Evaluation of Southwest Monsoon Change over Thailand by High-resolution Regional Climate Model under High RCP Emission Scenario

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Abstract. The 5×5 km resolution of Non-Hydrostatic Regional Climate Model (NHRCM) developed by Meteorological Research Institute, Japan was used to evaluate the southwest monsoon season that affects to Thailand during mid-May until mid-October in each years. Bulk-type cloud microphysics, Kain-Fritsch convective scheme, Mellor-Yamada-Nakanishi-Niino level 3 PBL scheme, clear-sky radiation scheme and Hirai-Ohizumi land surface scheme are used as model configuration to simulate climate data under high emission scenario-RCP 8.5. This research was conducted for 2 time periods, i.e., baseline period (1981–2000) and future period (2080–2099), to estimate the southwest monsoon season onset and offset over Thailand by using average wind vector and cumulative precipitation in consecutive 5 days (pentad). Furthermore, the rain-break phase, less precipitation ranges during the southwest monsoon season, had also been analysed.

1. Introduction

Thailand climate is controlled by 2 monsoons, i.e., northeast and southwest monsoons. The former monsoon brings cold and dry air from south China to Thailand which starts in mid-October and end in mid-February. The later one which firstly arrives by mid-May brings the warm and moist air from Indian Ocean and Bay of Bengal. In this research, only the southwest monsoon which brings high precipitation amount together with south-westerly wind, is interested.

1.1. Southwest monsoon

The southwest monsoon of Thailand starts by mid-May when the weakened easterly wind changes to the stronger westerly wind and ends by mid-October when the westerly wind becomes weakened. During the monsoon season in Thailand, the westerly wind is formed over the Indian Ocean and moves to Thailand, passes Bay of Bengal and brings the warm and moist air to Thailand. The combination of the monsoon and the Inter Tropical Convergence Zone (ITCZ) cause a large amount of rainfall over Thailand during rainy season (mid-May to mid-October). Interestingly, there is rain break period, during late June to mid-July, when the ITCZ moves upward and weaker south-westerly wind was found. It can be divided to 4 phases of the southwest monsoon season over Thailand.

1.1.1. Onset: : Heat capacity of land is about half of its water so that when the domain within latitude 30°N to 30°S gets high solar radiation from the sun that causes the difference of pressure between the land and the Indian Ocean. Therefore, westerly wind occurs and brings the warm moist air to Thailand in mid-May.
1.1.2. Rainy season: ITCZ where the northeast and southeast trade winds converge lies over Thailand also the equatorial zone obtains continuous solar radiation. In this phase, there is more convection so that large amount of rainfall occurs over Thailand.
1.1.3. Rain Break: ITCZ moves upward to southern China since June. The observation shows that daily precipitation during this period is usually less than 1 mm/day. After 2-4 weeks, the ITCZ moves southerly across Thailand again.
1.1.4. End of season: By mid-October when the westerly wind becomes weakened and ITCZ retreats to southern hemisphere so that the precipitation amount decreases most of Thailand.

1.2. Regional climate model
The Non-Hydrostatic Regional Climate Model (NHRCM) has been developed by Meteorological Research Institute, Japan. The model can be applied to study climate regimes over all regions of the world at high resolution, i.e., 5×5 km. The model was set up as the following configuration as shown in table 1.

Table 1. The model configurations were used to driven the model

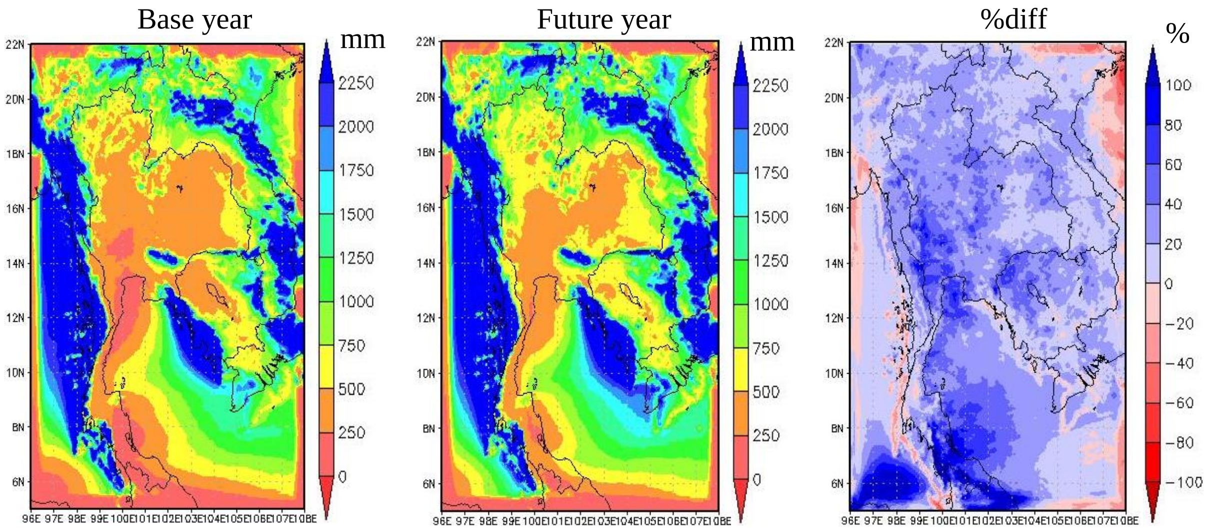
Physics options	Selected scheme
Cloud microphysics	Bulk-type Cloud microphysics (Ikawa et al. 1991)
Cumulus convective	Kain-Fritsch convective scheme (Kain and Fritsch 1990; Kato et al. 2010)
Planetary boundary layer	Mellor-Yamada-Nakanishi-Niino level 3 scheme (Nakanishi and Niino 2004)
Radiation	Clear-sky radiation scheme (Yabu et al. 2005) and cloud radiation scheme (Kitagawa 2000)
Land surface	Land surface scheme (Hirai and Ohizumi 2004)

1.3. Monsoon definition
There are variety of monsoon definitions, however, in this study, precipitations and horizontal winds were analysed to 5 consecutive days (pentad) and satisfied the following conditions:
1.3.1. Precipitation: The cumulative precipitation in the onset pentad must be higher than 25 mm. On the other hand, the precipitation of the end pentad of southwest monsoon season must be lower than 25 mm.
1.3.2. Horizontal wind: The wind direction at upper layer (250 mb) and lower layer (850 mb) must be changed at least 120° from the previous pentad.

2. Methodology
The simulations of southwest monsoon precipitation over Thailand were conducted by NHRCM at 5×5 km resolution with 50 vertical levels forced by the 20 km resolution MRI-AGCM3.2 model. The model was driven under the RCP 8.5 emission scenario, the highest emission of CO_2 in the exponential curve, cause of the increasing of CO_2 in nowadays – 21th century. The domain covers Thailand and parts of its neighbouring countries located in latitude of 4.6 °N - 22.1 °N and longitude of 93.7 °E - 107.7 °E. The simulated precipitation during monsoon period (JJAS) over future period (2080-2099) was compared to baseline period (1981-2000) to indicate precipitation change. To investigate the southwest monsoon onset and offset, accumulated rain for 5 consecutive days, and averaged pentad horizontal wind were analysed. (i) The precipitation amount in 1 pentad was higher than 25 mm. (ii) The 850 mb wind must change 120° from the previous pentad and must be in south or southwest direction. (iii) In the same pentad, the 250 mb wind direction must be changed to the opposite direction of the 850 mb wind.

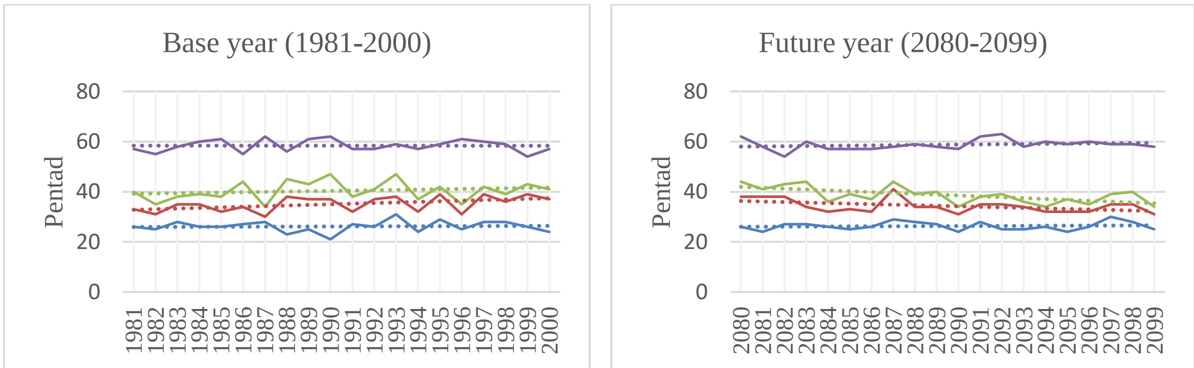
3. Results and discussion

Spatial pattern of total precipitation in the monsoon period (JJAS) over future projection (2080-2099) reveals the similar pattern as the baseline period (1981-2000) as shown in figure 1 (a) and (b). To clarify, high precipitation amount was obviously detected in the same regions, for example, leeward side of western Thailand. The increasing precipitation was found across Thailand (figure 1 (c)). The increasing precipitation was found over most regions especially over upper Malaysia (up to 100%), the lower south part of Thailand (80-100%) and central of Thailand (20-80%). However, precipitation over the west coast of Thailand and south Myanmar (Andaman coast) slightly decreases (0-40%). Figure 2 shows the time series of the monsoon onset, rain break and monsoon offset over Thailand during baseline period and projections.



(a) (b) (c)

Figure 1. The total precipitation in JJAS over (a) base year (1981-2000), (b) future year (2080-2099) and (c) percentage difference between projections compared to baseline period.



(a) (b)

Figure 2. Southwest monsoon onset (blue), beginning of rain break (red), end of rain break (green) and monsoon offset (purple) during (a) in the baseline period (1981-2000) and (b) future period (2080-2099).

The duration of southwest monsoon active in the projection remains the same as baseline period. The variation of southwest monsoon onset and offset seems reduce in the projection. The rain break phase occurs after the monsoon onset about 7-9 pentads. To evaluate the monsoon changes, average and standard deviation of the monsoon onset, beginning of rain break, end of rain break and monsoon offset were calculated as shown in the table 2.

Table 2. Average and standard deviation (pentad) of southwest monsoon onset, beginning of rain break, end of rain break and monsoon offset.

	Base year		Future year	
	Pentad	SD	Pentad	SD
Onset	26.15 (6 – 10 May)	2.1972	26.30 (6 – 10 May)	1.6462
Beginning of rain break	35.10 (20 – 24 June)	2.9309	34.30 (15 – 19 June)	2.6287
End of rain break	40.40 (15 – 19 July)	3.6932	38.65 (5 – 9 July)	3.2600
End of monsoon	58.35 (13 – 17 October)	2.3511	58.75 (13 – 17 October)	2.0218

Table 2 shows that, the average southwest monsoon onset over Thailand during baseline period would begin at the 26^{th} pentad (6 May – 10 May) and the average monsoon offset would occur at the 58^{th} pentad (13 October – 17 October). The standard deviation were 2.20 and 2.35 pentads during the monsoon onset and offset, respectively. In the future projection, the average onset day was also in the same pentad as the baseline period. The standard deviation were 1.64 and 2.02 pentads during the monsoon onset and offset, respectively. The future year rain break period was slightly different from the base year. In the baseline year, the averaged rain break period starts in 35^{th} pentad (20 June – 24 June) and ends in 40^{th} pentad (15 July – 19 July) with the standard deviation of 2.93 and 3.69 pentads, respectively. For the future year the average rain break starts in 34^{th} pentad (15 June – 19 June) and ends in 38^{th} pentad (5 July – 9 July) with the standard deviation of 2.63 and 3.26 pentads, respectively.

4. Conclusion

The average southwest monsoon precipitation in JJAS over Thailand increases in the end of century. It might be concluded that wetter condition in the future would be influenced by the global warming conditions since higher greenhouse gas emission had been included in model simulations. The weather conditions were found over most of Thailand especially over the lower south part of Thailand and central Thailand. The southwest monsoon onset, offset and duration would remain the same as the baseline but there would be less variation. The monsoon break would become one pentad earlier and slightly shorter than baseline period.

5. References

[1] Cruz D T, Sasaki H and Narisma G T 2016 *J. Meteor. Soc. Japan* A **94** 165

[2] Holt E and Wang J 2011 *J. Appl. Meteor. Climate.* **51** 2188

[3] Hueging H, Haas R and Born K 2012 *J. Appl. Meteor. Climate.* **52** 903-17

[4] Gao X, Shi Y, Song R, Giorgi F, Wang Y and Zhang D 2008 *J. Meteor. Atmos. Phys.* **100** 73-86

[5] Hirai M and Oh'izumi M 2004 *Japan Meteor. Agen.* **1** 4-8

[6] Ikawa M, Mizuno H, Matsuo T, Murakami M, Yamada Y and Saito K 1991 *J. Meteor. Soc. Japan* **69** 641-67

[7] Kain J S and Fritsch J M 1990 *J. Atmos. Sci.* **47** 2784-802

[8] Kieu-Thi X, Vu-Thanh H and Nguyen-Minh T 2016 *J. Meteor. Soc. Japan* **94** 135-50

[9] Kitagawa H 2004 *Quarter. J. Royal. Meteor. Soc.* **130** 3245-67

[10] McGregor G R and Nieuwolt S 1998 *Tropical Climatology: Seasonal Variations in Regional Circulation System: The Monsoon* (West Sussex: WILEY)

[11] Sasaki H, Kurihara K, Takayabu I and Uchiyana T 2008 *SOLA* **4** 25-28

[12] Wakazuki Y, Nakamura M, Kanada S and Muroi C 2008 *J. Meteor. Soc. Japan* **86** 951-67

Acknowledgement

The author would like to express our sincere to MRI for providing the NHRCM data and boundary conditions and facility to conduct the research. The model simulation was support by SOUSEI program. Master degree study also supported by DPST project of Thailand.