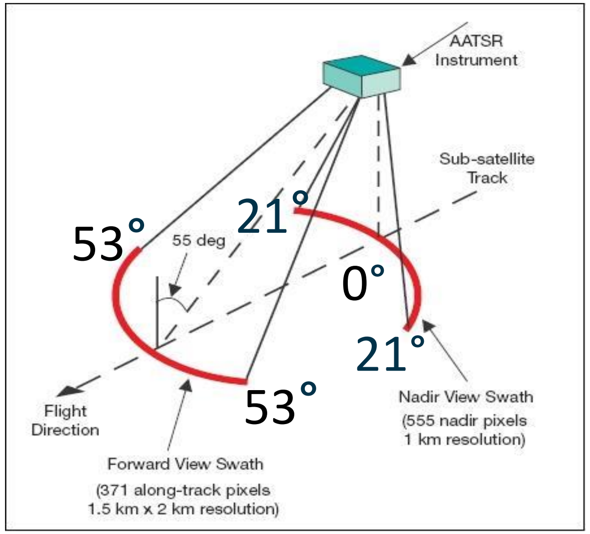
AIRWAVE-SLSTR: an algorithm to retrieve TCWV from Sentinel 3 SLSTR observations

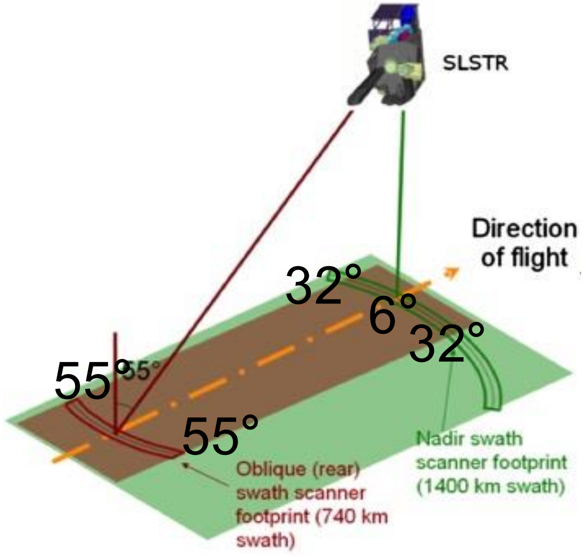
Enzo Papandrea[1], Stefano Casadio[2], Elisa Castelli[1], Bianca M. Dinelli[1], Paolo Pettinari[1], Margherita Premuda[1], Massimo Valeri[2], Bojan Bojkov[3]
(1) Istituto di Scienze dell’Atmosfera e del Clima (CNR-ISAC), Bologna; (2) Serco Italia S.p.A., Frascati (RM); (3) EUMETSAT, Darmstadt.

OUTLINE

- The **Advanced Infra-red Water Vapour Estimator** (**AIRWAVE**) **algorithm,** initially developed for the **ATSR instruments**, was **extended to the Sentinel-3 Sea and Land Surface Temperature Radiometer** (**SLSTR**) series of instruments [EUMETSAT project].
- **SLSTR** has an increase dual view swath width from **500 to 740 km centred on the sub-satellite track** (mean global coverage revisit time enhanced).
- **SLSTR** observes the Earth with **oblique (rear) and nadir views**, while **(A)ATSR-1/2** with **forward and nadir views.**
- Using only infrared channels at **11 and 12 µm**, the TCWV is obtained in both **day** and **night**. Only over **water** surfaces. **Native spatial res.** (1 km x 1 km).

- Here, we present the latest version of the **algorithm** and the results of the **validation of the obtained TCWV with ground-based** (AERONET and IGRA) and **satellite-based** (SSMI/S and AMTROC-MWR) products.





INTRODUCTION

The **first version** of the AIRWAVE-SLSTR TCWV products were validated against ground- and satellite-based reference datasets, founding a mean bias of about **-2 kg/m^2**. The bias had a seasonal behaviour and was latitude-dependent.

We recently produced and analysed **one year** (2021) of S-3A TCWV products (more than 176K chunks) with a **second version** of the code having the retrieval parameters computed with:

- the **new spectroscopic data** (HTRAN2008 → HITRAN2020),
- the **new water vapour continuum model** (MT_CKD2.5 → MT_CDK3.6),
- a **new temperature and water vapour climatology (IG2 climatology,** which refers to both water and land surfaces and made for MIPAS limb instrument, so the representation of the troposphere was not carefully studied → **ECMWF-ERA5 Re-analysis)**.

Validation against SSMI/S TCWV products

AIRWAVE-SLSTR TCWV products were **re-gridded on 0.25° x 0.25° grid** (SSMI/S spatial resolution).

We used the **SSMI/S F17** satellite products because they properly **cover the entire Sentinel - 3 SLSTR mission** period. Furthermore, the **local time of the ascending node** of the F17 satellite (about 18:00) is more **stable** in comparison to other available SSMI/S satellites.

We applied a filter on **clear sky percentage** (CSP) for each **grid cell**. We used only grid cell with a sky clear percentage greater than a **10% (**filter out possible worst outliers due to the presence of **undetected clouds)**.

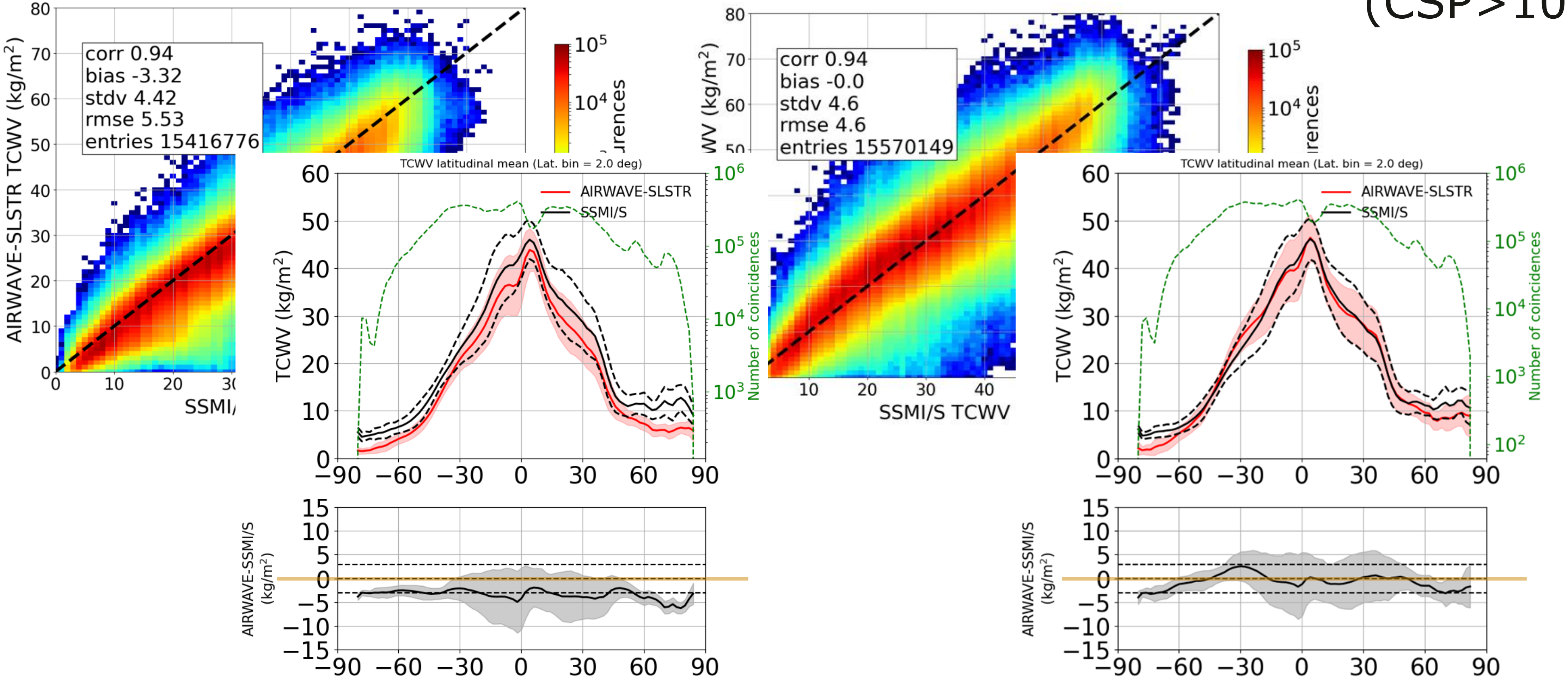
$$\text{CSP}_{\text{grid cell}} = \frac{(\text{N of clear sky AIRWAVE pixels over sea})_{\text{grid cell}}}{(\text{Sum of all AIRWAVE pixels over sea})_{\text{grid cell}}} * 100$$

Validation against SSMI/S TCWV products

AIRWAVE-SLSTR v1
May 2020 - Apr 2021

AIRWAVE-SLSTR v2
Jan 2021 - Dec 2021

Cloud Mask
(CSP>10%)

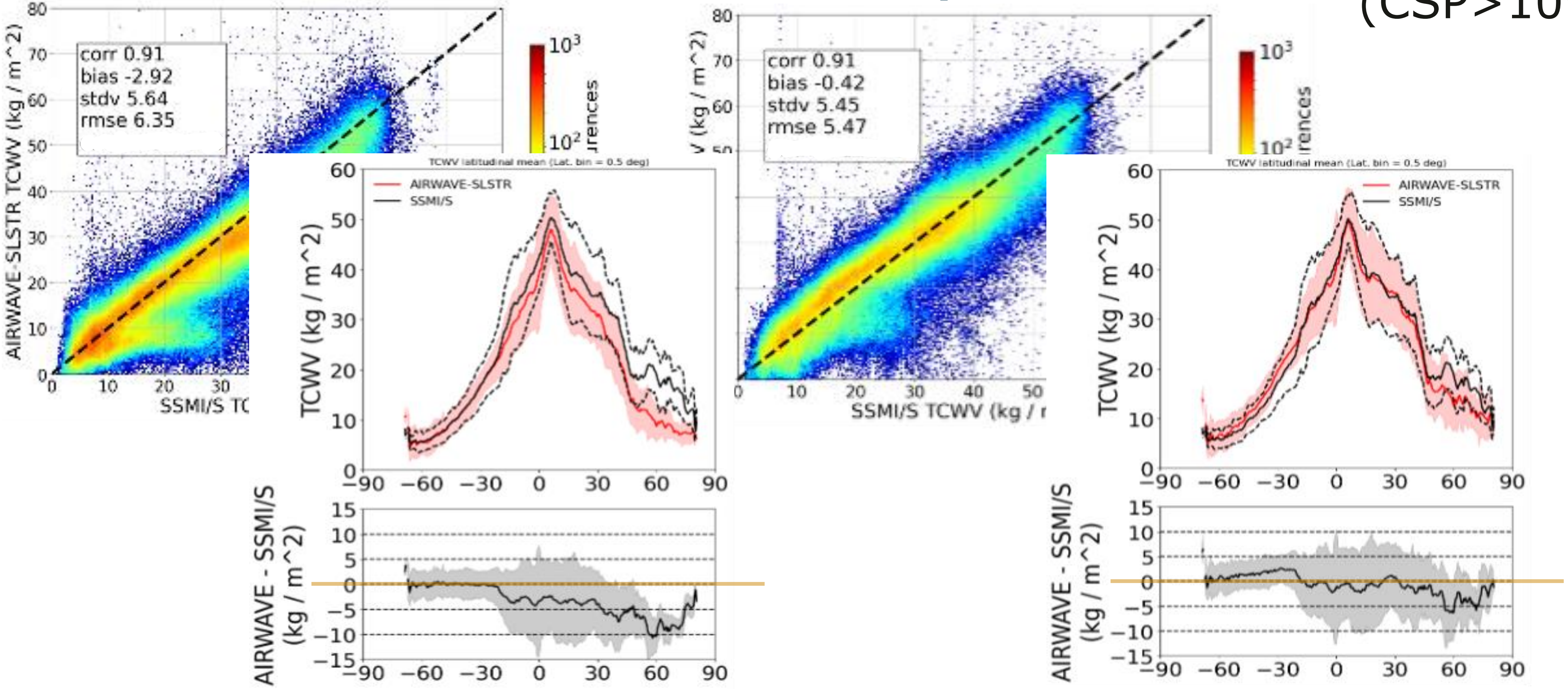


Validation against SSMI/S TCWV products

AIRWAVE-SLSTR v1
July 2021

AIRWAVE-SLSTR v2
July 2021

Cloud Mask
(CSP>10%)



Validation against AMTROC-MWR TCWV products

We performed the validation against AMTROC-MWR (same platform) TCWV products for **January and July 2021**.

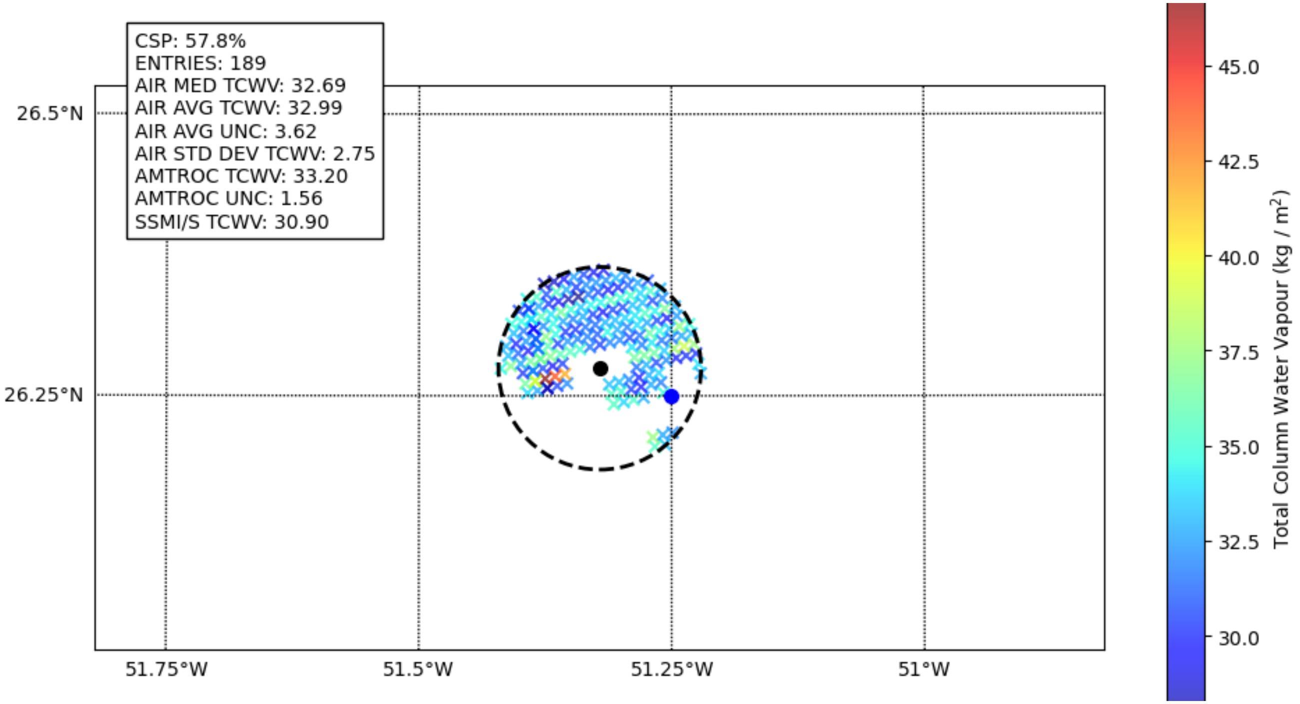
We performed the exercise adopting both **basic and Bayesian (not shown here) cloud masks.**

As an MWR-derived proxy of the presence of cloud, we excluded MWR products with **Liquid Water Path (LWP) > 0.**

Example of a single AIRWAVE-SLSTR / AMTROC-MWR match-up analysis

- **Black dot**: Centre of the MWR Instantaneous Field-Of-View
- **Dashed line**: Approximation of the MWR Instantaneous Field-Of-View
- $\mathrm{CSP}_{\mathrm{IFOV}} = \dfrac{(\text{N of clear sky AIRWAVE pixels over sea})_{IFOV}}{(\text{Sum of all AIRWAVE pixels over sea})_{IFOV}} * 100$

We used only grid cell with a **sky clear percentage higher than a 10%.**

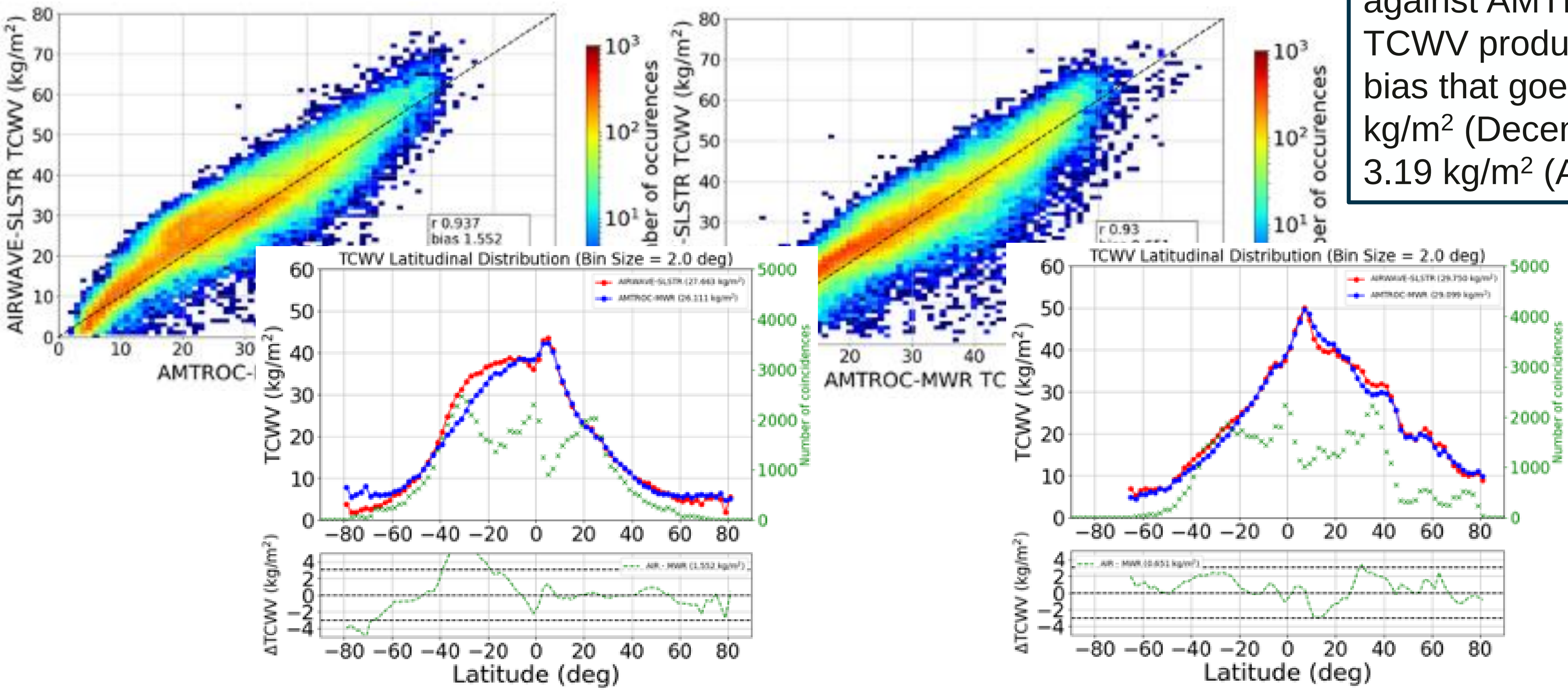


Validation against AMTROC-MWR TCWV products

AIRWAVE-SLSTR v2
January 2021

AIRWAVE-SLSTR v2
July 2021

A preliminary validation of AIRWAVE v1 was performed against AMTROC-MWR TCWV products showing a bias that goes from -2.15 kg/m^2 (December 2016) to -3.19 kg/m^2 (April 2017)



CSP>10%

Validation against AERONET and IGRA TCWV products

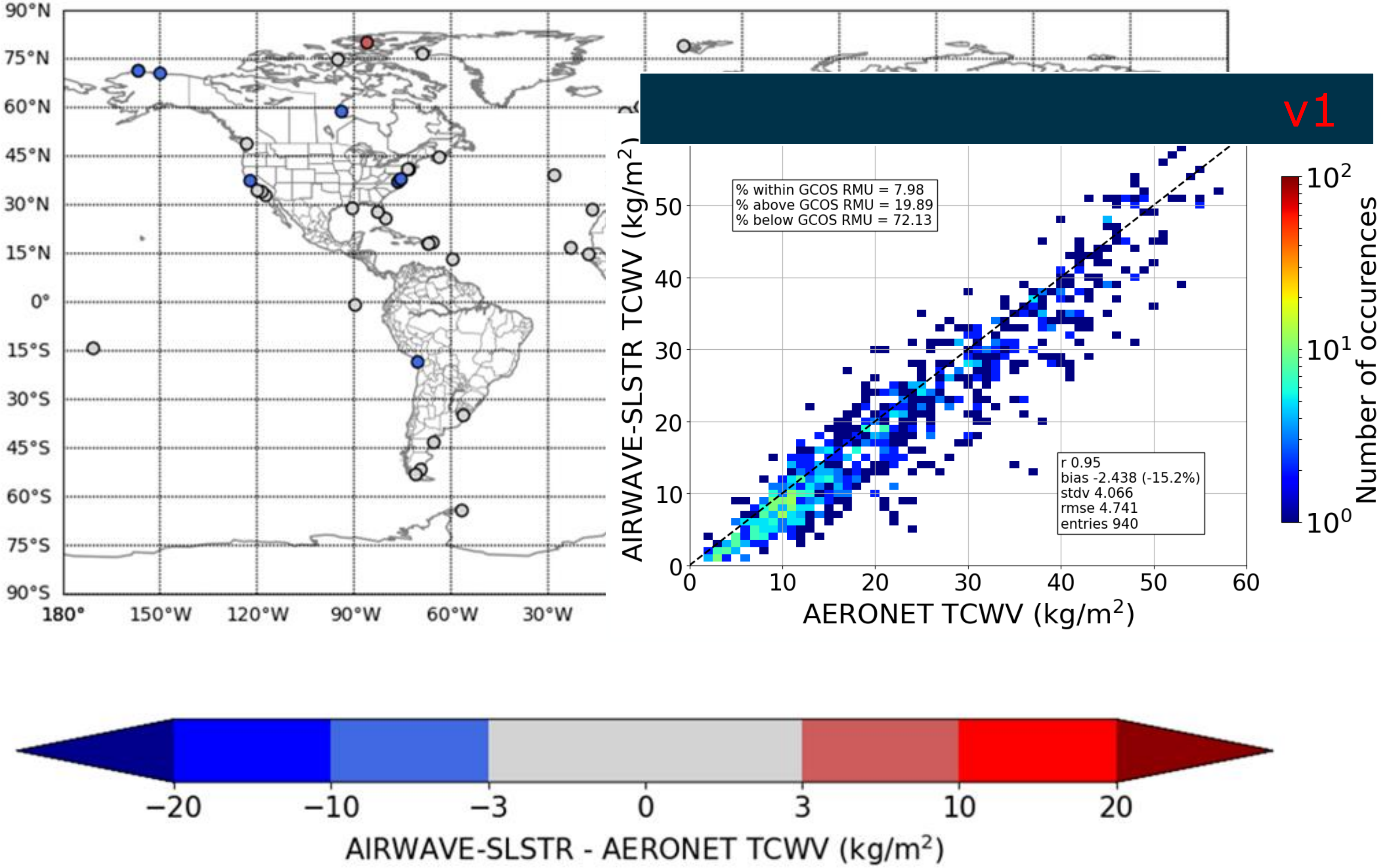
- **The AERONET network** (https://aeronet.gsfc.nasa.gov/) exploits the **CIMEL CE318 sun–sky radiometer**, a narrow band filter photometer able to perform measurements of **direct solar and diffuse sky irradiances** at some selected wavelengths and at several scattering angles. **Precipitable water vapour content** from this instrument (W) is calculated using the official AERONET inversion algorithm (Smirnov et al., 2004).
  - **Mean bias for the AERONET W product** that results from literature (e.g. Bennouna et al., 2013) is **−5/-10%.**
- **The Integrated Global Radiosonde Archive (IGRA) consists of radiosonde** and pilot balloon observations from more than 2800 **globally distributed stations.**

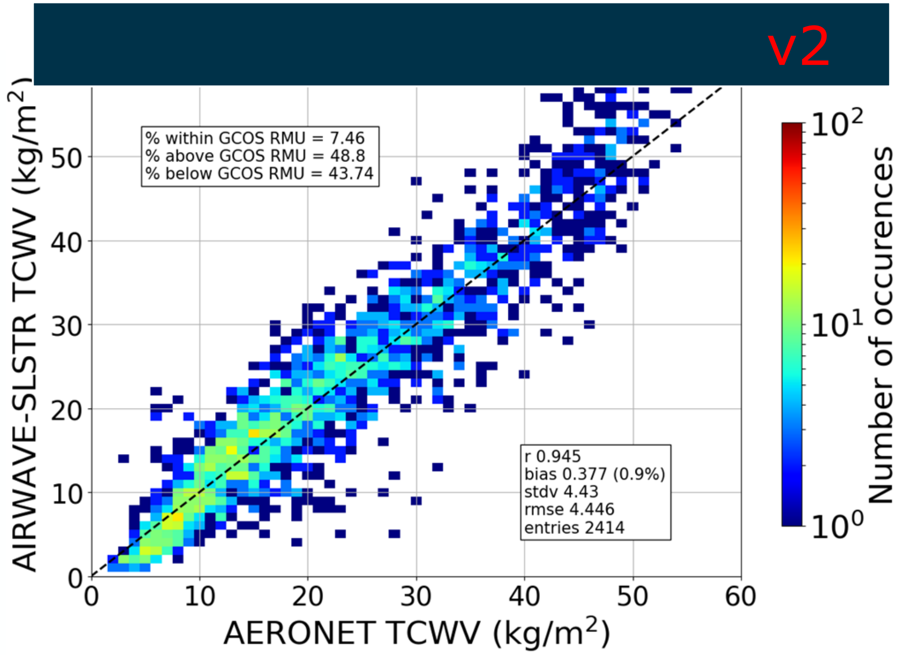
Co-location criteria and QA:

- The **products**, are automatically **cloud cleared** and **control procedures** are set to the data to **remove gross errors**.
- **Maximum distance allowed** (between sites and SLSTR measurement): **100 km**.
- **Maximum time interval: +/- 30 minutes**.
- **Only sites with a percentage of sea around them** (inside an area of radius 100 km) **higher than 20%**.

Validation against AERONET TCWV products

2021 – AIRWAVE-SLSTR **v2** – 122 AERONET Sites



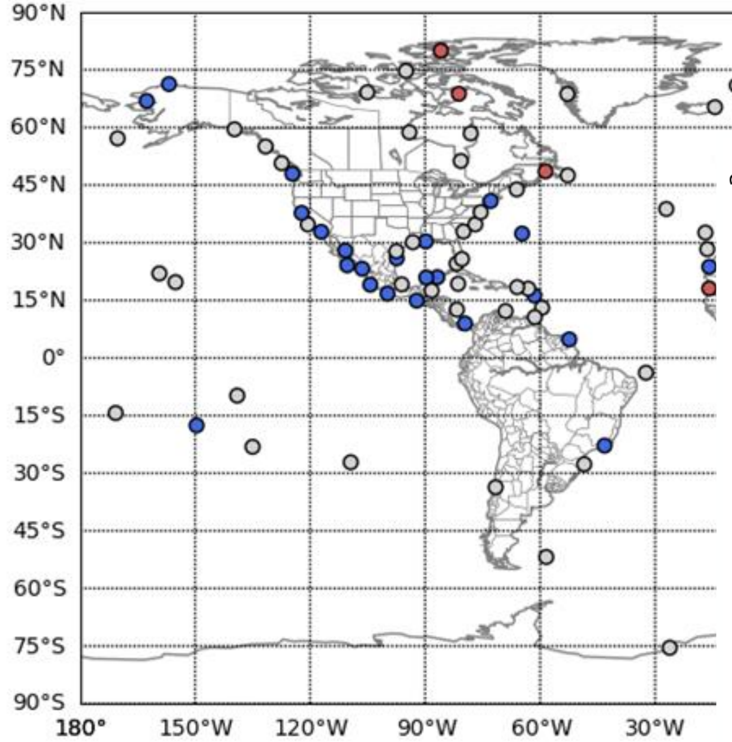


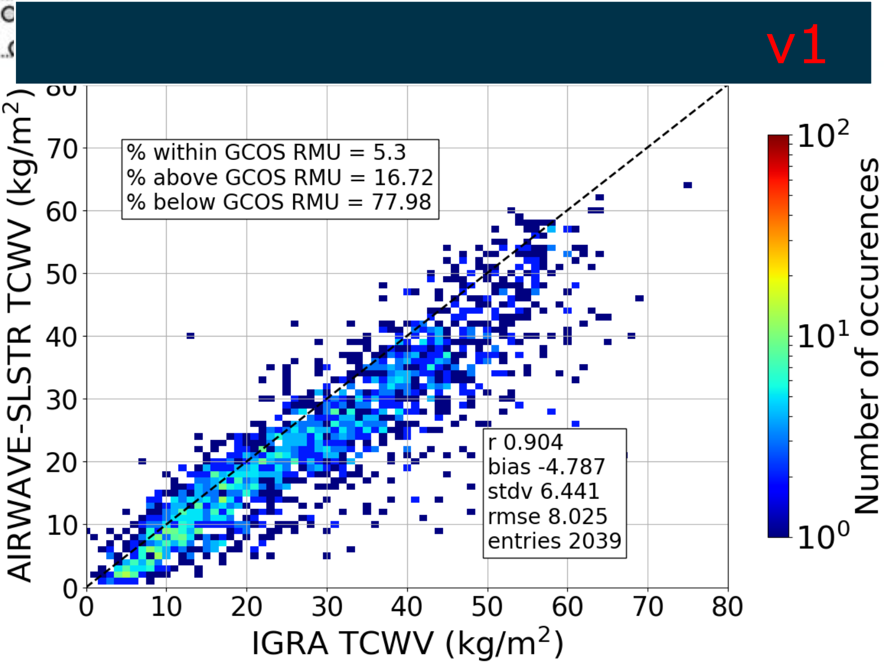
GCOS REQUIRED MEASUREMENT UNCERTAINTY ON TCWV = 2%

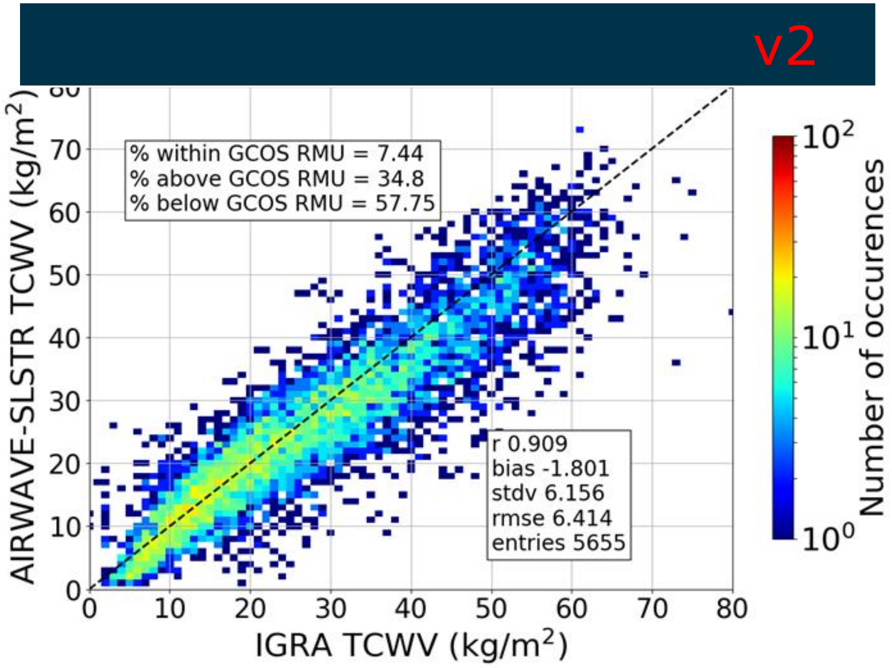
*Only Jan-Apr-Jul-Oct 2018 were considered

Validation against IGRA TCWV products

2021 – AIRWAVE-SLSTR **v2** – 200 IGRA Sites







GCOS REQUIRED MEASUREMENT UNCERTAINTY ON TCWV = 2%

*Only Jan-Apr-Jul-Oct 2018 were considered

CONCLUSIONS

- **Despite** the reference datasets used in this validation exercise exploit **different retrieval methods and spectral ranges**, we observed **a good correlation** (R) between AIRWAVE-SLSTR and all the different reference datasets **(> 0.9**).

		SSMI/S	AMTROC*	IGRA	AERONET**	MEAN
	R	0.94	0.94	0.91	0.95	0.94
BASIC	**BIAS**	0.00	1.33	-1.80	0.38	-0.02
	STD DEV	4.60	4.80	6.16	4.43	5.00
	R	0.94	0.93	0.90	0.93	0.93
BAYESIAN	**BIAS**	0.43	1.73	-1.53	1.01	0.41
	STD DEV	4.55	5.11	6.54	5.30	5.38

- With the **Bayesian cloud mask** (showing the worst results in terms of bias) the **overall bias is 0.41 kg/m^2** that, **considering an average TCWV value of 30 kg/m^2, corresponds to 1.4% (within the ESA Water Vapour CCI requirements of +/- 3%).** The **standard deviation** is **5.38 kg/m^2** corresponding to **17.9%**.

- Focusing on **coastal areas**, good agreement are found **(+/- 3%)**. Where we observed the major discrepancies, AIRWAVE-SLSTR tends to have a negative bias with respect to the reference products.

- **v2 major improvement** w.r.t. **v1**, mainly in terms of the magnitude of the bias, **a slight seasonality of the bias is still present, with worst results in the Southern Hemisphere**. This result is **more evident in the global validation with the satellite instruments** SSMI/S and AMTROC-MWR, as **ground-based instruments do not properly cover these regions**.