Results of comparison of TOMS and ground ozonometric data

M.A. Bondarenko, O.E. Bazhenov, and M.V. Grishaev

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk

Received December 23, 2005

The results of comparison of ground and satellite data on the total ozone content are presented. Principle sources of errors affecting the measurement accuracy of satellite instruments have been distinguished. It is shown that the TOMS data are representative and reflect the TOC values within their standard error level. Some regions with increased deviations of satellite data from the ground measurements are pointed out.

At present, the methods based on retrospective reconstruction of climatologic parameters, in particular, total ozone content (TOC) are widely used. The developed techniques are presented in Refs. 1–4. The reconstructed TOC values can cover a period up to a thousand of years and be of a great interest in investigations of the TOC global behavior. The techniques[1–4] use the available TOC data and the data on the density of tree annual rings (covering a rather short period of 25–50 years).

The TOMS satellite data reflect the most complete pattern of TOC. The geographical range of TOMS scanning covers almost the entire earth surface showing the TOC dynamics for the last 25 years. Thus, TOMS is the most important source of data actively used in the TOC retrospective reconstructions.

This work presents the results of comparison of the ground measurements and the satellite data. The following error sources affecting the measurement accuracy of the satellite instruments are distinguished:

– increased cloudiness;
– increased solar activity;
– variations of the earth surface reflectivity connected with the snow cover and other reasons.

Every error can manifest itself in one or several ways:

– as a random error,
– as an absolute error independent of time,
– as a trend.

As the ground data, we used the monthly averaged data taken from Internet (www.woudc.org) and those measured by the Dobson spectrophotometer. The Dobson spectrophotometer owing to its accuracy is considered as the etalon source. The comparison was carried out between 27 towns in various points of the globe. Table 1 presents mean discrepancies between the ground and satellite data for the period from 1996 to 2005.

The obtained results demonstrate the latitude dependence of the degree of the TOMS data deviation from the ground measurements. The dependence is presented in Fig. 1.

In order to understand the reasons, it is necessary to consider in detail the specificity of the northern regions characterized by the abundance of snow in winter periods, which can affect the accuracy of satellite measurements, since the snow cover changes the earth surface reflectivity for a rather long period.

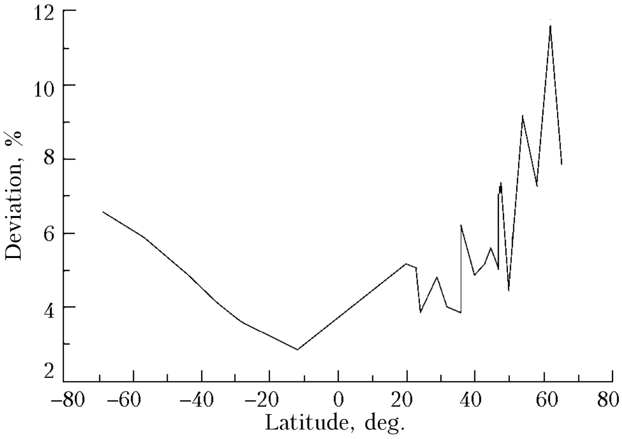

Fig. 1. The latitude dependence of average discrepancy between satellite and ground data.

The effect of clouds on the mean measuring error is less significant since it is relatively short and should not significantly manifest itself in the monthly averaged TOC data. For the same reason, the effect of increased solar activity on the accuracy of monthly averaged TOC parameters can be also neglected. Moreover, it should be taken into account that such an activity equally affects the discrepancy level over all range of geographical coordinates. The maxima of discrepancy with TOMS measurements, as well as dates of these discrepancies were considered for every ground station. The results presented in Table 1 demonstrate a randomness of the maxima for every station, and, thus, allow one to conclude that the increased solar activity does not essentially affect the validity of the monthly averaged TOMS measurements.

In order to be absolutely certain in the snow cover effect, additional comparisons were carried out separately for warm (April–September) and cold (October–March) periods. Based on the results presented in Table 2, it is possible to classify the investigated ground points into three categories.

0235-6880/06/09 699-04 $02.00

Table 1. Deviations between the TOMS and ground data

Ground station	Deviation. Dobson. units		Date of max. deviation	Latitude, deg.	Longitude, deg.	Number of points	Deviation, %
	average	maximum					
Yakutsk, Russia	11.5973	63	September, 01	62	129	72	3.1
Edmonton, England	9.1792	43	June, 98	54	−113	101	2.9
Fairbanks, USA	7.88225	32	April, 03	65	−147	66	2.2
Hohenpeissenberg, Germany	7.34504	45	December, 96	48	11	103	2.4
Goose Bay, Canada	7.34057	33	February, 04	53	−60	99	2.3
Churchill, Canada	7.27524	50	January, 00	58	−94	92	2.3
Bismarck, USA	6.93255	46	June, 01	47	−101	102	2.1
Syowa, Japan	6.60316	28	January, 99	−69	39	78	2.4
Nashville, USA	6.22551	46	April, 01	36	−87	99	2
Macquarie Island, Australia	5.78438	31	August, 02	−55	159	99	2
Uccle, Belgium	5.76122	27	January, 04	51	4	101	1.7
Halifax, Canada	5.61383	26	March, 01	45	−63	63	1.6
Sapporo, Japan	5.18561	22	March, 98	43	141	103	1.5
Mauna Loa, USA	5.16918	25	September, 02	20	−156	101	2
Tamanrasset, Algeria	5.05673	25	January, 01	23	6	61	1.8
Arosa, Switzerland	5.04341	24	February, 99	47	10	103	1.6
Boulder, USA	4.87563	21	December, 97	40	−105	103	1.5
Camborne, England	4.8697	23	December, 03	50	−5	87	1.4
New Delhi, India	4.82693	22	December, 97	29	78	103	1.7
Murmansk, Russia	4.50039	19	March, 00	69	33	48	1.4
Hradec Kralove, Czechia	4.45572	31	February, 99	50	16	103	1.3
Buenos Aires, Argentina	4.01523	17	January, 02	−34	−58	99	1.4
Kagoshima, Japan	3.98873	18	December, 96	32	130	103	1.4
Tateno, Japan	3.87296	17	May, 97	36	140	103	1.2
Minamitorishima, Japan	3.84775	17	August, 99	24	154	96	1.4
Brisbane, Australia	3.52439	17	October, 01	−27	153	100	1.2
Darwin, Australia	2.86323	12	March, 00	−12	131	99	1.1

Table 2. Deviations between the TOMS and ground data in warm and cold periods

Station	Average deviation		Latitude, deg.
	Cold half-year	Warm half-year	
Fairbanks, USA	8.9175	6.91973	65
Yakutsk, Russia	12.94244	10.32613	62
Edmonton, England	9.53732	8.80297	54
Goose Bay, Canada	8.7412	4.52027	53
Uccle, Belgium	6.21073	5.14377	51
Hradec Kralove, Czechia	5.12634	3.63408	50
Camborne, England	6.0088	3.38438	50
Hohenpeissenberg, Germany	9.43263	3.51881	48
Bismarck, USA	6.48102	7.30978	47
Arosa, Switzerland	5.41346	4.54618	47
Halifax, Canada	6.67438	4.37023	45
Sapporo, Japan	5.7699	3.45165	43
Boulder, USA	5.06933	3.71873	40
Nashville, USA	5.28259	7.11572	36
Tateno, Japan	4.09689	2.87487	36
Kagoshima, Japan	4.21355	3.64221	32
New Delhi, India	4.89653	4.65657	29
Minamitorishima, Japan	3.01386	4.44516	24
Tamanrasset, Algeria	5.76045	4.30653	23
Mauna Loa, USA	5.44893	4.39474	20
Darwin, Australia	3.2376	2.45053	−12
Brisbane, Australia	3.49933	3.54562	−27
Buenos Aires, Argentina	4.40605	3.62531	−34
Macquarie Island, Australia	4.63809	6.78578	−55
Syowa, Japan	6.60722	5.52328	−69

– Stations located in the equatorial zone. These geographical points are characterized by a high degree of agreement between the TOMS and ground data.

– Stations located in middle latitudes. These geographical points are characterized by a high degree of the TOMS data conformity with the ground data in the warm half-year. Nevertheless, in the cold half-year, these points demonstrate a higher discrepancy between satellite and ground measurements, although being within the standard TOMS error (3%).

– Stations located in high latitudes. These points are characterized by long periods of the snow cover both in warm and cold half-years. Therefore, mean errors of satellite data are higher during the year. The negative trend is always observed in errors for the northern latitudes (Fig. 2).

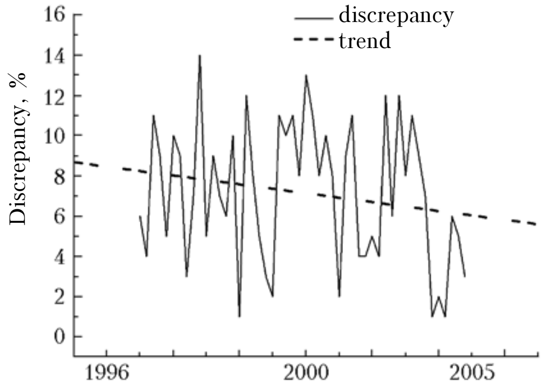

Fig. 2. Deviation trend for Hohenpeissenberg, Germany.

Having been convinced of the TOMS data validity (at least for the mid-latitudes) after their comparison with the Dobson spectrophotometer data, we compared them with the M-124 ozonometer measurements at the Siberian Lidar Station. The ozonometer operation at the Siberian Lidar Station covers the period from 1993 to 2005. The data validation was carried out for the period between 2003 and 2004.

At a Sun altitude angle of more than 10° the ozonometer measures (in relative units) the flow of integrated UV radiation from the Sun disk or a part of sky in zenith in three spectral ranges separated out by three light filters. Then the values, registered in the first two ranges, are recalculated into the values of the total ozone content in the atmosphere. The limit of the permissible relative error in the TOC determination by the ozonometer does not exceed 7%.

As follows from comparison of Figs. 3*a* and *b*, the behavior of curves qualitatively coincides.

However, quantitative coincidence is seldom enough. The TOMS curve, as a rule, is located below the ozonometer curve. The greatest qualitative agreement is observed in the first half-year on the annual interval and in 2004 on the biennial interval. The former fact, apparently, can be explained by a higher level of errors in the fall–winter period (the absence of Sun measurements, many cloudy days with low cloudiness, a short light day, low TOC values). The qualitative agreement is confirmed by a high correlation between these two data sets (0.95 for 2003 and 0.94 for 2004).

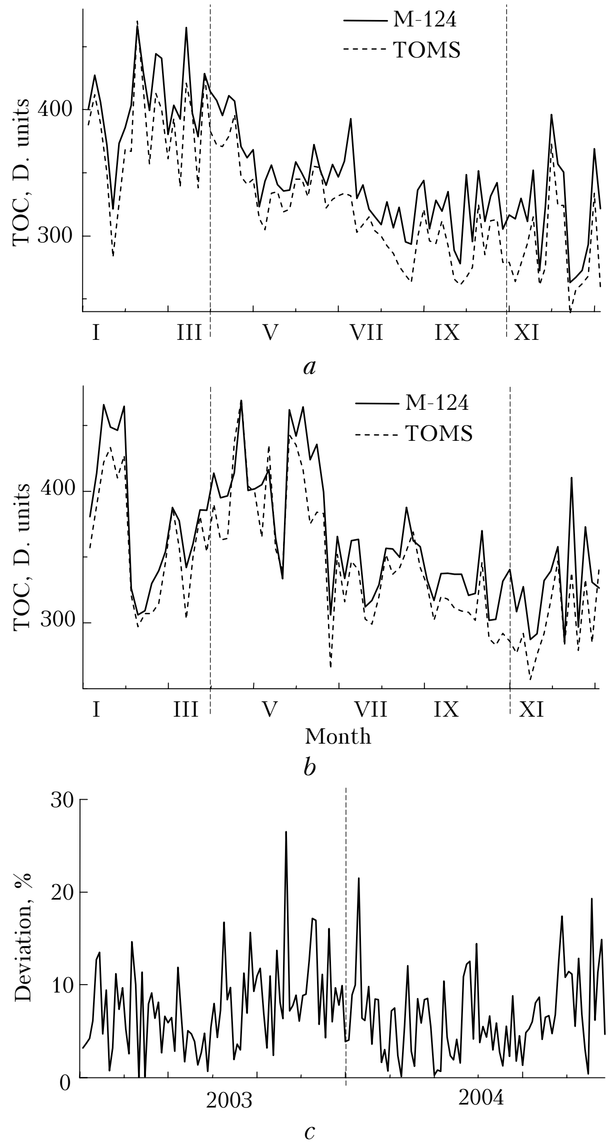

Fig. 3. Comparison between the TOMS and ozonometer data for 2003 (*a*), 2004 (*b*), and relative difference between them for the period 2003–2004 (*c*).

In addition, the quantitative analysis of discrepancies was carried out for some particular days. The difference between measurements for February 14, 2003 was 38.4 DU (possibly, because of the presence of mist), for February 21, 2003 it was 36.2 DU (possibly, due to very fast heating of the instrument by 20°). A difference of 44.5 DU for March 23, 2003 was the consequence of low overcast and the small number of day-time measurements; 49.5 DU for November 15, 2003 was caused by low cloudiness; 47.8 DU for April 24, 2004, was due to high errors in the evening because of the drizzle; 54.5 DU for October 12, 2004 is explained by the low overcast. The absolute mean difference for the period of two years is 23.94 DU, and the relative mean difference is 7.1%. Separately, for the warm and cold seasons, the relative differences made 6.6 and 7.3%, respectively, in 2003, and 6.6 and 5.9% in 2004.

As follows from Fig. 3, the in-depth analysis and rejection of measurements for a day are necessary to obtain the daily-average values. Undoubtedly, the data representativeness and accounting for the monitoring conditions are important requirements. Apparently, a higher measurement accuracy could be attained after the next instrument calibration.

In addition to the validation, within the framework of the "Ozone-2005" expedition, the TOC was measured from June 19 to 25 along the route Tomsk–Moshkovo–Podoinikovo–Zav'yalovo–Barnaul–Tomsk.

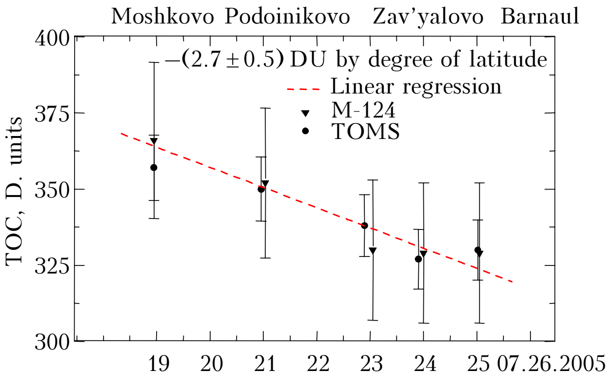

Fig. 4. Latitude and time TOC variations according to the satellite (TOMS) and ground (M-124) observations.

Analysis of the obtained TOC data, measured by the M-124 ozonometer (Fig. 4), has shown them to coincide with the TOC values within the limits of permissible errors. The latitude dependence of the TOC variation was estimated by the linear regression method. The obtained value of the negative trend is (2.7 ± 0.5) DU per the latitude degree, that agrees with the latitude TOC distribution in summer.

Conclusion

Results of the conducted work can be formulated in the following way:

– TOMS measurements are representative and reflect the TOC within the limits of their standard error.

– To increase the accuracy of these measurements, it is necessary to take into account the error in high latitudes, which manifests itself as a negative trend.

– Results of the TOC measurements by the M-124 ozonometer, as well as the analysis of the Siberian Lidar Station data have shown their good correspondence to the TOMS satellite measurements, that allows the use of the instrument in future investigations.

Acknowledgments

This work was financially supported by the Russian Foundation for Basic Research (Grants Nos. 03–05–65105 and 05–05–98003).

References

1. V.V. Zuev and S.L. Bondarenko, Amos. Oceanic Opt. **14**, No. 12, 1054–1057 (2001).
2. V.V. Zuev and S.L. Bondarenko, Issled. Zemli iz Kosmosa **6**, 19–24 (2002).
3. V.V. Zuev and S.L. Bondarenko, Dokl. Ros. Akad. Nauk **392**, No. 5, 682–385 (2003).
4. V.V. Zuev, Int. J. Remote Sens. **26**, No. 16, 3631–3639 (2005).