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Development Model Using Multi Predictors for Predicting the Onset of Rainy Season (Case Study in Northern Coastal West Java Province Indonesia)

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Abstract

The prediction of the onset of rainy season is very important for many sectors especially for agricultural sector in order to make the best planning for planting calendar to get optimum paddy yield. Monsoon onset is characterized by the change of significant atmospheric circulation such as changes of wind direction; inter tropical convergence zone location, etc. This research used 16 predictors which have been selected using spatial correlation test at and above 95% significant level. Northern coastal west Java is the main rice production center in West Java province and contribute about 30% of total production of West Java Province. The selected predictors in the next process become indicators for the variability of rainy season onset and becoming predictors for climate statistical model.

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Through the many techniques, 3 models are resulted which are multiple linier regression, stepwise regression and principal component regression. These models produce the better performance to predict the onset of rainy season over northern coastal area of West Java Province including some extreme years during strong El Nino or La Nina events.

Keywords: multiple regression model; stepwise regression; principal component regression; potential predictors; rainy season onset.

1. Introduction

Indonesia lies between latitudes 11°S and 6°N, and longitudes 95°E and 141°E. Indonesia also lies between two continents, Australia and Asia and between two oceans, the Pacific Ocean and Indian Ocean. Due to its location, Indonesia has a very complex tropical climate which impact for the rain patterns. In general, Indonesia has two seasons namely the rainy season and dry season. Indonesia is also a country that is affected by the monsoon.

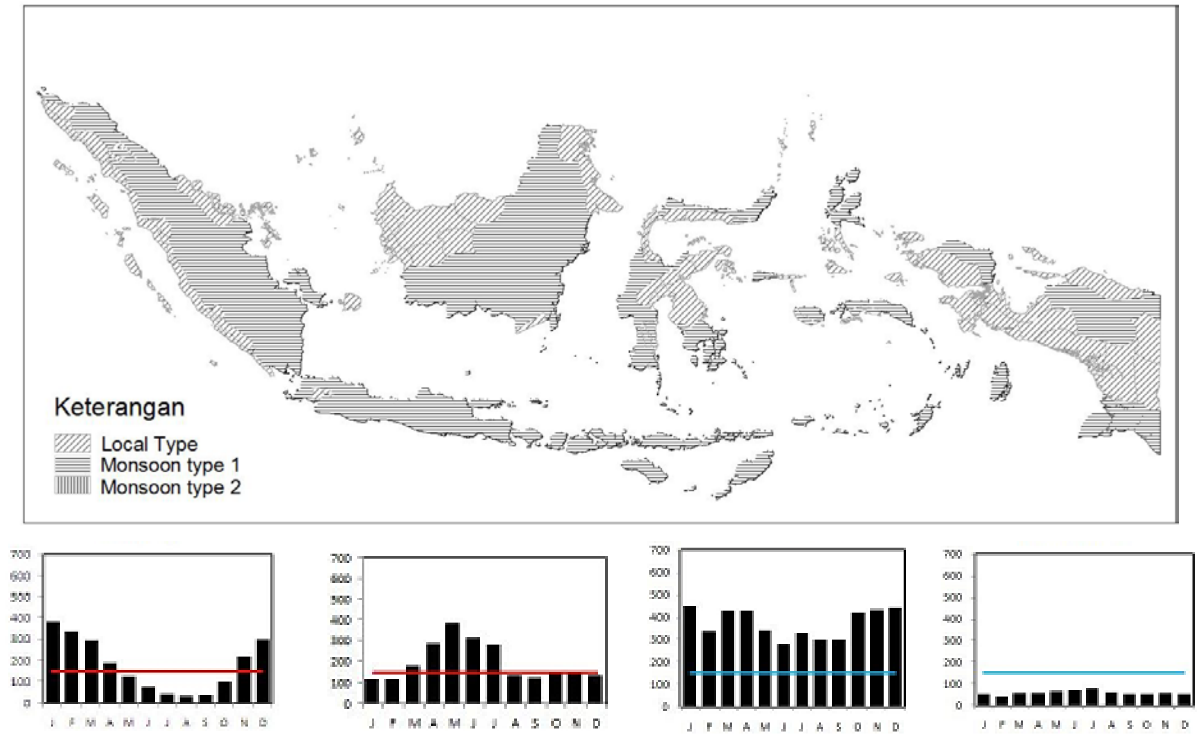
Recurring drought phenomenon characterized by the influence of El Nino. El Nino phenomenon in 1997 is very effected for Indonesia climate that caused the prolonged drought that disrupts the food sector, the economic and social development.

Indonesia is a country that is affected by the monsoon, so in general Indonesia has two seasons namely the rainy season and dry season. Indonesian climate is more complex where rainfall patterns are also influenced by local factors such as topography, land-sea interactions, high mountains and others. As shown in figure 1, the rainfall pattern in Indonesia are generally divided into three rainfall types, namely monsoon type 1 (figure 1a), monsoon type 2 (figure 1b), and local type including equatorial and local patterns (wet and dry throughout the year, figure 1c and 1d). Monsoon type 1 and 2 have a clear distinction between rainy and dry season. Equatorial rainfall type has two peaks monthly rainfall amount due to its location located near equator. The local rainfall patterns have almost no clear distinction between wet and dry seasons.

Rainfall in Indonesia is influenced by many factor, the main factor is the monsoon circulation. Disturbance in the monsoon often associated with impaired local, regional and global levels. Three phenomena that often affect the rainfall are SST Indonesia, Indian Ocean Dipole Mode and El Nino or La Nina.

Impact of ENSO extends almost all over the world that is associated with large-scale tropical circulation shifts the Walker and Hadley cells. Some of the tropics countries, including Indonesia, are directly affected by the dry conditions caused by ENSO events [1]. El Niño episodes of heat associated with increased rainfall along the Pacific Ocean and the eastern and middle above the normal dry conditions occurred in northern Australia, Indonesia and the Philippines. El Niño events in Indonesia identified with severe drought events particularly over middle and eastern part of Indonesia and other consequences is the number of forest fires.

In tropical areas of the greatest challenges for climate prediction models is how to develop a model with a high level prediction accuracy due to the complexity of the climate system and the interaction between local conditions, regional and global [2, 3, 4].



(a) (b) (c) (d)

Figure 1: Indonesia Rainfall Pattern

Each sector activity is strongly influenced by the climatic factor, whereas the model with the high accuracy result should be useful for the sectors to reduce the impact of climate extreme with the better planning. The users of climate information have to get the climate information soon as possible in order to have enough time for preparation and anticipation [5, 6, 7].

BMKG as national agency for climate services has divided Indonesian rainfall regime into two regimes which are seasonal forecast area (SFA) and non-seasonal forecast area (non SFA) as shown in figure 2. The SFA is area with clear different between rainy season and dry season period in a year. But the non SFA shows the climate with dominantly influenced by local effect and there are no clear different between rainy and dry season period. The unit to determine the onset of season is ten days unit. There are 36 ten days unit in a year because each month is divided into 3 ten days. For example, the first ten days unit is cumulative rainfall from 1st until 10th January, the second ten days unit is from cumulative rainfall from 11th until 20th January and the 3rd ten days unit is from cumulative rainfall from 21st until 31st of January and the 36th is cumulative rainfall from 21th until 31st December [8].

Base on the time series data is derived lots of information such as the average climate climate parameters, information of extreme climate events, trends of changing climate and other parameters. Time series data for the next processing is used to predict future rainfall by using statistical or dynamic techniques [9, 10, 11].

For parts of Indonesian climate, the biggest challenge now is how to generate the level of the high accuracy of climate model. The current climate models that have been applied in some national climate services and research center are still showing the low of performance especially for predicting extreme climate events [12, 3]. The question that always arises is whether the seasonal climate outlook for few coming months can be trusted and reliable. Due to this concern, the forecaster always try to find the best way to develop the climate model that have a consistency to predict the seasonal outlook with higher skill and also can be applied during climate extreme conditions such as the potency for the prolong of wet or dry condition for upcoming months [9, 10, 4]. The meaning of consistency of model performance is related to the consistency of the model output always shows the tend to be right or wrong to predict the upcoming climate condition included in the extreme conditions. If information of model consistency can be delivered to users, in the future they can define policies for planning in their respective fields.

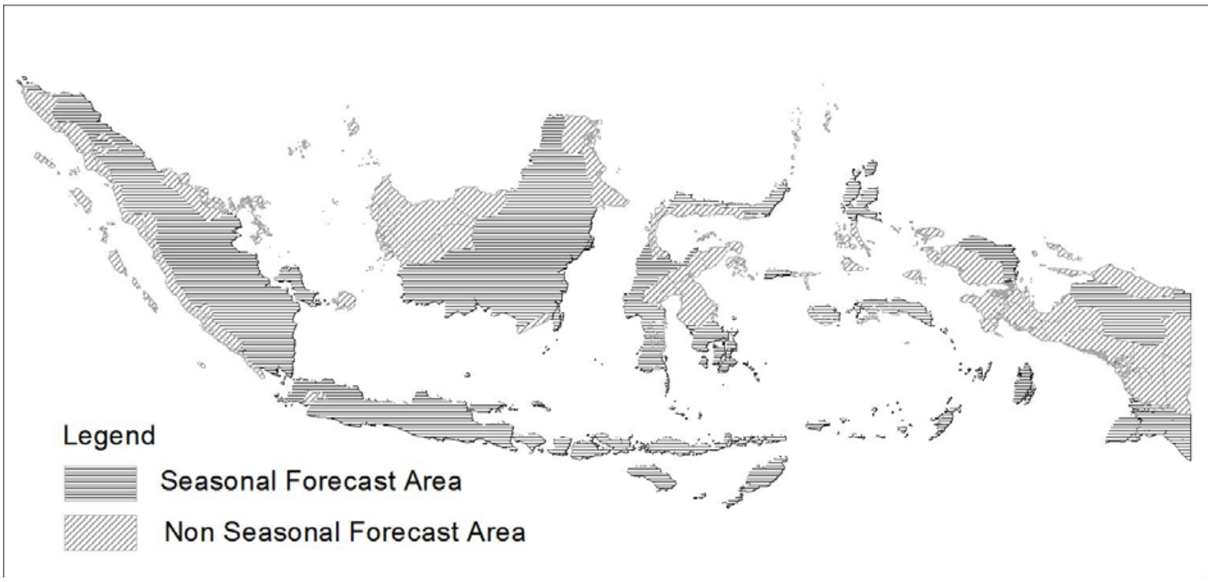


Figure 2: Spatial distribution of Seasonal and non seasonal forecast area base on data 1981-2010 (source: BMKG)

The objective of this research are to identify the factors of regional and global phenomena that affect local climate over research study area and making the elements of regional and global phenomena as predictor for climate model and also perform calibration and verification of model results.

To get climate model having a high degree of accuracy will require a comprehensive understanding of the phenomenon of local climate and what factors play an important role. This identification is needed for the construction of a complete model has input and have a low error [13, 14, 9].

In general, research activities are divided into 4 steps which are observational data collection for onset of the rainy season, global and regional climate data, the model design and model development.

2. Materials and Methods

2.1 Datasets

The data used in this study is the data of onset of rainy season which are collected from 13 rainfall stations located around northern coast of West Java province namely Batujaya, Pedes, Taluk Buyung, Salam Darma, Barugbug, Indramayu, Juntinyuat, Losarang, Dempet, Krangkeng, Sukadana, Kendal and Coral Gegesik with the observation period 1981-2010. The global data are collected from international agencies such as NOAA (United State), JMA (Japan) and Bureau of Meteorologi (Australia). The list of name of potential predictor, time and definition of geographical domain as listed at table 1.

Table 1: List of datasets are used for study.

No.	**Predictor**	**Time**	**Definition**
1	Nino34	July	Sea surface temperature anomaly (5S-5N, 170W-120W)
2	Nino3	July	Sea surface temperature anomaly (5S-5N, 150W-90W)
3.	Nino4	July	Sea surface temperature anomaly (5S-5N, 160W-150W)
4.	Nino West	July	Sea surface temperature anomaly (Equator-15N, 130E-150E)
5.	Southern Oscillation Index (SOI)	July	Surface pressure difference between Tahiti and Darwin
6.	Velocity Potential anomaly 850mb	July	30S-30N, 40W-270W
7.	Zonal wind 850mb	July	30S-30N, 40W-270W
8.	Zonal wind 200mb	July	30S-30N, 40W-270W
9.	Surface temperature	July	30S-30N, 40W-270W
10.	Surface pressure anomaly	July	30N-30N, 40W-270W
11.	Outgoing Longwave radiation (OLR)	July	30S-30N, 40W-270W
12.	Sea surface temperature over Indonesia water anomaly	July	Java sea, 6S-4S, 106W-116W Indian ocean southern part of Java, 12S-8S, 110W-116W
13.	Indian Ocean Dipole Mode Index (IOD)	July	IOD West (10S-10N, 50E-70E) IOD East (10S-Equator, 90E-110E) IOD=IOD West – IOD East

Due to operational reasons where BMKG release of the rainy season prediction are held every August each year, the global climate conditions for July are becoming indicators to be used as inputs to the model prediction. The datasets spatially can be seen as follows in figure 3 below.

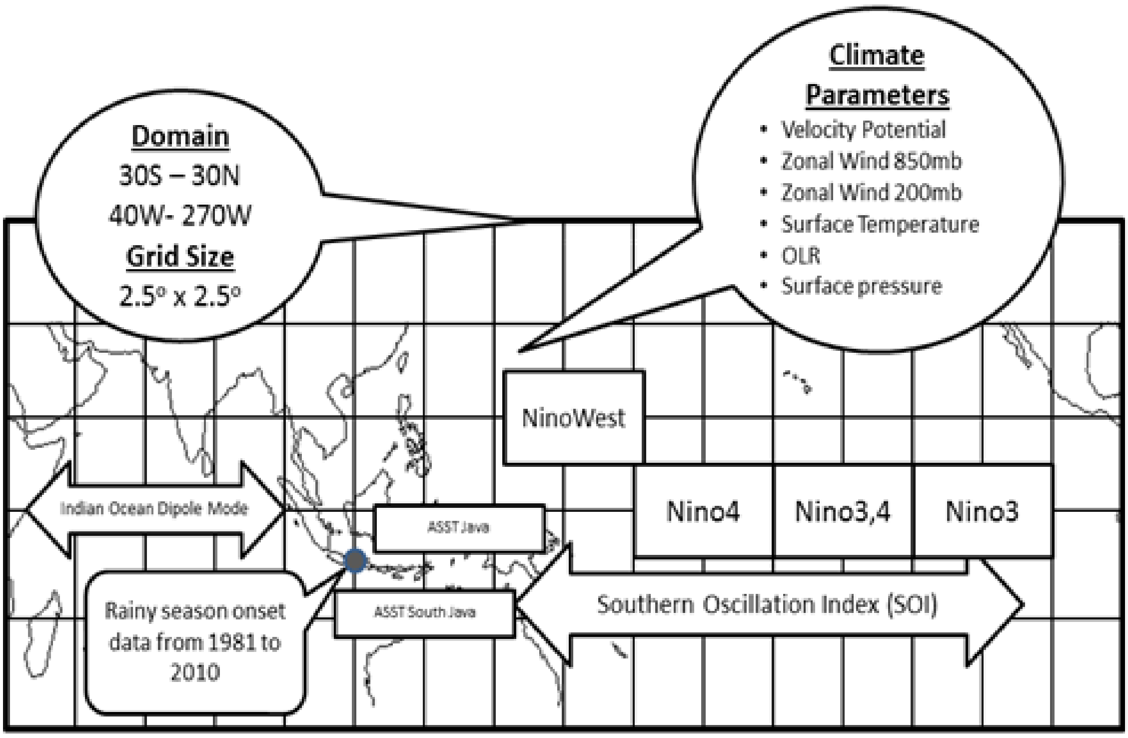


Figure 3: Spatial location of the potential predictors

3. Methods

For identification of the predictors, we used two kinds of predictors, first the common predictors such as ENSO indices, SOI, and IOD. The second predictors are named potential predictors that will be tested using spatial correlation to determine the location as smart predictors for the onset of rainy season. To find the smart predictor monthly data of velocity potential, wind, mean sea level pressure, surface temperature, and OLR over the Asia–Pacific region were analyzed. Hence in this study, the development of the model for the prediction of date of rainy season has been designed on the basis of predictors indicating the large scale circulation patterns. We have derived the data of predictors averaged over 1-31 July. For establishing the relationship of some of the climate variables such as mean sea level pressure, zonal wind, OLR, etc., with onset of rainy season, we have prepared spatial maps of correlation of date of MOK with these climate fields. The correlation maps were prepared using data for the period 1981–2010.

There are some definitions that used in this paper which are:

- Rainfall 1 mm: the volume of 1 liter rainwater that falls on an area of 1 m^2
- Ten days unit: cumulative amount of rainfall within a period of 10 days
- Onset of the rainy season are set based on the amount of rainfall in one ten days unit equal or more than 50

millimeters and is followed by the next of [8].

3.1 Site description

Study were conducted in commercial paddy field over northern coast of West Java province. Determining the research location was done by using the overlay technique by combining of paddy field areas and the location of seasonal forecast area of BMKG. By this technique, study area chosen which are district of Karawang, Subang, Indramayu and Cirebon (figure 4). The selection of these areas due to rainfall observation network has a fairly complete with observational data length for 30 years.

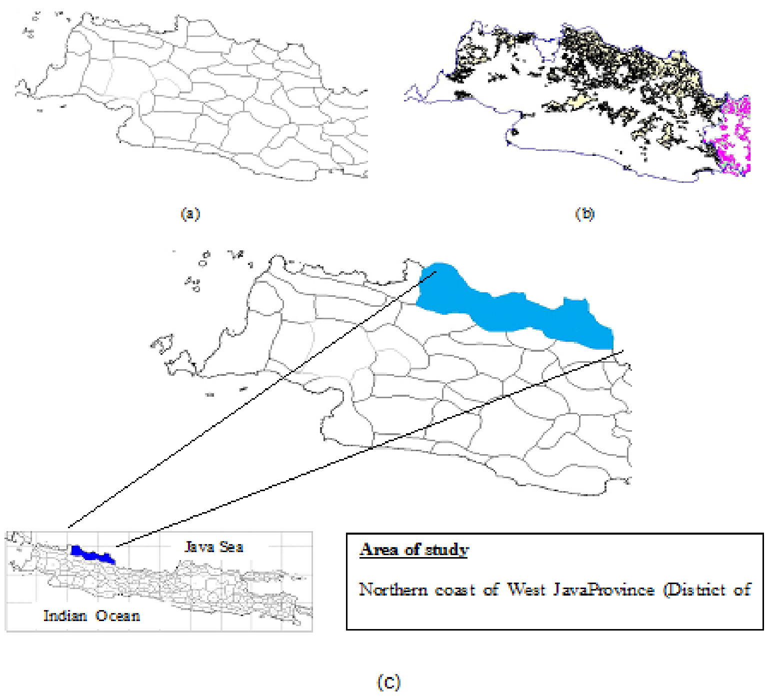


Figure 4: Determining study area by overlay technique, seasonal forecast area (a), paddy field area (b) and study area (c)

3.2 The selection of predictors

The process selection of predictors to be something important because this factor is expected to be a factor that can increase the level of accuracy of the model. Several previous studies indicate that the selection of predictors can improve the accuracy of prediction [10, 9]. To know the skill of a model commonly use some statistical parameters for evaluation such as value of the correlation coefficient (CC) and root mean square error (RMSE). This research will be foluces on the finding of predictors that have a significant role to variations in rainfall in the study area. For this purpose the CC test will be conducted between precipitation and atmospheric parameters on the horizontal and vertical dimensions. The coefficient of determination is a measurement tool used to determine the degree of relationship between variables X and Y. These coefficients can be determined based on the relationship between the two kinds of variations, namely: variation of the Y variable regression line (Y') and variation of the variable Y to the mean $(\bar{Y})$.

$$r^2 = 1 - \frac{\sum (Y - Y')^2}{\sum (Y - \bar{Y})^2} \quad (1)$$

As well as the determination coefficient, the correlation coefficient (CC) was also used as a measure of the relationship between two variables.

$$CC = \frac{\sum xy - \frac{\sum(x)(\sum y)}{n}}{\left[\left(\sum x^2 - \frac{(\sum x)^2}{n}\right)\left(\sum y^2 - \frac{(\sum y)^2}{n}\right)\right]^{\frac{1}{2}}} \quad (2)$$

3.3 Multiple linear regression model

Multiple linear regression model is a statistical analysis model that utilizes the relationship between two or more quantitative variables so that one variable can be predicted from the other variables.

$$\boldsymbol{y(t) = \beta_{0+}\beta_1 x_1(t) + \beta_2 x_2(t) + \cdots + \beta_k x_k(t) + e(t)} \quad (3)$$

Whereas y(t) (the date of onset of rainy season) is predictant, x1, x2,…,xk are predictors, e is error and β1, β2, …, βk are regression parameters are estimated from datasets.

3.4 Cross validation

Cross-Validation is a statistical method of evaluating and comparing learning algorithms by dividing data into two segments: one used to learn or train a model and the other used to validate the model. In typical cross-validation, the training and validation sets must cross-over in successive rounds such that each data point has a chance of being validated against [15]. There are 3 techniques is used for cross validation which are random subsampling, K-fold cross validation and Leave-one-out cross validation (LOOCV). This research use LOOCV techniques. The detail of cross validation technique is represented in figure 5.

Figure 5: The description of cross validation technique using LOOCV

3.5 Model evaluation

The Root Mean Square Error (RMSE) (also called the root mean square deviation, RMSD) is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modeled. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power. The RMSE of a model prediction with respect to the estimated variable X_{model} is defined as the square root of the mean squared error:

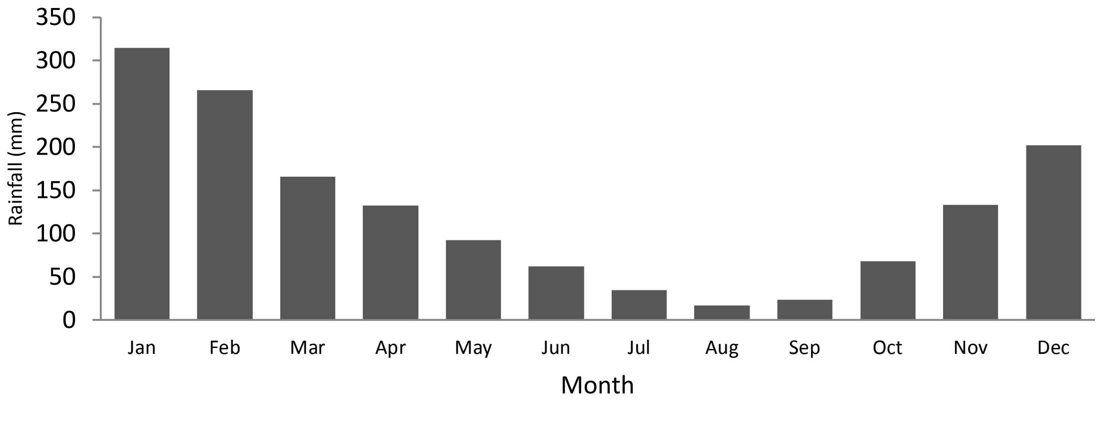
$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}\left(X_{Obs,i} - X_{Model,i}\right)^2\right]^{1/2} \quad (4)$$

Where $X_{obs,i}$ is observed values and $X_{model,i}$ is modeled values at time/place *i*.

3.6 Description of study area

The study was conducted in the northern coast of West Java province which includes district of Karawang, Subang, Indramayu and Cirebon. These districts was known as central areas of food production, especially rice and supplies about 30% of the rice in West Java province. The topography is generally relatively low in the northern part and the higher location located at southern part.

Monthly rainfall profiles indicate that the northern coast of West Java province is monsoonal regions that in one year there were clear differences between the rainy season and dry season period (figure 6a). The total annual rainfall ranges from 1039 mm s / d 1962 mm with an annual average of 1513 mm. The starting of the rainy season based on data from 1981-2010 showed that the rainy season over area of study generally start in ten days unit 33rd (or date 21st to 31st November). But the onset of the rainy season does not always come in line with the average, sometimes arriving early and late. Variability is the onset of the rainy season due to the dynamics of atmospheric anomalies or disorders at the time of the start of the rainy season. From the figure 6b shows that the beginning of the rainy season could come earlier than the average as in 1983 and 1996 are on ten days unit 30th, otherwise in 1982 the onset very late on ten days unit 36th or by the end of December.



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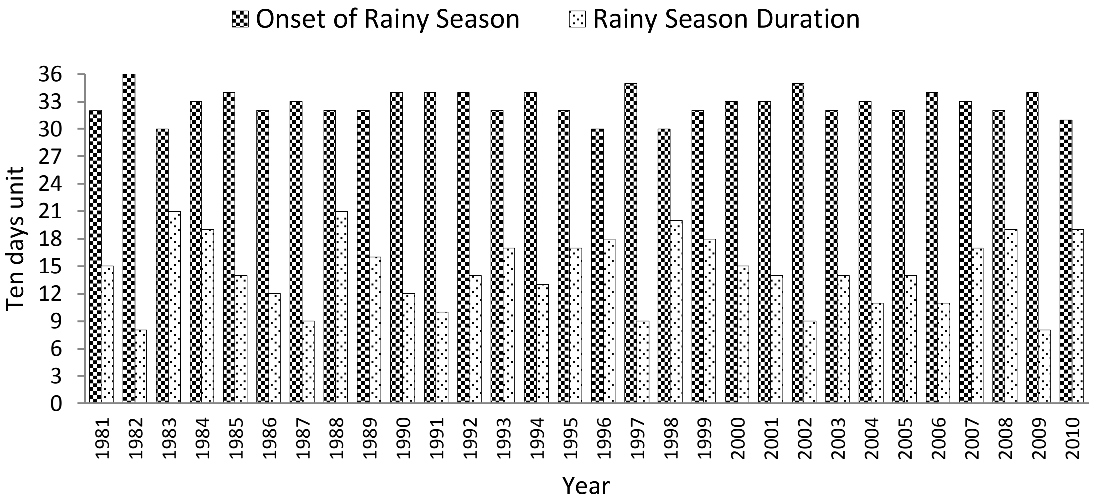


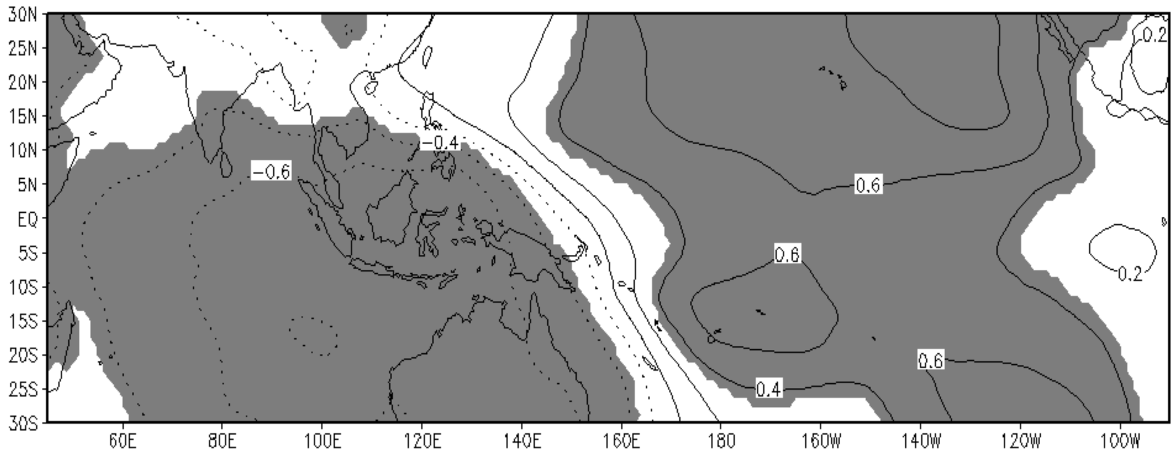
(b)

Figure 6: Monthly rainfall average (a) and onset and duration of rainy season (b) from 1981-2010

4. Result and Discussion

4.1 Correlation maps

Based on data from 1981-2010, the spatial maps of correlation coefficient are resulted. The spatial maps of correlation coefficient (CC) between date of rainy season onset and difference climate variables from which some of the predictors were derived for the present study are shown in the figure 7(a–f). The climate variables considered for preparing the correlation maps are potential velocity anomaly, zonal wind at 850mb, zonal wind anomaly at 200mb, surface temperature anomaly, surface pressure anomaly, and Outgoing Long wave radiation. In figure 7(a), the significant positive CC over the tropical Pacific areas of Pacific region and negative CC over Indian Ocean areas indicates below (above) normal velocity potential over the region during earlier (later) than normal date of rainy season years.



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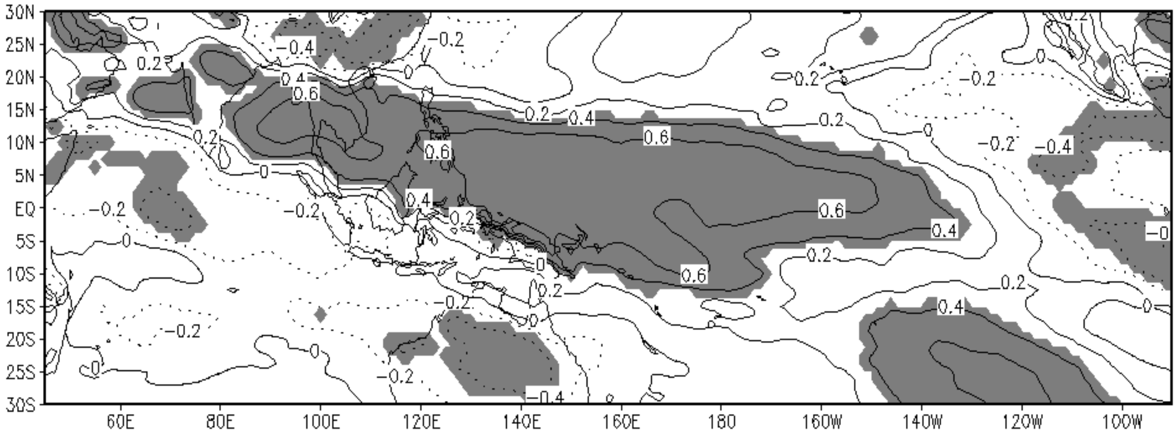
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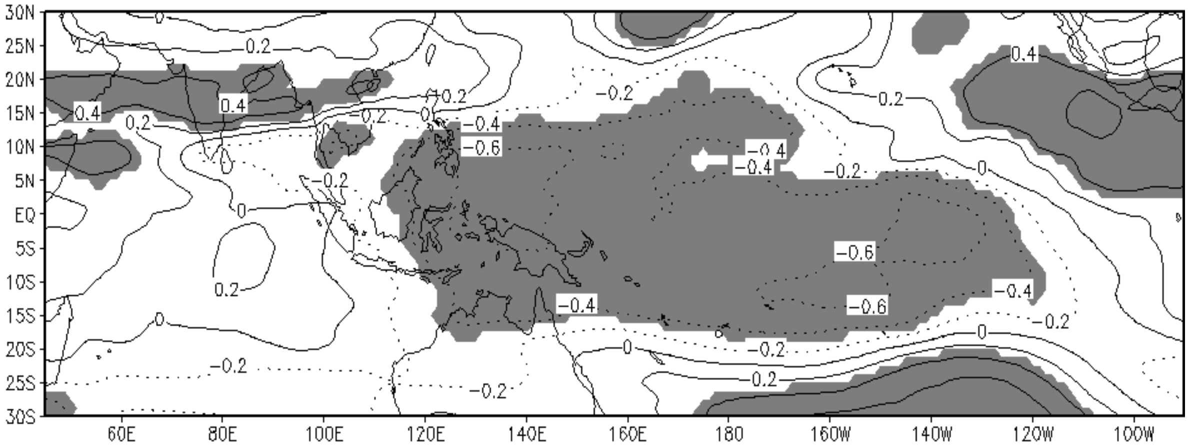
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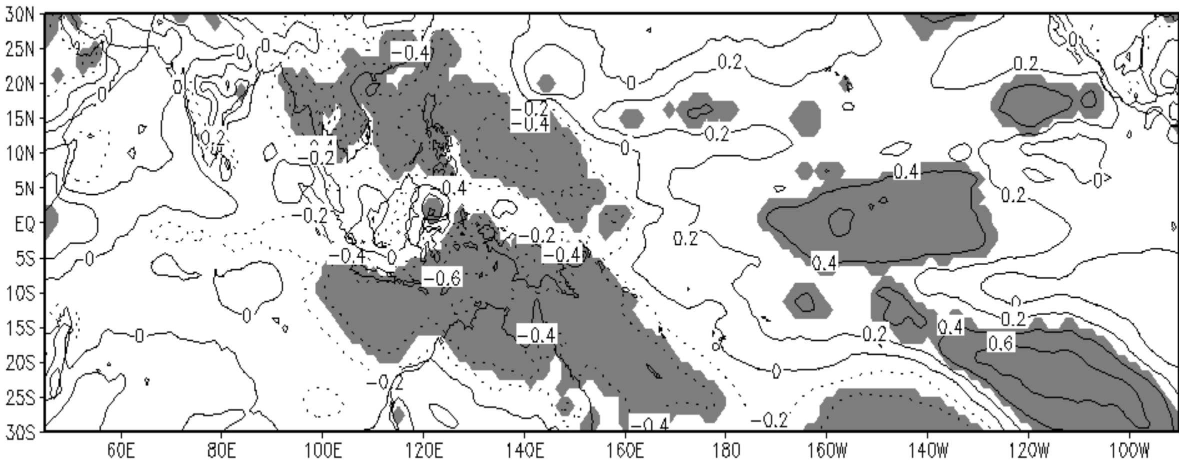
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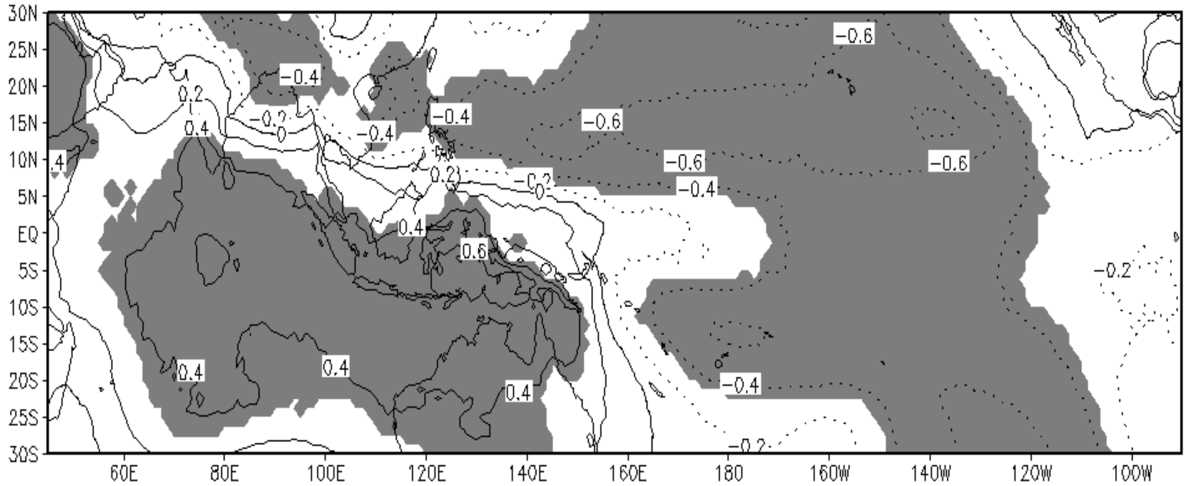

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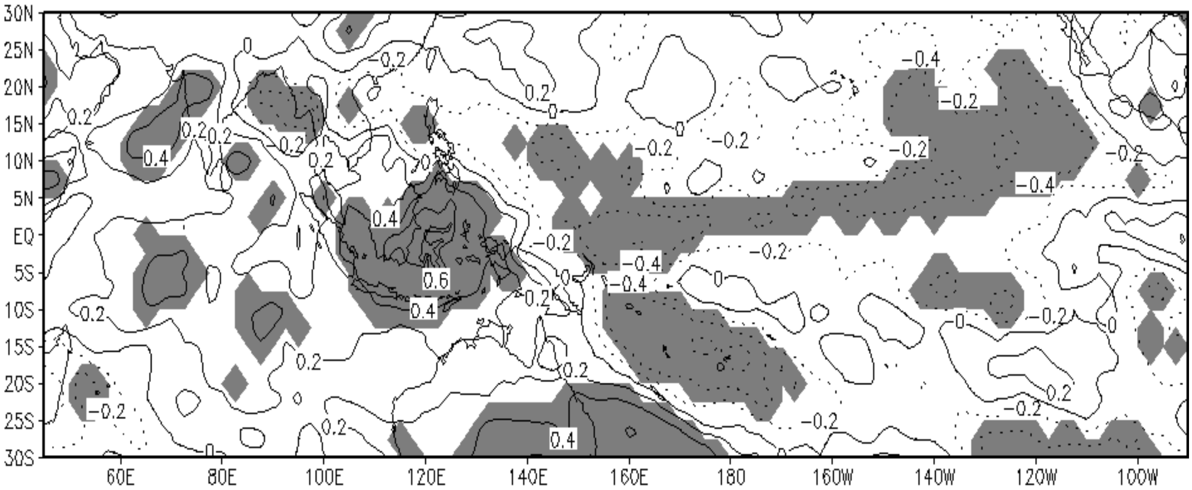


(f)

Figure 7: (a) Contour map of correlation coefficient (CC) between the potential velocity anomaly (averaged over July) over Asia–Pacific region and date of onset of rainy season. The CC was computed using data for the period 1981-2010. Solid (dotted) contours are used for positive (negative) CC. The contour interval is 0.2, the areas of CC significant at and above 95% significant level are shaded, (b) Same as figure 7(a) but for CC between zonal wind anomaly at 850 hpa (averaged over July) and the date of onset rainy season, (c) Same as figure 7(a) but for CC between zonal wind anomaly at 200 hpa (averaged over July) and the date of onset rainy season. (d) Same as figure 7(a) but for CC between surface temperature anomaly (averaged over July) and the date of onset rainy season. (e) Same as figure 7(a) but for CC between surface pressure anomaly (averaged over July) and the date of onset rainy season. (f) Same as figure 7(a) but for CC between outgoing long wave radiation (averaged over July) and the date of onset rainy season

4.2 Predictor dataset

Table 2 presents the details of the 16 predictors used for the three models. The geographical locations of the predictors are given in figure 8. The same technique was applied similar with [14] to define the predictors geographical location. Potential velocity, OLR, surface mean sea level pressure and zonal wind predictors were derived as the simple arithmetic average of the actual values over the respective geographical region whose domain is given in the fourth column of table 2. These geographical regions are derived from the correlation maps (figure 7) and correspond to the areas where the CC between the respective climate variable and onset of rainy season was at least significant at 5% level.

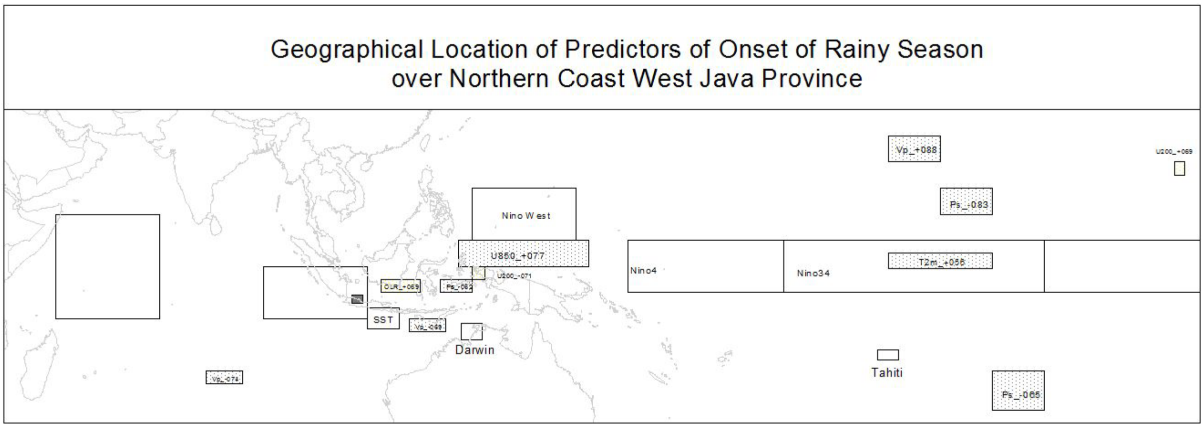


Figure 8: Geographical locations of the 16 predictors used in the models. The 16 predictors are listed in table 2. Dotted boxes are common predictors and blank boxes are smart predictors.

Table 2: List of selected predictors, location and its coefficient correlation

No.	Predictors	Time	Geographical location	CC	Definition
1.	Vp_+088	July	20N-25N, 210E-220E	+0.88	Potential Velocity
	Vp_-074		22.5S-20S, 80E-85E	-0.74	
	Vp_-069		12.5S-10S, 120E-125E	-0.69	
2.	T2m_+056	July	0-2.5N, 210E-230E	+0.56	Surface temperature anomaly
3.	Ps_-083	July	10N-15N, 220E-230E	-0.83	Surface pressure anomaly
	Ps_-065		30S-20S, 230E-240E	-0.65	

	Ps_-062		5S-2.5S, 127.5E-130E	-0.62	
4.	U850_+077	July	0-5N, 127.5E-152.5E	+0.77	Zonal wind at 850mb
5.	OLR_+069	July	5S-2.5S, 112.5E-120E	+0.69	Outgoing Long wave Radiation
6.	U200_-071	July	2.5S-0, 130E-132.5E	-0.71	Zonal wind at 200mb
	U200_+069		17.5N-20N, 265E-267.5E	+0.69	
7.	SST South Java	July	12S-8S, 110E-116E	-0.54	sea surface temperature anomaly
8.	Nino34	July	5S-5N, 170W-120W	+0.67	sea surface temperature anomaly
9.	SOI	July	-	-0.68	Surface pressure different between Tahiti and Darwin
10.	Nino West	July	0-15N, 130E-150E	-0.60	sea surface temperature anomaly indices
11.	Nino4	July	5S-5N, 160W-150W	+0.69	sea surface temperature anomaly indices

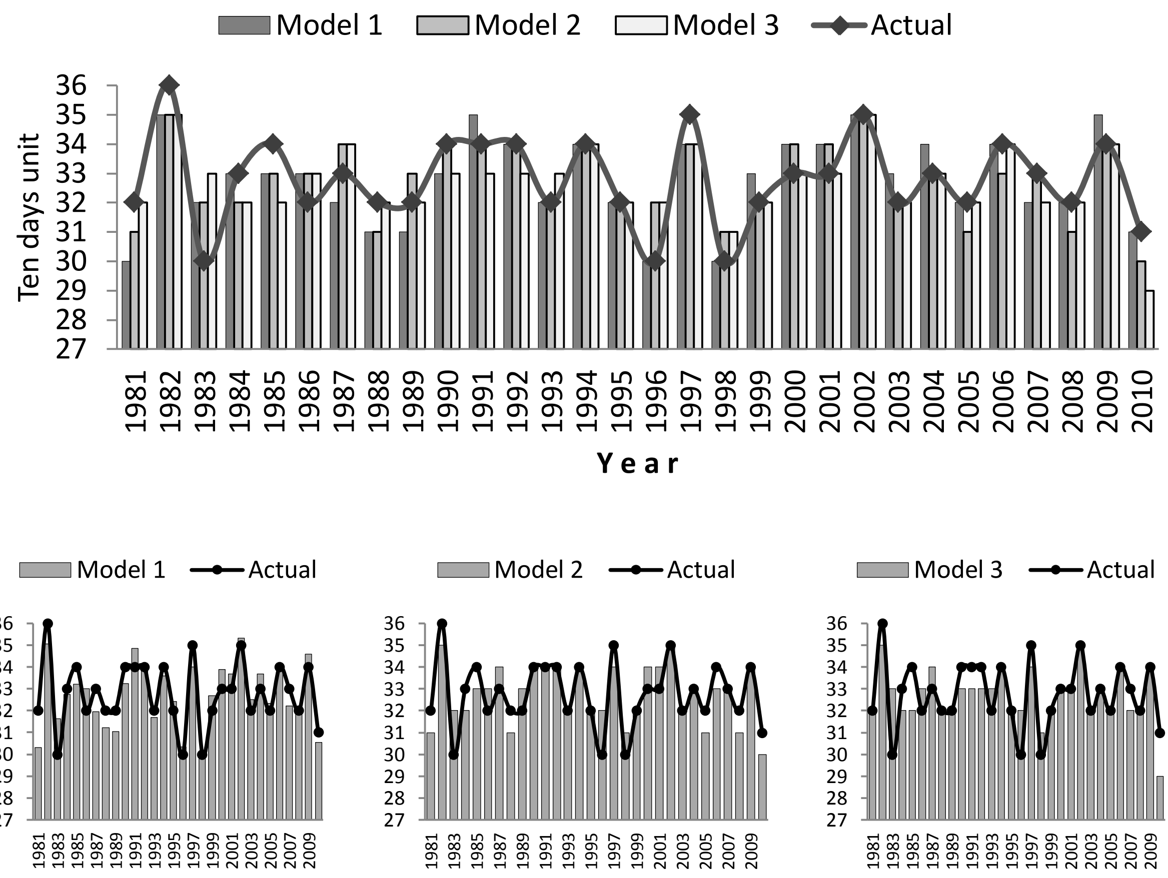
From the table 2, the predictors have been selected 16 predictors are considered to have a strong relationship to the variability of onset of rainy season over area of study which are velocity potential (3), surface temperature (1), surface pressure anomaly (3), the zonal wind at 850mb (1), OLR (1), the zonal wind at 200mb (2), SST south of Java (1), Nino34 (1), SOI (1), Nino West (1), and NINO4 (1), while IOD and Nino3 are not selected because who does not have a significant correlation coefficients so that the total will be used as predictors in the model is 16 predictors.

4.3 The performance of the models

To predict the onset of the rainy season for each year from 1981 to 2010 by using the multiple regression model for 3 models with input of predictors for each model. The list of model and it's predictors and geographical location are showed in table 3 and figure 9. The cross validation technique was applied, one used to learn or train a model and the other used to validate the model. For instance, to predict the onset date of rainy season 1981, the data of 1981 was removed and the others is used for generated the model and predict the 1981 condition. This technique was applied foe whole years and we got all predicted onset of rainy season for 30 years simulation.

Table 3: List of models, number of predictors and detail of predictors

No.	Model	Technique	Predictors
1	Model 1	Multiple Linier Regression	Vp_+088, vp_-074, vp_-069, T2m_+056, Ps_-083, Ps_-065, Ps_-062, U850_+077, U200_-071, U200_+069, OLR_+069, Nino34, SST South Java, SOI, Nino West, Nino4
2	Model 2	Stepwise Regression	
3	Model 3	Principal Component Regression	



(a) (b) (c)

Figure 9: The performance of model, model output vs actual

As seen in figure 9, all the model predictions have shown good performance during the independent training period. During all the years all the models were able to closely predict whether the onset of rainy season was earlier or later to the normal date. The root mean square errors of model predictions during the independent test period of 30 years (1981–2010) for all the models was about 0.86 ten days unit (0.76 for Model-1, 0.78 for model-2, 1.03 for model-3) which is less than the standard deviation of the onset of rainy season (1.48 ten days unit). The CC between the actual and predicted onset of rainy season for all the models was 0.82 as presented in figure 10. During the years like 1982, 1997, 2002 and 2010 when the onset of rainy season was earlier or later than the normal onset of rainy season date by more than or equal to 10 days, the prediction from Model-1 was closer to the observation than the prediction from model-2, and model-3.

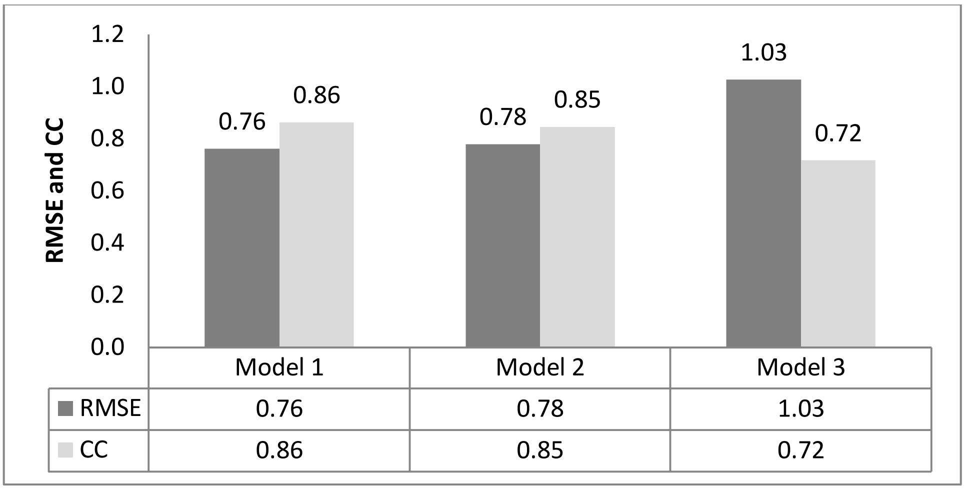


Figure 10: RMSE and CC for each model

5. Conclusions

The onset of rainy season over the northern coast of West Java Province around 21 until 31 November with a standard deviation of about 15 days. The arrival of the rainy season over the region is indicated by widespread, persistent and heavy rainfall replacing the occasional transition rains from dry season to rainy season. For the operational reason, the prediction should be delivered to users in August every year in order to prepare all sectors to make better planning to get high benefit particularly for agricultural sectors. In this paper, improvement were made to make use of all climate parameters available in the convective, thermal and circulation patterns over the Asia–Pacific region associated with the event to predict the date of onset of rainy season well ahead of the event.

With the combination of the selected input, generally we found that all model show the good performance by indicated with CC and RMSE but the best performance are resulted by model 1 by using multiple regression technique. All the models showed good skill in the prediction of the date of onset of rainy season during the independent test period of 1981-2010. The RMSE of the predictions from all the models during the independent test period was about 0.79 ten days unit. This study demonstrates that the prediction of the date of onset of rainy season with satisfactory accuracy can be made by the early of August itself.

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