The Performance of Ensemble Forecast in Predicting the weather over Kenya

Dr. Joseph R. Mukabana
Kenya Meteorological Department, P.O. Box 30259, Nairobi, Kenya
E-mail: mukabana@lion.meteo.go.ke

Abstract

Kenya's economy largely depends on rain fed agricultural production. Extreme weather affects the safety of lives and infrastructure in Kenya. Flooding is frequent in the large river basins and cities, whereas droughts have great impacts in marginal areas. Skilful prediction of severe weather is therefore important for a country like Kenya, whose economy cannot handle disasters, to ensure safety of lives and protection of property.
The main objective of this study is to improve existing weather/climate monitoring and prediction in Kenya. We assess the skill of dynamical ensemble forecasts in predicting weather over Kenya and parts of East Africa. The methodology comprises of qualitative analysis of the spatial model forecasts and the observed daily rainfall over Kenya.
It is observed that the National Centers of Environmental Prediction-Medium Range Forecast (NCEP-MRF) cumulative precipitation forecasts have fairly good forecast skill compared to Florida State University (FSU) super-ensemble forecasts for the wet season. Generally, the NCEP/Coupled-Ocean-Land-Atmosphere (COLA) MRF model under-predicts the precipitation during extreme rainfall events. The models are not able to pick shallow and medium level advection, for example, those associated with the morning rains experienced over Central, North Eastern Kenya and parts of East Africa.

1. Introduction

The East African region contains some of the most complex topography in the world. This topographical inhomogeneity includes large lakes, Rift Valleys, flat plains and snow-capped mountains on the Equator. Almost all facets of societal and economic activities in the region are critically dependent on the variability of seasonal rainfall, which occurs during boreal Spring (Long Rains, March-May) and Autumn (Short Rains, September/October-December). However, the societies are often unprepared to adjust quickly to dramatic deviations from normal rainfall regimes. Extremes in weather and climate result in loss of lives and damage to property including massive disruptions of existing infrastructures. These negative impacts have been detrimental to the economy.

Like other tropical countries, Kenya has unique and peculiar difficulties with the availability of long-time climate data. Available are the sparse surface observations, and only one operational upper-air observation network. Current weather and climate predictions are mainly based on persistence and statistical methods. It is very difficult for the developing countries to invest, especially individually, on expensive ventures such as the development of operational dynamical models, without assurance of direct benefit to the economy. One solution lies in the enhanced and proper use of dynamical forecast products available in real time, via Internet, from the advanced Centers such as the European Center for Medium-range Weather Forecasts (ECMWF), Bureau of Meteorology Australia, Meteo-France, UK Met-Office, NCEP, Deutcher Wetterdienst (DWD), among others.

Ensemble forecast combines several model outputs using weighted average. In general, this process reduces the impact of initial errors in a forecast. Not only can an ensemble lead to a better forecast, it can also reveal how reliable a forecast is in judging from the spread of the different forecasts (Buizza, 1997). As a result, ensemble products (forecasts and analyses) from advanced Centers are widely used in developing countries, since their availability constitutes a unique tool for forecasting and research activities.

One of the major objectives of ensemble forecasting, particularly in the short- and medium-range, is the probabilistic prediction of severe weather events. Severe weather is often extremely difficult to predict deterministically as its development can be very sensitive to small errors even at very short range. However, successful prediction of meso-scale local systems is of crucial importance to the success and credibility of any forecasting service. Operational dynamical models do not perform equally well in different regions due to lack of data to correctly define initial conditions and the complex terrain. Moreover, the skilful performance of these models should be treated cautiously, considering their resolution. Numerical Weather Prediction (NWP) quality evaluation determines the confidence related to a particular forecast over a specific region. However, the evaluation can also be thought of as a preliminary validation of simulated climate drift that can be expected from the model being tested. This idea is further illustrated by Kamga et al. (2000) who analyzed the systematic errors of the ECMWF operational model (120-h forecast) over tropical Africa. From this point of view, verification of model products can serve local forecast applications and a wider community that conducts research on a variety of timescales using global model forecasts and/or analyses.

The present study is aimed at evaluating extended range dynamical forecasts and analyses performance over Kenya and some parts of East Africa, in the months of February and April 2002, representing a generally dry and wet period, respectively. It is suggested that this work will provide some indications of quality for dynamical ensemble products that can aid in estimating their capability to describe mean weather. In addition, it can provide guidelines for the development of regional models that may be used for higher-resolution predictions over the region of interest. It should be noted that this case study is useful in evaluating the current dynamical forecasts over the region.

Section 2 briefly describes the data and analysis procedures used. The results and discussions are presented in Section 3.

2. Data and Analysis Procedures

Daily observed (24-hour) rainfall data over Kenya were used to evaluate the performance of the dynamical ensemble forecasts in the region bounded by latitudes 5ºN - 5.5ºS and longitudes 30ºE - 42ºE. A duration of two months, February and April 2002, is used, representing a dry and wet month, respectively.

Ensemble forecasts accuracy is determined by comparison of the disseminated forecast(s) with observation values. It should be noted that the resolution of dynamical forecasts might be difficult to verify compared with station data. The most frequent problem arises from accumulated time period. Most model outputs are available for 00/12Z whereas observed values are for 06Z. Observations are instantaneous measurements of current weather conditions and may not represent prevailing conditions during the forecast period.

Two ensemble forecasts have been used in this study:
(i) NCEP's global medium range forecast (NCEP-MRF; Toth and Kalnay, 1997) is composed of a number of models from both the Eta and Regional Spectral Model (RSM).
(ii) Florida State University (FSU) multi-model super-ensembles developed by Krishnamurti et al. (1999) using statistical combination of forecasts, based on past performance to obtain the best deterministic forecast.

3. Results and Discussion

Figures 1(a - i) shows some selected ensemble forecast and observed daily values of rainfall distribution during the month of April 2002. It should be noted that the panels have different scales, and the resolution of the ensemble outputs are larger than the local/regional convective processes. In general, the NCEP-MRF ensemble forecasts have a fairly good spatial pattern of observed distribution, compared to the FSU super-ensemble model. However, both models do not pick extreme rainfall events during the period.

The NCEP-MRF precipitation forecasts perform fairly well in the western and central parts of the region. It slightly underestimates precipitation in the central Rift Valley and overestimates over the western and coastal areas on 27^{th} April 2002 (Fig.1 (h)).

The FSU super-ensemble precipitation forecasts perform poorly in the whole region on the 27^{th} April. It generally underestimates the precipitation amounts for the whole region (Fig1 (i)). For the dry month of February 2002, the model had a poor spatial pattern of observed distribution of precipitation. Moreover, the model basically underestimated the precipitation amounts for the region.

Figures 2(a - c) shows some selected 5-day observed and NCEP forecasts of cumulative precipitation distribution during the wet month of April 2002. Just like the daily forecasts, the model captures the spatial patterns of observed rainfall distribution quite well but misses the extreme events completely. In the shown scenarios, the NCEP model generally under predicted the precipitation values over the region (fig2 (b and c).

From the study, both models seem to be predicting fairly well the convective type of precipitation but do quite poorly on the advective type of precipitation.

4. References

Davies, C., and E Carr, 2000: Summary of the 1998 Workshop on Mesoscale Model Verification. *Bull. Amer. Meteor. Soc.,* **81**, 809-819.

Kamga, A., S. Fongang, and A. Viltard, 2000: Systematic errors of the ECMWF operational model over tropical Africa. *Mon. Wea. Rev.,* **128***,* 1949-1959.

Krishnamurti et al., 1999: Improved weather and seasonal climate forecasts from multimodel super-ensemble. *Science,* **285**, 1548-1550.

Buizza, R., 1997: Potential forecast skill of ensemble prediction and spread and skill distributions of the ECMWF ensemble prediction system. *Mon. Wea. Rev.,* **125**, 99-119.

Toth, Z., and E. Kalnay, 1997: Ensemble forecasting at NCEP and the breeding method. *Mon. Wea. Rev*., **125**, 3297-3319.

Figures 2: 5-Day Cumulative precipitation, Observed and Ensemble Forecast from NCEP and FSU.

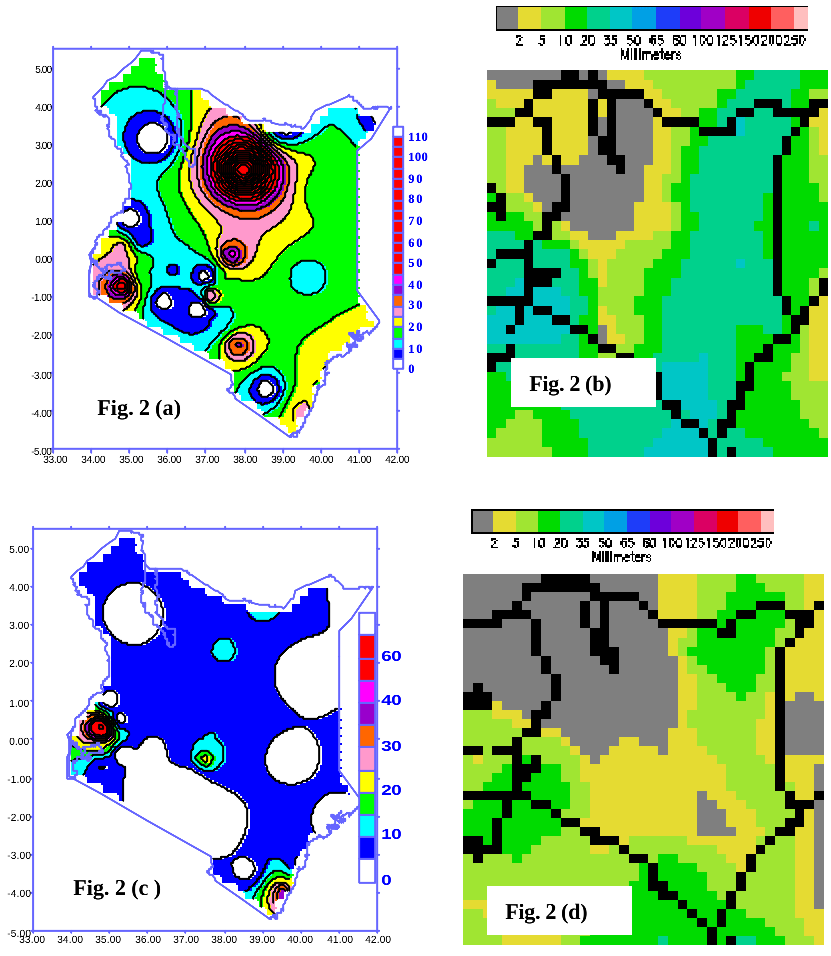

Fig.2(a) Observed 5-Day Cumulative rainfall (mm) from 31st Mar to 4th April 2002, (b) NCEP ensemble 5-day cumulative rainfall (mm) forecast from 31March to 5th April 2002, (c) same as (a) but from 5th to 9th April 2002, (d) Same as (b) but from 5th to 10th April 2002

Figure 1: Observed Daily Rainfall and Ensemble Precipitation (mm) Forecast from NCEP and FSU

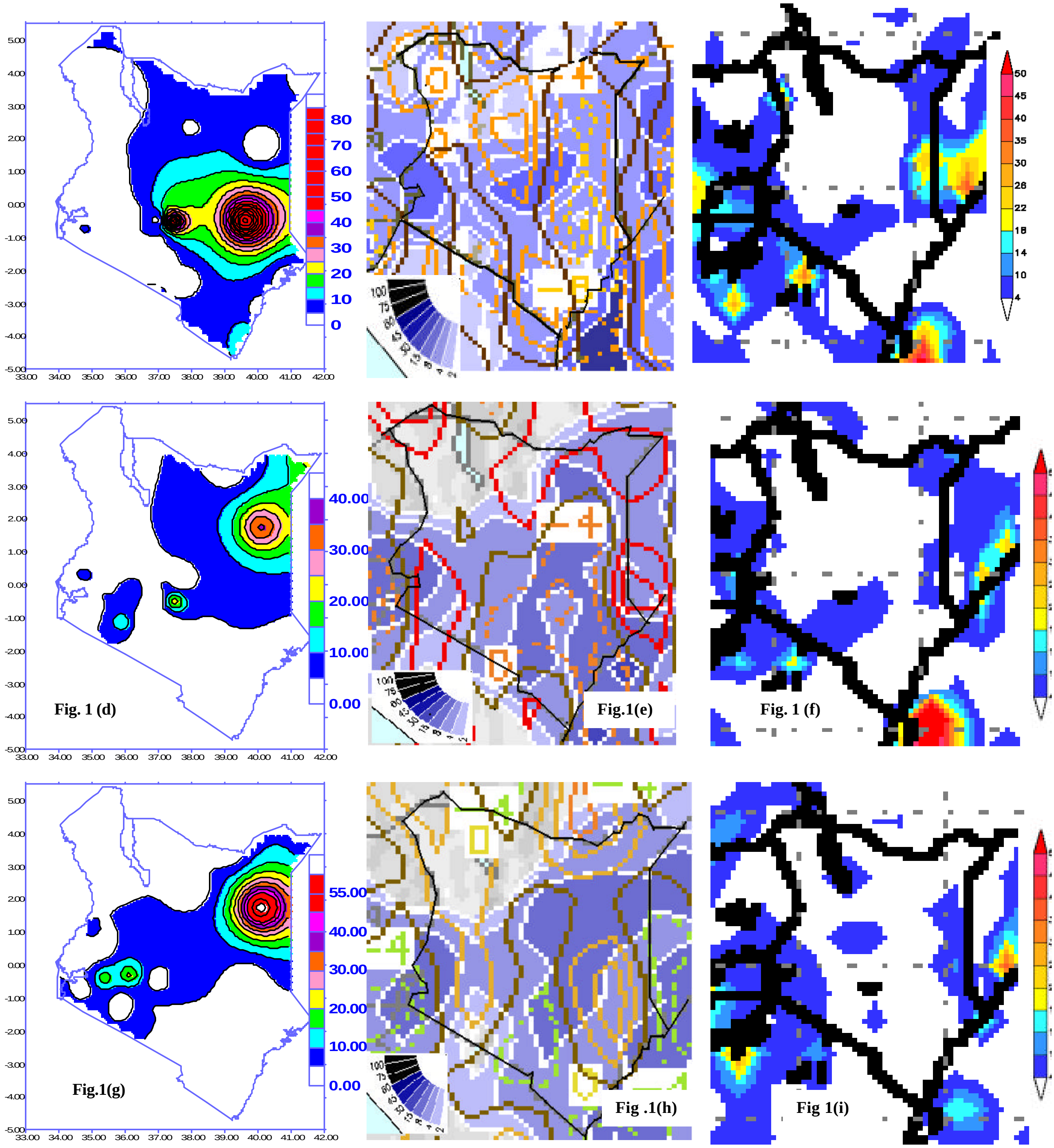

Fig 1 (a), (d), (g): Observed Daily Rainfall (mm) for 25th to 27th April 2002, respectively; Fig. 1 (b), (e), (h): 24hr,48hr,72hr NCEP ensemble Precipitation (mm) Forecast for 25th to 27th April 2002, respectively; Fig. 1 (c), (f), (i): 24hr,48hr,72hr FSU ensemble forecast for 25th to 27th April 2002 – 24 hr Precipitation (mm).