Use of dynamical seasonal forecasts in the consensus outlooks of African Regional Climate Outlook Forums (RCOFs)

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1 Introduction

The first Regional Climate Outlook Forum (RCOF), convened to generate and communicate a consensus view on climate prospects for the coming season, took place for the southern African region in September 1997 (RCOF Review 2008 and accompany material; Ogallo et al. 2008). At about the same time, experimental global-coverage seasonal predictions of temperature and rainfall, generated using initialised General Circulation Models, began to appear on the websites of prediction centres such as ECMWF and the Met Office – following a period of enhanced research into the methodology and prediction skill of 'dynamical' seasonal prediction (see e.g. Graham et al. 2000 and references therein).

Since these early beginnings there has been a great deal of development in both activities. Many regions of the world now convene RCOFs, with four established to cover sub-Saharan Africa. They are recognised as important instruments in the synthesis of diverse information on climate prospects, leading to production and communication of a consensus prediction as well as for regional climate science capacity development. Indeed, RCOFs form a key regional component of the infrastructure for the Global Framework for Climate Services (GFCS), developing under the UN system (GFCS implementation plan[1]).

Progress in dynamical seasonal prediction includes both developments in technology and in international collaboration to standardise prediction formats and make them accessible to users. For example since 1997, many prediction centres have replaced atmosphere-only systems, forced with persisted sea-surface temperature anomalies, with coupled ocean-atmosphere systems (see e.g. Graham et al. 2011). Development of international collaboration has been coordinated by the World Meteorological Organisation (WMO). Beginning in 2006 the Commission for Basic Systems (CBS) of WMO has designated 12 prediction centres as Global Producing Centres (GPCs) for

[1] Final draft of GFCS implementation plan: http://www.wmo.int/pages/gfcs/documents/2012.09.07GFCSImplementationPlan_FinalOrder.pdf

Long-range forecasts based on their adherence to CBS defined criteria (Graham et al. 2011). Forecasts from the GPCs are now available in standard format on a single website hosted by a dedicated Lead Centre (see: http://www.wmolc.org – password required). A dedicated Lead Centre has also been established to coordinate verification information on GPC forecasts (www.bom.gov.au/wmo/lrfvs).

In this paper we first briefly describe the RCOF network as it currently exists for sub-Saharan Africa and the format of the consensus seasonal forecast products (section 2). In section 3 we give some examples of pre-emptive relief interventions based on forecast information. In section 4 we describe the general procedure for preparing the consensus seasonal forecast and the role of dynamical forecast products in the process. In general, a similar approach is employed at all African RCOFs and we therefore focus on the approach followed at the Greater Horn of Africa Climate Outlook Forums (GHACOFs), coordinated by the IGAD Climate Prediction and Applications Centre (ICPAC).

As stated above, the physical basis of dynamical prediction systems and the availability of their products have improved considerably in recent years and RCOFs have become widespread and established regional prediction mechanisms. However, statistical methods of seasonal prediction still dominate forecast development at most African RCOFs (and indeed at African National Meteorological Services (NMSs)). Such methods are typically based on empirical/statistical relationships between seasonal rainfall and pre-season (mainly tropical) sea-surface temperature anomalies. There are a number of reasons for the limited use of dynamical methods including: a) the current competitive performance of statistical methods (particularly at shorter lead times), and their relative ease of implementation and low cost, b) lack of 'in house' capability for dynamical prediction, c) remaining limitations in the availability of GPC forecast products and support for their interpretation and use. Current usage of GPC products is, largely, confined to subjective assessment of visualised maps. In Section 5 we describe new research undertaken in collaboration with regional centres in Africa to explore objective approaches which use data products from the GPCs in combination with statistical predictors. We also discuss development of new dynamical seasonal forecast products such as forecasts of the timing of onset of the rainy season. A summary is provided in Section 6.

2 Regional Climate Outlook Forums in Africa and their consensus forecasts products

There are three African climate organisations coordinating RCOFs in Africa (Table 1): the African Centre for Meteorological Applications for Development (ACMAD), Niamey, Niger; the IGAD Climate Prediction and Applications Centre (ICPAC), Nairobi, Kenya and the Southern African Development Community Climate Services Centre (SADC-CSC). Although there are variations with region, the RCOF format typically consists of two stages: a 'pre-forum' workshop attended by climate scientists from the NMSs of the region, and a following forum attended by both the climate scientists and a range of users. RCOFs were initiated and are supported by WMO working with NMSs and other agencies as part of the Climate Information and Prediction Services (CLIPS) programme and WMO has conducted two reviews (see RCOF Review 2008) to monitor progress and make recommendations regarding the processes involved.

The pre-forum workshop is typically of between 1 and 2 weeks duration. Its purpose is to provide underpinning training in climate science and prediction techniques to assist the NMSs of the region to develop a national forecast for the upcoming season, and to prepare a consensus forecast for the region as a whole. The workshop trainers typically include staff from the hosting regional centre, associated local universities and partner organisations, and experts from international centres.

RCOF name	Region	Usual time of forum	Season forecast target period	Organising/Hosting centre
GHACOF	Greater Horn of Africa	Late February	March-May (MAM) ('long rains')	IGAD Climate Prediction and Applications Centre (ICPAC), Nairobi, Kenya http://www.icpac.net
		Late May	June-Sept (JAS) (north of region)	
		Late August	Sept-Dec (SOND) ('short rains')	
PRESAO	West Africa, Chad and Cameroon	Late May	July-Sept (JAS) (West African Monsoon)	African Centre for Meteorological Applications for Development (ACMAD), Niamey, Niger http://www.acmad.org
PRESAC	Central Africa	Late Sept	Oct-Dec (OND)	ACMAD http://www.acmad.org
SARCOF	Southern Africa	Late August	October-March OND and JFM	Southern African Development Community Climate Services Centre (SADC-CSC) http://www.sadc.int/

Table 1: RCOFs in sub-Saharan Africa at the time of writing. Note: in their role as a pan-African institution ACMAD also coordinate RCOFs for north Africa (PRESANOR) and a new RCOF for a group of African countries bordering the Indian Ocean.

Users attending the forum typically include representatives from water resources and hydro-electricity, agriculture and food security, health, disaster risk management and the media. Standing agenda items include a) a review of last year's consensus forecast, both in terms of its meteorological verification and in terms of how the forecast was used by different sectors and the benefits or disbenefits accrued and b) issuance of the forecast for the upcoming season and preparation and discussion of each sector's strategy for responding to the forecast. A forecast statement is prepared and released and later appears on the website of the coordinating regional centre. Current forecast statements from a number of RCOFs may be viewed at: http://www.wmo.int/pages/prog/wcp/wcasp/clips/outlooks/climate_forecasts.html

The consensus forecast statement includes a map product showing predicted probabilities for tercile categories of rainfall (below, near, and above average), with demarcation of zones sharing the same prediction for the category probabilities (see the examples in Fig. 1). Regions near the boundary of neighbouring zones are considered transition regions. The statement also includes contextual information summarising the state of the global climate and the methodology used to prepare the forecast.

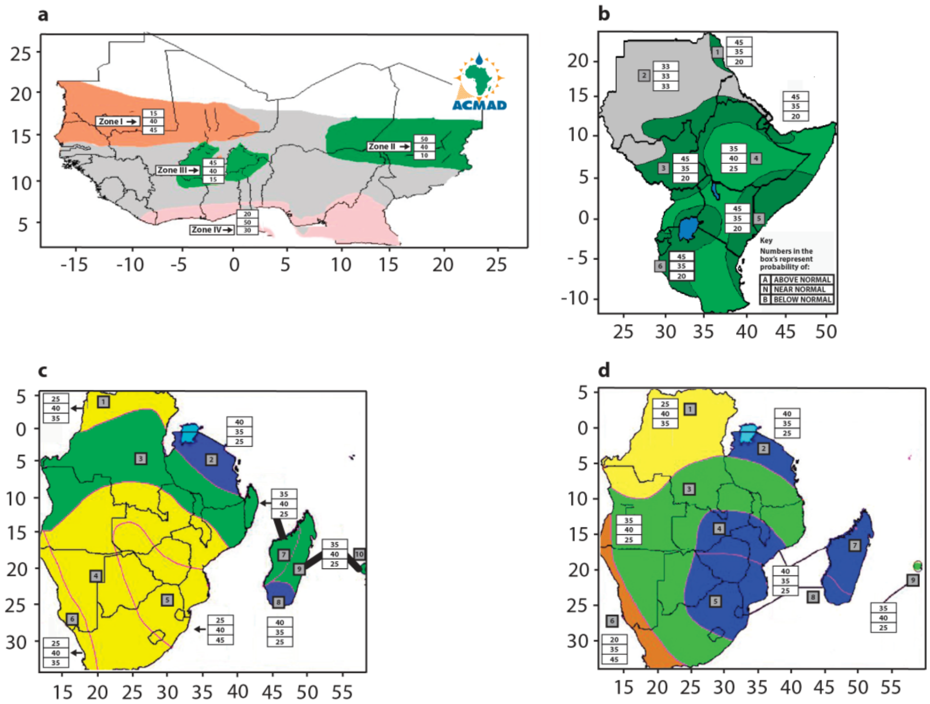

Figure 1: Example consensus regional forecasts illustrating the region covered, the typical division into zones (which vary from year to year depending on the spatial characteristics of the forecast), and the tercile category probability format. Note: the "baseline" climatological probability for each category is, by definition, 33%. a) PRESAO consensus for JAS 2012, b) GHACOF consensus for SOND 2012; c and d) SARCOF consensus for OND 2011 and JFM 2012 respectively. For each product, the stacked numbers for each zone refer to probabilities for seasonal rainfall totals in the upper, middle and lower tercile category (top, middle and bottom, respectively).

Mason and Chidzambwa (2008) conducted a verification study for the first 10 years of consensus forecast from PRESAO, SARCOF and GHACOF. It was concluded that forecasts for all regions have positive skill, meaning that they contain useful information that could potentially have been used to achieve some form of benefit. However, the forecasts also showed evidence of systematic errors, the most common being a tendency to overestimate the probability of the normal category (relative to its observed frequency).

3 Examples of the use and impact of RCOF consensus forecasts

In the last 4 or 5 years the International Federation of Red Cross and Red Crescent Societies (IFRC) and National Red Cross Societies have become increasingly engaged in the RCOF process, and this has led to some significant pre-emptive interventions based on the consensus seasonal outlooks. Some examples of these interventions are briefly summarised below. We focus here on cases when the observed rainfall category (below, near or above normal) was in general correspondence with the category predicted to have highest probability. It must be recognised that, even with a perfectly reliable probabilistic forecast system, counter cases do occur – though less frequently. For this reason interventions are ideally based on "no regrets" considerations - such that actions taken to mitigate impacts of the predicted likely rainfall outcome are of value whether or not the event occurs (e.g. pre-positioned relief supplies can be used later and/or for other purposes).

3.1 West Africa floods 2008

In June 2008 ACMAD issued an update to the consensus prediction for the West African Monsoon JAS season that included strongly elevated probabilities (up to 50%) of above normal seasonal rainfall in much of the Sahel and Soudan regions (Fig. 2a). The prediction was supported by, and partially based on, forecast output from a number of dynamical seasonal prediction centres (see Tall et al. 2012, Graham et al. 2009). The forecast implied increased risk of flooding in these areas, which was later realised (Fig. 2b). The forecast evidence was used to support an appeal for internal Red Cross funding for flood preparedness interventions (Tall et al. 2012). The appeal was granted and was used to activate prepositioning of non-food relief items (blankets, mosquito nets, soap, bottles, tents, etc.) in Dakar (Senegal), Yaoundé (Cameroon), and Accra (Ghana) (Fig. 2b). Without this pre-emptive action, these items would have been flown in after the floods had arrived (from the IFRC's Dubai warehouse), or procured separately, leading to a more time-consuming and costly shipment of relief supplies. Additional appeals for funding were also made to international donors – but unfortunately funds did not arrive before the flooding began. The example is notable for being the first time in the history of the Red Cross movement that, based on seasonal forecast information, funds were requested in advance to prepare for a potential emergency.

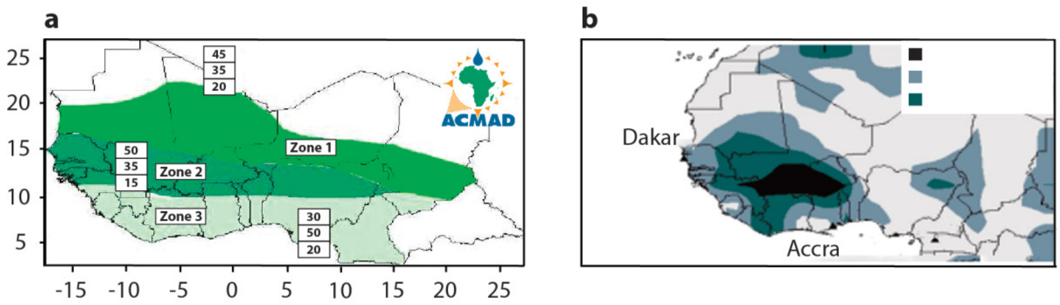

Figure 2: a) PRESAO consensus seasonal forecast for JAS 2008; b) Observed rains and location of stocks prepositioned by IFRC in June-August 2008 (triangles) (from Tall et al. 2012).

3.2 Greater Horn of Africa 'bumper' harvest, 2009

Seasonal forecasts can of course be used to trigger preparedness to maximise potential benefit when a favourable outlook is indicated as well as to mitigate the potential damaging impacts of an adverse outlook. An intervention by the Kenya Red Cross ahead of the SOND 2009 'short rains' season in the Greater Horn of Africa (GHA) is an example of the former case. Acting on the GHACOF consensus forecast that indicated highest probabilities for above or near normal rainfall, the Kenya Red Cross distributed $0.5 M dollars of mixed seed to 70,000 Kenyan farmers, sufficient to plant 1 additional acre each (personal communication, Abdishakur Othowai). Seasonal rainfall was indeed average or above average and contributed to a 'bumper' harvest valued at $2.5 M. The resulting enhanced stores of grain delayed the onset of shortages during the 2010/11 severe drought in the GHA, and brought 2 years of food security to the Ukambani region of Kenya (a region with high levels of poverty and frequent food insecurity).

3.3 The 2010/2011 severe drought in the Greater Horn of Africa

The previous two cases provide good evidence that pre-emptive mobilisation of relief funding on the basis of seasonal forecasts in Africa (rather than waiting for the potential event to materialise) can achieve significant benefit to lives, livelihoods and property. However, these lessons are yet to be fully assimilated into the process of mobilising relief on a large-scale from international donors. This is perhaps unsurprising given the currently limited procedures and infrastructure for communicating predicted climate signals to decision-makers in the international donor community and the few precedents for action taken on their basis. The 2010/11 severe drought in Africa is a case in point. The drought was triggered by the failure of two consecutive rainy seasons: the SOND (short rains) in 2010 and the MAM (long rains) in 2011. The GHACOF consensus forecast for SOND 2010 gave a clear signal for enhanced risk of below normal rainfall (Fig. 3a) and widespread rainfall deficits were observed. The prediction for the subsequent season, MAM 2011 (Fig. 3b), gave less signal for dry – the largest probability being on the average category. However, above normal rainfall was assigned the lowest probability (25%), indicating only low chances of substantial rainfall that might make good the existing deficits. The Kenya Red Cross made appeals to donor agencies (first in January and later in March 2011, see: http://www.kenyaredcross.org/ - humanitarian appeals) citing the GHACOF prediction and also that of the Kenya Meteorological Department but relief did not begin to appear until the crisis hit. The lack of early action, given the available information, is highlighted in a review of the international response to the drought (Hillier and Dempsey 2012), which concludes: "Governments, donors, the UN and NGOs need to change their approach to chronic drought situations by managing the risks, not the crisis. This means acting on information from early warning systems and not waiting for certainty before responding".

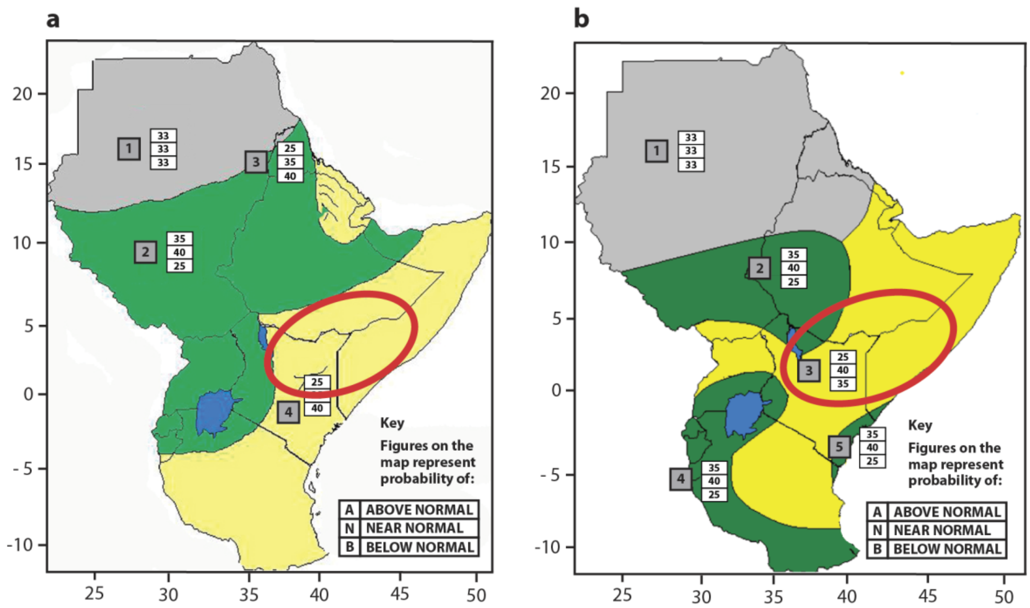

Figure 3: GHACOF consensus forecasts for a) the SOND 2010 season. The yellow shaded regions have predicted probabilities of: above normal=25%, near normal=35, below normal=40%; b) the MAM 2011 season, yellow shaded regions have predicted probabilities of: above normal=25%, near normal=40, below normal=35%. The approximate area most affected by severe drought is circled in red.

3.4 Food Security Outlooks

The Famine Early Warning Systems Network (FEWS-NET), a USAID-funded activity participate in the RCOF process and use the consensus seasonal forecasts as one component in production of food security outlooks for the season. The FEWS-NET products were one of the early warning systems referred to by Hillier and Dempsey (2012) in the context of the 2010/11 GHA drought. In this example we show the FEWS-NET products signalling alleviation of the drought during the SOND 2011 season. Figures 4a and 4b show, respectively, the FEWS-NET food security analysis for August-September 2011 and the food security outlook for OND 2011 generated using the GHACOF consensus seasonal forecast (Fig. 4c) and other factors such as expected cereal prices, regional trade embargoes and levels of human conflict.

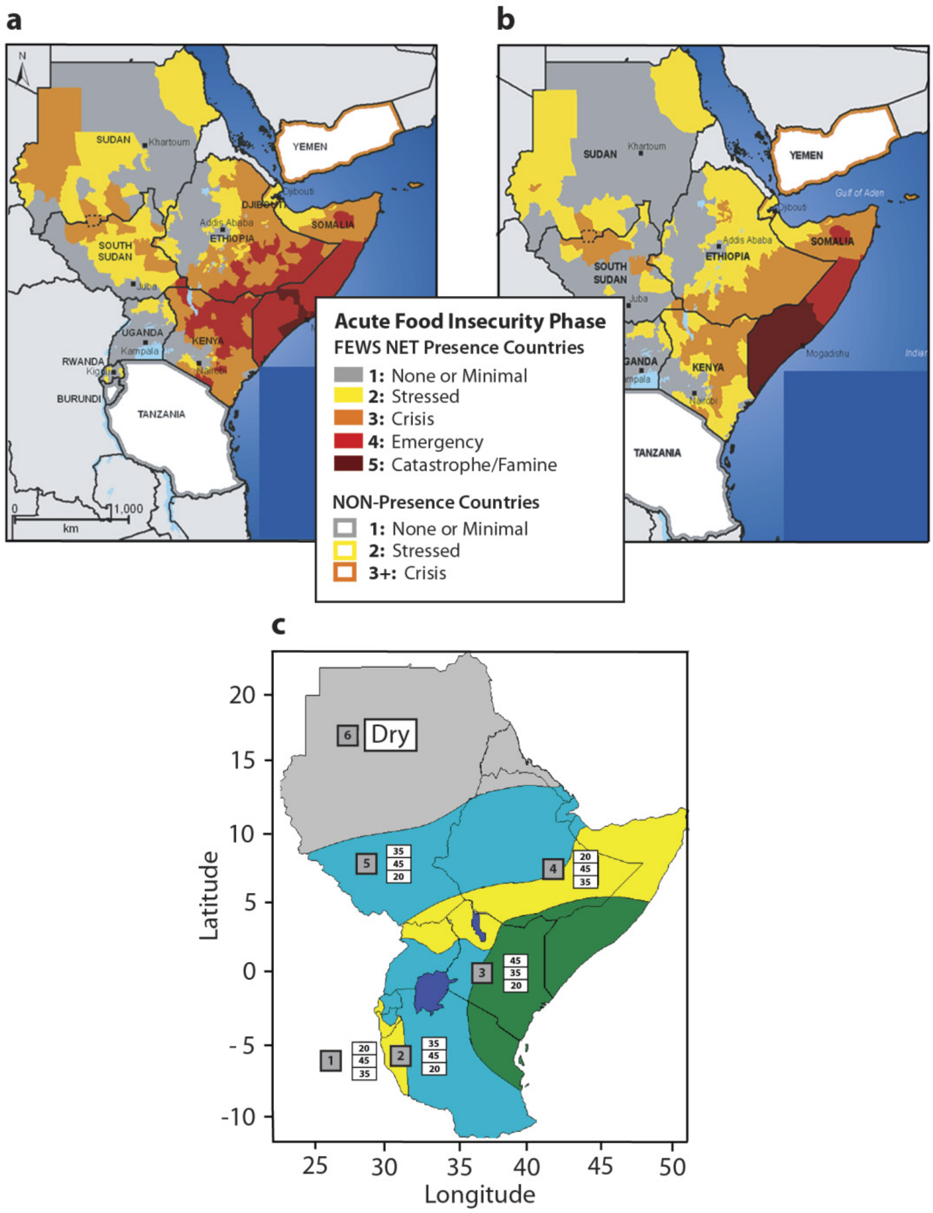

Figure 4: a) FEWS-NET food security assessment August-September 2011, b) FEWS-NET food security outlook for October to December 2011 prepared at GHACOF29 using (among other inputs) the consensus seasonal outlook (c).

Reductions in food insecurity are indicated in the main afflicted regions in response to elevated probabilities for above normal rainfall in the consensus forecast, though not in Somalia where breakdown of infrastructure associated with the civil war was a major factor. The consensus forecast reflects the dominant signal in GPC products considered during forecast preparation (Figs. 5a-c and Fig. 9) which indicated enhanced probability of above normal rainfall over a wide region. Figure 5c is an 8-GPC-model multi-model product generated by the WMO-designated Lead Centre for Long-range Multi-model Ensembles (LC-LRFMME) operated by the Korean Meteorological Association and NCEP. Above normal rainfall was indeed observed over large parts of Kenya, Tanzania, Uganda, Somalia and southern Ethiopia (Fig. 5d).

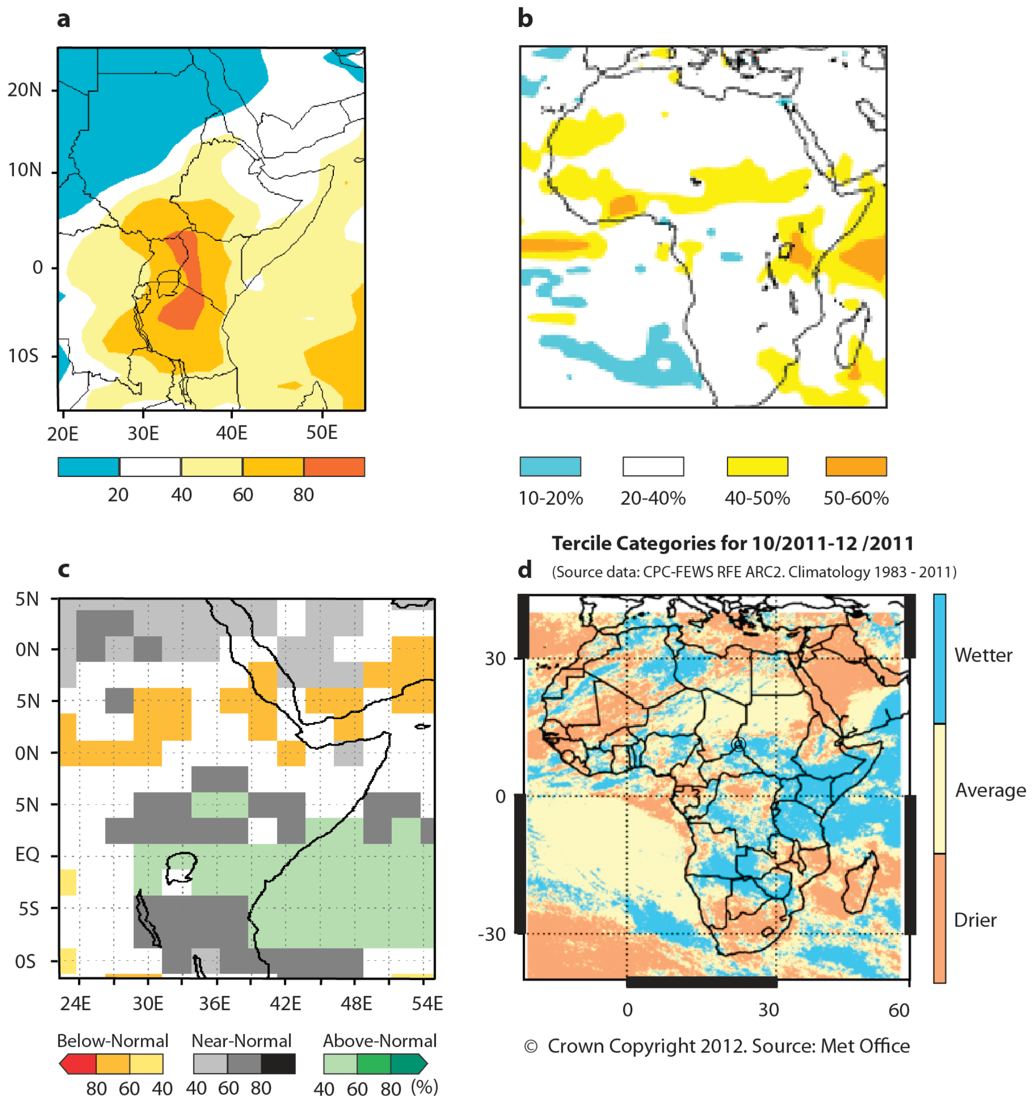

Figure 5: Dynamical model forecast inputs to the GHACOF29 consensus and observed OND2011 rainfall. Forecasts are a) probability for OND rainfall above the upper tercile from GPC Exeter (GloSea4 system), predicted from August; b) as (a) but for the EUROSIP system (EUROSIP is a multi-model combination of forecasts from GPCs ECMWF, Exeter, and Toulouse), c) Multi-model forecast probabilities for the most likely predicted tercile rainfall category (valid period = SON2011) from the WMO LC-LRFMME (in this example the component GPCs are: Beijing, Exeter, Melbourne, Montreal, Moscow, Seoul, Tokyo and Washington); d) Observed OND rainfall category (from CPC FEWS-NET daily rainfall estimates: http://www.cpc.ncep.noaa.gov/products/fews/Africa).

4 Procedure for development of the consensus outlook

The broad procedure for development of the consensus forecast product is illustrated schematically in Fig. 6. The schematic is intended to be indicative of commonalities in the procedures used in Africa RCOFs – differences in the detailed procedures do occur between the regions, and include differences in the weight given to GPC information and the timing at which it enters the consensus process (see also section 5).

In general, the first step is for each NMS participant in the pre-forum workshop to develop a statistical seasonal prediction model for their own country. Models are based on regression between historical observed rainfall data, typically from several stations representative of different sub-national climatic zones and timeseries of predictor variables (e.g. pre-season SST anomalies) maintained by the regional centre. Stepwise regression (typically using the SYSTAT software package) is used to select the best model, and this model is used with the latest observed predictor values to generate a forecast. For some countries an operational regression (or other – e.g. analogue) model is available and output from the newly developed regression model is used as supplementary information. The national forecasts are then compiled on a map of the region and inconsistency at national boundaries resolved through discussions between the countries concerned under guidance from the regional centre. This leads to the first draft of the consensus.

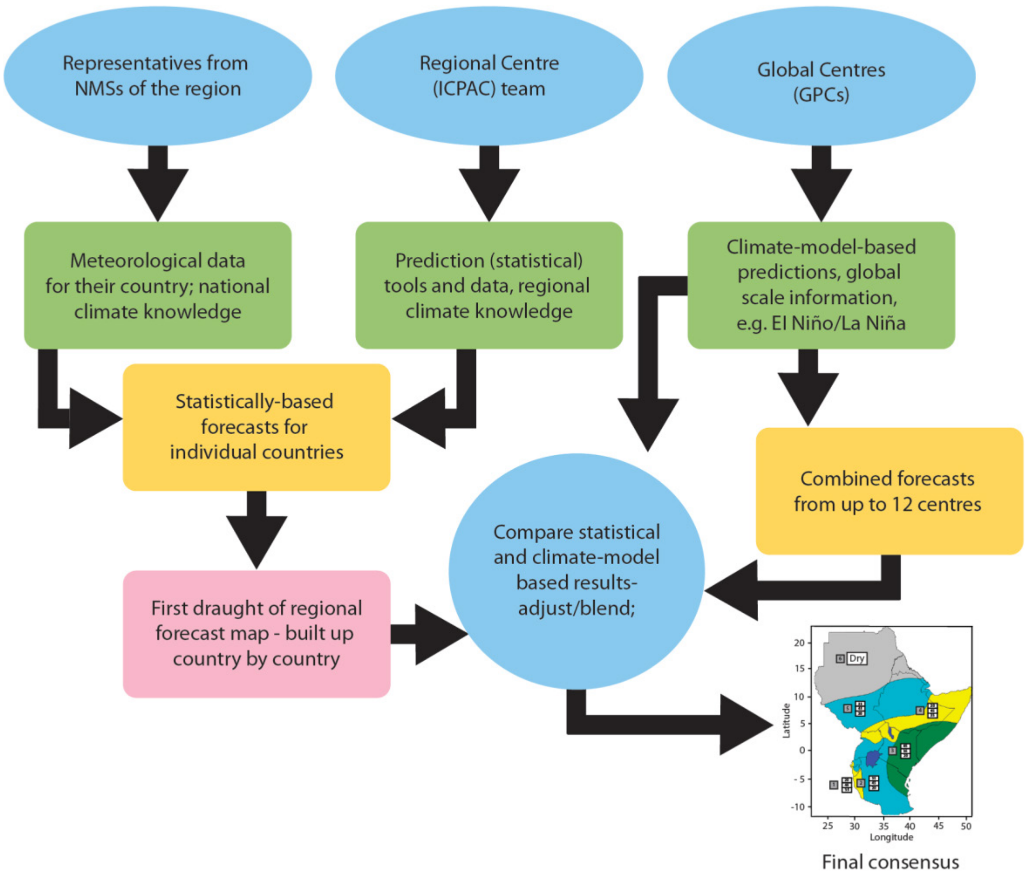

Figure 6: Schematic flow diagram showing the general processes in developing the consensus forecast (based on the process at GHACOF).

Statistical seasonal forecasting for the African continent has a long heritage (see e.g. Ogallo, 1989; Mutai et al., 1998; Folland et al. 1991; Landman and Mason, 1999), and as mentioned such methods are, at short lead, competitive with the skill of dynamical seasonal forecasts in some regions (though to the authors' knowledge no formal comparisons of the skill of statistical and dynamical methods have been published to date). Although potential predictors made available at RCOF meetings are not limited to SST-based parameters, these usually dominate in the stepwise regression. A useful summary of SST modes influential on African seasonal rainfall is given by Rowell (2013) and reproduced in Fig. 7.

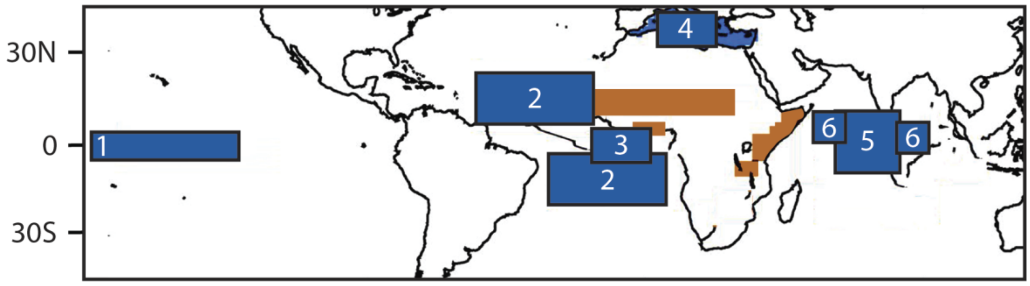

Figure 7: Modes of sea surface temperature variability influential on Africa seasonal rainfall; 1) ENSO; 2) Tropical Atlantic Dipole; 3) Equatorial East Atlantic; 4) Mediterranean; 5) Central Indian Ocean; 6) Indian Ocean Dipole. Brown shading indicates main regions influenced, only areas where seasonal rainfall exhibits high spatial and temporal (month to month through the season) coherency are shown. From Rowell (2013).

A particularly strong statistical relationship exists between ENSO and the GHA short rains season (September to December) – with El Niño associated with above normal rainfall and La Niña with below normal rainfall (Fig. 8) (see also e.g. Mutai et al., 1998). The observed Nino3.4 timeseries 2009 to 2011 (Fig. 8b) shows that El Niño was associated with above normal rainfall in the 'bumper harvest' season of 2009 (section 3) and La Niña with the dry season in 2010 (the first of two consecutive poor seasons leading to severe drought – see Lott et al. 2013). A similarly strong relationship exists for the Indian Ocean Dipole and the short rains season (Saji et al., 1999; Goddard and Graham, 1999). In regions/seasons with these strong statistical relationships, skill with statistical prediction methods can be competitive with that of dynamical methods at short lead times. In such cases the additional benefit of coupled dynamical model systems is the potential for skilful longer-lead (e.g. 3-6 months head) predictions – deriving primarily from skilful ENSO prediction – and this is discussed further in section 5. Skill at these long leads is low from statistical methods – because the implicit assumption of SST persistence weakens.

In preparation of the consensus forecast for the SOND 2011 season, one use of the 1-month-lead dynamical model output was to help judge which of two potentially competing teleconnection influences would dominate. International consensus indicated ENSO-neutral or marginal La Niña conditions would prevail (favouring an average or dry season) while a positive IOD was active in late summer (with continuation favouring a wet season). A summary of GPC outputs, indicating that a wet season had highest probability has been previously discussed (Fig. 5). Corresponding ensemble mean predictions from all 12 GPC models are shown in Fig. 9 – and indicate a

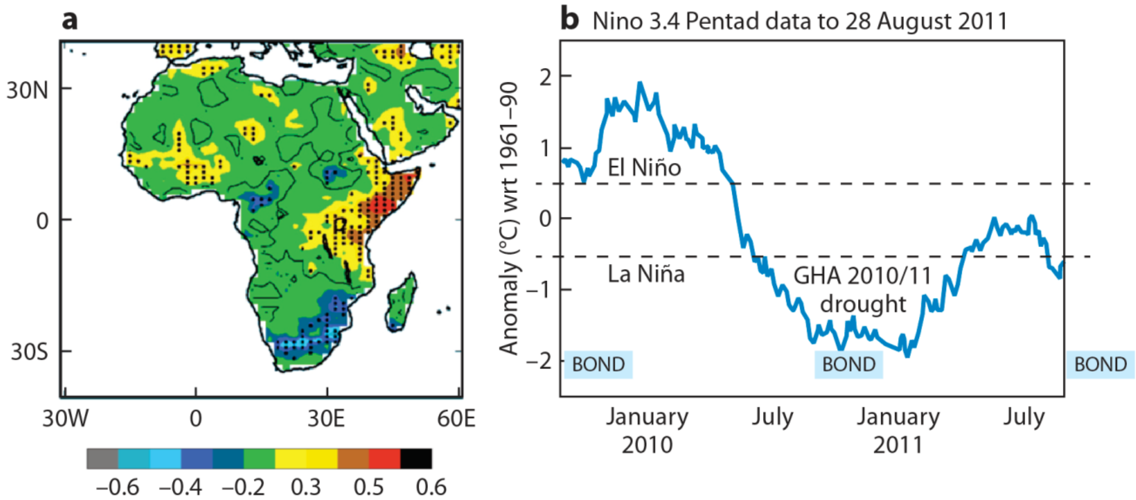

Figure 8: a) Simultaneous correlation of OND rainfall (from UDel2.01 - Johnson et al. 2003) and Nino3.4 1952-2008 SST (from HadISST1.1 - Rayner et al. 2003); b) Observed Nino3.4 anomalies from late 2009 to August 2011 during the El Niño of 2009/10 and La Niña of 2010/11 (from OSTIA – Roberts-Jones et al. 2012). The short rains seasons, Sept-Dec (SOND) are indicated.

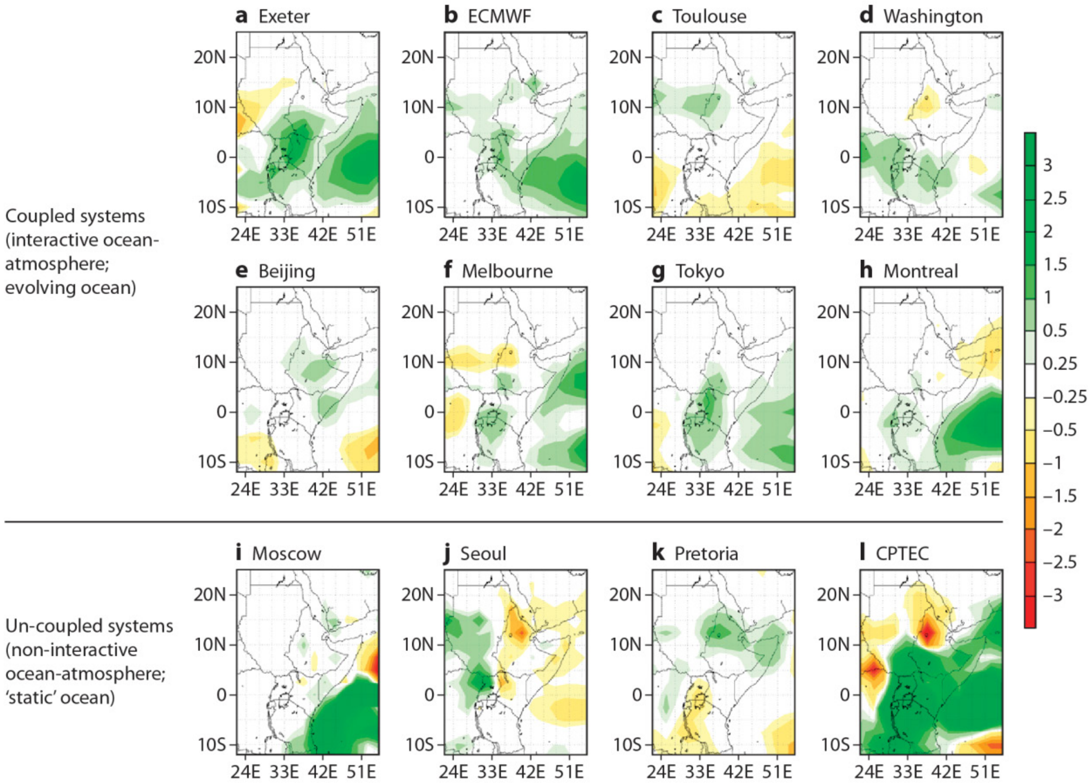

Figure 9: Ensemble mean forecasts for Greater Horn of Africa SON 2011 ("short rains") rainfall, initialised in August, from all individual GPCs (from the WMO LC-LRFMME website – see text). Top two rows are outputs from coupled systems, bottom row from uncoupled systems (Note: Montreal has since implemented a coupled model prediction system).

high degree of consensus for an average or wet season. Verification information for the GPC's forecast systems, to help judge the weight given to forecasts, is available from the WMO LC for the Standard Verification System for Long-range Forecasts (SVSLRF) at http://www.bom.gov.au/wmo/lrfvs. Further diagnostic information on GPC model characteristics, such as the models' ability to reproduce key teleconnection responses important for African rainfall variability, would also be useful in interpretation and use of the forecast products. Rowell, 2013 has made a study of this kind for (uninitialized) integrations from CMIP3 and CMIP5 GCMs.

5 New developments in the RCOF process and new forecast products

Much of the collaborative work described in this section has taken place as part of the DFID-Met Office Hadley Centre Climate Science Research Partnership (CSRP) for Africa (Graham et al. 2012; also http://www.metoffice.gov.uk/csrp). The overarching goal of the CSRP is to increase capabilities for sustainable poverty reduction in Africa through advancing the quality, relevance and uptake of climate services for the continent.

5.1 Use of longer-range GPC predictions

Because of the historical dependency on statistical prediction, which almost always works best when predictor indices are derived from the observed monthly fields immediately preceding the target season, RCOFs tend to be convened within 1 to 6 weeks of the season start (Table 1). This has the benefit of maximising skill, but the disadvantage that the relatively short-lead restricts the time available to communicate the forecast and (when necessary) mobilise pre-emptive relief interventions. Predictions from the GPCs – particularly those made with coupled model systems – have potential to increase the lead-time of the forecasts, allowing more time for the donor community to assimilate relief appeals and aid agencies to prepare responses. It is possible that communication of earlier, albeit provisional, warnings may have helped prompt a more rapid response from the international community (see discussion in section 3) by "pre-conditioning" to the risks later endorsed by shorter-lead forecasts.

This potential was noted at a GHACOF29 special session on the severe drought in the GHA. The session noted (amongst other things) the need to strengthen early warning systems. It made input to a discussion paper on improving resilience to disasters in the Horn of Africa presented to a Heads of State Summit, 8-9 September 2011 hosted by the Kenyan Prime Minister, to discuss ways to "put an end to drought emergencies in the Greater Horn of Africa".

Evidence that dynamical systems offer new potential for longer-lead predictions is given in Table 2 and Fig. 10. We use the GHA short-rains season which is strongly influenced by ENSO and the IOD, as an example. Short lead (August-start) model predictions of SON-season Nino3.4 and IOD are highly skilful (correlations of order or exceeding ~0.8), but are no better than persistence. This is not surprising for Nino3.4, since El Niño events, which tend to peak in December, are generally well established by the end of August. Responses to ENSO and the IOD will drive a major part (though not all) of the models' predicted rainfall and thus at, at this short lead, it is challenging for models to contribute significant additional precipitation skill to that obtained from statistical forecasts for this region/season. However, model skill for Nino3.4 predicted from May is significantly higher than persistence – with correlations still of order ~0.8. This gives good evidence of the availability of useful GPC information on prospects for the GHA short rains (SOND) season from as early as May. It should be noted that such skill is not available with statistical methods; because of their basis in persistence of SST (correlation scores for persistence are order 0.4 from May). Note that Table 2 also reveals current weaknesses in model predictions of the IOD, which do not achieve better scores than persistence at either range.

SON	August starts			May starts		
	GloSea4	ECMWFS3	Persist	GloSea4	ECMWFS3	Persist
Nino 3.4	0.91	0.90	0.98	0.78	0.79	0.4
IOD	0.77	0.79	0.87	0.25	0.31	0.36

Table 2: Correlation skill of ensemble mean predictions of September-November (SON) values of the Nino3.4 index and Indian Ocean Dipole from the GloSea4 (Exeter) and ECMWF (S3) systems, for predictions initialised 1st August and 1st May, and corresponding skill from persistence of observed July SST anomalies (as would be used in a persistence forecast issued in August) and April SST anomalies (as used for a May issued forecast) respectively.

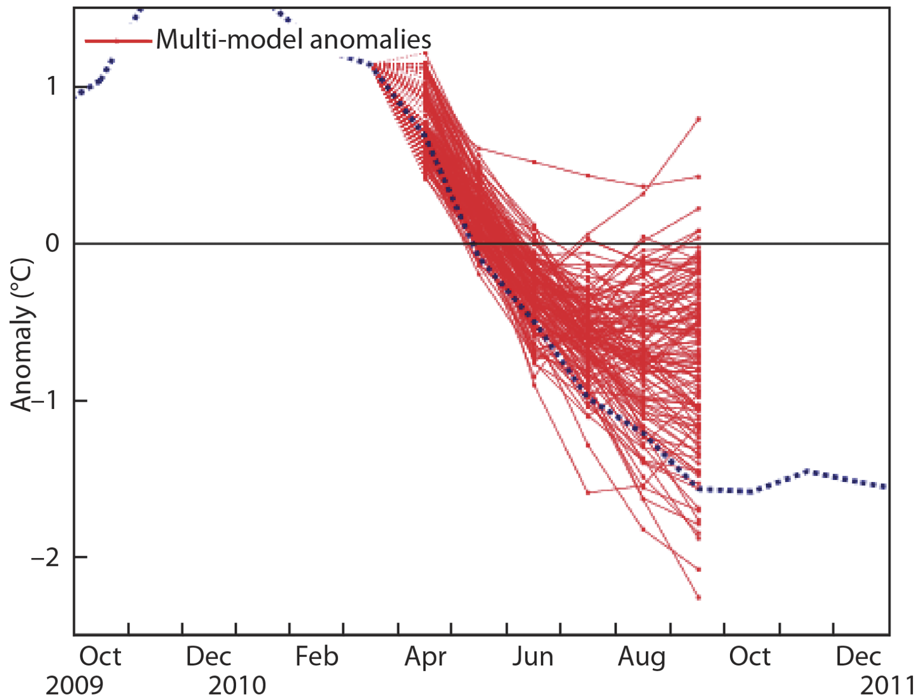

Figure 10: EUROSIP prediction of Nino3.4 SST anomalies from April 2010. The dotted blue line shows observed anomalies. (EUROSIP is a multi-model combination of forecasts from GPCs ECMWF, Exeter, and Toulouse.)

To illustrate further, Fig. 11 reproduces the EUROSIP Nino3.4 prediction from April 2010 which clearly indicated the observed rapid transition to La Niña conditions that contributed to depressed rainfall during the severe drought some 5-8 months later in the first of the two 'failed' seasons of the drought.

In some regions of Africa early warnings on timescales longer than seasonal may have sufficient skill for useful application. A new Met Office decadal prediction system developed as part of the CSRP programme has found positive skill for Nino3.4 out to 18 months ahead and for JAS season Sahel rainfall predicted from the preceding November, as well as for average JAS rainfall over the next 5 years ahead.

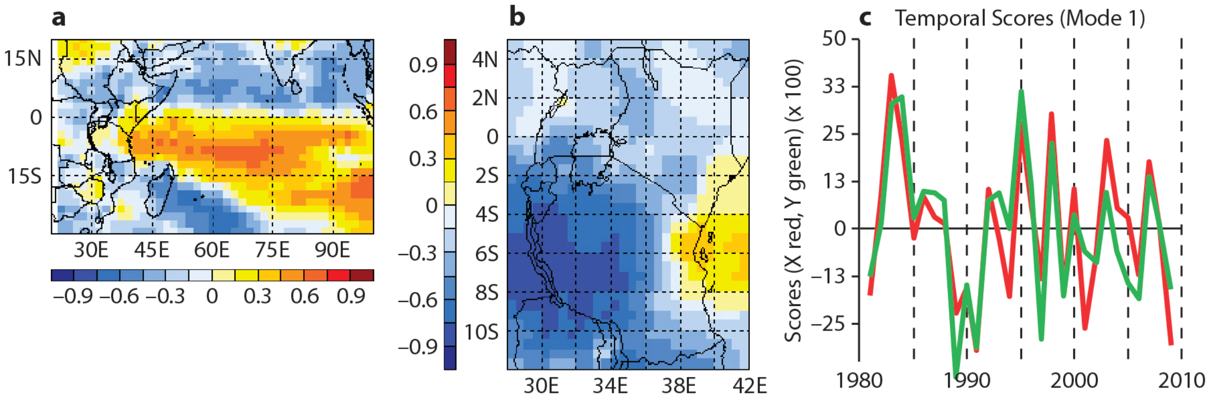

Figure 11: CCA of GPC Washington (CFS-1) MAM precipitation hindcasts (1981-2009) over an Indian Ocean domain with observed (PREC/L) MAM precipitation over the southern GHA, a) First CCA X mode for hindcast precipitation; b) corresponding Y mode for observed precipitation; c) timeseries 'scores' for hindcasts (X mode - red) and observations (Y mode - green).

5.2 Advanced calibration of dynamical model output

Calibration involves comparison of the 'track record' of the forecast system through comparisons of hindcasts (typically ensemble mean output) and observations to develop formulae that reduce systematic biases present in the direct model output. Use of such calibration methods is increasing in pre-forum workshops through the application of statistical processing available as part the Climate Predictability Tool (CPT)[2] developed by the International Research Institute for Climate and Society (IRI). The most common CPT tool used is Canonical Correlation Analysis (CCA). The principle involves finding paired patterns between model predicted fields and observed rainfall that are optimally correlated over the hindcast period. The covariance of the predictor (X variable) and predictand (Y variable) fields is represented by a series of paired modes. An example for the GHA region is shown in Fig. 12 and shows the first CCA X and Y modes for GPC Washington (CFS-1 system) ensemble mean hindcasts and observed rainfall (NOAA NCEP PREC/L dataset – Chen et al. 2002). It may be seen from comparing Figs 12a and 12b that when hindcasts show a coherent east-west oriented 'tongue' of above normal precipitation over the Indian Ocean (Fig. 12a) there is tendency for observed precipitation to be above normal over coastal regions (as also seen in hindcasts) but also a tendency for below normal precipitation over western Tanzania (Fig 12b) – a feature not seen in the hindcast pattern (Fig. 12a). The high

[2] IRI CPT:
http://portal.iri.columbia.edu/portal/server.pt?open=512&objID=697&PageID=7264&mode=2

temporal correlation of yearly projections of hindcast and observed rainfall onto these patterns is evident from Fig. 12c. The method thus has the potential to correct for systematic errors in local positioning and amplitude of climate anomalies and exploits the recognised strength of global models in predicting large scale patterns rather than local details. The downscaling aspect of the CCA operation is enhanced if station rainfall data is used for the predictand field.

Predictor fields other than precipitation may be readily used in the CCA approach. Ndiaye et al. (2012) and experience at RCOFs has shown that CCA predictions using model predicted 850hPa U and V fields as the X variable have comparable (or better) skill than use of precipitation as the X variable in some regions.

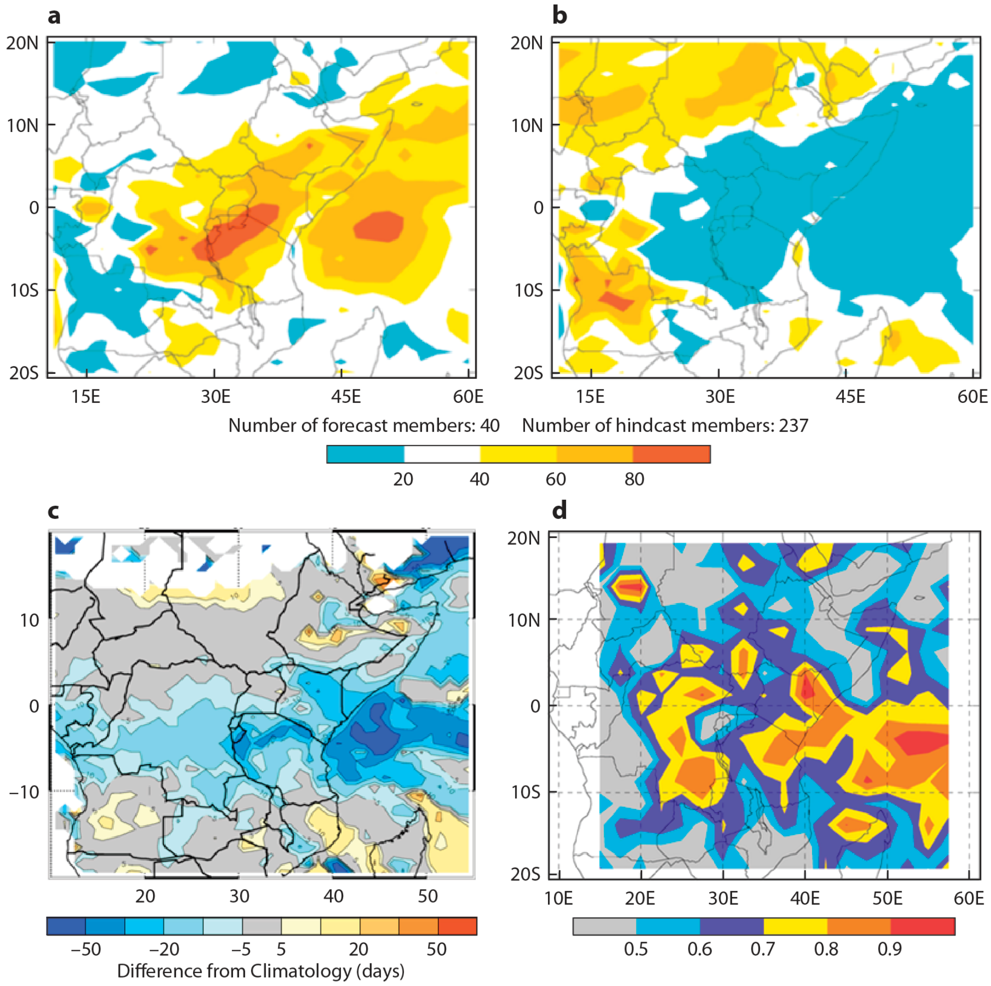

Figure 12: GloSea4 forecast probabilities (%) for early (a) and late (b) 'onset' of the 2011 short rains (Oct-Dec) over the Greater Horn of Africa, issued August 2011; c) Observed deviation in days from long-term average onset date (calculated from CPC FEWS-NET daily rainfall estimates: http://www.cpc.ncep.noaa.gov/products/fews/africa) negative values (blue) indicate early onset, in accord with raised forecast probability (orange/red in top left panel)); d) ROC scores for the late onset category calculated over 14 seasons (1996-2009) – scores for the early onset category are similar. Onset is defined here as the date on which 20% of the long-term local seasonal average has accumulated.

5.3 Combined statistical and dynamical forecasts

As described in section 4, most use of dynamical model forecasts at RCOFs is currently subjective. Kilavi and Colman (2012) have explored an objective combined statistical-dynamical prediction methodology for sub-national climate zones of Kenya. Combining is achieved by using, as predictors in linear regression models for each zone, indices of dynamical model output as well as the precursor SST and atmospheric circulation indices already employed. The dynamical model indices used were 1) predicted precipitation averaged over a rectangular area approximately covering Kenya; 2) Principle Components (PCs) of model precipitation and 850 hPa wind field for an extended domain covering most of Africa, the tropical Atlantic and Indian Ocean. Results were assessed from various combinations of these indices calculated using output from 4 dynamical prediction systems. Results so far indicate mixed benefits. There are encouraging results, with some notable improvements to forecast skill found in several zones indicating that the dynamical models are adding useful predictive potential on the scale of the climate zones. However, overall, over all seasons and climate zones it was found that skill was raised and lowered in about an equal number of cases. It was concluded that further research is needed to better understand the circumstances in which the dynamical models enhance prediction skill at these scales, in order to improve the combining methodology used.

5.4 Forecasting the timing of onset of seasonal rainfall and the frequency of extremes

The timing of the onset of the rainy season is of huge importance to African agriculture, through its role in determining the crop planting time and length of growing season, and development of new dynamical model forecasts of onset timing were given high priority in a consultation exercise conducted by the CSRP. Vellinga et al. (2012) found encouraging levels of skill (with traceable sources) in onset predictions for the West African Monsoon (WAM) and work is now being extended to the seasons of East and southern Africa with forecasts supplied to RCOFs for trialling and feedback.

An example onset prediction for the GHA SOND 2011 season, based on predicting the time of arrival of 20% of the long-term seasonal average rainfall is shown in Fig. 13. In this case early onset was predicted to have enhanced probability (Fig. 13a) and late onset reduced probability (Fig. 13b) - where early and late are defined using a 3 category tercile system. Early onset was observed to occur (Fig. 13c). A ROC score assessment over 14 years (1996-2009) (Fig. 13d) indicates spatially coherent scores in excess of 0.7 over parts of the region, suggesting useful levels of skill – a ROC score of 0.7 indicates that the forecasts correctly discriminate the event in about 70% of cases (Mason and Weigel, 2009) – at similar levels to those found for predictions of seasonal totals.

The frequency of dry spells and spells of extreme rainfall are also aspects of seasonal climatology of great interest to most users. Preliminary studies have found that these parameters have similar predictability to that of total seasonal rainfall. Specifically, in studies of the rainy season in 6 regions of Africa, GloSea4 predictions of the frequency of days with above 90th percentile precipitation ('extreme' rainfall days) were found to have similar correlation skill (in the range 0.2 – 0.6) to predictions of seasonal total rainfall (Fig. 14). Two methods of predicting the frequency of extreme days were tested. In the first they were counted in the daily model output, in the second they were inferred from the predicted seasonal total rainfall. Results were similar with each method. The predictability of dry spells was also investigated for the same regions/seasons. Correlation skill for ensemble mean predictions of the length of the longest consecutive run of dry days (daily rainfall less than 0.1mm) was found to be positive (0.2-0.6) in 4 of the 6 regions and generally similar to skill for predictions of the total (within the season) number of dry days.

These first results provide encouraging evidence of the potential of dynamical seasonal forecasting systems to provide useful long-lead guidance on prospects for sub-seasonal characteristics of African seasonal rainfall (onset, extreme rainfall, dry spells) in addition to (currently provided) predictions of seasonal rainfall totals.

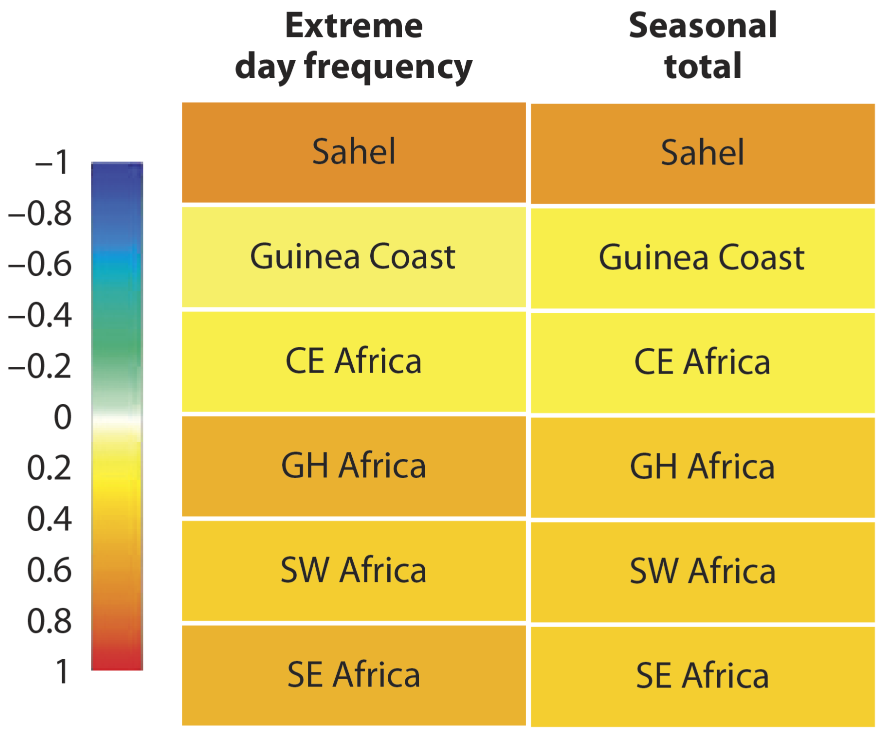

Figure 13: Comparison of correlation scores for GloSea4 ensemble mean predictions over 6 regions/seasons of Africa, top row: scores for forecasts of seasonal rainfall total; bottom row: scores for the in-season frequency of days with rain above the 90th percentile.

6 The developing WMO Global Seasonal Climate Update (GSCU)

(http://www.wmo.int/pages/prog/wcp/ccl/mg/documents/mg2011/POSTERS/11_gscu.pdf)

The GSCU is a new WMO initiative that will extend the existing WMO El Niño/La Niña updates by including 3-month-ahead global outlooks for temperature and rainfall based on output from the 12 WMO GPCs (using similar products to those shown in Fig. 5c and Fig. 9) as well as a monitoring component summarising the state of the global climate over the past 3 months. The objective is to provide an authoritative synthesis of predictive information from GPCs to assist primarily Regional Climate Centres, NMSs and RCOFs in all continents (including Africa) in preparation of regional and national forecast products. Development of the GSCU is a further step in international collaboration in seasonal forecasting that will contribute to the harnessing of international expertise on seasonal climate prospects to the benefit of users and will contribute to the GFCS vision of mainstreaming climate services into decision making. After implementation of the GSCU, a parallel product, tailored to the needs of aid agencies, is expected to be developed.

7 Summary

Regional Climate Outlook Forums have been active in Africa for 15 years. They are among the most developed platforms currently existing for synthesising diverse sources of climate prediction information and bringing it to the user community for the benefit of society. Independent studies have demonstrated that the consensus forecasts generated are skilful. Use of the forecasts is increasing and includes use for regional pre-emptive relief interventions and as input to derived products such as food security outlooks. Statistical forecast methodology still predominates in the forecast preparation – partly because of competitive levels of skill, at short lead, in some parts of Africa. Current use of dynamical forecasts is mainly subjective and centres on confirming or challenging the statistical results – which may influence final predicted probabilities - and the blending of individual national forecasts into a spatially coherent regional outlook.

The use of dynamical seasonal forecasts in the production of the consensus forecasts has increased in recent years, partly due to international collaboration, led by WMO, to develop standard forecast and verification products, and to improve their accessibility and usability for regional centres, NMSs and RCOFs. A number of GPCs, including the Met Office, have also been active in training on interpretation and use of the dynamical forecast products. In some regions, through the use of tools such as CPT, calibrated dynamical seasonal forecasts are now used increasingly to generate national seasonal forecasts and are therefore starting to carry similar weight in the regional consensus discussions as the forecasts produced by statistical methods. In collaboration with international centres, some regions have also begun researching objective combination of statistical and dynamical predictors.

In regions with relatively strong rainfall teleconnections to ENSO and other tropical SST modes, skill with statistical methods is, at short lead times, competitive with that of dynamical systems. In such regions a key potential benefit of coupled dynamical systems is to extend the lead time of predictions beyond that possible with statistical methods. It has been described, for example, how onset of the 2010 La Niña, implicated in the failure of the September to December 2010 rainy season in the Greater Horn of Africa and contributing to severe drought in the region, was foreseen with some confidence by dynamical systems as early as April 2010. Greater exploitation of this potential is important to strengthen climate early warning systems for the African continent.

Acknowledgement

The authors would like to acknowledge many discussions with climate scientists at the African regional centres ACMAD, ICPAC and SADC-CSC and support from a project funded by the UK Department for International Development for the benefit of developing countries. The views expressed are not necessarily those of DFID.

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