TRENDS IN INTENSITY & FREQUENCY OF PRECIPITATION EXTREMES IN MALAYSIA FROM 1951 TO 2009

Diong Jeong Yik, Subramaniam Moten, Munirah Ariffin and Siva Shangari Govindan
Research Section, Malaysian Meteorological Department
Jalan Sultan, Petaling Jaya, Malaysia
email : diong@met.gov.my

INTRODUCTION

Malaysia, located in the maritime continent of Southeast Asia, just north of the equator is influenced by the northern hemisphere summer and winter monsoons. Rainfall distribution is largely determined by intense convective precipitation and coastal areas facing the South China Sea by monsoonal rains during the winter monsoon season. The summer monsoon months are relatively drier except for Sabah, which is influenced by the effects of tropical cyclones in the WNP and SCS. Trends in extreme precipitation events is receiving global attention due to global warming and climate change. Past studies over Malaysia has being limited to a few stations, shorter period of records and analysis carried out using daily precipitation amounts. In this study we extend the analysis to include hourly precipitation and all stations with more than 30 years of record to examine trends at different time scales, from convective to durations covering the monsoon rain systems, trends at the seasonal and annual time scales, to elucidate comprehensively significant trends in extreme precipitation events.

Location of stations used in this study and its monthly mean precipitation.
Left panel Peninsular Malaysia (PM) and right panel East Malaysia (EM).

DATA & METHOD

Hourly precipitation data from 22 principal meteorological stations (minimum 30 years of record).

The trend analysis cover the periods from 1951 to 2009.

The indices and their trends are performed using RClimDex.

ID	INDEX	DEFINITIONS	UNIT
RX1	Maximum 1-day precipitation	Monthly maximum 1-day precipitation	mm
RX3	Maximum 3-day precipitation	Monthly maximum consecutive 3-day precipitation	mm
RX5	Maximum 5-day precipitation	Monthly maximum consecutive 5-day precipitation	mm/day
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (>1mm) in the year	days
R10	Number of heavy precipitation days	Annual count of days when PRCP≥10mm	days
R20	Number of very heavy precipitation days	Annual count of days when PRCP≥20mm	days
R30	Number of precipitation days above 30mm	Annual count of days when PRCP≥30mm	days
R50	Number of precipitation days above 50mm	Annual count of days when PRCP≥50mm	days
CDD	Consecutive dry days	Maximum number of consecutive days with PRCP<1mm	days
CWD	Consecutive wet days	Maximum number of consecutive days with PRCP≥1mm	days
R95	Very wet days	Annual total PRCP when RR>95th percentile	mm
R99	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR≥1mm)	mm

List of indices used in this study.

The regional averaged indices are calculated based on New *et. al.*, 2006

$$x_{r,t} = \sum_{i=1}^{n_t} (x_{i,t} - \bar{x}_i)/n_t$$

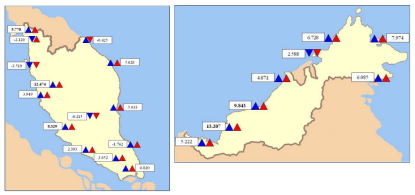
The indices are calculated in 3 different time-scale in order to analyze the trends in extreme events at convective, seasonal and annual time scales.

Cumulative hourly totals for 1,2 and 3 hours are examined to study extreme events trends at the convective time scales.

Statistical significant at various levels for the trends are based on the Kendall's tau statistic.

RESULTS

CONVECTIVE TIME SCALE- Trends in 2 hour maximum precipitation



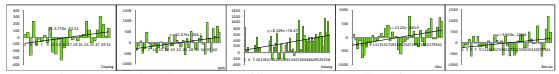
Frequency of Heavy Rainfall (blue) (>20mm) & Intensity (red) for 2 Hour Maximum Precipitation.
Number in box indicates trends in PRCPTOT.

Around 68% of stations show increasing trends in the maximum precipitation events, of which around 18% being statistically significant. Three quarters of the country shows upward trend in the frequency and intensity of extreme convective precipitation. Total amount of convective rainfall has increased in both PM and EM. However CDD in PM is on the rise while CWD days for convective time scales has decreased in both regions. More days are recording heavy and intense convective rain and the amount of convective rainfall on extreme rainfall days is showing upward trend in both regions.

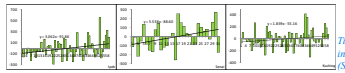
RESULTS

Index	Trend/Decade	
	P.M	E.M
RX1	0.06	0.00
RX5	0.02	0.08
SDII	**0.15***	0.05
R10	0.38	1.48
R20	**0.60****	1.41
R30	0.37	0.96
CDD	0.72	-0.66
CWD	-0.17	-0.04
R95	0.07	**0.20*****
R99	0.03	**0.16****
PRCPTOT	0.06	0.10

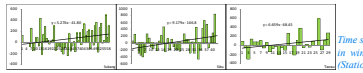
Regional averaged trends in the cumulative 2 hr max prcp. Significant at (***)90%,(**)95%, (*) 99% confidence level



Time series of PRCPTOT anomaly in 2 hour maximum rainfall. (Stations with statistically significant trends).



Time series of PRCPTOT anomaly in summer monsoon. (Stations with statistically significant trends).



Time series of PRCPTOT anomaly in winter monsoon. (Stations with statistically significant trends).

SEASONAL TIME SCALE- Trends in heavy precipitation during summer (JJA) and winter (NDJ) monsoon seasons

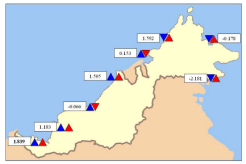
Frequency of Heavy Rainfall (blue) (>20mm) & Intensity (red) during Summer Monsoon. Number in box indicates trends in PRCPTOT.

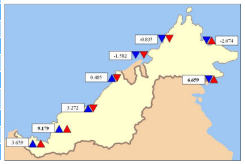
The summer and winter monsoon are getting wetter in both regions. In the case of summer monsoon, CWD has decreased in both regions while CDD has increased. The intensity of rain in both regions has strengthened during the summer monsoon. Meanwhile in EM, CDD has decreased marginally and CWD has increased during winter monsoon. However in PM, the trends are opposite where the CWD has decreased and CDD has increased.

The occurrence of extreme precipitation events in both regions shows increasing trend for both monsoon seasons.

Index	Trend/Decade (SUMMER)		Trend/Decade (WINTER)	
	P.M	E.M	P.M	E.M
RX1	0.03	**0.04*****	-0.00	**0.06****
RX3	0.03	**0.06*****	-0.01	0.02
RX5	**0.05***	0.03	-0.02	0.05
SDII	0.02	**0.16***	-0.01	0.00
R10	0.10	-0.11	0.10	0.07
R20	0.11	0.10	0.09	0.01
R30	0.09	0.07	0.05	0.03
R50	**0.07*****	**0.12*****	0.07	0.11
CDD	0.13	0.16	0.03	-0.00
CWD	-0.00	-0.05	-0.01	0.27
R95	0.03	0.07	0.01	0.08
R99	0.00	**0.05***	0.00	0.07
PRCPTOT	0.04	0.03	0.00	0.04

Frequency of Heavy Rainfall (blue) (>20mm) & Intensity (red) during Winter Monsoon. Number in box indicates trends in PRCPTOT.

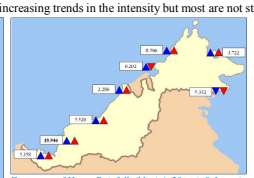




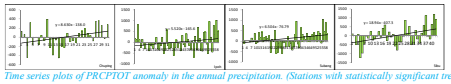
Regional averaged trends for seasonal rainfall.

ANNUAL TIME SCALE- Trends in heavy precipitation in the annual time scale

Most of the regionally averaged indices show increasing trends, however only a few are statistically significant. This is perhaps to be expected due to large interannual and decadal-scale variability of precipitation over the Malaysian region. The total amount of precipitation is showing marginally increasing trend in PM, while in EM the increasing trend is statistically significant. For both regions, CWD is decreasing and CDD is increasing. The total precipitation on the extreme rainfall days are showing upward trends in both region. Spatial variation based on trends at individual station shows majority of the stations having increasing trends in the intensity but most are not statistically significant. Thus there is generally a consistency between indices suggesting that the regionally averaged rainfall intensity (SDII) has increased along with the regionally averaged amount of rainfall on extreme rainfall days and the frequency.



Frequency of Heavy Rainfall (blue) (>20mm) & Intensity (red) for annual precipitation. Number in box indicates trends in PRCPTOT.



Time series plots of PRCPTOT anomaly in the annual precipitation. (Stations with statistically significant trends).

Index	Trend/Decade	
	P.M	E.M
RX1	0.03	**0.06***
RX5	0.02	**0.05*****
SDII	**0.10***	**0.16***
R10	-0.13	0.13
R20	0.10	0.52
R30	0.00	0.51
CDD	0.67	0.11
CWD	**-0.14***	-0.17
R95	**0.04***	**0.14***
R99	0.03	**0.10***
PRCPTOT	0.00	**0.08*****

Regional averaged trends in the annual rainfall.

CONCLUSIONS

This study provides a comprehensive analysis with regards to the spatial and temporal patterns of changes in the precipitation at 22 station across Malaysia for the period 1951 to 2009. One of the key findings of this study is that in general the intensity and frequency of extreme precipitation events are on the rise. The summer monsoon season is becoming wetter but at the same time prolonged dry spells are more frequent. During the winter monsoon the extreme precipitation events associated with the monsoon surges and other synoptic features are on the rise. Notable increasing trend in the annual precipitation is observed in EM with both the monsoon seasons possibly contributing to this trend.

SELECTED REFERENCE

New, M., et al.(2006), Evidence of trends in daily climate extremes over Southern and West Africa, *Journal of Geophysical Research*, 111, D14102

Zhang, X., et al. (2004), Rclimdex (1.0) user manual (Available at http://cccma.seos.uvic.ca/ETCCDMI/software.shtml)