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The influence of the variability of weather conditions on predicting rain events in surrounding Jakarta

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सार – जकार्ता महानगर एक ऐसा स्थान है जहां अक्सर बाढ़ आती है जो जान-माल दोनों के लिए हानिकारक होती है। मौसम विज्ञान, जलवायु विज्ञान और भूभौतिकीय एजेंसी (बीएमकेजी) द्वारा जारी मौसम पूर्वानुमान की जानकारी इस आपदा के पूर्वानुमान में बहुत महत्वपूर्ण होती है। इसलिए, मौसम पूर्वानुमान की सटीकता पर ध्यान देना महत्वपूर्ण है। इस अध्ययन का उद्देश्य जकार्ता क्षेत्र में वर्षा की परिघटनाओं में सटीकता में विविधता के प्रभाव की जाँच करना था, जिसमें मध्य जकार्ता, पूर्वी जकार्ता, पश्चिम जकार्ता, उत्तरी जकार्ता, दक्षिण जकार्ता, बेकासी, तांगेरांग, डेपोक और बोगोर शामिल हैं, जिन्हें जबोटाबेक के नाम से जाना जाता है। मौसम विज्ञान, जलवायु विज्ञान और भूभौतिकी स्कूल अथवा एसटीएमकेजी वेदर केयर ने मौसम की स्थिति, विशेष रूप से वर्षा की परिघटनाओं का स्वैच्छिक प्रेक्षण विकसित किया है। उत्तर देने वलों द्वारा फॉर्म भरा जाता है कि उस स्थान पर वर्षा हुई थी जहां वे रहते हैं और इसका मूल्यांकन द्विभाजित विधि का उपयोग करके किया जाएगा। यह अध्ययन जबोटाबेक क्षेत्र में वर्षा की पूर्वानुमान की 70.1% सटीकता को दर्शाता है, पूर्वानुमान की विफलता आम तौर पर एक अधिक अनुमान के कारण होती है। सबसे ज़्यादा सही पूर्वानुमान तब हुआ जब वर्षा नहीं हो रही थी। इसके अलावा, सबसे अच्छी सटीकता बेकासी शहर में रही है, और दक्षिण जकार्ता और पश्चिम जकार्ता सबसे खराब हैं। मूल्यांकन इस बात की पुष्टि करता है कि विस्तृत क्षेत्र में वर्षा की परिघटनाओं और प्रयुक्त पूर्वानुमान शर्तों के अनुसार पूर्वानुमान करना आसान नहीं है।

ABSTRACT. The metropolis of Jakarta is a place where floods often occur which are detrimental to both property and life. Weather forecast information released by the Meteorology, Climatology, and Geophysical Agency (BMKG) is very important in anticipating this disaster. Hence, it is important to pay attention to the weather forecast accuracy. The purpose of this study was to examine the effect of variations in accuracy in rain events in the Jakarta area including Central Jakarta, East Jakarta, West Jakarta, North Jakarta, South Jakarta, Bekasi, Tangerang, Depok, and Bogor as known Jabotabek. School of Meteorology Climatology and Geophysics or STMKG Weather Care developed voluntary observations of weather conditions, especially rain events. Respondents filled out the form whether there was rain in the place where they lived and would be evaluated using the dichotomous method. This study shows the accuracy of rain prediction in the Jabotabek area of 70.1%, with prediction failures generally being an overestimation. The highest number of correct predictions occurred when it was not raining. Moreover, the best accuracy is in Bekasi City, and South Jakarta and West Jakarta are the worst. The evaluation confirms that it is not easy to predict rain events in a detailed area and the prediction terms used.

Key words – Rainfall variability, Weather prediction, Jakarta, STMKG weather care.

1. Introduction

Jakarta as the capital city of Indonesia, which is densely populated, every flood event in Jakarta will be in the spotlight because of the threat of loss of property and life (BPBD, 2013; BAPPENAS, 2007). As a metropolitan city, Jakarta is supported by cities around it, namely Bogor, Tangerang, and Bekasi, andare commonly called Jabotabek. Without good planning anticipation, the risk of flooding in Jakarta will increase which is even predicted to increase to 180% by 2030 (Budiyono *et al.*, 2016). To reduce expected flood damage, it is important to increase the ability to assess flood damage for developing and implementing flood policies (Green *et al*., 2003; Mays, 2011; Fernandes, 2021). However, the ability to access this prevention depends on flood information in the

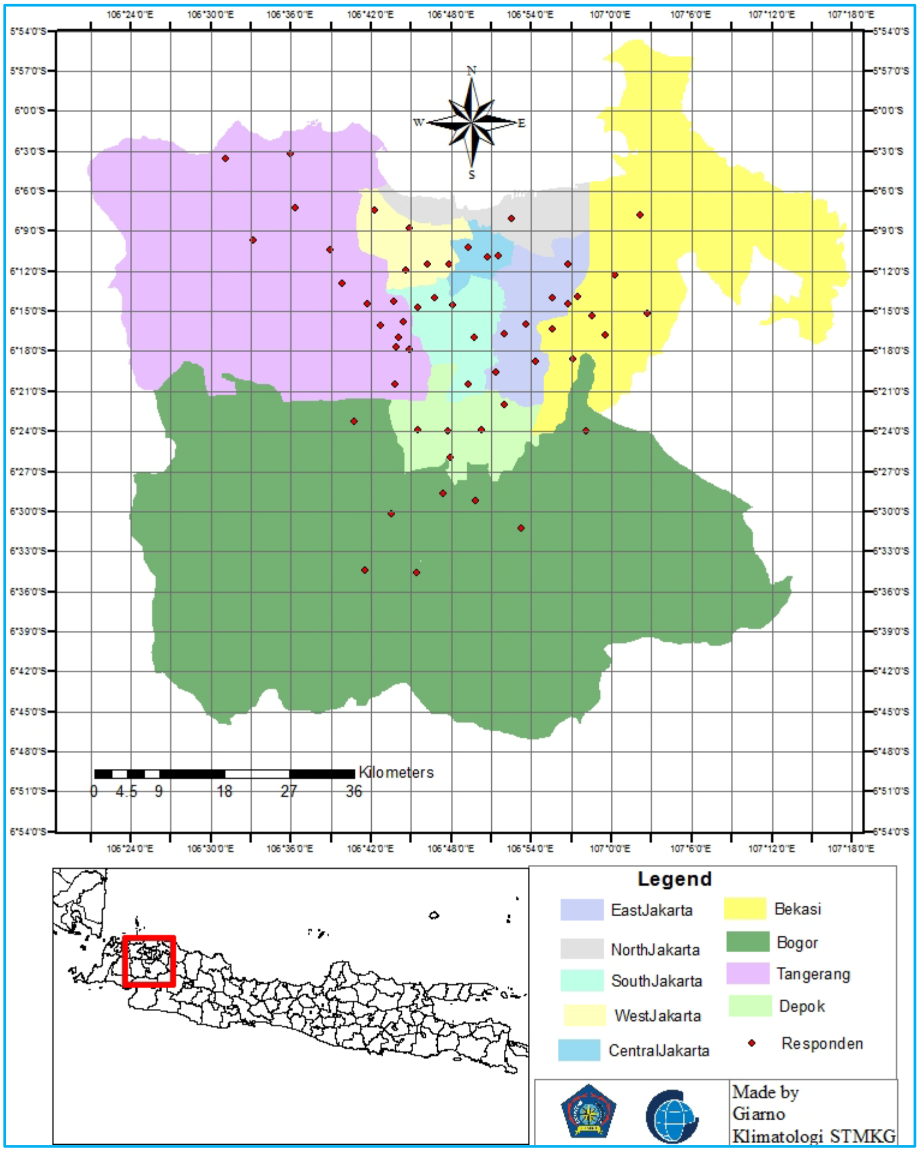

Fig. 1. Distribution of weather voluntary observation respondents in Jabotabek

field and accurate weather predictions. For flood information, it is very important to take advantage of the latest technological developments in flood reporting through mobile applications (Anta *et al*., 2021), while developing accurate weather predictions is also a key factor in decision-making regarding floods.

The Meteorology, Climatology and Geophysics Agency (BMKG), as the official government agency, issues weather forecasts, and warnings for all regions of Indonesia, and of course also Jakarta Megapolitan City. Several models are used to determine whether a location occurs rain or not. Comparison of several weather models, it is found that the accuracy of weather predictions varies over Indonesia (Ginting and Putuhena, 2014; Kiki and Alam, 2019). In addition to model selection, the evaluation of rain predictions is also constrained by the very limited number of raingauges in the observational network managed by BMKG.

Given the limitations of surface weather observation data, it is very important to increase voluntary weather observation on the surface, especially on land where humans live such as the collaborative rain, hail, and snow network (CoCoRaHS) program (Spaccio *et al*., 2021). This program started on June 17, 1998 and currently, there are more than 20,000 active observers throughout the United States who submit data every day. Recognizing the complexity of the weather in Indonesia, where this region is influenced by global weather cycles and also because the Indonesian territory consists of thousands of islands, hundreds of mountains, many seas, and straits makes the weather in Indonesia very complex (Neale and Sligo, J., 2003; D'Arrigo and Wilson, 2008; Hidayat and Kizu, 2010; As-syakur, 2010; Giarno *et al.*, 2012; Lee, 2015; Martono and Wardoyo, 2017). The dynamics of weather in Indonesia have an impact on the accuracy of weather models that are not good (Kiki and Alam, 2019), and even rainfall estimates from remote sensing observations such as satellites and radar are not always high accuracy (Giarno *et al.*, 2018), so the number of weather observation data in Indonesia needs to be increased.

The most popular social media in the world, namely WhatsApp or WA, a popular social media application (Jisha and Jebakumar, 2014), can be used for weather observation data collection. Especially during the Covid-19 pandemic which changed human behavior, where daily activities are carried out remotely including the cadets of the School of Meteorology Climatology and Geophysics (STMKG). The STMKG Weather Care program tried to promote voluntary weather observations to cover the shortage of observation data in the Jakarta Capital City and surrounding areas from June to September 2021. Especially, the area of Jakarta is very important because it is the center of Indonesia's economic growth and is prone to flooding caused by climate change, the increasing temperature, and extreme rainfall (Budiyono *et al*., 2016; Supari *et al*., 2017). The purpose of this study is to evaluate the forecast of rain events in Jabotabek (Jakarta Megapolitan City) by utilizing information reports from social media WhatsApp and Google form.

2. Data and method

This research uses questionnaire data from June to September 2021 filled out by 84 respondents spread across the Jabotabek area as shown in Fig. 1. Because of the current Covid-19 pandemic has changed human behavior, where daily activities are carried out remotely. Taking advantage of the moment when the students are in their own homes, this voluntary weather observation was developed. The respondents in this research are STMKG cadets located in Jakarta with a position as shown in Fig. 1 as volunteers who are currently still undergoing distance learning. Moreover, WhatsApp (WA) was used to spread the message for collecting weather observation data. The form follows the WMO and BMKG standard synoptic weather observation procedure that rules record rain events in the present weather and past weather using visuals (WMO, 1994; BMKG, 2006).

Weather predictions issued by the BMKG are renewed twice a day and updated as soon as possible if extreme conditions occur. The time of weather prediction updates is not the same because there are 3 time zones in Indonesia, and Jakarta is in the Western Indonesia time zone. However, the forecast update carried out by the BMKG forecaster follows the official schedule, which is 2 times a day, at 10.00 LT and 22.00 LT. Moreover, weather predictions use a 3-hour range, and respondents are asked to report the weather where they live and check the weather predictions on the link provided on the form as shown in Fig. 2. Therefore, the weather observer volunteer in filling out the form will be asked to see the weather forecast in their area which coincides with the time of the observation. Respondents fill out the form whenever they want and choose the weather forecast where they live at the time that corresponds to the time of reporting voluntary weather observations.

Inaccuracies in comparisons between voluntary weather observations over time and predictions using time ranges are ignored. Because the data is qualitative, it is not possible to compare the rainfall values so accuracy assessment in the form of correlation, root-mean-square-error, and the like could not be used. As a tropical country, the weather conditions in Indonesia are identical to the presence of rain events, so the main validation is the presence or absence of rain events. However, verification also calculates the details of the terms used to describe weather conditions. For example, no rain consists of clear weather, partly cloudy, and cloudy, while the term rain also considers the intensity of rain. Therefore, the verification of this research uses two methods, namely the general condition of the presence and absence of rain events and testing the suitability of the details of the terms used.

The most suitable method for this research is using dichotomous with a contingency table. This method is useful for the occurrence quantitatively of rainfall verification since it is easier to detect the existence of a specific event, such as a rain event. The detection accuracy of weather predictions using this method is relatively simple, especially to evaluate rain events in Indonesia (Giarno *et al.*, 2018). Both predictions and observations have two possibilities, namely rain and no rain, the suitability of which occurs in Table 1.

TABLE 1

Dichotomous rain event detection

		Observation	
Prediction	Event	rain	no rain
	rain	hits	false alarm
	no rain	miss	correct negative

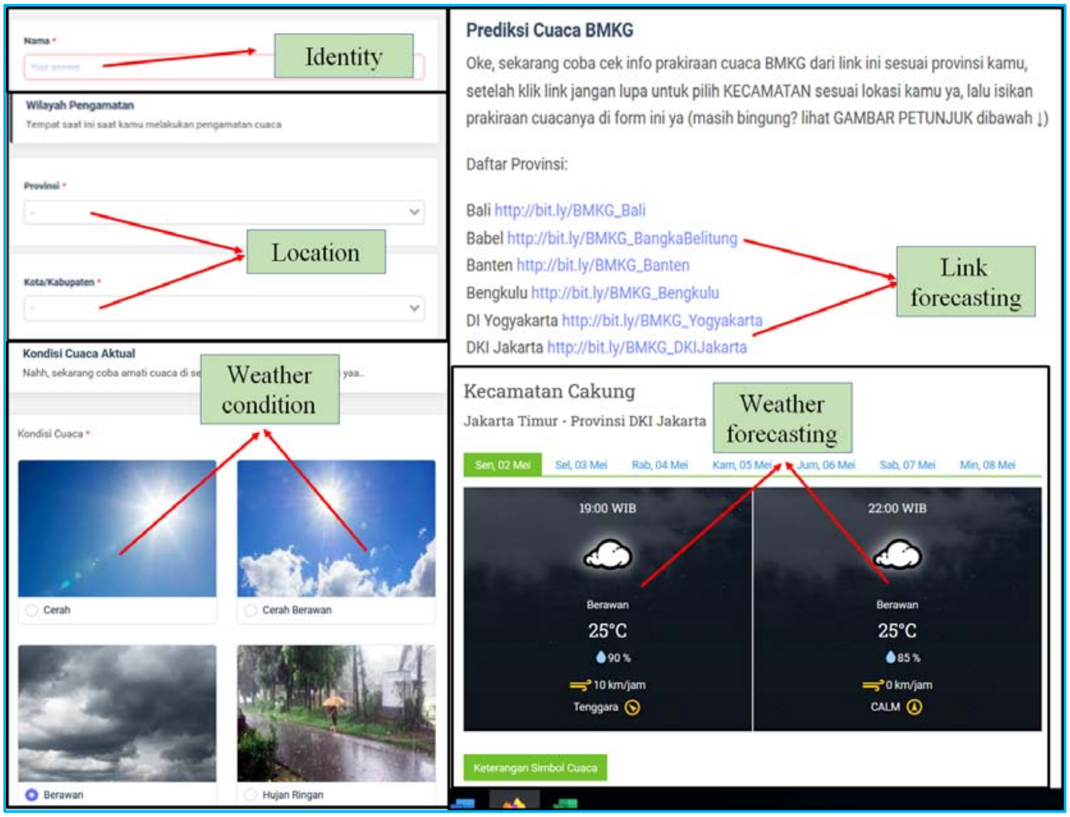

Fig. 2. Weather observation form (https://laporcuaca.stmkgweathercare.com/public/)

The suitability of events between prediction and observation has 4 conditions, namely hits, false alarms, missing, and correct negative. The first term refers to the number of observed rain events and observation has the same record of rain. Then, false alarm refers to the prediction states rain but observations not. While miss refers to the estimates state not rain but observation states rain and finally, correct negative refers, if observation and prediction state not rain.

The dichotomous indicators include ACC (Accuracy), BIAS, POD, CSI, ETS and TSS to measure rain prediction accuracy. Here, ACC value refers to correct prediction with a perfect score, 1 and BIAS refers to the ratio of false alarm to missing events that have a perfect value, 1. Furthermore, POD refers to the ability to detect correct predictions in certain categories, and CSI, known, also, as the threat score numbers hit divided by the number of estimated cases for that category. The ETS is widely used to operationally assess the performance in forecasting events over a range of thresholds. It has the advantage that a perfect forecast has a score of one and that a forecast no better than chance has a score of zero. Finally, the TSS or Hanssen - Kuipers skill score is another commonly used performance measure for evaluating forecast precipitation. All the statistical dichotomous indicators are calculated as follows:

$$\mathrm{ACC} = \frac{\mathrm{Hits} + \mathrm{Correct\_Negative}}{\mathrm{Total}} \tag{1}$$

$$\mathrm{BIAS} = \frac{\mathrm{Hits} + \mathrm{False\_Alam}}{\mathrm{Hits} + \mathrm{Miss}} \tag{2}$$

$$\mathrm{POD} = \frac{\mathrm{Hits}}{\mathrm{Hits} + \mathrm{Miss}} \tag{3}$$

$$\mathrm{CSI} = \frac{\mathrm{Hits}}{\mathrm{Hits} + \mathrm{Miss} + \mathrm{False\_Alam}} \tag{4}$$

There is no most powerful indicator, therefore all of them are used in the analysis of a rain event evaluation. In this study, accuracy is divided into two groups, namely the accuracy of rain events in general which refers to the presence or absence of rain events, and specific accuracy which is more detailed and includes the intensity of rain. The heavy rainfall will be analyzed more deeply because the risk of impact is more important than the weaker intensity. Accuracy will be compared to variations in rain

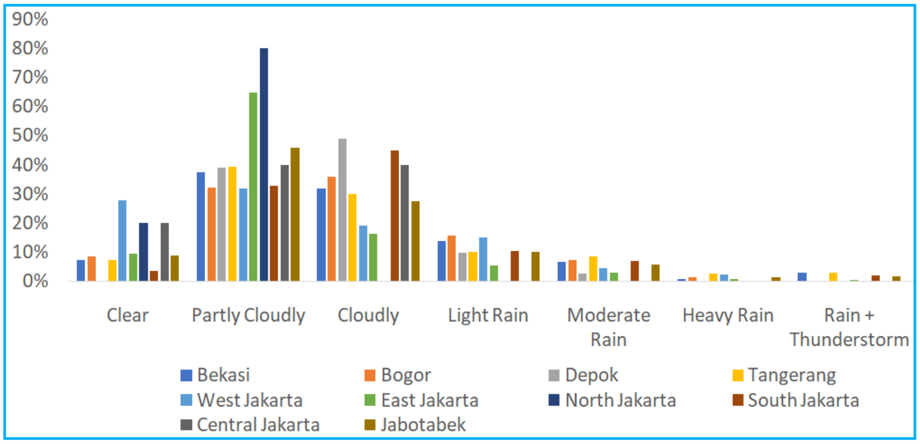

Fig. 3. Weather observation in Jabotabek

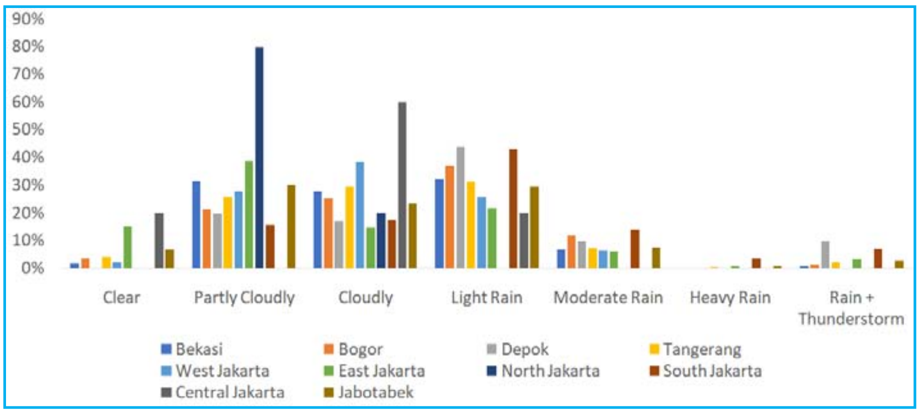

Fig. 4. Weather forecast in Jabotabek

events in each district to determine the effect of different rainfall events in one place on the accuracy of rain prediction.

3. Result

3.1. *Variations of Rain Events in Each City*

The Indonesian Meteorology, Climatology and Geophysics Agency (BMKG) published a dry season prediction book 2021, which stated that the dry season in 2021 would start between March to June, especially on Java Island (BMKG, 2021). Therefore, it was confirmed that in June when the respondent filled out the form, it was the really dry season. Because the number of respondents is not the same in each district, the analysis composition of weather observations is expressed in percentage events. The weather during the dry season is generally clear weather/sunny to cloudy, however, because Indonesia is a place surrounded by oceans and its position is between two continents, it is still possible for convergence activity as rain events in this area observed by respondents in Fig. 1. In almost all locations in Jakarta and its surroundings, there are still many reports of light rain to heavy rain.

On the other hand, BMKG predicted the early dry season in the Jabotabek area started between May to June 2021, and as predicted the weather observation throughout the Jabotabek region observed generally partly cloudy to cloudy as shown in Fig. 3. Meanwhile, the percentage of sunny weather and light rain observed is almost the same, while around 12% and 5% of the report states moderate to heavy intensity. North Jakarta and Central Jakarta have few respondents, so the analysis ignored these places. Moreover, weather variations can be seen from the comparison of weather reports for each city. The respondent reported the weather in East Jakarta was generally partly cloudy to other cities, while South Jakarta was cloudy. This means that in the Southern Jakarta area, cloud growth activity is more active than in other areas of Jakarta. Furthermore, there is a lot of rain with moderate

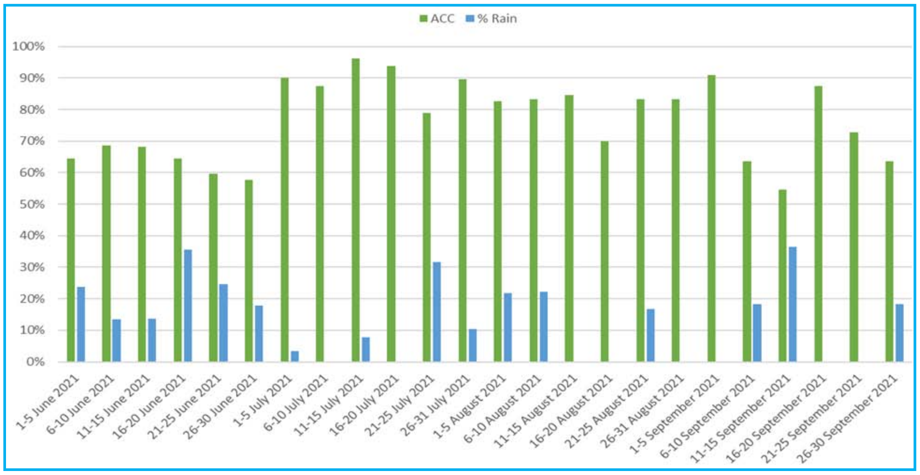

Fig. 5. ACC in 5 days average in Jabotabek

TABLE 2

Number of hits, missing, false alarms and correct negatives in each Jabotabek city

City	Hit	False Alarm	Missing	Correct Negative
Bekasi	34	36	9	103
Bogor	10	31	10	33
Depok	5	17	0	19
Tangerang	45	51	14	138
West Jakarta	9	6	1	31
East Jakarta	18	69	10	211
North Jakarta	0	0	0	5
South Jakarta	8	27	3	20
Central Jakarta	0	1	0	4
Jabotabek	129	238	47	564

intensity in South Jakarta, Tangerang and Bogor. These indications are based on June-September 2021 dry season observations and further longer period observations may be required to establish conclusions.

Meanwhile, weather conditions in Jabotabek are predicted by BMKG to be mostly partly cloudy to light rain as shown in Fig. 4. Compared with observations, the number of predictions of light rain events in Jabotabek seems more than observation. The BMKG forecaster also makes predictions of heavy rain which are less than observations of where the respondents live or underestimate. On the other hand, when rain prediction is accompanied by thunderstorms, it is more often done so that an overestimate occurs.

3.2. *Variation accuracy of rain prediction*

Detection of rain events by BMKG's forecaster showed that each city has a different accuracy. The accuracy of weather prediction in this research is divided into two, identification of only rain or no rain and the second more detailed predictions based on terms used by BMKG and observations. Evaluation based on all respondents' observations shows that errors due to missing events are higher (47 events) compared to false alarms (238 events) as shown in Table 2. This means that many forecasters predict that it will rain in Jabotabek, even though respondents reported that there is no rain where they live. Meanwhile, generally the high correct negative indicates the tendency of prediction and observation when

TABLE 3

Evaluation in each city

Events	Bekasi	Bogor	Depok	Tangerang	West Jakarta	East Jakarta	South Jakarta
No Rain	76%	76%	88%	76%	79%	91%	81%
Rain	24%	24%	12%	24%	21%	9%	19%
Indicators	Bekasi	Bogor	Depok	Tangerang	West Jakarta	East Jakarta	South Jakarta
ACC	0.753	0.512	0.585	0.738	0.851	0.744	0.483
BIAS	1.628	2.050	4.400	1.627	1.500	3.107	3.182
POD	0.791	0.500	1.000	0.763	0.900	0.643	0.727
CSI	0.566	0.393	0.463	0.556	0.660	0.685	0.345

there is no rain and the overall accuracy of rain prediction is 70.1%.

In June, rain events affect the prediction accuracy where forecasters have an accuracy of less than 70%. The share of rain events in this period is around 12%–25% as shown in Fig. 5. Then after this period, namely in July and August, the portion of rain events decreases, and on the other hand, the accuracy of predictions increases by more than 70%. Finally, in September, although the accuracy is still higher than in June, there has been a decline in accuracy.

The average accuracy of rain prediction throughout Greater Jakarta is 70.1%, with the lowest accuracy in South Jakarta (48%) and the highest accuracy in East Jakarta (85%). The portion that does not rain in Jabotabek from June to September reaches 82% and East Jakarta is a city that has sunny weather compared to other cities as shown in Table 3. Moreover, the cities located in the southen part of Jabotabek are South Jakarta, Bogor, and Depok. has a relatively less accuracy compared to other cities. Adding, the high ACC value during rainy weather does not interpret that the forecaster is very good at predicting rain events. Based on the BIAS value whose value is higher than 1, the forecaster is likely to make predictions of rain more often even though there is no rain. Further evaluation shows that the weather where the respondents settle is mostly no rain as shown in Table 3.

The number of rain events makes forecasters make false alarm errors, especially in Depok, East Jakarta, South Jakarta, and Bogor where the BIAS value is more than 2. This condition shows the number of errors due to false alarms is very large compared to errors due to missing. Moreover, in the cities of Depok and East Jakarta where the amount of rain is only less than 15%, many forecasters project that the weather will not rain. Then, based on the POD value, the rain prediction for Depok

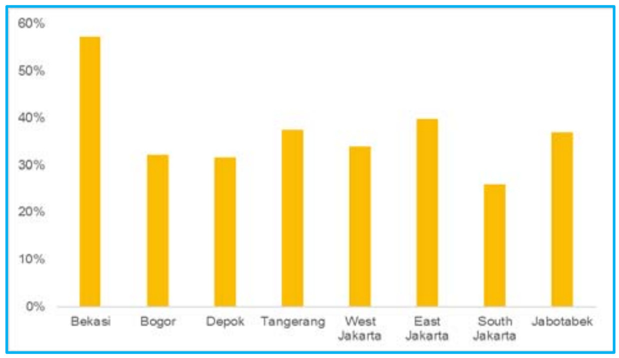

Fig. 6. Value ACC detailed weather item prediction in Jakarta and its surrounding

city has never been missing, so the POD value is perfect 1, while for Tangerang, West Jakarta and South Jakarta the number of missing is smaller than Bekasi, Bogor, and East Jakarta. Except for the Bogor, it seems that the more rain, the fewer errors due to missing. Forecaster BMKG is very good at predicting rain in West Jakarta which has 21% rain even where the CSI value is higher than in other cities.

Meanwhile, verification that uses comparisons in each detailed prediction and observation term used is Clear, Partly Cloudy, Cloudy, Light Rain, Moderate Rain, Heavy Rain, and Rain + Thunderstorm. However, North Jakarta and Central Jakarta were not included in the analysis because the amount of incoming data is not much. The highest ACC value is predicted in Bekasi City which reached 57%, while South Jakarta, Bogor, and Depok have low accuracy. The average accuracy in the entire Jabotabek area is 37% as depicted in Fig. 6.

As a country that adopted impact-based forecast (IBF), The Meteorology, Climatology and Geophysics Agency (BMKG) warns each severe potential hazard

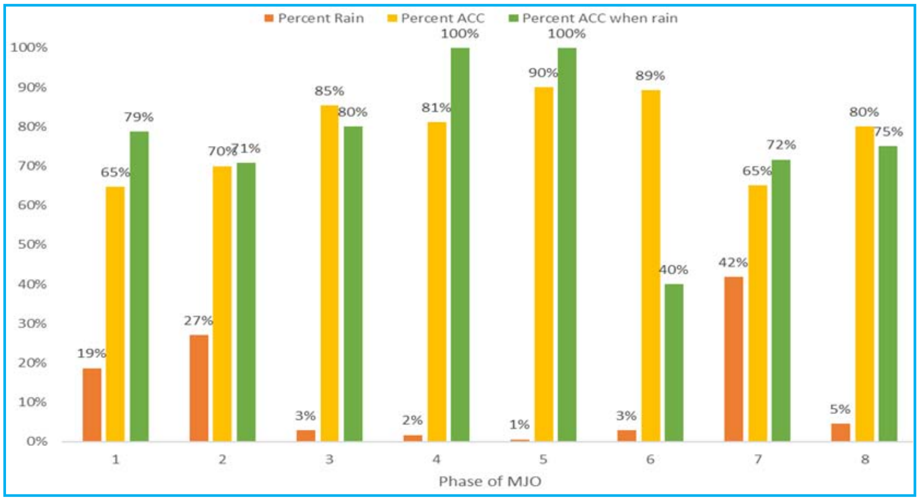

Fig. 7. Value ACC detailed weather item prediction in Jakarta and its surrounding

affected by hydro-meteorological variable. The purpose of warnings help to minimize the impacts and reduce the risk of the hazard by encouraging an appropriate and timely behavioral response. However, the existence of high rainfall intensity is important so that the occurrence of missing or false alarms can be analyzed according to the detailed predictions. The result showed the more detailed the weather prediction can reduce the accuracy from 40.5% compared to 70.1% in the first scheme. Meanwhile, of the 25 heavy spots of rain that occurred, 5 times were exactly as predicted, but 7 times were predicted to be sunny. Meanwhile, the forecaster error in determining the intensity of the prediction occurred 31 times, where the prediction of light rain but in the respondent's location reported moderate and heavy rain. In addition, when the forecaster makes predictions of heavy rain, and the weather in the respondent's location is sunny, it never occurs. When the prediction states heavy rain, generally the weather at the location is partly cloudy.

The effect of the MJO phase on rain in the 2021 dry season is different from phases 3 and 4 which are often mentioned as active phases on the Indonesian Maritime Continent. Respondents reported that a lot of rain occurred in phases 1, 2, 7 and 8 compared to phases 3, 4, 5 and 6 which was less than 5% as shown in Fig. 7. The portion of rain that occurred on all days in phase 7 during the months of June-September was 42%. Reliable forecasters make rain predictions during phases 3-6 and increase their prediction accuracy when rain occurs in phases 4 and 5 which reaches 100%. However, because the number of days for each phase is not the same, the calculation of high accuracy in phases 4 and 5 requires a more in-depth study. During the 4 months of this study, phases 2 and 7 had the largest portion, namely 30% and 38% of the total MJO phase, respectively.

4. Discussion

Accuracy is a very important issue in observing and predicting weather in Indonesia, considering that this place is very dominant in hydro-meteorological disasters. However, variations in the identification of rain and whether or not a place based on satellite observation data show that each place in Indonesia has different accuracy characteristics. Areas around the coast facing the cause of rain have better accuracy than mountainous areas (Giarno *et al.*, 2018) and also on weather radar. Therefore, this difference in estimation accuracy also occurs in several other places in the maritime continent (Prakash *et al.*, 2015; Tan *et al.*,2015; Guo *et al.*,2016). The magnitude of either overestimation or underestimation varies with time and place.

All-weather forecasting models have biases that vary from place to place and time to time. The model bias for rainfall prediction can change from overestimation to underestimation and is affected by lead time (Durai *et al.*, 2010). Meteorological parameters such as cloudiness for all the seasons were good with a high correct percent for all the seasons, in contrast, the wind speed and direction depicted poor forecast for all the seasons (Kothiyal *et al.*, 2017). Moreover, the accuracy of wind speed prediction was verified about 74 percent correct (Kaur and Singh, 2019), and the skill of forecasting affected the pre-monsoon and monsoon periods (Paparrizos *et al.*, 2020). The method of evaluation of skill prediction and lead time also impacts the accuracy (Rajavel *et al.*, 2019). The complex weather in the Indonesian maritime continent (BMI) makes weather forecasting difficult. Using the dichotomous technique showed forecasters failed in predictions of heavy rain events (Gustari *et al.*,2012). Moreover, the dynamics of weather in Indonesia have an impact on the accuracy of weather model prediction, which is about 40% on average (Kiki and Alam, 2019). However, the accuracy of the weather prediction model used can be improved by assimilation of the model with surface observation data (Sagita *et al*.,2016; Santi *et al*.,2019).

This research confirms that it is not easy to predict rain events in detail at each location and the prediction terms used. The results of the study obtained decreasing accuracy by almost half in the yes-no model predictions of rain events comparing detail their intensity. Moreover, the highest ACC value happened in Bekasi City and the low in South Jakarta and West Jakarta as a country that has adopted the impact-based forecast (IBF) model, it is very important to examine how extreme weather predictions result. This research shows heavy rainfall prediction still needs to be improved. The prediction of high rainfall intensity is generally overestimated where estimation is high-intensity rain but respondents reported sunny to cloudy. However, verification never happens if heavy rain is predicted and in the location, there is clear weather. However, this study has a weakness in terms of comparison time. Voluntary weather observations made at one time were compared with weather predictions using a 3-hour range. This difference allows for inaccuracies, where for three hours of weather conditions in the tropics (Indonesia), weather changes are very likely to occur.

The previous studies showed that MJO influence increasing and decreasing precipitation over Indonesia (Peatman *et al*., 2014; Vincent and Lane 2016). This study confirmed the increase in rainfall incidence not only in phases 4 and 5 (Hidayat and Kizu, 2010) but also in other phases such as phases 2-3 (Sakya *et al*., 2016). Based on the reports of respondents from voluntary weather observations for the Greater Jakarta area during the 2021 dry season, phases 2 and 3 are phases where there is a lot of rain, namely 30%, and 38%, respectively. The impact of the MJO phase on accuracy can be seen from the stable accuracy of about 70% in the MJO phases 2 and 3 but fluctuates in the small portion of the incident phase. Local influences are very likely to cause a weakening of the convective process (Zhang and Ling, 2017).

5. Conclusion

These research-based volunteer observations collected through social media showed that the accuracy of rain prediction in the Jabotabek region obtained 70.1%, with prediction failures in the event of overestimation. The highest number of correct predictions occurred when the locations experienced clear weather without rains. The number of rain events has an impact on false alarm errors, especially in Depok, East Jakarta, South Jakarta and Bogor. However, the prediction has very good accuracy at predicting rain in West Jakarta which has 21% rain even where the CSI value is higher than in other cities. The detailed predictions can reduce the accuracy from 40.5% compared to 70.1% in the general scheme. During the 4 months of this study, phases 2 and 7 had the largest portion, namely 30% and 38% of the total MJO phase, respectively. The rain that occurred mainly in phase 7 reached 42%. Thereafter, this research confirms that it is not easy to predict rain events in detail at each location and the prediction terms used. The estimation of high rainfall intensity causes overestimates that occur when the locations are sunny to cloudy.

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