Drying out the Nile? Regional Climate Change and Water Resources in East Africa with a focus on Lake Victoria and Lake Tana

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Introduction

Famed as the sources of the Nile River, Lakes Victoria and Tana are catchments projected to undergo substantial change in precipitation under future climate change scenarios. Extensive periods of drought are also seen in palaeo-records from the region, which the proposed DACEA project aims to explain with reference to regional and global teleconnections.

Here, we present high resolution (44km, 10km) simulations of the HIRHAM5 Regional Climate Model (RCM), driven at the boundaries by the ECHAM5/MPI-OM coupled GCM under the SRES A1B scenario. The 44km run covers 1950-2100, the 10 km run three time slices (1980 - 1999, 2046-2065, 2080 – 2099) over East Africa. These indicate a reduction in future precipitation and increase in potential evapotranspiration with important consequences for agriculture and hydropower production in the Nile basin.

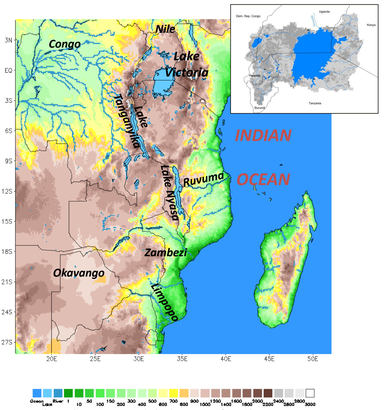

Figure 1 The climate model domain for the HIRHAM5 RCM with the 10km topography shown, emphasising the importance of high model resolution. Inset is the Lake Victoria catchment used in this study to plot figures 2 and 3

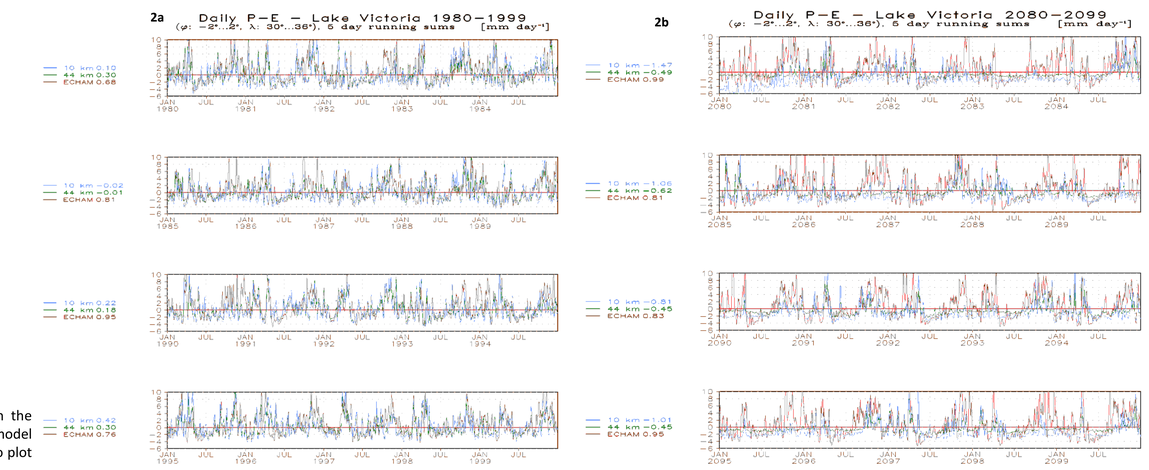

Figure 2 shows Precipitation – Evaporation (P-E) for the three models over two timeslices; 2a. the present day (1980-1999) and 2b. the end of the century (2080-2099); ECHAM5 (1.875°x1.875°) in brown, HIRHAM5 RCM at 44km (green) and at 10km resolution (blue). Numbers to the left of the plots indicate 5 year means for each period for each model. Note the substantial difference between the values of the different simulations, reflecting the differing resolutions, in particular during the period of short rains (approximately boreal spring).

Results

Model resolution is very important in capturing precipitation and evaporation variability, the 10km resolution (top row) has significantly more evaporation than the 44km run (lower row). Both models are able to simulate the bimodal distribution of precipitation at the present day with the long and short rains well represented. Note the decline in rainfall and increase in evaporation in the future. Later in the century the short rains in February-March become less reliable and occasionally fail completely.

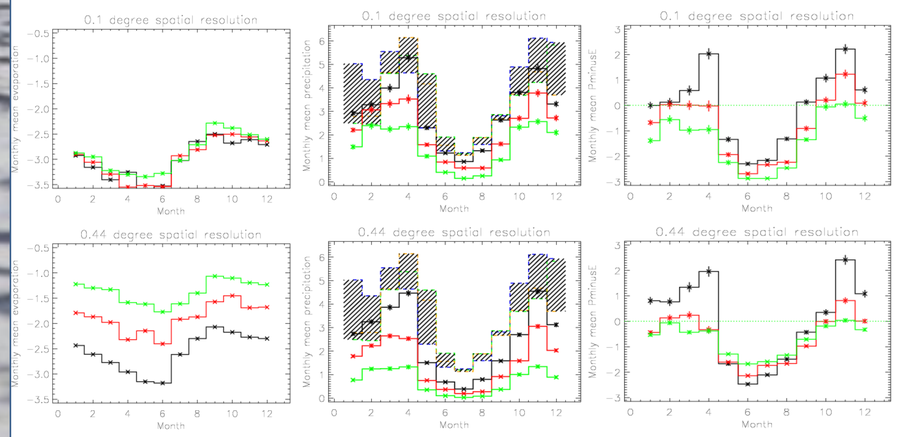

Figure 3 shows results from the 10km resolution run in the top row and the 44km run in the lower row. Colours indicate the different timeslices, black is the present day (1980-1999), red is the mid 21st century timeslice (2046-2065) and green the end of the century (2080-2099). The hatched box in the precipitation graphs indicate the observed present day precipitation variability according to three different reanalysis datasets (NCEP reanalysis, GPCP, Delaware reanalysis)

CMIP5 model results are contradictory for this region (IPCC AR5) and show a strong resolution dependence, hence the need for detailed further research to understand controls on regional climate

Hydrometeorology

We use the Penman-Monteith equation to calculate potential evapotranspiration (PEV) in the area around Lake Victoria.

$$\lambda_v E = \frac{\overbrace{\Delta(R_n - G) + \rho_a c_p (\delta e)\, g_a}^{\text{Energy flux rate}}}{\Delta + \gamma\,(1 + g_a/g_s)} \iff ET_o = \frac{\overbrace{\Delta(R_n - G) + \rho_a c_p (\delta e)\, g_a}^{\text{Volume flux rate}}}{(\Delta + \gamma\,(1 + g_a/g_s))\, L_v}$$

DJF and MAM show the largest increase in PEV, particularly close to the coast, while the Congo basin sees greater increases in PEV in the JJA and SON seasons which may reflect recent observations of drought in the Congo basin (Zhou, L. *et al.,* 2014). The region as a whole sees an increase in PEV through the whole year by the end of the century.

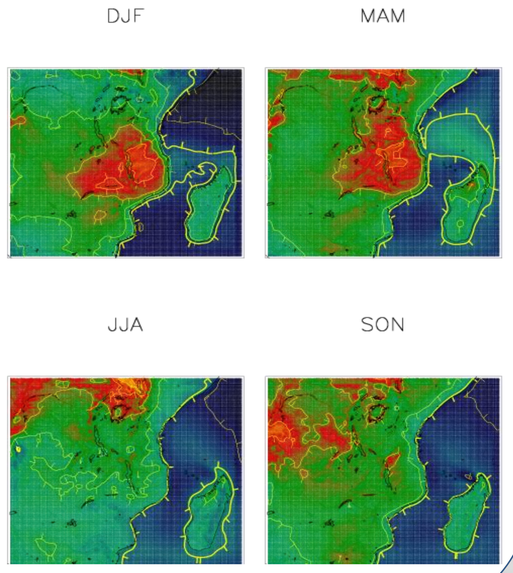

Figure 4 Change in seasonal evapotranspiration. These plots show the difference between the end of the century mean and present day mean in mm/day at the 10km resolution. Browns correspond to largest increase in evapotranspiration. Contours are 1mm/day apart. and the thickest contour is at 0 mm .

Drivers of Aridity Change in East Africa (DACEA) Project

The DACEA project will investigate regional and global teleconnections that affect aridity in East Africa and their environmental consequences using a combination of climate modelling and palaeoproxies from East African lakes including Lake Tana and Lake Victoria. Model experiments (Figure 5) examining the influence of orbital forcing and ocean circulation on the East African monsoon will be carried out with the EC-Earth GCM. Downscaling to regional and local scale will be carried out with the HIRHAM5 RCM and the MIKE-SHE hydrological model.

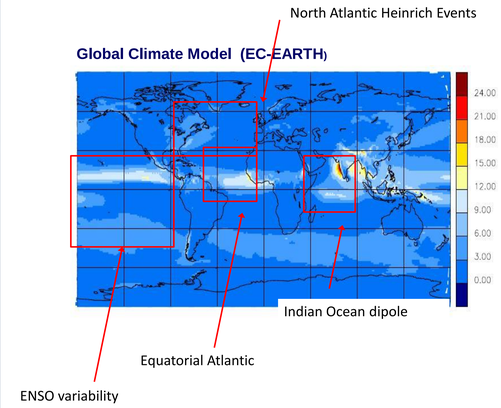

Figure 5 Mean precipitation in the GCM EC-Earth. Red boxes indicate the locations of planned model experiments to examine in detail the influence of regional and global climate on the aridity of East Africa. EC-Earth will be run both in palaeo mode (with appropriate orbital parameters to simulate Milankovitch forcing) and in the present day with RCP scenarios to simulate effects of climate change on East Africa.

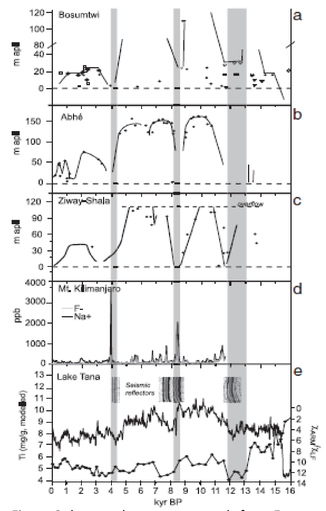

Figure 6 shows palaeo proxy records from East Africa; a,b and c are palaeo shorelines, d) is a dust record from Kilimanjaro ice cores and e) the sedimentary record from Lake Tana. Grey shading indicates dry periods during the Holocene. From Marshall et al., 2011

References: Stendel et al., in prep. ; Mottram et al., in prep. ; Thejll et al., in prep; Marshall et al., 2011; IPCC AR5 WG1 chapter 14; Zhou, L. et al., 2014, Nature

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