Lowermost tropospheric ozone observed from space by multispectral synergism of IASI (IR) and GOME-2 (UV)

J. Cuesta[1], M. Eremenko[1], X. Liu[2], G. Dufour[1], Z. Cai[3], M. Höpfner[4], T. von Clarmann[4], P. Sellitto[1], G. Foret[1], B. Gaubert[1], M. Beekmann[1], J. Orphal[4], K. Chance[2] , R. Spurr[5] and J.-M. Flaud[1]

(1) (2) (3) (4) (5)

Scientific motivation

Tropospheric ozone is a major atmospheric pollutant

- It directly affects public health, aggravating respiratory diseases and increasing premature mortality
- It damages ecosystems and reduces plants growth
- Emissions of precursors reduced significantly in the last decades in regions as Europe, but it has not been reflected in O_3 concentrations

➢ Monitoring tropospheric ozone is mandatory

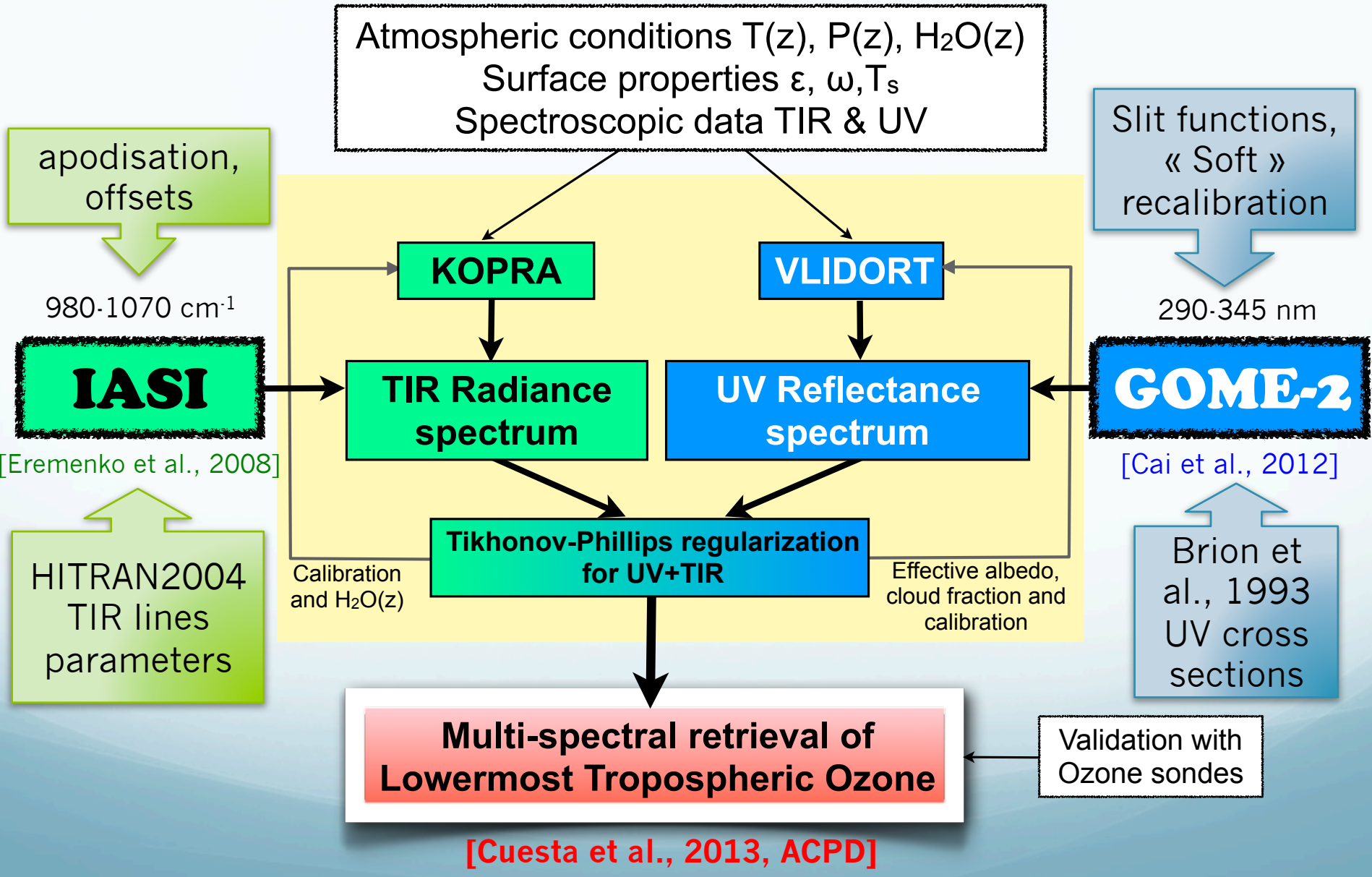
→ Only satellite observation can measure its daily and seasonal evolution at the regional and global scales

❑ How to observe O_3 in the lowermost troposphere from space ?

❑ Which UV/TIR spectrocopic data are coherent enough for synergism?

We propose a new multispectral synergism of IASI (IR) and GOME-2 (UV)

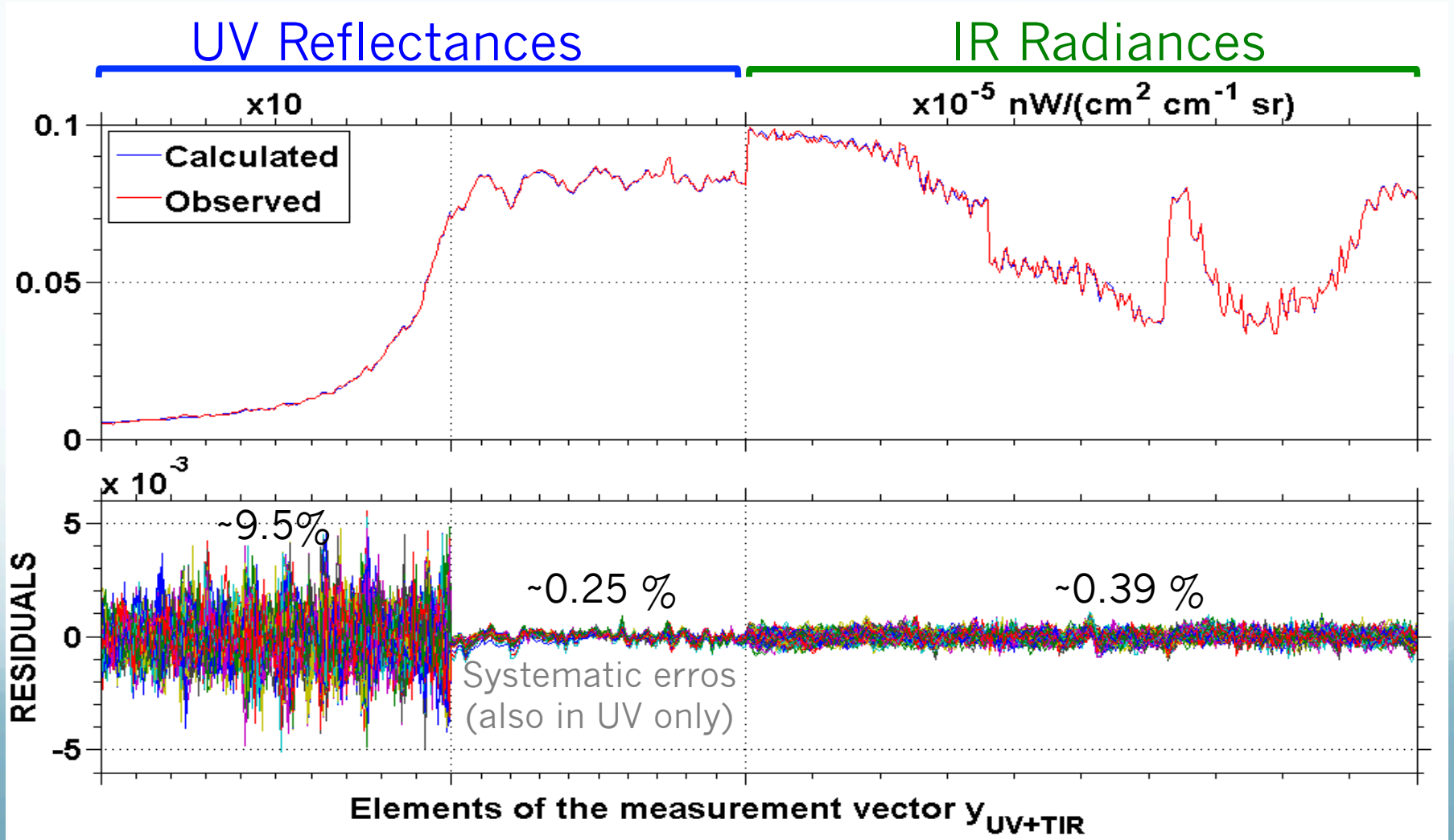
IASI+GOME-2: a new joint inversion of collocated IR and UV spectra using Tikhonov-Phillips constraints



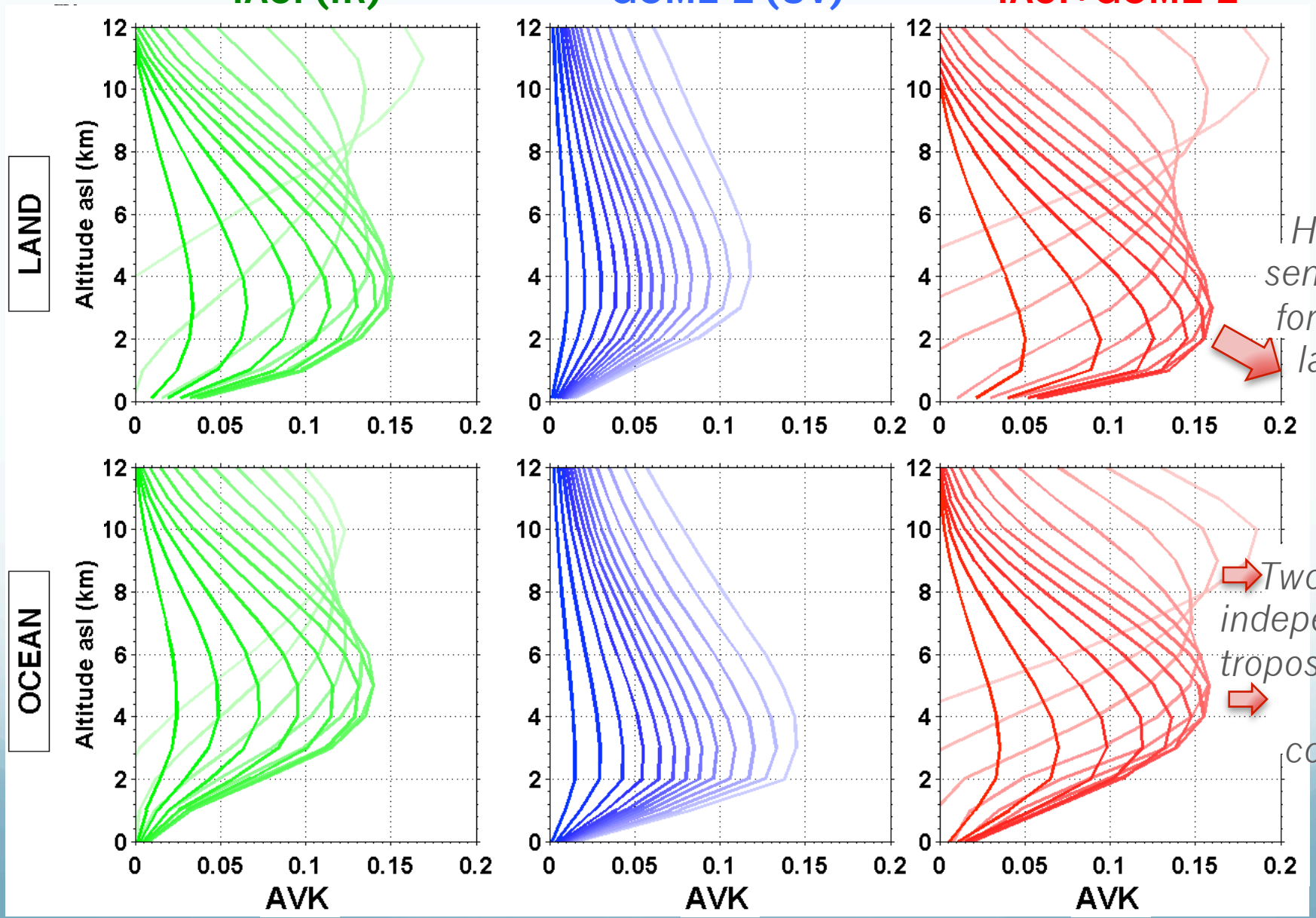
1. Multiple spectral fitting

Simultaneous fit of IR and UV spectra

Adjusting a unique Ozone profile and instrumental parameters

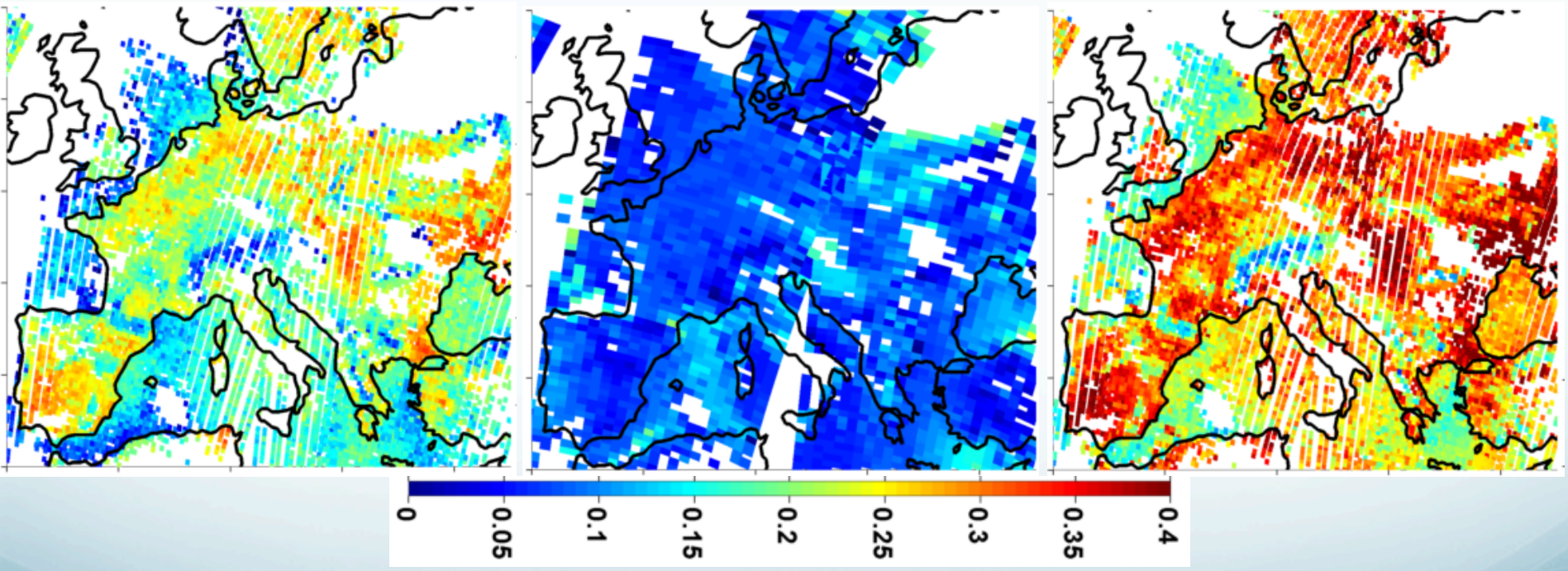


2. Multispectral sensitivity: Averaging kernels



2. Multispectral sensitivity: Degrees of freedom in the Lowermost Troposphere (up to 3 km asl)

IASI (IR) | **GOME-2 (UV)** | **IASI+GOME-2**



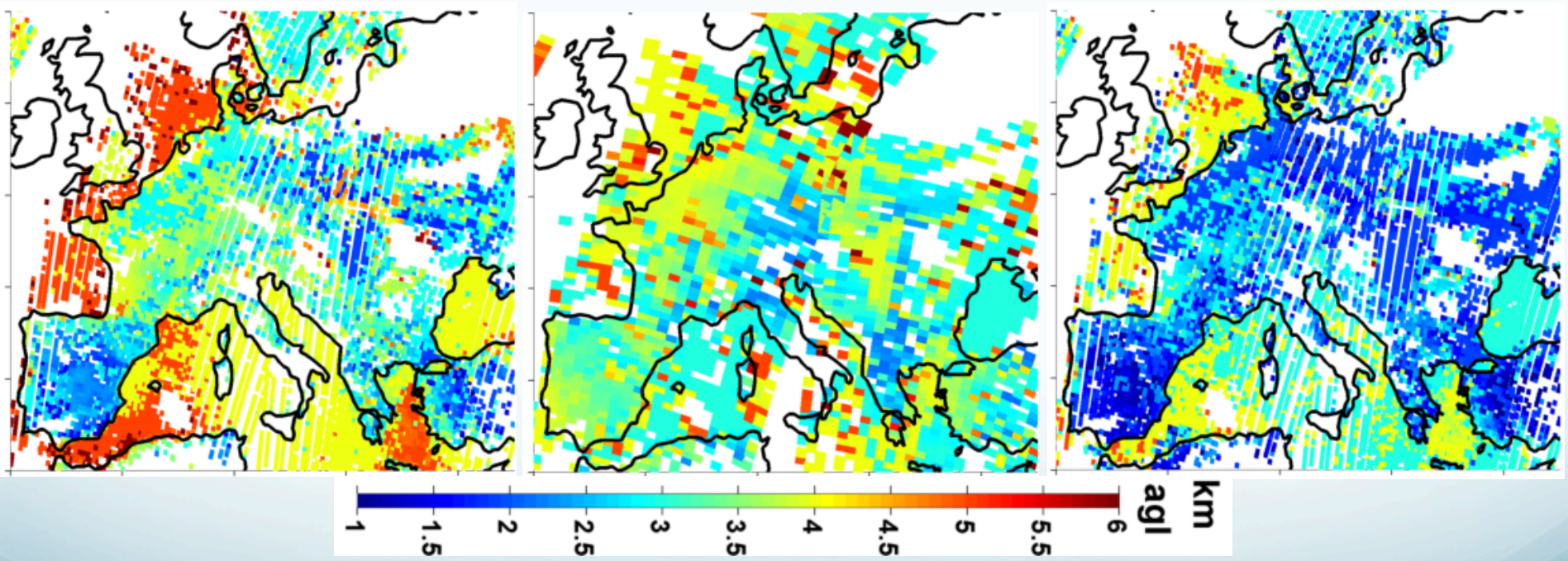
0.25 DOFs over land
0.15 DOFs over ocean

<0.10 DOFs

0.35 DOFs over land
0.25 DOFs over ocean
DOF_{IASI} + 40%

2. Multispectral sensitivity: Height of maximum sensitivity in the Lowermost Troposphere

IASI (IR) | **GOME-2 (UV)** | **IASI+GOME-2**



3 km agl over land
4.3 km agl over ocean

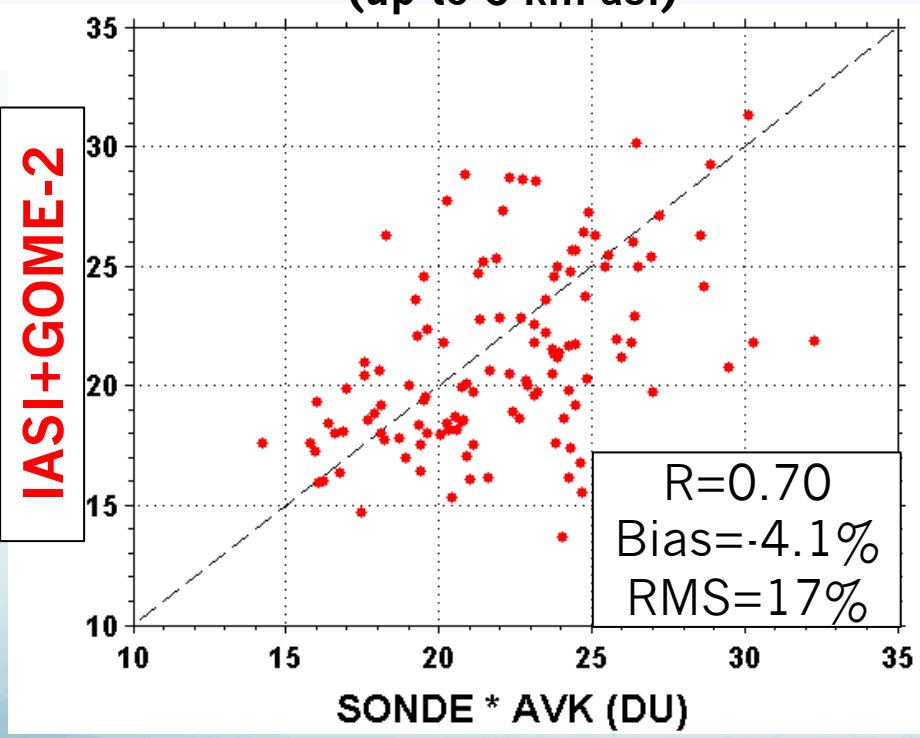
3.7 km agl

2.2 km agl over land
3.5 km agl over ocean
H_{IASI} *- 800 m*

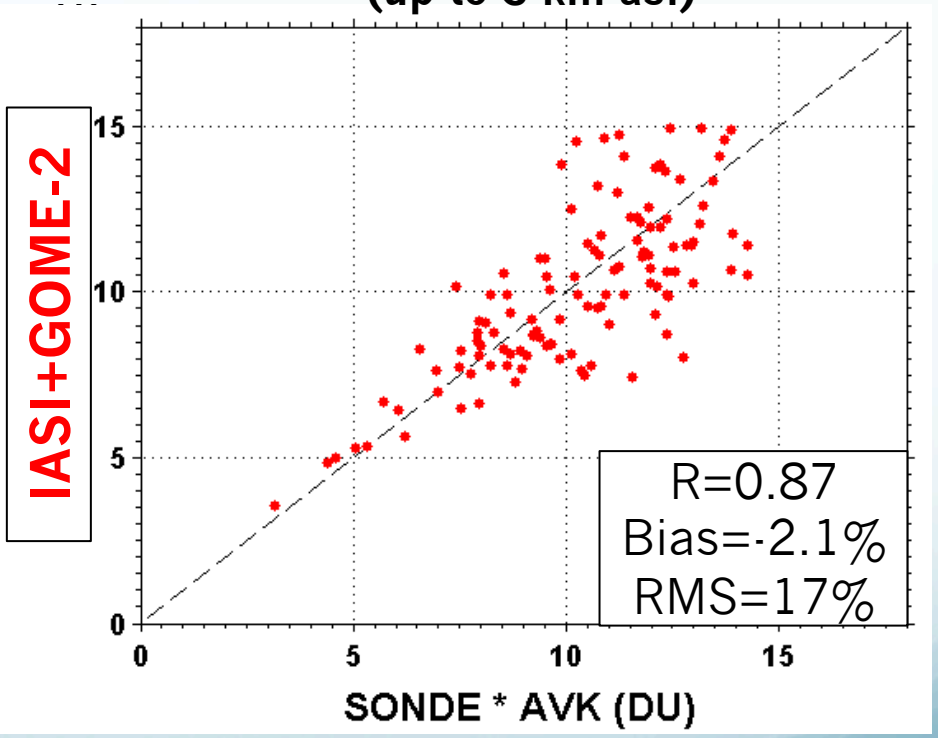
3. Validation against ozonesondes : IASI+GOME-2 vs. Smoothed Ozonesondes (HITRAN2004 + Brion et al., 1993)

119 sondes during the summer of 2009 (57 days), from 10 stations over Europe

Lower Troposphere (LT)
(up to 6 km asl)



Lowermost Troposphere (LMT)
(up to 3 km asl)

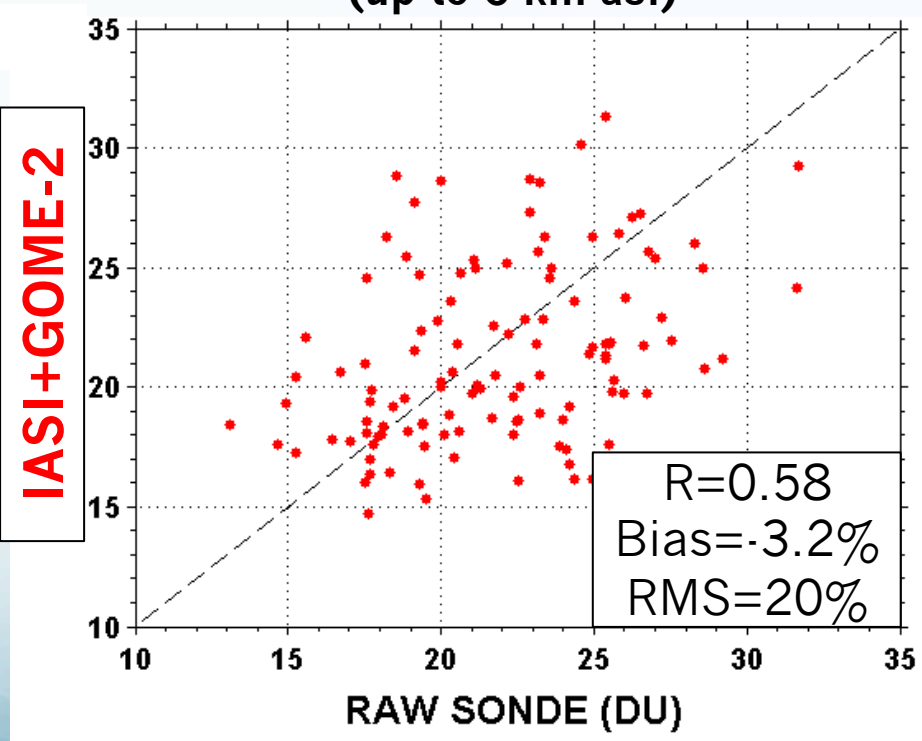


Good agreement: Low mean bias and reasonable RMS differences for the LT and LMT. Correlation is particularly good for the LMT

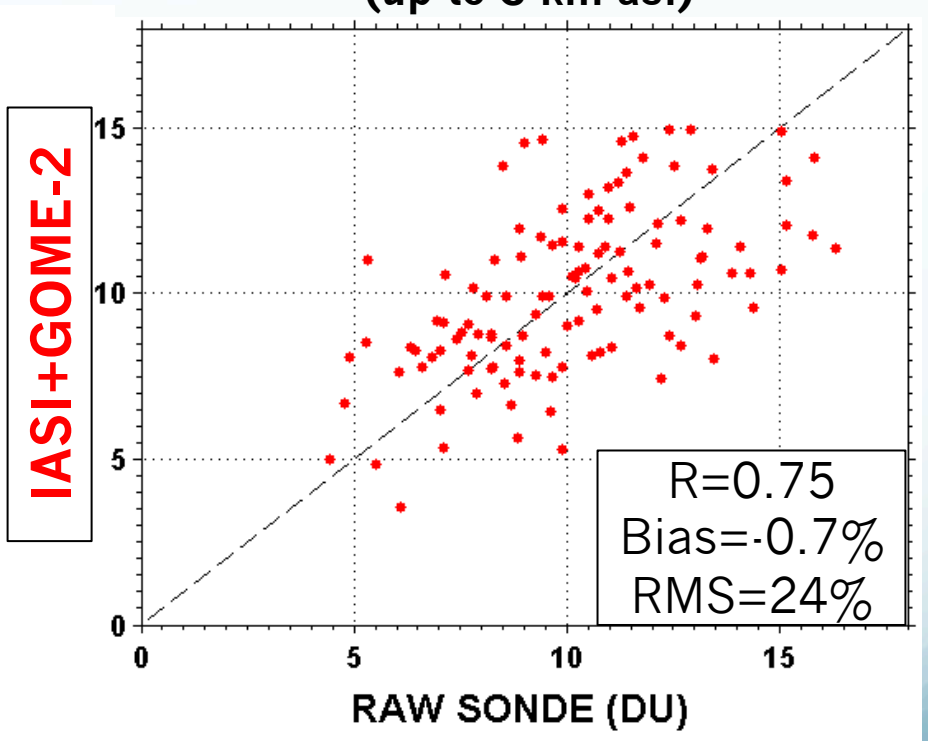
3. Validation against ozonesondes : IASI+GOME-2 vs. Raw Ozonesondes (HITRAN2004 + Brion et al., 1993)

119 sondes during the summer of 2009 (57 days), from 10 stations over Europe

Lower Troposphere (LT)
(up to 6 km asl)

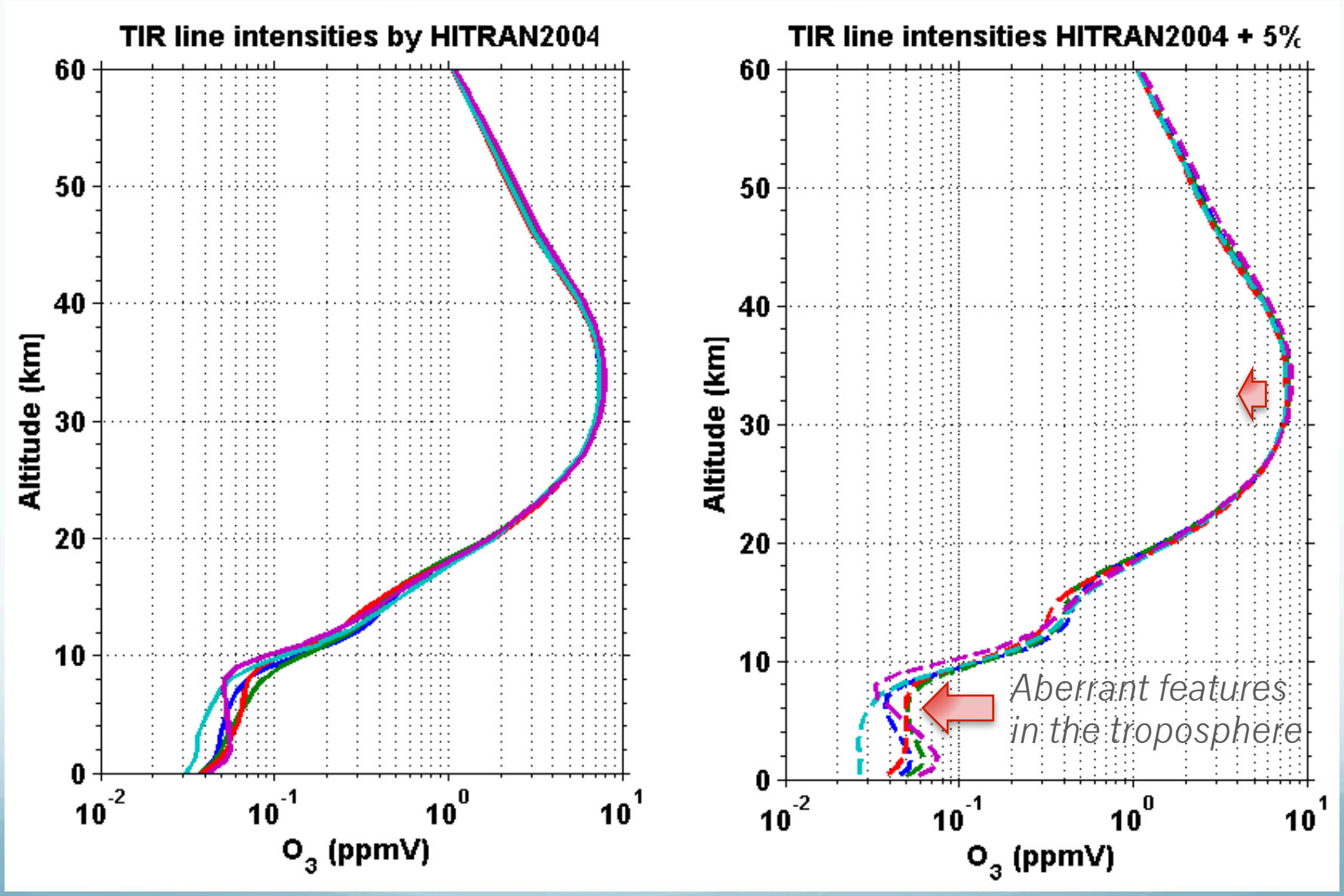


Lowermost Troposphere (LMT)
(up to 3 km asl)



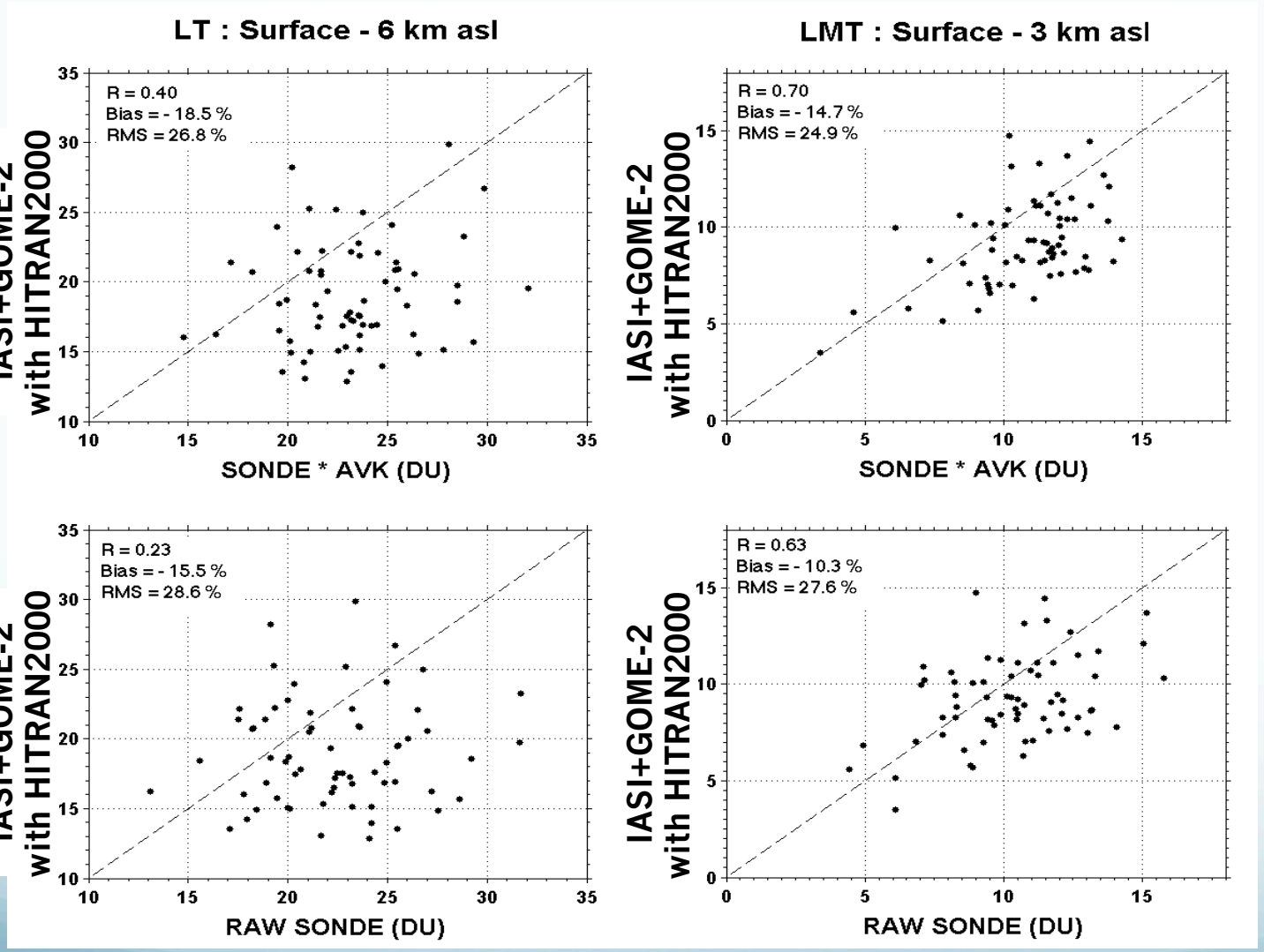
Direct comparisons: LMT retrieval also shows very low mean bias and good correlation

4. Spectroscopic coherence UV vs TIR ?



Similar results with UV cross sections -5%

4. Spectroscopic coherence : using HITRAN 2000 + Brion et al. 1993 ?

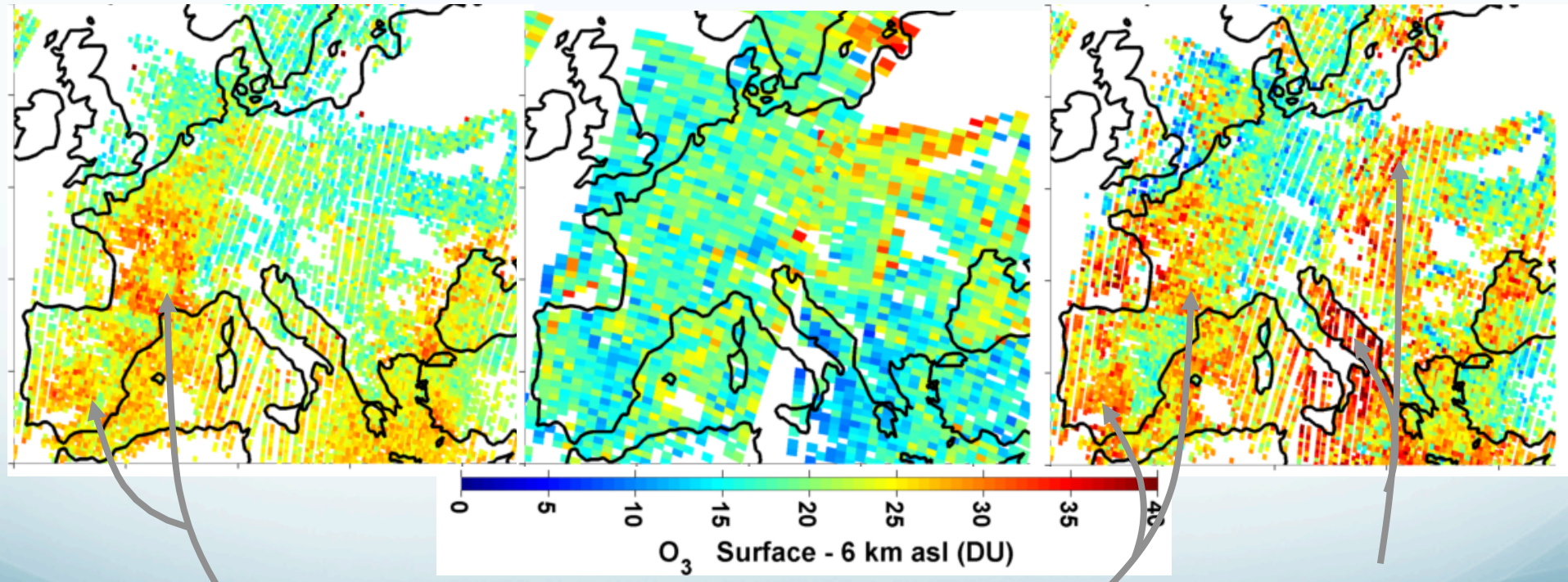


Strong negative bias, lower correlation and higher RMS

Among the tested data, the best spectroscopic parameters for IASI+GOME-2 is HITRAN2004+BRION1993

4. Lower tropospheric ozone observations : IASI+GOME-2 vs. IASI and GOME-2

19 August 2009

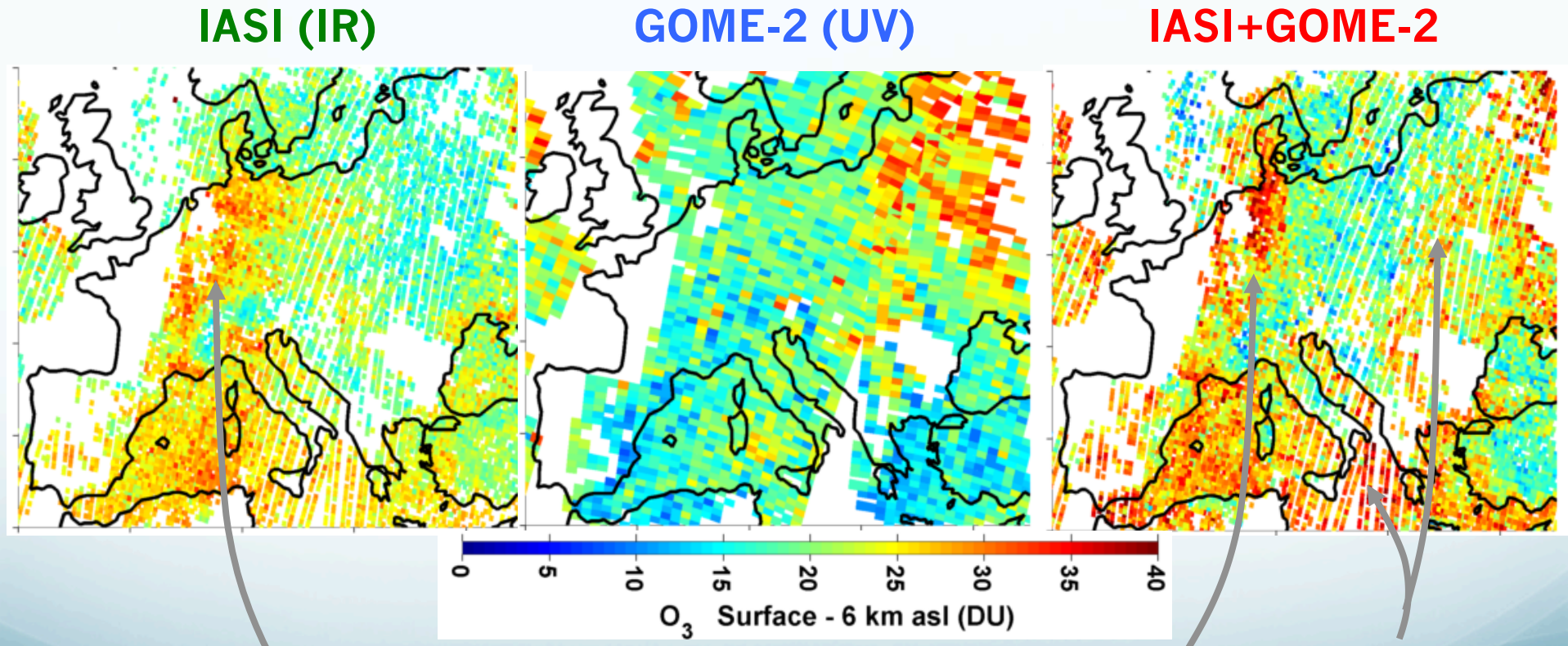


Ozone plumes depicted by both IASI and IASI+GOME-2

Only observed by IASI+GOME-2

4. Lower tropospheric ozone observations : IASI+GOME-2 vs. IASI and GOME-2

20 August 2009

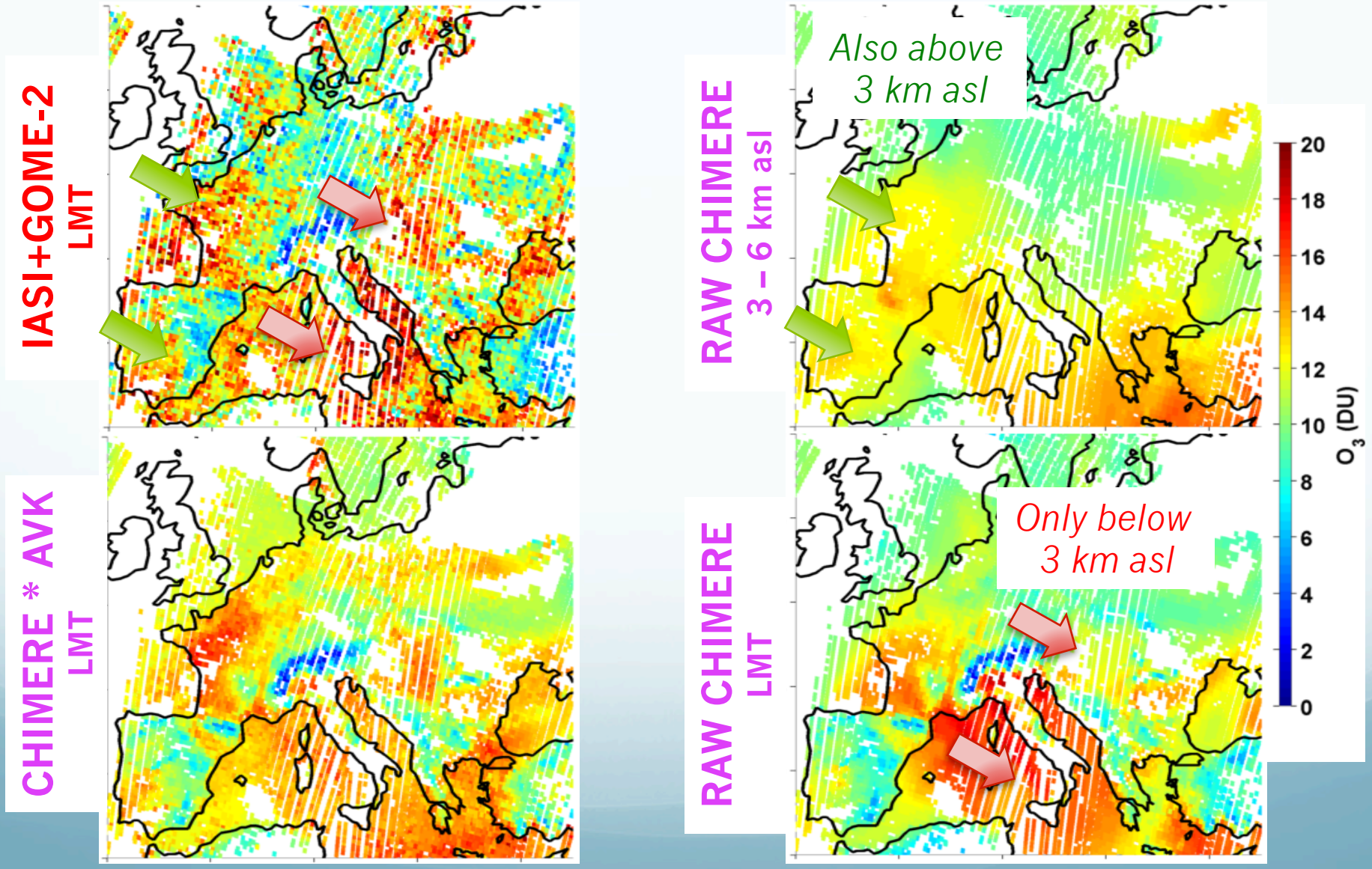


Ozone plumes depicted by both IASI and IASI+GOME-2

Only observed by IASI+GOME-2

5. Lowermost tropospheric ozone : IASI+GOME-2 observations vs. CHIMERE model

19 August 2009



5. Lowermost tropospheric ozone : IASI+GOME-2 observations vs. CHIMERE model

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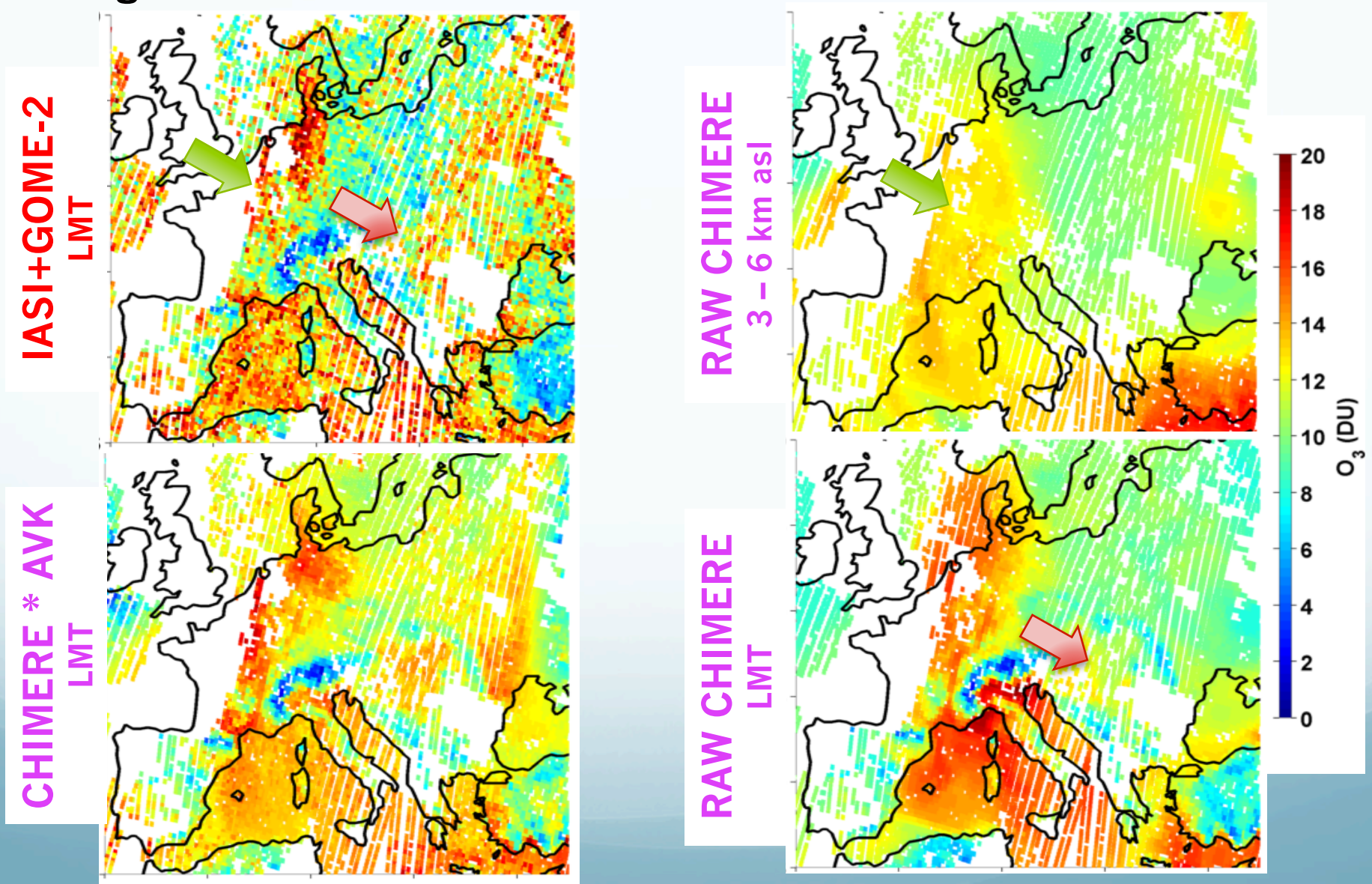

Summary

- We have developed a new multispectral method to observe tropospheric ozone from space: "IASI+GOME-2"
  - ✓ It simultaneously fits UV and TIR spectra
  - ✓ It enables a mean enhancement of sensitivity of 40% to ozone in the LMT
  - ✓ It uses HITRAN2004+BRION1993 → Best for IASI+GOME-2 (note that spectra are recalibrated within the method)
  - ✓ It shows a good agreement with ozonesondes, both smoothed by the retrieval AVK and raw measurements
  - ✓ Only IASI+GOME-2 depicts lowermost tropospheric ozone plumes (as shown by CHIMERE) → Air Quality studies

- *Future developments will focus on*
  - *The contribution of the Chappuis band in the visible, towards a three band TIR+UV+VIS ozone retrieval*
  - *Radiative effects of aerosols on ozone retrievals*

Acknowledgements

Suplementary material

		IASI+GOME-2		IASI		GOME-2	
	Atmospheric column	Land	Ocean	Land	Ocean	Land	Ocean
Degrees of freedom for signal DOF_{col}	LMT	0.34 (±0.04)	0.23 (±0.04)	0.24 (±0.03)	0.16 (±0.04)	0.08 (±0.01)	0.08 (±0.02)
	LT	0.75 (±0.05)	0.64 (±0.05)	0.62 (±0.03)	0.52 (±0.04)	0.25 (±0.03)	0.24 (±0.04)
	TROPO	1.72 (±0.07)	1.51 (±0.12)	1.52 (±0.06)	1.34 (±0.09)	0.67 (±0.04)	0.65 (±0.05)
	TOTAL	5.20 (±0.12)	4.92 (±0.19)	3.43 (±0.10)	3.20 (0.10)	3.41 (±0.10)	3.32 (±0.12)
Height of maximum sensitivity H_{col}^{max}	LMT	2.20 (±0.50)	3.48 (±0.56)	3.02 (±0.67)	4.26 (±0.51)	3.68 (±0.50)	3.64 (±0.65)
	LT	2.45 (±0.55)	3.83 (±0.57)	3.21 (±0.70)	4.36 (±0.53)	3.72 (±0.46)	3.66 (±0.64)

Suplementary material

Direct comparison of IASI+GOME-2 ozone retrieval vs. Raw ozonesondes					
Atmospheric column	Bias	RMS	R	s_{col}^{tot}	s_{col}^{smooth}
LMT	-0.1 (-0.7 %)	2.4 (24.2 %)	0.75	2.0 (20.2 %)	1.8 (18.0 %)
LT	-0.7 (-3.2 %)	4.4 (20.4 %)	0.58	2.6 (12.2 %)	2.2 (10.3 %)
TROPO	-2.0 (-4.5 %)	6.9 (15.6 %)	0.86	3.8 (9.0 %)	3.3 (7.7 %)
UPTO30	-4.7 (-1.8 %)	15.4 (5.7 %)	0.92	7.4 (2.9 %)	6.2 (2.5 %)

Suplementary material

IASI+GOME-2 with HITRAN 2000 / with -5% UV cross sections vs. Ozonesondes			
Atmospheric column	Bias	RMS	*R*
LMT	-1.6 / -1.2 (-14.7 % / -12.0 %)	2.7 / 2.4 (24.9 % / 22.8 %)	0.69 / 0.78
LT	-4.3 / -2.9 (-18.5 % / -13.0 %)	6.2 / 5.1 (26.8 % / 22.9 %)	0.40 / 0.54
TROPO	-5.4 / -4.4 (-10.9 % / -9.6 %)	8.7 / 7.7 (17.4 % / 16.4 %)	0.85 / 0.88
UPTO30	-6.6 / 4.0 (-2.5 % / 1.5 %)	16.6 / 14.8 (6.2 % / 5.7 %)	0.91 / 0.93