Study of nighttime image quality at Mt. Maidanak observatory for the period from 1996 to 2003

S.P. Ilyasov

Ulugh Beg Astronomical Institute, Uzbekistan Academy of Sciences, Tashkent

Received October 5, 2005

Data of nighttime image quality measurements carried out during the period from August 1996 to December 2003 at Maidanak observatory in Uzbekistan are presented. Nighttime image quality was measured with an ESO Differential Image Motion Monitor (DIMM). The median and mean values of ε_{FWHM}, the full width at half maximum of a long-exposure stellar image at zenith at $\lambda = 550$ nm, for the entire period of observations made 0.71″ and 0.77″, respectively. The best image quality is observed in Maidanak in October and November. Weak correlation has been revealed between the image quality and near-ground wind speed.

Introduction

Quality of astronomical ground-based observations is strongly restricted by atmospheric turbulence. A light beam from a star changes its direction when passing through the Earth atmosphere. Random fluctuations of this change are referred to as the *atmospheric image quality*, which is the key atmospheric parameter for an astronomical observatory. The present work is devoted to study of image quality at the Maidanak observatory in Uzbekistan.

The studies at the Mt. Maidanak are being carried out since the end of 1960ies by the researchers from the Astronomical Institute of the Uzbekistan Academy of Sciences (AI UAS) during field missions to mountainous regions of the Central Asia. Today there is the mountain Astronomical Observatory of the AI UAS at this mountain. In the past years, Maidanak astroclimate was studied repeatedly by a number of research groups using different techniques and instrumentation.[1–5]

Since the beginning of 1990s, tremendous upgrowth of new observation methods with high angular resolution has been observed, such as adaptive optics and interferometry; hence, a necessity of more detailed estimation of the astroclimate parameters has become an urgent task. Therefore, study of the Maidanak astroclimate with up-to-date instrumentation, estimating astronomical image quality objectively, is the issue of the day.

In August 1996, we began to monitor the key astroclimate parameter, i.e., image quality ε_{FWHM}. It was measured with an ESO Differential Image Motion Monitor (DIMM). Its optical arrangement and principles of operation can be found in Refs. 6 and 7, while the preliminary measurement results obtained with the device at Maidanak in Ref. 8. In our study, the measurement results of image quality and weather parameters at the Mt. Maidanak are presented for the 8-year period starting from August 1996 and until December 2003.

Image quality measurements

Full series for image quality observations at the Mt. Maidanak in the period from August 1996 to October 2003 is shown in Fig. 1. Lack of data for some periods is due to bad weather, instrument's electronics damages, or other engineering constraints. Total number of observation nights for the entire period amounts to 1134.

Statistics of the image quality is shown in Fig. 2. Median and mean values of the image quality for the entire period of observations made 0.71 and 0.77″, respectively.

Monthly mean and median values of ε_{FWHM} are given in the Table as well as ε_{FWHM} at 25 and 75%-level of the cumulative distribution over the observation period. As is evident from the Table, a long series of night observations with good image quality was obtained at the Mt. Maidanak from June to October. About 80% of maximum possible clear-sky night time available for observations occurred in this period.[4]

Month	Number of nights	Number of estimations	ε_{FWHM} (25%)	ε_{FWHM} (median)	ε_{FWHM} (75%)	ε_{FWHM} (mean)
I	74	6570	0.60	0.79	1.03	0.88
II	70	7171	0.6	0.77	0.98	0.84
III	43	3762	0.56	0.71	0.91	0.76
IV	52	4220	0.61	0.77	0.97	0.84
V	91	7596	0.55	0.70	0.88	0.75
VI	119	9326	0.57	0.71	0.9	0.76
VII	165	12630	0.59	0.74	0.93	0.79
VIII	176	16370	0.57	0.72	0.92	0.79
IX	197	22041	0.55	0.70	0.88	0.74
X	155	16938	0.53	0.69	0.88	0.76
XI	94	9464	0.51	0.65	0.82	0.70
XII	86	7364	0.57	0.72	0.92	0.78
Total	1322	123452	0.56	0.71	0.91	0.77

0235-6880/05/12 965-04 $02.00

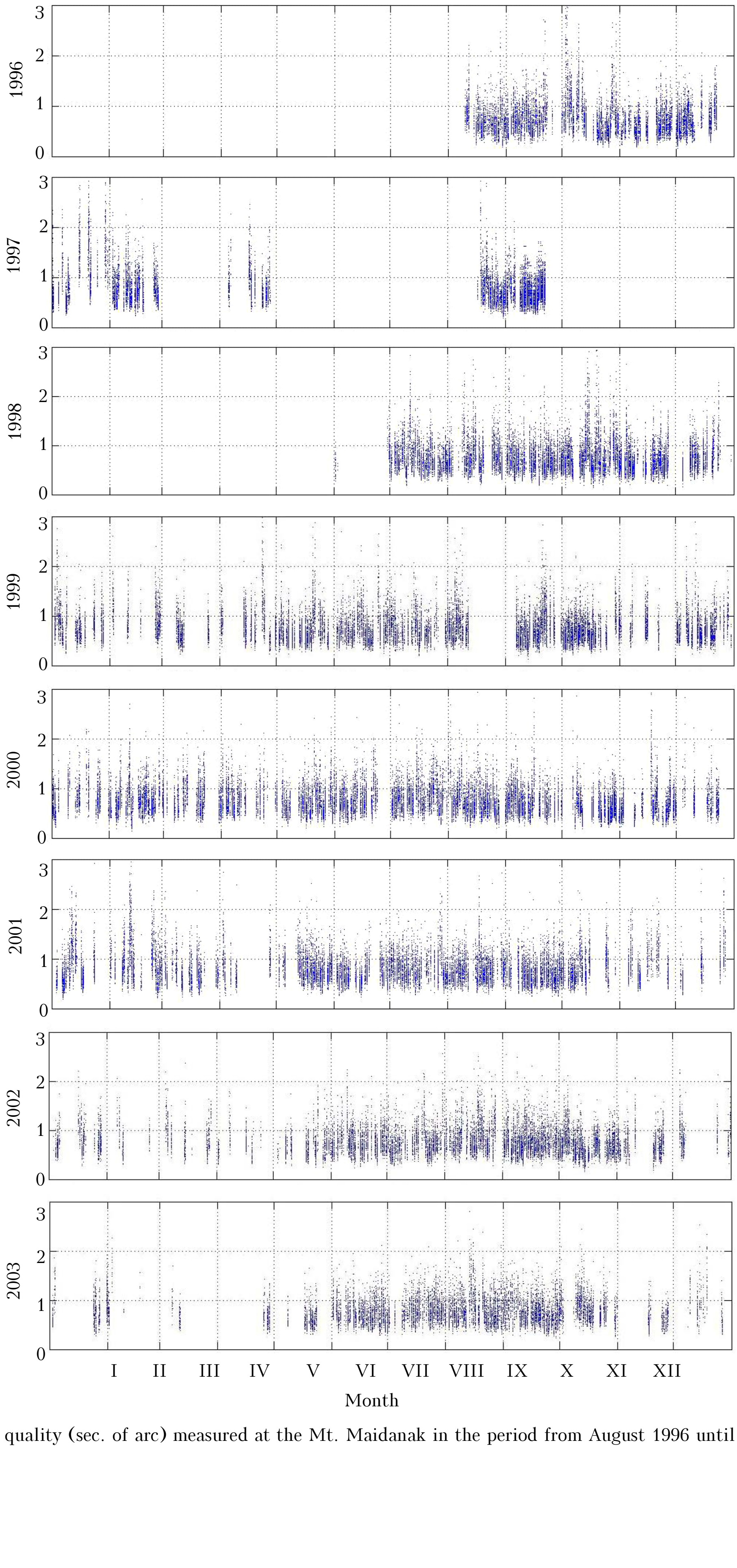

Fig. 1. Image quality (sec. of arc) measured at the Mt. Maidanak in the period from August 1996 until October 2003.

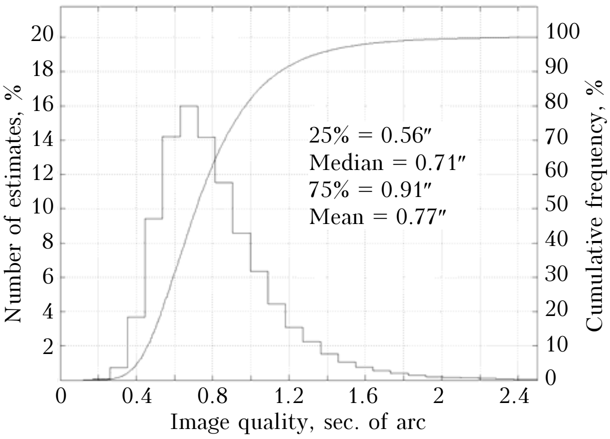

Fig. 2. Statistics of the image quality. The ordinate axis is on the right of the histogram and the cumulative distribution is on the left.

The best image quality was observed in October and November.

Influence of meteorological parameters on the image quality

In August of 1996 we began to record temperature and wind velocity along with image quality measurements to study the influence of meteorological parameters on the image quality. These parameters were recorded hourly at the height of the DIMM, equal to 6 m. Wind velocity was recorded with a Fouss anemometer, while wind direction was recorded visually by an observer. The parameters were recorded in the registry. Total amount of measurements was more than 3400 sessions starting from August 1996 to October 1999.

In May, 2000, an automated Basic Weather Station (BWS) by Campbell Scientific has been mounted at the same platform. It records wind velocity and direction, air temperature and relative humidity automatically.

In summer, average night temperature at the Mt. Maidanak is about +13°C, and −7°C in winter with occasional drops down to −15°C. Temperature drop during nighttime can reach 2°C. Sometimes winter storms can occur, with the wind velocity being quite moderate (up to 15 m/s).

The average wind velocity is 2.9 m/s, which is low for mountainous regions. All these data agree well with the data of previous observations.[4] Maximum wind velocity, equal to 15.8 m/s, was recorded in February 2001. As follows from data analysis, wind velocity didn't exceed 4 m/s in 74% of cases and 5 m/s in 85% of cases. Calm conditions made 7.8% of the total number of records. Dominant winds were from the south-south-east.

To study the influence of wind velocity on the image quality, wind data for the above period were analyzed. The dependence of ε_{FWHM} on wind velocity at the Mt. Maidanak is shown in Fig. 3.

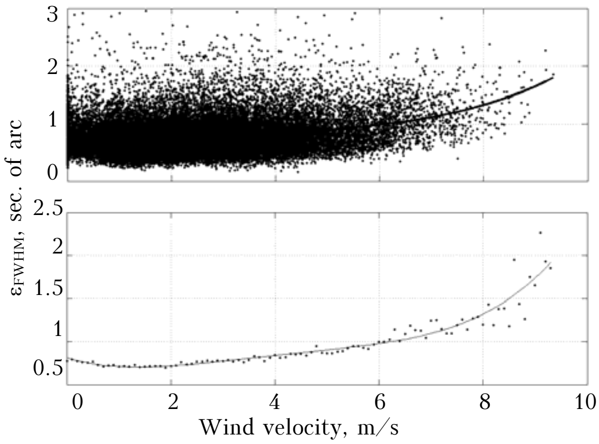

Fig. 3. The ε_{FWHM} as a function of wind velocity at the Mt. Maidanak for the period from May 2000 until October 2002. The bottom plot is made by averaging image quality values corresponding to the wind velocity range ΔV = 0.1 m/s.

As is seen from Fig. 3, image quality deteriorates at calm or low wind velocities (≤ 0.5 m/s); this is caused by inhomogeneities due to convection in the ground layer. Image quality is at the level of 0.7″ when wind velocity is 0.5–4 m/s. This can be explained by that the wind blows out and destroys the temperature inhomogeneities, thus reducing to minimum the image quality parameter in this wind velocity range. The ε_{FWHM} value gradually rises at wind of 4 m/s, i.e., image quality deteriorates. This is obvious because the wind deteriorates the homogeneity of the ground layer turbulence. Nevertheless, winds velocities higher than 5 m/s are infrequent (15% of cases) at the Mt. Maidanak.

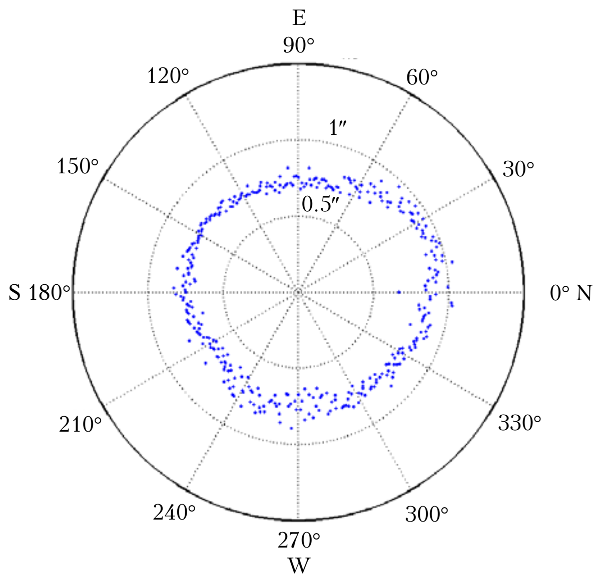

Fig. 4. Image quality as a function of ground wind direction; deterioration is pronounced at northers.

Figure 4 shows the dependence of image quality, measured by the DIMM, on the wind direction.

It is seen, that image quality deteriorates significantly when winds are blowing from the northwest, where the AZT-22 telescope tower is situated (24-m high), which causes formation of turbulent vortices that pass over the DIMM.

Conclusion

The main turbulence parameter, i.e., image quality was measured at the Maidanak observatory from August 1996 until December 2003 with a DIMM instrument, which was also used for quality estimation at La Silla and Paranal observatories.[6,7] The mean and median values for the entire period of observations made 0.77″ and 0.71″, respectively. The best median value equal to 0.65″ was observed in November. The median value of image quality was better than at La Silla and comparable with the one at Paranal.

Weak correlation was revealed between the contribution of the ground layer turbulence and wind direction. Influence of the ground layer becomes significant under infrequent northers (about 5% of cases) because of specific DIMM location (13 m lower and 80 m southward of the main AZT-22 telescope of 1.5 m).

Acknowledgments

The author is grateful to S.A. Ehgamberdiev and Y.A. Tillaev for useful advice.

References

1. G.V. Novikova, in: *Atmospheric Optics* (Nauka, Moscow, 1970), pp. 10–16.
2. V.S. Shevchenko, Astron. Zh. **50**, No. 3, 632–644 (1973).
3. B.P. Artamonov, S.B. Novikov, and A.A. Ovchinnikov, in: *Methods for Optical Telescopes Effectiveness Increase,* ed. by S.A. Gladyshev (MSU Publishing House, Moscow, 1987), pp. 16–27.
4. S.A. Gladyshev and M.G. Shirokova, in: *Methods for Optical Telescopes Effectiveness Increase,* ed. by S.A. Gladyshev (MSU Publishing House, Moscow, 1987), pp. 45–50.
5. A.E. Gur'yanov, M.A. Kallistratova, A.S. Kutyrev, I.V. Petenko, P.V. Shcheglov, and A.A. Tokovinin, Astron. and Astrophys. **262**, 373–381 (1992).
6. M. Sarazin and F. Roddier, Astron. and Astrophys. **227**, 294–300 (1990).
7. S.A. Ehgamberdiev, A.K. Bayjumanov, S.P. Ilyasov, Y.A. Tillayev, A.A. Tokovinin, and A. Ziad, Astron. Astrophys. Suppl. Ser. **145**, 293–304 (2000).
8. S.P. Ilyasov, A.K. Baizhumanov, M. Saratsin, Kh.B. Sultanov, and S.A. Ehgamberdiev, Pis'ma Astron. Zh. **25**, No. 2, 156–160 (1999).