Verification of COSMO Model in Nigeria: a case study of the Month of September 2013

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Abstract

In this era of climate change and variability, the reliability of high resolution numerical models especially in predicting extreme weather events, is crucial. This paper examines the level of predictability of high resolution regional forecast model of the Consortium for Small-Scale Modeling (COSMO(7KM)) of the German Weather Service , adapted for use in Nigeria, for the Month of September in 2013 .

The Verification was done using observed daily rainfall and maximum temperature values against the simulated rainfall and temperature values from the COSMO-Model.

The result suggests that the model has good spatial representation of rainfall and temperature distribution over Nigeria. The results also shows that the model has almost 70 percent accuracy forecasting rainfall in most places of the southern Nigeria especially South-eastern regions.

However, false alarm signals from the model could surge up to 70 percent in the Northern part of Nigeria especially the extreme North. Although the rainfall in the simulated results produced some appreciable values, however, the result shows that it is grossly low and shows no good correlation with the observed especially during rainfall extreme events.

Introduction

The ability of High Resolution Numerical Weather Prediction (HR-NWP) to realistically simulate future weather patterns from dynamics and atmospheric physics has tremendously improved over the years. The crucial role played by HR-NWP in today's weather forecasting centers to give a reliable weather and climate forecast is invaluable.

The Nigerian Meteorological Agency is one of the few developing nations involved in using a HR-NWP to make weather prediction and has been operationally active since 2010.

High-resolution limited-area meso-scale NWP (HRNWP) models have been developed to predict weather that has the potential for hazardous impacts, denoted as high-impact weather (Craig et al. 2010). High-impact weather in Nigeria does not only involves extreme rainfall and severe gust which are often related to deep moist convection, but also high temperature as in "heat-wave".

Although, high resolution models of 7km or less (because of their non-hydrostatic dynamics) are able to describe explicitly meso-scale processes forecasts (Skamarock and Klemp 2008; Saito et al. 2006; Staniforth and Wood 2008; Baldauf et al. 2011; Seity et al. 2011), it is still very important to know how well they could be relied upon in forecasting of extreme events particularly quantitative rainfall forecasting (QRF) and temperature in terms of verification and evaluation.

The study is based on the HR-NWP model COSMO-Nigeria, which is operated by DWD and modified for use in Nigeria.

This report focuses on the general performance of our HR-NWP model in the month of September 2013 with particular reference to the five major convective storms that transversed Nigeria on the 10th, 13th, 14th, 22nd and 23rd of the month.

The performance of two weather parameters (temperature and precipitation) will be verified.

Data and Methods

The model domain of COSMO-Nigeria covers Nigeria and some neighbouring countries like Ghana, Togo, Benin, Niger, Chad, Central African Republic, Ivory Coast, Congo, Gabon and Cameroun, with a horizontal grid spacing of 7 km and 401 × 481 grid boxes. The COSMO-Nigeria is nested into the global model GME (20 km), which provides 3hourly boundary and initial data, updated twice daily.

Observed daily data obtained from Nigerian Meteorological Agency Archive Consist of daily Temperature maximum and 24 hour Rainfall Accumulation over about 40 stations.

Daily GME initialized data from DWD were used for the simulation at 3hourly time-step as part of Nigeria daily routine.

The Forecast results consist of more than 90 meteorological parameters including Temperature and Rainfall accumulation in grib1 format.

Both model and observation data were subjected to temporal and spatial statistical analyses using several post-processing tools.

The verification is based on the comparison between observation data and simulation results. Meteorological observing stations are local, that is, the measured results represent the conditions at the measuring location only and are not regularly gridded. Usually the stations are chosen such that they are representative of the surrounding region. The simulation results are defined at the center of an Arakawa-C grid box.

In view of the different verification grid structures (regular versus irregular), the spatial location of simulation results and corresponding observations do not match exactly. To reach a compromise between both spatial representations, for the comparison of simulation results and observation data, a nearest neighbour approach has been used.

Results

This paper evaluates the spatial and temporal description of weather phenomena specifically rainfall and temperature for the month of September 2013. The spatial comparisons conducted for the five convective storm events (only two of the events will be shown here) as shown in Figures 1-2 suggest that the model was able to capture the distribution of rainfall associated with the traversed storms, especially in the Northern cities. Although, some level of rainfall was reproduced by the model in the Southern cities, it could not reproduce enough rain especially in the Delta areas that recorded extreme rainfall

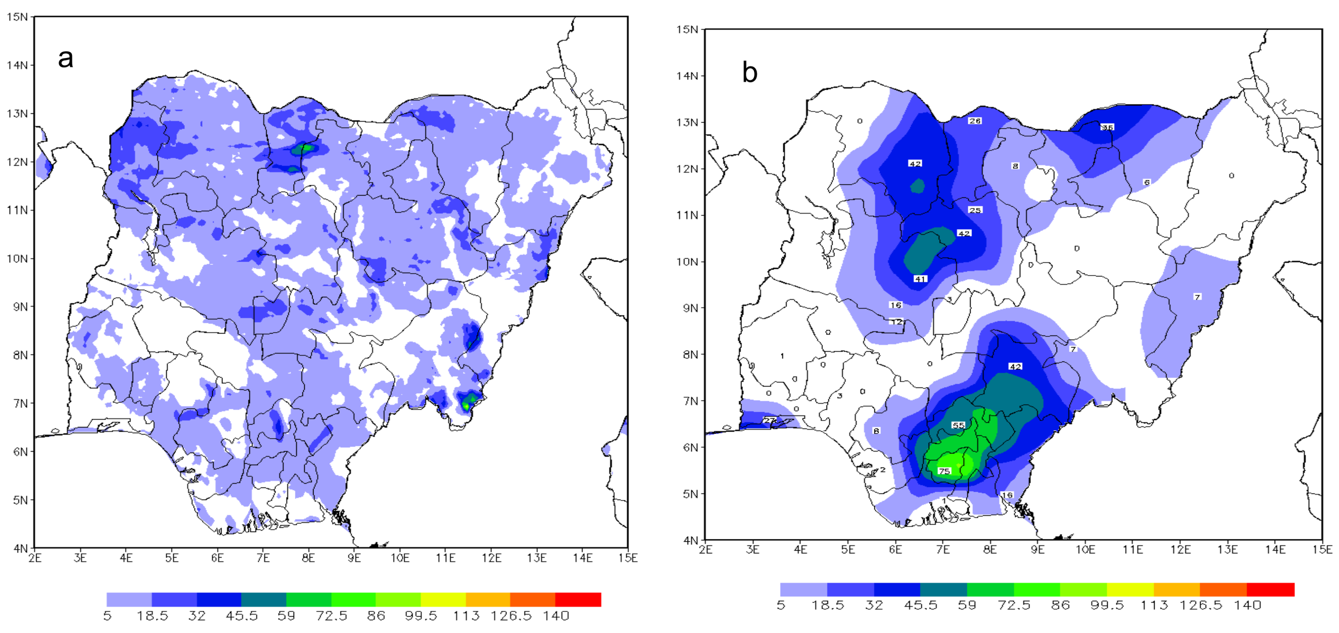

Fig.1.Showing rainfall distribution in COSMO(a) and the Observed(b) on the 13th September 2013

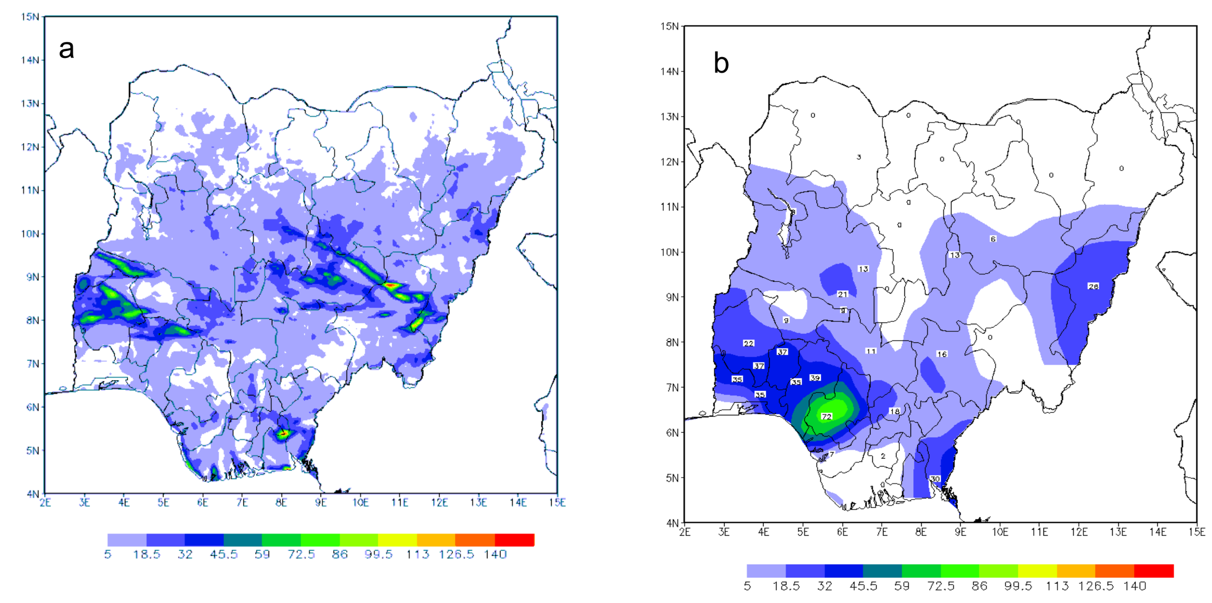

Fig.2.Showing rainfall distribution in COSMO(a) and the Observed(b) on the 22nd September 2013

Analysis of the monthly total of rainfall as in figures 3a, 3b, 4a, suggests that the model produced a significant amount of rain and high qualitative signal at each considered synoptic station in the month of September 2013. It also suggest significant underestimation of rainfall almost everywhere in the country especially in southern cities. The simulated model rainfall total have deviation range of between -400 to 100mm varying from station to station and correlation of about 0.05

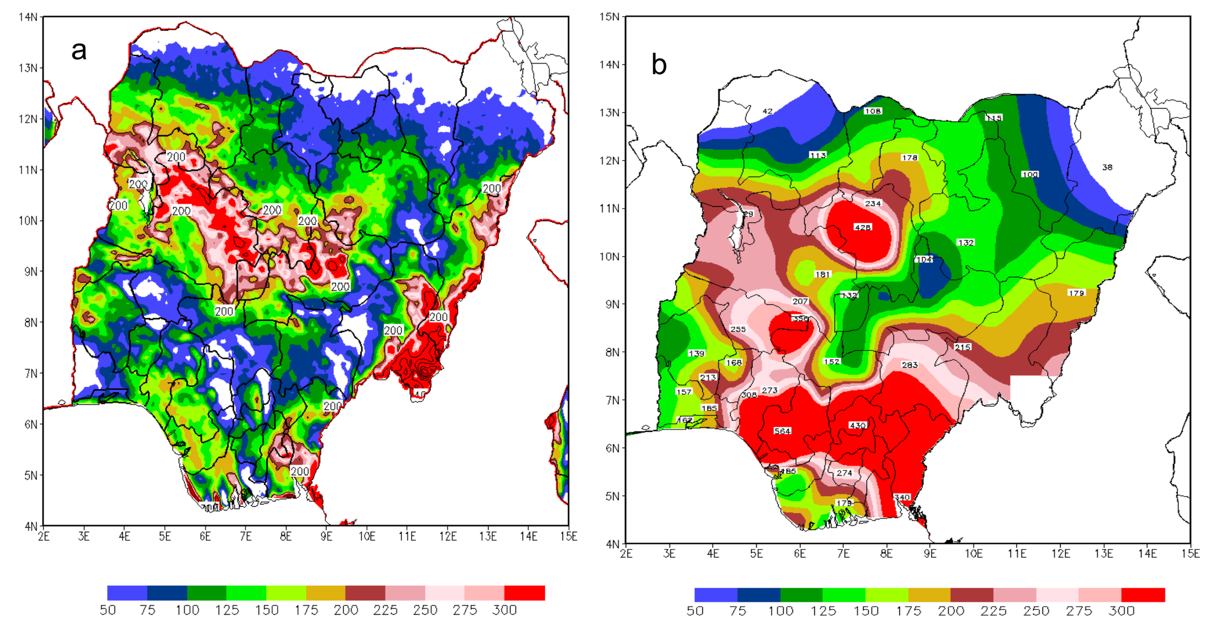

Fig.3.Showing Monthly sum of rainfall distribution in COSMO(a) and the Observed(b) in September 2013.

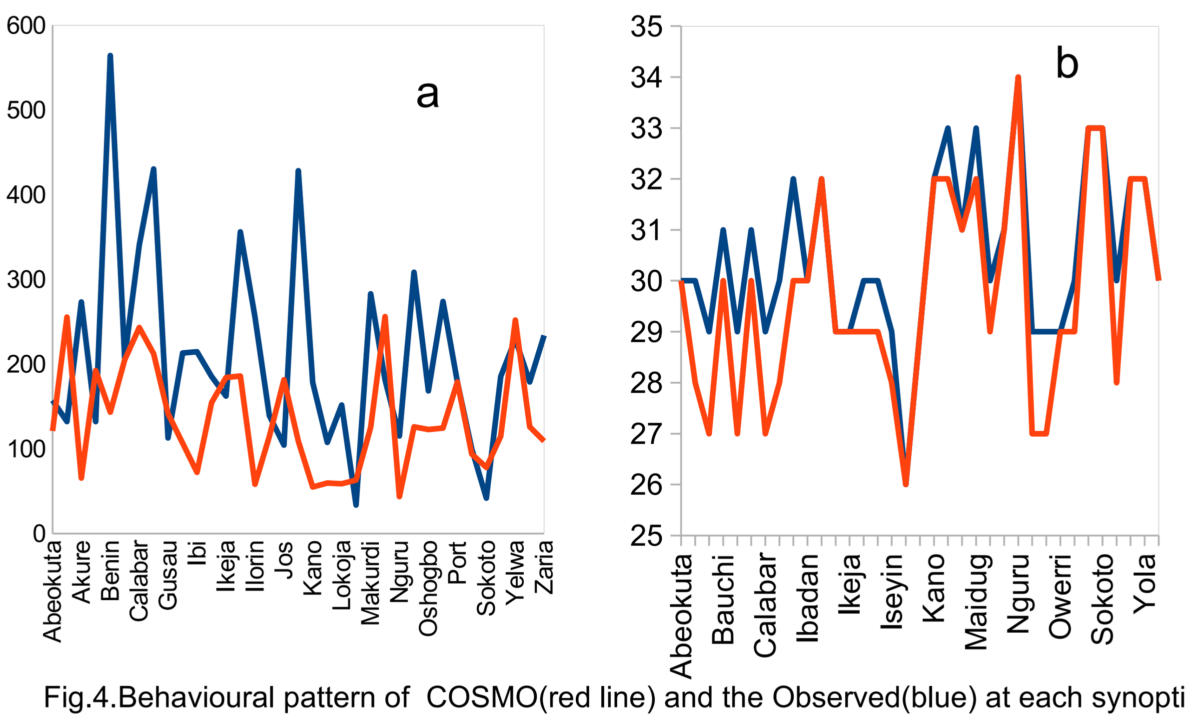

Fig.4.Behavioural pattern of COSMO(red line) and the Observed(blue) at each synoptic station, (a) monthly total of rainfall (b) average maximum temperature in September 2013.

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Results

Considering the analysis of the maximum temperature as shown in figures 5 (as one sample) during the same storm events suggests that the model was able to capture places of temperature extremes reasonably well. In contrast to monthly rainfall total, analysis of the monthly average of the maximum temperature as shown in figure4b, suggests significant quality of the model over the country and in all of the synoptic stations considered. Also with deviation of between 1 – 2ºC, the temperature in the simulated result correlates well with the observed with value of about 0.84.

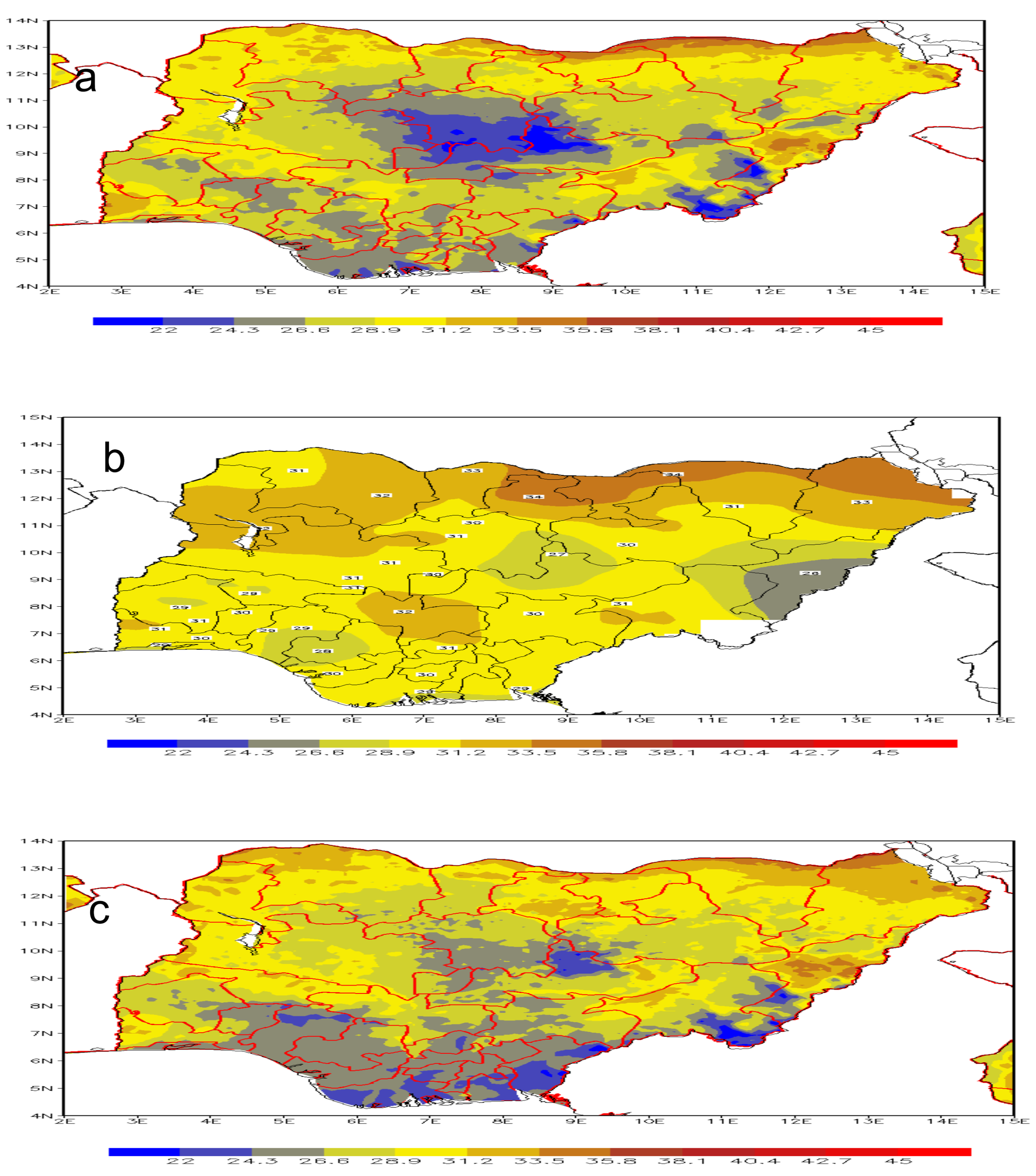

Fig.7.Showing COSMO Maximum temperature distribution in nowcast(a) and forecast(c) with the Observed(b) on the 13th September 2013

Conclusion

The objective of the work is to answer the question on how accurately meteorological phenomena especially rainfall and temperature in the month of September 2013 including days of extreme rainfall events can be reproduced by the high resolution regional model known as COSMO-Nigeria adapted from DWD Germany.

The results shown in this work suggests that the model has a good representation in terms of rainfall distribution especially in the Northern cities of the country. Although the rainfall in the simulated results produced some appreciable values, however it is grossly low and shows no good correlation with the observed.

It is important to note that even at a resolution of 2.8km quantitative rainfall forecast is still going to be extremely difficult. This is because of complex dynamical and micro-physical processes operating on a large range of scales and showing high temporal and spatial variabilities.

The results also suggest that the model displayed a good level of quality and quantity in term of how it produced and distributed the maximum temperature in Nigeria. Although it generally underestimated values between 1 and 2ºC, it has a correlation of about 0.84.

This implies that maximum temperature result from COSMO-Model simulation could be useful in determining daily variability of maximum temperature in operational forecasting.

The fairly good quality displayed by the COSMO-Model in the month of September 2013, may be a good signal for the model to effectively simulate the intra-seasonal rainfall variability in Nigeria.

If provided with necessary resources, the Numerical Weather Prediction section could conduct an experimental research to actually look into the ability of the model in simulating the intra-seasonal variability of some important meteorological elements like wind gust, temperature and precipitation.

This could serve as a spring-board in enhancing the performance of the Seasonal Rainfall Prediction(SRP), issued every year by the Agency, from the perspective of dynamical down-scaling up till 2km resolution, using COSMO-Model in climate model.

References

1. Baldauf, M., A. Seifert, J. Forstner, D. Majewski, M. Raschendorfer,and T. Reinhardt, 2011: Operational convective-scale numerical weather prediction with the COSMO model: Description andsensitivities. Mon. Wea. Rev., 139, 3887–3905.

2. Craig, G., and Coauthors, 2010: Weather research in Europe: A THORPEX European plan. WMO/TD-1531, WWRP/THORPEXRep. 14, 41 pp.

3. Kucken, et. al , 2012: A High-Resolution Simulation of the Year 2003 for Germany Using the Regional Model COSMO. App. Met and Clim, 51, 1889 - 1903.

4. Majewski, D., D. Liermann, P. Prohl, B. Ritter, M. Buchhold, T. Hanisch, G. Paul, and W. Wergen, 2002: The operational global icosahedral–hexagonal gridpoint model GME: Description and high-resolution tests. Mon. Wea. Rev., 130, 319–338.

5. Sabrina, B and Petra, F. 2012: Generating calibrating probabilistic quantitative precipitation forecast from the High-Resolution NWP model COSMO-DE. J.Wea and Forecasting., 27, 988-1002.

6. Seity, Y., P. Brousseau, S. Malardel, G. Hello, P. Bernad, F. Bouttier C. Lac, and V. Masson, 2011: The AROME-France convective-scale operational model. Mon. Wea. Rev., 139, 976–991.

7. Skamarock, W. C., and J. B. Klemp, 2008: A time-split non-hydrostatic atmospheric model for weather research and forecasting applications. J. Comput. Phys., 227, 3465–3485.

8. Staniforth, A., and N. Wood, 2008: Aspects of the dynamical core of a nonhydrostatic, deep-atmosphere, unified weather and climate-prediction model. J. Comput. Phys., 227, 3445–3464.