УКРАЇНСЬКИЙ АНТАРКТИЧНИЙ ЖУРНАЛ
УАЖ, №3, 5-9, (2005)

UDC 551.510

SEASONAL CHANGE OF DIFFERENCE BETWEEN THE GROUND-BASED AND EP-TOMS SATELLITE OZONE MEASUREMENTS

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Absrtact. The relative differences between the total ozone data from the Vernadsky Station and EP-TOMS satellite spectrometer are analyzed. The 2000-2003 period is considered. To estimate the cloudiness influence on data disagreement, comparison was made taking into account the conditions of cloud cover over station. The daily Dobson spectrophotometer measurements were selected to form the data files of "cloudy days" and "cloudless days". Mean relative differences of -0.6% and 6.9% were obtained for cloudy and clear sky, respectively. Seasonal changes of the data disagreement are different for cloudy and cloudless days. Observations in cloudy conditions show maximum positive difference in summer and negative one in the early spring and later autumn. In cloudless conditions TOMS-Dobson difference changes with some ascending trend. This analysis confirms the results of previous comparison of the EP-TOMS and Vernadsky ozone data for 1996-2000. The overestimation of the ground-based total ozone by the TOMS values in the clear sky conditions is perhaps caused by an erroneous interpretation of the snow covered surface reflection as the cloudiness one in the TOMS ozone retrieval algorithm.

Key words: total ozone data, season change, Vernadsky Station, EP-TOMS

Сезонні зміни розбіжності між наземними і супутниковими EP-TOMS вимірюваннями озону. Б.В. Кулініч, О.М. Євтушевський, М.А. Леонов, Г.П. Міліневський
Реферат. Проведено аналіз відносних різниць між даними вимірювань загального вмісту озону в атмосфері на станції Академік Вернадський та супутниковим спектрометром EP-TOMS. Розглядається період 2000-2003 рр. Для того, щоб оцінити вплив хмарності на розбіжність даних, порівняння виконувалося з урахуванням стану хмарного покриву над станцією. Щоденні вимірювання із спектрофотометром Добсона відбиралися в окремі ряди даних "хмарні дні" та "безхмарні дні". Середні відносні різниці становлять –0.6% та 6.9%, відповідно, для хмарного та ясного неба. Є відмінності сезонного ходу різниці для хмарних і безхмарних днів. За умов хмарності існує позитивна різниця влітку і негативна навесні та восени. В умовах безхмарного неба різниця TOMS-Добсон змінюється в середньому з деяким висхідним трендом. Даний аналіз підтверджує результати попереднього порівняння озонових даних EP-TOMS та станції Вернадський за 1996-2000 рр. Завищення вмісту озону в даних EP-TOMS порівняно з наземними, яке має місце в умовах чистого неба, ймовірно, пов'язане з помилковою інтерпретацією відбиття від поверхні, покритої снігом, як відбиття від хмар в алгоритмі TOMS для визначення озону.

Сезонные изменения расхождения между наземными и спутниковыми EP-TOMS измерениями озона. Б.В. Кулинич, А.М. Евтушевский, Н.А. Леонов, Г.П. Милиневский
Реферат. Проведен анализ относительных разностей между данными измерений общего содержания озона в атмосфере на станции Академик Вернадский и спутниковым спектрометром EP-TOMS. Рассматривается период 2000-2003 гг. Для того, чтобы оценить влияние облачности на расхождение данных, сравнение выполнялось с учетом состояния облачного покрова над станцией. Ежедневные измерения со спектрофотометром Добсона отбирались в отдельные ряды данных "облачные дни" и "безоблачные дни ". Средние относительные разности составляют –0.6% и 6.9%, соответственно, для облачного и ясного неба. Есть отличия сезонного хода разности для облачных и безоблачных дней. При условиях облачности существует положительная разность летом и отрицательная весной и осенью. В условиях безоблачного неба разность TOMS-Добсон изменяется в среднем с некоторым восходящим трендом. Данный анализ подтверждает результаты предыдущего сравнения озоновых данных EP-TOMS и станции Вернадский за 1996-2000 гг. Завышения содержания озона в данных EP-TOMS по сравнению с наземными, которое имеет место в условиях чистого неба, вероятно, связано с ошибочной интерпретацией отражения от поверхности, покрытой снегом, как отражения от облаков в алгоритме TOMS для определения озона.

1. Introduction

The Total Ozone Mapping Spectrometer (TOMS) is the instrument for satellite ozone measurements operating since 1978. Nimbus 7 TOMS ozone record during 1978-1993 agreed with

average ozone from the northern hemisphere ground-based stations to within ±1% (McPeters and Labow, 1996). Long-term drift relative to Dobson network was 0.29% per decade. During 1996-2000 the EP-TOMS data set shows a small positive bias of 1.1±5.6% in the northern hemisphere against the Dobson measurements, whereas in the southern hemisphere the mean offset is about 3.3±4.8% (Bramstedt et al., 2003). Little seasonal variation was observed.

Validation of the satellite ozone data for the southern hemisphere is important because the number of ground-based instruments in this region is much less than in the northern hemisphere. The Network for the Detection of Stratospheric Change (NDSC) coordinates the global intercomparison and the Dobson spectrophotometer No. 031 at Vernadsky station (former Faraday, 65º15´S, 64º16´W) is contributing instruments of NDSC (Lambert et al., 2000). Previous results of comparison of EP-TOMS and Vernadsky ozone data for period 1996-2000 were presented in (Gritsai et al., 2000, Milinevsky et al., 2002). In addition to estimation of the TOMS-Dobson difference by full data sets, the separate analysis for days with totally overcast skies and for days with clear skies was made. Such an approach was used to reveal the cloudiness effect in the data disagreement. A selection was made taking into account the code number of the observation kind in the Vernadsky ozone data archives. The conditions of the totally overcast sky (or clear sky) during all measurements within the individual date give the reason to suppose, that the satellite measurements in the same conditions were carried out. In this paper the results of TOMS-Dobson comparison for 2000-2003 are presented.

2. Analysis method

We had examined the Dobson data archives in order to find the days with the stable weather conditions. If all individual measurements during the day were coded as “0 - direct sun” and “2 - blue zenith sky”, the mean daily ozone in the file of “cloudless days” was included. In the file of “cloudy days” the dates with measurement conditions of “5 - zenith cloud” only were collected. By the EP-TOMS data for Vernadsky (Earth Probe TOMS, 2004) the daily total ozone of corresponding dates were found and the TOMS-Dobson differences were calculated separately for cloudy and cloudless days.

Permanent cloud cover presence (absence) during observational day means, that over wide area the cloudy (cloud-free) conditions exist. Therefore, there is a high degree of the confidence that the satellite measurements over the region of the station in the same atmospheric conditions are carried out. Because the days with the changeable and broken cloudiness were not included in the consideration, the uncertainty in the treatment of the cloud cover for the simultaneous ground-based and satellite observations is reduced as far as possible.

3. Comparison results

In this paper the differences between the EP-TOMS and Vernadsky daily ozone values are considered for the data of 2000-2003. Previous comparisons for the measurements of 1996-2000 were described in (Gritsai et al., 2000, Milinevsky et al., 2002).

The ten-month period of the continuos observations at Vernadsky station is the second half of July to the first half of May of the next year. During the rest two winter months the measurements are impossible due to the large zenith angle of the Sun. The relative percent differences of (TOMS-Dobson)/Dobson are shown in Fig. 1 (a) and (b) for clear and cloudy skies, respectively.

The ratio of clear (82) to overcast (405) days is 1/5, which displays the meteorological situation in the region of Antarctic Peninsula.

The first distinction of the comparison results for the two types of the weather conditions is in the average values of relative difference. The clear sky differences are mainly positive (Fig. 1a) with average value of 6.9±3.8%. But the ‘cloudy’ differences (Fig. 1b) in average are more close to zero level with value of -0.6 ±5.8%.

The seasonal change of the TOMS-Dobson difference exhibits the second distinction of the data disagreement for the cloudless and cloudy conditions. Linear fit to the values of the clear sky

difference gives positive trend of 0.5±0.2 percent per month. Polynomial fit of degree 2 shows almost symmetric change of cloudy sky differences relatively the middle of Antarctic summer.

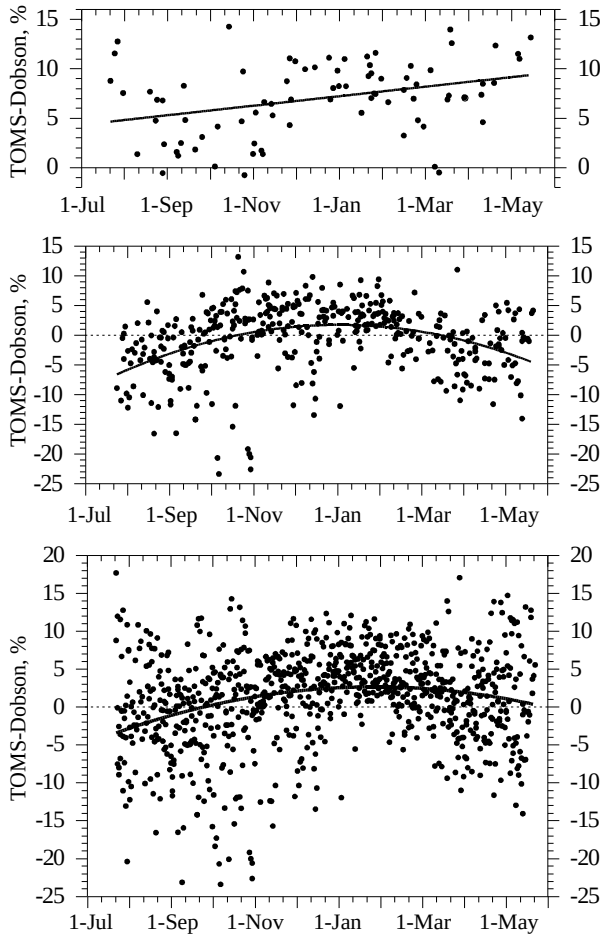

Fig.1. Variations of the percent relative difference between the EP-TOMS and Dobson (Vernadsky station) measurements of the total ozone content during 2000-2003; (a) clear sky conditions on 82 days, (b) cloudy sky conditions on 405 days, and (c) all measurements on 896 days.

In average the maximum summer difference is about 2%, and the negative value of about –5% is characteristic for the beginning and end of observation period.

A final step of our comparison is an estimation of the TOMS-Dobson difference including all daily total ozone of three observational periods in 2000-2003 with no selection on cloudiness conditions.

Average difference value of 1.1±6.5% is obtained by the total day number of 896 (Fig. 1c). The value dispersion shows some spring-autumn asymmetry in this case. It caused perhaps by the larger number of negative values during August-November (up to about -25%) relative to those during March-May (up to –15%). Besides, the effect of increasing trend inherent in the clear sky difference (Fig. 1a) can be present in some degree in a portion of days, which were under the changeable cloudiness. Their total contribution also increases the observed asymmetry.

4. Discussion and conclusion

Seasonal variations of the relative differences for Vernadsky station (Fig. 1a) coincide in general with the similar ones for the southern hemisphere presented in (Lambert et al.,1998, 2000; Bramstedt et al., 2003). But in mean difference values an agreement between the Dobson/Vernadsky and EP-TOMS measurements is better than by other estimations for the southern hemisphere.

The mean relative differences for Vernadsky during 1996-2000 (Milinevsky et al., 2002) and 2000-2003 (summary of this study) are presented in Table 1 and Table 2, respectively. Both all measurements and data separated by cloudy and clear sky conditions are presented. The number of days is pointed out in the brackets. All measurements give the relative difference of 2.3±5.2% (1996-2000, 1082 days) and 1.1±6.5% (2000-2003, 896 days).

Note, that by (Lambert et al., 2000) an overestimation of the ground-based data by TOMS is 4-8% at low and middle latitudes and 8-12% for the high latitude Antarctic site of Halley. By Bramstedt et al. (2003) the TOMS-ground relative difference for southern hemisphere in 1996-2000 was in average 3.3±4.8%.

Table 1. **Percent relative differences (TOMS-Dobson)/Dobson for Vernadsky Station, 1996-2000.** (Milinevsky et al., 2002)

Season	Cloudless sky	Cloudy sky	All measurements
1996-1997	11.1±7.0 (35)	-1.3±8.7 (105)	3.1±5.5 (289)
1997-1998	8.9±3.4 (34)	-0.5±4.3 (102)	2.6±4.9 (276)
1998-1999	6.0±2.0 (26)	-0.6±5.2 (149)	1.4±5.4 (267)
1999-2000	6.1±3.9 (38)	-0.4±4.2 (143)	2.2±4.5 (250)
1996-2000	**8.1±5.0 (133)**	**-0.7±5.7 (499)**	**2.3±5.2 (1082)**

Table 2. **Percent relative differences (TOMS-Dobson)/Dobson for Vernadsky Station, 2000-2003.**

Season	Cloudless sky	Cloudy sky	All measurements
2000 – 2001	8.4±3.4 (34)	1.4±5.1 (133)	3.2±5.5 (305)
2001 – 2002	6.1±4.9 (26)	-4.3±7.7 (79)	-0.6±7.9 (305)
2002 – 2003	6.3±3.5 (22)	-0.7±5.0 (193)	0.8±5.2 (286)
2000 – 2003	**6.9±3.8 (82)**	**-0.6±5.8 (405)**	**1.1±6.5 (896)**

Piacentini et al. (2000) give results of comparison for the latitudinal range of about 30°S to 90°S (including the Amundsen Scott USA South Pole station). During the July 1996-December 1999 period the mean systematic relative difference between EP-TOMS and ground was 5.0±2.3%.

The values of Table 1 and 2 show that the best data coincidence is observed on cloudy sky conditions. Relative differences are –0.7% and –0.6% in 1996-2000 and 2000-2003, respectively. But a very contrast situation is in differences obtained for the clear sky conditions. The relative values are 8.1% (Table 1) and 6.9% (Table 2). The absolute values of the cloudless and cloudy differences are in the same ratio in both data samples, 11.5:1, respectively. Thus, cloudless conditions give the difference, which exceeds the cloudy more than ten times.

Because of the significant data disagreement takes place for clear sky over Vernadsky station, obviously, an erroneous interpretation of surface properties in the TOMS retrieval algorithm caused this result.

The station is located on the Galindez Island, the Argentina Archipelago, where hills and mountains are covered with snow the whole year round. Besides, the mountains and glaciers of the Antarctic Peninsula, which is at the 10 km distance toward the east, have the same reflecting surface property. EP-TOMS instrument is unable to distinguish between reflection of snow and clouds. The snow/ice covered surfaces being misinterpreted as clouds in the EP-TOMS ozone retrieval algorithm can be a possible source of the total ozone overestimation during the cloud free conditions. Kylling et al., (2000) noted a similar effect in analysis of the surface UV irradiance. Also, it was noted in (Bramstedt et al., 2003), that the increased TOMS values in the southern hemisphere are most likely introduced by the algorithm and is independent of the instrument.

Due to the small number of cloudless days in the region of Vernadsky station the excess in EP-TOMS total ozone contributes insignificantly to the result of the overall data comparison. Although, in other regions of the southern hemisphere with lower level of cloudiness and high level of snow/ice cover this effect can input the more contribution in the data disagreement.

Seasonal change of ‘cloudy’ difference is similar in each of the two time periods under discussion. It is seen from Fig. 1b and Fig. 2 (solid curve). Fig. 2 is taken from (Milinevsky et al., 2002). Positive difference of about 2-3% is observed during Antarctic summer (December – February). During the spring and autumn on average the negative differences of -(3-5)% are prevailing. Seasonal changes of the cloud cover top height and cloud density can be concerned in this seasonal deviation of difference. Note, that only little seasonal variation of the EP-TOMS/Dobson relative difference was revealed from the southern hemisphere data of 1996-2000 in (Bramstedt et al., 2003).

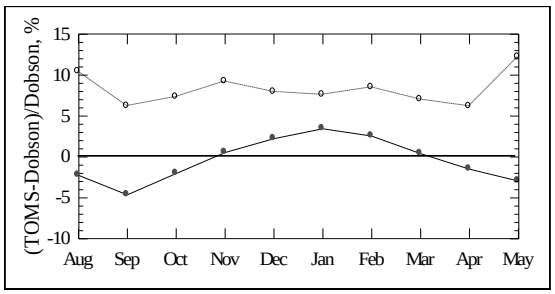

Fig. 2. Monthly mean differences between EP-TOMS and Dobson total ozone over Vernadsky station during 1996-2000; solid line – cloudy conditions, dashed line – clear sky conditions; by (Milinevsky et al., 2002).

The 'cloudless' difference had no evident trend in its month-to-month change during 1996-2000 (Fig. 2, dashed line) and show ascending trend during 2000-2003 (Fig. 1a). Further analysis of this effect is expedient using more long-term and multi-positional data sets.

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