VALIASI - Validation of IASI trace gas retrievals by GB - FTIR measurements

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Acknowledgments

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EUMETSAT

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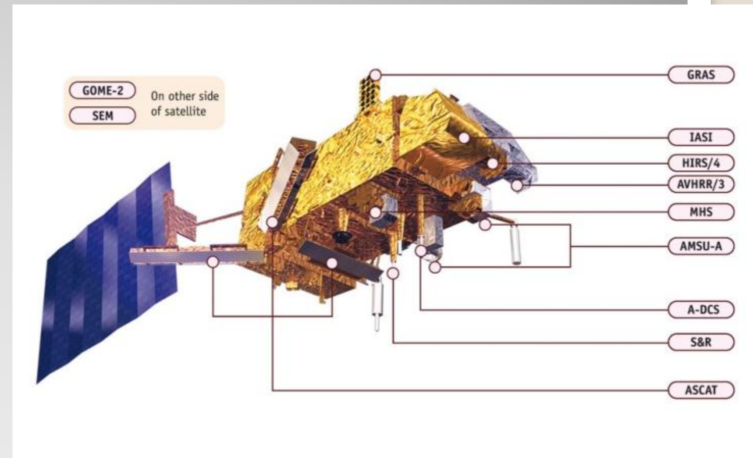
VALIASI

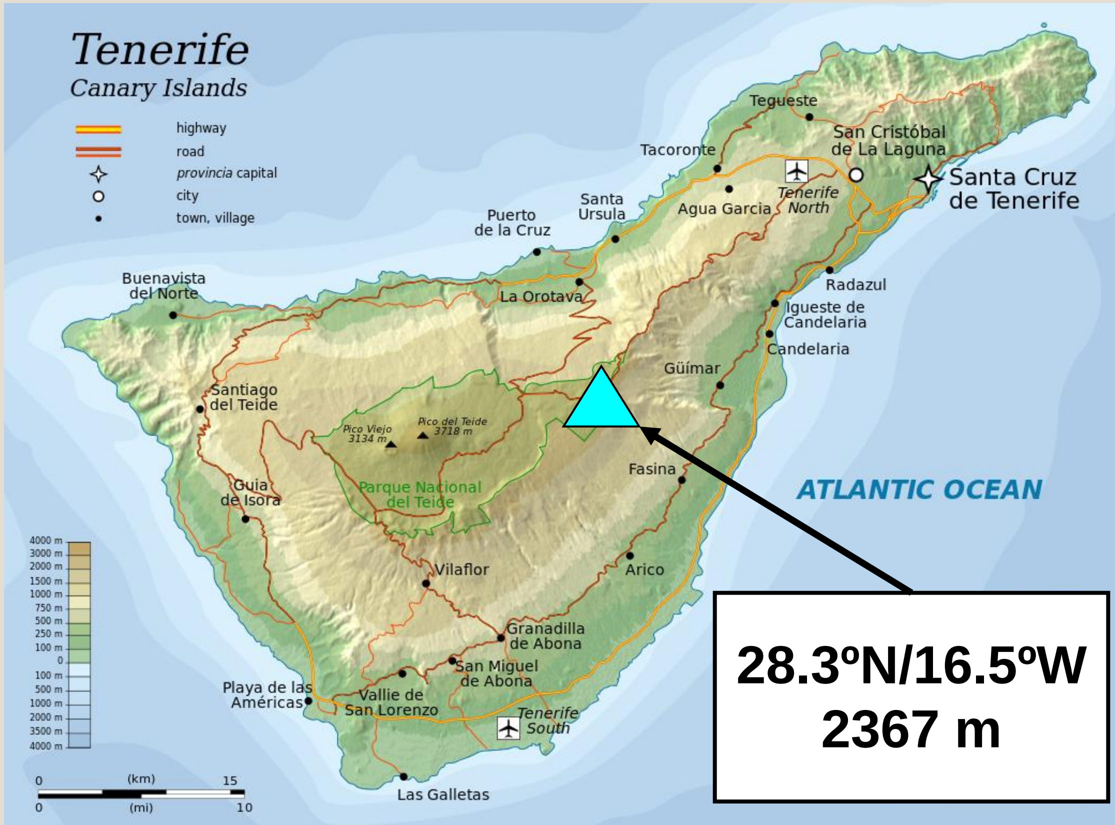
= Validation of IASI level 2 products

O_3 CO_2 H_2O

N_2O CH_4 CO T



Comprehensive, longterm validation
Main reference: GB-FTIR
Project start: Sep. 2013, Izana, TC from IASI-A
Later: IASI-B, Karlsruhe, Kiruna, T-profiles

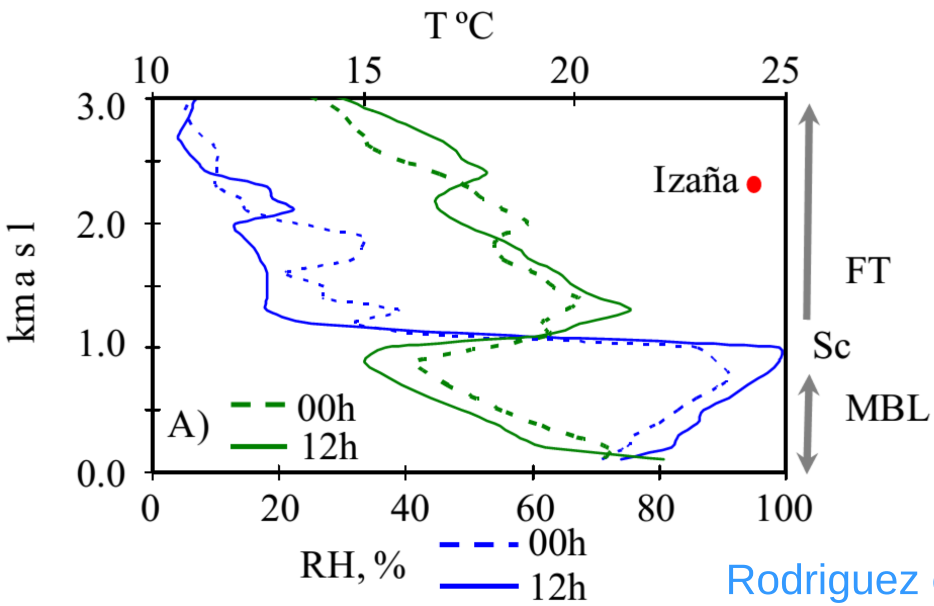


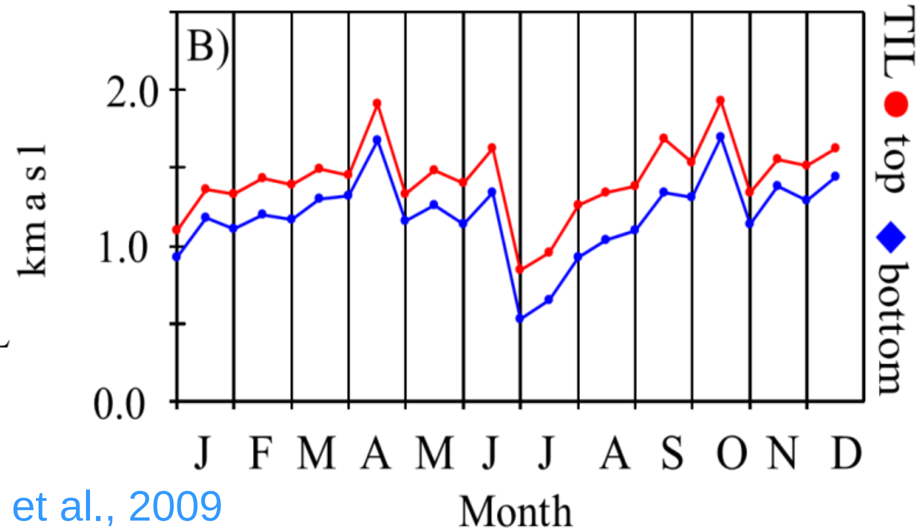
Since 1916 (since 1984: BAPMoN, 1989: GAW)
Brewer, in situ GC, LIDAR, GPS, Sondes (since 1992)
GAW / NDACC / TCCON / AERONET / BSRN
FTIR since 1999, in cooperation with KIT-IMK

Izana Atmospheric Observatory (IZO)

Agencia Estatal de Meteorología

Inversion layer





Rodriguez et al., 2009

Outline

1. VALIASI
2. IZO, GB-FTIR, further Measurements at IZO
3. IASI, comparison to FTIR
4. Molecules, natural variability
5. Collocation
6. First Validation results
7. Annual cycle
8. Summary

Measurements, main building, Measurement-Tower, vicinity











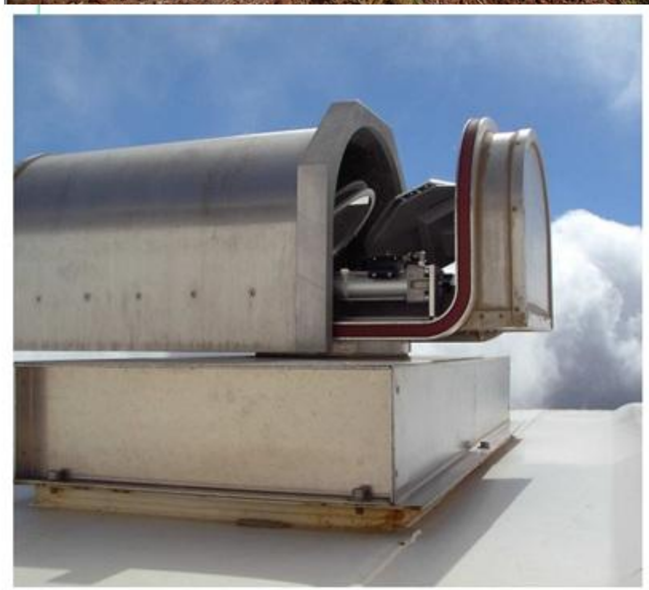

Garcia et al., 2012

IZAÑA Observatory (and vicinity): measurements relevant for VALIASI

- GPS: H_2O total column
  (ERGNSS network: IARC, and four additional sites (three Tenerife and one La Palma)
- ECC sondes: O_3-, Hr-, T-, p-profile, u,v
  1/ week (Wednesday)
  2010: simultaneous launches south and north of the Izaña Observatory → spatial inhomogeneity
- Radio sondes: p-, T-, Hr-profile, windspeed and direction
  2/day, 11:00 and 23:00
- Brewer: O_3 total column, calibration center for Europe
- GAW In Situ CO, CH_4, N_2O Gas chromatography, CO_2 IR
  (July 2011: IZO + Teide Observatory and the Roque de los Muchachos Observatory, La Palma,
  Summer 2012: Flight campaigns → vertical profile)

+ FTIR : H_2O, O_3, CO_2, CH_4, N_2O, CO, T

GB FTIR at Izana Observatory



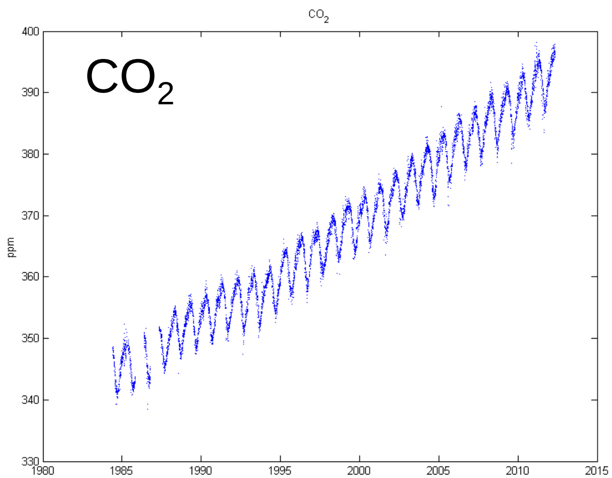
vmr profiles of: O_3, CO, CH_4, N_2O, H_2O, CO_2,T
Approx. 120 days of observation per year, measurements only for cloud-free conditions
Since 1999 : Bruker IFS 120 M
Since 2005 : 120/125 HR
Validated by Brewer, O_3 Sondes, GAW
Comprehensive error analysis
High precision

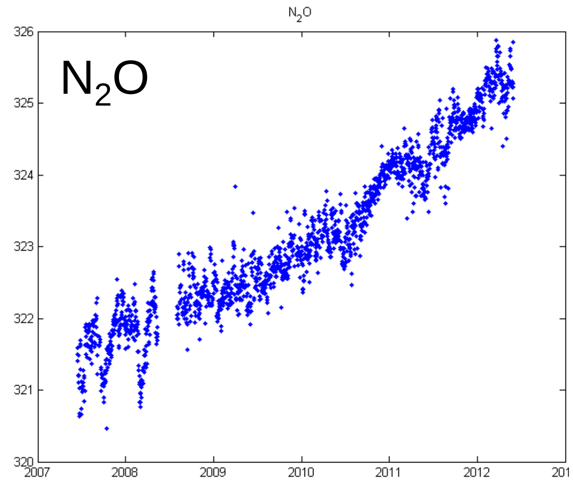
GB FTIR Retrievals

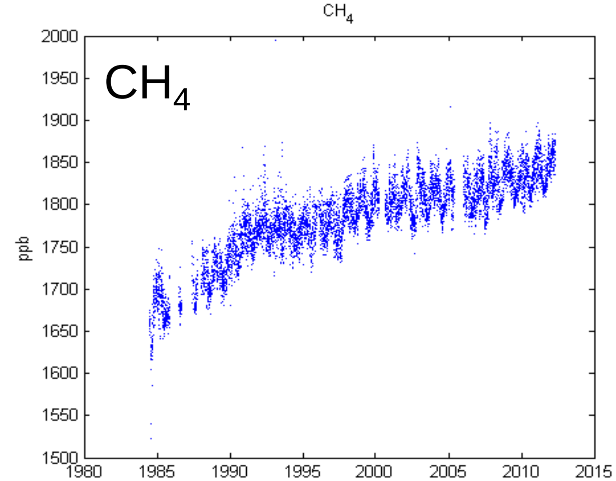
	Projects	References	Microwindows	typ. # DOF	Precision exper. (theor.)
CO_2	TCCON	Dohe et al., 2012	~ 5900, 6000 cm^{-1}	-	Correlation of 94% to in-situ
CO	NDACC	Velazco et al. (2007)	~ 2050, 2150 cm^{-1}	2	(<5%)
O_3	NDACC	Schneider et al., 2008, Garcia et al., 2012, 2013	~ 1000 cm^{-1}	4	0.4-0.7%; / (~1DU, 0.6%)
CH_4	NDACC	Sepulveda et al., 2012, 2013	~ 2600,2800 2900 cm^{-1}	2.5	0.97% / (0.9 %)
H_2O	NDACC MUSICA	Schneider et al., 2010, 2012	~ 2600 - 3000 cm^{-1}	3-4	Total column: 1% profiles: ~15% (<1%)
N_2O	NDACC		~ 2500 cm^{-1}	2.5	(~1%)

in situ GAW

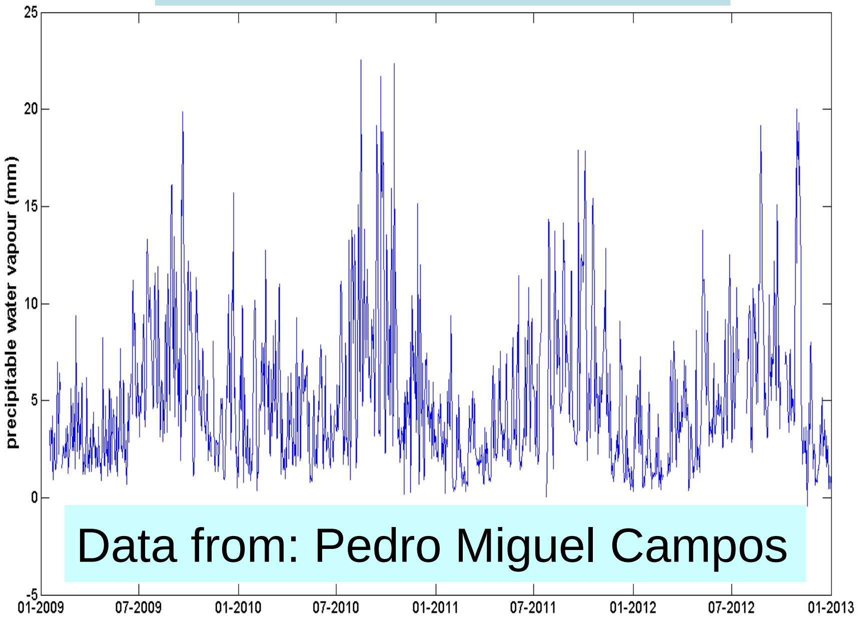
Data from: Angel Gomez Pelaez





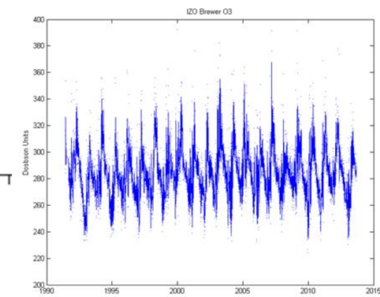


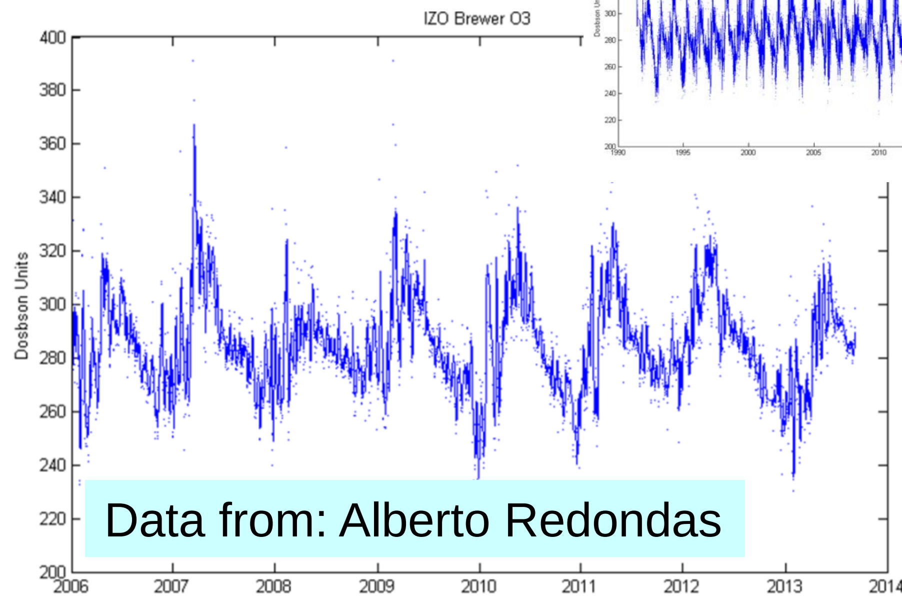
GPS H_2O prec.



Data from: Pedro Miguel Campos

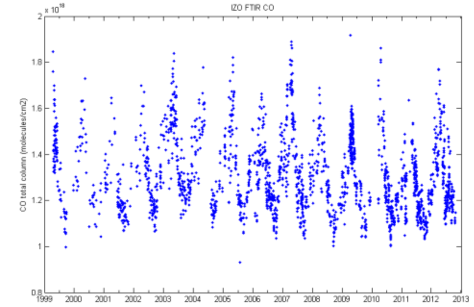
Brewer O_3 total column





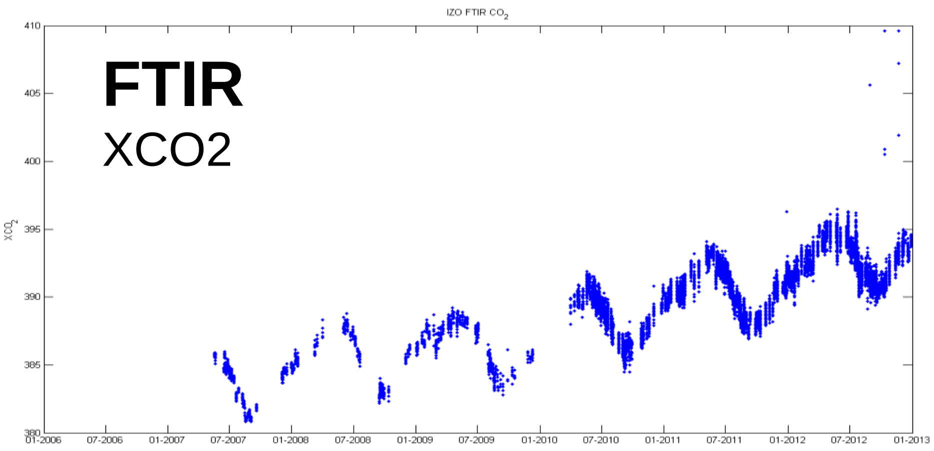
Data from: Alberto Redondas

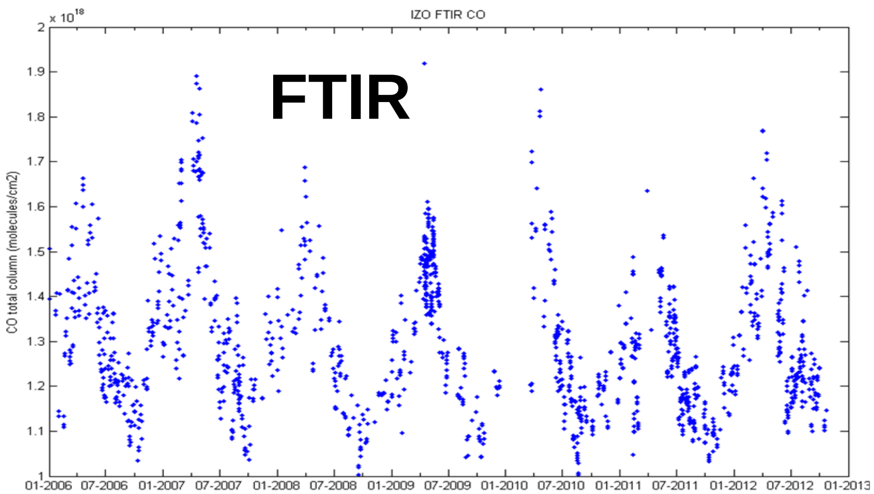
FTIR – in situ GAW

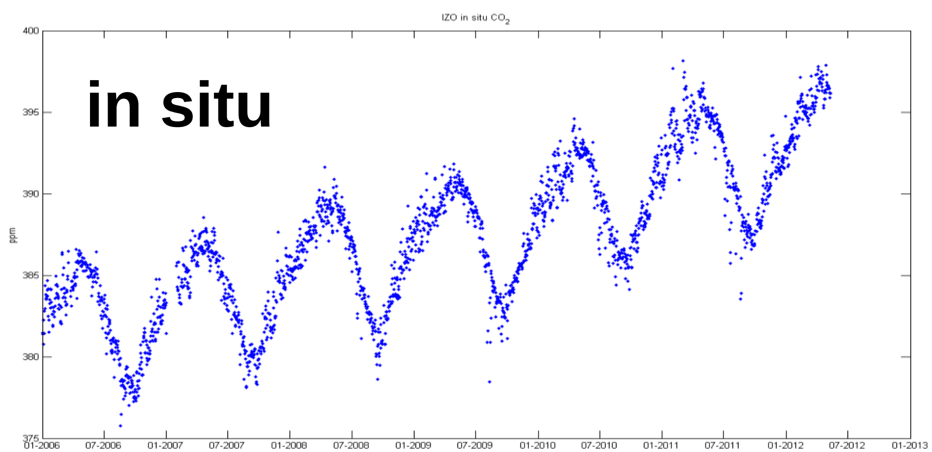


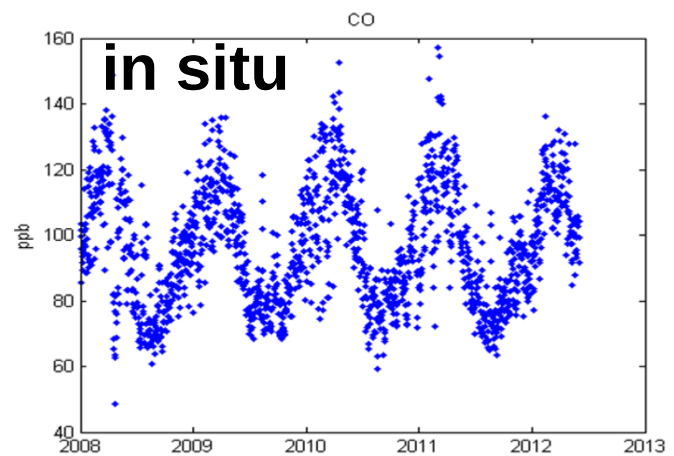
CO_2

CO

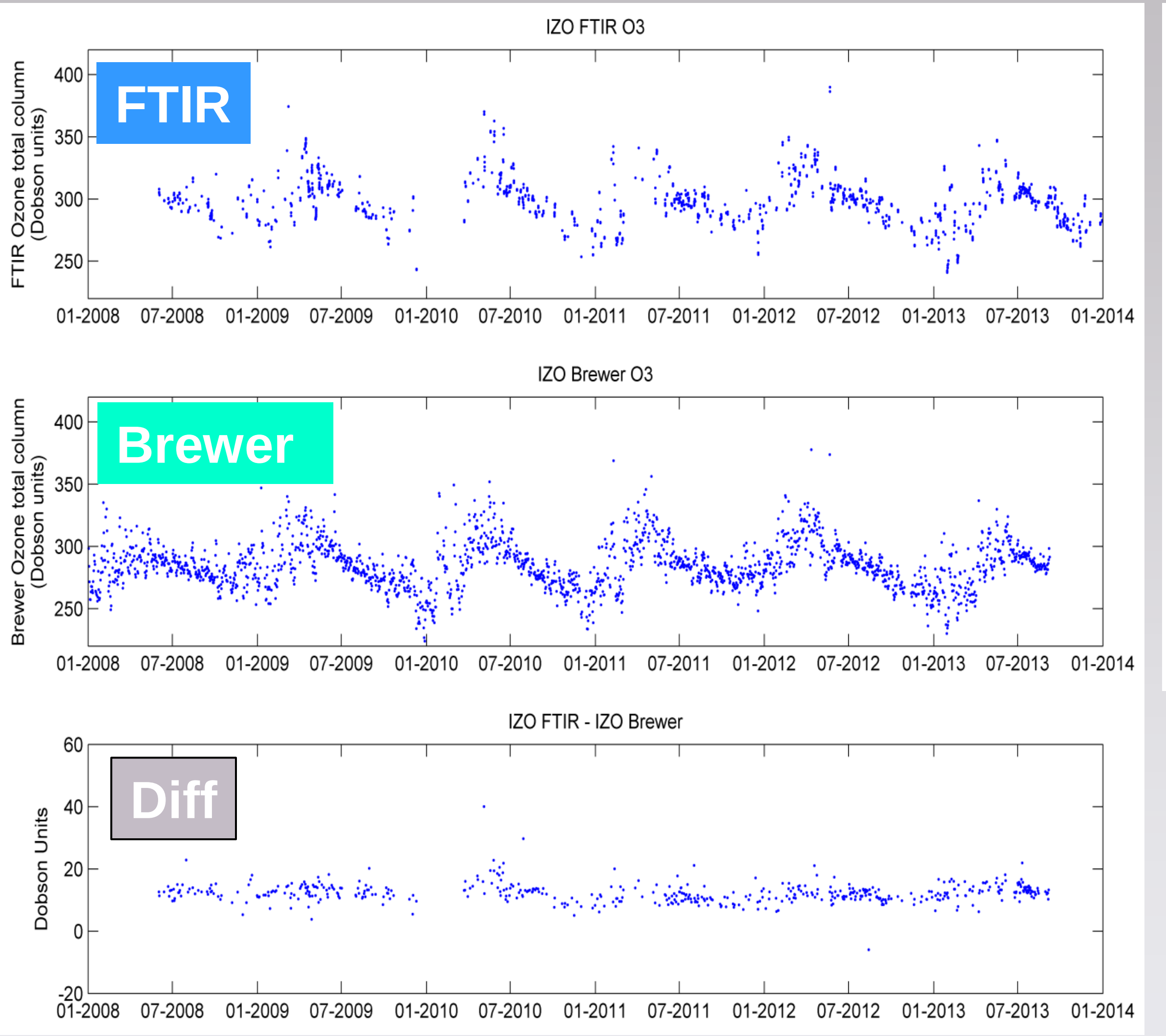


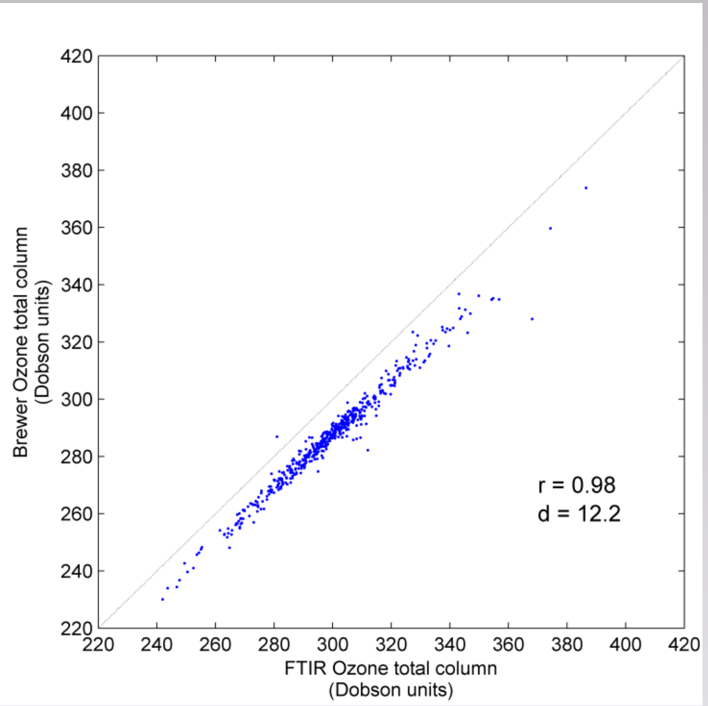






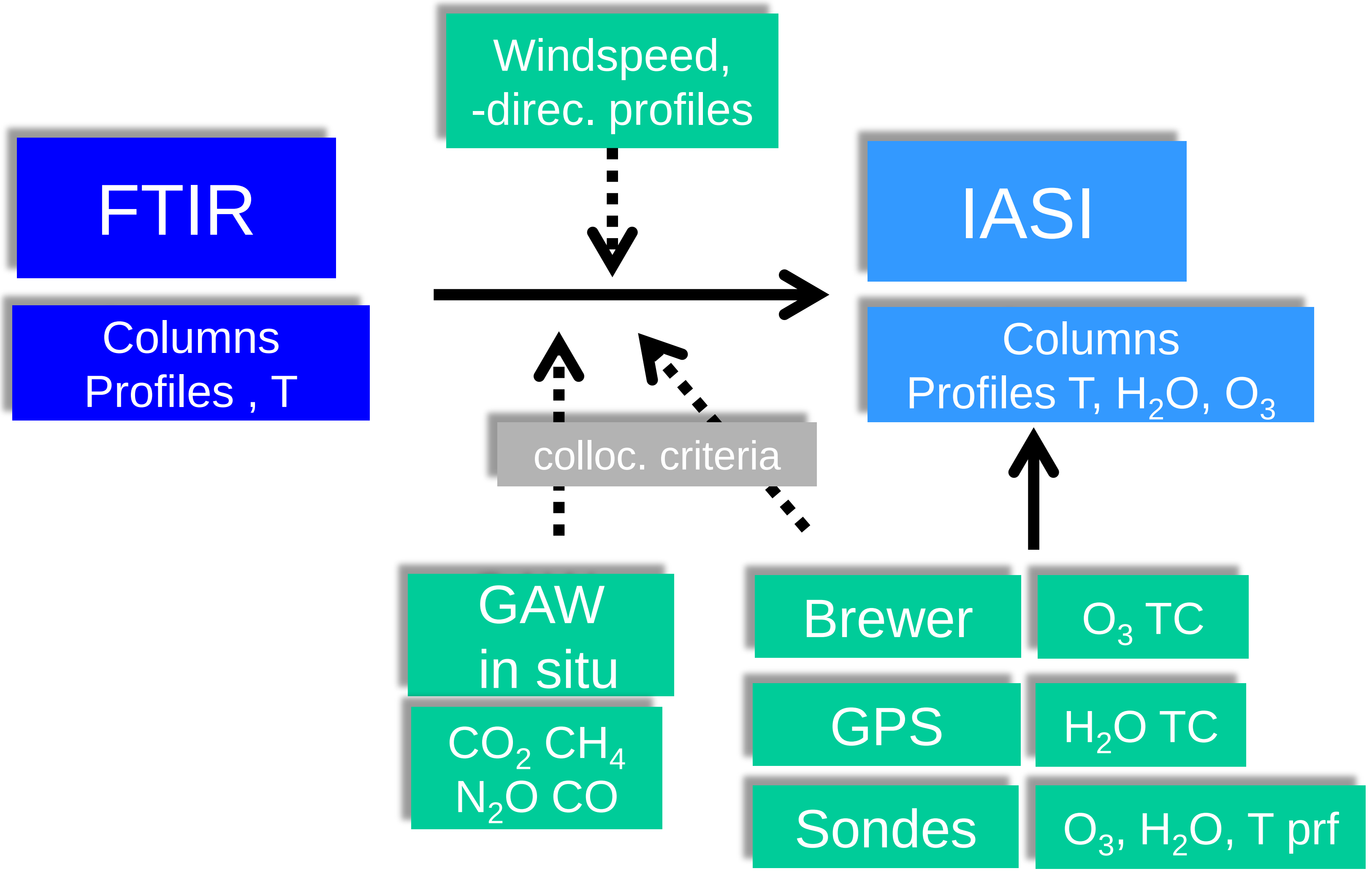
O_3 FTIR - Brewer

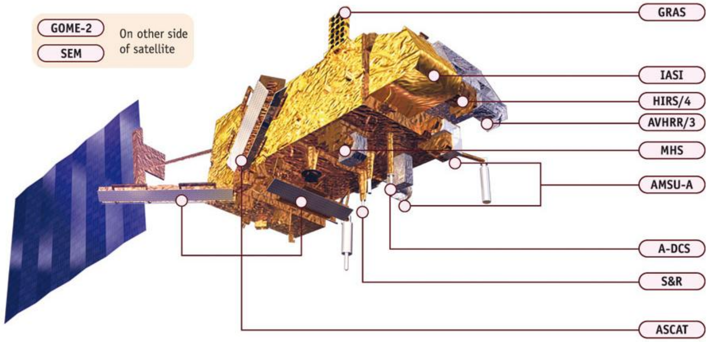




Abs. difference within uncertainty of spectro-scopic data (UV/IR)
Precision for Brewer and FTIR: ~1 DU

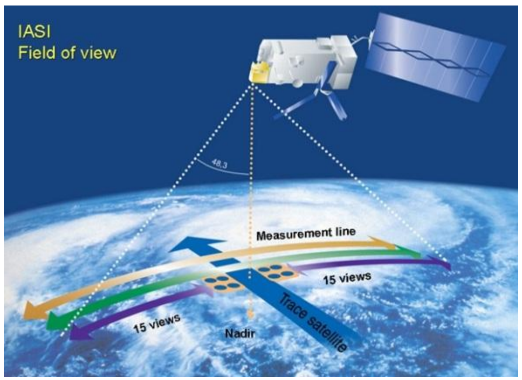
Datasets for IASI validation

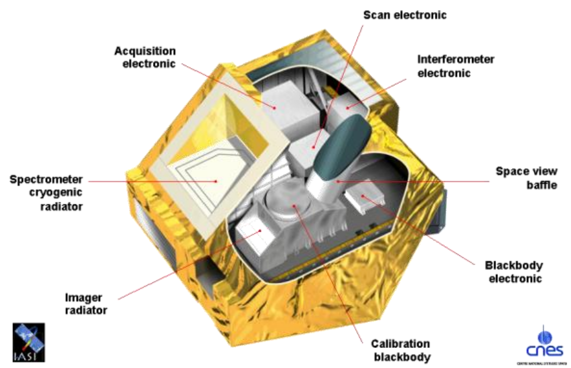




IASI

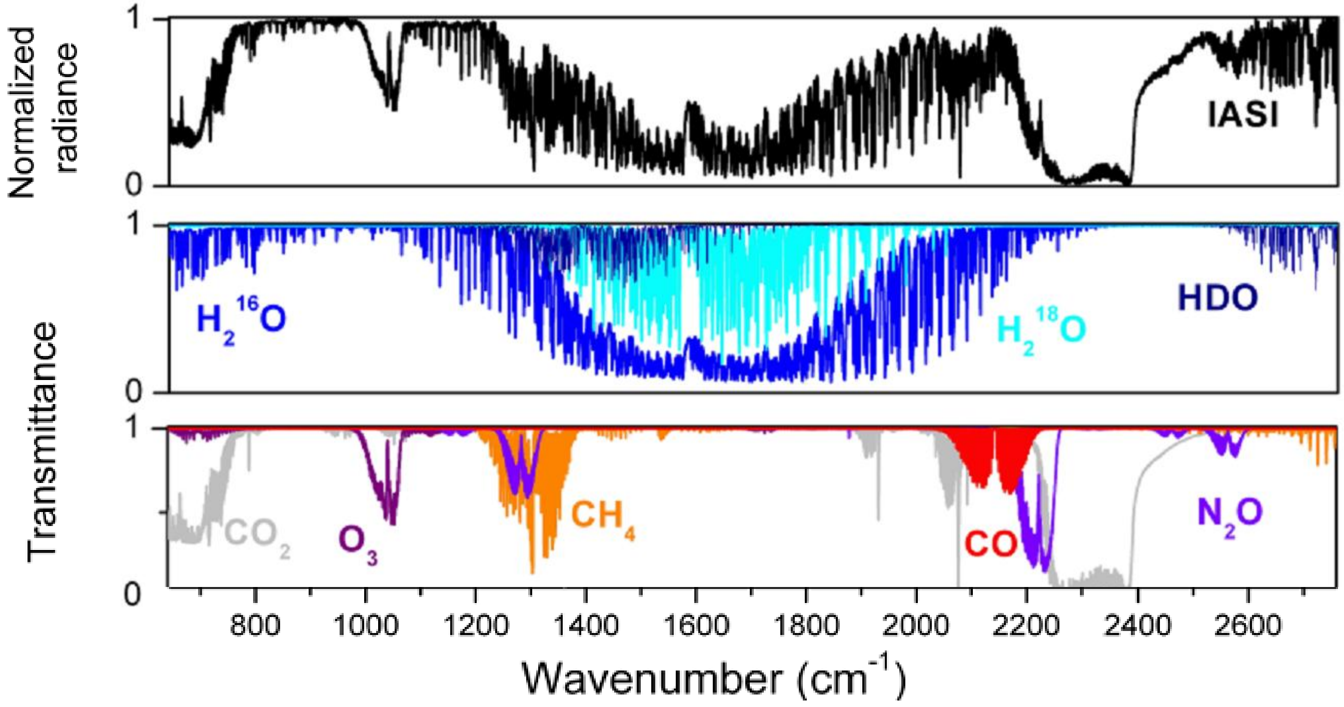
Metop A	Launched on October 19, 2006
Altitude	~817 km
Orbit	Polar sun-synchronous
Inclination	98.7° to the equator
Local time	~09:30, descending orbit
Time for one orbit	101 min
Repeat cycle	29 days (412 orbits)
IASI	Fourier transform spectrometer
Size and weight	1.7 m^3, 236 kg
Spectral range	645 to 2760 cm^{-1}
Spectral resolution	0.3–0.5 cm^{-1} (0.5 cm^{-1} apodized)
Radiometric noise	<0.1–0.2 K (650–1750 cm^{-1})
(NeΔT at 280 K)	0.2–0.4 K (1750–2500 cm^{-1})
Scan type	Step and dwell
Field of view	50 km (3.33°) at nadir, with 4 simultaneous pixels of 12 km
Full swath width	~2200 km (±48.3°), 120 pixels
Global Earth coverage	2 times per day
Data rate	1.5 Mbps (after onboard processing), 120 radiance spectra every 8 s ~1 300 000 observations per day
Lifetime	5 years





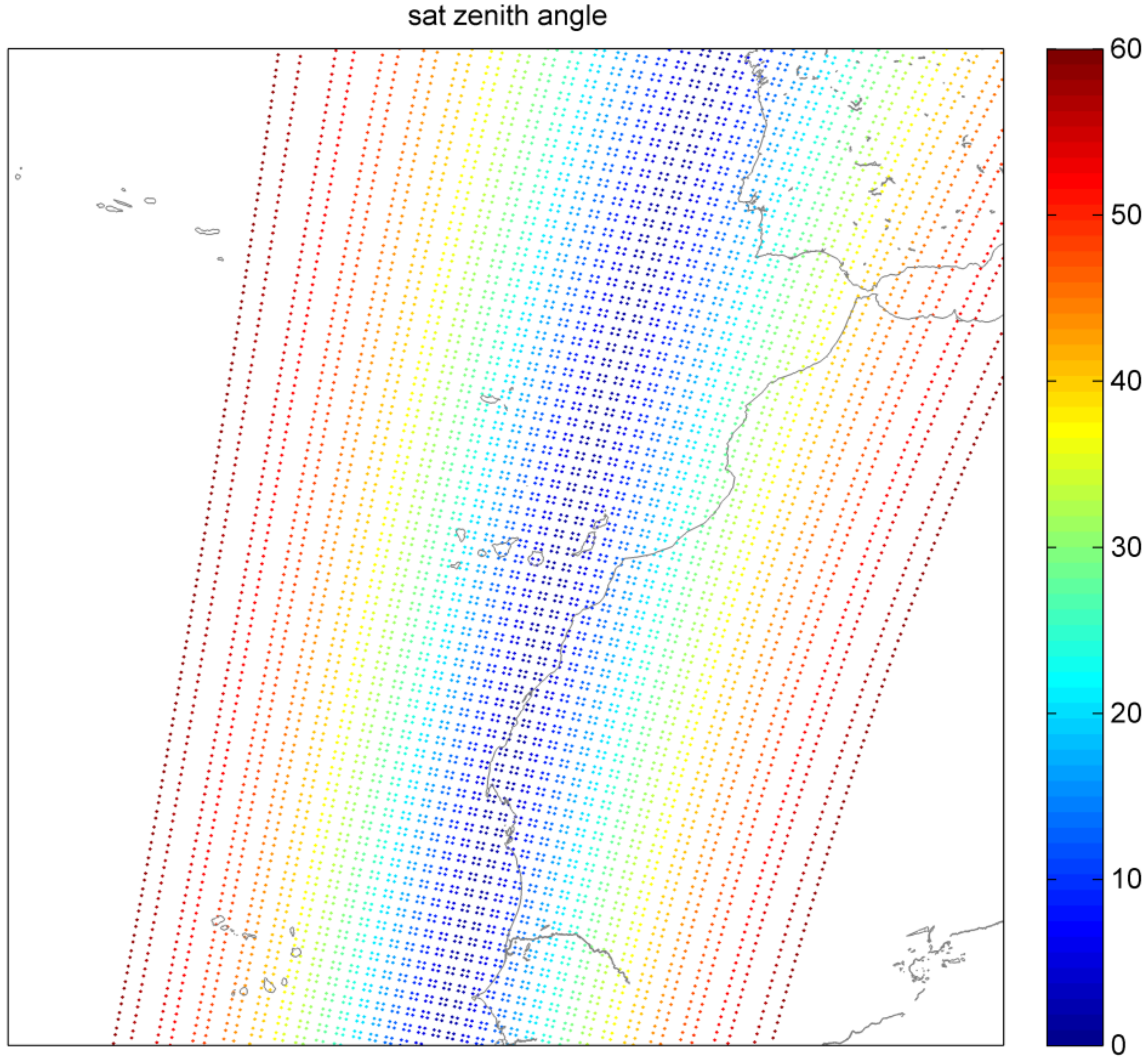
- Infrared Atmospheric Sounding Interferometer
- Fourier transform spectrometer with high resolution between 645 and 2760 cm^{-1} (3.6 µm to 15.5 µm)
- associated Integrated Imaging Subsystem (IIS): broad band radiometer with a high spatial resolution. only used for co-registration with the Advanced Very High Resolution Radiometer (AVHRR)
- main goal of the IASI mission: provide atmospheric emission spectra to derive temperature and humidity profiles with high vertical resolution and accuracy. Additionally: determination of trace gases such as ozone, nitrous oxide, carbon dioxide and methane, as well as land- and sea surface temperature and emissivity and cloud properties.

Clerbaux et al., 2009



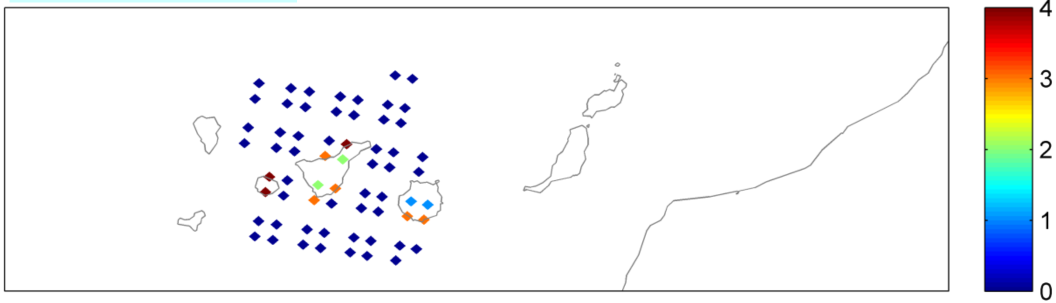
	H_2O	O_3	CO	CH_4	N_2O	CO_2
DOFs	5-6	3-4	1-2	1	<1	<1
Uncert.	<10%	< 5%	<10%	5-10%	5-10%	2%
status	oper.	oper.	oper.	exp.	exp.	exp.

one IASI orbit



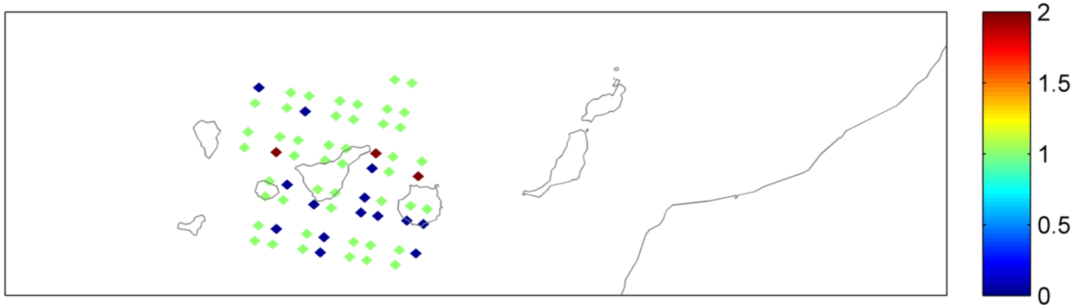
2011-03-15

flag landsea



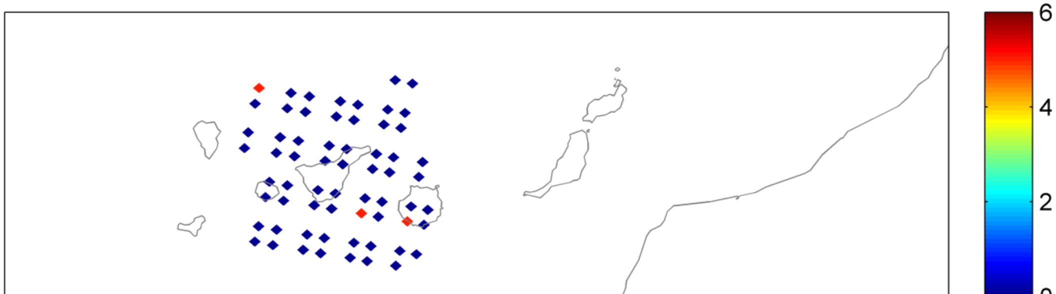
0	The IASI IFOV is completely covered by water
1	The IASI IFOV is completely covered by land, the variability of the surface topography is low
2	The IASI IFOV is completely covered by land, the variability of the surface topography is high
3	The IASI IFOV covers land and water, the variability of the surface topography is low
4	The IASI IFOV covers land and water, the variability of the surface topography is high

flag IASI clr



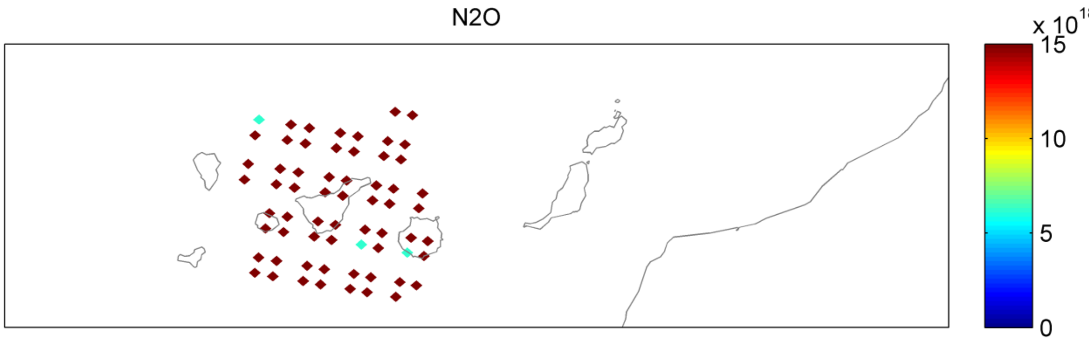
0	The IASI IFOV is clear
1	The IASI IFOV is partly cloudy
2	The IASI IFOV is completely cloudy

flag qual



0	No successful retrieval
1	Complete retrieval, errors within EURD objective
2	Incomplete retrieval, errors within EURD objective
3	Complete retrieval, errors within EURD threshold
4	Incomplete retrieval, errors within EURD threshold
5	Complete retrieval, errors outside EURD threshold
6	Incomplete retrieval, errors outside EURD threshold

N2O



3 obs. in 1x1 deg box
also days with no obs.
v6 : increase by factor 2

Comparison: GB-FTIR to IASI

GB FTIR	IASI
FTS	FTS
700 to 9000 cm^{-1}	645 to 2760 cm^{-1} (3.6 to 15.5 μm)
0.005 cm^{-1} , S/N ~ 2000	0.5 cm^{-1}
direct solar absorption	thermal emission
day	day + night
continuous (when clear sky)	10:00 + 22:00 (at Izana latitude)
2370 m to TOA	Surface to TOA (sensitivity)
28.3 N / 16.5 W	± 1 (0.5) deg (12 km)
land	sea (land)
8 min sampling (4 min CO_2)	8 sec (30x4 pixel)

Column below 2370 m

- Use indepedent measurements (SCIA, TES, …)
- In situ for 2370 km and below ?
- MUSICA/AMISOC flight campaign summer 2013
- O_3, H_2O sondes (but ...)
- study IASI sensitivity for boundary layer (thermal contrast, land sea, day night)
- use IASI profile (a priori) and AK information
  → add to FTIR profile (for v6)
- Use model data: WACCM

WACCM data on column below IZO

(partial column for 0 to 2370 m)

	H_2O	O_3	CO	CH_4	N_2O	CO_2
	-	(11 DU)	4.1e17	9.2e18	1.65e18	2.0e21
		(sondes: 8-10 DU)	**Very strong annual cycle**	± 0.2e18	± 0.05e18	± 0.05e21

REMARKS:

Correlation not affected !

Absolute values/differences not considered now

Outline

1. VALIASI
2. IZO, GB-FTIR, further Measurements at IZO
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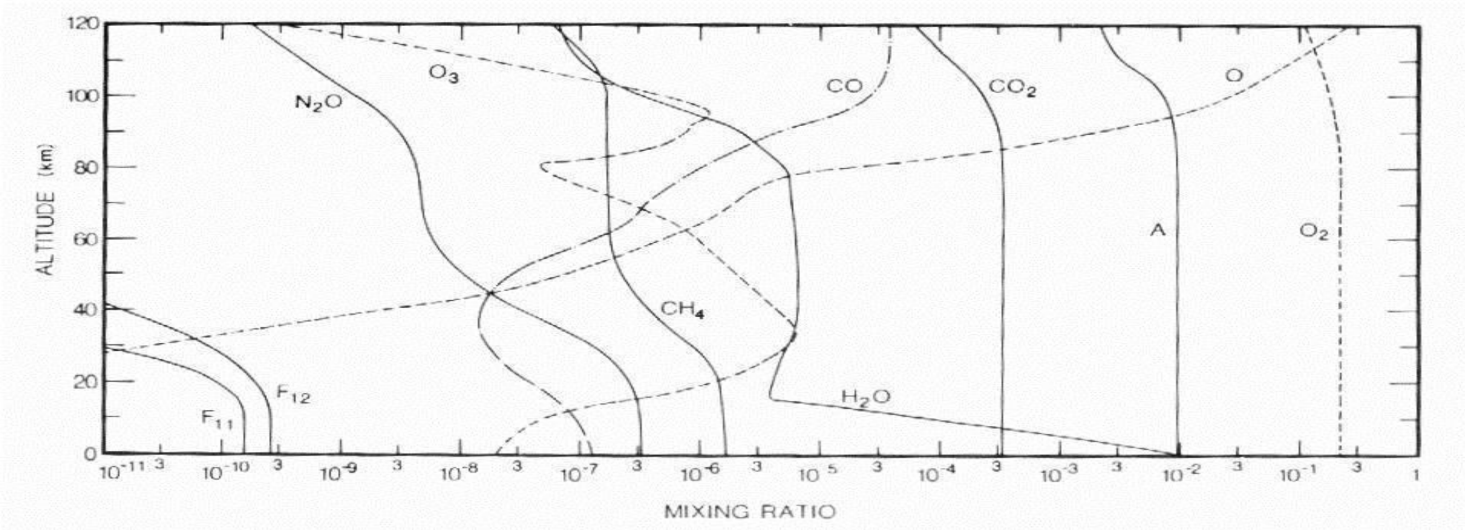
4. **Molecules, natural variability**
5. Collocation
6. First Validation results
7. Annual cycle
8. Summary

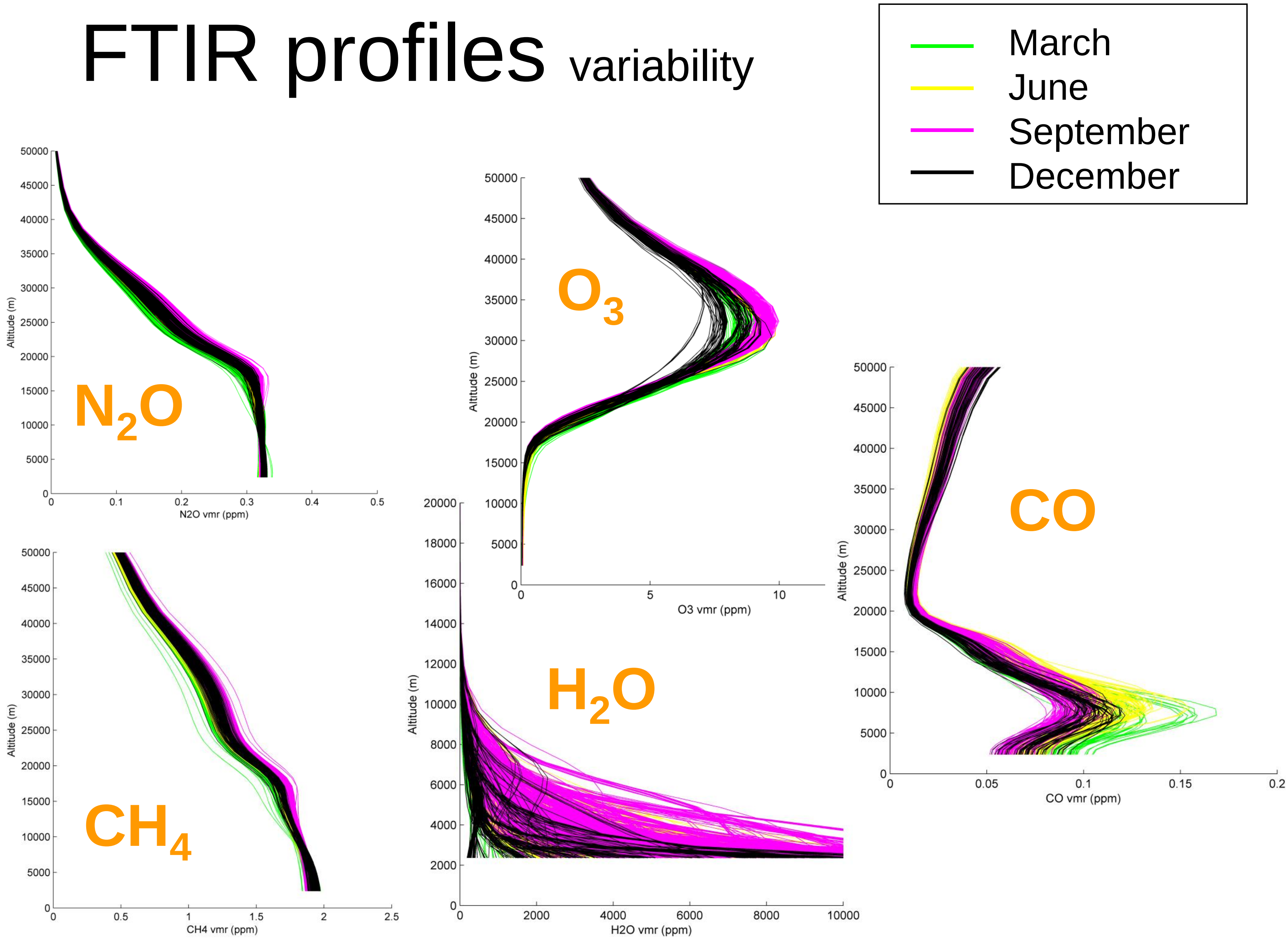
Molecules



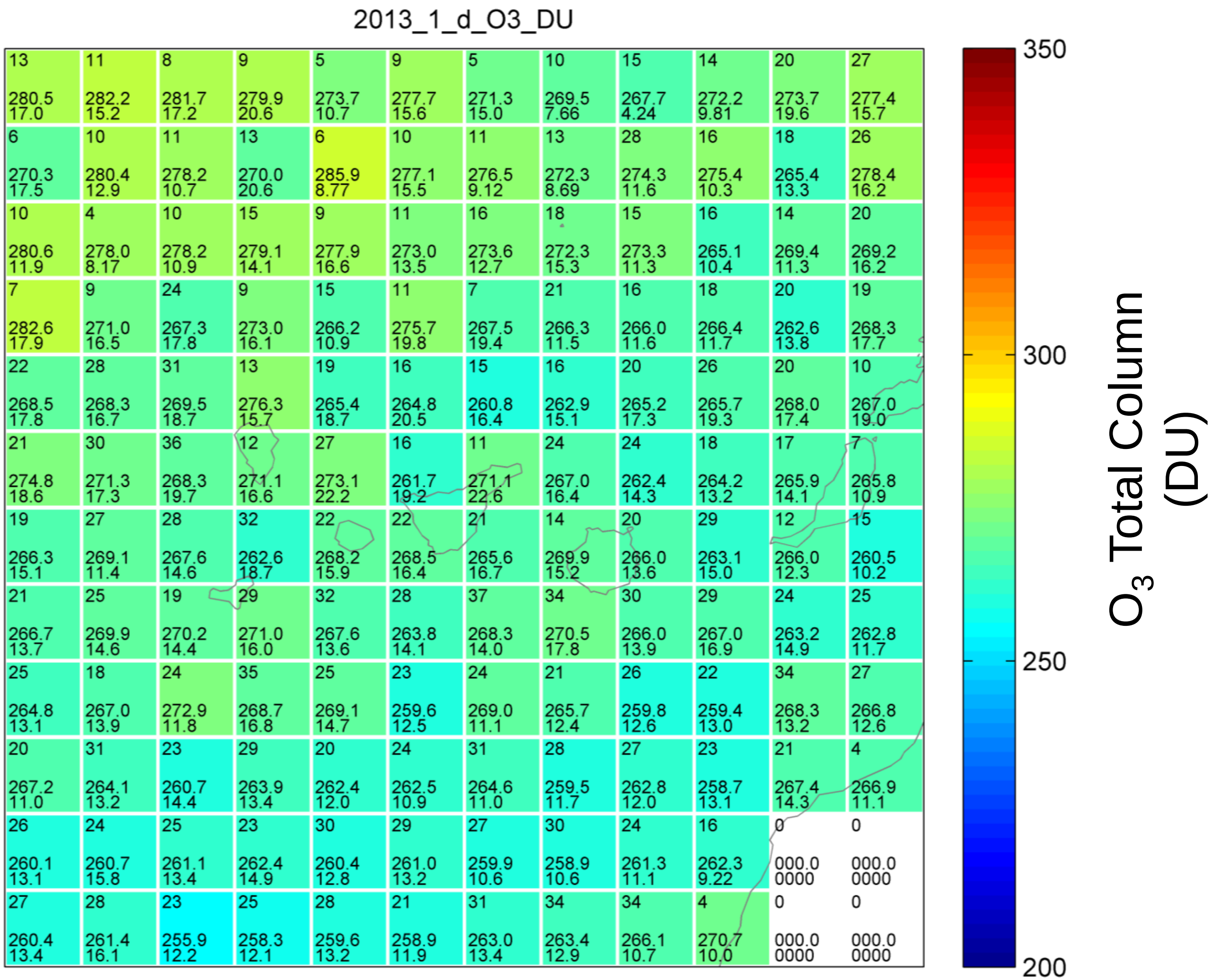
(from Goody and Yung, 1989)

	H_2O	CO	O_3	CO_2	CH_4	N_2O
Daily variability	very strong	mod. to strong	low to mod.	low	low	very low
Annual Cycle	very strong	very strong	moderate	moderate	moderate	small
year to year (trend)	(+)	-	±	+	+	+
spatial	< 10 km	< 50 km	> 50 km	~50 km	~50 km	> 50 km

FTIR profiles variability



IASI maps


2013_1_d_O3_DU
13 280.5 17.0
11 282.2 15.2
8 281.7 17.2
9 279.9 20.6
5 273.7 10.7
9 277.7 15.6
5 271.3 15.0
10 269.5 7.66
15 267.7 4.24
14 272.2 9.81
20 273.7 19.6
27 277.4 15.7
6 270.3 17.5
10 280.4 12.9
11 278.2 10.7
13 270.0 20.6
6 285.9 8.77
10 277.1 15.5
11 276.5 9.12
13 272.3 8.69
28 274.3 11.6
16 275.4 10.3
18 265.4 13.3
26 278.4 16.2
10 280.6 11.9
4 278.0 8.17
10 278.2 10.9
15 279.1 14.1
9 277.9 16.6
11 273.0 13.5
16 273.6 12.7
18 272.3 15.3
15 273.3 11.3
16 265.1 10.4
14 269.4 11.3
20 269.2 16.2
7 282.6 17.9
9 271.0 16.5
24 267.3 17.8
9 273.0 16.1
15 266.2 10.9
11 275.7 19.8
7 267.5 19.4
21 266.3 11.5
16 266.0 11.6
18 266.4 11.7
20 262.6 13.8
19 268.3 17.7
22 268.5 17.8
28 268.3 16.7
31 269.5 18.7
13 276.3 15.7
19 265.4 18.7
16 264.8 20.5
15 260.8 16.4
16 262.9 15.1
20 265.2 17.3
26 265.7 19.3
20 268.0 17.4
10 267.0 19.0
21 274.8 18.6
30 271.3 17.3
36 268.3 19.7
12 271.1 16.6
27 273.1 22.2
16 261.7 19.2
11 271.1 22.6
24 267.0 16.4
24 262.4 14.3
18 264.2 13.2
17 265.9 14.1
7 265.8 10.9
19 266.3 15.1
27 269.1 11.4
28 267.6 14.6
32 262.6 18.7
22 268.2 15.9
22 268.5 16.4
21 265.6 16.7
14 269.9 15.2
20 266.0 13.6
29 263.1 15.0
12 266.0 12.3
15 260.5 10.2
21 266.7 13.7
25 269.9 14.6
19 270.2 14.4
29 271.0 16.0
32 267.6 13.6
28 263.8 14.1
37 268.3 14.0
34 270.5 17.8
30 266.0 13.9
29 267.0 16.9
24 263.2 14.9
25 262.8 11.7
25 264.8 13.1
18 267.0 13.9
24 272.9 11.8
35 268.7 16.8
25 269.1 14.7
23 259.6 12.5
24 269.0 11.1
21 265.7 12.4
26 259.8 12.6
22 259.4 13.0
34 268.3 13.2
27 266.8 12.6
20 267.2 11.0
31 264.1 13.2
23 260.7 14.4
29 263.9 13.4
20 262.4 12.0
24 262.5 10.9
31 264.6 11.0
28 259.5 11.7
27 262.8 12.0
23 258.7 13.1
21 267.4 14.3
4 266.9 11.1
26 260.1 13.1
24 260.7 15.8
25 261.1 13.4
23 262.4 14.9
30 260.4 12.8
29 261.0 13.2
27 259.9 10.6
30 258.9 10.6
24 261.3 11.1
16 262.3 9.22
0 000.0 0000
0 000.0 0000
27 260.4 13.4
28 261.4 16.1
23 255.9 12.2
25 258.3 12.1
28 259.6 13.2
21 258.9 11.9
31 263.0 13.4
34 263.4 12.9
34 266.1 10.7
4 270.7 10.0
0 000.0 0000
0 000.0 0000
350
300
250
200
O_3 Total Column
(DU)

Seasonal cycles - Meteorology

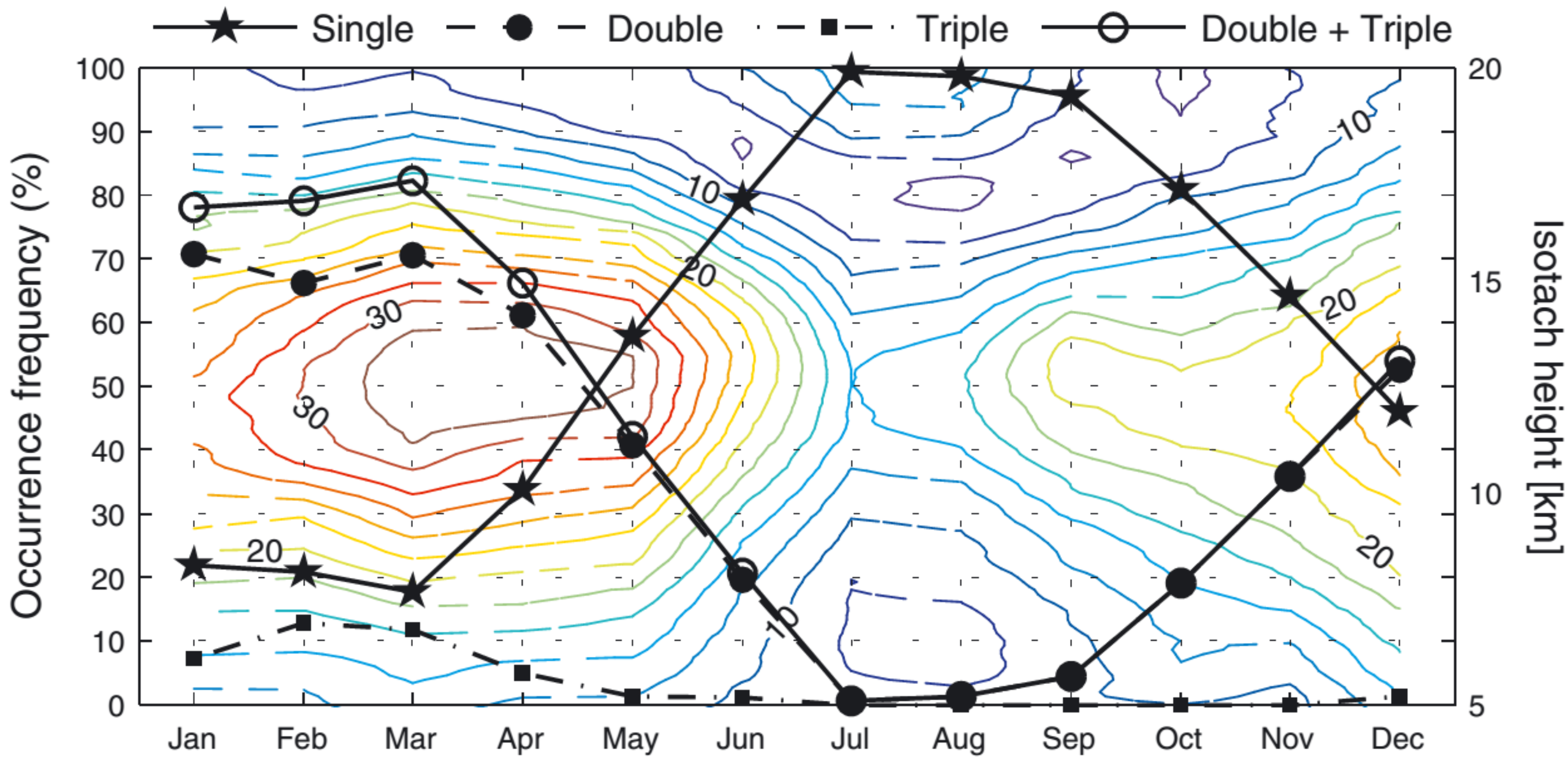


Figure 3. Seasonal cycle of single and multiple thermal tropopause occurrence frequency and wind speed over Tenerife derived from radiosondes data for the 1992–2011 period. Results are shown for single (solid stars with solid line), double (solid circles with dashed line), and triple (solid squares with dash-dotted line) tropopause events. Open circles with solid line denotes the sum of occurrence frequency for double and triple thermal tropopauses.

Rodriguez and Cuevas, JGR, 2013

Temporal and spatial collocation

Temporal criterium:

depends on natural variability of target gas and FTIR uncertainty

A) Intra-day variability < FTIR uncertainty: **DAILY MEANS**
B) Intra-day variability > FTIR uncertainty: **±1h IASI overpass**

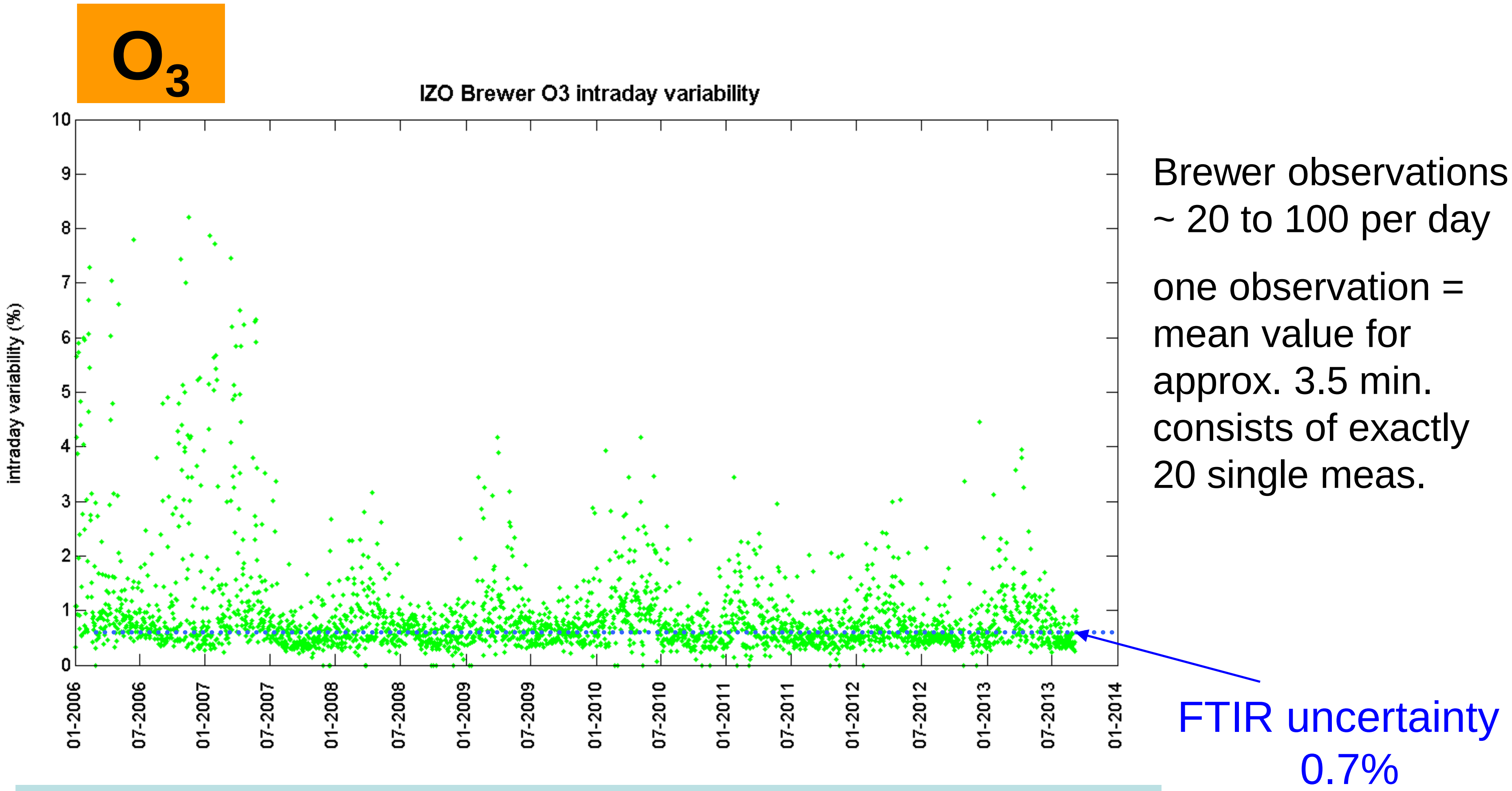
GAW, Brewer, GPS

Spatial criterium:

1) Determine region for air masses probed by FTIR
2) consider variability observed by IASI
different seasonal cycles
land, sea, day night
Windspeed, -direction

Temporal collocation

Example for O_3



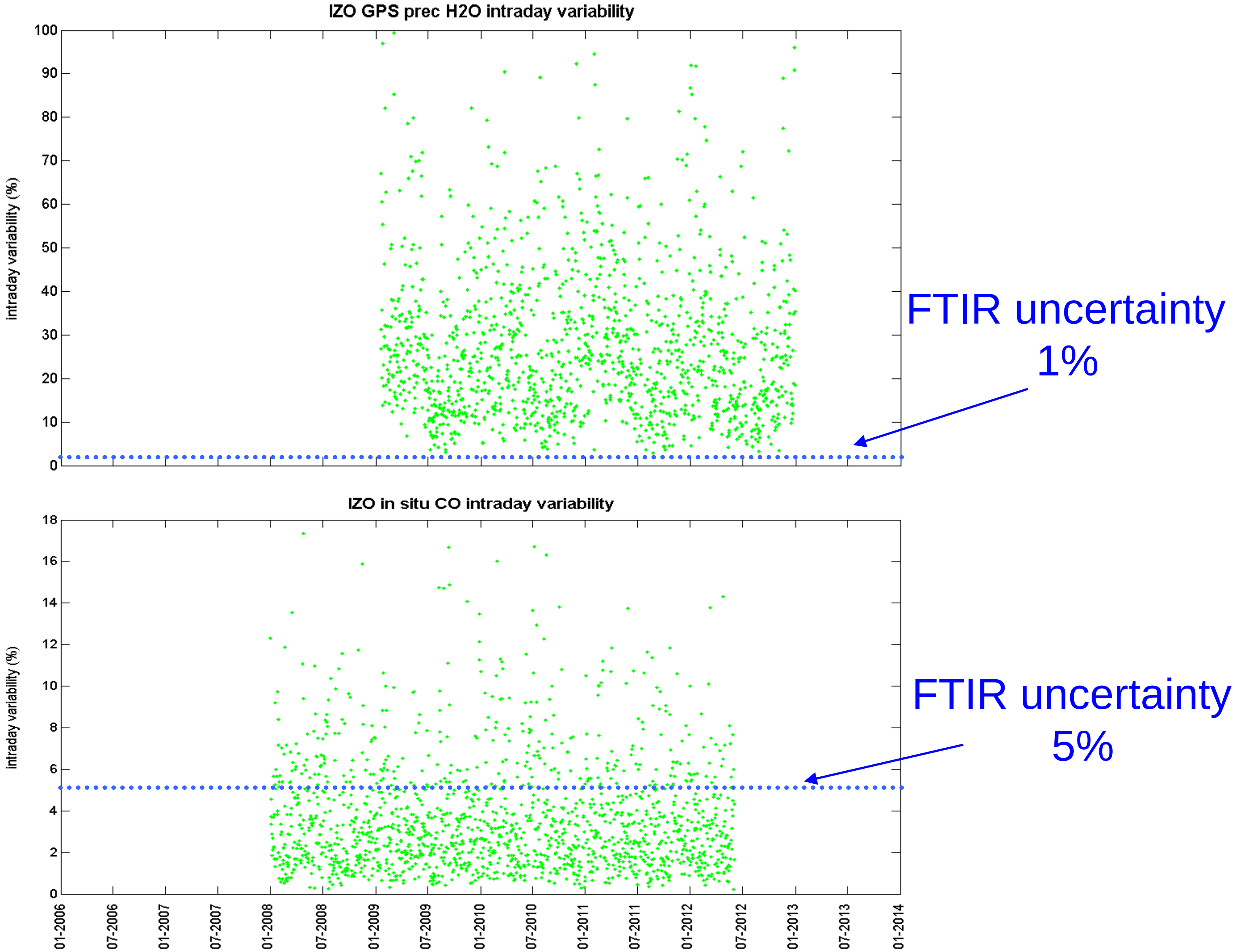
Brewer observations ~ 20 to 100 per day

one observation = mean value for approx. 3.5 min. consists of exactly 20 single meas.

Intraday variability larger than FTIR uncertainty → FTIR measurements throughout the day can differ significantly to those at IASI overpass time (10-12h)

H_2O

CO



For optimal collocation : only consider FTIR observations within 1 hour of IASI measurements

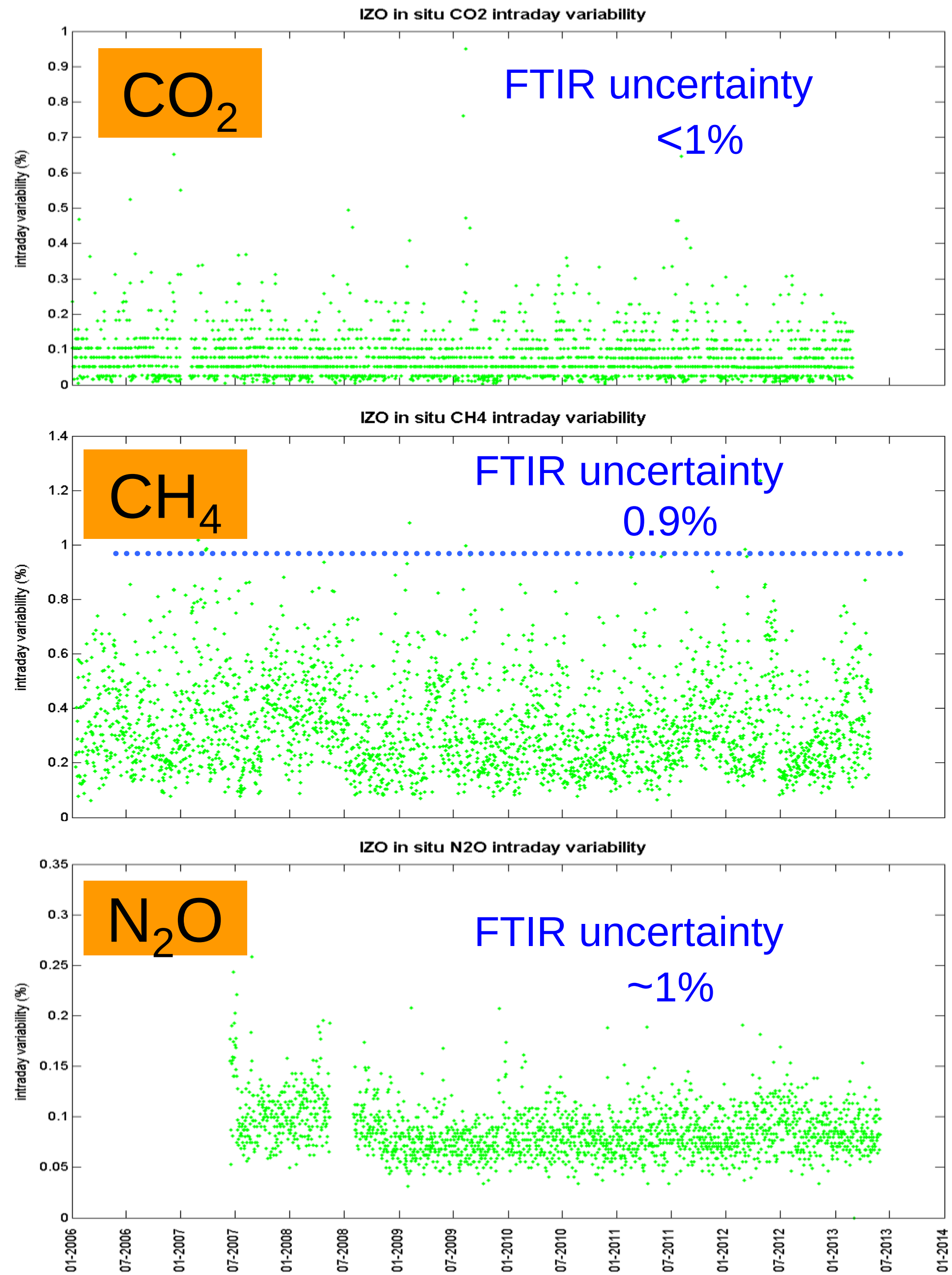
CO_2 CH_4 N_2O :

almost no diurnal variation

→ FTIR uncertainty larger than Intraday variability observed by GAW in situ measurements

→ Daily means of FTIR

No loss of information
No effect on validation results

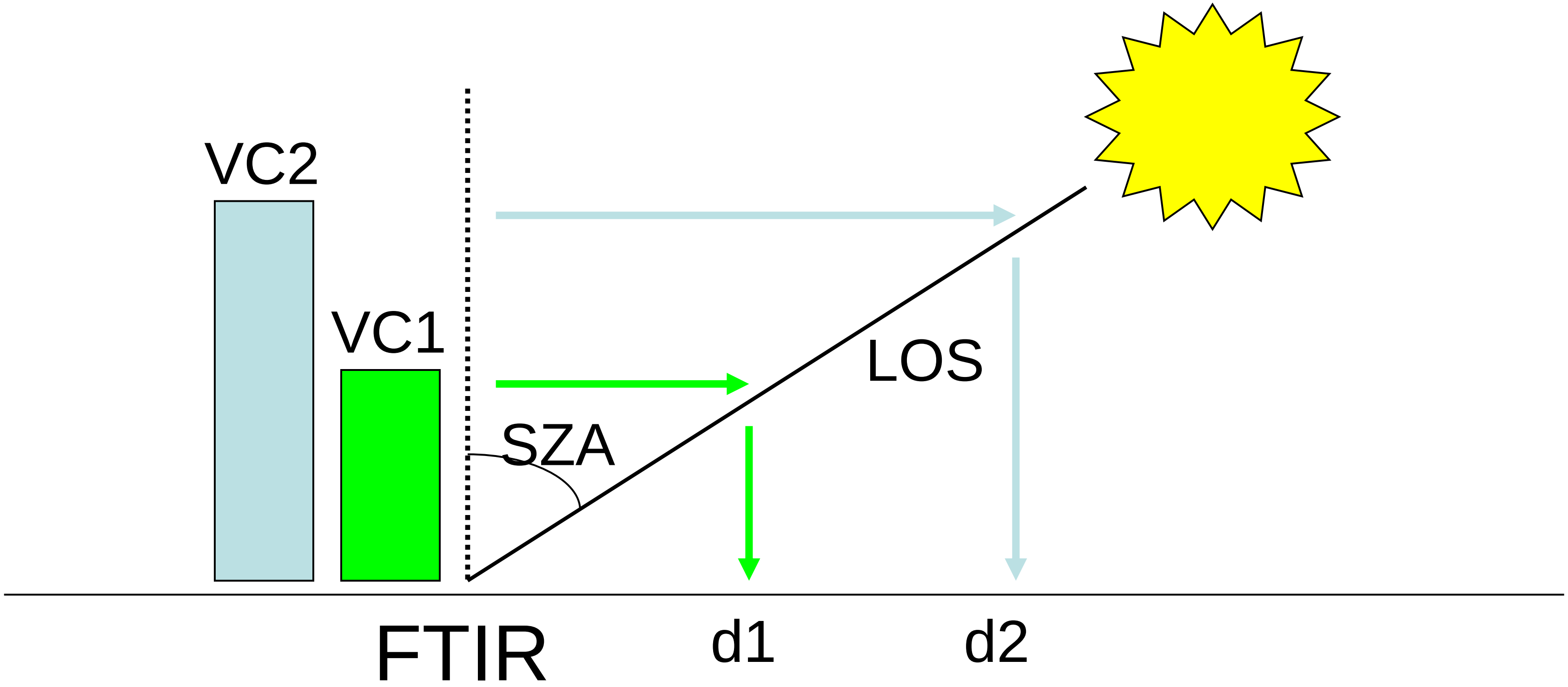


Spatial collocation

air masses probed by FTIR measurements determined by:

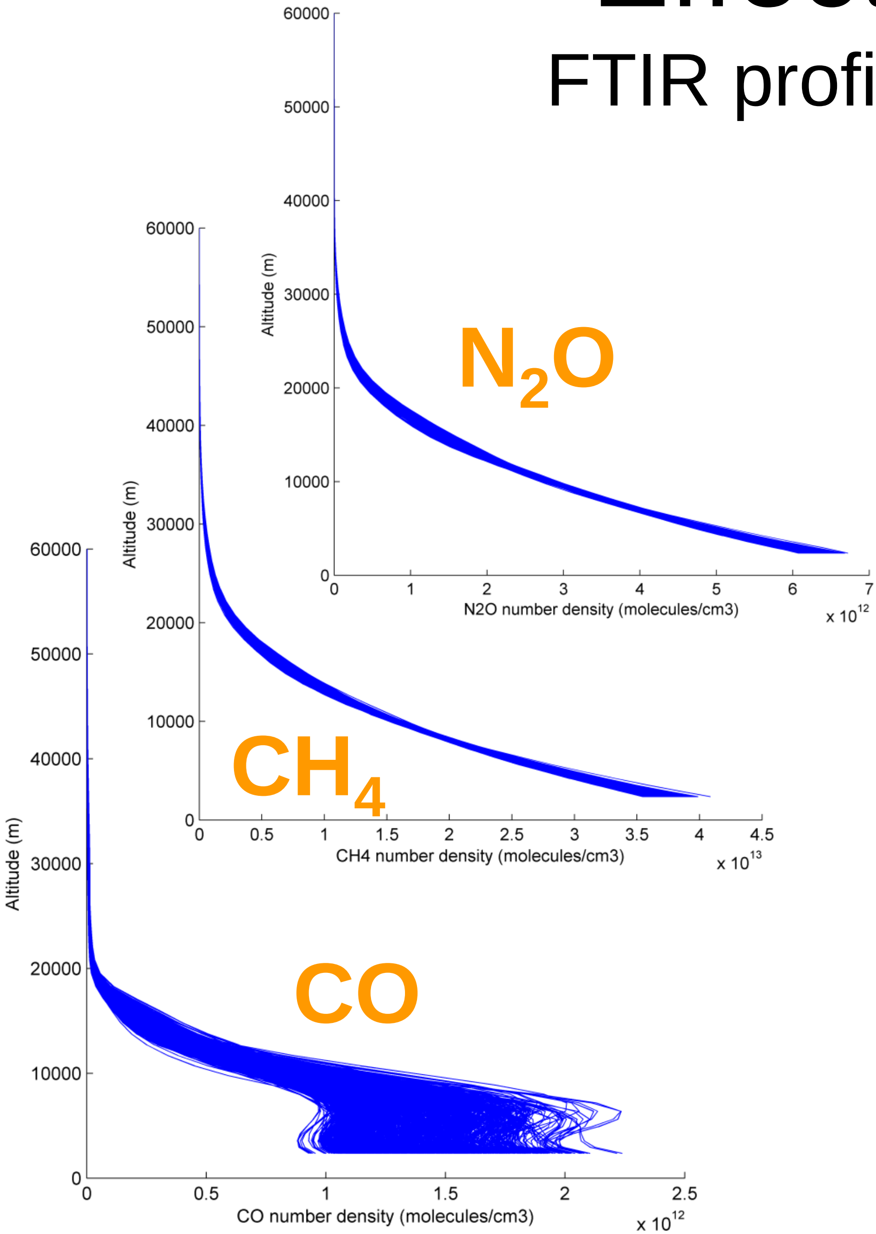
Vertical Column, Observation geometry (SZA, SAA)

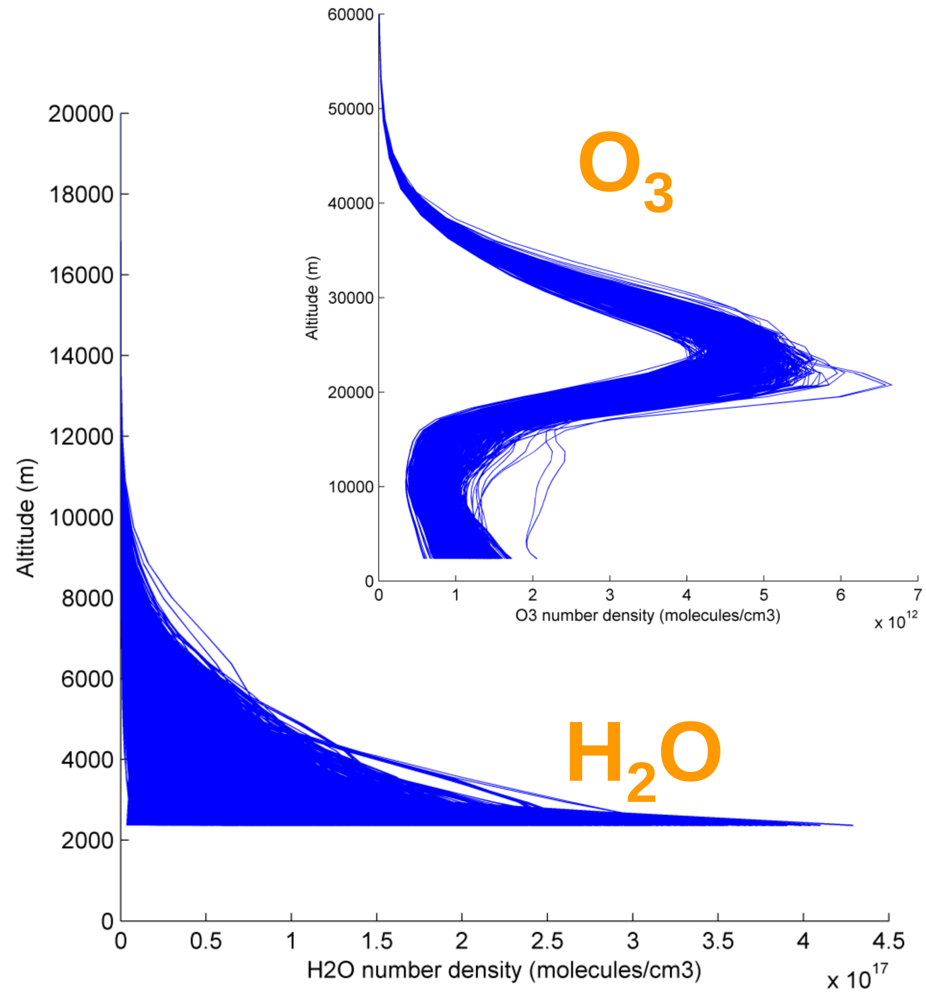
effective vertical column length → distance



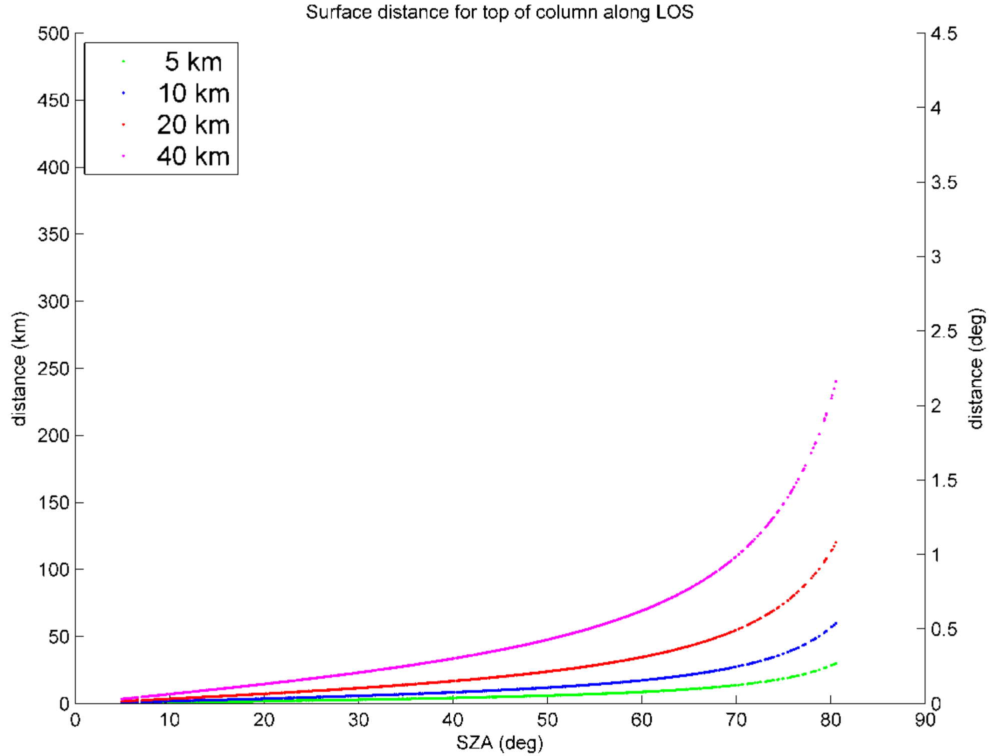
Effective Column :

FTIR profiles of number density

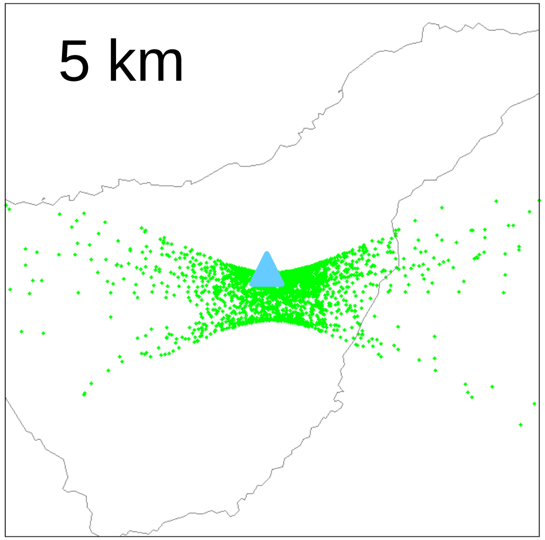


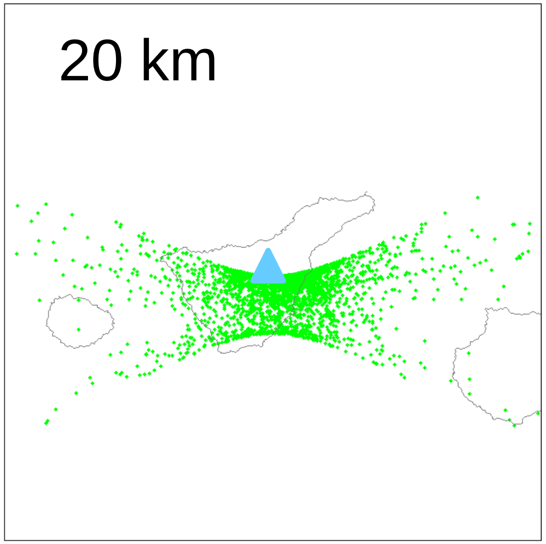


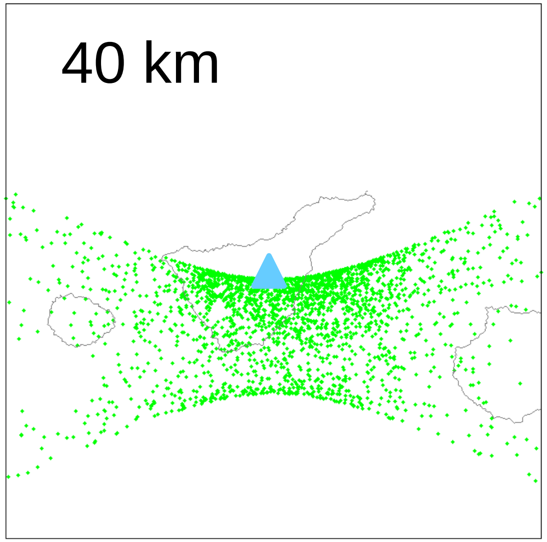
Distance for top of effective column along LOS from FTIR, at surface



H_2O: 5-10 km
N_2O, CH_4, CO, CO_2: 20 km
O_3 :   40 km







Summary: collocation

	H_2O	O_3	CO	CH_4	N_2O	CO_2
Region FTIR						
spatial	0.25 deg	1 deg	0.5 deg	0.5 deg	0.5 deg	0.5 deg
temporal	± 1h	± 1h	± 1h	**Daily mean**	**Daily mean**	**Daily mean**

Validation performed for

- different sets of collocation criteria
- results compared to optimal criteria

FTIR dataset

- For comparison:
- Jun 2008 to Dec 2013 (= v4-v5 of IASI lv2), cloud free days!
- 7561 profiles for CH_4, N_2O, H_2O, (CO_2)
- 1349 profiles for CO, 1594 for O_3
- 50% of profiles in 2012+2013

IASI dataset

- v4 : Jun 2008 to Sep 2010
- v5 : Sep 2010 to now
- Daily means for 1deg (0.5 deg) boxes around IZO
- Cloud free, sea-land pixel, day-night separate

v5: approx. 1200 days → IZO: 400 cloud free
→ IASI: 300 colloc. days (180 for 0.5 deg)

Outline

1. VALIASI
2. IZO, GB-FTIR, further Measurements at IZO
3. IASI, comparison to FTIR
4. Molecules, natural variability
5. Collocation
6. **First Validation results**
7. Annual cycle
8. Summary

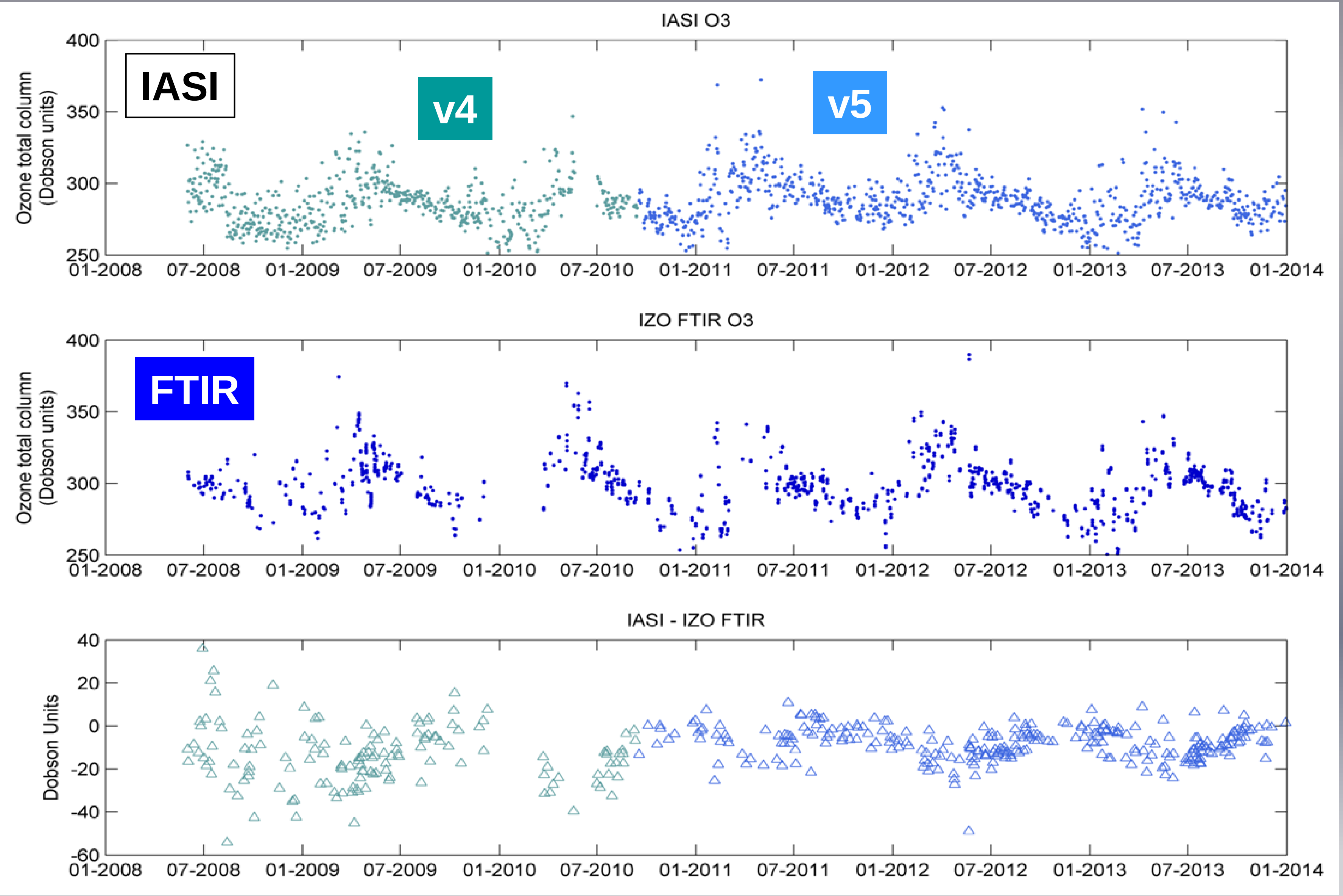
GOBIERNO DE ESPAÑA
MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE
AEMet Agencia Estatal de Meteorología
EUMETSAT
KIT Karlsruhe Institute of Technology

IASI - FTIR

- **1 deg box, sea pixel, daytime, v4-v5**
- **collocation criteria: 1degS, 0.5 deg, ± 1h**
- **day-night / land-sea**
- **Correlation coefficient (Pearson)**
- **Total columns: O_3, CO, CH_4, N_2O, CO_2**
- **Profiles H_2O, partial columns: O_3**

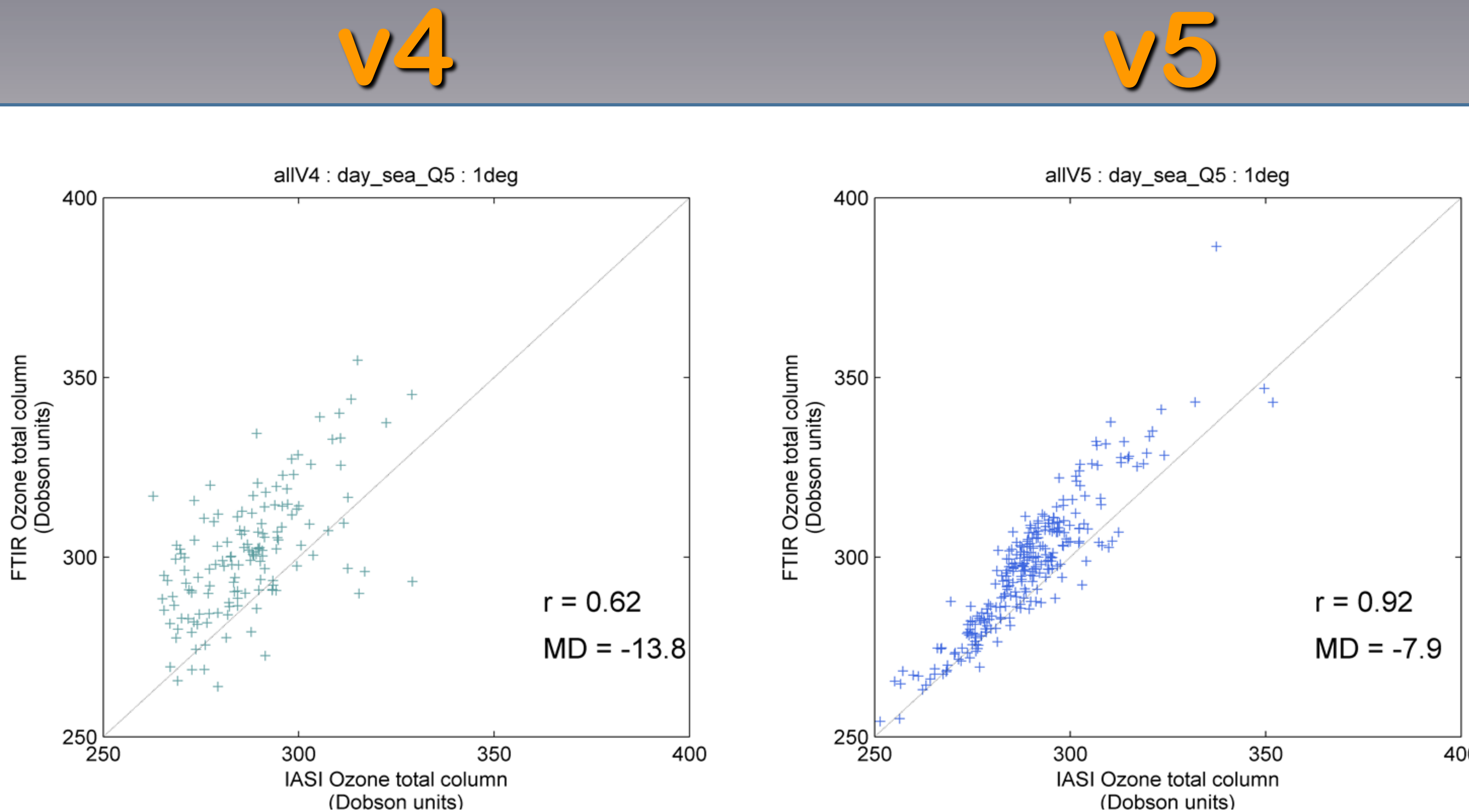
O_3

IASI v4 / v5



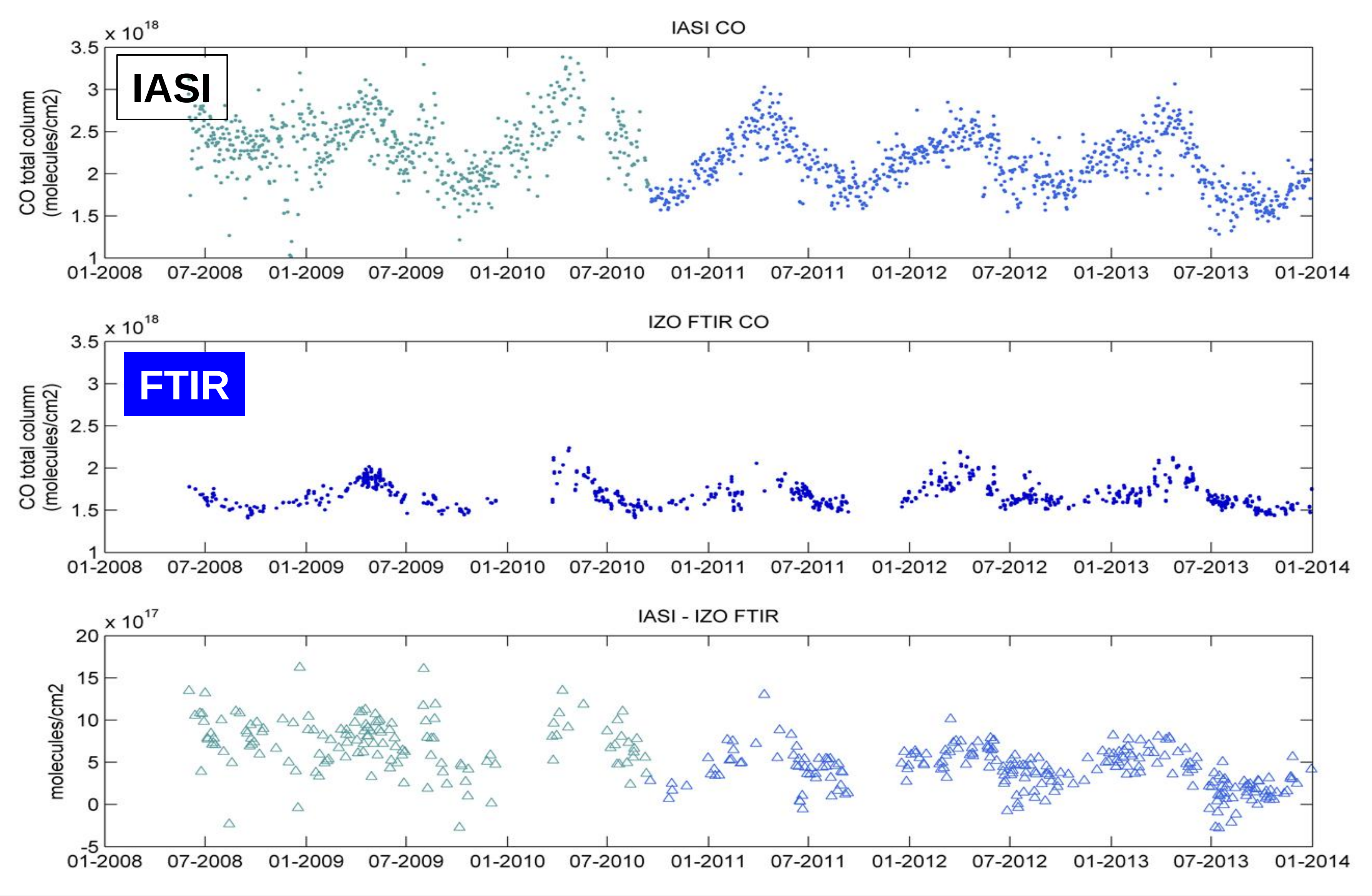
IASI O3
IASI
v4
v5
Ozone total column (Dobson units)
400
350
300
250
01-2008
07-2008
01-2009
07-2009
01-2010
07-2010
01-2011
07-2011
01-2012
07-2012
01-2013
07-2013
01-2014
IZO FTIR O3
FTIR
IASI - IZO FTIR
Dobson Units
40
20
0
-20
-40
-60

O_3


v4
v5
allV4 : day_sea_Q5 : 1deg
FTIR Ozone total column
(Dobson units)
IASI Ozone total column
(Dobson units)
r = 0.62
MD = -13.8
allV5 : day_sea_Q5 : 1deg
FTIR Ozone total column
(Dobson units)
IASI Ozone total column
(Dobson units)
r = 0.92
MD = -7.9

CO

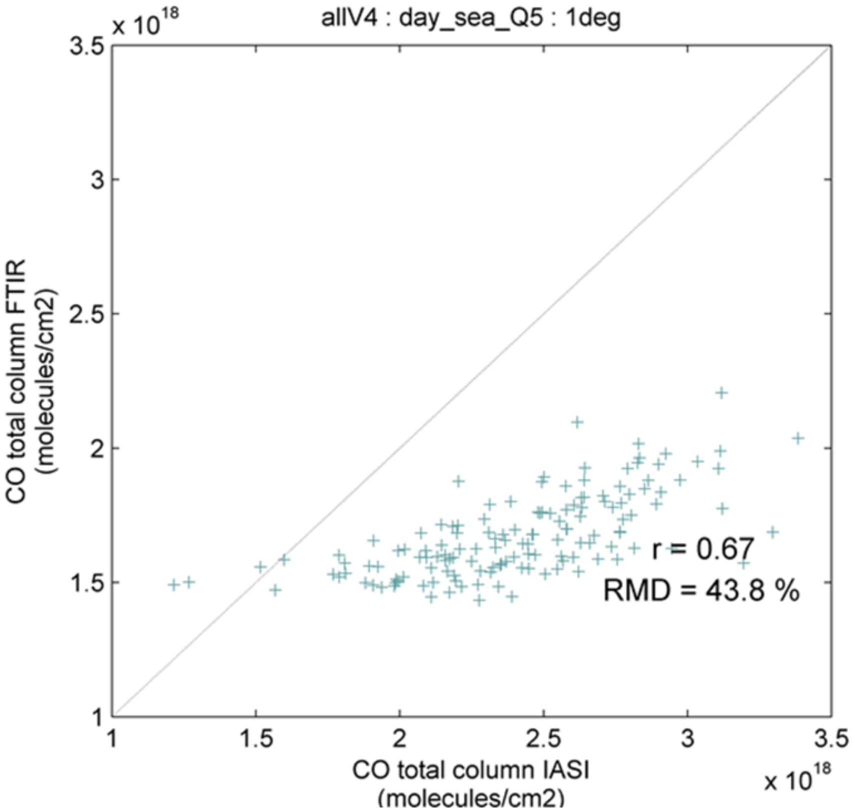
IASI v4 / v5



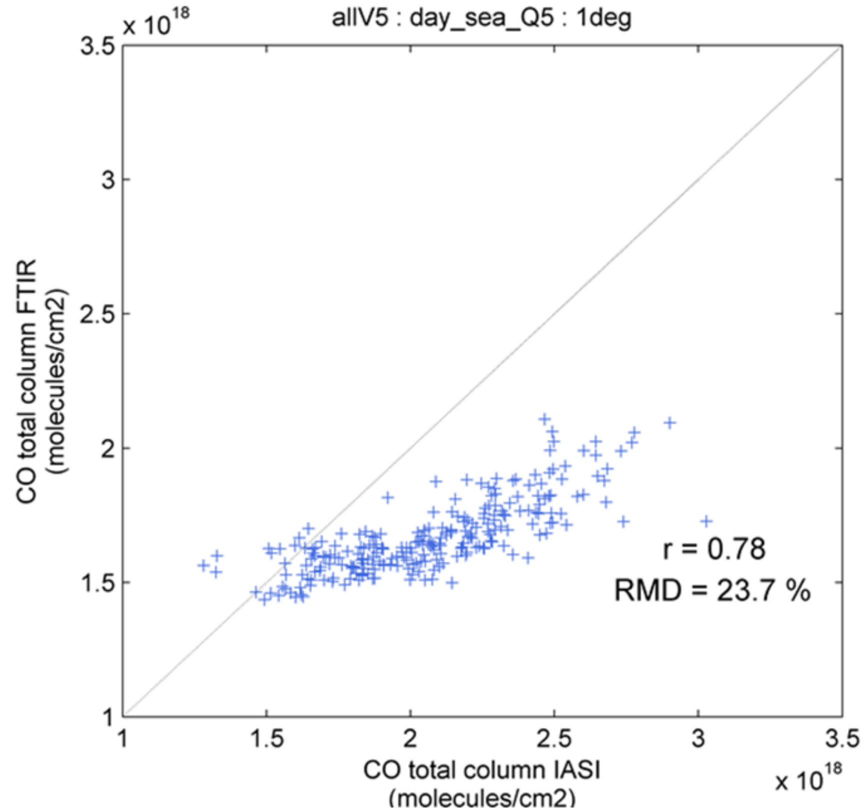
IASI CO
x 10^18
IASI
CO total column (molecules/cm2)
3.5
3
2.5
2
1.5
1
01-2008
07-2008
01-2009
07-2009
01-2010
07-2010
01-2011
07-2011
01-2012
07-2012
01-2013
07-2013
01-2014
IZO FTIR CO
x 10^18
FTIR
CO total column (molecules/cm2)
IASI - IZO FTIR
x 10^17
molecules/cm2
20
15
10
5
0
-5

CO

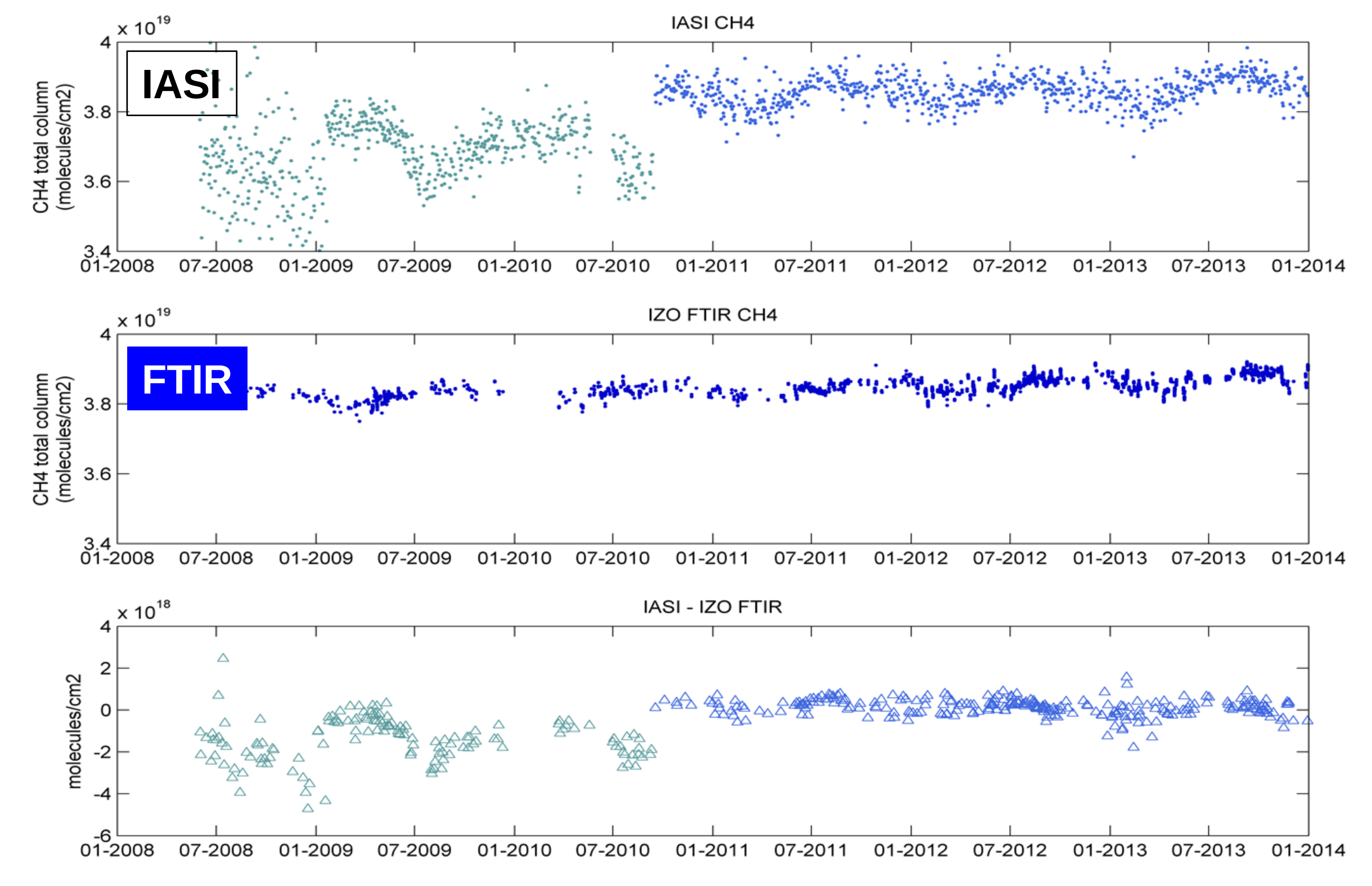
v4


allV4 : day_sea_Q5 : 1deg
x 10^18
CO total column FTIR
(molecules/cm2)
3.5
3
2.5
2
1.5
1
1
1.5
2
2.5
3
3.5
CO total column IASI
(molecules/cm2)
x 10^18
r = 0.67
RMD = 43.8 %

v5

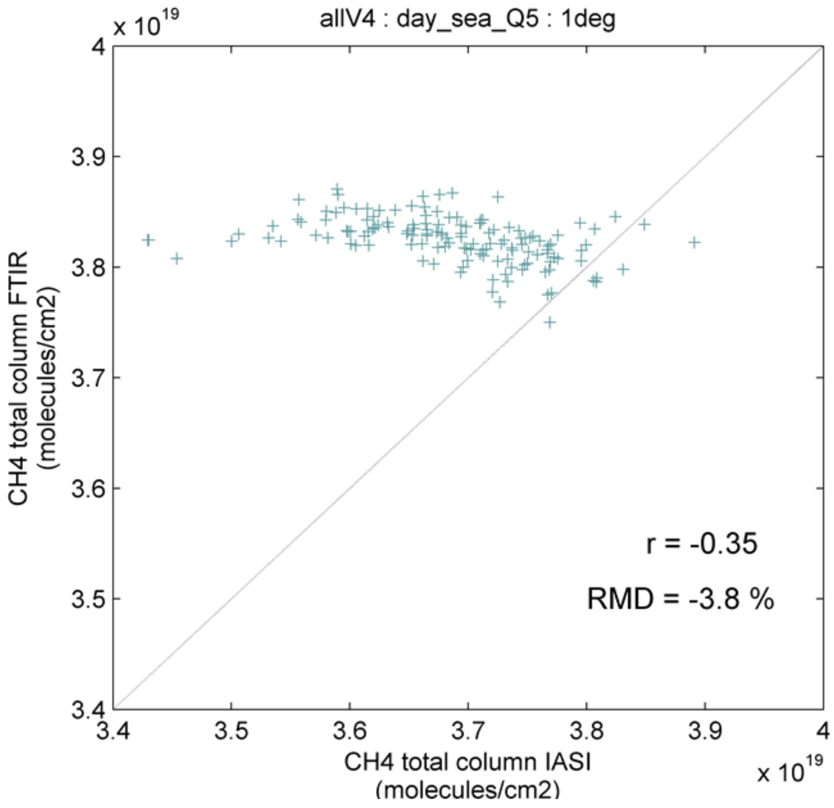

allV5 : day_sea_Q5 : 1deg
x 10^18
CO total column FTIR
(molecules/cm2)
3.5
3
2.5
2
1.5
1
1
1.5
2
2.5
3
3.5
CO total column IASI
(molecules/cm2)
x 10^18
r = 0.78
RMD = 23.7 %

CH_4 IASI v4 / v5

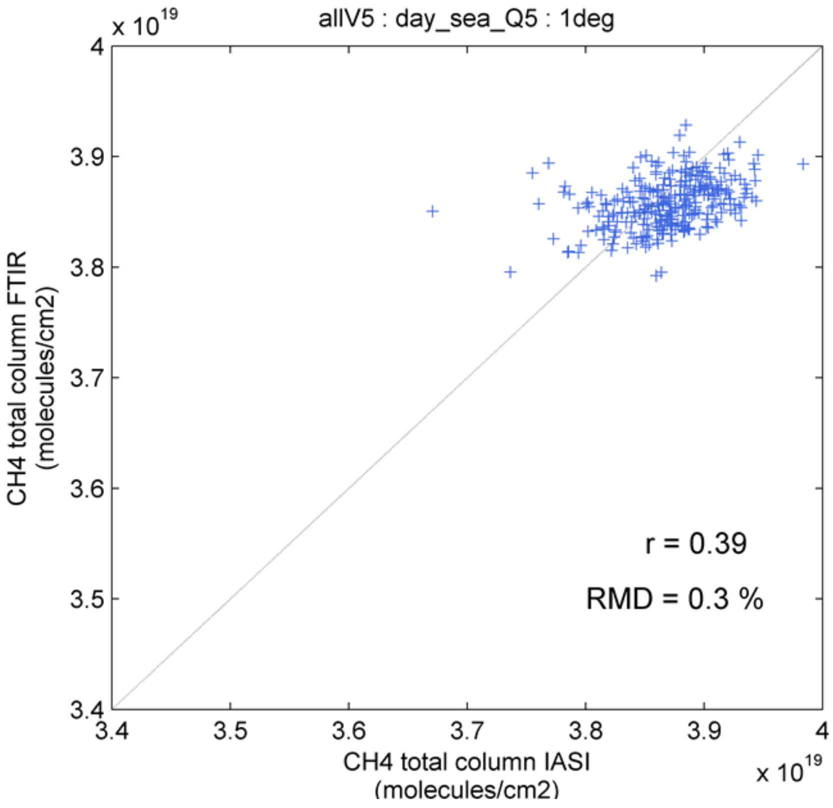


CH_4

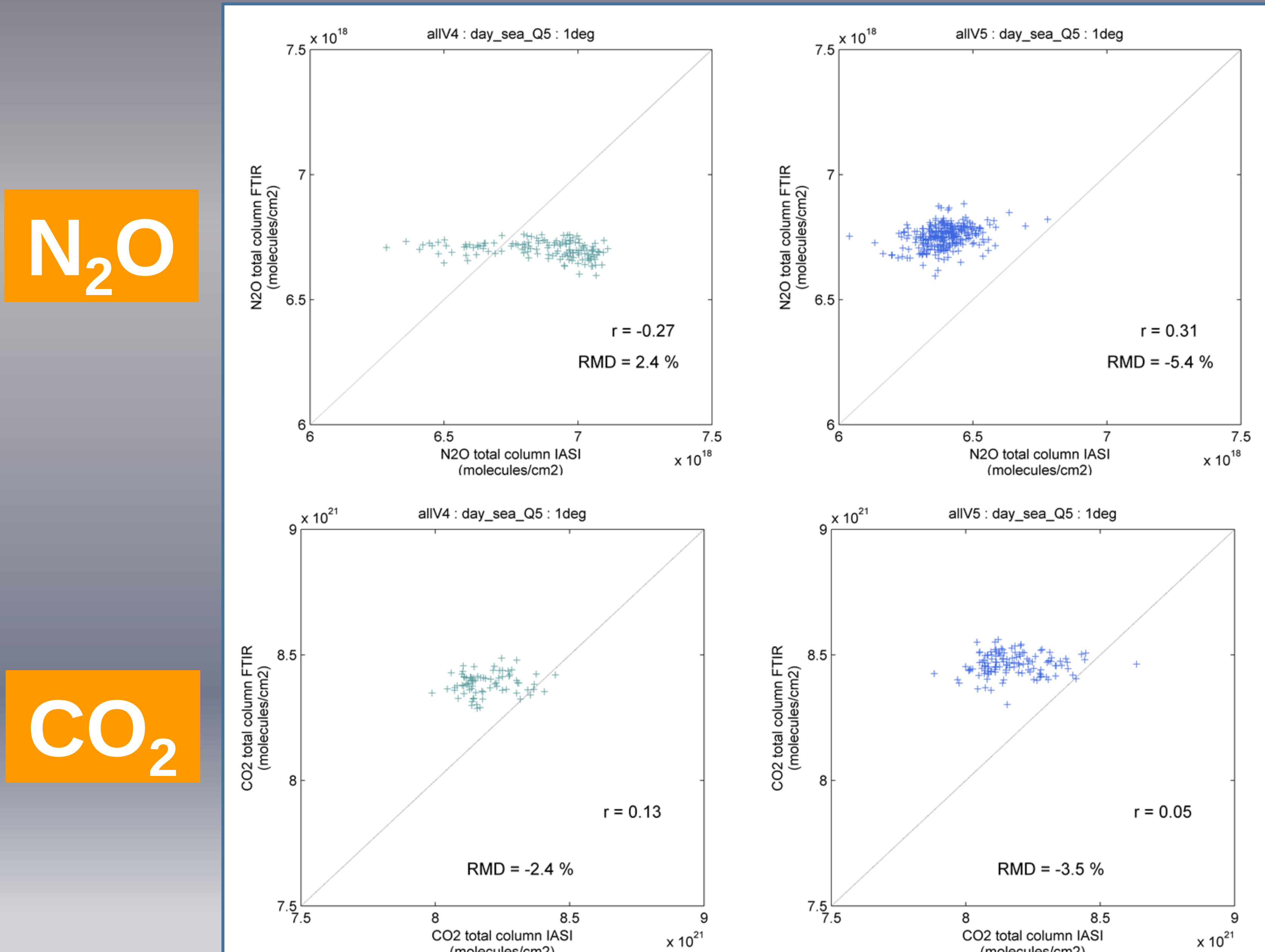
v4


allV4 : day_sea_Q5 : 1deg
x 10^19
CH4 total column FTIR (molecules/cm2)
CH4 total column IASI (molecules/cm2)
r = -0.35
RMD = -3.8 %

v5


allV5 : day_sea_Q5 : 1deg
x 10^19
CH4 total column FTIR (molecules/cm2)
CH4 total column IASI (molecules/cm2)
r = 0.39
RMD = 0.3 %

v4 v5



N_2O
CO_2
allV4 : day_sea_Q5 : 1deg
N2O total column FTIR (molecules/cm2)
N2O total column IASI (molecules/cm2)
r = -0.27
RMD = 2.4 %
allV5 : day_sea_Q5 : 1deg
r = 0.31
RMD = -5.4 %
CO2 total column FTIR (molecules/cm2)
CO2 total column IASI (molecules/cm2)
r = 0.13
RMD = -2.4 %
r = 0.05
RMD = -3.5 %

Summary on v4 / v5

		O_3	CO	CH_4	N_2O	CO_2	
v4		0.62	0.67	-0.35	-0.27	0.13	
v5		0.92	0.78	0.39	0.31	0.05	

1 deg box around IZO (center)
temp colloc. : daily mean

Following studies for v5 data:
different spatial colloc. (1 deg south, 0.5 deg)
temp colloc. : **± 1h** IASI overpass

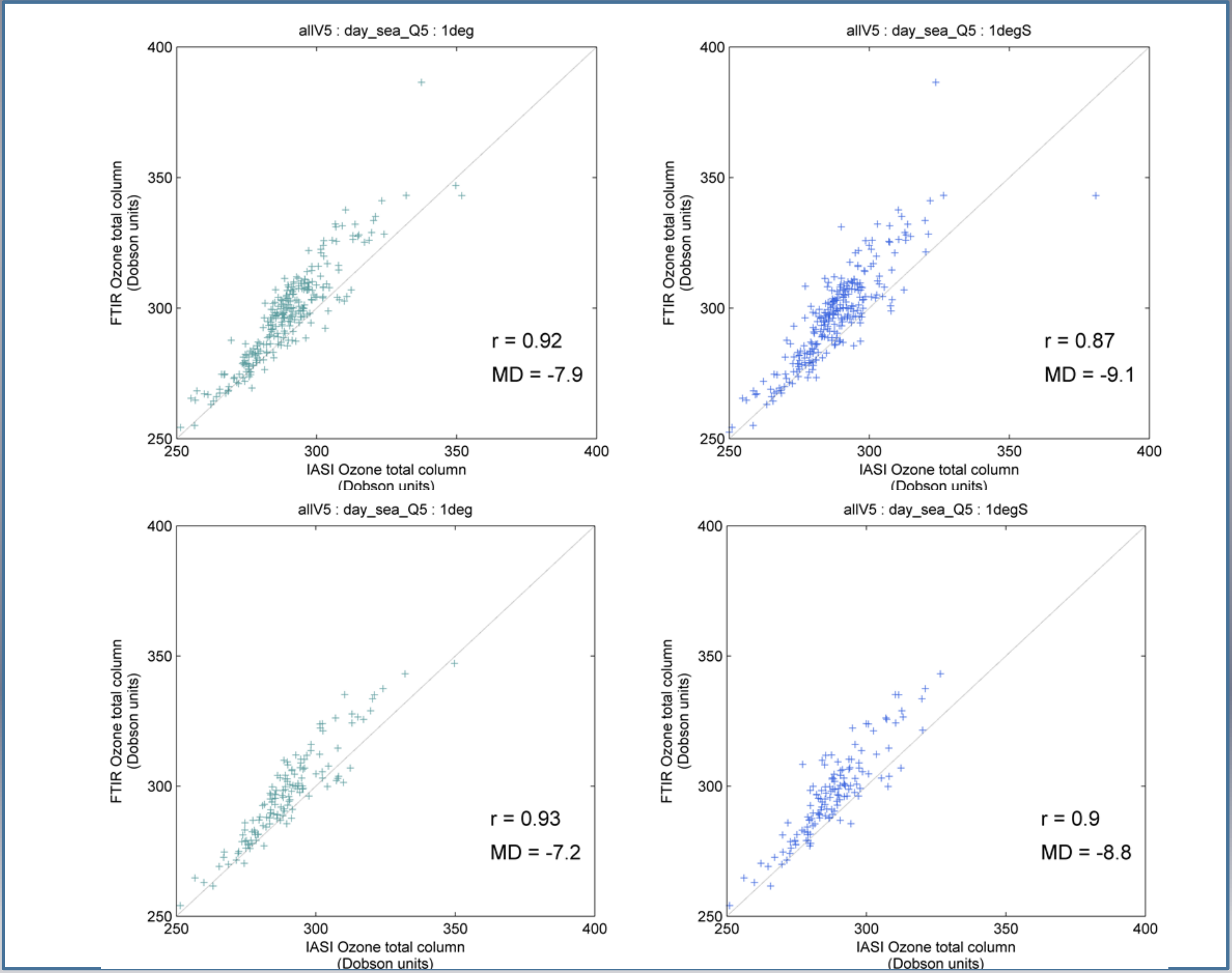
O_3

1deg

1deg S

Daily mean

± 1 h



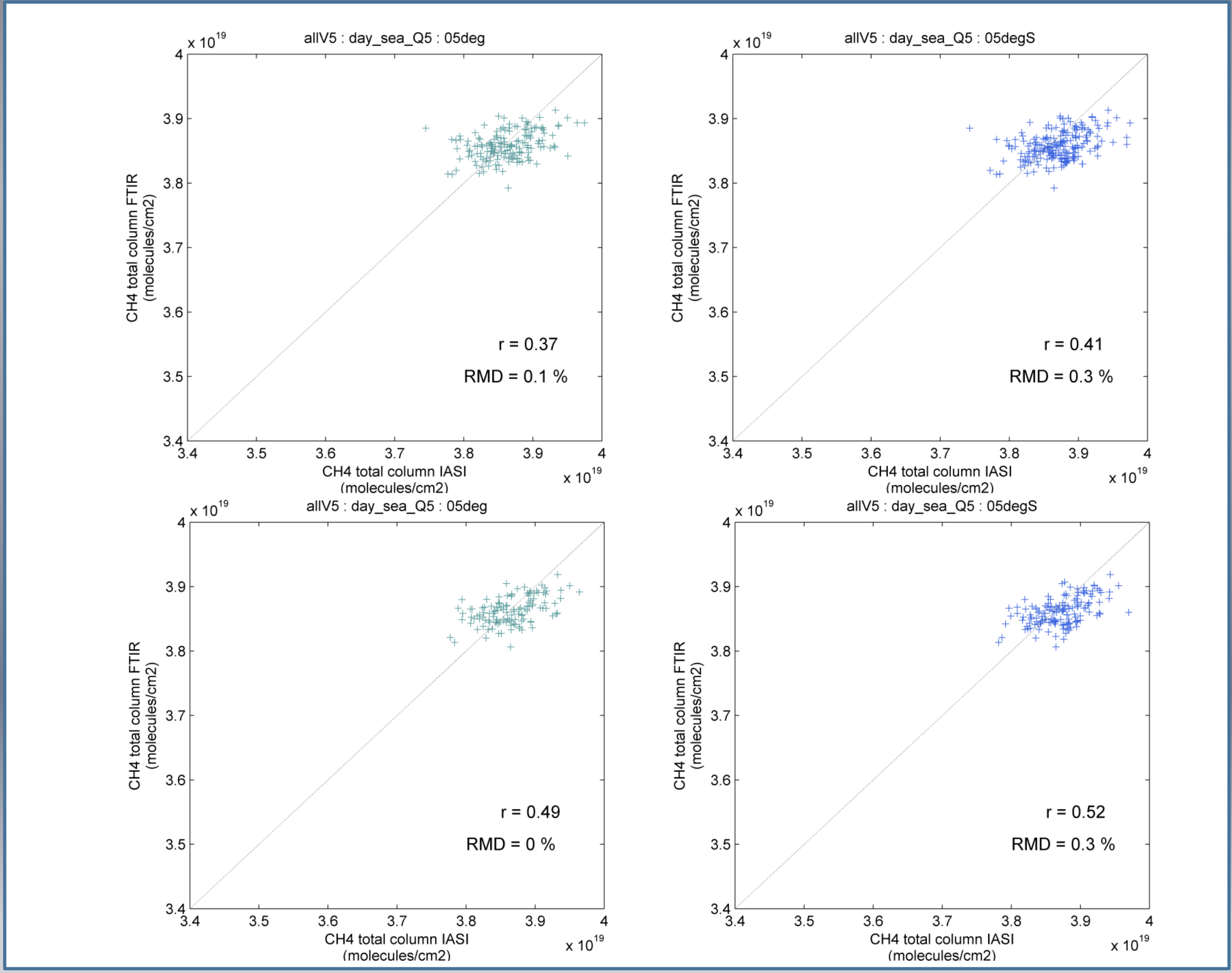
CH_4

0.5deg

0.5deg S

Daily mean

± 1 h

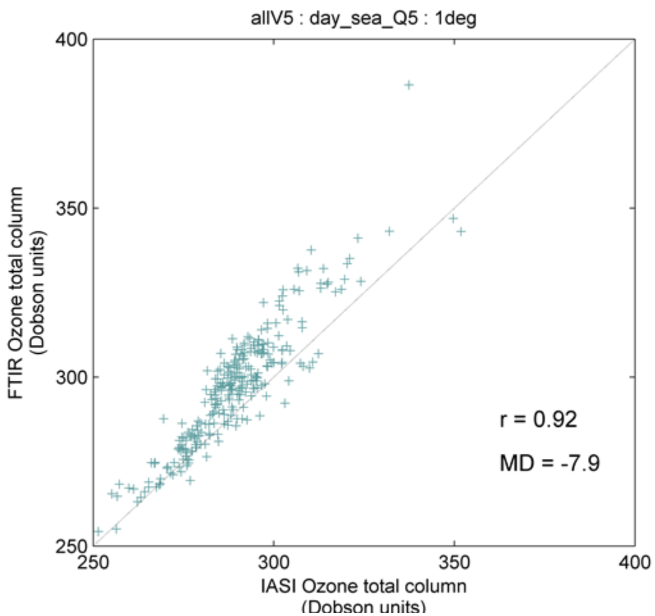


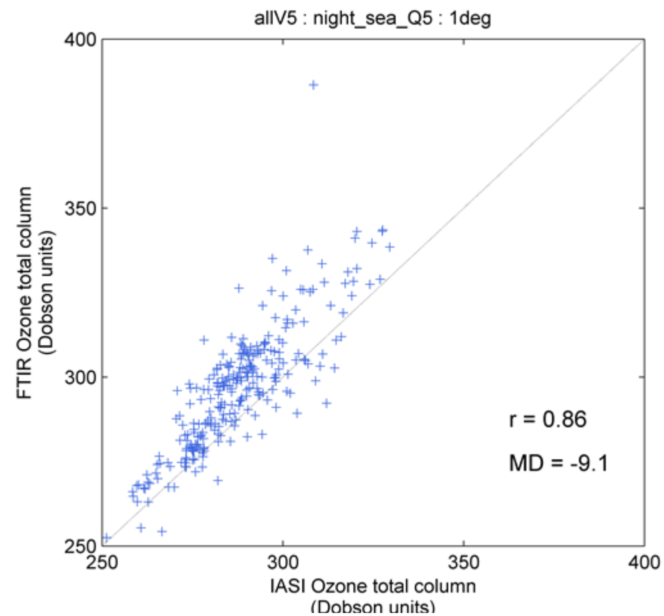
Summary on collocation

	O_3	CO	CH_4	N_2O	CO_2
1deg	0.92	0.78	0.39	0.31	0.05
1deg, t	**0.93**	**0.82**	0.44	0.34	0.15
1degS	0.87	0.74	0.39	0.32	0.07
1degS, t	0.9	0.8	0.44	0.39	0.21
0.5deg	0.93	0.8	0.37	0.25	0.12
0.5deg, t	**0.94**	**0.82**	0.49	0.34	**0.23**
0.5degS	0.92	0.78	0.41	0.38	0.08
0.5degS, t	0.93	0.8	**0.52**	**0.46**	0.16

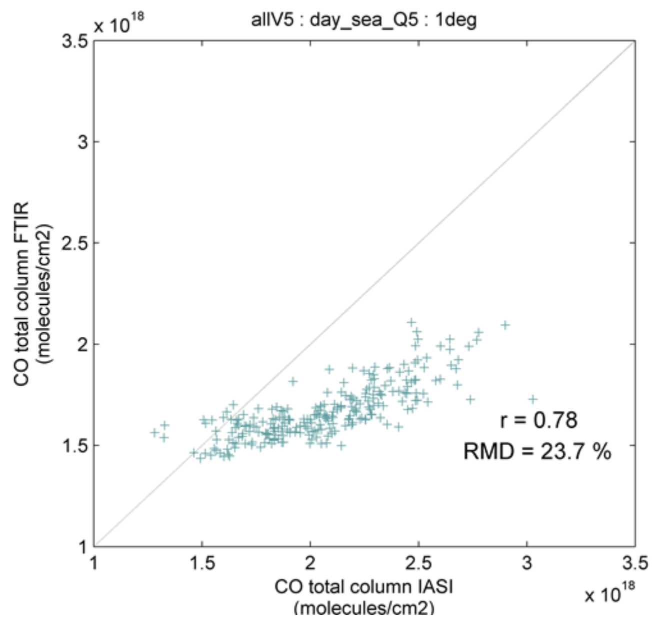
day **night**

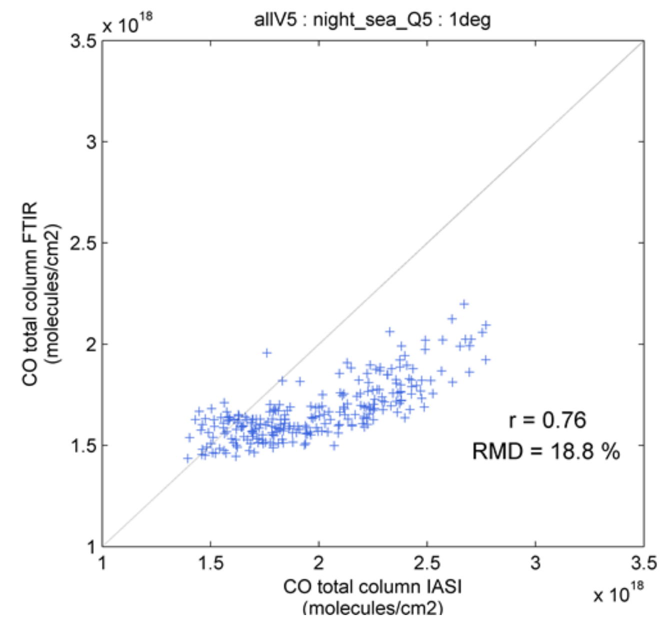
O_3

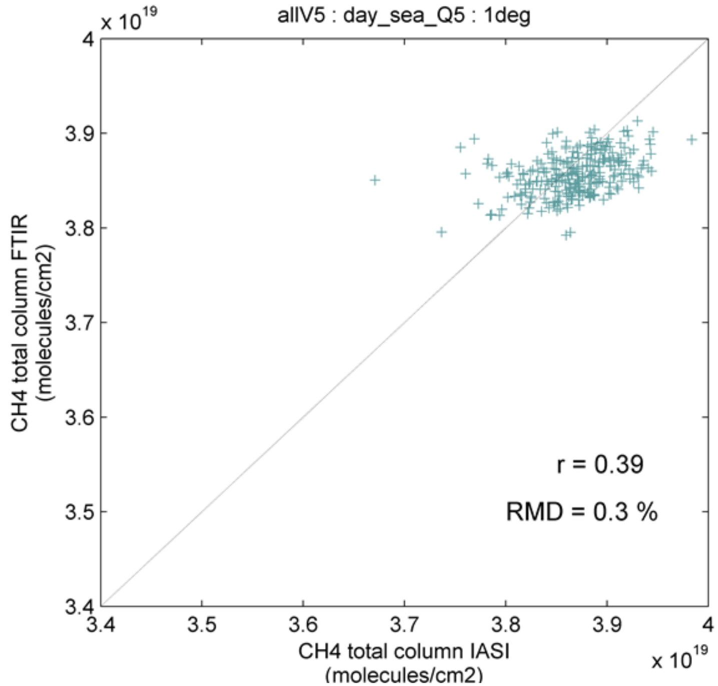


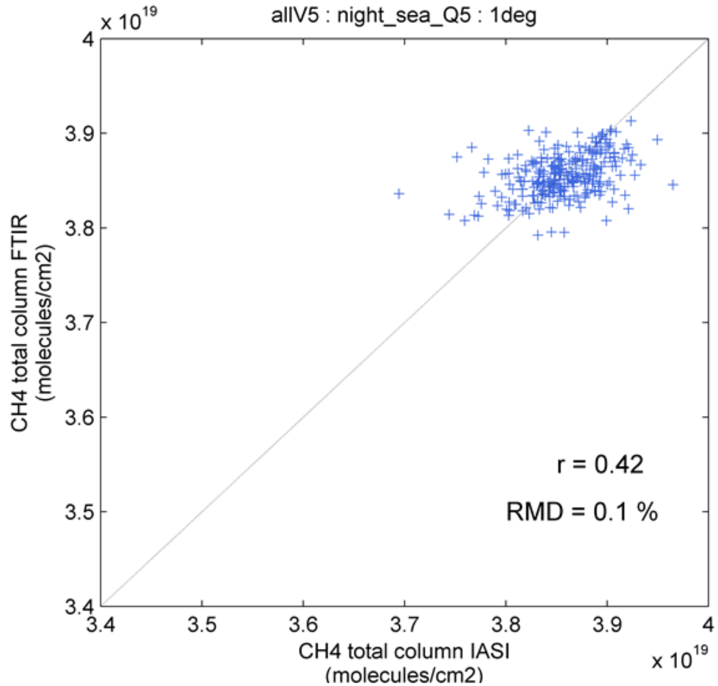


CO









Summary on day night

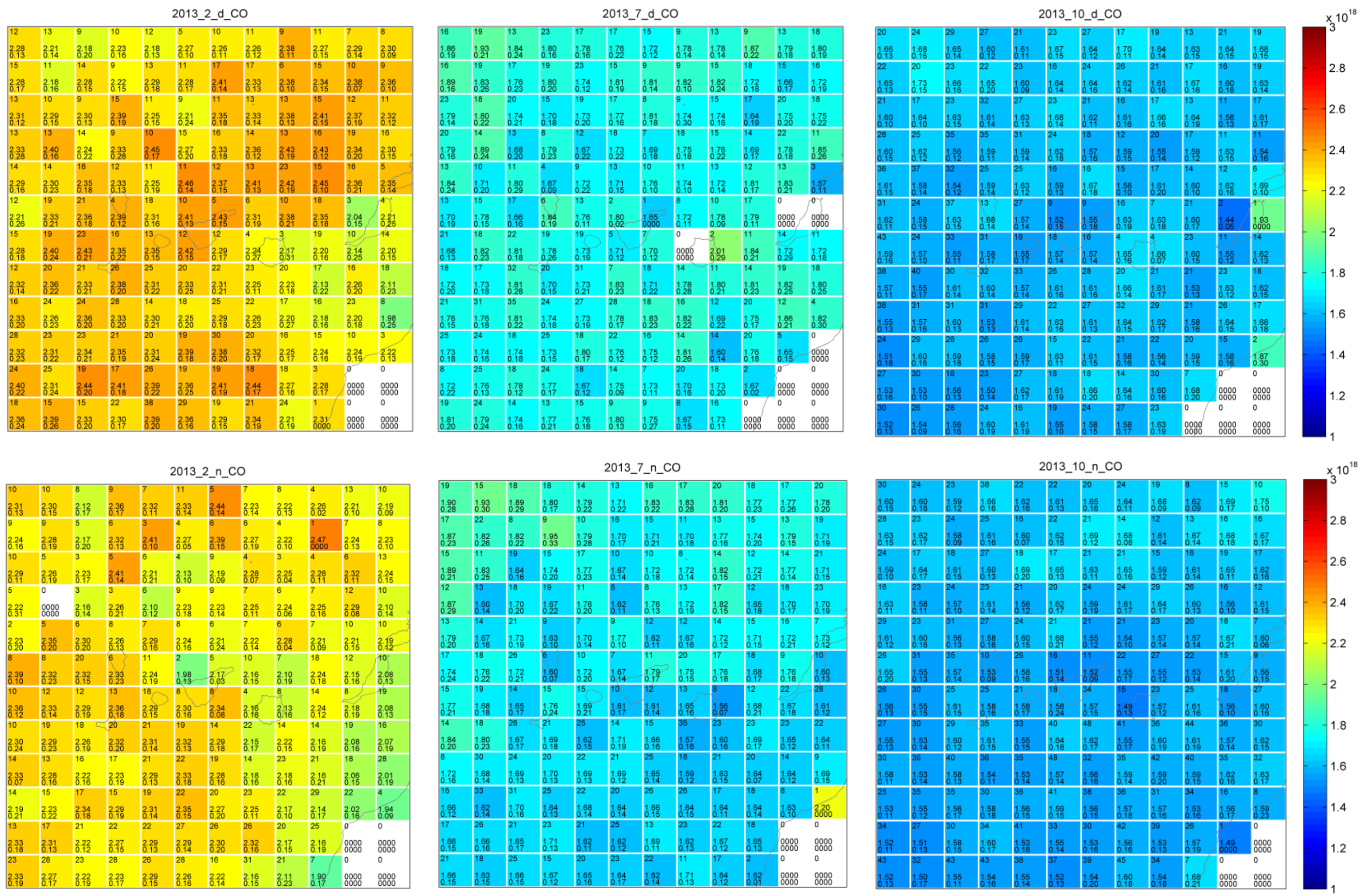
	O_3	CO	CH_4	N_2O	CO_2
day	0.92	0.78	0.39	0.30	0.05
night	0.86	0.76	0.42	0.36	0.15

CO

IASI day night

day

night



Feb Jul Oct

O_3

IASI day night

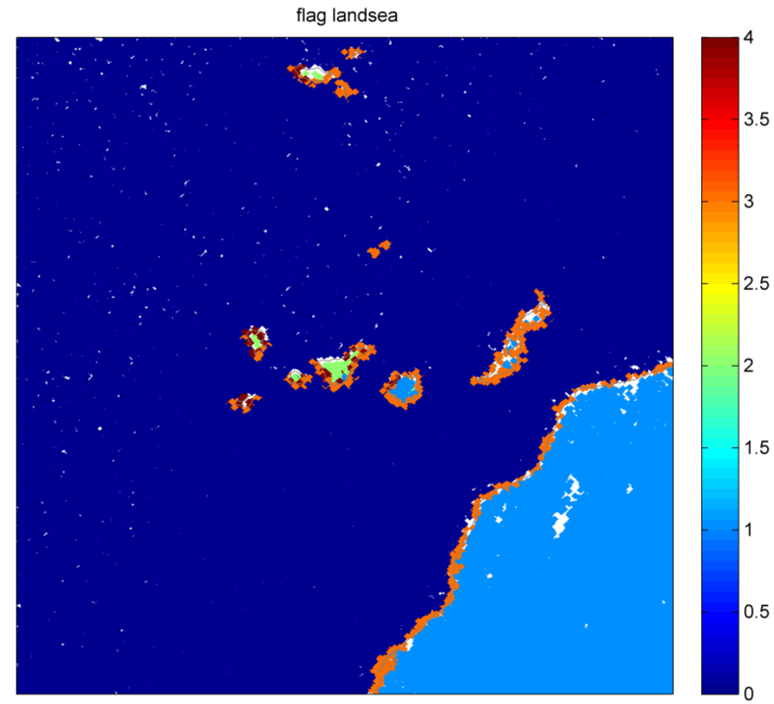
day

night

Feb Jul Oct

Land - sea

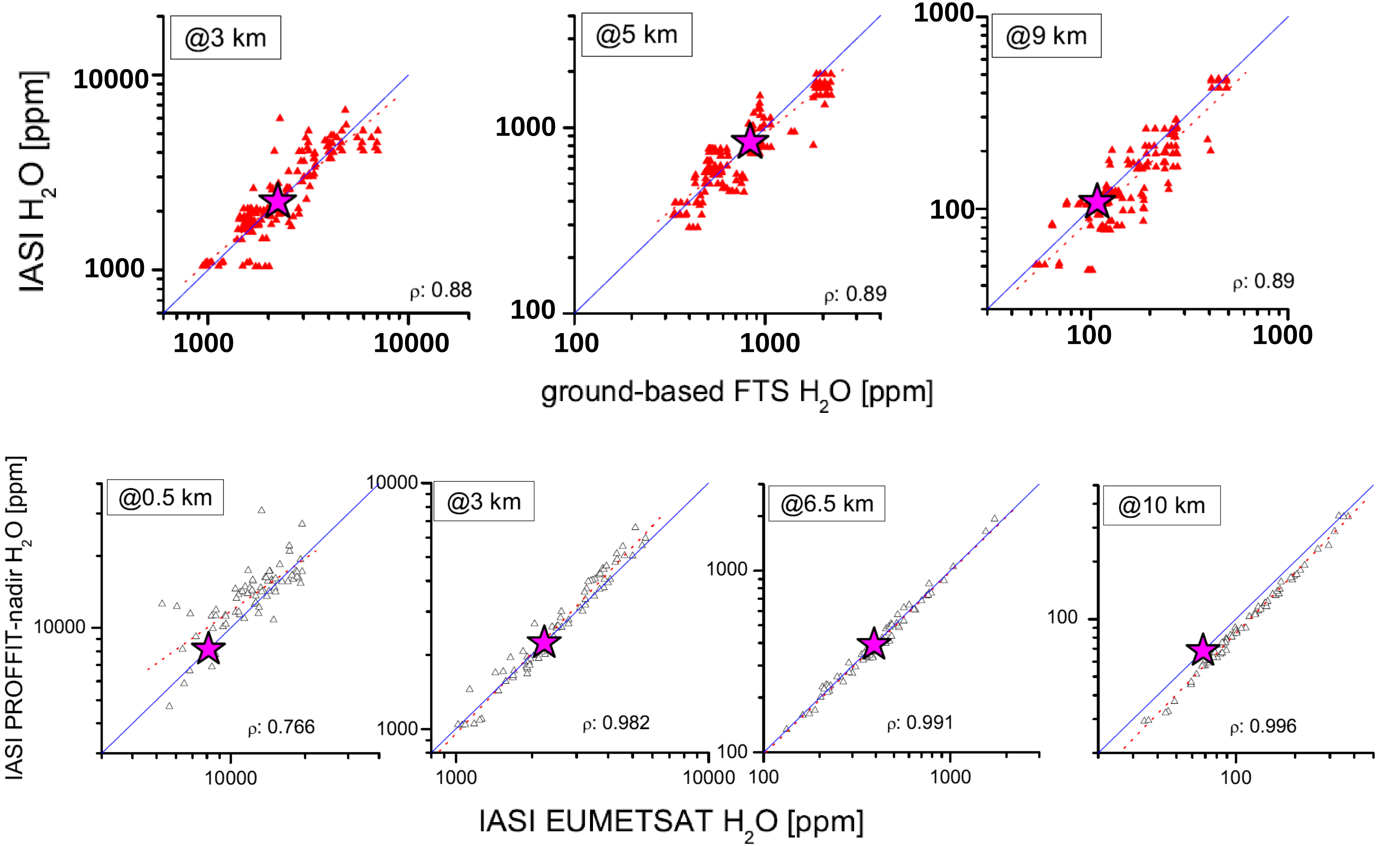
	O_3	CO	CH_4	N_2O	CO_2
sea	0.92	0.78	0.39	0.30	0.05
land	0.84	0.71	0.06	0.07	0.46



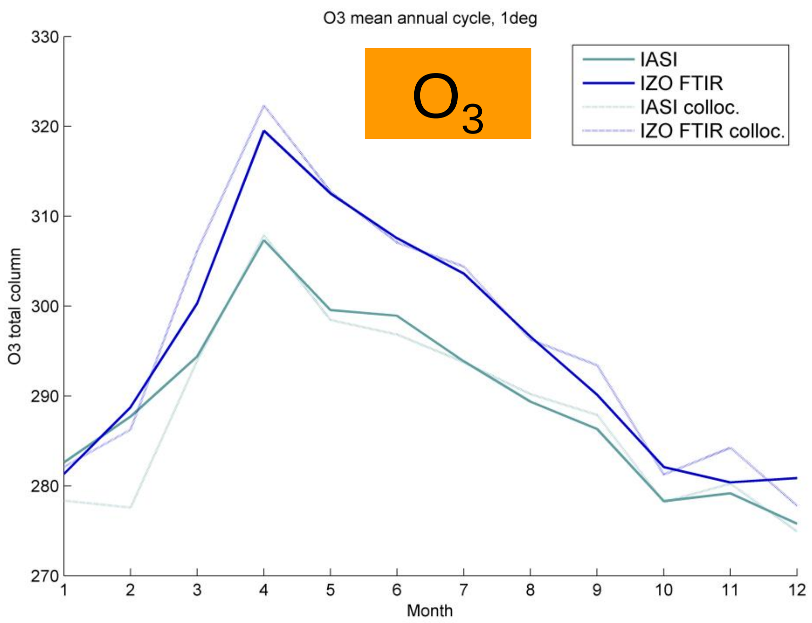
0	The IASI IFOV is completely covered by water
1	The IASI IFOV is completely covered by land, the variability of the surface topography is low
2	The IASI IFOV is completely covered by land, the variability of the surface topography is high
3	The IASI IFOV covers land and water, the variability of the surface topography is low
4	The IASI IFOV covers land and water, the variability of the surface topography is high

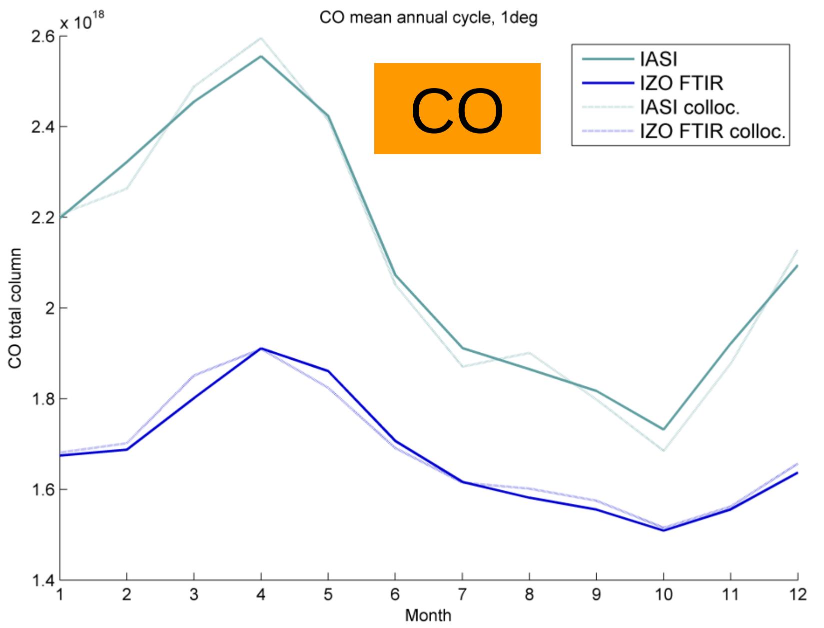
H_2O profiles

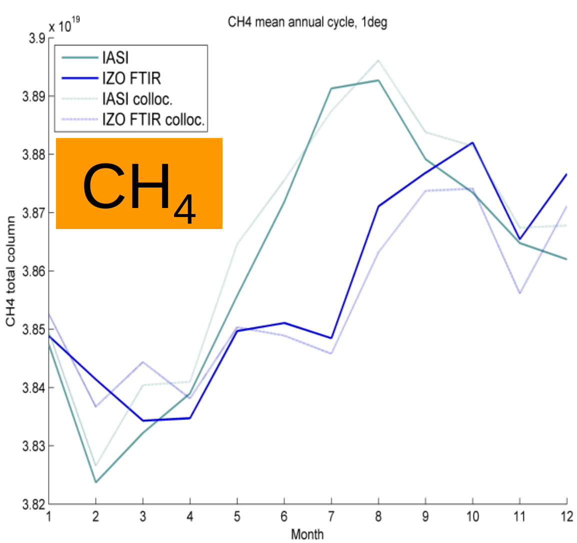
Schneider and Hase, ACP, 2011

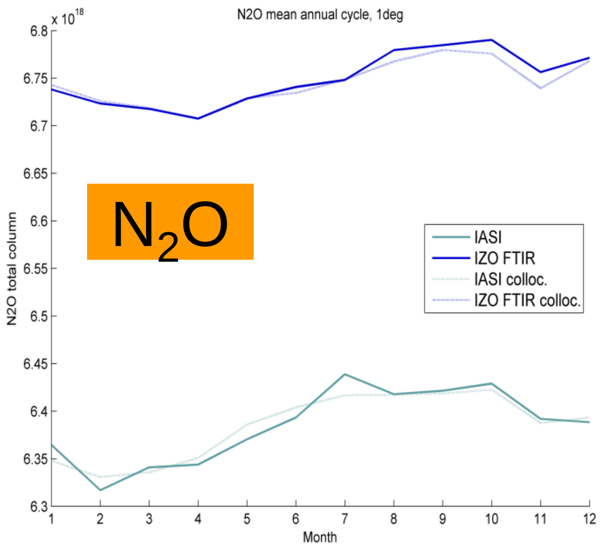


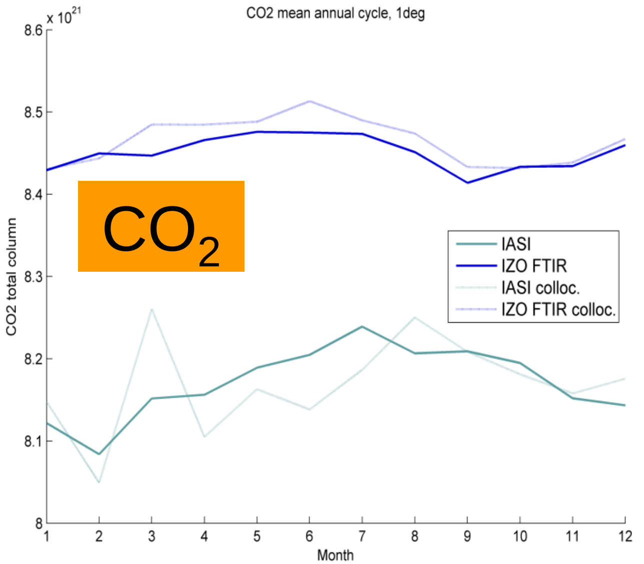
Annual cycles





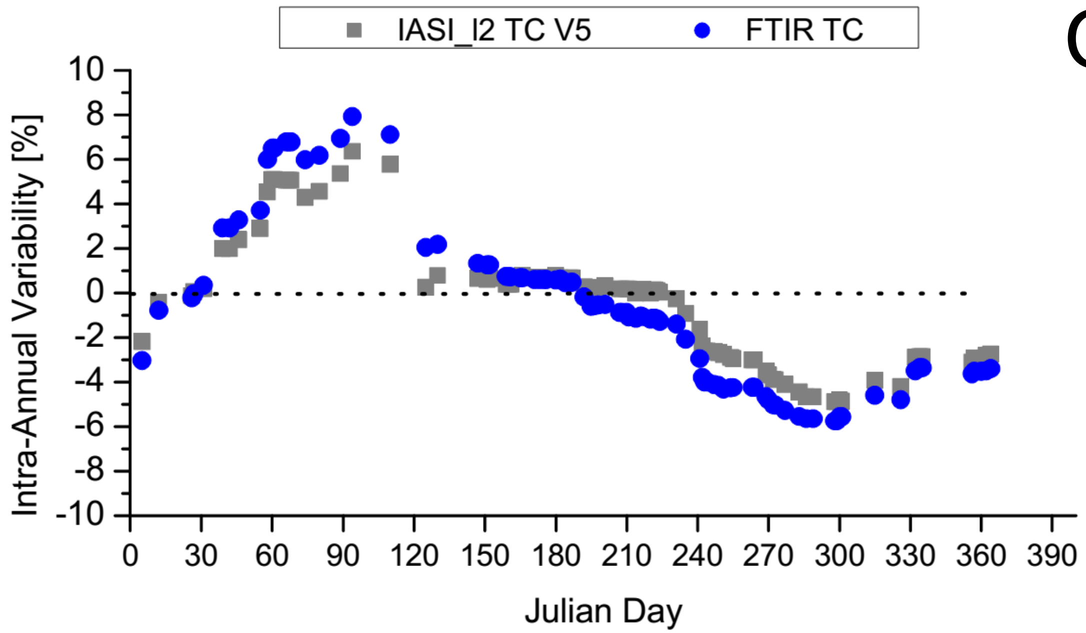






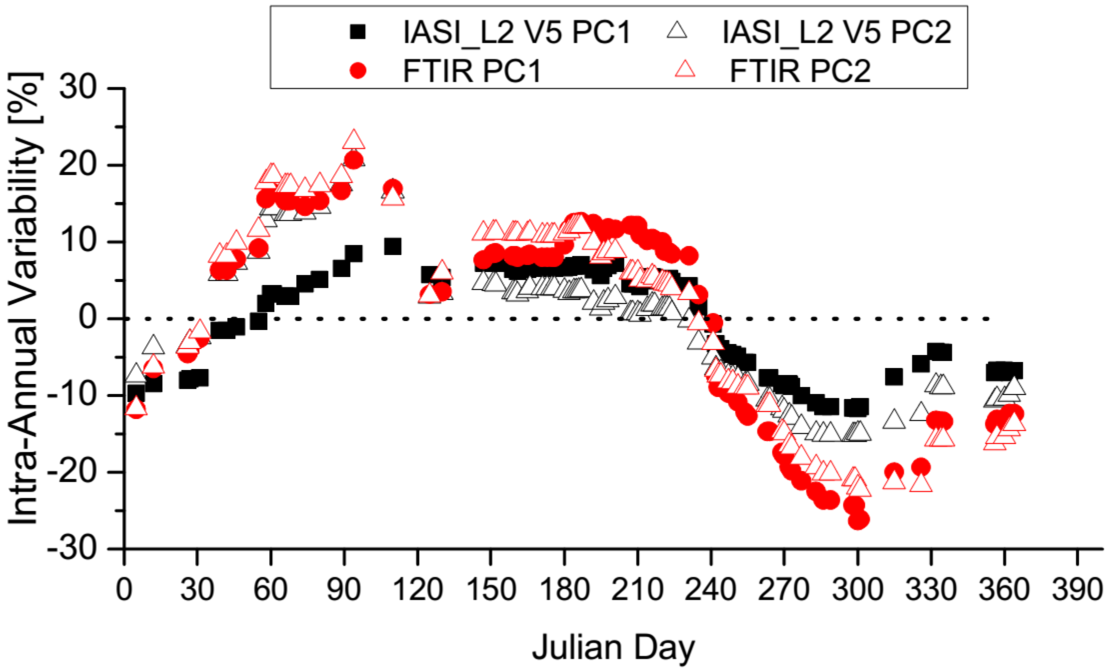
O_3, only v5

Detrended



PC1: ~6-12km

PC2: ~6-16km



García et al., 2013

Summary

Summary

- Natural variability
- collocation criteria
- Temporal: FTIR unc.
- Spatial: FTIR probed airmasses and var. IASI observations

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- Large: O_3, CO, mod.: CH_4
  Low for N_2O and CO_2


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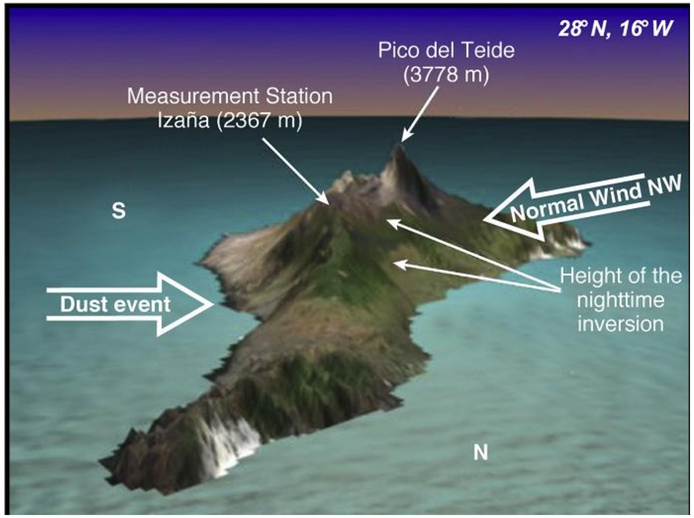
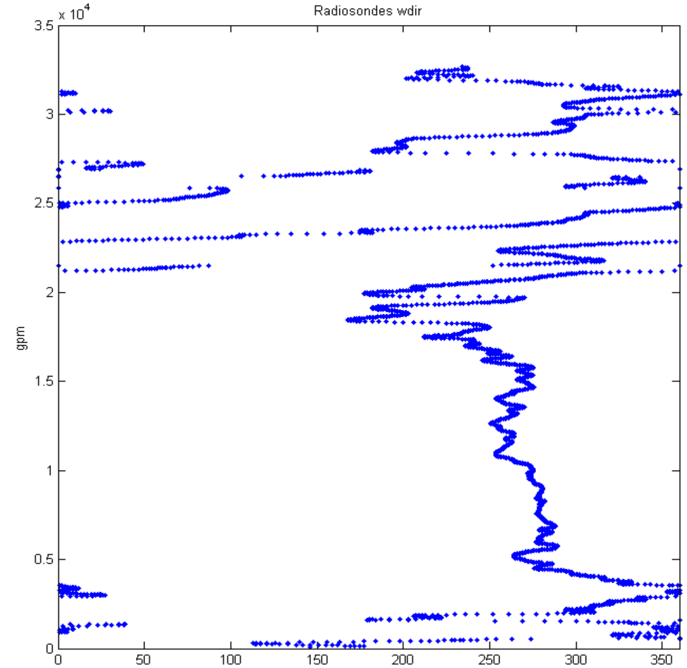
- day night : slight diff.
- land pixel : surf. alt. too var.
- Annual cycle: good agreement for O_3 and CO
- Agreement but also discr. for CH_4, N_2O and CO_2

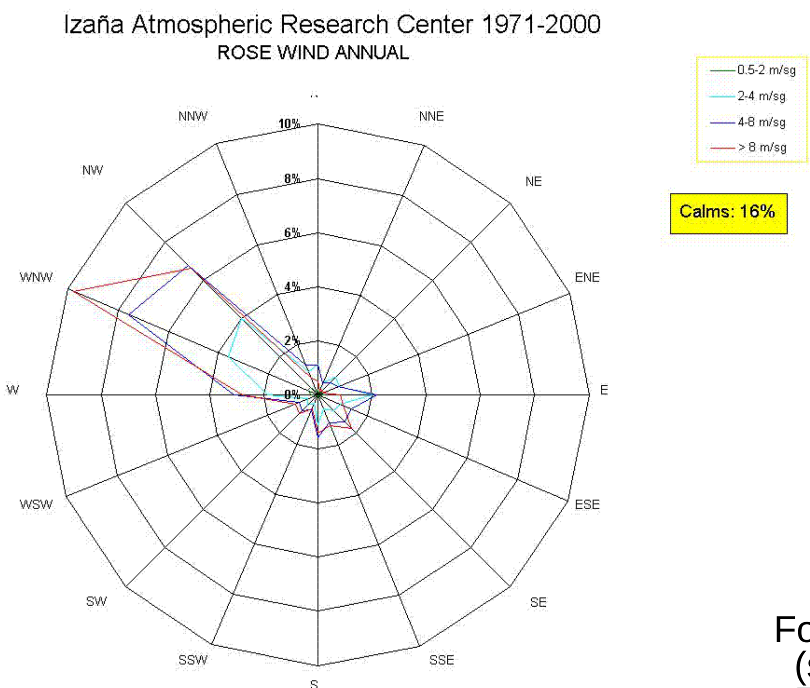
Outlook

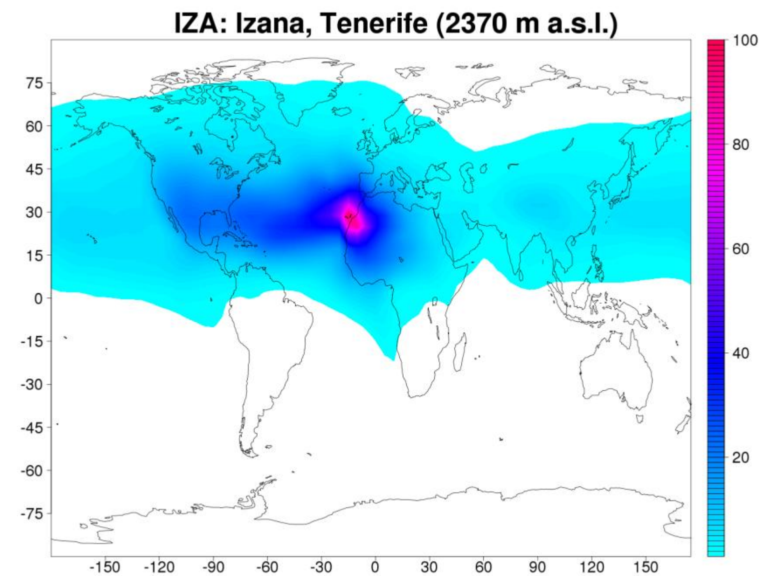
- Version 6 data : profiles for O_3 and CO,
  + AK, interpretaion of discrepancies
  → part.col. below IZO
  more data: retrieval for 2x pixels
- Land data: high resolution info on topography
- Transport: windspeed,-direction, Trajectories
- IASI-B, collocation criteria, outliers for IASI
- Include FTIR - stations at Karlsruhe and Kiruna
- T profiles

Winddirection









Footprint of source region for airmasses above IARC (shown are probabilities in %). Courtesy of Dr. Dietrich Feist, MPI for Biogeochemistry, Jena, Germany.