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Strengthening Climate Services in Africa:

PROGRESS, CHALLENGES AND OPPORTUNITIES

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Acronyms & Abbreviations

ACOF	Africa Climate Outlook Forum
ACMAD	African Centre of Meteorological Applications for Development
AfDB	African Development Bank
AGRHYME	Agriculture, Hydrology, and Meteorology
AMHEWAS	Africa Multi-Hazard Early Warning and Early Action System
AU	African Union
AUC	African Union Commission
CAPC-AC	Climate Application and Prediction Centre
CIRDA	Climate Information for Resilient Development in Africa
CIS	Climate Information Services
CLIMSA	Intra-ACP Climate Science and Related Applications
CPC	Climate Prediction Center
CS	Climate Service
CSAG	Climate Systems and Analysis Group
DCCMS	Department of Climate Change and Meteorological Services
DRR	Disaster Risk Reduction
ECCAS	Economic Community of Central African States
ECOWAS	Economic Commission for West Africa States
ENACTS	Enhancing National Climate Services
EWS	Early Warning Systems
GBON	Global Basic Observing Network
GCFS	Global Framework for Climate Services
GDPFS	Global Data-processing and Forecasting System
GFC	Green Climate Fund
GFCS	Global Framework for Climate Services
GHACOF	Greater Horn of Africa Climate Outlook Forum
HPC	High-Performance Computing
ICPAC	IGAD Climate Prediction and Applications Centre
IGAD	Intergovernmental Authority on Development
INGO	International Non-Governmental organisation
IP	Intellectual Property
JRP	Joint Research Program
M&E	Monitoring and Evaluation
NCOF	National Climate Outlook Forums
NFCS	National Frameworks for Climate Services
NGO	Non-Governmental organisation
NHMSs	National Meteorological and Hydrological Services
NRC	Norwegian Refugee Council
PPP	Public Private Partnerships
PRESAC	Prévisions Saisonnières en Afrique Centrale
PSP	Participatory Scenario Planning
RCC	Regional Climate Centres
RCOF	Regional Climate Outlook Forums
REC	Regional Economic Commissions
RSMCs	Regional Specialised Meteorological Centres
SADC	Southern African Development Community
SDG	Sustainable Development Goal
SOFF	Systematic Observations Financing Facility
UN	United Nations
UNDP	United Nations Development Programme
UNDRR	United Nations Disaster Risk Reduction
WFP	World Food Programme
WHO	World Health organisation
WISER	Weather and Climate Information Services for Africa
WMO	World Meteorological organisation

Executive summary

Africa stands at the forefront of the global climate crisis, facing escalating extremes weather events that threaten hard-won development gains. The record-breaking temperatures of 2024 underscores the urgent need to strengthen climate services for evidence-based adaptation, disaster risk reduction, and resilience building. Despite Africa's minimal contribution to global greenhouse gas emissions, its nations disproportionately endure climate floods, droughts, and heatwaves affected over 110 million people in 2022 alone.

This report evaluates the state of climate services in Africa, identifying progress, gaps, and emerging priorities. It focuses on improving the availability, accessibility, and usability of climate information to support effective risk-informed decision-making.

The analysis is grounded on a mixed-methods approach, incorporating analysis of academic literature and policy documents, interviews with Regional Climate Centres (RCCs), National Meteorological and Hydrological Services (NMHSs), UN agencies, and community actors, alongside focus group discussions, structured surveys, and case studies from Kenya. This methodology allowed balanced integration of technical insights with local experience and user perspectives.

Key findings reveal both advances and challenges. First, while climate services coordination and engagement structures has expanded – exemplified by the operationalization of 20 NFCS and digital platform innovations such as Open-Source tools like ClimWeb, the CAP Composer or Data transmission solutions, significant barriers remain. Nearly 15% of African National Meteorological and Hydrological Services (NMHSs) operate below basic functional capacity, and a majority of countries either lack sufficient ground-based observation networks or struggle to maintain and integrate existing ones. While some countries have installed dozens or even hundreds of observation stations, significant gaps remain in spatial coverage, maintenance, and real-time data transmission. In many cases, data collected from these stations remains stored locally due to limited digital infrastructure or weak institutional workflows, resulting in underutilization for forecasting, early warning, and planning. However, there is growing momentum toward improved data sharing, driven by the implementation of the WMO Information System 2.0 (WIS2) and the WMO Unified Data Policy on International Exchange of Earth System Data. Many African countries are now installing tools such as wis2box and Automated Data Loaders, which facilitate seamless international data exchange. For several countries, this marks the first time in their history that they are contributing national observation data to the global system an important step toward enhanced regional forecasting capacity.

Despite these advances, Institutional coordination is also highly fragmented, both within countries and across the regional landscape. Multiple agencies meteorological, disaster risk management, agriculture, and water often operate with overlapping mandates and without harmonized protocols for data sharing. This fragmentation hinders the development of integrated, multi-hazard early warning systems and limits the efficiency of investments in climate services. Climate information often fails to reach last-mile users in a timely or usable format, particularly women and marginalized groups. Weak user involvement in service design has eroded trust and uptake. Inadequate financing is another major constraint, with most services dependent on short-term donor funding, undermining long-term planning and sustainability. Gender disparities in climate information access persist, despite women's central role in climate-sensitive sectors such as agriculture.

Without systemic reforms, climate services in Africa risk remaining underutilized and inequitable. Strengthening regional coordination through harmonized governance frameworks and investment in NMHS infrastructure is essential. Co-production approaches integrating scientific and indigenous knowledge can enhance relevance and usability. Sustainable financing models such as public-private partnerships and pooled donor mechanisms are needed to mitigate reliance on short-term funding. Targeted capacity-building for RCCs, NMHSs, and local intermediaries is crucial to ensure timely, tailored and effective delivery of climate information products and advisories.

Based on these insights, the report recommends:

1. Strengthening the operational capacity of NMHSs and RCCs through predictable funding and digital infrastructure investment.

2. Continue to strengthen open-source solutions that provide digital public infrastructure across the climate information services value chain.

3. Institutionalizing co-design approaches involving communities, civil society, and sectoral ministries.

4. Scaling inclusive platforms such as Participatory Scenario Planning (PSP) and other User Interface Platforms (UIPs) to improve user engagement.

5. Embedding gender-sensitive design and delivery mechanisms, including initiatives like the Female Climate Accelerator Programme.

6. Supporting African nations in integrating climate services into adaptation strategies, early warning systems, and sectoral plans aligned with the Paris Agreement, Sendai Framework, and Agenda 2063.

This report advocates a transition from fragmented, short-term investments to systemic, sustainable, and inclusive climate services. Scaling regional and national coordination, harmonizing data-sharing protocols, and embedding climate services into core development strategies are imperative for building lasting resilience across Africa.

About NORCAP

NORCAP works to improve aid to better protect and empower people affected by crisis and climate change. We do this by providing expertise and solutions to humanitarian, development and peacebuilding partners, because we believe working together is the best way to reduce needs, risks and vulnerability over time. We seek and promote more effective ways of working at the global level and in local communities. NORCAP's aim is not only to reduce needs but also to create choice and opportunities for vulnerable people.

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NORCAP works in two complementary ways to improve aid:

- We provide targeted expertise to strengthen our partners' response.
- We collaborate with partners to develop solutions to un-met gaps and challenges.

NORCAP is part of the Norwegian Refugee Council.

Figure 1: NORCAP climate experts are working in multiple countries across the African continent.

Background and Context

In the face of unprecedented environmental challenges, the development, delivery and use of climate information services to enable climate action has never been more urgent. According to recent reports from the World Meteorological organisation (WMO), each of the past ten years ranks among the ten warmest on record, with 2024 being the hottest year yet with global temperatures averaging approximately 1.55°C above pre-industrial levels[1]. Africa remains one of the most vulnerable continents to climate change due to its heightened sensitivity to climate variability and limited institutional adaptive capacity[2]. Despite the continent's relatively low contribution to global greenhouse gas emissions, it faces disproportionate effects from climate change, with severe consequences for its socio-economic development[3]. About 60 per cent of the African continent is not covered by early warning systems (EWS), the highest gap globally[4]. The growing severity of weather and climate-related hazards across the continent highlights the urgent need for robust climate services—events in 2022 alone affected over 110 million people and caused more than $8.5 billion in economic damages[5]. But the true toll is likely to be much higher because of under-reporting.

The Global Framework for Climate Services (GFCS) was established to address these issues by improving the availability and use of climate services, particularly in developing regions like Africa. As of October 2023, 20 African countries launched and are implementing National Climate Services[6] Frameworks (NFCS)[7]. This policy evolution reflects recognition of the importance of climate information for building resilience. While significant progress has been made, 15 per cent of National Hydrological and Meteorological Services (NMHSs) in Africa operate at less-than-basic capacity, and challenges remain to ensure accessible, effective and sustainable[8] services. Nevertheless, the number of NMHSs providing advanced climate services has nearly doubled, from eight in 2019 to 15 in 2024, reflecting a shift toward more sophisticated, effective support for climate-informed decision-making.

Despite the recognised importance of climate services, their effective implementation across the continent is hindered by several barriers, including a lack of coordination among various stakeholders, such as NMHSs, regional economic commissions (RECs) and international organisations, resulting in inefficiencies and missed opportunities for collaboration.

Another barrier is the inadequate infrastructure for climate services, such as weather observation stations and data processing facilities, which limits the accuracy and timeliness of climate information. Lastly, there is a shortage of skilled personnel to interpret and disseminate data, particularly in many African sub-regions. As a result, critical climate information often fails to reach end-users such as farmers, policymakers and emergency responders, meaning that even when data is available, it may not be utilized.

Regional Climate Outlook Forums (RCOFs) have played a key role in strengthening the coordination and delivery of climate services in Africa. Initiated by the WMO, RCOFs convene climate experts, NMHSs, regional institutions and other stakeholders to produce consensus-based climate outlooks that inform decision-making across sectors. These forums build regional collaboration and help improve the accuracy and relevance of seasonal climate forecasts.

1. World Meteorological organisation, 2025, https://public.wmo.int/en/media/press-release/wmo-confirms-2024-warmest-year-record. Accessed 31 Mar. 2025.
2. AR6 Synthesis Report: Climate Change 2023. Intergovernmental Panel on Climate Change, 2023, https://www.ipcc.ch/report/sixth-assessment-report-cycle/. Accessed 31 Mar. 2025.
3. World Meteorological organisation. (2022). State of the Climate in Africa 2021. Retrieved March 29, 2025, fromhttps://wmo.int/publication-series/state-of-climate-africa-2021
4. World Meteorological organisation. Africa, https://wmo.int/about-us/regions/africa Accessed March 28, 2025.
5. "State of the Climate in Africa 2022." World Meteorological organisation, 4 Sept. 2023, https://wmo.int/publication-series/state-of-climate-africa-2022. Accessed 31 Mar. 2025.
6. World Meteorological organisation. Hydromet Gap Report 2024. https://library.wmo.int/records/item/68926-hydromet-gap-report-2024. Accessed 31 Mar. 2025.
7. Current Status of the Implementation of National Frameworks for Climate Services (NFCS)." World Meteorological organisation, n.d., https://gfcs.wmo.int/site/global-framework-climate-services-gfcs/components-of-gfcs/current-status-of-implementation-of-national-frameworks-climate-services-nfcs.
8. Mugume and Rautenbach (2021). "Numerical Weather Prediction and Climate Modelling: Challenges and Opportunities for the Southern African Development Community Region." Weather and Climate Extremes, vol. 33, 2021, article 100331. https://www.sciencedirect.com/science/article/pii/S2405880721000315.

Despite recent progress, the 2024 Hydromet Gap Report highlights persistent weaknesses in weather, climate and hydrological services, including weak observational infrastructure, limited data collection and sharing and the absence of centralised data management systems[9]. Addressing these gaps requires coordinated action from governments and development partners to strengthen hydrometeorological and multi-hazard early warning systems. Initiatives like the Enhancing National Climate Services (ENACTS) framework and the Weather and Climate Information Services for Africa (WISER) program have improved data availability and service quality. However, these efforts often lack comprehensive evaluation and fail to fully address the diverse needs of end-user, from smallholder farmers to national policymakers[10].

Objectives, purpose and scope of the report

This analysis aims to assess progress in enhancing climate services across Africa, identifying persistent barriers and pinpointing strategic areas for future interventions. Through case studies, this report also showcases NORCAP's response to these challenges. illustrating its role in providing expertise to partner organisations to support capacity strengthening for improved climate services. This approach is based on the view that developing, expanding and strengthening partnerships will maximize impact.

The methodology used to gather data for this report follows a mixed-methods approach, combining qualitative and quantitative data collection and analysis. This included a review of relevant academic literature and policy documents and project reports; key informant interviews with relevant stakeholders (including NMHHs, RCCs, United Nations (UN) agencies, international non-governmental organisations (INGOs), research institutes and NORCAP experts); focus group discussions with local communities; a structured online survey; case study analysis; and a role-play workshop.

9. World Meteorological organisation (WMO); Alliance for Hydromet Development (2024) Hydromet Gap Report 2024, https://library.wmo.int/records/68926-hydromet-gap-report-2024. Accessed 31 Mar. 2025.
10. Gudoshava, M., Otieno G., Koech, E., Misiani, H., Ongoma, J. G., Heinrich-Mertsching, C., ... & Artan, G. (2024). Advances, gaps and way forward in provision of climate services over the Greater Horn of Africa. Frontiers in Climate, 6, 1307535. https://www.frontiersin.org/journals/climate/articles/10.3389/fclim.2024.1307535/full to fully address the diverse needs of end-user, from smallholder farmers to national policymakers.

Climate services landscape in Africa

Mika Issa/NORCAP

Climate services landscape in Africa

With the past decade confirmed as the warmest on record, culminating in 2024 as the hottest year yet, the demand for climate services to inform decision-making in Africa is more urgent than ever. Figure XX illustrates the most pressing hazards, based on an analysis of nationally determined contributions (NDCs) from 53 African countries. Climate services deliver benefits at multiple levels: they help protect national infrastructure investments from long-term climate risks, support smallholder farmers in safeguarding lives and property and facilitate access to risk management tools such as index-based insurance.

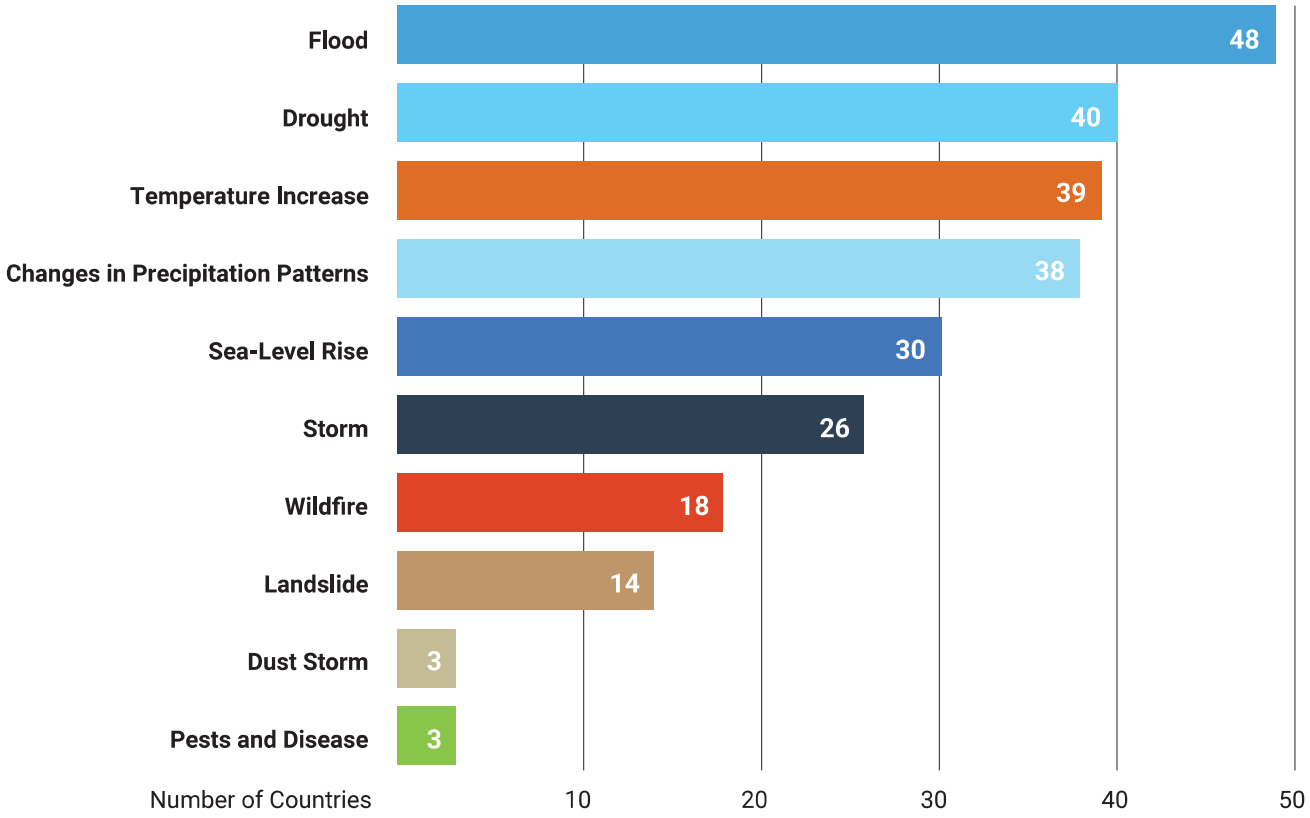


Figure 2: Hazards of greatest concern for the African region. This graph was generated by WMO using NDCs of 53 countries in Africa based on the active NDCs submitted in June 2024.

This section outlines the key gaps and challenges in generating and delivering climate services, reviews efforts to address them and presents case studies that highlight successful interventions. The findings are framed within existing literature to offer a comprehensive overview of the current state of climate services in Africa.

Progress in climate services in Africa

Despite escalating global climate challenges, Africa has made significant progress in enhancing climate services. For example, the number of NMHSs providing essential climate services grew from nine to 18 between 2019 and 2024. The ability of an NMHS to deliver these services hinges on its capacity to access and process observational data, to manage and analyse climate data and to produce relevant products to support decision making. Based on these criteria, NMHS capabilities can be categorized as: a) basic capacity; b) essential capacity; c) full capacity; and d) advanced capacity. This classification helps countries assess the capabilities required to provide climate, weather and hydrology services and identify areas for improvement within their own NMHSs. Figure 2 summarizes the number (per cent) of countries meeting different climate service provision capacity levels in 2019 and 2024. Despite progress, Africa still has the highest percentage of member states at the 'less-than-basic' capacity level (15 per cent).

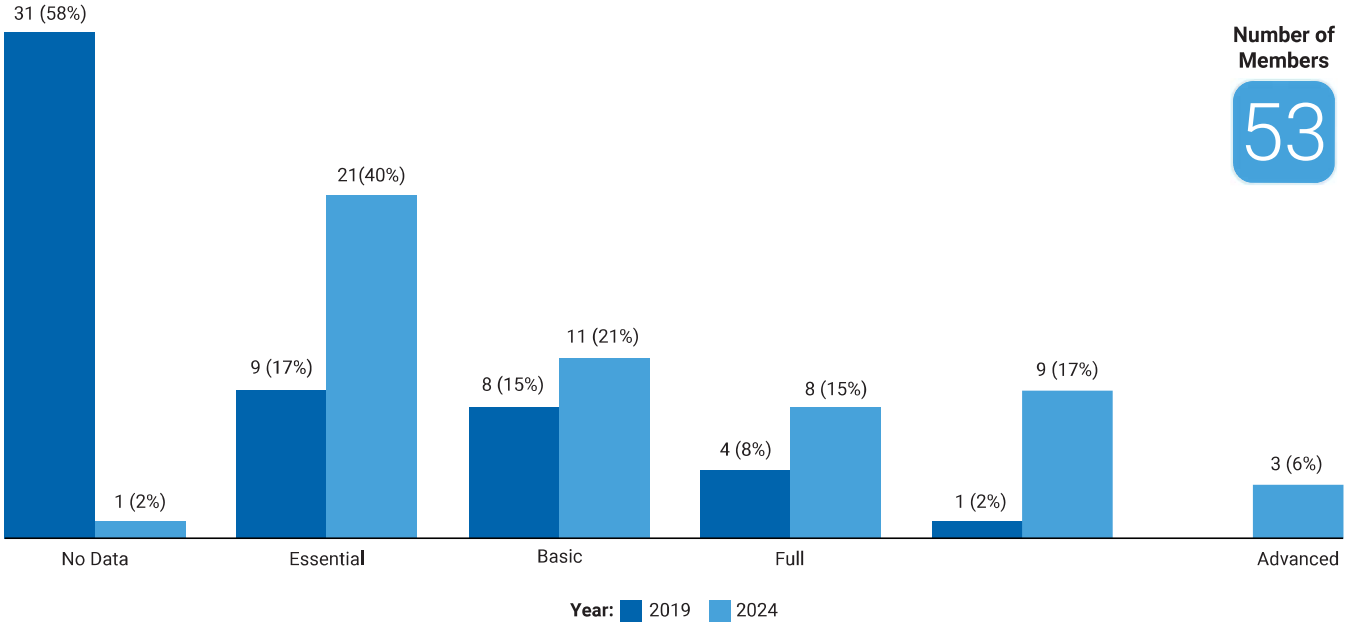


Figure 3: Overall capacity level of African countries for providing climate services.

In addition to NMHSs, which are responsible for providing observed and forecasted weather and climate information, including warnings of impeding hydroclimate threats at the national level, the WMO plays a crucial role in coordinating and supporting these services to fulfill their mandate. The WMO also coordinates Global Producing Centers for Long-Range Forecasts and a network of Regional Climate Centers (RCCs). RCCs deliver climate services at the regional level, bridging the gap between global and national information, while also strengthening the capacity of NMHSs. As key components of NMHSs' climate activities, RCCs are essential for contributing climate services aimed at improving the provision and use of climate services; They are fundamental components for achieving important climate initiatives designed to improve the provision and use of appropriate climate services[11]. In Africa, three RCCs (the African Centre of Meteorological Application for Development (ACMAD), IGAD Climate Prediction & Applications Centre (ICPAC) and the RCC network for northern Africa) have been designated as WMO RCCs of excellence.

RCCs are responsible for producing mandatory regional products such as climate data sets, climate monitoring tools and long-range forecasts, which are critical regional inputs for NMHSs. Four RCCs are currently in the demonstration phase, meaning they have gaps/needs that need addressing before they can generate these mandatory regional products. These include Southern African Development Community Climate Service Centre (SADC CSC), the Economic Commission for Central African States (ECCAS) Climate Application and Prediction Centre (CAPC-AC), Economic Commission for West Africa States (ECOWAS) Regional Climate Centre (AGRHYMET) and the Southwest Indian Ocean RCC (SWIORCC) Network.

However, the three designated RCCs still face challenges, notably capacity gaps in several areas that must be addressed to ensure the sustained and effective delivery of climate services.

Alongside efforts by NMHSS and RCCs, there has been a growing involvement of various actors in climate services production and development across Africa, including the private sector, non-governmental organisations (NGOs), academia, research institutions and program-based climate information initiatives. Academic and research institutions are intermediary users sometimes partner with national meteorological and hydrological services. They collaborate with forecasters to transform climate data into climate services, focusing on data compilation, analysis and product development. For example, the Climate Systems and Analysis Group (CSAG) at the University of Cape Town developed a climate information portal that provides a range of users.

11. An RCC–Network is a group of centres performing climate-related activities that collectively fulfil all the required functions of an RCC. Each centre in a designated RCC-Network is referred to as a Node and performs one or several of the mandatory RCC activities

The private sector is active across nearly all African countries, providing a variety of services and products for different sectors. In some countries, the private sector has begun providing value-added climate services that complement NMHSs. Companies, including mobile phone providers and index-based insurance schemes, are involved at various points along the value chain, ranging from weather observation support to developing and delivering tailored products and services to end users.

NGOs and civil society organisations play a vital role in enhancing climate services, particularly in sectors like agricultural extension, health and disaster preparedness and response. These non-state actors increasingly serve as technical advisors on climate services, contributing to analysis, capacity building and related research activities. They foster innovation and experimentation, particularly through two-way engagement with local actors and knowledge holders and establish feedback loops that connect stakeholders across the value chain.

The value chain approach to climate services, where multiple actors contribute at different stages until tailored information reaches users, whose feedback is then integrated back into the system, remains an aspirational model in Africa. Despite progress, several persistent gaps hinder its full realization, including limited access to adequate, high quality climate data, inadequate technical capacity, insufficient funding, weak infrastructure (including observation networks) and poor coordination among stakeholders.

A unified front: Policies and strategies across scales in Africa supporting climate services

Africa's climate service delivery is supported by existing policies, frameworks and initiatives at the global, continental, regional and national level.

Key policies/initiatives

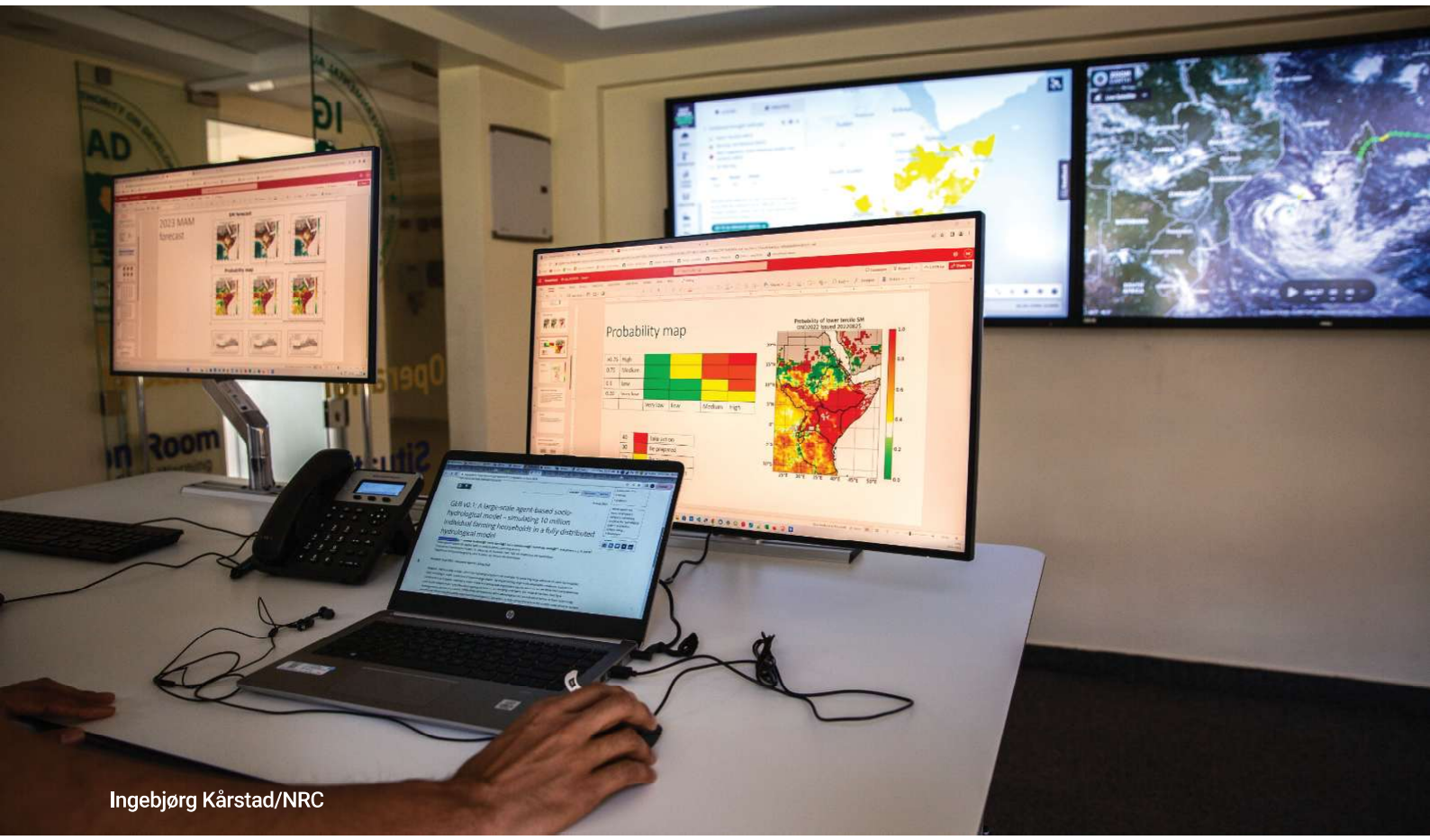
Policy/initiative	Key provisions supporting climate services	Regions
Paris Agreement	Integration of climate services into adaptation strategies for agriculture, water, and disaster planning. Requires country-specific adaptation strategies incorporating climate data.	Global with national Focus (NAPs)
Agenda 2030 Sustainable Development Goals	Strengthening early warning systems, disaster risk reduction, and adaptation strategies (SDG 13: Climate Action) while promoting food security (SDG 2), water management (SDG 6), and sustainable cities (SDG 11)	Continental, National
Global Framework for Climate Services (GFCS)&NFCS	Supports African countries in building the capacity of their National Meteorological and Hydrological Services (NMHSs). By focusing on key sectors agriculture, health, water, and disaster management GFCS has improved data availability and forecasting.	Global & National
Sendai Framework	Enhance multi-hazard early warning systems and disaster preparedness through climate services. Calls for multi-hazard early warning systems aligned with climate forecasts.	Global, with regional focus
Agenda 2063: The Africa We Want	Resilient development and integration of climate services into national policies. Encourages regional partnerships and capacity building for climate services integration.	Continental
Africa Regional Strategy for Disaster Risk Reduction (DRR)	Promote regional collaboration for disaster risk reduction using climate services. Emphasizes data sharing and collaborative risk reduction frameworks across regions.	Continental
National Adaptation Plans (NAPs)	Many African nations have developed NAPs under the UNFCCC framework, integrating climate services into adaptation strategies. Countries like Kenya and Ethiopia have included provisions for expanding observation networks and training NMHS personnel. While these plans are promising, their success depends heavily on sustained funding and international support.	National
Africa climate change strategy 2020-2030	strengthening resilience through regional collaboration, capacity building, and integrating climate services	Regional
IGAD Climate Adaptation Strategy (2023–2030)	Strengthen resilience to climate change in East Africa through climate services and adaptation planning.	Eastern Africa
IGAD Regional Climate Change Strategy and Action Plan	Enhance regional cooperation for climate adaptation, mitigation,and disaster preparedness.	Eastern Africa
SADC Climate Change Strategy and Action Plan	Integrate climate services into regional disaster riskmanagement, agriculture, and water sectors.	Southern Africa
ACMAD Strategic Plan	Provide advanced climate forecasting and capacity-building for African NMHSs.	Continental
Early Warning for All Action Plan for Africa	Ensure that timely and accurate information about natural hazards and impending disasters reaches all segments of African society, particularly the most vulnerable.	Continental
African Ministerial Conference on Meteorology (AMCOMET)	Provide political leadership, policy direction and advocacy in the provision of weather, water and climate information and services that meet sector specific needs; i.e. agriculture, health, and disaster risk reduction, among others.	Continental

While these policies and action plans have driven meaningful progress, their implementation is often fragmented across regional, national and subnational levels, reducing their overall impact. An overreliance on donor funding also raises sustainability concerns. For example, although initiatives like the GFCS and Sendai Framework have supported substantial advancements, their long-term success depends on stable funding and promoting local ownership[12].

A major feature of African climate policies is their emph asis on regional coordination from RCCs, which provide regional forecasting, facilitate cross-border data sharing and enhance NMHS capacity. Mainly, data sharing is regulated by the WMO open data policy and WIS2 and Countries are expected to share data through WIS2. However, fragmented governance and limited resources at the national level hinder the expansion of these operations. Progress in climate service varies across Africa's regions. East Africa has made substantial advances, with ICPAC playing a central role in delivering seasonal forecasts and improving disaster preparedness. Closing inequities requires targeted investments in infrastructure and enhanced collaboration.

Regional coordination is central to Africa's approach to climate service delivery, as reflected in frameworks like the Africa Regional Strategy for Disaster Risk Reduction, which promotes collaboration among RCCs and the integration of climate services into disaster risk reduction initiatives. However, the absence of harmonised data-sharing policies and monitoring and evaluation (M&E) systems limits the impact. While ACMAD provides valuable forecasting capabilities, its impact is constrained by inadequate funding and operational inefficiencies. Some countries have established NFCS to improve coordination between NMHSs, sectoral ministries and local governments, but many remain poorly implemented due to institutional fragmentation and weak policy enforcement.

Multiple stakeholders are driving initiatives to strengthen climate services by improving the generation, dissemination and use of climate information. The summary below highlights key initiatives, programs and projects, their objectives, achievements and the number of countries they engage.



Ingebjørg Kårstad/NRC

12. United Nations Office for Disaster Risk Reduction (UNDRR). (2015). Sendai Framework for Disaster Risk Reduction 2015–2030. https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030 (Accessed April 4, 2025)

Key climate services strengthening initiatives

Programme/Initiative	Purpose	Key achievements	No of countries
Intra-ACP Climate Services and Related Applications (ClimSA)	To improve the production, access, and use of climate information and services for decision-makers in ACP regions.	Strengthened climate services value chain in five priority sectors: agriculture, disaster risk reduction, energy, health, and water; enhanced capacity of Regional Climate Centers (RCCs) and National Meteorological and Hydrological Services (NMHSs).	Involves countries across Africa, the Caribbean, and the Pacific.
Weather and Climate Information Services for Africa (WISER)	To stimulate the uptake of climate information by policymakers and vulnerable groups, including youth and women.	Established frameworks for integrating climate information into policy decisions; enhanced capacity of regional climate centers.	Pan-African initiative.
Weather and Climate Information Services for Africa (WISER)	To stimulate the uptake of climate information by policymakers and vulnerable groups, including youth and women.	Established frameworks for integrating climate information into policy decisions; enhanced capacity of regional climate centers.	
Co-production of Climate Services for East Africa (CONFER)	To build resilience to climate impacts and reduce disaster risk in East Africa by co-developing dedicated climate services for the water, energy, and food security sectors.	Developed tailored climate services through stakeholder engagement; improved accuracy of seasonal forecasts using advanced modeling techniques.	Targets 11 countries in East Africa.
Clim-HEALTH Africa	To strengthen the resilience of African countries and communities by improving the management of the effects of climate variability and change on public health.	Promoted the creation of National frameworks linking weather, climate, and health services; enhanced capacity for climate-informed health interventions.	Pan-African initiative.
Climate Information for Resilient Development in Africa (CIRDA)	To support African countries in improving the effectiveness and sustainability of climate information and early warning systems.	Assisted 11 nations in modernizing climate observation networks; developed innovative tools for climate data collection and dissemination.	11
Africa Climate Change Fund (ACCF)	To support African countries in building resilience to the negative impacts of climate change and transitioning to low-carbon, sustainable development.	Provided grants to 27 projects totalling $16.89 million; assisted countries in accessing international climate finance.	Over 16
Climate Services for Africa (CCAFS)	To develop capacity for climate services that support agricultural adaptation in Africa.	Partnered with regional organisations to enhance climate information dissemination; developed tools for climate-smart agriculture.	Multiple countries across Africa.
African Adaptation Initiative (AAI)	To enhance concrete adaptation action and address loss and damage on the continent in the context of implementing Nationally Determined Contributions (NDCs), the African Union's 2063 Agenda, and the Sustainable Development Goals (SDGs).	Increased knowledge about climate adaptation; promoted collaboration and partnerships at sub-regional and regional levels; encouraged knowledge management and capacity building	Pan-African initiative.
Africa Adaptation Acceleration Program (AAAP)	To mobilize $25 billion for adaptation investments in Africa within the next five years.	Organized capacity-building workshops on early warning systems and risk insurance mechanisms; enhanced direct access for locally led adaptation initiatives.	Pan-African initiative.
Early Warning for All Initiative	Provide universal access to early warning systems by 2027, focusing on inclusivity and multi-hazard risks.	It directly enhances climate service delivery by improving risk knowledge, expanding observation networks, and strengthening forecasting and communication channels.	
Africa Mult-Hazard Early &Early Action (AMHEWAS).	Build continent-wide early warning systems integrating transboundary risks.		Pan-African initiative.

The initiatives outlined above have strengthened climate resilience by improving access to climate information, enhancing early warning systems and integrating climate data into decision-making across sectors. By modernising meteorological infrastructure, advancing climate modelling and building institutional capacity, they have improved the accuracy and accessibility of climate forecasts, benefiting agriculture, health, disaster risk reduction and energy planning. However, challenges remain including limited data sharing, weak cross-sectoral collaboration and inadequate last-mile communication to vulnerable communities. Some initiatives, also face sustainability challenges due to over-reliance on donor funding and project-based approaches, rather than long-term integration into national systems. Maximising impact will require better program alignment, stronger local ownership and a user-driven approach tailored to community needs.

Systemic gaps in the provision of climate services in Africa

A review of recent literature and stakeholders interviews highlight persistent gaps in climate service delivery, driven by infrastructural, technical and human resource limitations. A recurring challenging is the insufficient tailoring of climate services to the specific needs of user groups, particularly smallholder farmers and vulnerable communities.
Key challenges include limited integration of local knowledge and the lack of high-resolution, context-specific data. As one respondent noted, "*The information we provide is often too generalised and does not meet the specific needs of last-mile users*". This underscores the need for participatory design processes to make services actionable and relevant. Research, such as Hewitt et al. (2020), emphasise the importance of co-produced climate services that integrate scientific and indigenous knowledge systems. The existing engagement platforms such as the National Outlook Forums (NCOFs) and Regional Outlook Forums (RCOFs) adopt a linear hands-off approach, where users are engaged downstream of the production of the forecast and are not engaged early in the process so that their contexts and lived local realities inform designing the information and services. The sustainability of engagement forums between climate information users and producers is uncertain due to financial constraints. For example, the Central Africa RCC can only organize one RCOF per year instead of three due to financial constraints.

NMHSs face significant barriers in building robust climate databases, managing information flows and ensuring timely dissemination to users. These include outdated equipment, low digital penetration and inadequate IT infrastructure. As one participant from one NHMS noted, "*Our station networks are patchy, and data transmission is often delayed or incomplete*". Additionally, a shortage of trained personnel hampers effective data processing and interpretation. Another respondent observed, "*Without trained personnel, even the best tools are underutilised*". These challenges are not exclusive to Africa but are common across other low-income countries where limited funding and technological access hinder data collection and use.

Inadequate observational infrastructure remains a key challenge that most NHMSs face, along with several RCCs. The ECCAS regional Climate Application and Prediction Centre (CAPC) relies heavily on satellite-derived data because operational weather stations are scarce. As one participant explained, "*We depend on satellite observation data… most of our synoptic stations are non-functional, and even automatic stations are difficult to maintain due to a lack of resources.*" This reliance on estimated data and interpolation techniques introduces greater uncertainties in forecasting, limiting the accuracy and reliability of climate services. Addressing these gaps requires investment in maintaining and expanding in-situ observation networks. This observation aligns with Vogel's study on re-imagining an inclusive, robust and sustainable service, which emphasises the need for robust ground-based observation systems to complement satellite data. However, countries like Bangladesh have demonstrated progress by integrating low-cost sensor networks, potentially offering a practical model for African countries.

The delivery of actionable climate information to end-users remains inconsistent. Participants highlighted that the lack of user-friendly communication channels often undermines climate services. One respondent noted, "*There is a gap in how products are designed… the language barrier between technical climate information and what is useful for communities is significant*". Participatory tools and local radio and mobile platforms can improve accessibility, but sustainable feedback loops between providers and users are necessary for continuous service delivery refinements. This aligns with Hewitt's research on tailoring climate services to diverse user groups, particularly vulnerable populations. Approaches like participatory scenario planning (PSP), which integrates seasonal climate forecasts into decision making, should be promoted by developing more user engagement experts.

Another recurrent theme was the financial instability of climate service providers. Many NMHSs and especially regional centres operate through partner-led project-based funding, making long-term planning difficult. As one responded explained, "*Activities are project-based and not supported by continuous budgets, which limits sustainability.*" There were suggestions to establish sustainable funding streams, such as leveraging public-private partnerships and contributions from member states to ensure continuity of services. The reliance on short-term funding is highlighted inliterature , which identifies the lack of consistent financial mechanisms as a barrier to

effective service delivery. To address this financial instability, WMO is developing a guideline on enhancing the role of NMHSs on climate financing. It acknowledges the role of NMHSs in climate change decision-making and as a key enabler of climate finance mobilisation into a country and outlines strategies for empowering NMHSs to mobilise resources for both a country's climate ambitions and for NMHSs. However, strengthening the leadership of NMHSs to be visionary and capable of driving innovative changes is essential for developing and sustaining both institutional and infrastructural capacity. NORCAP is responding to this challenge through technical assistance to partner NMHSs and relevant government institutions in Africa such as in Niger under an ongoing Green Climate Fund (GCF) readiness project, for a readiness and preparatory program within two national institutions. The pilot is intended to inform and scale similar services to other partners and locations by strengthening capacity for resource mobilisation through proposal development.

Coordination gaps between national, regional and sub-national levels constitute a significant challenge. A respondent noted, "*We work with national meteorological services, but the private sector and other stakeholders, such as agriculture or health, are often excluded from discussions.*" Improved coordination mechanisms like centralised data-sharing platforms and regional dialogues are necessary to streamline efforts and minimize duplication.

Technical capacity-building efforts often lack the scale and depth needed to address challenges faced by NMHSs. While some training programs exist, such as those offered by ACMAD and Intra-ACP Climate Services and the related Application (CLIMSA) program, these are often insufficient to meet the growing demands for technical expertise. One representative explained, "*We train member states on multi-hazard early warning systems, but financial and technical support is needed to scale these efforts.*"E C C A S conducts on-the-job training sessions and week-long workshops, such as those facilitated by United Nations Disaster Risk Reduction (UNDRR) and the CIMA Foundation. Yet these sessions are insufficient to build long-term technical expertise among participants. Sustaining these programs depends heavily on external funding, which is not guaranteed. While the training activities are a good start, they require ongoing follow-up and financial backing. Additionally, many NMHSs lack access to the advanced tools and computational resources necessary for modelling and forecasting, such as satellite data and high-performance computing infrastructure, which remain unavailable in many countries. Expanding capacity-building programs and embedding them into national policies can enhance the resilience of NMHSs. The co-production of knowledge, bringing together local communities and scientific institutions, is important in building effective capacity. Equally important is integrating training programs with operational support systems to ensure that acquired skills translate into tangible, actionable results.

Data storage, protection and computational capacities are severely limited. ECCAS reported their high-performance computing system remains unused due to insufficient funds for installation and maintenance. "*The HPC has been here since 2020, still packed in boxes… we simply don't have the resources to make it operational,*" noted one participant. Addressing these constraints requires prioritized investment in infrastructure, including internet connectivity, data storage systems and computational tools. Robust data infrastructure ensures reliable, timely climate services. Additionally, poor internet connectivity significantly impairs the ability of NMHSs and RCCs to process and analyse climate data effectively.

Advanced climate forecasting tools, such as high-resolution models and machine learning algorithms, require strong computational power and continuous internet connectivity. Reliable internet access is critical for real-time data sharing, bias correction and the use of predictive models that underpin early warning systems. Without it, forecasting becomes fragmented and unreliable. As one respondent noted, "*Limited internet access at the national level delays data submissions and disrupts the regional flow of information.*" This bottleneck weakens the effectiveness of regional early warning systems, which rely on timely data to issue advisories. In countries like Mali and Burkina Faso, NMHSs often rely on manual communications methods such as radio broadcasts, as internet-based platforms remain largely inaccessible. As one respondent noted, "*We aim to use online platforms for dissemination, but poor connectivity makes it unfeasible in many areas.*" The internet connectivity was mostly affecting the West and Central Africa RCCs and NHMSs. Other regions were not without challenges. Many NMHSs operate on limited budgets that prioritize equipment and personnel, with little room for technological upgrades. Another representative emphasized that, "*The costs associated with cloud computing and internet infrastructure are prohibitive, especially for data-heavy applications like machine learning-based forecasting.*"

Limited involvement of end users in the design of climate services often results in products that are irrelevant or inaccessible. As one participant noted, "*The challenge is understanding how access to information is used and what outcomes it leads to.*" Engaging local stakeholders from the outset can ensure that services are relevant, actionable and sustainable. Hewitt's work on international progress under the Global Framework for Climate Services underscores the importance of co-production approaches that actively involve communities in both the design and delivery of climate services .

Regional and national disparities in climate service delivery

Ingebjørg Kårstad/NRC

Regional and national disparities in climate service delivery

ICPAC and ACMAD possess more developed operational capacities and modelling systems. In contrast, regions such as Central Africa, represented by ECCAS CAPC-AC, face significant infrastructural deficits. As one respondent noted, "*Central Africa operates with minimal observational infrastructure, relying heavily on satellite data and interpolation techniques due to inadequate station coverage*". Regional approaches also differ in terms of forecasting responsibilities. SADC focuses primarily on seasonal and sub-seasonal climate monitoring and forecasting, leaving short-term forecasting to member states. As explained by one representative, "*We are more involved in seasonal timescales and sub-seasonal timescales, but short-term forecasting is not a requirement for us*". Meanwhile, RCCs like IPAC in East Africa engage more comprehensively in short term forecasting, thanks to better resources and institutional support. Staffing shortages further hinder operations in some centres. For example, SADC CSC currently has only one senior program officer, despite a mandate that requires a larger team. Moreover, the heavy reliance on external projects such as CLIMSA, rather than sustainable member state funding. Limits long term capacity building. These disparities highlight the limited technical integration and institutional development of some RCCs compared to ICPAC, which has benefited from stronger development partnerships and more robust technical support.

On the other hand, many NMHSs lack the infrastructure to provide accurate, localized and timely climate information. According to Senegal's Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM), "*Stations are concentrated in urban areas, leaving rural and remote regions underserved*". This lack of spatial coverage increases inequities, as rural farmers and coastal communities often receive less accurate forecasts despite their high vulnerability to climate impacts. In addition, the reliance of NMHSs on outdated equipment, vandalism of weather stations and limited maintenance capacity, as noted by another respondent: *"Many instruments need replacement, but funding constraints delay these essential upgrades"*.

Some regions have demonstrated best practices in data sharing and coordination. For example, through the CLIMSA project, the SADC CSC has implemented structured stakeholder engagement via formalized User-Interface Platforms (UIPs) for sectors like agriculture, water and energy. These UIPs support collaboration and the co-production of tailored climate services. As one respondent from the SADC region noted, "*These UIPs ensure a systematic approach to stakeholder engagement, but they must be fully integrated into national systems for sustainability*". In contrast, ACMAD, a pan-African RCC, plays a key role in facilitating continental-scale collaboration but faces challenges in operationalizing robust data-sharing protocols. One respondent remarked *"ACMAD serves as a coordination hub, but the lack of formalized inter-RCC agreements limits seamless data exchange*".

At the national level, disparities in capacity remain inconsistent across the SADC region. While some countries demonstrate stronger observational networks and technical capacities, most, excluding South Africa and certain islands, struggle with inadequate infrastructure and a lack of engineering support for maintenance. These challenges highlight the need for targeted capacity-building efforts and resource mobilization to support under-resourced NMHSs.

Coordination between regional climate centres and NMHSs remains inconsistent. One respondent identified fragmentation as a key barrier, noting that "*the siloed implementation of climate services undermines integrated action*". Overlapping mandates also contribute to confusion, with NMHSs often viewing external organisations as encroaching on their roles, resulting in resistance to collaboration. These disparities are also evident at the sub-national level. While regional bodies like IGAD and SADC have developed frameworks, implementation rarely reaches local governments and communities. A recurring theme was the misalignment between climate services and user needs. As one respondent observed, "*Data often lacks relevance for last-mile users who need actionable advice tailored to their local contexts*". Similarly, a representative from a UN Agency emphasized the importance of "*adequate communication strategies that convey the right message to the right audience*".

Disparities in climate service delivery across different levels reflect deeper systemic inequities in resource access, technical capacity and governance structures. Without targeted interventions, the utility of climate services, particularly for vulnerable populations, will remain limited. Addressing these challenges requires a multi-stakeholder approach that combines investment, capacity building and policy reform at different levels. These findings highlight the need for a coordinated strategy to reduce regional and national disparities in climate service delivery. A unified pan-African framework could enhance data sharing, harmonize methodologies and improve resources efficiency. In particular, prioritizing capacity-building initiative, in data management and dissemination would help bridge critical gaps. As one respondent aptly noted, "*The real challenge lies not just in collecting data but in translating it into actionable insights for the most vulnerable*".

Coordination among NMHSs, regional institutions and international organisations remains fragmented, leading to duplicated efforts and inefficient use of resources. As one respondent noted, "*There is so much duplication… actors are often working in silos without sufficient collaboration*". This lack of effective coordination undermines the impact of individual initiatives and creates confusion among stakeholders. Consequently, climate information services are delivered in a fragmented manner and valuable opportunities for collaboration are frequently missed.

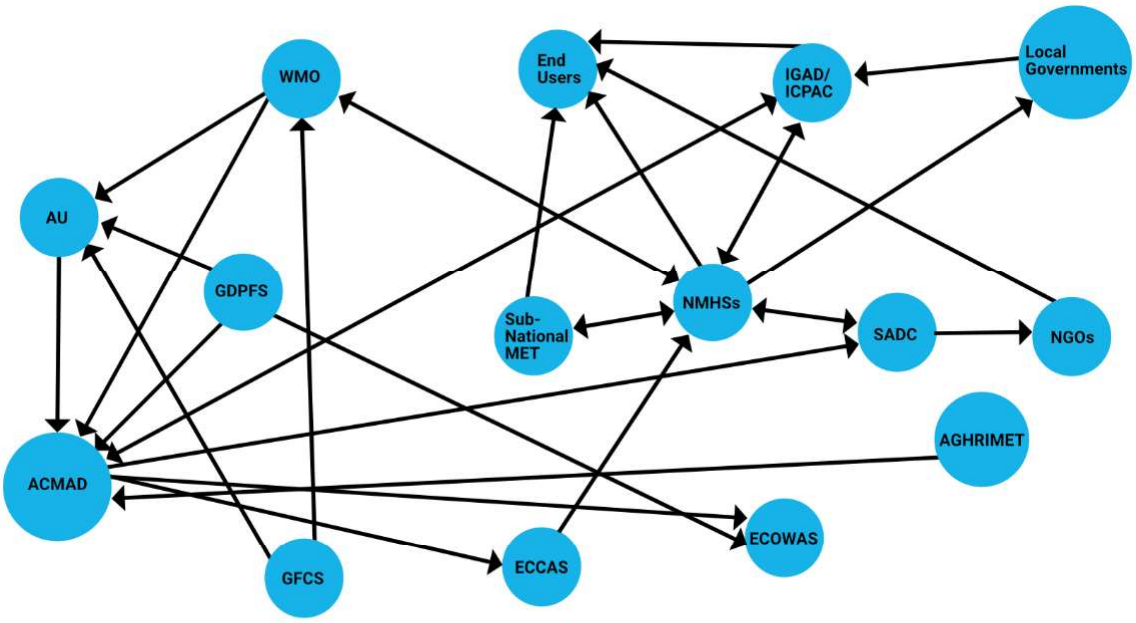


Figure 6: Coordination in Climate Service Delivery organisation chart (Source: Author)

The illustration below visualises the complex web of actors involved in delivering climate information services across Africa. Each node represents a different stakeholder level, from global organisations to local, last-mile users, while the directed edges indicate the flow of information and coordination between them. This visualization highlights potential areas for improved synergy and more efficient resource use. Strengthening project coordination to ensure alignment, minimize duplication and foster collaboration at all levels could greatly increase the collective impact of climate information services across the continent.

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The GFCS provides a foundation for collaboration among different actors, promoting the integration of climate information into decision-making across sectors. WMO plays a central role by guiding NMHSs, supporting capacity development and promoting data-sharing initiatives to strengthen climate services. GFCS provides overarching guidance and frameworks at both the global and regional level. At the continental level, AUC and ACMAD act as regional integrators, aligning global strategies with Africa-specific needs. IGAD/ICPAC, SADC-CSC, ECASS/CAPC-AC and AGRHYMET facilitate localized collaboration and capacity building at the RECs level. NMHSs deliver actionable data and forecasts while local governments, NGOs and development partners ensure that services are accessible and tailored to

user needs. Ultimately, these efforts empower local communities – the end users – to make informed climate-resilient decisions.

NMHSs serve as the primary entry points for disseminating climate information across African countries. They collaborate with regional centres such as ACMAD, IGAD/ICPAC, SADC-CSC, AGRHYMET, and ECCAS/CAPC-AC to adapt regional climate forecasts to local needs. As one ECCAS/CAPC-AC respondent noted, regional partnerships helps build on existing capabilities: "*We are really taking advantage of what has already been built by centres like ICPAC, AGRHYMET and SADC to avoid restarting everything from scratch*".

Collaboration with regional institutions ensures that NMHSs can access advanced technical resources, such as the HPCs supported by ICPAC. Regional forums like PRESAC and the Africa Climate Outlook Forum (ACOF) further promote coordination by harmonizing seasonal forecasts. These platforms allow stakeholders to agree on methodologies and share technical guidance, fostering coherence in climate information delivery. As one participant noted, "*ACOF brings*

together regional centres like ACMAD, SADC and ICPAC to form consensus on seasonal forecasts". While such collaboration strengthens the technical capacity of NMHSs, it also highlights regional disparities. For example, ICPAC is widely recognized as the most advanced in delivering objective seasonal forecasts, whereas centres like ECCAS/CAPC-AC lag due to limited technical and human resources and funding.

At the national level, weak coordination between national and sub-national actors often results in duplicated efforts. As one respondent noted, "*For example, a county may conduct participatory scenario planning (PSPs) twice due to funding from two separate organisations for the same forecast*." This inefficiency underscores the need for a clear coordination framework to streamline activities and avoid redundancy. Some countries have developed NFCS to strengthen coordination among NMHSs, sectoral ministries, and local governments. However, in many cases, these frameworks are poorly implemented due to institutional fragmentation and weak policy enforcement.

There is need to leverage regional strengths. For example, ICPAC's expertise in objective seasonal forecasting can be shared with less-resourced centres like ECCAS/CAPC-AC through trainings and capacity building. Many NMHSs lack the capacity to effectively store, process and publish data. One RCC representative noted, "*Many NMHSs are unable to publish their datasets due to limited computational power and infrastructure*". NORCAP has supported data transmission improvements by improving the Global Basic Observing Network (GBON) reporting and building the capacity of NMHSs to use the WMO WIS data exchange system. This has included the use of tools such as ClimWeb, and Africa Hazards Watch, a centralized platform for real-time weather and risk information. Capacity-building efforts have involved more than 1,060 hours of training and mentoring, strengthening the technical expertise of over 100 NMHS staff and improving the quality-of-service delivery.

Regional outlook forums such as PRESAC (Central Africa), GHACOF (Greater Horn of Africa) and others across the continent, serve as key platforms for data exchanges and consensus building. PRESAC, for example, produces seasonal outlooks tailored to the region's specific climate conditions, including Central Africa's year-round rainfall. These sessions also promote peer learning by incorporating insights from other regional centres. As one representative explained, "*We invite ICPAC and AGRIHYMET to learn how they deliver and disseminate forecasts to improve our processes*".

ACMAD is a pan-African institution that strengthens climate services by enhancing the capacity of African NMHSs and RCCs. As a data integrator, ACMAD helps bring observational gaps by leveraging satellite-derived data and climate models, particularly in areas lacking ground-based infrastructure. As one ECCAS respondent noted, "*We depend heavily on ACMAD to validate our models with satellite-derived data where ground stations are absent*". ACMAD also coordinates with

RCCs such as ICPAC, AGRIHYMET and SADC-CSC to promote regional coherence in climate services and participates in continental forums like the ACOF to harmonize methodologies for seasonal forecasting.

Despite its critical role, ACMAD faces several systemic and operational challenges, including inconsistent and insufficient funding from both member states and international donors. As one respondent observed, "*ACMAD depends heavily on project-based funding, which limits its ability to sustain long-term initiatives*". Another challenge is the lack of harmonized data-sharing protocols among RCCs, NMHSs and ACMAD which often leads to inefficiencies.

A respondent noted, "*There are gaps in how ACMAD interacts with RCCs, particularly in terms of real-time data sharing and operational alignment*". While existing partnerships have enhanced technical capacities, the absence of a unified regional coordination framework continues to create inefficiencies and missed opportunities. Strengthening partnerships through harmonized data-sharing protocols and clearly defined roles could address these challenges. NORCAP is strategically collaborating with ACMAD by providing technical expertise and capacity development for the creation for the Makau system, developed within ACMAD. This initiative, in partnership with the EU Joint Research Centre, aims to deliver critical drought information. The system allows users to interactively visualisorganisatione drought-related products and generate comprehensive reports.

Institutional interaction across different levels, often facilitated through regional forums, forms a value chain that supports the delivery of climate services to diverse stakeholder groups. This analysis draws on both primary insights and existing literature to highlight the key components, examples and implications of coordination efforts. NORCAP's role as a partnership broker is particularly noteworthy, enabling collaboration across institutional boundaries. As one respondent emphasized, "*NORCAP acts as a connector between actors and initiatives, (.....) being in strategic partnerships with so many different actors in this space in Africa, we have a unique role in being a partnership broker or connector between the different players, making sure that collaboration, coordination and learning improve between the actors*".

Barriers to effective coordination

Ingebjørg Kårstad/NRC

Barriers to effective coordination

A major barrier to effective coordination is the restriction of intellectual property (IP), particularly concerning climate models, tools and data-sharing protocols. These restrictions often extend beyond proprietary software or internally developed models to include modified versions of publicly available tools, effectively limiting access to some of the most advanced or locally adapted resources, those most critical for collaborative work. Although such assets may represent only part of an institution's intellectual capital, they frequently encompass the tools best suited for regional cooperation. Accessing these IPs typically requires formal approvals, licensing agreements, or institutional partnerships, all of which can be time-consuming and bureaucratic. This slows down collaboration and hampers scientific innovation. As one respondent noted, "*When intellectual property is closed, only insiders can benefit, but when it's open, scientists from different backgrounds can advance knowledge collectively.*" Restrictive IP policies not only inhibit the sharing of expertise but also prevent regional centres and NMHSs from working together effectively, ultimately undermining the broader goals of climate resilience and collective action.

Data sharing protocols between NMHSs and RCCs remain a significant barrier to effective coordination. Many NMHSs treat their data as strategic assets and restrict access to other institutions. As ACMAD noted, "*Countries are hesitant to use [Application Programming Interface] (APIs) or share datasets, fearing loss of control over their information*". This reluctance leads to fragmented and incomplete datasets, undermining the accuracy of forecasts and limiting the ability to monitor and respond to climate risks effectively. The absence of standardized data-sharing protocols also exacerbates regional disparities in service delivery, leaving neighbouring countries unprepared for shared climate risks, particularly in the case of transboundary challenges like droughts or floods.

WMO established a Unified Data Sharing Policy that requires NMHSs to provide, on a free and unrestricted basis, the core data necessary for providing services to support the protection of life and property and the well-being of nations. Full implementation of this policy in Africa requires capacity building, for example, in the use of WMO's Information System (WIS) which is the framework for WMO data sharing that supports implementation of the unified data policy.

Weak governance and shifting political priorities often result in the deprioritization of climate services. In fragile states, limited institutional capacity frequently leads to coordination gaps between NMHSs and regional or international partners. Disputes over institutional mandates can further exacerbate these tensions. As one respondent observed, "*Regional centres sometimes overstep their mandate by directly communicating forecasts to end users, bypassing NMHSs*". Such actions undermine the authority of NMHSs, create confusion among end users and erode trust in climate information systems. These challenges are symptomatic of broader governance weaknesses that hinder effective coordination and reduce the overall impact of climate services.

Opportunities and emerging priorities

Emerging technologies such as machine learning and AI are reshaping climate service delivery by enabling high-resolution forecasting and real-time analysis. Innovations in machine learning are significantly enhancing weather forecasting capabilities. For example, Google has developed a machine learning model capable of generating forecasts up to ten days in advance, while IBM and Microsoft are advancing foundation models for geospatial and geosciences applications. Despite these advances, a significant challenge is the limited availability of skilled personnel to implement and manage these technologies. One respondent observed "*There's strong potential to invest in innovations like a chatbot that can interact with users, facilitate knowledge transfer, and generate reports. However, this remains a relatively new area with limited capacity—both in terms of personnel and clarity on who should lead such efforts—especially given the already high demand for producing other essential products*". AI-driven platforms such as Google Earth Engine are increasingly being explored to process large datasets for drought and flood monitoring. However, meaningful adoption by NMHSs requires investments in training, infrastructure, and high-performance computing systems. As Ruti et al. (2021) highlight, AI holds considerable promise for improving seasonal forecast accuracy and supporting disaster risk reduction across Africa. Nonetheless, ethical considerations—such as accountability, transparency and equitable access—must be addressed when deploying AI technologies at scale.

Tools such as the African Flood and Drought Monitor integrate satellite data and ground-based observations to improve the monitoring and forecasting of climate-related hazards. Mobile technologies have also revolutionized the dissemination of early warnings. In Kenya, for example, mobile phones are used to transmit alerts, while platforms like M-pesa facilitate the delivery of financial support to at-risk populations, enabling timely and targeted responses (Tall et al., 2018). While technological solutions are crucial, the integration of community knowledge ensures the relevance and long-term sustainability of EWS. The Rural Resilience Initiative (R4), implemented by the World Food Programme (WFP) exemplifies this approach by combining scientific forecasts with local expertise. Implemented in drought-prone areas, R4 enables vulnerable farmers to improve food and income security through a mix of risk reduction strategies, insurance (risk transfer), livelihoods diversification and

and savings (risk reserves). These efforts empower communities to take proactive measures by providing resources such as insurance and savings schemes.

Exploring the intersection of climate services and peacebuilding is critical in fragile regions where resource scarcity and climate stress contribute to conflicts. In the Sahel, for example, drought monitoring tools have supported equitable water resource management, helping to reduce tensions among pastoralist communities. One of the NORCAP expert observed, *"Climate services can support peacebuilding efforts by providing data that mitigate resource-based conflicts, particularly in drought-prone areas*". Expanding the integration of climate services into peacebuilding initiatives, especially in conflict-sensitive regions like the Horn of Africa and Sahel, can contribute to greater stability and more sustainable development outcomes.

Strengthening the connection between climate data and health services is increasingly recognized as essential, as climate change intensifies health vulnerabilities, particularly for diseases such as malaria and cholera. Climate services play a critical role in forecasting weather conditions that contribute to disease outbreaks, thereby enhancing public health preparedness. In East Africa, seasonal forecasts have been successfully integrated into malaria prevention campaigns, enabling the timely distribution of mosquito nets and vaccines. A respondent noted, "*We are focusing on health as a priority sector, especially linking climate data to diseases like malaria, where early warning systems can save lives*". The flooding associated with El Niño increases cholera and malaria outbreaks. In addition, the World Health Organisation (WHO) collaborates with NMHSs to integrate climate data into health early warning systems. *"We use El Niño forecasts to pre-position medical supplies and coordinate with local governments for disease prevention campaigns,"* said one expert. The expert further explained that *"We've developed climate-health models that predict disease outbreaks, allowing us to issue early warnings and mobilize resources in time*". A significant challenge is the lack of localized climate-health data which delays targeted interventions. *"We need more granular data to predict how El Niño will affect health outcomes at the community level,"* said a WHO official. Strengthening partnerships with NMHSs and RCCs is key for integrating health and climate data, enabling timely responses to climate-related public health impacts. Prioritizing health-focused applications requires enhanced collaboration with health ministries and the development of region-specific tools for disease prevention and prediction.

There is growing evidence that user-friendly tools enhance the effectiveness of climate services by enabling vulnerable communities, such as smallholder farmers and pastoralists, to access and apply climate information. As one respondent noted, *"Live platforms where users can directly access forecasts and provide feedback are essential to improve climate service adoption*," For example, mobile applications delivering localized weather forecasts have been piloted in Malawi, reaching over 5,000 farmers with actionable advice. Strengthening feedback mechanisms and scaling up digital tools will help tailor climate services to community needs, build user trust and increase long-term uptake.

A NORCAP expert is supporting DCCMS to build a data platform allowing everyone to access weather forecasts produced by the department, thereby democratising weather forecast access.

Interviews highlighted gender mainstreaming as a critical priority in for effective climate service delivery, particularly in addressing the unique vulnerabilities and roles of women in rural and marginalized communities. Although women are often the primary users of climate information in smallholder farming, most tools and forecasts are not designed with their specific needs in mind . Integrating gender-sensitive approaches can promote equitable access to climate information. Effective strategies include co-producing agro-climatic advisories with women farmers and disseminating forecasts through women's groups. However, persistent challenges, such as limited access to mobile technology, continue to hinder women's full participation. "*We included women farmers in focus group discussions to co-design agro-climatic advisories that reflect their unique challenges and decision-making roles,*" noted one expert. Another respondent underlined the importance of low-tech solutions, "*We are working on integrating community radios and text-based advisories to bridge the gap for women without smartphones*". Gender should be a core component of any climate service framework

NORCAP, in collaboration with its partners, launched the Female Climate Accelerator Programme, which empowers female scientists with the technical, field and social skills to drive science-based climate solutions and promote gender inclusion. By increasing the number of female climate experts, the program not only provides marginalized communities with enhanced climate information but contributes to driving systemic change in traditionally male-dominated sectors. It creates a pipeline of skilled women to influence policy, industry practices, cultural norms and long-term systemic progress. This creates a ripple effect of empowerment and development. One key success of the program has been its impact at ICPAC, where gender mainstreaming has been integrated within the GHACOF process, ensuring balanced participation, gender-responsive advisories and marking a significant milestone in promoting equity within climate initiatives. This achievement underscores an important role of both climate and gender experts in advancing inclusive and equitable solutions in the face of climate challenges.

to ensure equitable access and benefits. Incorporating women-led organisations helps amplify women's voices and ensures their specific needs are met.

Investing in climate services; solutions to funding and resource challenges

Securing sustainable funding for climate services in Africa remains a persistent challenge, driven by misalignment between donor priorities and local needs, dependence on external donors and fragmented funding structures. Despite efforts by donors to align with capacity development and emerging technologies, gaps remain in addressing the entire ecosystem of climate service users. "*Donors have really tried to align their support, but many users who could benefit from climate information systems are not involved in their development*," one respondent noted. Inconsistencies arise from differing approaches among development partners and UN agencies. For instance, the National Frameworks for Climate Services in countries like Malawi aim to coordinate donor activities but face challenges in ensuring alignment with national goals like Vision 2063. These findings highlight a recurring issue: donor-driven projects often prioritize short-term outputs at the expense of systemic, long-term impacts.

The reliance on external funding creates vulnerabilities, particularly with short-term, and project-based funding cycles. As one respondent put it, "*We need to show results to maintain donor support,*" said one respondent. This dependency restricts NMHSs and regional climate centres from establishing sustainable programs, forcing them to prioritize donor agendas over local needs. Most funding focuses on adaptation and mitigation, with limited attention to operational climate services. As one respondent noted, "*To attract funding, we often have to frame climate services as an adaptation project rather than focusing on their direct operational needs*". This approach undermines the development of robust, sustainable service delivery systems.

Many NMHSs rely on donor-funded projects that are often short-term and lack sustainability. Consequently, investments in meteorological infrastructure and capacity-building programs frequently end when projects conclude. As an official from Burkina Faso's meteorological agency stated, "*We receive station donations, but lack the budget to maintain them, leading to gaps in long-term data collection*". Furthermore, government allocations for climate services are often insufficient, as national budgets prioritize sectors like security and social services. An expert in Niger noted, "*Climate services remain underfunded because government budgets prioritize security and social programs over long-term investments in meteorology*". The challenge is not only a lack of funding but also the unpredictability of financing, making it difficult for NMHSs to plan and execute long-term capacity-building efforts.

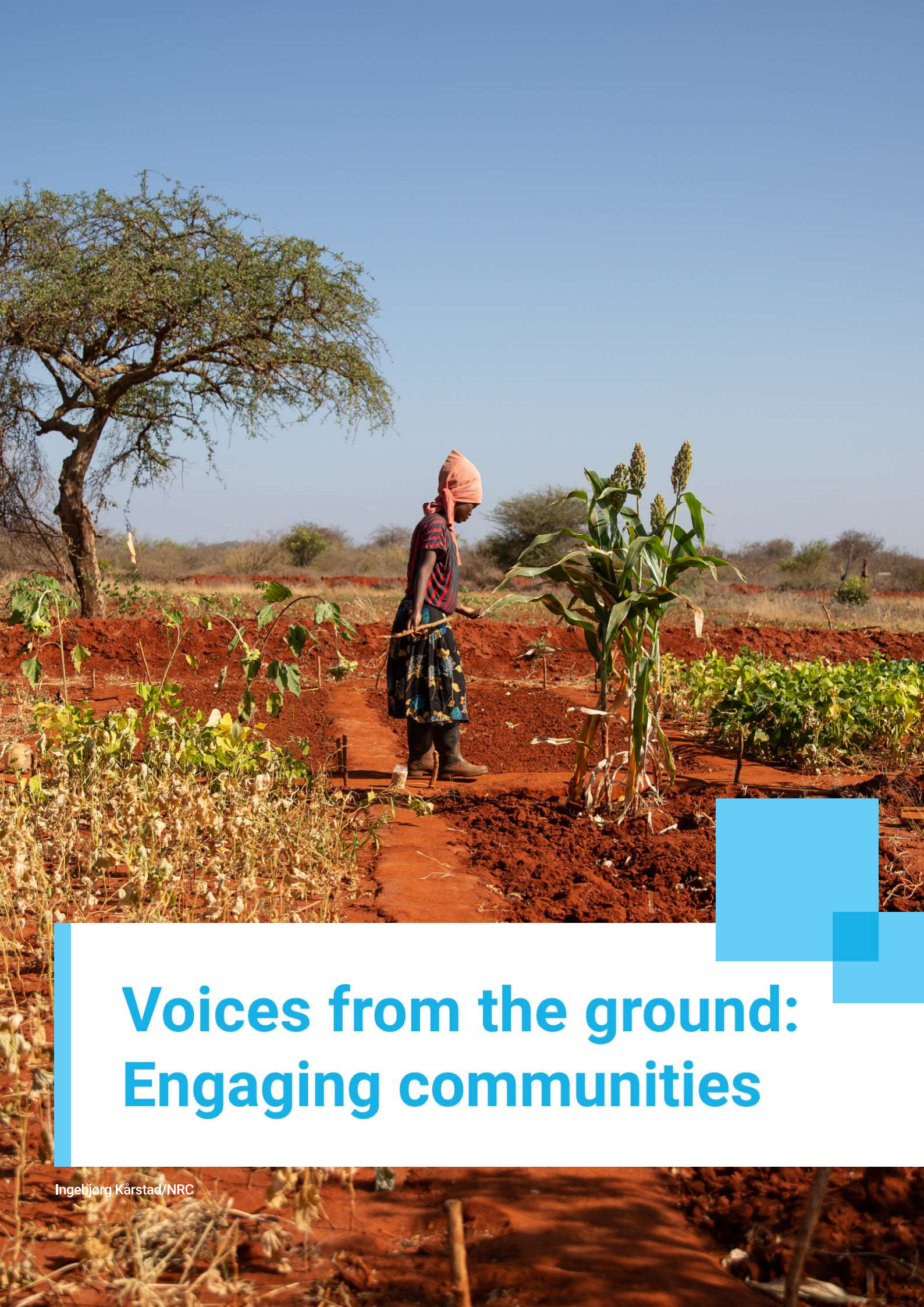
Emerging financing models, such as blended finance and PPPs, offer promising opportunities to diversify funding sources by combining public and private capital to support climate service projects, particularly in infrastructure development and technological innovation. Engaging the private sector in co-financing weather stations and data-sharing platforms is one example. These approaches align with GFCS recommendations which emphasize the need for innovative funding strategies to build resilience. Promoting these models, alongside capacity-building efforts to attract private sector investment, can help reduce reliance on traditional donor funding. PPPs and support for climate-resilient small and medium enterprises were identified as promising pathways to expand resource mobilization and impact.

To address financial constraints, innovative funding mechanisms are being explored. In counties like Kenya, PPPs are being piloted with private weather service providers working alongside government agencies to improve climate data accessibility. Weather index insurance schemes, such as those developed by Juhudi Kilimo, are also offering smallholder farmers financial protection against climate shocks. At the global level, initiatives like the Systematic Observations Financing Facility (SOFF), led by the WMO, aim to establish sustainable funding for essential climate observations.

Securing sustainable funding for climate services requires their integration into broader adaptation and development agendas. Advocacy by regional and international organisations plays a critical role in elevating the profile of climate services. However, demonstrating their long-term value remains a challenge. As one respondent observed, "*Donor advocacy is crucial to ensure climate services are seen as integral to adaptation and mitigation strategies.*" Development partners also struggle to track adaptation outcomes due to the complexity of defining global adaptation goals. While metrics like the number of beneficiaries provide a broad indicator, they offer limited insight into systemic change. As noted by another respondent, "*It's easier to measure progress at the output level, such as the number of weather observations or people receiving climate information*."

A critical gap persists in effectively reaching the full ecosystem of climate service users. As one participant noted, "*The donors have really tried to align their supports in climate services*," yet the exclusion of key user groups continues to limit overall impact. Donors themselves recognize systemic issues in the funding landscape, including limited financial sustainability and donor dependency. As one participant noted, "*Low capacity and unreliable funding for meteorological services hinder sustainable impacts beyond the implementation phase*". In addition, fragmented efforts across organisations often lead to duplication, inefficiencies and unmet needs.

In this context, stronger coordination among donors is essential avoid duplication and and promote complementary funding strategies. Initiatives like the informal Friends of Early Warning group offers a valuable model for donor alignment, particularly in specific sectors and national adaptation plans and sector-specific strategies.



Voices from the ground: Engaging communities

Ingebjørg Kårstad/NRC

Voices from the ground: Engaging communities

Kenya case study

This case study examines how communities in Kenya access climate information, integrate traditional forecasting methods and engage in co-designing tailored solutions. It highlights efforts aimed at ensuring that vulnerable populations, including women and marginalized groups, are actively included in the delivery of climate services.

Machakos county	Number of participants	Locations
KII and FGD with met officers	4 (4m)	Machakos
KII and FGD with agricultural research and extension officers	13 (4f, 7m)	Machakos
FGD with the media	5 (2f, 3m)	Machakos
FGD with farmers	51	Masii, Machakos
Survey of farmers	20	Masii
Taita Taveta county	**Number of participants**	**Locations**
KII and FGD with met officers	3 (3m)	Taita Taveta
KII and FGD with agricultural research and extension officers	14 (3f, 11m)	Taita Taveta
FGD with the media	7 (3f, 4m)	Taita Taveta
FGD with farmers	29 (22f, 7m)	Taita Taveta
Survey of farmers	18	Taita Taveta

Table 1: Key informant interviews, FDG: Focused group discussions

Access to climate information

Kenyan communities access climate information through a range of channels, including radio broadcasts, SMS alerts, community gatherings (barazas) and local agricultural extension officers. For example, the Machakos County Greenshed Farmer Group receives weekly and seasonal forecasts via SMS, brochures and local radio stations, such as Kamene FM and Misimi Radio. However, challenges persist, particularly in regions such as Mwala sub-county, where limited local data and unreliable forecasts hinder the delivery of specific, actionable advisories.

Efforts to improve access include participatory scenario planning (PSP) meetings at the county level, where meteorological officers, community leaders and agricultural experts collaborate to co-create localized advisories. However, feedback mechanisms remain limited, highlighting the need for greater investment to bridge the gap between data providers and end-users.

In Machakos and Taia Taveta counties, as in many parts of Kenya, traditional forecasting methods remain a core part of climate information systems. Farmers rely on natural indicators such as the flowering of Jacaranda trees, specific bird behaviors and the phases of the stars and the moon, to predict seasonal changes. While these methods are trusted for forecasting the season's onset, they lack precision in predicting rainfall intensity or duration. Combining traditional knowledge with scientific forecasts has shown promise. Programs like PSP promote the integration of these approaches, ensuring that forecasts align with community experiences while incorporating modern meteorological insights.

Firsthand perspectives: Stories and testimonials

A member of the green shed farmer group in Machakos recounted their journey of adopting drought-resistant crops based on climate advisories: *"Initially, we doubted the information provided by meteorologists, but after attending participatory scenario planning meetings, we realized the value of these forecasts. Now, we confidently plant the recommended crops and use water*

harvesting techniques to sustain them". This farmer's group operates a group model farm for agribusiness and learning. They have adopted drought-resistant crops and water harvesting techniques based on climate advisories. This testimony highlights the transformative impact of climate services when communities actively engage with and trust the information provided.

Some farmers expressed frustration with conflicting forecasts, noting instances where predictions of prolonged rains resulted in just a few days of rainfall. A farmer in Mwala sub-county shared: "*We were told to expect a month of rain, but only two days had significant rainfall. This inconsistency left us unprepared and caused major losses*". This highlights the need for local and reliable data to build trust and enhance uptake. The inconsistency also calls for the need for enhancing data accuracy and strengthening trust in meteorological services. Conversely, another farmer from Machakos County shared, "*My family is food secure; I selected suitable varieties during El Niño and had a successful harvest*". This highlights the importance of timely and actionable advisories in improving production.

Another example is the Lower Kaathi Self-Help Group, comprising 99 households engaged in diversified farming and table banking. These farmers rely on localized advisories disseminated through WhatsApp, radio and agricultural officers. Limited resources and gaps in climate information infrastructure limit their ability to fully utilize this service.

In Taita Taveta county, farmers embraced climate-smart agriculture and sustainable land management practices informed by local advisories. Community groups such as the Vuria Farmer Association highlight the value of seasonal forecasts to prepare for extreme weather events. A farmer shared, "*Before, we struggled to predict when to plant. Now, with timely updates from the Met Department, we have reduced crop losses and even increased yields*". Additionally, women's groups play an important role in disseminating climate information through savings and loan schemes tied to agricultural training sessions.

Women in Machakos county shared their perspectives on accessing climate information. One group member noted, "*Through our table banking meetings, we learn about upcoming weather patterns and share ideas on how to prepare. It has become a reliable source of knowledge and support for us*". This reflects how leveraging community social networks can enhance the dissemination and utilization of climate services.

Co-designing solutions

Co-production approaches have been instrumental in tailoring climate services to local needs. Programs facilitated by Kenya Meteorological Department (KMD), NGOs and community groups engage farmers and stakeholders in developing user-friendly advisories. For example, participatory workshops focus on translating complex meteorological data into actionable advisories, ensuring relevance and accessibility.

In Taita Taveta county, community-led climate forums were established to engage local farmers, extension officers and meteorologists. These forums ensure advisories address specific challenges such as erratic rainfall, soil degradation and pest outbreaks. Farmers actively contribute observations which are integrated with scientific data to create highly localized, actionable forecasts. One participant shared, "*The workshops helped us understand the science behind the forecasts, and we feel more confident in applying this knowledge to our farming practices*".

Community members are trained to interpret forecasts, disseminate information and provide feedback creating a dynamic feedback loop that continuously improves service delivery. In Machakos, farmers trained to teach other farmers shared their knowledge with their peers, enhancing the reach and impact of climate service approaches.

Gender inclusion

Women's groups are specifically targeted to ensure that advisories address their unique needs, such as guidance on subsistence crops and household water management to empower women to take proactive measures against climate risks. Research shows that women and men experience and respond to climate risks differently due to disparities in access to resources, decision-making power and social networks. For instance, women in rural areas often lack access to land tenure, financial resources and ICTs like mobile phones and radios which are common channels for disseminating climate information. Cultural norms can further restrict women's participation in training sessions and producer associations, limiting their ability to benefit from climate services. Men, on the other hand, are more likely to own mobile phones and participate in cooperatives, giving them greater access to information. Tailoring climate services to these differing needs such as providing women-specific advisories on subsistence farming and household management is essential for equitable outcomes.

Women also rely on personal interactions, such as community groups and farmer working networks, to access climate information. Leveraging these trusted networks and addressing the digital divide through subsidized ICTs can significantly enhance inclusivity. Additionally, engaging women in co-design processes and building their capacity to interpret and act on forecasts empowers them to take proactive measures against climate risks. Generational differences also play a role in accessing climate services. Younger, more educated individuals tend to use digital platforms, while older individuals rely on traditional knowledge and informal networks. Inclusive communication strategies that combine ICTs with community outreach can bridge these generational gaps and ensure broad information dissemination.

In conclusion, community engagement in Taita Taveta and Machakos counties demonstrates the transformative potential of climate services to enhance resilience among grass root communities. By integrating traditional knowledge, encouraging co-production and prioritizing inclusivity climate services can address the diverse needs of Kenyan communities and those in the region with similar challenges.

Strengthening climate services through strategic partnerships

Yacine Fall

Strengthening climate services through strategic partnerships

Climate services capacity strengthening

Over the past decade, investmen ts in climate service capacity strengthening in Africa has grown significantly, driven by increased recognition of the role climate information plays in resilience-building and disaster preparedness. Investments have focused on institutional strengthening, infrastructure enhancement and human resource training to ensure that climate services are not only available but also accessible and actionable . Programs such as the SOFF, the Climate Risk and Early Warning Systems (CREWS) initiative and the GCF provide resources to improve observational networks, early warning systems and forecasting capabilities.

Capacity strengthening in climate services requires a holistic approach that addresses institutional, infrastructural, procedural and the human resource dimensions of service delivery.T h e WMO capacity development strategy identifies four key areas necessary for a sustainable climate services framework: institutional capacity (policies, legal frameworks and governance structures), infrastructural capacity (data collection networks and IT systems), procedural capacity (operational guidelines and climate information standardization) and human resource capacity (continuous training programs for climate scientists and decision-makers). While some countries have made progress in implementing these capacities in the region, disparities remain in financial sustainability, personnel training and technological adoption.

One of the primary objectives of capacity strengthening initiatives in Africa has been to expand climate observation networks to improve forecasting accuracy and data availability. The Africa Hydromet Program, a collaboration between the World Bank, African Development Bank and WMO has significantly improved meteorological infrastructure by supporting NMHSs to upgrade weather stations, install automatic weather observation systems and expanding satellite-based climate monitoring . However, Africa still operates with only one-eighth of the recommended density of weather observation stations, limiting the granularity and accuracy of climate data, particularly in rural and remote areas where climate impacts are most severe. Despite these advancements, infrastructure investments often lack sustainability. Many NMHSs struggle to maintain weather stations due to financial constraints. One expert noted, "*One of the main challenges we face is not just installing weather stations but maintaining them. Many of our stations break down due to lack of spare parts, insufficient technical staff, and financial constraints. While donors support the procurement of equipment, long-term sustainability remains an issue. We need more investment in capacity building and operational budgets to ensure these systems remain functional over time*". This shows that there is a growing need for long-term investments that go beyond equipment procurement and focus on ensuring continued technical expertise and institutional development.

Human resource constraints persist, particularly in low-income countries, where NMHSs lack the financial capacity to recruit and retain skilled professionals. A representative from Malawi's Department of Climate Change and Meteorological Services highlighted this issue: "*Our staff are overstretched, and hiring freezes limit our ability to recruit skilled meteorologists and data analysts*". The brain drain phenomenon further exacerbates this challenge, as many trained meteorologists leave for better-paying jobs in international organisations.

Another major challenge is the limited use of climate services by end users. Despite improvements in climate services delivery, the uptake of climate information by farmers, local communities and businesses remains limited. Many users lack the understanding required to apply climate forecasts. An NMHS official noted: "*We provide seasonal forecasts, but farmers often lack the necessary training to interpret and use them effectively*". This calls for enhanced communication strategies and co-production of climate information, ensuring that forecasts are translated into actionable insights for different sectors.

Furthermore, weak coordination among climate institutions remains a significant challenge. Although RCCs such as ICPAC, ACMAD, and SADC-CSC play a key role in climate services capacity development, coordination between regional and national agencies remains weak. One RCC representative pointed out: "*We work with limited budgets, and our ability to provide continuous technical support to NMHSs is constrained*". There is need to strengthen the financial and operational capacity of RCCs to ensure more effective support to NMHSs.

Capacity-building efforts in the region have extended beyond member states to include international partnerships, such as the United Kingdon's (UK) Met Office and the University of Cape Town, which play crucial roles in enhancing weather and climate services. The UK Met Office has strengthened partnerships between regional meteorological services, research institutions and other stakeholders to enhance disaster risk reduction and climate services for key sectors like agriculture and water management. Similarly, under the CONFER project, the University of Cape Town has been instrumental in equipping stakeholders with expertise in climate information and early warning systems, reinforcing disaster risk management efforts.

In addition, since 2015, NORCAP experts have worked to strengthen the capacity of partner organisations to deliver climate services to vulnerable populations across Africa. This effort focuses on increasing access to weather and climate information and enabling vulnerable communities to better adapt to the impacts of climate change.

Through collaborative partnerships, NORCAP addresses identified capacity gaps using a value chain approach that encompasses data acquisition and management, forecasting, modeling, communication and engaging with users.

The role of partnerships in enhancing sustainability of climate services

Strengthening climate services requires collaboration between governments, regional bodies, the private sector and international development agencies. Multi-stakeholder partnerships can enhance the sustainability of climate services through shared resources, expertise and innovation. While NMHSs play central roles in climate service provision, their ability to sustain and scale their efforts often depends on external collaborations. Several models of partnerships have emerged to strengthen climate services across the continent, with varying degrees of success.

Intergovernmental collaborations play a crucial role in improving climate services through resource pooling and cross-border data sharing. Regional organisations such as the African Union Commission (AUC) and the African Ministerial Conference on Meteorology (AMCOMET) have advocated for continental frameworks. One example is AMHEWAS, a collaboration between the AUC, UNDP, UNDRR with the support of CIMA foundation. This initiative aims to integrate climate services into disaster risk reduction strategies across the continent, ensuring that national and regional institutions work together to provide timely and accurate early warnings. Additionally, some African countries have bilateral agreements to share meteorological data and improve forecasting accuracy.

Regional climate institutions such as the IGAD ICPAC, African Centre of Meteorological Applications for Development (ACMAD) and the SADC Climate Services Centre (SADC-CSC) play key roles in strengthening climate services. These centers serve as intermediaries between global climate data producers and national-level users, ensuring that climate information is tailored for specific regional needs. ICPAC has developed seasonal climate outlooks that guide agricultural decision-making in East Africa, while ACMAD has worked on drought monitoring and early warning systems in the Sahel. However, despite their contributions, these regional centers face funding and operational challenges. "*We have the mandate, but financial resources are limited and unreliable. Without sustained funding, we cannot ensure continuity in services or support Member States effectively*" one respondent noted. Sustainable funding mechanisms are needed to ensure that regional centers can continue to support national agencies effectively.

The private sector has also emerged as a key partner in climate services, particularly in the areas of technology development, data dissemination and financial sustainability. PPPs have improved the accessibility of climate information and introduced innovative solutions for forecasting and early warning. In Kenya, the KMD collaborates with Weather Impact, a private Dutch company, to provide localized weather forecasts to smallholder farmers via SMS. Similarly, IBM's Weather Company partnered with Southern African NMHSs to integrate AI and big data analytics into climate modelling, improving the accuracy and accessibility of forecasts. Another notable example is Ignitia, a Swedish weather service provider that collaborates with agribusinesses and mobile network operators in Ghana, Nigeria and Côte d'Ivoire to deliver hyper-local SMS-based weather forecasts to farmers. These partnerships demonstrate how private sector involvement can enhance the financial sustainability of climate services by offering commercially viable solutions while expanding access to climate information. In some countries NHMSs partner with telecommunication companies to deliver weather information through mobile applications. The existence of transnational telecommunication companies in the region, such as MTN, Airtel, Safaricom, Som-Tel, among others, offers an excellent opportunity for partnership and collaboration regionally.

UN agencies and multilateral donors play significant roles throughout Africa supporting climate services. Several initiatives have focused on infrastructure development, capacity building and integrating climate considerations into policy and planning. The United Nations Development Programme (UNDP), for example, launched the Climate Information for Resilient Development in Africa (CIRDA) program which has helped 11 countries modernize their climate observation networks and improve early warning systems. The World Bank's Africa Hydromet Program, in collaboration with WMO and the AfDB, has provided funding for meteorological infrastructure upgrades and capacity-building programs. Meanwhile, the FAO and the WFP integrate climate services into their anticipatory action frameworks, ensuring that early warnings lead to timely interventions that protect food security.These multilateral partnerships mobilize critical funding and technical expertise, helping African governments strengthen their climate services.

Academic institutions and research organisations also contribute to climate services sustainability by advancing climate science and training the next generation of climate experts. The Climate System Analysis Group (CSAG) at the University of Cape Town conducts applied research on climate variability and works closely with policy makers to develop actionable climate services. International research institutions, such as Columbia University's International Research Institute for Climate and Society (IRI), have supported African NMHSs by improving forecast verification techniques and climate impact assessments. These partnerships help to build a strong knowledge base and ensure that African climate services are informed by the latest scientific research.

Civil society organisations and community-based initiatives play a crucial role in translating climate science into actionable insights for local communities. The Red Cross Red Crescent Climate Centre has implemented community-based early warning systems that integrate local knowledge with scientific forecasts, ensuring that early warnings reach vulnerable populations in a timely manner. Similarly, BBC Media Action, with funding from NORAD, has partnered with NMHSs in Kenya, Malawi and Ethiopia

to enhance public understanding of climate forecasts through radio programs in local languages. CARE International's PS approach engages farmers, pastoralists and fishers in co-producing climate information, ensuring that forecasts are relevant to their needs. These grassroots partnerships bridge the gap between climate science and community action, making climate services more accessible and usable for local populations.

However, challenges remain in aligning partner priorities. As one expert noted, "*Donor-driven initiatives often dictate where investments go, rather than aligning with national needs*". To address this, countries must take a leadership role in defining climate service priorities and ensuring partnerships align with national development goals.

Featured initiatives

Case studies illustrate the impacts achieved, including on local communities' resilience and highlight challenges, opportunities and lessons learned from specific interventions across the climate services provision framework.

Digital Transformation of African NMHSs for effective climate services

This initiative focuses on:

- The development of Digital Public Goods to improve Climate Services. It included the agile co-development of four softwares (ClimWeb, CAP Composer, the Automatic Data Loader and Africa Hazards Watch) to strengthen the capacity of NMHSs to provide public services.
- Online mentoring focused on addressing the capacity gaps in Africa's NMHSs.

Key achievements include:

- 50 per cent of countries in Africa (27 countries) having improved their digital presence, and overall service delivery
- Our open-source software developed alongside 16 software packages to strengthen climate services across the value chain (ClimWeb, CAP Composer, Automatic Data Loader, Africa Hazards Watch).
- Significant enhancement in early warning communications, with countries using ClimWeb and the CAP Composer reporting a 2500% increase in the issuance of warnings formatted in the common alerting protocol (CAP).
- Data transmission rates from Africa are imrpoving significantly, with countries such as South Sudan, Seychelles, Togo, Mali, and Chad now sharing observational data internationally for the first time. This progress is the result of targeted support to help countries list their stations on OSCAR/Surface, configure them for international data exchange, install WIS2Box and the Automated Data Loader, and connect their Automatic Weather Stations and broader observing networks to global systems.
- Improvements in NMHSs observing networks and international data sharing from October 20 to May 2025:
- 412 per cent increase in GBON station affiliation — from 257 to 1,315 stations now set to share data internationally.
- 71 per cent increase in stations listed on OSCAR Surface (WMO Observing Systems Capability Analysis and Review) — with an increase of 1436 new stations, from 2,027 to 3463 stations Registering stations on this global system is a crucial step toward improving data transmission.
- 221 per cent increase in the number of countries declaring the minimum required stations to GBON — from 14 to 45 countries.
- These improvements mark a critical first step toward enhanced data transmission and are key to improving global forecasts.
- Overall, dozens of countries that previously lacked a digital presence, had never published warnings, or shared data internationally, have begun doing so—enabled by open-source tools and dedicated mentoring support from NORCAP experts seconded to WMO. This transformation was driven by over 1500 hours of capacity building and co-production with African NMHSs, involving 504 staff members trained through more than 800 online sessions.

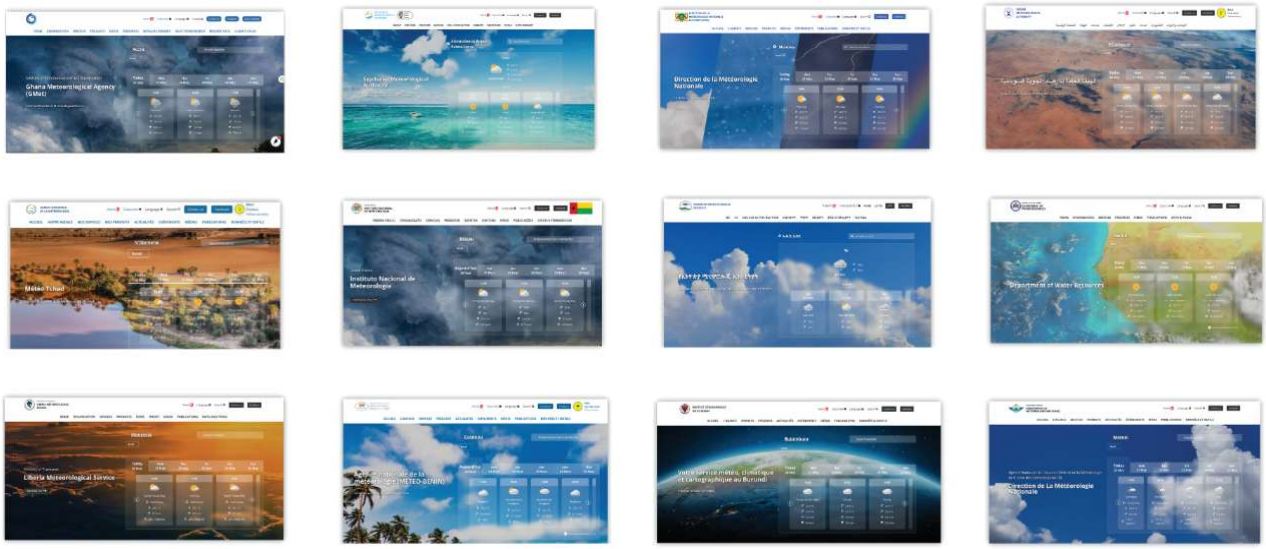


Figure 8: Some of the 27 websites developed as part of the Digital Transformation work

Ghana: https://www.meteo.gov.gh/	Mali: https://www.malimeteo.ml
Seychelles: https://www.meteo.sc/	Zimbabwe: https://www.weatherzw.org.zw/
Malawi: http://www.metmalawi.gov.mw/	Ethiopia: http://www.ethiomet.gov.et
Burundi: https://www.igebu.bi	Togo: https://www.anamet-togo.com/
Chad: https://www.meteotchad.org/	Democratic Republic of Congo: https://www.meteordcongo.cd/
Sudan: https://meteosudan.sd/	Guinea Bissau: www.meteoguinebissau.org
South Sudan: https://meteosouthsudan.com.ss/	The Gambia: https://meteogambia.org/
Niger: https://www.niger-meteo.ne/	Congo: https://dirmet.cg/
Benin: https://www.meteobenin.bj/	Hydrology Department Burkina Faso: https://dgre.gov.bf/
Burkina Faso: https://www.meteoburkina.bf/	Guinea: https://anmeteo.gov.gn/

Table 2: Some of the 27 websites developed as part of the Digital Transformation work

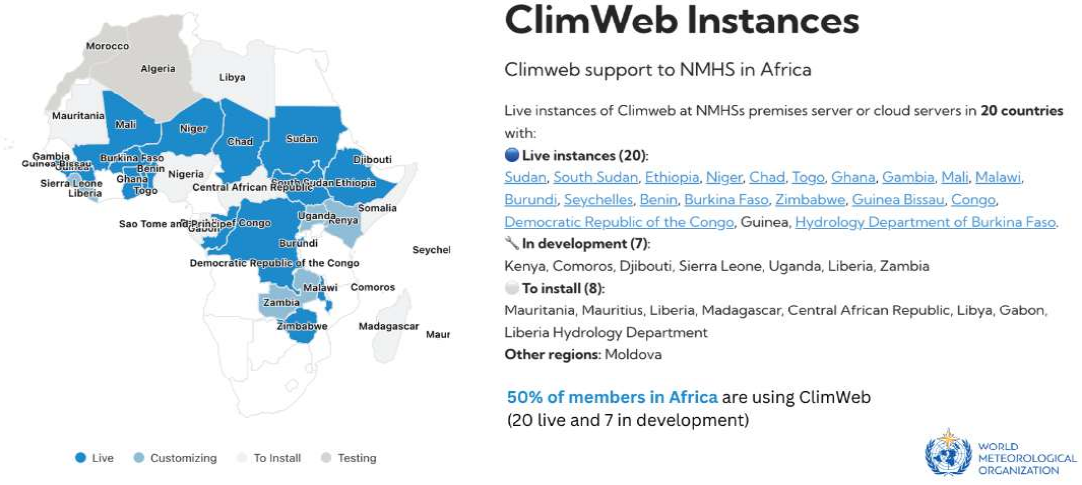


Figure 9: Countries that have a live instance of ClimWeb, the open-source software that allowed improve service delivery

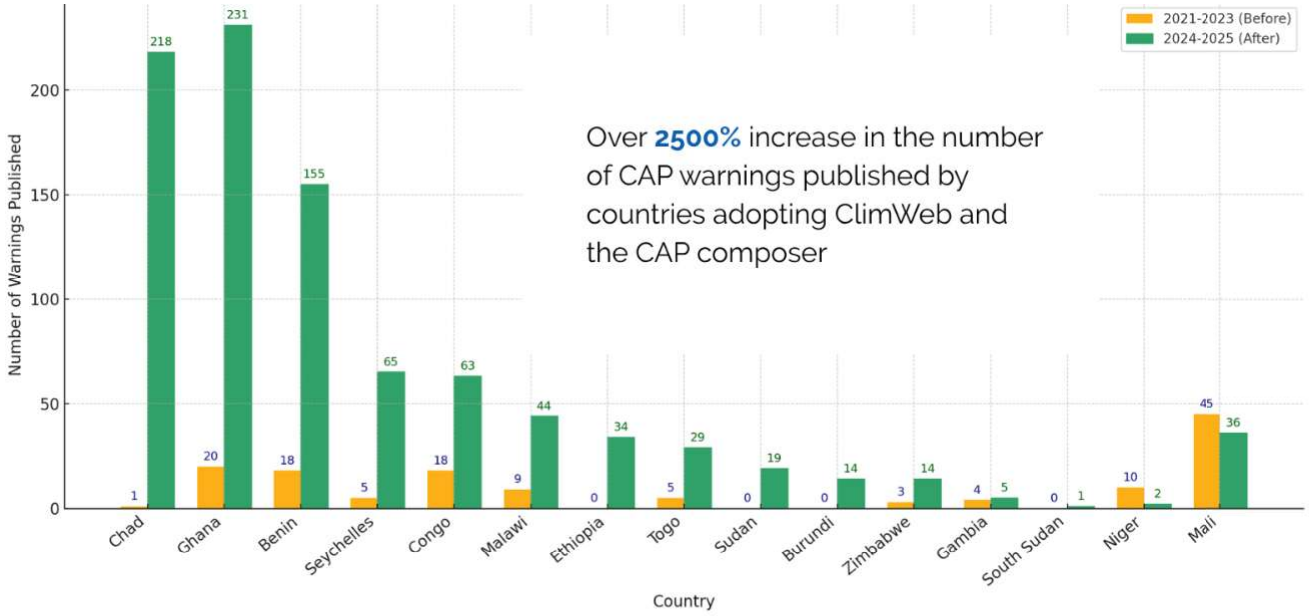


Figure 10: Increase in CAP warnings publisheing. Progression of Countries Publishing Warnings

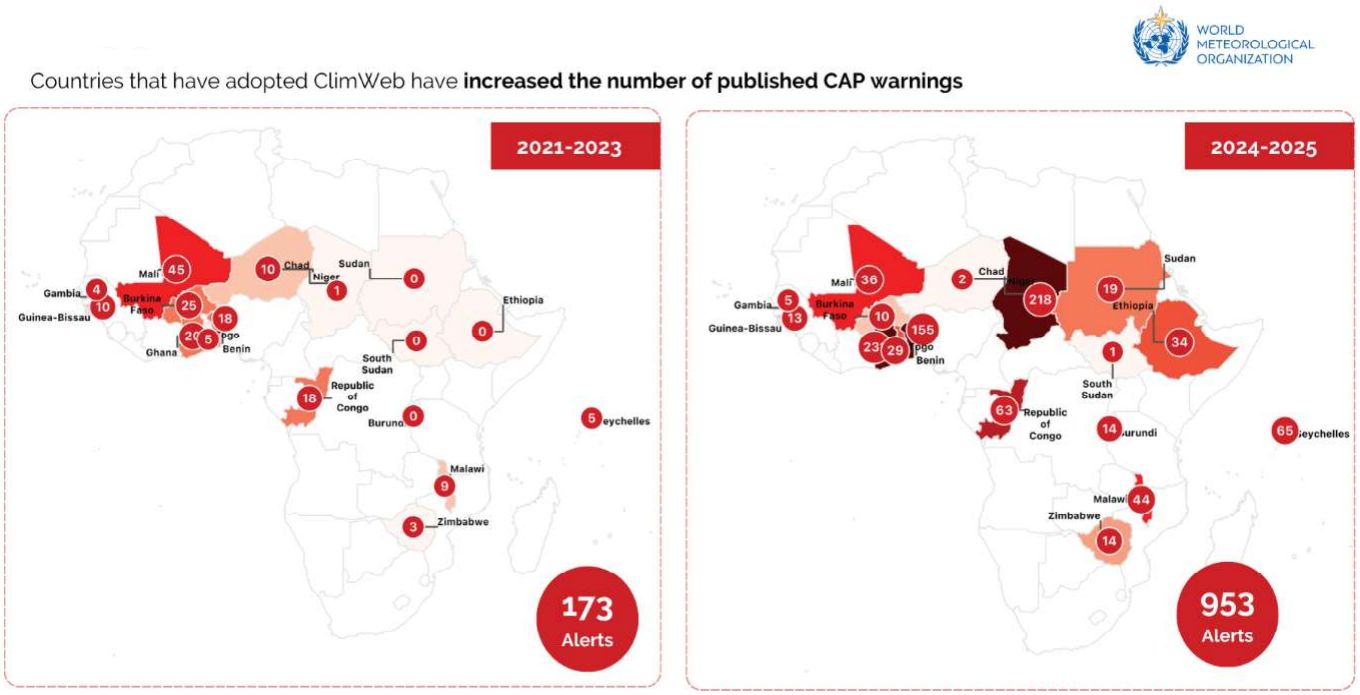


Figure 11: Increase in CAP Warnings publishing. Going global (next in line: Caribean, Moldova)

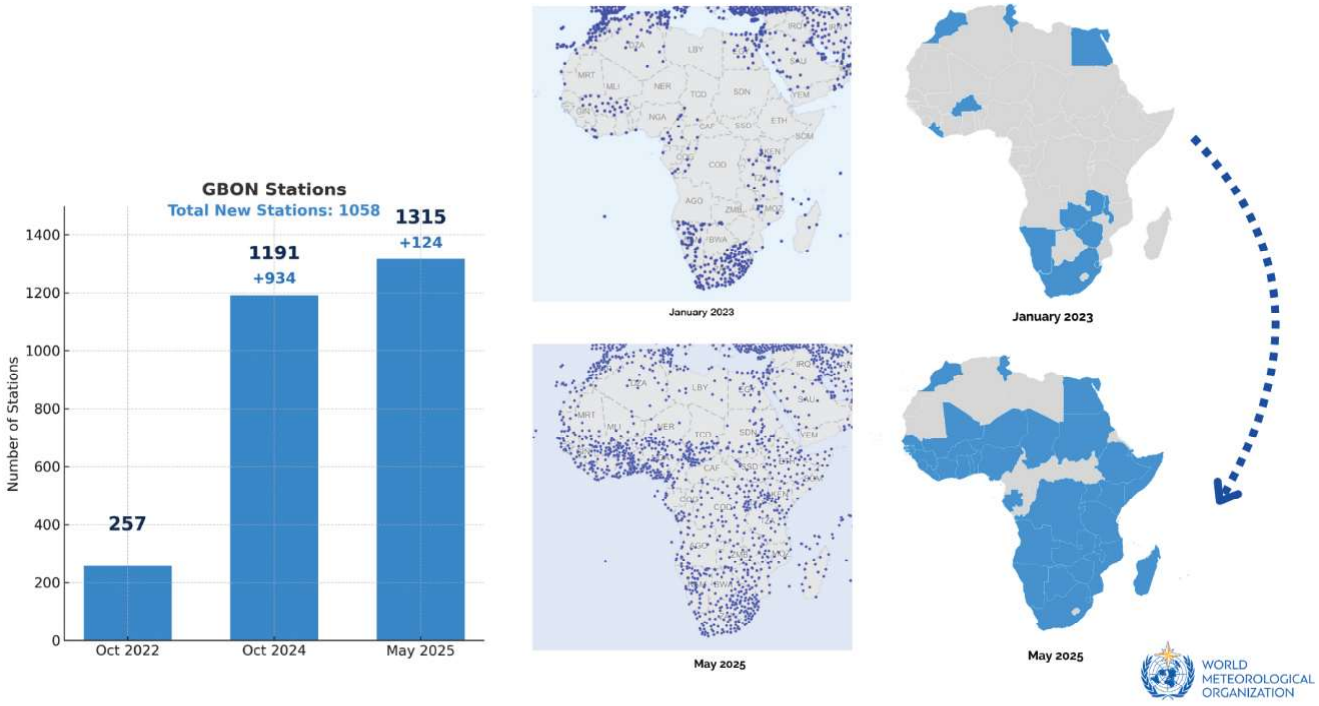


Figure 12: Increase in GBON stations before and after NORCAP's support. These are stations set to transmit data internationally.

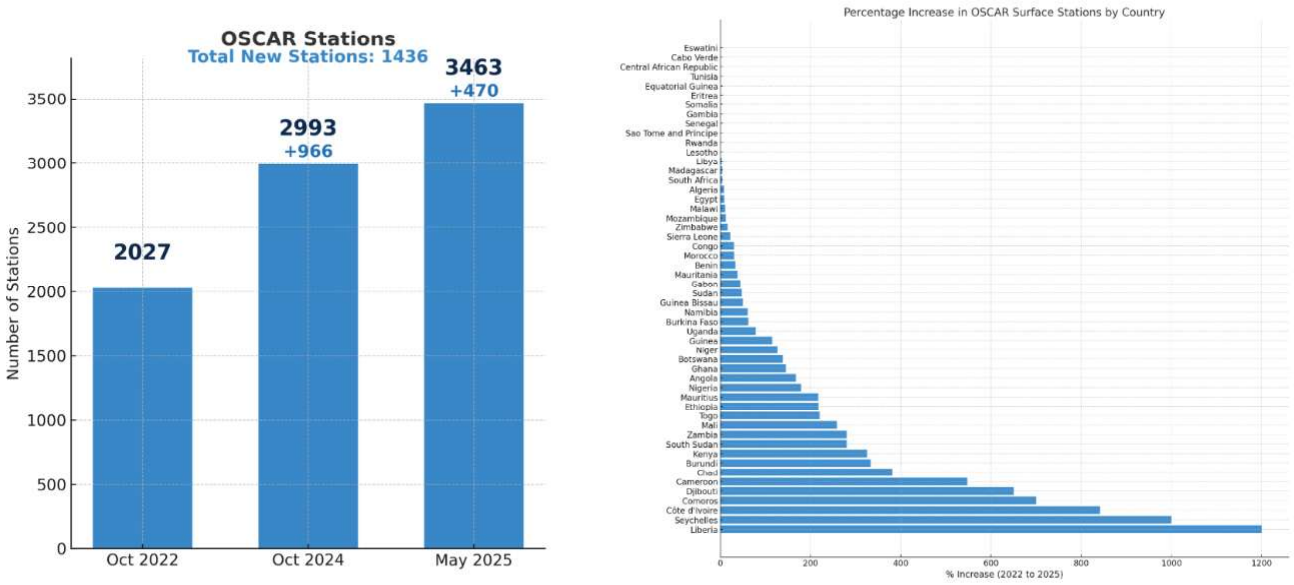


Figure 13: Increase in listing stations on OSCAR surface

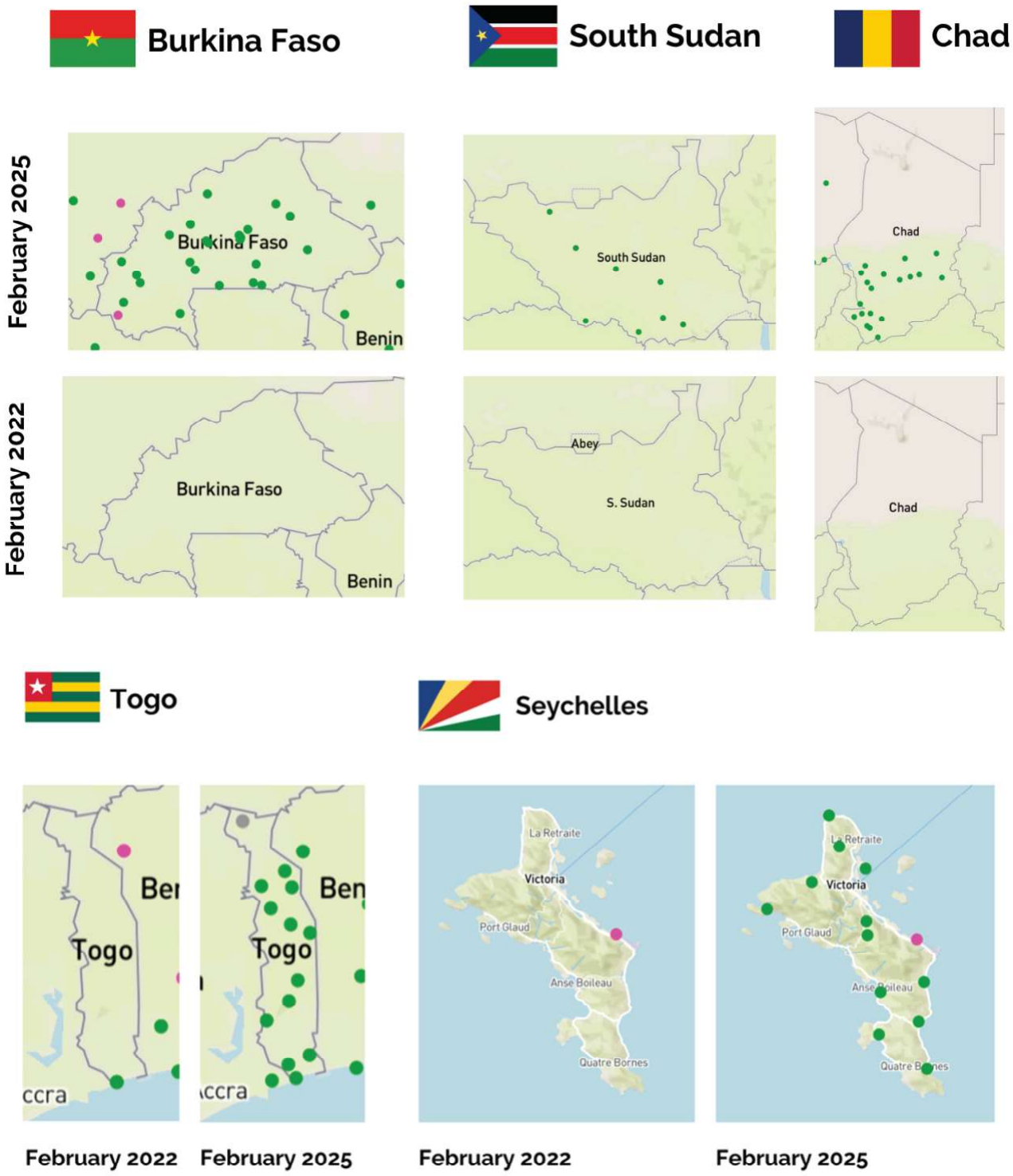


Figure 14: Countries initiating international data exchange in 2024 and 2025 thanks to NORCAP's support. For instance, Chad transmits now real-time data from 19 AWS through the WMO Information System (WIS2.0), enhancing global weather forecasts and supporting international climate data exchange. Before, none of Chad's AWS stations contributed to global data sharing.

Seychelles	https://www.meteo.gov.gh/
Ghana:	https://www.meteo.sc/
South Sudan:	https://meteosouthsudan.com.ss/
Chad:	https://www.meteotchad.org/
Burkina Faso:	https://www.meteoburkina.bf/
Mali:	https://www.malimeteo.ml
Malawi:	http://www.metmalawi.gov.mw/

Table 3: Some of the wis2box instances in countries supported

NMHSs face significant challenges that hinder effective climate service delivery. By January 2024, nearly 30 per cent of NMHSs lacked digital communication platforms. Many NMHSs struggled with limited capacity to assess and integrate software solutions leading to suboptimal service delivery. In January 2024, approximately 37 per cent of African countries had not issued weather warnings in six months, underscoring the inadequacy of warning systems. The majority of countries in Africa had not listed their entire observing network in global systems and most automatic weather stations were not sharing data globally due to software incompatibilities and ICT capacity challenges. Financial constraints further compounded these issues, as reliance on unsustainable funding made proprietary software impractical.

To address these challenges, a multidisciplinary team of NORCAP experts in collaboration with WMO worked over two and a half years to provide mentoring support and developed agile, open-source solutions tailored to NMHS needs across the value chain of climate information services. These digital public goods, such as ClimWeb, a user-friendly content management system for climate services, the CAP Composer, a tool to compose early warnings, the automatic data loader a software a tool that, alongside wis2box supports international data exchange from varied AWS vendors and types, and Africa Hazards Watch, a centralized platform for real-time weather and risk information, were introduced. Capacity-building efforts included over 1,500 hours of training and mentoring, improving the technical expertise of over 500 NMHS staff and enhancing climate services across the value chain. These initiatives not only addressed gaps in digital presence and capacity but also enhanced a scalable, sustainable approach to public service delivery.

The project is achieving significant milestones in advancing climate services across Africa.

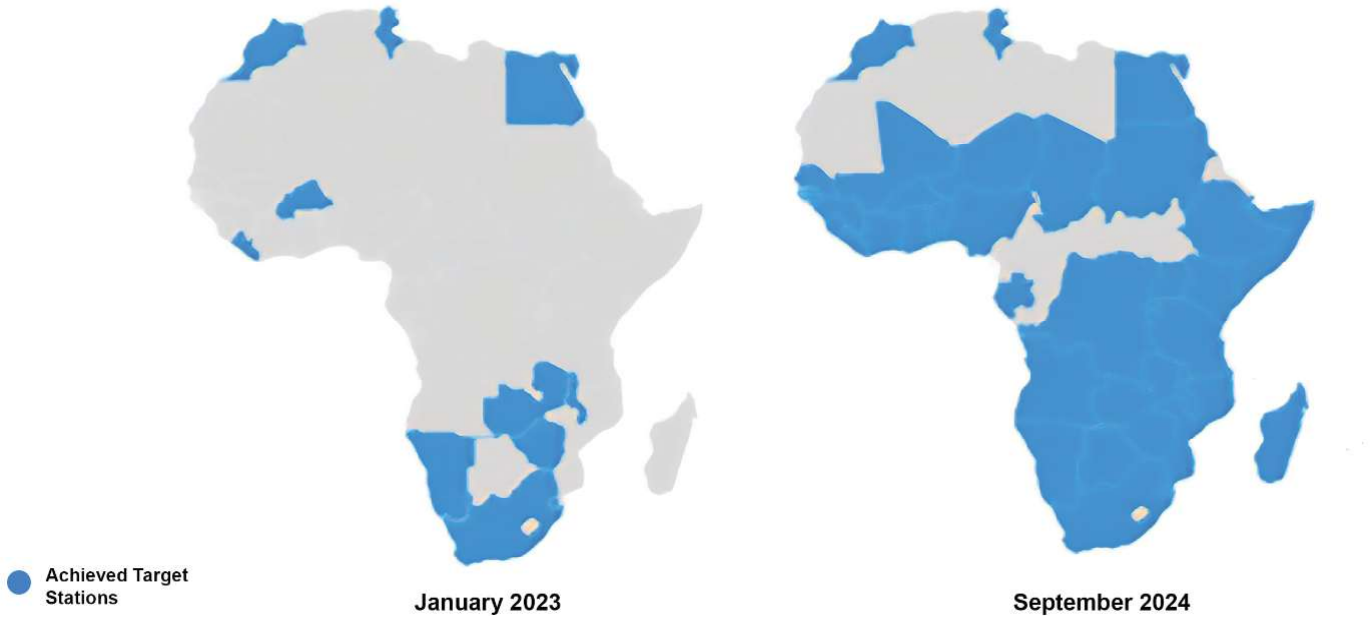


Figure 15: Increase in GBoN Station Designation

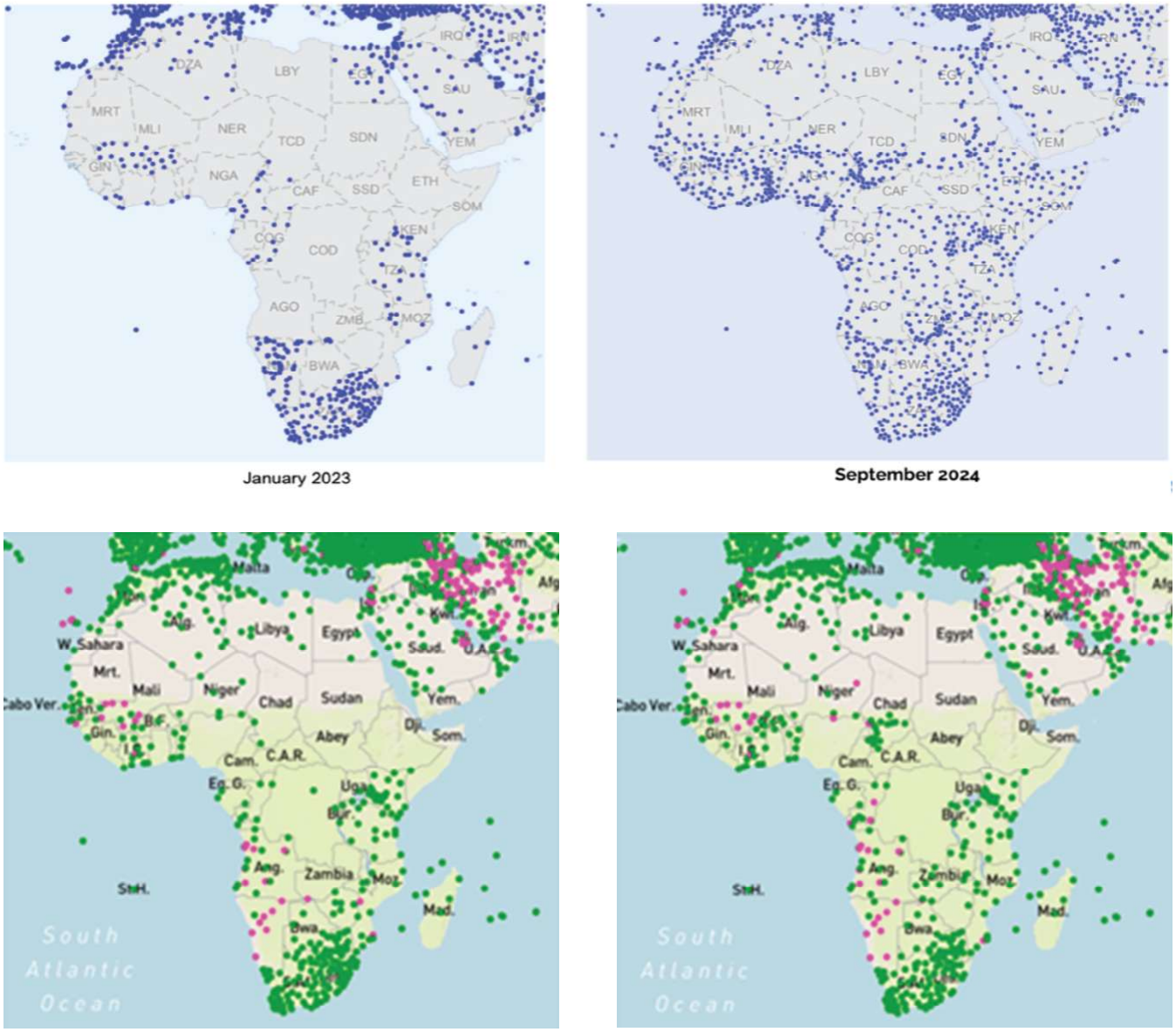


Figure 16: Increase in GBoN Station Designation

Figure 3: Additionally, the adoption of sustainable, open-source tools like ClimWeb, the CAP composer or the Automated Data Loader accelerate progress towards the SDGs and Paris Agreement targets by offering cost-effective, user-cen- tered solutions. These achievements highlight a critical shift in the region towards more robust, inclusive and sustain- able climate services. The tools developed are now being offered to other regions as official WMO Open-Source tools. The early adopters of the CAP composer include the Caribbean countries and Moldova.

Building digital public infrastructure for climate remains a relatively new approach, even within the UN and its member states. A bottom-up strategy for co-developing open-source systems ensures that the needs of governments and communities drive software development, fostering inclusive and scalable solutions. This approach, pioneered by NORCAP, has been particularly impactful in least developed countries (LDCs) and regions with limited resources, where it enhances the delivery of essential public services such as climate services, early warnings and disaster risk manage- ment.

Open-source solutions play a transformative role in climate action, aligning with global frameworks such as the SDGs, the Paris Agreement, the UN Early Warnings for All Initiative and the Sendai Framework for Disaster Risk Reduction. This approach is aligned with the UN Global Digital Compact promoting open, accessible and interoperable digital systems

and contributes to building a more agile UN. By improving access to cost-effective, adaptable digital infrastructure, these tools empower governments to enhance climate resilience, facilitate ecological transitions and build more resilient societies. They help ensure that even the most resource-constrained regions can benefit from high-quali- ty climate information and early warnings.

Digital public infrastructure in climate is key to accelerate implementation of the SDGs, the Paris Agreement and to improve resilience, inclusivity and access to climate information and services.

The initiative highlighted critical lessons for improving climate services in Africa. Co-development with public institutions proved essential to ensure tools align with user needs and achieve widespread adoption. Scalability emerged as a crucial factor, with open-source solutions providing a sustainable pathway for expanding services, especially in resource-constrained environments. Building local capacity through training, alongside the provision of state-of-the-art operational tools was identified as a key driver of long-term sustainability and independence for NMHSs. Additionally, adopting holistic approaches that simultaneously address technical, financial and infrastructural challenges significantly enhanced the overall effectiveness and impact of climate service deliv- ery. These insights underscore the importance of collabo- ration, adaptability and comprehensive strategies for future success.

This piece of work demonstrates the transformative potential of open-source solutions and capacity-building initiatives to address Africa's climate service challenges.

Implementation of national framework of climate services of Niger

The third World Climate Conference, which took place in Geneva in September 2009, introduced the concept of climate services and placed them on the agenda of international climate discussions for the first time. The term climate services cover information on climate change and its effects, provision of data for climate model outputs and the design of more sophisticated products to meet sectoral or individual demand,etc.

A global framework was created to effectively organize the delivery of climate information to all those who need it. It will enable producers, researchers and users to collaborate and increase the quality and volume of climate services available worldwide, particularly in devel- oping countries.

The NFCS is an effective tool in the climatological service helping especially in decision-making likely to improve the resilience of society to climate risks through five priority areas that are: a) disaster risk reduction and manage- ment, b) agriculture and food security, c) water resources, d) health, and e) energy. To improve the resilience of society in the face of climate risks, the NFCS proposes to create a solid climatological knowledge base and estab- lish a national channel linking climate information to action, supported by multidisciplinary working groups in each sector, to facilitate decision-making at the national level. Nevertheless, and although Niger already has a remarkable body of knowledge and systems that could provide a solid basis for the implementation of the NFCS, gaps still exist in the system, which means decision-mak- ers and users do not have sufficient access to climate information to help them make socio-economic decisions.

The need for climate services has been identified in dialogue between users and providers of meteorological information, but it is not of the same nature. For the agriculture sector, for example, technicians in the sector have requested information on the number of expected rainy days during the season, the start and end dates of the season as well as forecasts on pockets of drought, extreme rainfall and temperature. With such information, technicians can develop agrometeorological advice on preferred dates of sowing, daily monitoring of locust and forecasts of pastures for the benefit of rural communi- ties.

Action. NFCS implementation process in Niger started in August 2012 with a broad stakeholder consultation workshop, which resulted in a roadmap. Similarly, an action plan for the implementation of the NFCS was developed in late 2013 and early 2014 whose validation was an inclu- sive and participatory process.

The year 2016 was one of preparation for the implementation of the NFCS of Niger with the elaboration and valida- tion of the texts of creation, the designation of the sectoral focal points and the formulation of a first project to support the implementation.

From 2017 and 2018, the NFCS's order was signed, the meeting of sector focal points, the official launch of NFCS activities and the resource mobilization process: development of a regional program - GFC

From 2020, the activities of the thematic groups of the framework are implemented each year with the produc- tion of several bulletins.

Thus, it should be noted that throughout this process of implementation of the NFCS in Niger, NORCAP provided technical support through assignment of several experts. The experts contributed significantly to the design, preparation and implementation of activities up to now.

"During my deployment as a NORCAP Expert to the DMN, I was also fully engrossed in the implementation of the activities of the National Framework for Climate Services in Niger. My role was to prepare the meetings of the thematic groups, facilitate the meetings of these groups, consolidate the contents of the validated bulletins, proofread the contents after the montage of the bulletins, seek funding for the activities of the NFCS etc". Reflections of a NORCAP Expert.

The communication component was supported by NORCAP experts who supported the establishment of a strategy for reaching the public through NFCS newsletters.

The role of NORCAP through its experts was crucial and has now made it possible to name Niger among the countries with solid experience in implementing the National Framework for Climate Services.

The national framework for climate services in Niger has enabled:

- Production and dissemination of climate information to users of five thematic sectors and targeted advisories delivered to
- Sharing relevant recommendations to end-users.
- Dissemination of NFCS's thematic bulletins content in local languages.
- Increased decision-making assistance for users including policy makers, researchers, farmers, farmers' organisations and resilience of society in general and the agricultural sector in particular to climate extremes.
- Better use of climate information for crop monitoring, to prevent imminent extreme events (extreme rains and rainfall breaks) during the season for example Participatory Integrated Climate Services for Agriculture (PICSA), helping farmers use local climate data for decision-making.
- Dissemination of warnings on the risks of occurrence of extreme weather/climate phenomena.
- Capacity building and awareness raising, coupled with widely disseminated and understood seasonal forecasts, improved the capacity of the health sector to plan more effectively for potential weather/climate events that may have a health impact.
- Improving access to accurate and reliable climate information.

Some issues that need to be addressed when implementing the NFCS in Niger are:

- Insufficient financial resources to carry out activities during the year.
- The delay in data availability for the production of thematic newsletters.
- Diversification of financial partners beyond WFP.
- Dissemination of NFCS's thematic bulletins content in others local languages.

Discussion and conclusion

The findings of this analysis highlight the multifaceted challenges and opportunities in delivering climate services across Africa. NORCAP's efforts to enhance capacity by providing targeted expertise, coordination and technical training aligns closely with the broader objectives of increasing climate resilience. The analysis reveals significant systemic gaps, including insufficient tailoring of services for last-mile users, limited infrastructure and financial constraints. These findings emphasize the need for a participatory design process to align climate services with user needs, as those advocated by Hewitt et al. (2020).

The challenges identified range from outdated equipment to fragmented coordination mirror global issues in low-resource settings. For instance, Tall et al. (2018) highlighted th works, a key gap also noted in this study. However, findings also suggest potential solutions, such as leveraging low-cost sensor networks seen in countries like Bangladesh, to address Africa's infrastructural deficits.

Regional disparities further complicate service delivery. RCCs like ICPAC have demonstrated advanced capabilities in seasonal forecasting, while others, such as ECCAS, struggle with limited infrastructure and resources. Such discrepancies highlight the urgent need for harmonized frameworks to equalize capacity across regions. The ACOF exemplifies effective regional collaboration, promoting consensus on methodologies and promoting technical knowledge sharing among RCCs. Yet, as noted by a respondent, "*The real challenge lies not just in collecting data but in translating it into actionable insights for the most vulnerable*". This stresses the critical role of user-centered approaches in enhancing the utility of climate services.

The study also identifies barriers to data sharing, a persistent issue exacerbated by IP concerns and inadequate protocols. The reluctance of NMHSs to share datasets diminishes forecast accuracy and limits transboundary collaboration. As ACMAD emphasized, "*Countries are hesitant to use APIs or share datasets, fearing loss of control over their information*". Harmonizing data-sharing frameworks, as proposed by GFCS, could resolve these inefficiencies and enhance regional integration.

Emerging priorities, such as integrating climate services with health systems, peacebuilding and advanced technologies like AI reflect a forward-looking approach to addressing Africa's unique challenges. For example, seasonal forecasts linked to malaria prevention campaigns in East Africa demonstrate the life-saving potential of such integrations. However, the study highlights the need for investments in training and infrastructure to maximize the benefits of these innovations. Gender mainstreaming emerged as a critical yet underexplored priority. As one expert noted, "We included women farmers in focus group discussions to co-design agro-climatic advisories that reflect their unique challenges". Ensuring equitable access to climate information, particularly for women in rural areas, can significantly enhance community resilience.

The findings also emphasize the importance of sustainable funding mechanisms. The current reliance on project-based donor funding undermines long-term planning and systemic change. Innovative models, such as public-private partnerships and blended finance, present viable alternatives for diversifying funding sources. Aligning donor priorities with ground-level needs, as highlighted in this study, is key in advancing impactful interventions.

In conclusion, the case study provides critical insights into the systemic gaps, regional disparities, and emerging opportunities in Africa's climate service landscape. While the challenges are significant, the findings offer actionable pathways for improvement. Future work should focus on evaluating the impact of integrated approaches, particularly in health and gender mainstreaming, and exploring innovative funding models to ensure the sustainability of climate services. Addressing these gaps requires a coordinated effort across regional, national and global levels, prioritizing user-centered, inclusive and sustainable solutions.

Recommendations

This section is based on both the results and the respondents feedback, highlighting both general aspects to be considered by different stakeholders to strengthen the climate service delivery in Africa.

Recommendations for policy makers

- Policymakers should integrate climate services into National Adaptation Plans (NAPs) and DRR strategies. Integrating these services into national frameworks aligns them with broader sustainable development goals and secures funding for long-term climate resilience. For example, successful interventions like PSP should transition from pilot phases to national rollouts, supported by government budgets. Proven initiatives should be taken up and integrated into annual government activities

- Develop and enforce legislation that supports data-sharing protocols, intellectual property rights and clear mandates for NMHSs, RCCs and other stakeholders. This would enable seamless collaboration, improve coordination and enhance the reliability of climate information. Clear legal frameworks will also address barriers such as reluctance to share data, ensuring broader participation and equity in climate service delivery.

- Decentralize climate services and empower sub-national governments to establish participatory platforms for decision-making and last-mile delivery of climate services. Decentralization ensures inclusivity, particularly for vulnerable and rural communities, and allows for tailored interventions that meet local needs. "*Decentralized platforms bridge gaps and ensure decisions are informed by local contexts,*" emphasized one respondent.

- Lobbying and advocating for government buy-in and ownership of climate service initiatives. Pilot projects funded by external donors should serve as proof of concept to secure national budget allocations. Policymakers should design projects aligned with the priorities and needs of specific regions, increasing their likelihood of adoption by governments. "*Lobbying for government support ensures that successful interventions are sustained beyond the project lifecycle,*" as noted by a respondent.

- Create policies that incentivize private sector investment in climate services through PPPs. These policies could include tax breaks for private companies co-financing weather stations, data-sharing platforms or technological innovations such as mobile applications for last-mile dissemination.

Recommendations for development partners

- Transition from project-based funding to multi-year, flexible funding models to support the continuity of NMHS operations and infrastructure development. Project-based funding cycles limit the ability to establish long-term solutions.

- Align funding priorities with local needs and collaborate with NMHSs and RCCs to ensure proposals are demand-driven and context-specific, addressing actual gaps in climate service delivery.

Strengthening climate services through strategic partnerships

- Encourage PPPs to facilitate partnerships between public institutions and private entities to co-finance infrastructure, data platforms, and emerging technologies.
- Invest in modernizing meteorological infrastructure, including automated weather stations, satellite data reception and radar systems to improve data accuracy and accessibility.
- Establish multi-donor trust funds for climate services, which allow NMHSs to access predictable, long-term financing instead of relying on fragmented short-term donor projects.
- Establish regular dialogues among donors, regional climate centers and national governments to align funding priorities and reduce duplication.
- Fund efforts to translate climate advisories into local languages and use multiple dissemination channels (radio, SMS, social media and community meetings) to support translation and local dissemination.

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