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인공위성을 이용한 대류권 오존 추정치 비교 및 검증

Intercomparison and evaluation of satellite-derived tropospheric ozone

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1. Introduction

Fishman and Larsen (1987) derived tropical tropospheric column ozone by subtracting stratospheric column ozone measured by the Stratospheric Aerosol and Gas Experiment (SAGE) from total column ozone obtained by the Total Ozone Mapping Spectrometer (TOMS). Later, the Convective Cloud Differential (CCD) method (Ziemke et al., 1998) indicated stratospheric ozone is invariant with longitude and concluded the zonal variation of total ozone determines the zonal variation of tropospheric ozone. However, Kim et al. (1996) and Newchurch et al. (2001) suggested that the zonal wave-1 pattern in total ozone is due not only to tropospheric ozone but also to stratospheric ozone. Recently, Kim et al. (2001) developed the Scan-Angle Method (SAM) for determining tropical tropospheric ozone from TOMS without any assumption of the zonal structure of stratospheric ozone. The SAM showed the elevated tropospheric ozone over equatorial northern Africa in the northern burning season. This ozone abundance was not detected by other retrieval methods, such as CCD method. Therefore, we examine the tropospheric ozone determined from the two methods, the SAM and the CCD method, by using the indicators for burning-influenced ozone production, fire counts observed from the Along Track Scanning Radiometer (ATSR) and carbon monoxide observed from Measurements Of Pollution In The Troposphere (MOPITT).

2. The Scan-Angle algorithm

The TOMS experiment on board a sun-synchronous satellite measures UV radiances backscattered from the atmosphere, Earth's surface, and clouds. TOMS samples the radiances at 35 scan positions at 3-degree steps along a line perpendicular to the orbital track. Scan positions 1, 18, and 35 correspond to highest scan position to the right, nadir, and highest scan position to the left, respectively. 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 position. The retrieved total ozone at the nadir position is always closer to truth relative to the ozone at the high scan position. If the actual tropospheric ozone is less than the TOMS a priori tropospheric assumption, then the total ozone retrieved at the high scan positions will be greater than the ozone retrieved at the nadir position. On the other hand, 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 normalized difference in tropospheric ozone retrieval efficiency between nadir and high scan positions as a function of altitude is calculated. The averaging kernels show their peaks at 5-km altitude. Therefore, the differences between retrieved total ozone averaged over the high-scan positions and averaged over the nadir-scan positions can be used to derive tropospheric ozone. The derived relationship between O3 and the actual tropospheric ozone amount is as follows: Tropospheric ozone = 32 + 6.7 × Diff (Kim et al., 2001).

3. Results

In order to increase the number of TOMS measurements at both nadir and high scan positions, we use both ADEOS/TOMS and EP/TOMS data from December 1996 to February 1997, which corresponds to the northern burning season. Even though the patterns of both EP-only SAM and ADEOS+EP SAM results are similar to each other, significant reduction of noise is observed in the ADEOS+EP SAM results. The ADEOS+EP SAM results show that the maximum amounts of tropospheric ozone are observed over northern equatorial Africa. The CCD-derived tropospheric ozone shows that the maximum ozone is observed over southern tropical Atlantic. These distributions are very different from the SAM results. The total fire counts from ATSR shows broad intensive burning activity over northern Africa and weak burning over the limited area in South America and Indochina. No noticeable burning activity is observed over the southern tropical Africa. The maximum tropospheric ozone over northern equatorial Africa for December-February observed from the SAM results agrees well with the intensive burning activity. On the contrary, tropospheric ozone distribution from CCD is poorly related to the distribution of burning activity. MOPITT-derived CO measurements in the low troposphere for DJF show the maximum over northern equatorial Africa, which is highly correlated with the SAM results and the burning activity, but poorly correlated with the CCD results.

4. Summary and discussion

Many researchers have developed algorithms for determining tropical tropospheric ozone from satellite-based instrument with the assumption of zonally flat distribution in stratospheric ozone. The distribution of tropospheric ozone derived from these algorithms has shown a persistent maximum due to biomass burning over the south tropical Atlantic for all months of the year. Recently, Kim et al. (2001) developed the Scan-Angle Method (SAM) that presents higher ozone over northern equatorial Africa in the boreal burning season. This feature is consistent with the distribution of fire counts measured from ATSR and of carbon monoxide measured from MOPITT. This discrepancy is called the "tropical Atlantic paradox". It is notable to see that the Paradox occurs in boreal winter and spring when the planetary wave activity is the strongest. Therefore, it is challenging to investigate the impact of atmospheric dynamics on the zonal distribution of tropical stratospheric ozone. None of the techniques for determining tropical tropospheric ozone is perfect. In order to benchmark, we need better data sets from ground-based measurements with higher spatial and temporal resolution.

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