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Almost one year of TROPOMI/S5P total ozone column data: global ground-based validation

K. Garane[1], D. Balis[1], M.E. Koukouli[1], A. Bais[1], V. Fioletov[4], A. Pazmino[3], J-C. Lambert[2], T. Verhoelst[2], J. Granville[2], A. Bazureau[3], F. Goutail[3], J-P. Pommereau[3], C. McLinden[4], K.-P. Heue[5], D. Loyola[5], J. Xu[5], W. Zimmer[5], F. Romahn[5], C. Lerot[2], M. Van Roozendael[2], A. Redondas[6] and C. Zerefos[7]

1 Aristotle University of Thessaloniki, Greece (AUTH)
2 Royal Belgian Institute for Space Aeronomy, Belgium (BIRA-IASB)
3 Laboratoire Atmosphères, Milieux, Observations Spatiales, France (LATMOS-CNRS)
4 Environment Climate Change Canada
5 German Aerospace Centre *(DLR)*
6 Izaña Atmospheric Research Center (IARC), State Meteorological Agency (AEMET), Spain
7 Academy of Athens, Greece (AA)

***e-mail:** **agarane@auth.gr**

ABSTRACT

In this work we present the validation results of almost one year of TROPOMI Near Real Time (NRTI) and OFFLine (OFFL) data against ground-based quality-assured Brewer and Dobson total ozone column (TOC) measurements deposited in the World Ozone and Ultraviolet Radiation Data Center (WOUDC). Additionally, comparisons to Brewer measurements from the European Brewer Network (EUBREWNET) and the Canadian Network are performed, as well as to twilight zenith-sky measurements obtained with ZSL-DOAS (Zenith Scattered Light Differential Optical Absorption Spectroscopy) instruments, that form part of the SAOZ network (Système d'Analyse par Observation Zénitale) of the Network for the Detection of Atmospheric Composition Change (NDACC). Through the comparison of the TROPOMI measurements to the total ozone ground-based measurements from stations that are distributed globally, as the background truth, the dependence of the new instrument on latitude, cloud properties, solar zenith and viewing angles, among others, is examined. Validation results show that the mean bias and the standard deviation of the percentage difference between TROPOMI and QA ground TOC meet the product requirements.

S5p – TROPOMI TOC products

- **DOAS-based NRTI algorithm (S5P_TO3_DOAS):**
  1ST STEP: least-squares fitting of the effective total ozone slant column, based on Beer-Lambert extinction | 2ND STEP: a conversion to the vertical total ozone density
- *NRTI Data available through the **Sentinel-5P Pre-Operations Data Hub***
  https://s5phub.copernicus.eu/
- **OFFL algorithm (S5P_TO3_GODFIT) :**
  1 step non-linear least-squares inversion based on the direct comparison of simulated and measured backscattered radiances.
- *OFFL Data available through the **Sentinel-5P Expert Users Data Hub***
  https://s5pexp.copernicus.eu/

Comparison to Canadian Brewer measurements

The overall bias between **Tropomi_OFFL** and Canadian Brewers is **1.48 ± 0.42 %**

The standard deviation of the difference is **1.15 ± 0.15 %** (for distance <10 km)

► *The standard deviation is rapidly increasing with distance between Tropomi pixel and Brewer site.*

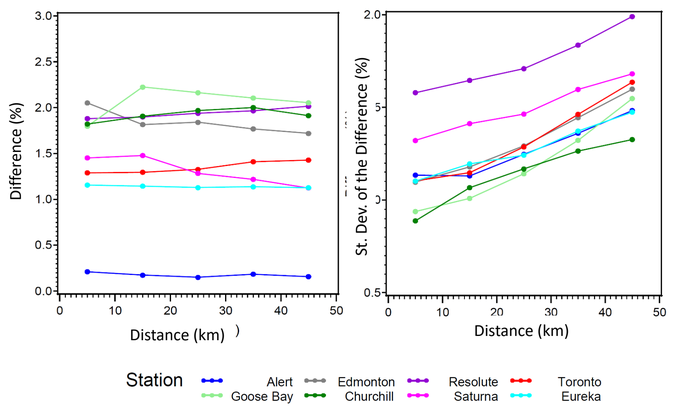
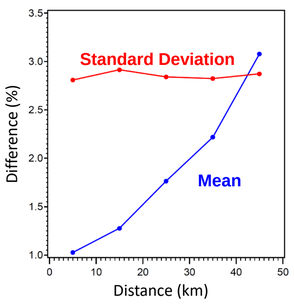


Figure 3: The mean % difference (left) and the standard deviation of the difference (right) vs distance between Brewer location and Tropomi pixel.

A case study: Mauna Loa, Hawaii



- MLO Elevation 3500 m.
- The terrain altitude declines steeply toward the ocean.
- The difference in the total ozone above MLO and over the ocean is captured in Tropomi data

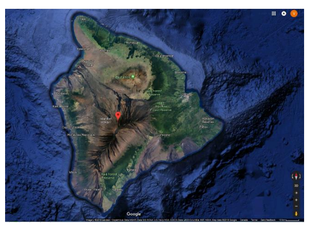
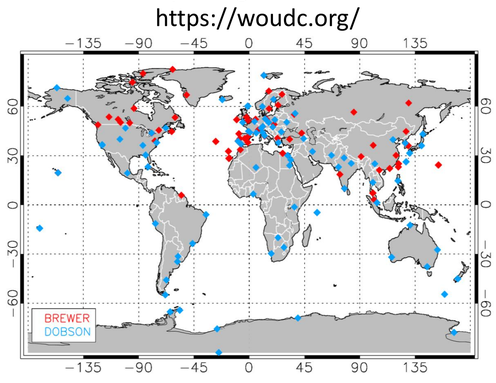


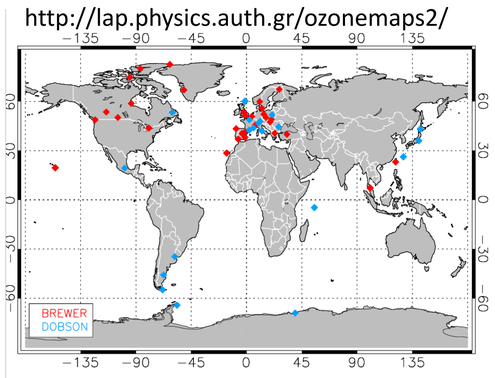
Figure 4: The % difference vs distance between Brewer location and Tropomi pixel.

The Ground Based measurements

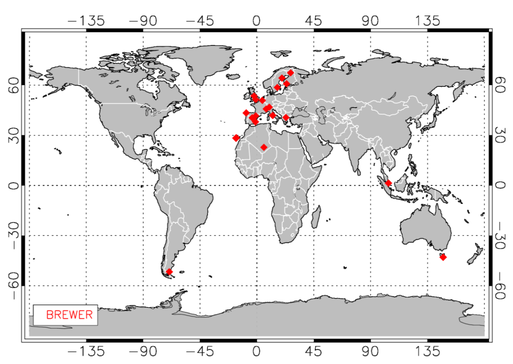
93 Brewer | 85 Dobson
Reporting to **WOUDC**
https://woudc.org/



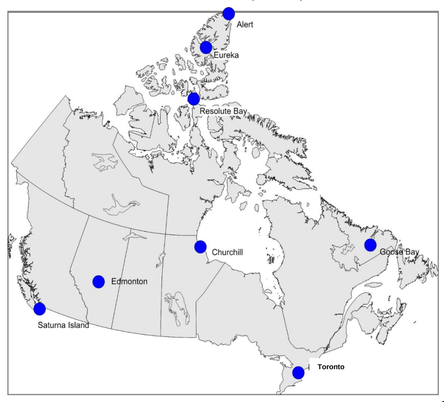
38 Brewer | 20 Dobson
Reporting to the **WMO Mapping Centre**
http://lap.physics.auth.gr/ozonemaps2/



25 Brewer
Reporting to **EUBREWNET**
http://rbcce.aemet.es/eubrewnet/



Reporting to the **Canadian Brewer Network:**
8 sites + Mauna Loa, Hawaii (MLO) and South Pole (SPO)

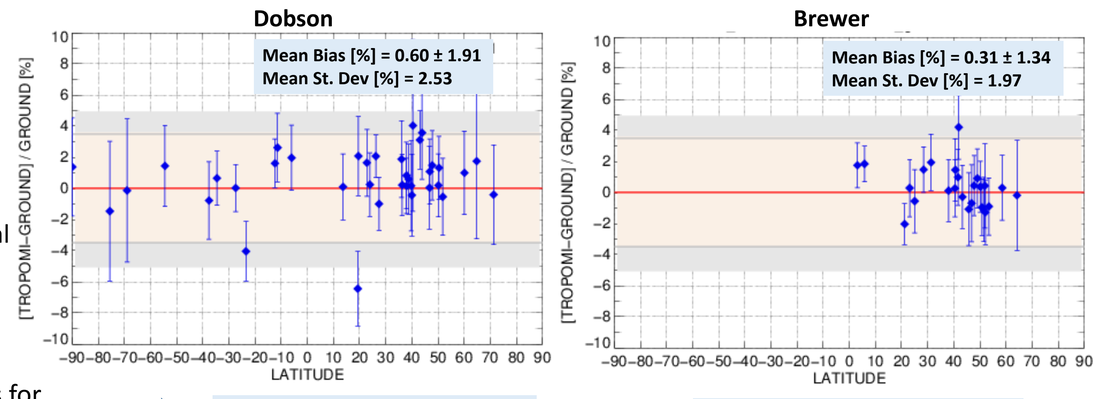


Acknowledgments:
Satellite data *were provided by ESA in the frame of the VALTOZ CalVal activity. The validation is performed in the frame of the ESA's S5P Mission Performance Centre. The ground-based data used in this publication were obtained as part of WMO's Global Atmosphere Watch (**GAW**) and the Network for the Detection of Atmospheric Composition Change (**NDACC**). They are publicly available via the World Ozone and UV Data Centre (**WOUDC**) and the NDACC Data Host Facility. We would like to acknowledge and warmly thank all the investigators that provide data to the repository on a timely basis, as well as the handlers of the database for their upkeep and quality guaranteed efforts. We thank the **European Brewer Network** (http://rbcce.aemet.es/eubrewnet/) and the **Canadian Brewer Network** (http://exp-studies.tor.ec.gc.ca) for providing access to the data and the PI investigators and their staff for establishing and maintaining the sites used in this investigation.*

Comparison to GB measurements from WOUDC

- Validated data: NRTI & OFFL_L2__O3 for the time period **7 Nov 2017 - 10 Oct 2018**
- **Dependency of the % diff (satellite-ground) on influence quantities:** nothing unexpected or out of the requirements

Figure 1: Latitudinal dependency of the mean % difference between **S5p_OFFL** and ground based data from WOUDC, for each individual station.



The respective statistics for the **S5p_NRTI** comparisons are:

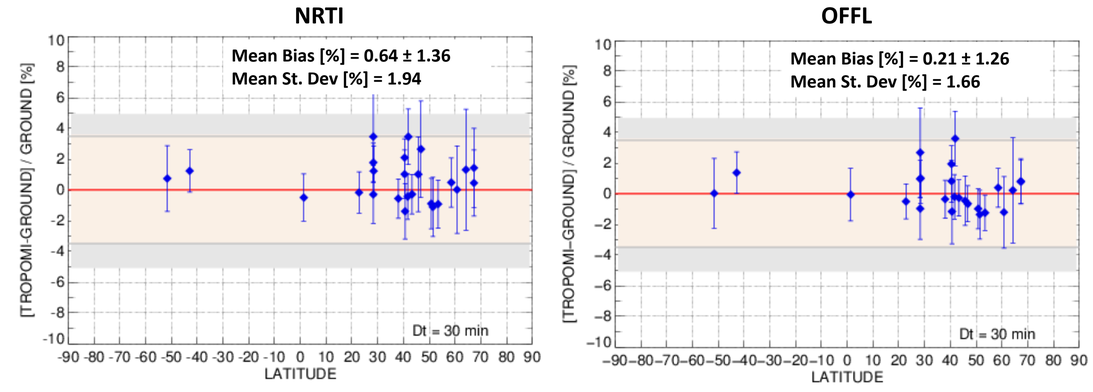
Mean Bias [%] = 1.07 ± 2.04
Mean St. Dev [%] = 2.64

Mean Bias [%] = 1.09 ± 1.24
Mean St. Dev [%] = 2.24

Comparison to GB measurements from EuBrewNet

- Only DS measurements from Brewers were used
- Validated S5p data: NRTI & OFFL_L2__O3 for the time period **7 Nov 2017 - 31 Oct 2018**
- Time window from the overpass time: ± 30 minutes

Figure 2: Latitudinal dependency of the mean % difference between **S5p_NRTI** (left) and **S5p_OFFL** (right) and Brewer ground based data from EuBrewNet, for each individual station.



Comparison to GB measurements from the SAOZ Network

Data:
- **SAOZ:** O_3 VCD at twilight (sunrise & sunset)
- **TROPOMI**: NRTI daily mean O_3 VDC
- Limited period of comparisons: July-September 2018

Comparison results:
- The Mean Bias is less than 3 % for each individual station
- The overall Mean Bias (all stations considered) < 0.2 %
- The Std. Dev. increases at high latitudes (particularly in SH winter)

A case study: Impact of co-location criteria

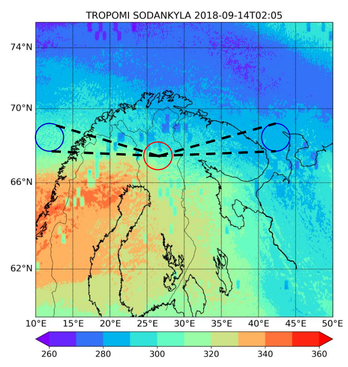


Figure 5: The Sodankyla site and the 3 criteria used for the investigation of their effect on co-location.

Criteria of co-location:
1. 50 km distance of station
2. 50 km distance from tangent point at 90° SZA
3. Cone shape (air masses from #2 and from a cone towards the geographical position of the station)

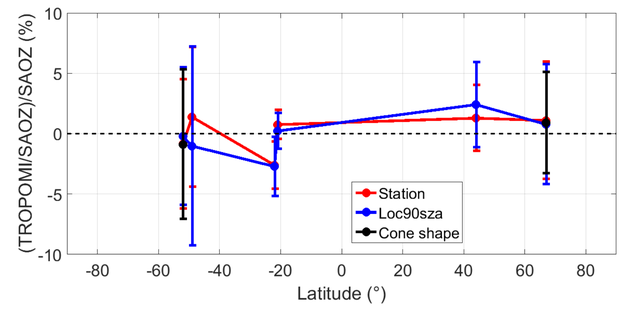


Figure 6: The latitudinal dependency of the % difference for the three criteria used

► **Investigation result:** Little influence of co-location methodology

Conclusions

- The TROPOMI NRTI & OFFL mean bias and mean standard deviation were found to be **within specifications** [***Mean Bias up to 3.5 – 5.0 % & Mean St. Dev. Up to 1.3 – 2.5 %***] for both NRTI and OFFL TOC products**:**

	NRTI TOC			OFFL TOC			
	WOUDC		EuBrewNet	WOUDC		EuBrewNet	Canadian Net.
	Dobson	Brewer	Brewer	Dobson	Brewer	Brewer	Brewer
Mean bias (%)	1.1 ± 2.0	1.1 ± 1.2	0.6 ± 1.4	0.6 ± 1.9	0.3 ± 1.3	0.2 ± 1.2	1.5 ± 0.4
Mean St. dev.	2.6	2.2	1.9	2.5	2.0	1.7	1.2

- The percentage differences deviate by less than 0.5% depending on the temporal variability of the sensing of the GB measurements (WOUDC: daily mean TOC, Eubrewnet: instantaneous TOC)
- The standard deviation of the comparisons is increasing with distance between TROPOMI pixel and Brewer site, as well as at high latitude sites hosting SAOZ instruments
- No unexpected dependency on influence quantities, such as SZA, VZA, clouds etc. is seen