From TOVS to ATOVS based ozone monitoring – implication for the quality and homogeneity

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Abstract

The satellite monitoring of the total ozone content over Poland has been performed with the use of NOAA/TOVS data since 1993. The total ozone amount is used for UV Index forecast as well as to analyse its changes over Poland. Meanwhile, the new generation of NOAA satellite with ATOVS instrument were launched implying the changes both, in type of data and software applied for ozone retrievals. Therefore, the quality of the total ozone amount derived from TOVS and ATOVS data for the period with simultaneous measurements, January 2006 – May 2007. The error of 12.2% for NOAA15 and 11.5% for NOAA-14 was obtained. Moreover, the seasonal variability of the quality of satellite derived total ozone amount was found. Change to NOAA-15 lead to decrease in error for summer and increase – for spring and winter, while for autumn no effect was found for autumn. Furthermore, effect of the transition from TOVS to ATOVS data on the total ozone series homogeneity was studied using Standard Normal Homogeneity Test. In general, the transition from NOAA-14 to NOAA-15 did not break the total ozone time series (since 1993) for the most months. However, for March, June and July the inhomogeneity was found in 2007. As it is the last year of the series, the analysis should be continued in order to confirm that result.

Introduction

Large world wide total ozone depletion observed during the last two decades of the 20th century (Bojkov, 1999; Solomon, 1999) as well as the results of the EU research programs on stratospheric ozone depletion in the Arctic and mid-latitudes (Knudsen et al., 1998; Rex et al., 1997a, 1999b), have clearly shown the importance of ozone monitoring. The satellite data are the irreplaceable source of information related to the global ozone distribution.

Total ozone amount has been operationally derived from NOAA/TOVS data since 1993 in Satellite Remote Sensing Centre of Institute of Meteorology and Water Management, Krakow, Poland, and used for ozone monitoring over Poland. Its quality has been routinely checked by comparing with ground measurements. The existing ozone data series has been also homogenized using the Standard Normal Homogeneity Test (SNHT) (Lapeta at el., 2007).

Meanwhile, the new generation of NOAA satellite with ATOVS instrument were launched implying the changes both, in type of data and software applied for ozone retrievals. Therefore, the quality of the total ozone amount derived from TOVS and ATOVS data for the period with simultaneous measurements, January 2006 – May 2007, was studied and the results are presented below. Furthermore, effect of the transition from TOVS to ATOVS data on the total ozone series homogeneity is discussed.

In the first part of this paper, the applied method for ozone data retrievals both from NOAA/TOVS and ATOVS satellite data are described together with the results of the comparative analysis for total ozone amount derived from satellite data and ground measurements.

In the second part of the paper, the effect of the transition from TOVS to ATOVS data on the total ozone series homogeneity is studied using Standard Normal Homogeneity Test.

Data

To retrieve the total ozone amount from NOAA/TOVS 9.6 μm ozone band, a physical model (Xia-Lin Ma et.al 1984) has been applied. It includes an iterative scheme, in which the first guess of the ozone profile is constructed using regression relation between the ozone concentration and the brightness temperatures observed in HIRS carbon dioxide channels. Additionally, in order to make the first guess of the ozone profile sufficiently accurate, the ozone mixing ratio profile is moved up or down by δN levels calculated from the following relationships (Xia-Lin Ma et.al 1984):

$$\delta N = \ 0.5 + 1.4 \ (T_{cal} - T_{obs}) \quad \text{for low latitudes, and}$$
$$\delta N \tilde{=} 0.2 + 1.8 \ (T_{cal} - T_{obs}) \quad \text{for middle latitudes,} \tag{1}$$

where T_{cal} and T_{obs} are the brightness temperatures calculated from the ozone guess profile and observed in the ozone 9.6 μm.

The above algorithm was used for NOAA/TOVS data during the period of 1993-1999. Since 2000, the PC-TOVS software package based on the ITPP from Wisconsin University has been applied with the first guess ozone profile from Thermodynamic Initial Guess Retrieval (TIGR) database.

Since beginning of 2006, total ozone amount has been additionally derived from NOAA/ATOVS data using IAPP software from Wisconsin University. The software was run with the use of UK NWP model data and internal data for first guess ozone profile.

For all ozone retrievals the calculations have been performed for 3x3 individual HIRS field of view. Quality of total ozone amount derived from satellite data have been estimated using ground total ozone measurements from Polish Academy of Sciences station located in Belsk (21.0°E, 52.0°N).

Quality analysis – monthly means

The total ozone amount operationally calculated from NOAA/TOVS and NOAA/ATOVS was compared with the ground measurements for Belsk for monthly mean values. In order to reduce the influence of ozone diurnal course on the obtained results, the analysis was performed only for NOAA14 and NOAA 15 morning overpasses.

To select satellite ozone value for the station localization, the ozone distribution derived from satellite data have been converted into a regular grid with 0.25° step resolution by the kriging spatialisation algorithm. Then, the total ozone amount for the station has been calculated as the inverted distance weighted mean value estimated from four nearest grids. The example maps of total ozone amount over Europe obtained from NOAA/TOVS and ATOVS data for the 3rd of March 2008 are presented on the Fig. 1. Although, the time difference between NOAA-14 and NOAA-15 morning overpasses was 3,5 hours, the reasonably significant differences both in ozone distribution and values can be observed on the maps.
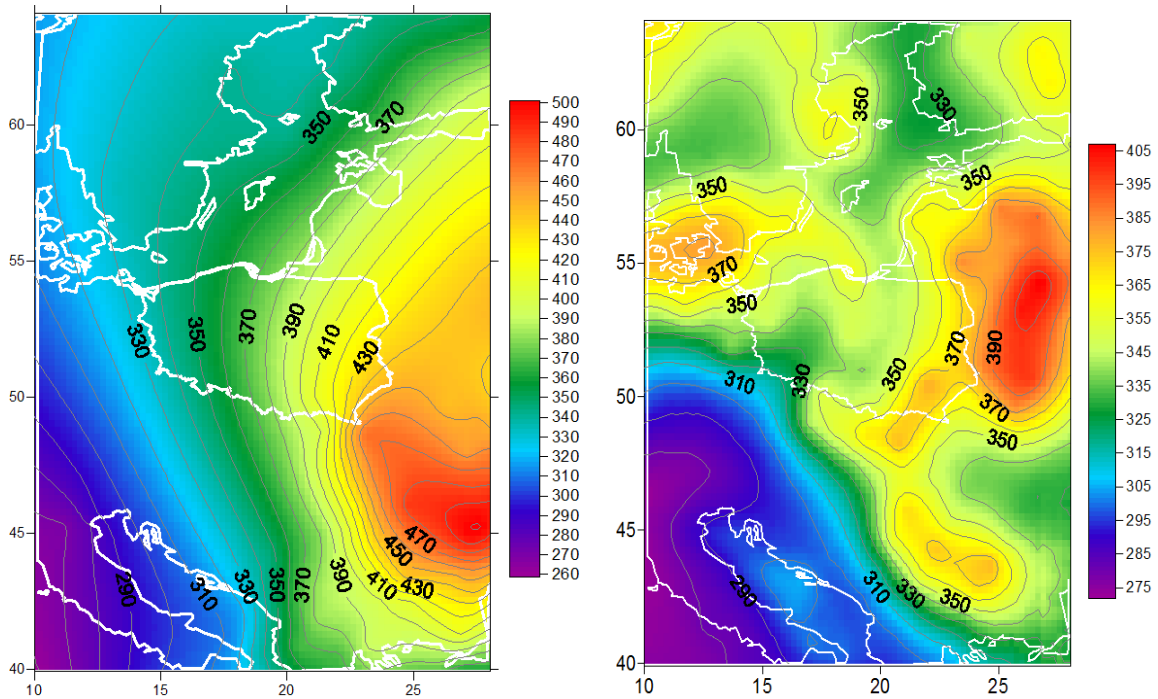
Fig.1: Total ozone amount distribution obtained from NOAA14, 08:41 UTC (left panel) and NOAA 15, 05:04 UTC (right panel) data for 03.03.2007 using kriging interpolation algorithm.

On the Fig.2, monthly means total ozone amount derived from NOAA-14, NOAA-15 satellite data and ground measurements are shown for the period of 2006-2007. One can easily see that the use of NOAA-15 data leads to the stronger underestimation of measured total ozone amount during spring and overestimation during winter, what results in smaller annual amplitude of total ozone amount calculated from NOAA/ATOVS data (blue curve) then from NOAA/TOVS and ground data (red and yellow curves, respectively).
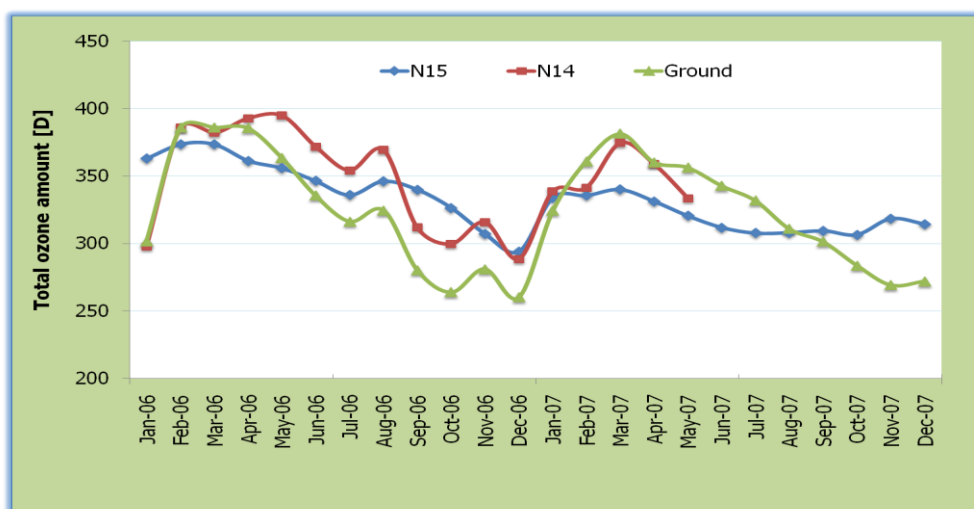

Fig.2: Total ozone amount derived from NOAA-14, NOAA-15 satellite data and measured Dobson spectroradiometer for Belsk station (21E, 52N) for the period of 2006-2007.

Statistical analysis performed for the seasons revealed that mean difference between satellite derived and measured total amount is of -27,4 DU for spring and 21,7 DU for winter for NOAA-15 and 1,1 DU and 3,4 DU respectively for NOAA-14. On the other hand, the difference obtained for summer for NOAA-15 is much smaller than for NOAA-14. For autumn the results obtained for both type of data are almost the same (Fig.3).
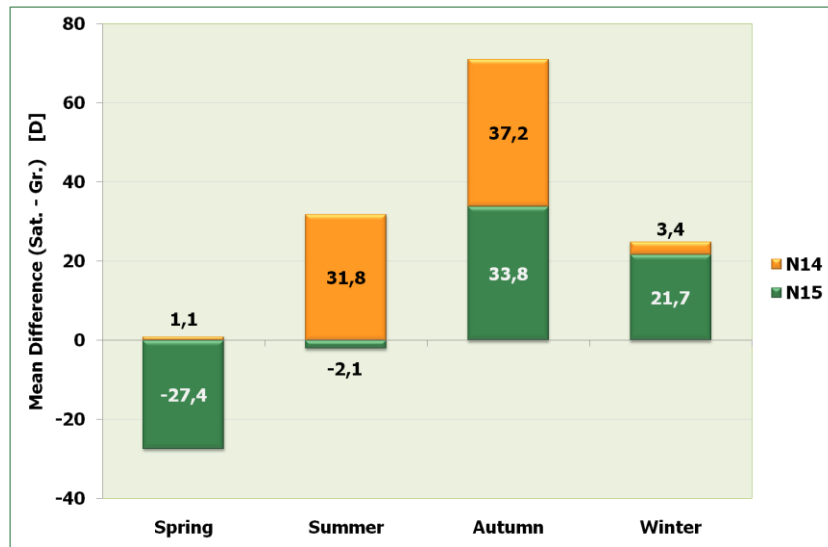

Fig.3: Seasonal variability of the mean difference between satellite derived total ozone amount and ground measurements for NOAA14 and NOAA15 data. Spring includes M-A-M, summer: J-J-A, autumn: S-O-N and winter: D-J-F (December of the previous year)

In order to obtain some quantitative information, mean total ozone amount derived from NOAA-15 and NOAA-14 satellite data, the values of mean difference, mean absolute difference, RMSE and percentage error (ratio of MAE and mean value of measured total ozone amount) have been calculated for the whole period. The results are presented in the Table 1. Although the mean difference obtained for NOAA-15 is smaller, the values obtained for other parameters are almost the same.

Tab.1: Results of statistical analysis obtained for NOAA14 and NOAA 15

	NOAA-15	NOAA-14
Mean [DU]	329.0	347.9
Mean Diff. [DU]	5.0	14.1
Mean Absolute Diff. [DU]	31.7	32.7
RMSE [DU]	40.5	40.1
Error %	12.3	11.5

Homogeneity test

The influence of the transition from TOVS to ATOS data on homogeneity of the monthly means of total ozone time series was analyzed using the homogeneous, TOVS derived ozone data for the period of 1993-2005 and NOAA-15 derived total ozone amount for the period of 2006-2007.

The SNHT test was applied to the 1993-2007 series of ozone data separately for each month. Ground measurements from Belsk were used as a reference data. The inhomogeneity in the series can be detected subjectively, on the base of SNHT values (T_i). The change points usually correspond to the well defined maximum of T_i values. On the Fig. 4, the SNHT test values for the months, for which significant inhomogeneity in 2007 was found, are presented.
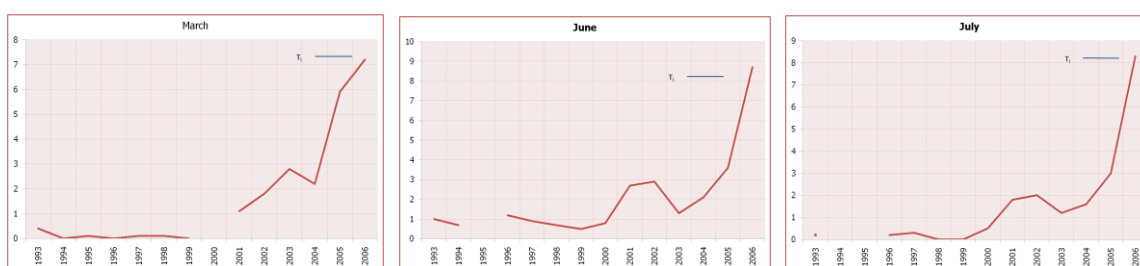

Fig. 4: SNHT values for 'satellite' total ozone series for Belsk and for selected months.

The test values obtained for all months are shown in the Table 2. Red color was used when T_0 value exceeded 95% of significance level (adjusted from 20 values around the change).

Tab. 2: Homogenization Overview for the period of 1993-2007.

Month:	Change	Test value T_O
Jan:	2005	3.96
Feb:	1999	2.49
Mar:	2007	7.89
Apr:	2006	5.26
May:	2007	4.64
Jun:	2007	8.75
Jul:	2007	8.27
Aug:	2001	4.92
Sept:	2005	2.97
Oct:	2005	2.77
Nov:	2004	2.79
	2003	6.58
Dec:	2004	2.832

Conclusions

The quality of the total ozone amount derived from TOVS and ATOVS data for the period with simultaneous measurements, January 2006 – May 2007, was studied using ground measurements from Polish Academy of Sciences station in Belsk.

The quality of monthly means of total ozone amount derived from ATOVS (NOAA-15) is almost the same as the one obtained for NOAA-14: error of 12.2% for NOAA15 and 11.5% for NOAA-14. However, day to day variability of total ozone amount is significantly lower for NOAA-15 then for NOAA14 and ground measurements.

Seasonal variability in quality of total ozone amount derived from satellite data was found. Change to NOAA-15 lead to decrease in error for summer and increase – for spring and winter, while for autumn no effect was found for autumn. Finally, the spring increase in total ozone amount is not as clearly marked as for ground measurements and NOAA-14 data.

Furthermore, effect of the transition from TOVS to ATOVS data on the total ozone series homogeneity was analyzed. Standard Normal Homogeneity Test was used to check the influence of transition from NOAA-14 to NOAA-15 (starting from January 2006) on homogeneity of total ozone amount time series. In general, the transition from NOAA-14 to NOAA-15 did not break the total ozone time series (since 1993) for the most months. However, for March, June and July the inhomogeneity was found in 2007. As it is the last year of the series, the analysis should be continued in order to confirm that result.

Acknowledgments

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