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PROFILE SHAPE DEPENDENCE IN BACKSCATTERED ULTRAVIOLET SATELLITE RETRIEVALS OF TOTAL OZONE

S.L. Taylor, C.J. Seftor, C.G. Wellemeyer, K. Klenk
Hughes-STX Corporation

R.D. McPeters
Goddard Space Flight Center

ABSTRACT

Total ozone operational algorithms use climatological mean ozone profiles. When the actual ozone profiles have significantly different shapes versus the climatology and the solar zenith angles are large, retrieved total ozone will have an error. Recalibrated SBUV profiles are used to estimate this error. Preliminary results suggest that, on the average, the change and variation in significant profile shapes can to a large degree be estimated by the SBUV derived profiles. Preliminary results suggest the average error in the report algorithm ozone trend (trend in reported ozone) from profile shape is relatively small during the north hemisphere winter (less than 2 percent) for solar zenith angles less than 82 degrees (for 60 degrees North Latitude).

1. INTRODUCTION

Present operational algorithms, which derive total ozone from backscattered ultraviolet (BUV) satellite measurements, use tables of theoretical directional albedos (earth-view radiances / solar irradiances). The tables are computed from climatological mean ozone profiles that vary only with changes in total ozone and latitude. At high solar zenith angles, when the actual atmospheric ozone profile differs significantly from the assumed table profile, there can be errors in the derived ozone (Klenk, et al, 1982).

Present operational algorithms derive ozone for pairs of channels (A using 313 and 331 nm, B using 318 and 331 nm, B-prime using 318 and 340 nm and C using 331 and 340 nm). At high solar zenith angles A-pair is the most sensitive to profile shape differences and C-pair the least sensitive. Thus, as solar zenith angles increase, the derived total ozone is based less on A-pair and more on B or B-prime-pair. At the very highest solar zenith angles, the derived total ozone is based mostly on the C-pair. Using recalibrated (Version 6) Nimbus 7 SBUV data to give difference in profile shape, this paper shows examples of estimated error for algorithm pair ozone error and reported total ozone.

2. ALGORITHM ERROR FROM DIFFERENCES IN PROFILE SHAPE

An example of pair ozone algorithm error sensitivity to differences in ozone profile at specific atmospheric levels (Umkehr Layers) is shown in Figure 1. Figure 1 gives algorithm pair ozone error in percent for a percent difference between the actual and the algorithm climatology. For example, if the actual ozone in only Umkehr Layer number 6

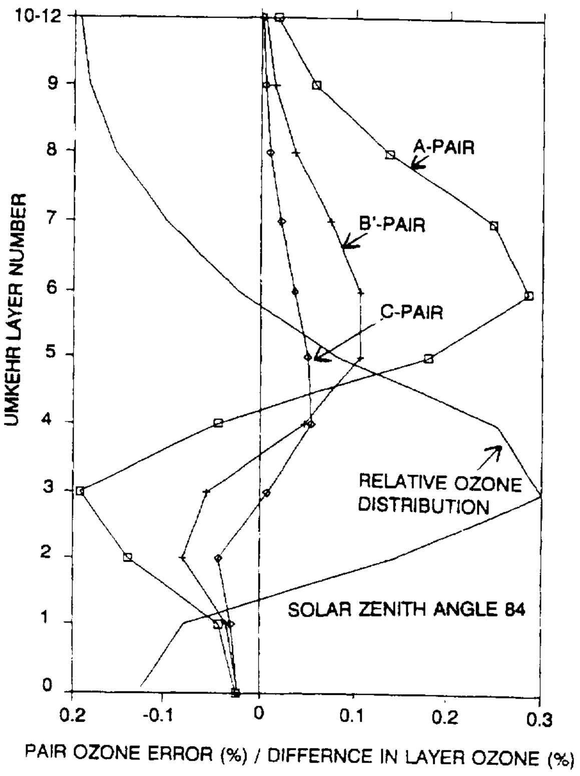

Figure 1. Algorithm pair zone Error (percent) for a percent difference in actual layer ozone from algorithm climatological ozone.

differs from the table assumed ozone by 10 percent, the error in retrieved A-pair ozone is 2.8 percent (0.28 from the x-axis times 10 percent). Likewise, the error in B-prime-pair is less at 1.0 percent (0.1 time 10 percent). Figure 1 shows that differences in profile ozone for layers above Umkehr Layer 3, the algorithm pair ozone overestimates the difference. For layers below layer 3, the algorithm pair ozone underestimates the difference. An algorithm pair error is estimated by summing the products for each layer sensitivity times the difference in ozone (SBUV profile minus algorithm climatology).

Figure 2 shows the algorithm derived Total Ozone error for differences in an Umkehr Layer ozone for a range of solar zenith angle conditions. The reported ozone error

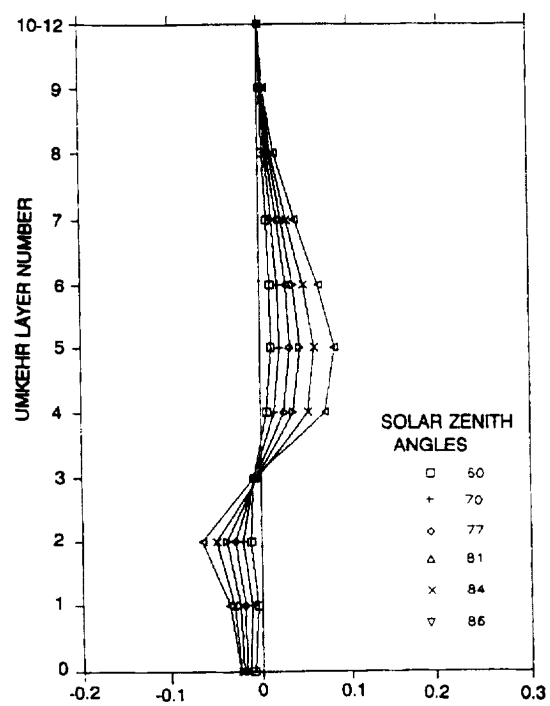

Figure 2. Algorithm reported ozone error (percent) for a percent difference in actual layer ozone from algorithm climatological ozone.

sensitivities for solar zenith angle 84 in Figure 2 are considerably reduced compared to the A and B-prime-pair in Figure 1 because derived ozone at 84 solar zenith angle is mostly based on C-pair.

3. CALCULATION OF ALGORITHM ERROR USING SBUV PROFILES

The recently recalibrated Nimbus 7 SBUV provides profile information generally in the range of Umkehr Layers 5 to 9. SBUV derived profile information for the lower layers are overall based on the SBUV derived total ozone with climatological assumptions defining the distribution in Layers 1 through 4. At high solar zenith angles, ozone in Layer 1 and 2 is not part of the total ozone measurement unless there is a highly reflecting surface below this ozone (i.e. snow or ice).

The error in derived pair ozone is estimated by first taking the difference of the an SBUV profile layer minus algorithm climatology layer and then multiplying this difference times the respective layer error sensitivity. The products for all layers are summed to give the an estimated error in derived pair ozone. This partial derivative calculation is reasonably accurate provided 1) the differences in the profiles are not larger than about 20 percent, 2) the solar zenith angle is less than approximately 82 degrees for the A-pair and 3) the solar zenith angle is less than approximately 86 degrees for the B-pair.

4. EXAMPLE RESULTS

Figure 3 shows the estimated algorithm A, B and C-pair ozone trend error in Dobson Units (DU) versus year for February between 55 and 65 degrees north latitude. As

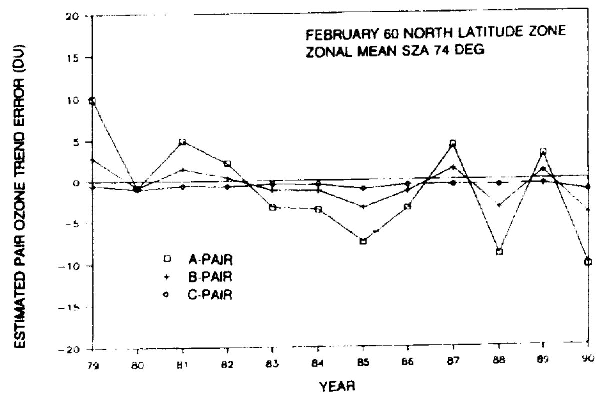

Figure 3. Estimated algorithm pair ozone trend error for February between 55 and 65 degrees latitude.

predicted by the sensitivities, A-pair shows the largest variation and more trend (overall slightly negative) compared to B-pair. Likewise, B-pair shows more variation and more trend than the C-pair. Figure 4 shows the corresponding change in SBUV layer 5, 6 and 7 ozone from the respective 12 year average. The pattern in these ozone layers is very

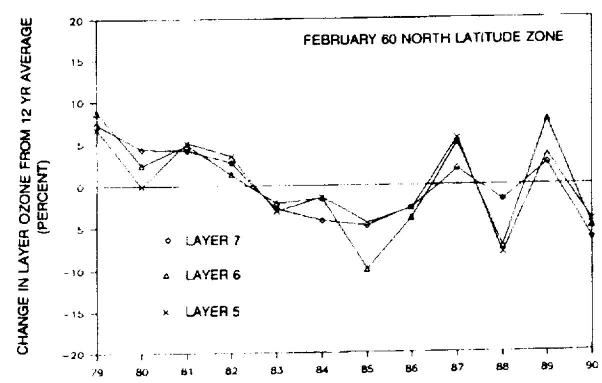

Figure 4. Change in layer ozone from 12 year average for February between 55 and 65 degrees latitude; Layers 5, 6 and 7.

close to the pattern of estimated errors in Figure 3. However, overall the pattern of layer ozone changes above layer 7 and below layer 5 are different and do not closely track the pattern of estimated errors. As shown in Figure 1, the sensitivity to ozone differences is relatively small above layer 7. Likewise, at or near the maximum ozone concentration (layer 3 in Figure 1), the sensitivity is small. However, just above and just below the ozone maximum concentration, there are significant sensitivities where the SBUV retrieved profile does not have the corresponding detailed shape information.

Figure 5 shows the difference in A-pair minus B-pair ozone errors from Figure 3. Figure 5 also shows the difference in SBUV algorithm A-pair minus B-pair which very closely

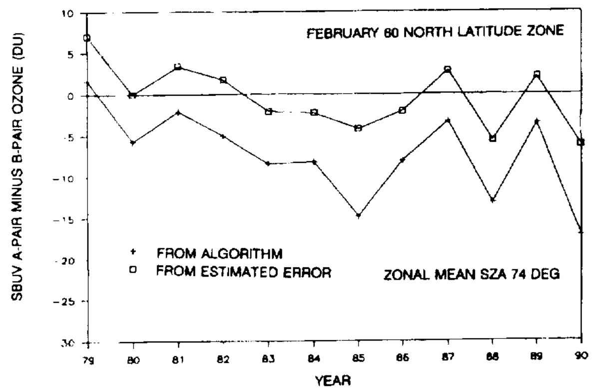

Figure 5. SBUV A-pair minus B-pair ozone; from algorithm versus from estimated algorithm error; February Between 55 and 65 degrees latitude.

parallels with the estimate A-pair minus B-pair error difference. The offset between the algorithm and estimated trend errors is probably due to an absolute calibration error and certain algorithm seasonal errors which do not significantly affect the long-term trends. The close parallel structure of pair differences (estimated error parallel to algorithm) for this example suggest that on the average the bulk of the actual atmospheric profile changes that affect the A and B-pair are "seen" by the SBUV retrieval for layers 5 through 7.

Figure 6 shows estimated errors in reported ozone computed from pair errors in Figure 3. Average values for this weighting are given in Figure 6. Overall, the data in Figure 6 suggest the possibility of a small negative trend. However,

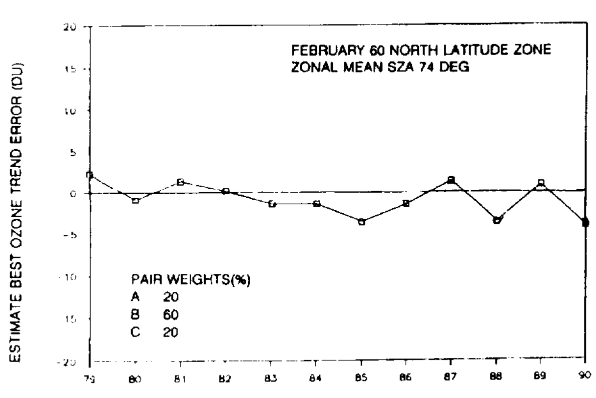

Figure 6. Estimated SBUV reported ozone trend error; February between 55 and 65 degrees latitude.

the SBUV data from 1988 through 1990 is preliminary data because of degraded instrument performance (chopper wheel out-of-sych) starting in March 1987. This data has not been archived. Investigations are continuing to define impacts on data accuracy before the data is archived. Data previous to March 13, 1987 have been archived at the National Space Science center.

The above example has an average solar zenith angle of 74 degrees. Figure 7 shows the A-pair minus B-pair results for an example with a larger average solar zenith angle of 82 degrees (January from 55 to 65 degrees north latitude). As with first example, the algorithm A-pair minus B-pair closely

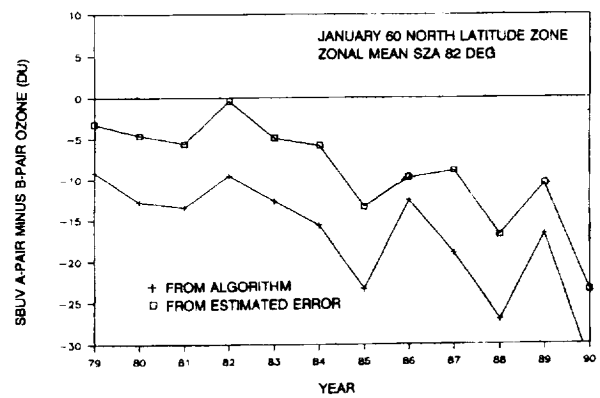

Figure 7. SBUV A-pair minus B-pair ozone; from algorithm versus from estimated algorithm error; January between 55 and 65 degrees latitude.

parallels the estimated A-pair minus B-pair error from profile shape differences (largest exception in 1986). This solar zenith angle is the upper limit of estimating A-pair error from profile shape differences using the partial derivative calculation.

The example in Figure 7 and other examples with the larger solar zenith angle conditions often have large trends in estimated A-pair and B-pair errors from profile shape differences as indicated by the corresponding A-pair minus B-pair differences. However, even with these large A-pair and B-pair errors, the estimated reported ozone errors are not particularly large, as shown in Figure 8 for the second example. At the larger solar zenith angles, there is less

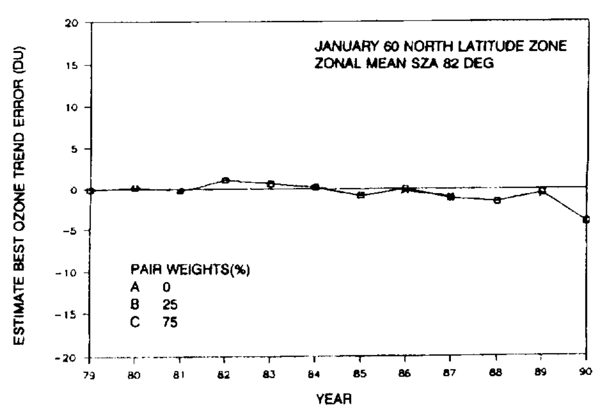

Figure 8. Estimated SBUV reported ozone trend error; January between 55 and 65 degrees latitude.

weighting of the pairs that are sensitive to actual atmospheric changes in profile shape.

5. CONCLUSION

Preliminary analysis suggest that the average change and variation in profile shapes, that cause errors in algorithm derived pair ozone trends, can to a significant degree be estimated by the SBUV derived profiles. Limited examples, plus additional examples not shown in this paper, suggest the average error in the report algorithm ozone trend from profile shape is relatively small during the north hemisphere winter (less than 2 percent) for solar zenith angles less than 82 degrees (for 60 degrees north latitude).

6. FUTURE PLANS

Characterize errors in reported Nimbus 7 SBUV and TOMS derived total ozone at large solar conditions from differences in profile shape using SBUV profiles.

This preliminary analysis only address the error in ozone trends from changes of profile shapes as defined by the recalibrated SBUV profiles. The absolute errors from profile shape and other absolute errors sources is presently being addressed. For a particular latitude, the total absolute error will change as the solar zenith angle changes from month to month.

REFERENCES

Klenk, K.F., Errors due to Profile Shape in the Derivation of Total Columnar Ozone From Nadir Measurements of the Solar Backscattered Radiance, NASA Contract No. NAS5-24416, March 1979.