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Astronomical climate in the region of Astrophysical Observatory of Moldova University

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Abstract. Using the measurements made in 1979–1993, astronomical climate characteristics in the region of the Astrophysical Observatory of Moldova State University were investigated. The obscurity of the horizon is mainly due to the trees and amounts to 20 %. The meteorological characteristics are close to the mean characteristics of this region of many years. The number of clear nights in a year is about 100, the number of clear night hours is over 700 a year. The root-mean-square amplitude of seeing is most often within $0\overset{''}{.}3 - 0\overset{''}{.}5$. The extinction coefficients vary from $0\overset{m}{.}24$ to $0\overset{m}{.}88$ in the B band and from $0\overset{m}{.}20$ to $0\overset{m}{.}58$ in the V band of the UBV photometric system. The night sky background level is, on average, $21.8^m/\square''$ in the B band and $20.7^m/\square''$ in V.

Key words: atmospheric effects – site testing

1. Meteorological situation

1.1. General meteorological characteristic of the region around the observatory

The Astrophysical Observatory of Moldova State University is situated in the Central Moldova Upland (CMU), at a height of 370 m above sea level. The surroundings in this part of Moldova is hilly and partially covered with forests. The observatory is situated on one of the hills and surrounded by forests, but for the south-east. The nearest big villages are 8 km away from it, the city of Kishinev is at a distance of 40 km.

The climate of Moldova is temperate-continental with a short little-snow winter, a long warm summer and a small amount of precipitation falling mainly in warm time of the year as short-time heavy showers. The average amount of sun-shine per year is from 2060 hours in the north to 2320 in the south, which makes 50–55 % of possible duration for the interval of latitudes of the Republic. The annual average wind speed varies over the territory from 2.5 to 4.5 m/s. The probability of wind speed exceeding 10 m/s is 6–10 %. The monthly average relative humidity of air varies from 60–70 % in summer to 80–90 % in winter. On average, 30–60 days for a year are foggy in Moldova.

The increased heights and large forest areas in the region of Central Moldova Upland cause increasing precipitation (over 550 mm). The duration of fogs is also large here — from 200 to 500 hours. Moreover, they have rarely been observed to last less than 200 hours. The region of the CMU is most liable to be covered with ice. An annual average of 18 days of ice-crusted ground and 16 days of hoar-frost can be observed here (Lasse 1978).

1.2. Degree of obscuration of the horizon

The degree of obscuration of the horizon was measured from the domes of the two telescopes available at the observatory with the aid of a theodolite every 5° in azimuth with an accuracy of 1° in altitude (see Fig. 1). In the place where the telescope AZT-3 is located, the horizon is obscured from 4° to 16°. From the telescope AVR-2, which is situated at a somewhat higher altitude, the obscurity is somewhat lower (from 0° to 9°), except for the north–east where it reaches 20°. In both cases the obscurity of the horizon is due to trees, for the observatory is on a clearing surrounded by the forest. For this reason, in principle, by elevating the dome of the telescope by a few meters, the obscurity of the horizon can be significantly reduced.

1.3. Atmospheric pressure, temperature and wind speed

Regular measurements of the atmospheric pressure had been conducted at the observatory since January 1979, of air temperature — since December 1979, of wind speed — since December 1980. These observa-

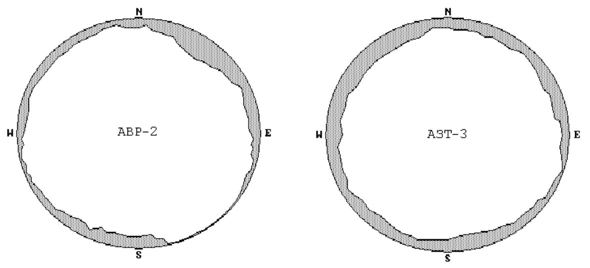

Figure 1: *The obscurity of the horizon for telescopes AVR-2 and AZT-3.*

tions had been conducted until 1983 April. The measurements were made four times a day: at 7–8 a.m., 2–3 p.m., at 8–9 p.m. and near midnight. The atmospheric pressure was measured with a barometer to an accuracy 0.2–0.3 mm hg, the temperature was measured with a mercury thermometer with an accuracy of 1° C, the wind speed was measured with a hand-held anemometer with an accuracy of 0.3–0.5 m/s at a height of about 6 m above ground surface.

In Table 1 are listed monthly average values of the atmospheric pressure in

No noticeable seasonal variations of the average pressure is observed. At the same time, seasonal fluctuations in the pressure (shown in Fig. 2) are strongly pronounced. The greatest fluctuations of the atmospheric pressure occur during winter months, the least — in summer. The maximum and minimum recorded pressure (750.8 and 707.8 mm hg) was observed in 1979 February.

The data on monthly average air temperature are presented in Table 2. The coldest months are January and February, the warmest ones are June and July. The monthly average temperature fluctuations does not show seasonal trend and makes, on the average, about 20°. The largest temperature fluctuations are observed in March, the smallest — in September. During the whole period of observations the maximum temperature was observed to be +34° C in 1981 June, the minimum temperature (−16°) was observed in 1981 January. The most unstable month as far as the temperature is concerned is March.

The wind speed around the observatory was measured, as has been noted, from December 1980 to June 1983, that is for 2.5 years. The monthly average values show a slightly defined seasonal trend. In the summer months the wind speed is somewhat lower than in winter and amounts to an average of about 1.7 and 2.2 m/s, respectively. Fig. 3 shows a histogram of the distribution of wind speed in per cent of the total number of measurements for all terms of observations. It can be seen from it that the dominating wind speed is from 0 to 2 m/s, which is 60 % of the total number of measurements. In nearly 80 % of cases the wind speed does not exceed 3 m/s.

The distribution of wind velocity in the night time is exhibited in Fig. 4. During the night, in 68 % of cases the wind speed is no higher than 2 m/s, and in 84 % of cases 3 m/s. During clear nights the wind speed does not exceed 2 m/s in 90 % of cases. There are only a few clear nights per year with a wind speed above 4–5 m/s.

1.4. Precipitation, fog

During the years 1980–1982, apart from the above-mentioned parameters, the presence of precipitation and fog was also recorded. Even if on some days only slight precipitation or thin fog were observed during the morning hours, these days were considered to have precipitation or fog. From November to March more than 60 % of the days are observed to be foggy, and Nowember and December are considered to be the most foggy. 31 % of all foggy days fall within these two months. It is observed that fogs are the most rare from May to September. About 23 % of days in these months are foggy. The fog generally arises after thunder storms because of intensive avaporation and is kept for a certain time by the forests surrounding the observatory, i.e. it is of local character.

We have computed the number of days with precipitation and fog for each year, the data are collected in Table 3.

Table 3: *Number of days with precipitation and fog for each years*

Year	With precipitation	With fog
1980	111	77
1981	102	72
1982	90	61
Average	**101**	**70**

If during the night there was precipitation and then fog, then the night was considered to be both with precipitation and fog, i.e. it was contained in both the columns. As a result, the total number of nights is smaller than the sum of the numbers in the two columns.

1.5. Amount of clear time

One of the most important astroclimatic characteristics is the amount of clear time. Observations of this parameter were conducted for 3.5 years: from the beginning of 1980 to the middle of 1983 in the same terms as the rest of the meteoparameters were observed, that is, 4 times a day. The cloudiness was estimated visually by 5-number scale:

1 – totally overcast sky;

Table 1: *Monthly averaged values of the atmospheric pressure in mm hg for every year and averaged over the years 1979–1983*

Years	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
1979	730.0	732.9	729.0	728.6	734.2	732.5	731.9	730.8	734.3	735.8	732.9	731.4
1980	732.8	733.9	730.7	728.9	729.5	728.5	728.9	731.4	735.5	732.0	731.5	730.2
1981	740.2	732.5	730.0	731.2	730.0	732.0	730.3	-	735.0	732.0	730.9	723.7
1982	733.1	735.9	734.4	729.0	734.7	-	731.0	731.2	735.9	736.2	736.1	731.1
1983	732.8	731.0	731.0	728.5	-	-	-	-	-	-	-	-
1979–1983	733.8	733.2	731.1	729.2	732.1	731.0	730.5	731.1	735.2	734.0	732.9	729.1

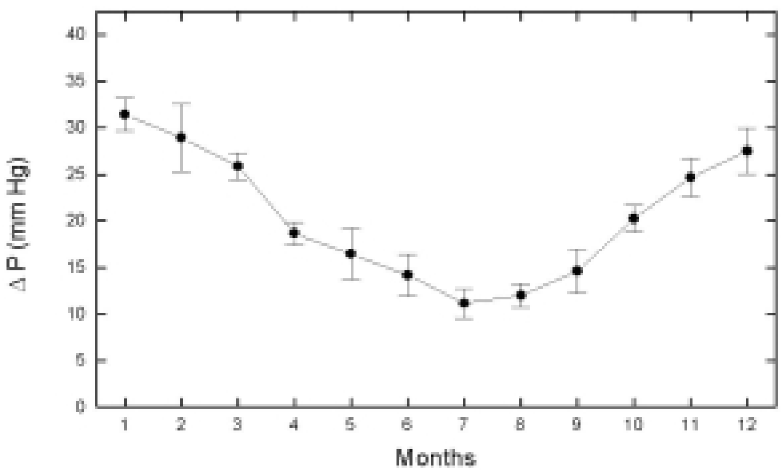

Figure 2: *Differences between maximum and minimum pressure in the given month, averaged for the years 1979–1983, with root-mean-square deviations.*

2 – broken sky;

3 – 50 % of the sky is covered with clouds;

4 – clear sky with rare individual clouds or with haze;

5 – completely clear sky.

To characterize the probability of clear sky, the number of estimates of cloudines according to the scale for each month was calculated in per cent over all the terms of observations and separately over night observations. These data averaged for 3.5 years are listed in Table 4.

The numerators correspond to all the terms of observations, the denominators to the night observations. The last column presents the values averaged over 3.5 years, from which it is seen that, on the average, the probabilities of clear sky during 24 hours and in the night time are practically the same.

Astronomical observations are conducted in the nights with estimates of cloudiness 4 and 5. When counting the number of clear nights in each month, we introduced corrections, basing on the data of the logs of observations with the telescope AZT-3. If, for instance, at about midnight the sky was cloudy, but from the log of observations the observations were made after midnight, then we considered that only half the night was clear. And vice versa, if around midnight the sky was clear, but from the log the observations were stopped after midnight, then only half of the night was also considered to be clear. Thus, the number of clear nights in each month for 3 years was counted (see Fig. 5).

The largest number of clear nights is from May to October. The greatest number (19) of clear nights was in September 1982. A total of 290 clear nights over the three years were observed, which, on the average, amounts to 97 nights a year.

Since the length of night varies during a year, the number of hours with a clear sky is more informative. It is obtained by multiplication of the number of clear nights in each month by the number of hours

Table 2: *Monthly averaged values of the air temperature (degrees Celsius) for every year and averaged over the years 1980–1983*

Years	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
1980	-5.9	-2.5	-0.5	7.5	13.0	17.5	19.5	18.0	12.8	10.0	2.9	0.2
1981	-4.9	-1.7	3.6	6.1	14.6	21.5	21.6	-	16.5	12.6	2.1	-0.1
1982	-3.3	-3.7	2.2	7.2	17.1	-	19.0	19.5	18.0	10.2	4.2	2.5
1983	0.4	-1.3	5.0	10.8	-	-	-	-	-	-	-	-
1980–1983	-3.4	-2.3	2.6	7.9	14.9	19.5	20.0	18.8	15.8	10.9	3.1	0.9

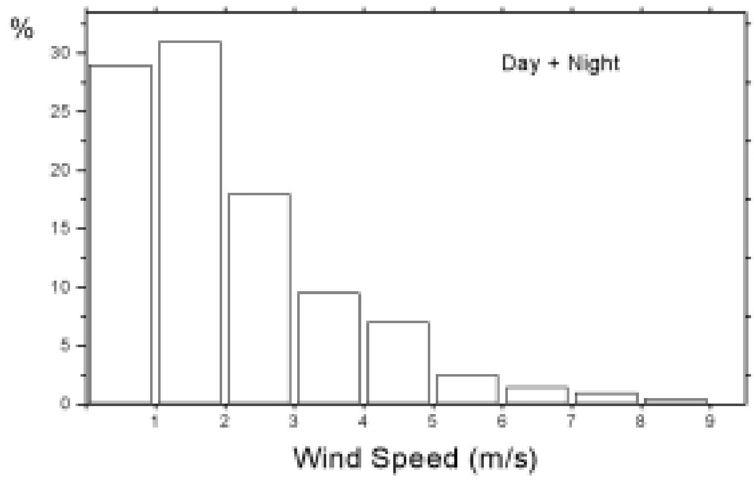

Figure 3: *Histogram of the wind speed distribution in per cent of the total number of measurements over all terms of observations (December 1980 – June 1983).*

with a clear sky. As the night duration, one may take the time from the end of the evening astronomical twilight to the onset of the morning one. However, the author's practice of 15 years of observations has shown that many astronomical observations can be carried out from the end of the evening to the onset of the morning nautical twilights. For this reason, we considered the night duration to be the time from the end of the evening to the onset of the morning nautical twilights, i.e. when the Sun is under the horizon below 12°.

Fig. 5 shows the annual trend of monthly average number of night hours with a clear sky over 3 years. The largest number of such hours is observed in September, October and January, on average, 100 hours. December is the worst in this respect — slightly more than 40 hours. The total number of night hours with a clear sky was 704, 747 and 1056 in 1980, 1981 and 1982, respectively. On the average, it turns out 836 hours per year during the three years. If the night time is reckoned from the end to the beginning of the astronomical twilight, these numbers should be decreased by about a factor of 1.2.

2. Seeing

From 1979 to 1985 we obtained about 100 photographic traces of flickering of star images, about half of which in 1982. The photography was performed only in completely clear nights at air masses no more than 3.0–3.5. The telescope AZT-3 (Cassegrain system) with the mirror diameter 45 cm and focal distance 10 m was used. The image scale is 20.6 arcsec per 1 mm. The traces were taken by means of stopping the clock-work of the telescope. The linear diameter of the field of view at the Cassegrain focus was 60 mm. A star image passes across the whole field of view during 1.3 minutes. The clock-work was stopped 1–2 minutes before the star appeared in the field of view to make the telescope completely quiet.

The traces were measured by the standard procedure (e.g. see the paper by Esikov et al. 1967) with a

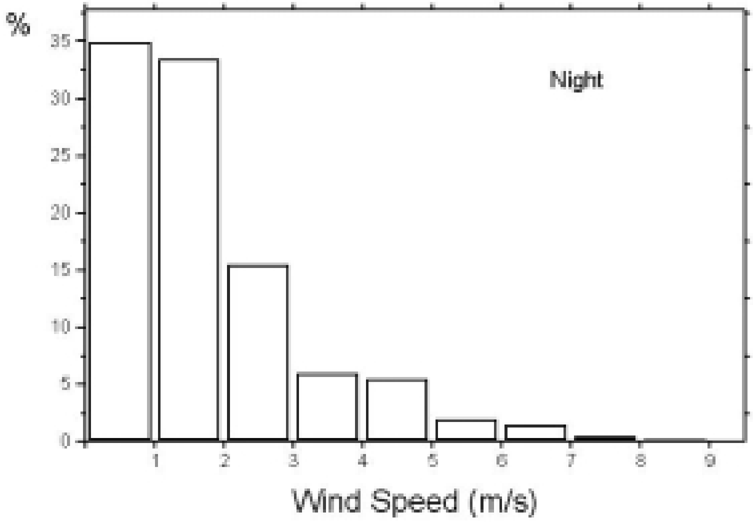

Figure 4: *Distribution of wind speed during the night time.*

Table 4: *The averaged for 3.5 years estimates of cloudiness according to the scale, in per cent over all the terms of observations (numerators) and over night observations (denominators)*

Scale number	Months												
	1	2	3	4	5	6	7	8	9	10	11	12	**Average**
1	59/58	64/66	57/58	53/47	38/40	38/40	33/35	38/37	21/22	32/26	61/63	67/75	**48/48**
2	8/9	6/5	10/11	14/12	13/10	11/10	12/12	9/4	12/5	14/12	7/8	8/4	**10/8**
3	8/7	7/8	8/11	11/17	15/12	15/10	19/13	23/30	15/17	17/19	10/9	9/6	**13/13**
4	9/10	11/12	13/9	11/16	15/15	21/31	22/25	15/13	18/18	19/23	12/11	8/10	**14/16**
5	16/16	12/9	12/11	11/8	19/23	15/9	14/15	15/16	34/38	18/20	10/9	8/5	**15/15**
4+5	**25/26**	**23/21**	**23/20**	**22/24**	**34/38**	**36/40**	**36/40**	**30/29**	**52/56**	**37/43**	**22/20**	**16/15**	**29/31**

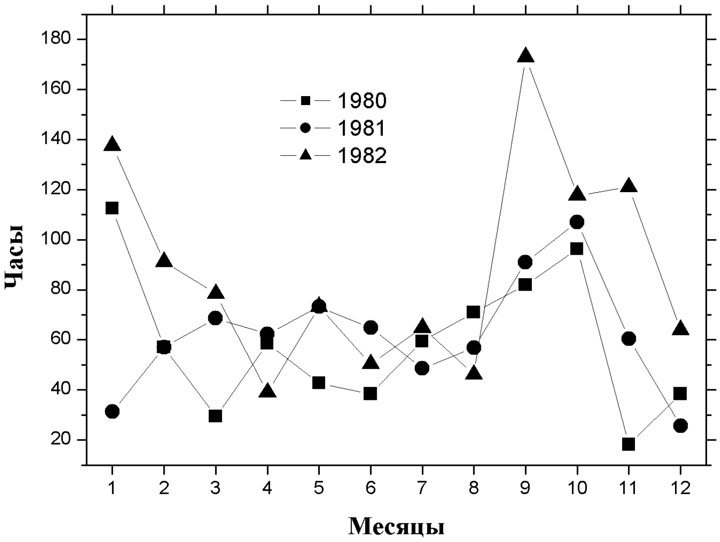

Figure 5: *Distribution of clear night time in hours.*

microscope every 50 μm. The central part of the trace 40 mm long was used, which gave 800 counts for each trace.

The derived root-mean-square amplitudes of the flickering traces were reduced to the zenith by the law $secZ$. The results are presented as a histogram in Fig. 6. It follows from the histogram that the most frequently (in more than half of the cases) flickering within 0.3–0.5 arcsec is observed. Every fifth clear night (20 %) the r.m.s. amplitude of the flickering does not exceed $0\farcs3$, every second night (50 %) — $0\farcs4$. In 90 % of cases the flickering is no higher than $0\farcs6$.

3. Atmospheric extinction

Systematic measurements of the atmosphere transparency at the Astrophysical Observatory of Moldova State University were made by I.M. Naku from 1979 to 1985. The observations were conducted by means of a stellar spectrophotometer with the telescope AVR-2 (D = 20 cm, F = 3 m) in four regions of the spectrum. The description of the instrumentation, procedure of observations and reduction and also the results are presented by Naku, Chernobaj (1981a, b) and Naku (1986). Here we present the mean values of the extinction coefficients α over the time of observations (Table 5) together with the wavelength λ and the half-width of the used interference filters $\Delta\lambda$.

Table 5: *Mean values of extinction coefficients (1979–1985)*

λ, nm	$\Delta\lambda$, nm	α, ^{m}
410	8	0.55
497	15	0.36
530	3	0.31
694	4	0.20

The values obtained are characteristic of the places with the low level above sea (Lasse 1978; Neizvestny 1983).

Besides, in 1989–1993, when the author investigated the photometric system BV of the photoelectric complex of the telescope AZT-3 (Smykov 1990), and in observations of variable stars, extinction coefficients were determined by the method of Buger. For the B band the coefficients were determined during 20 nights, for V — 8. In the B band the extinction coefficient varies from $0\overset{m}{.}24$ to $0\overset{m}{.}88$ with an average value of $0\overset{m}{.}47$, in V it varies from $0\overset{m}{.}20$ to $0\overset{m}{.}58$ with an average value of $0\overset{m}{.}36$, which is close to those presented in Table 5.

4. Brightness of night sky background

One of the most important characteristics of astronomical climate is the night sky brightness. This characteristic together with others (transparency, seeing) allows determination of potential possibilities of the given site for recording of weak cosmic radiation.

No special investigations of the night sky brightness were conducted at AO of Moldova State University. However, in 1989–1993 the author carried out photoelectric observations of rather faint (14^m – $14\overset{m}{.}5$) variable stars, during which the sky background was thoroughly measured every 10–15 minutes. The observations were made with the telescope AZT-3 (D = 45 cm, F = 10 m) at the Cassegrain focus with the aid of the photoelectric complex in the B and V bands of the system UBV. The recording was performed by the photon-counting technique. The acquisition time was 100 s. A diaphragm with a diameter of 22 arcsec was used. The accuracy of the background measurements was $0\overset{m}{.}1 - 0\overset{m}{.}3$.

To determine the level of the sky background, we used only observations obtained during moonless nights after the end of astronomical twilight at zenith angles up to 60°. Part of the results is published in the paper by Smykov (1990). The number of such nights came up to 47, during 2 of these nights observations were made only in the B band. Thus, for the B band, data over 47 nights are available, for the V band over 45 nights.

As a result of reduction, the following was obtained. In the blue region of the spectrum (B) the level of the night sky background varies from 21.0 to $22.9\,^m/\Box''$ with a mean value of $21.8\,^m/\Box''$, in the yellow (V) — from 20.3 to 21.6 with a mean value of $20.7\,^m/\Box''$. The background level is strongly dependent on the atmosphere haziness. During the nights with very clear atmosphere, which is observed more frequently in Autumn and Winter, the background level approaches its minimum value.

5. Conclusions

As a result of the conducted investigations, it has been obtained that the meteorological situation actually does not differ from the mean climatological data of the region. Attention is attracted by a rather low wind speed especially at night (< 2 m/s). At the same time about 20 % of days with fogs are observed, which is too much. The quantity of clear time (about 1000 hours a year) is characteristic of the given geographical region. The seeing may be considered not bad for the given height above sea level (about 400 m). The same is true for the atmospheric extinction. The best months for observations are September and October.

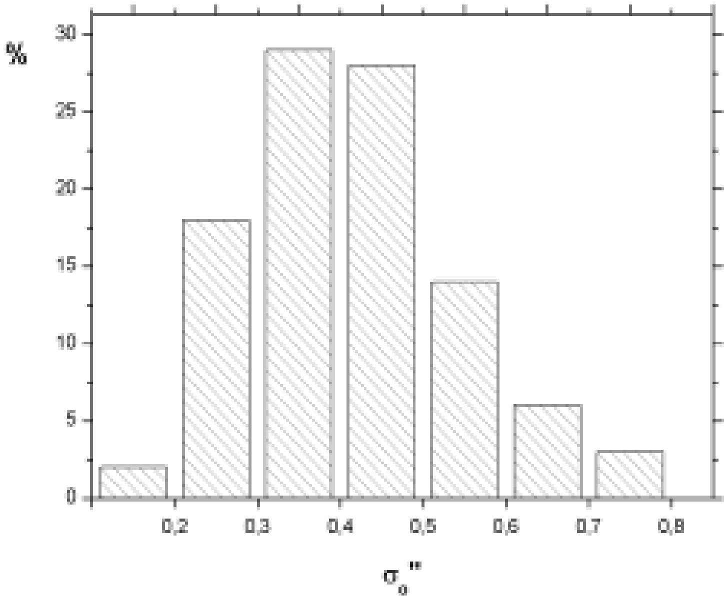

Figure 6: *Distribution of flickering amplitudes.*

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