What JULES can tell us about change in the Horn of Africa bimodal rainfall region in 2014 (the ACE-Africa project)

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Lancaster, 29th June 2016

The ACE-Africa project

Drought forecasted in Jun 2014.

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?*

My role in this research has been 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.

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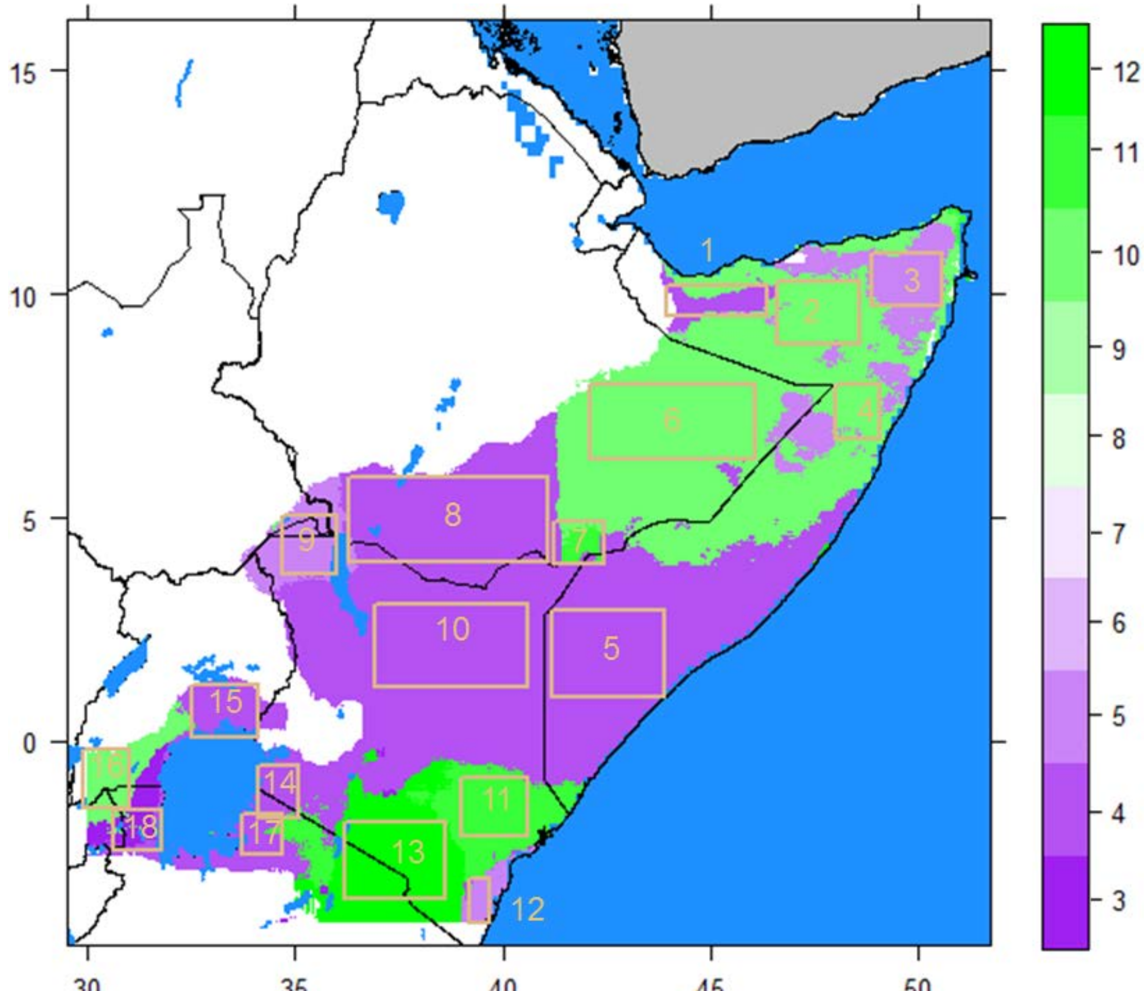
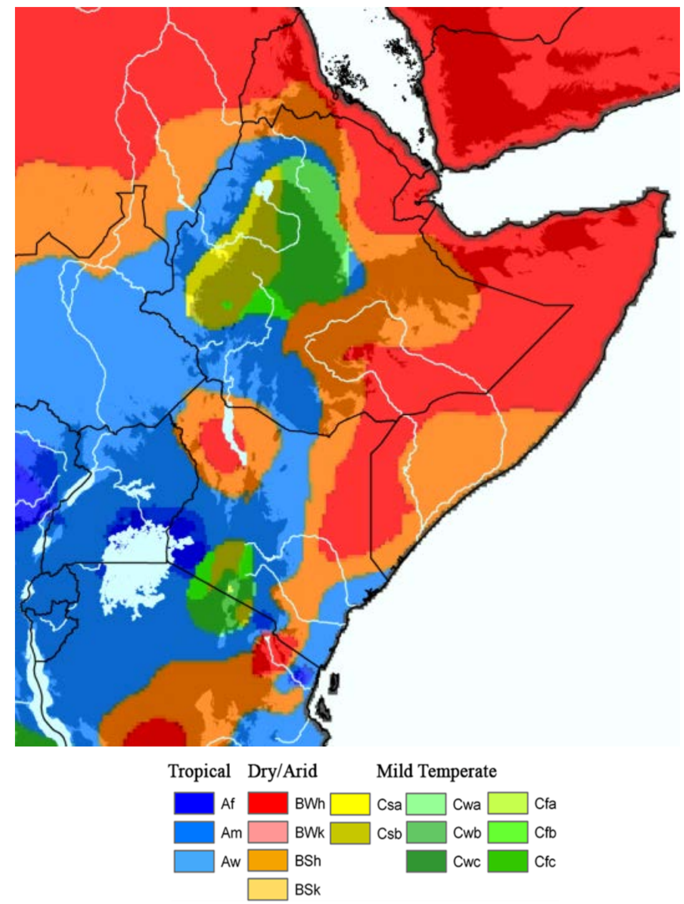
The Horn of Africa bimodal rainfall region





Shaded area = the zone of bimodal rainfall in this area of Africa (the ‘long rains’ March to May and the ‘short rains’ October to December) from TAMSAT data 1983-2012.

Shades of violet = modal rainfall in Mar, April or May; green = October, November or December.

Right: Köppen-Geiger arid and semi-arid zones

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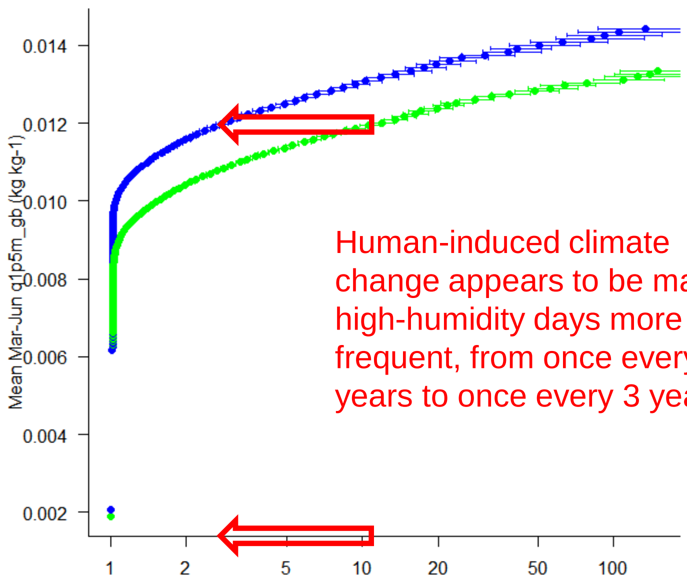
Probabilistic Event Attribution (PEA)

We have used 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 used **two ensembles**:

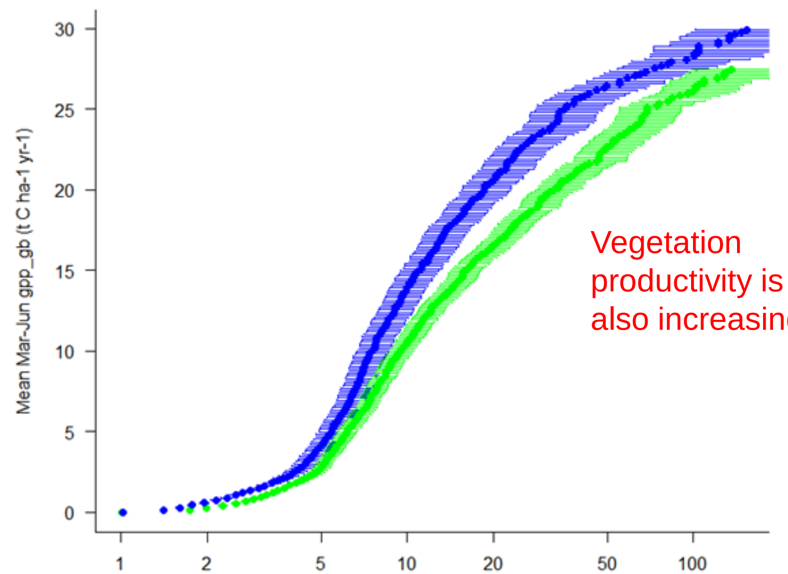
- One ***factual*** using climate data that describes the real climate of 2014
- One ***counterfactual*** using an atmosphere without human greenhouse gas emissions.

Specific humidity



Return time of extreme event (years)

Gross Primary Productivity (*GPP*)



Return time (years)

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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

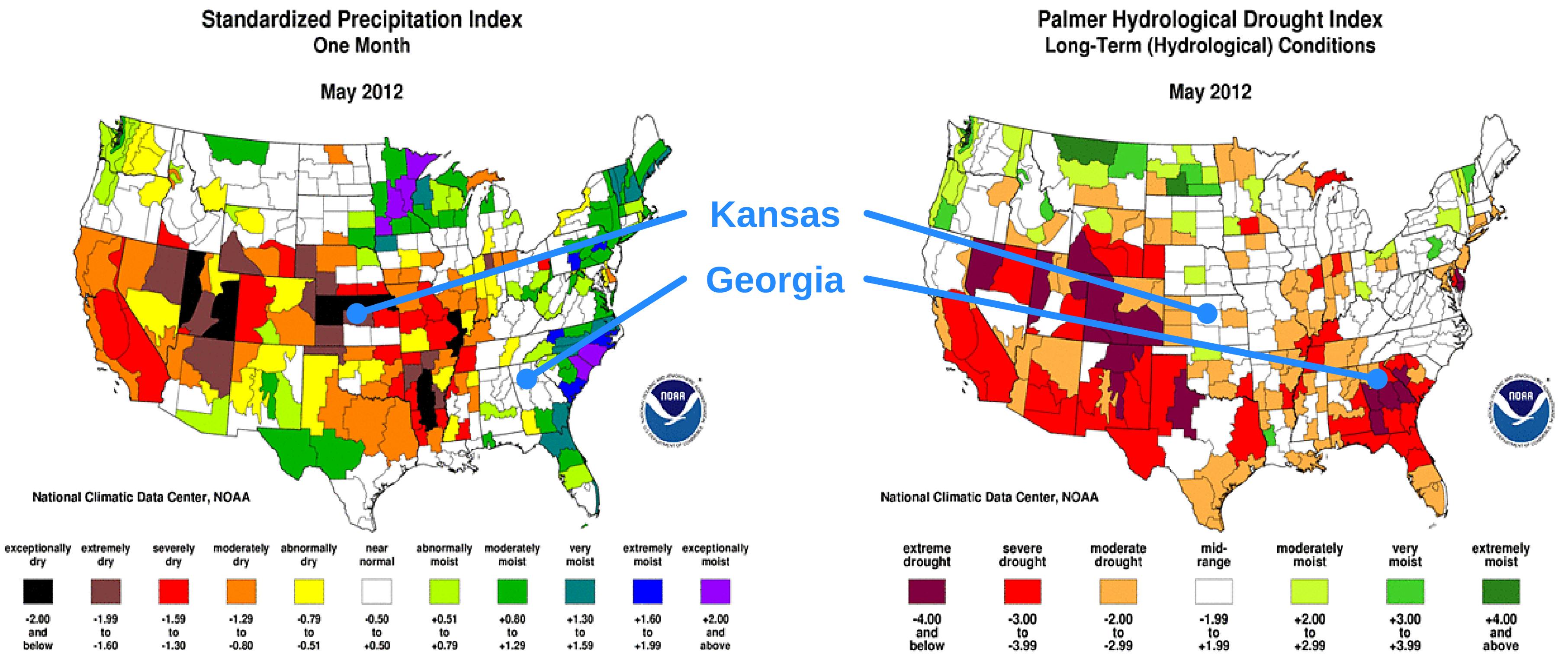
No spin-up,1 year straight run for Dec 2013 - Nov 2014 using factual ensemble members.

Counterfactual runs

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

Remember there are different types of drought

Where drought occurs depends importantly on how you define it: for example, *climatological drought* (i.e. unusual precipitation deficit) and *hydrological drought* (i.e. reduced soil moisture and/or streamflow) did not always coincide in 2012 in the USA.



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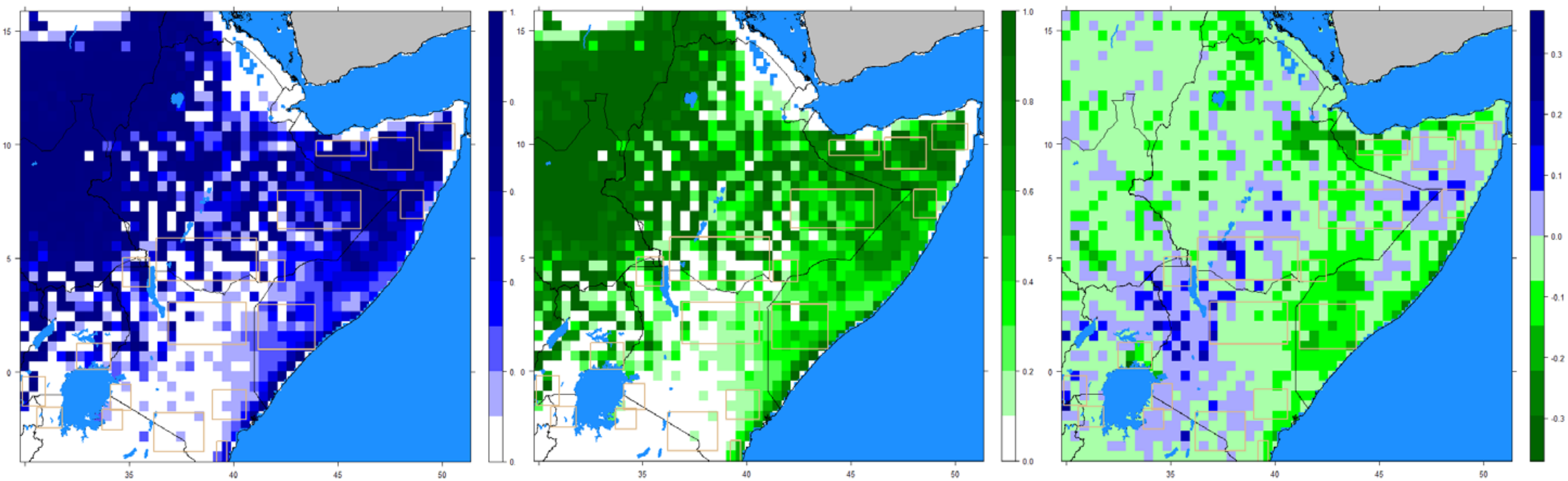
Results

Climatological drought areas during the East African Long Rains season 2014 (all maps are averages over the March-May season). Here, drought is defined by the Standardised Precipitation Index *SPI* being more than 1.0 standard deviation lower than the long-term mean (the standard level for “moderately dry or drier” environments, WMO 2012), calculated from the regional climate model HadRM3P.



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

Climatological drought risk seems to be increasing in W Kenya, Uganda and NE Somalia but *de*creasing in the agricultural heartland of SW Somalia and the coast.

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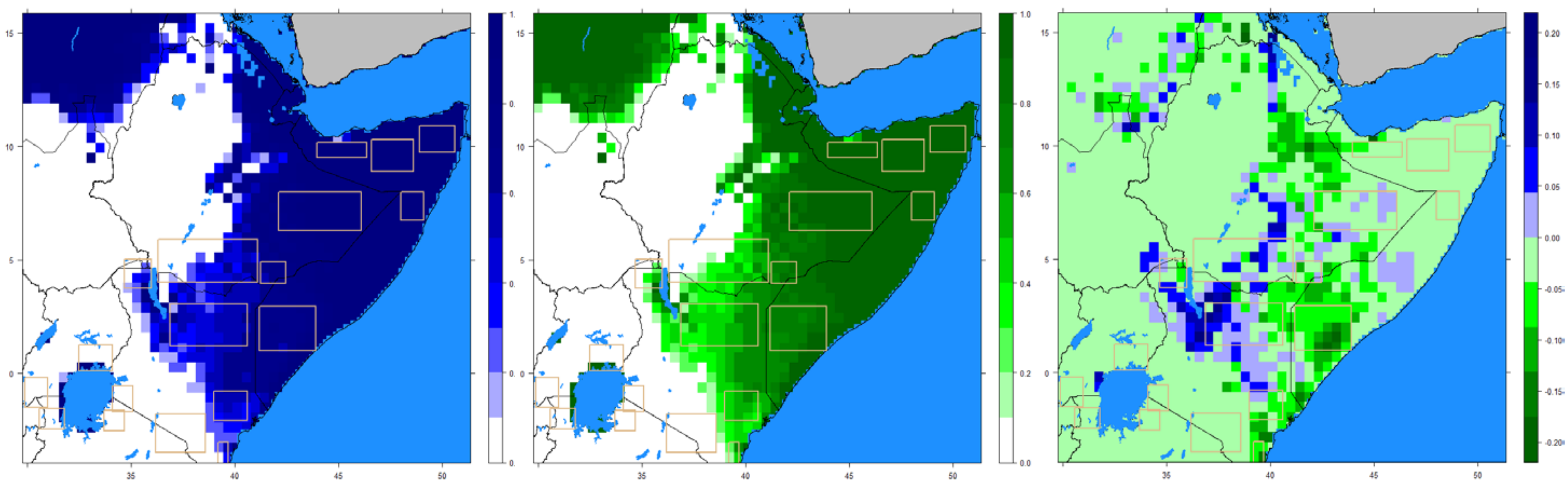
Results

Land surface drought areas during the East African Long Rains season 2014 (all maps are averages over the March-May season). Here, drought is defined by actual evapotranspiration (*ET*) being <1 mm/day, calculated from the land surface model JULES.



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Land surface drought risk seems to be increasing in NW Kenya but *de*creasing in SW Somalia, but the distribution is not the same as for climatological drought.

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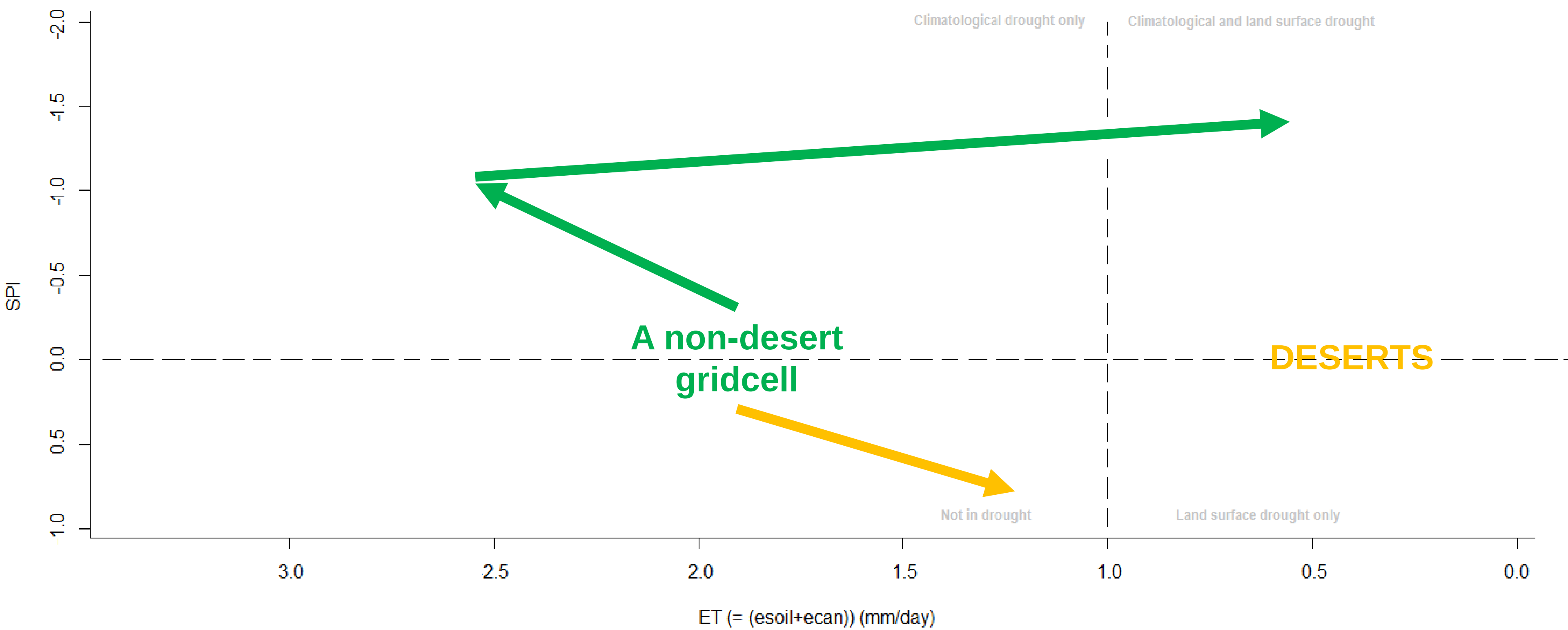

- A state-space plot: Climatological drought on y and land surface drought on x (note both scales are inverted so highest drought status is top right)
- Permanently arid regions (deserts) usually have evapotranspiration (*ET*) <1 mm/day and have SPI close to zero, but this is not climatological drought in terms of SPI because precipitation levels are already minimal and cannot be reduced in comparison to baseline conditions.
- What would happen to a non-desert gridcell in the middle of Kenya if it suddenly experienced very low rainfall? Well, SPI would decrease and ET would initially increase, but after a while the available water in the soil column will decrease and then ET rates will drop.
- Instead, what if rainfall increased, but became more episodic? In these sandy soils, large amounts of water will simply drain through to groundwater recharge, with the odd effect that increased rainfall can lead to reduced ET (Taylor *et al.* 2012).

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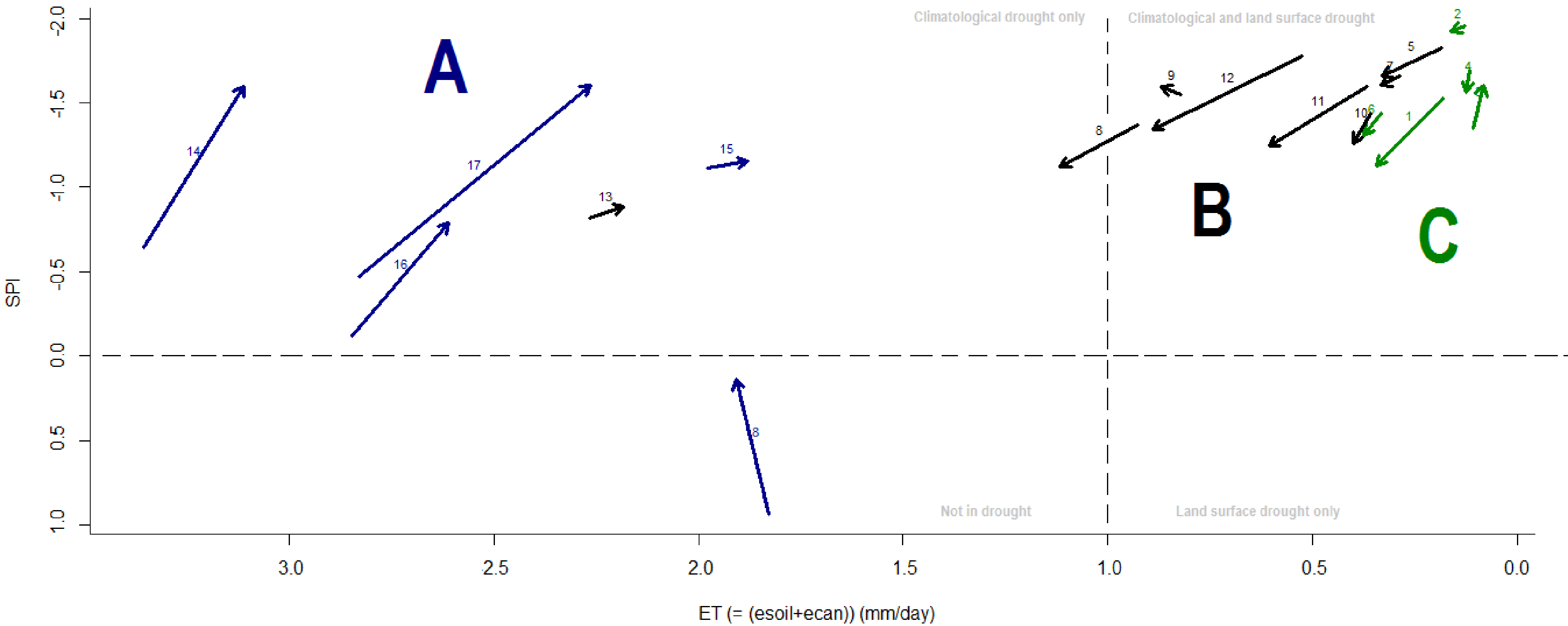

•Here are the trajectories for my 18 study regions, grouped into three distinct 'drought trajectories' in the Horn of Africa bimodal rainfall zone (arrows run from counterfactual to factual ensemble means):

•Trajectory A: an attributable worsening of drought for the Lake Victoria part of the zone as a result of human-induced climate change

•Trajectory B: An attributable drift out of drought for the central part of the zone as a result of human-induced climate change

•Trajectory C: Drought status in E. Ethiopia and N. Somalia broadly unaffected by climate change in the remaining eastern parts of the zone

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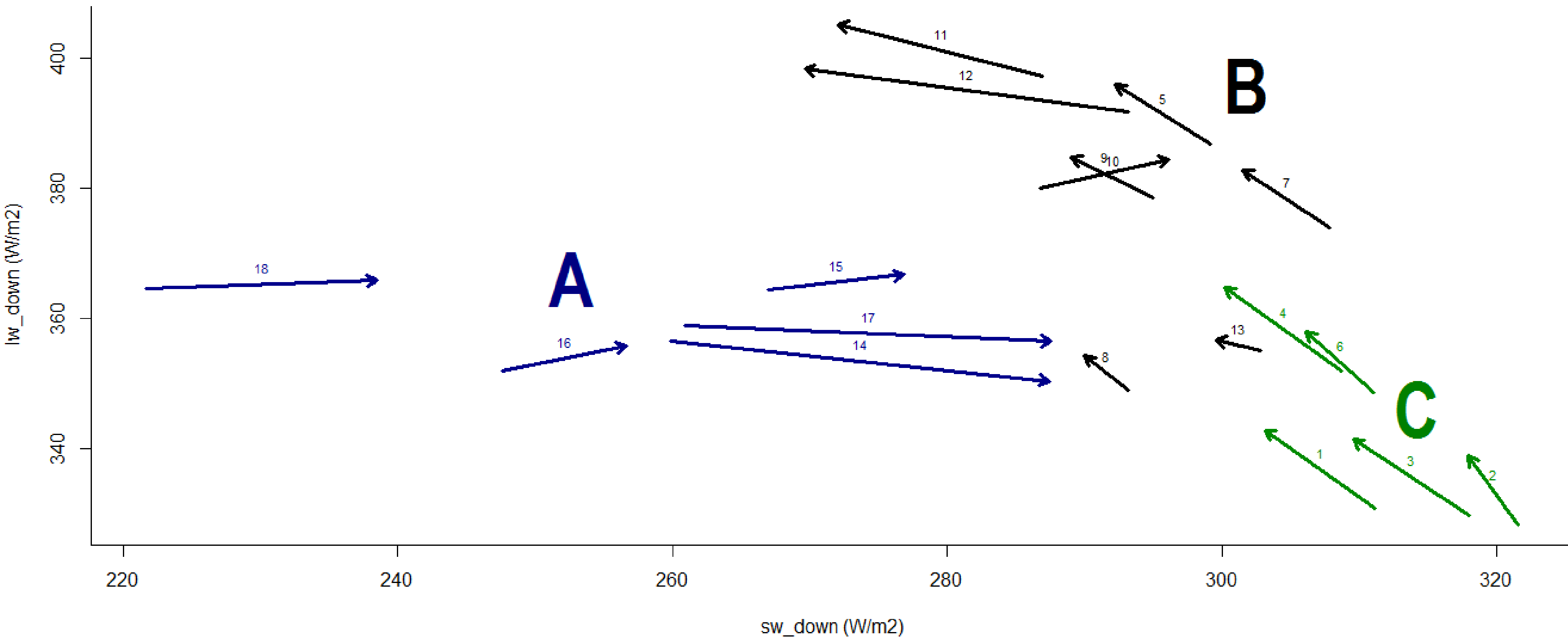

•Variation in down-welling radiation across the bimodal rainfall zone of the GHoA. Regions in the vicinity of Lake Victoria have blue arrows, those in eastern Ethiopia and northern Somalia have green arrows while the remainder have black arrows. The drought trajectories are:

•Trajectory A: An attributable increase in mean SW radiation as a result of human-induced climate change, with no change in LW radiation received.

•Trajectory B: An attributable decrease in mean SW radiation as a result of human-induced climate change, accompanied by an increase in LW as well (indicating increasing cloud cover).

•Trajectory C: A slight decrease in SW accompanied by an increase in LW received at the surface

•Arrows run from counterfactual to factual ensemble means.

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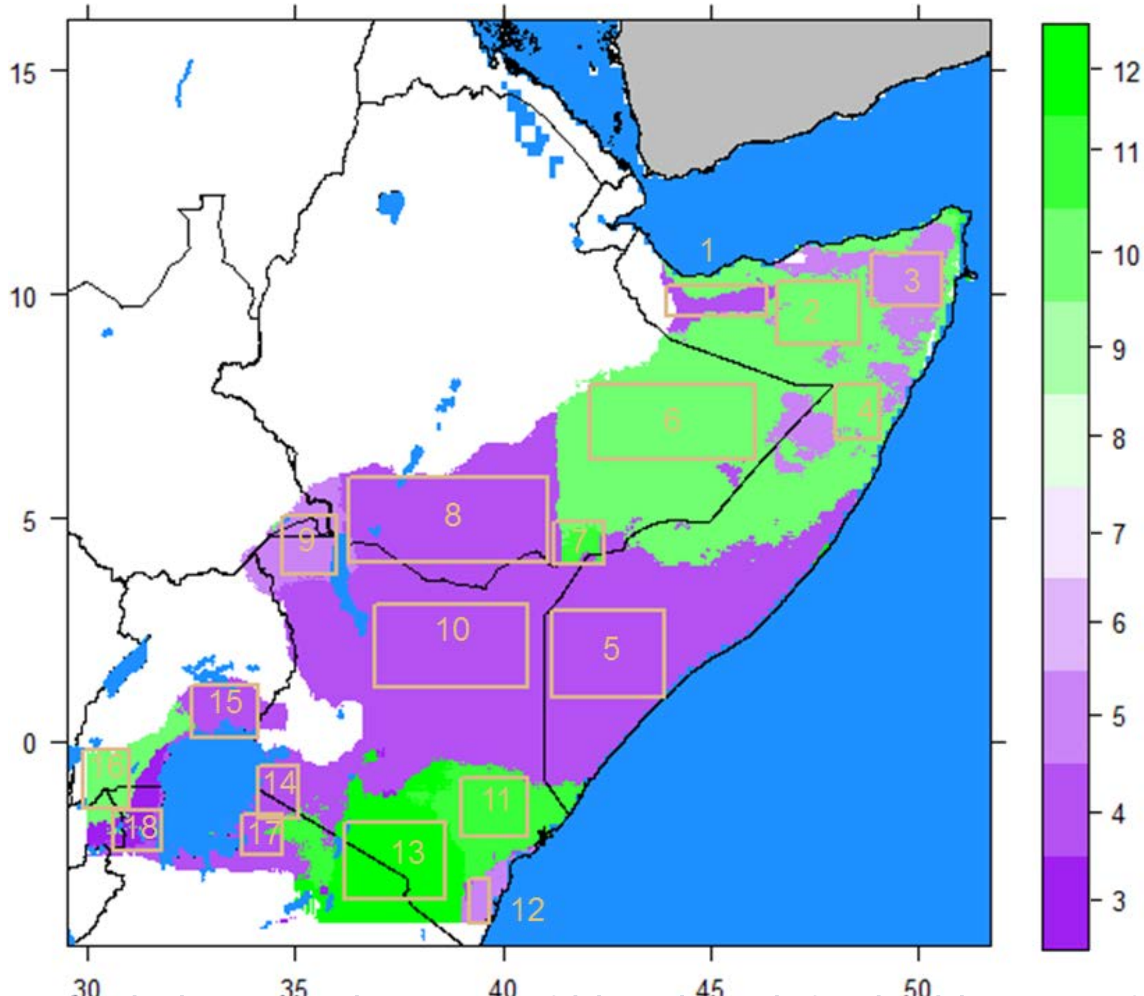

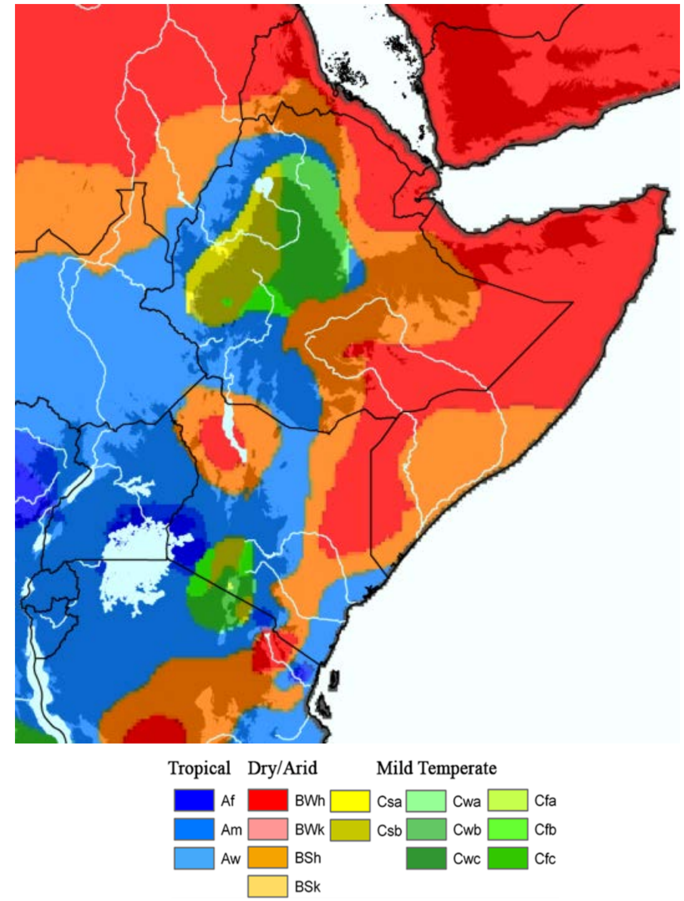

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Conclusions

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!) and we have identified three different ‘trajectories’ according to the differing impacts of anthropogenic climate change.

- The paradigm presented here may be of use in better understanding the climate across the Horn of Africa and planning appropriate response strategies for future droughts in these East African countries.

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A final comment

- There are great benefits from looking at ecosystems simultaneously from both the perspective of the carbon cycle and the perspective of the water cycle (e.g. is this a 'floodplain' or a 'riparian ecotone' or a 'gridcell with ~5% open water surface'?).

- Ecologists are trained to be comfortable thinking of forest-savanna transitions and ecotones (e.g. Amazon-Cerrado). Hydrologists are also very comfortable thinking of wetlands that grow and shrink with the seasons (e.g. Okavango). I think modellers need similar flexibility: we mustn't let convenient quick-fix modelling solutions too easily become standard modelling 'configurations'. For example, constant global fields of SW diffuse fraction, PFTs, river courses with negligible surface area: all are sometimes very reasonable modelling assumptions, but nevertheless very unreasonable in particular environments.


Thank you very much!
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