WORLD
METEOROLOGICAL
ORGANIZATION

ClimSA

INTRA-ACP CLIMATE SERVICES AND RELATED APPLICATIONS PROGRAMME

An initiative of the Organisation of African, Caribbean and Pacific States funded by the European Union

Workshop on Strategic and Implementation Planning for Sustainable Observations

13-16 April 2026

Pretoria, South Africa

Technical Report

Funded by
the European Union

This document was produced with the financial assistance of the European Union. The views expressed herein can in no way be taken to reflect the official opinion of the European Union.

Contents

1. Background

National Meteorological and Hydrological Services (NMHSs) play a critical role in supporting societies to manage risks, adapt to climate change, and promote sustainable development. To fulfill this role, countries require a strategic approach to the planning, operation, and modernization of their observing systems. The development of a National Observing Strategy provides such a framework together with proper implementation and operation plans, ensuring that national observing networks are demand-driven, cost-effective, and aligned with global standards under the WMO Integrated Global Observing System (WIGOS).

The Strategy serves as a guiding framework for NMHSs and their national partners to address the needs of all data users across the atmospheric, marine, hydrological, and cryospheric domains while simultaneously strengthening their ability to plan investments in systems, science, and people. It also creates opportunities to establish effective partnerships that allow for shared infrastructure and knowledge, while ensuring that observing systems remain robust, sustainable, and environmentally responsible.

A well-developed National Observing Strategy together with implementation and operations plans positions the NMHS as a strategic national asset, essential for the security of transport, food, water, energy, and health—pillars of the Global Framework for Climate Services (GFCS), contributing to climate adaptation and mitigation, and sustainable development goals. It also strengthens the contribution of the NMHS to the safety of their people through disaster risk reduction, including through the UN Early Warning for All (EW4All) initiative.

At the same time, aligning the Strategy with WMO technical regulations and exploring innovative, sustainable technologies—such as renewable energy sources, reusable infrastructure, and environmentally friendly materials—will help countries build resilient, future-ready observation networks.

The workshop was conducted as part of the ClimSA Project Task 3.1 which aims to strengthen climate observing network, and support ClimSA focus countries in developing national strategic plans for sustainable observation networks.

The implementation of Task 3.1 was carried out through the workshop on Strategic and Implementation Planning for Sustainable Observations, which helped focus countries enhance their understating of the WIGOS Framework, GBON and RBON principles, remote sensing network design, innovative monitoring solutions as well as step-by-step methodology, vision, strategic axes, KPIs, for strategic planning for observation.

Additional activities under output 3.1 were carried out in some focus countries. E.g. development of National Maintenance Plan in Burkina Faso and Cameroon, assessment report on existing gaps in climate observing networks and climate services in Samoa, Jamaica, Kenya, Angola, Burkina Faso and Cameroon as well as additional activities related to enhancing international and national exchange of data and metadata in Burkina Faso and Cameroon while assisting with WIS2.0 implementation at the national level. Discussions and activities were initiated with Mauritius, Comoros, Seychelles and Madagascar mainly for the development of a national WIGOS implementation plan and WIS2Box installation.

As part of ClimSA Project Tasks 4.3 and 5.1, countries' testimonies on observation networks were recorded during the workshop, with the goal of publishing them on the ClimSA Knowledge Platform promoting knowledge sharing among ClimSA focus countries.

2. Objective of the Workshop

The workshop provided a platform for NMHSs and stakeholders to:

- Review key principles for developing National Observing Strategies and National WIGOS Implementation plans;
- Exchange experiences and best practices;

- Identify opportunities for innovative and sustainable observing solutions;
- Share views on applicability and impact of the available related guidance material (e.g. WIGOS Guide) to be compliant with WMO's technical regulations
- Foster collaboration at the national, regional, and global levels
- Enhance partnership and promote data and metadata acquisition and sharing.
- Review national operations and maintenance plans to ensure reliability and sustainability of observational systems.
- Record countries testimonies and collect information for the ClimSA Knowledge Platform

Through this collective effort, NMHSs will be better positioned to meet evolving user requirements and ensure that their observing systems contribute effectively to national priorities as well as to global initiatives such as WIGOS, GFCS, and EW4ALL.

3. Workshop Opening Ceremony

In the welcome remarks, the Chief Executive Officer of the South African Weather Service (SAWS) warmly welcomed participants attending both in person and online, and expressed appreciation for hosting the workshop under the ClimSA Programme. He emphasized the shared commitment of participants to strengthening climate services and ensuring that observing systems remain fit for purpose in a rapidly changing climate.

The remarks highlighted the urgency of the workshop in light of the latest WMO State of the Global Climate report, which confirms that the Earth's climate system is increasingly out of balance. Particular attention was drawn to the disproportionate impacts of extreme weather events—such as floods, droughts, and tropical cyclones—on African, Caribbean, and Pacific countries, despite their limited contribution to global greenhouse gas emissions. This context underscored both a moral and practical responsibility for coordinated and purposeful action.

The speaker stressed that observations are the foundation of effective meteorological and environmental services, enabling credible forecasts, early warnings, and informed decision-making. He highlighted the importance of National Observing Strategies and associated implementation and operation and maintenance plans as key instruments for guiding investments, prioritizing actions in resource-constrained environments, and ensuring alignment with global standards. WIGOS was presented as a powerful integrated framework, while noting that its success depends on effective national implementation, integration of observing networks, and strong collaboration across institutions and sectors.

The remarks further emphasized the critical role of partnerships, regional cooperation, and shared responsibility in addressing transboundary climate challenges. The ClimSA Programme was recognized for its achievements in capacity building, stakeholder engagement, and support for data exchange and best practices across the ACP regions.

The speaker concluded by encouraging participants to engage actively, embrace innovation, strengthen collaboration, and use the workshop as an opportunity to reinforce partnerships and advance a shared vision for resilient and sustainable climate services.

In his opening remarks, the Director of WIGOS emphasized the central role of the WMO Integrated Global Observing System as the unifying framework for all WMO observing systems, supporting an integrated and modernized approach to surface- and space-based observations. He highlighted the contribution of the ClimSA Programme in strengthening national and regional observation and monitoring capacities, improving data exchange, and reinforcing the climate services value chain across beneficiary countries.

The address underlined the critical role of NMHSs in managing climate risks, supporting disaster risk reduction, and enabling climate adaptation and sustainable development. Participants were encouraged to develop comprehensive National Observing Strategies, complemented by implementation and operation and maintenance plans, aligned with WMO technical regulations, national priorities, and global initiatives such as the Global Framework for Climate Services and the

Early Warnings for All initiative. The workshop was presented as a key opportunity to strengthen understanding of WIGOS principles, support the review and development of national strategies, and foster collaboration among NMHSs, WMO regional centres, and partners toward more resilient, sustainable, and harmonized observing systems.

Finally, the ClimSA Project Manager within WMO outlined in his opening remarks the purpose of the workshop within the broader context of the ClimSA Programme, which has been supporting beneficiary countries since its design in 2016, in alignment with the pillars of the Global Framework for Climate Services (GFCS). He highlighted that the programme delivers extensive support to focus countries and Regional Climate Centres through a large portfolio of activities aimed at strengthening climate services systems, including observation, data exchange, and capacity development.

He emphasized that the workshop represents a key milestone in the project's final phase, particularly in supporting the development of sustainable national observing strategies and implementation plans. Appreciation was expressed to the South African Weather Service for hosting the workshop and to colleagues across the WMO Secretariat and regional offices for their collective efforts in delivering the project's activities, despite challenges such as COVID-19-related delays and changing country participation.

The remarks also highlighted the importance of documenting and consolidating results achieved under ClimSA, including the preparation of country-focused reports capturing good practices, progress made, and remaining gaps. These outputs were presented as valuable inputs for future initiatives and continued collaboration. The Project Manager encouraged participants to actively engage in the workshop discussions, contribute to knowledge-sharing efforts, and support the timely completion of project deliverables, noting that the workshop plays a central role in ensuring a strong and sustainable legacy for ClimSA.

4. Structure and programme of the Workshop

The workshop was designed to provide both a solid conceptual foundation and practical guidance for the development and implementation of National Observing Strategies, ensuring that participants are able to translate principles into actionable national plans, particularly for WIGOS implementation and for operations and maintenance. It adopted a hybrid format to maximize accessibility and participation, combining in-person sessions with online engagement.

The workshop programme (Annex 1) began with two online sessions during which each ClimSA focus country presented the status of its observing networks, including aspects related to strategic planning, available human resources, and resources dedicated to maintenance and calibration. The presentations highlighted key challenges and existing opportunities. The information shared proved valuable in shaping the workshop content, including the technical presentations and practical exercises.

The in-person workshop, held in Pretoria, was structured around two main parts. The first part focused on establishing the technical and strategic context. It included an overview of national WIGOS implementation principles and guidance, presentations on key elements of the WMO guidelines for hydrometeorological networks design—covering surface-based observing systems and weather radars—and a review of relevant WMO Technical Regulations.

Practical case studies from Australia, Switzerland, the United Kingdom, and the Weather Ready Pacific programme of the Secretariat of the Pacific Regional Environment Programme were presented to illustrate how countries and regional organizations have approached strategic planning for observations, and how innovative, sustainable, and cost-effective solutions have been successfully implemented.

The second part of the workshop was dedicated to the review and/or development of national observing strategies, building on existing plans within the beneficiary countries. Participants were guided through the core WIGOS principles and key components of such strategies, with a particular emphasis on ensuring alignment with the vision of the NMHSs and national development priorities.

Special attention was given to the preparation of national operation and maintenance plans, which are essential for the long-term sustainability of observing systems.

To support this work, a range of practical tools was introduced to facilitate a comprehensive (360-degree) assessment of user requirements for hydrometeorological observations, the identification of challenges, and the evaluation of strengths, opportunities, threats, needs, and stakeholder expectations. Step-by-step methodologies and standardized templates were presented, enabling participants to develop initial drafts of national observing strategies tailored to their specific country contexts.

Particular emphasis was placed on the sustainability of national observing networks. Key challenges were identified, and relevant WMO guidance on operations and maintenance was presented, supported by national case studies. An outline for the development of national operation and maintenance plans was provided and used as a basis for participants to draft context-specific plans.

Discussions also explored approaches to integrating user requirements, strengthening partnerships with relevant stakeholders, and ensuring that national strategies remain responsive to evolving global and regional initiatives.

In summary, the overall objectives of the workshop encompassed

1. To strengthen participants' understanding of WIGOS principles and WMO guidelines for planning, implementing and operating WIGOS.
2. To support the review of relevant existing strategic and operating plans, through examples from other countries.
3. To facilitate dialogue on the drafting of strategic and operating plans, taking into consideration the WIGOS principles and WMO guidelines.
4. To facilitate dialogue and collaboration between NMHSs of the ClimSA focus countries and relevant WMO regional centres, and other partners, thereby promoting a harmonized approach to observation planning and capacity development.

   By the end of the workshop, participants had a clear roadmap for advancing national strategic and implementation planning for sustainable observing systems, supported by practical insights and resources that can be readily applied within their respective institutional and national contexts.

5. Target Audience

The primary target audience comprised mid- to senior-level representatives from the NMHSs of ClimSA focus countries. Each country nominated at least two participants to attend the workshop in person. Participants included NMHS managers responsible for observing system management, officers in charge of network operations and maintenance, as well as national hydrological advisers or hydrological network managers.

The secondary target audience, invited to participate remotely, consisted of technical staff directly involved in the management, operation, and maintenance of observing networks.

The workshop brought together approximately 25 participants (see Annex 2) from several ClimSA focus countries, including Angola, Burkina Faso, Cameroon, Comoros, Jamaica, Kenya, Madagascar, Mauritius, and Seychelles.

The workshop was delivered by experts from the WMO Secretariat, the Direction Générale de la Météorologie (DGM) of Morocco, and the South African Weather Service (SAWS), who facilitated and led the technical sessions.

6. National presentations

6.1. Context and Objectives of the National Presentations

As part of the preparatory phase for the training workshop on *strategic planning and implementation for sustainable observing systems*, the nine ClimSA focus countries, along with selected hydrological advisors, delivered structured national presentations. These presentations followed a common template and aimed to provide a comprehensive assessment of the current status of national observing systems. They covered key dimensions including the composition and performance of observing networks, governance and institutional arrangements, key operational challenges, opportunities for improvement, and lessons learned from ongoing and past projects. This collective exercise enabled a comparative analysis across countries and helped identify both common constraints and emerging good practices.

6.2. Diversity and Evolution of Observing Networks

The presentations highlighted a high degree of heterogeneity in the design, density, and level of automation of observing networks across NMHSs. While some countries still rely heavily on manual observation systems, including rain gauge networks and staffed synoptic stations, others have made significant progress toward automated observing systems, particularly through the deployment of Automatic Weather Stations (AWS). However, the coexistence of manual and automated systems often remains poorly integrated, with limited interoperability and coordination between the different components.

A key trend identified across countries is the transition from a situation characterized by scarcity of observations to one increasingly defined by expanding infrastructure and growing volumes of data. Despite this progress, important operational limitations persist. A significant proportion of stations—often estimated at around one-third or more—are non-functional at any given time, reflecting persistent issues related to maintenance, logistics, and resource constraints. In addition, the spatial distribution of observing stations remains uneven, with relatively dense coverage in accessible regions and substantial gaps in remote or underserved areas, limiting the representativeness of national observations.

At the same time, important gaps remain in complementary systems such as weather radar networks and marine observations, which are critical for strengthening forecasting capabilities and early warning systems. However, several ongoing and planned initiatives are expected to partially address these deficiencies and support further modernization of national observing systems.

6.3. Governance, Institutional Arrangements, and Coordination Mechanisms

The institutional and governance frameworks underpinning observing systems vary considerably across countries. In some NMHSs, dedicated and clearly defined units are responsible for the management, maintenance, and operation of observing networks. These structures generally benefit from better coordination with procurement, logistics, and IT services, resulting in more efficient and streamlined operations.

In contrast, other countries operate under less formalized arrangements where responsibilities are fragmented across multiple departments, such as climatology, forecasting, and operations. In these cases, the absence of clearly designated roles often leads to inefficiencies, duplication of effort, and reduced accountability. A recurrent issue raised during the presentations was the lack of coordination between IT units and technical teams responsible for observing systems, which negatively impacts system performance, data management, and operational continuity.

More broadly, several institutional constraints were identified, including weak legal and regulatory frameworks, limited institutional authority of NMHSs, and restrictions affecting data sharing and exchange. Administrative bottlenecks and delays further complicate implementation processes, while misalignment between externally funded projects and national priorities can undermine long-term sustainability.

6.4. Key Challenges Affecting the Sustainability of Observing Networks

The national presentations converged on a set of recurring challenges that significantly affect the sustainability and performance of observing systems.

From a financial perspective, limited and unstable funding remains a major constraint. Many NMHSs rely heavily on external donor support, which introduces uncertainty and limits long-term planning.

Procurement processes are often lengthy and complex, and funding for essential activities such as maintenance, calibration, and spare parts is insufficient, posing a risk to the continuity of operations.

Infrastructure-related challenges are also prominent. These include aging equipment, limited availability of suitable sites due to urbanization and land-use constraints, unreliable communication networks, and unstable power supply. The lack of redundancy in IT systems further increases vulnerability to disruptions. In parallel, maintenance and logistics constraints—including shortages of spare parts, absence of maintenance contracts, and limited field mobility—contribute to delays in repairs and prolonged station downtime.

Human resource limitations constitute another critical constraint. Many NMHSs face a shortage of qualified technical personnel, coupled with insufficient training in key areas such as installation, calibration, and data management. Resistance to technological change, particularly in the transition from manual to automated systems, was also reported. This situation is compounded by the lack of structured IT support and the need for continuous skills development in emerging fields such as digital technologies and artificial intelligence.

In terms of data management, participants reported weak data management systems, persistent quality issues, and limited IT infrastructure. Challenges related to data exchange with global systems such as WIS and GBON were also highlighted, alongside growing concerns regarding cybersecurity risks associated with increased digitalization. Additionally, security issues, including vandalism and theft of equipment—particularly in remote locations—represent a significant operational risk, affecting both data availability and infrastructure sustainability.

6.5. Hydrological Observations: Specific Challenges and Opportunities

Hydrological observing networks face similar structural and operational challenges. While in some cases sufficient funding is available for network expansion, maintenance of existing stations remains inadequate, and supporting observers in remote locations is often difficult. Furthermore, IT infrastructure is frequently insufficient to support real-time data collection, centralization, and integration into hydrological models and early warning systems.

At the same time, several opportunities were identified, including the development of regional approaches and transboundary cooperation, access to regional funding mechanisms, and the adoption of innovative technologies to improve monitoring efficiency and reduce vandalism risks. Emerging approaches such as spatial hydrology, which allows for effective monitoring with fewer ground stations, were also highlighted as promising solutions.

6.6. Achievements and Added Value of Projects

Despite the challenges, the presentations emphasized the significant progress achieved through various national, regional, and international projects. These initiatives have contributed to the expansion and modernization of observing networks, including the deployment of AWS, radar systems, and marine observation platforms. They have also improved spatial coverage and reduced data gaps, particularly in previously underserved regions.

In addition, projects have strengthened the technical capacity of NMHS staff through targeted training and have facilitated better integration into global frameworks such as WIGOS and WIS2.0. Increased support from international initiatives has also enhanced access to funding and technical resources. In some cases, structured handover processes have supported greater national ownership and sustainability of project outcomes.

6.7. Lessons Learned from Implementation of Projects

The experience gained from project implementation has highlighted several critical lessons. A recurring concern is the limited involvement of NMHSs during the design phase of projects, which can lead to misalignment between project objectives and national priorities. Procurement constraints, including supplier restrictions and cost-driven approaches, may compromise the quality and suitability of equipment.

Other challenges include lack of standardization, weak knowledge transfer, and continued dependence on external expertise. In some cases, insufficient attention to legal and administrative aspects—such as land ownership or station hosting agreements—has created difficulties during implementation. These issues underscore the importance of ensuring stronger national ownership and better integration of projects into national systems.

6.8. Recommendations and Way Forward

To enhance the sustainability and effectiveness of observing systems, participants identified several priority actions. These include strengthening sustainable financing mechanisms, improving procurement processes, and accelerating the modernization of infrastructure and IT systems. Equally important is the need to invest in human capital development, including training, recruitment, and workforce planning.

Improvements in data management, quality control, and exchange frameworks are also essential, along with the reinforcement of governance structures and institutional mandates. Expanding partnerships—with both public and private stakeholders—and promoting regional cooperation were identified as key enablers for resource mobilization and knowledge sharing. Finally, greater attention should be given to risk management, resilience, and security measures to ensure the long-term sustainability of observing systems.

6.9. Emerging Good Practices and Innovations

Finally, the presentations highlighted emerging best practices that could be scaled up across countries. These include the adoption of tiered network designs to enhance resilience, the use of innovative and cost-effective technologies (including locally manufactured equipment), and the establishment of regional maintenance hubs. Efforts to better integrate projects into broader national and regional strategies were also recognized as critical for ensuring coherence, sustainability, and long-term impact.

7. WIGOS as a Global Framework and Benefits for National Implementation

7.1. WIGOS as a Global Framework for Integrated Observing Systems

The presentation on WIGOS as a global framework emphasized its central role in enabling the integration and coordination of all observing systems contributing to the World Meteorological Organization (WMO) mandate. WIGOS is designed as a comprehensive “system of systems”, bringing together multiple domain-specific observing systems—such as the Global Observing System (GOS), Global Atmosphere Watch (GAW), Global Climate Observing System (GCOS), and hydrological and ocean observing systems—into a unified and interoperable framework.

The primary objective of WIGOS is to meet evolving user requirements for observations by facilitating access to data from a wide range of sources, including systems operated by NMHSs as well as external partners. It promotes interoperability through the adoption of international standards, recommended practices, and common data management procedures, ensuring compatibility and consistency of observations across domains and regions.

A key principle highlighted in the presentation is that WIGOS implementation is the responsibility of individual WMO Members, who are expected to plan, operate, and sustain their observing systems at the national level, while contributing to regional and global networks. This includes participation in initiatives such as the Global Basic Observing Network (GBON) and collaboration with Regional WIGOS Centres (RWCs), which play a critical role in monitoring performance and supporting implementation.

The presentation also stressed the importance of adopting a holistic and evolving approach to observing system design, taking into account technological advancements, changing user needs, and resource constraints. WIGOS promotes long-term sustainability by encouraging Members to plan networks with a lifecycle perspective, including maintenance, upgrades, and performance monitoring.

At the national level, WIGOS implementation requires strong coordination across institutions and sectors, ensuring that data from multiple sources are effectively integrated and shared. Tools such as OSCAR/Surface for metadata management, WDQMS for data quality monitoring, and the GBON compliance framework are essential components supporting this process. The framework also encourages the designation of national focal points and the use of standardized identifiers to facilitate data exchange and interoperability.

Overall, WIGOS provides a structured and internationally recognized framework that enables countries to optimize their observing systems, improve data quality and availability, and strengthen their contribution to global Earth system monitoring and early warning services.

7.2. Leadership of NMHSs in National WIGOS Implementation

The presentation on NMHS leadership highlighted the strategic role of NMHSs in driving the implementation of WIGOS at the national level. NMHSs are expected to act as the central coordinating authority for all Earth system observations, leveraging the WIGOS framework to integrate meteorological, hydrological, oceanographic, and environmental data across different sectors.

A key message of the presentation is that WIGOS offers NMHSs an opportunity to strengthen their institutional mandate and visibility by positioning themselves as the primary providers and coordinators of observational data and services. This leadership role is achieved through enhanced coordination with national stakeholders, including government agencies, research institutions, and the private sector, as well as through active engagement in data sharing and exchange mechanisms.

The expected outcomes of national WIGOS implementation include the development of a fully integrated observing system, improved identification and closure of observational gaps, enhanced data quality and availability, and stronger compliance with WMO Technical Regulations. These improvements ultimately support more effective service delivery, including weather forecasting, climate monitoring, and early warning systems.

To achieve these outcomes, NMHSs are required to undertake several key activities. These include conducting comprehensive gap analyses, aligning national policies with WMO data exchange principles, establishing governance mechanisms and partnerships, and developing both a **National Observing Strategy and a National WIGOS Implementation Plan (N-WIP)**. The N-WIP serves as a practical tool to define priorities, activities, timelines, and performance indicators, ensuring a structured and realistic approach to implementation.

The presentation also emphasized the importance of adopting a user-driven approach to observing system planning, ensuring that investments in infrastructure, technology, and human resources are aligned with national needs and priorities. This includes applying the Rolling Review of Requirements (RRR) process to assess user requirements and guide decision-making.

Finally, the sustainability of WIGOS implementation depends on long-term planning, resource mobilization, and capacity development. NMHSs must ensure that sufficient resources are allocated for both system development and ongoing operations, while continuously strengthening technical and human capacities. Through effective leadership and coordination, NMHSs can ensure that WIGOS implementation leads to more resilient, efficient, and integrated national observing systems.

7.3. WIGOS Data Partnerships and their role in strengthening observing systems

The presentation on WIGOS partnerships focused on the critical role of collaboration between NMHSs and non-NMHS data providers in enhancing national observing capabilities. Given the increasing demand for high-resolution, real-time environmental data, NMHSs alone cannot meet all observational requirements. WIGOS therefore promotes the integration of observations from external sources, including private sector operators, research institutions, and citizen networks.

A fundamental principle of WIGOS partnerships is the concept of mutual benefit, where both NMHSs and external data providers gain from collaboration. For NMHSs, partnerships offer several advantages, including the ability to fill observation gaps, particularly in data-sparse regions, improve access to real-time data, and enhance cost-efficiency by leveraging existing infrastructure and resources. Partnerships also contribute to strengthening national observing systems and improving data quality through increased redundancy and diversity of observations.

From the perspective of non-NMHS operators, incentives for collaboration include access to a broader pool of observational data, improved services that support their operational needs, opportunities for commercial engagement, and enhanced credibility through association with national and international public-good programmes. Additionally, NMHSs can provide technical support, quality assurance, and data archiving services, which add value to the observations collected by partners.

Data quality was identified as a key challenge in integrating external observations. WIGOS addresses this issue through the concept of “documented known quality”, which emphasizes the importance of metadata and transparency in data collection and processing. This approach allows users to assess the suitability of data for specific applications, even when quality standards vary across sources.

The presentation also outlined the respective roles of NMHSs and their partners. NMHSs are responsible for leading the partnership framework, establishing agreements (e.g. Memorandums of Understanding), promoting the use of WIGOS standards, and ensuring the integration and quality control of observations. Non-NMHS partners, in turn, are expected to provide relevant observations, maintain metadata, and adhere as much as possible to WMO standards and recommended practices.

Finally, the implementation of WIGOS partnerships requires well-defined governance mechanisms, clear data policies, and structured coordination at national, regional, and global levels. When effectively implemented, these partnerships significantly enhance the coverage, quality, and sustainability of observing networks, while supporting more comprehensive and user-oriented environmental services.

8. WMO Guidelines for Observing Network Design, including GBON and RBON

8.1. WMO Principles and Guidelines for Observing Network Design

The presentation on WMO principles for observing network design provided a comprehensive overview of the regulatory and guidance framework underpinning the planning, development, and management of observing systems. This framework is primarily defined through the WMO Technical Regulations (WMO-No. 49) and supported by key guidance documents such as the Manual on WIGOS (WMO-No. 1160) and the Guide to WIGOS (WMO-No. 1165), which together establish both mandatory requirements and recommended practices for Members.

A central element of this framework is a set of 13 core observing network design principles, which aim to ensure that networks are fit for purpose, efficient, and sustainable. These principles emphasize that observing networks should be designed to serve multiple application areas, respond to clearly defined user requirements, and meet not only national needs but also regional and global observational requirements.

From a technical perspective, the design of observing systems must consider appropriate spatial and temporal resolution, data homogeneity, and the need for reliable and stable operations over time. The concept of a tiered network design is particularly important, whereby high-quality reference observations support and enhance the value of wider observational networks. Cost-effectiveness is also a key consideration, requiring optimization of available resources while maintaining required performance levels.

Equally important is the emphasis on data availability and metadata management. Observational data should be made accessible in a timely manner and accompanied by comprehensive metadata describing instruments, methods, and environmental conditions, enabling proper interpretation and use. Long-term sustainability is another critical principle, requiring that observing networks be designed with a lifecycle perspective, including maintenance, continuity, and gradual modernization.

In addition, the presentation highlighted the relevance of climate monitoring principles defined by GCOS, which stress continuity of observations, calibration traceability, data quality assessment, and long-term preservation. These principles reinforce the need for stable, consistent datasets that enable reliable climate analysis and long-term environmental monitoring.

Finally, the WMO Quality Management Framework for WIGOS introduces broader organizational principles, including user focus, leadership, process-based management, and continuous improvement. These elements ensure that observing systems are not only technically sound but also effectively managed and continuously adapted to evolving requirements.

Overall, the WMO guidelines provide a comprehensive and harmonized approach to observing network design, ensuring that systems are interoperable, efficient, and capable of supporting a wide range of meteorological, hydrological, and environmental services.

8.2. Global Basic Observing Network (GBON): Concept and Design Requirements

The Global Basic Observing Network (GBON) represents a key regulatory component of WIGOS and is designed to ensure the availability of essential observations at the global scale, particularly to support Numerical Weather Prediction (NWP) and climate reanalysis. The presentation highlighted that high-quality global forecasts depend on the continuous, real-time exchange of observations from all regions of the world, making GBON a critical element of the global observing system.

GBON is defined as a subset of the WIGOS surface-based observing system, complemented by space-based observations, and is governed by mandatory requirements specified in the WMO Technical Regulations. Its primary objective is to ensure that all Members contribute to a minimum set of observations necessary for global forecasting and climate monitoring.

The design of GBON is based on clearly defined technical requirements, including station density, observation frequency, measured variables, and data exchange obligations. For example, surface land stations are required to provide key variables such as pressure, temperature, wind, and precipitation at hourly intervals, with typical horizontal spacing on the order of 100–200 km. Upper-air observations, which are critical for atmospheric profiling, are required at defined spatial intervals and temporal frequencies, ensuring adequate vertical and horizontal coverage.

A fundamental requirement of GBON is that observations must be exchanged internationally in real time, primarily through WIS2, enabling their immediate use in global models and forecasting systems. This reinforces the importance of data sharing as a core principle under the WMO Unified Data Policy.

The implementation of GBON has been further strengthened through dedicated mechanisms such as the Systematic Observations Financing Facility (SOFF), which provides technical and financial support to countries facing capacity constraints. This is particularly important for ensuring global equity in observational coverage and addressing gaps in data-sparse regions.

Monitoring of GBON implementation and compliance is carried out through specialized tools, including the GBON compliance application, which allows Members to assess their performance and identify gaps in their observing systems. This supports a results-based approach to implementation and continuous improvement.

Overall, GBON establishes a globally coordinated baseline for observations, ensuring that all countries contribute to and benefit from a robust and reliable global observing system, which is essential for improving weather forecasts, early warning systems, and climate services worldwide.

8.3. Regional Basic Observing Network (RBON): Design Approach and Implementation

The Regional Basic Observing Network (RBON) builds upon the GBON framework by addressing specific regional requirements, particularly those related to high-impact weather, climate, and hydrological hazards. RBON is designed and implemented at the level of WMO Regional Associations, allowing it to reflect regional priorities and environmental challenges.

RBON is defined as a network of surface-based observing stations and platforms that support regional service delivery, including early warning systems and risk reduction initiatives such as the Early Warnings for All (EW4All) initiative. It integrates not only traditional surface observations but also a wider range of technologies, including radar systems, lightning detection networks, and marine observations, reflecting its multidisciplinary nature.

A key feature of RBON design is its risk-driven approach. In the case of Regional Association I (Africa), the design process begins with the identification and prioritization of key hazards, such as floods, droughts, heatwaves, storms, and cyclones, based on their impact, frequency, and socio-economic relevance. These hazards are then translated into observation requirements, which define the key variables, spatial resolution, temporal frequency, and observing technologies needed.

The RBON design process follows a structured and iterative methodology, including:

- Identification of regional challenges and hazards
- Definition of application areas and user needs
- Selection of key variables and observing technologies
- Assessment of existing capabilities and gaps
- Development of network design based on agreed requirements

Capabilities assessments conducted within regions have revealed significant gaps in observational coverage and performance, highlighting the need for targeted investments and coordinated efforts to strengthen networks. The process also emphasizes the importance of testing and validating proposed network designs, considering local factors such as topography, population density, and feasibility constraints.

RBON implementation relies heavily on the active participation of Members, who are responsible for proposing and maintaining stations, ensuring data availability in near-real time, and contributing metadata to systems such as OSCAR/Surface. Long-term sustainability is a key requirement, with Members expected to commit to the operation of RBON stations over extended periods.

Importantly, RBON is fully integrated within the broader WIGOS framework, with GBON forming a core subset of RBON, ensuring consistency between global and regional observing requirements. The implementation of RBON also promotes stronger regional cooperation, knowledge sharing, and coordination, supported by dedicated structures such as RBON coordination groups.

In conclusion, RBON represents a regionally tailored extension of the global observing system, enabling countries to better address local and regional challenges while contributing to global objectives. By combining risk-based planning, coordinated implementation, and integration with global frameworks, RBON plays a critical role in strengthening resilience and enhancing the effectiveness of weather, climate, and hydrological services.

8.4. Hydrological Network Design Guidelines: Key Messages from the Presentation

The presentation on WMO guidelines for hydrological network design provided an overview of the ongoing development of a comprehensive guidance document aimed at strengthening the design, planning, and sustainability of hydrological observing networks. This work is being undertaken by the Network Design Subgroup under the WMO Technical Team on Hydrological Networks (TT-EHN), in response to requests from Member States for more detailed and updated guidance. The draft document represents the outcome of approximately three years of expert work and is expected to be submitted for approval at INFCOM-4 in November 2026.

The new guidance adopts an Earth System approach, ensuring that hydrological network design is aligned with broader meteorological and environmental observing systems across global, regional, and national scales. It builds upon and extends existing WMO guidance, particularly the *Guide to Hydrological Practices (WMO-No. 168)*, by providing a more integrated, structured, and operational framework.

8.4.1. Structure and Scope of the Guidelines

The draft guidance is organized into several core chapters, covering the full lifecycle of hydrological network design. These include network design principles, design considerations, design methods, and network sustainability, complemented by practical tools such as checklists and case studies.

A central component of the guidance is the application of WIGOS-aligned observing network design principles, ensuring consistency with the broader WMO framework. These principles emphasize the need to design networks that are user-driven, cost-effective, reliable, and sustainable, while meeting requirements at national, regional, and global levels. They also promote the adoption of tiered network structures, effective data sharing, proper metadata management, and the integration of environmental sustainability considerations.

8.4.2. Key Design Considerations for Hydrological Networks

The guidelines highlight the importance of adopting a comprehensive, multi-domain approach to hydrological observations. Network design must account for a wide range of variables, including:

- Hydrometeorological parameters, such as precipitation, evaporation, snow, and soil moisture;
- Surface water observations, including river discharge, lake and reservoir levels, and sediment transport;
- Groundwater monitoring, particularly water levels;
- Water quality measurements, reflecting increasing environmental and management needs.

  This integrated perspective ensures that observing networks can support diverse applications, including water resource management, flood forecasting, climate monitoring, and environmental protection.

8.4.3. Network Design Methods

The presentation outlined a range of methodological approaches available for designing hydrological networks, recognizing that no single method is universally applicable. Instead, a combination of approaches is often required, depending on national context and priorities. These include:

- Pragmatic approaches, based on dividing regions according to topography and climate characteristics;
- Empirical or rule-of-thumb methods, using established density guidelines adjusted for variability, terrain, and operational constraints;
- Risk-based approaches, focusing on areas with higher vulnerability or critical importance;
- Geostatistical methods, which assess spatial relationships and optimize station spacing using quantitative techniques;
- Multi-criteria analysis, incorporating multiple variables and decision factors;
- Data-driven performance assessments, which evaluate how network configurations influence forecast accuracy and uncertainty.

These approaches can be combined progressively, allowing countries to move from simple to more advanced methodologies as capacity and data availability improve.

8.4.4. Sustainability and Operational Considerations

A major emphasis of the guidelines is on long-term sustainability, recognizing that the effectiveness of hydrological networks depends not only on initial design but also on their continued operation and maintenance. Key elements include:

- Adequate provision for capital investment and operational costs;
- Integration of maintenance, calibration, and human resource requirements;
- Application of cost-benefit analysis to support decision-making;
- Consideration of policy, governance, and institutional frameworks;
- Assessment of technology readiness and suitability.

This comprehensive approach ensures that networks remain functional, reliable, and capable of delivering high-quality data over the long term.

8.4.5. Practical Guidance and Application

To support implementation, the guidelines include a practical checklist for network designers, as well as detailed annexes addressing specific applications. One notable example is the annex on hydrological network design for flood forecasting, which provides concrete recommendations on measurement frequency, data transmission intervals, and system requirements based on basin size and hydrological dynamics.

This annex highlights the importance of real-time and high-frequency data for disaster risk reduction, particularly in small catchments prone to flash floods, where rapid hydrological changes require frequent monitoring and timely data transmission. It also emphasizes the need for resilient systems, redundancy, and effective data sharing mechanisms to support early warning systems.

8.5. Weather Radar Systems: Design, Implementation and Operational Considerations

The presentation on remote sensing network design for weather radar systems provided a comprehensive overview of the key technical, operational, and strategic aspects involved in establishing and maintaining effective radar networks. It emphasized that weather radars are a critical component of modern observing systems, enabling real-time monitoring of precipitation, severe weather, and atmospheric processes, and significantly enhancing forecasting and early warning capabilities.

8.5.1. Role and Importance of Radar Networks

Weather radar networks play a central role in supporting high-resolution observations over large spatial areas, particularly for monitoring rainfall, storms, and extreme weather events. The presentation highlighted that radar systems complement traditional in-situ observations by providing continuous spatial coverage, which is essential for nowcasting, flood forecasting, and disaster risk reduction.

8.5.2. Radar Technology Selection and Trends

A key aspect of radar network design is the selection of appropriate technology, which must balance performance, cost, and environmental conditions. The presentation reviewed major radar technologies, including magnetron, klystron, and solid-state transmitters, each with distinct advantages and limitations. While magnetron systems remain widely used due to their cost-effectiveness, solid-state technologies are emerging as a future-oriented solution offering higher reliability, better signal quality, and reduced maintenance requirements.

The importance of dual-polarization radar technology was strongly emphasized, as it has become a global standard. Dual-polarization enables improved measurement accuracy, including better estimation of precipitation and the ability to distinguish between different types of hydrometeors (e.g., rain, snow, hail).

Radar system selection must also consider frequency bands (S, C, X), which are influenced by climatic conditions, topography, and intended applications. For example:

- S-band radars are suitable for heavy rainfall and long-range applications;
- C-band radars offer a balanced compromise between cost and performance;
- X-band radars provide high-resolution data for localized applications but have limited range and higher sensitivity to attenuation.

Emerging trends include the adoption of phased-array radar systems, artificial intelligence for signal processing, and advanced data assimilation techniques, all contributing to more accurate, faster, and intelligent radar observations.

8.5.3. Siting and Coverage Design

The presentation underscored that site selection is one of the most critical factors influencing radar performance. Even advanced technology cannot compensate for poor siting decisions. Optimal radar placement requires:

- Clear, unobstructed visibility (minimal beam blockage);
- Strategic elevation and positioning;
- Consideration of terrain, infrastructure, and electromagnetic interference;
- Availability of power, telecommunications, and secure access.

Coverage design involves addressing the trade-offs between maximum range and minimum detectable altitude, while accounting for factors such as Earth curvature and terrain-induced shadow zones. To mitigate coverage gaps, overlapping radar coverage and redundancy are recommended, particularly in high-risk areas.

Advanced tools, including digital elevation model (DEM)-based analysis and propagation modeling, are used to simulate radar coverage, optimize site selection, and identify blind spots. These tools are essential for ensuring accurate and efficient network design.

8.5.4. System Integration and Data Sharing

The effectiveness of radar systems depends heavily on their integration within broader observing and forecasting systems. Radar networks should be designed to:

- Ensure compatibility with existing systems;
- Support integration with numerical weather prediction (NWP) and nowcasting tools;
- Use standardized data formats for interoperability;
- Enable real-time data sharing at national, regional, and global levels.

The presentation emphasized that radar systems deliver maximum value when their data are actively integrated into decision-making processes, including early warning systems and operational forecasting platforms.

8.5.5. Operational Challenges and Limitations

Several operational challenges were highlighted, including:

- High costs and delays associated with spare parts and maintenance;
- Need for continuous service availability;
- Risks of radio-frequency interference;
- Technical constraints related to radar physics.

In addition, inherent limitations of radar systems must be considered. These include beam blockage by terrain, signal attenuation (especially at shorter wavelengths), and decreasing resolution with distance as the radar beam spreads and rises.

8.5.6. Human Capacity and Institutional Requirements

A critical success factor identified in the presentation is the availability of qualified human resources. Effective radar operation requires expertise in:

- Installation and commissioning;
- Radar operation and data interpretation;
- Electronic and radio-frequency maintenance;
- Data processing, quality control, and integration with forecasting systems.

The presentation stressed that technology alone is insufficient without skilled personnel, and continuous capacity development is essential to ensure sustainable operation.

8.5.7. Governance, Planning and Strategic Implementation

From a governance perspective, radar network development must be guided by a clear strategic roadmap, aligned with national priorities and WMO standards. Key elements include:

- Needs assessments and feasibility studies;
- Compliance with international standards (e.g., WMO guidance and ISO standards);
- Phased deployment and continuous optimization;
- Strong institutional coordination and policy support.

8.6. Lightning Detection Systems: Key Concepts and Implementation Considerations

The presentation on lightning detection systems highlighted their increasing importance as a complementary observing capability within modern meteorological networks. These systems enable the real-time detection and monitoring of lightning activity, including the location, intensity, and frequency of strikes, using ground-based sensors that capture electromagnetic, acoustic, and optical signals.

Lightning observations provide significant added value for weather forecasting, early warning systems, and disaster risk reduction, particularly for severe convective events. They contribute to improved public safety, support infrastructure protection, enhance aviation safety, and provide valuable datasets for scientific and climate research.

8.6.1. System Architecture and Technologies

Lightning detection systems typically consist of a network of ground-based sensors combined with a central processing server. Sensors detect lightning signals and synchronize measurements using GPS timing, while central processing systems use techniques such as Time of Arrival (TOA) and triangulation to accurately determine strike locations.

Different technology options are available, including TOA, direction-finding (DF), and hybrid approaches combining both methods. Hybrid systems are considered the most effective, offering a balance between high detection efficiency, accuracy, and coverage. Satellite-based systems can provide global coverage but are generally less precise, highlighting the complementary role of ground networks.

8.6.2. Network Design and Performance

Effective network design requires careful consideration of sensor density, spacing, and environmental conditions. Typical sensor spacing ranges between 150 and 350 km, while performance depends on factors such as topography, electromagnetic noise, and system synchronization.

Key performance indicators include detection efficiency, location accuracy, and redundancy. Increasing sensor density improves both accuracy and reliability, and simulations are commonly used to optimize network configuration. As an indicative benchmark, around six sensors per 100,000 km^2 may be required to achieve optimal performance.

8.6.3. Operational Models and Implementation Approach

Countries can either deploy their own national lightning detection network or access data through external service providers. While national systems offer greater control and customization, they require significant investment and technical expertise. Conversely, external services provide faster and more cost-effective access to data but with less control and dependency on providers.

Implementation typically follows a phased approach, including design and assessment, pilot deployment, and full-scale operational deployment, supported by system validation and optimization.

Operational Requirements and Benefits

Lightning detection systems are relatively low in operational complexity, as they are passive systems requiring limited maintenance and moderate technical expertise. Routine tasks include system monitoring, GPS synchronization checks, and basic IT and data management activities.

9. Regional Approaches to Strategic Planning of Observing Systems

The workshop highlighted two complementary regional approaches to the strategic planning and implementation of observing systems: the SADC meteorological observing network, the SADC transboundary hydrometeorological networks (SADC-HYCOS) and the Pacific Regional Observations Network Strategy. Together, these examples illustrate how regional coordination frameworks can address common challenges related to sustainability, capacity, and data sharing.

9.1. SADC Observing Network

The presentation on the Southern African Development Community (SADC) observing network provided an overview of the current status, challenges, and performance of observing systems across the region. Comprising 16 Member States, the SADC region is highly dependent on weather and climate information, as it is frequently exposed to droughts, floods, tropical cyclones, and heatwaves, with climate variability (e.g. ENSO) further intensifying risks.

9.1.1. Structure of the Observing Network

The SADC observing network is composed of a wide range of systems operated by National Meteorological and Hydrological Services (NMHSs), including:

- Surface meteorological stations and precipitation networks
- Automatic Weather Stations (AWS)
- Upper-air radiosonde systems
- Hydrological and climatological stations
- Limited radar infrastructure

Overall, the region has a large and diverse network, but with strong variability in capacity and distribution among countries.

The observational strategy adopts a requirements-driven and system-of-systems approach, aligned with WIGOS global observing framework. It integrates observations across multiple domains (surface, upper-air, marine, climate) to provide a holistic Earth system perspective.

A central feature is the tiered network concept, which enables prioritization of investments:

- Reference (advanced) stations supporting global systems such as GBON and GCOS;
- Operational stations forming the backbone of national services;
- Supplementary stations addressing local or sector-specific needs.

  This structure allows countries to optimize resources while progressively strengthening their networks.

9.1.2. Key Findings on Network Capacity

The analysis highlighted several structural characteristics of the observing network:

- Surface and precipitation observations dominate, forming the backbone of routine monitoring.
- Automatic Weather Stations are expanding, but deployment remains uneven across countries.
- Upper-air observations are critically limited, constraining forecast accuracy and regional modelling capacity.
- Weather radar coverage is minimal and geographically concentrated, limiting real-time monitoring of severe weather.
- Hydrological and agricultural networks are unevenly distributed or insufficient, despite high vulnerability to water-related hazards.
- GBON implementation is progressing, but remains concentrated in a few countries, leaving gaps in regional representation.

These findings indicate that while a foundational network exists, significant gaps persist in key observing domains, particularly for high-impact services.

9.1.3. Operational Performance and Data Availability

The presentation also differentiated between declared and assessed station performance:

- Declared status (from OSCAR/WIGOS metadata) suggests that most stations are officially operational, reflecting institutional commitment.
- However, assessed performance (based on actual data reporting via WDQMS) reveals inconsistencies, including partially operational, silent, or non-reporting stations.

  This discrepancy highlights a key issue: nominal capacity does not always translate into effective data delivery.

  Monitoring through WDQMS further shows that:

- Upper-air observations are sparse, and interruptions have a strong impact on regional forecasting.
- Surface observations (e.g. pressure) are uneven, with inconsistent reporting across stations.
- Even when stations are operational, data completeness is not always achieved, reducing their usefulness for global applications such as NWP and climate monitoring.

9.1.4. Key Challenges

The SADC observing network faces several systemic challenges:

- Uneven geographical distribution of stations and capacities
- Operational interruptions and silent stations
- Limited upper-air and radar capabilities
- Data availability and reporting inconsistencies
- Imbalance between declared capacity and actual performance

As a conclusion, The SADC region possesses a substantial but uneven observing network, with strong foundations in surface observations but significant gaps in upper-air, radar, and specialized networks. Improving the effectiveness of the system will require strengthening operational performance, enhancing data availability, and addressing uneven capacity across countries, particularly in support of GBON implementation and regional early warning systems.

9.2. SADC Transboundary Hydrometeorological Networks (SADC-HYCOS)

The SADC-HYCOS programme represents a regional initiative focused on transboundary hydrometeorological observation and data sharing, particularly in the context of shared river basins.

9.2.1. Regional Context and Rationale

Southern Africa includes over 15 major transboundary river basins, such as the Zambezi, Limpopo, and Orange-Senqu, which are critical for socio-economic development and regional cooperation.

Effective monitoring is essential for:

- Flood and drought management;
- Water resource planning;
- Environmental protection;
- Compliance with the SADC Protocol on Shared Watercourses.

The SADC-HYCOS was established under the WMO WHYCOS framework to:

- Strengthen hydrological monitoring systems;
- Promote real-time data collection and sharing;
- Develop regional information systems;
- Support early warning systems and decision-making.

The programme has deployed regional monitoring infrastructure, including data collection platforms across multiple countries, and supported the development of databases and communication systems.

9.2.2. Evolution and Achievements

Over successive phases, SADC-HYCOS has:

- Enhanced field observation networks;
- Established regional hydrological information systems;
- Enabled data sharing across countries;
- Supported flood forecasting and early warning systems;
- Developed decision-support tools, including basin-scale information systems and modelling frameworks.

  It has also contributed to institutional cooperation and harmonization, strengthening transboundary water governance. The initiative has improved:

- Real-time monitoring of floods and hydrological events;
- Data availability for decision-makers;
- Regional coordination in disaster response;
- Long-term water resource planning.

9.2.3. Challenges

Despite progress, key challenges persist:

- Maintenance of monitoring infrastructure;
- Limited financial sustainability;
- Data sharing constraints;
- Dependence on external expertise;
- Outdated equipment and spare parts shortages.

9.2.4. Future Outlook

SADC-HYCOS, being integrated into broader initiatives such as the SADC Climate Resilient Water Investment Programme aiming to enhance climate resilience and expand observation capabilities, represents a programmatic and operational approach, demonstrating how regional cooperation can enable shared data systems and early warning services in transboundary contexts.

9.3. Pacific Regional Observations Network Strategy

9.3.1. Regional Context and Strategic Rationale

The Pacific Regional Observations Network Strategy presents a comprehensive and forward-looking framework aimed at strengthening observing systems across Pacific Island countries. This initiative is developed in response to the region's high vulnerability to extreme weather events, including tropical cyclones, sea-level rise, and climate variability, all of which place significant demands on the reliability and continuity of observational data. Within this context, the strategy recognizes that effective observation networks are essential for supporting weather forecasting, climate monitoring, and multi-hazard early warning systems, which are critical for safeguarding lives, infrastructure, and economic activities.

The strategy is grounded in a detailed understanding of the regional context, which is characterized by geographical dispersion, logistical constraints, and limited national capacities. Pacific Island countries often face significant challenges related to maintaining observational infrastructure, including limited human resources, funding constraints, and high operational costs linked to remote and isolated locations. A central issue identified in the strategy is the growing gap between increasing demand for observations and the ability of national systems to sustain them over time. This gap has been exacerbated by the historically fragmented nature of network development, where many observing systems were established through short-term, project-based investments without sufficient planning for long-term maintenance, institutional ownership, or integration with national and regional frameworks.

9.3.2. Strategic Objectives and Design Approach

In response to these challenges, the strategy proposes a coordinated regional approach aligned with the WMO Integrated Global Observing System (WIGOS) and the WMO Unified Data Policy. The objective is to establish a coherent and sustainable observing system that not only meets national and regional needs but also contributes effectively to global observing networks such as the Global Basic Observing Network (GBON), the Global Surface Network (GSN), and the Global Upper-Air Network (GUAN). While the initial focus of the strategy is on land-based meteorological and climate observations essential for numerical weather prediction and climate monitoring, it also anticipates future expansion to include hydrological, marine, aviation, and geohazard observations, thereby supporting a more integrated Earth system approach.

A key feature of the strategy is its emphasis on a requirements-driven design philosophy, which prioritizes the needs of users rather than focusing solely on infrastructure deployment. This approach ensures that observations are designed to meet specific requirements in terms of spatial coverage, temporal resolution, and data quality, enabling them to support operational services such as forecasting and early warning. The strategy further adopts a system-of-systems perspective, integrating multiple observation domains into a unified network. By combining surface, upper-air, marine, and partner observations, the strategy seeks to maximize the overall effectiveness and value of the observing system and to enable its application across multiple sectors.

9.3.3. Tiered Network Concept

Another central element of the strategy is the introduction of a tiered network structure, which provides a practical mechanism for prioritizing investments and optimizing resource allocation. Within this framework, stations are categorized according to their role and importance. Reference or advanced stations are designed to meet the highest international standards and contribute to global systems such as GBON and GCOS, providing critical data for numerical weather prediction and climate monitoring. Operational stations form the backbone of national and regional services, supporting routine weather forecasting and warning functions. Supplementary stations address more localized or sector-specific needs, such as agriculture or tourism, and may not always contribute directly to global data exchange. This tiered approach enables countries to focus limited resources on the most critical observations while retaining flexibility to address local priorities.

9.3.4. Regional Backbone Network Concept

Building on this framework, the strategy introduces the concept of a Regional Backbone Network, which consists of a subset of critical observing stations that underpin the overall system. These stations are prioritized for maintenance, technical support, and investment, with particular attention given to ensuring data quality, metadata completeness, and reliable communication systems. By focusing resources on this backbone, the strategy aims to ensure continuity of essential observations and to provide a stable foundation for future network expansion and integration.

9.3.5. Governance, Coordination and Performance Monitoring

Governance and coordination are also highlighted as essential components of the strategy. Given the systemic nature of many challenges, such as data sharing, capacity constraints, and infrastructure sustainability, the strategy emphasizes the need for strong regional coordination mechanisms and alignment with international frameworks. This includes collaboration with regional bodies such as the Pacific Meteorological Council and alignment with ongoing initiatives and programmes. Clear definition of roles and responsibilities, particularly in relation to data stewardship and system management, is considered critical for ensuring accountability and long-term sustainability.

The strategy places significant emphasis on data management and performance monitoring, recognizing that the value of an observing system depends not only on the availability of infrastructure but also on the quality, accessibility, and consistency of the data produced. It promotes the use of WIGOS tools such as OSCAR/Surface for metadata management and WDQMS for monitoring data quality and availability. These tools enable continuous assessment of network performance, identification of gaps, and implementation of corrective actions, thereby supporting a culture of continuous improvement.

Long-term sustainability and resilience are core principles underpinning the strategy. The approach acknowledges that establishing an observing network is only the first step, and that sustained operation requires ongoing investment in maintenance, human capacity, and institutional support. Particular attention is given to ensuring that infrastructure is resilient to environmental hazards common in the Pacific region, including cyclones and extreme weather events. Measures such as robust station design, redundancy in communication systems, and lifecycle planning are emphasized to ensure the durability and reliability of the network over time.

Finally, the strategy is based on an evidence-driven and participatory development process, combining technical assessments, the use of WIGOS tools, and extensive national consultations. It also aligns with complementary initiatives such as SOFF and ClimSA to ensure coherence and avoid duplication of efforts. Implementation is envisaged as a gradual process, focusing initially on stabilizing critical stations, addressing performance gaps, and progressively expanding the network to cover additional domains and services.

In conclusion, the Pacific Regional Observations Network Strategy represents a holistic approach to observation system planning that integrates technical, institutional, and financial considerations. By combining a clear prioritization framework, strong regional coordination, and a focus on sustainability and resilience, the strategy provides a robust model for developing effective observing systems in resource-constrained and climate-vulnerable regions. It demonstrates that the long-term success of observing networks depends not only on infrastructure but also on governance, data management, and sustained operational commitment.

10. National Approaches to Strategic Planning of Observing Systems

10.1. Strategic planning for observation: national study case of Switzerland

10.1.1. Background and Starting Point

MeteoSwiss operates a broad and diverse portfolio of observation systems, encompassing in-situ measurements (e.g. automatic weather stations), remote sensing (e.g. radar), upper-air observations (radiosondes, profilers), as well as specialized monitoring systems such as pollen observations. Each of these systems has historically been developed with its own measurement concept and operational purpose, resulting in a landscape that is technically rich but structurally fragmented.

In addition to its in-house infrastructure, MeteoSwiss has increasingly integrated third-party observational data into its operations. This process began in 2005 and has been pursued in a more systematic manner since 2012. The integration includes data from federal institutions, cantonal networks, private partners, and international sources, particularly from neighbouring countries. The primary motivation has been to increase spatial observation density in a cost-effective manner and to fill gaps in critical regions, especially those relevant for warning services. However, this expansion has also introduced challenges, most notably concerning data quality assurance, which required the development of certification procedures for external stations.

At the same time, MeteoSwiss recognized the significant untapped potential in combining different observing systems. By integrating complementary datasets, it becomes possible to overcome individual system limitations and generate more robust and comprehensive observational products. This requires a shift in mindset, encouraging collaboration across traditionally separate expert domains.

10.1.2. Strategic Drivers for Change

The initiative to develop a new national observation strategy is driven by several interrelated factors.

First, MeteoSwiss faces a situation where operational demands are increasing while resources remain constrained or are even declining. This necessitates a more efficient and strategic use of available infrastructure and funding.

Second, the evolving landscape of meteorology and environmental monitoring introduces new scientific challenges and technological opportunities, including advances in remote sensing, data processing, and modelling. These developments create both pressure and opportunity to modernize observation systems.

Third, there is a growing requirement for integration at multiple levels. This includes integration between different observing systems, between observational data and derived products, and across domains such as surface and space-based observations.

Finally, MeteoSwiss must ensure compliance with international frameworks and obligations, particularly those associated with WIGOS, the WMO Unified Data Policy, and emerging global network concepts such as GBON and RBON.

Together, these drivers require a fundamental rethinking of how observation systems are designed, managed, and evolved.

10.1.3. Paradigm Shift in Observation Strategy

A key aspect of the MeteoSwiss approach is a conceptual transformation in how observation systems are understood and organized.

Traditionally, observation strategies have been structured around individual systems, with each system optimized independently. MeteoSwiss is transitioning away from this system-centric perspective toward a variable-based and integrated strategy. In this new paradigm, the primary focus is on identifying which meteorological variables are required, and then determining the most effective way to observe them, regardless of the specific system involved.

This shift aligns closely with the principles of WIGOS and the Rolling Review of Requirements (RRR), and it supports the broader MeteoSwiss enterprise strategy. The transition represents not merely a technical adjustment but a fundamental change in organizational thinking, requiring coordination across departments and disciplines.

10.1.4. Objectives of the New Observation Strategy

The development of a new observation strategy aims to provide a comprehensive and structured basis for decision-making.

A central objective is to establish a clear overview of the entire observation landscape, answering fundamental questions about what data are collected, where, how, and for what purposes. This includes the introduction of standardized documentation for all observing systems, covering both their technical characteristics and their operational roles.

Another key objective is to enable cost-benefit analysis across observation systems. By systematically documenting costs—including operational, personnel, lifecycle, and investment costs—MeteoSwiss aims to ensure that resources are allocated in a way that maximizes impact and efficiency.

The strategy also emphasizes the identification of stakeholder requirements in a solution-neutral manner, meaning that needs are defined independently of specific technologies or systems. This facilitates a more flexible and future-oriented approach to system design.

Furthermore, the strategy seeks to promote integration and exploit synergies between different observation systems. For example, combining in-situ measurements with remote sensing data can significantly enhance overall observational capability.

Additional objectives include the identification of opportunities for automation, the exploration of budget scenarios and their implications, and the incorporation of evidence from impact studies and OSSEs to support informed decision-making.

10.1.5. Methodological Approach

The methodological foundation of the strategy development is the Rolling Review of Requirements (RRR) framework.

This approach distinguishes between two main components: requirements and capabilities.

Requirements are derived from multiple sources, including internal applications (such as forecasting and numerical weather prediction), WMO-defined application areas, and external customer needs. A structured process involving stakeholder surveys and interviews is used to collect and refine these requirements, ensuring that they are aligned with MeteoSwiss products, services, and business processes.

Capabilities, on the other hand, refer to the existing observation systems and data sources that provide meteorological data. These include both MeteoSwiss-operated systems and external data providers. A comprehensive inventory of these systems is established, accompanied by detailed fact sheets for each system.

Each fact sheet includes information on measurement methods, observed variables, spatial and temporal resolution, responsible entities, and a SWOT analysis. Importantly, it also includes detailed cost information and lifecycle considerations, as well as an assessment of future potential.

The requirement analysis uses the standard RRR criteria—such as resolution, timeliness, and uncertainty—and incorporates budget scenarios to identify critical thresholds and priorities. This allows MeteoSwiss to understand the consequences of different levels of investment and to define realistic targets.

10.1.6. From Analysis to Implementation

Following the analysis phase, a gap analysis is conducted to identify discrepancies between requirements and existing capabilities. This process is currently performed manually, reflecting the complexity of the task and the absence of automated tools.

The results of this analysis are used to develop Statements of Guidance, which in turn feed into the formulation of the new observation strategy. The strategy is expected to be dynamic, allowing for updates and adjustments as conditions evolve.

Implementation of the strategy is recognized as a resource-intensive and cross-cutting effort, requiring contributions from multiple departments. In particular, the development of integrated products that combine data from different observation systems will require new algorithms and workflows.

The strategy will also be subject to periodic reviews, ensuring that it remains relevant and effective over time.

10.1.7. Integration with Data Strategy

An important insight of the MeteoSwiss approach is that observation strategy cannot be separated from data strategy.

Changes in observation systems directly affect the data they produce, which in turn impacts data management, dissemination, and usage. As a result, MeteoSwiss is developing its observation strategy in close coordination with a broader data strategy.

This data strategy addresses issues such as data dissemination, product catalogues, storage and archiving, metadata management, data quality, and governance. Data products serve as a key interface between the observation and data domains, linking measurement processes to user-facing services.

10.1.8. Collaboration and Community Building

Recognizing that many meteorological services face similar challenges, MeteoSwiss has contributed to the creation of an informal international community of practice focused on observation strategies.

This initiative brings together multiple institutions to share experiences, methodologies, and best practices. Activities include thematic discussions, documentation of lessons learned, and the establishment of collaboration platforms.

The approach highlights the value of collective learning and cooperation in addressing complex strategic challenges, and it is recommended as a model that could be adopted by other organizations.

10.1.9. Key Lessons learned

Several key lessons emerge from the MeteoSwiss experience.

First, there is significant value in the integration of data from multiple sources, including external partners, which can enhance spatial and temporal coverage in a cost-effective way.

Second, the development of an observation strategy should follow an iterative approach, summarized by the principle “think big, start small.” This allows for gradual progress while maintaining a clear long-term vision.

Third, communication and stakeholder engagement are critical to success, as organizational change requires time and consensus-building.

Fourth, in a context of limited resources, it is essential to prioritize investments based on impact, using tools such as budget scenarios to guide decisions.

Finally, the integration of observation systems and the development of combined products offer substantial potential to overcome the limitations of individual systems, provided that experts collaborate openly across institutional and disciplinary boundaries.

10.2 Observations network planning and strategy in Australia

10.2.1 Observing networks in Australia

The Australian observing network, managed by the Bureau of Meteorology (BoM), is one of the most extensive and diverse in the world, providing critical data to support weather forecasting, climate services, hydrology, and environmental monitoring. The system integrates observations across land, ocean, atmosphere, and space, including surface weather stations, radars, satellite receiving systems, ocean buoys, and specialized monitoring sites. This multi-platform approach enables comprehensive coverage of Australia’s vast and varied geography and supports a wide range of applications, from disaster risk reduction and aviation safety to water resource management and climate policy.

A key feature of the Australian system is its strong reliance on automation combined with complementary human and partnership-based observations. While most data collection is automated, a long-standing network of volunteer observers and external contributors continues to play an important role in maintaining historical continuity and local data coverage. The observing system is therefore both technologically advanced and socially embedded, reflecting the need to balance innovation with the preservation of long-term climate records and community engagement.

Over the past decade, Australia has pursued a significant modernization agenda aimed at strengthening the resilience, security, and efficiency of its observing infrastructure. The Bureau’s large-scale “Robust” transformation program (2017–2024) upgraded key observing systems, including radar networks, automated upper-air systems, flood warning infrastructure, and communications networks, alongside major investments in digital platforms, cybersecurity, and high-performance computing. This program responded to identified vulnerabilities in system stability and resilience, demonstrating a strategic focus on ensuring continuity of operations and improving the reliability of services in the face of growing environmental and technological risks.

10.2.2. Key challenges and threats

Despite these advancements, the Australian observing system faces several structural and strategic challenges. The network is geographically extensive and asset-intensive, comprising thousands of instruments distributed across remote and often harsh environments, which creates significant maintenance and lifecycle management demands. Some components of the system, particularly traditional rainfall observing networks, have experienced long-term declines in coverage, raising concerns about data continuity and spatial representativeness. In addition, past assessments have highlighted the need for improvements in asset management frameworks, lifecycle planning, and performance monitoring to ensure the long-term sustainability of infrastructure investments.

Financial sustainability remains a central consideration in the Australian strategy. The observing network represents a substantial share of the Bureau’s asset base and requires ongoing operational funding for maintenance, calibration, and system upgrades. The experience of underinvestment in earlier periods has reinforced the importance of stable, long-term funding models that support both modernization and sustained operations. Strategic investments have therefore increasingly focused not only on expanding capability but also on strengthening lifecycle management, resilience, and cost efficiency.

10.2.3. First National Strategy for Observation

In response to these challenges, Australia's observing system strategy emphasizes several key priorities. These include modernizing legacy infrastructure, increasing automation, and improving data transmission and digital integration across platforms. There is also a clear focus on enhancing the resilience of the system to cyber threats, power outages, and climate-related extremes, as well as improving governance and asset management practices. At the same time, efforts are being made to incorporate data from external partners and non-traditional sources, aligning with global initiatives such as the WMO Integrated Global Observing System (WIGOS), and to strengthen interoperability and data sharing across sectors.

Overall, Australia's observing network strategy reflects a shift toward a resilient, integrated, and future-ready system, balancing technological innovation with sustainability and governance. While the country benefits from a highly advanced and geographically comprehensive observing infrastructure, its long-term effectiveness depends on continued investment, improved asset management, and the ability to adapt to evolving environmental, technological, and societal demands.

As part of the national strategic plans, BoM has developed a comprehensive and structured approach to planning and managing its national observing network, designed to ensure sustainable, high-quality meteorological, climate, and environmental services ensuring that the observing system integrates a wide range of platforms such as automatic and manual weather stations, upper-air systems, weather radars, ocean and drifting buoys, satellite reception systems, and specialized monitoring networks for ozone, solar radiation, and space weather. This extensive and diverse configuration reflects a highly coordinated "network of networks," enabling a comprehensive and interoperable understanding of environmental processes across Australia and surrounding regions.

A defining characteristic of the Australian observing system is its emphasis on integration, collaboration, and distributed data collection. The network combines automated systems with cooperative and volunteer-based observations and incorporates contributions from external partners, particularly in marine and remote environments. This approach enhances spatial coverage and preserves long-term climate records while addressing the challenges posed by the scale and diversity of the Australian continent. The spatial distribution of observing assets, with higher density in coastal and populated areas and lower density inland, reflects the need to balance observational requirements with logistical feasibility and cost efficiency.

The strategic framework guiding this system focuses on developing a modern, efficient, and sustainable observing network that improves service delivery while reducing operational costs and strengthening workforce effectiveness. This framework adopts a holistic, enterprise-level perspective structured around key pillars including people, services, network management, systems and tools, and technology. Together, these elements emphasize aligning workforce capacity with operational needs, enabling continuous service improvement, streamlining governance across interconnected networks, and increasing automation to ensure operational robustness. Technology is positioned as a key enabler for agility and responsiveness to evolving user demands and increasing data requirements.

10.2.4. Concepts for the new strategy for Observation

To ensure the network evolves in a controlled, transparent, and consistent manner, Australia has implemented robust governance and analytical processes. All changes affecting observations are subject to formal review and stakeholder consultation, ensuring alignment with strategic objectives and international frameworks such as those of the World Meteorological Organization. Medium-term decision-making is supported by an Observations Planning Analysis process, which allows the system to adapt to changing user requirements, technological developments, budget constraints, and operational challenges. This analytical framework is applied in practice through targeted studies, such as reviews of specific observation networks, where decisions are informed by assessments of customer value, scientific contribution, cost-effectiveness, and opportunities to leverage external data sources.

At the longer-term level, the evolution of the observing network is guided by structured planning studies that define strategic direction over a one- to ten-year horizon. These studies follow a systematic methodology that includes scoping, requirements analysis, capability assessment, impact evaluation, environmental scanning, and the formulation of strategic recommendations. This ensures that network development is coordinated, evidence-based, and aligned with both current operational needs and future opportunities.

This multi-layered approach is further integrated through an Observations Ecosystem Roadmap, which provides a high-level vision and coordination framework for the next decade and beyond. The roadmap aims to ensure that the right data are delivered to the right place at the right time, enabling trusted and resilient services across weather, water, climate, ocean, and space weather domains. It aligns efforts across the Bureau, coordinates observation deliverables, and identifies new initiatives that add value to the overall system. Governance is provided through a dedicated steering structure, and the roadmap is regularly updated to reflect evolving priorities and technological advances.

A key feature of the roadmap is the use of structured prioritisation methods to guide investment and development decisions. Proposals are first defined through structured inputs, then analysed by a dedicated evaluation team, and finally ranked using multi-factor criteria. These criteria include the delivery of customer value, long-term return on investment, efficiency gains and cost reduction potential, and alignment with strategic objectives. The prioritisation process also considers resourcing requirements and broader strategic linkages, ensuring that decisions are balanced across impact, feasibility, and sustainability. By linking customer benefits, financial performance, and strategic alignment within a transparent evaluation framework, the Bureau ensures that limited resources are allocated to initiatives that deliver the highest overall value.

Overall, Australia's approach represents a mature and forward-looking model for observing system planning, combining extensive technical capabilities with a clear strategic framework, robust governance mechanisms, structured analytical processes, and long-term coordination through an integrated ecosystem perspective. While the system benefits from strong integration, advanced technologies, and collaborative partnerships, its complexity requires continuous coordination, sustained investment, and adaptive management. The emphasis on modernization, automation, lifecycle planning, and evidence-based prioritisation ensures that the observing network remains resilient, efficient, and capable of meeting future environmental, operational, and societal demands.

10.3. Morocco Case Study – Strategic Planning for Observation (Vision 2030)

10.3.1. Strategic Context and Rationale for Transformation

Morocco's national meteorological service (DGM) has embarked on an ambitious transformation programme under its Vision 2030, aimed at fundamentally reshaping the country's observation infrastructure into a modern, integrated, and performance-driven system. This initiative reflects a growing recognition that meteorological observations are no longer a purely technical function, but rather a strategic national asset, underpinning public safety, economic resilience, and climate adaptation.

The need for transformation arises from a convergence of pressures. On the one hand, Morocco is experiencing increasing exposure to extreme weather events, including floods, droughts, and severe convective storms, which require more localized and accurate forecasting capabilities. On the other hand, national services must align with evolving international standards and obligations, particularly those established by the World Meteorological Organization (WMO), which call for higher spatial and temporal resolution and improved data quality.

In this context, DGM's strategy is not limited to incremental improvements, but instead represents a system-wide reconfiguration, combining infrastructure expansion, technological modernization, and organizational reform into a single coherent vision.

10.3.2. From Fragmented Capacity to Integrated Observation Ecosystem

A key conceptual feature of the Moroccan strategy is the transition from a fragmented observation landscape to a fully integrated observation ecosystem. Historically, observation systems have developed incrementally, often in response to specific needs such as aviation, hydrology, or climatology. As a result, different subsystems—surface stations, radars, marine systems, and upper-air measurements—have operated with varying levels of coordination.

The Vision 2030 programme addresses this fragmentation by introducing the concept of a centralized operational framework, in which all observation components are interconnected and feed into a unified "central intelligence platform". This platform is intended to enable real-time data integration, automated processing, and seamless dissemination of information across all operational domains.

Such integration is crucial not only for technical efficiency but also for decision-making, as it allows different data streams to be combined into coherent products that support forecasting, early warning, and climate analysis.

10.3.3. Current Baseline: Strengths and Structural Limitations

Morocco already possesses a relatively extensive observation infrastructure, which includes:

- A network of automatic weather stations and rainfall gauges
- Aviation observation systems (AWOS)
- Weather and marine radar systems
- Lightning detection sensors
- Upper-air sounding stations
- Satellite data reception capabilities

In addition, the presence of provincial meteorological centres ensures that meteorological information is disseminated at the local level and supports civil protection services.

Despite these assets, the current system is characterized by significant structural limitations.

The most critical issue is insufficient spatial coverage. With approximately 337 out of 1,538 communes covered, the network currently reaches only around 24–25% of the national territory. This level of coverage is insufficient to support the high-resolution modelling and localized warning services required for modern meteorology.

Another important limitation is the heterogeneity of the network, with multiple station types, varying measurement capabilities, and equipment sourced from different manufacturers. While this reflects the historical evolution of the network, it poses challenges in terms of standardization, maintenance, and interoperability.

At the upper-air level, the system is affected by coverage gaps and aging infrastructure, particularly in regions that are most vulnerable to extreme weather. These gaps reduce the effectiveness of radar-based monitoring and limit the ability to detect and track hazardous phenomena in real time.

10.3.4. Strategic Drivers and National Priorities

The Moroccan approach is strongly shaped by national priorities, which are clearly articulated in the Vision 2030 framework.

A first priority is the transition toward commune-scale forecasting, which requires a dense observation network capable of capturing local variability, particularly in complex terrain. This reflects a shift from generalized forecasting to impact-based, location-specific services, where meteorological information is directly linked to decision-making processes.

A second priority is ensuring full compliance with WMO standards, including spatial density requirements that vary according to terrain and meteorological variability. These standards provide a benchmark for network design, but must be adapted to national conditions, such as Morocco's diverse geography, ranging from coastal zones to mountainous regions and desert areas.

A third priority is the complete modernization and automation of the observation network, including the elimination of outdated instruments and the transition to digital, real-time data acquisition systems. This modernization is essential not only for performance but also for compliance with international environmental agreements.

10.3.5. Scaling Up: A National Expansion Strategy

One of the most striking aspects of the Moroccan strategy is its scale and ambition.

To achieve full national coverage, DGM plans to expand its surface observation network from its current level to more than 1,500 stations, effectively ensuring that every commune is covered by at least one observation point. This involves the deployment of over 1,100 additional stations, making it one of the most significant network expansion efforts in the region.

Importantly, this expansion is not uniform, but follows a tiered and adaptive approach. Different types of stations are deployed depending on the needs of each area, ranging from high-capacity stations measuring multiple variables to simpler stations focusing on key parameters such as temperature and rainfall.

This approach is complemented by a geography-sensitive density model, where station spacing is adjusted according to terrain complexity and meteorological variability. For example, mountainous regions require much higher density than desert areas, reflecting the greater variability of weather conditions.

10.3.6. Strengthening Upper-Air and Multi-Domain Observations

In parallel with surface network expansion, significant investments are planned in upper-air and remote sensing systems.

The radar network is being modernized through both replacement and expansion, with the goal of eliminating current coverage gaps and ensuring continuous monitoring across the entire territory. Additional systems, such as marine radars and lightning detection networks, are being strengthened to provide multi-domain observational capability, covering atmospheric, coastal, and marine environments.

This multi-layered approach is essential to building a comprehensive situational awareness capability, where different observation technologies complement each other and provide a complete picture of atmospheric processes.

10.3.7. Operational Sustainability: Maintenance as a Strategic Pillar

A particularly noteworthy aspect of the Moroccan case is the strong emphasis on maintenance and operational sustainability.

The rapid expansion of infrastructure introduces significant operational challenges, including increased maintenance workload, logistical complexity, and the need for rapid intervention across a geographically diverse territory. The current system, which relies partly on external contractors and lacks centralized management tools, is not sufficient to support this scale.

To address this, the strategy proposes a transition toward a proactive, digitally managed maintenance model, centred on the implementation of a Computerized Maintenance Management System (CMMS). This system will enable real-time tracking of assets, planning of preventive maintenance, and monitoring of performance indicators.

In addition, measures are planned to strengthen human and logistical capacity, including workforce development, fleet modernization, and the establishment of service-level agreements with suppliers. The objective is to achieve and maintain a 90% system uptime, ensuring the reliability of the entire observation network.

10.3.8. Data Quality, Calibration, and Trust in Observations

Ensuring the quality and credibility of observational data is another central component of the strategy.

Morocco has established a strong foundation in this area through its metrology laboratory and Regional Instrumentation Centre, which provide calibration and training services at both national and regional levels.

Building on this capacity, the Vision 2030 strategy introduces a more systematic and scalable approach to calibration, including regional calibration centres and rotation-based protocols. These measures ensure that all instruments remain traceable to international standards and maintain consistent performance over time.

This focus on metrology reflects an understanding that the value of an observation network depends not only on its coverage, but also on the accuracy, reliability, and comparability of its data.

10.3.9. Integration and Partnerships: Expanding the Data Ecosystem

Another key element of the Moroccan strategy is the emphasis on integration beyond institutional boundaries.

Through the development of the State Climate Network (RCE), DGM aims to connect observation systems operated by different actors, including public institutions and private entities, into a unified national network. This approach significantly increases data availability while avoiding duplication of investments.

The RCE also facilitates standardization, quality control, and data sharing, enabling more efficient use of available resources and strengthening national capacity for forecasting and climate analysis.

10.3.10. Phased Implementation and Realistic Planning

Recognizing the scale and complexity of the transformation, the strategy is structured into sequential phases, allowing gradual implementation and continuous adjustment.

The initial phase focuses on establishing the foundations, including priority deployments and the introduction of management systems. Subsequent phases scale up the infrastructure and complete the network, culminating in full national coverage and operational stabilization by 2030.

This phased approach reflects a pragmatic understanding of constraints, ensuring that the strategy remains achievable within available resources and institutional capacity.

10.3.11. Strategic Lessons and Transferable Insights

The Moroccan experience offers several valuable insights for other national meteorological services.

First, it demonstrates the importance of aligning observation strategies with national priorities, particularly in relation to disaster risk reduction and climate resilience.

Second, it highlights that infrastructure expansion must be accompanied by operational reform, especially in maintenance and human resource management.

Third, it illustrates the benefits of integrating multiple observation domains and data sources, including partnerships beyond the core meteorological service.

Finally, it underscores the importance of adopting a long-term, phased approach, balancing ambition with realism and ensuring sustainability.

In summary, Morocco's Vision 2030 represents a holistic and forward-looking approach to observation system development. By combining large-scale investment, technological innovation, and institutional strengthening, it seeks to transform meteorological observations into a robust, integrated, and sustainable national capability.

This case study exemplifies how countries can move beyond incremental improvements toward systemic transformation, aligning observation strategies with both national needs and global frameworks, and ensuring that meteorological services remain relevant and effective in an increasingly complex and risk-prone environment.

10.4. Observing networks and strategic priorities in Indonesia

The presentation delivered by BMKG (Indonesia's Meteorological, Climatological, and Geophysical Agency) provided a comprehensive overview of its national observing network, governance structure, strategic priorities, and future development plans. The presentation highlighted both the achievements and the key challenges faced in maintaining and evolving a large and diverse observational infrastructure in support of weather, climate, and environmental monitoring.

BMKG operates an extensive national observing system comprising approximately 1,400 automated instruments, including Automatic Weather Stations (AWS), rainfall gauges (ARG), upper-air stations, climate stations, air quality monitoring systems (including PM2.5, PM10, and greenhouse gas stations), as well as marine observing platforms such as buoys, tide gauges, and HF radars. This broad network supports nationwide data collection across meteorological, climatological, and geophysical domains, enabling forecasting and early warning services. While the majority of stations are owned and operated by BMKG, a number of observing sites are managed by other governmental agencies and private entities, with ongoing efforts to integrate these external systems into BMKG's centralized data infrastructure.

From a governance perspective, the design of observing systems is driven by end-user requirements, particularly forecasting needs, and involves coordination between technical departments and infrastructure units. Operations, maintenance, and data management functions are centralized within the infrastructure department, with clearly defined performance targets, including service level agreements exceeding 98% and operational level agreements above 95%. Collaboration is emphasized at multiple levels, including national partnerships with academia and the private sector, as well as regional and global cooperation within WMO frameworks such as RBON and GBON.

A key part of the presentation focused on challenges affecting the sustainability and effectiveness of the observing network. These include financial constraints limiting procurement and maintenance, gaps in technical capacity and training—particularly at regional levels—, risks of vandalism (especially for marine equipment), and difficulties in ensuring standardized data management and exchange across heterogeneous systems. The "One Observation Policy" provides a national framework for data integration, but further development is needed to harmonize standards, especially for externally sourced data.

BMKG's strategic planning is aligned with international frameworks, particularly WIGOS and GBON, and prioritizes the provision of high-quality, sustainable observation data to support forecasting and global data exchange. Key strategic objectives include maintaining high system availability, strengthening maintenance capabilities through local technical training, and improving supply chains for spare parts. The agency also places strong emphasis on awareness-raising and stakeholder coordination to protect observation infrastructure and ensure long-term sustainability.

The presentation also showcased ongoing and planned investment projects aimed at expanding observational capacity, including maritime meteorological systems and radar deployments. BMKG has engaged with development banks and bilateral partners to support these initiatives. Lessons learned highlight the importance of securing adequate and sustained funding, as financial limitations can lead to suboptimal network design and reduced system performance. Project implementation typically involves close collaboration with vendors and turnkey delivery approaches.

Finally, BMKG identified several opportunities to strengthen its observing systems, including increased access to domestic and international funding, enhanced regional data sharing through RBON, and the development of public–private partnerships. At the same time, potential threats were noted, particularly shifting national priorities that may constrain budgets and affect long-term sustainability. Overall, the presentation underscored the importance of integrated planning, strong partnerships, and continuous capacity development to ensure resilient and effective national observing systems.

10.5. South African Weather Service (SAWS): capabilities and strategic direction

The South African Weather Service (SAWS) operates a comprehensive and integrated national observing system that underpins weather forecasting, climate monitoring, and broader environmental services. This system combines surface observations, upper-air measurements, radar and lightning detection, marine observations, atmospheric composition monitoring, and satellite data. Together, these components provide a multi-hazard, end-to-end observational capability that supports both national decision-making and international data exchange frameworks under the World Meteorological Organization (WMO). With coverage ranging from approximately 50% to full national reach depending on the network, and centralized coordination through the National Forecasting Centre, SAWS demonstrates strong operational capacity and a well-established infrastructure base.

Despite these strengths, the observing system faces significant operational and structural challenges. Much of the infrastructure is aging, leading to increased downtime and higher maintenance requirements. In addition, data transmission is often affected by power instability, telecommunications outages, and limited system redundancy. The coexistence of manual and automated stations creates inefficiencies, while gaps remain in technical expertise in areas such as instrumentation, information and communication technology, and data engineering. At a broader level, SAWS must contend with rising capital and operational expenditures, driven by the need to modernize infrastructure and meet increasing demand for high-frequency, high-quality data, particularly in the context of more frequent and intense climate-related events.

These challenges are compounded by a range of financial, institutional, and risk-related factors. Operational funding (OPEX) is often constrained or unstable, while investment (CAPEX) tends to rely on short-term, project-based funding without sufficient long-term sustainability planning. Infrastructure is also vulnerable to vandalism, theft, difficult site access, and exposure to environmental extremes, all of which affect system reliability. Human resource risks are significant, with the loss of experienced personnel and limited availability of specialized skills making it difficult to sustain and expand operations. Furthermore, gaps in metadata management and data continuity pose compliance and reputational risks, particularly in relation to WMO frameworks such as WIGOS and performance monitoring by INFCOM.

In response to these challenges, SAWS has defined a clear strategic direction for the period 2025–2030. The focus is on ensuring a reliable, sustainable, and high-quality observing network while modernizing aging infrastructure and accelerating the transition toward automation. Strengthening the resilience of data transmission systems, improving data management and metadata governance, and optimizing the balance between capital and operational expenditure through lifecycle planning are also key priorities. In parallel, there is a strong emphasis on building partnerships with other sectors and institutions to enhance resource mobilization and system integration.

To operationalize this strategy, several priority actions have been identified. First, there is a need to elevate the observing system as national critical infrastructure and promote stronger cross-government ownership beyond SAWS alone. Financial sustainability must be improved by shifting from project-based investments to lifecycle-based funding models, complemented by co-financing arrangements with key beneficiary sectors such as aviation, water management, and climate services. Operationally, the emphasis should move toward improving data availability and quality rather than simply expanding the network, supported by performance-based monitoring aligned with international standards. Finally, preparing the system for future demands will require investment in automation, remote monitoring, and smart diagnostics, alongside the adoption of emerging technologies while safeguarding core reference networks.

Overall, SAWS possesses a robust and strategically important observing system, but its long-term effectiveness depends on addressing interrelated technical, financial, and institutional challenges. Achieving a sustainable and future-ready system will require a coordinated approach focused on modernization, resilience, efficiency, and strengthened governance.

10.6. South African Hydrological Observing capabilities

The presentation on South African hydrological observing capabilities, delivered by the Directorate of National Hydrological Services, provided a comprehensive overview of the country’s surface water and groundwater monitoring systems, their institutional mandate, operational challenges, and strategic approaches to ensuring sustainability. The presentation emphasized the critical role of hydrological observations in supporting water resource management, risk reduction, and long-term planning under increasing climate variability.

The hydrological monitoring mandate in South Africa is strongly grounded in national legislation and policy frameworks, including the National Water Act (1998), the National Water Resources Strategy (NWRS-2), and the National Development Plan (2030). These frameworks require the establishment of coordinated national monitoring programmes to generate reliable and accurate data for informed decision-making, water security, and climate resilience. Monitoring activities are therefore central to ensuring sustainable water supply in terms of both quantity and quality, with regular reporting mechanisms in place across national and regional levels.

The national observing system comprises two main components: surface water and groundwater monitoring networks. The surface water network is the backbone of the system and includes several sub-programmes, such as dam monitoring (223 sites), evaporation and rainfall monitoring (approximately 500 sites), and streamflow monitoring (683 sites). These systems operate at varying temporal resolutions, ranging from real-time measurements at 12-minute intervals to daily and weekly observations, supported by approximately 800 real-time data transmission systems. Data are managed and analysed primarily through the HYDSTRA platform.

The groundwater monitoring network is similarly extensive and includes both quantity and quality monitoring programmes. Groundwater levels are monitored across approximately 1,800 sites, while groundwater quality monitoring is conducted at more than 379 active stations, with additional specialized monitoring for priority areas such as acid mine drainage. Measurements include physical and chemical parameters collected at different frequencies, ranging from monthly to biannual sampling. Combined, these networks provide a comprehensive picture of national water resources, supporting both operational decision-making and long-term planning.

The presentation also highlighted the diversity of monitoring infrastructure deployed across the country. This includes river gauging stations, radar-based discharge measurement systems, dam level observation infrastructure, rainfall and evaporation stations, boreholes, and groundwater recharge stations. Advances in technology, such as non-contact radar systems and modern hydrometric equipment, are being adopted to improve measurement accuracy and operational efficiency.

Despite this extensive infrastructure, significant challenges affect the sustainability and effectiveness of the observing network. A major concern is chronic underinvestment, which has led to the deterioration of monitoring stations and equipment, creating risks of network redundancy and costly future rehabilitation. In the groundwater network, insufficient funding has resulted in the removal of data loggers at some sites, leading to critical data gaps. Additional challenges include vandalism and theft of equipment, damage to stations from extreme weather events such as floods, ageing infrastructure and workforce, limited access to monitoring sites, and gaps in maintenance and supporting infrastructure such as roads.

Operational constraints further impact the accuracy and reliability of observations. For example, some stations are unable to measure extreme flood flows due to technical limitations, while others face institutional and regulatory challenges related to land access and environmental compliance. These issues underscore the need for sustained investment and improved governance to maintain and expand the monitoring network.

In response to these challenges, South Africa is implementing several strategic measures to enhance network sustainability. A key initiative is the standardization of hydrological equipment, which has been ongoing since 1996 and aims to ensure consistency, reliability, and comparability of data across the network. Updated specifications for hydrometric equipment, developed in 2022, provide a framework for procurement, operation, and maintenance, balancing cost and performance considerations. Regular reviews of these standards are planned to keep pace with technological development.

Additional sustainability strategies include the adoption of new technologies, development of vandal-resistant infrastructure, and strengthening collaboration with key stakeholders such as the South African Weather Service (SAWS), research institutions, and environmental organizations. Partnerships with organizations managing complementary observing networks, as well as the promotion of citizen science and community engagement, are also highlighted as important approaches to enhancing data collection and protecting infrastructure.

Overall, the presentation underscored the importance of a well-maintained, standardized, and integrated hydrological observing system to support national water security and climate resilience. It also emphasized that sustained funding, institutional coordination, technological innovation, and stakeholder engagement are essential to ensure the long-term effectiveness and sustainability of hydrological monitoring in South Africa.

10.7. Observing networks and strategic priorities in Kenya

This report summarizes the presentation delivered by representatives of the Kenya Meteorological Department (KMD). The presentation examined the current status of Kenya's national observing systems, highlighting institutional arrangements, infrastructure capacity, operational challenges, strategic direction, and opportunities for strengthening meteorological observations.

KMD Observation Network Division operates under a structured governance system led by a Director and supported by technical and operational departments. Core functional areas include observations, data management and quality control, radar and remote sensing, aviation meteorology, marine services, and project coordination. This structure is intended to ensure effective policy direction, operational management, and coordination of national observing networks.

10.7.1. Status of Observing Systems

The presentation provided a comprehensive overview of the current status of Kenya's meteorological observation infrastructure. The country maintains an extensive network comprising of automatic weather stations (AWS), manual observing stations, rainfall gauge stations, upper-air systems, marine observation systems, radar installation, and atmospheric monitoring facilities.

Despite the apparent size of the infrastructure, operational efficiency remains a concern. A significant proportion of installed systems are non-functional, particularly among AWS. Upper-air observations are limited, with only one active station in Nairobi. The network also includes both government-owned and privately operated rainfall stations, creating complexities in data integration and management.

10.7.2. System Performance and Coverage

The observing network exhibits uneven spatial distribution, with notable gaps in arid and semi-arid lands (ASALs) and other remote regions. Data collection from manual stations is inconsistent, while marine and upper-air observations remain insufficient. Additionally, communication systems supporting data transmission are unreliable, affecting real-time data availability.

The presentation outlined several ongoing and planned initiatives aimed at improving observational capacity. These include:

a) Procurement of advanced systems such as X-band radar and aviation data exchange platforms (SADIS)

b) Upgrade of upper-air observation systems

c) Expansion of AWS coverage in data-sparse regions

d) Rehabilitation of non-functional stations

e) Transition from manual to automated observing systems countrywide

Funding is sourced from the Government of Kenya, development partners, climate financing mechanisms, and emerging public-private partnerships. It is hoped that the WMO SOFF would also be availed to Kenya.

10.7.3. Key Challenges

Several challenges affecting the effectiveness of observing systems were identified:

a) Infrastructure Constraints: Aging equipment, frequent system breakdowns, and limited availability of spare parts

b) Technical Capacity Gaps: Inadequate personnel for maintenance and limited expertise in advanced systems

c) Data Gaps: Sparse station coverage and inconsistencies in data collection

d) Communication Limitations: Weak telemetry systems and unreliable data transmission networks

e) Financial Constraints: Insufficient funding for maintenance, expansion, and capacity building

f) Security Risks: Vandalism and theft of equipment, particularly in remote areas

10.7.4. Strategic Planning Framework

Although a fully operational national strategic plan is not yet in place, KMD has established key strategic foundations. These are structured around four main axes:

a) Spatial Planning: Optimal siting of observation stations

b) Quality Assurance: Compliance with international standards

c) System Integration: Development of a unified national observing system

d) Sustainability: Strengthening maintenance systems and availability of spare parts

The framework aligns with global standards such as WIGOS and GBON, though compliance remains partial.

10.7.5. Project Experience and Lessons Learned

KMD has implemented several projects, including the Kenya Climate Smart Agriculture Project (KCSAP) and Famine Early Warning Systems Network (FEWSNET), which have contributed to expanded observational capacity and improved early warning systems.

Key lessons include:

- Technology deployment must be accompanied by sustainable maintenance frameworks
- Local capacity building is essential for long-term system functionality
- Community engagement enhances system security and sustainability
- Projects often emphasize installation over long-term operational support

10.7.6. Opportunities for Improvement

The presentation identified several opportunities to enhance observing systems:

- Modernization through expansion of AWS and radar networks
- Strengthening real-time data transmission and integration platforms
- Improving data quality control and standardization
- Expanding coverage in underserved regions
- Enhancing maintenance systems for sustainability

Strategic partnerships with international organizations, regional bodies, research institutions, and the private sector were highlighted as critical enablers.

10.7.7. Threats and Risks

Key risks affecting observing systems include:

- Damage to infrastructure from climate variability and extreme weather events
- Continued vandalism and theft of equipment (AWS)
- Financial instability and reliance on donor funding
- Rapid technological changes leading to system obsolescence
- Meteorological equipment host institutions development activities causing station relocations

10.7.8. Strategic Recommendations

The presentation emphasized the following actions:

- Prioritize maintenance and rehabilitation of existing infrastructure over new installations

- Strengthen the linkage between observational data and decision-making processes in sectors such as agriculture, disaster risk reduction, and urban planning
- Improve institutional coordination and accountability across national and regional levels
- A tiered approach in the deployment of costly legacy and low-cost AWS

The presentation concluded that Kenya has established a substantial meteorological observational infrastructure. However, the effectiveness of this system depends on improving functionality, strengthening maintenance and technical capacity, enhancing system integration, and ensuring sustainable financing. A shift toward a more coordinated, people-centered, and impact-driven approach is necessary to fully realize the value of meteorological observations in national development.

11. Strategic planning for observation

11.1. Strategic planning for observation: Methodology, vision, strategic axes, KPIs, action plan

The presentation provided a comprehensive framework for strategic planning in observation systems, emphasizing a structured, long-term approach to guiding the development and sustainability of national observing networks. Strategic planning was defined as a systematic process that helps organizations determine their future direction, set priorities, and align resources to achieve desired outcomes. It addresses key questions on current position, future goals, and the actions required to achieve them, ensuring coordinated decision-making and governance.

A clear distinction was made between strategic and operational planning, where strategic plans focus on long-term direction and outcomes, whereas operational plans translate these into short-term actions and implementation details. The presentation introduced several strategic planning models, including basic, issue-based, scenario-based, and hybrid approaches, enabling organizations to adapt their planning processes to complexity, capacity, and environmental uncertainty.

Strategic planning was presented as a continuous cycle, comprising key phases: preparation, assessment and analysis, strategy design, implementation, performance monitoring, and review. This cyclical approach ensures adaptability, learning, and continuous improvement. Central to this process are well-defined vision and mission statements, where the vision describes a desired future state and the mission explains the organization’s purpose and role in achieving that vision.

The presentation highlighted structuring strategies around axes (pillars) that group related objectives for prioritization and investment. For observation systems, these include network coverage, data quality, system sustainability, data management, capacity development, and governance. These support clear, measurable strategic objectives rather than just activities. The roles of KPIs, which track performance in coverage, data quality, reliability, and sustainability, and of action plans, which outline activities, timelines, responsibilities, and resources, were also emphasized.

11.2. Planning Tools

This presentation introduces a set of strategic planning tools designed to support the development of sustainable meteorological observation systems. It emphasizes that effective strategic planning requires more than ideas; it relies on structured approaches to analyze the current context, identify key issues, define a clear vision, and prioritize actions. The session is positioned within a broader WMO workshop context, where participants engage in co-creation through group work, using these tools to move from analysis to actionable strategies.

The presentation highlights the strategic planning cycle as a continuous and iterative process, starting with context analysis (internal and external), followed by the identification of strategic needs and challenges, the formulation of strategy (vision, objectives, and action plans), and finally implementation and performance assessment through key performance indicators. A key message is that strategic planning is not a one-time exercise but a dynamic loop of improvement, where learning and evaluation feed future decisions.

Several complementary frameworks are introduced to support different steps of this cycle. SWOT analysis provides a structured diagnostic of strengths, weaknesses, opportunities, and threats. The NOISE model goes further by focusing on action, identifying needs, improvements, and opportunities while leveraging strengths and successful practices. The SOAR framework adopts a forward-looking perspective, emphasizing aspirations and measurable results to build a shared vision.

The three complementary strategic planning frameworks: SWOT, NOISE, and SOAR were introduced and discussed to support structured thinking for sustainable observation systems.

The SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) provides a balanced framework for assessing both internal capacities and external factors. It is particularly useful for establishing a baseline understanding of current conditions, identifying risks, and informing strategic positioning. However, its focus on weaknesses and threats may sometimes lead to a more problem-oriented perspective.

In contrast, the NOISE framework (Needs, Opportunities, Improvements, Strengths, Exceptions) emphasizes actionable insights and continuous improvement. By focusing on what needs to be addressed, what already works well, and where improvements can be made, NOISE supports operational planning and adaptive management of observation systems. It places less emphasis on risks, instead encouraging solution-driven discussions.

The SOAR framework (Strengths, Opportunities, Aspirations, Results) adopts a forward-looking and strengths-based approach. It is particularly well suited for fostering stakeholder engagement and defining a shared vision for the future of sustainable observations. By focusing on aspirations and measurable results, SOAR promotes innovation and alignment, although it may underrepresent existing constraints or vulnerabilities.

In summary, while SWOT is best suited for comprehensive situational analysis, NOISE supports practical improvement and implementation planning, and SOAR enables vision-building and strategic growth. The combined use of these tools can provide a robust and balanced approach to the planning and development of sustainable observation initiatives.

In addition, the Impact–Effort matrix was also presented which helps prioritize actions based on their expected impact and required resources, ensuring efficient decision-making in resource-constrained environments.

Overall, the whole presentation demonstrates how combining these tools enables a comprehensive and practical approach to strategic planning. Applied to meteorological observing systems, they support better decision-making, stronger stakeholder alignment, and more effective investment in observation infrastructure and services.

11.3. 360° User Feedback

This presentation focuses on the identification of end-user requirements as a fundamental step in developing sustainable and effective meteorological observing systems. It emphasizes that observing systems must be user-driven rather than technology-driven, ensuring that investments are aligned with real needs and generate tangible operational impact. This approach is consistent with WIGOS principles and supports the development of high-value services such as early warning systems, impact-based forecasting, and climate services. The central question guiding this process is: who needs what information, for what purpose, and with what level of timeliness and accuracy.

A comprehensive 360-degree stakeholder approach is presented to ensure that all relevant actors are considered. These include internal users (such as forecasters and technical teams), economic sectors (agriculture, aviation, energy), government institutions, media, the public, scientific communities, partners, and international organizations. The observing system is seen as a “system of systems” supported by an internal value chain, where each function—from observation and maintenance to data management and forecasting—contributes to transforming raw data into actionable services. The effectiveness of the system depends on the coordination and performance of this entire chain.

To capture user needs effectively, the presentation proposes a structured 360-degree feedback logic, distinguishing between upstream, midstream, and downstream users, each with different expectations in terms of data type, resolution, accuracy, and delivery. Multiple methods are required to collect these needs, including surveys for broad coverage, workshops for co-creation and consensus building, and interviews for in-depth insights. These complementary approaches ensure both quantitative and qualitative understanding of requirements. The collected needs are then organized into a User Requirements Matrix, allowing for standardization, comparison, and identification of priorities and gaps.

Finally, the presentation shows how structured requirements inform decision-making. They guide observation network design, support investment prioritization, and enhance service development while feeding into strategic planning processes. This is presented as a continuous and iterative cycle, where stakeholder engagement, feedback, and evaluation continuously refine the observing system. The key message is that sustainable observing systems evolve over time and must remain aligned with user needs, as their ultimate value lies not in what can be measured, but in what is truly needed by users.

12. Low cost and innovative solutions for hydrometeorological observations

12.1. Use of 3D-Printed Automatic Weather Station Technology

The Kenya Meteorological Department (KMD) presented its experience in strengthening national observation capabilities through the adoption of innovative and cost-effective technologies, notably 3D-printed Automatic Weather Stations (3D-PAWS). Developed in collaboration with the University Corporation for Atmospheric Research (UCAR) and the US National Weather Service, these systems offer a significantly more affordable alternative to conventional commercial AWS, with production costs of less than USD 1,000 compared to over USD 20,000 for traditional systems. The ability to manufacture components locally has enabled KMD to reduce reliance on global supply chains, allowing rapid replacement of damaged parts and minimizing station downtime.

To date, KMD has deployed at least twenty-one (21) 3D-PAWS across rural and flood-prone areas, effectively addressing critical observational data gaps. These stations provide near real-time measurements of key meteorological parameters, including rainfall, temperature, and humidity, at 15-minute intervals, supporting the delivery of high-resolution data for Early Warning Services (EWS). Recent upgrades have also incorporated wind sensors, further enhancing data coverage.

Despite these advantages, some operational challenges associated with low-cost AWS solutions were noted. The workshop concluded that 3D-PAWS are best implemented within a tiered observation network, serving as a complementary solution to conventional (Tier 1) AWS, particularly in areas where installation of standard systems is constrained by cost, security, or logistical limitations.

12.2. KMD experience in the use of low-cost weather stations

The presentation also highlighted the role of the Trans-African HydroMeteorological Observatory (TAHMO) in strengthening surface observation networks in Kenya and across sub-Saharan Africa. TAHMO is a continent-wide initiative aimed at deploying up to 20,000 affordable and robust weather stations, addressing the long-standing decline and spatial gaps in meteorological observations across Africa.

In Kenya, the TAHMO network complements national observing systems by providing additional coverage, particularly in underserved and data-sparse regions. The stations are designed to be low-cost, easy to install, and resilient, enabling dense spatial monitoring of key atmospheric variables such as rainfall, temperature, humidity, and pressure. This expanded observational footprint contributes to improved data availability for forecasting, climate monitoring, and research.

A key objective of TAHMO is to transform observational data into actionable services, particularly for climate-sensitive sectors such as agriculture. The data collected are made available on real time on a dedicated web site and are used to generate tailored weather information services for farmers, supporting decision-making related to planting, irrigation, and risk management. By enhancing access to localized and timely weather information, the initiative contributes to building resilience to climate variability and change.

12.3. WMO HydroHub Innovation: Advancing Sustainable Hydrological Monitoring

The presentation introduced the WMO HydroHub as a global initiative aimed at enhancing and sustaining hydrological monitoring systems to support NMHSs in delivering effective services for disaster risk reduction, water resource management, and climate adaptation. The HydroHub focuses on strengthening capacity, optimizing stakeholder engagement, and accelerating the operational uptake of innovative technologies.

The need for such an initiative is underscored by the fact that approximately 66% of developing countries report declining capabilities in hydrological monitoring. Key challenges identified include inadequate monitoring networks, limited technical capacity, insufficient funding, and low uptake of existing innovative technologies. These constraints highlight the growing demand for cost-effective, scalable, and sustainable solutions.

To address these challenges, the HydroHub has established an "Innovation Calls" mechanism, which supports the deployment of low-cost, open-source, and locally adaptable hydrological solutions. These projects, typically funded between USD 50,000 and 100,000, are implemented through partnerships between NMHSs, research institutions, and private innovators. The approach emphasizes sustainability through capacity development, local ownership, and training, while ensuring that solutions are suitable for operational use and scalable across regions.

Examples of implemented projects demonstrate the diversity of innovations being tested and operationalized. These include low-cost monitoring equipment for remote areas, lidar-based non-contact water level sensors, artificial intelligence for automated quality control, and open-source tools for river flow estimation. Several projects have focused on surface velocimetry techniques, using image-based methods and camera systems to measure river discharge in a cost-effective and non-intrusive manner. Pilot implementations have taken place in countries including Tanzania, Fiji, Argentina, Belize, and India.

The presentation highlighted key enabling factors for success, including strong involvement of NMHSs, the use of open hardware and software, local capacity development, and collaboration between stakeholders. At the same time, challenges remain in ensuring long-term sustainability, including maintenance, standardization, and scaling of solutions beyond pilot phases.

Looking ahead, the HydroHub aims to scale up successful innovations through dedicated programmes that promote wider adoption, strengthen partnerships, and enhance the operational integration of new technologies into national systems. Future efforts will focus on empowering NMHSs, fostering collaboration with local stakeholders, and improving the delivery of hydrological services, particularly for early warning and community resilience.

13. Group Activities

The in-person and online participants were divided into six groups. Each group consisted of five participants from different countries, except for the sixth group, which was composed entirely of online participants and facilitated by a representative from SAWS.

The trainers acted as facilitators, ensuring that participants understood the objectives of the activity, providing guidance, and responding to any questions raised.

13.1. Applying strategic planning tools to analyze national contexts

Following the introductory sessions on strategic planning methodologies, participants received practical training on the main context analysis tools used during the preparation of a National Observation Strategy, namely SWOT (Strengths, Weaknesses, Opportunities and Threats), NOISE (Needs, Opportunities, Improvements, Strengths and Exceptions), SOAR (Strengths, Opportunities, Aspirations and Results), and the Priority Matrix. The training highlighted the comparative advantages of each methodology, their respective use cases, and how they can be applied to systematically assess the national context prior to the development of a strategic plan for observation systems.

For the first group activity, participants were divided into groups and tasked with applying one of the analysis frameworks (SWOT, NOISE, or SOAR) to a national observation context. The objective was to simulate the initial stage of a strategic planning process by identifying key internal and external factors influencing the performance and sustainability of national observing networks. Participants worked collaboratively to analyse their assigned country context and present the outcomes of their discussions to the plenary.

The exercise generated rich discussions and demonstrated a high level of engagement among participants. Despite working independently and using different analytical frameworks, a strong level of convergence emerged across the groups' findings. Participants consistently identified similar strengths, weaknesses, opportunities, and challenges affecting observation systems across their respective countries. This alignment was particularly noteworthy given the diversity of countries represented in the workshop and highlighted the common realities faced by many National Meteorological and Hydrological Services (NMHSs) in Africa.

One of the groups that applied the SWOT methodology identified several notable strengths, including the existence of operational surface observation networks, upper-air sounding systems, lightning detection networks, solar radiation monitoring stations, radar systems, and other observational infrastructure. Participants also highlighted the availability of qualified technical staff and the benefits of participation in regional and global observing networks. Compliance with WMO standards and aviation requirements was considered a key strategic strength and an important foundation for future network development.

At the same time, groups identified a number of recurring weaknesses affecting national observation systems. Among the most frequently cited were inadequate communication links between observing sites and national data centres, maintenance and calibration gaps, ageing infrastructure, insufficient geographical coverage, uneven distribution of technical personnel, and budget constraints limiting maintenance and modernization efforts. Limited human resources and challenges related to site security were also repeatedly mentioned.

Participants further identified significant opportunities that could support the strengthening of national observation systems. These included increased collaboration with national stakeholders and partner institutions, modernization through the adoption of new technologies, enhanced support for climate research and emerging sectors such as renewable energy, expansion of observational networks, greater opportunities for regional data sharing, and increased automation of observational infrastructure.

The threat analysis revealed additional concerns shared by many countries. Participants highlighted environmental degradation affecting observing sites, increasing maintenance costs, vandalism and theft of equipment, cybersecurity and data security risks, and rising infrastructure and operational costs. These threats were considered important factors to be addressed within future observation strategies to ensure long-term sustainability and resilience of observing networks.

Across all groups, a strong consensus emerged regarding the main challenges facing national observation systems. These included inadequate funding, aging infrastructure, limited network coverage, weaknesses in communication and data transmission systems, shortages of skilled personnel, maintenance and calibration deficiencies, and increasing operational costs. Participants also highlighted concerns related to site security, vandalism, cybersecurity, and the long-term sustainability of observation networks. The high degree of consistency in the findings across countries demonstrated that many NMHSs face similar technical, financial, and institutional constraints, reinforcing the value of regional cooperation and shared solutions in the development of National Observation Strategies.

Beyond the technical findings, participants reflected on the co-creation process itself. Several groups reported positive collaboration dynamics, benefiting from the extensive operational knowledge present within the teams. While language differences occasionally created communication challenges, participants noted that collaboration remained effective and productive. Importantly, the exercise reinforced the recognition that many countries face comparable constraints and priorities, creating opportunities for peer learning, regional cooperation, and the sharing of common solutions.

Overall, the exercise successfully demonstrated the practical value of SWOT, NOISE, and SOAR analyses as decision-support tools for strategic planning. It provided participants with hands-on experience in conducting context assessments and confirmed that, despite country-specific differences, many African observation systems share common development priorities related to infrastructure modernization, sustainable financing, human capacity development, network resilience, and enhanced stakeholder collaboration. The strong consistency observed across the different group outputs underscored the relevance of adopting a structured analytical approach as a foundation for the development of National Observation Strategies.

Group 5 Results (SWOT Analysis)

The online Group 5 conducted a SWOT analysis of a national observation network and identified the following key findings:

Strengths

The group highlighted the existence of a relatively comprehensive observation infrastructure, including:

- Surface observation networks;
- Upper-air sounding networks;
- Lightning detection systems;
- Solar radiation monitoring networks;
- Radar networks;
- Webcam and web-based observation systems.

Participants also noted:

- Availability of qualified and skilled human resources;
- Well-established regional and global collaboration networks;
- Strong mission-critical observation systems;
- Compliance with WMO standards and aviation requirements (ICAO regulations), which provide a solid basis for operational activities and future development.

Weaknesses

The main weaknesses identified were:

- Poor and unreliable communication links between observation stations and central data collection systems;
- Site safety and security concerns;
- Maintenance and calibration deficiencies;
- Limited observational coverage in some areas;
- Uneven distribution of technical staff;
- Aging infrastructure and technologies;
- Insufficient human resources;

- Budget limitations, particularly for maintenance and operational sustainability.

Opportunities

The group identified several opportunities for strengthening observation systems:

- Enhanced collaboration with national and regional stakeholders;
- Modernization through adoption of new technologies;
- Increased climate research opportunities, particularly in support of renewable energy sectors such as solar and wind energy;
- Expansion of observation networks;
- Greater regional cooperation for data review and data sharing;
- Increased automation of observational infrastructure and processes.

Threats

Key threats affecting network sustainability included:

- Environmental degradation affecting observation sites and increasing maintenance requirements;
- Vandalism and theft of equipment;
- Cybersecurity and data security risks;
- Rising costs of infrastructure and observation equipment procurement and maintenance.

Results of the Priority Matrix Group

The group assigned to the **Impact-Effort Priority Matrix** assessed possible interventions for strengthening national observation systems and categorized them according to their expected impact and implementation effort.

High-Priority Actions

The group emphasized actions capable of generating significant improvements while remaining achievable within short- to medium-term planning horizons. These included:

- Strengthening human capacities through targeted training;
- Developing the skills of existing staff to operate specialized equipment and systems;
- Building local capacity for interpretation and maintenance activities instead of relying heavily on externally recruited specialists.

A specific example discussed was radar operations. Rather than hiring dedicated radar specialists, participants considered it more sustainable and cost-effective to train existing personnel to operate, interpret, and maintain radar systems.

Lower-Priority / Higher-Effort Actions

Participants considered some investments important but requiring significant planning, financial resources, and logistical preparation, including:

- Procurement of high-end servers and advanced infrastructure;
- Large-scale modernization projects requiring substantial capital investment.

The group concluded that, while desirable, such projects should be implemented over a longer time horizon, as existing infrastructure could still support essential operations in the interim.

Group Reflections

Participants described the co-creation process as highly positive and benefited from the strong expertise present within the group. Members demonstrated a good understanding of observation networks in their respective countries, which facilitated the identification of priorities and challenges.

The principal challenge encountered was language diversity, requiring interpretation between English- and French-speaking participants. Despite this, collaboration was considered effective.

An important conclusion from the exercise was the realization that observation network challenges are largely shared across countries. Participants noted that issues they initially considered country-specific were common throughout the region, reinforcing the need for collective solutions and regional cooperation.

Key Takeaway

Although the SWOT and Priority Matrix groups used different analytical methods, both arrived at remarkably similar conclusions. Across countries, the main priorities were:

- Strengthening human capacity;
- Improving maintenance and sustainability mechanisms;
- Addressing communication and data transmission challenges;
- Modernizing aging infrastructure;
- Expanding stakeholder collaboration and partnerships;
- Securing sustainable funding for observation networks.

Common Challenges Reported Across Groups

A clear outcome of the exercise was the strong convergence of findings across all groups, regardless of whether they used SWOT, NOISE, SOAR, or the Priority Matrix. Participants repeatedly noted that many countries face similar challenges in managing and developing their national observation systems.

The most frequently reported challenges were:

- Limited and unsustainable funding, particularly for maintenance, calibration, modernization, and network expansion. Budget constraints were consistently identified as a major obstacle to improving observation systems.
- Aging observation infrastructure and technology, with many countries operating networks that require upgrading or modernization to meet current operational needs.
- Weak communication and data transmission systems between observation stations and central data processing centres, leading to data availability and reliability issues.
- Insufficient human resources and technical expertise, including shortages of specialized personnel for maintenance, calibration, operation of advanced equipment, and data management.
- Maintenance and calibration gaps, which affect the quality, reliability, and continuity of observations.
- Limited spatial coverage of observation networks, resulting in observation gaps, especially in remote, rural, and high-risk areas.
- Site security concerns, including vandalism and theft of equipment, which compromise network sustainability and increase operational costs.
- Growing operational and infrastructure costs, making it difficult for NMHSs to sustain and expand networks without additional financial support.

- Data management and cybersecurity challenges, including concerns about data security, system resilience, and reliable access to observations.
- Language and communication barriers during regional collaboration, although participants noted that these challenges were generally overcome through teamwork and interpretation support.

Common themes emerging across all groups

The discussions also reinforced the importance of distinguishing between strategic priorities and implementation activities, ensuring a clear linkage between strategic axes, goals, SMART objectives, indicators and implementation actions.

1. Strong convergence across groups Although each group selected different strategic lenses and priority areas, the presentations revealed a high degree of convergence in the challenges faced by NMHSs. Common themes included:

- ageing observation infrastructure;
- maintenance and calibration gaps;
- insufficient communication and data transmission systems;
- shortages of skilled technical personnel;
- limited financial resources;
- the need for modernization and automation;
- vulnerabilities related to site security, vandalism, theft and cybersecurity.

2. Strategic planning versus implementation planning A recurring lesson from the facilitator was that participants often tended to formulate implementation activities instead of strategic objectives. Considerable attention was given to distinguishing:

- strategic axes (priority areas);
- strategic goals;
- SMART objectives;
- KPIs and targets; and
- implementation actions.
  Participants were encouraged to formulate long-term outcomes rather than short-term operational activities.

3. Importance of systems sustainability Several groups highlighted that sustainability extends beyond installing new equipment and should include:

- lifecycle management of observing assets;
- maintenance systems;
- infrastructure renewal planning;
- reliable power and communications;
- site protection and security measures.

4. Human capacity as a strategic priority Capacity development emerged as one of the most frequently cited priorities. Discussions emphasized:

- training and upskilling of existing staff;

- addressing shortages of technical expertise;
- ensuring institutions have the skills necessary to operate and maintain modern observing systems;
- developing training plans and competency frameworks.

5. Growing focus on digitalization and cybersecurity Beyond traditional observing network issues, several groups highlighted:

- data management systems;
- communication and data-feed reliability;
- ICT infrastructure modernization;
- cybersecurity and data protection; as increasingly important components of sustainable observation systems.

13.2. Collecting observations end-user feedback

Prior to the practical stakeholder consultation exercise, participants received dedicated training on methodologies for collecting 360-degree feedback from national stakeholders involved in weather, water, and climate services. The session emphasized that user requirement collection is a fundamental step in the development of a National Observation Strategy, ensuring that future investments in observation infrastructure are aligned with the needs of all sectors that depend on hydrometeorological information.

The training introduced participants to a structured stakeholder engagement process, including methods for identifying and mapping key stakeholders across government agencies, the private sector, academia, non-governmental organizations, community representatives, and end-user groups. Participants were guided on how to prioritize stakeholders based on their dependence on weather, water, and climate information, their role in decision-making, and their potential contribution to national observing systems.

Special attention was given to the design of user requirement surveys and consultations. Participants were introduced to the key questions that should be addressed during stakeholder engagement, including: the sector of activity and area of responsibility; geographic areas requiring enhanced observations; priority meteorological, hydrological, marine, and climate variables; required observation density and coverage; temporal frequency and timeliness of observations; preferred data formats and dissemination channels; current challenges in accessing and using observational data; and recommendations for improving national observation networks. The training also highlighted the importance of understanding both current and future information requirements to ensure that observation strategies remain relevant over the long term.

Several consultation mechanisms were presented and discussed. These included the distribution of paper-based questionnaires through official correspondence, the use of online surveys to reach a broad range of stakeholders efficiently, the organization of national stakeholder workshops to facilitate dialogue and consensus building, and the engagement of specialized consultants to conduct interviews and synthesize user requirements where resources permit. The advantages and limitations of each approach were reviewed, with emphasis placed on combining multiple consultation methods to maximize stakeholder participation and ensure comprehensive feedback.

Following this introductory session, participants took part in a practical group exercise aimed at applying the concepts and tools presented during the training. Participants were assigned the role of different national stakeholders and invited to complete an online survey developed specifically for the exercise. The objective was to simulate a national consultation process and demonstrate how stakeholder requirements can be systematically collected and analyzed.

The responses reflected the needs of a wide range of sectors, including agriculture, water resources management, disaster risk reduction, aviation, marine and coastal management, energy, public health, infrastructure development, environmental protection, transportation, tourism, and academia. Participants identified priority observation areas such as coastal zones, watersheds and river basins, rural communities, urban centres, and highland regions. Frequently requested variables included precipitation, temperature, wind, humidity, atmospheric pressure, soil moisture, river water levels, sea-state parameters, and solar radiation. Most stakeholders emphasized the need for real-time or near real-time observations to support forecasting, early warning services, climate monitoring, water resource management, agricultural planning, infrastructure design, renewable energy applications, and scientific research.

The exercise also highlighted common challenges associated with existing observation networks, including inadequate spatial coverage, data gaps, limited availability of real-time information, inconsistent data quality, and difficulties in accessing and interpreting observations. Participants recommended network expansion, modernization of observing infrastructure, increased automation, improved data management systems, enhanced radar and satellite capabilities, and stronger dissemination mechanisms for warnings and information products.

The exercise further emphasized the growing interest in innovative technologies such as weather radar, lightning detection systems, remote sensing products, artificial intelligence, machine learning applications, and advanced hydrological monitoring systems. Participants recognized that these technologies could significantly enhance forecasting accuracy, support impact-based warning services, improve resource management, and strengthen climate resilience across sectors.

Overall, the activity provided participants with practical experience in stakeholder engagement and requirements gathering while illustrating how user-driven requirements can inform investments in observation infrastructure and contribute to the preparation of a comprehensive and sustainable National Observation Strategy.

13.3 Drafting a National Observation Strategy

Following the presentations on stakeholder requirements and strategy development, participants took part in a practical group exercise designed to simulate the development of a National Observation Strategy. The exercise enabled participants to apply the concepts presented throughout the workshop and translate them into strategic planning elements that could be used by their own National Meteorological and Hydrological Services (NMHSs).

The purpose of the activity was to guide participants through the process of developing a strategic framework for a national observation system. Building on earlier sessions on SWOT analysis, stakeholder engagement, user requirements, and the Moroccan strategy development experience, participants were asked to populate a National Observation Strategy template that had been shared previously.

Participants were expected to work through selected sections of Chapter 5 of the template and develop:

- Strategic Axes (or Pillars)
- Strategic Goals
- SMART Objectives
- Key Performance Indicators (KPIs), if time permitted.

The facilitator emphasized that the exercise should focus on strategic change and desired outcomes rather than technical activities or equipment procurement. Objectives were expected to describe improvements to the observing system rather than listing operational tasks.

During the exercise, facilitators provided examples of possible strategic pillars that national observation strategies commonly include:

- Observation coverage and network design

- Data quality, standards and interoperability
- System sustainability and resilience
- Data management and digital infrastructure
- Human and institutional capacity
- Governance, partnerships and financing.

Participants were reminded that:

- Strategic axes should represent priority themes or pillars.
- Objectives should focus on improvements and outcomes.
- Activities such as "install AWS stations" should not be stated as strategic objectives.
- SMART objectives and KPIs should provide measurable targets linked to strategic outcomes.

Examples of Group Inputs

Strategic Axis 1: Observation Coverage and Network Design

The group considered national observation coverage as a key strategic pillar, focusing on ensuring adequate spatial representation of observations across priority areas and climate-sensitive regions.

Proposed focus areas included:

- Improving observation coverage in underserved regions
- Expanding the representativeness of the network
- Strengthening mission-critical observing capabilities.

Example strategic goal:

Improve the reliability and effectiveness of the national observation network to adequately support weather, climate and early warning services.

Strategic Axis 2: System Sustainability and Resilience

A major theme emerging from the group discussion was the need to ensure observing systems remain operational and resilient despite technical failures, vandalism, communication disruptions and infrastructure challenges.

Participants discussed:

- Reliable power supplies
- Reliable communication systems
- Backup systems and redundancy
- Site security to reduce vandalism
- Maintaining technological relevance through modernization.

Example focus areas identified:

- Reliable support networks (power and communications)
- Keeping pace with technological developments
- Site security and protection of observing assets.

Illustrative strategic goal:

Ensure sustainable and resilient observation systems through reliable support infrastructure and strengthened operational continuity.

Illustrative SMART objective discussed by the group:

Achieve at least 98% network availability through performance-based maintenance and communication service arrangements within a defined implementation period.

Strategic Axis 3: Data Management and Digital Infrastructure

The online group identified data management as a critical strategic area because reliable observations depend not only on measurement but also on the timely transmission and accessibility of data.

Topics discussed included:

- Stable communications infrastructure
- Reliable data feeds
- Digital platforms and connectivity
- Performance monitoring of communication services.

Possible strategic goal:

Strengthen data management and digital infrastructure to ensure continuous, secure and timely delivery of observation data.

Potential SMART objective:

Increase the availability of real-time observation data through enhanced communication networks and improved service-level agreements with data providers.

Strategic Axis 4: Human and Institutional Capacity

Participants also considered organizational capacity as a strategic priority. Discussion focused on ensuring that institutional structures and staffing arrangements support future observation requirements.

Issues discussed included:

- Capacity building
- Skills development
- Organizational alignment
- Matching staff competencies with operational requirements.

Proposed focus area:

Alignment of organizational structures with operational observation requirements.

Example strategic goal:

Strengthen institutional and human resource capacity to support sustainable management of observing systems.

Illustrative SMART objective:

Conduct regular organizational and competency reviews to ensure observation services are adequately resourced and aligned with strategic priorities.

Learning Outcomes

The exercise demonstrated how information generated during previous workshop sessions could be systematically transformed into strategic planning elements:

Previous Activity	Contribution to Strategy Development
SWOT Analysis	Identified strengths, weaknesses, opportunities and threats affecting observing systems.
User Requirement Survey	Identified stakeholder needs and observation priorities.
Strategy Presentations	Provided examples of observation strategy frameworks and methodologies.
Group Strategy Exercise	Converted findings into strategic pillars, goals, objectives and indicators.

The exercise was intended to help participants move from operational discussions about stations, equipment and data collection toward a strategic, outcome-oriented vision for national observing systems. By defining strategic pillars, goals and measurable objectives, participants began constructing the core elements of a National Observation Strategy that could later be expanded into action plans and implementation roadmaps.

14. Strategic Planning for Operation and Maintenance of Observing Systems

The final day of the workshop focused on developing strategic approaches for the effective operation and sustainable maintenance of observing systems, with particular emphasis on calibration and measurement traceability. Participants discussed the critical role of well-structured maintenance frameworks in ensuring data quality, reliability, and continuity over time.

Key discussions highlighted the integration of calibration activities into routine operational plans, including the establishment of regular calibration schedules, adherence to traceability standards, and documentation practices aligned with international best practices. The importance of linking observing systems to recognized reference standards was emphasized to ensure consistency and comparability of measurements across networks.

Participants also explored practical strategies for resource planning, including budgeting for maintenance, capacity building, and strengthening institutional coordination. Risk management approaches—such as contingency planning for equipment failure and prioritization of critical assets—were considered essential components of sustainable system management.

The session concluded with group reflections on developing actionable strategic plans at national and regional levels, incorporating governance structures, technical requirements, and long-term sustainability considerations. Overall, the discussions reinforced the necessity of embedding calibration and maintenance into the core design and operation of observing systems to support high-quality climate data and informed decision-making.

14.1. Measurement Traceability Assurance

The presentation emphasized that traceability to internationally recognized standards (SI units) is essential for ensuring data quality, reliability, and comparability across observing networks.

It puts emphasis on the key concepts, including calibration, measurement uncertainty, and traceability, highlighting the importance of maintaining an unbroken chain of calibrations supported by proper documentation and quality management practices.

A structured, three-level approach to traceability assurance was presented as a practical framework for planning, depending on national capacities:

- **Level 1:** Use of field verification kits for basic performance checks, with periodic recalibration through accredited laboratories.

- **Level 2:** Reliance on external calibration services (e.g., Regional Instrument Centres, National Metrology Institutes, or accredited laboratories), complemented by regular field verification.
- **Level 3:** Establishment of in-house calibration laboratories within NMHSs, supported by appropriate infrastructure, skilled personnel, and quality management systems aligned with ISO/IEC 17025 standards.

The presentation highlighted that no single approach fits all contexts; instead, countries should adopt progressive and adaptable strategies based on their technical capacity, available resources, network size, and partnerships. Strategic planning should therefore integrate calibration and maintenance into routine operations, ensure access to traceability services, and include resource mobilization and capacity development.

Overall, the presentation reinforced that embedding calibration and traceability assurance into operational and maintenance strategies is critical for sustaining high-quality observations and supporting effective climate services and decision-making.

14.2. Overview of an Operations and Maintenance Plan for Observing Systems

This presentation provided an overview of the key components required to develop and implement effective operations and maintenance (O&M) plans for observing systems. Emphasis was placed on ensuring the long-term functionality, reliability, and sustainability of observational networks through structured planning and resource management.

Participants explored the main elements of an O&M plan, including routine inspections, preventive and corrective maintenance, asset management, and lifecycle planning for instruments and infrastructure. The importance of clearly defined roles and responsibilities, as well as standard operating procedures, was highlighted as essential for consistent and efficient system performance.

The presentation also addressed the integration of calibration and quality assurance processes into O&M plans, ensuring that observations remain accurate and traceable over time. Participants discussed the need for maintaining comprehensive documentation, including maintenance logs, calibration records, and metadata, to support transparency and data quality.

Additional discussions focused on resource considerations, such as budgeting, supply chain management, spare parts availability, and capacity development for technical staff. Risk management strategies, including contingency planning and prioritization of critical assets, were identified as key factors in minimizing system downtime.

Overall, the presentation underscored that a well-designed and regularly updated operations and maintenance plan is fundamental to sustaining observing systems, supporting high-quality data production, and enabling effective weather and climate services.

14.3. Procurement strategies as key element for sustainable operations

The Key elements for sustainable operations: Procurement strategies presentation emphasized the critical role of procurement strategies in ensuring the sustainability of observation networks, highlighting that procurement must extend beyond acquiring equipment to encompass long-term operational resilience. A combination of traditional procurement methods—such as open and selected tendering, Requests for Proposals (RFP), and framework agreements—was presented as essential for ensuring transparency, technical quality, and cost-effectiveness.

The presentation emphasized that procurement should be approached as a lifecycle management function, rather than a one-time transactional activity. This includes adopting a Total Cost of Ownership (TCO) approach that integrates capital expenditure (CAPEX) and operational expenditure (OPEX), ensuring that assets can be maintained, repaired, upgraded, and replaced over time. Key requirements include service-level agreements, lifecycle planning, vendor support, and provisions for obsolescence management.

Moreover, the sustainability of observation systems relies greatly on access to spares, consumables, and technical support. It is recommended to include initial spare parts kits, establish long-term supply agreements, and develop redundancy strategies. Additionally, training and capacity building are key procurement elements, necessitating structured programs, including commissioning training, refresher courses, and training-of-trainers, to maintain technical expertise.

The presentation emphasized that strong procurement governance and compliance frameworks are vital for ensuring quality and accountability. This involves establishing clear technical specifications, balanced evaluation criteria, ongoing performance monitoring, and risk management strategies to address issues such as supply chain disruptions, vendor failures, and technology obsolescence. Long-term framework agreements and strong supplier partnerships are critical for maintaining continuity, minimizing downtime, and controlling costs predictably. Additionally, procurement plays a key role in advancing modernization, automation, and digital transformation through investments in interoperable systems, ICT infrastructure, and reliable data transmission. At the same time, collaborative procurement and partnerships at the national, regional, and global levels are shown to be effective in reducing costs, sharing resources, and building capacity.

14.4. Generic Tender Specifications for Automatic Weather Stations (AWS)

This presentation aimed to promote the use of the generic technical specifications for the procurement of Automatic Weather Stations (AWS) developed jointly by the World Bank and the WMO, aimed at ensuring consistency, quality, and long-term sustainability of observing systems. Participants were guided through the essential components of this well-structured tender document, including technical requirements, performance standards, and compliance with international guidelines.

The presentation emphasized the importance of clearly defining functional and technical specifications for AWS components such as sensors, data loggers, power supply systems, and communication interfaces. Attention was given to ensuring that instruments meet recognized standards and are suitable for local environmental conditions, while also supporting interoperability within national observing networks which is well described and detailed in the generic technical specifications for the procurement of AWSs.

Key aspects of procurement planning were discussed, including the inclusion of installation, commissioning, calibration, training, maintenance, and after-sales support within tender requirements. The need for detailed documentation, quality assurance procedures, and acceptance testing protocols should be included in the tender to ensure that delivered systems meet expected performance criteria. Examples are provided in the generic technical specifications for the procurement of AWSs and could be used and adapted to the national context.

Participants also examined strategies to promote sustainability through procurement, such as standardization of equipment, availability of spare parts, vendor reliability, and long-term service agreements. The session underscored the value of aligning tender specifications with broader operational and maintenance plans to reduce lifecycle costs and enhance system resilience.

Overall, the session reinforced that well-prepared tender specifications are critical for acquiring robust, high-quality AWS systems that support reliable data collection and long-term operational efficiency. It was showcased how the generic technical specifications for the procurement of Automatic Weather Stations can be used to guide participants and observing networks managers in drafting well structured tenders.

14.5. Coordination Challenges in Observing Systems in RA I (Africa)

This presentation addressed the key coordination challenges affecting observing systems across WMO Regional Association I, with a focus on strengthening collaboration, governance, and efficiency in the management of meteorological and climate observations. It highlighted the institutional, technical, and operational barriers that hinder the effective coordination of observing networks at national and regional levels.

Key issues discussed included fragmentation of responsibilities among stakeholders, limited coordination between national institutions and regional initiatives, and challenges in data sharing and interoperability. The presentation emphasized the need for clearer governance structures, improved communication mechanisms, and enhanced collaboration among NMHSs, regional centres, and partner organizations.

The presentation also highlighted constraints related to resources, including limited funding, insufficient technical capacity, and gaps in infrastructure, which impact the sustainability and performance of observing systems. The importance of aligning national efforts with regional and global frameworks such as WIGOS and GBON was underscored to improve standardization, data quality, and integration.

Practical recommendations focused on strengthening coordination platforms, fostering partnerships, improving information exchange, and supporting capacity development. The session concluded by reinforcing that effective coordination is essential to optimize investments, reduce duplication of efforts, and ensure the delivery of high-quality observational data to support weather, climate, and disaster risk reduction services.

14.6. Financing Maintenance and Operations of Hydrometeorological Observing Systems

This presentation focused on the financial aspects of sustaining observing systems, emphasizing the importance of securing adequate and predictable funding for ongoing operations and maintenance (O&M). Participants discussed how insufficient or irregular funding is a major constraint affecting the performance, reliability, and sustainability of meteorological and climate observing networks.

Key highlights from the presentation includes the need for a lifecycle costing approach, where financial planning goes beyond initial capital investments to include recurring costs such as maintenance, calibration, spare parts, staffing, training, and system upgrades. The presentation underscored that sustainable financing strategies must be integrated into national planning frameworks and aligned with operational priorities.

The presentation identified potential funding sources, including national budgets, development partners, and international initiatives, as well as opportunities for partnerships and cost-sharing mechanisms. Strengthening financial planning, improving budgeting practices, and enhancing the ability of NMHSs to advocate for resources were identified as critical actions.

The presentation also emphasized the importance of linking financial planning with technical and operational strategies, ensuring that investments in observing systems are efficient, coordinated, and aligned with international frameworks such as WIGOS and GBON.

Overall, this session reinforced that sustainable and well-structured financing mechanisms are essential to ensure the long-term operation, maintenance, and performance of observing systems, thereby supporting the delivery of reliable weather and climate services.

14.7. Group Activities: Drafting a National Operations and Maintenance (O&M) Plan for Observing Networks

Following the presentations by David Hiscock (UK Met Office) on the draft WMO Operations and Maintenance Plan framework and discussions on calibration, procurement, maintenance models, and sustainability, participants took part in an interactive group exercise focused on developing the foundations of a National Operations and Maintenance Plan for observing networks. The exercise built directly on the template and examples presented during the morning sessions, including examples from South African Weather Service (SAWS) and the draft WMO O&M framework.

The purpose of the activity was to encourage participants to move beyond technical maintenance actions and consider maintenance as a strategic organisational function that supports network sustainability, data availability, compliance with WMO requirements, and long-term return on investment.

Participants were asked to reflect on:

- How maintenance should be organised nationally.
- Whether maintenance functions should be centralized or decentralized.
- Whether maintenance should be performed internally or outsourced.
- What governance, staffing, logistics, spare parts, and calibration arrangements would be required to sustain observing networks over time.

The facilitators stressed that the objective was not simply to describe an ideal solution, but to identify realistic approaches based on available resources, capacities, and institutional constraints.

Background Inputs Used During the Exercise

Participants were encouraged to use lessons learned from three key presentations delivered earlier that day:

1. Measurement Traceability and Calibration Strategy

Mr. Ercan Buyukbas presented three possible calibration models:

- Field verification approach
- Use of external calibration laboratories
- Operation of NMHS-owned calibration laboratories

Participants were reminded that every NMHS must adopt a calibration and traceability strategy appropriate to its resources and operational needs.

2. WMO Operations and Maintenance Framework

David Hiscock presented the draft WMO O&M framework and emphasized that:

- Maintenance is a strategic function rather than only a technical activity.
- Successful observation networks depend more on sustainable maintenance than on initial procurement.
- O&M plans should include governance, KPIs, risk management, calibration, spare parts management, staffing, ICT support, preventive maintenance, corrective maintenance, and quality assurance.

3. Procurement and Lifecycle Planning

Procurement discussions highlighted that maintenance sustainability starts during procurement.

Participants were reminded to consider:

- Spare parts provisioning
- Maintenance contracts
- Calibration tools
- Training and skills transfer
- Lifecycle costs
- Service-level agreements (SLAs)

Maintenance Organisation Model

Compare:

- Centralized maintenance
- Decentralized maintenance

Identify:

- Advantages
- Disadvantages
- Preferred model

- Conditions required for success

Service Delivery Model

Compare:

- Internal maintenance (NMHS staff)
- External maintenance (contractors/service providers)

Identify:

- Advantages
- Disadvantages
- Risks
- Preferred approach

Groups were also encouraged to distinguish between maintenance arrangements for:

- Automatic Weather Stations (AWS)
- Weather Radars
- Upper-Air Systems
- Marine Observation Systems
- Other critical observing infrastructure.

Example Group Inputs

The online group (Group 5) discussed a number of concrete points that illustrate the type of outputs generated during the exercise.

Example 1: Centralized Maintenance Model

Advantages Identified

Participants noted that centralized maintenance can provide:

- Greater standardization of maintenance procedures.
- Consistent technical practices across the network.
- Concentration of specialist expertise.
- Better skills development and transfer among technicians.
- Easier quality control and governance oversight.
- More efficient use of scarce specialized equipment and calibration tools.

Example Group Discussion

The group highlighted that centralized teams often develop deeper technical expertise because specialists work together regularly and support each other.

One participant emphasized that centralized maintenance promotes:

“skills transfer,” because technicians working with highly specialized teams gain practical experience during maintenance activities.

Disadvantages Identified

Participants also noted that a centralized model may lead to:

- Slower response times for remote stations.
- Higher travel and logistics costs.

- Dependence on a single management point.
- Delays when specialized equipment or personnel must travel long distances.
- Centralized calibration tools needing to be transported to regional stations.

Example 2: Decentralized Maintenance Model

Advantages Identified

Participants observed that decentralized maintenance can improve:

- Faster response to failures.
- Reduced travel costs.
- Better regional support coverage.
- More immediate access to spare parts.
- Improved support for remote stations.

Example Group Observation

One participant highlighted:

"quick response time" as a major benefit of decentralized maintenance because technicians are located closer to observing sites.

Groups also suggested maintaining regional stores of critical spare parts so that failures can be addressed immediately without waiting for shipments from headquarters.

Disadvantages Identified

Challenges associated with decentralization included:

- Need for more trained personnel.
- Risk of uneven skill levels across regions.
- More complex coordination and management.
- Potential duplication of resources.
- Risks of inconsistent maintenance practices.

One participant noted that decentralization creates:

"management concerns" because coordinating activities across multiple regions becomes more complicated.

Example 3: Hybrid Model (Preferred Solution)

The Morocco example presented by Tarek strongly influenced discussions. The Moroccan model combines:

Centralized Functions

- Technical standards
- Procurement specifications
- National maintenance planning
- KPI monitoring
- Spare parts management

- Specialized maintenance for complex systems (radars, upper-air systems, lightning detection systems)

Decentralized Functions

- Routine AWS maintenance
- Regional inspections
- First-line fault diagnosis
- Preventive maintenance activities
- Rapid intervention at field stations

This hybrid approach was presented as combining:

- Centralized expertise and governance
- Decentralized responsiveness and operational efficiency.

Several group discussions appeared to favour this model because it balances technical quality with operational efficiency.

Example Draft Maintenance Plan Output

Based on the discussions, one typical group output has been structured as follows:

Maintenance Vision

Ensure sustainable, reliable, and cost-effective operation of the national observing network through risk-based maintenance and continuous performance monitoring.

Preferred Maintenance Model

Hybrid centralized-decentralized approach.

Centralized Responsibilities

- Maintenance standards and procedures
- Procurement specifications
- Calibration management
- Spare parts warehouse management
- National maintenance KPI monitoring
- Specialized technical interventions

Regional Responsibilities

- Preventive maintenance
- Routine inspections
- Minor corrective interventions
- Local stakeholder engagement
- Spare parts storage
- Site security checks

Key Performance Indicators

- Station availability (% uptime)
- Mean time to repair

- Calibration compliance rate
- Number of preventive maintenance visits completed
- Data availability (%)
- Percentage of stations meeting GBON requirements
- Number of satisfied maintenance requests
- Mean time between failures

Main Risks

- Insufficient maintenance budgets
- Lack of skilled personnel
- Difficult access to remote stations
- Lack of spare parts
- Vandalism and theft
- Delays in procurement

Mitigation Measures

- Regional spare-part inventories
- Multi-year maintenance contracts
- Annual training programmes
- Preventive maintenance schedules
- Equipment redundancy
- Service Level Agreements with suppliers

The exercise helped participants understand that an Operations and Maintenance Plan is not simply a technical maintenance schedule. Rather, it is a strategic document that links governance, staffing, procurement, calibration, logistics, risk management, and performance monitoring into a coherent framework designed to ensure the long-term sustainability of national observing systems.

In addition, participants were introduced to the role of a **Computerized Maintenance Management System (CMMS)** as an important tool for supporting the implementation and monitoring of a National Operations and Maintenance (O&M) Plan. The CMMS was presented as a mechanism to plan, schedule, record, and track preventive and corrective maintenance activities, manage assets and spare parts inventories, and automatically generate key performance indicators (KPIs) such as station availability, maintenance compliance rates, mean time to repair (MTTR), and equipment downtime. Examples of open-source CMMS solutions were also shared, demonstrating how such systems can strengthen maintenance governance, improve operational efficiency, and support evidence-based decision-making.

15. Inclusion of Women and Youth in Strategic Planning and Implementation of Sustainable Hydrometeorological Observing Systems

The final session of the workshop addressed a critical and forward-looking question: how to effectively integrate women and youth into the strategic planning and implementation of sustainable hydrometeorological observing systems, including their operation and maintenance. This discussion underscored that achieving sustainability in observing networks is not only a matter of technical design and financial investment, but also of inclusive human resource development and participation across all levels of NMHSs.

Participants acknowledged that, in many NMHSs, strategic planning processes are traditionally led by top management, typically composed of highly experienced and senior professionals. While this approach ensures strong institutional memory and technical expertise, it can inadvertently limit the integration of emerging perspectives, innovative approaches, and future-oriented needs. Given that observing systems are long-term investments designed to operate over decades, the importance of including youth and women—who represent both the current and future workforce—becomes essential.

From the discussions, it was emphasized that observing systems are not ends in themselves, but enabling tools that support a wide range of users, including observers, forecasters, database managers, numerical modelers, and decision-makers. These user groups are increasingly diverse and include young engineers, technicians, and women professionals who play operational and technical roles within NMHSs. Their inclusion in the analysis of national needs, system design, and prioritization processes is critical, as they are often closest to emerging technologies, evolving workflows, and user expectations.

Moreover, younger professionals bring fresh technical competencies, particularly in the context of the ongoing transformation of hydrometeorological observing systems. With the rapid evolution of digital technologies, observing systems are increasingly transitioning from traditional mechanical and manual instruments to integrated, automated, and IT-driven infrastructures. This shift requires new skill sets in areas such as data management, software systems, remote monitoring, and cybersecurity. As such, young technicians and engineers are key assets in ensuring the sustainability, scalability, and adaptability of these systems.

Participants highlighted that early involvement of youth in the design, procurement, and implementation phases is essential. Engaging them from the outset ensures that systems are tailored not only to current operational realities but also to future technological developments. It also fosters a sense of ownership and responsibility, which is fundamental for long-term operation and maintenance (O&M). However, this involvement must be complemented by targeted training and capacity development (CD) initiatives, ensuring that young staff are equipped with both the technical knowledge and practical skills required to manage and sustain observing networks effectively.

The discussion also explored the role of women in the hydrometeorological workforce. While in some contexts there may still exist perceptions or structural barriers limiting women's participation in field-based activities, participants emphasized that women play a critical and often underutilized role across many dimensions of observing system management. For example, women are actively engaged in real-time monitoring operations, data quality control, and information management. They contribute significantly to the maintenance of metadata and station registries through platforms such as the WMO WIGOS, including tools like WDQMS and OSCAR/Surface.

In addition, women could be well represented in calibration laboratories, where precision, attention to detail, and adherence to standards are critical. They also contribute to quality management systems, performance evaluation, incident reporting, and documentation processes, all of which are essential components of sustainable observing system operations. Recognizing and strengthening these roles can greatly enhance the overall performance and reliability of observing networks.

Importantly, in many countries, particularly those facing significant human resource constraints, maximizing the contribution of all available staff—regardless of gender, age, or seniority—is not only beneficial but necessary. The inclusion of women and youth should therefore not be seen as an optional or secondary objective, but rather as a strategic imperative for institutional resilience and sustainability.

To operationalize this inclusion, participants suggested several practical measures. These include:

- Promoting participatory planning processes, where staff at different levels can contribute to strategic discussions and decision-making;
- Establishing mentorship and knowledge transfer mechanisms between senior experts and younger staff;
- Ensuring equal access to training, capacity development, and career advancement opportunities for both women and men;

- Actively encouraging women’s participation in technical and leadership roles, including field operations where feasible;
- Integrating inclusivity criteria into project design and procurement processes, ensuring that systems and workflows are accessible and adaptable to diverse users.

16. Key Outcomes of the workshop

Key outcomes of the workshop included an enhanced technical understanding of WIGOS principles, WMO guidance on network design—including for hydrological observations—and relevant regulatory frameworks. Participants were also introduced to a range of methodological approaches, including the RBON design approach and the Multi-Criteria Decision Analysis (MCDA) method. In addition, they were exposed to best practices and innovative solutions, particularly the use of low-cost technologies for hydrometeorological applications. Requirements for the implementation of remote sensing observing methods were also presented, with a particular focus on weather radars and lightning detection systems.

A range of practical tools was introduced to support the 360-degree collection of user requirements for hydrometeorological observations, identification of challenges, and assessment of strengths, opportunities, threats, needs, and stakeholder expectations. Step-by-step methodologies and templates were presented, enabling participants to develop initial drafts of national observing strategies tailored to their country contexts.

By the end of the workshop, participants had developed initial drafts and outlines of national strategic and implementation plans tailored to their respective country contexts. They also gained practical tools and methodologies to refine these plans and align them with WIGOS principles and guidelines.

The workshop also fostered dialogue between NMHSs, WMO regional centres, and technical partners, contributing to a more harmonized approach to observation planning and capacity development in the region. It highlighted the role of NMHSs as leaders in observations and highlighted the importance of investing in sustainable, resilient observing systems.

The workshop reaffirmed that sustainable hydrometeorological observing systems depend as much on people as on technology. By fostering inclusive approaches that engage youth and women in both strategic planning and implementation, NMHSs can build stronger, more adaptive, and future-ready observing networks. Such inclusivity not only enhances technical outcomes but also contributes to organizational innovation, knowledge continuity, and long-term sustainability.

17. Workshop training materials

The workshop agenda and associated training materials are available on the workshop website.

18. Evaluation of the training workshop

Upon the workshop's conclusion, attendees were urged to complete the online survey, sharing their feedback on the courses, facilitators, and provided facilities. Participants were specifically asked to provide insights into the strengths and areas for improvement in the training.

30 participants, including 2 remote attendees and 7 female (23%), responded to the questionnaire, yielding an overall score averaging around 4.3 out of 5. Annex 3 provides a summary of the survey results.

The workshop was highly praised for the expertise and preparedness of the trainers, who effectively delivered well-structured and relevant content. Participants particularly appreciated the interactive and participatory nature of the event, notably the group discussions, group work sessions, and practical exercises, which fostered active engagement and peer learning. Many highlighted the value of experience sharing and interaction with colleagues from other NMHSs and countries, noting that common challenges and collaborative discussions helped identify practical solutions.

The technical content was also highly valued, especially sessions on WIGOS, observation network installation and maintenance, strategic planning of observation networks, and the development of national observation and maintenance plans.

Several participants emphasized the relevance of the topics, the quality and clarity of the presentations, and the learning methodology used.

Overall, respondents expressed strong satisfaction with the organization, relevance, and knowledge gained, with particular recognition of the National Observations Strategic Plan sessions and the collaborative atmosphere of the workshop.

Participants mainly suggested improvements related to time management and workshop duration. Many felt that the agenda was too dense for the time allocated and recommended extending the workshop by one or more days to allow better absorption of the content, particularly for practical work and group discussions. There was a strong call for fewer presentations and more time dedicated to hands-on exercises, group work, and discussions, especially on strategic planning and national observation plans.

Additional suggestions included improving logistical arrangements and better managing breakout sessions. A few participants proposed using a pilot country case study to structure the training more coherently around a concrete example.

Overall, the feedback indicates high interest in the content, with a desire for more time and focus to fully achieve the workshop objectives.

19. Conclusions and Next Steps

The workshop confirmed strong national commitment to develop strategies for sustainable observation networks. Under ClimSA (closing on 17 May 2026) and WIGOS, WMO will continue to support NMHSs through technical assistance, knowledge exchange, and capacity development to strengthen observing systems.

20. Photo Gallery


CAMEROON


South African
Weather Service
WMO


South African
Weather Service
JAMAICA
KENYA


Strenght
Experienced Technical staff
Existing National Observation
Strong Institutional partnership
Needs
1) Capacity Development for complex systems
2) Human (Technical Staff) Maintanance
3) Expand & Automate/Upgrade surface observation
4) Diversification
Opportunities
1) Regional Partnership
2) International Funding Programmes
3) Data Sharing platforms
Improvement
1) Automate & Upgrade
2) AIMMS/Monitoring Network
3) Intergriation of AI for regular Data Quality Control
4)


MAURITIUS


South African
Weather Service

ANNEX 1 – Workshop Agenda

ClimSA Training Workshop on strategic and implementation planning for sustainable observations

Online Pre-Sessions: **8-9 April 2026**		
Date & Time	***Content/Topics***	***Facilatator/Speaker***
8 April 14:00 – 16:30 pm (CEST)	*Country presentations: National observing networks: challenges and opportunities, existing NSPs, Sustainability aspects.* • *Comoros,* • *Madagascar* • *Cameroon* • *Angola* • *Jamaica* • *Cameroon - HA hydrology*	***Krunoslav Premec (WMO)***
9 April 12:00 – 14:30 pm (CEST)	*Country presentations: National observing networks: challenges and opportunities, existing NSPs, Sustainability aspects. (continued)* • *Seychelles* • *Mauritius* • *Burkina Faso* • *Kenya* • *Samoa*	***Rabia Merrouchi (WMO)***

13-16 April 2026, Pretoria, South Africa – Hybrid

Day-1 of Training Workshop

Monday, 13 April 2026 (Morning Session) **Facilitator: Rudzani Malala/S. Linnerts/K. Premec**			
Item	***Time***	***Content/Topics***	***Speaker***
	08:30-08:55	Registration of participants	
	08:55-09:00	Housekeeping	Hotel representative

1	09:00-09:30 (30 mins)	Opening session • Welcome Remarks SAWS • Welcome Remarks WMO • Introduction and purpose of workshop	Dr. Jonas Mphepya, the SAWS Acting CEO Albert Fischer – WMO (online) Saeed Vazifehkhah (WMO)
2	09:30-10:30 (60 mins)	• WIGOS as the global framework for integrated observing systems • Leadership role of NMHSs in national WIGOS implementation (Chapter 5) • Q & A session	K. Premec (WMO) R. Merrouchi (WMO)
3	10:30-11:00 (30 mins)	Coffee Break & Group Photo	
4	11:00-12:15 (75 mins)	• WIGOS implementation and partnerships (Chapter 6) • WMO Principles and guidelines for observing network design, planning and management • GBON and RBON concepts and design principles • RBON design and implementation in RA I o Hazard identification and prioritization o Key Variables selection o Requirements identification o Network design based on the key variables identified by the RA	R. Merrouchi (WMO) K. Premec (WMO) K. Premec (WMO) S. Linnerts (S. Africa)

5	12:15-12:30 (15 mins)	Q & A session	R. Merrouchi (WMO)
	12:30-14:00 (90 mins)	Lunch Break	

Day-1 of Training Workshop (Cont.)

Monday, 13 April 2026, (Afternoon Session) **Facilitator: K. Premec**			
Item	***Time***	***Content/Topics***	***Facilatator/Speaker***
1	14:00-14:30 (30 mins)	• New draft of hydrological network design guidelines	J. Naidoo (S. Africa)
2	14:30-15:00 (30 mins)	• Integrating Observations and Earth System Modelling in a Data-Sparse Region	M-J. Bopape (S. Africa)
3	15:00-15:40 (40 mins)	• Remote sensing network design: ○ *Weather radars Technology selection, coverage, siting, competencies* ○ *Lightning detection, Technology selection, coverage, siting, competencies* ○ Q & A	T. Soubai (Morocco)
	15:40-16:00 (20 mins)	Coffee Break	
4	16:00-16:30	• Regional perspective: Southern African Development	S. Linnerts (S. Africa)

	(30 mins)	Community (SADC) observing networks	
5	16:30-17:20 (50 mins)	• Transboundary hydrometeorological networks in the SADC region • Transboundary hydrometeorological networks in the Nile region	M. Musariri (S. Africa) W. Otieno, WMO - online
6	17:20-17:30 (10 mins)	• Q & A and wrap up	K. Premec (WMO)

Day-2 of Training Workshop

Tuesday, 14 April 2026, (Morning Session) **Facilitator: S. Linnerts**			
Item	***Time***	***Content/Topics***	***Facilatator/Speaker***
1	09:00 -09:15 (15 mins)	• Review of the first day	R. Merrouchi (WMO)
2	09:15-10:30 (75 mins)	• Pacific Regional Observations Network Strategy • The Australian approach to observations planning and strategy • BMKG observation strategy • *Introduction to WIGOS RRR*	A. Chandra - online R. Braaten (Australia) - online R. Yasmin (Indonesia) - online K. Premec (WMO)
	10:30-10:45 (15 mins)	Coffee Break	

3	10:45-11:15 (30 mins)	• SAWS existing infrastructure, challenges and opportunities	Rudzani Malala (SAWS)
4	11:15-11:45 (30 mins)	• DGM existing infrastructure, challenges and opportunities	T. Soubai (Morocco)
5	11:45-12:15 (30 mins)	• Existing National capabilities: Recap of the pre-sessions concerning national challenges and opportunities and lessons learned	R. Merrouchi (WMO)
6	12:15-12:30 (15 mins)	Q & A session	R. Merrouchi (WMO)
	12:30-14:00 (90 mins)	Lunch Break	

Tuesday, 14 April 2026 (Hybrid) - Afternoon Session **Facilitator: B. El Johra**			
Item	***Time***	***Content/Topics***	***Facilatator/Speaker***
1	14:00-14:30 (30 mins)	• MeteoSwiss' way to a new observation strategy	Estelle Grueter (Switzerland) - online
2	14:30-15:00 (30 mins)	• *Strategic planning for observation - Methodology, vision, strategic axes, KPIs, action plan*	S. Linnerts (S. Africa)
3	15:00-15:30 (30 mins)	• South Africa Hydrological observing capabilities and strategic planning for observation	Maswuma Zacharia, DWS South Africa
	15:30-15:45	Coffee Break	

	(15 mins)		
4	15:45-16:15 (30 mins)	• Case study - : DGM Strategic planning for observation	T. Soubai (Morocco)
5	16:15-16:35 (20 mins)	• Low Cost observing networks: lessons learned ○ *3D printed stations, TAHMO*	J. Mungai (Kenya)
6	16:35-17:00 (25 mins)	• Innovative and sustainable solution in Hydrology	Salvador Peña-Haro, HydroHub think Tank - online
7	17:00-17:30 (30 mins)	• Multi-criteria analysis applied to observational networks	R. Merrouchi (WMO)
8	17:30-17:45 (15 mins)	Q & A session *and Wrap up of the day*	K. Premec (WMO)

Day-3 of Training Workshop

Wednesday, 15 April 2026, (Morning Session) **Facilitator: M. Musariri**			
Item	***Time***	***Content/Topics***	***Facilatator/Speaker***
1	09:00 -10:45 (105 mins)	• Existing National capabilities: Recap of the pre-sessions concerning national challenges and opportunities and lessons learned • Multi-criteria analysis applied to observational networks • Developing a Step-by-Step Methodology for a National Observation Strategy	R. Merrouchi (WMO) S. Linnerts (S. Africa)

	10:45-11:00 (15 mins)	Coffee Break	
	11:00-11:15 (15 mins)	• Overview of strategic planning tools: o *SWOT, NOISE, SOAR* o *Impact–Effort matrix, prioritization matrices* • Introduction to the group work	B. El Johra (Morocco)
	11:15-12:30 (45 mins)	Group sessions (drafting session) o *Either SWOT or NOISE applied to national context* o *Key challenges and opportunities*	Group moderators: R. Merrouchi (WMO), K. Premec (WMO) B. El Johra (Morocco) S. Linnerts (S. Africa) M-J. Bopape (S. Africa)
	12:30-13:00 (15 mins)	Group presentations	Rapporteurs
	13:00-14:00 (60 mins)	Lunch Break	

Wednesday, 15 April 2026, (Afternoon Session) **Facilitator: M. Musariri**			
Item	***Time***	***Content/Topics***	***Facilatator/Speaker***
	14:00-14:15 (15 mins)	• Identification of end-user requirements: o *Key stakeholders (360° feedback collection)*	B. El Johra (Morocco)

		○ *Methods for collecting user needs (survey, online questionnaire, workshop...)*	
	14:15 – 14:55	Filling out User requirements survey • Introduction to the group work • Group work	R. Merrouchi (WMO)
	14:55 – 15:30	The vision - DGM example	B. El Johra (Morocco)
	15:30-15:50 (15 mins)	Coffee Break	
	15:50-16:00	Introduction to the group work – national observation strategic plan - template • Ch 5 – Strategic framework	S. Linnerts (S. Africa)
	16:00-17:00 (40 mins)	• Group sessions (drafting session) ○ *Ch 5 – Strategic framework*	Group moderators: R. Merrouchi (WMO), K. Premec (WMO) B. El Johra (Morocco) S. Linnerts (S. Africa) M-J. Bopape (S. Africa)
	17:00-17:45 (45 mins)	• Group presentations	Rapporteurs
	17:40-17:45 (5 mins)	• Q & A session and Wrap up of the day	R. Merrouchi (WMO)

Day-4 of Training Workshop

Thursday, 16 April 2026, (Morning Session)

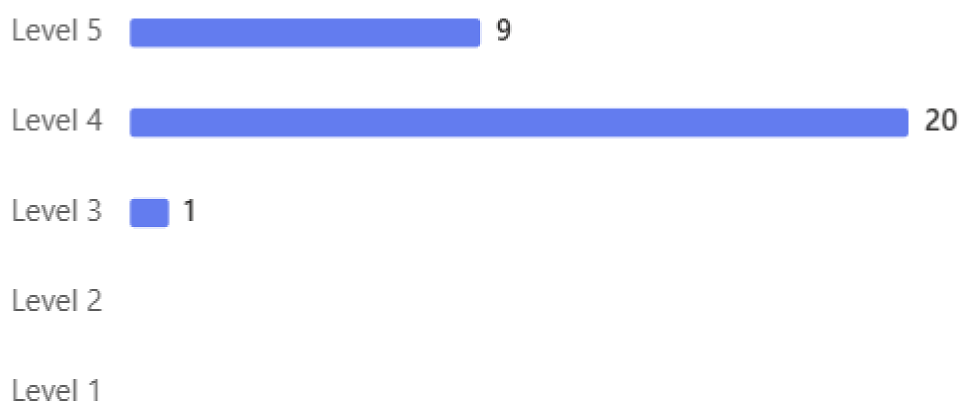
Facilitator: Kruno			
Item	***Time***	***Content/Topics***	***Facilatator/Speaker***
	09:00-09:30 (30 mins)	• Measurement traceability assurance	E. Buyukbas (WMO) - online
	09:30-10:00 (30 mins)	• Guidlines on development of Operation and maintenace plan	D. Hiscock (UKMO) - online
	10:00-10:30 (30 mins)	• Key elements for sustainable operations: *Procurement strategies* o *Procurement (Training, documentation, spare parts, tools)*	S. Linnerts (S. Africa)
	10:30-11:10 (40 mins)	• AWS generic tender specifications	R. Merrouchi (WMO)
	11:10-11:30 (20 mins)	Coffee Break	
	11:30-12:00 (30 mins)	Coordination and challenges	Erick Otenyo (WMO RAF)
	12:00-13:15 (75 mins)	Group work – interactive discussion: • Maintenance organization models: o *Centralized vs decentralized (pros and cons)* o *Internal vs external (pros and cons)*	R. Merrouchi (WMO) S. Linnerts (S. Africa)
	13:15-14:00 (45 mins)	Lunch Break	

Thursday, 16 April 2026 (Afternoon Session)			
Item	***Time***	***Content/Topics***	***Facilatator/Speaker***
	14:00-14:20 (20 mins)	Financing maintenance and operations. e.g for hydrology	W. Otieno (WMO) - online
	14:20-15:00 (20 mins)	• Group presentations	Rapporteurs
	15:00-15:45	• Group sessions (drafting session) ○ Introduction to the group work ○ *Review of the initial outline of a National Maintenance and Operations Plan.*	S. Linnerts (S. Africa) Group moderators: R. Merrouchi (WMO), K. Premec (WMO) B. El Johra (Morocco) S. Linnerts (S. Africa) M-J Bopape (S. Africa)
	15:45-16:15 (25 mins)	• Group presentations	Rapporteurs
	16:15-16:35 (20 mins)	• Inclusion of women and youth in strategic planning and implementation of sustainable hydrometeorological observing systems	R. Malala (SAWS) / K. Premec (WMO)
	16:35-16:40 (5 mins)	Closing Remarks	Mariane Diop Kane (WMO RAF)
	16:40	Closure	R. Malala (SAWS) On behalf of SAWS Acting CEO

ANNEX 2 - Evaluation

Results of the evaluation

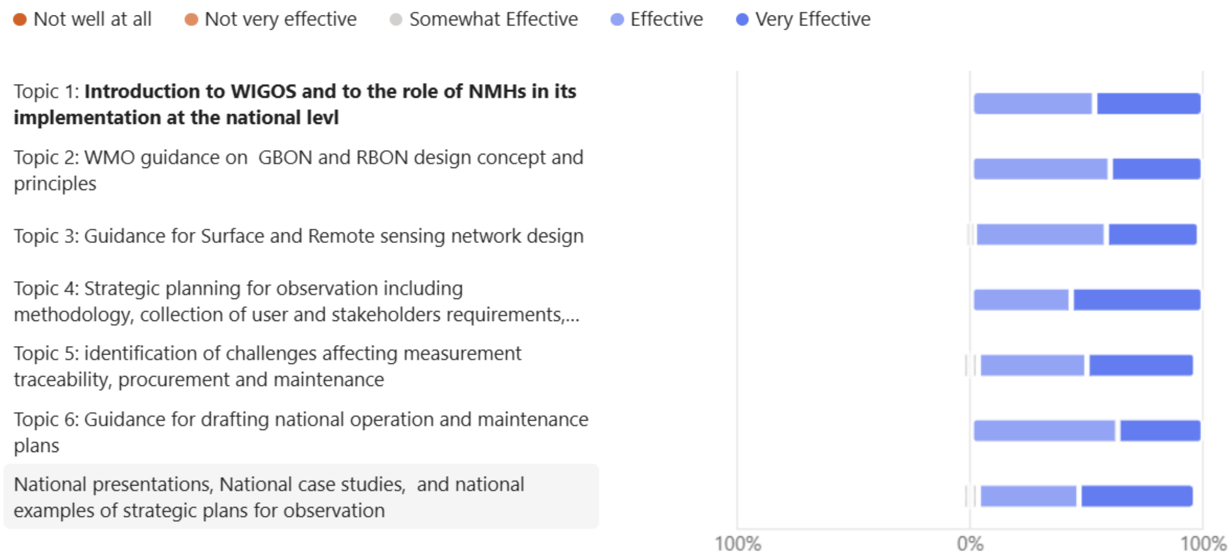
1. **Overall, how satisfied are you with the event?** **4.27**



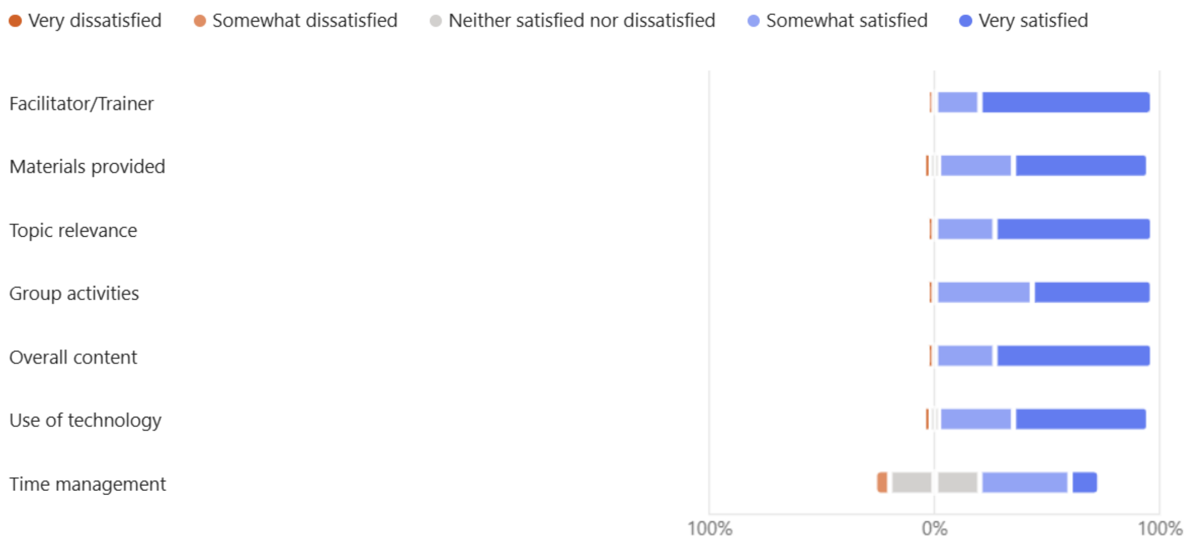
2. **How did you attend the workshop?**

3. **Your gender**

4. **Rate the overall effectiveness of each training topic.**

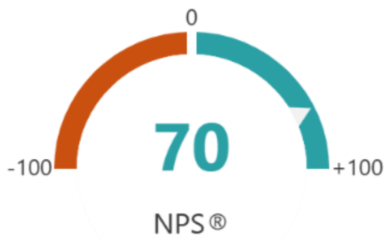


5. How satisfied are you with the following aspects of the event?



6. How likely are you to recommend a similar event to a colleague?

Promoters	21
Passives	9
Detractors	0



7. What were your expectations about the event?

8. This training will be useful to your tasks ?

9. What did you like most about the event?

Participants expressed their satisfaction and appreciated:

- Strong appreciation for group discussions, group work, and interactive sessions
- High value placed on experience sharing and learning from other NMHSs and countries
- Recognition that participants face common challenges, fostering collaboration and mutual learning
- Positive feedback on practical exercises and real-world examples
- High relevance of the technical content, particularly on:
- WIGOS implementation
- Observation network installation, maintenance, and calibration
- Strategic planning of observation networks
- Development of national observation and maintenance plans
- Appreciation of the learning methodology and the clarity and depth of presentations
- Positive comments on the organization of the event and venue
- Special emphasis on the usefulness of the National Observations Strategic Plan sessions
- Overall satisfaction with the workshop, especially for first-time participants, despite its intensity

10. How could the event have been improved?

Participants mainly suggested improvements related to time management and workshop duration. Many felt that the agenda was too dense for the time allocated and recommended extending the workshop by one or more days to allow better absorption of the content, particularly for practical work and group discussions. There was a strong call for fewer presentations and more time dedicated to hands-on exercises, group work, and discussions, especially on strategic planning and national observation plans.

Additional suggestions included improving logistical arrangements—such as accommodating participants in a single location—and better managing breakout sessions. A few participants proposed using a pilot country case study to structure the training more coherently around a concrete example. Overall, the feedback indicates high interest in the content, with a desire for more time and focus to fully achieve the workshop objectives.

Annex 3 – List of Participants

Member	Participant name	Email	Participation
Cameroon	Abba Amazia	abbaamazia1@gmail.com	In person
Cameroon	Saint-Clair Manfo Lontsi	saintclair.lontsi@yahoo.com	In person
Kenya	John Mungai	jon.mungai@gmail.com	In person
Kenya	Claudius Ogundu	claudiusogundu@gmail.com	In person
Burkina Faso	Gilles Bagre	bagres000@live.fr	In person
Burkina Faso	Salif Wandaogo	salifbintou1@gmail.com	In person
Mauritius	Mohammad Fawwaz Dilmahomed	meteo@govmu.org	In person
Comorros	Wathik Chahabane Youssouf	chabwath@gmail.com	In person
Comorros	Abdou Mondoha Mohamed	mohamedgaby@gmail.com	In person
Jamaica	Jacqueline Spence-Hemmings	j.spence@metservice.gov.jm	In person
Sychelles	Tojo Nomenjanahary	t.nomenjanahary@meteo.sc	In person
Sychelles	Samuel Ekwacu	samuel.ekwacu@meteo.sc	In person
Cameroon	Jean Claude NTONGA – Hydrological PA	ntonga_jc@yahoo.fr	In person
Madagascar	Solomampionona Rivo Herilala Randrianarison	herrnews@gmail.com	In person
Madagascar	Miora Linah Helene Rakotonirina	mioralinah.rakotonirina@gmail.com	In person
Mauritius	Vijay Soneechur	vsoneechur@govmu.org	In person

Angola	**Felix António de Freitas**	felixdefreitas13@gmail.com	In person
Angola	**Lino Nvuala Cuala**	nvualacuaia@hotmail.com	In person
Madagascar	**Mohamed NASSURDINE**	hounas20@gmail.com	In person
SAWS	**Malala Rudzani**		In person
SAWS	**Gambushe Ambrose**		In person
SAWS	**Dibetle Charmaine**		In person
SAWS	**Jardine Rydall**		In person
SAWS	**Njoro Dineo**		In person
SAWS	**Links Abel**		In person
DWS-SA	**Musariri Musariri**		In person
SAWS	**Mohlala Oliver**		In person
SAWS	**Sengane Bafentse**		In person
SAWS	**Bokaba Oratilwe**		In person
SAWS	**Samantha Linnerts**		In person
DWS-SA	**Naidoo Jeremy**		In person
SAWS	**Manona Zoleka**		In person
SAWS	**Jonas Mphepya**		In person
WMO-Instruc	**Krunoslav Premec**	kpremec@wmo.int	In Person
WMO-Instruc	**Rabia Merrouchi**	rmerrouchi@wmo.int	In person
WMO	**Beatrice Giovinazzo**	bgiovinazzo@wmo.int	In person
DWS SA	**Maswuma Zacharia**		In person
DGM-Morocc	**Bouchra El-Johra**	eljohra.bouchra@marocmeteo.ma	In person
DGM-Morocc	**Tarek Soubai**	soubai.tareq@marocmeteo.ma	In person

Jamaica	**Romayne Robinson**	**r.robinson@metservice.gov.jm**	Online
SAWS	**Yusuf Katcodia**		Online
WMO	**Ercan Buyukbas**		Online
UK Met Office	**David Hiscock**		Online
	Anuragh Chandra		Online
SAWS	**Bongiwe Mtongana**		Online
SAWS	**Mandisa Manentsa**		Online
SAWS	**Christina Botai**		Online
SAWS	**Henerica Tazvinga**		Online
SAWS	**Thato Mothopi**		Online
SAWS	**Siviwe Mcako**		Online
SAWS	**Josef Klaasen**		Online
SAWS	**Shadrack Podile**		Online
WMO	**Erick Otenyo**		Online
SAWS	**Prudy Matsebula**		Online
SAWS	**Zimbini Faniso**		Online
SAWS	**Grace Amondi Ochieng**		Online
WMO	**Mariane Diop Kane**		Online
WMO	**Washington Otieno**		Online
SAWS	**Maropeng Phalane**		Online
SAWS	**Zukisa Gqwabaza**		Online
SAWS	**Syfred Funde**		Online
SAWS	**Peter Cloete**		Online
SAWS	**Dipuo Tawana**		Online

SAWS	**Lethabo Selala**		Online
UNISA	**Bopape MaryJane**		Online
SAWS	**Linwyll Martin**		Online
SAWS	**Charne Reyneke**		Online
SAWS	**Sudmisile Muthwa**		Online
SAWS	**Carla Ramjukadh**		Online
SAWS	**Mpolokeng Motaung**		Online
SAWS	**Tshepo Nkopane**		Online
SAWS	**Eddie Cindi**		Online
SAWS	**Stella Nake**		Online
SAWS	**Phumza Mbali**		Online
SAWS	**Siyabonga Nozwane**		Online
SAWS	**Maropeng Sathekge**		Online
SAWS	**Michael Mengistu**		Online
SAWS	**Mduduzi Mthembu**		Online
SAWS	**Winnie Nkosi**		Online
Australia	**Robert Braaten**		Online
WMO	**Albert Fischer**		Online
WMO	**Johanna Koronen**		Online
BMKG	**Regina Yasmin**		Online
MeteoSwiss	**Estelle Grueter**		Online
WMO HydroHhink Tank	**Salvador Peña-Haro**		Online
SAWS	**Busizi Nomvuzo**		
SAWS	**Tikayo Benele**		