Tropical tropospheric ozone columns from nadir retrievals of GOME-1/ERS and SCIAMACHY/Envisat

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Tropospheric ozone columns can be retrieved from space-born observations with the Convective Clouds Differential (CCD) technique (Ziemke et al. 1998) using total ozone column and cloud retrievals. The CCD technique uses the clear-sky and above-cloud ozone column measurements to derive a monthly mean tropospheric column amount by the subtraction of the above cloud column from the total column. An important assumption here is that stratospheric ozone is zonally invariant which is only approximately true in the tropical region. A CCD algorithm has been developed and is applied to GOME/ERS (1995-2003) and SCIAMACHY/Envisat (2002-2012) measurements so that a unique long-term record of monthly averaged tropical tropospheric ozone columns (20°S – 20°N) can be created starting in 1995. First results of the CCD application, including validation by comparisons with SHADOZ ozonesonde data, are presented.

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1 Introduction

The Global Ozone Monitoring Experiment (GOME) on board the ERS platform, and the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) on board the Envisat platform, are two European passive satellite instruments that had been measuring total ozone columns along with other atmospheric constituents in nadir viewing mode. They have nearly identical UV spectral channels (237-793 nm and 214-2380 nm respectively) so that the same retrieval algorithm for total ozone and derived products from it, such as tropospheric column ozone, can be adapted to both instruments without large changes (Weber et al. 2013).

2 Data and Methodology

2.1 Data

The Weighting Function Differential Optical Absorption Spectroscopy (WFDOAS), developed at the Institute of Environmental Physics (IUP) at the University of Bremen, is applied to retrieve total ozone columns from nadir observations in the UV spectral window 326–335 nm (Coldewey-Egbers et al. 2005). The WFDOAS algorithm fits vertically integrated ozone weighting functions rather than the ozone cross-sections to the sun-normalised radiances which enables a direct retrieval of vertical column amounts. For GOME the FRESCO algorithm (Koelemeijer et al. 2001) is used to derive cloud properties as cloud-top-height (cth) and cloud fraction (cf). This cloud information is then used to correct for missing ozone below clouds in the retrieved total columns (Coldewey-Egbers et al. 2005). These cloud properties are also used to infer the tropospheric ozone column as will be discussed below. The agreement of WFDOAS total ozone for GOME with ground data is within ±1% (Bracher et al. 2005). For SCIAMACHY an alternative cloud algorithm, SACURA/OCRA (Kokhanovsky et al. 2005) is used. The correlation between FRESCO and SACURA/OCRA is pure over land but relatively good over water (Lelli 2013).

2.2 Methodology

The Tropical Tropospheric Column of Ozone (TTCO) can be retrieved from satellite data by using the total column of ozone and cloud information with the Convective Clouds Differential (CCD) technique (Ziemke et al. 1998). The original technique, applied in TOMS data, assumes that the stratospheric column (no ghost column correction) above deep convective clouds (ACCO) is identical to all stratospheric columns in the same latitude band. This *ACCO* is then subtracted from clear-sky ozone column measurements to yield the tropical tropospheric column of ozone. A basic assumption in the CCD method is that the tropopause (~100 hPa) lies close to the top of the deep convective clouds (DCC), which are high, thick and bright clouds with greatest occurrences over the *Intertropical Convergence* **Zone** (ITCZ), the western Pacific and Indian Ocean (Hong et al. 2007). It is known that DCC tops only reach the bottom of the tropical tropopause layer or the 'tropical transition layer' (TTL) (Sherwood and Dessler 2001), which is well below the thermal (cold point) tropopause (~150 hPa). Only in rare occasions DCCs overshoot beyond the top of the TTL (Hong et al. 2007).

The CCD method works well under the assumption that the mean Above-Cloud-Column is zonally invariant in the Pacific region, although it is known that a zonal variability on the order of 10 DU exists (Ziemke and Chandra 1999). In the Pacific, very low ozone concentrations are present inside and above DCCs due to the vertical convection of ozone poor oceanic air from the marine boundary layer into the upper troposphere (Ziemke et al.

2009). Hence, the error from ozone below the thermal tropopause is minimum if the retrieved ozone columns above the clouds are taken from that region.

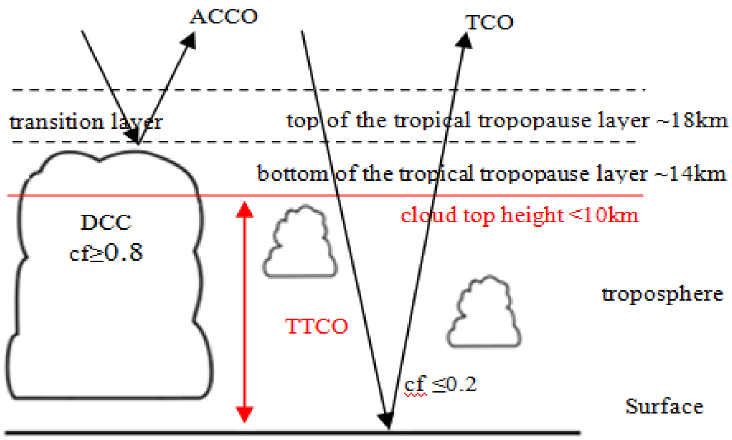


Fig. 1 Illustration of the Convective Clouds Differential (CCD) technique. DCC are the deep convective clouds, cf is the cloud fraction, ACCO is the above cloud column of ozone, TCO is the total column of ozone and TTCO is the tropical tropospheric column of ozone.

The Above Cloud Ozone Columns were determined in the Western Pacific area (70°W-170°E, 20°S-20°N) for each latitude band of 2.5^o by monthly averaging the ozone columns over all cloudy scenes with cloud fraction cf≥0.8 and cloud tops greater than 10 km (Valks et al. 2003). The cloud-free total ozone columns from scenes with cf≤0.2 were averaged in grid boxes of 2.5^o×5^o between 20^{o}N-20^{o}S into monthly mean values. Finally, for each latitude band the appropriate *ACCO* was subtracted from the gridded clear-sky total ozone columns (TCO), resulting in a gridded monthly mean tropical tropospheric ozone column (Valks et al.2003).

3 Results

The accuracy of the method was tested by comparisons with collocated tropospheric ozone columns below 200hPa, derived from the Southern Hemisphere ADditional OZonesondes (SHADOZ) network (Thompson et al. 2003). The sonde sites shown here are: Ascension (8°S, 14.4°W), Java (7.6°S, 111°E), Samoa (14.4°S, 170.6°W) and Natal (5.4^{o}S, 35.4^{o}W) from 1998-2002 for the GOME and from 2003-2008 for the SCIAMACHY validation.

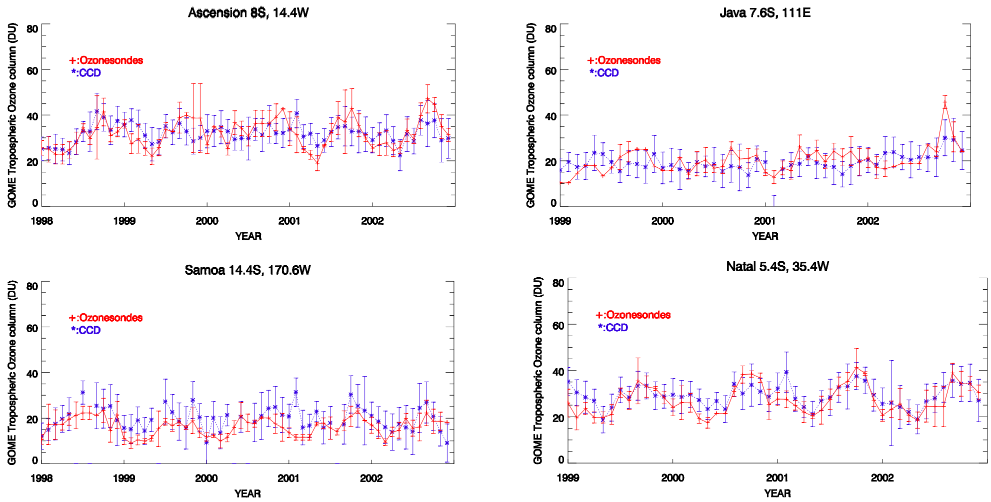
Figure 2 shows the comparison for the four sonde sites for both instruments. On average there were 3-5 sonde launches per month, exept from Java where there is only one from in most cases. A clear overestimation can be noticed in the Pacific site of Samoa (bias 3.5/3.82) where low ozone columns are retrieved (~20DU). The differences are smaller for both instruments in Ascension (bias -0.08DU for GOME and -0.02DU for SCIAMACHY), although an increment can be seen in Autumn (~40DU), as expected, by upper tropospheric ozone production from lightning NOx combined with the biomass burning in Africa and the large-scale Walker circulation (Martin et al. 2002).

According to Table 1, for both insruments, in all sites the bias is less than 4 DU (negative at Ascension and Java, for both instruments) and the RMS between 1.51(Natal) and 2.90DU (in Java). The correlation with ozonesondes is better at Samoa and Natal for both instruments. SCIAMACHY correlates better with sondes compared to GOME.

Figure 3 shows the tropospheric ozone columns for October 2001(GOME) and 2009 (SCIAMCHY). The same pattern (wave-1) in maximums (Southern Atlantic) and minimums (western Pacific), is clearly visible. For the latitudes Southern of 12.5^o, no tropospheric ozone column is plotted due to limited data per latitude band for the *ACCO* calculation.

Conclusively, both instruments present relatively good agreement with sondes and between them in range, inter-annual variation and variance.

(a)



(b)

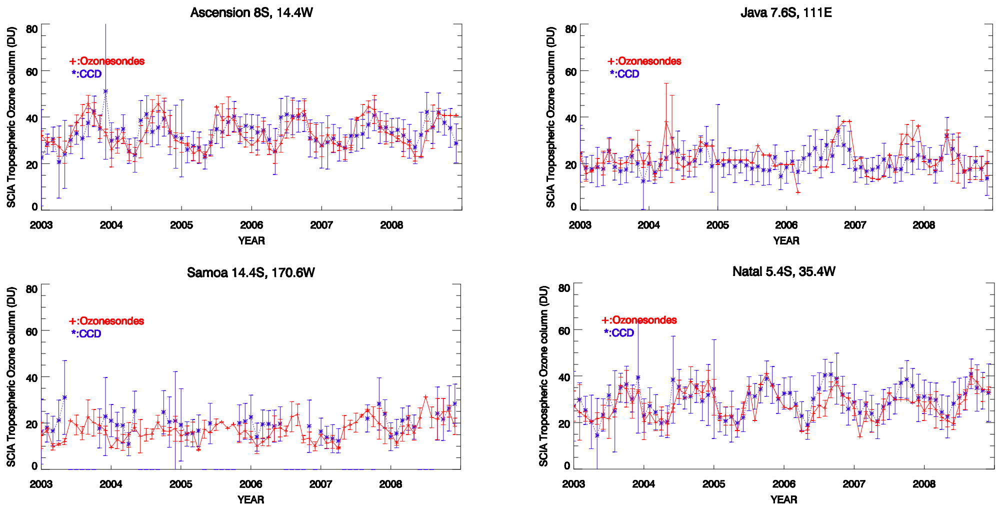
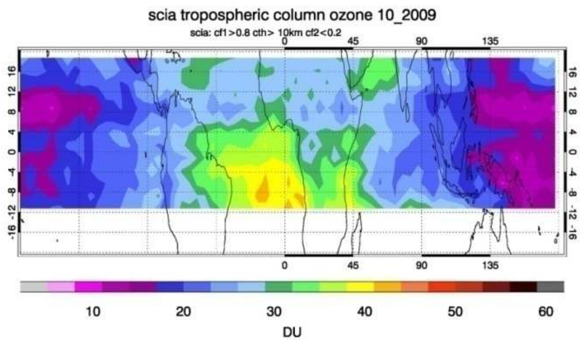


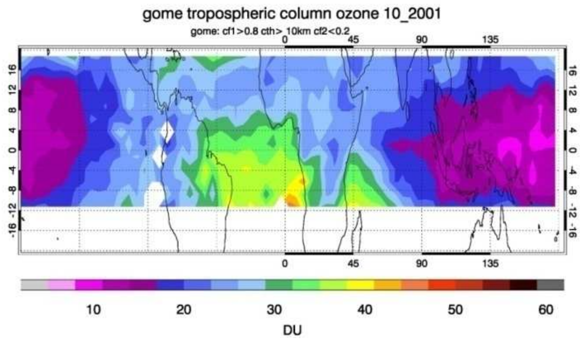
Fig. 2. 8 Validations of TTCO (over 10km) with four ozonesonde stations from SHADOZ Network. (a) GOME (1998-2002) and (b) SCIAMACHY (2003-2008). Error bars indicate the standard deviation of the monthly mean. For months with only one ozone sonde launch available in a given month, no error bars are shown.

Table 1. Statistical comparison between a) GOME and ozonesondes TTCOs and b) SCIAMACHY and ozonesondes for four SHADOZ sites. Information presented here: the ozonesonde site, the mean TTCO for GOME/SCIAMACHY and for ozonesondes, the bias and the RMS difference between CCD TTCO and sondes and finally the correlation coefficient. The values are in DU.

Sonde site	Period	GOME	SONDES	BIAS	RMS	R
Ascension	1998-2002	31.9	32.0	-0.08	2.25	0.57
Java	1999-2002	19.4	20.1	-0.7	2.90	0.60
Samoa	1998-2002	19.9	16.4	3.50	2.35	0.80
Natal	1999-2002	29.1	27.3	1.82	1.74	0.75
Sonde site	Period	SCIAMACHY	SONDES	BIAS	RMS	R
Ascension	2003-2008	33.1	33.1	-0.02	2.29	0.61
Java	2003-2008	20.7	22.4	-1.6	1.16	0.69
Samoa	2003-2008	20.3	16.5	3.82	2.00	0.93
Natal	2003-2008	29.6	27.5	2.06	1.51	0.75



(a)



(b)

Fig. 3. Tropical tropospheric ozone column (TTCO) derived with the convective cloud differential (CCD) technique for October 2001 and 2009 with (a) GOME and (b) SCIAMACHY

4 Conclusions

First results of tropospheric ozone columns were derived with the CCD method using GOME and SCIAMACHY WFDOAS data for the time period of 1998-2002 between 20^{o}N-20^{o}S. The initial comparison with ozonesondes shows good agreement (0.57<R<0.94) for both instruments (and between them) in range, inter-annual variation and variance. Further optimization of the data is planned (use of SACURA/OCRA algorithm for cloud properties in WFDOAS for all satellite data) to improve the consistency between satellite datasets for long-term trend and variability studies. Later, the CCD method will be adapted to GOME-2 data (2007-present). Validation with limb-nadir-matching observations will follow.

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References

Bracher A, Weber M, Bramstedt K. et al. (2005) Global satellite validation of SCIAMACHY O3 columns with GOME WFDOAS, Atmos. Chem. Phys. Discuss.

Coldewey-Egbers M, Weber M, et al. (2005) Total ozone retrieval from GOME UV spectral data using the weighting function DOAS approach. Atmospheric Chemistry and Physics

Hong GP, Yang B-C, Gao B, Baum A, et al. (2007) High cloud properties from three years of MODIS Terra and Aqua collection-4 data over the tropics. J. Appl. Met. Clim.

Koelemeijer RBA, Stammes P, Hovenier JW, de Haan JF (2001) A fast method for retrieval of cloud parameters using oxygen A-Band measurements from GOME. JGR. Vol 106

Kokhanovsky A, Rozanov V, Burrows JP, et al. (2005) The SCIAMACHY cloud products: algorithms and examples from ENVISAT. Advances in Space Research, 36.

Lelli L (2013) Studies of global cloud field using measurements of GOME, SCIAMACHY and GOME-2, PhD Thesis, Institute of Environmental Physics, University of Bremen, Otto-Hahn-Allee 1, 28334, Bremen, Germany

Martin RV, Jacob DJ, Logan JA, Bey I, Yantosca RM et al. (2002) Interpretation of TOMS observations of tropical tropospheric ozone with a global model and *in situ* observations. J. Geophys. Res. 107

Sherwood SC, Dessler AE (2001) A model for transport across the tropical tropopause. J. Atmos. Sci, 58, 765–779

Valks P, Koelemeijer R, Van Weele M, et al. (2003) Variability in tropical tropospheric ozone: Analysis with Global Ozone Monitoring Experiment observations and a global model. Journal of Geophysical Research 108

Weber M, Chehade W, Fioletov VE, Frith SM, Long CS, Steinbrecht W, Wild JD (2013) Stratospheric Ozone [in State of the Climate in 2012], Bull. Amer. Meteor. Soc, 94.

Ziemke JR, Chandra S, Bhartia PK (1998) Two new methods for deriving tropospheric column ozone from TOMS measurements: The assimilated UARS MLS/HALOE and convective-cloud differential techniques", J. Geophys. Res

Ziemke JR, Chandra S (1999) Seasonal and interannual variabilities in tropical tropospheric ozone, J. Geophys. Res, 104 (D17), 21425–21442.

Ziemke JR, Joiner J, Chandra S, Bhartia PK et al. (2009) Ozone mixing ratios inside tropical deep convective clouds from OMI satellite measurements, Atmos. Chem. Phys, 9, 573-583.