Combinatorial optimization of physics schemes in RegCM5 using a micro-genetic algorithm for precipitation and temperature simulations in Southeast Asia

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Introduction

➢ **Recent release of RegCM5**

- The fifth version of the regional climate model (RegCM5) has recently been released, incorporating updates in several model components such as the **dynamic core** and **physical parameterizations**.

➢ **The Need for advanced optimization techniques to increase efficiency and effectiveness**

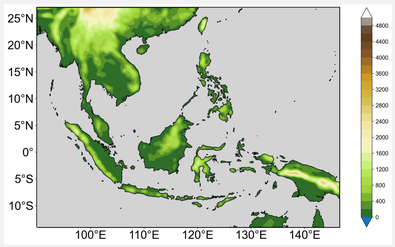
- Traditionally, sensitivity tests based on random selection have been employed to identify the optimal sets from various combinations of model dynamics and physics. → **largely limited by computing power**
- To overcome these limitations, advanced optimization techniques have emerged to efficiently **explore the complete range of possible combinations**, without relying solely on random-based sensitivity tests.

➢ **Research Objectives**

- In this study, we employ a **micro-genetic algorithm (micro-GA)** for **combinatorial optimization** of the parameterization schemes using the newly released RegCM5.
- The focus is on comparing the simulated **precipitation** and **temperature** patterns in Southeast Asia based on a series of experiments using the coupled RegCM5-micro-GA interface.
- The findings from this study will provide valuable insights to **facilitate the wider use of RegCM5** by **customizing** its performance **over the target regions**.

Method & Data

➢ **RegCM5 Domain with 0.22° horizontal resolution**



➢ **Integration period:** 20110701-20110801

➢ **Dynamic core**: Non-hydrostatic, height-based coordinate (MOLOCH)

➢ **Initial and Boundary Conditions:**

❖ ***ECMWF Reanalysis v5 (ERA5) data***

- **Temporal resolution**: 6 hours
- **Spatial resolution**: 0.25° × 0.25°

➢ **Observation data for validation:**

❖ ***ERA5-Land surface data***

- **Temporal resolution**: hourly
- **Spatial resolution**: 0.1° × 0.1°

➢ **Parameterization schemes to be optimized**

Schemes	Choices
icup_lnd (Cumulus convection scheme Over Land)	2 (Grell), 4 (MIT), 5 (Tiedtke), 6 (Kain-Firtsch)
icup_ocn (Cumulus convection scheme Over Ocean)	2 (Grell), 4 (MIT), 5 (Tiedtke), 6 (Kain-Firtsch)
Ibltyp (Boundary layer scheme)	1 (Modified Holtslag), 2 (UW-PBL)
Ipptls (Moisture scheme)	1 (SUBEX), 2 (Nogherotto-Tompkins)

➢ **Fitness functions tested**

- Normalized Root Mean Square Error (NRMSE) for
  - Temperature (Temp) only
  - Precipitation (Precip) only
- Summed NRMSE for temperature and precipitation

$$NRMSE = \frac{\sqrt{\frac{(X-\hat{X})^2}{n}}}{\sigma}$$

X: RegCM5 simulated Temp or Precip
$\hat{X}$: Observed Temp or Precip
n: Number of samples (i.e., timesteps)
σ: Standard deviation of observed Temp or Precip

➢ **Observation data for calculating fitness:**

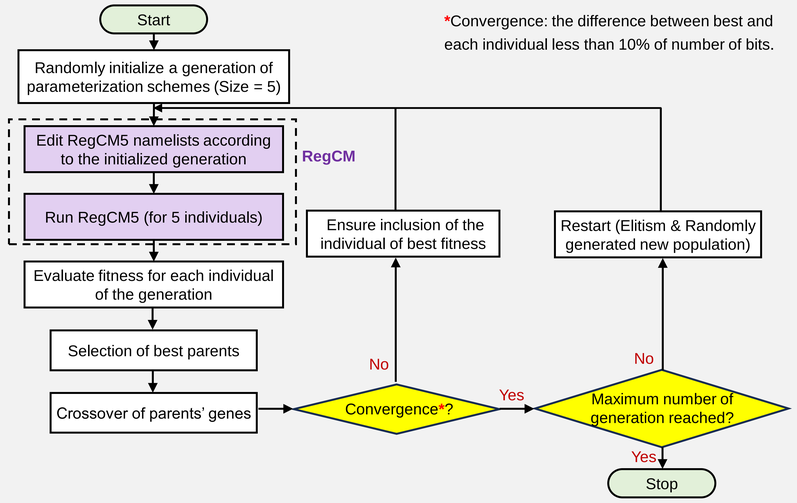
❖ ***Temperature: ERA5-Land surface data***

- **Temporal resolution**: hourly
- **Spatial resolution**: 0.1° × 0.1°

❖ ***Precipitation: Integrated Multi-satellitE Retrievals for GPM (IMERG)***

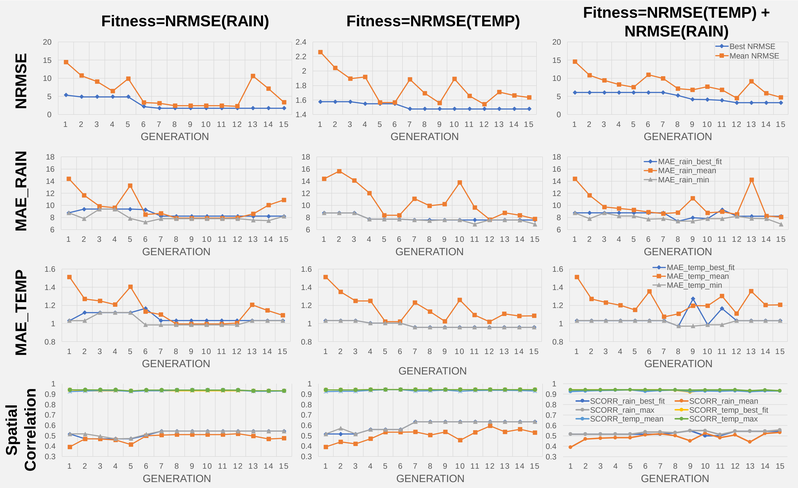
- **Temporal resolution**: daily
- **Spatial resolution**: 0.1° × 0.1°

Micro-GA-RegCM Algorithm Structure



*Convergence: the difference between best and each individual less than 10% of number of bits.

Results: Sensitivity to Different Fitness Functions



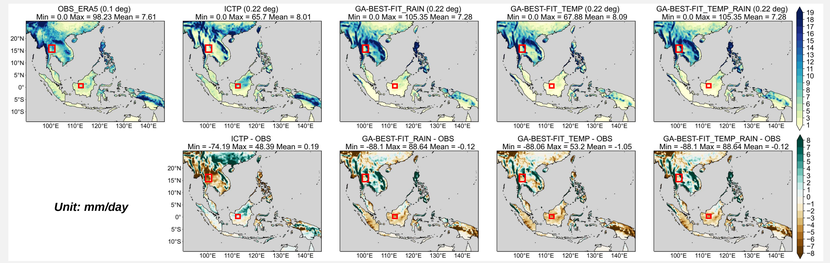
- NRMSE and MAE (spatial correlation) tend to decrease (increase) by generations → **Effectiveness of GA**
- Fitness based on TEMP tend to reach convergence and trigger reinitialization more often, possibly due to less uncertainty in temperature patterns than precipitation. → **Considerations for fitness choice**
- NRMSE (RAIN) achieves same results as NRMSE (RAIN) + NRMSE (TEMP) → **Precipitation dominate**

Results: Performance of Optimized Simulations

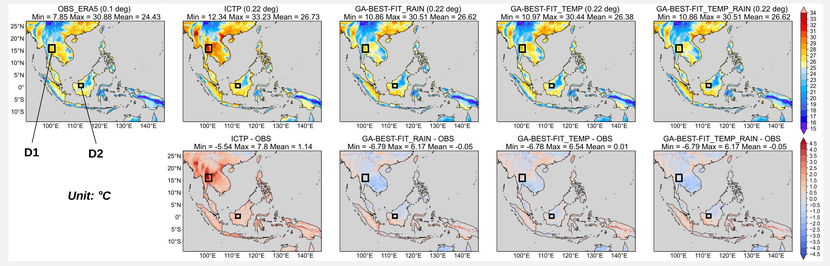
➢ **Optimized Scheme Combinations**

	Fitness (RAIN)	Fitness (TEMP)	Fitness (TEMP+RAIN)	ICTP Recommendation
icup_lnd (Cumulus convection scheme Over Land)	5	5	5	5
icup_ocn (Cumulus convection scheme Over Ocean)	4	5	4	5
Ibltyp (Boundary layer scheme)	2	2	2	1
Ipptls (Moisture scheme)	1	1	1	2

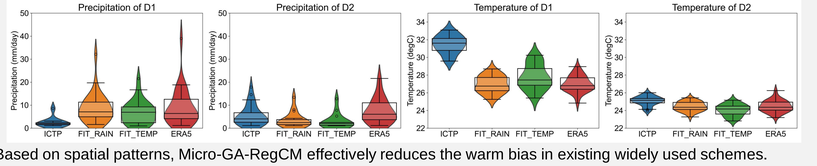
➢ **Precipitation Monthly Climatology**



➢ **Temperature Monthly Climatology**



➢ **Local distribution of daily temperature and precipitation**



- Based on spatial patterns, Micro-GA-RegCM effectively reduces the warm bias in existing widely used schemes.
- Although GA reduces wet bias in China peninsula, there seems to be an enhanced dry bias in Maritime continents.
- The distribution shape illustrated by the violin plots, combined with the statistics provided by the box plot, clearly demonstrates the superior performance of the GA-Best simulations compared to the ICTP-recommended version.

Acknowledgement

This research was supported by project GRF16308722, which was funded by the Research Grants Council (RGC) of Hong Kong.