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## **IASI - New Generation onboard EPS-SG: Expected impact on accuracy and vertical resolution for atmospheric variables**

Cyril Crevoisier, Cathy Clerbaux, Vincent Guidard, Thierry Phulpin, Raymond Armante, Brice Barret, Claude Camy-Peyret, Jean-Pierre Chaboureau, Gaelle Dufour, Juliette Hadji-Lazaro, et al.

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**ITSC-18**

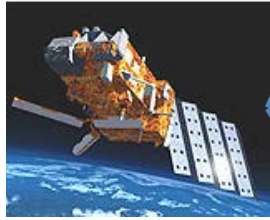
Toulouse, 21-27 March 2012

# **IASI-New Generation onboard EPS-SG: Expected impact on accuracy and vertical resolution for atmospheric variables**

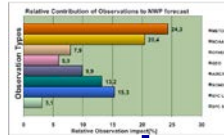
**Cyril Crevoisier, Cathy Clerbaux, Vincent Guidard, Thierry Phulpin,  
Raymond Armante, Brice Barret, Claude Camy-Peyret,  
Jean-Pierre Chaboureau, Gaelle Dufour, Juliette Hadji-Lazaro,  
Hervé Herbin, Nicole Jacquinet, Lydie Lavanant, Sébastien Payan,  
Eric Péquignot, Clémence Piérangelo, Didier Renaut, Claudia Stubenrauch**



# IASI onboard MetOp-A

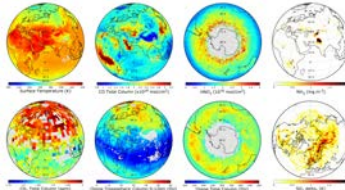


## Numerical Weather Prediction



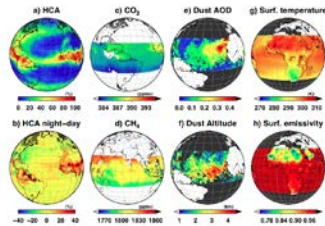
Global NWP, LAM, mesoscale models

## Atmospheric composition



More than 20 species detected, some well quantified ( $O_3$ ,  $CO$ ,  $CH_4$ ), some only detected ( $SO_2$ ,  $HNO_3$ ,  $NH_3$ , formic acid, methanol) in special situations (fires, volcanoes)

## Climate

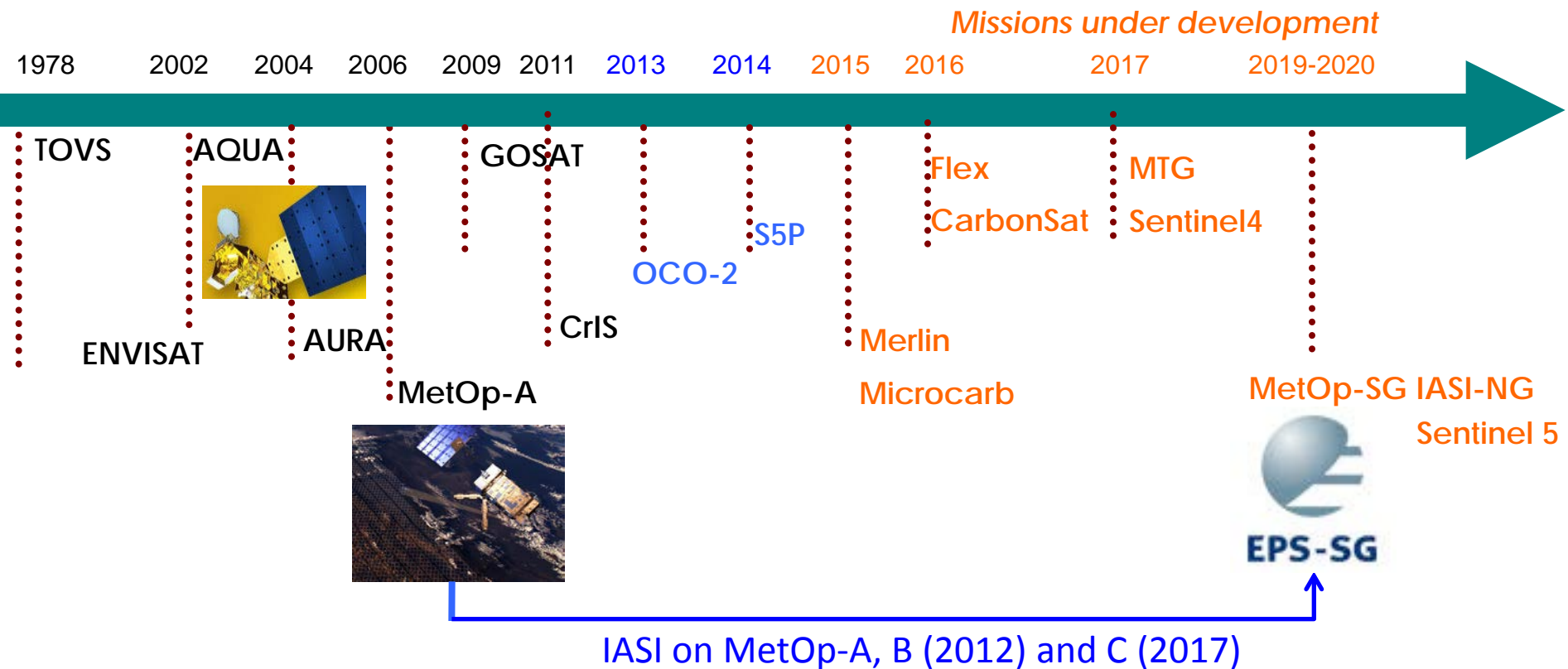


- Essential Climate Variables: T, WV, GHG, Surface characteristics, Clouds, Aerosols.
- Reference for the GSICS.

## Lessons learned with IASI onboard MetOp-A:

- IASI benefits **three communities** that will be more and more **connected** (eg: MACC-GMES, Essential Climate Variables)
- Covering continuously the **whole TIR domain** is very useful.
- To retrieve several variables, other atmospheric data (cloud, T, WV) are mandatory.
- **Spectral and radiometric stabilities** are very important.
- Retrievals over **land/sea** by **day/night**.

# What's next? IASI-NG as part of Eumetsat EPS-SG



## •EPS-SG

- PFA : MetIMAGE, MWS, IASI-NG, RO, UVNS, 3MI
- PFB : SCATT, MWI, RO

## •Status:

- Phase-A studies at CNES since January 2010, end in April 2012.
- Two industrial studies are conducted in parallel (Astrium-France and Thales Alenia Space).

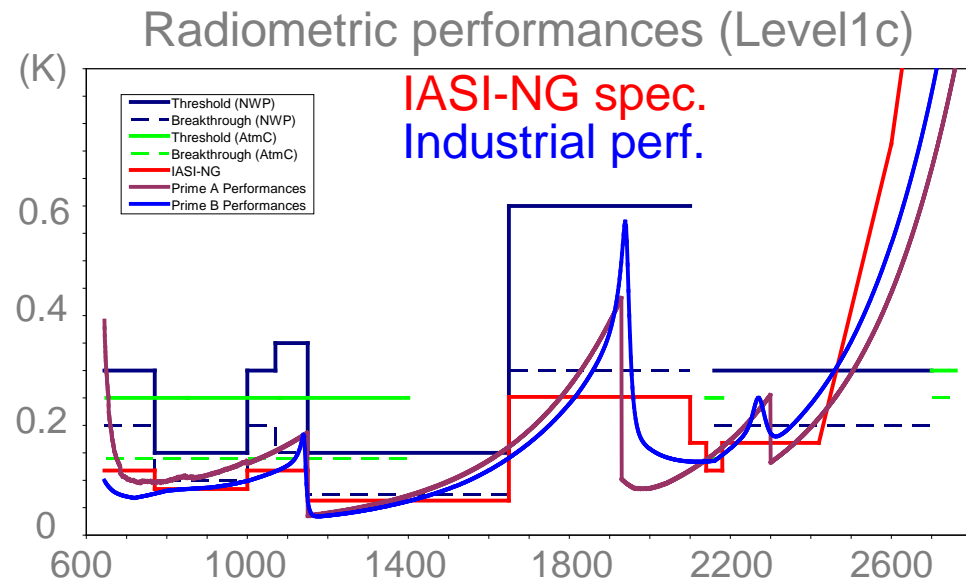
# IASI-New Generation

## •Objectives of the mission:

- To assure the **continuity** of IASI for NWP, atmospheric chemistry and climate applications.
- To **improve the characterization of the lower part of the troposphere, the UT/LS region** and, more generally, **of the full atmospheric column**.
- To **improve the precision** of the retrievals and to allow the detection of new species.

## •Characteristics:

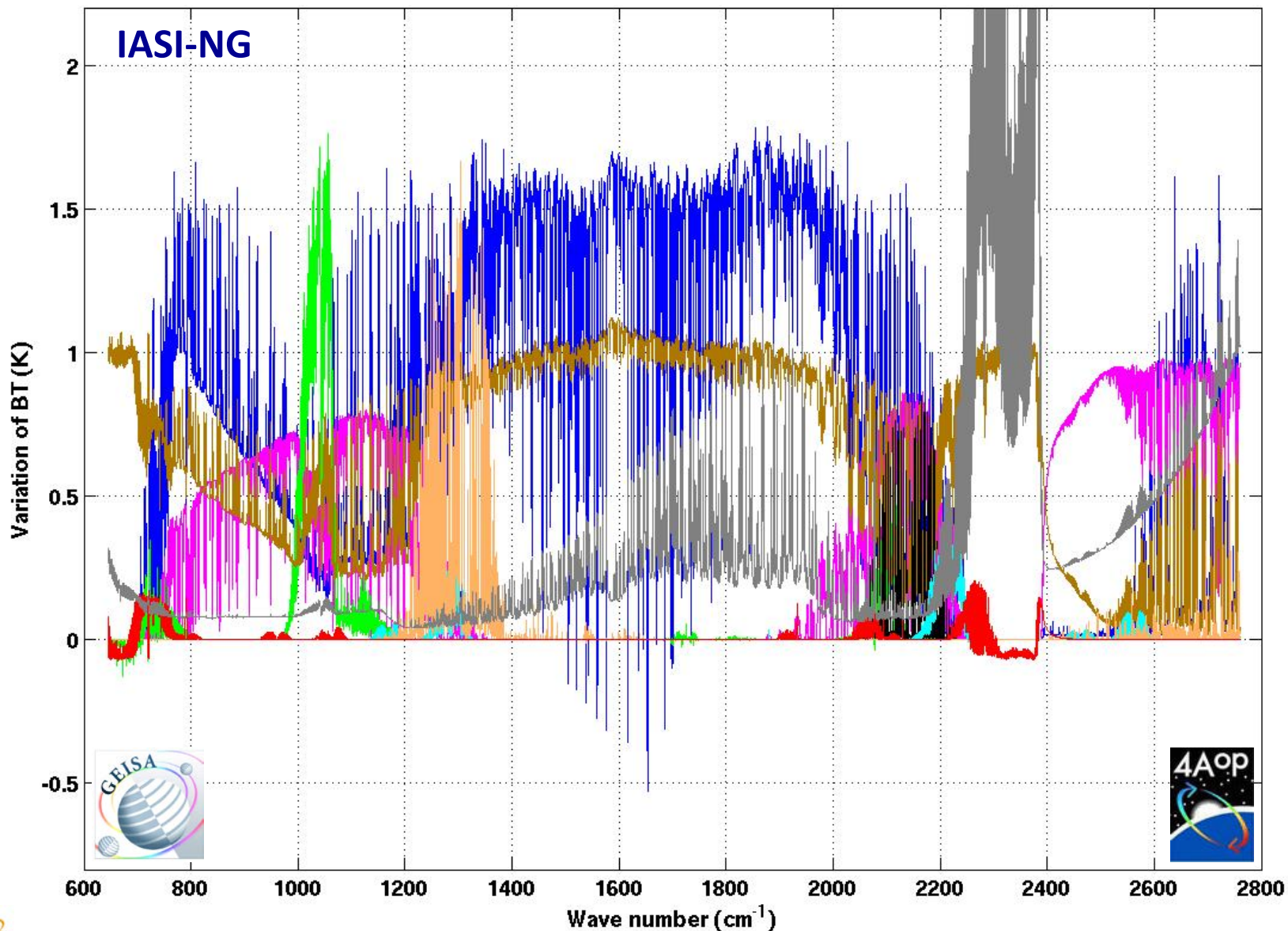
- spectral coverage: **645 - 2760  $\text{cm}^{-1}$**
- spectral resolution: **0.25  $\text{cm}^{-1}$**  after apodisation (**0.50  $\text{cm}^{-1}$  for IASI**)
- spectral sampling: **0.125  $\text{cm}^{-1}$**  (**0.25  $\text{cm}^{-1}$  for IASI**).
- reduction of the radiometric noise by **a factor of ~2** as compared to IASI.
- spatial sampling: 12km FOV.



➔ factor of 2 on the spectral resolution, sampling and the radiometric noise

# IASI-NG - Sensitivity analysis - Full spectrum

IASI-NG sensitivities - Tropical TIGR situations

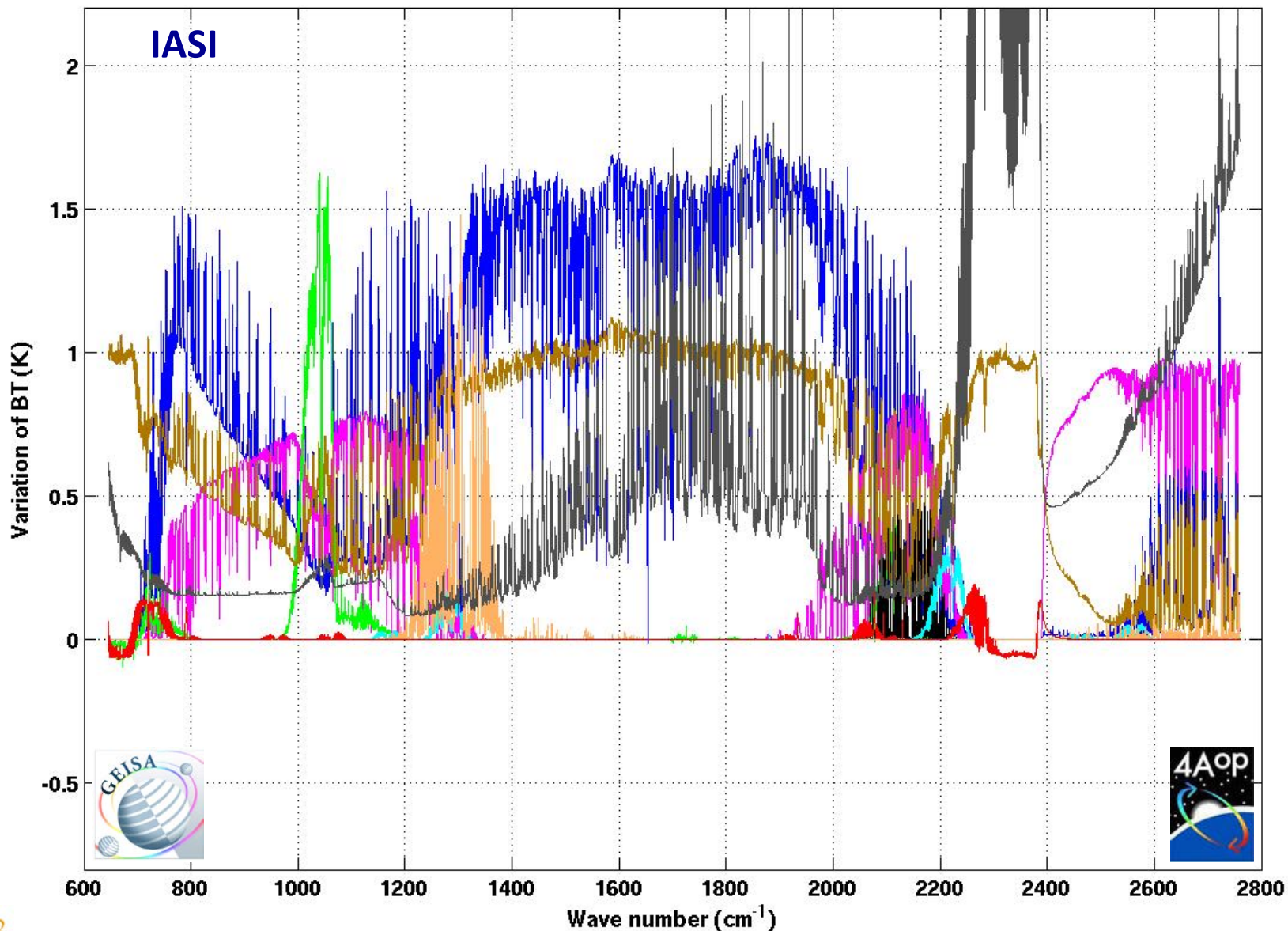


T (1K) H<sub>2</sub>O (20%) CO<sub>2</sub> (1%) O<sub>3</sub> (10%) N<sub>2</sub>O (2%) CO (10%) CH<sub>4</sub> (10%) T<sub>surf</sub> (1 K)



# IASI-NG - Sensitivity analysis - Full spectrum

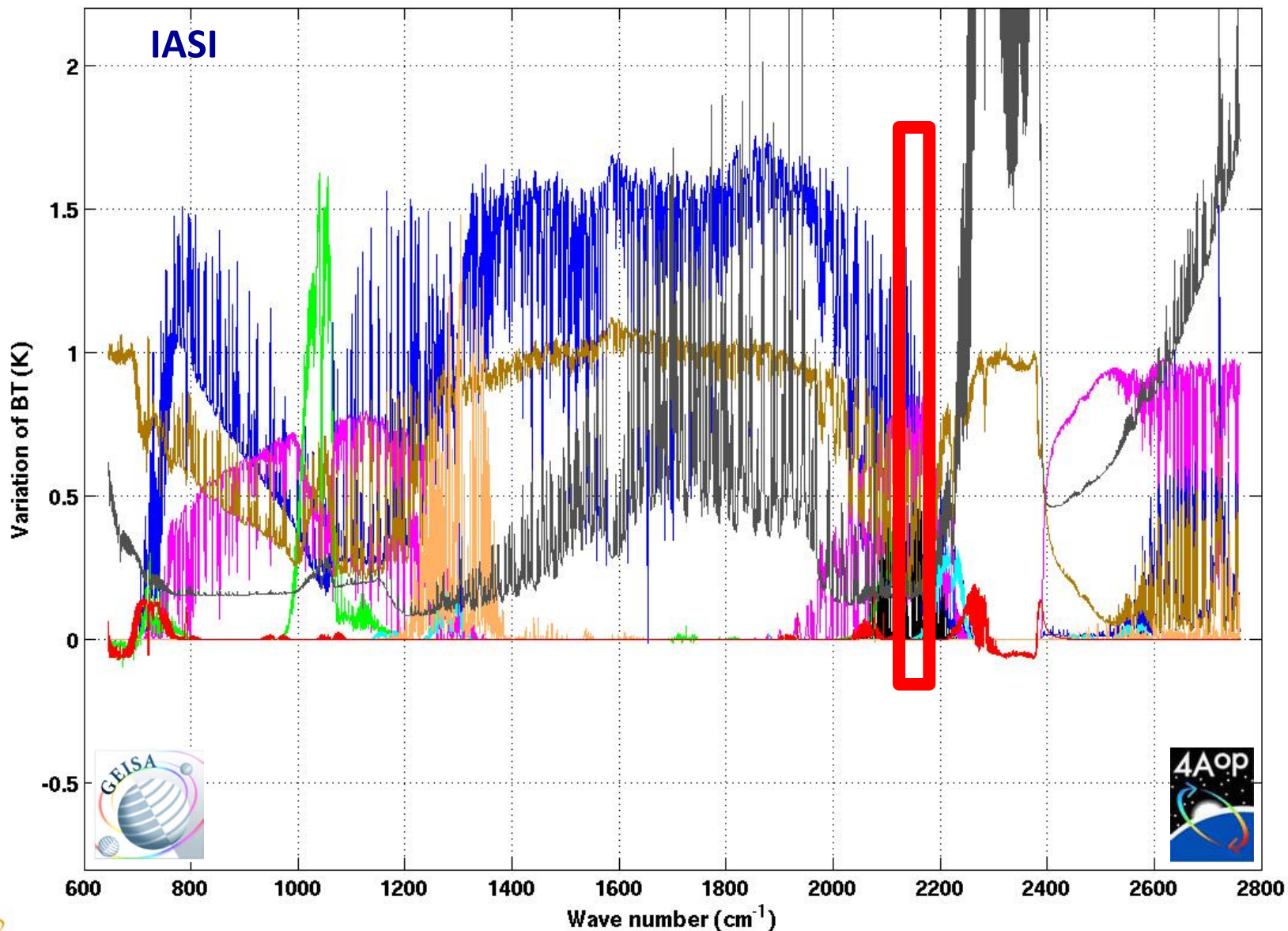
IASI sensitivities - Tropical TIGR situations



T (1K) H<sub>2</sub>O (20%) CO<sub>2</sub> (1%) O<sub>3</sub> (10%) N<sub>2</sub>O (2%) CO (10%) CH<sub>4</sub> (10%) Tsurf (1 K)

# IASI-NG - Sensitivity analysis - Full spectrum

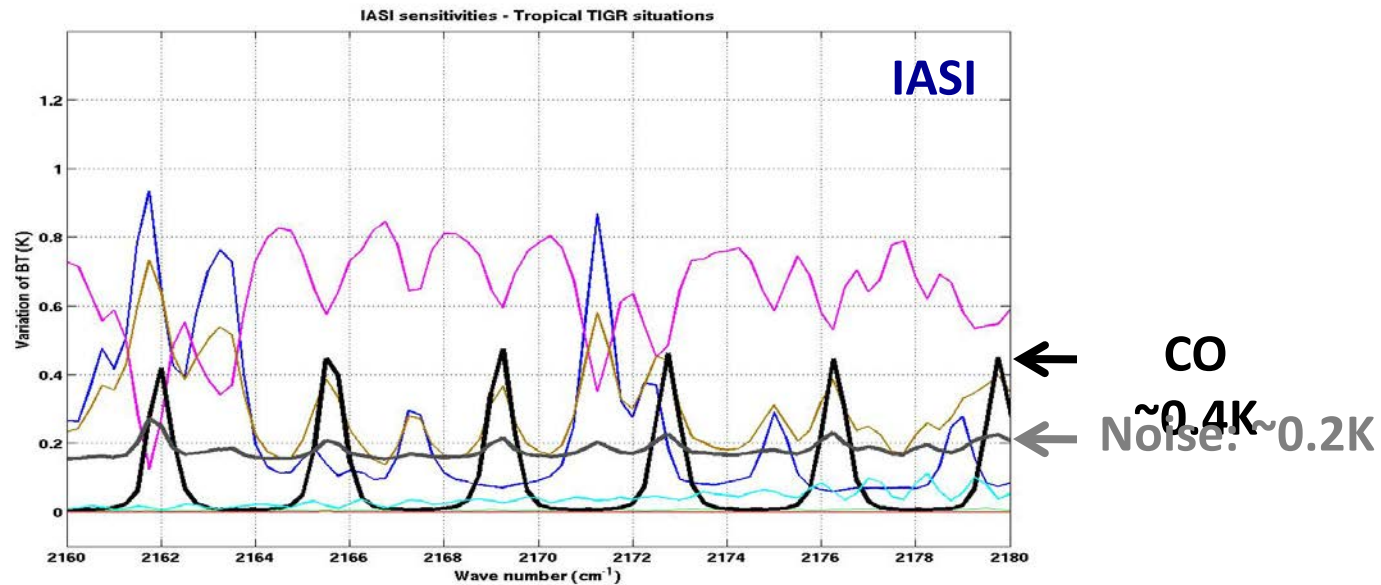
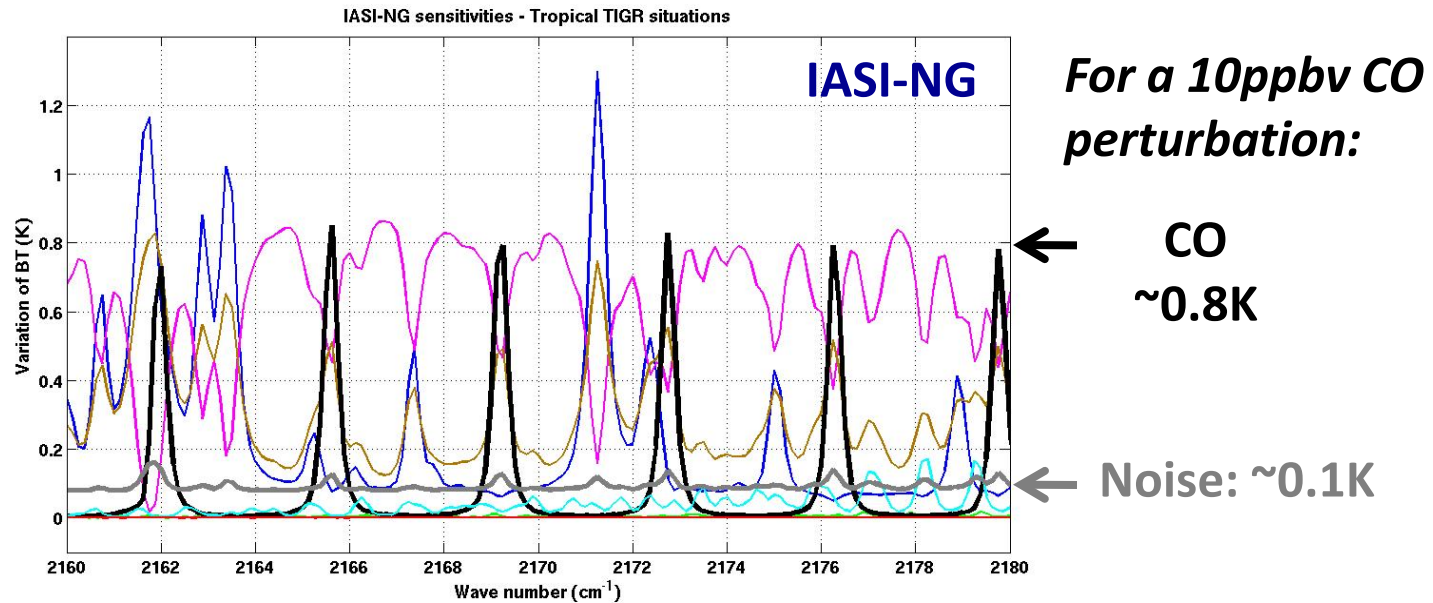
IASI sensitivities - Tropical TIGR situations



T (1K) H<sub>2</sub>O (20%) CO<sub>2</sub> (1%) O<sub>3</sub> (10%) N<sub>2</sub>O (2%) CO (10%) CH<sub>4</sub> (10%) Tsurf (1 K)



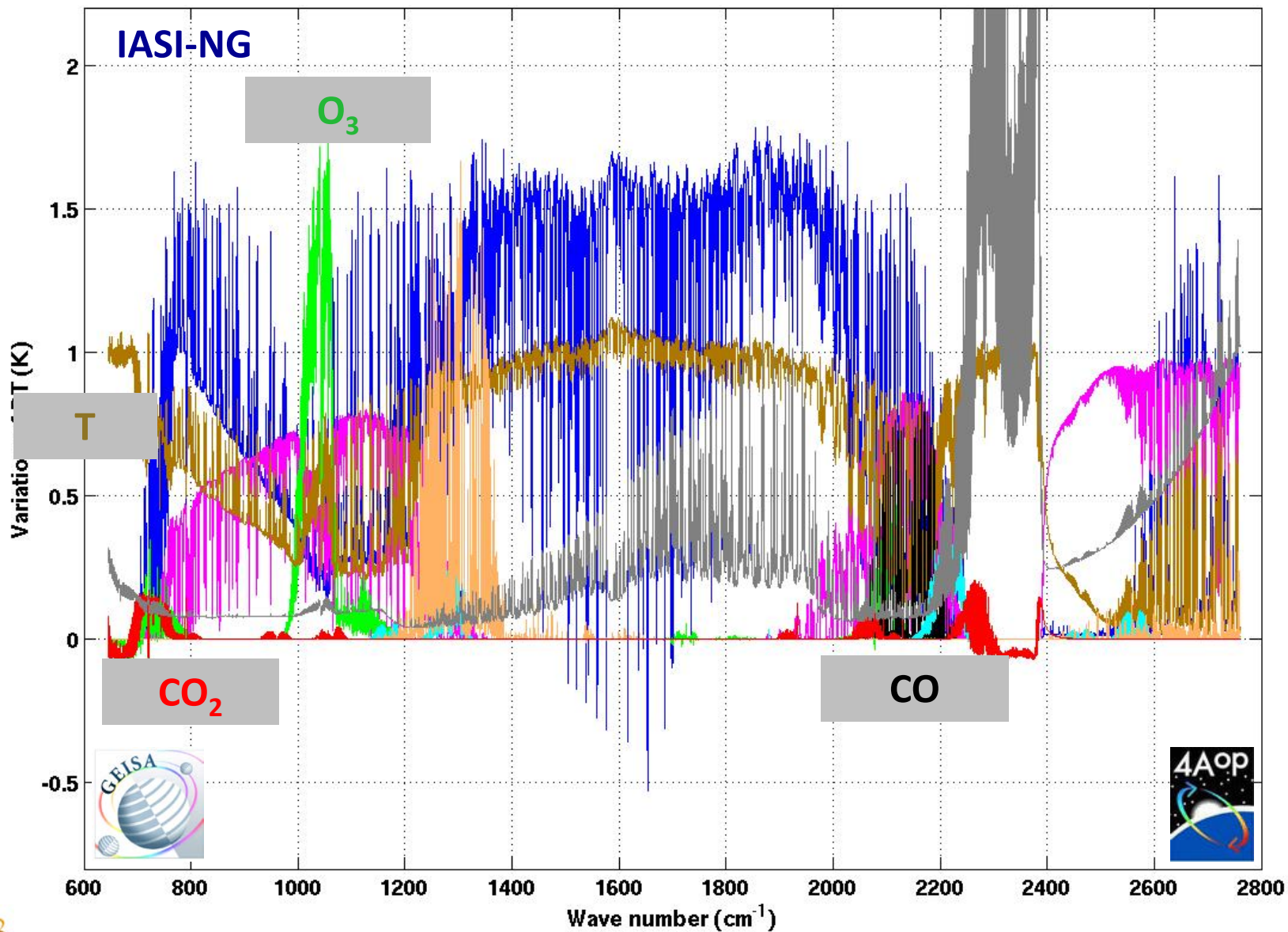
# IASI-NG - Sensitivity analysis - Full spectrum



T (1K) H<sub>2</sub>O (20%) CO<sub>2</sub> (1%) O<sub>3</sub> (10%) N<sub>2</sub>O (2%) CO (10%) CH<sub>4</sub> (10%) Tsurf (1 K)

# IASI-NG - Sensitivity analysis - Full spectrum

IASI-NG sensitivities - Tropical TIGR situations

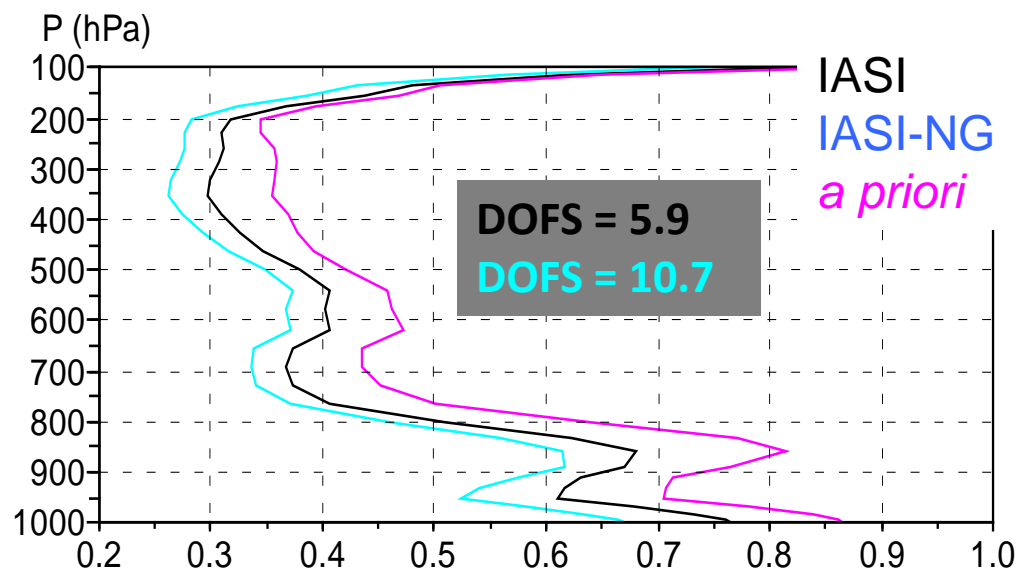
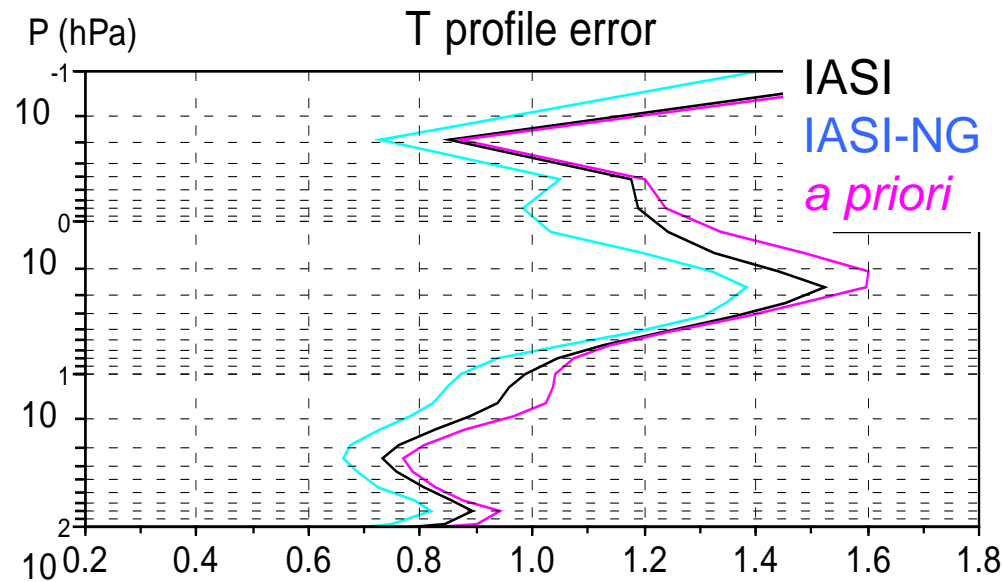


T (1K) H<sub>2</sub>O (20%) CO<sub>2</sub> (1%) O<sub>3</sub> (10%) N<sub>2</sub>O (2%) CO (10%) CH<sub>4</sub> (10%) T<sub>surf</sub> (1 K)

# Impact of IASI-NG on Temperature profile sounding

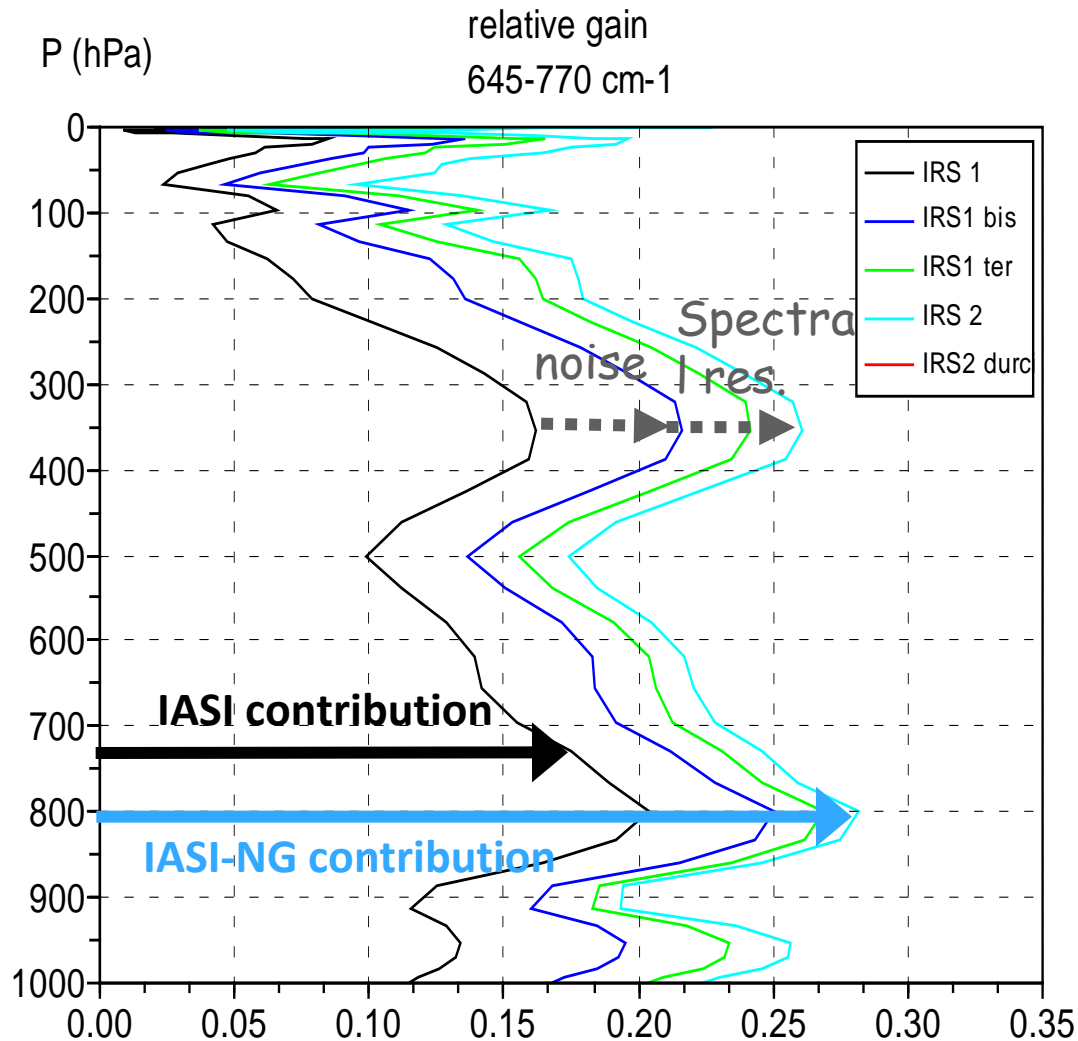
- The T profile is retrieved using the 15  $\mu\text{m}$  and 4  $\mu\text{m}$  CO<sub>2</sub> bands
- Tropical atmosphere
- Noise contribution from uncertainties on surface temperature and emissivity, humidity profile.
- *A priori* covariance from ECMWF.

With respect to the *a priori* uncertainty, the contribution of **IASI-NG** is about twice the contribution of **IASI**.



# Impact of IASI-NG on Temperature profile sounding

## Contribution of spectral resolution and radiometric noise



Noise	Spectral resolution
<b>IASI</b>	<b>IASI</b>
<b>IASI/2</b>	<b>IASI</b>
<b>IASI/(2√2)</b>	<b>IASI</b>
<b>IASI/2</b>	<b>IASI/2</b>

- The relative gain (or error reduction) is defined as:  
(a posteriori-a priori)/(a priori)
- It is in the range 5 - 25%.

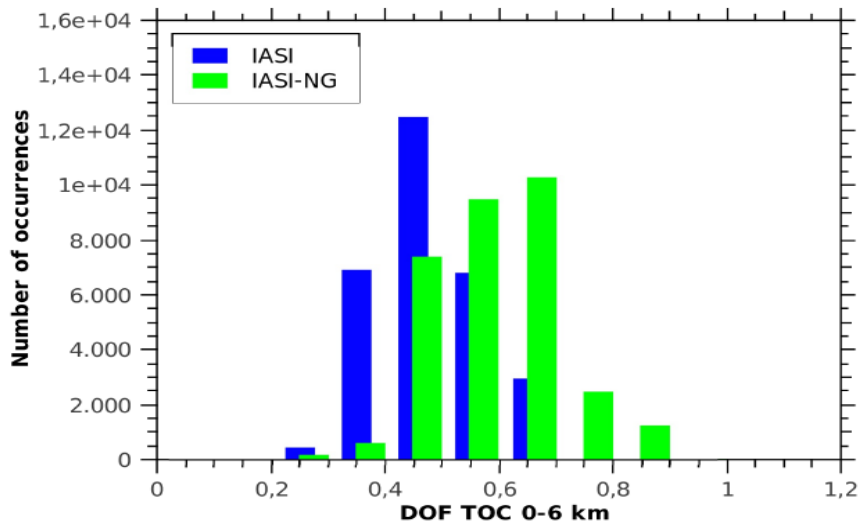
Spectral resolution improves the instrument contribution beyond noise reduction by increasing the number of channels.



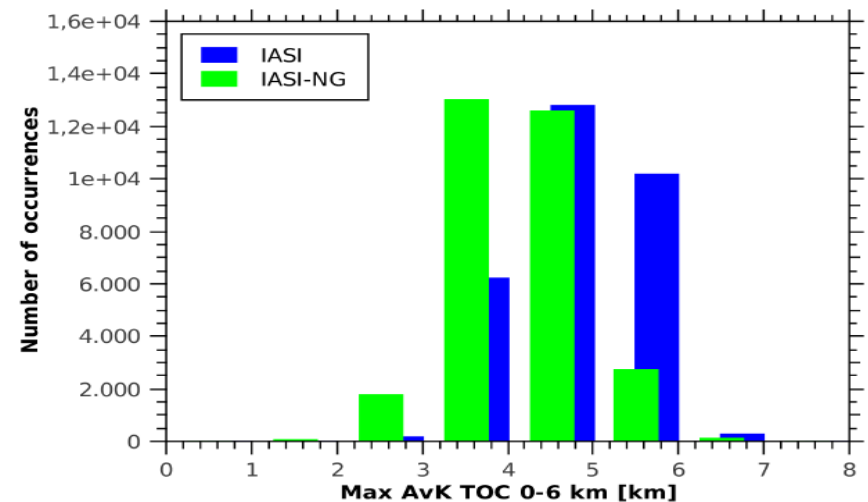
# Retrieval of ozone partial columns

- Design of OSSEs experiment, based on KOPRA RT code.
- The retrieval scheme is based on the one developed for IASI (Eremenko et al., GRL, 2008; Dufour et al., ACP, 2010)

Number of Degrees of Freedom on the vertical



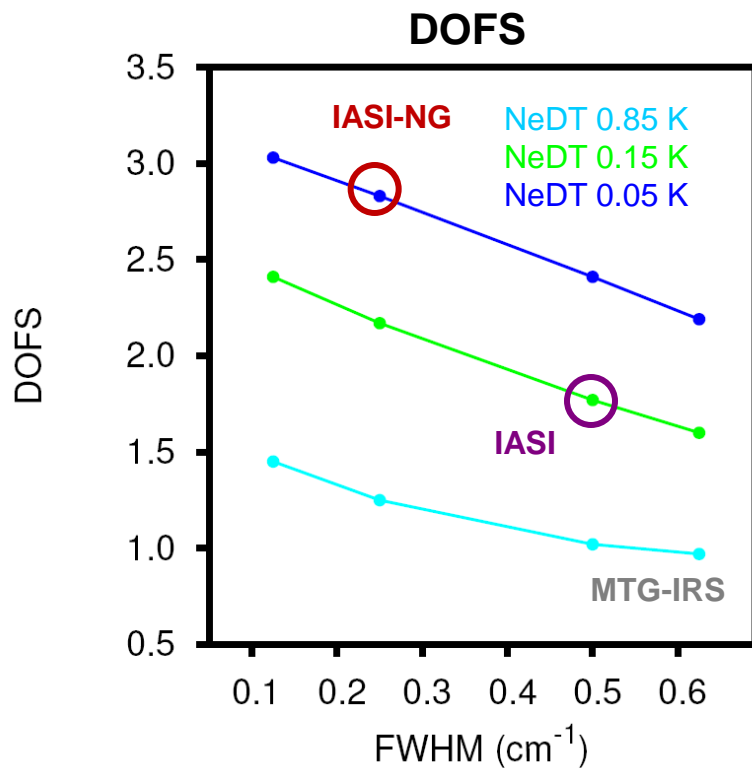
Altitude of the maximum of the averaging kernels



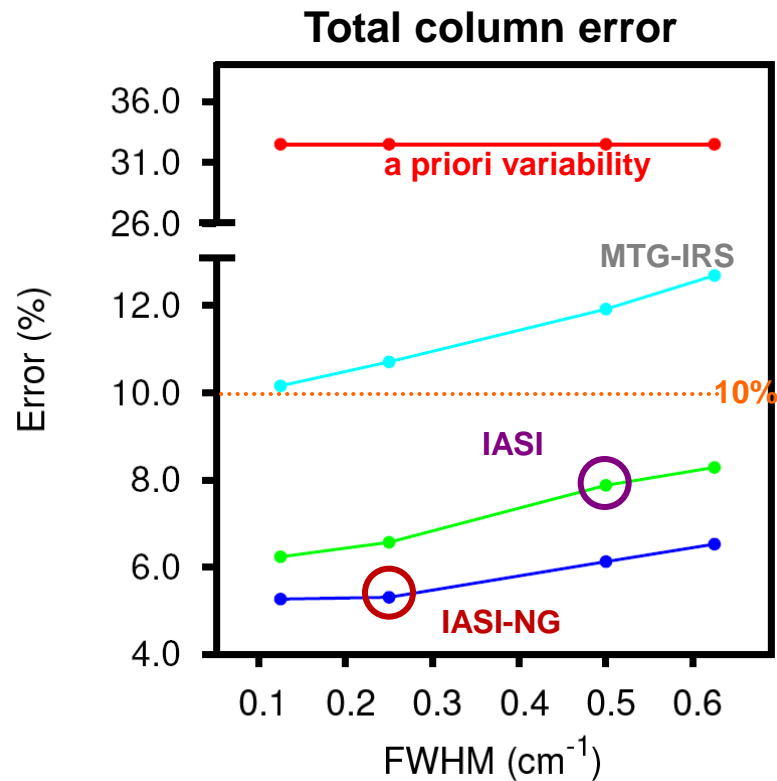
**For ozone [0-6 km]: IASI-NG will bring 50% more info on the vertical and sensitivity 1 km lower + gain 30% on accuracy**

## Summary of the Sensitivity analyses

- Study of retrieval performances by varying spectral resolution and noise
- Use of CO retrieval scheme from George et al., ACP, 2009.



Improved vertical resolution



Improved accuracy

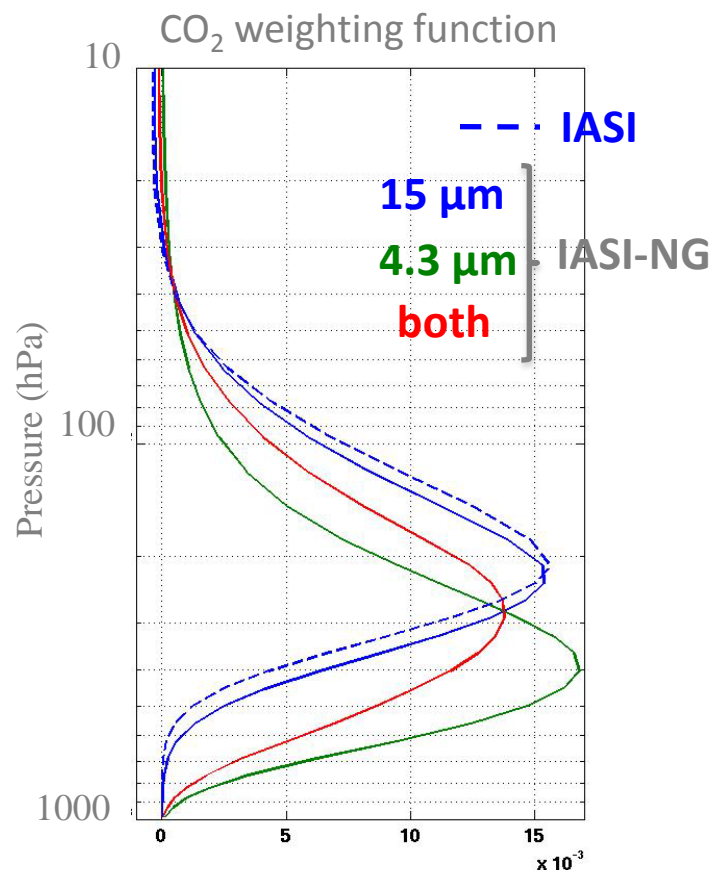
# Retrieval of CO<sub>2</sub> integrated content

- Using the LMD inference scheme (Crevoisier et al., ACP, 2009), we have studied the evolution of the precision with various configurations compared to the IASI current precision (which uses the 15 μm band only):

Spectral bands for IASI-NG	Noise	Improvement of the precision
15 μm	IASI/2	30 %
4.3 μm		0 %
15 + 4.3 μm		45 %

• IASI-NG will enable the use of 4.3 μm channels, giving access to a lower part of the atmosphere, with a much improved precision.

- Strong and needed complementarity with SWIR obs. (GOSAT, OCO-2, UVNS).



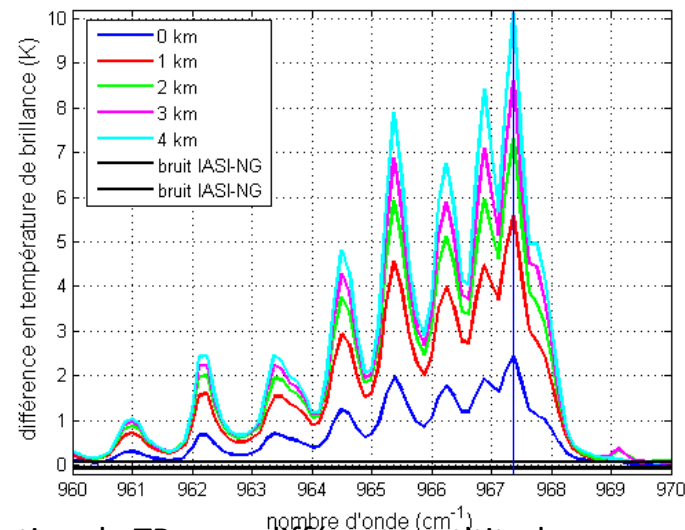
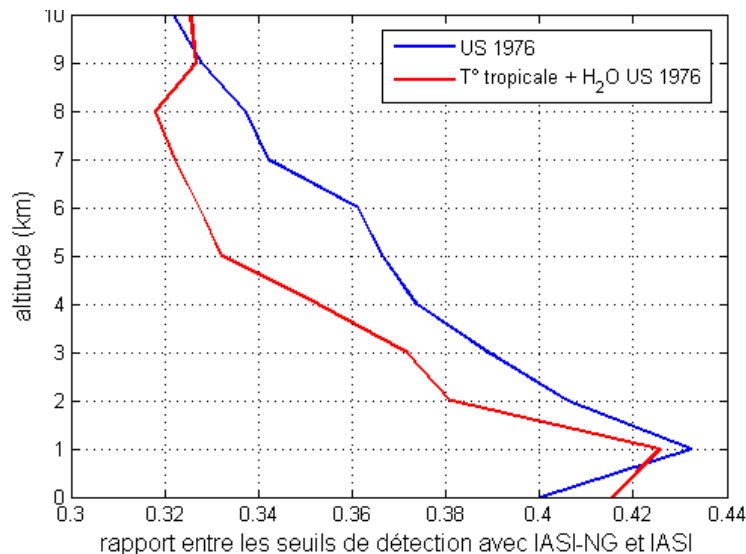
100-400 hPa, max at 200 hPa

100-500 hPa, max at 300 hPa

200-650 hPa, max at 400 hPa

# Detection of trace gases

- **Ammonia [0-2 km]:** gain of 40 % on the detection limit.



Variation de TB pour différentes altitudes pour un cas de pollution et un contraste thermique positif (+10K)

- **SO<sub>2</sub>:** a 45 % gain on the detection threshold + some information on the vertical structure of the plumes.
- **Volcanic ash:** improvement on the detection limit.

→ **Improvement of volcanic eruption alert**  
(and more species will be retrieved: SO<sub>2</sub>, H<sub>2</sub>S, H<sub>2</sub>SO<sub>4</sub>, ash)



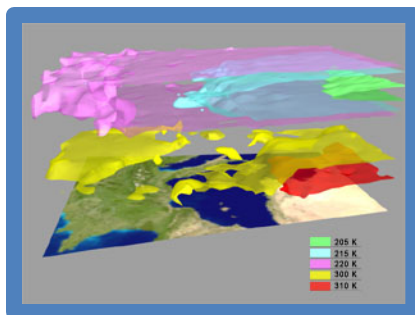
	IASI		IASI-NG		
<i>Chemistry</i>	<i>DOFs</i>	<i>Error (%)</i>	<i>DOFs</i>	<i>Error (%)</i>	<i>What the 'NG' brings</i>
O <sub>3</sub>	3-4	PBL : 60% Tropo : 11%	4-5	PBL : 40% Tropo : 8%	More information in PBL
CO	1-2	PBL : 16% Tropo : 8%	2-3	PBL : 10% Tropo : 6%	More information in PBL
HNO <sub>3</sub>	1 or less		2		Both tropo and strato
NH <sub>3</sub> <sup>a</sup>	detected	-	measured	-	> instrumental noise
Methanol <sup>a</sup>	detected	-	measured	-	> instrumental noise
C <sub>2</sub> H <sub>4</sub> <sup>a</sup>	detected	-	measured	-	> instrumental noise
SO <sub>2</sub> -volcanos	If > 2DU	-	If > 1 DU	-	+ Altitude of the plume
<i>Climate</i>	<i>DOFs</i>	<i>Error (%)</i>	<i>DOFs</i>	<i>Error (%)</i>	<i>What the 'NG' brings</i>
H <sub>2</sub> O	5-6	~13%	6-7	~10%	Error improved by 1.5
T	6	~0.6K	12	~0.45 K	Error improved by 2.5
CO <sub>2</sub>	1 or less	~1%	1-2	<1%	Low troposphere
CH <sub>4</sub>	1or less	~3%	1-2		Less interferences
N <sub>2</sub> O	detected	-	measured	-	
<i>Aerosols</i>	dust				More types
<i>Emissivity</i>		0,04 @4μm		0,02 @4μm	

# Conclusions

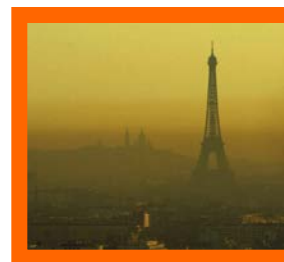
- The **improved spectral resolution and radiometric noise of IASI-NG** will enable:
  - (1) a **better coverage of the vertical**, especially in the lower part of the troposphere;
  - (2) an **improvement of the accuracy** of the retrieved variables because of less interferences between the species in the channels and a better signal to noise ratio.
- The increase of **spectral resolution** has a clear impact on several signatures: sharper CO 'lines', easier separation of CH<sub>4</sub> vs. H<sub>2</sub>O, etc.
- The lower the **noise**, the better! That really matters for the weak spectral features embedded in stronger ones (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, and most of other chemical species only detected by IASI).
  - **The reduction of the noise is a priority in the SW.**
- The retrieval of several variables will depend on:
  - (1) the **synergy** between IASI-NG and EPS-SG/MWS, EPS-SG/Vis.
  - (2) the **knowledge of surface characteristics**, which will be the key for using new spectral regions (SW).
  - (3) **spectroscopy** compliant with the evolution of new generation instruments.

# IASI-NG improved contributions to...

Atmospheric  
profiling



Improvement  
on pollution  
forecast  
3 EU controlled  
pollutants (CO,  
O<sub>3</sub> and NH<sub>3</sub>)



Better tracking  
of long range  
pollution (e.g.  
fire emissions)



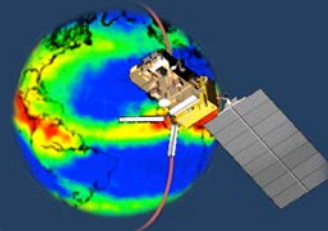
Improved  
volcanoe alerts  
Early alerts  
possible + SO<sub>2</sub>  
and ash tracking



Essential Climate  
Variables  
monitoring and  
understanding  
Clouds, GHG,  
aerosols



IASI-NG



IASI-NG has the potential for strongly benefiting the NWP, chemistry and climate communities, in addition to assuring the continuity of high quality observations delivery.

# IASI-New Generation : supports

F  
R  
A  
N  
C  
E

**CNRM** : N. Fourrié, V. Guidard, F. Rabier

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**LATMOS** : C. Clerbaux, J. Hadji-Lazaro, M. George

**LISA** : J. Cuesta, G. Dufour

**LMD** : R. Armante, V. Capelle, A. Chédin, C. Crevoisier, N. Jacquinet, N. Scott, C. Stubenrauch

**LOA** : H. Herbin

**LPMAA** : C. Camy-Peyret, S. Payan

**LSCE** : F. Chevallier

O  
T  
H  
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R

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**University of York** : P. Bernath

**University of Edinburg**: P. Palmer

**Dalhousie University**: R. Martin

**KNMI**: P. Levelt

**NCAR**: D. Edwards, L. Emmons

+ ECMWF, MACC,  
MeteoFrance and the  
MetOffice support letters

V  
O  
L  
C  
A  
N  
O

**Volcanic Ash Advisory Centers/ London VAAC (UK Met Office)** : R. Saunders

**MetOffice, UK** : J. Haywood

**U.S. Geological Survey, Alaska Volcano Observatory** : D. Schneider

**Meteorological Authority, Civil Aviation Authority of New Zealand** : P. Lechner

**Operational coordinator, VAAC Montreal** : D. Bensimon

**VAAC Toulouse, MeteoFrance**: Ph. Husson

**University of Alaska Fairbanks (Anchorage VAAC)** : P. Webley

**German Airline Pilots' Association** : K. Sievers