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Atmospheric Measurement Techniques Discussions

Interactive comment on "A new discrete wavelength BUV algorithm for consistent volcanic SO_2 retrievals from multiple satellite missions" *by* B. L. Fisher et al.

Anonymous Referee #1

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Review of Fisher, et al., A new discrete wavelength BUV algorithm for consistent volcanic SO2 retrievals from multiple satellite missions.

I encourage publication of this paper because it represents a step forward in characterizing a factor in global climate change, is generally well-written, has a comprehensive review of background work, references the important publications, and describes all the procedures used to characterize the retrieval results, including simulations for error analysis. Exceptions needing correction are stated below.

This paper is significant because for the first time the entire four-satellite TOMS record since 1978 has been processed for SO2 column amounts and made available for anal-

ysis. The new algorithm can further extend the data record using the next generations of UV mapping instruments following TOMS. The existing TOMS volcanic record was constructed by processing individual eruptions that had been reported or accidentally detected. The analysis involved manual selection of a limited geographical region containing the plume because of long data processing times. This new dataset will allow a nearly complete census of essentially all eruptions of climate significance.

Earth satellites offered the first platforms for observation and measurement of the largest explosive volcanic eruption plumes. The ash clouds could usually be identified in AVHRR visible light images. However, the total erupted mass could best be obtained by measuring the quantity of absorbing gas in the eruption cloud. Sulfur dioxide was a volcanic gas that was rare in the atmosphere. Anomalous ozone retrievals from the Nimbus-7 TOMS instrument over Mexico were diagnosed as sulfur dioxide interference in the 1991 eruption of El Chichon that absorbed the UV wavelengths used for ozone measurements. The six instrument wavelengths had been selected for global ozone retrievals without consideration of sulfur dioxide interference since that gas is not a permanent atmospheric component. Thus, the task of discriminating sulfur dioxide from ozone absorption was not easy.

This paper clearly documents the evolution of TOMS ozone algorithms and the ad hoc ones developed to discriminate SO2 from ozone absorption in nadir observations. This history is useful because after 30 years the background of current work tends to get lost.

The original Krueger SO2 algorithm assumed that total ozone was unperturbed by the volcanic cloud and could be interpolated from extra-plume regions in TOMS traces across the cloud. Then sulfur dioxide was computed from the residual radiance at absorbed wavelengths.

In the succeeding algorithm, four parameters - sulfur dioxide, ozone, aerosol index (a measure of non-Raleigh scattering and aerosol absorption), and surface reflectivity -

were retrieved by inverting a 4 x 4 matrix. It was adapted for satellites from the algorithm that Jim Kerr had produced for Brewer Spectrophotometer data on overhead drifting volcanic clouds. This Krueger - Kerr method produced reasonable SO2, AI, and surface reflectivity results and was used routinely for many years to measure the position and sizes of eruption SO2 and ash clouds. The simultaneous observations of the sulfur dioxide and ash clouds showed that the ash would separate and fall out in a few days while the sulfur dioxide cloud drifted on, even in the largest eruption clouds. However, the model was too simple for accurate ozone retrievals and the iterative table search procedure used too much computer time so that it was executed only for select geographic regions that included the volcanic plume. Thus the entire TOMS dataset was never processed for sulfur dioxide until the work described in this paper was conducted.

The new MS_SO2 algorithm takes advantage of the operational TOMS ozone retrieval, TOMRAD radiative transfer look-up-tables that now include Jacobians, and the methodology of the K - K algorithm. The fixed absorption coefficients in the K-K matrix have been replaced by Jacobians, presumably resulting in faster processing times. Only the longest four of the six TOMS wavelengths are used based on a review of deviations of linearity in large SO2 and ash loadings at the shorter wavelengths.

The most error-prone SO2 retrievals are from very fresh major eruption plumes filled with water aerosols, sulfate, ash, sulfur dioxide, and other ejecta. The TOMS observations have shown that these situations persist only from hours to a couple of days as the ash falls out from the gas cloud and drifts away with the underlying wind field. After that the retrieval is much simpler given a nearly Raleigh-scattering atmospheric column. The MS_SO2 algorithm adds a Step 2 retrieval that is used when when the early complex plume conditions are detected by co-located large SO2 anomalies and high AI values. In this case the ozone is specified by interpolation across the cloud rather than computed, like the original SO2 algorithm.

Sect. 4.2 Systematic errors. . .

This paper estimates the retrieval errors due to lack of information about the height of the plume through modeling of the dependence of the Jacobians on plume height. The UV radiances contain no direct information about the height of the plume, so the uncertainties due to a wrong height assumption are important. They appear to be reasonably small except for high latitude plumes. However, a reference to non-existent Tables 1,2, and 3 needs to be corrected.

Sect 4.2.2. The aerosol sensitivity analysis using an OSSE is a useful tool for characterizing the range of linearity for the retrieval. Curiously both sulfate and absorbing aerosols produce the same negative deviations suggesting that non-Rayleigh scattering is more important than absorption.

Sect. 5. Comparison with PCS SO2 retrievals.

“Validation” of the MS_SO2 data with results from a new TOMS-adapted PCA algorithm seems to be a stretch. A “comparison” of results is certainly appropriate. However, this is not a validation in the usual sense of the word because the TOMS PCA algorithm is not itself validated. The hyperspectral PCA algorithm is well documented, and it should be straightforward to verify that the TOMS-PCA version produces the same result for an eruption covered by both multi-spectral and hyperspectral instruments. If there is documentation on this new 5 PC algorithm and data then it should be referenced. Or, if the changes can be shown to be inconsequential that should be stated. The authors should consider documenting the new PC algorithm is it does not already exist.

Having said that, the agreement between data from the two discrete band algorithms is impressive. This brings up new questions: What are the reasons to prefer one algorithm over the other? Is the MS_SO2 algorithm the best for processing the dataset?

Sect 5.1 Pinatubo eruption. Figure 11 shows AI maps that are not very useful due to confusion with unrelated dust clouds. Which are the ash clouds? It would be more useful to overlay SO2 images with AI images as that would illustrate the separation of the two eruption components.

Specific comments:

p11, line 20. ....in which large O3 anomalies.... do you mean large SO2 anomalies? On the next page you refer to either SO2 > 15 DU ... or AI > 6. Please check for consistency.

p 12, line 6. "Step 2" instead of step 2. Note the other cases in the same section where "Step" is not capitalized.

p 18, line28. Tables 1, 2, and 3 do not exist.

p 21, line11. delete “an” in "The no aerosol case confirms an unbiased SO2 retrievals...".

p 22, line22. Define SLER.

Appendix

P 2, line 10. Eqs. (15a,b) could not be found.

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