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Validation of GOSAT TANSO-FTS IWV (Integrated Water vapour) using BAQUNIN-APL and CNR-ISAC AERONET data

Abstract : This TN describes the validation of GOSAT TANSO-FTS total column (integrated) water vapour using BAQUNIN and CNR-ISAC instrumental suite

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Change History

This document shall be amended by releasing a new edition of the document in its entirety. The Amendment Record Sheet below records the history and issue status of this document.

ISSUE	DATE	REASON
1.0	20 Nov 2019	First version
2.0	15 Mar 2021	Validation repeated with updated TANSO-FTS datasets and using urban and semi-rural AERONET data

1. INTRODUCTION

GOSAT (Greenhouse gases Observing Satellite) is a JAXA (Japan Aerospace Exploration Agency) mission within the GCOM (Global Change Observation Mission) programme of Japan. The GOSAT mission goals call for the study of the transport mechanisms of greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4). The emphasis is on atmospheric monitoring to clarify the sources and sinks of CO_2 on a sub-continental scale. The overall mission objective is to contribute to environmental administration by estimating the Green House Gases (GHGs) source and sink on a sub-continental scale and to support the Kyoto protocol that was adsorbed at COP3/UNFCCC (3rd session of the conference in the framework of climate change) in 1997. The protocol calls for a reduction of greenhouse gases, in particular CO_2; it requires all parties to reduce their emissions by 5% below the level of the year 1990, for the period of 2008-2012. Table 1 reports the GOSAT mission characteristics.

Table 1 GOSAT mission facts and figures

Facts and figures	
Operators	JAXA (Japan Aerospace Exploration Agency)
Date of Launch	23 January 2009
Status	Operating nominally
Orbit Height	666 km
Orbit Type	Sun-synchronous
Repeat Cycle	3 days
Resolution	(CAI instrument): 0.5 km (spectral bands 1,2,3), 1.5 km (spectral band 4)
Swath Width	(CAI instrument): 1000 km (Channels 1-3), 750 km (Channel 4)
Onboard Sensors provided under TPM	• TANSO-FTS (Thermal And Near infrared Sensor for carbon Observation - Fourier Transform Spectrometer) • TANSO-CAI (Thermal And Near infrared Sensor for carbon Observation - Cloud and Aerosol Imager)

The TANSO-FTS instrument on-board GOSAT satellite features high optical throughput, fine spectral resolution, and a wide spectral coverage (from VIS to TIR in four bands). The reflective radiative energy is covered by the VIS and SWIR (Shortwave Infrared) ranges, while the emissive portion of radiation from Earth's surface and the atmosphere is covered by the MWIR (Mid-Wave Infrared) and TIR (Thermal Infrared) ranges. These spectra include the absorption lines of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and water vapour (H_2O). Details on the TANSO-FTS H_2O retrieval schemes can be found in [Ohyama et al. 2013].

The BAQUNIN-APL AERONET station, based at the Atmospheric Physics Laboratory of the Physics Department of Sapienza University (APL, Rome downtown) is active since early 2017. The BAQUNIN-APL instrument is owned by University of Lille and run under BAQUNIN staff responsibility. The BAQUNIN (Boundary-layer Air Quality analysis using Network of INstruments) project is an ESA activity devoted to the establishment and operation of an atmospheric remote sensing super-site, with the mandate of performing satellite Cal/Val and atmospheric science research activities (https://www.baqunin.eu/).

The CNR-ISAC AERONET station, based at the CNR-ISAC Tor Vergata site (PI F. Barnaba, CNR-ISAC), has been continuously active from 2001 to 2019. During 2019, the instrument experienced serious hardware problems, leading to a virtual interruption of its operations.

In what follows, the TANSO-FTS IWV products will be compared separately to the urban (APL) and semi-rural (CNR-ISAC) AERONET sites, in order to verify possible impacts of differences in the surface properties in the satellite IWV retrieval.

The water vapour columnar content, or precipitable water vapour or integrated water vapour, is routinely retrieved by the AERONET network. Details on the quality of this product can be found in [Perez-Ramirez et al. 2014].

2. METHOD AND RESULTS

1) The validation period for the urban and semi-rural sites is:
   a. APL (urban) from 2017 to 2020
   b. CNR-ISAC (semi-rural) from 2009 to 2019
2) For the validation exercise, we use the AERONET level 1.5 IWV products. Uncertainties on AERONET IWV are not available (not produced).
3) The TANSO-FTS H2O (SWIR) products have been downloaded from: https://data2.gosat.nies.go.jp/GosatDataArchiveService/usr/download/DownloadPage/view. The Level 2 daily files (".nc') are stored in a monthly collection (tar file), all data from year 2009 to year 2020 have been downloaded and uncompressed. A tool for the data selection has been developed in IDL, and the IWV units have been converted from [mol m^{-2}] to [cm]. The TANSO-FTS IWV uncertainty parameters (see Annex 1 for details) are combined to estimate a total uncertainty value.
4) The TANSO-FTS Level 2 V02.90/V02.91 used in this work are described in "ReleaseNote_FTSSWIRL2_V02.90-V02.91_en.pdf"
5) The Search Radius was set to 20 km (i.e. the distance from centre of the TANSO-FTS footprint and APL and CNR-ISAC must be smaller than 20 km). The time distance between measurements is set to 1 hour. The adopted criteria minimises the "collocation error" and make sure that the satellite and ground based measurements are virtually contemporary.

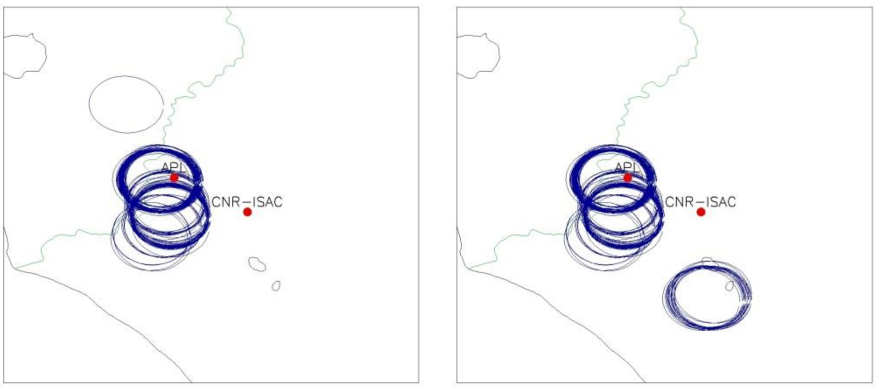

Figure 1: TANSO-FTS collocation with BAQUNIN-APL (left) and CNR-ISAC (right). The red dots indicate the position of the AERONET sites, the blue lines the instantaneous footprint of a TANSO-FTS measurement

6) The time series of the selected instantaneous IWV data obtained from the satellite and the ground stations is shown in Figure 2, where the red dots are the TANSO-FTS IWV data and the green dots are the AERONET IWV (Level 1.5).

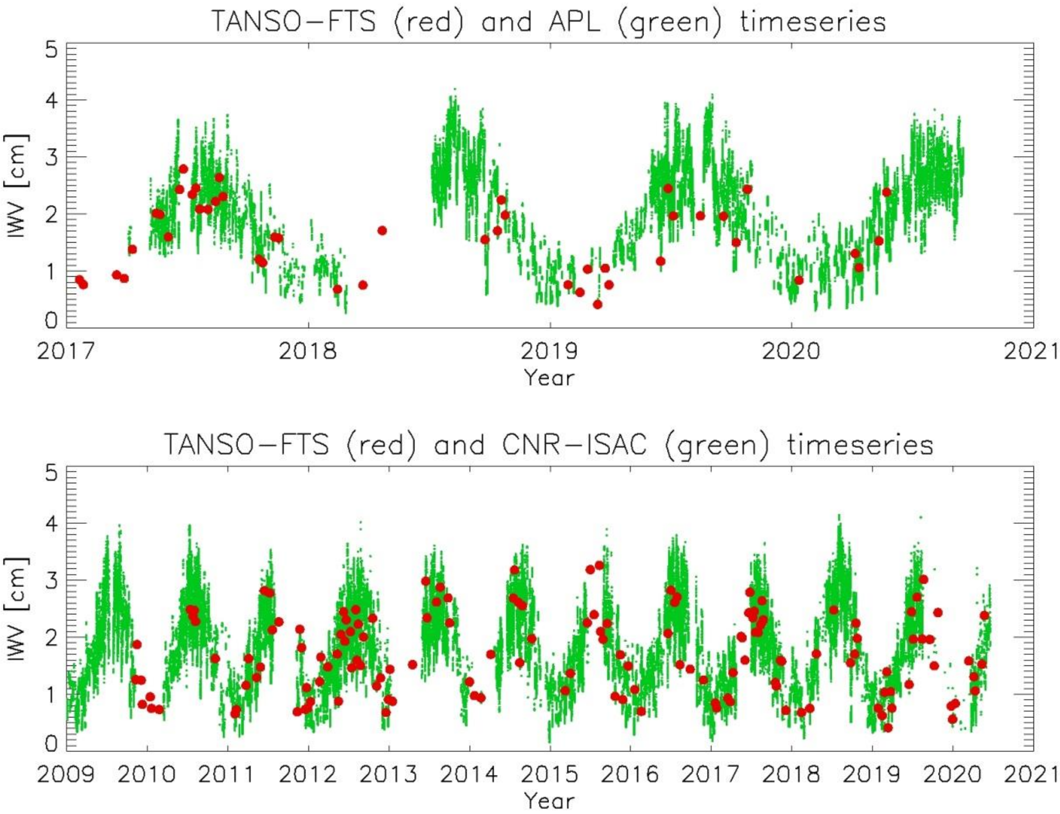

Figure 2 Time series of IWV from TANSO-FTS (red dots) and BAQUNIN-AERONET (blue dots). Upper panel: AERONET V1.0; centre panel: AERONET V1.5; lower panel AERONET V2.0

It can be noted that the two matchup datasets include all seasons and the full range of IWV usually observed in the region of interest. Thus, it can be considered statistically significant in terms of TANSO-FTS data quality..

7) For the comparison exercise, the AERONET data are averaged in the 1 hour time across the satellite overpass, and the related STD is used here as an estimate of the uncertainty of the AERONET IWV. For the TANSO-FTS data, the reported uncertainty is used. The satellite vs. ground station IWV scatter plots are shown in Figure 3, in which the results of the statistical analysis are reported for each AERONET site. The vertical lines represent the TANSO-FTS uncertainty (very small indeed), the horizontal lines are the AERONET STD (2xσ) in the overpass ± 1 hour time range.

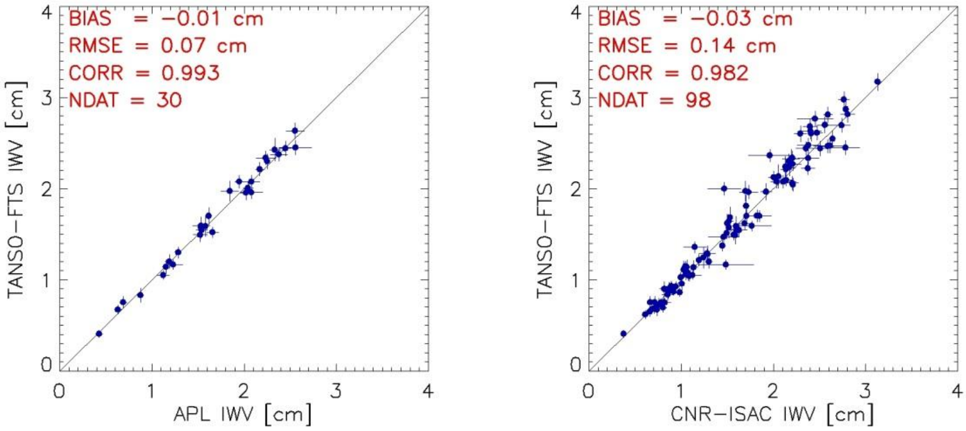

Figure 3 TANSO-FTS vs. BAQUNIN-APL IWV (left panel) and CNR-ISAC (right panel)

The statistical parameters reported in Figure 3 are:

a) CORR: correlation coefficient
b) RMSE: root mean square error [cm]
c) BIAS: absolute bias [cm]
d) NDAT: number of collocations

Table 2: Summary statistical results

AERONET	NCOL	CORR	RMSE	BIAS
APL	30	0.993	0.07	-0.01
CNR-ISAC	98	0.982	0.14	-0.03

8) The results of validation exercise show that the IWV from TANSO-FTS is of excellent quality. In fact, the satellite data show negligible offset, very high correlation and extremely small scatter when compared to both urban and semi-rural AERONET site data.

9) However, based on all above, the reported TANSO-FTS uncertainties seem to be slightly underestimated.

3. OUTLOOK

The results of the TANSO-FTS vs. AERONET IWV for two close-by AERONET sites validation exercise (urban and semi-rural), show that the agreement between the matchup datasets is excellent. In practice, the FTS IWV products have no bias, extremely small RMSE and extremely high correlation coefficient when compared to the ground based data.

3.1 Relevance of BAQUNIN super-site for TANSO-FTS validation

The great advantage of BAQUNIN supersite, is the possibility to compare atmospheric products in a urban environment with virtually no collocation errors, as the TANSO-FTS footprint is centred on the city of Rome, and APL is always contained in the satellite footprint. This implies that any discrepancy between datasets is caused by instrumental or algorithmic factors, being the atmospheric horizontal variability contribution minimised.

Finally, the BAQUNIN-APL site is more than appropriate for GOSAT TANSO-FTS validation, not only for what concerns water vapour. In fact, it would be extremely interesting (on both sides) if BAQUNIN could be equipped with a ground based FTIR for the estimation of columnar CO2 and CH4 in the urban environment, for which the horizontal inhomogeneity is generally an important limitation factor when performing Cal/Val exercises.

4. REFERENCES

Ohyama, H., Kawakami, S., Shiomi, K., Morino, I., and Uchino, O., 2013, "Atmospheric Temperature and Water Vapor Retrievals from GOSAT Thermal Infrared Spectra and Initial Validation with Coincident Radiosonde Measurements", SOLA, 2013, Vol. 9, 143−147, doi:10.2151/sola.2013-032

Pérez-Ramírez, D., D. N. Whiteman, A. Smirnov, H. Lyamani, B. N. Holben, R. Pinker, M. Andrade, and L. Alados-Arboledas, 2014, "Evaluation of AERONET precipitable water vapor versus microwave radiometry, GPS, and radiosondes at ARM sites", J. Geophys. Res. Atmos., 119, 9596–9613, doi:10.1002/2014JD021730.

4.1 Web sites

AERONET: https://aeronet.gsfc.nasa.gov/new_web/aerosols.html (free download)

BAQUNIN: https://www.baqunin.eu/

CNR-ISAC (CIRAS): https://www.isac.cnr.it/index.php/en/infrastructures/ciras

5. ANNEX 1 TANSO-FTS H2O LEVEL 2 DATA STRUCTURES

The following two tables report the H2O parameter characteristics (example).

Table A1.1 Geolocation parameters

AIRMASS	FLOAT	Array[418]
FOOTPRINTLATITUDE	FLOAT	Array[418, 36]
FOOTPRINTLONGITUDE	FLOAT	Array[418, 36]
HEIGHT	INT	Array[418]
LANDFRACTION	FLOAT	Array[418]
LATITUDE	FLOAT	Array[418]
LATITUDEORIGINAL	FLOAT	Array[418]
LONGITUDE	FLOAT	Array[418]
LONGITUDEORIGINAL	FLOAT	Array[418]
SATELLITEATTITUDE	DOUBLE	Array[418,4]
SATELLITEAZIMUTH	FLOAT	Array[418]
SATELLITEPOSITION	DOUBLE	Array[418,3]
SATELLITEZENITH	FLOAT	Array[418]
SOLARAZIMUTH	FLOAT	Array[418]
SOLARZENITH	FLOAT	Array[418]
SUNGLINTFLAG	INT	Array[418]

Table A1.2 H2O Total Column parameters

H2OTOTALCOLUMN	FLOAT	Array[418]
H2OTOTALCOLUMNEXTERNALERROR	FLOAT	Array[418]
H2OTOTALCOLUMNINTERFERENCEERROR	FLOAT	Array[418]
H2OTOTALCOLUMNRETRIEVALNOISE	FLOAT	Array[418]
H2OTOTALCOLUMNSMOOTHINGERROR	FLOAT	Array[418]

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