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Potential impacts of forestation on heatwaves over West Africa in the future

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ABSTRACT

Previous studies have projected future climate change impacts on heatwaves in West Africa, but without including the influence of ongoing forestation activities in the region. The present study investigates how the ongoing forestation activities in West Africa may influence the characteristics of heatwaves over the region in the future. The study characterised heatwave using two metrics (excess heat factor (EHF), and a percentile based index (TXI)). A regional climate model (RegCM) is used to simulate characteristics of heatwave for the past (1970–2000) and future (2030–2060; IPCC RCP4.5) climates in West Africa with and without forestation of the Savannah zone (area between 8°N and 12°N). While RegCM gives a realistic simulation of extreme temperature thresholds (i.e. 95th percentile of daily mean temperature and 90th percentile of daily maximum temperature) and seasonal distribution of heatwave days, it fails to reproduce the spatial distribution of heatwave number, days and duration as in observation. Both heatwave indices (TXI and EHF) generally show similar patterns of heatwave characteristics over West Africa, except that heatwave number and days are substantially greater with TXI than with EHF. The results show that the RCP 4.5 emission scenario would induce longer and more frequent heatwave events and days over the whole region and that the increase of heatwave days is likely to occur in all months of the year. The results further indicate that forestation, on the average, may increase the number of heatwave events and days over the forested zone (Savannah), and decrease them over the Sahel and along the Guinea coast. This study has application in the use of large scale forestation activities as a climate change mitigation option in West Africa.

1. Introduction

Heatwaves, one of the most dangerous natural hazards, can have devastating impacts on society, the environment and economy. They can increase human morbidity and mortality rates (Anderson and Bell, 2011), especially among elderly and infants (Basu and Samet, 2002), and induce stress on crops and animals (Chung et al., 2014; Ciais et al., 2005; Lanning et al., 2011). Furthermore, they can lead to food scarcity by increasing the price of agricultural products (Chung et al., 2014). For example, during the devastating heatwaves of 2003 in Europe, more than 40,000 heat-related deaths were recorded (García-Herrera et al., 2010; Hémon et al., 2003). The heatwave that occurred in Russia in the summer of 2010 was characterised by exceptionally high temperature, which increased death rates in many regions of the country (Dole et al., 2011). More recently (in 2015), heatwave killed thousands of people (predominantly, the poor) in India and Pakistan (Rafferty, 2015). In Africa, few records of heatwave exist, because many heatwave events often go unnoticed or unreported. However, the World Meteorological organisation (WMO, 2013) reported extremely hot events

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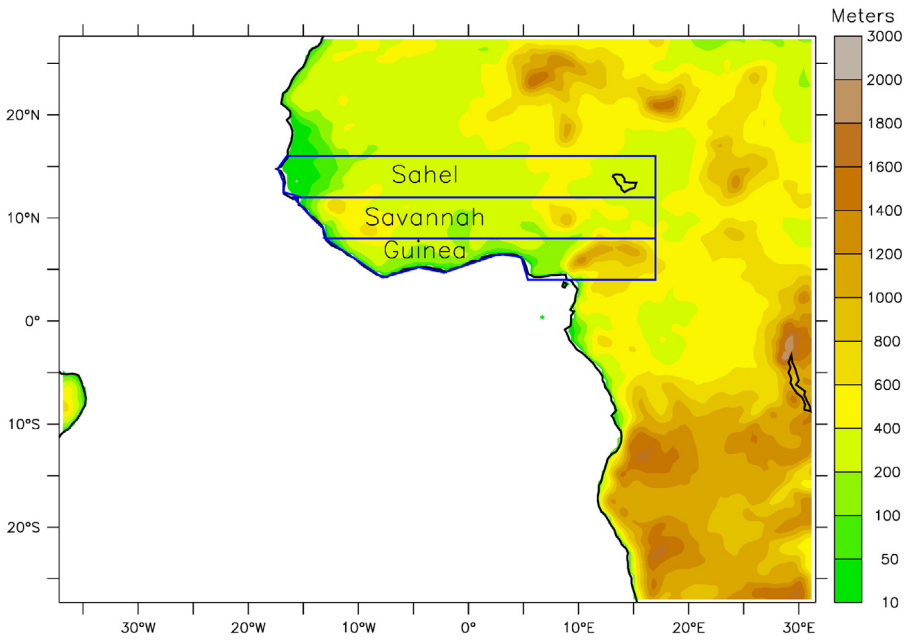

Fig. 1. The model simulation domain showing West African topography (shaded, m) as seen by the model and the regions designated as Sahel, Savannah and Guinea in this study.

in West Africa, with abnormally high temperature (up to 50.6 °C) in the Sahara, during the boreal summer of 2002. As the influence of anthropogenic warming on climate extremes (i.e. extreme temperatures, extreme precipitation, and droughts) becomes more evident, there is a concern that the warming may escalate the intensity, frequency, and duration of heatwaves in the future (IPCC, 2014). For instance, Russo et al. (2014) showed that, in the last few decades (1980–2012), heatwaves have extended to more regions of the world, and, by the end of the 21st century, very extreme heatwave events are likely to occur more often (i.e. as often as once every 2 years in many regions of the world, including Africa). Vizy and Cook (2012) also projected that climate change may increase the frequency of heatwave days in West Africa during the mid-twenty-first century (2041–2060). Abiodun et al. (2013) projected increases in future occurrence of extreme temperature events over all ecological zones in Nigeria. However, most of the future projection studies over West Africa did not account for the impacts of ongoing forestation activities (African Union Commission; AUC, 2006) in their projections. As the forestation activities could increase or decrease the intensity, frequency and duration of extreme events in future over the region, there is a need for detailed studies on how these activities may alter the future projections. The results of such study will be valuable to policy-makers on how to minimise the impacts of heatwave events on socio-economic activities, human health and security in West Africa. The present study is in that direction.

Some studies have demonstrated how forestation could alter the ecology and future climate in Africa, but the direction of the alteration differs across the continent. For example, while Abiodun et al. (2012a,b) found that forestation in West Africa would lower the projected warming over the forested area, Naik and Abiodun (2016) showed that forestation in Southern Africa would have the opposite impacts. However, both studies did not consider the impact of forestation on heatwaves. Only Abiodun et al. (2012b) examined the potential impacts of forestation on heatwaves in Nigeria and found that while the forestation would lower the frequency of heatwaves over some areas, it would increase it elsewhere outside the forested area. Nevertheless, the focus of Abiodun et al. (2012b) was over Nigeria, so the results of the study may not be representative of the entire West African sub-region because Nigeria is small part of the sub-continent and all the forestation scenarios considered were within the country. Hence, there is need for further studies on how the ongoing regional forestation activities in West Africa (AUC, 2006) may alter the ecology and the characteristics of heatwaves in the future.

The aim of the present study therefore is to investigate the potential impacts of forestation and the attendant ecological dynamics on the possible occurrence and characteristics of heatwaves over West Africa in the future. The study analyses simulations from a regional climate model (RCM) to assess the potential impacts of forestation on the characteristics of future heatwaves as a response to the changed vegetation canopy. A brief description of the RCM and simulations used in the study is given in Section 2. Section 3 discusses the results of the analysis while Section 4 gives the concluding remarks.

2. Methodology

2.1. Data

This study used two types of datasets: observation datasets and model simulation datasets. The first observation dataset is produced by the Climatic Research Unit (hereafter, CRU TS3.23; Harris et al., 2014; Mitchell and Jones, 2005) at the University of East Anglia and consists of global monthly observations from meteorological stations across the world (excluding ocean areas). The dataset, which is gridded at $0.5^\circ \times 0.5^\circ$ horizontal resolution, is available from 1901 to 2014. The second observation dataset is the Princeton University Global Meteorological Forcing Dataset for land surface modelling (hereafter, PGF), produced by the Terrestrial Hydrology Research Group of Princeton University (Sheffield et al., 2006). PGF is an observation-reanalysis hybrid dataset that consists of global 3 hourly data constructed from combining sets of global observation-based datasets and the National Centre for Environmental Prediction–National Centre for Atmospheric Research (NCEP-NCAR) reanalysis (Sheffield et al., 2006). The PGF is gridded at $1^\circ \times 1^\circ$ resolution for the period 1948–2008. We used CRU and PGF maximum and minimum temperatures for the period