Regional Climate Projection of the Maritime Continent using the MIT Regional Climate Model

Eun-Soon Im[1] and Elfatih A. B. Eltahir[2]

[1]Singapore-MIT Alliance for Research and Technology, Center for Environmental Sensing and Modeling
[2]Ralph M. Parsons Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts

Massachusetts Institute of Technology
Department of Civil & Environmental Engineering, Massachusetts Institute of Technology
SMART Singapore-MIT Alliance for Research and Technology
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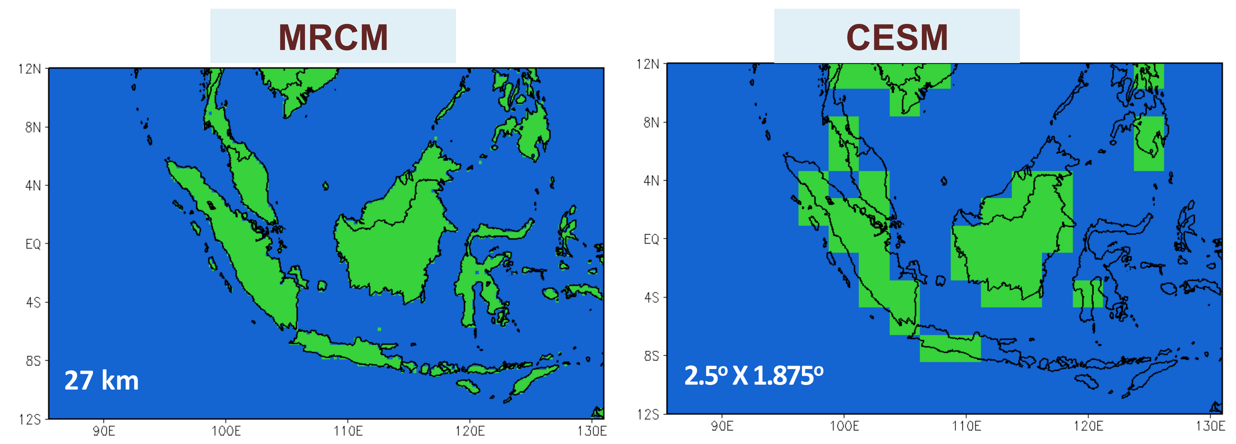
Abstract

Given that warming of the climate system is unequivocal (IPCC AR5), accurate assessment of future climate is essential to understand the impact of climate change due to global warming. Modelling the climate change of the Maritime Continent is particularly challenge, showing a high degree of uncertainty. Compared to other regions, model agreement of future projections in response to anthropogenic emission forcings is much less. Furthermore, the spatial and temporal behaviors of climate projections seem to vary significantly due to a complex geographical condition and a wide range of scale interactions. For the fine-scale climate information (27 km) suitable for representing the complexity of climate change over the Maritime Continent, dynamical downscaling is performed using the MIT regional climate model (MRCM) during two thirty-year period for reference (1970-1999) and future (2070-2099) climate. Initial and boundary conditions are provided by Community Earth System Model (CESM) simulations under the emission scenarios projected by MIT Integrated Global System Model (IGSM). Changes in mean climate as well as the frequency and intensity of extreme climate events are investigated at various temporal and spatial scales. Our analysis is primarily centered on the different behavior of changes in convective and large-scale precipitation over land vs. ocean during dry vs. wet season. In addition, we attempt to find the added value to downscaled results over the Maritime Continent through the comparison between MRCM and CESM projection.

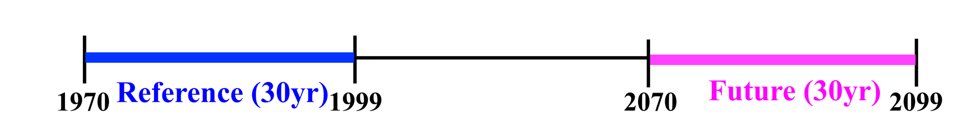
MIT Regional Climate Model (MRCM) driven by Community Earth System Model (CESM)

✧ MRCM domain & land-sea mask comparison between MRCM and CESM



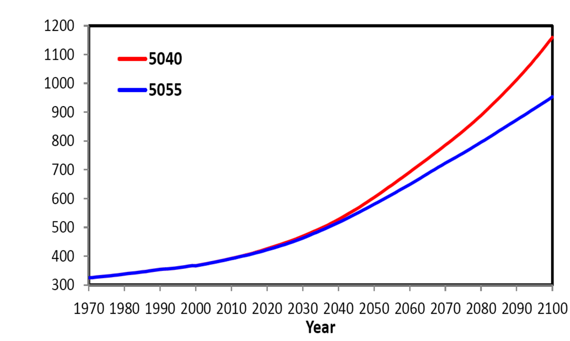
- Global model is less suitable for investigating detailed feature of climate behavior over the Maritime Continent due to its complex geographical features. As indicated by land-sea mask, the Maritime Continent is a representative region that highlights the necessity of downscaling because fine-scale regional model is able to prescribe much more realistic surface forcing.

✧ Downscaling period: Reference (30yr) & Future (30yr)



✧ Emission Scenario : 040 & 055 [Sokolov et al. 2009]

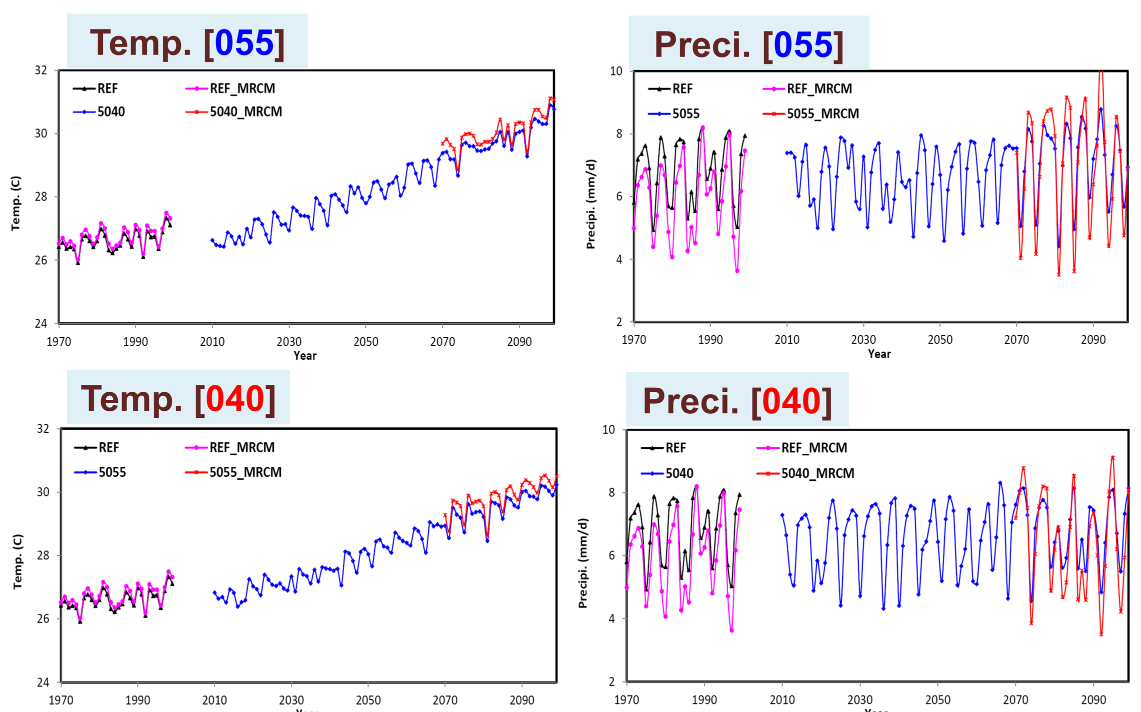
From MIT Integrated Global System Model (IGSM)



- Among very large number of ensemble members produced by MIT IGSM, we randomly pick up two emission scenarios (040&055).
- CO_2 concentrations are continuously going up to 900 ppm by the end of 21st century, thus they are considered aggressive scenarios, indicating above the level of RCP 8.5.

Long-term Trend of Temperature and Precipitation

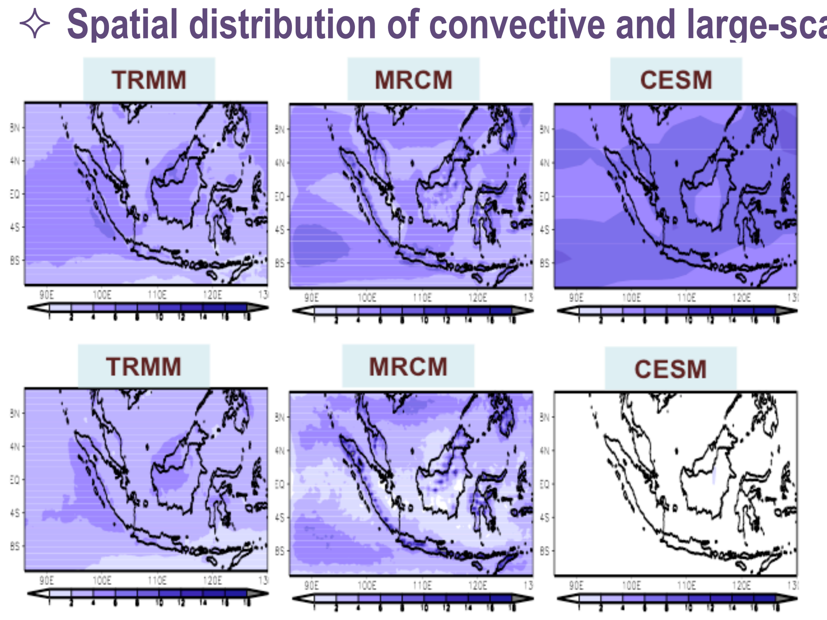
✧ Temporal evolution of annual mean temperature and precipitation averaged over the Maritime Continent derived from CESM and MRCM projections



- During the reference period, temperature shows a gradually increasing pattern, then the degree of warming is sharply accelerated at the twenty-first century, indicating a well-defined increasing trend. Two members driven with different greenhouse gases (GHGs) concentrations show different degree of warming. Higher emission forcing produces more sharply increasing trend. Therefore, temperature response is roughly proportional to the emission forcing, and this is in line with many other future projections.
- In contrast to temperature, precipitation change shows little sensitivity to emission forcing. There is no relevant difference between two members. It can not be seen any visible long-term trend, as well. Moving to the future projection, precipitation from even higher emission scenario shows slightly lower and less variability in the late 21 century. Thus, precipitation changes seemingly do not respond monotonically to emission forcing
- In general, MRCM shows the similar patterns with those from the CESM global projection. Both of them look very similar with close phase coherence, but MRCM shows more enhanced warming and large variability.

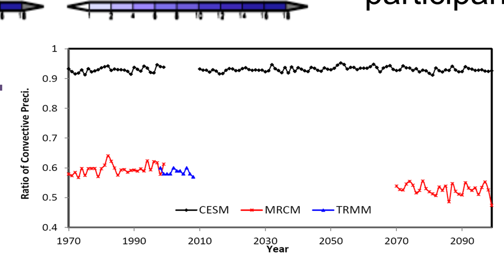
Added value of MRCM downscaled simulation

✧ Spatial distribution of convective and large-scale precipitation



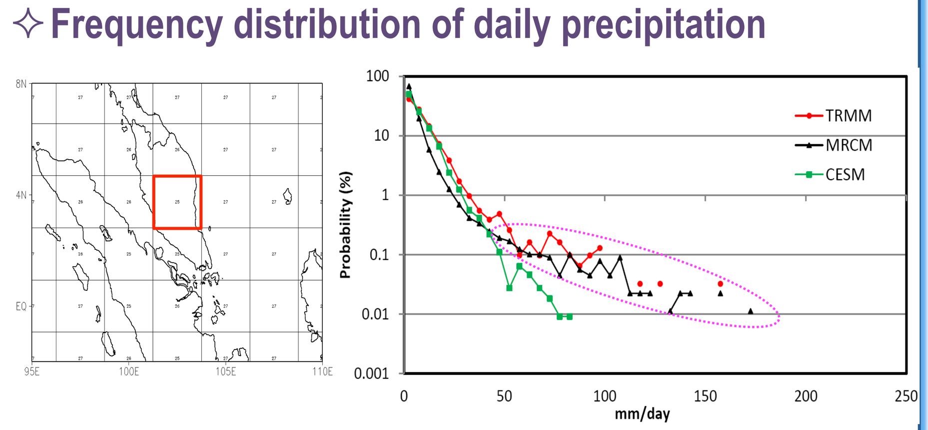
- In contrast to the similar behavior of total precipitation, MRCM and CESM show the different details such as partitioning of convective and large-scale precipitation.
- While MRCM shows similar ratio of convective precipitation with TRMM (around 60%), CESM consistently shows more than 90% of convective precipitation, and almost no large-scale precipitation.
- Such a problem is not limited to only CESM global model, but rather seems to be typical behavior found in many other CMIP5 participant models.

✧ Ratio of convective precip. to total precipitation



- Thus, it is reasonable to assume that physical realism is more plausible in MRCM compared to global model.

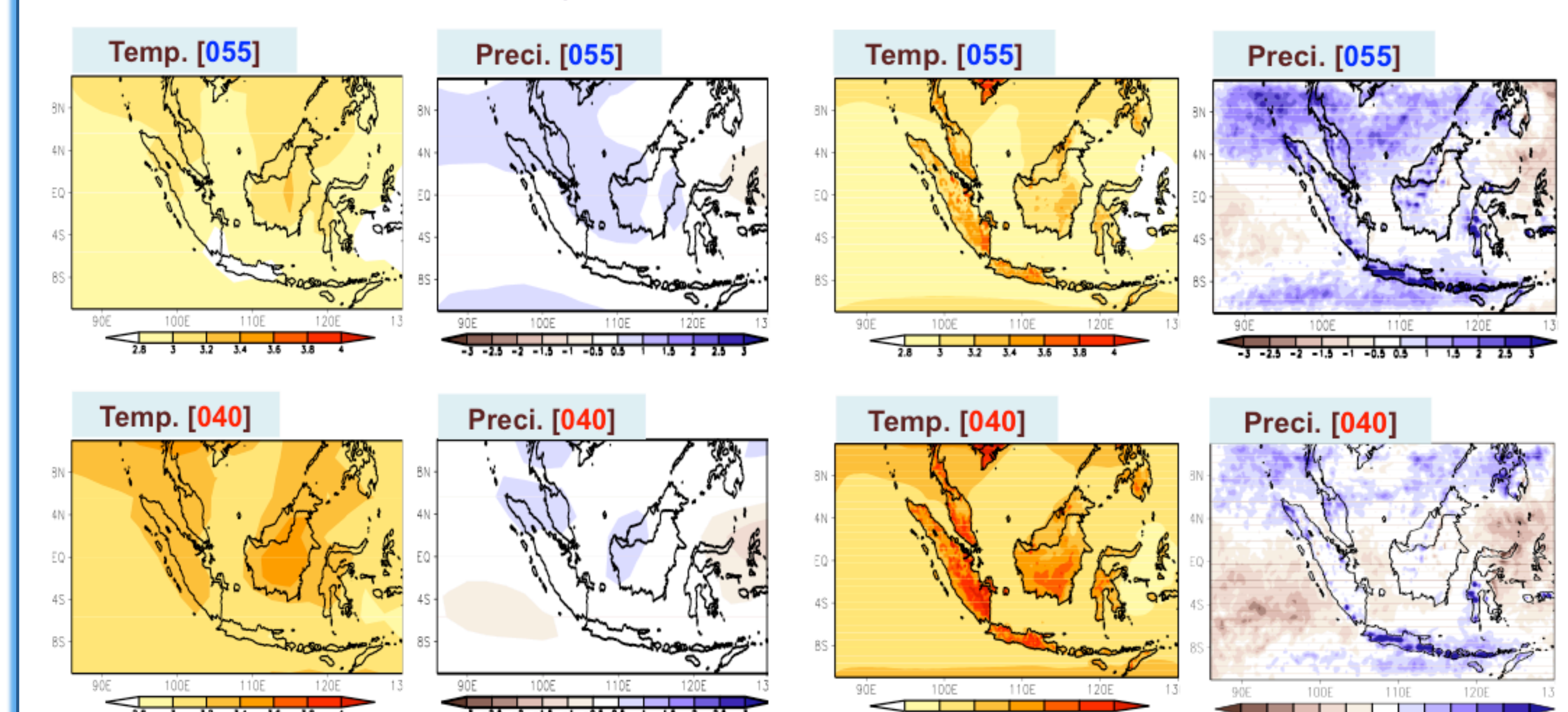
✧ Frequency distribution of daily precipitation



- In addition to better physical realism, MRCM provides the possibility to capture extreme precipitation episodes.
- Based on the frequency distribution of daily precipitation at one particular grid box, MRCM has a longer tail at the high intensity range, and this behavior is closer to TRMM observation. On the other hand, CESM fail to capture high intensity precipitation
- This indicates that regional climate model with fine-scale is critical for simulating extreme events over the region.

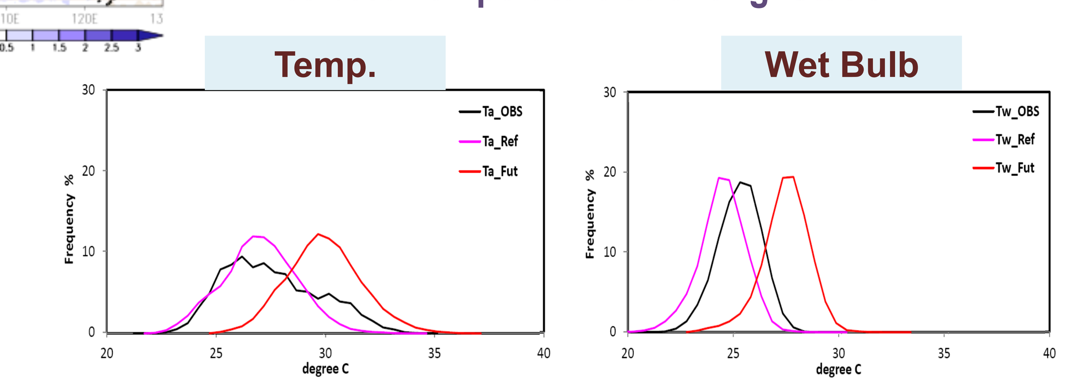
Projection of Future Climate Change (2070-2099)

✧ Spatial distribution of changes in annual mean temperature and precipitation derived from CESM and MRCM projections



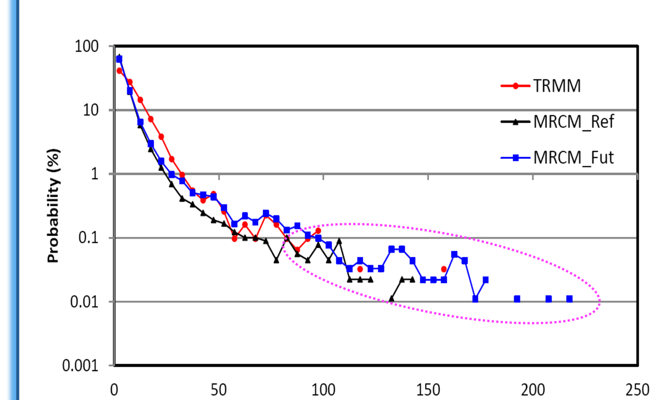
- The changes of spatial pattern are also consistent with temporal evolution.
- MRCM and CESM all project significant warming across entire domain.
- Both of them show generally consistent pattern. But MRCM shows much more enhanced warming particularly over land.
- For the precipitation, both of them roughly agree increasing or decreasing sign, but MRCM produce much stronger magnitude.

✧ Frequency Distribution of 3-hour Temperature and Wet Bulb Temperature at Changi Station



- Wet-bulb temperature is used as the indication to measure heat stress.
- The distribution shape of wet bulb temperature is narrower and more peaked than surface temperature with lower mean value. MRCM is capable of capturing these characteristics.
- In the future, both distributions are shifted toward warmer climate. This shift has an important implication because it accompanies the changes in the extreme events due to changes in the upper and lower tail bounds.

✧ Frequency Distribution of Daily Precipitation at Changi Station



- An enhancement of high intensity precipitation and a resultant increase of frequency and intensity of heavy precipitation are projected in the future under global warming.
- This implies a greater vulnerability against flood hazards due to an increased probability of more severe extreme events, which is in line with previous studies that assessed the changes in extreme precipitation due to global warming

Summary

- **Considering that the Maritime Continent is traditionally very difficult region to simulate accurate climate using any climate model, it is reasonable to estimate that MRCM has the potential of skillful transferability over this region. Compared to global simulation or other regional simulations, MRCM provides the possibility to capture some important climate phenomena including extremes with more physical realism.**
- **Downscaled climate projection using our modeling system is critical for assessing climate change impact at regional to local scales and establishing tailored adaptation strategy.**

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