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Comparison of seasonal prediction outputs based on dynamic atmosphere model and observations (case study: seasonal prediction in 2016 - 2017)

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Comparison of seasonal prediction outputs based on dynamic atmosphere model and observations (case study: seasonal prediction in 2016 - 2017)

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Abstract. Seasonal predictions are considered as an important factor for many sectors in Indonesia, especially for the agriculture sector. In Indonesia, the variability of seasonal characteristics is influenced by various regional atmospheric phenomena, such as monsoon, ENSO, and IOD. With such urgency, this research is conducted using dynamic models to generate accurate medium-term predictions. The dynamical atmospheric model, Cubical Conformal Atmospheric Model (CCAM) is used to produce daily predictions up to 8 months. CCAM result has been tested on major islands in Indonesia such as Java, Sumatra, Sulawesi, Borneo and Papua. It shows that during the rainy season, the value of rainfall predictions is lower than observations. Meanwhile, the rainfall predictions are overestimate when compared to observations during dry season. Nevertheless, the patterns of rainfall predictions are following satellite rainfall observations patterns, especially in Java.

Keywords : seasonal, prediction, dynamic atmosphere model, rainfall, CCAM

1. Introduction

Seasonal prediction is an attempt to provide information about atmospheric conditions, especially temperature and rainfall, on a time scale of one or several seasons ahead. The ability of numerical and dynamical models in predicting the season has increased sharply since the start of the development of data assimilation systems in the 1990s. The system of dynamical season prediction began operating in the United States around 1995 with the National Meteorological Centre's Medium Range Forecast (NMC). The first seasonal prediction that operated is CFS version 1 in August 2004, providing predictions for the world's climate [1] and showed reasonable skills in predicting the major features of large-scale climate such as ENSO [2] and Asian monsoon [3]. CFSv1 was replaced to NCEP CFSv2 (National Version for Environmental Prediction Climate Forecast System version 2) in 2011 [4].

In Europe, the ECMWF (European Centre for Medium-Range Weather Forecasts) season prediction system began in 1996 as ECMWF Ensemble Prediction System (EPS) [5]. The seasonal prediction system in Australia has developed since 2002 and known as the POAMA (Predictive Ocean Atmosphere Model for Australia). The first operational version of POAMA called POAMA-1 that ran from 2002 to 2007, and was subsequently replaced by version POAMA-1.5b in 2007. At the end of 2011, further updates resulted in the multi-model version POAMA-2.4 (POAMA-2 herein) [6]. Development of numerical season prediction systems that are operational in these countries through years of intensive



research. While the performance of CFSv2 for the Indonesian region has been studied by Zhang et al. (2016) which investigating CFSv2 output in Maritime Continent (MC) in wet and dry seasons [4].

Nowadays, Indonesia's climate was difficult to predict. The main reason is Indonesia as the maritime continent is like a boiler box [7] which has a large amount of latent heat due to the rain process, and moved by Hadley Cell and Walker Circulation. In addition, Indonesia has a unique and complex geographical location, among others the distribution of land, oceans and terrains which contribute to rainfall variations in both spatial and temporal [8]. Indonesia is located between the Indo-Pacific heat pools, where evaporation increases atmospheric moisture, and the circulation transmits water vapor from the ocean toward Indonesia [9]. This is a new challenge for atmospheric researchers in terms of predicting, especially predictions until the next few seasons. Conformal-Cubic Atmospheric Model (CCAM) is an atmospheric numerical model developed by CSIRO, Australia which previously developed the Division of Atmospheric Research Limited Area Model (DARLAM). CCAM is one of the global atmospheric models developed effectively starting in 1994 by the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia [10]. CCAM not only has been adapted and developed with the purpose to increase the weather prediction capability in producing more reliable forecasts but also can be integrated with high resolution on a specific domain [12]. A lot of researchers using CCAM in predicting weather conditions with different data. For example, the prediction of temperature and rainfall of CCAM which validated using observation data at 128 stations in Vietnam shows that forecast temperature tends to be lower than observation data in most climatic regions across the country, but generally it has low value of error. The correlation coefficient between CCAM and observation is very high [13]. Yulihastin et al. (2015) has been using CCAM to show the correlation between rainfall anomalies over Indonesia when Madden Julian Oscillation (MJO) activated. The result shows that CCAM can identify MJO activities over Indonesia quite well [13]. Therefore, this study has a purpose to compare the predicted rainfall of the season using CCAM models and GSMaP rainfall for the Indonesian region. Also, this research is aimed to improve Indonesia's prediction by the season and the first step to make the seasonal predictions in Indonesia using dynamic models, especially using CCAM.

2. Data and Methods

2.1. Data

The data that used in this study are the input for CCAM which includes 2 data, namely initial condition data from the Global Forecasting System (GFS) and input data on sea surface temperature (SST) from the predicted POAMA results.

The season prediction simulation using CCAM is carried out for the period March 2016 to March 2018. The initial condition data that is used in this study is the first GFS data of each month with a resolution of 1° , and simulations are conducted monthly, starting March 2016 to March 2018. CCAM also can be used to simulate atmospheric by using the forcing of SST with initial condition from GFS. CCAM can be run as Atmosphere General Circulation Model (AGCM) with only SST forcing. Therefore, this research using SST prediction data from POAMA which has 2.5° spatial resolution, where this data is actually a surface temperature data that has been converted to sea surface temperature by eliminating data on the mainland. The SST data from POAMA prediction has 3 classes, namely m24a, m24b and m24c where in each class consists of 11 ensembles (e00, e01, ..., e10) and 1 mean ensemble (emn). But in this study, only one predicted surface temperature data of POAMA is used i.e. m24b_emn. The spatial resolution of CCAM prediction results is 0.28° or equivalent to 31.8km. GSMaP satellite data provided by JAXA (<http://sharaku.eorc.jaxa.jp/GSMaP/>) is used for the spatial and temporal comparison of rainfall parameters. The spatial distribution of rainfall from GSMaP has spatial resolutions $0.1^\circ \times 0.1^\circ$, daily and near real time observation.

The locus of this research is the entire territory of Indonesia with a limit of $95^\circ - 145^\circ\text{E}$ and $6^\circ\text{N} - 12^\circ\text{S}$. This is the result of the downscaling from domain 1 (global - 1° resolution) to domain 2 (Indonesia - 0.28°), as shown in Figure 1a.

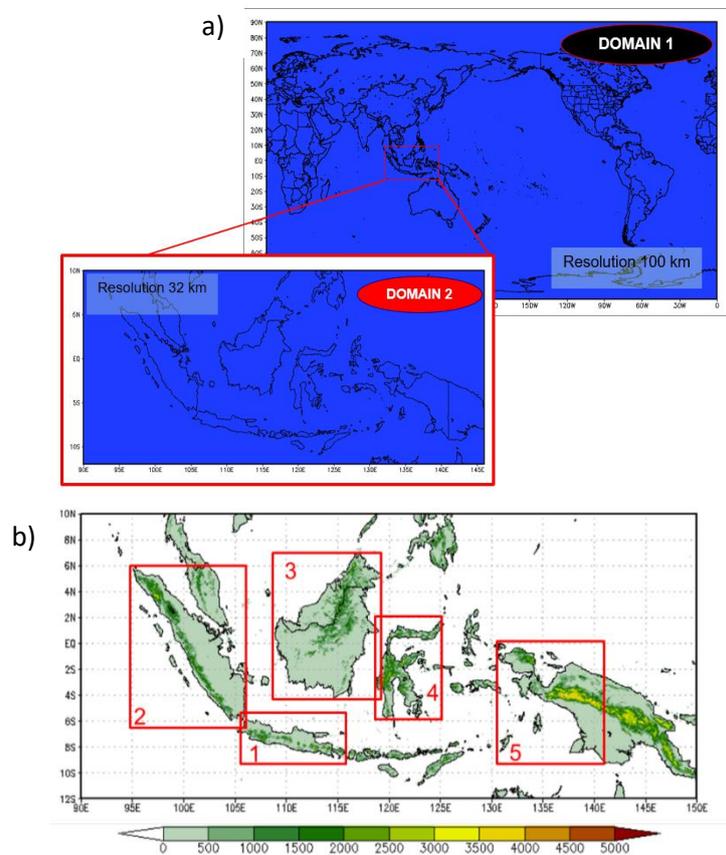


Figure 1. a) Domain of the CCAM simulation and b) topography of the Indonesian Region using USGS DEM data and research study area. The box in Figure 1b is the area boundary for the analysis of rainfall per large island in Indonesia (1. Java-Bali, 2. Sumatra, 3. Borneo, 4. Sulawesi, and 5. Papua).

2.2. Methods

CCAM uses conformal cubic grid which each panel has 48x48 grid points (for C48 grid format), 6 cube sides, and 18 vertical levels, so the number of grid points is 248,832 [11]. But in this study using the C96 format, which has 96x96 grid points in each panel. This aims to be able to produce a broader domain with a denser resolution. The value of 32 km of the prediction output in this study is the optimal consideration from the use of the C96 format. Another advantage of CCAM is that it has the ability to provide high flexibility for dynamical downscaling results from GCM data by using sea surface temperature data and some nudging from the host model [11]. But in this study, CCAM was used to make seasonal predictions with GFS data input and SST predictions from POAMA. Before running the CCAM model, the input data have to be set into cubical so it can be processed in CCAM. Furthermore, CCAM can be run after adjusting land settings to obtain the results of the topographic and vegetation description of a domain area using executable file called *runtopo*. The domain area used in the CCAM in this study is the territory of Indonesia with an output resolution of 0.28° or equivalent to 31.8km. After the prediction output is obtained, the monthly rainfall calculation and analysis plot are carried out. Prediction simulations are carried out at the beginning of each month (March 2016 to March 2018) and produce predictions for the next 8 months from the initial condition, resulting in daily temporal resolution. The research workflow can be seen in Figure 2a and simulation scheme of the seasonal prediction in this study is shown in Figure 2b.

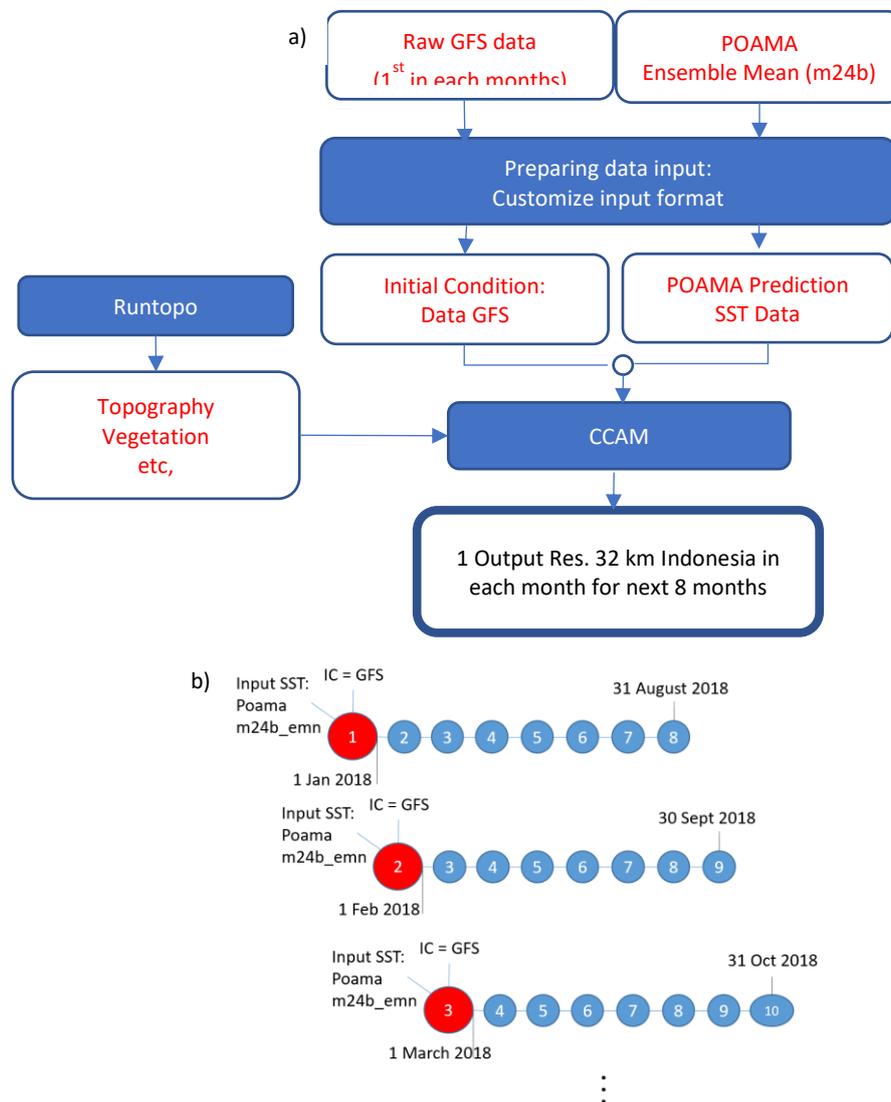


Figure 2. a) Research flowchart and b) scheme simulation of the seasonal prediction using CCAM (the date for both the initial and end date of simulation are just example)

Calculation of the correlation coefficient between the results of the season prediction simulation and GSMaP data is used to analyze the validation of the prediction. In addition, an area average method is used from several large islands in Indonesia to find out the accuracy of rainfall simulation and which island has a pattern and value of rainfall close to GSMaP data.

3. Results and Discussions

3.1. Temporal comparison

Comparison of monthly rainfall values between GSMaP satellite data and CCAM output on 5 island in Indonesia is shown in Figure 1. Rainfall values are the average area of rainfall in Java (105-116E, 5.5S-9.5S), Sumatra (95-108E, -6N-7S), Borneo (108-120E, 8N-5S), Sulawesi (105-116E, 9.5S-5.5S) and Papua (130-141E, 1N-10S), where the rainfall used is rainfall on land (rainfall in the ocean is eliminated).

From Figure 3, it can be seen that predicted precipitation has a tendency to be wetter during the dry season and drier during the rainy season. Of the several major islands in Indonesia, the similarity of predictive rainfall patterns that approach GSMaP's monthly rainfall patterns are in Java and Bali. Predictive rainfall in Java and Bali has a pattern that resembles monthly rainfall from GSMaP data, although rainfall from the dry season and rainy season shifts slightly from 1 to 2 months compared to GSMaP. While the monthly rainfall pattern on other islands is still not good / does not resemble the GSMaP rainfall pattern.

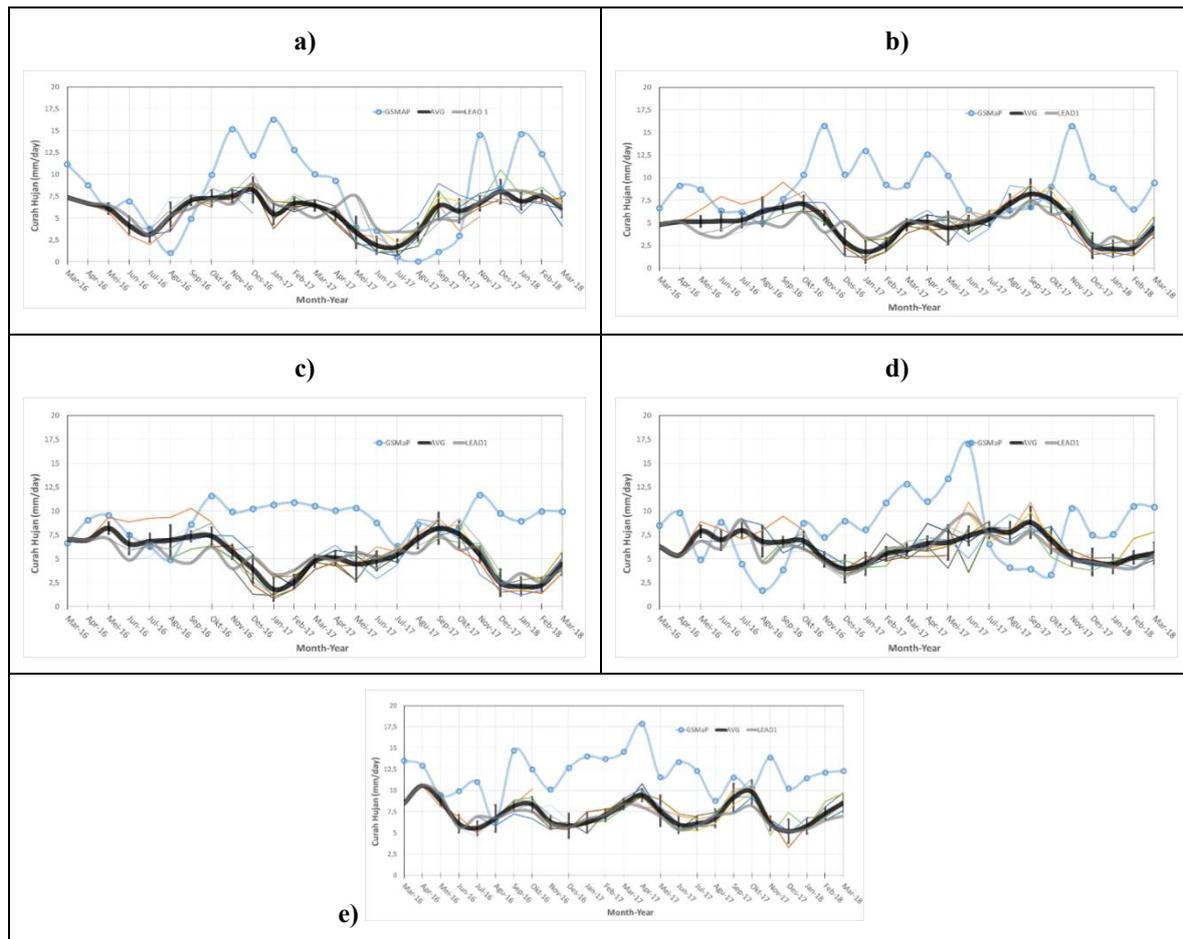


Figure 3. Comparison of the average rainfall area predicted by CCAM in various initial conditions and GSMaP for: a) Java Island, b) Sumatra, c) Borneo, d) Sulawesi and e) Papua. Small lines are the monthly rainfall of CCAM ensemble results in different initial conditions, thick black lines are the average rainfall and standard deviation of CCAM ensembles, thick grey lines are rainfall every 1st month of each CCAM output (lead month 1) and the blue line is GSMaP rainfall.

Linear correlation analysis between monthly rainfall prediction and GSMaP can be seen from Figure 4, both on average and lead 1-month ensemble. Figure 4 shows more clearly that in general the predicted rainfall in Java and Bali (both the average and the predicted 1-month lead) has not been able to show high rainfall from GSMaP. Even so, the prediction of ensemble average rainfall has a correlation of 0.64 and rainfall prediction of 1-month lead has a correlation of 0.69 when compared to GSMaP rainfall.

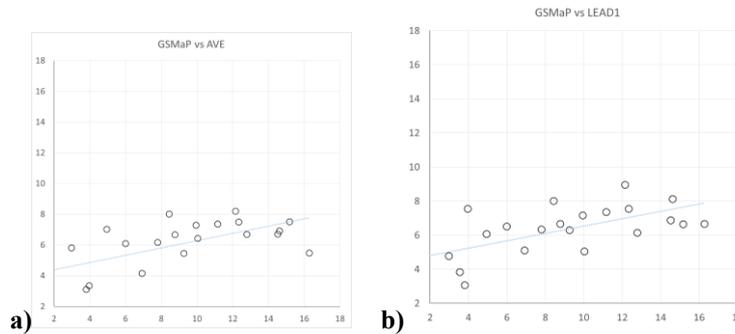


Figure 4. Scatter-plot of the average rainfall area predicted by CCAM a) average and b) lead 1 in various initial conditions and GSMaP for Java

3.2. Spatial Comparison

Spatial comparisons of monthly rainfall between prediction results and GSMaP are shown in Figures 5 and 6. In the dry months, namely JJA (as shown in Figure 5), CCAM prediction rainfall tends to show a lower value compared to GSMaP in almost all region. Rainfall falls gradually from June to August. The peak of the dry season for the southern region (Java, Bali and Nusa Tenggara) is in August. The decrease in rainfall is also seen in the CCAM prediction results even with a value below the GSMaP rainfall value. Rainfall in northern Sumatra such as Aceh and North Sumatra which despite entering the JJA period still shows high rainfall, cannot be shown by CCAM.

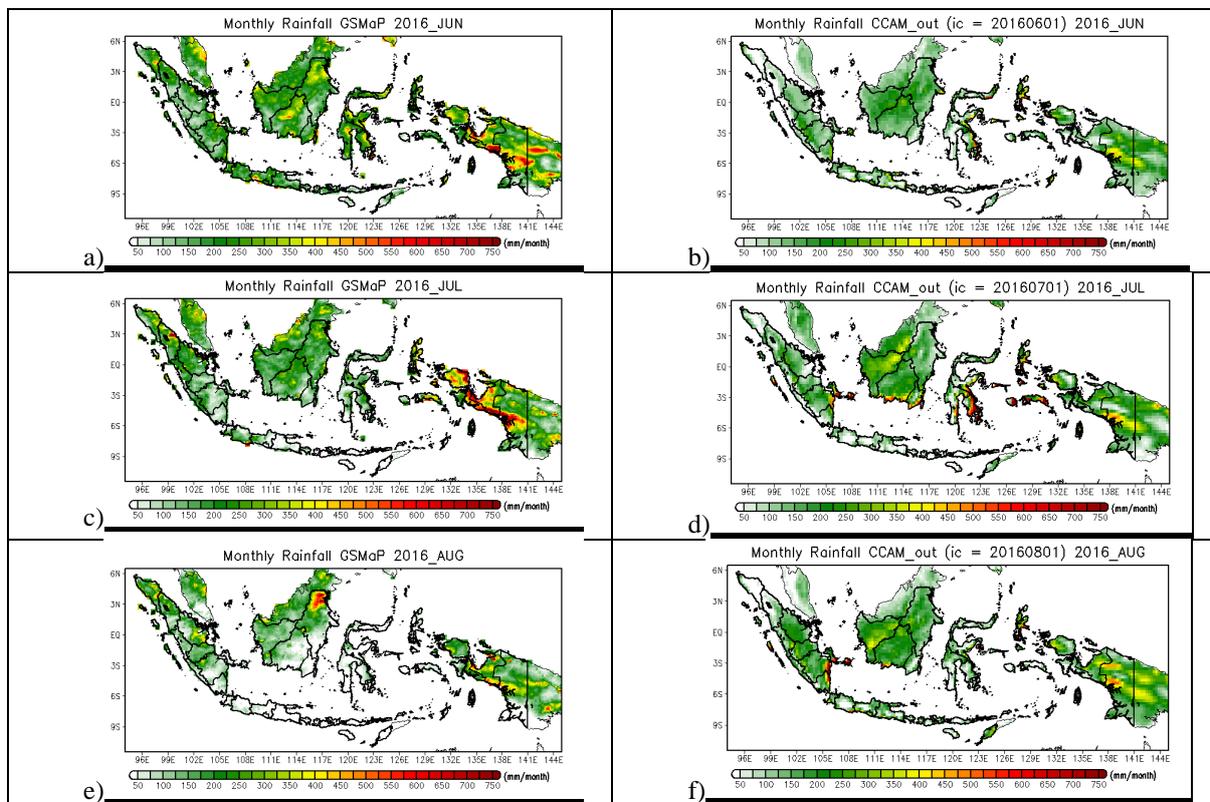


Figure 5. Spatial pattern comparison of monthly rainfall predicted by CCAM on 1-month lead and GSMaP during dry months 2016 (JJA), which are respectively a) GSMaP for June, b) CCAM for June, c) GSMaP for July, d) CCAM for July, e) GSMaP for August and f) CCAM for August.

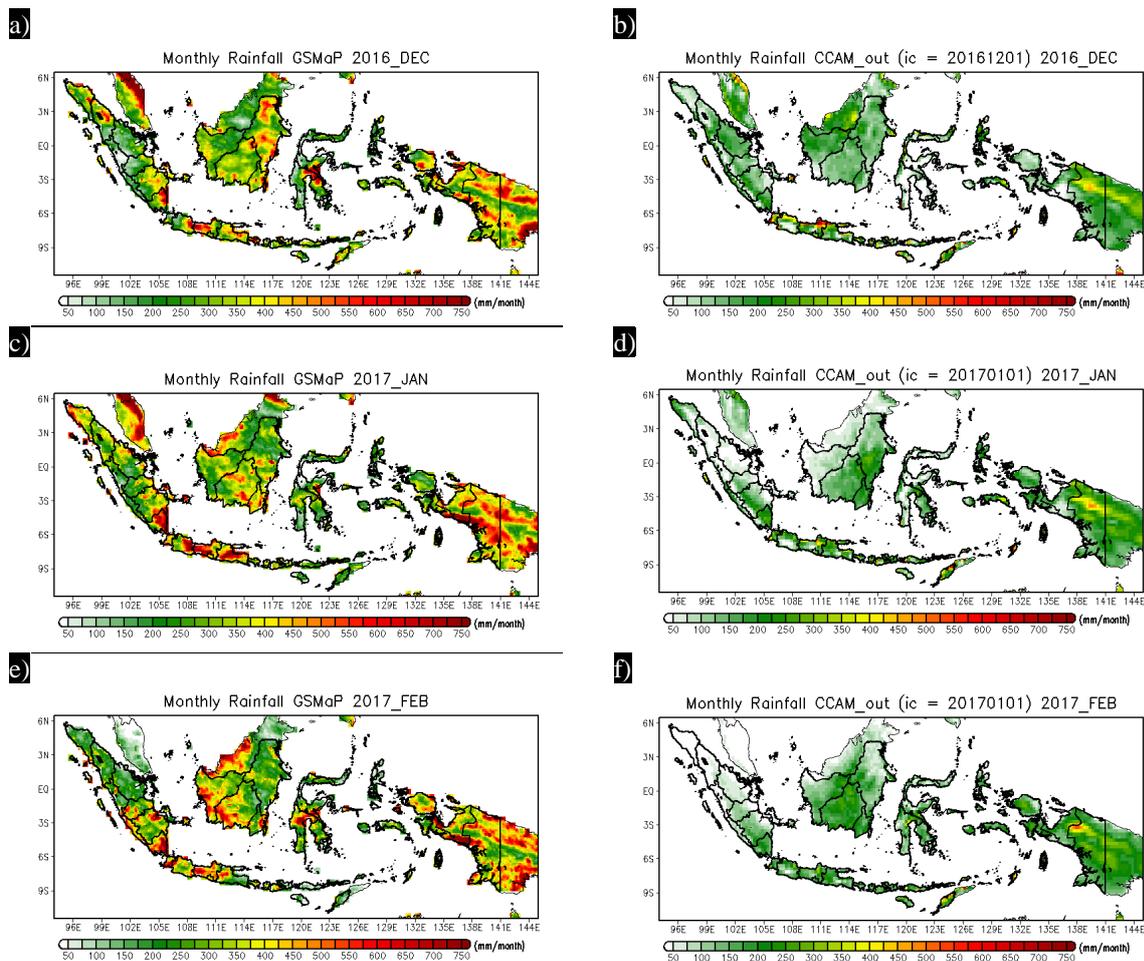


Figure 6. Same as Figure 5, but during wet months 2016/2017(DJF), which are respectively a) GSMaP for December 2016, b) CCAM for December 2016, c) GSMaP for January 2017, d) CCAM for January 2017, e) GSMaP for February 2017 and f) CCAM for February 2017

While the prediction of CCAM for rainfall in the DJF 2016/2017 (wet months) (Figure 6), has a high difference with the underestimate value compared to GSMaP. High rainfall that occurs in these months, still cannot be shown by the results of the prediction, although there is an increase in rainfall predicted results when compared with the predicted rainfall in the dry months. But the results are almost the same as the prediction in the dry months, namely the northern region (northern Sumatra, northern Borneo). This will be the focus for future research, the other way is to multiply experiments using different SST ensemble predictions, different initial data or different parameterize models.

4. Conclusion

The season prediction conducted in this study resulted in a prediction of spatial rainfall with a spatial resolution of 32 km for the Indonesian region. CCAM's predicted monthly rainfall for Java and Bali Island has a high correlation when compared to GSMaP rainfall. Even so, in general the predicted precipitation tends to be below the GSMaP rainfall value. Whereas for the northern Sumatra and northern Borneo regions, the CCAM prediction results are still unable to provide good results, both predictions of wet and dry months. And the high rainfall that occurs during the wet months is still not well demonstrated by the CCAM prediction results, although the decrease of rainfall during the dry

months and the increase of rainfall in the wet months in the southern part of Indonesia already well predicted by CCAM.

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