Report on Sky Brightness, Seeing, and Weather Measurements at Timau Observatory, East Nusa Tenggara

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Abstract. In 2015, a joint collaboration project to build a new observatory in Mount Timau, East Nusa Tenggara was initiated between LAPAN, ITB, UNDANA, Kupang Regency and East Nusa Tenggara governments. The site selection is based on preliminary studies conducted on nearby location. This paper presents in situ measurements report on seeing, weather and sky brightness obtained on July 2018 using Differential Image Motion Monitor (DIMM) with 20 cm-telescope, Davis Vantage Vue automatic weather station, and Sky Quality Meter, respectively. Despite the high humidity and foggy condition on the afternoon, the site has good seeing condition with median of 0.93 arcsecond and sky brightness around 22.18 magnitude per arcsecond square after midnight.

1. Introduction

The project to build a new astronomical facility in Mount Timau, East Nusa Tenggara was started with the signing of memorandum of understanding between National Institute of Aeronautics and Space (LAPAN), Institut Teknologi Bandung (ITB), Nusa Cendana University (UNDANA), Kupang Regency and East Nusa Tenggara governments in 2015. The site is selected based on initial studies of global atmospheric parameters [1] and cloud cover over Indonesia from 1996 to 2010 [2]. It is suggested that East Nusa Tenggara is a promising candidate of an astronomical site since it has more than 60% clear sky fraction over the year.

For an optical observatory, the parameters that determine quality of the site are cloud coverage, sky brightness, air turbulence (seeing), atmospheric extinction, and climatology (pressure, temperature, humidity, wind speed, and rainfall). In general, the atmospheric extinction, transparency, and turbulence are related to the altitude of the site since the atmosphere tends to become more turbulent at the planetary boundary and thermal inversion layer [3]. Clouds are also usually trapped in these layers. Due to these reasons, the follow up expedition and site survey since 2013 are conducted at relatively high altitude area around Mount Timau at East Nusa Tenggara (123° 56' 47.64" East, 9° 35' 46.2" South, 1281 m above sea level) which is a remote area surrounded by a protected forest.

A special permit from Ministry of Environment and Forestry is needed to conduct some activity in this region. Hence, on 2013-2017, the preliminary study of sky brightness and seeing were carried out ex situ at the nearest district office of Amfoang Tengah (124° 00' 04" East, 09° 40' 28" South, 1071 m above sea level), around 11 km from the site. The sky brightness and seeing at this location are 21.4 magnitude per arcsecond square [4] and between 0.87-1.65 arcsecond from three nights of observation [5], respectively.
Seeing and weather may vary on different location and very dependent on local terrain and conditions, hence an in situ site evaluation must be carried out. This paper presents report of in situ measurements of seeing, weather and sky brightness obtained on 19-27 July 2018. The measurements were conducted during dry season in Indonesia which is suitable for astronomical observation.

2. Data acquisitions

The instruments and methods used in this work are described as follow. Sky brightness were measured automatically every 30 seconds using Unihedron Sky Quality Meter (SQM). It is consist of CMOS camera equipped with HOYA CM-500 filter which has spectral response similar to human eye. The SQM is factory-calibrated using NIST meter, EXTECH instruments model 401027 with absolute precision of 0.10 magnitude per arcsecond square (mag/arcsec^2). During measurement, the SQM was pointed at 15° zenith angle to the north to avoid Galactic center and to allow any rainwater or dew attached to the lens to dry faster.

The seeing measurements were conducted using Differential Image Motion Monitor (DIMM) technique [6]. The instruments consist of a 20 cm telescope (f/9.75) equipped with an aperture mask with two 4.5 cm holes separated at 14 cm distance. During measurement, the telescope was pointed to bright star around zenith. A CCD video camera was used to record the stellar images at 10 fps with slightly defocus position. Since the starlight was passed through the telescope from different hole, the star will be recorded as two object separated at certain distance. This distance may change due to atmospheric turbulence. The difference of relative distance on stellar images is represent the seeing. To obtain a single seeing data, the stellar images were averaged every 50 frames.

Lastly, the weather condition was recorded using Davis Vantage Vue automatic weather station every minute. The instrument was installed on a pole, around 3 m above the ground.

Sky brightness and weather condition were initially planned to be collected for a year. Unfortunately, the SQM was damaged and stolen on July 24. Due to security reason, the measurement was ceased and all remaining instruments were retrieved on 27 July 2018. Seeing measurement only conducted for two nights, i.e. 18 and 19 July 2018 because the instruments have to be operated manually.

3. Analysis and discussions

On July 18, the weather is foggy and cloudy at the afternoon until around 11.00 p.m. Seeing measurement is started at midnight until morning. On the following day, the weather is worse and seeing measurement only last for an hour. The results are displayed on figure 1. Seeing condition is determined from the histogram (see figure 2). The calculated median seeing on 18 July, 19 July, and for all combine data are 0.93, 1.24, and 0.93 arcsecond, respectively.

![Figure 1. Seeing measured on (a) 18/19 July 2018 and (b) 19 July 2018.](image_url)
The temperature and humidity data are displayed on figure 3. It is shown that the humidity at the site is relatively high, i.e. between 72-100% and the temperature difference between day and night is up to 7°C, causing fog to be formed easily in the afternoon. This condition is compounded by the topography. The site is located at the south of the mountain peak while the wind is mildly blow mostly from southeast to northwest, passing through a dense forest area (see figure 4).

Figure 2. Histogram of seeing measured on (a) 18/19 July 2018, (b) 19 July 2018, and (c) all data combined.

Figure 3. Temperature and humidity data obtained using automatic weather station.

Figure 4. (a) Histogram of average wind speed and (b) wind direction obtained using automatic weather station on 19-27 July 2018.
The sky brightness data are displayed on figure 5. The fog are cause the gradient of sky brightness before midnight. The weather is stabilized after midnight and the darkest sky brightness is recorded at 22.58 magnitude per arcsecond square. From the data distribution, there are two sky brightness median value, i.e. 19.63 and 22.18 magnitude per arcsecond square. These value may represent sky brightness on foggy and clear sky conditions.

Figure 5. Sky brightness recorded on 18-24 July 2018.

Figure 6. Histogram of sky brightness from 18 to 24 July 2018. Two data clumps are fitted using frequentist approach.

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