Report on seeing, sky brightness, and meteorological properties measurements at Timau National Observatory site

M B Saputra¹, M D Danarianto¹, M D Murti¹, M A Alwan¹, R J Yanti¹ and Chikmah²

¹ National Observatory Operational Office (Balai Pengelola Observatorium Nasional), National Research and Innovation Agency, Kupang 85361, Indonesia
² Astronomy Study Program, Institut Teknologi Bandung, Bandung 40132, Indonesia

Email: muhammad.bayu.saputra@brin.go.id

Abstract. With the existence of the Timau National Observatory, the site testing of the observatory location must be carried out to provide supporting data regarding the quality of the National Observatory site. Some site testing that needs to be done are seeing, sky brightness, and meteorological properties measurements. In this paper, the seeing and sky brightness measurements in July-August 2021 are presented. These measurements were conducted using the Differential Image Motion Monitor (DIMM) method with a 20 cm telescope and a Sky Quality Meter (SQM) respectively. From the results of these measurements, it was found that the site of Timau National Observatory has good seeing conditions with median of 0.92 arcsecond and most sky brightness values are around 22.02 magnitude per square arcsecond. The monitoring results of meteorological properties, such as air temperature, barometric pressure, relative humidity, and wind speed and direction during August 2021 that recorded by an automatic weather station are also presented.

1. Introduction
The Timau National Observatory, which is a collaboration between LAPAN and ITB, Nusa Cendana University, the East Nusa Tenggara Provincial Government, and the Kupang Regency Government, is currently under construction on the slopes of Mount Timau (9°35'50.2" S, 123°56'48.5" E), Kupang Regency, East Nusa Tenggara, with an altitude of about 1300 masl. Timau National Observatory will eventually have a 3.8-meter-diameter telescope facility [1]. This location was chosen because this area has a clear night sky fraction of roughly 60% throughout the year, making it one of Indonesia's clearest night sky areas [2]. The study examined data from weather satellites over 15 years. In the meantime, there have not been many in situ measurements and monitoring that had been carried out.

Supporting data is required for the building of the Timau National Observatory to assess the quality of the observatory site. As a result, site testing is required to determine the characteristics and in situ conditions of the Timau National Observatory location, such as night sky brightness, seeing conditions, and meteorological properties. This type of process is widely used at numerous observatories, both at the site selection and planning stage [3,4] and the operating stage [5,6].

The previous measurement conducted in July 2018 shows that the median seeing in the Timau National Observatory site is 0.93 arcseconds and the night sky brightness is around 22.18 magnitude per square arcsecond [7]. The results of in situ measurements of seeing and night sky brightness carried out
on July-August 2021 and meteorological properties measurements taken on August 2021 are presented in this report. The measurements were carried out during the dry season in Indonesia, which is appropriate for astronomical observation.

2. Data acquisition

The instruments and methods that have been used to obtain the site testing parameters are as follows. Seeing was measured using the Differential Image Motion Monitor (DIMM) method [8,9]. The DIMM method also widely used to characterize the seeing parameter such as in Ali and Muztagh-at site in China [10,11] and Iranian National Observatory project at Mount Gargash [12]. Measurements were made using a telescope with a diameter of 20 cm with a focal length of 195 cm (f/9.75). This telescope is also equipped with an aperture mask that has two holes with 4.5 cm in diameter and 14 cm apart from each other. A CMOS detector is used to record the effect of seeing on the observed stars. The seeing measurement was conducted by taking images of bright stars around the zenith with a CMOS camera detector at 10-20 frames per second (fps) in a slightly defocused position.

The light from one star will enter the sub-apertures and be observed as two objects in one field of view as seen in figure 1. The distance between the two objects will vary over time due to atmospheric turbulence that changes the wavefront of starlight reaching the telescope. The relative difference in the distance between the two objects each time can represent the amount of seeing. The seeing measurements were conducted using the Vixen VMC200L telescope, iOptron CEM60 mounting, and the QHY-5L-II-M CMOS camera on 15-16 July and 10-12 August 2021.

Night sky brightness was measured automatically using a Sky Quality Meter (SQM) with data logger type from Unihedron. The SQM is directed towards the zenith and measurements are taken every minute from sunset to sunrise. The measurements were carried out on 1 July-31 August 2021. Meanwhile, meteorological properties are measured every 15 minutes using the Davis Vantage Pro2 Plus automatic weather station (AWS). The meteorological properties measured were air temperature, relative humidity, barometric pressure, rain rate, wind speed, and wind direction. These measurements were conducted on 10-31 August 2021. The data acquisition of the night sky brightness using SQM and the meteorological properties using AWS are also used to measure those parameters in site testing activities for selecting the site to host 12-meter Large Optical/infrared Telescope (LOT) [13] and Iranian National Observatory (INO) [12].

Figure 1. Image result of the star in the detector with a slightly defocused position after the starlight enters the aperture mask. The star in the image is Diphda and was observed on 16 July 2021.

3. Result and discussion

After the measurements were made, the following results were obtained. The seeing measurements results are displayed in figure 2. On 15 July, seeing measurements started on 21.45 until 04.30 local time. Unfortunately, around 22.15 - 01.00 local time, the sky was cloudy with fog. So, there is no measurement data on that period. On that night, a good median seeing was obtained, which was 0.78 arcseconds with the smallest seeing value reaching 0.36 arcseconds and the maximum seeing value
being 2.64 arcseconds. As for the measurements on 10-12 August 2021, the obtained median seeing was larger than before and reached a value of 0.94 arcseconds.

The median seeing value obtained in July 2021 is smaller than the results obtained in the previous measurement in July 2018 [7]. While for the measurement in August 2021, the value is approximately the same with the previous result. From those two measurement times combined, the median seeing for July-August 2021 is 0.92 arcseconds with a minimum value of 0.36 arcseconds and a maximum value of 2.93 arcseconds. The histograms of the seeing value distribution that has been obtained are displayed in figure 3.

**Figure 2.** Seeing measured on (a) 15-16 July and (b) 10-12 August 2021.

**Figure 3.** Histogram of seeing measured on (a) 15-16 July and, (b) 10-12 August 2021, and (c) all data combined.
The night sky brightness measurements are shown in figure 4. The night sky brightness value for July and August is around the value of 22 magnitude per square arcsecond (mag/arcsec²). The decrease in the night sky brightness values in the third week of each month is caused by the moonlight. From the measurement results, it is found that the median value of night sky brightness in July is 21.80 magnitude per square arcsecond and in August is 21.83 magnitude per square arcsecond. Meanwhile, when the data are combined, a median value of 21.81 magnitude per square arcsecond is obtained with the peak distribution being at a value of 22.02 magnitude per square arcsecond as seen in figure 5.

**Figure 4.** Daily value of night sky brightness in (a) series and (b) stacked plot measured on 1 July – 31 August 2021.

**Figure 5.** Histogram of night sky brightness measured on (a) 1-31 July and, (b) 1-31 August 2021, and (c) all data combined.
Meteorological properties measurement results on 10-31 August 2021 are shown in figure 6. There was a data gap on 12-17 August. It is because the data was not stored in the data logger at that time. The temperature difference between day and night is quite large, it can reach up to 12 degrees with an average temperature of 19.5°C. The air temperature distribution peaked at 17.81°C. At the Timau National Observatory site, the average humidity reaches 78%. During the day, humidity drops to a minimum value of 27% and increases at night to a maximum value of 98%. The high humidity can cause the telescope to become foggy.

At the end of the month, there was also a pattern that after the humidity peaked towards the evening and then it decreased again throughout the night. It is estimated that the increase in humidity is due to the formation of fog in the afternoon until the evening accompanied by a considerable decrease in temperature. From the relative humidity distribution, it is found that there are two most common values, which are 72% and 92%. It shows that the humidity on the site is relatively high.

For the barometric pressure on the site, the average value is 1012.3 millibar. The lowest value reaches down to 1007.3 millibars with the maximum value being 1015.7 millibars. From the rain rate profile with a continuous value of zero, it is known that there was no rain during 10-31 August 2021.

Figure 6. Meteorological properties measurements: (a) air temperature, (b) relative humidity, (c) barometric pressure, and (d) rain rate on 10-31 August 2021. The left panel is the measurements data and the right panel is the histograms.
Figure 7. (a) Wind speed measurement and histogram and (b) wind direction measurement on 10-31 August 2021.

The average wind speed can reach 5.4 m/s with instantaneous wind speed that can reach up to 9 m/s. The average value for the wind speed is 1.22 m/s. However, for the most part, there is no gust of wind or only a light breeze of less than 1 m/s. The wind throughout the month of August is dominated by winds from the east-northeast (ENE) (see figure 7).

4. Conclusion
In this paper, the results of the seeing and night sky brightness measurements in July-August, and meteorological properties measurements in August 2021 for the Timau National Observatory site have been presented. The median value of the seeing is 0.92 arcseconds. The night sky brightness median value is 21.81 magnitude per square arcsecond with the peak distribution being at a value of 22.02 magnitude per square arcsecond. Lastly, the average value for the meteorological properties measured, namely air temperature is 19.48°C, humidity is 77.58%, barometric pressure is 1012.3 millibar, rain rate is 0 mm/hour, wind speed is 1.22 m/s, and dominant wind direction is from the east-northeast.

From these results, several considerations can be taken regarding the construction of the Timau National Observatory in the future. The need to maintain the quality of the night sky brightness which is already very good at this location by setting the use of artificial light around the Timau National Observatory area. In addition, consideration of the use of telescopes (either optical or radio telescopes) and domes also needs to pay attention to meteorological profiles such as wind and humidity to maintain the quality and condition of the astronomical observation equipment.

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