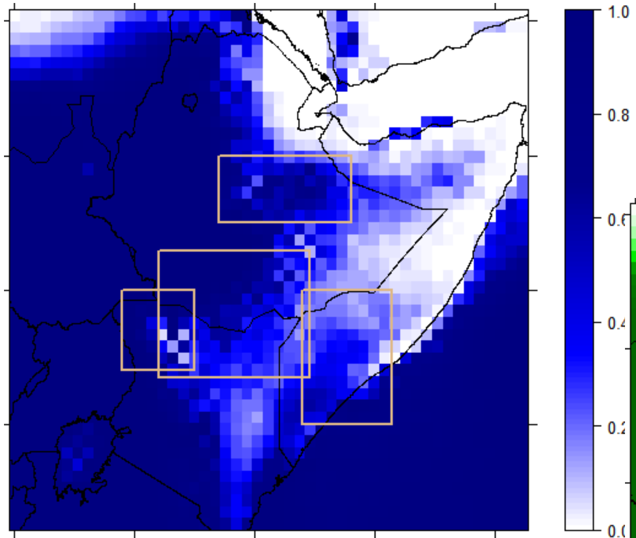
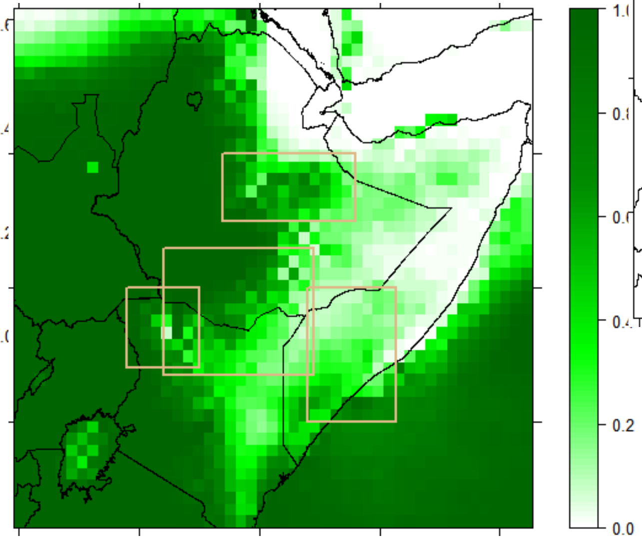
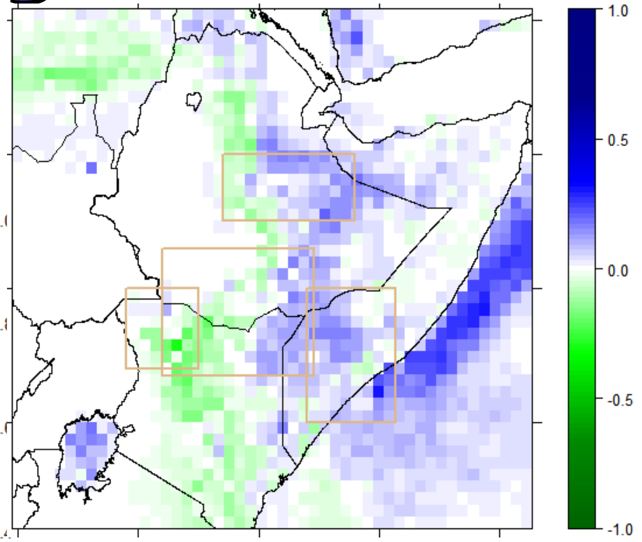
The 2014 drought in the Horn of Africa: attribution of meteorological drivers



Blue = High precipitation areas in the Horn of Africa under present day climate



Green = High precipitation areas under a climate without GHG emissions



Difference map: left plot minus centre plot

www.TobyMarthews.com

CEH, 30th June 2015

NERC SCIENCE OF THE ENVIRONMENT

CEH Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

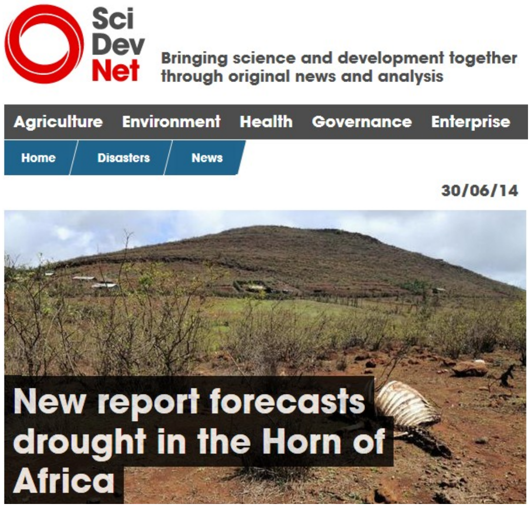
SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

The ACE-Africa project

In 2014 there was a severe drought in the Greater Horn of Africa region (GHoA), estimated to have displaced more than 1.1 million people internally in Somalia alone.

In the ACE-Africa project, we ask *Has human-induced climate change played any role in the 2014 drought in the GHoA?*



Sci Dev Net
Bringing science and development together through original news and analysis

30/06/14

New report forecasts drought in the Horn of Africa

Drought forecasted in Jun 2014.

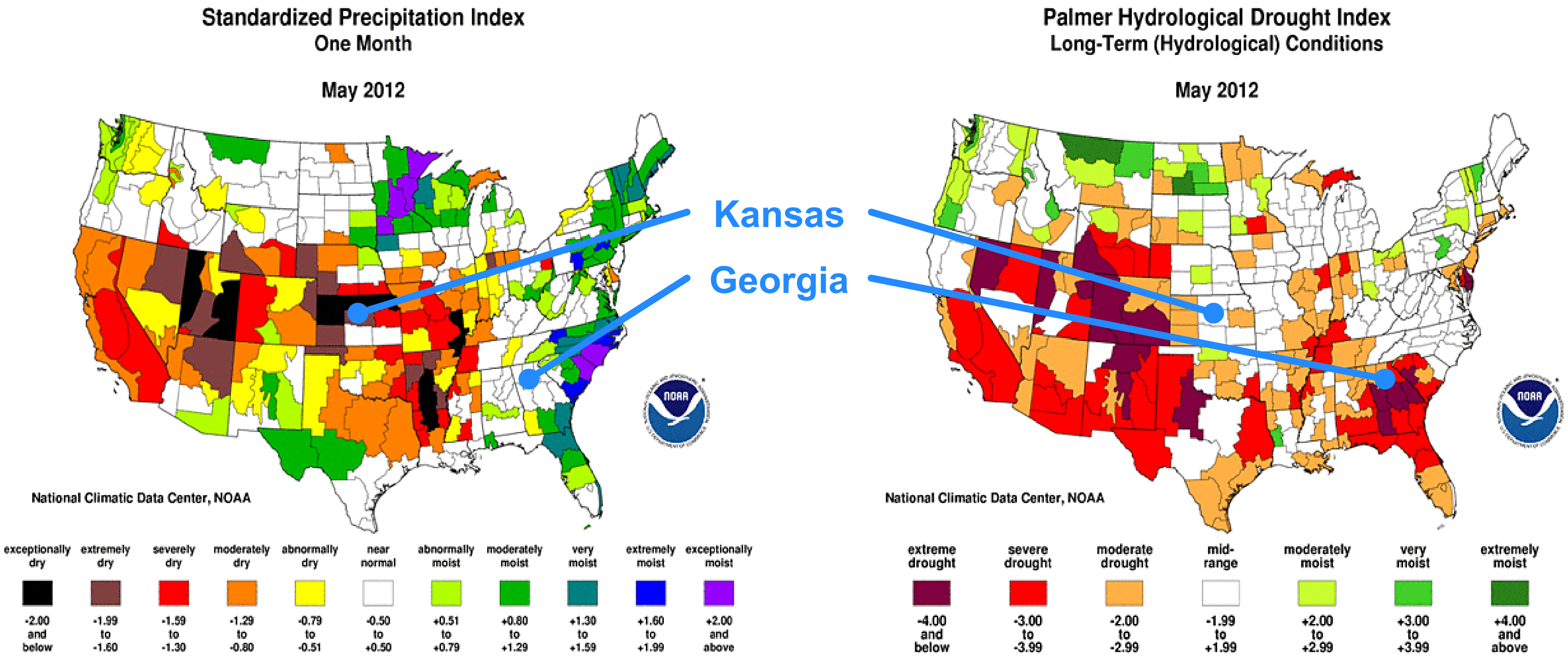
My role in this research is to use the land surface model JULES to simulate areas of drought across the landscape and assess where drought risk has changed as a result of human-induced climate change.

The Attribution of Climate-related Extremes in Africa (ACE-Africa) project, Univ. Oxford.

NERC SCIENCE OF THE ENVIRONMENT
Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL
Met Office
SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT
UNIVERSITY OF OXFORD

Types of drought

I'm considering two types of drought: *climatological drought* (i.e. unusual precipitation deficit) and *hydrological drought* (i.e. reduced soil moisture and/or streamflow). For example, in the USA in May 2012, northern Georgia experienced hydrological but not climatological drought and the reverse was experienced by central Kansas.



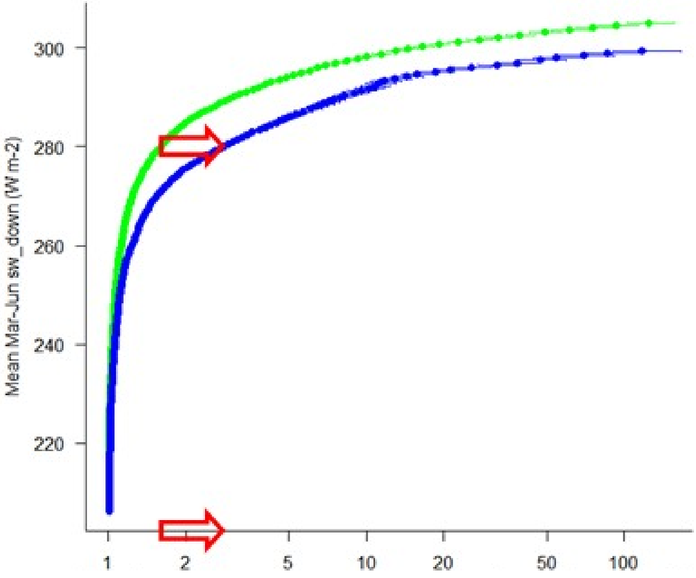
NERC SCIENCE OF THE ENVIRONMENT
CEH Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL
Met Office
SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT
UNIVERSITY OF OXFORD

Probabilistic Event Attribution (PEA)

We use PEA techniques to estimate the human contribution to observed changes (Allen 2003, *Nature*), which involves an ensemble approach to estimating the uncertainty in the response of the climate system to external forcing. We use **two ensembles**:

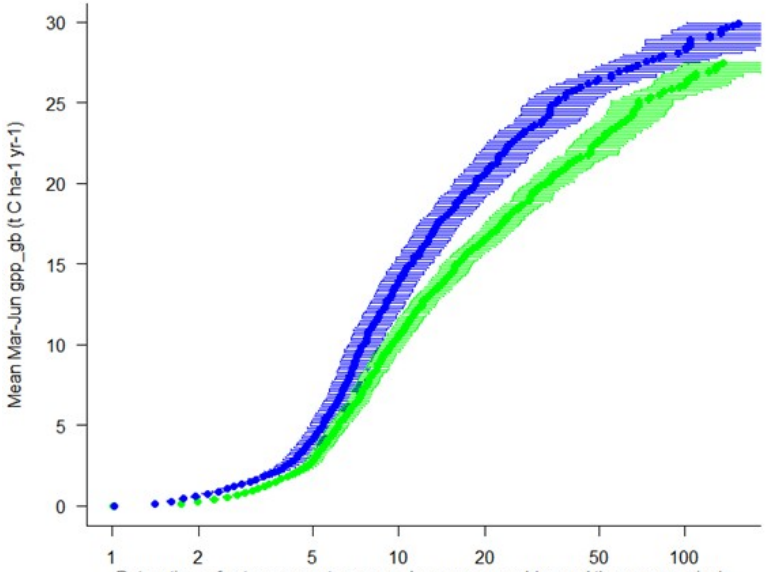
- One ***factual*** ensemble based on perturbations around a set of initial conditions and parameters that describes as closely as possible the real climate at simulation start
- One ***counterfactual*** based not on the ‘world that is’ but rather the ‘world that might have been’ without higher greenhouse gas emissions.

Shortwave down (a reduction is attributable)



Return time of extreme event (years)

Gross Primary Productivity (GPP; an increase is attributable)



Return time (years)

NERC
SCIENCE OF THE ENVIRONMENT

CEH
Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

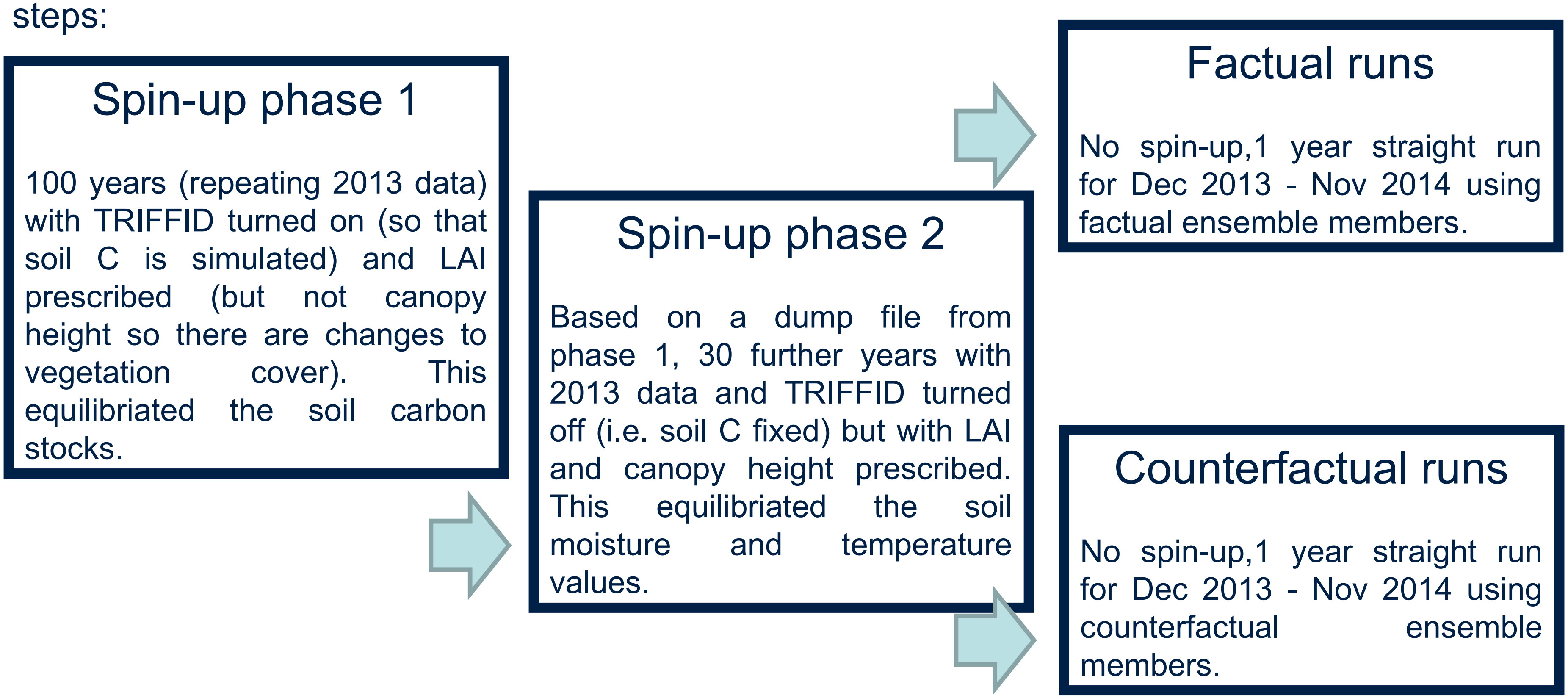
SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

JULES simulations

My factual and counterfactual ensemble members are derived from repeated runs of the Hadley Centre Regional Climate Model 3P (HadRM3P) with boundary conditions provided by the Hadley Centre Atmospheric general circulation Model 3P (HadAM3P), run over a 0.44° resolution simulation domain (~50 km at the Equator).

I receive these data, reformat the NetCDF files for JULES (v.3.4.1) and follow the following steps:



Spin-up phase 1

100 years (repeating 2013 data) with TRIFFID turned on (so that soil C is simulated) and LAI prescribed (but not canopy height so there are changes to vegetation cover). This equilibriated the soil carbon stocks.

Spin-up phase 2

Based on a dump file from phase 1, 30 further years with 2013 data and TRIFFID turned off (i.e. soil C fixed) but with LAI and canopy height prescribed. This equilibriated the soil moisture and temperature values.

Factual runs

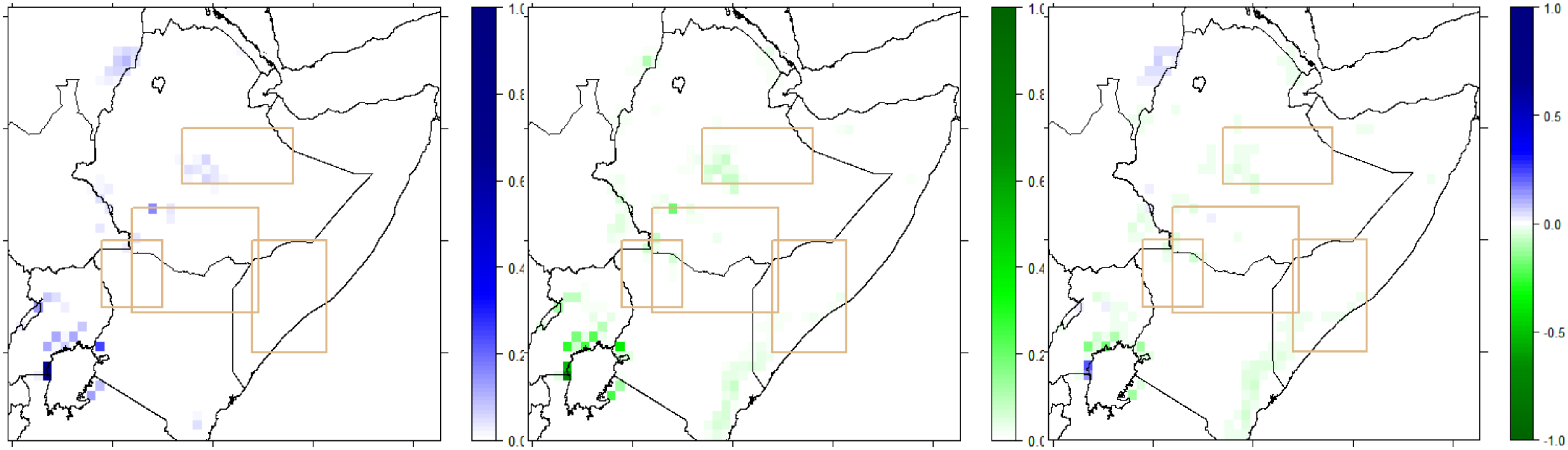
No spin-up,1 year straight run for Dec 2013 - Nov 2014 using factual ensemble members.

Counterfactual runs

No spin-up,1 year straight run for Dec 2013 - Nov 2014 using counterfactual ensemble members.

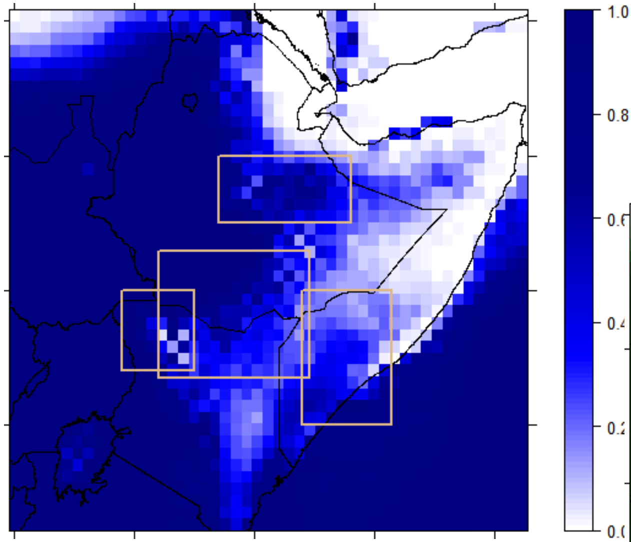
Results

Climatological drought areas defined by Standardised Precipitation Index (threshold: *SPI* < -1.5, the standard level for "very dry" or “extremely dry” environments), calculated in comparison to the TAMSAT 1983-2012 baseline precipitation climatology and then restricted to values ±5.

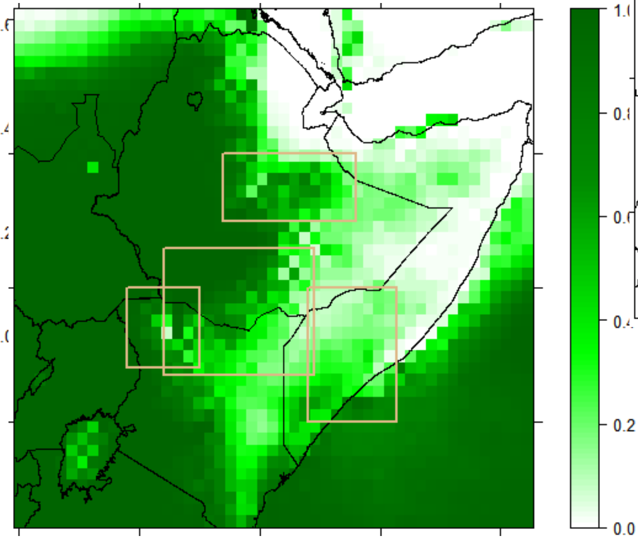


LEFT and CENTRE: coloured areas show areas where rainfall is decreasing (blue=factual ensemble mean). RIGHT: blue areas show areas where more drying is found under our simulations of actual 2014 conditions than found in our counterfactual simulations for 2014, and green areas show the reverse. Overall message of these plots: *no change* (surprisingly!).

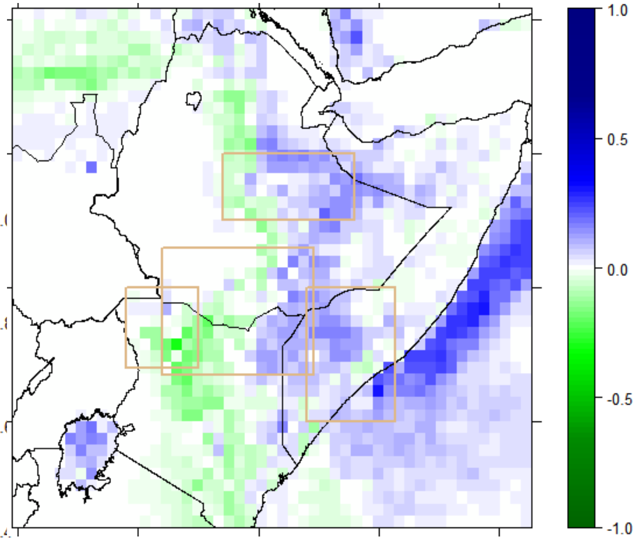
The 2014 drought in the Horn of Africa: attribution of meteorological drivers



Blue = High precipitation areas in the Horn of Africa under present day climate



Green = High precipitation areas under a climate without GHG emissions



Difference map: left plot minus centre plot

www.TobyMarthews.com

CEH, 30th June 2015

NERC SCIENCE OF THE ENVIRONMENT

CEH Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL

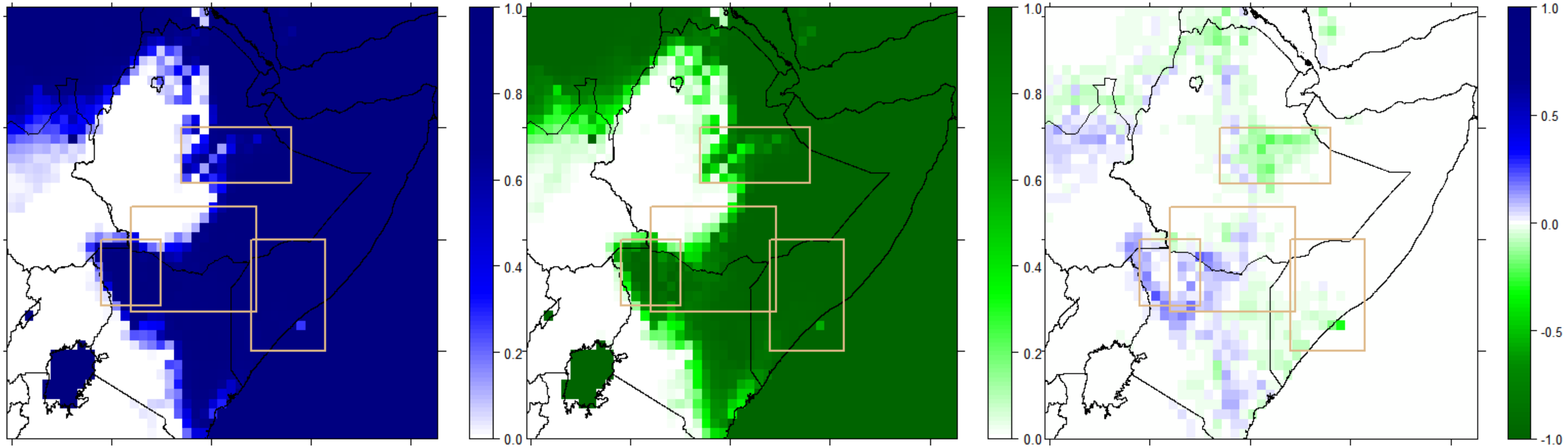
Met Office

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

UNIVERSITY OF OXFORD

Results

Hydrological drought areas defined by effective soil saturation (threshold is S_e<30%, a commonly-used mean value for dry soils), calculated from *JULES* (*TOPMODEL* option, using my new topographic index values as ancillary, Marthews *et al*. 2015, *HESS*).

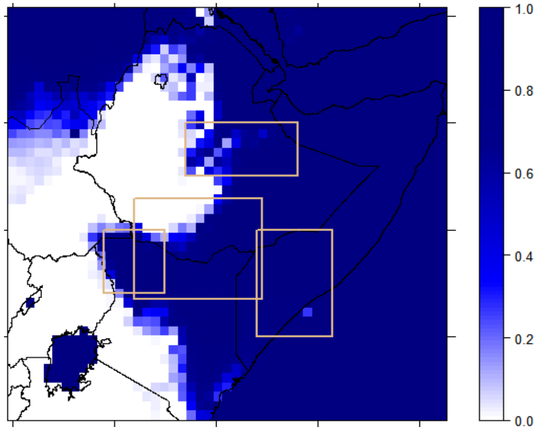


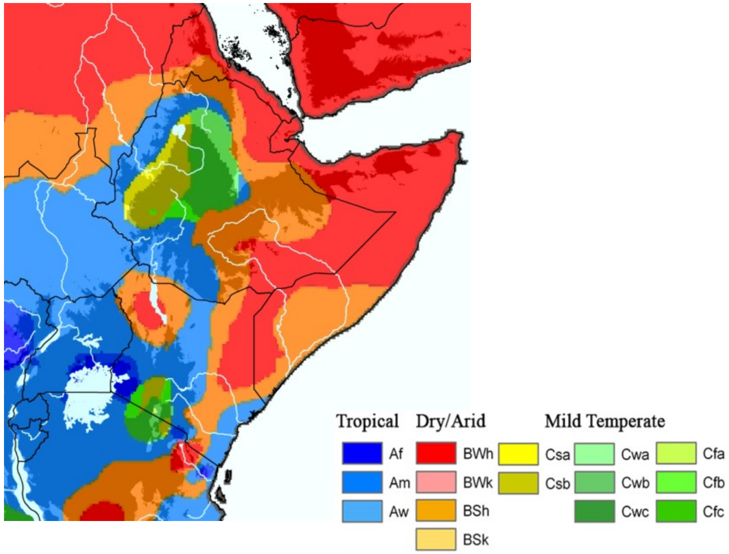
LEFT and CENTRE: coloured areas show high probabilities of dry soil (blue=factual ensemble mean). RIGHT: blue areas show areas where more drying is found under our simulations of actual 2014 conditions than found in our counterfactual simulations for 2014.

Hydrological drought risk seems to be increasing in NW Kenya but *de*creasing in the Ahmar Mts and SW Somalia.

Results

Note that the predicted areas of hydrological drought, rather than climatological drought, correspond most closely to the Köppen-Geiger arid and semi-arid zones of the region because although this is a ‘climatic’ system biome distributions are taken into consideration in its formulation (Peel *et al.* 2007).





I think the ability of JULES to return the Köppen-Geiger arid regions from its independent simulations is a surprisingly good validation of our model simulations.

Conclusions

In this study we asked whether human-induced climate change has played any role in the 2014 drought in the GHoA. We have shown that:

- Drought risk is progressively changing across the Horn of Africa region and that some of this is indeed attributable to anthropogenic climate change.

- However, regional patterns differ (greatly!) between climatological drought risk and the risk of hydrological drought.

- In areas where climatological drought is increasing, we recommend prioritising efforts against short-term water shortages (e.g. more water trucking in Ethiopia).

- In areas where hydrological drought is increasing, we recommend instead more effort to combat longer-term desertification impacts.

Next steps

Met Office

River routing in JULES

Implementation Report

vn1.0
November 2014
Huw Lewis

•None of our analysis has been carried out using the new routing modules implemented in JULES v4.x. Will adding overbank inundation modify our results?

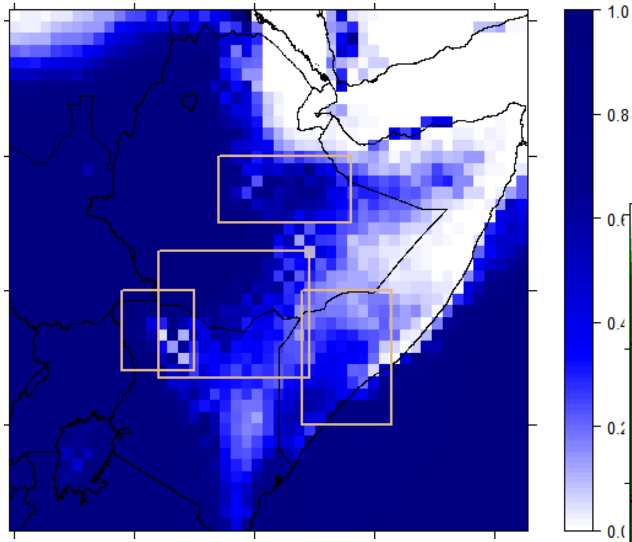
•For these simulations I have used my own parameters for tropical vegetation (from Marthews *et al.* 2012, *GCB*), rather than Anna Harper's new PFTs or JULES-CROP, which might modify my GPP results.

•How reliable are the drought indices we've used? There are several alternatives.

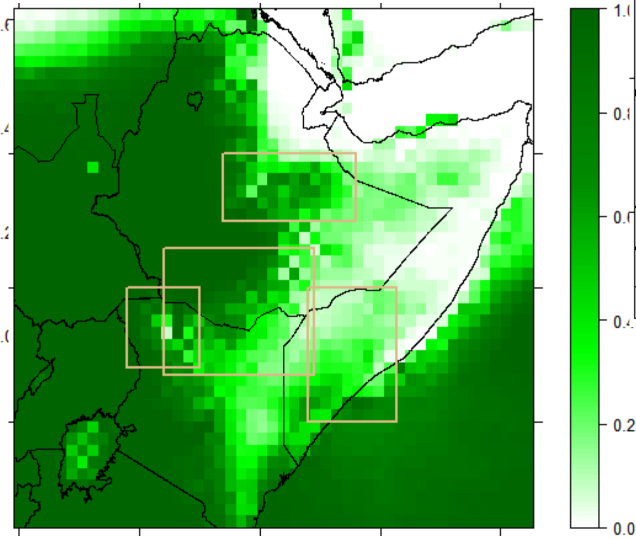
•We have identified areas of heightened drought risk. Ethiopia and Sudan are both investing heavily in hydroelectric power. How will this affect our recommendations for infrastructural responses?

NERC SCIENCE OF THE ENVIRONMENT
CEH Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL
Met Office
SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT
UNIVERSITY OF OXFORD

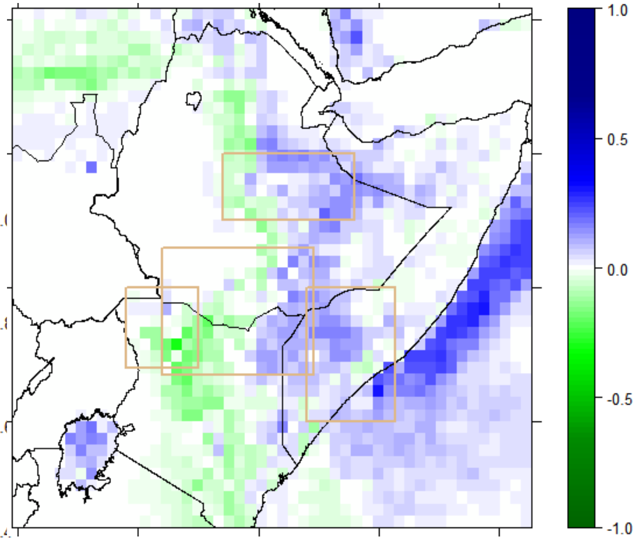
Thank you very much for your attention



Blue = High precipitation areas in the Horn of Africa under present day climate



Green = High precipitation areas under a climate without GHG emissions



Difference map: left plot minus centre plot

www.TobyMarthews.com

NERC SCIENCE OF THE ENVIRONMENT

CEH Centre for Ecology & Hydrology NATURAL ENVIRONMENT RESEARCH COUNCIL

Met Office

SCHOOL OF GEOGRAPHY AND THE ENVIRONMENT

UNIVERSITY OF OXFORD