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Accuracy of cumulonimbus cloud prediction using Rapidly Developing Cumulus Area (RDCA) products at Pattimura Ambon airport

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सार – कपासी वर्षी (सीबी) बादलों के कारण होने वाली प्रचंड मौसम घटनाओं का विमानन क्षेत्र से गहरा संबंध है, जो इंडोनेशिया में परिवहन का मुख्य साधन है। इस प्रकार, उड़ान सुरक्षा को सहायता देने और इसके कारण होने वाले प्रभाव को कम करने के लिए सीबी अनुमानों के बारे में जानकारी के वितरण को अनुकूलित करने की आवश्यकता है। हिमावारी उपग्रह से आरडीसीए उत्पाद कपासी बादलों के अनुमान के लिए एक समाधान हो सकता है जिनमें अगले 1 घंटे के भीतर सीबी बनने की क्षमता है। आरडीसीए की अनुमान कितनी सटीक है, इसे अंबोन पट्टीमुरा हवाईअड्डा क्षेत्र में इसके अनुप्रयोग में लागू किया जाना महत्वपूर्ण माना जाता है। यह अध्ययन मौसम रेडार डेटा और सतह प्रेक्षणों का उपयोग करके द्विभाजित सत्यापन से श्रेणीबद्ध अंकों के स्थानिक और सांख्यिकीय विश्लेषण पर केंद्रित है, जिन्हें कई प्राचलों का उपयोग करके सत्यापित भी किया गया। जुलाई और दिसंबर 2021 में विश्लेषण के आधार पर, सतह प्रेक्षण डेटा के साथ संरेखित मौसम रेडार का उपयोग करके आरडीसीए सत्यापन परिणाम बताते हैं कि आरडीसीए के पास अगले 10-60 मिनट में सीबी की अनुमान लगाने के उच्च सटीकता मान हैं। इस बीच, कई प्राचलों के साथ अनुसंधान के परिणामों में सटीकता का एक कुशल स्तर होता है, हालांकि कुछ मामलों में, अभी भी काफी गलत अलार्म और कमियाँ हैं, जो दर्शाता है कि आरडीसीए बिंदु पूरी तरह से अनुमानित नहीं हो सकता। इस शोध के परिणामों से आरडीसीए उत्पादों की सटीकता प्राप्त करने की तकनीकों या तरीकों के विकास में प्रगति हुई है। आरडीसीए के अनुप्रयोग की सटीकता के परिणामों का उपयोग तात्कालिक अनुमान प्रतिफलों के साथ-साथ विमानन में परिचालन परिप्रेक्ष्य से व्यावहारिक उपयोग के आधार के रूप में किया जा सकता है। सत्यापन प्रतिफलों में से सतह डेटा या प्रेक्षणों का उपयोग करने के अलावा, यह शोध उष्णकटिबंधीय क्षेत्रों में खासकर अंबोन में आरडीसीए उत्पादों की सटीकता का आकलन करने का प्रारंभिक कदम है।

ABSTRACT. Extreme weather conditions caused by cumulonimbus (Cb) clouds are closely related to the world of aviation, which is the main mode of transportation in Indonesia. Thus, the delivery of information regarding Cb predictions needs to be optimized to support flight safety and minimize the impact that can be caused. The RDCA product from the Himawari satellite can be a solution for predicting cumulus clouds that have the potential to become Cb within the next 1 hour. How accurate is the prediction of the RDCA, is considered important to be carried out in its application in the Ambon Pattimura airport area. This study focuses on the spatial and statistical analysis of categorical scores from dichotomous verification using weather radar data and surface observations, which were also verified using several parameters. Based on analysis in July and December 2021, RDCA verification results using weather radar aligned with surface observation data show that RDCA has a high accuracy value in predicting Cb in the next 10-60 minutes. Meanwhile, the results of research with several parameters have a proficient level of accuracy, although in certain cases, there are still quite a lot of false alarms and misses, indicating that the RDCA point cannot predict perfectly. The results of this research have led to progress in the development of techniques or ways to obtain the accuracy of RDCA products. The results of the accuracy of the application of RDCA can be used as a basis for nowcasting considerations as well as practical use from an operational perspective in aviation. In addition to using surface data or observations as one of the verification considerations, this paper is a initial step in assessing the accuracy of RDCA products in the tropics, especially in Ambon.

Key words – Cumulonimbus, RDCA, Radar, Contingency analysis.

1. Introduction

As an archipelago country, Indonesia needs suitable transportation to get from one island to the other. As a result, during the past ten years, air travel has emerged as Indonesia's greatest method of linking all its provinces. Since the pandemic, the number of international visitors has increased (Kemenlu, 2021) and this form of transportation is crucial to the aviation business and the tourism sector (Dharmawan, 2012; Ricardianto *et al*., 2017). However, the growth of this mode of transportation comes with a number of challenges that might impede the efficient operation of air travel, including flight delays, one of which is the weather (Kulesa, 2003; Dermadi *et al*., 2019). As important components in the aviation sector, weather conditions have a considerable impact on how aircraft land and take off (Dissanayaka *et al*., 2018). Low cloud growth, fog, and heavy rain can suddenly impair horizontal visibility. Notably, lightning and thunderstorms can significantly affect an aircraft's performance which are extremely connected to cumulonimbus (Cb), the most hazardous clouds in aviation. Cb clouds have a significant vertical area, which is about ten kilometers, and are formed by convective processes (WMO, 1956).

Meteorological information for aviation, both related to weather parameter conditions at certain times and weather forecasts at airports, have a substantial aspect in the process of landing and departing aircraft (Schultz *et al*., 2018). To ensure flight safety and mitigate the possible impact, information submission about the potential of Cb growth needs to be optimized. It is the responsibility or a challenge for a forecaster to find a simple method that can be used quickly, precisely, and operationally effectively, and is easily understood by users. Therefore, it is considered that implementing remote sensing technology, such as radar and weather satellites, can solve these issues.

Weather radar has a significant role in generating early warnings to assist in disaster risk reduction (Rosell *et al*., 2020). When compared to satellites, which have a greater coverage area, weather radar still has limitations, particularly in the observation coverage area (Liu *et al*., 2014). Meanwhile, the Himawari-8 satellite, which is also a remote sensing tool, has good spatial and temporal resolution. The Japan Meteorological Agency (JMA) continually works to maintain and enhance the series of satellites with the goal of providing continuous monitoring of relevant meteorological events in an area (Tan, 2014).

One of the derivative products developed by JMA from the Himawari Satellite, is the Rapidly Developing Cumulus Area (RDCA) product, which can be utilized specifically in serving flight meteorological information (JMA, 2018). The RDCA product is used to determine the location of cumulus clouds that have the potential to become Cb, with a coverage area of 10 km^2, within the next 1 hour (Sumida *et al*., 2016; Suzue, 2016). Cb clouds can be predicted using the outputs of the spatial analysis between the RDCA products and radar data (Harjupa *et al*., 2022). Research on the RDCA's accuracy and reliability in predicting Cb clouds is considered crucial because it is for seen that it will become a useful instrument used by all weather forecasters.

This study will examine how accurate the RDCA product is in predicting the occurrence of Cb in Ambon airport area. The data used as verification is weather radar data where the reflectivity value is more than or equal to 35 dBZ, as well as surface observation data, especially weather parameters such as cloud types (Cb), thunderstorm (TS), and lightning from Pattimura Ambon Meteorological Station.

The objective of this study is to acquire categorical scores from dichotomous verification, particularly the accuracy of RDCA implementation in the Ambon Pattimura airport region, and to provide research output in the form of a map to make it more informative.

This map can serve as a starting point for nowcasting analysis, namely its usefulness for aircraft operations. In specifically for aviation meteorology, this research will enhance RDCA products to make them more operationally valuable in the future. Knowing in advance how accurate RDCA products are when applied to the Pattimura Ambon airport region and then spatially presenting them in a new product in the form of a map are various methods to accomplish this.

2. Data and methodology

2.1. *Study area and data*

This study located in a circle with a radius of 30 nautical miles, or 55.56 kilometers, from the "AMN" VOR's focal point, with the coordinates of 3° 36' 53.71" S and 128° 11' 09.82" E, this area is called Ambon Control Zone (AMBON CTR) (AIP, 2021; Indoavis, 2021) and Pattimura Meteorological Station with geographic coordinates 3° 42' S 128° 05' E as shown in Fig. 1.

The research period sample is July 2021 and December 2021, when Cb cloud events are detected by

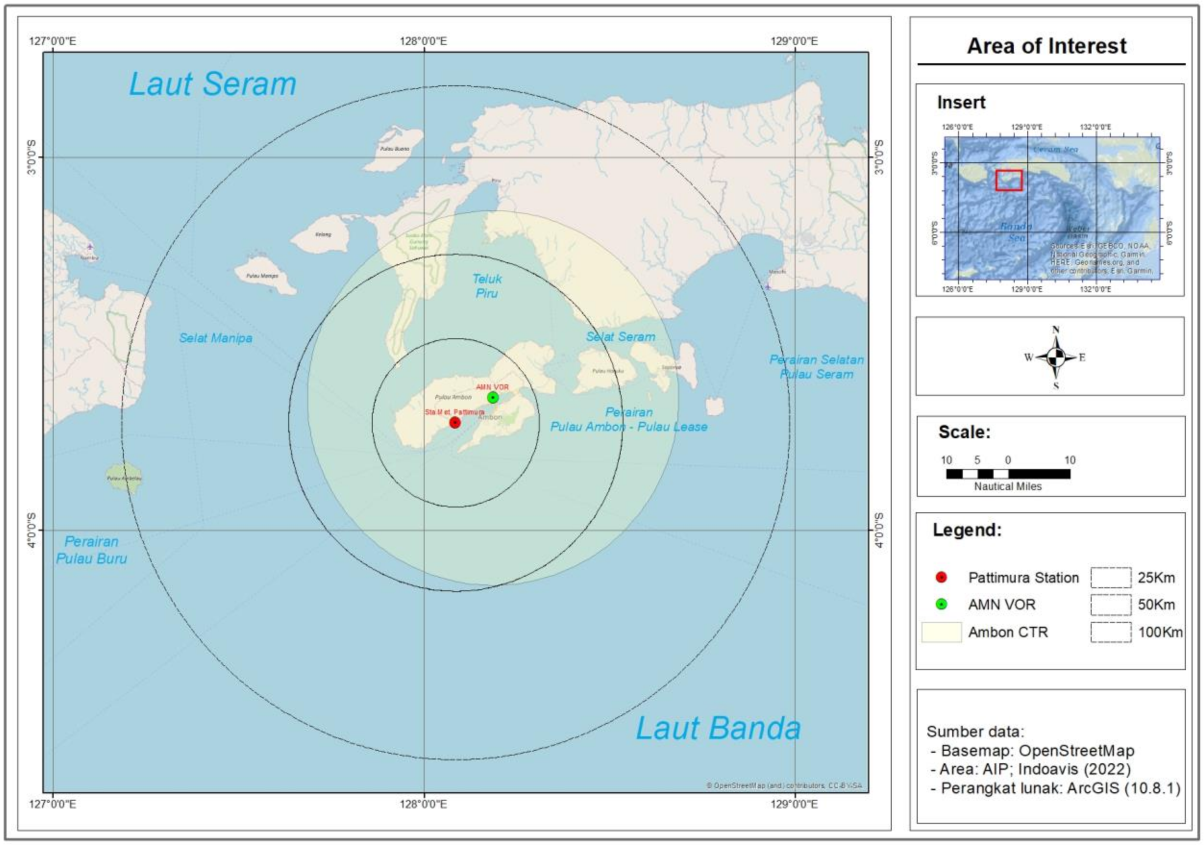

Fig. 1. Area of interest

weather radar. This period was chosen as the initial basis for the research sample, because July is the month where the peak of the rainy season is and December is the month of transition (rainy to dry season) in the Ambon Island region.

RDCA data was obtained from the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) with a 10-minutes temporal resolution and a spatial resolution of 0.02° × 0.02° in the form of a spatial map that displays the potential for the formation of Cb clouds in coordinate point, to analyze 50 Cb cloud events, 300 data RDCA in text format (*.txt) were applied.

Radar data is downloaded in image file format for storing raster graphics (*.tif), the MAX product is used because it can represent the distribution of cloud types so that it can be used for weather analysis and forecasts within the next 1-2 hours (Ali *et al*., 2019; Selex, 2013). Weather radar data is used as a reference for verification of cumulonimbus events during observation hours, which achieve a reflectivity value of more than or equal to 35 dBZ. Hourly surface meteorological observation data is used as a verifier, along with factors such cloud types and

TABLE 1

Contingency table schematic

		Observation		
		Yes	No	Forecast
Forecast	Yes	a	b	a+b
	No	c	d	c+d
	TotalObservation	a+c	b+d	a+b+c+d=n

significant weather reports pertaining to the presence of Cb clouds, specifically thunderstorms and lightning.

2.2. *Methodology*

The verification method in this study use of a contingency table with two categories (dichotomy), which displays the probability of predictions and events that are "yes" or "no", as detailed in Table 1, with four distributions, including hits, false alarms, misses and correct negatives (Ebert, 2009; Perdana and Septiadi, 2021).

The contingency table is a two-dimensional table that provides an overview of the joint-sample discrete distribution of a deterministic forecast and categorical observations (Jolliffe and Stephenson, 2012).

The inter-grid approach method is also applied, specifically the comparison of the RDCA-predicted and observed radar areas, where each prediction and analysis data will display the results of verification. This method is intended to determine the quality of the results of RDCA identified for events captures by observations on radar. Spatial analysis of the overlay of these two datasets will be used for verification of RDCA data.

The reflectivity of the MAX product as measured by ground-based operational radar, primarily the weather radar of the Pattimura Meteorological Station, with a value greater than or equal to 35 dBZ on the initiation of Cb cloud growth over a period of 10 to 60 minutes, is the definition of convective initiation used in this study. Cumulus clouds with the potential to develop into precipitation or thunderstorms are identified during this time period. This criteria was chosen because mature Cb clouds develop at a rate that is well correlated with the intensity of rainfall (Roberts and Rutledge, 2003). Also, the threshold of the radar reflectivity factor 35 dBZ, which marks the beginning of convection, can be utilized to anticipate extreme weather by Cb in advance (Gamache and Houze, 1982; Mecikalski and Bedka, 2006; Walker *et al*., 2012).

After evaluating the RDCA's accuracy with the radar, the following step is to check the RDCA data using surface observation data. Cloud type (C) and current weather (WW) codes (WMO, 2019), as well as parameters and passwords connected to cloud Cb, will be sorted as RDCA verifier data. Spatially and temporally, the dichotomous verification analysis using surface observation data was also carried out by considering the division of distance and time, namely distances of 0 to 25 km, 50 km and 100 km from the center point of Pattimura Meteorological Station, the following radius were also selected for uniformity based on the sampling research of the three closest radius displayed on the Vaisala weather radar at the station. This is intended to demonstrate whether the accuracy results change based upon the location in reference to the station. In the meantime, the cloud detection parameters, are utilized to determine the distinction between day and night (Sumida and Suzue, 2017). The time is divided into the day, 22-09 UTC (Universal Time Coordinated), and night, according to the local time in Ambon (10-21 UTC).

Evaluation of the convective initiation nowcasting ability is quantified using the categorical prediction scores as follows:

(*i*) *Proportion correct (PC)*

PC represents how much the predicted event is correct. This category will provide results in the form of an accuracy value, and answer questions about what percentage of the prediction results are correct, whether the RDCA product predicts the occurrence of Cb or not. The value is perfect if the PC has a value of 1 which indicates all RDCA predictions are correct, while a PC value of 0 indicates all predictions are wrong. PC is calculated using the formula in Equation 2.1.

$$\mathrm{PC} = \frac{\mathrm{Hits} + \mathrm{Correct\ Negatives}}{\mathrm{Total}} \qquad (2.1)$$

(*ii*) *Hit rate / probability of detection (POD):*

POD shows the percentage of incidents with a radar reflectivity value of ≥ 35 dBZ which is predicted to be correct. Sensitive to hits, but ignores the category of false alarms, so that in the analysis it is good to use it together with the false alarm ratio. Like PC, POD has a range of values from 0 to 1, with a perfect score of 1. POD is calculated using the formula in Equation 2.2.

$$\mathrm{POD} = \frac{\mathrm{Hits}}{\mathrm{Hits} + \mathrm{Misses}} \qquad (2.2)$$

(*iii*) *False Alarm Ratio (FAR)*

The number of forecasted or predicted events that do not occur is defined by the False Alarm Ratio (FAR), which is based on observations. In statistics, FAR is the probability of a method being wrong in predicting. In this study, FAR is the number of RDCA events that are predicted to occur as Cb clouds but are not present on radars with a reflectivity value of 35 dBZ. Sensitive to false alarms but ignores the missed category. The model is considered perfect if the FAR is 0, which means there are no missed forecasts, while the FAR is bad if it is 1. FAR is calculated using the formula in Equation 2.3.

$$\mathrm{FAR} = \frac{\mathrm{False\ Alarms}}{\mathrm{Hits} + \mathrm{False\ Alarms}} \qquad (2.3)$$

(*iv*) *Frequency bias (B)*

A comparison between actual findings of observations and true forecasts is bias. In other words, ascore indicating the percentage of events predicted to be

TABLE 2

Contingency table for July 2021

		Observation		
		Yes	No	Total Forecast
Forecast	Yes	1085	960	2045
	No	1255	7580	8835
	Total Observation	2340	8540	10880

TABLE 3

Contingency table for July 2021

		Observation		
		Yes	No	Total Forecast
Forecast	Yes	124	514	638
	No	428	9974	10402
	Total Observation	552	10488	11040

Cb clouds compared to RDCA events. In statistics, the bias score has a range of values from 0 to infinity, with a perfect score of 1. In this study, the RDCA verification results are considered overforecast if the bias value is more than 1, and underforecast if the value is less than 1. The frequency bias is calculated using the formula in Equation 2.4.

$$B = \frac{\text{Hits} + \text{False Alarms}}{\text{Hits} + \text{Misses}} \quad (2.4)$$

(*v*) *Threat score (TS) or critical success index (CSI)*

CSI shows how good the forecast is for an event (predictive accuracy) to the observation results. CSI in this study is a score that indicates the percentage of hits compared to predictions, observations, or both, which indicates the presence of Cb clouds. CSI has a range of values from 0 to 1, a value of 0 indicates no skill (in predicting) with a perfect score of 1. CSI does not take into account correct negative events, so it is widely used because of its ability to calculate rare event performance. CSI is calculated using the formula in Equation 2.5.

$$CSI = \frac{\text{Hits}}{\text{Hits} + \text{False Alarms} + \text{Misses}} \quad (2.5)$$

In order to verify RDCA data, surface observation data is combined with significant weather reports that are directly related to the presence of Cb, such as thunderstorms and lightning. The predictive value method (Sobajima, 2012), namely by prioritizing only hits and misses parameters which are considered to have a significant role in the accuracy of predictions (hits) and the tendency of prediction failure (miss). This accuracy method is obtained by dividing the number of hits by the number of hits and passed or misses, which indicates that if a lightning or thunderstorm really occurs and the RDCA is detected, it will be categorized as a hit, and vice versa, it is categorized as a miss.

TABLE 4

Predictive results of verification parameter calculations for July and December 2021

Indicator		Score	
		July	December
Proportion Correct	PC	0.80	0.91
Probability of Detection	POD	0.46	0.22
False Alarm Ratio	FAR	0.47	0.81

3. Results and discussion

3.1. *Radar data verification of the dichotomy of prediction results*

The results of the verification are the number of hits, misses, false alarms, and correct negatives in the form of a contingency table, which is shown in Table 2 for the results of July data processing and Table 3 for the results of data in December 2021. Each of them takes 25 samples of radar data per month for a total sample size of 50 case studies.

During July 2021, out of a total of 10880 RDCA points which are predicted to become Cb, the 'Yes' forecast or positive forecast is 2045 and the 'No' forecast or null forecast is 8835 events. Meanwhile, 'Yes' observations or radar imagery show the presence of Cb clouds totaling 2340 events and 'No' observations or not monitoring the presence of Cb clouds totaling 8540 events. There were 1085 incidents of hits and 960 incidents of false alarms. Meanwhile, there were 1255 incidents of misses and 7580 incidents of correct negatives.

Out of a total of 11040 RDCA points that are expected to develop into Cb during December 2021, 638 events have a prognosis of "Yes", or a positive forecast, and 10402 events have a forecast of "No", or no forecast. In the meantime, there were 10488 events with "No" observations or not monitoring the presence of Cb clouds compared to 552 events with "Yes" observations or radar imaging showing the presence of Cb clouds. There were 124 hit events and 514 false

TABLE 5

The contingency table for July 2021, based on verification using observational data

		Observation		
		Yes	No	Total Forecast
Forecast	Yes	181	131	312
	No	25	407	432
	Total Observation	206	538	744

TABLE 6

The contingency table for December 2021, based on verification using observational data

		Observation		
		Yes	No	Total Forecast
Forecast	Yes	82	204	286
	No	39	419	458
	Total Observation	121	623	744

alarm incidents. There were 428 verified misses compared to 10488 correct negatives.

The prediction score results in convective initiation nowcasting are shown in Table 4. In terms of accuracy or Proportion Correct (PC), during July 2021, the prediction score showed a value of 0.80 which indicates a fairly good result, RDCA products are able to provide correct results for both Cb clouds and those that are not. The Probability of Detection (POD) score is 0.46, indicating that less than 50% of the total Cb cloud events are predicted correctly. The False Alarms Ratio (FAR) score is good if it is close to 0 which means that there were no missed predictions, the 0.47 result obtained indicates that less than half of the events predicted to occur in Cb do not occur within the next 10-60 minutes. The value of frequency bias (B) is considered underforecast with a score of 0.87. The Cb cloud event's Critical Success Index (CSI) score was 0.33, which indicated that the RDCA product was still unable to predict rare events.

The forecast score for the time frame concluding in December 2021 is 0.91, which is extremely good considering it is near to a value of 1. This means that RDCA products can anticipate both Cb clouds and those that aren't accurately. Only a fraction of the total Cb events were accurately predicted, as shown by the POD score of 0.22. With a FAR score of 0.81, it can be shown that more than half of the events that were expected to happen in Cb clouds did not in fact happen within the following 10 to 60 minutes.The result of 1.16 shows that the value of B is overestimated. The Cb event received a CSI score of 0.12 overall.

TABLE 7

Predictive results for calculating the verification parameter for July and December observation data

Indicator		Score	
		July	December
Proportion Correct	PC	0.59	0.67
Probability of Detection	POD	0.91	0.68
False Alarm Ratio	FAR	0.60	0.71
Frequency Bias	B	2.29	2.36
Threat Score	TS/CSI	0.38	0.25

3.2. *RDCA verification results using surface observation data*

Surface observation data is used to confirm RDCA data following radar verification, with the same radius of 0-50 km from the center point. The verification findings are presented in Tables 5&6 for the results of data processing for July and December 2021. Each hourly RDCA point was validated over the course of a month using weather parameter datasets for cloud type (Cb), thunderstorm (TS), and lightning.

The accuracy value of the RDCA product for the Pattimura Meteorological Station in July along with the contingency analysis, shown in Table 7, PC reached 0.59 or 59%, which means that more than half of the prediction results from the RDCA product are correct. The POD value in July, where the estimated hits when compared to the total hits and misses, is very good and close to the value 1, which is 0.91. However, the FAR value is still slightly above 50%, namely 0.60, the bias value is also quite large, reaching 2.29 indicating that the forecast tends to overforecast or overestimate. In this study, the overestimate did not have much effect due to the limitations of the observer, so that the observed Cb clouds could have come from other areas. The skill value indicating the level of confidence in this forecast is 0.38 or 38%.

Whereas in December, the accuracy of the RDCA product in terms of PC was slightly higher, namely 0.67 or 67%, which means that the RDCA product has better accuracy when predicting Cb clouds in transitional

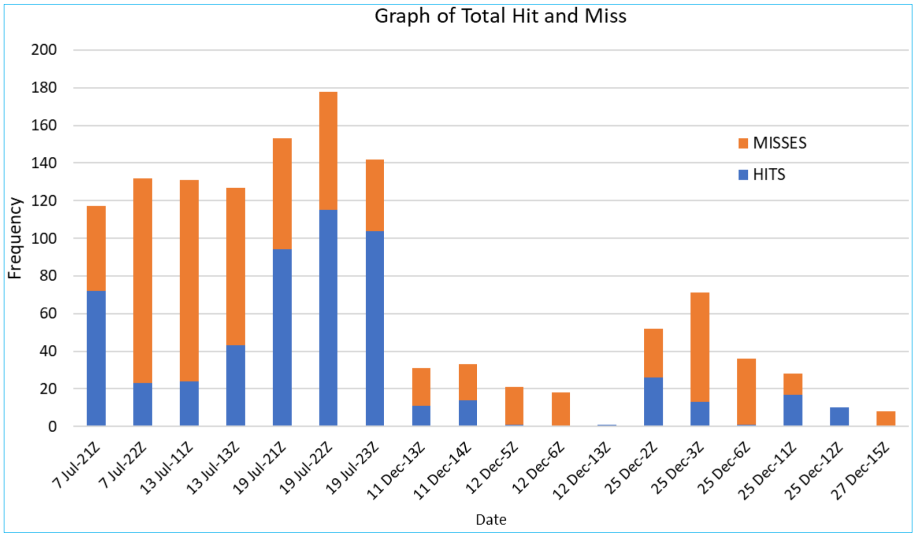

Fig. 2. The number of weather-related hits and misses over study period

TABLE 8

Results of verification of the RDCA dichotomy by surface observation data with several parameters

Month	Parameter	Dichotomy Verification Results								
		Hits	False Alarms	Misses	Correct Negatives	PC	POD	FAR	B	CSI
July	25 km	181	131	25	407	0.79	0.88	0.42	1.51	0.54
	50 km	187	285	19	253	0.59	0.91	0.60	2.29	0.38
	100 km	197	338	9	200	0.53	0.96	0.63	2.60	0.36
	Day (22-09 UTC)	121	105	14	132	0.68	0.90	0.46	1.67	0.50
	Night (10-21UTC)	66	180	5	121	0.50	0.93	0.73	3.46	0.26
December	25 km	59	49	62	574	0.85	0.49	0.45	0.89	0.35
	50 km	82	204	39	419	0.67	0.68	0.71	2.36	0.25
	100 km	96	262	25	361	0.61	0.79	0.73	2.96	0.25
	Day (22-09 UTC)	48	91	25	208	0.69	0.66	0.65	1.90	0.29
	Night (10-21UTC)	34	113	14	211	0.66	0.71	0.77	3.06	0.21

months compared to peak season. rain, accompanied by a POD value of 0.68. However, the FAR value is 0.71 and the bias obtained is still quite large, reaching 2.36 (more than 1) which also tends to be overestimated. The skill value that shows the level of confidence in this forecast is 0.25 or 25%, but the results of this skill value will look better or meaningful when the weather conditions tend to be accompanied by thunderstorms or lightning.

3.3. *Dichotomous verification with several parameters using surface observation data on RDCA*

The accuracy method by obtaining predictive value (Sobajima, 2012), which only takes hits and misses parameters, was also investigated during the research month period. The other two contingency parameters, namely false alarms and correct negatives are not used,

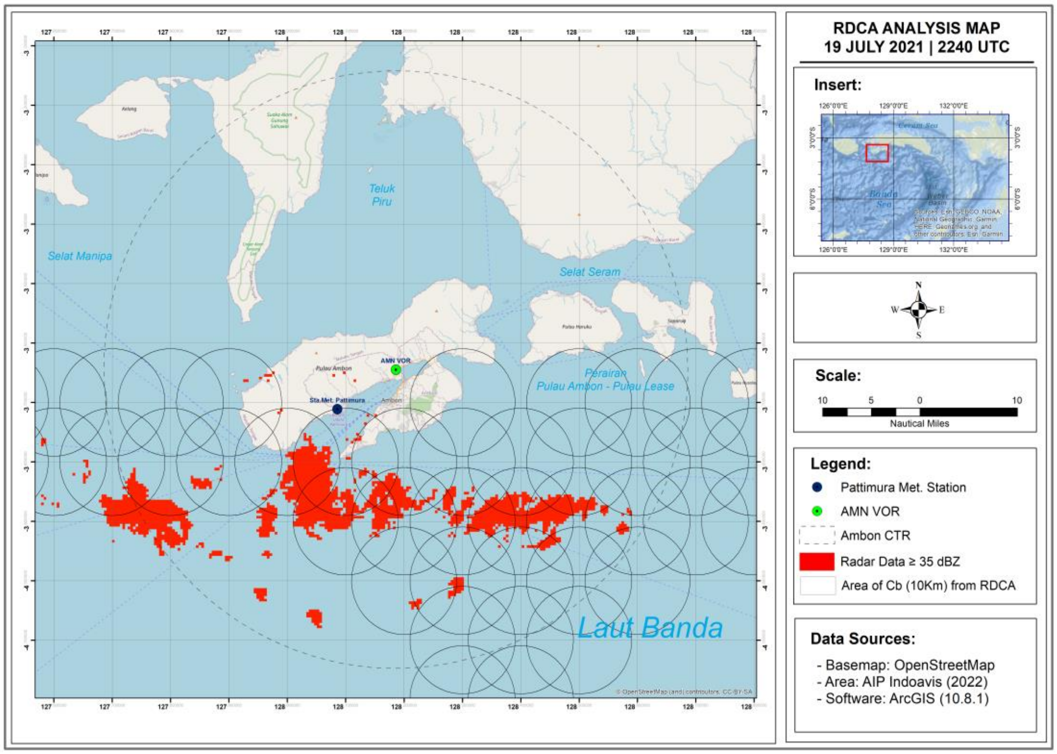

Fig. 3. RDCA and radar results for 19 July, 2021, 2240 UTC

because they are not directly related to the results of observations that have been verified as Cb clouds. Thus, significant weather conditions that are clearly related to Cb clouds, namely thunderstorms and lightning (Holle, 2014), are taken as research samples in obtaining predictive value. Research with Fig. 2 shows the number of hits and misses in July and December 2021 which indicate significant weather (thunderstorm and lightning).

The predictive value is 0.48 in July and 0.30 in December. This shows that the predictive value of RDCA products compared to observational data is slightly better in July than in December. The difference in predictive value between July and December is due to the seasonal conditions associated with that month. In July, Ambon Island and its surroundings are in the rainy season and in December is in the transition month (the transition from the rainy season to the dry season). Atmospheric conditions in July on Ambon Island are generally in an unstable condition. This unstable atmospheric condition strongly supports the life phase of convective clouds, especially Cb clouds (Isnoor *et al.*, 2017).

In December, even though the convectivity system is quite active, rain clouds, especially Cb clouds, are not formed continuously. In general, Cb cloud growth will occur within a radius that is not so wide, even though it is going through the normal phase of Cb cloud growth. This condition makes it quite difficult for the RDCA algorithm to be able to detect the convective initiation of the cloud.

Table 8 shows the results of the verification carried out on the RDCA using several conditions or parameters, Such as ; radius 25 km, 50 km and 100 km from the station, as well as the difference with day and night periods.

Based on several parameters for a radius of 25 km, 50 km 100 km, in conjunction with the difference of daytime and nighttime observation periods, both in July and December 2021. The highest accuracy value in the table is for the parameter with a distance of 0-25 km from the station point, both in July 2021 it was 0.79 and 0.85 in December 2021 in terms of the correct proportion. Meanwhile, the lowest accuracy value is at a distance of 0-100 km from the station point, where in July 2021 it was 0.53 and in December 2021 it was 0.61. It can be concluded that the FAR value is higher if the radius distance is farther from the station center point, as well as the frequency bias value. The CSI value, on the other hand, will increase as the

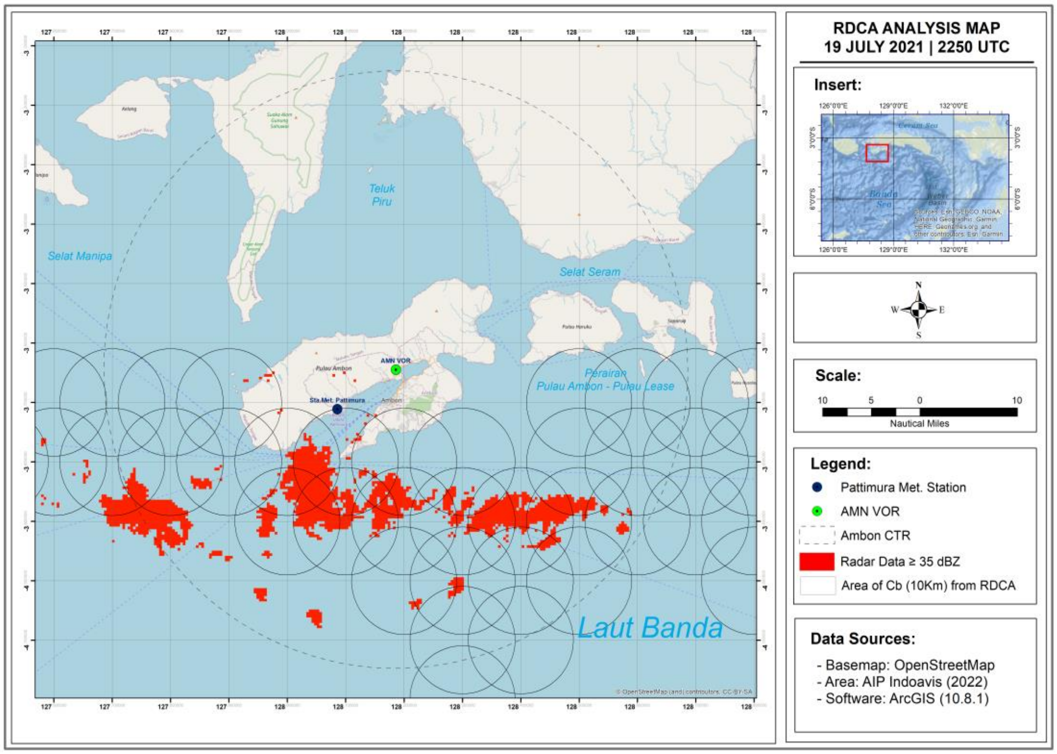

Fig. 4. RDCA and radar results for 19 July, 2021, 2250 UTC

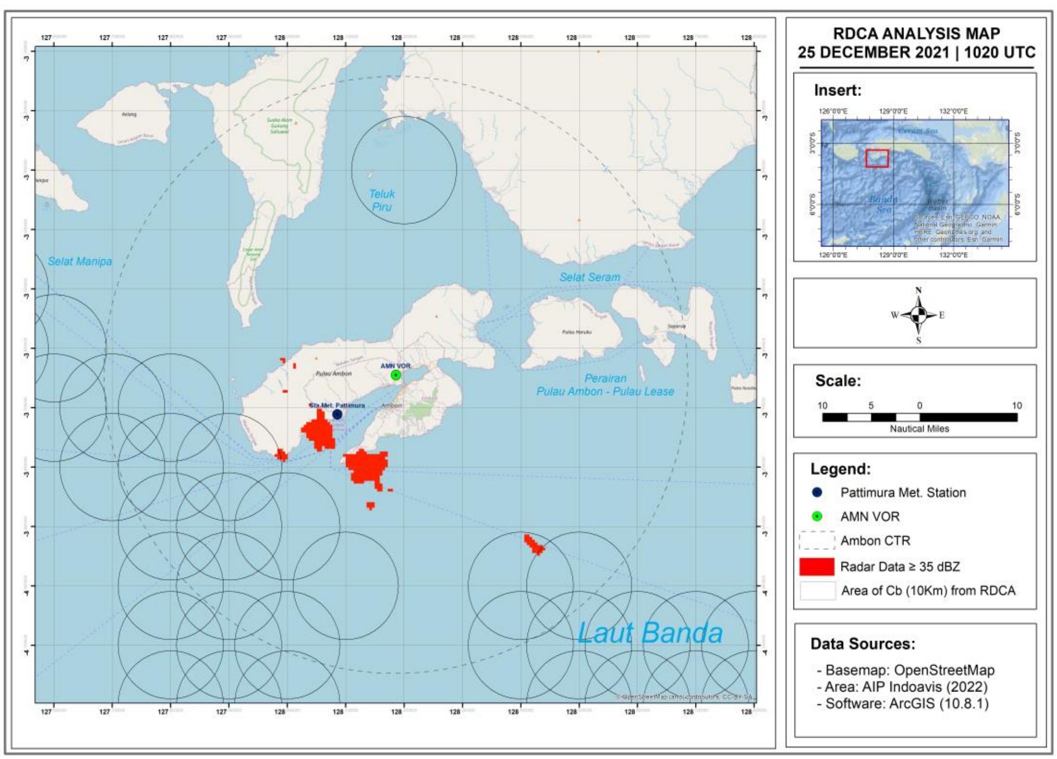

Fig. 5. RDCA and radar results for 25 December, 2021, 1020 UTC

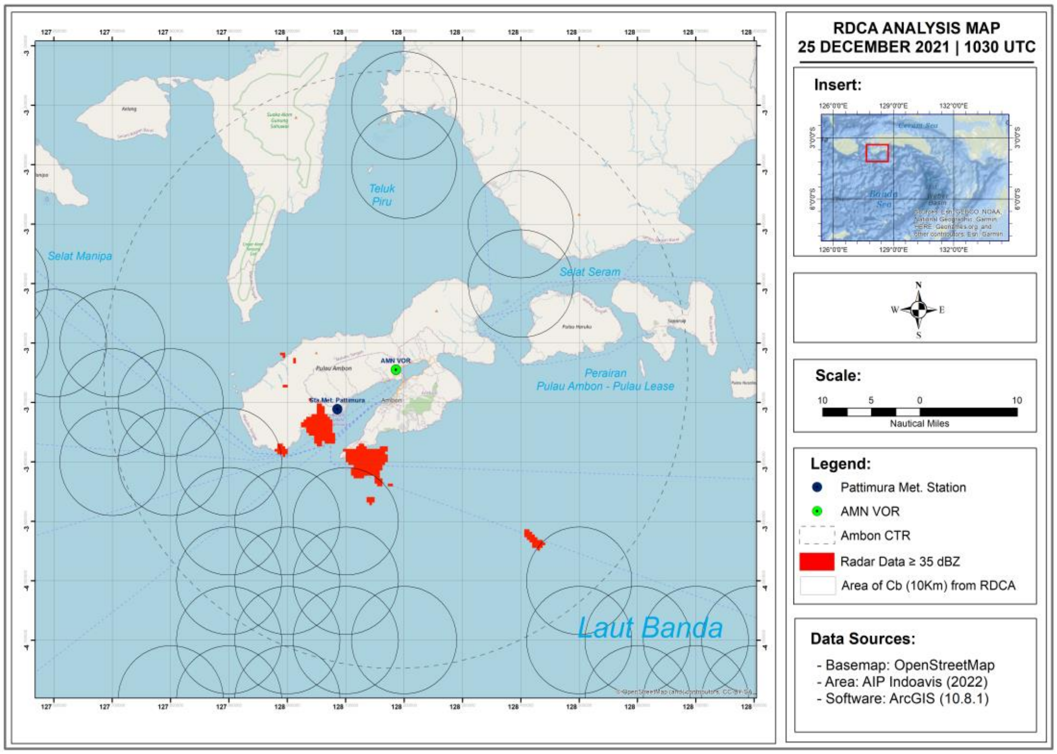

Fig. 6. RDCA and radar results for 25 December, 2021, 1030 UTC

observation verification point near. But overall, the accuracy is quite good, because more than half or 50% of the Cb prediction points from RDCA are considered correct, when verified using surface observation data.

The accuracy value is based on the division of the time of day and night in each month, indicating that the RDCA is sufficient both during the day and at night. This is evidenced by the fact that the accuracy values during the day in both July and December 2021 are not too far apart, only slightly higher compared to observations at night. With a PC value in December 2021 during the day, which is 0.69 and at night, it is 0.66. Meanwhile, in July 2021 at night it was 0.50 and during the day it was 0.68. The POD value in July was 0.9 and in December it was 0.7. This proves that the RDCA product, which in its algorithm uses several detection parameters especially only during the day, will still be optimal if applied at night as well.

3.4. *Spatial analysis of case study examples*

Various examples of different case studies will be taken as incident samples to help understand the analysis results with varying weather conditions. In the first case study, namely a case study where the RDCA product has a fairly high hit value.

On July 19, 2021, at 2240 UTC (Fig. 3) and at 2250 UTC (Fig. 4), the RDCA point predicts Cb clouds in the areas to the west, east and south of Ambon Island, especially around the waters of Ambon Island to Lease Island, next to south of the Manipa Strait and the northern part of the Banda Sea. Meanwhile, based on weather radar analysis, it was observed in the southern region of Ambon Island, the northern part of the Banda Sea and parts of the southern region of the Manipa Strait. This condition indicates that the RDCA point has been verified by weather radar, which is capable of predicting Cb clouds in these areas.

The second case study is based on weather radar analysis that successfully observes Cb clouds, but the RDCA product cannot predict 10-60 minutes in advance, which represents misses or failed predictions. Figs. 5&6 from December 25, 2021, at 1020 and 1030 UTC indicate the frequency of numerous misses, where the RDCA point predicts the potential for Cb clouds in the area around Piru Bay, northern Banda Sea, southern Ambon Island and the Straits area Manipa. Meanwhile, based on weather radar analysis, Cb clouds were only detected in the Ambon Island region, especially Ambon Bay, Ambon Bay District and parts of Nusaniwe District. Verification results show that RDCA is unable to predict Cb clouds according to the area indicated by the weather radar.

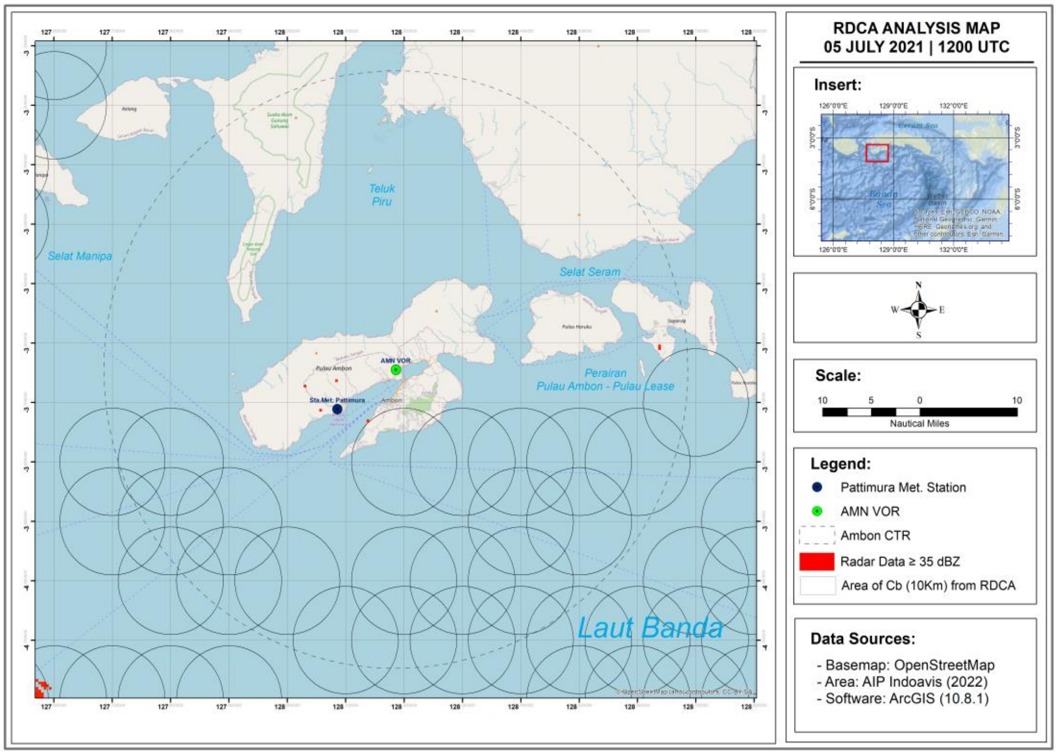

Fig. 7. RDCA and radar results for 5 July, 2021, 1200 UTC

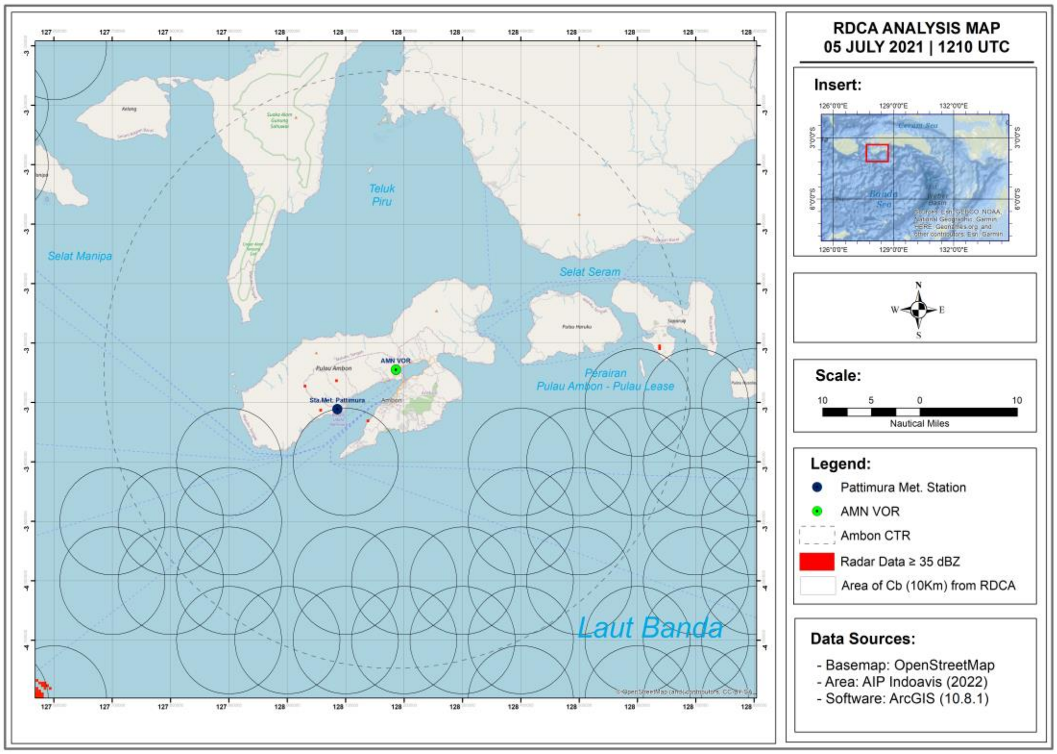

Fig. 8. RDCA and radar results for 5 July, 2021, 1210 UTC

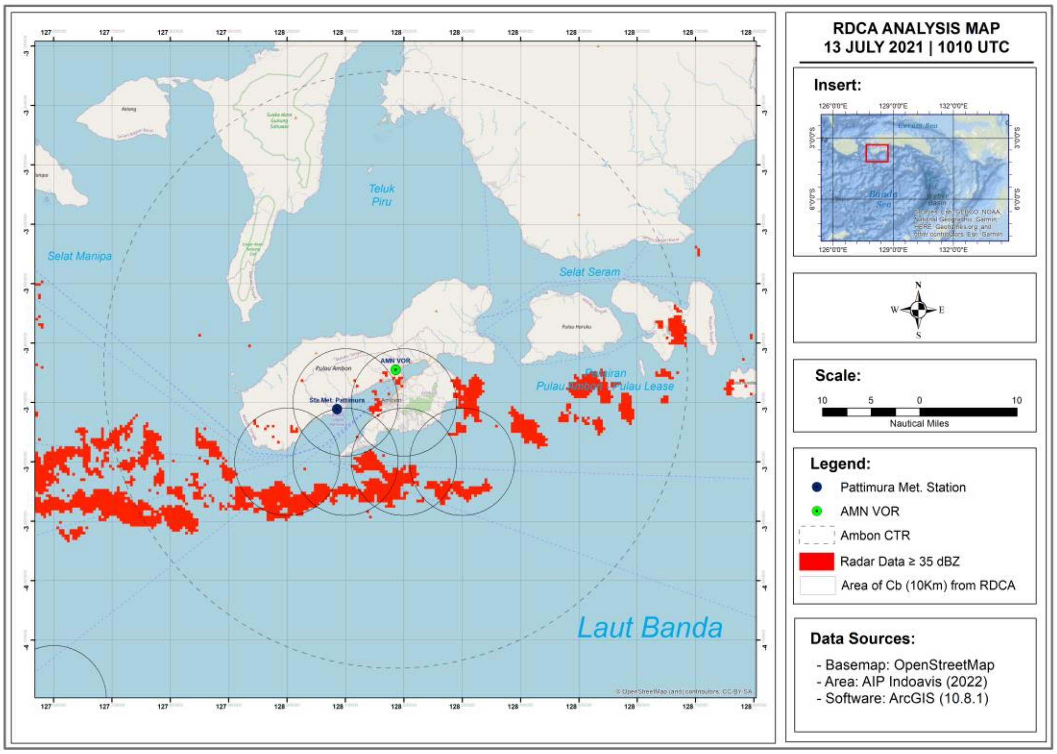

Fig. 9. RDCA and radar results for 13 July, 2021, 1010 UTC

The third case study is that the RDCA point predicts the presence of Cb clouds, but based on weather radar analysis no Cb clouds are observed. On July 5, 2021, at 1200 UTC (Fig. 6) and 1210 UTC (Fig. 7) many False Alarms were observed. The RDCA points were monitored in the southern part of Ambon Island, the waters of Ambon Island - Lease Island, the northern part of the Banda Sea and parts of the Manipa Strait. Meanwhile, based on the results of weather radar analysis, Cb were not detected. This condition shows that the Cb cloud predicted by the RDCA point does not form as a Cb cloud according to the area shown on the weather radar.

In several case studies, Cb clouds that are not detected by radar, or which show values of less than 35 dBZ, can be caused by high rainfall caused by other types of clouds (Tuomola, 2021). This is due to attenuation by rain which will reduce the accuracy of radar observations (Kosasih *et al*., 2021).

Case study on July 13, 2021, at 1010 UTC (Fig. 8). RDCA points are predicted to be in the Ambon Island region, especially in the districts (Teluk Ambon, Leihitu, Sirimau, Nuaniwe and West Leihitu). Meanwhile, based on the results of weather radar analysis, it shows Cb cloud coverage in the waters of Ambon Island - Lease Island, south of Ambon Island, northern Banda Sea, south of Manipa Strait, Haruku Island to Nusalaut Island. This condition indicates that not all Cb cloud growth can be predicted accurately by RDCA.

4. Conclusion

Based on the results of the verification carried out on the RDCA (Rapidly Developing Cumulus Area) using weather radar data equal to or more than 35 dBZ, it can be concluded that July and December 2021 showed quite good values. In general, from the verification results, within the next 10-60 minutes, the RDCA point indicates that there is a Cb cloud that forms at a distance of 10 km around the prediction point. However, in certain cases, false alarms and misses by RDCA against verification using radar data indicate that RDCA has not been able to predict Cb cloud growth perfectly. This gives a general picture that Cb can be predicted by RDCA according to the area of the research area (Ambon CTR) on a spatial basis.

The results of the verification using weather radar data are consistent with the results of the RDCA verification using surface observation data. Several conditions or parameters indicating the type of cloud Cb, thunderstorm (TS), and lightning, then dividing the distance (25, 50 and 100 km) and time of day (day and night), produce a fairly good accuracy value. Based on the verification results, more than half or 50% of the incident samples, RDCA was able to predict Cb clouds accurately. This level of accuracy indicates that it has been confirmed with the same results in both verifications, even though the verification using weather parameters is only in the form of points on station observations with a predetermined distance. Thus, based on the results of data processing, it provides a clear picture that RDCA can be used as one of the optimal products in predicting Cb cloud growth areas.

In addition, the results of this research have brought progress in the development of techniques or methods for obtaining the accuracy of RDCA products. The use of two verifiers, both radar and observation data, accompanied by several studies based on distance and time distribution, can make this writing a first step in assessing the accuracy of RDCA products in the tropics, especially at Ambon's Pattimura airport. The results of this study are very useful from an operational perspective at meteorological stations, especially those serving flight information services. The output of the research results in the form of a map can be used as a basis for consideration for forecasters in predicting Cb.

This research provides options for further study that is more specific to verification of RDCA data in the future. Among them is by applying computation-based data processing methods or programming languages. Then to expand and enrich case studies in various places in the tropics, especially Indonesia, the research area can be adjusted to the location of the responsibilities of each Technical Implementation Unit (UPT).

Adjustment of the cumulonimbus reflectivity threshold by radar, different verification methods, as well as with a longer research period, with the aim of obtaining verification results that match the weather characteristics in each area. Further research can also be carried out by other meteorological agencies outside Indonesia, or the role of the central BMKG (Meteorology, Climatology and Geophysics Agency), by participating and supporting research related to RDCA in the future. This is a preliminary approach to improve or enhance the RDCA algorithm, particularly for the tropical regions.

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