VOL. 10, NO. 15, AUGUST 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

RECENT VARIATIONS IN DAILY EXTREMES OF TEMPERATURE AND PRECIPITATION IN HAINAN ISLAND OF SOUTH CHINA

Mao-Fen Li[1], Yu-Ping Li[1] Peng-Tao Guo[2] and Wei Luo[2]
[1]Institute of Scientific and Technical Information, Chinese Academy of Tropical Agriculture Sciences, Danzhou, China
[2]Institute Chinese Academy of Tropical Agriculture Sciences, Danzhou, China

ABSTRACT

Hainan Island, as the biggest island in the tropical region of China, the daily extremes of temperature and precipitation may cause serious regional and global consequences, but observation-based research in Hainan is scarce. In this paper, recent annual changes of daily temperature and precipitation extremes at 7 meteorological observing stations in Hainan Island from 1975 to 2012 were studied. Twelve extreme temperature and 11 extreme precipitation indices are selected referring to the CCI/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices. The results indicated that changes indeed occur in daily temperature and precipitation extremes in Hainan Island, but the changes are not uniform at different locations in the region. Over Hainan Island, coldest night (TNn), coldest day (TXn), cool days (TX10p), warmest night (TNx), warmest day (TXx), warm nights (TN90p), warm days (TX90p), warm spell duration indicator (WSDI) showed warming trends, whereas cool nights (TN10p), cold spell duration indicator (CSDI) and diurnal temperature range (DTR) showed cooling trends between 1975 and 2012. Additionally, the magnitude of trends for indices of TN10p, TN90p, TX90p, WSDI are more pronounced than those of TXx, TNn, TXn, TX10p, CSDI, TNx and DTR. All the regional annual series for the indices in precipitation over Hainan Island have an upward tendency during 1975-2012. Annual total wet-day precipitation, maximum 1-day and 5-day precipitation, very wet and extremely wet day precipitation, annual count of days when Pt≥10mm, Pt≥25mm and Pt≥50mm in the study area generally showed growing patterns. It is noteworthy that the shifts of the probability distribution function (PDF) curves of TN90p, TX90P, TNx, TXx and TX10P are less evident in 2005-2012 during the past four decades. While the shift of the PDF curves of precipitation extremes are more evident than those of temperature. The PDF curves of P10mm, P25mm, P95 and P99 were the most evident in 1985-1994.

Keywords: tropical Island, climate extremes, temperature extremes, precipitation extremes, South China.

INTRODUCTION

With significant global warming from the Fourth Assessment Report of IPCC [1], it is widely conceived that the warming consequence will possibly result in the increase of precipitation amount and intensity. In recent years, extreme meteorological and hydrological events have been extensively discussed due to the considerable impact on agriculture, ecology and infrastructure, and disruption to human activities [2-4]. In south China, the frequent disturbance of typhoon and chilling injury has done a great damage to rubber plantations [5-7] and other tropical crops. In the last decade, Hainan Island, the biggest tropical island in China, has experienced the coldest chilling injury in January, 2008 since the 1970s, with a low temperature around 10°C and a duration of nearly 20 days [6, 7]. These injuries are usually accompanied with long-term second damages such as tree dieback, farmland drowned and crop failure. However, the changes in daily climate extremes in Hainan Island are overlooked.

Several works have been done taking into account the investigation of climate extreme changes and trends based on long time observed series with minimum, maximum or mean temperatures and precipitation under various climates, such as western central Africa, Guinea Conakry, and Zimbabwe [8], Central America and northern South American [9], Georgia [10, 11], central and south Asia [12], India [13], Europe [14], the western Tibetan Plateau [15] and China [16]. However, the extreme changes in temperature and precipitation are diverse in both space and time. Contrasts to subtropical regions, the meteorological stations are sparse in tropical region and little research have related to the daily extremes about tropical region.

IPCC reported a decrease of daily cold extremes and cold nights, while an increase of warm extremes and warm nights during 1906-2005 [1]. Wang *et al*. [17] have investigated the changes of extreme precipitation and streamflow processes in the Dongjiang River Basin in south China and shown that little change was observed in annual extreme precipitation in terms of various indices using data of 4 meteorological stations between 1956 and 2004. South China is often affected by a variety of extreme weather and climate events. Hot days and heat waves are commonly seen and floods nearly hit south China every year due to the abundant monsoon rainfall [16]. Hainan Island, as the biggest island in the tropical region of China, the daily extremes of temperature and precipitation may cause serious regional and global consequences. Up to now, there have been few reports on extremes climate about tropic area and the daily extreme variations of temperature and precipitation in Hainan Island is still unclear. The current study concerning daily extremes of precipitation and temperature in Hainan Island

ARPN Journal of Engineering and Applied Sciences

of South China could represent a further contribution to the study of local observed changes in a range of climate indices. The main goal of this study was to present the long-term changes in daily temperature and precipitation extremes over Hainan Island to research the changes in frequency, intensity and duration of climate extremes during 1975-2012.

DATA AND METHODOLOGY

A. Study area and data

Hainan Island is located in the South China Sea. As the China's southernmost biggest island, Hainan Island has a tropical monsoon climate with plenty of sunshine and good rainfall. However, the climate of Hainan Island change little difference in south and north because of Niuling Mountain, an important geographical and climatic dividing line of south and north Hainan Island. The climate is less warm and relative humility is higher in the north of Niuling. Whereas the climate in the south of Niuling is dry and rainless with long sunshine hours. In addition, sunshine duration is different in different area and it is the most in the west coast area and least in the central mountain regions.

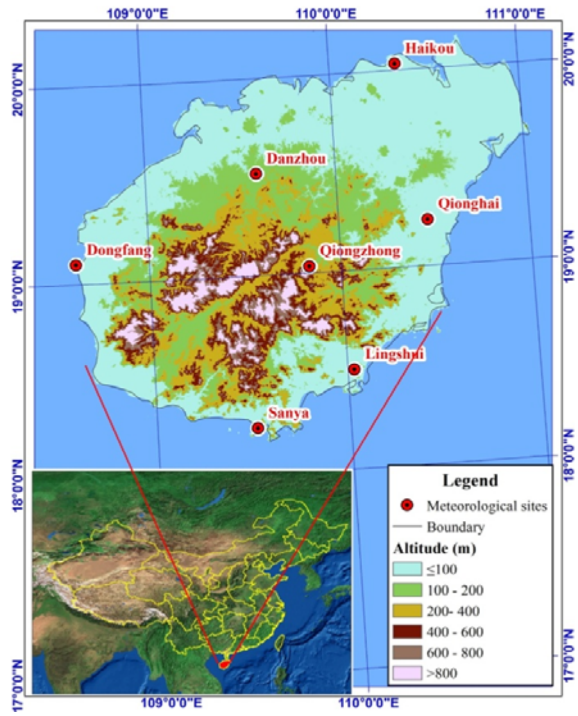

Figure-1. Study area and location of observation stations in Hainan Island, South China.

Table-1. List of selected stations with latitude, longitude, altitude and annual mean daily temperature and precipitation from 1975 to 2012 in Hainan Island, South China.

Station	Abb.	Latitude (N)	Longitude (E)	Altitude (m)	Temperature (°C)	Precipitation (mm)
Haikou	HK	20.0	110.4	13.9	24.9	4.6
Dongfang	DF	19.1	108.6	7.6	25.6	2.7
Danzhou	DZH	19.5	109.6	169	24.7	5.1
Qiongzhong	QZH	19.0	109.8	250.9	23.9	6.6
Qionghai	QH	19.2	110.5	24	25.3	5.6
Sanya	SY	18.2	109.5	6	26.3	3.9
Lingshui	LSH	18.5	110.0	13.9	25.9	4.7

The observed meteorological data of 7 meteorological stations in Hainan Island from 1975 to 2012, including daily maximum temperature (Tmax, °C), minimum temperature (Tmin, °C) and precipitation (Pt, mm), were acquired from the National Meteorological Information Center (NMIC) of China Meteorological Administration (CMA). All the studied stations spread uniformly over Hainan Island (Figure-1 and Table-1). Among these stations, stations of Dongfang and Sanya are coastal. Dongfang located in the southwest coast whereas Sanya was the southern-most station.

B. Quality control and homogeneity

Data quality control was done and the errors were corrected by the National Meteorological Information Center of China Meteorological Administration [15]. Subsequently all the observed daily temperature and precipitation data have been subject to strict quality control (including extreme value test and time homogenization test) using the software RClimDex V1 written in R from http://etccdi.pacificclimate.org. A website, http://etccdi.pacificclimate.org/software.shtml, provided details of quality control procedures and references to relevant literature. The program can replace all the missing or unreasonable values with NaN (not available) that the software recognizes. In addition, the potential outliers for temperature have to be manually validated and corrected. In the current study, the threshold for outliers was defined as the mean plus/minus 3 times standard deviations, according to previous studies [18].

C. Indices calculation

A total of 23 extreme climate indices are selected in this paper (Table-2), which are considered to be core indices and recommended by the CCI/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices. These indices were calculated by RClimDex V1, which had been widely used to assess the variations in daily precipitation and temperature extremes [12, 15, 19]. In this study, some indices, including the number of heavier precipitation days and rainstorm days (daily Pt≥25 mm and Pt≥50mm, respectively) are calculated on purpose to examine the frequencies of rainfall with tropical monsoon climate in the South China Sea.

To detect the linear trends for extreme indices of temperature and precipitation, the widely used ordinary least squares regression was applied in the current study. A trend is considered to be statistically significant if the P≤0.05 using a two-tailed t-test. Regional annual series for extreme indices were calculated as an arithmetic mean value of 7 stations over Hainan Island.

Besides the aforementioned variations, the probability distribution functions (PDF) of these indices are also calculated for the four decades, providing an insight into the decadal variability of temperature and precipitation extremes.

RESULTS AND DISCUSSIONS

A. Changes in temperature extremes

Figure-2 showed the decadal trends in extremes between 1975 and 2012 for the cold-related indices of temperature over Hainan Island, and the linear trends for each individual station were demonstrated in Table-3.

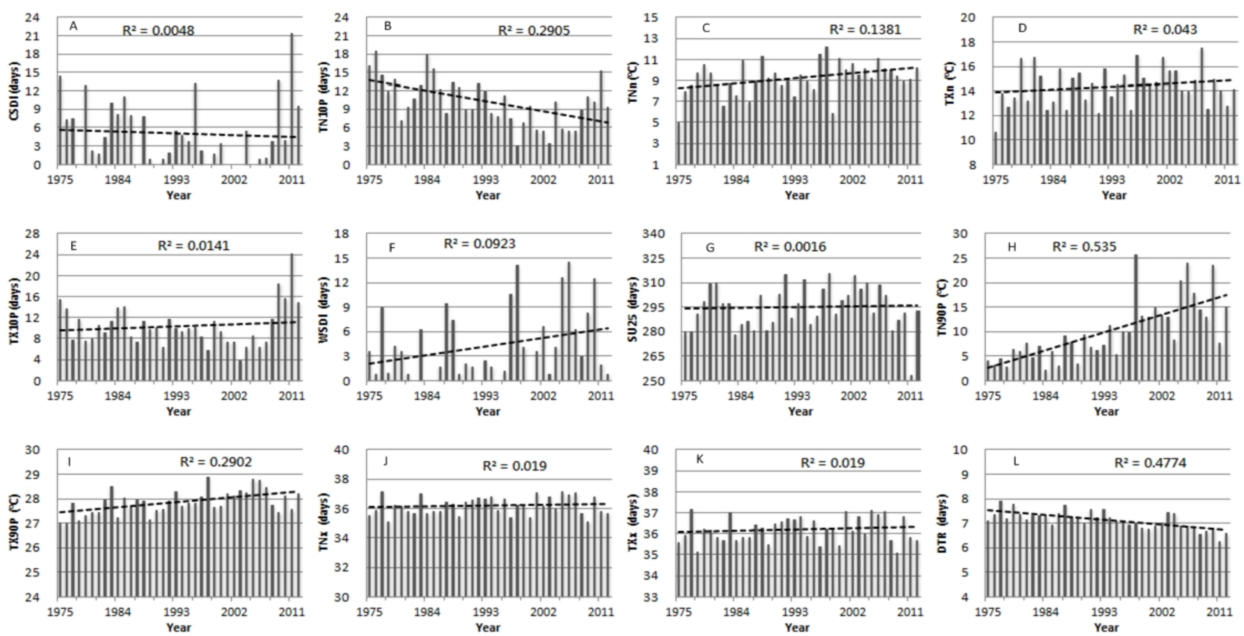

Figure-2. Regional annual series for the indices in temperature over Hainan Island during 1975-2012. (The dashed line is the linear trend and R2 is its correlation coefficient. A-E are cold-related indices; F-K are warm-related indices; L is variability index.).

ARPN Journal of Engineering and Applied Sciences

Table-2. Definitions of the temperature and precipitation indices used in this study.

Index		Descriptive name	Definitions	Units
Temperature	CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when Tmin<10th percentile	days
	WSDI	Warm spell duration indicator	Annual count days with at least 6 consecutive days when Tmax>90th percentile	days
	DTR	Diurnal temperature range	Monthly mean difference between Tmax and Tmin	^oC
	SU25	Summer days	Annual count of days when Tmax>25 ^oC	days
	TN10P	Cool nights	Days when Tmin<10th percentile of 1975-2012	days
	TN90P	Warm nights	Days when Tmin>90th percentile of 1975-2012	days
	TX10P	Cool days	Days when Tmax < 10th percentile of 1975-2012	days
	TX90P	Warm days	Days when Tmax > 90th percentile of 1975-2012	days
	TNn	Coldest night	Annual lowest Tmin	^oC
	TNx	Warmest night	Annual highest Tmin	^oC
	TXn	Coldest day	Annual lowest Tmax	^oC
	TXx	Warmest day	Annual highest Tmax	^oC
Precipitation	Prtot	Wet day precipitation	Annual total precipitation from wet days	mm
	SDII	Simple daily intensity index	Average precipitation on wet days	mm/day
	Pmax1day	Maximum 1-day precipitation	Annual maximum 1-day precipitation	mm
	P95	Very wet day precipitation	Annual total precipitation when Pt>95th percentile of 1975-2012 daily precipitation	mm
	P99	Very wet day precipitation	Annual total precipitation when Pt>99th percentile of 1975-2013 daily precipitation	mm
	Pmax5day	Maximum 5-day precipitation	Annual maximum consecutive 5-day precipitation	mm
	CDD	Consecutice dry days	Maximum number of consecutive dry days	day
	CWD	Consecutice wet days	Maximum number of consecutive wet days	day
	P10mm	Number of heavy precipitation days	Annual count of days when Pt≥10mm	day
	P25mm	Number of heavier precipitation days	Annual count of days when Pt≥25mm	day
	P50mm	Number of rainstorm days	Annual count of days when Pt≥50mm	day

ARPN Journal of Engineering and Applied Sciences

Table-3. Linear trends in temperature indices in different stations over Hainan Island from 1975 to 2012.

Index		Unit of linear trend	Station name						
			Haikou	Dongfang	Danzhou	Qiongzhong	Qionghai	Sanya	Lingshui
Cold-related indices	CSDI	days/decade	-0.199*	-0.092	-0.172	-0.239*	-0.245*	0.847*	-0.128
	TN10P	days/decade	-0.21*	-0.194**	-0.268**	-0.365**	-0.28**	0.291	-0.285**
	TNn	ºC/decade	0.051*	0.049*	0.045*	0.079*	0.055*	0.017	0.066*
	TXn	ºC/decade	0.035	0.025	0.03	0.049	0.048	-0.027	0.043
	TX10P	days/decade	-0.102	-0.06	-0.055	-0.08*	-0.114*	0.846*	-0.141*
Warm-related indices	WSDI	days/decade	0.187	0.076	0.013	-0.054	0.205**	0.209	0.194
	SU25	days/decade	0.378	0.32	0.144	0.251	0.345	-1.475*	0.37
	TN90P	ºC/decade	0.348**	0.33**	0.398**	0.493**	0.503**	0.374*	0.375**
	TX90P	ºC/decade	0.168*	0.108	0.072	0.114	0.324*	0.267*	0.346**
	TNx	days/decade	0.022*	0.017*	0.042**	0.04*	0.032	-0.004	0.015*
	TXx	days/decade	0.014	-0.008	-0.001	0.014	0.037*	-0.032	0.027*
Variability indices	DTR	ºC/decade	-0.008	-0.019*	-0.027**	-0.032**	-0.014*	-0.046**	-0.01*

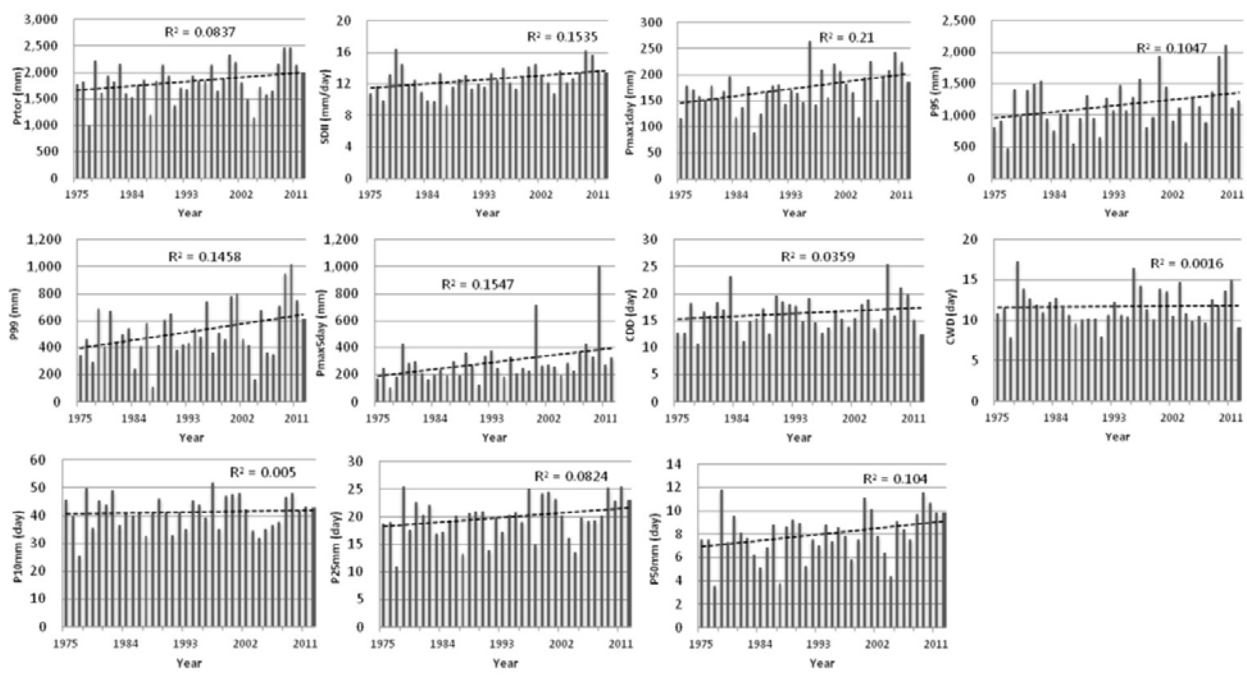

Figure-3. Regional annual series for the indices in precipitation over Hainan Island during 1975-2012. (The dashed line is the linear trend and R^2 is its correlation coefficient.).

TNn and TXn have increased by 0.052 and 0.029 ºC/decade, respectively. And the regional trend of TNn is statistically significant ($P \leq 0.05$). All stations except Sanya have significant positive TNn whereas none of the studied stations can pass the significant test at the 0.05 level. The linear trend for TN10p and TX10p are -0.187 and 0.042 days/decade, respectively. And all the stations except Sanya showed the significant negative trend for TN10p ($P \leq 0.05$). For CSDI, the linear trend is -0.033 days/decade. The value fluctuation becomes more feeble gradually during the study period, while CSDI for each station shows different magnitudes ranging from -0.245 (Qionghai) to 0.847 (Sanya) days/decade. For stations, Sanya showed different linear trend for cold-related indices compared with other stations in the study area (Table-3).

ARPN Journal of Engineering and Applied Sciences

SU25 have increased by 0.048 days/decade, and only Sanya station shows the significant negative trend at the 0.05 level. TNx has significantly increased by 0.023 ºC/decade and TXx shows a relatively lower trend of 0.007 ºC/decade. And all the stations except Sanya showed the significant positive trend for TNx (P≤0.05) similar to the indice of TN10p. All the studied stations exhibit a significant positive linear trend with averaged value of 0.403 days/decade for TN90p. For WSDI, the averaged trend is 0.119 days/decade for the current study area and only one station (Qionghai) can pass the significant test with WSDI of 0.205 days/decade (P≤0.001).

Changes in DTR are also shown in Table 3. Linear trend is -0.022 ºC/decade. Among the studied stations, Danzhou, Qionghai and Sanya have passed the significant test at the 0.001 level.

B. Changes in precipitation extremes

Regional annual series for the indices in precipitation over Hainan Island during 1975-2012 are demonstrated in Figure-3. All the linear trends for each index are not statistically significant for stations of Danzhou, Qionghai, Qiongzhong and Lingshui as shown in Table-4. CDD and CWD days show little positive trends but failing to pass the significant test at the 0.05 level. Annual Prtot has increased by 7.751 mm/decade during the study period. Pmax1day and Pmax5day precipitations show increasing trends of 1.53 and 1.555 mm/decade, respectively, and only Haikou and Qionghai stations showed a statistically significant trend. For P95 and P99, the linear trends are 8.724 and 6.845 mm/decade, respectively. The inappreciable increase of SDII (0.077 mm/day/decade) is also shown in Table-4 and Sanya has passed the significant test at the 0.001 level with SDII of 0.149 mm/day/decade. P10mm, P25mm and P50mm in the study area generally show up growing patterns. However, P10mm at Haikou, Qiongzhong and Qionghai stations show negative tendencies and all of them cannot pass the significant test. Indices of P25mm and P50mm at Sanya station show significant increasing trends of 0.198 and 0.099 day/decade (P≤0.05), respectively.

In particular, a high value of Rx5 usually suggests flood. Nevertheless, paroxysmal large amount of water could be the prerequisite, which mainly attribute to heavy precipitation events (e.g. rainstorms) [20].

Table-4. Linear trends in precipitation indices in different stations over Hainan Island from 1975 to 2012.

Index	Unit of linear trend	Station name						
		Haikou	Dongfang	Danzhou	Qiongzhong	Qionghai	Sanya	Lingshui
Prtot	mm	12.494*	5.390	5.981	-2.546	10.481	14.653*	7.805
SDII	mm/day	0.082*	0.124*	0.035	0.008	0.077*	0.149**	0.063
Pmax1day	mm	3.44*	2.092	0.764	-1.529	3.354*	1.691	0.897
P95	mm	14.214*	6.976	5.955	-0.005	10.974*	14.61*	8.346
P99	mm	15.469*	5.843	3.712	-3.405	12.766*	9.224*	4.307
Pmax5day	mm	5.637*	3.292	-1.708	-2.658	5.64*	2.008	-1.325
CDD	day	-0.002	-0.068	0.123	0.068	0.008	0.118	0.132
CWD	day	0.055	0.006	0.032	0.018	-0.029	-0.033	0.004
P10mm	day	-0.002	0.002	0.091	-0.074	-0.041	0.181	0.104
P25mm	day	0.094	0.021	0.101	0.048	0.076	0.198*	0.109
P50mm	day	0.083	0.054	0.055	0.011	0.074	0.099*	0.037

Note: * are statistically significant at the 0.05 level, ** are statistically significant at the 0.001 level.

C. Changes of probability distribution functions (PDF)

In order to further investigate the temporal variation characteristics in temperature and precipitation extremes, especially the interdecadal change trends, abrupt step change years and change cycles. Figure-4 and Figure-5 show the PDFs of the occurrence of annual temperature and precipitation extremes in the past four decades, respectively.

It is noteworthy that the shifts of the PDF curves of warm nights (TN90p), warm days (TX90P), warmest nights (TNx), warmest day (TXx) and cool days (TX10P) are less evident in 2005-2012. For instance, the probabilities of TN90p, TX90P, TNx, TXx and TX10P in 1995-2004 were about 10%, 12%, 9.5%, 5.9% and 13.5%, respectively (Figure-4). Whereas the probabilities of these indices quickly decreased to 6%, 6.6%, 5%, 3.6% and 5% in 2005-2012, respectively (Figure-4). For cool nights (TN10P) (Figure-4A), the maximum probability did not change much (around 10%) in the latest three decades (1985-2012), while it was a little lower (8%) in 1975-

ARPN Journal of Engineering and Applied Sciences

1984. The more evident shifts of PDF curves of coldest night (TNn) occurred in 2005-2012; the probability of TNn in 1995-2004 was about 20% while the probability in 2005-2012 increased to about 47%.

For the PDFs of precipitation extremes, indices of P10mm, P25mm, P50mm, P95 and P99 were selected to study the interdecadal change trends, abrupt step change years and change cycles (Figure-5). It is noteworthy that the shifts of the PDF curves of precipitation extremes are more evident than those of temperature. The PDF curves of P10mm, P25mm, P95 and P99 were the most evident in 1985-1994. Whereas the PDF curve of P50mm was evident in 2005-2012. This indicates that annual count of days when Pt≥50mm was increased in 2005-2012 and the maximum probability (28%) of days when Pt≥50mm were 10 days. However, the maximum probability (22%) of days when Pt≥50mm in the first three decades were about 7-8 days. The PDF curve of P25mm in 1985-1994 and that of P99 in 1995-2004 both have two peaks, respectively.

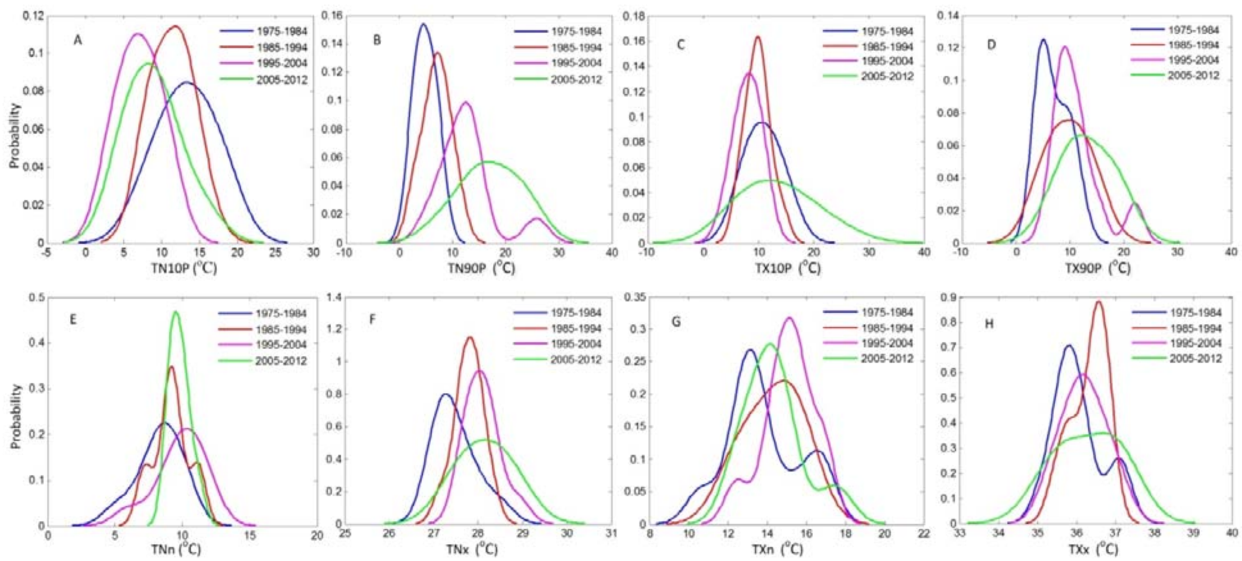

Figure-4. The probability functions (PDF) of annual (A) TN10p, (B) TN90p, (C) TX10p, (D) TX90p, (E) TNn, (F) TNx, (G) TXn and (H) TXx over Hainan Island in the past four decades.

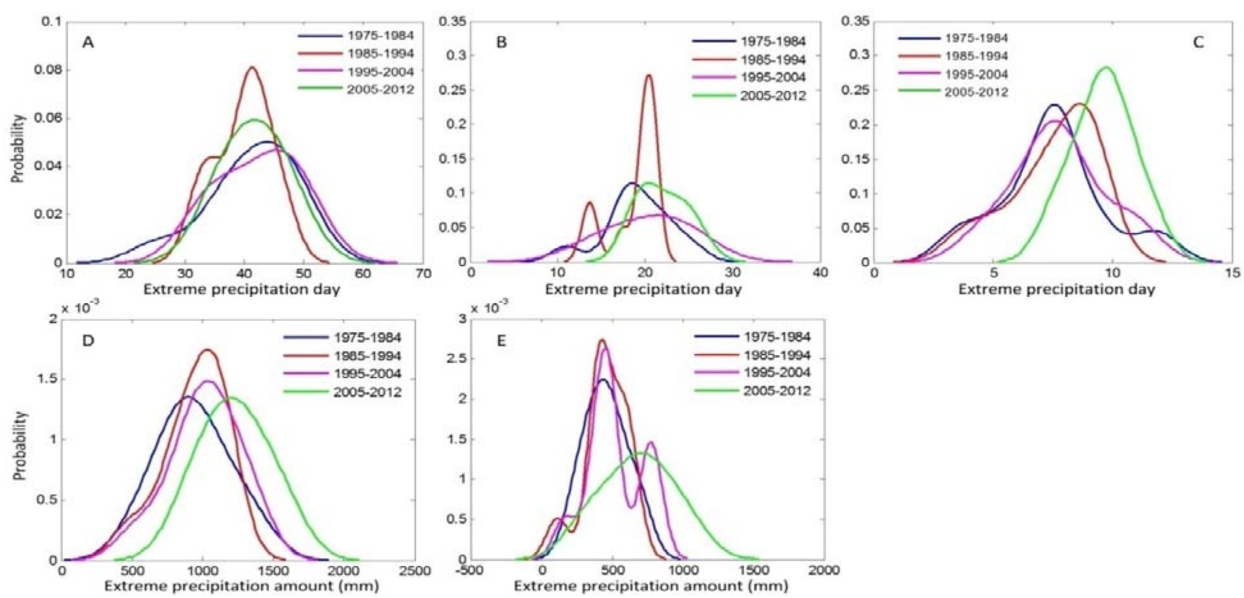

Figure-5. The probability functions (PDF) of annual (A) P10mm, (B) P25mm, (C) P50mm, (D) P95 and (E) P99 over Hainan Island in the past four decade.

VOL. 10, NO. 15, AUGUST 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

D. Comparison with other studies

Changes of daily temperature and precipitation extremes at the Hainan Island also have been compared with the previous studies (Table-5). In general, the trends are broadly similar, but there are some differences. The regional trend of temperature extremes generally is lower than elsewhere, which may be caused by the trend computation method or indicated less climatic warming over study region [18]. The time periods in Table 5 differ slightly, the current study pay more attention to recent changes of climate extremes. Warm-related extremes of TX90P, TN90P, TXx, TNx in this study also show significant warming trend similar with other studies.

Comparison of precipitation indices with those for other regions is difficult because of the non-significant trend (Table-5) except SDII. The value of SDII is much higher than those in other regions and closer to central and southern Asia (1961-2000) [21].

Table-5. Comparison of trends of temperature and precipitation extremes between this study and other sources (Trends significant at the 5% level are in bold).

Index	Hainan Island (1975-2012)	China (1961-2005)	Global (1951-2003)	Central and southern Asia (1961-2000)	Central and northern south America (1961-2003)	Western central Africa (1955-2006)
TN10P	-0.187	-2.06	-1.26	-1.63	-2.4	-1.71
TX10P	0.042	-0.47	-0.62	1	-2.2	-1.22
TXn	0.054	0.35	0.37	0.18	0.3	0.13
TNn	0.052	0.63	0.71	0.27	0.3	0.23
TX90P	0.200	0.62	0.89	2.24	2.5	2.87
TN90P	0.403	1.75	1.58	2.35	1.7	3.24
TXx	0.007	0.07	0.21	0.16	0.3	0.25
TNx	0.023	0.21	0.3	0.19	0.2	0.21
SU25	0.048					
CSDI	-0.033			-0.5		
WSDI	0.119			2.4		
Prtot	7.751	3.21	10.59	-0.05	8.7	-31.13
SDII	0.077	0.06	0.05	0.08	0.3	0.06
Pmax1day	1.530	1.37	0.85	0.05	2.6	-0.87
P95	8.724	4.06	4.07	0.02	18.1	-12.19
P99	6.845					
Pmax5day	1.555	1.9	0.55	0.33	3.5	-1.54
CDD	0.054	-1.22	-0.55	3.57	0.4	-0.06
CWD	0.008					
P10mm	0.037					
P25mm	0.092					
P50mm	0.059					
Data sources	This study	[22]	[23]	[21]	[9]	[8]

CONCLUSIONS

Due to the absence of long-term observation at tropical regions, previous research in climate extremes over the tropical island in China are limited. This study analyzed changes in temperature and precipitation extreme indices in Hainan Island based on daily maximum and minimum temperatures and precipitation for the period 1975-2012. The current study could improve the understanding of recent changes in the variability, intensity, frequency and duration of climate extreme events over Hainan Island in South China. Following changes for temperature and precipitation indices were observed in the study area:

ARPN Journal of Engineering and Applied Sciences

There are warming trends in Hainan Island for TNn, TXn, TX10p, TNx, TXx, TN90p, TX90p, WSDI between 1975 and 2012. Cooling trends revealed through TN10p, CSDI and DTR. The magnitude of trends for indices of TN10p, TN90p, TX90p, WSDI are more pronounced than those of TXx, TNn, TXn, TX10p, CSDI, TNx and DTR.

All the regional annual series for the indices in precipitation over Hainan Island have an upward tendency during 1975-2012. Prtot, Pmax1day and Pmax5day, very P95 and P99, P10mm, P25mm, P50mm in the study area generally show up growing patterns.

It is noteworthy that the shifts of the PDF curves of TN90p, TX90P, TNx, TXx and TX10P are less evident in 2005-2012 during the past four decades. While the shift of the PDF curves of precipitation extremes are more evident than those of temperature. The PDF curves of P10mm, P25mm, P95 and P99 were the most evident in 1985-1994.

ACKNOWLEDGEMENT

This study is supported by the National Science-technology Support Plan Projects of China (2013BAD15B01) and Hainan Science Foundation (20154184). This study is also supported by Key Laboratory of Practical Research on Tropical Crops Information Technology in Hainan, China. We are very grateful to the National Meteorological Information Center (NMIC) of China Meteorological Administration (CMA) for data offering and to the reviewers for their constructive comments and thoughtful suggestions.

REFERENCES

[1] IPCC. Climate Change. 2007. The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, 2007.

[2] M.P., Fearnside. Forests and global warming mitigation in Brazil: opportunities in the Brazilian forest sector for responses to global warming under the “clean development mechanism”. Biomass Bioenergy. 1999, 16 (3), pp.171-189.

[3] P.M.Cox, R.A.Betts, C.D. Jones, S.A.Spall, I.J. Totterdell. Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature, 2000,408, pp.184-187.

[4] I. Kurane. The effect of global warming on infectious diseases. Publ. Health Res. Perspect. 2010, 1 (1), pp. 4-9.

[5] K.He, D.Huang, Rubber Culture in the Northern Part of Tropical Area. Guangdong Science and Technology Press, Guangdong. 1987.

[6] K. Liyan, X.Guishui, T. Zhongliang, Y. Lifu, C. Zhifu, Analysis on rubber tree cold injury in 2007/2008 winter in Hainan. Chin. Agric. Sci. Bull. 2009, 25, pp. 251-257.

[7] B. Chen, J. Cao, J. Wang, Z. Wu, Z. Tao, J. Chen, C. Yang, G. Xie. Estimation of rubber stand age in typhoon and chilling injury afflicted area with Landsat TM data: A case study in Hainan Island, China. Forest Ecology and Management. 2012, 274, pp. 222-230.

[8] E. Aguilar, A. AzizBarry, M. Brunet, L. Ekang, A. Fernandes, M. Massoukina, J. Mbah, A. Mhanda, D.J. do Nascimento, T.C. Peterson, O. Thamba Umba, M. Tomou, X. Zhang, Changes in temperature and precipitation extremes in western central Africa, Guinea Conakry, and Zimbabwe 1955-2006. J. Geophys. Res. 2009, 114, D02115, http://dx.doi.org/10.1029/2008JD011010.

[9] E. Aguilar, T.C. Peterson, P. Ramírez Obando, R. Frutos, J.A. Retana, M. Solera, I. González Santos, R.M. Araujo, A. RosaGarcía, V.E. Valle, M. BrunetIndia, L. Aguilar, L. Álvarez, M. Bautista, C. Castañón, L. Herrera, R. Ruano, J.J. Siani, G.I. Hernández Oviedo, F. Obed, J.E. Salgado, J.L. Vázquez, M. Baca, M. Gutíerrez, C. Centella, J. Espinosa, D. Martínez, B. Olmedo, C.E. Ojeda Espinoza, M. Haylock, R. Núñez, H. Benavides, R. Mayorga, Changes in precipitation and temperature extremes in Central America and northern South America, 1961-2003. J. Geophys. Res. 2005, 110, D23107, http://dx.doi.org/10.1029/ 2005JD006119.

[10] E.Sh. Elizbarashvili, M.R. Tatishvili, M.E. Elizbarashvili, Sh.E. Elizbarashvili, R.Sh. Meskhiya. Air temperature trends in Georgia under global warming conditions. Russ. Meteorol. Hydrol. 2013, 38, pp. 234-238, http://dx.doi.org/10.3103/S1068373913040043.

[11] I. Keggenhoff, M. Elizbarashvili, A. Amiri-Farahani, L. King. Trends in daily temperature and precipitation extremes over Georgia, 1971-2010. Weather and Climate Extremes. 2014, 4, pp. 75-85.

[12] A.M.G. Klein Tank, T.C. Peterson, D.A. Quadir, S. Dorji, X. Zou, H. Tang, K. Santhosh, U.R. Joshi, A.K.

ARPN Journal of Engineering and Applied Sciences

Jaswal, R.K. Kolli, A.B. Sikder, N.R.Deshpande, J.V. Revadekar, K. Yeleuova, S. Vandasheva, M. Faleyeva, P. Gomboluudev, K.P. Budhathoki, A. Hussain, M. Afzaal, L. Chandrapala, H. Anvar, D. Amanmurad, V.S. Asanova, P.D. Jones, M.G. New, T. Spektorman. Changes in daily temperature and precipitation extremes in central and south Asia. J. Geophys. Res. 2006, 111, D16105, http://dx.doi.org/10.1029/2005JD006316.

[13] P. Indrani, A.T. Abir. Trends in seasonal precipitation extremes - An indicator of 'climate change' in Kerala, India. J. Hydrol. 2009, 367 (1-2), pp. 62-69.

[14] M.M. Millán. Extreme hydrometeorological events and climate change predictions in Europe. J. Hydrol. 2014, 518, pp. 206. http://dx.doi.org/10.1016/j.jhydrol.2013.12.041.

[15] S. Wang, M. Zhang, B. Wang, M. Sun, X. Li. Recent changes in daily extremes of temperature and precipitation over the western Tibetan Plateau, 1973-2011. Quaternary International, 2013, 313-314, pp.110-117.

[16] X. Xu, Y. Du, J. Tang, Y. Wang. Variations of temperature and precipitation extremes in recent two decades over China. Atmospheric Research. 2011, 101, pp. 143–154.

[17] M. Boccolari, S. Malmusi. Changes in temperature and precipitation extremes observed in Modena, Italy. Atmospheric Research, 2013, 122, pp. 16-31.

[18] Z. Li, Y. He, P. Wang, W. H. Theakstone, W. An, X. Wang, A. Lu, W. Zhang, W. Cao. Changes of daily climate extremes in southwestern China during 1961-2008. Global and Planetary Change, 2012, 80-81, pp. 255-272.

[19] W. Liu, M. Zhang, S. Wang, B. Wang, F. Li, Y. Che. Changes in precipitation extremes over Shaanxi Province, northwestern China, during 1960-2011. Quaternary International. 2013, 313-314, pp. 118-129.

[20] M. Liu, X. Xu, A. Y. Sun, K. Wang, W. Liu, X. Zhang. Is southwestern China experiencing more frequent precipitation extremes? Environ. Res. Lett. 2014, 9, 064002 (pp. 1-14).

[21] M. New, B. Hewitson, D. B. Stephenson, A. Tsiga, A. Kruger, A. Manhique, B. Gomez, C. A. S. Coelho, D. N. Masisi, E. Kululanga, E. Mbambalala, F. Adesina, H. Saleh, J. Kanyanga, J. Adosi, L. Bulane, L. Fortunata, M. L. Mdoka, R. Lajoie. Evidence of trends in daily climate extremes over Southern and West Africa. J. Geophys. Res. 2006, 111, D14102. doi:10.1029/2005JD006289.

[22] Q.You, S.C. Kang, E. Aguilar, N. Pepin, W.-A. Flügel, Y.P. Yan, Y.W. Xu, Y.J. Zhang, J. Huang. Changes in daily climate extremes in China and their connection to the large scale atmospheric circulation during 1961–2003. Clim. Dyn. 2011, 36(11-12), pp. 2399-2417.

[23] L.V. Alexander, X. Zhang, T. C. Peterson, J. Caesar, B. Gleason, A. M. G. Klein Tank, M. Haylock, D. Collins, B. Trewin, F. Rahimzadeh, A.Tagipour, K. Rupa Kumar, J. Revadekar, G. Griffiths, L. Vincent, D. B. Stephenson, J. Burn, E. Aguilar, M. Brunet, M. Taylor, M. New, P. Zhai, M. Rusticucci, J. L. Vazquez-Aguirre. Global observed changes in daily climate extremes of temperature and precipitation. J. Geophys. Res. 2006, 111, D05109. doi:10.1029/2005JD006290.