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Asian Monsoon Years (2007-2012): Extremity of the Extreme Rainfall Events Observed in Taiwan

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Abstract

The temperature in Taiwan shows a clear warming trend over the past one hundred years. Among the warmest ten years since 1896, seven of them appeared after 2000. The average temperature of the most recent five years, from 2006-2010, is 0.11ºC warmer than the temperature from 2001-2005. The purpose of this study is to assess the extremity of 2006-2010 in terms of the occurrence frequency of the extreme rainfall events. Unusually high frequency of the rainfall events in particular the ones with long durations, from 24 to 72 hours, are identified at 3-4 stations located near the southern and northern tips of Taiwan and at the high central mountain range. Main causes of the unusual extremes can be attributed to the anomalous cyclonic circulation over the northern part of the South China Sea and Philippine Sea that resulted in strong southwesterly winds to the west of the Luzon Island and southeasterly winds blowing from the west Pacific through the Philippine Sea towards Taiwan. The fluctuations of the Asian-Northwestern Pacific Monsoons at the lower-latitudes provided a favorable condition for the rainfall events in Taiwan to reach the extremes. After examining the frequency contrasts between five warmest (non-successive) years and five coldest years measured by the global and Taiwan annual mean temperatures during the period of 1961-2010, respectively, we concluded that the unusually high extremity of the recent five years is less influenced by climate change than monsoon fluctuations.

Data and Stations

1. Data: The 50-year hourly rainfall data at 21 stations maintained by the Central Weather Bureau of Taiwan during 1961-2010 are used.
2. The rainfall events associated with typhoons are identified according to whether a typhoon center can be identified within the 300 km boundary marked by the red circle in Fig. 1. The typhoon information is obtained from NOAA's IBTrACS project (http://www.ncdc.noaa.gov/oa/ibtracs/).

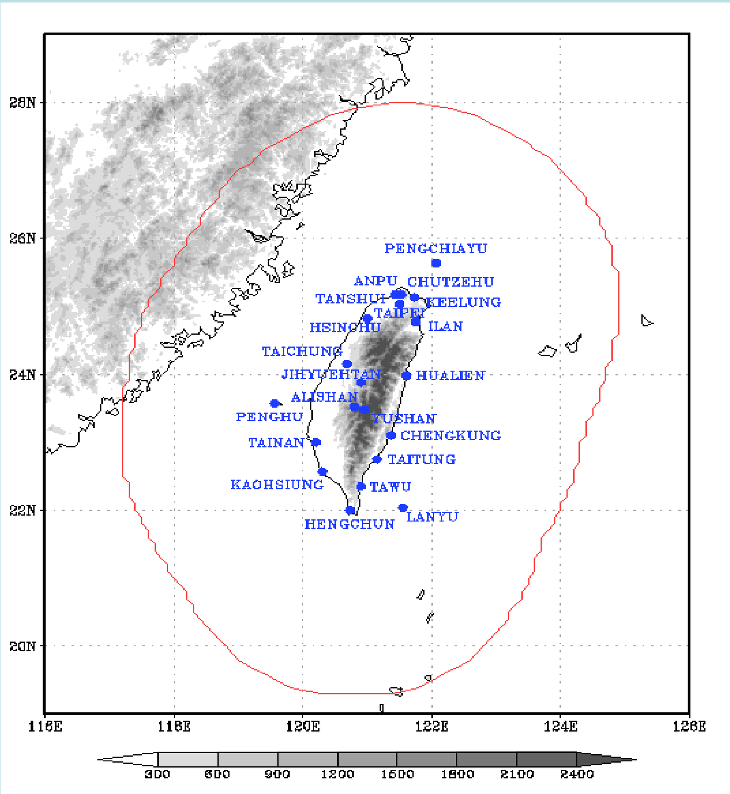

Fig. 1 Locations of the 21 weather stations used in this study. The red circle marks the boundary used for identifying typhoon rain.

Extreme Event Frequency Analysis

Analysis Procedure

1. Group the hourly data set into different subsets defined by the duration of a rainfall event. The rainfall events are defined using a sliding window to select the maximum accumulated rain with the durations of 1hr, 2hr, 3hr, 6hr, 12hr, 24hr, 48hr and 72hr. Only one event with a specific duration is defined within a long-lasting episode.
2. Simulate the "heavy" rainfall events by GPD. Then estimate the return period T-year on the GPD basis.
3. The rainfall events of T >= 2 year are hazardous and defined as the "extreme rainfall events" in this study.

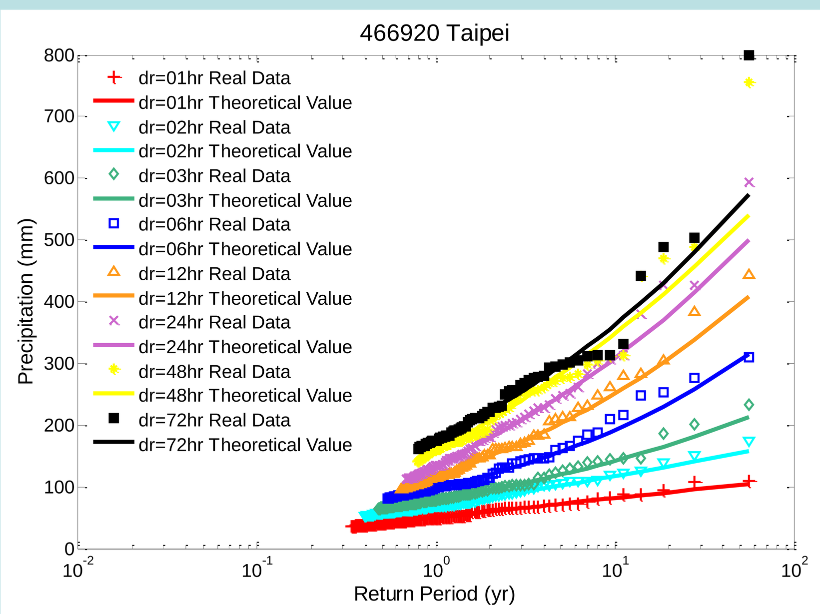

Fig. 2 GPD fitted to the sample of Taipei "heavy" rainfall events with the different durations

Evaluating the Extremity of the Rainfall Extremes during 2006-2010

Evaluation Procedure

1. Establish the background climatology of five-year occurrence frequency of the extreme rainfall events. The climatology is simulated using a simple random sampling method that first randomly select five individual (non-successive) years from 1961-2010 for 10000 times.
2. Compute the 10000 five-year accumulated frequencies and present their distribution in the Box Whisker Plots (BWP).
3. Use the BWP as a yardstick to evaluate the extremity of the extremes.

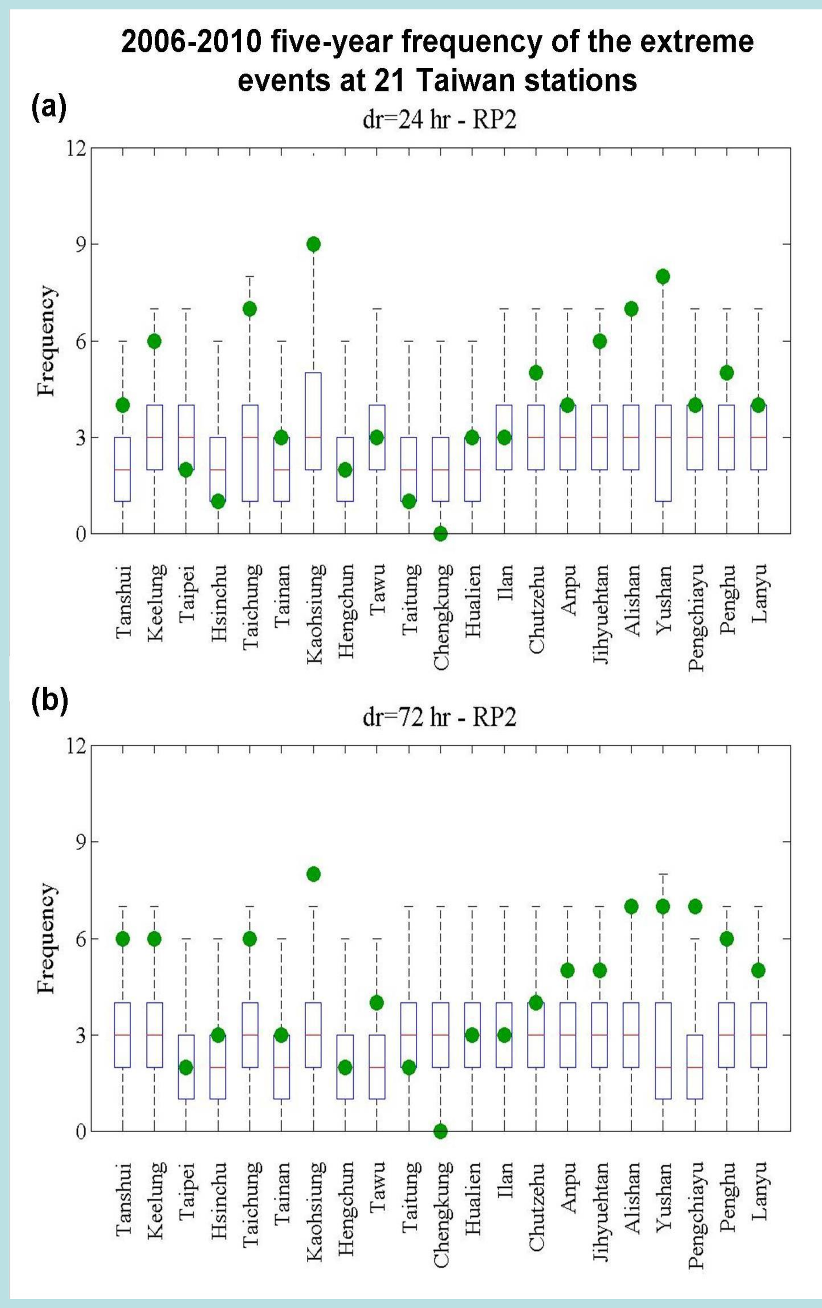

Fig. 3 The green circles are the five-year frequencies of the extremes at 21 stations during 2006-2010. Large inter-station difference mainly resulted from the complex terrain is noticed. (a) For the 24-hr extremes, the extremity at Kaohsiung, Alishan and Yushan stations reach or beyond the sample maximum, while Chengkung station shows minimum extremity. Eight (38%) of the twenty-one stations reach the upper quartile or higher, and half of them are mountain stations (Chuzehu, Jihyuehtan, Alishan, Yushan) with the altitude above 600m. (b) For the 72-hr extremes, fifteen (71%) of the twenty-one stations reach the upper quartile or higher. Station Kaohsiung appears as an outstanding outlier, so does Pengchayu.

Attribution of the Unusual Extremity during 2006-2010

Comparing the 2006-2010 monthly mean flow and precipitation patterns, we found very subtle but critical difference between the recent five years and the climatology before 2000. It appears that the large-scale circulations favor monsoon moisture surges to occur. The moisture surges are often associated with typhoons, Mei-Yu fronts and the coherent effect of mid-latitude fronts and tropical cyclones during autumn.

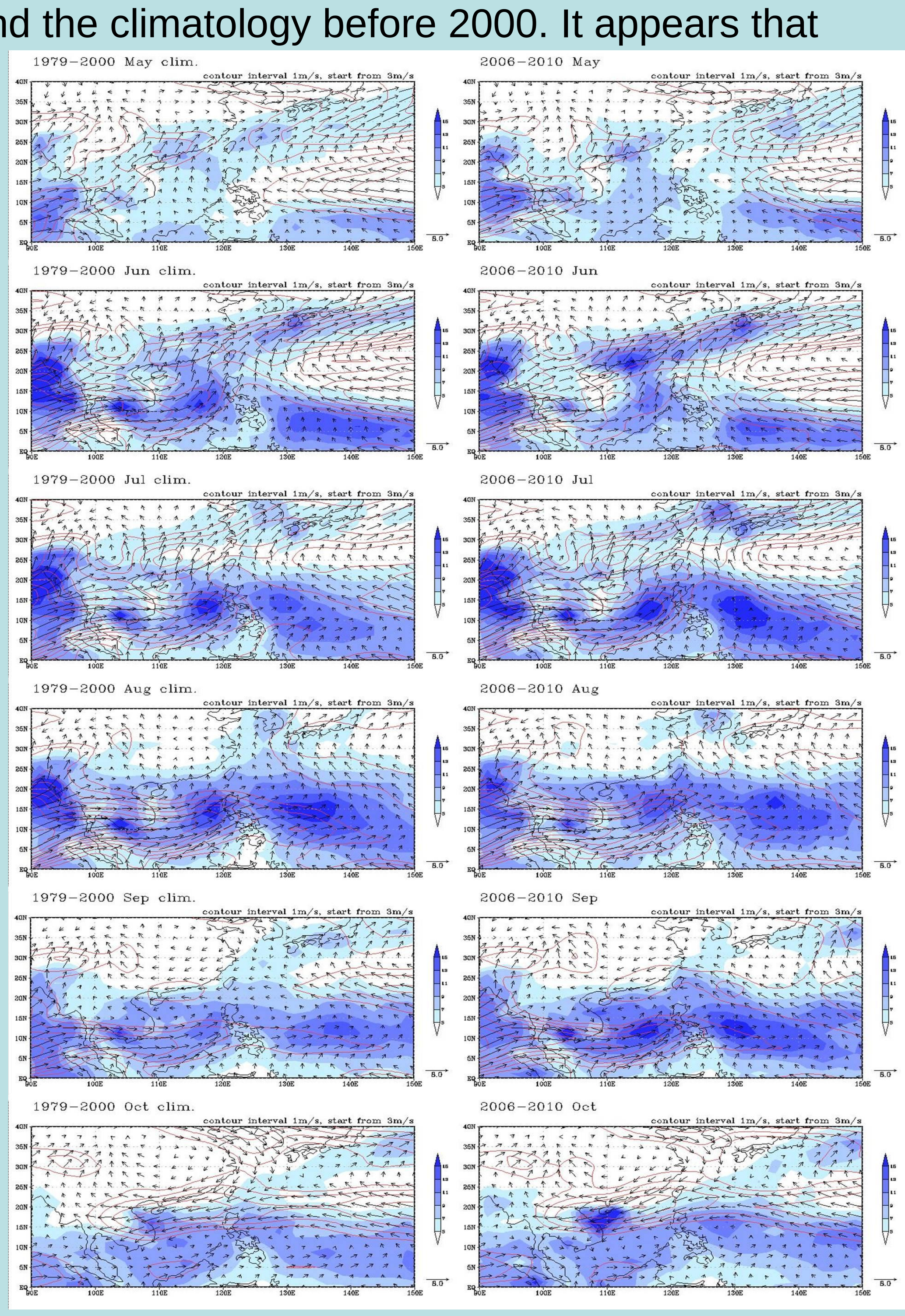

Fig. 4 <Left> The 1979-2000 climatology of the monthly mean winds at 850 hPa, wind speed (contour) and CMAP precipitation (color). <Right> The 2006-2010 monthly mean patterns of the same variables.

Assessing the Contribution of Global Warming Effect

We use the frequency contrast between five warmest (non-successive) years and five coldest years to roughly estimate the influence of warming effect on the extremity. The contrast between warm and cold years suggests that the extreme precipitation events do occur more frequent during the warm years than the cold years, but the inter-station difference is large. Although the warm years show more frequent extreme events, the frequencies of the cold years at many stations are above median. It suggests that the influence of the global mean temperature is weak. The stations (Tables 1 and 2), where the unusually frequent extremes during 2006-2010 are detected, do not show distinct difference in the frequencies between the warmest and coldest groups.

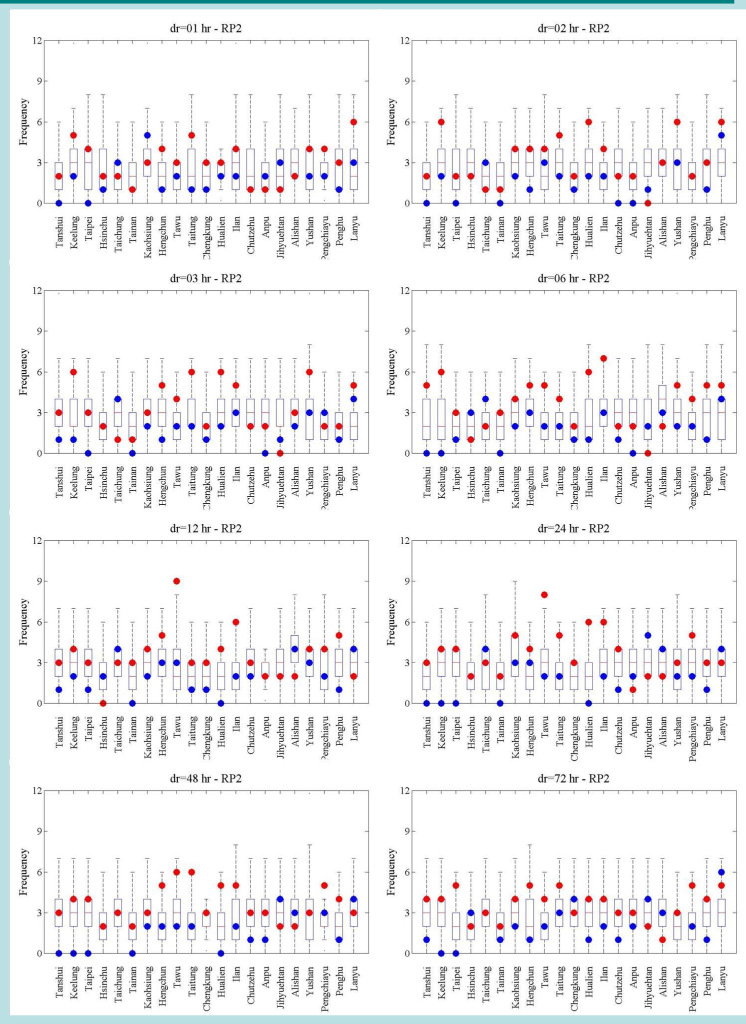

Fig. 5 The frequency contrasts between five warmest years (red circles) and five coldest years (blue circles) measured by the global annual mean temperatures during the period of 1961-2010. The warm years: 1998, 2002, 2003, 2005 and 2010; cold years: 1964, 1965, 1971, 1974, 1976.

Table 1 The 24-hr extreme events at the stations with unusually frequent occurrence of the extremes during 2006-2010.

YYMM DDHH	station	Rainfall (mm)	cause
06060905	Alishan	836.5	monsoon surge
06060906	Yushan	562.5	monsoon surge
06060914	Kaohsiung	357.5	monsoon surge
06070802	Kaohsiung	245	EWINIAR
06071318	Yushan	352.5	BILIS
06071405	Kaohsiung	301	BILIS
07081305	Kaohsiung	487	monsoon surge
07100609	Yushan	422	KROSA
07100610	Alishan	987.5	KROSA
08060419	Kaohsiung	231	monsoon surge
08061521	Kaohsiung	377	monsoon surge
08071707	Kaohsiung	322	KALMAEGI
08071711	Yushan	411	KALMAEGI
08071716	Alishan	590.5	KALMAEGI
08072803	Yushan	346	FUNG-WONG
08072807	Alishan	538	FUNG-WONG
08091306	Yushan	471.5	SINLAKU
08091318	Alishan	790.5	SINLAKU
08092815	Yushan	312.5	JANGMI
08092817	Alishan	720	JANGMI
09080714	Kaohsiung	537.5	MORAKOT
09080815	Alishan	1623.5	MORAKOT
09080816	Yushan	879.3	MORAKOT
10091907	Kaohsiung	480	FANAPI

Table 2 The 72-hr extreme events at the stations with unusually frequent occurrence of the extremes during 2006-2010

YYMM DDHH	station	Rainfall (mm)	cause
06060605	Pengchiayu	280.5	monsoon surge
06060809	Alishan	1333	monsoon surge
06060811	Kaohsiung	398.5	monsoon surge
06060815	Yushan	1143.5	monsoon surge
06071211	Yushan	554	BILIS
06071222	Alishan	773	BILIS
06071323	Kaohsiung	355	BILIS
06090903	Pengchiayu	246	monsoon surge
07060724	Pengchiayu	257	monsoon surge
07081207	Kaohsiung	608.5	monsoon surge
07081717	Alishan	756.5	SEPAT
07081718	Yushan	445.5	SEPAT
07091610	Pengchiayu	214.4	WIPHA
07100419	Alishan	1084	KROSA
07100420	Yushan	491.5	KROSA
08060219	Kaohsiung	335	monsoon surge
08061321	Kaohsiung	519	monsoon surge
08071509	Kaohsiung	328.5	KALMAEGI
08091216	Pengchiayu	663.5	SINLAKU
08091216	Yushan	843.5	SINLAKU
08091219	Alishan	1446.5	SINLAKU
08092624	Alishan	845	JANGMI
08092702	Yushan	485.5	JANGMI
09080603	Pengchiayu	296.5	MORAKOT
09080701	Alishan	2735.5	MORAKOT
09080702	Yushan	1914.2	MORAKOT
09080704	Kaohsiung	759.5	MORAKOT
10082815	Pengchiayu	361.1	NAMTHEUN
10091707	Kaohsiung	480	FANAPI

Conclusion

The recent five years from 2006-2010 are identified as a period with unusually high extremity in terms of the occurrence frequency of extreme rainfall events. The fluctuations of the Asian-Northwestern Pacific Monsoons at the lower-latitudes show more direct influence than the global and regional warm climate.

Acknowledgements

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