Downscaling Projection of Future Daily Rainfall over Malaysia using Non-Homogeneous Hidden Markov Model

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Introduction

General circulation models (GCMs) are crucial tools in projecting the future climate changes. However, GCMs are not suitable to be used directly in regional applications. The low resolution of GCMs have much lower skill for regional scale (e.g. Southeast Asia region). Downscaling is needed to infer fine scale information from the coarse grid GCMs variables. Malaysian climate is basically characterized by two monsoon regimes, summer (southwest) monsoon from late May to September and winter (northeast) monsoon from November to March. During the winter monsoon, areas facing the South China Sea, such as the east coast of Peninsular Malaysia often experience higher rainfall, which may lead to severe flooding. Therefore, the analysis of rainfall characteristics over Malaysia is becoming important and it is useful for the purpose of decision making and predictions. The Non-homogeneous hidden Markov model (NHMM) was introduced by Hughes & Guttorp (1994), which extend the hidden Markov model (HMM) used by Zucchini & Guttorp (1991) by incorporating synoptic atmospheric information. The purpose of this study is to project the future daily rainfall changes in Malaysia based on the SRES emission scenario A2 and B1 by using a statistical downscaling model, Non-homogeneous hidden Markov model (NHMM).

Data & Methods

Data

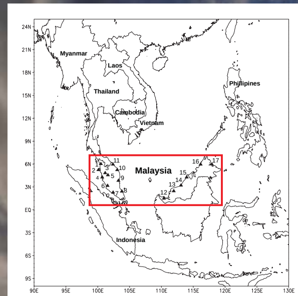
- Observed daily rainfall amount data at 17 stations (1970-2004)
- NCEP reanalysis data (1970-2004)
- 13 GCMs dataset from CMIP3: 20C3M (1981-2000), SRES A2 (2081-2100)

Season

- Winter monsoon, November to February (NDJF)

Atmospheric variables

- Combination of sea level pressure and air temperature at 850 hPa



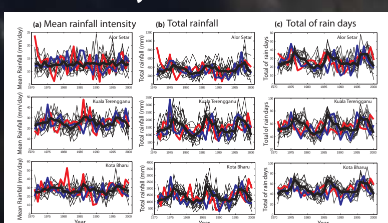
The Geographical Location of 17 Stations

Table: List of 13 Global Climate models from the CIMP3 database

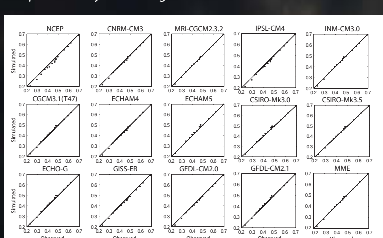
Modeling Center	Model ID
Canadian Centre for Climate Modeling and Analysis, Canada	CGCM3.1(T47)
Mété - France/Centre National de Recherches Météorologiques, France	CNRM CM3
Commonwealth Scientific and industrial Research Organisation (CSIRO) Atmospheric Research, Australia	CSIRO - Mk3.0 CSIRO - Mk3.5
Max PlaInstitute for Meteorology, Germany	ECHAM4 ECHAM5
Meteorological Institute of the Unversity of Bonn, Meteorological Research Institute of the Korea Meteorological Administration (KMA), and Model and Data Group, Germany/Korea	ECHO - G
U.S. Department of Commerce/National Oceanic and Atmospheric Administration (NOAA) Geophysical Fluid Dynamics Laboratory (GFDL), USA	GFDL - CM2.0 GFDL - CM2.1
NASA/GISS, USA	GISS - ER
Institute for Numerical Mathematics, Russia	INM - CM3.0
Institute Pierre Simon Laplace, France	IPSL - CM4
Meteorological Research Institute, Japan	MRI - CGCM2.3.2

Results

1 Present day Simulations

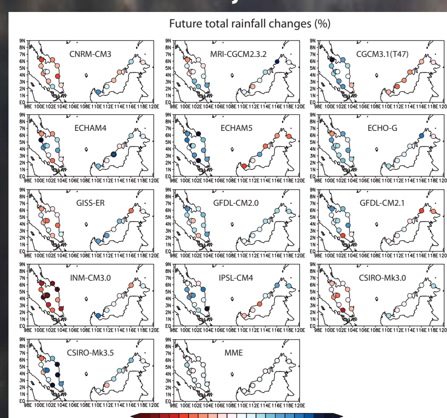


Time series of (a) mean rainfall intensity, (b) total rainfall and (c) total of rain days for NDJF. Red line represent observed, blue line is NCEP simulation, black bold line represent the multi-model ensemble mean (MME) and light black lines are simulations of 13 GCMs. The MME simulation is well reproduce the observed variability compared to any others single GCMs simulation.

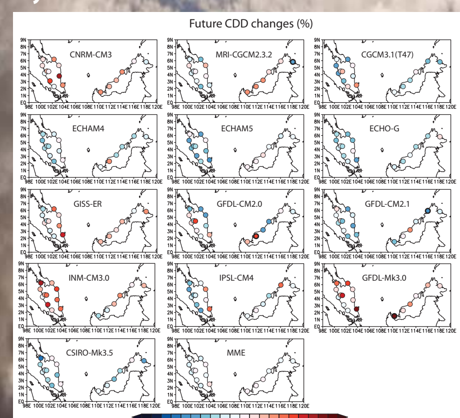


Observed versus simulated probability of rainfall occurrence at 17 stations for winter monsoon (NDJF). The downscaled GCMs simulations (20C3M) are able to reproduce the observed rainfall probability.

2 Future Rainfall Projections of the 21st century based on SRES A2 scenario



Projected total rainfall changes (%) of 13 GCMs and multi-model ensemble mean (MME) for the period 2081-2100 relative to 1981-2000 based on the SRES A2 scenario. Station with bolded ring correspond to the change is significant at 95 level. Some models project positive changes, while others project negative changes.



Projected maximum number of consecutive dry day(CDD) changes (%) of 13 GCMs and multi-model ensemble mean (MME) for the period 2081-2100 relative to 1981-2000 based on the SRES A2 scenario. Station with bolded ring correspond to the change is significant at 95 level.

Conclusions

The downscaled GCMs simulations reproduce the rainfall probability reasonably well. The rainfall indices that were indicative of rainfall occurrence were better modeled compare to those indicative of rainfall intensity. In general, the projected station rainfall changes driven by the 13 GCMs show remarkable inter-model variations.

Acknowledgements

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Reference

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Zucchini, W & Guttorp, P 1991. A hidden Markov model for space-time precipitation. Water Resources Research 27: 1917-1923.

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