STUDY ON THE POSSIBILITY OF PREDICTING THE ONSET AND RAINFALL OF WET SEASON IN YOGYAKARTA SPECIAL PROVINCE, INDONESIA

by

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ABSTRACT

Indonesian region frequently experiences a prolonged drought and/or flood hazard. One of the key factors that often triggers these hazards is the occurrence of seasonal rainfall anomaly. To minimize the possible impact of such extreme event, it is necessary to develop a model that can be applied to predict the wet season onset and wet season rainfall. This paper is a preliminary effort on this matter. As a pilot study, Yogyakarta Special Province (DIY) has been selected for this purpose. In particular, the analysis is emphasized on the Adisucipto airport station, Yogyakarta, as it is one of the first-class climatological station in DIY which has a very good and long data required for such intention.

Detail objectives of this study are to address the following three questions: (1) is it possible to predict wet season onset in Adisucipto airport station using local and regional atmospheric indicators? (2) if it is possible and the model(s) have been developed, can the model(s) be applied for predicting the onset of wet season in other parts of DIY and its surround? (3) does an early or late onset of wet season provide any indication to subsequent rainfall during the wet season?

To achieve these objectives, the study requires several types of data including daily rainfall data, monthly air pressure data, Southern Oscillation Index (SOI) and Sea Surface Temperature data. Most of the data cover the period of 1976 to 2001. Methods that have been applied to meet the goals are statistical descriptive and simple liner regression analysis.

The results suggest that: (1) wet season onset time in Yogyakarta can be predicted using both local and regional atmospheric factors, namely August and September SOI, and air pressure index at Adisucipto airport station in June, July and August; (2) models that have been developed for Adisucipto airport station are modest enough to be applied for predicting the onset of wet season at other location; (3) the onset of wet season cannot be used as an indicator to estimate rainfall in wet season itself.

Keywords: prediction, wet season onset, Southern Oscillation Index (SOI)

INTRODUCTION

Indonesia undergoes a seasonal reversal wind known as the monsoon. During June-September the wind blows from the southeast while during December-March the wind blows from the northwest. In the world, there are three monsoonal system, i.e. African monsoon, Asian monsoon and Australian monsoon. In this case, the Indonesian monsoon is part of the Asian monsoon system (McGregor and Nieuwolt, 1998) which consists of Indian monsoon and East Asian monsoon. This monsoon is responsible for two distinct seasons throughout the year, namely dry and wet (rainy) season with transition periods in between. Dry season is a period when the south-easterly wind brings a dry Australian continental air masses during the Northern summer whereas wet season is the period when mainland Asian and Pacific Ocean air masses are brought in to Indonesia by the north-westerly flows during the Northern winter.

Although the variation of Indonesian season is quite small, anomalous or extreme climatic condition may still exist and it has been observed that the anomaly tends to be more frequent since the 90s (Tapper, 2000). Climate anomaly may be a delay on the start of the wet season and/or be a reduction of the amount of wet season rainfall that often produces a prolonged and devastating drought. The 1997/1998 drought, for example, resulted in a national economy losses that were close to US$9 billion (BAPPENAS, 1999). In that year, wet season onset in Yogyakarta has been delayed up until 1.5 month and caused a massive reduction of agricultural production (Kirono and Khakhim, 1998).

To reduce the impact of such anomaly condition, it is necessary to develop a scheme that enable people to predict the event in advance. For doing so, it should be born in mind that the inter-annual variability of the monsoon is associated with the variation in both position and intensity of the components of the monsoon system (Thao and Chen, 1987). The dominant inter-annual influence on monsoon is the large scale phenomenon known as the Southern Oscillation which is also often called as the El Nino Southern Oscillation (ENSO). A growing body of modelling and observational evidence suggests that surface boundary conditions like sea surface temperature (SST), soil moisture, sea ice and snow at the earth's surface may influence the location and intensity of adiabatic heat sources that drive the atmospheric circulation, including the monsoon (Shukla, 1987).

Such knowledge convinced Kung and Sharif (1982) to develop a forecasting system for the onset of the season in India based on several indicators including Indian SST and Indian upper surface atmospheric parameters. In Australia, Nicholls *et al.* (1982) have successfully developed a forecasting system for Darwin, Northern Australia, based on the air pressure over the Darwin city itself. Since Indonesia is influenced by the monsoon system that is similar to the monsoon in India and Australia, it is hypothesized that similar forecasting schemes developed in those countries are potential to be developed for Indonesian condition. Unfortunately the available knowledge to support this idea is rather limited (McBride, 1992). Consequently, there is a problem needs to be addressed first before a model can be constructed, namely whether or not such forecasting approach is really applicable for Indonesian condition.

Besides the above problem, there is also another issue which requires an attention, i.e. the fact that the number of rainfall and climatological station with good data are limited (Kirono *et al.*, 1999). Thus, even a forecasting system has been exist, it may not be applicable for all parts of the region, particularly the ones that do not have climatological station. This raises a couple of questions, namely (1) can prediction for an areal rainfall be conducted based on data of only a single station? (2) can the onset of the season be an indicator for estimating the amount of rainfall that may be received?

This study is to address the three problems mentioned above. To do that, Yogyakarta Special Province (DIY), particularly Adisucipto airport station has been chosen as a pilot study (Figure 1). In detail, the objectives of this paper are threefold:

a) to study whether the onset of wet season at Adisucipto airport station can be predicted using local and regional indicators such as air pressure and SST surround Indonesian region;
b) to study whether the onset of wet season in DIY can be predicted using information at one station only. In this regard, Adisucipto airport station is selected as a candidate of the predictor for other station(s). The reason for this is the fact that Adisucipto airport station is a first-class climatological station and is part of the national/ international network, therefore, it has high quality climatological data and it is guaranteed to always have a good record in the long run;
c) to study whether wet season onset can be used as a predictor for predicting the amount of rainfall in wet season in DIY.

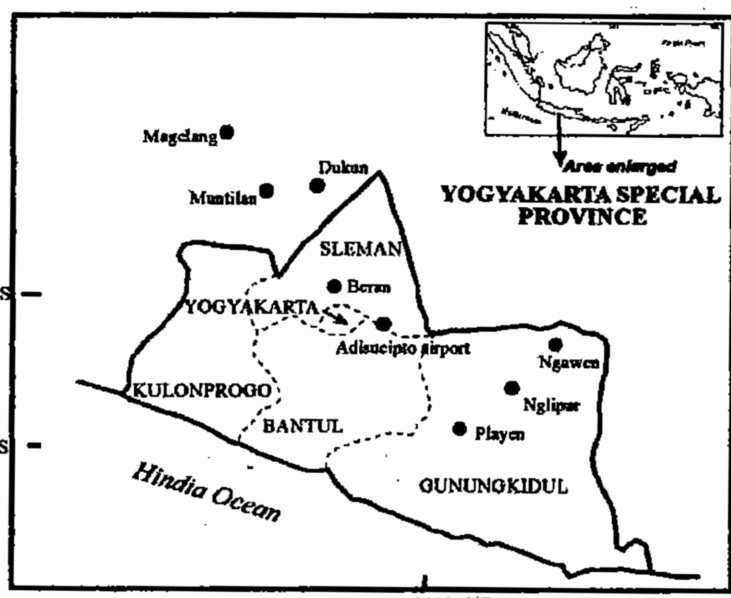

Figure 1. Location of rainfall stations (shown in a black dot) That are used in this study

DATA AND ANALYSIS

Data which are utilized in this study are as follows.

1. Daily rainfall data at Adisucipto Airport station for the period of January 1976 to July 2001 (25 years). This study also uses daily rainfall data at several station in DIY and its surround, including Beran, Dukun, Muntilan, Playen, and Ngawen stations as depicted in Figure 1. The available data for these stations are varied with station.
   Based on these data, the onset of wet season and rainfall amount of wet season at each station in each year are calculated. To do this, firstly, the daily rainfall data is aggregated into "*dasarian*" rainfall data that is a ten-days rainfall data. In this case, each month has three *dasarians*, so that there are 36 *dasarians* in a year. *Dasarian* 1 is the first ten-days of January while *dasarian* 36 is the third ten-days of December. After *dasarian* rainfall data are available, the onset of wet season and the amount of rainfall can be calculated. The onset of wet season is determined by applying a definition recommended by the Indonesian Bureau of Meteorology (BMG), i.e. that the onset of wet season is the time when the amount of rainfall in a given *dasarian* is more than 50 mm and followed by another *dasarian* with rainfall of more than 50 mm. On the contrary, the offset (end) of season is the time when rainfall in a given *dasarian* is less than 50 mm and followed by another *dasarian* with rainfall amount of less than 50 mm. Once the onset and the end of season are determined, it can be then followed by the calculation of the length and the rainfall amount of wet season.
   As an illustration, if the onset of the wet season is *dasarian* 31 (year 2000) and the end of the season is *dasarian* 7 (year 2001), then it means that the 2000-wet season starts in the first ten-days of November 2000 and ends in the first ten-days of March and, therefore, the length of the 2000-wet season is 13 *dasarian* (±130 days).
2. Monthly air pressure data at Adisucipto Airport station (January 1981 to July 2001).
   These data are transformed into an air pressure index (PI) using the following formula:

$$PI = \frac{P_m - \bar{P}}{Std}$$

PI	=	monthly air pressure index
P_m	=	air pressure at a particular month
$\bar{P}$	=	average air pressure at a particular month
Std	=	standard deviation of air pressure at a particular month

3. Monthly Southern Oscillation Index (SOI) which is obtained from the Australian Bureau of Meteorology (January 1976 to July 2001). SOI is the most common and widely used index for representing the Southern Oscillation. This index shows the difference between the mean sea level pressure (MSLP) at Tahiti and MSLP at Darwin, Australia.
4. Monthly data of the Pacific Sea Surface Temperature (SST) from January 1976 to November 1997. This data is spatially aggregated, using an Empirical Orthogonal Function (EOF), from many SST measurements. This data are provided by Drosdowsky of Australian Bureau of Meteorology (Drosdowsky, *pers.comm.*, 1998) who has shown that there are 12 EOFs (dominant pattern) of SST over the Pacific. Not all these 12 EOFs are applied for this study. EOF-SST that are used in this study include EOF1 (representing ENSO pattern), EOF9 (representing Western Pacific pattern) and EOF12 (representing Indonesian pattern).

When all the required data are available, a statistic-descriptive analysis is performed in order to study general character of wet season onset and wet season rainfall in Yogyakarta, viz Adisucipto airport station. Subsequently, to achieve goal number one, i.e. to study whether the onset of wet season in DIY can be predicted using local and regional indicators, a simple correlation analysis is conducted. In this case, wet season onset is the dependent variable while local atmospheric factor (monthly air pressure index or PI) and regional atmospheric factors (monthly SOI and SSTs) are the independent variable.

To study whether the onset of wet season in DIY can be predicted using information at one station only, the researchers conduct a spatial correlation analysis to see any relation between wet season onset at Adisucipto airport station and wet season onset at other stations (e.g. Beran, Dukun, Playen, Muntilan and Ngawen stations). The assumption here is that, if the wet season onset at other station is highly correlated with wet season onset at Adisucipto airport station, then the prediction of wet season rainfall in DIY is indeed be able to be conducted based on information from one best-station only, i.e. Adisucipto airport station. To study whether wet season onset can be used as a predictor for predicting the amount of rainfall in DIY, a correlation analysis for wet season onset (independent variable) and wet season rainfall (independent variable) at Adisucipto station is carried out.

RESULTS AND DISCUSSIONS

Variability of Wet Season Onset at Adisucipto airport station

Interannual variation of wet season onset at Adisucipto Airport in the period of 1976 to 2000 is depicted in Figure 2. It is shown that the onset of the wet season varies from *dasarian* 29 (middle October) to *dasarian* 35 (middle of December) with an average of *dasarian* 31.8. This implies that, normally, wet season onset in Yogyakarta starts in around early November but it can vary for about 2 *dasarians*, hence the onset can be either twenty days earlier or later.

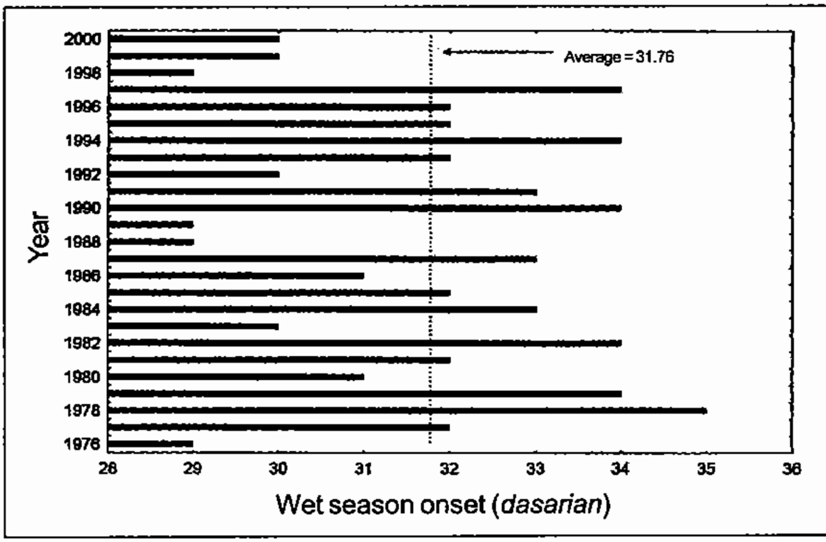

Figure 2. Wet season onset at Adisucipto station from 1976 to 2000. *Dasarian* 28 is the first ten-days of October, while *dasarian* 36 is the third ten-days of December. The average wet season onset for this station is *dasarian* 31.76 (middle of November) while the standard deviation is 1.82 *dasarian*. Can the season onset be predicted using local air pressures?

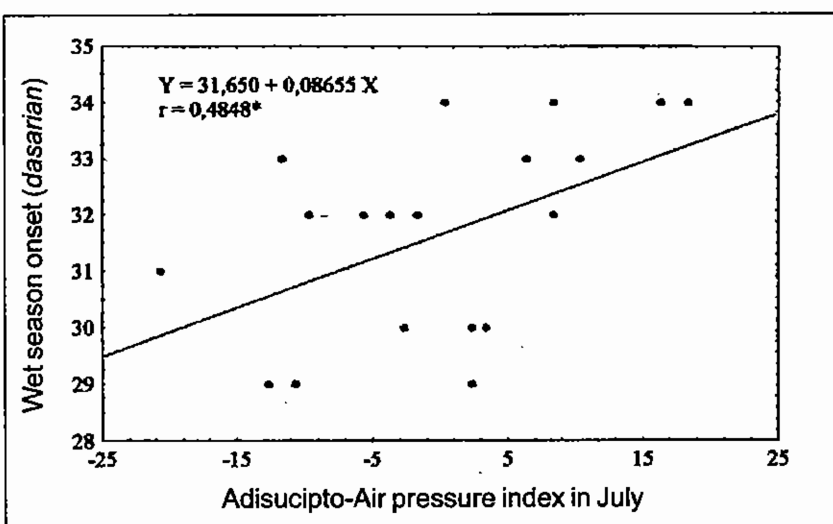

Figure 3. Scatter-plot for showing the relationship between wet season onset and July-air pressure index at Adisucipto station

The graph also indicates that the delay or the advance of the onset can be fairly extreme, i.e. more than 2 *dasarians*. For example, wet season onsets that were so late took place in year 1978, 1979, 1982, 1990, 1994 and 1997 which resulted in a severe drought condition. These extreme years are in accordance with the occurrence of El Nino phenomena. On the other hand, wet season onsets come so early in year 1976, 1988, 1989 and 1998 (La Nina years). All these results show that there is a clear signal of ENSO influence on wet season onset in Yogyakarta. It opens the possibility of using ENSO as an indicator to predict the onset of the season before hand. This will be further explored in the subsequent section of this paper.

Can the season onset the predicted using local air pressures?

In order to answer the above question, a simple correlation analysis has been performed, i.e. to examine the nature of relationship between wet season onset and air pressure index (PI). The results are summarized in Table 1. Clearly, the onset of the season is significantly related to air pressure in June, July, August, October and November. This means that there is a possibility of predicting the onset of the season using PI for about four months in advance. In another words, we are able to know, as early as month of July, whether the wet season onset in a particular year will be delayed, advanced or just to be normal. As an example, the scatter-plot of wet season onset versus July-air pressure is shown in Figure 3 along with the regression formula for that relationship. A complete summary of the formulae resulted from similar analysis are provided in Table 2.

Table 1. Correlation coefficient between wet season onset and monthly air pressure index at Adisucipto station. * shows that R is significant at $p < 0.05$

MONTH	R
January	-0.10
February	-0.21
March	0.44
April	0.20
May	0.36
June	0.46*
July	0.48*
August	0.51*
September	0.23
October	0.68*
November	0.62*
December	0.13

Table 2. Linear regression formulae for predicting wet season onset (OS) based on air pressure index in June (PI_{june}), July (PI_{july}), and August (PI_{august}). ABSE is the absolute standard error.

MODEL NUMBER	LINEAR REGRESSION FORMULA	R^2	ABSE (DASARIAN)
Model 1	$OS = 31.650 + 0.08182\ PI_{june}$	0.21	1.3
Model 2	$OS = 31.650 + 0.08655\ PI_{july}$	0.23	1.3
Model 3	$OS = 31.650 + 0.09136\ PI_{august}$	0.26	1.3

Related to the skill of the models, graphically, Figure 4 provides an illustration about how well the prediction is compared to the observed (measured) value of wet season onset. In Table 2, it is also printed the value of Absolute Standard Error (ABSE) of each model when the model is applied to predict wet season onset at Adisucipto airport. Evidently, the predicted value is quite close to the observed value. For all formulae, the prediction error is 1.3. This means that the linear regression model resulted from the analysis has a potential error of only about 13 days. This value is below the natural variation of wet season onset in Adisucipto airport station itself. Therefore, the formulae can be recommended for predicting the onset of the wet season at Adisucipto airport station.

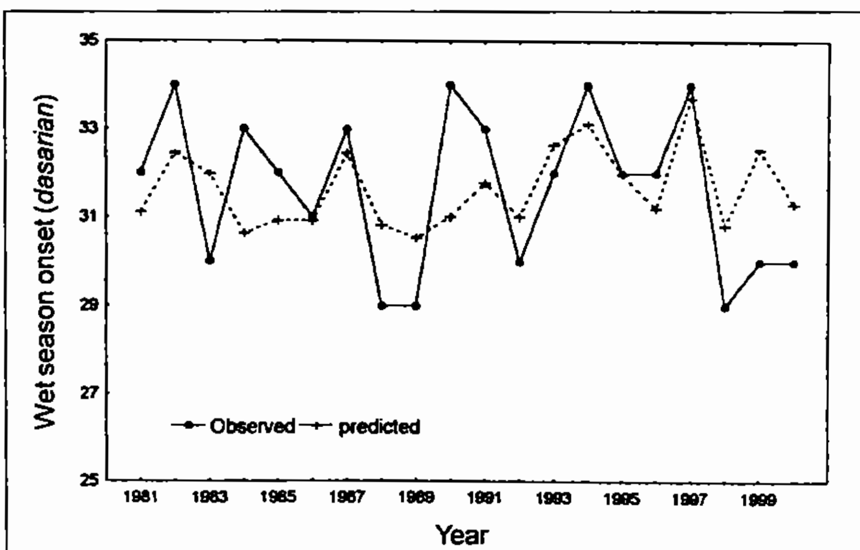

Figure 4. Comparison between the observed and predicted wet season rainfall (using August-air pressure index, i.e. model number 3).

Can the season onset be predicted using previous SOI?

As it is expected, direction of relationship between wet season onset and SOI is negative. In particular, a strong relationship is found between wet season onset and SOI in August, September, and October. Accordingly, there is a possibility of using SOI to predict wet season onset for at least three months beforehand.

A scatter-plot for showing the nature of relationship between August SOI and wet season onset is provided in Figure 5, while linear regression formulas are presented in Table 4. As an example, Figure 6 shows the performance of model number 4 when it is used to predict the wet season onset. In this case, the wet season onset is predicted using the value of August-SOI and compared to the observed wet season onset. It is obvious that the model performs quite well. The model is able to follow the temporal pattern of the wet season from year to year. The value of ABSE represented in that table suggests that the possible error for the prediction using the models is close to 1.3 dasarian (more or less 12 days). Again, this error is below the natural variation of the wet season at Adisucipto station. For that reason, it is confirmed that such model can be useful in predicting wet season onset ahead of time.

Table 3. Linear regression model for predicting wet season onset (OS) Using SOI in August and September

MODEL NUMBER	FORMULA	R^2	ABSE (DASARIAN)
Model 4	$OS = 31.473 - 0.0944SOI_{august}$	0.22	1.3
Model 5	$OS = 31.570 - 0.1054SOI_{september}$	0.23	1.3

Table 4. Correlation coeficient between wet season onset and monthly SST-EOF1, SST-EOF9 and SST-EOF12. * means significant at $p<0.05$

MONTH	R		
	EOF1	EOF9	EOF12
Januari	0.16	-0.05	-0.08
Februari	0.18	0.13	-0.01
March	0.26	0.29	-0.09
April	0.27	0.06	-0.07
May	0.19	-0.01	-0.25
June	0.15	-0.16	-0.28
July	0.17	-0.16	0.02
August	0.31	-0.13	0.26
September	0.27	-0.38	0.36
October	0.35	-0.49*	-0.40*
November	0.17	-0.48*	-0..17
December	0.33	-0.07	-0.28

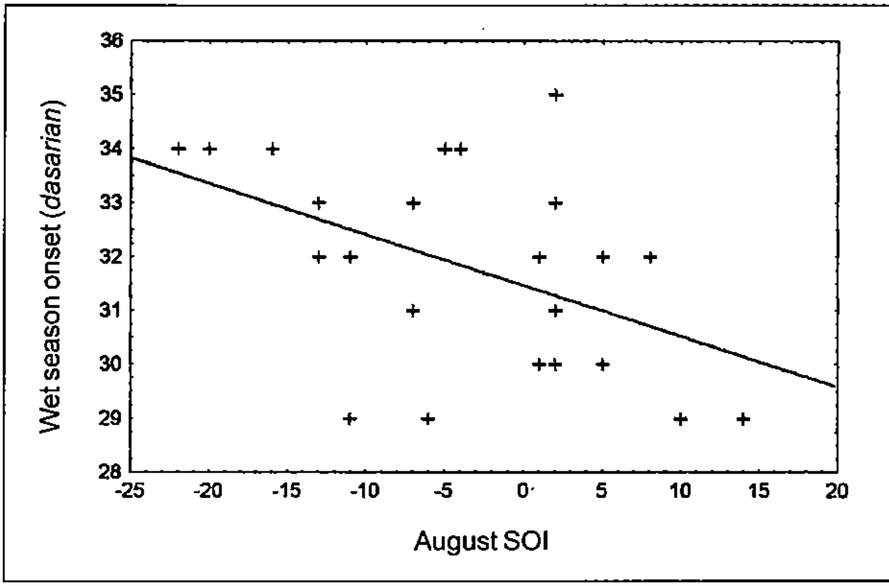

Figure 5. Scatter-plot for showing the relationship between wet season onset and August SOI

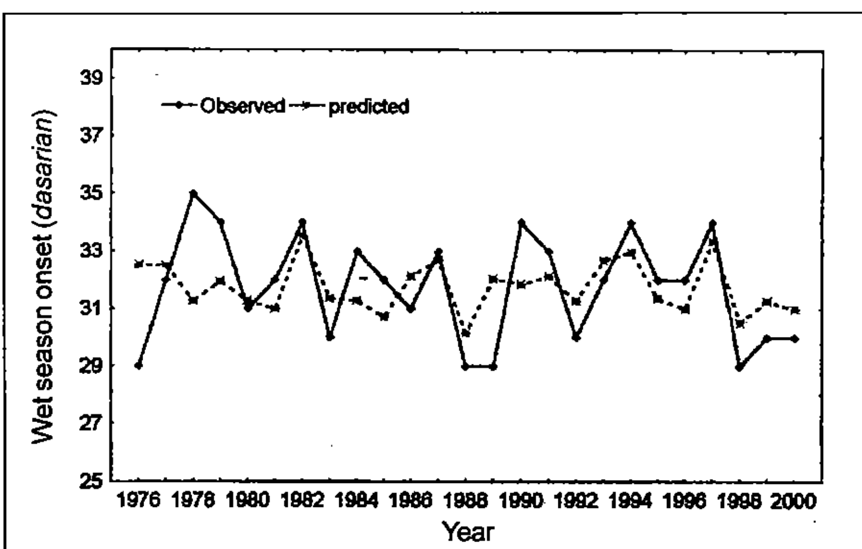

Figure 6. Comparison between the observed and predicted wet season rainfall (using model number 4)

Can the onset of wet season be predicted using preceding SST?

It has been mentioned previously that SST indicators which are investigated in this study are SST-EOF1, SST-EOF9, and SST-EOF12. In the analysis, monthly data of each SST are linked with wet season onset at Adisucipto station. The results are presented in Table 5.

Table 5. Correlation coefficient between wet season onset at some station and wet season onset at Adisucipto station. * shows significant at $p < 0.5$.

STATION	R
Beran, Sleman	0.53*
Dukun, Magelang	0.69*
Magelang, Magelang	0.31
Muntilan	0.50*
Ngawen, Gunungkidul	0.70*
Nglipar, Gunungkidul	0.11
Playen, gunungkidul	0.44

The table demonstrates that wet season onset do not significantly correlate with SST-EOF1 at all but correlate with SST-EOF9 for month of October and November. Significant relationship is also seen between wet season onset with SST-EOF12 (Indonesian pattern) for month of October. Based on these results, it can be said that prediction of wet season onset is likely to be calculated based on October or November SST. However, to be useful such prediction must be performed further away in advance. As the normal wet season in DIY itself is around early November, hence if one wants to predict wet season onset in late October based on the knowledge of October-SST, it would be useless because it is too close with the occurrence of the expected time. Even so, the prediction will be fail if the onset is earlier than normal. In this regard, the use of SST indicator is less possible to predict the onset of wet season.

Spatial coherence between rainfall at Adisucipto station with rainfall at other stations

Before studying the possibility of using rainfall data at Adisucipto airport stasion as an indicator to predict rainfall at other stations, it is necessary to examine the nature of relationship between the two. The examination is completed by applying a simple correlation analysis whose results are depicted in Table 6. The table points up that almost all stations have strong relationship with rainfall at Adisucipto airport station. With these results in mind, the researchers performed an experiment to see the performance of several linear regression models, developed in the previous section, to predict wet season onset at some other stations considered in this study. The skill of the models is judged from the error they make when being used. The error (ABSE) is calculated by comparing the "prediction" with the "real or observed data" that are not used for model development. The skill of each model in predicting wet season onset at other stations are written in Table 6. In general, the models are quite skillful as the possible error is approximately less than 2 *dasarians* (20 days). This results lead to a deduction that the model developed for Adisucipto station may also be useful for predicting wet season onset at other station which does not have a climatological station nearby.

Table 6. Value of absolute standard error (ABSE) when Adisucipto models are applied to predict wet season onset at other places

MODEL NUMBER	ABSE (DASARIAN)				
	Beran	Dukun	Muntilan	Playen	Ngawen
Model 1	1.8	2.6	2.0	1.6	1.7
Model 2	1.8	2.5	1.3	1.5	1.7
Model 3	1.6	2.5	1.8	1.5	1.6
Model 4	1.6	2.7	1.6	1.4	1.1
Model 5	1.5	3.0	1.4	1.3	1.1

Relationship between rainfall and onset of the season

Knowledge about association between the time when wet season begins and how much rainfall will be experienced is important because it will help the researchers to determine whether the time of wet season onset can provide a clue for the coming rainfall. Figure 7 illustrates a clear signal of relationship between wet season onset and wet season rainfall at Adisucipto airport station. In this case, wet season rainfall reflects the delay or the advance of the wet season, i.e. when the onset is delayed the rainfall is decreased and vice versa. However, when a quantitative assessment is implemented, it is found that such relationship is not statistically significant. This means that the onset of wet season does not strongly influence the amount of wet season rainfall. Indeed, this result is in agreement with the finding of Nicholls *et al.* (1982) and Dhar *et al.* (1980). The former shows that in Northern Australia rainfall amount is not influenced by the onset of a season. The latter shows similar finding for Indian monsoon. This result suggests that for predicting wet season rainfall, it is better not to use the onset of wet season as an indicator.

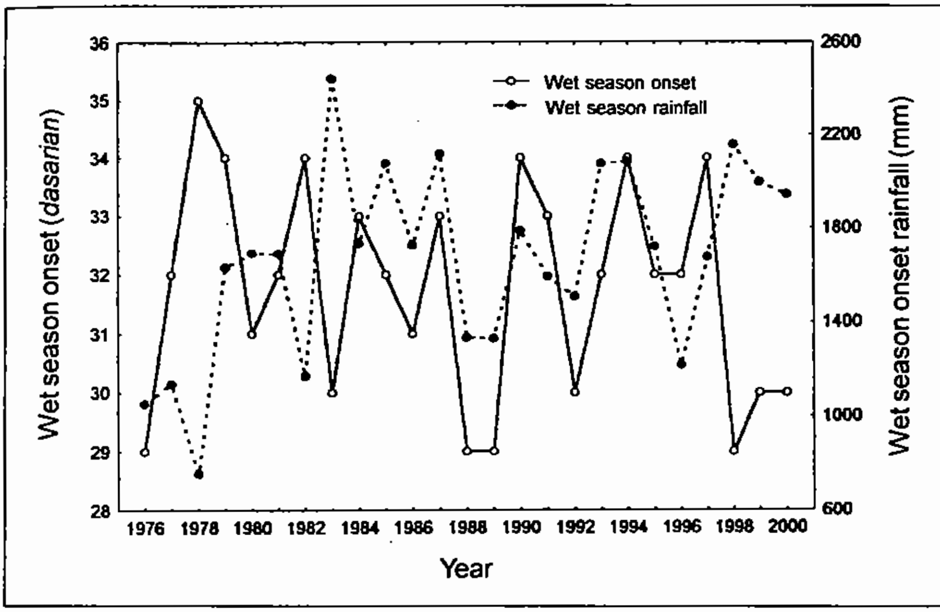

Figure 7. Inter-annual variation of both wet season onset and wet season rainfall at Adisucipto station

CONCLUSIONS

The objectives of this study are to address the following three questions: (1) is it possible to predict wet season onset at Adisucipto airport station using local and regional atmospheric indicators? (2) if it is possible and the model(s) have been developed, can the model be applied for predicting the onset of wet season in other parts of DIY and its surround? (3) does the early or late onset of wet season provide any indication to subsequent rainfall during the wet season? The results show that:

1) wet season onset at Adisucipto station can be predicted using local and regional atmospheric indicators. The very potential indicators are: August and September SOI, and air pressure index (PI) at Adisucipto station in June, July and August;
2) in most cases, model(s) that have been developed at Adisucipto station can also be applied for predicting wet season onset at other parts of DIY and its surround such as Beran (Sleman district), Dukun (Magelang district), Ngawen and Playen (Gunungkidul district);
3) early or late onset of wet season does not offer a signal that can be used for estimating the amount of rainfall in that season.

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