Modelling the changing water balance in West Africa

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The BRAVE2 Project

“BRAVE: Building understanding of climate variability into planning of groundwater supplies from low storage aquifers in Africa – second phase”

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Investigators from the University of Reading, the British Geological Survey, and a large number of water resources research, governance, and (international) aid agency partners in Ghana and Burkina Faso

Emphasis is on water balance extremes and how these may change in the future, in relation to the management of water resources
Modelling Study

Data are derived from the Met Office Unified Model (GA3) ensemble of high resolution (N512) atmosphere-only model runs (UPSCALE)

These simulations were forced with OSTIA SSTs for present climate (5 runs of 1985-2011), and with OSTIA + the SST change between 2000-2100 (RCP8.5) for future climate (3 runs also of 27 years)

Atmospheric variables from UPScale are used to drive the JULES land-surface model over West Africa in distributed fashion, individual grid boxes between 17W-15E 4-21N, considering the soil and vegetation processes including the vegetation seasonal cycle, to calculate the water balance
Changes are seen in the annual distribution of rainfall and also have increased daily rainfall intensity between the present and future climate.

The resulting water balance will be affected by the rainfall intensity, but also by increased CO₂ concentration in the future climate, and by changes in the vegetation coverage.
The changes due to increased rainfall and increased CO$_2$. 
Increased rainfall, increased CO$_2$, or change in vegetation
Results

UPSCALE predicts increased rainfall in central and northeast West Africa but reduced in the west and south, with greater percentages of rain >16 mm/day for the same annual rainfalls.

With the changes in rainfall, there is increased transpiration from the soil and vegetation, and some increases in surface runoff and drainage, with little change in soil moisture.

However with the increased CO$_2$ as well, transpiration is reduced (due to the vegetation CO$_2$ response) while surface runoff, drainage and soil moisture are all increased.

Going from vegetation coverage with all broadleaf trees to all C4 grass leads to increased evapo-transpiration but some reductions in surface runoff, drainage and soil moisture.
JULES-UPSCALE rainfall change with results from 11 CMIP5 models, Historical (1986-2005) to RCP8.5 (2081-2100), and the overall mean percentage change
Summary

This study using JULES driven by daily meteorological data from UPSCALE predicts significant changes for the West African monsoon in the future climate (similar to the predictions from the CMIP5 models).

A number of different factors influence the surface water balance and here we have examined the effects of increased rainfall, increased CO$_2$ (the vegetation CO$_2$ response), and changing vegetation coverage.

This work is ongoing, particularly into the subtle influences of soil conditions and vegetation coverage on water balance.
JULES-UPSCALE drainage change with results from 11 CMIP5 models, Historical (1986-2005) to RCP8.5 (2081-2100), and the overall mean percentage change.
Results 3

The different CMIP5 models show a variety of changes in the West African monsoon from Historical runs (1986-2005) to RCP8.5 (2081-2100), but most of the models show wetter conditions in the North and East but drier conditions in the South and West.

The models also show a variety of changes in the amount of drainage across West Africa, but most of the models show significant increases particularly in the North.
Results 2

The West African monsoon is also predicted to progress further to the north and to occur later in the year, resulting in increased soil moisture and drainage to the north of 8N.
The West African Monsoon

Rainfall in West Africa is strongly seasonal and at present many people have no other water for irrigation, so it is very important to determine the likely spatial and temporal changes in the monsoon from present (~2000) to future climate (~2100).

Also examining how changes in the amount of rain and in the rainfall intensity will affect the surface water balance, and hence the amount of drainage from the soil.
Configuration of Model Experiments

Individual grid boxes (91x72) between 17W-15E and 4-21N

JULES driven by daily meteorological data from UPScale, the daily rainfall is disaggregated, with hourly time steps

4 soil levels (0.1, 0.25, 0.65, 2.0m) with 9 soil parameters (from file), and 9 values of vegetation fractional coverage (from file) with a monthly climatology of Leaf Area Index

Using Brooks and Corey soil hydraulic model, excess water is pushed up, and Cox et al. soil thermal conductivity model

$\text{CO}_2$ mass mixing ratio of $5.241e-4$ for present climate, and $1.4217e-3$ for future climate