# MONITORING AIR POLLUTION AT GLOBAL SCALE USING IASI THERMAL INFRARED INSTRUMENT

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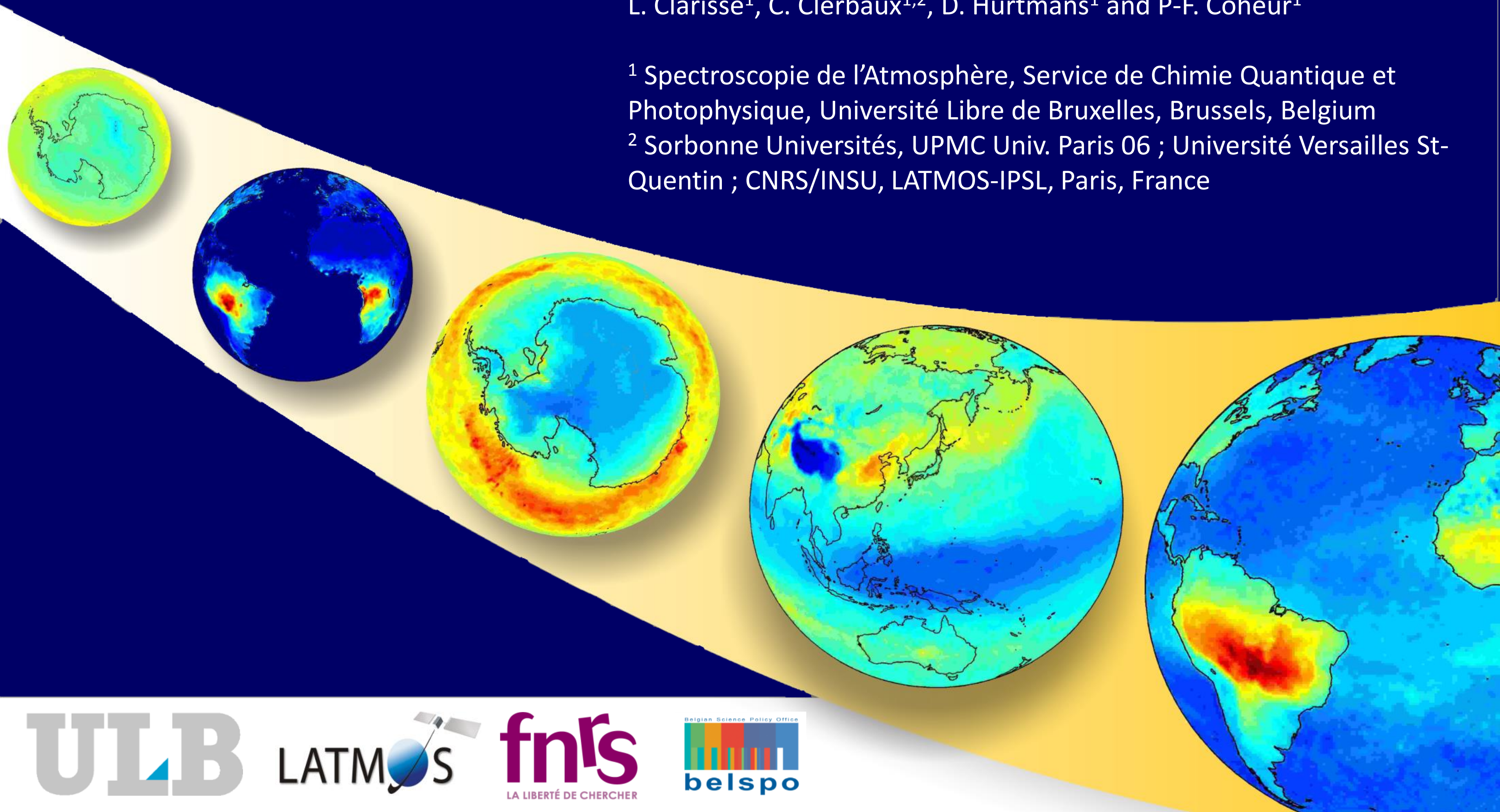

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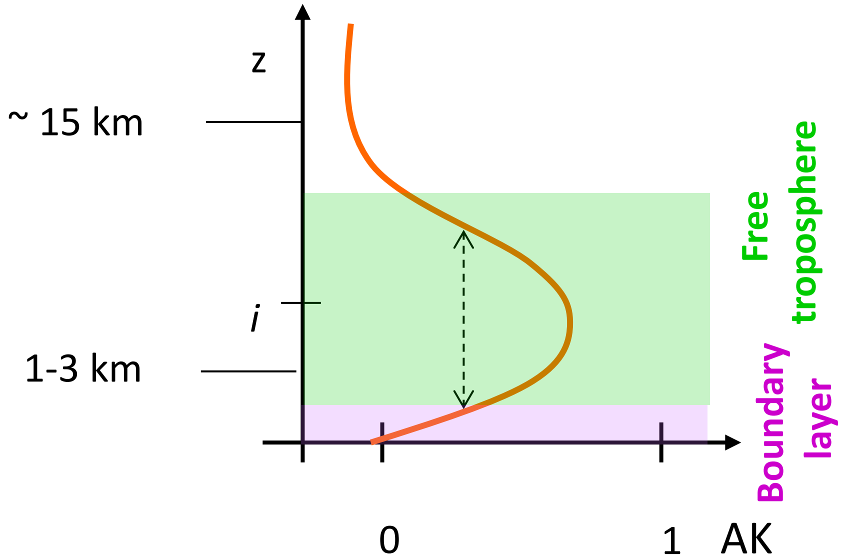
# Introduction

## Monitoring air quality using TIR observations

**Difficulty:** Sensitivity limited by the thermal contrast ($TC = T_{skin} - T_{air}$)

**Typical vertical sensitivity function for a TIR nadir sounder (Averaging kernels AK)**

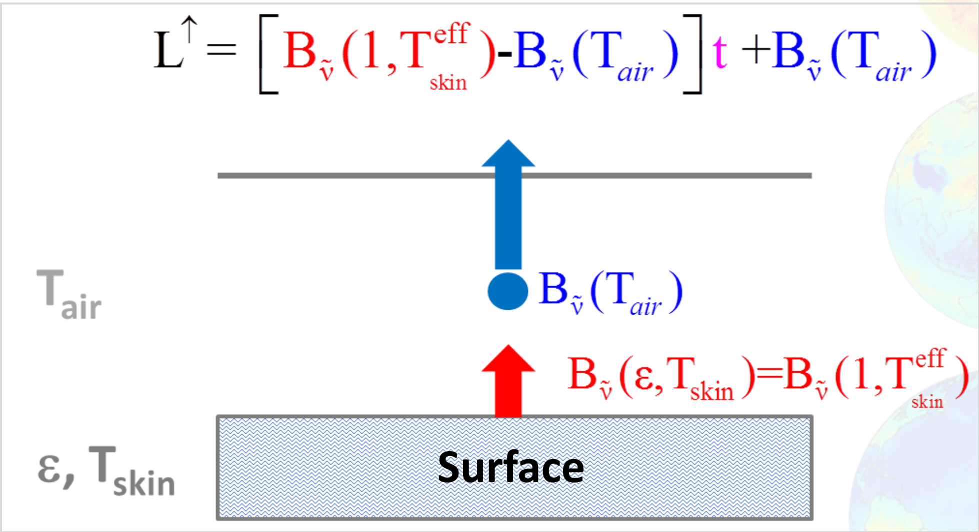



→ Maximum sensitivity of TIR sounders in the mid troposphere

# Introduction

## Monitoring air quality using TIR observations

## How deep can we see?




Three general cases:

- $T_{skin}^{eff} = T_1$ → we're blind
- $T_{skin}^{eff} > T_1$ → **absorption** from the first layer (usual case during day time)
- $T_{skin}^{eff} < T_1$ → **emission** from the first layer (temperature inversion)

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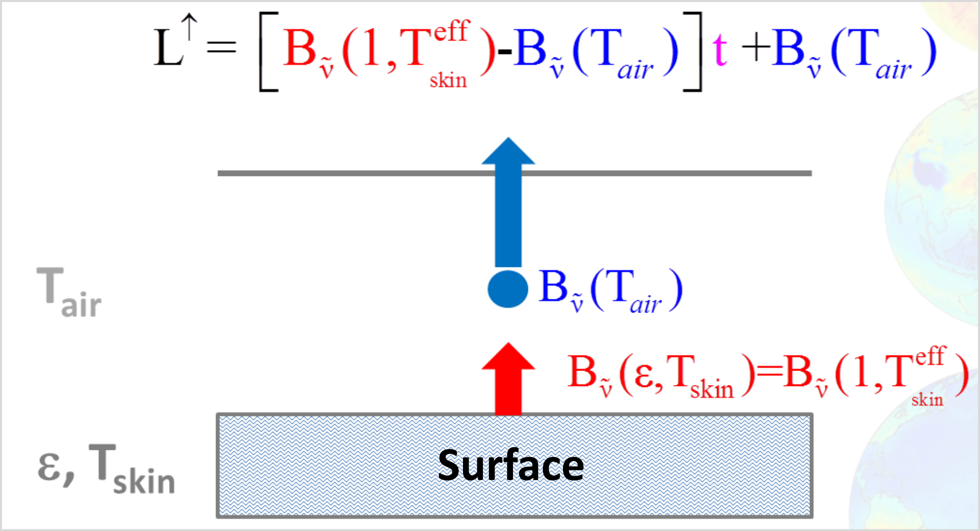


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→ **The larger the thermal contrast, the better the sensitivity of TIR sounders to ABL**

# Introduction

Recent studies have demonstrated the capabilities of TIR sounders to monitor near-surface pollution from local to global scales in favorable conditions

$NH_3$

Conversion of radiance indexes into columns using LUT

$SO_2$

NRT OE using LUT for spectroscopy (FORLI)

CO

# Introduction

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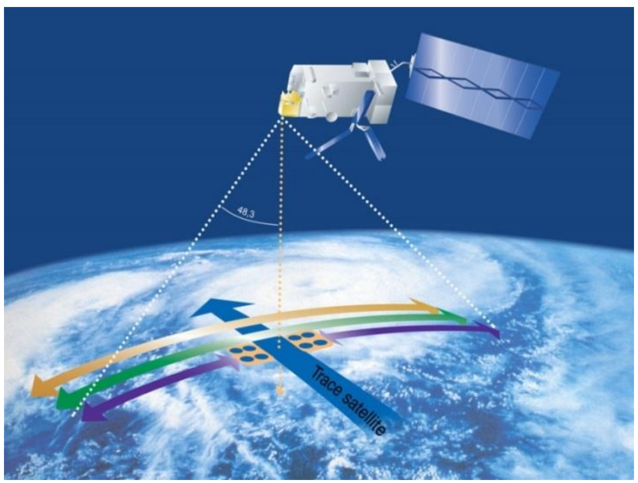
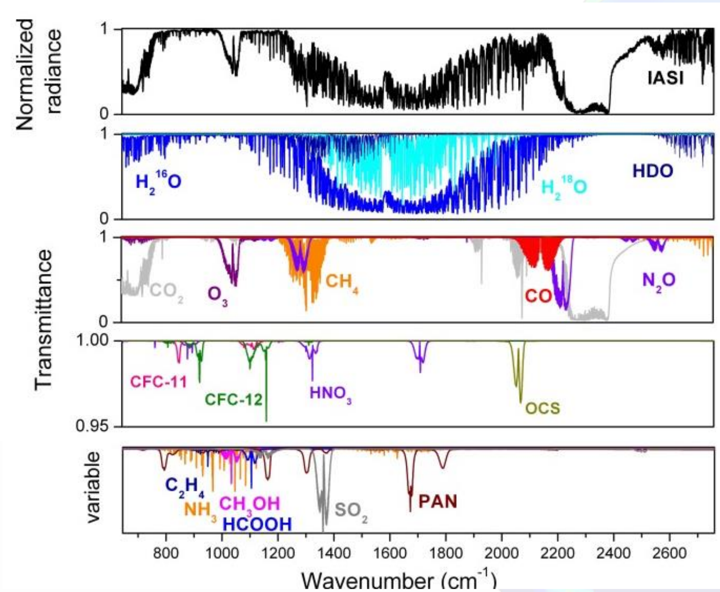
- $NH_3$ — Conversion of radiance indexes into columns using LUT
- $SO_2$
- CO — NRT OE using LUT for spectroscopy (FORLI)

## Use of IASI observations




- Spectral range: 645-2760 $cm^{-1}$
- Spectral resolution after apodization: 0.5 $cm^{-1}$
- Radiometric noise: ~ 0.1K – 0.2K




- 12 km pixel x 4 @ nadir
- 120 spectra along the swath (±48.3° Scan → 2400 km), each 50 km along the trace

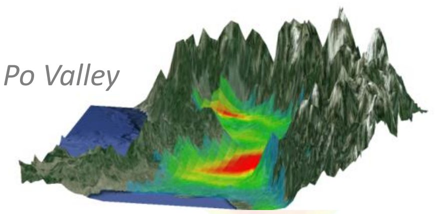
**Small ground pixel size**

**Global coverage twice daily**
(morning and evening orbits)

# NH$_3$ global product

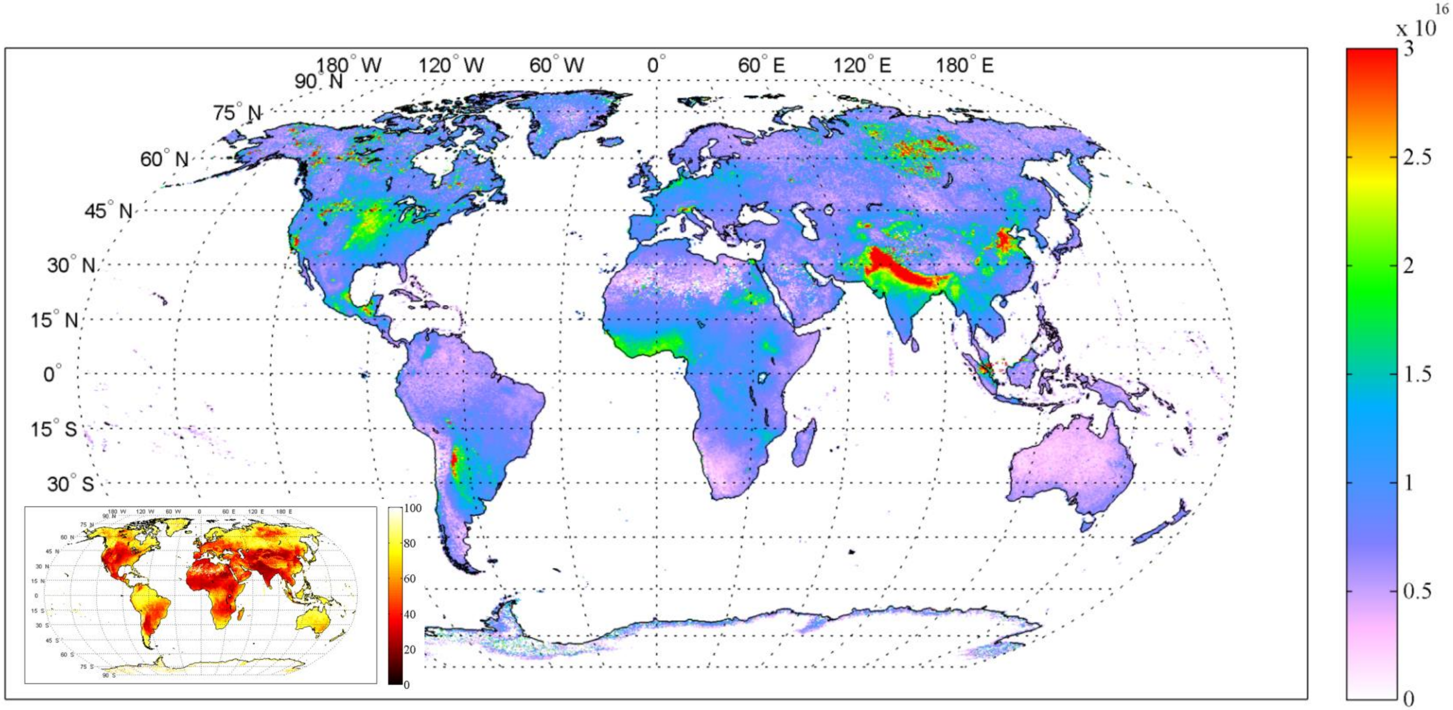
Developed at the ULB by M. Van Damme[1]

- Method based on Walker et al. (2011, AMT)
- **<u>Idea</u>**: computation of radiance indexes (HRI), which represent the strength of NH$_3$ spectral signal, and conversion into NH$_3$ total column using LUT
- **<u>Results</u>**: 7 years of NH$_3$ measurements, global distributions, temporal evolution in the NH and SH, validation[2], comparison with models[3],…




**Credit M. Van Damme**

AM and PM over land for 2013
No filtering

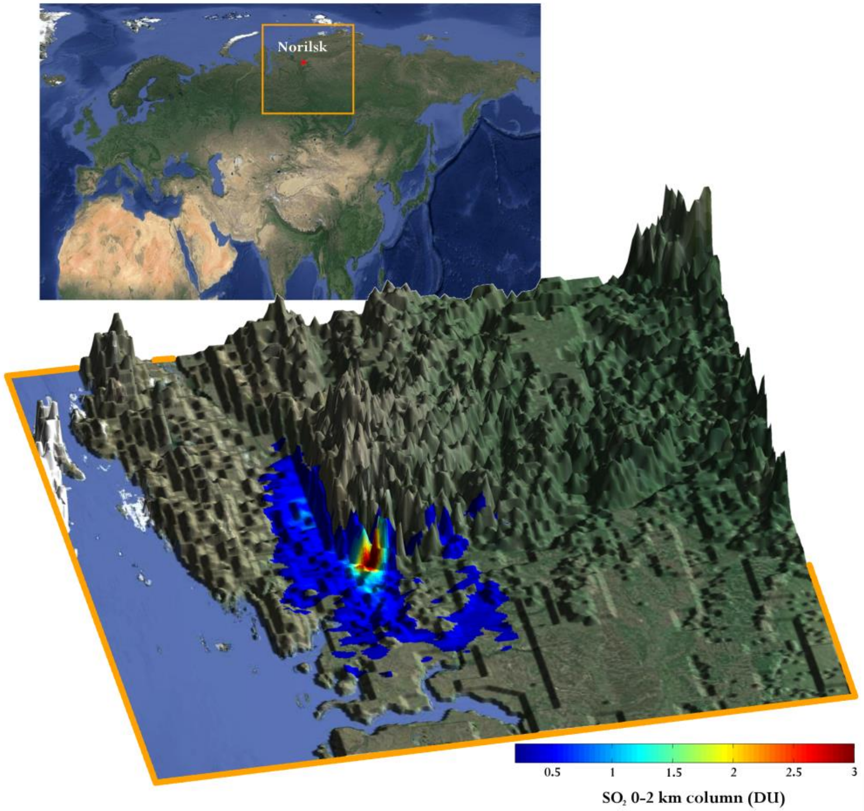



[1]Van Damme et al. (2014, ACP)
[2]Van Damme et al. (2015, AMT)
[3]Van Damme et al. (2014, JGR)

# $SO_2$ near-surface local studies

1. **In Norilsk**[1]

- Retrieval of very low altitude $SO_2$ plumes
- High sensitivity in winter (high **negative TC**, **low $H_2O$**)




[1]*Bauduin et al. (JGR, 2014)*

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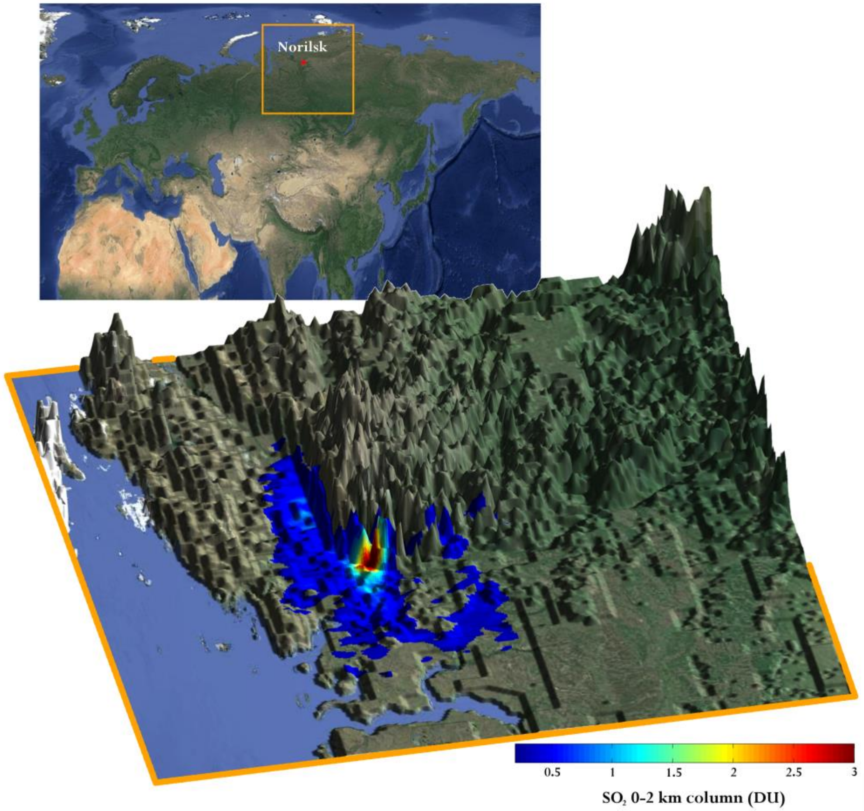


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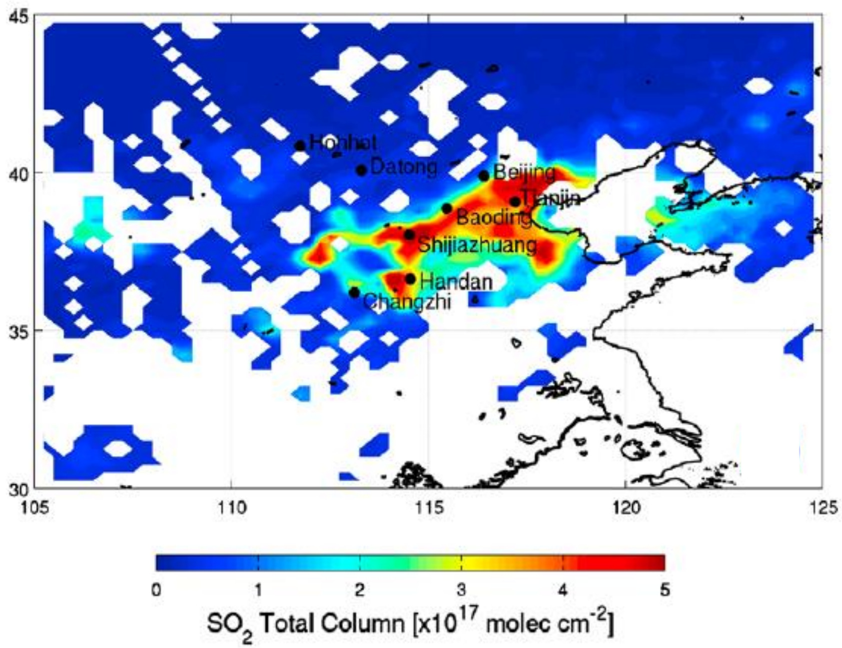
## 2. In the North China Plain[2]

- Simultaneous retrievals of 4 different pollutants (CO, **$SO_2$**, $NH_3$, $(NH_4)_2SO_4$)
- Buildup of pollutants + **large temperature inversions**

***Boynard et al. (GRL, 2014)***




[2]*Boynard et al. (GRL, 2014)*

# $SO_2$ near-surface local studies

**BUT**

- Two studies limited to local sources
- Limited to negative thermal contrast

→ Positive thermal contrast can also be exploited

→ Development of global product allowing the retrieval of near-surface $SO_2$ columns from IASI observations

# $SO_2$ near-surface global product

- Method based on the one developed by *Walker et al. (AMT, 2011)*
- **<u>Idea:</u>** calculation of a radiance index (HRI), which represents the strength of the $SO_2$ signal in IASI meaurements, and conversion of this index into $SO_2$ concentrations
- **Problem:** one index per spectrum → integrated over the whole atmosphere → no vertical information!
- **Solution:** determination of the altitude of the plume

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**Procedure in 2 steps:**

1) Determination of the altitude of the plumes
   - ➢ Method developed by Clarisse et al. (2014, ACP) for the eruption of Nabro
   - ➢ Based on the computation of radiance indexes

→ **Selection of plumes below 4 km of height**

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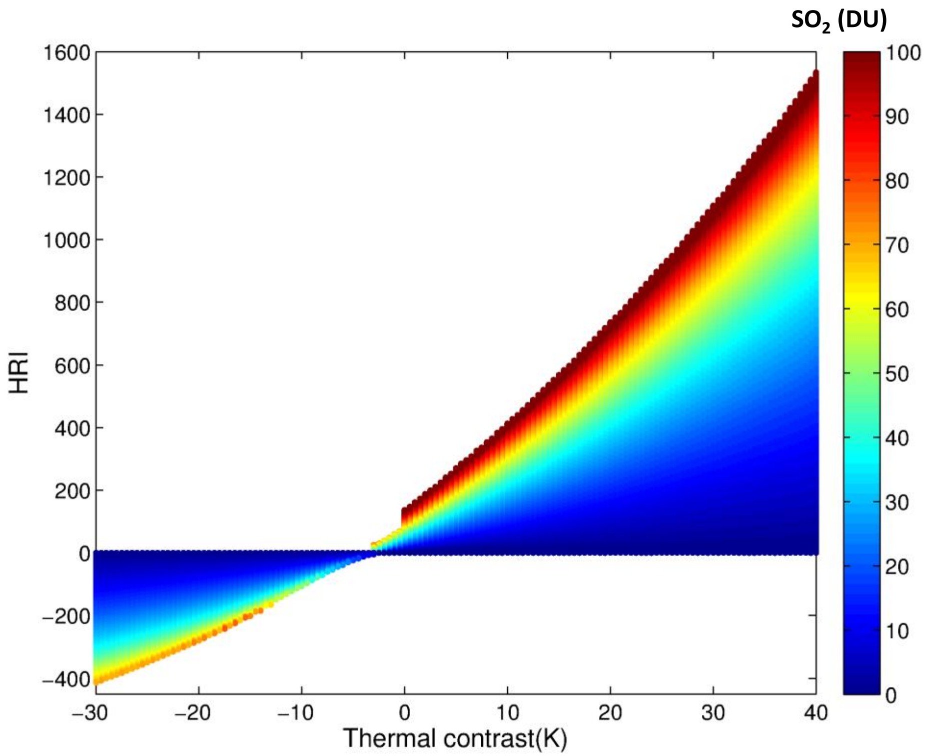
2) Retrieval of near-surface $SO_2$ column
   - Calculation of HRI and conversion into $SO_2$ columns using LUT
   - Thermal contrast, $H_2O$ total column and the zenithal angle are taken into account
   - One LUT per bin of 5° of zenithal angle

# $SO_2$ near-surface global product

Example of LUT for the bin 0-5° of zenithal angle, total column of $H_2O=2 \times 10^{20}$ molec/cm²



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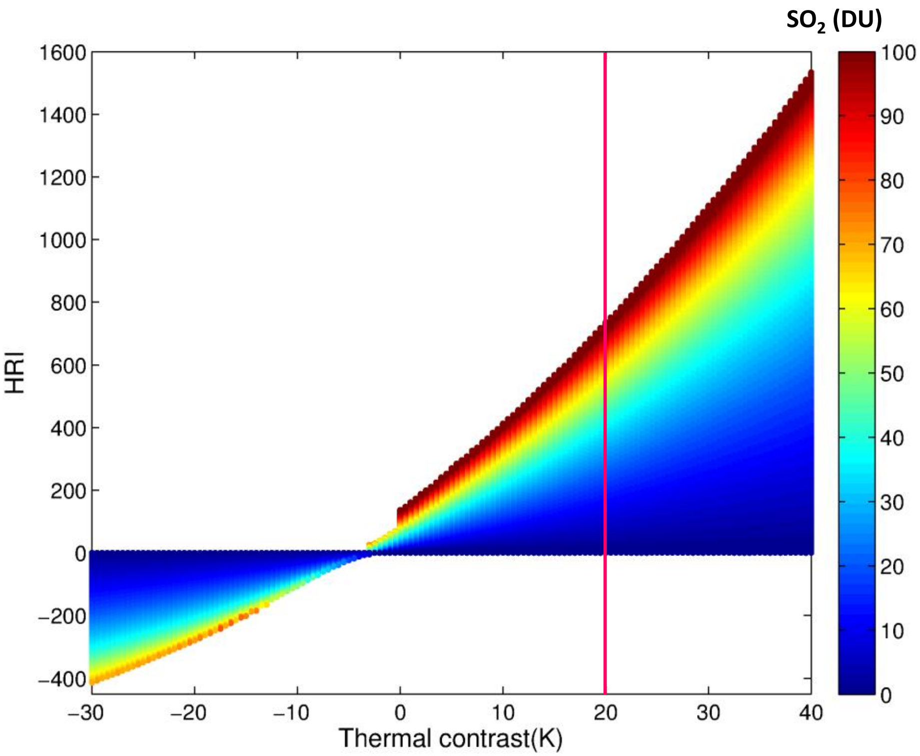

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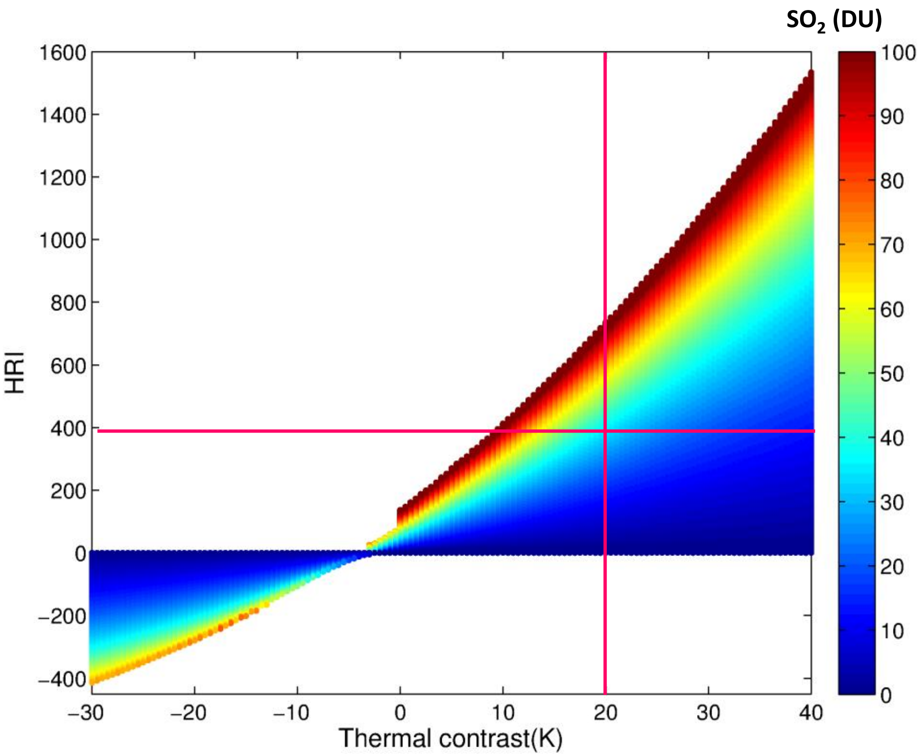

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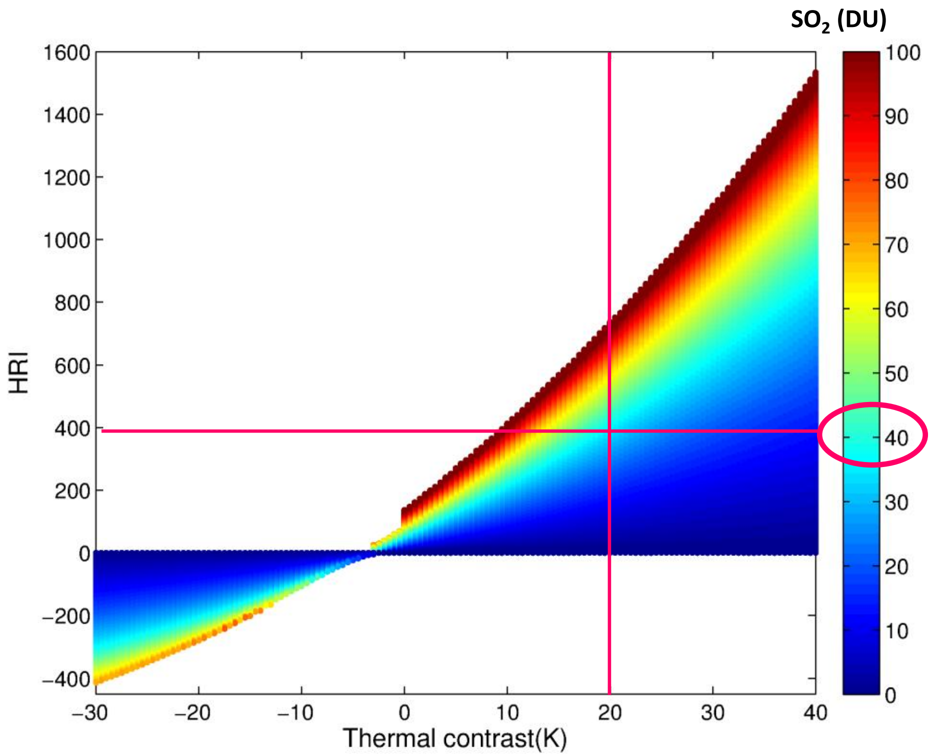

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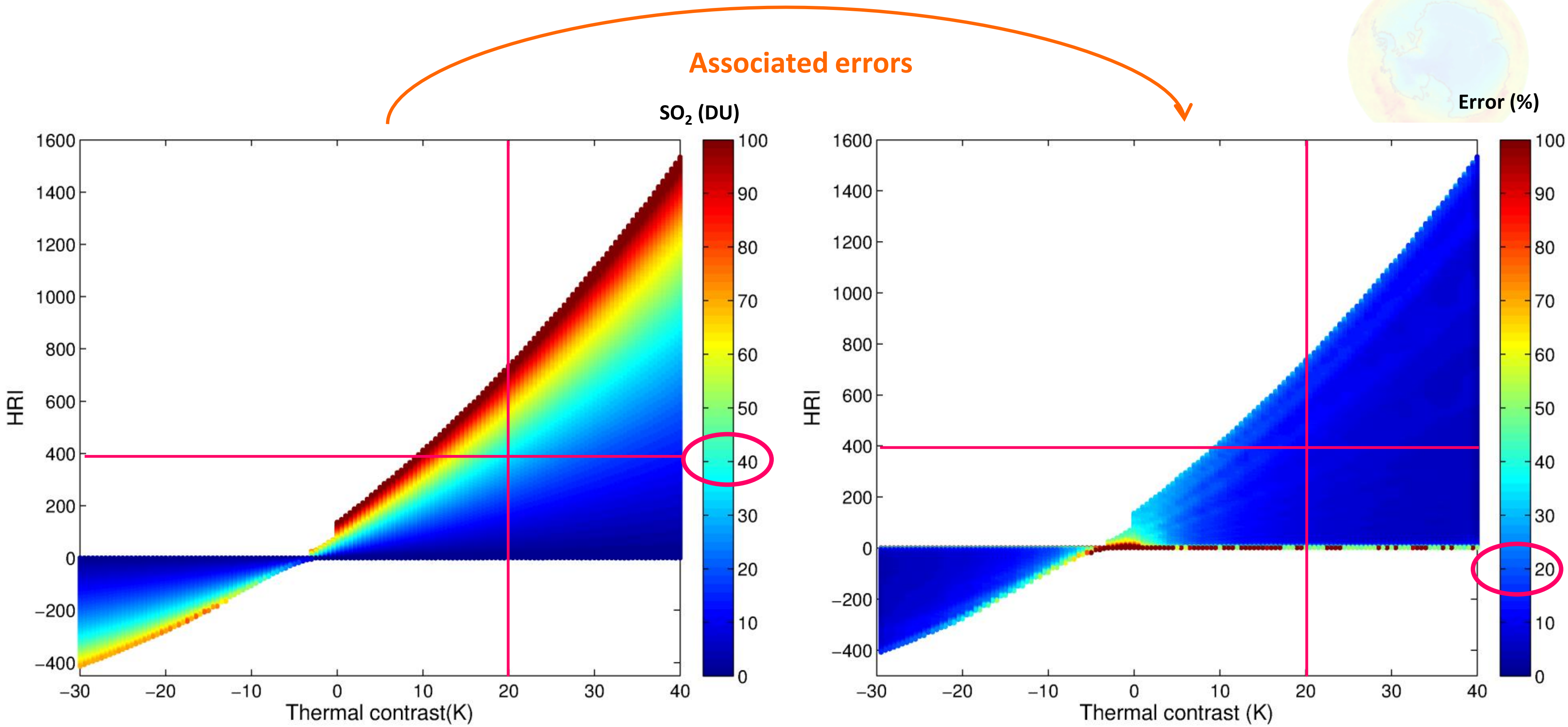



- If $SO_2 = f(TC, H_2O, HRI)$, the associated error is estimated using:

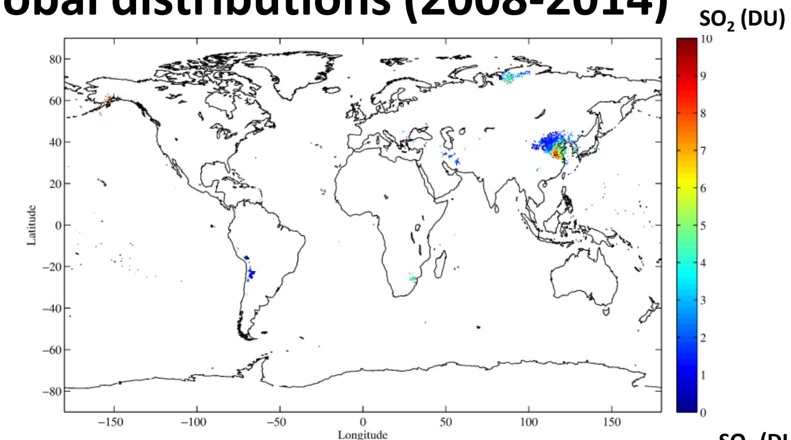
$$\sigma_{SO_2} = \sqrt{\sigma_{TC}^2\left(\frac{\partial f}{\partial TC}\right)^2 + \sigma_{H_2O}^2\left(\frac{\partial f}{\partial H_2O}\right)^2 + \sigma_{HRI}^2\left(\frac{\partial f}{\partial HRI}\right)^2}$$

Avec $\sigma_{TC} = \sqrt{2} \times 1\text{K}$, $\sigma_{H_2O} = 10\% Col_{H_2O}$, $\sigma_{HRI} = 1$

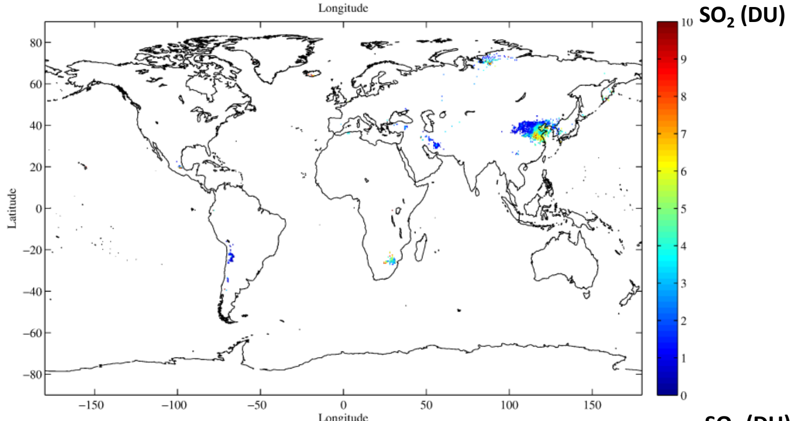
# $SO_2$ near-surface global product

## 1) Global distributions (2008-2014)

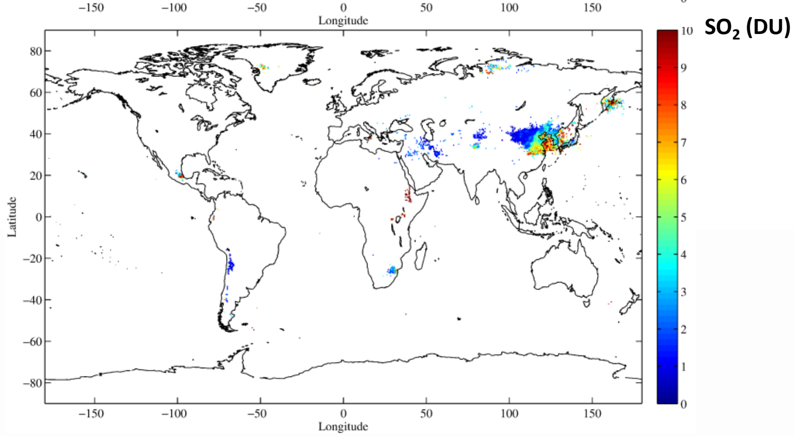
2009



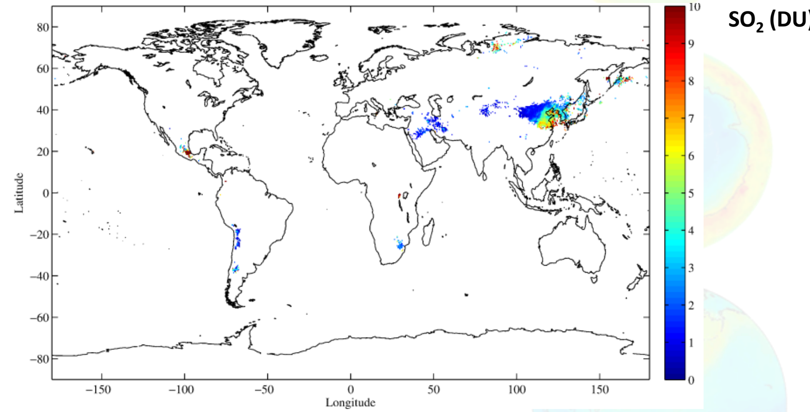

2010



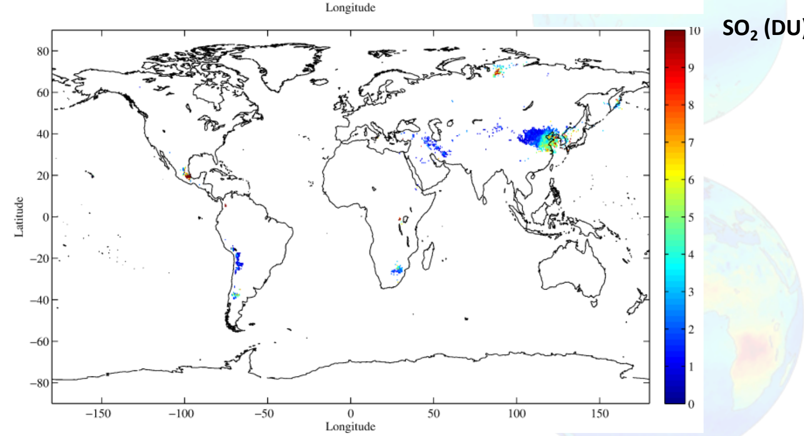

2011



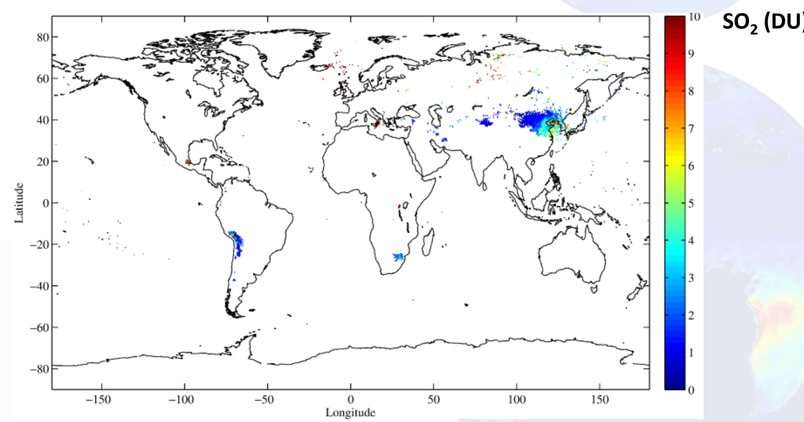

2012




2013




2014

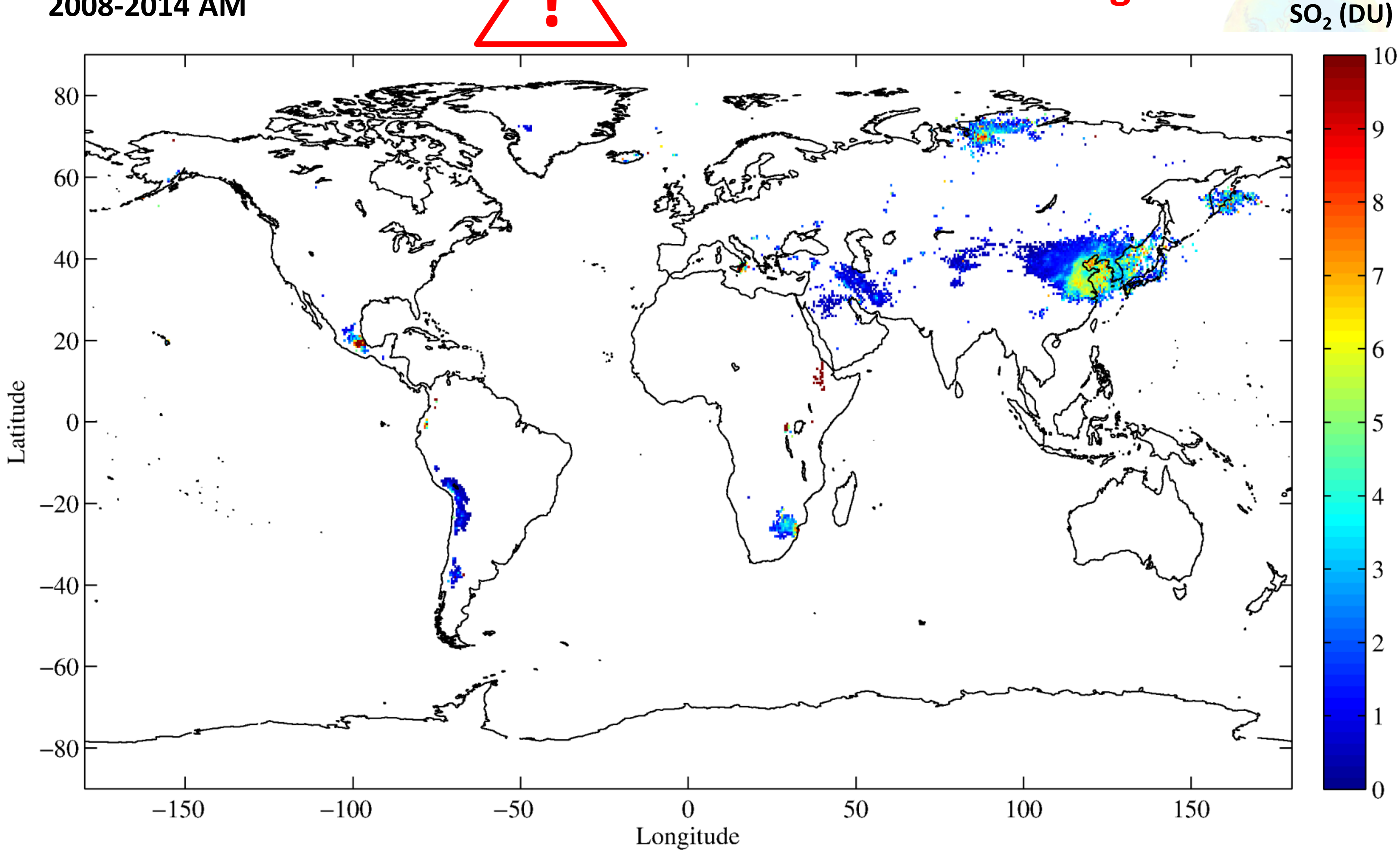


# $SO_2$ near-surface global product

## 1) Global distributions

**2008-2014 AM**

**Plumes below 4km of height**



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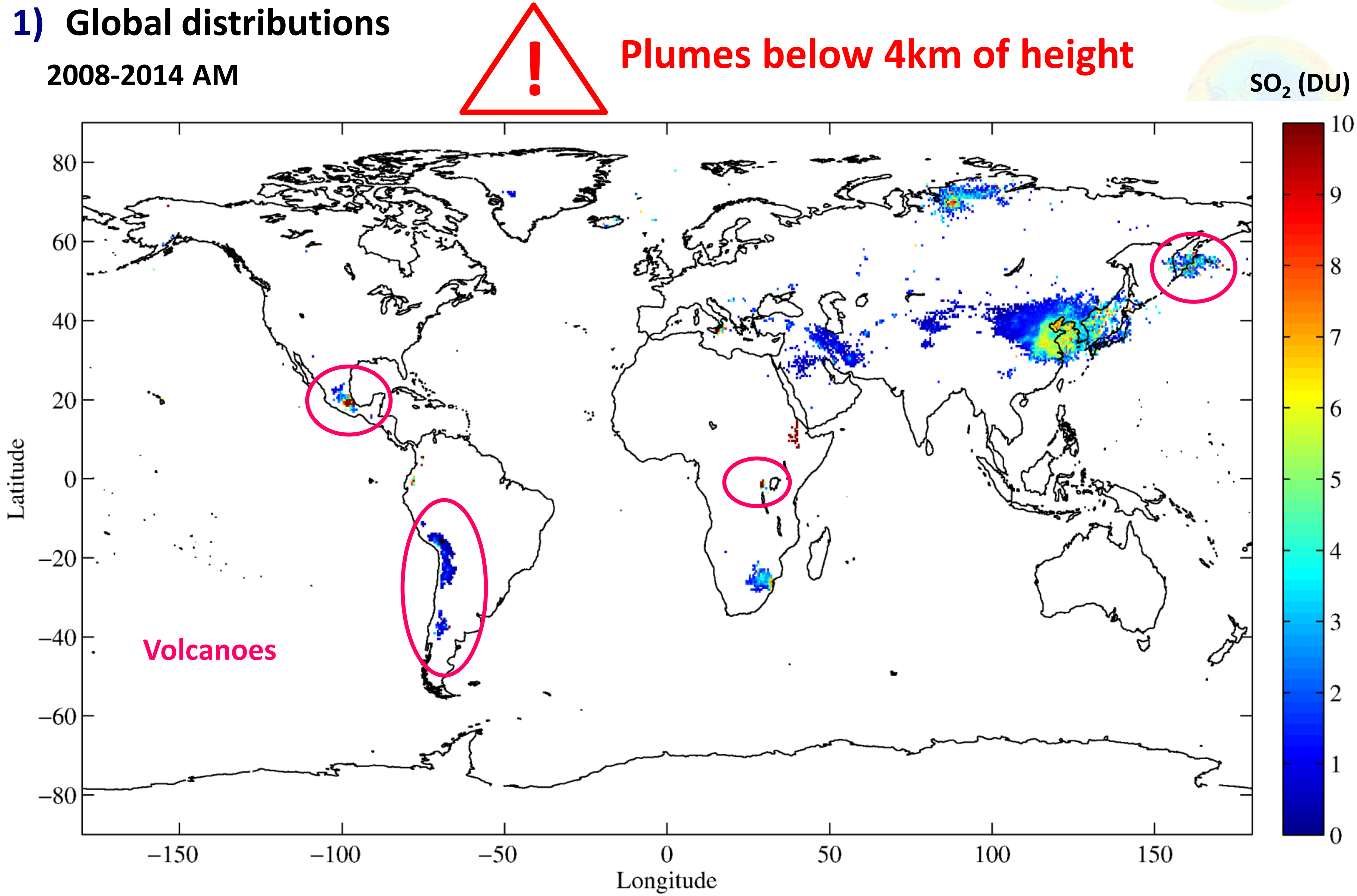

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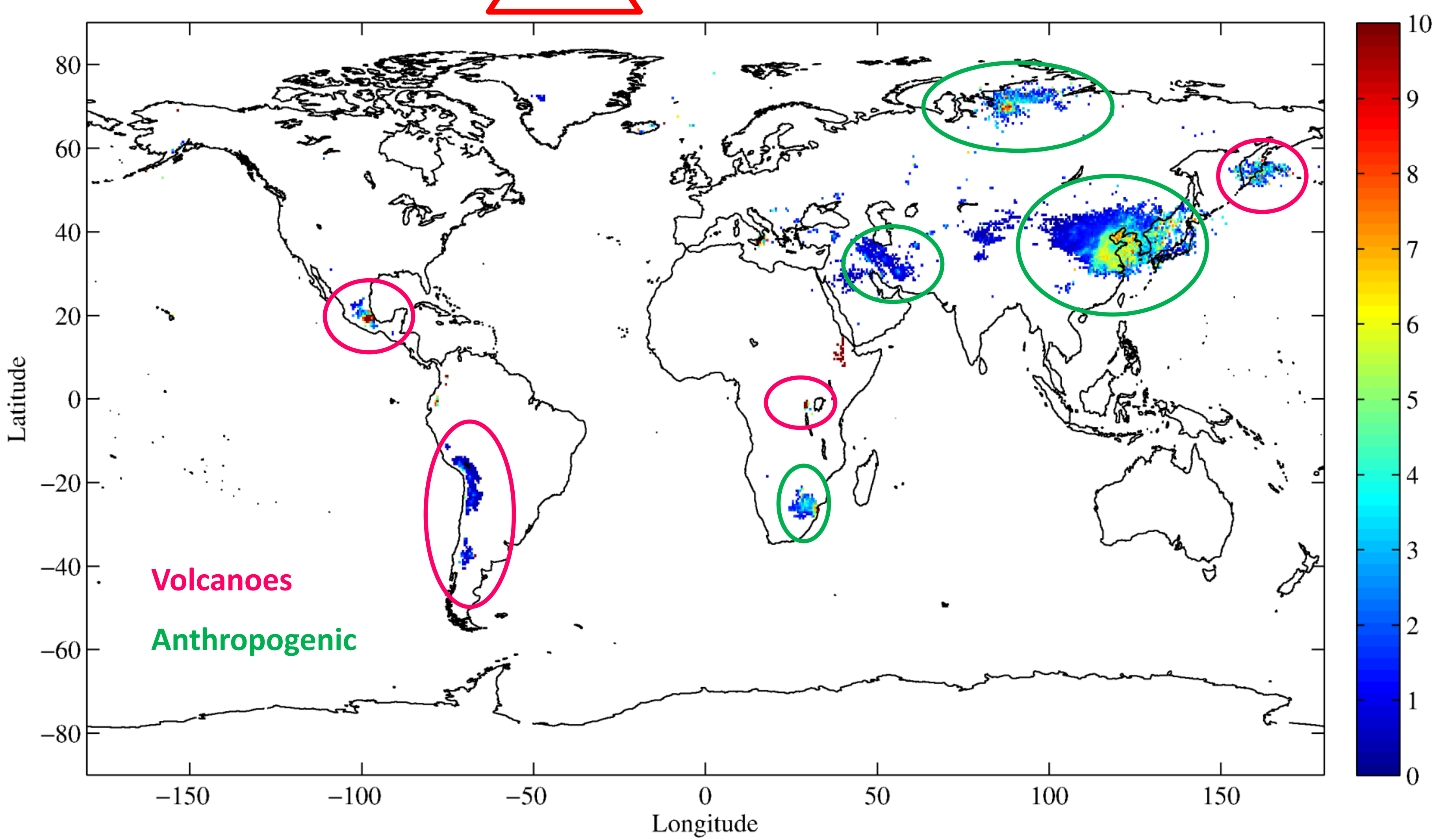

# $SO_2$ near-surface global product

- 7-year time series (Beijing, Sar Cheshmeh) → temporal evolution of IASI sensitivity as function of TC and $H_2O$ total column
- Comparison with measurements made in Bauduin et al. (2014) above Norilsk → the agreement is excellent
- Comparison with OMI observations (use of data from DOAS algorithm developed by N. Theys at BIRA) → good agreement given the biases of the instruments and the difference in the overpass times

→ ***Retrieval of near-surface sulfur dioxide ($SO_2$) concentrations at a global scale using IASI satellite observations*** **in preparation**

# Near-surface CO (still on-going)

- This work has begun with the SIROCCO (*Synergetic SWIR and IR retrievals of near-surface concentrations of $CH_4$ and CO for Earth and Planetary atmospheres*) Project (ESA)*

  → **See poster 75**

*This work was funded by the SIROCCO Project under ESA contract number 4000107088. The project was conceived and supervised by A.G. Straume-Lindner and O. Witasse

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- **<u>Our contribution on Earth:</u>** investigating the sensitivity of IASI to near-surface $CH_4$ and CO

  1) Theoretical approach (theoretical characterization using OE diagnostic)
  2) Retrievals of test cases and comparison with in-situ measurements

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- Demonstration of the capability of IASI to measure near-surface CO in case of sufficiently large thermal contrasts
  → theoretically and with real retrievals
- E.g.: retrievals above Windhoek airport and comparison with MOZAIC aircraft measurements

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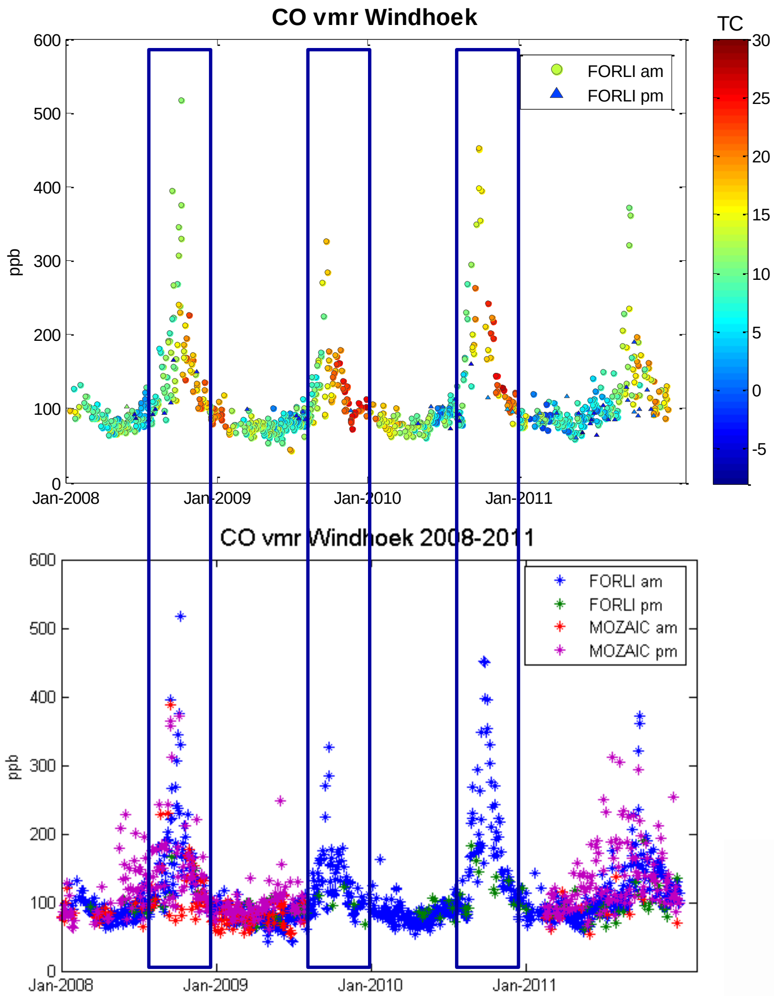


Correlation between seasonal cycle of CO and seasonal cycle of thermal contrasts:

- High CO vmrs from late summer to November when TC are large (≥10K)

During these episodes, IASI is sensitive to the surface and high CO concentrations are catched in the PBL (also found for MOZAIC)

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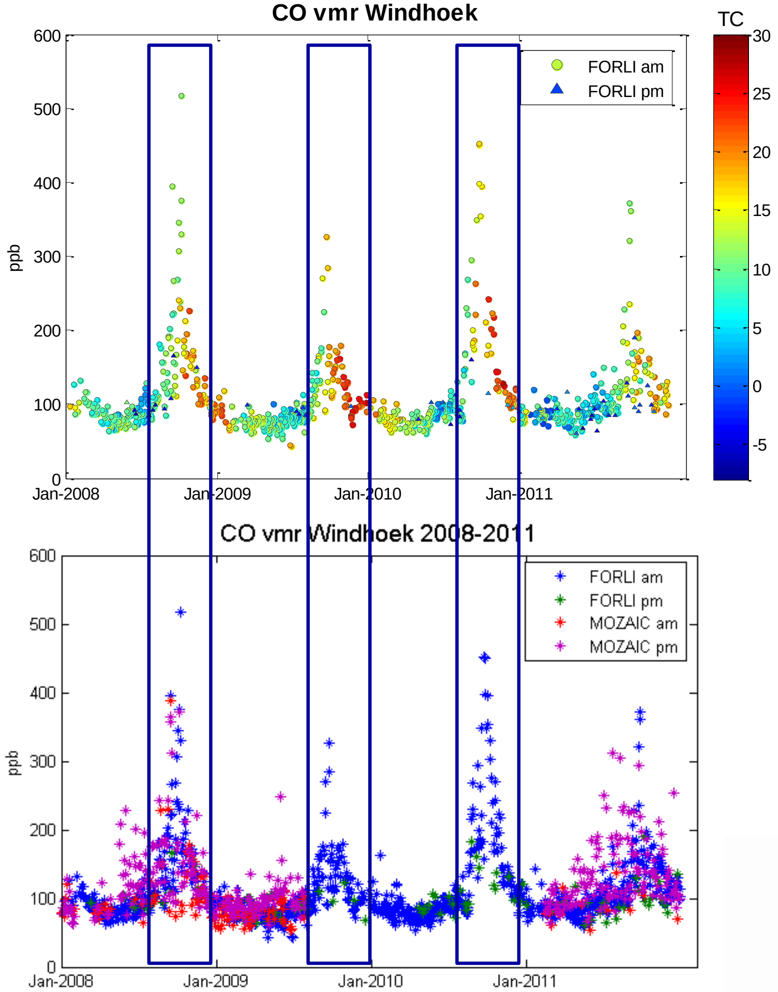


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Same results for Hyderabad.

In Frankfurt, the agreement between the seasonality observed with MOZAIC and FORLI is worse → thermal contrast!

# Conclusions and perspectives

- Demonstration of the capability of IASI to measure near-surface pollutants in case of high thermal contrast

  → $NH_3$, $SO_2$ and CO (still on-going)

- Two products for the retrieval of near-surface concentrations at global scale:

  1) $NH_3$
  2) $SO_2$

  } Calculation of radiance indexes and conversion into columns using LUT

- Validation of $SO_2$ retrieval scheme should be done

- Theoretical studies and local retrievals performed for CO in the frame of the SIROCCO project

  → extension to the globe and generalization using the FORLI algorithm, which allows retrieving CO profiles for the globe in NRT

# Thank you!