Total ozone measurements from the NDACC Izaña Subtropical Station: Visible spectroscopy versus Brewer and satellite instruments

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Abstract

Ozone total columns measured at twilight using a zenith-sky UV-Visible spectrometer installed at the NDACC Izaña Subtropical Observatory (28ºN, 16ºW) in October 1998 are compared with the RBCC-E reference instrument Brewer #157 at the same location. DOAS retrievals were performed in the visible range (450-535 nm) according to improved settings recommended by the NDACC and using homogenized daily AMFs based on the TOMS V8 (TV8) column-resolved ozone profile climatology. The station is located at 2370 masl well above the Marine Boundary Layer and outside of pollution environment. Comparisons have been performed for the 13-years dataset using daily means to minimize the impact of instruments differences in measurements time. Overall results show an excellent agreement. The UV-Visible to Brewer mean difference is of +1.0% with a standard deviation of 3% and a slight dependence on the amount of ozone. Discrepancies on individual days due to changes in the tropospheric O3 content and different air masses sampling in fast O3 changing conditions were identified. The temperature dependence of the UV cross-sections has been found to have a negligible impact at these low latitudes. Seasonal discrepancies are of only few tens of a percent. The station being affected by desert dust from Sahara, cloud filtered data have been split in two sets to examine the potential influence of aerosol scattering and absorption on measurements. Results show a similar behaviour of both techniques also under high aerosol loading conditions. Comparisons with satellite instruments show an average agreement better than 1% for TOMS-V8, OMI and SCIAMACHY and of 1.1% and 1.6% for GOME and GOME-2, respectively with a standard deviation of 3%. However, considering that 2.7 to 3.0 % of the total column resides below the altitude of the station, these values actually point to an underestimation of the satellite instruments in comparison to our ground-based data. Possible causes of these differences are discussed.

Introduction

+ In last years, recommendations have been made to improve O3 measurements quality to converge up to 1% as required for trends studies (*IGACO-2004, GMES Atmospheric Core Service 2009*)

+ NDACC Izaña Observatory host high quality instrumentation in the UV (Brewer #157 operated by AEMET), Visible (DOAS/RASAS operated by INTA) and IR (FTIR operated by IMK) spectral ranges. In addition, regular Ozonesounding are performed once a week since 1992, providing a good climatology on ozone vertical distribution.

+ Previous studies have intercompared Brewer to FTIR (Schneider et al., 2008, Viatte et al., 2011) finding an excellent agreement if absorption cross-sections differences in both spectral ranges are corrected.

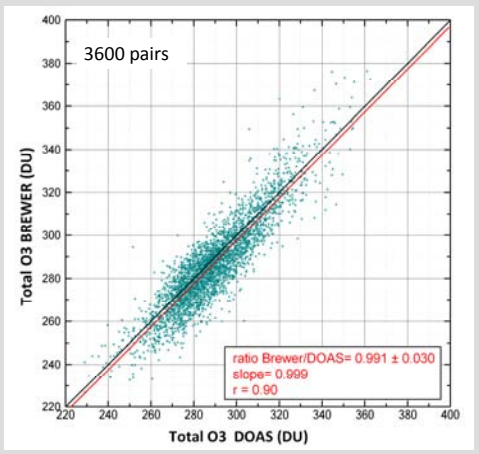
+ The aim of this work is to carry-out a similar analysis with the zenith DOAS instrument running since 1999.

+ DOAS standard analysis consist in a two-step process. First, slant columns are retrieved by a non-linear fitting. Secondly, Air Mass Factors are applied to refer to a vertical column density (VCD) or TOC.

+ In standard mode, DOAS operates during twilight. Two measurements per day (am, pm) obtained as the average of individual measurements between Solar Zenith Angles of 88º to 91º (typically, 5). For comparison purposes, a daily mean is obtained as the am and pm average.

+ Satellite O3 instruments operating in nadir mode have been included in the analysis.

DOAS & Brewer



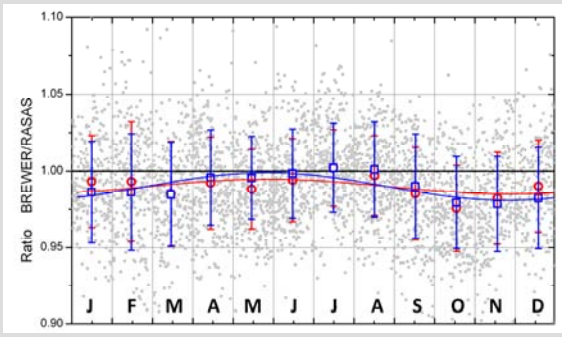
* Agreement to 0.9 %

* Departure from diagonal at large values due to occasional pollution events not captured by DOAS (little tropospheric sensitivity)

* Identified real differences due to a) differences in time b) differences in space (observation geometry makes that DOAS scanned air masses are 200-300 km apart from the station)

The use of a single set of AMF all year round result in a seasonality in the ratio Brewer/DOAS (blue). Seasonality is reduced to less than 1% when using daily AMF as recommended by NDACC (Hendrick et al, 2011)

Blue squares = One single AMF set for all year
Red open circles = New NDACC AMF
Blue and red lines = sin fits



Conclusions

+ O_3 data from DOAS instruments (RASAS and RASAS-2) operating at Izaña Observatory since late 1998 have been compared to the RBCC-E Brewer #157 and nadir satellite overpassing data.

+ Agreement between all instruments intercompared are within 1% with a standard deviation of 3%.

+ Satellite data are 1% lower than ground-based if we consider that 3% of the ozone column resides below the station.

+ No difference in the agreement between UV-direct Sun (Brewer) and Zenith visible (DOAS) has been found under Saharan dust conditions with respect to normal no-dust conditions (AOD <0.05)

+ The excellent O_3 agreement between instruments (keeping in mind differences in spectral range, cross-sections, geometry, FOV, evaluation procedures, etc) shows that the aim of reaching measurements at the 1% level can be reached at Subtropical latitudes where tropospheric O_3 variability is small.

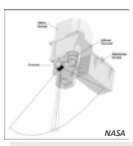
Future work:
This work will be completed by including the FTIR instrument on the DOAS intercomparison.

Station and Instruments

High mountain free troposphere Izaña Observatory is located in Northern Subtropics at 2370 masl

BREWER

DOAS/RASAS



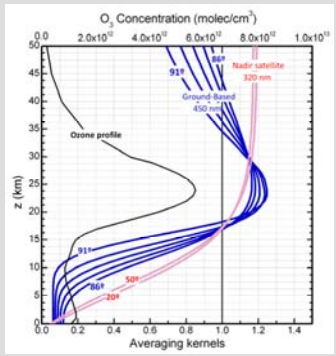
TOMS

SCIAMACHY

GOME
GOME-2

OMI

Technical differences between Brewer, DOAS and satellites



Averaging kernels (AK) describe the sensitivity of total column of a tracer to changes in a given layer. It can be computed as the ratio of the AMF at certain layer to the total AMF. Plot shows AK for a) DOAS at solar zenith angles (sza) of 86º to 91º and wavelength 450 nm. b) Nadir satellite at 20-50 sza and wavelength of 320 nm. Ozone profile used in the calculations is shown as reference. Tropospheric sensitivity is limited and reduces as sza increases. Increasing wavelength results lowering of the maximum of sensitivity.

+ Spectral range: Brewer UV DOAS : Visible

+ Sensitivity to atmospheric layers. Zenith measurements at twilight are almost insensitive to tropospheric ozone. Nadir instruments have a limited tropospheric sensitivity, as well (see figure)

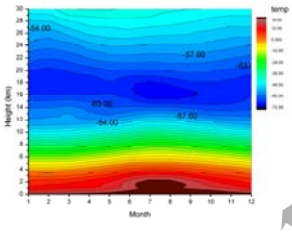
+ AMF are sensitive to aerosols content. Both instruments are affected. The effect in diffuse light is larger than at direct sun but is minimum at twilight.

+ Temperature dependence. Negligible in visible but not in the UV.

	Ground-Based			Satellites				
	Brewer	RASAS	RASAS-II	TOMS	GOME	SCIA	OMI	GOME-2
Algorithm		DOAS-INTA	DOAS-INTA	OMTO3-v8	WF-DOAS	WF-DOAS	OMTO3-v8.5	WF-DOAS
Retriev. range (nm)	306-320	430-535	430-520	312,331	326-335	326-334.5	317.5, 331.2	325-334.5
Samples/nm	5 single λ	3.4	8.9	2 single λ	11.1	10.7	2 single λ	11.1
Resolution (nm)	0.6	1.3	0.5	1	0.17	0.25	0.6	0.29
FOV (degrees)	3º	11º	1º					
Scanned area or footprint (approx. km)	Direct Sun	Zenith[1]	Zenith[1]	Nadir (100x100)	Nadir (320x40)	Nadir (30x60)	Nadir (100x100)	Nadir (80x40)

[1]Diffuse light, Effective slant path results from the intensity-weighted integration of all individual paths. At twilight effective location is about 200-300 km toward the sun direction

•OMTO3 v8 = O3 below clouds added to results. Clouds taken from TOMS climatology
v8.5 = RRS used to estimate photons penetration

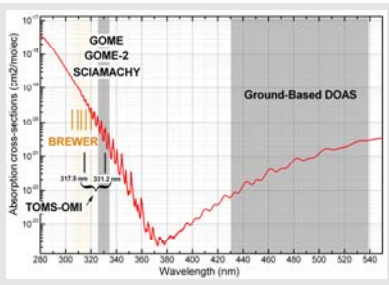


Evolution of T over Canary Islands

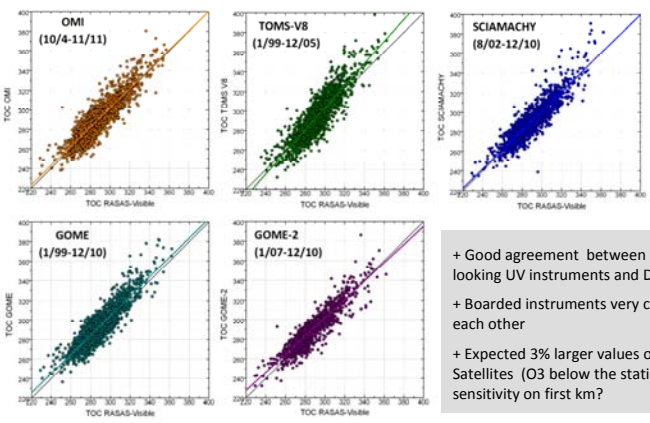
+ Brewer and satellites measure in the 300-330 nm band (Huggins) where Cross-sections are temperature dependent.

+ Ground-based DOAS measures in the visible band (Chappuis) where differential cross-sections are temperature independent.

+ The effect is minor in tropical/Subtropical regions since there is little temperature variability along the year.



DOAS & Nadir-looking Satellite Instruments



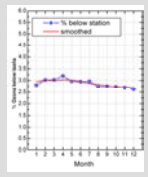
	Period	Version	Ratio
Brewer	1/1999-12/2011		0.99 ± 0.030
TOMS	1/1999 - 12/2005	v8	1.007 ± 0.036
GOME	1/1999 - 12/2010	Bremen WFDOAS	1.016 ± 0.032
SCIA	8/2002 - 12/2010	Bremen WFDOAS	1.007 ± 0.036
OMI	10/2004 - 11/2011	OMTO3 v85	1.008 ± 0.031
GOME-2	1/2007 - 12/2010	Bremen WFDOAS	1.011 ± 0.029

Scia degradation = 0.2- 0.4%/year (since 2002, at least) Lerot et al., AMT 2009

+ Good agreement between nadir-looking UV instruments and DOAS.

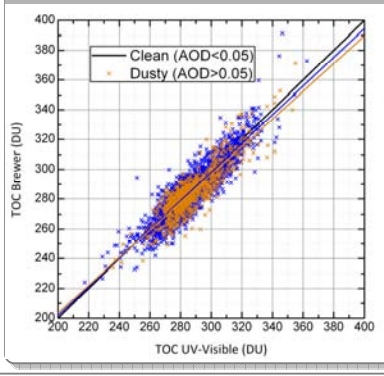
+ Boarded instruments very close each other

+ Expected 3% larger values on Satellites (O3 below the station). Low sensitivity on first km?



% of the O3 column below Izaña

Effect of Saharan dust on ozone retrievals: Differences Brewer &DOAS



Clean
Brewer/DOAS = 0.990±0.030
slope = 0.96
r = 0.90

Dusty
Brewer/DOAS = 0.991 ± 0.026
slope = 0.93
r = 0.88

Saharan dust absorbs UV radiation and strongly enhance radiation scattering. Episodes of heavy outbreaks up to 1 AOD for few days are common .

We have explored the potential influence of Saharan dusts events on retrieved ozone amounts by analyzing separately clear non-dusty days and clear dusty days (cloudy days were removed).

No significant differences have been found for Brewer and DOAS spectrometers.

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Acknowledgements:

We acknowledge IUPB for providing GOME, GOME- and SCIAMACHY overpassing data.
Url: http://www.iup.uni-bremen.de/gome/wfdoas/merged/

OMI and TOMS data are from overpassing as well .
Url: http://avdc.gsfc.nasa.gov/index.php?site=830165109

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