FORUM GEOGRAFI
ISSN: 0852-0682 | E-ISSN: 2460-3945
HTTPS://JOURNALS.UMS.AC.ID/INDEX.PHP/FG/

Verification of Weather Predictions Using Voluntary Weather Observations Via WhatsApp and Google Forms During the Dry Season 2021

Giarno*, Munawar, Ervan Ferdiansyah, Fendy Arifianto, Asri Pratiwi, Silvia Yulianti

[1]School of Meteorology Climatology and Geophysics, South Tangerang, 15221, Indonesia

*) Correspondence: giarnostmkg@gmail.com

Citation:

Giarno, G., Munawar, M., Ferdiansyah, E., Arifianto, F., Pratiwi, A., & Yulianti, S. (2022). Verification of Weather Predictions Using Voluntary Weather Observations Via WhatsApp and Google Forms During the Dry Season 2021. Forum Geografi, 36(1).

Article history:
Received: 17 November 2021
Accepted: 22 February 2022
Published: 08 August 2022

Abstract

The weather data that can be obtained through government institutions is very limited, whereas in order to increase the accuracy of weather predictions a homogeneous and dense distribution of data is needed. Due to the limited number of observation data, evaluation can be made using voluntary weather observation data through Google Forms and distributed via the most popular social media app today, namely WhatsApp. However, such observation data need to be corrected for input based on identity and typo, while the results can be used to evaluate the accuracy of weather forecasts. Comparison of observation and prediction data can be made using the dichotomous method of comparison of the presence or absence of rain and the details of the terms used in weather prediction. The test results show that social media has the potential to be used to support voluntary weather data. The form developed is clear enough for respondents to make relatively few mistakes in terms of its main content. Moreover, the mistakes that are often made by respondents include ones related to filling in their ID, and typing sub-districts, which requires manual correction. Based on the results of voluntary observations spread across almost all the provinces of Indonesia, with most incoming data originating from the provinces of Central Java and East Java. With reference to the evaluation results of 4 months of testing, weather variations and their predictions can be identified with an accurate distribution, and with an average accuracy of 0.79. Differences in the methods used in verification may affect accuracy.

Keywords: Volunteer, Weather, Indonesia, STMKG, Evaluation.

1. Introduction

The network of rainfall gauge stations in most watersheds, especially for analysis, (Awadallah, 2012) is far from sufficient, based on the standards recommended by the World Meteorological Organization (WMO) (WMO, 1994). The institution recommends a certain density of rain gauge stations based on the type of equipment, topography, location and population density. Based on these guidelines, in small mountainous areas with irregular rainfall, one station per 25 km^2 is recommended, a number that increases in urban areas, where the advised density is one station per 10–20 km^2. Although around the world there are many weather observation vehicles (The Maritime Executive, 2020), there are still an insufficient number, especially in urban areas.

Recognizing the lack of weather observation data, for observations at sea WMO recommends a weather monitoring program on ships. At present, volunteer weather observations on board ships can be found on almost 1,000 ships worldwide (NOAA, 2021). While for such observations on land, WMO does not officially give a mandate, considering the significant impact of weather felt by most people, the National Weather Service (NWS) encourages voluntary weather observations, especially of rain and snow, through the community collaborative rain program, hail and snow network (CoCoRaHS). This program educates independent low-cost weather observations, which are very useful in natural resource applications, education and research (Cocorahs, 2021; Spaccio *et al.,* 2021).

Atmospheric conditions in the Indonesian maritime continent (BMI) are influenced by global weather phenomena (Neale & Sligo, 2003; D'Arrigo & Wilson, 2008; Hidayat & Kizu, 2010; As-syakur, 2010). Moreover, the Indonesian territory consisting of thousands of islands, hundreds of mountains, and many seas and straits, makes the weather in the country very complex (Giarno *et al.*, 2012; Lee, 2015; Martono & Wardoyo, 2017). The dynamics of weather in Indonesia have an impact on the accuracy of remote sensing observations. Comparing satellite rainfall estimates occasionally a high correlation (Gunawan, 2008; Mamenun *et al.*, 2014; Rahmawati & Lubczynski, 2018, Fatkhuroyan *et al.*, 2018), while on the other hand, evaluation of extensive areas can lead to different conclusions (Prasetia *et al.*, 2013; Giarno *et al.*, 2018; Giarno *et al.*, 2019).

Besides affecting the accuracy of satellites and radar, the dynamics of the weather in Indonesia is also difficult to predict. Comparing several weather models, it has been found that the accuracy of weather predictions varies over the country (Ginting & Putuhena, 2014; Kiki & Alam, 2019). Data assimilation and adaptation of appropriate model parameterization are needed to improve model performance (Burrahman *et al.*, 2018). As a country that experiences many hydrometeorological disasters (Murdiyanto & Gutomo, 2015; Kompas, 2019), attention needs to be paid to the intensity of rainfall in the evaluation of predictions. Based on the evaluation of very heavy rainfall predictions in Indonesia, it is shown that accuracy still needs to be improved (Gustari *et al*., 2012), including in terms of early warning of extreme weather (Hutagalung *et al.*, 2015). In addition to model selection, evaluation is also constrained by the very limited number of raingauges in the observational network managed by BMKG (Didihariyono & Giarno, 2021), so the level of weather observation data in Indonesia needs to be increased. The current Covid-19 pandemic has changed human behavior, with daily activities being conducted remotely, including on one of the most popular social media applications in the world, WA or WhatsApp (Orbelo, 2021), which is very popular with the younger generation (Jisha & Jebakumar, 2014). The purpose of this study is to verify weather forecasting in the Jabotabek area using voluntary weather observations.

2. Research Method

2.1. Data and location

Respondents in this study were 523 STMKG cadets spread throughout Indonesia, consisting of 34 provinces whose distribution can be seen in Figure 1. These islands are spread around the equator which has a tropical climate. The most populous island is the island of Java, where more than half (65%) of Indonesia's population. Meanwhile, the 5 major islands in this region include Java, Sumatra, Kalimantan, Sulawesi, and Irian Jaya. The distribution of respondents in this study is indeed mostly concentrated in densely populated places, namely urban areas in Java and outside Java.

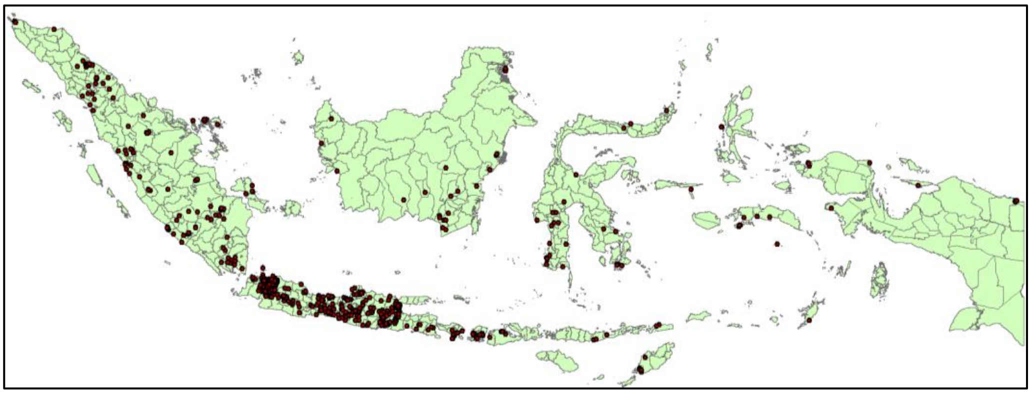

Figure 1. Respondents position of voluntary weather observation.

2.2. Forms for Voluntary Weather Observation

The current Covid-19 pandemic has changed human behavior, with daily activities conducted remotely, including on one of the most popular social media applications in the world, WA or WhatsApp (Orbelo, 2021), which is very popular among the younger generation (Jisha & Jebakumar, 2014). Used together with Google Forms, the app has the potential to serve the needs of weather observation data collection.

The form for this study was developed based on the WMO standard synoptic weather observation procedure (WMO, 2018). In addition to observations that record the accumulation of rainfall, others also indicate the present and past occurrence of rain when reporting weather conditions (WMO, 2019). In this regulation to rain observation, it is also possible to observe wind speed manually. If the anemometer equipment is normal, then the wind speed data can be obtained from what is listed on the tool, but WMO also provides a wind data column using the Beaufort scale in the case of the anemometer being damaged or absent (BMG, 2006). In line with this, the procedure for manual weather observations on two weather parameters that greatly influence hydrometeorological disasters is also recognized by WMO. To minimize errors, the form also includes pictures for easy identification, as shown in Figure 2. This survey technique also "forces" respondents to become accustomed to paying attention to BMKG weather predictions, as a form of education for them to always pay attention to weather predictions published by BMKG.

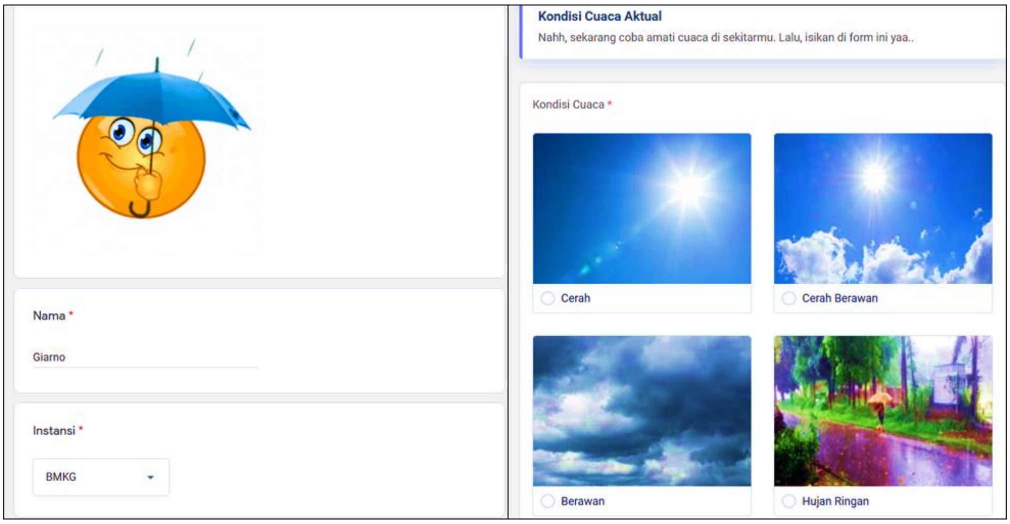

Figure 2. Voluntary weather observation form (https://laporcuaca.stmkgweathercare.com/public/).

2.3. Checking Respondent's Error and Variability Weather Condition

The location of the respondent entered in the form is at the sub-district level and as the name implies, the name of this sub-district is entered manually. This allows for typos so that they must be checked for correctness and consistency. Meanwhile, regarding the weather data, checking cannot be done because there is no comparable data, so it is assumed that the respondents are correct and honest. The data obtained from google form are simple manual observations, only weather conditions are reported, namely no rain represented by sunny, sunny cloudy, cloudy and rainy weather represented by light to heavy rain. The calculation of accuracy is carried out using the dichotomous method with the help of a contingency table as can be seen in Table 1. The indicator used based on the contingency table is the ACC value or accuracy which describes the suitability between predictions and accuracy (Jolliffe and Stephenson, 2003).

Table 1. Contingency evaluation terms.

	Observation		
Prediction	Event	Rain	No Rain
	Rain	Hits	False Alarm
	No Rain	Miss	Correct Negative

where

Hits refers prediction and observation states rain.

False alarm refers rain in prediction, but observasi not rain.

Miss refers not rain in prediction, but observation rain.

Correct Negative refers prediction and observation states not rain.

Indicator in this research:

Accuracy (ACC) is the value used for the question of how correct the forecast is. The value ranges from 0 to 1. This indicator will be useful if the verified event is not too extreme often or, conversely, occurs too infrequently.

3. Results and Discussion

3.1. Types of Respondent Error

There are 2 types of respondent errors in filling out the form, namely errors by the cadets in filling in the cadet registration number (NIT) and errors in filling in the name of the sub-district

(Dist_Name). Each of these errors is further divided into 2 types, namely typos and errors adding spaces, there are excessive or insufficient spaces. The number of NIT spaces occurred 38 times, consisting of 10 excess and 28 less spaces, while NIT typos occurred 13 times. On the other hand, the number of spaces Dist_Name occurs 590 times consisting of 502 times excess and 88 times less, while the Dist_Name typo occurs 91 times which is partially illustrated in Figure 2.

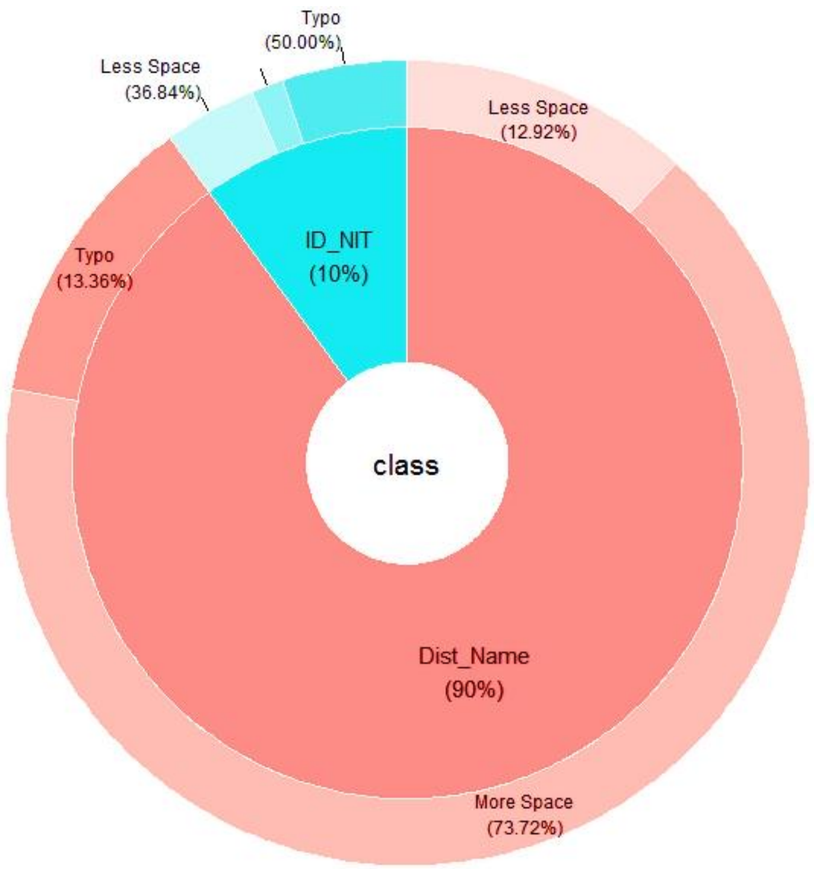

Figure 3. The portion of respondents' errors.

Based on Figure 3, it can be seen that respondents made many mistakes when filling in the name of the sub-district or Dist_Name with a portion reaching 90%. A deeper analysis shows that the errors in filling in the sub-districts are generally excess spaces which reach 73.72%, while typos and lack of letters in writing sub-districts are almost the same. On the other hand, when filling in the identity of the cadets, the number of typos and spacing errors was almost the same, where typos reached 50%, while the second position was the incomplete NIT. Errors in filling out through social media platforms are inevitable (Fattah, 2015; Barhoumi, 2015; Mbukusa, 2018), but these errors are still quite relevant considering the data that can be collected in this program reaches more than 7856 observations.

Based on the distribution of respondents, Java Island occupies the top position in filling out manual weather observation data. Respondents in East Java and Central Java have observations more than 1000 times during June to September 2021. Furthermore, the number of observations between 300 and 1000 times was carried out by respondents in the provinces of South Kalimantan, West Java, DKI Jakarta, South Sumatra and North Sumatra. The distribution of these respondents is very unequal when compared to the number of observations in the provinces of Papua, West Sulawesi, Gorontalo, Central Sulawesi, North Kalimantan, East Kalimantan, and Aceh which are 7, 11, 23, 4, 9, 19 and 33, respectively. in the Bangka Belitung Islands, there are no observations at all as can be seen in Figure 4.

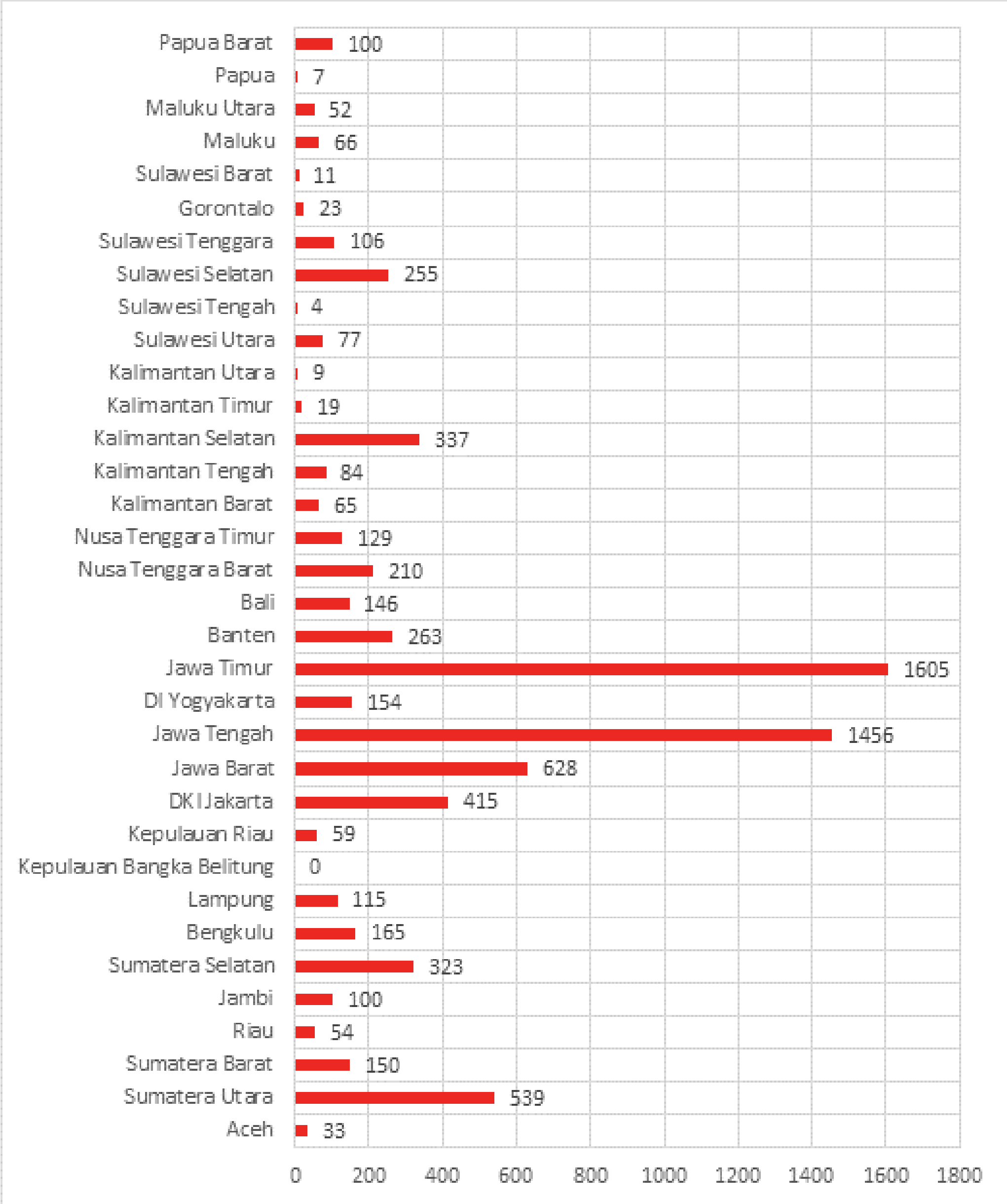

Figure 4. Number of observations in each province.

The very small amount of data can affect the identification of weather changes in an area where this lack of data will also affect the synergy of the combination of surface data and satellite data (Balsamo *et al*., 2018). The combination of many sources of observational data is very important in the development of weather and climate modeling. The combination of a multiparametric platform network will offer opportunities for new and improved in situ observations (Centurioni *et al.*, 2019). Advances in sensor technology (e.g., low-cost wave sensors), wide-ranging communication technologies, evolving cyber infrastructure, and information systems and data science have the potential to increase the coverage, efficiency, integration, and sustainability of sea level observation systems, need to be explored so that more and more weather data.

3.2. Rain and Forecast Distribution

From June to September, southern Indonesia is experiencing a dry season with a peak in July-August (Avia, 2019). Based on the respondent's observations, it seems very clear that along the island of Java to East Nusa Tenggara the weather is sunny to partly cloudy, which indicates the weather is relatively sunny as can be seen in Figure 5(a).

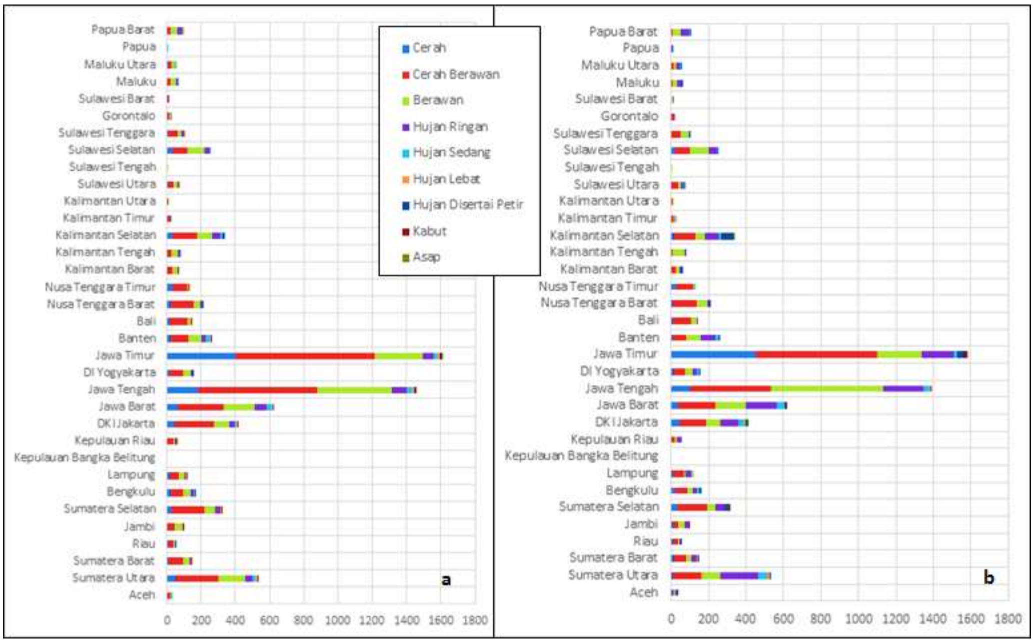

Figure 5. Distribution of observed (a) and predicted (b) weather in each province.

However, the dry season does not mean there is no rain. As shown in Figure 5(a), rain can still fall in many places throughout Indonesia. This proved that Indonesia has indeed convection activity throughout the year (Bayong, 2004). Moreover, the days with a lot of clouds are found in Indonesia, especially in Central and Northern Indonesia, such as the provinces of West Papua, North Sumatra, Papua, South Sulawesi, South Kalimantan and several other provinces with a portion of cloudy to almost 50% rain. Compared to the weather observations, BMKG prediction has a slight difference where the portion of rain prediction is quite large as can be seen in Figure 5(b). The large number of predictions in the dry season has the potential to cause overestimates when compared with the results of observations.

3.3. Accuracy of Rain Forecast

Accuracy scores were calculated using 2 ways, firstly comparing rain or not rain on observations and predictions that respondents record on the form. The second uses a more detailed comparison, namely the similarity of terms. Due to the unequal number of respondents, the accuracy analysis differs according to the amount of data entered in each province, namely >1000, 300-1000, 100-300 and <100 observations. The results of the calculation using the first method show that the prediction accuracy in each province in Indonesia is very diverse. Although the average ACC value is 0.79, there are areas with very accurate weather predictions with an accuracy value or ACC reaching 1 to quite accurate with an ACC value of 0.57 as shown in Table 2.

Rain prediction accuracy in areas with more than 1000 observations, namely Central Java and East Java, the accuracy values are 0.86 and 0.85. Incidentally, the position of the two provinces is close together, namely in the middle to the east of Java Island which tends to be drier than the west of the island. Meanwhile, for areas with data between 300 and 1000, the accuracy varies more from 0.57 in North Sumatra in 0.78 in South Sumatra. It seems that areas very close to the equator or in the northern part of the equator have lower accuracy such as North Sumatra. While the number of observation data is 100–300, the areas located in the southernmost position of Indonesia, namely West Nusa Tenggara and East Nusa Tenggara have much higher accuracy reaching more than 0.92 compared to other regions. Then the evaluation of data that is less than 100 then found areas with perfect accuracy 1, namely in East Kalimantan, North Kalimantan and Central Sulawesi.

Table 2. Prediction accuracy is based on rain existing and its term to number of Obs (observations).

No	Province's name	Obs.	Verify based on rain existing					Verify based on term pred.		
			HIT	FA	MISS	CN	ACC	CORECT	FALSE	ACC
1	Aceh	33	3	8	2	20	0.7	8	25	0.24
2	Sumatera Utara	539	57	209	23	250	0.57	153	386	0.28
3	Sumatera Barat	150	13	28	5	104	0.78	77	73	0.51
4	Riau	54	3	7	4	40	0.8	24	30	0.44
5	Jambi	100	5	17	1	77	0.82	48	52	0.48
6	Sumatera Selatan	323	19	55	17	232	0.78	171	152	0.53
7	Bengkulu	165	19	26	4	116	0.82	100	65	0.61
8	Lampung	115	9	27	5	74	0.72	56	59	0.49
9	Kep. Bangka Belitung	0	0	0	0	0	X	0	0	X
10	Kepulauan Riau	59	9	15	2	33	0.71	26	33	0.44
11	DKI Jakarta	415	38	113	11	253	0.7	155	260	0.37
12	Jawa Barat	628	83	133	29	383	0.74	331	297	0.53
13	Jawa Tengah	1456	94	162	46	1154	0.86	756	700	0.52
14	DI Yogyakarta	154	9	29	5	111	0.78	86	68	0.56
15	Jawa Timur	1605	43	187	57	1318	0.85	864	741	0.54
16	Banten	263	47	56	14	146	0.73	99	164	0.38
17	Bali	146	1	4	5	136	0.94	87	59	0.6
18	Nusa Tenggara Barat	210	5	9	7	189	0.92	128	82	0.61
19	Nusa Tenggara Timur	129	0	3	1	125	0.97	93	36	0.72
20	Kalimantan Barat	65	7	9	2	47	0.83	27	38	0.42
21	Kalimantan Tengah	84	10	5	9	60	0.83	52	32	0.62
22	Kalimantan Selatan	337	59	92	17	169	0.68	117	220	0.35
23	Kalimantan Timur	19	1	0	0	18	1	16	3	0.84
24	Kalimantan Utara	9	0	0	0	9	1	6	3	0.67
25	Sulawesi Utara	77	10	18	6	43	0.69	27	50	0.35
26	Sulawesi Tengah	4	0	0	0	4	1	2	2	0.5
27	Sulawesi Selatan	255	17	36	18	184	0.79	152	103	0.6
28	Sulawesi Tenggara	106	6	7	18	75	0.76	48	58	0.45
29	Gorontalo	23	3	5	1	14	0.74	13	10	0.57
30	Sulawesi Barat	11	1	2	0	8	0.82	5	6	0.45
31	Maluku	66	11	12	2	41	0.79	27	39	0.41
32	Maluku Utara	52	7	17	2	26	0.63	15	37	0.29
33	Papua	7	2	1	0	4	0.86	3	4	0.43
34	Papua Barat	100	26	25	13	36	0.62	48	52	0.48

Forecaster 's BMKG predicts the weather of a place based on running models and their experience. Based on the results of the evaluation carried out in this research, it shows that the forecaster's decision is better than the weather model used. Comparing weather model's predictions and the BMKG forecaster's decisions, based on this work showed the BMKG forecasters decisions are still better in accuracy than 4 models (Kiki, and Alam, 2019). The highest accuracy of model predictions is only 0.75 in North Maluku and has an average of about 0.4. Moreover, based on this evidence, it means that BMKG forecasters may add knowledge and experience so that their predictions are better than the models used. Even, comparing the accuracy of radar and satellites rainfall estimates (Giarno *et al.,* 2019; Giarno *et al*., 2020), the BMKG prediction value is quite high. However, the accuracy of weather predictions, especially extreme conditions, needs to be improved in an effort to build an early warning system (Ginting and Putuhena, 2014). Selection of the appropriate weather model (Kiki and Alam, 2019), parameterization schemes that are suitable for maritime continents, and assimilation of data can improve the accuracy of weather predictions (Burrahman *et al*., 2018).

Decreasing accuracy happens when using the second verification scheme or detail verification. Based on each term of prediction and observations as shown in Table 2 (right), accuracy became 0.49 with most diverse variations. The highest ACC value of this method is 0.84, while the lowest is 0.24. Moreover, weather predictions in areas with more than 1000 observations, Central Java and East Java have accurate values of only 0.52 and 0.54 respectively. Meanwhile, for areas with data between 300 and 1000 have almost same accuracy where the lowest value is 0.28 in North Sumatra and the highest is 0.53 in South Sumatra and West Java, which located in the southern part of the equator. Then, for location which 100 and 300 data have the highest accuracy values in West Nusa Tenggara and East Nusa Tenggara, namely 0.61 and 0.72. This value same with accuracy of Bengkulu, Bali, and South Sulawesi. Meanwhile, for location that has less than 100 data such as Central Sulawesi has ACC value 0.50, however in East Kalimantan and North Kalimantan has accuracy 0.84 and 0.67 in.

Based on the comparison of the two verification schemes, it is clear that the terms used and compared greatly affect the accuracy value. The more detailed terms used, the more effort is required in obtaining good accuracy. Moreover, detailed describe weather conditions that are increasingly specific to the predicted weather conditions so that forecasters must be very precise in estimating conditions in the location. Then, it is also important to forecaster understanding in the knowlegde of community so that the terms used in weather prediction can be understood. Meanwhile, in terms of verification work, it is also necessary to use a verification method that is easily understood by the public (Didiharyono and Giarno, 2021).

4. Conclusion

Technological advances especially with the popularity of social media have the potential to be used in voluntary weather observations. Users fill out various forms scattered throughout Indonesia which can be used to evaluate variations in the accuracy of weather predictions that are even more precise. The result verification showed that existing rain prediction has better accuracy than detail prediction with an accuracy ratio of 0.79 and 0.49. The number of observations also affects the accuracy where Central Java and East Java have more than 1000 observations, the accuracy values are 0.86 and 0.85. However, for smaller quantities the accuracy varies with smaller values. Meanwhile, by using the detailed terms the accuracy drops to 0.49 with variations in accuracy from 0.84 to 0.24. Rainfall predictions in monsoon areas are generally higher than in equatorial areas where rainfall patterns are more varied.

Acknowledgements

The authors express their deep gratitude for the assistance of STMKG's cadets (School of Meteorology Climatology and Geophysics) who were willing to fill out the form. We are highly grateful to the Head of STMKG, Dr. Nyoman, for supporting the necessary administration for the STMKG Weather Care project.

References

As-syakur, A.R. (2010). Pola spasial pengaruh kejadian la nina terhadap curah hujan di indonesia tahun 1998/1999; observasi menggunakan data TRMM multisatellite precipitation analysis (TMPA) 3B43. Prosiding Pertemuan Ilmiah Tahunan MAPIN XVII Bandung.

Avia, L. Q. (2019). Change in rainfall per-decades over Java Island, Indonesia, IOP Conf. Series: Earth and Environmental Science, 374, 012037.

Awadallah, A.G. (2012). Selecting Optimum Locations of Rainfall Stations Using Kriging and Entropy. International Journal of Civil & Environmental Engineering, 12(1), 36-41.

Balsamo, G., Agusti-Panareda, A., Albergel, C., Arduini, G., Beljaars, A., Bidlot, J., Blyth, E., Bousserez, N., Boussetta, S., Brown, A., Buizza, R., Buontempo, C., Chevallier, F., Choulga, M., Cloke, H., Cronin, M.F., Dahoui, M., De Rosnay, P., Dirmeyer, P.A., Drusch, M., Dutra, E., Ek, M.B., Gentine, P., Hewitt, H., Keeley, S.P.E., Kerr, Y., Kumar, S., Lupu, C., Mahfouf, J.-F., McNorton, J., Mecklenburg, S., Mogensen, K., Muñoz-Sabater, J., Orth, R., Rabier, F., Reichle, R., Ruston, B., Pappenberger, F., Sandu, I., Seneviratne, S.I., Tietsche, S., Trigo, I.F., Uijlenhoet, R., Wedi, N., Woolway, R.I. and Zeng, X. (2018). Satellite and In Situ Observations for Advancing Global Earth Surface Modelling: A Review. Remote Sens. 10(2038). https://doi.org/10.3390/rs10122038.

Barhoumi, C. (2015). The Effectiveness of WhatsApp Mobile LearningActivities Guided by Activity Theory on Students' Knowledge Management. Contemporary Educational Technology, 6(3), 221-238.

Bayong, T.H.K. (2004). Klimatologi. Bandung. Penerbit ITB.

BMG. 2006. Tata cara tetap pengamatan, penyandian, pelaporan dan pengarsipan data meteorologi permukaan, Perka KBMG No: SK.38/KT.104/KB/BMG-06, Jakarta

Burrahman, H., Silitonga, A. K., Batubara, I. H., Fadlan, A. (2018). Pengaruh asimilasi model cuaca weather research forecast (WRF) dengan data radiasi satelit terhadap estimasi curah hujan (Studi Kasus Stasiun Meteorologi Pattimura–Ambon Tanggal 24-25 Juli 2013). Prosiding SNFA (Seminar Nasional Fisika dan Aplikasinya)

Centurioni, L.R., Turton, J., Lumpkin, R., Braasch, L., Brassington, G., Chao, Y., Charpentier, E., Chen, Z., Corlett, G., Dohan, K., Donlon, C., Gallage, C., Hormann, V., Ignatov, A., Ingleby, B., Jensen, R., Kelly-Gerreyn, B.A., Koszalka, I.M., Lin, X., Lindstrom, E., Maximenko, N., Merchant, C.J., Minnett, P., O'Carroll, A., Paluszkiewicz, T., Poli, P., Poulain, P.M., Reverdin, G., Sun, X., Swail, V., Thurston, S., Wu, L., Yu, L., Wang, B. and Zhang, D. (2019). Global in situ Observations of Essential Climate and Ocean Variables at the Air–Sea Interface. Front. Mar. Sci. 6(419) doi: 10.3389/fmars.2019.00419.

Cocorahs. (2021). CoCoRaHS's 20th Anniversary. Available Online at: https://cocorahs.org/Content.aspx?page=20years [October 12, 2021].

Didiharyono and Giarno. (2021). Application of the Simple Verification Method to Estimate the Weather at Makassar Maritime Station, Indonesia. Walailak Journal of Science and Technology (WJST), 18(18), https://doi.org/10.48048/wjst.2021.9542.

D'Arrigo, R. and Wilson, R. (2008). El Ni˜no and Indian Ocean influences on Indonesian drought: implications for forecasting rainfall and crop productivity. International Journal of Climatology. 28, 611-616.

Fatkhuroyan, Wati, T., Sukmana, A., and Kurniawan, R. (2018). Validation of Satellite Daily Rainfall Estimates Over Indonesia. Forum Geografi, 32(2), 170-180.

Fattah, S. F. E. A. (2015). The Effectiveness of Using WhatsApp Messenger as One of Mobile Learning Techniques to Develop Students' Writing Skills. Journal of Education and Practice. 6(32), 115-127.

Giarno, Zadrach L. D., and Mustofa, M. A. (2012). Kajian awal musim hujan and awal musim kemarau di Indonesia. Jurnal Meteorologi and Geofisika. 1, 1–8.

Giarno, Hadi, M. P., Suprayogi, S., and Murti, S. H. (2018). Distribution of accuracy of TRMM daily rainfall in Makassar Strait. Forum Geografi, 32(1), 38-52.

Giarno, Hadi, M. P., Suprayogi, S., Murti, S. H. (2019). Daily quantitative precipitation estimates use weather radar reflectivity in South Sulawesi. IOP Conference Series: Earth and Environmental Science 256 (1), 012042

Giarno, Hadi, M. P., Suprayogi, S., and Murti, S. H. (2020). Impact of rainfall intensity, monsoon and MJO to rainfall merging in the Indonesian maritime continent. J. Earth. Syst. Sci/ 129(164) https://doi.org/10.1007/s12040-020-01427-8.

Ginting, S., and Putuhena, W.M. (2014). Sistem peringatan dini banjir Jakarta. Jurnal Sumber Daya Air, 10(1), 71-84

Gunawan, D. (2008). Perbandingan curah hujan bulanan dari data pengamatan permukaan, satelit TRMM and model permukaan NOAH. Jurnal Meteorologi and Geofisika. 9(1), 1–10.

Gustari, I., Hadi, T. W., dan Hadi, S., Renggono, F. (2012). Akurasi Prediksi Curah Hujan Harian Operasional di Jabodetabek: Perbandingan dengan Model WRF. Jurnal Meteorologi dan Geofisika, 13(2), 119-130.

Hidayat, R., and Kizu, S. (2010). Influence of the Madden–Julian Oscillation on Indonesian rainfall variability in austral summer. International Journal of Climatology. 30, 1816-1825.

Hutagalung, F., Yulianur, A., and Meilianda, E. (2015). Tingkat akurasi sms dan efektivitas SOP peringatan dini hujan ekstrim di Medan (Studi Kasus BBMKG Wilayah I dan Stasiun Meteorologi Klas I Kualanamu). Jurnal Ilmu Kebencanaan, 2(4), 12-31

Jisha, K. and Jebakumar. (2014). Whatsapp: A trend setter in mobile communication among Chennai youth. IOSR Journal of Humanities and Social Science (IOSR-JHSS). 19(9), 1-6.

Jolliffe, I.T. and Stephenson, D.B. (2003). Forecast verification: A practitioner's guide in atmospheric science, Jhon Wiley & Sons.

Kiki and Alam, F. (2019). Verifikasi parameter presipitasi akumulasi 24 jam pada model cuaca numerik tahun 2017. Buletin BBMKG Wilayah II. 9(2), 1-5.

Kompas. (2019). Data Bencana BNPB pada 2019, 1.538 Kejadian dan 325 Korban Meninggal. Kompas, Available Online at: https://nasional.kompas.com/read/2019/04/30/19322341/data-bencana-bnpb-pada-2019-1538-kejadian-dan-325-korban-meninggal [October 12, 2021].

Lee, H. S. (2015). General Rainfall Patterns in Indonesia and the Potential Impacts of Lokal Seas on Rainfall Intensity. Water. 7, 1750-1768.

Mamenun, Pawitan, H., and Sophaheluwakan, A. (2014). Validasi dan koreksi data satelit TRMM pada tiga pola hujan di Indonesia, Jurnal Meteorologi dan Geofisika, 15(1), 13-23

Martono, M. and Wardoyo, T. (2017). Impacts of El Niño 2015 and the Indian Ocean Dipole 2016 on Rainfall in the Pameungpeuk and Cilacap Regions. Forum Geografi. 31(2), 184–195.

Mbukusa, N. R. (2018). Perceptions of students on the use of WhatsApp in Teaching Methods of English as Second Language at the University of Namibia. Journal of Curriculum and Teaching. 7(2), 112-119.

Murdiyanto and Gutomo, T. (2015). Bencana Alam Banjir dan Tanah Longsor dan Upaya Masyarakat dalam Penanggulangan. Jurnal PKS, 14(4), 437-452.

Neale, R. and Sligo, J. (2003). The Maritime Continent and Its Role in the Global Climate: A GCM Study. Journal of Climate. 16, 834-848.

NOAA (2021). United States Voluntary Observing Ship Program. Available Online at: https://www.vos.noaa.gov/ [October 12, 2021].

Orbelo. (2021). Most Popular Social Media Platforms in 2021, Orbelo, Available Online at: https://id.oberlo.com/statistics/most-popular-social-media-platforms. [October 12, 2021].

Prasetia, R., As-syakur, A. R., and Osawa, T. (2013). Validation of TRMM Precipitation Radar satellite data over Indonesian region. Theory Applied Climatology, 112, 575–587.

Rahmawati, N., Lubczynski, M.W., (2018). Validation of satellite daily rainfall estimates in complex terrain of Bali Island, Indonesia. Theor Appl Climatol 134, 513–532.

Spaccio, J., DeGaetano, A. and Doesken, N. (2021). COVID-19 stay-at-home orders result in a decrease in the number of missing daily precipitation observations. Bulletin of the American Meteorological Society. 102, 207–209.

The Maritime Executive. (2020). COVID-19 Impacting Weather Forecasts. Available Online at: https://www.maritime-executive.com/article/covid-19-impacting-weather-forecasts [October 12, 2021].

WMO. (1994). Guide to hydrological practice: Data acquisition and processing analysis and forecasting and other applications. Geneva, WMO-No.168.

WMO. (2018). Guide to Meteorological Instruments and Methods of Observation. WMO-No.8 Volume I – Measurement of Meteorological Variables, WMO, Geneva.

WMO. (2019). Manual on Codes International Codes Volume I.1. WMO-No. 306 Annex II to the WMO Technical Regulations, WMO, Geneva