Met Office
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Targeting climate research and services to development needs in Africa:

The DFID-Met Office Hadley Centre Climate Science Research Partnership (CSRP)

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ABSTRACT:
The objectives of the DFID-Met Office Hadley Centre Climate Science Research Partnership (CSRP) are improved understanding of the drivers of African climate variability and change, improved prediction on monthly-to-decadal timescales, development of climate monitoring and attribution systems and strengthened use of climate science in Africa. Objectives have been shaped through consultation with Africa stakeholders to optimise usefulness of the research to the development agenda.
To contribute to improvement of climate models and reduced uncertainty in climate predictions a study has been made to investigate, for the whole African continent, the ability of climate models to represent remote influences (teleconnections, e.g. from the El Niño Southern Oscillation), on rainfall variability. Most climate models are found to have inadequate representations of several important teleconnections, and this provides a baseline for focussing model improvement. Higher horizontal resolution of models has been found to improve representation of teleconnections to African rainfall.
Rigour in attributing the role of human-induced climate change in extreme climate events will help avoid potential for misguided adaptation measures. To inform this, a climate-model-based near-real-time attribution system is in development. Preliminary analysis of the severe 2010/11 drought in the Greater Horn of Africa suggests a human-induced drying trend for the March-May 2011 season – however differences between this result and those of some other studies must be understood to bring more clarity to the issue.
Encouraging skill has been found for seasonal prediction of onset timing for West, East and southern Africa and experimental onset forecasts for the 2011/12 rainy seasons have been trialled at the Regional Climate Outlook Forums of these regions.
Through a CSRP fellowship scheme eleven African climate scientists, studying at African institutes, are collaborating on aspects of the programme's objectives. A workshop to strengthen use of dynamical seasonal forecasts has been delivered to representatives from 9 National Meteorological Services in countries of the Greater Horn of Africa.

1. INTRODUCTION

The Department for International Development (DFID) of the UK Government and the Met Office Hadley Centre have embarked on a climate science research programme known as the Climate Science Research Partnership (CSRP). The CSRP programme's overarching purpose is to advance capabilities for sustainable poverty reduction in Africa through improved understanding of the drivers of African climate variability and change, improved prediction on monthly-to-decadal timescales and strengthened capacity for use of climate science in Africa. Project objectives have been shaped through a consultation process with African stakeholders to determine the climate variables/parameters for which improved prediction is most urgent and to identify priority requirements for capacity building.

The CSRP is a 3-year programme running from January 2010 to December 2012. The work plan is organised in 5 output areas which are grouped into a science component and a knowledge management component. The top level objectives of the 5 output areas are summarised in section 2 (more information is available at http://www.metoffice.gov.uk/csrp). Selected results from the science component and activities from the knowledge management component are presented in section 3. A summary and plans for future work are in section 4.

2. CSRP OUTPUT AREAS

2.1 Science component

Output 1: Improved understanding and modelling of African climate and its drivers: The top level objective of this output area is to improve our understanding of the key drivers of African climate and their representation in climate models, leading to more reliable monthly-to-decadal prediction for Africa. Analysis is focussed on the new Met Office Hadley Centre climate model (HadGEM3) but includes analysis of models from other centres. Remote influences (e.g. ENSO) and local processes (e.g. land-atmosphere coupling) on climate variability are being investigated, as well as sensitivity to model resolution. The improved understanding will be consolidated into HadGEM3 development. A Working Group on African Climate has been set up to share outputs from CSRP, to harness UK-wide expertise and to link with African climate science networks.

Output 2: Seamless HadGEM3 monthly-seasonal-decadal prediction system and products: The top level objectives of this output area are to develop a seamless monthly-to-decadal prediction system for Africa using the improved HadGEM3 model emerging from output 1; to develop experimental prediction products for priority 'stakeholder variables' identified in the consultation process and to develop a near-real-time monitoring and attribution capability – providing advice on the contribution of anthropogenic effects on observed climate events.

Output 3: Dynamical downscaling: The Met Office's regional climate modelling system, PRECIS (Providing Regional Climates for Impact Studies) is being re-configured using the improved HadGEM3 model emerging from output 1 and evaluated for Africa, including as part of the Coordinated Regional Downscaling Experiment (CORDEX) established by the World Climate Research Programme. An experimental capability to run PRECIS 'in-country' at African centres using boundary conditions from the global seasonal prediction system will be developed. A capability to incorporate regional forcing scenarios into PRECIS is also being developed, including aerosols, tropical deforestation and other land-use changes.

2.2 Knowledge management component

Output 4: Strengthening climate science in Africa: A fellowship scheme has been implemented through which eleven African climate scientists at African institutes will work with CSRP outputs advancing the programme's objectives and enhancing their professional development. Fellowship projects are centred on 7 research themes closely aligned with CSRP aims. Engagement of African scientists will also be achieved through development of links between the Working Group on African Climate (see above) and African climate science networks (e.g. AMMA-Africa).

Output 5: Development of research products that target demand and are accessible to users: Workshops with African climate scientists and end users will be held to build capacity for pulling research into use (the first workshop, hosted by ICPAC, Nairobi, was held in June 2011). Key users being engaged include the climate service providers in Africa (e.g. regional climate organisations, Regional Climate Outlook Forums and National Meteorological and Hydrological Services). Other outputs include accessible technical papers, drawing on CSRP research, to inform policy forums and raise awareness of state-of-the-art capabilities for e.g. attribution, dynamical downscaling and decadal prediction.

Through its consultation process and knowledge management activities the CSRP responds to the need for much closer and sustained partnerships between producers and users of climate information, agreed as essential in the development of the Global Framework for Climate Services (initiated by World Climate Conference-3).

3. PROGRESS AND SELECTED RESULTS

3.1 Consultation with Africa stakeholders

A total of 52 interviews were held with a wide range of stakeholders in 8 African countries. Stakeholders included the main regional climate organisations, National Meteorological and Hydrological Services, universities, NGOs, government ministries and 'boundary organisations' acting on climate information to aid vulnerable communities. The overriding aim was to help identify research directions that will best contribute towards enhancing the range and quality of climate information available to users in Africa. The scope focussed on needs for monthly-to-decadal predictions, as these timescales are of most practical interest in developing resilience to climate variability and change. Key results are as follows:

- There was wide recognition that there is an urgent need to improve understanding and modelling of African climate to provide reliable climate early warning systems and information for adaptation;
- Improvement of seasonal-range predictions (to 6 months ahead) were seen as higher priority than multi-annual to decadal-range predictions, though the need for decadal-range information for adaptation is seen as urgent;
- There was a very strong signal that development of capability to predict temporal distributions of rainfall (e.g. season onset, duration, and dry spell frequency), was the highest priority need (Fig. 1). These findings are generally in accord with those of Ingram et al (2002).

The consultation also addressed training needs and possible ways to respond. The results of both the research and training prioritisation exercises were then used to make adjustments to the project's science and training components – see sections 3.2.3 and 3.3 respectively for further details

3.2 Selected results from the science component

3.2.1 Assessment of the ability of climate models to represent observed relationships between global-scale sea surface temperature and regional African rainfall: It is widely recognised that uncertainty in climate change predictions for Africa, most notably for changes in rainfall (see e.g. Conway, 2011), is a key impediment to their use in climate change adaptation. To reduce prediction uncertainty, improved climate modelling for the continent is needed and this in turn requires research to better understand the processes that drive climate variability over the continent and to improve the representation of these processes in climate models.

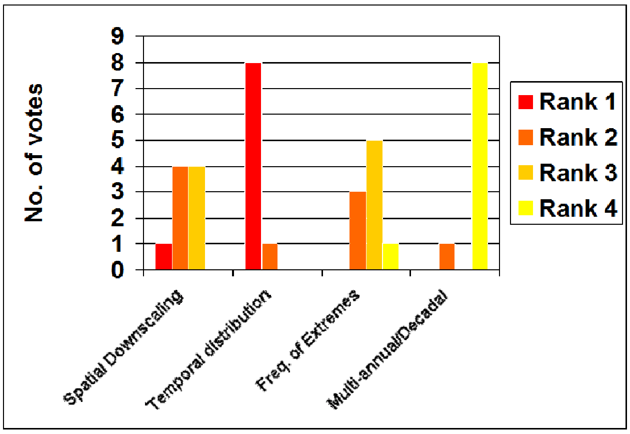

Figure 1: Counts of priorities (rank 1 = highest priority) expressed by nine regional and national suppliers of climate predictions who took part in the consultation. Respondents were asked to rank four potential areas for improvement of dynamical seasonal and longer-range precipitation predictions in terms of user demand. The four areas for which rankings were requested were: spatial downscaling of forecasts; seasonal forecasts of the temporal distribution of rainfall; forecasts of extreme rainfall events and longer-range forecasts (multi-annual to decadal). Note the clear priority given to the need to improve predictions of the temporal distribution of seasonal rainfall.

The role of remote influences on African rainfall variability is one area in need of research. It is well known that inter-annual rainfall variability in many parts of Africa is influenced by anomalies in global-scale sea surface temperature (SST) through so-called ‘teleconnection’ responses. For example, SST anomalies in the equatorial East Pacific associated with the El Niño Southern Oscillation (ENSO) phenomenon are well correlated with rainfall anomalies over parts of the Greater Horn of Africa during the short-rains (October to December) season. To date there has been no continent-wide assessment of the ability of current climate models to represent these observed teleconnections and the underlying mechanisms. Adequate representation of such processes is important to obtain reliable model predictions of climate variability (seasonal predictions) and also to provide a sound basis for anthropogenic changes in global ocean temperatures to be plausibly translated to regional Africa precipitation changes in climate change simulations.

CSRP research has assessed the ability of 22 climate models participating in the Coupled Model Intercomparison Project (CMIP3) and 2 versions of the new Hadley Centre climate model (HadGEM3) to reproduce observed teleconnections between 6 major SST modes and rainfall over 7 African regions/seasons. Key results are summarised in Fig. 2, a full analysis is in Rowell (2012). Teleconnections that are well represented by the majority of models (most pixels in corresponding squares of Fig. 2 are green) include: Indian Ocean to Kenya-Somalia (Oct-Dec) and Tanzania (Oct-Dec) and southwest Africa (Dec-Feb).

Teleconnections that are poorly represented by the majority of models (most pixels in corresponding squares are red) include: Indian Ocean to Sahel (July-Sept), Equatorial Atlantic to Guinea Coast (July-Sept) and ENSO (Nino3.4) to Kenya-Somalia (Oct-Dec). Research to improve model representation of these latter teleconnections is clearly a priority.

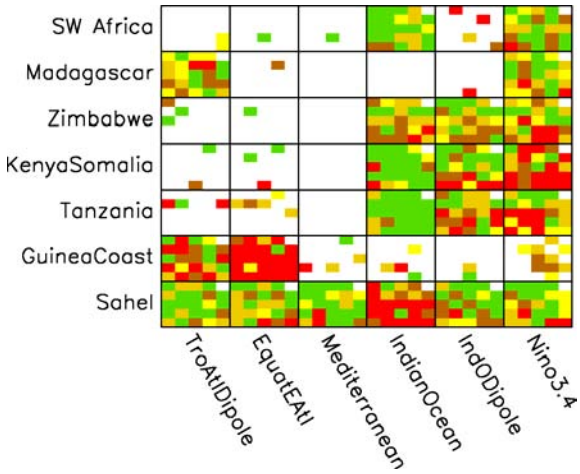

Figure 2: Assessment of 24 climate models in terms of modelled teleconnection between 6 key SST modes and rainfall total in 7 regions/seasons of Africa. The 7 rainfall regions (periods) are: Sahel (Jul-Sept), Guinea Coast (Jul-Sept), Kenya-Somalia (Oct-Dec), Tanzania (Oct-Dec), Zimbabwe (Nov-Dec), Madagascar (Oct), southwest Africa (Dec-Feb), but note that these regions do not correspond precisely to national boundaries. The 6 SST modes are: Tropical Atlantic Dipole, Equatorial east Atlantic, Mediterranean, Central Indian Ocean, Indian Ocean Dipole and Nino3.4. Indices of the SST modes are evaluated over the same months as defined for the rainfall regions. Observed correlations are generated over the 85-year period 1921-2005, with observed data from the University of Delaware monthly precipitation dataset. Model correlations are each generated using climate simulations of length 75-148 years.
Each of the 42 boxes contains results of the teleconnection assessments for one SST mode and one region. Each pixel within the boxes provides results for one of 24 models (excepting the top right pixel in each box which is not used). The assessment is based on the significance level at which the observed and modelled correlations between region rainfall and SST mode fail the null hypothesis that they derive from the same populations. The colour code is as follows:

- Green: observed and modelled correlations are not significantly different at the 10% level (model representation is acceptable);
- Brown-red: observed and modelled correlations are significantly different at the 5% at least (model representation is poor to very poor);
- Yellow: observed and modelled correlations with SST are significantly different at the 10% level, but not at the 5% level (model representation is marginal);
- White (except for top right pixel): no teleconnection (|corr| < 0.25) in both obs and model).

The analysis provides an important guide for targeting research and model development. In further analysis (not shown) an overall ranking of the CMIP3 models in terms of ability to represent teleconnection processes over Africa has been developed which may provide a basis for advising climate change impact studies on the best subset of models to use for a given African region.

Additional studies with HadGEM3 have found that higher global model horizontal resolution in both the atmosphere and ocean generally improves model representation of rainfall/SST teleconnection responses over Africa (Fig. 3). Further investigations have shown that the improvement derives mainly from improved SST variability in the higher resolution model and that improved resolution in the ocean alone is not sufficient to effect the improvement.

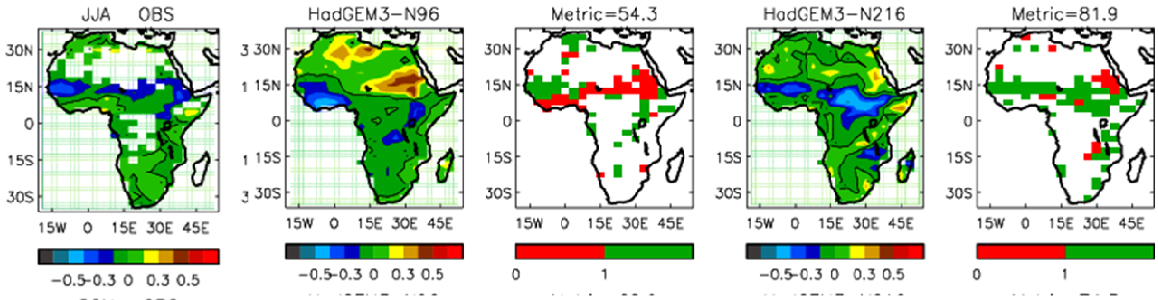

Figure 3: Left: observed correlation of June-July-August rainfall with tropical Pacific sea-surface temperature (SST – specifically, the Nino3.4 index). Note the negative correlation in Sahel region, implying (on average) dry conditions in El Niño years. The next 2 plots show equivalent correlations in the N96 version of HadGEM3 (horizontal resolution: atmosphere = ~ 120km; ocean, = 1º), and results of a statistical test for similarity of model and observed correlations (green=test passed; red=test failed); last two plots show corresponding correlations and tests for the N216 (horizontal resolution: atmosphere = ~60km; ocean = 0.25º) version of HadGEM3. Note the better agreement of correlations obtained by the higher resolution (N216) version with observed correlations, and greater area for which the similarity test is past.

3.2.2 Attribution of current and recent climatic events over Africa to natural and human-induced causes: A question often asked in the aftermath of extreme climate events such as drought or flood is: 'to what extent did human-induced climate change play a role?' There is a growing tendency to attribute all observed climate extremes to anthropogenic increases in greenhouse gases whereas, in fact, other drivers such as natural climate variability and land use changes (e.g. deforestation) can be of first order importance. To avoid potential for (potentially expensive) mal-adaptation, development planners need rigorous advice on climate change detection and attribution. To address this issue, the CSRP programme is developing a near-real-time attribution system that will examine current and recent climate events in Africa and estimate the degree to which human-induced climate change has increased the risk of such events. The increased risk is often referred to as the fraction of attributable risk (FAR).

The methodology used is as follows. The climate event under consideration is simulated using a climate model (in this case the Met Office climate model, HadGEM3), run in ensemble mode. Two simulations are run: an 'actual world' simulation, which is configured with observed global ocean and atmosphere data and a 'counter factual world' simulation for which the accumulated influence of greenhouse gases are removed from the configuring data. Both the actual and counter factual runs generate probability distributions for the variable of interest for the season and region in which the extreme was observed, with the wings of the distribution indicating the prior risk that the event would be extreme. The difference in area under the two probability curves is an estimate of the changed risk of the event due to human-induced climate change (Fig. 4). The estimate of the FAR will be subject to deficiencies in the climate model. To account for this an analysis of the historical reliability of the model in reproducing the extreme events is being included in the attribution methodology.

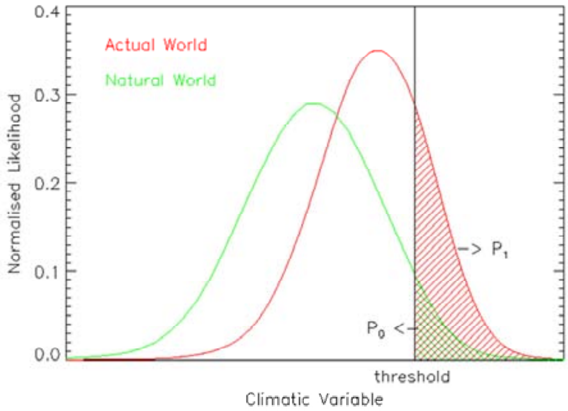

Figure 4: Schematic showing hypothetical probability distributions of a climate variable generated from ensemble runs from the actual (red) and counter factual or natural world (green) runs. P_0 (the area under the green curve) is the probability of exceeding an (arbitrary) extreme threshold in the natural world; P_1 is the probability of exceeding the same threshold in the real world. The fraction of the risk of exceeding the threshold (in the actual world) that can be attributed to human-induced climate change (F_{AR}) is given by $F_{AR}=1-(P_0/P_1)$.

The methodology is currently being applied to investigate the role of climate change in the recent (2010/11) drought in the Greater Horn of Africa – with analysis focusing on the Kenya-Somalia area. The drought was characterised by below-normal rainfall in two successive rainy seasons: the September to December 2010 season and the March to May 2011 season. A preliminary application of the attribution system suggests that human-induced climate change increased the risk of below-normal rainfall in the March-May season. This result is in accord with the conclusions of Funk et al (2008) who used primarily a process-based analysis. An advantage of the attribution method discussed here is that, when the analysis is completed, a quantitative estimate of the increased risk due to human-induced climate change will be available. In contrast to the result obtained for the March-to-May season, preliminary results for the October-to-December 2010 season indicate little detectable impact from human-induced factors – with the primary 'driver' of the below-normal rains being the prevailing La Niña event. These preliminary results run counter to signals from the GCM ensemble used in IPCC's Fourth Assessment Report (AR4), which generally indicate a climate-change trend to wetter conditions in the East Africa (including the Greater Horn region). The reasons for this discrepancy are not currently understood and must be uncovered to bring more clarity to the sign of the climate-change attribution signal for Greater Horn of Africa rainfall. A key question is the extent to which the differences arise from the use of a prescribed (non-interactive) ocean in the attribution method and use of fully coupled interactive ocean-atmosphere models in the AR4 ensemble.

3.2.3 Predicting onset timing of Africa's rainy seasons: investigations of climate model performance and development of trial products: As discussed in section 3.1 the consultation exercise concluded that research into using dynamical climate models to predict the temporal distribution of seasonal rainfall, including the timing of season onset, is a high priority. In this section, results of research into onset prediction for the West African monsoon (WAM), the East African short-rains season and southern African season are summarised. Analysis focuses on results with development versions of HadGEM3 (Hewitt et al. 2011) including the Met Office's seasonal prediction system (known as GloSea4 – Arribas et al. 2010). In addition results for CMIP3 models are also shown for the West African monsoon case.

A first step in the investigations for each region was to examine how well the models can reproduce the observed average temporal/geographical evolution of the rainy season. The latitude/time plot in Fig. 5 compares the observed (average) evolution with the corresponding model evolution for the case of the WAM. Observations (left) show a distinct and rapid shift of the region of most intense rainfall (orange/red) from around 5°N (Guinea Coast) to around 12°N (Sahel) in early July – corresponding to rainfall onset in the Sahel. The model representation of this shift (right) captures well the key observed features, e.g. the timing of the shift (early July) and the geographical location of the most intense rain (near 12°N) – though the model generates too much rainfall in the core rainfall regions.

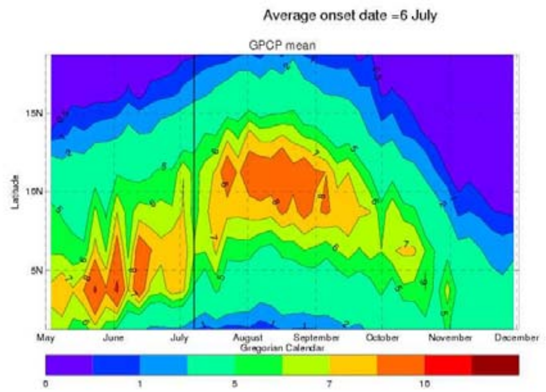

Figure 5: Latitude/time plot showing the average evolution of West Africa monsoon rainfall (mm/day) from May to December as observed (GPCP – left) and as represented in a version of the HadGEM3 climate model (right). Rainfall values plotted at each latitude are averaged over the zonal strip 10ºW to 10ºE. Here the average onset date is defined as the date on which the zonal strip with largest averaged rainfall moves (and stays) north of 10º north. The average observed onset date is 6th July and compares well with the HadGEM3 average of 8th July. The observed period used is 1989 – 2002, the HadGEM3 plot is generated from 30 years of simulation.

Figure 6 shows corresponding latitude/time plots from a selection of GCMs that contributed to the IPCC's Fourth Assessment Report (AR4). It may be seen that although a few of the models also capture the characteristic 'jump' representing onset the majority do not. For several of the models that do capture some kind of discontinuity the timing is too late in the season.

Relative to state-of-the-art modelling that contributed to AR4, the good HadGEM3 simulation of the WAM represents a significant advance. If the model changes that brought about the improved representation can be understood there may be an opportunity to improve representation of the WAM in models across the international modelling community. This would represent an important step towards a better physical basis for climate change scenarios over West Africa and towards improved confidence in predictions.

With regard to future work it should be noted that, firstly, the models used in AR4 are now relatively old – and the comparison with HadGEM3 should therefore be repeated with output from the latest versions of other modelling systems (currently being compiled for the Fifth Assessment Report), when available. Secondly, assessment of proposed upgrades to HadGEM3 based on improved physics and changes targeted at global systematic errors has shown that good simulation of the WAM onset is not robust. Initial investigations suggest that this sensitivity is related to delicate balances in processes important to onset e.g. the relative importance of latent and sensible heat sources and Pacific and Atlantic sea surface temperature influences. Focus on understanding these delicate balances is important to ensure model development meets requirements of Africa stakeholders. The result also highlights the importance of monitoring the impacts of continued global model development on quality of model outputs important to stakeholders in Africa.

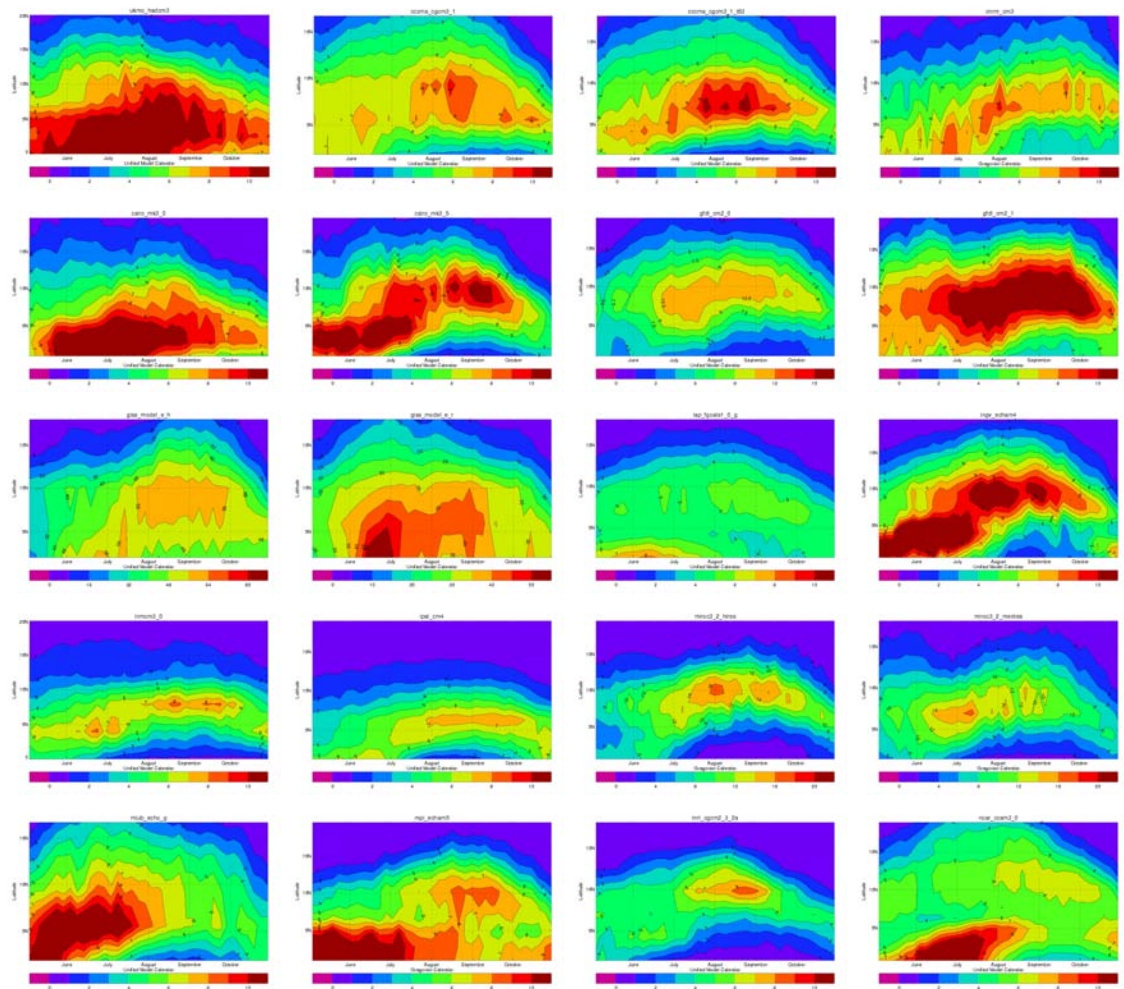

Figure 6: As Fig. 5 but for 20 GCMs from that contributed to IPCC's fourth assessment report.

The good representation of the monsoon evolution in HadGEM3 climatology is encouraging and has led to investigations into the predictability of year-to-year variations in onset timing using seasonal forecasts. Two approaches have been developed. The first approach, specific to the West African monsoon, addresses prediction of the timing of the large-scale northward 'jump' of the main rain band. The second approach addresses local onset by predicting the time of the arrival of a given percentage of the long-term average seasonal total. Positive prediction skill has been found for West Africa using both approaches. Here we focus on the second 'local' approach because it has greater potential for application in other regions of Africa where season onset is less characterised by a sudden large-scale discontinuity.

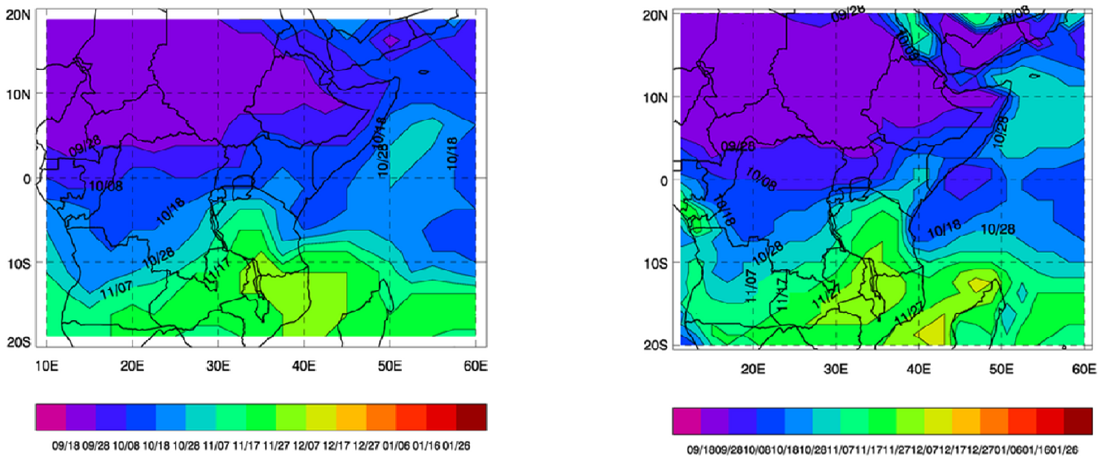

Figure 7: Isochrones of average date at which 20% of the local long-term average (1996-2009) seasonal rainfall is received. Isochrones labels refer to month/day. Left: observations (GPCP); right GloSea4 retrospective seasonal forecasts initialised in early September.

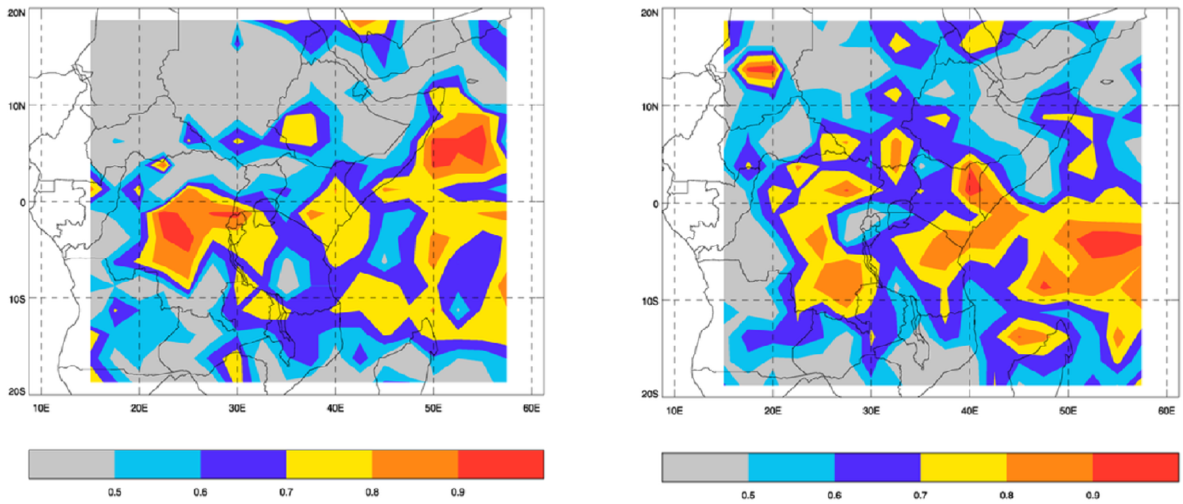

Figure 8: Relative Operating Characteristic (ROC) scores for probabilistic predictions of the events: early onset (left) and late onset (right). Note that ROC scores may be interpreted as the percentage of occasions on which the forecasts correctly discriminate the observed event (Mason and Weigel, 2009). Thus results indicate that forecasts correctly discriminate both early and late onset events over parts of Tanzania and Kenya on 70% of occasions or more. Here, onset timing is tentatively defined as the date, for the season/year predicted, on which accumulated rainfall reaches 20% of the (local) long-term seasonal average and 'early' and 'late' (and also 'normal' – not shown) onset timings are defined using a tercile categorisation (defined over the period 1996-2009).

Figure 7 compares observed and GloSea4-modelled isochrones of the average time of arrival of 20% of the local long-term average seasonal rainfall for the East African October to December (short-rains) season. It may be seen that the average southward migration of the rainfall zone over the period is well captured by the model in most regions. Figure 8 shows maps of prediction skill for early and late arrival of 20% of the long-term seasonal average rainfall (used here tentatively to indicate early / late onset). The skill measure used is the Relative Operating Characteristic (ROC) score (Mason, 2003). There is evidence of relatively good skill (ROC scores exceeding 0.7) over parts of Kenya, Tanzania and Somalia – though in other regions ROC scores are of order 0.5, indicating the forecast cannot discriminate years with early (or late) onset.

The isochrone method has also been evaluated for prediction of onset timing for the West African and southern African seasons. As for East Africa, positive skill is also found over substantial parts of each of these regions, and this is encouraging evidence that dynamical seasonal predictions may be of assistance in preparation of onset forecasts issued by many National Meteorological Services in the regions. On this basis trial onset forecasts, giving 1-2 months lead time have been provided to the Regional Climate Outlook Forums held for the West African 2011 season, the Greater Horn of Africa 2011 short-rains season, and the southern African 2011/12 season. Feedback from these forums has been sought to facilitate improvements in the forecast methodology and presentation.

3.3 Results from the knowledge management component

3.3.1 The CSRP fellowship scheme: Following a call for applications issued in December 2010, 11 African climate scientists have been awarded CSRP fellowships from a total of around 80 applicants, and project work is underway. The application procedure was based on that used by the African Climate Change Fellowship Programme (ACCFP), coordinated by START and the African Academy of Sciences. Fellows will conduct their fellowship at an African institute – either their home institute or as a visiting scientist at a host institute. Met Office scientists, and particularly a specific Met Office mentor, will help guide the research. The fellows will visit the Met Office early during their fellowship to retrieve data for their research and to consolidate plans with their project mentors. Four fellows completed their visits during summer 2011.

Three types of fellowship have been awarded: Postgraduate Research Fellowships and Postdoctoral Research Fellowships (both of maximum length of 12 months) as well as Applications Project Research Fellowships (maximum length of 6 months). The fellowship projects cover the following themes, all designed to be closely aligned with the CSRP outputs:

1) Evaluation of HadGEM3 representation and predictability of climate variability;
2) Investigation of the mechanisms underlying climate variability;
3) Evaluation and use of dynamical seasonal forecasts;
4) Decadal forecast evaluation and demonstration of potential uses;
5) Construction of regional historical observation datasets;
6) Downscaling investigations and applications.

The focus of the fellowship project work, and the fellows themselves, are well distributed across sub-Sahelian Africa: 4 in East Africa, 4 in West Africa, 2 in southern Africa and 1 in Central Africa. More information on the fellows and their research projects may be viewed at http://www.metoffice.gov.uk/csrp/fellowships .

3.3.2 The first CSRP training workshop: A 2-week workshop entitled "Training workshop on appreciation and use of dynamical seasonal forecasts for the Greater Horn of Africa and outlook for the JAS season in the northern sector" was delivered jointly with the IGAD Climate Applications and Prediction Centre (ICPAC), at ICPAC, Nairobi 6-17 June 2011. A total of 15 climate scientists participated in the workshop as representatives of the National Met Services of Sudan, Eritrea, Djibouti, Ethiopia, Uganda, Burundi, Rwanda and Tanzania, and Kenya. Research Assistants from ICPAC also participated. Resource persons included senior staff from the Met Office Hadley Centre, ICPAC, Nairobi University, North Carolina State University, University of Connecticut and the International Research Institute for Climate and Society (IRI).

In addition to the training programme, the workshop developed a consensus seasonal outlook for the July-September 2011 season over the Greater Horn of Africa which was presented at the 29th Greater Horn of Africa Climate Outlook Forum held on the final day. The forum was the first ever to be held for the July-September season and was attended by representatives from Kenya Red Cross, UN International Strategy for Disaster Risk Reduction (UNISDR), Famine Early Warning Systems (FEWS-NET) and participants from a Disaster Risk Management workshop that was held concurrently at ICPAC.

The training segment of the workshop had 5 key aims:

- To take stock of current seasonal forecasting methods in use by the countries of the GHA;
- To strengthen understanding of dynamical seasonal forecasts systems and products;
- To generate new knowledge on the performance of 4 prominent dynamical (i.e. climate model based) seasonal forecast systems;
- To investigate the potential for improved forecast skill by post-processing output from dynamical seasonal forecast systems;
- To make recommendations on procedures for integrating dynamical forecast products into the RCOF processes.

Recommendations of the workshop included:

- Continued involvement of the CSRP workshop participants in future GHACOF activities. This will be achieved by supplying each participant, at their home institutes and ahead of each future GHACOF meeting, with dynamical seasonal forecast data to process, using methods discussed at the workshop. Model data supplied will be from selected models from the WMO-designated Global Producing Centres for long-range forecasts (GPCs). This will have the benefits of consolidating and continuing learning initiated at the workshop and allowing advance analysis of the forecast signals from dynamical models before participants meet to prepare the consensus forecast.
- The workshop noted that El Niño and La Niña events are important drivers of variability in the September to December short-rains season and that dynamical model predictions for the state of El Niño/La Niña over this season have relatively good skill from the preceding May. This suggests potential for issuing a long-lead forecast for the SOND season in the preceding May or June. Such a long-lead forecast would provide a preliminary outlook for users ahead of the final consensus forecast issued in August, and may help provide useful additional lead-time to prepare for potentially adverse (or favourable) rainfall. This recommendation was contributed to discussions at the GHACOF29 meeting (Entebbe, 1-3 September 2011) which, in light of the severe drought crisis of 2010/11, included a specific focus on the need for a

'paradigm change' in strategies to increase resilience to drought and other climate hazards in the Greater Horn of Africa.

4. SUMMARY, OTHER WORK AND FUTURE PLANS

The DFID-Met Office Hadley Centre Climate Science Research Partnership (CSRP) is a 3-year programme of climate research, product development and capacity building with an exclusive focus on the African continent. The programme's objectives have been shaped through consultation with Africa stakeholders. Key results summarised in this paper include:

Consultation: There was a very strong signal that, to improve on available seasonal forecast information, development of capability to predict temporal distributions of rainfall (e.g. season onset, duration, and dry spell frequency), was the highest priority need. Development of dynamical downscaling of forecast information to provide more geographical precision, prediction of extreme events and longer-range (multi-annual to decadal) forecasts were also considered important areas for research and development.

The ability of climate models to simulate large-scale SST teleconnections to African rainfall: A comprehensive analysis of the ability of HadGEM3 and 22 CMIP3 models to reproduce observed teleconnection responses over Africa has been conducted. The results reveal overall 'gaps' in the ability of all current models to represent important features of African rainfall variability. For example, although some teleconnections are well represented, very few models represent adequately teleconnections between: the Pacific Ocean (El Niño Southern Oscillation) and the Greater Horn of Africa; the Central Indian Ocean and the Sahel; the equatorial Atlantic and the Guinea coast. The analysis provides an important guide for targeting research and model improvement to benefit African stakeholders. Research has also shown that improved horizontal resolution in models, both in the atmosphere and ocean generally results in better representation of SST teleconnections to African rainfall.

Attribution of current and recent climatic events over Africa to natural and human-induced causes: A prototype attribution system for Africa has been developed and is being used to examine the role of human-induced climate change in the severe 2010/11 drought over parts of the Greater Horn of Africa. Preliminary results suggest human-induced climate change has increased the risk of below-normal rains in the March-May long-rains season. To help bring more clarity in diagnosing the climate change signal in this region, further research is underway to understand the discrepancy between this result and the signal for increasing rainfall found in the GCM ensemble used in IPCC's Fourth Assessment Report.

Predicting onset timing of Africa's rainy seasons: Development versions of the HadGEM3 model have been to shown to simulate well the characteristic onset features of the West Africa Monsoon. The simulation is substantially better than the typical performance of GCMs used in the IPCC's Fourth Assessment Report. This has provided an opportunity, with more research, to understanding the delicate balances in various processes important to onset timing which in turn may lead to improvements in the physical basis of future IPCC assessments of climate change for West Africa. Encouraging levels of skill have been found for seasonal prediction of onset timing for West Africa, East Africa and southern Africa and experimental onset forecasts for the 2011/12 rainy seasons have been supplied for trial at the Regional Climate Outlook Forums of these regions.

Knowledge management and capacity building: A fellowship scheme has been implemented through which eleven African climate scientists, working at African institutes, are engaging with CSRP outputs to advance the programme's objectives and to enhance their professional development. A 2-week training workshop with the central aim of strengthening understanding and use of dynamical seasonal forecasts systems and products has been delivered to representatives from 9 National Meteorological Services in countries in the Greater Horn of Africa.

The research described above will be further developed over the remainder of the programme along with other ongoing research not highlighted in this report. Key topics include:

- Investigation of the role of regional/local processes in driving climate variability over Africa – including the role of African Easterly Waves (Bain et al. 2012) and rainfall responses to soil moisture (Comer and Best, 2012). This research complements work on remote teleconnections;
- Full assessment of, and trial products from, a monthly-to-decadal 'seamless' forecast system which is being developed as part of the programme.
- Additional experimental seasonal forecast products providing information on the temporal evolution of seasonal rainfall: onset forecasts will be refined and, subject to prediction skill, experimental forecasts of season cessation and the expected frequency of dry spells will be introduced;
- A suite of observational rainfall monitoring products developed in consultation with climate service providers in Africa will be further refined;
- Full assessment of a new version of PRECIS (PRECIS V3) employing the new Met Office Hadley Centre climate model (HadGEM3) will be completed and the system made ready for implementation 'in house' in African centres to downscale seasonal forecasts;
- On completion of the CSRP fellowship projects results will be shared and discussed at a plenary meeting/conference;
- A second CSRP training workshop will be held in mid-2012.

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