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FOCUS-AFRICA

Final report on the project capacity development Final report on the project capacity development

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Summary

The FOCUS-Africa (FA) project supports sustainable and tailored climate services in the Southern African Development Community (SADC) region, targeting four key sectors: agriculture and food security, water, energy, and infrastructure. Work Package (WP) 7 of the project focuses on capacity building and includes deliverables such as capacity gap analysis, the development of online training materials, and the organization of training sessions for National Meteorological and Hydrological Services (NMHSs), the Southern African Development Community Climate Services Centre (SADC-CSC), research institutes, and other identified climate service providers. The training topics included the generation of tailored, science-based, innovative, and technology-driven climate products, information, and services. Online tools have been developed under FOCUS-Africa to support Southern African seasonal forecasting processes. These include (i) AquaBEHER: An R package for estimating the wet-season calendar and soil-water balance for agriculture, developed by SSSA and (ii) Vignette Tool: A tool for calibration and verification of seasonal forecasts, developed by BSC. Training materials and manuals to facilitate the use of these tools, along with others such as CPT, CFT, and R6ClimDex, have been developed and will be upgraded through ACMAD and other regional Climate Centres' programs. Additional efforts have been identified to customize these training materials and tools, emphasizing the satisfaction of local-scale needs. There is broad recognition of the value of collaboration in sustaining and expanding the use of FOCUS-Africa tools within the Southern Africa Regional Climate Outlook Forum (SARCOF). The African Centre of Meteorological Applications for Development (ACMAD) and WMO have led the development of training materials covering the climate of Southern Africa, its variability and drivers, statistical and dynamical methods for seasonal forecasting, and objective steps for operational seasonal forecasting. These practices are progressively being introduced into the operations of SARCOF and other Regional Climate Outlook Forums (RCOFs) as part of the modernization and harmonization of seasonal forecasting practices in Africa. ACMAD, in partnership with organizations such as BSC and UKMO, will continue to contribute regularly to SADC-CSC training sessions conducted as part of SARCOF. The vignette tool specifically implements some of the methods described in the training mater...

Approval

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Final report on the project capacity development implementations and results

Deliverable D7.3

Lead Beneficiary: African Centre of Meteorological Applications for Development (ACMAD)

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About FOCUS-Africa

FOCUS-Africa – Full-value chain Optimised Climate User-centric Services for Southern Africa – is developing sustainable tailored climate services in the Southern African Development Community (SADC) region for four sectors: agriculture and food security, water, energy and infrastructure.

It will pilot eight case studies in six countries involving a wide range of end-uses to illustrate how the application of new climate forecasts, projections, resources from Copernicus, GFCS and other relevant products can maximise socio-economic benefits in the Southern Africa region and potentially in the whole of Africa.

Led by WMO, it gathers 14 partners across Africa and Europe jointly committed to addressing the recurring sustainability and exploitation challenge of climate services in Africa over a period of 48 months.

For more information visit: www.focus-africaproject.eu

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Executive Summary

[The FOCUS-Africa (FA) project supports sustainable and tailored climate services in the Southern African Development Community (SADC) region, targeting four key sectors: agriculture and food security, water, energy, and infrastructure. Work Package (WP) 7 of the project focuses on capacity building and includes deliverables such as capacity gap analysis, the development of online training materials, and the organization of training sessions for National Meteorological and Hydrological Services (NMHSs), the Southern African Development Community Climate Services Centre (SADC-CSC), research institutes, and other identified climate service providers.

The training topics included the generation of tailored, science-based, innovative, and technology-driven climate products, information, and services. Online tools have been developed under FOCUS-Africa to support Southern African seasonal forecasting processes. These include (i) AquaBEHER: An R package for estimating the wet-season calendar and soil-water balance for agriculture, developed by SSSA and (ii) Vignette Tool: A tool for calibration and verification of seasonal forecasts, developed by BSC.

Training materials and manuals to facilitate the use of these tools, along with others such as CPT, CFT, and R6ClimDex, have been developed and will be upgraded through ACMAD and other regional Climate Centres' programs. Additional efforts have been identified to customize these training materials and tools, emphasizing the satisfaction of local-scale needs.

There is broad recognition of the value of collaboration in sustaining and expanding the use of FOCUS-Africa tools within the Southern Africa Regional Climate Outlook Forum (SARCOF). The African Centre of Meteorological Applications for Development (ACMAD) and WMO have led the development of training materials covering the climate of Southern Africa, its variability and drivers, statistical and dynamical methods for seasonal forecasting, and objective steps for operational seasonal forecasting. These practices are progressively being introduced into the operations of SARCOF and other Regional Climate Outlook Forums (RCOFs) as part of the modernization and harmonization of seasonal forecasting practices in Africa.

ACMAD, in partnership with organizations such as BSC and UKMO, will continue to contribute regularly to SADC-CSC training sessions conducted as part of SARCOF. The vignette tool specifically implements some of the methods described in the training materials on statistical and dynamical methods for seasonal forecasting.

Training on methodologies prior to tool manipulation is proposed as a critical aspect of capacity building for effective service delivery. Additionally, extending FOCUS-Africa's capacity-building activities, based on outputs from all work packages, is proposed to maximize the value embedded in research and innovation investments through FOCUS-Africa.]

Keywords

FOCUS-Africa, Southern Africa, Capacity Building, Tailoring, Seasonal Forecasting, Harmonization, methodology

1. Background

FOCUS-Africa (FA) has developed innovative, sustainable, and tailored climate services in the Southern African Development Community (SADC) region for four sectors: agriculture and food security, water, energy, and infrastructure. The project consists of eight case studies and eight work packages, one of which focuses on capacity building (Work Package 7, WP7).

Work Package 7 of FOCUS-Africa has contributed to the development of the capacity of National Meteorological and Hydrological Services (NMHSs), the Southern African Development Community Climate Services Centre (SADC-CSC), research institutes, and other identified climate service providers to generate tailored, science-based, innovative, and technology-driven climate products, information, and services in an operational mode.

The specific objectives of WP7 include (i) assessing the training needs of regional climate service providers, (ii) reviewing and upgrading the training curricula on climate monitoring and forecasting, climate change detection, and scenario development for impact studies, (iii) developing and testing training materials in collaboration with the intra-ACP GFCS program, RCOFs, and other relevant ongoing activities and initiatives in Africa and (iv) developing online resources for inclusion in existing platforms/portals.

WP7 had three components and three deliverables. The first deliverable, “SADC Regional Climate Services Gap Analysis: In-Depth Analysis of SARCOF and SWIOCOF Training Needs and Materials,” was produced in August 2021, and the findings are summarized in Section 2. The second deliverable focused on the development and documentation of online training materials, some of which are included in this report (Deliverable 7.2). The third deliverable provides the results of capacity-building activities conducted under FOCUS-Africa (Deliverable 7.3).

2. Summary of FOCUS-Africa key findings and issues in-relation to capacity building

Deliverable 7.1 of FOCUS-Africa (SADC Regional Climate Services Gap Analysis: In-Depth Analysis of the SARCOF and SWIOCOF Training Needs and Materials) identified gaps in available training materials, using the WMO Competency Framework for Climate Services as a reference for the needs assessment. For this report, the WMO Competency Framework was used as the primary structure for analysis, and the results were presented according to the five competency areas which include (i) create and manage climate data sets, (ii) derive products from climate data sets, (iii) create and interpret climate forecasts and models (iv) ensure quality of climate forecasts and (v) communicate information to users.

The analysis began with a review of the WMO Competency Framework in relation to climate services. Training materials and relevant documents were compiled and reviewed, and gaps were identified in alignment with the competency framework. A climate services questionnaire titled “Checklist for Climate Services Implementation” was distributed to 16 SADC member states, with 14 providing responses. The questionnaire responses were analyzed to produce descriptive statistics on the gaps currently faced in the region in relation to implementing climate services.

The results of the survey revealed significant challenges in climate data management, processing, and the monitoring and evaluation of climate services. A broader assessment highlighted gaps in capacity and training materials, including (i) data rescue, (ii) indices generation, (iii) statistical and dynamical downscaling, (iv) model output interpretation and verification (v) impact-based forecasting, (vi) performance assessment, (vii) quality assurance and control, (viii) driver detection and analysis and (ix) predictor definition and identification. Based on these identified capacity gaps, a list of recommendations was compiled for each competency area. While the report outlines broader capacity-building needs, not all identified gaps are intended to be addressed under FOCUS-Africa.

At the continental level, ACMAD organizes on-the-job training, secondments, and internships for the entire African region, including SADC NMHSs. Experts trained at ACMAD have become trainers for SARCOF and other training events organized by SADC-CSC. Most practical training for SADC NMHSs occurs before SARCOF, which started in 2024 with SADC-CSC. However, SARCOF itself is held only twice a year for 10 days, limiting capacity-building activities to those focused on producing seasonal forecasts. While this approach aligns with the focus of many RCCs, there is a need for additional opportunities to build capacity in areas such as (i) data rescue and management, (ii) derivation of products from datasets, (iii) quality assurance and communication of climate services, (iv) integration of findings and methodologies from various projects, partners, and initiatives, including FOCUS-Africa. Currently, SADC-CSC does not conduct sub-seasonal forecasting or monitoring.

While WP7 addresses regional capacity-building needs for the provision of climate services, capacity building is also integrated into each of the eight climate services case studies being developed under the project. The objective of capacity building at the case study level is to ensure that national climate service providers and their users can effectively generate, adopt, sustain, and use the climate services being developed.

3. Training materials per work package or case study

3.1 Vignette for the calibration and verification of seasonal forecasts

The Vignette tool addressed three (3) of the climate services competency areas; 2-Deriving products from Climate data sets- uses data from the Copernicus data store; 4-Ensure quality of climate forecasts – it is a verification tool that performs skill assessments and applies bias correction techniques; 5-Communicate information to users – uses visualization to communicate forecast uncertainties.

The Vignette ‘Calibration and verification of seasonal forecasts’ is an in-depth tutorial coded in R designed to be a comprehensive example of the process to bias correct seasonal forecasts with various calibration methods. This tutorial also includes the computation of different skill scores for the calibrated and non-calibrated forecasts to assess their quality. Finally, these results are visualized for better understanding and comparison. The vignette example covers a South-African domain (including the SADC), along a reference period going from 1995 to 2015. It uses the "t2m" variable, which accounts for ‘air temperature 2 meters above the ground level’. The initialization month of the hindcast — which is the forecast when initialized in the past (also known as retrospective forecast) — is November and the analysis is done for the seasonal aggregation of November, December and January (NDJ). One of the key features of this tutorial is its flexibility: it offers the possibility of choosing a different variable, region, and reference period than those specified in the example. Moreover, it provides an option to download seasonal climate data from the Climate Data Store - Copernicus (CDS).

The primary objective of the Vignette tool is to provide a user-friendly tutorial that helps fill some of the capacity gaps identified in deliverable 7.1. These gaps primarily encompass the downloading and processing of seasonal forecast data, bias adjustment, verification, and visualization. The tutorial is specifically designed to be a real workflow from the work developed in WP4, but with a clear emphasis on making the content more understandable and the examples easily reproducible. The main aim is to improve the user's proficiency in skill assessment and bias correction techniques with seasonal forecasting systems. The secondary objective of the Vignette tool is to introduce users to a set of climate tools based on the R programming language. In this regard it is designed not only to be a learning resource but also to serve as a benchmark for further user developments after adequate training.

The Vignette is accessible on the Barcelona Supercomputing Center (BSC) GitLab repository (https://earth.bsc.es/gitlab/focus-africa-bsc/vignette) and can be executed in a Jupyter Lab environment (installation instructions: https://jupyter.org/install) or any similar platform that supports an R environment using version “3.6.1”. In terms of execution, the Vignette provides two primary methods: online virtual execution through the Binder platform (https://mybinder.org/) or locally offline execution on a personal computer. To assist with these processes, the repository contains links and tutorials for both methods. The Vignette is designed to be a practical training facility executed line-by-line to enable users to explore and understand all the steps involved in handling seasonal forecasting data, which includes downloading, loading, calibrating, verifying, and visualizing these data. This step-by-step interaction ensures users gain a comprehensive understanding of the processes involved, promoting both learning and the development of their practical skills.

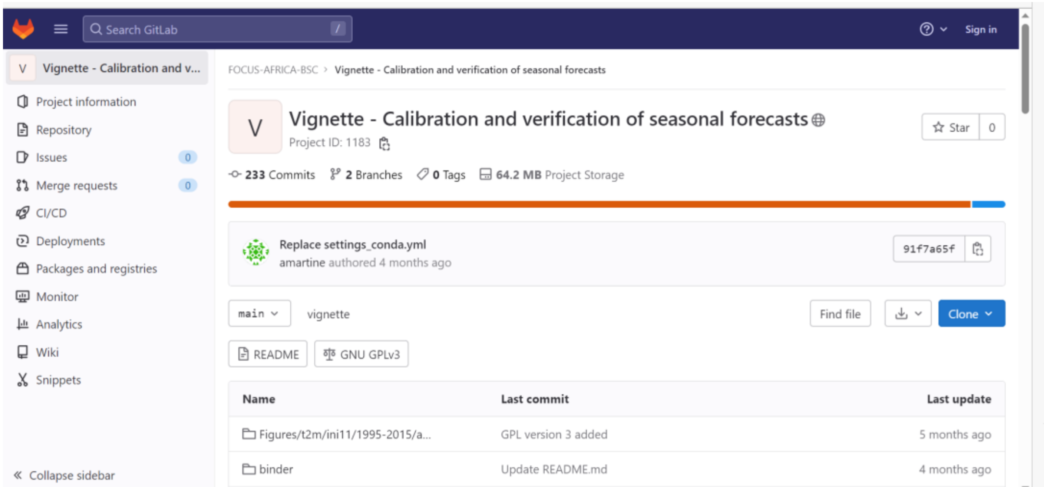

Figure 1: Snapshot of the seasonal calibration vignette

The main focus at the moment is on having the tool tested by experts in Southern Africa either at the SADC-CSC or the NMHSs or other regional partners. ACMAD and partners have organized the training on Focus-Africa tools hosted by the university of Cape Town and as part of SARCOF training events. On the job training, secondment and internship programmes at ACMAD are including Vignette as part of tools supporting training on seasonal forecasting including verification.

3.2 AquaBEHER: an R package for estimation of wet-season calendar and soil-water balance for Agriculture

The AquaBEHER tool addresses four (4) of the climate services competency areas and these are: 1- Create and manage climate data sets – users will learn both how to use their own data sets and online data sets including Copernicus Climate Data store (CDS); 2- Derive products from climate data sets- agronomic onsets, cessation and duration can be derived from this tool; 3- Create and interpret climate forecasts and models – tool will eventually be able to produce forecasts and even input NMHS’s forecasts to produce products useful for crop production. and 5 – Communicate information to users – it generates end user product to assist with agronomic onset and cessation for crop production.

The Case Study 3 (CS3) team, in collaboration with the Instituto de Investigação Agrária de Moçambique (IIAM), Mozambique's Agricultural Research Institute, the Instituto Nacional de Meteorologia (INAM), Mozambique's National Meteorology Institute, and Plan-International under the Focus-Africa project, worked to develop and demonstrate tailored climate services for the agriculture and food security sector in Mozambique using this tool. During the climate service development process, the CS3 team identified through surveys and focus group discussions that variability in the timing of the growing season posed a significant challenge for farmers and the crop production community. In response to the expressed interest of farmers and crop production stakeholders, the team developed agroclimatic indices to characterize the wet season calendar, which were intended to support decision-making in crop production. These indicators were critical for managing the crop production process and provided strategic planning tools for future agricultural operations.

To facilitate the demonstration and usability of the developed agroclimatic indicators, the "AquaBEHER" tool was developed. The package is capable of computing and integrating evapotranspiration into a daily water balance model to characterize and predict the calendar of the wet season based on agroclimatic/agronomic approach intended for crop production decision support. This tool is a R-based package used to compute and visualize Wet Season Calendar (WSC). It is distributed through the Comprehensive R Archive Network (CRAN) repository https://cran.r-project.org/web/packages/AquaBEHER/index.html. It offers its users the functionality of computing and integrating daily reference evapotranspiration (Eto) into a daily soil-water balance model to estimate the agronomic calendar of a wet-season. The tool can be used to estimate and plot/map characteristics (onset, cessation and duration) of the wet-season calendar using climate data obtained from weather stations or farm locations and from spatial objects over regions.

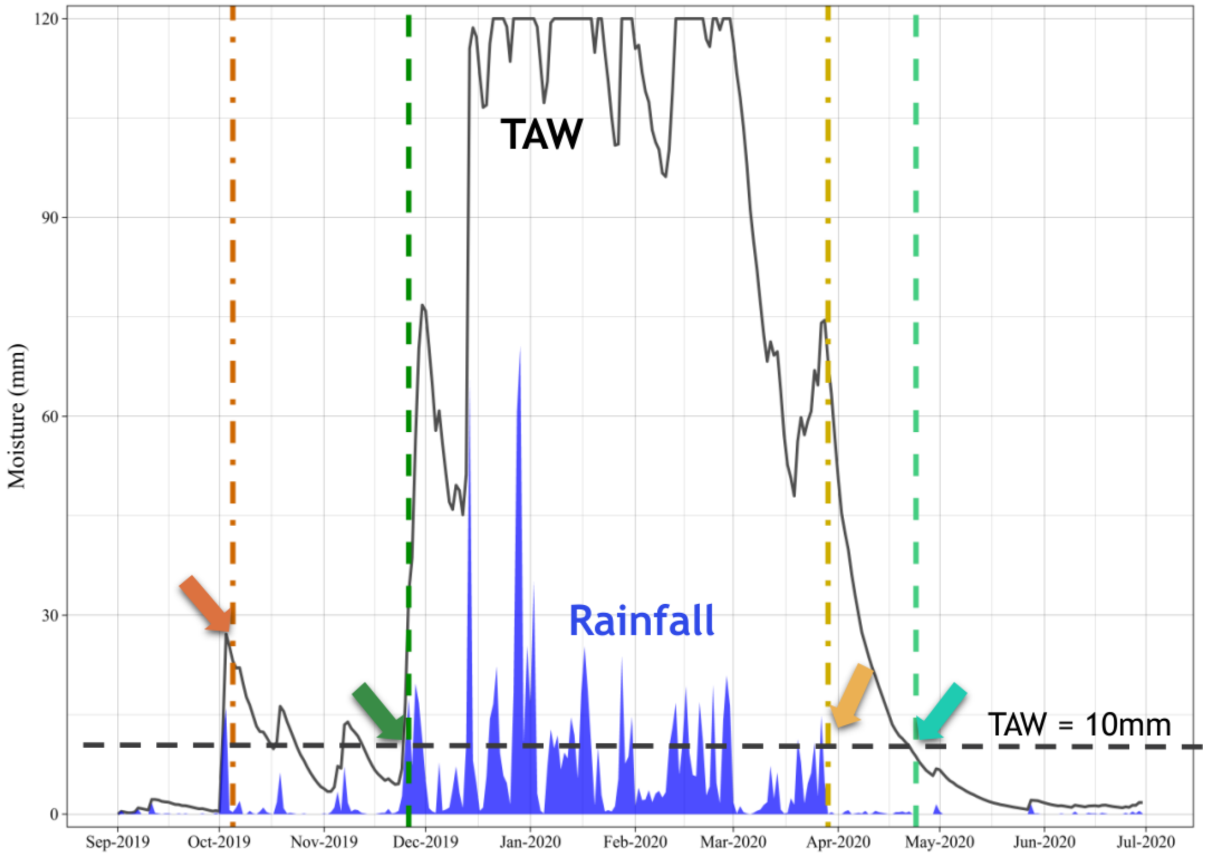

Figure 2: Hypothetical example of onset and cessation date determination

To improve the user experience and ensure to accommodate a range of users in various sectors, including non-specialized staff, we developed a graphical user interface (GUI) version of AquaBEHER, named AquaBEHERgui. AquaBEHERgui is available on GitHub (https://robeltakele.github.io/AquaBEHERgui) allows flexible usage and an interactive environment. Considering the multitude of user abilities, preferences and tasks, the GUI version is developed in such a way to be interactively in tight interplay with the users. The interface requires attractive functionalities such as uploading and downloading input/output datasets, easy data processing and visualizations in the form of graphics and maps available intuitively with a simple click of a button.

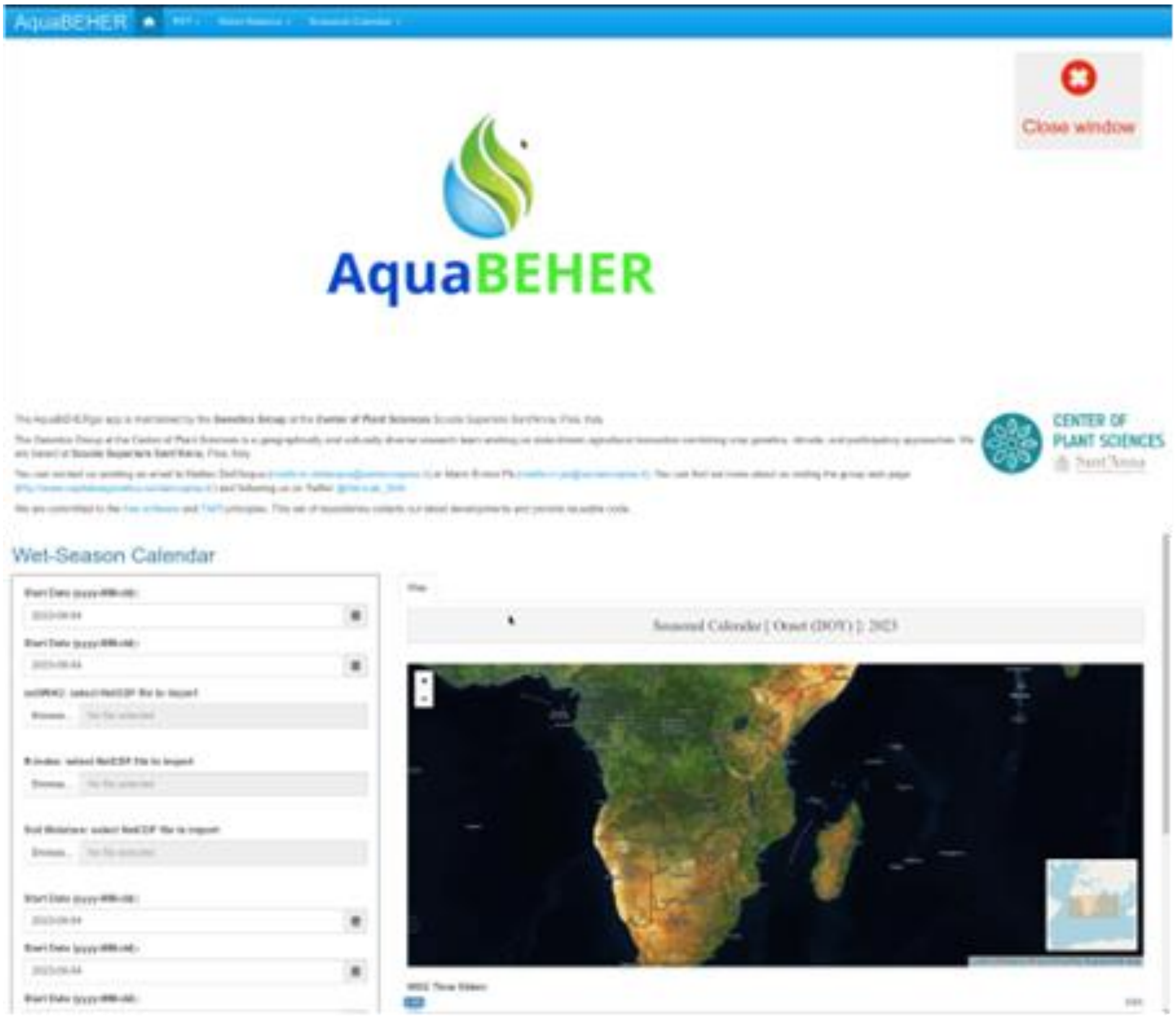

Figure 3: The Graphical user interface of aquabeher

To facilitate the usability of the AquaBEHER package an installation guide (https://robeltakele.github.io/AquaBEHER/) and associated Vignette (long-form guide to the package) was developed and incorporated to the package (https://cran.r-project.org/web/packages/AquaBEHER/vignettes/AquaBEHER.html). The vignette will explain the usage of each function and demonstrate the estimation procedure and visualization using embedded data. A hands-on training during the 4th FOCUS Africa Stakeholder workshop on AQUABEHER for agrometeorological rainy season onset (AquaBEHER tool) led by the Sant'Anna School of Advanced Studies (SSSA) in Pisa-Italy was organized. There were over 40 participants (25 men and 15 women) at the training, including representatives of NMHSs of 12 SADC NMHSs.

Figure 4: Training session at the 4th Stakeholder Workshop

3.3 Climate change training materials (ACMAD)

To support climate change impact assessments, definition and Harmonization of climate change detection and Indices were published by the WMO through its Expert Team (ET) on Climate Change Detection and indices (CCDI). The climate change detection and indices are used for detecting climate change based on indices related to impact sectors. These indices are 27 but 22 were analysed for this effort to build training materials for meteorological services staff on climate change assessment studies supporting national communication and adaptation to climate change planning processes.

3.4 Seasonal forecast training materials (ACMAD)

Based on the gaps identified in deliverable 7.1 and findings in FOCUS-Africa and other research initiatives on the climate of Southern Africa, training materials are prepared and made available online by ACMAD on seasonal climate forecasting (see annexe 1). These materials will be contributing to training sessions at SARCOF, other fora and workshops. Major topics include the following:

- Seasonal Climate of Southern Africa
- Climate variability and its drivers in Southern Africa
- Statistical seasonal forecasting for Southern Africa
- Dynamical seasonal forecasting for Southern Africa
- Model validation and verification of seasonal forecasts
- Consolidation of seasonal forecasts

Materials in these topics provide an overview of the seasonal climate of the SADC region focused on the raining season from October-November to March-April of the following year. Based on literature review, climate variability and related drivers are provided to support update of knowledge and understanding of seasonal climate variability of southern Africa useful for operational forecasters. The two key approaches used in operational seasonal forecasting (i.e., statistical and dynamical) are described to provide the basis for understanding and using of tools like VIGNETTE as well as their output products. To improve the quality and value of seasonal forecasts, efforts to move from consensus to more objective approaches in consolidating seasonal forecasts generated with different methods are promoted to make the process better documented and reproductible.

Links are described in the annex and provide access to training materials on climate variability and drivers of Southern Africa seasonal climate variability. ACMAD will sustain and support the use of these online materials for seasonal climate forecasting trainings in Southern Africa.

3.5 Teal tool: Web-based interface for rainy season historical and forecast indicators (WEMC)

3.5.1 Overview of the Teal tool for FOCUS-Africa

Teal[1] is a web-based tool designed with a user-friendly interface to facilitate access to climate data, allowing easy visualization through maps and plots, and functions to download images and data. The current public version of the tool provides maps and graphs of climate data from 1950 to near real-time. Climate variables include temperature, precipitation, solar radiation and windspeed at both country and sub-country levels presented at different temporal resolutions. An example is shown in **Figure 5** for annual precipitation.

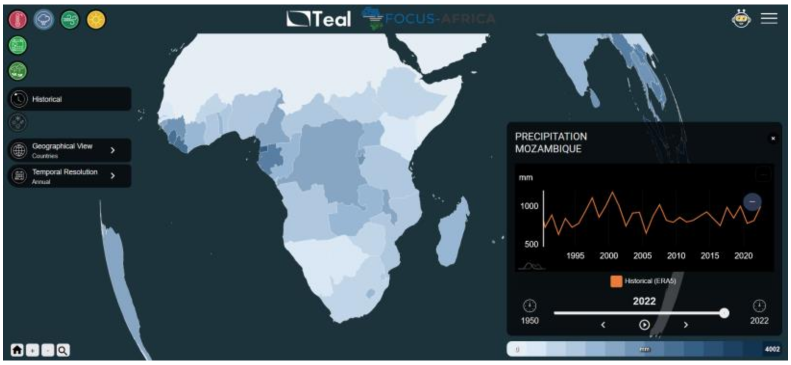

Figure 5: TEAL tool screenshot: Example of precipitation indicator map with timeseries plot of a selected region

A new bespoke version of Teal has been developed concentrating on data and indicators critical for FOCUS-Africa partners and users. It is designed to be of benefit for the users of the project who need to make informed decisions and can utilize the additional information this tool provides. In addition to climate variables described above, users can explore specific precipitation indicators such as seasonal accumulations, illustrated in **Figure 6**, and will be able to access forecasts of important variables including precipitation anomalies and the date of the onset for the upcoming rainy season, with an example shown in **Figure 7**.

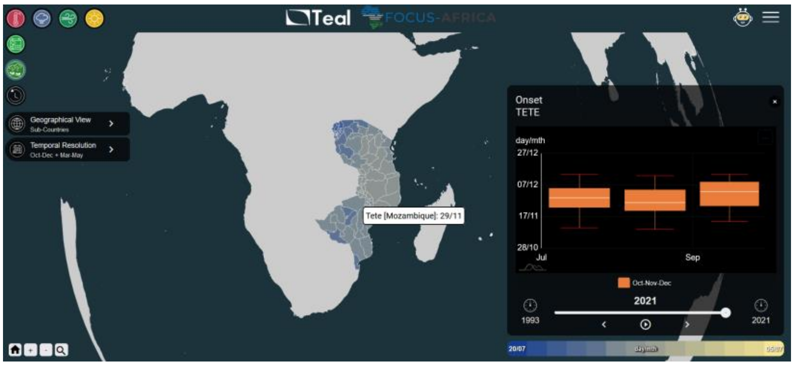

Figure 6: Teal tool screenshot: example of seasonal forecast information for OND rainy season onset date for a selected region

[1] https://tealtool.earth

3.5.2 In-country training in Mozambique

During the in-country training session held in Mozambique, time was dedicated to the demonstration of the use of Teal tool as a versatile platform for illustrating the tailored climate data for the region developed in the project. This session was aimed not only at introducing the functionality of the tool but also at encouraging hands-on experience for the attendees. Those participating included potential users such as local weather services and professionals from energy, water, agriculture, and insurance sectors. Feedback and insights gathered during this session have already been, and will be, instrumental in enhancing the tool's future development, to align with the users' needs and expectations. The group discussed ways to improve the delivery of trial climate services by the Teal tool, summarized in **Table 1**.

Table 1: Summary of feedback on Teal from training session in Mozambique

Topic	Comment/Feedback	Immediate Response	Subsequent/ Future Work
Background Information	It would be useful to have an explanation, as well as some basic analysis as background information for the users to make sure they understand it well	Already available information was highlighted, including the use of the embedded AI bot TealBot	Improve information available - on data, methodologies and functionality
Different regions for small countries	Different/ higher resolution sub-country areas for small countries like Mauritius	It was explained that there are already sub-country areas for Mauritius	There has been further discussion on sub-country areas with partners/ users
Consider additional indicators	Could consider additional indicators (e.g. SPI) as well as display of anomalies	Some of this is under development, based on user feedback	Other indicators are under development and specifications are being sought with partners/ users
Consider additional indicators (specifically for Mauritius)	Useful to have consecutive dry days (for sugar cane, tea, maize as north of the island is dry); and there is also a strong demand for the onset season, and the number of wet days, so planning for sowing time can be optimised	Noted	As above
Accessibility tests	Have accessibility tests been done (e.g. appropriate colour schemes for colour blindness)	It was indicated that attention has been paid to this, but it is regularly reviewed	Ongoing task to review accessibility
Point specific forecasts	It was asked whether there will there be point specific forecasts	The tool is built around shapefiles rather than points, but the shapes can be very small	No current plans for gridded data to be visualised
Button for feedback	It would be useful to have a button for feedback	There used to be one in previous versions and could be	Keeping under review

		reinstated, it was noted that there is also TealBot and contact information	
User-set specific thresholds	It would be useful for users to set specific thresholds (e.g. 400 mm of rain)	This would not be so easy as these need to be precomputed as it would take too long to compute them 'on the fly', but we could select and precompute a set of thresholds	Further review on whether / which thresholds would be useful to have available
Alternative precipitation datasets	Could consider use of other precipitation datasets such as Tamsat	Noted	Tamsat has been assessed. Plans for multiple datasets to be included as options in final version are being considered
Open-Source code for tool	Is the code for the tool Open Source	The code is not currently Open Source, but plans are being made to ensure the sustainability of the tool for users long term	This was discussed in detail internally and in consultation within the project, and the current shared view is that the present arrangement is the most appropriate; but this will be kept under review.

4. Trainings conducted during the project

4.1 First regional training: Objective seasonal forecasting (OSF)

The afternoon of day 2 of the third FOCUS-Africa stakeholders' workshop held in Pretoria, South Africa in June 2022, was dedicated to a capacity building session on seasonal climate forecasts for the National Meteorological and Hydrological Services (NMHSs), with focus on Objective Seasonal Forecasting (OSF). Climate experts present were from 11 SADC countries, namely Angola, Botswana, Comoros, Lesotho, Madagascar, Malawi, Mozambique, Seychelles, Tanzania and Zimbabwe. There was also an expert present online from Zambia.

The objectives of the training were twofold:

- Increase understanding of and awareness on Objective Seasonal Forecasting (OSF); and
- Gather the views of the NMHSs on OSF and the implications and further capacity building needs for them both at national level and regional level.

As background to OSF, in 2017 World Meteorological Organisation (WMO) recognized that use of dynamical forecasts from its network of producers was largely subjective and that subjectivity of the widely-used consensus approach limited the usability of forecasts and also the verifiability. In 2018-19 a WMO expert team produced a technical document where ten principles of using an objective approach was described titled "Guidance on Operational Practices for Objective Seasonal Forecasting". Objective forecasting uses dynamical climate models as the primary basis. In essence the guidance document encourages use of objective forecasting as it follows a procedure that is traceable, reproducible, well-documented, with forecasts amenable to verification. More accurate tercile probabilities could be produced using OSF. Three cases were presented to demonstrate the point.

- **Case 1**: was done for October-November-December 2019, and it was the only time the 55% probability was used. This was to say that it was going to be wetter than normal, which happened.
- **Case 2**: was for March-April-May 2021, which produced a 33% probability across the different categories, highlighting that the season could be any case from dry to wet, and not normal like most people would interpret (i.e. 33% meant there was no skill in the prediction).
- **Case 3**: Here examples of new and more user relevant products were highlighted based on improved forecast probabilities. In summary, the benefits of objective forecasting are that it is capable of bolder probabilities/sharpness and confronting uncertainty, while also allowing automation of some aspects and reproducibility of forecasting processes.

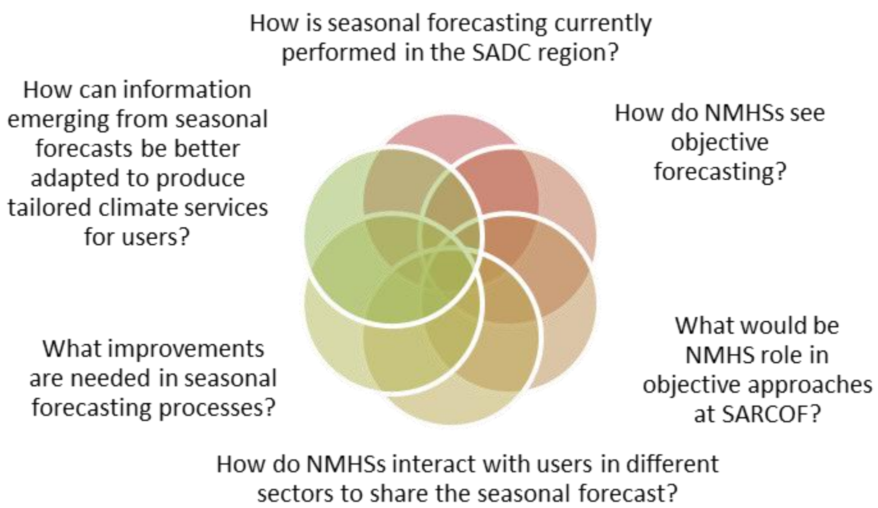

Figure 7: Points raised during the session on objective seasonal forecasting

ACMAD shared the OSF methodology being supporting across Africa which incorporates 9-steps and strikes a balance between what the NMHSs and Regional Climate Centre's (RCCs) currently do, and the OSF guidelines developed by WMO. The session did not go into full details on a specific OSF method but rather introduced the theory, described different OSF methods, and shared examples of application of OSF in other regions. Key issues and questions that emerged during the session included:

- What would be NMHS role in objective approaches at the Southern Africa Regional Climate Outlook Forum (SARCOF) – the NMHSs and the national processes and national forecaster skill has traditionally played a key role in the regional forecast process and a move to OSF would seemingly reduce their role.
- The implications for countries who are involved in two Regional Climate Outlook Forums due to their location e.g., Comoros which participates in both South-West Indian Ocean Climate Outlook Forum (SWIOCOF) and Southern African Regional Climate Outlook Forum (SARCOF)

processes and have two teams participating in these forums to come up with the regional forecasts, which themselves have overlaps but are not always consistent.
- The need for capacity building (technical and infrastructural) on dynamical seasonal forecasting, which is complicated and computationally intensive.

It was agreed to continue the discussions between SADC CSC, ACMAD, WMO and the respective NMHSs on support to the SADC region on OSF and harmonization where relevant of seasonal forecasting methodologies and procedures in Africa. Practical instructions manuals or guides are to be developed or updated facilitating production of consistent forecasts, supporting quality assurance and control of climate services.

4.2 In-country training in Mozambique: characterizing the wet-season calendar

A training workshop was conducted by the Sant'Anna School of Advanced Studies (SSSA) on predicting rainy season characteristics and Crop Water Balance (CWB) for agricultural crops on 19 - 20, September 2022 hosted by the Mozambique National Institute for Meteorology (INAM). Eleven (5 female, 6 male) experts from INAM, Mozambique Institute of Agricultural Research (IIAM) and the World Food Programme (WFP) participated. The aim of the training was to test and evaluate the usage and applicability of the tools being developed under case study 3 and increase awareness of the trainees on the current state of the art on predicting agroclimatic indicators, such as rainy season onset. At the end of the training, the trainees were able to estimate and characterize agroclimatic indices using the developed scripts and functions. The complexity of the tool (code/command based) was the major challenge during the training and the participants suggest that a tool with a flexible interface and user-friendly visualization is needed.

4.3 Second regional training: seasonal onset calculation

The training session at the 4th stakeholder workshop focused on methodologies for calculation of seasonal onset. This included, training and discussion on seasonal forecasting in Eastern and Southern Africa led by the UK Met Office, overview of the approach used by ACMAD to calculate rainy season onset, introduction to an alternative monsoon onset calculation method for Tanzania and Malawi led by the World Energy and Meteorology Council (WEMC), and a hands on training on a new tool for agrometeorological rainy season onset that is being developed under FOCUS-Africa (AquaBEHER tool) led by the Sant’Anna School of Advanced Studies (SSSA). There were over 40 participants (25 men and 15 women) at the training, including representatives of NMHSs of 12 SADC NMHSs.

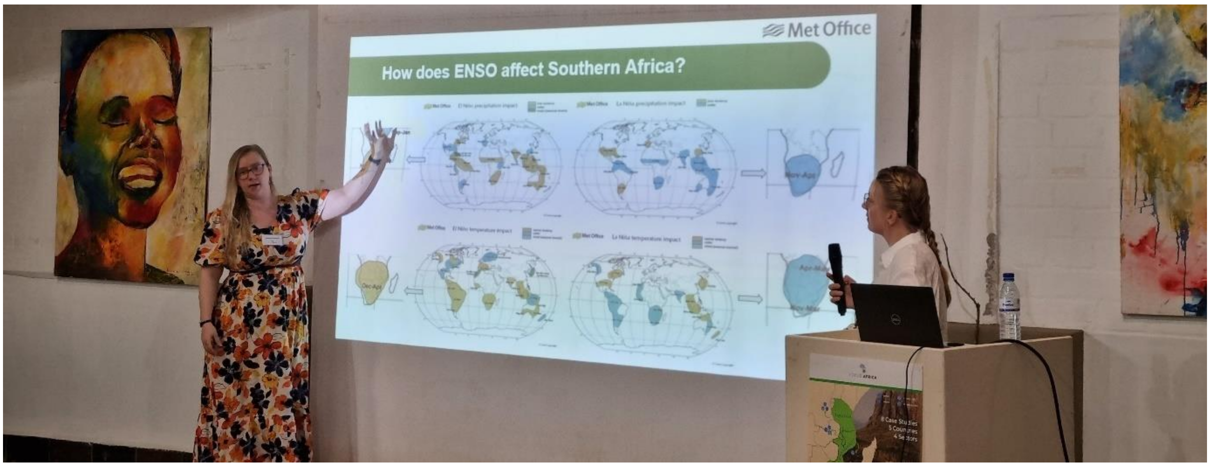

Figure 8: Training session at the 4th stakeholder workshop on Enso and climate variability in southern Africa

Ahead of the capacity building session, participants were asked to fill a preworkshop survey, which included questions on aspects like, how they calculate seasonal onset and the key capacity needs related to seasonal forecasting.

Seasonal onset definitions by participating countries

- The start of rains is the first occurrence of any specified rainfall amount (20 mm) in 1 or 2 consecutive days with no dry spell of 10 days or more within the next 30 days.
- Omotosho et al (2000) rainfall onset is the beginning of the first 10-day period with cumulative rainfall of 20mm, above one of which is 10mm.
- Three consecutive days on which a total of 25mm is attained and no consecutive dry days of more than 9 in the next 21 days.
- Rainfall Onset: The start of the rains is defined as the first occasion after the first of November that the 7-day total is equal to or exceed 50mm and includes at least four rainy days.

Capacity gaps with onset calculation

- Limited capacity to compute or forecast the onset and cessation of the rain season.
- Lack verification capacity.
- Insufficient data for calculation of products
- Inability to use S2S products.
- Uncertainty in forecasts – i.e., exact date or range not easily forecast.
- Dry and wet spell forecasts is important yet still not up to standard required by users.
- Some countries rely completely on SADC CSC seasonal forecast – no internal capacity.

The seasonal forecasting broader training by the Met Office covered issues such as drivers of seasonal rainfall (e.g. the El Nino Southern oscillation (ENSO) and Indian Ocean Dipole (IOD)); predictability of these drivers and their impacts in Southern Africa; the principles of seasonal forecasting using different model types (dynamical and statistical); forecast verification; and access to seasonal data (e.g. from ECMWF, WMO LRF MME (wmoic.org) and Copernicus).

To broaden perspectives before delving into the practical aspects of the AquaBEHER tool, participants were also introduced to two other methods for calculating the rainy season onset.

ACMAD presented on the start of the agriculture season approach, which is based on a methodology used by the Australian Bureau of Meteorology. The methodology also facilitates detection of early and late onset starts and uses accumulation of daily rainfall climatology during a reference period and actual cumulative recorded daily rainfall for the target season of interest. Specifically, the method is detailed as follows:

- Calculate the daily average rainfall for a reference period (i.e., 1991-2020). This generates the average over the refence period of the annual cycle of daily rainfall.
- Calculate the cumulative daily averages and its 75% and 125% thresholds.
- Identify the dates corresponding to 50 mm of cumulative rainfall on the average, 75% and 125% of the average rainfall graphs
    - The date corresponding to the 50 mm cumulative rainfall on the 75% of the cumulative average daily rainfall graph represents the first date of a late Start of Season

- The date corresponding to the 50 mm cumulative rainfall on the 125% of the cumulative average daily rainfall graph represents the last date of an early Start of Season
- The date corresponding to 50 mm of cumulative rainfall on the accumulated average daily rainfall graph represents the climatological or “normal” start of the agriculture season.
- The date corresponding to 50 mm of observed cumulative daily rainfall computed with rainfall recorded starting one month before the climatological start of agriculture season date, is the actual start of agriculture season for a given selected year of interest.

The methodology has been validated in Ethiopia, Nigeria, Cameroon, Cote d’ivoire and Guinea. Products of this methodology applied using tools and platforms developed by ACMAD and partners are becoming parts of technical notes for 10 day and monthly climate diagnostics and monitoring reports of Regional and national Climate Centres. ACMAD is testing the so-called harmonic method using rainfall anomalies for rainfall season onset, cessation and rainy season duration calculation. Pilot experiments with this method are underway with interns, on the job trainees and seconded experts from NMHSs across Africa.

Other commonly used methods were noted to include the Sivakumar method for rainfall onset dates, which is also based on 3-day cumulative rainfall and is defined over West Africa as “the date after 1 May when rainfall accumulated over three consecutive days was at least 20 mm and when no dry spell within the next 30 days exceeded 7 days”.

The second methodology by WEMC, was based on early monsoon onset calculation using a cumulative rainfall anomaly method. Examples from Tanzania were used using various data sources and showing how the calculated onset could be different based on the method used. The standard definition by the Tanzania Meteorological Authority (TMA) for the onset of rains is calculated as the first occasion during the OND (or MAM) season when a) 20 mm or more rainfall is received in four consecutive days, b) with at least two wet days and c) no dry spell of 10 days or more within the following 30 days. A wet day is defined when there is 1 mm or more rainfall in the day, while during dry spells days less than 1mm of daily rainfall should be recorded. The alternate technique by WEMC is based on only cumulative rainfall anomalies and aims to identify the date at which the cumulative rainfall anomalies rise consistently for the onset and the date at which the cumulative rainfall anomalies fall consistently for the cessation. The use of machine learning to enhance forecasts was also demonstrated.

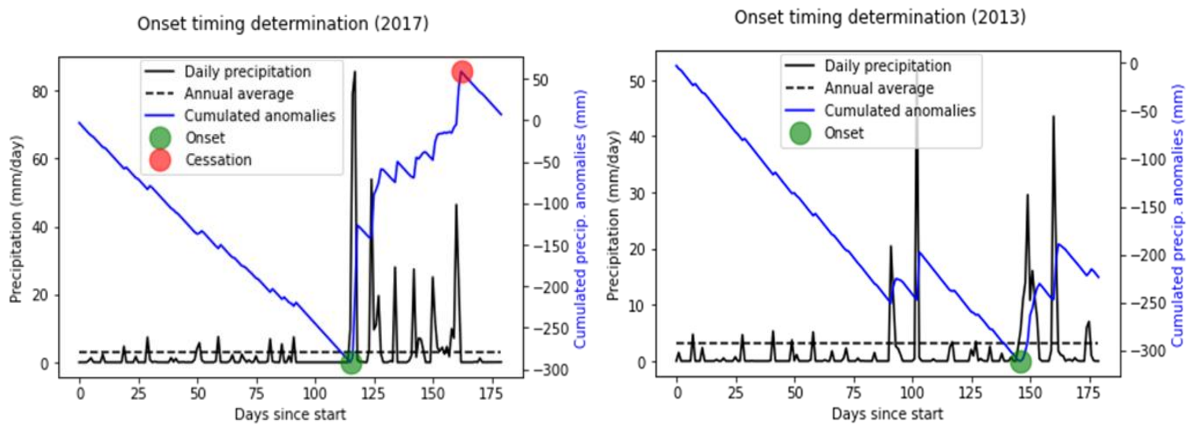

Figure 9: Two examples of the computation of the onset and cessation dates for the OND monsoon in Kibaha using the alternate technique based on cumulative rainfall, based on CHIRPS data. Left: for 2017; in this case the onset is 23rd October, and the cessation is 9th December. 2017 was a normal year. Right: for 2013.

Table 2: Comparison of Onset days based on two methods, Standard Technique (ST, using several dataset) and Alternate Technique (AT, using CHIRPS data)

Year	CHIRPS (using AT)	Date (for AT)	Station Data	CHIRPS	MSWEP	ERA5	MERRA2	ERA5 Land
2008	299	26th Oct	301	301	311	285	299	336
2009	340	6th Dec	301	314	313	342	299	316
2010	339	5th Dec	320	313	320	319	317	321
2011	309	5th Nov	286	274	319	268	266	283
2012	328	24th Nov	331	313	307	314	274	308
2013	327	23rd Nov	278	274	276	275	276	277
2014	303	30th Oct	338	259	308	307	259	338
2015	302	29th Oct	310	314	309	305	310	323
2016	360	26th Dec	366	285	366	325	279	366
2017	296	23rd Oct	299	299	308	264	298	307
2018	319	15th Nov	279	279	345	299	299	347
2019	275	2nd Oct	276	279	278	276	254	278
2020	285	12th Oct	287	287	315	287	286	290
Average (Std. Dev.)	314 (23)	10th Nov	306 (26)	292 (18)	313 (23)	297 (23)	286 (19)	315 (27)

Following these presentations, a full-on practical demonstration of the AquaBEHER agronomic onset calculation tool was done with all participants. The training was used as a platform for broader testing and piloting of the developed climate service, awareness raising and familiarizing experts and stakeholders on its capabilities and getting their feedback on its use.

Participants installed the software on their laptops and tested it using either sample data or their own data to characterize Soil Water Balance (SWB) parameters and calendar of the wet season as a means to support crop decision making.

Overall, the stakeholders characterized the developed tool as quite useful and targeting a much required and frequently demanded climate service for agriculture. They expressed satisfaction with the developed tool and were eager to consider its integration into their operational services, as demonstrated by follow-up communications between the CS3 team and participants at the event.

The tool has a few glitches that need to be resolved, though overall it has good potential for supporting NMHSs with calculation of agronomic onset. Specifically, the following were noted:

- Technical aspects on underlying data and models
  - It would be useful to include an alternative method for producing the seasonal forecast of the wet season calendar by integrating the official seasonal forecast of NMHS with the water balance model at the core of AquaBEHER.
  - It would be useful to include in the tool seasonal forecasting capabilities for additional relevant agroclimatic and climate-stress indices such as:
    - Dry and wet spells;
    - Soil moisture indices;
    - Indicators of agricultural drought;
    - WRSI for Maize, rice, ground nuts and common beans.
- Computational aspects on GUI presentation of the tool
  - Include an option to display multiple variables/indices in a single plot;
  - Include a function to display aggregated statistics of the derived indices over various levels of administrative boundaries;
  - Including a comprehensive user guide and manual with the tool;

- Provide additional comprehensive hands-on training by providing sufficient allocated time for every aspect of the tool;
- Including a function to download and pre-process the required input datasets;
- Minimize and simplify the complexity with the dependencies in the installation process.

The next version of the AquaBEHER tool will include a functionality to produce seasonal forecast of the wet-season calendar by integrating seasonal tercile rainfall forecast produced by NMHS. This new functionality will be incorporated in the coming months after the technical testing and validation of the proposed method is finalized. The upcoming version of the package will also address some of the inputs and suggestions raised by users and stakeholders. A web-based version of the AquaBEHER tool with comprehensive tutorial and user guides is under development and planned to be released along with the next version of the package.

For the training overall, the following key issues were noted:

- Most of the training focused on calculation methods using historical data and participants requested to understand more on how forecast methodologies will be integrated into this work. This aspect is currently being worked on by the project partners.
- Participants noted the need to better forecast wet and dry spells, in addition to the onset and duration of the season. Satellite-derived indices for agriculture monitoring were also highlighted as an area for agriculture monitoring.
- Machine learning for seasonal forecasting was briefly discussed and could be an area of focus in the next cycle of WMO activities from 2024 e.g., understanding machine learning applications in forecasting parameters relevant for agriculture.

The integration of climate issues with genomics under case study 3 was noted as being a good example of innovation in climate services and could also be an area of further research in the next cycle of WMO activities from 2024.

4.4 SADC CSC level training: status and opportunities

As SADC-CSC did not manage to become a project consortium member, this posed some challenges with having SADC level trainings and the strategy was instead to invite countries to trainings conducted by the project. Despite this, engagements with the SADC-CSC have continued. FOCUS-Africa partners initiated a meeting with SADC-CSC and the SADC ClimSA project, and discussions were held on collaboration between the two projects, particularly given that there are some common partners (e.g., University of Cape Town (UCT)). The ClimSA project does not produce climate services user end products, and there was general agreement that FOCUS-Africa findings could be integrated into the SADC-CSC trainings being carried out under the ClimSA project. As a result, during SARCOF-26 in August 2022, ACMAD provided training on the RPSS verification method and determination of analogue years. The cumulative daily rainfall for the analogue years were used to determine the trend of the upcoming rainfall season, which assisted in determining the onsets, dry spells and cessation.

ACMAD continues to provide regular contribution to SADC-CSC trainings conducted as part of the SARCOF. Ultimately, ACMAD will integrate Focus-Africa tools and customize continental level training materials (including those developed under other projects and initiatives) to the Southern Africa context and use these in future SARCOFs. The three online tools already developed under FOCUS-Africa have already been shared with SADC-CSC experts for testing to be a part of their regular operational processes.

4.5 FOCUS Africa Online Capacity Building

The training program, initiated by ACMAD in collaboration with the WMO under the FOCUS-Africa project, aimed to enhance climate services capacity across the SADC region, particularly in agriculture, energy, water, and infrastructure. Conducted in three stages, the program included an online phase of ten sessions between April and June 2024, an in-person workshop in July 2024. The training focused on introducing tailored climate tools and methodologies, aligning with the WMO competency framework. These sessions emphasized data management, seasonal forecasting, socio-economic assessments, and practical applications to improve climate risk decision-making.

Participants engaged with tools such as AquaBEHER, RClimdex, and statistical models, with sessions addressing climate variability, socio-economic impacts, and software configuration. Practical challenges included time constraints, data management gaps, and technical limitations with software compatibility. The training highlighted the importance of localized climate service customization and the need for significant donor support for in-person training to complement online approaches.

The program concluded with the development of climate tools and manuals aimed at improving SARCOF's capacity to deliver actionable climate information. Future initiatives will focus on addressing data gaps, expanding regional collaboration, and ensuring sustained capacity development in Africa through partnerships between ACMAD, WMO, SADC/CSC, ICPAC, and other advanced NMHSs. These efforts underscore the importance of mobilizing resources to build a robust, locally relevant climate services framework across the region.

Annex 1: Summary of the available online tools and resources

Name of training materials	Brief description of the training/ tool	Links to web-based tool and/ or downloadable application	Link to training manual if available online
1-Vignette for calibration and verification of seasonal forecasts	A vignette which provides an example of code written in R that can be used to calibrate seasonal forecasts using several calibration methods. For each calibration method, different skill scores are calculated, compared to the ones obtained by using a non-calibrated forecast and finally displayed	https://earth.bsc.es/gitlab/focus-africa-bsc/vignette	https://earth.bsc.es/gitlab/focus-africa-bsc/vignette
2-AquaBEHER: an R package for estimation of wet-season calendar and soil-water balance for Agriculture	Computes and integrates daily potential evapotranspiration (PET) into a soil-water balance model to estimate wet-season calendar	https://github.com/RobelTakele/AquaBEHER https://github.com/RobelTakele/AquaBEHER/releases/download/v0.1.0/AquaBEHER_0.1.0.tar.gz	https://robeltakele.github.io/AquaBEHER/
3- Teal tool: Web-based interface for rainy season historical and forecast indicators	Teal[2] is a web-based tool designed with a user-friendly interface to facilitate access to climate data, allowing easy visualization through maps and plots, and functions to download images and data	https://tealtool.earth	https://tealtool.earth
4- Climate of Southern Africa, its variability and related drivers	Provides understanding of climate and its variability in southern Africa, supports identification and analysis of climate variability and extremes in southern Africa	Not Applicable	module 1 and 2 -climate and variability -SADC
5- Statistical and dynamical seasonal	Supports identification and interpretation of the climate teleconnections and interactions driving climate variability, presents forecasting methods and tools,	Not applicable	module3 and 4 -climate and variability -SADC

[2] https://tealtool.earth

Name of training materials	Brief description of the training/ tool	Links to web-based tool and/ or downloadable application	Link to training manual if available online
forecasting for Southern Africa	facilitates interpretation of climate products to deliver reliable climate information		
6- Introduction to climate services	**Overview of the FOCUS Africa project:** - Objectives and importance of tailored climate services - The full-value chain of climate services and work packages overview	Not applicable	Link
	SADC regional climate services gap analysis (1): Assessment of End-User's Challenges and Climate Services Requirements	Not applicable	link
	SADC regional climate services gap analysis (2): Capacity Development Needs Assessment	Not applicable	link
	Engagement of Stakeholders in Responsible Research and Innovation (RRI): Introduction to RRI and co-designing climate services through the RRI lens	Not applicable	link
7-Climate Data Management, Processing and Derived Products	**Climate data management:** Introduction to data, data types, quality assurance and control	link	link
	Extreme events identification and variability: Climate extremes in seasonal forecasting and climate variability		link
	Understanding Climate Processes: Fundamental understanding of southern Africa Climate dynamics at climate change timescales		link
	High-resolution climate projections analysis		link
	Analogue and composite approaches in Seasonal forecasting		link
8-Climate Model Outputs and Forecasts	**Seasonal Forecast quality assessment (1)**: - Visual and objective verification of seasonal forecasts with activity verify SARCOF-27 OND Forecast using RPSS	SOP for gridding data using Surfer and analysing using QGIS	FOCUS-Africa Capacity Building Online Training ACMAD VERIFICATIO

Name of training materials	Brief description of the training/ tool	Links to web-based tool and/ or downloadable application	Link to training manual if available online
Interpretation	- Activity using Malawi as an example – Implementing RPSS, plotting using SURFER 16 then analyzing using QGIS	Calcul_RPSS_JFM_BOTSWANA_ORIGINAL Calcul du RPSS_OND_2023_MALAWI	N_FORECAST
	Climate projection and decadal assessment - Decadal assessment - Methods and tools for forecast verification. • Vignette for calibration and verification of seasonal forecasts + shiny tool for visualization		Training - Seasonal and multiannual predictions - BSC
	Statistical Downscaling for Seasonal Forecasting		statistical downscaling for seasonal forecasting - ACMAD
	Statistical and dynamical seasonal forecasting in southern Africa (decadal and climate change timescales)		
9- Climate Services Development and Communication (User-Interface)	**Development of end-user tailored climate services prototypes:** Data requirements, and guidelines, for development of climate services communication		Development of end-user tailored trial climate services - WEMC
	Derived Product for Climate Projections - Indices based on NWP (forecast and climate projection products - Calculations and uses of Climate Change Detection Indices (ETCCDI)		Calculations and Uses of Climate Change Detection Indices (ETCCDI): Indices Based on NWP (Climate Projection Products)
10-Quality Processes for	**Methods and tools for socio-economic impact assessment of climate services** - Impact assessment		training on socio-economic impact assessment - WP6

Name of training materials	Brief description of the training/ tool	Links to web-based tool and/ or downloadable application	Link to training manual if available online
Climate Monitoring	- General socio-economic methodology presentation - Presentation on market study aspects - Focus on agriculture - Focus on energy		
11-Climate Services Development and Communication (User-Interface): *Derived products and tools for Agriculture and food security*	Precipitation datasets assessment over Tanzania		FOCUS-Africa Precipitation datasets assessment in Tanzania - WEMC
	Derived products and tools for Agriculture and food security - Demonstration of Teal tool	**Onset dates computation materials:** link **Scripts:** link	FOCUS Africa Teal tool presentation
	Use of historical climate statistics and seasonal forecasts of indicators relevant to rainy season/Onset determination methods and tools		
	Practical application of Aquabeher in Agriculture and food security - Use seasonal forecasts and projected data for local adaptation on crop types. - method to estimate agronomic onset and cessation of the wet season	materials and files	Estimation and Prediction of Agronomic Calendar of the Wet Season - PPT
12-Climate Services Development and Communication (User-Interface):	**Derived products and tools for Energy Sector - Practical application of TEAL tool** - Assessment of inflow data / Evaluation against ground stations and using GLOFAS/ Hydropower applications		
	Factors to consider when applying climate projections in Agricultural finance: climate/crop models		
	Seasonal forecast post processing with Xcast		
	Climate service prototype development for Mauritius	materials and files	Case Study 8 – Climate service prototype development for

Name of training materials	Brief description of the training/ tool	Links to web-based tool and/ or downloadable application	Link to training manual if available online
			Mauritius ppt