GCRF AFRICAN SWIFT

Project Deliverable Cover Sheet

Title of Deliverable: Testbed 1: Synoptic forecasting and nowcasting.

Deliverable no.: **D-C2.2**

Work Package no. and title: **WP-C2 - Testbeds**

Author(s)/delivery person (lead first) and their institute(s):

Jennifer Fletcher (University of Leeds, NCAS) and Doug Parker (University of Leeds), with contributions from Andrew Hartley (Met Office), Elias Nkiaka (UoL), Elijah Adefisan (African Centre of Meteorological Applications for Development), Sam Clarke (UoL), Thorwald Stein (University of Reading), David Koros (Kenya Meteorological Department), and Beth Woodhams (UoL)

Due date: **December, 2019**	Date submitted: **9 March 2020**

Date cover sheet completed: **9 March 2020**

A. Short Report on the deliverable. Please provide a short (e.g. 1-page) summary of your deliverable. Please see guidance, below, on detail you should provide for different deliverable types. Your answers will enable quick and accurate review of your deliverable by another member of the SWIFT consortium, and help us to promote the results more widely. Please attach related deliverable documents (i.e. finished paper; report; link to the tool; event survey feedback, etc.).

Short summary:

This document describes the activities and outcomes of the GCRF African Science for Weather Information and Forecasting Techniques (SWIFT) Weather Forecasting Testbed 1. Testbed 1 was the first event of its kind conducted in Africa, and brought together operational forecasters and researchers to forecast African weather patterns in real time. The results of the exercise are being used to steer research, training and operational forecasting development in Africa.

Testbed 1 was conducted in the first part of 2019, from an operational forecasting office at IMTR Nairobi, at the Kenya Meteorological Department (KMD). Other centres connected to the Testbed by video-conference.

The Testbed was designed to support SWIFT's programme of research capability-building in the science of weather prediction. New forecasting and evaluation products were tested. The outcomes of the Testbed will be used to steer the research and development of these tools, as well as to provide meteorological case studies and to stimulate new hypotheses.

Successes of Testbed 1 include the real-time use of satellite-based Nowcasting products (NWC SAF products), convection-permitting model ensembles from the UK Met Office and systematic forecast evaluation. Testbed 1 also devised and refined an effective programme of work for operational synoptic forecasting, nowcasting and evaluation, which could form the basis for new Standard Operating Procedures.

For all deliverables, please also provide a short (100-word) summary suitable for the web/a general audience

B. Impact of this work towards the three primary outcomes of SWIFT

There is a requirement that all work contributes to the three primary impacts of SWIFT, stated below. Using the prompts as suggestions please demonstrate how your work adds value. (guide: up to 100 words each)

1. **Research advances needed for significant improvements in weather forecasts in Africa, and the tropics more generally, from the hourly to the seasonal timescale**
   (How does this work advance our scientific understanding of the weather and climate of tropical Africa? How has collaborative research with our African partners benefitted these scientific outcomes?)

The Testbed has been a critical moment in the SWIFT project, focussing our theoretical work in universities and research groups, on the daily challenges of delivering accurate weather forecasts.

2. **Capability-building among UK and African partners to improve, maintain and evaluate operational tropical forecasts in future**
(How does this work link through to help inform or design potential future weather services? What specific economic development or social welfare outcomes in tropical Africa could this work contribute to?)

For many of the African and UK researchers, this was their first experience of operational forecasting (to be extended in Testbed 1 in January / April-May 2019). Therefore this had a significant influence on the insight of African and UK researchers into forecasting issues.

3. **Development of African partners' capacity for sustained training of forecasters, in partnership with African academic institutions and international agencies**
(How does this work progress collaborative relationships between UK and African weather scientists? e.g. is it a joint paper / collaborative project? Does the work involve visiting scientists? Has a training programme been devised?)

The testbed has also had an influence on training in synoptic forecasting and nowcasting: the methods used are being turned into practical activities at some centres. This was initiated by the prior training event in Togo (Deliverable D-C1.5).

GCRF AFRICAN SWIFT TESTBED 1 REPORT

Document authors: Jennifer Fletcher (University of Leeds, NCAS) and Doug Parker (University of Leeds), with contributions from Andrew Hartley (Met Office), Elias Nkiaka (UoL), Elijah Adefisan (African Centre of Meteorological Applications for Development), Sam Clarke (UoL), Thorwald Stein (University of Reading), David Koros (Kenya Meteorological Department), and Beth Woodhams (UoL)

1. Summary

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2. Aims

GCRF African SWIFT Testbed 1 created an opportunity for developmental testing of forecasting systems for Africa in a quasi-operational environment among researchers, operational meteorologists, and users. See Ralph *et al*. (2013) for a general description of the concept of forecasting testbeds and Appendix G for a short summary of SWIFT.

Ideas developed in the Testbed will be followed-up in research and operational activities of the GCRF African SWIFT research programme (2017-2021), and the long-term activities of SWIFT's partners.

Through these interactions, we aim to contribute to improving the delivery of useful forecast information based on Numerical Weather Prediction products to users in Africa.

The specific scientific focus of Testbed 1 was the integration of research and operational practice in the area of **synoptic weather forecasting and nowcasting** for Africa (0 to 120 hours) and the **evaluation of these forecasts**.

We aimed to implement new forecasting, nowcasting and evaluation tools, perhaps for the first time in tropical Africa, notably

- convection-permitting NWP model data, including convection-permitting (CP) ensembles, and
- satellite-based Nowcasting tools, generated from the NWC SAF[1] software.

[1] Nowcasting Satellite Application Facility: http://www.nwcsaf.org/

More detailed objectives of the Testbed, and a discussion of progress on each one, are given in Section 7.

3. Arrangements

SWIFT Testbed 1 was hosted at KMD / IMTR Nairobi. The event was split into 2 distinct activities:

a) <u>Testbed 1A: 24-29th January 2019 (6 days)</u>

This event was a preliminary activity as a dry-run to prepare tools and methods for the bigger Testbed 1b event to follow in April. Testbed 1a was scheduled to contribute support to the **HyVic-Pilot** flying campaign (Woodhams et al, 2020) over Lake Victoria that forms part of the World Meteorological Organisation (WMO) HIGHWAY (High Impact Weather Lake System) project. The HIGHWAY project exists to deliver improved forecasting capability for the Lake Victoria region specifically for users engaged in fishing and transport on the lake.

The event was conducted as a virtual, distributed event, with most participants contributing by video-link from their home institution. The forecasts and discussions were coordinated from a hub in Nairobi, with a small group of researchers and forecasters based in KMD.

This event was a preliminary activity which should stimulate the development of tools, methods and outputs for Testbed 1B.

b) <u>Testbed 1B: Tuesday 23rd April to Monday 6th May 2019 (14 days)</u>

Testbed 1B was the main activity in Testbed 1, and was attended in person at the Kenya Meteorological Department by more than 40 researchers, forecasters, and academics from the following institutions:

<u>SWIFT partners</u>
The African Centre of Meteorological Applications for Development (ACMAD)
Kenya Meteorological Department (KMD)
University of Nairobi (UoN)
Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM), Senegal
Université Cheikh Anta Diop (UCAD), Senegal
Ghana Meteorological Agency (GMET)
Nwame Nkrumah University of Science and Technology (KNUST), Ghana
Nigerian Meteorological Agency (NiMet)
Federal University of Technology, Akure (FUTA), Nigeria
University of Leeds (UoL)
University of Reading (UoR)
UK Met Office (UKMO)

<u>Non SWIFT partners</u>
l'Ecole Africaine de la Météorologie et de l'Aviation Civile (EAMAC)
Tanzania Meteorological Agency (TMA)
Uganda National Meteorological Authority (UNMA)

Additional data was supplied by researchers from the Centre for Ecology and Hydrology (SWIFT partners) in the UK.

Reports and planning documents are kept on the SWIFT password-protected wiki[2], and those documents can be made available to collaborators on request. The remainder of this report is focussed on Testbed 1B.

[2] https://projects.ncas.ac.uk/projects/gcrf-african-swift/wiki/WP-C2_Forecast_testbeds

4. Organisation of forecasting operations

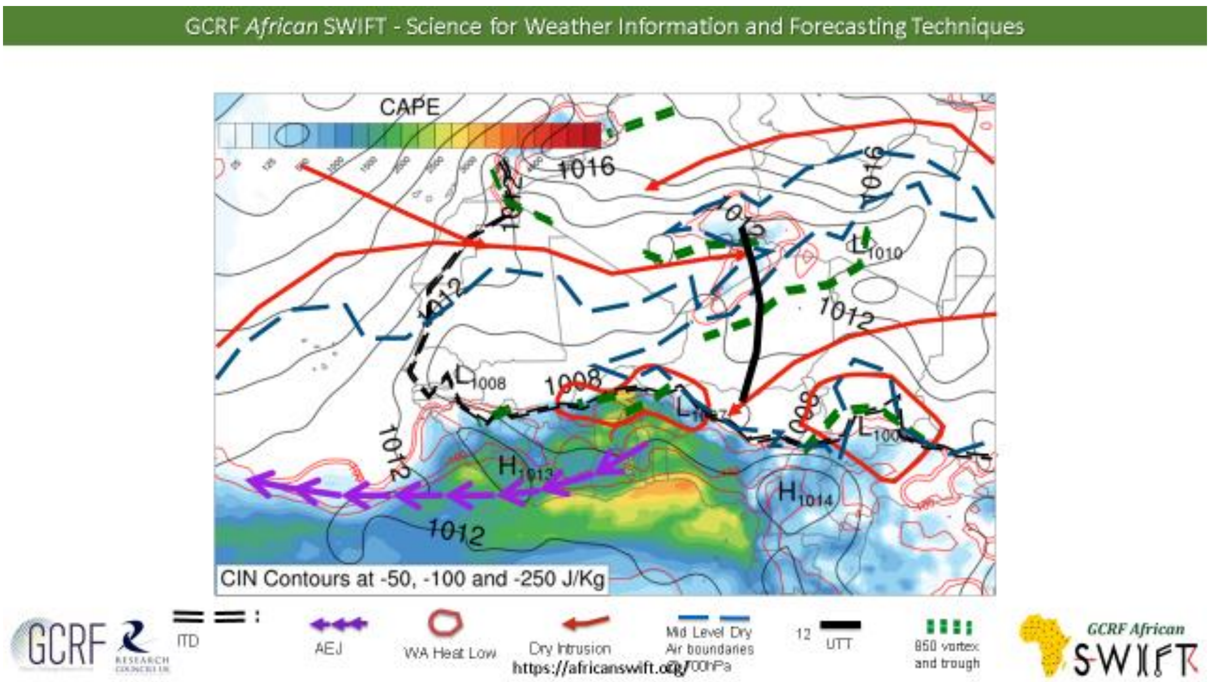
Testbed participants were divided into three groups:

- Synoptic forecasting
- Nowcasting
- Evaluation

Most participants rotated through all three groups over the course of the testbed, with individuals typically spending 2-4 days in a given group before moving to the next. The primary purposes of the groups were as follows (the activities of the groups are provided in detail in the Appendices A-C).

<u>I: Synoptic forecasting</u>

Synoptic forecasting was divided into three desks: pan-Africa, west Africa, and east Africa. The primary duties of the synoptic shift were to give a 1-3 day forecast for each of those regions. The pan-African forecast included attention to large scale and sub-seasonal features such as the MJO. For West Africa, duties included producing a West Africa Synthetic Analysis/Forecast (WASA/F; see Lafore et al. 2017). For East Africa, there is no agreed upon synthetic analysis, but forecasters described the position and strength of important high pressure centres and other synoptic features (see Appendix B). In reality, all of these activities were carried out according to the skills and experience of the leading individuals on shift, underlining the need for more training prior to the testbed.



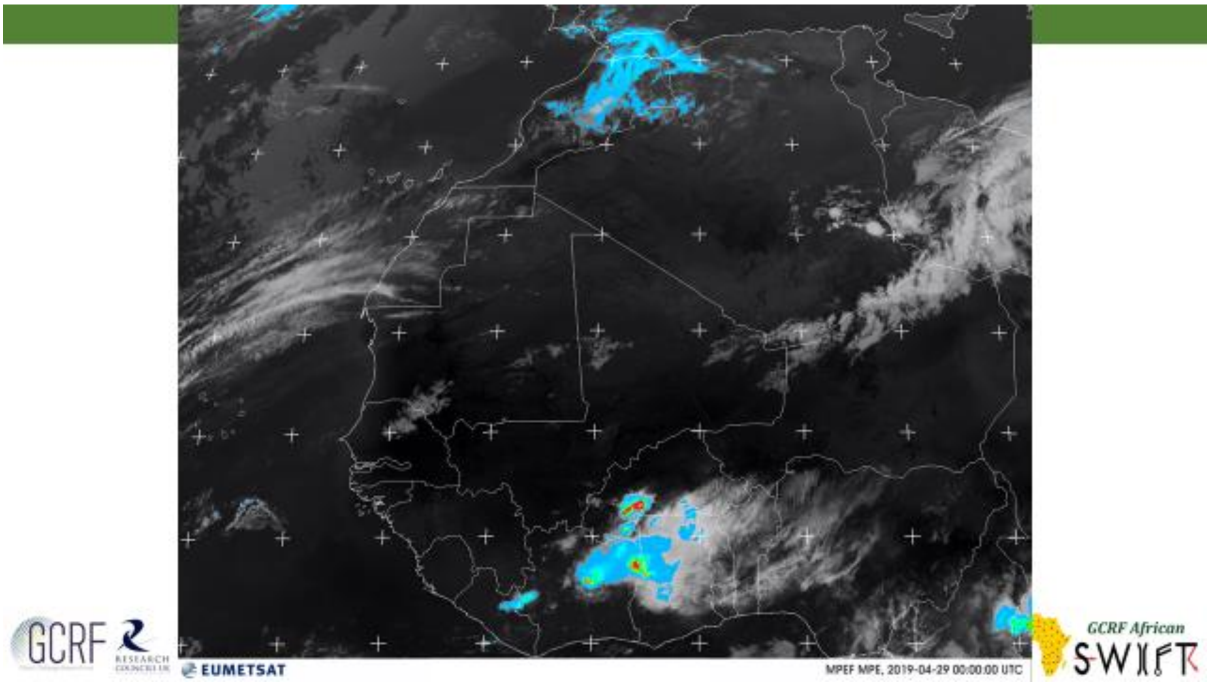


Figure 1: Example WASA chart for Monday 29th April 2019 0000Z, showing how the synoptic analysis helps explain the CAPE distribution. This, along with the wind-shear provided by the AEJ, gives guidance on the behaviour of the resulting storms (lower panel).

The synoptic group was also charged with producing short-range (24h) high impact weather forecasts for West and East Africa. This forecast was to follow the procedures of SWFDPincluding filling in the SWFDP table described in more detail in Section 6, but was more finely resolved in time (giving an interval of hours in which severe weather is expected) and space. The short-range forecast was entered into a standard spreadsheet, used subsequently for evaluation, and is accompanied by a powerpoint showing key forecast features, However, as with the 3-Day forecasts, the spatial and temporal precision of the forecasts was inconsistent from day to day, and not everyone used the spreadsheet.

The final task of the synoptic group was to provide a daily briefing to the evaluation and nowcasting teams on both the 3-day forecast and the 1-day high impact weather forecast.

II: Nowcasting

Use the NWC SAF products (see description of this products in Appendix G) to identify (label), track, and predict the development and motion on time scales of 0-6 hours of severe storms over West and East Africa. In practice the brightness temperature product from the Met Office Africa Web Viewer was also used, because at the time of Testbed 1B the SWIFT implementation of NWC SAF had a latency of about 60 minutes. Nowcasting was performed over the afternoon and evening and through the night, the time of day when storms over these regions are most active.

Nowcasters documented their activity either through building a database of storms through the evening or, more commonly, with an ongoing powerpoint presentation where they captured images from their nowcasting tools and labelled storms. It was common to produce roughly one slide per hour, including analysis of the current state of storms with predictions of the storms in coming hours. Nowcasters also mused on the possible physical mechanisms associated with specific storms and noted times when model forecasts missed storms. This latter exercise proved very useful to the Evaluation team.

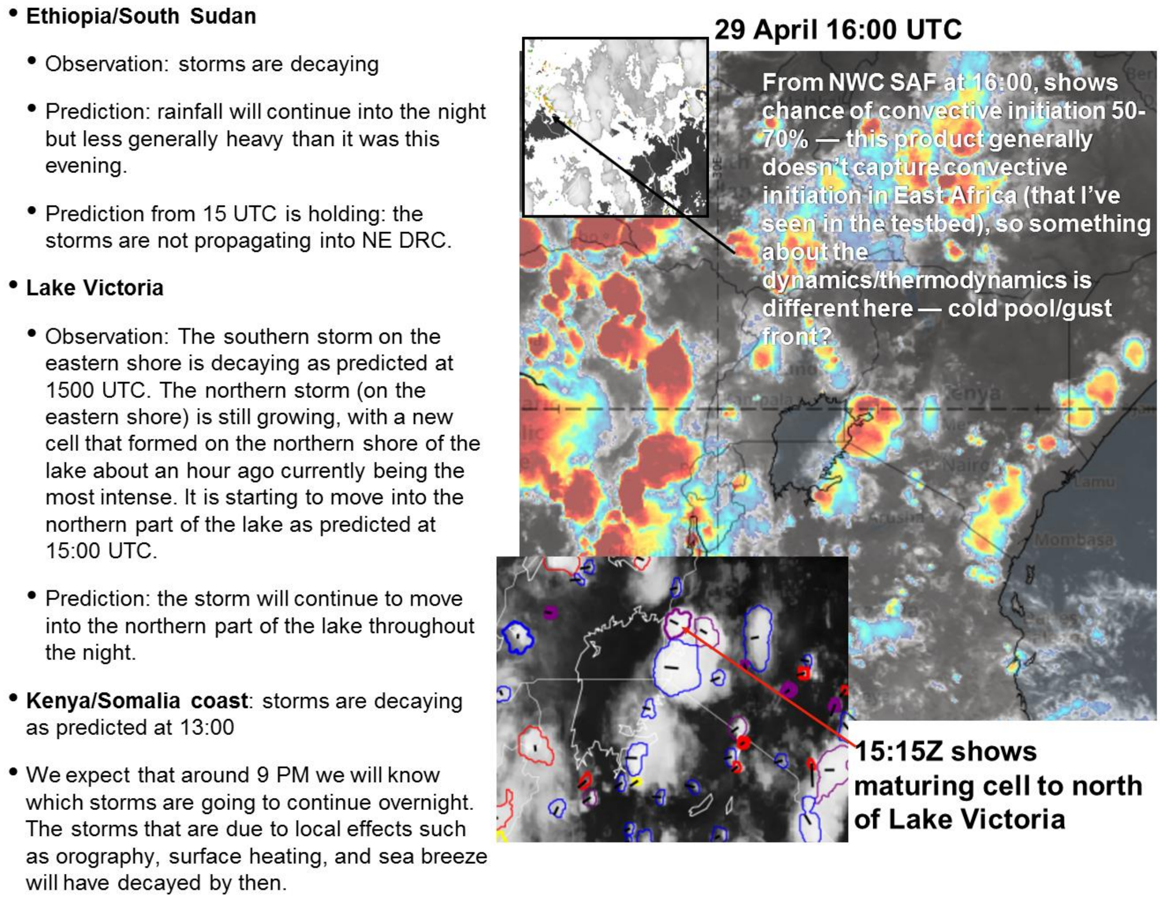


Figure 2: Sample nowcasting slide for East Africa

This group was also tasked with providing a commentary on the usefulness of different NWC SAF products. These remarks are being used to prioritise research into the NWC SAF products and will be fed back to the SAF development team.

III: Evaluation:

This group evaluated the previous synoptic forecasts, with an emphasis on the previous day's high impact weather forecast. This was done by qualitatively evaluating forecasts by comparing to analysis, and satellite observations (including GPM rainfall, when available) in map view. They also compared GPM accumulations with areas forecasters suggested high rainfall totals; checked GPM accumulations against missed storms highlighted by nowcasting groups; and studied GFS analyses to attempt to find reasons for bad/good forecasts. When the previous day's synoptic forecasting group filled in the forecast side of the evaluation table, these forecasts could be quantitatively evaluated. The group would use observations and analysis to fill in the evaluation side. For some locations they were able to use ground stations by looking at station rainfall reports and then checking if there had been rainfall forecast there. This ground station data was physically brought in by a KMD meteorologist or found through Ogimet.

The three groups worked in staggered shifts to provide 24 hour coverage in a quasi-operational environment. The shifts were:

06:00-14:00 LT: Evaluation

09:00-17:00 LT: Synoptic forecasting

14:00-22:00 LT: Nowcasting I

22:00-06:00 LT: Nowcasting II

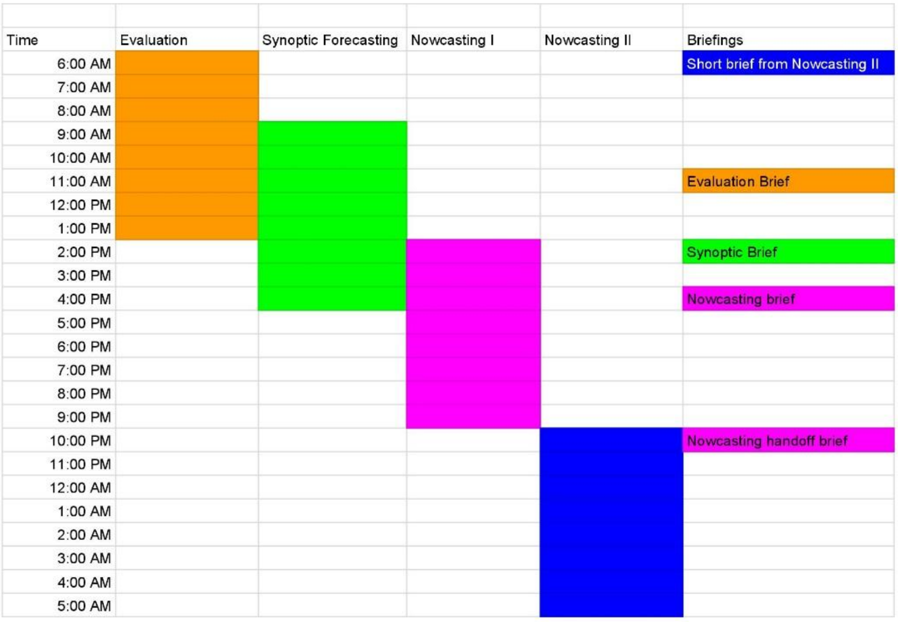


Figure 3a: Details of the daily schedule of forecasting, nowcasting and evaluation.

These shifts were determined by the natural diurnal cycle of deep convection over east and west Africa (Figure 3): convective triggering is maximised around 1500 local time and organises into active MCSs overnight. Therefore, Nowcasting is best conducted overnight, and the synoptic forecast naturally precedes this. This scheduling of shifts was found to be very effective in matching forecasts to the actual weather activity, and in maintaining communications between different forecasting functions.

Additionally, each group provided a daily briefing. These were done formally by the Evaluation and Synoptic forecasting groups.

At 1100 each day, one or two members of the Evaluation group presented their evaluation of the previous day's forecast to all present. This provided useful real time feedback to the synoptic forecasters not only on the quality of their predictions but also on how it was presented and, importantly, how readily it could be quantitatively evaluated (e.g. 'high chance of rainfall exceeding 10 mm in coastal Kenya from 00Z to 06Z' vs 'heavy rain in coastal Kenya').

At 1400 each day, several members of the synoptic forecasting group briefed all present on their forecasts, including pan-Africa, East and West Africa synoptic (1-3 days), and East and West Africa high impact weather (1 day). This brief was useful to the synoptic forecasters working on different desks; the evaluation team whose shift was ending (as many of them would be evaluating that forecast the next day); and most notably to the afternoon nowcasting shift who used the information to focus their attention on specific locations and to use the information about the synoptic flow to inform their short term predictions.

The nowcasting groups also provided briefings, though in practice these tended to be informal. In particular, the afternoon nowcasting team always briefed the nighttime nowcasting team at the shift change.

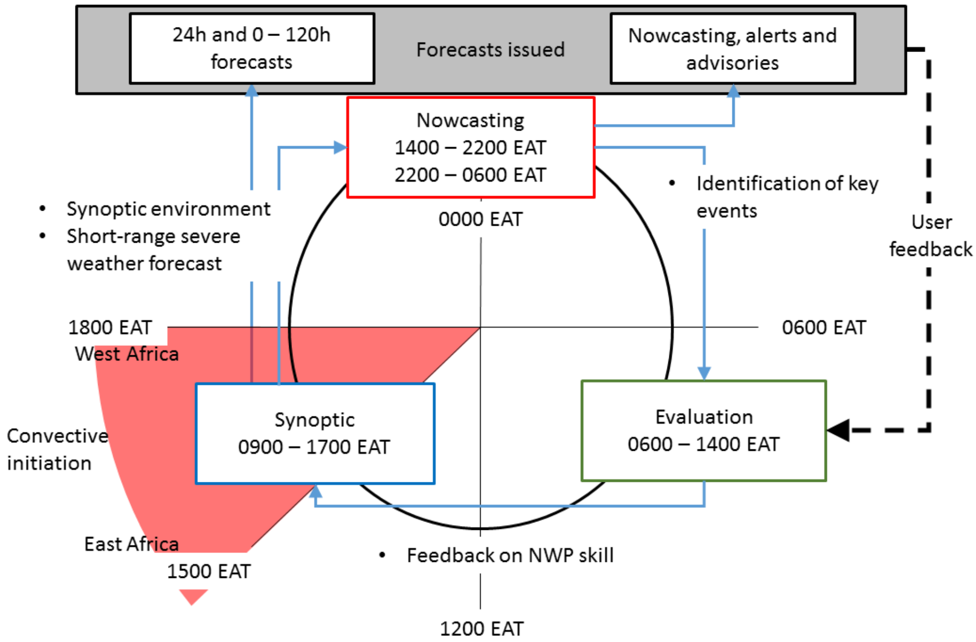


Figure 3b: Schematic diagram of interactions between the 3 groups. The three groups working in shifts following the natural cycle of convection, shown here in relation to Eastern Africa Time (EAT). The cycle of activity enables information to be passed from one team to another in order to inform their work: for instance, the Nowcasting team begin their shift making use of the synoptic analysis and forecast prepared by the Synoptic group. A rapid increase in deep convective activity tends to occur around 1500 local time, which corresponds to 1500 – 1800 EAT for activity occurring from East to West Africa.

Programs of work, amounting to 1 to 2 pages of guidelines for each group's activity-- see Appendices A-C -- were developed for the 3 groups through the following process:

- Ideas were developed during Testbed 1A, and in particular for the Synoptic group, and were documented as first drafts.
- More complete programs of work were developed during a series of teleconferences preceding Testbed 1B.
- The programs of work were refined once, around the mid-point of Testbed 1B.
- The final programs of work were edited on the basis of the final washup session of Testbed 1B.

Two formal roles were also defined, to manage the daily operations:

Role	Duties	Details
Group leaders	Chairs group briefings, makes sure each group executes part of the group main tasks.	One for each group. Nominated in advance, with a deputy, for each shift / for a few days.

Scientific secretaries	Take notes of forecast discussions, type up drafts of summaries for approval by the groups. Organise files pace. Collate files and images into quick looks for each day.	1-2 for each group. This should be shared among a number of students/PDRAs.

5. Data sources and visualisation.

(a) NWP data
   i. Model output (ARPEGE, ECMWF, UKMO) from PUMA stations using Synergie software
   ii. Met Office CP model and ensembles – available through Met Office CEDA webpages. Some were also available on the VCP Africa Web Viewer.
   iii. GFS data pre-plotted for synoptic charts available from web and pushed to a local server at KMD
      i. Synoptic charts automatically pre-plotted and pushed to a local server at KMD: see list of fields in Appendix E.
      ii. The plotting variables, domain, etc were selected from Testbed 1A and in teleconferences leading up to Testbed 1B.
   iv. WRF, as run by KMD, ANACIM, and GMet
   v. COSMO as run by NiMet

(b) NWC SAF products were made available from the NCAS SWIFT catalogue[3] (latency was typically 60-90 minutes). The full list of fields is in Appendix G: in practice the most-used fields were:
   i. Rapidly developing thunderstorms (RDT)
   ii. Convective rainfall rate (CRR)
   iii. Cloud type
   iv. K index/lifted index
   v. Chance of convective initiation

(c) Near real-time brightness temperature images from Meteosat on the VCP African web viewer. -- latency was as little as two minutes!

(d) University of Wisconsin water vapour movies.

(e) Surface data -- CEH soil moisture anomaly plots (not used), surface observations from KMD (East Africa only) from the East Africa high impact weather teleconference (SWFDP), Ogimet.

Note the standard diagnostics generated for different models and now available for comparison, are listed in Appendix E

Visualisation was done by inserting images from model and observational output into Microsoft Powerpoint. Automated plots of GFS forecasts were done with transparent backgrounds making it possible to layer images.

[3] https://sci.ncas.ac.uk/swift/

6. Outcomes

Some conclusions and lessons learned are documented here.

I Synoptic

(a) Generating synthetic charts (see Fig. 1) is critical, but many people, including forecasters, are not familiar with this process. The synthetic chart is essential in setting the framework for Nowcasting. When the WASA was not produced, we found that the Nowcasting West Africa desk were forced to reproduce it in their own shift. The need for systematic analysis of the synoptic chart when considering Nowcasting emphasises the interactions between forecasting activities in the forecasting cycle (Figure 3b).

(b) Researchers in synoptic dynamics plan to study the physical mechanisms on the relevance of high pressure systems to the weather of East Africa.

(c) The short-range HIW forecast was very exciting, and using CP models and ensembles we were able to push the limits in locations and timings: we attempted to forecast rainfall events to a temporal resolution of 3 hours or better.

(d) There was a symbiosis of the short-range HIW forecasting work with the Evaluation activities. Experience on the Evaluation desk was found to be extremely valuable to the Synoptic forecasters, who could then generate forecasts which were useful and well resolved in time and space. Further investigation of the interaction between forecasting and evaluation will be a key focus for SWIFT.

(e) The synoptic forecasting triggered some science questions to pursue further:

    i. How does the Met Office CP ensemble compare with the multi-model ensemble for rainfall events?

    ii. Does the CP model have sufficient ensemble spread? (we already know it doesn't) Is this different for regions with and without coherent triggering features (hills / lakes etc) in the topography?

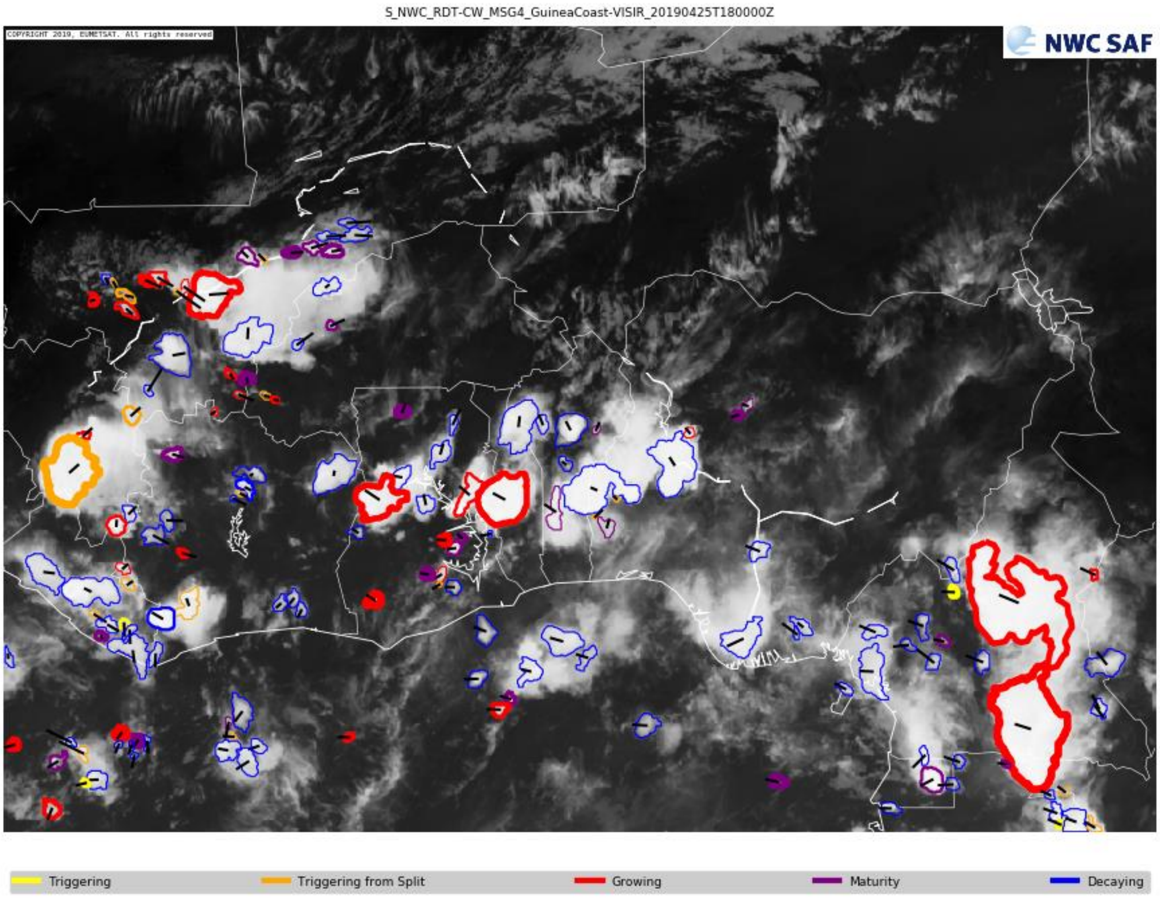
    iii. What are the best ways to represent information from the CP ensemble?

    iv. We have evidence that the CP models are able to represent convective types and lifecycles: can forecast evaluation take account of these Lagrangian characteristics?

II Nowcasting

Nowcasting is not currently being performed systematically in any of the African operational centres of the SWIFT consortium; these partners represent some of the leading centres in Africa. We are not aware that NWC SAF is being used in Africa, apart from at the South African Weather Service (SAWS), which provides nowcasting for southern Africa as far north as southern Tanzania. Storms, especially in West Africa, have lifecycles over several hours, making satellite-based Nowcasting a valuable possibility.

The SWIFT Testbed 1 has demonstrated that the NWC SAF products were successful in providing guidance on convective rainfall on the 0-6 hour timescale. The Rapidly Developing Thunderstorm (RDT) products were particularly valuable.


S_NWC_RDT-CW_MSG4_GuineaCoast-VISIR_20190425T180000Z
NWC SAF
Triggering
Triggering from Split
Growing
Maturity
Decaying

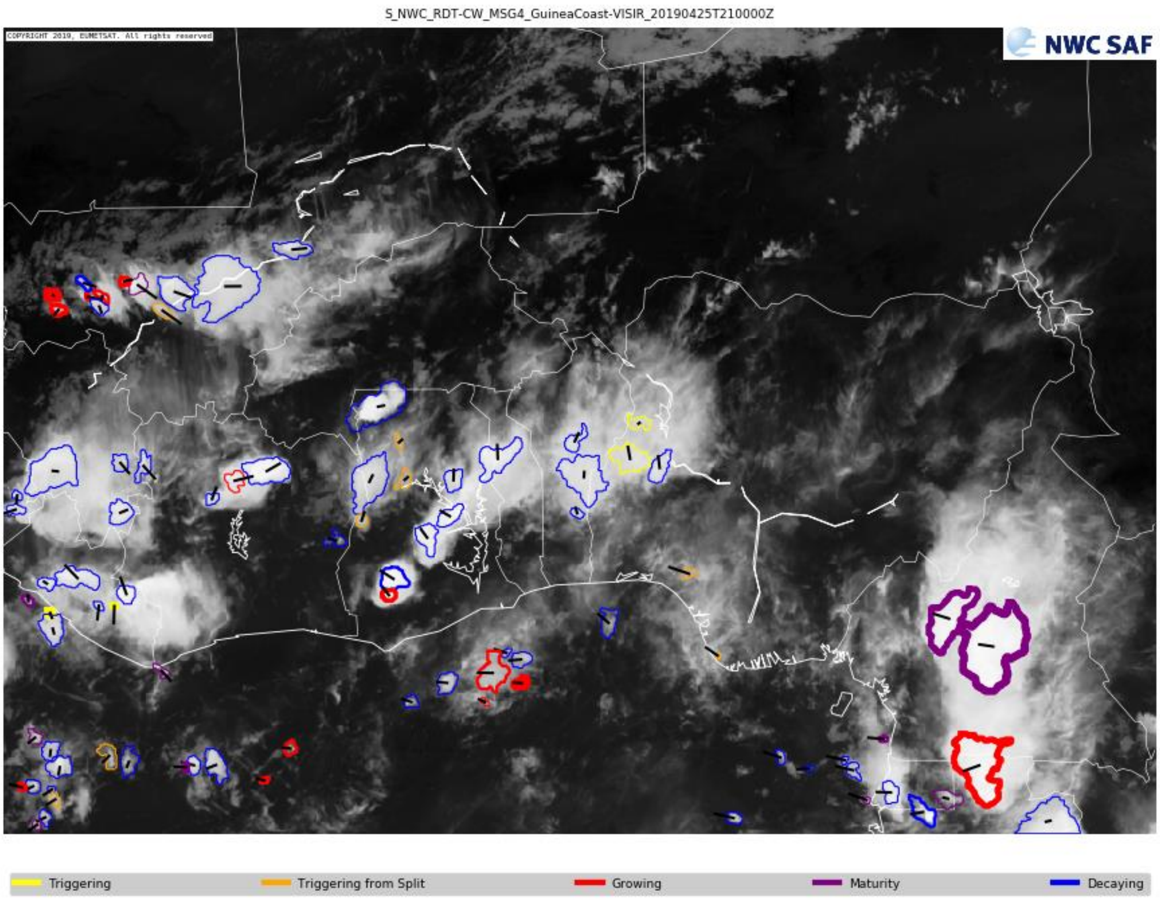

S_NWC_RDT-CW_MSG4_GuineaCoast-VISIR_20190425T210000Z
NWC SAF
Triggering
Triggering from Split
Growing
Maturity
Decaying

Figure 4: Example showing storm propagating over a few hours in the RDT product (25 April 2019, 1800 and 2100 UTC. The identification of small, developing cells (red contours) was found to be particularly valuable in identifying activity which could not be inferred "by eye".

Nowcasting would have been enhanced by a deeper connection with specific, perhaps vulnerable, user applications. When conducting Nowcasting for many events in a map such as that shown in Figure 4, there needs to be some underlying risk, or vulnerability map, so that the nowcaster can focus attention on a subset of the storms in view. For the future SWIFT events, we will generate an overlay risk map for this purpose.

In collaboration with NWC SAF, SWIFT has made the NWC SAF products freely available on the web for three regions in Africa in near-real time. There is an opportunity now for operational centres to start Nowcasting. Many African forecasters who attended Testbed 1B commented that the NWC SAF product could provide a significant change in near-term forecasting in their region. ACMAD is also in the process of documenting its installation and usage in order to pass it on to other NMHSs through on-job training.

Because the NWC SAF has been developed and calibrated using observations from Europe, some of its tuning parameters are not ideal for tropical continental conditions (e.g., some temperature thresholds are too cold). During Testbed 1B, nowcasters identified a number of potential areas of improvement to NWC SAF that would increase its usefulness for tropical Africa. These potential areas of improvement will be discussed with NWC SAF developers.

III Evaluation

The evaluation group used – and expanded – the Severe Weather Forecasting Demonstration Project (SWFDP) spreadsheet which is currently used to evaluate forecasts in east Africa.[4] This systematic approach allows for the identification of hits, misses, false alarms, and correct negatives, as well as displacements in space and time. The evaluation group also downloaded near real time GPM rainfall observations to quantitatively evaluate rainfall forecasts. These observations were compared with human forecasters' predictions rather than with model rainfall output.

Specifically, the SWFDP methods, which forecast severe weather for the coming 24 hours on sub-national scales, was extended to allow for the capability of CP models to better resolve rainfall in time and space. These observations were compared to ground-based rain gauge data, where available and compared with human forecasters' predictions made the previous day rather than with model rainfall output. The ability of the evaluation group to carry out their tasks was hampered by the availability of observations in countries that do not routinely distribute observations via the WMO GTS. This made it more difficult to evaluate the forecasts in these countries, and led to an over-reliance on satellite-based products such as GPM IMERG.Specifically, the SWFDP methods, which forecast severe weather for the coming 24 hours on sub-national scales, was extended to allow for the capability of CP models to better resolve rainfall in time and space.

Table 1. Contingency table showing the subjective evaluation forecaster's predictions. Statistics are based on 95 different forecasts made over a 2-week period.

		Observed		
		Y	N	Total
	Y	74%	8%	82%

[4] http://www.wmo.int/pages/prog/www/swfdp/SWFDP-EA.html

Forecast	**N**	2%	16%	18%
	Total	76%	24%	100%

Table 2. Statistics from the locational assessment of the UK Global and CP 4.4km models

	UK Global	**UK CP 4.4km**
Identified exact location	10	11
Within 50km	7	14
Within 150km	78	3
Within 250km	1	2
Total	96	30

7. User workshop

During the testbed, a two-day workshop on *"How to support users' understanding and use of climate and weather services in Kenya*" was organised as a parallel event to the testbed on Tuesday 30th April and Friday 4th May 2019. The workshop brought together different stakeholders including professional forecasters, research scientists and users of weather and climate information from the ForPAC project, Brookside Dairies, Ministry of Water Resources, Kenya Electricity Generating Company (KENGEN) and Kenya Broadcasting Cooperation (KBC). Activities during the workshop focused on:

- User-evaluation of current forecast provision.
- Exploring how the communication of forecast products and tools could be improved
- Exploring the potential for Impact Based Forecasting in Kenya.

Key lessons from the workshop are summarised below:

- There was a general consensus among workshop participants that the quality of forecast provided by the Kenya Meteorological Department (KMD) has substantially improved in recent years. However, to make forecast more accessible to members of the public and users in specific sectors, it was recommended that KMD develop different methods of communicating forecast so that users can select the method that suits their needs e.g. radio, TV, emails, interactive web application, SMS.
- Monthly forecast bulletins should be prepared in two formats – one for policy makers and the other with detailed information including advisory notes for users in specific sectors.
- Participants also expressed a need for KMD to improve forecast delivery by producing interactive forecast maps whereby a user can move a cursor across the map and get forecast information for a particular locality/catchment as opposed to analogue maps.

- It was equally recommended that forecast for high-impact weather events should be issued using colour-coded warnings so that members of the public can better understand the risk posed.
- Participants also expressed a need for KMD to conduct a survey among members of the public to understand their perception about the current forecast provided by KMD and how the products can be improved. There has been a follow-up to this recommendation and through the SWIFT project, a survey is currently on-going in Kenya targeting members of the public and users of weather and climate services in specific sectors.

8. Short evaluation of the Testbed

SWIFT Testbed 1 achieved some significant milestones in regard to African weather prediction.

I. CP ensembles were used and evaluated in Africa for the first time.
II. Nowcasting was conducted systematically and successfully using a state-of-the-art satellite-based tool (NWC SAF). Previous Nowcasting efforts in tropical Africa are few and far between.
III. The short-range HIW forecast and evaluation was successfully pushed beyond the levels of current operational practice, to be more time-focussed (giving rainfall forecasts with a range of hours) and location-specific.
IV. The daily operational schedule was excellent, allowing flow of information from Synoptic (daytime) to Nowcasting (afternoon to early morning) to Evaluation (morning).
V. The programmes of work represent a significant amount of effort in planning, and in learning, among the science teams. These offer practical guides to operational forecasting procedure which we recommend to be taken forward, to develop new operational practice, as soon as possible.

A number of operational and scientific objectives were stated in the planning of the testbed and are reviewed here.

a. Forecasters and researchers will jointly create forecasts.

A key element for success is the exchange of knowledge both ways between the research and forecasting communities bringing each closer together. For example, in East Africa the strength and position of various subtropical highs are influential in directing the flow and thus the rainfall. Forecasters shared this knowledge with researchers over the course of the testbed. Similarly, researchers shared knowledge of MJO dynamics and its effect on east African rainfall with forecasters.

b. We will make use of real-time observations and explore their value.

Use of the NWC SAF was a big success. For most participants this was the first time they had attempted Nowcasting. A critical review of the NWC SAF products was collected.

Additionally, the evaluation team made substantial use of the near real time GPM rainfall product.

Access to surface-based data was more problematic, with the lack of a single repository for these data.

c. We will work with users in real time (impact-based forecasting).

Our products were shared with the FORPAC Project, who used them in some analysis of Nairobi flood forecasting and the Nzoia catchment, in particular they received rainfall output from global and convection permitting ensembles to carry out analysis of flood forecasting. This work is ongoing since the testbed.

The Testbed coincided with a user-engagement workshop and two joint sessions were held with users and forecasters. However, this workshop was not well-integrated into the testbed, and including it was premature at this stage.

d. We will evaluate models, and create an environment for model intercomparison.

Testbed participants routinely compared the GFS model to the UK Met Office model (both the global UM and the limited area convection permitting model). This was done both for forecasts and evaluation. New forecast evaluation tables were devised, extending beyond what current practice (e.g. SWFDP), and comparing models. There is potential to develop (simplify) and use these table to refine Standard Operating Procedures (SOPs) for forecasting in SWFDP and operational centres.

African modelling centres produced six-hourly plots of forecast output for the WRF (ANACIM and GMET) and COSMO (NiMet) models. Due to technical problems these plots were inaccessible during the testbed, however they are still available and stored at the University of Leeds and may be used for post-analysis and model intercomparison. We aim to generate new ideas for visualisation of forecast information, and thereby improve the delivery of model and observational data to forecasters.

The automated GFS plotting produced figures with a uniform domain and transparent backgrounds, enabling testbed participants to overlay plots as they wished. This was particularly useful for generating WASA/F images. An example of a WASA image using GFS plots is shown in Figure 5.

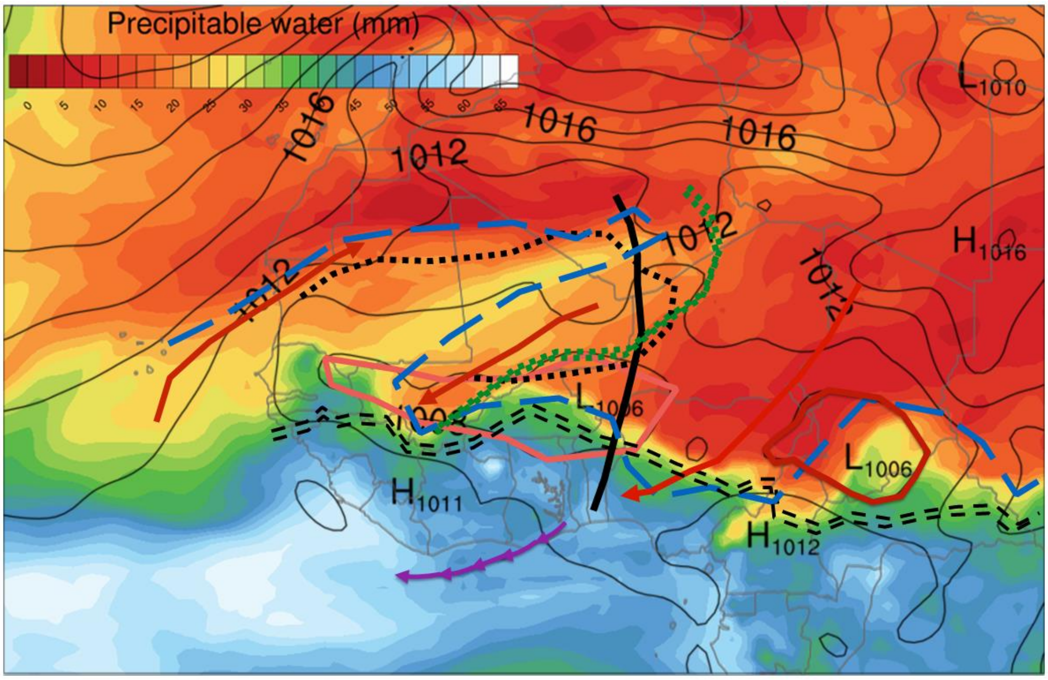


Figure 5: WASA produced in powerpoint using GFS images of MSLP and precipitable water. Valid time is 28/04/2019 00Z.

e. Improved understanding of Numerical Weather Prediction (NWP) modelling issues

The convection permitting models appeared to produce high quality forecasts of low level flow and precipitation in both East and West Africa. The evaluation of CP models is a major activity within SWIFT and the testbed gave researchers an opportunity to develop hypotheses and intuition about the CP model performance.

The CP ensembles were a significant innovation in the testbed. Participants often used the CP ensembles to assess probability of rainfall exceeding specified thresholds over a given period. Testbed participants noted that because this probability was calculated at each grid point, the probabilities tended to be very low due to small spatial variations among ensemble members. Researchers implemented a neighbourhood approach that substantially changed these plots. This example illustrates how the quasi-operational environment of the testbed enabled quick identification of problems that could at times be solved (or solutions could be tested) within the testbed itself.

The testbed also highlighted problems with NWP. For example, one evening during the Testbed, nowcasters noted a large storm over Uganda which had been completely missed by both the global MetUM and the CP model. The next morning, the evaluation team investigated and found that the CP model produced low level convergence at the right time and location as the storm, but that the atmosphere was very dry in both the global and CP models. This highlights the significance of humidity biases in NWP as well as the profound need for assimilation of all available observations into NWP, as the Entebbe radiosondes are currently not sent on the GTS.

Furthermore, the testbed environment exposed participants to some best practices in using new products. For example, many participants who were inexperienced using CP models at first tended to use the CP rainfall products at very short integration times. However, through testbed experience and through interactions with more experienced users of CP models, participants learned that CP models inherit the biases of the driving model and are therefore often better used at slightly longer integrations of at least 12 hours.

f. New insight on operational practice

The Programmes of work for the 3 groups, and the refinement of the daily forecasting schedule were very effective. These ought to be useful in the development of new Standard Operational Procedures for African forecasting centres.

g. Development and implementation of new theory

The SWIFT research programme is taking forward ideas in East African synoptic dynamics.

8. Summary, conclusions and recommendations

8.1 This was a landmark event.

- We believe that this was the first weather forecast testbed in Africa[5]
- New tools were developed and exploited in the 3 areas:
  - CP ensembles for synoptic forecasting.
  - NWC SAF products for Nowcasting.
  - Expanded evaluation tables, evaluating new models.
- The tools and methods used were new to many of the forecasters in the testbed. They remarked afterward that these tools are extremely useful to them; however, there are still many steps needed to integrate these tools into operational practice.

8.2 Some things didn't work so well

(a) Visualisation software was a challenge.
   i. Synergie is useful for forecasters who are familiar with it, but it is also difficult to learn to use, and the limited number of Synergie stations isn't conducive to a collaborative testbed environment. Furthermore, the range of products available on Synergie was much less than the number the Testbed aimed to exploit.
   ii. The UK Met Office are developing a web tool called FOREST which might prove useful for forecast visualisation in future testbeds.
   iii. Powerpoint remains the best tool for organisation and annotation of forecast charts (and it is used operationally by SWFDP). The pre-generated GFS synoptic plots were reasonably easy to insert and overlay in powerpoint. However, powerpoint is not always efficient for handling large numbers of figures and overlays.

(b) Internet connectivity was an issue. We attempted to forestall this somewhat by bringing a server to KMD which individuals could connect to directly even without functioning internet. GFS images were pushed to this server overnight, when we had hoped internet issues would be less of a problem. However, the internet was completely down so often, with ad hoc solutions every time, that it worked better to manually access figures at the times when it was available.

(c) Plans to work with users (tailoring forecasts, and getting user feedback day by day) were premature. However, the FORPAC project collaboration was useful and holds potential for future extension.

(d) Use of surface observations in forecast evaluation and in Nowcasting was very limited, in large part because those observations weren't available for most of the testbed. Systematic

[5] We acknowledge that a number of field programmes in Africa, notably GATE (1974) and AMMA (2005-2007) included operational forecasting activities integrated with the field campaigns, and AMMA in particular used these to advance forecasting methodologies – results on which SWIFT has relied heavily.

access to observations is not easy for most scientists (outside the Synergie system) and many participants were obtaining surface observation *ad hoc* from their own web links.

(e) The shift schedule made it difficult for nowcasters to share their results with other groups. In practice it was found that nowcasters often identified errors in high impact weather forecasts, and this was useful to share with the evaluation team the following morning. The lack of overlap between nowcasting and evaluation was a challenge for that. However, at 0600 EAT, after a long night, the Nowcasting team were reluctant to stay longer for discussions with the Evaluation group, so the Nowcasting conclusions and recommendations had to be left as written documents.

8.3 Recommendations:

8.3.1 SWIFT will take the results of Testbed 1 forward in the following ways.

- The SWIFT programme of research will take account of the priorities identified in Testbed 1 and discussed in this document.
- SWIFT is currently considering interim “Demonstration Exercises” to work in a focussed way with specific user groups, delivering forecasts (following the Testbed 1 methods) to them and getting feedback for evaluation.
- We aim to implement the local acquisition of NWC SAF at SWIFT African centres.
- Testbed 2 (Subseasonal-to-seasonal, S2S forecasting, 2019-2021): We have provided recommendations, advice and priorities for this activity, from this document and through planning meetings.
- Testbed 3 is scheduled for 2021 and will address the same 0-120h timescale of Testbed 1. Testbed 3 will start with a strong programme of work developed in Testbed 1, and will aim to advance these methods making use of research from SWIFT and its partners in the intervening 2 years. Other priorities for Testbed 3 will be to bring in users from the start.

8.3.2 We recommend that other programmes and agencies should do these things:

- All SWIFT African centres should be able to implement Nowcasting on the basis of NWC SAF products. We can discuss making those available on the NCAS site for bespoke regions.
- Implementation of the local acquisition of NWC SAF at more centres should be an international priority.
- The development of new SOPs and training of forecasters is a long-term process which will need to be supported beyond the end of SWIFT (2021). The Programme of Work for SWIFT Testbed 1 is a useful basis for the development and refinement of SOPs.

9. References

Lafore JP, Chapelon N, Diop M, Gueye B, Largeron Y, Lepape S, Ndiaye O, Parker DJ, Poan E, Roca R, Roehrig R, Taylor C. 2017. Deep convection. In: Parker DJ; Diop-Kane M (eds.) Meteorology of Tropical West Africa: The Forecasters' Handbook. Chichester, UK: John Wiley & Sons, Ltd, pp. 90-129

Parker D. J. and Diop-Kane M. (Eds.) 2017, Meteorology of Tropical West Africa: The Forecasters Handbook, Wiley Blackwell, Chichester, UK.

Ralph FM, Intrieri Andra Jr. D, Atlas R, Boukabara S, Bright D, Davidson P, Entwistle B, Gaynor J, Goodman S, Jiing J-G, Harless A, Huang J, Jedlovec G, Kain J, Koch S, Kuo B, Levit J, Murillo S, Riishojgaard LP, Schneider T, Schneider R, Smith T, and Weiss S. 2013. The Emergence of Weather-Related Test Beds Linking Research and Forecasting Operations. Bull. Am. Met. Soc. 94, 1187-1211. https://doi.org/10.1175/BAMS-D-12-00080.1

Woodhams, B.J. and co-Authors, 2020: Aircraft observations of the lake–land breeze circulation overLake Victoria from the HyVic pilot flight campaign. *in prep*.

Appendices

Appendix A: Program of work for Evaluation group in Testbed 1B

First: appoint roles.

Group Lead: makes sure everyone is on task for the day

Scientific Secretary: Takes attendance, Uploads documents to Redmine

Desk presenters: for each desk, appoint 1 person to give the presentation.

Each group will be further split into desks, with each desk focussing on a specific region.

Important role: scientific secretary. This person organises the outputs from the group into a standard format and makes sure they are recorded in a consistent way each day. One scientific secretary per group plus an overall person.

Main tasks

1. Read through summaries from the synoptic forecasting groups from the previous day as well as the nowcasting groups. Nowcasters often note the forecast quality of high impact weather as it is happening.

2. On <~ one day time scales, qualitatively evaluate forecasts by comparing to analysis, satellite observations (including GPM rainfall, when available).
    a. Compare GPM accumulations with areas forecasters suggested high rainfall totals.
    b. Check GPM accumulations against missed storms highlighted by nowcasting groups
    c. Study GFS analyses for reasons for bad/good forecasts, looking at winds/ convergence and humidity fields; check this against Deterministic model fields.

3. The synoptic forecasting group will have filled in the forecast side of the evaluation table. Use observations and analysis to fill in the evaluation side.

4. Briefing: present to TB1B participants on forecast errors and discuss evaluation methods used and sources of model error.

Appendix B: Program of work for Synoptic forecasting group in Testbed 1B

First: appoint roles.

Group Lead: makes sure everyone is on task for the day

Scientific Secretary: Takes attendance, Uploads documents to Redmine

Desk presenters: for each desk, appoint 1 person to give the presentation.

Each group will be further split into desks, with each desk focussing on a specific region.
1-2 people from each desk must be responsible for looking at the ensembles.

Important role: scientific secretary. This person organises the outputs from the group into a standard format and makes sure they are recorded in a consistent way each day. One scientific secretary per group plus an overall person.

- Desk 1: Pan Africa forecast (including large scale features e.g. subtropical highs, MJO)
- Desk 2: East Africa synoptic analysis and forecast, 0 to 4 days.
- Desk 3: West Africa synoptic analysis and forecast, 0 to 4 days.
- Desk 4: East Africa short-range high impact weather/user focussed forecasts
- Desk 5: West Africa short-range high impact weather/user focussed forecasts

If time is short and there are not enough participants, forget about Desk 1 and make sure that Desks 2-4 are active.

Main tasks

1. Read the most recent documents from the Nowcasting Group (on redmine) and talk with the Evaluation Group regarding any particular priorities for the day.

2. Generate daily summaries (powerpoints and written summaries) of the following:
   a. **Desk 1 only:** Large scale patterns and modes: MJO, ITD, tropical cyclones etc, tropical wave activity, and 1-5 day forecasts of the same.

   b. **Desks 2 and 3:** plot and present the important synoptic features from the lists which we have for East and West Africa (see below). Choose those features which are relevant to the particular situation. For instance, is there an upper level trough, or a low level moisture surge influencing conditions? Use GFS global model plots and annotate the plots in powerpoint.

      Consider the implications of this synoptic chart for the forecast of heavy rain, and of high surface winds / dust.
      i. Analysis for 0000 previously.
      ii. Forecasts out to day plus 3, at 0000 UTC each day.

   c. **Desks 4 (East Africa) and 5 (West Africa):** Make a comparison of the heavy precipitation features seen in different model forecasts:
      i. Consider 0600 today to 0600 tomorrow.
      ii. Make a powerpoint with one slide per day, comparing GFS, Met Office Global, and Met office tropical Africa, **3-hour accumulated rainfall, every 3 hours** (8 slides).
      iii. For every 6 hours, make a slide comparing the Met Office 8.8km ensemble fields (probably of 6-hour precipitation > 25 mm) for different lead times.

iv. (East Africa only). For every 6 hours, add a panel to the slides, comparing 4.4km and 8.8km ensembles.

For examples, you can take a look at the powerpoints generated on 29 / 4 /19.

d. **Desks 4 and 5:** Fill in the Short-range high-impact weather forecasting forms for the different regions, and provide any necessary maps and time series. Make sure to consider the UKMO CP ensemble data. These forms have been designed with the evaluation group, and are an extension of the SWFDP forms.

https://docs.google.com/spreadsheets/d/1rdTwSJKPvDruqtXhbxshNiSaBHR1Gg70ZC4k-n-cwBU/edit?usp=sharing

3. Coordination: ensure that Desks 1-5 communicate with each other during the day. It is particularly important for the 2 West African and East African groups to discuss the situation (i.e. to link the Short-range HIW forecast with the synoptic situation.

4. Briefing: present the above to TB1B participants every day, probably with powerpoint. This briefing will also be the daily videoconference with satellite centres.

5. Write a short summary (3 or 4 bullet points) of the synoptic analysis and forecast, noting any key highlights which the forthcoming shifts need to be aware of. Put this on the final slide of the powerpoint.

6. Put the powerpoints on the web using a standard filename beginning with the date in the form yymmdd_....pptx

i. West Africa (WASA/F)

Priority for April Testbed	Lower priority for April Testbed.
Synoptic state Use mslp as a basis for the WASA/F. • West African Heat Low. • Intertropical discontinuity/front (ITD or ITF). • (Subtropical Jet – considered but not plotted) • Upper tropospheric troughs. • Mid-level 700 hPa dry air boundaries. • Monsoon layer advection (925-600 hPa winds). • 850 hPa vorticies and troughs. Convective parameters • Shear 650-925 hPa • Precipitable water / Moisture depth. • CAPE/CIN	• Tropical Easterly Jet. • Monsoon trough. • African Easterly Jet. • African Easterly Waves (troughs and ridges).

ii. East Africa (EASA/F) *suggested diagnostics*

Phenomena:

- Large scale high / low pressure systems in the subtropics: Heat Lows; Arabian ridge; …
- Intertropical discontinuity/front (ITD or ITF) or Intertropical convergence zone (ITCZ)
  - including meridional and zonal branches.
  - Congo Air Boundary
- Vortices.
- Tropical cyclones.
- Tropical plumes.

Fields:

- Mid-level streamlines/vortices [e.g. 850, 600 hPa]
- Mid-level dry intrusions/boundaries [700, 600, 500 hPa]
- Low level advection/moisture advection [e.g. 925-600 hPa over low terrain].
- Low level shear
- Divergence: with caution!
- Precipitable water/precipitable water anomalies.
- Monsoon depth / moisture depth
- Instability / inhibition (CAPE/CIN)
- Surface convergence lines (and sea breeze fronts).
- Soil moisture.

Appendix C: Program of work for Nowcasting group in Testbed 1B

First: appoint roles.

Group Lead: makes sure everyone is on task for the day

Scientific Secretary: Takes attendance, Uploads documents to Redmine

Desk presenters: for each desk, appoint 1 person to give the presentation.

Important role: scientific secretary. This person organises the outputs from the group into a standard format and makes sure they are recorded in a consistent way each day. One scientific secretary per group plus an overall person.

Note: split the group into 2 (or even 3) desks, each desk having a distinctive task. This will ensure that everyone is actively involved and not just sitting around watching one person work. These desks could be divided according to region, according to the type of forecast, etc. **For example (feel free to choose different categories):**

- Desk 1: East Africa
- Desk 2: West Africa

Main tasks

1. Use NWC-SAF (and **Synergie** and other online products) to monitor the initiation, growth, and propagation of storms in East Africa and West Africa.

1. Afternoon: present a briefing to TB1B participants summarising the current state of storms in both regions (including notes from the previous night, see below).
2. Maintain the shared spreadsheet <the template is on redmine> summarising storm activity during your shift that can be accessed by all participants; or produce a document with images and commentary including analysis and predictions on 0-6 hour time scales.
3. Finally, complete the template document summarising your shift, and highlighting the most significant events. This way e.g. evaluation and synoptic groups will know what happened the previous evening.

For example:

a. On afternoon shift, a large storm develops over the Tanzania highlands. Afternoon Nowcasting team includes this in their spreadsheet and highlight the storm in their writeup.

b. On the night shift, the storm grows and propagates over Lake Victoria. Night shift documents this in the same section of the writeup.

c. When evaluation and synoptic teams start their shifts the next day, one member reads the previous day's document and summarises it to the rest of their group.

<u>Detailed Nowcasting guidance</u>

1. First steps (Shift 1: 1 – 2 hours)
   a. Label and identify existing storms. Put a map in powerpoint and number the storms 1,2,3, … Note that it may be necessary to group complex storms into a cluster and number this instead.
   b. Put all the information into the spreadsheet template.
   c. Describe the origins, movement and environment of each storm (in the template).
   d. Attempt to make a prediction of where new storms might initiate, using model products, climatology and local knowledge.
   e. Make basic projections for each storm or group of storms (growing, moving etc).

   f. Predict arrival time of propagating storms at major centres e.g. large cities.
2. Consolidation
   a. Discuss synoptic controls on the storms.
   b. Make comments on the NWCSAF products, on the feedback spreadsheet <link>.
3. Practical considerations
   a. Over West Africa 1500 UTC gets busy, when new cells are emerging and organizing.
   b. It is useful to have the VCP viewer open to see the very latest imagery and to get lat / lon for labelling storms.
   c. It is useful to put a couple of images (e.g. convective rainfall rate) into powerpoint to label the numbered systems on the map.
4. Summary and synthesis.
   a. Fill in the Nowcasting template providing comments on the main storms, and guidance for the Evaluation and Synoptic Groups.
   b. Upload the powerpoint, spreadsheet and document to Redmine.

Appendix D: Evaluation spreadsheet.

This spreadsheet may be accessed at
http://homepages.see.leeds.ac.uk/~earjf/SWIFT_Testbed1B_Fcst_Eval.xlsx

Appendix E: List of fields from NWP (East/ West Africa).

Priority for evaluation and model comparison	Model diagnostics	desired frequency	GFS
	surface (2m or 10m):		
x	pressure	3 hourly	mslp (3 hrly)
x	temperature	3 hourly	2m T (3 hrly)
x	dew point temperature	3 hourly	2m DP (3 hrly)
x	wind vectors	3 hourly	10 m winds (3 hrly)
	streamlines	3 hourly	10 m streamlines (3 hrly)
	925 hPa:		
	potential temperature	3 hourly	3 hrly
x (WA)	dew point temperature	3 hourly	3 hrly
	relative vorticity	3 hourly	3 hrly
x (WA)	wind vectors	3 hourly	3 hrly
	850 hPa		
x	potential temperature	6 hourly	3 hrly
x	relative vorticity	6 hourly	3 hrly
x	wind vectors	6 hourly	3 hrly
	streamlines if possible	6 hourly	3 hrly
x	relative humidity	6 hourly	3 hrly
	convergence	6 hourly	3 hrly
	700 hPa		
x (EA)	dew point temperature	6 hourly	3 hrly
x (EA)	relative vorticity	6 hourly	3 hrly
x	wind vectors and isotachs	6 hourly	wind vectors (3 hrly)
	streamlines if possible	6 hourly	3 hrly
x	relative humidity (700)	6 hourly	3 hrly
	600 hPa		
	Wind vectors and isotachs	6 hourly	3 hrly
	500 hPa		
	dew point temperature	6 hourly	3 hrly
x	temperature	6 hourly	3 hrly
x	relative humidity	6 hourly	3 hrly

	200 hPa		
x	wind vectors and isotachs	6 hourly	3 hrly
x	geopotential height	6 hourly	3 hrly
	divergence	6 hourly	3 hrly
	Potential vorticity		
	700 hPa	6 hourly	3 hrly
	upper level (which one?)	6 hourly	3 hrly (200 hpa but can be chnaged to match others)
	integral measures:		
x	Total column water	6 hourly	Precipitable water (3 hrly)
x (but need a climatology, might not be possible)	PW* (anomaly from mean ...)	6 hourly	
	Monsoon depth: thermodynamic	3 hourly	3 hrly
	mean meridional wind in 950-600 hPa layer	6 hourly	3 hrly
	mean wind vectors in 950-850 hPa layer	6 hourly	3 hrly
	mean winds 800-600 for east Africa	6 hourly	3 hrly
x	model precipitation	3 hourly	3 hrly (not at analysis time)
	CAPE and CIN (or K index)	3 hourly	CAPE and CIN 3 hrly
x	OLR or brightness temperaure	6 hourly	
x	surface pressure tendency (24 hour difference)		
	Ancillary plots:		
	Coastlines and country borders		
	Other plots:		
	hovmoeller of vorticity and rainfall over the study period (plus/minus a couple of days?)		

Appendix F: List of participants

Nairobi

Jennifer Fletcher
Samantha Clarke
Jacob Agyekum
Karmara Mouhamadou Moustapha
Marian Amoakowaah Osei
Jemimah Gacheru
Bethany Woodhams
David Koros
Michael Padi
Ayodeji Oluleye
Mary Kilavi
Coumba Niang
Eniola Olaniyan
Papa Ngor Ndiaye
Joseph Kagenyi
Rosaleen McDonnell
Ronald Barette
Kamoru Abiodun Lawal
Helena Msemo
Chris Kiptum Ngetich
Bethwel Kipkoech Mutai
Douglas Parker
Elijah Adesanya Adefisan
Ogungbenro Stephen Bunmi
Abdou Lahat Dieng
Vincent Olanrewaju Ajayi
Alexander Roberts
Joan Birungi
Zerbo Hamidou
Alassani Alassanbiga
Kituusa Mohammed
Victor Savatia Indasi
Thorwald Stein
Peter Hill
Carlo Cafaro
Temidayo Israel Popoola
Andrew Ryan
Andrew Hartley
Christopher Graham Tubbs
Samuel Osusu Ansah
Joachim Philipo
Peter Tuju
Emily Nyaboke Bosire
Joseph Mutemi
Wilson Gitau

Remote participants

Caroline Baine
Johnson Ameho Kwesi
Olubi Adedamola Charles
John Marsham
Alabi Benjamin Oluwasola
Jesse Nii Noi Ashong
Oghaego-Ngwube Amarachi
Ugbah Paul Akeh
Cheikh Abdoulahat Diop
Oluwaseun Wilfred Idowu

Appendix G: List of NWC SAF products available

The following NWC SAF (http://www.nwcsaf.org/web/guest) products were made available on the SWIFT catalogue: https://sci.ncas.ac.uk/swift/

- Automatically assigned weather codes (ASII)
- Chance of convective initiation - 30 mins (CI)
- Chance of precipitation (PC)
- Chance of precipitation (PC-Ph)
- Chance of tropopause folding (ASII-NG)
- Cloud drop effective radius (CMIC)
- Cloud ice water path (CMIC)
- Cloud liquid water path (CMIC)
- Cloud mask (CMA)
- Cloud mask - dust (CMA)
- Cloud optical thickness (CMIC)
- Cloud top altitude (CTTH)
- Cloud top pressure (CTTH)
- Cloud top temperature (CTTH)
- Cloud type (CT)
- Cloud water phase (CMIC)
- Convective rainfall intensity (CRR)
- Convective rainfall intensity (CRR-Ph)
- Effective cloudiness - 0 to 1 (CTTH)
- K index (iSHAI)
- Lifted index (iSHAI)
- Precipitable water - total column (iSHAI)
- Precipitable water in high layer - 500 hPa to TOA (iSHAI)
- Precipitable water in low layer - surface to 850 hPa (iSHAI)
- Precipitable water in middle layer - 850 hPa to 500 hPa (iSHAI)
- Rapidly developing thunderstorms (RDT)
- Showalter index (iSHAI)
- Skin temperature (iSHAI)
- Wind barbs - 100 hPa to 400 hPa (HRW)
- Wind barbs - 400 hPa to 600 hPa (HRW)
- Wind barbs - 600 hPa to 800 hPa (HRW)
- Wind barbs - 800 hPa to 1000 hPa (HRW)
- Wind barbs - all pressure levels (HRW)
- Wind barbs - shaded by wind speed (HRW)
- Wind trajectories - 100 hPa to 400 hPa (HRW)
- Wind trajectories - 400 hPa to 600 hPa (HRW)
- Wind trajectories - 600 hPa to 800 hPa (HRW)
- Wind trajectories - 800 hPa to 1000 hPa (HRW)
- Wind trajectories - all pressure levels (HRW)

Appendix H: About GCRF African SWIFT

The **GCRF African SWIFT** (Science for Weather Information and Forecasting Techniques) project is a research and capacity building program led by the National Centre for Atmospheric Science (NCAS) and funded by the UK Global Challenges Research Fund (GCRF), 2017-2021.

The project aims to **develop physical understanding of weather system**s over Africa and **actively contribute to improvements in forecasting** for the region, particularly improvements for the provision of forecasts for **high impact weather** events such as urban flooding or prolonged droughts.

The project focuses on a broad range of timescales (hourly to seasonal) and spans science, forecaster and user communities.

The GCRF African SWIFT consortium builds upon existing partnerships between forecasting centres and research universities in four African partner countries (Senegal, Ghana, Nigeria and Kenya). A total of 15 partner institutions are involved (listed below) and the **WMO** is a Partner to the project.

- 5 based in the UK (**NCAS**, **University of Leeds**, **University of Reading**, Centre for Ecology and Hydrology; **CEH** and UK **Met Office**)
- 2 based in each of the African partner countries
    - Senegal (Agence Nationale de l'Aviation Civile et de la Meteorologie; **ANACIM** and Universite Cheikh Anta Diop; **UCAD**)
    - Ghana (Ghana Meteorological Agency; **GMet** and Kwame Nkrumah University of Science and Technology; **KNUST**)
    - Nigeria (Nigerian Meteorological Agency; **NiMet** and Federal University of Technology Akure; **FUTA**)
    - Kenya (Kenyan Meteorological Department; **KMD** and University of Nairobi; **UoN**)
- African Centre of Meteorological Application for Development (**ACMAD**)
- IGAD (InterGovernmental Authority on Development) Climate Prediction and Applications Centre (**ICPAC**).