Correlation between Heat Flux over the Indian Ocean and Rainfalls in Coastal Thailand by using the MM5 Numerical Model

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Abstract

Correlation between heat flux over the Indian Ocean and rainfalls in coastal Thailand by using the Pennsylvania State University / National Center for Atmospheric Research mesoscale model: MM5 is the method to study monsoon onset in Thailand. The study areas are over the Indian Ocean from Latitude 30\textdegree\ S to 30\textdegree\ N and Longitude 40\textdegree\ E to 120\textdegree\ E. The used data were during May to October since the years 1996 to 2000, and also covered the years where El Ni\~{n}o and La Ni\~{n}a were present. When the heat flux over the Southeast Indian Ocean was increased about 100 w/m\textsuperscript{2}, this persisted for approximately five consecutive days before the average onset date of the 15\textsuperscript{th} May in Thailand. Once the recorded increase in heat flux of five days had passed, it was then observed that after a period of eleven days this caused the onset of rainfalls at nine Thai meteorological stations. From the observations recorded the results showed a correlation between the development of heat flux and rainfalls. During the normal years (1996, 1999 and 2000) the correlation of the heat flux with the rainfalls data at the twelve primary meteorological stations in Thailand were computed by linear regression analysis and the best of these resulted in coefficient of determination($R^2$)= 0.782. The results (correlation between heat flux which obtained from MM5 model and amounts of rainfalls from weather observation stations) of this study is possible to be utilize by the Thai Meteorological Department to predict the onset day of southwest monsoon rainfall, mainly for agricultural activities more accurately procedure.

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1. Introduction

The origin of the southwest monsoon for Thailand is in the Southern Indian Ocean on the west side of Australian continent. Since Thailand is an agrarian economy, the onset of rainy season is an important factor for planning the growing activities of the agricultural industry. This study has assumed that all changes of heat flux over the Indian Ocean have correlation with rainfall in Thailand.

Since the in-situ meteorological data from the ocean is rare, the Pennsylvania State University / National Center for Atmospheric Research mesoscale model (known as MM5) model which has been cited as an effective model to use for the nature of this study (Bunker, 1976) was applied to investigate the onset of the southwest monsoon rain along the coast of Thailand during a five year period from 1996 to 2000. This covered the normal years of 1996, 1999 and 2000, as well as the years of 1997 and 1998 in which El Niño and La Niña were respectively presented. The rainfall data at the thirteen Thai primary meteorological observation stations were used to investigate the linkage of the meteorological data over the Indian Ocean and the onset monsoon rain in Thailand.

The result of correlation between heat flux obtained from MM5 model and amounts of rainfalls from weather observation stations showed that the changing pattern of heat flux over the Southeast Indian Ocean near Australia can be used to predict the onset of monsoon rain in Thailand rather accurately. The research will assess the new technique and methodology to predict the phenomena in each period of southwest monsoon on El Niño, La Niña and the normal years, also the pattern of the changing of monsoon in Thailand by using MM5 model technique to represent traditional technique which always depends on meteorologist experience. This study can be used as basic database for the concerned agencies and also for future research.

2. Methodology

Data and studying Areas

The study area covered the Indian Ocean and Southeast Asia from Latitude 30° S to 30°N and Longitude 40°E to 120° E. The vast Indian Ocean was divided into two areas. Area 1 was between Latitude 30°S to 30°N and Longitude 40°E to 120°E with grid size of 2.5×2.5 degree. Area 2 was between Latitude 30° to 28°N and Longitude 77°E to 109°E with grid size of 36×36 km² as shown in figure 1. The study period is 5 years from 1996 to 2000.

Since the in-situ meteorological data from the ocean is rare, the MM5 model has been cited as an effective model to use for the nature of this study. The Mesoscale Model MM5 has been developed by the US National Center for Atmospheric Research (NCAR) and has been used extensively around the world. (African countries, European countries, many countries of Asia: Thailand Bangladesh, Malaysia, China, Korea, Japan, India, Sri Lanka, Middle East countries, All of the Nordic countries and America)

The initial input data were derived from the European Centre for Medium-Range Weather Forecasts (ECMWF) with original grid size of 2.5×2.5 degree, such as air temperature (°C), u- and v- components of horizontal wind (m/s), relative humidity (%), geo-potential height (GPM), sea-level pressure(hPa), sea surface or skin temperatures (°C) at 00, 06, 12 and 18 UTC during April to October from 1996 to 2000. Excepted on the 1st to the 15th May 1996-2000 these data were computed hourly. The model was run with the following physical parameterization options: the simple ice resolvable-scale microphysics scheme, the Medium-Range Forecast (MRF) planetary boundary layer scheme, and the cloud radiation scheme.

(Note: UTC = Universal Time Coordinate, Thailand Local Time = UTC + 7).
This numerical model is based on the derivation of thermodynamic equation, the derivation of pressure tendency equation, the vertical momentum equation, and coordinates transformation. Data from Thailand were compiled from twelve primary meteorological observation stations which were Phetchabun, Ayuthaya, Prachinburi, Kamphaengsaen, Bangkok, Chanthaburi, Klongyai (Trat), Ranong, Takuapa, Phuket Airport and the town of Phuket and especially Rayong as shown in Figure 2, which are the most affected areas by the southwest monsoon. In this study, the value of coefficient of determination: $R^2$ of 0.75 (75%) is chosen as the criteria for acceptance (Haaland, 1989 and Hu, 1999). The outputs from this model are the twenty three vertical levels produced over twenty variables such as temperature, evaporation, wind including the heat flux etc. During the rainy season of Thailand from 1996-2000, we had compared rainfalls between result from MM5 model and rainfalls which obtained from observation stations of TMD all around the country. In the cases, this model has been used for forecasting and estimating convective system and the results indicate that the MM5 model has a good capability to estimate rainfall. (N.Akter and M.N. Islam, 2007)
3. Results and Discussion

Results

This numerical model was run and obtained more than meteorological 20 parameters such as heat flux as shown in Figure 3, moisture and wind pattern etc. MM5 model had calculated 18 levels from surface and vertically upward. Thus, some events or changes of some parameters over the Indian Ocean in detail are shown.

Based on study by the Thai Meteorological Department (TMD) using the long historical data normalized for the principal meteorological stations, the average onset of the southwest monsoon rain in Thailand occurs usually on the 15th of May every year (Personal communication with Mrs. Kornrawee Sithicheewapab, Senior Meteorologist of TMD).
In the El Niño year of 1997 the onsets of rainfalls at the meteorological stations of Phetchabun, Ayuthaya, Prachinburi, Kampaengsaen and Bangkok were different from the average date of the 15th of May. While in La Niña year of 1998, only Phetchabun, Kampaensaen and Rayong were later than the average onset date. This deviation from the average onset date may be caused by many local factors such as the location and topography of the meteorological observation stations (Siripong and Prakhammintara, 2001). However during the normal years the onsets of rainfalls at many stations were nearly the same as the average date of May 15th as for regions such as Chanthaburi, Rayong, Bangkok, Ranong, Takuapa and Phuket (as shown in Figure 4).

**Discussion**

**During Normal Years** (1996, 1999 and 2000): The result of MM5 model showed that the pattern of heat flux in the Southeast Indian Ocean during the onset of the southwest monsoon rainfalls in Thailand had slightly increased. We have looked carefully on the daily patterns by hours of heat flux during 1st of May to 15th of May and found out that the heat flux increased continuously from 00 UTC to 18 UTC with a maximum value reached at 15 UTC. From the 5th to the 6th May 1996 before the southwest monsoon onset in Thailand, the heat flux over the east side of Madagascar situated at Latitude 15°S to 30°S and Longitude 60°E to 100°E, and at the Bay of Bengal clearly showed significant increasing changes in the value of heat flux present. This changing pattern can be a sign of the southwest monsoon season to start its development in Southeast Asia (Murakami, 1992). That means that if there is the correlation between heat flux at the Indian Ocean and monsoon rainfalls in Thailand, then when heat flux over east side of Madagascar had changed, it can also indicate the significant change of monsoon rain in Thailand.
In this regard, during the pre-southwest monsoon onset in Thailand (from the 1st to the 15th of May 1996 to 2000), the heat flux nearby the coastal stations where the daily rainfalls data were collected, and the stations which receive the initial direct effect of southwest monsoon from the sea, showed insignificant changes. Moreover, before the onset of southwest monsoon in Thailand, the heat flux did not change significantly either in Indian Ocean area, except for that of the Bay of Bengal where the heat flux showed a significant decrease (Fein, 1980; Murakami, 1992; Ramanadham et al., 1973). We can use this lowering change of heat flux in the Bay of Bengal as an indication of the beginning of the onset of rainfall in Thailand. During the 4th to the 6th of May 2000 at the eastern side of Madagascar, the heat flux showed a continuous increase up until the 11th of May; especially on the 10th of May at the Southeast Indian Ocean on the Western side of Australia between Latitude 20°S to 30°S and 80°E to 110°E. This area is the major source of heat of the southwest monsoon and the onset of rainfall in Thailand (as shown in figure 4).

To determine the correlation of the heat flux in the ocean and rainfall at the twelve meteorological stations, both on the coast and inland, a linear regression analysis was used to compare the results for the stations in Thailand. When the heat flux over the Southeast Indian Ocean increased about 100 w/m², this persisted for approximately five consecutive days before the average onset date of the 15th May in Thailand. Once the recorded increase in heat flux of five days had passed, it was then observed that after a period of eleven days this caused the onset of rainfalls at nine Thai meteorological stations. From the observations recorded, the results showed a correlation between the development of heat flux and rainfalls. During the normal years, the correlation of the heat flux with the rainfalls data at the twelve primary meteorological stations in Thailand were computed by linear regression analysis and the best of these resulted in Rayong province with $R^2 = 0.782$. Where the physiography of the coast is similar to the Andaman Seacoast of Thailand, it usually has the direct effect of the southwest monsoon rain.

During the El Niño year (1997) the rainfall quantities at all twelve stations showed lesser values when compared to normal years (Grantz, 1996). For example, at Chanthaburi along the eastern coast of Thailand during the 21st to 30th of May 1997, there was no rain at all. A delay of the onset of the monsoon rains compared to the average start date of May 15th was also observed at most stations for El Niño year. Most stations showed the delay of the onset of monsoon rainfall during the El Niño year, except those situated along the west coast of the southern peninsula. For the stations located along the west coast, it was observed that the quantities of rainfall were nearly the same as the normal values and the onsets of
monsoon rain were close to the average day. This is probably due to the physiography of the Thai southern peninsular when compared to the northern mainland.

During the La Niña year (1998) the rainfall quantities were above the normal at all twelve stations. However, the onset date of rainfall was earlier from the average start of May 15th by five days. For a detailed study at the coastal stations as Rayong, Chanthaburi, and inland station Prachinburi during (as in Figure 4) for the pre-onset and monsoon onset periods. During the La Niña year of 1998 the rainfall quantity in Prachinburi was higher than that in the El Niño year of 1997 but when compared to a normal year, it was nearly the same except a few stations which recorded a delay of seven to eight days.

The rainfall quantities in May 1996 to 2000 were lesser than normal in the El Niño year of 1997 at all thirteen stations but during the year of La Niña in 1998 most stations showed higher than normal rainfalls; with the exception of Phetchabun, Ayuthaya, Pathumthani, Bangkok and Chanthaburi which are all inland stations (as shown in figure 5).

![Fig. 5. The Amount of Yearly Rainfall for the Month of May from 1996 to 2000](image)

![Fig. 6. Correlation between Heat Fluxes and Rainfalls at Rayong Province on MAY 1996](image)
4. Conclusion

Since the heat flux in the Southeast Indian Ocean near the west side of Australia is the source area of the southwest monsoon season in Thailand, in using a linear regression analysis a correlation of heat flux to the rainfall intensities and the onset of monsoon rainfall at Rayong province was recorded ($R^2 = 0.782$).

In analyzing the twelve Thai meteorological stations, it was observed that the Rayong station in the Gulf of Thailand had the highest correlation. This station seemed to have been affected the most by the direct effect of the southwest monsoon rainfall that originates from the Andaman seacoasts off Thailand. This outcome is important for the prediction of the onset of the southwest monsoon rain in Thailand to plan agricultural activities and developments affected by the volume of rainfall in the region.

The use of the MM5 Model to study the changing pattern of heat flux in the Indian Ocean, and to predict the onset of monsoon rain, is a technique which has never been adopted before by the Thai Meteorological Department.

It can be used to substitute the traditional method which takes longer time. Not only heat flux, the study on other related factors such as moisture and wind pattern are important to be investigated in more detail for more accurate prediction of the onset of monsoon rainfall in Thailand.

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References