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Effect of Partially-Clouded Scenes on the Determination of Ozone

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Abstract

Differences in wavelength pair ozone values determined from Backscattered Ultraviolet (BUV) instrument measurements are directly correlated with scene reflectivity which, in turn, is a function of scene cloudiness. At low solar zenith angles (overhead sun), maximum discrepancies between pair values of 2 to 3 percent are seen for reflectivities of 50 percent. These discrepancies are believed to be due to algorithmic behavior and imply a mean error in the final derived ozone of approximately 5 percent for cases of 50 percent reflectivity. Results using a new algorithm show a significant decrease in pair discrepancy and, therefore, in the error of the final derived ozone.

1. Introduction

The calculation of total ozone from BUV instruments combines the measurements of total ozone from three different wavelength pairs.[1] Ideally, the difference in measurements between individual wavelength pairs should not be systematic in nature and should not exhibit any structure. The presence of systematic differences may indicate initial calibration errors while the presence of structure may indicate limitations in the current ozone retrieval algorithm. In this paper a correlation is demonstrated between differences in pair ozone and effective reflectivity. This correlation indicates an inability of the current algorithm to accurately model partially-clouded scenes to the one percent level. An alternate technique to more accurately model these conditions is proposed and results are presented.

2. Current Algorithm

Figure 1 shows the difference (in Dobson Units, DU) between total ozone determined from the A pair (312.5 nm and 331.2 nm) and from the B pair (317.5 nm and 331.2 nm) as a function of reflectivity for the SBUV instrument onboard the Nimbus-7 satellite.

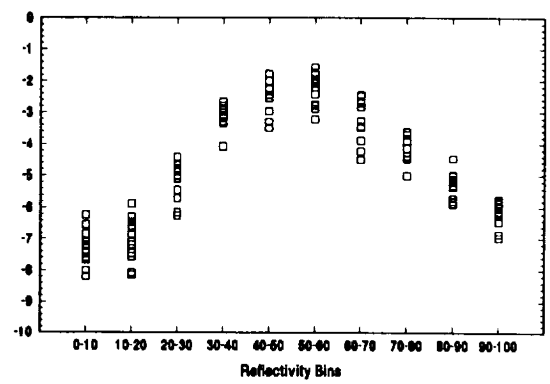

Figure 1: Ozone difference between A and B pair for current algorithm. Data is for a latitude band from 5 degrees south to 5 degrees north.

Reflectivity has been divided into 10 bins of 10 percent width. Each open square represents a monthly average of all data between 5 degrees south and 5 degrees north latitude for November, 1980 through October, 1981.

An overall systematic offset, possibly due to initial calibration errors, is seen along with a strong correlation with reflectivity and, therefore, percent cloudiness of the scene. A similar correlation can be seen in the AC and BC pair differences and for different latitude bands. This correlation leads to a 2-3 percent discrepancy in the AB pair difference for middle reflectivity situations at the equator (the percent discrepancy varies between pairs and decreases with increasing latitude). The similarity of low reflectivity (minimally clouded) differences with high reflectivity (fully clouded) differences calls into question the current method used by the algorithm to deal with middle reflectivity (partially clouded) situations.

The technique currently used to model partially-clouded scenes is based on radiative transfer models and uses measured radiances to determine ozone values for pressures of 0.4 and 1.0 atmospheres. The algorithm then uses an estimated effective scene pressure to mix these two ozone values to obtain a final value. The effective scene pressure is determined using the following formula:

$$P = (1-w)P_{cloud} + wP_{terrain}$$

where P_{cloud} is the cloud-top pressure, $P_{terrain}$ is the terrain pressure, and w is a weighting function that is based on measured surface reflectivity. The weight is set to unity for a reflectivity less than 20 percent, zero for a reflectivity of greater than 60 percent, and is obtained by a linear interpolation as a function of reflectivity for intermediate values. Terrain pressures are determined from terrain heights available from the National Oceanic and Atmospheric Administration Meteorological Center. Cloud-top pressure is estimated from an empirical climatology based on studies using THIR measurements:

$$P_{cloud} = 0.3 + 0.15[1-\cos(2 \times latitude)].$$

3. Proposed Algorithm

Rather than mixing two table-derived ozone values, a proposed technique derives and mixes albedos (radiance divided by irradiance) in an attempt to more accurately reflect the physical processes occuring in the atmosphere. Table radiances are used to determine these albedos for both the terrain and cloud level, and an effective percentage cloud cover is estimated and used to perform the mixing:

$$A = fA_{terrain} + (1-f)A_{cloud},$$

where $A_{terrain}$ and A_{cloud} are the terrain and cloud-top albedos, respectively and f is the percentage cloud cover factor. The ozone is then determined from the resulting albedo value.

A simulation of both algorithms was performed using radiances calculated with a radiative transfer model. In the simulation the irradiance is chosen to be unity so that the albedos are given by the radiances. The terrain pressure was assumed to be 1 atmosphere and the cloud-top pressure was assumed to follow the THIR climatological model. For the proposed algorithm, reflectivity was used as the percentage cloud cover factor. The AB pair difference was then calculated for both algorithms. The difference in this result between the two algorithms as a function of reflectivity is shown in Figure 2. Both the shape and magnitude of the structure closely matches the shape and magnitude of the structure seen in the Figure 1.

The proposed algorithm was then used to determine the pair difference for Nimbus-7 SBUV data from November 1980 through October 1981. In the calculation of the terrain albedo the terrain pressure is used and a surface reflectivity of 10 percent is assumed. In the calculation of cloud albedo the above empirical formula is used to determine the cloud-top pressure and a cloud

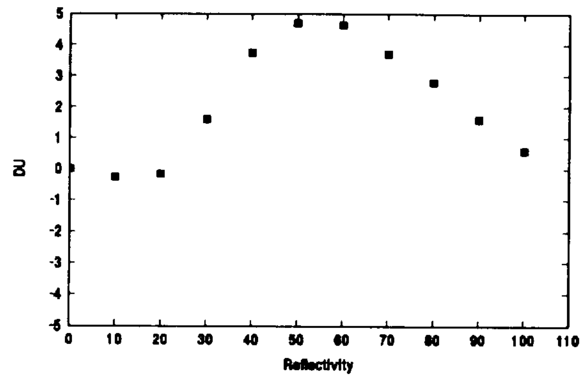

Figure 2: The difference in the AB pair difference between the application of the two algorithms.

reflectivity of 86 percent is assumed.

The effective percentage cloud cover is estimated using the measurements from the photometer onboard the Nimbus-7 satellite. Using the photometer measurement, an albedo is calculated for the terrain situation (using the terrain pressure and a reflectivity of 10 percent) and for the cloud-top situation (using the cloud-top pressure and a reflectivity of 86 percent). The measured photometer albedo is then used to determine the effective percentage cloud cover:

$$f = \frac{A_{cloud} - A_{measured}}{A_{cloud} - A_{terrain}}.$$

Results are shown in Figure 3. The structure seen in the current algorithm is no longer present, leaving a constant offset which is probably due to initial calibration errors. Figures 4 and 5 show A pair and B pair ozone, respectively, for both algorithms. A difference of up to 20 DU (approximately 5 percent) in ozone can be seen between the two algorithms. Since most ozone retrieval measurements take place for low reflectivity situtations (below 30 percent), the actual errors in pair measurement will be less.

4. Conclusions

The use of current ozone retrieval algorithms used for BUV-type instruments leads to errors of up to 5 percent in individual pair ozone measurements for partially clouded scenes. Simulation studies have led to the development of an alternative method to deal with these situations. Application of the proposed algorithm on real data indicates a significant decrease in the error.

Future refinements of the proposed algorithm will concentrate on more accurate determinations of cloud reflectivity, more accurate determination of percentage cloud cover, and the problems associated with ozone retrievals over snow or ice.

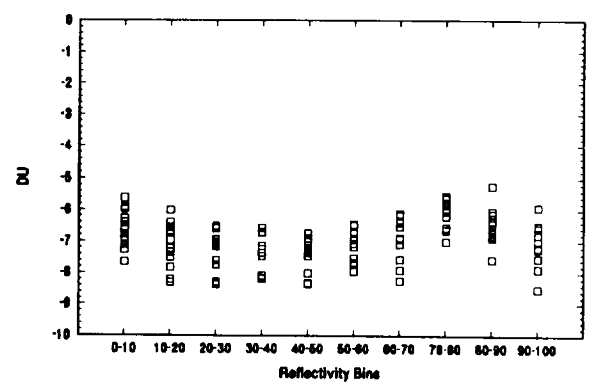

Figure 3: Ozone difference between A pair and B pair for the proposed algorithm.

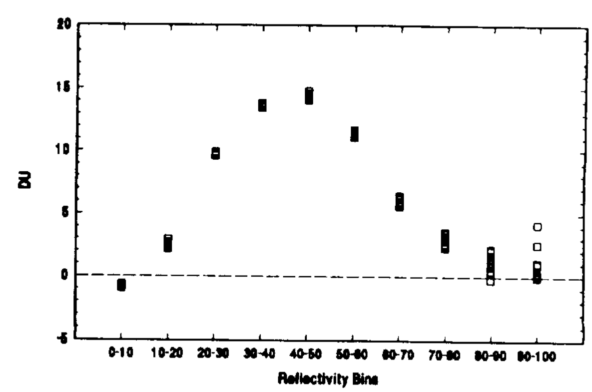

Figure 4: The difference in A pair ozone between the current and the proposed algorithm.

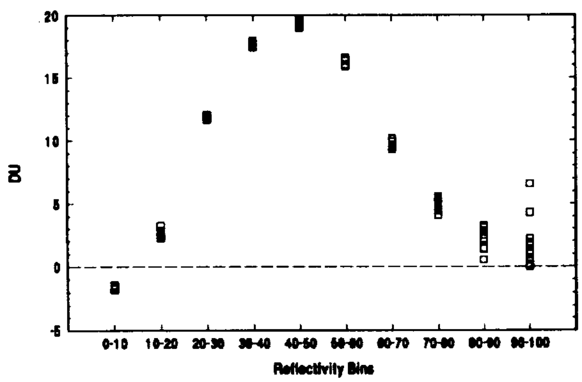

Figure 5: The difference in B pair ozone between the current and the proposed algorithm.

4. References

1. Klenk, K.F., et.al., "Total ozone determination from the Backscattered Ultraviolet (BUV) experiment, *J. Appl. Meteor.*, *21*, 1672-1684, 1982.