IMPACT OF CUMULUS PARAMETERIZATION SCHEMES ON PRECIPITATION FORECASTING IN WRF WEATHER MODEL: APPLICATION TO NILWALA RIVER BASIN IN SRI LANKA

D.A. Sachindra, K.D.W. Nandalal and U.R. Ratnayake

Department of Civil Engineering, University of Peradeniya

Introduction

Weather modeling is a part of atmospheric modeling that comes under atmospheric sciences. A numerical atmospheric model is a mathematical model based on a set of primitive dynamic equations which governs atmospheric motions. Primitive equations consist of three main sets of equations: 1) conservation of momentum, 2) thermal energy equations and 3) continuity equation. The atmosphere is a fluid. Numerical weather prediction samples the state of the fluid at a given time and uses the equations of fluid dynamics and thermodynamics to estimate the state of the fluid at some time in the future. Numerical weather models could widely be classified into two categories; global weather models and regional weather models. Global models predict the weather conditions over the whole globe meanwhile regional weather models confine their predictions to a predefined limited area. WRF 3.0 (Weather Research and Forecasting Version 3.0) model is one of the regional weather models designed for both research and operational applications. The WRF model contains a number of physics options that could be varied to fine tune the model to suit its operational environment. Cumulus parameterization scheme in WRF is one of the physics options in the model which takes the effect of cloud convection into account in predicting weather. The direct concern of it is to predict convective precipitation. The representation of the effects of the cumulus convection in a numerical model is known as cumulus parameterization, which is of fundamental importance in atmospheric sciences (Kuo et al, 1996). The WRF 3.0 incorporates Kain-Fritsch, Betts-Miller-Janjic, Grell-Devenyi and New Grell cumulus schemes.

This study checks the impacts of rainfall predictions generated by the WRF with various aforementioned cumulus schemes, on its application to Nilwala river basin in southern Sri Lanka. Area of the river basin is approximately 1,073 km^2. It lies mainly in the Matara district within the latitudes 5° 55' - 6° 13' and longitudes 80° 25'- 80° 38'.

Methodology

WRF model was applied to the Nilwala basin with various cumulus schemes keeping all the factors such as domain configuration, domain size, and other physics options etc., unchanged. Ferrier microphysics scheme was employed with RRTM (Rapid Radiative Transfer Model) long wave radiation scheme, Dudhia short wave radiation scheme, Monin-Obukhov surface layer, thermal diffusion land surface model and

Yonsei University (YSU) boundary layer scheme as other physics options of WRF. Initial and lateral boundary conditions were obtained from the Global Forecast System (GFS) for initiating the WRF model (Awad et al, 2007). GFS Model which is run by National Center for Environmental Prediction (NCEP) is initialized using observed data from radiosondes weather satellites, and surface weather observations. For the analysis two global data sets were downloaded from the GFS on 09/12/2008 and 19/03/2009. In this study, 45/15/5 km (1800x1800 km/645x645 km/245x245 km) domain configuration was tested with various cumulus schemes available in WRF for a forecast time of 24 h. The cumulus schemes employed in the study were Kain-Fritsch, Betts-Miller-Janjic, Grell-Devenyi and New Grell available in WRF. Cumulus schemes were only applied to the 1st and 2nd domains in all the model runs. The model accuracy was monitored by comparing the predictions with observed point rainfalls, at the gauging stations at Mapalana, Kekanadura, Thihagoda, Thelijjawila, Goluwatta, and Mawarella Estate. Since the output of WRF is spatially distributed and the field observed rainfall data are in point format, these point rainfall data were spatially distributed on 5 km x 5 km horizontal grid for comparison purposes with the predictions. For checking the accuracy of model predictions the differences between the WRF predictions and observed precipitation (spatially distributed) were plotted over the watershed. The 0–5 mm over/under predictions were considered as acceptable forecasts. Area inside the basin in which the predictions were within the above specified +/-5 mm range was expressed as a % of the total area of the basin (Correctly Predicted Area %, CPA). This was taken as the measure of success of predictions. Figure 1 shows the difference between WRF prediction & observed rainfalls on 10/12/2008 while Figure 2 denotes the difference between WRF prediction and observed rainfalls on 20/03/2009 graphically. Table 1 gives correctly predicted area by different cumulus schemes giving a numerical comparison of results.

Results

Table 1. CPA % for various cumulus schemes

Rain event on 10/12/2008		Rain event on 20/03/2009	
Cumulus scheme	CPA %	Cumulus scheme	CPA %
Kain-Fritsch	63	Kain-Fritsch	82
Betts-Mellor-Janjic	39	Betts-Mellor-Janjic	55
Grell	9	Grell	22
New Grell	71	New Grell	16

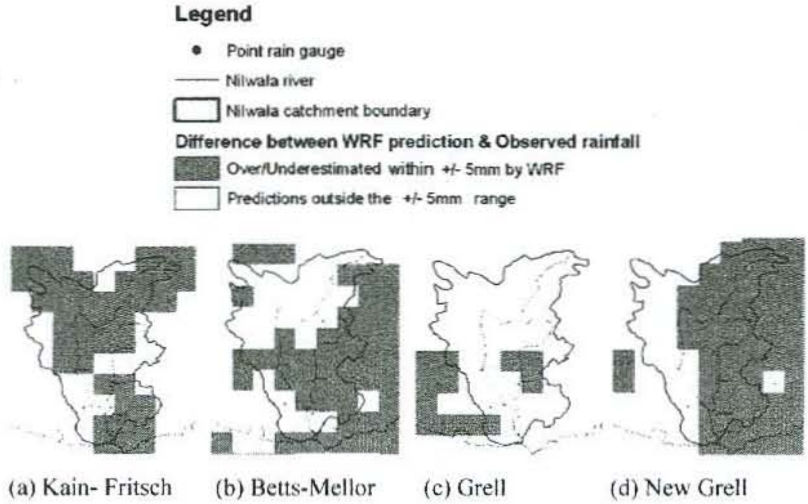

Figure 1. Difference between WRF prediction and observed rainfalls on 10/12/2008

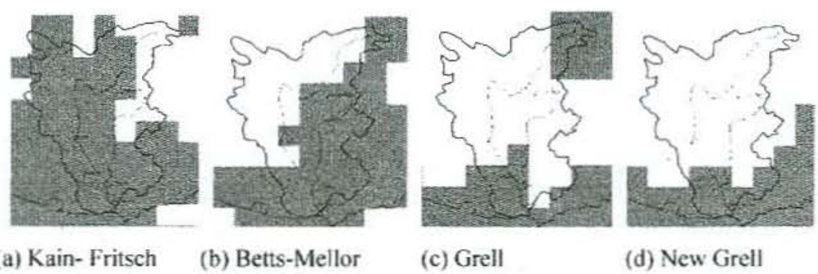

Figure 2. Difference between WRF prediction and observed rainfalls on 20/03/2009

Conclusions

Results showed that for the two rain events over the basin the best predictions have been made by New Grell scheme (CPA=71%) and Kain-Fritsch scheme (CPA =82%), respectively. Kain-Fritsch produced reasonably good forecasts for both rain events with CPA=63% and CPA=82%. The ability of Kain-Fritsch scheme in rainfall forecasting over the basin was further proven as it produced a CPA of 91% for a rain event on 06/04/2009.

Acknowledgement

Financial assistance by NSF Research Grant RG/2007/W & E/02.

References

Awad, A.K.A, Ajjaji, R. and Dhanhani, A. (2007). Automatic two-way nested WRF weather forecast application, WRF user's workshop.

Kuo, H.Y., Bresch, J.F., Cheng, M.D. and Kain, J. (1996). Mini Workshop on Cumulus Parametrization for Mesoscale Models.