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Trends in Extreme Rainfall Events over Vietnam: Historical data and Model Verification

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Abstract

Extreme rainfall events have great impact on human life, society and ecosystems especially for developing country such as Vietnam. In this study, high quality rainfall records from 44 stations and the Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE's Water Resources) data are analyzed. Observed trends of the intensity, frequency, fraction and duration of rainfall extreme events are estimated over land area of Vietnam for the period 1961-2000. The results indicate that the positive trends of different extreme rainfall indices are highly spatially coherent in the south of Vietnam whereas the trends in the north are much less coherent. The majority of stations have low statistically significant trend.

Comparisons of observationally - based APHRODITE trends with those simulated by the Regional Climate Model Version 4.2 (RegCM4.2) are also conducted to access the model skill in simulating rainfall extremes. Results show that the spatial trend patterns of all indices are rather similar between the model and the observation. However, the observed negative trends in North Central Vietnam are not well simulated by the model. Moreover, RegCM4.2 overestimates the positive trends of the indices in the south of Vietnam.

1. Introduction

Climate extreme events have received increased attention due to the large loss of human life, severe damage and major impact on ecosystems. In Vietnam, disasters have caused 481 deaths, 672 injuries, and over U.S. $ 450 million in property damages (approximately 1.07% of GDP) over the period 1999-2009[1]. Extreme rainfall events are highly correlated with flooding events in the north and center of Vietnam. From 1990 to 2005 there are nearly 300 flash floods caused approximately U.S. $ 100 million in property and crop damages. The most devastating event in this period was the 1990 flash floods that resulted in an estimated U.S. $ 15 million in damages[2]. Recently, heavy rainfall with flash flood

[1] http://www.gso.gov.vn
[2] http://www.nchmf.gov.vn/web/vi-VN/71/29/45/Default.aspx

on May 12, 2013 in Lao Cai caused 1 deaths, 7 injuries and about U.S. $ 1.5 million in monetary losses[3]. In some regions the rain amount is up to 100mm during only 2 hours.

Some past studies have examined the trends of extreme rainfall in Asia. Klein Tank et al. (2006) investigated the changes in daily rainfall extremes in central and south Asia and found a little change in the regional wet extreme indices in the period 1961-2000. The spatial trend coherence is low with mixed positive and negative trends. Manton et al. (2001) detected the trend of extreme daily rainfall in Southeast Asia and the South Pacific for the period 1961-1998. They found that the frequency of extreme rainfall events decreased at most stations except French Polynesia. However, the statistical significance of extreme rainfall trend is low. According to Manton et al., the PhuLien station in Vietnam showed insignificant trend for all extreme rainfall indices that were analyzed. The Asia pictures of trend in extreme rainfall typically show large areas with sparse data coverage or lack of data over Vietnam such as the research of Klein Tank et al. (2006). There are quite few studies to date on extreme rainfall events over Vietnam. Endo et al. (2009) showed that heavy precipitation increases in southern Vietnam while it decreases in northern Vietnam during 1950s to 2000s. Ha et al. (2011) also agreed that extreme rainfall increases for most sub-regions over Vietnam except the north-delta and the north-center sub-regions.

In this study, trends of rainfall extreme events over Vietnam for the period 1961-2000 are estimated and the model skill in simulating rainfall extremes is also accessed. The indices of extreme rainfall were referred to as extreme frequency, extreme intensity, extreme percent and extreme durations.

2. Data and Indices

There are about 170 meteorological stations over Vietnam. Among them, there are 72 stations that have long daily rainfall data for research on trend of extreme rainfall. Penalba and Robledo (2009) pointed out that data quality assessment is an important requirement for extreme rainfall studies. Figure 1 shows the locations of these rainfall stations and the 7 sub-regions of Vietnam. The sub-regions are named North-West (N1), North-East (N2), North-Delta (N3), North-Central (N4), South-Central (S1), Highland (S2), and South (S3). Data quality control is performed for all the sub-regions. After the data quality control process, it remains only 44 stations with high quality daily rainfall records.

[3] http://www.thanhnien.com.vn/pages/20130512/loc-xoay-lu-quet-gay-thiet-hai-nang.aspx

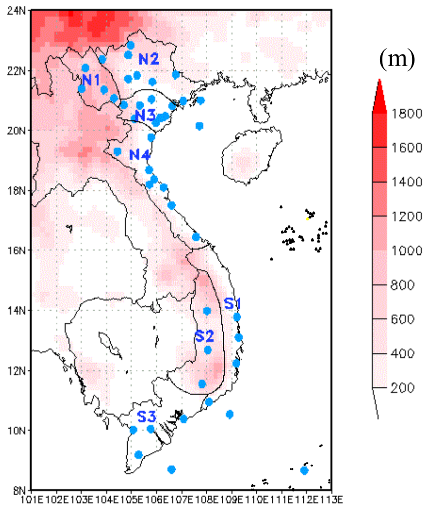

Figure 1. Distribution of 44 stations over Vietnam (dots) with terrain height (color).

The six indices of extreme rainfall were calculated at each stations and each grid point for the observationally - based APHRODITE data and the RegCM4 simulation:

* The maximum one-day rainfall (Rx1day), referred to as extreme intensity;

* The number of events above 50mm (R50mm) and the number of events above the long-term 99th percentile (R99p), referred to as extreme frequency;

* The proportion of total rainfall from the events above the long-term 99th percentile (R99tot), referred to as extreme percent;

* The maximum Consecutive Heavy rainfall Days (CHD) and Number of Heavy rainfall Spell (NHS), heavy rainfall is defined by the event above 50mm, referred to as extreme duration.

3. Model and Experiment design

Regional climate model use in this research is RegCM4.2, the fourth version of International Centre for Theoretical Physics (ICTP) RCM. RegCM is a hydrostatic, compressible, sigma-p vertical coordinate model run on an Arakawa B-grid. The dynamic of RegCM4.2 is based on the Mesoscale Model version 4 (MM4) of National Center for Atmospheric Research (NCAR). The physics in RegCM4.2 include the radiation scheme, the land surface model, the planetary boundary layer scheme, convection scheme, flux model and large-scale precipitation scheme. There are some improvements compared with previous version (RegCM3) in terms of software code and physics. The convections scheme is an important component in RegCM4.2 for rainfall simulation. RegCM4.2 includes 3 options for representing cumulus convection. The first is a simplified version of the Kuo-type scheme of Anthes (1977). The second is that of Grell (1993) in the implementation of (Giorgi et al., 1993) with Two different closures can be used: an Arakawa-Schubert type closure and a Fritsch-Chappell type closure. A third scheme is MIT scheme (Emanuel, 1991; Emanuel and Zivkovic-Rothman, 1999). A major different in RegCM4 convection scheme compared to previous versions is the capability of running different convection schemes over land and ocean. Different schemes have different performance over different regions, and in particular over land versus ocean areas.

RegCM4.2 is used to simulate rainfall extreme over Vietnam for the period 1981- 2000 and access the model skill in simulating rainfall extremes. The ERA40 reanalysis data are used to provide the boundary conditions for RegCM4. The physical schemes used in this study are the cumulus convection scheme of Grell with Arakawa-Schubert type closure; the modified planetary boundary layer scheme by Holtslag et al. (1990); the resolved scale precipitation scheme SUBEX of Pal et al. (2000) and the ocean fluxes scheme of Zeng et al. (1998). RegCM4.2 was set up with configuration of 20 km horizontal resolution and 18 vertical levels over the domain of 6^0 to 28^0 N, 95 to 118^0 E.

4. Result

Figure 2 shows trends in extreme rainfall indices at 42 meteorological stations mentioned above. All indices of intensity, frequency, fraction and duration of rainfall extreme events have increased at most stations in southern Vietnam. The spatially coherents of trend in the north of Vietnam are much less than those in the south. In most case, the sign of trend in extreme intensity matches the trend in extreme frequency. However, there are some stations in the north of Vietnam have the opposite trend sign in extreme intensity compared to extreme frequency. The contrast between R50mm and R99p is also present in some stations in the north. Trend in the north of Vietnam is weaker and less significant than in the south.

The extreme intensity (fig. 2a) shows increasing trends at most stations. Among them, 5 stations have increasing trends at 95% significant level and 3 stations have decreasing trends at 95% significant level. The highest significant positive trend is identified at Tuyhoa station with the rate of 55.4 mm/decade, whereas Thaibinh has the highest significant negative trend of -17.8 mm/decade.

The extreme frequency (fig. 2b,c) shows the difference of trends between the two indices R50mm and R99p in the north of Vietnam. The trend of R50mm is much greater than that of R99p. For example, the R50mm trend at Tuyhoa station is 2.6 day/decade while the R99p trend is only 0.5 day/decade.

Trends in proportion of total rainfall from the events (fig. 2d) increases at most stations. The highest increasing rate at 95% significant level is 5.6 %/decade at Tuyhoa station. The statistical significant negative trends are only identified at Mocchau and Hoixuan stations and the values are -1.9% and -1.7 % per decade, respectively.

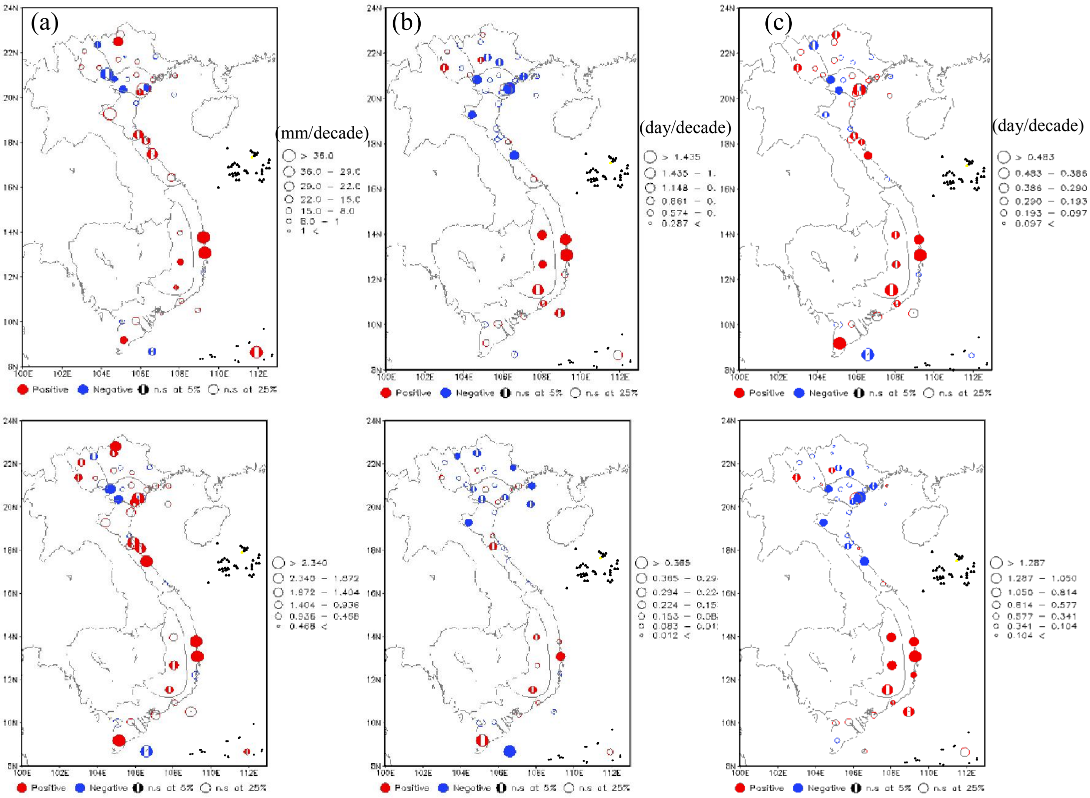

Figure 2. Trend in extreme rainfall indices, close circles show statistically significant trends, close circles with vertical bar show insignificant trends at 5% and open circles show insignificant at 25%; (a) - Rx1day; (b) - R50mm; (c) - R99p; (d) - R99tot; (e) - CHD; (f) – NHS

The CHD and the NHS indices (fig. 2e,f) represent the maximum consecutive heavy rainfall days and the number of heavy rainfall spells, respectively. Trend in CHD index is less than NHS index indicating the un-prolonged duration of the longest heavy rainfall spell. The highest decrease rate of statistical significant trend in CHD is -0.3 day/decade at Condao station, whereas the highest positive rate in NHS is 1.8 day/decade at Tuyhoa station.

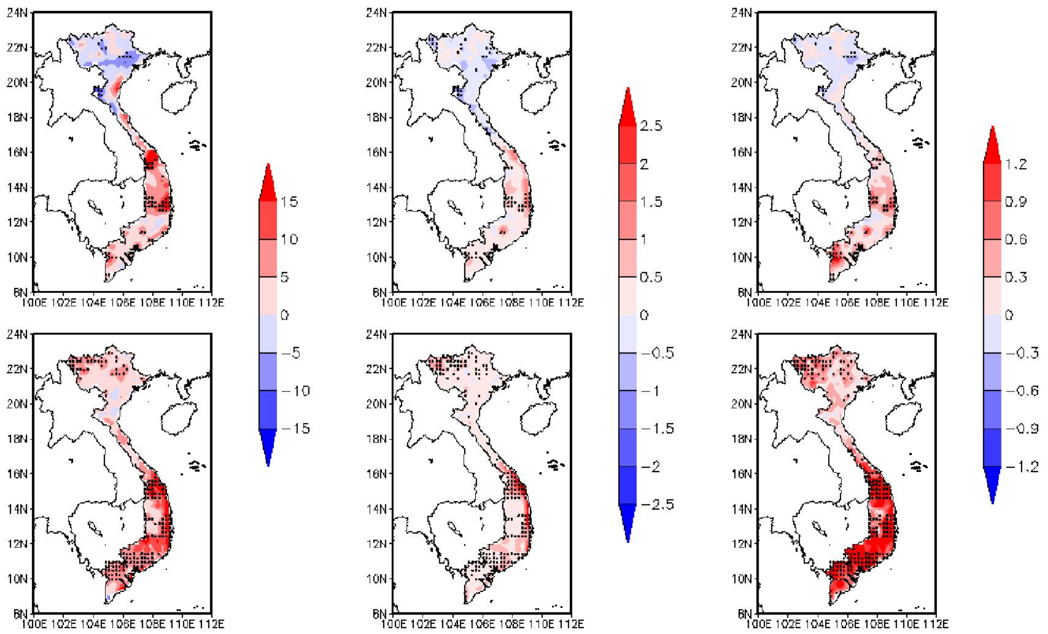

Figure 3. Trend in extreme rainfall indices, upper: APHRODITE, below: RegCM4.2 simulations; stippling shows trend at 95th significant level; (a) - Rx1day; (b) - R50mm; (c) - R99p

Figure 3 and Figure 4 show the spatial patterns of extreme rainfall trends computed for the period 1961-2000 to provide a comparison of the APHRODITE trends with those simulated by RegCM4.2.

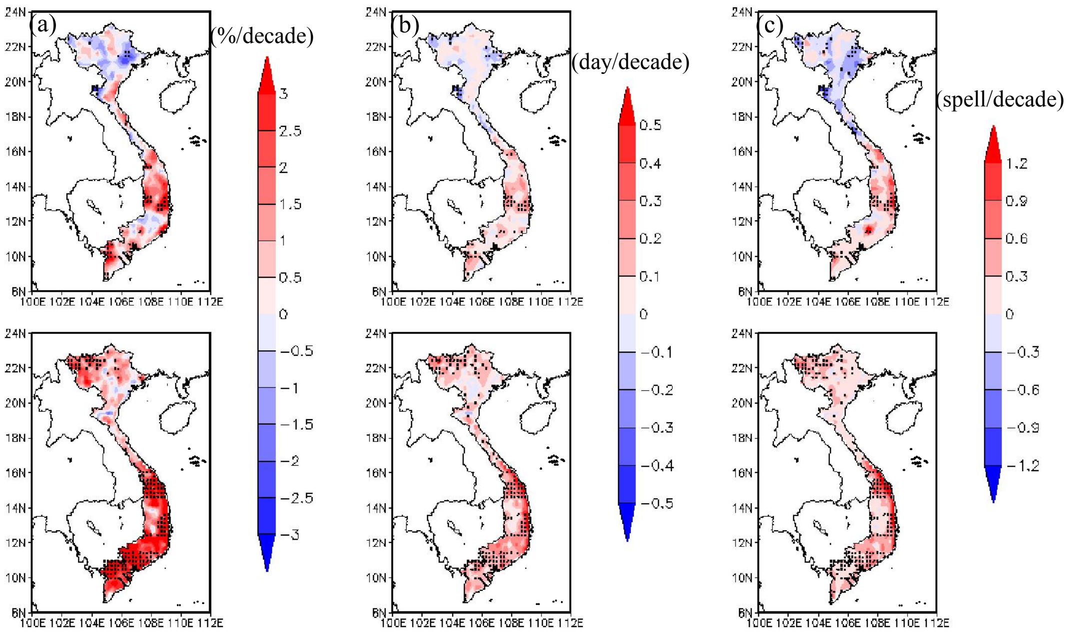

Figure 4. Trend in extreme rainfall indices, upper: APHRODITE, below: RegCM4.2 simulations; stippling shows trend at 95th significant level; (a) - R99tot; (b) - CHD; (c) - NHS

It is shown that simulated extreme rainfall in the south of Vietnam is better reproduced than that in the north. The model tends to overestimate the extreme rainfall trends in the south and create the inverse trends in the north compared to the observations. The area of simulated significant trends is wider than that of observation.

The observed positive trends of the maximum one-day rainfall (fig. 3a) in southern Vietnam are also reproduced by RegCM4.2 but with higher rate and the trends are more statistical significant. Comparing between the model and the observation in extreme frequency (fig. 3b,c) reveals that the model has the best skill in South-Central Vietnam. The model overestimates R99tot (fig.4a) in South-Central and South Vietnam. The model simulation skill for extreme duration indices is similar to other indices with a relatively better skill in South Vietnam.

Table 1. Regional average of the intensity, frequency, fraction and duration of rainfall extreme events; Left of slash: observation; right of slash: simulation; Bold: significance at 95%.

	Extreme intensity	Extreme frequency		Extreme percent	Extreme duration	
Region	*Rx1day*	*R50mm*	*R99p*	*R99tot*	*CHD*	*NHS*
N1	-1.222/**4.643**	-0.067/**0.429**	-0.007/**0.591**	0.040/**1.839**	**-0.037/0.131**	-0.046/**0.323**
N2	-2.360/**3.579**	-0.191/**0.243**	-0.088/**0.324**	-0.423/**0.803**	-0.011/**0.103**	-0.177/**0.206**
N3	-3.715/1.181	-0.357/0.136	-0.094/0.208	-0.417/0.146	0.007/0.014	**-0.355**/0.146
N4	2.204/2.464	-0.313/0.169	-0.013/0.24	0.400/0.370	-0.042/0.074	-0.283/0.144
S1	**12.218/14.127**	**0.736/1.155**	**0.404/1.233**	**2.095/3.072**	0.139/**0.351**	**0.524/0.769**
S2	**4.581/6.879**	**0.277/0.282**	0.228/**1.035**	0.668/**2.012**	**0.089/0.130**	**0.247/0.258**
S3	**3.498/6.305**	**0.179/0.289**	**0.420/1.196**	**1.136/2.999**	**0.080/0.153**	**0.166**/0.247

Table 1 shows the regional average of rainfall extreme events for each sub-region of Vietnam. The simulated trends of all regional average extreme rainfall indices are positive. The trends are dominantly significant in the southern sub-regions including N1, N2 and N3. The observed trends are negative only in the northern sub-regions.

5. Conclusion

Observed patterns of trends in different extreme rainfall indices are spatially coherent in South Vietnam. Extreme rainfall trends in the north are weaker and less statistical significant than in the south. The majority of stations throughout Vietnam show low statistically significant trends. Amongst all stations only Tuyhoa shows positive trends in different indices with high significant level.

The spatial trend patterns of all the indices simulated by RegCM4.2 in the southern sub-regions are much better than those in the northern sub-region in comparison with the observations. The observed negative trends in North Central Vietnam are not well reproduced by the model. Moreover, RegCM4 overestimates the positive trends of the indices in South Vietnam.

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