Comparison of tropospheric ozone derivation from TOMS and OMI

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ABSTRACT:
This study compared between tropospheric column ozone by applying the SAM method to TOMS and OMI data for northern summer. Tropospheric ozone from the SAM represents a peak over the tropical Atlantic, where it is related with biomass burning. This feature is also seen in the distribution of the model and CO. Additionally, enhancement of the SAM ozone over the Middle East, and South and North America agrees well with the model and CO distribution. However, the SAM results show more ozone than the model results over the northern hemisphere, especially the ocean (e.g. the North Pacific and the North Atlantic). The tropospheric ozone distribution from OMI data shows more ozone than that from TOMS data. This can be caused by different viewing angle, sampling frequency, and a-priori ozone profiles between OMI and TOMS. The correlation between the SAM tropospheric ozone and CO is better than that between the model and CO in the tropics. However, that correlation is reversed in the mid-latitude.

KEY WORDS: Tropospheric ozone, TOMS, OMI, CO

1. Introduction

Two kinds of tropospheric ozone retrieval algorithm exist; the direct and indirect method. The indirect method is the tropospheric residual-based method, and the direct methods are the Scan-Angle Method (SAM) and Global Ozone Monitoring Experiment-Tropospheric Column Ozone (GOME-TCO) method.

The performance of the methods shows a reliable distribution of tropospheric ozone over the tropics than higher latitude where strong variation of stratospheric ozone exists. There have been a few studies that extend the retrieval to higher latitude with residual and GOME-TCO method. However, the application of the SAM to tropospheric ozone retrieval over higher latitude suffers a significant error because it strongly depends on spatial resolution of field of view from a satellite.

In the course of the time, Ozone Monitoring

Instrument (OMI) was launched in July 2004 onboard the Aura spacecraft platform. The OMI has measured total ozone with a very high spatial resolution (13km X 24km) about 8 times better than TOMS. The increased resolution resulting in the increase of sampling enables the SAM to retrieve tropospheric ozone over higher latitudes. Recently, Ziemke et al. (2006) have utilized the new OMI data based on the residual-based method.

The purpose of this study is to analyze and evaluate how the SAM technique performs in tropospheric ozone retrieval over higher latitude. We will use OMI total ozone measurements for boreal summer of 2005 when climatological stratospheric ozone variation is relatively small and smooth. For comparison with OMI-derived tropospheric ozone, TOMS data for boreal summer of 1996-2000 has been used. Also, the comparison will be performed with respect to products from GOME-TCO and OMI/MLS-TCO (Liu et al., 2006; Ziemke et al., 2006). To evaluate the performance of the OMI-results, we have used CO from Measurements Of Pollution In The Troposphere (MOPITT) and tropospheric ozone from the Goddard Earth Observing System chemical transport model (GEOS-CHEM).

2. Data

In this study, we have used Version 7 Level-2 TOMS data under clear sky condition for boreal summer of 1996 to 2000 because the TOMS data contains a noticeable error after 2001 [*McPeters*, 2003]. The constituent record provided by TOMS is improved by its successor OMI that was launched onboard the Aura spacecraft in July 2004. This study has utilized the Version 8 Level-2 OMI data with a clear sky for JJA 2005. TOMS and OMI data were obtained from the GSFC/DAAC website. We have applied the SAM technique to TOMS and OMI data for deriving tropospheric ozone over higher latitudes.

There is a difference between TOMS and OMI in a-priori ozone profiles used to generate the look-up-table. A-priori ozone profile of TOMS is binned two-dimensionally: in 50 DU total ozone bins, and 30° latitude bins. With improving accuracy of the ozone measuring system, OMI uses a-priori ozone profile that varies with total ozone, latitude (10° bins), and month.

3. Methodology

The SAM determines the distribution of tropical tropospheric ozone directly from the TOMS data, on the basis of the differences in the ozone-column detection from the TOMS being dependant on the scan-angle geometry (Kim et al., 2001). TOMS scans its field of view (FOV), using a mirror perpendicular to the orbital track, at 35 sample positions at 3-degree intervals. Scan positions 1, 18 and 35 correspond to the highest right scan position, nadir, and the highest left scan position. In the SAM, scan positions of 1, 2, 3, 33, 34 and 35 are defined as the high scan position, and scan positions of 16, 17, 18, 19 and 20 as the nadir scan positions.

The total ozone retrieved at the nadir position tends to be a truer value relative to the ozone at the high scan position. If the actual tropospheric ozone is less than the TOMS assumption, then the total ozone retrieved at the high scan positions will be greater than the ozone retrieved at the

nadir. Conversely, if the actual tropospheric ozone is greater than the TOMS assumption, then the retrieval at the high scan positions will be less than at the nadir retrieval. The calculated averaging kernels for the difference between TOMS nadir and high viewing angles maximize in the troposphere with a peak near an altitude of 5 km (Kim et al., 2001). Therefore, the kernels suggested that the difference in the retrieved total ozone, between nadir and high scan positions, can be used to detect the signal from tropospheric ozone. This study has applied this principle to TOMS and OMI data and derived tropospheric ozone with the background tropospheric ozone (32DU).

4. Results

Figure 1 compares tropospheric ozone between the SAM technique and the GEOS-CHEM model for June-August. Tropical tropospheric ozone from the SAM exhibits a noticeable enhancement over the southern Atlantic and a minimum over the central Pacific, which is also seen in the tropical distribution of tropospheric ozone produced from the GEOS-CHEM model (Figure 1c). This feature is consistent with the tropical distribution of CO measurements in JJA. It is also in good agreement with the biomass burning activity for JJA, which corresponds to the southern burning season.

In mid-latitude of Figure 1, very low ozone is observed over the remote Pacific Ocean and the Indian Ocean, while elevated ozone is observed over Saudi Arabia possibly associated with a complex interplay of transport and. Relatively moderate elevation of tropospheric ozone is observed over North and South America. These distributions shown in Figure 1 appear to match well with the source regions of tropospheric ozone as well as CO distribution, the ozone precursor.

The peak of tropospheric ozone distribution from the SAM in mid-latitude is lower than that in tropical southern Atlantic. This feature is also seen in the CO distribution. However, the peak of model products in mid-latitude is larger by 4 DU than in the tropics.

The overall structures between the SAM and the model are similar. However, there are slightly differences in ozone amounts. Comparing of the difference of tropospheric ozone between the SAM and the model products for JJA, the SAM-OMI results agree well with model, with biases of -3.9 ± 11.7 DU. There are positive differences in the southern hemisphere, while there are negative values in the northern hemisphere. It indicates that the SAM-OMI tropospheric ozone is higher in the southern hemisphere and is lower in the northern hemisphere. The agreements are better in differences between the SAM-TOMS and model with biases of -9.5 ± 6.4 DU. The difference distribution shows negative differences in most regions. It indicates that the SAM-TOMS tropospheric ozone is lower over the entire regions except for tropical ozone maximum regions (e.g. tropical southern Atlantic and Africa). The SAM results show lower ozone than the model results in the northern hemisphere, especially the ocean.

The SAM-OMI results agree with the SAM-TOMS results, with positive biases of 37.3 ± 8.4 DU. The SAM-OMI tropospheric ozone is higher

than the SAM-TOMS results over all regions, especially the tropical biomass burning regions. It can be due to difference between OMI and TOMS in viewing angle, data sampling, and a-priori ozone profile.

5. Conclusions

This study has applied the SAM technique to TOMS and OMI data for boreal summer, and compared tropospheric ozone derived from the SAM with tropospheric ozone from GEOS-CHEM model and CO from MOPITT. The SAM tropospheric ozone between 20°S and 40°N has been investigated in terms of the spatial distribution, ozone difference, and correlation.

Tropical tropospheric ozone from the SAM using both TOMS and OMI exhibits an enhancement over the southern Atlantic in JJA, the southern burning season. This feature agrees well with the distribution of GEOS-CHEM model and MOPITT/CO. In mid-latitude, elevated ozone from the SAM is observed over North America and Saudi Arabia possibly associated with a complex interplay of transport and chemistry. This distribution appears to match well with the model and CO.

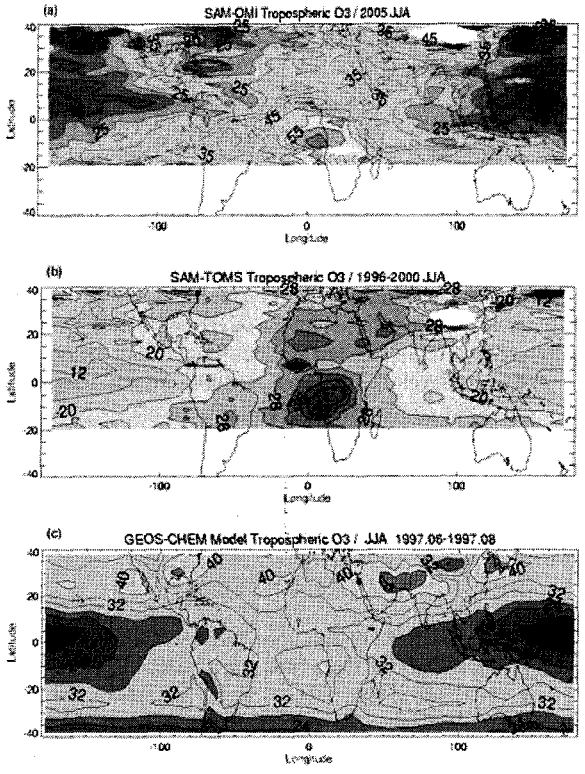

Figure 1. The distribution of tropospheric ozone (DU) derived from (a) the SAM using OMI data for June-July-August (JJA) 2005, (b) the SAM using TOMS data for JJA 1996-2000, and (c) the GEOS-CHEM for JJA 1997.