Detection of volcanic gases from Altzomoni, Mexico

Centro de Ciencias de la Atmosfera,
Universidad Nacional Autonoma de Mexico - UNAM, Mexico City, Mexico

Wolfgang Stremme, Jorge Baylon, Michel Grutter
Alejandro Bezanilla, Eddy Plaza, Noemi Taquet ,
Israel Meza, Benedetto Schiavo, Josue Arellano

Facultad de Ciencias
Universidad Nacional Autonoma de Mexico - UNAM, Mexico City, Mexico
Claudia Rivera

Institute for Meteorology and Climate Research, Karlsruhe Institute of Technology - KIT, Karlsruhe, Germany.

Thomas Blumenstock, Frank Hase

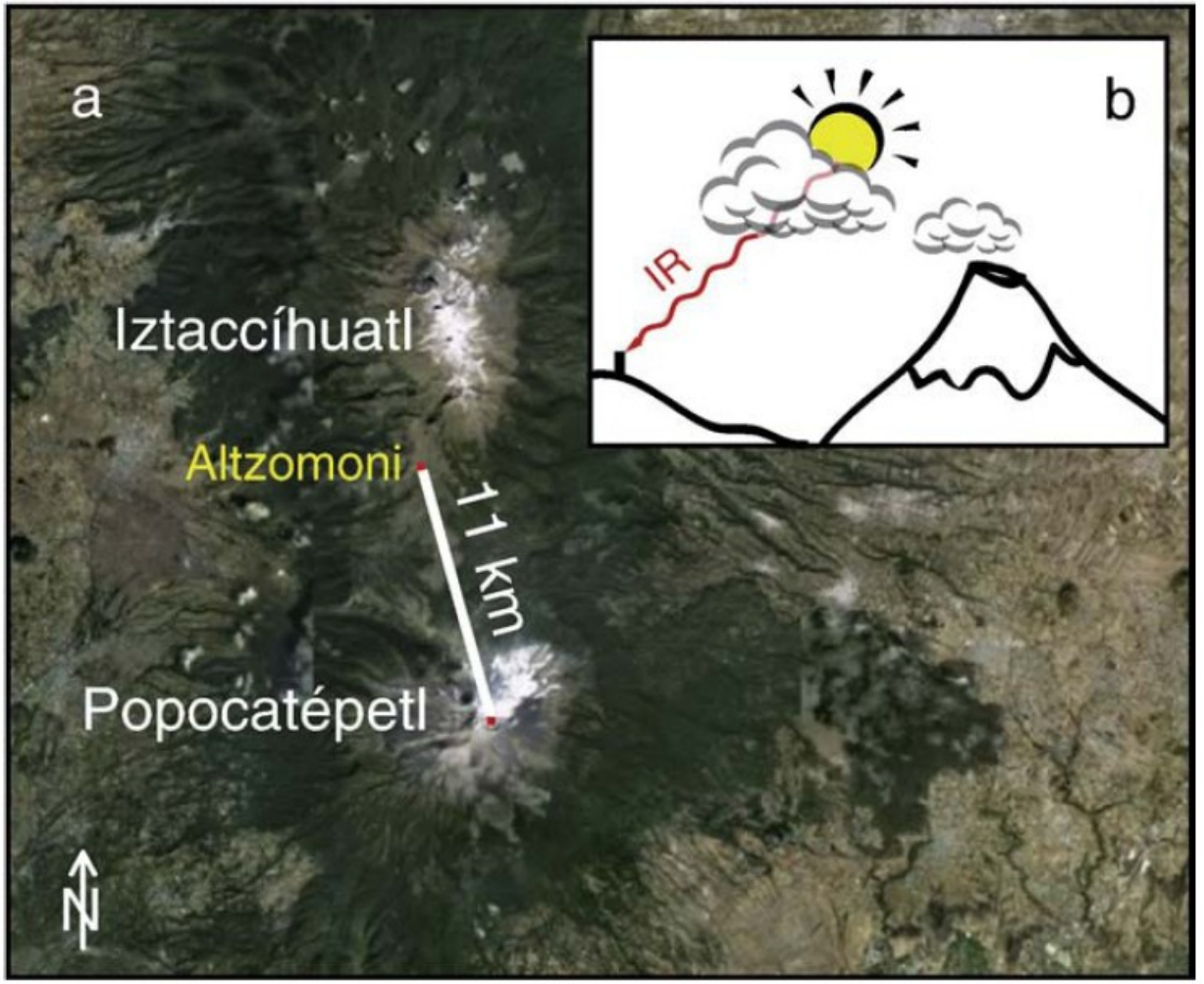
outline

1) Altzomoni and Popocatepetl
2) Why measureing volcanic gas plumes?
3) SO2 in different spectral regions:
4) Timeseries of SO2 and HCl
5) Timeseries of stratospheric HCl
6) Timeseries of the volcanic HCl/SO2 ratios
7) ¿CO2/HF from Popocatepetl?
8) Other FTIR-measurements (thermal emission)

Discussion:

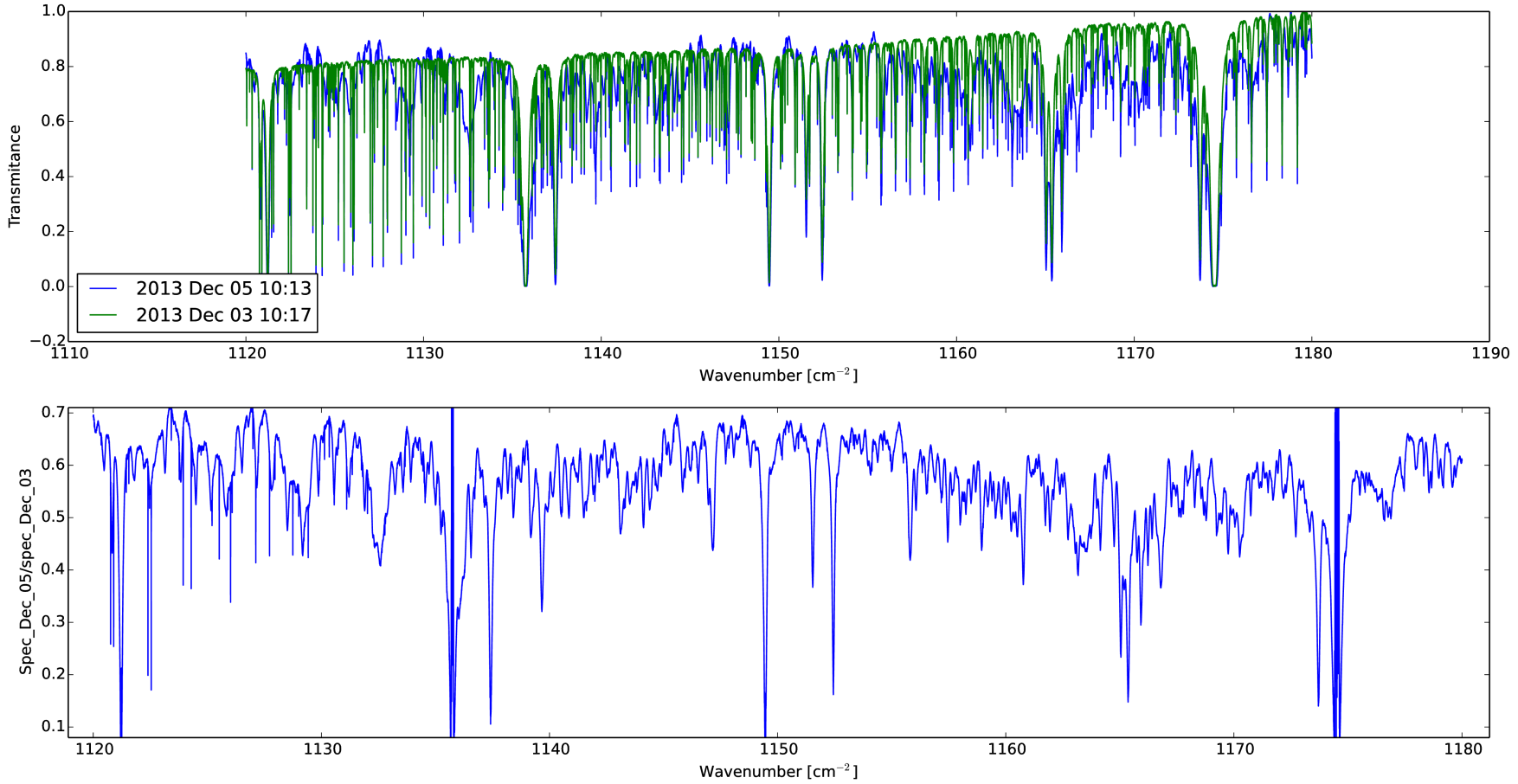
Should we clean the NDACC-timeseries for local events?

Altzomoni and Popocatepetl

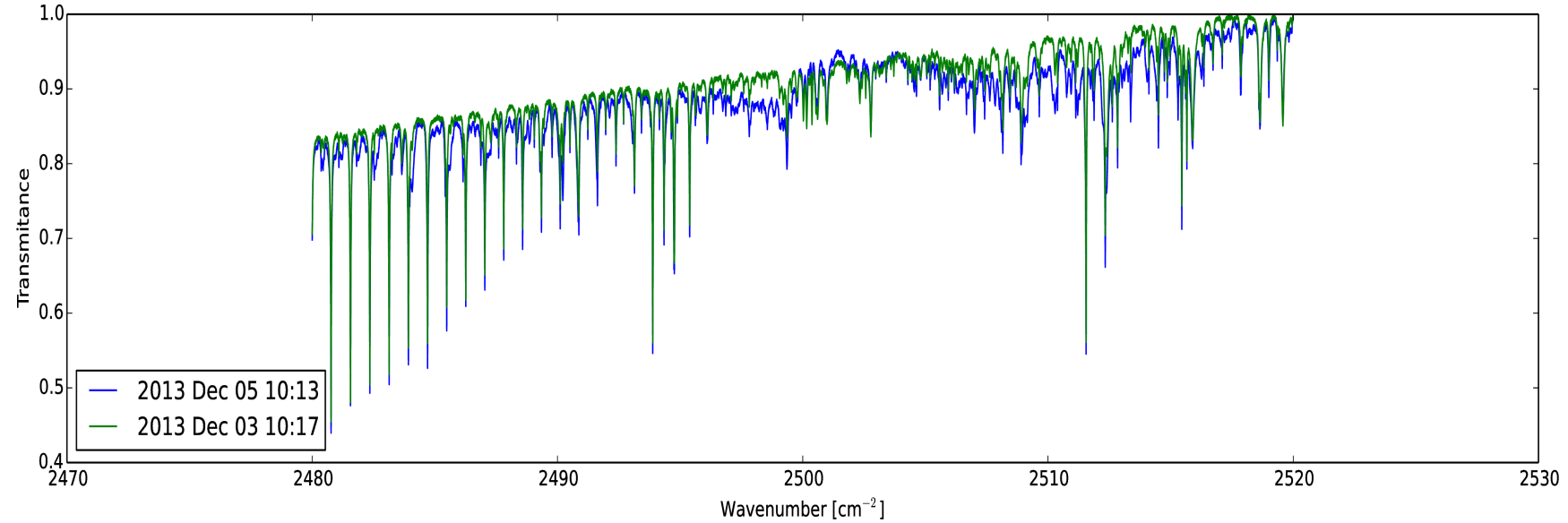


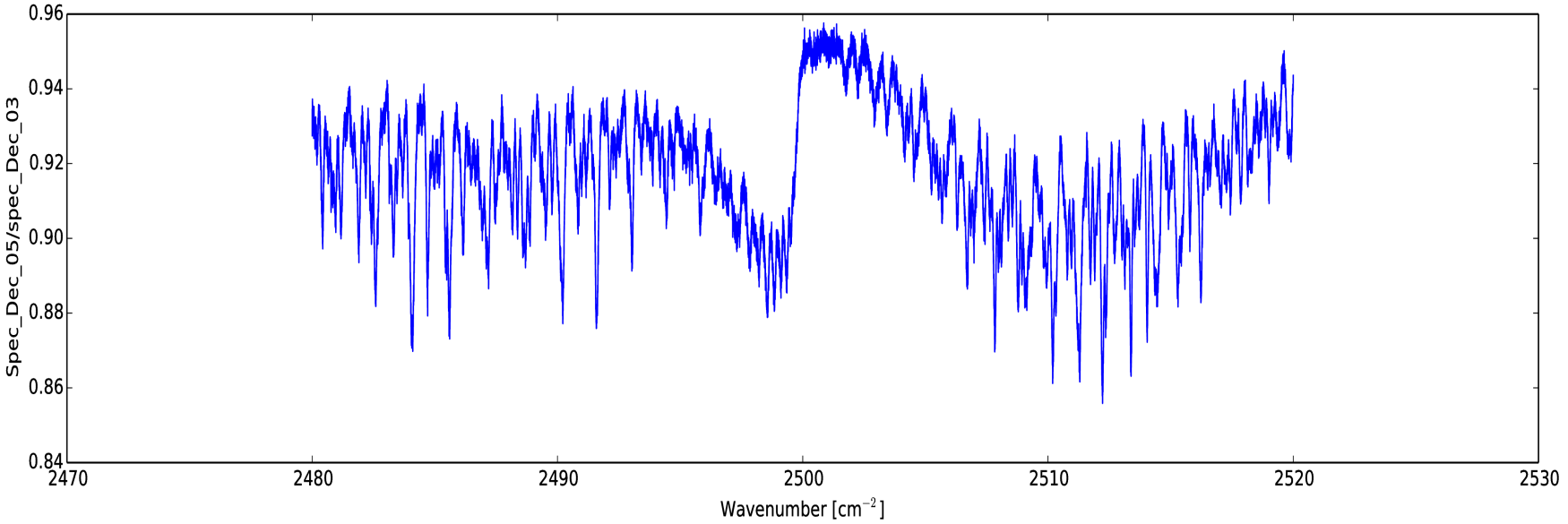
22 November 2012 7:45
passive degassing

SO2 @ 1150cm-1

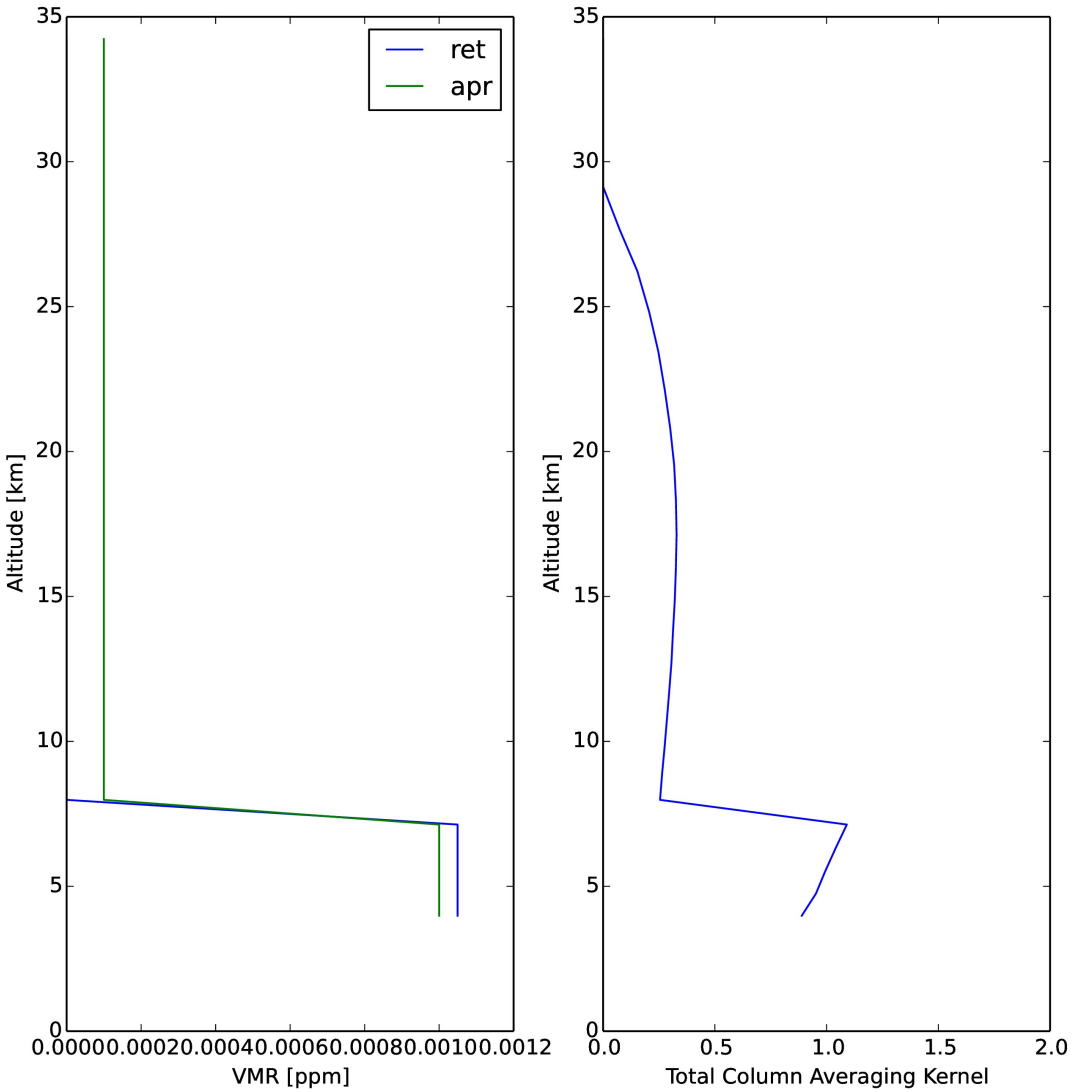

Transmitance
Wavenumber [cm^{-2}]
2013 Dec 05 10:13
2013 Dec 03 10:17
Spec_Dec_05/spec_Dec_03
Wavenumber [cm^{-2}]

SO2 @ 2500cm-1

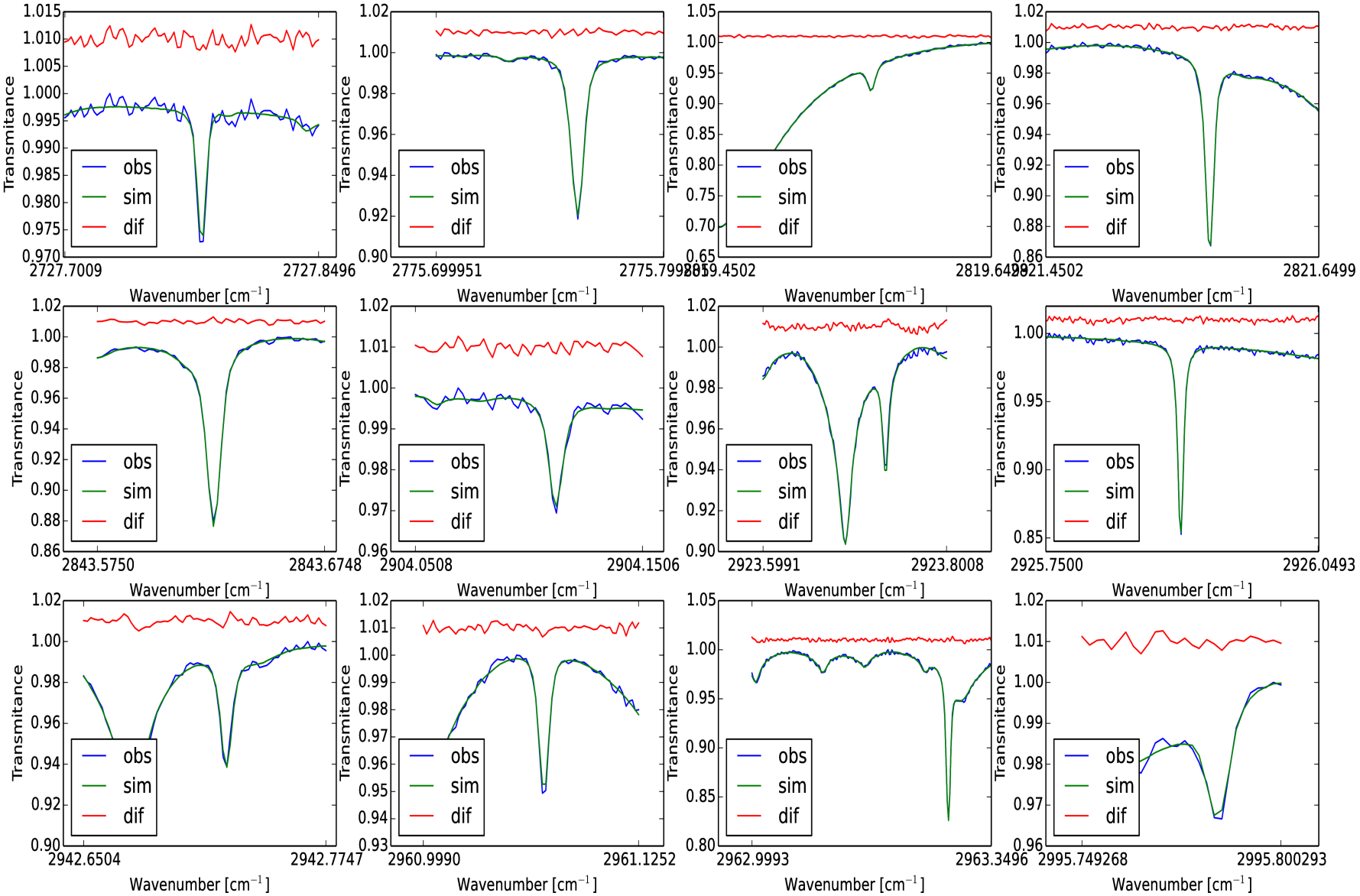

Transmitance
Wavenumber [cm^{-2}]
2013 Dec 05 10:13
2013 Dec 03 10:17


Spec_Dec_05/spec_Dec_03
Wavenumber [cm^{-2}]

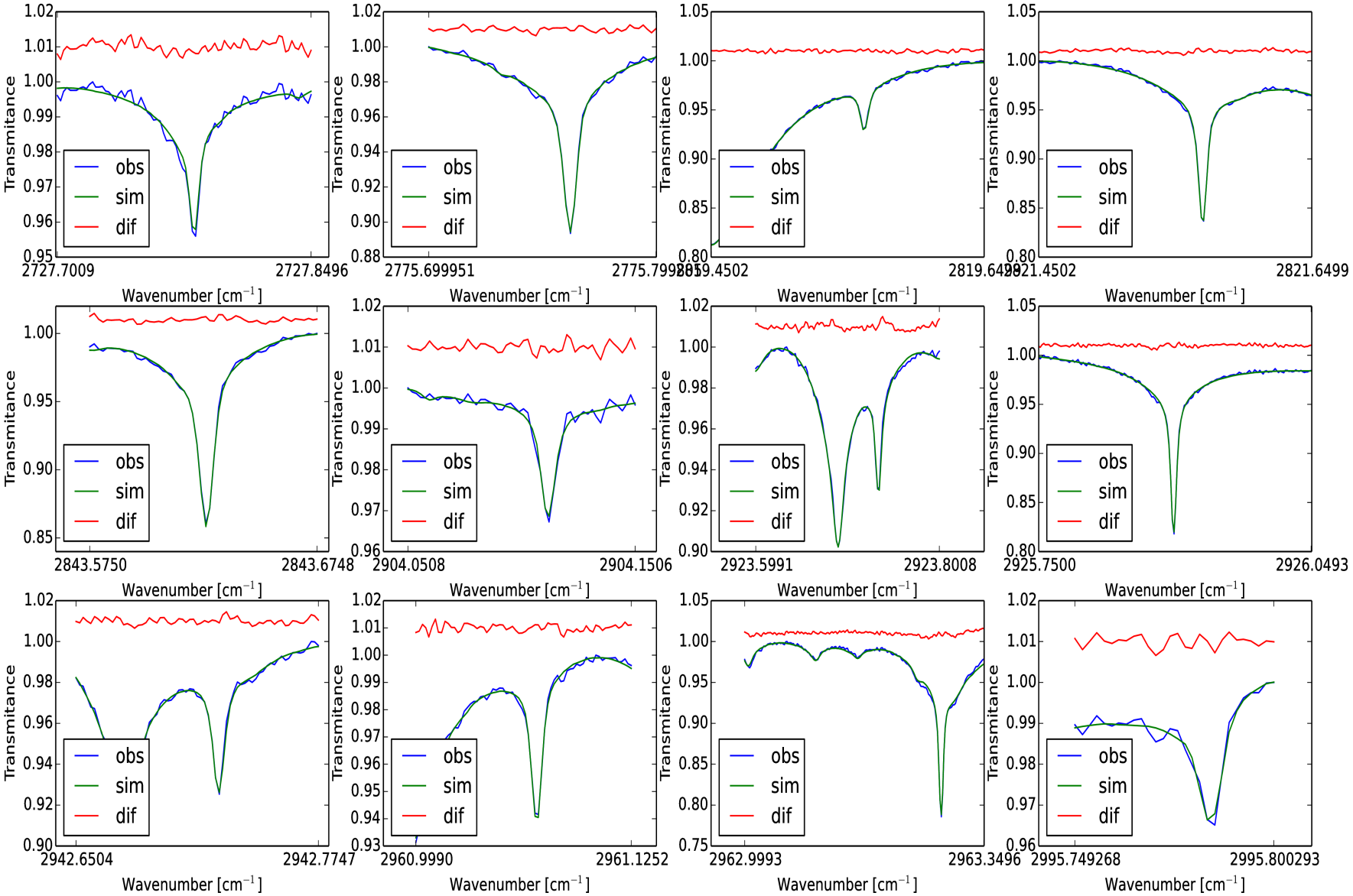
SO2


ret
apr
Altitude [km]
VMR [ppm]
0.00000.00020.00040.00060.00080.00100.0012
0
5
10
15
20
25
30
35
Altitude [km]
Total Column Averaging Kernel
0.0
0.5
1.0
1.5
2.0

HCl


Transmitance
Wavenumber [cm^{-1}]
obs
sim
dif
2727.7009
2727.8496
2775.699951
2775.799805
2819.4502
2819.6499
2821.4502
2821.6499
2843.5750
2843.6748
2904.0508
2904.1506
2923.5991
2923.8008
2925.7500
2926.0493
2942.6504
2942.7747
2960.9990
2961.1252
2962.9993
2963.3496
2995.749268
2995.800293

HCl


Transmitance
Wavenumber [cm^{-1}]
obs
sim
dif
2727.7009
2727.8496
2775.699951
2819.4502
2821.4502
2821.6499
2843.5750
2843.6748
2904.0508
2904.1506
2923.5991
2923.8008
2925.7500
2926.0493
2942.6504
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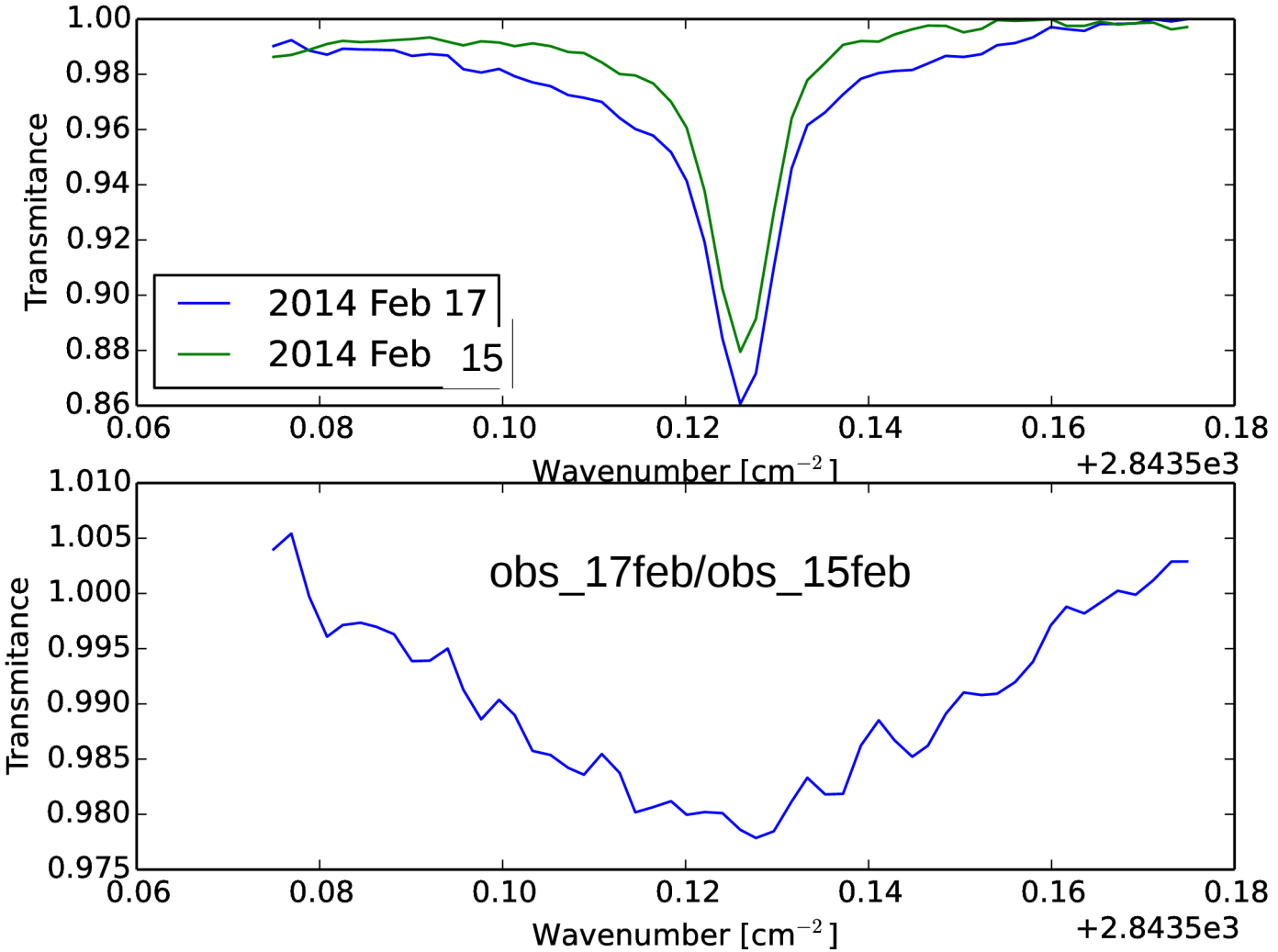
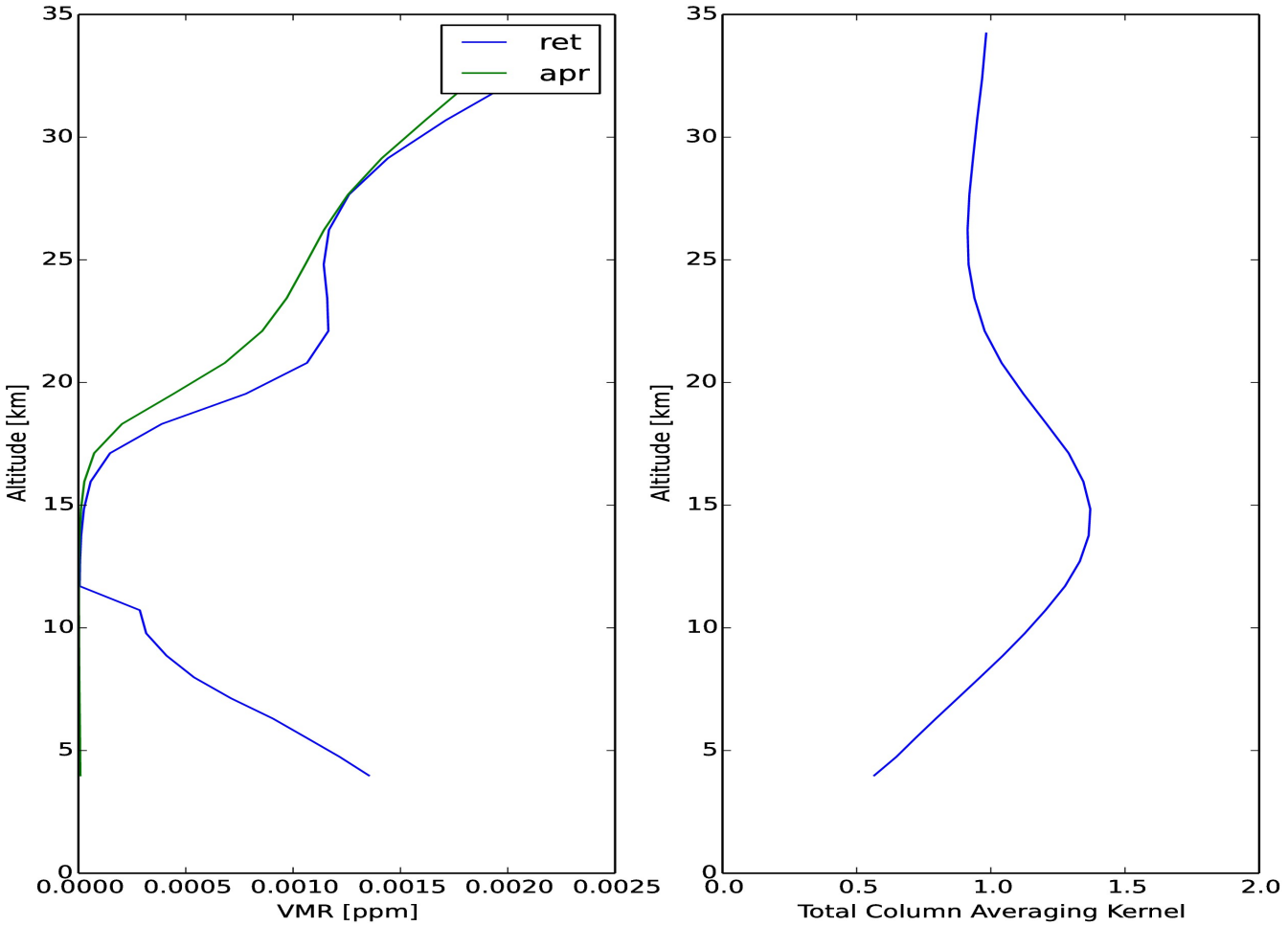
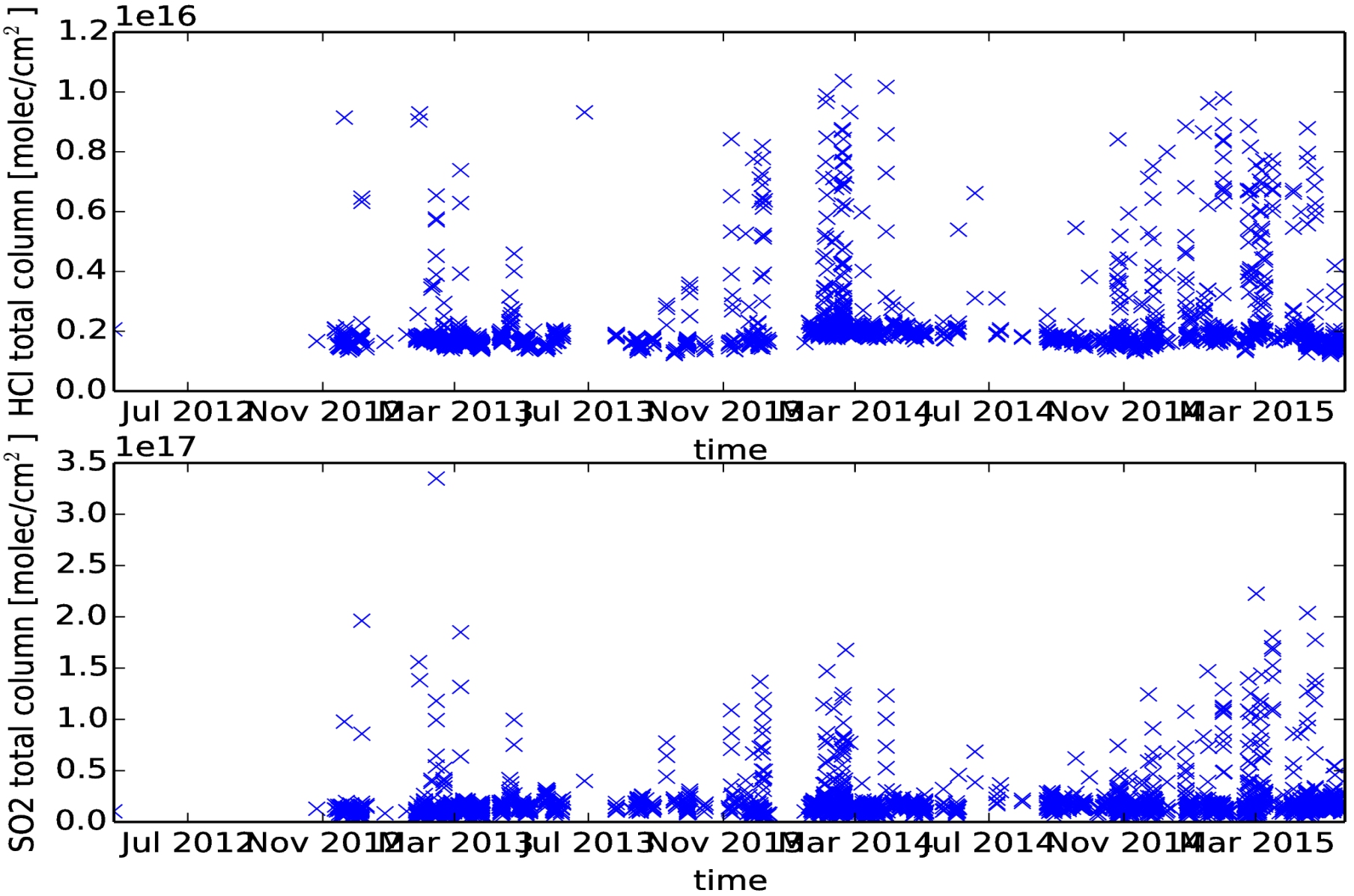
2961.1252
2962.9993
2963.3496
2995.749268
2995.800293


1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
Transmitance
2014 Feb 17
2014 Feb 15
0.06
0.08
0.10
0.12
0.14
0.16
0.18
Wavenumber [cm^{-2}]
+2.8435e3
1.010
1.005
1.000
0.995
0.990
0.985
0.980
0.975
Transmitance
obs_17feb/obs_15feb
0.06
0.08
0.10
0.12
0.14
0.16
0.18
Wavenumber [cm^{-2}]
+2.8435e3

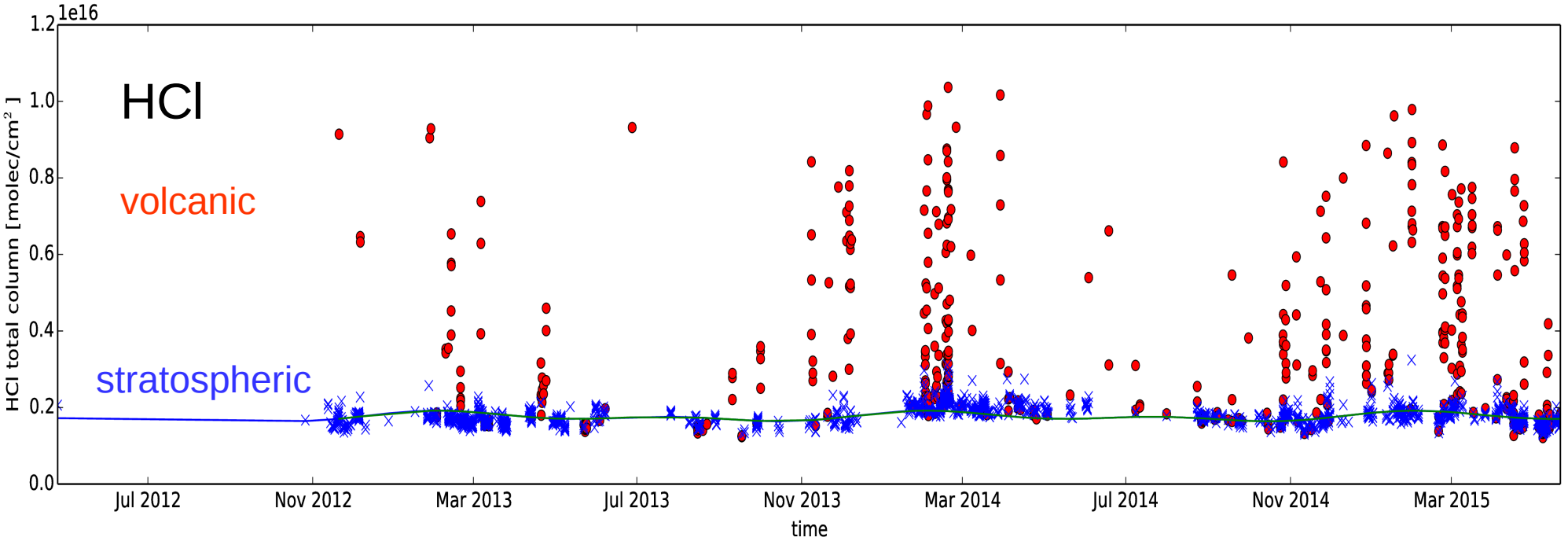
HCl

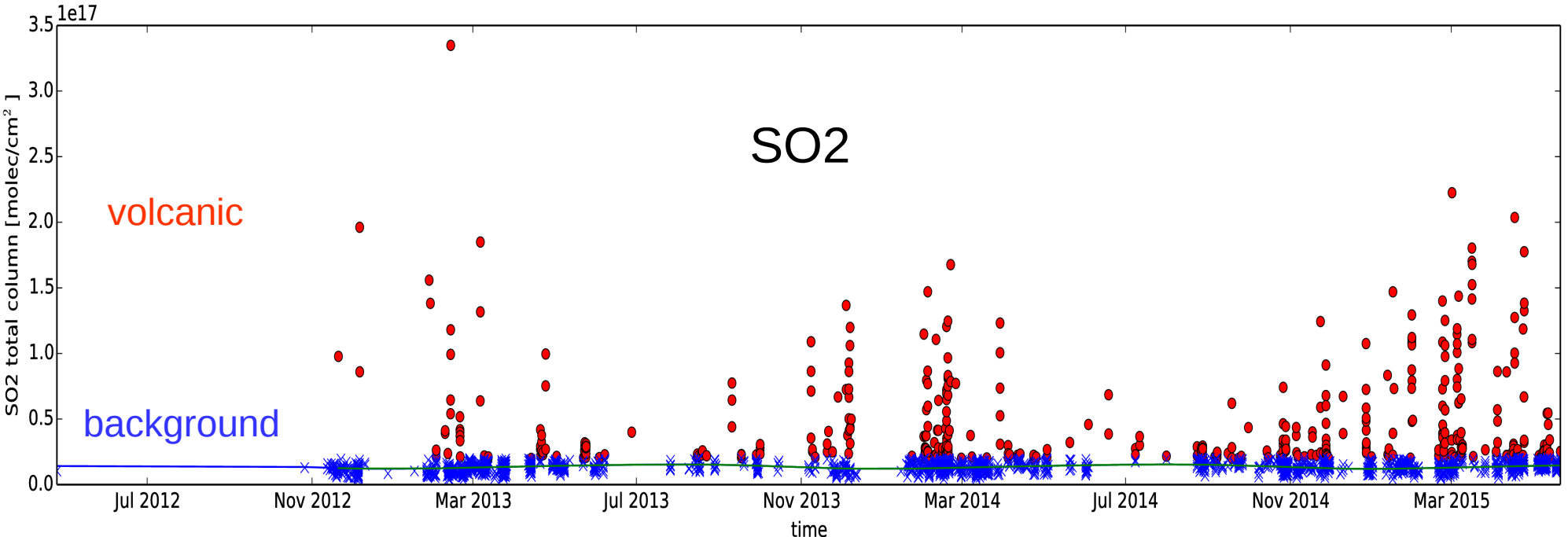

ret
apr
Altitude [km]
VMR [ppm]
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
0
5
10
15
20
25
30
35
Altitude [km]
Total Column Averaging Kernel
0.0
0.5
1.0
1.5
2.0

SO2 y HCl

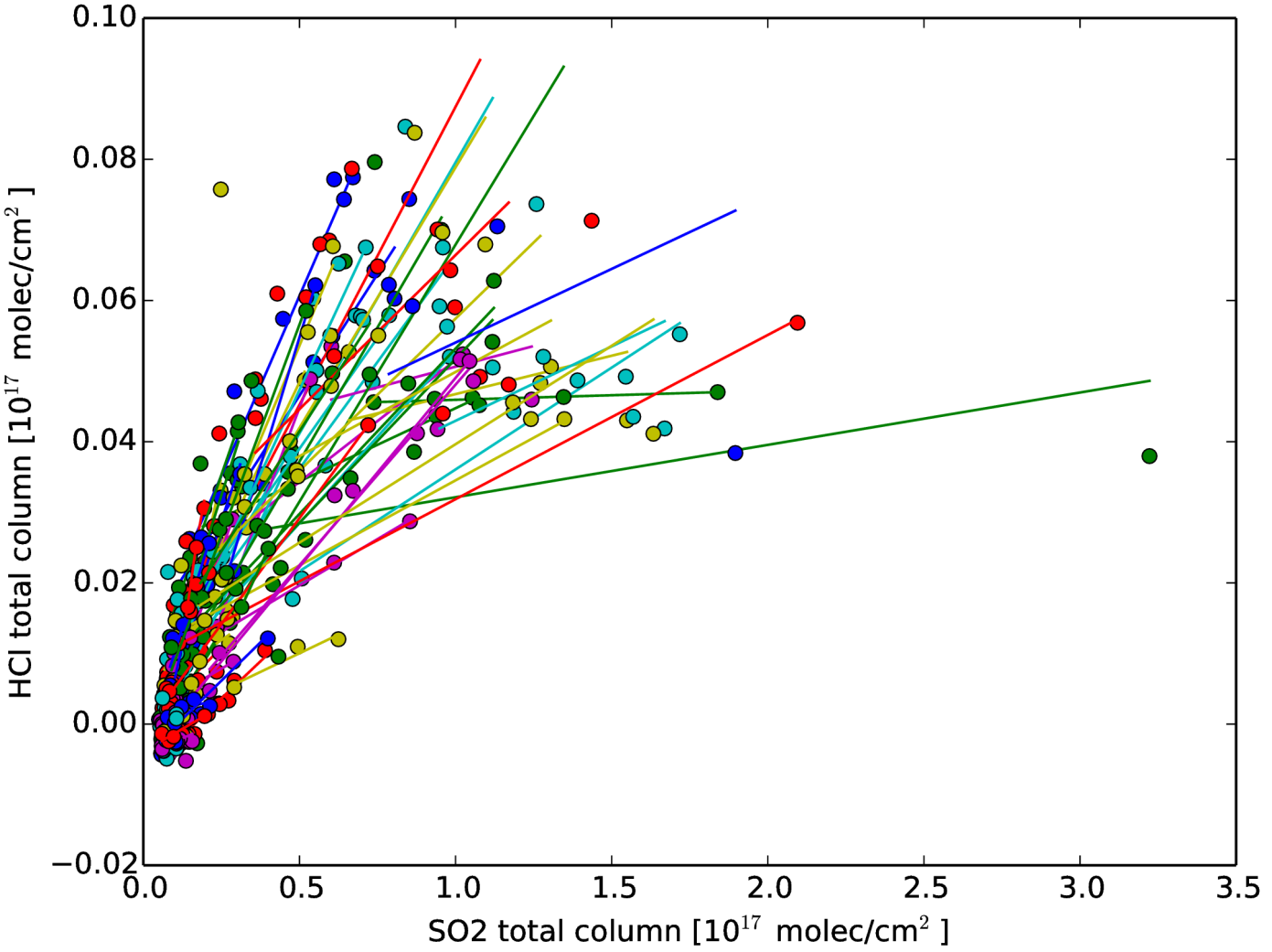

1e16
1.2
1.0
0.8
0.6
0.4
0.2
0.0
HCl total column [molec/cm^2]
Jul 2012
Nov 2012
Mar 2013
Jul 2013
Nov 2013
Mar 2014
Jul 2014
Nov 2014
Mar 2015
time
1e17
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
SO2 total column [molec/cm^2]
Jul 2012
Nov 2012
Mar 2013
Jul 2013
Nov 2013
Mar 2014
Jul 2014
Nov 2014
Mar 2015
time

SO2 y HCl

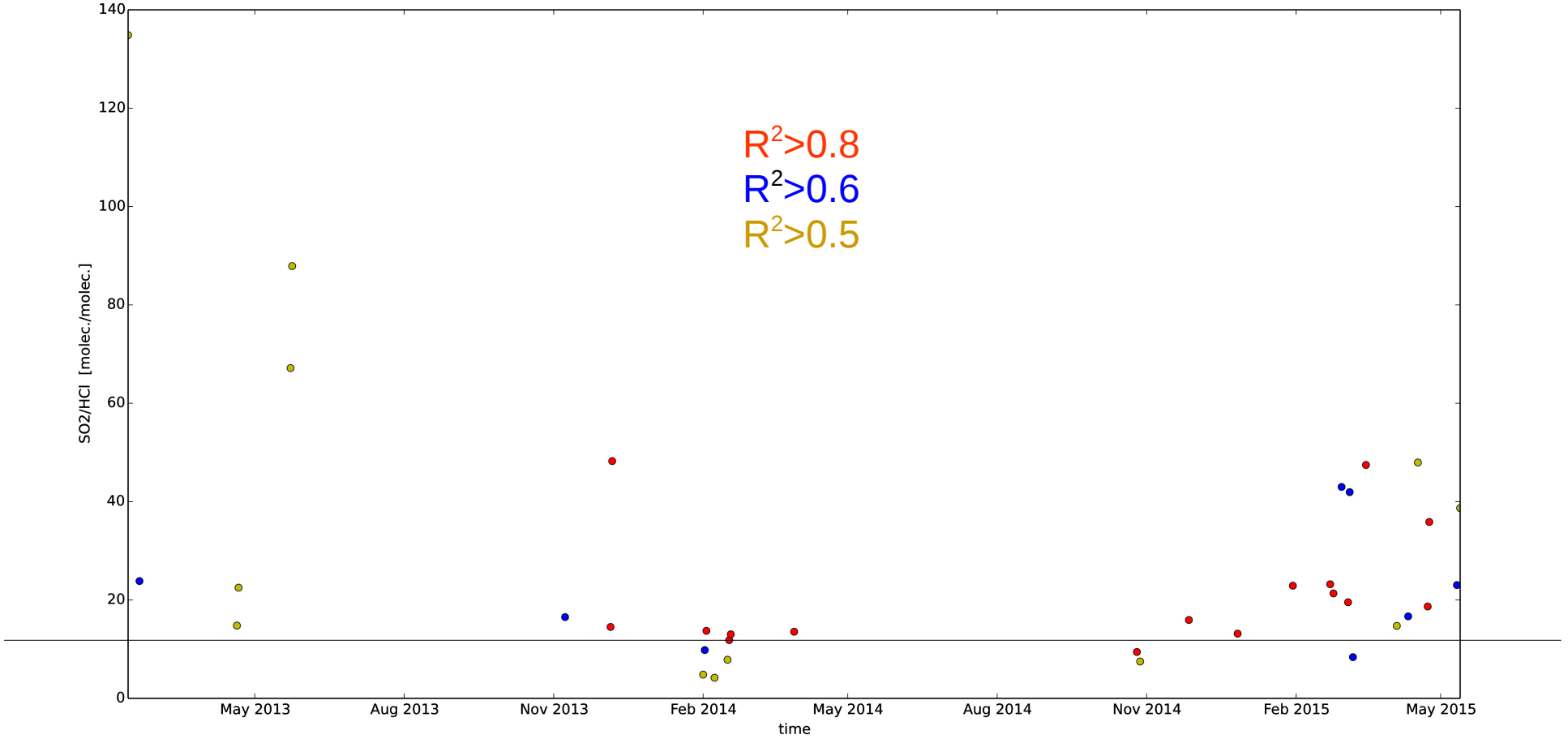

1e16
1.2
1.0
0.8
0.6
0.4
0.2
0.0
HCl total column [molec/cm^2]
HCl
volcanic
stratospheric
Jul 2012
Nov 2012
Mar 2013
Jul 2013
Nov 2013
Mar 2014
Jul 2014
Nov 2014
Mar 2015
time


1e17
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
SO2 total column [molec/cm^2]
SO2
volcanic
background
Jul 2012
Nov 2012
Mar 2013
Jul 2013
Nov 2013
Mar 2014
Jul 2014
Nov 2014
Mar 2015
time

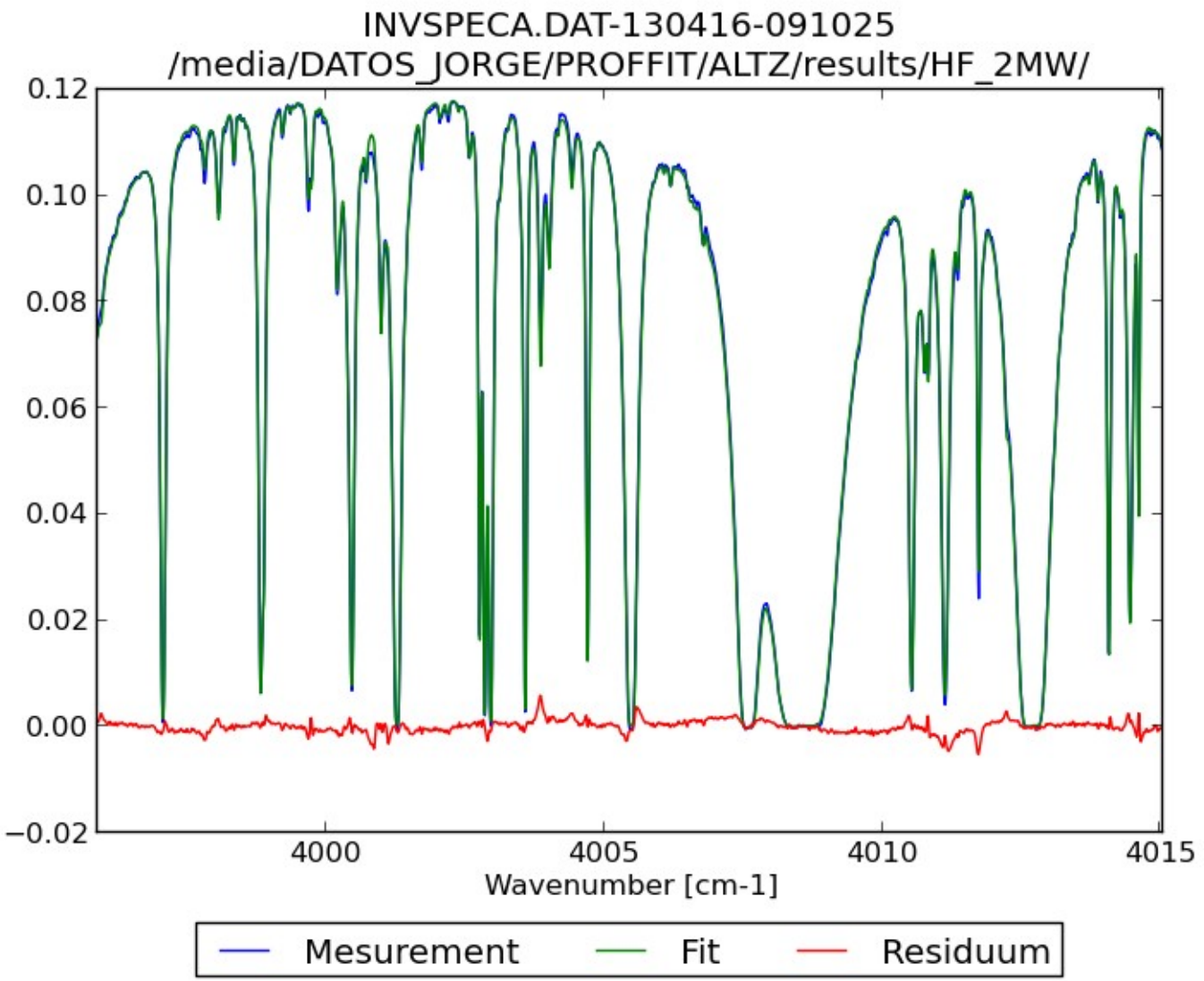
correlation



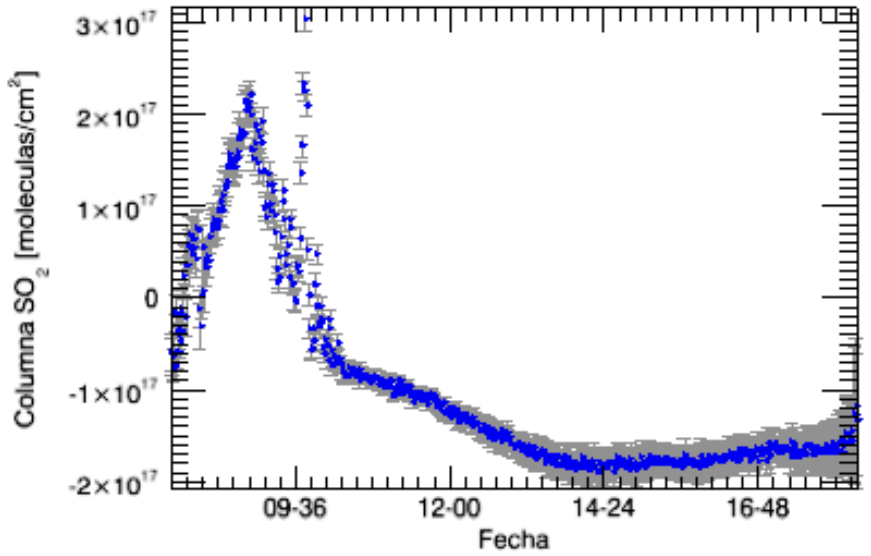
SO2/HCl


R^2>0.8
R^2>0.6
R^2>0.5
SO2/HCl [molec./molec.]
0
20
40
60
80
100
120
140
May 2013
Aug 2013
Nov 2013
Feb 2014
May 2014
Aug 2014
Nov 2014
Feb 2015
May 2015
time

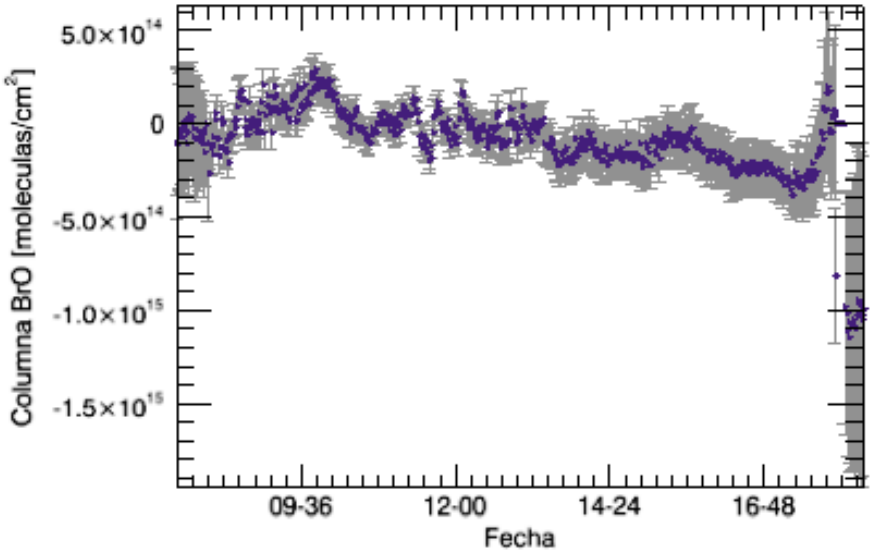
HF-Spectra


INVSPECA.DAT-130416-091025
/media/DATOS_JORGE/PROFFIT/ALTZ/results/HF_2MW/
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
4000
4005
4010
4015
Wavenumber [cm-1]
Mesurement
Fit
Residuum

Direct-sun-DOAS measurements 16 April 2013

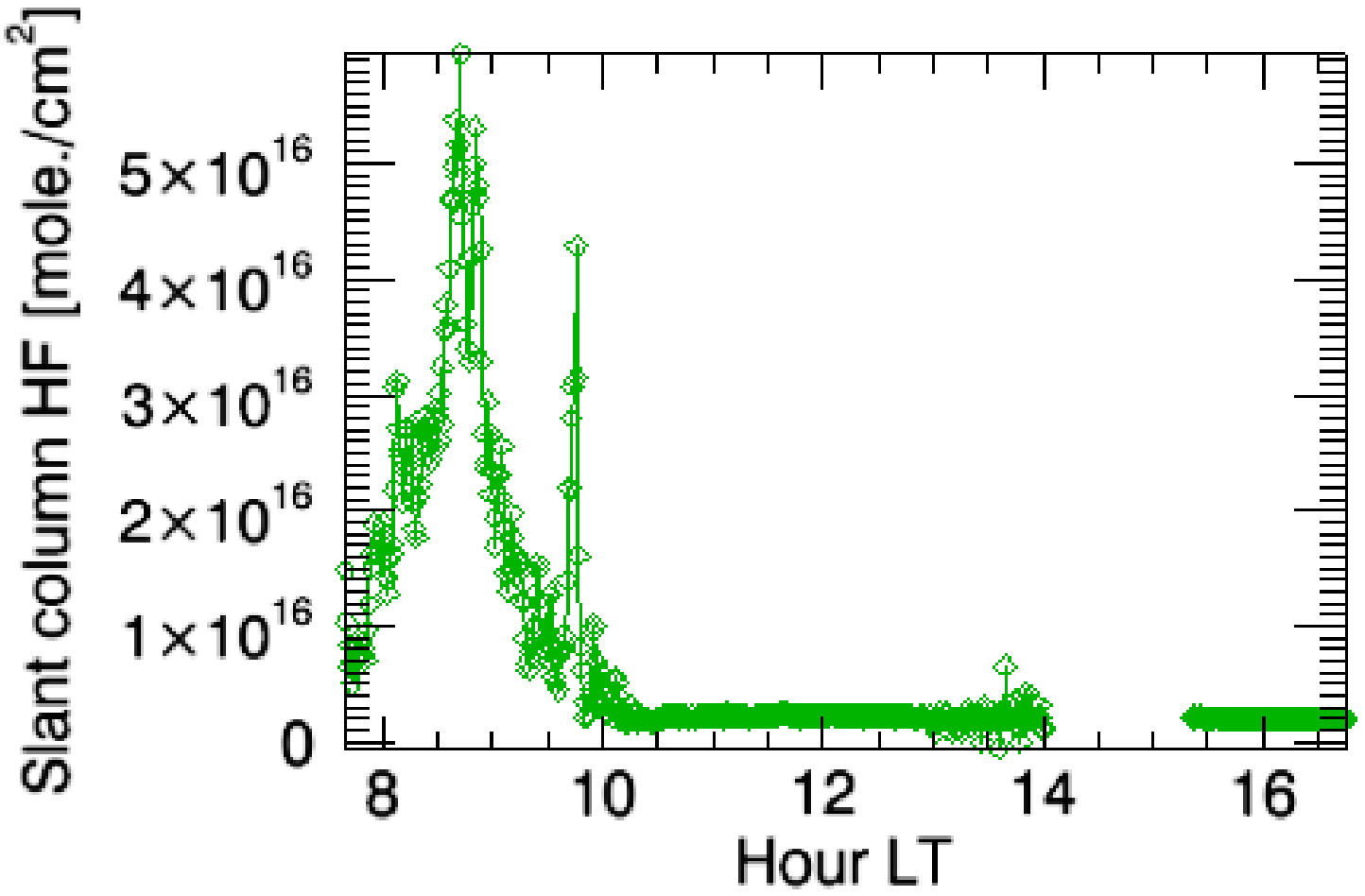


Slant column SO2

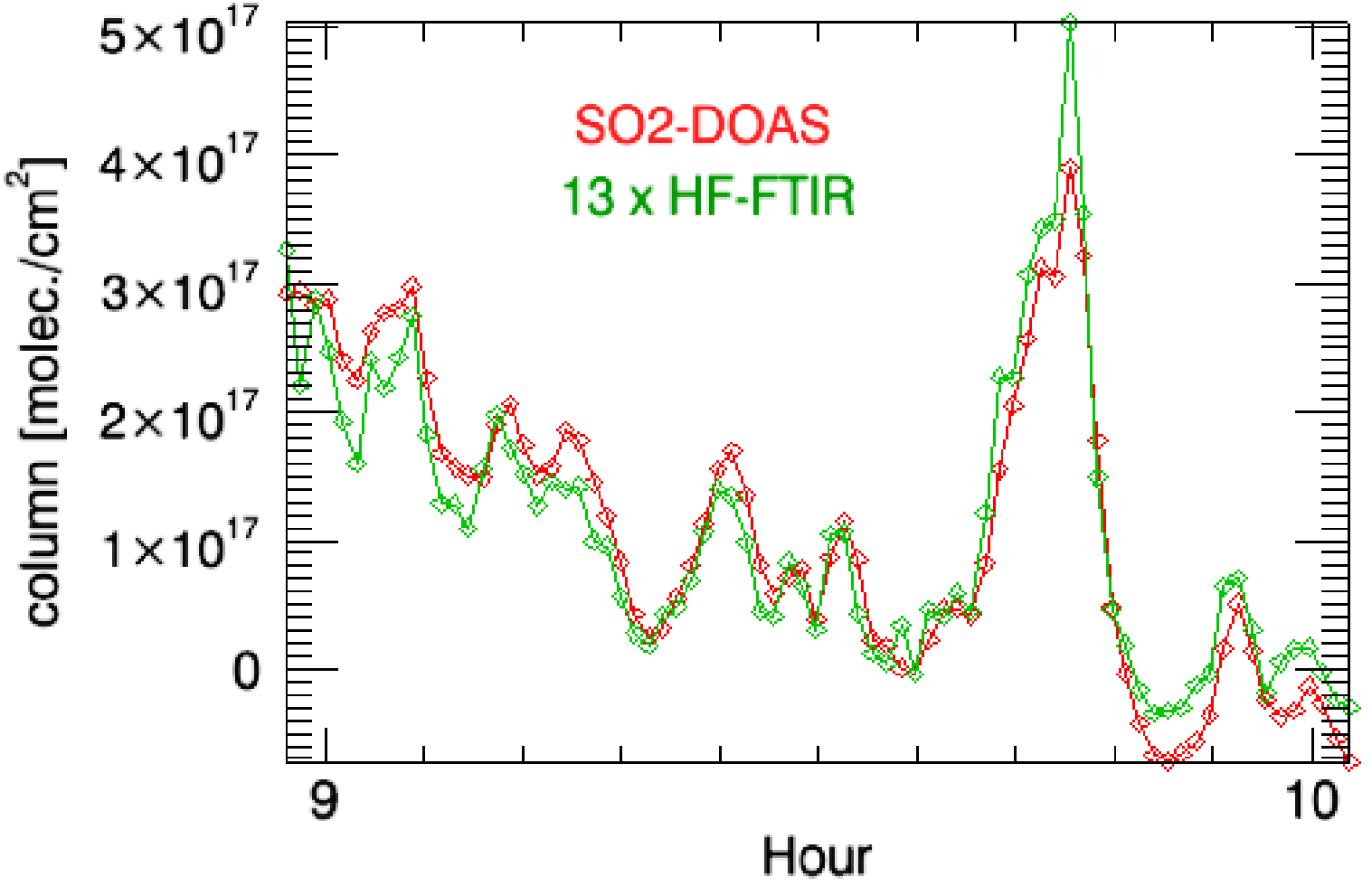


Slant column BrO

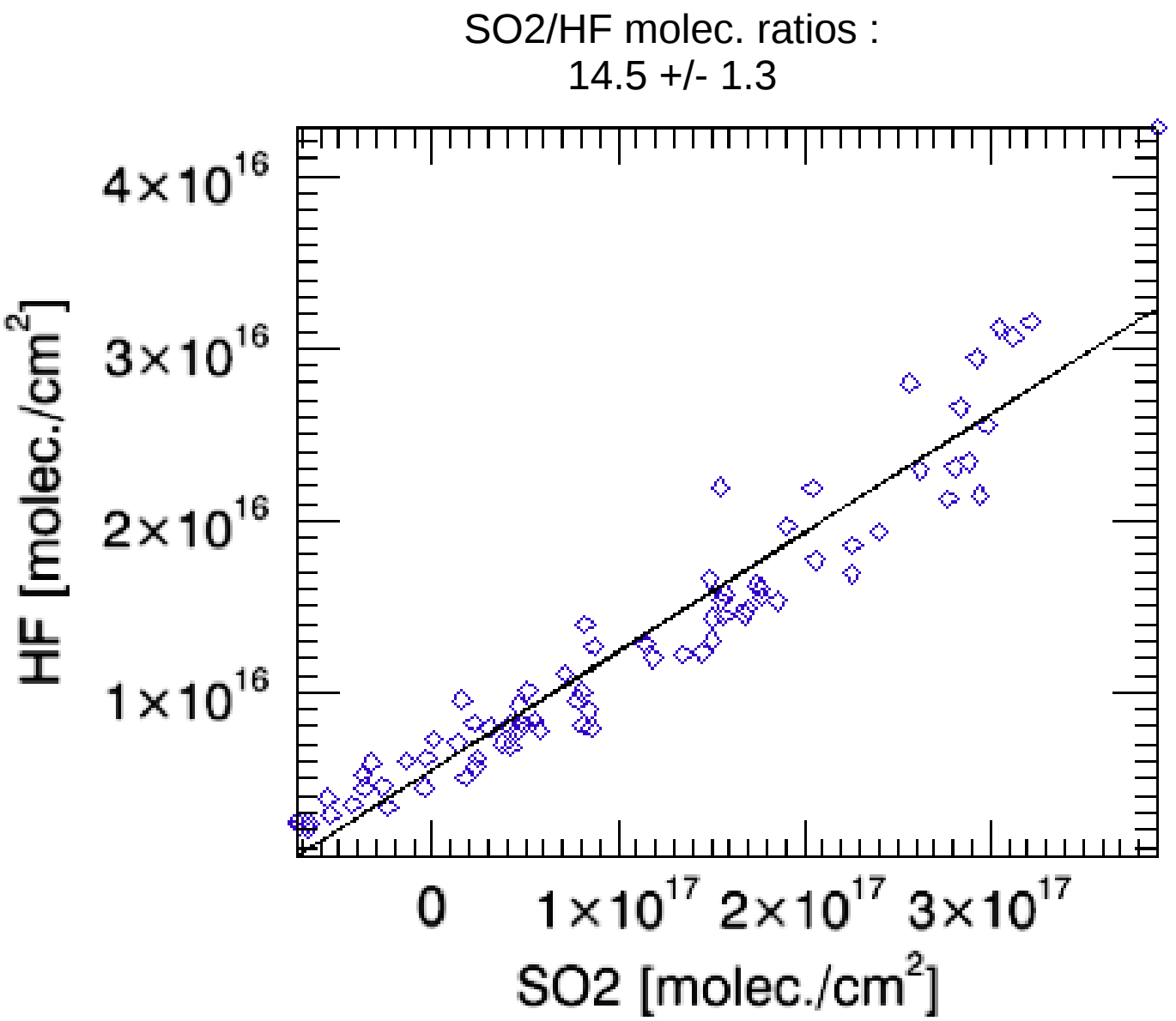
HF
16 April 2013



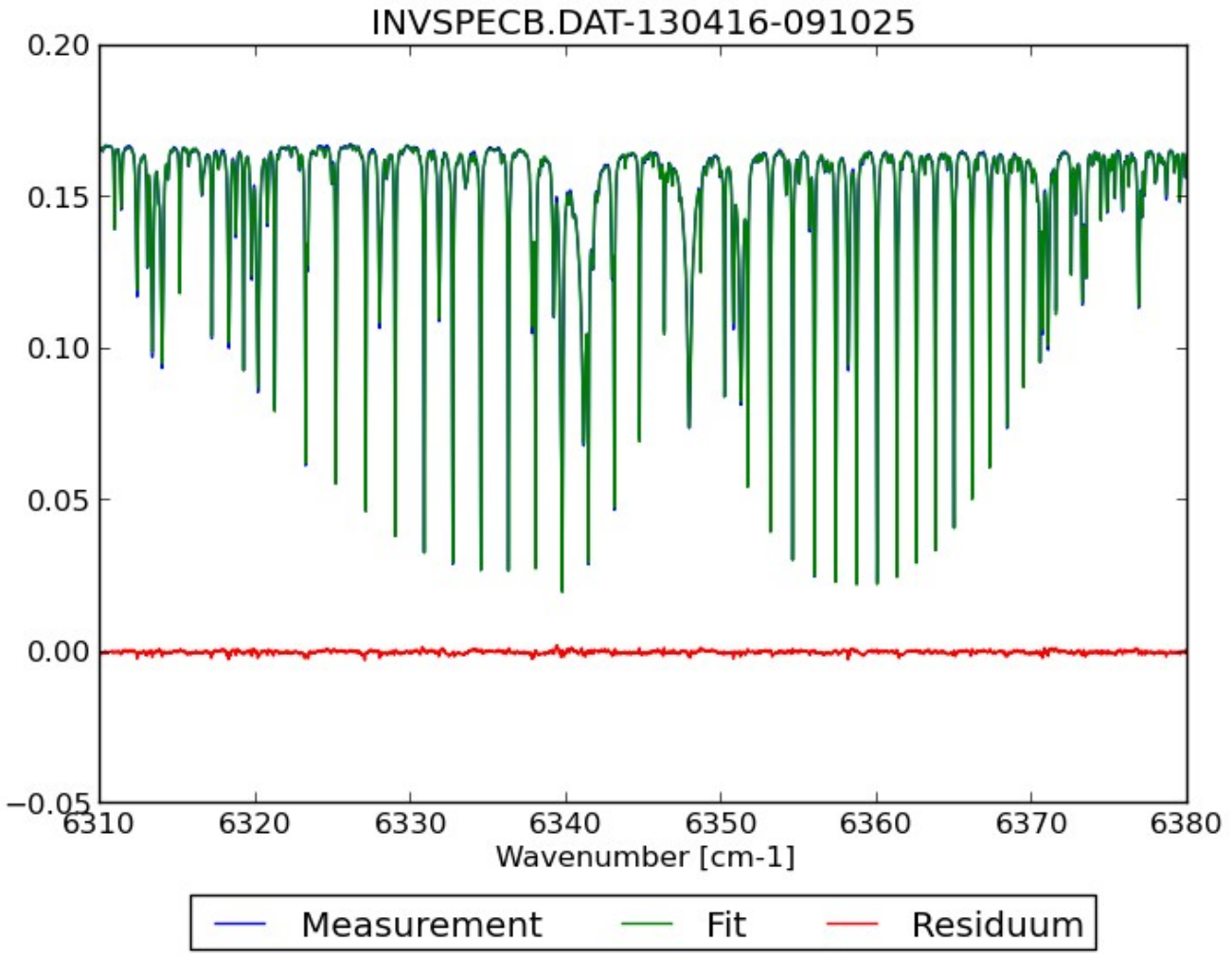
HF/SO2 16 April 2013



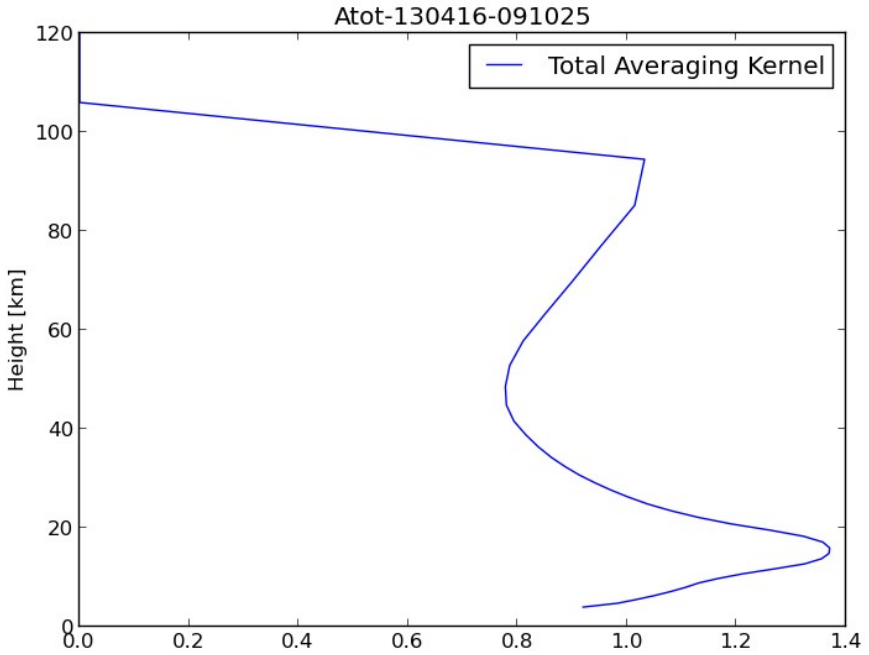
HF/SO2 16 April 2013

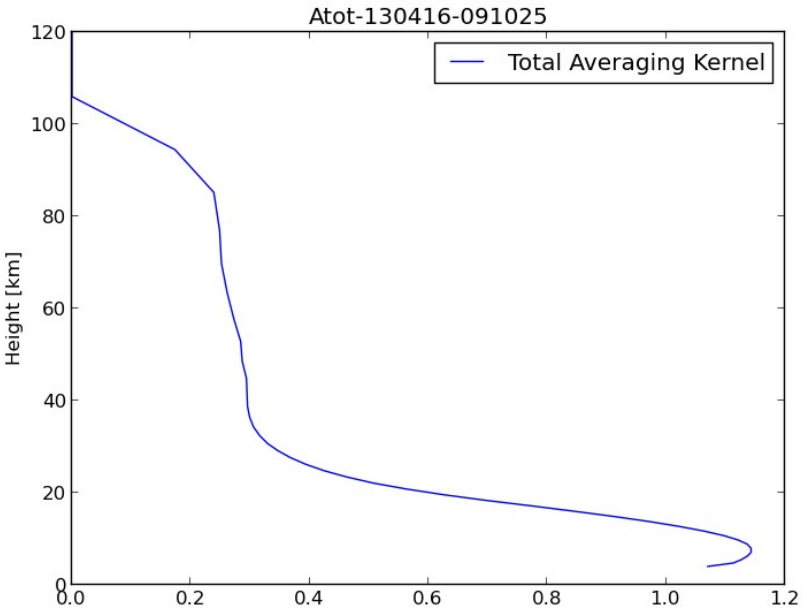


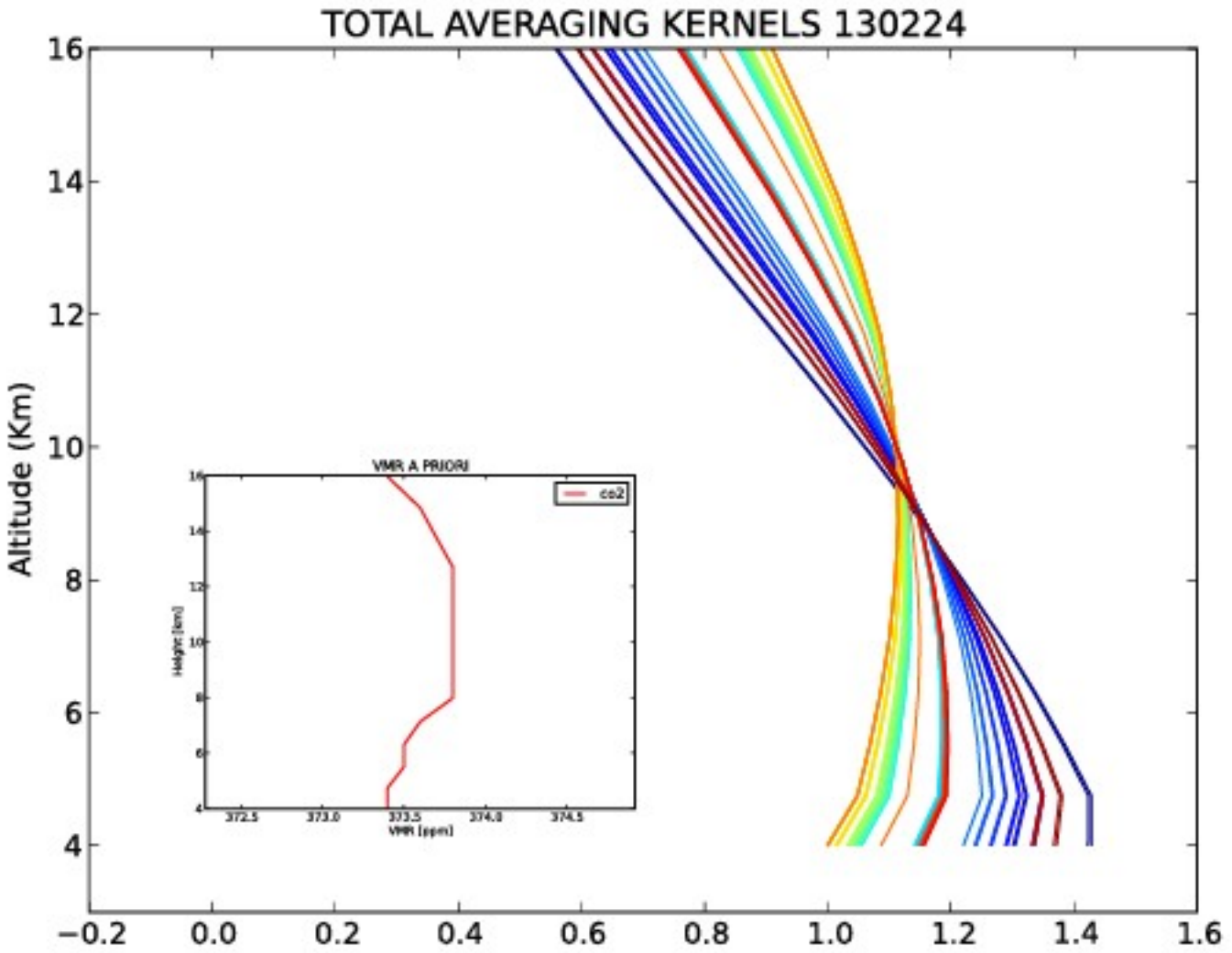
NIR-spectra


INVSPECB.DAT-130416-091025
0.20
0.15
0.10
0.05
0.00
−0.05
6310
6320
6330
6340
6350
6360
6370
6380
Wavenumber [cm-1]
Measurement
Fit
Residuum

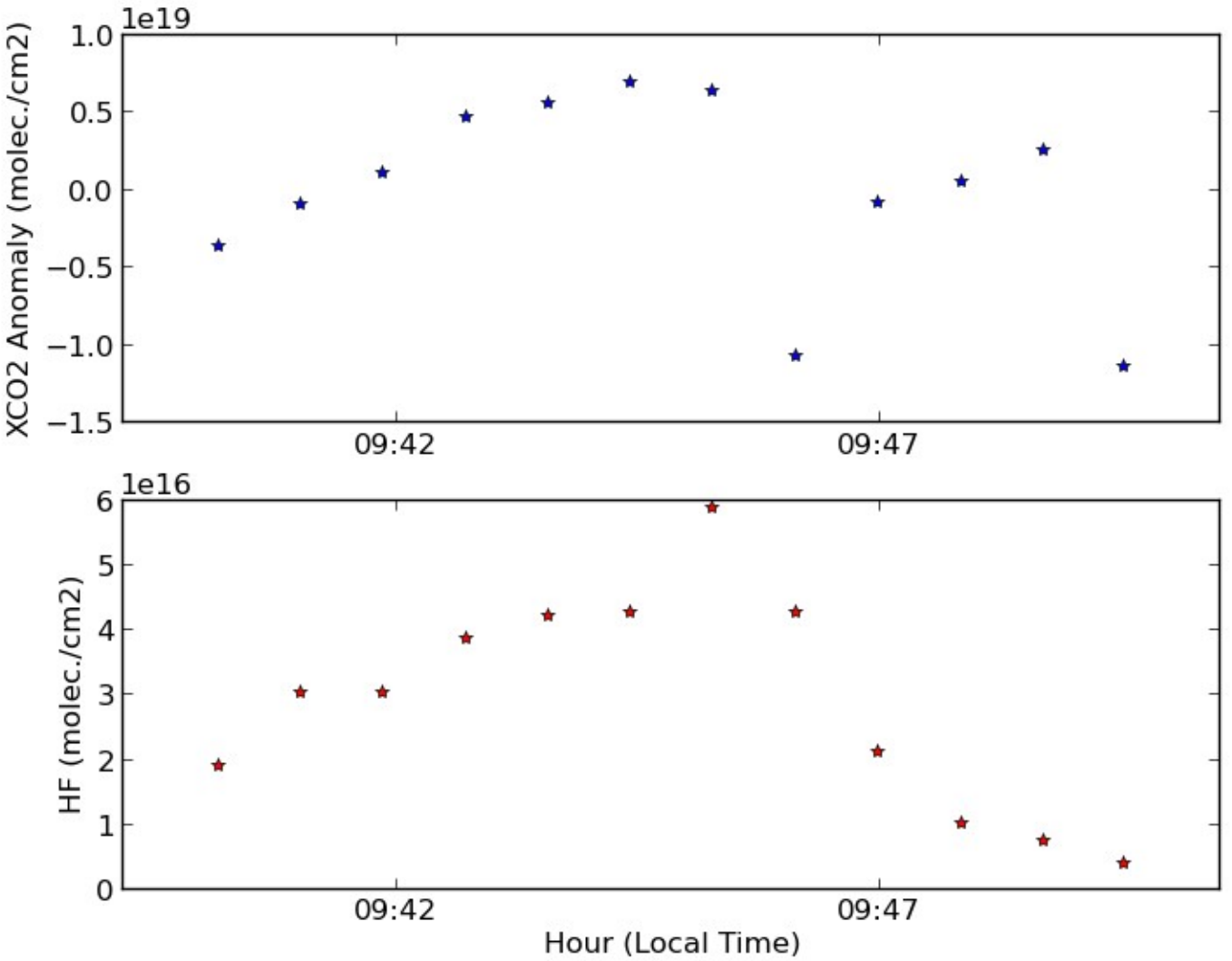
Averaging Kernel HF y CO2



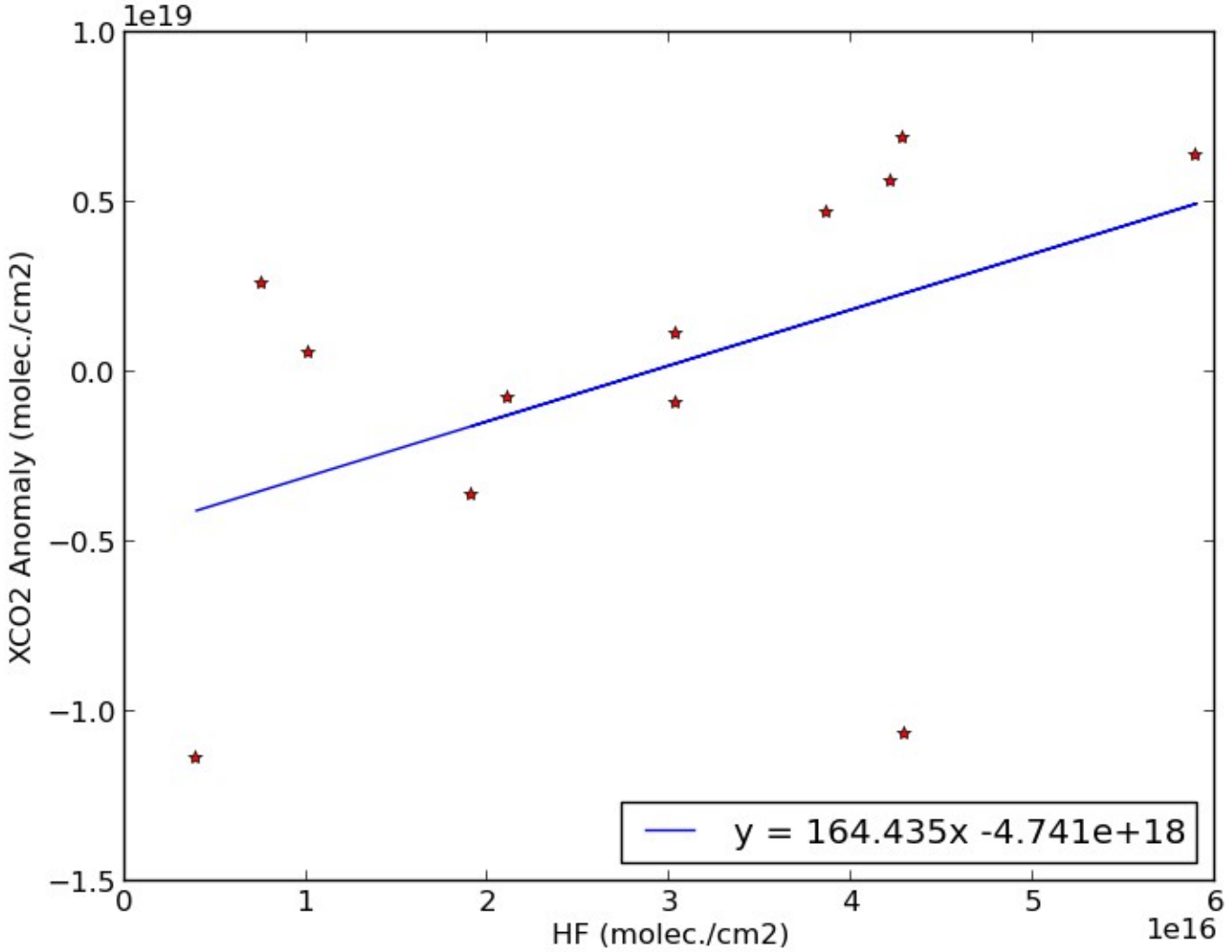



TOTAL AVERAGING KERNELS 130224
Altitude (Km)
16
14
12
10
8
6
4
−0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
VMR A PRIORI
co2
Height [km]
372.5
373.0
373.5
374.0
374.5
VMR [ppm]

CO2


1e19
1.0
0.5
0.0
−0.5
−1.0
−1.5
XCO2 Anomaly (molec./cm2)
09:42
09:47
1e16
6
5
4
3
2
1
0
HF (molec./cm2)
09:42
09:47
Hour (Local Time)

CO2 v HF

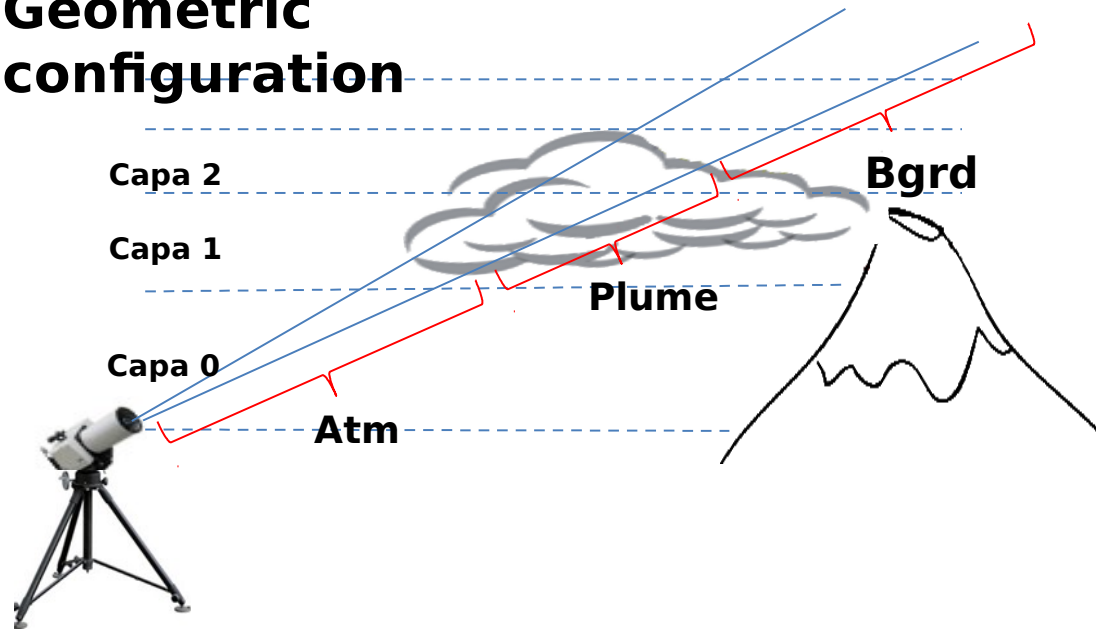

1e19
1.0
0.5
0.0
−0.5
−1.0
−1.5
XCO2 Anomaly (molec./cm2)
0
1
2
3
4
5
6
1e16
HF (molec./cm2)
y = 164.435x -4.741e+18

Thermal emission: Principle

Instrumentation: OPAG 22-Bruker

- Spectral range (MIR, 700-4500 cm-1)
- Spectral resolution : Max. 0.5 cm-1
- Field of view: 7.5 mrad (30 mrad)
- Speed of Acquisition: < 1min

Geometric configuration



Location of measurements: Altzomoni station, 12 km from the crater of Popocatepetl volcano

Thermal emission: Data Process

Plume measurement

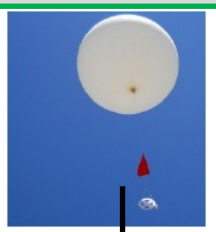
Blackbody measurment

Cell measurements (HCl, N_2O)

HITRAN library

Climatic models (WACCM)

Atmosferic sounding



Calibration *(OPUS, Python)*

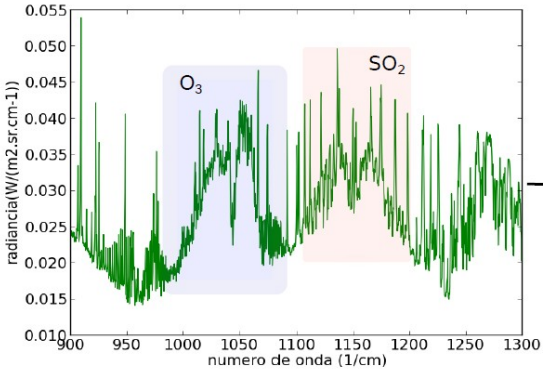
*Line Shape function (**ILS**) (LINEFIT)*

Lines parameters (Hbin code, SFIT4)

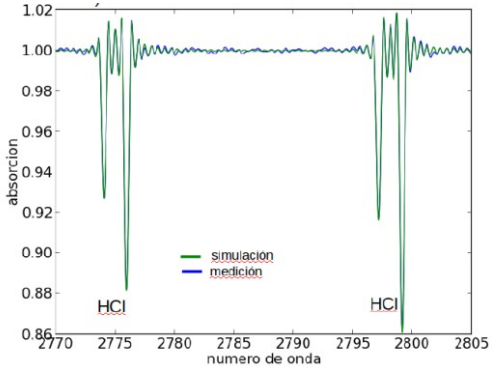
Atmospheric profiles VMR (H_2O, O_3, CO_2, CO, CH_4) (Python, ...)

Atmospheric profiles T, P (gFortran)

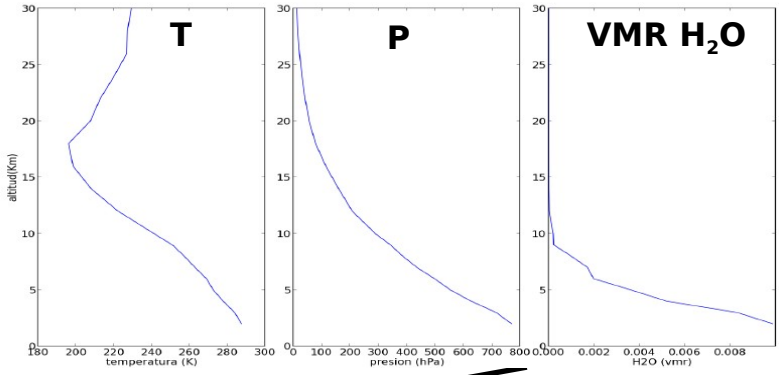
Radiance spectrum



ILS



Atmospheric profiles



Radiance Spectrum

FORWARD MODEL

SFIT 4

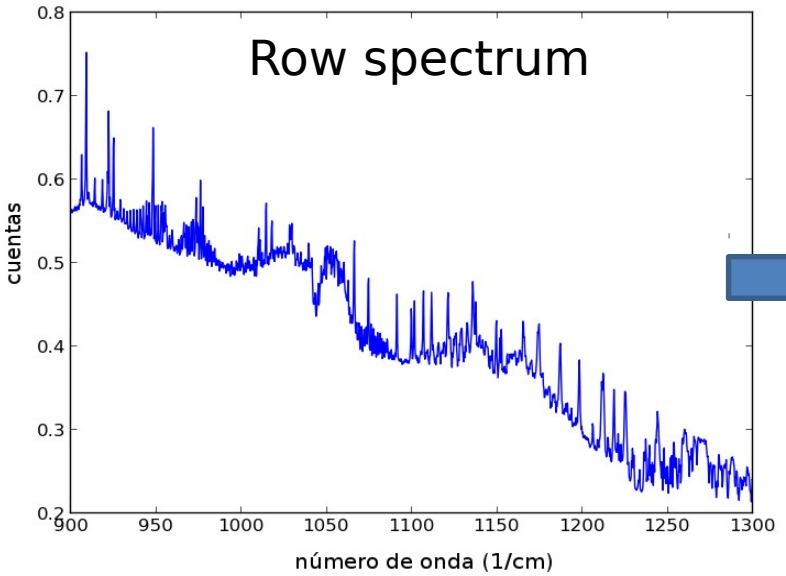
Simulated spectrum

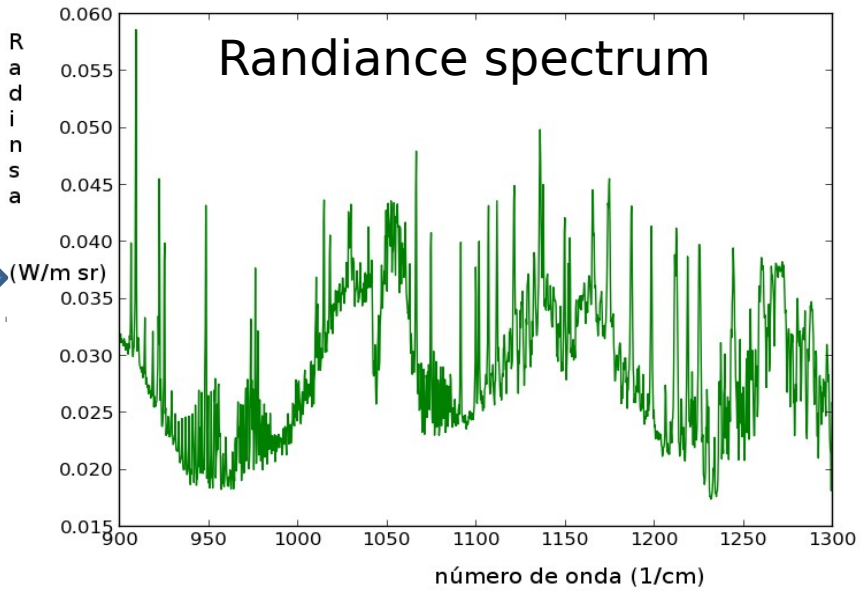
RETRIEVAL MODEL

Quantification of gases

Error diagnostic

Thermal emission: Radiometric calibration





Calibration with power spectra

$$S_{atm}calib = \frac{(S_{atm} - S_{frio})}{(S_{cal} - S_{frio})} \times (bb_{cal} - bb_{frio}) + bb_{frio}$$

$$Ganancia:\ G = \frac{(S_{cal} - S_{frio})}{(bb_{cal} - bb_{frio})}$$

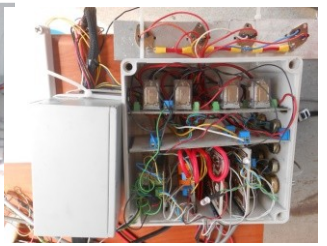
$$Offset:\ O = S_{frio}/G - bb_{frio}$$

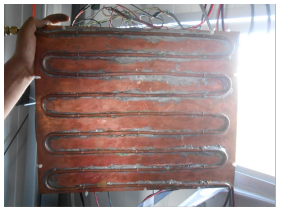
Calibration with complex spectra (Reverbomb et al., 1998)

$$S_{atm}calib = Re[\frac{(S_{atm}.ei^{\varphi atm} - S^{frio}.ei^{\varphi frio})}{(S_{cal}.ei^{\varphi cal} - S^{frio}.ei^{\varphi frio})}] \times (bb_{cal} - bb^{frio}) + bb_{frio}$$

Calibration with complex spectra (2)

$$S_{atm}medido = (G \times S_{atm}calib + O^{ext}).e^{i\varphi ext} + (O^{int}).e^{i\varphi int}$$





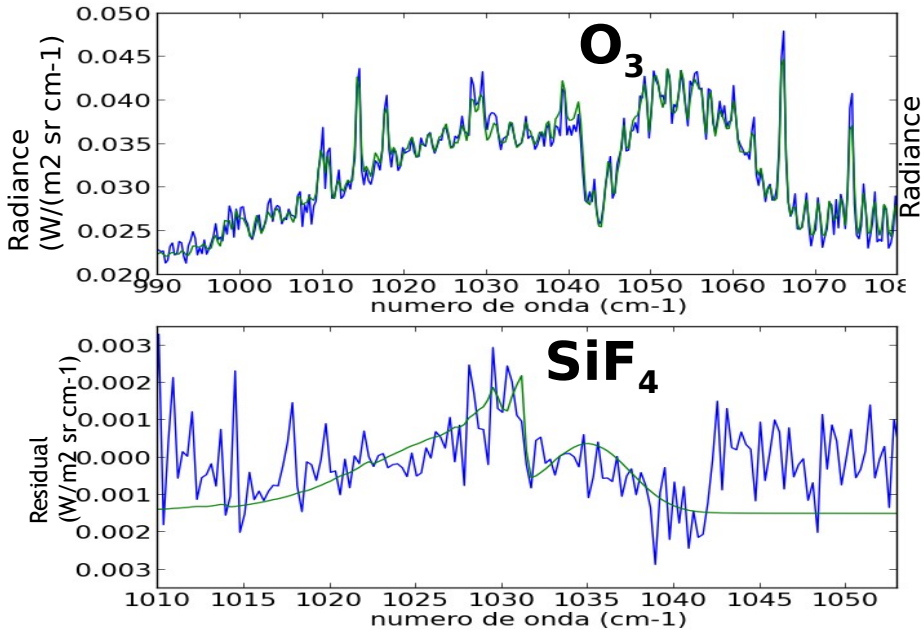
Thermal emission: Preliminar results

2009-05-28

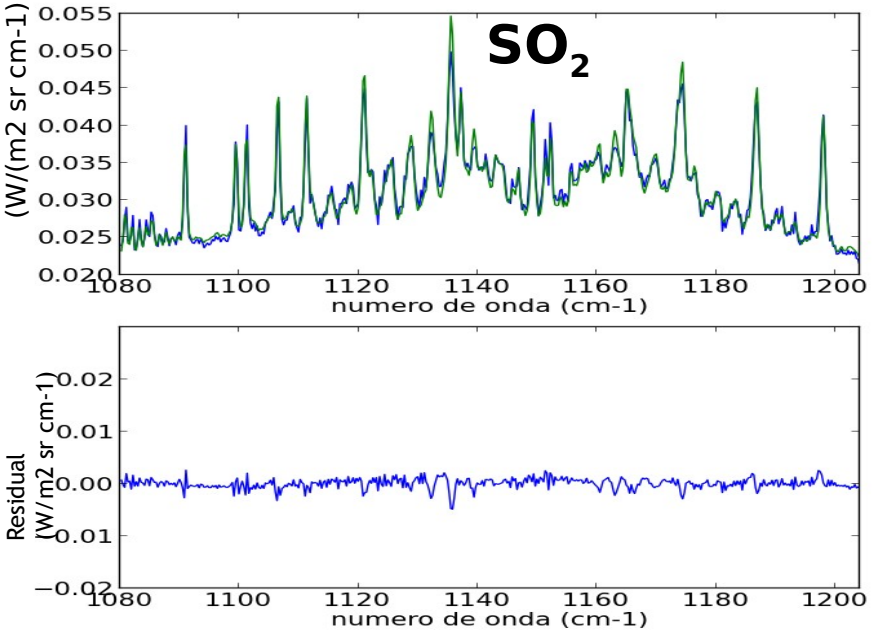
Measured radiance

Simulated spectrum

Total col. O_3: 1.606E+19 mol.cm^{-2}

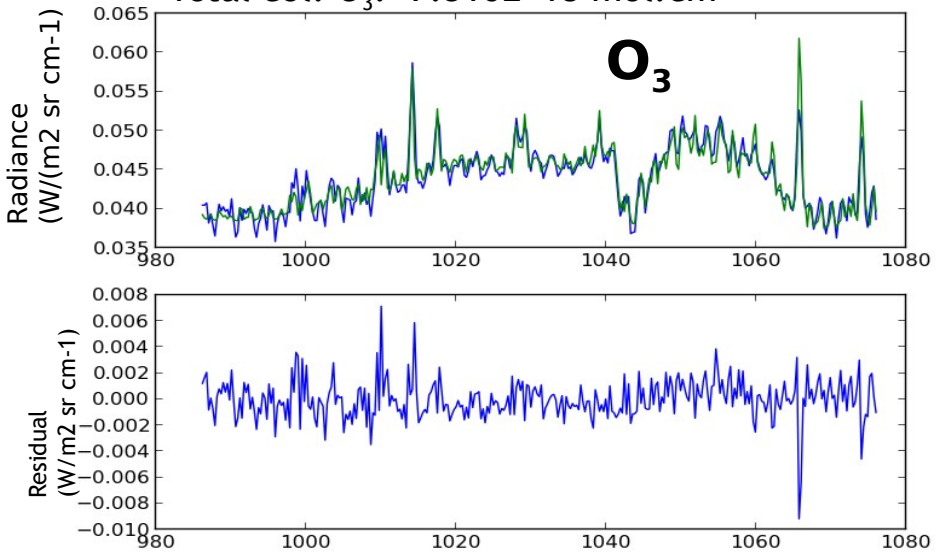


Total col. SO_2: 1.572E+18 mol.cm^{-2}

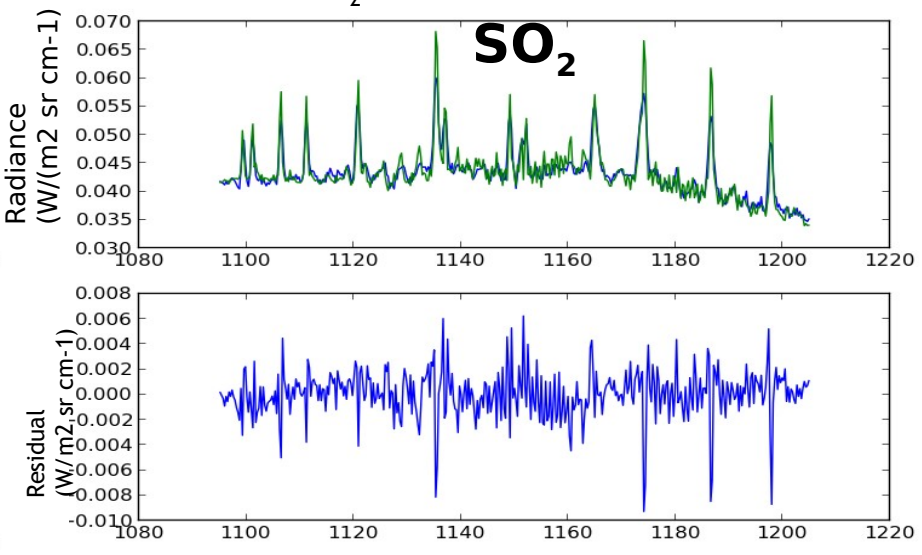


2015-01-28

Total col. O_3: 7.316E+18 mol.cm^{-2}



Total col. SO_2: 5.521E+17 mol.cm^{-2}



Conclusion and Summary:

- Altzomoni is an NDACC site with possibility to measure volcanic plumes
- It is easy to select non volcanic spectra using SO2 as proxy
- A clean timeseries of stratospheric HCl and HF can be produced.
- The volcanic ratio of SO2/HCl is arround 10-20 and is variable.
- Measureing CO2/HF is possible but dificult.
- For usefull CO2 measurement high precision is needed.
- The ratio SO2/CO2 is affected by dispersion.
- Thermal emission measurements are carried out.

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