Evaluation of the UK Met Office's HadGEM3-based regional climate model over the Greater Horn of Africa (GHA)

Geoffrey Sabiiti, Makerere University
Laban A Ogallo, ICPAC
Wilfran Moufouma-Okia, UK Met Office
David Hein, UK Met Office
Richard Graham, UK Met Office

(A) Summary

This study was undertaken to understand the systematic errors and biases associated with different RCM configuration outputs over the GHA region. These RCMs include a regional version of the newly developed Hadley Centre's Global Environmental Model version 3 (HadGEM3) and the HadRM3P RCM (based on the earlier HadCM3 global model). The latter RCM is run separately with two distinct Met Office Surface Exchange Schemes (MOSES1 and MOSES2). The performance of the Met Office RCMs has also been compared against selected RCMs from the CORDEX (Coordinated Regional Downscaling Experiments) over the Africa domain. The RCM experiments were run at ~50 km resolution for the period 1989-2008 and used the ERAINTERIM dataset to provide the lateral boundary conditions. The study compares monthly and seasonal rainfall and temperature outputs of the RCMs against those of gridded observations (UDEL, CRU, GPCC, ERAINTERIM and TRMM).

(B) Motivation

- Climate patterns that know no political or national boundaries affect almost all socio-economic sectors (agriculture, water, energy, and transport) within the GHA.
- Present day and future climate information derived from high resolution regional climate models is vital for climate impacts and vulnerability assessments in the region.
- Climate model outputs at various spatial and temporal scales are characterized with systematic errors and biases resulting from modeling pitfalls listed in Denis et al., 2002.
- Some of these modeling pitfalls include; numerical nesting methodology, physical parameterization consistencies, horizontal and vertical interpolation errors, domain sizes, quality of driving data and climate drift or systematic error.
- Hein 2008, described the implications of these modeling pitfall on model precipitation errors and biases using a number of case studies.
- The systematic errors and biases in RCM outputs, therefore, have to be assessed and understood before the operational use of model outputs.

(C) Objectives of the study

- Examine systematic errors in Hadgem3-Ra model rainfall simulations over the GHA
- Compare the performance of Hadgem3-Ra against other regional Climate models

(D) The Greater Horn of Africa and its climatology

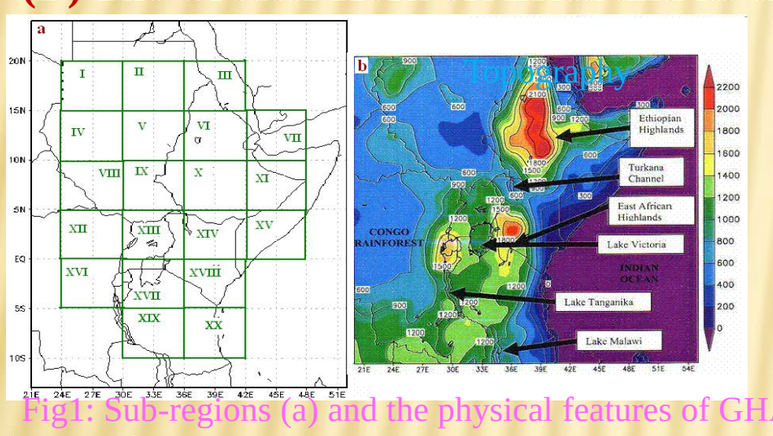

Fig1: Sub-regions (a) and the physical features of GHA region

Topography

Other climate systems

- ITCZ
- Congo air mass
- Inland lakes
- IOD
- ENSO
- Subtropical anticyclones
- MJO

- Rainfall and temperature are the major parameters that characterize the climate of most regions in the GHA
- Temperature is dependent on topographic effects the Sun is never far from the Zenith.
- The temporal and spatial variability of rainfall in the region is, however high.
- The mechanisms responsible for this very high rainfall variability are due to the complex interactions between different systems that govern the rainfall climatology.
- The major rainfall belt in the region follows the belt of maximum convergence – ITCZ, which controls the rainfall seasonality
- JJA – Northern part of the region, DJF – Southern part of the region, MAM & SOND – Equatorial part of the region

Task: "Both large and sub-grid processes that govern the region's climate require accurate representation within the regional climate model for accurate model outputs"

(E) Methods

The study used model performance indices to understand errors and biases in RCM rainfall and Temperature. These were; model percentage bias, Pearson Moment correlation coefficient, mean absolute errors and the refined Willmott index of model performance (Willmott 2011).

(F) Results

RCMs have a good skill in reproducing the observed temperature variations BUT not rainfall variations. With respect to rainfall, the models are able to reproduce the climatology patterns in the month to month variations within the year (annual cycle) BUT model rainfall amounts significantly deviate from the observations. The errors in an individual model vary significantly with time and location. Time series analysis focusing over the sub-domains, indicated that the absolute mean precipitation error varied between 0.44 to 5.75 mm/day, while the spatial correlation varied between –0.35 and 0.9. The RCMs, however, reproduced reasonably the north-south shift of the rainfall maxima, which is consistent with the movement of the Inter Tropical Convergence Zone (ITCZ) which is a major driver of the rainfall climatology in the region.

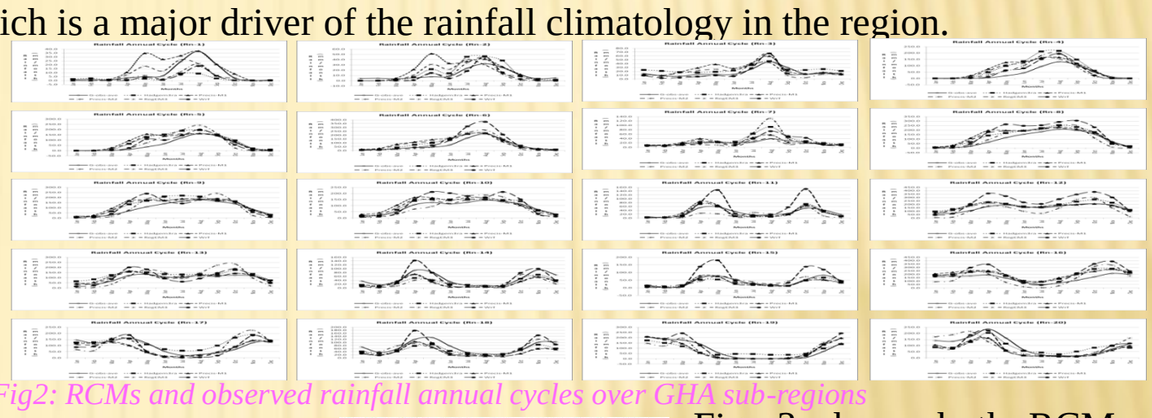

Fig2: RCMs and observed rainfall annual cycles over GHA sub-regions

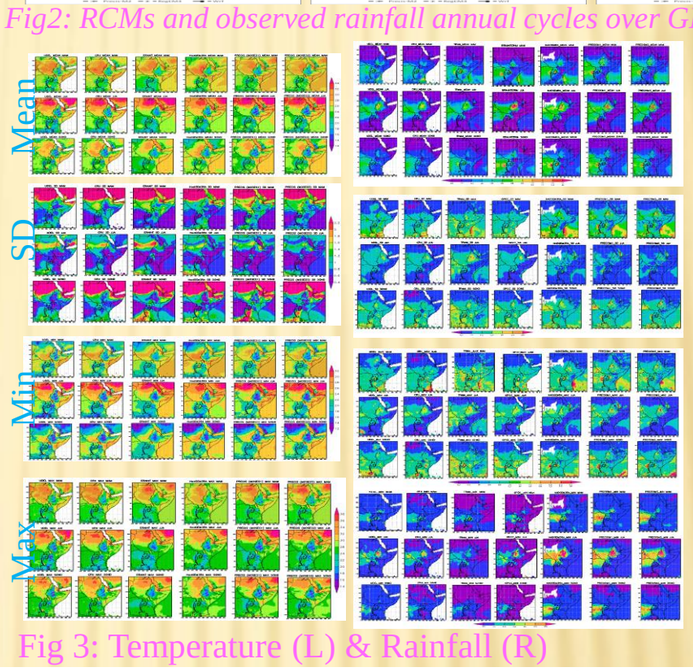

Fig 3: Temperature (L) & Rainfall (R)

Fig. 3 shows both RCMs and observed seasonal average temperature (L) and rainfall (R) for the three seasons (MAM, JJA & SOND) over the GHA region

The results show a fairly good agreement between the models' simulated and observed patterns of the two climate parameters across the region during the different seasons. Models though tend to over estimate rainfall in some cases.

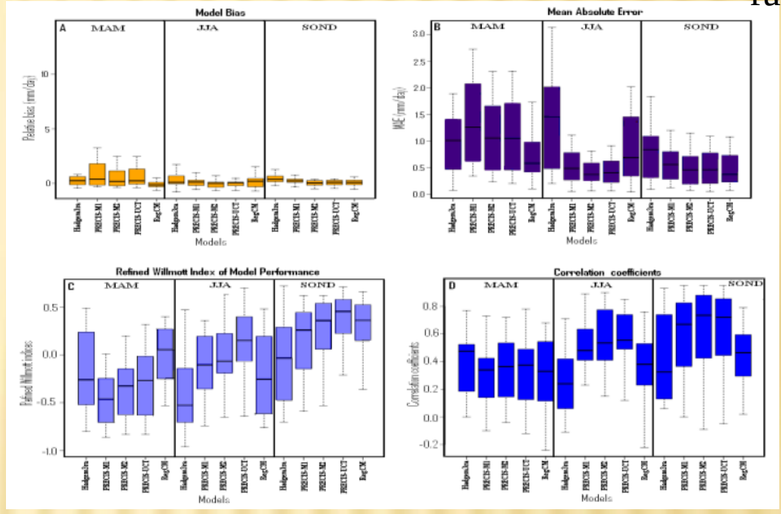

Fig4: RCMs performance indices over GHA

The overall performance of each model in the region for the three seasons of March-May (MAM), June-August (JJA) and September-December (SOND) based on a particular index has been presented.

Fig.1 presents a summary of results obtained from statistical analysis based on relative bias (A), Mean Absolute Error (MAE) (B), the refined Willmott index (C) and the Person moment correlation coefficients (D). The box and whisker plots have been used to summarize and present results of these four model performance indices based on twenty (20) sub-regions across the GHA.

(G) Conclusions

- The performance of the RCMs over the GHA region depends strongly on their ability to accurately represent the processes associated with the relevant regional features.
- Major systems include the presence of steep orography, the Congo river basin, the Lake Victoria and the Indian Ocean Dipole
- Our study contributes to improved understanding of the RCMs errors over the GHA regions, and in the validation of physical parameterization packages suitable for use over the region across a wide range of time and space scales.

(H) References

• Denis B, Laprise R, Caya D, and Cote J, (2002): Downscaling ability of one-way nested regional climate models: the Big-Brother Experiment. Climate Dyn., 18, 627-646
•Hein D, (2008): The representation of Extreme Precipitation in HadRM3P Regional Climate Model. MSc. Dissertation, University of Reading, UK.
• Willmott C.J, Robeson S.M, and Matsuura K, (2011): Short Communication: A refined index of model performance. International Journal of Climatology

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