Customer	:	ESRIN	Document Ref	:	BAQ-MGT-TEN-SER-017
Contract No	:	4000126749/19/I-NS	Issue Date	:	22 November 2019
WP No	:	All	Issue	:	1.0

Validation of GOSAT TANSO-FTS IWV (Integrated Water vapour) using BAQUNIN–AERONET data

Abstract : This TN describes the validation of GOSAT TANSO-FTS total column water vapour using BAQUNIN instrumental suite

Author : **S. Casadio**

Approval :

Distribution :

TABLE OF CONTENTS

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

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 (CO2) and methane (CH4). The emphasis is on atmospheric monitoring to clarify the sources and sinks of CO2 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 CO2; 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 (CO2), methane (CH4) and water vapour (H2O). Details on the TANSO-FTS H2O retrieval schemes can be found in [Ohyama et al. 2013].

The BAQUNIN-AERONET station, based at the Atmospheric Physics Laboratory of the Physics Department of Sapienza University (APL, Rome downtown) is active since early 2017. The AERONET instrument is owned by University of Lille and run under BAQUNIN staff responsibility.

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 spans from January 2017 to September 2019
2) For this exercise we use the BAQUNIN-AERONET Station APL (Rome Sapienza). The AERONET version 1.0, 1.5 and 2.0 data have been used in order to verify the impact of cloud screening on validation results. For version 1.0 (no AERONET cloud screening) the IWV data have been screened assuming as IWV validity thresholds 0.1 cm (minimum) and 5 cm (maximum). With this approach, the number of available data is slightly larger with respect to what is available from the 1.5 and 2.0 versions. 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 January 2017 to September 2019 have been downloaded and uncompressed. A tool for the data selection has been developed in IDL, 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 Search Radius was set to 10 km (i.e. the distance from centre of the TANSO-FTS footprint and APL must be smaller than 10 km). The time distance between measurements is set to 1 hour. The adopted criteria minimises the "collocation error" by requiring that the APL site lies inside the TANSO-FTS ground pixel (about 15 km radius) and that the measurements are virtually contemporary.
5) In the period of interest, the number of collocations were 37 for AERONET V1.0, 35 for V1.5 and 22 for V2.0. As shown in Figure 1, the position of APL within the TANSO-FTS footprint is suitable for a validation exercise. The footprint data are included in the TANSO-FTS Level 2 files (see Annex 1 for TANSO-FTS data format).

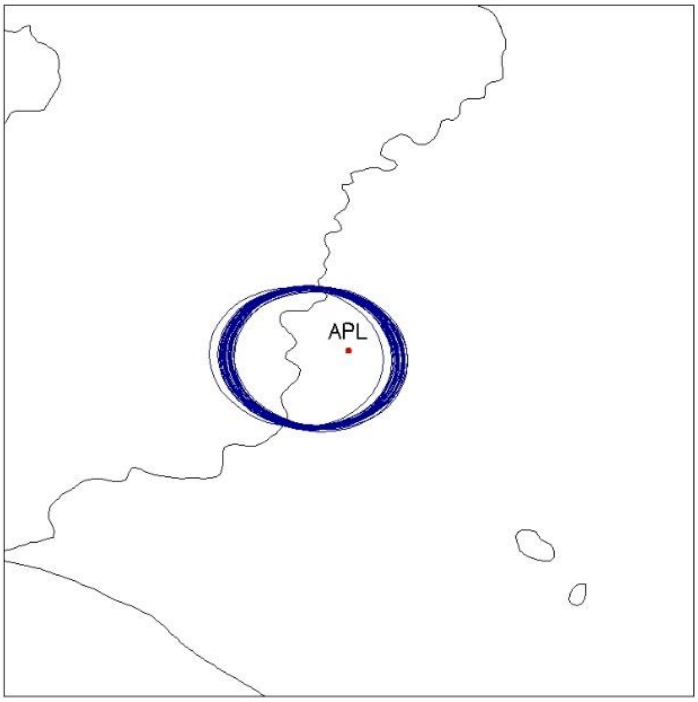

Figure 1: Collocation between TANSO-FTS and BAQUNIN-AERONET. The red dot indicates the APL site, the blue lines the instantaneous footprint of a TANSO-FTS measurement

6) The time series of the selected instantaneous IWV data obtained from the satellite and the ground station is shown in Figure 2, where the red dots are the TANSO-FTS IWV data and the blue dots are the BAQUNIN-AERONET IWV (version 1.0 with ad hoc screening applied).

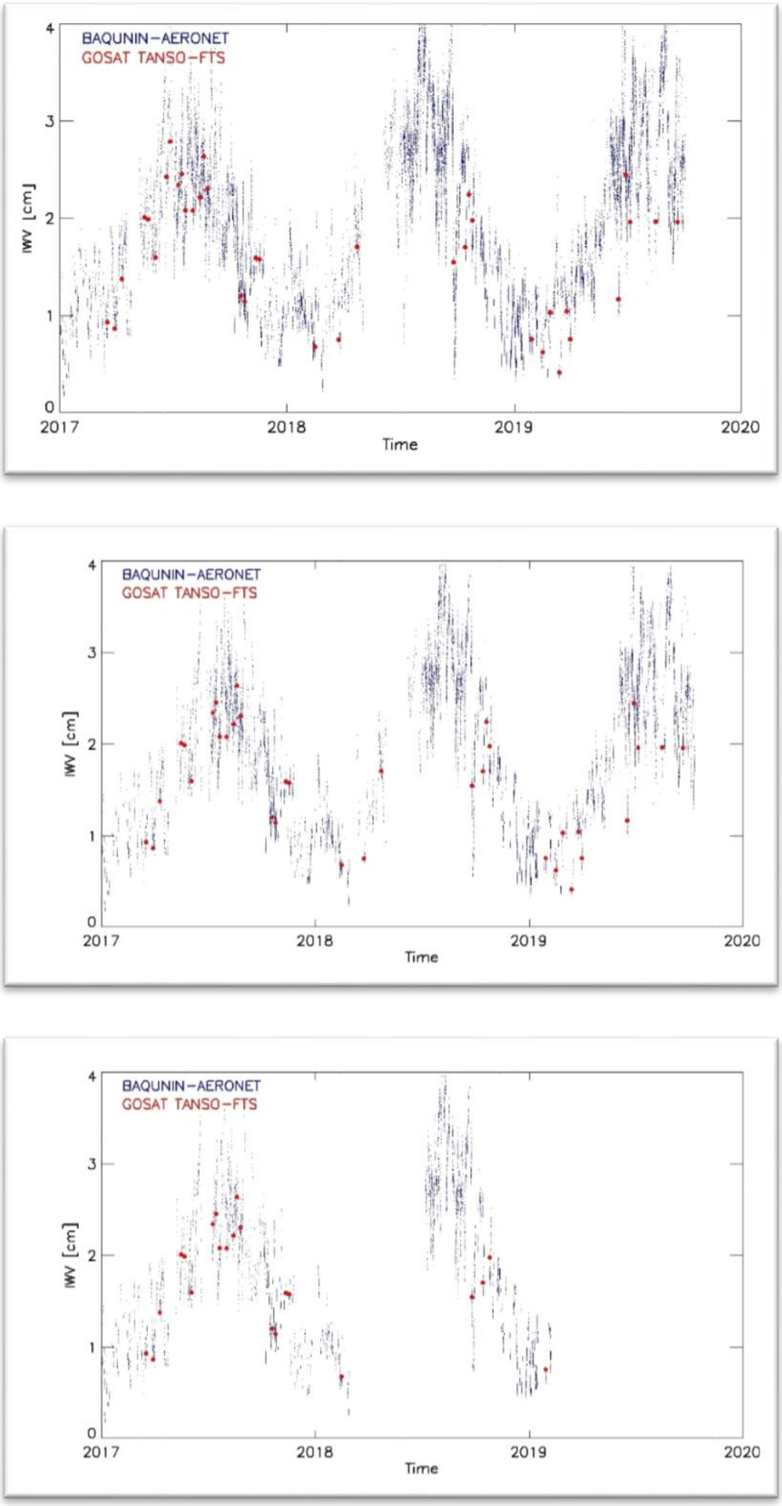

Figure 2 Time series of IWV from TANSO-FTS (red dots) and BAQUNIN-AERONET (blue dots). Upper panel: AERONET V1.0; centre panel: AERONET V1.5; lower panel AERONET V2.0

It can be noted that the dataset includes 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. The lower number of available data for the V2.0 version is due to the calibration schedule of the AERONET stations, the 2019 data will be available after recalibration of the BAQUNIN instrument to be performed on March 2020.

7) For the comparison exercise, the BAQUNIN-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 data version (upper panel = V1.0, centre panel = V1.5, lower panel V2.0). The vertical lines represent the TANSO-FTS uncertainty (very small indeed), the horizontal lines are the BAQUNIN-AERONET STD (2xσ) in the overpass ± 1 hour time range.

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) GAIN: slope of the “y = m·x+q” fit (x = AERONET, y = TANSO-FTS)
e) OFFS: intercept “q” of linear fit [cm]
f) NCOL: number of collocations

Table 2: Summary statistical results

AERONET	NCOL	CORR	RMSE	BIAS	GAIN	OFFS
1.0	37	0.992	0.08	0.0	1.01	-0.01
1.5	35	0.992	0.08	0.0	1.02	-0.03
2.0	22	0.993	0.07	0.0	1.00	0.00

8) The results of validation exercise show that the IWV from TANSO-FTS is of excellent quality. However, based on all above, the reported uncertainties seem to be significantly underestimated.

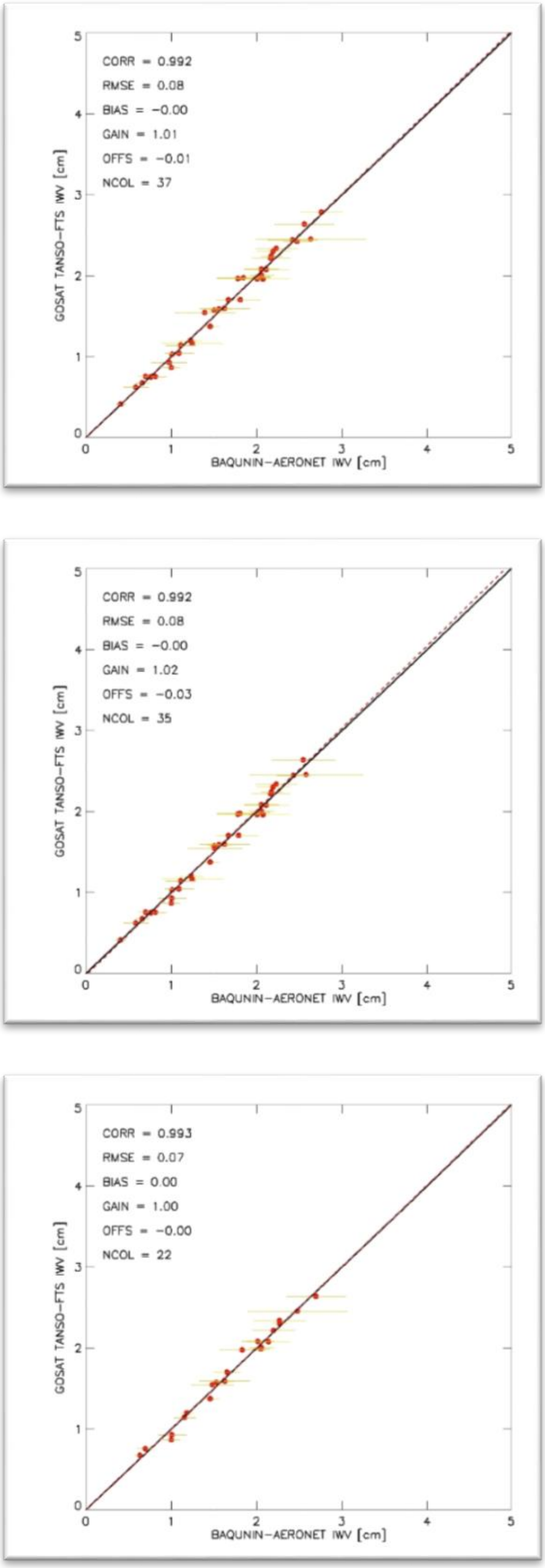

Figure 3 TANSO-FTS vs. BAQUNIN-AERONET IWV. Upper panel: AERONET V1.0; centre panel: AERONET V1.5; lower panel: AERONET V2.0

3. OUTLOOK

The results of the TANSO-FTS vs. BAQUNIN-AERONET IWV validation exercise shows that the agreement between the two 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 CO_2 and CH_4 in a 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)

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]

End of Document