Projected Changes in Seasonal Precipitation Extremes in Malaysia under Global Warming of 2°C and 4°C

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Introduction

- Southeast Asia region highly exposed and vulnerable to the impact of Climate change.
- Low resilience and adaptive capacity – mostly developing and least developed countries in the Southeast Asia region
- Malaysia has been experiencing extreme climate events in the past and may continue to do so in decades to come as climate continues to warm.
- There has been no detailed study of future changes in precipitation extremes over Malaysia.
- Huge challenge in achieving the main goal of Paris Agreement to limit global warming below 2°C relative to pre-industrial level.
- This study provides information of future changes in precipitation extreme in Malaysia under global warming of 2ºC and 4ºC.

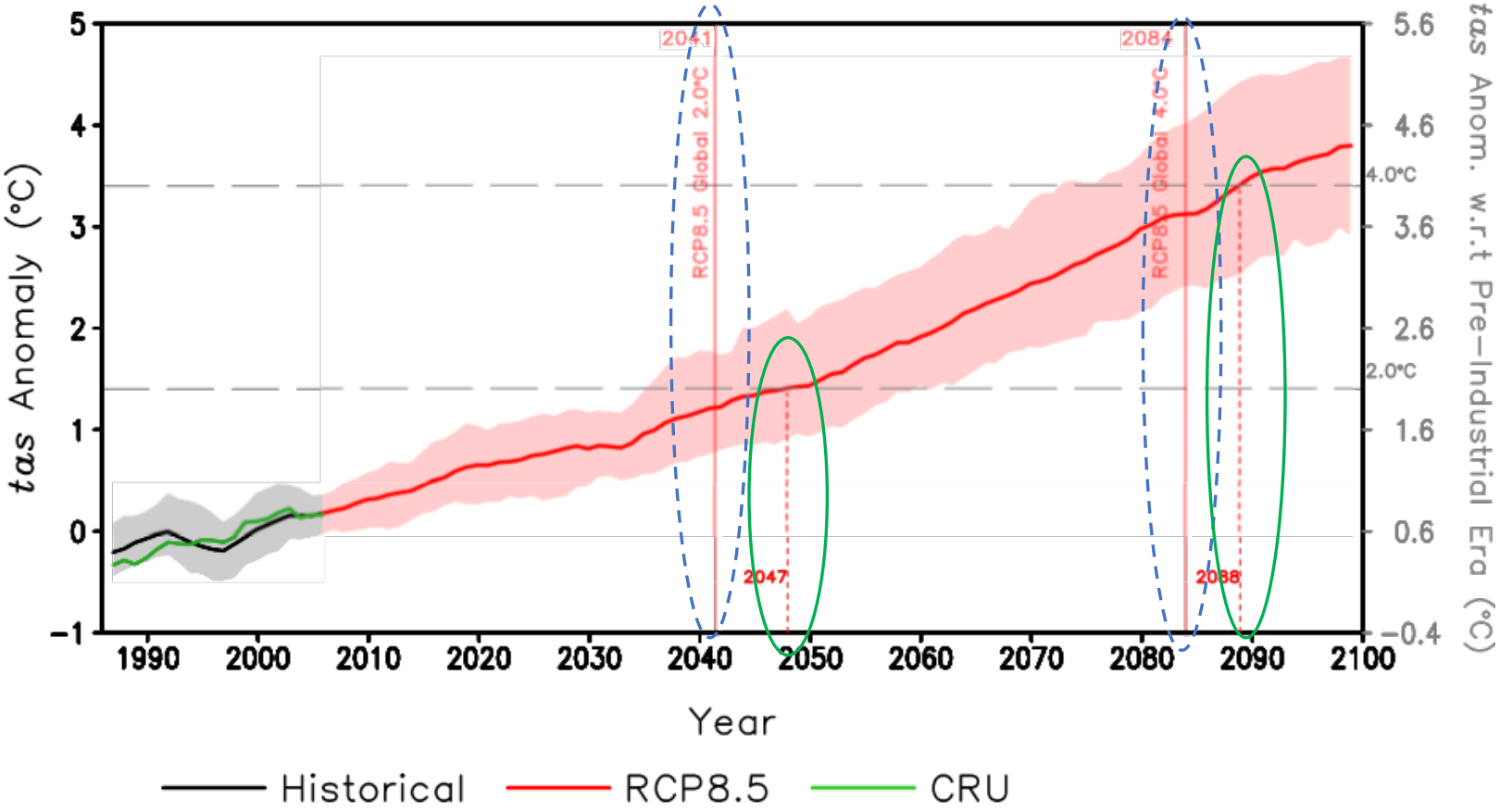
Methodology

TABLE 1: List of GCMs and RCMs considered in this study.

Ensemble member	GCM	RCM
1	CNRM-CM5 (CNRM, France)	RegCM4 (ICTP, Italy)
2	HadGEM2-AO (Hadley Centre, UK)	RegCM4 (ICTP, Italy)
3	MPI-ESM-MR (MPI-M, Germany)	RegCM4 (ICTP, Italy)
4	EC-Earth (EC-Earth consortium)	RegCM4 (ICTP, Italy)
5	CSIRO MK3.6 (CSIRO, Australia)	RegCM4 (ICTP, Italy)
6	HadGEM2-AO (Hadley Centre, UK)	WRF (NCAR USA)
7	CNRM-CM5 (CNRM, France)	RCA4 (SMHI, Sweden)
8	HadGEM2-ES (Hadley Centre, UK)	RCA4 (SMHI, Sweden)
9	HadGEM2-ES (Hadley Centre, UK)	PRECIS (Hadley Centre, UK)
10	MPI-ESM-LR (MPI-M, Germany)	ROM (GERICS-AWI, Germany)

TABLE 2: List of extreme indices considered in this study.

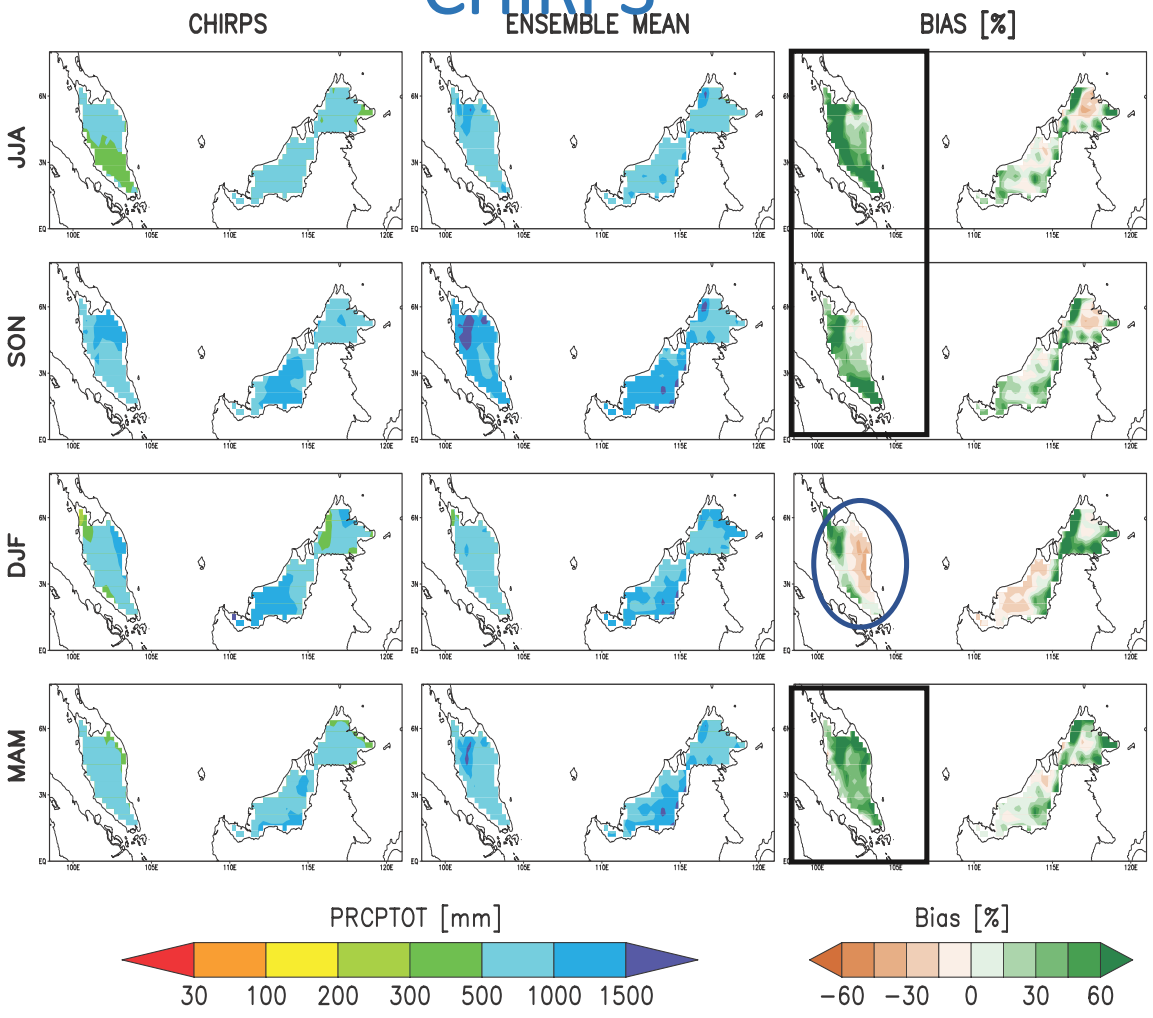
Index	Abbreviation	Description	Units
Total Precipitation	PRCPTOT	Seasonal total precipitation in wet days (> 1 mm)	mm
Consecutive Dry Days	CDD	Seasonal maximum number of consecutive days when daily precipitation < 1 mm	days
Number of extremely heavy precipitation days	R20mm	Seasonal count of days when daily precipitation ≥ 20 mm	days
Maximum 1-day precipitation amount	RX1day	Seasonal maximum 1-day precipitation	mm



Ensemble mean annual temperature anomalies (solid line) and its spread (shaded) averaged over Malaysia following the RCP8.5 scenario. The scale on the left y-axis indicates the change relative to the average over the historical period (1986–2005), while the scale on the right y-axis shows the change relative to pre-industrial level. In the historical period, the ensemble mean (black) is compared with observed temperature anomalies from the Climatic Research Unit (CRU) (green). The vertical lines indicate the years when global warming (solid line) and the warming over Malaysia (dashed line) reach 2°C and 4°C (relative to pre-industrial level).

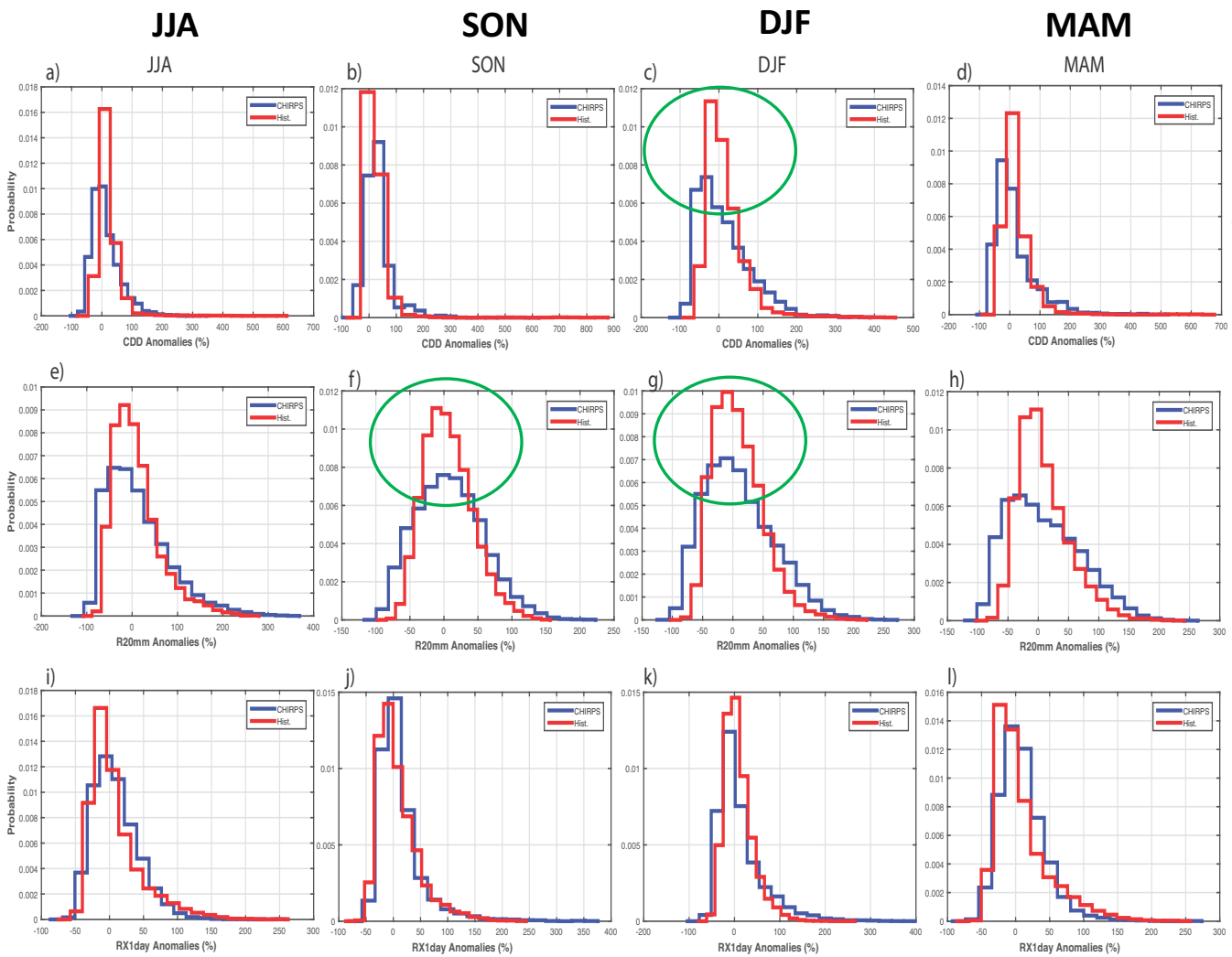
Results and Discussion

Bias between modelled and CHIRPS



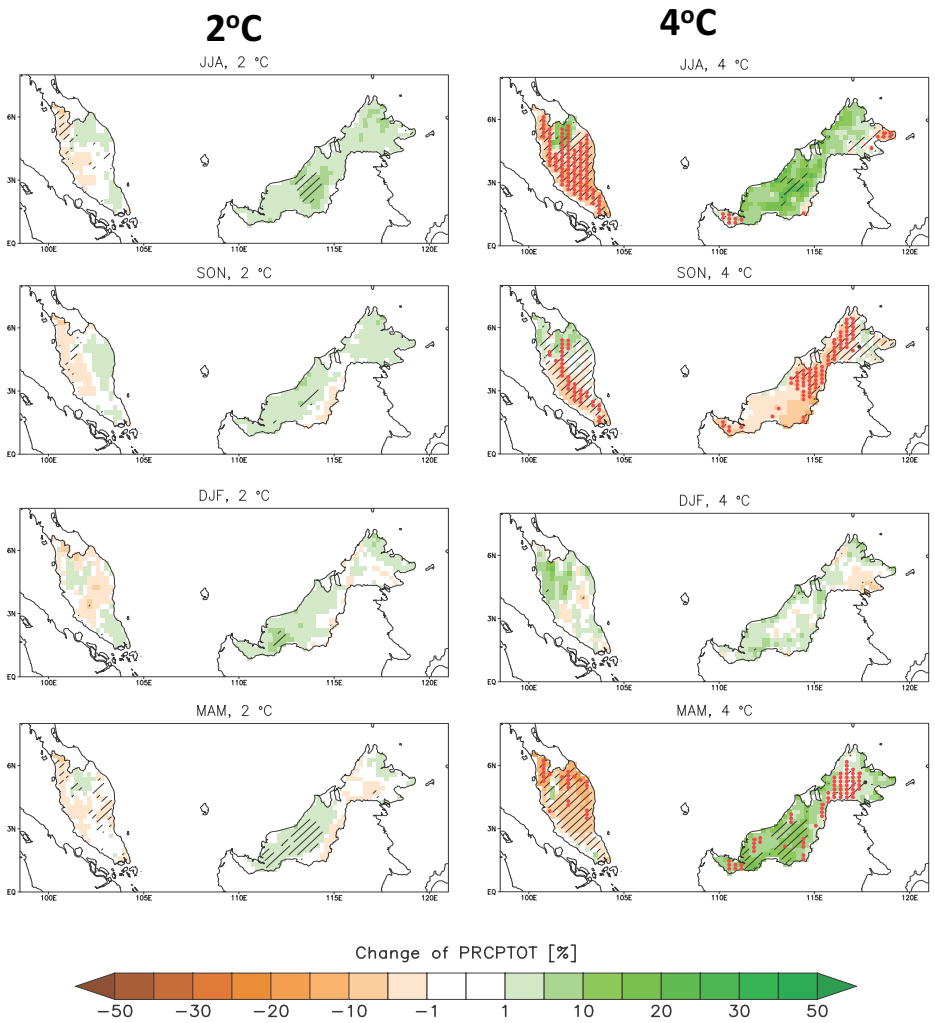
- There is a tendency for **wet biases** over **Peninsular Malaysia** during JJA, SON and MAM.
- the systematic biases - the **shortcoming in the model parameterization schemes**
- Interestingly, during DJF, dry biases - eastern parts of Peninsular Malaysia
- could also be associated with **failure capturing the monsoon and its associated circulations, including cold surges and Borneo vortex.**
- Over **Sabah and Sarawak**, some **patches of wet and dry biases** can also be seen.
- while **model's inadequacies** can be the prime suspect for any biases, the **shortcomings in gridded** observations certainly contribute too

PDF of the seasonal anomalies



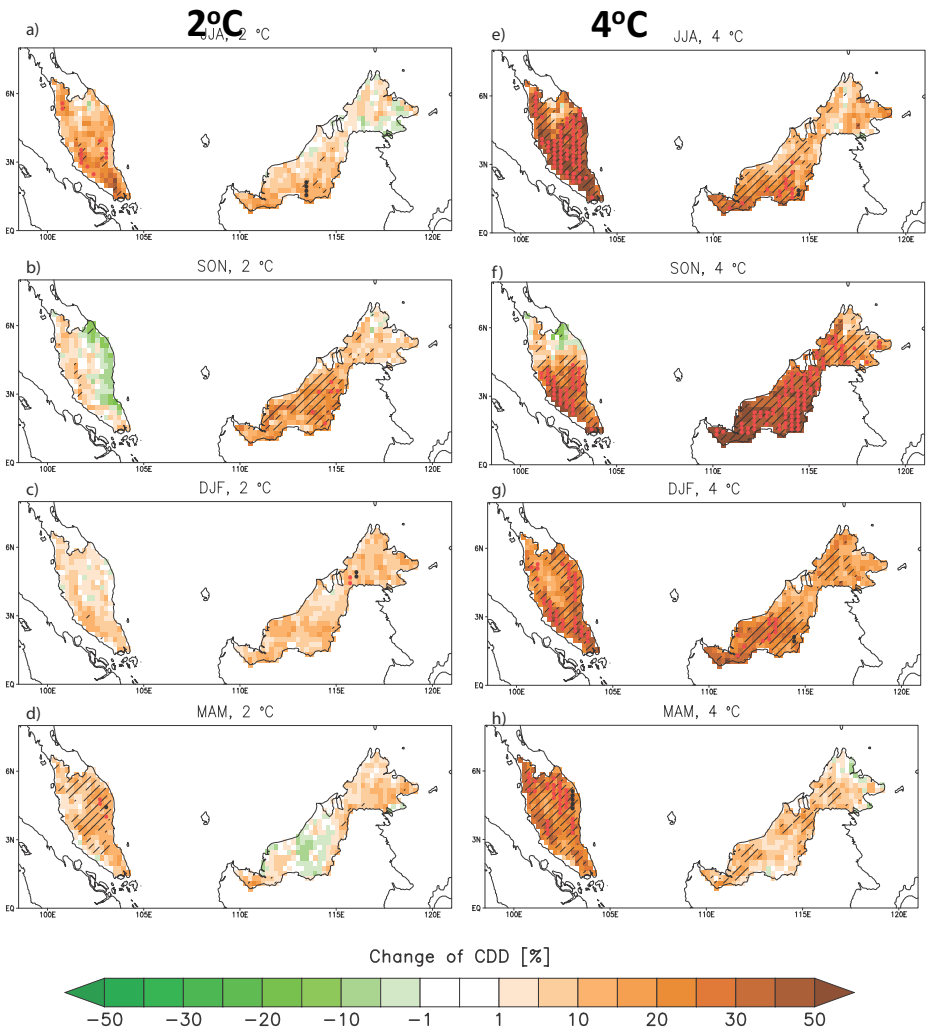
- observed (blue) and modelled (red) indices for the historical period.
- Model captures the distributions of anomaly of extremes rather well
- Generally, for all seasons and indices, the spreads of the modelled and observed PDFs match each other very well.
- However, the kurtosis of modelled R20mm and CDD PDFs were slightly higher than those observed.
- For R20mm, higher kurtosis indicates that greater number of modelled R20mm values reside closer to the mean.

Projected changes of seasonal PRCPTOT 2°C and 4°C thresholds



- hatched(significant), red dotted(robust).
- useful to analyze the projected changes of PRCPTOT as any changes in extreme precipitation will affect the total precipitation.
- 2°C thresholds - the percentage of change is generally relatively small.
- Only small area over Malaysia are projected to experience significant increases and decreases but changes not robust.
- The increases and decreases percentage of PRCPTOT are projected to enhance at 4°C for all seasons except for DJF.
- During SON the northern East Malaysia is projected to experience significant decreases percentage of PRCPTOT and robust.

Projected changes of seasonal CDD



JJA

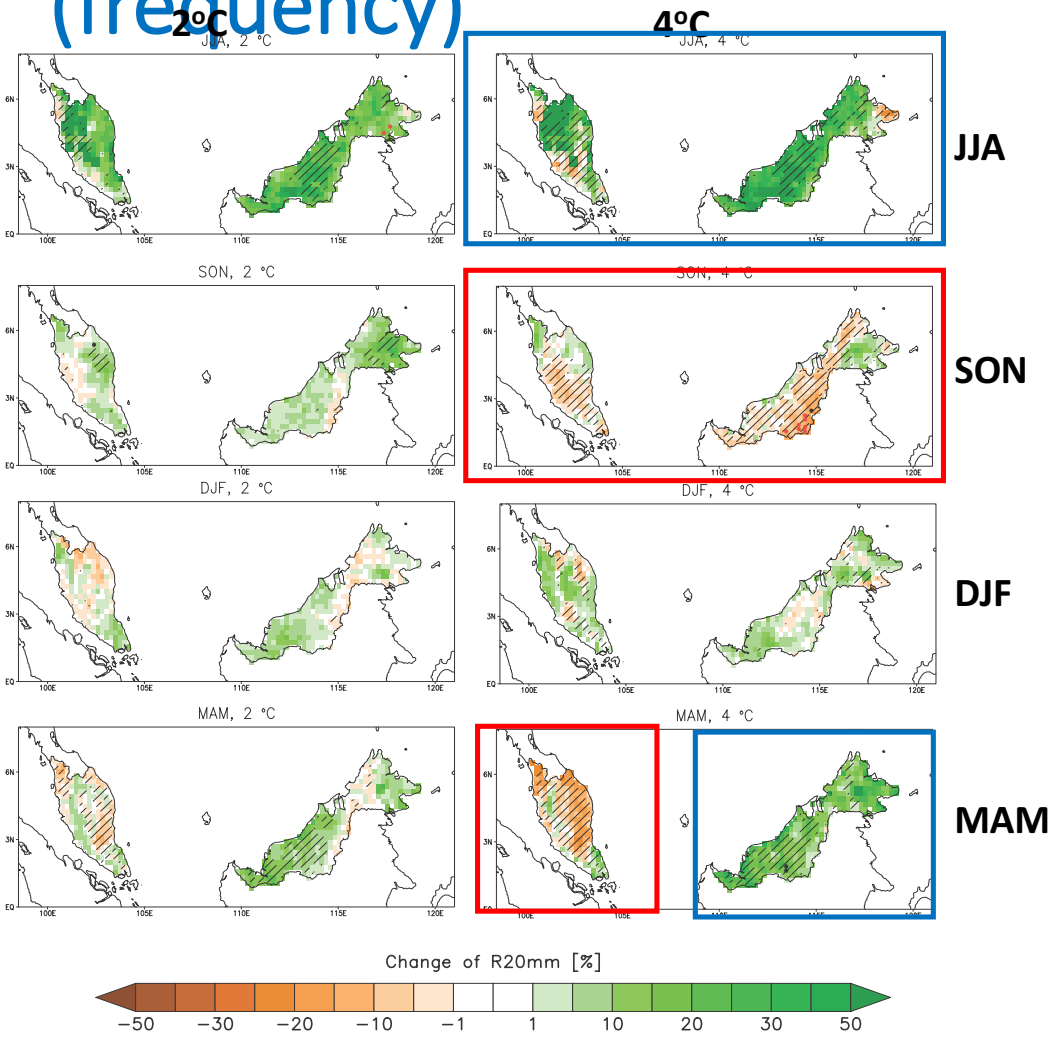
SON

DJF

MAM

- Generally, seasonal CDD is projected to increase over Malaysia when the global mean temp reaches 2ºC above pre-industrial level.
- The CDD is projected to increase significantly and robust in some area of Peninsular Malaysia during JJA and MAM.
- Over East Malaysia the projected increase CDD is significant and robust only during SON.
- Generally, the increases of CDD at 4ºC is projected to enhance significantly and also robust for all seasons.
- Despite the tendency to have prolonged dry days in the future, not all Malaysia region is projected to experience significant reduction in total rainfall especially over the East Malaysia.

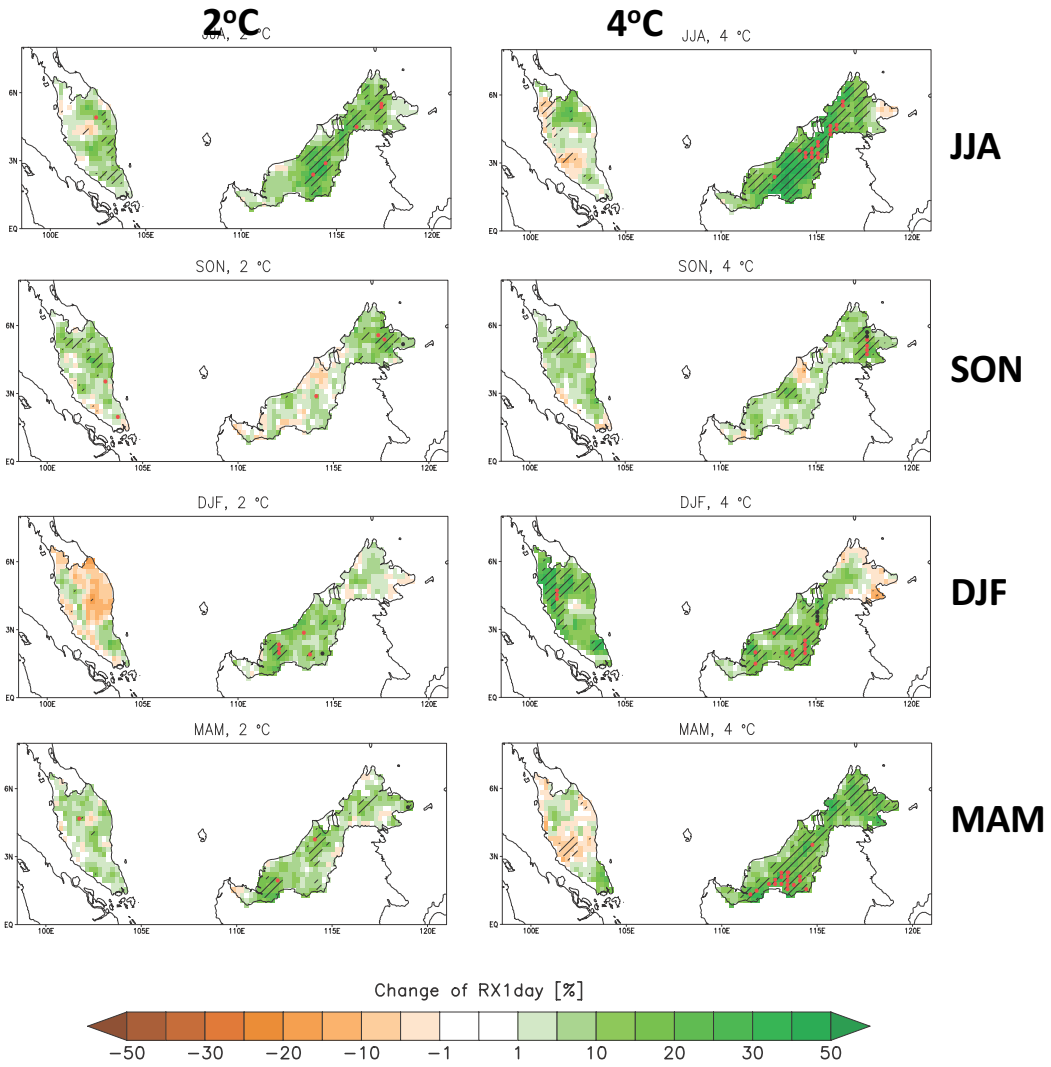
Projected changes of seasonal R20mm (frequency)



- The decrease in rainfall due to the increase in CDD could be offset by the increase in either frequency or intensity of extreme rainfall or both.

- At 2°C , generally, the frequency of extreme precipitation events largely show increased projected changes over Malaysia albeit not significant during SON and DJF seasons.
- At 4°C, the increased projected changes in frequency enhanced during JJA and over East Malaysia during MAM season.
- However, projected changes in frequency is decrease significantly during SON and over Peninsular Malaysia during MAM season.
- But the projected changes are not robust.
- This indicates extreme precipitation events under global warming of 2°C is projected to be more frequent for all seasons.
- However, at 4°C some area over Malaysia will experience increase and decrease frequency of extreme precipitation events depending on the season.

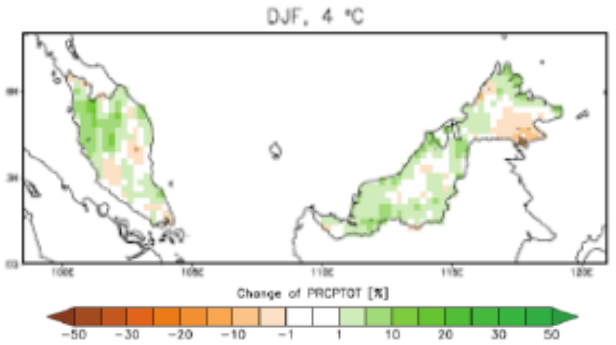
Projected changes of seasonal RX1day (intensity)



- At 2°C, generally Malaysia is projected to experience increase in intensity of extreme precipitation events but most area are not significant and robust.
- The significant increase projected changes enhanced at 4°C with few dots of robustness especially over East Malaysia.
- This suggests the occurrence of more intense rainfall events over Malaysia in future especially at 4°C.

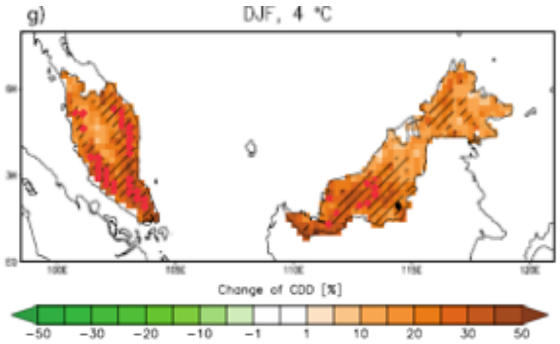
The decrease in rainfall due to the increase in CDD could be offset by the increase in either frequency or intensity of extreme rainfall or both.

PRCPTOT



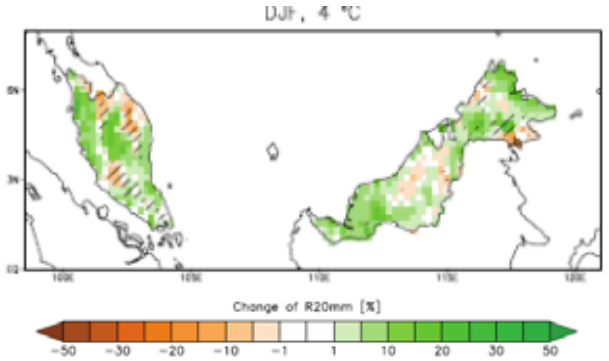
DJF

CDD



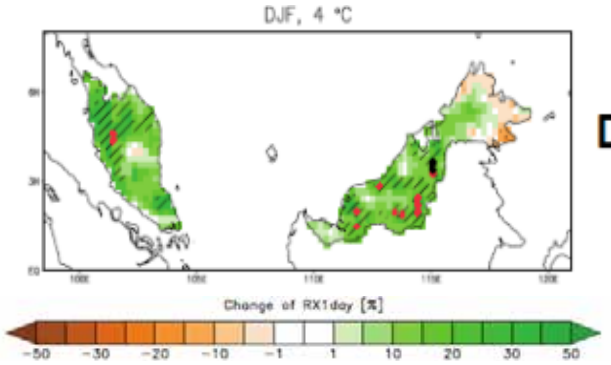
DJF

R20mm (frequency)



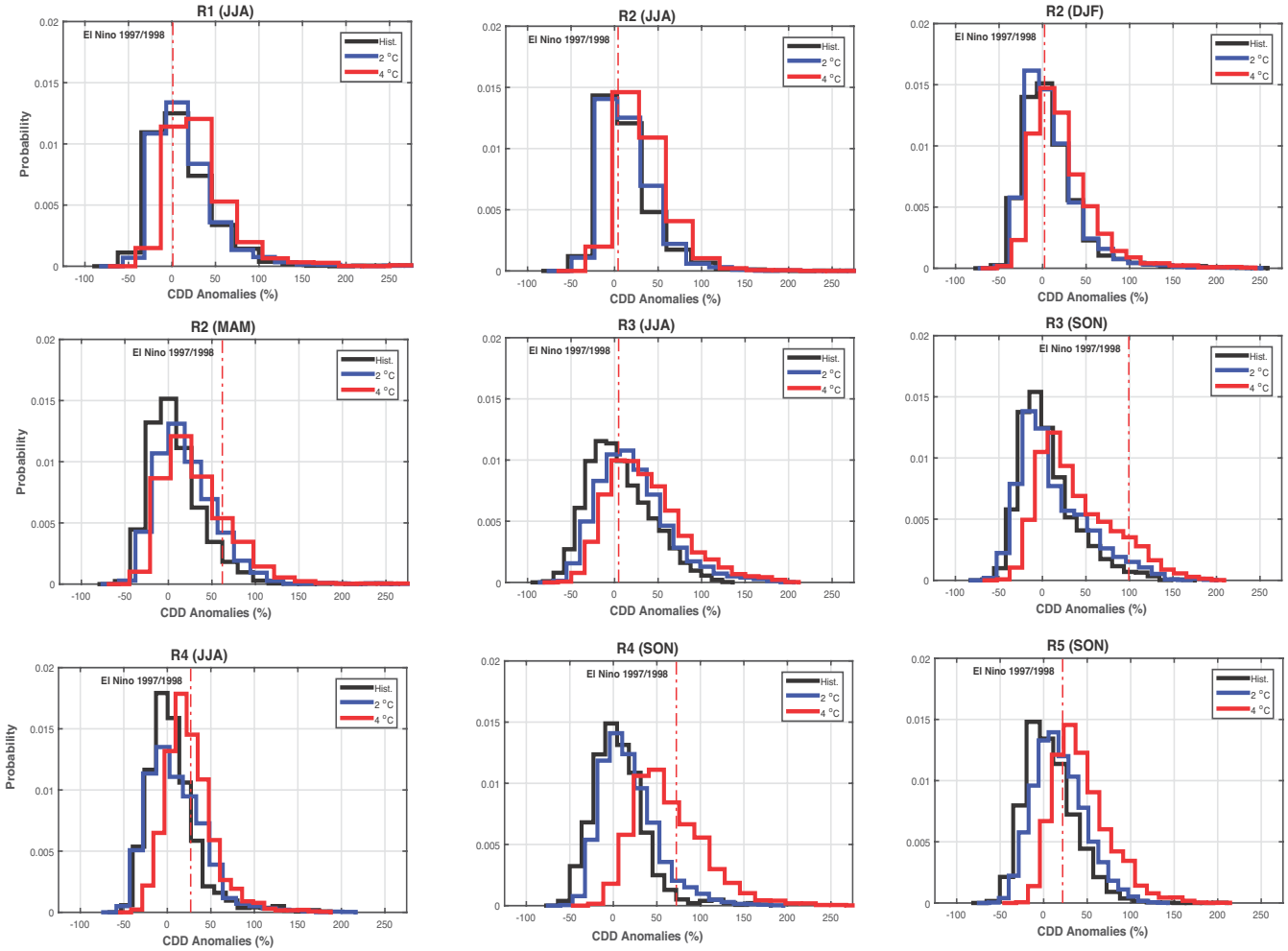
DJF

RX1day(intensity)

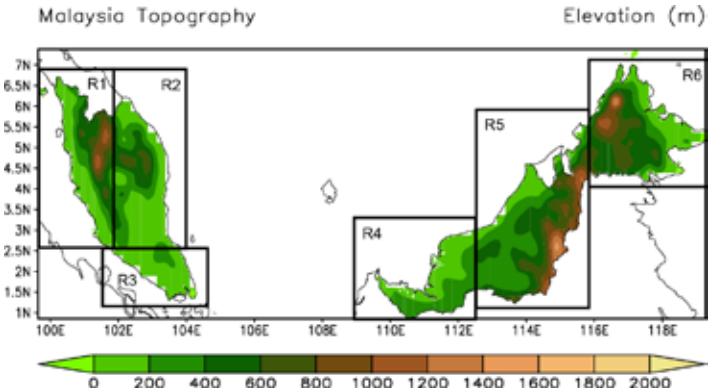


DJF

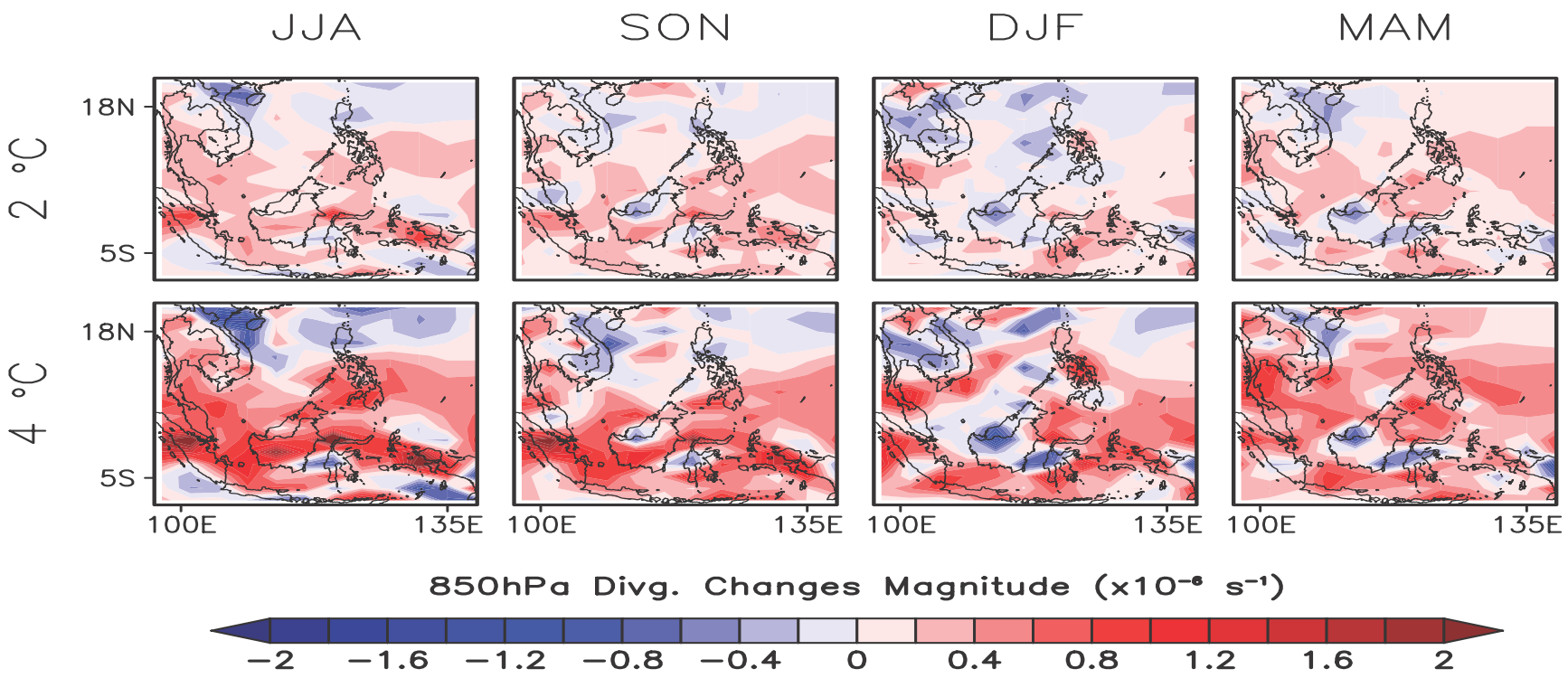
projected changes of CDD of sub-regions



- **Historical (Black), 2°C (blue)** and **4°C (red)** indices for sub-regions.



Projected divergence



Generally, more subsidence is projected in the future over the Southeast Asia Region.

Conclusion

- This study evaluates the changes in seasonal precipitation extremes in Malaysia under global warming of 2^{o}C and 4^{o}C – unmitigated climate change scenario (RCP8.5).
- There is a tendency for wet biases over Peninsular Malaysia
- The modelled able to simulate the characteristics of the observed seasonal extreme precipitation anomalies over Malaysia.
- Robust increases in CDD imply impending drier condition over both Peninsular and East Malaysia.
- Increases in RX1day (intensity) and R20mm (frequency) suggest more intense rainfall events.
- could be the offset of the decrease in rainfall due to the increase in CDD over Malaysia.
- Both Peninsular and East Malaysia are projected to experience increases and decrease in CDD, R20mm and RX1day depending on the area and seasons, suggesting Malaysia may face more serious repercussions in future.
- The projected changes enhanced under 4°C global warming.