IASI on MetOp A : highlights on the current results

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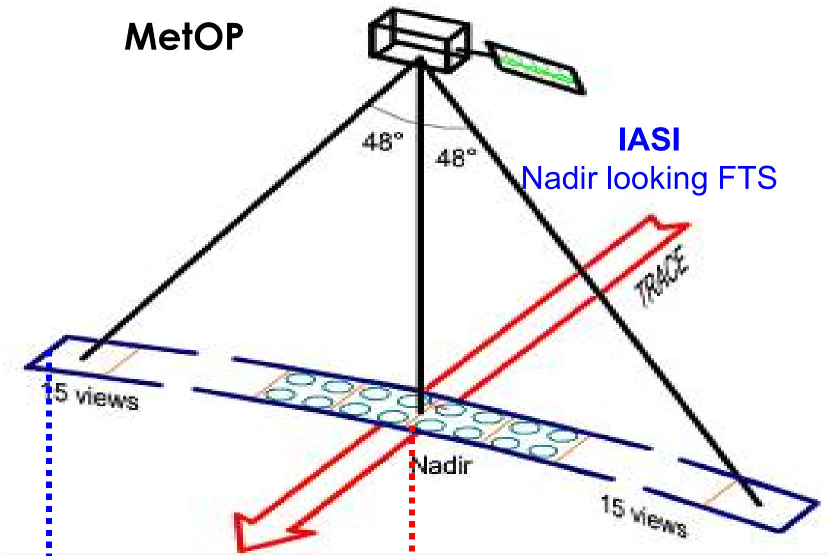
With many contributions

CENTRE NATIONAL D'ÉTUDES SPATIALES

Outline

- **IASI description**
- **IASI performances**
- **Impact on NWP**
- **Products**
  - Temperature and humidity profiles
  - Surface Temperature and emissivity
  - Clouds
  - Aerosols
  - Emissions: NH_3, biomass burning emissions (methanol, formic acid, etc.)
  - Transport O_3, CO, HNO_3, Ash
  - Ozone Columns and Profiles
  - CO for GEMS-MACC
  - GHG : CO_2, CH_4, N_2O, CFC
- **Conclusions**

IASI instrument and observing mode

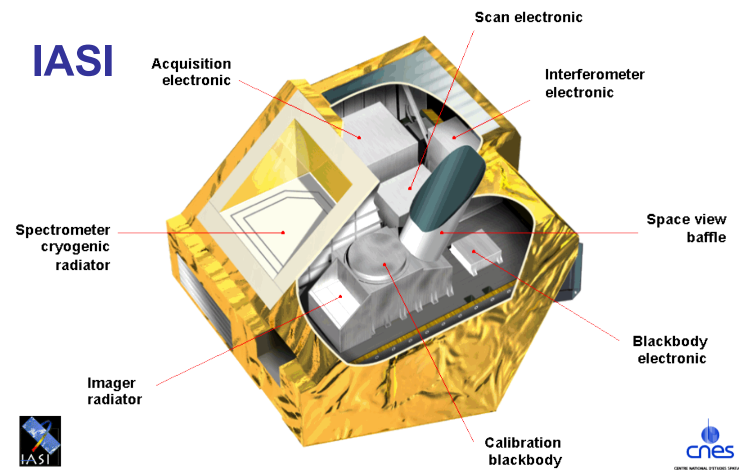


- 12 km pixel x 4 @ nadir
- 120 spectra along the swath (±48.3° Scan →2100 km), each 50 km along the track

Small ground pixel size

Global coverage twice daily
(morning and evening orbits)

MetOp: First European meteorological platform on polar orbit (EPS system) **launched by Eumetsat** & IASI built by CNES.



- Spectral coverage = 645-2760 cm^{-1}
- Spectral resolution = 0.5 cm^{-1}
- Radiometric noise ~ <0.1-0.2 K

Broad spectral coverage without gaps

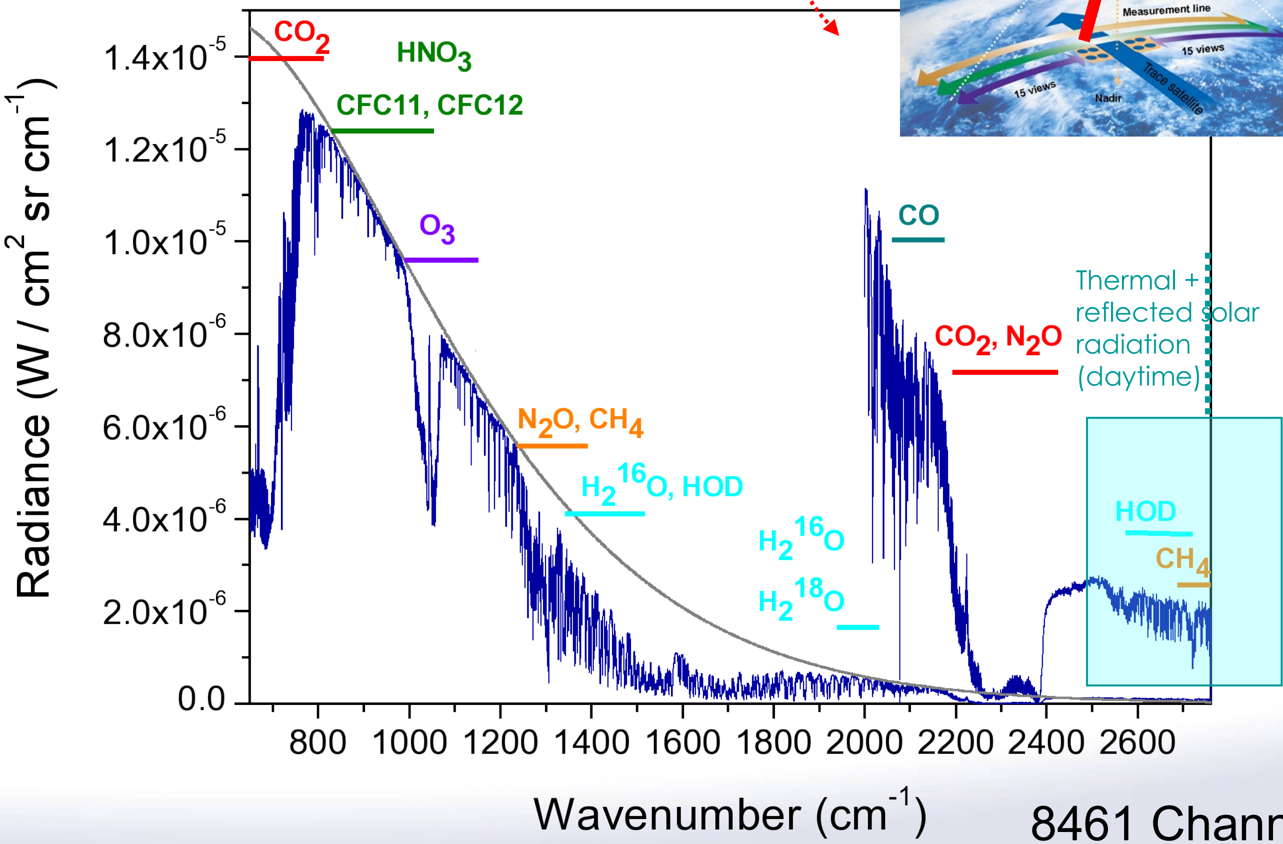
Medium spectral resolution

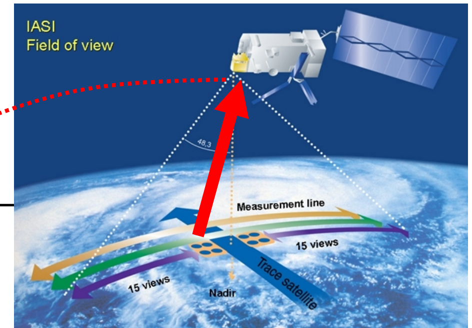
High radiometric performances

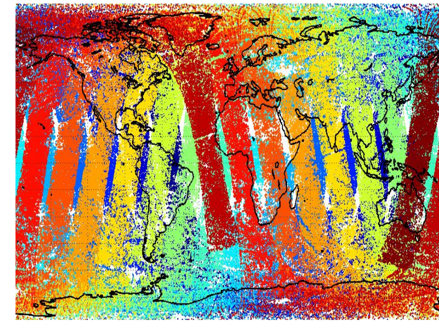
IASI instrument and observing mode

Level 1 radiance spectrum

LATMOS/CNRS – ULB



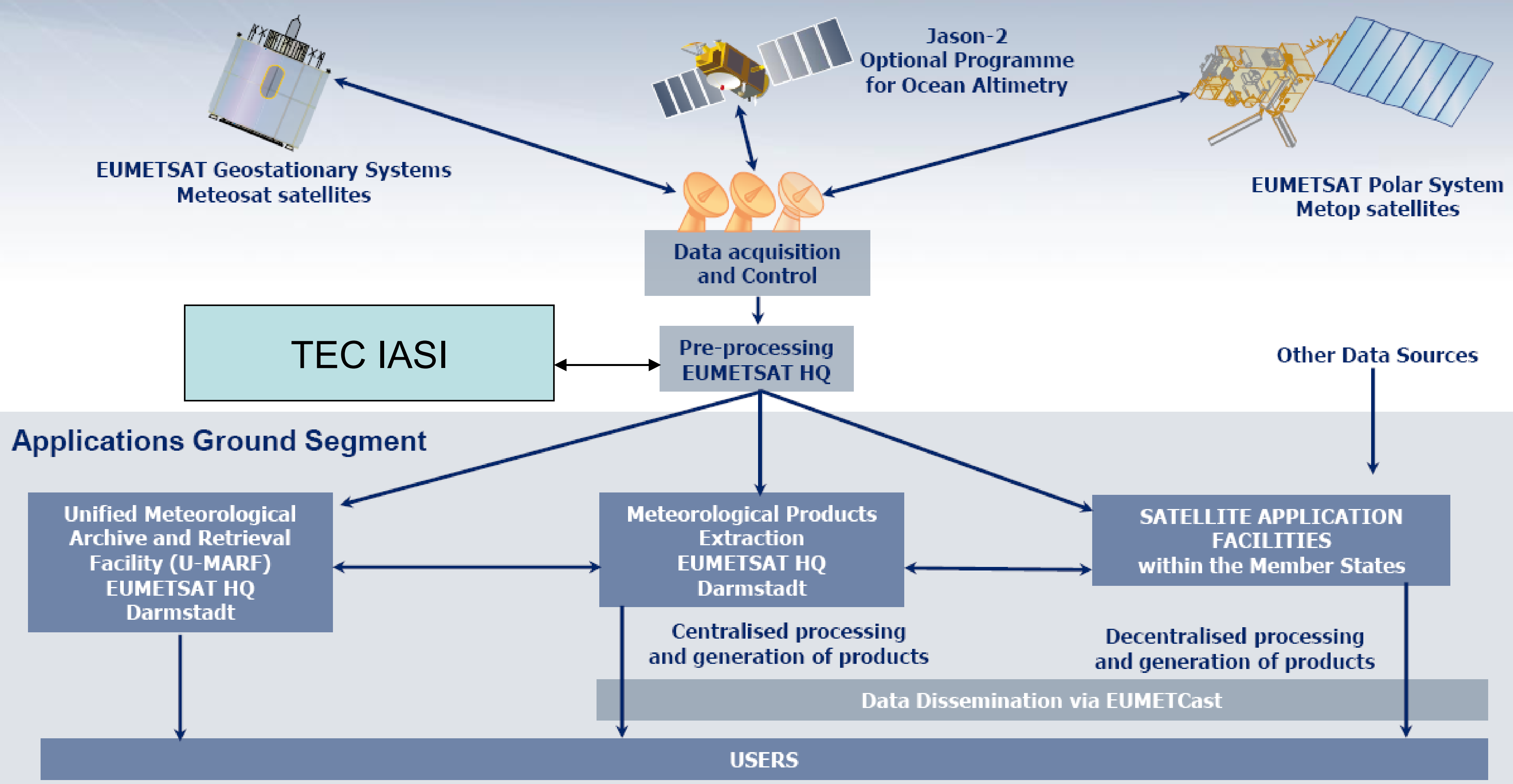




1.3 10⁶ spectra (16 Gb)
Global coverage 2 x day

8461 Channels

Overview of the EUMETSAT Ground Segment



EPS Milestones

2010-2012:

- Metop-B TV-test and launch preparations
- Preparation of the EPS ground segment to support 2 Metop satellites in parallel
- Launch of Metop-B in March 2012 from Baikonour

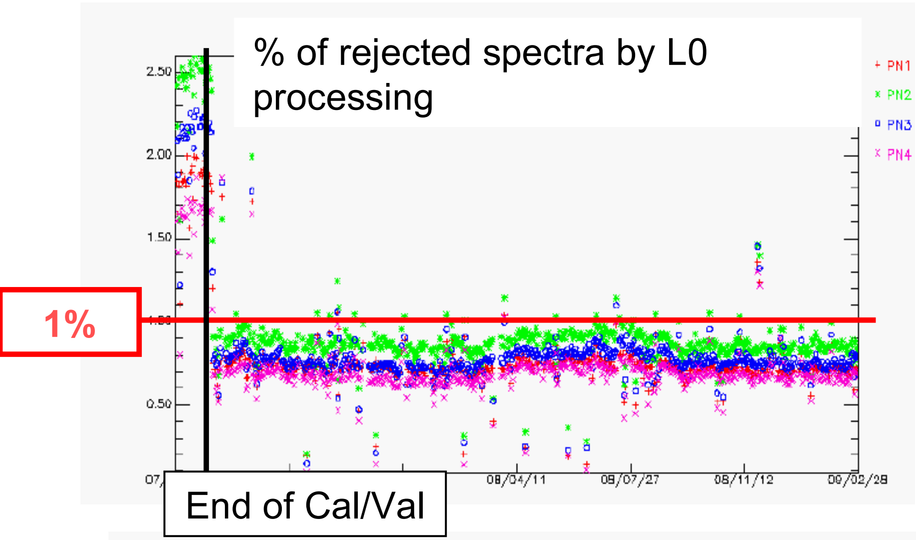
2016

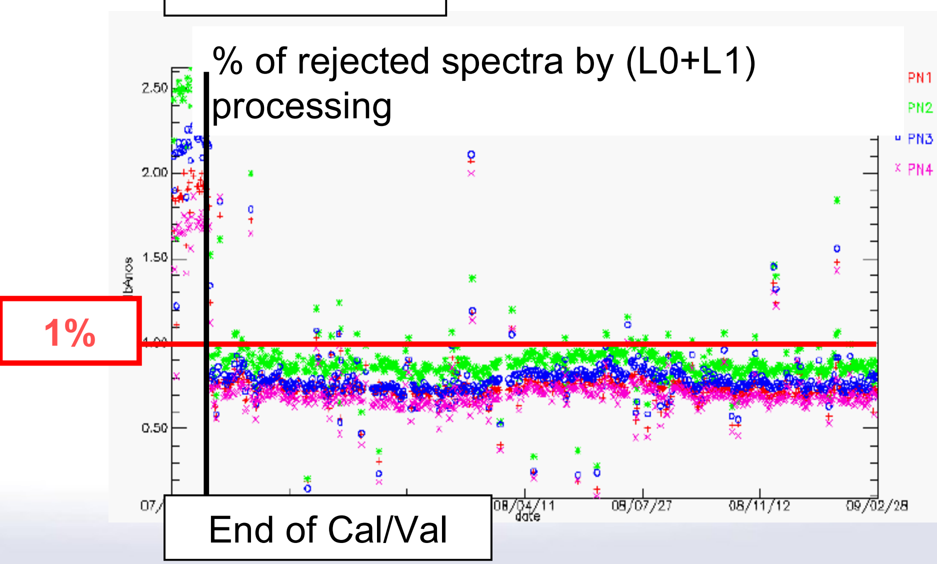
- Launch of Metop-C

IASI Performances monitoring

- TEC (CNES Toulouse): designed and developed Level1 processing, carried out commissioning, monitors instrument and software performances and proposes actions. Periodic meeting with Eumetsat
- Eumetsat : in charge of command/control (change of parameters), runs level1 (and 2) processing. Monitoring of level1 spectra
- End users : feedback on data quality

Overall quality of L0/L1 data





	PN 1	PN 2	PN 3	PN 4
Total % of rejected spectra	0.83	1.01	0.88	0.77
% of rejected spectra by L0 processing (on-board)	0.81	0.99	0.86	0.75

- Main contributors : spikes in B3 (0.55%), NZPD detection failure (0.15), Radiometric calibration failure (0.02%), Over/Underflows (0.02%)
- In NOp, 99% of good quality spectra
- Ground segment is very reliable

Stable since end of Cal/Val

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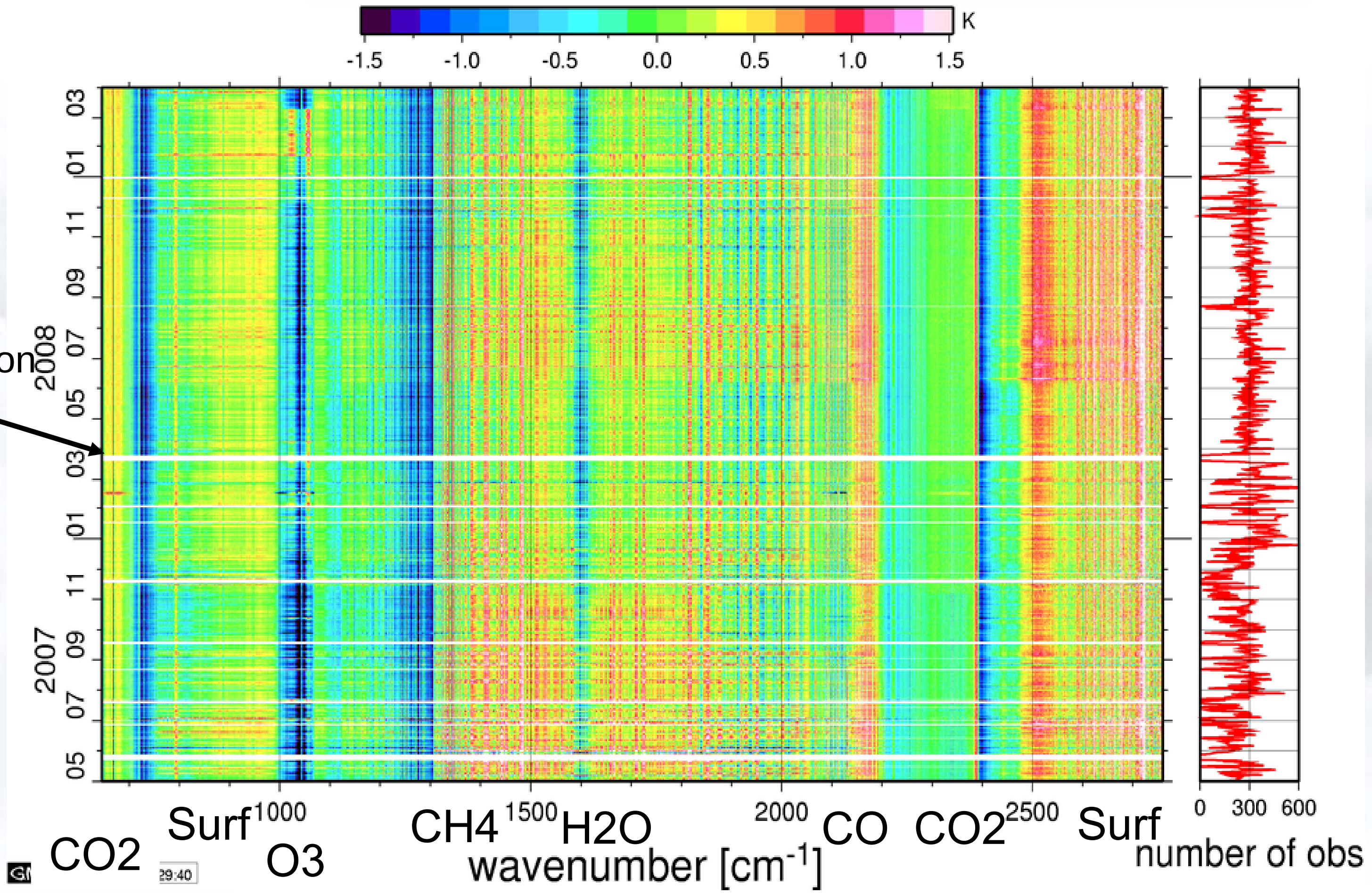
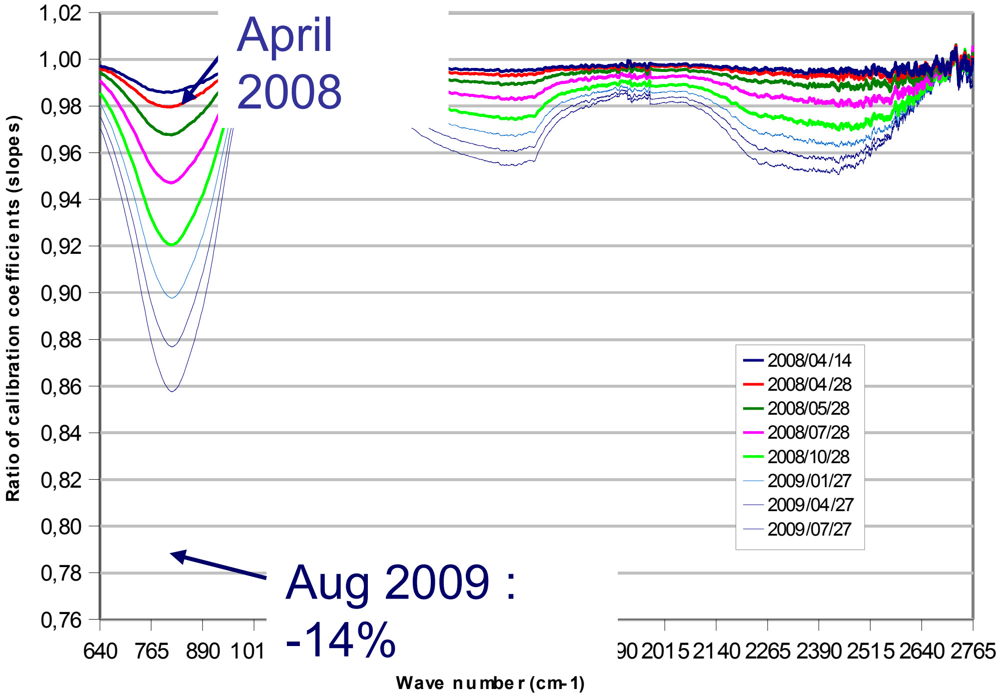
IASI RM: OBS-CALC – Radiance Difference 24h avg

IASI Decontamination

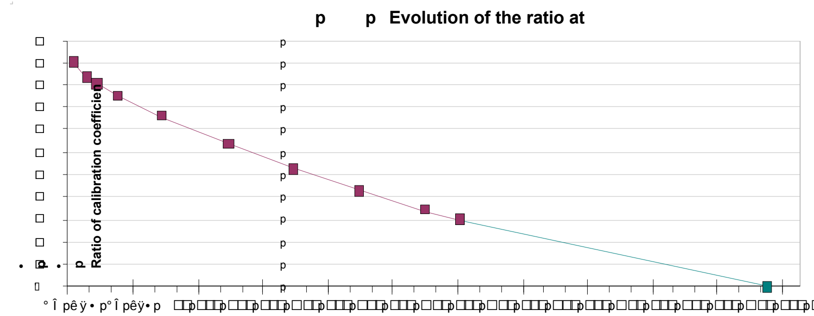


Instrument transmission since last decontamination (March 2008)

Instrument transmission evolution



Next decontamination

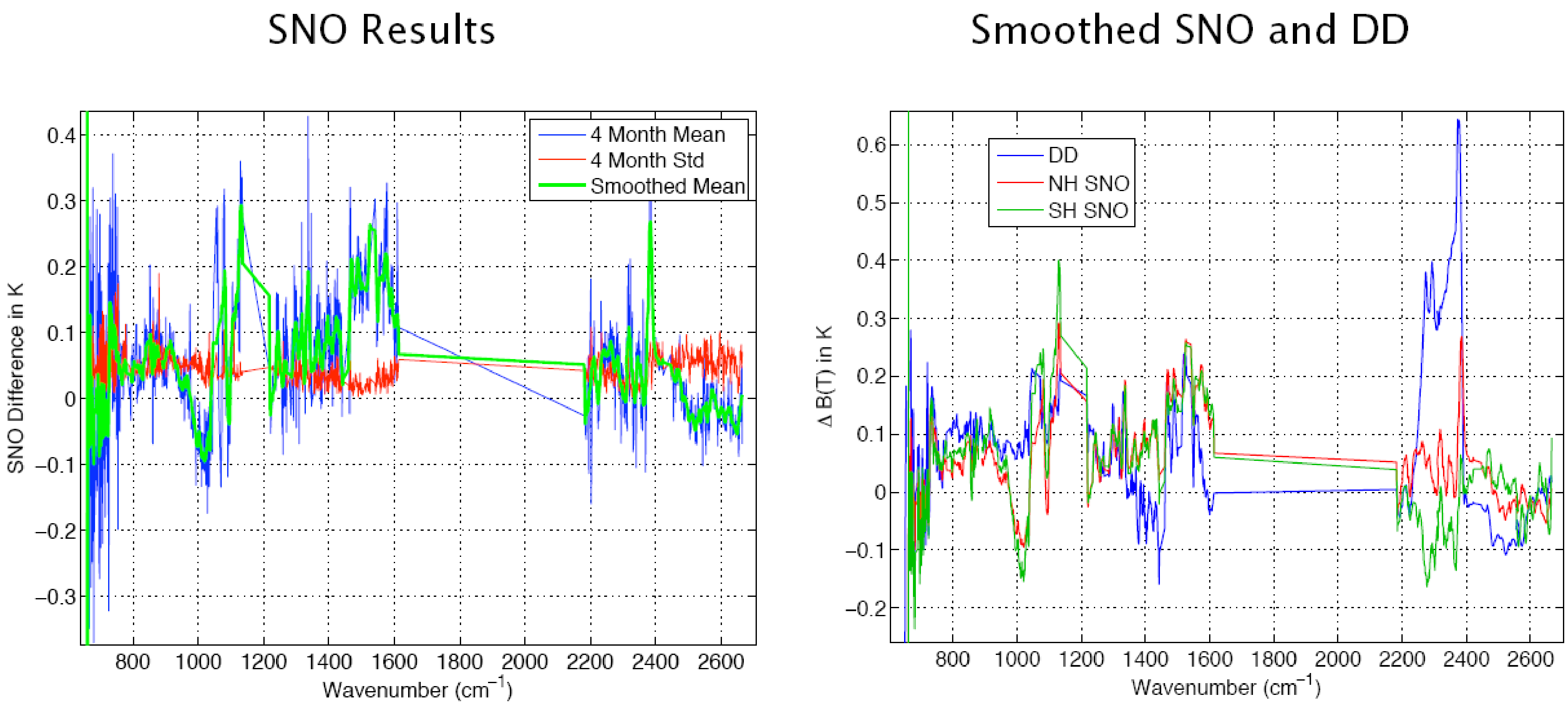


- **<u>Criteria :</u> maximum noise increase of 20% (= transmission loss of 20%)**

- **<u>Last IASI decontamination :</u> 21-24th March 2008 (1.5 year after launch)**

- **<u>Next one :</u> End of 2010**

Double-Difference versus SNOs



Longwave SNOs smaller than DD, DD spectra have more contrast
SNO and DD agree to ~ 0.1K or better *except* near 1000 cm^{-1}
1000 cm^{-1} disagreement may be AIRS scene dependent polarization

ASL

Conclusions

- ✓ After 36 months in orbit
  - **IASI is performing very well**
    - **no redundancy used**
    - **all mission requirements are met : both instrument and processing**
    - **the instrument is extremely stable : radiometry, spectral, geometry**
    - **mechanisms (Cube Corner, Scan) show no evolution in orbit**
    - **radiator (passive cooling) show no evolution in orbit**

- ✓ During the routine phase, IASI Technical Expertise Center (IASI TEC in CNES premises in Toulouse) takes care of :
    - In-depth Performance monitoring, Processing parameters updating

- ✓ In parallel with the operational monitoring performed by the EUMETSAT EPS/CGS teams :
    - Near Real Time PDU analyses, Radiance monitoring

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NWP

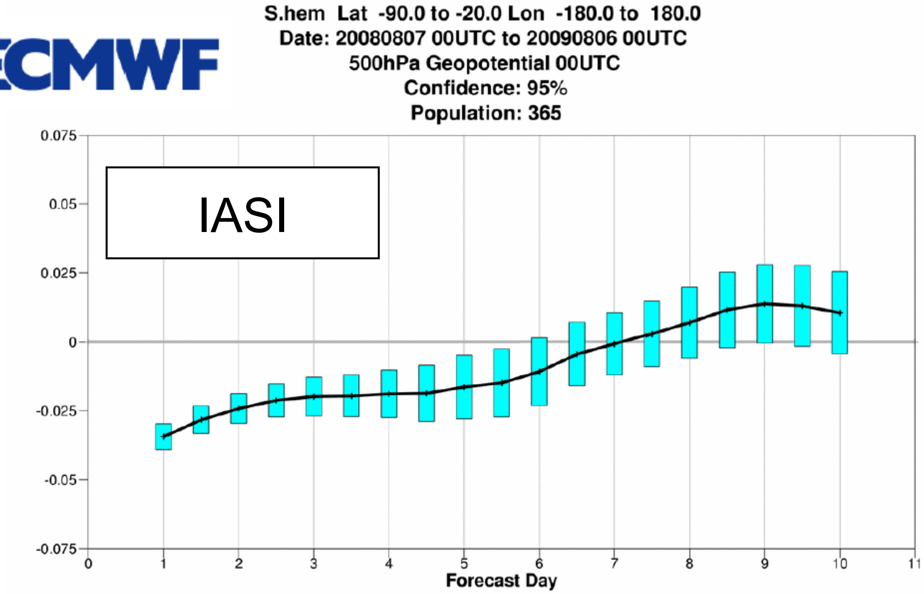
Summary of models and data usage

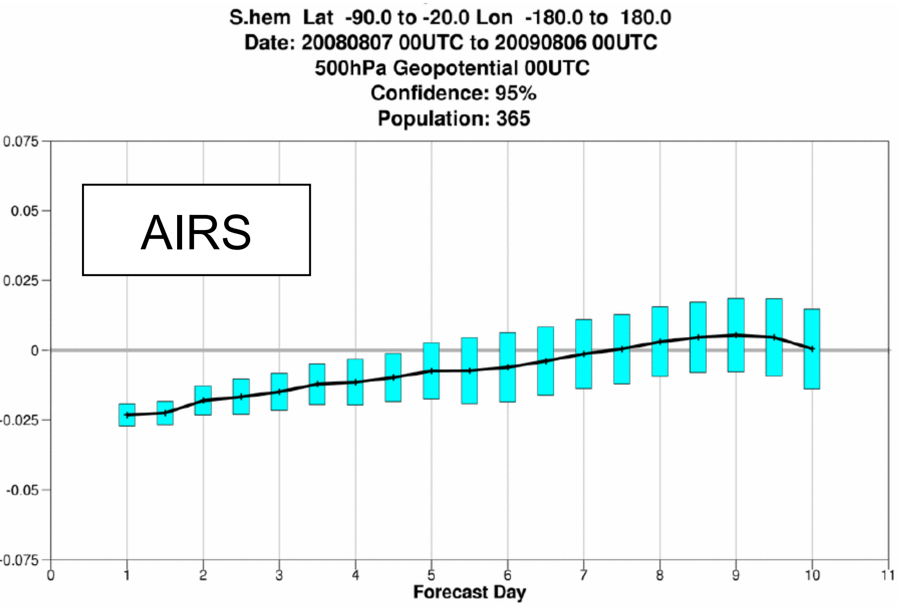
Testing Operational

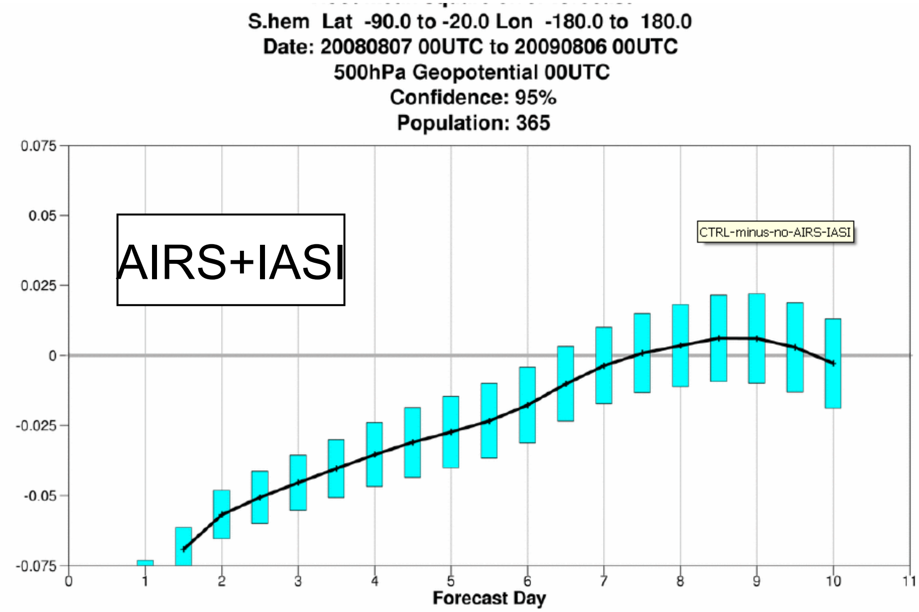
	Model	Domain	Model Top/ N Levels	Horiz. Resn.	Assimilation System	Bias Correction
Met Office	Global NAE UK4/UKVD	Global N Atlantic & Europe UK	80km/L70 39km/L38 40km/L70	~60km ~12km 4/1.5km	4D-Var 4D-Var 3D(or4D)-Var	Harris&Kelly Harris&Kelly Harris&Kelly
Météo-France	ARPEGE ALADIN AROME	Global W Europe France	0.1hPa/L60 0.1hPa/L70 1hPa/L60	10-60km 7.5km 2.5km	4D-Var 3D-Var 3D-Var	VarBC VarBC VarBC
ECMWF	Global	Global	80km/L91	~25km	4D-Var	VarBC
DWD	GME COSMO-EU	Global Europe	10hPa/L60 20hPa/L40	40km 7km	3D-Var Nudging	Harris&Kelly Harris&Kelly
met.no	HARMONIE	N Pole & Europe	0.2hPa/L60	11-16km	3D-Var	VarBC
NCEP	GFS NAM	Global Regional	0.27hPa/L64 2hPa/L60	~35km 12km	3D-Var 3D-Var	VarBC VarBC
Env. Canada	GEM	Global	0.1hPa/L80	~33km	4D-Var	Dynamic, self-updating “H&K-like”
NRL	NAVDAS-AR	Global	0.4hPa/L42	~55km	4D-Var	Harris&Kelly

Global NWP

Impact of IASI data



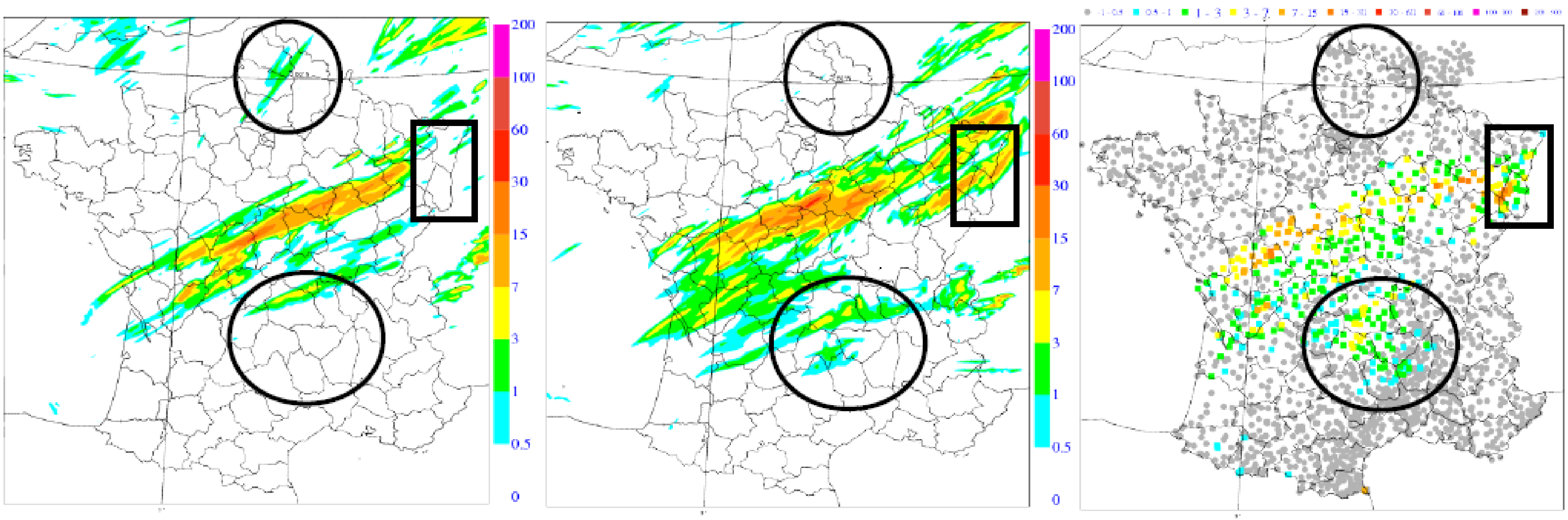




2. Impact of IASI when preparing next operational of AROME

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

12h forecast range



Reference: no IASI **First step: IASI 125km** **Verif.: Rain gauges**

METEO FRANCE
Toujours un temps d'avance

Impact on forecasts

- Impact in global models is very positive, even on top of ATOVS and AIRS
- More impact in Southern Hemisphere
- All variables are improved (each with a different amplitude)

- Impact in limited-area models
  good for upper-air fields (from geop. to wind)
  precipitation forecast somewhat improved

Issues & Areas of research

- Usage of water vapour still far less than we expected
- Description / retrieval of surface parameters is a keypoint for a wider usage over land / sea-ice
- When assimilating cloud-affected radiances, interaction with model microphysical variables is an ultimate goal
  - moving forward aerosol-affected radiances
- Statistics used in the assimilation can be improved: background and observation error covariance matrices

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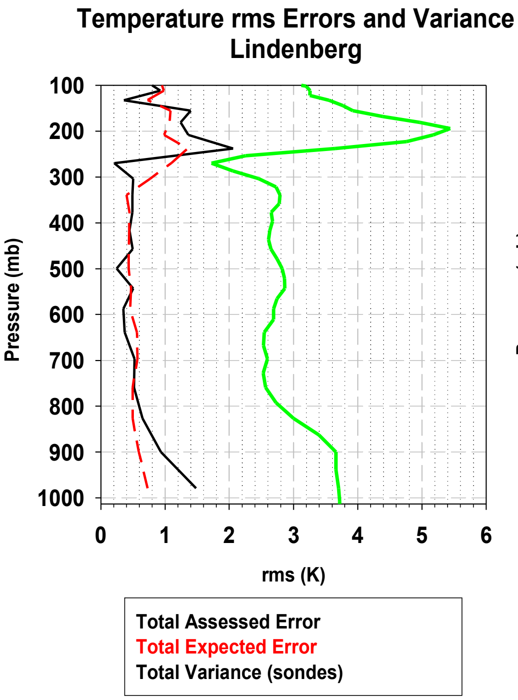
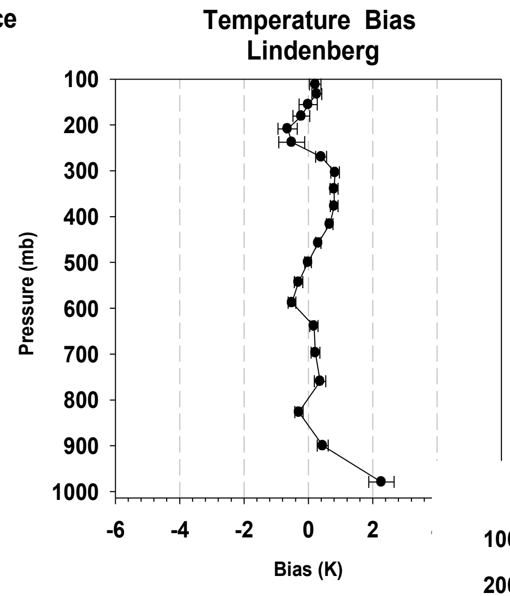
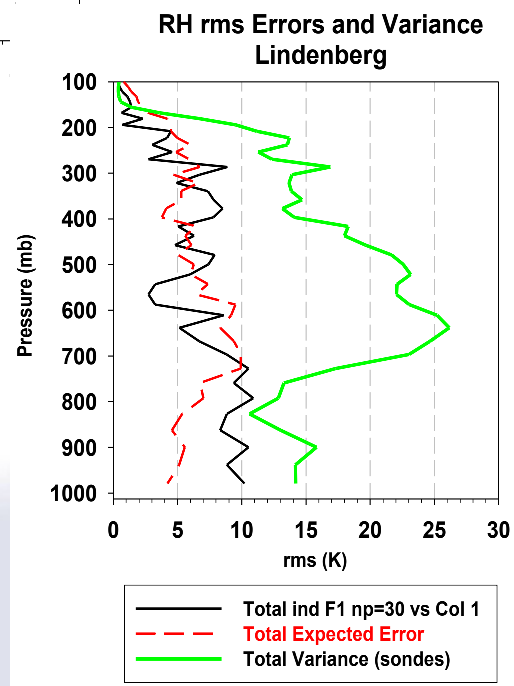
TEMPERATURE AND HUMIDITY PROFILES

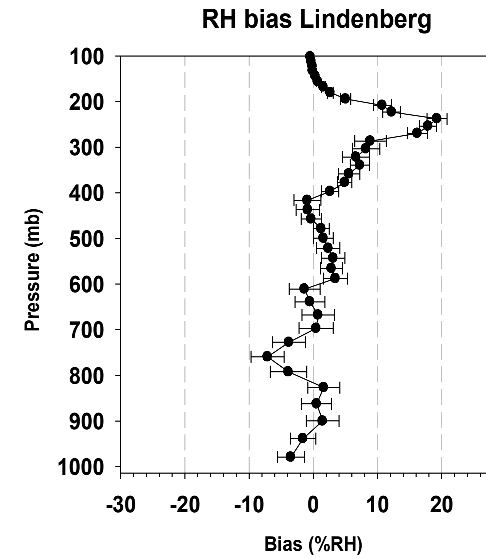
atmospheric temperature



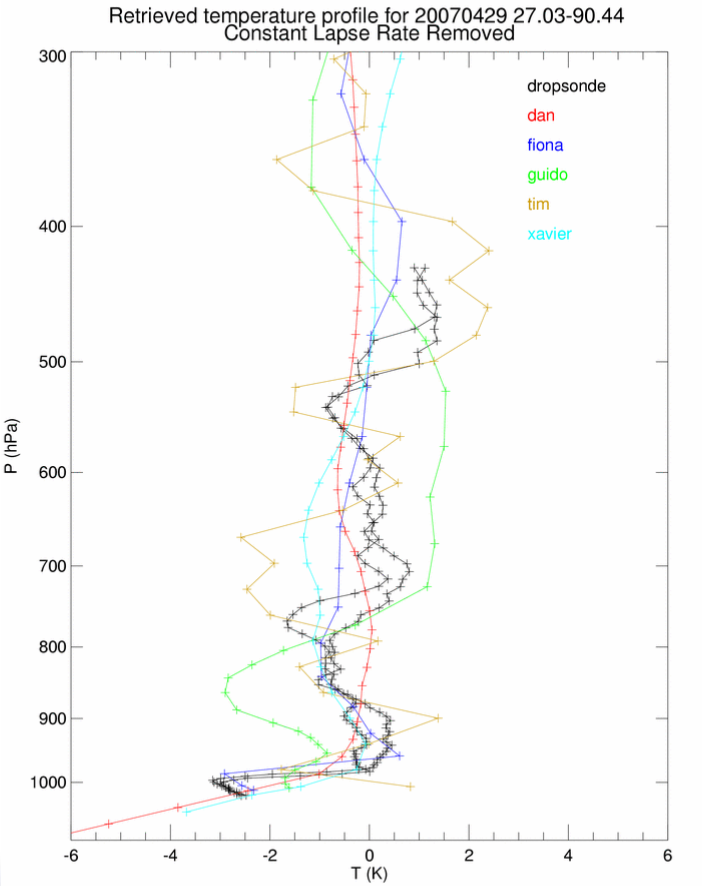


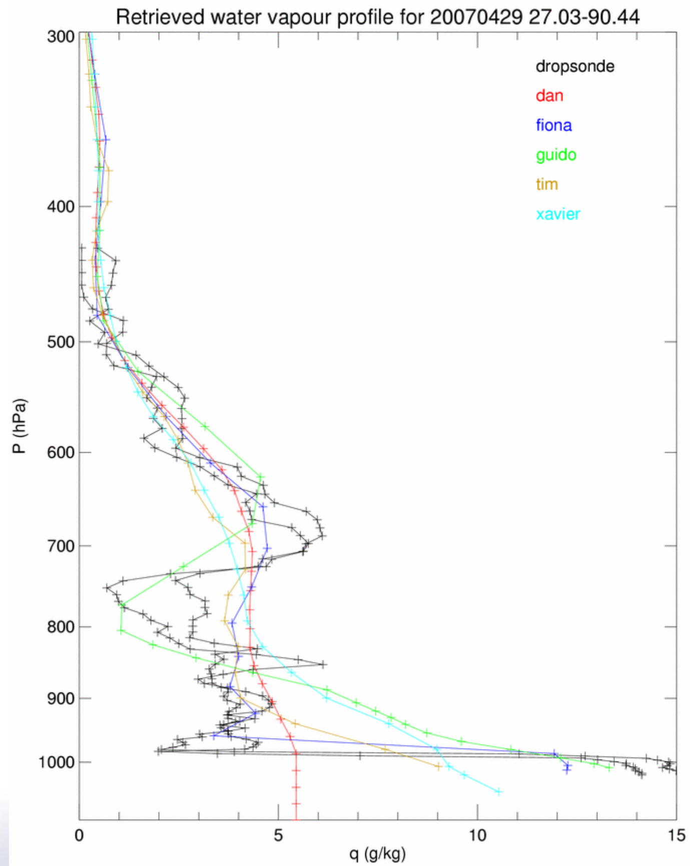
atmospheric water vapour





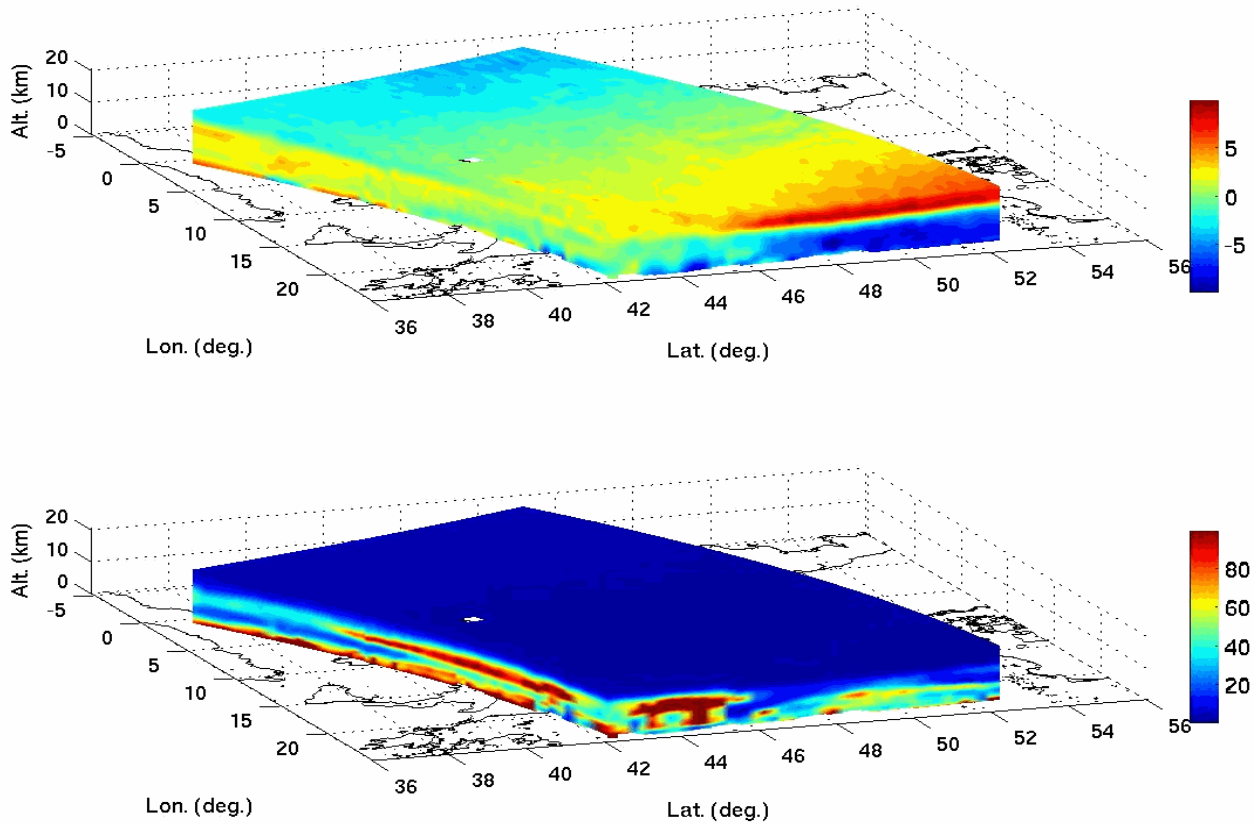
29/04/07 Case Study – JAIVEX campaign
27.03 -90.44



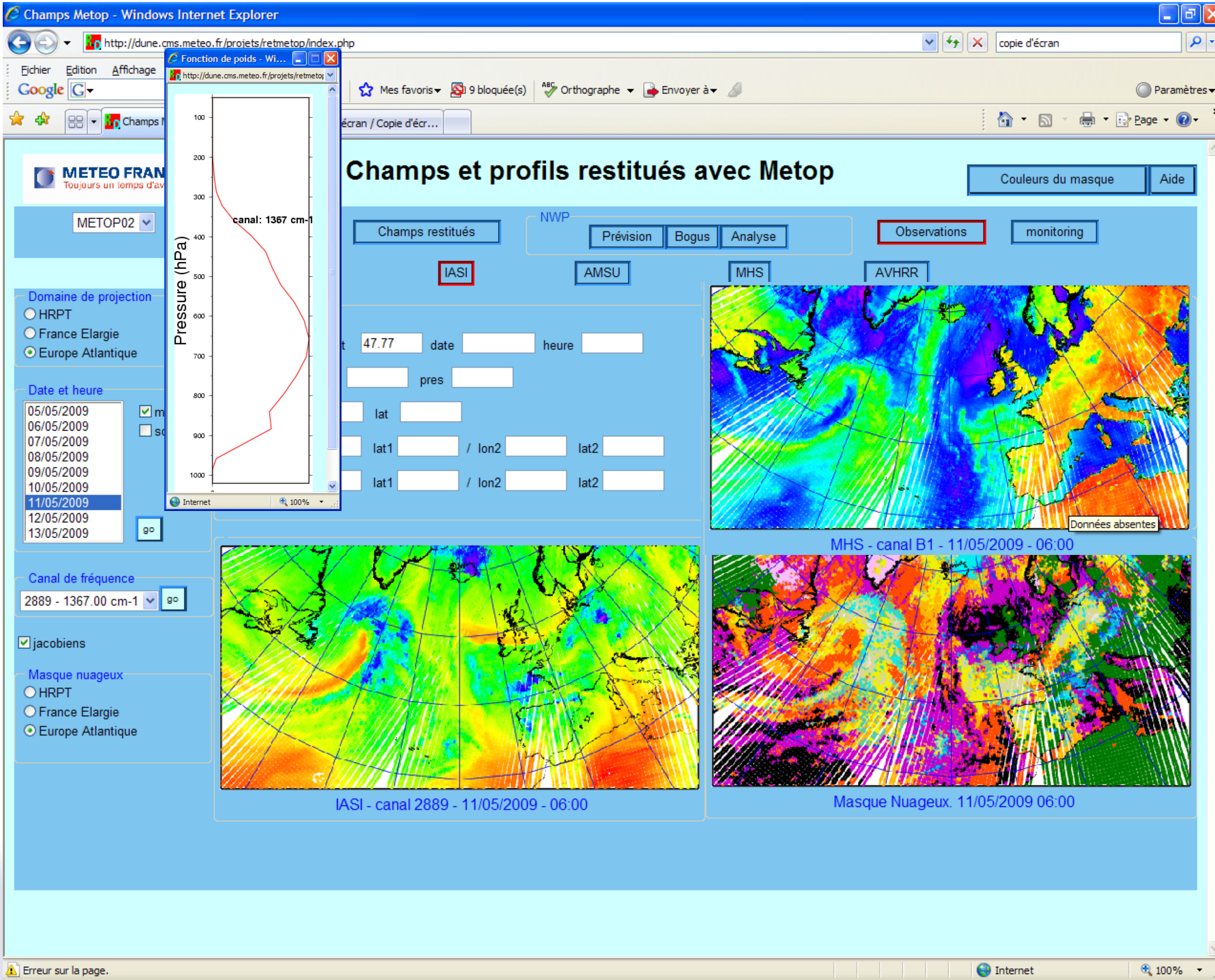


3-D Atmospheric Temperature, H_2O, O_3, and CO Structure over France

- A movie showing IASI T, H_2O, O_3, and CO cross-sections on November 4, 2007
  - T and H_2O as a function of altitude
  - T and H_2O along satellite track
  - T and H_2O x-track
  - CO and O_3 as a function of altitude



Thanks to Xu Liu, CIMSS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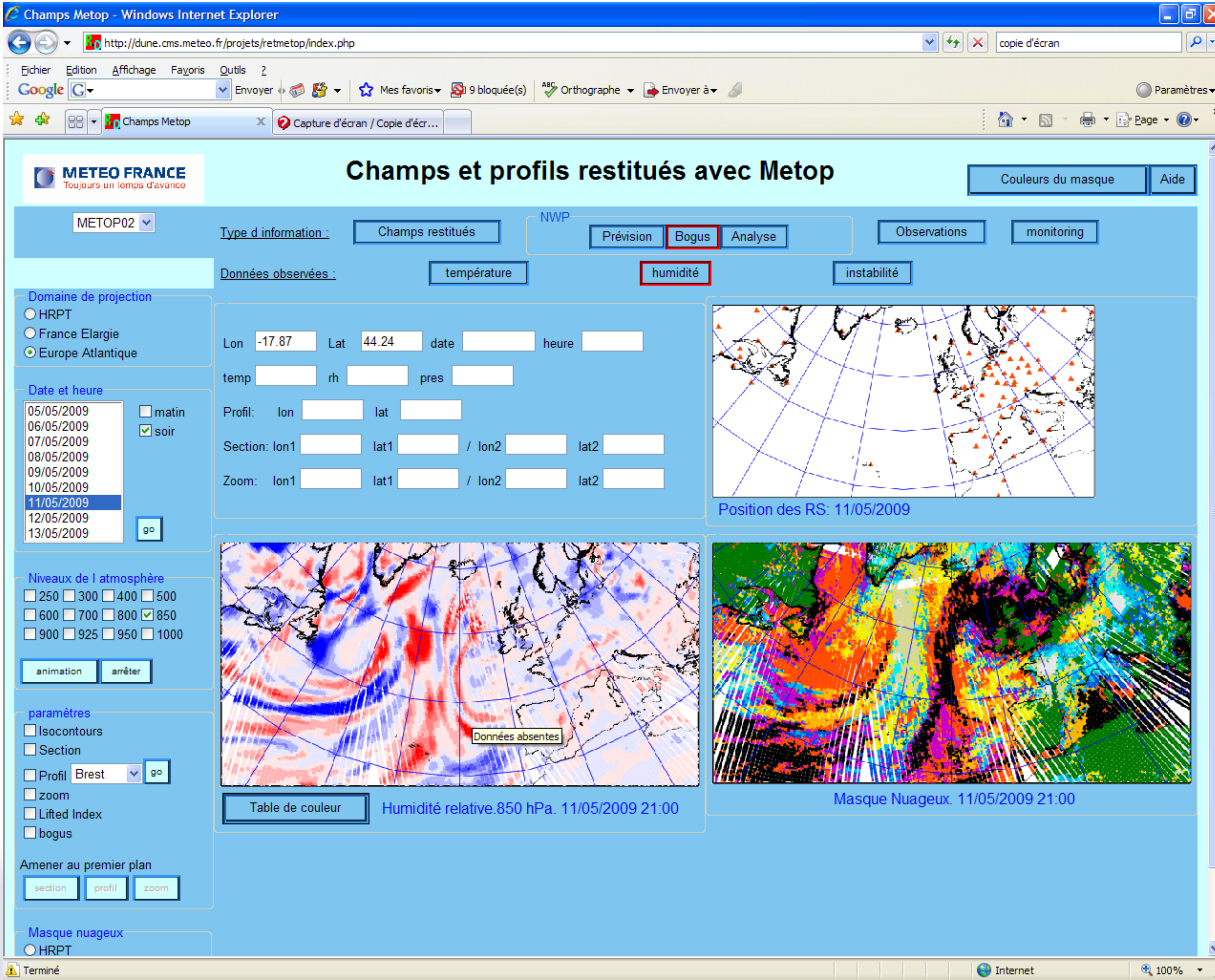
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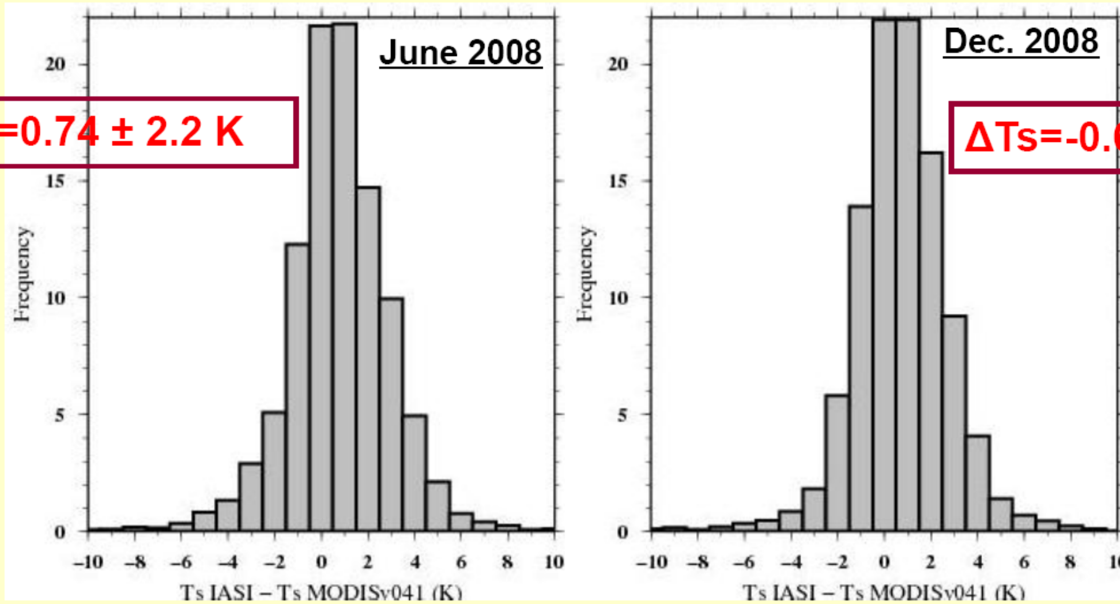
SURFACE TEMPERATURE AND EMISSIVITY

Estimation of TS: comparison with MODIS

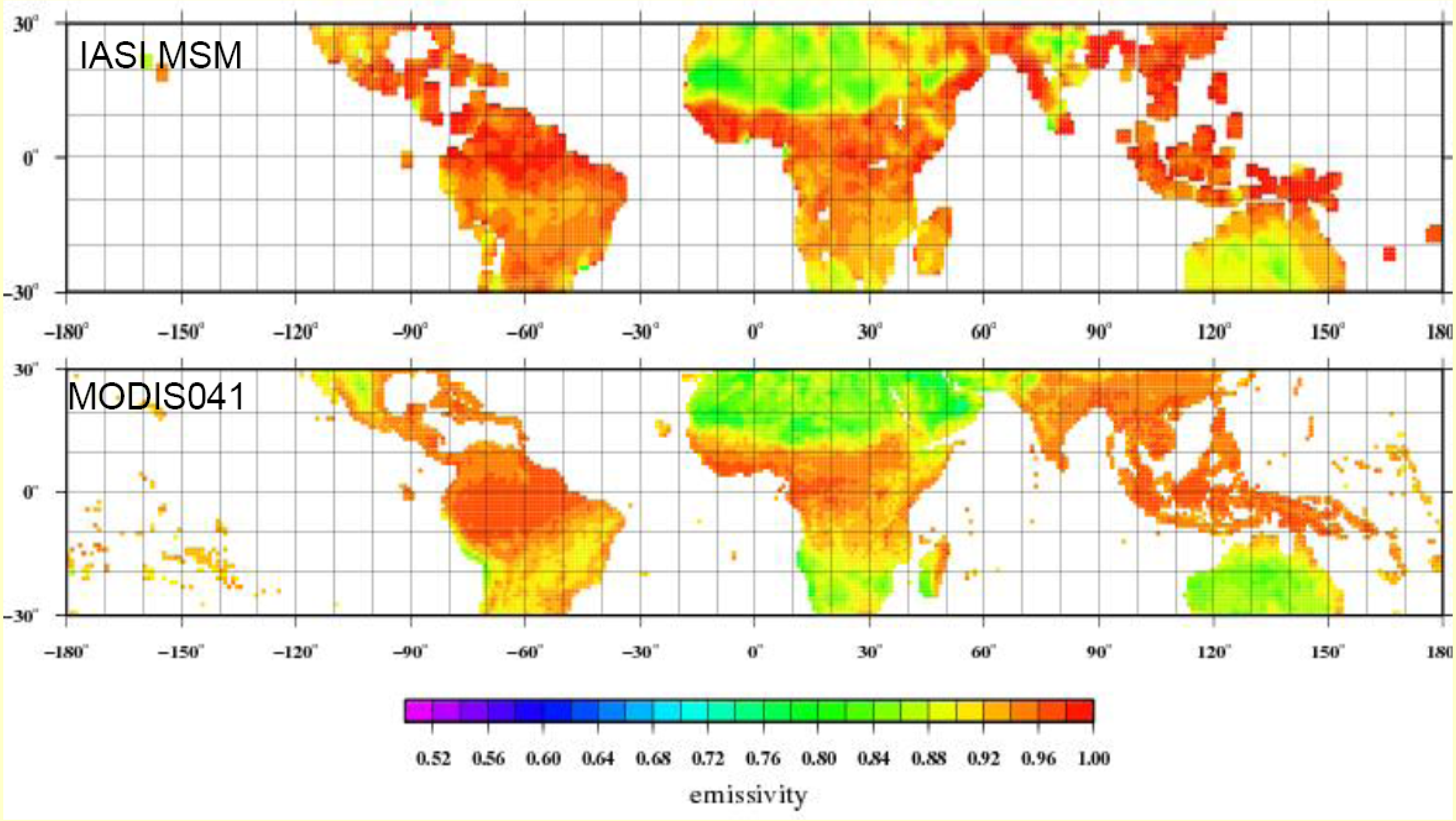


ΔTs=0.74 ± 2.2 K

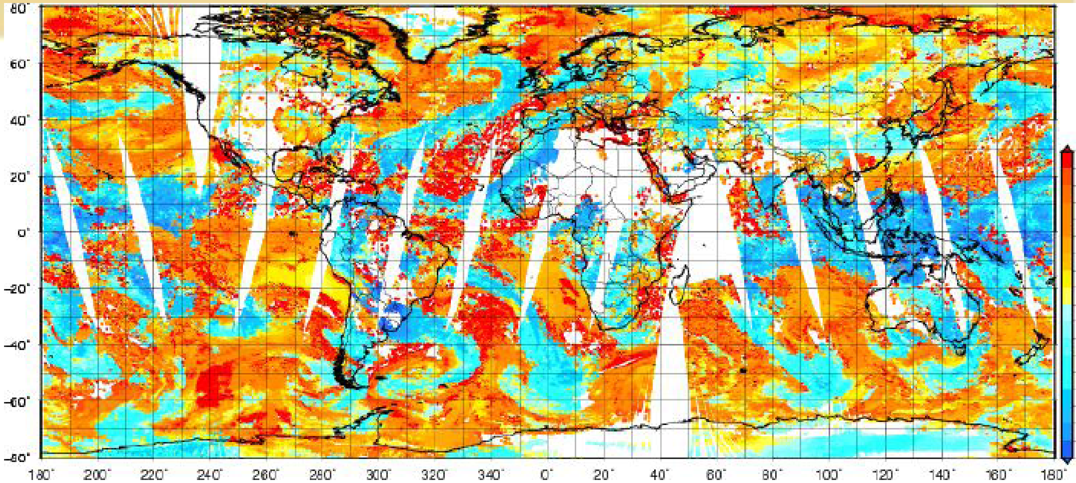
ΔTs=-0.69 ± 2.1 K

- **Values consistent with reported errors on Ts found in the literature.**
- **Bias : keep in mind the 1 hour time shift between IASI and TERRA (21h30 .vs. 22h30).**

Map of emissivity at 4.05 microns for IASI and MODIS041 for June 2008

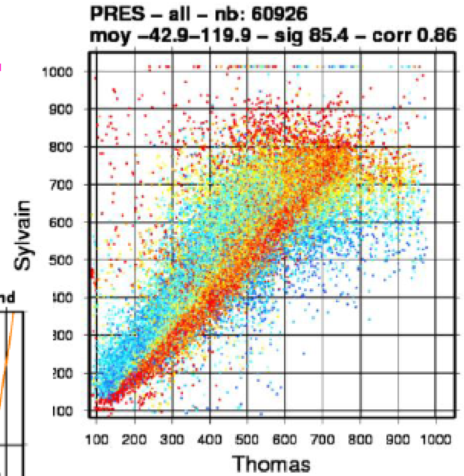


Comparison of MetOp IASI Cloud Products



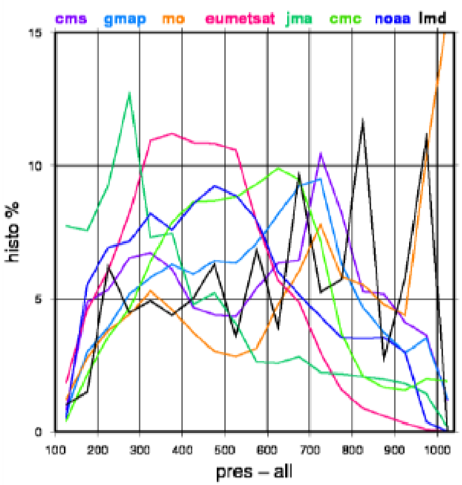
Cloud products comparison:

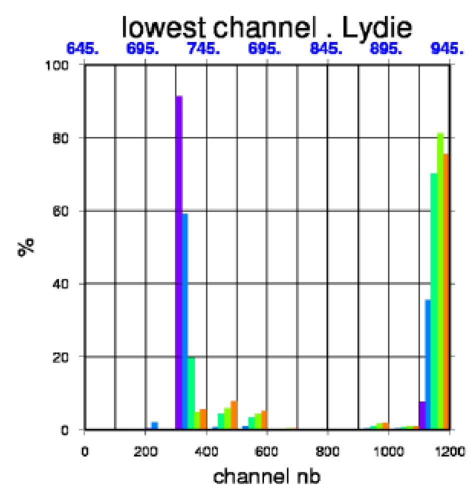
- •Cloud Pressure maps and scatter plots
- •Effective amount differences
- •Distribution of cloud layers
- •…

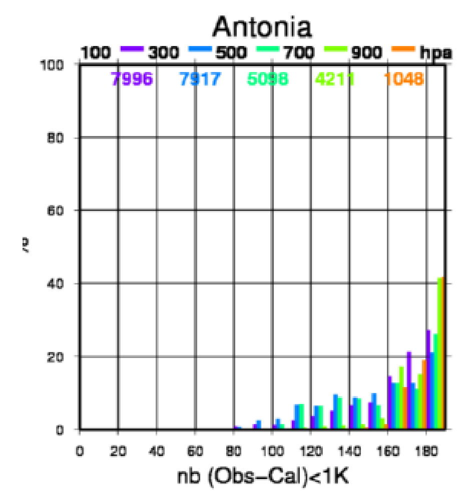


Impact on use of cloudy channels:

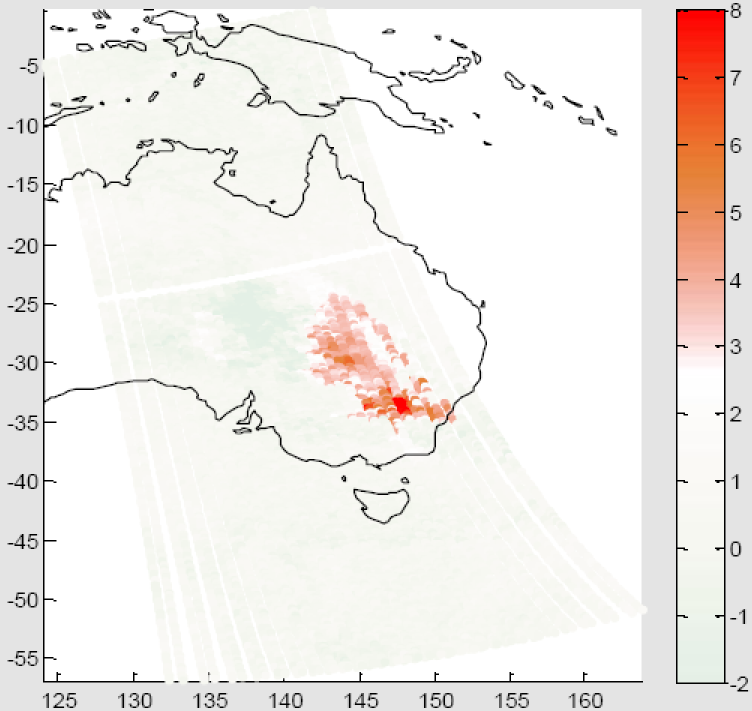
- •Nb of channels with (Btcal – Btobs) <1K
- •Lowest assimilated channels

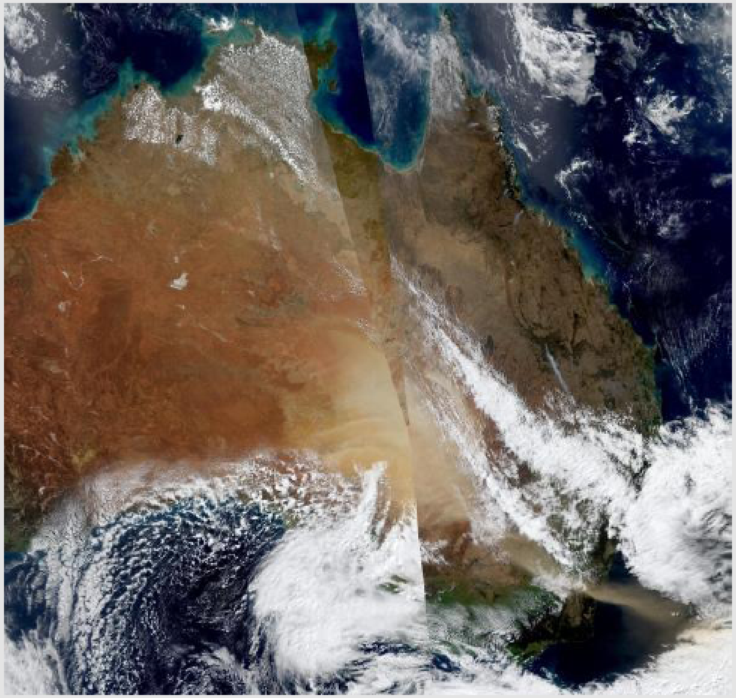


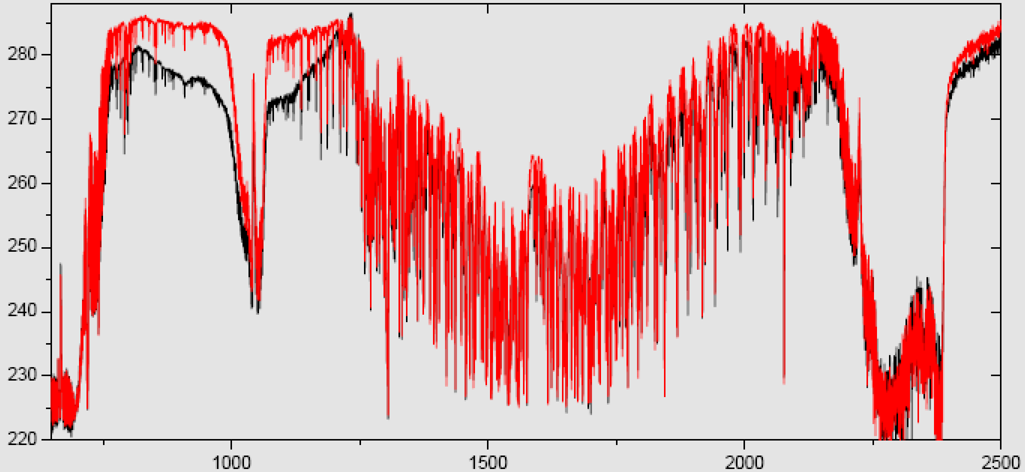




Example 4: Australian dust storm (Sep 2009)

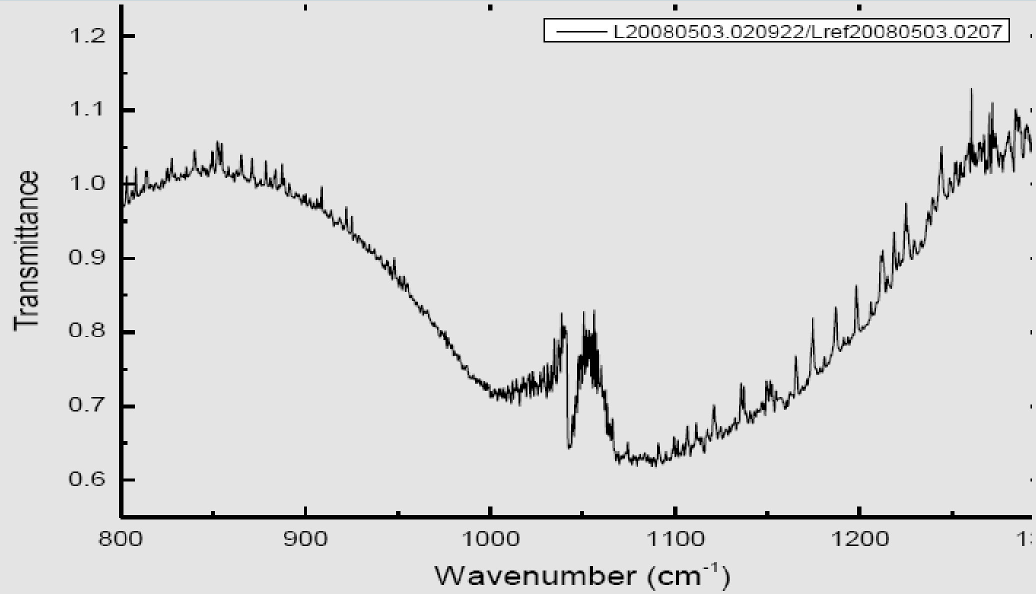


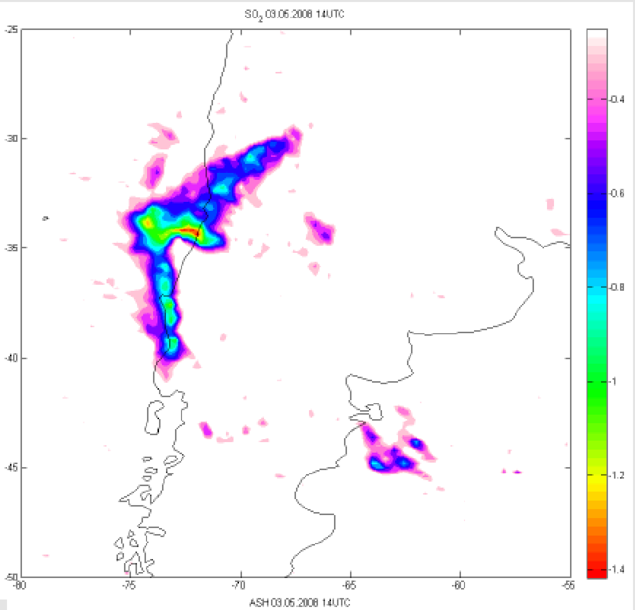


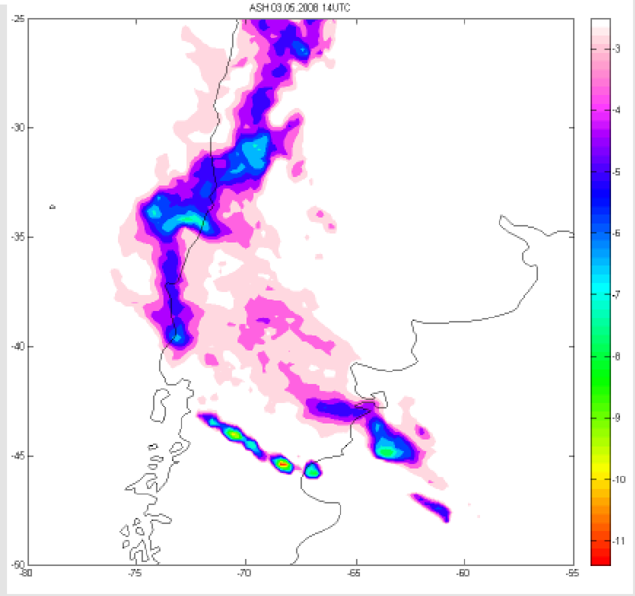


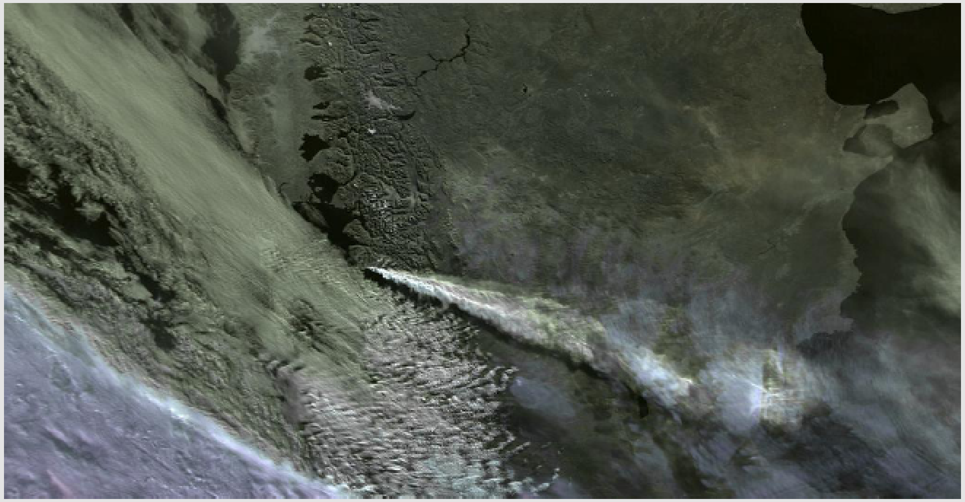
Lieven Clarisse, Annecy, 26 January 2010

Example 1: Chaiten Volcanic Eruption (May 2008)



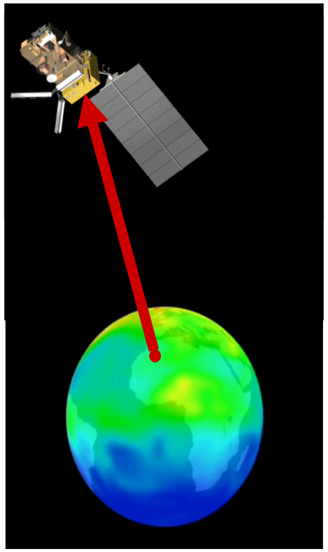


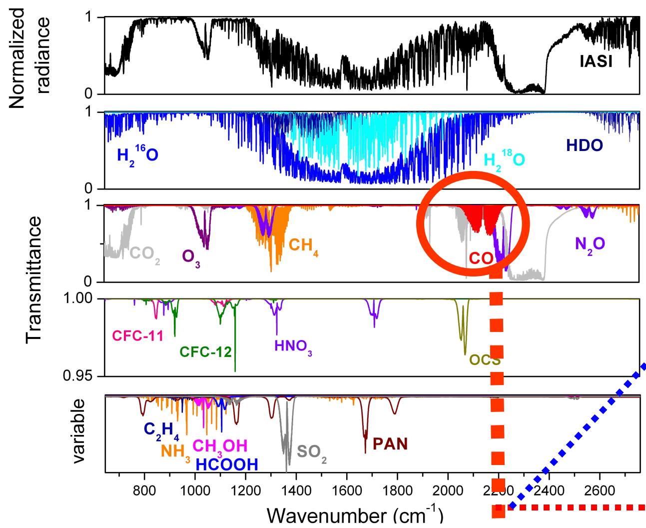




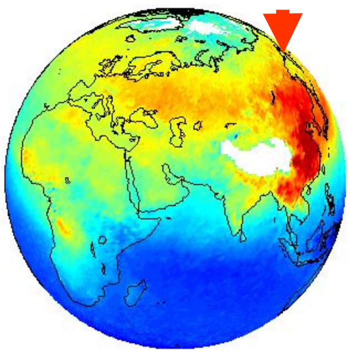
LATMOS ULB

Trace gases





Cloud free scenes



Atmospheric concentrations

Operational L2 products from Eumetsat processing

T and humidity profiles, cloud information

CO_2, CH_4, N_2O columns

O_3 total and partial columns

CO columns

Science L2 products from various processing chains

- NOAA (AIRS Team)

- France: LATMOS/ULB + LMD, LA, LISA, LPMAA

- Autres: Leicester, University of Basilicata, SRON, RAL

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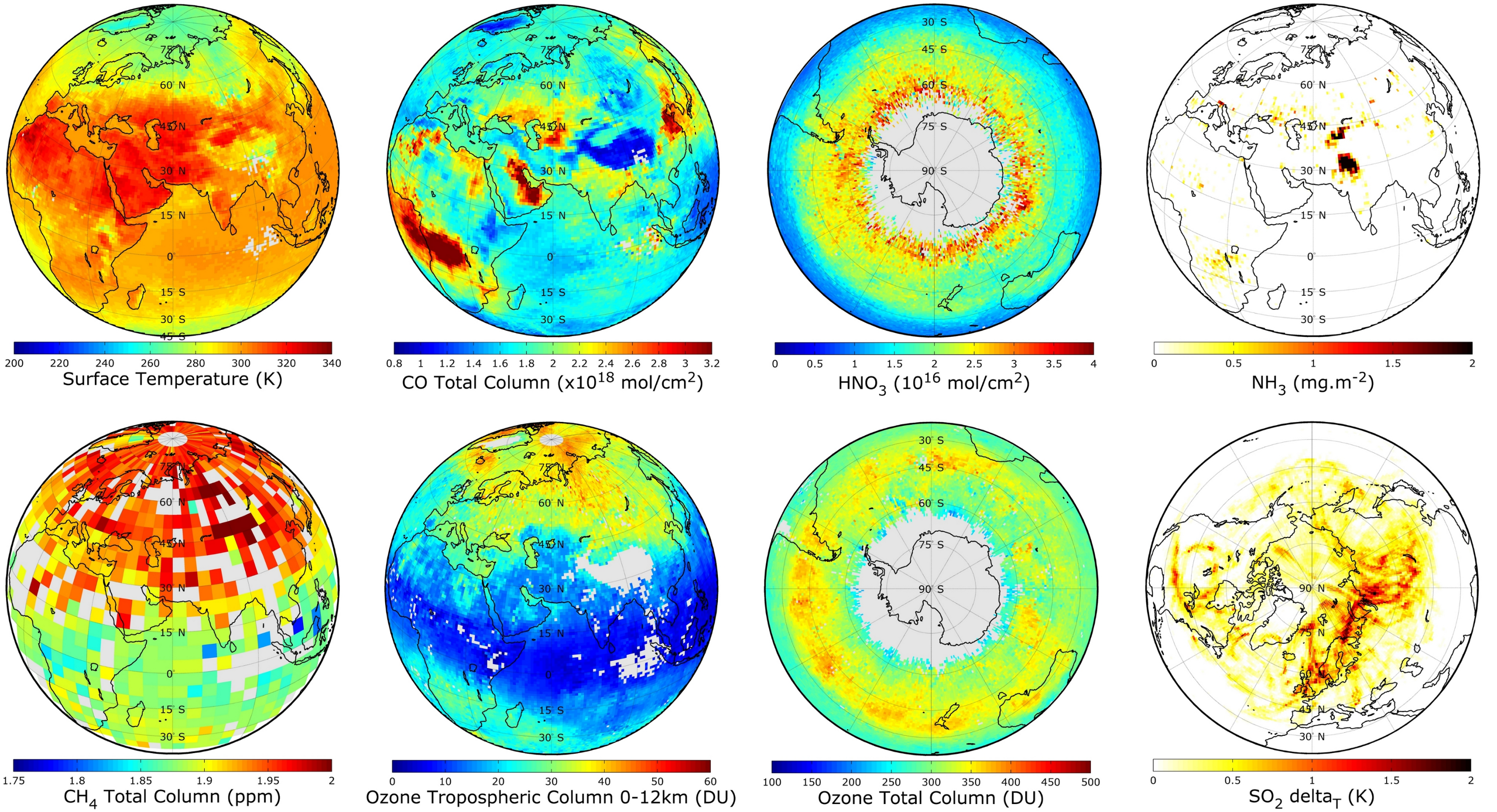
Trace gas products from IASI

Average 1°x1°, 10 days, 18-28 August 2008



Clerbaux et al, ACP IASI Special Issue, 2009

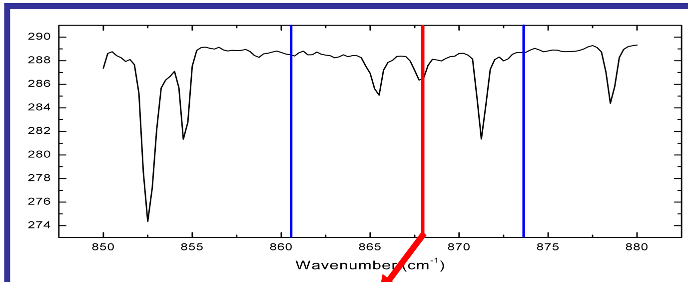
Tropospheric emissions

Tropospheric sources

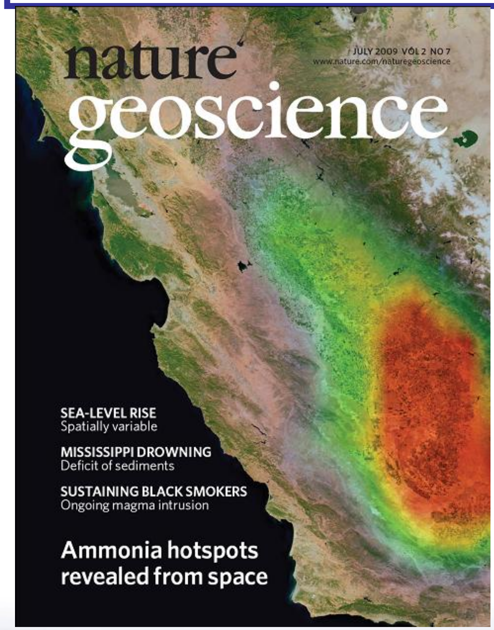
→ **Ammonia**

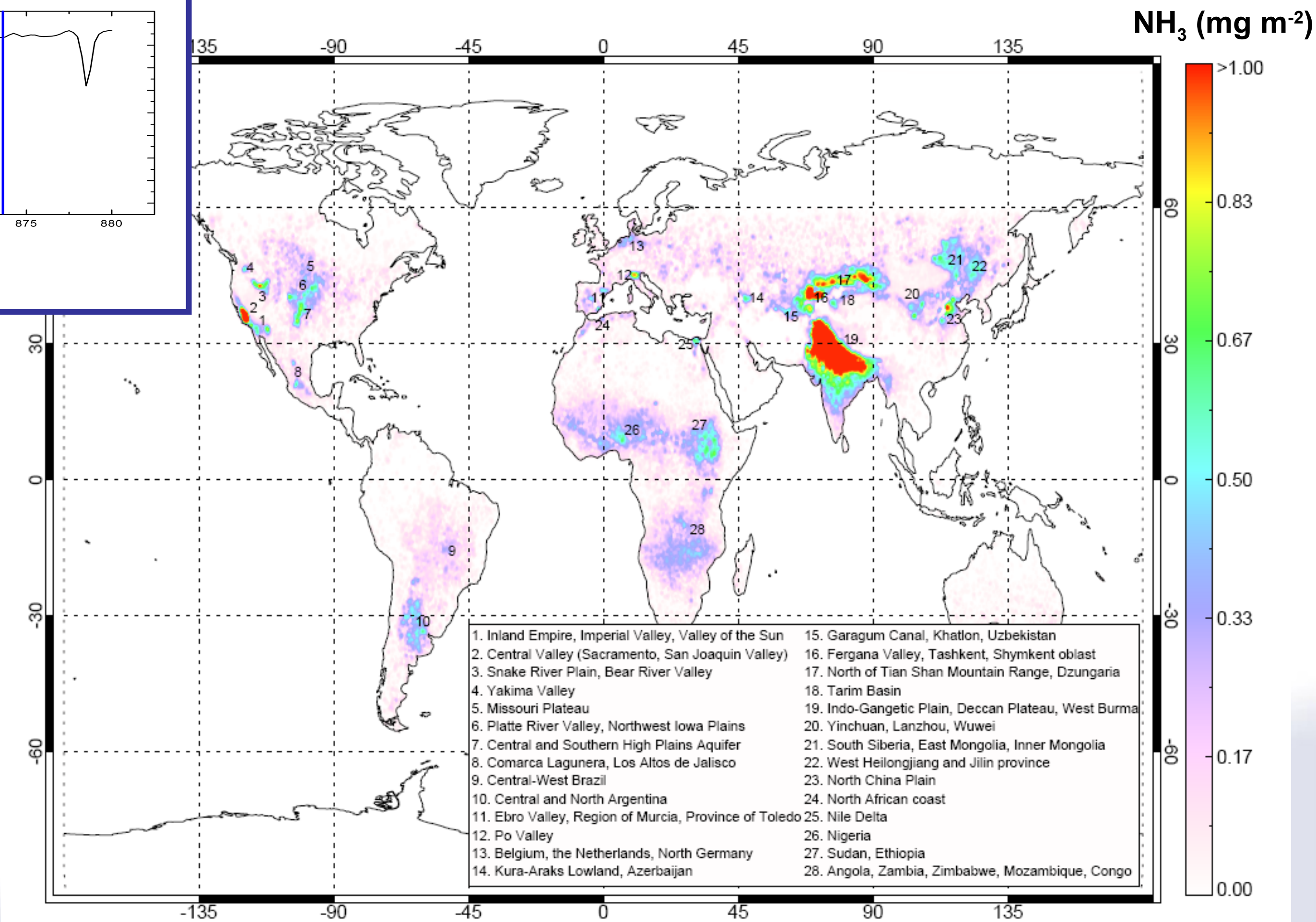
2008 average

Clarisse et al., Nature Geo 2009



Target feature at 867.75 cm^{-1}





Mapping from local to global scale

→ 28 emission hotspots identified

Monthly/seasonal variations

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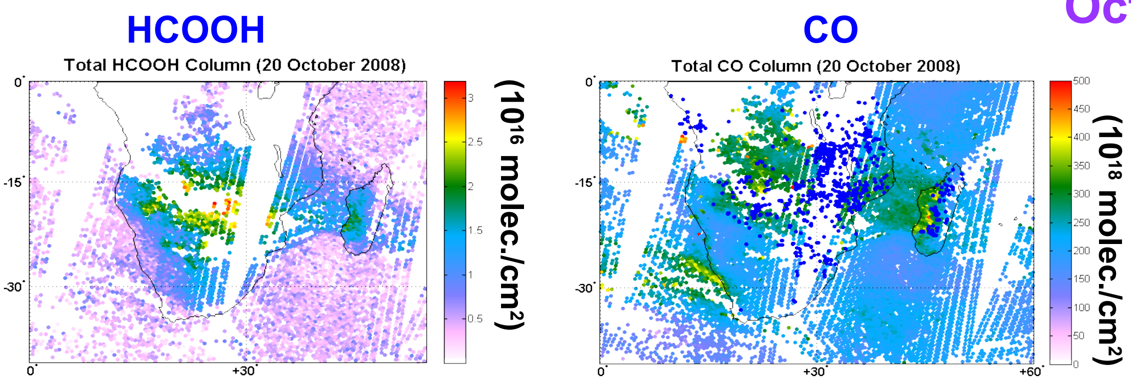
Tropospheric sources → VOCS HCOOH, CH_3OH

F. Karagulian, A. Razavi

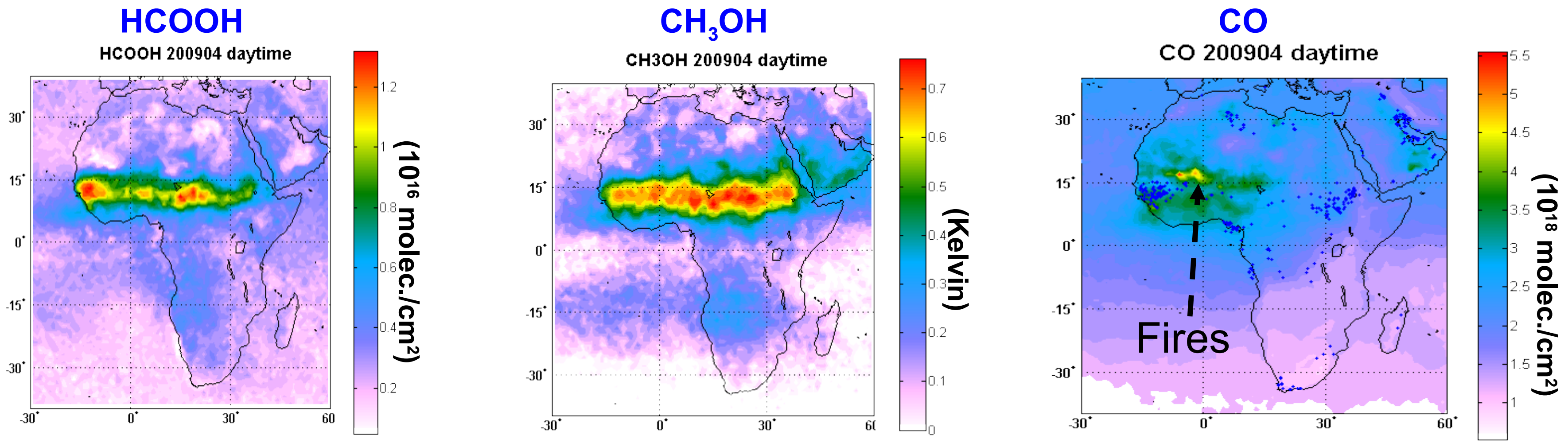


October 2008

High correlation HCOOH/CO/fire
→ **Biomass burning**

April 2009

High correlation HCOOH/CH_3OH
Weak correlation HCOOH/CO/fires
→ **Biogenic emissions?**



Chemistry/Transport

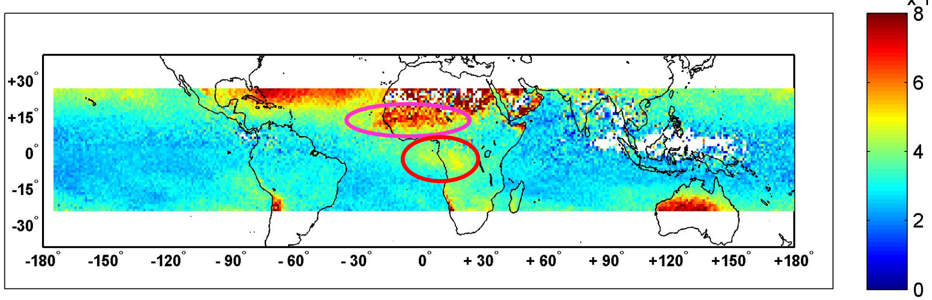
→ Nitric acid

No vertical information in the measurement → stratospheric column has to be subtracted

Using a stratospheric assimilated field (Bascoe)

$[HNO_3]_{tropo} = [HNO_3]_{total/IASI} - [HNO_3]_{strato/BASCOE}$

Averaged HNO_3 tropospheric columns (June) /IASI-BASCOE [molecules/cm^2]

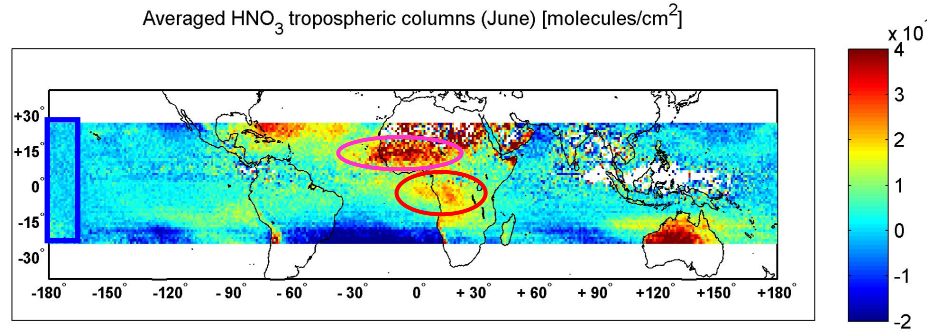


Global but requires computational efforts
Stratospheric contamination remain

Using a background column

$d[HNO_3]_{tropo} = [HNO_3]_{total/IASI} - [HNO_3]_{background}$

Averaged HNO_3 tropospheric columns (June) [molecules/cm^2]



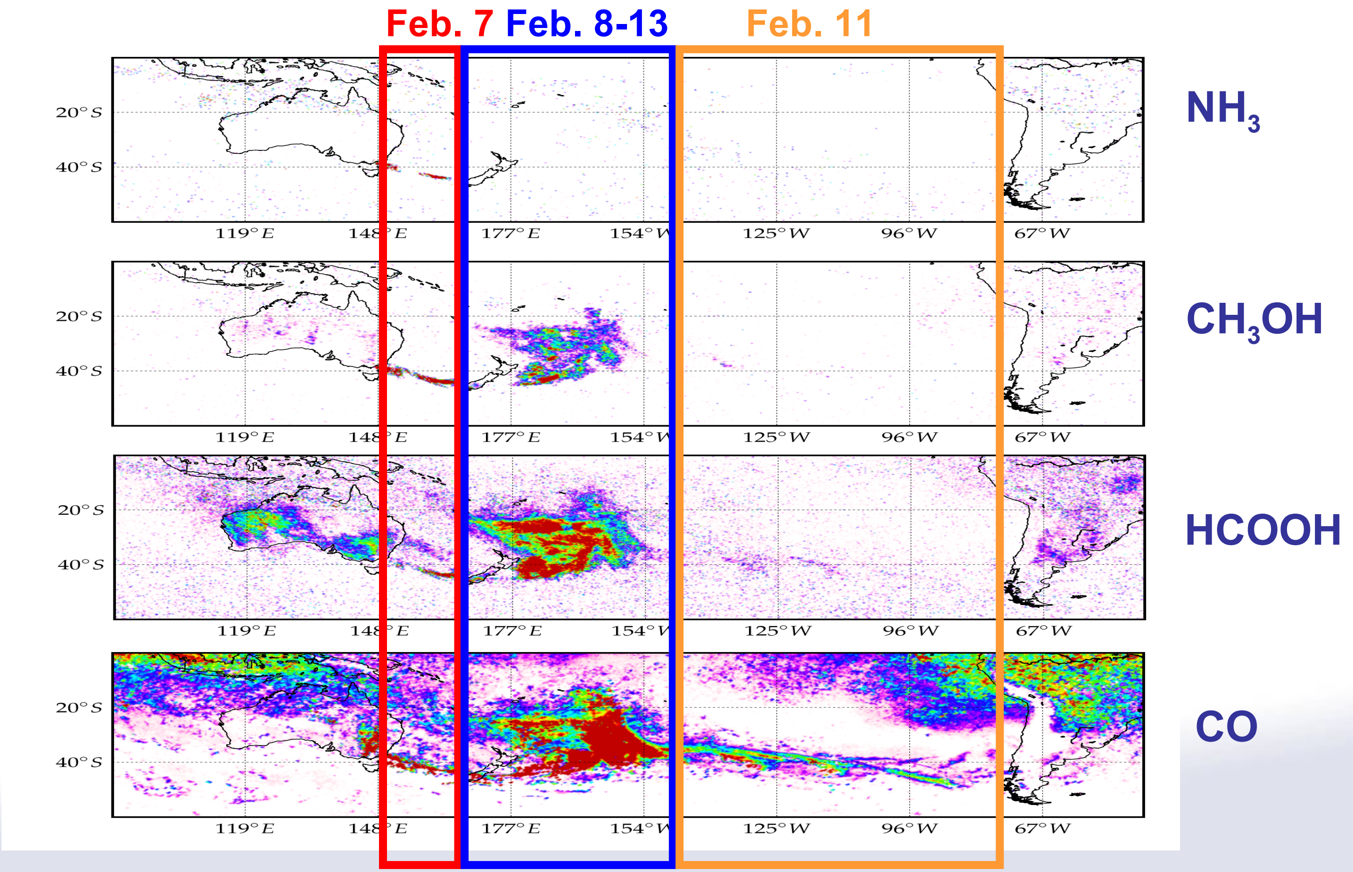
Simple, robust but tropical regions mainly.
Provides a tropospheric “enhancement” rather than a column

Chemistry/Transport

→ Chemistry in fire plumes

Australian fires (February 2009)

Integrated from 7 to 15 February 2009

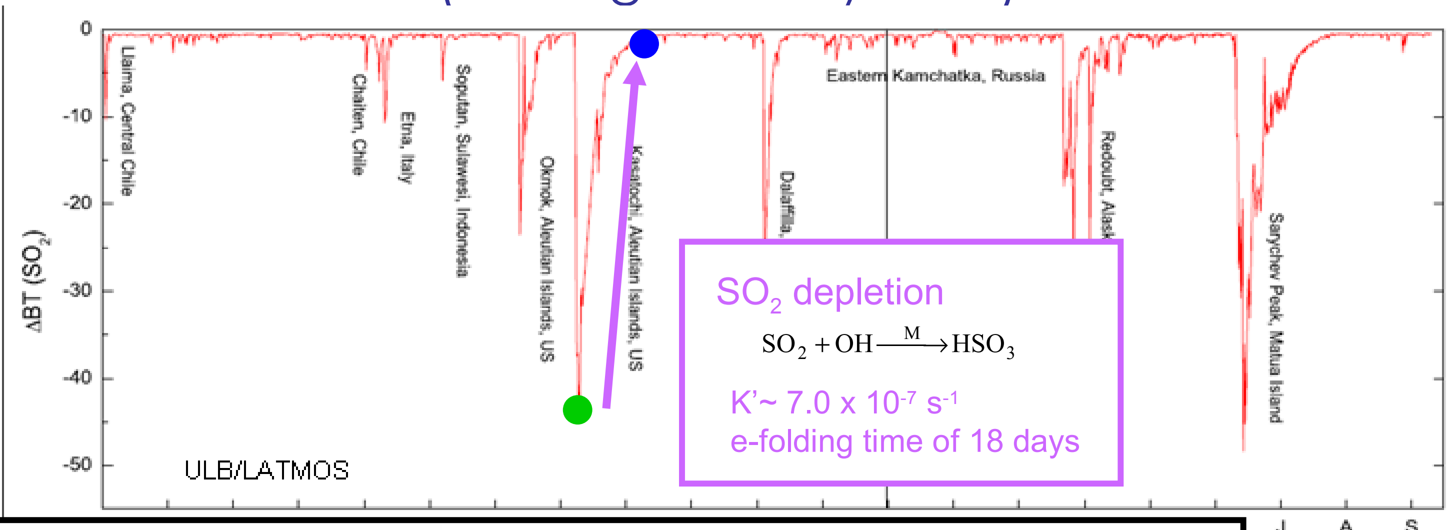


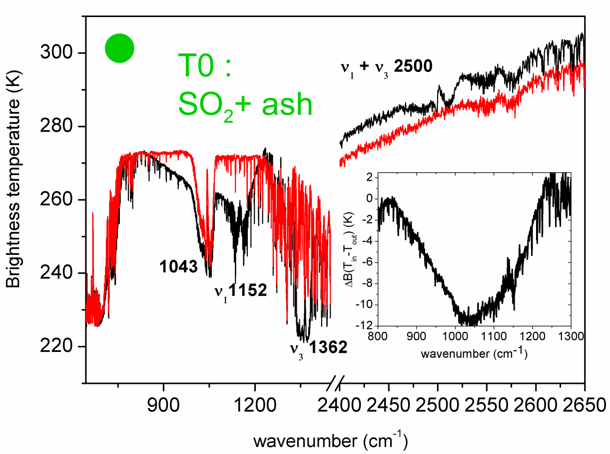
Enhancement ratios ΔX/ΔCO vs. time → chemistry in the fire plume
Coheur et al., ACP, 2009

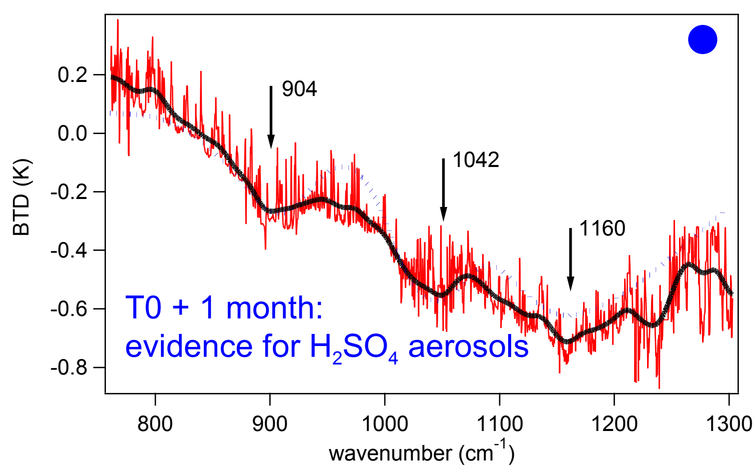
Chemistry/Transport

→ SO_2 in volcanic plumes

Volcanic plumes tracked by IASI
(starting January 2008)







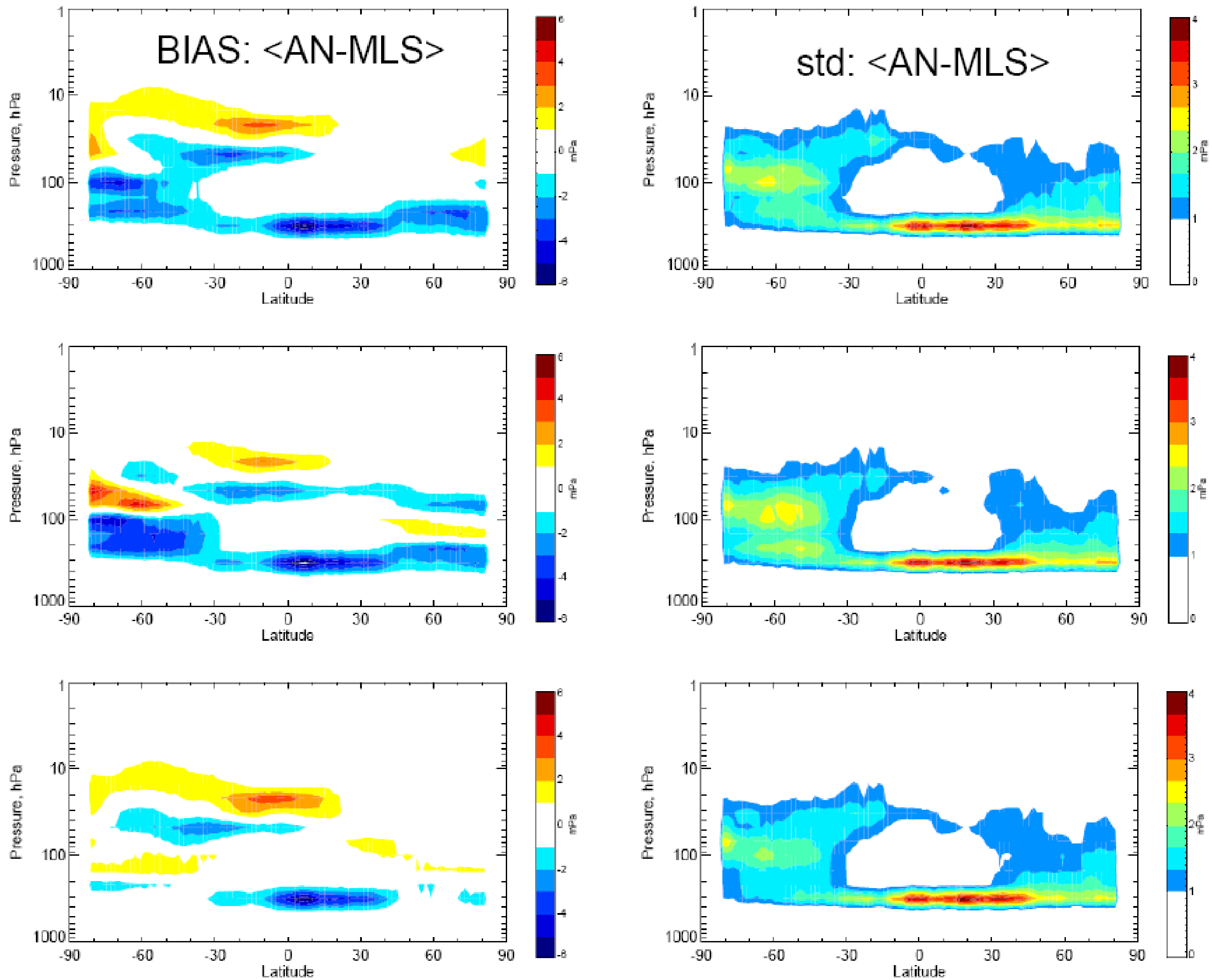
O3 (ECMWF)

Verify against MLS (20090615-20090630)

BASELINE
No O3 OBS

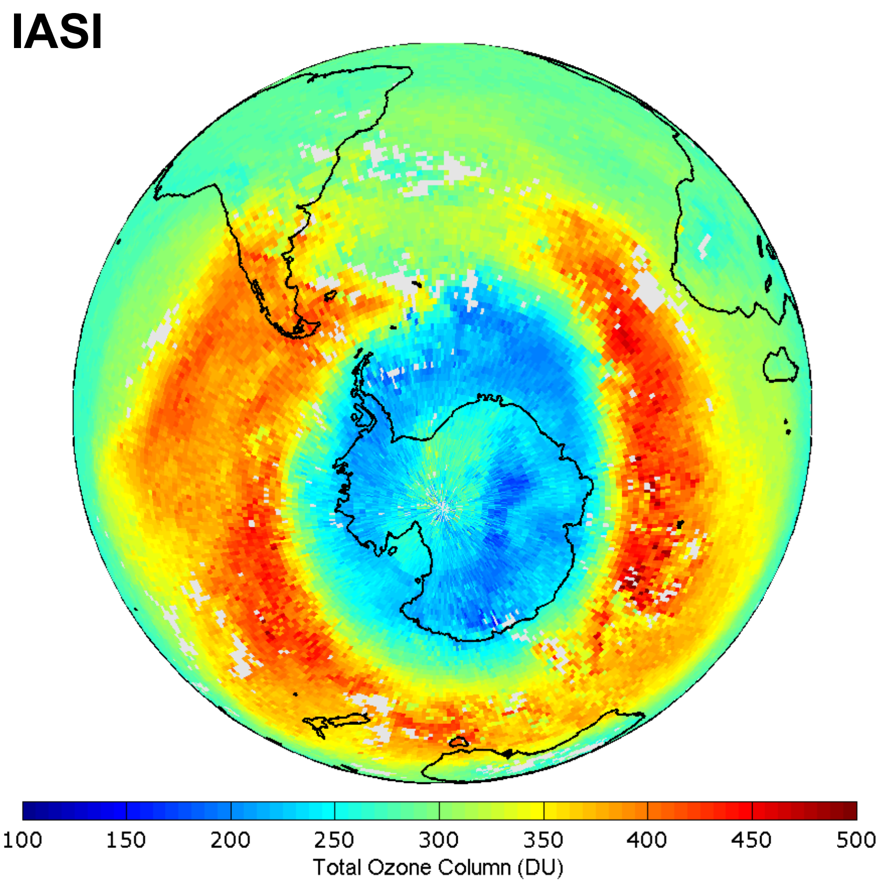
BASELINE
+SBUV+OMI

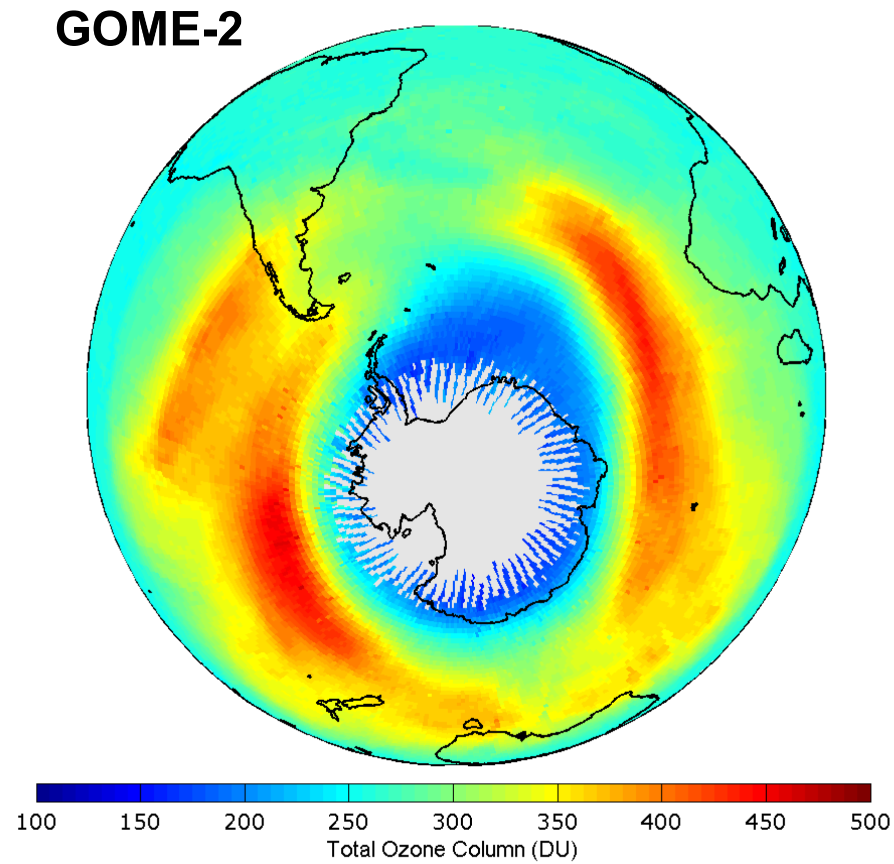
BASELINE
+IASI 16 O3 Channels



Ozone, total column: polar ozone

Sept 4 to Sept 7 (2009)



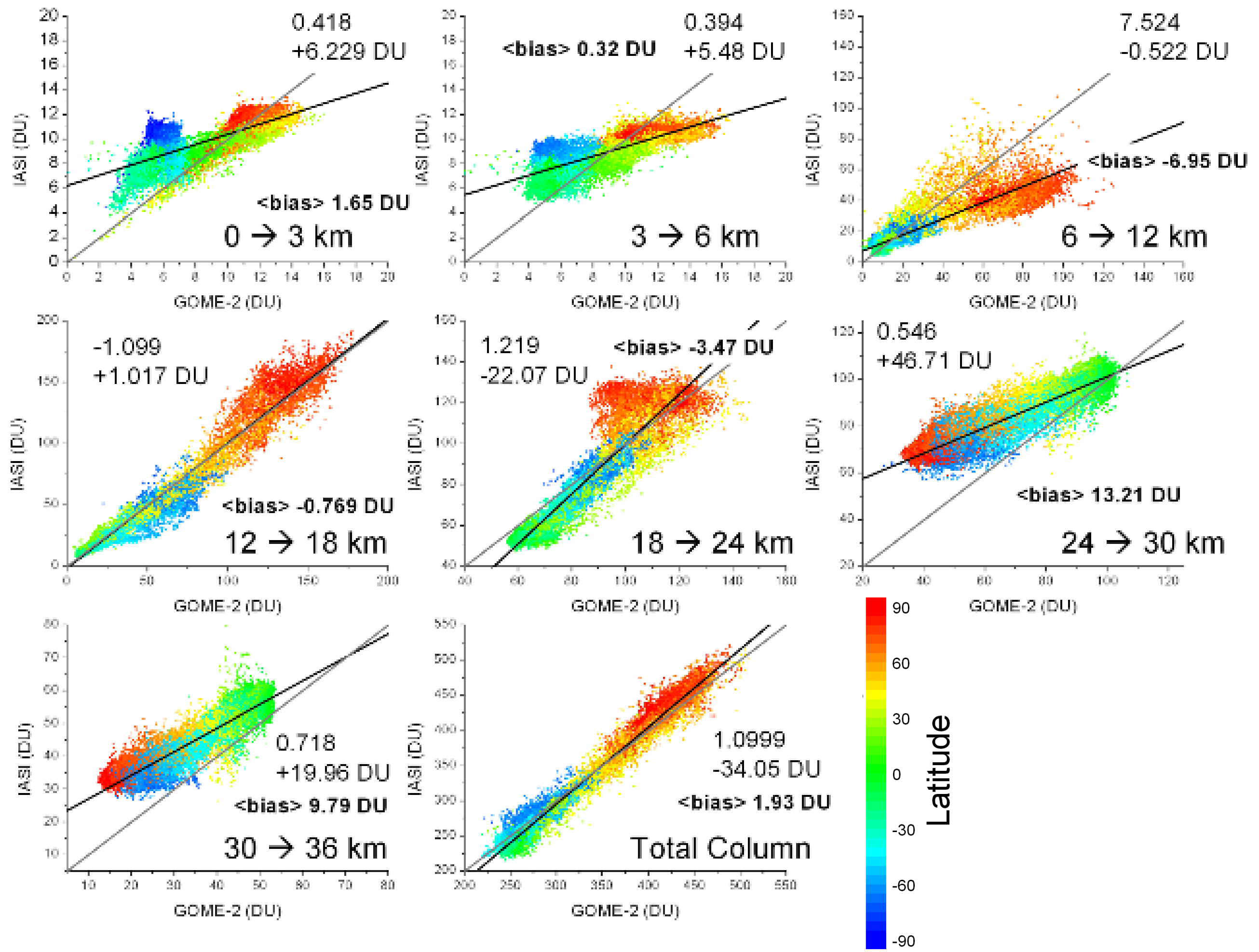


Courtesy A. Boynard, LATMOS, 2009

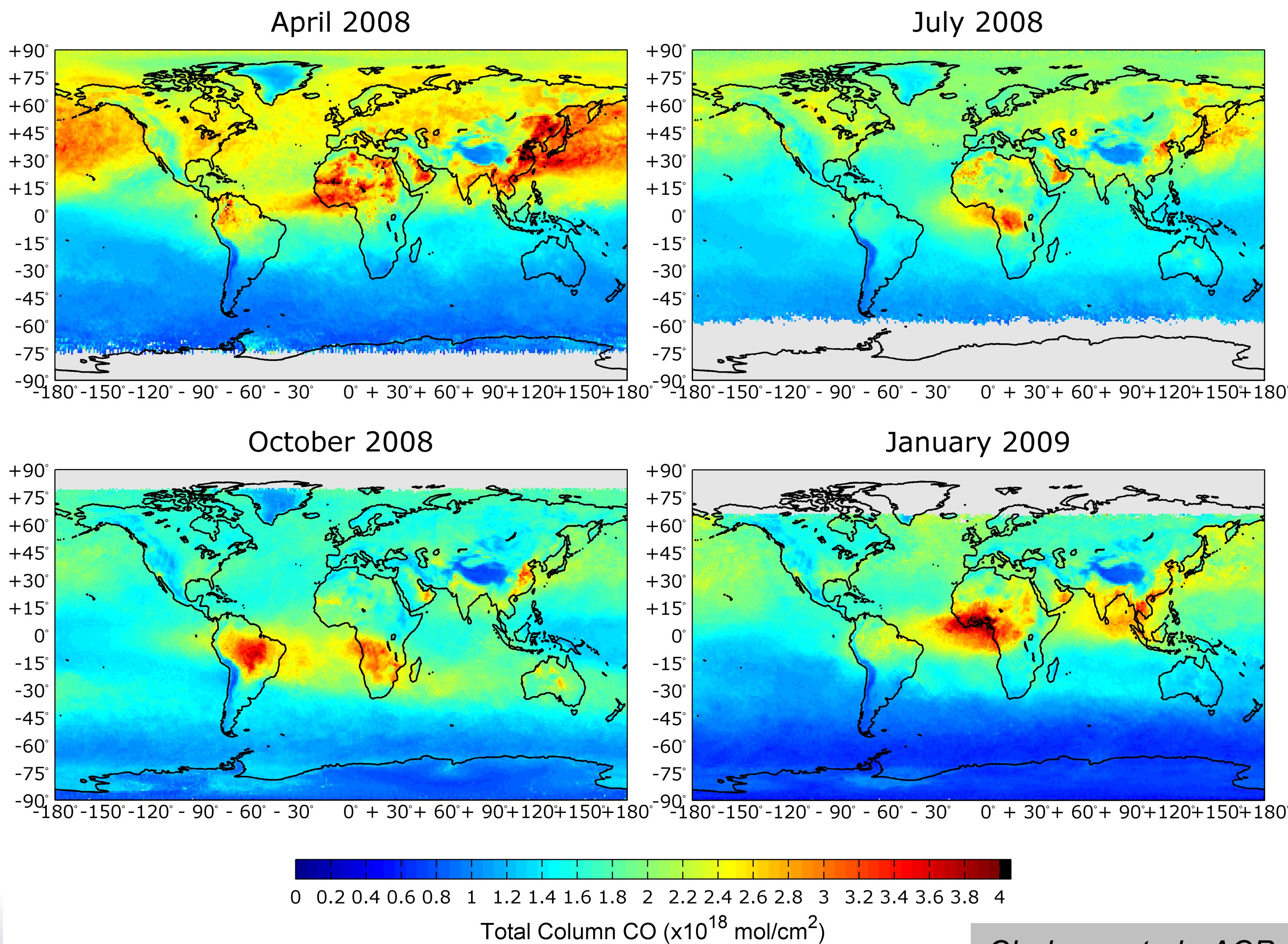
Ozone *profiles*

New results: Global profiles and PC from FORLI

Preliminary comparisons with GOME-2 partial columns (from operational profiles)



Carbon monoxide total column

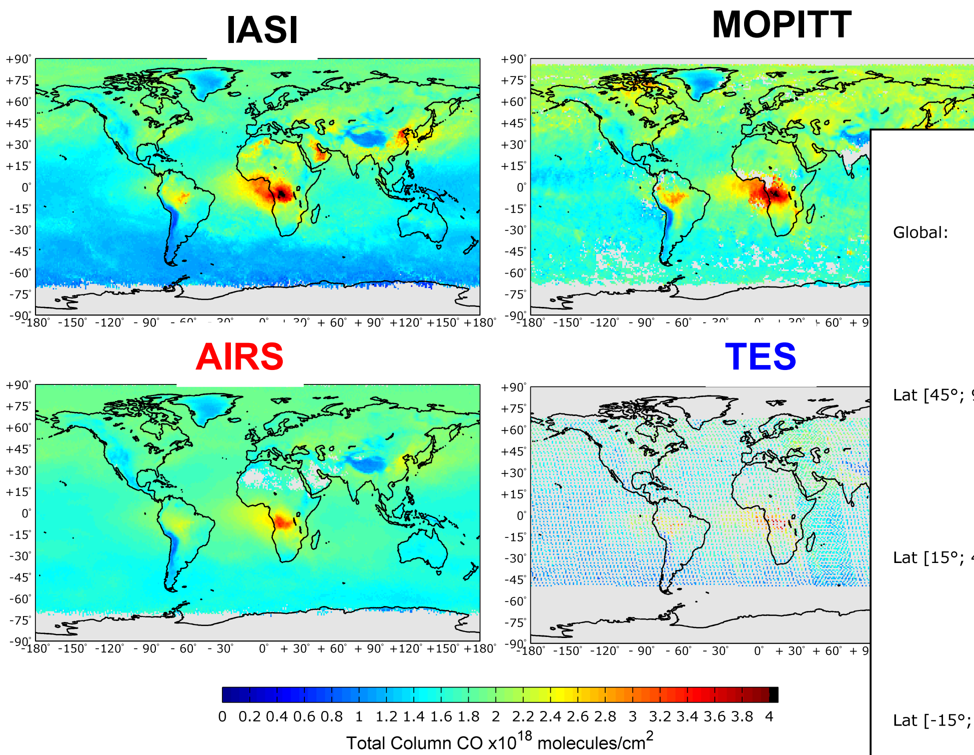


Clerbaux et al., ACP, 2009

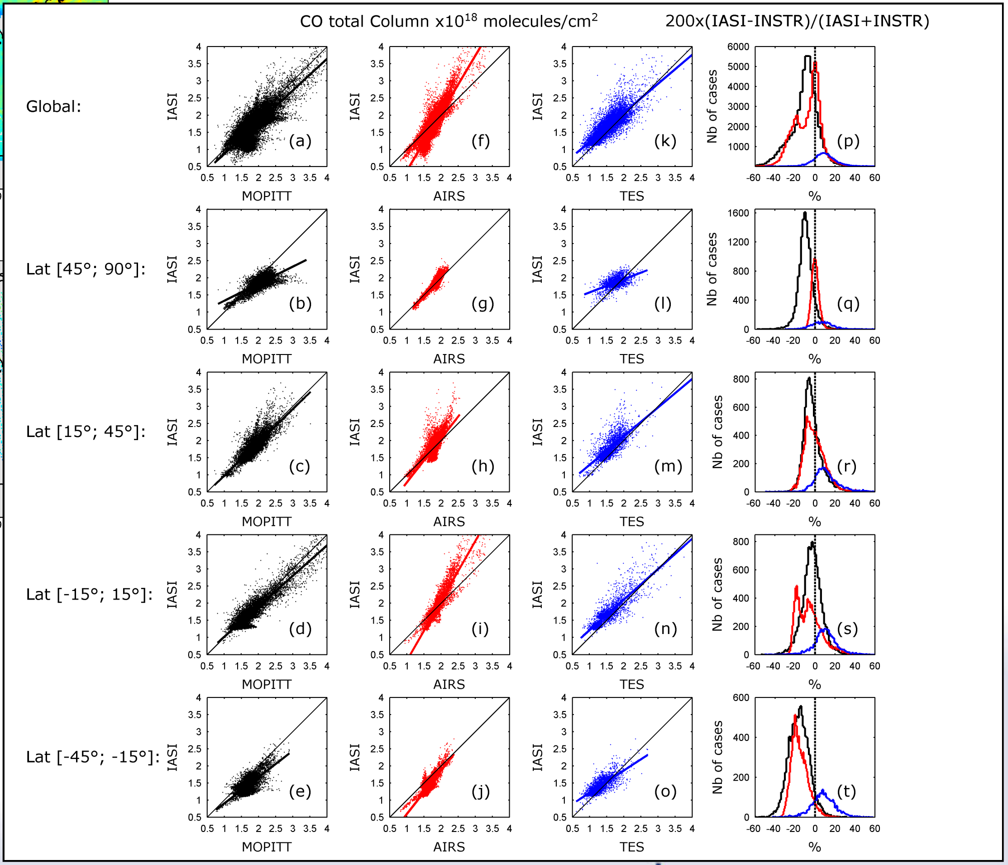
Medium-lived trace gases

Carbon monoxide

Comparisons with other satellite data; Preliminary cross-validation



TES<IASI<MOPITT



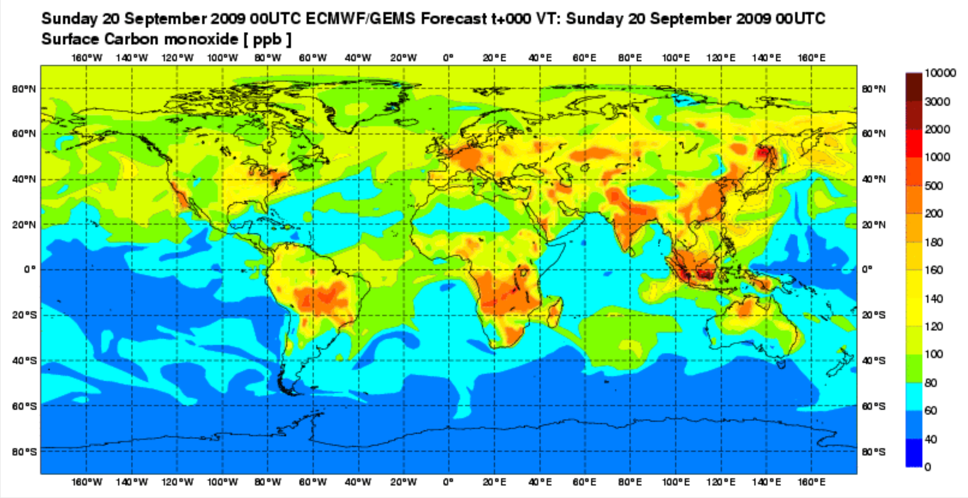
George et al., ACPD, 2009

Assimilation of NRT CO total column data from IASI

- Near-real time CO total column data from IASI produced by LATMOS-ULB have been assimilated in the GEMS/MACC near-real time analysis began on 12 February 2009, 0z

- Data look good. Departures and standard deviations are a considerably smaller than they were for the previously monitored (and assimilated) EUMETSAT CO product

- Analysis is drawing to the data. Bias and standard deviation of departures are reduced.



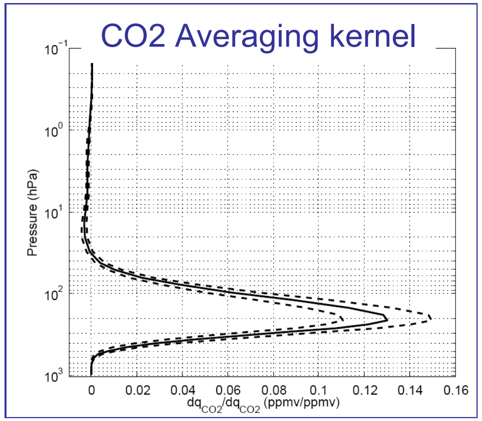
A word on climate: CO_2 / CH_4

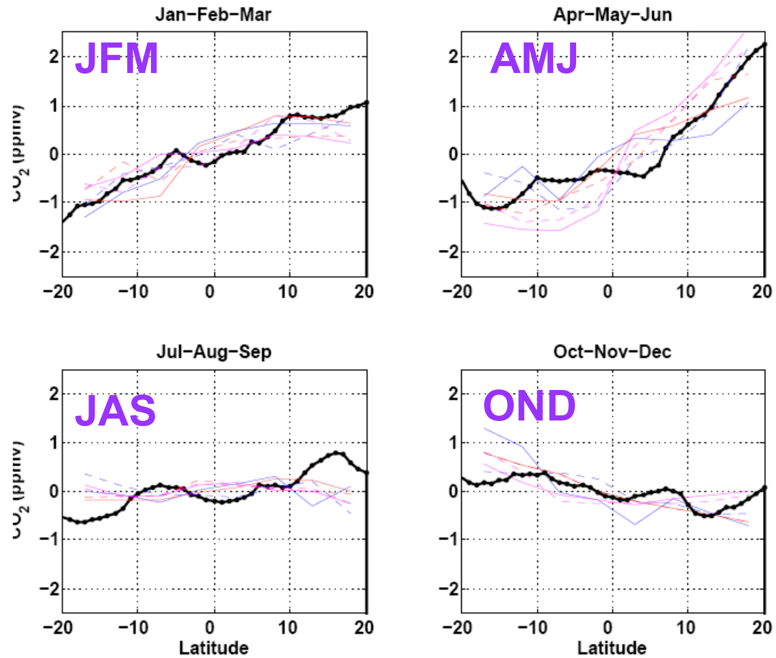
Crevoisier et al., ACP, 2009

NN retrieval approach

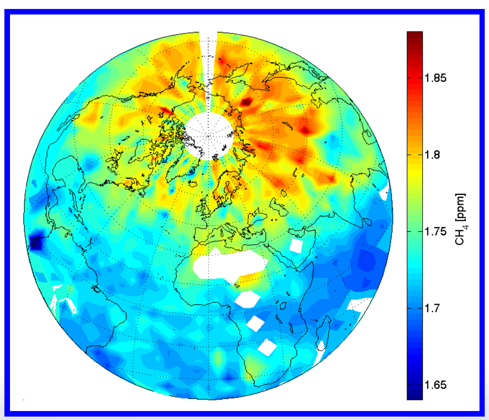
retrieval of an UT integrated content **representative of the 11–15 km range**

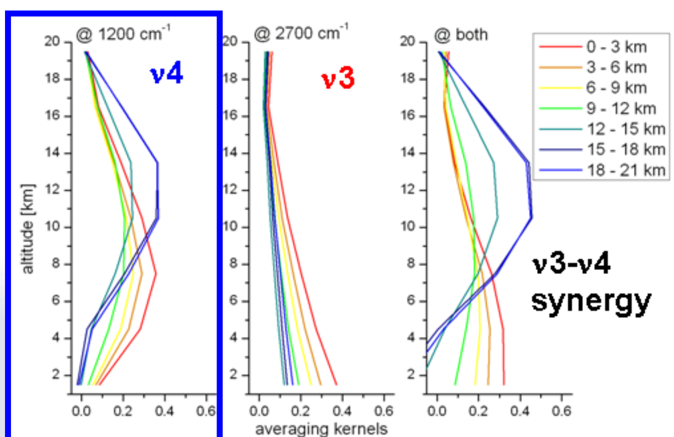
Retrieval @ 5°x5° resolution
Uncertainty ~2ppmv (0.5%)





CH_4: 4 days average (October 2008) on a 4x4° grid





Razavi et al., ACPD, 2009

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Conclusions

IASI measures a dozen of species with a range of lifetimes, *routinely* and *globally* twice a day

Long-lived species (years)

→ ***Climate***

ESA-ECVs?

+ CO, O_3 (months)

→ ***Chemistry, AQ, Transport***

Air quality
CO (O3?) in ***FP7-***GEMS/MACC; ***FP7-***CITIZEN

Short-lived species + aerosols (days)

→ ***Sources, emission inventories***

Fire monitoring
(POLARCAT; ***ESA-***STSE/ALANIS?

Volcanic monitoring
(***ESA-***SAVAA/SACS+; ***FP7-***EVOS)

Open issues

Thermal contrast:
situation better than expected; how reliable are Ts-T1 from operational L2?

PCA:
what will be lost? study ongoing. Other alternatives to compression? (for current application 750-1400 cm^{-1} + 2140-2180 cm^{-1} range is used)

RT Algorithms:
Many research algorithms in addition to operational EUMETSAT. Cross-validation needed. Next step?

CONCLUSIONS

- **Excellent performances**
- **Development of applications in progress**
  - AC : From detection to to quantisation

    From science to operational
  - NWP : Cautious introduction going towards wider use (areas, cloudy conditions, channels, etc.)
  - Assisting weather forecast
- **Many expectations**
  - Specially for climate (>15 years and more with IASI –NG on Post EPS)
  - More on weather forecast specially in LAM
  - With CONCORDIASI!

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