Met Office
Hadley Centre

The DFID-Met Office Climate Science Research Partnership (CSRP): overview

UKaid from the Department for International Development

Major progress in reducing poverty sustainably in Africa can be achieved through improved predictions of climate variability and change. This needs improved understanding and modelling of the African climate and its drivers. The African Climate Science Research Partnership (CSRP) between the UK government's Department for International Development (DFID) and the Met Office Hadley Centre (MOHC) is working, in consultation with African stakeholders, to: improve understanding of the drivers of African climate variability and change, improve prediction on monthly-to-decadal timescales, develop climate monitoring and attribution systems and support use of climate science in Africa.

Consultation
Establish the climate variables for which improved prediction is a priority to guide the research and maximise usefulness in practical decision making.

CSRP-Africa

Improved understanding and modelling of African climate
Hadley Centre climate model evaluated and developed for improved monthly-seasonal-decadal prediction over Africa.

Real-time monthly-seasonal-decadal prediction products
Experimental forecast products and early warning systems, jointly designed with users.

Monitoring and attribution
Near real-time observational monitoring and attribution system – providing advice on the contribution of man-made climate change to observed climate extremes.

Downscaling
Develop and evaluate trial downscaled seasonal predictions using the MOHC PRECIS system (Providing Regional Climates for Impact Studies) run at African centres.

Knowledge management
Workshops and study fellowships at African institutions focus the research and enhance professional development of African scientists.

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Consultation

As part of the consultation, a questionnaire was fielded to nine African organisations providing climate services (including regional centres and National Meteorological and Hydrological Services).

The aim was to help identify research directions that will best contribute towards meeting demand in Africa.

Climate-model-based seasonal forecasts of 3-month rainfall totals, expressed in terms of probabilities of below-, near- and above-normal rainfall, are relatively well established operational products available to climate service providers in Africa to use along with other tools for providing climate services. These products were used as a reference point for the questionnaire, with respondents asked to rank, in order of priority, 4 options for developing/extending these existing prediction products:

1) Provision of finer geographical detail, through downscaling;

2) Provision of information on the temporal distribution of rainfall (e.g. onset and cessation of rainy season);

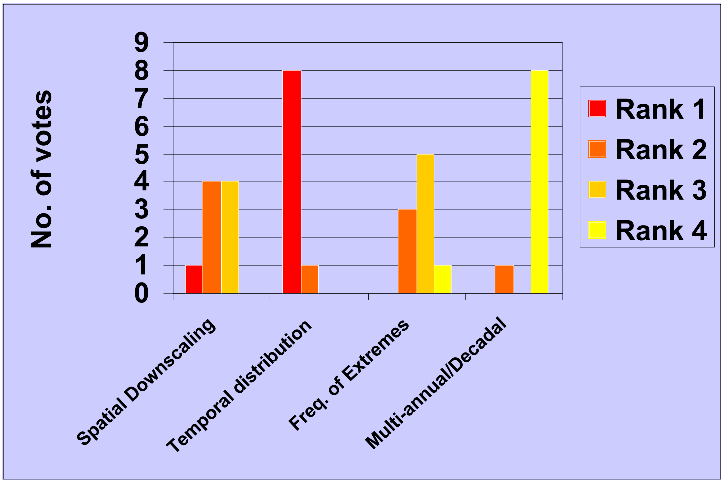
3) Provision of information on the likely frequency of ‘extreme’ daily events within the 3-month season;

4) Extension of the prediction range to cover interannual- to decadal -range predictions.

Results are shown below.

Predictions of the temporal distribution of rainfall were seen as the highest priority, with information on downscaling and the frequency of extreme rainfall events approximately equal in second place. Interannual to decadal predictions were seen as very important to develop, but of lower priority than developing reliable and useful predictions on seasonal timescales. These results were broadly endorsed by other organisation types across 8 African countries.

Ranking of priorities



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CSRP: model testing – Africa teleconnections

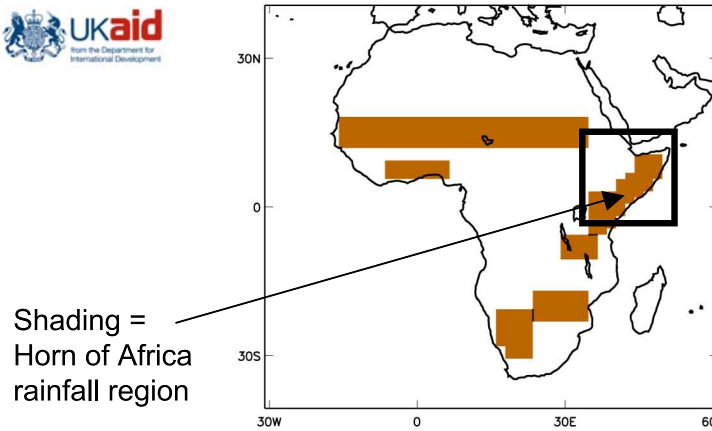
How well are processes driving African rainfall represented in current climate models?

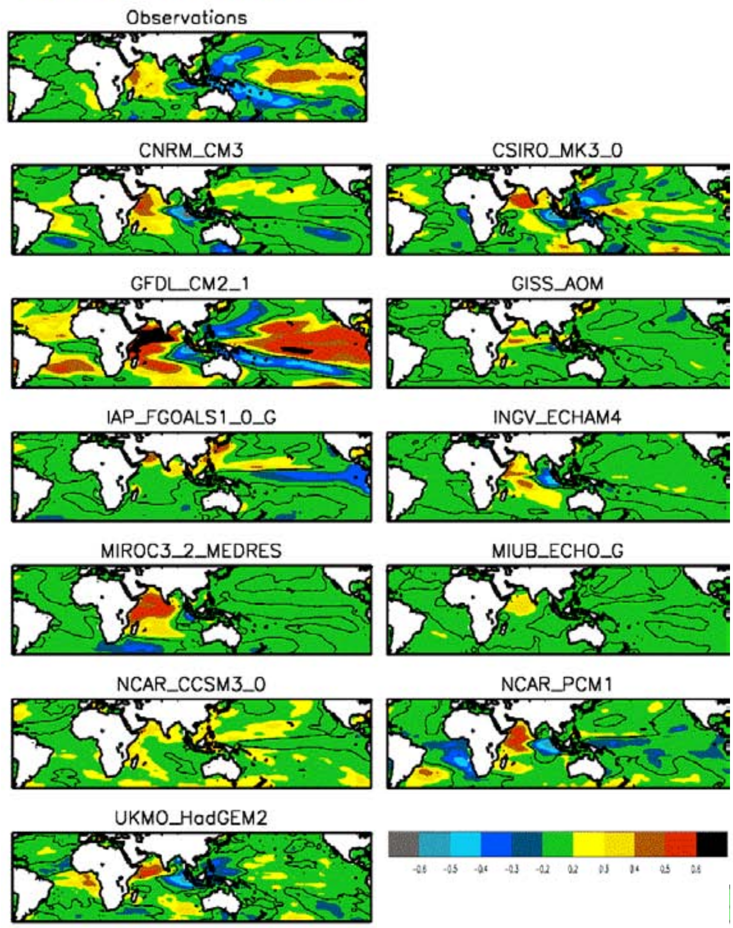
Answers to this question are essential for **a)** informing our confidence in climate predictions for Africa, and **b)** identifying model weaknesses over Africa to be prioritised for improvement.

The CSRP is undertaking important performance 'benchmarking' for Africa, that is driving model improvements. As an example, the figures on the right show observed and modelled correlations of global sea surface temperature (SST) with October-December rainfall over the Horn of Africa area **–** which has recently experienced severe drought. Observed correlations (top) show the well known 'teleconnection' links between Horn of Africa rainfall and variability in the surface temperature of tropical Pacific and Indian Oceans.

None of the ocean-atmosphere models used in the IPCC's 4th Assessment Report fully reproduced these connections in long simulations and important 'teleconnection' effects are missing in these models at present. In contrast, seasonal predictions – which are of shorter range than these long climate simulations - generally have a much better representation of key teleconnections.

Further CSRP research is in progress to uncover the reasons for the poor model teleconnections for this and other parts of Africa to provide a basis for improved climate modelling for Africa.





Ocean temperature patterns driving Horn of Africa rainfall

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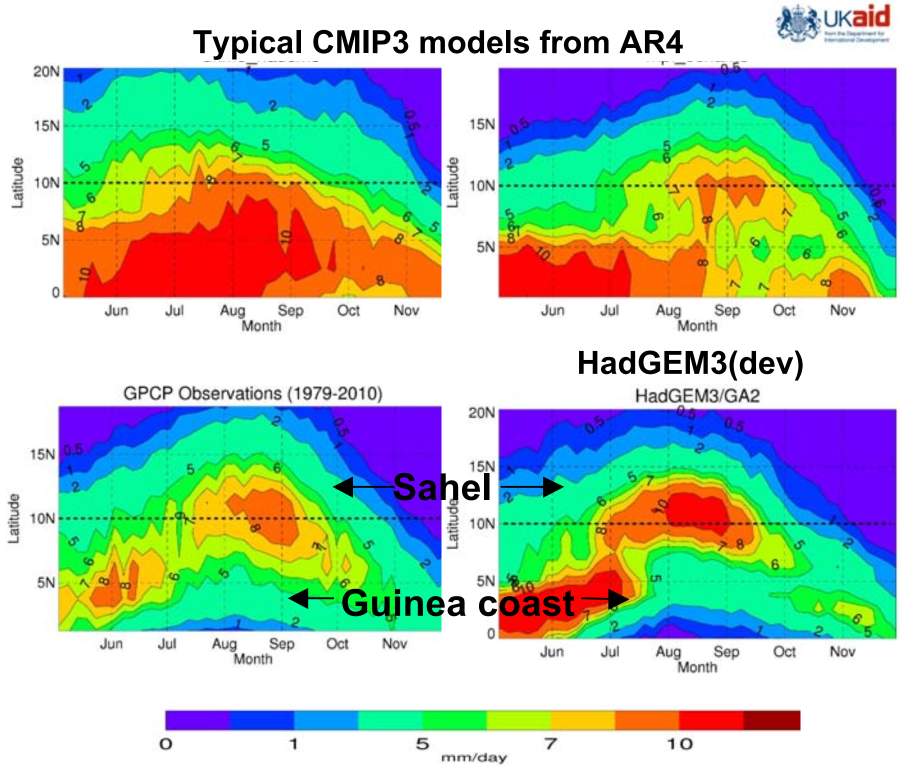
CSRP: model testing – African climate systems

Climate models used in the IPCCs 4th Assessment Report (AR4) show no consensus in the sign of future precipitation changes over West Africa. Improvement of climate models may reduce this uncertainty. How well is the primary rain-bringing system – the West African Monsoon (WAM) – currently represented in climate models?

Simulation of the northward progression of rains during the WAM is typically inadequate in AR4 models (compare typical results from 2 models (row 1) with the observed average progression (row 2, left). The horizontal (time) axis runs from May to December. A reference line at 10ºN is drawn on the vertical (latitude) axis. Shading shows the intensity of rain (mm/day) averaged over the east-west strip 10ºW-10ºE. In general the AR4 models do not achieve sufficient advancement of the rains north of 10ºN into the Sahel (‘Sahel onset’). The timing at which the most intense rain shifts from the Guinea coast to the Sahel, early July in observations, is reasonable in some models but not in others (e.g. too late in row 1, far right).



This less than adequate representation of the WAM likely hinders both reliable seasonal prediction of rainfall and projections of regional climate change.

A development version of the Met Office HadGEM3 model has been found to have a relatively good representation of the WAM (row 2, right), with realistic northward advancement of the rains and good Sahel onset timing. This good simulation suggests that factors controlling onset are realistically represented in HadGEM3, and that we can use the model as a proxy for the real atmosphere to learn more about the important processes controlling onset. Results have identified global patterns in sea surface temperature variations that influence onset timing and an important role for the land surface over the Sahel, particularly soil moisture.

Understanding of this kind is required to help improve climate models and to establish a physical basis for reduced prediction uncertainty.

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CSRP: tailored climate prediction and monitoring products

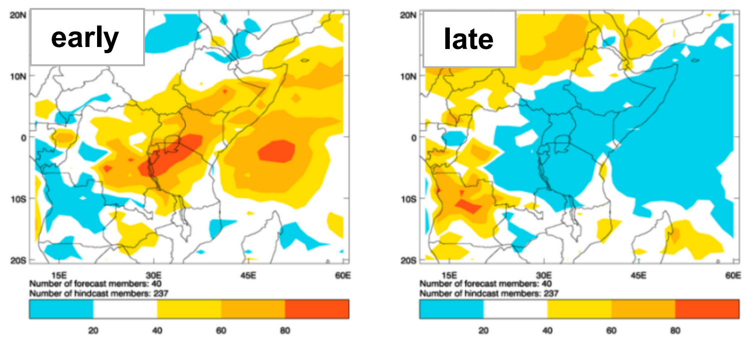
Improved seasonal climate predictions of the temporal distribution of rainfall through the season (e.g. timing of season onset and cessation) were highlighted as a priority in results from the CSRP consultation. This reflects the continent's strong socio-economic dependence on rain-fed agriculture.

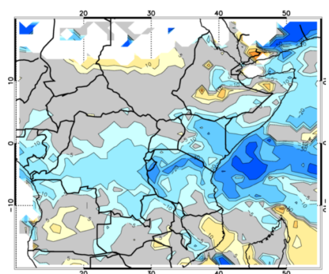
Many National Meteorological and Hydrological Services in Africa issue predictions of onset and cessation timing using statistical methods. Working with African users, and employing the Met Office's GloSea4 seasonal prediction system, CSRP research is developing experimental prediction products that will provide additional tools to help users prepare regional and national predictions of onset timing. These new products are being trialled at Regional Climate Outlook Forums in East, West and southern Africa – with encouraging results.

In these products the predicted early(late) arrival of 20% of the long-term average seasonal total (20%LTA) is taken as an indicator of early(late) season onset.

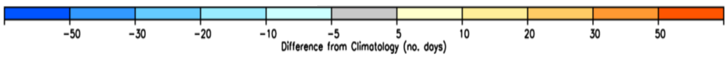
(For a number of reasons, standard definitions of onset based on absolute daily rainfall values are generally unsuitable for use with climate model output).

Probability forecast for onset: short-rains 2011





2011 short-rains monitoring:
Left: observed timing of the arrival of 20% of the local long-term average short-rains seasonal total. Expressed by difference in days (negative = early) from the long-term average time of arrival. Derived from CPC FEWS Rainfall Estimates.



Row 1 gives an example forecast, issued in August, for the 2011 October-December short-rains season over the Greater Horn of Africa. The predicted probability of early arrival of 20%LTA was >60% in many regions (orange-red shading – row 1, left), much higher than the 'usual' (climatological) risk of early arrival (33%) and higher than the predicted probability of late arrival (<20%: blue shading, row 1, right). The arrival of 20%LTA was indeed observed to be early (up to 30 days in some regions) over much of the area where this was predicted with high probability (row 2). Although striking, this single case is not enough to evaluate the performance of the forecasting method – rather we must assess the method over many forecasts. Assessment over 14 years of retrospective forecasts is encouraging, and indicates that late/early onset is correctly identified in about 70% of cases over parts of Kenya and Tanzania.

Used with local prediction methods and expertise these trial forecasts have potential to provide valuable information on onset to the agricultural community, and thus to increase food security.

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CSRP: increasing seasonal forecast detail with regional climate models

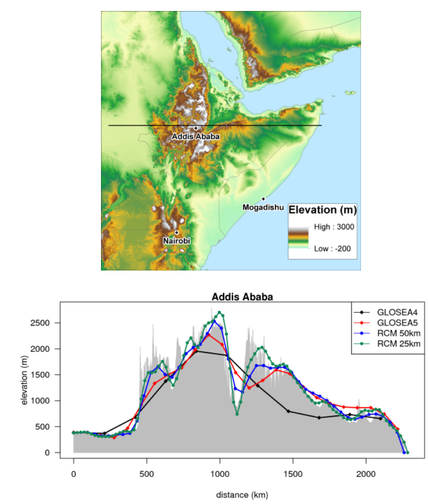
"The forecast is for El Niño – how will this effect the rain in our agricultural regions and the water in our rivers?" Regional Climate Models (RCMs) help answer such questions by adding local detail to global-scale forecasts.

Forecasts from seasonal prediction systems based on global climate models (GCMs) are used in forming consensus seasonal outlooks issued by regional centres in Africa and elsewhere.

As the name suggests, GCMs cover the whole world – as they must to capture the global interactions of the climate system – for example the influence that El Niño has on rainfall over many regions. Thus GCMs focus on the large scale rather than the regional details. In contrast, RCMs represent atmospheric and land-surface processes as well as topographical features with greater detail than GCMs through focusing on a limited geographical region. If the two are coupled together, the RCM adds a 'magnifying lens' to GCM forecasts – a process known as 'downscaling'. The use of RCMs to downscale seasonal forecasts is relatively new.

The CSRP has developed a new RCM based on the Met Office Hadley Centre (MOHC) model, HadGEM3, and implemented it at the IGAD Climate Prediction and Applications Centre (ICPAC), Nairobi. This has initiated a collaboration exploring the use of RCM downscaled seasonal forecasts to enhance regional seasonal consensus forecasts for the Greater Horn of Africa (GHA) region.

A workshop at ICPAC examined RCM seasonal forecasts for 4 short-rains (Sep – Dec) seasons, noting benefits and challenges (see example) that need further investigation as well as scoping strategies for potential sustained use of the RCM in generating regional outlooks.



Above: Complex terrain in the GHA can drive important local climate variations. The section through Addis Ababa shows that terrain elevation as represented in the RCM (green – 25km grid) is much closer to reality (grey) than that of some current global models (black and red).

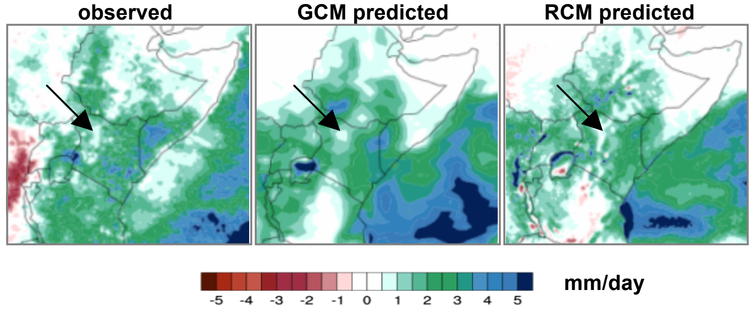
A case study (below, right) illustrates some potential benefits and challenges:

The study looked at differences in rainfall between 2005 and 2006 (both observed and predicted). The generally wetter conditions in 2006 (an El Niño year with widespread flooding) relative to 2005 (a La Niña year with drought) is clear in observations (left). This difference is generally well captured using selected forecasts from the MOHC GCM seasonal system (middle) and by RCM downscaling of the GCM forecasts (right).

- The RCM provides a more useful indication of a narrow band (arrowed) along the Turkana basin/Rift Valley where rains in 2005 and 2006 were similar.
- The RCM adds realistic detail over the Ethiopian highlands – but it is not clear whether this generally improves on the GCM forecasts. Some added RCM detail appears unrealistic (e.g. large differences over coastal Tanzania).
- The RCM cannot improve the GCM forecasts where the latter have substantial errors (e.g. over much of Tanzania).

Difference (mm/day) between short rains rainfall 2006 and 2005 (2006-2005)

observed | **GCM predicted** | **RCM predicted**



Green/blue shading = 2006 wetter than 2005

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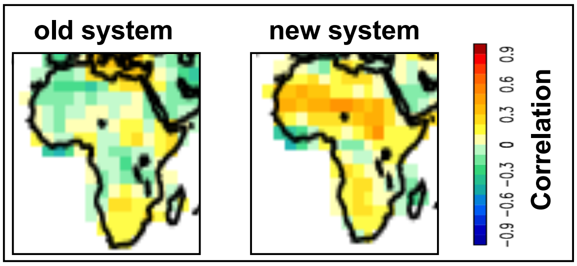
CSRP: development of decadal predictions for Africa

Decadal prediction: "Over the next five to ten years will rainy seasons in my region bring predominantly below, normal or above normal rainfall?"

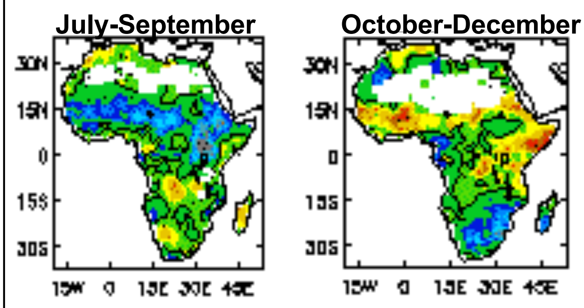
A new version of the Met Office's Decadal Prediction System, based on the HadGEM3 climate model, is enhancing our ability to address this and similar questions crucial to development of climate resilience.

Predicting one to two years ahead: Sea surface temperature fluctuations in the tropical Pacific associated with the El Niño/La Niña cycle are key drivers of year-to-year variability in African rainfall (right, top). Prediction of the cycle is thus an important part of anticipating rainfall variability – and the further ahead we can predict, the more time gained to prepare responses to potential drought or flood. The Decadal System's predictions of El Niño/La Niña show significant correspondence with the observed cycle out to 18 months ahead (right, bottom) – offering potential for much longer-lead advisories on African rainfall than currently available.

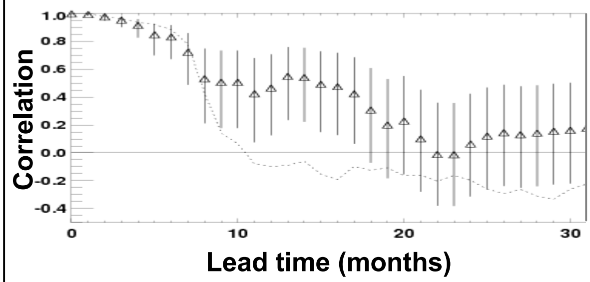
Predicting for the next five to ten years: Reliable predictions of average rainfall over the next five to ten years will provide valuable insight into near-term climate trends. The science for such predictions is still developing, but the new Decadal System has made significant advances in our capability (below).



Assessment (using correlation) of Decadal System predictions of the next 5-year annual rainfall average, evaluated over 22 retrospective forecasts. Left – previous decadal system; right new decadal system. Correlations are positive (yellow/red) over a much larger proportion of Africa in the new system. Improvements are substantial in the Sahel region where correlations scores for the new system reach 0.6.



Influence of tropical Pacific El Niño/La Niña index on rainfall. Blue shading: El Niño(La Niña) typically brings below(above) normal rains. Yellow/red shading: El Niño(La Niña) typically brings above(below) normal rains. July-September (left) is the peak season of the Sahel; October-December (right) is a key season for both the Greater Horn of Africa and southern Africa.



Correspondence of Decadal System predictions of a monthly El Niño/La Niña index (known as Nino3.4) with the observed index, as measured by correlation (Corr). Corr = +1 signifies perfect forecasts; Corr = 0 implies no correspondence between forecasts and observations (i.e. forecasts are no better than guesswork). Triangles show correlation values, vertical lines the 95% confidence range. Correlations decrease with lead time – but exceed zero (with high confidence) out to 18 months.

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CSRP: attribution of extreme events in the African climate

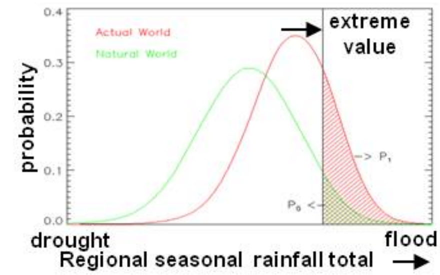
A question often asked in the aftermath of extreme climate events like drought or flood is: 'to what extent did human-induced climate change play a role?'

Such questions must be rigorously addressed to avoid inappropriate (potentially expensive) adaptation measures. Therefore the CSRP is developing attribution methodology that estimates the role of human-induced climate change in increasing the risk of extreme events. Work is focusing on the recent severe drought in the Greater Horn of Africa (GHA), in which both the October-December 2010 'short rains' season and the March-May 2011 'long rains' season failed.

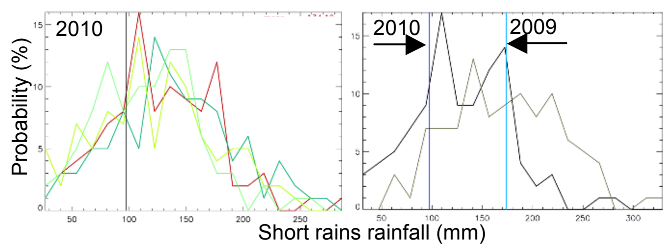
Methodology: The HadGEM3 climate model is used to re-create the global climatic factors that prevailed during the drought. The rainfall response to these factors is then simulated for the 'actual' (present-day) world and a 'natural' (pre-industrial) world from which the accumulated effects of human influences are removed. That is, we generate realistic simulations of the green and red schematic curves described opposite (top).

The role of natural variability: The short rains seasons of 2010 had very different global factors operating relative to the previous year: in 2010 La Niña prevailed, while in 2009 El Niño was active. The 'actual' world simulated rainfall responses over the GHA show a marked relative shift to dry conditions in 2010 indicating increased chance of drought (below right). This result is consistent with the known influence of El Niño/La Niña over the GHA and indicates that natural forcing played an important role in the failed short rains.

The role of climate change: For the 2010 short rains, the actual world 'curve' shows shows no appreciable dry/wet (left/right) shift relative to three estimates of the natural world curve (below, left) in contrast to the schematic. This suggests that climate change had little impact on the failed 2010 short rains. However, for the long rains this may not be the case. Analysis of the 2010 and 2011 long rains is ongoing – results will be in our next update.



Above: Schematic illustrating the technique of event attribution, which determines how natural and/or man-made factors influence the probability of extreme climate events. The red curve represents the distribution of possible rainfall in the world as it is today, following changes in the climate. The green curve represents the 'natural' world that might have been without man-made climate change. The vertical line denotes a value of rainfall, beyond which events are considered extreme. This is usually based on an observed event in the real world such as a flood or drought. By comparing the area under the curves beyond this line (*i.e.* comparing P_1 to P_0), we may determine how climate change has increased or decreased the probability of an extreme event. In this illustration flood events become more likely but in reality shifts of both directions are expected, depending on the region.



Above left: Simulated rainfall probabilities for the 2010 short rains in the GHA, in the 'actual' world (red) and 3 possible 'natural' worlds (green). Although there are differences in detail, no overall dry/wet shift is seen.
Above right: 'Actual' world simulations for the short rains of 2010 (a La Niña year – black), and 2009 (an El Niño year – grey). Note the shift to dry of the 2010 'curve'.
Both: Vertical lines show observed rainfall totals.

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CSRP: knowledge management

Through a fellowship scheme, 11 African climate scientists have been funded to work on research themes related to CSRP outputs – helping to advance the project's objectives while strengthening their professional development. Additionally, in collaboration with African climate centres, the CSRP is holding workshops – contributing to the strengthening of climate science in Africa.

UKaid from the Department for International Development

The CSRP fellowship scheme:

Eleven fellows have been appointed: 4 from East Africa, 4 from West Africa, 2 from southern Africa and 1 from Central Africa.

Fellows are conducting their studies at an African Institute, with a 1-month visit to the Met Office to consolidate research plans, collect data for their project and to meet with groups working on African climate at UK Universities.

Themes covered by fellowship projects include: investigation of climate processes, evaluation of global and regional climate models, seasonal forecasting, decadal forecasting and construction of observational datasets.

Each fellow is working with a Met Office scientist (mentor) specialising in the chosen research theme.

Left to right below: CSRP Fellows Ismaila Diallo (Senegal), Wilfried Pokam Mba (Cameroon) and Arlindo Meque (Mozambique), standing next to their appointed Met Office mentors.

The first CSRP workshop:

A 2-week training workshop on appreciation and use of dynamical seasonal forecasts for the Greater Horn of Africa (GHA) was delivered jointly with the IGAD Climate Prediction and Applications Centre (ICPAC), who also hosted the workshop at their headquarters in Nairobi, 6-17 June 2011.

The workshop was designed to develop participants' skills in interpretation of forecast products from climate-model-based seasonal prediction systems – to strengthen the use of such products alongside existing statistical prediction tools. The workshop also constructed the first ever consensus prediction for the July-September season in the north of the GHA, and this was delivered and discussed in a forum with users.

Fifteen climate scientists participated including representatives from the National Meteorological and Hydrological Services of 9 countries: Sudan, Eritrea, Djibouti, Ethiopia, Uganda, Burundi, Rwanda, Tanzania and Kenya.

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