REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: United Kingdom

This form needs to be submitted via the relevant National Meteorological Service.

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Tim Palmer

Project Title:

Diagnosing subseasonal to seasonal predictability of the East African long rains

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** __________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2018-2020: (To make changes to an existing project please submit an amended version of the original form.)		**2018**	**2019**	**2020**
High Performance Computing Facility	(SBU)	30m		
Accumulated data storage (total archive volume)[2]	(GB)	30,000 Gb		

***An electronic copy of this form must be sent via e-mail to**:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

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Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

Principal Investigator: **David MacLeod**

Project Title: **Diagnosing subseasonal to seasonal predictability of the East African long rains**

As part of the NERC/DFID funded project ForPAc: Forecast-based Preparedness Action, we are investigating predictability over East Africa. Establishing the skill and reliability of probabilistic forecasts at subseasonal and seasonal timescales will feed into the ultimate aim of the project, which is to build and improve early warning systems for hydrometeorological hazards over Kenya. Such systems will aid governments, NGOs and communities to take actions in advance of damaging events, minimizing risk and mitigating loss. A systematic approach to taking forecast-based action has been developed by the Red Cross; project partners include the Kenyan Red Cross and the Kenya Meteorological Department amongst others.

Two results have been established from initial investigations into subseasonal and seasonal predictability of the long rains season over East Africa (March-April-May). Developing this initial work, we request 30m SBU in order to further probe model behaviour and test hypotheses. The results and experimental plans are described in turn below, followed by an estimation of the resources required.

Diagnosing errors in poor seasonal SST teleconnections

Using the 110-year seasonal hindcast ASF-20C (produced as part of the special project SPGBWEIS and described in Weisheimer et al 2017), baseline seasonal predictability of the long rains has been established for IFS/NEMO. The model has poor predictability, with a statistically significant but low ensemble mean correlation for seasonal total precipitation of around 0.1-0.2. Poor predictability of the East African long rains in dynamical models has been observed elsewhere (Batté and Dequé 2012). However, predictive models for MAM precipitation based on dynamical precursors (e.g. remote January zonal and meridional winds) suggest that higher correlations of around 0.6-0.7 are possible (Nicholson 2014).

Further investigation has revealed that the modelled teleconnection of long rains with remote SSTs is unrealistic (figure 1). The ASF-20C prescribed-SST simulations show strong links with the Pacific and Indian Ocean, whilst the teleconnection of observed rainfall with SSTs is much weaker. This is partly related to the lack of air-sea coupling, and the modelled teleconnection in coupled seasonal hindcasts (System 4) is better, particularly over the Indian Ocean. However, the coupled model still has an unrealistically strong link with SSTs, over the Pacific and also over the South Atlantic. The strong negative correlation with Atlantic SSTs is in fact worse in the coupled system than it is in the prescribed SST run.

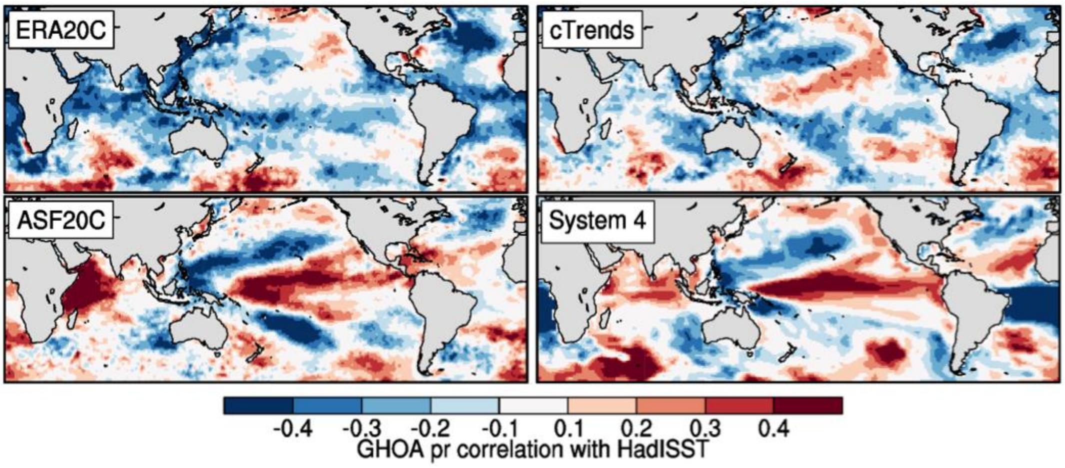

Figure 1: Teleconnections between Greater Horn of Africa MAM precipitation and concucrrent global gridpoint SST. Precipitation comes from (clockwise from top left): ERA20C reanalysis, Centennial Trends observed monthly precipitation (cTrends, Funk et al 2015a), ASF-20C prescribed SST hindcast (Weisheimer et al 2017) and System 4. All results are shown for the common period 1981-2009, though the pattern is similar when measured over the entire 20th period available for ERA20C, cTrends and ASF20C.

Note that the model seems to be reproducing the same strong SST teleconnection in the long rains that it simulates for the short rains (OND, not shown). During the short rains this strong teleconnection is much closer to reality, which shows a much stronger link with El Nino and the Indian Ocean Dipole.

It is hypothesised that the processes leading to long rains variability are more subtle than the short rains, likely involving air-sea coupling in multiple regions, and model is unable to simulate beyond the primary forcing by SST. Furthermore we speculate that any weaker sources of long rains predictability other sources (e.g. the land surface) are being swamped by the strong unrealistic SST forcing. Efforts to target and improve poor teleconnections may then lead to improvements in the seasonal predictions of long rains predictability.

In order to diagnose such errors in teleconnections, we propose a series of atmospheric relaxation seasonal hindcast experiments. In separate experiments, the atmosphere in different regions will be constrained to match reanalysis. Analysing the global atmospheric dynamics and SST teleconnections of experiments will improve understanding of model processes underlying the production of the long rains, aid diagnosis of the sources of teleconnection error and offer guidance for model development.

Three separate relaxation experiments are proposed, targeting separately the Indian, Pacific and South Atlantic Ocean. Existing relaxation code will be used to perform these experiments, which has been previously at Oxford for tropical relaxation experiments (see the final special project report for SPGBWEIS).

Establishing the source of predictable long rains onset

The onset of the long rains shows significant variability; in successive years the rains may arrive anywhere from early February to April. Rain-fed agriculture is widespread in East Africa, and onset forecasts would be valuable, guiding preparation and crop planting decisions. Indeed, onset forecasts are often cited as a primary need from users in the region (Richard Graham UK Met Office, personal communication). However the predictability and skill of onset forecasts has not yet been established.

Initial work at Oxford has evaluated the skill of onset forecasts in the extended range 46-day prediction system, for 1st February and subsequent start dates. Here the operational hindcast covering 1996-2015 with 11 ensemble members is used. Initial conditions come from ERA-Interim for the atmosphere and ERA-Land for the land surface.

Note that defining onset is not trivial and many definitions exist, ranging from local threshold-based (see references in Dunning et al 2016) to global-scale process-based indicators (Vellinga et al 2013). Here, we define onset for a gridpoint as the date when accumulated model precipitation exceeds 10% of the climatological seasonal average. Note that the 46-day forecast is then continued using daily mean model climatology, in order to produce a forecast onset date for every ensemble member (since a particularly dry member may not cross the 10% threshold by the end of the forecast). A full methodology will be included in future publication.

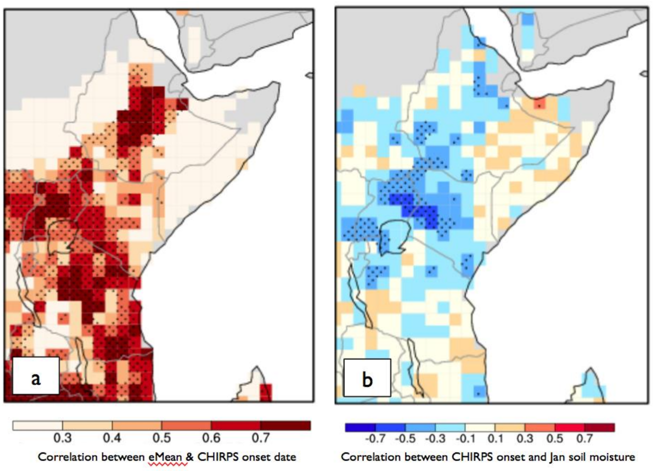

Figure 2: Initial results for onset forecasting. Left panel indicates ensemble mean correlation between 1-Feb initialized onset forecast from the extended-range system, verified against the CHIRPS precipitation dataset (Funk et al 2015b), across the common period 1996-2015. Right panel shows the correlation between observed onset date in CHIRPS and the precursor January total soil moisture anomaly, calculated across the CHIRPS period 1981-2016.

Results show that there is significant skill in predicting onset date (figure 2a), with ensemble mean correlations of over 0.7 in some regions. To give confidence in this result, sources of predictability are being investigated, including the initial land surface soil moisture. A first look at this compares the ERA-Land soil moisture in January against the observed onset date (figure 2b). This shows significant negative correlations over part of the region where the model is able to predict the onset (around Lake Victoria).

This leads to two hypotheses. Firstly, that initial soil moisture in advance of the long rains is linked to variations in the timing of onset. That is, a soil moisture deficit leads to a delayed onset, whilst the rains will arrive early if the soil is particularly wet at the end of January. Secondly, we hypothesise that the observed skill in the extended range forecasts in the region around Lake Victoria is arising from initialised soil moisture.

We propose to test these experiments by running two complementary extended-range experiments with modified land surface initial conditions. In the first, the 1st February start date will be simulated across 1981-2017, but with the land surface initial state for each year replaced with the same dry synthetic initial conditions. This will be created offline and modified to have an extremely dry soil. This will be repeated for a second experiment where the land surface will be initialized with a particularly wet soil.

These experiments will in general establish the extent to which land surface initial state contributes to onset predictability, and in particular, allow us to test our two hypotheses. If the first hypothesis is true, we expect years in the 'dry' hindcast experiment to have systematically later onset than the control, whilst the rains in the 'wet' experiment will arrive earlier. If the second hypothesis is true, then the onset correlation of both the experiments against observations should be lower than the control.

The experimental land surface initial conditions will be calculated offline using python and grib_api and subsequently stored on ECFS. The IFS code will then be modified to pick these up instead of extracting the 'correct' data from MARS. A similar method was used previously to perform SST denial experiments, described in the final special project report for SPGBWEIS.

Calculation of expected supercomputing resources

We request 30m SBU in total: 18m for the seasonal relaxation experiments, 10m for the subseasonal land surface predictability experiments and 2m to account for testing and allow for some uncertainty in SBU estimates. 30,000Gb has been estimated for storage.

Seasonal relaxation experiments

We plan to carry out three relaxation experiments plus a control. Ideally we would like to use the setup of the new release of the seasonal forecast, SEAS5. At the time of writing, an estimate of the cost of one month of the operational system is 8100 SBU (Tim Stockdale, personal communication). This is based on ¼ degree NEMO and TCo319L91.

8100 SBU per month is too expensive to carry out experiments with reasonable hindcast and ensemble size. However it is not clear at this point what the 'research' resolution of SEAS5 will be.

As such we estimate using 1200 SBU per month of our experiments. This is based on previous experiments with CY41R1 and T255 resolution costing around 1000 SBU per month, slightly increased to account for increases in cost arising from cycle changes (and moving to the new grid).

In total we plan four experiments, each comprising a 25-member ensemble initialized on each 1-Feb start date, 1981-2017 (37 start dates total). Each simulation will last four months (covering FMAM).

In total for one experiment, 1200 SBU per month results in a total of:

25 x 37 x 4 x 1200 = 4.44m SBU

For three experiments plus control we therefore require 18m SBU. Note that we require vertical velocities at all levels for the analysis, so we must therefore run a control and cannot use any existing simulations, which do not save monthly averaged vertical velocities by default.

Subseasonal land surface predictability experiments

Conversations with user support have resulted in an estimate for the cost of a single 46 run at operational resolution to of around 18,000 SBU (10,000 SBU for day 1-15 at TCo639 and 8100 SBU for 16-46 at TCo319). This is too expensive to carry out substantial hindcast experiments.

Instead we anticipate using lower resolution for both components, with day 1-15 at TCo319 costing 4050 (based on one month costing 8100, see previous section) and day 16-46 at TCo199 to cost around 4000 SBU (it was not possible to get an reliable figure for TCo199, so we assume a 50% decrease in cost from using TCo319: this is slightly uncertain).

Overall then, we estimate one 46 day run at TCo319, switching to TCo199 at day 15 to cost 8050 SBU.

The operational hindcast is 11 members and 20 years. We would like to run a longer hindcast, from 1981-2017, to put our initial results in broader context. Therefore we estimate the control experiment of 11 member ensembles across 37 start dates to cost:

$11 * 37 * 8050 = 3.27$m SBU.

We plan to run two experiments (‘dry’ and ‘wet’) plus a control. Therefore overall we require 10m SBU.

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