Interpretation of tropical tropospheric ozone derivation from TOMS

Sunmi Na and Jae-Hwan Kim
Department of Atmospheric Science, Pusan National University, Korea
Corresponding author address: Sunmi Na, Department of Atmospheric Science,
Pusan National University, Pusan 609-735, Korea
(E-mail) sunmi@pusan.ac.kr

ABSTRACT:

A persistent maximum over the southern tropical Atlantic in the latitudinal tropospheric ozone distribution from the CCD method is seen in the latitudinal tropospheric ozone distribution from the TOMS-Pacific method. The tropical Atlantic paradox exists in the results of both the CCD and TOMS-Pacific methods. During the northern burning season, the latitudinal distributions in the tropospheric ozone derived from the TOMS-SAGE and TOMS-Sonde methods show higher tropospheric ozone over the northern tropical Atlantic than the southern Atlantic due to a stronger gradient in stratospheric ozone relative to that from the CCD and TOMS-Pacific methods.

KEY WORDS: Tropical tropospheric ozone, Residual-type method, Biomass burning, Atlantic paradox

1. Introduction

The residual-type methods assume zonally invariant stratospheric ozone and always show a maximum over the southern tropical regions. However, SAM and the Geophysical Fluid Dynamics Laboratory Global Chemical Transport Model (GFDL/GCTM) derive a maximum over southern tropical regions during boreal summer and autumn, and northern tropical regions during boreal winter and spring, so that the individual maximums correspond to the biomass burning seasons in each tropical hemisphere. This discrepancy is called the tropical Atlantic paradox (Thompson *et al.*, 2000). In order to explore the paradox, most of studies have tried to interpret in-situ measurements and adjust the model to fit to the ozone distribution from the residual-type methods. However, no one has ever investigated how a small deviation in the zonally-flat stratospheric ozone influences the latitudinal stratospheric and tropospheric ozone distribution over the Atlantic. The purpose of this paper is to investigate how the latitudinal stratospheric ozone distribution influences the latitudinal tropospheric ozone distribution over the Atlantic.

2. Methodology

2.1 Convective Cloud Differential Method

The CCD method requires preliminary work in order to determine the latitudinal distribution of stratospheric ozone. After examining the high convective regions using International Satellite Cloud Climatology Project (ISCCP) cloud top pressures and a sophisticated statistical scheme, the latitudinal stratospheric column ozone is derived by averaging total ozone measured over the tropical Pacific Ocean between 120°E and 180°E. Then, the CCD method determines the tropospheric ozone by subtracting the zonally invariant stratospheric ozone from TOMS total ozone when the skies are clear. This implies that if any method measures the climatological latitudinal stratospheric ozone distribution for a single longitude band, the entire amount of tropical stratospheric ozone can be determined because of the zonal mean assumption.

2.2 TOMS-Pacific Method

The TOMS algorithm efficiently retrieves the amount in the stratosphere but less efficiently in the troposphere. If the amount of tropospheric ozone varies only slightly over a spatial domain, any variation in the total ozone will arise from variations in stratospheric ozone because the algorithm would not have recognized any differences in the troposphere. We have applied this physical concept to the longitudinal TOMS total ozone distribution over two selected regions: the Pacific Ocean (120°E-180°E) with clean environment and the Atlantic (15°W-15°E) with elevated tropospheric ozone from biomass burning. The latitudinal stratospheric ozone distribution from the CCD is quite different from that over the Atlantic because of the strong variability in the latitudinal tropospheric ozone distribution. On the contrary, the latitudinal total ozone distribution subtracted by 26 DU over the Pacific Ocean (TOMS-Pacific method) agrees remarkably well with the latitudinal stratospheric ozone distribution from the CCD.

2.3 TOMS-SAGE method

We have used the improved SAGE-II V6.1 measurements based on the assumption of zonally invariant stratospheric ozone. Tropospheric ozone is derived by subtracting averaged stratospheric ozone measured by SAGE from total ozone measured by TOMS (TOMS-SAGE method).

2.4 TOMS-Sonde method

Thompson *et al.* (2003) examined the distribution of longitudinal tropospheric ozone by using SHADOZ measurements that were arranged longitudinally at given latitude. We used this concept for the distribution of latitudinal ozone from SHADOZ stations. Tropospheric column ozone was determined from the soundings and then subtracting it from the total amount of ozone measured by TOMS at each station to determine the stratospheric column ozone (TOMS-Sonde method).

3. Results

In figure 1, the latitudinal tropospheric ozone derived from the CCD and the TOMS-Pacific during the DJF period present a peak over the southern tropics because the relatively lower amounts of stratospheric ozone in the southern tropical Atlantic is subtracted from the total amount of ozone determined by TOMS. On the other hand the latitudinal tropospheric ozone distributions from the TOMS-SAGE and the TOMS-Sonde exhibits a maximum over the northern tropical Atlantic.

The TOMS-Sonde attributes the latitudinal total ozone variation during the MAM period over the Atlantic mostly to tropospheric ozone, but the CCD, the TOMS-Pacifc, and the TOMS-SAGE attribute the variation mostly to stratospheric ozone. In addition, the CCD, the TOMS-Pacific, and the TOMS-SAGE show maximum tropospheric ozone over the south Atlantic, while the TOMS-Sonde shows a local maximum over the north Atlantic for the MAM period.

The latitudinal stratospheric ozone distribution from the CCD perfectly matches the distribution from the TOMS-Pacific in tendency and magnitude for the JJA period. The latitudinal stratospheric ozone distribution from the TOMS-SAGE and the TOMS-Sonde follows the same tendency as the CCD and the TOMS-Pacific. For the SON period the latitudinal tropospheric ozone distribution derived from all methods shows a southern maximum and northern minimum due to a strong north-south gradient in total ozone over the Atlantic.

The CCD corrected for the TOMS error associated with clouds intensifies the southern tropospheric enhancement during the southern burning season. The tropospheric ozone from the corrected CCD shows the peak moving northward during the northern burning season.

4. Conclusions

Despite distinct differences in stratospheric ozone sampling, the latitudinal distribution of stratospheric ozone from the TOMS-Pacific method shows remarkable agreement with that from the CCD method that always observes higher tropospheric ozone over the southern tropical Atlantic than over the northern. Therefore, the sophisticated CCD method can be replaced by the simple TOMS-Pacific method. However, both the TOMS-SAGE and the TOMS-Sonde exhibit a maximum over the northern tropical Atlantic during the northern burning season and over the southern tropical Atlantic during the southern burning season, which is consistent with the oscillation of burning. This latitudinal discrepancy is due to the difference in north-south gradient of stratospheric ozone. Therefore, the latitudinal tropospheric ozone distribution can be reversed depending on what data is used to determine the stratospheric component.

A correction for the effect of clouds on stratospheric ozone determined by CCD changes the latitudinal tropospheric ozone distribution. Uncertainty in the amount of stratospheric ozone over the Atlantic can be an important cause of the paradox. Therefore, the residual-type method using reliable stratospheric ozone data will resolve the paradox.

References from Journals:

Thompson, A. M., et al., 2000. A tropical Atlantic paradox: Shipboard and satellite views of a tropospheric ozone maximum and wave-one in January-February 1999, *Geophys. Res. Lett.* 27: 3317-3320.

Thompson, A. M. et al., 2003. Southern Hemisphere Additional Ozonesondes (SHADOZ) 1998-2000 tropical ozone climatology 1. Comparison with Total Ozone Mapping Spectrometer (TOMS) and ground-based measurements, *J. Geophys. Res.*, 108(D2), 8238: doi:10.1029/2001JD000967.

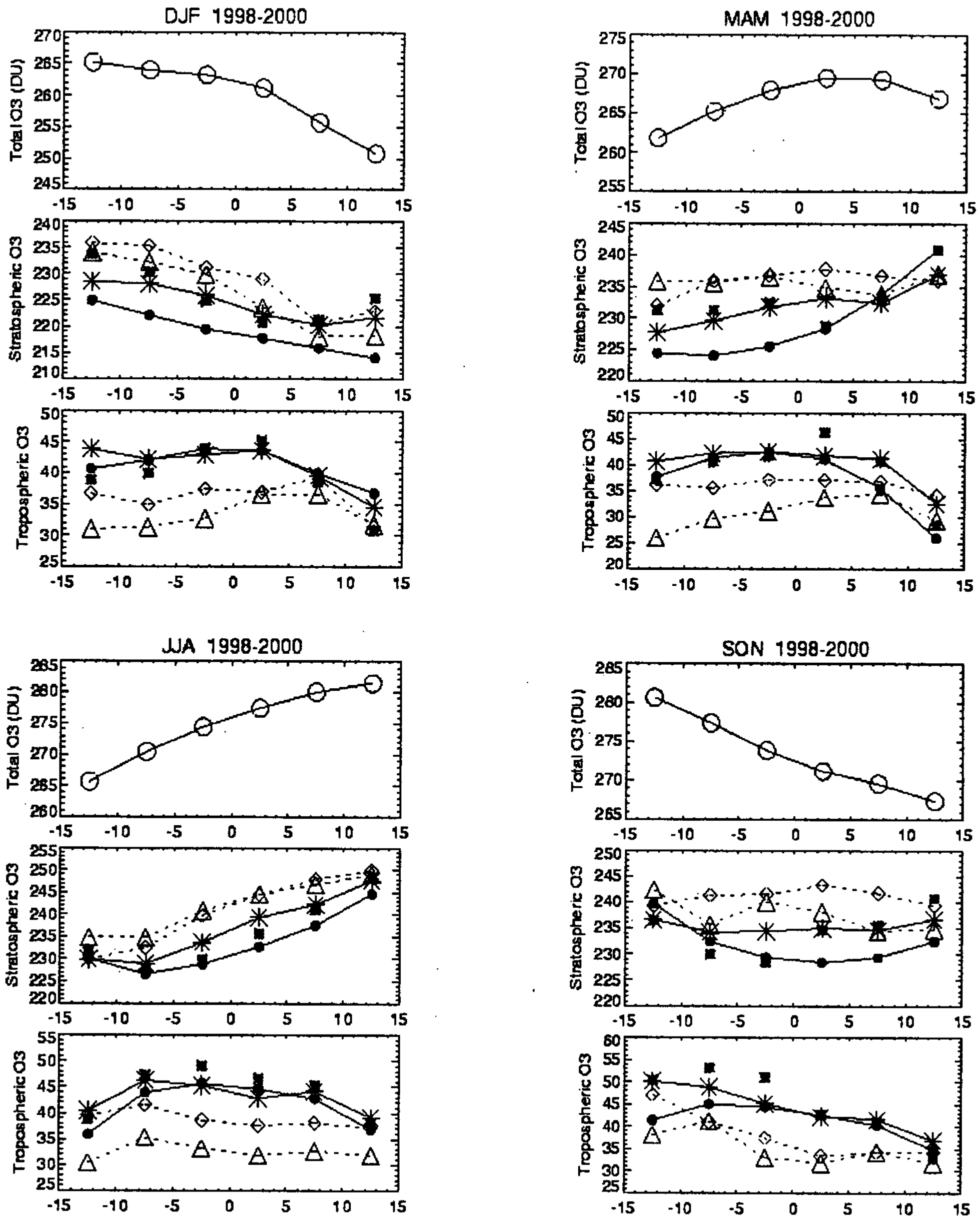

Figure 1. The latitudinal distribution of total ozone (top panel), stratospheric ozone (middle panel), and tropospheric ozone (bottom panel) from the TOMS-SAGE method (diamonds), the TOMS-Sonde method (triangle), the TOMS-Pacific method (closed circles), and the CCD method (asterisks) over the Atlantic Ocean (15W-15E) for 1998-2000. The thick asterisk marks indicate the corrected CCD products from cloud interference.