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The Distribution of Total Ozone Amounts and Intercomparison of their characteristics Derived from the TOVS Observations over the Korean Peninsula

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TOVS로 부터 도출한 한반도 부근의 전오존량 분포 및 그특성 비교

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Abstract

The International TOVS(TIROS Operational Vertical Sounders) Process Package (ITPP-VI), which has been installed at Korea Meteorological Administration(KMA), is only for a global usage to need a surface data to generate atmospheric soundings and total ozone amount. If the initial input process in the ITPP-VI is not modified, it takes climatic surface data for producing sounding data and total ozone amount in general. KMA is trying to improve the quality of TOVS total ozone amount using real-time synoptic observations in various ways instead of climatological data because this retrieved data in the new scheme for total ozone presently used at the KMA may critically provide to analyze the long-term trend of ozone structure over the Korean peninsula.

Two cases in this study show that TOVS retrieved total ozone amounts used by synoptic surface observations can delineate more detailed ozone structures rather than those used by climate surface data. The distribution of TOVS retrieved ozone amount fields with the synoptic surface analyzed data(TOVS-GPV) show more in detail relatively than those with the climatic data(TOVS-CLIMAT) as expected. In addition, the collocated inter- comparisons of TOVS-GPV with TOVS-CLIMAT, TOMS observations and Dobsometer observations are performed statistically. TOVS-GPV fields with TOMS observations show smaller bias relatively than TOVS-CLIMAT and also reduce the differences.

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요 약

기상청에서는 1990년부터 Smith등(1984,1986)이 개발한 ITPP-VI(Internatiional TOVS Program Package)를 사용하여 직접 물리 해법을 이용한 연직온도분포 및 총오존량을 산출하여 예보현업에 이용하고 있다. 그러나 현재의 초기입력자료로 사용되는 기후값은 너무 오래되었고, 국지효과나 한반도 부근의 특성이 제외되었으므로 도출된 전오존량의 분포를 직접 사용하기에는 그 정확성이나 신빙성이 희박하다. 따라서 ITPP-VI로부터 오존량 산출자료의 질적 개선을 위해 초기 입력자료중 지표값을 기후자료 대신에 GPV(Gridded Point Values) 자료를 입력하여 오존량 도출을 수행하였다.

GPV자료의 입력을 통한 TOVS 오존량 자료(TOVS-GPV)가 정량적으로 어느 정도 개선되었는지 알아보기 위하여 두경우의 총오존분포도를 비교하였다. GPV 지표자료의 입력으로 도출한 총오존량은 기후값으로 도출한 총오존량(TOVS-CLIMAT)에 비해 한반도 부근에서의 오존량 변화를 더 자세하게 표현하였다. 정량적으로 질적 개선을 알아보기 위해 1994년 2월 한달동안 지상 관측자료로써 연세대학교의 오존분광기(Dobsometer)로 관측한 오존량(UY), TOVS-GPV(UG), TOVS-CLIMAT(UC), 그리고 TOMS(Total Ozone Monitoring System) 관측값(UM)을 이용하여 나타낸 결과, 월변화의 경향은 연세대학교 총오존량값의 변화에 대해 TOVS-GPV(UG), TOVS-CLIMAT(UC)와 TOMS(UM) 값들의 변화는 크지만, 새로운 TOVS-GPV 오존량은 TOVS-CLIMAT 오존량에 비해 TOMS 오존량과 연세대학교 관측치와 유사한 경향을 보였다.

1. Introduction

Satellites play an important role in monitoring the trends of total ozone amount distribution on a large scale basis. The retrieval of ozone amount from the satellite observations is very interested in retrieving due to the high spatial and temporal resolutions in remote sensing basis. The 9.7 μm ozone absorption band is used in conjuction with other HIRS(High resolution Infrared Radiation Sounder) thermal infrared bands, and temperature and water vapor profiles(Rodger, 1976) to obtain total ozone column in TOVS. Although there have been significant problems in measurement associated with operating HIRS-2, TOVS observations provide important information on the large scale distribution of ozone(Lienesch, 1988; Smith, 1970; Yoshito, 1992). The ITPP-IV installed by the KMA is made for a global usage, which needs a surface data to generate atmospheric soundings(Cho et al., 1991). If the initial input process in the ITPP -IV is not modified, it takes climatic surface data for producing sounding data in general. KMA is trying to improve the quality of TOVS total ozone data using real-time synoptic observations which employ a new processing technique and an updated calibration through using the ITPP-IV which is the basis of the algorithms used in. The method described here employs the radiative transfer equation and uses the statistical relationships between HIRS radiances and ozone amount to establish a first-guess profile(Ma et al., 1984; Susskind et al., 1983). Results from the new algorithm are compared with those from the original and with surface-based observations of total ozone used by Dobson spectrophotometer measurements.

2. Data and Processing procedure

2.1 Data

Two cases of ozone distributions for 00UTC 15 which is the poor-sounding retrieval and 1200UTC 23 March, which is the well-sounding retrieval, 1994, respectively are chosen for intercomparisons of retrieved ozone fields. The interested domain is 10N - 60N in latitude and 90E - 160E in longitude. Furthermore, for statistically analyzing and comparing the accuracy of retrieved ozone amount, the daily mean ozone amounts in Seoul for a month(Feb. 1994) are calculated by and compared with the collocated intercomparisons of TOVS synoptic retrieved ozone amounts with three other observations. This data set employs a new processing technique and updated calibration through the ITPP-IV in KMA. Quantitatively the statistical character of the retrieved data through the new technique is looked for as comparing the daily differences of one month's ozone amounts(February, 1994). The daily ozone amounts for Yonsei Dobsometer observations, TOVS-GPV, TOVS-CLIMAT, and TOMS observations are collected, respectively.

2.2 The total ozone retrieval algorithm of ITPP-IV

Infrared radiances from TOVS have already been used to retrieve ozone contents, using statistically and/or physically based on the various methods(Smith, 1970; Susskind et al, 1983). This total ozone retreival algorithm to be employed here can be summarized as following. To specify the initial guess field of ozone amount may be used by HIRS radiances with the regression relationships between the radiances and total ozone amount. The detailed Radiative Transfer Equation(RTE) of a physical temperature sounding method of Smith(1970) can be expressed as

$$I^{(n)}(\lambda)=B^{(n)}(\lambda,T_s)\,\tau(\lambda,P_s)+\int_{ps}^{0} B^{(n+1)}(\lambda,T_{(p)})\left[\frac{\partial\tau(\lambda,p)}{\ln p}\right] d\ln p \qquad \text{..................(1)}$$

where $I^{(n)}(\lambda)$ is the n-th radiance at a particular wavenumber (λ), $B^{(n)}(\lambda,T_s)$ is the n-th Planck function of temperature, $\tau(\lambda,P_s)$ is the transmittance from the pressure level p to the top of the atmosphere. The subscript s denotes surface values, either ground or cloud.

For the n+1st iteration, compute a new Planck function profile $R(\lambda)$ for each channel

$$R(\lambda)=I^{(n+1)}(\lambda)=B^{(n+1)}(\lambda,T_s)\,\tau(\lambda,P_s)+\int_{ps}^{o} B^{(n+1)}(\lambda,T(p))[\frac{\partial\tau(\lambda,p)}{\partial \ln p}]\,d\ln p \quad ......(2)$$

Then compute the difference between the observed intensity and the computed intensity of the nth iteration(I^o is the initial guess)

$$R(\lambda)-I^{(n)}(\lambda) = [B^{(n+1)}(\lambda, T_s) - B^{(n)}(\lambda,T_s)]\,\tau(\lambda,P_s)+$$

$$\int_{ps}^{o} [B^{(n+1)}(\lambda, T_{(p)}) - B^{(n)}(\lambda, T_{(p)})\,[\frac{\partial\tau(\lambda,p)}{\partial \ln p}]\,d\ln p \quad ....(3)$$

Associated with each channel, compute Planck function for the given layer for the n+1st iteration

$$B^{(n+1)}(\lambda,T_{(p)}) = B^{(n)}(\lambda,T_{(p)}) + (R(\lambda) - I^{(n)}(\lambda) \quad ....(4)$$

Produce the new estimate of temperature $T^{(n+1)}(p)$ (n-th brightness temperature) at the level p with the appropriate weight factor as following

$$T^{(n+1)}(\lambda, p) = B^{-1}(\lambda)\,[B(\lambda)\,(T^{(n+1)}(p)] \quad ....(5)$$

After comparing of the computed $I^{(n)}(\lambda)$ with the observed $T^{(n+1)}(\lambda, p)$ the remnant of the difference can be derived. If the remnant $\Delta^{(n)} = |R(\lambda)-I^{(n)}(\lambda)|/R(\lambda)$ is less than the critical value of 10^{-4}, then $T^{(n+1)}(P)$ will be a solution. If the remnant is larger than the critical value, repeat the steps (2) - (5) described above until it converges. The nearest approximation to the real temperature at the given layer p can be calculated by the independent estimate of weight factor as following

$$T^{(n+1)}(\lambda, p) = \Sigma^M T^{(n+1)}(\lambda, p)\,W(\lambda, p)/\,\Sigma^M W(\lambda, p) \quad ....(6)$$

where the appropriate weighting factor ($W(\lambda, p)$) can be approximated by

$$W(\lambda, p) = d(\lambda, p) \quad p < ps \text{ and } \tau(\lambda, p) \quad p = p_s$$

Once the profiles have been assigned to a class, the mean profiles of radiance temperature, temperature and moisture are generated. In addition, a relationship is derived to make the measured radiances agree with calculated values. These steps are done once and are not part of the retrieval steps for a specific profile. Once a measurement is obtained, the radiance temperatures are adjusted to minimize any inconsistencies between measured and calculated radiance temperatures. Next, the measured radiances are compared to the radiances for the class means. Then the Bayesian probability that the radiance vector belongs to each class is generated. Finally, the class with the highest probability is selected, and the mean quantities for the class become the guess.

Using the computed temperature and humidity structures mentioned above, the procedure(Yoshito, 1992) to derive total ozone amount through the RTE of ozone channel will be follown as below

a) To calculate the total ozone amount through iterating the radiative transfer equation using the ozone channel measurements
b) To compare total ozone amount derived from the given climatology
c) To simulate the RTE of ozone channel radiance and iterate them until the difference between the calculated and observed ozone amounts is less than the determined critical value as given above
d) To generate gridded data of daily ozone amount.

3. Results and discussion

For comparing TOVS-GPV with TOVS-CLIMAT, two cases of total ozone amount are selected for 0000UTC 15 March 1994, which is the poor sounding retrieval of TOVS and 1200UTC 23 March 1994, which is the good sounding retrieval of TOVS, respectively.

Figure 1 and 2 represent the total amounts computed by the new retrieval algorithm(TOVS-GPV) and the climatological ones (TOVS- CLIMAT).

Figure 1 and 2 represent the total amounts computed by the new retrieval algorithm(TOVS-GPV) and the climatological one (TOVS- CLIMAT), respectively. These show that the TOVS observations of both are well correlated with the TOMS observations field which are closer to the ground truth, although the correction on board Nimbus-7 TOMS, which measures the solar ultraviolet radiation backscattered by the Earth's atmosphere and reflected by the clouds and the terrestrial surface, has been providing the primary source of total ozone data. Figure 1 shows that the trough shape of high ozone values between TOVS-GPV and TOMS is well delineated and elongated over the East Sea and central Korean peninsula, but TOVS-CLIMAT shows the the contrasting shape and less detailed feature for the poor sounding case.

In Fig. 2, the trough shapes of high ozone values between TOVS-CLIMAT, TOVS-GPV and TOMS are comparatively well-agreed with and elongated over the Yellow Sea for the well-retrieved sounding case.

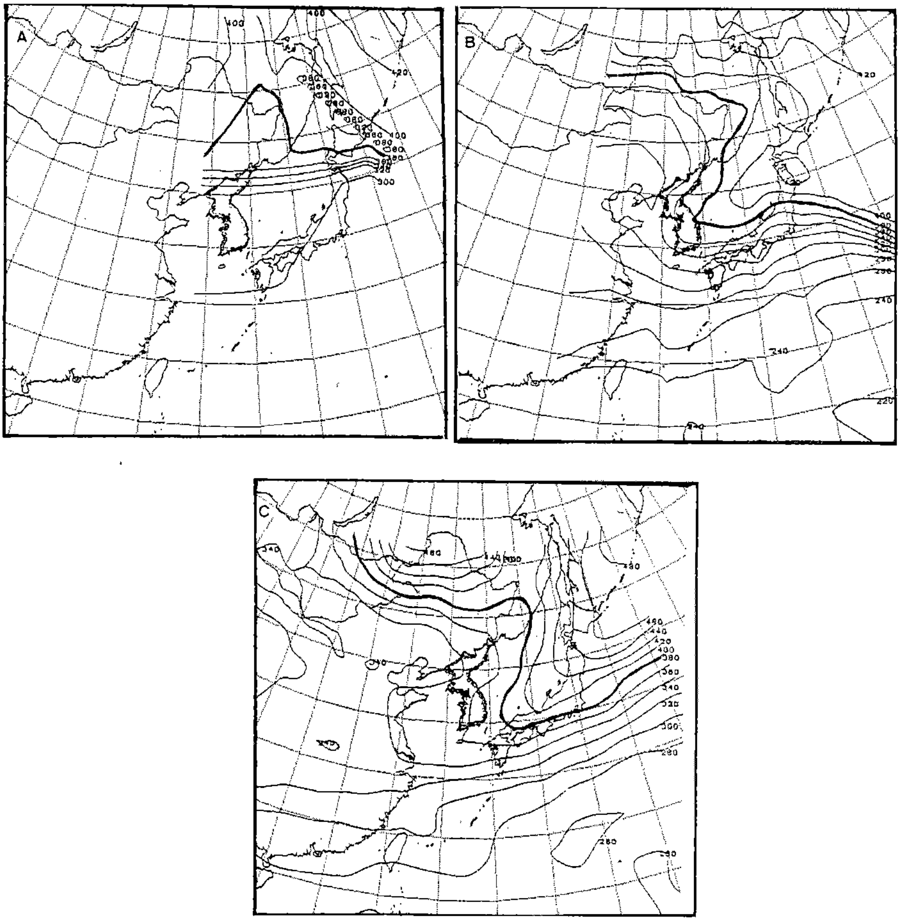

Fig. 1. Contour maps of TOVS retrieved total ozone with (A) climate data, (B) GPV data field and (C) TOMS data at 0000UTC 15 March 1994, respectively.

Quantitatively the statistical character of the retrieved data through the new technique is looked for as comparing the daily differences of one month's ozone amounts(February, 1994). Figure 3 represents the daily ozone amounts for Yonsei Dobsometer observations, TOVS-GPV, TOVS-CLIMAT, and TOMS observations.

Table 1 shows the differences of simultaneous and collocated ozone amounts such as Yonsei Dobsometer's, TOVS-GPV using the new method, TOVS-CLIMAT, and TOMS. The daily differences of TOVS-GPV with Yonsei Dosometer's show smaller bias relatively rather than those of TOVS-CLIMAT and less differing a few degrees of agreement from TOMS's Yonsei Dobsometer's.

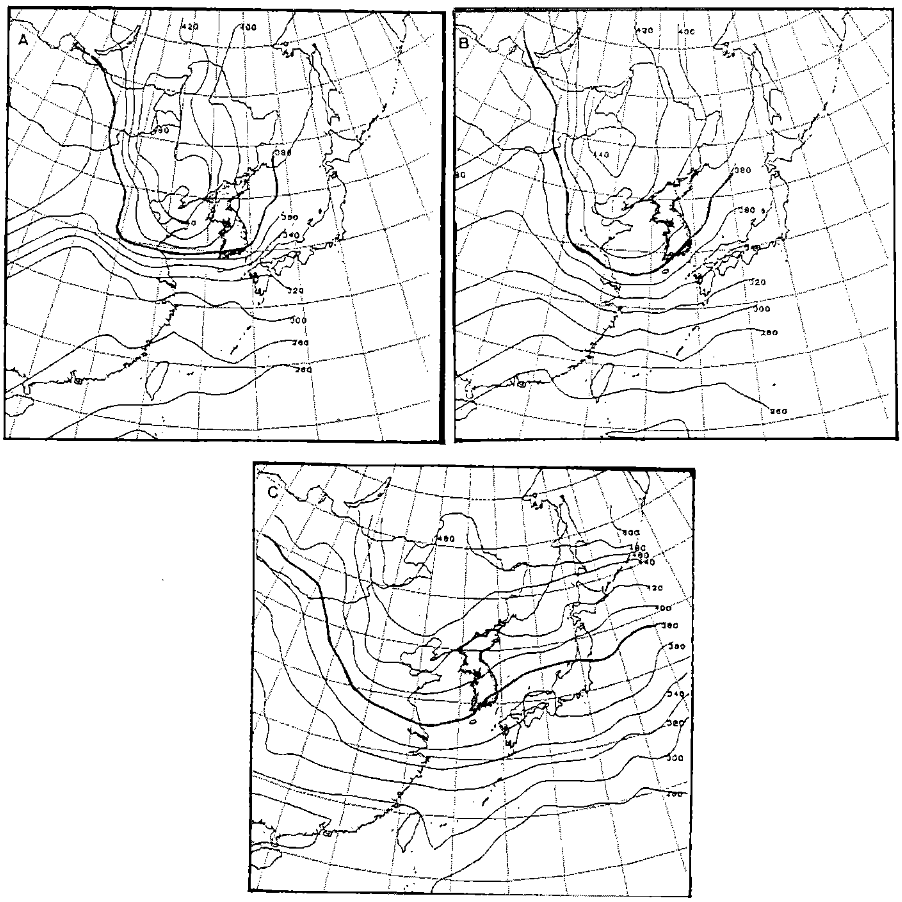

Fig. 2. Same as Fig. 1 except for 1200UTC 23 March 1994.

4. Summary

This study shows that the TOVS retrieved total ozone amount used by synoptic surface observations can delineate more accurate rather than those used by climate surface data. Two cases of total ozone distributions for comparing synoptic TOVS ozone amount with climatic TOVS ozone amount are selected for 0000UTC 15 March 1994 which is the poor-sounding retrieval and 1200UTC 23 March 1994 which is the well-sounding retrieval, respectively.

Intercomparisons of the new TOVS-GPV and TOVS-CLIMAT derived from TOVS

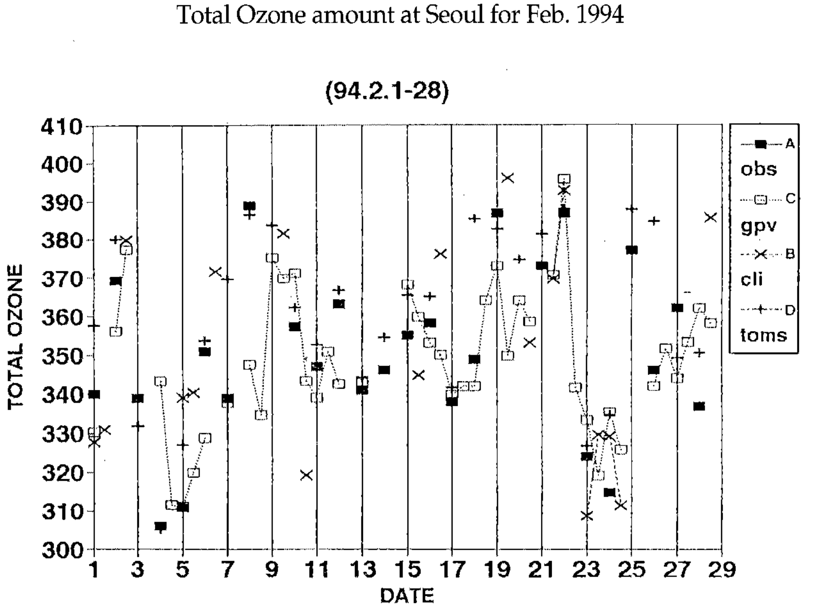

Fig. 3. Intercomparisons of (A) Yonsei Dobsometer obs., (B) TOVS-CLIMAT data, (C) TOVS-GPV data, and (D) TOMS data for Feb. 1994, respectively.

Table 1. The differences of total ozone amounts between Yonsei obs.(UY), TOVS-GPV(UG), TOVS-CLIMAT(UC), and TOMS obs.(UM) for Feb. 1994, simultaneously.

UY	UG	UC	UM
340	-9.6	-10.7	17.6
311	4.7	28.7	16.1
357	0.7	-37.6	5.1
341	1.6	-45.5	3.3
355	8.8	-10.3	10.2
358	-6.3	18.0	6.8
387	-25.6	-9.0	-4.3
373	-2.4	-3.6	8.5
387	-18.3	5.8	1.0
324	2.4	-4.9	2.8
315	15.7	5.4	19.7
337	22.9	48.6	13.5

observations using ITPP-VI with TOMS and Dobsometer data exhibit differing some amount of agreement which could be acceptable. TOVS-GPV ozone amounts using the new method show smaller bias relatively rather than TOVS-CLIMAT ozone amounts and less differing a few degrees of agreement from TOMS's Yonsei Dobsometer's. In addition, the total ozone amounts from TOVS data are analyzed for Feb. , 1994 and evaluated by the horizontal distribution of the total ozone amount on Seoul. The improvement in the new retrieval scheme for total ozone at the KMA may provide to be still critical to analyze the long-term trend of ozone amout. In the near future a regression method should be applied to derive the accurate total ozone amounts from TOVS observations received at KMA, and the regressional coefficients should be determined by the Yonsei Dobsometer's and Pohang observations.

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