The influences of solar radiation changes on the meteorological variables during the total solar eclipse of 9th March 2016 in Central Bangka, Indonesia

Ryantika Gandini¹, Nanang Dwi Ardi¹, M. Iid Mujtahiddin²

¹Physics Department, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No 229 Bandung 40135
²BMKG Stasiun Geofisika Bandung, Jl. Cemara No. 66 Bandung

E-mail: ryantikagandini@gmail.com, nanang_dwiardi@upi.edu

Abstract. Observations of the meteorological variables have been conducted in Terentang coastal area, Central Bangka which is located in totality path of Total Solar Eclipse on March 9, 2016. These measurements were made before, during, and after the solar eclipse using a portable automatic weather station with 1 Hz data recording to investigate the influence of total solar eclipse on the incoming solar radiation and other weather variables. Due to the cloudiness at the first phase of the eclipse, the reduction of the radiation was not proportional to the percentage of the solar obscuration. Along with the disappearance of thick clouds, solar radiation changes reach the lowest value from 123 W/m² to zero point at 5 minutes before the maximum phase. In contrast to the radiation decrement, decreasing air temperature was not comparable to the solar obscuration because it was not only determined by radiation, but also surrounding environment. High relative humidity, on average 89%, was discovered as an effect of the low atmospheric pressure which was affected by the insolation decline. The effect of total solar eclipse can be seen more clearly with spectrum analysis using Fourier transformation to identify periodogram patterns of each meteorology variable. This transformation produced a spectrum’s peak totality which is higher than before and after the event on the insolation. The spectrum represents that total solar eclipse has considerable effect to the incoming solar radiation and others which is indicated by the change of the amplitude.

1. Introduction

The abrupt change of the incoming solar radiation (insolation) during solar eclipse has inspired meteorologist to study the response of the atmosphere [1], the study includes meteorology variables such as solar radiation, air temperature, atmospheric pressure, relative humidity, wind speed and wind direction. The dramatic reduction of solar radiation reach the lowest value at maximum phase or contact, analogues with solar obscuration that has been found by [2], similar to the results obtained by [1]. Although the results of most meteorological studies provide similar pattern of temperature changes, the solar eclipse is unique event because the precise drop may differ depending on several factor (e.g. timing, synoptic situation, surrounding environment, percentage of solar occultation etc) [3].

This research aimed to study of the effect of total solar eclipse (TSE) on March 9, 2016 by monitoring changes in the weather parameters before, during and after TSE by observing the changes and performing spectrum analysis using Fourier transformation. Besides, the observation aims to correct a
reduction of insolation model [4] which does not take the atmosphere and other factors into account [5]. We aim to obtain insolation reduction model which considering the correction of the atmosphere and clouds. Calculation of percentage numbers on this was study done by comparing it with normal day data.

2. Measurements sites, weather background and instrumentation

Bangka is one of the islands in Indonesia which is traversed by the totality path of 9th March’s solar eclipse [6]. This research was conducted in Terentang Coastal area, Central Bangka (-2.44S, 106.32E). It is located far from huge building and surrounded by Natuna Sea in the north and east.

In general, on the day of the eclipse, the sky was covered with thick clouds. Thick clouds covered the sky 26 minutes before the eclipse until 12 minutes after the first contact. The thick clouds gradually disappeared nearly in the totality phase. The observations of the meteorological variables were conducted using portable automatic weather station with 1 Hz data recording. The occurrence times of total solar eclipse in Terentang Beach are shown in table 1.

| Event                  | Time (UTC) | Time (Local Time) |
|------------------------|------------|-------------------|
| Start of partial eclipse | 23:20:58   | 06:20:58          |
| Start of total eclipse  | 00:22:11   | 07:22:11          |
| Maximum eclipse         | 00:23:07   | 07:23:07          |
| End of total eclipse    | 00:24:02   | 07:24:02          |

3. Results and analyses

Our data are changes in meteorological parameters. Total solar eclipse in Terentang Beach shows significant effects on solar radiation or insolation which control the weather [8][9]. Generally there are changes (fluctuations) in the increasing insolation pattern during the eclipse (marked in red line in figure 1(a)). In the initial phase of the eclipse, the solar insolation decreased by 61.36% compared with the previous day insolation. In 2nd and 3rd phase, it decreased by 100%, while in 4th phase it decreased by 58%.

![Figure 1](image1.png)

**Figure 1.** Meteorological variables changes in Terentang Beach, before (blue line), during (red line) and after (green line) TSE March 9, 2016. (a) Solar radiation/insolation, (b) Air temperature, (c) Air pressure, (d) Humidity.
Corrected model which has been carried out generates the insolation reduction model which has similar but lower value than Jagannathan model [5] (figure 2 (left)). Fluctuations of insolation for 20 minutes at the initial phase of eclipse occur due to thick clouds in the first phase of the eclipse. The presence of thick clouds during the measurement also is demonstrated by the drastic reduction in insolation compared to the theory and models (indicated by a green circle in figure 2 (right)).

Based on the corrected model, due to thick clouds during the TSE, the insolation reduces around 50.98%-66.45%. This value indicates that the presence of the clouds during the solar eclipse was not able to remove all radiation. Thus direct observation without any protection, despite the thick clouds, can harm the eyes.

The reduction of solar insolation has caused the decrease of energy received by the Earth so that the air temperature dropped by 0.1°C 11m16s after the totality. The pattern of temperature decrease is influenced by the circumstances on the site. It is situated on the beach surrounded by oceans which causes differences in the rate of temperature decline due to the heat capacity of the sand and water.

In addition, it is also due to the eclipse time that was in the early morning when the air temperature was still cold and the nearby vegetation which was capable of storing heat. Thus the air temperature did not decrease significantly at that time. While the air pressure (figure 1(c)) decreased by 0.334mb at the totality time. The pattern of air pressure was lower than the normal air pressure, or in other words the air pressure was more inert than in normal day.

Decrease in air temperature accompanied by decrease in air pressure resulted significant changes to humidity, which continued to decline toward noon. The high value of humidity (89%) began to decline at 7:55:35 AM (UTC+7) (figure 1(d)). The high value of the air humidity signifies the rich content of the water vapour due to the absence of the solar energy that reached the Earth. So that at the totality, air humidity has greater value than in a normal day.

Figure 2. The results of corrected model (left). The existence of thick clouds formed during TSE indicated by a green circle (right).

Figure 3. Periodogram of solar radiation. Period on the graphs are in seconds.
Solar insolation reduction has changed the periodogram pattern of insolation, air temperature, pressure and relative humidity. Through Fourier transformation, we found changes in weather parameters during TSE. Total solar eclipse changed the period of maximum insolation into every 134 minutes 39 seconds. This indicates a major influence of TSE on the pattern of maximum insolation changes, around 66% compared to the normal day. Period changes of other meteorological variables are shown in table 2 which differ only 1.25% from normal day.

Table 2. Period of Spectrum Pattern of Each variables

| Meteorological Variables | 8th March | 9th March | 10th March |
|--------------------------|----------|----------|------------|
| Solar Radiation          | 45m 27s  | 134m 39s | 45m 48s    |
| Temperature              | 68m10s   | 67m19s   | 68m13s     |
| Pressure                 | 45m 27s  | 44m 52s  | 45m 48s    |
| Relative Humidity        | 68m 10s  | 67m19s   | 68m13s     |

Changes of period of maximum activity that occurs during the TSE indicate TSE influence on weather parameters besides the solar radiation reduction, which is characterized by a reduction in the period of air temperature, air pressure and relative humidity.

4. Conclusions
Corrected models have shown that the presence of clouds during TSE reduce solar radiation by 50.98% -66.45%. This shows that the presence of thick clouds will not be able to protect the eyes from solar radiation. We conclude that TSE significantly influence the weather. Changes due to TSE are clearly seen after conducting Fourier transformation to all data which show a drastic change in the period periodogram insolation by 66%, while other weather parameters only showed a change of 1.25%.

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