



# Multi-model Ensemble Regional Climate Projection of the Western Maritime Continent using the MIT Regional Climate Model

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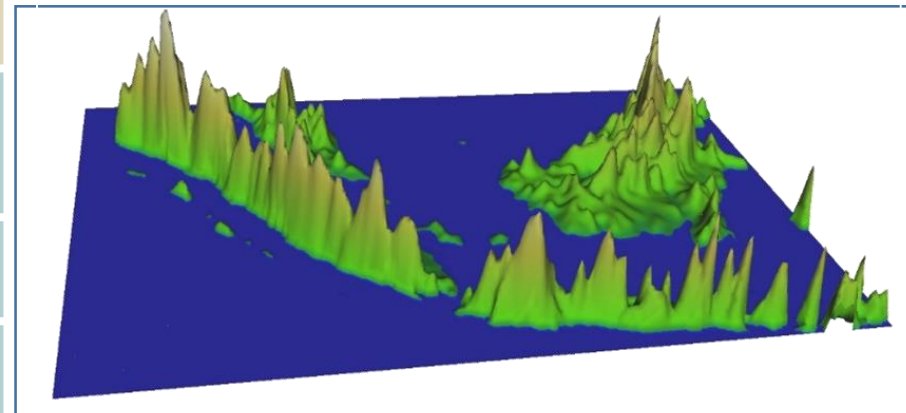
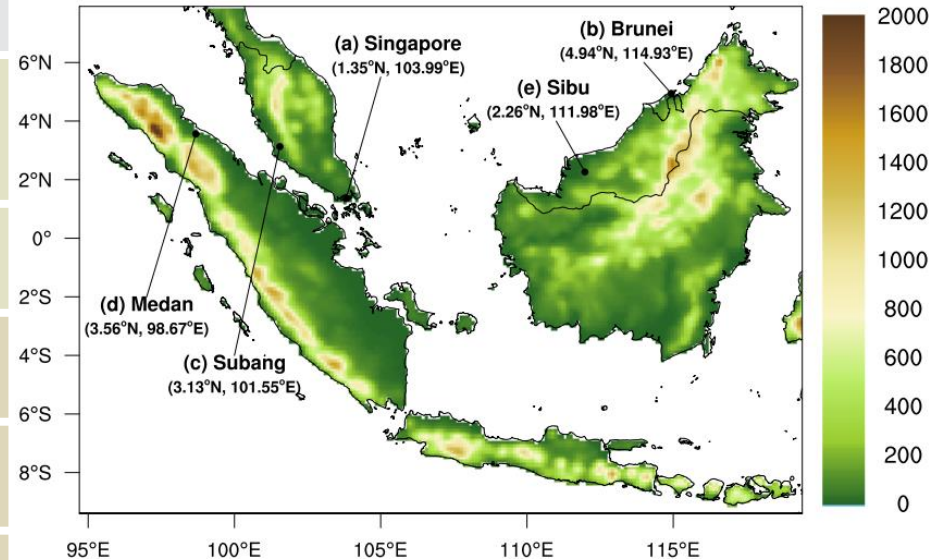
# Projection of Future Climate Change



## MRCM, MIT Regional Climate Model

## Domain & Topography

Physics	New Features	Key References
Aerosols & Chemistry	New treatment of lateral boundary for mineral aerosol	Marcella & Eltahir 2010
	Sub-grid variability of dust emission	Marcella & Eltahir 2011
Convective Rainfall & Cloud	New convective cloud fraction scheme	Gianotti & Eltahir 2014
	New convective rainfall autoconversion scheme	Gianotti & Eltahir 2014
	Modified boundary layer height & boundary layer cloud scheme	Gianotti 2012
Land Surface	Integrated Biosphere Simulator (IBIS) Land Surface Scheme	Winter et al. 2009
	New surface albedo assignment	Marcella & Eltahir 2012
	New irrigation module	Marcella & Eltahir 2014 Im & Eltahir 2014

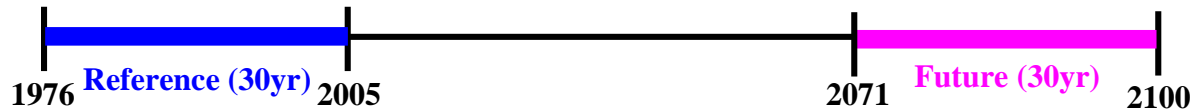


# Projection of Future Climate Change



## Experimental Design

- Resolution: 12 km
- Initial & Boundary Condition: **CCSM4**, **MPI-ESM-MR** and **ACCESS 1.0**
- Integration Period : Reference Climate (1976-2005:30yr) - Historical  
: Future Climate (2071-2100:30yr) – RCP 4.5 and RCP 8.5



## Bias Correction method

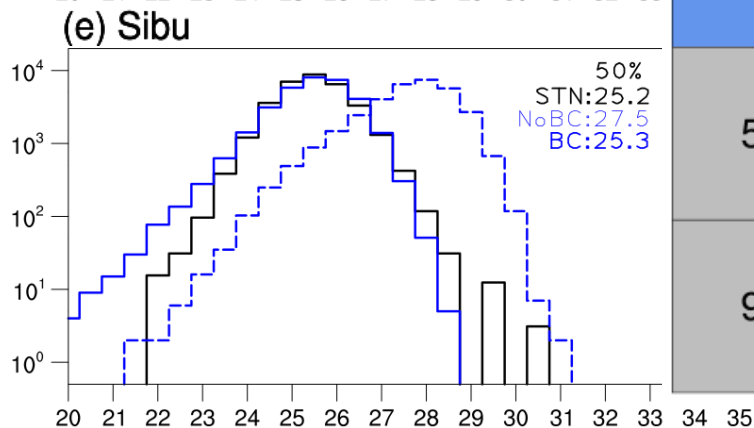
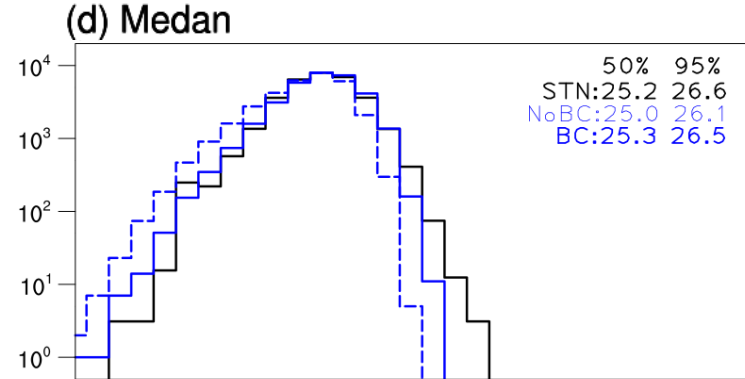
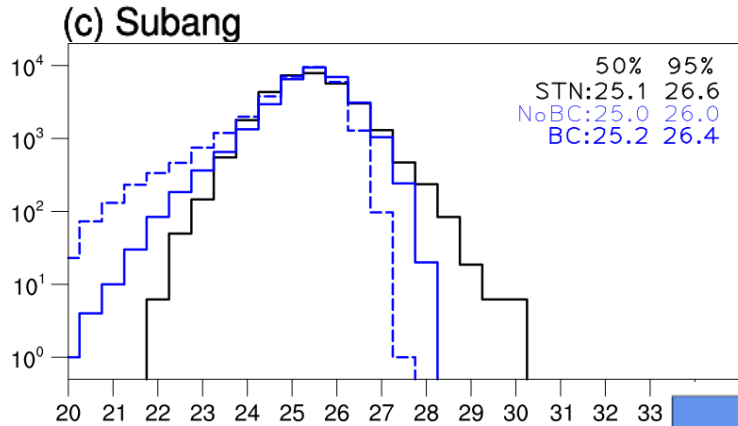
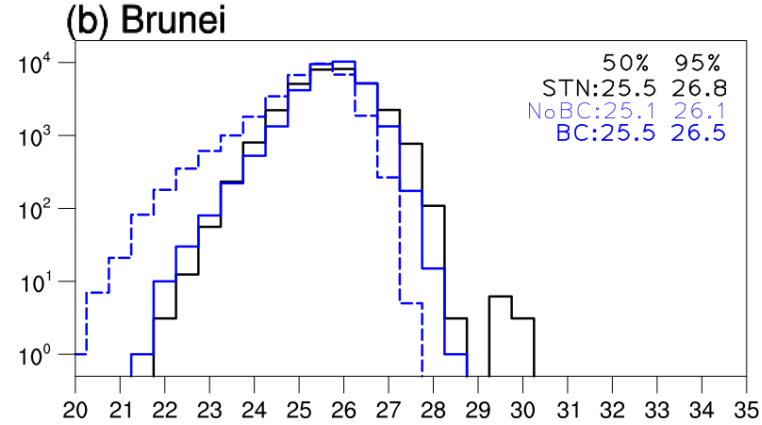
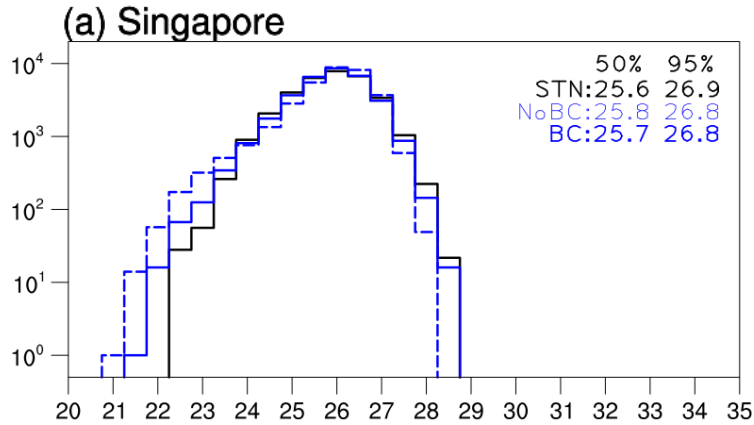
- Wet-bulb temperature & temperature : Remove daily climatological mean bias  
- *Jeremy Pal and Elfatih Eltahir (2015)*
- Precipitation : Parametric Quantile Mapping (gamma distribution)  
- *Piani et al. (2010)*



# 1. Wet-bulb temperature

- Combination of temperature and humidity
- Good index : human adaptability to heat stress
- Theoretical limit : 35°C

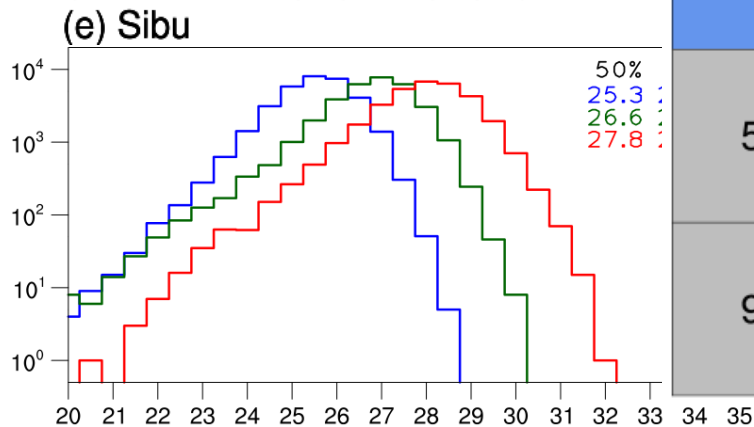
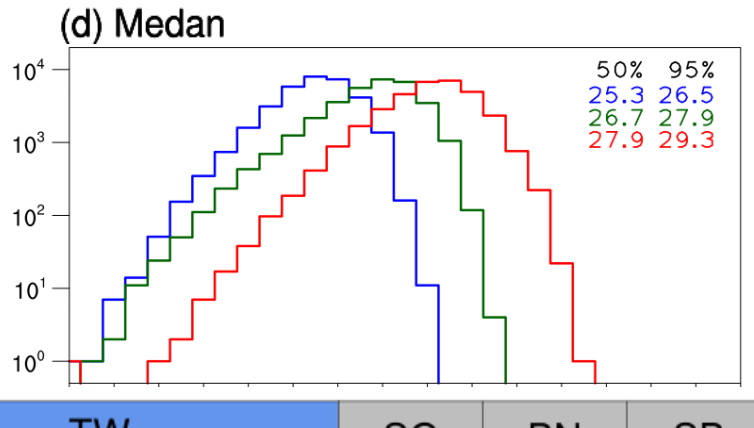
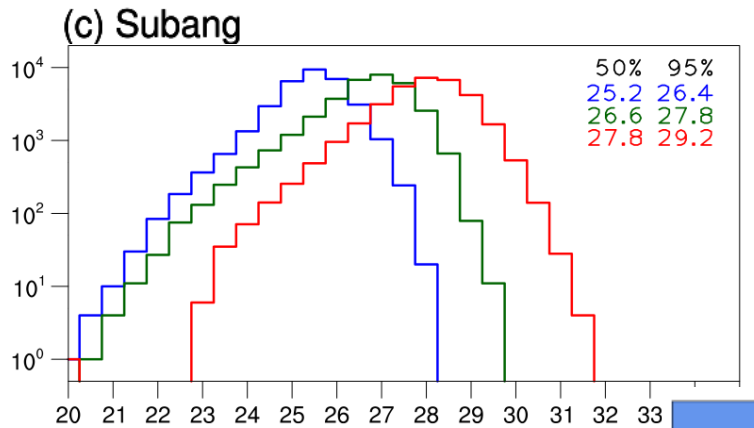
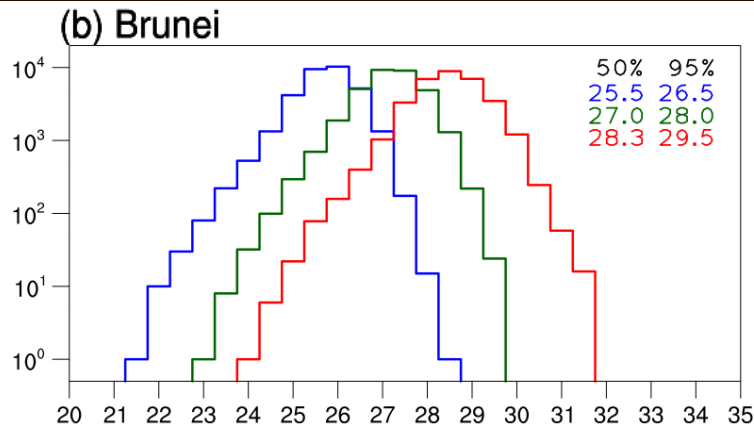
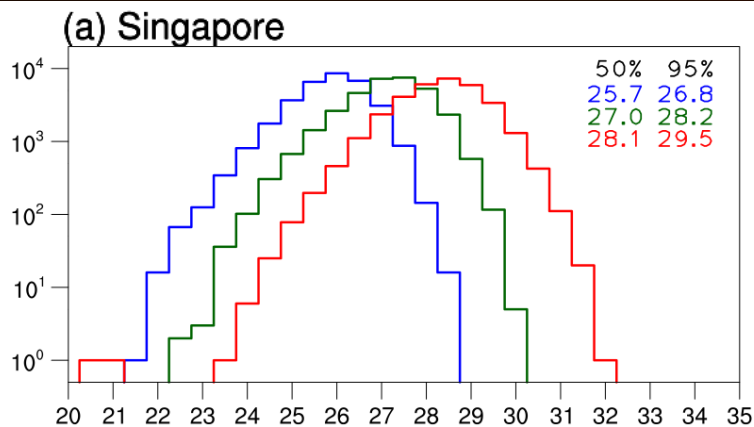
# Verification of bias-corrected results



$TW_{max}$		SG	BN	SB	MD	SI
50%	Station	25.6	25.5	25.1	25.2	25.2
	Uncorrected	25.8	25.1	25.0	25.0	27.5
	Corrected	25.7	25.5	25.2	25.3	25.3
95%	Station	26.9	26.8	26.6	26.6	26.6
	Uncorrected	26.8	26.1	26.0	26.1	28.8
	Corrected	26.8	26.5	26.4	26.5	26.5

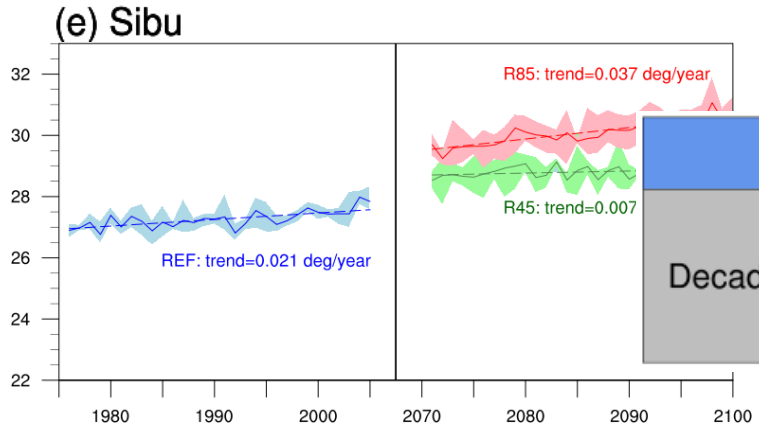
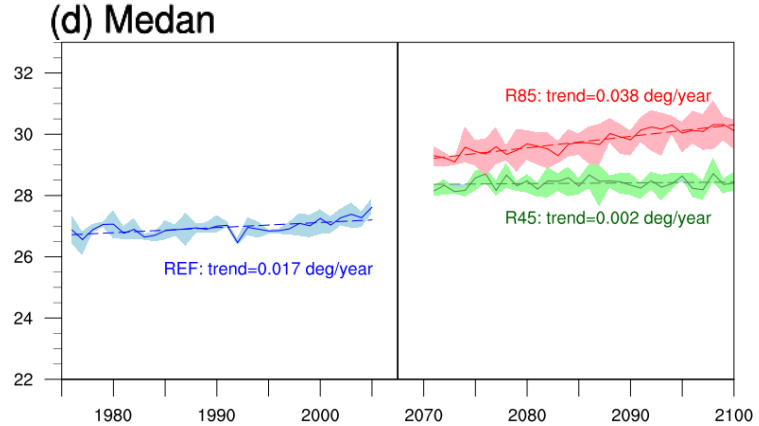
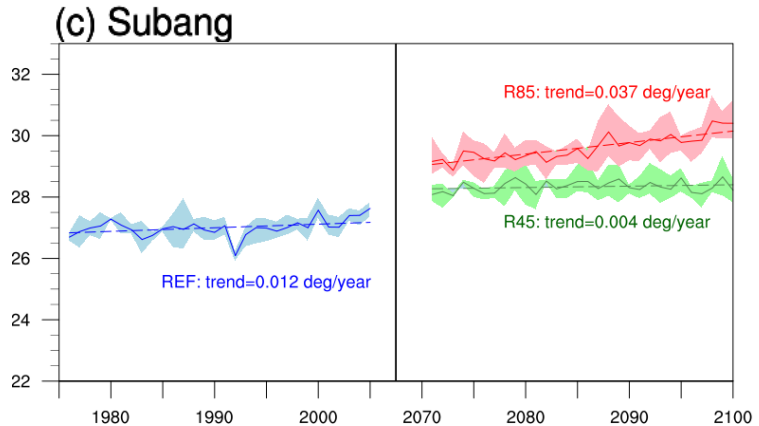
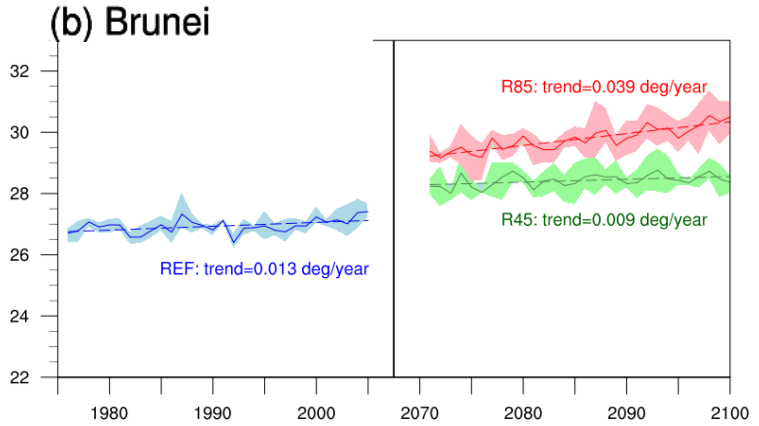
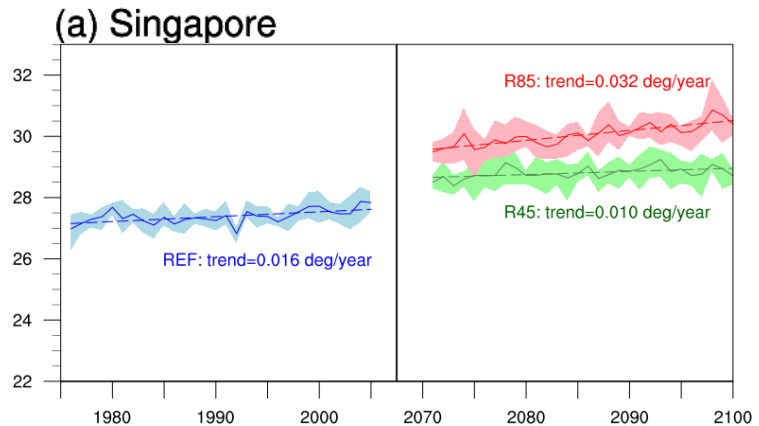


# Projection of daily Max. TW.



TW <sub>max</sub>		SG	BN	SB	MD	SI
50%	REF	25.7	25.5	25.2	25.3	25.3
	RCP4.5	27.0	27.0	26.6	26.7	26.6
	RCP8.5	28.1	28.3	27.8	27.9	27.8
95%	REF	26.8	26.5	26.4	26.5	26.5
	RCP4.5	28.2	28.0	27.8	27.9	27.9
	RCP8.5	29.5	29.5	29.2	29.3	29.3

# Time series of annual Max. TW.



TW <sub>max</sub>		SG	BN	SB	MD	SI
Decadal trend	REF	0.2	0.1	0.1	0.2	0.2
	RCP4.5	0.1	0.1	0.0	0.0	0.1
	RCP8.5	0.3	0.4	0.4	0.4	0.4

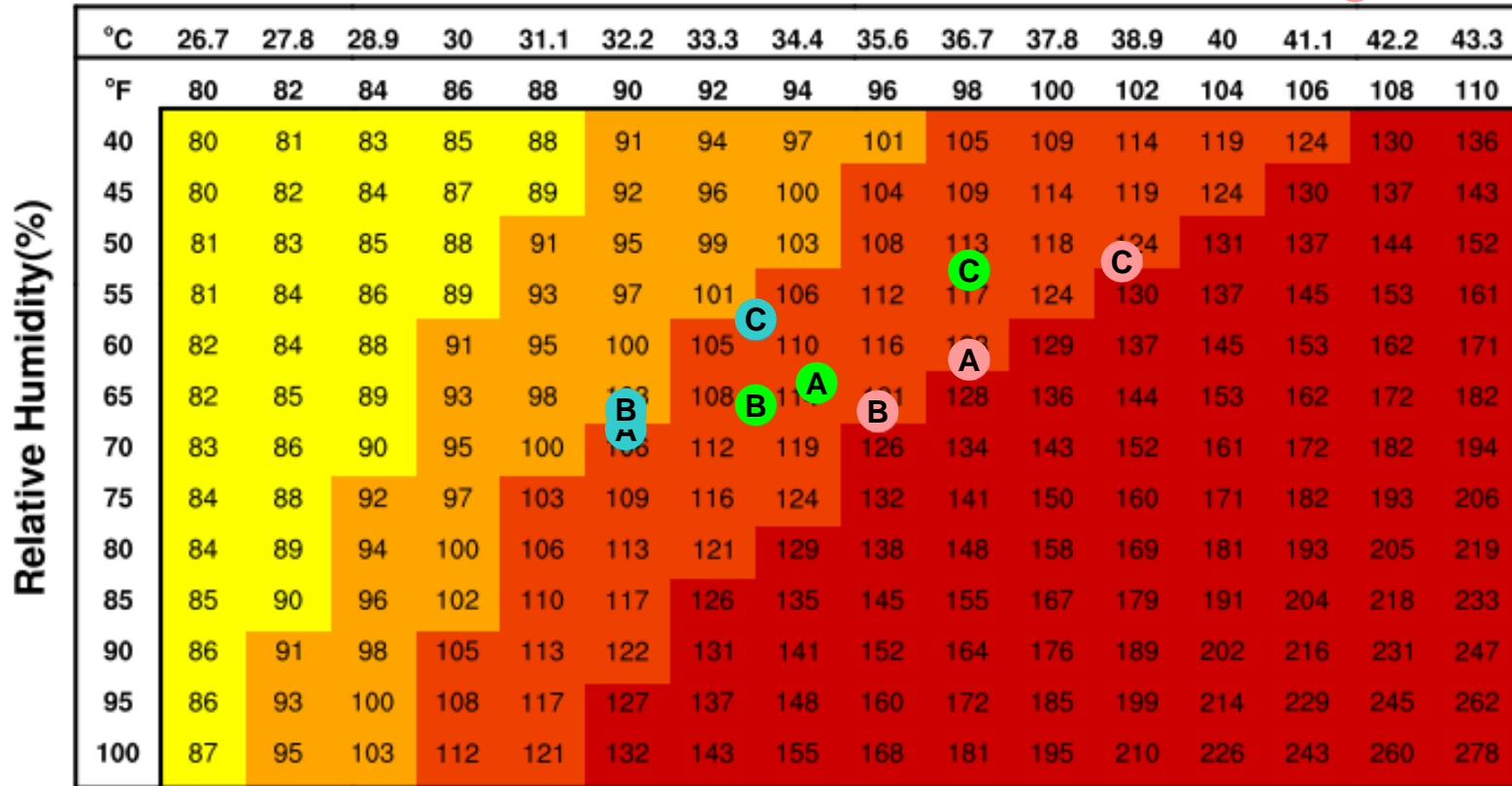
# Projected change in 95<sup>th</sup> daily Max. TW.



## NOAA National Weather Service Heat Index

Temperature(°F)

- REF
- RCP4.5
- RCP8.5



Caution
  Extreme Caution
  Danger
  Extreme Danger

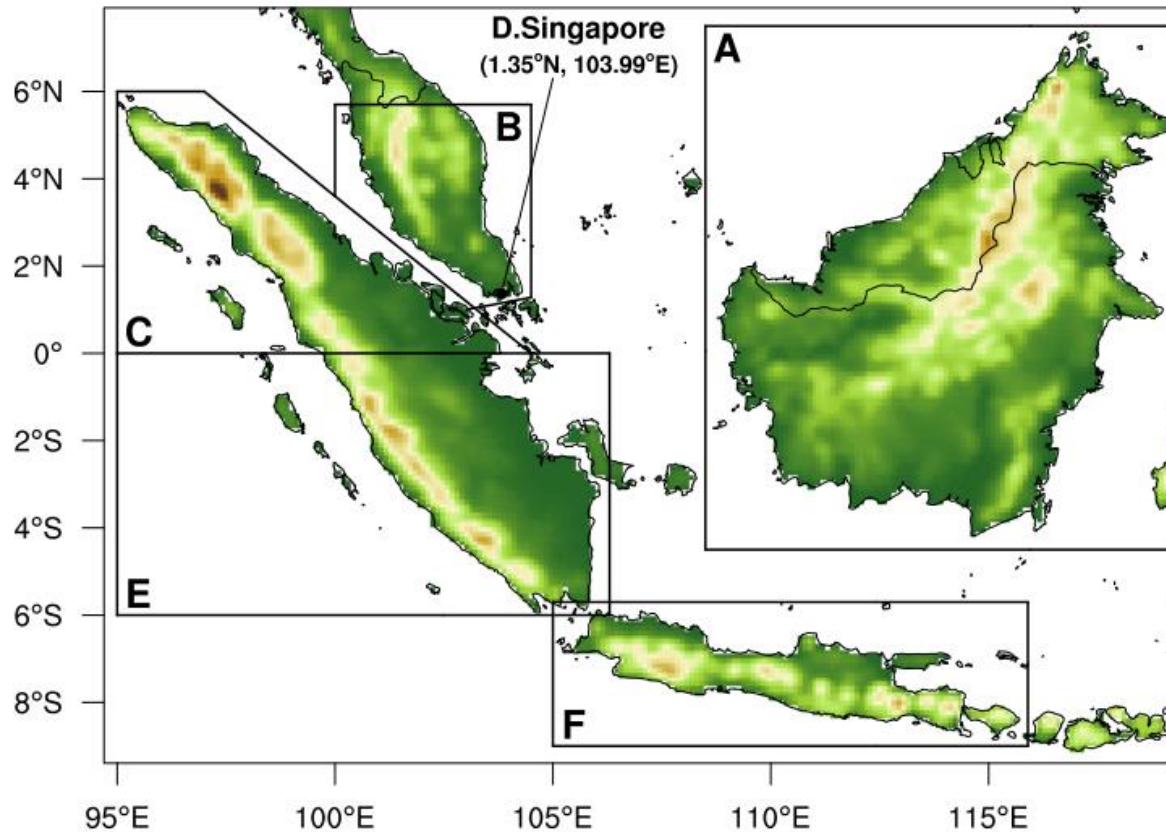
**A: Singapore, B: Brunei, C: Subang (Kuala Lumpur)**





## **2. Precipitation**

# Model domain and six sub-grid regions



A: Borneo

B: Malay Peninsular

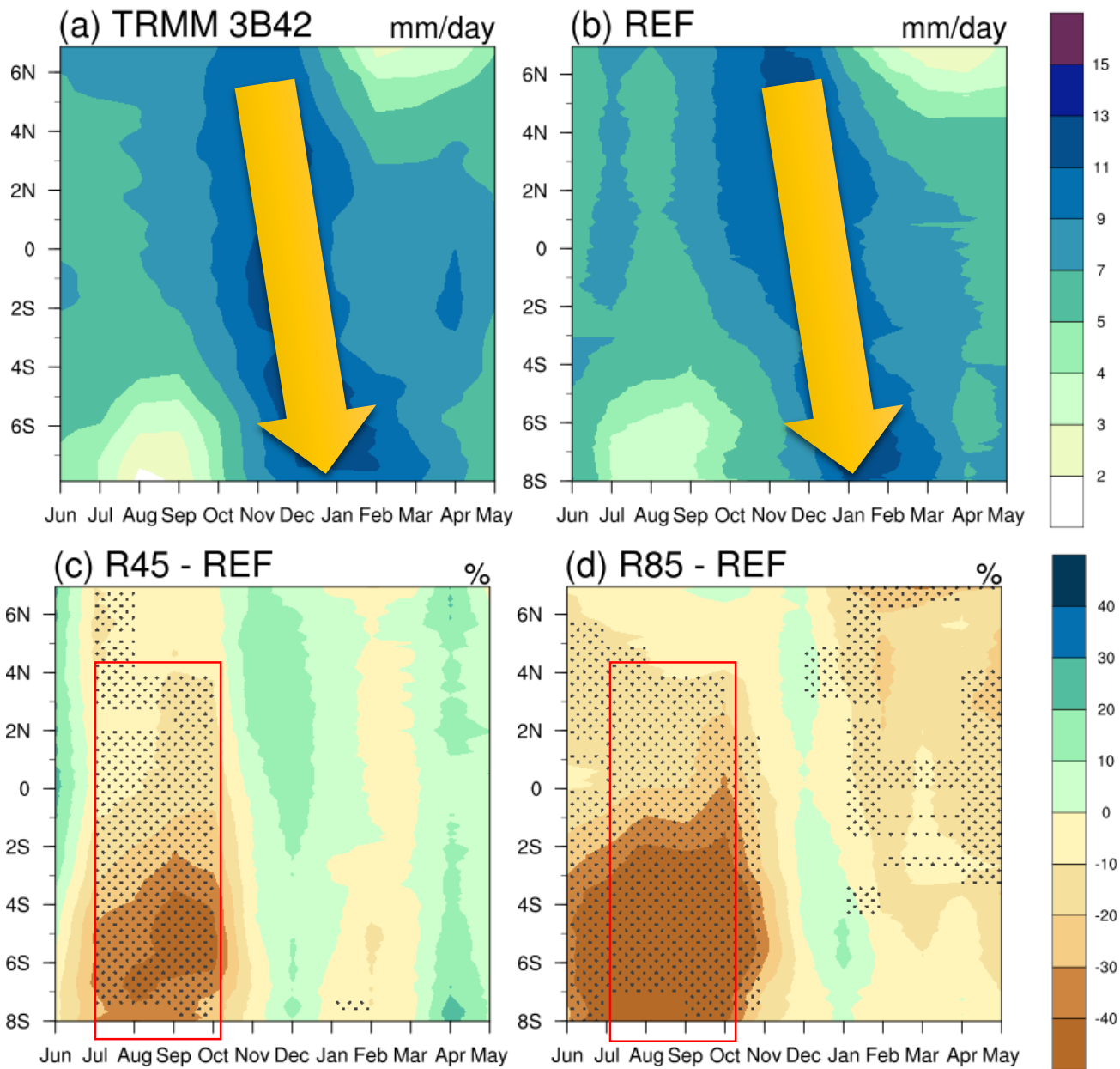
C: Northern Sumatra

D: Singapore

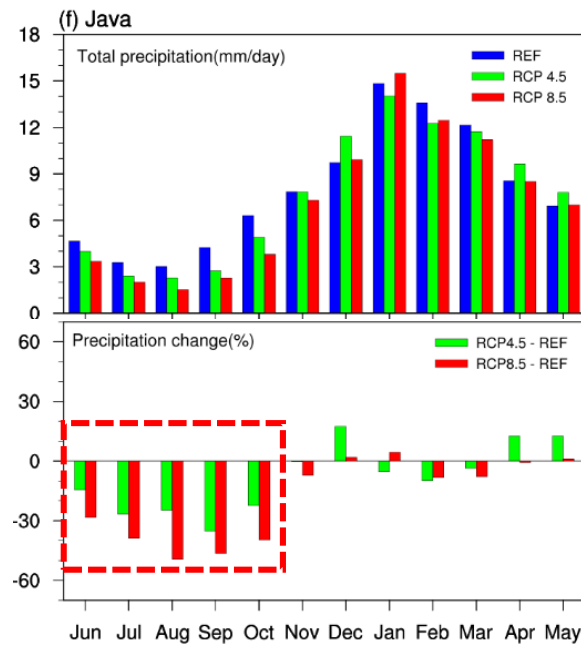
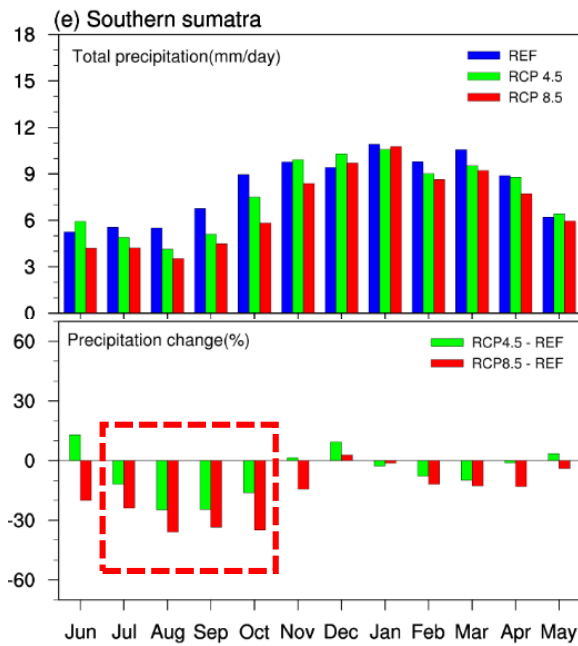
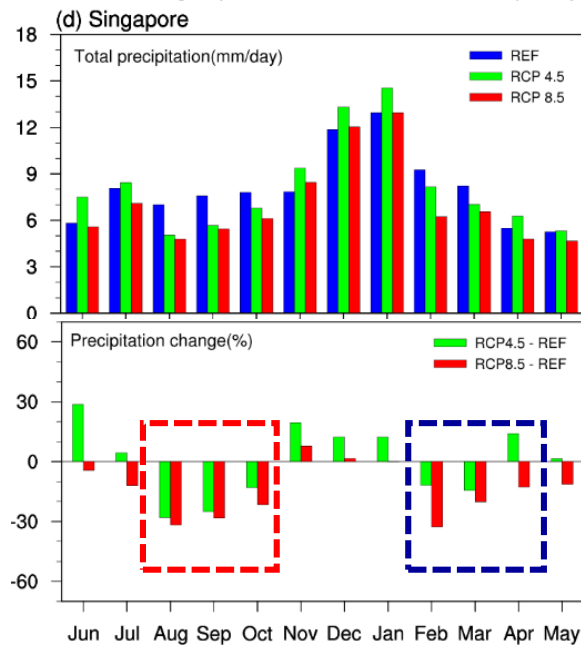
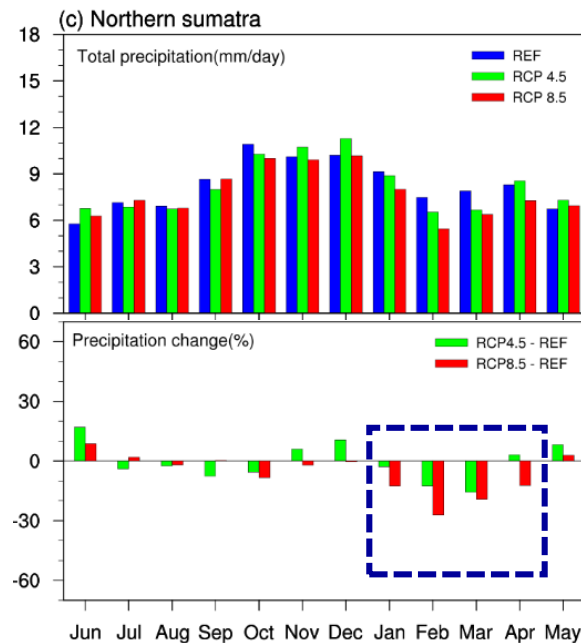
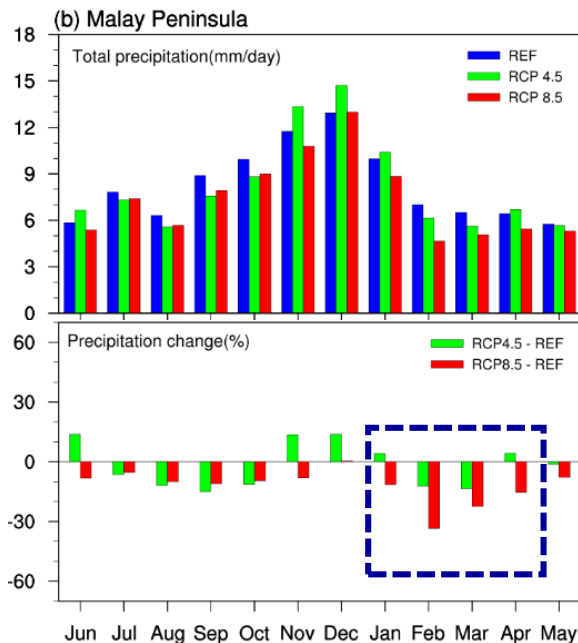
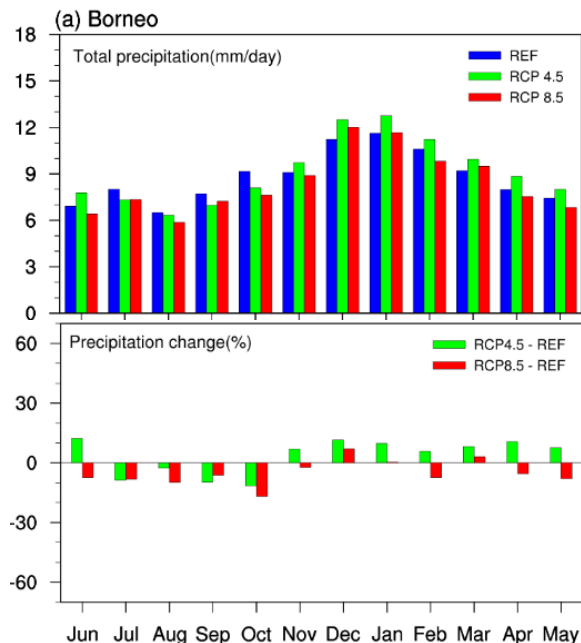
E: Southern Sumatra

F: Java

# Latitude-time cross-section (95°E-119°E)



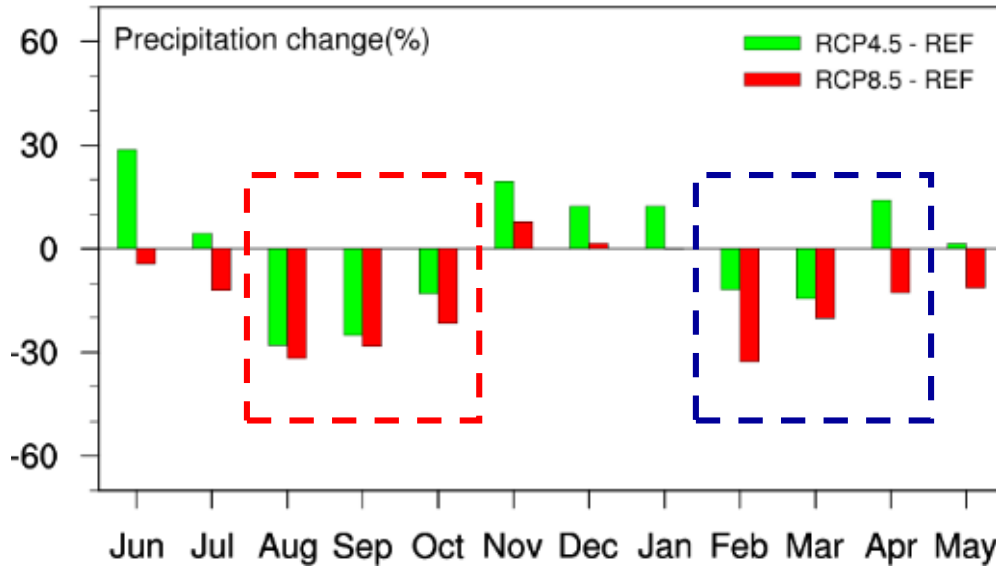
# Monthly precipitation and change



# Seasonal changes in the type of precipitation



(d) Singapore



	ASO			FMA		
	REF	RCP4.5	RCP8.5	REF	RCP4.5	RCP8.5
<b>Total Precipitation</b>	7.5	5.8 (-23%)	5.5 (-27%)	7.7	7.2 (-6%)	5.9 (-23%)
<b>Convective Precipitation</b>	6.0	4.6 (-23%)	4.2 (-30%)	6.6	5.6 (-15%)	5.0 (-24%)
<b>Large-scale Precipitation</b>	1.5	1.2 (-20%)	1.3 (-13%)	1.1	1.6 (+45%)	0.9 (-18%)

# Rainfall seasonality and its change



$$S = \frac{R_{max} - R_{min}}{\bar{R}}$$

*S* : rainfall seasonality

*R<sub>max</sub>* : Maximum monthly rainfall

*R<sub>min</sub>* : Minimum monthly rainfall

*$\bar{R}$*  : Annual mean rainfall

Sub-region	A: BN	B: MP	C: NS	D: SG	E: SS	F: JV
REF	0.6	0.9	0.6	0.9	0.7	1.5
RCP4.5	<b>0.7 (17%)</b>	<b>1.1 (22%)</b>	0.6 ( - )	<b>1.2 (33%)</b>	<b>0.8 (14%)</b>	1.5 ( - )
RCP8.5	<b>0.7 (17%)</b>	<b>1.1 (22%)</b>	0.6 ( - )	<b>1.2 (33%)</b>	<b>1.1 (57%)</b>	<b>2.0 (33%)</b>

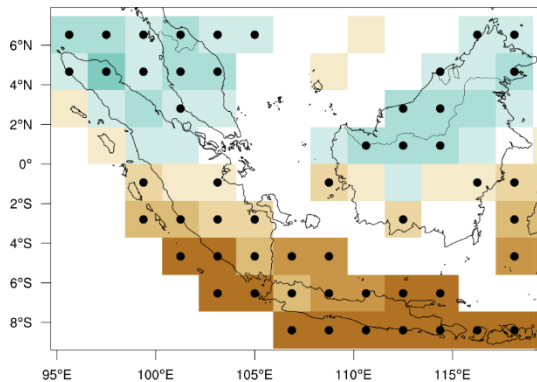
- In summary, significant rainfall reduction is projected under both RCPs during the ASO and FMA season, it leads to increasing rainfall seasonality over Western Maritime Continent



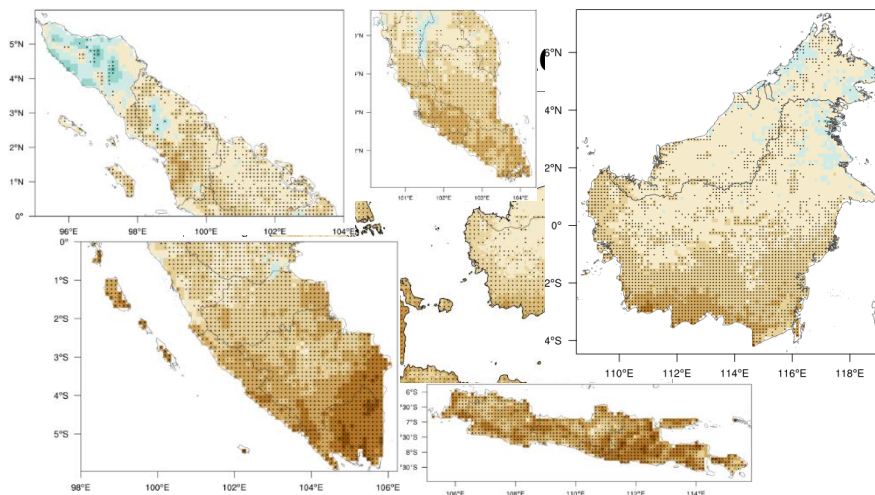
# Projected ASO precipitation changes



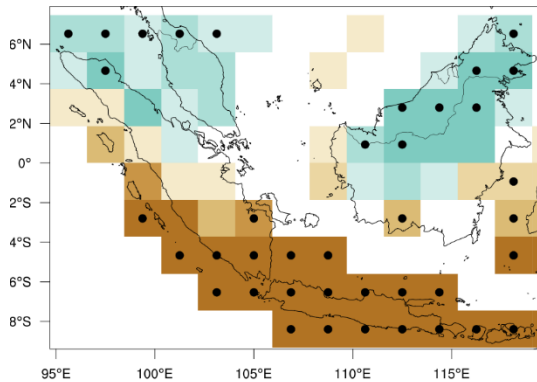
(a) GCM ensemble: RCP 4.5



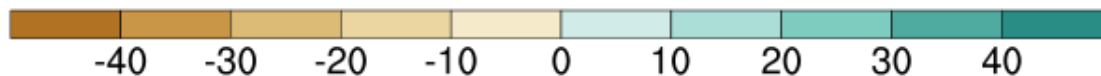
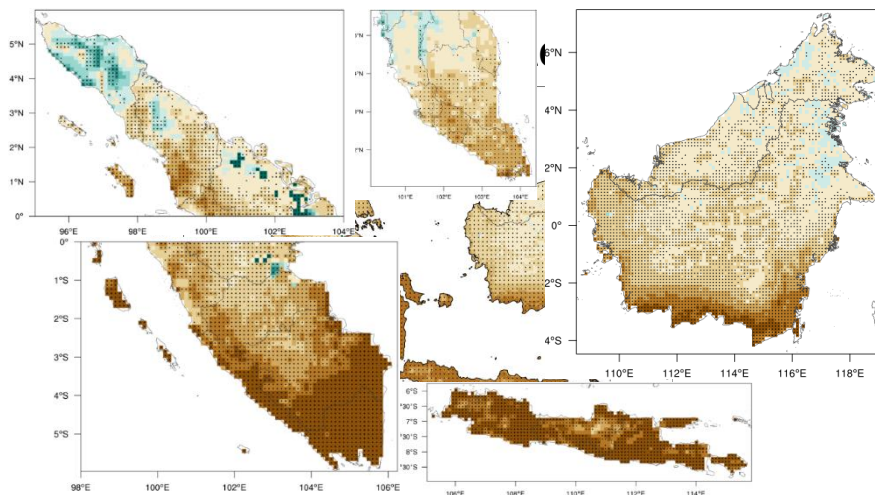
(b) MRCM ensemble: RCP 4.5



(c) GCM ensemble: RCP 8.5



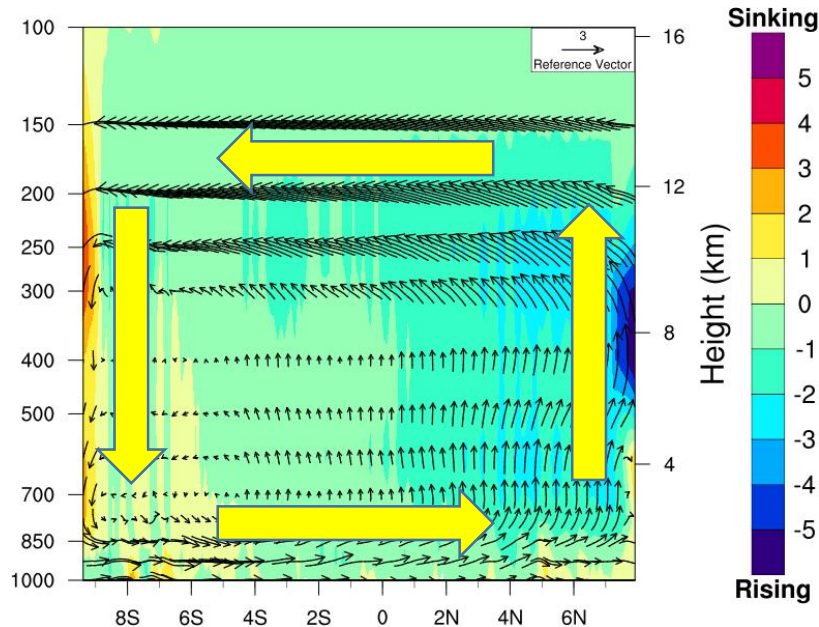
(d) MRCM ensemble: RCP 8.5



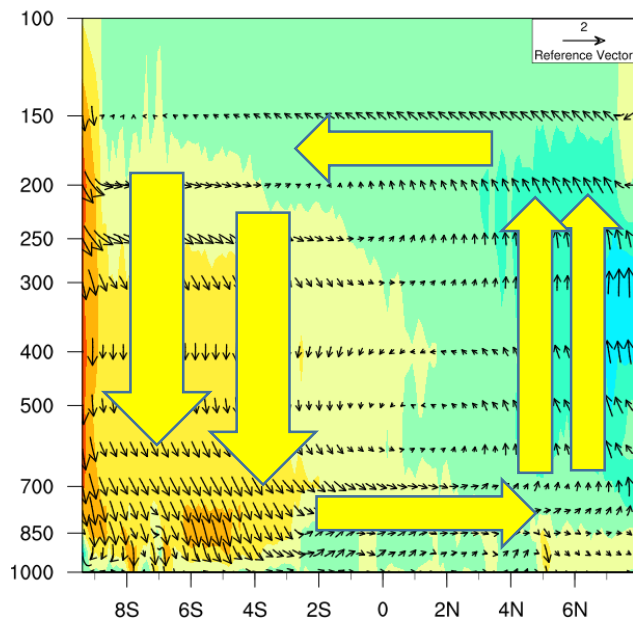
# Projected ASO meridional circulation changes



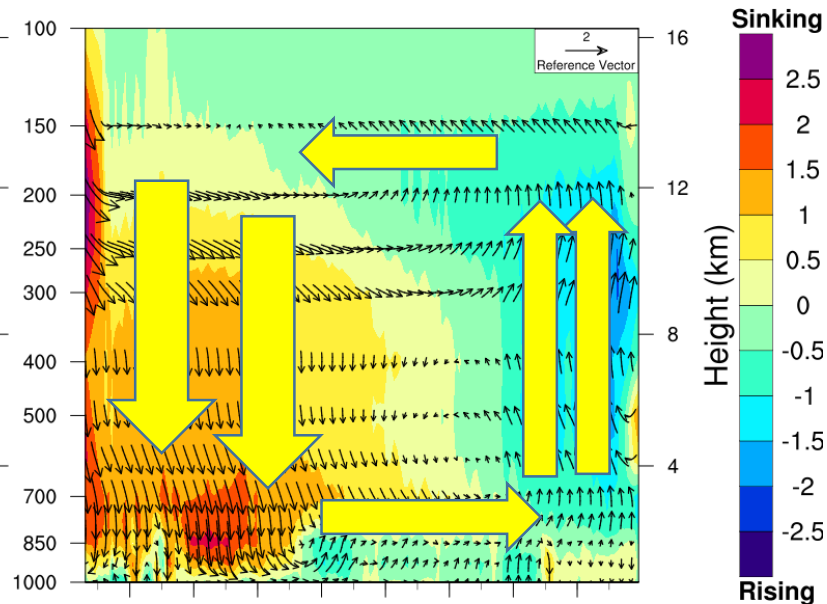
**(a) REF**



**(b) R45 - REF**



**(c) R85 - REF**



# Take home message



- $TW_{\max}$  projected to increase over the WMC.
  - Even under RCP 8.5,  $TW_{\max}$  will not exceed theoretical limit  $35^{\circ}\text{C}$ .
  - However, uncommonly high  $TW_{\max}$  in present climate will characterize the normal condition in the future.
  
- Rainfall projected to decrease over the WMC.
  - Significant rainfall reduction is projected under both RCP scenarios during the ASO and FMA season, it leads to increasing rainfall seasonality.
  - Rainfall change in the future may be at least partly caused by change in convective activity (Meridional circulation).



**Thank you  
for your  
attention!!**

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