Mobile Campaign of Sky Brightness Measurement in Indonesia

A G Admiranto¹, SK Haida², R Priyatikanto¹, S Maryam¹, Ellyyani¹, N Suryana¹

¹Space Science Center, Jl Dr Djundjunan 133, Bandung 40173, Indonesia
²Department of Astronomy, Institut Teknologi Bandung, Jl Ganesha 10, Bandung 40132, Indonesia

Abstract. The bright sky caused by light pollution is a problem for astronomical research. One of the first steps in dealing with the effects of light pollution is to calculate the level of light pollution. Measurement of sky brightness using Sky Quality Meter (SQM) can be done massively through mobile campaign/observations. LAPAN conducted such observations at several places namely Sumatera Barat, Sumedang, Jawa Tengah, Jawa Timur and Kupang by using SQM attached on vehicles. Those campaigns covers 80 to 980 km journey and the total distance traveled was about 2870 km. The obtained data show that the sky brightness above regions surveyed vary from 10 magnitude per arcsec² (mpsas), especially around Surabaya, Jawa Timur to 22 mpsas. The results then compared radiance map of the Earth surface from Visible Infrared Imaging Radiometer Suite (VIIRS) aboard Suomi National Polar Orbiting Partnership (NPP). Moderate correlations between in-situ sky brightness data and the radiance map are achieved. Further analyses are required prior to utilization of those relations in the development of Indonesia’s sky brightness map which is presumably more accurate than the existing global map of sky brightness.

1. Introduction

A good sky condition is an important prerequisite to get good information through space observation. Not only naked eye observation, but also photometric and spectroscopic observations by using telescopes will also interfered with by light pollution. Besides disturbing astronomical observations, the existence of light pollution, due to the current development, raises problems in various aspects. Excessive lighting such as in hotel and building facade, billboards, concert lights, and street lights also cause problems in economic aspects, biotic life, human health, and other nature protection [1]. Therefore, it is necessary to immediately overcome the effects of light pollution that may result in other problems.

Tackling light pollution does not mean that we have to prohibit external lighting. We just have to apply the lighting as we need. The only lights which need to point skywards at night are those delineating airport runways. Easy solutions to reduce light pollution are adjusting energy-saving street lamps and making security lights and spotlights to point downwards. Illuminated advertising board should be switched off at night and some regulations to impose curtains in every window are also possible to decrease light pollution significantly [6].

But, due to the diverse factors that cause the light pollution problem, it is necessary to map the sky brightness. Such map can be the basis for the mitigation effort to be more focused. Previously, there
had been a map of the world’s sky brightness which computed through light pollution propagation software using new high-resolution satellite data [2], [3]. Established maps of world sky brightness were developed from model of light propagation which were tuned using in-situ measurements conducted at high latitude regions [4], [5]. To make it more accurate, we need more locally made observations in other parts of the world. To map Indonesia’s sky brightness, it is necessary to do direct measurement in various environmental conditions.

This paper aims to report our endeavor in conducting in-situ measurement of sky brightness over Indonesia through mobile campaigns at several places. Those campaigns were conducted almost simultaneously at Sumatera Barat, Sumedang, Jawa Tengah, Jawa Timur and Kupang. The data obtained can be compared to radiance map constructed from satellite images in order to establish an empirical model as the basis of the sky brightness map of Indonesia.

2. Methodology
Mobile campaigns were conducted to measure the sky brightness using moving vehicles through various conditions, ranging from cities to villages, highlands to lowlands (see Table 1 and Figure 1). Six different teams conducted the campaigns almost simultaneously on June 24-26, 2019 during which the weather was relatively good and the moon light does not contaminated the sky excessively. During that period, the moon age was 20 to 23 days and the fraction of illumination was 63% to 45%.

The instrument used in the campaigns were Unihedron SQM-LU (Sky Quality Meter with data logger attached through a USB port). To make it work as it should, SQM equipped with a battery charger and inserted into a tube that can be placed outside the vehicle. The Unihedron Device Manager application is also installed on a computer that is connected to Shared GPS application on Android. In addition, GPS logger application on Android is also needed as a backup application. Data were sampled all along the trip with 10 second intervals. Each row contains time and location of observation, temperature, voltage, and sky brightness in units of magnitude per square arcsecond (mpsas).

Table 1. The routes and the distance taken in the campaigns.

| No. | Area | Designation | Distance covered |
|-----|------|-------------|------------------|
| 1.  | Pasuruan-Probolinggo- Jember-Blitar-Blitar-Mojokerto-Pasuruan | PSR | 590 km |
| 2.  | Surabaya-Lamongan-Bojonegoro-Ponorogo-Nganjuk-Pasuruan | SBY | 532 km |
| 3.  | Bandung-Cirebon-Semarang-Kudus-Ngawi-Salatiga-Kebumen | BDG | 987 km |
| 4.  | Agam-Bukittinggi-Batusangkar-Sawahlunto-Solok-Padang-Pariaman-Padang Panjang | AGM | 292 km |
| 5.  | Sumedang | SMD | 94 km |
| 6.  | Oelndi-Kupang-Kuanheun | KOE | 80 km |

Following the work of [6], sky brightness obtained in campaigns are compared with the radiance map of Earth surface at night acquired by satellite. Composite radiance map of June 2018 produced by the Earth Observation Group (EOG), National Centers for Environmental Information (NCEI) from Visible Infrared Imaging Radiometer Suite (VIIRS) on board Suomi National Polar Orbiting Partnership (NPP) [4]. VIIRS uses highly sensitive optical sensors to see lights at night.
Figure 1. Upper panel depicts regions covered in the campaigns. Lower panels show the routes taken by each team. Different colors (red, green, orange) represent different night of observation. This map is superposed with radiance map of VIIRS (in nW/m$^2$/sr).

3. Results
In total, the campaigns covers 2870 km of journeys covering big cities (e.g. Surabaya, Jawa Timur) with high sky brightness of 10 mpsas to the suburban and rural area with low sky brightness of 21 to 22 mpsas. The higher the magnitude of the sky brightness, the lower the light pollution is. The data is dominated by sky brightness between 17 to 21 mpsas. It is noteworthy that a fraction of data obtained is contaminated by glare from external lightings which decrease the magnitude. During the passage, some trees may also cover the view of the SQM such that instruments record artificially darker sky. These kind of contamination can be reduced by proper data filtering.

Moving observations are the first step toward building an alternative sky brightness maps. The night sky observation data from VIIRS can be directly compared with the SQM data to get an
empirical model. Figure 2 shows the correlation plots between those two kinds of data. Two dimensional distributions of the data are provided as density plots where darker colors mark regions with higher density.

![Density plots](image.png)

**Figure 2.** Density plot of SQM data with radiance map from VIIRS (in logarithmic). Dashed line represents empirical model from [6].

There is a clear trend of increasing sky brightness (or decrease in mpsas) inline with the increase of surface radiance measured by VIIRS. However, the correlations are somewhat weak due to contamination from terrestrial light sources, i.e. light from traffic, street lighting, and buildings. Furthermore, the sky conditions during the observation were varied, and this seems to affect the results significantly because thick clouds scatter back some incoming radiation from the Earth’s surface. In this respect we need some more observations which conducted in dark and clear night conditions.

As the benchmark, we revoke the empirical model from [6] which assumes that the logarithm of VIIRS radiance and the sky brightness data in mpsas follow simple linear function:

$$\text{SQM} = 20.595 - 3.090 \log \text{RADIANCE}$$

(1)

This formula can be interpreted as the linear effect of artificial light generated on the Earth’s surface on the amount of light scattered in the atmosphere which is translated into the observed sky brightness. Since sky brightness is expressed in magnitude or logarithmic scale, then the VIIRS radiance also needs to be expressed logarithmically. The deviation from this simple function may indicate how severe the contamination to data is. For example, from Figure 2 panel SBY, there is a significant fraction of data or regions with radiance of around 10 nW/m²/sr whose SQM gives <14 mpsas. In other words, these regions have brighter sky than expected by the simple model. In big cities, glare becomes a serious problem to unfiltered sky brightness measurements.
4. Conclusion
Moving night sky brightness observations had been successfully carried out at several regions in Indonesia. This campaign is the first observation of its kind which recorded the sky quality above certain locations. The results showed that there are some areas in Indonesia which have severe light pollution, but there are also some areas which have good sky qualities. However, the observations itself were not carried out in some ideal condition. Contaminations from street lights, buildings, and moving vehicles need to be handled more carefully. The sky was not entirely clear such that some kind of reflection from the cloud contaminated the results further.

However, there are some relations between VIIRS data with sky observations data as a linear relationship. These relationships can be used to make some kind of preliminary sky brightness map. This work will be continued, especially in observing the night sky brightness with different sky condition from the ones we have reported here. Hopefully the results will give us more comprehensive map of the light pollution in Indonesia.

5. References
[1] Haim, B. A. Portnov, Light Pollution as a New Risk Factor for Human Breast and Prostate Cancers (Springer, Dordrecht, 2013).
[2] Cinzano, P. Night sky photometry with Sky Quality Meter, 2015, Thiene, Italy
[3] Cinzano, P, Elvidge, C D Night sky brightness at sites from DMSP-OLS satellite measurements. Mon. Not. R. Astron. Soc., (2004)
[4] Elvidge, C D, Baugh, K E, Zhizhin, M, Hsu, F-C. Why VIIRS data are superior to DMSP for mapping nighttime lights. Proc. Asia-Pac. Adv. Network 35, (2013).
[5] Falchi, F, Cinzano, Pierantonio, et al. The new world atlas of artificial night sky brightness. 10.1126/sciadv.1600377 (2016)
[6] Priyatikanto, R., Admiranto, AG, Putri, GP, Elyyani, Maryam, S and Suryana, N, Map of Sky Brightness over Greater Bandung and the Prospect of Astrotourism, Indonesian Journal of Geography, 51, 190, DOI: 10.22146/ijg.43410, (2019)
[7] Rich, C, Longcore, T, Ecological Consequences of Artificial Night Lighting (Island Press, Washington, DC, 2005).