Use of IASI data for tropospheric trace gas retrieval

Current studies for new IASI products supported by CNES

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CENTRE NATIONAL D'ÉTUDES SPATIALES

GOALS

IT IS ESSENTIAL FOR CNES (French space agency) TO DEMONSTRATE THE SOCIETAL BENEFITS OF SPACE PROJECTS LIKE IASI.

To foster use of IASI data for meteorology and other areas of application (Climate, air quality monitoring, environment, etc.) by supporting research, distributing high level products and initiating new services.

TRYING TO IDENTIFY THE LIMITATIONS (with IASI) TO BE USED IN DEFINITION OF NEXT GENERATION (PEPS)

Contribution and support to research

- **Expand IASI sounding to cloudy pixels (Level1)**
- **Improve current level 2 products**
- **Study additional products**
- **Implement and distribute Level 3 or Level 4 products**

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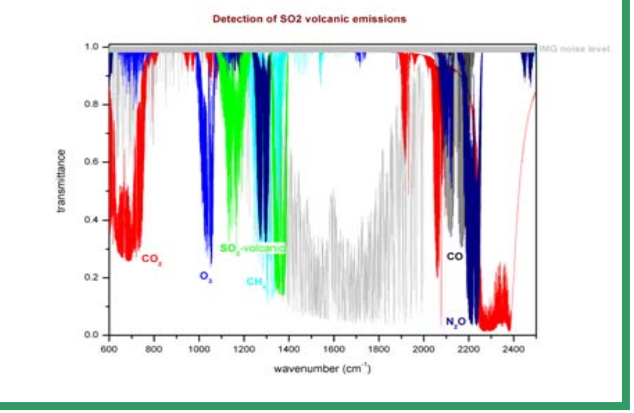

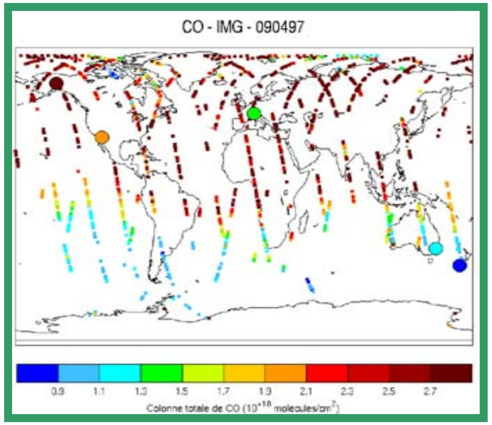

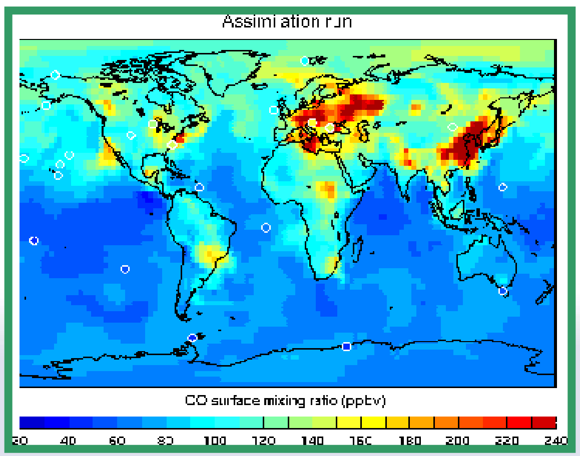

METOP [2007-2020]

IASI - GOME2

Inversion algorithms

O_3, CO, CH_4, N_2O, CO_2,

HNO3,
SO2 (volcans),
CFCs

O_3, NO_2,
SO_2, H_2CO

CTM + Data assimilation

Tropospheric chemistry
Pollution transport, AQ
Emissions

Level 1

Atmospheric spectra

+Declouding

Level 2

Concentrations

Level 3

Global Averaged distributions

Level 4

Global distributions (multisensors)

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PROCESSING HETEROGENEOUS SCENES
(B. Tournier, S. Bijac, O. Lezeaux, P. Prunet)

- **Use of heterogeneous pixels to increase the coverage**

- **Benefits :**
  - Atmospheric profiles on the edges of frontal systems
  - Reducing integration time and spatial averaging domain for trace gases retrieval (CO_2)

- **Issue of spectral shift and pseudo noise due to composition of different spectra at different location within off axis pixels**

  (see P. Schlüssel Poster)

IASI heterogeneous scene algorithm

- **Two algorithms are designed**
  - Scenes decomposition (studied for Eumetsat)
    - Suitable for radiances direct assimilation.
    - The selection of the homogeneous scene to be retrieved is allowed.
    - Retrieved scene type can be chosen, suitable for chosen cloud type and leads to cloud parameters retrieval.
    - **Amplification of the noise due to scene decomposition not controlled.**
    - **Amplification of the noise due to spectral post calibration.**

    OLD
  - Direct model combination
    - Suitable for full scene retrieval (all homogeneous components shall be considered simultaneously). **Needs accurate FRTM for Cloudy pixels and knowledge of surface emissivity spectra**
    - **No noise added**
    - System ready for any progress in direct models in the frame of clouds processing.

    NEW

These two approaches are currently under development and will be compared. The most accurate and fast will be implemented for test on a routine basis

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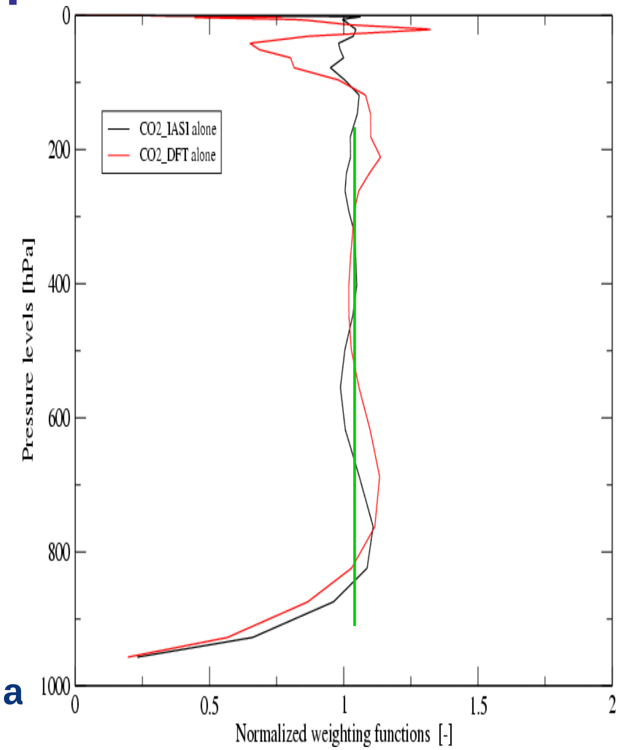
CO_2

Mission specification : Requirements

- Requirement on the IASI column weighted averaged

Boundary layer (pressure)	Boundary layer (height)	Weight with weighting function IASI/SPECTRE	Weight with weighting function IASI/DFT
1013-900 hPa	1.0 km	0.45	0.35
1013-720 hPa	2.7 km	0.77	0.7

Boundary layer (pressure)	Boundary layer (height)	Required accuracy on mean content (ppmv) IASI/SPECTRE	Required accuracy on mean content (ppmv) IASI/DFT
1013-900 hPa	1.0 km	0.9	0.7
1013-720 hPa	2.7 km	1.54	1.4



Required accuracy of about 1 ppmv on the IASI CO2 column weighted a

- High spatial and temporal sampling of IASI

  Spatial averaging : ~ 1000 measurement points for $(10^3 \times 10^3)$ km^2

  Temporal averaging : 60 measurements/month

  5 % of clear data (20 % with cloud-clearing ?)

  Theoretical noise reduction ratio of about 50

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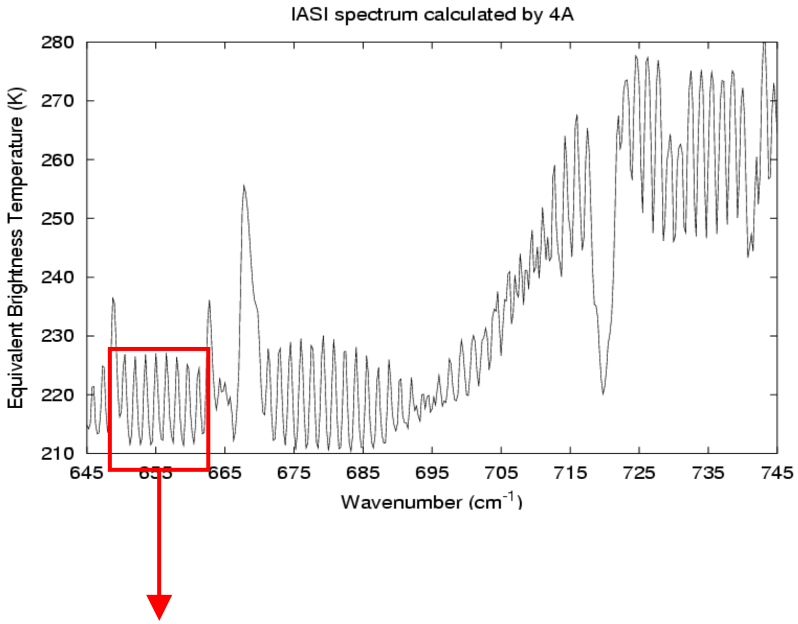
CO_2

Data processing : Discrete Fourier Transform (DFT) methodology

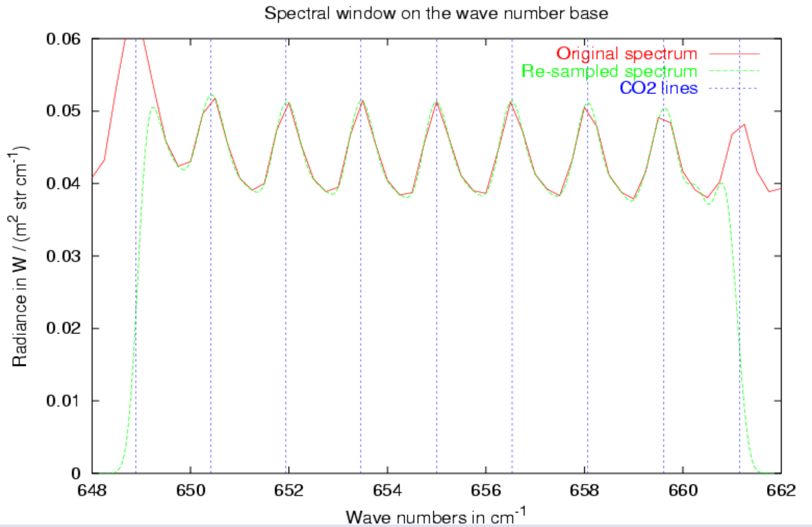


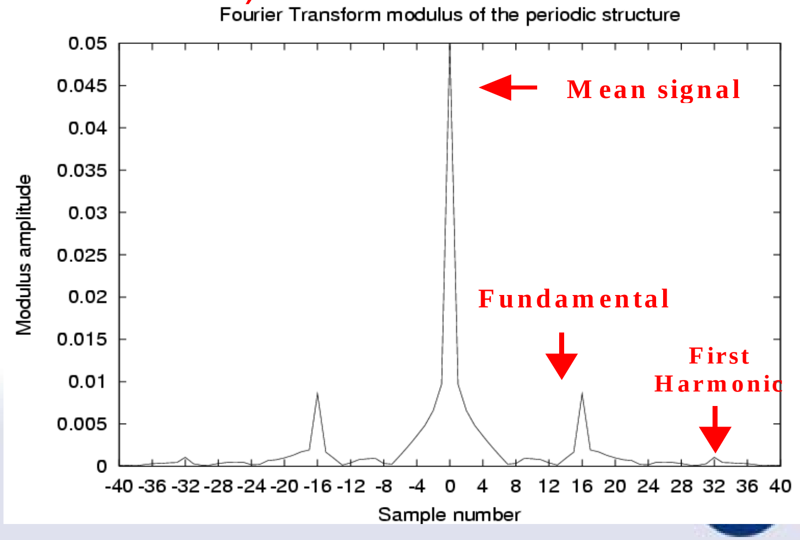
Selection of 16 specific spectral windows (1282 spectral samples): regions with strong atmospheric CO2 absorption or emission

From the quasi periodic line structure of the IASI spectrum

- re-sampling on a periodic base built from the spectral transitions of the CO_2 lines
- application of a Discrete Fourier Transform to specific spectral windows

DFT pseudo data (mean, fundamental and first harmonic)





CO_2

TEMPORARY CONCLUSIONS

DFT approach

- Permits an efficient extraction of the CO_2 information
  - **Filtering the impact of other variables (to be confirmed for surface parameters)**
  - No significant loss of information (to be confirmed near the surface)
  - **Data compression**
- Gives reliable results on measured noisy data, consistent with independent estimates, showing the robustness of the algorithm

Validation on representative sets of data

Retrieval accuracy from a single spectrum

- IASI Balloon
  - 4 ppmv (1 %) on the column averaged mixing ratio
  - no reliable estimate in low troposphere
- IASI Metop
  - 1.2 ppmv (0.3 %) on the column averaged mixing ratio
  - 20 ppmv (5 %) in low troposphere: information correlated with free troposphere

CO2 information from IASI is at the level of mission specifications for a single spectrum
Retrievals from simulated data indicate that IASI CO_2 product on 3 layers would be more efficient than a column average, in order to exploit the low level information present in the data

Remaining to be done :Explore the potential of spatial and temporal averaging
Explore the CO2 processing in partially cloudy scenes, in order to separate upper and lower troposphere information

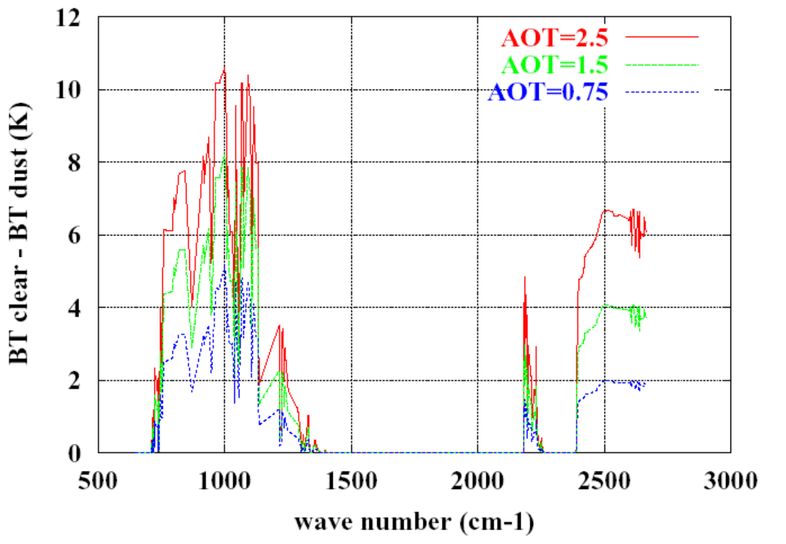
THIS GOING TO BE STUDIED IN THE NEXT MONTHS

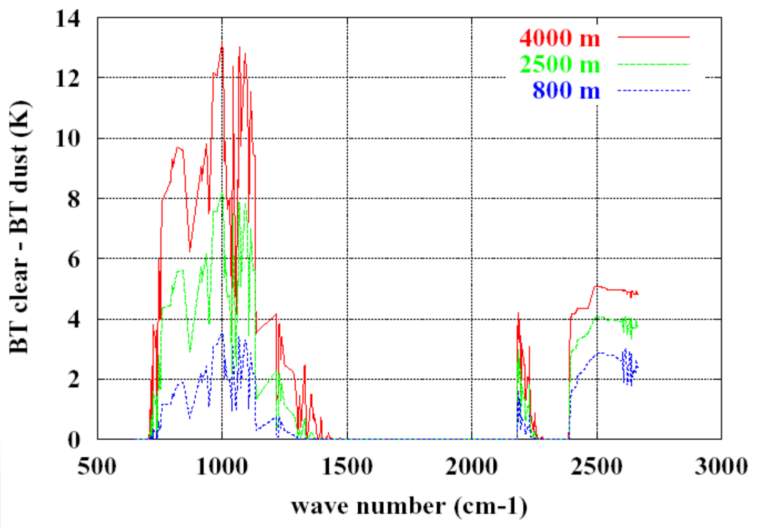
Aerosols

- Infrared spectra are sensitive to aerosols specially absorbing aerosols like sand dust, volcanic ash and biomass burning

- Important parameters which can be retrieved from spectra are optical depth and altitude (Pierangelo, 2005)

- Algorithm developed at LMD and applied to AIRS has been expanded to IASI. A selection of IASI channels dedicated to aerosol has been proposed.





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TRACE GAS RETRIEVAL FROM IASI

- Level 2 Processing based on Neural network at stage 1.

- Those networks have been trained using pseudo IASI spectra simulated from IMG data

- Alternative inversion method is 1d Var. This method has been used to analyze sensibility of retrievals to various parameters. It will be implemented in a research mode and tested to compare its results with operational retrievals

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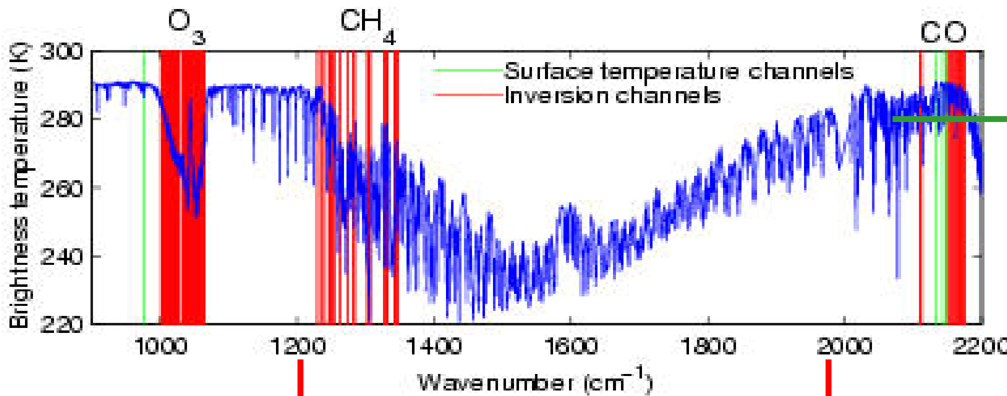
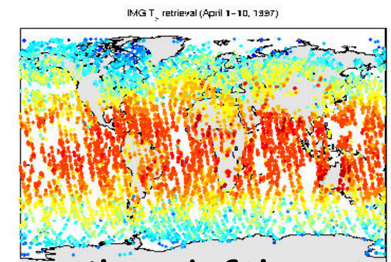
IMG distributions using IASI processing tools **(operational mode)**



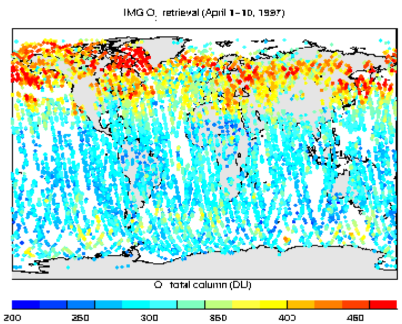
Ts



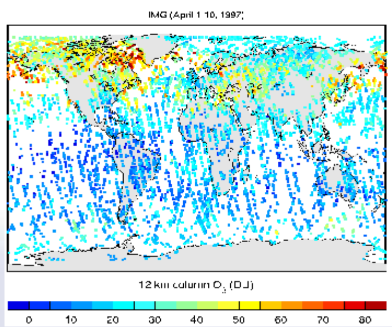
+ Cloud filtering

Hadji-Lazaro et al., GRL 2001

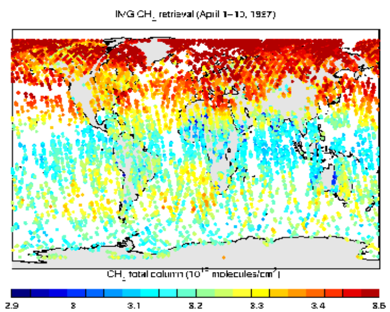
O_3



Turquety et al. GRL 2002

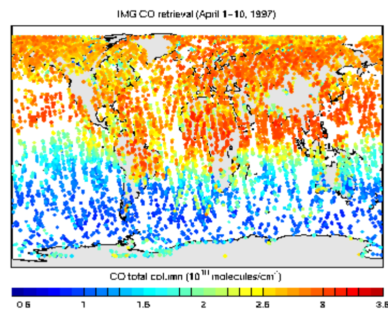


CH_4



Clerbaux et al., ACP 2003

CO



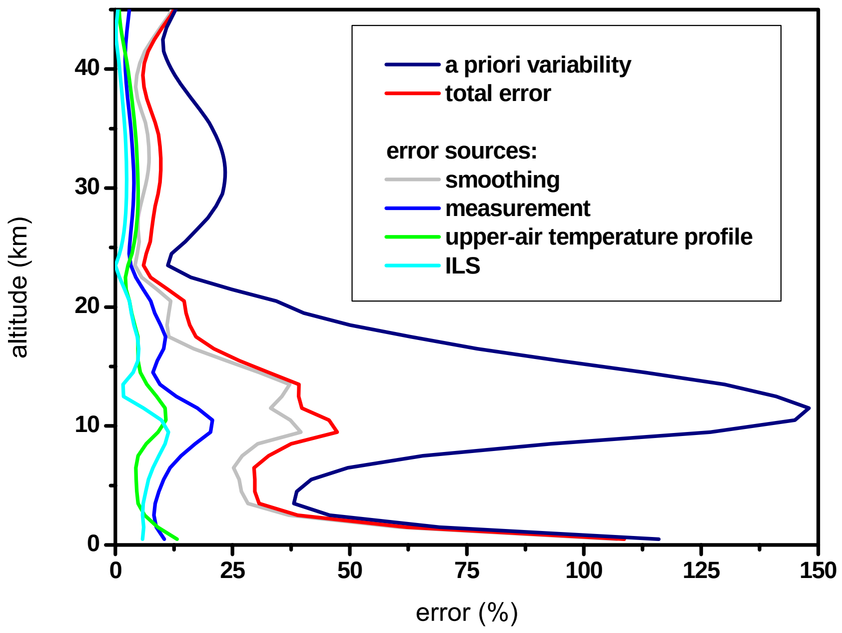
Clerbaux et al., IEEE 1999; JGR 2001
Hadji-Lazaro et al., JGR 1999

SA-Neural network [Turquety et al, JGR 2004] **implemented in the Eumetsat ground segment for IASI real-time data processing**

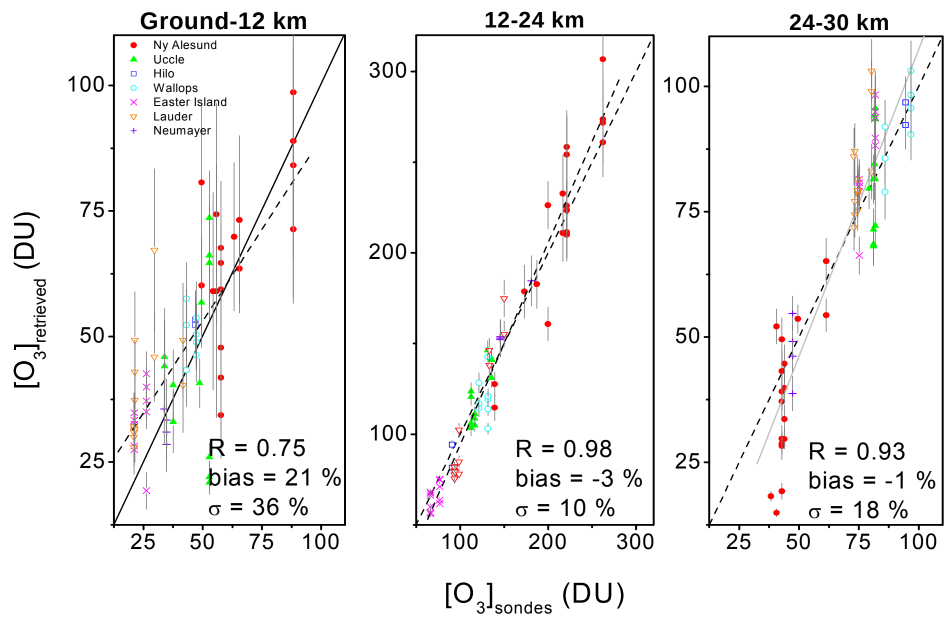
OZONE

Errors

Vertical profiles



Partial columns



Accuracy and precision:

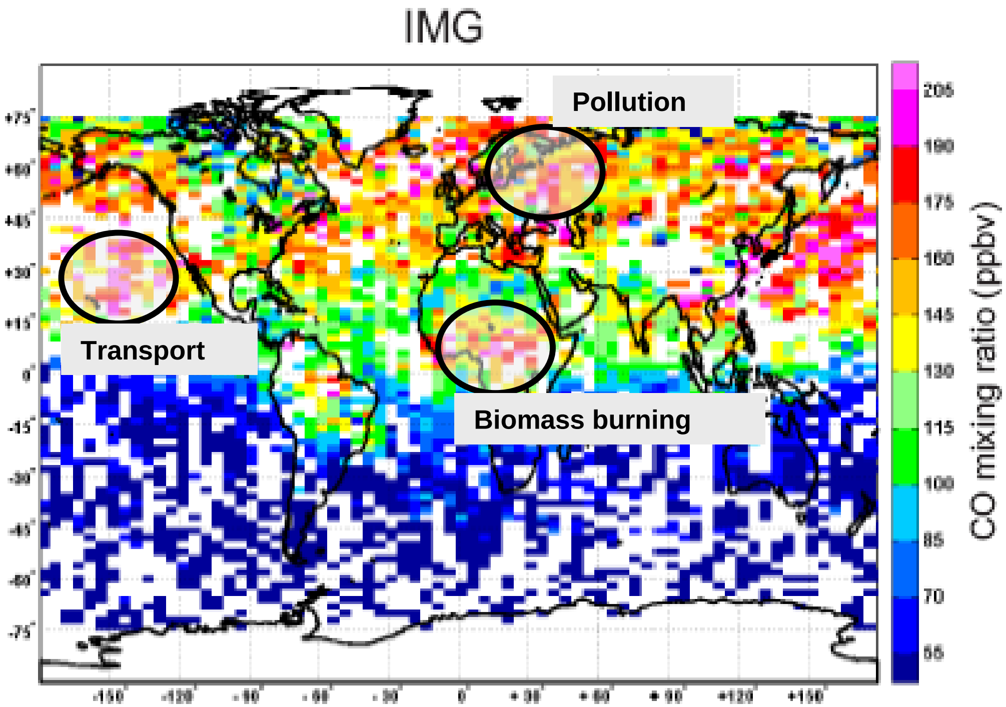
► High for the lower and midlle stratospheric columns

► Good for the tropospheric columns in most cases (bias decreases to 4% partial columns < 25 DU are neglected)

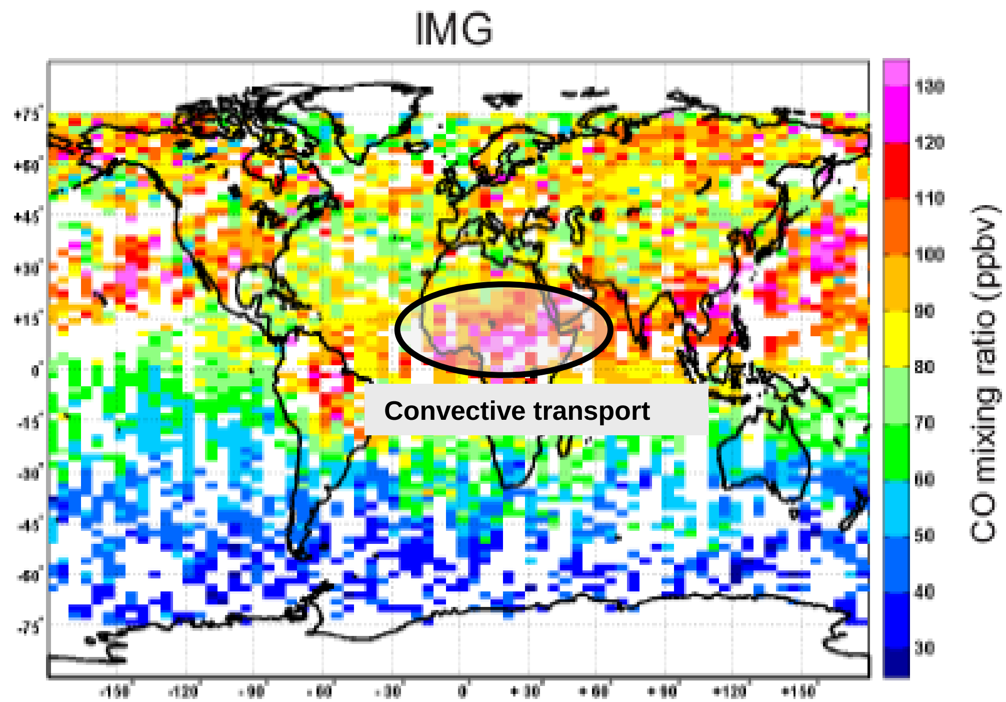
[Coheur et al. JGR 2005]

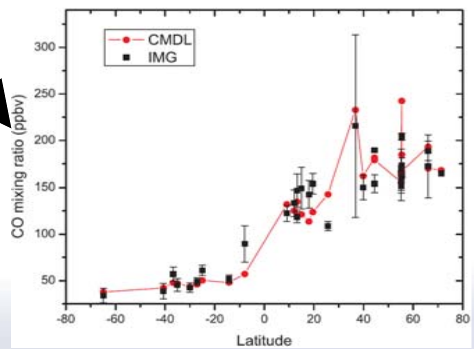
CARBON MONOXIDE

Boundary layer CO (1 km)



Upper tropospheric CO (10 km)

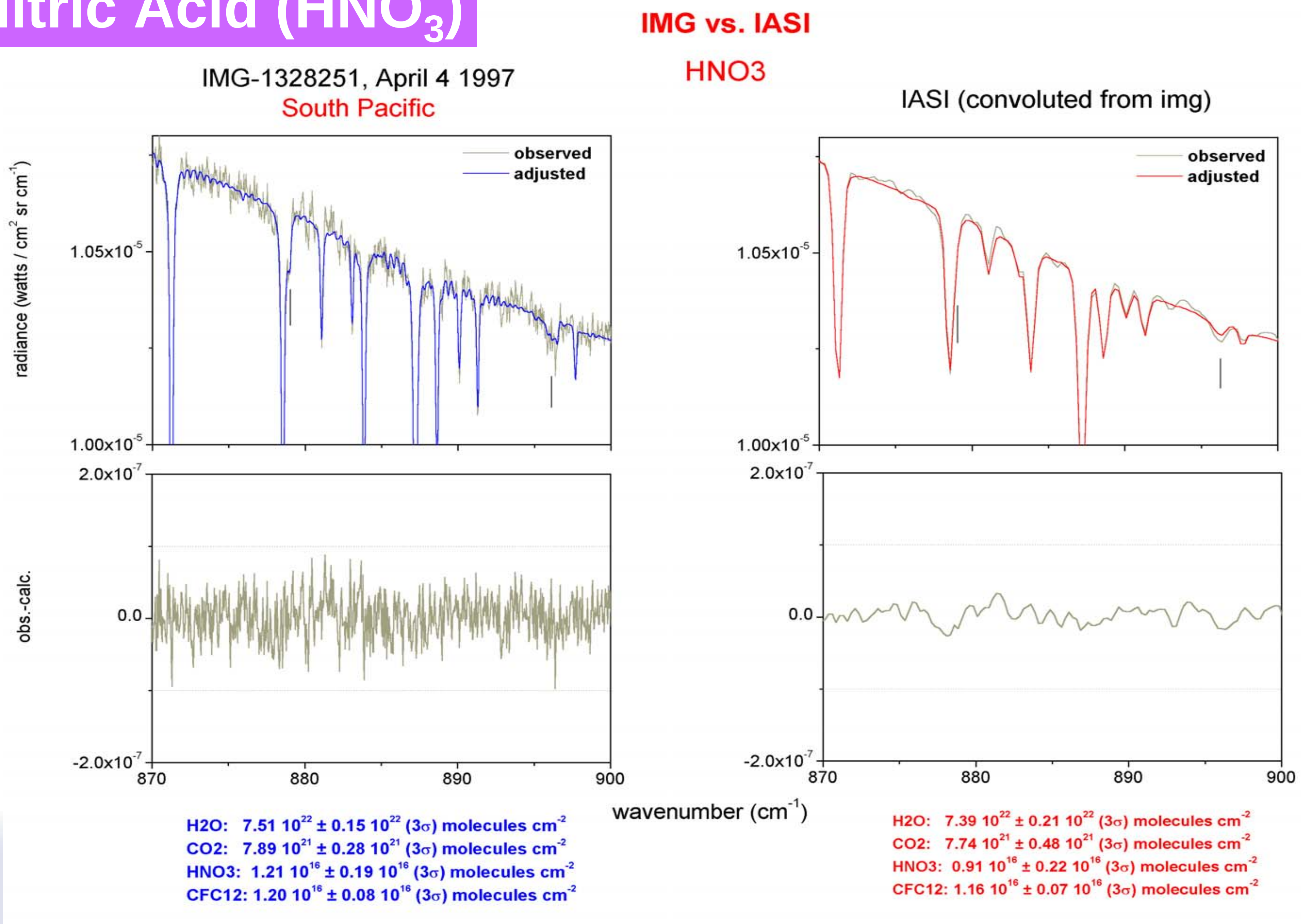




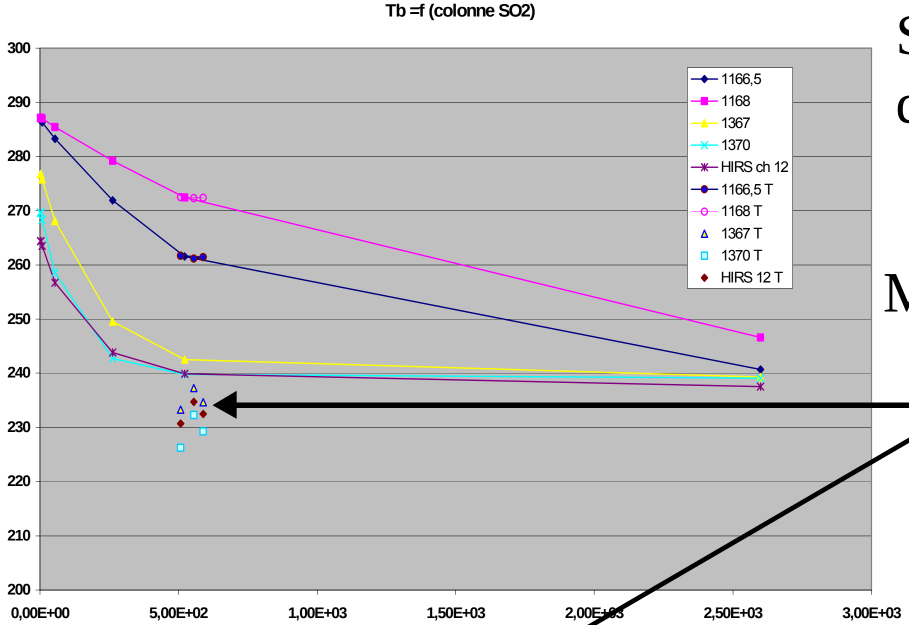
Good agreement with surface measurements (CMDL network) and model distributions (GEOS-CHEM)

[Barret et al. ACPD 2005]

Nitric Acid (HNO_3)



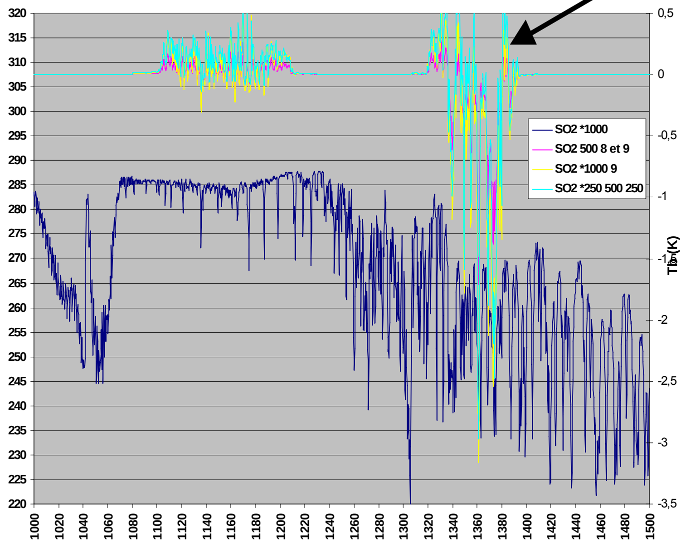
Volcanic plumes (SO_2)

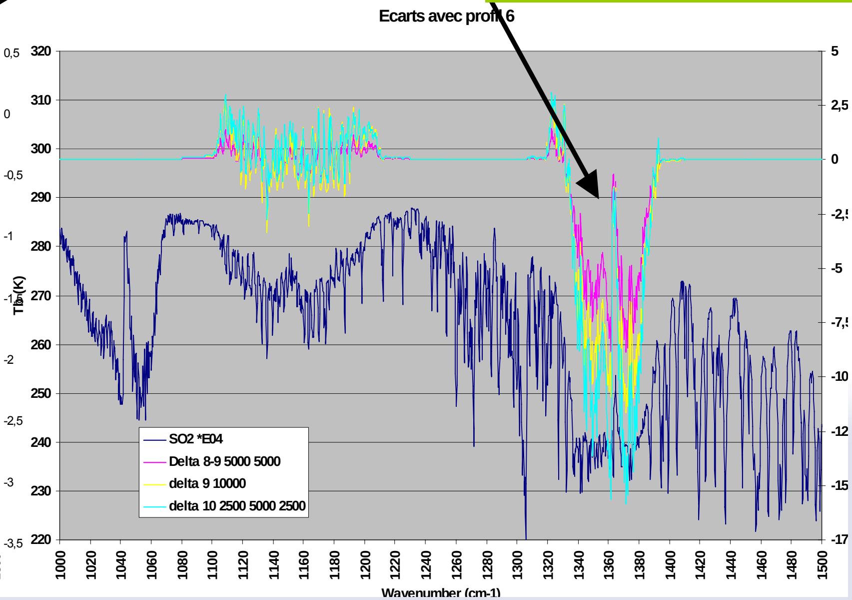


Sensitivity to level and distribution of SO2

Much stronger at 1350 cm-1

If strong amounts a combination of the two bands could be used to retrieve Integrated amount and plume altitude

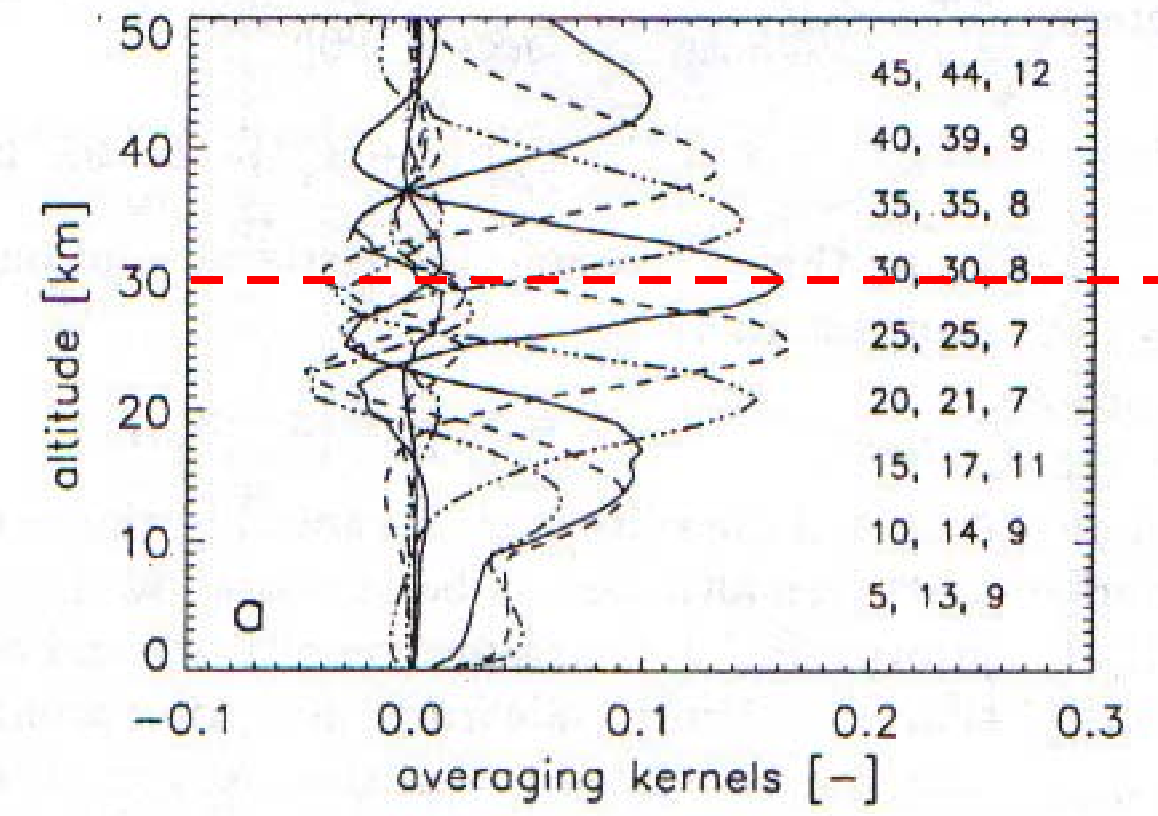




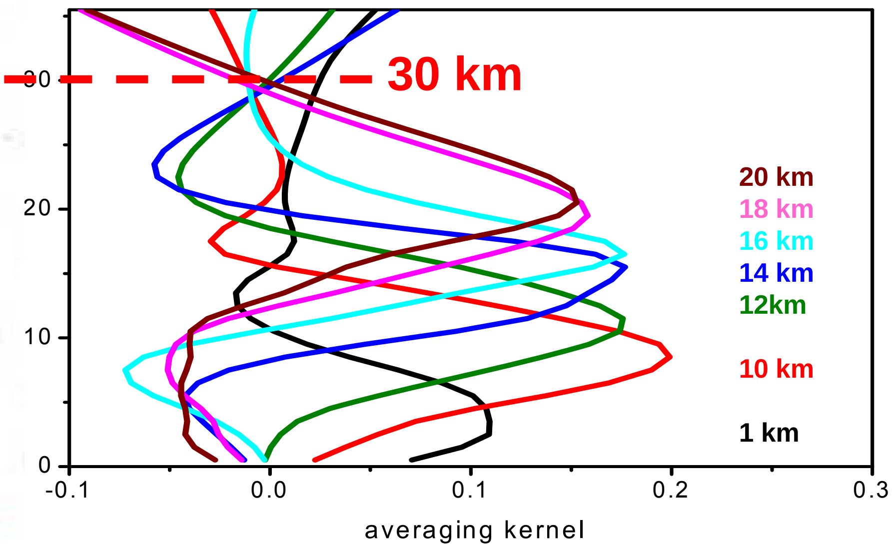
OZONE FROM IR-UV

Vertical sensitivity

GOME AVK



IMG AVK



OZONE PROFILE FROM IR AND UVS SPECTROMETERS

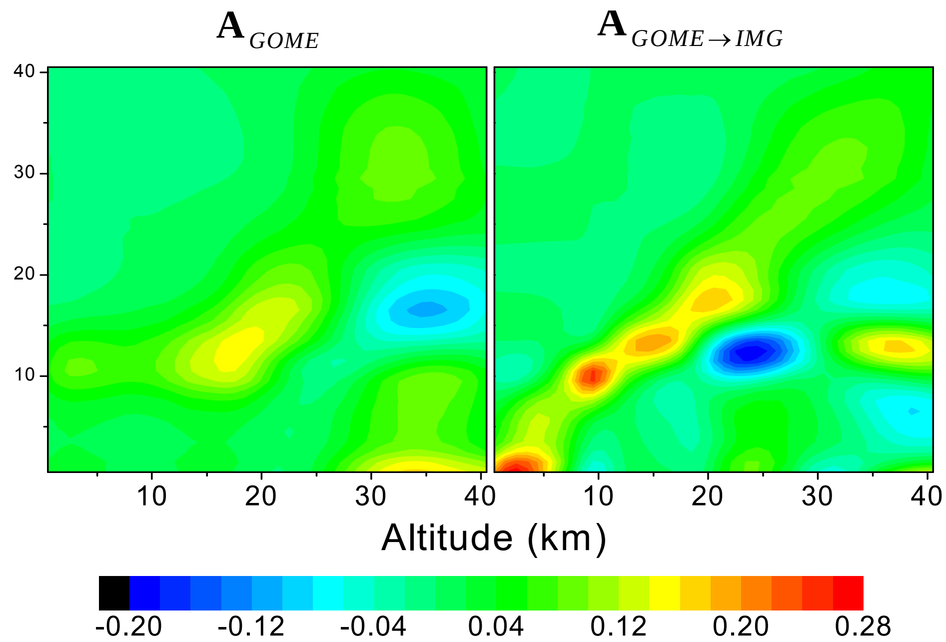
(P. Coheur et al.)

Taking advantage of multiple instruments

- Synergetic retrievals

O_3 profile retrieval from IR and UV measurements

d_s	
UV	3.4
IR	5.4
UV-IR	7.7



Application to GOME-2 / IASI

Solène Turquety, Roeland Van Oss

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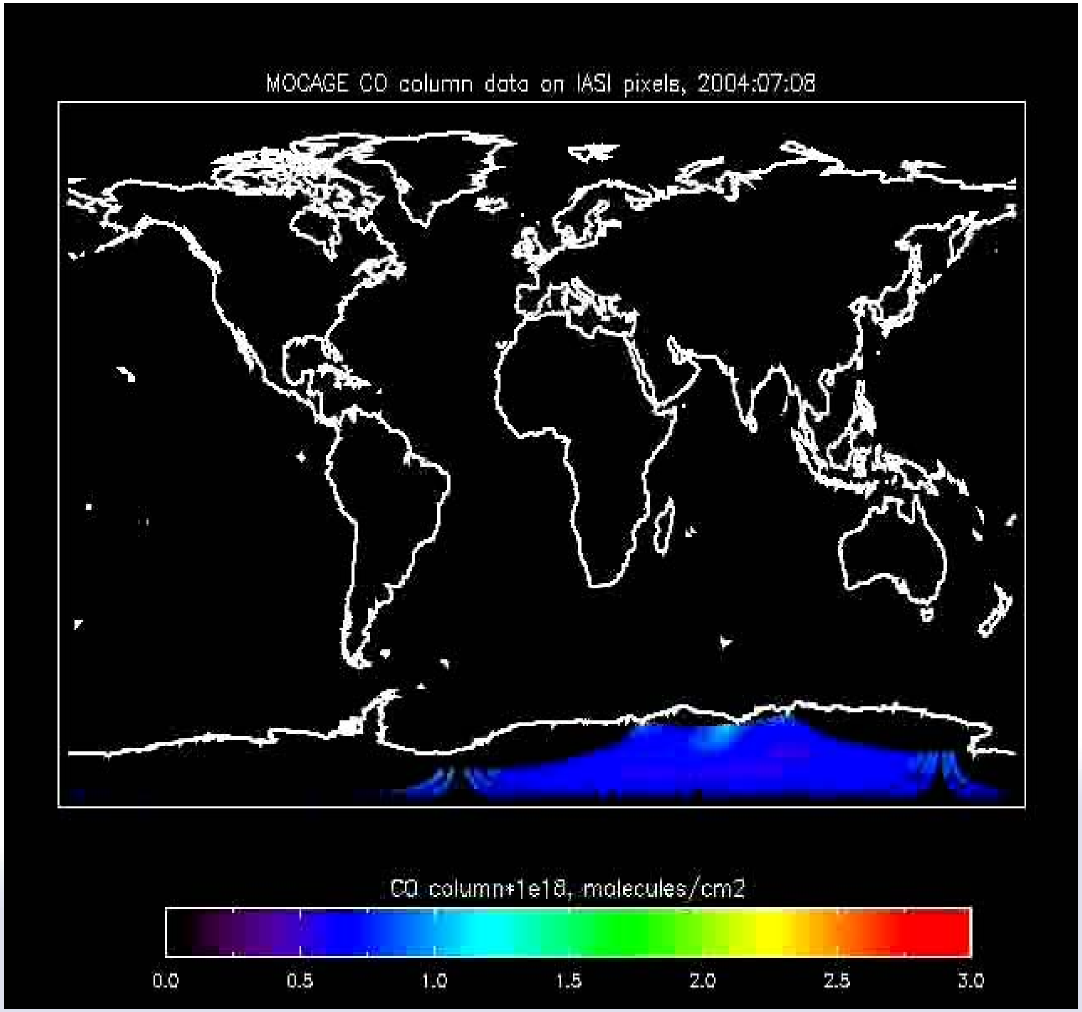
CARBON MONOXIDE

ASSIMILATION OF CO DERIVED FROM IASI IN A CTM (C. Clerbaux and A. Klonecki)

OBSERVATION OPERATOR BASED ON MOPITT DATA



STRATEGY

- **DEVELOPEMENT AND TESTS IN LABS BASED FIRST ON SIMULATED DATA AND THEN ON DATA SAMPLES FROM UMARF**
- **IMPLEMENTATION IN ROUTINE PSEUDO OPERATIONAL PROCESSING**
  - AT CMS FOR LOCAL
  - AT METEO France TOULOUSE FOR GLOBAL
  - OR ON **ETHER** (National Data Center for Atmospheric chemistry) FACILITIES
- **COMPARISON WITH OTHER GROUPS IN THE FRAMEWORK OF THE ISSWG**
- **EITHER IMPLEMENTATION IN THE CGS, THE SAFs OR DISTRIBUTION BY ETHER**

Conclusions

Besides its capacity for atmospheric profiles through assimilation in NWP models,

POTENTIAL APPLICATIONS OF IASI ARE NUMEROUS AND MANY ADDITIONAL PRODUCTS ARE TO BE DEVELOPED

According to simulations, IASI looks then very promising for greenhouse gases monitoring.

Studies are continuing and new topics like cloud properties retrieval, surface parameters are being considered

About one year after MetOp launch CNES and Eumetsat organize a Joint Workshop (study conference?) on the first IASI results which will initiate ISSWG phase 2. We hope to see you there!!!

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