Observing the atmospheric composition of fire plumes
With IASI

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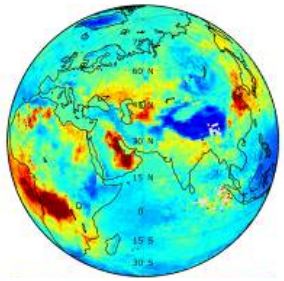
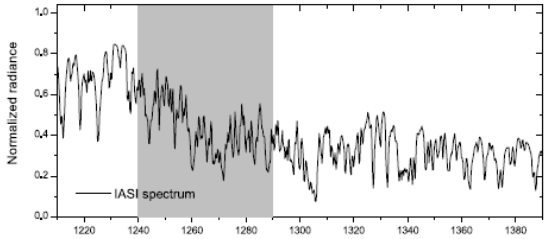
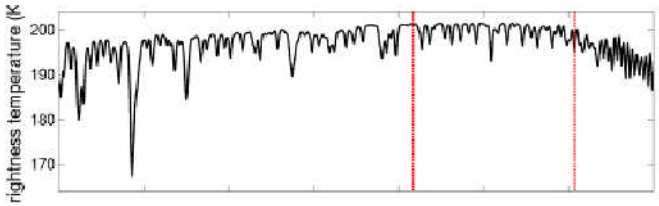
Outline

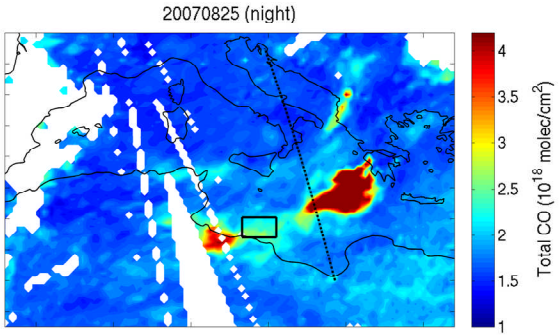
(1) IASI/METOP trace gas observations





(2) More details on retrievals in fire plumes





(3) Main issues and future capabilities?

Atmospheric measurements from nadir IR sounding

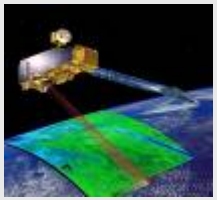
1995

IMG/ADEOS

CO, O_3, HNO_3 profiles, HDO
Few days of measurements
High spectral resolution

2000

MOPITT/TERRA



CO profiles (2 trop. Inf)
Global coverage 3 days
Atm. Chemistry

2005

AIRS/AQUA

CO, O_3, CO_2, CH_4, H_2O, volcanic SO_2
Global coverage daily
Coarse spectral res.
NWP

2007

TES/AURA

CO, O3 profiles (2 trop. Inf)
HDO, NH_3, CH_3OH
Global coverage 14 days
High Spectral resolution
Atm. Chemistry

Nadir TIR satellite sounding

→ Tropospheric sensitivity with, in the best cases, *vertical profile information* for a series of species (mainly with *long to medium lifetimes*)

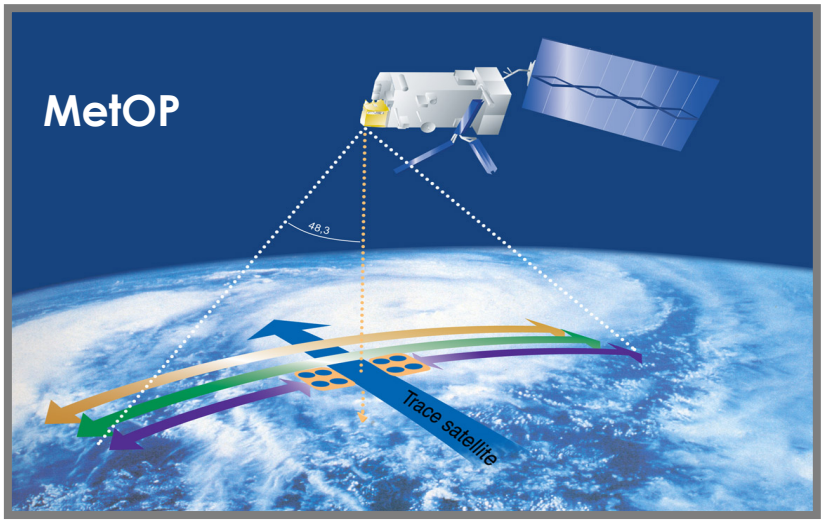
→ Surface sensitivity strongly dependent of thermal contrast→ Can we monitor / quantify sources?

IASI/METOP

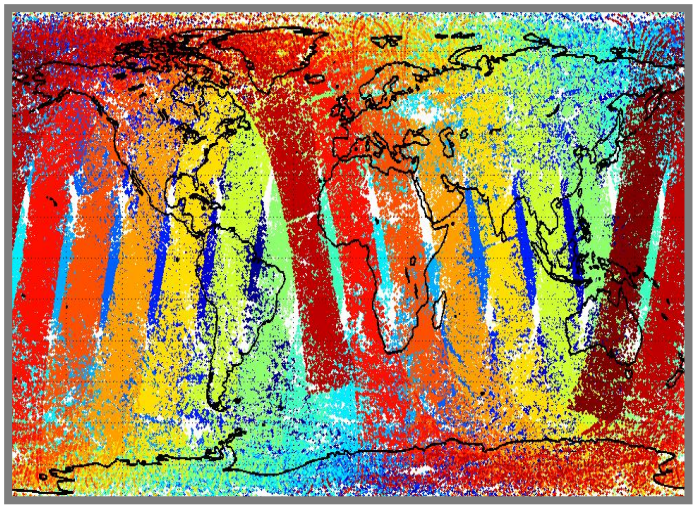
LATMOS ULB

IASI instrument – Launched Oct. 2006

Launched onboard METOP-A in Oct 2006
MetOp: First European meteorological platform on polar orbit (EPS system)
3 successive satellites: 15 years of data



(1 day of data)

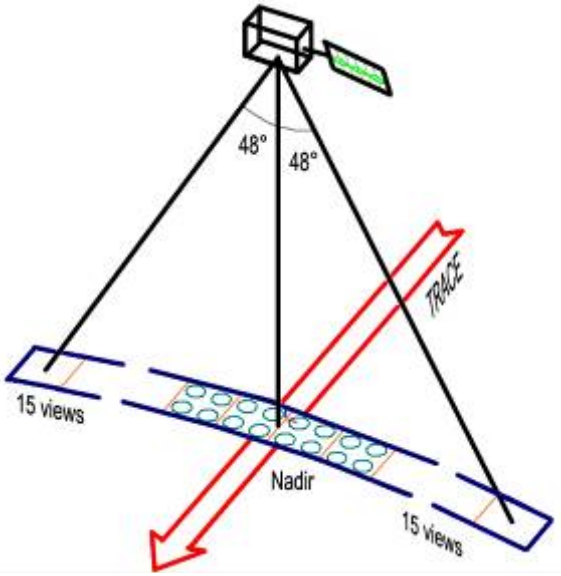


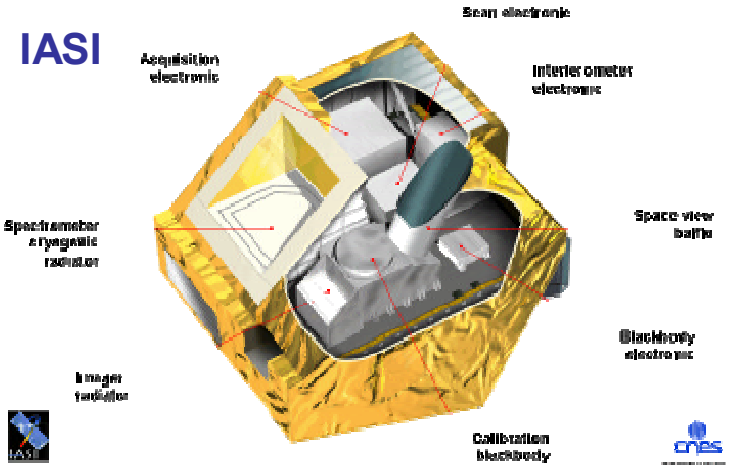
120 spectra along the swath (2400 km)
Each 50 km along the trace

> Up to 1.3 10^6 spectra/day (16Gb)

→ Oct. 19, 2006 MetOp-A launch
→ Jun. 4, 2007 L1C Operational dissemination (Eumetcast)
→ Sep. 27, 2007 L2 (P, T, clouds) operational dissimination
→ Mar. 1, 2008 L2 (trace gases) operational dissimination

IASI instrument – Launched Oct. 2006





- 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)

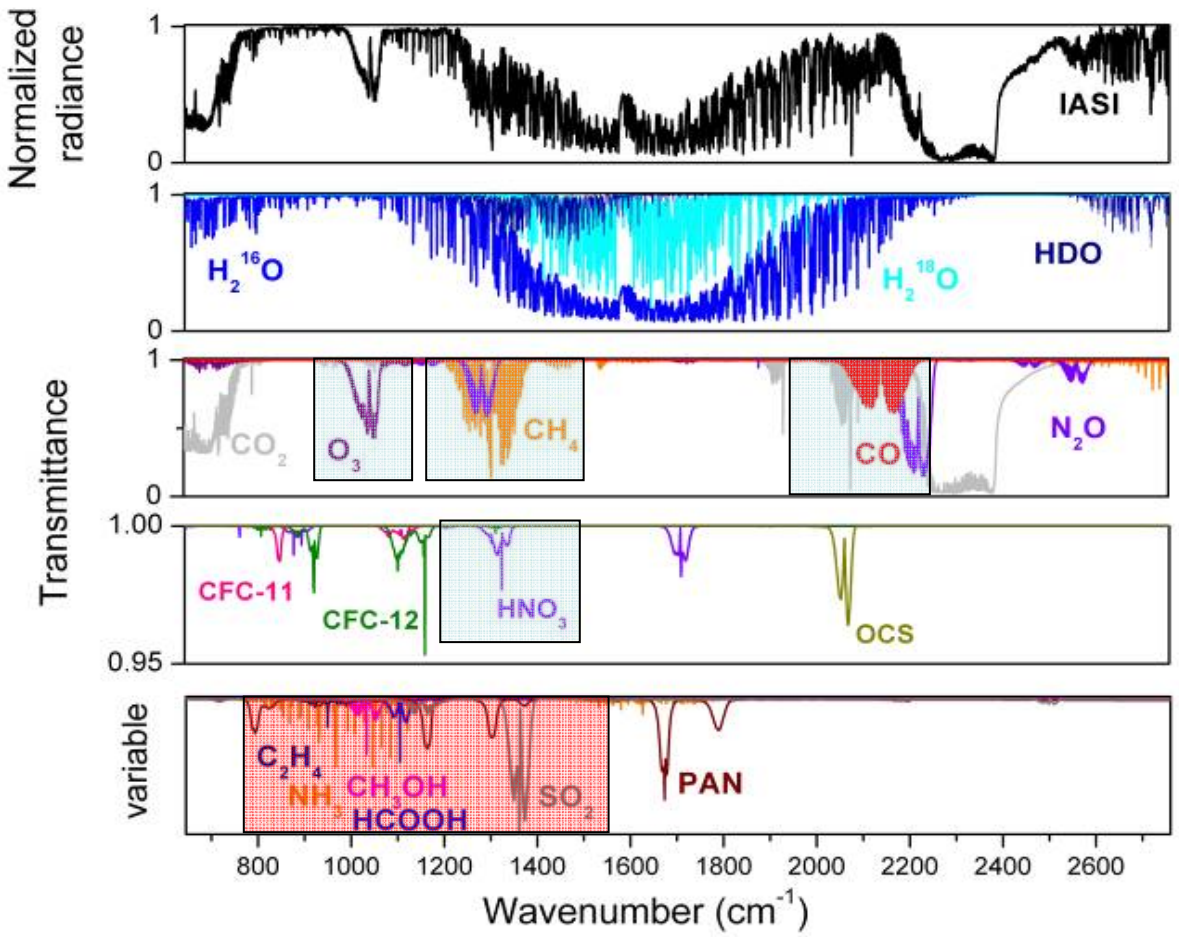
- Spectral coverage = 645-2760 cm^{-1}
- Spectral resolution = 0.5 cm^{-1}
- Radiometric noise ~ <0.1-0.2 K

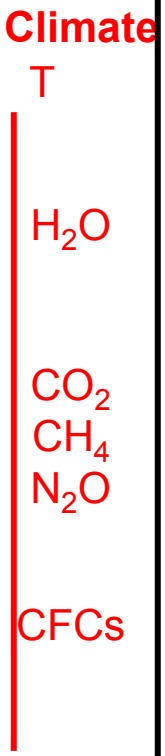
Broad spectral coverage without gaps

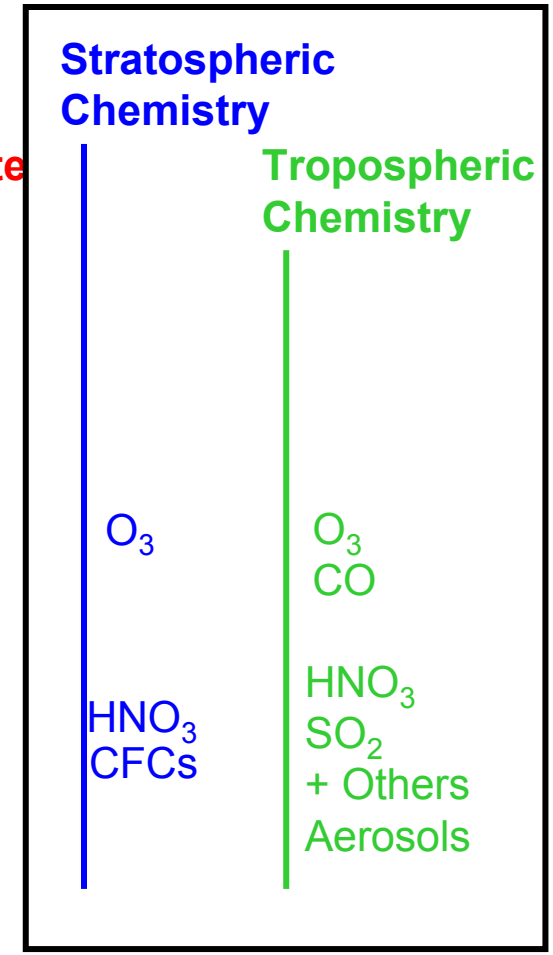
Medium spectral resolution

High radiometric performances

Measurements and Products







+ Operational applications

Operational L2 trace gases (EUMETCAST) : O3, CO

Main characteristics of retrievals in research groups

➔special issue ACPD

LMD/CNRS

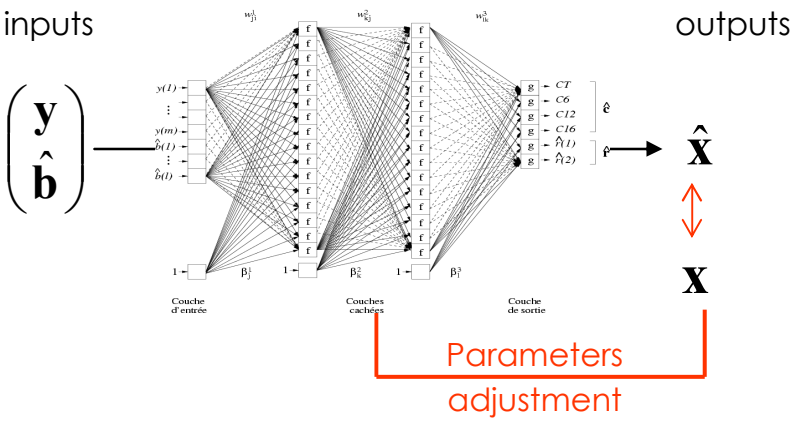
LATMOS ULB

Retrievals at LATMOS/CNRS and ULB: 2 complementary tools

→ **Towards NRT retrievals: use of precalculated tables**
***FORLI* algorithm**
(Turquety et al., 2009, George et al., 2009)

Operational retrieval

SA-NN



→ Total columns CO, CH_4

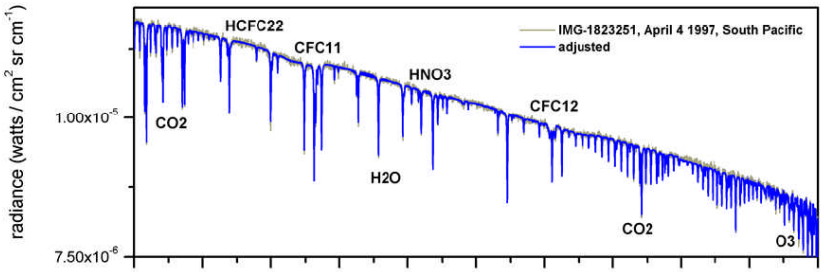
→ Partial columns O_3

[Hadji-Lazaro et al., 1999; Clerbaux et al., 2001; Turquety et al., 2002, 2004]

A priori information (CTM) provided during the training phase

Resear

Adjustment of radiances using optimal estimation method

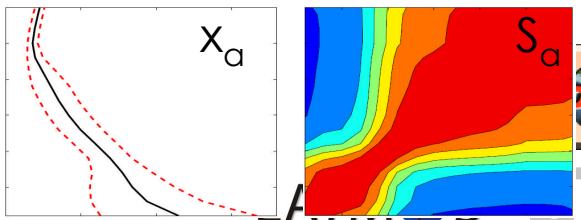


$$\hat{\mathbf{x}} = \mathbf{A}\mathbf{x} + (\mathbf{I} - \mathbf{A})\mathbf{x}_a + \mathbf{G}\boldsymbol{\varepsilon}$$

→ Columns / Profiles absorbing species

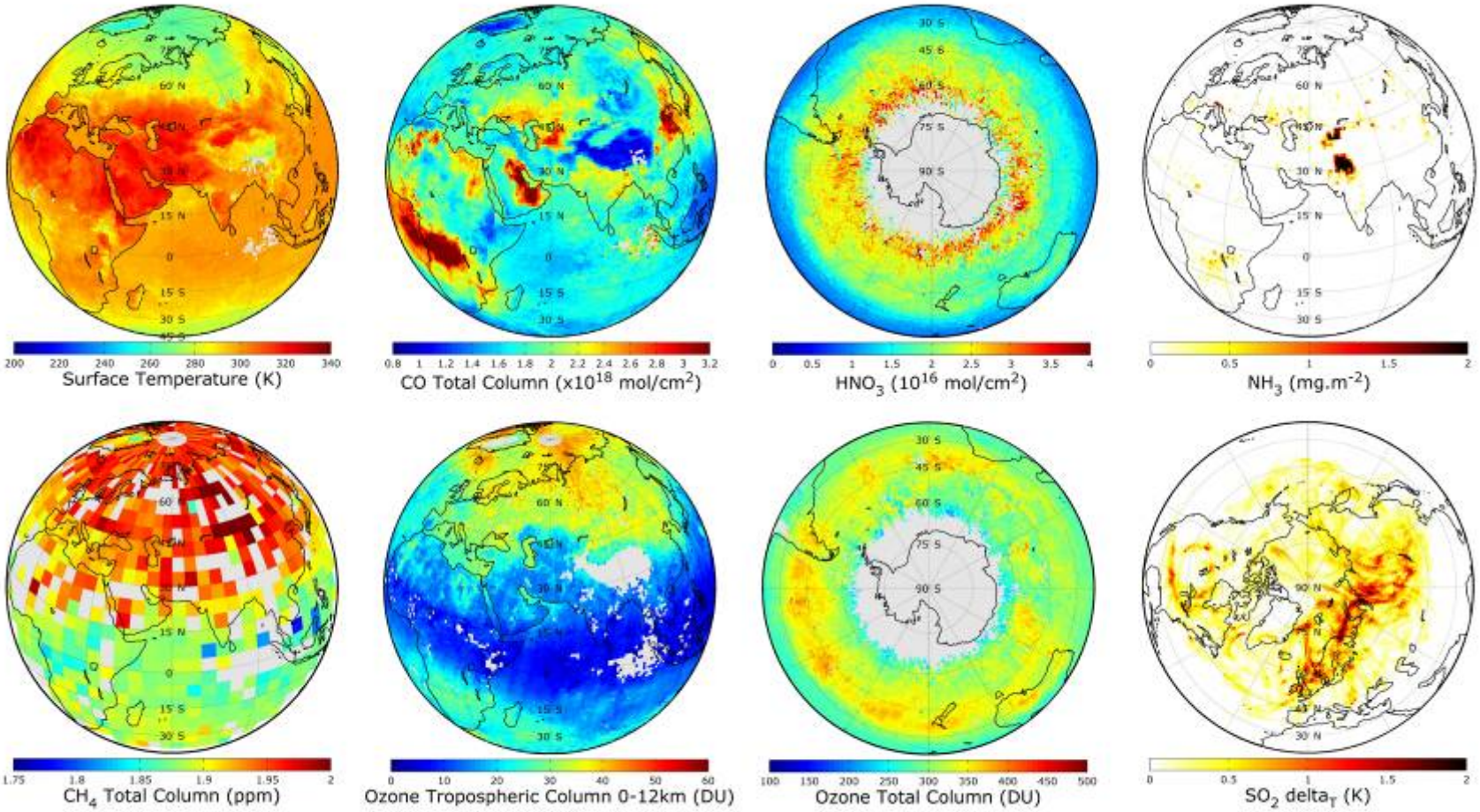
→ Error analysis

[Coheur et al., 2003, 2005 ; Barret et al., 2005]



NRT Retrievals at LATMOS/CNRS and ULB

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



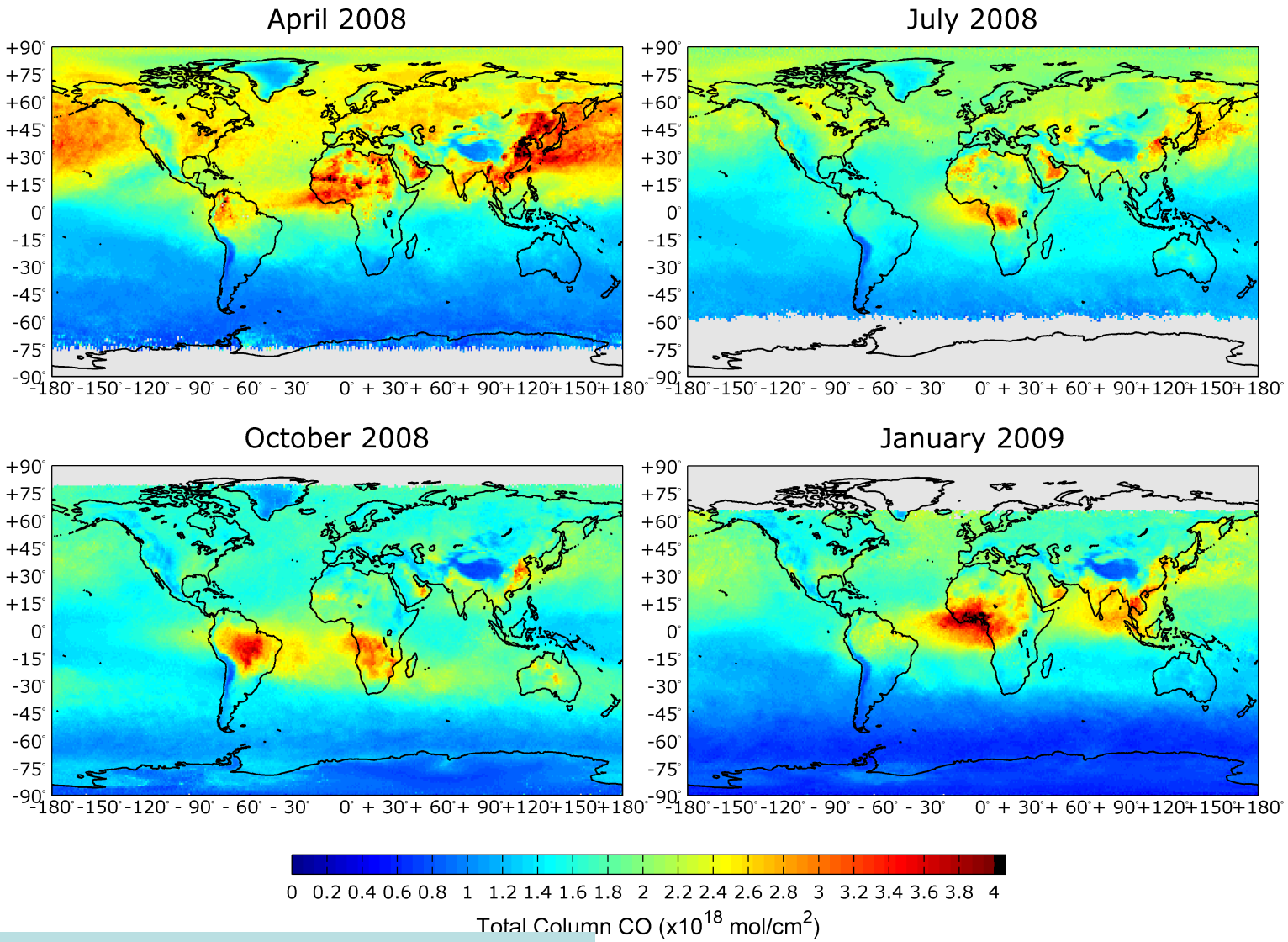
CO, O_3, HNO_3, SO_2 in near real time

CO profiles, very soon O3 profiles

Clerbaux et al,

ACP IASI Special Issue, 2009

Carbon monoxide (ULB/LATMOS)



Clerbaux et al, ACP IASI Special Issue, 2009

Preliminary validation: George et al., ACPD, 2009

LMD/CNRS LATMOS ULB

A few words about retrieval error…

→ Uncertainty on the radiances (radiometric noise): measurement error
=> only error accounted for in theoretical retrieval error

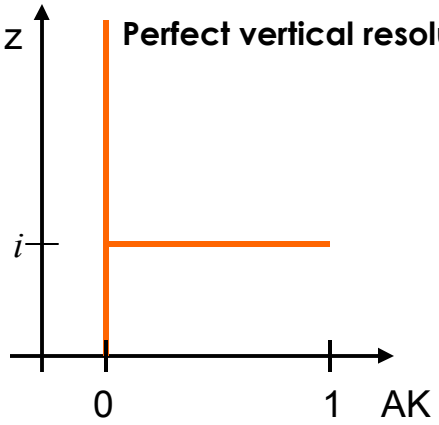
→ Uncertainty on the atmospheric and surface parameters (e.g. emissivity, temperature and water vapor profiles)

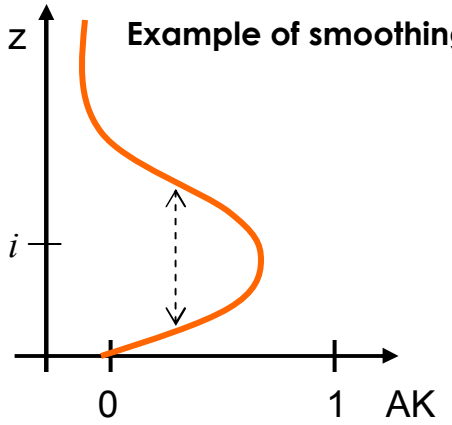
→ Lack of vertical resolution: **smoothing error**

characterized by the averaging kernel and the derived degrees of freedom of signal:

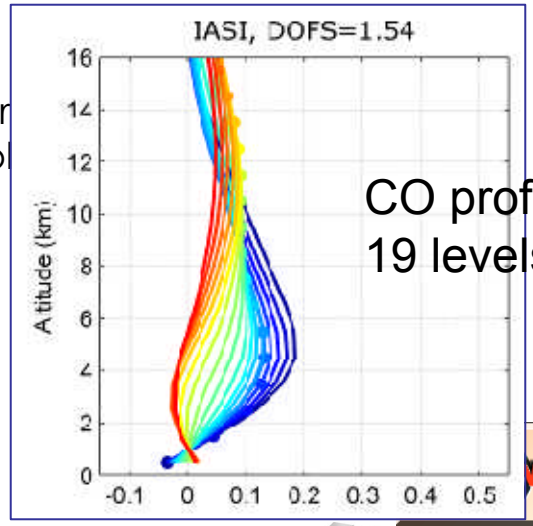
$$\mathbf{A} = \frac{\partial \hat{\mathbf{x}}}{\partial \mathbf{x}}$$

$$DOFS = trace(\mathbf{A})$$



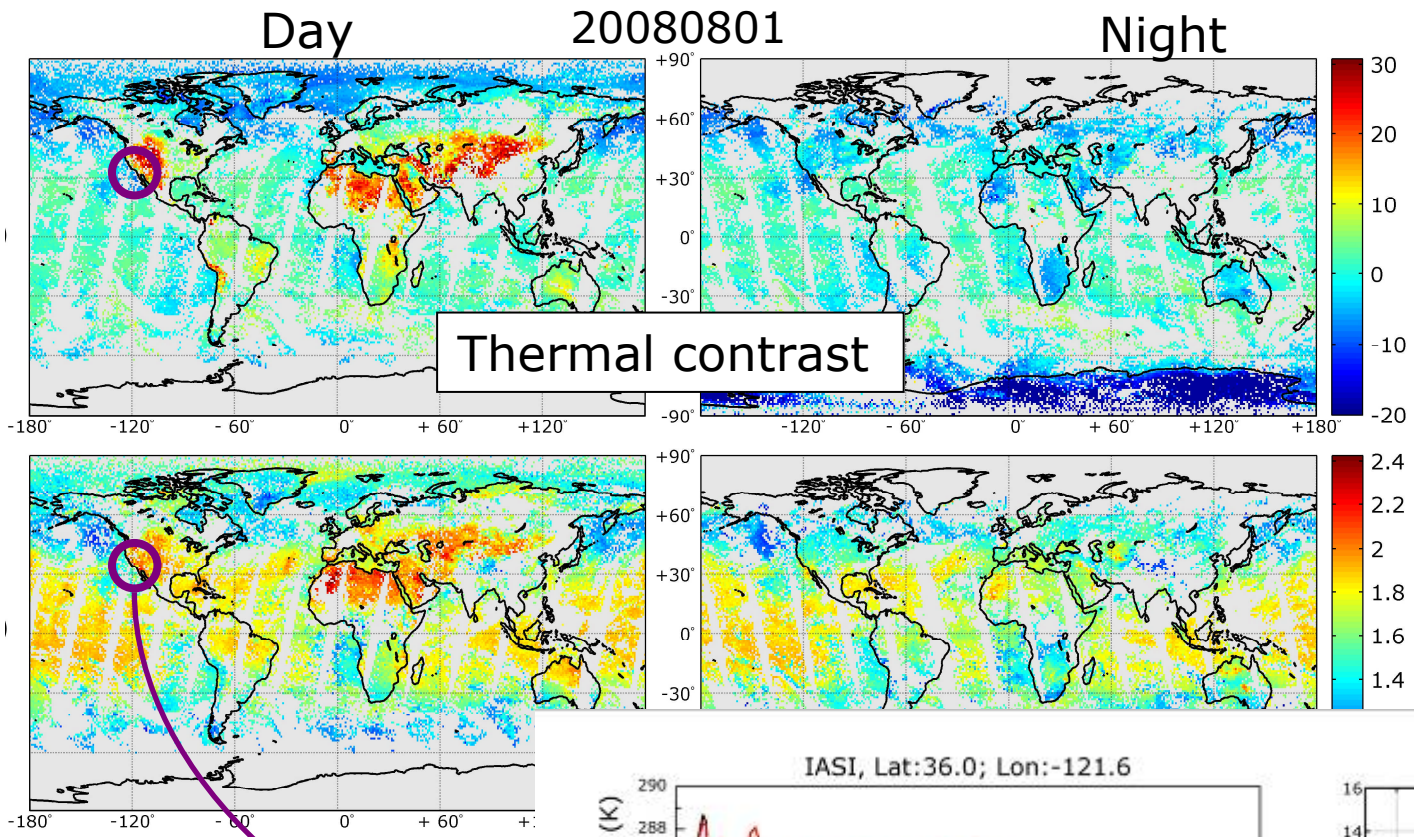


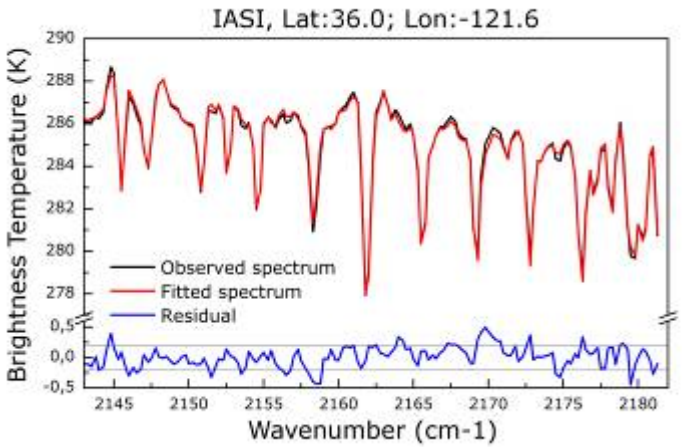
Infor
reso

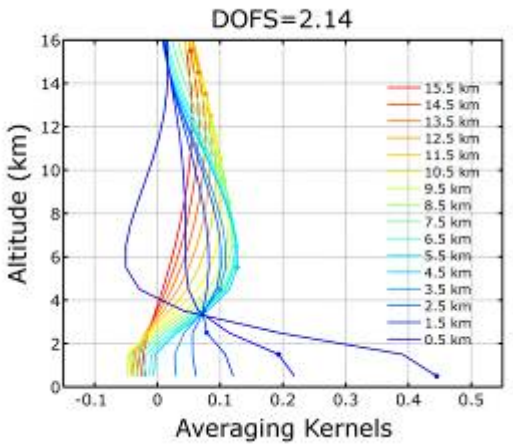


CO profile
19 levels

Degrees of freedom for signal (DOFS)

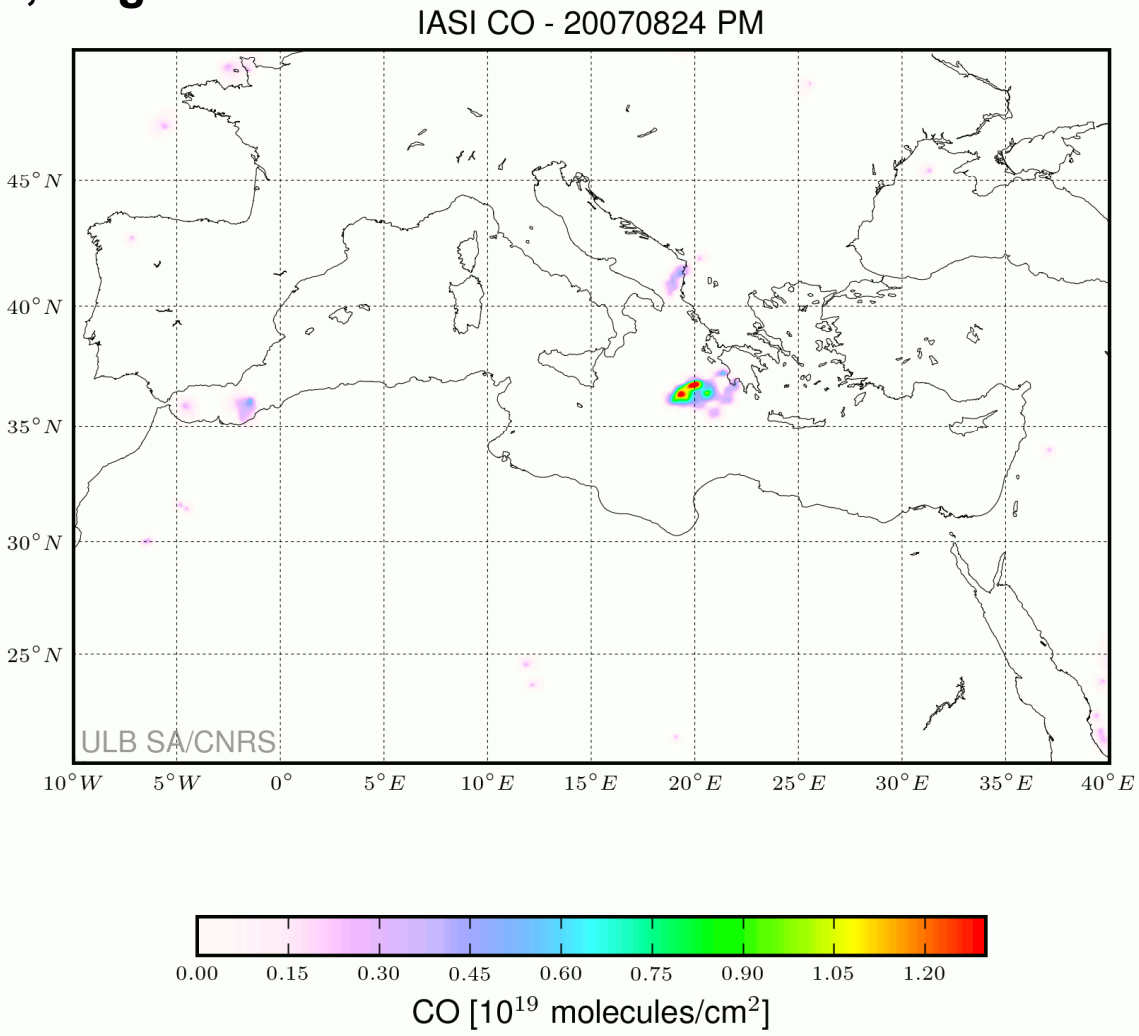






Extreme events: wildfires

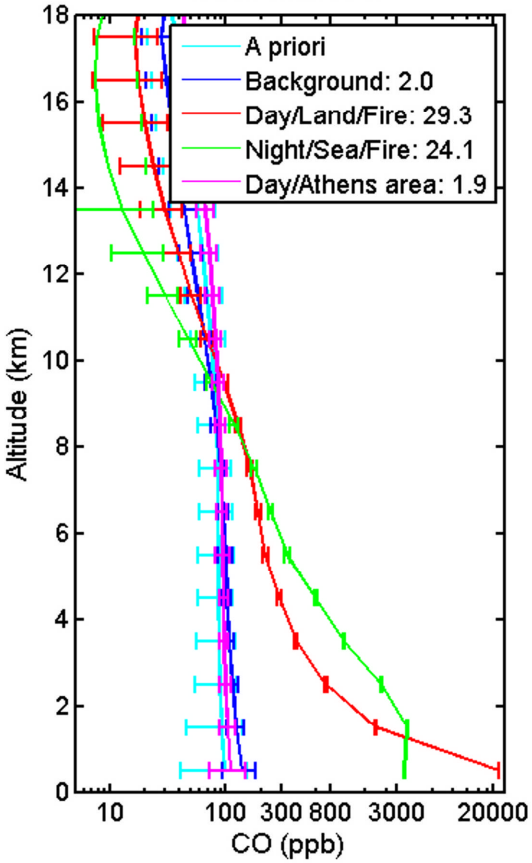
Greek fires; August 2007

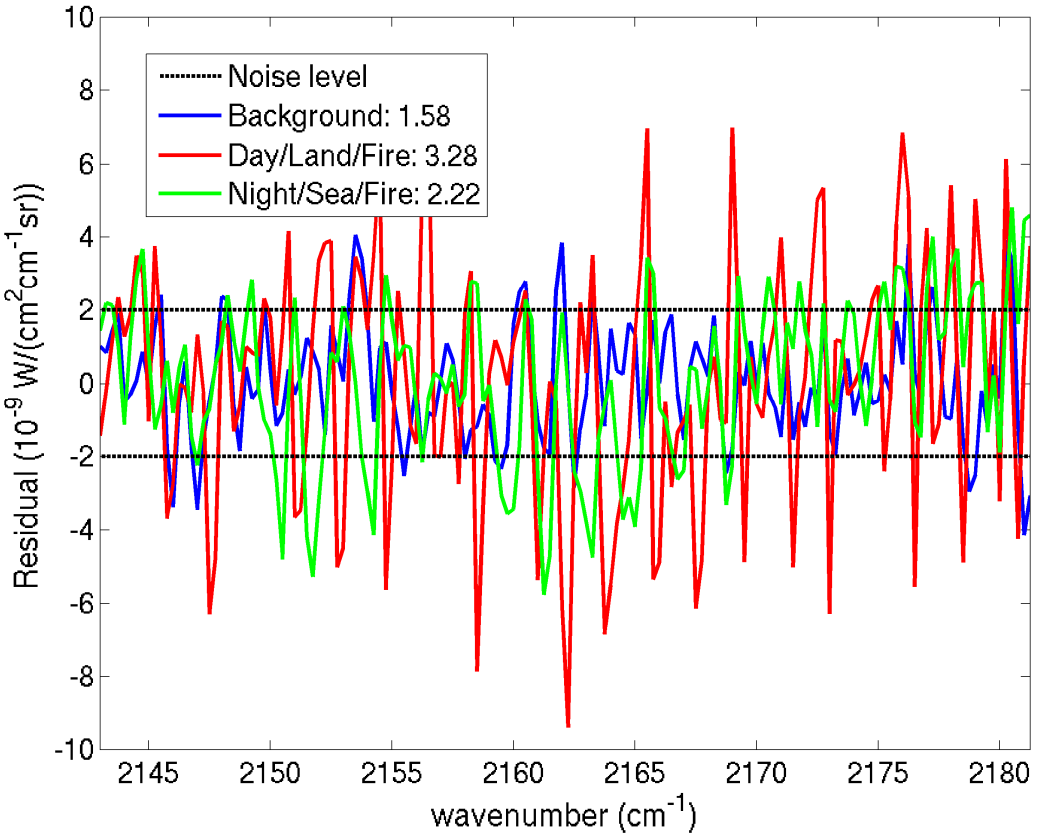


CO burden from fires = 0.321 Tg,
~40% annual anthropogenic emissions in Greece

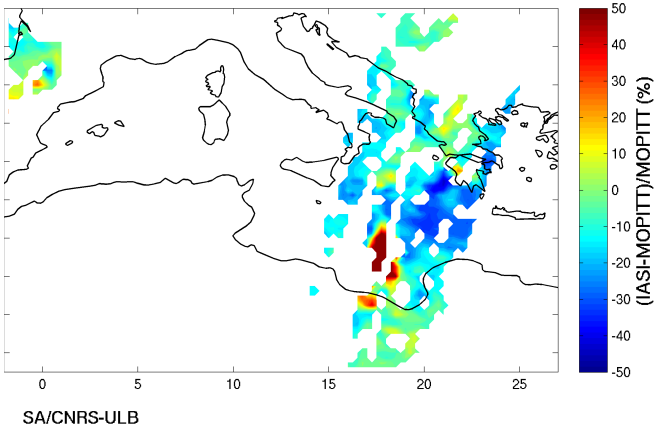
Turquety et al, ACP IASI Special Issue, 2009

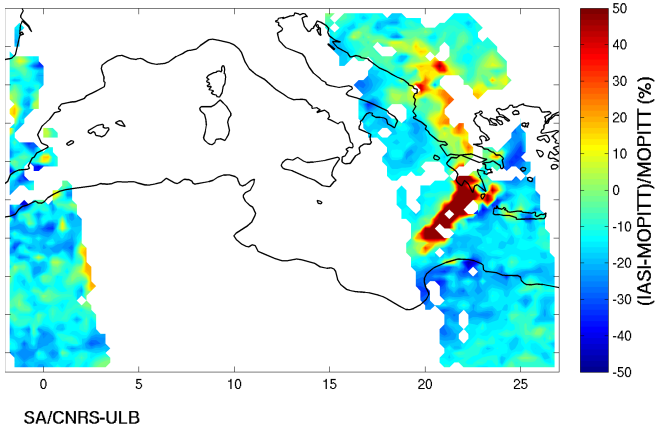
Evaluation of CO retrievals during the 2007 Greek fires





Comparisons to MOPITT/Terra CO (v3 L2 data)





➔ IASI background lower
➔ IASI larger in BB plumes

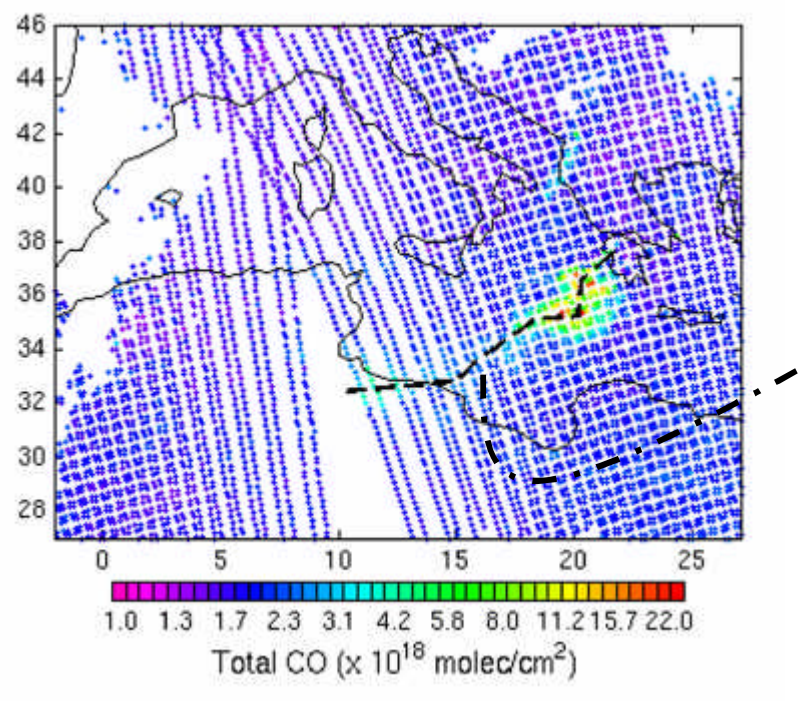
⇨ Strong implication for inversion results!

MOPITT v4: low bias in large plumes corrected

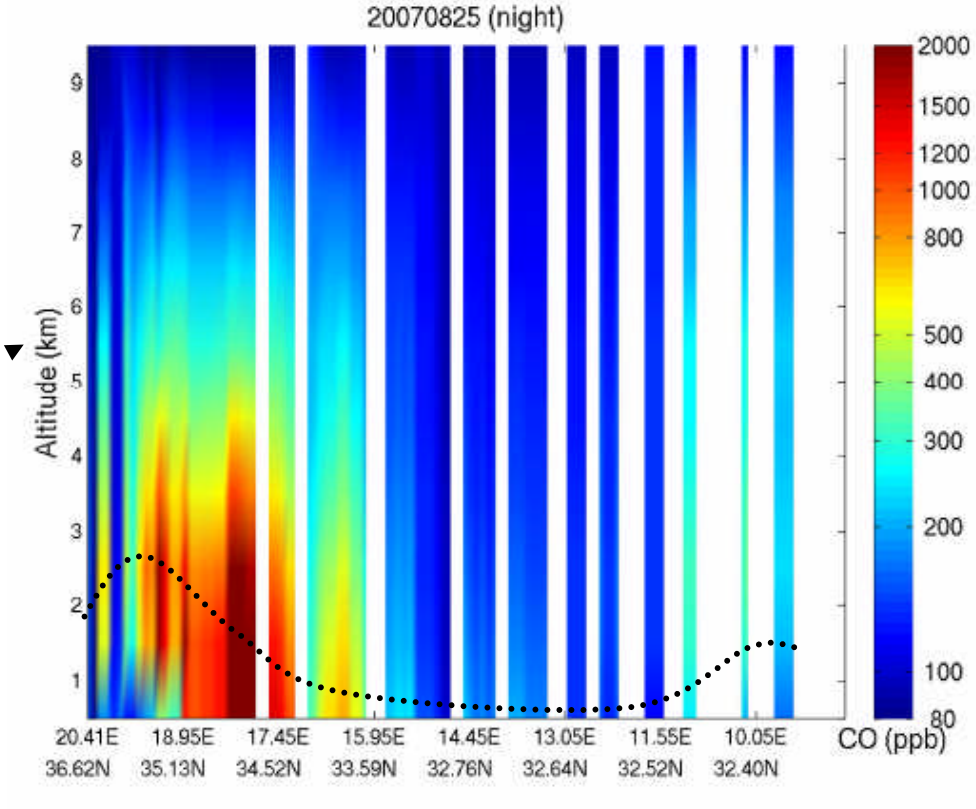
LMD/CNRS
LATMOS ULB

Information on vertical transport?

Total CO, August 25, PM

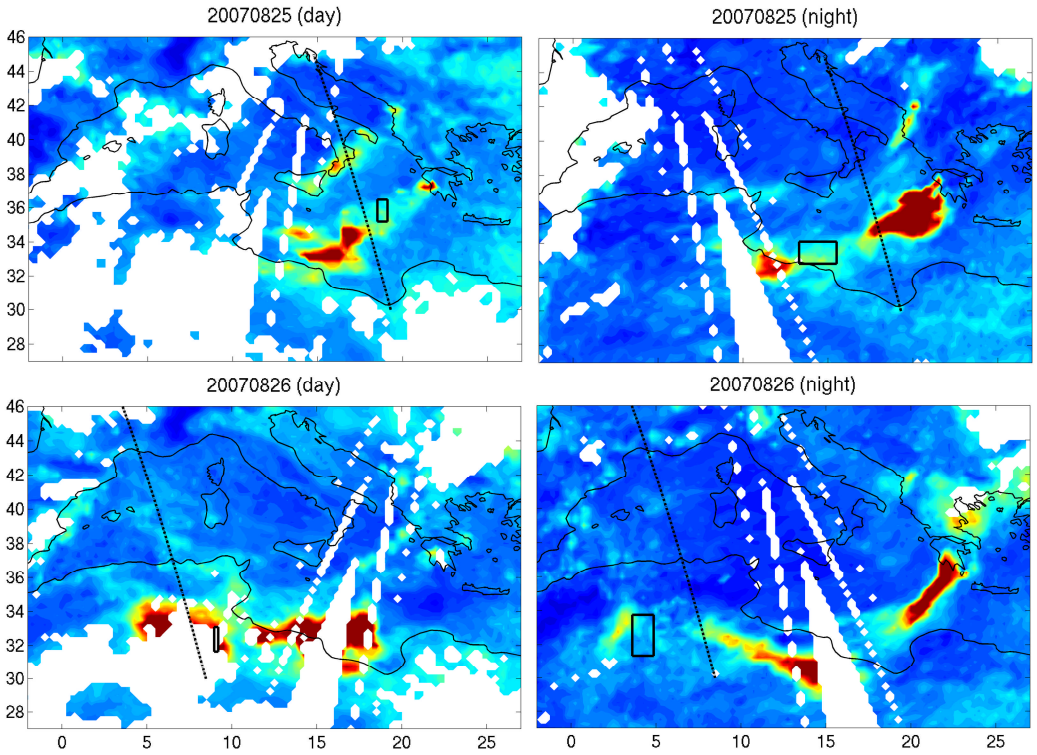


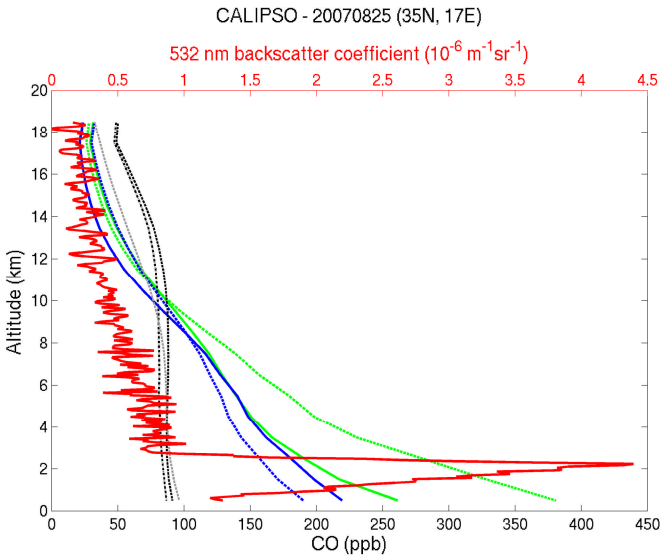
CO vertical profile along the plume, August 25, PM

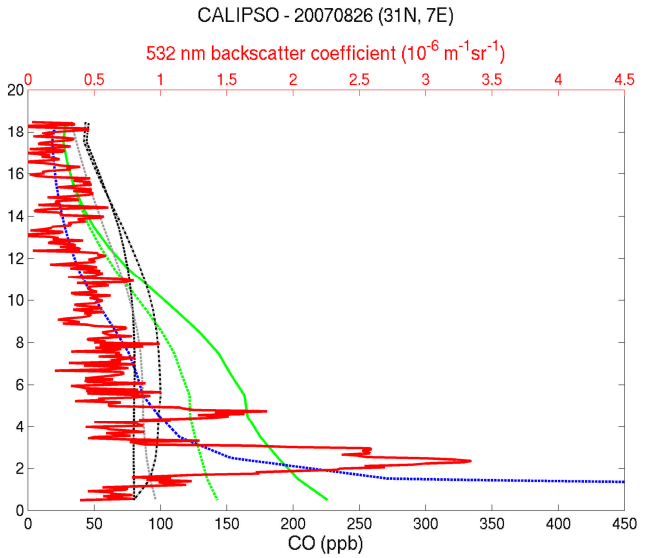


Turquety et al., ACPD 2009

Information on vertical transport?







Wildfires: short lived species detection

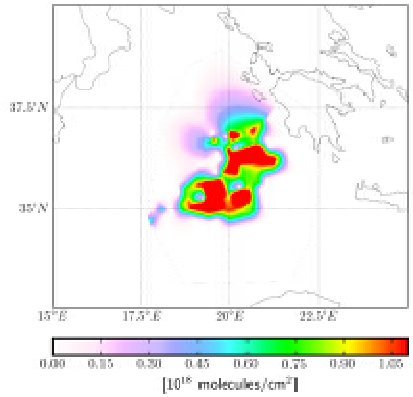
Coheur et al., ACP 2009

Greece fires (August 2007)

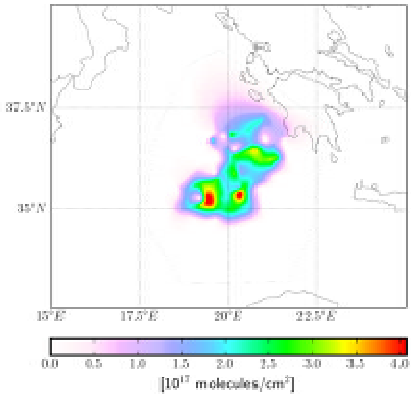
August 25, PM

Measurements of short-lived species

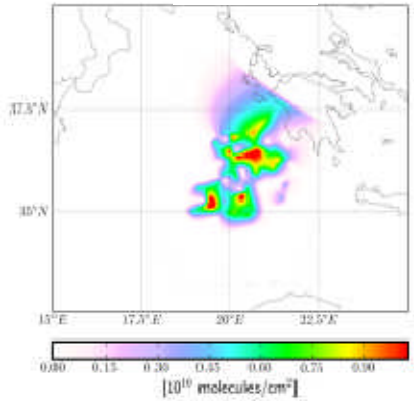
CO



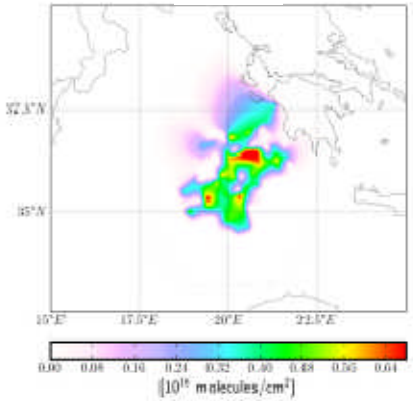
NH_3



CH_3OH

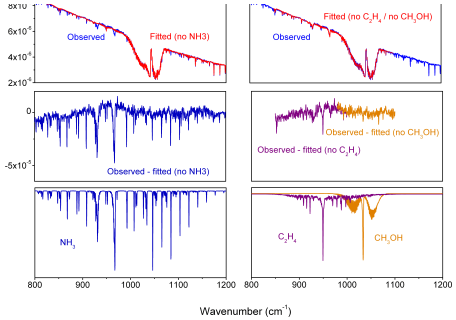


C_2H_4



Spectral signatures

NH3



C2H4 CH3OH

LMD/CNRS

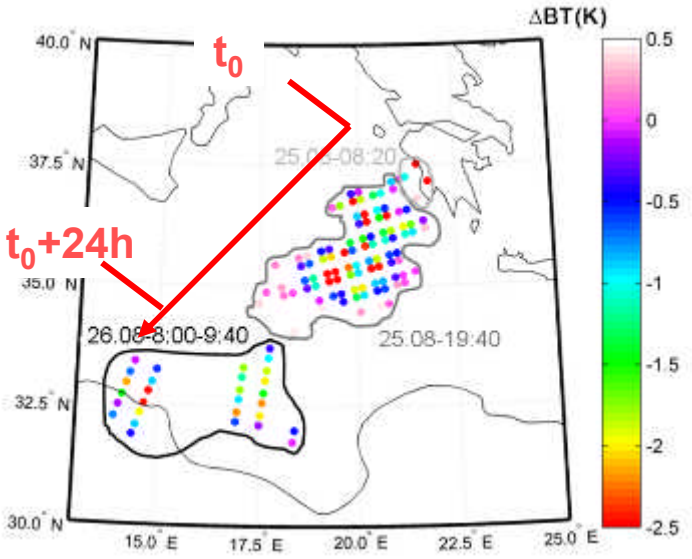
LATMOS ULB

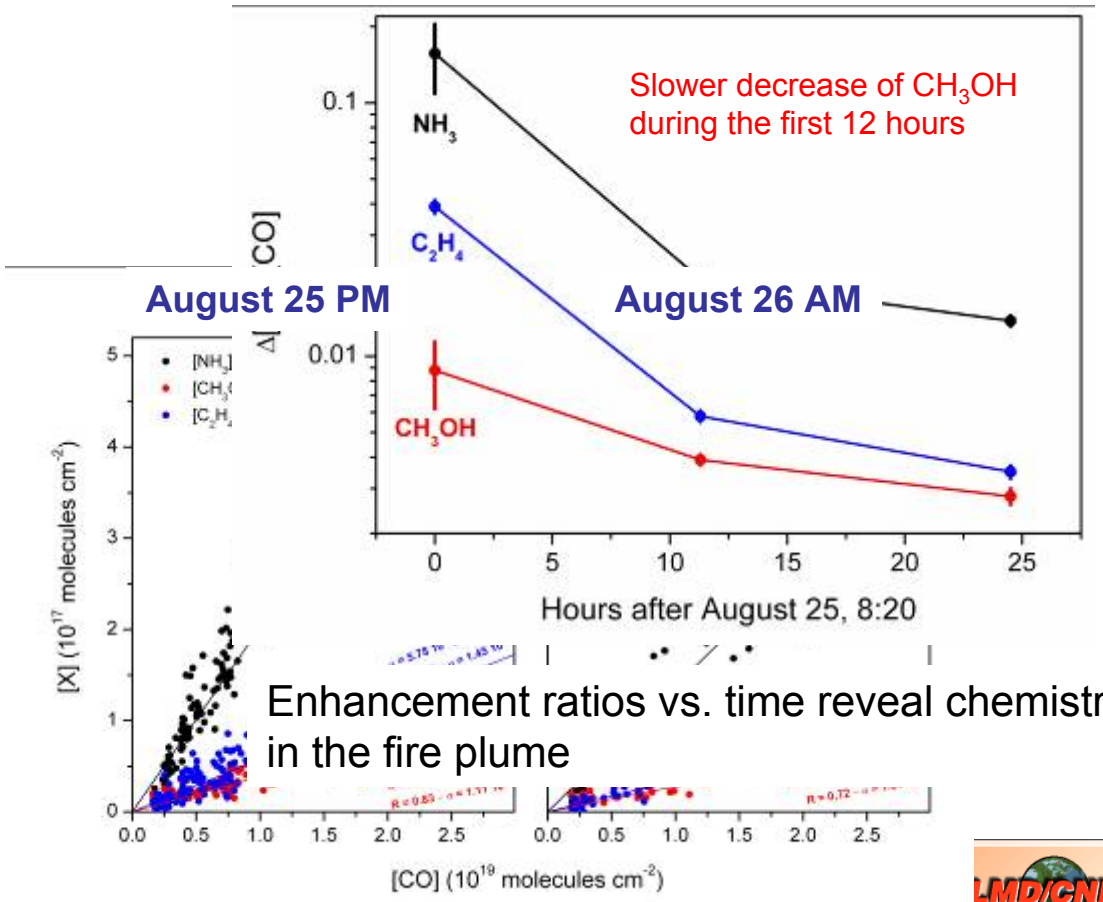
Wildfires: short lived species detection

Coheur et al., ACP 2009

Greece fires (August 2007)

Chemistry and transport





Slopes vs. CO give *enhancements ratios* Δ[X]/Δ[CO]

Enhancement ratios vs. time reveal chemistry in the fire plume

LMD/CNRS LATMOS ULB

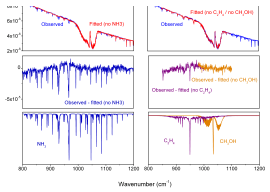
Wildfires: short lived species detection

Coheur et al., ACP 2009

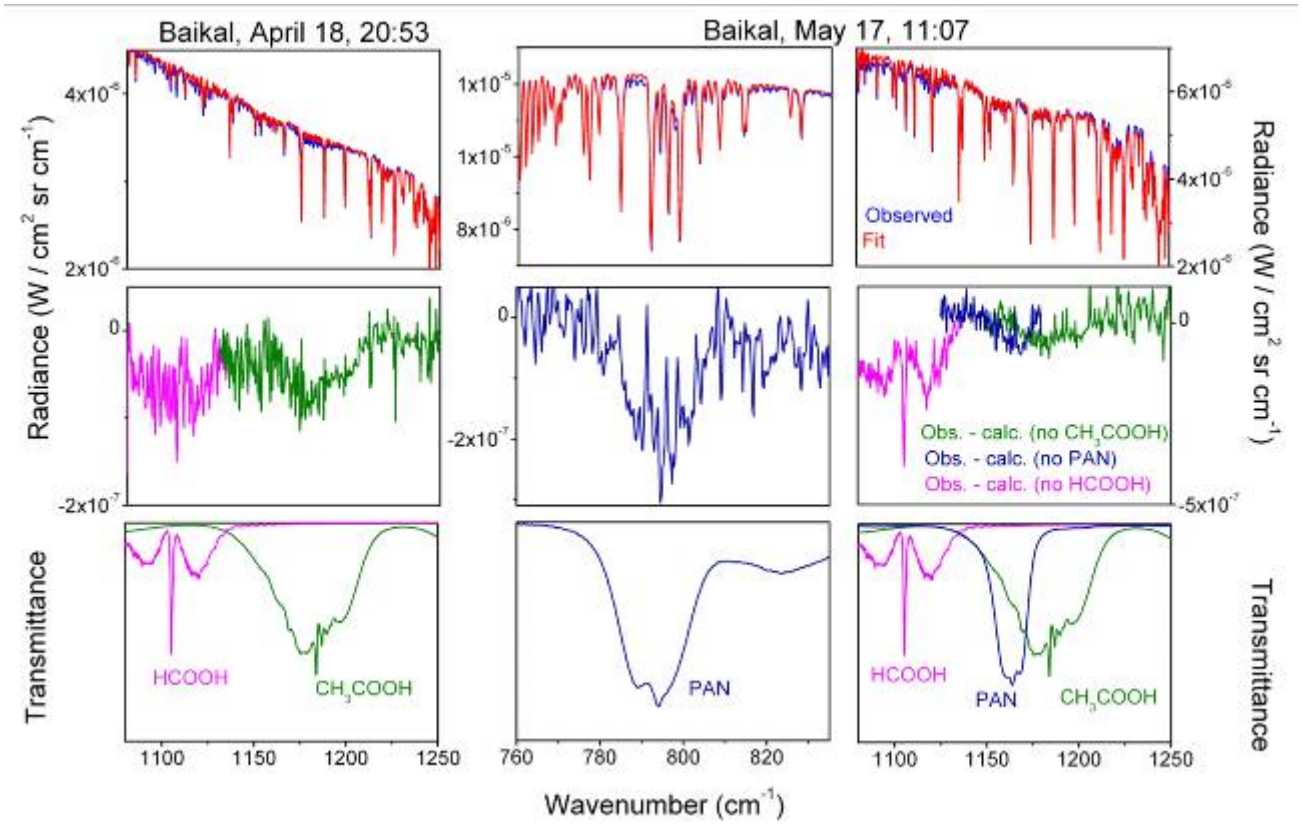
Siberian fires (April-May 2008)

Measurements of short-lived species

NH_3



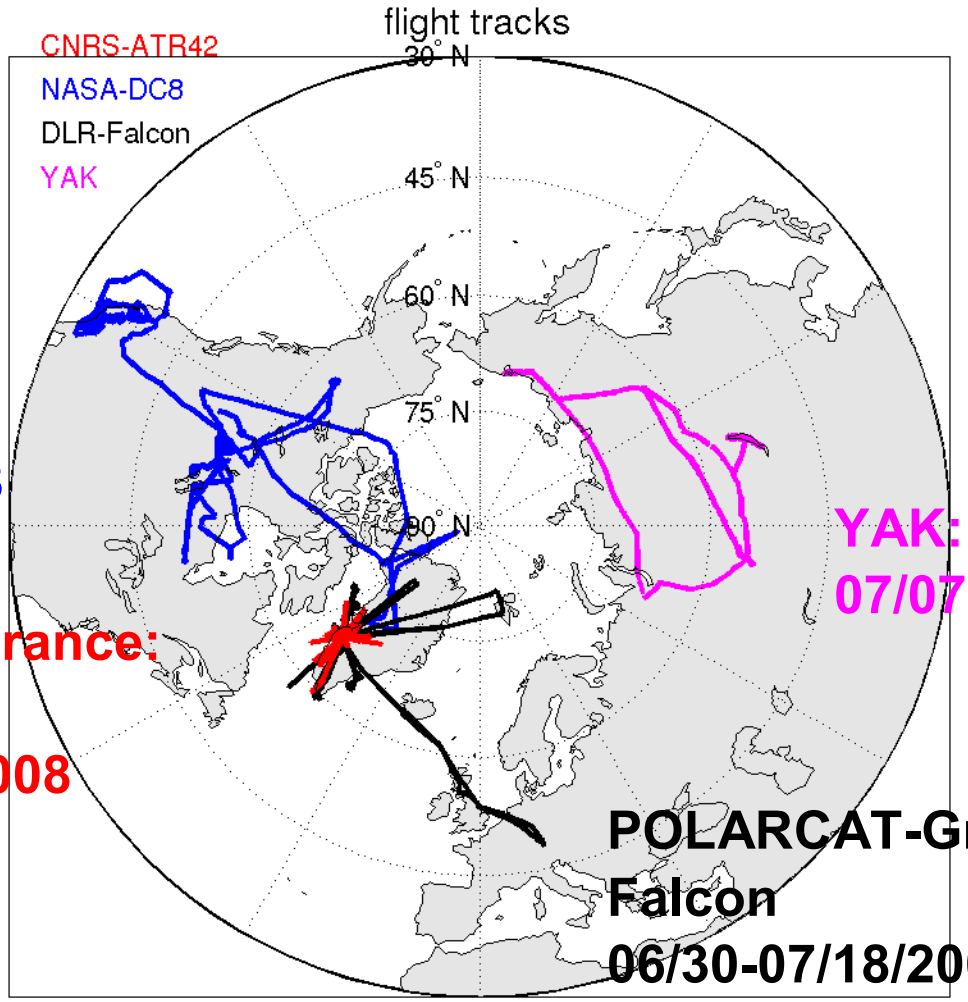
C_2H_4 CH_3OH



HCOOH, CH_3COOH, PAN

+ New results:
C_2H_2, HCN, HONO…

Validation against in situ observations during the POLARCAT campaign



ARCTAS: DC8
06/18-07/13/2008

POLARCAT-France:
ATR-42
06/30-07/14/2008

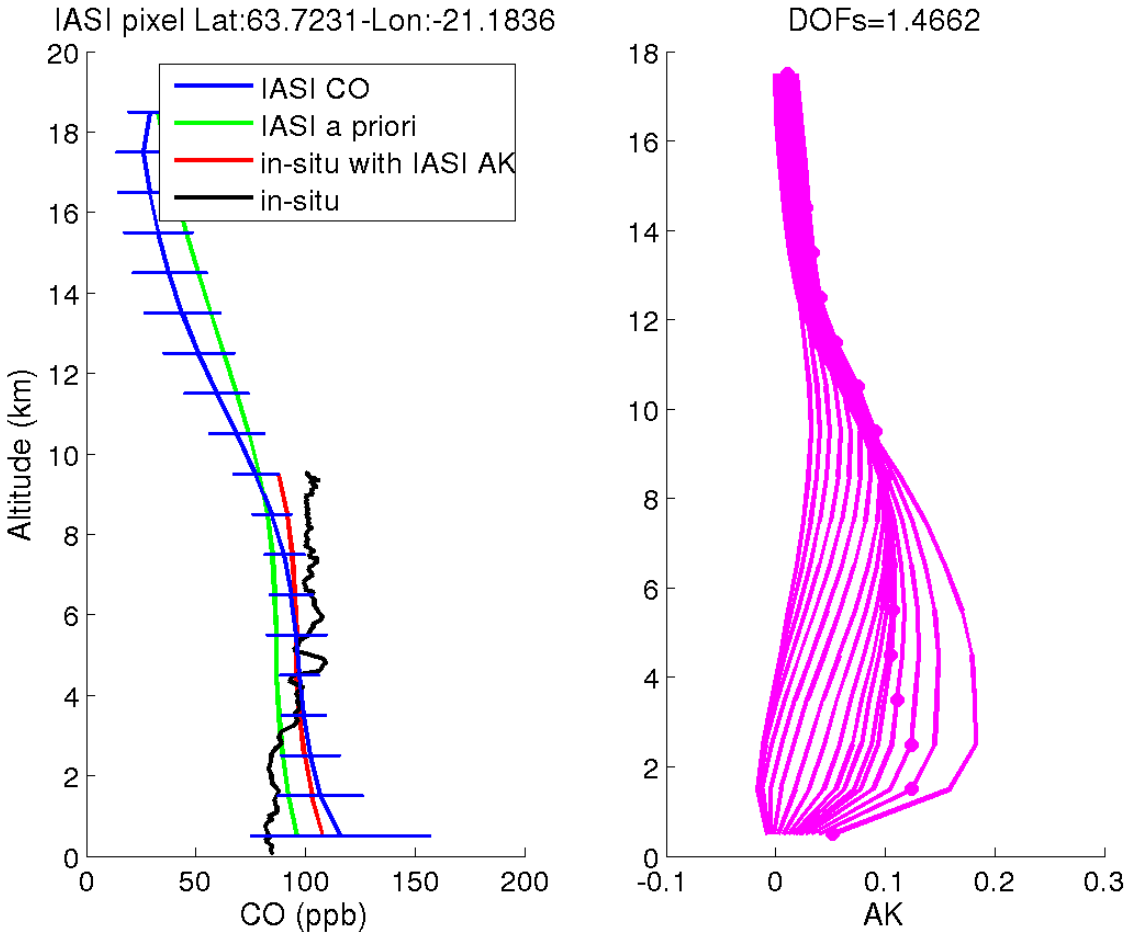
YAK:
07/07-07/29/2008

POLARCAT-Grace:
Falcon
06/30-07/18/2008

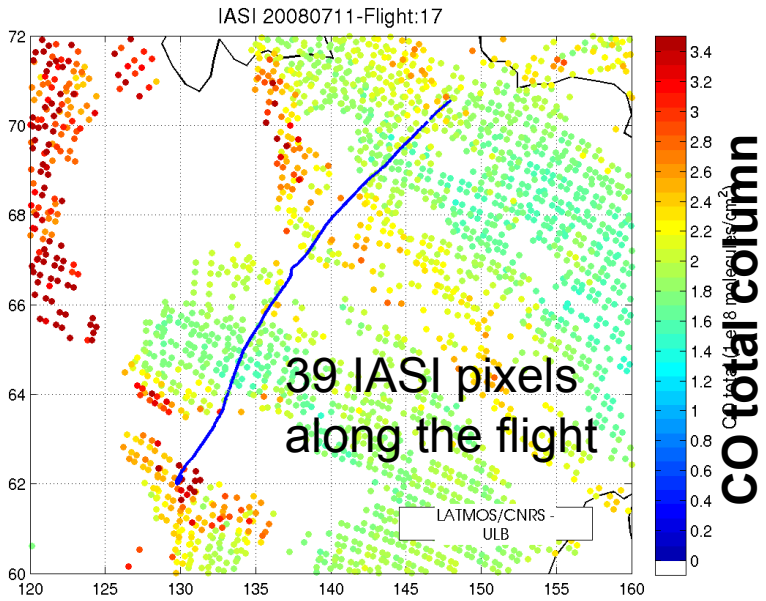
(M. Pommier, S. Turquety)

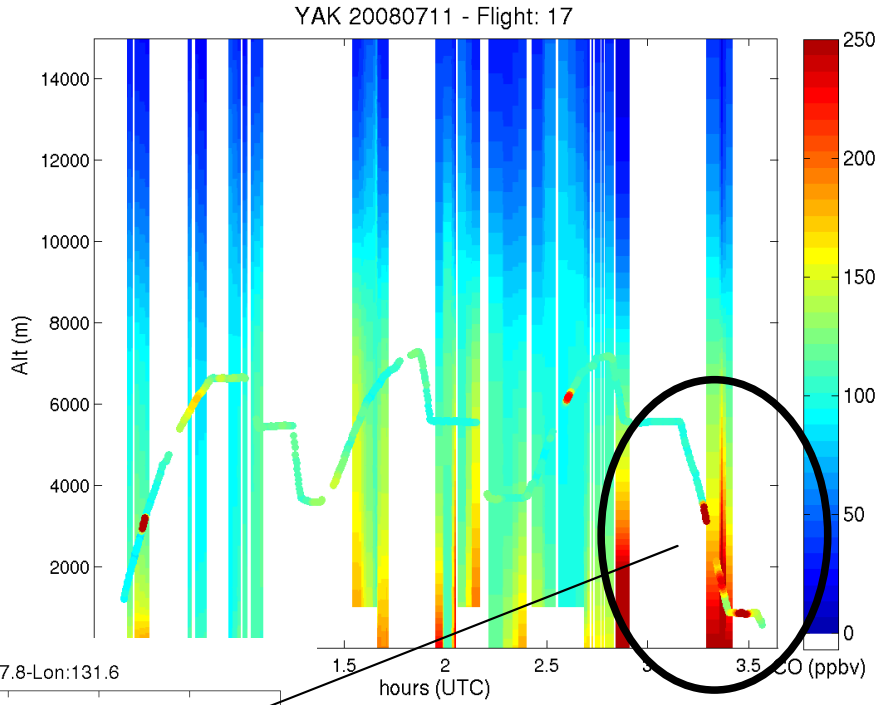
Example of validation profile

Background air above Greenland (DLR flight)



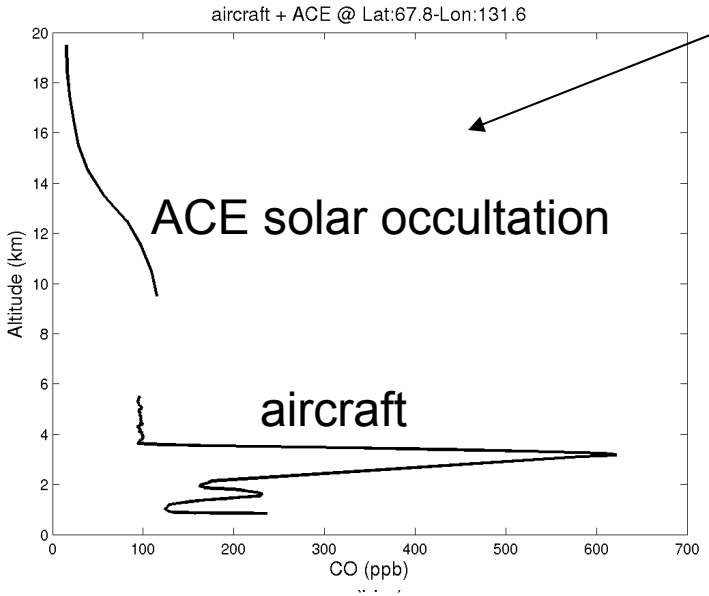
Siberian pollution (Forest Fire): Flight YAK July 11th 2008





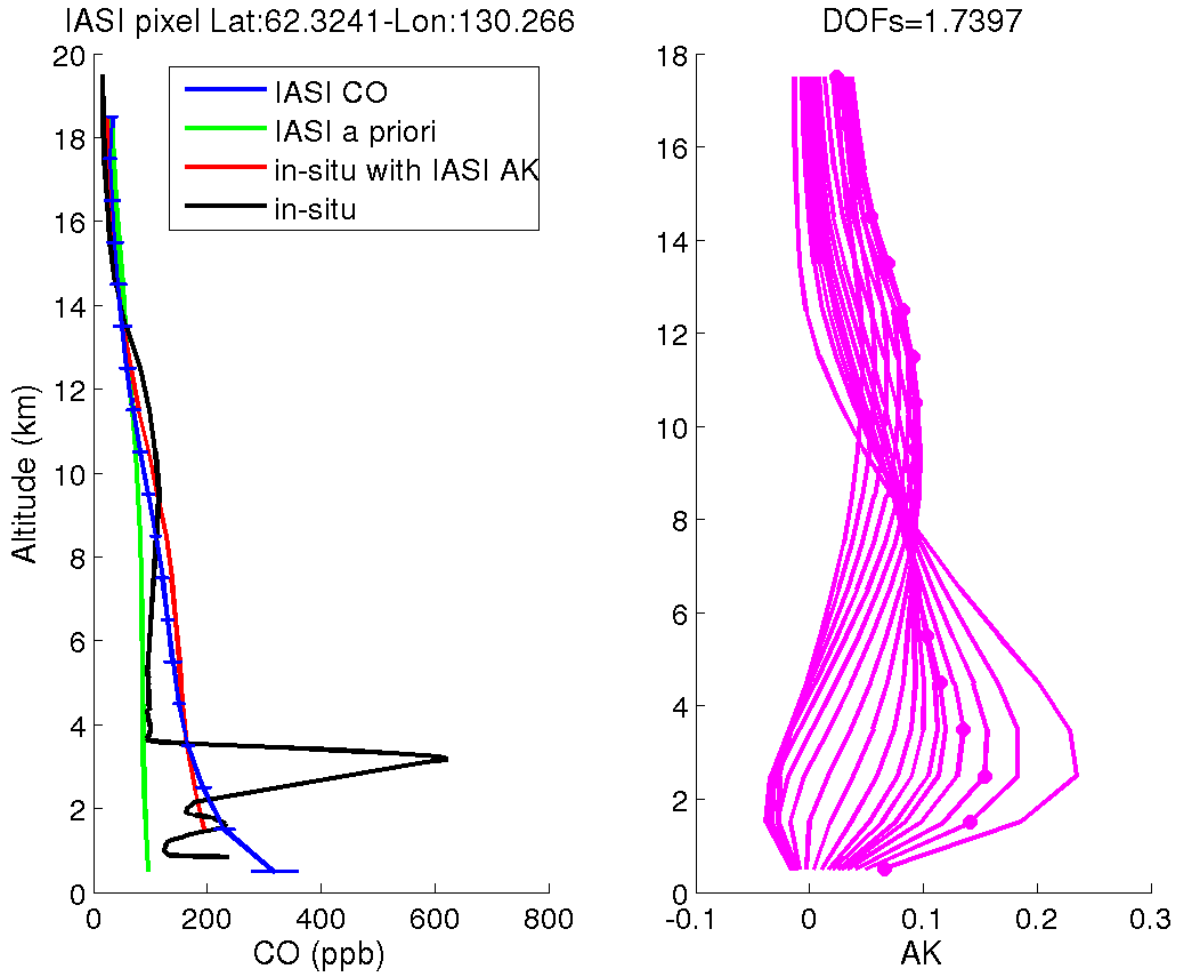
only +-1h around the aircraft position

in a box +- 0.2°around the plane



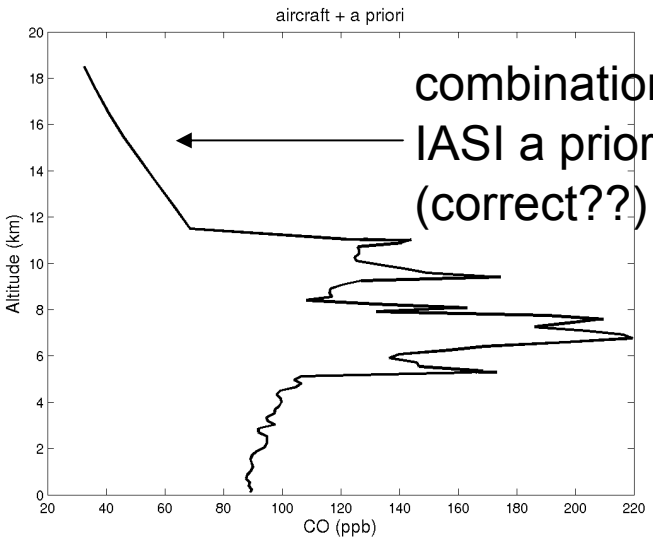
IASI CO vertical distribution .vs. YAK in situ CO measurements:
P. Nédélec, J.-D. Paris

Siberian pollution (Forest Fire): YAK July 11th 2008

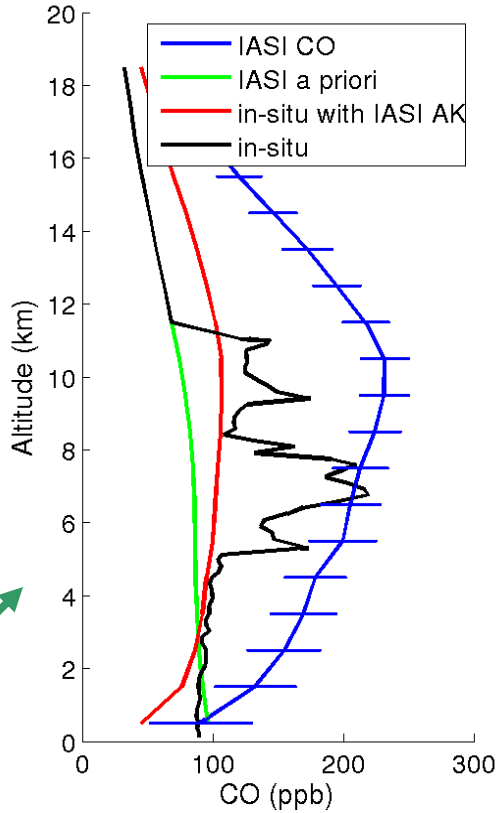


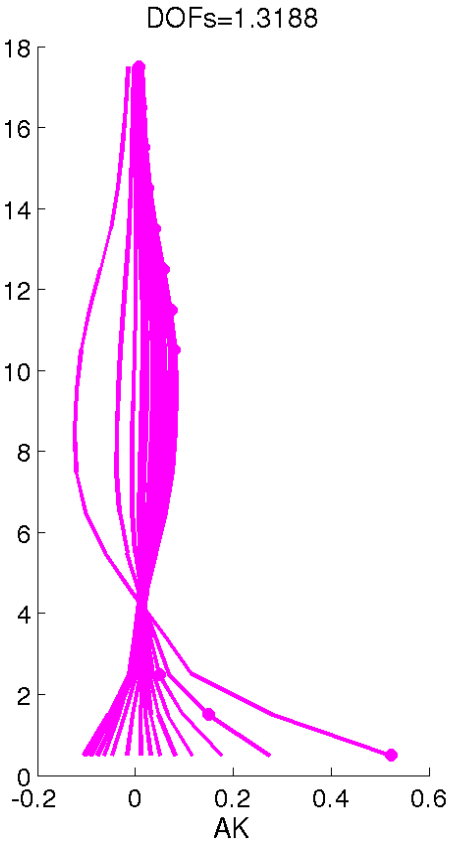
Enhancement in the IASI CO in the lower troposphere
BUT not able to resolve the plume shape

North American pollution (Forest Fire): DC8 July 5th 2008



combination with IASI a priori (correct??)



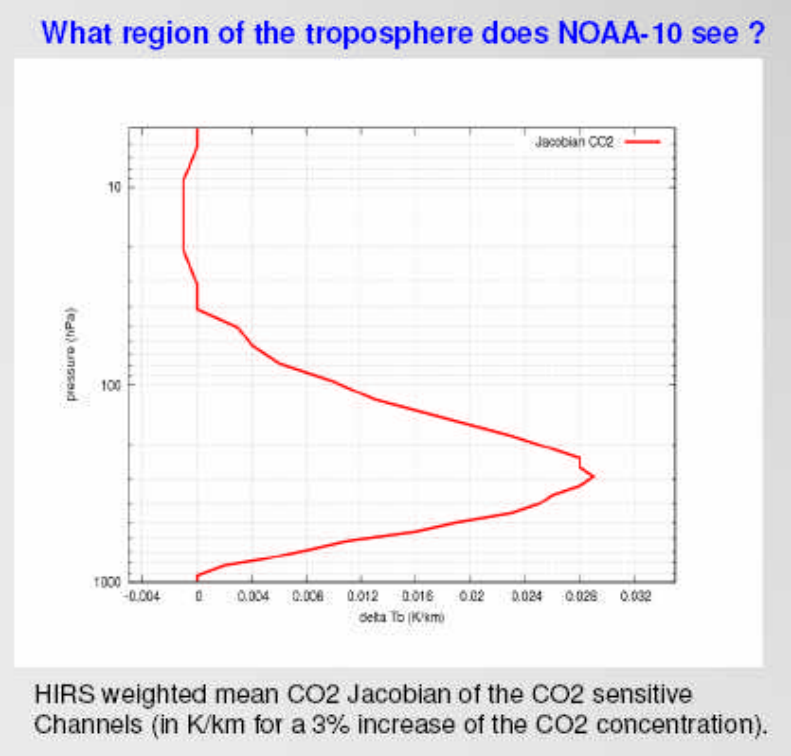


Enhancement in the IASI CO in the upper troposphere
BUT

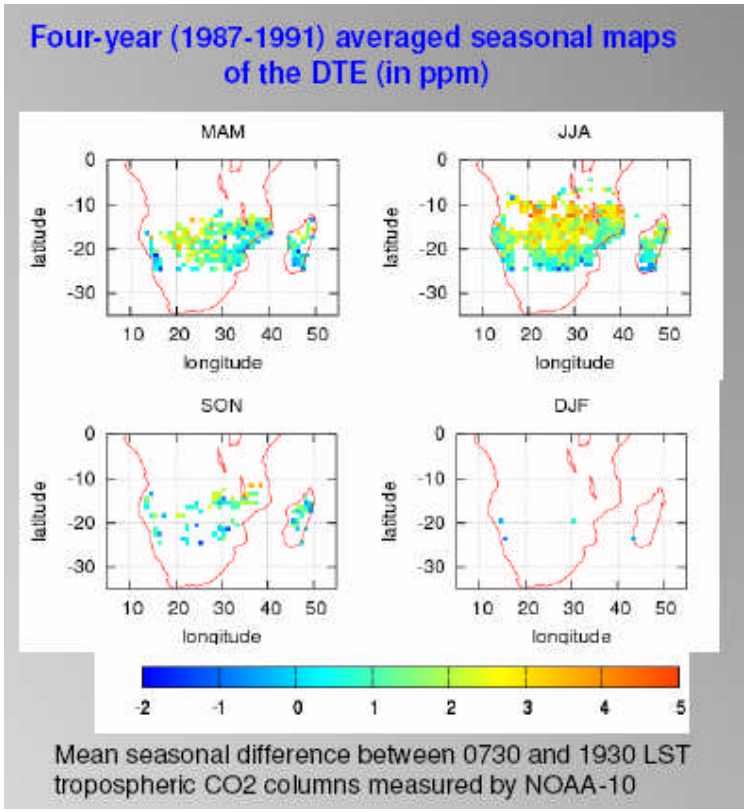
- not able to resolve the plume shape
- too large CO?
- problem of validation:
  large correlation with CO above 12km but no in situ observation…

Possible constraint on injection height from IR observations?

Daily tropospheric excess of CO2 seen by the NOAA-10 in 1987-1991



HIRS weighted mean CO2 Jacobian of the CO2 sensitive Channels (in K/km for a 3% increase of the CO2 concentration).



Mean seasonal difference between 0730 and 1930 LST tropospheric CO2 columns measured by NOAA-10

Correlation of DTE seasonal cycle with fire emissions;
Variability of CO2 only reproduced by LMDz if pyro-convection is accounted for.

Chédin et al., ACPD, 2009; Rio et al., ACPD, 2009

Conclusions

Trace gas observations from satellite:
(+) Good spatial and temporal coverage allow the monitoring of plumes
(+) Relatively long records
(-) Lack vertical resolution
(-) Retrieval error often difficult to assess accurately!

Specific problems for fire plumes:
• Huge pollution : far from the a priori statistics
• Impact of aerosols (probably important for O3)
• LACK VALIDATION DATA

Next step:
• **Analyse observations with a CTM to check the available constraint**
• **Use model as a intermediate for validation**

Future:
• **IASI for at least 15 years**
• IASI-like observations on MTG (2015) BUT probably lower spectral resolution
➔ Geostationary observations

Thank you for your attention!

Check IASI NRT CO maps : www.iasi-chem.aero.jussieu.fr

IASI Level 1 data received through the EUMETcast distribution service

To use retrievals from LATMOS and ULB, please contact

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Pierre-François Coheur, ULB, *pfcoheur@ulb.ac.be*