

COUNTRY HYDROMET DIAGNOSTICS

Informing policy and investment decisions
for high-quality weather forecasts, early
warning systems, and climate information
in developing countries.



October 2023

Rwanda Peer Review Report

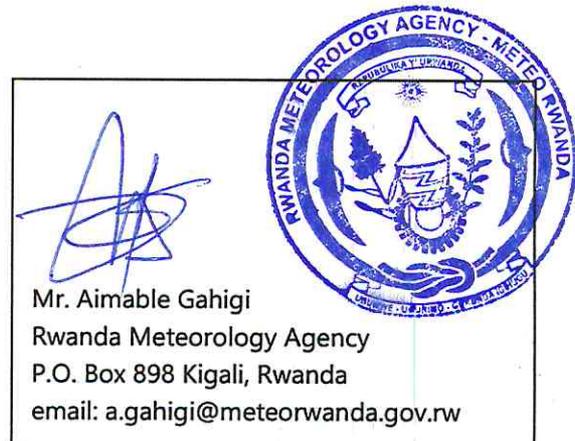
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List of Abbreviations

AWS – Automatic Weather Station

CAP – Common Alerting Protocol

CREWS – Climate Risk and Early Warning Systems

DRR – Disaster Risk Reduction

ECMWF – European Centre for Medium-Range Weather Forecast

EWS – Early Warning Services

FINKERAT – Finland, Kenya, Rwanda and Tanzania Meteorology project

FMI – Finnish Meteorological Institute

Meteo Rwanda – Rwanda Meteorology Agency

NGO – Non-Governmental Organization

NMS – National Meteorological Service

NWP – Numerical Weather Prediction

QA/QC – Quality Assurance/Quality Control

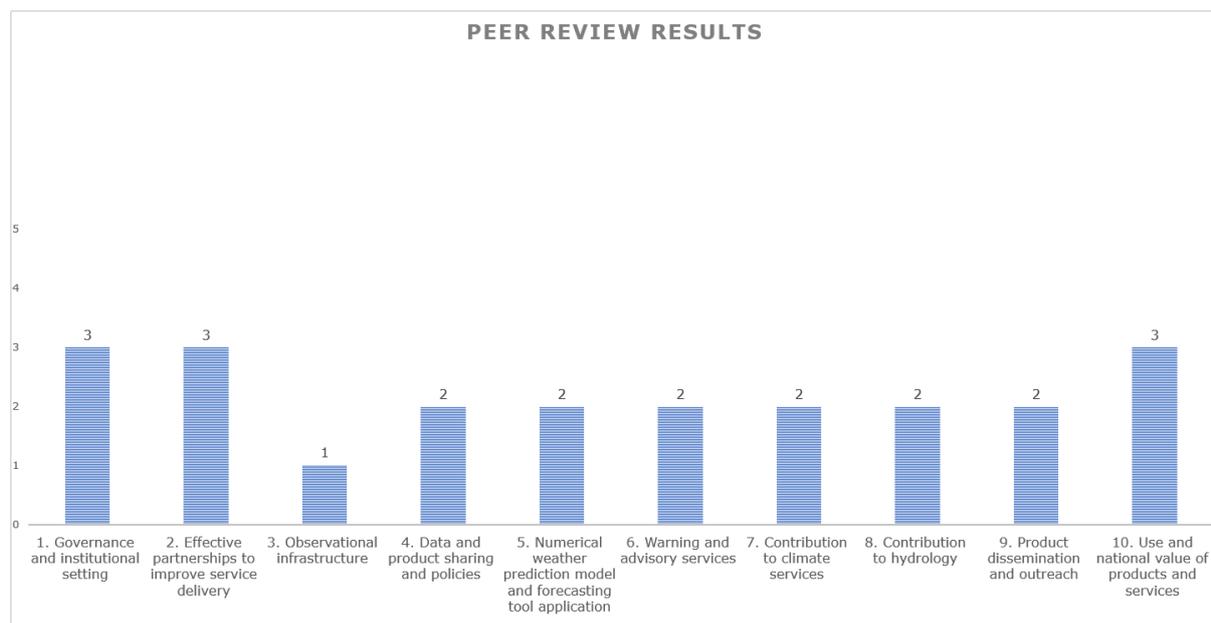
SWFP – Severe Weather Forecasting Programme

UNDP – United Nations Development Programme

WMO – World Meteorological Organization

WRF – Weather Research Forecast

Executive Summary



Element	Maturity level score
1. Governance and institutional setting	3
2. Effective partnerships to improve service delivery	3
3. Observational infrastructure	1
4. Data and product sharing and policies	2
5. Numerical weather prediction model and forecasting tool application	2
6. Warning and advisory services	2
7. Contribution to climate services	2
8. Contribution to hydrology	2
9. Product dissemination and outreach	2
10. Use and national value of products and services	3

Meteo Rwanda needs development support throughout the value chain of providing weather and early warning services. Following critical gaps have been identified:

- The current legal framework does not allow cost recovery services for Meteo Rwanda. Cost recovery would give additional resources for Meteo Rwanda by enabling the sustainability of operations and increasing motivation to develop added value services based on the end-user needs. The amendments of legal framework to enable cost recovery is in process in the Rwandan government. It is highly recommended to amend the legal framework accordingly as soon as possible.
- Meteo Rwanda observation system has some critical gaps that do not currently allow an efficient delivery of nowcasting and early warning services e.g.: No lightning locating system, weather radar data does not cover the whole country (only one weather radar with limited use of data), no upper air sounding system, no lidar systems, surface weather observation system is semiautomatic (the data transfer is operated manually, and thus, does not allow near-real time 24/7 data exchange), no integrated Data management system to store and process all observation data in one system and allow automated data processing, QA/QC and data dissemination for further use.
- Customer engagement process is only partial. Meteo Rwanda does not collect user feedback regularly to improve its services. The cocreation process to develop tailored services based on the user needs is missing. The customer process should be enhanced together when new tailored services are developed. There is no mobile phone application to disseminate efficiently forecasts and warnings to the citizens. There is a project ongoing to develop weather app for agriculture sector. There is an urgent need to develop a weather app also for general public for the efficient dissemination of public weather services and warnings.
- The weather forecasting and early warning process is mostly manual and lacking new modern software's and tools for automation, dissemination and to allow forecasters to devote their expertise in actual forecasting instead of manual processing of information. This gap is improving within the implementation of FINKERAT project where modern forecaster workstation and automated forecast production system and warning tool are being implemented. The impact-based forecasting should also be further developed. The NWP system and available global NWP data (e.g., ECMWF) should be further developed and made available. The forecast verification is currently made manually and include very limited number of verification scores. There is urgent need to implement new automated forecast verification system with multiple verification scores to enable continuous development of forecast accuracy.
- The meteorology is not currently included in the curriculum of any Rwandan Universities. Meteo Rwanda does not have efficient internal training system in place to conduct internal trainings for its staff. Internationally funded projects should address the critical training need in both Rwanda and specifically in Meteo Rwanda to ensure the sustainability of the project results. Twinning partnerships/Peer advisor cooperation is highly recommended to enhance the operational capacity of Meteo Rwanda during the modernisation of its systems. In longer term the Universities of Rwanda capacity should be strengthened so that they would be able to provide basic meteorological training.
- The cooperation between other governmental authorities should be further strengthened specially in DRR and new partnerships established with the NGO sector to allow an efficient use of information provided by Meteo Rwanda by the grass root level users.

Chapter 1: General information

Introduction

Rwanda is a land-bound country in East-Africa covering about 26 338 km² with highly inhomogeneous topography. The country is, thus, called the county of thousand hills. The population of Rwanda is 13.4 million people (in 2021). The country belongs to subtropical climate zone with two rain seasons per year. Today exact time window for rain seasons may differ from historical expectations. Due to its highly variable topography, several microclimates can also be identified. Thus, different parts of country are optimal for keeping life stock while others are better for growing coffee, crops, and vegetables of different kind. The economy and lifestyle relay much on agriculture, and thus, any weather-related extremes and natural hazards are expected to cause major impacts at all levels of society.

According to the State of the Climate in Africa, 2019 issued by WMO¹, "Temperatures in Africa have been rising in recent decades at a rate comparable to that of most other continents and thus somewhat faster than global mean surface temperature. The year 2019 was among the three warmest years record for the continent. Annual rainfall in Africa exhibited sharp geographical contrasts in 2019, with above-average rainfall recorded particularly in East Africa." High rainfall amounts lead to floods and landslides which were last time witnessed in Rubavu district, Rwanda in May 2023. Several casualties and disruption in the provision of basic services were caused by the event. Further information on climatological data analysis, observation and forecast for Rwanda can be found on the web pages of Rwanda Meteorology Agency² (Meteo Rwanda).

Meteo Rwanda is a Government Agency under the Ministry of Environment with legal personality, administrative and financial autonomy. Meteo Rwanda is considered as key contributor to the Sustainable Development Goals (SDGs), the Rwanda's vision 2050, the Rwanda National Strategy for Transformation (NST1³); the Nationally Determined Contributions (NDCs), the Disaster Risk Reduction (DRR), the Strategic Plan Agriculture Transformation (PSTA4) and other national strategies and policies. Its critical contribution cut across in all the pillars of the NST1 where its products and early climate information services serve and are expected to inform decision making in infrastructure development and maintenance through availing ease of access to historical, monitoring and prediction climate data for specific locations.

¹ [State of Africa](#)

² [Climate data analysis](#)

³ [NST1](#)

CHD methodology



Figure. Field mission to identify potential surface stations to improve and include in SOFF programme. From left Herve Murenzi, DG Aimable Gahigi, Anne Hirsikko, Fidele Kamanzi, Didace Musoni, Aminadab Tuyisenge, Constantine Ingeli, and Constantin Ngomanzungu on 26th June 2023.

The Country Hydromet Diagnostics (CHD) work preceded preparing National Gap Analysis and Contribution Plan. Work towards these documents served as a good platform to become familiar with topics included in SOFF CHD and to identify a practical way to conduct CHD work.

During the SOFF Readiness project, the project execute team organized

- a remote workshop to review gaps in terms of GBON compliance followed by preparing the Gap Analysis document.
- one week-long workshop with Meteo Rwanda experts including a field trip to survey two surface weather stations in Rwanda. National Contribution Plan document was prepared based on this mission.
- one and half day-long workshop outside Kigali to collect information for Country Hydromet Diagnostics (CHD). Invitees included representatives from Meteo Rwanda, Rwanda Standard Board, Rwanda Airport Company, Ministry for Environment, Ministry in Charge of Emergency Management, Rwanda Water Resources Board, and Rwanda Civil Aviation Authority⁴.
- In June WMO CREWS SWFP- Eastern Africa Training Workshop on Severe Weather and Impact-based Forecast and Warning Services was organized. Meteo Rwanda together with its stakeholders participated in during the second week of workshop to seek stakeholder feedback for early warning impact and advisory information. The workshop also served as awareness raising and engagement event between Meteo Rwanda and its stakeholders in early warning provision.

⁴ [News](#)

Chapter 2: Country Hydromet Diagnostics

Element 1: Governance and institutional setting

1.1 Existence of Act or Policy describing the NMHS legal mandate and its scope

Meteo Rwanda has a very comprehensive presidential order and legislation describing its tasks:

- PRESIDENTIAL ORDER N° 031/01 OF 06/05/2022 GOVERNING RWANDA METEOROLOGY AGENCY⁵.
- Law governing Meteo Rwanda⁶
- Prime Minister order for job positions⁷
- Cost recovery mechanism is, however, still missing.

The presidential order determines the vision, mission, and responsibilities of Meteo Rwanda:

- to provide hydro-meteorological information such as weather forecasts, climate data, analysis, reanalysis, climate projections, early warnings for extreme weather events, advisories and related service for the benefit of all socio-economic development sectors, including participation in disaster risk management according to national plan⁸.
- to guide and assist public and private entities as well as individuals to integrate weather and climate information into their short and long-term investments for their productivity and sustainability.
- to provide aeronautical meteorological services and information through air navigation services
- to establish and maintain the national meteorological data center and telecommunication system for the provision of weather and climate data in accordance with guidelines provided by the World Meteorological Organization (WMO), the International Civil Aviation Organization (ICAO), the Intergovernmental Panel on Climate Change (IPCC) and other international and regional bodies working in meteorology.
- to set up meteorological stations, regulate the surface and upper air meteorological observations, standardize national meteorological data and information as well as the publication of climatological statistics and studies in Rwanda.
- to conduct and support research and training on weather, climate, and climate change sciences as well as in related fields, and to assist in coordinating the international aspects of such research and trainings.
- to ensure an implementation of international agreements that are ratified by Rwanda related to meteorology, climate services, as well as advise the Government on weather and climate related matters.
- Meteo Rwanda collaborates with Rwanda Environmental Management Authority (REMA) in monitoring of **air quality**. **Hydrological services** are carried out in the Rwanda Water Resources Board (RWB). **Agrometeorological services** are carried out in partnership with the Ministry of Agriculture and Animal Resources. **Climatological services** are carried out by Meteo Rwanda. Meteorological watch office at the Kigali International Airport is under the management of Rwanda Airport Company. Meteo Rwanda ensures that aeronautical services comply ICAO requirements.

⁵ [Presidential order](#)

⁶ [Governing law](#)

⁷ [Order for job positions](#)

⁸ [Disaster risk management](#)

1.2 Existence of Strategic, Operational and Risk Management plans and their reporting as part of oversight and management.

The Strategic plan is effective until 2024. The new strategy (2025-2030) is under development. Annual work and budget planning is based on strategic goals, and thus, results are reported and reviewed by the line Ministry once a year. The existence of a Quality Management System⁹ suggests that the NMS is already focused on maintaining quality standards in its operations and has an ability to integrate risk management practices into the new strategy. Risk management is included in the descriptions of each process through risk matrixes.

1.3 Government budget allocation consistently covers the needs of the NMHS in terms of its national, regional, and global responsibilities and based, among others, on cost-benefit analysis of the service. Evidence of sufficient staffing to cover core functions.

The ordinary budget is composed of two parts: Recurrent operational and development costs composing 38% and 62% of the total budget (1300 000 000 RWF in fiscal year 2021-2022), respectively. The main sources of funding include Government and external (domestic and international collaboration and development projects). The primary source of funding is the government. A significant portion of the budget is stable, covering the main functions of the institute. A smaller fraction of the budget is dynamic which is for new investments and development projects.

Governmental budget allocation for Meteo Rwanda has been increasing in the past 5 years. According to the Governmental plan, next 3-year scenario still includes budget increase. Cost recovery mechanism is not yet in place, but a proposal is under review by the relevant authority.

Recent cost-benefit analysis of weather and climate services in Rwanda indicated that a ratio of benefit to cost is 4:1 RWF¹⁰.

1.4 Proportion of staff (availability of in-house, seconded, contracted- out) with adequate training in relevant disciplines, including scientific, technical, and information and communication technologies (ICT). Institutional and policy arrangements in-country to support training needs of NMHS.

According to a new organizational structure set by the Government, the number of permanent staff is 101 in total. The current number of employees with contracts is, however, only 80. The following table shows more detailed staff information. Meteo Rwanda is in a process to recruit an additional 21 staff members to fill the vacant positions. The current gender balance includes 30% female and 70% male staff members.

⁹ [QMS](#)

¹⁰ [Cost-benefit](#)

Staff information	Total number		
Managers (All administration support staff)	10		
Met (Forecasters, Met Application, Data quality control specialist, 2 Division managers)	28		
Met Techn (Observation officers and supervisors, Instruments Maintenance and Calibration Officer)	23		
Research	1		
Technology and Information (IT)	11		
Others (Data quality control officer, Obs Processing Officer, Big Data Specialist)	7		
Total current employee	80		
Staff Disaggregated by Gender	Number	Percentage	
Male	56	70%	
Female	24	30%	

Additionally, there are 5 persons providing shared services at Ministerial level (human resources, planning specialist, internal auditor, legal advisor as well as expert for monitoring and evaluation). Project staff is hired on contractual basis.

The capacity building plan is a priority for the government of Rwanda through endorsement by the prime minister's order. Every year, all public institutions including Meteo Rwanda make a capacity development plan to ensure enhancing staff capacity. In the national level, coordination is made by the government chief skills office in the Rwanda Development Board. Meteo Rwanda, however, is dependent on external capacity building activities since in-house arrangements for capacity building are immature.

Currently, it is not possible to study meteorology as main subject at the university in Rwanda. However, the revised curriculum in the physics department provides courses in meteorology. Additionally, training on maintaining meteorological sensors is missing in Rwanda, and thus, internal training is currently needed to support such a capacity.

1.5 Experience and track record in implementing internationally funded hydromet projects as well as research and development projects in general.

Meteo Rwanda has vast and strong track record in implementing internationally funded hydrometeorological projects. Additionally, the organization owns strong partnerships with national and international organizations to ensure sustainable and impactful results from projects. In the following recently finished and on-going projects are elaborated

- FINKERAT¹¹ – Finish Meteorological Institute, Kenya Meteorological Department, Rwanda Environmental Management Authority, Rwanda Meteorological Agency, Tanzania Meteorological Authority Project: Funded by the Ministry for Foreign Affairs of Finland
- Weather and Climate Information Services for Africa¹² (Phase II): Funded by Foreign Commonwealth Development Office, United Kingdom
- HIGHWAY¹³ – High Impact Weather Lake System: Funded by Foreign Commonwealth Development Office, United Kingdom
- VCRP¹⁴ – Volcanoes Community Resilience Project: Funded by World Bank
- CREWS¹⁵- EA: Funded by WMO

¹¹ [FINKERAT](#)

¹² [Weather and Climate Information Services for Africa](#)

¹³ [HIGHWAY](#)

¹⁴ [VCRP](#)

¹⁵ [CREWS](#)

- Science and Research Cooperation Initiative: Funded by German International development (GIZ)
- Building¹⁶ the capacity of Rwanda government to advance the national adaptation planning process (NAP- GCP): Funded by Green Climate Fund
- KIIWP¹⁷ – Kayonza Irrigation and Integrated Watershed management Project: Funded by USAID

One recent publication exists: “Downscaling climate projections for national adaptations in Rwanda”. More research results are available online¹⁸.

Summary score and recommendations for Element 1

Summary score for the element is 3 on the CHD scale, reflecting “Moderately well mandated, managed and resourced and clear plans for, and sufficient capacity to address operational gaps.”.

Strengths: The legislative background and support for Meteo Rwanda is strong and clearly distributes responsibilities. Funding scheme supports filling operational duties and development activities. Implementation of internationally funded projects is also a strength of Meteo Rwanda.

Gaps: Cost-recovery mechanism is not in place. It is, however, foreseen that the mechanism will be awarded to the Meteo Rwanda during coming years. In-house capacity building arrangements require further development to ensure sustainability and independence in the terms of institutional capacity. The organization would benefit from stronger institutional capacity in the value chain of strategy (from planning to overseeing and reporting).

Element 2: Effective partnerships to improve service delivery

2.1. Effective partnerships for service delivery in place with other government institutions.

Meteo Rwanda is solely responsible for climate services based on its mandate. When a private partner wants to establish a weather station, a permission from Meteo Rwanda is required. Meteo Rwanda follows a national open data policy and shares observational data with national and international organisations. Data can be accessed online through Meteo Rwanda's website. Automatic Message Switching System is used to share data internationally.

Meteo Rwanda attends in daily teleconferences with weather services in neighbouring countries, e.g., Kenya, Tanzania, Uganda, and Burundi. Regional teleconference supports discussion on the performance of past day forecast and making consensus on upcoming forecast.

National agriculture sector is active in sharing climate data. Rwanda Environmental Management Authority (REMA) is strong collaboration partner, e.g., in air quality monitoring.

2.2. Effective partnerships in place at the national and international level with the private sector, research centres and academia, including joint research and innovation projects.

Meteo Rwanda has agreement on research cooperation with the University of Rwanda. AWS synoptic data is shared between Meteo Rwanda and civil aviation operator. MoU exists with the following organizations:

- Rwanda Standard Board to calibrate meteorological sensors (under development)
- Meteo Rwanda VIAMO for disseminating weather forecasts.

¹⁶ [NAP-GCP](#)

¹⁷ [KIIWP](#)

¹⁸ [Publications](#)

- privately owned weather stations for data sharing.

Additionally, an agreement on toll free line for farmers exists with telephone company. Support on demand in weather radar maintenance is based on agreement with the supplier.

In Rwanda, there exist platforms for Meteorological thematic working group (where Meteo Rwanda is a lead, meets twice a year), National Climate Outlook Forum (where Meteo Rwanda is a lead, meets twice a year), National Emergency Command Center (where MINEMA is a lead, meetings every ten day and in the case of hazard).

2.3. Effective partnerships in place with international climate and development finance partners.

Meteo Rwanda has a vast network of partnerships with international climate and development finance organizations. As an example: REWS, GCF, FMI, WISER, UNDP, World Bank. The current international projects are identified in readiness phase funding request and National Contribution Plan documents.

2.4. New or enhanced products, services or dissemination techniques or new uses or applications of existing products and services that culminated from these relationships.

New services are planned and in the pipeline through the following projects:

- FINKERAT (weather and early warning products)
- World Bank (Flooding early warning in the volcano region): Meteo Rwanda is the lead of consortium with MINEMA and Rwanda Water Resources Board
- CREWS East-Africa project supports in regional early warning service development
- Green Gicumbi Project (pilot project funded by Rwanda green fund FONERWA from GCF): aim is to publish mobile phone app (in process) for farmers in the specific area

Summary score, recommendations, and comments for Element 2

Summary score for the element is 3 on the CHD scale, reflecting *“Moderately effective partnerships but generally regarded as the weaker partner in such relationships, having little say in relevant financing initiatives.”*

Meteo Rwanda is recommended to ensure strong contribution and active role in national Early Warning Services for multi-hazards. As a weather service, Meteo Rwanda has the key knowledge in likelihood for hazardous weather and its impacts. The joint service is led by MINEMA.

Meteo Rwanda needs a mechanism for co-creation of services and products. Subsequent institutional capacity building and partnerships are encouraged to establish.

Element 3: Observational infrastructure

3.1. Average horizontal resolution in km of both synoptic surface and upper-air observations, including compliance with the Global Basic Observing Network (GBON) regulations.

Average coverage of one automatic surface weather station is 446 km² (ca. 20 km x 22km). Only four surface weather stations are sharing data with GTS through manual data transfer. Nine surface stations are registered in OSCAR.

3.2. Additional observations used for nowcasting and specialized purposes.

Weather radar and ground weather station observations (METAR) are available for nowcasting purposes. No tailored nowcasting products are being generated.

3.3. Standard Operating Practices in place for the deployment, maintenance, calibrations, and quality assurance of the observational network.

The deployment and regular preventive maintenance of surface weather stations are based on SOPs that are guided by manufacturers' manuals. AWS SOPs were reviewed and additional guidance for enhancing procedures in maintenance SOP given through FINKERAT-project. A calibration of surface weather station sensors will be a new activity in Rwanda, and thus, relevant SOPs must be developed. Meteo Rwanda does only view QC operations to surface based weather observation data. When increasing the number of QC checks in data related SOP must be developed.

The national WIGOS focal person has recently been nominated. No WIGOS governance mechanism in place which must still be established. Two staff members have been trained for the use of OSCAR/surface. They need further training on (1) How to update information in OSCAR surface, and (2) General training on WIGOS and OSCAR surface.

Additionally, incident management system report is provided by Tanzania data hub when an issue takes place and Meteo Rwanda works to solve the raised issues. Regional meetings are organized irregularly to discuss and solve previously mentioned issues together. Next steps to further develop the process will include taking the responsibility for solving issues by newly nominated focal point.

3.4 Implementation of sustainable newer approaches to observations.

There is a lack of capacity (number of people and knowledge capacity) to configure new stations through AMSS and WIS2.0. Support through WMO is urgently needed.

3.5. Percentage of the surface observations that depend on automatic techniques.

Based on gap analysis, Rwanda operates both automatic and manual surface weather stations: information about the existing observation stations in Meteo Rwanda can be found from the table below. The observational data from third parties are shared with the Meteo Rwanda.

Type of station	Number of stations	Owner of station	Measured variables
Fully automatic surface weather station	42/59 functional*	NHMS	T, H, W, P
Agro-synoptic stations	12/13 functional*	NHMS	T, H, W, P
Climate station	75	NHMS	T, P
Manual rain station	74	NHMS	P
Automatic rain stations	40/97 functional*	NHMS	P
Community stations	16/18 functional	communities	T, P

*Out of 59 full automatic surface stations only 42 are operationally functional and can provide observations to Meteo Rwanda every 10 minutes time schedule. Out of 97 automatic rain station only 40 are regularly providing data into Meteo Rwanda data server. The poor performance of automatic rain stations is due to aging sensors that need to be upgraded.

Many of automatic sensors are being duplicated with manual sensors. Data transfer is made via email or AMSS. Data from four surface weather stations is transferred to GTS manually. Currently, data is not transferred to WIS2.0.

Summary score, recommendations, and comments for Element 3

Summary score for the element is 1 on the CHD scale, reflecting “No or limited, basic surface observations and no upper-air observations.”

Urgent development needs include modernization of outdated surface observation technique and data loggers together with an automatization of data transfer from station to stakeholder interface. Need for tailoring nowcasting products especially from weather radar observation was raised by aviation sector stakeholders. Meteo Rwanda will need support from international collaboration partners in this area.

Element 4: Data and product sharing and policies

4.1. Percentage of GBON compliance – for how many prescribed surface and upper-air stations are observations exchanged internationally. Usage of regional WIGOS centres.

Four surface weather stations report to WIGOS and GTS (not WIS2.0). None of them are compliant with GBON requirements (Gap analysis). Data transfer is done through Kenyan WIGOS hub. Kenya hub contacts data providers when there is an issue in Quality Control and data availability. There is no national plan for WIGOS implementation, and thus, the plan must be developed. Meteo Rwanda needs support to initiate and keep up automatic data transfer to WIGOS/WIS2.0.

One GHG station is operated by Rwanda Space Agency. Rwanda does not have upper-air station.

4.2. A formal policy and practice for the free and open sharing of observational data.

Open data policy determined by Government of Rwanda exists. In organizational level the policy must still be approved. Open data sharing is made on request through data portal and data remains as a property of Meteo Rwanda¹⁹. Between East-African countries sharing of synoptic and climate data is made manually through email.

Quality Control (QC) process exists. However, a number of QC checks is heavily limited. There is a need to enhance human capacity and upgrade database management system to support sufficient and effective QC.

Rwanda Standard Board together with Meteo Rwanda and Rwanda Environmental Management Agency has established a calibration center for meteorological and air quality sensors. Currently, they are in a process to initiate calibration activities. The maintenance of automatic sensors has been lacking capacity and spare sensors.

4.3. Main data and products received from external sources in a national, regional and global context, such as model and satellite data.

Rwanda accesses EUMETSAT satellite products through ground-based satellite receiver (images). It also has access to different global and regional model outputs such as

- ECMWF products (rainfall accumulation, wind, cloud cover, temperature) through PUMA system
- GFS (rainfall accumulation, wind, cloud cover, temperature) through Web portal
- ARPEG (wind, temperature, humidity, CAPE, Vertical velocity, etc)
- SADIS (wind, cloud cover, enroute weather) through web portal access at airport
- products from ICPAC, access to web portal
- ACMAD (10 days seasonal, monthly forecast, early warning) access through email and web portal

¹⁹ [Open data](#)

- AMSS (synop, wind, meteograms) through RSMC Nairobi (EAC area)
- from Dar es Salaam for Lake Victoria area (rainfall accumulation, wind, warning) through web pages.

Meteo Rwanda runs inhouse WRF model for 10 days and monthly weather forecast. Some of above-mentioned models have coarse resolution. Thus, there is a need for a high-resolution model output down to 2 km resolution.

Summary score, recommendations, and comments for Element 4

Summary score for the element is 2 on the CHD scale, reflecting *"A limited amount of GBON compliant data is shared internationally. The existing data sharing policies or practices or the existing infrastructure severely hamper two-way data sharing."*

Urgent development needs must be directed to a modernization of data pipeline from station to user interface. Automatization and developing QC together with enhancing human capacity are foreseen as key success factors of this element.

Element 5: Numerical model and forecasting tool application

5.1. Model and remote sensed products form the primary source for products across the different forecasting timescales.

Meteo Rwanda has access to a wide range of forecast products, including those provided by the Nairobi RSMC and other institutes offering global Numerical Weather Prediction (NWP) model outputs including ECMWF, DWD, Meteo-France and GFS. The Nairobi RSMC contains a variety of model and observation data, along with WMO (World Meteorological Organization) e-learning training material. Meteo Rwanda receives information on ten days, monthly and seasonal forecast, warning, and advisories as well synoptic meteorological conditions such as ENSO, IOD, MJO conditions from the WMC/RSMCs.

The Meteo Rwanda benefits from a wealth of remote sensing data, including EUMETSAT satellite imagery and a C-band radar. However, the visualization of satellite data and radar information occurs in separate workstations, leading to challenges for weather forecasters. Moreover, the radar data is continuously affected by interference from mountainous regions, as well as potential disturbances caused by insects or birds. Meteo Rwanda offers a comprehensive range of forecasts from short to medium-range forecasts and extending to seasonal forecasts.

5.2. a) Models run internally (and sustainably), b) Data assimilation and verification performed, c) appropriateness of horizontal and vertical resolution.

Meteo Rwanda runs Weather Research Forecast (WRF) model with ca. 10 km spatial resolution. There is a need to scale down to 2 km spatial resolution with WRF modelling. Meteo Rwanda has a process for verifying its operational weather forecasts against the observations of rain. However, they are not verifying raw model output. The verification of weather forecasts is done manually in Excel. This means that the verification process lacks automation. Numerical weather forecasts are available only as image products which causes a significant limitation for Meteo Rwanda to conduct effective database operations for weather forecasting and verification. Currently, two staff members have access and are trained for forecast generation and output verification (e.g., WRF).

5.3. Probabilistic forecasts produced and, if so, based on ensemble predictions.

Weather forecasters have access to probabilistic forecast products provided by ECMWF, as they are nowadays freely available. However, these forecasts are currently available only as image products and not in raw data format. It also appears that probabilistic information is only included in seasonal

forecasting but not in short and medium-range scales. Even in seasonal forecasts, probabilistic information is sometimes just for a guidance for weather forecasters and this probabilistic approach is not reflected in the end-users' products.

Summary score, recommendations, and comments for Element 5

Summary score for the element is 2 on the CHD scale, reflecting *"Basic use of external model output and remote sensed products in the form of maps and figures, covering only a limited forecast time range."*

The whole value chain of deploying, verifying and assimilating weather forecasts requires development to ensure that the most benefit can be gained from available information. Good elements and practices exist, but new tools and automation would fill a missing link and bring effectiveness into the weather forecasting process. Through FINKERAT-project, Meteo Rwanda is in a process of making a roadmap for developing in short-, medium- and long-terms and ensuring sustainability (including human resources, capacity in the organization, a lifecycle of IT hardware, regional collaboration etc.) in NWP modelling in the organization. Special attention must be given to the high rate of job change and subsequently escaping capacity. Kenya and Tanzania have good skills in NPW modelling, and thus, the East-African region is encouraged to benefit from the existing knowledge through capacity building and collaboration.

Element 6: Warning and advisory services

6.1. Warning and alert service cover 24/7.

Meteo Rwanda issues impact based early warning messages²⁰ when an extreme event is expected. Sometimes, impact-based forecast can be issued in 10-days forecast²¹. Meteo Rwanda has capacity to issue warning within 30 minutes lead time. Preparedness information is also disseminated to the general public.

There is no regulating act for multi-hazard platform in technical perspective, but there is MHEWS-working group/expert network called National Emergency Command Center. The Center is permanent entity with permanent staff, and office. MINEMA (leader), Meteo Rwanda and Rwanda Water Resource Board coordinate MHEWS activities. Based on feedback, working group could strengthen its role and be more proactive actor in warning. Further coordination in district (including disaster officer) and sector (local administration) levels are in place.

6.2. Hydrometeorological hazards for which forecasting and warning capacity is available and whether feedback and lessons learned are included to improve warnings.

Meteo Rwanda issues warning on wind, rain, and thunderstorm. The flood monitoring and warning are conducted by Rwanda Water Resources Board. Meteo Rwanda provides impact analysis alongside their weather outlooks for the public MHEWS coordination.

Developing the operation of National Emergency Command Center, which is led by MINEMA, towards seamlessly coordinated collaboration is recommended. Additionally, there is a need for capacity building of permanent staff for MHEWS. Rwanda has a need to update flood national risk map for different scenarios²².

²⁰ [Weather warning](#)

²¹ [10-days forecast](#)

²² [Wind Atlas](#)

Tailoring of new services and warnings are urgently needed. As an example, the following were identified by stakeholders:

- tailored wind and wave warnings for lake area
- discomfort warnings for tourism
- wind and draught warnings and impact information how severe weather will impact on energy sector
- draught, rain, incidence of disease by using RH warning for farmers
- airport warnings depend on nowcasting results: automated nowcasting products from weather radar observations, utilize lightning network observations in warning generation in TAF. Impact-based warning products for aviation operators is a priority for the Meteo Rwanda.
- New warning ideas include also UV index, heat stress.

6.3. Common alerting procedures in place based on impact-based services and scenarios taking hazard, exposure and vulnerability information into account and with registered alerting authorities.

WMO CAP EWS software is installed and the staff of Meteo Rwanda has received training. Additionally, the Meteo Rwanda will be soon ready to deliver in CAP format with SmartMet Alert tool installed within FINKERAT project. CAP is not used nationally, and therefore, work with stakeholders is required. Meteo Rwanda has initiated process with the line ministry to use CAP data format for data sharing. National concept for CAP distribution (delivery and approval) is missing.

Summary score, recommendations, and comments for Element 6

Summary score for the element is 2 on the CHD scale, reflecting *"Basic warning service is in place and operational but with limited public reach and lacking integration with other relevant institutions and services."*

Meteo Rwanda is recommended to benchmark with other agencies for MHEWS e.g. in flooding. Coordination and collaboration between MHEWS actors require further development to ensure effective response in the case of emergency.

While disseminating warnings through different channels, information may not reach all because there can be challenges in understanding the message. Here all related actors are recommended to put effort to ensure that weather does not surprise anybody. Additional challenge is the lack of a comprehensive warning map, presenting weather warning information in a user-friendly format so that warning would be readily available for the public to see immediately the overall weather situation.

Automated tools for publishing nowcasting information based on weather radar observation is urgently needed to deploy the full capacity of such expensive investment.

Element 7: Contribution to Climate Services

7.1. Where relevant, contribution to climate services according to the established capacity for the provision of climate services.

Rwanda is currently in the process of developing a robust national framework for climate services, guided by the principles outlined by the World Meteorological Organization's (WMO) Global Framework for Climate Services (GFCS) guidelines. Presently, Rwanda has progressed to level 2 of the NFCS implementation. The relevant stakeholders have been identified and a consultation workshop has been conducted. The framework strategic plan is still pending.

The NMS has regional climate projections in place. The longest time series of weather observation data dates to 1907. Gridded climate data is only available from 1981 onwards. User interface for past weather data requires enhancement, as data retrievals are made manually by experts. Meteo Rwanda provides point observations in CSV format but can also provide gridded data as NETCDF, even though, challenges with database management have been reported by staff.

Educational needs within the meteorological field are apparent due to the absence of a master's degree program in meteorology. However, the University of Rwanda has programme of Atmospheric sciences (including courses in Meteorology). Furthermore, Meteo Rwanda has the division of Weather, climate services and applications which is lacking capacity for specialised services (e.g., agrometeorology).

Summary score, recommendations, and comments for Element 7

Summary score for the element is 2 on the CHD scale, reflecting "*Basic Capacity for Climate Services Provision*".

The whole value chain of climate services from national framework to service provision at customer interface is under development. Support and development are needed in every area of the value chain. Rwanda can significantly enhance its climate services by focusing on specific elements and systematically building capacities and capabilities in the following areas:

- Governance: Strengthen national governance mechanisms to facilitate coordination for climate services; enabling contributions from National Meteorological and Hydrological Services (NMHS) to national adaptation planning.
- Basic systems: Develop robust observation networks, data collection, data management, and monitoring and forecasting systems. These foundational elements are essential for the production and delivery of accurate climate information and services.
- User interface: Implement mechanisms, tools, and systems that foster interaction between climate service users and providers. This interaction is critical for co-producing and tailoring services to meet the specific needs of decision-makers, as well as ensuring effective decision support and feedback.
- Provision and Application of Climate Services: Develop decision-support products and services that cater to the diverse needs of users. These services should be designed to provide valuable insights and guidance to support informed decision-making processes.
- Monitoring and Evaluation of Socio-economic Benefits: Establish monitoring and evaluation systems to assess the socio-economic benefits derived from climate services. This evaluation should encompass observing networks, data management, monitoring, and forecasting systems, enabling the continuous improvement of climate services.
- Capacity Development: Provide technical advisory services and training programs to address the capacity development needs for both climate service provision and utilization. By enhancing the skills and knowledge of professionals in this field, Rwanda can ensure the effective delivery and utilization of climate services.

Element 8: Contribution to hydrology

8.1. Where relevant, standard products such as quantitative precipitation estimation and forecasts are produced on a routine basis according to the requirements of the hydrological community.

Hydrological services in Rwanda are under the responsibility of the Rwanda Water Resources Board (RWB). The RWB manages flood-related concerns encompassing river basin floods, flash floods, and

urban floods. Despite having a riverine flooding model, the incorporation of topographical data is an ongoing challenge. For flash and urban floods there are no models available.

Meteo Rwanda has a role in the value chain of providing hydrological services through providing precipitation data upon request. Automated systems are not yet implemented (gap). These observations are utilized as input for the hydrological models. The absence of database operations also hampers the effective utilization of radar data, which currently serves as guidance rather than a fully integrated resource (gap). Weather radar observations visualized on a TV-screen are shared for near-real time monitoring purposes with the following stakeholders:

- Rwanda Airport Company
- National Emergency Command Center (NECC)
- The Ministry of Defence (MoD)
- The Ministry of Environment (MoE)
- Gabiro Air base
- Zipline

While Rwanda Water Board is capable of issuing warnings for river floods, the absence of warnings for flash floods and urban floods is notable. However, the NMS does include information about these potential impacts in its general forecast texts. NMS also provides advisory information on precipitation and floods in their seasonal forecasts.

8.2. SOPs in place to formalize the relation between Met Service and Hydrology Agency, showing evidence that the whole value chain is addressed.

The legal framework (mandates) is in place outlining distinct roles and responsibilities for meteorological and hydrological institutes: Meteo Rwanda and Rwanda Water Resources Board (RWB). Additionally, a national contingency plan addressing flood-related scenarios is available.

Despite these established frameworks, it is observed that there is currently no formal agreement or Memorandum of Understanding (MoU) between Meteo Rwanda and RWB. Collaboration between the two institutes is informal in nature, indicating that there is room for enhanced coordination. While formal agreements seem limited, staff members mention existing agreements related to the calibration of hydrological sensors.

Existing Quality Management System (QMS) lays a strong foundation for drafting operational cooperation (and SOP's) between Meteo Rwanda and RWB. Current ongoing projects funded by the World Bank address hydro-meteorological challenges. Notably, specific concerns regarding flooding in the volcano region and the urban area of Kigali are being addressed. However, there are also other flooding hot spots, and these types of projects must be deployed for the whole country.

8.3. Data sharing agreements (between local and national agencies, and across international borders as required) on hydrological data in place or under development.

Flooding stands out as a huge environmental risk in Rwanda. This underscores the imperative to improve the entire spectrum of processes: from refining observations and forecasts to bolstering models, database operations, flood mapping, and formal cooperation. RWB has portal where data can be loaded (national distribution). Rwanda Water Resources Board is working on flood risk maps (to identify "hot spots") and plans.

8.4 Joint projects/initiatives with hydrological community designed to build hydrometeorological cooperation.

There is project called Volcanoes Community Resilience Project (VCRP) that is especially tailored for enhancing hydrological services in collaboration with Meteo Rwanda, Ministry in Charge of Emergency Management, and RWS.

Summary score, recommendations, and comments for Element 8

Summary score for the element is 2 on the CHD scale, reflecting *"Meteorological input in hydrology and water resource management happens on an ad hoc basis and or during times of disaster"*.

There is need to enhance use as well as the automatic and effective processing of observational information, such as near-real time weather radar and in-situ rain data.

Legal background for sharing responsibilities in hydrological services is strong and clear. Collaboration between Meteo Rwandan and RWB is, however, informal in nature which can hamper the effectiveness and quality of services.

Element 9: Product dissemination and outreach

9.1. Channels used for user-centred communication and ability to support those channels (for example, does the NMHS operate its own television, video or audio production facilities? Does it effectively use cutting-edge techniques?).

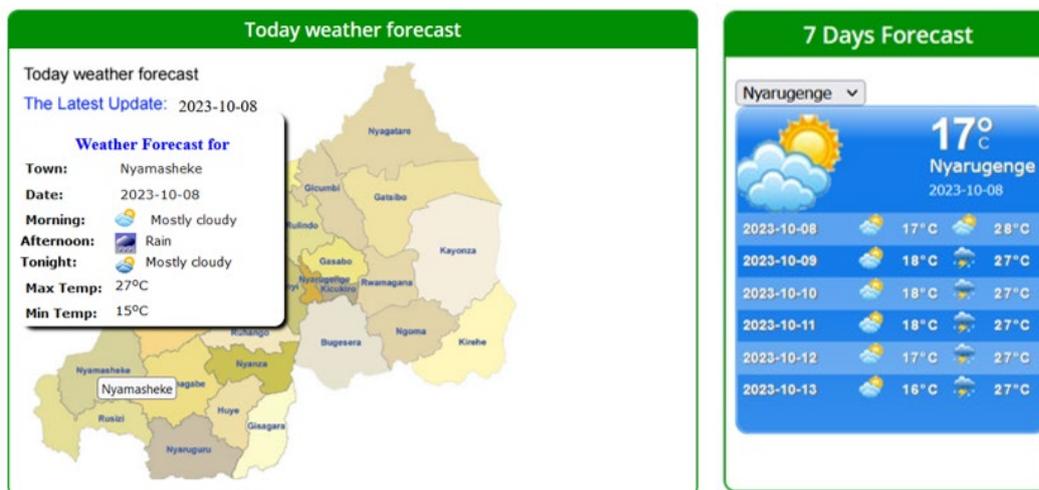
Weather forecasts and early warning are broadcasted through TV and radio. As an example, radio broadcasts twice a day routine forecast (every 6 hours updated forecast). About 85-90% of people have access to radio, less has access to TV and mainly in urban areas. All households do not have access to internet. Further significant gap was identified. All private radio and TV channels do not broadcast weather and climate information. This leaves some groups of people outside weather and early warning information.

Meteo Rwanda publishes weather and early warning information through its web pages²³. Other dissemination methods include:

- SMS are being sent to 6000 people representing central and local management
- email communication
- WhatsApp groups with 3000 receivers from e.g., different districts, emergency services
- Twitter (18k followers)
- Facebook (5 k followers)
- Youtube (> 1000 followers).
- Pre-recorded weather forecast for phone (has a cost, and thus, limited use).
- Toll free number (ca. 10-20 calls per day, rainy season 200 calls/day, mainly farmers call).



²³ [Meteo Rwanda web page](#)



Figures. Screenshots of weather forecast products presented in Meteo Rwanda’s web pages on 8th October, 2023.

9.2. Education and awareness initiatives in place.

General public needs training through radio and TV to better interpret weather information. As an example, during rainfall seasons talk shows in TV and radio (contracts exist) are presented to build awareness. National Climate Outlook Forum (once a year) aims general awareness raising for selected end user groups. Targeted awareness raising workshops with institutes and local communities, e.g., training of farmers (farmer facilitators, training of trainers), local authorities and disaster managers are also carried out. However, those events are not regular due to insufficient and unsecured funds.

Meteo Rwanda has once organized training for media and an awareness raising event in school. Some university students conduct an internship or field visit to Meteo Rwanda. Today, in a curriculum of schools, weather and climate concept is included which supports youth when interpreting weather and climate information shared by Meteo Rwanda. A lot of good practices exists but they are recommended to conduct on a regular basis.

9.3. Special measures in place to reach marginalized communities and indigenous people.

Weather services are shared by using official national languages²⁴; written weather forecasts (maps etc.) on webpages can be found in English language, and social media material and spoken information can be received in Kinyarwanda language. French language speakers’ services are less developed compared to Kinyarwanda and English language services.

Youth uses social media, and thus, can be more easily reached. As an example, Youtube channel is used to share climate information. Volunteer weather observers (over 100) can collect weather data and receive weather forecast through a smart phone. They may also share that information in their communities. Every last Saturday of each month exists a community workday, where current weather information can be disseminated and communicated directly to citizens (including people in vulnerable position such as female, elderly, youth). Capacity building is also provided at community level through existing initiative from the Government and other partners. Identified gap: female is less reached with weather information and awareness raising methods.

²⁴ [Weather forecast](#)

Summary score, recommendations, and comments for Element 9

Summary score for the element is 2 on the CHD scale, reflecting *“Traditional communication channels and a basic dedicated website is used to disseminate forecasts and basic information.”*.

Meteo Rwanda is encouraged to seek ways to ensure that weather information also reaches those in the most vulnerable position (e.g., youth, elderly, female, people with disabilities). Support from and in collaboration with NGOs and other stakeholder (e.g., MINEMA) is foreseen as a key success factor in this effort. Mobile phone application for weather does not exist which would support in disseminating forecasts and warnings.

Meteo Rwanda considers that websites should be more interactive and new improved products to attract end users and be easy to interpret. This is strongly encouraged and supported approach.

Ways to ensure regular events for capacity and awareness raising are recommended to seek. Additionally, simple capacity building material to share is encouraged to develop. Video material can be created in Meteo Rwanda’s own video studio. It is recommended to increase the number of researchers to support a work of enhancing awareness.

Element 10: Use and national value of products and services

10.1. Formalized platform to engage with users in order to co-design improved services.

Users (such as stakeholders, the representatives of districts and communities) are engaged through workshops. The workshops are being organized by different organization as a part of different projects funded by national or international programmes. At the end of every workshop stakeholder feedback is collected. A report of the feedback is included in annual evaluation and planning of NMS activities. Plan and funding scheme for organizing engagement workshops in regular basis are missing.

During COVID 19, SMS (sample of 6000 SMS receivers) feedback was also collected to receive information on user needs. Meteo Rwanda does not carry out user satisfaction surveys in regular and coordinated manner.

Meteo Rwanda has MoU with key stakeholders and responsibilities between organisations are clearly shared. Regular one-to-one discussion with these customers is carried out. Recent cost-benefit analysis is from 2017²⁵.

10.2. Independent user satisfaction surveys are conducted, and the results used to inform service improvement.

Demand from general public for weather service used to be weak, however, their interest has been increasing. Users feedback is collected using different tools such as survey, toll free number, and social media channels. A responsibility of giving feedback is left to end user.

Obvious gaps include:

- Satisfaction and feedback surveys are not conducted regularly
- lack of technological tools to analyse the collected feedback.

The verification of forecast accuracy and timeliness of rainfall is conducted on daily basis. The accuracy level reaches 84%. An efficiency and impact of forecast verification would benefit from enhancing the level of automatization and including more variables (e.g., wind, temperature) in the analysis. Feedback

²⁵ [Cost-benefit](#)

mechanism: verification results are reviewed, and mitigation measures enquired in the Meteo Rwanda's board of directors' meetings in regular basis.

10.3. Quality management processes that satisfy key user needs and support continuous improvement.

Aviation sector has ISO9001:2015 certified QMS (since 2018, last audit in 2021) and is fully implemented. Meteo Rwanda has ISO9001:2015 certified QMS (since 2018, last audit in 2022, valid until 2025) including all branches of service. Socio-economic impact study is missing from last 10 years.

Summary score, recommendations, and comments for Element 10

Summary score for the element is 3 on the CHD scale, reflecting "*Services development draws on regular dialogue with major stakeholders.*".

Meteo Rwanda is encouraged to enhance co-development of products while collaborating with multiple actors instead of mainly one-to-one collaboration.

Meteo Rwanda is encouraged to include regular user satisfaction surveying in its next strategy which will be effective from 2025 onwards. Regular satisfaction surveying is the key element which gives direct demand and justification for a continuous improvement and development of services.

Annex 1 Consultations (including experts and stakeholder consultations)

- CREWS East-Africa project was consulted to coordinate activities and investment planning between SOFF investment phase in Rwanda.
- The following stakeholders participated in CHD workshop: Rwanda Standard Board, Rwanda Airport Company, Ministry for Environment, Ministry in Charge of Emergency Management, Rwanda Civil Aviation Authority.
- Consultation of WMO in WIS2.0 matter will continue even after SOFF readiness phase project.

Annex 2 Urgent needs reported

Meteo Rwanda needs development support throughout the value chain of providing weather and early warning services. The most urgent needs can be summarized in the following way:

Following critical gaps have been identified:

- The current legal framework does not allow cost-recovery services for Meteo Rwanda. Cost-recovery would give additional resources for Meteo Rwanda for enabling sustainability for operations and motivation to develop added value services based on the end-user needs. The amendments of legal framework to enable cost recovery is in process in the Rwandan government. It is highly recommended to amend the legal framework accordingly as soon as possible.
- Meteo Rwanda observation system has some critical gaps that do not currently allow an efficient delivery nowcasting and early warning services e.g.: No lightning locating system, weather radar data does not cover whole country (only one weather radar with limited use of data), no upper air sounding system, no lidar systems, surface weather observation system is semiautomatic (the data transfer is operated manually, and thus, does not allow 24/7 near-real time data transfer), no integrated Data management system to store and process all observation data in one system and allow automated data processing, QA/QC and data dissemination for further use.
- Customer engagement process is only partial. Meteo Rwanda does not collect user feedback regularly to improve its services. The cocreation process to develop tailored services based on the user needs is missing. The customer process should be enhanced hand in hand when new tailored services are developed. There is no Mobile phone application to disseminate efficiently forecasts and warnings to the citizens. There is a project ongoing to develop weather app for agriculture sector. There is urgent need to develop a weather app also for general public for efficient dissemination of public weather services and warnings.
- The weather forecasting and early warning process is mostly manual and lacking new modern software's and tools for automation, dissemination and to allow forecasters to devote their expertise in actual forecasting instead of manual processing of information. This gap is improving within the implementation of FINKERAT project where modern forecaster workstation and automated forecast production system and warning tool are being implemented. The impact-based forecasting should also be further developed. The NWP system and available global NWP data (e.g., ECMWF) should be further developed and made available. The forecast verification is currently made manually and include very limited number of verification scores. There is urgent need to implement new automated forecast verification system with multiple verification scores to enable continuous development of forecast accuracy.
- The meteorology is not currently included in the curriculum of any Rwandan Universities. Meteo Rwanda does not have efficient internal training system in place to conduct internal trainings for its staff. Internationally funded projects should address the critical training needs in both Rwanda and specifically in Meteo Rwanda to ensure the sustainability of the project results. Twinning partnerships/Peer advisor cooperation is highly recommended to enhance the operational capacity of Meteo Rwanda during the modernisation of its systems. In longer term the Universities of Rwanda capacity should be strengthened so that they would be able to provide basic meteorological training.

- The co-operation between other governmental authorities should be further strengthened specially in DRR and new partnerships established with the NGO sector to allow an efficient use of information provided by Meteo Rwanda by the grass root level users.

Annex 3 Information supplied through WMO

Peer adviser acknowledges the numerous lists of references provided by SOFF in templates and guiding material throughout the Readiness phase. Especially, information and guidance given in the CHD data inventory and review sheet for Rwanda is appreciated.

Annex 4 List of materials used

In addition to WMO guides, the following material was utilised:

- online material included as references to this document
- the web pages of Meteo Rwanda
- Meteo Rwanda also shared some material about their organization (e.g., user statistics of web pages etc.) with peer adviser.