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With contributions from the ISSWG

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Outline

What we gained so far from IASI

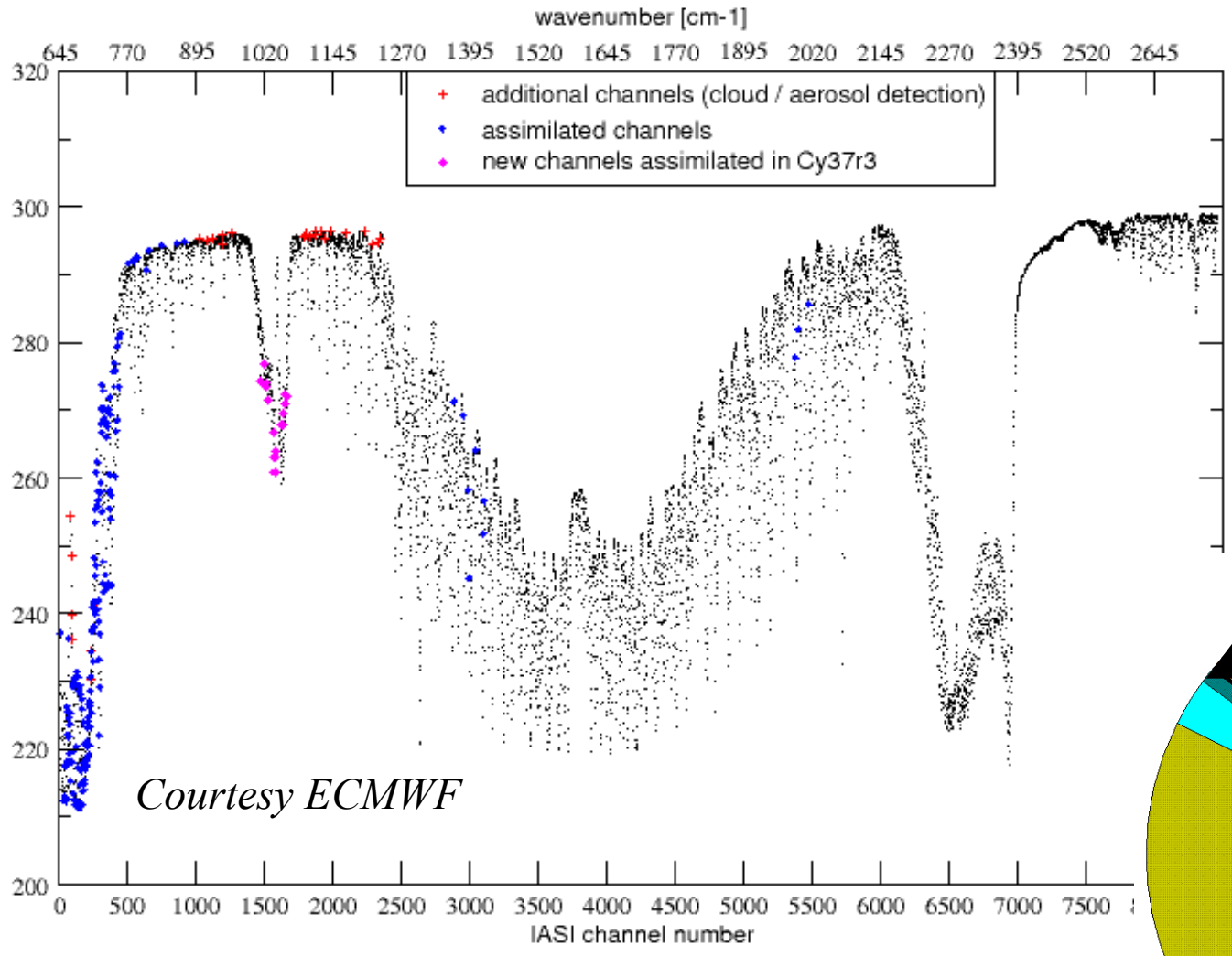
- In Numerical Weather Prediction (NWP), global models and mesoscale models
- In atmospheric chemistry
- In climate studies

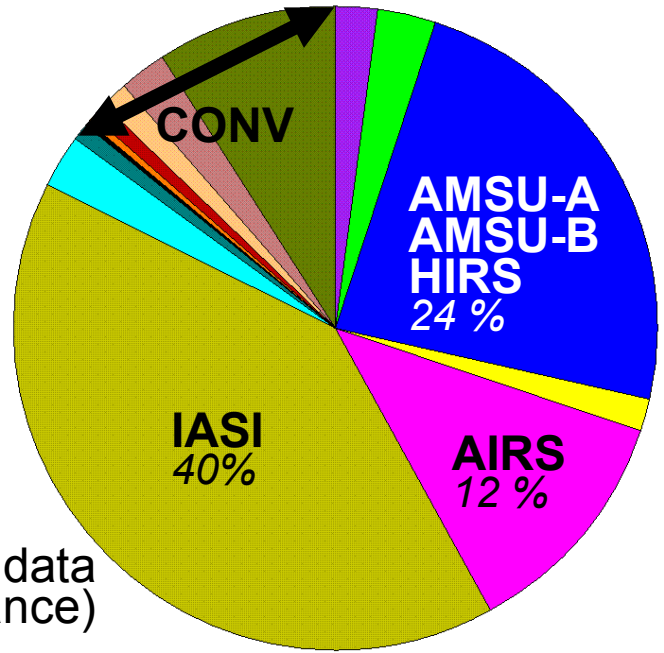
What are the lessons and limitations from IASI ?

What are the expectations from IASI-NG

- For temperature sounding
- For atmospheric chemistry
- For climate monitoring and models

Channel selection / data usage for NWP



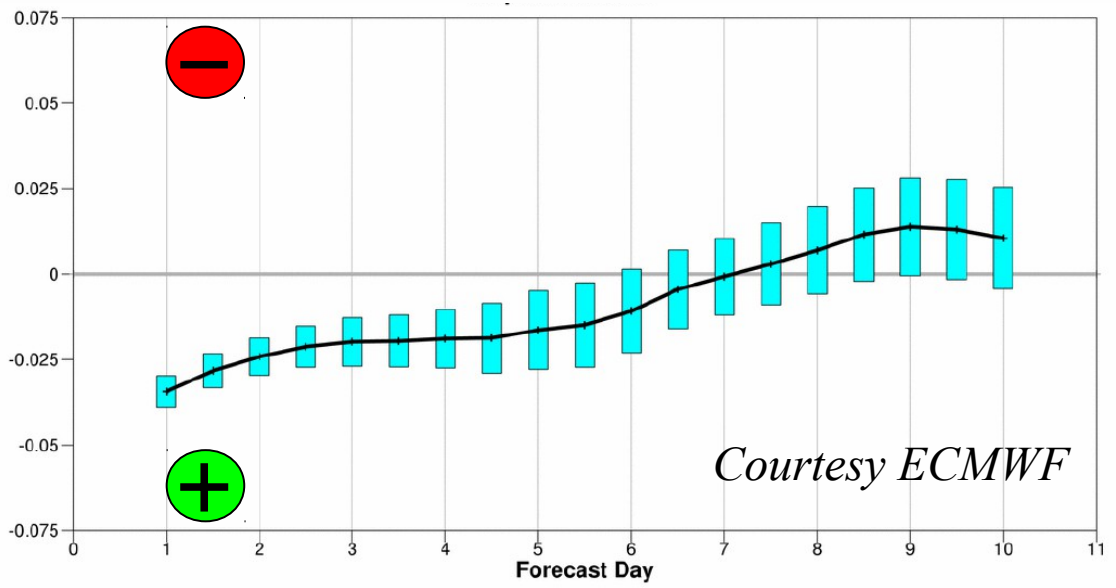


Data usage:
IASI represents ~40% of assimilated data in global model ARPEGE (Météo-France)

Impact in global NWP models

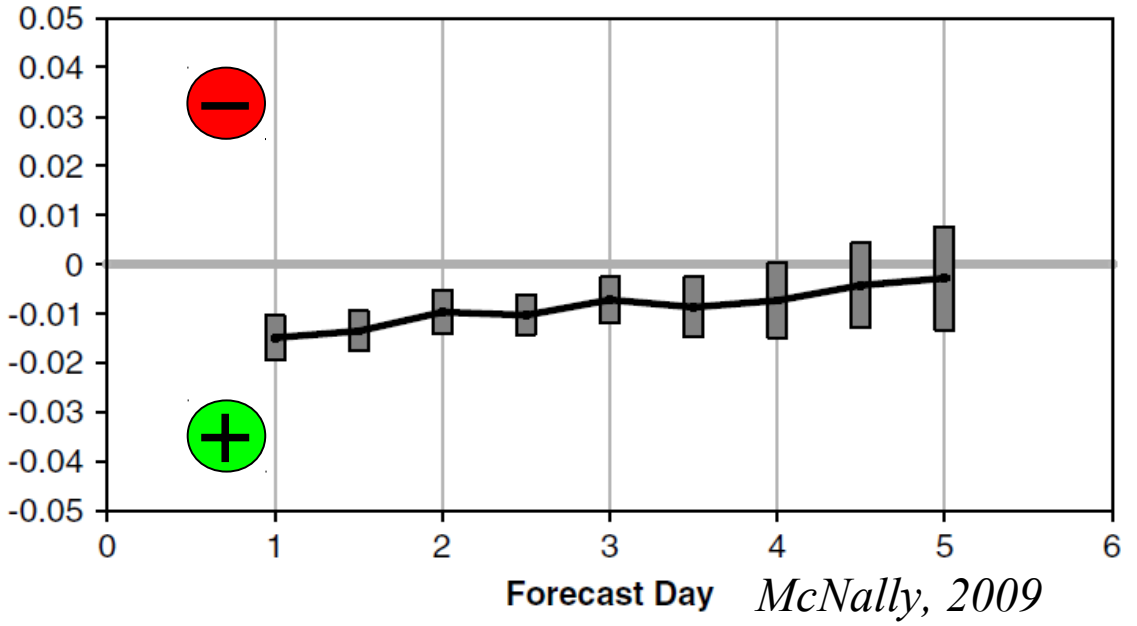
Impact on forecast skill :
Clear sky radiances
Large improvement, even on top of a very accurate system using 50+ other satellite intruments

example : geopotential @ 500 hPa
In Southern Hemisphere
over a 1-year trial experiment



Impact on forecast skill :
IFS at ECMWF
Cloudy overcast radiances on top of clear radiances

example : temperature @ 700 hPa
In the Tropics
over a 3-month trial experiment
Relative RMS reduction

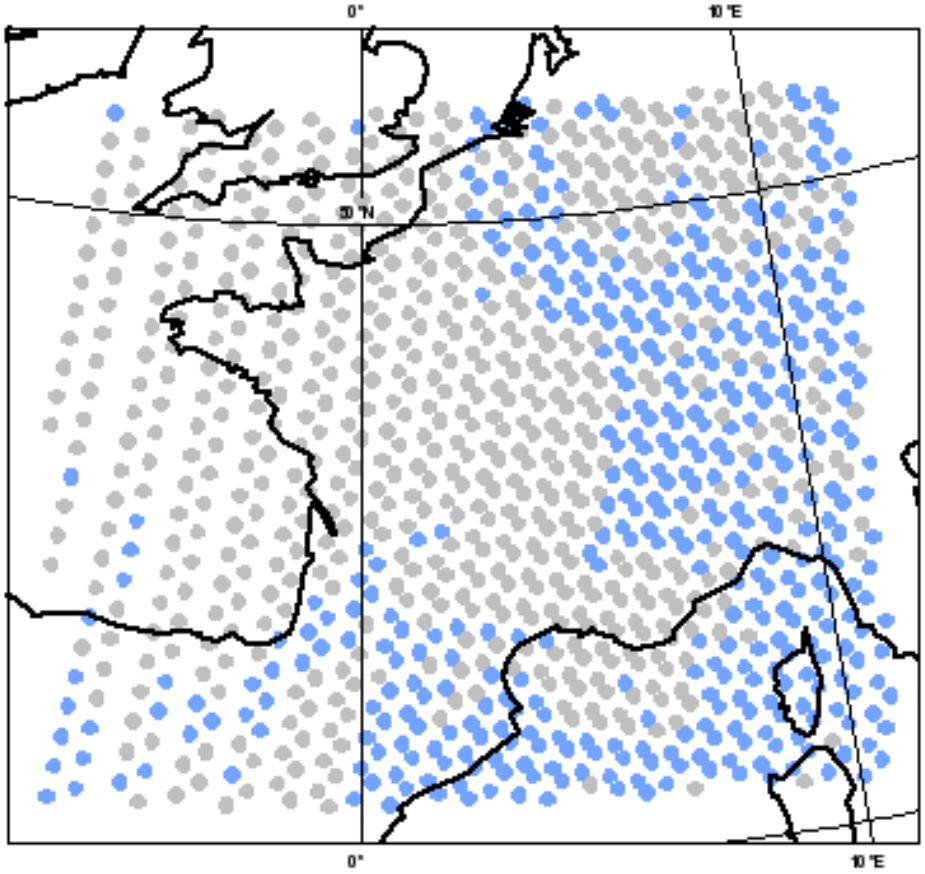


Field of view selection and horizontal sampling for mesoscale NWP model

Case of French mesoscale model AROME (horizontal mesh of 2.5 km)

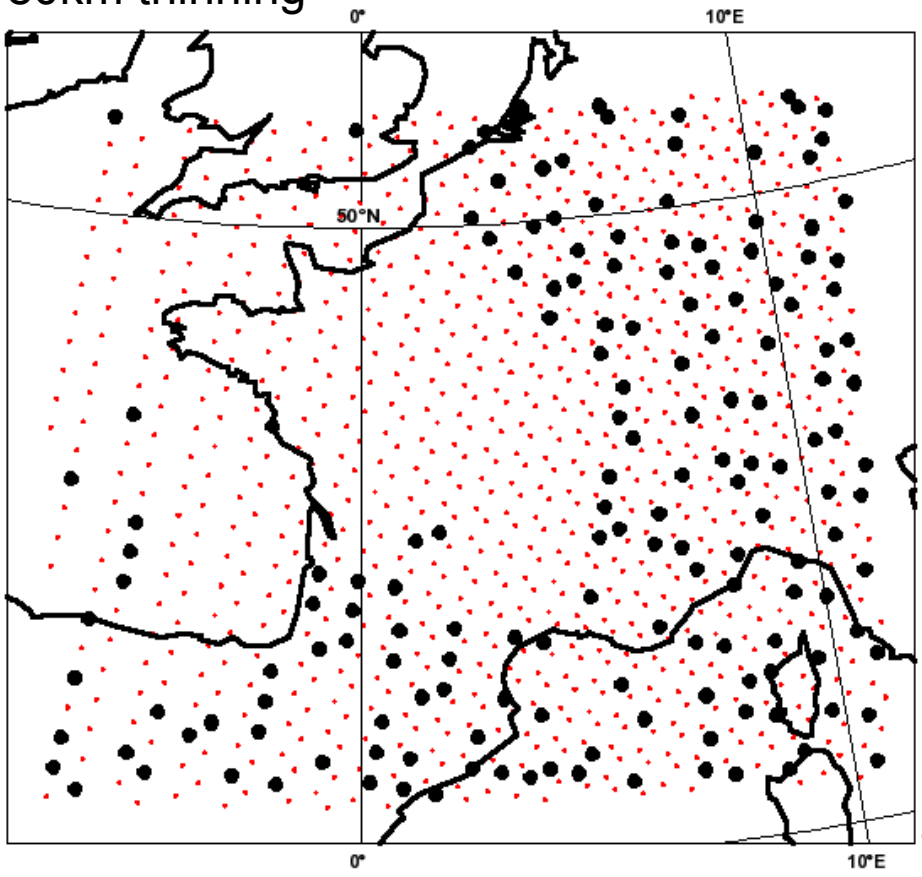
Cloud detection

clear cloudy



Horizontal thinning :

80km thinning

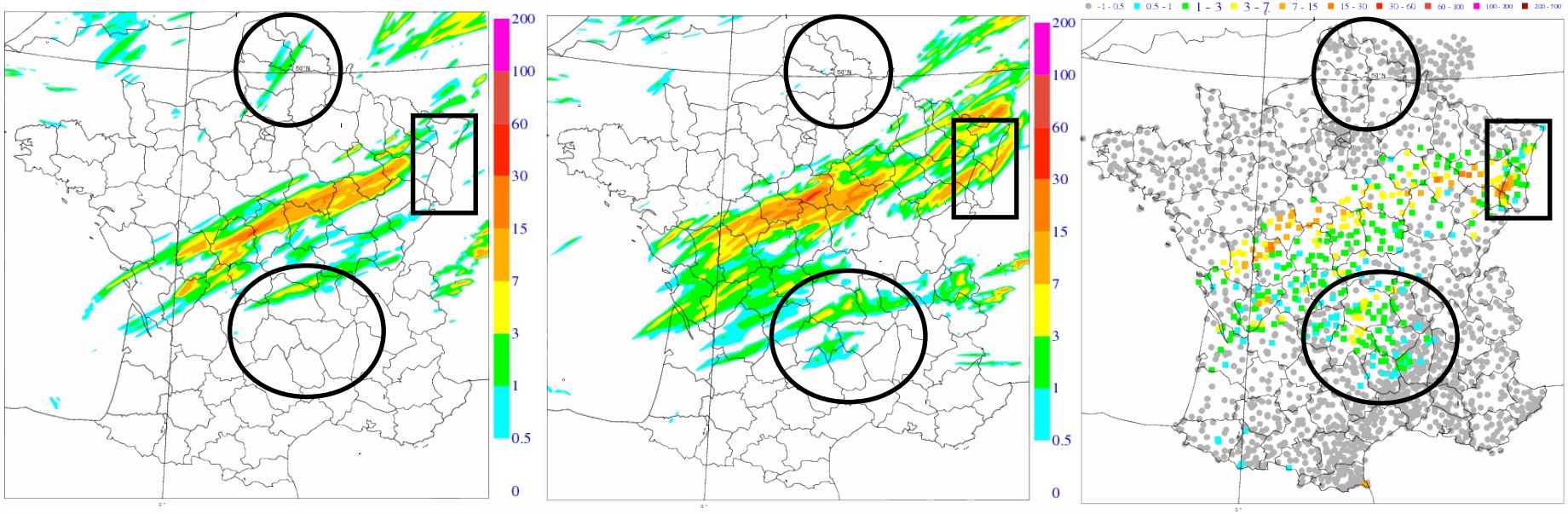


IASI channel 706.25 cm^{-1} (mid-troposphere)

Impact in mesoscale NWP model: case of French AROME

Impact on precipitation prediction
example of 12h precipitation between 00 and 12UTC
on 21 May 2009

12h forecast range



Reference: no IASI **Experiment: with IASI** **Verif.: Rain gauges**

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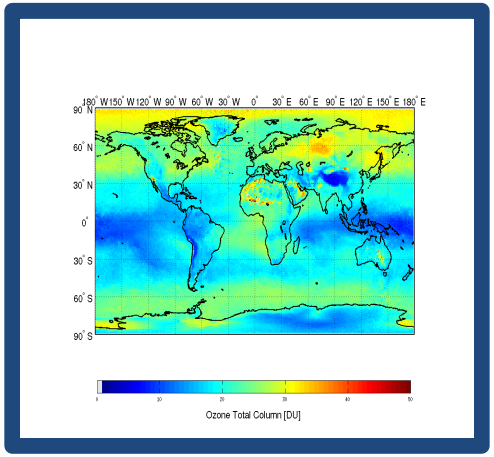
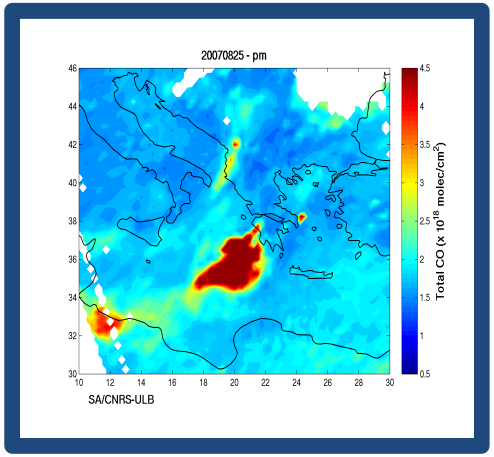
Atmospheric chemistry: near real time processing for IASI

Pollution forecast



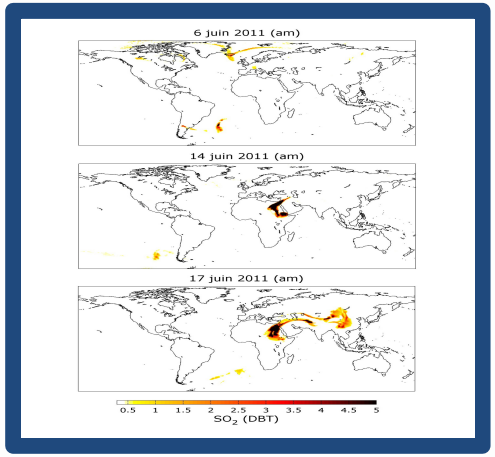
Ozone peaks
NH3 sources

Fire detection



Long-range
pollution

Volcanic plumes



Aviation threat

Latmos/ULB near real time processing for IASI
Courtesy C. Clerbaux

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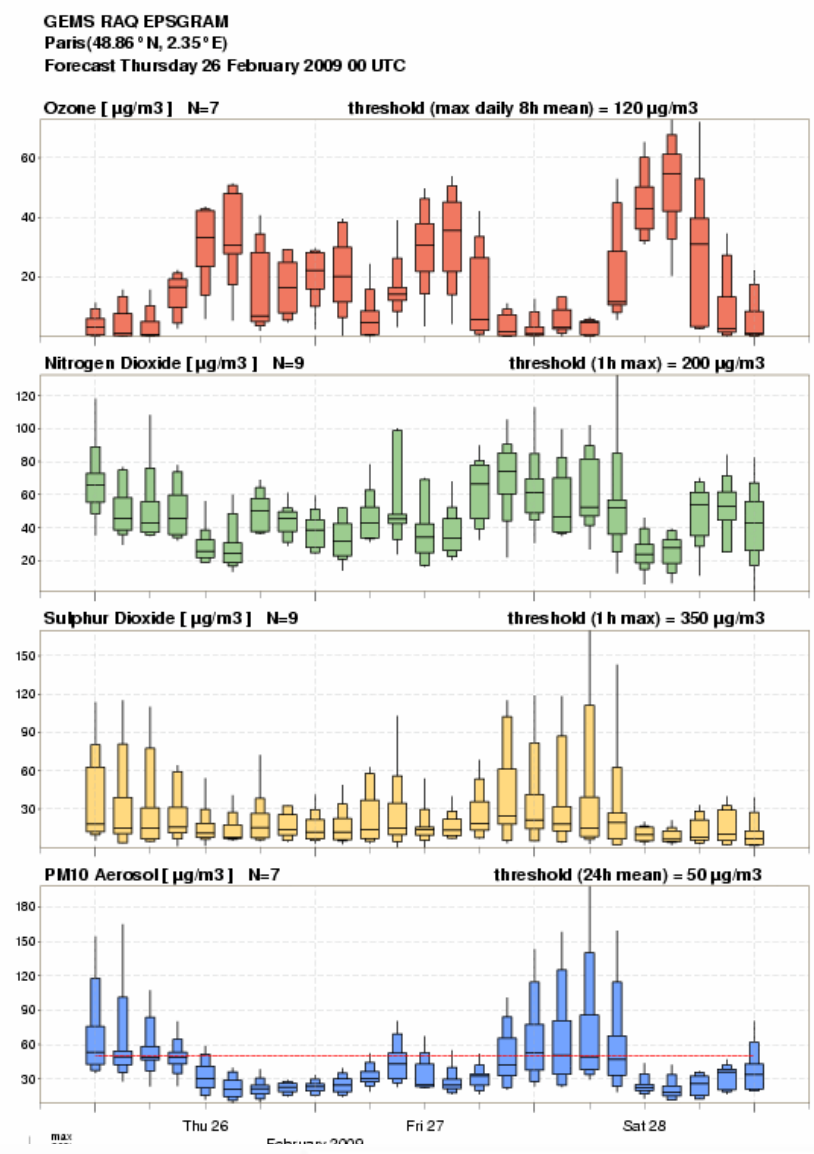
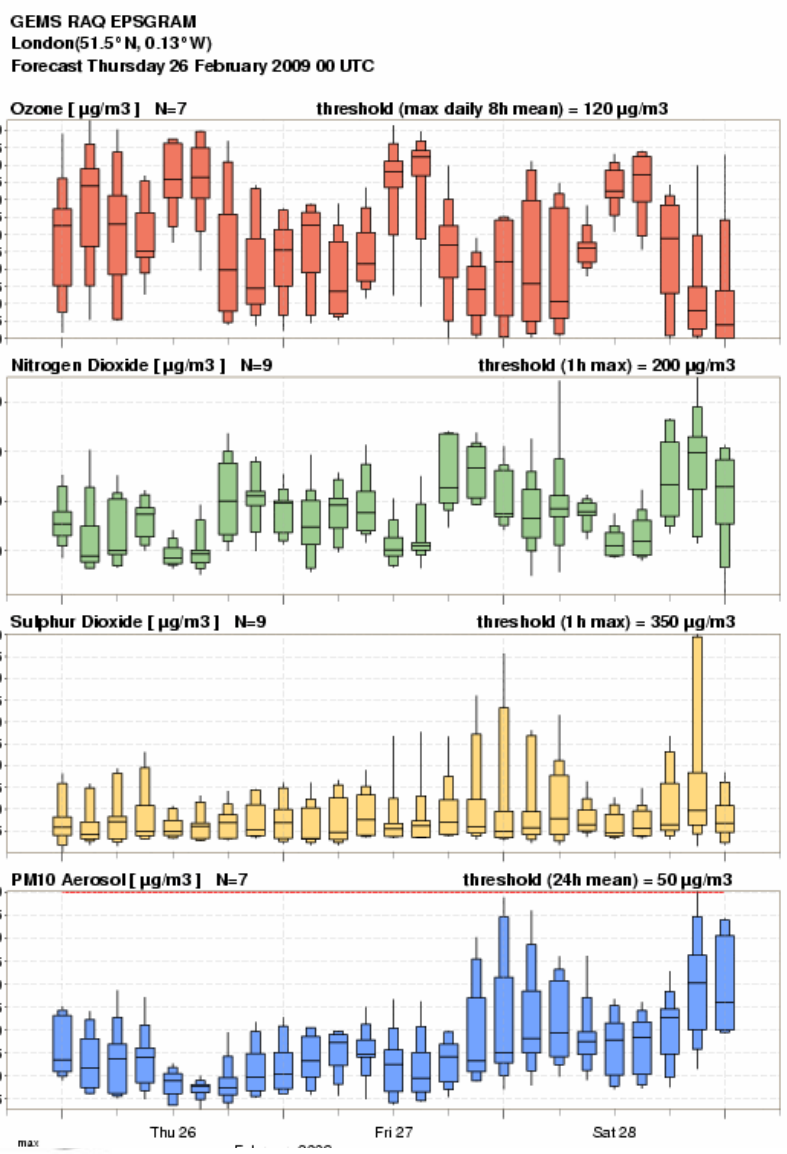
Probabilistic approach to European air quality forecasting

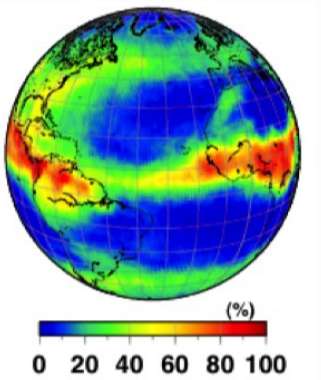




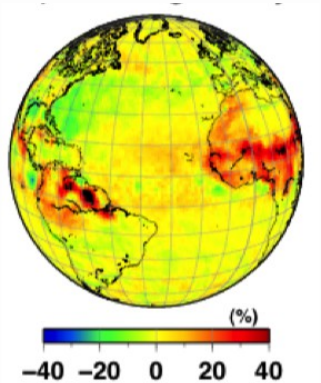
Contribution of IASI to climate studies

IASI contributes to the monitoring of several **Essential Climate Variables**

Cloud coverage and microphysical properties

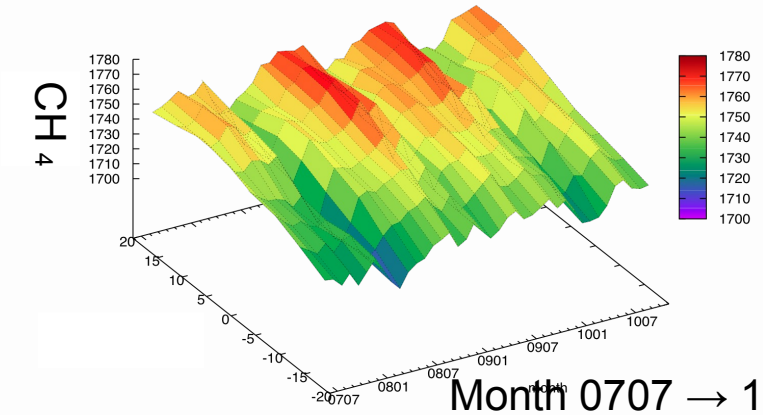


High Cloud Amount



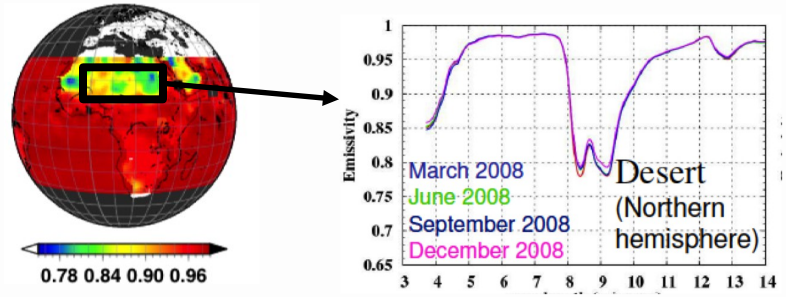
Diurnal cycle

Greenhouse gases (CO_2, CH_4)



Month 0707 → 1108

Surface characteristics



Spectral emissivity of continental surfaces

Thanks to its very good spectral and radiometric characteristics,

IASI is now **the reference of** the Global Space-based Inter-Calibration System (**GSICS**)

Courtesy C. Crevoisier, LMD

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Which limits to IASI ? Which requirements ?

IASI has proven to be an essential component of numerous applications

- Operation NWP (global et mesoscale models)
- Near-Real Time Atmospheric Chemistry
- Climate monitoring

Lessons learned from IASI:

- 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.

IASI in flight until 2019 (12 y) → Continuity / follow-on is mandatory !

We need to go much further than IASI

- Improve temperature / humidity retrievals
- Better characterize cloud and surface properties
- Improve chemical species retrievals
- Improve precision and vertical accuracy, especially in lower troposphere
- Detect more chemical species

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:
IASI-NG will provide:

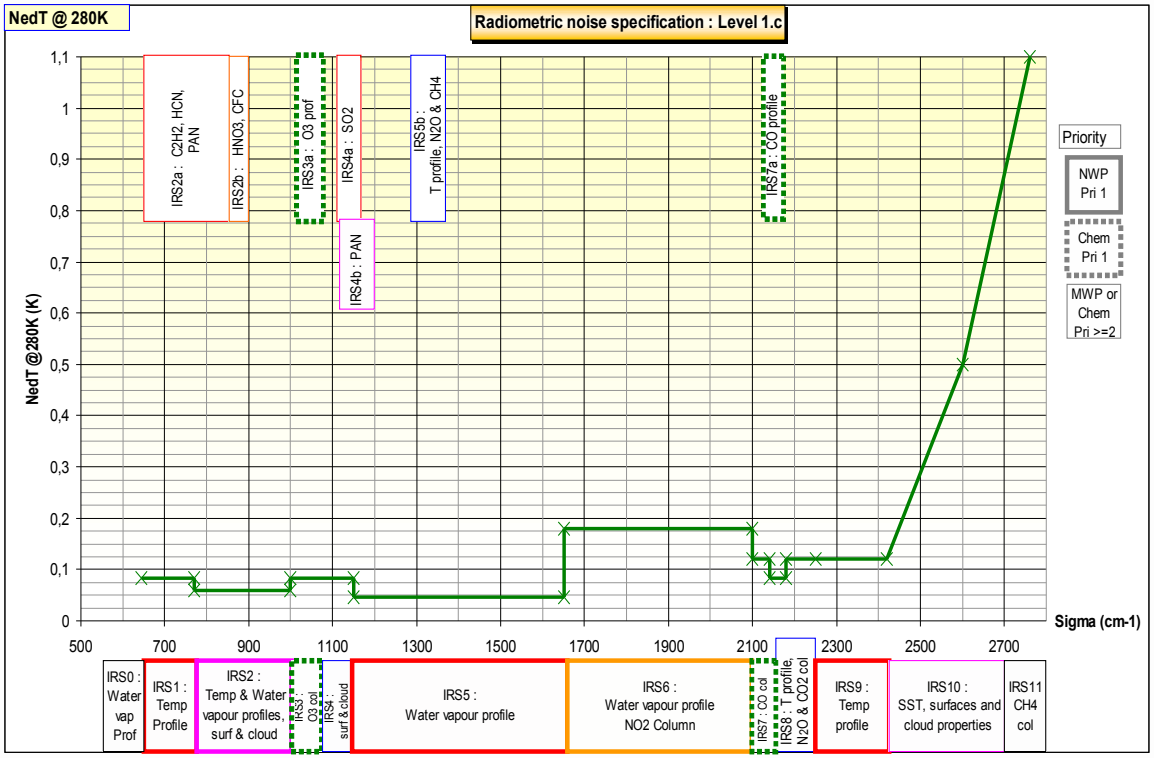
- 16921 spectral channels between 645 and 2760 cm^{-1} (15.5 - 3.63 µm)
- with a spectral resolution of 0.25 cm^{-1} after apodisation (*0.50 cm^{-1} for IASI*)
- the spectral sampling interval will be 0.125 cm^{-1} (*0.25 cm^{-1} for IASI*).
- a reduction of the radiometric noise by at least a factor of 2 as compared to IASI.

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

IASI-NG Phase A specification Wrt MRD

IASI-NG performance objective is to improve the IASI demonstrated performances by a factor of 2 at level 1c

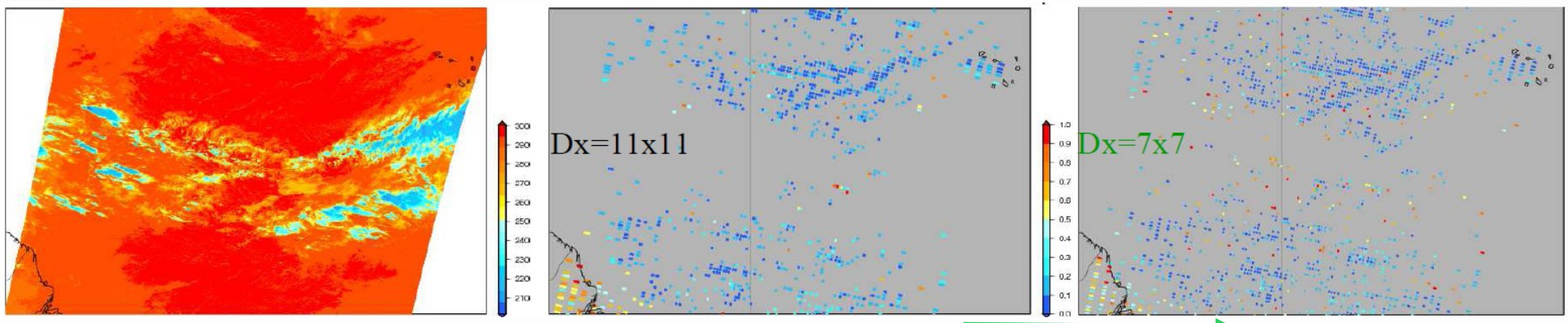
- Spectral sampling : 0.125 cm-1
- Spectral resolution : 0.25 cm-1
- Radiometric noise (see graph)
- Spatial sampling and resolution
- like IASI
  - pixel ~ 12 km diameter
  - Ground sampling 25km average



■ Goal : continuity with IASI but with significantly enhanced performances

Courtesy CNES

Pixel size: IASI-NG = IASI = 12 km at nadir



IR homogeneous pixels (where sigma < 1 K), **+25 % pixels**

Tropical Atlantic Ocean scene *Courtesy L. Lavanant, Météo-France*

More homogeneous pixels could be found with a smaller pixel.
Homogeneous scenes are easier to simulate and then to assimilate.

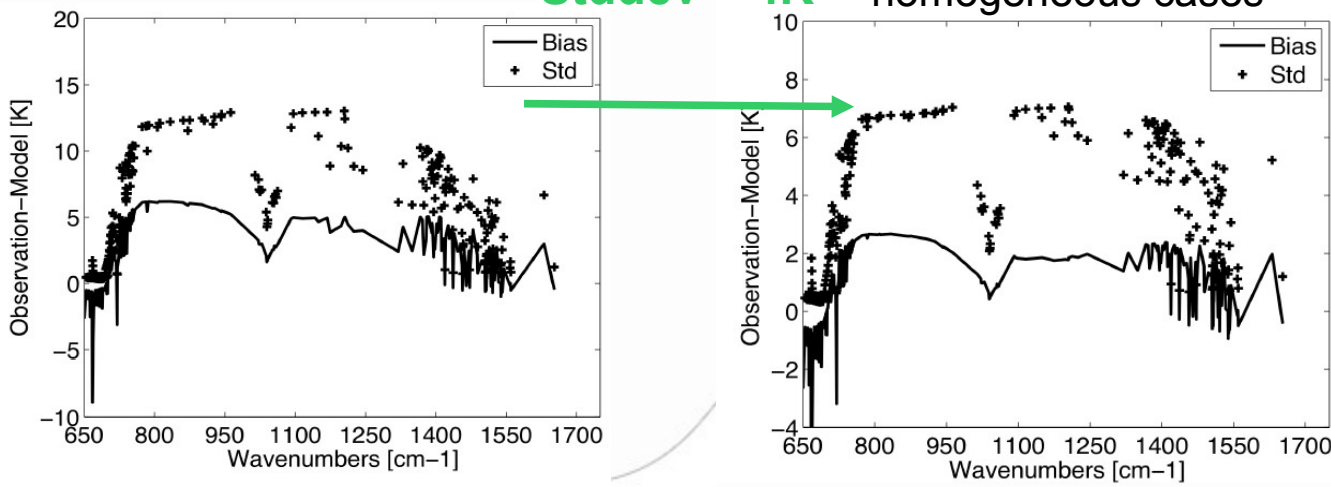
Observation – simulation using RTTOV-CLOUD (which uses model microphysics in addition to T, q profiles)

Courtesy P. Martinet, Météo-France

All cloudy cases

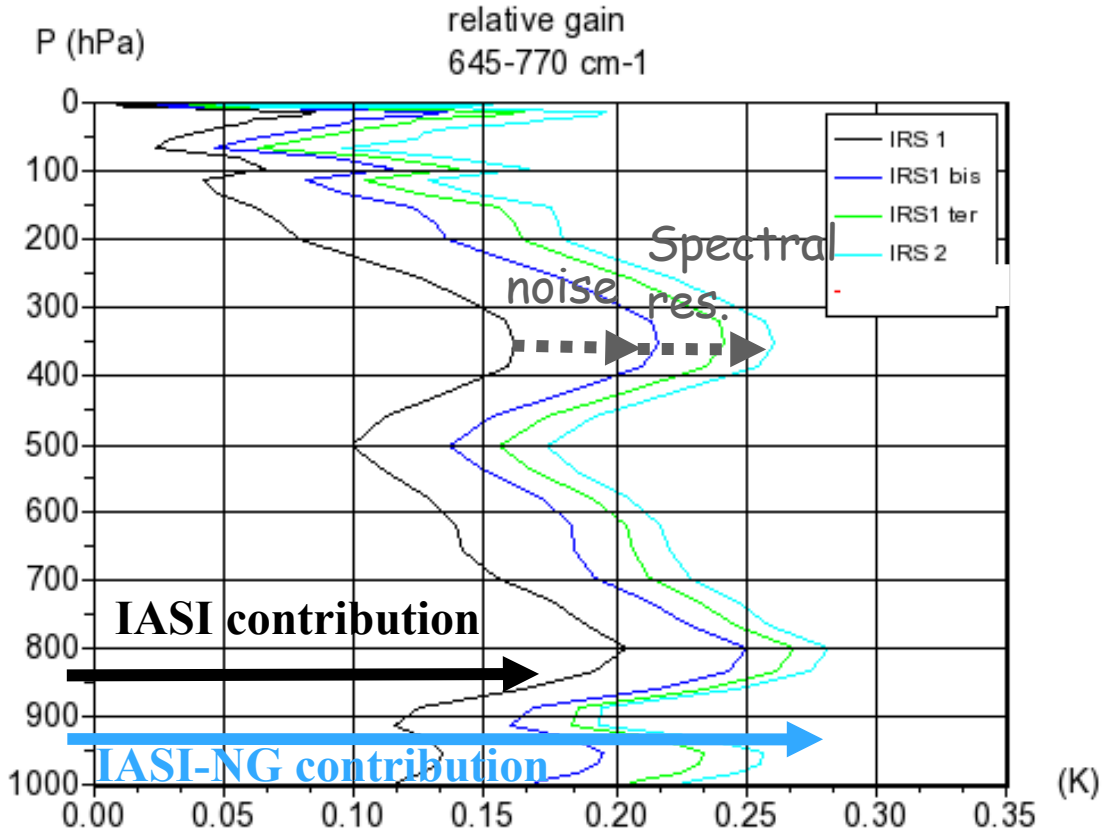
Bias / 2
Stddev – 4K

Opaque homogeneous cases



Temperature sounding: expected improvements IASI-NG *vs* IASI

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



Noise	Spectral resolution
IASI	IASI
IASI/2	IASI
IASI/(2√2)	IASI
IASI/2	IASI/2

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

Atmospheric chemistry: expected improvements IASI-NG *vs* IASI

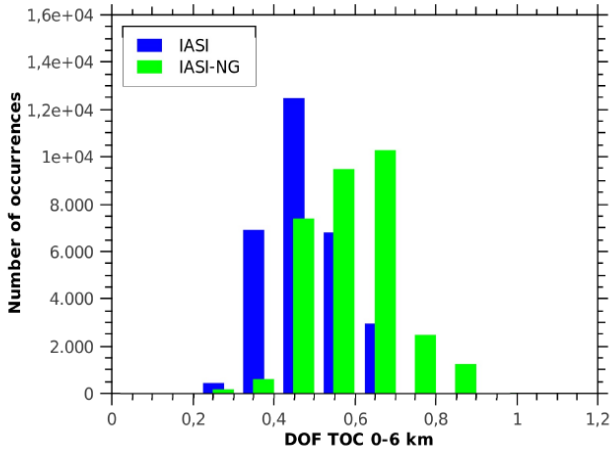
Pollution forecast

Three of the EU controlled pollutants are routinely measured by IASI: CO, O3 and NH3.

None of these data are used yet by pollution forecast regional models as they lack accuracy in the lower atmosphere.

For ozone [0-6 km]:

gain 50% info on the vertical and sensitivity
1 km lower

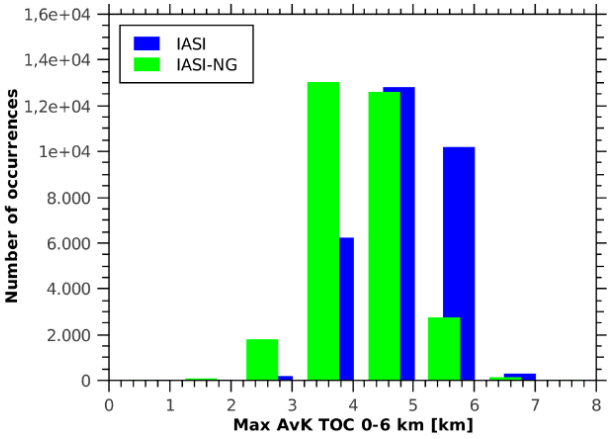


$\overline{DOF}_{IASI}$ = 0,41

$\overline{DOF}_{IASI-NG}$ = 0,62

51.2% better!

gain 30% on accuracy



$\overline{MaxAvK}_{IASI}$ = 4,2 km

$\overline{MaxAvK}_{IASI-NG}$ = 3,5 km

16,7% better!

IASI and IASI-NG pseudo-observations simulated over Europe during a 3-days period (19-21/08/09)

Courtesy G. Dufour et al., LISA/IPSL

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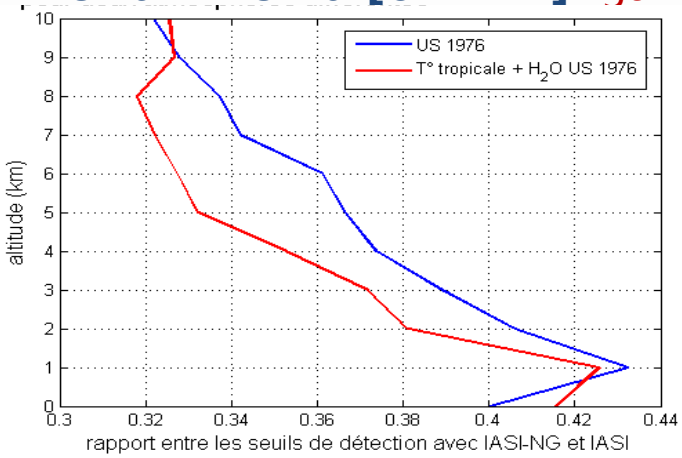
Atmospheric chemistry: expected improvements IASI-NG *vs* IASI

Pollution forecast

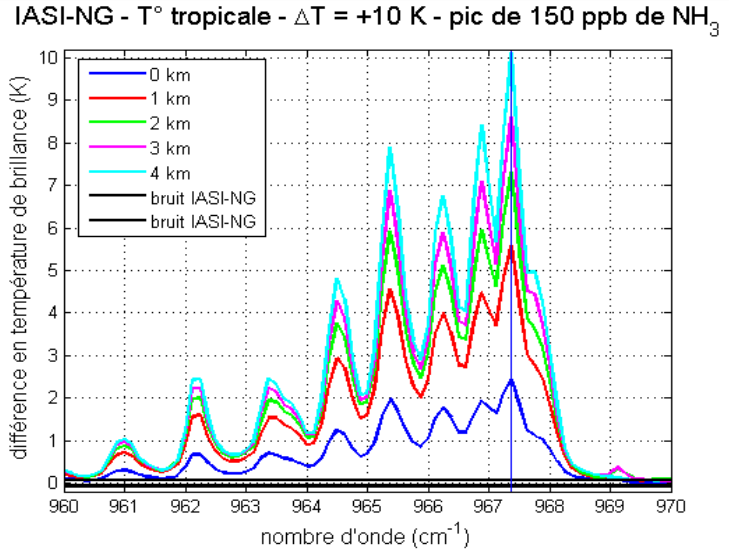
Three of the EU controlled pollutants are routinely measured by IASI: CO, O3 and NH3.

For ammonia [0-2 km]: gain 40% on detection limit



Detection limit improvement as a function of altitude (left) ; impact on brightness temperature for different altitudes compared with noise for a polluted case

Courtesy J. Hadji-Lazaro, LATMOS/IPSL.

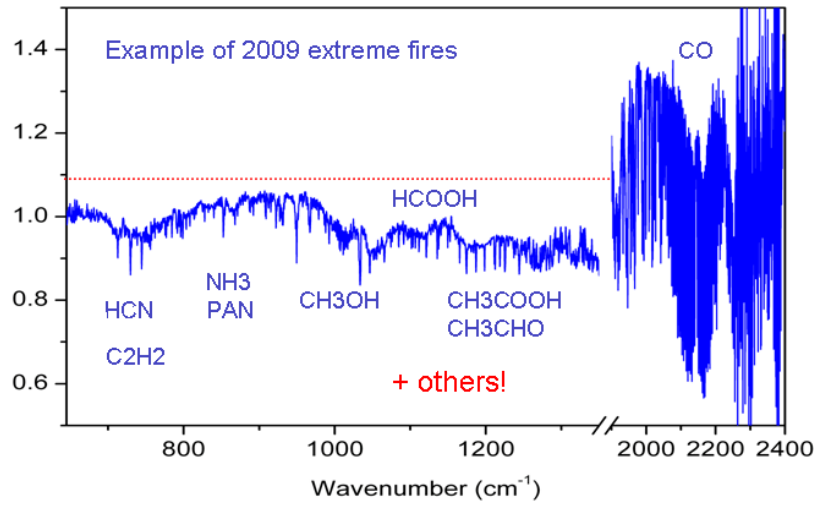


Atmospheric chemistry: expected improvements IASI-NG *vs* IASI

Fire detection

Study of transport of pollution due to fires, and composition of the fires due to different burning species

The vertical information is coarse. Most of the gases are retrieved with a large uncertainty as absorption lines are within the instrumental noise



List of species that were detected by IASI in fires:
CO NH3 PAN HONO C4H4O C2H2 C2H4 C3H6 CH3OH HCOOH CH3COOH CH3CHO SO2

For CO : More info on the vertical
For weak absorbers : improved detection limit, measured instead of detected

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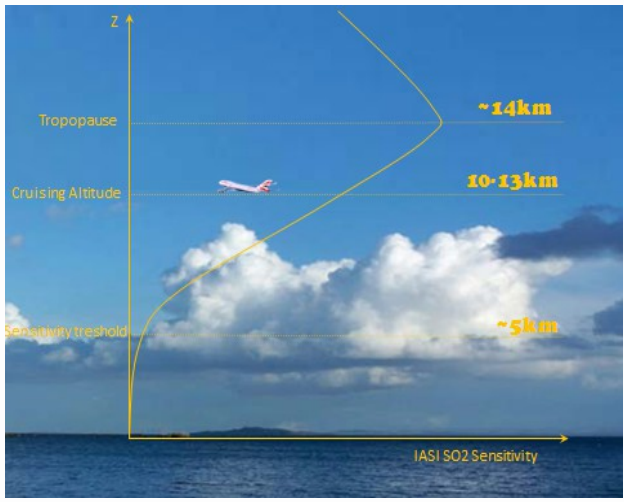
Atmospheric chemistry: expected improvements IASI-NG *vs* IASI

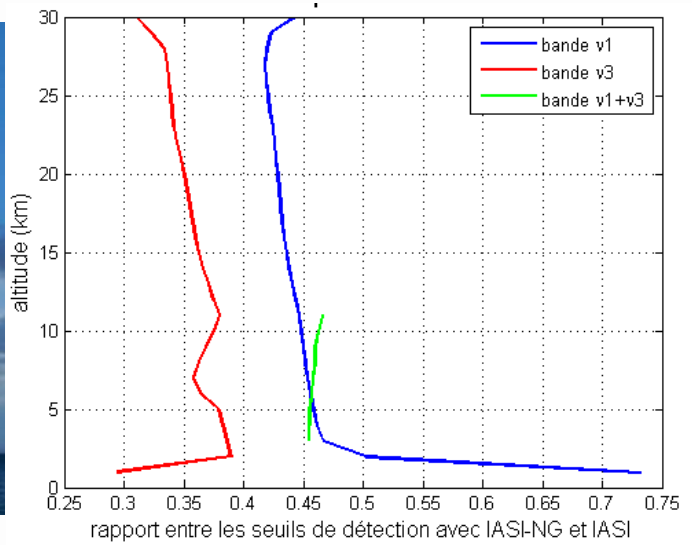
Volcanic plumes

Early alerts possible + SO2 and ash tracking

The vertical information is missing. Detection limits are still quite high (in the troposphere)



Courtesy L. Clarisse, ULB



Detection limit improvement as a function of altitude for the SO2 absorption bands
Courtesy J. Hadji-Lazaro, LATMOS/IPSL.

More species will be measured: SO2, H2S, H2SO4, ash

For SO2 : gain 45% on detection limit + some vertical information

For ash : improved detection limit

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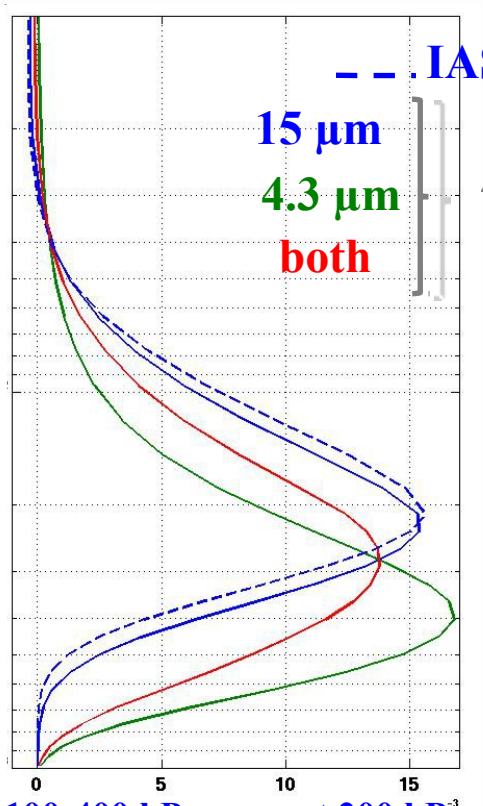
Greenhouse gases: expected improvements IASI-NG *vs* IASI

Carbon dioxide (CO_2)

Only LW (15µm) channel available with IASI.

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

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



Methane (CH_4)

Less interferences with WV and improved noise will improve the precision of the retrievals.

Courtesy C. Crevoisier, LMD

	IASI		IASI-NG		
	DOFs	***Error (%)***	***DOFs***	***Error (%)***	***What the 'NG' brings***
O_3	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_3	1 or less		2		Both tropo and strato
NH_3, C_2H_4, Methanol	detected	-	measured	-	> instrumental noise
SO_2-volcanos	If > 2DU	-	If > 1 DU	-	+ Altitude of the plume
H_2O	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_2	1 or less	~1%	1-2	<1%	Low troposphere
CH_4	1or less	~3%	1-2		Less interferences
N_2O	detected	-	measured	-	
Aerosols	dust				More types
Emissivity		0,04 @4µm		0,02 @4µm	

Courtesy C. Crevoisier, LMD

To sum up

IASI in flight until 2019 (12 y) → Continuity / follow-on is mandatory !
with same spectral range and better performances for climate, NWP and AC

In >2020, NWP and Chemistry transport models will be fully coupled to each other

- Improvements in retrievals for atmospheric chemistry will benefit to NWP models

The improved spectral resolution and radiometric noise of IASI-NG will enable :

- a better coverage of the vertical,
  especially in the lower part of the troposphere ;
- 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 retrieval of several variables will depend on / benefit from:

- the synergy between IASI-NG and other sensors onboard EPS-SG (MicroWave Sounder, Imager)
- the synergy between IASI-NG and other missions (MTG, Sentinel 5, etc.)
- spectroscopy compliable with the evolution of new generation instruments

Gains for atmospheric chemistry / climate studies are very promising


1015.
1020.
1025.
1030.
1035.
1040.
1005.
1010.
cnrs
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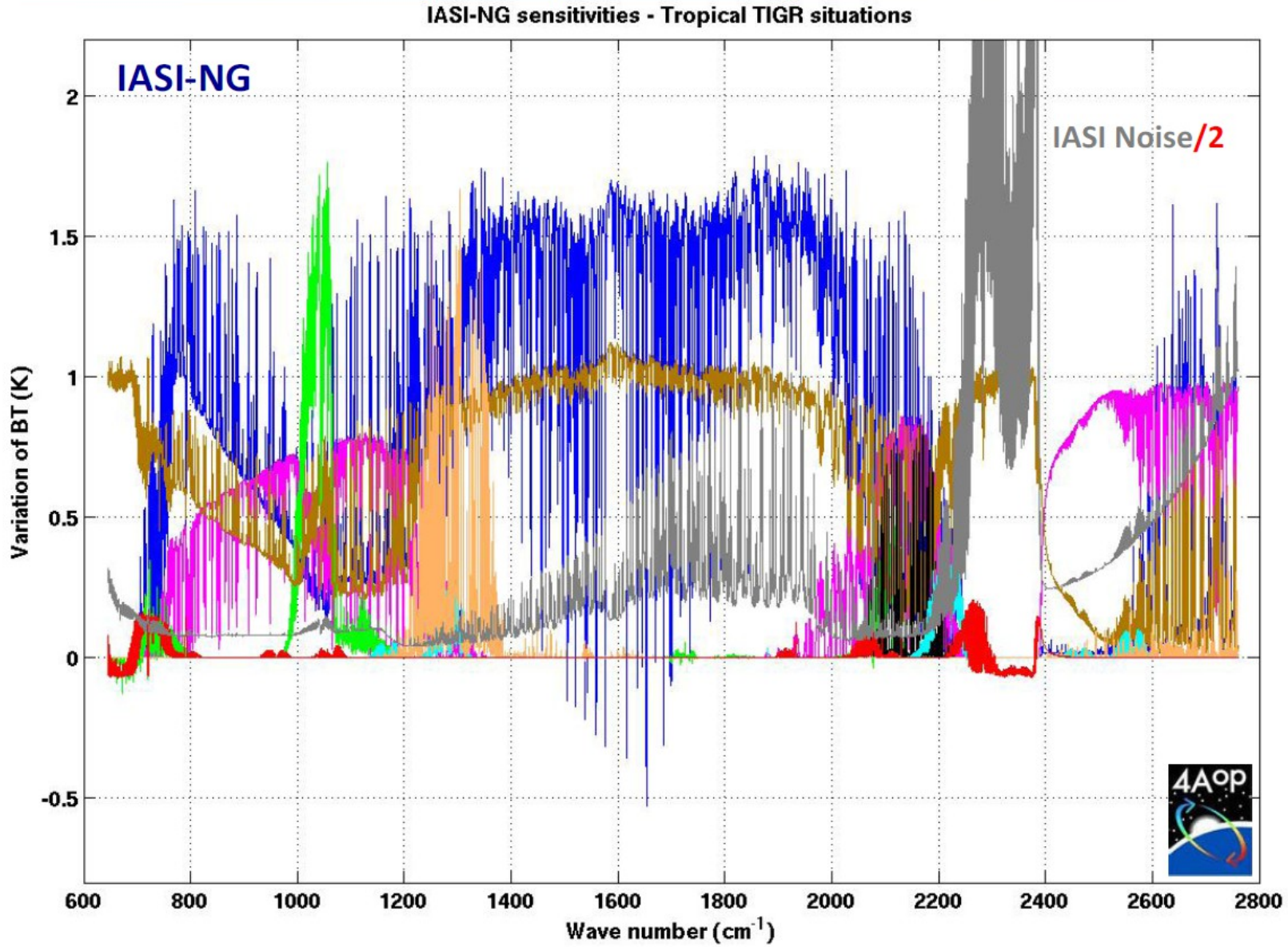
IASI-NG - Sensitivity analysis - Full spectrum with noise



Courtesy C. Crevoisier, LMD

T (1K) H_2O (20%) CO_2 (1%) O_3 (10%) N_2O (2%) CO (10%) CH_4 (10%) Tsurf (1 K)

LMD/CNRS