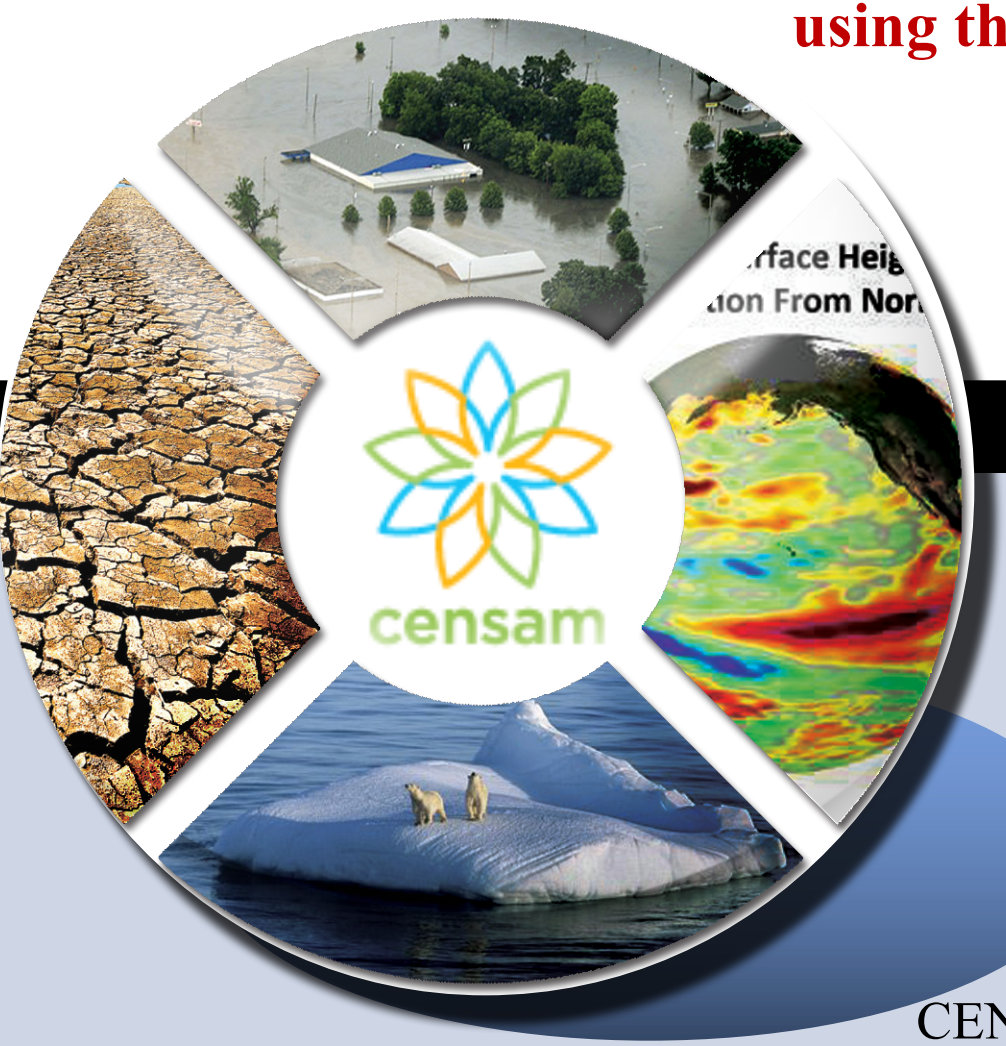
Regional Climate Change over the Maritime Continent

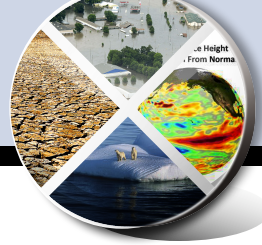
using the MIT Regional Climate Model



Eun-Soon Im & SuChul Kang (SMART)
Jeremy Pal (Loyola Marimount U.)
Elfatih A.B. Eltahir (MIT)

CENSAM SAB REVIEW/ 23-24 June 2016

CENSAM Regional Climate Modeling



High Resolution MRCM Development

- **Development and Improvement of the MIT Regional Climate Model (MRCM)**

: To maximize MRCM performance over the Maritime Continent, we has performed the optimization of resolution and physics schemes.

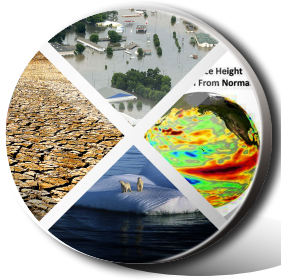
: To investigate the resolution effect, both simulations with 27km and 12km horizontal resolutions are performed and compared with an emphasis on the diurnal variation of rainfall

Ensemble Regional Climate Projection

- **Projection of Anthropogenic Impacts on Regional Climate System**

: To obtain fine-scale reliable climate projections, dynamical downscaling is performed based on multi-GCMs (e.g. CCSM & MPI & ACCESS) and multi-scenarios of future greenhouse gases emissions (RCP4.5 & RCP8.5).

: To assess the human adaptability limit to climate change due to heat stress, wet-bulb temperature, which integrates metrics of temperature and humidity, is analyzed.

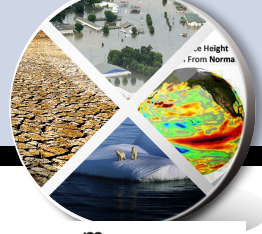


Validation of Present Climate Simulation

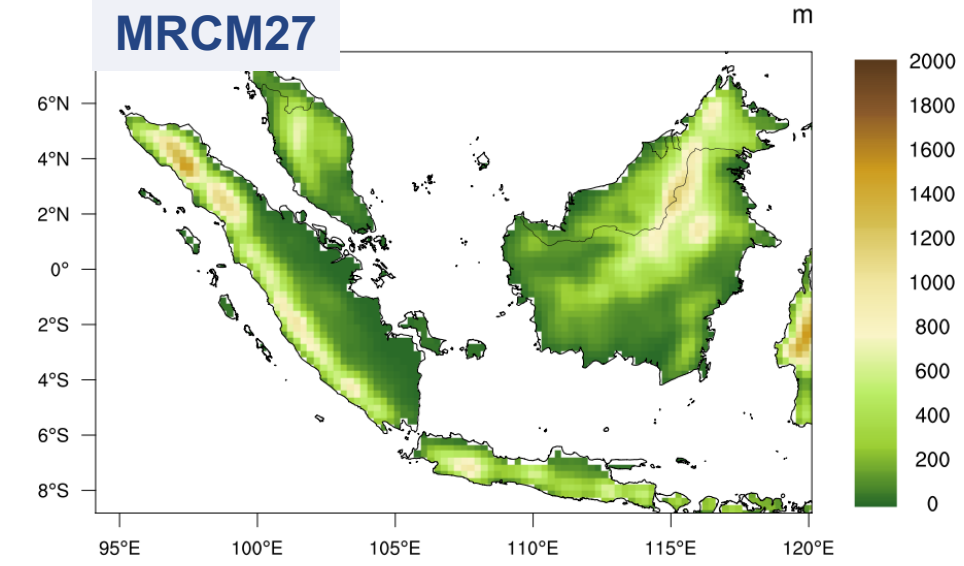
Experimental Design

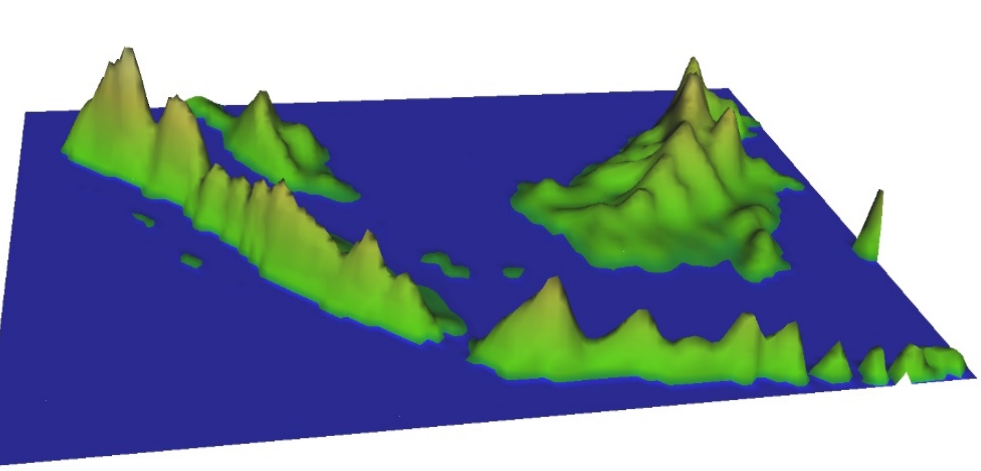
- Resolution: 27 km [MRCM27] vs. 12 km [MRCM12]
- Initial & Boundary Condition: ERAInterim Reanalysis (1.5deg)
- Integration Period: 1989-2008 (20yr)

Domain & Topography

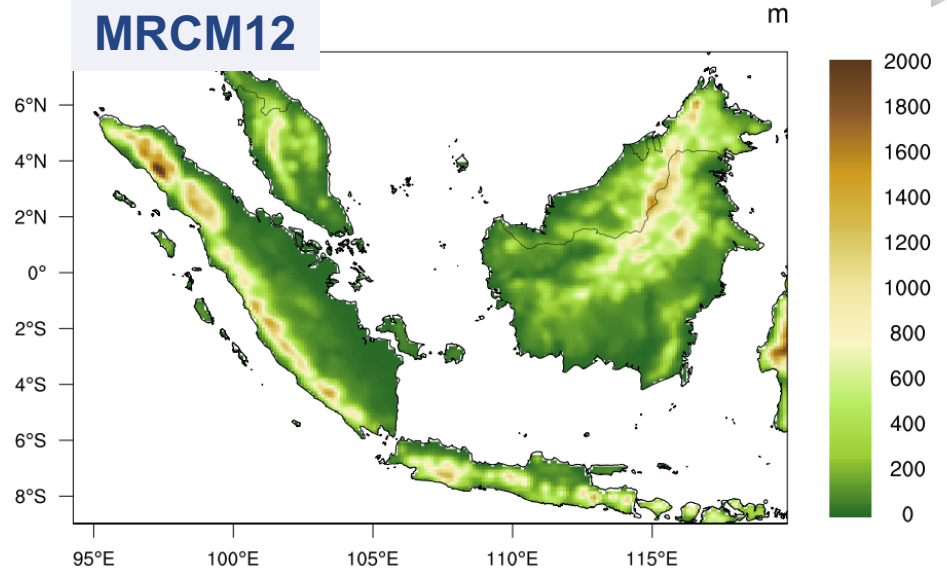


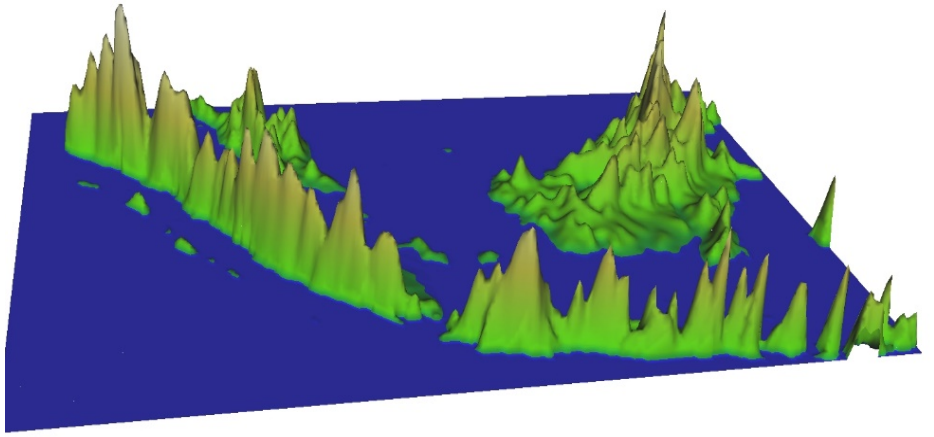
MRCM27





MRCM12

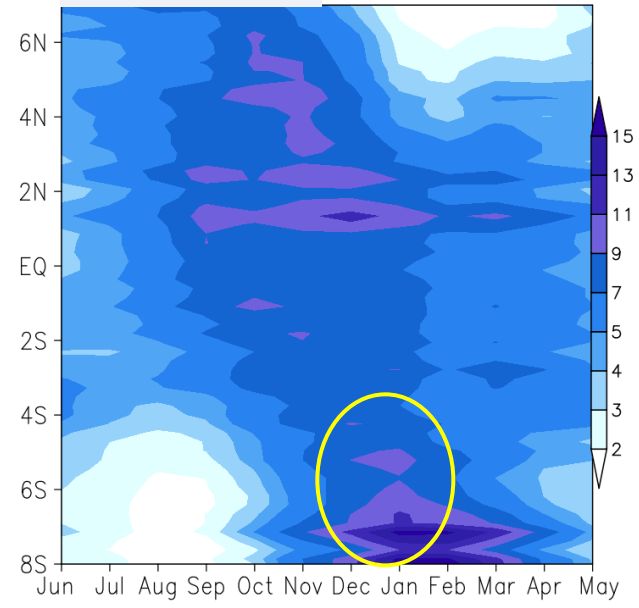




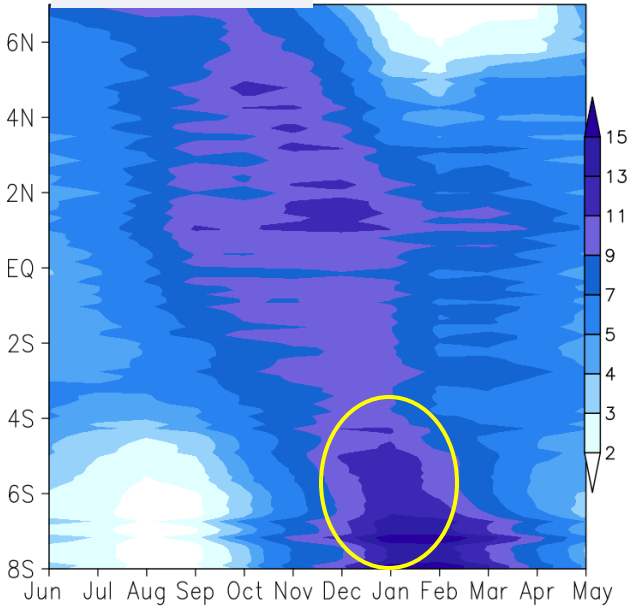
Seasonal Evolution of Rainfall

❖ Latitude-Time Cross-Section of Monthly Mean Rainfall Averaged from 95E to119E

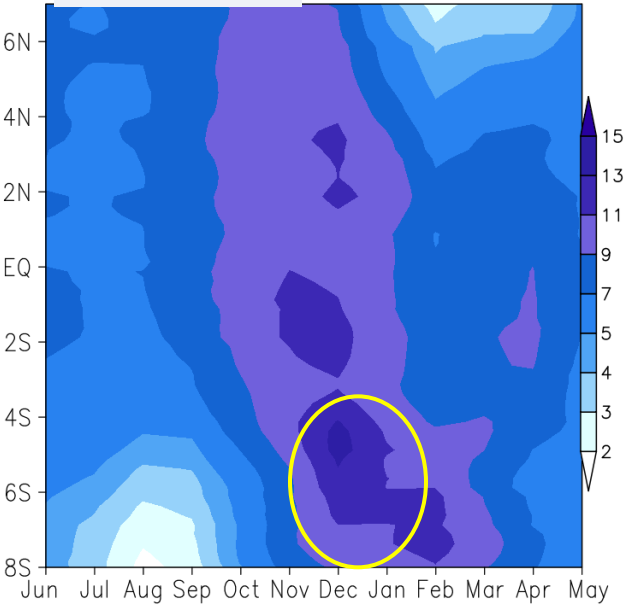
MRCM27



MRCM12



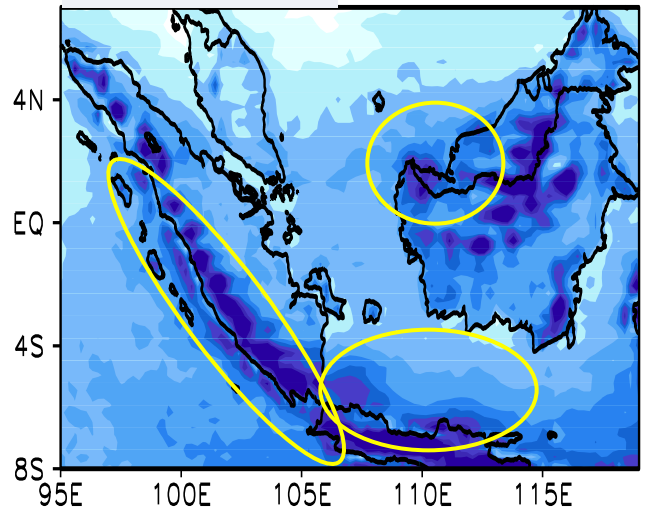
TRMM



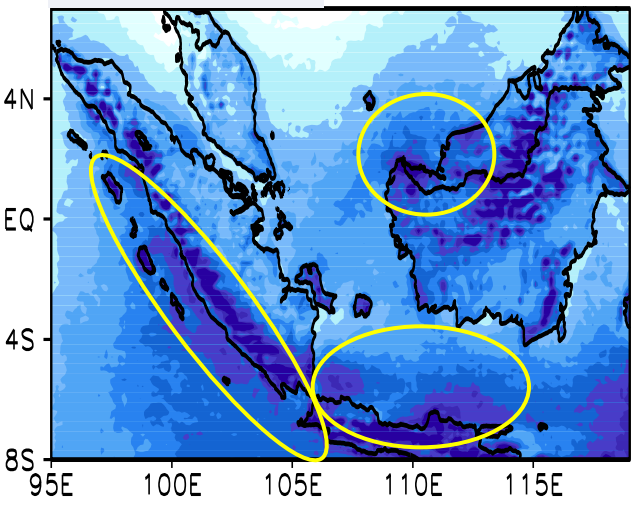
Spatial Distribution of Rainfall

❖ Spatial Distribution of Rainfall Climatology During Wet Season (DJF)

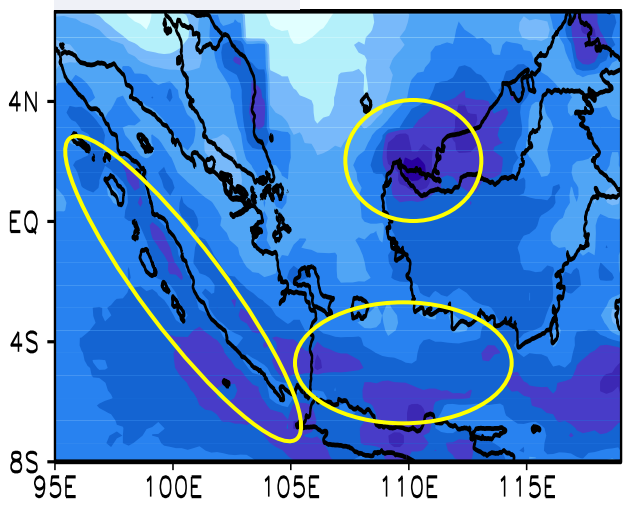
MRCM27



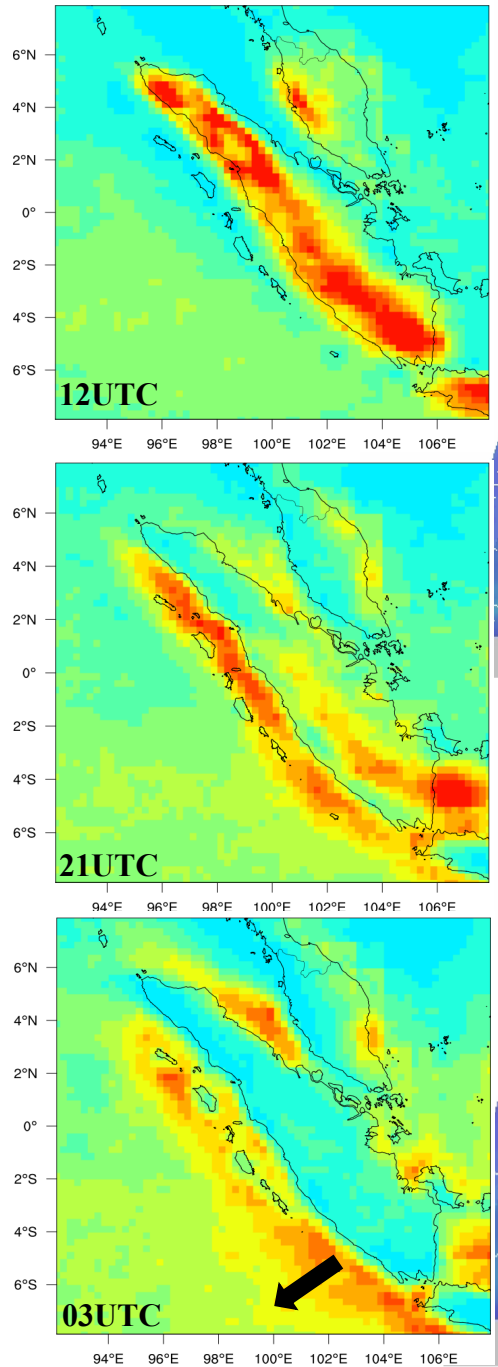
MRCM12

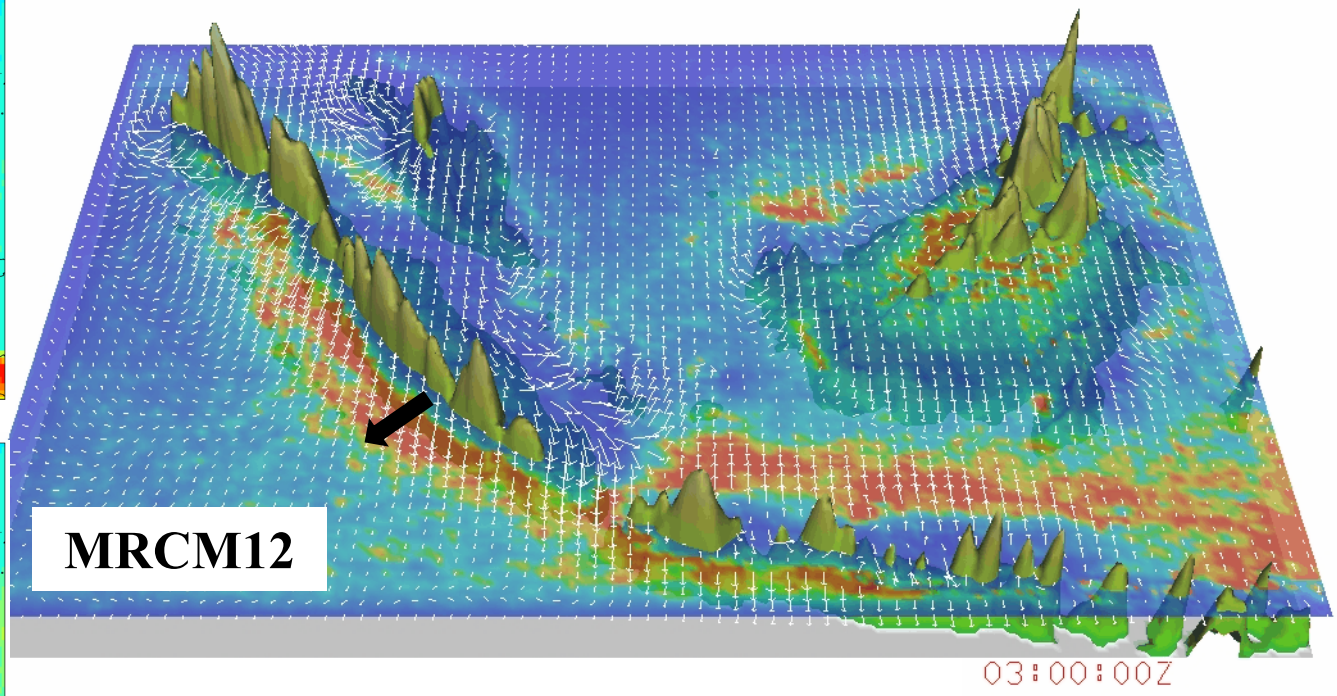


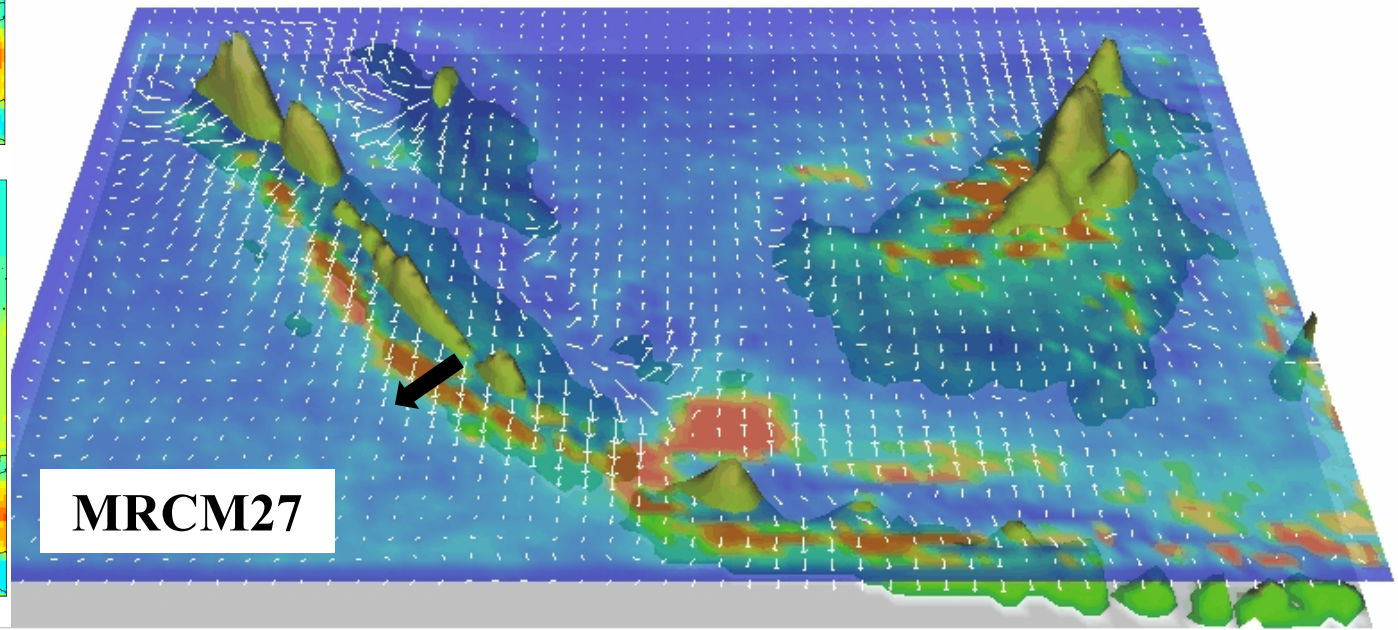
TRMM

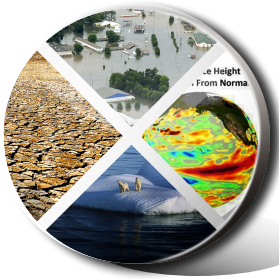


Diurnal Variation of Wind & Rainfall [3-hour]









Projection of Future Climate Change

Experimental Design

- Resolution: 12 km
- Initial & Boundary Condition: CCSM/MPI/ACCESS RCP4.5 & RCP8.5 Projections
- Integration Period: Reference Climate (1976-2005:30yr)
  : Future Climate (2071-2100:30yr)

Research Strategy

❖ Development of Reliable Climate Change Projection over the Maritime Continent

GCM Selection

Regional Climate Projection

Impact Assessment

Control
RCP 4.5
RCP 8.5
CCSM[1]

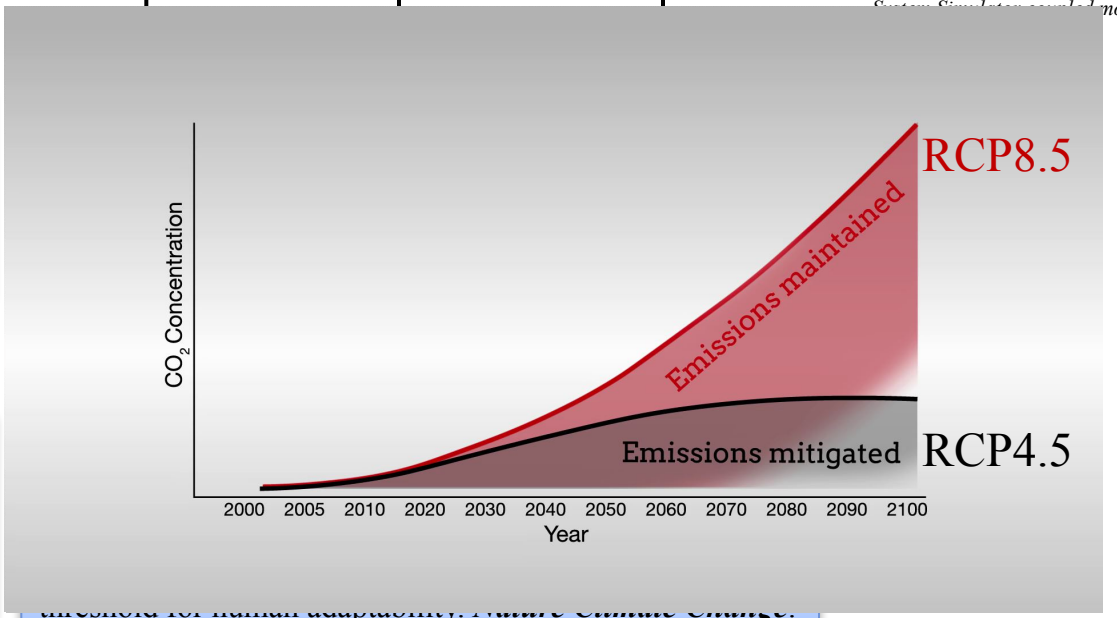
Control
RCP 4.5
RCP 8.5
MPI[2]

Control
RCP 4.5
RCP 8.5
ACCESS[3]

[1] **CCSM** : *Community Climate System Model (NCAR)*

[2] **MPI** : *Coupled models at the Max-Planck-Institute for Meteorology*

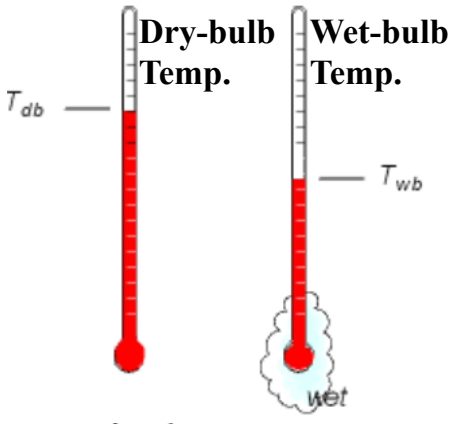
[3] **ACCESS** : *The Australian Community Climate and Earth System Simulator coupled model*



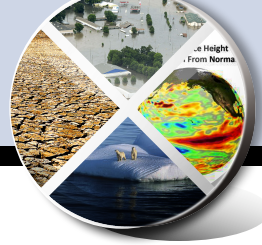
Human Adaptability to Heat Stress

Combined Measure of Temperature & Humidity

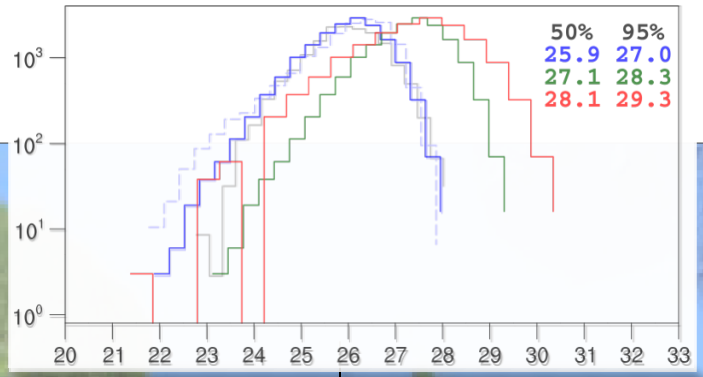
- The wet-bulb temperature (TW) is the lowest temperature that air can be cool to be evaporating water. Therefore, TW can be a good index to measure human adaptability to heat stress, rather than dry-bulb temperature referred to as simple temperature (T)
- 35˚C is the threshold value of TW beyond which any exposure for more than 6-hour would likely be intolerable even for the fittest of humans resulting in hyperthermia.
- In current climate, TW rarely exceeds 31˚C, TW provides a physically based relationship to the human body's core temperature.



Regional Projection : Daily Max. Tw



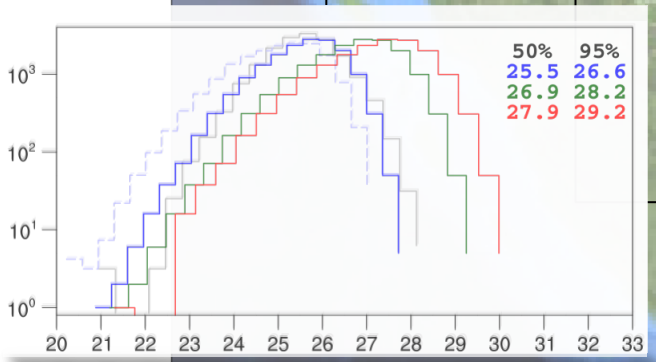
RCP8.5 [Bias correction]

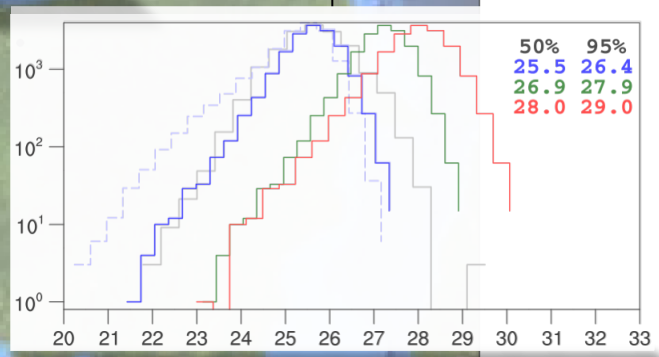


Medan
(3° 35 ' N, 98° 40 ' E)

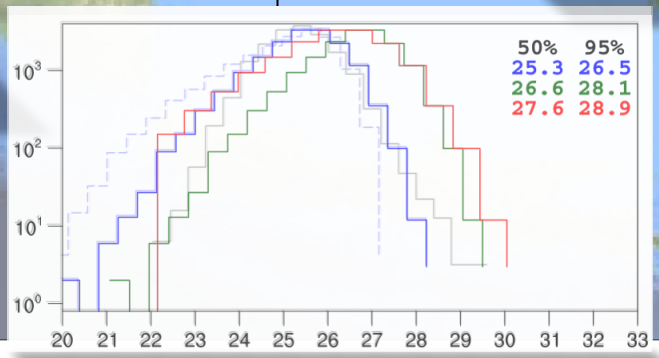
Singapore
(1° 21' N, 103° 49' E)

Brunei
(4° 30 ' N, 114° 40' E)





Subang
(03°07 ' N 101°32'E)



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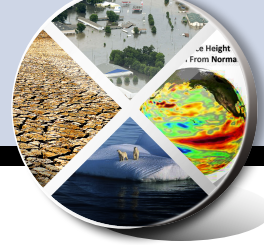
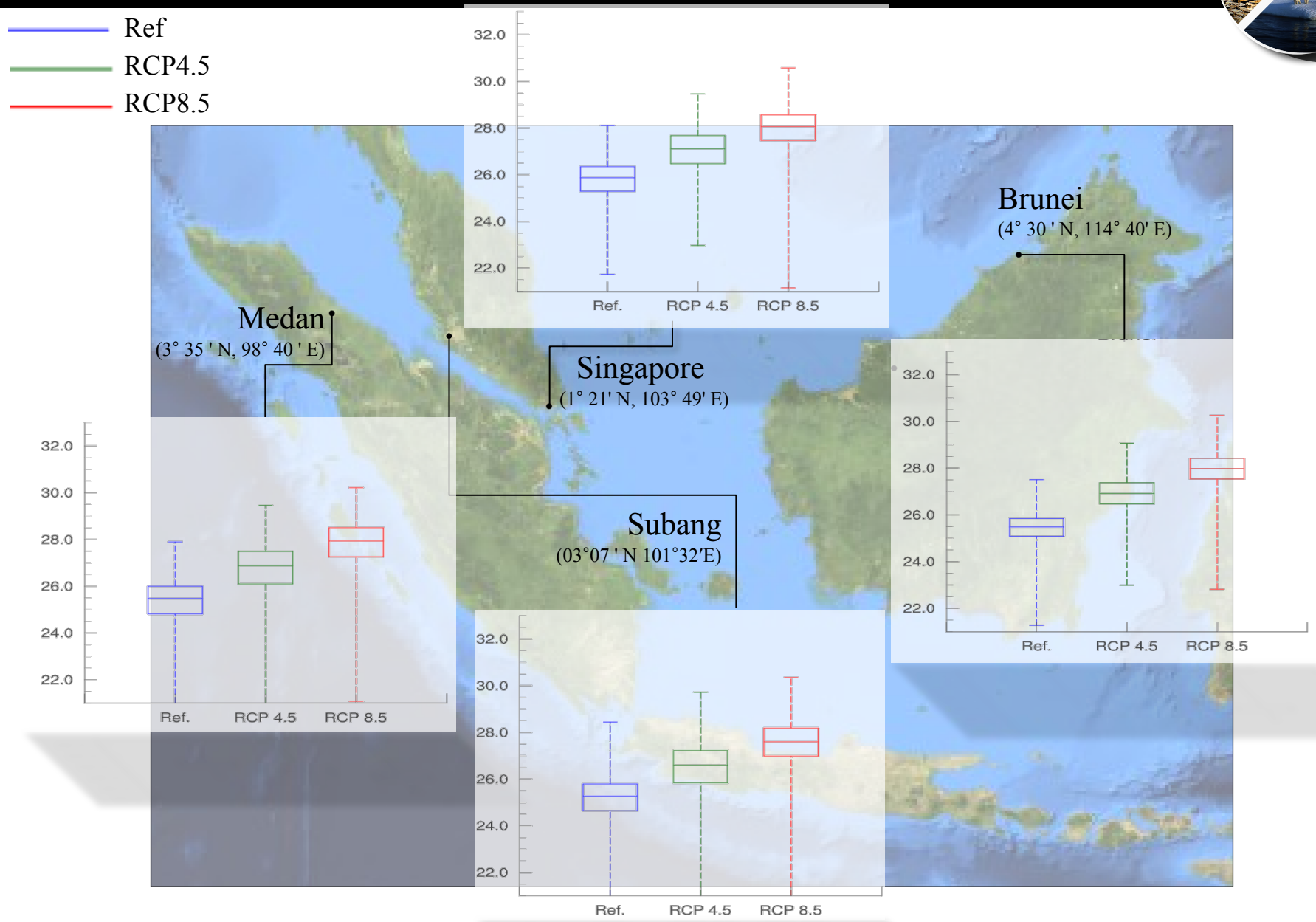
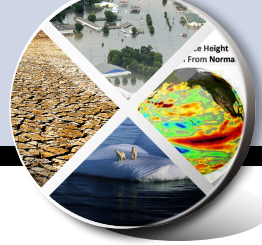




Likelihood Heat Disorders: Max.Tw 50%



Wet-bulb Temperature

Tempearature (^{0}F)

Relative Humidity (%)

^{0}C	26.7	27.8	28.9	30.0	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40.0	41.1	42.2	43.3
^{0}F	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	17.0	17.8	18.7	19.6	20.4	21.3	22.1	22.9	23.8	24.6	25.5	26.4	27.3	28.2	29.1	30.0
45	17.9	18.8	19.7	20.6	21.4	22.3	23.2	24.1	25.0	25.9	26.8	27.7	28.7	29.6	30.5	31.4
50	18.8	19.7	20.6	21.5	22.4	23.3	24.2	25.2	26.1	27.1	28.0	29.0	29.9	30.9	31.8	32.8
55	19.7	20.6	21.5	22.5	23.4	24.3	25.3	26.3	27.2	28.2	29.2	30.2	31.1	32.1	33.1	34.0
60	20.5	21.4	22.4	23.3	24.3	25.3	26.3	27.3	28.3	29.3	30.3	31.3	32.3	33.2	34.2	35.2
65	21.3	22.3	23.2	24.2	25.2	26.2	27.3	28.3	29.3	30.3	31.3	32.3	33.3	34.3	35.3	36.4
70	22.1	23.0	24.0	25.1	26.1	27.2	28.2	29.2	30.3	31.3	32.3	33.4	34.4	35.4	36.4	37.4
75	22.8	23.8	24.8	25.9	27.0	28.0	29.1	30.1	31.2	32.2	33.3	34.3	35.4	36.4	37.5	38.5
80	23.5	24.6	25.6	26.7	27.8	28.9	30.0	31.0	32.1	33.1	34.2	35.3	36.3	37.4	38.4	39.5
85	24.2	25.3	26.4	27.5	28.6	29.7	30.8	31.9	32.9	34.0	35.1	36.2	37.2	38.3	39.4	40.5
90	24.9	26.0	27.2	28.3	29.4	30.5	31.6	32.7	33.8	34.9	35.9	37.0	38.1	39.2	40.4	41.5
95	25.6	26.7	27.9	29.0	30.1	31.2	32.4	33.5	34.6	35.7	36.8	37.9	39.0	40.1	41.3	42.5
100	26.3	27.4	28.6	29.7	30.9	32.0	33.1	34.2	35.3	36.5	37.6	38.7	39.8	41.0	42.2	43.5

Ref
RCP4.5
RCP8.5

Caution
Extreme Caution
Danger
Extreme Danger

Heat Index [NOAA Weather Service]

Tempearature (^{0}F)

Relative Humidity (%)

^{0}C	26.7	27.8	28.9	30.0	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40.0	41.1	42.2	43.3
^{0}F	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	92	96	100	104	109	114	119	124	130	137	143
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137	144	152
55	81	84	86	89	93	97	101	106	112	117	124	130	137	145	153	161
60	82	84	88	91	95	100	105	110	116	123	129	137	145	153	162	171
65	82	85	89	93	98	103	108	114	121	128	136	144	153	162	172	182
70	83	86	90	95	100	106	112	119	126	134	143	152	161	172	182	194
75	84	88	92	97	103	109	116	124	132	141	150	160	171	182	193	206
80	84	89	94	100	106	113	121	129	138	148	158	169	181	193	205	219
85	85	90	96	102	110	117	126	135	145	155	167	179	191	204	218	233
90	86	91	98	105	113	122	131	141	152	164	176	189	202	216	231	247
95	86	93	100	108	117	127	137	148	160	172	185	199	214	229	245	262
100	87	95	103	112	121	132	143	155	168	181	195	210	226	243	260	278

Caution
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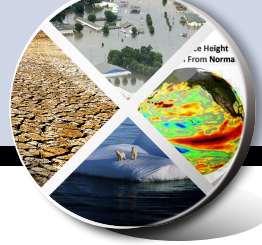
Danger
Extreme Danger

Likelihood Heat Disorders: Max.Tw 95%



Wet-bulb Temperature

Tempearature (^{0}F)

Relative Humidity (%)	^{0}C	26.7	27.8	28.9	30.0	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40.0	41.1	42.2	43.3
	^{0}F	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
	40	17.0	17.8	18.7	19.6	20.4	21.3	22.1	22.9	23.8	24.6	25.5	26.4	27.3	28.2	29.1	30.0
	45	17.9	18.8	19.7	20.6	21.4	22.3	23.2	24.1	25.0	25.9	26.8	27.7	28.7	29.6	30.5	31.4
	50	18.8	19.7	20.6	21.5	22.4	23.3	24.2	25.2	26.1	27.1	28.0	29.0	29.9	30.9	31.8	32.8
	55	19.7	20.6	21.5	22.5	23.4	24.3	25.3	26.3	27.2	28.2	29.2	30.2	31.1	32.1	33.1	34.0
	60	20.5	21.4	22.4	23.3	24.3	25.3	26.3	27.3	28.3	.3	30.3	31.3	32.3	33.2	34.2	35.2
	65	21.3	22.3	23.2	24.2	25.2	.2	27.3	28.	29.3	30.3	31.3	32.3	33.3	34.3	35.3	36.4
	70	22.1	23.0	24.0	25.1	26.1	27.2	28.2	29.2	30.3	31.3	32.3	33.4	34.4	35.4	36.4	37.4
	75	22.8	23.8	24.8	25.9	27.0	28.0	29.1	30.1	31.2	32.2	33.3	34.3	35.4	36.4	37.5	38.5
	80	23.5	24.6	25.6	26.7	27.8	28.9	30.0	31.0	32.1	33.1	34.2	35.3	36.3	37.4	38.4	39.5
	85	24.2	25.3	26.4	27.5	28.6	29.7	30.8	31.9	32.9	34.0	35.1	36.2	37.2	38.3	39.4	40.5
	90	24.9	26.0	27.2	28.3	29.4	30.5	31.6	32.7	33.8	34.9	35.9	37.0	38.1	39.2	40.4	41.5
	95	25.6	26.7	27.9	29.0	30.1	31.2	32.4	33.5	34.6	35.7	36.8	37.9	39.0	40.1	41.3	42.5
	100	26.3	27.4	28.6	29.7	30.9	32.0	33.1	34.2	35.3	36.5	37.6	38.7	39.8	41.0	42.2	43.5

Ref
RCP4.5
RCP8.5

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Heat Index [NOAA Weather Service]

Tempearature (^{0}F)

Relative Humidity (%)	^{0}C	26.7	27.8	28.9	30.0	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40.0	41.1	42.2	43.3
	^{0}F	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
	40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
	45	80	82	84	87	89	92	96	100	104	109	114	119	124	130	137	143
	50	81	83	85	88	91	95	99	103	108	113	118	124	131	137	144	152
	55	81	84	86	89	93	97	101	106	112	117	124	130	137	145	153	161
	60	82	84	88	91	95	100	105	110	116	123	129	137	145	153	162	171
	65	82	85	89	93	98	103	108	114	121	128	136	144	153	162	172	182
	70	83	86	90	95	100	106	112	119	126	134	143	152	161	172	182	194
	75	84	88	92	97	103	109	116	124	132	141	150	160	171	182	193	206
	80	84	89	94	100	106	113	121	129	138	148	158	169	181	193	205	219
	85	85	90	96	102	110	117	126	135	145	155	167	179	191	204	218	233
	90	86	91	98	105	113	122	131	141	152	164	176	189	202	216	231	247
	95	86	93	100	108	117	127	137	148	160	172	185	199	214	229	245	262
	100	87	95	103	112	121	132	143	155	168	181	195	210	226	243	260	278

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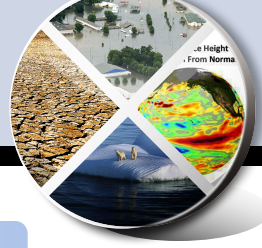
Extreme Caution
Danger
Extreme Danger

Take Home Message

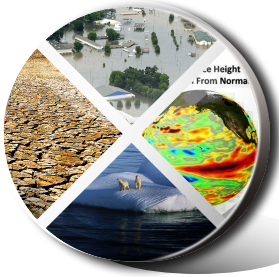


MRCM is a useful scientific tool for climate change study

- MRCM is capable of reproducing the key climate features over the Maritime Continent.
- Higher resolution improves the diurnal variation of rainfall through better resolving the complex topography and land-sea contrast.

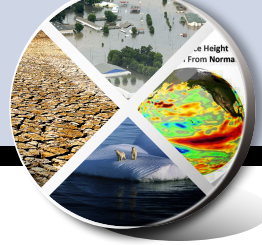
Tw projected to increase over the Maritime Continent

- Even under the business as usual emission scenario, Tw will not exceed 35C threshold that would threaten human survivability.
- However, uncommonly high Tw (e.g. above 95%) that occurs in the present climate will characterize the normal in the future.



Thank you for your attention!

Likelihood Heat Disorders: Max.Tw 95%



Wet-bulb Temperature

Tempearature (^{0}F)

^{0}C	26.7	27.8	28.9	30.0	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40.0	41.1	42.2	43.3
Relative Humidity (%) / ^{0}F	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	17.0	17.8	18.7	19.6	20.4	21.3	22.1	22.9	23.8	24.6	25.5	26.4	27.3	28.2	29.1	30.0
45	17.9	18.8	19.7	20.6	21.4	22.3	23.2	24.1	25.0	25.9	26.8	27.7	28.7	29.6	30.5	31.4
50	18.8	19.7	20.6	21.5	22.4	23.3	24.2	25.2	26.1	27.1	28.0	.0	29.9	30.9	31.8	32.8
55	19.7	20.6	21.5	22.5	23.4	24.3	25.3	.3	27.2	.2	.2	30.2	31.1	32.1	33.1	34.0
60	20.5	21.4	22.4	23.3	24.3	25.3	26.3	27.3	28.3	.3	30.3	31.3	32.3	33.2	34.2	35.2
65	21.3	22.3	23.2	24.2	25.2	.2	27.	28.	29.3	30.3	31.3	32.3	33.3	34.3	35.3	36.4
70	22.1	23.0	24.0	25.1	26.1	27.2	28.2	.2	30.3	31.3	32.3	33.4	34.4	35.4	36.4	37.4
75	22.8	23.8	24.8	25.9	27.0	28.0	29.1	30.1	31.2	32.2	33.3	34.3	35.4	36.4	37.5	38.5
80	23.5	24.6	25.6	26.7	27.8	28.9	30.0	31.0	32.1	33.1	34.2	35.3	36.3	37.4	38.4	39.5
85	24.2	25.3	26.4	27.5	28.6	29.7	30.8	31.9	32.9	34.0	35.1	36.2	37.2	38.3	39.4	40.5
90	24.9	26.0	27.2	28.3	29.4	30.5	31.6	32.7	33.8	34.9	35.9	37.0	38.1	39.2	40.4	41.5
95	25.6	26.7	27.9	29.0	30.1	31.2	32.4	33.5	34.6	35.7	36.8	37.9	39.0	40.1	41.3	42.5
100	26.3	27.4	28.6	29.7	30.9	32.0	33.1	34.2	35.3	36.5	37.6	38.7	39.8	41.0	42.2	43.5

Ref
RCP4.5
RCP8.5

Caution
Extreme Caution
Danger
Extreme Danger

Heat Index [NOAA Weather Service]

Tempearature (^{0}F)

^{0}C	26.7	27.8	28.9	30.0	31.1	32.2	33.3	34.4	35.6	36.7	37.8	38.9	40.0	41.1	42.2	43.3
Relative Humidity (%) / ^{0}F	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	92	96	100	104	109	114	119	124	130	137	143
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137	144	152
55	81	84	86	89	93	97	101	106	112	117	124	130	137	145	153	161
60	82	84	88	91	95	100	105	110	116	123	129	137	145	153	162	171
65	82	85	89	93	98	103	108	114	121	128	136	144	153	162	172	182
70	83	86	90	95	100	106	112	119	126	134	143	152	161	172	182	194
75	84	88	92	97	103	109	116	124	132	141	150	160	171	182	193	206
80	84	89	94	100	106	113	121	129	138	148	158	169	181	193	205	219
85	85	90	96	102	110	117	126	135	145	155	167	179	191	204	218	233
90	86	91	98	105	113	122	131	141	152	164	176	189	202	216	231	247
95	86	93	100	108	117	127	137	148	160	172	185	199	214	229	245	262
100	87	95	103	112	121	132	143	155	168	181	195	210	226	243	260	278

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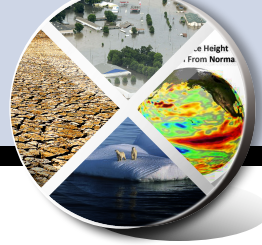
Likelihood Heat Disorders: Max.Tw 50%



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	60	20.5	21.4	22.4	23.3	24.3	25.3	26.3	27.3	28.3	29.3	30.3	31.3	32.3	33.2	34.2	35.2
	65	21.3	22.3	23.2	24.2	25.2	26.2	27.2	28.3	29.3	30.3	31.3	32.3	33.3	34.3	35.3	36.4
	70	22.1	23.0	24.0	25.1	26.1	27.2	28.2	29.2	30.3	31.3	32.3	33.4	34.4	35.4	36.4	37.4
	75	22.8	23.8	24.8	25.9	27.0	28.0	29.1	30.1	31.2	32.2	33.3	34.3	35.4	36.4	37.5	38.5
	80	23.5	24.6	25.6	26.7	27.8	28.9	30.0	31.0	32.1	33.1	34.2	35.3	36.3	37.4	38.4	39.5
	85	24.2	25.3	26.4	27.5	28.6	29.7	30.8	31.9	32.9	34.0	35.1	36.2	37.2	38.3	39.4	40.5
	90	24.9	26.0	27.2	28.3	29.4	30.5	31.6	32.7	33.8	34.9	35.9	37.0	38.1	39.2	40.4	41.5
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	100	26.3	27.4	28.6	29.7	30.9	32.0	33.1	34.2	35.3	36.5	37.6	38.7	39.8	41.0	42.2	43.5

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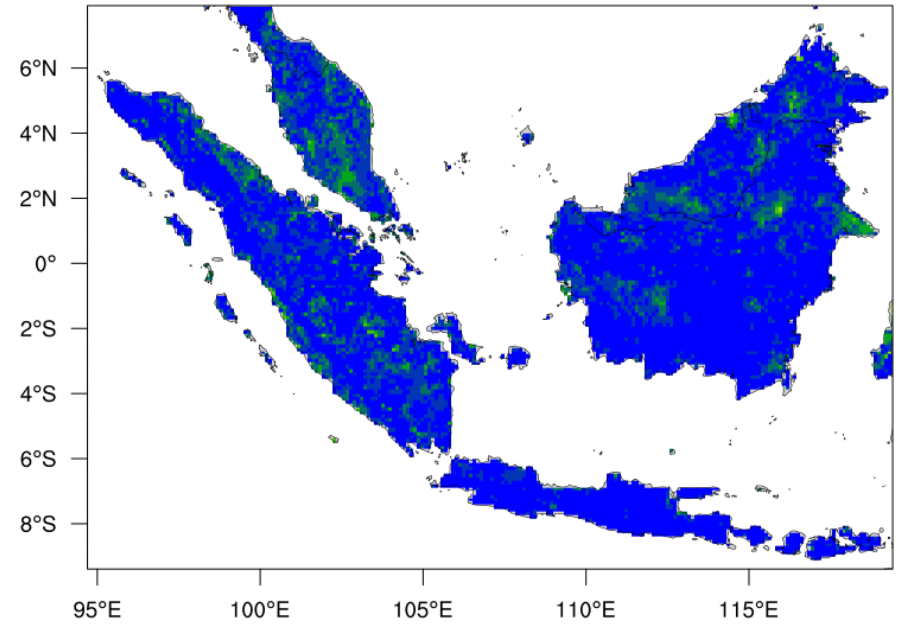
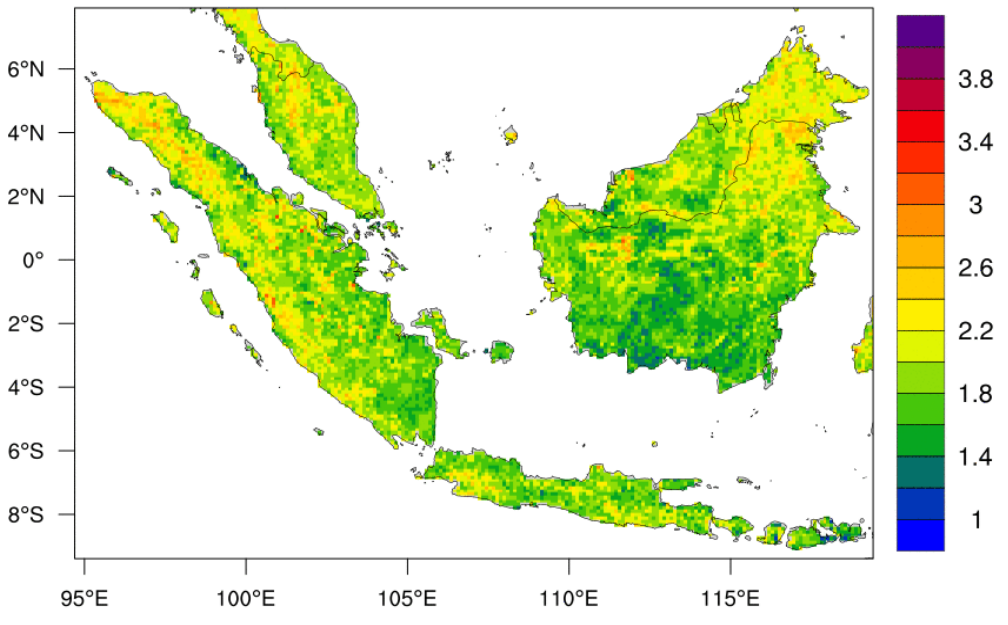
RCP4.5

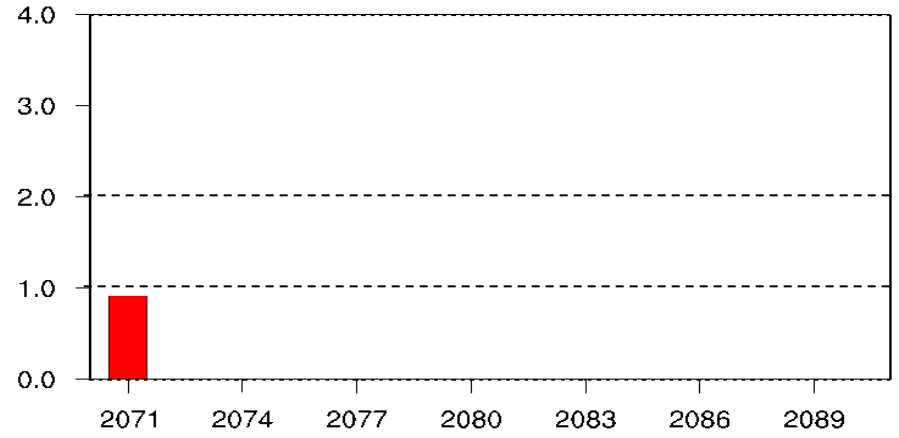
YEAR : 2071

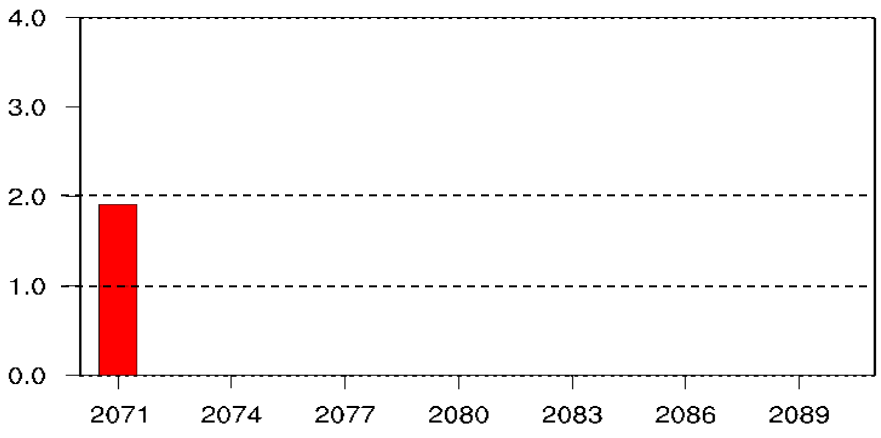


RCP8.5

YEAR : 2071







Regional Projection - TA

zdef 8 levels 02 05 08 11 14 17 20 23
*zdef 8 levels 18 21 24 03 06 09 12 15