SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2018.
Project Title:	Diagnosing subseasonal to seasonal predictability of the East African long rains
Computer Project Account:	spgbmacl
Principal Investigator(s):	Dr David MacLeod Prof Tim Palmer
Affiliation:	University of Oxford
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	1-Jan 2018
Expected end date:	31-Dec 2018

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)			30m	11.6m
Data storage capacity	(Gbytes)			30,000 Gb	unknown

Summary of project objectives

(10 lines max)

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.

The objective of this special project is to use climate model experiments explore and understand the predictability characteristics of the two East African rainfall seasons as well as forecast performance on subseasonal to seasonal timescales.

Summary of problems encountered (if any)

(20 lines max)

The initial plan was to perform experiments with a setup similar to the new operational system SEAS5. Due to the prohibitaive cost of these runs it is not possible to run the operational version, rather a reduced-resolution research version was planned. However at the time of the start of this SP, the technicalities of the setup of this version were not entierly worked out, and it appeared that this would still be quite expensive. Instead, it was decided to proceed with a slighlty older version of the model: CY41R1. This has the advantage of being ready-to-go (previous work at Oxford has run experiments with this version of the model), and also is much cheaper - allowing many more experiments/ simulations to be carried out.

The downside of course is that it is slightly ‘out-of-date’. However it is understood that the impacts of model changes from CY41R1 to SEAS5 (CY43R1) are not major (Antje Weisheimer, personal communication), so it is unlikely that using CY41R1 will lead to any degradation in the quality of scientific insight from these experiments.

A second modification from the original plan was made. The initial project proposal described a work plan to investigate a hypothesized link between long rains onset and precursor soil moisture. This was motivated by an apparent correlation between long rains onset and january soil moisture (see original special project report). However, further investigation revealed that this correlation was largely an artifact of the metric used to define onset (accumulated rainfall). After moving to a more sophisticated metric (based on the turning point of accumulated daily anomalies), this apparent correlation was reduced to a value below significance. Experiments to investigate this link were therefore no longer necessary and so resources instead repurposed to target other hypotheses, as described below. NB work done to diagnose onset predictability in the ECMWF subseasonal and seasonal forecasts has been accepted and will be in press soon (MacLeod, 2018).

Summary of results of the current year (from July of previous year to June of current year)

This special project has been running for almost six months and appart from the divergence from the original plan outlined above, progress has been smooth. Almost half the resources have been used on two investigations: **"Diagnosing long rains predictability and teleconnections"**, and **"Insight on seasonal predictions of 2015 El Nino impacts over east Africa"**. It is planned that each of these will contribute separately to papers in preparation; details are provided below.

Diagnosing long rains predictability and teleconnections

The east African long rains has low skill in dynamical seasonal hindcasts (Dutra et al 2011), although statistical models using atmospheric precursors as predictors have suggested higher skill is possible (Nicholson 2014). Recently Vellinga & Milton (2018) have identified three potential drivers of the long rains seasonal total: Northwest Indian Ocean SSTs, overall seasonal MJO strength, and the phase of the QBO.

To diagnose further the drivers of long rains predictability, and look at the sensitivity of seasnoal forecasts to atmospheric processes in remote regions, several experiments using the technique of atmospheric relaxation (a.k.a. nudging). Three question guided the experimental design:

1. Which tropical region is the most important for east Africa during the long rains?
2. Are the long rains more sensitive to the upper or lower troposphere?
3. What is the sensitivity of the long rains to the north-west Indian Ocean region? (described as an important driver in Vellinga & Milton 2018)?

A coupled seasonal hindcast was run as a control, for 1-Feb start dates 1981-2014 with forecasts integrated over 4 months. 10 member ensembles were used, where the number of members was selected following initial analysis to ascertain an appropriate number of ensemble members needed in order to robustly estimate teleconnection strength.

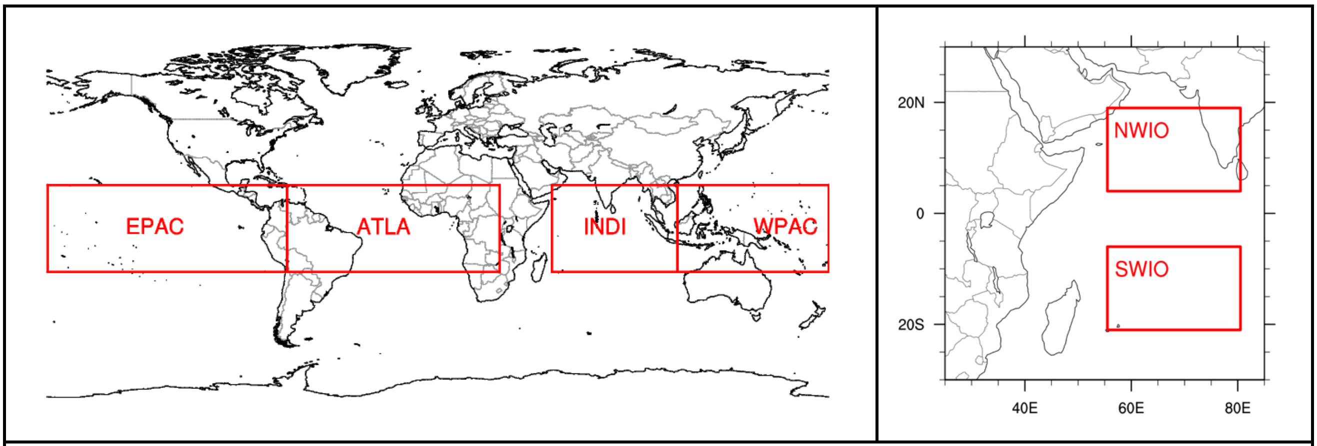
Following this, a series of nudging experiments were carried out following the control, but with sub-regions 'nudged' toward ERA-Interim (with some exponential smoothing at the boundary). The nudging method follows that described in Hansen et al (2017) where additional technical details may be found.

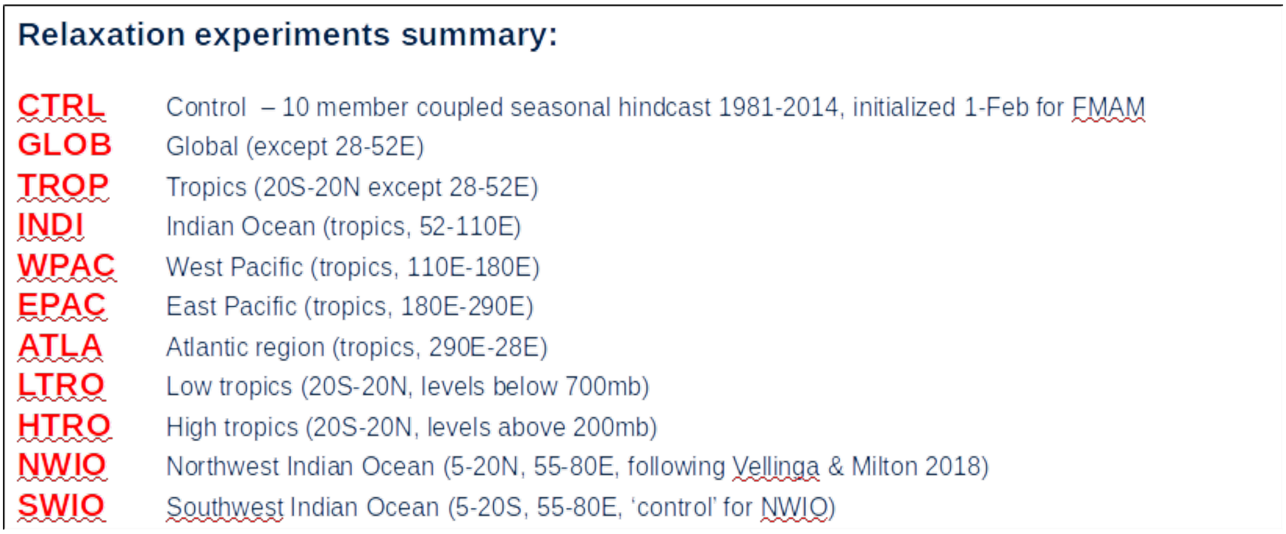
To answer the first question above, four tropical regions were selected; these are shown in figure 1a. In addition to these, experiments covering the whole tropics, and the whole globe were also run (TROP and GLOB).

The second question was addressed by running two experiments; where the relaxation of the TROP experiment was limited to the low tropics (LTRO, below 700mb) and high tropics (above 200mb) separately.

The final question was addressed by defining a box according to the sensitive region in the north west Indian Ocean described in Velinga & Milton (2018) (55-80N and 5-20N, NWIO). As a control for this relaxation, a second experiment with relaxation mirrored in the equator (55-80N and 5-20S) was run. The null hypothesis in this case is: if east Africa is not particularly sensitive to the NWIO region, then both the NWIO & SWIO should show similar impacts on the long rains forecast in the experiments (being as they are, a relatively similar distance to the region).

A summary of the experiments is provided in figure 1(c).




Relaxation experiments summary:

CTRL	Control – 10 member coupled seasonal hindcast 1981-2014, initialized 1-Feb for FMAM
GLOB	Global (except 28-52E)
TROP	Tropics (20S-20N except 28-52E)
INDI	Indian Ocean (tropics, 52-110E)
WPAC	West Pacific (tropics, 110E-180E)
EPAC	East Pacific (tropics, 180E-290E)
ATLA	Atlantic region (tropics, 290E-28E)
LTRO	Low tropics (20S-20N, levels below 700mb)
HTRO	High tropics (20S-20N, levels above 200mb)
NWIO	Northwest Indian Ocean (5-20N, 55-80E, following Vellinga & Milton 2018)
SWIO	Southwest Indian Ocean (5-20S, 55-80E, 'control' for NWIO)

Figure 1: (a,b) some regions used to diagnose long rains predictability; (c), summary of the region definitions for all long rains relaxation experiments

Results of these experiments are being prepared for publication and will be presented at an ECMWF seminar in July. A full description of the results will be provided in the final special project report. Here a summary is presented in figure 2, showing the relaxation regions in each case providing the most impact on the seasonal forecast of the long rains.

The Indian Ocean region dominates the north and east across all months, however the Atlantic region also has some influence, particularly over Tanzania (figure 2, top panel). The lower tropics has more influence over the high tropics (figure 2, middle), whilst the north west Indian Ocean is shows much greater influence over the regional climate compared to the south west, consistent with the results of Vellinga & Milton (2018). However, processes in the the south west Indian Ocean play a role in the end of season precipitation, in May (figure 2, bottom right). This is likely linked to the strengthening of the Somali jet and the setup of the Indian Monsoon.

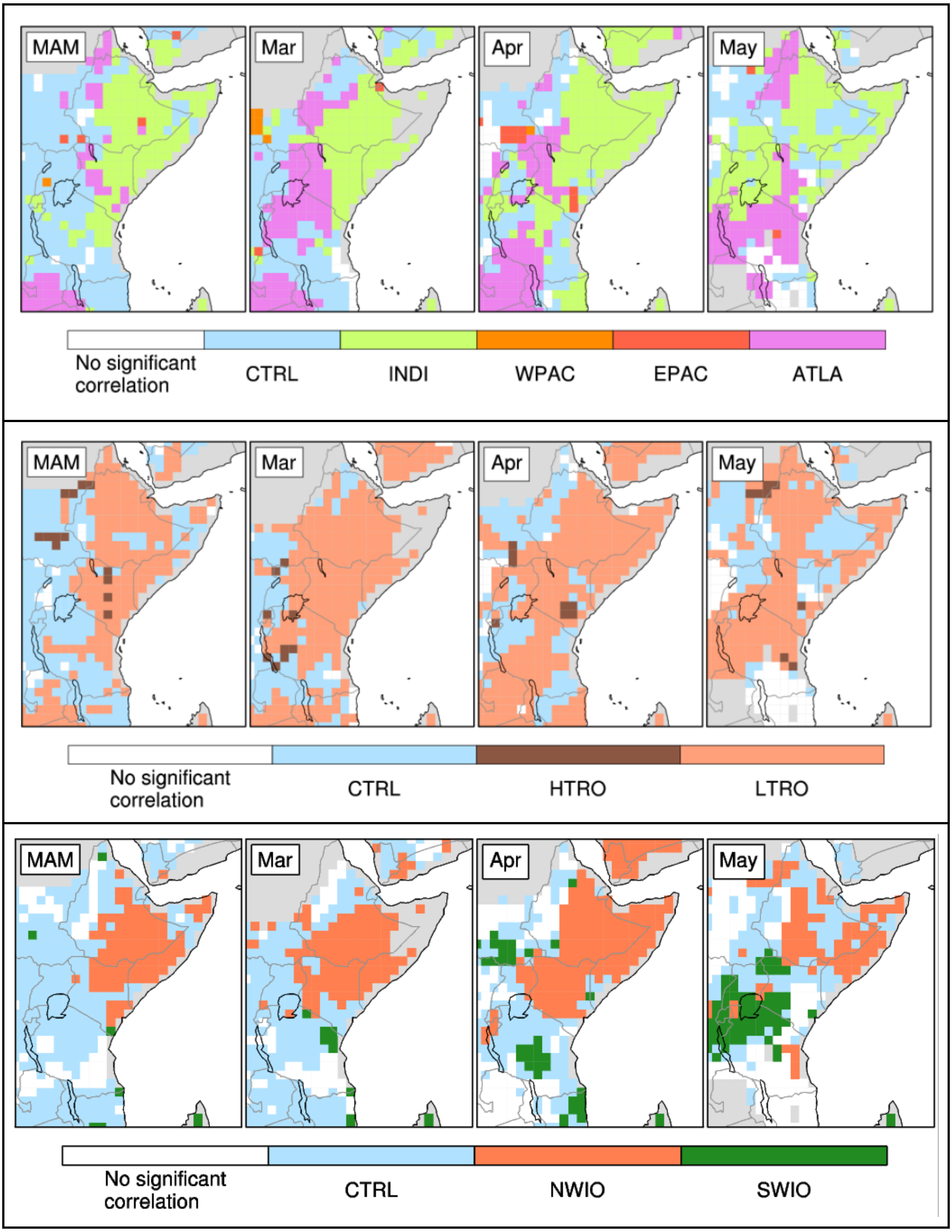


Figure 2: Impact of relaxation experiments on ensemble mean correlation over the long rains (MAM) and its constituent months (left to right). Top: comparison of the tropical sub-regions, middle: comparison of the high or low tropics experiments, bottom: comparison of the northwest or southwest Indian Ocean region. In each plot the colour indicates the experiment giving the largest significant increase in ensemble mean correlation over the control. Where it is coloured CTRL, no experiment gives significant increase and where it is coloured "No significant correlation", neither experiments nor control had significant ensemble mean correlation against observations (here, the CHIRPS precipitation observations were used as a reference).

El Nino during the east African short rains (OND) is often associated with increased rainfall and flooding. During the 1997 El Nino the region experienced one of the wettest seasons ever recorded, and was impacted by significant flooding (figure 3). However during the short rains of 2015 despite the strongest El Nino on record the impacts over much of east Africa were relatively mild (figure 3, right panel). This was linked to processes in the Indian Ocean, where the Indian Ocean Dipole (IOD) was more moderate compared to 1997.

Though an extreme rainfall year was not observed over much of the region, particularly over the dry north east of Kenya, the ECMWF seasonal forecast predicted an extremely wet anomaly from forecasts issued 1-Sep (figure 4). Though only parts of the region experienced a 1 in 5 wet year (i.e. a 80th percentile event), System 4 indicated that a the probability of this event over the whole region more than doubled. This might reasonably be considered a false alarm. Studying the SST anomalies (figure 4, right) indicates that the model predicted a more extreme zonal SST gradient over the Indian Ocean than observed, consistent with a too-strong IOD pattern, associated with increased easterlies at the surface and westerlies at height.

To explore this forecast event seasonal hindcasts were carried out, where the atmosphere of the east Indian Ocean was relaxed toward ERA-Interim. This allows examination of the sensitivity of the seasonal forecasts to the model processes in this region.

A control experiment was run, with a coupled 25 members forecast initialized on 1-Sep 2015, integrating for four months. Three nudging experiments were run based on this control:

- IOD2: nudging between 90-110E and 10S-equator
- IOD2+: 70-110E and 10S-equator
- IOD2++: 70-110E and 10S-10N

These regions are shown in figure 5. The first experiment was chosen to coincide with the east box used to define the IOD (IOD2) and subsequent experiments used enlarged regions. In each experiment nudging was only carried out below 700mb.

Results indicate that each nudging experiment reduced the precipitation signal in the west Indian Ocean, but it is only extending the relaxation box west and north of the IOD2 box (IOD2+ and IOD2++) that significant reductions in the wet signal over east Africa are seen. Forecasted precipitation anomalies for the control and three experiments are shown in figure 7. These results suggest that the source of the overprediction of 2015 wet anomalies over east Africa may be attributed to processes in the east Indian Ocean, where System 4 simulated a too-strong IOD. This too-strong IOD had associated easterly zonal surface winds and westerly winds at height (not shown).

Analysis of this work is in preparation and will be submitted shortly. Full details will be provided in the final report for this special project, which will be submitted in June 2019.

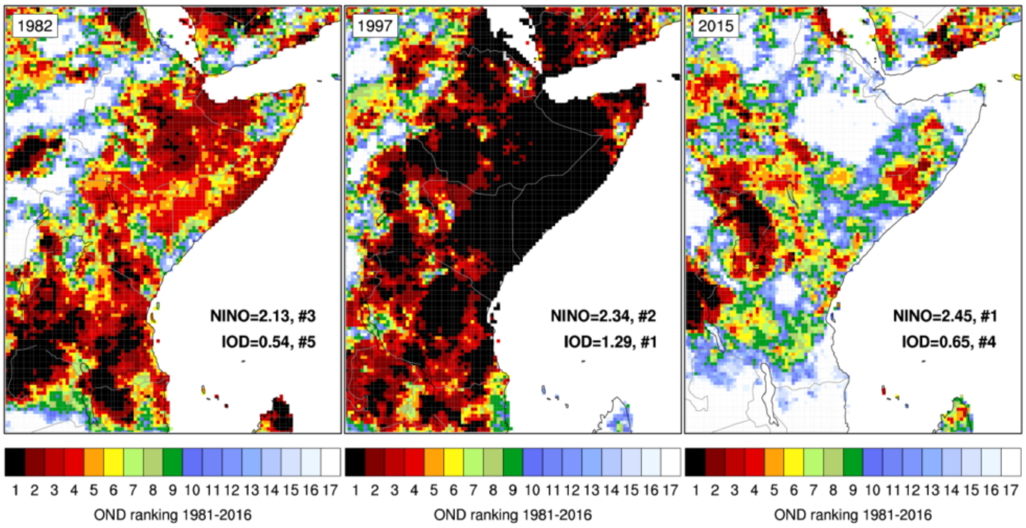


Figure 3: the ranking of the short rains season relative to 1981-2016 during the strongest three El Nino events in that period (1982, 1997, 2015 left-right). Inset are the average ENSO and IOD indices during the season (using N3.4 SST and the DMI IOD index from the Australian Bureau of Meteorology).

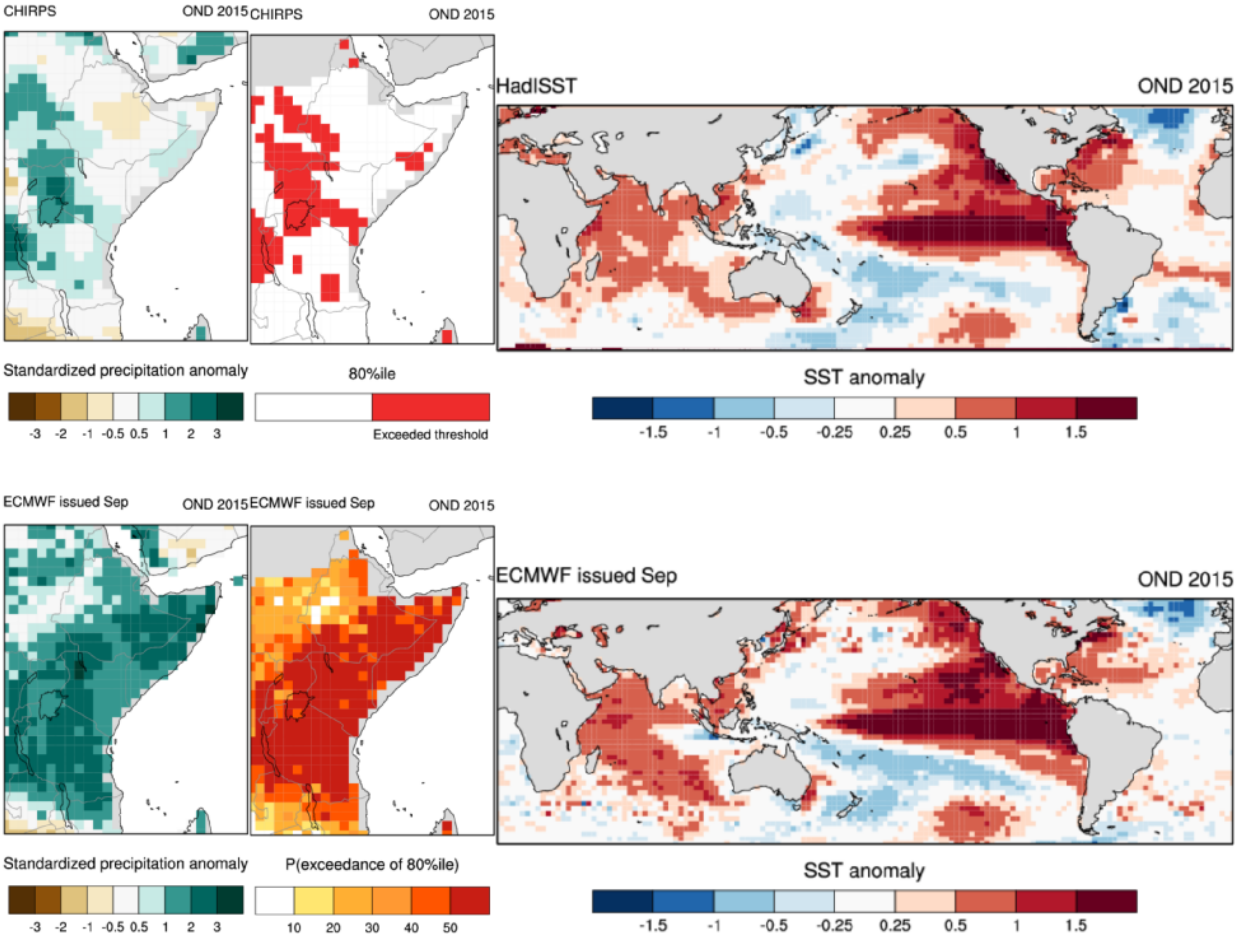


Figure 4: OND 2015: CHIRPS precipitation standardized anomaly (top left) and regions where CHIRPS indicated OND 2015 was an 1 in 5 year event (top middle). Top right shows the coincident observed SST from HadISST. Bottom row shows System 4 forecast from the event, from forecasts initialized 1-Sep. From left to right: standardized ensemble mean precipitation anomaly, % of 51 members indicating a 1 in 5 year events, and ensemble mean SST anomaly.

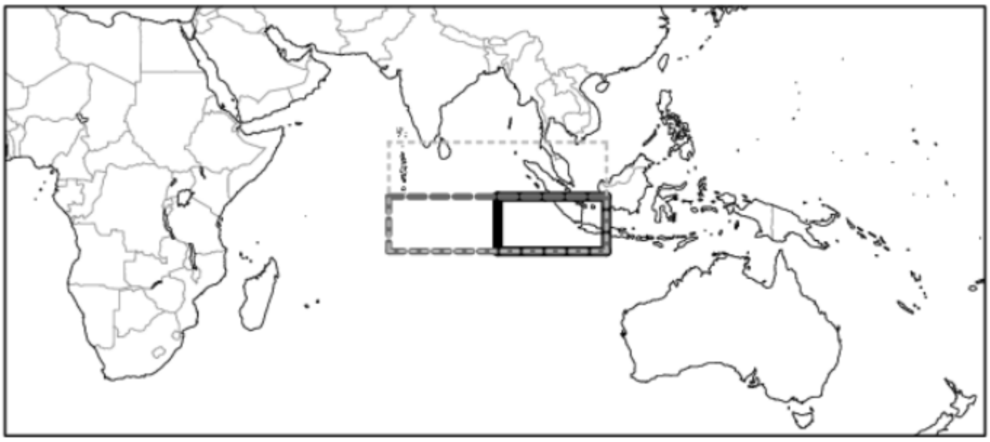


Figure 5: Regions used for atmospheric relaxation experiment. IOD2+ (thick black), IOD2++ (medium dashed dark grey), IOD2++ (thin dashed light grey).

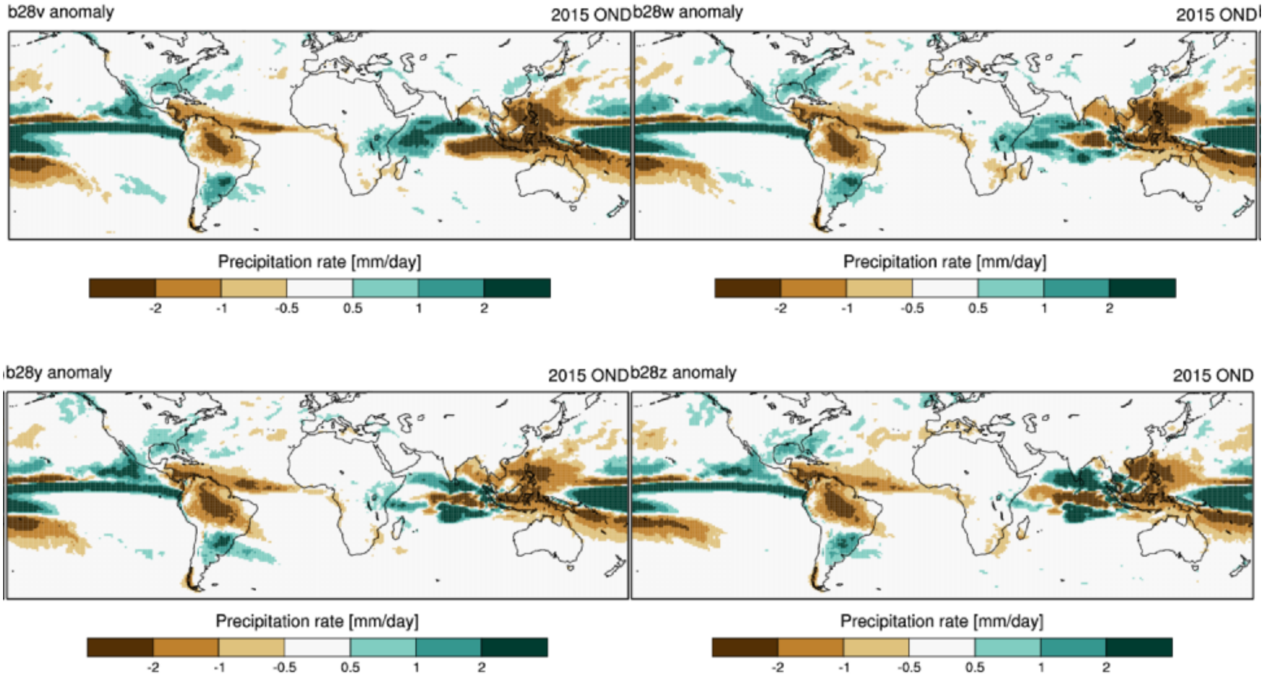


Figure 6: ensemble mean precipitation anomaly in the relaxation experiments: control (top left); IOD2 (top right), IOD2+ (bottom left) and IOD2++ (bottom right).

List of publications/reports from the project with complete references

Planned publications arising from this special project:

MacLeod D & Caminade C, “Seasonal prediction of the 2015 El Nino over East Africa; insight from atmospheric nudging experiments”, in preparation

MacLeod D “Insight on drivers of the east African long rains from nudging the atmosphere in coupled seasonal hindcast experiments”, in preparation

Publications referenced in this report:

Dutra, E, et al. "The 2010–2011 drought in the Horn of Africa in ECMWF reanalysis and seasonal forecast products." International Journal of Climatology 33.7 (2013): 1720-1729.

Hansen, FRJ et al. “Remote control of North Atlantic Oscillation predictability via the stratosphere”. Quart. J. Roy. Meteor. Soc., 143, (2017) 706–719.

MacLeod, D, “Seasonal predictability of onset and cessation of the east African rains (2018), Weather and Climate Extremes (accepted)

Nicholson, SE, “The Predictability of Rainfall over the Greater Horn of Africa. Part I: Prediction of Seasonal Rainfall”. J. Hydromet. 25: (2014) 1011-1027. doi: 10.1175/JHM-D-13-062.1

Nicholson, SE “Long-term variability of the East African “short rains” and its links to large-scale factors” Int. J. Climatol., 35 (2015), pp. 3979-3990,

Vellinga M and Milton S “Drivers of interannual variability of the East African “Long Rains”, Quarterly Journal of the Royal Meteorological Society (2018), accepted, https://doi.org/10.1002/qj.3263

Summary of plans for the continuation of the project

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Over half of the SBU for this project remain. These will be used for:

- Investigating a potential link between January south Pacific SST and March rainfall over east Africa (work with Richard Graham UKMO and Abubakr Salih IPCAC).
- Understanding the drivers of short rains drought over east Africa - Nicholson 2015b indicate that whilst wet seasons have clear climate drivers, dry seasons are less well understood. A combination of relaxation and forced SST experiments will be carried out to investigate this question.