VALIASI fellowship:

VALidation of IASI Level 2 products

ELIEZER SEPULVEDA

EUMETSAT fellowday, 06 March 2017

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- · Validation including another retrieval algorithms:
  - · O3-FORLI
  - · CH4 & N2O -MUSICA

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1. INTRODUCTION

1. INTRODUCTION

IASI
Infrared Atmospheric Sounding Interferometer

Vertical profiles and total column amounts of:
H_2O, O_3, CO, CH_4, N_2O and CO_2.

Are these IASI products validated?

To date…

- Validation activities only for short periods (e.g., Keim et al., 2009; Viatte et al., 2010; Schneider and Hase, 2011).

- Specific Trace gases

- Different measurement techniques (e.g., Brewer spectrometer, meteorogical radiosondes, FTS,…)

VALIASI proposes…

-Validation of the historical time series.

- All trace gases

-Just one single measurement technique

OBJECTIVE:

Comprehensive validation of IASI level 2 humidity and trace gas (O_3, CO, CO_2, CH_4 and N_2O) products generated by the EUMETSAT Polar System (EPS) Core Ground Segment by means of ground-based high-quality Fourier Transform Infrared (FTS) spectrometry.

BENEFITS:

· Empirically assessment and documentation of the overall quality of the IASI L2 humidity and trace gas products.

· New insight in the importance of different error sources: latitude dependency, viewing geometry/swath angle, surface emissivity, atmospheric aerosols,…

· Conclusions for further improvements.

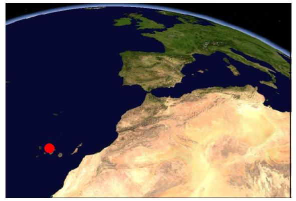
VALIASI: Validation of EUMETSAT's Operational IASI Trace Gas Products by ground-based FTS.

VALIASI fellowship life-time:

Fellowship approved in 2013 (1 year + 2 year):

1st year → 2013/2014 by Sven Külh

2nd year → march 2016/ march 2017 by Eliezer Sepúlveda



VALIASI fellowship location: Izaña Observatory (IZO)

FTS

http://izana.aemet.es/

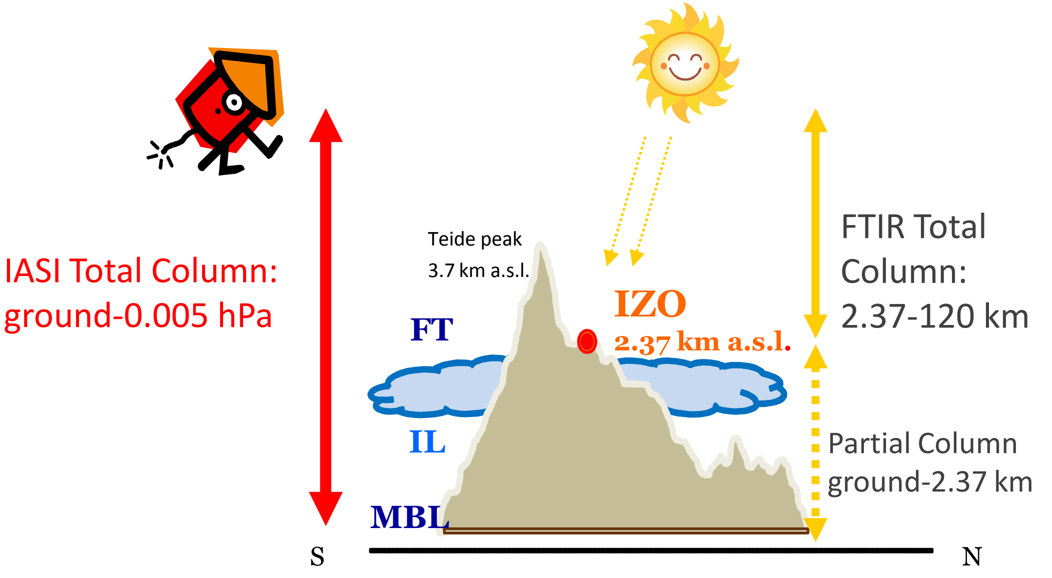
WMO/GAW Report No. 219, 2015

IZAÑA OBSERVATORY (IZO)

▪ IZO is located above a strong trade-wind subtropical temperature inversion layer and far away from sources/sinks of the trace gases considered.

IZO most part of the year is representative of the free troposphere.

The latitudinal and longitudinal gradients of these gases are rather smooth at oceanic subtropical latitudes.



FTIR missing partial column (below IZO) → It is not crucial as IASI has a weak sensitive at those lower layers of the atmosphere (see O3 AVK later)

REFERENCE INSTRUMENT

FOURIER TRANSFORM INFRARED SPECTROMETER (FTS)

From the direct solar absorption spectra, simultaneous different atmospheric constituents can be retrieved by means of an Optimal Estimation method (OEM)

→

Total Column Amounts and rough Vertical Profiles

	NETWORK	MW [cm^{-1}]	~ DOFS	TC Precision [%] Expr (theor)	References
O3	NDACC	~1000	4	0.4-0.7 (0.6; ~1DU)	Schneider et al., 2008
CO	NDACC	~2050, 2150	2	(<5)	Velazco et al., 2007
CH4	NDACC	~2600, 2900	2.5	0.97 (0.9)	Sepulveda et al., 2012, 2014
H2O	NDACC/MUSICA	~2600, 3000	3-4	~1 (~1)	Schneider et al., 2010, 2013
N2O	TCCON	~2500	2.5	(~1)	
CO2	TCCON	~5900, 6000		~0.25	Messerschmidt et al., 2011

NDACC: Network for the Detection of Atmospheric Composition Change. (https://www2.acom.ucar.edu/irwg)
TCCON: Total Carbon Column Observing Network. (https://tccon-wiki.caltech.edu/)

REFERENCE INSTRUMENT

VALIASI perform an important experimental part

- FTS routine measurements (NDACC & TCCON)
- Calibration Cell & Maintenance of FTS spectrometer and Peripherals (solar tracker, pumps,…)
- Retrieval of target gas concentrations

Advantage:

-Control of all the steps from the adquisition of the spectra to the final FTS product

- Knownlodge on the measurement technique

Crucial for a comprenhensive validation exercise

Disadvantage:

-Time consuming, especially when instrumental failures:

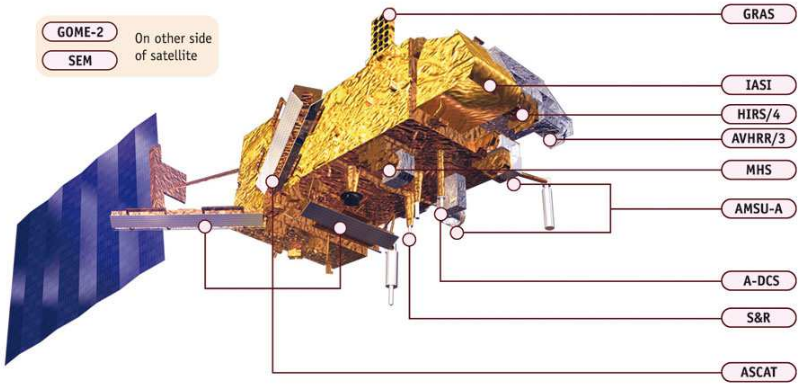
- -Laser
- - XPS/Cam Tracker
- -Vacuum Pump
- - LN2 pump system

Since summer 2016 to date

FTS and IASI main features

The IASI sensor and FTIR instrument use similar measurement technique Fourier Transform Infrared Spectrometry but…

	FTIR	IASI
Type of Observation	Direct solar absorption	Thermal infrared emission
Spectral Range [cm^{-1}]	700 – 9000	645 – 2760
Spectral Resolution [cm^{-1}]	0.005	0.5
Field of View	0.2 º (< solar disc)	At nadir 4 pixels of 12 km
Frequency of Observation	weather permit, ~3 days/week	twice per day, at IZO region around 10 am / pm
Sample Duration	6-8 min	8s (30x4 pixels)
Data Availability	Station dependent	Since 2007 MetOp-A/IASI Since 2012 MetOp-B/IASI



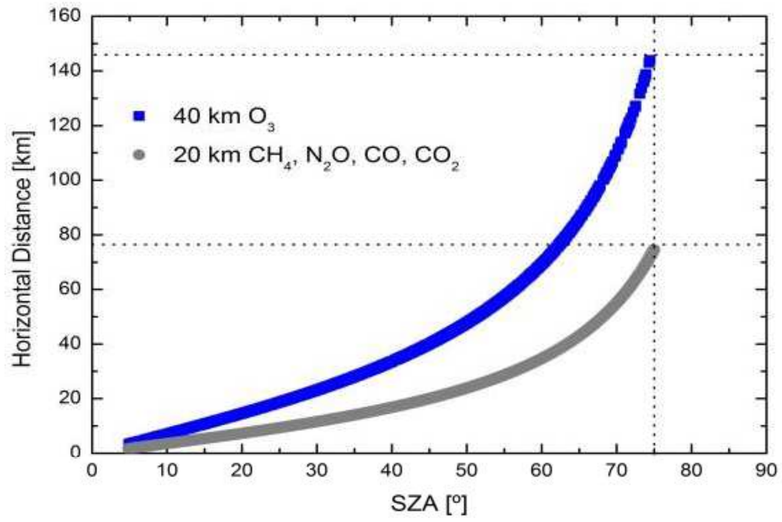
2· FIRST STEPS

VALIDATION METHODOLOGY

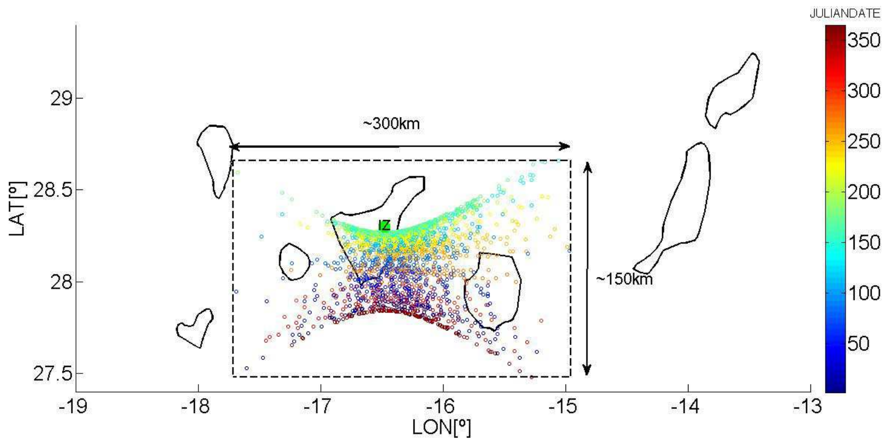
1. ESTHABLISMENT OF COLLOCATION CRITERIA

1.1 SPATIAL CRITERIA

▪ Firstly, it is calculated the altitude in [km] where the 95% of the target gas Total Column Amount is concentrated. Then, the horizontal projection is obtained considering the FTS observing geometry.



▪ *Validation box*: The projected horizontal distance covered by IZO FTS observations up to solar zenithal angle of 75º is between 80 km (CH_4, N_2O, CO and CO_2) and 150 km (O_3)



Example of validation box for O3 @ IZO

VALIDATION METHODOLOGY

1. ESTHABLISMENT OF COLLOCATION CRITERIA

1.2 TEMPORAL CRITERIA

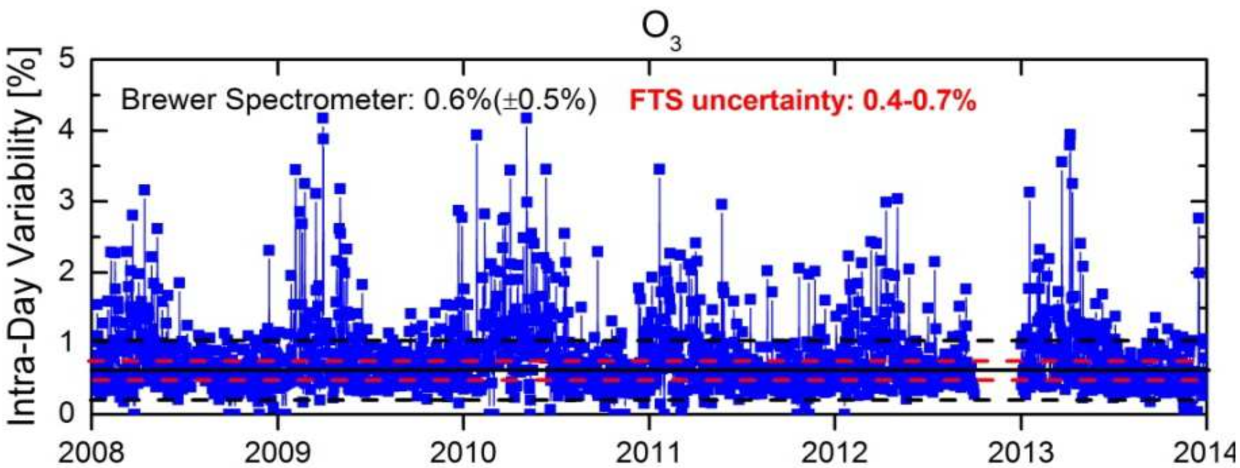
Depends on natural variability of the target gas and FTS uncertainty

Intra-day Variability > Theoretical Uncertainty FTS

±1h IASI overpass for O_3 and CO

Intra-day Variability < Theoretical Uncertainty FTS

Daytime medians for CH_4, N_2O and CO_2



VALIDATION METHODOLOGY

2. TEMPORAL DECOMPOSITION

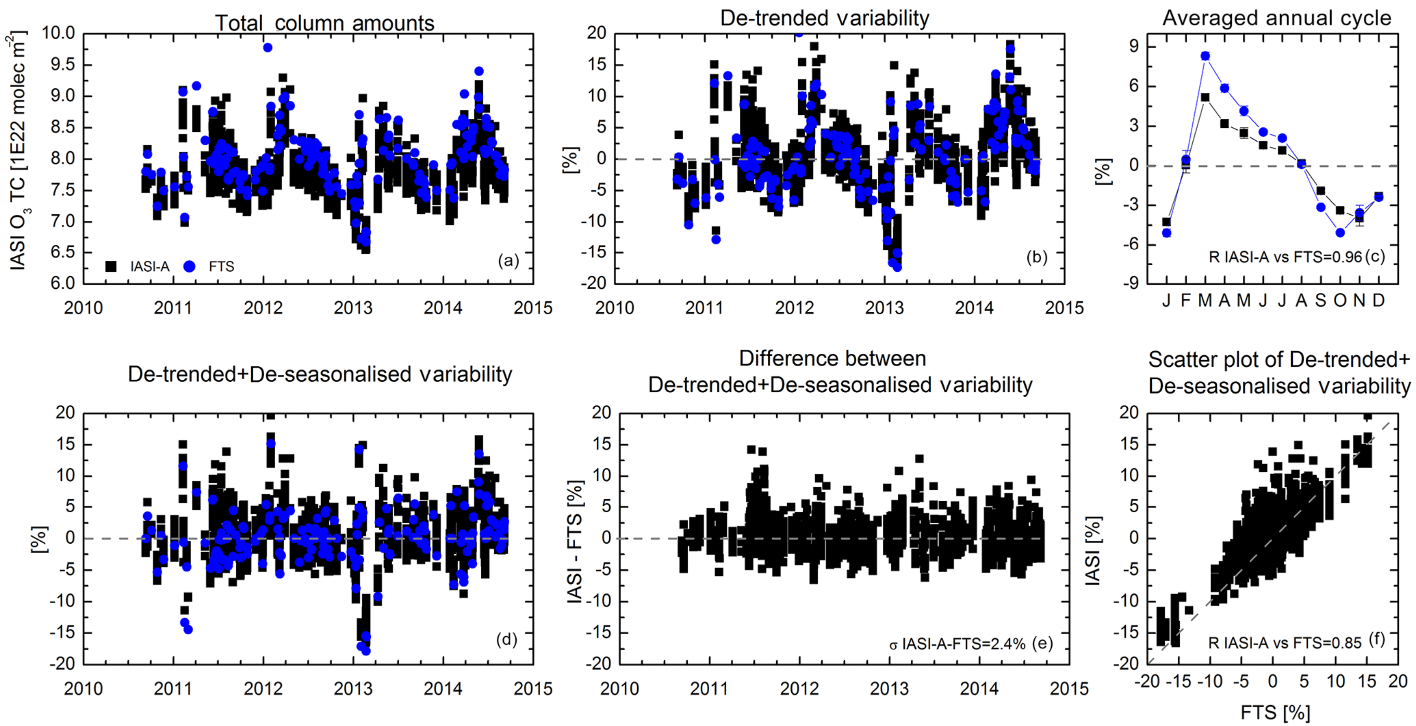
The validation exercise is performed comparing the variabilities observed for each instrument at different time scales: intraday, annual cycle and long term trend.

Annual Cycle Variability:

Original O3 Time Series – Fitted Linear Trend

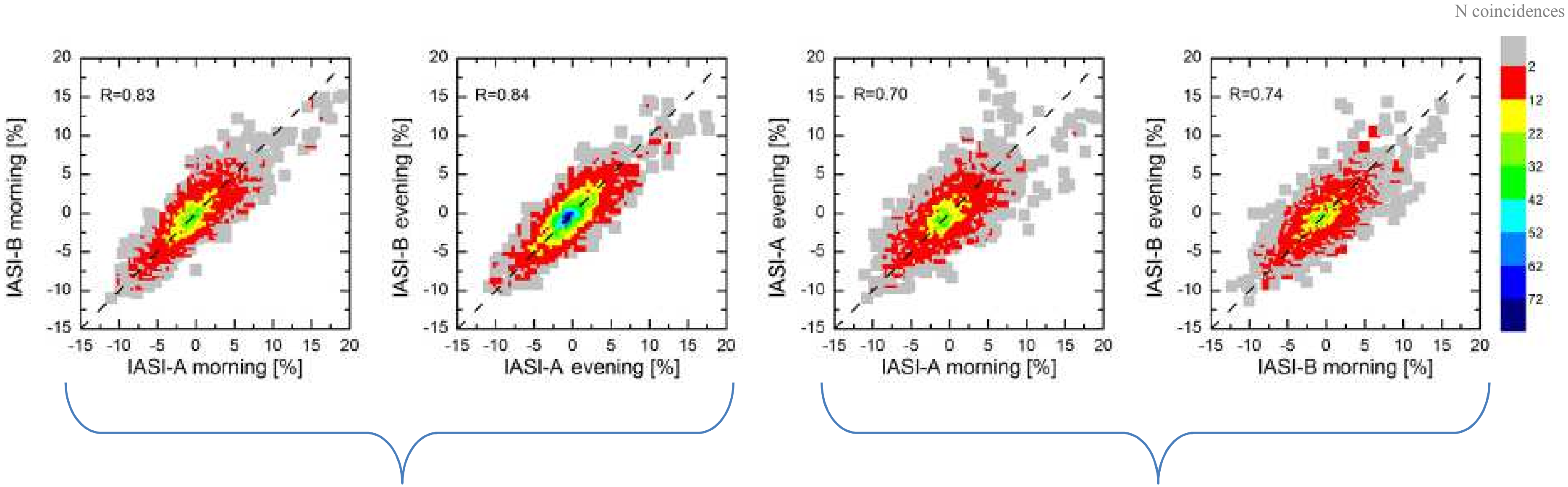
Intra-day Variability:

Original O3 Time Series – (Annual Cycle + Linear Trend)



VALIDATION MAIN RESULTS (O3 @ IZO)

IASI-A / IASI-B consistency



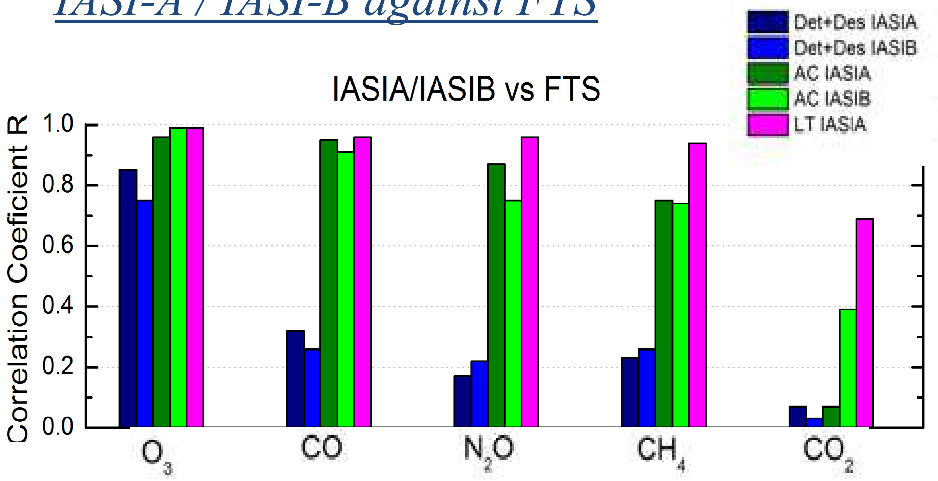
· The observations between IASI-A and IASI-B sensors are consistent (no bias, no temporal drift)

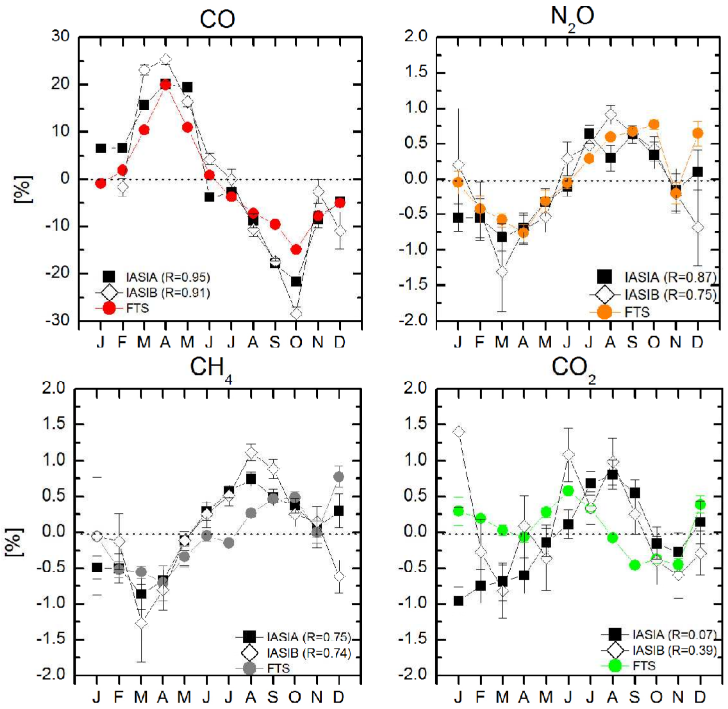
· Both sensors similarly reproduce the atmospheric composition variations.

· Each IASI sensor is able to capture the intraday O3 variability

VALIDATION MAIN RESULTS (O3 @ IZO)

IASI-A / IASI-B against FTS

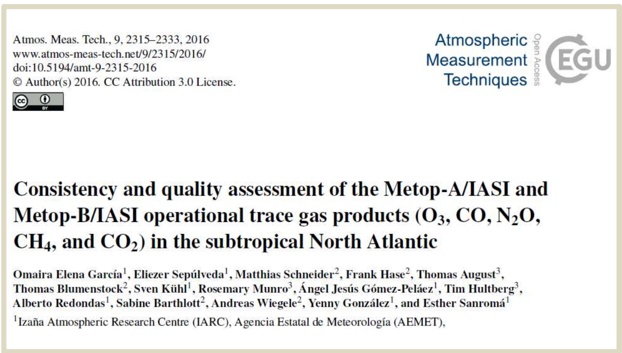




1) Only the EUMETSAT IASI L2 O3 & CO products well reproduce the intraday FTS observations

2) The EUMETSAT IASI L2 demostrational products (CH4, N2O and CO2) need further developments

3) All the EUMETSAT IASI L2 products reproduce the annual cycle FTS observations


Atmos. Meas. Tech., 9, 2315–2333, 2016
www.atmos-meas-tech.net/9/2315/2016/
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Atmospheric Measurement Techniques

Consistency and quality assessment of the Metop-A/IASI and Metop-B/IASI operational trace gas products (O_3, CO, N_2O, CH_4, and CO_2) in the subtropical North Atlantic

Omaira Elena García[1], Eliezer Sepúlveda[1], Matthias Schneider[2], Frank Hase[2], Thomas August[3], Thomas Blumenstock[2], Sven Kühl[1], Rosemary Munro[3], Ángel Jesús Gómez-Peláez[1], Tim Hultberg[3], Alberto Redondas[1], Sabine Barthlott[2], Andreas Wiegele[2], Yenny González[1], and Esther Sanromá[1]

[1]Izaña Atmospheric Research Centre (IARC), Agencia Estatal de Meteorología (AEMET),

Prospect:

1) Extending the EUMETSAT/IASI versus FTS comparison to other NDACC stations to analize the latitudinal dependence, emissivity, topography, observing geometry, …

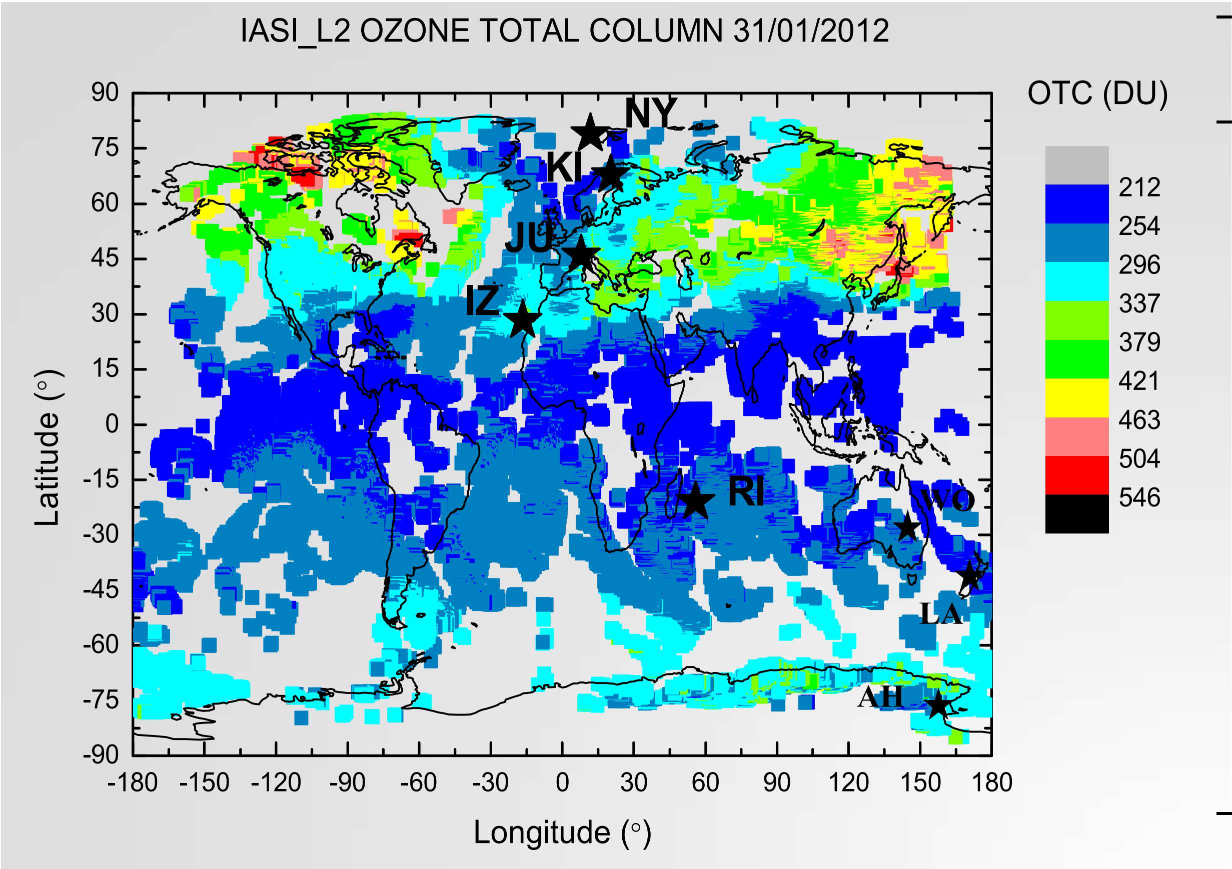
2) Including other IASI retrieval algorithms to evaluate to what extent the different strategies influence the IASI products:

· The *O3-FORLI* from LATMOS (kindly provided by C. Clerbaux)
· The *CH4 & N2O -MUSICA* products from IMK-ASK, KIT

3) Applying these studies to the new EUMETSAT/IASI products in collaboration with T. August group from EUMETSAT.

3· CURRENT STEPS

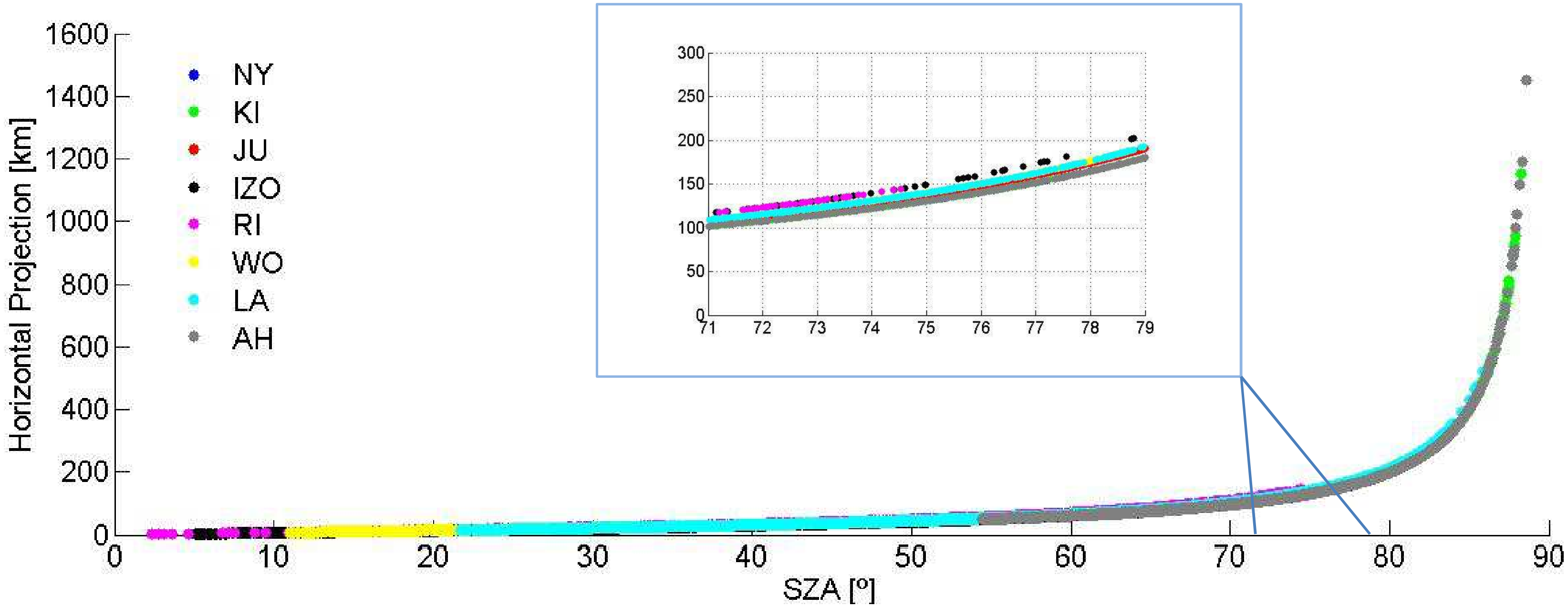
Extending the EUMETSAT/IASI L2 O3 & CO versus FTS comparison to other NDACC stations

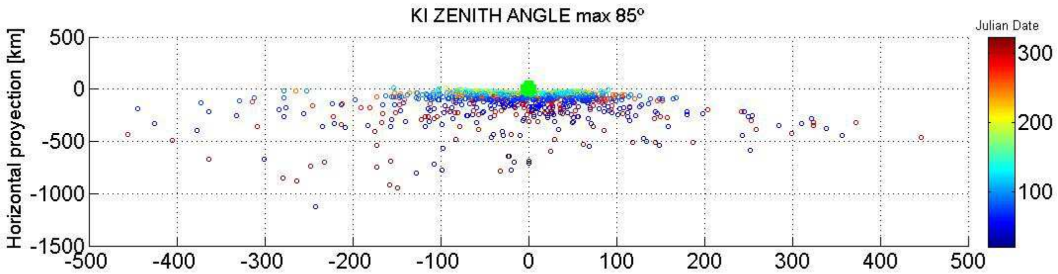


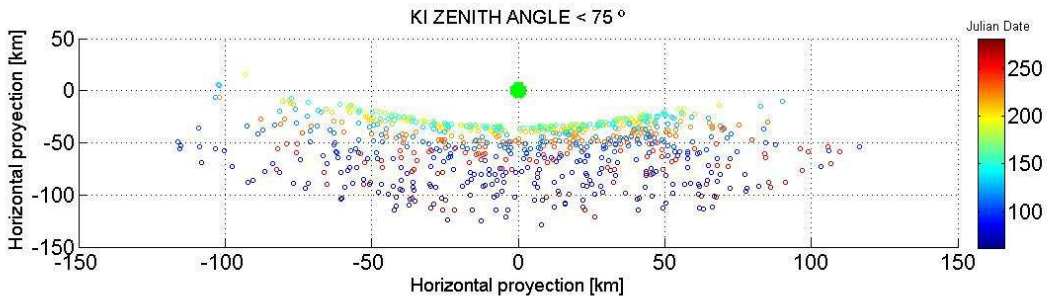
NDACC Site (Acronym)	Altitude a.s.l. [m]	Starting measurements
Ny-Ålesund (NY)	15	1995
Kiruna (KI)	419	1996
Jungfraujoch (JU)	3580	1990
Izaña (IZ)	2370	1999
Reunion Island Maido (RI)	2155	2013
Wollongong (WO)	30	1994
Lauder (LA)	370	1990
Arrival Height (AH)	250	1997

Remind that only the EUMETSAT/IASI O3 & CO products have enough quality to be validated on an intraday scale.

COLLOCATION CRITERIA







- *Spatial criteria*: the validation box is site dependent, according to horizontal projection up to SZA (75º)

- *Temporal criteria*: +/ 1 hr from the IASI overpass.

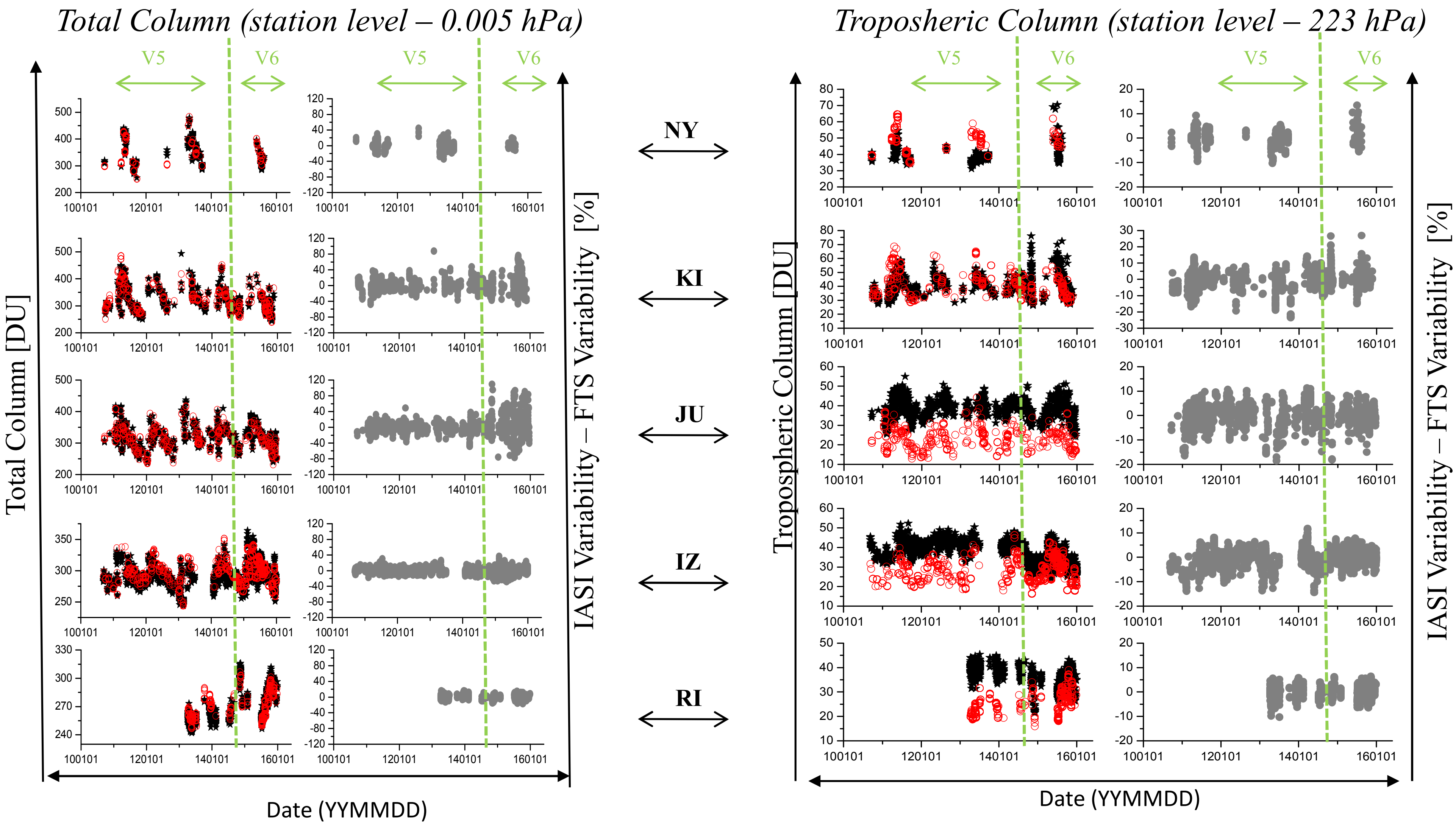
O3 case of study:

The EUMETSAT/IASI Level 2 (L2) O3 operational products generated by the EUMETSAT Polar System (EPS) Core Ground Segment with processor version 5 (09/2010-09/2014) and version 6 (10/2014-to date) (August et al., 2012; IASI Guide, 2014).

- The processor V5: under cloud-free conditions, the O3 profiles are simultaneously retrieved together with the humidity and temperature profiles (on a 90 level grid extending between 0.005 and 1050 [hPa]) and the surface temperature using an OEM. A global a priori (single unique covariance matrix) is computed from a collection of ECMWF (European Centre for Medium-Range Weather Forecasts) analysis records covering all seasons.

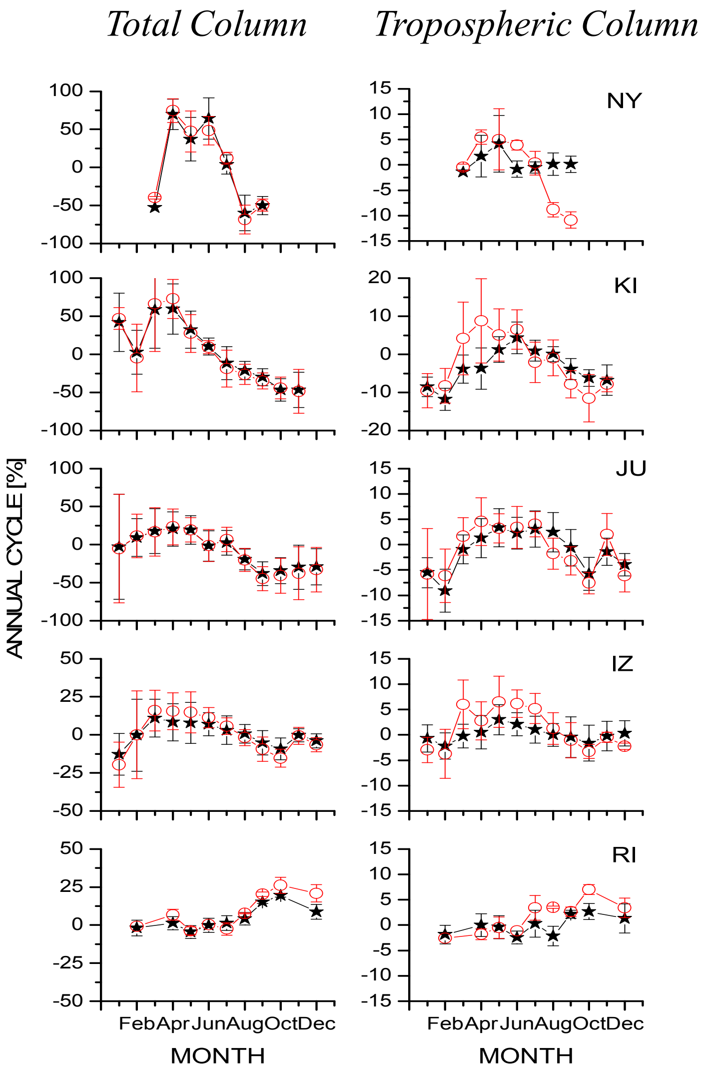
- The processor V6 incorporates for the first time the retrieval of O3 mass mixing ratio profiles on a 101 level grid extending between 0.005 and 1050 [hPa] and the full retrieval error estimates, from which the IASI vertical sensitivity (averaging kernel matrices) can be derived. The first-guess of the OEM is obtained from a statistical method (Piece-Wise Linear Regression method) using the input measurement available: IASI and/or AMSU/MHS.

EUMETSAT/IASI-A L2 O3 Total and Partial Column vs NDACC FTS intraday variability



The above two set of figures show: on the left pannel, the absolute time series of the NDACC FTS (**O**) and the IASI-A L2 V5&V6 (★) for clouds free, daytime, no sunglint and for the land/sea flag equal 0 (NY, IZ & RI) and equal 1 (KI & JU).
The right pannel shows the differences of the intra-day variabilities.

EUMETSAT/IASI-A L2 O3 Total and Partial Column vs NDACC FTS annual cycle



The above set of figures show the annual cycles for the IASI-A L2 V5 (O) and NDACC FTS (★).

- Intraday: The agreement between the O3 tropospheric column amount as observed by NDACC FTS and IASI L2 version 6 shows an improvement wrt to version 5, likely due to the improvements in the temperature and humidity profiles in the lower troposphere introduced in V6. However, for the total column amounts no improvements are found.

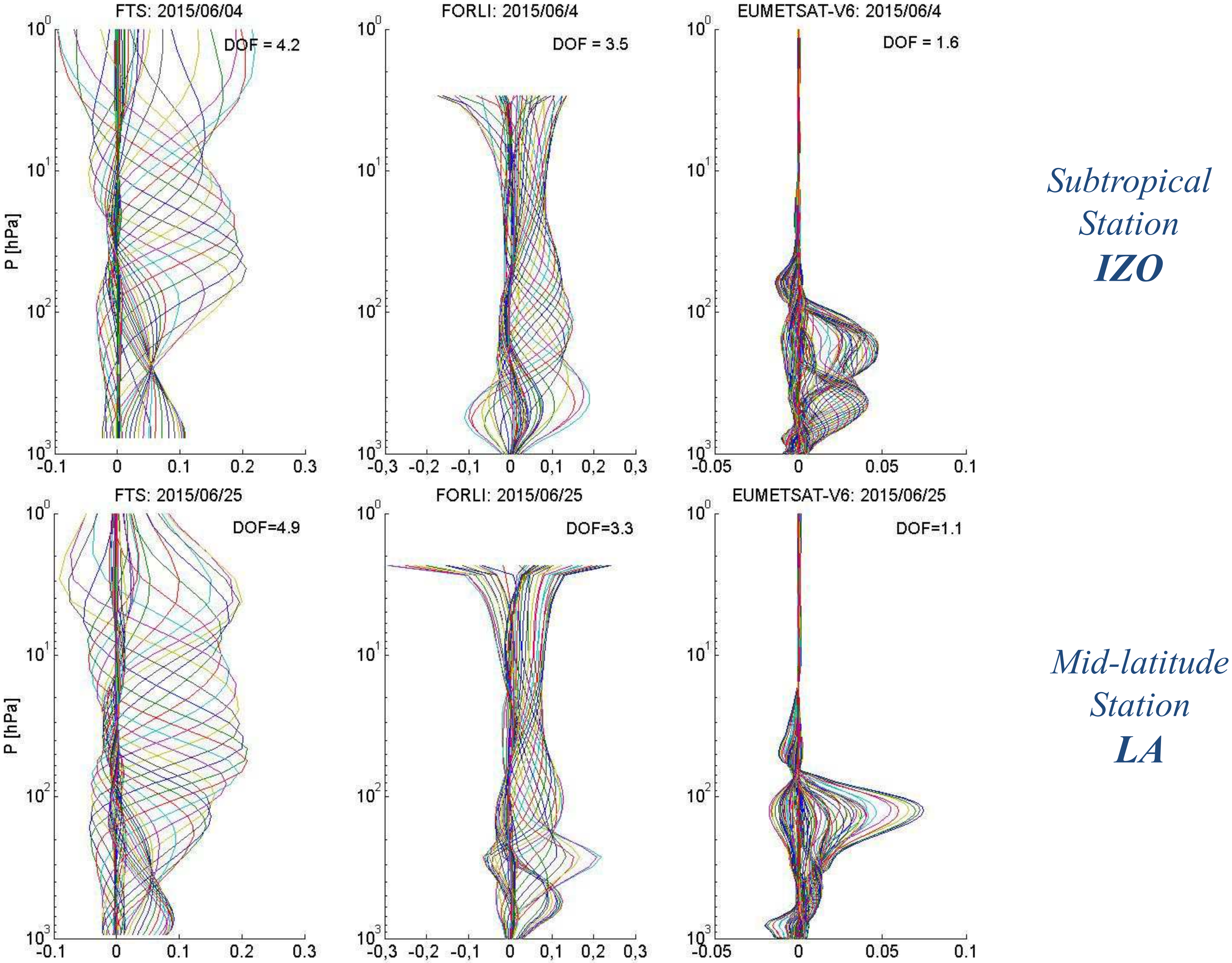
- Annual Cycle: For the total and tropospheric column amount comparison no significant improvements are found between EUMETSAT/IASI processor versions.

-Including another retrieval algorithm to analize the IASI capabilities to monitor O3 concentrations.

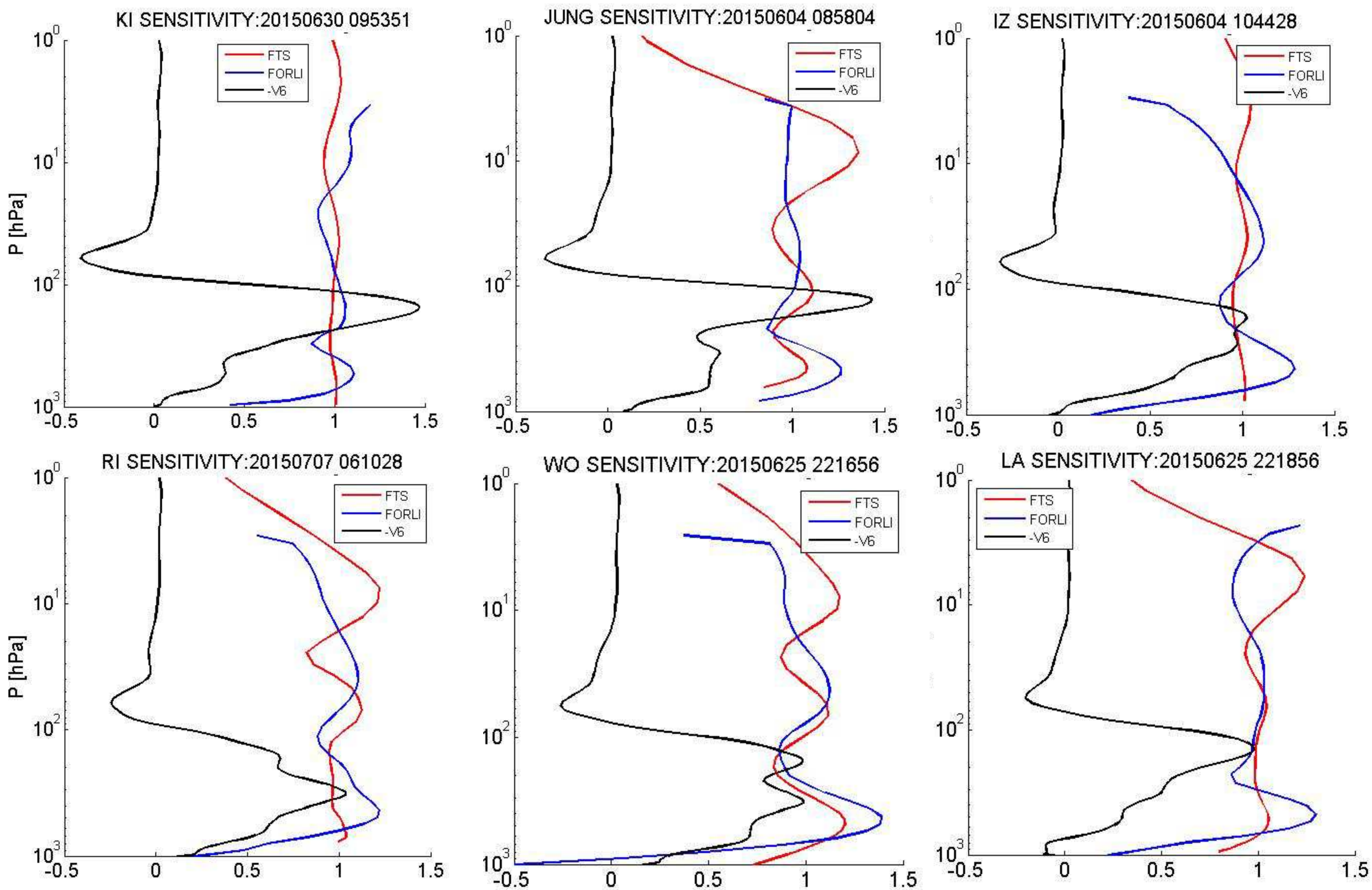
O3 validation including the 'Fast Optimal Retrievals on Layers for IASI' (FORLI)

	O3 FTS	O3 IASI (*version v5/v6*)	O3 IASI (*FORLI*)
Microwindow [cm^{-1}]	780 - 1015	1001 - 1065	1025 - 1075
Retrieval Method	Tikkonov Phillip	OEM	OEM
a-priori	Constant site dependent obtained from WACCM	Constant global apriori obtained from collection of ECMWF. First-guess from PWLR method.	Constant global apriori obtained from the McPeters/Labow/Logan ozone profile climatology
Spectroscopy	HITRAN 2008	?	HITRAN 2012
Pressure grid	~42 levels (site dependent)	90 level grid/101 levels	41 levels

VERTICAL SENSITIVITY



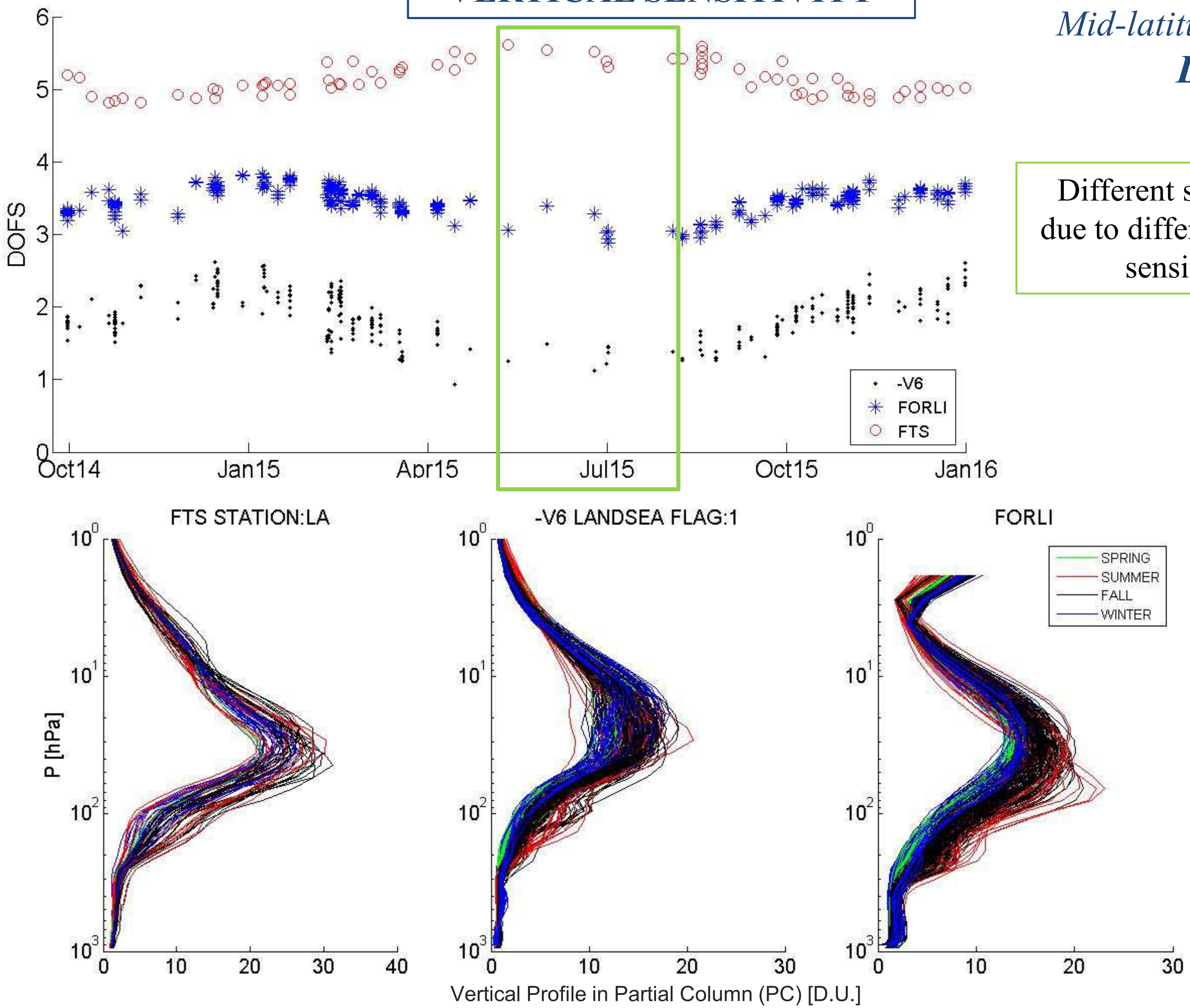
VERTICAL SENSITIVITY



Obviously the comparison is difficult due to the different vertical sensitivities

VERTICAL SENSITIVITY

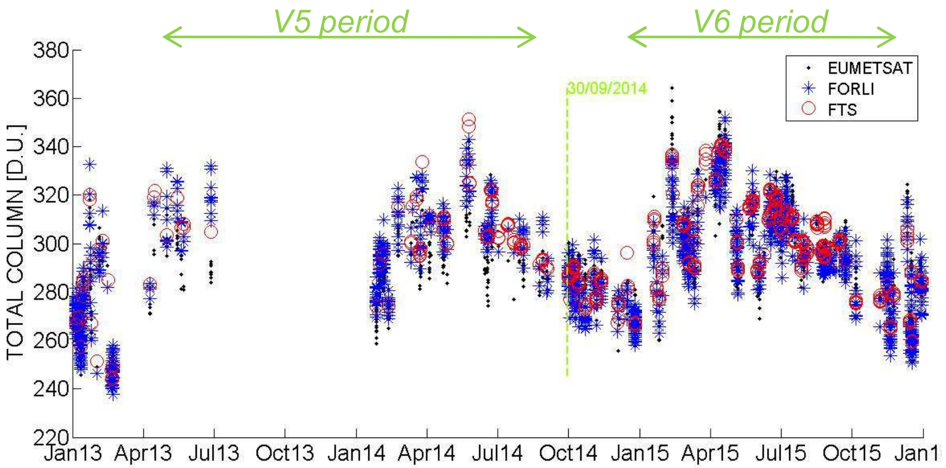
Mid-latitude Station
LA



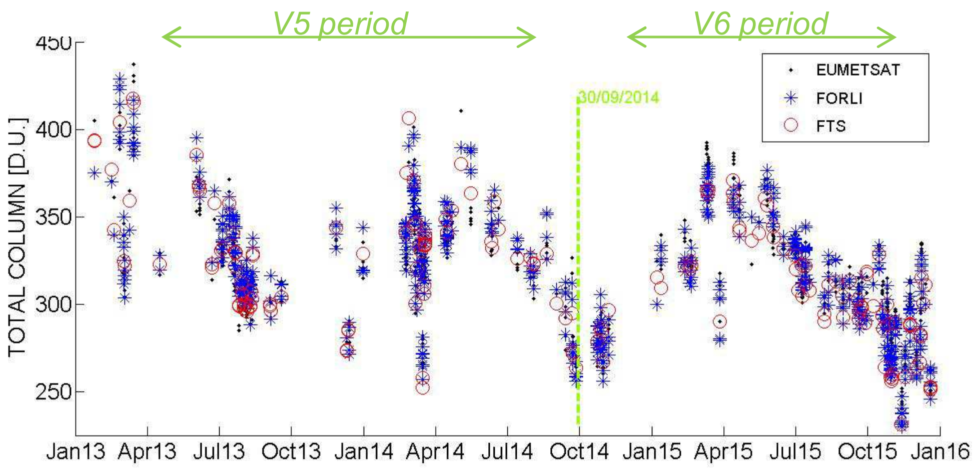
Different seasonality due to different vertical sensitivity

TOTAL COLUMN: Absolute values

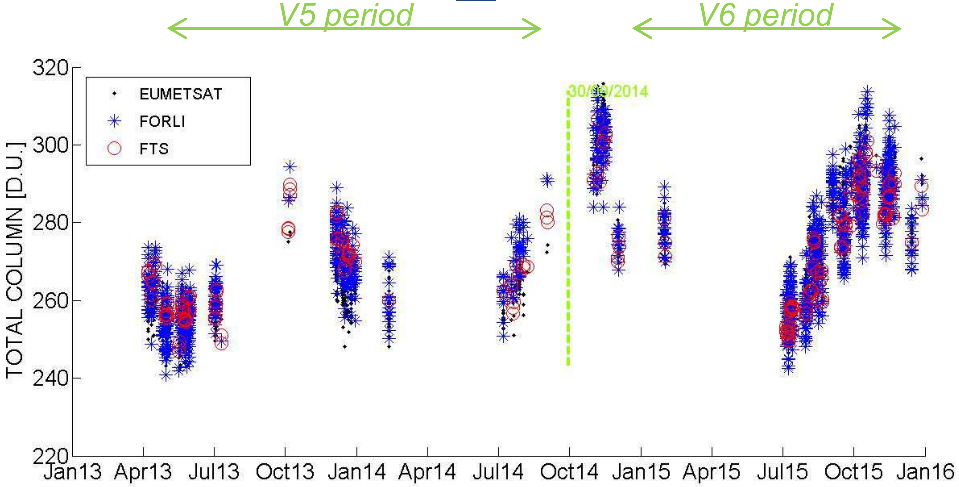
IZO



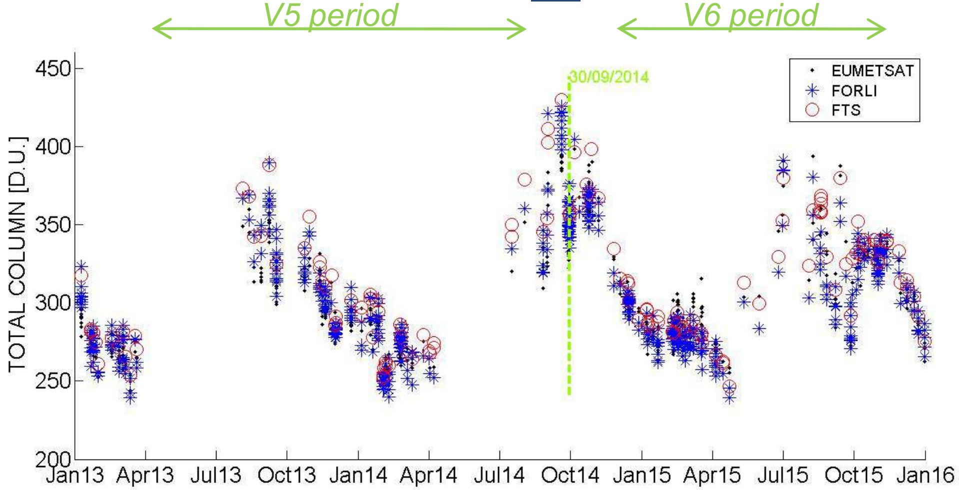
JU



RI



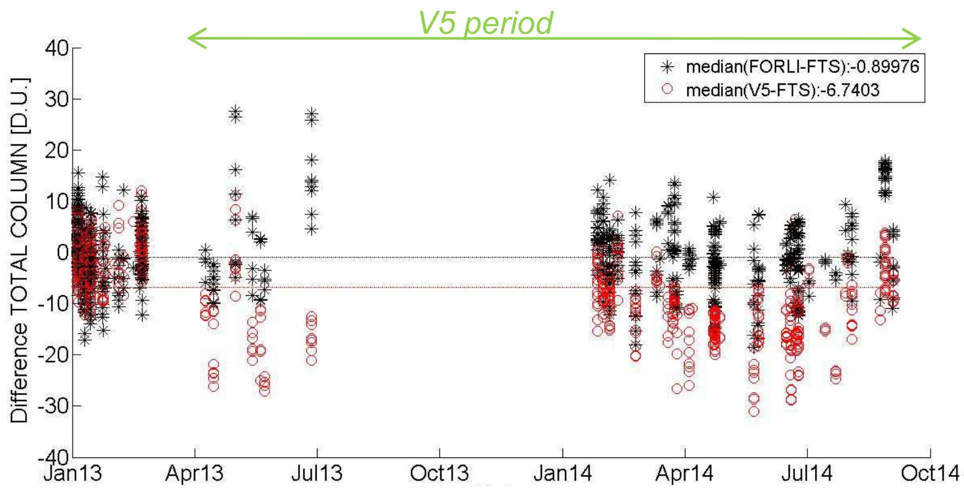
LA

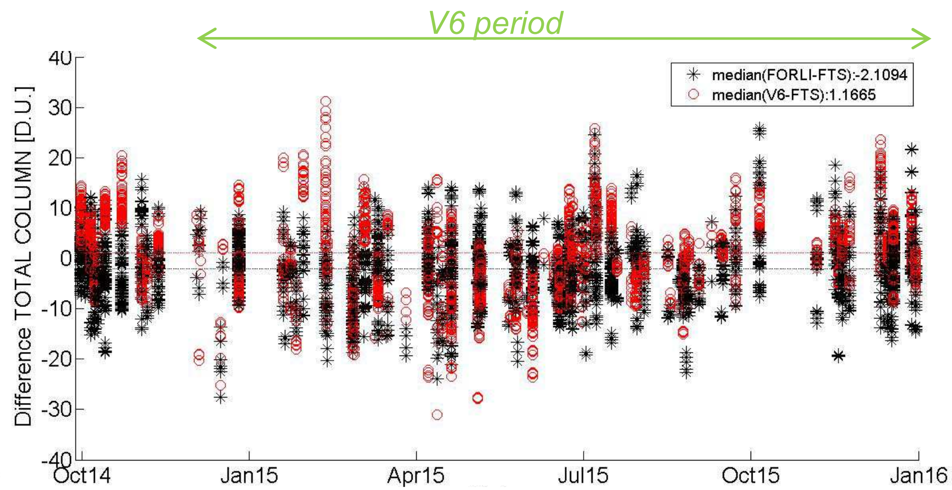


The time period selected is forced by RI site as its measurements started in 2013!!
The data set corresponds to the coincidences EUMETSAT-IASI; FORLI-IASI; NDACC-FTS

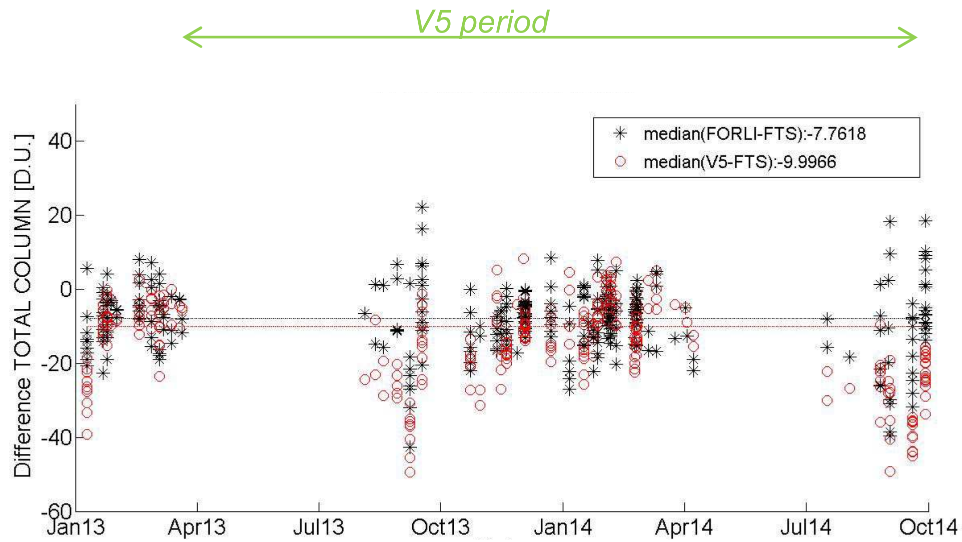
TOTAL COLUMN: Bias (median of absolute values)

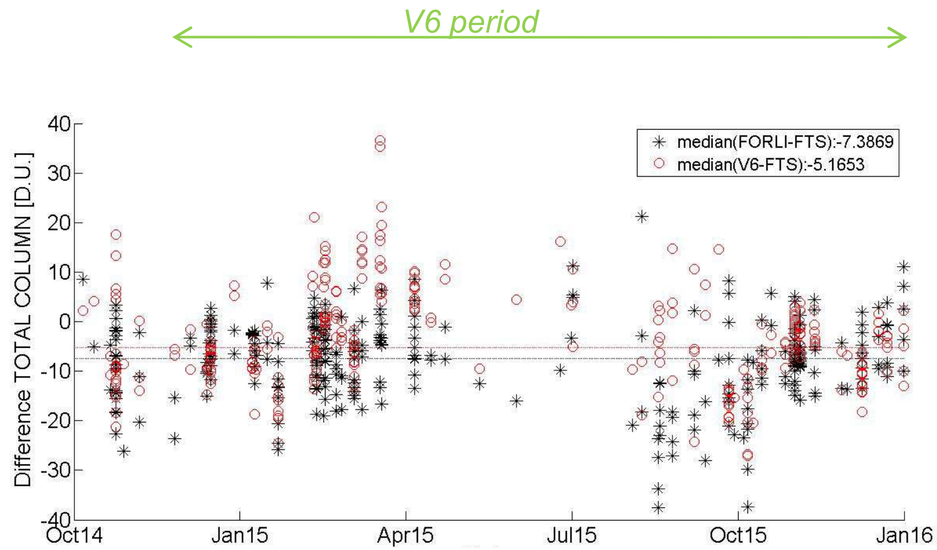
IZO



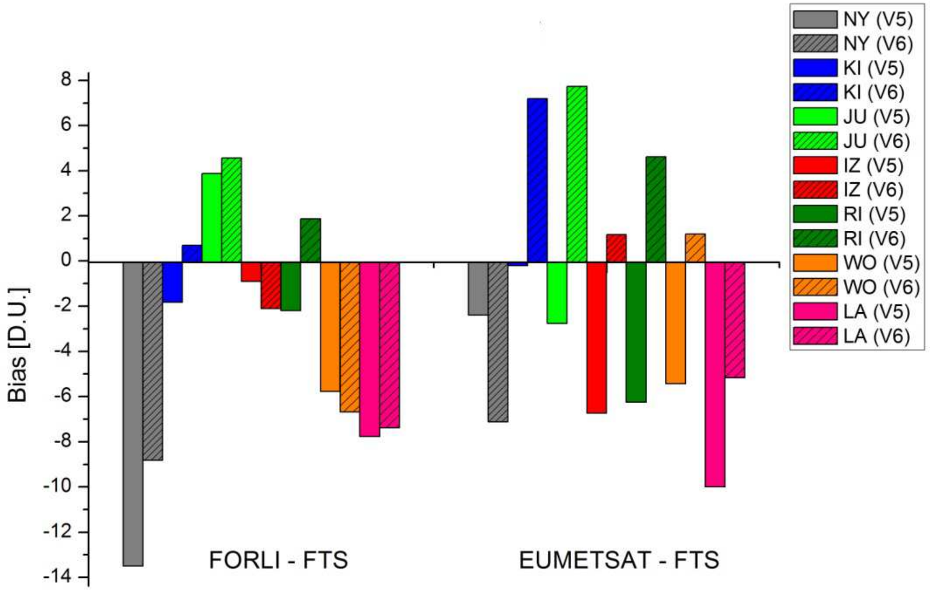


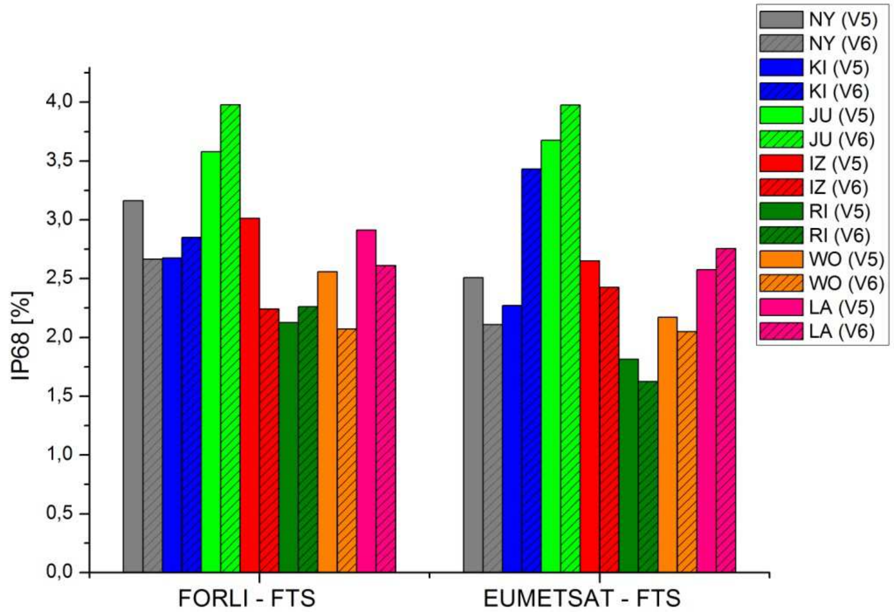
LA





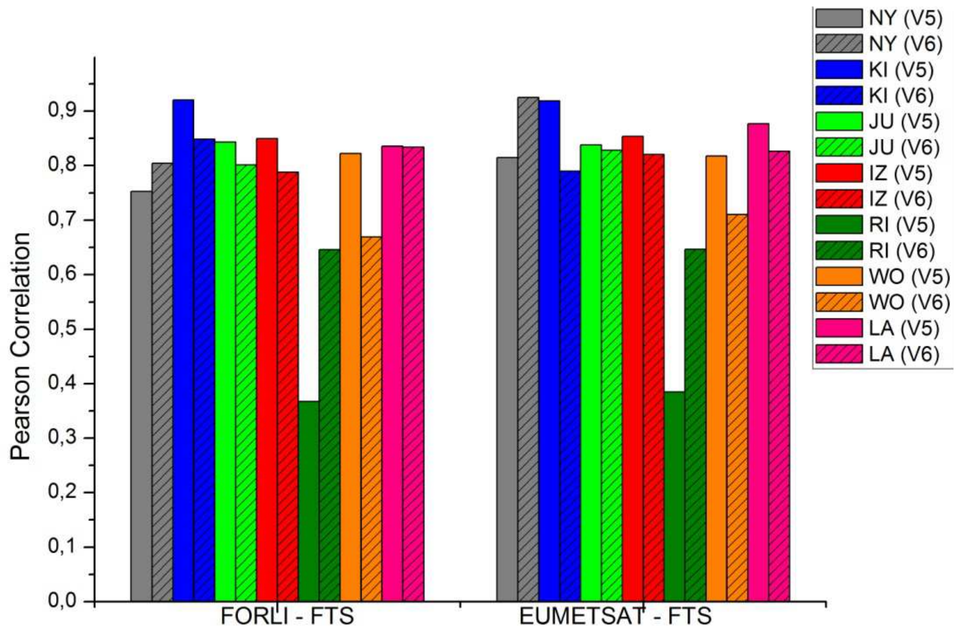
TOTAL COLUMN: intraday variability (detrended+deseasonalized)





IP68: semi 68% inter-percentile → IP68 = 0.5 [$Q_{84}(\Delta X) - Q_{16}(\Delta X)$]

where Q_{84} *and* Q_{16} are the 84 and 16% percentiles of the difference distributions: (FORLI-FTS) and (EUMETSAT-FTS)

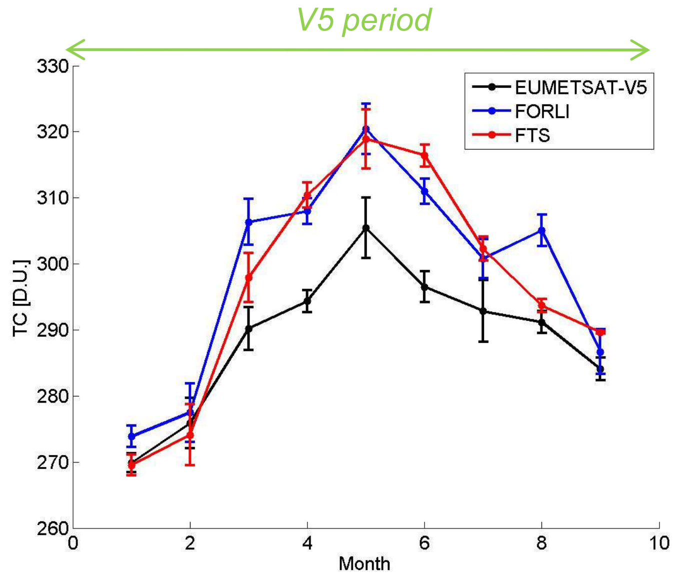


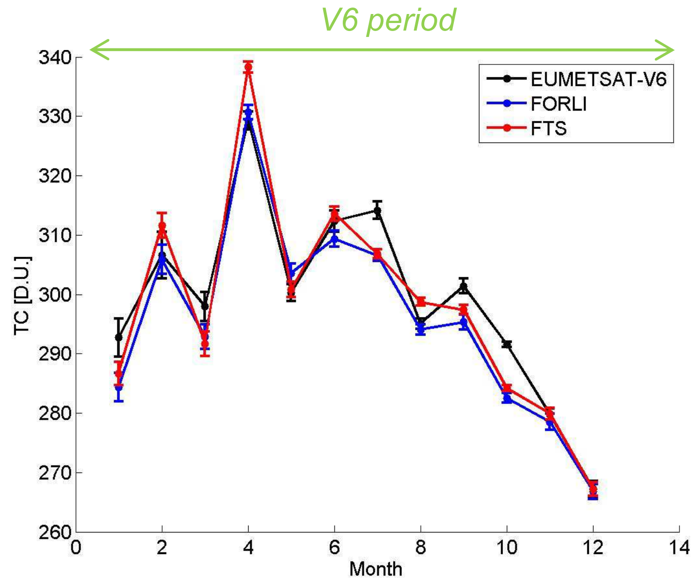
- The scatter observed by EUMETSAT and FORLI is consistent versus FTS (similar latitudinal behaviour).
- The IASI precision is between (2.5-3) % (conservative value)
- The bias in the EUMETSAT versions do not show similar behaviours.

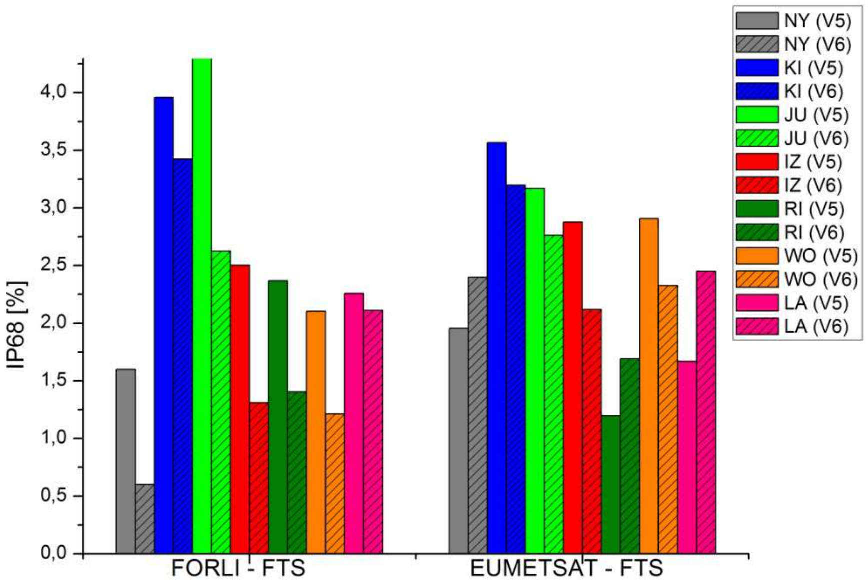
3. CURRENT STEPS

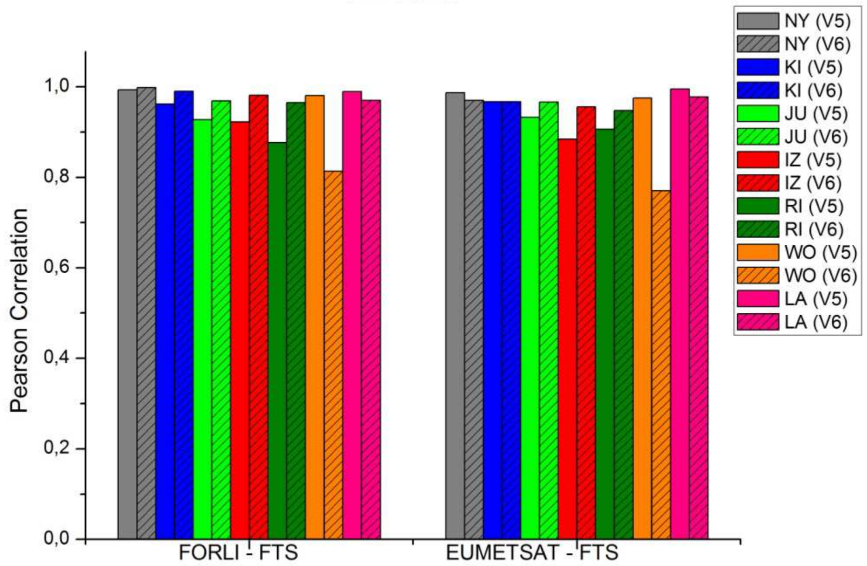
TOTAL COLUMN: annual cycle (detrended)

IZO

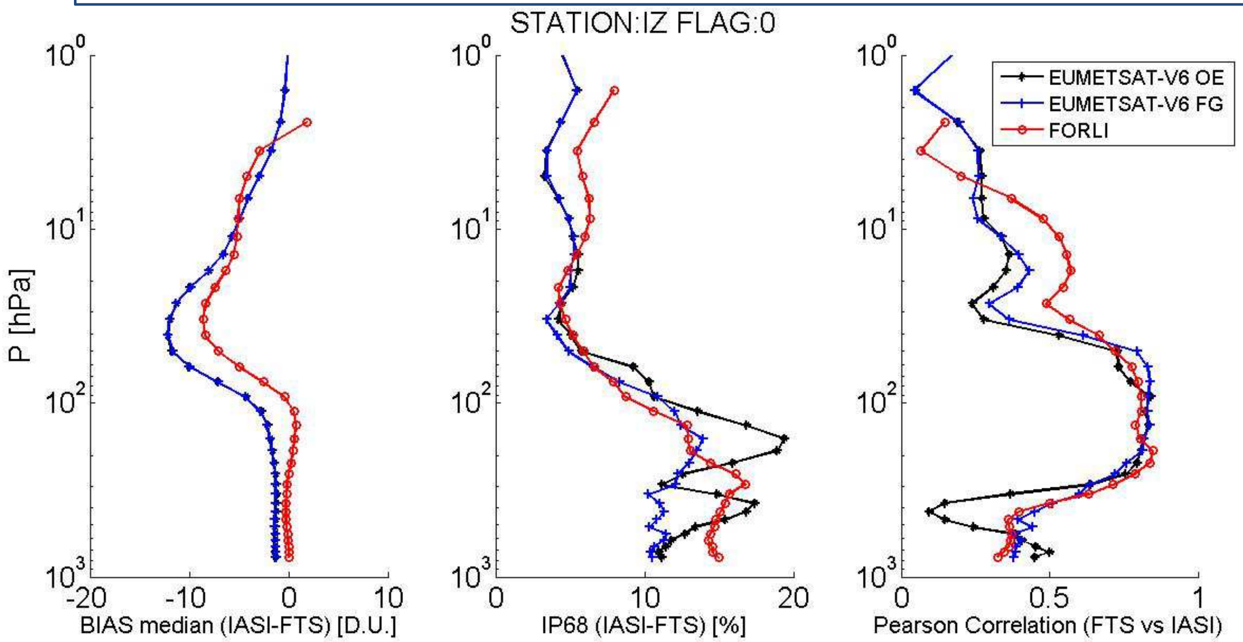




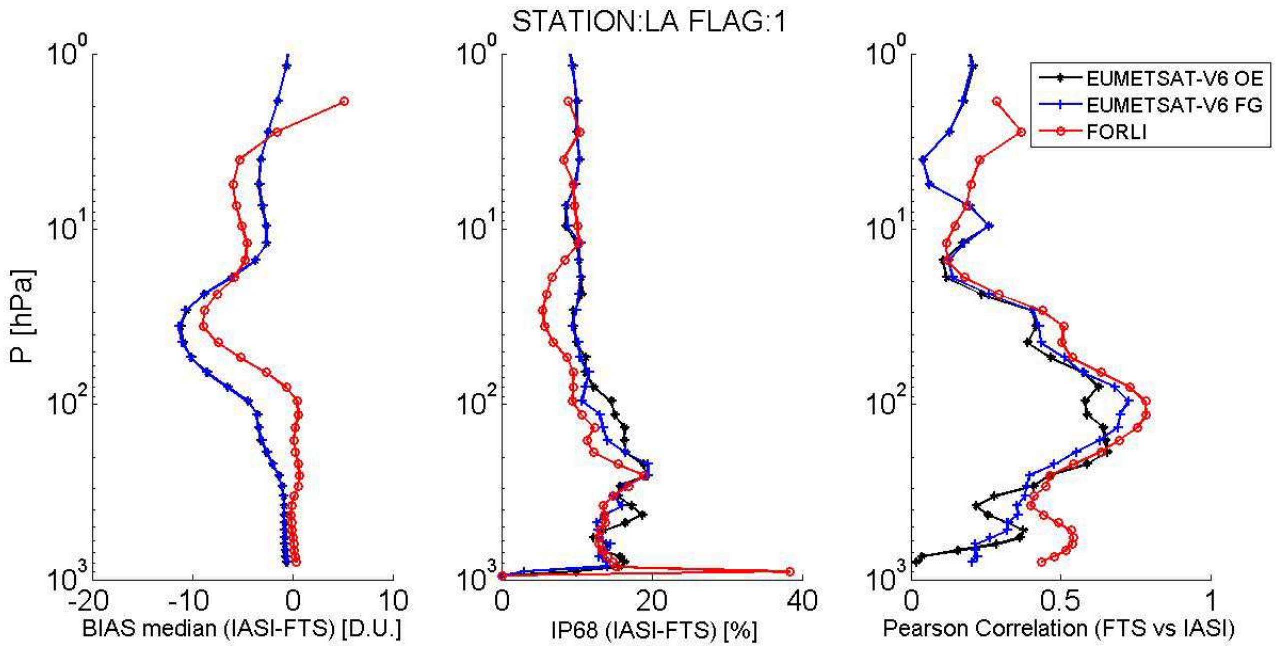




PARTIAL COLUMN VERTICAL PROFILE intraday variability (detrended+deseasonalized)



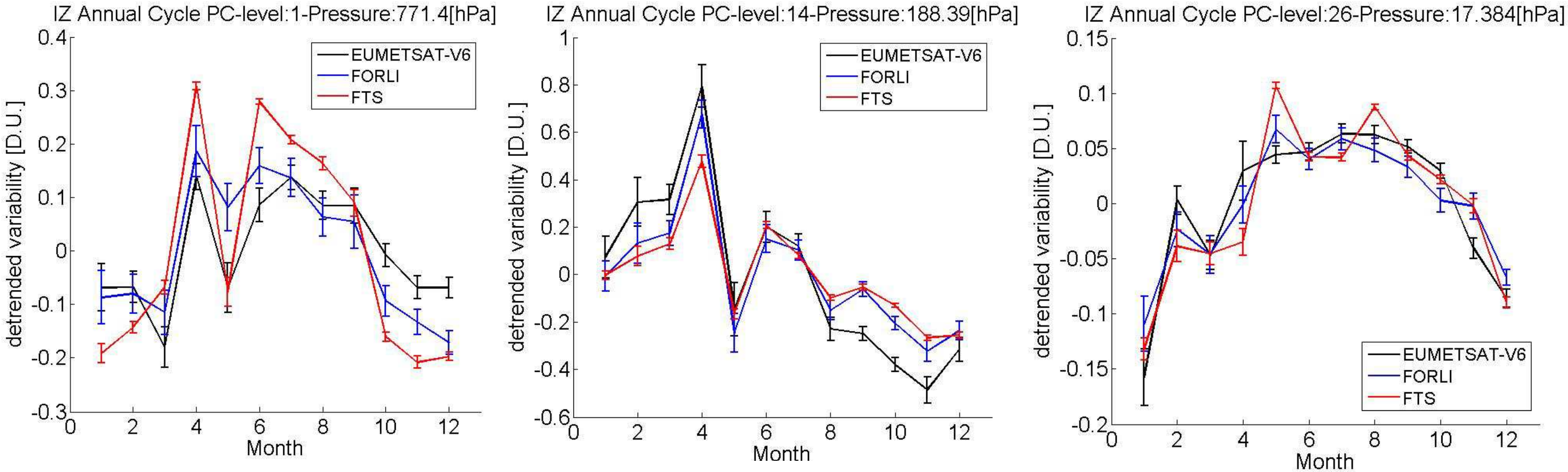
Subtropical Station ***IZO***



Mid-latitude Station ***LA***

OE: Optimal Estimation Method
FG: First Guess

PARTIAL COLUMN VERTICAL PROFILE annual cycle (detrended)



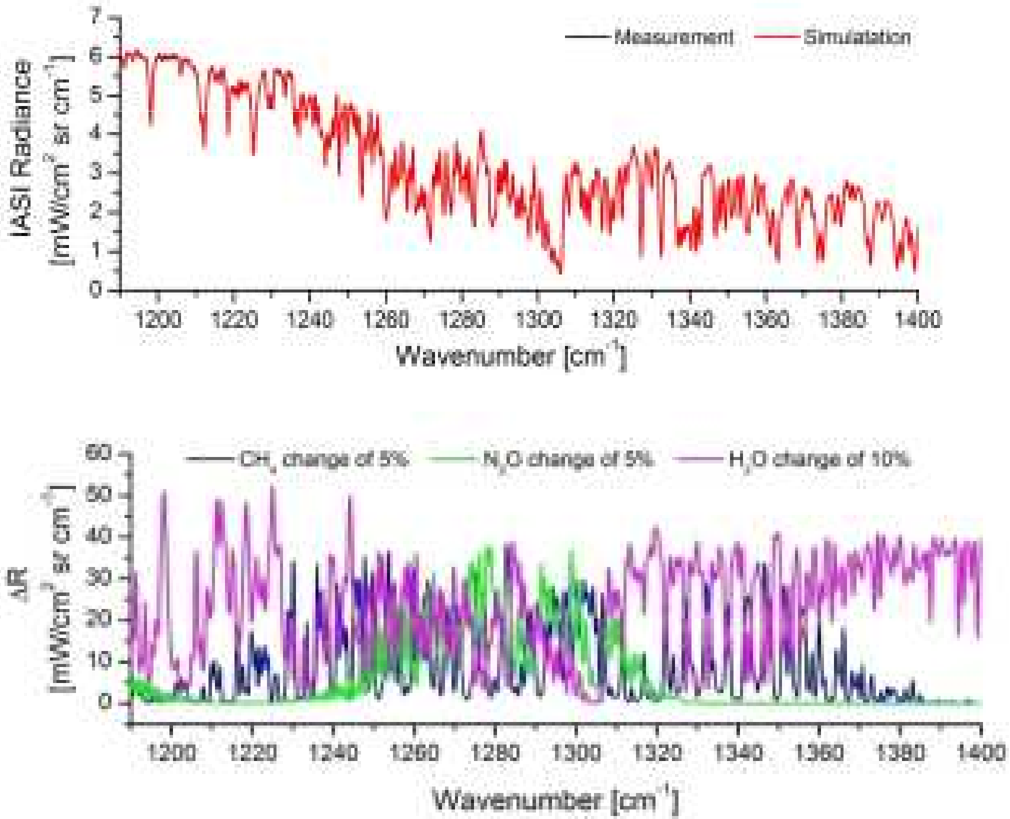
	771.4 [hPa]	*188.39 [hPa]*	*17.38 [hPa]*
Pearson Correlation			
FORLI - FTS	0.92	0.98	0.96
EUMETSAT - FTS	0.84	0.95	0.88
IP68 [%]			
FORLI - FTS	10.19	5.90	2.68
EUMETSAT - FTS	14.04	21.02	3.31

The MUSICA CH4 & N2O retrieval algorithm

AIM: Analysing the potential of IASI for observing global CH4 and N2O distributions.

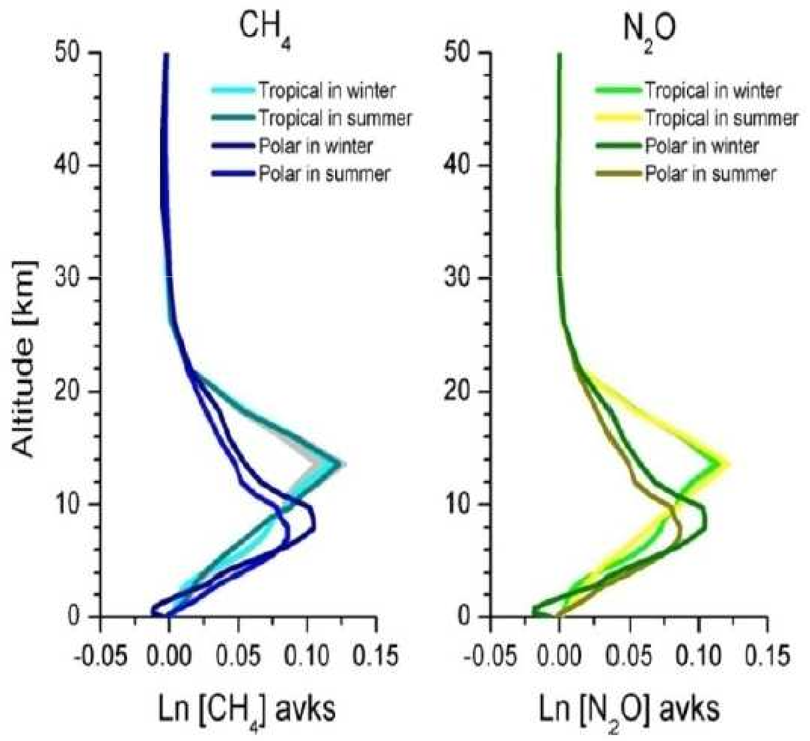
MUSICA is an European Research Council project : MUlti-platform remote Sensing of Isotopologues for investigating the Cycle of Atmospheric water. (https://www.imk-asf.kit.edu/musica.php)

Volume Mixing Ratio (VMR) CH4 and N2O profiles are retrieved in 1190-1400 cm^{-1} spectral window using the retrieval code **PROFFIT-Nadir** [Schneider and Hase, 2011]

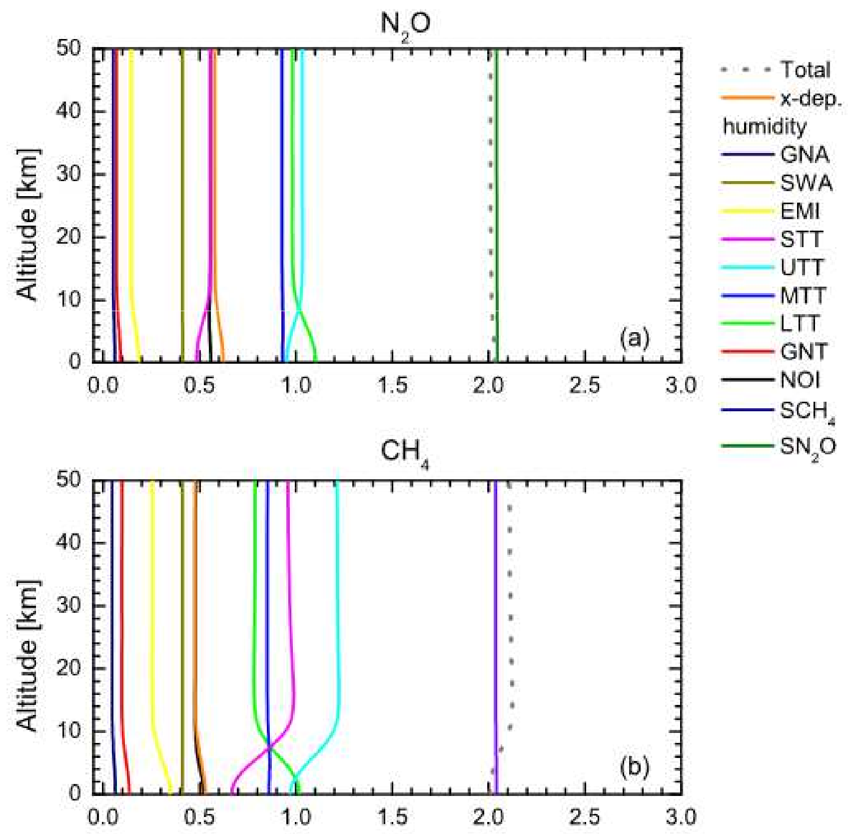


The MUSICA CH4 & N2O characterisation

MUSICA strategy is able to provide IASI CH4 andN2O global distributions in the upper troposphere (at 350-300 hPa) with a theoretical precision of 2%.



(FWHM of sensitivity: ~10km)

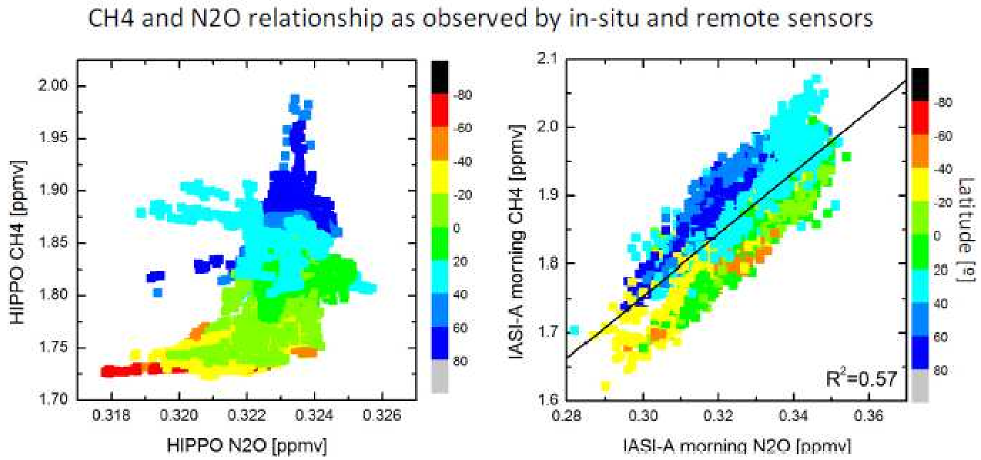


The MUSICA CH4 & N2O combined product

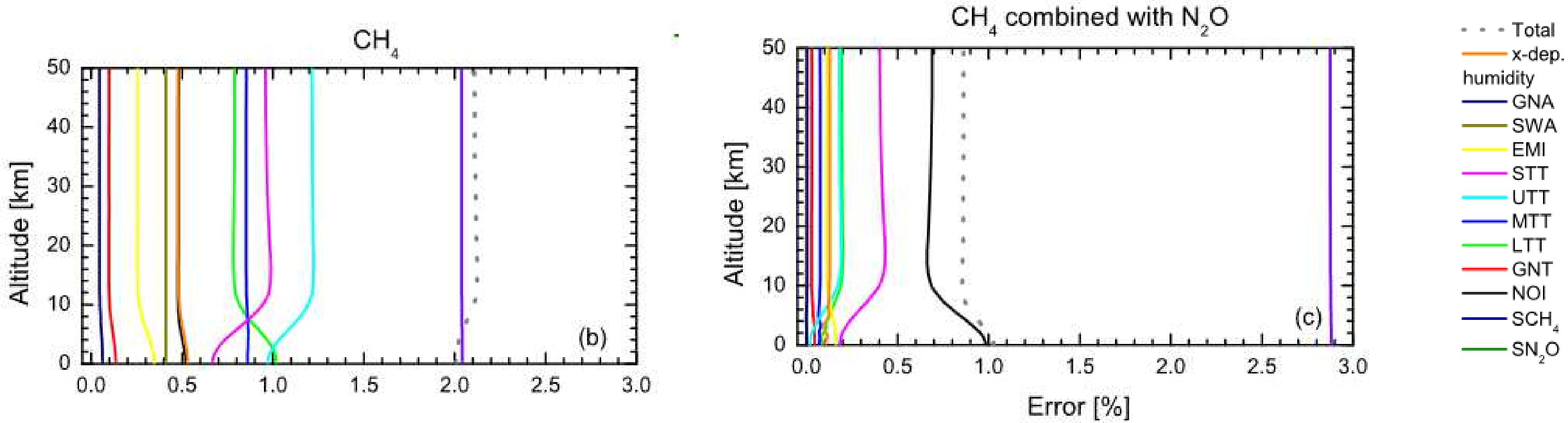
CH4 A-POSTERIORI CORRECTION

1) The radiative response of CH4 and N2O similarly behaves to common errors, such as temperature, clouds and emissivity.

2) The atmospheric N2O concentrations are rather stable (much more than CH4 values) could be well represented by the a-priori information.

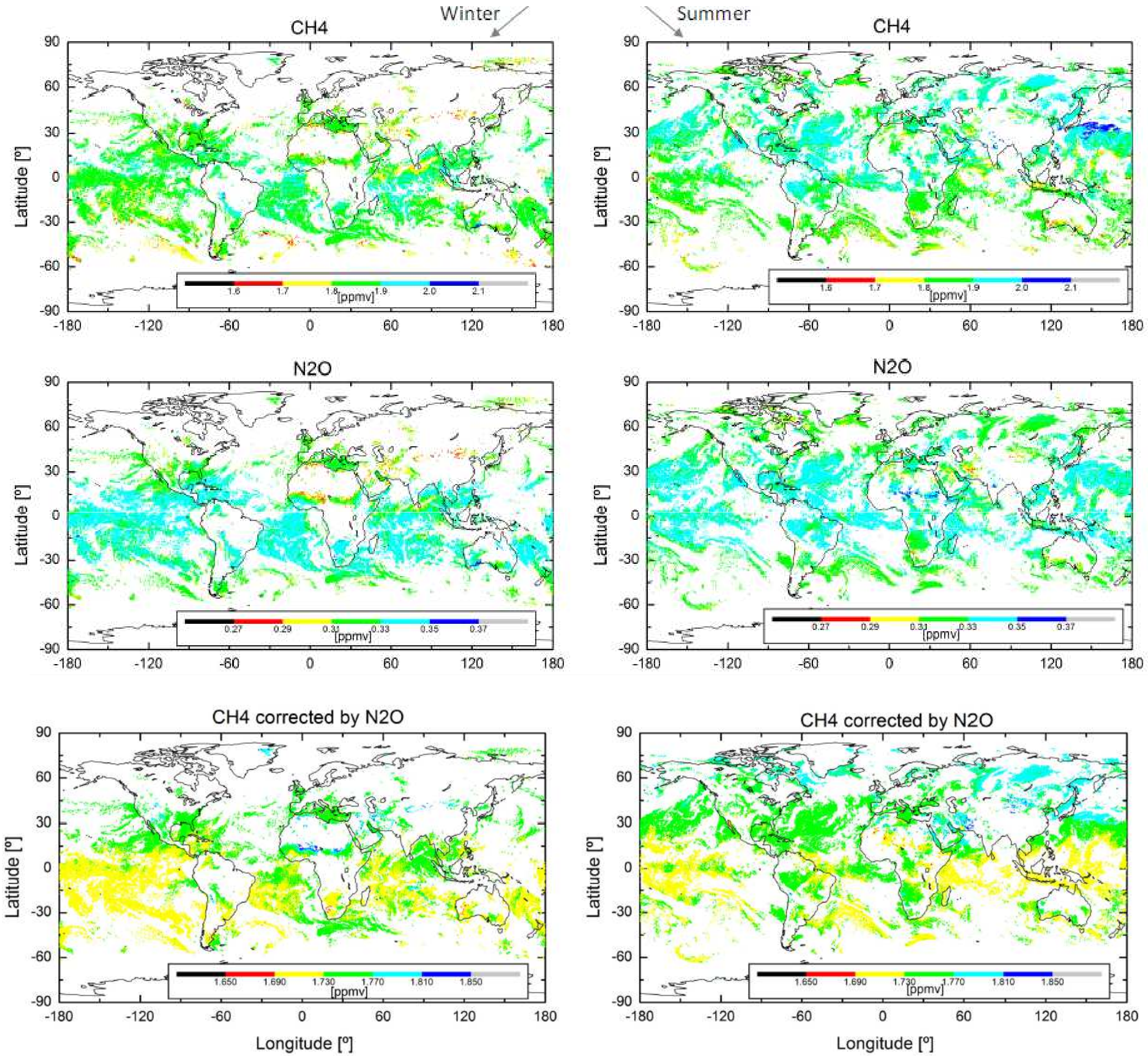


The observed deviations from the a-priori profile (N2O residues) are assumed to be introduced by the common errors and are used to correct the CH4 estimates according to Razavi et al. [2009], Worden et al. [2012]:

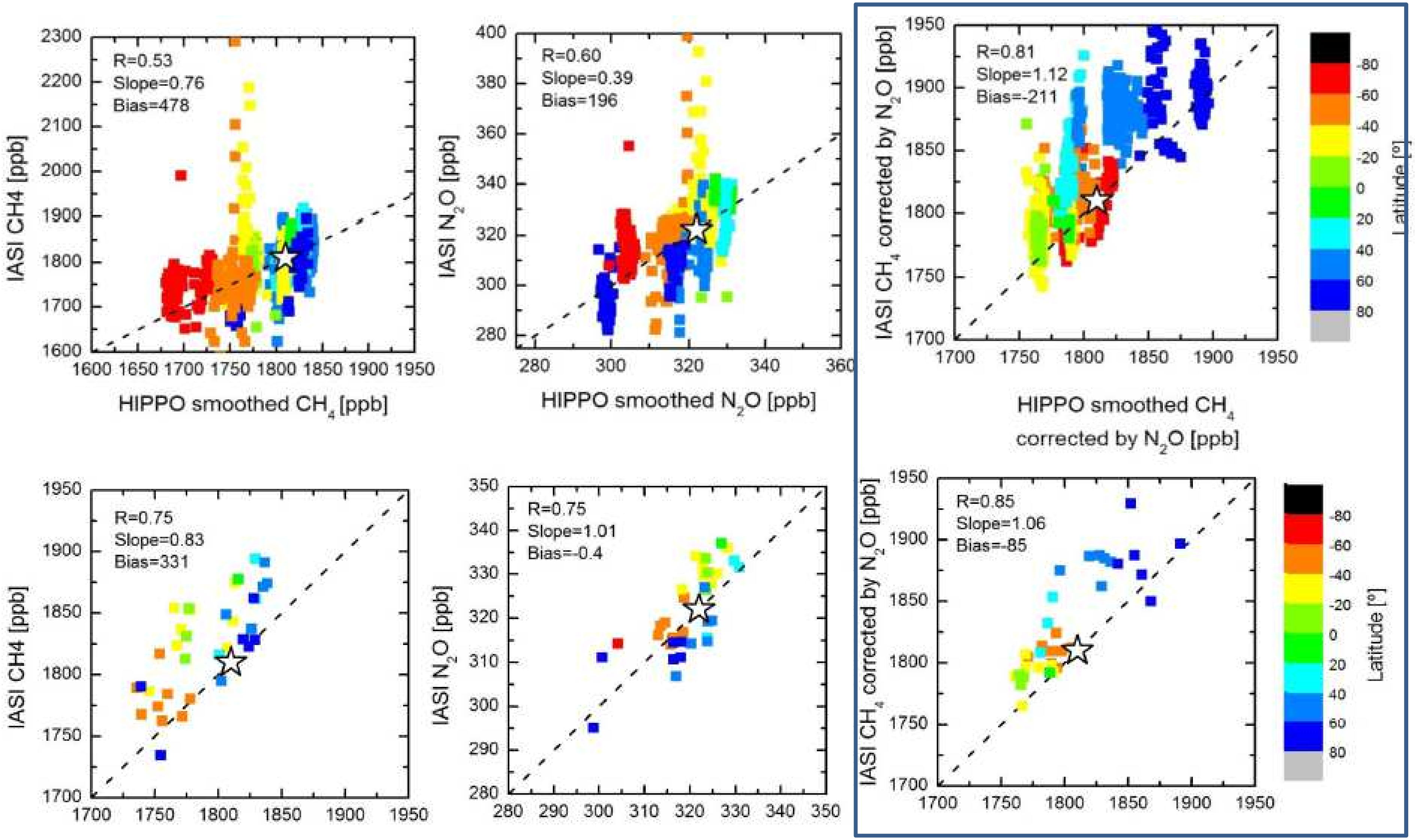


The a-posteriori correction reduces significantly the estimation errors

The MUSICA CH4 & N2O global distribution



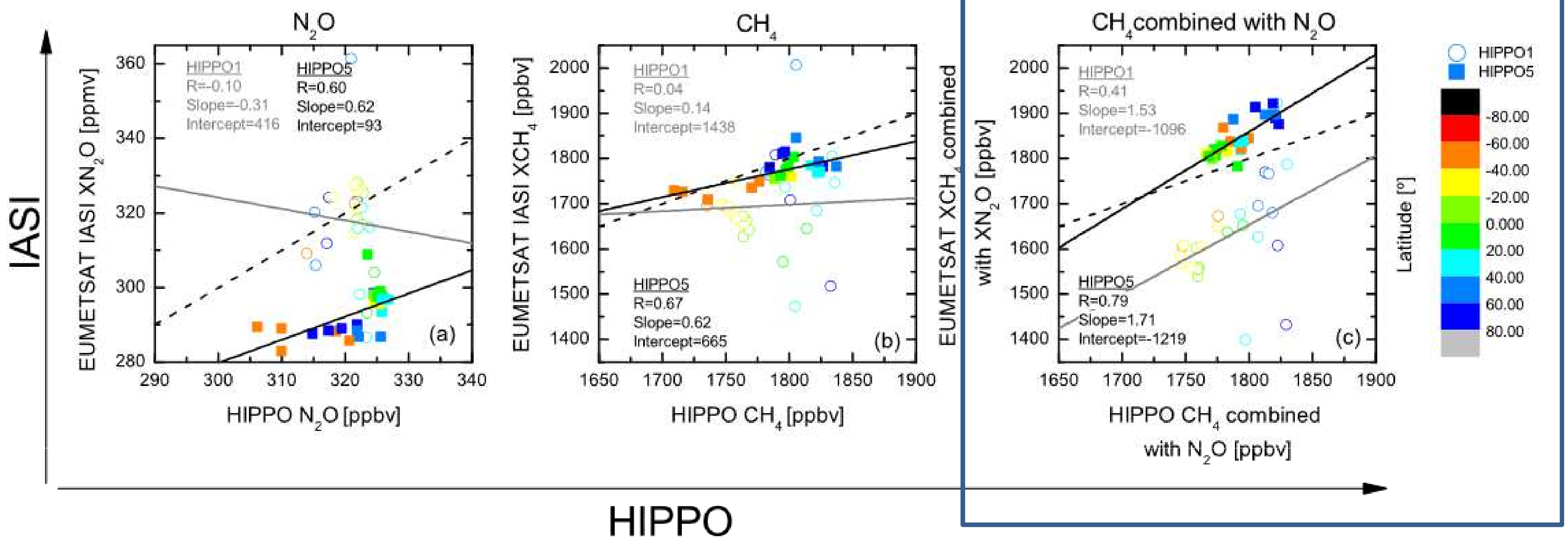
The MUSICA CH4 & N2O: Empirical Validation



Validation dataset: The HIAPER Pole-to-Pole Observations (HIPPO) project (http://hippo.ucar.edu/) mission 1 and mission 5.

The combined product improves the precision of the IASI CH4 product.

The EUMETSAT/IASI CH4 & N2O: Empirical Validation



For EUMETSAT/IASI the a-posteriori correction also improves the precision of the CH4 product.

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Upper tropospheric CH_4 and N_2O retrievals from MetOp/IASI within the project MUSICA

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VALIASI collaborates with several projects:

The Spanish INMENSE project (IASI for surveyiNg the MethanE and NitrouS oxide in the troposphere): MINECO, 2017-2019

INMENSE will generate a new global observational data set of middle/upper tropospheric concentrations of CH_4 and N_2O with high and well-documented quality.

The Spanish NOVIA project (Towards a Near Operational Validation of IASI level 2 trace gas products): MINECO, 2013-2015

NOVIA aims at performing the first comprehensive scientific long-term validation of the operational EUMETSAT/IASI atmospheric trace gas products.

The European MUSICA project (Multi-platform remote sensing of water isotopologues): ERC, 2011-2016

The MUSICA project focuses on developing strategies for observing tropospheric water vapour isotopologues.

4. OUTLINE AND CONCLUSIONS

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1. 'EUMETSAT/IASI and FORLI/IASI versus NDACC/FTS comparison. First results are promising, however several issues have to be investigated:
   - Sampling issues?? → using longer time period.
   - FORLI last layer → Why increase¿?
   - Arrival Height FTS data issues → Vertical profiles ¿?
   - EUMETSAT/IASI version 6 First Guess correlates better wrt FTS than the Optimal Estimation method (specially for subtropical and mid-latitude sites) ¿?

2. Comparison study for the EUMETSAT/IASI version 6 whole reprocessed time serie ¿?

3. INMENSE project collaboration
   - Providing excellent opportiunity for testing CH_4 and N_2O retrieving for IASI

4. Continuiting with the FTS activities.

5. Applying these studies to the new EUMETSAT/IASI products in collaboration with T. August group from EUMETSAT ¿?

6. Publication of these results.

Peer-reviewed articles

- Garcia, O. E., Sepulveda, E., Schneider, M., Hase, F., August, T., Blumenstock, T., Kuhl, S., Munro, R., Gomez-Pelaez, A. J.,Hultberg, T., Redondas, A., Barthlott, S., Wiegele, A., Gonzalez, Y., and Sanroma, E.: Consistency and quality assessment of the Metop-A/IASI and Metop-B/IASI operational trace gas products (O3, CO, N2O, CH4, and CO2) in the subtropical North Atlantic, Atmos. Meas. Tech., 9, 2315-2333, doi:10.5194/amt-9-2315-2016, 2016.

- Garcia, O. E., Sepulveda, E., Schneider, M., Wiegele, A., Borger, C., Hase, F., Barthlott, S., Blumenstock, T., de Frutos, A. M.:Upper tropospheric CH4 and N2O retrievals from MetOp/IASI within the project MUSICA, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-326, 2017

Contributions to conferences

- Sepulveda, E., O.E. Garcia, M. Schneider, T. August, F. Hase, T. Blumenstock, T. Hultberg, M.E. Sanroma, V. Carreno , A. M. De Frutos , J. Notholt, E. Mahieu and M. De Maziere, VALIASI: Ozone Total Column Amounts and Vertical Profiles comparison between satellite-based IASI and ground-based NDACC FTIRIASI: Ozone Total Column Amounts and Vertical Profiles comparison between satellite-based IASI and ground-based NDACC FTIR, EUMETSAT Conference 2016, Darmstadt (Germany), 26-30 September, 2016.

- Sepulveda, E., O.E. Garcia, M. Schneider, T. August, F. Hase, T. Blumenstock, E. Sanroma, A. Gomez-Pelaez, T. Hultberg, A. Redondas, P.M. Romero-Campos, V. Carreno, and Y. Gonzalez, A Quasi Near-Real Time Operational Validation of IASI Level 2 Trace Gas Products, IASI Conference 2016, 11-15 April, Antibes Juan-les-Pins, France, 2016.

- Sepulveda,E., O.E. Garcia, M. Schneider, T. August, F. Hase, T. Blumenstock, E. Sanroma, T. Hultberg, A. Redondas, E. Cuevas, N. Peinado, X. Calbet, E. Lopez-Baeza, VALIASI: IASI ozone total column amounts and vertical profiles validated at subtropical, mid-latitude and polar-latitude, IASI Conference 2016, 11-15 April, Antibes Juan-les-Pins, France, 2016.

• Sanroma M.E., O. E. Garcia, M. Schneider, F. Hase, T. Blumenstock, E. Sepulveda, Ozone isotopologue monitoring from groundbased FTIR spectrometry, Quadrennial Ozone Symposium-2016, Edinburgh, 4-9 September, 2016.

• Garcia, O.E., M. Schneider, A. Wiegele, F. Hase, S. Barthlott, T. Blumenstock, E. Sepulveda, Y. Gonzalez and E. Sanroma, The MUSICA METOP/IASI Methane and Nitrous Oxide products and its validation, EUMETSAT Conference 2016, Darmstadt (Germany), 26-30 September, 2016.

• Garcia, O.E., M. Schneider, A. Wiegele, F. Hase, S. Barthlott, T. Blumenstock, E. Sepulveda, Y. Gonzalez and E. Sanroma, Middle-Upper Tropospheric Methane and Nitrous Oxide Retrievals from Metop/IASI within the project MUSICA, IASI Conference 2016, 11-15 April, Antibes Juan-les-Pins, France, 2016.

• Peinado-Galan, N., X. Calbet, O. E. Garcia, E. Lopez-Baeza, A. Redondas, E. Sepulveda, M. E. Koukouli, I. Zyrichidou, I. Fountoulakis, D. Balis, A. Bais, T. Karppinen, J. Lopez-Solano, B. Hernandez-Cruz, M.E. Sanroma, QUALITY ASSESSMENT OF IASI/Metop-A AND OMI/Aura OZONE COLUMN AMOUNTS BY USING EUBREWNET GROUND-BASED MEASUREMENTS, Quadrennial Ozone Symposium-2016, Edinburgh, 4-9 September, 2016.

• Peinado-Galan, N., O. E. Garcia, X. Calbet, E. Lopez-Baeza, E. Sepulveda, M. E. Koukouli, I. Zyrichidou, I. Fountoulakis, D. Balis, A. Bais, A. Redondas, T. Karppinen, J. Lopez-Solano, and B. Hernandez-Cruz, Comparison of IASI/MetopA and OMI/Aura ozone column amounts with EUBREWNET ground-based measurements, EUMETSAT Conference 2016, Darmstadt (Germany), 26-30 September, 2016.

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- O.E. Garcia, A. Gomez-Pelaez, A. Redondas, P. M. Romero-Campos, E. Sanromá

-T. August, T. Hultberg

- M. Schneider, F. Hase, T. Blumenstock

- A. de Frutos