บทคัดย่อ

ได้มีการศึกษาเพื่อเสนอเนื้อหาใหม่สำหรับกำหนดวันเริ่มต้นฤดูร้อนสำหรับประเทศไทย โดยศึกษาพฤติกรรมของลมที่ระดับ 850, 500 และ 200 hPa ความคงตัวอากาศที่ระดับทะเลปานกลาง ความชื้นในพื้นที่บันทึก อุณหภูมิอากาศที่มีพื้น และ sensible heat flux ที่มีพื้น ซึ่งได้บันทึกไว้ในช่วงเดือนพฤษภาคม ล้ำแต่ปี พ.ศ. 2539 ถึง 2543 จากการจำลองลักษณะอากาศตามแบบจำลองทางเทคนิคศาสตร์ MM5 เวอร์ชั่น 3 ในบริเวณลองจุด 40 องศา 120 องศาตะวันออก ละติจูด 30 องศาใต้ ถึง 40 องศาเหนือ ขนาดของกริด 50 x 50 กม. การจำลองลักษณะอากาศมีระยะเวลา 11 วันโดยมีกำลังการเริ่มต้นฤดูร้อนอยู่ที่กลาง ผลการศึกษาพบว่า อุณหภูมิอากาศที่มีพื้นมีค่าอยู่ที่ 30 - 31°C ในช่วงก่อนวันเริ่มต้นฤดูฝน และมีค่าอยู่ที่ประมาณ 30°C ในวันที่ฤดูฝนเริ่มต้นก่อนจะมีค่าลดลง ส่วนความชื้นสัมพัทธ์ของอากาศที่มีพื้นพบว่ามีค่าอยู่ยา 80 - 85, 80 - 90 และ 85 - 95 ในช่วงก่อนวันเริ่มต้นฤดูฝน ในการศึกษาพบว่าความคงตัวอากาศที่ระดับทะเลปานกลางจะค่อนข้างคงที่แต่จะลดลงเล็กน้อยในช่วงเริ่มต้นฤดูฝน โดยค่าเฉลี่ยของความคงตัวอากาศมีแนวโน้มเคลื่อนที่ไปทางทิศตะวันตก ผลด้วยระหว่างความคงตัวอากาศสำหรับประเทศไทยกับความคงตัวอากาศสูงกว่าบริเวณประเทศอินเดียโดยมีค่าอยู่ในช่วง 10 - 12 hPa ค่อนข้างชั้นเป็นประมาณ 14 hPa ในวันเริ่มต้นฤดูฝน และลดลงอยู่ที่ประมาณ 10 hPa ในระยะต่อมา เมื่อพิจารณา sensible heat flux ที่มีพื้นบริเวณประเทศไทย พบว่ามีค่าสูงในช่วงก่อนวันเริ่มต้นฤดูฝนหลังจากวันมีค่าคงที่ต่ำกว่าเริ่มต้นฤดูฝนเป็นต้นไป เมื่อระดับ 850 hPa ส่วนใหญ่เป็นเส้นที่ชัดเจนในช่วงก่อนวันเริ่มต้นฤดูฝนและมีพิกัดวงจรที่วันสุดท้ายได้มากขึ้นในช่วงเริ่มต้นฤดูฝนและหลังเริ่มต้นฤดูฝน ที่ระดับ 500 hPa ที่คาดว่าจะมีอยู่ในช่วงที่ผ่านวันเดี่ยว พบผ่านผ่านเวลาก่อนมีอิทธิพลทางอากาศในช่วงก่อนวันเริ่มต้นฤดูฝน ซึ่งจะเคลื่อนที่อยู่บริเวณประเทศอินเดียและอาจถูกผนวกรวมในช่วงเริ่มต้นฤดูฝนและหลังจากนั้นในเวลาต่อมา ส่วนที่ระดับ 200 hPa เป็นแหล่งรถของลมที่สำคัญ นอกจำกมีการกระจายของความชื้นในพื้นที่นั้นที่ต้องการแสดงให้เห็นว่ามีการเปลี่ยนที่ต่างของมวลอากาศที่มีความชื้นสูงในช่วงก่อนวันเริ่มต้นฤดูฝนด้วย

คำสำคัญ : แบบจำลองทางเทคนิคศาสตร์ MM5 / ช่วงขยายแนวทางอากาศระบายพลังงานกลางประเทศไทย / ฤดูร้อน / อุณหภูมิ / ความชื้นในพื้น / ความคงตัวอากาศ / พลังงานความร้อนที่รู้สึกได้ / ร่องมวล

1. นักศึกษาระดับปริญญาโท นักวิชาการสายวิศวกรรมฯ นักวิชาการสายวิศวกรรมฯ
2. นักวิชาการสายวิศวกรรมฯ นักวิชาการสายวิศวกรรมฯ
3. นักวิชาการสายวิศวกรรมฯ นักวิชาการสายวิศวกรรมฯ
4. นักวิชาการสายวิศวกรรมฯ นักวิชาการสายวิศวกรรมฯ
Proposed New Criteria for Southwest Monsoon Onset Date in Thailand

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Abstract

A study had been conducted in order to achieve a new criteria to identify the southwest monsoon onset in Thailand. The elements used in this study included wind directions at the 850; 500; and 200 hPa levels, mean sea level pressure, relative humidity at the surface level, surface air temperature, and heat flux at the surface level, recorded in May since 1996 until 2000. The Mesoscale Model version 5 (MM5) was used to simulate the above elements. The domain in this study was located within 40°E to 120°E in longitude and 30°S to 40°N in latitude. The grid size was set to be 50 by 50 kilometers. The simulation had been processed for 11 consecutive days, with the assumed first date of the rainy season in the middle. The results revealed that surface air temperature in Thailand had been 30 – 31°C before the beginning of the rainy season. Such value was about 30°C on the onset date and would reduce afterward. For the relative humidity, it was found to be 80 – 85 %, 80 – 90 %, and 85 – 95 % prior to the monsoon onset, on the onset date, and later on, respectively. In case of the mean sea level pressure, it had been rather stable, but slightly dropped on the onset date. The location of a low pressure cells had a tendency to move toward the west. The difference between the low pressure cell above India and the high pressure area above Indonesia had been in the range of 10 – 12 hPa before the onset date. It had increased to be about 14 hPa on the onset date before dropping down to about 10 hPa afterward. When examining sensible heat flux at the surface level in Thailand, it had been in the high level before the monsoon onset and remained constant since the onset date. The majority of the wind field at the 850 hPa level over Thailand had been southerly before the monsoon onset. It later became more southwesterly since the monsoon onset date. The wind field at the 500 hPa level had portrayed a trough over the eastern area of India prior to the monsoon onset before it shifted to be over Bangladesh and the upper part of the Gulf of Bengal on the onset date and later on, respectively. For the wind field at 200 hPa level, it had been easterly since before till after the onset date. In addition, the distribution of relative humidity in the vertical axis represented the downward movement of moist air masses prior to the onset date also.

Keywords: MM5 / ECMWF / Monsoon / Temperature / Relative Humidity / Pressure / Sensible Heat Flux / Trough

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1. Introduction

Thailand is located in the southwestern part of the Indo-China Peninsula. The weather and climate on Thailand are strongly influenced by the monsoon from the India Ocean (Southwest monsoon) and cold air mass from the East-Asia continent. The agriculture and other industries in Thailand are favored by the tropical monsoon climate. Therefore the onset of southwest monsoon is very important for Thailand agriculture.

The onset of the southwest monsoon is preceded by an increase in temperature over almost all the monsoon regions. During the southwest monsoon season, the monthly mean surface air temperatures exceed 33-35°C in the land areas of northwest India and adjoining areas [1]. The surface air temperatures, particularly the daytime temperatures, drop dramatically with the onset of the southwest monsoon, the monthly mean temperature falling to less than 30°C [2]. The progressive development of heat lows before and during the monsoon season is considered to be one of the major causative factors of the Indian summer monsoon circulation [3]. Jay and Pamela [4] said the monsoon rain and winds are the end result of heating patterns produced by the sun and the distribution of land and ocean. Near the west coast of India, the winds were west southwesterly to westerly, with speeds of 5-10 m/s, while the mean speed was 5 m/s inland. This pattern persists throughout the active phase of the southwest monsoon [2].

The monsoon troughs were investigated at the 500 hPa level. The monsoon troughs were over India during the monsoon onset before moving eastward after the monsoon onset. An important part of the anatomy of the monsoon circulation is the mean trough running from West Pakistan to the north Bay of Bengal. This trough extends from the sea level to 500 hPa, with southward slope [5]. Saman and Kumar [6] examined the circulation and moisture change over India associated with the onset of the southwest monsoon over south Kerala.

2. Material and Methods

2.1 Model Description

The PSU/NCAR mesoscale model [7] is a limited-area, nonhydrostatic or hydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale and regional-scale atmospheric circulation. It has been developed at Penn State and NCAR as a community mesoscale model and is continuously being improved by contributions from users at several universities and government laboratories.

The Fifth-Generation NCAR/Penn State Mesoscale Model (MM5) is the latest in a series developed from a mesoscale model used by Anthes at Penn State in the early 70's that was later documented by Anthes and Warner (1978). Since that time, it has undergone many changes designed to broaden its usage.

The MM5 model is supported by several auxiliary programs, which are referred to collectively as the MM5 modeling system.

MM5 has been used for a broad spectrum of theoretical and real-time studies, including applications of both predictive simulation and four-dimensional data assimilation to monsoons, hurricanes, and cyclones.

2.2 Study Domain

The study was done for the five years 1996, 1997, 1998, 1999, and 2000. In each case, the five days before the onset date, the onset date, and five days after the onset date were considered.
2.3 Data Collection

The pressure levels data (u & v wind components, geopotential, temperature, and relative humidity, at all levels) and surface data from 1996-2002 were obtained from the European Center for Medium Range Weather Forecasting (ECMWF). The 12-hr (00 and 12 UTC) data with resolution of 2.5°x2.5° in the area of 40°E to 120°E in longitude and 30°S to 40°N in latitude are selected in this study. The precipitation data are obtained from Thai Meteorological Department (TMD).

2.4 The TMD Official Criteria of Southwest Monsoon Onset Date in Thailand

- There are three consecutive rainy days in a five day period.
- The consecutive rainy days must have not less than 5 mm each day.
- The accumulated rain of the five rainy days must not be less than 25 mm.
- The low level wind direction must change to westerly or southwesterly.
- The upper level wind direction must change to easterly.

Special conditions of rainfall, such as tropical cyclones or the intertropical convergence zone, strongly affect the southwest monsoon onset date estimation. The estimation of southwest monsoon onset dates performed in 1996, 1997, 1998, 1999 and 2000 are shown in Table 1.
3. Results and discussion

3.1 Input Data and Model Running

All MM5 required data were prepared in 12 hour period data and then input to the model. The model run with 150 second time step, Grell scheme physical method [8]. The study was done for the five years 1996, 1997, 1998, 1999, and 2000. In each case, the five days before the onset date, the onset date, and five days after the onset date were considered. The 2002 data were used to verify the study model. The model was run with horizontal grid resolutions of 50x50 km and 23 levels in the vertical. The models were started at 00 UTC using 12-hr analysis data with resolution of 2.5°x2.5° in the area 40°E to 120°E in longitude and 30°S to 40°N in latitude.

3.2 The model output evaluations

To evaluate the model outputs, the surface air temperature, surface relative humidity and sea level pressure contour patterns from the model were compared with those contour patterns from the observed data. Quantitative comparisons were obtained by calculating various statistical averages and root mean square error analyses.

The world meteorological organization WMO [9] issued standard limits for errors of meteorological parameters as shown in Table 2. The errors of the model forecast parameters are less than the WMO limits for errors. Therefore, the sensible heat flux will be estimated by the models and the results are assumed to be valid.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>7th May</td>
<td>18th May</td>
<td>17th May</td>
<td>4th May</td>
<td>15th May</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 The estimated southwest monsoon onset date by TMD.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Temp (°C)</td>
<td>1.36</td>
<td>0.93</td>
<td>1.49</td>
<td>0.97</td>
<td>1.02</td>
<td>4 °C</td>
</tr>
<tr>
<td>PSLV (hPa)</td>
<td>0.43</td>
<td>1.22</td>
<td>1.51</td>
<td>0.43</td>
<td>0.42</td>
<td>2 hPa</td>
</tr>
<tr>
<td>RH (%)</td>
<td>1.74</td>
<td>1.52</td>
<td>1.59</td>
<td>1.72</td>
<td>1.69</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 2 Comparison of model RMSE values with WMO Standards.
- Surface Air Temperature
During the pentad before the southwest monsoon onset, low pressure cells or high temperatures are found over the Bay of Bengal and Thailand. Low pressure cells with temperature 29-30°C are located over India and the Bay of Bengal (15-20°N, 75-80°E), and about 28-29°C over Thailand, and 28-29°C over the South China Sea during the pentad before the monsoon onset (Fig. 2a).

Lows pressure cells with temperature 30-31°C are located in India and the Bay of Bengal (15-20°N, 75-80°E), 29-30°C over Thailand, and 29-30°C over the South China Sea during the onset period. The system of high temperature shifted from northern India to the west coast of Thailand (Fig. 2b).

The air temperature are still high about 28-29°C over India, the Bay of Bengal, Thailand and the South China Sea. The air temperature over Thailand decreased during the pentad after the monsoon onset. When precipitation and cloud occurs, the heating of the surface decreases because the specific heat of soil increases with the addition moisture and the heat from the sun is used in evaporation (Fig. 2c).

Figs. 2a), 2b), and 2c) show the surface air temperature (°C) at 00 UTC on 13/5/1997, 18/5/1997, and 23/5/1997 respectively.
- Sea level pressures

3a)

3b)
Fig. 3a shows the sea level pressure at 00 UTC on 13/5/1997, it found that the low pressure area with the central pressure 1,002-1,006 hPa and strong gradient to the north is found over northeastern India and western the Bay of Bengal. The sea level pressure over Thailand was 1,007-1,010 hPa, and was 1,009-1,013 hPa over the South China Sea. High pressures are found over northern Myanmar, the South China Sea and Indonesia.

Fig. 3b shows the sea level pressure at 00 UTC on 18/5/1997, it found that the heat low pressure areas are found over northeastern India, Bangladesh and the northern Bay of Bengal with central pressure 1,001-1,007 hPa and a steep gradient to the north (25-28°N and 85-93°E), 1,008-1,010 hPa over northeastern Thailand, and 1,009-1,011 hPa over south China. The high pressure persisted over northern Myanmar with 1,016 hPa central pressure, and the other high system remained over Indonesia. Fig. 3c shows the sea level pressure at 00 UTC on 23/5/1997, it found that the low pressure area with pressure 1,001-1,003 hPa is found over northeastern India and western Bay of Bengal. The sea level pressure over Thailand was 1,009-1,011 hPa, and was 1,009-1,013 hPa over the South China Sea. High pressures are found over northern Myanmar, the South China Sea and Indonesia. Low pressure cells occurred over land areas throughout the period before, during and after the monsoon onset. The sea level pressure was lowest over Bangladesh and Thailand.
- Surface relative humidity
The surface relative humidity during the pentad before the monsoon onset was rather high: 80-95% over the Bay of Bengal, 75-92% over Thailand, and 80-90% over the South China Sea. Low relative humidities are found over the continent of Bangladesh and India (Fig. 4a).

The surface relative humidity during the monsoon onset was 80-95% over the Bay of Bengal, 80-90% over Thailand, and 80-95% over the South China Sea. Low relative humidities are found over the continent of Bangladesh and India (Fig. 4b).

The surface relative humidities during the pentad after the monsoon onset are 85-95% over the Bay of Bengal, 85-92% over Thailand and 80-90% over the South China Sea. Low relative humidities are found over the continent of Bangladesh and India (Fig. 4c).
- Surface sensible heat flux
The surface sensible heat flux at 00 UTC was about 0-50 W/m² in both the Bay of Bengal and the South China Sea. The surface sensible heat flux was 100-200 W/m² over Thailand. A high surface sensible heat flux more than 400 W/m² occurred over South China (Fig. 5a).

The surface sensible heat flux at 00 UTC was about 0-50 W/m² in both the Bay of Bengal and the South China Sea. The surface sensible heat flux was 150-300 W/m² over Thailand. A high surface sensible heat flux more than 400 W/m² occurred over South China (Fig. 5b).

The surface sensible heat flux at 00 UTC was about 0-50 W/m² in both the Bay of Bengal and the South China Sea. The surface sensible heat flux was 100-200 W/m² over Thailand. A high surface sensible heat flux more than 400 W/m² occurred over the South China (Fig. 5c).

Figs. 5a), 5b), and 5c) show the surface sensible heat flux (W/m²) at 00 UTC on 13/5/1997, 18/5/1997, and 23/5/1997 respectively.
- Wind field at 850 hPa
Figs. 6a), 6b), and 6c) show the wind fields at 850 hPa at 00 UTC on 13/5/1997, 18/5/1997, and 23/5/1997 respectively.

The winds over Thailand at 850 hPa at 00 UTC were southerly with speeds of 5-10 m/s (Fig. 6a).

The winds over Thailand at 850 hPa at 00 UTC were southwesterly with speeds of 10-15 m/s (Fig. 6b).

The winds over Thailand at 850 hPa at 00 UTC were northeasterly to southwesterly with speeds of 5-10 m/s (Fig. 6c).
- Wind field at 500 hPa
Troughs were found over Bangladesh with axes along latitude 15-30°N and longitude 92-93°E. Northwesterly winds and wind speeds of 5-10 m/s were found in the areas behind the trough. Southwesterly winds and wind speeds of 10-20 m/s were found in front of the trough (Fig. 7a).

Troughs persisted over Bangladesh with axes at latitude 15-30°N and longitude 93-94°E. Northwesterly winds and wind speeds of 5-10 m/s were found in the areas behind the trough. Southwesterly winds and wind speeds of 10-20 m/s were found in front of the trough (Fig. 7b).

Troughs persisted over the Bay of Bengal with axes at latitude 5-30°N and longitude 95-96°E. Southeasterly winds and wind speeds of 5-20 m/s were found in the areas behind the trough. Northeasterly winds and wind speeds of 5-30 m/s were found in front of the trough (Fig. 7c).

Figs. 7a), 7b), and 7c) show the wind fields at 500 hPa at 00 UTC on 13/5/1997, 18/5/1997, and 23/5/1997 respectively.
- Wind field at 200 hPa

8a)

8b)
The winds at 200 hPa at 00 UTC during the pentad before the monsoon onset were northeasterly to easterly over southern Thailand and westerly over northern Thailand with speeds of 5-10 m/s (Fig. 8a).

The winds at 200 hPa at 00 UTC during the monsoon onset were northeasterly to easterly over southern Thailand and westerly over northern Thailand with speeds of 5-10 m/s (Fig. 8b).

The winds at 200 hPa at 00 UTC during the pentad after the monsoon onset were northeasterly to easterly over southern Thailand and westerly over northern Thailand with speeds of 10-15 m/s (Fig. 8c).

Figs. 8a), 8b), and 8c) show the wind fields at 200 hPa at 00 UTC on 13/5/1997, 18/5/1997, and 23/5/1997 respectively.
- Vertical Relative Humidity

9a)

9b)
The vertical relative humidity during the pentad before the monsoon onset showed moisture layers around 90% at heights 1,000-700 hPa and 500-100 hPa (Fig. 9a).

The vertical relative humidity during the monsoon onset showed moisture layers around 90% at heights 1,000-900 hPa and 500-100 hPa (Fig. 9b).

The vertical relative humidity during the pentad after the monsoon onset showed moisture layers around 90% at heights 1,000-600 hPa, 700-300 and 200-100 hPa (Fig. 9c).

The lower moisture layers persisted over Thailand and shifted northward during the monsoon onset period, and the upper moisture layers were stationary or shifted down.

4. Conclusion

According to investigation of meteorological parameters, it was found that 3 elements (: surface air temperature, sea surface temperature, and sensible heat flux at the surface level) showed high relationship with the beginning of the rainy season in Thailand. Both surface air temperature and sensible heat flux at the surface level had increased prior to the first day of the rainy season before the values of both parameters declined. In case of sea surface temperature, its value had either increased or remained the same ahead of the first date of the rainy season before it either remained the same or decreased, respectively.

Figs. 9a), 9b), and 9c) show the vertical relative humidity at 00 UTC on 13/5/1997, 18/5/1997, and 23/5/1997 respectively.
The values of relative humidity at the surface level and the same element in the vertical axis with in the latitude 20°S – 35°N and along the longitude 100°E show moderate relationship with the first date of the rainy season. What could be noticed were the facts that moist air masses had covered Thailand at the lower altitude and tended to move northward on the very first date the rain was observed whereas moist air masses at the higher altitude was in the rather stable condition or tended to move downward on the date the rain took place.

As this study was set to investigate any changes of related elements within 11 days only (5 days before and another 5 days after the first date of the rainy season), no changes of the wind directions at the 850, 500, and 200 hPa levels could be detected although they are regarded as main features of the Southwest Monsoon. The summarizes all the results showed in Table 3.

Table 3 The change of meteorological parameters during the monsoon onset periods.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before the monsoon onset</th>
<th>During the monsoon onset</th>
<th>After the monsoon onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface air temperature °C</td>
<td>28-29</td>
<td>30</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Surface relative humidity (%)</td>
<td>80-85</td>
<td>80-90</td>
<td>85-95</td>
</tr>
<tr>
<td>Sea level pressure (hPa)</td>
<td>1007-1010</td>
<td>1,008-1,010</td>
<td>1,009-1,011</td>
</tr>
<tr>
<td>Sensible heat flux (W/m²)</td>
<td>100-200</td>
<td>150-300</td>
<td>100-200</td>
</tr>
<tr>
<td>Wind field at 850 hPa (m/s)</td>
<td>Southerly, 5-10</td>
<td>Southwesterly, 10-15</td>
<td>Southwesterly, 5-10</td>
</tr>
<tr>
<td>Wind field at 500 hPa (m/s)</td>
<td>Northeasterly, 5-10, B</td>
<td>Northeasterly, 5-10, B</td>
<td>Northeasterly, 5-10, B</td>
</tr>
<tr>
<td>Wind field at 200 hPa (m/s)</td>
<td>Northeasterly to easterly, 5-20</td>
<td>Northeasterly to easterly, 5-20</td>
<td>Northeasterly to easterly, 5-20</td>
</tr>
<tr>
<td>Vertical 90 % relative humidity (hPa)</td>
<td>1,000-700 and 500-100</td>
<td>1,000-900 and 500-100</td>
<td>1,000-600, 700-300, and 200-100</td>
</tr>
</tbody>
</table>

5. Acknowledgments

This work was supported by the Joint Graduate School of Energy and Environment, King Mongkut’s University of Technology Thonburi. Special thanks are offered to the European Centre for Medium-Range Weather Forecasts (ECMWF) and Thai Meteorological Department (TMD) for data supported and Penn State/NCAR for (MM5) version 3 model and documents.

6. References


2. G.B. Pant and K Rupa Kumar, 1997, Climate of South Asia, John Wiley & Sons Chichester, New York, USA.


