# A meteorological study of the sea and land breezes in Bangka Indonesia during the total solar eclipse on March 9, 2016



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# A meteorological study of the sea and land breezes in Bangka Indonesia during the total solar eclipse on March 9, 2016

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**Abstract**. Of all mesoscale phenomena, sea and land breezes have been the most studied, both observationally and theoretically. During the total solar eclipse (TSE), some parameters vary anomalously in response to the occurrence of TSE on 9th March 2016 in Bangka, Indonesia. As it occurred during morning hours, it is considered to be much more significant because of its effect in sea and land breezes pattern, especially in term of lag time. We use Portlog Rainwise Automatic Weather Station which is able to measure data in 1 Hz accuracy. Comparison of hourly observations during first contact until final contact result a slow cooling temperature reduction of 0.1°C until totality phase. A significant weakening in wind speed of about 2.5 $ms^{-1}$ was observed clearly from the instrument. Unfortunately, the reduction is not coincided with the change of wind direction until the third contact. A near constancy in temperature and the wind's behaviour during TSE result delay time in sea and land breezes pattern after the totality. The lag time occurred in three days measurement data, especially sea breeze onset on the next morning day. The lag time in sea breeze was about one hour retardation. The effect of eclipse on the onset timing of sea and land breeze may be attributed to the proportion of heat accumulation due to the obscuration.

## 1. Introduction

One of the natural phenomena that have a dominant influence on parameter changes in coastal areas and small islands is the meteorological phenomenon. The influential phenomenon can be monitored as early as possible through a variety of field measurements [1].

Sea and land breeze is one result of the impact of changes in meteorological parameters. The sea breeze system begins at some distance offshore from the coast and expands further offshore [2]. The sea breeze is a recognized occurrence, which disturbs seaside areas primarily during the warm season. It is driven by the temperature change between land and sea, which characteristically peaks during the afternoon hours. Effects of the sea breeze include local changes in temperature, humidity, wind speed, wind direction, cloud cover, and sometimes precipitation.

Changes in solar irradiance, temperature, wind and other variables caused by a total solar eclipse are not quite the same as those occurring during the transition from day to night, because during the diurnal changes the variation of the solar elevation angle is large and gradual. During an eclipse, the Sun is hidden by the moon in a few minutes; therefore its elevation angle does not change much [3]. The upsurge of wind speed was attributed to a cold front in the penumbra and deceleration of wind speed was attributed to stabilization of surface layer following the temperature drop and suppression of turbulent process [4]. Moreover, retrospective analysis in deduced wind and temperature change was introduced by Clayton more than a century ago [5].

## 2. Methods

Central Bangka Regency is regency in the province of Bangka Belitung, Indonesia. This area was chosen due to the best view in term of Total Solar Eclipse (TSE) path on March 9, 2016. The measurement site is selected are shown below which is based on obscuration predicted model by Jubier, 2016 [6] (figure 1), where the umbral path is also shown. By applying *Portable Weather Logger* (*Portlog™) Rainwise Automatic Weather Station* (PRAWS) in 1 Hz accuracy for 163893 data (figure 2), solar radiation, air temperature, air pressure, and relative humidity have been successfully measured in three days (figure 5) [7]. This instrument was prepared on seashore of Terentang Beach with longitude 106°19'34.31"E and latitude 2°26'37.38"S, roughly 10 meters from coastline.

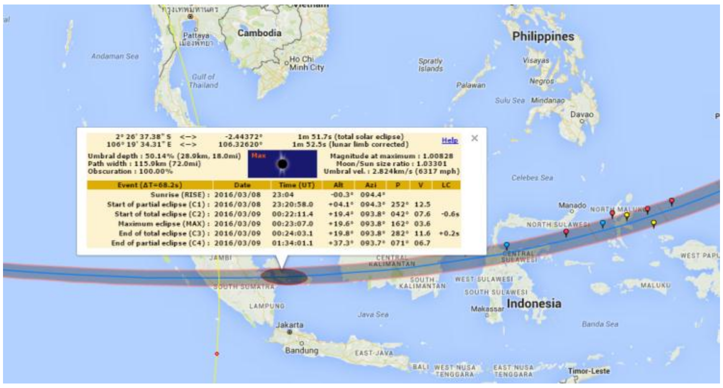


**Figure 1.** Measurement site of weather parameters in Central Bangka (http://xjubier.free.fr/)

**Figure 2**. Portlog™ Rainwise Automatic Weather Station (PRAWS) in 1 Hz accuracy; in between thousand visitors (left side); during totality of TSE (right side).

## 3. Result and discussion

Figures 3 and 4 show the change of wind behaviour in three days measurements. The behaviour was indicated by its speed and direction. For the speed, wind data shows a deceleration from 1.9 m.s$^{-1}$ at 2:07:57 Local Time (LT) and becomes zero at 7:27:00 LT in March 9, 2016. The wind drop value during transition phase of sea and land breeze affected on lag time, especially in speed term. For example, after 4 minutes totality, wind speed returned to the actual pattern of the previous day. Unfortunately, we did not have an exact time on average onset of sea and land breeze in the site. Not only in morning time, the wind at noon was also disturbed in its speed. Then, it induced that the sea and land breeze have experienced retardation more than one hour. Extension of time occurs in land breeze when swapping to the sea breeze and ends when the land gets warm at the end of totality [8]. Unfortunately, this time extension was not accompanied by a significant drop in temperature (only 0.1 ◦C) during the total phase (figure 5).

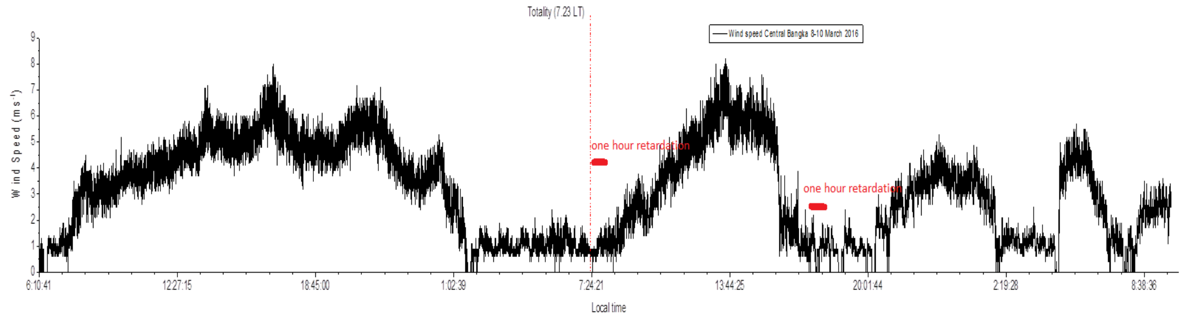


**Figure 3.** Day-to-day variations in wind speed from 8 until 10 March 2016.

The disturbance in wind condition was clearly seen on three days variation data (figure 4) which is presented in wind rose diagram mode. The diagram depicts accumulation in speed and direction of the wind. At the measurement site, we remarked that prevailing direction of the wind was either from the northwest or from the southwest and the mean of wind speed was 3.1 m.s$^{-1}$ with the maximum at 8.2 m.s$^{-1}$. The condition would be valid on one day before and one day after totality (figure 4). However, this condition did not apply to the total solar eclipse phase which overall showed wind direction to the southwest and the peak dropped to 4 m.s$^{-1}$. The reversal of wind direction during the totality is a response induced by the cooling of the surrounding environment. Then, we found that the onset of sea breeze over the site was delayed on the next day about one hour. It seems that the time delay is the shift period between sea breeze dropping to zero power and land breeze reaching modest wind speed.

In general, the lag time of sea breeze is affected by slow cooling during obscuration. Fortunately, this common assumption is indicated by several weather parameters data which have been simultaneously measured by the wind sensor (figure 5). Nevertheless, the delayed on sea and land breeze might be caused by several environmental factors like cloudiness, day-to-day variation of weather parameters and solar obscuration (indication was clearly figured on stability during first contact until the end of obscuration) (figure 5). The three parameters (air temperature, air pressure, relative humidity) show a static stability which is caused wind remaining stable on the fixed orientation during totality. For example, the temperature and the pressure are a near constancy during the embezzlement. Similarly, humidity has a stable value at 90% before the end of 4$^{th}$ phase. In contrast to the three previous parameters, solar radiation turns to zero value during the totality phase. This behaviour was not in accordance with the daily variation of irradiance in the mornings which it tends to be linear pattern. This condition during totality might decrease in fluctuation generated turbulence in the air condition compared to normally diurnal variation. The sign of reduction turbulence was emphasized by wind reduction in speed and orientation.

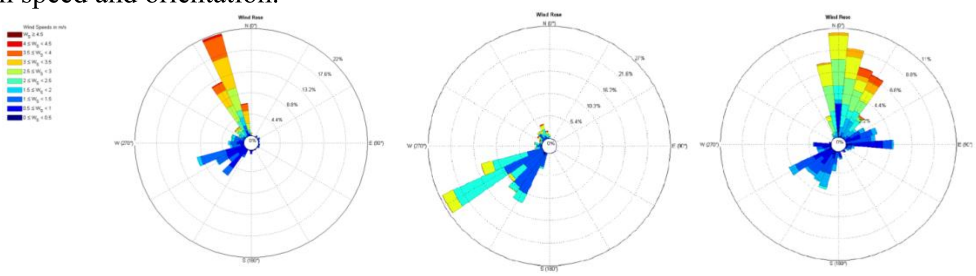

**Figure 4**. Wind direction data variations in three days measurement, at 8$^{th}$ March (*left side*), 9$^{th}$ March of totality (*center*), and 10th March (*right side*).

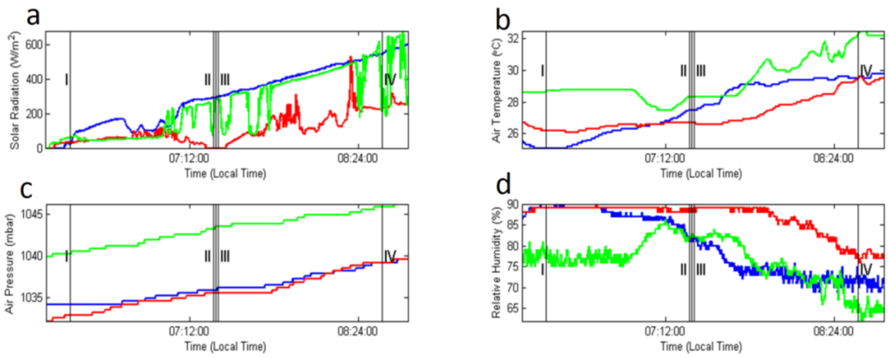


**Figure 5**. Temporal variation of (a) solar radiation, (b) air temperature, (c) air pressure, and (d) relative humidity during 1st contact (Ⅰ) until last contact (Ⅳ) at 8th March (*blue line*), 9th March (*red line*), and 10th March (*green line*).

## 4. Conclusions

As in case of solar irradiance, decrease in temperature as the eclipse developed toward totality was inferred. As a result of the drop, the wind speed decreased and also the orientation of local wind has changed to the southwest. Delay of one to two-hour onset sea breeze and land breeze as a result of cooling on the eclipse day was detected on the day after the eclipse. This delay was made possible because of the static stability perturbation by total solar eclipse for daily conditions at the measurement site. Lastly, from measurements at Central Bangka, we discovered a substantial eclipse induced influence on all the surface layer parameters.

## References

[1] Supriharyono 2000 *Pelestarian dan pengelolaan sumberdaya alam di wilayah pesisir tropis* (Jakarta: PT Gramedia Pustaka Utama)
[2] Laughlan G P 1997 *The User's Guide to the Australian Coast* (New Holland: Frenchs Forest) p 213
[3] Fernandez, Castro W, Wright J, Hidalgo H and Sfienz A 1993 *J. Earth, Moon, and Planets* **63** 119-132
[4] Aplin K L and Harrison R G 2003 *Proc. Royal Society* (London) p 353-371
[5] Clayton H 1901 *The eclipse cyclone and the diurnal cyclones Ann. Astron. Observ* (The United State: Harvard College) pp 5–22
[6] http://xjubier.free.fr/en/site_pages/solar_eclipses/TSE_2016_GoogleMapFull.html (accessed on February 2016)
[7] http://www.rainwise.com/products/attachments/6735/20150710010448.pdf (accessed on February 2016)
[8] Murthy B S, Latha R, Sreeja P and Dharmaraj T 2012 *J. of Atmos. and Solar-Terrestrial Phys.* **89** 33–39