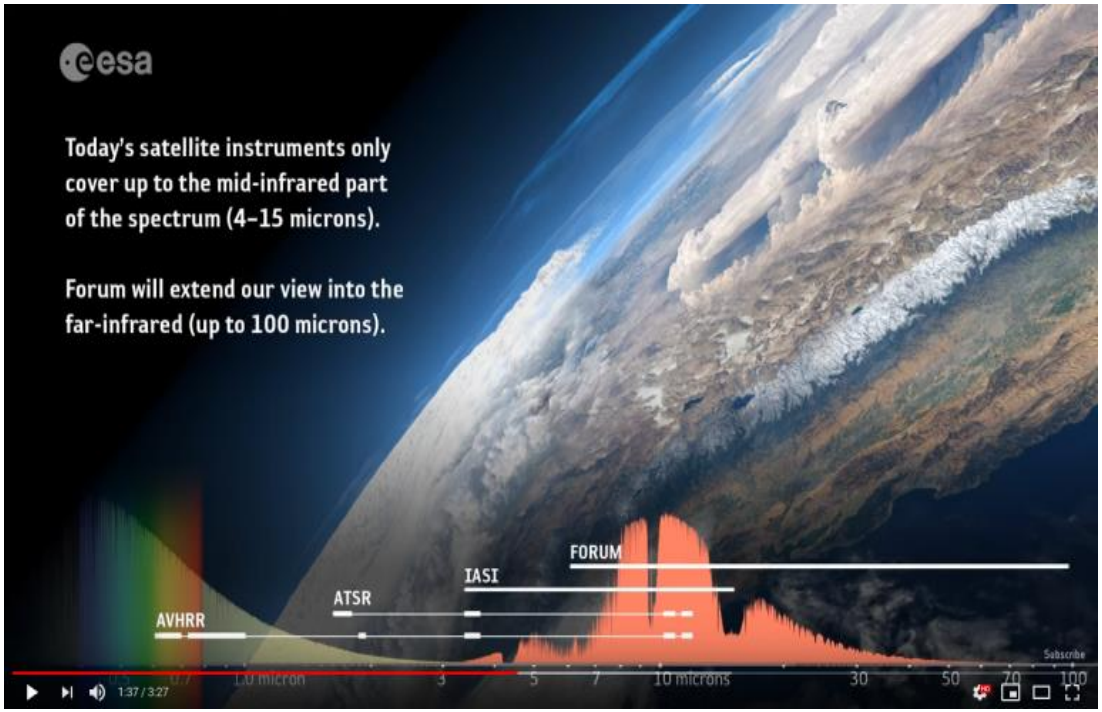
- twice better instrument performances
- Similar sampling (12km on-ground pixel size at nadir)

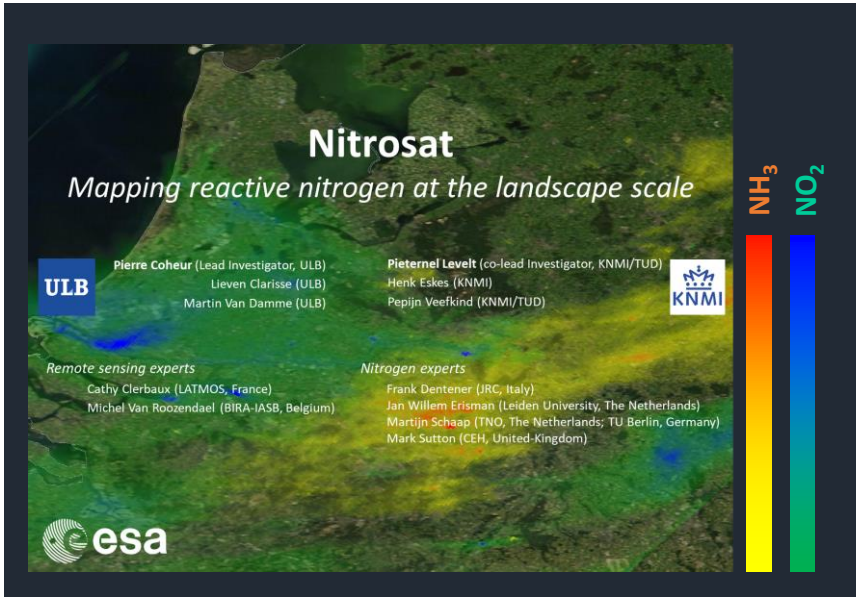
⇨**Continuing / improving the IASI records for another 20 year**

**IRS = IR hyperspectral sounder on geostationary satellites**

- 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

**Earth Explorer 9**
FORUM mission will provide new insight into the planet's radiation budget




**Candidate Earth explorer 11**
Nitrosat would provide new insight into the budget of reactive nitrogen and its cascade of environmental impacts by *mapping ammonia and nitrogen dioxyde at 500 m resolution*.

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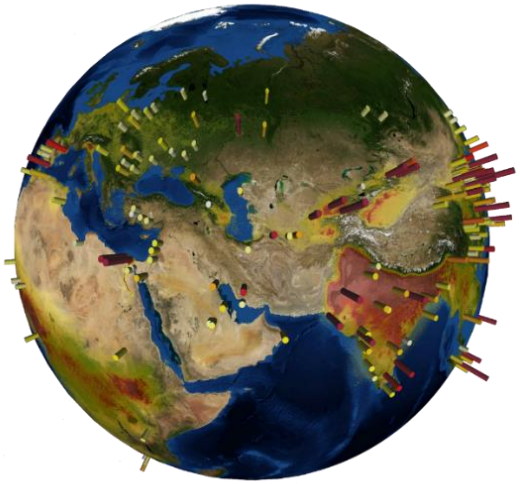
P. Coheur • GTEO Air-Atmosphère • Nov. 2020



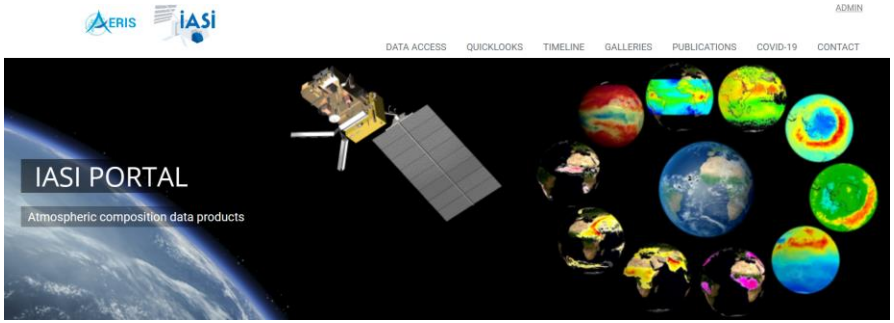
Ammonia point sources

Van Damme et al., 2019

EUMETSAT AC SAF ATMOSPHERIC COMPOSITION MONITORING

**OPERATIONAL PRODUCTS**

https://acsaf.org/




**SCIENCE PRODUCTS AND ARCHIVE**

https://iasi.aeris-data.fr/

○ Applications

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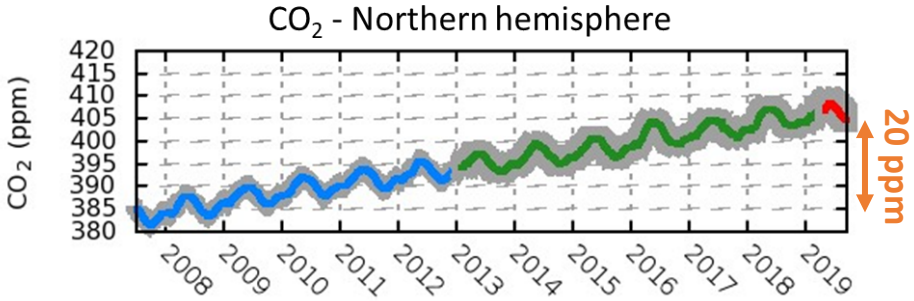
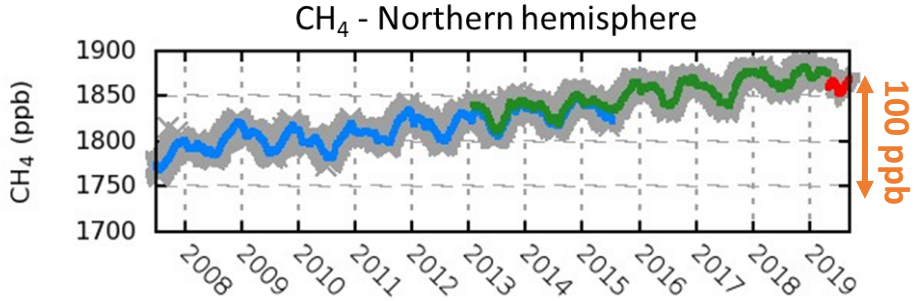
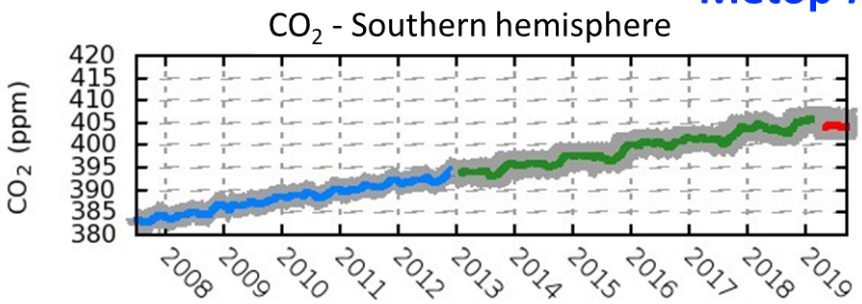
First space mission to study atmospheric composition for at least 18 years

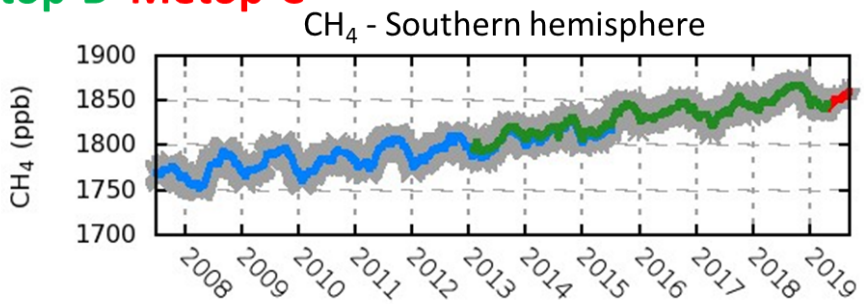
# Greenhouse gases



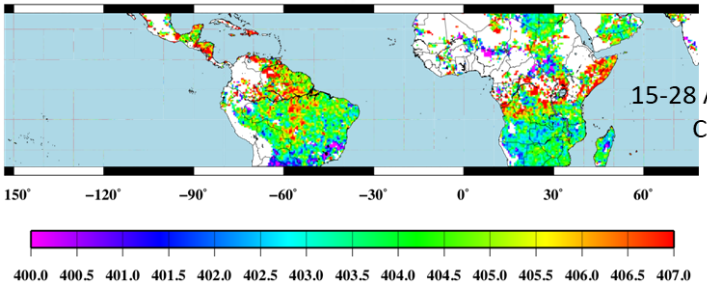




**Metop-A Metop-B Metop-C**




- Monitoring of global-trend
  → +5.5 % rise over 12 years.
- Identification of climate signals.
- Study of specific emissions (e.g. fires in Amazonia)




15-28 August 2019
$CO_2$ IASI

Crevoisier et al., 2013, 2020

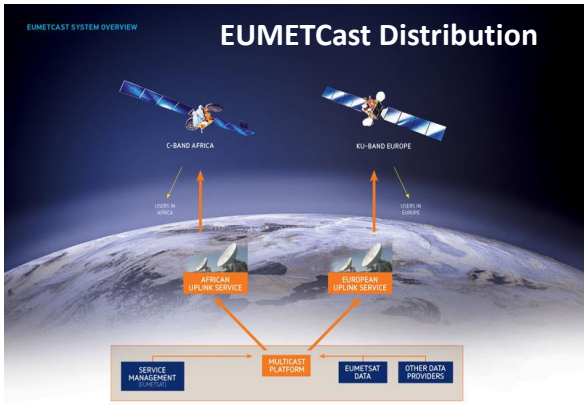
LMD

## PORTFOLIO OF PRODUCTS

### IASI and IASI-NG

ULB
- $O_3$ profiles and column (+ L3) — **demonstration**
- CO profiles and column (+L3) — **operational**
- $HNO_3$ profiles and column — **demonstration**

LATMOS
- $SO_2$ column — **operational**
- $SO_2$ plume altitude
- $NH_3$ total column
- Dust Optical depth
- Ash Optical depth



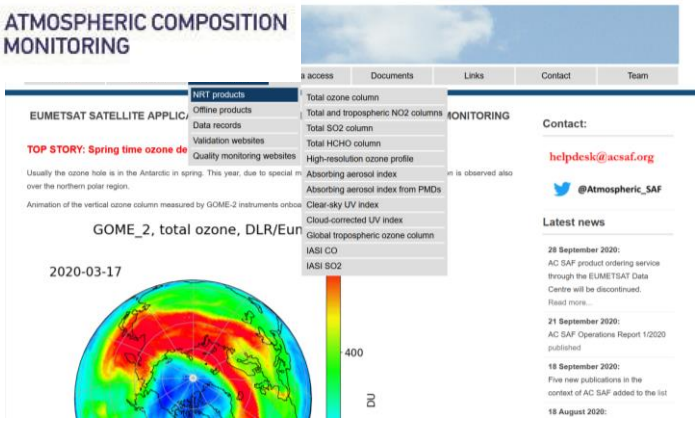

To come (2021-2025)

LMD
- $CO_2$ column (+L3)
- $CH_4$ column (+L3)

BIRA-IASB
- Dust altitude

IRS
- CO total column
- $NH_3$ total column
- $SO_2$ and dust flags
- $CO_2$ column
- $CH_4$ column

EUMETSAT AC SAF
ATMOSPHERIC COMPOSITION MONITORING




https://acsaf.org/