# Report on the Regional Training on Sub-seasonal Prediction for Eastern Africa


**Date:** 02–06 September 2025
**Venue:** Addis Ababa, Ethiopia

**Organizer:** IGAD Climate Prediction and Applications Centre (ICPAC)

# 1. Introduction

The Regional Training on Sub-seasonal Prediction for Eastern Africa was held from 02–06 September 2025 in Addis Ababa, Ethiopia. The training brought together experts and practitioners from National Meteorological and Hydrological Services (NMHSs) to strengthen capacity in the generation, interpretation, and application of sub-seasonal climate forecasts.

The training was hosted by Ethiopia Meteorological Institute and facilitated by the IGAD Climate Prediction and Applications Centre experts. It aimed at equipping participants with hands-on skills in the use of the Python-based Climate Predictability Tool (PyCPT v2.8.1) for sub-seasonal rainfall prediction and enhancing understanding of the drivers, methodologies, and challenges of sub-seasonal forecasting.

Sub-seasonal prediction, which bridges the gap between short-term weather forecasts and seasonal climate outlooks, has emerged as an important area of climate services in support of decision-making for agriculture, food security, health, water resources management, and disaster risk reduction. The training aimed to provide both theoretical knowledge and hands-on skills to enable participants to generate, interpret, and apply sub-seasonal forecasts effectively.

The training was jointly supported by the Climate Risk and Early Warning Systems (CREWS) Greater Horn of Africa Project and the World Bank-funded Accelerating Impacts of CGIAR Climate Research for Africa (AICCRA) Project. The CREWS Greater Horn of Africa Project aims to strengthen national capacities to access, process, and analyze climate information across multiple timescales through a regional cascading mechanism, thereby enhancing the resilience of agricultural sectors to climate-related risks. Similarly, the AICCRA Project works to expand access to climate information services and validated climate-smart agriculture technologies across Africa, supporting countries in building more climate-resilient agricultural systems.

# 2. Objectives of the Training

The main objectives of the training were to:

- Enhance understanding of sub-seasonal prediction, its progress, challenges, and relevance to the region.
- Build technical capacity in the installation and use of PyCPT v2.8.1 for sub-seasonal forecasting.
- Train participants on statistical methods such as Model Output Statistics (MOS), including MLR, PCR, and CCA.
- Provide practical skills in configuring PyCPT for regional applications and generating forecasts.
- Explore sensitivity analyses related to predictor domains, MOS methods, training seasons, and dynamical models.
- Promote collaborative learning through group discussions, interpretation exercises, and participant-led presentations.

# 3. Training Proceedings

## Day 1: Tuesday, 02 September 2025

The training commenced with registration, introductions, and opening remarks from ICPAC. This was followed by an overview of the workshop goals and agenda delivered by **Dr. Hussen Seid**. Speaking on behalf of the IGAD Climate Prediction and Applications Centre (ICPAC), Dr. Hussen welcomed participants to the Regional Training on Sub-seasonal Prediction for Eastern Africa, organized under the CREWS Greater Horn of Africa and AICCRA projects. In his remarks, he underscored the overarching objectives of these initiatives to strengthen national capacities to access, process, and apply climate information across multiple timescales, with a particular focus on enhancing resilience in the agricultural sector. He further noted that sub-seasonal prediction, covering the period from two weeks to two months, remains one of the most challenging to forecast, yet it is among the most critical for effective planning and preparedness.

Emphasizing the significance of addressing this prediction gap, he outlined the purpose of the training: to equip IGAD member state forecasters with the knowledge and practical skills to use the Python-based Climate Predictability Tool (PyCPT v2.8.1) for sub-seasonal forecasting. He noted that over the course of five days, participants will engage in hands-on exercises, knowledge exchange, and collaborative learning, ultimately strengthening regional forecasting capacity and enhancing preparedness across Eastern Africa. Following the opening session, participants took part in a group photo and a networking coffee break, providing an opportunity to interact informally, build connections, and share expectations ahead of the technical sessions.

Technical sessions began with an **introduction to sub-seasonal forecasting** by **Dr. Masilin Gudoshava**, covering recent advances and challenges in the field. The session commenced with a lively and interactive start as she engaged participants through a series of brain teasers, setting an energetic tone for the day's discussions. Following the introduction, Dr. Masilin delved into the topic of Sub-seasonal to Seasonal (S2S) predictability, explaining its importance in bridging the gap between weather and seasonal forecasting and its potential to enhance preparedness and decision-making across various climate-sensitive sectors. She elaborated on the sources of predictability, emphasizing the intricate interactions between the atmosphere, land, and ocean systems that collectively influence climate variability at sub-seasonal timescales. Dr. Masilin went on to review the progress made so far in understanding S2S processes, highlighting significant advancements in identifying and interpreting key climate drivers that affect forecast skill and regional climate outcomes.

She further introduced participants to the emerging role of Artificial Intelligence (AI) in improving forecast accuracy, discussing several techniques used to integrate AI into prediction systems and illustrating her points with an example of an operational AI-based model currently being utilized in the field. In addition, Dr. Masilin showcased examples of private-sector applications of sub-seasonal forecasts, demonstrating how these forecasts are being used to inform decision-making in industries such as agriculture, energy, and insurance. The session also underscored the importance of international cooperation and collaboration, as Dr. Masilin highlighted ongoing global initiatives and partnerships that contribute to enhancing data sharing, research, and model development in S2S forecasting. She then discussed the relevance of S2S forecasts in decision-making processes, illustrating how sub-seasonal information can be applied to guide planning, risk management, and preparedness actions in various sectors. To conclude the session, Dr. Masilin outlined some of the key challenges faced in advancing S2S forecasting, including issues related to data quality, model limitations, and the need for improved user engagement. She wrapped up by sharing a list of websites and online resources that participants will use for accessing data, forecast products, and other materials relevant to the workshop's ongoing activities.

Dr. Titike Bahaga delivered a presentation on sub-seasonal climate drivers over Eastern Africa, focusing on the key drivers that influence the region's climate across both seasonal and sub-seasonal timescales. The objective of the session was to strengthen the capacity of forecasters to interpret climate signals and improve decision-making processes. At the seasonal scale, Dr. Bahaga highlighted the El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) as the dominant drivers of rainfall and temperature variability. ENSO was described as the primary source of inter-annual climate variability in the region, with El Niño events generally linked to wetter-than-normal conditions during the short October–December (OND) rains, while La Niña often produces the opposite effect. He further noted that in the northern parts of Eastern Africa, ENSO has opposite impacts during the June–September (JJAS) season. The IOD was presented as another key driver, with positive phases enhancing the short-rains and negative phases suppressing them. Importantly, Dr. Bahaga emphasized that the interaction between ENSO and IOD can amplify or mitigate rainfall anomalies, making their joint monitoring essential. Moving to the sub-seasonal scale, the presentation discussed drivers that operate over 2 weeks to 2 months, including the Madden-Julian Oscillation (MJO), Equatorial Rossby Waves, and tropical cyclone activity. The MJO, an eastward-moving atmospheric wave, was highlighted as a critical modulator of rainfall, with its active phase enhancing convection and precipitation and its suppressed phase associated with dry spells. Equatorial Rossby Waves were noted for their role in influencing short-term rainfall variability and extreme events such as localized floods, while tropical cyclones in the Southwest Indian Ocean and associated moisture transport were shown to contribute to sub-seasonal rainfall anomalies. Dr. Bahaga concluded by stressing that monitoring both seasonal and sub-seasonal climate drivers is crucial for improving forecast accuracy and supporting critical planning decisions in Eastern Africa.

**Dr. Hussen Seid** delivered a presentation on the Evaluation of the Skill of Sub-seasonal Forecasts from Global Prediction Systems during the Long Rains over the Greater Horn of Africa (GHA), based on work conducted under the African Science for Weather Information and Forecasting Techniques (SWIFT) project and published in the Weather and Forecasting journal. In his presentation, he highlighted the challenges associated with predicting the March–May (MAM) rainfall season, which, despite contributing the largest share of annual rainfall in the region, remains less predictable compared to the October–December (OND) and June-September (JJAS) rains. Dr. Hussen emphasized that sub-seasonal analysis offers significant potential for improving forecast skill in this challenging season. His presentation evaluated 11 global prediction systems (BoM, CMA, CNRM, ECCC, ECMWF, HMCR, ISAC, JMA, KMA, NCEP, and UKMO) against the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset for the 1999–2010 period. He outlined the challenges of evaluating sub-seasonal forecasts and reforecasts from the S2S archive due to differences in model configurations, ensemble sizes, initialization frequencies, and coupling strategies, which complicate model intercomparison. For the study, rainfall reforecasts with up to one-week lead time for monthly forecasts were analyzed over the common period 1999–2010. Dr. Hussen further stressed that forecast quality is multifaceted and cannot be fully captured by a single verification metric, thus requiring the use of multiple approaches. He elaborated on various deterministic and probabilistic verification methods, including mean error, RMSE, correlation, RPSS, ROC scores, and spread–error ratios, while also outlining their respective strengths and limitations. The assessment showed that ECMWF generally demonstrated the strongest performance, while other models exhibited mixed skill levels, underscoring the importance of multi-model ensembles and careful model selection. He also highlighted the value of the WMO/WCRP S2S prediction initiative in providing access to near real-time sub-seasonal forecasts and recommended the need to evaluate forecast skill of the global prediction systems across different regions and seasons, as the performance of forecasting systems varies significantly in space and time.

**Dr. Tamirat Bekele** successfully delivered a basic Python programming training aimed at equipping participants with essential programming skills to support climate science applications, particularly in the context of the PyCPT (Python Climate Predictability Tool) workflow. The primary objectives of the python programming training were to enhance participants' capacity to process, analyze, and visualize climate datasets; strengthen their ability to manipulate data inputs and outputs for sub-seasonal and seasonal forecasting; and build foundational coding skills required for implementing and customizing PyCPT scripts. The training covered fundamental Python programming principles, including the use of interactive computing environments (Python shell, Jupyter Notebook, and Spyder), core data types (numbers, strings, lists, tuples, dictionaries), and basic operations such as slicing, variable handling, and list comprehension. Special emphasis was placed on leveraging Python's built-in scientific modules for efficient climate data management and reproducible scientific computing.

As a result of the demonstrations and exercises, participants developed practical competencies in handling climate datasets, performing essential data transformations, and visualizing outputs using xarray and matplotlib. Through hands-on exercises, they learned to format and manipulate numerical and textual data, create and manage complex data structures, and apply these skills to postprocess and analyze datasets for PyCPT applications. The outcomes of the training included improved confidence in using Python for climate modeling workflows, enhanced skills for adapting and running PyCPT in operational and research settings and strengthened regional capacity to produce evidence-based sub-seasonal to seasonal forecasts.

## Day 2: Wednesday, 03 September 2025

The day opened with a session on **Model Output Statistics (MOS)** methods, including Multiple Linear Regression (MLR), Principal Component Regression (PCR), and Canonical Correlation Analysis (CCA)**.**

**Dr. Tamirat Bekele** delivered a comprehensive training on Model Output Statistics (MOS) for Subseasonal Climate Forecasting, designed to strengthen the application of bias correction and statistical post-processing techniques within the PyCPT (Python Climate Predictability Tool) framework. The training aimed to enable participants to effectively correct systematic biases in dynamical model outputs, downscale coarse-resolution forecasts, and calibrate probabilistic predictions for subseasonal timescales. Participants were introduced to classical MOS techniques such as linear regression, Principal Component Regression (PCR), Canonical Correlation Analysis (CCA), and advanced machine learning approaches, with a strong emphasis on their integration into PyCPT workflows for operational and research purposes.

Through hands-on sessions, participants learned to collect and postprocess model forecasts (predictors), match them with observed datasets (predictands), and apply cross-validation techniques (e.g., leave-one-out) to assess and enhance forecast skill. The training demonstrated how MOS can significantly improve PyCPT outputs by reducing mean bias error, improving correlations with observations, and enhancing probabilistic reliability using tools such as ROC curves and reliability diagrams. As a result, participants acquired practical skills to generate calibrated, bias-corrected, and region-specific climate forecasts that are both actionable and reliable. These enhanced forecasts support improved early warning systems for planting windows, malaria risk management, flood and drought preparedness, and hydropower demand forecasting across the IGAD region.

Dr. Masilin Gudoshava introduced participants to the sub-seasonal forecast data available in the IRI Data Library, highlighting the variety of global forecast datasets accessible through the platform. She explained the distinction between seasonal and sub-seasonal forecast systems, noting that sub-seasonal forecasts bridge the gap between short-term weather and longer-term seasonal outlooks. This intermediate timescale is crucial for enhancing early warning and informed decision-making. She outlined that the IRI Data Library hosts standardized global sub-seasonal forecast datasets from leading international centers. In particular, she highlighted two major real-time forecast systems available through the platform: the **NOAA/NCEP Global Ensemble Forecast System (GEFSv12)** and the **European Centre for Medium-Range Weather Forecasts (ECMWF)** model. These datasets are made accessible through the **SubX** and **S2S Project** databases within the IRI Data Library. She further demonstrated how participants can access the real-time forecast data using the following links:

- **GEFSv12:** https://iridl.ldeo.columbia.edu/SOURCES/.Models/.SubX/.EMC/.GEFSv12_CPC/.forecast/
- **ECMWF:** https://iridl.ldeo.columbia.edu/SOURCES/.ECMWF/.S2S/.ECMF/.CY49/.forecast/

Later, **Dr. Hussen Seid** guided participants through the detailed process of configuring **PyCPT** for sub-seasonal prediction. He explained that configuring PyCPT involves setting up several critical components that together optimize the forecast process and enhance its usability for decision-making. The configuration process includes defining the choice of dynamical model, observed dataset, Method of Statistical Post-Processing (MOS), predictor and predictand spatial domains, forecast dates, training seasons, and forecast lead intervals. He noted that each of these elements plays a distinct role in shaping the quality and relevance of the forecasts.

One of the key aspects discussed was the **choice of MOS method**. The Method of Statistical Post-Processing (MOS) is essential for improving the accuracy of sub-seasonal forecasts by correcting systematic errors and enhancing the skill of model outputs. PyCPT supports multiple MOS methodologies, notably **Canonical Correlation Analysis (CCA)** and **Principal Components Regression (PCR)**. These techniques establish statistical relationships between large-scale climate predictors and regional climate outcomes, enabling more reliable forecast products.

Another important configuration element is the **forecast date and training season length**. Sub-seasonal forecasts are typically initialized on a weekly basis, with multiple start dates available within each period. To increase the robustness and reliability of forecasts, Dr. Hussen highlighted the importance of expanding the training dataset by incorporating a longer period of hindcasts, provided that it remains within a climatologically homogeneous season (e.g., the March–April–May (MAM) season). This approach strengthens the statistical relationships and improves forecast skill by drawing from a larger sample size.

The session also emphasized the significance of defining **predictor and predictand spatial domains**. In methods such as CCA or PCR, careful selection of these domains is crucial. The **predictor domain** should be sufficiently broad to capture large-scale atmospheric and oceanic structures that drive sub-seasonal to seasonal (S2S) predictability across the region of interest. Expanding the predictor domain increases the likelihood of capturing influential teleconnections and improves model performance. In contrast, the **predictand domain** is more localized and focused, representing the specific area for which forecasts are generated, such as the Greater Horn of Africa or a particular country. Defining this domain ensures that the forecasts are tailored to the needs of end-users in the region.

Through this session, participants gained practical insights into how each configuration choice impacts the accuracy, skill, and usability of sub-seasonal forecasts. The step-by-step guidance helped to bridge theoretical understanding with hands-on practice, equipping participants with the capacity to effectively apply PyCPT in operational forecasting contexts. Sessions concluded with group discussions on interpreting deterministic, probabilistic, and flexible format forecasts, as well as assessing forecast skill scores.

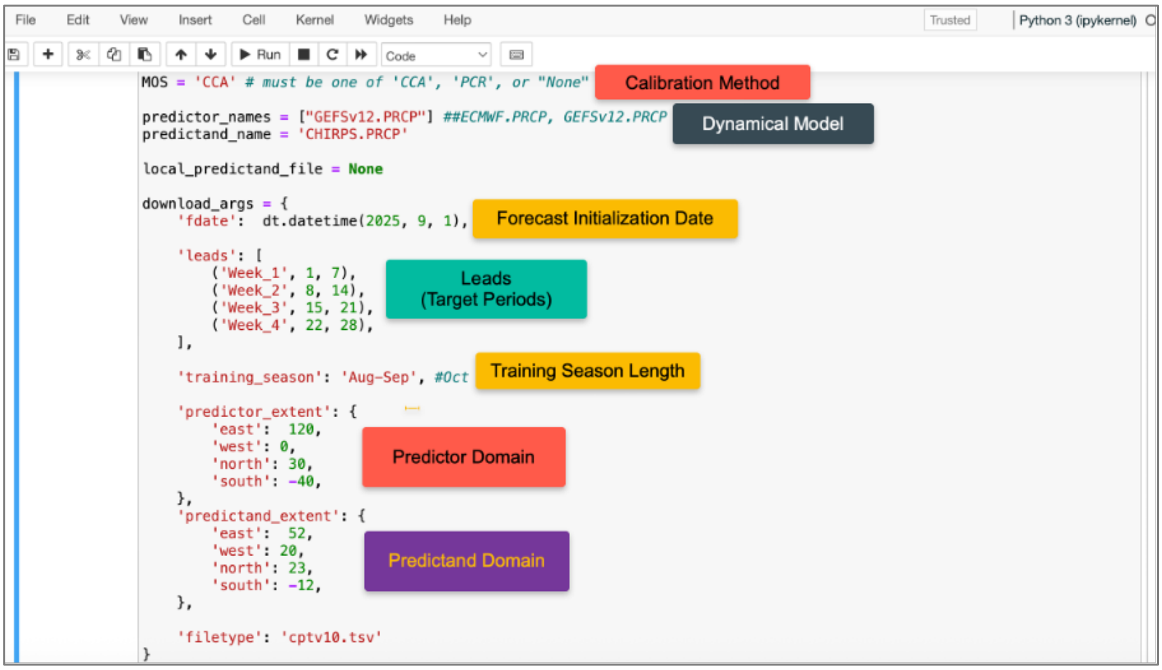



Figure 1. Configuration process of PyCPT for sub-seasonal prediction, highlighting key components such as the choice of dynamical model, observed dataset, statistical post-processing method (MOS), predictor and predictand spatial domains, forecast dates, training seasons, and forecast lead intervals.

## Day 3: Thursday, 04 September 2025

Day three emphasized optimization and sensitivity analysis. **Dr. Masilin Gudoshava** facilitated a session on optimizing sub-seasonal rainfall forecasts for specific regions of interest. Participants then engaged in hands-on exercises to test the sensitivity of forecasts to predictor domains and MOS methods. The day ended with a plenary discussion that allowed participants to reflect on forecast sensitivities and share their perspectives on implications for operational forecasting.

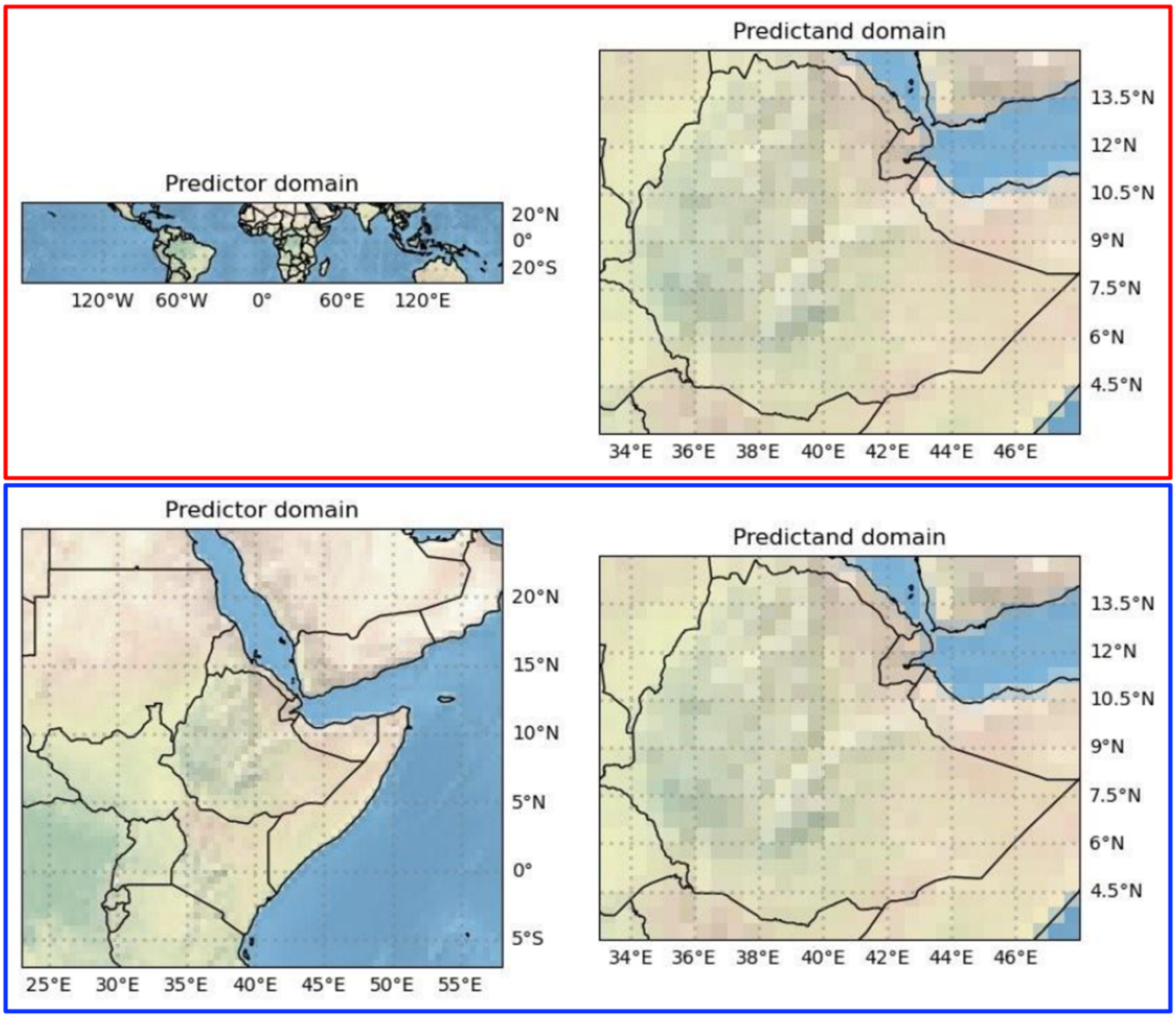



Figure 2: Maps illustrating the predictor and predictand domains used to assess the sensitivity of forecast skill to the choice of predictor domain for Ethiopia. The top panel uses the entire tropics as the predictor domain, while the bottom panel uses the Greater Horn of Africa (GHA) and Indian Ocean region.

## Day 4: Friday, 05 September 2025

The fourth day continued the sensitivity analysis theme. Participants conducted hands-on exercises to examine the impact of different training seasons and dynamical model choices on forecast skill. The afternoon was dedicated to group preparation of presentations, where participants synthesized their learning experiences, practical outputs, and reflections.

## Day 5: Saturday, 06 September 2025

The final day featured participant presentations, where groups showcased their applied forecasting exercises (extreme event cases studies and sensitivity analysis), discussed key challenges, and highlighted practical applications in their national contexts.

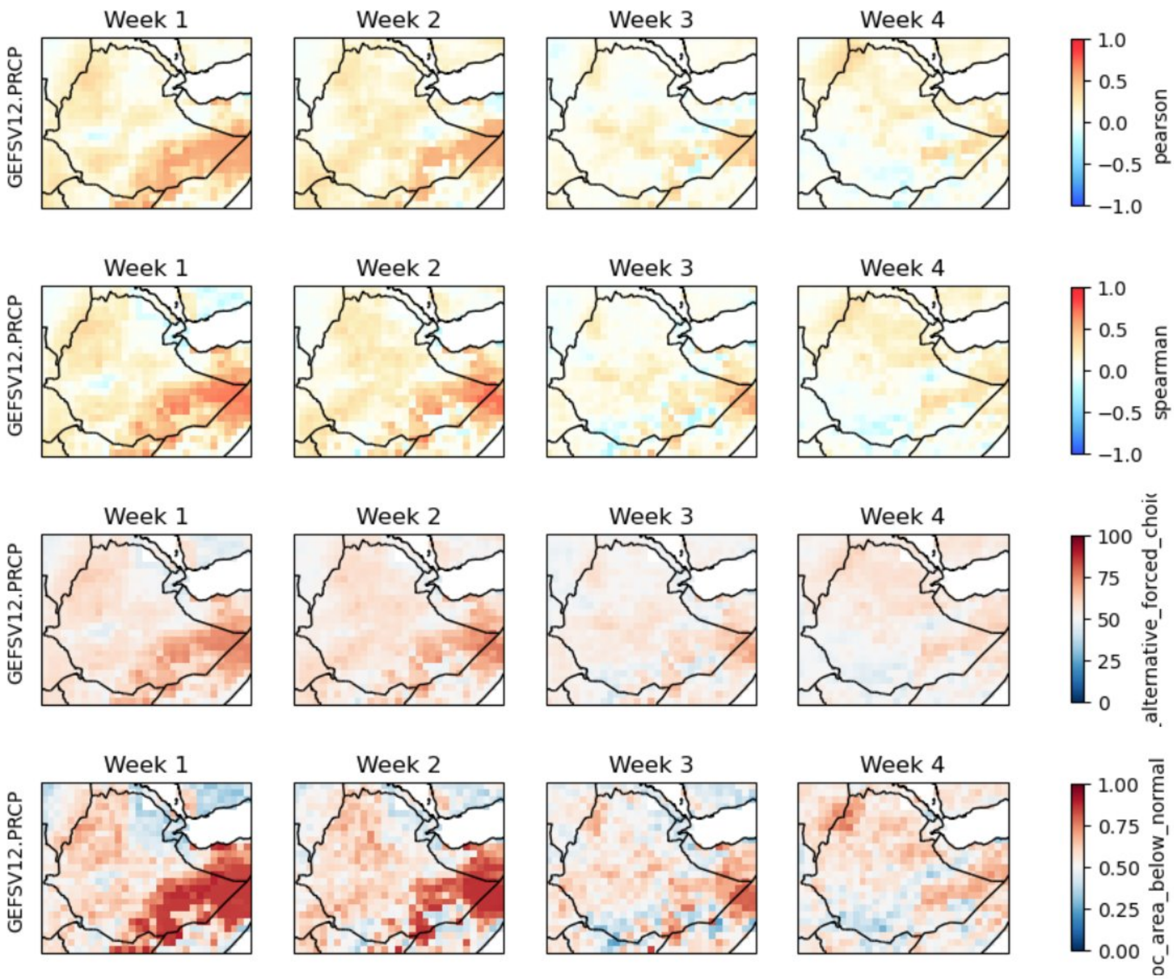



Figure 3a: Skill of the sub-seasonal forecast for Ethiopia across different forecast lead weeks, highlighting variations in forecast accuracy over time.

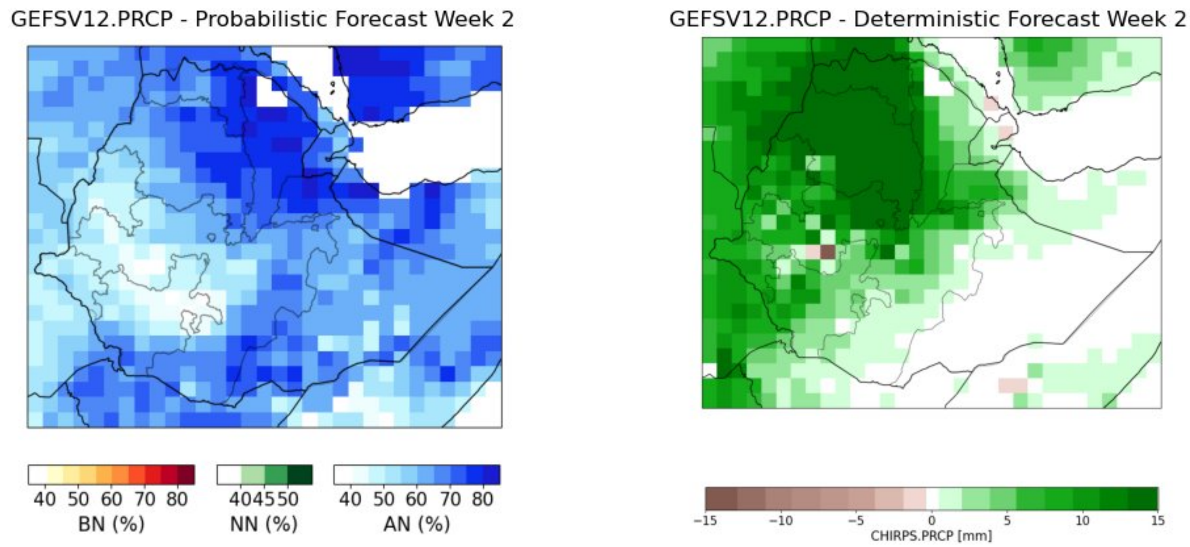



Figure 3b: Deterministic and probabilistic forecasts for Ethiopia for the identified flood case study.

After the participants presented the case studies they had conducted, ICPAC facilitated a comprehensive workshop evaluation to gather feedback for future improvements. The key outcomes of the training are summarized in Section 4, while participants' recommendations are detailed in Section 5. The workshop concluded with closing remarks, recognizing the valuable contributions of facilitators, participants, and partners, as outlined in Section 6.

# 4. Key Outcomes

- **Improved understanding of sub-seasonal prediction capabilities and limitations:** The sessions provided clarity on the drivers, sensitivities, and challenges of sub-seasonal forecasting in the region.
- **Enhanced technical skills:** Participants gained practical knowledge in configuring and running PyCPT for sub-seasonal forecasting, as well as interpreting forecast outputs.
- **Collaboration and knowledge exchange:** Participants actively engaged in group discussions and presentations, promoting peer-to-peer learning.
- **Strengthened regional forecasting capacity:** The training contributed to building a pool of experts capable of producing and applying sub-seasonal predictions to support climate services in Eastern Africa.

# 5. Recommendations

- **Conduct in-country trainings:** Participants recommended organizing national-level trainings on sub-seasonal forecasting to enable broader participation and build the capacity of more forecasters at the national level.

- **Provide continued virtual support:** Participants suggested ongoing remote (virtual) mentorship and technical support following the regional training to consolidate the skills gained and address emerging challenges.
- **Enhance understanding of key statistical methods:** Additional guidance and practical exercises were recommended on the interpretation of **CCA (Canonical Correlation Analysis)**, **EOF (Empirical Orthogonal Functions)**, and **Probability of Exceedance (PoE)** outputs to strengthen participants' analytical capabilities.
- **Improve data accessibility:** Given the current challenges in accessing forecast data directly from the IRI Data Library, participants recommended exploring alternative and more stable data sources or mirror servers for S2S datasets to ensure reliable access.
- **Refine the PyCPT tool:** It was suggested that minor coding bugs and naming inconsistencies in the PyCPT software be corrected to enhance usability and accuracy.
- **Develop a user manual:** Participants recommended preparing a detailed manual explaining the statistical methods and steps used in the downscaling process to support self-learning and future reference.
- **Expand training on data handling and tools:** More sessions were requested on the use of the IRI Data Library, Jupyter Notebook, and relevant Python libraries to improve participants' ability to process, visualize, and analyze forecast data.
- **Include deterministic forecast outputs:** Participants suggested incorporating absolute (deterministic) rainfall forecasts alongside anomaly maps, as these are easier for non-technical stakeholders to interpret and can be directly applied in sectoral decision-making.

# 6. Conclusion and Closing Remarks

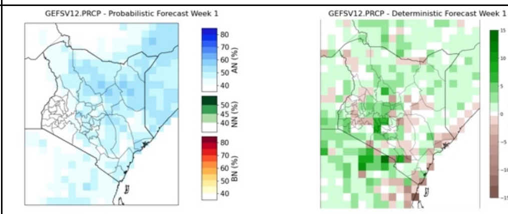
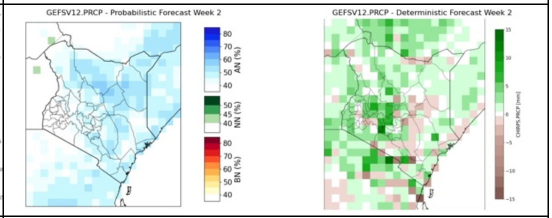
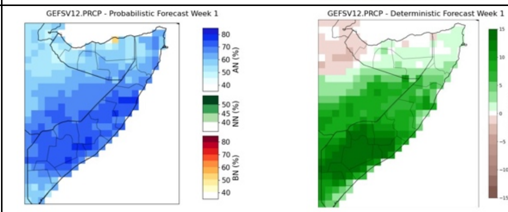
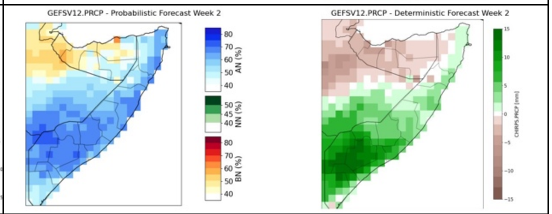
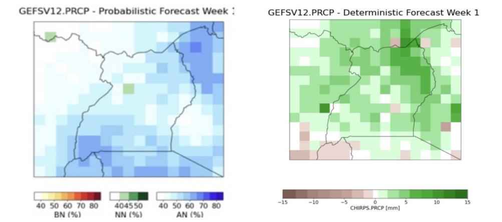
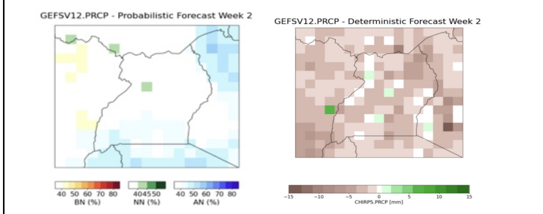
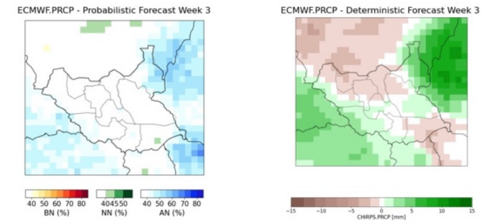
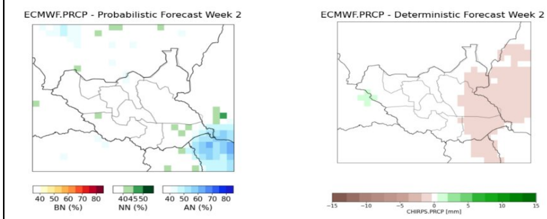
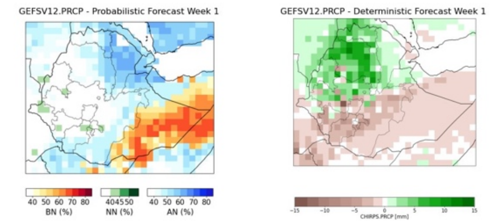
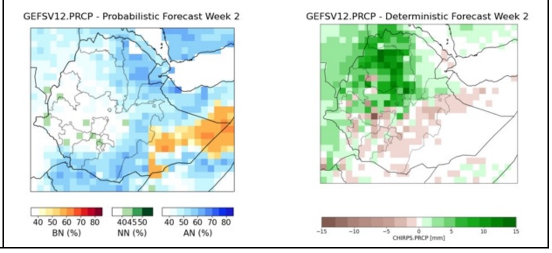
The regional training on sub-seasonal forecasting for Eastern Africa concluded with heartfelt closing remarks delivered by Dr. Hussen Seid on behalf of ICPAC. He began by sincerely thanking all participants and facilitators for their active engagement, contributions, and commitment throughout the training period. He emphasized that the high level of enthusiasm witnessed during the sessions demonstrated the shared dedication to advancing climate prediction capacity in the region.

Dr. Hussen underscored that sub-seasonal forecasting remains a relatively new and emerging field, yet it is an increasingly important timescale for decision-making across critical sectors in Eastern Africa. He highlighted that through the training, participants had strengthened their understanding of the key drivers of sub-seasonal variability, deepened their knowledge of skill assessment metrics, and gained hands-on experience with practical tools and methodologies to generate and apply forecasts. These outcomes, he noted, are essential steps toward improving climate services that can directly support agriculture, disaster risk management, water resources, and other vital sectors.

Acknowledging the challenges inherent in forecasting, Dr. Hussen reminded participants that, as scientists, they should not be discouraged by errors. Forecasts will never be perfect, and mistakes are part of the process of scientific discovery and refinement. Drawing a parallel with programming, he stressed that just as programmers encounter syntax errors, scientists too face challenges in applying models and methods. Each error, however, represents an opportunity to learn, improve, and innovate. What matters most, he said, is the collective ability to continually refine methods and translate scientific advances into practical solutions that benefit communities and institutions.

In his final reflections, Dr. Hussen urged participants to carry forward the skills and knowledge gained during the training to strengthen forecast services at both national and regional levels. He emphasized that these efforts should ultimately contribute to building a more climate-resilient Eastern Africa. He closed by extending his warm wishes for safe travel to all participants and expressed optimism for continued collaboration, partnerships, and joint learning in the journey ahead.

## Annex 1: Sample products from case studies conducted by participants for different countries, focusing on dry and wet periods

| Country | Week-1 | Week-2 |
|---|---|---|
| **Kenya** |  |  |
| **Somalia** |  |  |
| **Uganda** |  |  |
| **Djibouti** |  |  |
| **South Sudan** |  |  |
| **Ethiopia** |  |  |

## Annex 2: Workshop Photos