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# ASTRONOMICAL STATION VIDOJEVICA: ASTRO-CLIMATE

M. JOVANOVIĆ[1], M. STOJANOVIĆ[1], N. MARTINOVIĆ[1], M. BOGOSAVLJEVIĆ[1], I. SMOLIĆ[2] and B. ACKOVIĆ[2]

[1]*Astronomical Observatory of Belgrade, Volgina 7, 11060 Belgrade, Serbia*
*E–mail: milena@aob.rs*

[2]*Institute of Physics Belgrade, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia*

**Abstract.** Astronomical Station Vidojevica[1] is located on Mt. Vidojevica near Prokuplje, Serbia. The equipment for measuring astro-climate conditions was installed in November 2010. The main characteristics of All-sky Camera, Weather Station and Seeing Monitor are presented. In addition, some preliminary results obtained using the instruments are discussed. The results presented here are part of our long- term monitoring campaign of astro-climate characteristics for this site, which will be useful in planning observations with the future robotic telescope Milanković.

## 1. INTRODUCTION

Astronomical Station Vidojevica (hereafter ASV) is the new observing facility of Astronomical Observatory of Belgrade. It is located on Mt. Vidojevica near Prokuplje ($\varphi = 43°08'25''$, $\lambda = 21°33'20''$), at an altitude of $h = 1155$m. Satellite data shows that Vidojevica is one of the few places with a moderately dark night sky remaining in Serbia. During the previous years, the main building and the dome for a 60 cm telescope ($D/F = 60$cm/600cm) have been constructed on the site. The site is also reserved for the construction of the new robotic 1.5 m ($D \sim 1.5$m) telescope Milanković. We have started a long-term campaign to measure astro-climate conditions on this location and to assess its quality for astronomical observations.The instruments mounted at ASV are presented. The initial measurements obtained and plans for the future will also be discussed. The results of this monitoring campaign will be used during the design of the 1.5 m telescope and future projects that can be performed at this station.

## 2. INSTRUMENTATION AND RESULTS

The instruments used for this monitoring campaign are the following:

- Weather Station
- All-sky Camera
- Seeing Monitor

[1]http://vidojevica.aob.rs/

2. 1. WEATHER STATION

Figure 1: Weather Station

The Weather Station[2] (Figure 1) is a DAVIS Wireless Vantage Pro2$^{tm}$ with 24-Hour Fan Aspirated Radiation Shield. The Weather Station (WS) is battery and solar-panel powered, therefore it is capable for autonomous measurements and data storage. It proved to be the most stable of all the instruments.

WS had almost continuous coverage of measurements beginning with April 2011 and thus provided us with the first long-term direct and detailed measurements of meteorological parameters at the summit of Mt. Vidojevica. WS is composed of an integrated sensor suite (ISS, mounted outdoors at an elevation of 10m above ground level) an indoor sensor and receiver. Thirty-four parameters in total are being measured or calculated at regular intervals of 5 min. The ISS combines a rain collector, temperature and humidity sensor, anemometer and solar panel as the sole package. WS uses frequency hopping spread spectrum radio technology for wireless transmission of weather data at distances up to 300 m. The ISS can also be powered by AC-power adapter or batteries. We have created online access to real-time weather reports.

Temperature measurements during the period from April to September 2011 are divided into two periods for each day - one period is from sunrise to sunset and we called it day-time in this paper; the other period is from sunset to the sunrise the next day and it is called night-time. Black line is connecting average temperatures during day-time (up) and night-time (down) in figure 2. Variations between minimum and maximum temperatures for each day are represented by gray shadowed area. In the Figure 3 the daily average humidity for the same period of time is shown. We can note that the humidity is fairly high for an observatory site, the average being around 70 %. More importantly, during the summer season of 2011, which has been moderately dry, the minimal humidity was approximately 40 %. We explain this as the consequence of the location of the ASV, which is a mountain summit immersed in dense vegetation. Humidity is the second most significant constraint on the quality of an astronomical site, with the cloud coverage being the most significant.

Other important parameters measured with WS are wind direction and speed. The so-called Wind Rose (Figure 4) is representing those two parameters graphically. We observe on ASV that there is a dominant wind direction, with almost a quarter of the

[2]http://www.davisnet.com/weather/products/weather_product.asp?pnum=06153

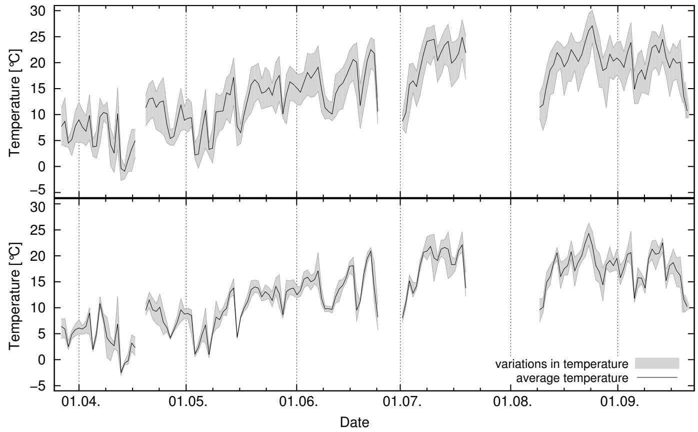


Figure 2: Average temperature with variations between minimum and maximum for day-time (up) and night-time (down) from April to September 2011.

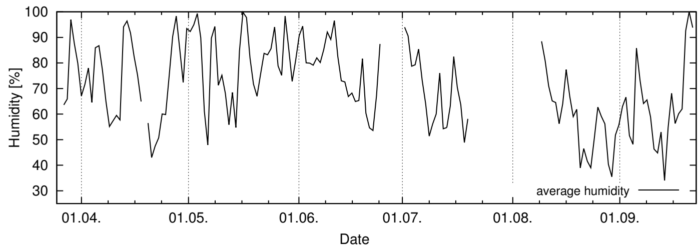


Figure 3: Average daily humidity from April to September 2011.

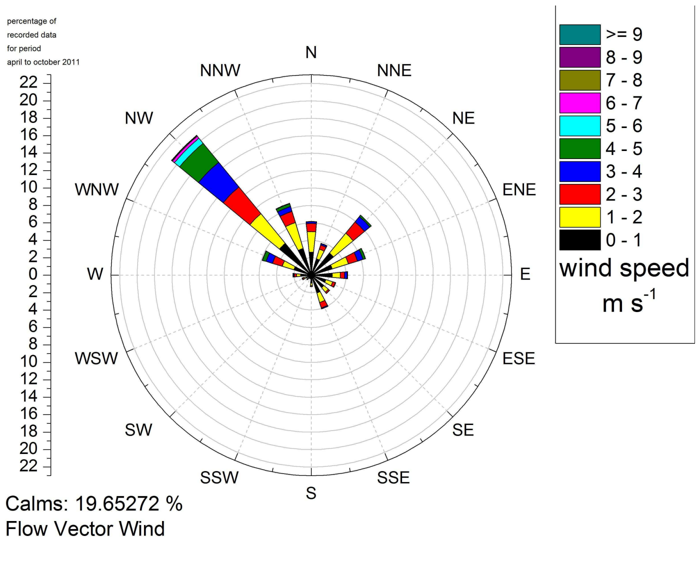


Figure 4: Wind Rose for data from April to September 2011.

all recorded wind coming from the Northwest. During the period of measurement the wind was rarely stronger than 4m/s.

Figure 5: All-sky Camera.

Figure 6: Seeing Monitor.

### 2. 2. ALL-SKY CAMERA

The camera[3] (Figure 5) is SBIG All-Sky 340, containing the highly sensitive Kodak KAI-340 CCD with 640x480 pixel resolution, 7.4 microns square pixel size. The fisheye lens incorporated is Fujinon with 1.4 mm focal length, F/1.4, giving a horizon to horizon coverage.

This camera has 95 % sky coverage and good quality images with low noise. Images are being taken using 60 s exposure time continuously. While image download takes place the subsequent exposure is started. With this exposure time, the camera regularly detects stars up to the $6^{th}$ magnitude in the center of the image.

We have been able to derive the World Coordinate System (WCS) solution for these all-sky images, Figure 7 (left). This algorithm for WCS solution will be a part of automated measurement of cloud coverage from all-sky images, which is under development.

The WCS solution also facilitates measurements of bright transient events such as meteors, variable stars, surveying for sudden events (like supernovae, GRB) etc. We provide an example in Figure 7 (right). The image shows a meteor, and its fragments, captured on $12^{th}$ of November, 2010, at 19:27 local time, as it was passing above Vidojevica. At its peak it was brighter than the Moon (also seen near the edge of the frame).

The current all-sky picture and some meteorological data are available online[4]. We plan to make all of the automated measurements available at this site in the future.

### 2. 3. SEEING MONITOR

The SBIG All Weather Seeing Monitor[5] (Figure 6) has been used for monitoring seeing conditions at the site. It has been installed on a 1.5 m high pillar in the vicinity of the 60 cm telescope dome. The Seeing Monitor uses an uncooled, shutterless version of the SBIG ST-402ME camera mated to the 150 mm focal length f/5.3 lens inside the weatherproof box. The lens and the box are permanently pointed to the North Celestial Pole. Field of view of the seeing monitor is wide enough to capture Polaris rotating around the Celestial Pole during the whole night. The software measures

[3] http://www.sbig.com/images/documents/products/Allsky340%20Manual.pdf
[4] http://vidojevica.aob.rs/
[5] http://ftp.sbig.com/sbwhtmls/online.htm

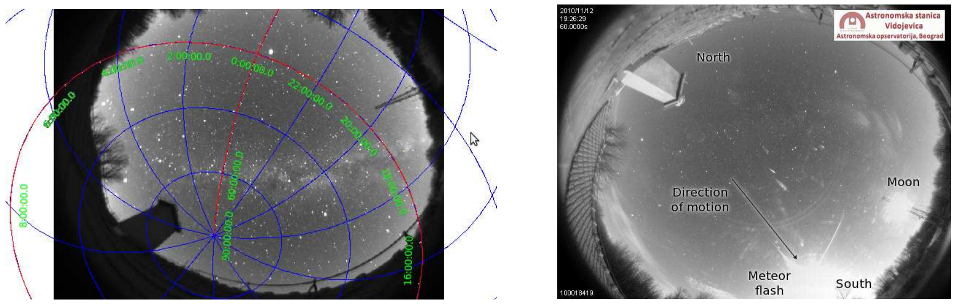


Figure 7: Snapshot from All-sky with WCS solution applied (left); Meteor flash captured by All-sky Camera (right).

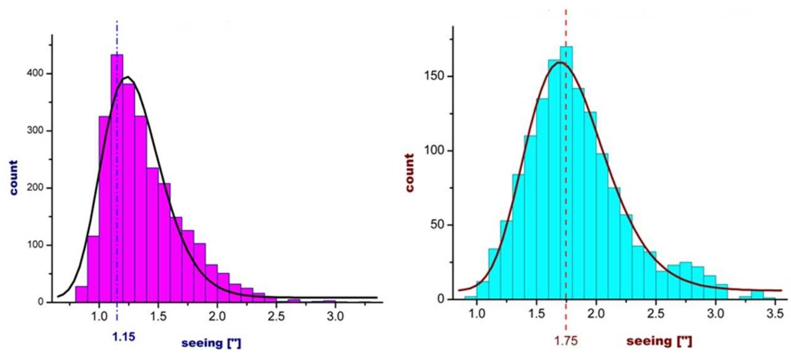


Figure 8: Seeing histograms: Clear Sky (left); Partly Clear Sky (right). The histograms are fitted with a log-normal distribution.

Polaris perturbation by seeing, and automatically calculates the FWHM scaled to the zenith. The readout is fast and continuous, so a new measurement of the Polaris position is obtained every 5ms.

Due to technical difficulties and frequent power outages at the ASV site, we have thus far been able to record the seeing only for a fraction of nights in the period from November 2010 to March 2011. Further measurements are necessary to characterize seeing, covering a time span of one year. The results presented here were done in combination with visual cloud coverage estimates from the all-sky images.

In the analysis we only considered observing nights for which we had both the data from the Seeing Monitor and the All-sky Camera. The data were divided in two sets. The first set of the data is for almost completely clear sky and the histogram of the seeing (Figure 8, left) for this set has a median value of $1''.15$. The second set of seeing measurements was taken during low cloud coverage (mostly transparent cirrus). The seeing histogram shows a mean value around $1''.75$ (Figure 8, right).

Both histograms are fitted quite well with a log-normal distribution. We conclude that seeing statistics is reasonably well behaved even in the presence of some cloud coverage. The average value for the seeing is acceptable for an observatory site under clear sky conditions, and it is also our opinion that useful data can be obtained even in the presence of thin clouds. In other words, it is the number of clear nights in a given year which is the determining factor of the quality of the ASV site. When cloud coverage is low, our measurements show that the expected average seeing at the ASV should be well below $2''$.

We compared our measured seeing with a simple model of the atmosphere (Racine, 2005). This model gives a prediction of the mean seeing value based on the thickness of the free atmosphere layer, boundary layer and ground layer of the atmosphere. The model uses just the altitude of the site and elevation of the instrument as input values, to provide an expected value of the mean seeing. From this model we obtain an expected value of the seeing for altitude 1155 m and elevation 1.5 m:

$$\langle W \rangle = 1\overset{''}{.}21 \pm 0\overset{''}{.}05$$

We find that the predicted seeing is fully achieved under clear sky conditions. Based on the same model we derive that the future 1.5 m ($D \sim 1.5$m) telescope on this location, if raised to 10 m elevation, will be able to achieve mean seeing under $0\overset{''}{.}8$.

Future plans include comparison with more detailed atmospheric and meteorological models. For the best seeing measured, we plan to determine which of the meteorological conditions are the most likely cause.

## 3. CONCLUSION

During the operating time of our instruments, the observed meteorological and seeing values at the ASV are considered acceptable for an observatory site. The data shows that the selection of this location was justified for building the station and placing the 60 cm telescope and the planned 1.5 m Milanković telescope.

Unfortunately, since November 2010 the data coverage has been incomplete. In the future, we plan to resolve issues with power supply by upgrading our UPS system. With the all-sky camera, seeing monitor and meteorological station in operation we now have a system of sensors to integrate towards a more automated operation of the 60 cm telescope. The implementation of software which will enable centralized monitoring of all those systems together with the telescope will be finished in near future. That experience will be of great value for us when designing the 1.5 m telescope and infrastructure for phase two of the development of the Astronomical Station Vidojevica.

### Acknowledgments

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