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# Total Ozone Variations 1970–74 Using Backscattered Ultraviolet (BUV) and Ground-Based Observations

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## ABSTRACT

The most long-lived satellite set of ozone observations, to date, is that derived from the Backscatter Ultraviolet (BUV) ozone sensor on Nimbus 4 and extends from April 1970 through 1976. Unfortunately, this experiment suffered spacecraft power limitations which limited the spatial and temporal coverage and also appears to have suffered from long-term drifts which may be associated with changes in the instrument characteristics or the incident solar flux. We have developed techniques to account for these problems and our purpose here is to present results of the BUV total ozone variations and compare them with those from ground-based observations, specifically the computations of Angell and Korshover (1978).

After adjustments for the spatial gaps and comparison with concurrent Dobson ground-based observations, no significant trend was found in the BUV data over the years 1970–74. This finding is in contrast to a general decrease of ~2% during the same period appearing in the data of Angell and Korshover. The difference in these results is discussed in terms of the geographic sampling and the methods of hemispheric integration.

## 1. Introduction

With the threat of a possible anthropogenic influence on atmospheric ozone (e.g., National Academy of Sciences, 1979; NASA, 1979), significant emphasis has been placed on evaluating the available long-term total ozone measurements. The longest ozone records are those from the ground-based Dobson and M-83 instruments which tend to be grouped among the major continental areas with significant areas effectively unsampled. Thus, the question of global representativeness arises and, recently, Miller *et al.* (1979a) have presented evidence that this sampling bias can result in erroneous decadel trends of several percent.

More recently, emphasis has been placed on the use of satellite data. While several systems have been utilized in the past, the most long-lived experiment to date has been the Backscatter Ultraviolet (BUV) experiment on Nimbus 4 from April 1970 through 1976. The basic measurement technique has been described by Mateer *et al.* (1971). From these data, monthly average hemispheric analyses have been constructed and area average ozone calculated. Unfortunately, though, the Nimbus 4 experiment suffered from two severe limitations that have raised questions on the determination of ozone trends from these data. The first is that the experiment diffuser plate, which allows the solar flux measurements to be made at precise wavelengths, degraded within several months after launch in a possibly wavelength-dependent manner. Hence, any variations in time of the ozone determinations are dependent on the relative accuracy of the presumed to the actual solar fluxes and on the long-term stability of the instrument characteristics. Consequently, such variations must be judged against other available data such as Dobson, Umkehr, rocketsondes, etc. The second limitation is that the solar panels on the Nimbus spacecraft also suffered degradation in time resulting in limited power, which in turn limited the time the experiment could be on and, hence, the spatial coverage of the data.

For this paper techniques have been developed to account for these problems and our purpose here is to present results of the BUV total ozone variations and compare them with those from the ground-based observations, specifically the computations of Angell and Korshover (1978). The results indicate a significant difference in the trend as determined from BUV and Angell and Korshover which indicates the difficulty in arriving at true values.

## 2. BUV spatial coverage

In terms of depicting a monthly average total ozone field, the representativeness of the field de-

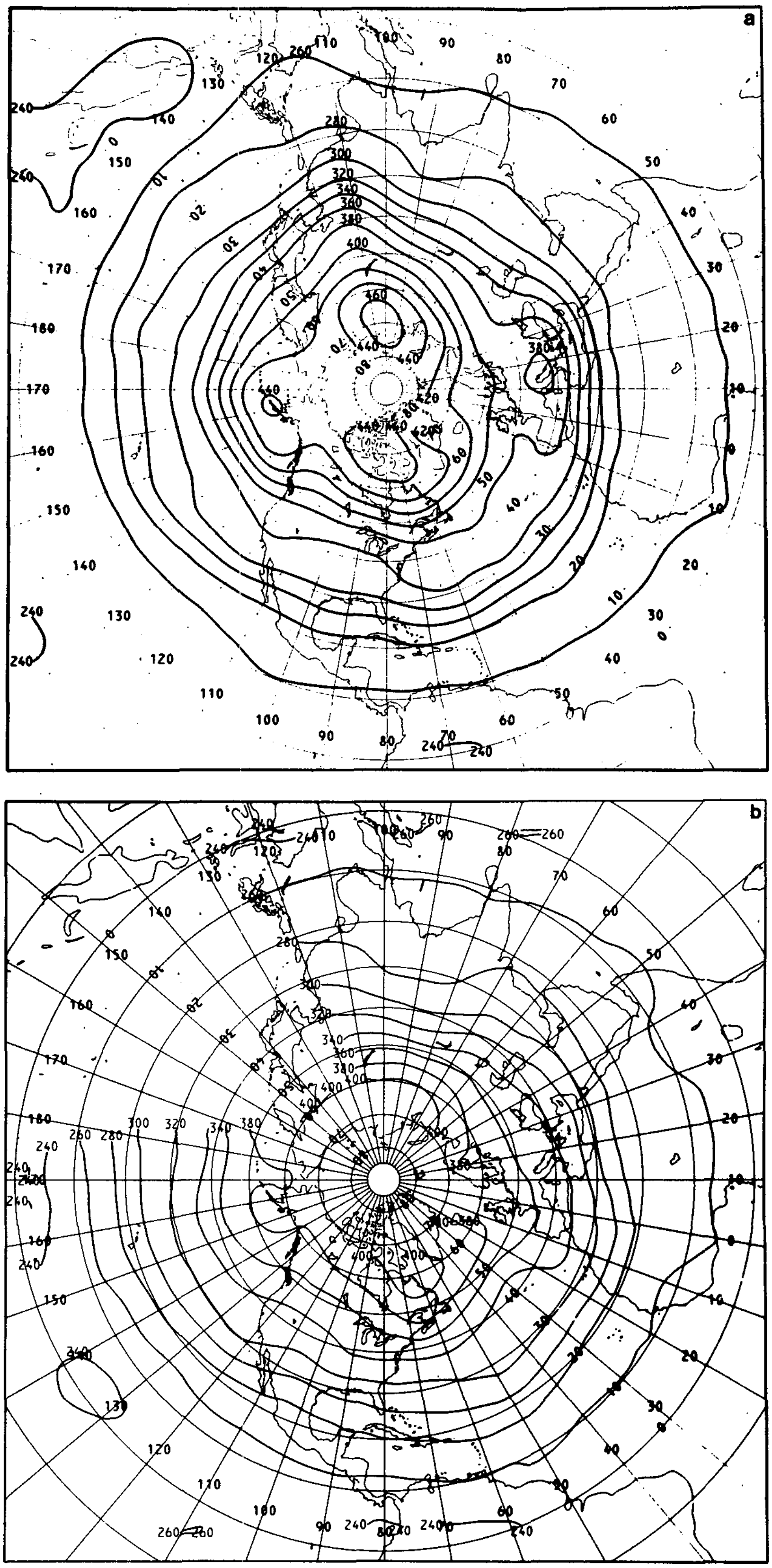

FIG. 1. Monthly average, Northern Hemisphere, BUV total ozone (Dobson units) analyses for (a) May 1970, (b) May 1972, (c) May 1973 and (d) May 1975.

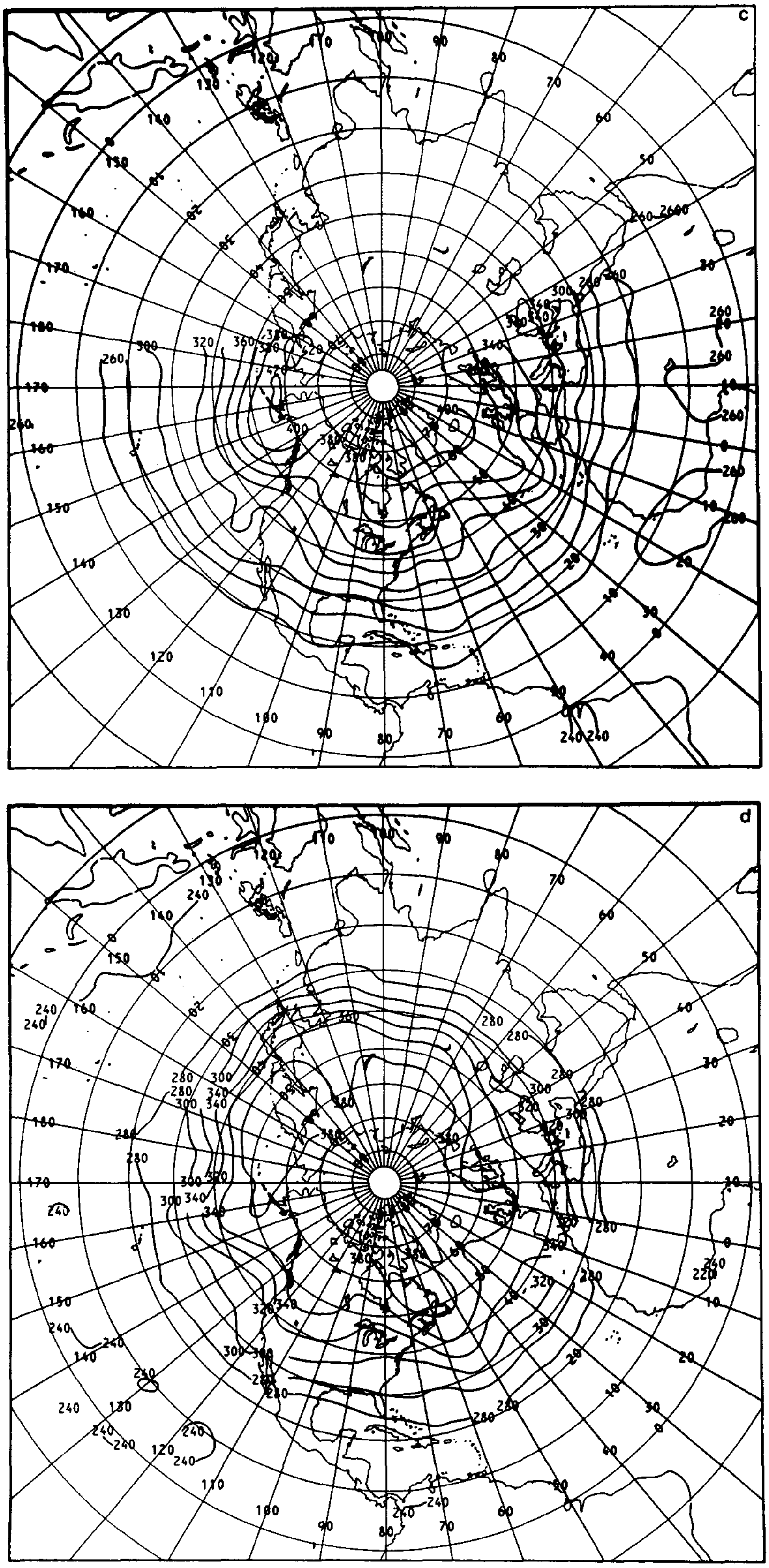

FIG. 1. (*continued*)

TABLE 1. Average total ozone-100 mb height correlation, May–December 1970.

| Latitude (°N) | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
|---|---|---|---|---|---|---|---|---|---|
| Correlation | −0.59 | −0.78 | −0.84 | −0.82 | −0.73 | −0.72 | −0.75 | −0.71 | −0.64 |

pends, of course, on the quality of the data, the number of data points and its spatial coverage. The quality of the BUV data has been presented by Mateer *et al.* (1971) and Miller *et al.* (1979b,c) and, along with the number of data points, will be discussed further below. Here, the emphasis is on the spatial coverage. As mentioned in Section 1, spacecraft power degradation in time limited the number of soundings available on a daily basis, which was reflected in the area coverage. This is shown in Figs. 1a–d which depict monthly average analyses for May 1970, 1971, 1973 and 1975. The greater coverage in 1975 over 1973 was the result of a decision to spread the limited operation of the spacecraft over a greater area.

Clearly, we see that the limited coverage presents a substantial problem in depicting a "true" area average and our approach is to utilize the available meteorological information and its general correlation with the total ozone as a means of estimating the impact of the ozone data gaps. Specifically, we utilize the well-recognized relationship between total ozone and 100 mb height fields (e.g., Ohring and Muench, 1960; Reed, 1950; Miller *et al.*, 1979a) in the following statistical estimation of sampling error.

We assume a linear relationship of the form

$$\hat{O}_3 = a + b(H - \bar{H}) + \epsilon, \qquad (1)$$

where $\hat{O}_3$ is the total ozone, $H$ the 100 mb height available from the National Meteorological Center, $\bar{H}$ the average over the data and $\epsilon$ the random error. This regression is calculated for each monthly average field at 5° latitude increments (10° longitude grid); in all cases, the calculation was done over the actual domain of the ozone data (the meteorological fields were not limited spatially), but with a lower latitude limit of 20°N. This value was chosen on the basis of the increased noise of the meteorological fields at lower latitudes and that we would not expect the dynamical height-ozone relationship to extend into the tropical domain.

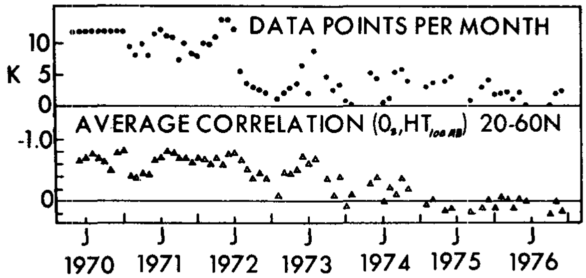

FIG. 2. Number of BUV data points (thousands) per month available for Northern Hemisphere analysis (top) and average monthly correlation, 20–60°N, between BUV total ozone and NMC 100 mb height fields.

Given values of $a$ and $b$ within the data region, this relationship is extended into the ozone gap region to compute an average estimated value as

$$\bar{O}_3^{\text{gap}} = (\hat{O}_{3_1} + \hat{O}_{3_2} + \cdots \hat{O}_{3_N})/N, \qquad (2)$$

where $\hat{O}_3$ is the ozone amount at 10° longitude increments estimated in the data gap region via Eq. (1). This is then averaged, weighted by area, with the average in the original data domain.

In the tropical belt, 0–20°N, where the longitudinal variance of total ozone is relatively small (e.g., Crosby *et al.*, 1980), the measured average ozone value is utilized. Finally, integral values for the region 0–60°N are calculated for both the non-adjusted and adjusted data.

The degree to which we can have confidence in this technique is dependent on how well the ozone and 100 mb height data are correlated. The average correlation for May–December 1970 is shown in Table 1 as a function of latitude. This period is chosen for presentation as the spatial coverage is virtually complete and, hence, provides the best estimate of the correlation. A more detailed view of the correlation on a daily and monthly basis will be the subject for a future paper and here we simply state that the daily correlations are quite consistent with the monthly values presented here. We see from Table 1 that the correlation ranges from −0.59 to −0.84 which means that we can account for about 36–71% of the ozone variance from the 100 mb heights. Also, the latitudinal variation of the correlation is such that the average correlation, 20–60°N, is a reasonable statistic to examine the long-term consistency of the correlation and this is presented in Fig. 2 along with the number of data points per month for the Northern Hemisphere.

Looking first at the monthly number of data points, we see that up to about June 1972, the number is quite substantial, about 8–12 K, but drops precipitously in July. This was due to the failure of one of the solar panels on the spacecraft. Following this, the number appears to decline in a slower manner. The impact on the average correlations is shown in the lower portion of the figure where we see that, apart from January 1973, the correlation holds somewhat steady, between −0.5 and −0.8, up to July 1973, is reduced to ~ −0.3 through 1974 and is near zero in 1975 and 1976. As the correlation is computed over the domain of the ozone data, our interpretation of the above is that through July 1973 (again January 1973 apart), the coverage is sufficient to provide a meaningful data set where it was obtained. After that, the coverage tends to be spread out in space, but at the cost of achieving a representative value of the monthly average at a point. Utilizing the correlation coefficient as an index, then, it appears that we should not use the data beyond 1974 in a trend determination and should be somewhat careful of the data from mid-1973 through 1974. In particular, the months of very low correlation (January, October, December 1973, January, June and August 1974) should be used with extreme caution. Note also that either because the meteorological analyses were not available or the ozone values did not extend from 0–60°N, the months of April 1970, December 1972, August 1973, January–March 1974 and November–December 1974 are not included.

In Table 2 we show for May 1972 and May 1973 (maps shown in Fig. 1) the total ozone-100 mb height correlation by latitude and the difference between the zonal average with the regression in the data gap included, and the zonal average without. We see that the correlations for each month are quite comparable with the averages presented in Table 1. In particular, we note the consistency of the correlation in 1973 within the very limited spatial domain. The adjustment is, of course, much larger in 1973 than in 1972 with the former as large as 9 Dobson units and all latitudes of the same sign.

The effect of averaging the adjusted total ozone over the region 0–60°N is shown in Fig. 3 in which is plotted the monthly average ozone with and without the adjustment for the data gaps. We see that, in general, the integrated adjustment is rather small through 1972, but can be up to about 7 Dobson units in 1973. From Table 2, however, it is clear that the area averaging process smoothes out individual latitudinal adjustments that can be quite substantial or alternating in sign.

TABLE 2. Correlation coefficient and difference (Dobson units) of zonal average ozone with regression in data gap minus zonal average ozone without for May 1972 and 1973.

| Latitude (°N) | May 1972 |  | May 1973 |  |
|---|---|---|---|---|
|  | Correlation | $O_3$ | Correlation | $O_3$ |
| 60 | −0.92 | +1.3 | −0.76 | −2.6 |
| 55 | −0.89 | +2.1 | −0.88 | −1.3 |
| 50 | −0.90 | +1.1 | −0.82 | −1.6 |
| 45 | −0.81 | +0.2 | −0.59 | −3.3 |
| 40 | −0.81 | −1.1 | −0.73 | −9.0 |
| 35 | −0.82 | −1.9 | −0.76 | −8.7 |
| 30 | −0.72 | −2.3 | −0.75 | −6.6 |
| 25 | −0.68 | −1.6 | −0.78 | −6.2 |
| 20 | −0.40 | −0.5 | −0.59 | −1.4 |

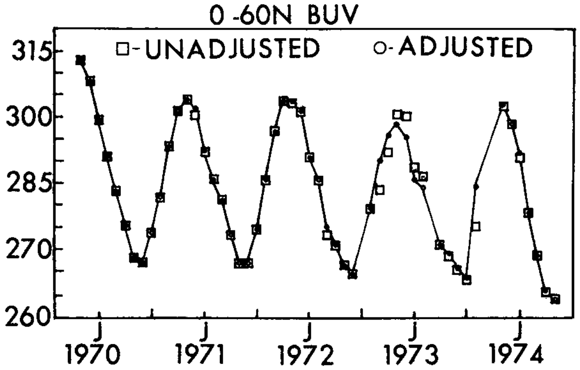

FIG. 3. Monthly average BUV total ozone (Dobson units) integrated over domain 0–60°N, unadjusted and adjusted for spatial gaps.

Using the above regression technique to estimate the impact of the data gaps, we can also estimate the error that this entails. From Eq. (1) (Hald, 1952) the variance of the ozone estimate, $v\{\hat{O}_3\}$, can be estimated from

$$v\{\hat{O}_{3_i}\} = v\{a\} + v\{b\}(H_i - \bar{H})^2 + S^2, \qquad (3)$$

where

$$S^2 = \sum_{j=1}^{k} (O_{3_j} - \hat{O}_{3_j})^2/(k-2),$$

$$v\{a\} = S^2/k,$$

$$v\{b\} = S^2/\sum_{j=1}^{k} (H_j - \bar{H})^2.$$

and $k$ is the number of observations.

The variance of the average ozone estimate in the gap region [Eq. (2)] is given by

$$v\{\bar{\hat{O}}_3^{\text{gap}}\} = \frac{1}{N'}\sum_{i=1}^{N} v\{\hat{O}_{3_i}\},$$

where $N'$ is less than $N$ to account for the serial correlation of $\hat{O}_{3_i}$ in longitude. After consideration of the spatial scales and the 10° longitudinal resolution within our methodology, we have used $N' = N/3$.

Physically, the implication of Eq. (3) is that the greater the correlation, the smaller the variance, but for a given level of correlation the larger the departure of the individual 100 mb height in the gap from the mean, the greater the variance. The confidence of the adjustment, then, depends on both the general level of correlation and the wave pattern in the domain of missing data. The results are shown in Fig. 4, where the variance is plotted for each month. We see that in the early part of the record, when the coverage is virtually complete, the variance is quite low. February 1971 is an exception that appears to be due to a somewhat larger data gap than surround-

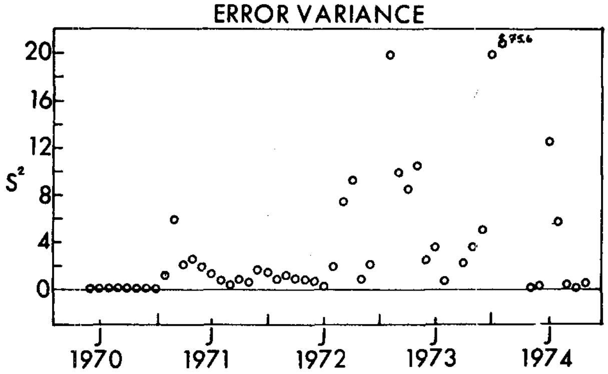

FIG. 4. Estimated monthly error variance in BUV Northern Hemisphere integrals (Dobson units) 0–60°N (see text).

ing months. By late 1972, the impact of the coverage starts to have a major effect and this continues through the rest of the period. The four very high variances, greater than 12, are associated with very low correlations, e.g. <0.15.

Within the domain of the actual ozone measurements, the variance of the average is dependent on the random noise of the BUV data (~2.5%), the number of data points (*NN*), and the possible incomplete sampling of shorter-scale and traveling wave patterns (~1%) (Federal Coordinator for Meteorological Services and Supporting Research, 1981; Miller *et al.*, 1979c). On a percentage basis, then,

$$v\{\bar{O}_3^{\text{measured}}\} = \frac{6.25}{NN} + \frac{1\%}{30(\text{days})} \qquad (4)$$

and the variance of the final zonal average is determined by appropriately weighting the measured (converted to Dobson units) and the gap region.

Finally, the variance of the integrated area (0–60°N) is determined by appropriately weighting each latitude and using the measured variance as the estimate below 20°N in the gap region. To allow for latitudinal correlation in the estimate only four independent values were assumed.

Both the correlation and the variances indicate the degree of confidence that we can have in the monthly ozone data and will be examined further below in discussion of the temporal trend in the data.

## 3. BUV data calibration

As mentioned above, with the degradation of the instrument diffuser plate, it was clear that any variations in the BUV ozone data would have to be judged against other available data such as Dobson observations. A detailed paper on the individual Dobson-BUV comparisons is currently in preparation and should be available shortly. Here we will focus on the collective aspects and the impact on trend detection. It should be recognized at the outset, however, that as Dobson and BUV measure radiation in different wavelength bands and both require knowledge of the ozone absorption coefficients within these bands, we might anticipate some difference between the two measurements.

In Fig. 5 we show the difference, Dobson minus BUV, for each Dobson station averaged over the period April–December 1970. Each point represents one Dobson station and Boulder (B) and Arosa (A) have been delineated along with their 95% confidence limits. On average, each station includes about 40–50 matchups with BUV, a matchup defined when the BUV data point was within ~2° latitude, longitude of the Dobson site. The Dobson measurements are usually taken near local noon, which is very close to the BUV overpass time.

The very large scatter among the stations is a continuing feature of the comparisons and is felt to reflect, in most cases, the substantial inter-station differences that have been found to occur in Dobson instrument calibration. Such scatter puts a severe limitation on the precision with which we can compare the BUV in time and, if these are calibration effects, they can be expected to be only slowly varying in time.

When a plot similar to Fig. 5 is examined for 1974, we see that a general shift in the overall level of the differences occurs, but the scatter between stations is as great as in 1970. The question, then, is how to compare the Dobson and BUV data in time to resolve this difference. Our approach is to examine the monthly average comparisons for each station through the period of record, 1970–76, utilizing a statistical regression approach. Initially, it was suggested that a model of the form

$$\Delta O_3 = a_0 + a_1\lambda + a_2T + a_3\lambda * T \qquad (5)$$

be employed where $\Delta O_3$ is the bias, Dobson minus

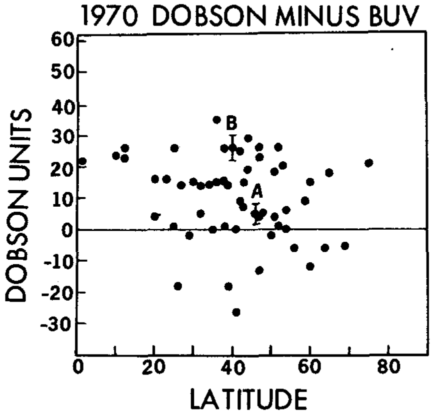

FIG. 5. Annual average, 1970, of Dobson minus BUV at each Dobson station as a function of the absolute value of latitude. Each dot represents one station: B is Boulder, Colorado and A is Arosa, Switzerland along with their 95% confidence limits.

BUV, $\lambda$ the absolute value of latitude in degrees and $T$ time in months.

This was applied to the collection of monthly average Dobson station differences (in Dobson units) from April 1970 to December 1976 with the results

| | Estimate | Standard error | MSE (mean square error) |
|---|---|---|---|
| $a_0$ | 18.495 | 1.77 | |
| $a_1$ | −0.207 | 0.041 | 242.38 |
| $a_2$ | 0.118 | 0.043 | |
| $a_3$ | 0.00104 | 0.00101 | |

The argument is quite strong, then, that both a latitudinal and temporal trend exist in the data, but there is little statistical support for a latitudinal dependent time change. As an added test, the above regression was also made with the $\Delta O_3$ differences in percent ($\Delta O_3/\mathrm{BUV}$). The results were very similar.

Inspection of the residuals from regression (1), however, did suggest an annual cycle in the results and this was then added. Using a model of the form

$$\Delta O_3 = a_0 + a_1\lambda + a_2T + a_3\lambda * T + a_4 \cos\frac{2\pi T}{12} + a_5 \sin\frac{2\pi T}{12}, \quad (6)$$

the results were as follows:

| | Estimate | Standard error | MSE |
|---|---|---|---|
| $a_0$ | 17.94 | 1.76 | |
| $a_1$ | −0.211 | 0.041 | 238.41 |
| $a_2$ | 0.140 | 0.043 | |
| $a_3$ | 0.000961 | 0.001 | |
| $a_4$ | 3.05 | 0.468 | |
| $a_5$ | −0.254 | 0.435 | |

Here the annual cycle does appear significant and, once again, the cross-product term does not.

On the basis of the above, the statistical regressions were computed without the cross-product terms where the results were as follows:

$$\Delta O_3 = a_0 + a_1\lambda + a_2T + a_3 \cos\frac{2\pi T}{12} + a_4 \sin\frac{2\pi T}{12}. \quad (7)$$

| | Estimate | Standard error | MSE |
|---|---|---|---|
| $a_0$ | 16.647 | 1.12 | 238.40 |
| $a_1$ | −0.179 | 0.023 | |
| $a_2$ | 0.179 | 0.0137 | |
| $a_3$ | −3.055 | 0.4678 | |
| $a_4$ | −0.246 | 0.434 | |

Finally, we considered two time variations other than linear. The first was the addition of a $T^2$, $T^3$ variation and the second was a jump in June 1972 when a solar panel failed and the instrument operation was changed. The results for the former are

$$\Delta O_3 = a_0 + a_1\lambda + a_2T + a_3T^2 + a_4T^3 + a_5 \cos\frac{2\pi T}{12} + a_6 \sin\frac{2\pi T}{12}. \quad (8)$$

| | Estimate | Standard error | MSE |
|---|---|---|---|
| $a_0$ | 16.59 | 1.71 | |
| $a_1$ | −0.18 | 0.02 | 236.01 |
| $a_2$ | 0.014 | 0.14 | |
| $a_3$ | 0.009 | 0.004 | |
| $a_4$ | −0.000091 | 0.000031 | |
| $a_5$ | −2.62 | 0.48 | |
| $a_6$ | −0.30 | 0.43 | |

These results suggest that most of the time variation is accounted for by the second and third order terms so that neglecting the first order term results in

$$\Delta O_3 = a_0 + a_1\lambda + a_2T^2 + a_3T^3 + a_4 \cos\frac{2\pi T}{12} + a_5 \sin\frac{2\pi T}{12}. \quad (9)$$

| | Estimate | Standard error | MSE |
|---|---|---|---|
| $a_0$ | 16.718 | 1.103 | 235.91 |
| $a_1$ | −0.176 | 0.023 | |
| $a_2$ | 0.009 | 0.0009 | |
| $a_3$ | −0.000094 | 0.000012 | |
| $a_4$ | −2.62 | 0.469 | |
| $a_5$ | −0.304 | 0.432 | |

Finally, including a jump in 1972 results in:

$$\Delta O_3 = a_0 + a_1\lambda + a_2\delta(T) + a_3 \cos\frac{2\pi T}{12} + a_4 \sin\frac{2\pi T}{12}. \quad (10)$$

| | Estimate | Standard error | MSE |
|---|---|---|---|
| $a_0$ | 19.523 | 1.04 | |
| $a_1$ | −0.186 | 0.023 | 239.49 |
| $a_2$ | 7.92 | 0.629 | |
| $a_3$ | −2.275 | 0.460 | |
| $a_4$ | 0.435 | 0.433 | |

The residuals from all of the above regressions were plotted as a function of latitude and time with little evidence of any additional effects that should be included. Actual adjustments for Eqs. (7), (9) and (10) are plotted in Fig. 6 in addition to the yearly adjustment calculated without the latitudinal dependence (Miller *et al.*, 1979b).

Of the three time variations, there is little statistical evidence to insist on one versus the other, with

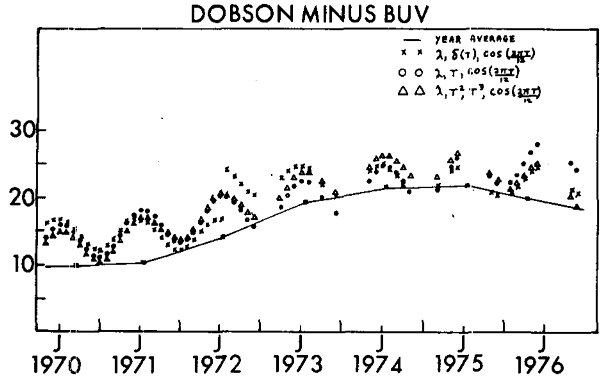

FIG. 6. Monthly adjustments (Dobson units) to BUV data based on the three techniques for time variation. In addition, solid line is that based on the yearly average data with no latitudinal effect.

the Dobson-BUV bias change ~8 Dobson units over the comparison period. The large significance computed for the latitudinal variation appears much greater than would be suggested by Fig. 5 and is most likely due to the serial correlation in the Dobson data and the effect of the few tropical stations. The actual statistical significance of this latitudinal bias may be questioned, then, but as this is a constant factor and does not influence the time variations we have included it as computed above.

As there is little rationale to insist on one adjustment over another, we carry out all further comparisons of the BUV time variations using all three adjustment factors [Eqs. (7), (9) and (10); hereafter referred to as $T$, $T^2$, $T^3$ and $\delta(T)$].

## 4. BUV temporal variability

From the discussion above and Figs. 2 and 4, it is clear that all BUV monthly average ozone values were not created equal and that we must assign a confidence factor to each month. By custom, this might be the correlation coefficient divided by the error variance. However, because of the distribution of the BUV data, such a weighting factor gives unduly large weight to the first eight values in 1970 when the coverage was greatest. Consequently, we have approached the problem in a different manner.

Following the discussion above concerning the correlation coefficient (Fig. 2), the data set can logically be divided into two series, 1970 to mid-1973 and 1970 to October 1974, and in the following we treat each data record separately. Within each record, certain months stand out as particularly low correlation coefficients or as particularly high error variance. Rather than try to develop a non-standard weighting function we have chosen to eliminate those values with a correlation less than 0.15 or an error variance greater than 4. Thereafter, each remaining value is considered with equal value. Undoubtedly, this is only one of many possible procedures, but given the type and quality of the data, seems to be a reasonable approach.

As the most general ground-based total ozone record against which to compare the BUV results is that from Angell and Korshover (1978), we have attempted to make the BUV data comparable by deseasoning it in a manner similar to Angell and Korshover. That is, for each month we subtract the 1970–74 average for that month and convert it to percent by dividing by the average value. Angell and Korshover employ a seasonal average versus our monthly average, but this should not be of major consequence.

A first consideration, however, is the evaluation of our decision not to include certain monthly data and in Fig. 7 we show the impact of this choice. For clarity, we show only the monthly average percent departure with the Dobson-BUV adjustment from Eq. 7. The circles represent the data that has passed our criteria for consideration, the triangles those that have been excluded. Basically, we see that, overall, the impact of the excluded data on a trend analysis would probably be slight.

In Fig. 8 we show the monthly average BUV data for each of the three adjustments with time. As we would expect from the previous discussion of Fig. 6, the largest disparities are in the late 1972–early 1973 time frame when the $T$ and $T^2$, $T^3$ adjustments smooth through the period of the time jump. Also, the $T^2$, $T^3$ values have lower values in 1970, 1971 and higher values in 1974. Included, in addition, in this diagram are the seasonal values from Angell and Korshover for this same period. We note that Angell and Korshover (A&K) have very kindly recomputed their data to reflect the 0–60°N integration area of the BUV. For comparison purposes we have normalized their results to the 1970–74 period by subtracting the time average. In many respects the BUV

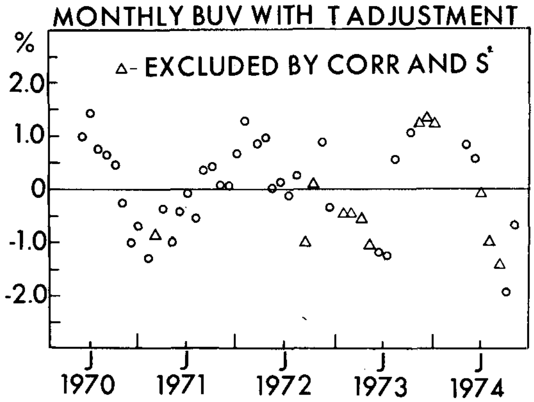

FIG. 7. Monthly average (percent) integrated (0–60°N) BUV total ozone data. Triangles are those data points excluded by the correlation and/or error variance criteria (see text).

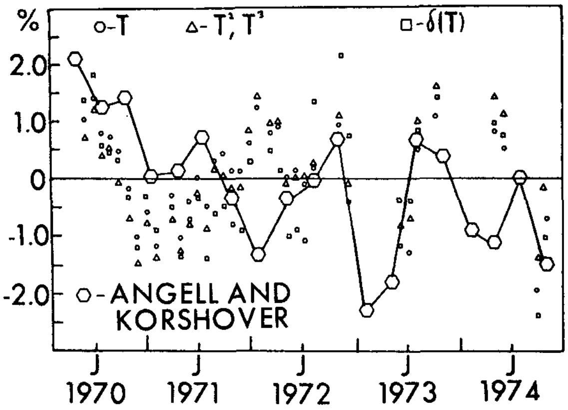

FIG. 8. Monthly average (percent) integrated (0–60°N) BUV total ozone data adjusted by the three techniques to fit the Dobson matchups. Also included are the integrated (0–60°N) seasonal values from Angell and Korshover.

and Angell and Korshover (A&K) curves show similar behavior, but large discrepancies exist in the winter of 1971–72 and spring 1974 (no BUV data in early 1973), with BUV greater than A&K, suggesting a possible ground-based sampling difficulty during these periods. This is supported by the results of Miller *et al.* (1979a). At the same time, the tendency is for the A&K curve to lie above the BUV in the early years and below in the later years. This suggests a difference in trend between the data sets and is the subject for discussion below.

In order to quantify the above differences, we have applied a linear trend analysis to both the three sets of BUV data and the A&K data for the two time periods 1970–73 and 1970–74. The results are listed in Table 3 where the trend is of the form

$$O_3 = A + B(T - \bar{T}), \qquad (11)$$

and the curves are shown in Figs. 9 and 10.

TABLE 3. Linear time trend analysis of total ozone data from Angell and Korshover (A&K) and the three adjusted data sets of BUV.

| | $A$ | Standard error ($A$) | $B$ | Standard error ($B$) |
|---|---|---|---|---|
| *1970–73* | $O_3 = A + B(T - \bar{T})$ | | | |
| A&K | 1.8429 | 0.267 | −0.063 | 0.022 |
| BUV ($T$) | 0.060 | 0.035 | −0.018 | 0.013 |
| BUV ($T^2$, $T^3$) | −0.093 | 0.147 | 0.0037 | 0.015 |
| BUV $\delta(T)$ | −0.100 | 0.175 | −0.004 | 0.0174 |
| *1970–74* | | | | |
| A&K | 1.6474 | 0.219 | −0.042 | 0.013 |
| BUV ($T$) | 0.0528 | 0.134 | −0.011 | 0.0091 |
| BUV ($T^2$, $T^3$) | 0.0083 | 0.145 | 0.010 | 0.010 |
| BUV $\delta(T)$ | −0.072 | 0.172 | −0.0026 | 0.012 |

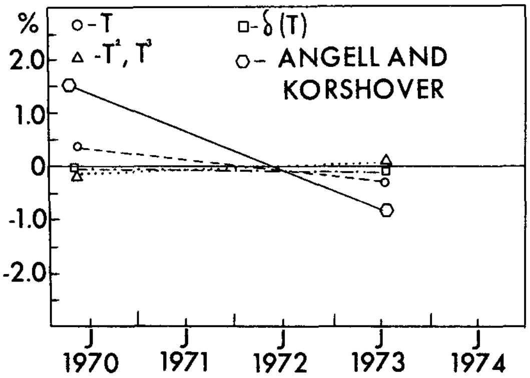

FIG. 9. Linear trend regression curve fit to the three adjusted BUV integrated data sets and to the data of Angell and Korshover for the period mid-1970 to mid-1973.

We see from Table 3 that the BUV trend with time ($B$) is not significantly different from zero for either time period or for any of the three adjusted data sets. This is in contrast to the A&K results that include a downward trend significant at the 95% confidence level. It is of interest that Miller *et al.* (1979a) in their separate analysis of the ground-based sampling problem at 50°N suggested that the A&K calculations show an artificial decrease in the 1970–74 time period of ~1%. While the above analysis was restricted to the mid-to-high latitude region, the results agree in sign, although of slightly smaller magnitude, with the present computations. This, then, supports the idea that at least part of the difference in BUV and A&K is associated with the ground-based sampling.

As a further test of the sensitivity of our trend results, we computed the BUV linear trends with all data included (no exclusion for low correlation, etc.) with no significant difference in results which suggests that we have not biased our results by discarding particular data points.

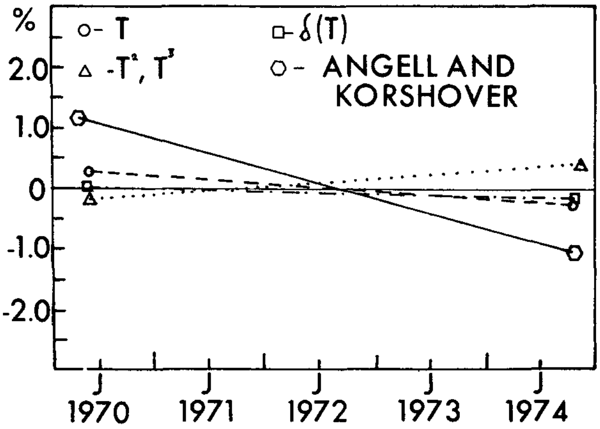

FIG. 10. As in Fig. 9, but for the period mid-1970–74.

## 5. Final remarks

To the extent that there is no net drift with time in the Dobson total ozone data ensemble used to normalize the BUV data, no significant trend was found in the Northern Hemisphere total ozone burden for the 1970–74 time period. This is in contrast to a general decrease of ~2% over the same period as found by Angell and Korshover from the ground-based data.

It should be recognized, however, that the Angell and Korshover numbers are a result of their particular technique of data assimilation. For example, given the substantial gaps in the spatial coverage of the ground-based data, the methodology used to weight the specific observations to *estimate* the hemispheric integral can be critical and is non-unique. In fact, other schemes have been mentioned in the literature (e.g., Hill *et al.*, 1977) and it is possible that over a particular period any one technique, by chance, does better than another. Over a longer period, however, the basic problem of inadequate sampling still exists and any technique must inevitably suffer. The results presented here, then, which indicate a substantial difference in the ozone trend as determined from BUV and Angell and Korshover, should be considered as indicative of the magnitude of the problem.

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