Contenu en information d'interférogrammes parcellaires mesurés par un imageur hyperspectral innovant : étude de cas du monoxyde de carbone provenant d'une expérience d'occultation solaire au sol

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Context and interest of the work

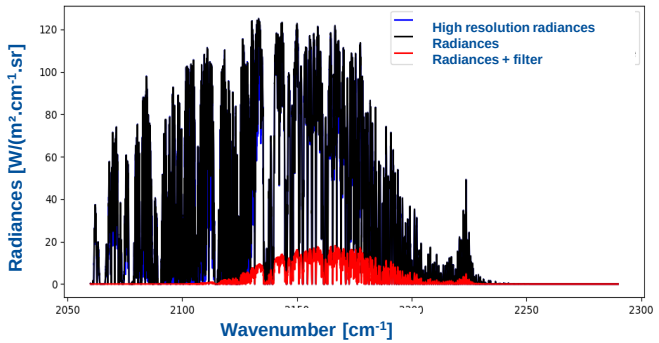
- A large number of Earth atmosphere observation missions based on Fourier Transform spectroscopy

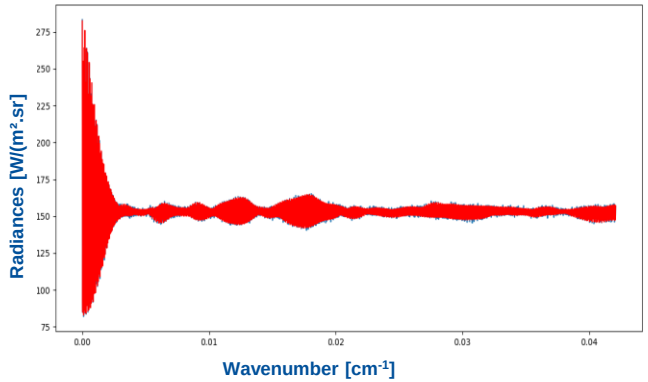
=> interferograms =>radiances

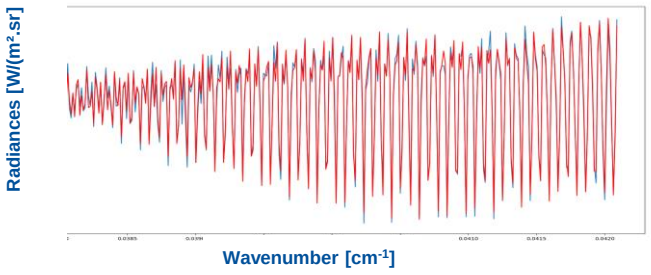
- Useful information concentrated in a small portion of the interferogram appeared in the late 1970s [Kyles 1977, Fortunato 1978]

=> Partially sampled interferograms can be used to retrieved atmospheric variables

- Interest demonstrated for the nadir measurement of atmospheric trace components (CO_2, CO, CH_4 and N_2O): [Serio 2011, Grieco 2012]
  - ↘ biases induced by H_2O or temperature profiles uncertainties,
  - method is totally insensitive to the ground background in the spectral region of IASI-Metop.
  - the signal-to-noise ratio of the data to be processed and thus the instrumental sensitivity





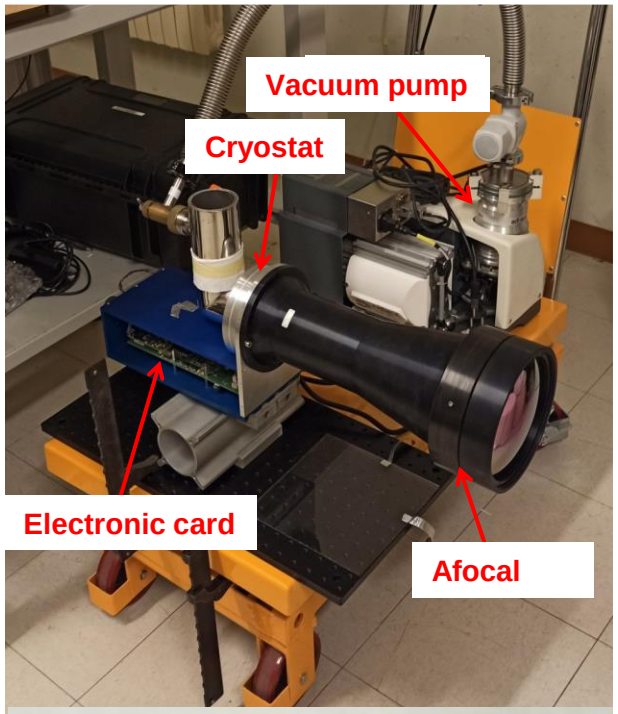


imSPOC, a spectro-imager intrinsically based on partial interferograms

- We are currently developing new spectro-imagers founded on the acquisition of partial interferograms (UGA+ONERA patent)

- Based on an innovative concept of static Fourier transform spectro-imager called imSPOC

- Several demonstrator realized and under study
  - SPACEOBS demonstrator for the measurement of the total column of carbon monoxide in solar occultation
  - SCARBO : measurement of anthropogenic CO_2 and CH_4 emissions from a constellation of small satellites



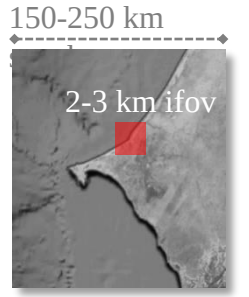
ImSPOC concept (ONERA-IPAG)

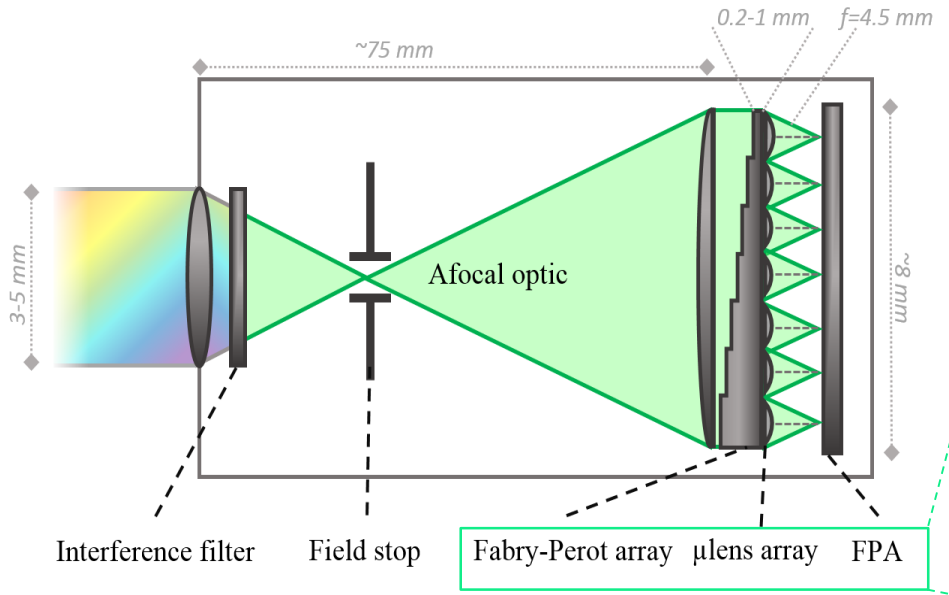
- **Principe :**

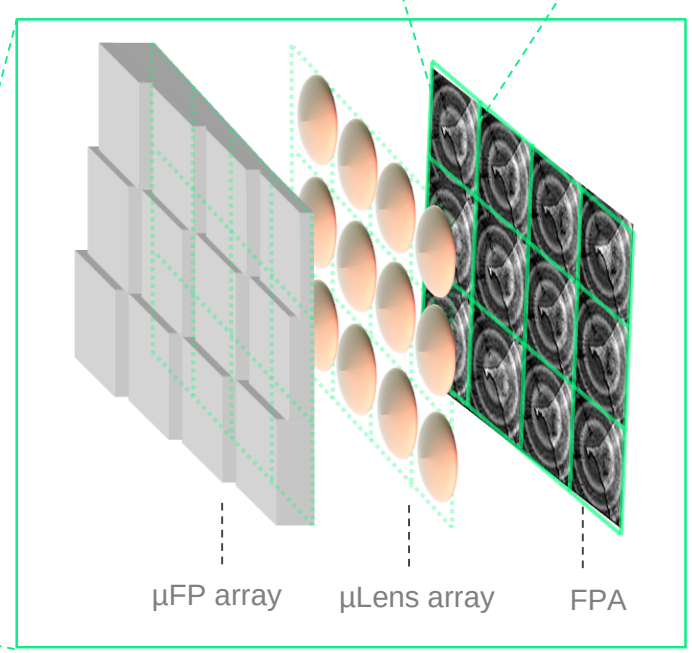
➢ Miniaturized (~15x4x4 cm^3) imaging spectrometer

➢ Full static Fourier Transform Spectrometer

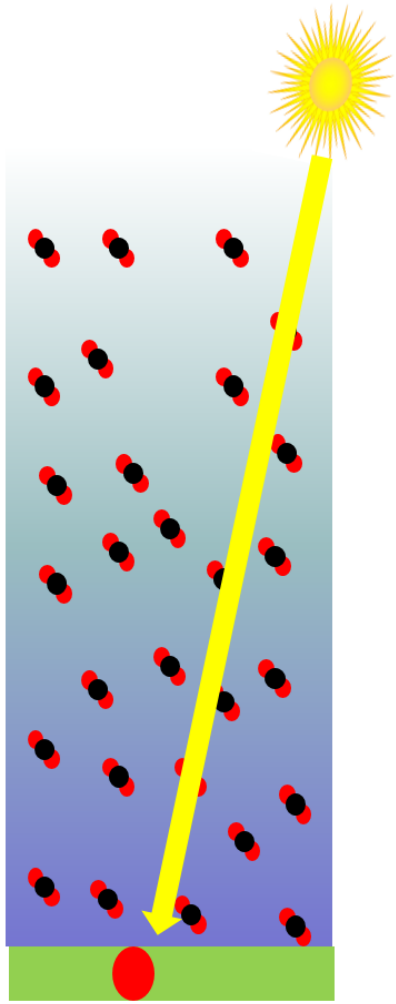
  – Each FP thickness chosen to target a particular Optical Path Difference (OPD)
  – Focal Plan Array (FPA) intensity modulated by low finesse Fabry-Perot array
  – Snapshot acquisition mode







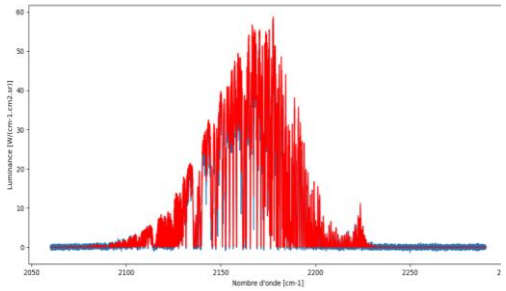
MEDOC: a forward et backward based on partially sampled interferograms



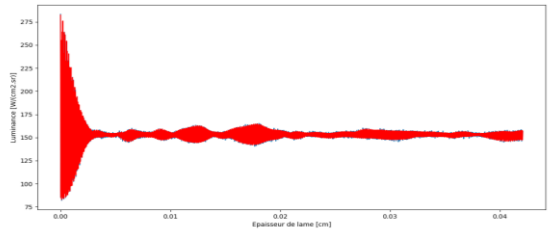
- A new tool
- Allows performing calculations with
  - a forward approach (performance assessment in the design phase)
  - a backward approach (performance assessment and optimization in the design phase, and exploitation of the acquired data).

Preliminary results:

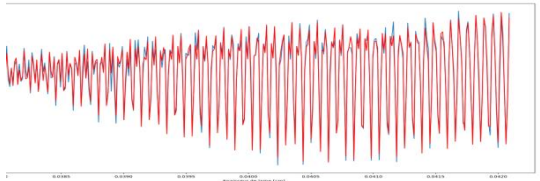
- demonstration of the possibility of jointly retrieving geophysical parameters such as the total column of CO and H_2O and instrumental parameters such as the temperature of the interferometer from a partial interferogram.
- Relevant information is contained in the selected part of the interferogram



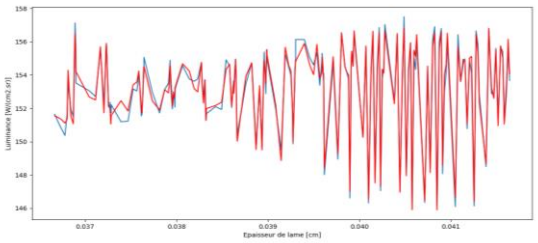
Err: H_20 0.008%, CO: 0.02 %



Err: H_20 0.27%, CO: 1.1 %,T=0.12%

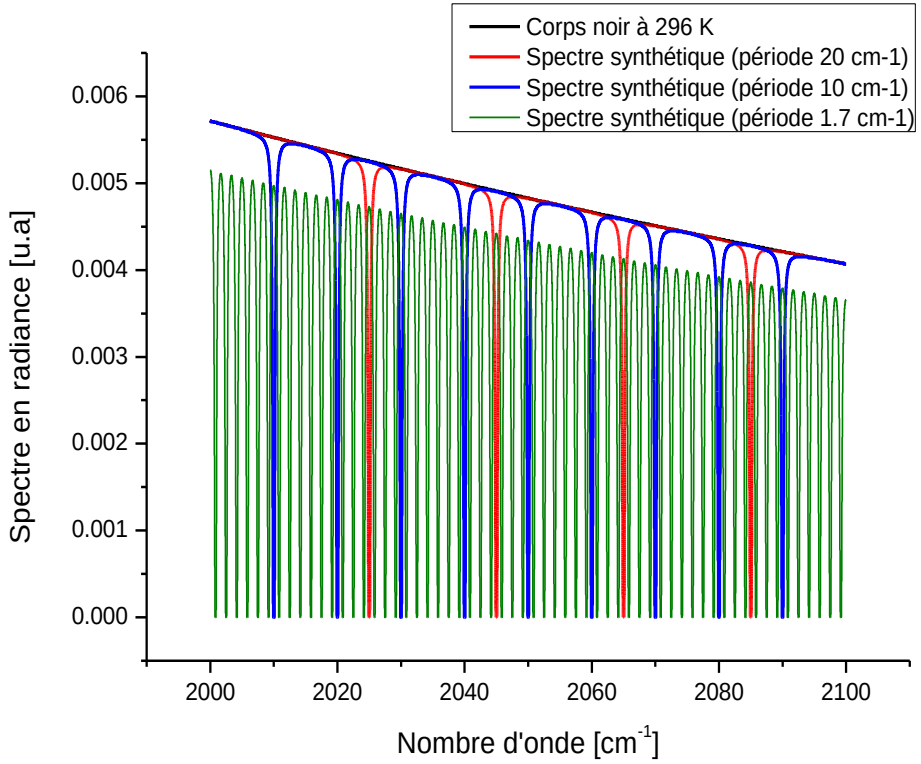


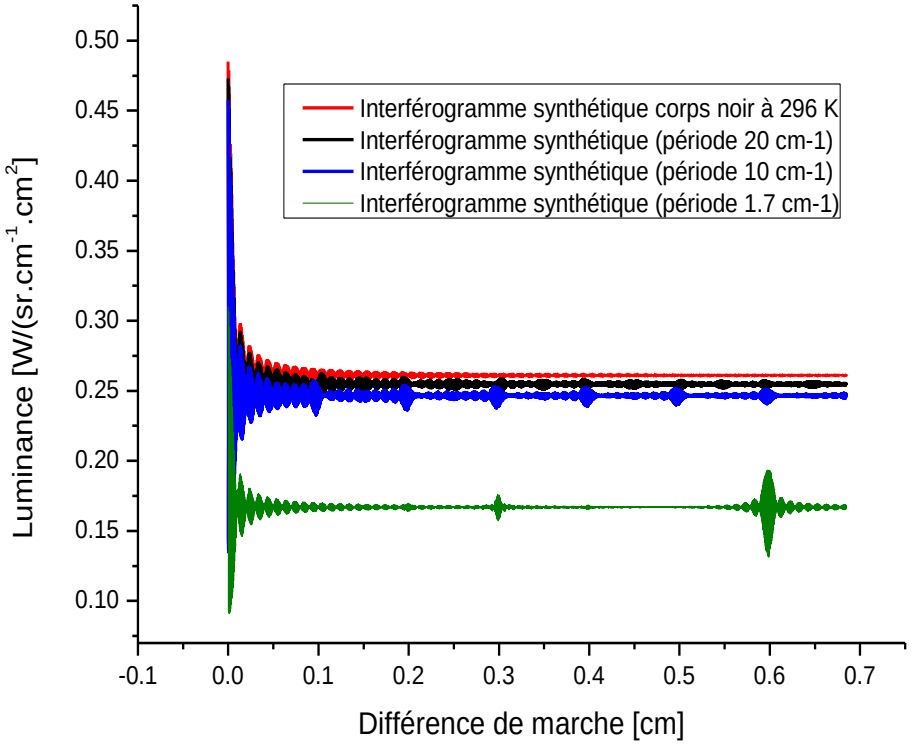
Err: H_20 0.27%, CO: 1.0 %, T=0.22%



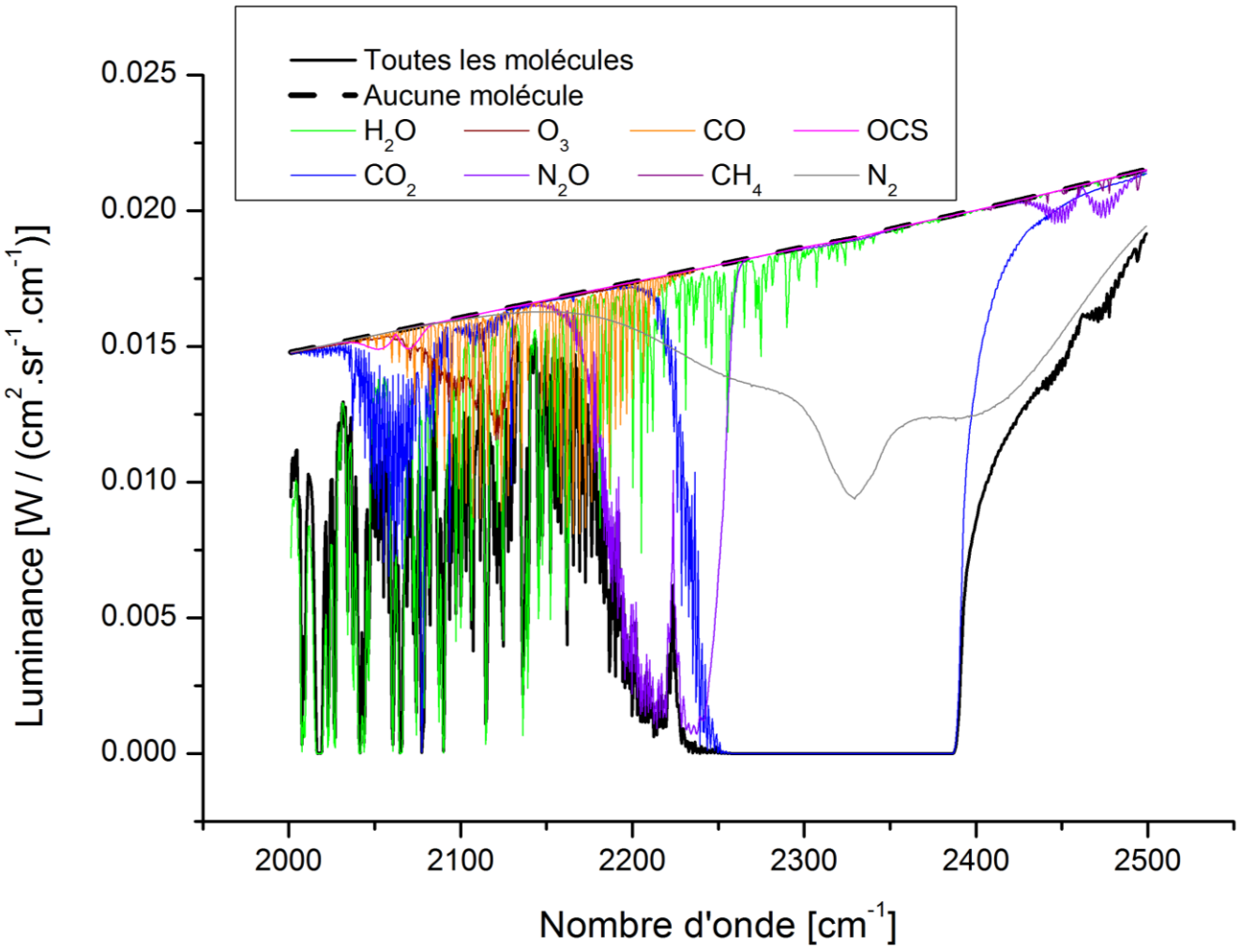
Err: H_20 0.45%, CO: 1.7 %, T=0.34%

Information content in a partial interferogram





Case study for CO (solar occultation – SPACEOBS project



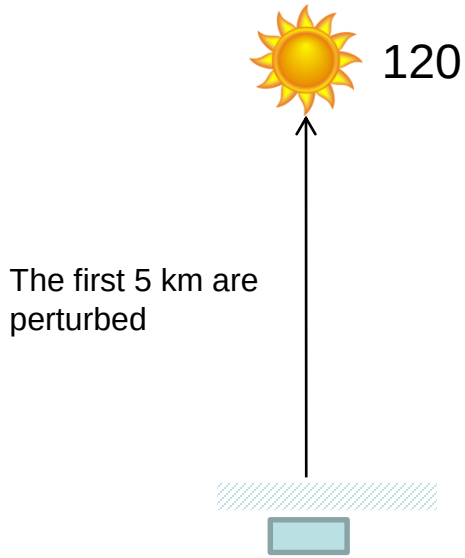
Simulations of measurement of the total column of CO in zenith view (in emission and in solar occultation) for realistic cases from the article above and typical relative humidities of Ile-de-France.

Observations of carbon monoxide and aerosols from the Terra satellite: Northern Hemisphere variability

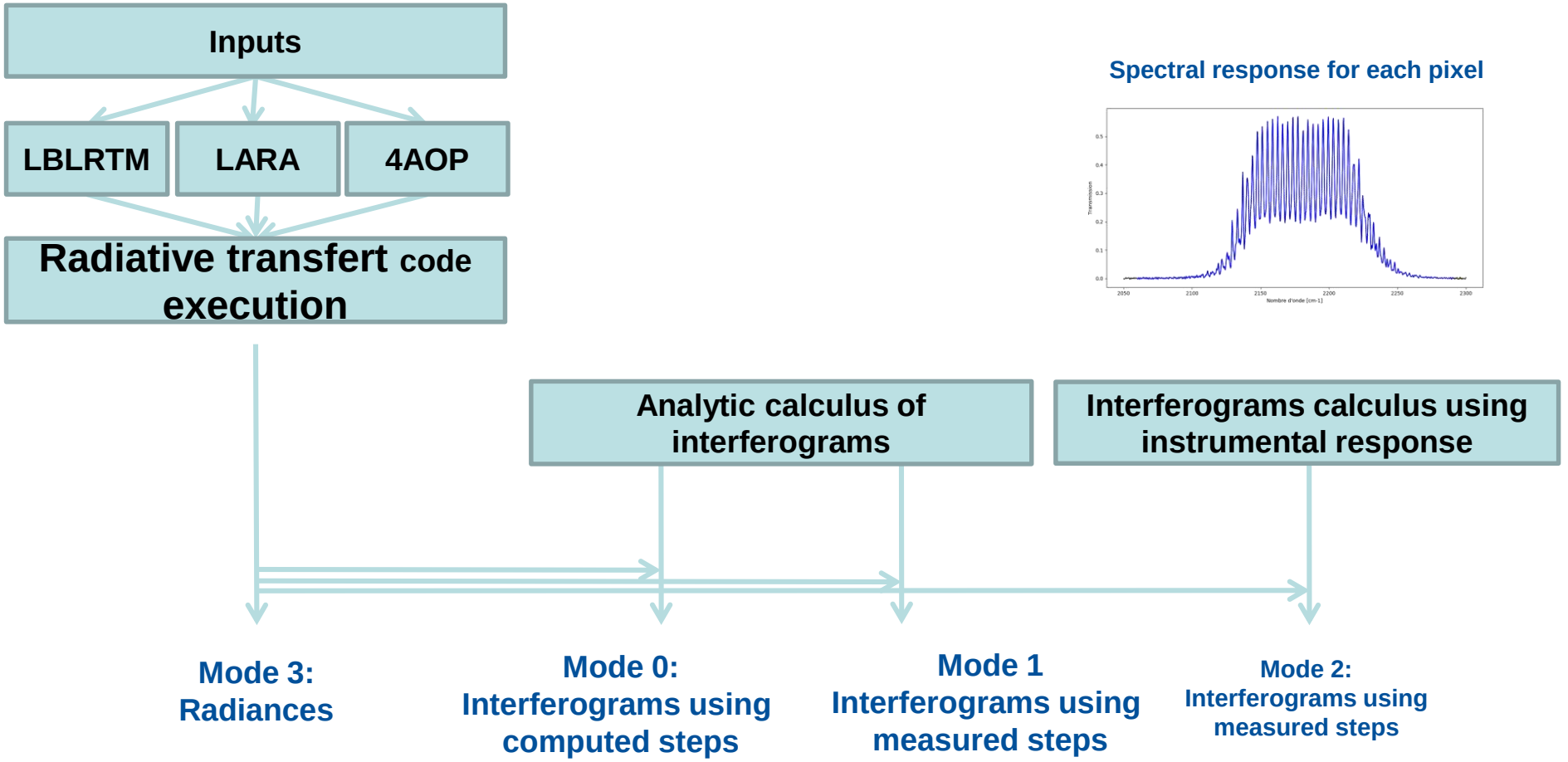
D. P. Edwards,[1] L. K. Emmons,[1] D. A. Hauglustaine,[2] D. A. Chu,[3] J. C. Gille,[1] Y. J. Kaufman,[4] G. Pétron,[1] L. N. Yurganov,[5] L. Giglio,[4] M. N. Deeter,[1] V. Yudin,[1] D. C. Ziskin,[1] J. Warner,[1] J.-F. Lamarque,[1] G. L. Francis,[1] S. P. Ho,[1] D. Mao,[1] J. Chen,[1] E. I. Grechko,[6] and J. R. Drummond[7]

Received 2 March 2004; revised 13 May 2004; accepted 30 June 2004; published 16 December 2004.

[1] Measurements from the Terra satellite launched in December of 1999 provide a global record of the recent interannual variability of tropospheric air quality: carbon monoxide (CO) from the Measurement of Pollution in the Troposphere (MOPITT)

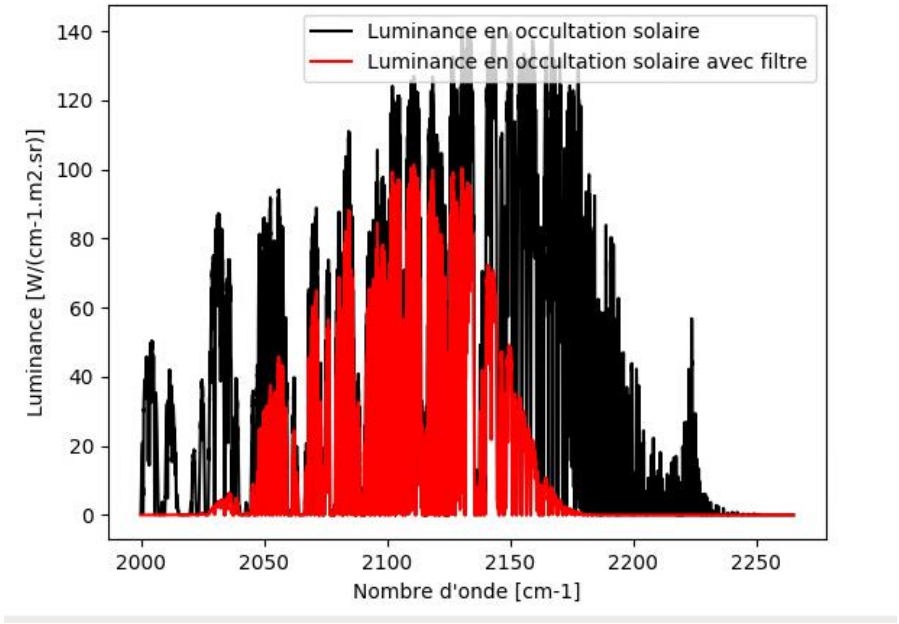


MEDOC tool behavior breakdown

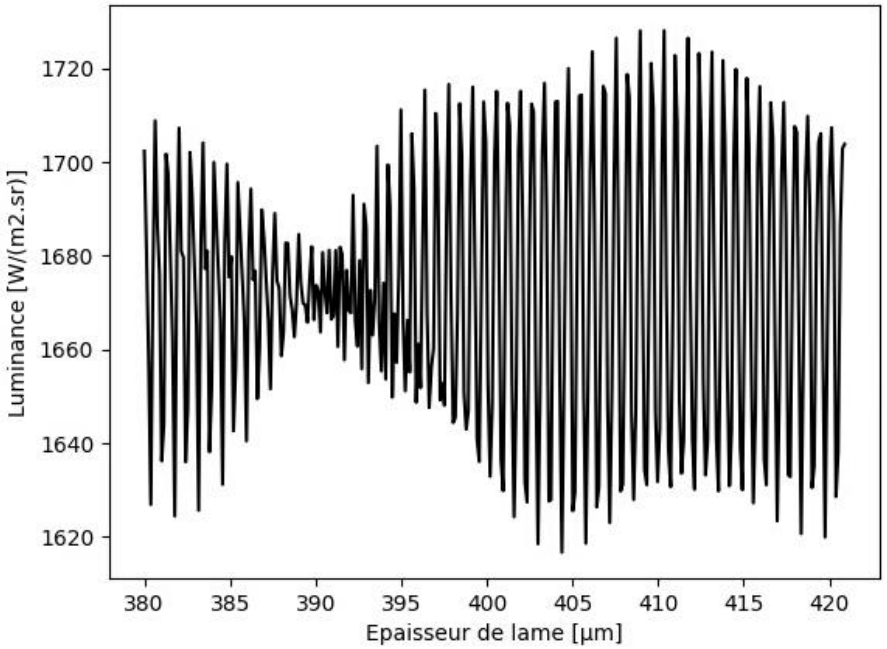


Simulation results

- Production of radiances in solar occultation configuration (LARA)
- Production of interferograms according to this radiance, CO signature in the interferograms



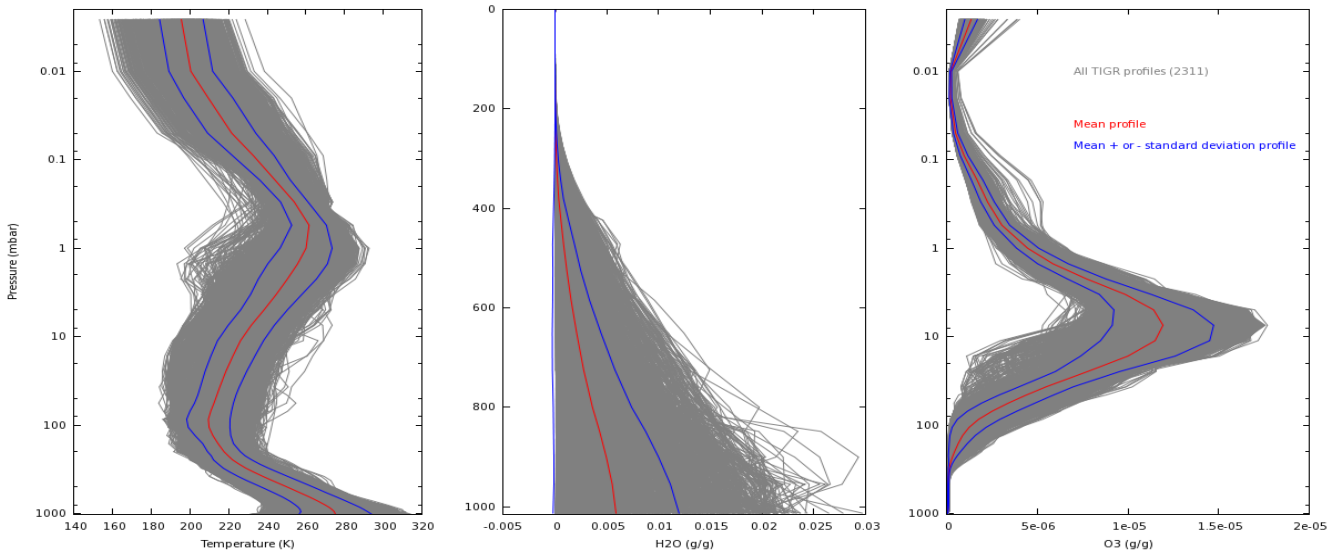
Computed Radiance



Related Interferograms

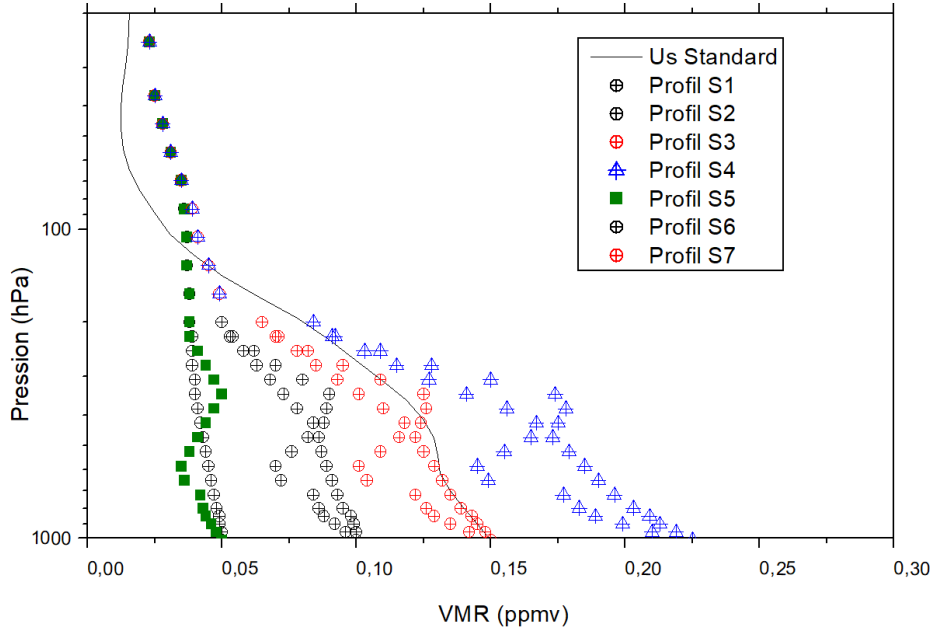
Training data set

- Use of the climatological library of 2311 representative atmospheric situations selected by statistical methods from 80,000 radiosonde reports (Chédin et al., 1985; Achard, 1991; Chevallier et al., 1998).
- Each situation is described, from the surface to the top of the atmosphere (0.0026 hPa), by the values of the temperature, water vapour and ozone concentrations on a given pressure grid.
- atm4atigr2000_v1.2_43lev



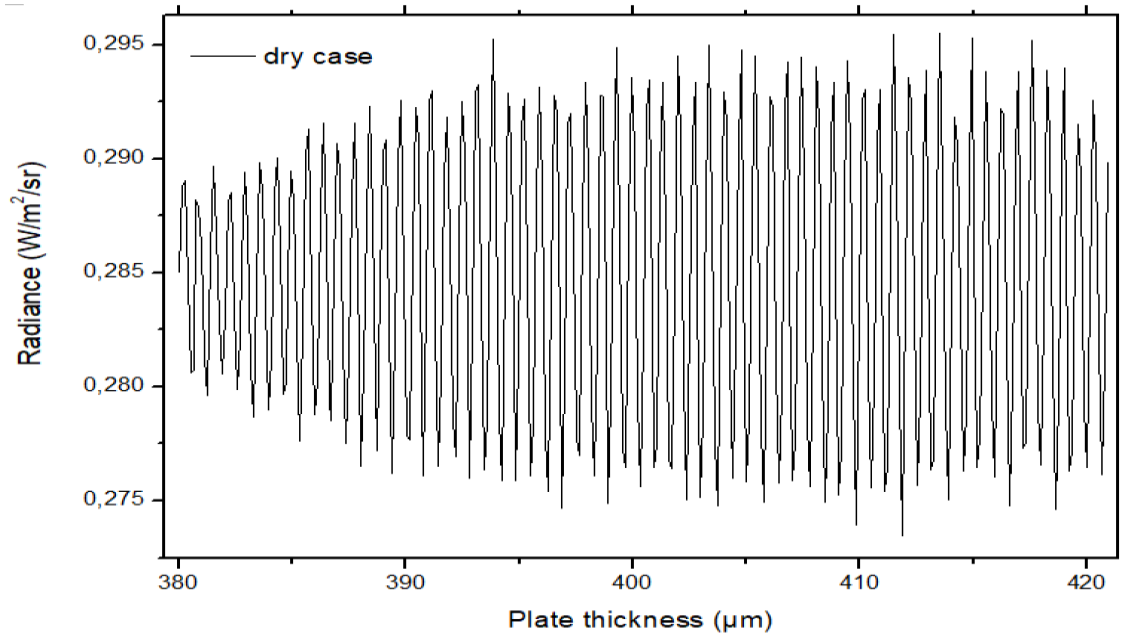
Airmass	Atmospheres
Tropical	1 to 872
Mid-lat1	873 to 1260
Mid-lat2	1261 to 1614
Polar1	1615 to 1718
Polar2	1719 to 2311

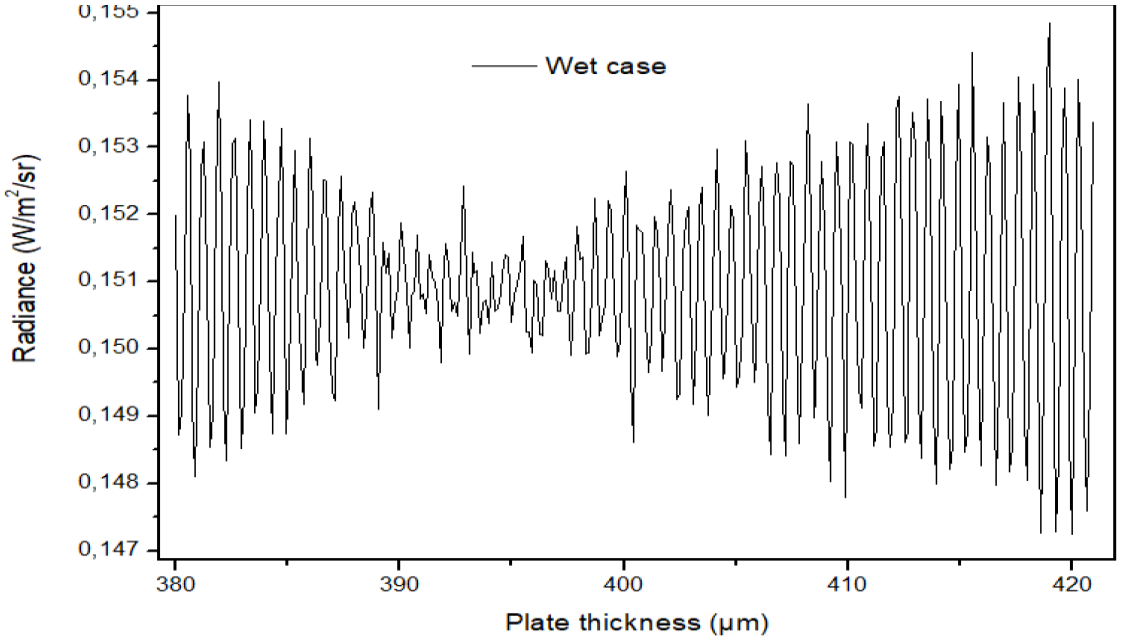
- 8 profiles to describing CO concentration

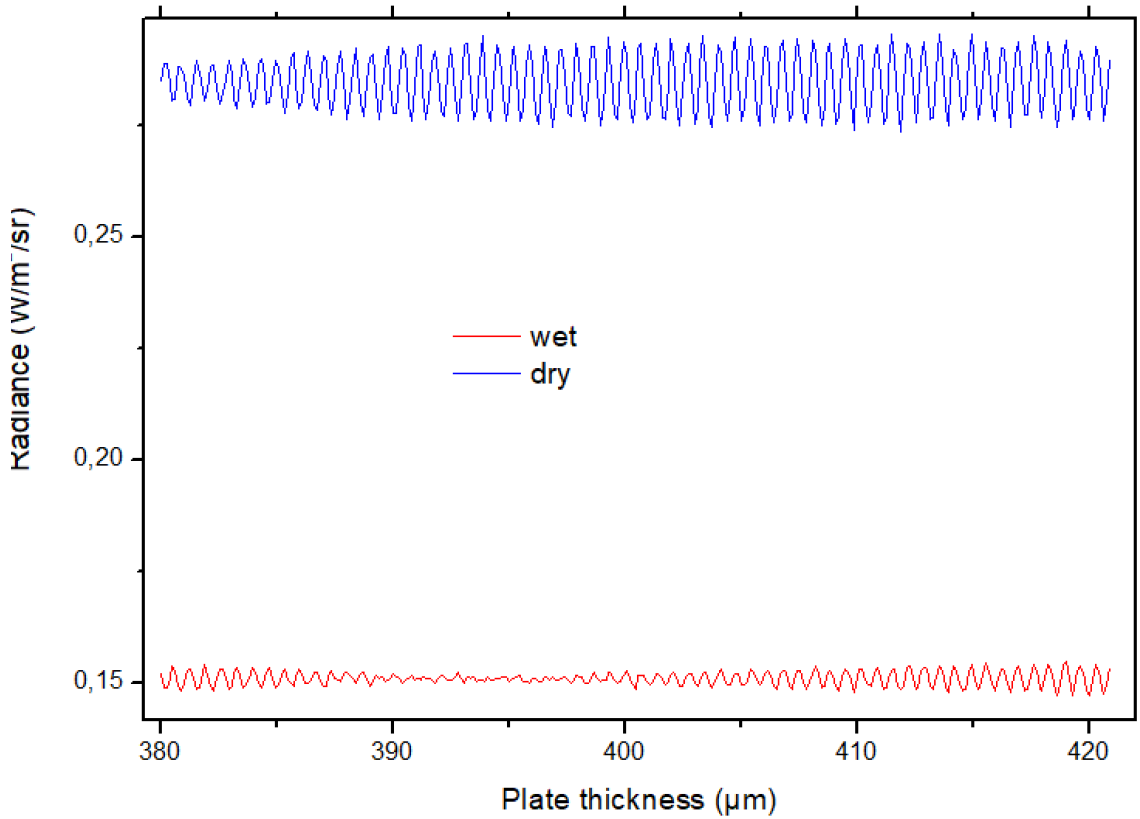


Simulation data training for retrieval :

2311 TIGR atmospheres
x
8 CO type profile
=
18448 interferograms + noise







Related Interferograms

Inversion de CO : premières statistiques

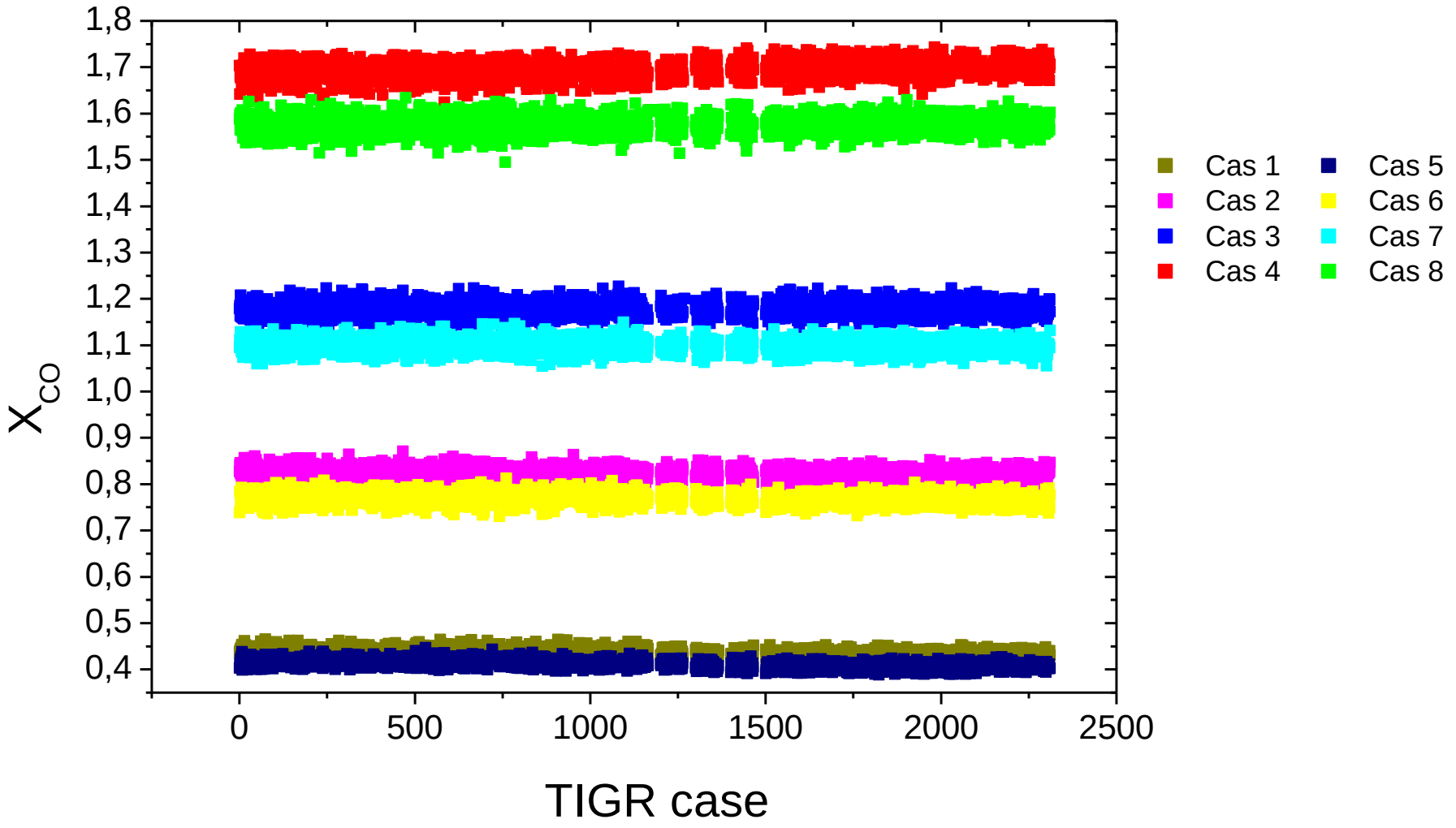
2311 TIGR atmosphere x 8 CO type profile = 18448 noised interferograms to retrieve

Initial guess :
- True P and T profile
- True H_2O profiles
- Mean CO profile

Retrieval of T_{plate}, X_{H2O} and X_{CO}

Filtrage des résultats :
- DevStd > 0,008
- X_{CO} Outliers (~300)

→ 16009 retrievals



Inversion de CO : premières statistiques

2311 TIGR atmosphere x 8 CO type profile = 18448 noised interferograms to retrieve

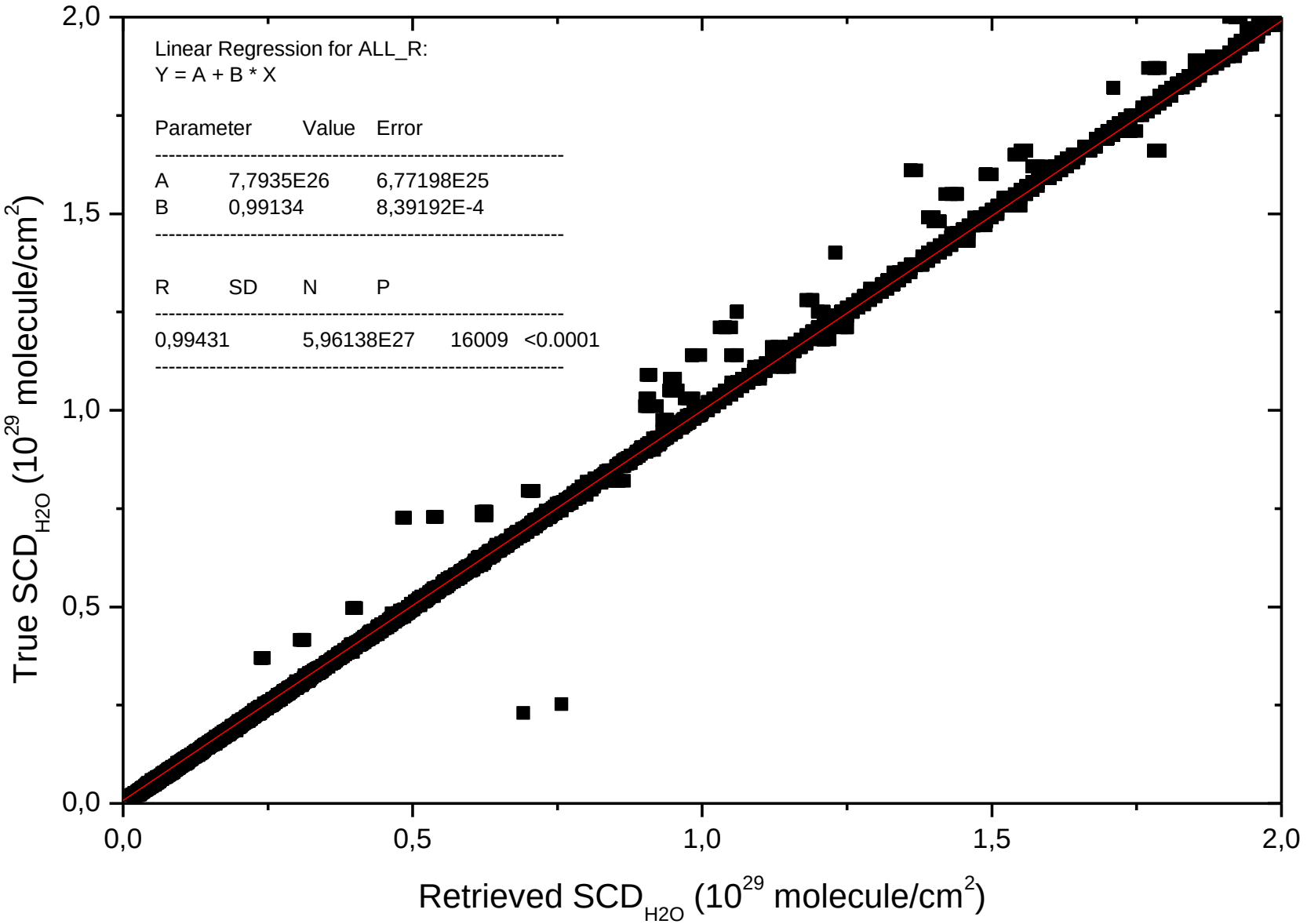
Initial guess :
- True P and T profile
- True H_2O profiles
- Mean CO profile

Retrieval of T_{plate}, X_{H2O} and X_{CO}

Filtrage des résultats :
- DevStd > 0,008
- X_{CO} Outliers (< 300)

SCD = Slant Column Density

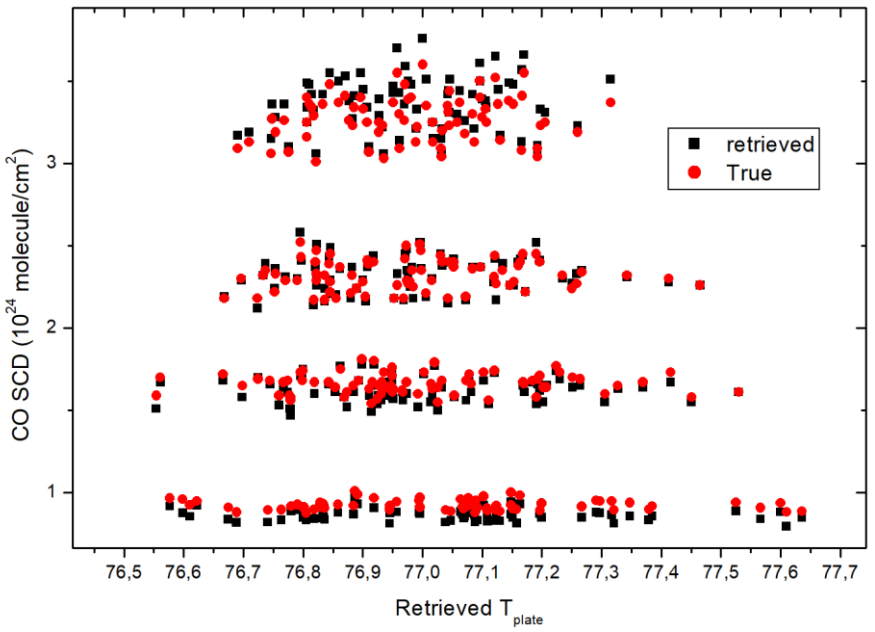
→ 16009 retrievals

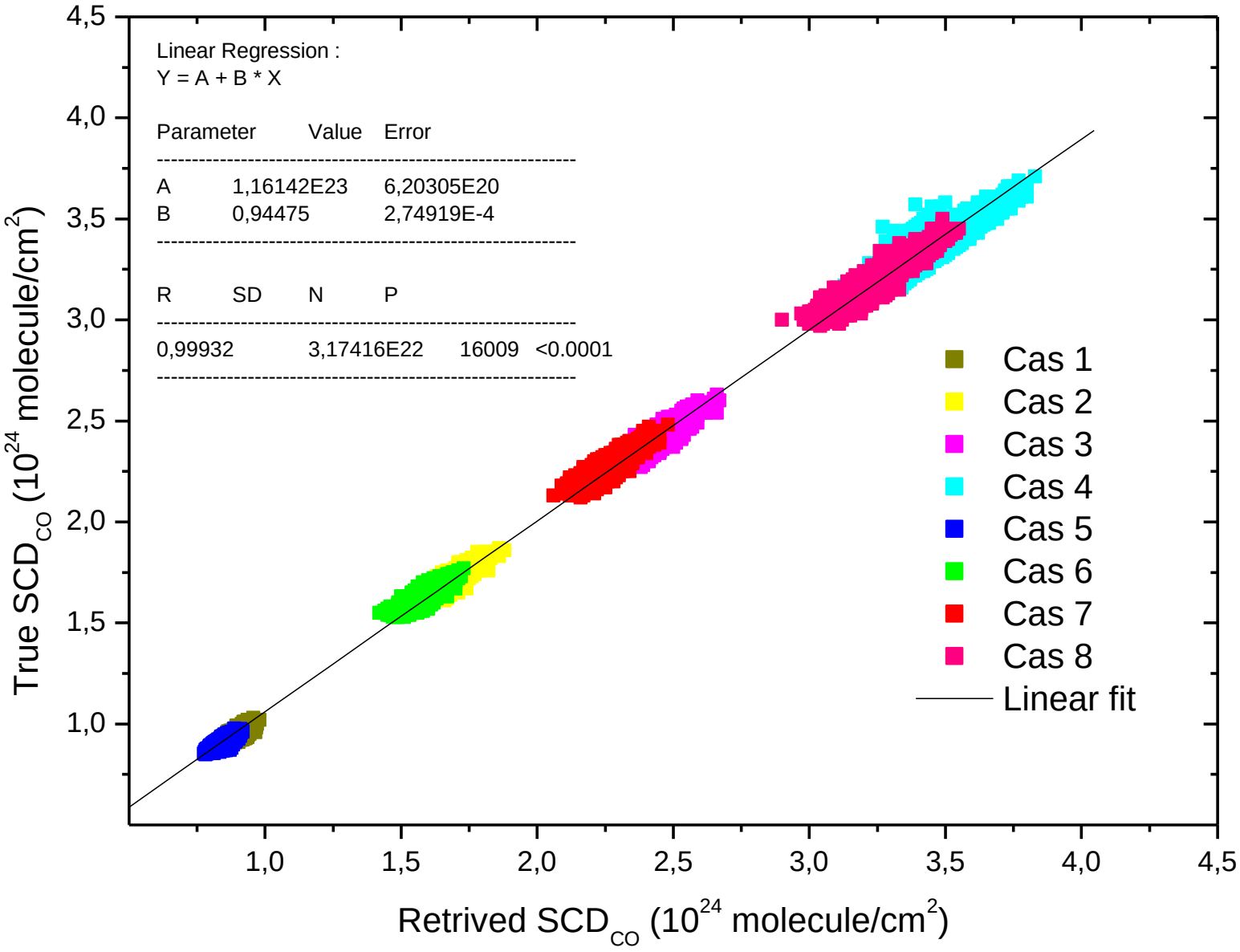


Inversion de CO : premières statistiques

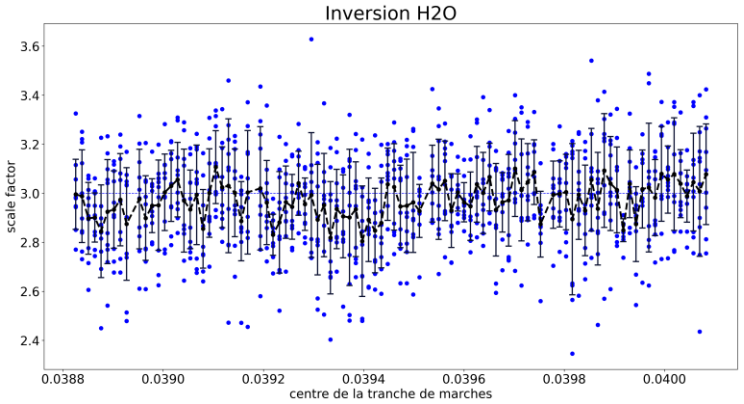
Retrieved T_{plate} :
76.97 +/- 0,23 K

No correlaation with X_{H2O} or X_{CO}





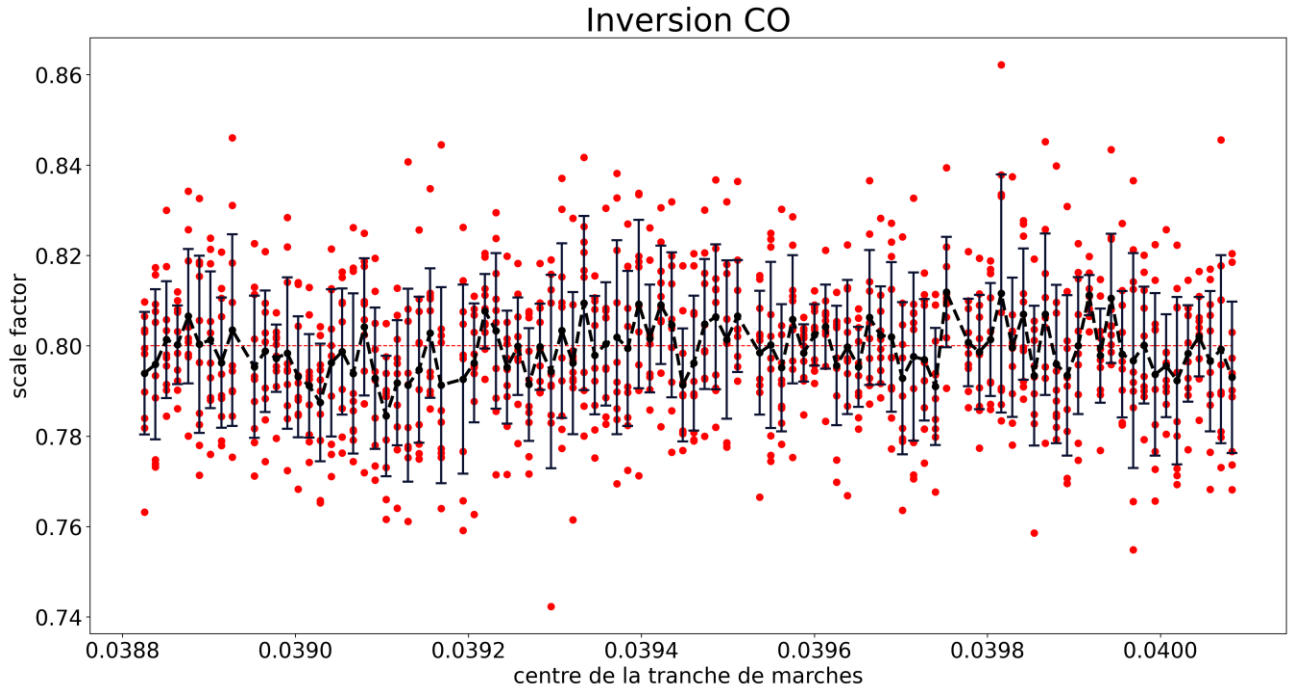
Test de l'impact de la partie de l'interférogramme couverte



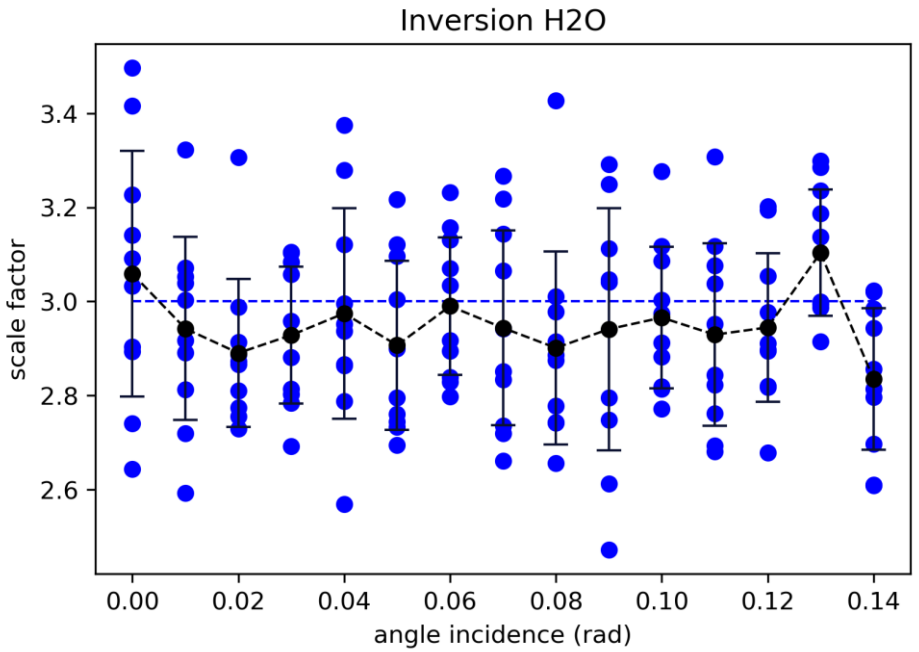
100 variations de 130 points
10 essais effectués à chaque variation

- Moy_H2O = 2.97
- Std_H2O = 0.174

- Moy_CO = 0.799
- Std_CO = 0.0147



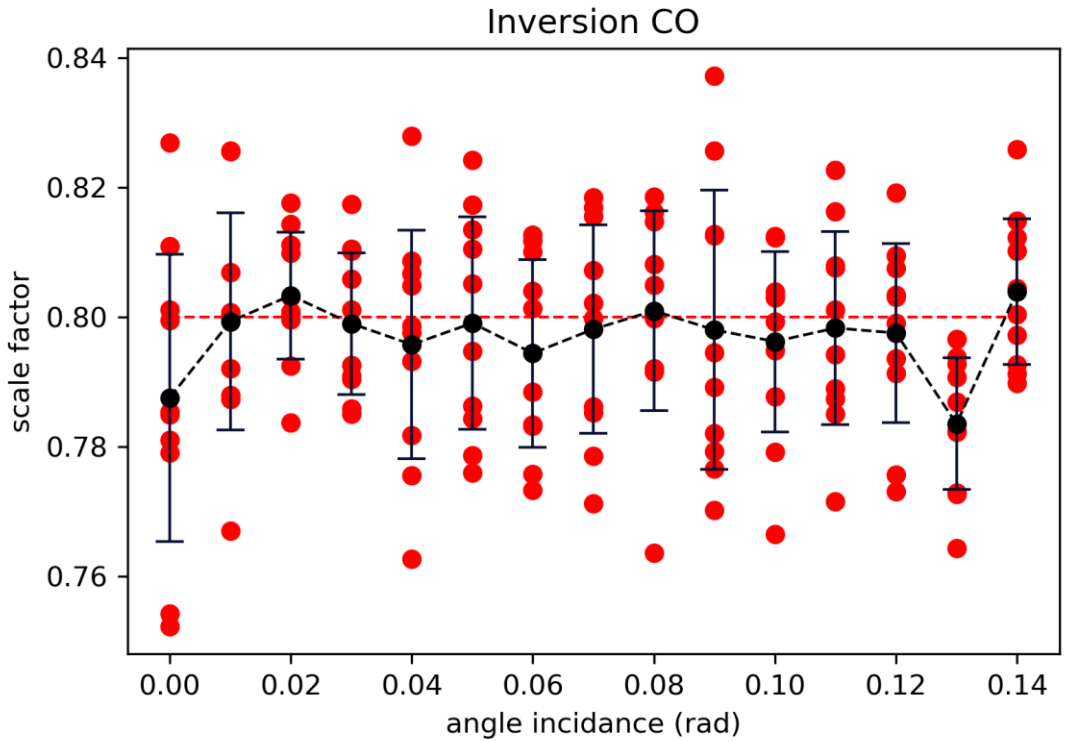
Test de l'angle d'incidence dans la lame



Angle d'incidence de 0 à 0.14 rad, soit de 0° à 8.02°
10 essais effectués à chaque angle

- Moy_H2O = 2.95
- Std_H2O = 0.18

- Moy_CO = 0.797
- Std_CO = 0.015



Conclusion and outlook

- New retrieval approach intrinsically based on partial interferograms : not easy !
- First results for a case study of CO from solar occultation :
  - bricks of the modelling have been assembled → MEDOC V1.00
  - Generation of a training data set
- Preliminary results are very encouraging
- Results for CO not clear yet and need to be explored (correlation of retrieval with column density)
- Information on the vertical : to be confirmed in more realistic training (unknown H2O)
- Implement Variance – covariance information and DOFS calculation : work in progress
- Plan to test our approach and algorithms on IASI, IASI-NG and MTG-IRS (PhD Nejla Eco)

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