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Numerical simulation of rainfall pattern in Thailand during El Niño event

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Abstract: In this research, the Regional Atmospheric Model System (RAMS) version 6.0 was used to simulate the rainfall in the early rainy season (May) during El Niño years 1992 and 1997 as the case studies. The rainfall in normal year 1995 was also simulated by RAMS. The simulation results correspond closely with the observed data. The decrease or increase of rainfall for both simulation and observation appears in most sub-regions in Thailand in the El Niño years, especially in North, North east and Central sub-regions. Although, temperature is also related to amount of water vapor by evaporation process but cause of decrease of water vapor during El Niño is mainly due to the weakness of the southwest monsoon and vertical motion. The weak wind and vertical motion occurred over the Indian Ocean in El Niño years can not bring a lot of water vapor to Thailand causing less water vapor and became weak rainfall over the country.

Key word: El Niño, ENSO, Rainfall, RAMS, Rainfall Simulation

INTORDUCTION

Agriculture, and especially rice production, is an essential component of Thailand's economy and culture. Over 80% of the Thai population eats rice as their main meal. Thailand is also the world's largest rice exporter. The country's rice exports in last year are monitoring to exceed 8 million tones (FAO 2009). Nonetheless, Thailand suffered in many times from economic losses related to rainfall variation. The main share of that was from crop yield losses (ADB 2009).

An important factor for the variation of rainfall is El Niño events which is the warm phase of El Niño Southern Oscillation or ENSO. During this events, drought is a problem in many tropical areas including Thailand that depend on the arrival of the summer monsoon rains (D'Aleo and Grube 2002). Kerdsuk (2009) said that Thailand drought during rainy season in El Niño year resulted in water shortages and heavy losses in crop production.

Over the past, numerous studies have studied the relationship between the El Niño events and its impact on the rainfall variation over Thailand includes the Southeast Asia (Boochabun 1998; Ichiyanagi and Yamanaka 2005; Kripalani and Kulkarni 1998; Kumar et al. 1999; Prakhammintara 2002; Singhrattna et al. 2005). Most of these studies have analyzed the observed data for studying its impact. There are no attempts have been made to simulate these events and study its impacts at the regional scale. At the present, several researchers used the meteorological model to simulate the climate variability.

The Regional Atmospheric Modeling System (RAMS) also was a meteorological model that was adopted for simulation in many studies. Castro et al. (2007) used RAMS to downscale 53 years of the NCEP-NCAR Reanalysis to generate the summer climate of the Contiguous United States. Hasler et al. (2005) evaluated RAMS for a Mediterranean semiarid region, Castilla-La Mancha, central Spain, in long-term (1 year) implementation and found that the model can capture general spatial and temporal precipitation features, such as the timing of precipitation events and approximate location of storms. Kanae et al. (2001) adopted RAMS for studying the impact of deforestation on regional precipitation over the Indochina Peninsula during 1st to 25th August and 6th to 30th September in 1992, 1993 and 1994 with 60-km grid spacing (50×50 grid points) and found that simulated mean precipitations were in good agreement with the Global Precipitation Climatology Project (GPCP) dataset.

Figure 1 shows the 3 month moving average of rainfall anomaly in Thailand. During pre-1982 period, the amount of rainfall in El Niño event is usually near or above the normal. The rainfall amount in El Niño event appears a below normal during post-1982. Especially, it can be seen clearly that the positive rainfall anomaly was found in El Niño in year 1982-1983, 1987, 1991-1992, 1997-1998 and 2004.

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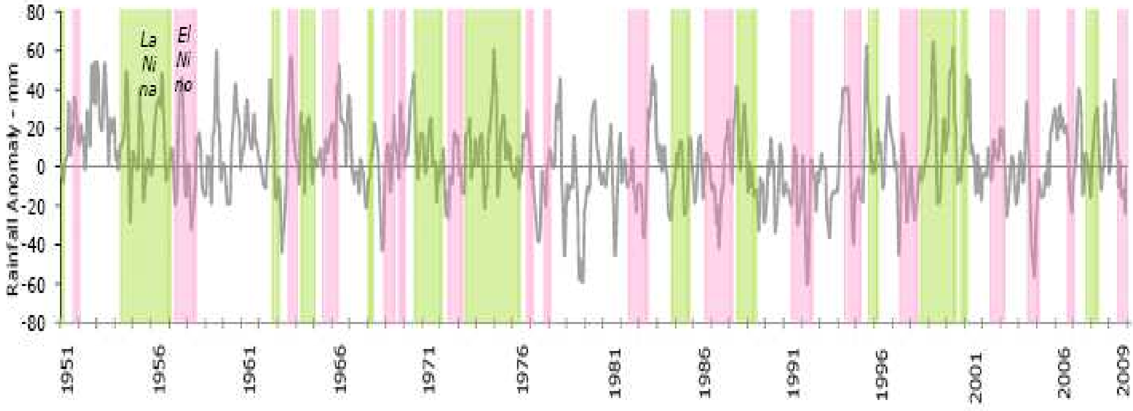


Fig. 1: Thailand rainfall anomaly (compiled by Thai Meteorological Department)

Impacts of El Niño 1992 and 1997 were significant and had relationships with decrease in the average amounts of rainfall in Thailand. Figure 2a and b shows the rainfall anomaly in El Niño 1992 and 1997, respectively. The Sea Surface Temperature Anomalies (SSTA) in the Niño3.4 region, which is one of the well known indexes used to defined ENSO is included in these figures (CPC/NCEP 2008). The SSTA for El Niño are greater (0.5 °C) than those. In year 1992, El Niño was continuously from year 1991 in May and ended in July 1992. The rainfall pattern in this year found decrease during January to June. For El Niño year 1997, it started in May and ended in April, 1998. The decrease in rainfall is in May to June and September to November. It can be seen that the largest of decrease in rainfall are in May both in 1992 and 1997.

(a) El Niño year 1992 *(b) El Niño year 1997*

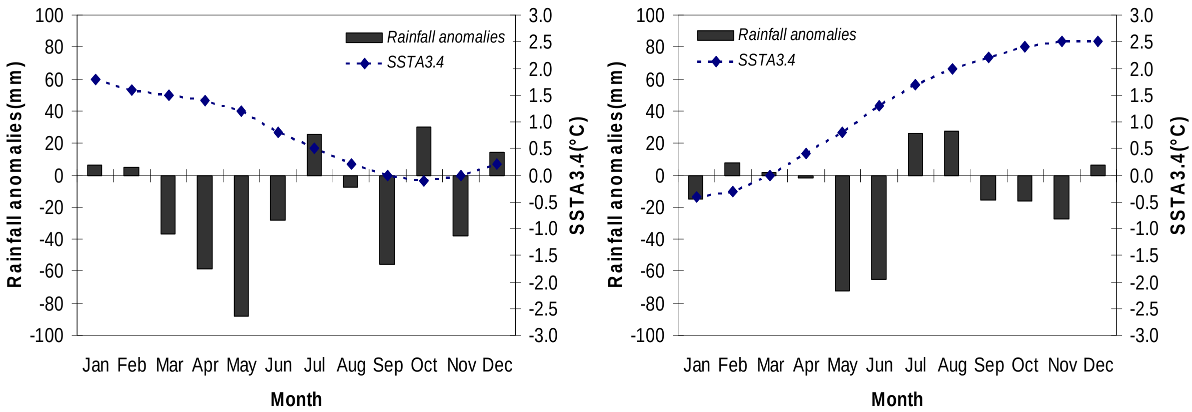


Fig. 2: Rainfall anomalies in (a) 1992 and (b) 1997 compared with the SSTA in the Niño-3.4 region

In this paper, numerical simulations of rainfall pattern over Thailand are shown and discussed. The strength of El Niño during the early rainy season month (May) in El Niño 1992 and 1997 was selected as the case study. The year 1995 was selected as the normal year, due to rainfall in this year being closed to the long-term mean (30-year averaged) rainfall for all region of Thailand.

MATERIALS AND METHODS

Model Description:

RAMS version 6.0 was used for simulating the meteorological data. The basic equations in this model are a set of nonhydrostatic compressive dynamic equations and a thermodynamic equation. This model solves these equations in a terrain-following coordinate system, and has telescoping, two-way interactive grid-nesting capability. A Mahrer/Pielke shortwave radiation and a Chen (Chen and Cotton 1987) long wave radiation parameterization scheme are adopted here. Convective precipitation is parameterized with the A Kain–Fritsch cumulus parameterization scheme (Castro et al. 2002; Tremback and Walko 2004). Subgrid-scale land-atmosphere exchanges of heat and moisture are parameterized with LEAF-2 (Walko et al. 2000), where the land surface consists of a mosaic of tiles (Avissar et al. 1989). Each tile consists of a vegetation layer over a multilayer soil profile or, alternatively, a body of water. Prognostic temperature and moisture variables are computed for bare soil (McCumber and Pielke 1981; Tremback and Kessler 1985) and vegetation by solving the surface energy and water balance equations, while accounting for vertical diffusion in the soil. Vegetation and soil characteristics are provided for 30 land-cover classes, and 11 soil textural classes (Walko et al. 2000).

Domain:

The study area was set to one domain of horizontal grid points with a grid spacing of 30 km, encompassing Thailand and some parts of the Indian Ocean, as shown in Figure 3. The model uses a vertically stretched grid with a maximum vertical grid spacing of 1200 m. The minimum vertical grid spacing is 100 m with a vertical stretch ratio of 1.2. There are 30 levels in the vertical. The polar stereo projection is used, and the center of the domain is located at 14.0 N, 102.0E.

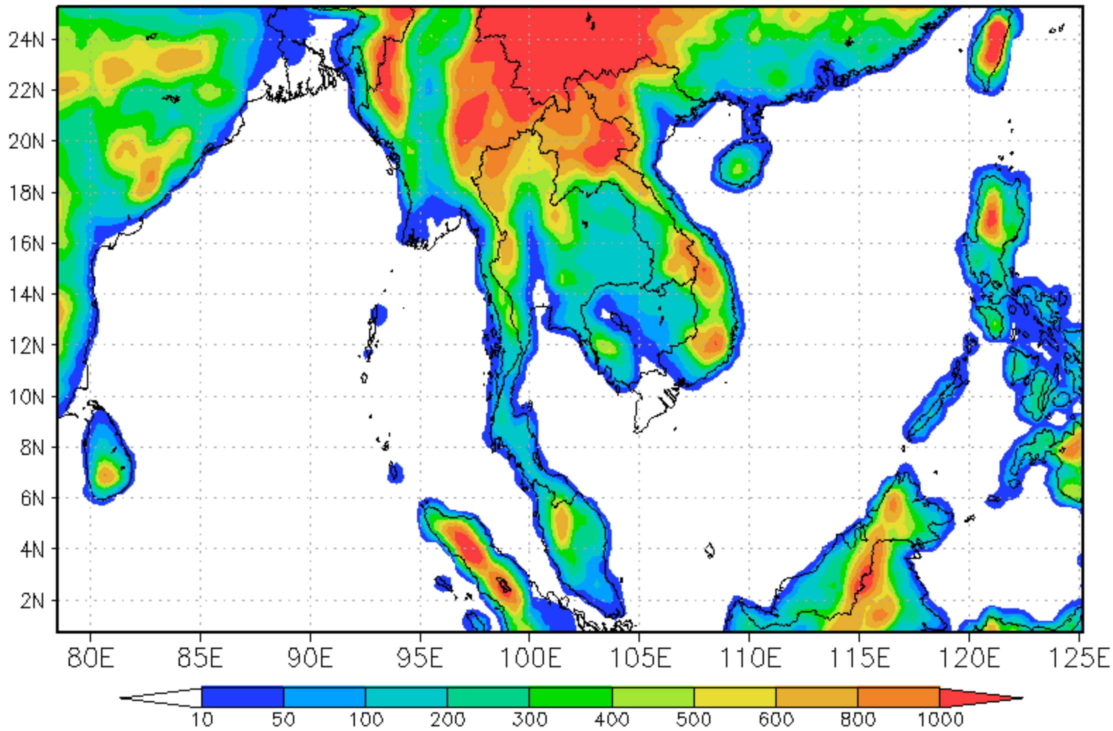


Fig. 3: Topography in the model domain.

Initial and Boundary Conditions:

The meteorological initial and boundary conditions of the model were interpolated from the National Centers for Environmental Prediction (NCEP) daily reanalysis. These datasets consist of east-west (u) component (m/s), north-south (v) component (m/s) of wind, temperature (K), geopotential height (m), and relative humidity (%) in the level of 1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20 and 10 hPa. The NCEP datasets are available for every 6 hours (00:00, 06:00, 12:00, and 18:00 UTC) with 2.5×2.5 degree horizontal resolution which can be downloaded from ftp://ftp.cdc.noaa.gov/Datasets/ncep.reanalysis /pressure/.

RESULTS AND DISCUSSIONS

Results:

The observed rainfall data in 1992, 1995 and 1997 for model evaluation was taken from 58 TMD rain gauge stations. The percentage difference is used to compare a model and observation data. It is comparing the rainfall in El Niño year to normal year as formula [(rainfall in El Niño – rainfall in normal year)/ (rainfall in normal year)] ×100.

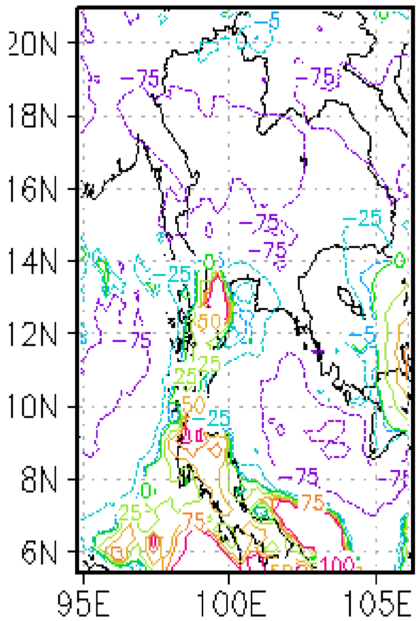
Figure 4 shows the percentage difference of simulated rainfall between El Niño years 1992 and 1997 and normal year 1995 in the left column, whereas the right column is the percentage difference of observed rainfall between El Niño year 1992 and 1997 and normal year 1995. The minus sign denotes decreasing rainfall.

Figure 4(a1) shows the simulated rainfall in El Niño year 1992 was less than the simulated rainfall in normal year 1995 about 75% in North, Central 25% in North east and South sub-region. Figure 4(a2) shows the observed rainfall in El Niño year 1992 was less than the observed rainfall in normal year 1995 about 75 -100 % in North, 25-50 % in Central, 25% in North east and 75 % along east coast in South, and 25% in some part of

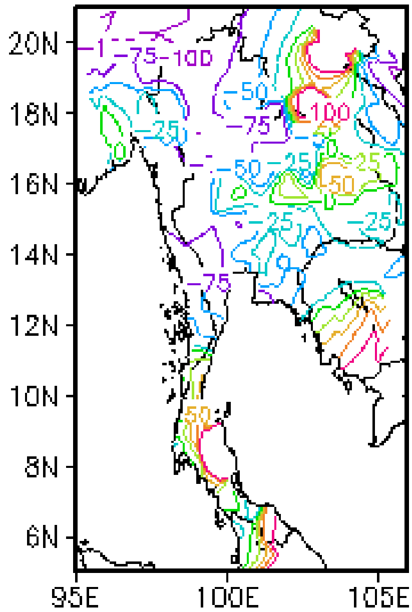
South sub-regions. Generally, the simulated rainfall shows a similar pattern with the observed rainfall, although there are different in some area. However, the greater amount of rainfall about 25-100% occurred in South both from simulations and observations.

In El Niño year 1997, The North, North east and Central sub-regions were also found the decreased rainfall. But, the percentage of difference between rainfall in El Niño year 1997 and normal year in North, North east and Central were in the range of -5% to -75% both from simulations and observations see figures 4 (b1) and (b2). It indicated that rainfall in El Niño year 1997 for the whole of Thailand was more than rainfall in El Niño year 1992. Moreover, rainfall along east cost in South and west cost in South decreased about 25% both from simulation and observation. Generally simulated rainfall in South for El Niño year was below the rainfall in normal year, whereas the observed rainfall in El Niño year was greater than normal year. However the RAMS model can capture the rainfall anomalies in El Niño year.

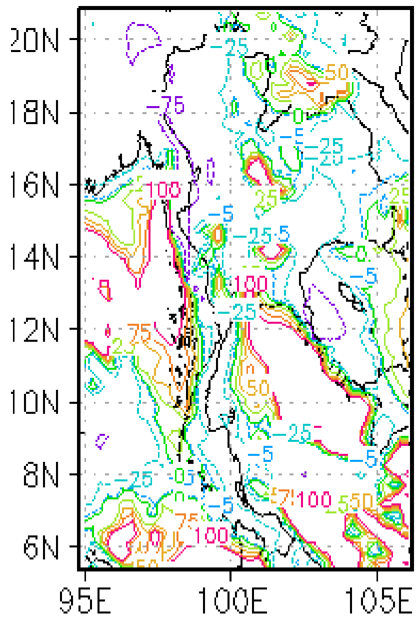
(a1) Simulated rainfall:
El Niño 1992 - normal 1995



(a2) Observed rainfall:
El Niño 1992 - normal 1995



(b1) Simulated rainfall:
El Niño 1997 - normal 1995



(b2) Observed rainfall:
El Niño 1992 - normal 1995

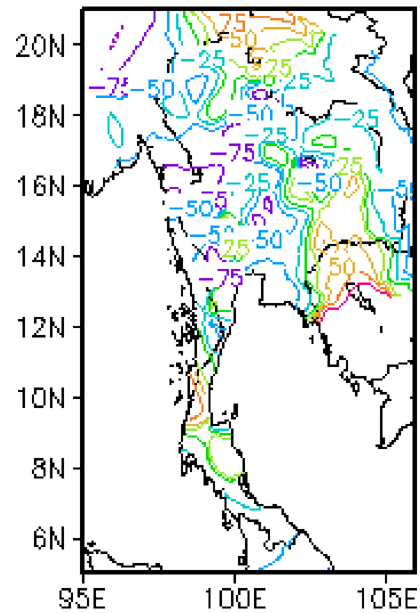


Fig. 4: Percentage differences of (a) simulated rainfall and (b) observed rainfall between El Niño years 1992 and normal year 1995.

Discussion:

Usually, the onset date of summer monsoon in Thailand is on 9th of May (Zhang et al. 2002). But, the monsoon onset on 4th, June and 18th , May, in El Niño 1992 and 1997 respectively which found late onset of monsoon both in El Nino year of 1992 and 1997 (TMD 1998; Zhang et al. 2002) . The changes of onset of monsoon in Indochina associated with the Walker circulation and local Hadley circulation related to ENSO (Singhrattna et al. 2005; Zhang et al. 2002). During El Niño, weakness convective activities were maintained by the convergence between the anomalous southwesterlies in the Indian Ocean and northeasterlies over the northern South China Sea. The anomalous southwesterlies in the Indian Ocean is induced by both the anomalous Walker circulation associated with El Niño and anomalous land–sea thermal contrast resulting late onset of monsoon. In addition, the increasing in cloudiness and rainfall in tropical zones are associated with the rising air as a driver of the vertical motion and horizontally divergent wind fields in the upper troposphere (Miller 1953). Singhrattana et al. (2005) found that shift in the Walker circulation is also instrumental for the non-stationary in relationship of ENSO and monsoon in Thailand. In El Nino event, the descending limb of the Walker circulation over the Thailand-Indonesian region effect to significantly reducing convection and consequently, rainfall over Thailand. Ronghui et al. (2000) also found the water vapor transportation by the summer monsoon was weak in the summer of 1992.

Conclusion:

The RAMS model was used to simulate the rainfall in El Niño years 1992, 1997 and normal year 1995 during the early rainy season (May). The comparisons between simulated and observed rainfall from TMD sites show that the simulations generally corresponded to the observations. The decrease or increase of rainfall for both simulation and observation appears in most sub-regions in Thailand in the El Niño years, especially in N, NE and C sub-regions.

Due to the water vapor in the upper troposphere is not only come from evaporation process which is only related to temperature, but in upper troposphere level, water vapor may be governed by other sources. Then, the cause of decrease of water vapor during El Niño is due to the weakness of the southwest monsoon and vertical motion. The weak wind and vertical motion occurred over the Indian Ocean in El Niño years can not bring a lot of water vapor to Thailand causing less water vapor and became weak rainfall over the country.

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