Aerosols and gases parameters retrieval from high resolution infrared instruments.

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aerosol monitoring:

-**Passive measurements :** broadband sensors from UV to IR (AVHRR, TOMS, SAGE, MODIS, POLDER…).

→ Detection and Characterization.

-**Active measurements :** Lidar (CALIOP).

→ Accurate altitude determination of the aerosol layer.

→ **Why to study aerosols from high resolution infrared instruments?**

Advantages:

- Good sensitivity to larger particles (coarse mode).
- Observations available daytime and nighttime and over ocean and land .
- Access to the mean aerosol layer altitude.
- Low dependency on particle shape.
- Good sensitivity to aerosol type.

And the ability to obtain the atmospheric gaseous composition simultaneously.

Disadvantages:

- High sensitivity to surface properties (Ts, emissivity).
- Limited sensitivity to smaller particles (fine mode).
- Limited sensitivity when there is a weak thermal contrast between aerosol layer and the surface (ie boundary layer).

And the retrieval of information on aerosols from high resolution IR sounders is notoriously difficult and applications are particularly sparse.

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IASI/Metop (2006-2021)

Fourier transform spectrometer

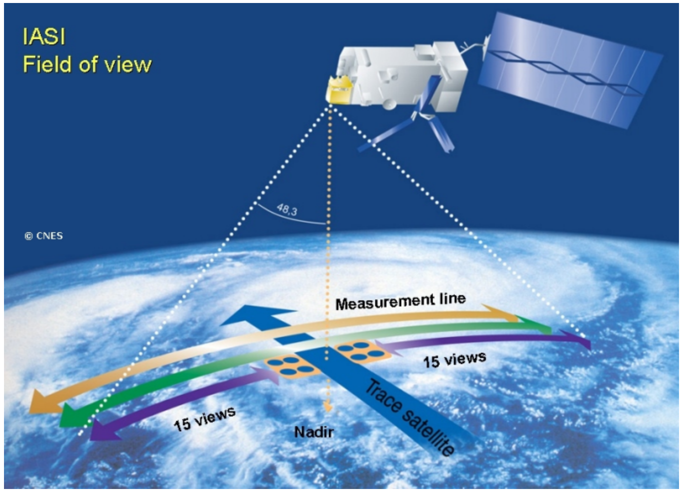
Spectral range : 645 – 2760 cm^{-1}

Spectral resolution : 0.5 cm^{-1} (apodized)

Spatial Resolution (Nadir) : 12 km

Global Earth coverage : twice a day

Data amount : **8460** channels * 1.2 10^6 spectra per day



Tanso-FTS/Gosat (2009-2013)

Fourier transform spectrometer

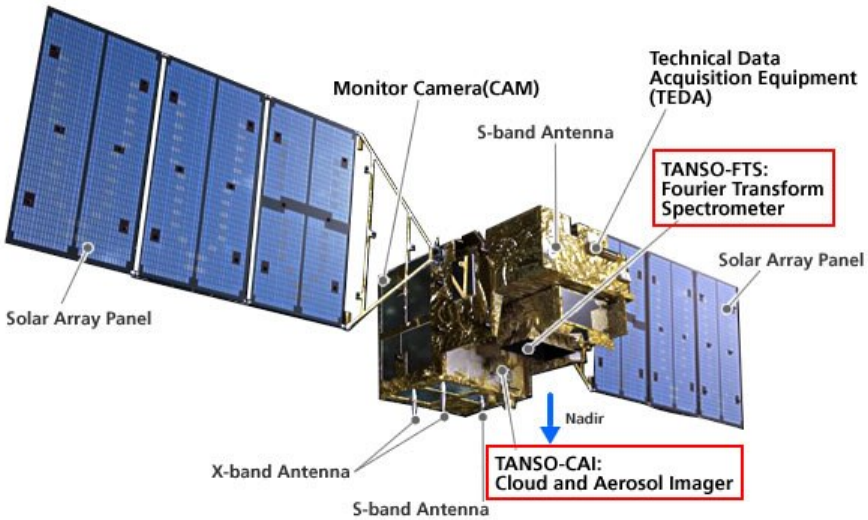
Spectral range : TIR (700 – 1800 cm^{-1}), SWIR (4800 – 5200 and 5800 – 6400 cm^{-1}) and visible (12900 – 13200 cm^{-1})

Spectral resolution : 0.27 cm^{-1} (apodized)

Spatial Resolution (Nadir) : 10.5 km

Global Earth coverage : every 3 days

Data amount : **12000** channels * 1 10^4 spectra per day



Detection algorithms

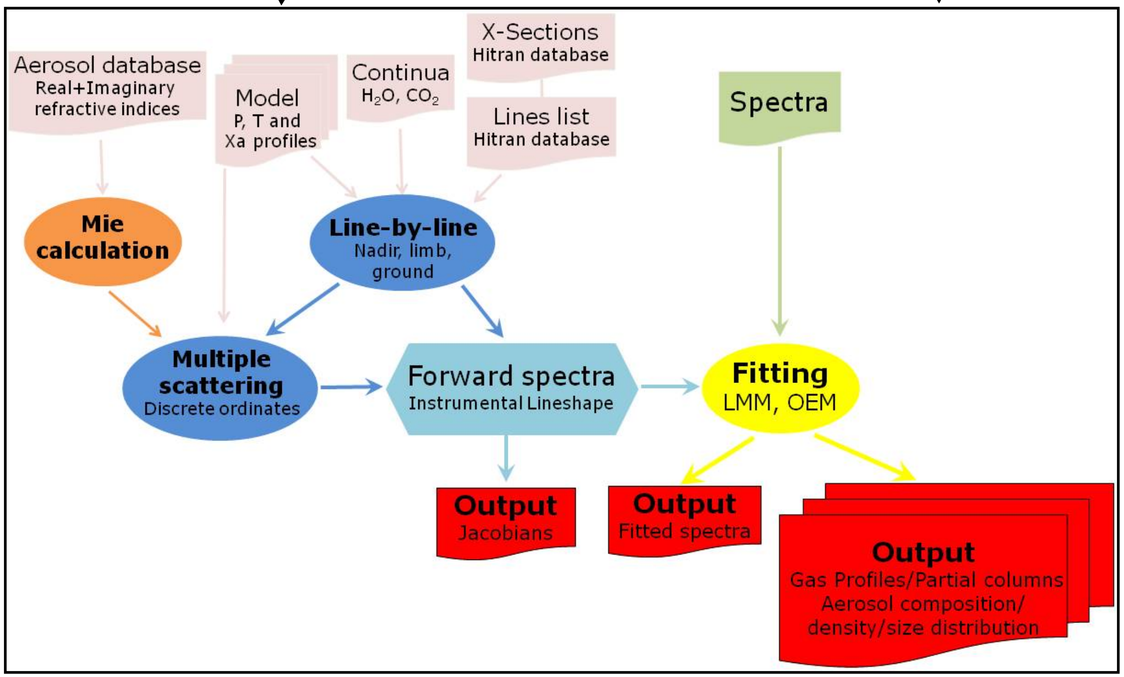
Gas

Method : brightness temperature differences (ΔBT) and if ΔBT > threshold value, the spectrum is selected to be retrieved.

Aerosol

Method : slope or concavity between 750 and 1250 cm^{-1}.

Retrieval algorithm



Gas vertical profiles and Aerosol parameters measured simultaneously for special events (Dust storm, volcanic eruption, biomass burning, hurricanes...

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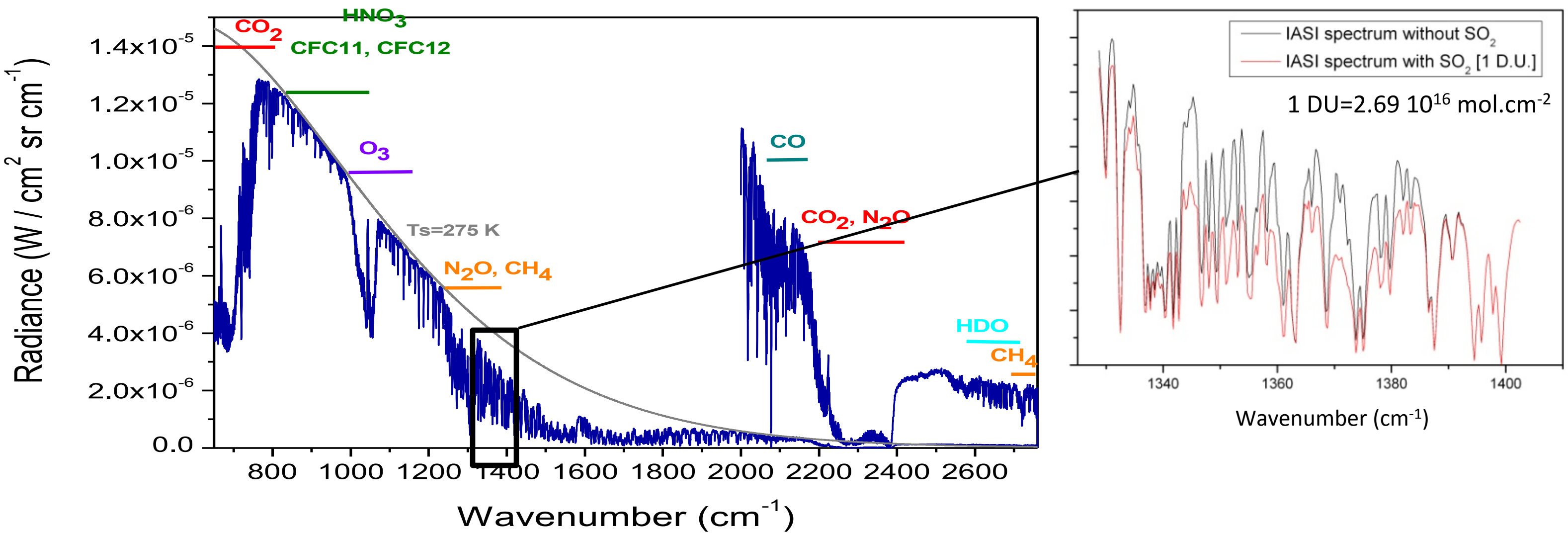
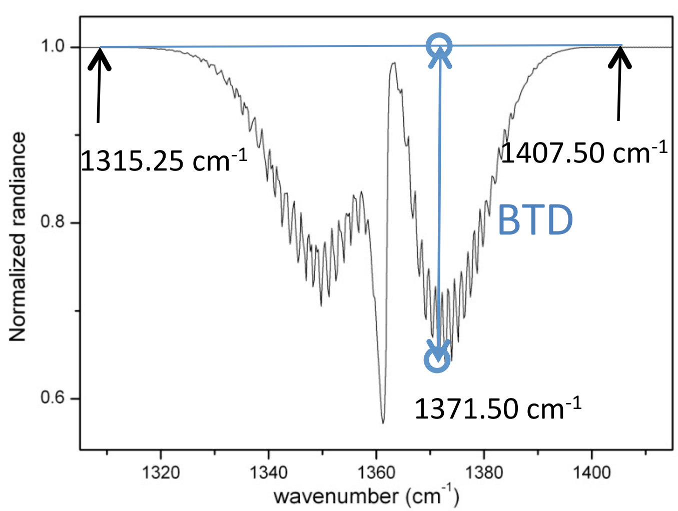
Gas detection: Example of SO_2 from IASI.





- Only spectra with $\Delta BT>n$, with n a threshold value determined from simulations for different SO_2 and interfering species concentrations, are selected to be retrieved.

- We can apply the same method for any gaseous component.

Method very quick : Special events detection in near real time conditions is available.

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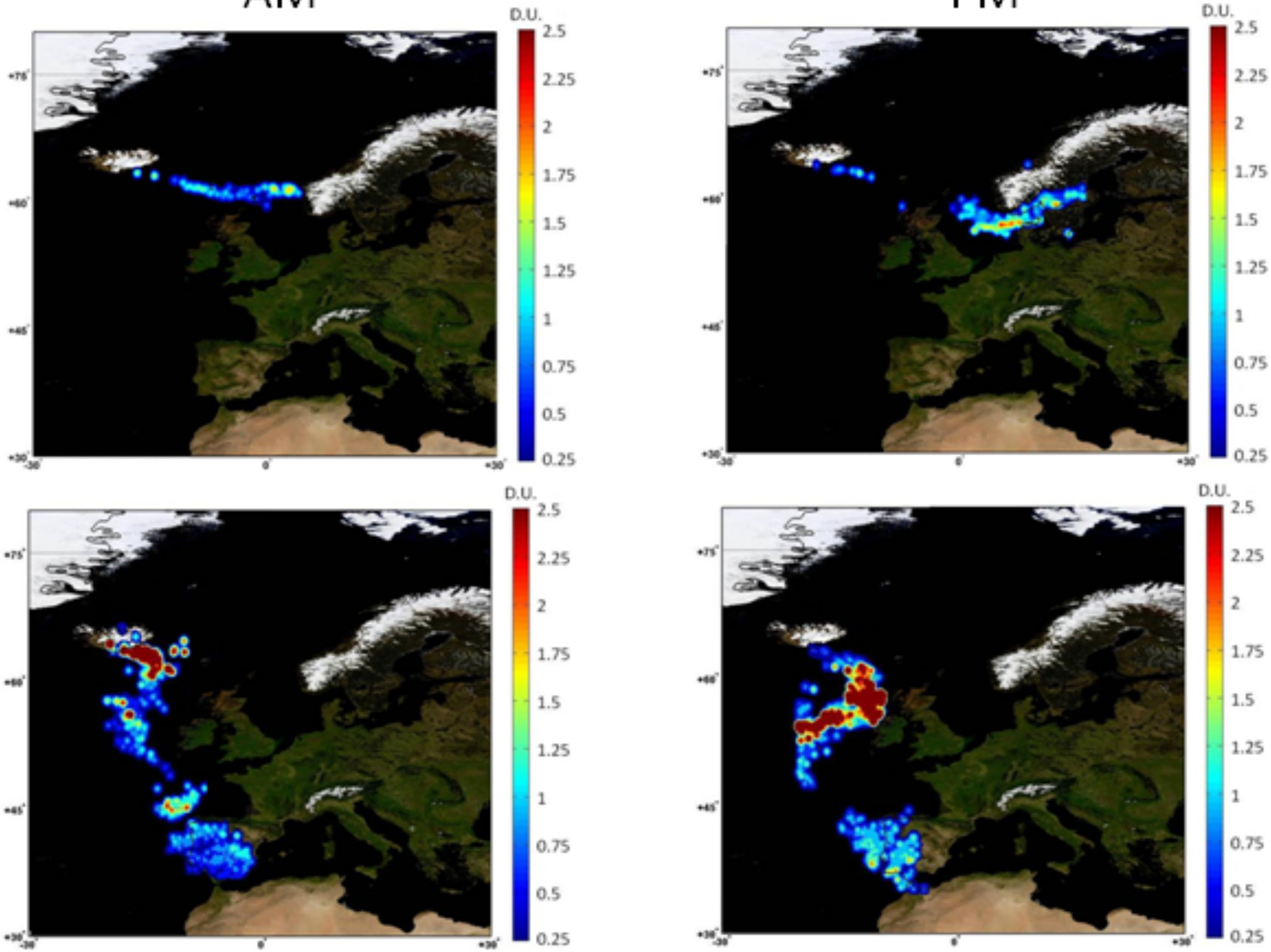
SO_2 detection example : Eyjafjöll volcano eruption (april 2010).

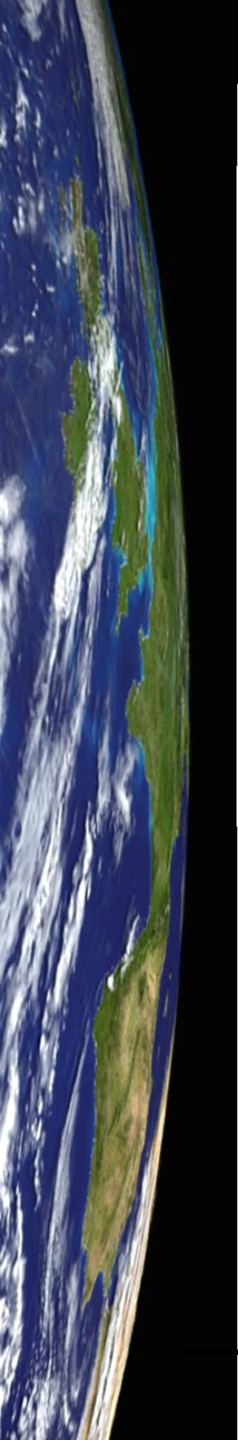
AM PM

15/04

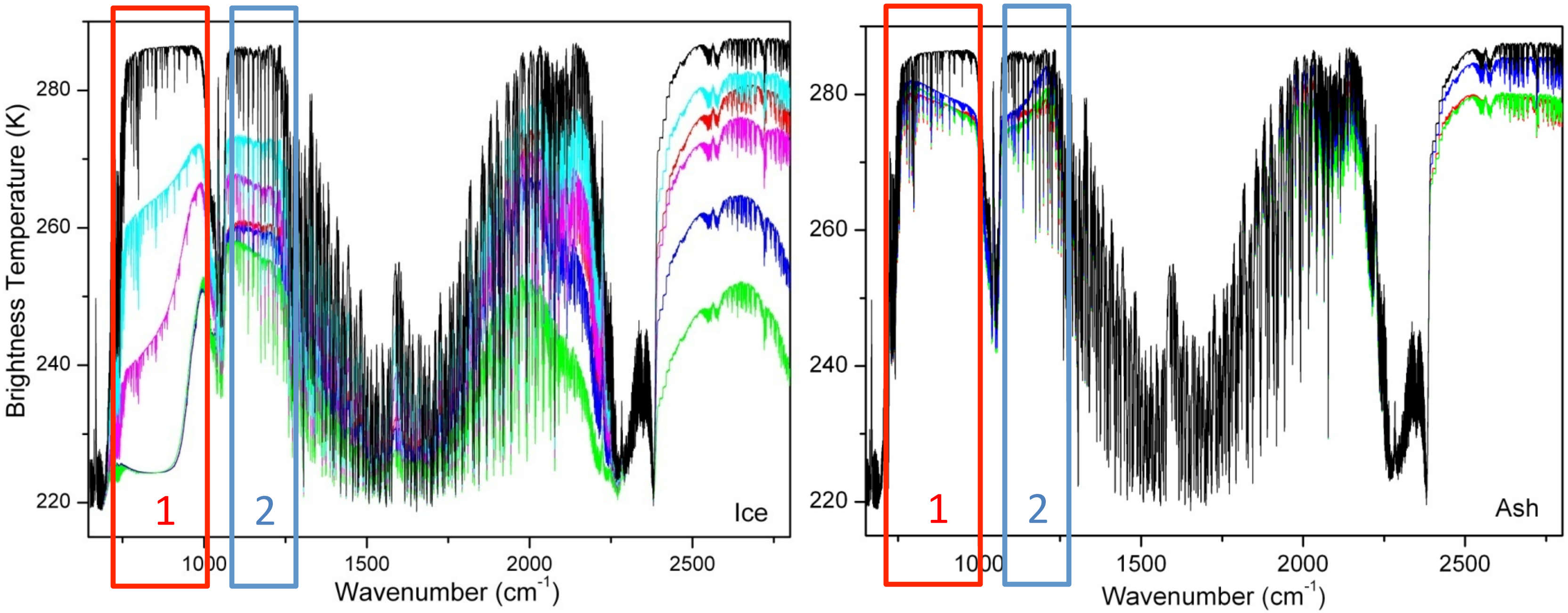
06/05



(D. Tanré et al., to be published)



Aerosol detection: Ice cloud and Ash plume examples.



The black line is for clear sky conditions, the red, blue, green, magenta and cyan colors are for 0.1, 0.5, 1, 5 and 10 µm effective radii respectively. (OD(10µm)=1).

Two spectral ranges (1: 750-980 cm^{-1} and 2: 1075-1215 cm^{-1}) are used to determine the particle type.
The first approach consist to determine the sign of the slopes, examples:

detection
- If 1: s>n1 and 2: s≤n2 ⟹ **Ice flag**
- If 1: s<n1 and 2: s≥n2 ⟹ **Ash flag**

with n1 and n2, threshold values determined from simulations for different optical depth.
This method can be refined by a second approach ("concavity" method) to distinguish different particles compositions *(Gangale et al., 2010)*.

Method very quick : Special events detection in near real time conditions is available.

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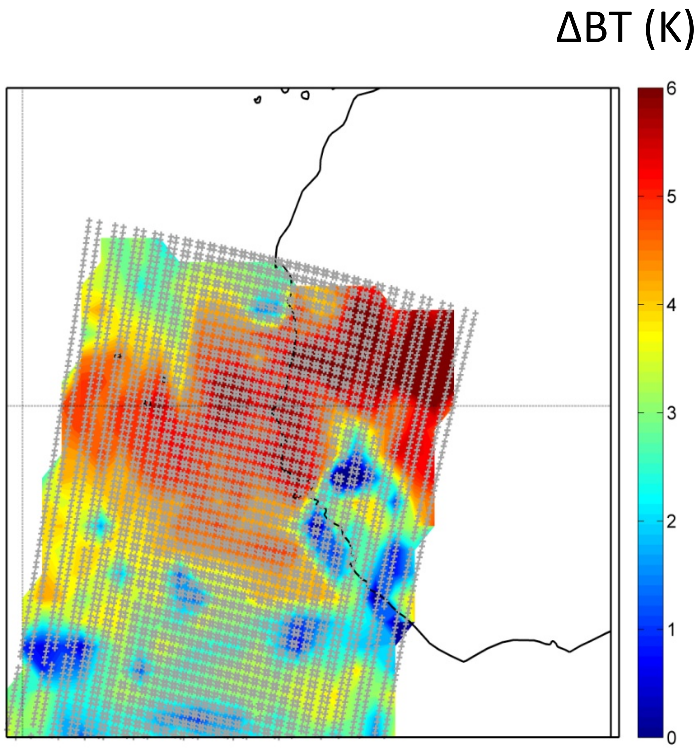
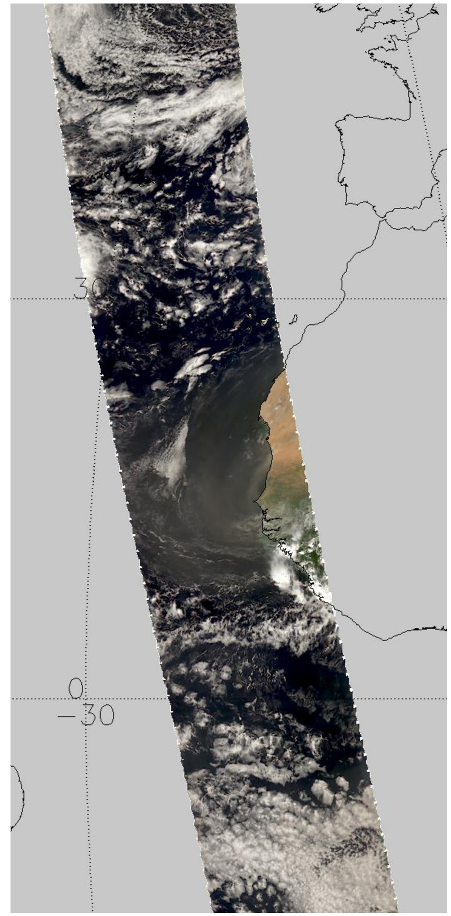
Dust storm example : September 2007

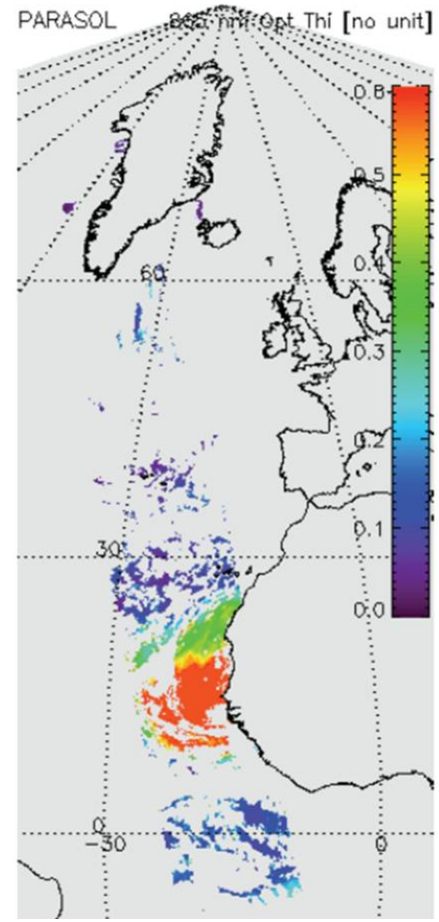
- **IASI**



- **MODIS**



- **Parasol**
865 nm optical thickness



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Forward model

Absorption of gaseous constituents:

•Line-by-line RTC 600-50000 cm^{-1}. *(Dubuisson et al., 1996, 2005)*

•Hitran 2008 (or Geisa) + Voigt line-shape+ continua (H_2O, CO_2)

Aerosol absorption and scattering:

•Refractive index database + Mie code (log-normal, bimodal)

Atmospheric description:

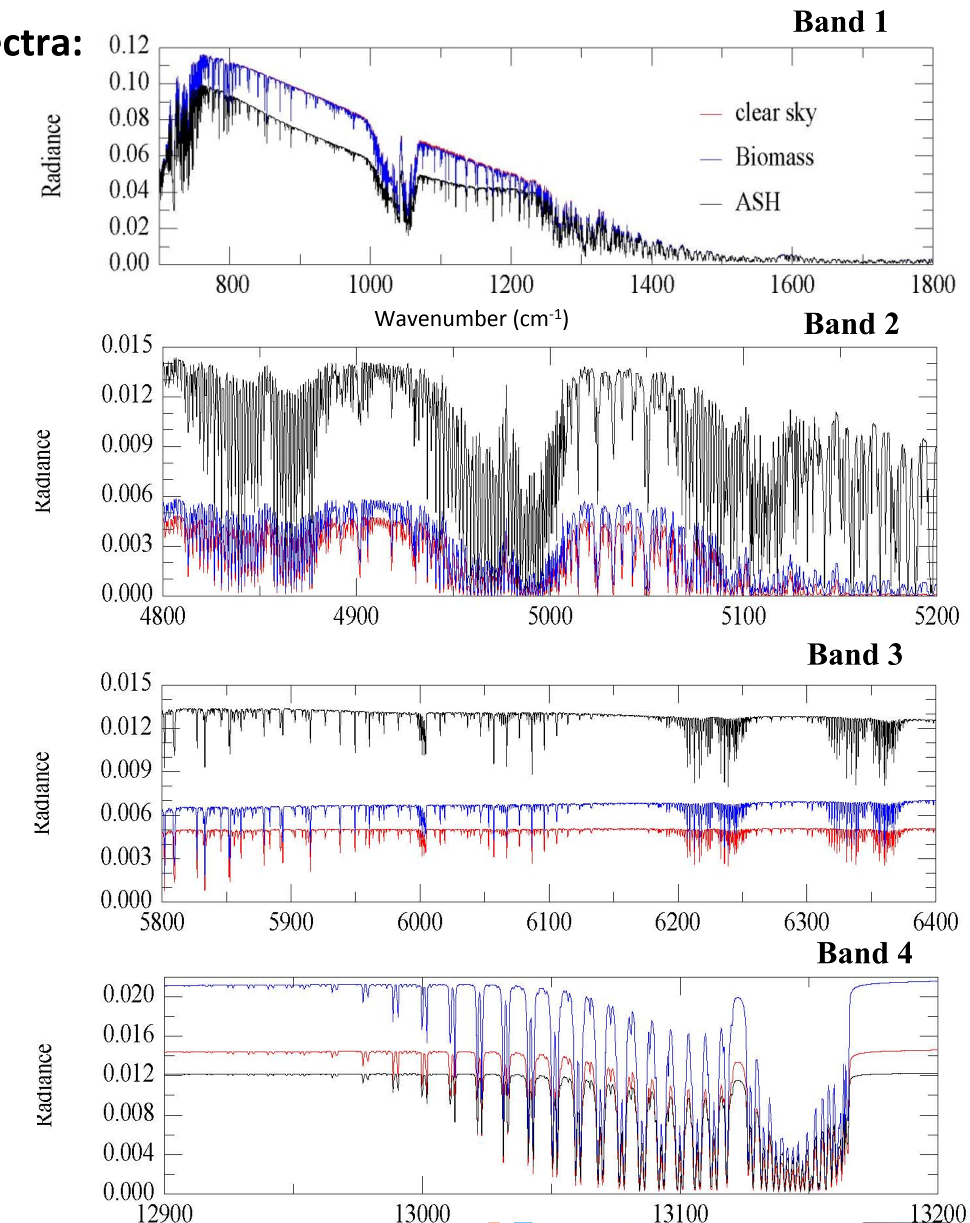
•Surface properties, P, T and Xa a priori profiles

RT is resolved by discrete ordinates method (DISORT)

•Simulated spectra

•Jacobians and sensitivity studies

Examples of TANSO-FTS simulated spectra:



Clear sky : P, T US Standard

***BIOMASS (3-5 km):** OD(440nm) = 1

-Cf = 7.906 10^9 part/m3

-Rf = 0.0943 µm

-σf = 0.4 µm

-Cc = 1.686 10^6 part/m3

-Rc = 0.588 µm

-σc = 0.79 µm

***ASH (5-7km):** OD(865nm) = 1

-Cf = 1.003 10^8 part/m3

-Rf = 0.13 µm

-σf = 0.37 µm

-Cc = 3.123 10^7 part/m3

-Rc = 0.805 µm

-σc = 0.76 µm

**(Dubovik et al., 2001)*

•Band-to-band differences related to the aerosol properties.

Retrieval process

Iterative method : To retrieve the most probable state using measurement, measurement error, first guesses, expected variability and correlations. *(Rodgers, 2000)*

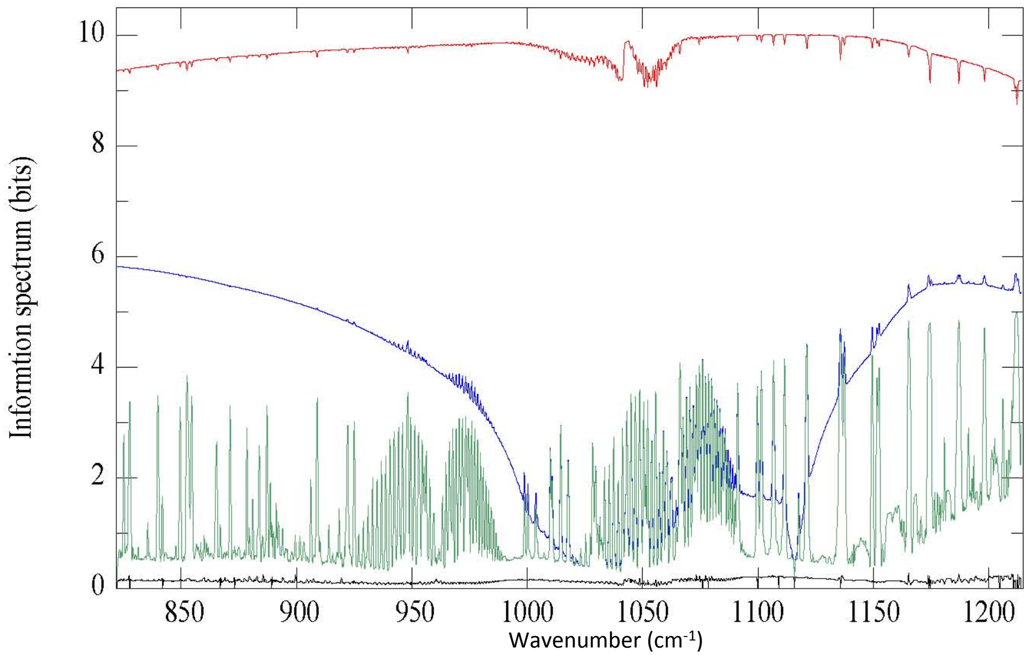
Non-linear least squares calculation:

- Gauss-Newton Method
- Levenberg-Marquardt

- Gaseous columns or vertical profiles
- Aerosol parameters (effective radius, standard deviation, concentration)

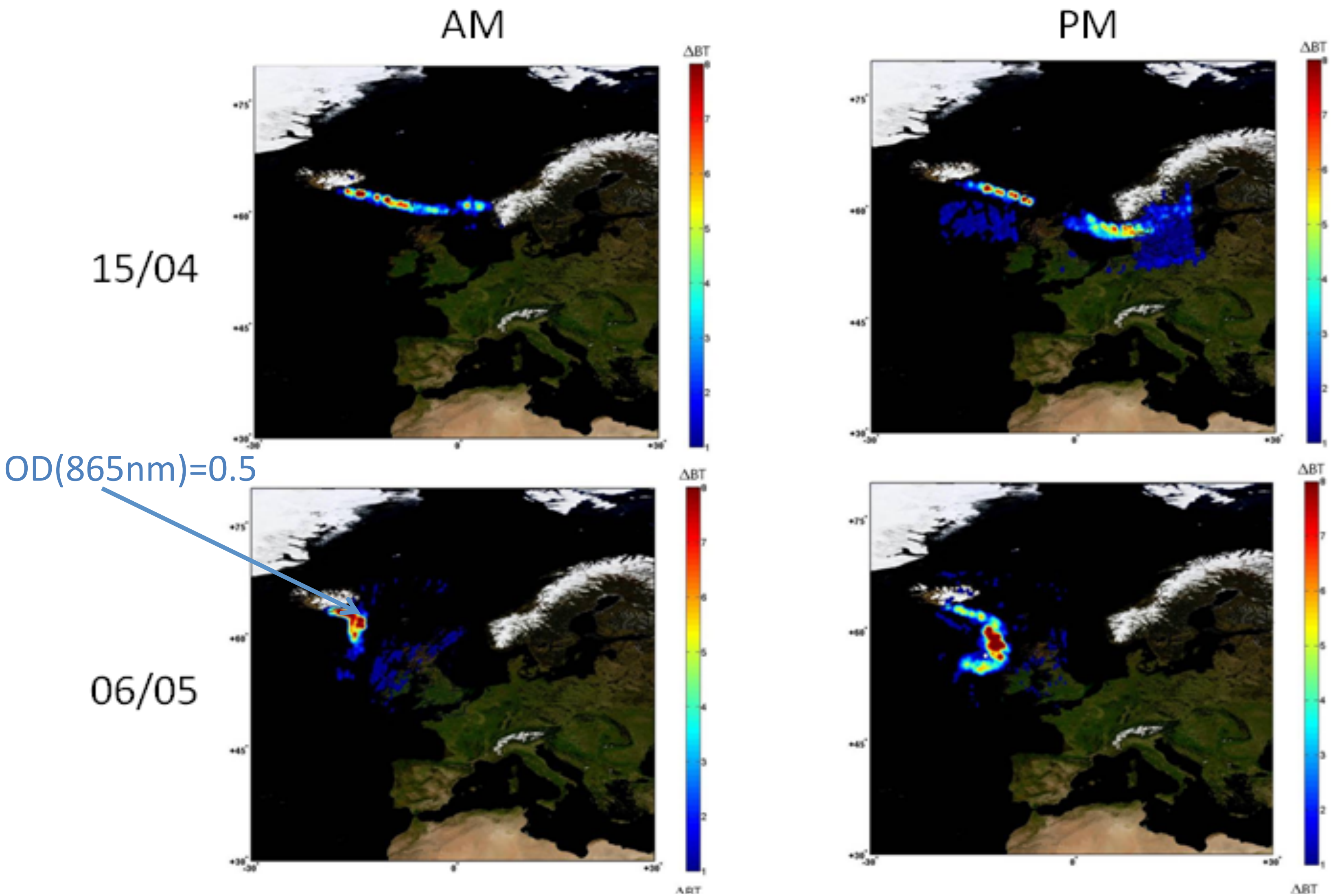
Example of information content and channels selection:

- State vector : 11 levels H_2O, 1 column CO_2, 1 column CH_4, Aerosol concentration, radius and deviation .



On this spectral range, 16 parameters can be retrieved with only 25 channels instead of 1600!!!

Volcanic ash example : Eyjafjöll volcano eruption (april 2010).



(D. Tanré et al., to be published)

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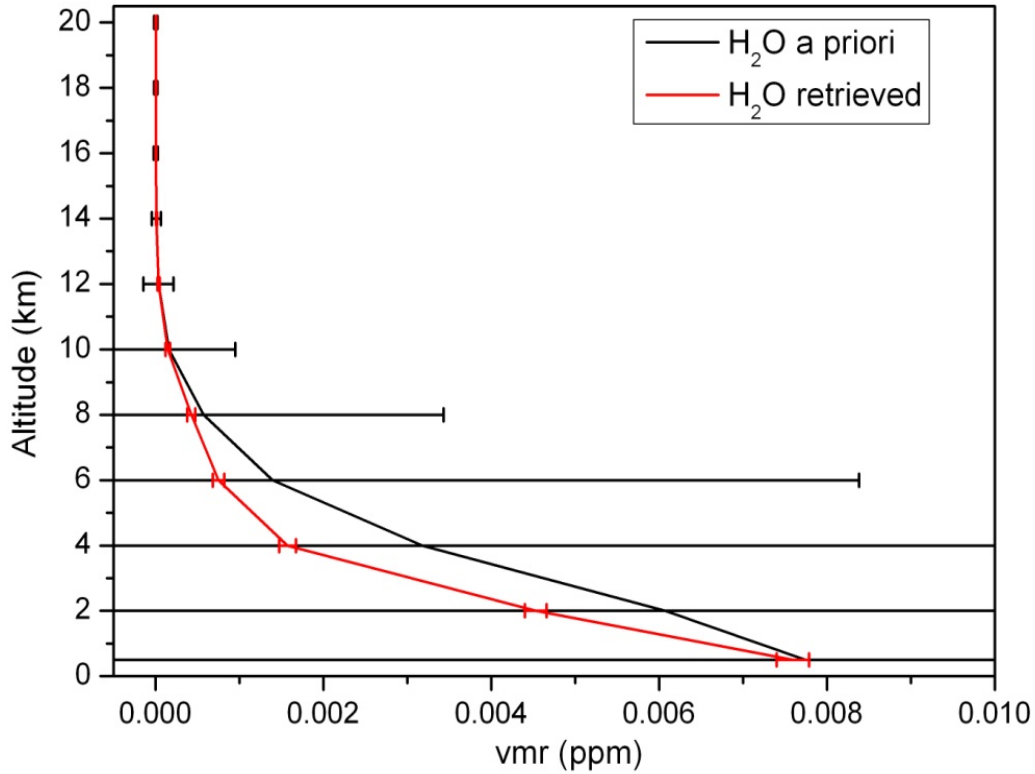
Results :

parameters	CO_2 (ppm)	CH_4 (ppm)	C (part.m^{-3})	R_g (µm)	σ_g (µm)
a priori	$2.97\ 10^{-4} \pm 1.5\ 10^{-3}$	$1.4\ 10^{-6} \pm 7\ \ 10^{-6}$	$5.000\ 10^{6} \pm 2.5\ 10^{7}$	0.8 ± 4	1.8 ± 9
retrieved	$3.59\ 10^{-4}$	$1.3\ 10^{-6}$	$8.288\ 10^{6}$	1.4	2.3
error	$1.40\ 10^{-5}$	$8.8\ 10^{-7}$	$3\ 10^{3}$	0.9	0.7

(Herbin et al., to be published)



•RMS = $5.35\ 10^{-6}$ W/cm² sr cm^{-1}

•IASI estimated noise = $2\ 10^{-6}$ W/cm² sr cm^{-1}

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A new algorithm able to retrieve gas and aerosol parameters simultaneously from high resolution infrared sounders (IASI an TANSO-fts).

The first algorithm dedicated to special atmospheric events monitoring:

- Detection of trace gases and aerosols in near real time conditions.
- Gas vertical profiles retrieval.
- Aerosol parameters (concentration, radius and deviation) retrieval.

The first results are very encouraging, but some points have to be improved...

- To Speed up the computation time
- To retrieve the surface properties (Ts, emissivity)

Outlook:

- Spectral synergy (ex: Tanso-FTS + Tanso-CAI)
- Refractive indices

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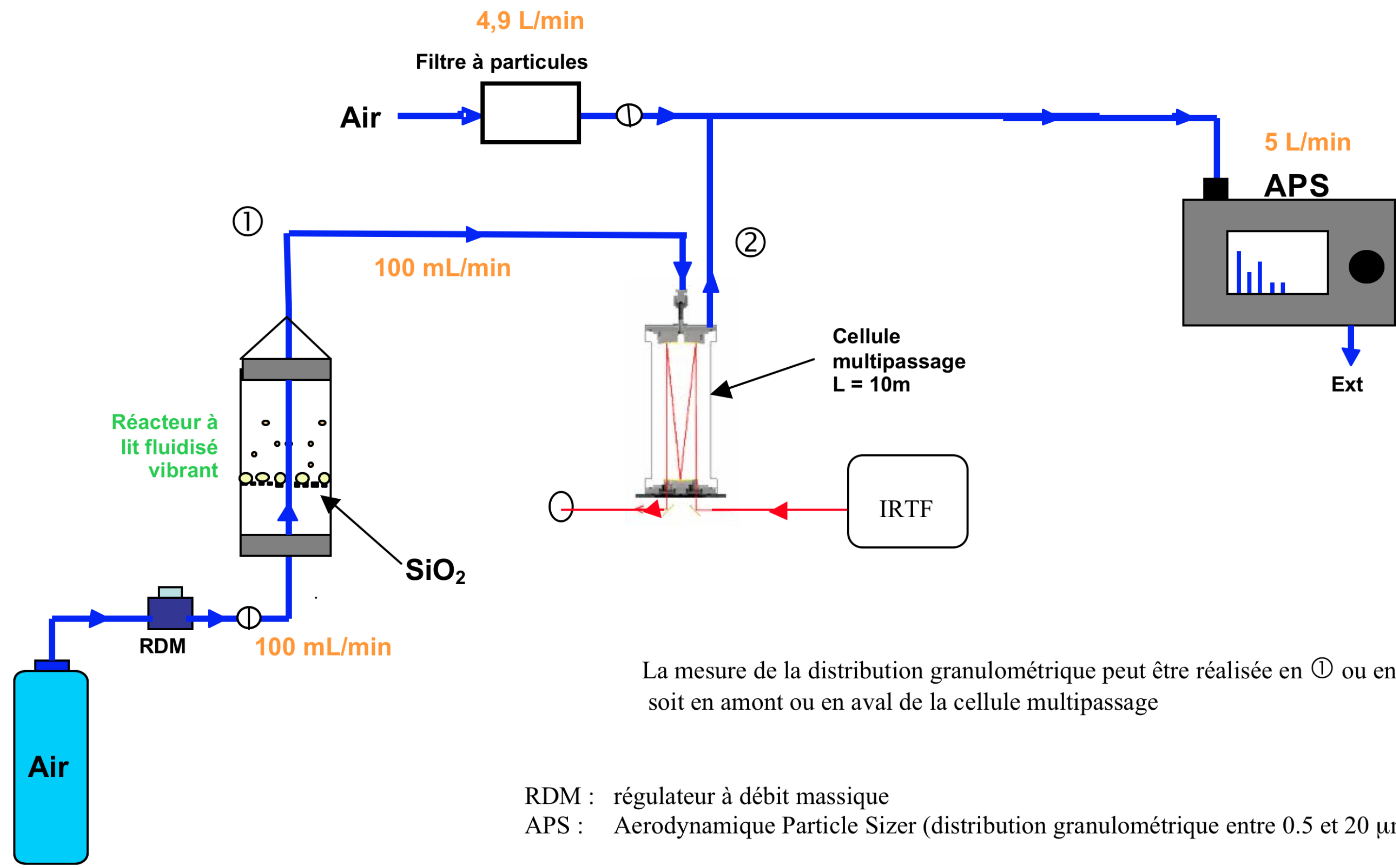
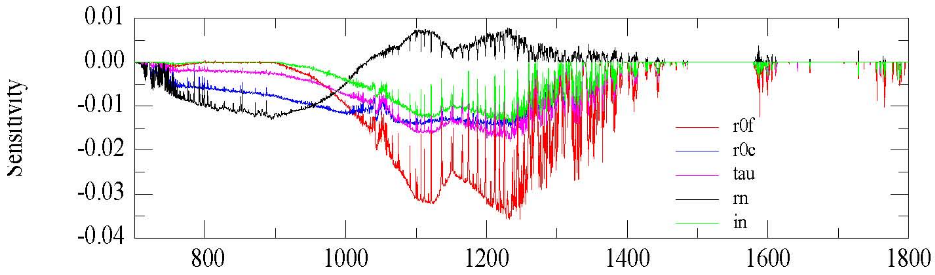
Thank you!!



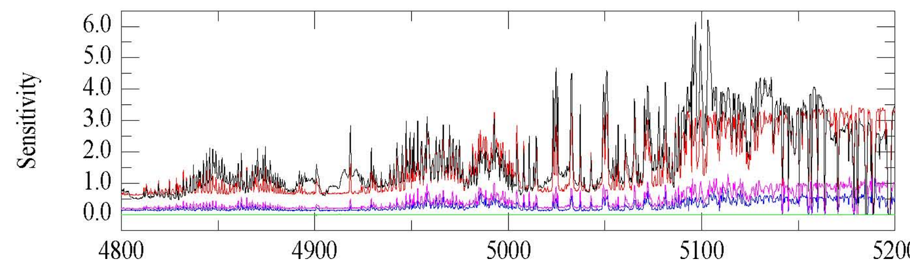
La mesure de la distribution granulométrique peut être réalisée en ① ou en ② soit en amont ou en aval de la cellule multipassage

RDM : régulateur à débit massique
APS : Aerodynamique Particle Sizer (distribution granulométrique entre 0.5 et 20 µm

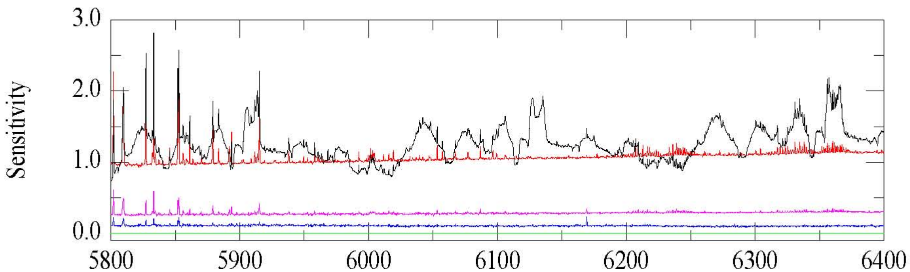
S - bande 1



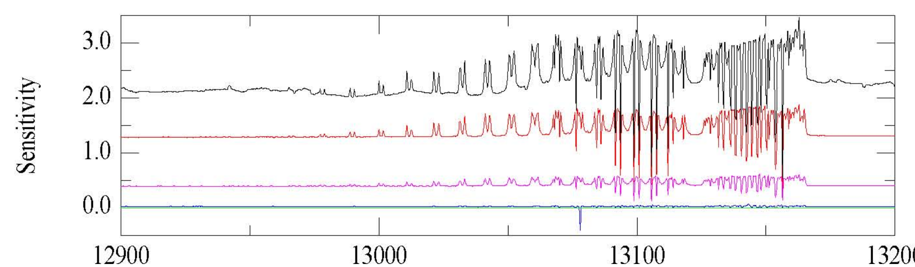
S - bande 2

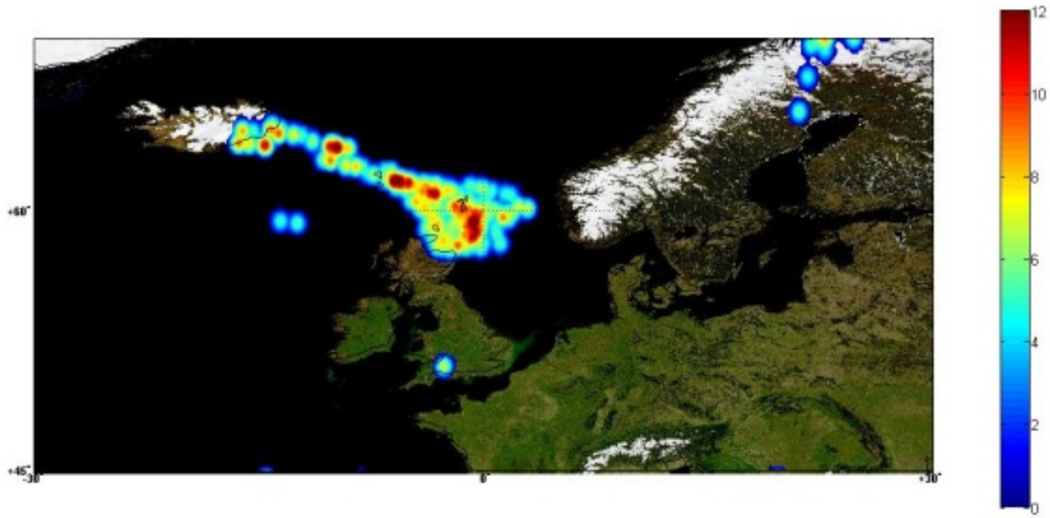


S - bande 3



S - bande 4

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