551

# Seasonal Climatology Studies for Tropical Region - Borneo Island Case Study

551

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## 1 Introduction – Study Area

- The Maritime Continent, consisting of Brunei, Indonesia, Malaysia, Philippines, Thailand and surrounding areas between 10°N and 10°S, plays an important role in the southeast Asian monsoon.
- The winter monsoon of this large land-sea area with heavy precipitation serves as the biggest heat source for the planetary-scale circulation.
- The different land portions exhibit different atmospheric characteristics. The northern part attains a precipitation peak as part of Indian summer monsoon, whereas the southern part gets maximum rainfall in winters and is considered to be part of Australian monsoon (see figure to the right).
- The Maritime Continent has dominant annual precipitation cycles (average monthly total ~ 300-500mm) and also has significant inter-annual variations which are related to ENSO, shorter time-scale disturbances like MJO and cold surges in South China Sea.

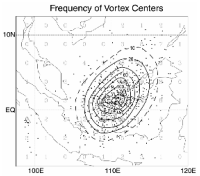

The annual cycle mode at rainfall stations. The phase of the cycle is shown as a 12-month clock with a northward arrow indicating maximum rainfall in January. The arrow rotates clockwise with eastward, southward and westward arrows indicating April, July and October, respectively. The length of the arrow defines the amplitude of the cycle. (From Chang et al. 2005b).

- Borneo, the area focused in this study, is considered to be in the transition region between the monsoon.
- Borneo has one of the largest tropical rainforests, which plays an important role in driving the global climate in the form of anthropogenic forcing. It is the home to a large and highly varied plants and animals, which enhance biodiversity, medicine, food and absorption of carbon dioxide.
- Modeling of the tropical region is particularly difficult because of the large scale forcing of atmospheric circulation by tropical sea surface temperature (SST).
- Moreover, the climate anomalies in the tropics affect climate around the world through atmospheric tele-connection and hence, is an important contributor towards predicting global climate.

### Motivation & Objective

The case study area for this work, the island of Borneo, is of greater interest due to following special characteristics:

- Other than Borneo, all other land portions have distinct dry season (as shown in figure on right) as it is located in the transition region of summer and winter monsoons.
- A long coastline along the South China Sea (SCS), is influenced by large scale disturbances like synoptic-scale northeasterly cold surges and quasi-stationary low level cyclonic disturbances.
- During Asian winters, interaction between the northeast monsoon and terrain blocking along SCS coastline generates the so-called "Borneo-Vortex".




- The synoptic cold surges and Borneo Vortex play an important role in the convection over equatorial SCS.
- This initial study will help in understanding the effect of climate change on the Borneo rainforest for our future work.

## 2 Regional Climate Model (RCM)

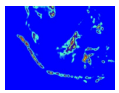
**Background about this region has been validated in an extended study by Chang et al. (2005a,b. The main objective of the current work is to capture regional climate variability in the rainfall and to study the dominant synoptic features like the Borneo Vortex and cold surges in the equatorial SCS using a high resolution regional climate model.**

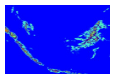
The focus of this study is on the validation of the WRF-ARW model as an RCM in recent five years and on finding an optimal setup for future simulations for the target region. The following questions are aimed to be addressed for this region composed of a land-sea complex.
(1) How well does the WRF model agree with observations when run with "ideal" boundary conditions (NCEP reanalysis) ?
(2) Do weather model simulations improve the driving reanalysis data?

In this work, some preliminary results from our analysis in Borneo are presented

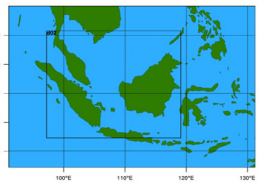
### Model Setup

- WRF-ARW model with an inner nest covering the Maritime Continent at 10km resolution and outer domain at 30km resolution on a regular latitude-longitude projection.
- Simulations performed for the five-year period between 2005 to 2009. NCEP/NCAR reanalysis data have been used as initial and lateral boundary conditions (1° x 1° resolution with 27 vertical levels, available at every six hours).
- Lower boundary condition, time-varying SST, has been taken from NCEP/NCAR (which is at 0.5° x 0.5° resolution and available daily from 2005 to 2009).
- Sensitivity study has been performed with different cumulus schemes such as Tiedtke, Betts-Miller-Janjic, etc. to capture the rainfall cycle.
- The model domain is shown in below along with the topography of the two domains. The other model parameters are also listed.


Topography of mother domain


Topography of nested domain

WRF Nested Domain Configuration




**WRF-ARW (Advanced Research WRF) model**

**ARW Solver**
- Prognostic Variables: Velocity components (u,v,w), potential temperature, geopotential and surface pressure.
- Horizontal grid: Arakawa C-grid staggering.
- Time Integration: 3rd Runge-Kutta scheme.
- Mapping to sphere: Mercator.
- Nesting: Two-way interactive with one nested domain.

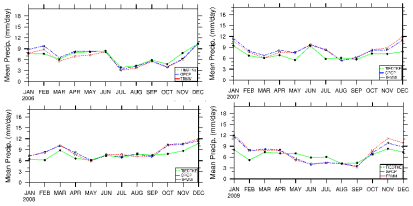
**Model Physics**
- Microphysics: WSM-3
- Longwave and Shortwave Radiation – RRTMG
- Surface Layer – Eta similarity
- Land Surface – Noah LSM
- Planetary Boundary Layer – MYJ

**Model Resolutions**
- Outer Domain: 30km x 30km horizontal with 38 vertical levels.
- Inner Domain : 10km x 10km horizontal with 38 vertical levels.

## 3 Results and Inferences

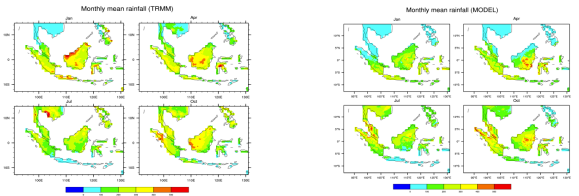
- We show the results for the precipitation only, an extended comparison of all the variables like surface temperature, surface pressure, wind with respect to other reanalysis data (e.g., MERRA) will be included in the manuscript under preparation.
- Precipitation has been compared against TRMM and GPCP data. The resolution of TRMM data are 0.25° x 0.25° and GPCP data is available at 1° x 1° resolution.

**Year-wise Annual Rainfall Cycle**




- **In this figure the annual cycle of rainfall averaged over Borneo region is presented.**
- **TRMM, Model output (with Tiedtke), GPCP are shown in red, green and blue colors respectively.**
- **Since the winter monsoon is more dominant in Borneo, as visible in the plots, thus it is of more interest to see the model performance for those months.**
- **Model output matches the TRMM and GPCP data well in terms of capturing annual cycle and rainfall magnitude.**
- **For the year 2006. which was a weak winter monsoon year for Borneo, the three values almost overlap each other, whereas for other years the maximum rainfall rate is slightly underestimated by the model.**
- **As observed in the plots there is no distinct dry season in this region (Borneo) of the Maritime Continent.**

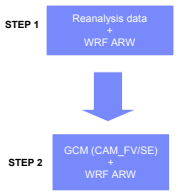
**Average Monthly Mean Rainfall Comparison**




- **The figures above show monthly average accumulated rainfall for different months over the Maritime Continent using TRMM data (left) and model output (right)**
- **The dry season of the northern part of the Maritime Continent (Jan – Apr) has been captured well by the model. Also the areas of maximum rainfall in the months shown above, have been well simulated by the model.**
- **The peak values of the rainfall are underestimated throughout the region both in summer as well as winter monsoons.**
- **More interestingly, the rainfall along the coastline (with SCS) of Borneo is further underestimated in all the months. Also, this is the area most influenced by synoptic systems like the Borneo Vortex and cold surges.**

## 4 Future Work

- The current study only focused on analyzing precipitation from the model. We plan to perform a detailed analysis of the wind systems in this region, where we shall focus on genesis and structure of the vortices along the tropical SCS during the winter season. We shall set up a higher resolution nest (~3-4 km) with one-way coupling over the vortex genesis area as identified by the current runs.
- The impact of the Borneo vortex and cold surge on rainfall will also be analyzed with the aforementioned model configuration with a higher resolution nest. This will also be useful in overcoming the underestimation of rainfall along the SCS coastline of Borneo as discussed in the results section.
- To run future climate simulations for 10-20 years, we require WRF to be driven by a global climate model (GCM), for example, CAM (Community Atmospheric Model). Running future simulations will enable us to study climate change effects on the Borneo rainforest area. The approach given in the schematic on the right will be adopted for producing future projections.




- High resolution RCM simulations
- Identifying current seasonal characteristics of the area
- Tuning the regional model for current climate using reanalysis data
- Finer-resolution GCM simulations are used to force the boundary data
- Fine tuning of the GCM to produce coherent course-resolution climate projections
- Configuration used for producing climate projections

**References**


- **Chang, C.-P., P. A. Harr, and H. J. Chen, 2005a: Synoptic disturbances over the equatorial South China Sea and western Maritime Continent during boreal winter. Mon. Wea. Rev., 133, 489-503.**
- **Chang, C.-P., Z. Wang, J. McBride, and C. H. Liu, 2005b: Annual cycle of Southeast Asia - Maritime Continent rainfall and the asymmetric monsoon transition. J. Climate, 18, 287-301.**