Differences in the Same OMI/MLS Aura Tropospheric Ozone Data Set Published Before and After January 2013

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Abstract**—**On the website “NASA Goddard Homepage for Tropospheric Ozone”, global data of tropospheric ozone obtained from observations of OMI and MLS Aura satellite instruments, are reported. In mid-2013, the data was covering the period between October 2004 and January 2013. Subsequently, in early 2014, the time series was extended until December 2013. At present time, the published series has been extended to December 2014. Analysing this new series, we observed that the data already published to January 2013 had been replaced; not only the missing months of 2013 were added but all the values published since 2004 were recalculated. We present the detected differences in the comparison between common data to both time series (the original, before January 2013, and the new one, currently published on the website). These differences are important considering that they represent the result of the same satellite observation and should be considered when comparing results before/after January 2013, especially when adopting a certain confidence level in the spectral analysis of these data to intraseasonal scale. A warn of caution is suggested in the use of these observations and intercomparison with other values of these and other instruments, because of possible recurrent problems of instrumental calibration.

Keywords**—**Intraseasonal Variations; OMI/MLS Aura; Tropospheric Ozone.

Abbreviations**—**Dobson Units (DU); id est, latin expression (i.e.); Outgoing Longwave Radiation (OLR); Multitaper Method (MTM); Tropospheric Ozone (O3T).

I. INTRODUCTION

SINCE mid-2013 we have been analysing tropospheric ozone (O3T) data provided by the website NASA Goddard Homepage for Tropospheric Ozone [1], one of the main references of the observations of the OMI (Ozone Monitoring Instrument) and MLS (Microwave Limb Sounder) instruments of the remote sensing satellite Aura [2]. Monthly averages of O3T, released under public domain since October 2004, are easily accessible in plain text from the following URL [3].

In a previous study, we used these data to perform spectral analysis on them searching for intraseasonal cycles, with the aim to compare with our detected periodicities in solar irradiance measurements made in situ. That analysis was performed over an area focused at 33.5° S, 60.25° W which includes the northern part of the central Argentina's Pampas and the important agro-industrial city of San Nicolás de los Arroyos [4] (Figure 1 in this paper). Multitaper analysis (MTM) allowed us to relate four months intraseasonal variations in the abovementioned data sets of O3T, with similar periodicities in daily solar radiation determined at the study site with a confidence level of 95%.

This spectral coincidence, together with a regression analysis of monthly precipitation fields, outgoing longwave radiation (OLR) and sea surface temperature on the O3T time series, suggested that seasonal variations in atmospheric opacity as deduced from OLR, with a clear four-monthly signal, altered both the solar radiation and the available O3T quantity. The local OLR anomalies were associated to regional effects induced by a quasi-stationary Rossby waves propagating from the Indo-Pacific basin to southern South America, which ultimately are induced by anomalous tropical convection. These preliminary results were presented at the Atmospheric Physics Division of the 98th annual meeting of the Argentinian's Physical Association in September 2013, and widely disseminated in the repository arxiv/astro-ph (Cornell University) and ADS (NASA-Harvard) [5]. Later, in 2014, as we advanced in the theoretical work of analysing atmospheric waves at seasonal scale, we realized about the publication of new O3T data in the abovementioned website, for which the original series was completed until December 2013. The existence of significant differences between these values and those originally obtained in early 2013 became evident when analysing this new series, which is currently published. This means that the O3T original series was fully replaced; not only had been added the missing months of 2013, but all the values published since October 2004 had been modified.

It is noteworthy that there is no note or warning indication anywhere about these changes. Then, people who got this new series did not notice that the values prior to January 2013 were different from those obtained by others after that date. These differences presuppose a total reanalysis of satellite's observations, which could be due to a change in the observational reduction algorithm (i.e., the algorithm to obtain measurements or physically meaningful units from instrumental units) or a recalibration of the instrument (modification of the constants that allow to obtain reliable instrumental units of a given observation). However, there is nor advise neither a note of warning about these changes, neither about their causes.

We immediately contacted the administrator (curator) of the mentioned website, Dr. Jerald Ziemke, who kindly answered our questions about the topic. Dr. Ziemke explained to us that he was not aware of the changes, but he recognized that such changes occurred after we sent both datasets to him. He assumed that the values changed due to "changes probably made by the groups responsible for MLS/OMI instruments" [6]. Likewise, Dr. Ziemke informed us about the existence of other O3T-released data, obtained with the trajectory-mapped method [7] and also described in the abovementioned website. These new data are not as readily available as they involve the use of a proprietary program under IDL (interactive data language).

Regarding to other related works, we do not found another papers dealing with the internal consistency of the final products released by OMI/MLS instruments. The O3T data provided by OMI/MLS are being used widely (see e.g, [8], [9], [10], [11]). We do not intend to evaluate or establish the accuracy of the data provided by MLS/OMI, this has already been discussed elsewhere (e.g., [12],[13],[14]); certainly, OMI's instrument algorithm needs refinement, being detecting differences with ground-based estimates up to 25% [14]. Instead of, our main aim is to highlight changes in the final product published by that abovementioned MLS/OMI reference, related to monthly averages of O3T, and remark their possible consequences for the analysis of intraseasonal periodicities of atmospheric phenomena involving at least, similar cycles. The differences outlined in the given data, can serve as an estimate of the accuracy thereof.

II. Data and Methodology

The O3T data are accessed in a gridded matrix of monthly averages of 288 x 120 cells (grid-points of longitude x latitude) representing the domain between 179.375° W - 179.375° E and 59.5° S - 59.5° N, divided into sectors of 1.25° in longitude and 1° in latitude. Since the former analysis was focused on atmospheric processes developed in southern South America, here we used the same cell used in [5], centred at 33.5 ° S, 60.25 ° W, i.e., approximately in the Argentinian city of San Nicolas (SN), but also other cell centred at 23.5° S, 46.75° W, representing the Brazilian's city of Sao Paulo (SP) (see Figure 1). San Pablo is a big city of great importance in ozone studies [15]. We compare the two O3T time series in each site: one corresponding to the original series (O), published before January 2013, and the other corresponding to the new series (N), published after that date. Both time series were retrieved taken as published from [3], i.e., in the period extended from October 2004 to January 2013.

Figure 1: The map shows the portion of South America related to our study. The grey squares mark the locations under analysis around San Nicolás in Argentina and San Pablo in Brazil

III. Results

Figures 2 and 3 show the relative differences (O-N)/N for the two sites under study. We can observe relative differences mainly negatives, close to 10% on average, with peaks up to 30%. Strong systematic effects can be seen, especially from 2004 to early 2008, the latter corresponding to the order umbers 40-45 in both time series. This temporal pattern is consistent in both regions, SN and SP. However, in the SP time series a very obvious systematic effect remains after 2008, because almost all differences are negative (the average value of the relative differences after that date is -3.60 DU, DU: Dobson units), while the SN time series exhibits differences more standardized (Gaussian), with a mean of -1.08 DU after 2008. In both cases, after February 2012 (order 90), the values of both time series tend to be similar, appearing again differences towards the end of 2012. This observed behaviour in the relative differences is not easy to explain, but it suggests a recurrent calibration problem in the MLS/OMI instruments, which we can explain as follows. When both time series (which represent the same satellite observation) exhibit larger differences, the instrument is out of calibration; on the contrary, when the instrument is on calibration, the reprocessing of the observational data do not differ significantly from those previously obtained.

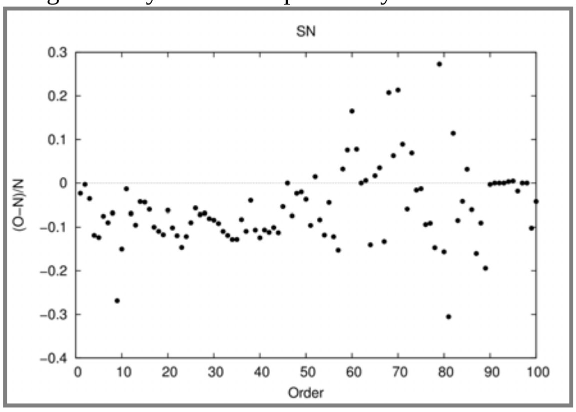

Figure 2: Relative differences (O-N/N) for SN zone of Argentina. Strong systematic effects can be seen since 2004 until middle 2008; these last values correspond to orders 40-45 of the time series. Later, the differences show a more stochastic behaviour. Note the coincidence between both data set at beginning/mid 2012 (orders 90-98)

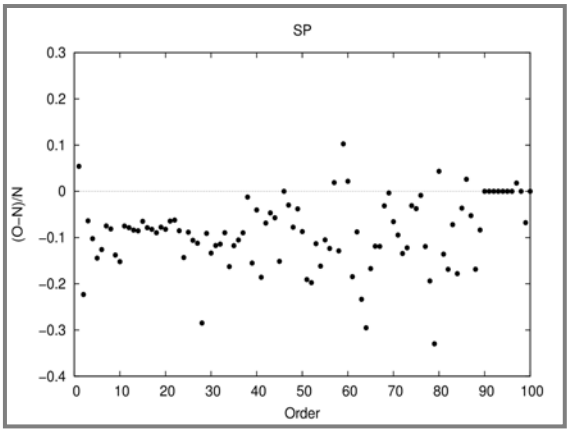

Figure 3: Relative differences (O-N/N) for SP zone of Brazil. A similar systematic pattern as in Figure 1, can be seen. Nevertheless, notable systematic effects persist after 2008. Note the coincidence between both data set at beginning/end 2012 (orders 90-98)

Particularly, for the time series of SN, the annual cycle is modified in the new edition (N) over the previous one (O), presenting the major differences from November to March and, particularly, in June (Figure 4a). Specifically, the May minimum detected in the O series, runs through June in N series, and then it changes rapidly in July, suggesting a secondary (relative) peak, which essentially alters the shape of the annual cycle that was previously observed in O time series. The month-to-month correlation between the two series is 0.86. However, when the annual cycle is removed; i.e., when we take into consideration the series of anomalies (Figure 4b), the correlation between the time series (monthly values) falls to 0.67, indicating that at intra-annual scale (at monthly to yearly variations) the mutual relationship is less strong. Also, the series of anomalies show slightly uneven intrannual behaviour: the new series has a significant linear trend (r = 0.21) that does not exist in the original series. This trend, suggests the presence of a non-stationary stochastic process, which could produce the accumulation of systematic errors and could be due to calibration errors. Since 2009, it is also evident an increase in the month-to-month variability in the N series that skew the data toward positive higher values.

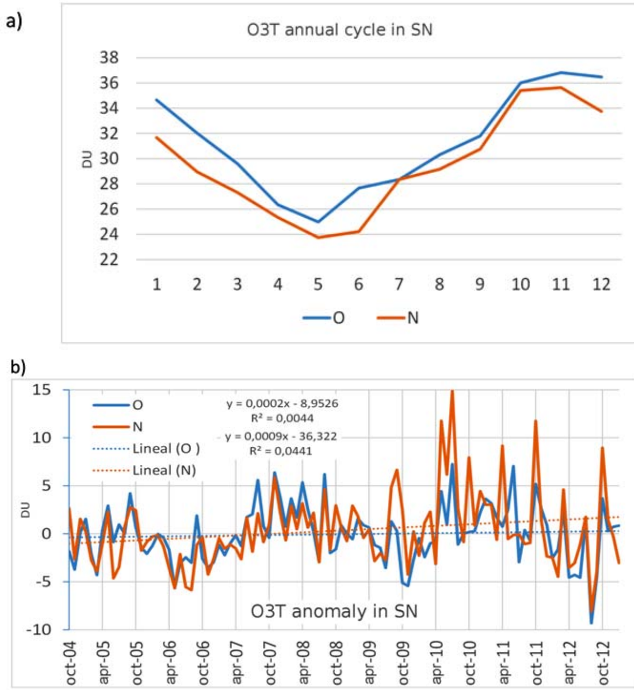

Figure 4: a) Annual cycle of tropospheric ozone (O3T) in San Nicolas (SN) for the original time series (O) and the new time series (N), estimated as the monthly means throughout each record. DU: Dobson units. 3b) Tropospheric ozone (O3T) monthly anomaly time series in San Nicolas (SN) for the original time series (O) and the new time series (N). Linear trend curves and associated equations. R^2: variance explained by the trend

3.1. *Intraseasonal Spectral Differences*

To analyse the spectral differences between O and N series in both SN and SP cities, we performed the same analysis as in [5] using the multitaper (MTM) technique to obtain the power spectrum of the OMI/MLS data into consideration. This technique is very suitable for short and noisy signals

[16]. Figures 5 and 6 show the raw spectra for both zones under study, including the main periodicities present. In panel a) of both figures, the spectrum obtained with O data time series is shown; the panel b) depicts the corresponding to N time series. The detected differences in the time series of O3T alter the confidence level of the signals under study. While the spectral power of the annual cycle remains constant, intraseasonal periodicities of about 2-4 months are modified by varying the level of significance of the most prominent peaks between 90 and 95%. For example, for the SN zone, the originally periodicities detected at about 3 and 4 months with a confidence level of 90 and 95% respectively, are reshaped in two shorter bands at about 2 and 3 months, with a 95% level of confidence, while the original 4-monthly periodicity decays, reaching almost the 90% level (Fig. 5a and 5b). A similar effect, although less marked, can be seen in the analysis of the time series for SP, where the spectral power obtained at about 3.5 months in the O time series with a confidence level higher than 95%, falls to a confidence level below 90% in the N series (Fig. 6a and 6b). Thus the spectral power originally detected at about 3.5 months, are then redistributed in the shorter bands of 2 and 3 months in N series, with a higher level of confidence than previously observed at these scales (say, more than 95%).

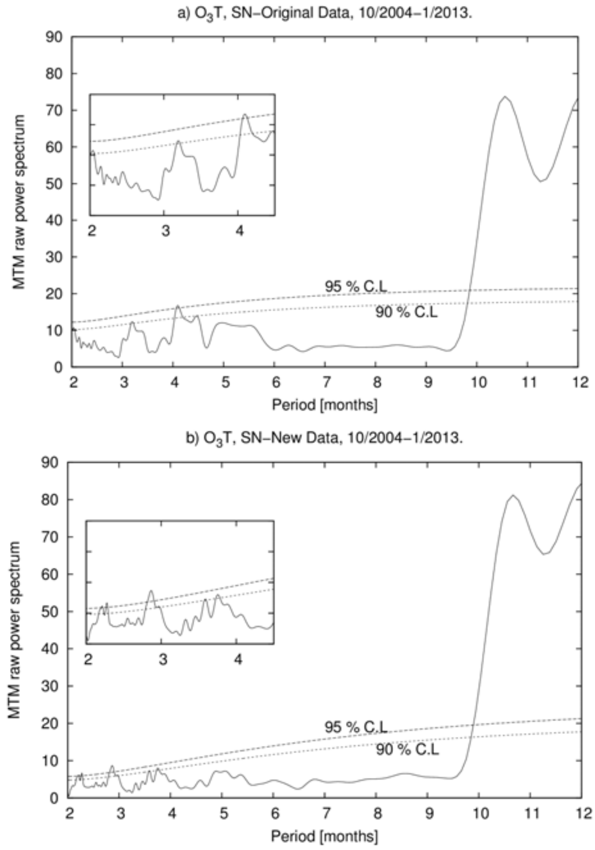

Figure 5: a) Multitaper raw power spectrum of the original data (O) for SN zone. With a confidence level of 95%, only one periodicity of 4 months is clearly visible. b) The same analysis for the new time series (N). With the same confidence level, other peaks of lesser periods are still present, whereas the 4 month periodicity just exceeds the 90% confidence level

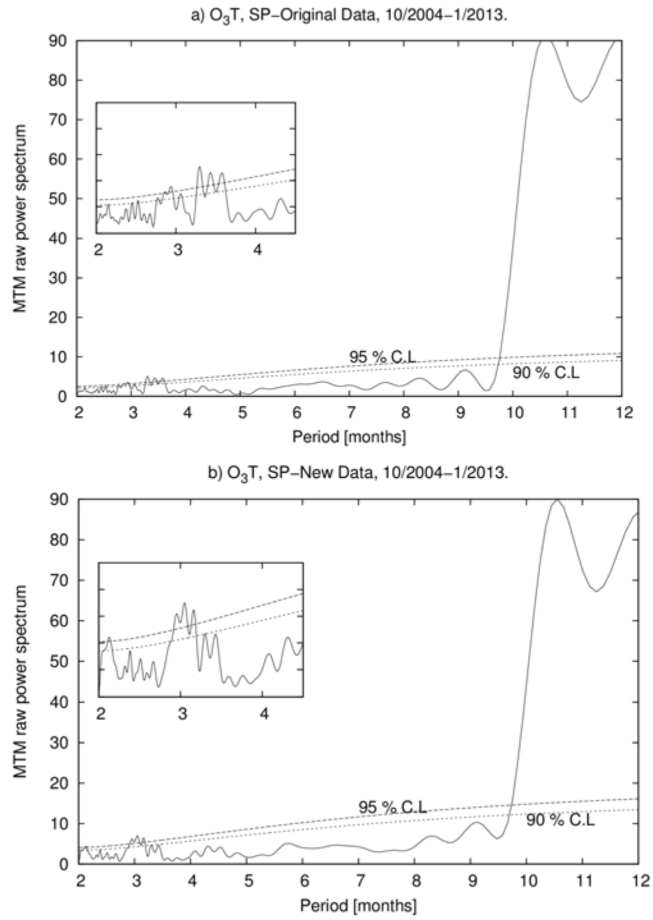

Figure 6: a) Multitaper raw power spectrum of the original data (O) for SP zone. With a confidence level of 95%, spectral power around 3-3.5 months is observed. b) In the new series this signal is reshaped in two bands of 2 and 3 months, with high confidence level (more than 95 %)

IV. CONCLUSIONS

This preliminary analysis shows that both released sets of data, representing the same ozone observations made by the OMI/MLS Aura satellite instruments from October 2004 to January 2013, differ up to 30% and they have systematic effects that are possibly latitude dependent, as shown by significant variations in them by comparing data representative of central Argentina and Sao Paulo, Brazil, both distant at about 12 degrees in latitude. We assume that these differences are due to calibration problems of the OMI or MLS instruments; or both of them, and these effects are recurring, because in some time span (February to October 2012) the compared series tend to coincide, appearing again systematic differences at the end of 2012.

Changes in the reduction observational algorithm would imply reanalyse all the same observations, which in principle would have produced different O3T values in both data set, making not easy to explain the almost null differences from February to October 2012 in both areas under study. Whatever the cause of the changes, they were not properly clarified in the web of OMI/MLS Aura data. The suggestion to use new values from the method of trajectory and the warning about that classic O3T data "will eventually be phased out and replaced with the trajectory- mapped products" [17], made explicit on the web immediately after our intervention with the curator of it, suggests that our current study has been very convenient in order to know the final quality of the reported data.

Despite those systematic effects found, intraseasonal periodicities continue to emerge, albeit with a subtle shift in the detected spectral power and its confidence levels. Therefore, theoretical modelling of possible effects related to these periodicities must take into consideration that O3T data have systematic errors which impact in the determination of intraseasonal periods with estimated variations of about 2 months. Our logical recommendation to these potential data users is to stay updated regarding changes, and if possible, to compare the retrieved data with observations and surveys conducted in situ.

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