VALIDATION OF OMI TOTAL OZONE USING GROUND-BASED BREWER OBSERVATIONS

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ABSTRACT

Near-to-real time as well as "archive quality" Brewer total ozone observations, which are performed with well maintained and calibrated instruments over the Northern Hemisphere have been used for the validation of the total ozone column product of the Ozone Monitoring Instrument (OMI) aboard the NASA EOS-Aura satellite. During the commissioning phase of OMI, the near-to-real time ground-based data, which are submitted to the WMO Northern Hemisphere Ozone Mapping Centre within few hours after observation, have been employed to check the behaviour of the OMI instrument as a function of measuring geometry. In addition the near-to-real time ground based data are also used as an early warning tool for the detection of possible problems during the operation of OMI. Archived ground-based data have been used to validate more than one year of OMI-TOMS and OMI-DOAS total ozone measurements. The comparisons show an agreement of better than 1% for the OMI-TOMS measurements and better than 2% for OMI-DOAS.

1. INTRODUCTION

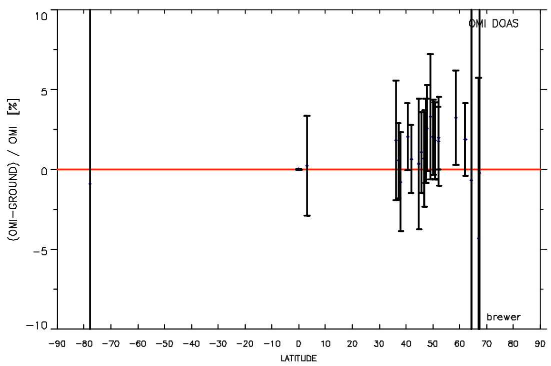
The Ozone Monitoring Instrument (OMI) is one of four instruments on the NASA EOS-Aura satellite, which was successfully launched on July 15th, 2004. OMI is a compact nadir viewing, wide swath, ultraviolet-visible (UV/Vis) imaging spectrometer that was contributed to the Aura mission by The Netherlands and Finland. With its high spatial resolution and daily global coverage, OMI promises highly interesting scientific results that could make a major contribution to our understanding of stratospheric and tropospheric chemistry and climate change. Concerning total ozone measurements there are two products available. The OMI-TOMS product is based on TOMS v8 algorithm [1] and has been publicly released while OMI-DOAS is a DOAS type algorithm [2], [3] developed for OMI by KNMI and currently is characterized as provisional. In this paper we present comparison results for OMI using ground-based Brewer total ozone measurements as well Dobson. The error of individual total ozone measurements for a well maintained Brewer instrument is about 1% for optimal observation conditions and the standard deviation of the difference between Brewer and satellite data can be as low as 2% for these conditions. The errors are higher (about 5%) at lower sun elevation and in polar winter with mostly zenith sky measurements. Despite the similar performance between the Brewer and Dobson stations, small differences within ±0.6% are introduced due to the use of different wavelengths and different temperature dependence for the ozone absorption coefficients [4]. The temperature sensitivity, and to a lesser extent the altitude distribution of the ozone, influence the used absorption cross sections in the Huggins bands, and therefore affect the performance of the Dobson and Brewer instruments. In particular, the atmospheric temperature seasonal changes are followed by seasonal variations in the Dobson and Brewer ozone data. The effect is estimated to be up to 4% in Dobsons [5] and less than 1% in Brewers [6]. In addition, stray light problems in single Brewers and in Dobsons may cause seasonal or solar zenith angle effects [5].

2. VALIDATION OF OMI TOTAL OZONE PRODUCTS

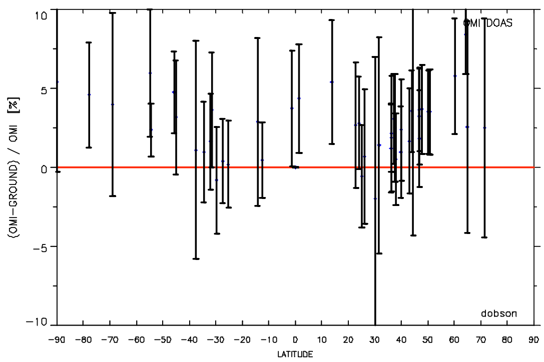
On a daily basis updated monthly files with near-to-real time preliminary Brewer total ozone observations from about 30 stations from the Northern Hemisphere are uploaded to the OMI archive of KNMI to be used for a first preliminary validation of OMI-TOMS and OMI-DOAS products. The procedure is running successfully since October 2004 and comparisons with these data have been presented in many OMI-related meetings. During the commissioning phase the preliminary Brewer data were extremely useful to check the behaviour of OMI as a function of measurement geometry and test the dependencies on solar and viewing zenith, solar and viewing azimuth. The corresponding archived data available at WOUDC have also been extracted and comparisons have been updated using these data. The comparisons between OMI and preliminary Brewer data, and the comparisons between OMI and archived data are consistent and do not show significant differences. For the off-line validation of the OMI total ozone, we used in addition also archived

Dobson data, available at WOUDC database. All data used correspond to stations that have been compared in the past with other satellite data (GOME, TOMS) [7, 8] and their quality status has been assessed. Data from 22 Brewer and 47 Dobson instruments have been used. For each of these stations time series of the differences have been generated and features like offsets, scatter, seasonal dependence and SZA dependence have been examined. Here we present a summary of the comparison results.

Figure 1 (a,b,c,d) shows the mean percent differences between the satellite data and the ground based total ozone observations separately for the Brewer and Dobson instruments. Global average differences can only be estimated from the Dobson comparisons, since there are almost no Brewer instruments in the southern hemisphere. The average difference between OMI-DOAS and Brewer observations is 1.03% (fig. 1a) while the corresponding difference between OMI-TOMS and Brewer observations is -0.12% (fig. 1c), which indicates that OMI-DOAS shows an offset of about 1% relative to OMI-TOMS data. These results are however valid only for the northern hemisphere comparisons and mainly for the latitudes 30-60^{o}N. The average difference between OMI-DOAS and Dobson observations, which have a better latitudinal coverage is about 2.7%, showing however better agreement over 30-40^{o}S (see fig 1b). The average difference between OMI-TOMS and Dobson observations is about 1%, with higher values for the tropics (fig 1d). This difference between OMI-TOMS and OMI-DOAS comparisons with the Dobson data are consistent with OMI-Brewer comparisons but are not directly comparable since they don’t represent the same geographical coverage. Comparison results from high latitude stations cannot be considered at present significant since they are based on few observations, which is demonstrated in the large standard deviations of the mean values, however, they provide a first estimate for the performance of the instrument and the algorithms.



(a)



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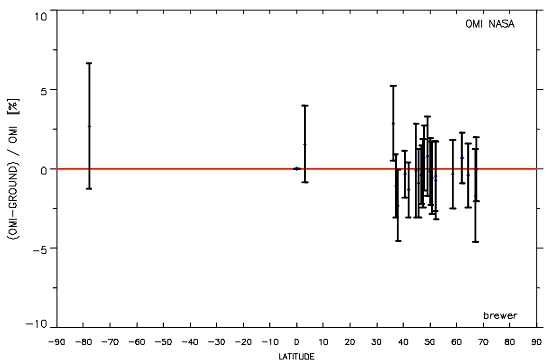

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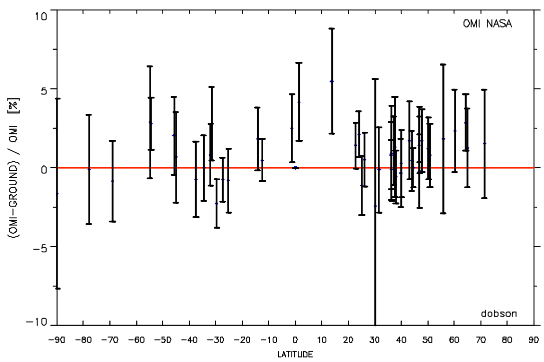

(d)

Fig. 1. Mean differences between satellite data (OMI-DOAS and OMI-TOMS) data and ground based total ozone data (separately for Dobson and Brewer instruments)

Figure 2 (a,b,c,d) shows time series of the monthly mean differences between satellite data and ground-based total ozone observations for the northern hemisphere. OMI-DOAS comparisons show indications for a seasonal dependence with an amplitude of 1.5% for the Brewer comparisons (fig. 2a) and slightly larger but in phase (2%) for the Dobson comparisons (fig. 2b). This seasonality is similar in phase with the one found in GDP4.0-ground comparisons, which was mainly attributed to the different temperature dependence between the DOAS algorithm and the different temperature dependence of the ozone absorption cross sections used in Brewer and Dobson retrievals due to the different wavelengths used [8]. OMI-TOMS-Brewer comparisons presented in fig. 2c do not show any seasonality and are remarkably stable around 0%. OMI-TOMS-Dobson comparisons show seasonality similar to the OMI-DOAS-Dobson comparison with reduced amplitude (fig. 2d). It has to be noted here that although OMI uses the same algorithm with EP-TOMS this results is not consistent with TOMS v8 data, where comparisons with Dobson data showed almost no seasonality and comparisons with Brewer data showed a weak seasonality.

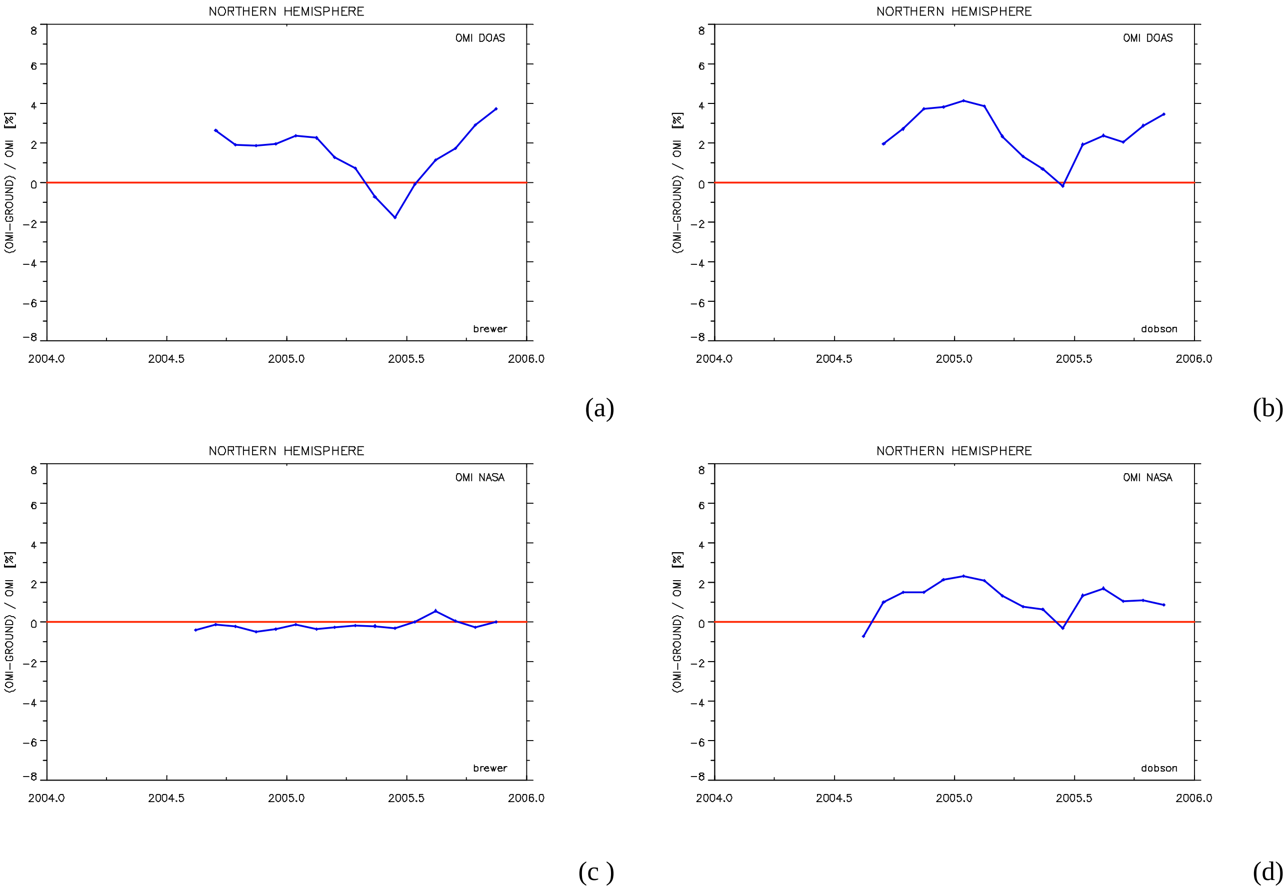

Fig. 2. Monthly mean differences between satellite data and ground-based total ozone measurements averaged over the northern hemisphere.

There are only few Brewer instruments situated in the southern hemisphere and for this region we therefore only calculated time series of the monthly mean differences between satellite data and Dobson total ozone observations. The results are shown in Figures 3a and 3b for the two different algorithms considered. OMI-DOAS comparisons shown in fig. 3a show an offset of 2% while OMI-TOMS comparison shown in fig. 3b has no offset. At the end of the time series the high differences observed are mostly due to the limited number of coincidences, since at the time of writing there were only limited ground-based observations for the last months of 2005.

Both show an indication for a small seasonal variability with amplitude less than 0.5%, which is expected if we consider the seasonal dependence found in the northern hemisphere comparisons with a six month phase shift. It is remarkable however to note here that the seasonal variability in the southern hemisphere both for OMI-TOMS and OMI-DOAS is much weaker than the one found in the northern hemisphere comparisons. Similar differences but less pronounced were also found when considering EP-TOMS and GDP4.0 data [6], indicating that the temperature variability in the northern hemisphere exhibits larger annual variability than in the southern hemisphere.

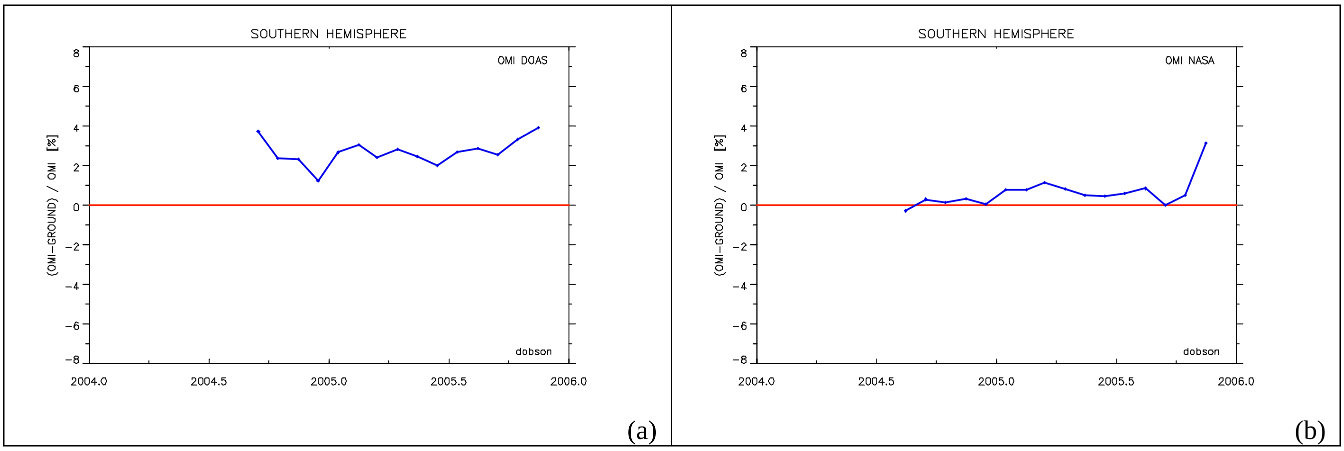

Fig. 3. Monthly mean differences between satellite data and ground-based total ozone measurements over the southern hemisphere

In order to study in more detail this seasonal behaviour, we estimated the monthly mean differences between the satellite data and the ground-based observations as function of latitude. The results are shown in fig. 4 (a,b,c,d). When examining the OMI-TOMS-Dobson comparisons (fig. 4a) we can see a small in amplitude seasonality of the differences over the middle latitudes of both hemispheres. An overestimation of 3% is found over the tropics during Sep-Dec period. Over Antarctica OMI-TOMS seems to underestimate on the average total ozone by 2%, a result based on few observations. Over the high latitudes of the northern hemisphere the amplitude of the seasonal dependence of the differences is larger than over the middle latitudes. The corresponding estimates for the Brewer comparisons are presented in fig. 4b, where we can observe that the amplitude of seasonal behaviour of the differences is smaller both over the middle latitudes and the tropics. Over the southern hemisphere there is only one Brewer located in Antarctica with few spring observations available, which however show a good agreement

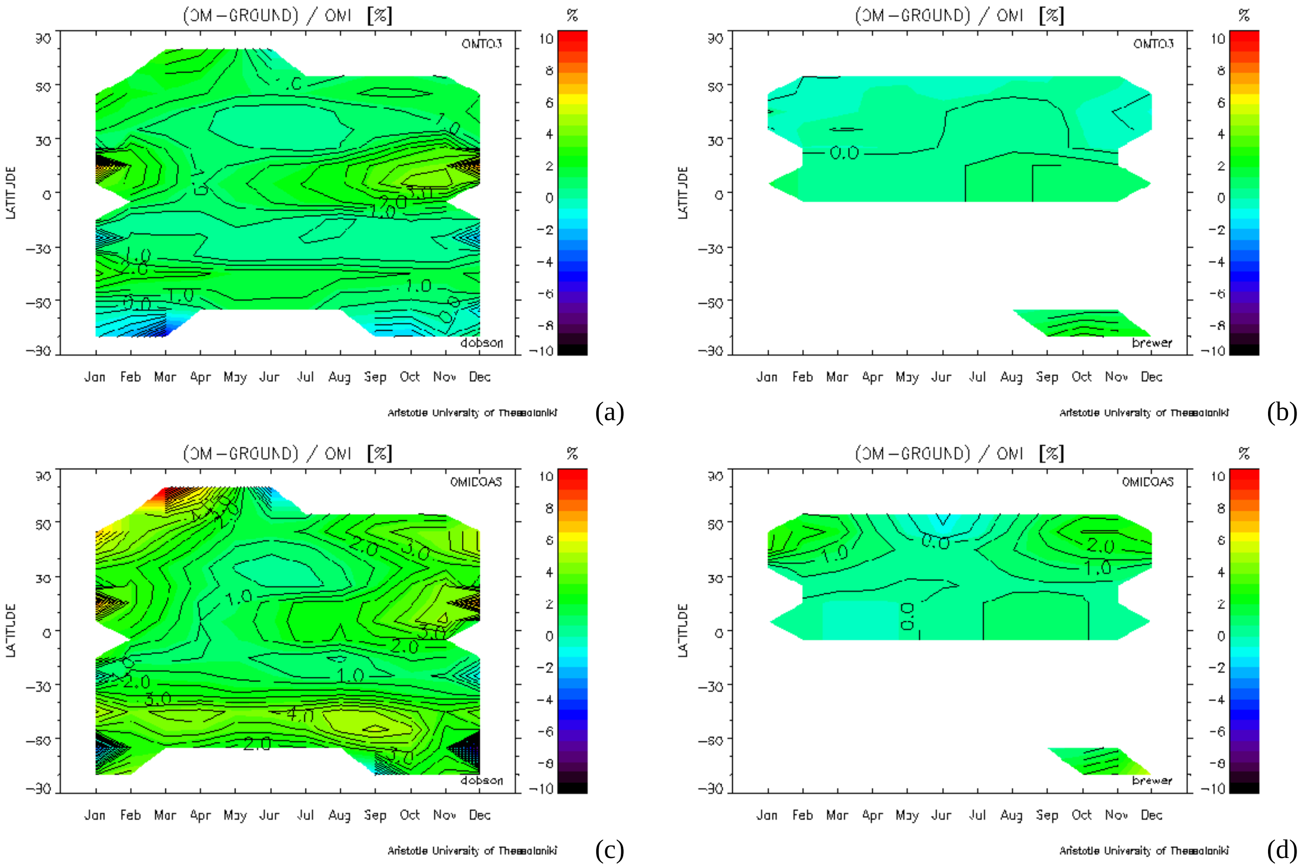

Fig. 4. Month-latitude cross-section of the relative difference between OMI-DOAS and OMI-TOMS ground-based total ozone. The results obtained by comparison with Dobsons and Brewers are presented separately.

The OMI-DOAS-Dobson comparisons (fig. 4c) show larger amplitude concerning the seasonality of the differences over the middle latitudes of both hemispheres but in phase compared to the OMI-TOMS-Dobson comparisons. A similar overestimation of 3% is found again over the tropics during Sep-Dec period, indicating possibly quality issues of the ground-based data used for this period. Over Antarctica OMI-DOAS seems to overestimate on the average total ozone by more than 2%, a result based on few observations. Over the high latitudes of the northern hemisphere the amplitude of the seasonal dependence of the differences is also here larger than over the middle latitudes. The corresponding estimates for the Brewer comparisons are presented in fig. 4d, where we can observe that the amplitude of seasonal behaviour of the differences is smaller both over the middle latitudes and the tropics.

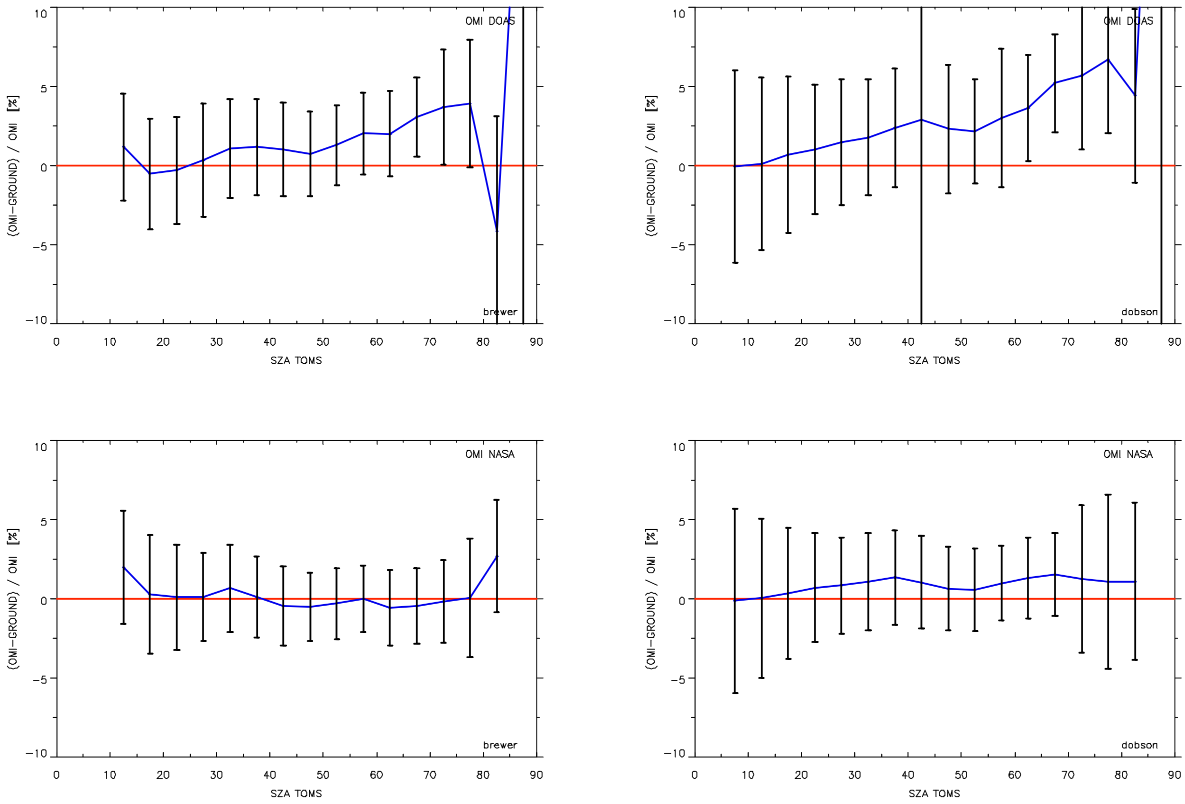

Fig. 5. SZA dependence of the differences between satellite and ground-based total ozone observations.

Figure 5 (a,b,c,d,) shows the solar zenith angle (SZA) dependence of the differences between satellite and ground-based total ozone observations. OMI-DOAS comparisons with Brewer observations indicate that at large SZA OMI-DOAS overestimates total ozone by 3 to 5%. In order to explain and quantify, however, the SZA dependence as an independent source of error, it is required to study comparisons of multiple OMI daily overpasses over sunlit areas, which is the case during polar summer days, against ground-based observations with fixed SZA. Such comparisons have not been performed here due to the limited availability of such data. OMI-TOMS comparisons do not show any significant SZA dependence.

3. INCLUSION OF OMI DATA TO WMO OZONE MAPS OF THE NORTHERN HEMISPHERE

Operational provision of EP-TOMS level-3 total ozone stopped on the 31st of December 2005. Necessary changes have been adopted at the WMO Northern Hemisphere Ozone Mapping Centre to use level 3 OMI-TOMS data, which has become publicly available recently, and since 1st of January 2006 EP-TOMS data have been replaced with OMI data. A sample of maps that are now operationally available at the Mapping Centre (http://lap.phsyics.auth.gr/ozonemaps) are shown in fig. 6. The Centre's web-site has been recently upgraded and now includes also the option to choose different satellite sensors to combine with ground-based data (for the time being SCIAMACHY assimilated total ozone data [9].

In this way it will be possible to have a first quick comparison between different instruments, concerning mainly their consistency.

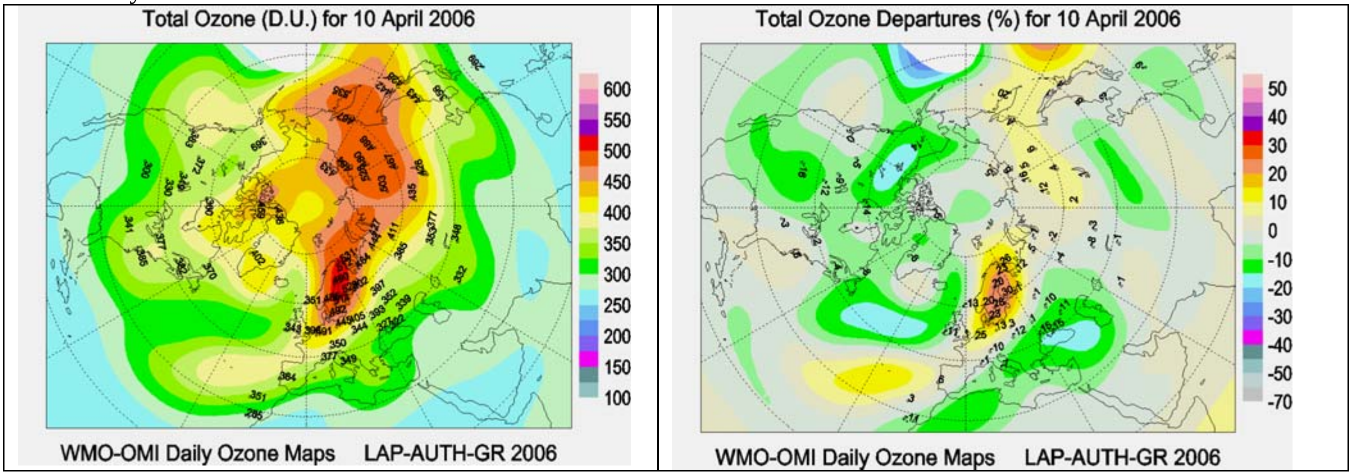

Fig. 6. Sample of combined ground-based and OMI maps of the Northern Hemisphere available at http://lap.physics.auth.gr/ozonemaps

Acknowledgments

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