Influence of ENSO on Deviation of The Season Onset in Java Based on CCAM Downscaling Data

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Abstract. The research of season onset in Java is very important, considering Java is the center of agriculture in Indonesia. The onset of the rainy and drought season in Java are strongly influenced by global atmospheric phenomena, such as monsoon and El Nino Southern Oscillation (ENSO). This study used spatial analysis from previous researches focusing on insitu data. The data used in this current study based on the downscaling output of atmospheric model with ±15km spatial resolution. The result shows that the season onset deviation in Java Island exist when El Nino and La Nina occurred. When the El Nino (La Nina) occurred, the onset of drought season in Java has a tendency to come faster (slower) than neutral conditions. On the other hand, when El Nino (La Nina) occurs, the onset of rainy season in Java comes slower (faster) compared to the neutral condition. This is probably related to disturbance of monsoon in Indonesia when El Nino and La Nina occurred. The study also confirmed that the effects of El Nino and La Nina in the rainy season are stronger than in the dry season.

1. Introduction

Research on the onset of the season in Indonesia, especially in Java is crucial due to its role as the center of agriculture and food production in Indonesia and many Javanese have jobs as farmers. Agriculture is in desperate need the season onset information, both the onset of the rainy season or drought for the determination of planting, fallow and harvest periods.

However, the season onset research in Java is still mostly done with in-situ observation data [1], resulting in less thorough analysis. Related to that, this research using downscaling data from atmospheric and climatic models, it is expected to obtain spatial information with high resolution data. In addition, the use of model data gives in flexibility for choosing the research period, which is not obtained using satellite data, which mostly began to operate in the early 20th century. Research on the season onset taken from Indonesian Agency of Meteorology, Climatology, and Geo-physic (BMKG) based on dasarian rainfall in Indonesia has been done using Tropical Rainfall Measuring Mission (TRMM) satellite data. However, it still has limitations in the analysis period (1998 - 2009) [2, 3].

Dasarian rainfall data that resulted by downscaling using the Conformal Cubic Atmospheric Model (CCAM) has been compared and validated using TRMM data, both values and patterns [4]. Comparisons using satellite rainfall data have similar patterns and values, although there is a difference. CCAM downscaling data can still follow TRMM data on low rainfall, but for high rainfall value, downscaling data is still under-estimate comparing to TRMM rainfall [5]. However, the
comparative results still include the sea area around Java, in case the sea part was eliminated, and only use of rainfall in the mainland, then the value of under-estimate can be minimized [4].

The monsoon event greatly influences the pattern of the rainy and dry seasons in Indonesian Maritime Continent (IMC). The monsoon refers to an annual cycle that strictly distinguishes atmospheric conditions during the dry and wet phase. The dry phase is influenced by the winter that occurs in various continents with the air mass in the cold and dry atmosphere [6]. In contrast, the wet phase is influenced by summer with humid air. The monsoon is awakened by the warming differences between the oceans and the mainland due to the pseudo movement of the sun, the shape and topography of the continent, both Asian, European, African, Maritime Continent, American and Australian [7,8,9]. The geographical location of IMC is located between the regional monsoons crossing area of the Asia-Australia monsoon. Besides monsoon, Aldrian et al. (2007) suggested that the monsoon and the El Nino Southern Oscillation (ENSO) are more likely to drive the seasonal variation and inter-annual variations of the rainfall and extreme events in Indonesia [10]. In general, the rainfall pattern in Java Island has a monsoonal pattern where in one year there is one peak of rainfall, which generally occurs in December - February. Research on the influence of ENSO which occurring in the Pacific Ocean on rainfall in Indonesia has been widely studied [11]. But its influence on the onset of the season in Indonesia, especially Java is still need to be study furthermore. Therefore, the purpose of this study was to analyze the influence of ENSO, both in neutral, La Nina and El Nino conditions towards the beginning of the rainy and dry seasons in Java. In addition, this study also analyzes how far the onset of the season in Java deviates (forward or backward), when La Nina and El Nino compared to neutral conditions.

2. Materials and Methods
This research used downscaling data using CCAM, which can give the information about high resolution climate parameter. Downscaling data has an adjustable resolution depending on the research needs, but this study uses data with spatial resolution of 15 km for Java Island in the period 1990-2010. Related to further analysis of the season onset, the research area was split in 2 areas, Western Java (WJ) and Eastern Java (EJ), as shown in Figure 1.

![Figure 1](image_url)

**Figure 1.** Research areas, where: a) Western part of Java (WJ) (5.8° – 7.8°S and 105.2° – 110°E); and b) Eastern part of Java (EJ) (6.3° – 8.9°S and 110° – 114.7°E)

The criteria for the onset of the season in Indonesia according to BMKG (2009) are based on dasarian rainfall. The onset of the rainy season is occurred if the dasarian rainfall is greater than or equal to 50 mm in one dasarian, followed by the next two dasarians. The opposite is applicable for the onset of the dry season, where the onset of the dry season is occurred if the dasarian rainfall is less
than 50 mm in one dasarian and followed by the next two dasarians [12]. The meaning of dasarian (10-
days accumulation or decade, decade is not mean 10-years but refer to 10-days, and then will be called
dasarian in this paper) is rainfall accumulation in 10 days, but in the end of the month, it can be only 8,
9, 10 or 11 days. Thus in 1 year has 36 dasarians.

This research also used indexes, such as Southern Oscillation Index (SOI) to describing ENSO and
Australian Monsoon Index (AUSMI) to describe monsoon and 850mb wind. SOI was one of the
methods used by Australian Bureau of Meteorology (BOM) to identification of ENSO, based on
calculating the difference of pressure anomaly between Darwin and Tahiti [13]. While AUSMI is the
area average of 850mb wind in the area 110-130E, 15S-5S [14].

\[ SOI = \frac{P_{\text{diff}} - P_{\text{diff}}} {SD(P_{\text{diff}})} \] .................................................(1)

where:

\[ P_{\text{diff}} = (\text{pressure msl})_{\text{Tahiti}} - (\text{pressure msl})_{\text{Darwin}} \]

\[ P_{\text{diff}} = \text{average of } P_{\text{diff}} \text{ long time periods} \]

\[ SD(P_{\text{diff}}) = \text{standart deviation of } P_{\text{diff}} \]

AUSM Index (AUSMI) = U850(110 − 130E, 15S − 5S) .................................................(2)

where:

U850 = area average of wind in 850mb, the boundary of the area is 110E-130E,15S-5S

The identification of the El Nino, La Nina and Neutral years is processed by selecting the SOI
values as illustrated in Figure 7. However, it is done by separating the SOI on JJA for dry season
analysis and SOI on DJF for rainy season analysis.

3. Result and Discussion

At the time of the El Nino occurred, rainfall in Java was generally reduced, although there are areas
that have high rainfall such as in the south of West Java due to local circulation and topographic
influence [11]. In addition to the reduced rainfall, ENSO events also affect the onset of the rainy
season as shown in Figure 2. The colors in Figures 2 and 3 show the time of the season onset, both
drought and rain, with dasarian units. The sooner the season onset is shown by the color purple - blue,
while the yellow - red color indicates the the season onset that comes more slowly.

While ENSO in neutral conditions, the onset of the rainy season in Java on average occurred in 26th
− 32nd dasarian. However, the onset of the rainy season in Java came faster than neutral conditions at
the time of El Nino occurred. The onset of the rainy season withdraw from 2 to 4 dasarians and
become 28th – 35th dasarian, even in eastern part of Java there are areas that have the beginning of
rainy season more than 35th dasarian. On the contrary, when La Nina occurred, the onset of rainy
season in Java is generally more advanced to 25th - 30th dasarian, even some areas experiencing the
beginning of the rainy season is less than 25th dasarian. It is commonly found in western Java. Thus
Figure 2 explains that there was a difference of the season onset in Java according to 3 types of ENSO
conditions. While El Nino occurred, the onset of the rainy season in Java tends to occur more slowly
compared to La Nina and neutral conditions. In contrast, the onset of the rainy season while La Nina is
come faster than neutral conditions.

The onset of the dry season has a contrary impact compared to the onset of the rainy season toward
the influence of ENSO. While El Nino occurred, the onset of the dry season on the Java island comes
faster, while when La Nina slower than neutral conditions. When ENSO in neutral condition, Java had
the onset of the dry season on average in dasarian to 10 -18. While at El Nino, the onset of the dry
season in Java comes faster than the neutral ENSO conditions. This is marked by the many areas
which experiencing the onset of the dry season less than dasarian 10. The interesting phenomenon was, while La Nina with most of areas have slower dry season. The impact in western Java is more affected compared to the eastern part. Western Java had the onset on 15th dasarian until more than 20th dasarian.

The use of satellite rainfall data TRMM explains that the onset of the rainy season on Java Island starts on the 26th dasarian, begin in Banten, then moves to east until comes to East Java in 32nd dasarian. The reverse movement occurs for the onset of the dry season, where the early dry season occurs in East Java on the 11th dasarian then moving westward [2].

The ENSO's effect difference on the season onset in the western and eastern part of Java can be shown in Figure 2, 3 and 4. The onset of the rainy season begins from the western area and then moves eastward, as shown in Figure 4, the onset value of the rainy season is lower for WJ compared to the EJ. However, in several years such as 2000/2001, 2001/2002 and 2007/2008, there was contrary value which caused by many areas in the west that were not detected in the season onset due to the influence of La Nina. First area that had the onset of the dry season is eastern Java, then moves westward (Figure 3), this is also shown by lower value of the EJ area in the season onset than WJ (Figure 4).

Figure 2. Spatial distribution of the rainy season onset (unit in dasarian) in Java based on CCAM downscaling data of 1990-2010 during (a) La Nina, (b) El Nino, and (c) neutral condition.

Figure 3. Spatial distribution of the dry season onset (unit in dasarian) in Java based on CCAM downscaling data of 1990-2010 during (a) La Nina, (b) El Nino, and (c) neutral condition.
Figure 4. The diagram shows the onset of the rainy (above) and dry season (below) for the light areas represent to the Western part of Java (WJ) and the dark areas represent to the Eastern part of Java (EJ), whereas the line is the Southern Oscillation Index (SOI) value indicating the ENSO condition.

Table 1. Statistical parameter of ENSO to the onset and the length of season in Java (Western part of Java (WJ), Eastern part of Java (EJ)). All parameter have dasarian in unit, except the correlation. Correlation is relation between SOI and the season onset and Standard Deviation (Stdev) show the deviation of the season onset.

| Statistic Parameter | Rainy Season Onset | Dry Season Onset | Rainy Season Length | Dry Season Length |
|---------------------|--------------------|------------------|---------------------|-------------------|
|                     | WJ     | EJ     | WJ     | EJ     | WJ     | EJ     | WJ     | EJ     |
| Mean                | 30     | 32     | 10     | 8      | 16     | 13     | 20     | 23     |
| Correlation         | -0.40  | -0.44  | 0.39   | 0.50   | 0.34   | 0.63   | -0.70  | -0.64  |
| St dev              | 3      | 3      | 2      | 2      | 3      | 3      | 3      | 3      |
| Min                 | 24     | 25     | 7      | 6      | 12     | 9      | 13     | 16     |
| Max                 | 33     | 36     | 17     | 13     | 22     | 20     | 25     | 29     |

Table 1 shows the statistical values of the season onset in Java, both western and eastern during 1990-2010 period. The average of rainy and dry season onset for WJ is on the 30th and 10th dasarian, therefore the average length of the rainy and dry season for WJ is 16 and 20 dasarians. Whereas for EJ, due to the onset of the rainy season that always comes more slowly and the onset of the dry season that comes faster than WJ, the WJ area has a shorter rainy season and longer dry season, which is 12 and 24 dasarians. The correlation between the season onset, both rain and drought and the value of SOI is also higher for EJ than WJ. Nevertheless, the WJ and EJ areas have the same in the deviation of the rainy season onset during 1990-2010 period, which is ±3 dasarians, whereas the dry season onset at ±2 dasarians. The rainy season onset for EJ ever reaches the fastest point to come in 25th dasarian and
for the dry season onset in 6th dasarian, while for the slowest comes in 36th dasarian for the rainy season onset and 13 for dry season. The western part (WJ) has the fastest of the rainy season onset on the 24th dasarian and the slowest in 33rd dasarian. While the onset of the dry season, the WJ region had the fastest coming in 7th dasarian and the most lately in 17th dasarian. This value is the onset of the dry season in 2010, which is the largest deviation from the average.

The extreme El Niño events were depicted in 1997 and examples for the onset of the season while La Nina event were described in 1998. These two years are shown by Figure 5 examples in studying the influence of ENSO on the season onset. While JJA period in 1997, the SOI value reached -17.8 and consistent at -17.3 until DJF 1997/98, it related to indicates that an extreme El Niño occurred. The SOI values in the middle of 1998 changed drastically to 11.4 and 12.5 in the end of the year, indicating the occurrence of La Nina. The onset of the dry season in 1997 came faster in almost all areas of Java, whereas the beginning of the rainy season was coming too late. In 1998, the onset of the dry season was almost undetectable because it tended to get wet from the beginning of the year, and the rainy season onset was detectable came faster. This shows the extreme El Nino effect that occurred in 1997 and extreme La Nina in 1998 toward the season onset in Java.

The ENSO was also influences the length of the season in Java, where shown by Figure 6. The length of the rainy season when El Nino has change becomes shorter, while the length of the dry season is longer than La Nina and the neutral conditions. However, when La Nina is the opposite, the rainy season becomes longer and the dry season becomes shorter. The rainy season at El Nino 1997 was only about 13 dasarians in WJ and 10 dasarians in EJ, whereas during La Nina 1998, the rainy season became longer at 20 and 16 dasarians for each WJ and EJ. The dry season in 1997 (El Nino) became longer, i.e. 29 for WJ and 25 for EJ, and when La Nina (1998) is shorter 7 dasarians for WJ and 4 dasarians for EJ compared to the average (Table 1).
Figure 6. The diagram shows the length of the (a) rainy and (b) dry season, for the light areas represent to the Western part of Java (WJ) and the dark areas represent to the Eastern part of Java (EJ), whereas the line is the Southern Oscillation Index (SOI) value indicating the ENSO condition.

Figure 7. Australian Monsoon Index (AUSMI) and Southern Oscillation Index (SOI) values for a) DJF (December, January and February) and b) JJA (June, July and August), where the circle (○) signs mark El Nino condition and rectangle(□) signs mark La Nina.
The influence of ENSO on the early seasons in Java is due to the disrupted monsoon cycle. Westerlies that occurred during DJF obstructed by an El Nino, and vice versa will be faster during La Nina. This can be explained by the occurrence of a strong El Nino in 1998 resulted DJF westerlies become very weak (Figure 7). This condition also causes during DJF westerlies that blow over Java has a shorter duration during the El Nino and long duration when La Nina. In contrast to DJF, the easterly winds over JJA period have longer durations during El Nino, but shorter durations during La Nina, although the intensity is less affected by ENSO. Figure 7b explains that AUSMI variation is not affected by ENSO events. Despite the extreme El Nino occurred in 1997, it did not make more slowly the easterly winds.

4. Conclusion
The influence of ENSO during the rainy season December-January-February (DJF) and drought June-July-August (JJA) results in an early deviation of the rainy and dry seasons in WJ and EJ with different variations. For the DJF, at the time of La Nina occurs, the beginning of the rainy season occurs early between 3-4 dasarians in most WJ and a small part of EJ. While at El Nino, the beginning of the rainy season retreats about 2-3 dasarians in a small portion of WJ and EJ. For JJA, La Nina has postponed the start of the dasarian dry season in most of the WJ and EJ. While El Nino does not really have an impact on the acceleration of the dry season except for a small part of the area south of WJ and EJ. Thus it can be concluded that the beginning of the rainy and dry season in WJ and EJ experienced greater deviations when La Nina compared with El Nino. In addition, although WJ is locally farther from the Pacific Ocean than EJ, the results of this study prove that WJ is more sensitive in responding to ENSO compared to EJ. This is an interesting new finding to further explore the cause through subsequent research. Other new findings also prove that the powerful El Nino DJF 1998 and 2010 have affected the weakening of the western winds so that it impacts slow the beginning of the rainy season and shorten the duration of the rainy season. However, during the time of strong La Nina during the DJF 1999, 2000, 2008, there was no western wind. For the JJA period, winds appear stable from year to year and their variability is not compromised by the ENSO phenomenon.

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