Application of the Ems-Wrf Model in Dekadal Rainfall Prediction over the Gha Region

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ABSTRACT

The IGAD Climate Prediction and Applications Centre exists to monitor and predict the patterns of rainfall over the greater Horn of Africa region, and provide early-warning products and information, particularly concerning recurrent drought episodes and localized flooding. Forecasting on dekadal (ten-day) timescales is critical because it is the bridge that links short term scales, called the NWP range, and seasonal scales. This study seeks to assess the validity of downscaled GCM rainfall outputs by the Environmental Modelling System's Weather Research and Forecasting (EMS-WRF) model in 2011. The results reveal that the EMS-WRF model, by and large, performs well over the region, but the excellence of the forecast products varies temporally and spatially. Nonetheless, the model exaggerates rainfall amounts over certain areas, particularly that forced by mesoscale systems. Moreover, the model generally underestimates the rainfall amounts arising from unexpected storms, and displaces the areas of the highest rainfall intensity in several respects. The EMS-WRF model is useful for predicting the distribution of dekadal rainfall over the GHA, but may perform better through improving the ocean-atmosphere interactions and feedback processes and employing multi-model ensemble forecasting techniques. The model should be used cautiously in tandem with other forecasting techniques.

Key words: EMS-WRF model, rainfall, prediction, forecasting, dekad, dekadal, ICPAC

INTRODUCTION

Dynamical prognostic modelling as a tool for weather and climate outlooks over a variety of timescales has gained global acclaim in the recent past. The predictive capability of dynamical models in the tropics, more so in the Greater Horn of Africa (GHA) region, however, is not well understood and remains a matter for investigation, not having been quantified sufficiently.

The capacity of dynamical models to replicate observed climatological patterns on seasonal scales has been demonstrated for the East African region. Sun *et al*. reported good simulation of the climatological and month to month rainfall patterns[8]. Mutemi reported reproduction of the climatological mean patterns excepting extreme El Niño episodes[5]. Anyah *et al*. reported replication of rainfall variability, apart from the central highlands and north-eastern parts of Kenya[1]. Fewer studies have been done on shorter time scales.

Temporal variability of weather/climate over the GHA is mainly driven by quasi-permanent and migratory weather systems and SST patterns; spatial variations in the region are considerably influenced by the appreciable diversity in topography and large water bodies[4, 6]. Mesoscale influences are particularly important in dekadal (i.e., ten-day) forecasting.

Gichira reported on the ability of the Global Forecasting System (GFS) model to accurately replicate the day to day rainfall events over Kenya on extended NWP timescales, although the rainfall was generally underestimated by the model on wet days, and overestimated on dry days[3]. Sagero reported good forecasting skill of the Environmental Modelling System-Weather Research and Forecasting (EMS-WRF) model for three-day forecasts of rainfall and temperature over Kenya for low thresholds, but failed to predict the occurrence of storms, especially over the coastal area[7]. Gathura reported on the fairly high skill of the High Resolution Model (HRM) in simulating precipitation for one-day forecasts, but the amounts were underestimated, especially during storms[2].

The IGAD Climate Prediction and Applications Centre exists to monitor and predict the patterns of rainfall over the greater Horn of Africa region, and provide early-warning products and information on recurrent drought episodes and localized flooding, for which dekadal forecasting is very important. This study seeks to determine the usefulness of the EMS-WRF model in forecasting dekadal rainfall distributions at zero lead times over the GHA during 2011.

The Environmental Modelling System Weather Research and Forecasting Model

The Environmental Modelling System-Weather Research and Forecasting (EMS-WRF) model supports a variety of capabilities in the dynamic and physics functionalities and in the gridding and nesting options. The EMS-WRF model employed in this study makes use of analysis fields from 6-hourly datasets at 1° by 1° resolution from global analyses, typically from the GFS, which are interpolated to the mesoscale grids by the EMS-WRF preprocessing system, constituting the initial conditions. Real-time forecasts are made for 8 day periods at a time.

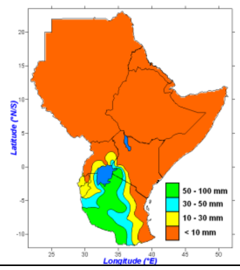
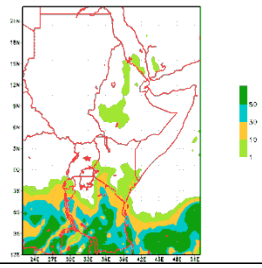
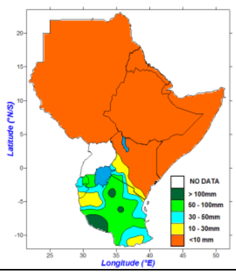
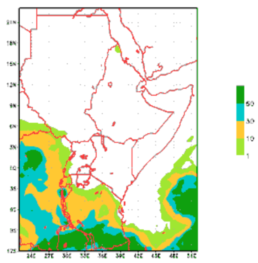
The version of EMS-WRF applied in this study employs non-hydrostatic dynamics with no gravity wave drag and a positive-definite horizontal advection scheme over a domain spanning 5°E to 60°E and 14°S to 23°N to account for the response of the observed circulations to the dimensionality of the forcing by the Congo Air Mass and the Indian Ocean systems as well as to resolve the complex flows in this region. The model employs a 50 kilometer horizontal Arakawa-E grid system and 45 variably spaced terrain-following sigma levels in the vertical, which is bounded at 50 mb.

The model physics comprise the rapid radiation transfer model longwave radiation scheme and Dudhia shortwave radiation scheme, the Mellor Yamada Janjic (MYJ) scheme in the boundary layer, the Monin-Obukhov similarity scheme for the surface layer, the Kain-Fritsch (KF) cumulus scheme[9], and the Lin microphysics scheme[10].

Performance of WRF in Dekadal Rainfall Forecasting

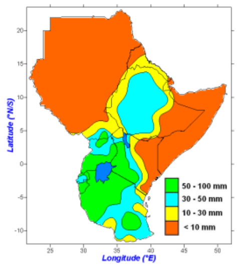
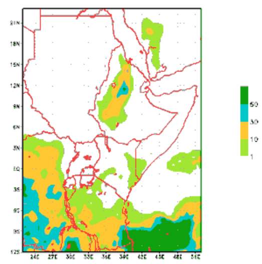
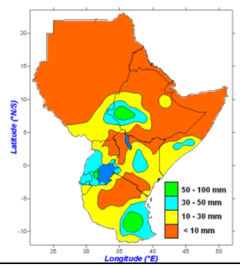
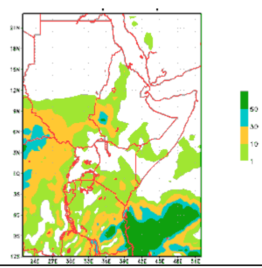
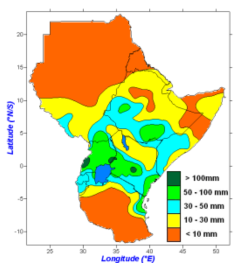
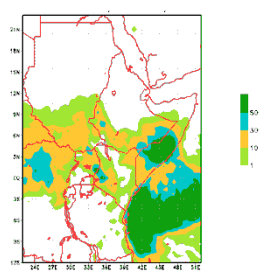
The performance of the EMS-WRF model over the GHA during the January-February season is exemplified in Table 1. This season is characterized by rainfall in the southern sector of the GHA. In the second dekad (11-20 January), the model was able to simulate the rainfall pattern over the study domain, except that it over-predicted rainfall over the coastal regions of Kenya and Tanzania. In the sixth dekad (21-28 February), the model replicated the rainfall regime, but failed to capture the rainfall over western and southern Kenya, whilst exaggerating the rainfall amounts over southern Tanzania; rainfall data over Uganda was not available. The distribution of rainfall was generally well simulated in the rest of the region.

Table 1: Examples of the EMS-WRF Model Performance in Rainfall Prediction in the Jan-February Season of 2011

Dekad	Observed	Model	Remarks
2 (11-20 Jan 2011)			❑ False alarms evident eastern and southeastern Tanzania. ❑ No misses were identified
6 (21-28 Feb 2011)			❑ Misses evident over western and southern Kenya ❑ Rainfall overestimated over southern Tanzania ❑ No data for Uganda

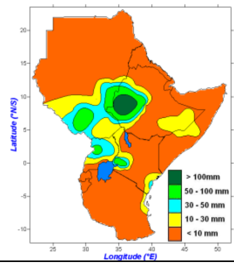
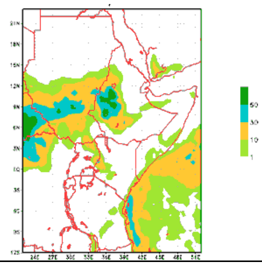
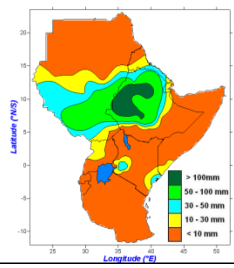
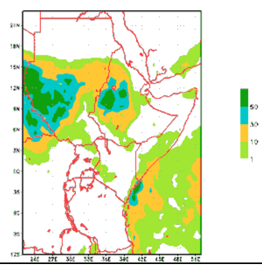
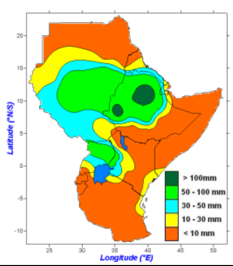
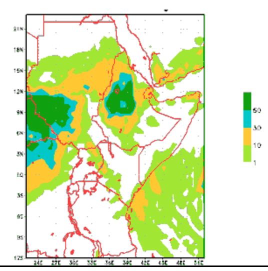
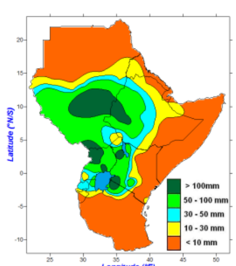
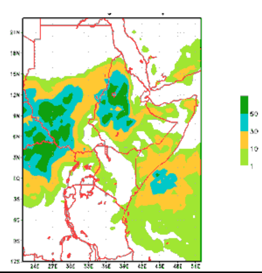
The performance of the EMS-WRF model over the GHA during the March-May season is exemplified in Table 2. This is one of the two main rainfall seasons in the equatorial sector of the GHA. In the eighth dekad (11-20 March) the model did not capture the rainfall over Uganda, central and western Kenya and northern Tanzania, and underestimated the rainfall over Ethiopia. In the 11th dekad, the rainfall over Uganda was not captured, and the model underestimated the rainfall over central Kenya, central Somalia and western Ethiopia. In the 13th dekad, misses were evident over much of Uganda, Rwanda, Burundi and parts of central Ethiopia. The rainfall distribution in the rest of the region was generally well simulated.

Table 2: Examples of the EMS-WRF Model Performance in Rainfall Prediction in the March-May Season of 2011

Dekad	Observed	Model	Remarks
8 (11-20 Mar 2011)			❑ Misses evident over Uganda, central and western Kenya and northern Tanzania ❑ Rainfall underestimated over western Ethiopia ❑ No false alarms identified
11 (11-20 Apr 2011)			❑ Misses evident over much of Uganda ❑ Rainfall underestimated over central Kenya, central Somalia and western Ethiopia
13 (01-10 May 2011)			❑ Misses evident over much of Uganda, Rwanda, Burundi and parts of central Ethiopia ❑ Rainfall underestimated over central and coastal Kenya. ❑ Generally a good forecast

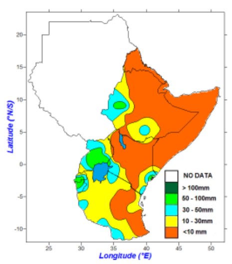
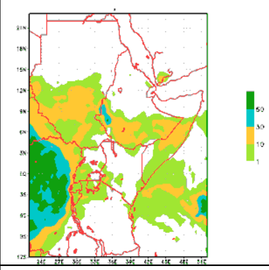
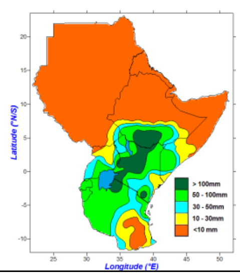
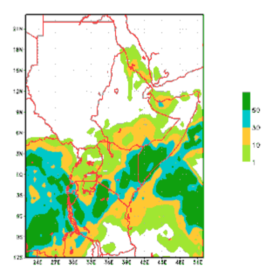
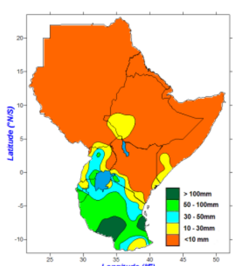
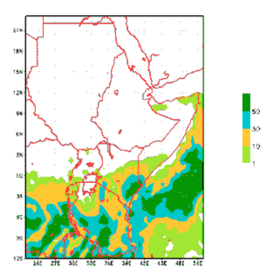
The performance of the EMS-WRF model over the GHA during the June-September season is exemplified in Table 3. This is the main rainfall season for the northern sector. In the 16th dekad, misses were evident over Uganda, coastal Kenya and the Ethiopia-Somalia border. In the 20th dekad, misses were evident over northern Uganda and southern South Sudan; the model also underestimated the rainfall over western Kenya. In the 22nd dekad, the model failed to capture the rainfall over Uganda. In the 25th dekad, the model missed to capture the rainfall over most of Uganda and western Kenya. The rainfall patterns in the northern parts of the GHA was well simulated, as was the dryness in the rest of the region.

Table 3: Examples of the EMS-WRF Model Performance in Rainfall Prediction in the June-September (JJAS) Season of 2011

Dekad	Observed	Model	Remarks
16 (01-10 Jun 2011)			❑ Misses evident over Uganda, coastal Kenya and Ethiopia-Somalia border ❑ No false alarms identified
20 (11-20 Jul 2011)			❑ Misses evident over northern Uganda and southern South Sudan ❑ No false alarms identified ❑ Rainfall underestimated over western Kenya
22 (01-10 Aug 2011)			❑ Misses evident over much of Uganda ❑ No false alarms identified
25 (01-10 Sep 2011)			❑ Misses evident over most of Uganda and western Kenya ❑ No false alarms identified

The performance of the EMS-WRF model over the GHA during the October-December season is exemplified in Table 4. This is the second rainfall season over the equatorial sector. In the 28th dekad, the model missed to simulate the rainfall over coastal Kenya, southern Tanzania and most of Uganda, while a false alarm was identified over central Somalia. The model underestimated the rainfall over southern Uganda, Rwanda and Burundi. The rainfall data over Sudan and South Sudan was not available. In the 33rd dekad, no misses were evident but the rainfall over central Somalia was overestimated. In the 35th dekad, misses were evident over southwestern Ethiopia and much of Uganda and a false alarm was identified over coastal Kenya. The rainfall distribution in the rest of the region was generally well simulated.

Table 4: Examples of the EMS-WRF Model Performance in Rainfall Prediction in the October-December (OND) Season of 2011

Dekad	Observed	Model	Remark
28 (01-10 Oct 2011)			❑ Missing data over Sudan and South Sudan ❑ Misses evident over coastal Kenya, southern Tanzania and most of Uganda ❑ False alarm identified over central Somalia ❑ Rainfall over southern Uganda, Rwanda and Burundi underestimated
33 (21-30 Nov 2011)			❑ No misses evident ❑ Rainfall over central Somalia overestimated ❑ Generally a good forecast
35 (11-20 Dec 2011)			❑ Misses evident over southwestern Ethiopia and much of Uganda ❑ False alarm identified over coastal Kenya

CONCLUSIONS

This study sought to demonstrate the usefulness of the EMS-WRF model in dekadal forecasts over the GHA. Whereas the dekadal outlooks are given over periods of 10 days, the model forecasts are restricted to a maximum period of 8 days because of the lack of operational real-time data for longer periods.

The model failed to capture the observed rainfall over various places, the most notorious of which was over Uganda, where the model missed most of the heavy rainfall episodes. Poor skill of dynamical forecasting over the GHA region was attributed to a multiplicity of factors, but primarily the unanticipated changes in the circulation patterns over the forecast periods, especially those arising from the developments of easterly waves and cyclonic storms in the Indian Ocean over the north eastern sector of the GHA during the Northern Hemisphere summer season and the south-eastern sector of the GHA in the Southern Hemisphere summer season.

By and large, for zero forecast lead times, the EMS-WRF model is a useful tool for predicting the distribution of dekadal rainfall over the GHA. The skill of the model may be bettered by improving the inherent ocean-atmosphere interactions and feedback processes, as well as through employing multi-model ensemble forecasting techniques alongside products from other dynamical models. The model should be used cautiously in tandem with other forecasting techniques.

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