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Simulation of Large Scale Resolution IAP DCP Model for Pre-Monsoon and Southwest Monsoon Events over Indo China Peninsular

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Abstract: The aim of this research was to use the Institute of Atmospheric Physics Dynamical Seasonal Prediction (IAP DCP) Model to simulate rainfall over the Indochina Peninsular with a domain of 5° by 4° grid spacing. The IAP DCP Model was shown to simulate monsoon events over the ICP during the pre-monsoon and Southwest monsoon seasons during a period starting in the year 2000 and concluding in 2015. The observation data was compared to the results from The Global Precipitation Climatology Project Version-2.3 (GPCP). Gathering the area average rate of rainfall was the first step in comparing the results between the IAP DCP and GPCP. The second step used a statistical method (RMSE and MAE) to compare the results from the IAP DCP. The third step, regarding the mean rate of rainfall spatial distribution of pre-monsoon, can capture the trend rate of rainfall over the centre and North of Thailand. In the same way, the mean rate of rainfall spatial distribution of Southwest monsoons is accepted over India, Myanmar, Laos and Thailand. In general, the performance of simulation by the IAP DCP gave a good rate of rainfall area prediction when compared with GPCP data over the ICP. However, the mem_mean performed better in simulating statistics and spatial distribution when compared with other members. The mem_mean technique of seven members demonstrated an improved performance for the rate of rainfall and showed good statistical value in this research.

Key words: LAP DCP, GPCP, pre-monsson, Southwest monsoon, statistical, rainfall, Physics

INTRODUCTION

The Indo China Peninsular (ICP) is a geographically unique entity situated between the Indian subcontinent and East Asia. This area is quite variable because it's more influenced by monsoon events such as the South Asian, East Asian and Australian monsoons. The countries in the ICP include Cambodia, Laos, Myanmar, Vietnam, Thailand and some territories of Malaysia (Sooktawee *et al*., 2012, 2014). Climate change over the ICP affects not only the agriculture within this region but also the local economy. Hence, the full prediction of the impacts of climate variability on inter-season inter annual and inter-decadal time scales is of primary importance for countries in and around the ICP, especially, regarding rainfall and temperature parameterisations. The climate variability and study mechanisms of monsoons over the ICP has been summarised in many previous studies (Matsumoto, 1997; Wang and Fan, 1999; Wu and Wang, 2000; Takahashi and Yasunari, 2006; Caesar *et al*., 2011, Zhou *et al*., 2011; Sooktawee *et al*., 2012, 2014; Hsu *et al*., 2014). By Chen *et al.* (2012), it was shown that the inter-annual variations of autumn rainfall in central Vietnam is influenced by rain-producing weather systems. Nguyen *et al.* (2014) investigated rainfall and temperature variability for the whole of Vietnam during the period 1979-2010, revealing relationships between El Nino-Sothern Oscillation (ENSO) and rainfall and temperature variability. Matsumoto (1997) described rainfall over the inland area of the ICP during pre-monsoon season. Chen and Yoon (2000) have shown that the ICP Southwest monsoon rainfall is related to the variation in sea surface temperature and the frequency of the occurrence of Westward-propagating weather disturbances in the Western tropical Pacific monsoon.

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Kodama *et al*. (2005) have identified large-scale seasonal changes in rainfall such as an increase in rainfall during pre-monsoon season over land and over sea in the beginning of the Southwest monsoon season. Takahashi *et al*. (2010) described the seasonal changes of the diurnal rainfall cycle over the ICP with a focus on the pre-monsoon season and the first and second halves of the monsoon season. Although, understandings of seasonal climate change over the ICP have been noted, this research addresses one of the most challenging problems of protection from natural disaster by examining the simulation and forecasting of seasonal climates over the ICP using the dynamic model prediction. A good estimate of climate is crucial to helping the risk assessment policies for increasing demands from agricultural industrial and domestic sectors in the ICP.

Following by Chen and Yoon (2000), this is consistent with the IAP DCP Model, since, this model can simulate and forecast climate depending on initial data from an atmosphere and initial data from Sea Surface Temperature (SST). However, in undertaking this research, we adopted 16 years of forecasting results from the IAP DCP Model to simulate the rate of rainfall during pre-monsoon and Southwest monsoon seasons over the ICP. The result of simulation was compared with the rate of rainfall from the Global Precipitation Climatology Project (GPCP). These figures will provide information for the improvement of rainfall simulation over the ICP.

MATERIALS AND METHODS

The IAP DCP is an Atmospheric General Circulation Model (AGCM). It was developed and designed by the Institute of Atmospheric Physics, Chinese Academy of Science (Xinzhong, 1996; Chidiezie *et al*., 1997; Qingcun *et al*., 1998). The IAP DCP is a global grid point model with 5×4 horizontal resolution and nine unequally spaced vertical layers with a top at 10 hPa, following by Xinzhong (1996)'s description of the structure of the IAP DCP Model and detail of Physics options. The Physics options of the IAP DCP include moist processes, radiation, Planetary Boundary Layer (PBL) and land surface. The moist, dry and moist adjustment processes are assumed to occur in the free atmosphere and instantaneously redistribute the atmospheric properties in the vertical column while no precipitation or cloud is produced. In contrast, both shallow and penetrative convections are assumed to originate in the PBL and are thought to carry its mean properties into the free atmosphere. Shallow (non-precipitating) cumulus convective is parameterised by the Albrecht *et al*. (1986) scheme and the penetrative (precipitating) cumulus convection is simulated by the Arakawa and Schubert (1974) scheme as implemented by Lord. The radiation and both solar and terrestrial radiation schemes are adopted from NCAR CCM1 from Kiehl *et al*. (1987), except for cloud emissivity and surface Albedo/emissivity. The PBL has the same water vapour content as the model lowest layer. The land surface consists of the two layers soil model, a surface energy balance model and a primitive plant canopy model, coupled with the PBL Model.

Much research was used in conjunction with the IAP DCP to simulate monsoons over the coun. The findings of Lin *et al*. (1996) were modified by introducing a set of climatological surface albedo data and monthly mean features of the Southwest monsoon rainfall over East Asia. The results show a good performance of rainfall simulation with great potential to serve as a useful tool for the prediction of Southwest drought and flood events over East Asia. Chineke found that the model holds great promise in simulating the African climate within and across the season. Feng *et al*. (2001) used the IAP DCP to simulate the global monsoon system. The results indicate that the model completely simulates the monsoon system over a low troposphere. Lang *et al*. (2003) studied the extra seasonal short term ensemble simulation of a winter climate over a 30 years period (1969-1998) and used the IAP DCP 9 level to predict global models in this case. Lang *et al*. (2004) used the IAP DCP, 9 level to predict a global extra seasonal short-term model in predicting Southwest climates based on ensembles taken in June, July and August (JJA) simulation during 1970-1999. Hong and Zhao-Hui (2009) used the IAP DCP to simulate the inter-annual variation of the South China Sea Southwest Monsoon (SCSSM). All of the above studies indicate good performance of the IAP DCP in simulated climatology, climate changes and so on which undoubtedly increases our confidence in using it to perform extra seasonal short-term predictions during pre-monsoon and Southwest monsoon seasons over the ICP.

The simulation described in this study was performed by the IAP DCP. For each simulation, the model atmosphere was initialised from the National Centers for Environmental Prediction (NCEP) with 1×1 horizontal resolution including 26 level geopotential height, air pressure, wind, relative humidity, air temperature and near-ground geopotential, air pressure, wind and air temperature. The initial data of real-time global monthly mean SST with 1×1 during 2000-2015 was also obtained from the NCEP. The observation data used in this study is The Global Precipitation Climatology Project Version 2 (GPCP). The GPCP Version 2 mnthly pecipitation analysis is described. This is a globally complete, monthly analysis of surface precipitation at 2.5×2.5° resolution. This data is available from January 1979 to the present. It is a merged analysis that incorporates precipitation estimates from low-orbit satellite microwave data, geosynchronous-orbit satellite infrared data and surface rain gauge observations. The merging approach utilises the higher accuracy of the low-orbit microwave observations to calibrate or adjust the more frequent geosynchronous infrared observations (Robert *et al*., 2003; Huffman *et al*., 2009).

In this research, we focus our attention to the period during pre-monsoon (March-April-May (MAM)) and Southwest monsoon (June-July-August (JJA)) of Asian monsoon for each year for the period 2000-2015. Each of the Southwest runs was started on February 22-28 and ran through to the end of August, respectively; we analyse the March-April-May (MAM) means and June-July-August (JJA) means. For each year, anomalies for the AGCM simulations are computed by subtracting the model climatology from an ensemble mean of seven simulations with each ensemble member differing in both the starting time and initial atmospheric conditions. The model climatology is the JJA average of control runs for 2000-2015.

This study included the Root Mean Square Error (RMSE) which is one of the statistic methods to measure model performance. RMSE is also known as an error. If RMS = 0, there is no error if the root mean is square the error is nearly 0, simulations are good results from the model and RMS = 0 is a perfect result from the model. Each simulation-observation pair gives an error value. This measure sums the absolute values of these errors and divides by the number of forecasts to give an average error. If the MAE is near 0, the simulations are a good estimate and MA = 0 for a perfect estimate (Wilks, 2006). The RMSE is defined by the following equation:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (x_i - y_i)^2}{n}}$$

Where:

RMSE = A Root Mean Square Error
x = The simulation value
y = The observation value and
n = The number of
i = Pairs of observation and simulation values

The MAE is defined by the following equation:

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |x_i - y_i|$$

Where:

RMSE = A Root Mean Square Error
x = The simulation value
y = The observation value and
n = The number of
i = Pairs of observation and simulation values

RESULTS AND DISCUSSION

In this study, we used 15 years of simulation by the IAP DCP Model to simulate the rate of rainfall during the pre-monsoon (MAM) and Southwest monsoon (JJA) seasons over the ICP. The results of simulation were compared with the rate of rainfall from the Global Precipitation Climatology Project (GPCP). The results shown were an average monthly rate of rainfall, mean rate of rainfall spatial pattern and the computing of RMSE and MAE during 2000-2015.

The ICP region is located at a latitude of 5-30° North and a longitude of 90-110° East and consists of Cambodia, Laos, Myanmar, Vietnam, Thailand and some territories of Malaysia as shown in Fig. 1.

The average monthly rate of rainfall between the IAP DCP and GPCP in March-August. The average seasonal rate of rainfall between IAP DCP and GPCP in the pre-monsoon and Southwest monsoon seasons. Figure 2 and 3 show the area average monthly rate of rainfall during 2000-2015 for the month of March, (Fig. 2a), April (Fig. 2b), May (Fig. 2c), June (Fig. 3a), July (Fig. 3b) and August (Fig. 3c), respectively. Figure 4 shows the area average seasonal rate of rainfall during the 2000-2015 pre-monsoon (Fig. 4a) and Southwest monsoons (Fig. 4b), respectively. The dash line represents the seven members from the IAP DCP, the black line shows the member mean of seven members and the blue line indicates GPCP data.

The area average rate of rainfall in March (Fig. 2a) during 2000-2015, almost all the years of IAP DCP was

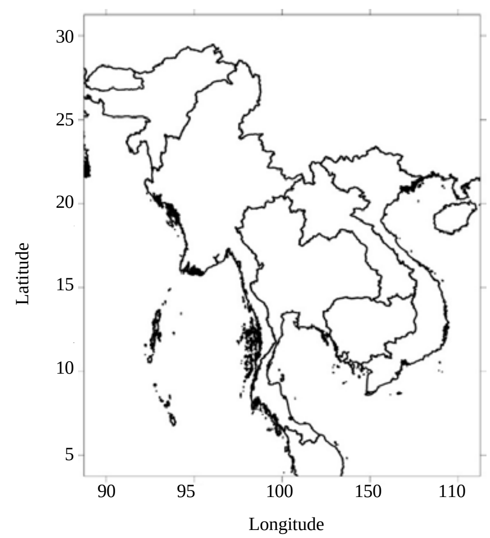

Fig. 1: The modelling domain was covered by a latitude of 5-30° North and a longitude of 90-110° East for the purpose of this research

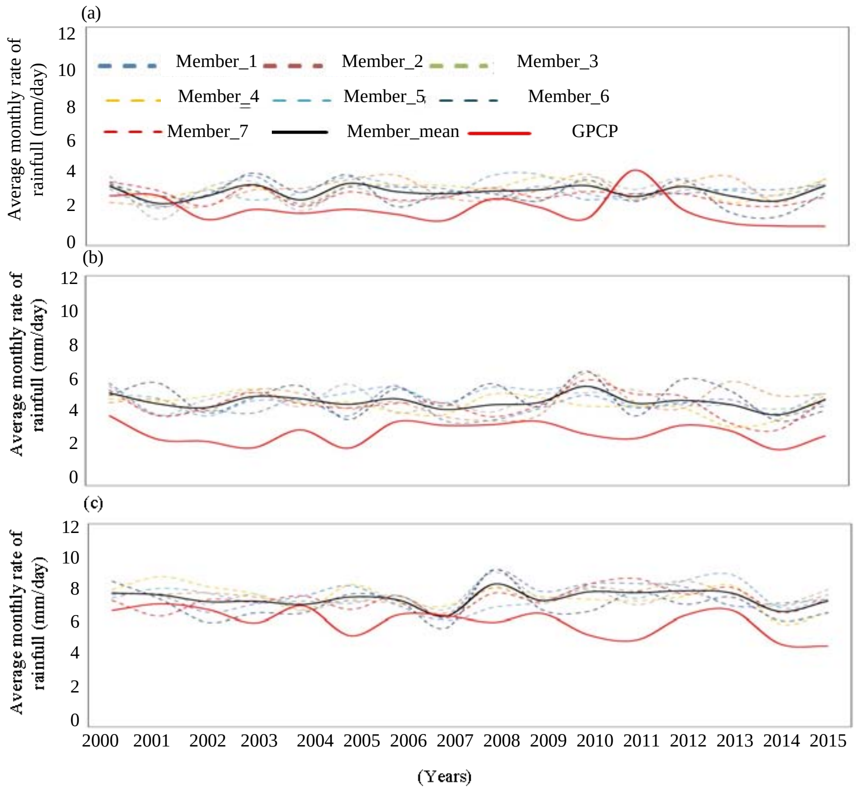

Fig. 2: The comparison of the observed average monthly rate of rainfall (mm/day) over the ICP in a) March; b) April and c) May during 2000-2015

overestimated in GPCP data but in 2001 and 2011 was underestimated in GPCP data. In the case area average rate of rainfall in April (Fig. 2b) during 2000-2015, it was shown to be overestimated in all case simulations. Figure 2c shows an overestimate from IAP DCP with GPCP in almost all cases for the month of May during 2000-2015 but this month has shown a good performance result in 2004 and 2007. The result of June Fig. 3a shows good trend results and captured good performance results in 2005-2015. The month of July, Fig. 3b has shown a good trend, similarly to June and captured good performance results in 2003- 2015. The case area average rate of rainfall in August (Fig. 3c) during the period 2000-2015 was shown to be underestimated in all case simulations and showed good performance rates in 2001.

The area average rate of rainfall in pre-monsoon (Fig. 4a) during 2000-2015 was underestimated in all instances of case simulation. The results of the Southwest monsoon (Fig. 4b) showed good trend results and captured good performance results in 2001-2015.

However, the results from the IAP DCP captured the trend of an area average rate of rainfall with GPCP data. The results were shown to overestimate the rate of rainfall in March-May and pre-monsoon season. On the other hand, the results were shown to underestimate rate of rainfall in August. Obviously, the IAP DCP results showed a good performance rate of rainfall with GPCP data in June, July and Southwest monsoon.

The Root Mean Square Error (RMSE) and Mean Square Error (MAE) were used for comparison. Table 1 shows the RMSE and MAE of seven members with a member mean for March-August, pre-monsoon and Southwest monsoon during 2000-2015. The comparison with GPCP data reveals that the RMSE and MAE have good performance. The RMSE is a first step method to check the accuracy and performance of a model. The great RMSE values for March-August, pre-monsoon and Southwest monsoon are mem_1(1.583), mem_3(3.039), mem_3(4.129), mem_5(4.556), mem_7(4.360), mem_7(3.359), mem_3(2.537) and mem_7(3.840), respectively. The smaller RMSE values for March-August, pre-monsoon and Southwest monsoon are mem_mean(1.306), mem_mean(2.687), mem_mean(3.558), mem_mean(3.904), mem_mean(3.689), mem_mean(3.105), mem_mean(2.352) and mem_mean (3.598), respectively.

The MAE is a second statistics method to check an accuracy and performance from model. The greater

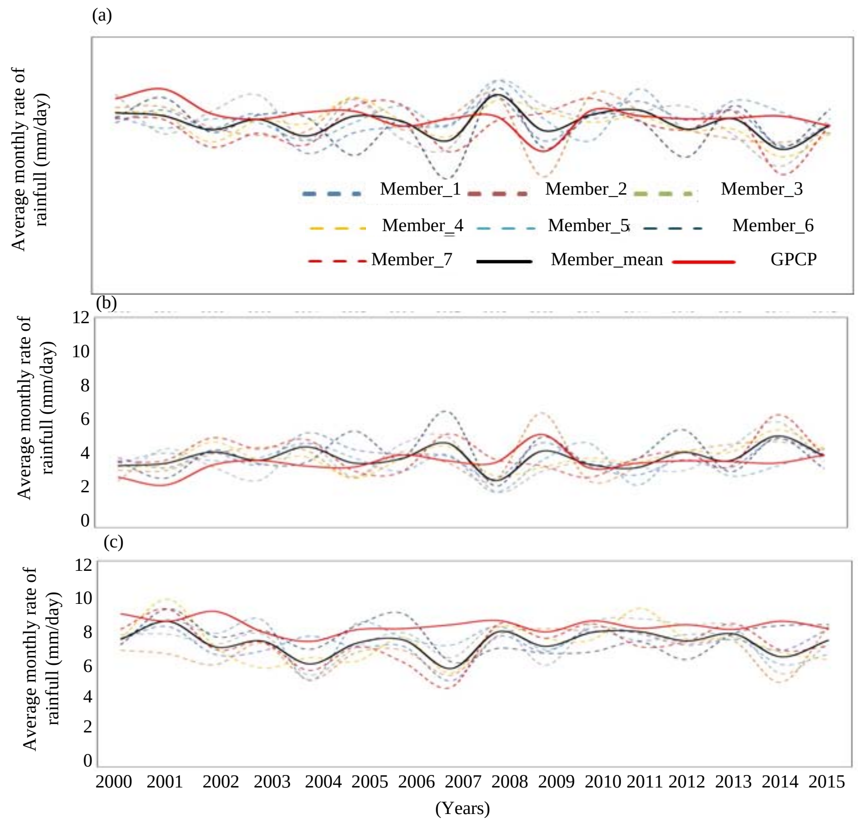

Fig. 3: The comparison of the observed average monthly rate of rainfall (mm/day) over ICP in a) June; b) July and c) August during 2000-2015

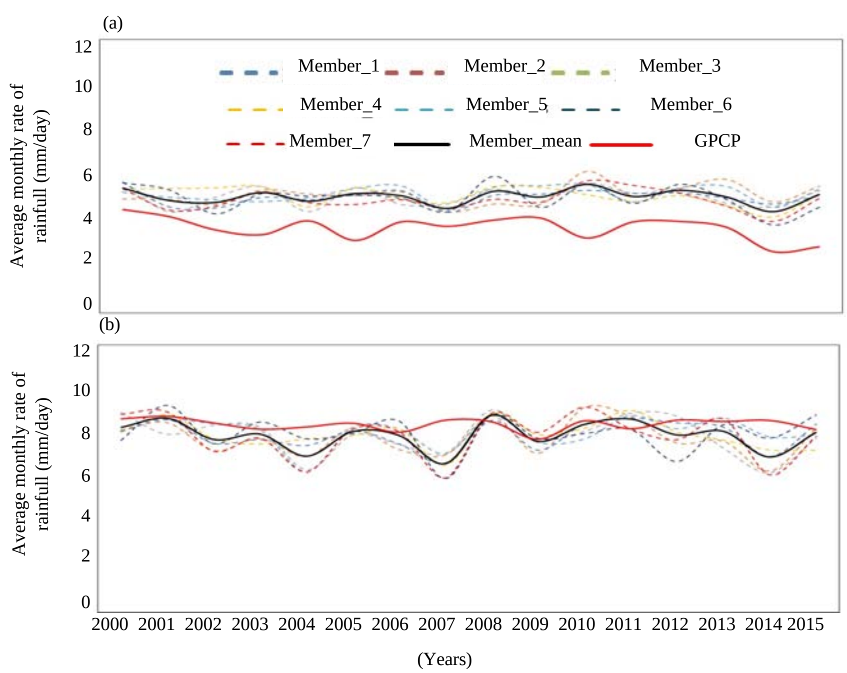

Fig. 4: The comparison of the observed average monthly rate of rainfall (mm/day) over the ICP in the; a) Pre-monsoon and b) Southwest monsoons during 2000-2015

Table 1: Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) of 7 members from results of IAP DCP during 2000-2015

Years/Factors	mem_1	mem_2	mem_3	mem_4	mem_5	mem_6	mem_7	mem_mean
March								
RMSE	1.583	1.486	1.486	1.560	1.572	1.540	1.521	1.306
MAE	1.490	1.457	1.413	1.550	1.509	1.395	1.328	1.237
April								
RMSE	2.968	2.849	3.039	2.922	2.889	2.849	2.941	2.687
MAE	2.655	2.625	2.667	2.589	2.501	2.714	2.535	2.491
May								
RMSE	3.831	3.809	4.129	3.612	4.027	3.993	3.863	3.558
MAE	3.149	3.133	3.330	2.900	3.290	3.267	3.178	2.850
June								
RMSE	4.508	4.491	4.155	4.262	4.556	4.081	4.321	3.904
MAE	3.149	3.133	3.330	2.900	3.290	3.267	3.178	2.850
July								
RMSE	4.242	4.177	4.316	4.320	4.212	4.194	4.360	3.689
MAE	3.163	3.149	3.278	3.194	3.164	3.124	3.350	3.065
August								
RMSE	3.369	3.480	3.343	3.338	3.337	3.275	3.359	3.105
MAE	2.755	2.849	2.664	2.673	2.766	2.624	2.754	2.586
Pre-monsoon								
RMSE	2.494	2.425	2.537	2.408	2.534	2.446	2.420	2.352
MAE	2.226	2.192	2.306	2.177	2.232	2.172	2.110	2.081
Southwest monsoon								
RMSE	3.826	3.833	3.766	3.771	3.819	3.666	3.840	3.598
MAE	2.967	2.993	2.915	2.898	3.010	2.826	3.019	2.804

MAE values for March-August, pre-monsoon and Southwest monsoon are mem_4(1.550), mem_6(2.714), mem_3(3.330),mem_3(3.330),mem_7(3.350),mem_2(2.849), mem_3(2.306) and mem_7(3.019), respectively. The smaller MAE values for March-August, pre-monsoon and Southwest monsoon are mem_mean(1.237), mem_mean(2.491),mem_mean(2.850),mem_mean(2.850), mem_mean(3.065), mem_mean(2.586), mem_mean(2.081) and mem_mean (2.804), respectively.

However, the value of RMSE and MAE show good accuracy and performance in all results from the IAP DCP. The mem_3 shows a greater value RMSE than other members in the month of pre-monsoon (April and May) and pre-monsoon. The mem_3 of MAE shows a greater value than other members in the month of the Southwest monsoon (April) and pre-monsoon. It is guaranteed that the mem_3 will give lower accuracy than other members in the pre-monsoon. The mem_7 shows a greater value of RMSE than other members in the month of the Southwest monsoon (July and August) and Southwest monsoon. The mem_7 of MAE shows a greater value than other members in the month of the Southwest monsoon (July) and Southwest monsoon. It is guaranteed that the mem_7 will give lower accuracy than other members in the Southwest monsoon. It is guaranteed that the mem_7 will give lower accuracy than other members in the Southwest monsoon. On the other hand, the mem_mean shows a lower RMSE than other members in the month of pre-monsoon (March, April and May) and pre-monsoon. The mem_mean of MAE shows a lower rate than other members, similarly to RMSE. It is guaranteed that the mem_mean will give good accuracy when compared to other members in the pre-monsoon. The mem_mean was shown the lower RMSE than other member in month of the Southwest monsoon (June-August) and Southwest monsoon. The mem_mean of MAE was shown to be lower than other members, similarly to RMSE. It is guaranteed that the mem_mean will give good accuracy when compared to other members in the Southwest monsoon.

Following the statistical method which concludes that the mem_mean shows greater accuracy and performance than other members, the mean spatial rainfall rate distribution of the pre-monsoon and Southwest monsoon over the ICP during 2000-2015 was compared between mem_mean with GPCP data. This study focused on the seasonal prediction, so, we were interested in seasonal results rather than monthly. Hence, the spatial pattern shows the rate of rainfall in the pre-monsoon and Southwest monsoon from IAP DCP compared with GPCP data. Figure 5a shows the IAP DCP mean rate of rainfall distribution for pre-monsoon during 2000-2015 over the ICP. The rate of rainfall was shown at the highest value of 8-12 mm/day over the Andaman Sea, Myanmar, North of Thailand, North of Laos, North of Vietnam and South of China. The rate of rainfall of about 2-6 mm/day covers the Centre and Northeast of Thailand, Centre of Laos and centre of Vietnam. The GPCP data (Fig. 5b) shows a higher rainfall pattern value of 8-12 mm/day over the lower Andaman Sea, around bound North and South of Myanmar, North of Cambodia and South of China.

Figure 6a shows the IAP DCP mean rate of rainfall spatial distribution during the Southwest monsoon (JJA) between 2000 and 2015 over the ICP. The highest rate of

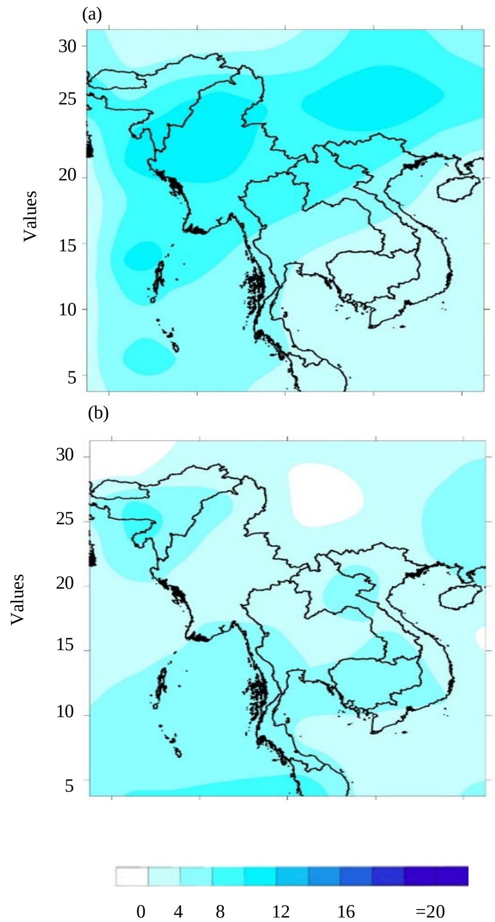

Fig. 5: The mean spatial pattern rate of rainfall (mm/day); a) The ensemble mean of IAP DCP and b) GPCP data on pre-monsoon (MAM)

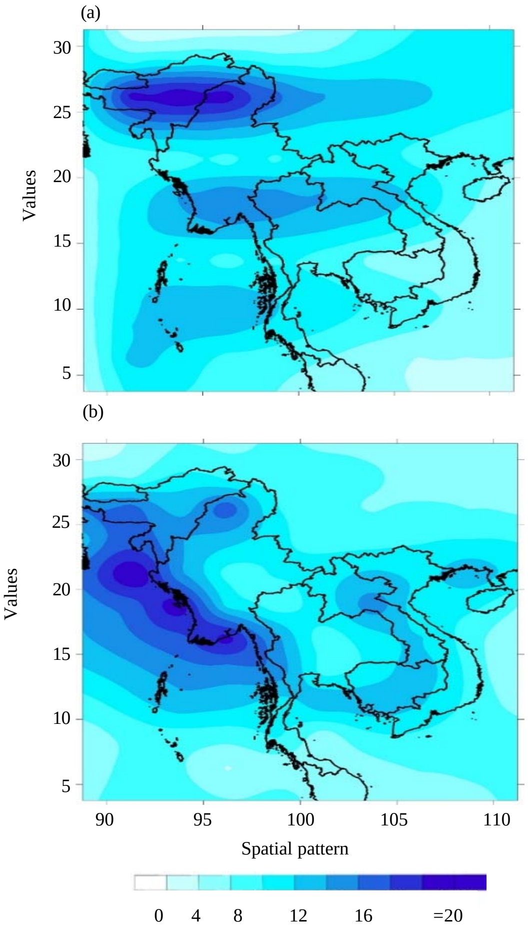

Fig. 6: The mean spatial pattern rate of rainfall (mm/day); a) The ensemble mean of IAP DCP and b) GPCP data on the Southwest monsoon (JJA)

rainfall value is 18-20 mm/day shown around India. The rate of rainfall pattern was show higher value 8-12 mm/day over Andaman Sea, Myanmar, Thailand, Laos, Vietnam and South of China. The value of about 2-6 mm/day covers the Centre of Vietnam, Centre of Cambodia and Centre of Vietnam. The GPCP data (Fig. 6b) shows the highest rate of rainfall pattern (18-20 mm/day) over India and bound towards Myanmar near the Andaman Sea. The rate of rainfall pattern was shown to be of a higher value of 8-12 mm/day over the lower Andaman Sea, bound North and South of Myanmar, North of Cambodia and South of China.

In general, from the ensemble of IAP DCP results on the pre-monsoon, we can capture the trend of rainfall spatial distribution and conduct acceptable simulations using the IAP DCP for the centre and Northeast of Thailand. In the case of Southwest monsoon results, we can capture the trend rate of rainfall spatial distribution over India, Myanmar, Laos and Thailand.

CONCLUSION

This research investigates the IAP DCP for the simulation of monsoons over the ICP. The 16 years of simulation from the IAP DCP simulated the rate of rainfall during the months of pre-monsoon, Southwest Monsoon, Pre-Monsoon (MAM) and Southwest monsoon (JJA) over the ICP. The results of simulation were compared to the rate of rainfall from the Global Precipitation Climatology Project (GPCP) which in the case of the month in pre-monsoon was shown to overestimate the area average. The rate of rainfall in August was shown to be underestimated with GPCP data. Obviously in the IAP DCP, results were shown to have a good performance rate of rainfall when compared with GPCP data in June, July and the Southwest monsoon. In statistical part, the results of the mem_mean from the IAP DCP presented with good performance compared to other members in all case simulations. The mean rate of rainfall spatial distribution for the pre-monsoon can capture the trend rate of rainfall over the centre and North of Thailand. In the same way, the mean rate of rainfall spatial distribution of the Southwest monsoon is accepted over India, Myanmar, Laos and Thailand. In general, the performance of simulation by the IAP DCP gave a good rate of rainfall area prediction, compared to GPCP data over the ICP. However, the mem_mean performed better in simulating statistics and spatial distribution, compared to the other members. The mem_mean technique of seven members demonstrated an improved performance rate of rainfall and showed good statistical value in this research.

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