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Chapter 10

Modification of Ozone TOMS Ancillary Data Interpolation

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Abstract

The method for interpolating the Total Ozone Mapping Spectrometer (TOMS) ozone data used for level-2 processing has been changed as a result of new information about the generation of the files by the TOMS Project. Previously, all ancillary data files [National Centers for Environmental Prediction (NCEP), TOMS ozone, and the Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) ozone] were assumed to be generated as global gridded files for fixed epochs, so that the entire file could be assumed to have the same time tag. For the TOMS data, a single file has been generated for each GMT day, so the time tag was assumed to be 12:00 UTC on the day. In recent discussions with the TOMS Project, it has been learned that the TOMS ozone data are actually generated in a similar manner to the SeaWiFS level-3 binned products, in that the data are gridded for whatever time (or times) the sensor viewed the locations on that day. In addition, the TOMS satellite orbit has a local noon descending node, like that of SeaWiFS, so the observations times for SeaWiFS and TOMS are fairly close (within approximately 1/2 orbit). Based on this, it was decided to change the TOMS ozone data interpolation to reflect the actual observation times for the gridded data, which vary continuously from 0:00 UTC at 180° longitude, to 24:00 UTC at −180°. The interpolation for the other ancillary data types is unchanged. The new method and comparison of the old and new results are described in this report.

10.1 INTRODUCTION

The interpolation of ancillary meteorological and ozone data used for level-2 processing is made in two steps. Gridded ancillary counts are spatially and temporally approximated for all pixels within a SeaWiFS swath. The interpolation in space uses rectangular bilinear approximation. The interpolation in time follows the spatial interpolation and applies a simple linear approximation.

The ozone interpolation employs gridded equidistant cylindrical maps of ozone obtained by the Total Ozone Mapping Spectrometer (TOMS) and the Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) instruments. Figure 1 shows an example of a TOMS daily map with the latitude and longitude, and starting and ending times for the four corners of the grid. The latitudinal distance between consecutive grid points is 1.0° and the longitudinal distance between the grid points is 1.25°. Hence, ozone maps are composed of 180 points in the vertical direction and 288 points in the horizontal direction.

Three TOMS or TOVS files are normally submitted for spatial and temporal approximation of ancillary ozone data for a whole SeaWiFS swath. Two files out of the three are used at the ancillary ozone approximation of each SeaWiFS scan line.

The modification was introduced to the temporal approximation of TOMS ozone ancillary data to take advantage of the actual times of ozone data capture. So far, the TOMS ozone interpolation has assumed a common time tag for each grid of an ozone daily map to be 12:00 UTC. The revised algorithm calculates the true time for each ozone grid point based on information provided within a TOMS file header.

10.2 NEW OZONE SCHEME

The linear function of time in terms of longitude for ozone TOMS files is given in Fig. 2. The function can be written as,

$$T_T = \frac{-(T_\mathrm{e} - T_\mathrm{s})\ \mathrm{lon}}{360.0} + \frac{(T_\mathrm{s} + T_\mathrm{e})}{2.0}, \qquad (1)$$

where T_T is a Julian time of TOMS ozone observation along a given longitude, lon is the corresponding longitude, and T_s and T_e are Julian times for the start and end, respectively, of the TOMS file.

The modified temporal approximation of ozone TOMS ancillary data applies the difference, ΔT, between the time of the SeaWiFS observation of the current scan line and the

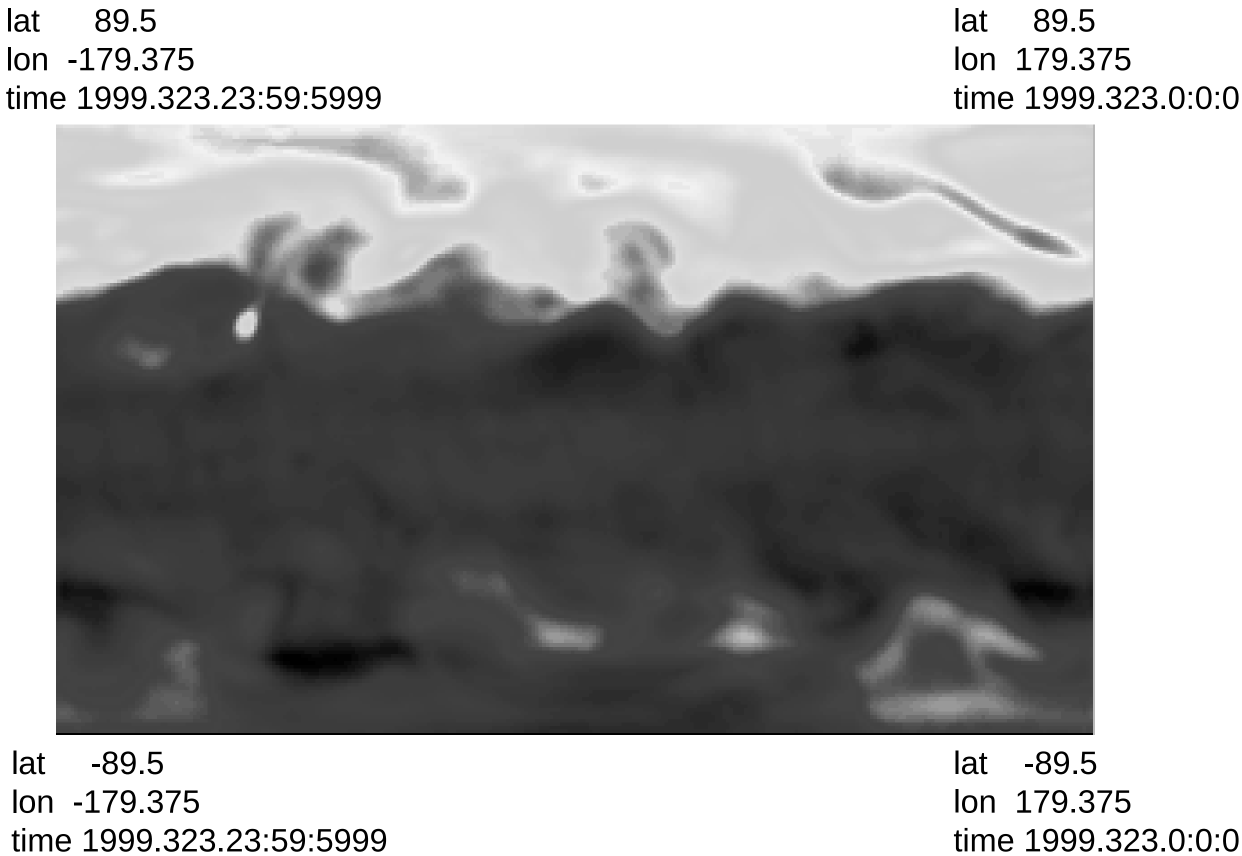

Fig. 1. Spatial and temporal characteristics of ozone TOMS files.

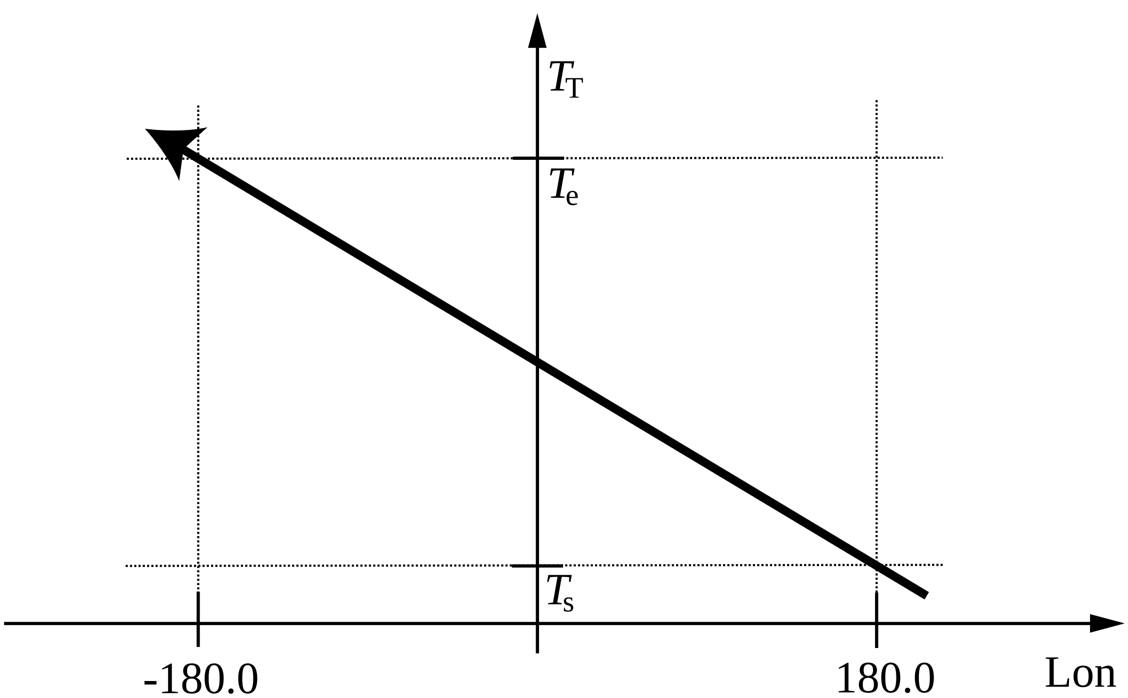

Fig. 2. Linear function of time versus longitude for the new scheme of ozone TOMS interpolation.

TOMS time associated with the corresponding longitude for each scan line pixel:

$$\Delta T^{\mathrm{N}} = | T_{\mathrm{sc}} - T_T |, \quad (2)$$

where T_{sc} is the time of SeaWiFS capture of the present scan line. The same time, T_{sc}, is used for all pixels within a scan line because a fraction of a second, which it takes SeaWiFS to attain the complete scan line, can be neglected in the calculations.

The old temporal approximation defined ΔT as a difference of scan line time from the beginning of the TOMS file:

$$\Delta T^{\mathrm{O}} = | T_{\mathrm{sc}} - T_{\mathrm{s}} |, \quad (3)$$

Although the old interpolation scheme (ΔT^{O}) assumed the T_{s} to be 12:00 UTC for an entire daily ozone map, it was reading the actual T_{s} value from the TOMS file header which returned the time around 0:00 UTC.

Temporal approximation computes weights for ozone grid points on the corners of the cell which spatially encompasses a SeaWiFS scan line point. The weights are calculated for both ancillary TOMS files used in the interpolation, W_1 and W_2 for the first and second file, respectively. Two ΔT values (ΔT_1 and ΔT_2) for each file are in the same way converted into weights for the old and new processing:

$$W_1 = \frac{\Delta T_2}{\Delta T_1 + \Delta T_2}, \quad (4)$$

and

$$W2 = \frac{\Delta T_1}{\Delta T_1 + \Delta T_2}. \quad (5)$$

The final interpolation equation is as follows:

$$O_2 = W_1 F_1 + W_2 F_2, \quad (6)$$

where O_2 is the interpolated ozone count and F_1 and F_2 are spatially approximated ozone values within the TOMS first and second file, respectively.

The new approximation puts the highest weight on ozone grid cells from the ancillary file that is most concurrent with the given scan line point. A low weight is given to ozone grid cells from the other ancillary file further in time. A switch of ancillary files takes place when a scan line crosses the International Date Line.

The old approximation algorithm allocates a higher weight to ozone grid cells from the ancillary file whose start time is the closest to the scan line time. This gives higher weights to the nonconcurrent ozone counts at the start of the TOMS map.

Coincidence of the acquisition times of TOMS and SeaWiFS results in ΔT being progressively low for ozone grid cells from the ancillary file which is most concurrent with scan line points.

The new algorithm works well for all ancillary file data captured over a period of time, such as ozone TOMS where $T_{\mathrm{e}} - T_{\mathrm{s}} \approx 24\,\mathrm{h}$. It is also appropriate for ancillary data where the common time for the whole file is mid-time, T_{m}, and $T_{\mathrm{m}} = T_{\mathrm{e}} = T_{\mathrm{s}}$. Therefore, the general concept of the method could also be applied with other ancillary files, such as TOVS. Currently, the new processing only activates when there are two ancillary files submitted to the approximation of a scan line and both are ozone TOMS.

10.3 RESULTS

The new scheme of ozone TOMS approximation introduces noticeable differences for SeaWiFS swaths in both ozone contents and chlorophyll concentration.

The modified algorithm was executed on eight day data and produced level-2 products. A two day run was also done which output level-2 and quality control products for both conventional and altered algorithms of ozone TOMS approximation.

10.3.1 Ozone Comparison

Old and modified ozone TOMS approximation schemes were compared. There was a substantial difference in ozone counts both with over- and underestimation. Figure 3 compares histograms based on the ozone value differences between the old and new schemes for a near-noon and near-midnight (near the International Date Line) SeaWiFS swaths.

Within the entire two day sequence of SeaWiFS processing, the new method of ozone approximation from TOMS files produces a difference of up to 20% from the previous algorithm.

The switch of the concurrent TOMS files along the International Date Line results in discontinuities in the ozone approximation values. The artifacts are created because successive day-to-day ozone maps do not continuously fall one into another and the new scheme puts the highest weight on the ozone cells located in the most concurrent file causing the switch at the International Date Line. The amount of the discontinuity reaches up to 12–17%.

10.3.2 Chlorophyll Comparison

The modified algorithm of ozone approximation from TOMS files has caused measurable changes in the chlorophyll concentration values compared to the old method. The results were obtained on SeaWiFS GAC data captured over two days and processed using ozone information calculated according to the old and new scheme of TOMS interpolation. In the comparison of old and new chlorophyll concentration results, only these pixels were considered which were not flagged by either level-2 processing algorithm.

Figure 4 shows two scatterplots of the differences in chlorophyll levels produced by the old and new methods as a function of chlorophyll concentration obtained by the old ozone approximation scheme. The first plot shows the

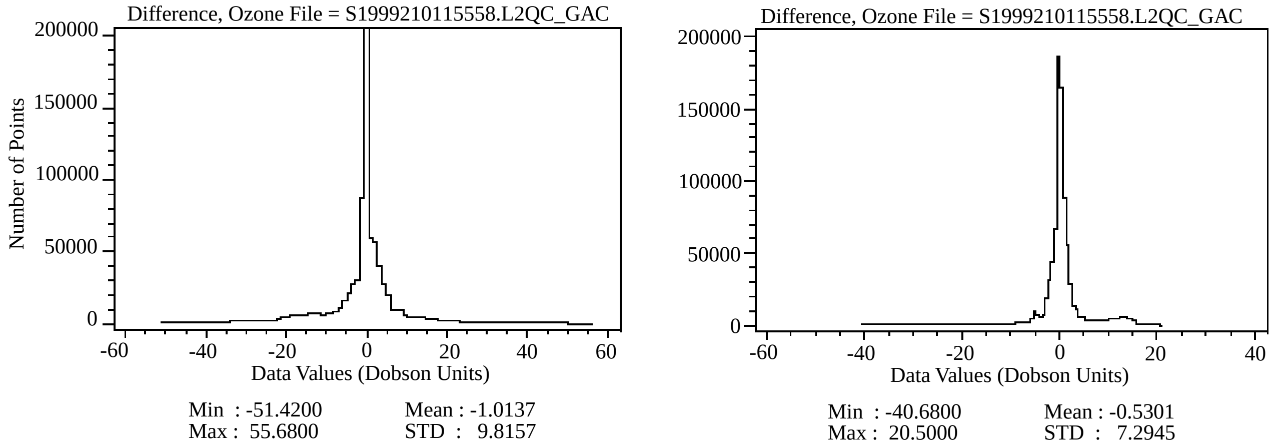

Fig. 3. Histograms of ozone differences between the old and new schemes of TOMS approximation for SeaWiFS swaths captured around noon (the first) and the International Date Line (the second).

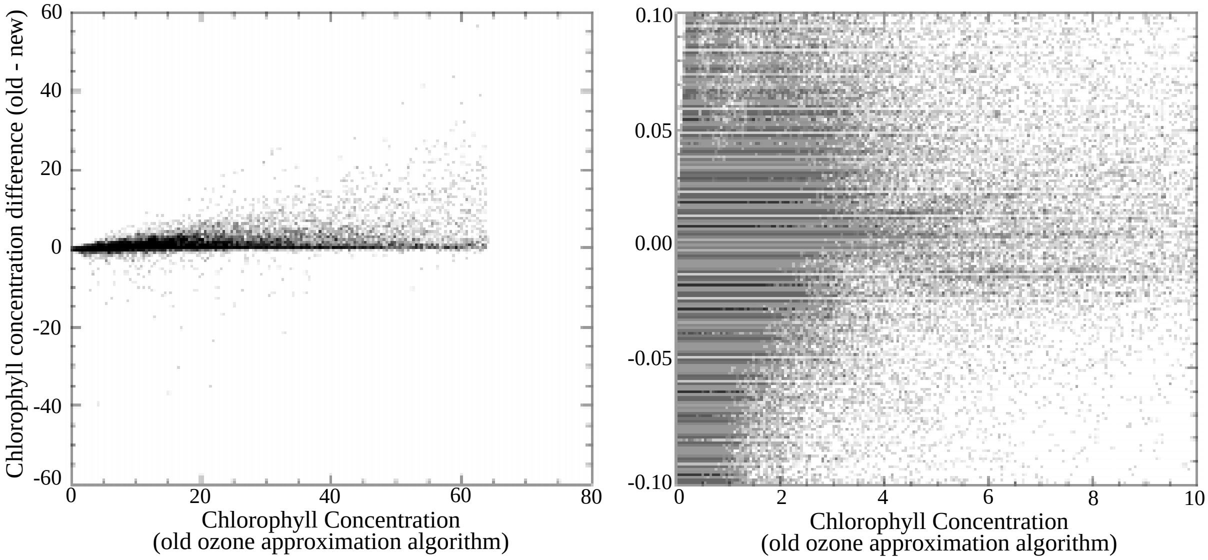

Fig. 4. Scatterplots of two day chlorophyll concentration values obtained by the old approximation scheme as a function of chlorophyll level difference between the old and new algorithms.

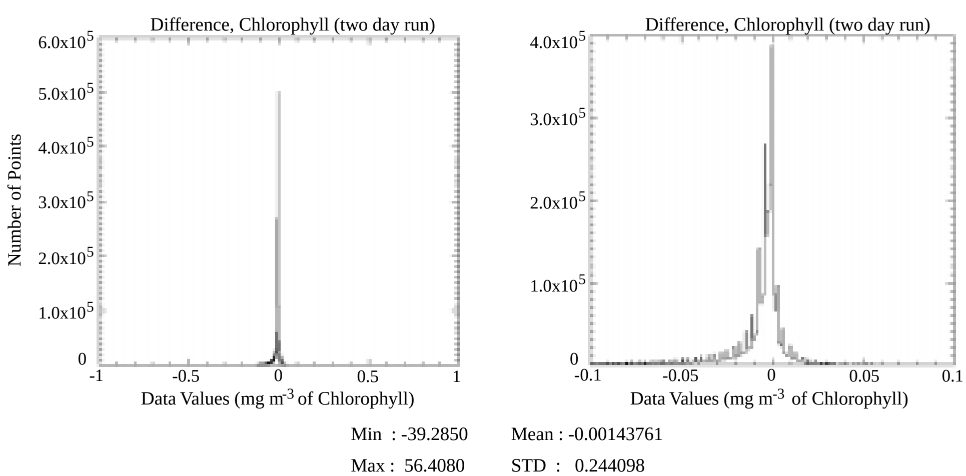

Fig. 5. Histograms of differences in chlorophyll concentrations between chlorophyll levels obtained using the old and new ozone approximation schemes for two day's worth of SeaWiFS data.

full scale of chlorophyll levels and data differences and the second plot zooms in on the smaller chlorophyll concentrations and difference values. The scatterplots indicate that there are some isolated pixels for which the difference in chlorophyll levels between the two methods reaches as much as 100%.

Histograms of chlorophyll concentration differences between the two schemes for a two day period of SeaWiFS capture are displayed in Fig. 5. The same data are shown for two ranges of differences in chlorophyll levels. The percentage of significantly changed chlorophyll values is small, therefore, only narrow domains around the zero level of chlorophyll difference can show on the histogram.

Overestimation of chlorophyll levels by the old algorithm is much more common, about 72%, for larger chlorophyll difference values exceeding $0.1\,\mathrm{mg\,m^{-3}}$. Within the lower difference range below $0.1\,\mathrm{mg\,m^{-3}}$, 74% of counts are underestimated by the old method in comparison with the new scheme.

The overwhelming majority of 96.8% of chlorophyll concentration variances between the two methods account for chlorophyll level differences smaller than $0.1\,\mathrm{mg\,m^{-3}}$. This value could be nonetheless significant as the chlorophyll concentration of much of the global ocean is in the range of $0.1\,\mathrm{mg\,m^{-3}}$. The bulk of 70% of chlorophyll changes is below $0.01\,\mathrm{mg\,m^{-3}}$.

The discontinuity of new ozone approximation along the International Date Line is not visually discernible even in rescaled chlorophyll concentration images. The difference can only be observed in comparison with chlorophyll counts obtained with the old method of ozone approximation. Within the limited data set only intermediate chlorophyll concentration levels around $0.3\,\mathrm{mg\,m^{-3}}$ were observed for the International Date Line regions. The differences between the two algorithms in these areas can be estimated up to 20% for either side of the date line.

10.4 CONCLUSIONS

A new scheme of temporal interpolation of ancillary ozone TOMS data was needed to reflect the actual observation times for TOMS gridded maps. The new scheme introduces measurable differences in chlorophyll concentration counts compared to the old algorithm. In 96.8% of the cases, however, the change is below $0.1\,\mathrm{mg\,m^{-3}}$ and in 70% of the cases the change is below $0.01\,\mathrm{mg\,m^{-3}}$. Within the 3.2% range there are some isolated occurrences when the new method causes a large variation in chlorophyll readings reaching as much as 100%.