PREDICTION OF CUMULONIMBUS (CB) CLOUD BASED ON INTEGRATED FORECAST SYSTEM (IFS) OF EUROPEAN MEDIUM-RANGE WEATHER FORECAST (ECMWF) IN THE FLIGHT INFORMATION REGION (FIR) OF JAKARTA AND UJUNG PANDANG

Prediksi Awan Cumulonimbus (Cb) Berbasis Model Integrated Forecast System (IFS) European Medium-Range Weather Forecast (ECMWF) Pada Flight Information Region (FIR) Jakarta dan Ujung Pandang

Achmad Fahruddin Rais[1)*], Fani Setiawan[1)], Rezky Yunita[1)], Erika Meinovelia[1)], Soenardi[1)], Muhammad Fadli[1)], Bambang Wijayanto[1)]

[1)] Badan Meteorologi Klimatologi dan Geofisika. Jl. Angkasa I No.2 Kemayoran, Jakarta Pusat 10720
*E-mail: achmad.rais@bmkg.go.id

Abstract

This study was focused on cumulonimbus (Cb) cloud prediction based on Integrated Forecast System (IFS) European Medium-Range Weather Forecast (ECMWF) model in the Flight Information Region (FIRs) Jakarta and Ujung Pandang. The Cb cloud prediction was calculated using convective cloud cover (CC) of the precipitation product. The model predictability was examined through categorical verification. The Cb cloud observation was based on brightness temperature (BT) IR1 and brightness temperature difference (BTD) IR1-IR2. The results showed that CC 50%' predictor was the best predictor to estimate the Cb cloud. The study in the period other than 2019 is suggested for the next research because Indian Ocean Dipole (IOD) is extreme that may affect the Cb cloud growth in the study area.

Keywords: Cumulonimbus, Integrated Forecast System, Flight Information Region

Intisari

Studi ini berfokus pada prediksi awan cumulonimbus (Cb) berbasis model Integrated Forecast System (IFS) European Medium-Range Weather Forecast (ECMWF) pada Flight Information Region (FIR) Jakarta dan Ujung Pandang. Prediksi awan Cb menggunakan perhitungan convective cloud cover (CC) dari produk presipitasi. Kemampuan prediksi model diuji dengan menggunakan verifikasi kategorik terhadap observasi awan Cb dari brightness temperature (BT) IR1 dan brightness temperature difference (BTD) IR1-IR2. Hasil studi menunjukkan bahwa prediktor CC 50% merupakan prediktor terbaik untuk memprediksi awan Cb. Kajian pada periode selain 2019 disarankan pada kajian selanjutnya karena Indian Ocean Dipole (IOD) bersifat ekstrim pada periode tersebut yang memungkinkan mempengaruhi pertumbuhan awan Cb di wilayah kajian.

Kata Kunci: Cumulonimbus, Integrated Forecast System, Flight Information Region

1. INTRODUCTION

Cumulonimbus (Cb) cloud is a kind of cloud influencing the aircraft flight operational. A thunderstorm appearing from Cb is the main factor of the take-off delay of aircraft (Peck, 2015). The delay can cause a high disadvantage for the flight operation (Evans, 1995 and Klein *et al.*, 2009). Cb can produce microbursts with low-level turbulence, severe icing, lightning, high liquid water, and hail (Bhawan, 2013). In the cruising and descending phases, in-cloud turbulence is the most factor in aircraft accidents (Mazon *et al.*, 2018). Cb is also a potential cloud producing severe turbulence (WMO, 2018). Therefore, the Cb prediction is a necessity for the safety and efficiency of the flight operation.

In the research of Eastman and Warren (2014), a comparison of several pictures have shown that Indonesia is one of the distribution areas of a significant number of Cb clouds both over land and sea. Cb clouds' distribution has seasonal characteristics concluded to be triggered by monsoons (Sipayung and Risyanto, 2014). The distribution of lightning originating from Cb is also most common in Indonesia (Christian *et al.*, 2003). Therefore, the research on Cb prediction in Indonesia is very interesting.

The World Area Forecast Centers (WAFC) London and Washington have issued blended Cb predictions up to 36 hours (Met Office and

NOAA, 2012). However, the output of the dissemination model used has a coarse resolution (1.25˚). Therefore, we will examine the use of European Medium-Range Weather Forecast (ECMWF) Integrated Forecast System (IFS) products with better resolution (0.125˚).

This study investigates the prediction performance of the Cb cloud based on the IFS ECMWF model on Jakarta and Ujung Pandang Flight Information Region (FIRs). The ECMWF IFS model is a high resolution (HRES) model issued by ECMWF with a 9 km cycle 41r2. In its dissemination, the model resolution was changed to 0.125˚ (13.5 km). This model is processed with initial conditions at 00UTC and 12UTC. HRES also uses couplings with Dynamic Ocean models (NEMO) and Wave models (ECWAM). This model uses the assimilation of 4-DVar, which involves many cloud-sensitive observations and precipitation (Geer *et al.*, 2017). Information about IFS ECMWF HRES can be found on the web page https://confluence.ecmwf.int//display/FUG/HRES+-+High-Resolution+Forecast

2. METHOD

As an input processing in the research, we used satellite data Himawari-8 channels IR1 (10.4 µm), IR2 (12.4 µm) and IFS ECMWF HRES every 3 hours of the prediction of the 6th hour (T+6) to the 36th hour (T+36) with initial conditions of 00 UTC and 12 UTC on the first day of each month in 2019. The study location was Jakarta and Ujung Pandang FIRs and was limited by the polygon lines in Figure 1.

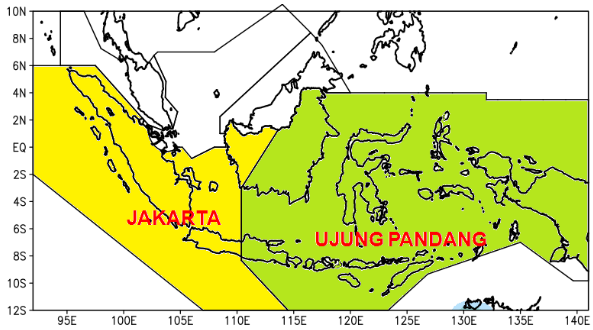

Figure 1. Jakarta (yellow) and Ujung Pandang (green) Flight Information Regions.

To get observations of Cb cloud coverage, we used a combination of brightness temperature (BT) IR1 channel and brightness temperature difference (BTD) IR1-IR2 satellite Himawari-8. Inoue (1987) used a 250˚K threshold for BT IR1 and 0˚K to 0.5˚K for BTD IR1-IR2. In the subsequent research, Inoue (1989) changed the BTD IR1-IR2 threshold to 0˚K to 1˚K and BT IR1 threshold to -20˚C. Hamada *et al.* (2004) used threshold 0˚K to 0.5˚K for BTD IR1-IR2 and 259˚K for BT IR1. Suseno and Yamada (2012) made a Cb classification with traces of -2˚K to 2˚K for BTD IR1-IR2 and 245˚K for BT IR1. Purbantoro *et al.* (2019) limited the Cb classification to 0.6˚K (0.9˚K) for BTD IR1-IR2 and 253˚K (258˚K) for BT IR1 in winter (summer). From all the Cb cloud determination thresholds, we used all the maximum threshold values of previous studies with -2˚K to 2˚K for BTD IR1-IR2 and 259˚K for BT IR1 (Figure 2).

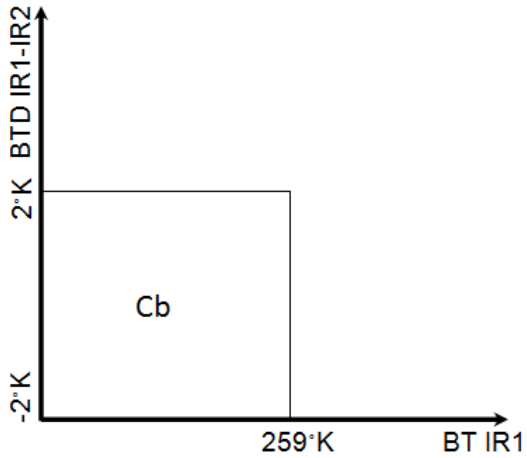

Figure 2. Illustrated graph of Cb based on BTD IR1-IR2 and BT IR1.

The method used to estimate the spread of the Cb cloud was convective cloud cover (CC) in Slingo and Slingo (1991). WAFC London also used a formulation of precipitation relationship with CC (Maisey, 2012). We used CC 40%, 50%, and 60% for Cb cloud prediction. The CC was then synchronized with the total cloud cover (40%, 50%, and 60%) of the IFS ECMWF HRES output model through an intersection between the estimated CC and the total cloud cover.

Table 1. Contigency table

		Observation	
		Cb	Non Cb
Prediction	Cb	*a*	*b*
	Non Cb	*c*	*d*

We conducted verification of all prediction data of IFS ECMWF HRES every 3 hours of predicting the 6th hour (T+6) to the 36th hour (T+36) with initial conditions of 00 UTC and 12 UTC on the first day of each month in 2019. The verification was processed by comparing the frequency and calculating qualitative values from the contingency table in table 1. We used the probability of detection (POD), probability of false detection (POFD), and percent correct (PC) sourced from https: // www.cawcr.gov.au/projects/verification/#Methods_for_dichotomous_forecasts.

$$POD = \frac{a}{a+c} \quad [1]$$

$$POFD = \frac{b}{b+d} \quad [2]$$

$$PC = \frac{a+d}{a+b+c+d} \quad [3]$$

POD was a measure of a model's ability to predict the probability of a Cb cloud with a maximum value of 1. In contrast, POFD was a measure of a model's ability to predict the probability of the absence of a Cb cloud with a maximum value was 0. POD and POFD values could be 0/0 or undefined. We marked it as a white color in Figure 4. Simultaneously, the PC was a measure of model accuracy because of the model's ability to predict the presence and absence of the Cb cloud. PC had a maximum value of 1.

3. RESULT AND DISCUSSION

Figure 3 shows that the Cb frequency of CC 40-60% T+6 to T+36 tends to overestimate Jakarta and Ujung Pandang FIRs to satellite-based Cb frequencies. It seems that the Cb frequency of CC 60% is the closest. In general, the Cb cloud frequency spatial pattern can be captured by models that show smaller Cb cloud frequencies in the southern part of Jakarta and Ujung Pandang FIRs and also the northern waters of Celebes and Mollucas.

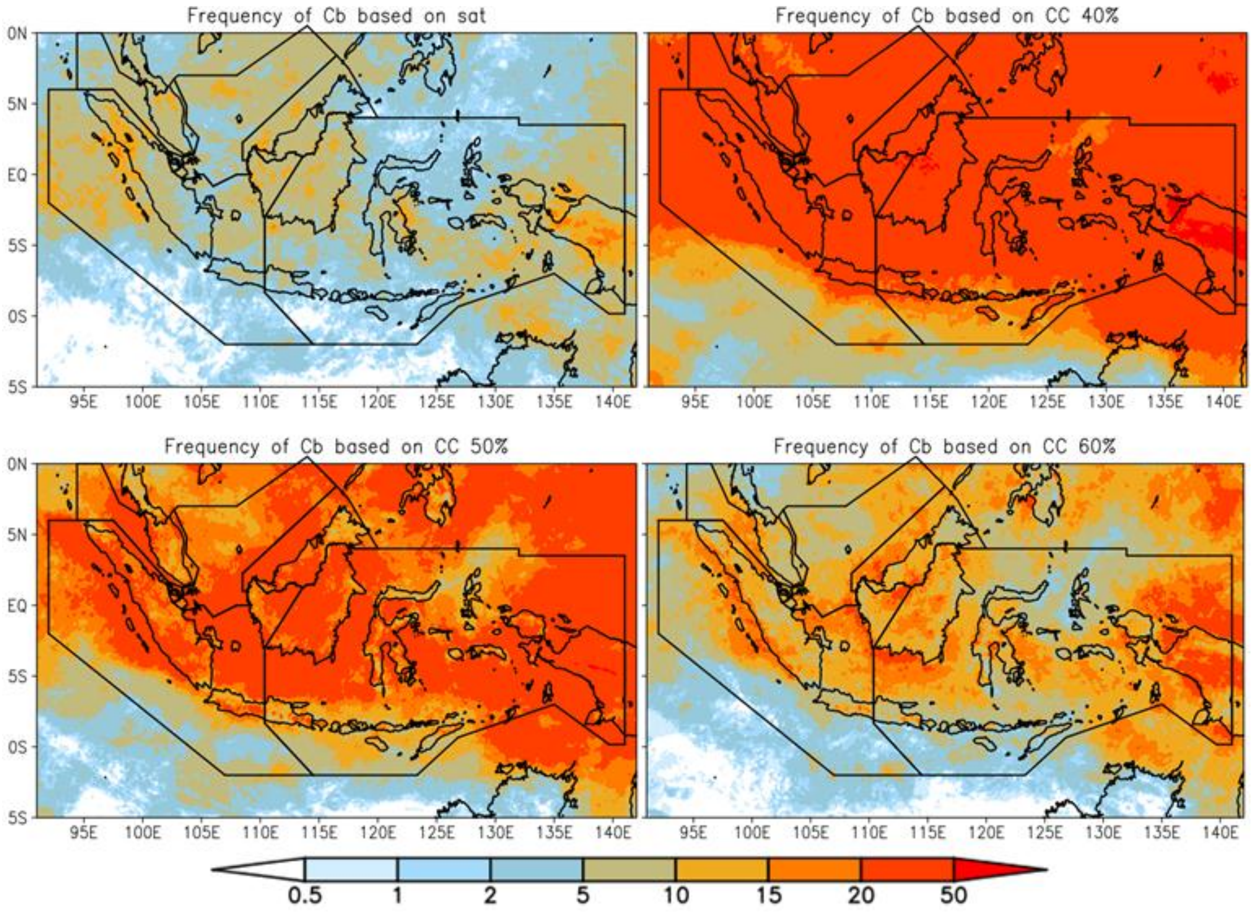

Figure 3. Cb frequencies (%) of Satellite and CC 40%, 50%, and 60% for T+6 to T+36.

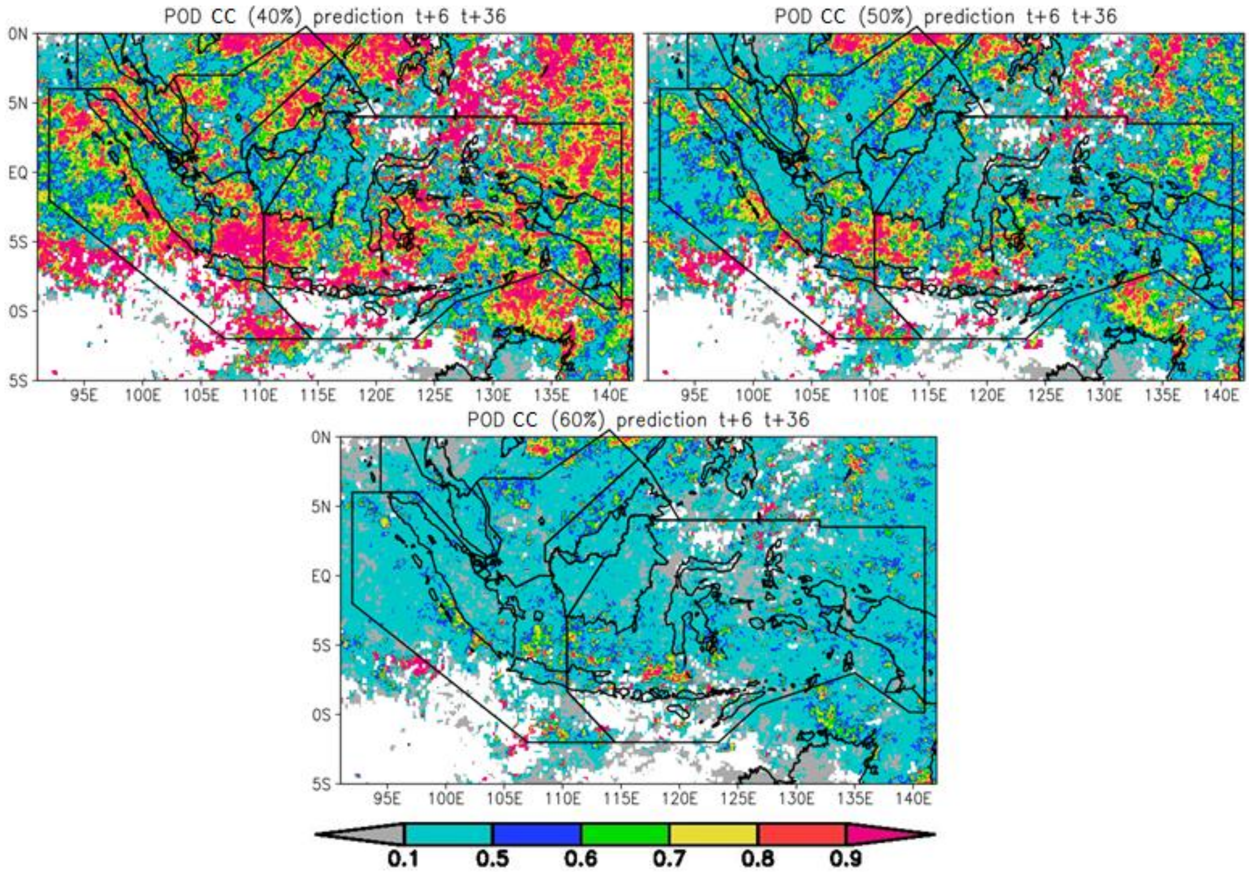

Figure 4. PODs of CC 40%, 50%, and 60% for T+6 to T+36.

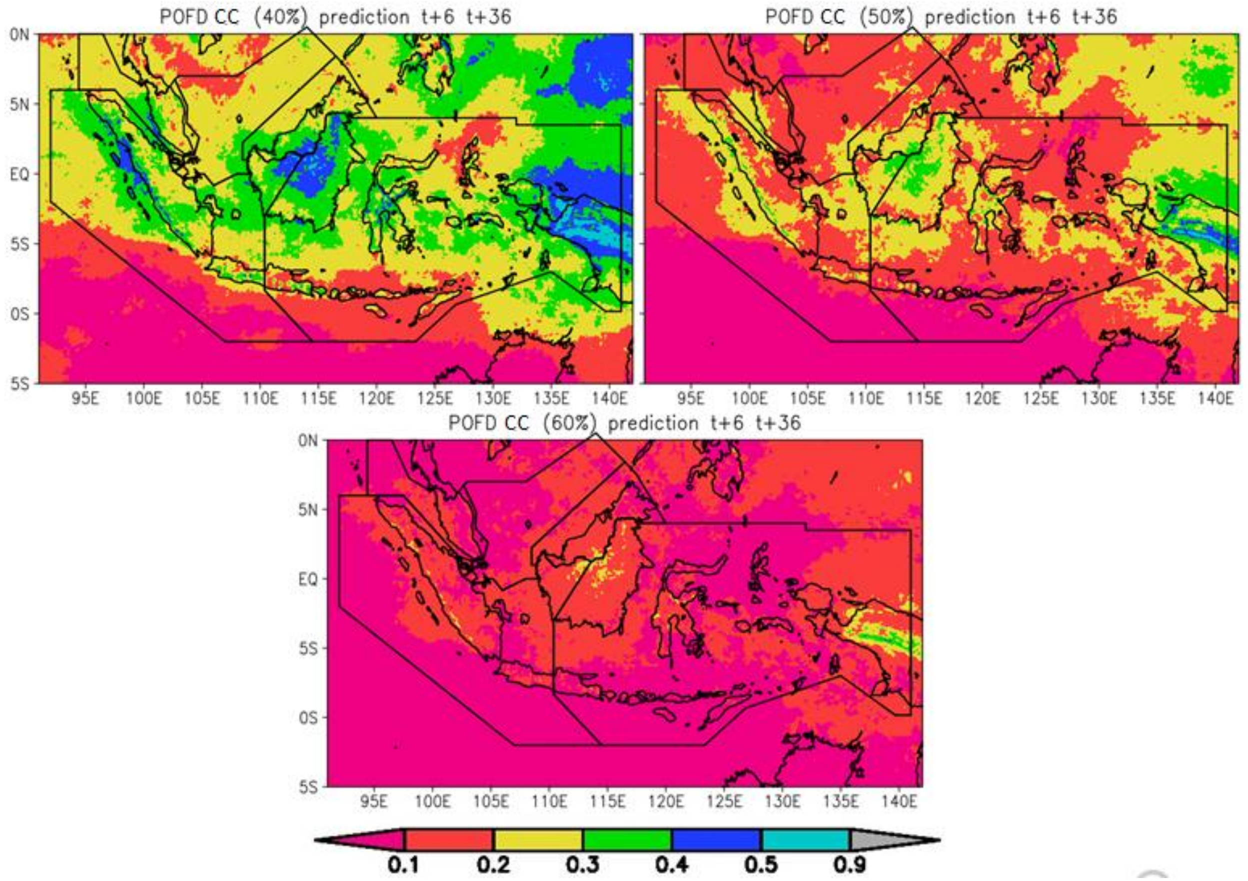

Figure 5. POFDs of CC 40%, 50%, and 60% for T+6 to T+36.

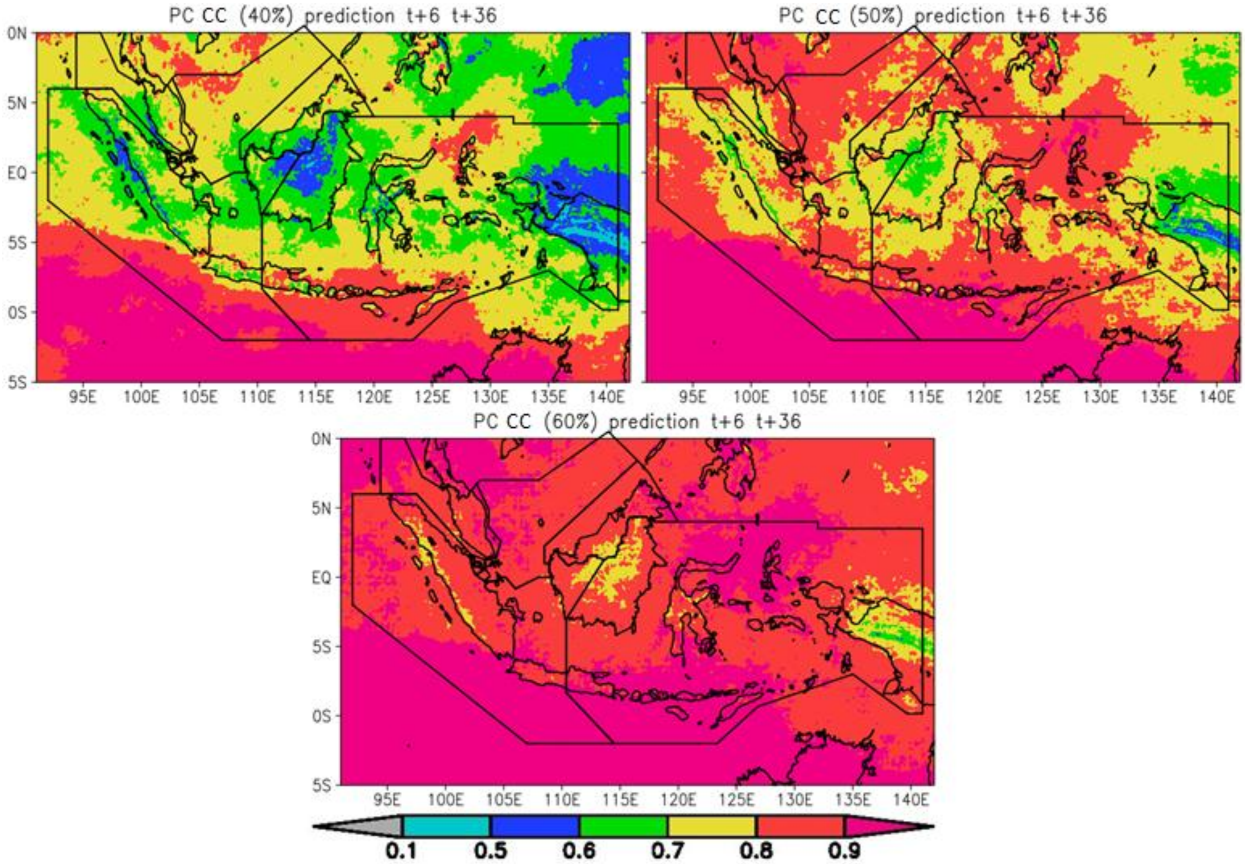

Figure 6. PCs of CC 40%, 50%, and 60% for T+6 to T+36.

Figure 4 shows that the POD of CC 40% >0.9 is generally distributed in the waters, both in Jakarta and Ujung Pandang FIRs. Only a small portion is spread evenly on the islands. Whereas the POD of CC 40% <0.5 is mostly over the islands. The POD of CC 50% >0.9 is also distributed in the waters but with a smaller area than the CC 40% >0.9. In contrast, the POD spatial distribution of CC 50% <0.5 is wider than the POD of CC 40% <0.5. The POD of CC 60% <0.5 seems to dominate the entire Jakarta and Ujung Pandang FIRs, only a small area is >0.9. In the Maisey study (2012), the Cb blended PODs of WAFC for CC 40-60% were in June-July-August (JJA) 2010, JJA 2011, and December-January-February (DJF) 2011-2012 around 0.7, 0.7, and 0.05. The POD of WAFC on the DJF is very small, whereas the DJF is the dominant period of the maximum phase of the Cb cloud frequency in Indonesia (Suaydhi *et al.*, 2015). Comparing the PODs of WAFC to Figure 5 shows that CC 40% and 50% can produce POD ≥0.7, which is widely distributed in Jakarta and Ujung Pandang FIRs.

Figure 5 shows the opposite. In general, the POFD of CC 40% is more significant than CC 50% and 60%. Most of the POFD <0.3 is indicated by CC 50%, although the POFD >0.5 is also indicated by CC 50% in central Papua. In contrast, the POFD of CC 60% has a very low value dominated by values <0.2. Compared to the blended Cb POFD of WAFC for CC 40-60% in June-July-August (JJA) 2010, JJA 2011, and December-January-February (DJF) 2011-2012, which are 0.15, 0.25, and 0 (Maisey, 2012), the CC 50-60% can produce POFD <0.2 which is dominant in the study area.

The PC in Figure 6 has a color distribution similar to Figure 6 but with an inverse value. This indicates that d in table 1 dominates the PC. The PC of CC 40% generally has the smallest value even though most of the values are still > 0.6, except in western Sumatra waters, central Borneo, central Papua, and northern Papua waters. The PC of CC 50% and 60% are generally > 0.7 and > 0.8 and <0.5 that is also found in central Papua. The PC of CC 60% >0.7 is mostly in Jakarta and Ujung Pandang FIRs.

4. CONCLUSION

In this research, we examined the predictability of Cb T+6 to T+36 based on CC 40-60% calculated from the IFS ECMWF HRES model's predicted precipitation through a comparison of frequency, POD, POFD, and PC. Because the CC 50% had a better frequency than CC 60%, its POD ≥0.7 which was quite widely spread in the study area, and its POFD <0.2 and PC >0.7 were dominant in Jakarta and Ujung Pandang FIRs, we concluded that the CC 50% was the best predictor of Cb.

Besides the CC 50% had a better spatial resolution than the WAFC product, the CC 50%

also showed better accuracy through higher POD and lower POFD. This result indicated that CC 50% of the IFS ECMWF model could be used for the operational aviation meteorology over the Jakarta and Ujung Pandang FIRs.

This research was conducted in the 2019 period, an extreme Indian Ocean Dipole (IOD) period. It might affect the Cb cloud frequency. So the next study is suggested to involve the neutral period of IOD.

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