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

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= Validation of IASI level 2 products







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)

TIT



Inversion layer





Outline

- 1. VALIASI
- 2. IZO, GB-FTIR, further Measurements at IZO
- 3. IASI, comparison to FTIR
- 4. Molecules, natural variability
- 5. Collocation
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Measurements, main building, Measurement-Tower, vicinity



Garcia et al., 2012

IZAÑA Observatory (and vicinity): measurements relevant for VALIASI

<u>GPS</u>: H₂O total column

(ERGNSS network: IARC, and four additional sites (three Tenerife and one La Palma)

<u>ECC sondes:</u> O₃-, Hr-, T-, p-profile, u,v

1/ week (Wednesday)
 2010: simultaneous launches south and north of the Izaña Observatory → spatial inhomogeneity

- <u>Radio sondes:</u> p-, T-, Hr-profile, windspeed and direction 2/day, 11:00 and 23:00
- Brewer: O₃ total column, calibration center for Europe
- <u>GAW In Situ</u> CO, CH₄, N₂O Gas chromatography, CO₂ IR

(July 2011: IZO + Teide Observatory and the Roque de los Muchachos Observatory, La Palma, Summer 2012: Flight campaigns \rightarrow vertical profile)

+ FTIR : H₂O, O₃, CO₂, CH₄, N₂O, CO, T

GB FTIR at Izana Observatory





vmr profiles of: O_3 , CO, CH₄, N₂O, H₂O, CO₂,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, O₃ Sondes, GAW Comprehensive error analysis High precision

GB FTIR Retrievals

	Projects	Referen ces	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%)
CH₄	NDACC	Sepulveda et al., 2012, 2013	~ 2600,2800 2900 cm ⁻¹	2.5	0.97% / (0.9%)
H ₂ O	NDACC MUSICA	Schneider et al., 2010, 2012	~ 2600 - 3000 cm ⁻¹	3-4	Total column: 1% profiles: ~15% (<1%)
N ₂ O	NDACC		~ 2500 cm ⁻¹	2.5	(~1%)

in situ GAW

Data from: Angel Gomez Pelaez







FTIR - Brewer



Datasets for IASI validation





- Infrared Atmospheric Sounding Interferometer
- Fourier transform spectrometer with high resolution between 645 and 2760 cm $^{-1}$ (3.6 μm to 15.5 $\mu m)$
- 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.



	H ₂ O	O ₃	СО	CH₄	N ₂ O	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

sat zenith angle





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

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

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 μ m)
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
- O₃, H₂O 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 ₂ O	O ₃	СО	CH4	N ₂ O	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

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Molecules



	H ₂ O	СО	O ₃	CO ₂	CH ₄	N ₂ O
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

IASI maps

2013	1 d	O3	DU
_		_	_

13	11	8	9	5	9	5	10	15	14	20	27		350	
280.5 17.0	282.2 15.2	281.7 17.2	279.9 20.6	273.7 10.7	277.7 15.6	271.3 15.0	269.5 7.66	267.7 4.24	272.2 9.81	273.7 19.6	277.4 15.7			
6	10	11	13	6	10	11	13	28	16	18	26			
270.3 17.5	280.4 12.9	278.2 10.7	270.0 20.6	285.9 8.77	277.1 15.5	276.5 9.12	272.3 8.69	274.3 11.6	275.4 10.3	265.4 13.3	278.4 16.2			
10	4	10	15	9	11	16	18	15	16	14	20			
280.6 11.9	278.0 8.17	278.2 10.9	279.1 14.1	277.9 16.6	273.0 13.5	273.6 12.7	272.3 15.3	273.3 11.3	265.1 10.4	269.4 11.3	269.2 16.2			
7	9	24	9	15	11	7	21	16	18	20	19			<u> </u>
282.6 17.9	271.0 16.5	267.3 17.8	273.0 16.1	266.2 10.9	275.7 19.8	267.5 19.4	266.3 11.5	266.0 11.6	266.4 11.7	262.6 13.8	268.3 17.7	۹.	200	Ĩ
22	28	31	13	19	16	15	16	20	26	20	10		- 300	
268.5 17.8	268.3 16.7	269.5 18.7	276.3 15.7	265.4 18.7	264.8 20.5	260.8 16.4	262.9 15.1	265.2 17.3	265.7 19.3	268.0 17.4	267.0 19.0			\overline{O}
21	30	36	12	27	16	11	24	24	18	17	5 mg			O
274.8 18.6	271.3 17.3	268.3 19.7	271.1 16.6	273.1 22.2	261.7 19.2	271.1	267.0 16.4	262.4 14.3	264.2 13.2	265.9 14.1	265.8 10.9			ສ
19	27	28	32	22	22	21	14	20	29	12	15			ō.
266.3 15.1	269.1 11.4	267.6 14.6	262.6 18.7	268.2 15.9	268.5 16.4	265.6 16.7	269.9 15.2	266.0 1,3.6	263.1 15.0	266.0 12.3	260.5 10.2			F
21	25	19 🗅	29	32	28	37	34	30	29	24	25			ဂိ
266.7 13.7	269.9 14.6	270.2 14.4	271.0 16.0	267.6 13.6	263.8 14.1	268.3 14.0	270.5 17.8	266.0 13.9	267.0 16.9	263.2 14.9	262.8 11.7		050	U
25	18	24	35	25	23	24	21	26	22	34	27		250	
264.8 13.1	267.0 13.9	272.9 11.8	268.7 16.8	269.1 14.7	259.6 12.5	269.0 11.1	265.7 12.4	259.8 12.6	259.4 13.0	268.3 13.2	266.8 12.6			
20	31	23	29	20	24	31	28	27	23	21	4			
267.2 11.0	264.1 13.2	260.7 14.4	263.9 13.4	262.4 12.0	262.5 10.9	264.6 11.0	259.5 11.7	262.8 12.0	258.7 13.1	267.4 14.3	266.9 11.1			
26	24	25	23	30	29	27	30	24	16	Ø	0			
260.1 13.1	260.7 15.8	261.1 13.4	262.4 14.9	260.4 12.8	261.0 13.2	259.9 10.6	258.9 10.6	261.3 11.1	262.3 9.22	000.0	000.0 0000			
27	28	23	25	28	21	31	34	34	4	0	0			
260.4 13.4	261.4 16.1	255.9 12.2	258.3 12.1	259.6 13.2	258.9 11.9	263.0 13.4	263.4 12.9	266.1 10.7	270.7 10,0	000.0 0000	000.0 0000		200	

(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:

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

FTIR measurements throughout the day can differ significantly to those at IASI overpass time (10-12h)

ntraday variability (%)

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

$CO_2 CH_4 N_2 O$:

almost no diurnal variation

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

 \rightarrow 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

Summary: collocation

	H ₂ O	O ₃	СО	CH ₄	N ₂ O	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 CH₄, N₂O, H₂O, (CO₂)
- 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 \rightarrow IZO: 400 cloud free \rightarrow IASI: 300 colloc. days (180 for 0.5 deg)

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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: O₃, CO, CH₄, N₂O, CO₂
Profiles H₂O, partial columns: O₃

JASJ v4 / v5

CO

Summary on v4 / v5

	O ₃	CO	CH ₄	N ₂ O	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

0.5deg S

0.5deg

Daily mean

Summary on collocation

	0 ₃	CO	CH ₄	N ₂ O	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

CO

Summary on day night

	O ₃	CO	CH ₄	N ₂ O	CO ₂
day	0.92	0.78	0.39	0.30	0.05
night	0.86	0.76	0.42	0.36	0.15

IASI day night

2013_7_d_CO

1.81 1.74 1.74 1.64 0.18 0.30 0.16 0.19

1.69 1.75 1.76 1.69 1.78 0.18 0.18 0.22 0.17 0.18

1.76

1.74 1.72

0000

2.01 1.84 0.29 0.21

1.78 1.83 1.82 1.69 1.75 1.86 1.82 0.17 0.23 0.22 0.22 0.17 0.21 0.30

1.81 0.23

1.78 1.87 1.79 1.80 0.14 0.22 0.18 0.19

> 1.66 1.72 0.17 0.19

> > 8888

1.75

0000

1.82 1.80 0.25 0.25

1.76 1.72 1.78 0.22 0.12 0.14

1.77

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1.71 1.70

1.83 1.71 1.78 1.80 0.23 0.22 0.28 0.21

1.73

1.74 1.73 0.18 0.19

1.78

1.74 1.81 1.81 1.82 1.82 1.72 0.12 0.19 0.14 0.10 0.24 0.18

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2.32	2.36	2.33	2.38	2.31	2.33	2.31	2.25	2.23	2.13	2.26	2.11
16	24	24	28	14	18	25	22	17	16	23	8
2.33	2.26	2.36	2.33	2.30	2 25	2.29	2.26	2.20	2.18	2.20	1.98
28	23	23	21	20	19	30	20	16	15	10	3
2.32	2.31	2.34	2.35	2.31	2.39	2.38	2.32	2.25	2.24	2.24	2.22
24	25	19	17	26	19	19	18	18	3	0	0
2.40	2.31 0.24	2.44 0.20	2.41 0.18	2.39	2.36	2.41 0.19	2.44	2.27	2.28 0.17	0000	0000
18	15	15	22	38	29	19	21	24	1 /	0	0
2.36 0.24	2.39 0.26	2.33 0.20	2.30 0.17	2.39 0.20	2.36 0.16	2.29 0.15	2.34 0.19	2.21 0.19	2.31	0000	0000
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					2013_	2_n_C	0				
10	10	8	9	7	11	5	7	8	4	13	10
0.13	0.15	0.17	0.17	0.11	0.14	0.14	0.14	0.13	0.02	0.10	0.09
9	9	5	6	3	4	6	6	4	1	í	8
2.24 0.16	0.19	0.20	0.13	0.10	0.05	0.15	0.19	0.10	0000	0.13	0.10
10	5	3	5	6	4	9	4.	3	4	6	13
0.11	0.19	0.17	0.14	0.21	0.10	0.09	0.07	0.04	0.11	0.11	0.15
5	00000	3	3	5	9	9	0.05	0.04	0.05	12	10
<u>5.31</u>	0000	0.14	0.21	0.12	0.18	0.14	0.11	0.06	0.16	0.08	0.14
2 23	2 25	2 30	0	2 20	2.24	2 21	2.22	2.28	2.21	2.21	2.10
0.20	0.20	0.20	0.13	0.16	0.16	0.24	0.14	0.04	0.09	0.15	0.42
2 20	2 22	2 22	222	2.24	1.09	217	2.16	2 10	2.24	2.15	2.09
0.10	0.23	0.15	0.23	0.19	0.13	0.03	0.15	0.19	0.18	0.16	0,13
2.36	2.33	2.29	2.36	2.29	2.30	2.34	2.16	2 13	2.24	2.18	2.08
0.12	0.14	0.19	0.18	0.15	0.16	0.08	0.18	0.16	0.12	0.19	0.13
2.30	2.29	2.26	2.32	2.31	2.32	2.29	2.15	2.22	2.16	2.08	2.07
0.24 14	0.23	0.19	0.20	0.14	0.13	0.18	0.17	0.15	0.19	0.16	0.19
2.33	2.28	2.22	2.23	2.29	2.33	2.28	2.18	2.18	2.16	2.06	2.01
0.07	0.16	0.16	0.19	0.13	0.18	0.16	0.16	0.16	0.21	0.15	0.19
2.19	2.23	2.34	2.29	2.31	2.35	2.27	2.25	2.17	2.14	2.02	1.94
0.21 13	0.22	0.18	0.19	0.14	0.15	26	0.11	0.10	0.17 25	0.16	0.09
2.33	2.31	2.22	2.27	2.29	2.29	2.30	2.32	2.17	2.16	0000	0000
0.18 23	28	23	28	26	28	0.20	31	21	7	0000	0000
2.33	2.27	2.22	2.23	2.29	2.26	2.22	2.16	2.11	1.90	0000	0000
0.19	0.17	0.19	0.17	0.15	0.16	0.14	0.15	0.23	0.1/7	0000	0000

Feb

2013_2_d_CO

2.27

2.27 2.33 2.36 2.43 0.20 0.18 0.12 0.19

2.25 0.15 0.24

2.25 0.19

2.31 2.41 0.16 0.13

2.35 2.42

2.35

2.26 2.26 2.38 2.27 2.29 2.30 0.11 0.12 0.11 0.15 0.14 0.09

2.35 2.33 2.38 0.18 0.14 0.13

2.43 2.31 2.38 0.15 0.19 0.21

2.29 2.24 0.17 0.27 2.42 2.45

2.35 0.18

3 19 2.17 2.20 0.31 0.16 2.04 2.21 0.15 0.25

2.14 2.20 0.25 0.15

2.41

2.36

2.32

2.30

2.21 2.18 2.23 2.18 0.14 0.20 0.16 0.13

2.18 2.28 2.22 2.29 2.28 2.41 2.33 2.38 2.34 0.16 0.15 0.15 0.18 0.17 0.14 0.13 0.10 0.15

2.40

0.18	0.16	0.18	0.15	0.17	0.12	0.12	0.26	0.14	0.18	0.15	
8	25	18	24	18	14	1	20	18	2	ľ	
1.72 0.22	1.76 0.13	1.78 0.12	1.77 0.17	1.67 0.12	1.75 0.09	1.73	1.70	1.73	1.67	0000	
19	24	14	13	15	9	9	8	16	• /	0	
1.81 0.20	1.79 0.24	1.74 0.16	1.77 0.21	1.76 0.18	1.80 0.13	1.75 0.27	1.67 0.15	1.73	0000	0000	
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19	15	18	18	14	13	16	17	20	18	17	
1.90 0.28	1.93 0.30	1.89	1.80	1.79 0.22	1.71	1.83 0.22	1.83	1.81 0.20	1.77 0.23	1.77 0.26	
17	22	8	9	10	16	15	11	13	15	13	
1.87 0.23	1.82 0.26	1.82 0.22	1.95 0.33	1.79 0.28	1.70	1.71 0.21	1.70 0.18	1.77 0.16	1.74 0.20	1.79 0.15	
15	11	19	15	17	10	10	8.	14	12	14	
1.89 0.21	1.83 0.25	1.64 0.16	1.74	1.77 0.23	1.67 0.14	1.72 0.18	1.72 0.14	1.82 0.15	1.72 0.21	1.77 0.14	
12	13	18	19	11	8	8	13	17	12	18	
1.87 0.29	1.60 0.14	1.70 0.20	1.67 0.22	1.76 0.20	1.62	1.76 0.13	1.72 0.19	1.82 0.15	1.65	1.70 0.17	
13	14	21	9	7	9	12	12	14	15	16	
1.79	1.67	1.73	1.63	1.70	1.77	1.62	1.67	1.72	1.71	1.72	
17	18	26	6	10	7	11	20	17	18	9	
1.74	1.76	1.72	1.60	1.72	1.67	0.17	1.75	1.76	1.68	1.76	
15	19	14	15	15	10	32	13	8	12	22	
1.77	1.68	1.65	1.76	1.69	1.61	1.61	1.65	1.56	1.68	1.67	
14	18	26 0	21	25	14	15	35	23	23	23	
1.84	1.80	1.67	1.69	1.62	1.71	1.66	1.57	1.60	1.69	1.65	
8	30	24	20	22	21	25	18	21	20	14	
1.72	1.68	1.69	1.70	1.69	1.69	1.65	1.59	1.63	1.64	1.64	
16	33	31	25	22	20	26	26	17	18	8	
1.66	1.62	1.70	1.64	1.68	1.64	1.66	1.64	1.64	1.64	1.63	
17	26	21	23	21	25	13	23	22	18	0	
1.66	1.66	1.65	1.71	1.62	1.62	1.69	1.62	1.67	1.65	0000	
21	18	25	15	20	23	22	11	17	2 /	0	
1.66	1.63	1.66	1.67	1.65	1.64	1.62	1.71	1.64	1.62	0000	

Jul

20	24	29	27	21	23	27	17	19	13	21	19		1
1.66	1.68	1.65	1.60	1.61	1.67	1.64	1.70	1.64	1.63	1.64	1.68		
22	20	23	22	23	16	24	26	21	17	16	19	-	2
1.65 0.13	1.73	1.66	1.65	1.60	1.64	1.64 0.16	1.62 0.14	1.61	1.67 0.16	1.60	1.63		
21	17	23	32	27	23	21	16	17	13	11	17	_	
1.60 0.10	1.64 0.10	1.63 0.15	1.61 0.14	1.63 0.13	1.68	1.62 0.11	1.61 0.16	1.66	1.64 0.19	1.58 0.13	1.61 0.17		Ľ
28	25	35	35	31	24	18	12	20	17	11	11		I.
1.60 D.15	1.62 0.12	1.56 0.12	1.59 0.11	1.59 0.14	1.62 0.18	1.57 0.16	1.59 0.15	1.55 0.14	1.59 0.12	1.63 0.15	1.54 0.16		ľ
36	37	32	25	25	16	16	15	17	14	12	6		L
1.61 0.15	1.58 0.14	1.54 0.12	1.59	1.63	1.59 0.13	1.67 0.18	1.58 0.10	1.61	1.60 0.10	1.62 0.16	1.69		1
31	24	37	13	27	9	9	16	7	21	2	1		
1.62 0.11	1.58 0.15	1.63 0.15	1.68	1.57 0.14	1.52	0.18	1.63	1.63	1.60 0.17	0.05	1.93		
43	24	33	31	18C	18	16	<b>1</b> ح	4	23	1	14		ľ
1.59 0.16	1.57 0.10	1.55	1.58	1.55	0.14	1.57 0.14	1.65	1.66	1.60	1.55	1.62 0.13		
38	40	30 0	32	33	26	28	20	21	21	23	18		ľ
1.57 0.11	1.55	0.14	0.14	0.14	1.61	1.61	0.14	1.61	1.53	1.63	1.62		
38	31	31	31	29	22	27	32	29	21	26	17		ŀ
0.13	0.16	0.13	0.13	0.14	0.16	0.13	0.15	0.17	0.16	0.15	0.18		
24 	29	28	20	26	15	22	21	22	20	15	2		
0.18	0.16	0.18	0.15	0.17	0.11	0.15	0.16	0.14	0.15	0.16	0.30		
	1.62	1.60	1.60	1.62	1.01	1.00	1.64	1.60	1.00	00000	0000		
0.16	0.10	0.13	0.14	0.17	0.19	0.20	0.16	0.16	0.20	00000	0000		ľ
1.52	1.54	1.56	1.60	1.61	1.55	1.58	1.58	1.63	0000	0000	0000		
0.13	0.09	0.16	0.19	0.19	0.10	0.15	0.17	0.19	0000	0000	0000		

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					2013_	10_n_	со				
30	24	23	38	22	22	20	24	19	8	15	10
1.60	1.60	1.59	1.66	1.62	1.61	1.65	1.64	1.68	1.62	1.69	1.75
28	23	24	25	16	22	21	14	12	13	16	16
1.63 0.15	1.62	1.58	1.61	1.60	1.62	1.69	1.68	1.61	1.67	1.68	1.67 0.17
24	17	18	27	18	17	21	21	15	16	19	17
1.59 0.10	1.64	1.61	1.60	1.69	1.65	1.63	1.65	1.59	1.61	1.65	1.62
16	23	24	23	21	20	24	24	29	26	16	12
1.63 0.11	1.58	1.57	1.61	1.58	1.62	1.59	1.61	1.64	1.60	1.56	1.61
29	23	31	27	24	21	21	21	23	20	18	7
1.61 0.12	1.60 0.16	1.56 0.13	1.58	1.60	1.68 0.21	1.55	1.54	1.57	1.57	1.67 0.21	1.60
26	31	35	10	26	16	11	22	27	22	15	197
1.65	1.55	1.57	1.53	1.58	1.51	1.52	1.55	1.55	1.53	1.61	1.56
26	30	25	25	21	18	34	15	23	25	18	-27
1.56 0.13	1.55	1.61	1.58	1.58	1.58	1.57	1.49	1.57	1.61	1.56	1.60
27	30	29 C	35	33	40	48	41	36	44	36	30
1.55	1.53	1.60	1.61	1.55	1.64	1.62	1.55	1.60	1.61	1.57	1.62
30	36	40	36	35	48	32	35	42	40	35	32
1.58	1.53	1.58	1.54	1.53	1.57	1.56	1.59	1.59	1.59	1.62	1.63
25	35	35	30	36	41	38	36	31	34	16	8
1.53	1.55	1.56	1.58	1.56	1.59	1.56	1.57	1.57	1.53	1.56	1.59
34	27	30	34	41	33	30	42	39	26	1	0
1.52	1.51	1.58	1.60	1.53	1.55	1.53	1.56	1.53	1.57	1.49	0000
43	32	43	43	38	37	39	45	34	7	0	0
1.52	1.50	1.55	1.54	1.55	1.52	1.54	1.60	1.54	1.68	0000	0000

Oct

## IASI day night

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2010	<u> </u>	u	00	00	

					-			-		1 - C	
283.6 22.4	277.7 21.4	270.8 14.3	264.4 16.0	260.0 19.5	261.9 16.8	263.7 18.3	266.3 22.2	283.1 17.7	267.0 20.8	275.6 23.3	272.2 13.9
15	11	14	9	13	11	17	17	6	15	10	9
276.0 25.7	274.5 22.7	268.6 20.5	264.4 12.6	258.7 13.5	268.8 17.4	263.7 12.3	270.0 18.8	270.8 18.8	271.6 15.0	275.1 15.0	283.3 13.9
13	10	9	15	11	9	11	13	13	15	12	11
276.6 24.6	262.1 15.1	267.2 12.1	271.5 20.5	261.5 17.7	263.9 15.2	266.0 16.1	266.1 15.1	273.5 11.0	273.5 9.75	275.4 21.6	282.3 17.4
13	13	14	9	10	15	16	14	13	16	19	16
271.4 16.0	266.2 13.5	262.2 15.4	261.0 17.1	276.0 20.8	268.3 21.3	267.0 17.3	277.6 16.0	270.9 15.1	273.5 14.0	276.1 17.0	274.9 20.0
14	14	18	10	11	11	11	13	21	13	16	5
264.3 13.1	259.7 12.1	270.9 17.6	268.3 14.6	265.9 15.7	274.6 14.4	272.1 19.6	273.5 11.6	268.7 16.3	277.5 14.4	274.9 23.6	284.1 11.6
12	19	19	4 }	17	10	4	5	10	17	3	47
266.0 15.2	264.3 16.8	271.4 22.3	284.3 7.92	265.8 16.0	266.9 8.40	279.0 5.43	267.1 18.7	273.9 19.5	267.4 16.6	258.0 9.31	270.7 2,85
15	19	22	16	12	11	12	4 ~~	3	19	10	-14
260.7 16.9	269.1 21.0	269.7 23.3	272.6 18.1	265.8 16.3	277.1 12.0	259.9 14.7	277.8 21.3	282.5 27.6	268.2 21.0	274.8 26.4	277.7 17.4
12	20	20 <	26	24	19	22	23	18	17	16	18
283.8 30.7	270.4 15.4	264.7 16.4	268.3 16.3	264.4 17.0	265.7 16.4	272.4 17.6	274.1 15.4	272.5 16.3	263.3 20.0	278.1 17.2	278.0 20.5
16	24	24	28	14	18	25	21	17	16	23	8
274.7 23.8	269.2 16.8	273.7 16.5	269.1 15.2	266.4 16.4	267.3 16.9	270.8 17.3	271.2 17.7	266.5 15.7	274.5 18.9	276.9 17.5	273.2 11.8
28	23	23	21	20	19	30	20	16	15	10	3
272.8 21.1	272.0 16.9	268.6 14.8	270.6 16.1	269.9 15.4	267.6 14.7	274.9 14.9	270.7 14.9	273.1 15.4	274.7 13.8	278.4	263.9 2.83
24	25	19	17	26	19	19	18	18	3	0	0
268.2 14.8	267.1 11.8	266.2 12.7	270.3 11.0	267.7 13.2	276.5 11.8	276.7 8.60	274,6 6.95	272.3 13.4	270.3 10.0	000.0	000.0
18	15	15	22	38	29	19	21	24	1	0	0
269.8	267.9	265.6	264.6	271.6	268.2	265.5	270.7	270.2	271/3	000.0	000.0

	10	1.0	0.2	47	47	1.6	0	10	0	4.2	10
10	19	13	23			10		13	9	15	10
298.3 4.82	297.7 4.55	297.5 4.40	299.4 4.43	298.8 4.97	300.3 5.03	300.0 5.42	299.1 3.80	298.6 5.77	297.0 6.00	298.6 5.83	297.9 5.47
16	19	17	19	23	15	9	9	15	18	15	16
296.1 4.65	296.8 5.52	296.7 4.43	298.1 4.43	299.7 6.54	297.6 6.25	296.9 3.21	298.7 3.63	297.9 6.19	297.1 5.78	297.3 3.79	295.8 5.29
23	18	20	15	19	17	8	9	15	17	20	18
296.3	296.2	297.3	296.5	297.7	297.9	296.9	296.4	297.1	298.1	296.3	294.5
20	14	13	8	12	18	6	18	15	14	22	11
295,2	297.2	295.4	295.7	295,4	298.5	294.7	295.1	297,5	296,7	293.0	295.3
13	10	11	4	9	13	10	11	13	12	13	3
293.7	294.2	295.7	292.9	292.2	294.4	295.4	295.0	293.8	293.1	292.3	296.5
13	15	17	6	13	2	1	8	10	17	0	10
294.0 6.81	293.0	292.6	295.0	292.9	294.6	294.0	291.5	294.0 4 47	292.8	000.0	000.0
21	18	22	19	19	5	7	0	2	11	14	-11
295.7	292.5	294.0	296.5	294.5	296.3	291.9	0000.0	289.0	290.7	291.9	289.7
18	17	32 🗆	20	31	7	18	14	11	14	19	18
294.6	293.0	293.3	294.3	293.6	290.7	292.2	291.7	290,8	287.4	291.0	288.0
21	31	35	24	27	28	18	16	12	20	12	4
290,6	294.0	293.0	292.4	292.0	293,5	293.6	291,9	293,4	292,4	288,8	291.4
25	24	18	25	18	22	16	14	14	20	5	0
290.7	291.7	290.4	291,2	289.5	293,7	292,6	292.4	294,8	290,5	287.5	000.0
8	25	18	24	18	14	7	20	18	2	0	0000
290.6	291.9	291,0	289.5	292.5	293.2	290.9	291.7	289.4	291,8	000.0	000.0
3.20 19	4.48	5.44 14	5.07	5.69	5.97	4.97	8.61	8.07	6.47 0	0000	0000
									- /		

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![](_page_51_Figure_5.jpeg)

												1.04	0.70
13	10	11	4	9	13	10	11	13	12	13	3	36	37
293.7 3.61	294.2 4.64	295.7 4.10	292.9 2.59	292.2 4.17	294.4 4.94	295.4 5.33	295.0 7.67	293.8 6.63	293.1 6.94	292.3 5.30	296.5 4.27	277.	2 277.7
13	15	17	6	13	2	1	8	10	17	0	P	31	24
294.0 6.81	293.0 6.73	292.6 7.45	295.0 6.71	292.9 3.88	294.6 3,10	294.0 0000	291.5 3.98	294.0 4.47	292.8 3.99	800.0	000.0	278	3 275.5
21	18	22	19	19	5	z	0 ~~	3	11	14	-11	43	24
295.7 7.65	292.5 5.33	294.0 5.64	296.5 5.58	294.5 5.99	296.3 3.99	291.9 3.40	0000	289.0 0.72	290.7 4.78	291.9 8.42	289.7 5.62	277.	1 277.1
18	17	32 🗠	20	31	7	18	14 ~	11	14	19	18	38	40
294.6 7.76	293.0 5.92	293.3 5.90	294.3 5.68	293.6 6.14	290.7 4.45	292.2 5.53	291.7 5.75	290.8 4.78	287.4 5.38	291.0 4.70	288.0 5.33	275	6 276.4
21	31	35	24	27	28	18	16	12	20	12	4	38	31
290.6 4.02	294.0 5.66	293.0 4.57	292.4 5.96	292.0 6.12	293,5 5.57	293.6 4.41	291.9 5.52	293,4 7,98	292.4 6.89	288.8 5.54	291.4 4.61	278	4 275.3
25	24	18	25	18	22	16	14	14	20	5	• /	24	29
290.7 5.70	291.7 6.79	290.4 4.59	291.2 4.71	289.5 3.85	293.7 7.57	292.6 6.18	292.4 7.85	294.8 10.4	290.5 7.07	287.5 3.66	0000	277	9 276.7
8	25	18	24	18	14	7	20	18	2	0	0	27	30
290.6 3.20	291.9 4.48	291.0 5.44	289.5 5.07	292.5 5.69	293.2 5.97	290.9 4.97	291.7 8.61	289.4 8.07	291.8 6.47	000.0	000.0	277	7 279.3
19	24	14	13	15	9	9	8	16	0	0	0	30	26
288.6	290.7	292.7	293.2 4.92	291.0 5.34	292.5 6.63	291.5 9.96	285.8 3.26	286.4 6.43	0000	0.000	000.0	275	3 276.1

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				20		00					
10	10	8	9	7	11	5	7	8	4	13	10
265.7	265.5	258.1 13.9	277.2	297.2 21.4	278.2	293.9 18.2	279.4 25.3	282.2	285.1	286.4	294.2 30.7
9	9	5	6	3	4	6	6	4	1	7	8
276.3	264.5	256.9	270.1	264.1	263.3	276.8	262.7	273.7	337.8	267.5	283.4
10	5	3	5	6	4	9	4	3	4	6	13
262.0	259.8	246.0	266.6	263.0	256.7	269.1	261.8	253.8	270.1	268.7	274.0
5	0	3	3	6	9	9	7	6	7	11	10
264.4	000.0	261.8	270.0	267.5	264.6	266,8	266.9	264.4	277.3	264.8	270.1
2	5	6	8	7	8	5	7	6	7	8	10
271.4	281.9 10.9	267.8	259.6 11.5	258.1	269.2 17.2	266.7	266.5	261.1	264.0	277.7	271.3
8	8	20	6	11	2	5	10	7	18	12	10
279.2 18.5	269.9 12.8	270.9	272.3	268.3 25.8	246.4	276.0	265.1 14.9	273.4 18.0	271.5	284.1	273.1
10	12	12	13	18	8	8	4	8	14	8	19
262.5	276.5	268.4	273.2	272.9	277.8	268.2	260.1	259.4	269.4	266.3	265.4
10	19	18 🔾	20	21	19	14	22	14	14	19	16
279.1	276.9	273.6	275.2	276.5	275.9	270.2	272.1	266.7	266.7	269.7	267.6
14	13	16	17	21	22	19	14	23	21	18	25
282.8	280.2	280.2	271.8	283.7	273.2	267.6	270.8	267.5	265.7	273.3	266.6
14	15	17	15	19	22	20	23	22	29	22	4
273.2	267,5	274.9	276.9	270.7	268.0 15.0	266.3	272.6	266.9	267.0	269.9	269.9
13	17	21	22	22	27	26	26	20	25	0	0
278.5	274.5	277.7	273.1	272.9	270.3	271.5	266.8 16.3	269.4 15.0	268.6	0000.0	000.0
23	28	23	28	26	28	16	31	21	7	0	0
274.9	273.3	269.0	265.6	272.3	265.9	264.2	266.0	268.0	270.7	000.0	000.0

19	15	18	18	14	13	16	17	20	18	17	20
296.8 4.06	295.7 3.72	296.5 5.12	299.6 8.12	299.0 6.45	298.7 4.67	298.6 4.04	298.4 6.06	297.6 6.81	297.8 3.24	296.3 4.26	295.8 5.49
17	22	8	9	10	16	15	11	13	15	13	19
296.8 5.45	294.2 3.77	298.0 8.11	296.8 6.11	297.2 4.02	297.7 3.89	298.5 3.59	297.5 5.65	295.3 5.89	295.9 4.64	295.5 5.32	294.6 4.41
15	11	19	15	17	10	10	8	14	12	14	21
295.9 6.81	293.1 6.43	295.9 4.85	296.4 4.59	296.2 5.20	294.0 6.55	296.6 4.69	292.9 4.80	295.6 6.22	294.8 3.90	292.5 5.41	293.3 5.29
12	13	18	19	11	8	8	13	17	12	18	23
292.7 5.42	294.6 7.29	294.3 7.57	296.0 6.07	293.0 5.23	295.0 3.59	293.4 3.33	293.0 4.19	293.9 2.76	294.1 4.71	294.8 3.54	294.2 5.35
13	14	21	9	7	9	12	12	14	15	16	7
293.2 7.04	291.2 3.65	294.2 4.81	292.0 4.34	292.5 4.70	292.8 1.36	293.8 4.15	295.0 8.71	292.1 4.08	294.4 4.97	291.8 4.45	291.7 3.96
17	18	26	6	10	7	11	20	17	18	9	10
290.5 5.60	293.1 4.95	293.7 5.91	290.0 3.95	288.2 5.18	290.3 4.24	289.1	291.6 4.83	291.4 3.70	292.3 3.93	292.4 5.46	288.9 3,40
15	19	14	15	15	10	12	13	8	12	22	28
293.5 3.06	289.3 4.88	290.8 5.48	290,1 4,74	290.3 4.91	291.1 7.58	290.2 4.88	290.9 3.65	288.7 4.49	288.6 3.86	289.3 4.92	290.4 4.34
14	18	26 🧠	21	25	14	15	35	23	23	23	22
291.3 4.61	290.4 4.23	290.7 4.84	291.5 4.99	292.0 4.84	290.7 4.31	288.7 3.42	289.4 5.84	287.8 3.97	289.5 4.98	287.7 5.42	286.3 4.96
8	30	24	20	22	21	25	18	21	20	14	8
289.4 4.00	292.5 5.13	290.1 5.53	293,6 4,48	289.5 6.00	291.2 3.63	286.8 5.50	287.6 4.99	287.0 5.26	287.3 5.57	286,6 4.23	286.6 5.24
16	33	31	25	22	20	26	26	17	18	8	0
289.6 4.84	291.9 6.75	289.7 4.95	290.9 4.94	289.0 4.43	287.0 5.15	287.7 6.04	286.3 4.36	288.5 5.62	286.5 5.52	286.2 4.69	000.0
17	26	21	23	21	25	13	23	22	18	0	0
289.3 5.40	292.3 6.49	288.4 5.44	288.9 3.66	290.6 4.67	289.1 4.56	286.4 6.16	288.2 5.82	286.1 4.19	285.5 5.62	0000.0	000.0
21	18	25	15	20	23	22	11	17	2	0	0
289.4	290.9	288.8	288.3	288.4	289.5	289,1	284.7	287.3	281,3	0.000	000.0

2013	10	n (	D3	DU
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![](_page_51_Figure_11.jpeg)

300

250

Feb

Jul

### Land - sea

	O ₃	CO	CH ₄	N ₂ O	CO ₂
sea	0.92	0.78	0.39	0.30	0.05
land	0.84	0.71	0.06	0.07	0.46

flag landsea

![](_page_52_Figure_3.jpeg)

8.5	0	The IASI IFOV is completely covered by water
2.5	1	The IASI IFOV is completely covered by land, the variability of the surface topography is low
2	2	The IASI IFOV is completely covered by land, the variability of the surface topography is high
1.5	3	The IASI IFOV covers land and water, the variability of the surface topography is low
0.5	4	The IASI IFOV covers land and water, the variability of the surface topography is high

![](_page_53_Figure_0.jpeg)

## Annual cycles

![](_page_54_Figure_1.jpeg)

![](_page_55_Figure_0.jpeg)

![](_page_56_Picture_1.jpeg)

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

![](_page_57_Picture_5.jpeg)

![](_page_57_Picture_6.jpeg)

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

- Partial column below IZO: WACCM
- correlation coef. FTIR-IASI
- Improvement from v4 to v5
- Large: O₃, CO, mod.: CH₄
   Low for N₂O and CO₂

![](_page_58_Picture_9.jpeg)

- Natural variability
- collocation criteria
- Temporal: FTIR unc.
- Spatial: FTIR probed airmasses and var. IASI observations
- Different collocation criteria (temp/spat)
- Best corr. for optimal coll. for O₃ and CO
- For CH₄ and N₂O best corr. for ±1h IASI overpass

- Partial column below IZO: WACCM
- correlation coef. FTIR-IASI
- Improvement from v4 to v5
- Large: O₃, CO, mod.: CH₄
   Low for N₂O and CO₂

![](_page_59_Picture_12.jpeg)

- Natural variability
- collocation criteria
- Temporal: FTIR unc.
- Spatial: FTIR probed airmasses and var. IASI observations
- Different collocation criteria (temp/spat)
- Best corr. for optimal coll. for O₃ and CO
- For CH₄ and N₂O best corr. for ±1h IASI overpass

- Partial column below IZO: WACCM
- correlation coef. FTIR-IASI
- Improvement from v4 to v5
- Large: O₃, CO, mod.: CH₄
   Low for N₂O and CO₂
- day night : slight diff.
- land pixel : surf. alt. too var.
- Annual cycle: good agreement for O₃ and CO
- Agreement but also discr.
   for CH₄, N₂O and CO₂

### Outlook

![](_page_61_Picture_1.jpeg)

Version 6 data : profiles for O₃ 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

![](_page_62_Figure_0.jpeg)

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

#### Winddirection

![](_page_62_Figure_3.jpeg)

Izaña Atmospheric Research Center 1971-2000 ROSE WIND ANNUAL

-2-4 m/sq

----- 4-8 m/sg

— > 8 m/sg

![](_page_62_Figure_5.jpeg)