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Comparative Study of Weather Model WRF & RegCM Weather Prediction in a Tropical Mountainous Terrain

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Abstract— **Climate change has become one of the most widely discussed topics in the world due to its significant impact on human lives. Climate change impact prediction is the key feature when it comes to select suitable adaptation strategies for future climate change scenarios. The weather and climate prediction at basin scales can be done by downscaling of global weather data predicted by many weather models available. This study aims to compare the performance of downscaling of WRF and RegCM models on a tropical mountainous terrain. The WRF (Weather Research & Forecasting Model) & RegCM (Regional Climate Model) Models were calibrated and validated to the upper Mahaweli basin using observed point rainfall data of four gauging stations within the study area and Global Climate Model (GCM) data. During the calibration process the Physics options of both models were changed to fine-tune the models to our study area. Three known extreme events were used for calibration, validation and comparison respectively. Precipitations of the selected dates were forecasted using the WRF & RegCM models. The output of WRF model was analysed using the ARC GIS software while the output of RegCM was analysed using GRADS tool. WRF, RegCM output and the observed precipitation were obtained on grids of size 0.1 degrees which were used as a method of comparison by calculating the percentage error, RMSE and Mean Absolute Model Error (MAME). Results of both RMSE and MAME suggest that the accuracy of Precipitation prediction in Upper Mahaweli basin by WRF model is much better compared to that of RegCM model.**

Index Terms— **Downscaling, WRF, RegCM**

I. INTRODUCTION

Day to day life of mankind is being affected significantly by weather. The weather consists of the short-term (minutes to months) changes in the atmosphere in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind and atmospheric pressure. On the other hand climate is the long term pattern of weather or the average weather for a particular region and time period, usually taken over 30-years (NASA, 2005).

Climate change has become one of the most widely discussed topics in the world due to its significant impact on human lives. The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a change in climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere. Greenhouse gas emission is considered as the key cause of climate change. Intergovernmental Panel on Climate Change (IPCC) suggests that hot extremes, heat waves and heavy precipitation events will become more frequent all over the world (IPCC- AR4, 2007).

Climate change impact prediction is the key feature when it comes to select suitable adaptation strategies for future climate change scenarios. Atmospheric modeling comes in handy for this purpose. Atmospheric modeling is simulating the natural atmosphere by using numerical (computer) models is the main tool that is used for both climate and weather prediction.

General Circulation Models or Global Climate Models (GCMs) and Regional Climate Models (RCMs) are such mathematical models used to simulate the natural atmosphere. GCMs are based on the general principles of fluid dynamics and thermodynamics. GCMs and RCMs can be used to predict various climate parameters like surface temperature, precipitation patterns, extreme events, cloud patterns, storm tracks etc.

The climate change has resulted in the increase of frequent extreme events. This scenario has a great impact on the weather and demands a need for prediction of the weather to overcome the consequence of weather changes. The weather and climate prediction can be done by many weather models available. But the accuracy of the predictions is very crucial for better handling of the weather problem, since it varies depending on the model used and the geography of the study area. Therefore the study of different models and their performance in different geographical condition will result in a good prediction

The Weather Research and forecast model (WRF) is a numerical weather prediction and atmospheric system designed for both research and operation application. WRF-Preprocessing system and WRF-DA are the two major components of the WRF Model. WPS performs functions such as, defining simulation domains, interpolating terrestrial data (such as terrain, land use, and soil types), degribbing and interpolating meteorological data from another model to this simulation domain. The WRF model offers multiple options for physics schemes that could be varied to change the model to suite to its operating environment.

RegCM is an open source Regional Climatic Model developed by the Abdus Salam International center for Theoretical Physics which is run by Giorgi (Hui Liang D et al, 2011). It is used to downscale GCM data which is much coarser. The first generation RegCM was built in the 1980's.

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The dynamical component of the model originated from that of the MM4 (Mesoscale Model Version 4) which is a compressible finite difference model with hydrostatic balance and vertical sigma coordinates. This included the Biosphere-Atmosphere Transfer scheme(BATS) for surface process representation, The Radiative Transfer scheme of the NCAR Community climate Model, A medium resolution local Planetary boundary layer scheme, the Kuo-type cumulus convection scheme and the explicit Moisture scheme (Bi Xunqiang). With time many improvements were done to the Model, Addition of new schemes, new options and replacing of some of the schemes with another etc., were done to upgrade the model for an accurate prediction. Though this study was performed using the version 4.4, the latest version of RegCM is 4.5.

II. STUDY AREA & METHODOLOGY

Study Area

The selected study area is the upper Mahaweli river basin which starts from the Polgolla area. This is a part of the Mahaweli river basin, one of the largest river basins in Sri Lanka. The study area consists of a tropical mountainous terrain. This study area passes through two districts Kandy and Nuwara-Eliya covering an area of about 788 km^2. Fig.1 shows the study area.

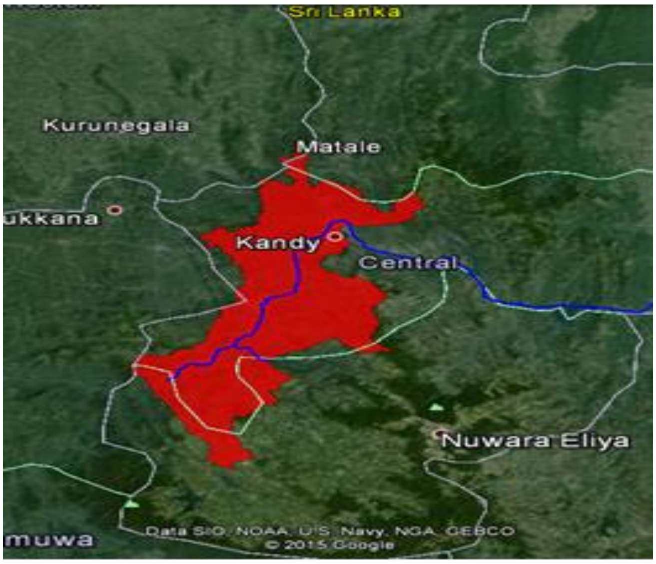


Fig.1. The study area

Data Collection

Since the precipitation prediction was to be used as the mode of comparison, four rainfall gauging stations were identified throughout the study are and the corresponding precipitation data for the period 2001-2005 was purchased. Moreover the GCM data for both models were downloaded from the relevant websites.

Setting up & the simulation of Models

Both Models were run on high performance computers. Both models were set up for the upper Mahaweli basin by employing suitable grid configuration with a pre-determined forecast time. After the installation of the models to the server, few test runs were carried out in both models in-order to check the completeness of the installation.

WRF domain configuration which is having three nets of coarse to fine grid size of 30/10/3.3 km (2940 km * 3210 km, 860 km * 950 km, 237 km * 267 km) was employed. While in the RegCM, the model was set to run in its least horizontal resolution of 20km. (version 4.4). Fig. 2 shows the domain configuration of WRF model.

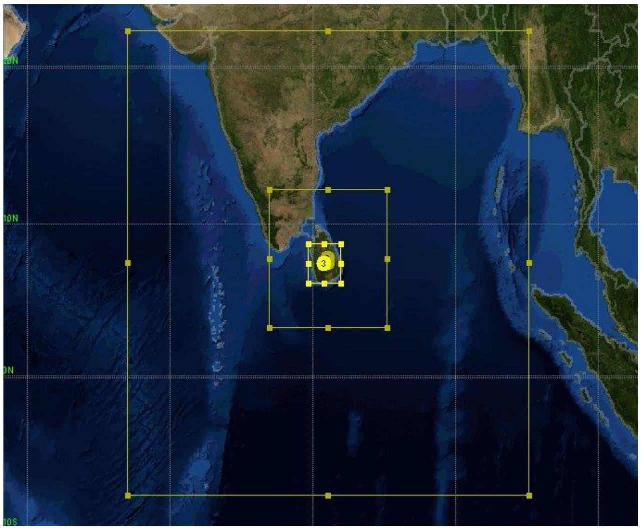
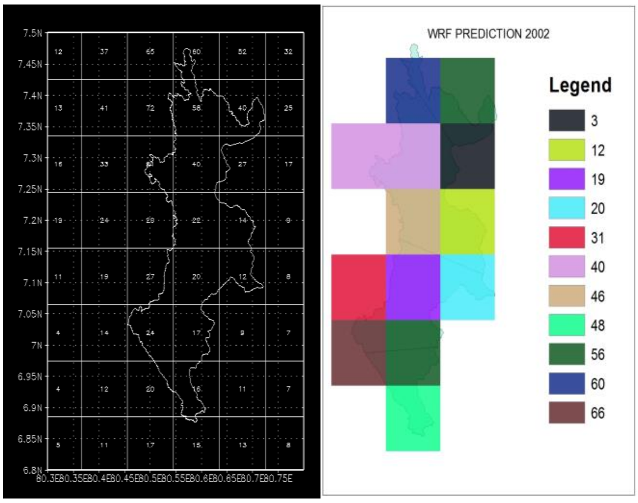


Fig.2 WRF Domain configuration

Post processing

WRF model output was processed using the Arc GIS software, while the RegCM output was post processed using the Grads tool. As the whole purpose of the study was to compare the performance of the models it was vital to bring both the outputs to a single platform. In order to achieve that task, the outputs of both models were taken in gridded format as shown in the fig. 3. All the grids were of 0.5 degrees size. The observed rainfall was also spatially distributed and was obtained in gridded format.



(a) (b)

Fig.3. (b) WRF (a) RegCM output in Gridded format

Grids were numbered using a defined method and then there outputs were recorded to make statistical decisions about the performance of both models. With the available predicted and observed data, the error percentage plots, Mean Absolute Model Error (MAME) and Root Mean Square Error (RMSE) were derived.

III. Models Calibration & Validation

Both models were calibrated to an extreme evet that occurred on the 10th of May 2002, which had a recorded precipitation of 74mm. Table 1 and 2 summarizes some of the physics options chosen during calibration of WRF & RegCM Models respectively. Both models were validated to an extreme event that occurred on the 25th of March 2004, which had an observed precipitation of 60mm.

Table 1 shows the results obtained during calibration and validation.

Table.1 Calibration and validation results

Stage	RMSE of WRF prediction/mm	RMSE of RegCM prediction/mm
Calibration	30	17
Validation	33	54

Table.2 Some of the physics options chosen in WRF model

Physics scheme	Physics option selected
Cumulus	Kain-Fritsch scheme
Planetary Boundary layer	Mellor-Yamada Nakanishi and Niino Level
Land Surface	RUC Land Surface Model
Microphysics	Goddard microphysics scheme.

Table.3 Some of the physics options chosen in RegCM Model

Physics Option	Physics scheme
Boundary layer scheme	Holtslag PBL
Cumulus convection scheme	Emanuel
Moisture scheme	Explicit moisture

IV. Results and Discussion

Though it was seen from the validation results that the RMSE of RegCM is higher than the RMSE of WRF model, another extreme event was chosen and the models were run for this date.

It was an extreme event that happened on the 4th of September 2005 which had an observed precipitation of 102mm. Fig.4 shows the gridded output of the observed precipitation in millimeters.

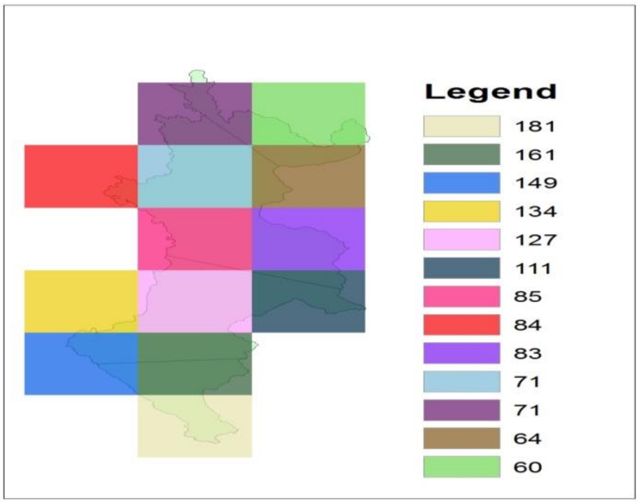
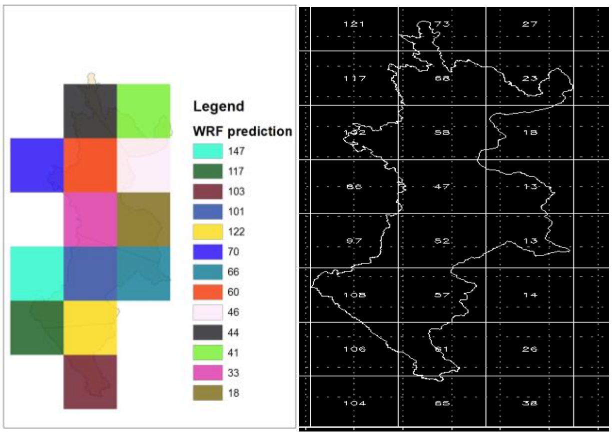


Fig.4 Observed precipitation

Fig.5 shows the WRF and RegCM predicted precipitation values in millimeters.



(a) (b)

Fig.5 (a) WRF, (b) RegCM predicted precipitation in millimeters

Table 2 shows a summary of the grid values extracted from the output files

Table.4 Summary of values extracted from the grids

Grid Number	Observed precipitation/mm	WRF predicted/mm	RegCM Predicted
1	71	44	88
2	60	41	23
3	84	70	102
5	64	46	18
6	85	33	47
7	83	18	13
8	134	147	97
9	127	101	52
10	111	66	13
11	149	117	108
12	161	122	57
13	181	103	61

Accordingly above results were used to get the following results.

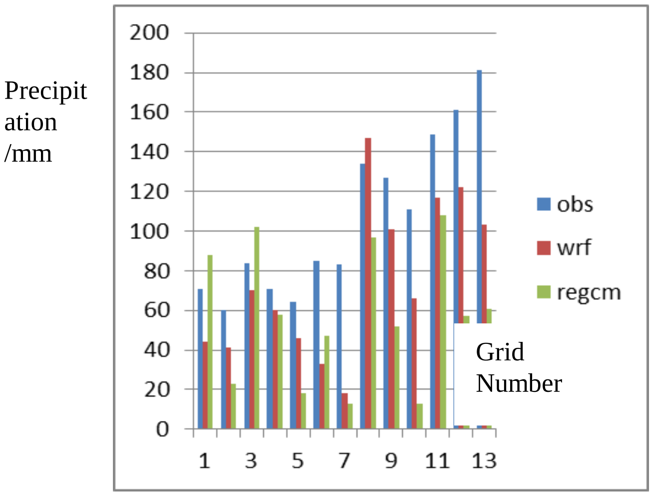


Fig.6 Observed, WRF and RegCM precipitations in millimeters

Error %

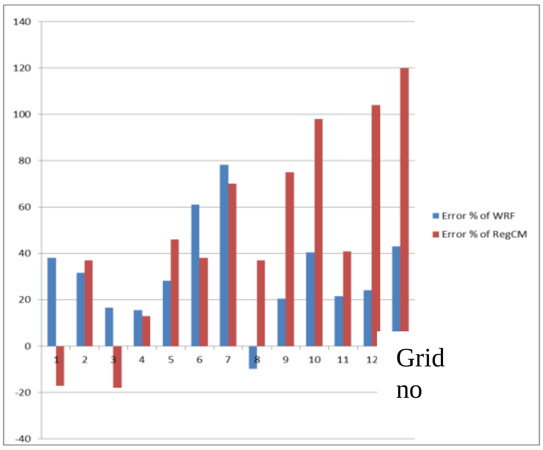


Fig.7 Error percentages of WRF & RegCM predictions

% Area

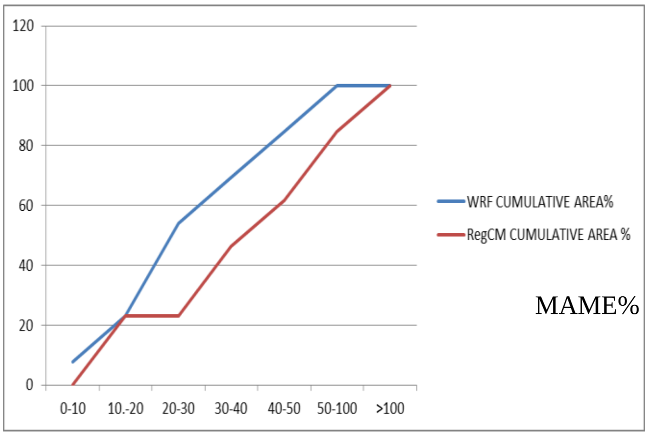


Fig.8 Mean Absolute Model Error

Fig.8 shows that the error percentage of RegCM model is greater than that of WRF model for nine grids out of the thirteen grids. Also the RMSE value of WRF (39mm) was greater than the RMSE of RegCM (65mm).

If we consider Fig.8 it shows the percentage area of the basin which is falling within a defined range of error percentage. The WRF plot is above the RegCM plot, meaning that the error percentage of WRF is much lesser compare to RegCM error percentage.

V. CONCLUSIONS AND RECOMMENDATIONS

- Results show that the WRF model has been performing much accurately than the RegCM model for the Mahaweli basin.
- In the WRF model the combination of Goddard microphysics scheme, Kain-Fritsch cumulus parameterization scheme, CAM shortwave radiation scheme, RRTM long wave radiation scheme, Yonsei University scheme for planetary boundary layer scheme, RUC land surface scheme and Revised MM5 surface layer scheme with other default physics options was the most suitable physics combination for the upper Mahaweli basin which has a mountainous terrain.
- In the RegCM model the combination of Relaxation, exponential technique Lateral Boundary conditions scheme, Holtslag PBL (Holtslag, 1990) Boundary layer scheme, Emanuel (1991) Cumulus convection scheme with auto conversion threshold water content (g/g) over land = 0.00091 and Maximum precipitation efficiency (land) = 0.444 and Explicit moisture (SUBEX; Pal et al 2000) Moisture scheme with other default options was the most suitable physics combination for the upper Mahaweli basin which has a mountainous terrain.
- In this research WRF was used with three domains which were used as domain configuration of WRF model for rainfall prediction and it is recommended to go another small domain as domain 4 which will give more accurate predictions over the study area but this will increase the running time and results sizes of model outputs.
- Analysing both model outputs using GrADS with the help of a programing language like python will reduce error and increase the analysis efficiency
- Though the resolution used in this study is 20km due to using the RegCM 4.4.5 version, The resolution of RegCM can be reduced up to 1 km by using the new hydrostatic version of RegCM which is under development known as RegCM 4.5 in the future.
- It is also suggested that verifying the model for more events may be able to give accurate predictions when handling the model for future forecasting purposes.

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