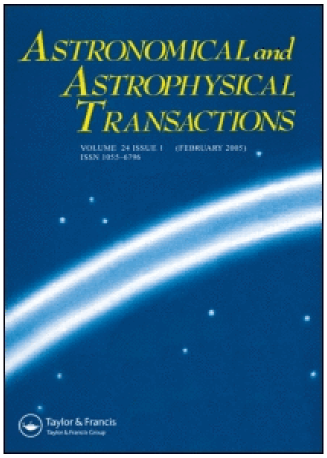


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# SEASONAL AND LONG-TERM VARIATIONS IN THE ATMOSPHERIC EXTINCTION IN CRIMEA ON THE BASIS OF THE 1979–2002 OBSERVATIONS

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Seasonal and long-term variations of atmospheric extinction are investigated using several observational programmes in standard *UBV* photometric system during 24 years (about 1300 measurements for 592 nights). The seasonal curve has a wide maximum from the end of March up to the middle of September and a narrower minimum from the middle of November to the beginning of February. These features are connected apparently with motions of the air masses due to the global atmospheric circulation. In summer there is an additional narrow maximum, which is more strongly expressed in ultraviolet. It is connected apparently to enhanced content of dust. On average, the values of extinction coefficients for $V$, $B$ and $U$ are equal to 0.19, 0.35, 0.74 magnitudes at minima and 0.43, 0.65 and 1.12 at maxima respectively. The scatter of individual values is very great; during any season, almost from the minimally possible (Rayleigh scattering) up to approximately twice the average maximum. All numerical values correspond to extinction on clear nights since they are obtained from the measurements of stars. The relation between the long-term variations and the cycles of solar activity is very weak. However, some improvement in transparency which probably is connected to the decrease in industrial emissions in the atmosphere in adjoining territories, has been recorded in the last 7–9 years.

*Keywords*: Atmospheric extinction; Astronomical climate

## 1 INTRODUCTION

During 24 years in the Crimean laboratory of the Sternberg Astronomical Institute (SAI), different programmes of ultraviolet ($U$)–blue ($B$)–visible ($V$) observations demanding the use of precision photoelectric standards have been carried out. Basically, observations of low-amplitude variable stars, reference stars for satellite programmes, stationary stars with the purpose of confirming the constancy of their brightness, and stars of solar type have been made. There are few suitable precision standards; therefore it was necessary to measure stars at significant angular distances from these standards, always determining the factors of atmospheric extinction. During 24 years, astronomical observations have provided, at first sight, 'a by-product', namely, a transparency of the atmosphere above Crimea on clear nights and the character of its changes. However, this could be useful to astronomical observers and also interesting for the geophysicists engaged in studying the terrestrial atmosphere.

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Besides our work, a few investigations of extinction coefficients were made in Crimea. Basically astroclimatic research has been directed towards measurements of the visibility and brightness of the sky background. The first data on atmospheric transparency were published by Zajtseva and Lyuty (1973). Then the results received during the first 7 years of our work (Voroshilov and Metlov, 1986) were published. In the 1970s and 1980s, researchers at SAI also carried out similar investigations in the SAI observatory near Alma-Ata (Moshkalyov and Khaliullin, 1985).

Our 24 year investigations, firstly, cover two whole cycles of solar activity, secondly, include the time when there was the powerful eruption of a volcano which has appreciably increased the dust contents at the higher levels in the atmosphere and thirdly, include the period in which, most probably, over extensive territories adjoining Crimea there was an appreciable reduction in emissions in the atmosphere of the products of human activity because of recession in industrial production that occurred in many countries of the former USSR and eastern Europe in the 1990s.

## 2 OBSERVATIONS

The photon-counting *UBV* photometer developed by Lyuty (1971) was used in all our observations. Each night of observations had excellent sky conditions, with stable and good atmospheric transparency, and with no clouds or inhomogeneous haze up to the horizon. These requirements were required by both the programmes of observations and the method of obtaining the transparency of the atmosphere: quasisimultaneous observations of several (most often two) pairs of stars with a difference in air masses of 1–2 were used. Stars in each pair had close spectral classes. Standard stars from the high-precision *UBV* system of the photoelectric standards determined earlier by Khaliullin *et al.* (1985) were used. Every night a number of transparency measurements (between one and seven, but usually two or three) were made.

The total extinction coefficients result in the magnitudes $A = -2.5\, lg(p)$, where $p = I/I_o$ is the transparency factor, that is the ratio of radiation flux $I$ in the given spectral band reaching the observer to the extra-atmospheric flux $I_o$. The coefficients $A$ were reduced to a single air mass in the zenith and to the spectral class A0V (Zdanavichus, 1975). They were determined almost always in three bands, but occasionally in one $V$ or in two ($V$ and $B$), hands. The accuracies of the coefficients $A_V$, $A_B$ and $A_U$ (in the $V$, $B$ and $U$ bands) are not worse than 0.01, 0.01 and 0.02 respectively.

The procedure of measurements of sufficiently bright stars and standards (up to fourth $V$ magnitudes) and the following reduction to the standard *UBV* system was described by Kolotilov and Metlov (2000). However, one should note the following. The above-mentioned system of standards employed by Khaliullin *et al.* (1985) contains $R$, $V$, $B$ and $W$ magnitudes. We used only the $V$ and $B$ values from that system, while the $U$ values were taken from the BS catalogue.

## 3 DATA REDUCTION

According to our data, essential (of 1.5 times or more) changes of a transparency during a night occur seldomly, in several per cent of cases. Therefore all measurements within a night were averaged, and only average values for every night were used further. The next analysis (revealing the seasonal and long-term changes) cannot be made by simple averaging of the data: for every month in each of 24 years, for every year, etc. This is caused by the following circumstances revealed even in the preliminary analysis.

(i) Measurement runs are extremely non-uniform owing to non-uniformity of the distribution of time allocated to our observations and different degrees of stability of weather during different seasons. There are series of measurements of up to ten sequential nights and also on separate nights; the maximal interval between sequential nights of observations is more than half a year. In some years almost all observations were executed during one season (for *e.g.* with poor transparency); therefore their averaging would not correspond to an annual average.
(ii) The transparency can change very strongly within several days, and sometimes (approximately 10% of cases) during a day. During a season with poor transparency, nights occur when the extinction coefficients correspond to the best for a good season (*i.e.* are almost equal to the values caused by Rayleigh molecular scattering and absorption in the ozone layer). During a good season the lowest values of transparency correspond to the average for a poor season.
(iii) Sometimes there are series of several sequential nights with a transparency strongly different from the average. Such series of nights (and sometimes one separate night) can provide all the available observations in the given month.
(iv) There are transition seasons, in which the coefficients $A$ almost always change sharply and in one direction: growth in March and decrease at the end of September and October.
(v) Quite often fast autumn improvement in the transparency happens earlier, but in different years it occurs at various times: from the beginning of August up to the end of September. As a result the files containing all data show a very large dispersion on a background of smooth improvement in transparency at this time.

Taking into account all the above list, the following method of data processing is chosen.

To study seasonal changes, phase curves with a period of 1 year for $A_V$, $A_B$ and $A_U$ are constructed.

To research long-term changes, the deviation of separate points from the obtained seasonal phase curves, but not average for every year values of an extinction, is analyzed.

In both cases the following are used as points:

(a) average values for one night:
(b) average values for 10 day or $1/3$ months periods or, to be more accurate, from the first up to the tenth day of each month, from the eleventh up to the twentieth day of each month, and from the twenty first up to the last date of each month.

Then phase curves were obtained by averaging points in the phase intervals equal to $1/3$ month. Variants (a) and (b) give, within the limits of uncertainties, similar results. The variant(a) contain too many points merging on graphs near to average values, and some points, on the contrary, have too large a scatter. Therefore the variant (b) is given further in all figures.

## 4 RESULTS, ANALYSIS AND DISCUSSION

### 4.1 Seasonal variations

Figures 1(a), (b) and (c) show the seasonal variations in extinction coefficients in the $U$, $B$ and $V$ bands, respectively. For convenience of consideration and comparison of three graphs they are constructed as follows. The intervals of values on the ordinate axes are identical everywhere and equal to a magnitude of 1. The minimal $A$ values located on the abscissa axis approximately correspond to the values of extinction coefficients caused by average Rayleigh scattering for a height of 600 m above sea level and absorption in an ozone layer (from the data obtained by Allen (l977)). The full circles show the average values in each corresponding $1/3$ month during all the 24 years, if any observations in one or more nights took place. Open circles and the curve connecting them are average values of the calculated phase curve for intervals of $1/3$ month; the solid curve is the result of their averaging adjacent values. Total number of observational nights during each month in the 24 years is also given.

In Figure 2 the results are generalized so that they can be used. The average (over intervals of $1/3$ month) values of extinction in the $U$, $B$ and $V$ bands, together with their uncertainties, and results of averaging adjacent values given. All 592 nights of observations during 1979–2002 are included.

From examination of Figures 1 and 2 the following is seen. If only the $U$ band itself is examined also the $B$, variation in the extinction could be approximated by a smooth increase in the spring, thus the wave at the end of March, April and in the beginning of May is not significant extinction at the beginning of May. However, in the $V$ band this wave is significant; thus the probability of such deviations from the obtained curve which would allow linear growth from March until June is less than 0.003. The reason for this becomes clear if to take into account that the extinction increases d$A$ from January to April in all three spectral bands are comparable ($\mathrm{d}A_V = 0.17$, $\mathrm{d}A_B = 0.19$, and $\mathrm{d}A_V = 0.22$), and from April to the end of July these increases are much more strongly expressed in the short-wave area ($\mathrm{d}A_V = 0.06$, $\mathrm{d}A_B = 0.09$ and ($\mathrm{d}A_U = 0.15$). It appears that the wave in the spring is usually accompanied considerably by a smaller reddening in comparison with the wave in July and August. As a result, on a background of points with a large scatter, it is judged that the spring wave in $U$ ostensibly is not significant. However, taking into account the result in $V$ and that all this is caused by quite physical reasons, it is necessary to recognize this wave really exists in all three $U$, $B$ and $V$. The physical reasons are these: in the summer in the atmosphere there is more dust (reddening), but humid aerosols prevail in the spring; they result in haze and ground fogs from particles of larger sizes, causing more neutral absorption of light.

The following interpretation of the results represented in Figure 2 is possible. On all averaged curves the wide maximum approximately from the second half of March up to the middle of September, and also an additional narrow maximum from the second half of June up to the middle of August are seen. The second maximum is expressed more in the short-wave area, that is apparently connected to the dust content of the atmosphere. It is interesting that, according to our data, the maximum temperature in the small town of Nauchny and in the SAI Crimean laboratory is observed on average at the end of July or at the beginning of August, the same as the almost 100 years of data for the city of Simferopol (Logvinova, 1976). The greatest quantity of thunderstorms is observed only a little earlier (June and July), apparently owing to a reduction in the moisture content in the atmosphere in August. All this testifies that the vertical convection in the atmosphere at this time occurs more strongly in comparison with other seasons of year. Accordingly, atmospheric aerosols including dust are distributed at higher atmospheric levels. All this is easily visible in the summer when, because of convective instability, deep cumulonimbus clouds with very highly located tops are quite often formed, thunderstorms are observed, the atmospheric haze is very dense, and the sky in the afternoon looks whitish and at night appear very hazy, even when all the clouds are dissipated.

Thus, a narrower maximum caused by absorption by the dust and coincident in phase with the maximum in the temperature curve is imposed on the wide spring-and-summer maximum centred at the date of the summer solstice and caused by the directions of moving air masses in global atmospheric circulation.

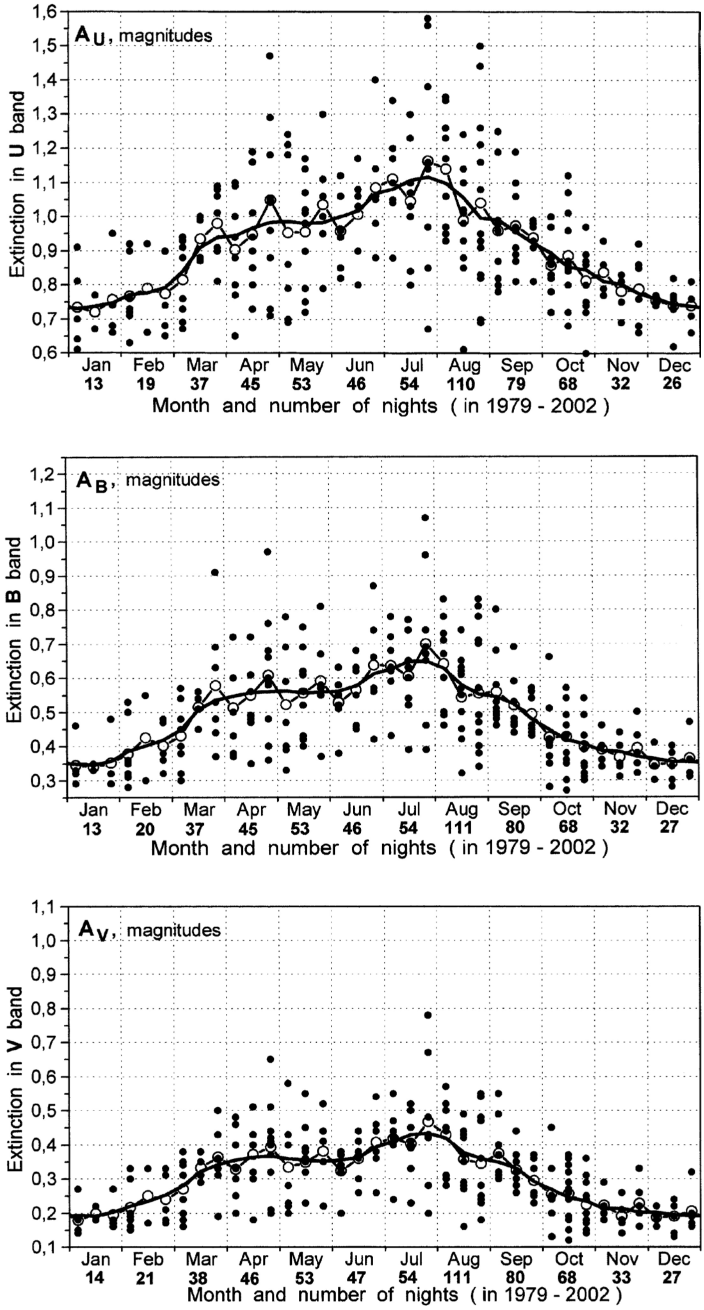


FIGURE 1 Seasonal variations in extinction coefficients for the (a) *U* band, (b) *B* band and (c) *V* band: •, all available individual 1/3 month values during the total 24 years; ○ average phase curve for intervals; result of adjacent averaging. The number of observational nights in each month is given for the total 24 years.

The minimal values of extinction are observed in December–January, and in the short-wave spectral region it occurs later than in the long-wave region.

It should be noted also that the distinction between the winter and summer values of extinction coefficients calculated by Zajtseva and Lyuty (1973) turned out to be underestimated

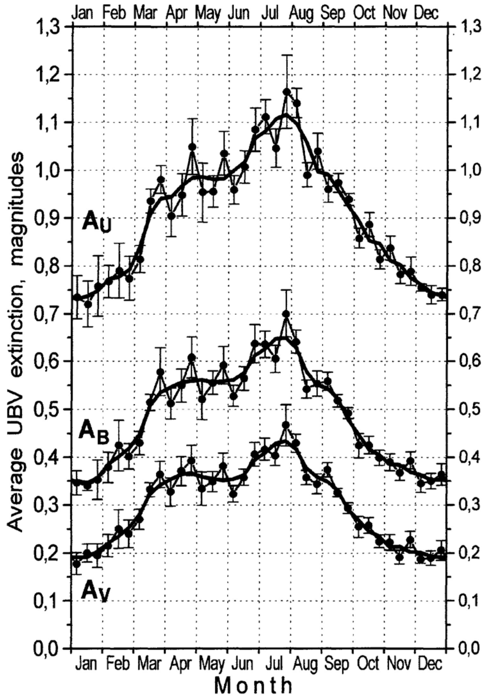


FIGURE 2 Average (for intervals of 1/3 month) values of extinction in the U, B, and V bands, with their uncertainties, and results of adjacent averaging. All 592 observational nights in 1979–2002 are included.

for the reason that the changes in transparency during different seasons have not been well investigated. The winter months have been taken to be December–March, and the summer months June–September. This has essentially gathered together the winter and summer values of an extinction obtained at such averaging, as seen from Figure 2.

The average extinction coefficients for the period 1979–2002 are given for each month in Table I (averaged values for each night were used to calculate standard deviations and standard errors). The first column shows the months, the second to fourth columns give the $A_V$, $A_B$ and $A_U$ average values respectively, the fifth column list the standard deviations SD($A_V$) of $A_V$, the sixth column provides the standard errors SE($A_V$) of $A_V$ and the seventh column the numbers

TABLE I Average (1979–2002) values of extinction coefficients, together with their uncertainties for intervals of 1 month (see text for explanation of the symbols).

| *Month* | $A_V$ | $A_B$ | $A_U$ | $SD(A_V)$ | $SE(A_V)$ | $n_V$ |
|---|---|---|---|---|---|---|
| January | 0.20 | 0.35 | 0.75 | 0.05 | 0.013 | 14 |
| February | 0.24 | 0.40 | 0.78 | 0.08 | 0.020 | 21 |
| March | 0.31 | 0.49 | 0.88 | 0.12 | 0.020 | 38 |
| April | 0.37 | 0.56 | 0.97 | 0.13 | 0.019 | 46 |
| May | 0.35 | 0.55 | 0.98 | 0.12 | 0.017 | 53 |
| June | 0.37 | 0.58 | 1.02 | 0.08 | 0.012 | 47 |
| July | 0.42 | 0.64 | 1.10 | 0.14 | 0.020 | 54 |
| August | 0.39 | 0.59 | 1.06 | 0.14 | 0.013 | 111 |
| September | 0.33 | 0.52 | 0.96 | 0.09 | 0.010 | 80 |
| October | 0.25 | 0.42 | 0.86 | 0.10 | 0.011 | 68 |
| November | 0.21 | 0.38 | 0.80 | 0.05 | 0.009 | 33 |
| December | 0.19 | 0.36 | 0.76 | 0.05 | 0.010 | 27 |

$n_v$ of nights of observations in the $V$ band. The uncertainties in $A_{\boldsymbol{B}}$ and $A_{\boldsymbol{U}}$ are not given in order to prevent the table from becoming complicated. From the practical point of view their concrete values are not important, and it is necessary to note only that they exceed the corresponding values in the $V$ band by 1.3–1.5 and 1.7–2 time respectively. All these uncertainties are caused by significant variations in the transparency, instead of errors in the measurements.

For practical purposes it is possible to use also the average values for intervals of 1/3 month, smoothed by the method of averaging adjacent values. It is especially preferable to do this during 'intermediate' seasons when there is a fast change in transparency (especially in March, September and October). At this time the differences between the adjacent values for intervals of 1/3 month appreciably exceed the standard errors of these values. In these cases the standard errors for these values for intervals of 1/3 month are found to be even less than the standard errors for values for intervals of 1 month, despite a smaller number of nights by approximately 3 times.

These average (1979–2002) values $A_{\boldsymbol{V}}$, $A_{\boldsymbol{B}}$ and $A_{\boldsymbol{U}}$ for intervals of 1/3 month are given in Table II.

## 4.2 Long-term variations

To research the long-term changes in a transparency, by virtue of the above mentioned reasons, the deviations d$A$ in the extinction coefficients from the obtained average phase curves with the period of 1 year have been taken. Individual values d$A$ have a large scatter similar to those in figure 1; therefore for illustration only the values for the $V$ band are shown in Figure 3. Each point showing the average value for an interval of 1/3 month contains on average the data for two to three nights (four to six measurements). The best linear fit (straight line) is drawn. The best step-line fit (intervals 1979–1993 and 1994–2002 (dashed line)) is also given. The significance level (the probability of zero slope or zero height of a step) is less than 0.01 in both cases.

The variations in the midannual values d$A$ during 24 years are for the $U$, $B$ and $V$ bands very similar. These results for $V$ and for the difference $U - V$ are shown in Figure 4. The values of the errors (error bars are given) show that the majority of small waves on curves are not significant. Long-term changes in the extinction are noticeable. Therefore, to improve the

TABLE II Average (1979–2002) values of extinction coefficients for intervals of 1/3 month.

| *Interval* | $A_V$ | $A_B$ | $A_U$ | Interval | $A_V$ | $A_B$ | $A_U$ |
|---|---|---|---|---|---|---|---|
| 1–10 January | 0.19 | 0.35 | 0.75 | 1–10 July | 0.41 | 0.63 | 1.08 |
| 11–20 January | 0.20 | 0.35 | 0.74 | 11–20 July | 0.43 | 0.65 | 1.10 |
| 21–31 January | 0.21 | 0.36 | 0.75 | 21–31 July | 0.43 | 0.65 | 1.12 |
| 1–10 February | 0.22 | 0.38 | 0.76 | 1–10 August | 0.42 | 0.63 | 1.10 |
| 11–20 February | 0.24 | 0.40 | 0.77 | 11–20 August | 0.38 | 0.59 | 1.06 |
| 21–28/29 February | 0.26 | 0.42 | 0.79 | 21–31 August | 0.36 | 0.56 | 1.01 |
| 1–10 March | 0.28 | 0.45 | 0.83 | 1–10 September | 0.35 | 0.54 | 0.98 |
| 11–20 March | 0.32 | 0.50 | 0.89 | 11–20 September | 0.33 | 0.52 | 0.96 |
| 21–31 March | 0.34 | 0.52 | 0.93 | 21–30 September | 0.30 | 0.48 | 0.92 |
| 1–10 April | 0.36 | 0.55 | 0.95 | 1–10 October | 0.27 | 0.44 | 0.89 |
| 11–20 April | 0.37 | 0.56 | 0.97 | 11–20 October | 0.25 | 0.42 | 0.86 |
| 21–30 April | 0.37 | 0.56 | 0.98 | 21–31 October | 0.23 | 0.40 | 0.84 |
| 1–10 May | 0.36 | 0.56 | 0.98 | 1–10 November | 0.22 | 0.39 | 0.82 |
| 11–20 May | 0.35 | 0.55 | 0.98 | 11–20 November | 0.21 | 0.38 | 0.80 |
| 21–31 May | 0.35 | 0.55 | 0.98 | 21–30 November | 0.20 | 0.37 | 0.78 |
| 1–10 June | 0.36 | 0.56 | 1.00 | 1–10 December | 0.20 | 0.37 | 0.77 |
| 11–20 June | 0.37 | 0.58 | 1.02 | 11–20 December | 0.19 | 0.36 | 0.76 |
| 21–30 June | 0.39 | 0.61 | 1.05 | 21–31 December | 0.19 | 0.36 | 0.75 |

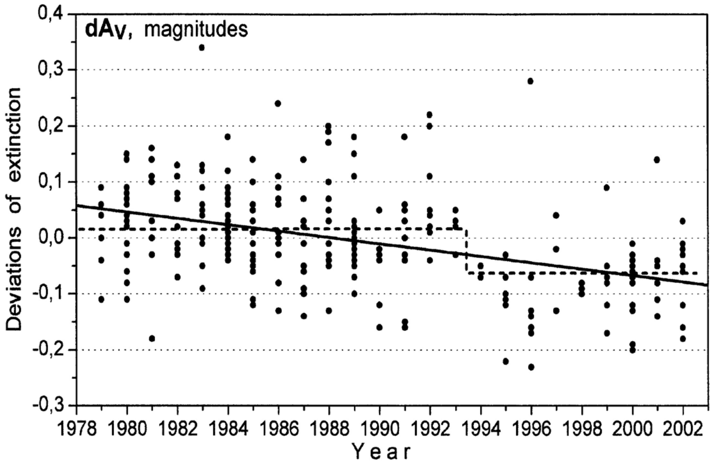


FIGURE 3 Deviations of the extinction coeficient in the ***V*** band from the long-term mean seasonal curve. All available individual 1/3 month values during the total 24 years are given. The best linear and step-line fits are drawn.

accuracy of our conclusions it was decided to examine the common changes in all these three bands. The ratio of the deviations d$A$ to the average extinction value $A_{\mathrm{mean}}$ suits this purpose; these value are approximately the same for all three hands (no more than 20%–25% difference, and usually about 10%). In Figure 4 the result of averaging the d$A/A_{\mathrm{mean}}$ values for the three bands ($U$, $B$ and $V$) is given also: $P$ is the mean deviation for 1 year as a percentages of the long-term average $U$, $B$ and $V$ extinctions. The results of adjacent averaging of the d$A_V$, d$A_{U-V}$ and $P$ values are drawn; in each case, three points are taken for smoothing.

All the data obtained for the first half of the 24 year interval has the best accuracy (see error bars) because, during the first 12 years, 70% of the measurements are made. This also applies to the intervals corresponding to the two levels of a step curve; during the last 37.5% of time (1994–2002), only 17.1% of the measurements were made.

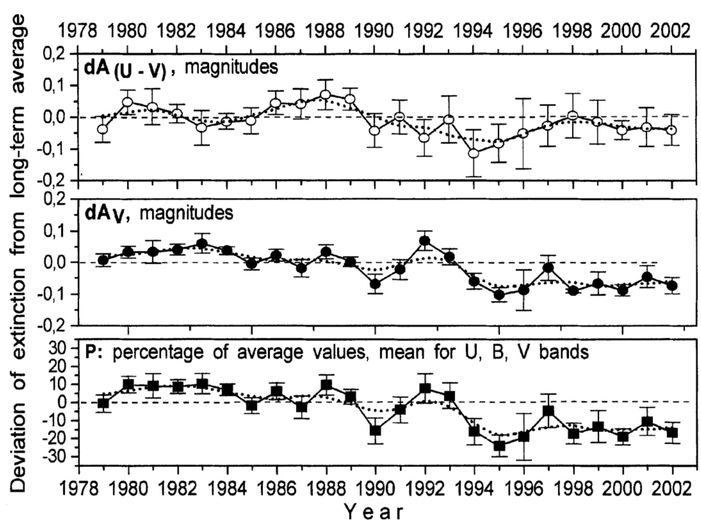


FIGURE 4 Deviations of the extinction coefficients from the long-term average seasonal curves, where the average deviations for every year, together with their uncertainties, are given: . . . ., results of adjacent averaging; — — —, zero levels.

It should be noted that the relation between the changes in the atmospheric extinction and cycles of solar activity during two such cycles is very weak. This can be seen from Figure 4, meaning that the maximum solar activity took place in 1979–1982, in 1989–1992 and in the last 3 years. Apparently, the influence of terrestial reasons here is not less than the role of space factors. For example, in 1982 there was a very powerful eruption of volcano the Al'-Chichon in Mexico, accompanied by the emission of eruption materials to a height of about 35 km. In the summer when the transparency was poor, weak effects were not appreciable, but in the autumn–winter 1982–1983 the transparency was the worst for the given season in all the 24 years (see some uppermost points in Figure 1, from the end of October to the end of December). After that eruption the increased dust in the top atmosheric layers coincided with the recession of solar activity. As a result, changes in the extinction in 1979–1992 are represented by some small waves (Figure 4), which are probably not connected with the cycle of solar activity.

Separate short waves on the $\mathrm{d}A(t)$ curves are not significant, but it is definitely seen that either $\mathrm{d}A$ slowly decreases, or there was one fast reduction in 1993–1995 on a background of small fluctuations. The calculated line fits (see Figure 3 for the $V$ band) show a significant improvement in transparency and correspond to the decrease in midannual extinction coefficients for 24 years:

$$\mathrm{d}A_V = -0.13 \pm 0.05, \quad \mathrm{d}A_B = -0.17 \pm 0.06, \quad \mathrm{d}A_U = -0.23 \pm 0.08.$$

It is possible to divide also the data into two parts (for the years 1979–1993 and 1994–2002), giving in the case of the step-line fit, within the limits of errors, two constant values of the extinction, differing by

$$\mathrm{d}A_V = -0.08 \pm 0.03, \quad \mathrm{d}A_B = -0.10 \pm 0.03, \quad \mathrm{d}A_U = -0.15 \pm 0.04.$$

This step-like dependence (but most probably with a recession during 2–3 years) looks more preferable than a linear dependence, which has essentially more $\mathrm{d}A$ values. The recession in industrial production and reduction in emissions into the atmosphere over territory adjoining Crimea in the 1990s confirm this choice. It is interesting that in 1993–1996 a recession in solar activity was observed. However, in 1999–2002 no increase in extinction coefficients was detected, despite an increase in solar activity.

It is necessary to note that the obtained values of the straight-line slope and of the step height correspond more to a season with poor transparency (April–September) since it contains a much larger number of measurements. During this season the $\mathrm{d}A$ values are only a little higher, and in the winter months are lower by a factor of approximately 2 than calculated above.

### 4.3 Summary of seasonal and long-term variations

In Table III, values of the extinction coefficients and their long-terms changes (in the $V$, $B$, and $U$ given in the second, third and fourth columns, respectively) for two basis seasons (1979–1993, and 1994–2002) are given, together with the average for the total 24 years. The interval of averaging is specified in the first column. The total number of nights of observations for corresponding intervals of time is specified in the fifth column. Uncertainties for extinction coefficients are not given. Because the accuracy of the average values in some cases reaches almost 0.001, these standard errors have only formal significance; real changes in the transparency are noticeably larger and occur quickly.

More detailed curves of the extinction changes are obtained only for the total 24 year interval as a whole (Figure 2 and Table II). They display the change in transparency more correctly,

TABLE III Long-term average values of extinction coefficients.

| *Intervals of averaging* | $A_V$ | $A_B$ | $A_U$ | $n_V$ |
|---|---|---|---|---|
| 1979–1993, 21 March–20 September | 0.40 | 0.61 | 1.06 | 312 |
| 1979–1993, 11 November–10 February | 0.21 | 0.37 | 0.79 | 50 |
| 1979–1993, for the total year | 0.33 | 0.51 | 0.94 | 491 |
| 1994–2002, 21 March–20 September | 0.31 | 0.48 | 0.88 | 65 |
| 1994–2002, 11 November–10 February | 0.17 | 0.32 | 0.69 | 21 |
| 1994–2002, for the total year | 0.25 | 0.41 | 0.80 | 101 |
| 1979–2002, 21 March–21 September | 0.38 | 0.58 | 1.02 | 377 |
| 1979–2002, 11 November–10 February | 0.20 | 0.36 | 0.76 | 71 |
| 1979–2002, for all the total year | 0.31 | 0.49 | 0.91 | 592 |

especially during the transition seasons (between the above-stated two seasons) and during an additional narrow maximum in the summer.

### 4.4 Comments on atmospheric extinction from the viewpoint of aerophysics

All measurements were carried out by means of star observations at different zenith distances. Therefore all data obtained were for, strictly speaking, that condition of the atmosphere when there is very good clear weather. It is quite possible that during the same season even when partly cloudy or for cloudy or at overcast weather, the transparency of the air is not the same as for a clear sky. For example, it is know (Borisov, 1967) that, when there are Arctic air masses, in the winter there is clear weather more often and, in the summer, on the contrary, there is a cloudy sky more often. For the air masses from the Atlantic and those from the tropics, the situations are opposite. Hence, if it is true, that the good transparency is caused by Arctic air, this means that for cloudy weather (and on the average) our data will be worse in the winter and better in the summer. In this case, seasonal variations in the extinction if measured under any weather conditions would appear less than in out data.

## 5 CONCLUSIONS

In general, within 1 year it is possible to allocate two basic seasons.

In one of these (spring and summer), with a duration of about $\frac{1}{2}$ year and centred approximately at the date of the summer solstice, the transparency of the atmosphere is on the average poor. Thus, at this time, sometimes there is an improvement in the transparency of up to the best possible, and stronger deterioration down to the values occasionally corresponding to 1 magnitude in $V$ and 2 magnitudes in $U$ at the zenith. In the other season (the end of autumn–winter) of duration about 3 months and which is centred approximately at the date of the winter solstice, the transparency on the average is good, that is not much worse than that due to only the effects of molecular scattering and absorption in an ozone layer.

On examining the long-term changes in the transparency, apparently it is possible to note that some improvement has taken place in the last 7–10 years. In all long-term variations, the terrestial reasons (eruptions of volcanos, industrial emissions, etc.) apparently do not have a smaller role than cycles of solar activity. As a result a complex picture of events takes place.

These basis conclusions are quantitatively brought together in Table III, and detailed curves of the changes in extinction are shown in Figure 2 and Table II.

The results obtained are interesting to observers in Crimea. Although for modern charge-coupled device observations the reed for carefully taking into account the atmospheric conditions has disappeared, in the case of exact photoelectric observation (*e.g.* measurements on standard stars) it is rather necessary not only to take into account the average values of extinction coefficients, but also each time to determine their values during such observation.


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