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# GBON National Contribution Plan of Madagascar

Systematic Observations Financing Facility

**Weather and climate data for resilience**

# GBON National Contribution Plan
# Madagascar

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## List of Abbreviations

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|---|---|
| AD2M | Project to Support Development in the Menabe and Melaky Regions |
| AfDB | African Development Bank |
| AJ | AFFAIRE JURIDIQUE |
| ASECNA | Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar |
| AWS | Automatic Weather Stations |
| BNCCREDD+ | Bureau National des Changements Climatiques et de la REDD+ |
| BNGRC | Bureau National de Gestion de Risques et des Catastrophes |
| CDMS | Climate Data Management System |
| CERVO | Centre d'Etudes, de Réflexion, de Veille et de l'Orientation |
| CMS | Content Management System |
| CP-CS | Climate-related Products and Services |
| CPGU | Cellule de Prévention et Gestion des Urgences |
| CPT | Climate Predictability Tool |
| CREWS | Climate Risk and Early Warning Systems |
| DEM | Direction des Exploitations Météorologiques |
| DGM | Direction Générale de la Météorologie |
| DRAE | Direction de l'agriculture et de l'élevage |
| DRDH | Direction des Recherches et Développements Hydrométéorologiques |
| DRM | Disaster Risk Management |
| DRR | Disaster Risk Reduction |
| ECMWF | European Centre for Medium-Range Weather Forecasts |
| EEZ | Exclusive Economic Zone |
| ENEAM | École Nationale d'Enseignement de l'Aéronautique et de la Météorologie Antananarivo - RTC Madagascar |
| ENTRO | The Eastern Nile Technical Regional Office (ENTRO) is an intergovernmental partnership of Egypt, Ethiopia, South Sudan, and Sudan |
| EPS | Ensemble Prediction System |
| ESPA | École Supérieure Polytechnique d'Antananarivo |
| EUMETSAT | European Organisation for the Exploitation of Meteorological Satellites |
| EWS | Early Warning System |
| EW4All | Early Warnings for All Initiative |

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|---|---|
| FOSS | Free and Open Source System |
| FTP | File Transfer Protocol |
| GBON | Global Basic Observation Network |
| GEFS | Global Ensemble Forecast System |
| GFCS | Global Framework for Climate Services |
| GFS | Global Forecast System |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit (German Development Cooperation) |
| GTA | Groupe thématique agrométéorologique |
| GTS | Global Telecommunication System |
| HPC | High Performance Computer |
| HWRF | Hurricane Weather Research and Forecast |
| ICT | Information and Communication Technology |
| IOC | Indian Ocean Commission |
| ISO | International Organization for Standardization |
| IRI-CPT | International Research Institute for Climate and Society’s Climate-Predictability Tool |
| IT | Information Technology |
| LAM Arome-IO | Limited-area coupled model called AROME-Indian Ocean |
| LDCs | Least Developed Countries |
| LPS | Lightening Protection System |
| MOS | Model Output Statistics |
| MOGREPS | Met Office Global and Regional Ensemble Prediction System |
| MHEWS | Multi-Hazard Early Warning System |
| NOAA | National Oceanic and Atmospheric Administration of the USA |
| NMHS | National Meteorological and Hydrological Service |
| NWP | Numerical Weather Prediction |
| OGC | Open Geospatial Consortium |
| OSCAR | Observing Systems Capability Analysis and Review Tool |
| PACARC | Projet d’Amélioration des Capacités d’Adaptation et de Résilience des Communes Rurales face aux Changements Climatiques |
| PIROI | Plateforme d'Intervention Régionale de l'Océan Indien |

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|---|---|
| PND | Plan National de Développement |
| PNGRC | Politique Nationale de Gestion des Risques et des Catastrophes |
| PNLCC | Politique Nationale de Lutte contre le Changement Climatique |
| PrAda | Projet d' Adaptation des chaînes de valeur agricoles au changement climatique Change |
| PRM PG | President de la Republique Malagache – Politique Gernerale de l'Etat |
| PUMA | Preparation for the Use of Meteosat in Africa |
| PyCPT | Python Climate Predictability Tool |
| QMS | Quality Management System |
| RAID | Redundant Array of Independent Disks |
| RA I TCC | Regional Association I Tropical Cyclone Committee |
| RMC | Regional Maintenance Center |
| RCC-Network | Regional Climate Centre Network |
| RCRP | Regional Climate Resilience Program for Eastern and Southern Africa Project |
| REGCM | Regional Climate Model |
| REDD+ | Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries |
| RSMC Pretoria-SAWS | Specialized Meteorological Centre Pretoria – South African Weather Service |
| RSMC-TC La Reunion | Tropical Cyclone Regional Specialized Meteorological Centre of Réunion |
| SADC | Southern African Development Community |
| SBDAH | Service de la Banque des Données et Archives Hydrométéorologiques |
| SIDS | Small Island Developing States |
| (S)FTP | Secure File Transfer Protocol |
| SMIT | Service de la Maintenance et Installations Techniques |
| SNGRC | Stratégie Nationale de Gestion de Risques et de Catastrophes |
| SOFF | Systematic Observations Financing Facilities |
| SRM | Service Regional de la Météorologie |
| SRVC | Service des Recherches sur la Variabilite Climatique |
| SWFP SA | Severe Weather Forecasting Programme South Africa |
| SWIOCOF | Southern Western Indian Ocean Climate Outlook Forum |
| TAHMO | Trans-African Hydro Meteorological Observatory |

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|---|---|
| ToT | Training of Trainers |
| UA | Upper-Air radiosonde station |
| UKMO | United Kingdom Meteorological Office |
| UNDP | United Nations Development Programme |
| UPS | Uninterruptible power supply |
| WDQMS | WIGOS Data Quality Monitoring System |
| WFP | World Food Programme |
| WIGOS | WMO Integrated Global Observing System |
| WIS | WMO Information System |
| WRF | Weather Research and Forecasting model |
| WMO | World Meteorological Organization |
| WMO SWFP | WMO Severe Weather Forecasting Programme |
| WW3 | WAVEWATCH III |

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## Glossary

**Beneficiary countries:** In its initial three-year implementation period, SOFF will prioritize support to SIDS and LDCs for all phases of support. All other OECD ODA- eligible developing countries will be eligible for SOFF support under the Readiness phase only.

**Climate Data Management System (CDMS):** An integrated computer-based system that facilitates the effective archival, management, analysis, delivery, and utilization of a wide range of integrated climate data.

**GBON Gap Analysis:** Defines the gap between the mandatory requirements of the GBON regulations and the existing country surface - and upper-air station networks. In other words, it serves as the basis for identifying the number of observing stations that need to be installed or rehabilitated to become compliant with the mandatory requirements of the GBON regulations.

**Global Basic Observing Network (GBON):** Internationally agreed standard specifying obligations of WMO Members to acquire and internationally exchange certain observations: which parameters to measure, how often, at what horizontal and vertical resolution, when and how to exchange them, and which measurement techniques are appropriate to use.

**Implementing Entities:** Entities that serve as SOFF Implementing Entities for the investment phase – these include the major multilateral development partners that play a role in hydromet project implementation. All Implementing Entities must be members of the Alliance for Hydromet Development.

**National Meteorological and Hydrological Services (NMHS):** NMHS own and operate most of the infrastructure that is needed for providing the weather, climate, hydrological and related environmental services for the protection of life and property, economic planning and development, and for the sustainable exploitation and management of natural resources. The NMHSs from the SOFF beneficiary countries are the focal points for SOFF support.

**Numerical Weather Prediction (NWP):** A series of processes to predict future atmospheric conditions by solving dynamics and physics equations that explain the movements and changes of the atmosphere.

**Peer advisors:** NMHSs that are members of WMO are eligible to serve as peer advisors for SOFF. NMHSs interested in becoming SOFF peer advisors must demonstrate (i) substantial expertise in the areas of advisory services required for SOFF, (ii) a track record in partnering with and supporting other NMHSs, and (iii) a commitment to make available adequate human resources.

**SOFF Secretariat:** The Secretariat is responsible for the administration, reporting, monitoring and evaluation, communications, and resource mobilization of the SOFF UNMPTF. The SOFF Secretariat is accountable to the Steering Committee and supports its functioning as well as the functioning of the Advisory Board. It is administratively hosted by WMO in Geneva, Switzerland, and follows WMO administrative policies and procedures.

**The Commission for Observation, Infrastructure and Information Systems (Infrastructure Commission) (INFCOM):** Contributes to the development and implementation of globally coordinated systems for acquiring, processing, transmitting, and disseminating Earth system observations, and related standards; coordination of the production and use of standardized analysis and model forecast fields; and development and implementation of sound data and information management practices for all WMO programmes and their associated application and services areas.

**Global Telecommunication System (GTS):** The communications and data management component, as a key component within the WMO Information System (WIS), allows the World Weather Watch (WWW) to collect and distribute information critical to its processes. It is implemented and operated by National Meteorological and Hydrological Services of members and by international organizations.

**WMO Information System (WIS):** Connects all National Meteorological and Hydrological Services and regions together for data exchange, management, and processing.
**WIS 2.0:** WIS2 in a box (wis2box) is a Free and Open Source (FOSS) Reference Implementation of a WMO WIS2 Node. The project provides a plug and play toolset to ingest, process, and publish weather/climate/water data using standards-based approaches in alignment with the WIS2 principles. wis2box also provides access to all data in the WIS2 network. wis2box is designed to have a low barrier to entry for data providers, providing enabling infrastructure and services for data discovery, access, and visualization. Please refer to the Manual on the WMO Information System (WMO-No-1060 ): Appendix VII to the WMO Technical Regulations, here. For more general information on WIS and WIS 2.0 please refer to the here.

**WMO Observing Systems Capability Analysis and Review Tool (OSCAR):** Contains quantitative user-defined requirements for observation of physical variables in application areas of WMO (i.e. related to weather, water, and climate). OSCAR also provides detailed information on all earth observation satellites and instruments, and expert analyses of space-based capabilities.

**WMO Technical Authority:** WMO serves as SOFF Technical Authority and provides basic technical support to the peer advisors, IEs and beneficiary countries on GBON regulations. WMO is also responsible for the technical screening of the GBON Gap Analysis and the National Contribution Plan against the GBON regulations and the independent verification of the status of beneficiary countries' stations against the GBON regulations.

# Module 1. National Target toward GBON compliance

In order to achieve the Global Basic Observation Network (GBON) National Contribution Target for Madagascar, the WMO Secretariat has determined a required number of 15 surface stations and 3 upper-air stations[1] (UA). The following GAP analysis conducted for Madagascar, revealed the need for 9 surface stations to be upgraded and 2 new stations to be established to reach the target of 15 GBON-compliant stations. In addition, one more upper-air station needs to be established (see Table 1)

**Table 1:** GBON Global Contribution target

| Type of station | Baseline (Results of the GBON Global Gap Analysis) | | | | GBON National Contribution Target | |
|---|---|---|---|---|---|---|
| | Target (# of stations)[2] | GBON-compliant stations (#) | Gap | | To improve | New |
| | | | New | To improve | | |
| **Surface** | 15 | 4 | 0 | 11 | 9 | 2 |
| **Upper-air** | 3 | 0 | 1 | 2 | 0 | 1 |

At the moment there are 24 synoptic surface observation stations of which 20 are currently operated by the General Directorate of Meteorology Madagascar[3] (DGM) and 4 by the Agency for Air Navigation Safety in Africa and Madagascar[4] (ASCENA) and 2 upper-air (UA) stations, also operated by ASECNA. All of the ASECNA stations are already GBON-compliant. As part of the Gap Analysis, stations suitable for upgrading according to the GBON criteria due to their location, accessibility and existing infrastructure were selected during the inventory in consultation with the DGM. The Gap Analysis showed that 9 stations could be upgraded. However, for six of the nine stations, upgrading means completely replacing the stations with new Automatic Weather Stations (AWS); only some of the existing infrastructure can still be used, as repairing them would no longer be economical. While there may exist additional stations that could benefit from improvement, the construction of 2 new stations (one close to the capital region at Arivonimamo and one at Ambatondrazaka airport with a high population density and relatively good infrastructure) is considered more sustainable and appropriate due to accessibility and infrastructure. New stations in this area improve maintenance possibilities and early warning for a large proportion of the population, which is mainly concentrated around the capital and along the east coast.

For the location of the third upper-air station, Antsiranana (Diego Suarez) was chosen. This is a former site of an upper-air station and it will also ensure coverage of the north in addition to a station in the south and center. The two already existing UA stations will continue to be operated by the third-party company ASECNA, while the third UA station will be operated by DGM (see Figure 1). Capacity building regarding the installation, operationalization and maintenance of the UA will need to be provided to DGM staff in charge. In addition, the budget must not only include the procurement of the UA station but also consider long-term operating and maintenance costs, including trainings, spare parts and disposables etc., of the station.

Ensuring the required maintenance for durability and functionality presents one of the most significant challenges currently. This is attributed to several factors. Firstly, there is insufficient funding for

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[1] When the term upper-air station is used, we only refer to radiosonde observations.

2 For SIDS, for the WMO GBON Global Gap Analysis in January 2022, the EEZ area has been added to the total surface area which is the basis for the target number of stations. The standard density requirements for SIDS have been calculated with 500 km for surface stations and 1000 km for upper-air stations.

3 Direction Générale de la Météorologie Madagascar

[4] l'Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar

maintenance, covering everything from petrol costs for travel to the stations through to spare parts. Secondly, Madagascar has many qualified meteorologists and technical staff, but they can only be employed through the Malagasy Ministry of Transport and Meteorology. Unfortunately, the Ministry does not have the resources to pay staff according to their degree or to hire additional staff who are urgently needed to meet the demand. This led to a recruitment freeze that has been in place since 1990. A lack of personnel with the appropriate profile is also preventing the NMHS from obtaining WMO certification. According to DGM, it would require an additional 200 employees and four Regional Maintenance Centers to fulfil its official mandate (for more details see ***Regional Maintenance Center (RMC)*** and the Country Hydromet Diagnostics Madagascar, E1).

See Figure 1 for an overview of the proposed observation network for Madagascar, presenting suggested sites for new stations as well already existing stations.


**Figure 1:** Map of current and planned observation network of Madagascar (source: own compilation with ArcGIS pro).

# Module 2. GBON Business Model and Institutional Development

## 2.1. Assessment of national governmental and private organizations of relevance for the operation and maintenance of GBON

The National Meteorological and Hydrological Service of Madagascar (NMHS) consists of the DGM and its subordinate directorates, the Directorate of Meteorological Operations [5] (DEM) and the Directorate of Hydrometeorological Research and Development[6] (DRDH).

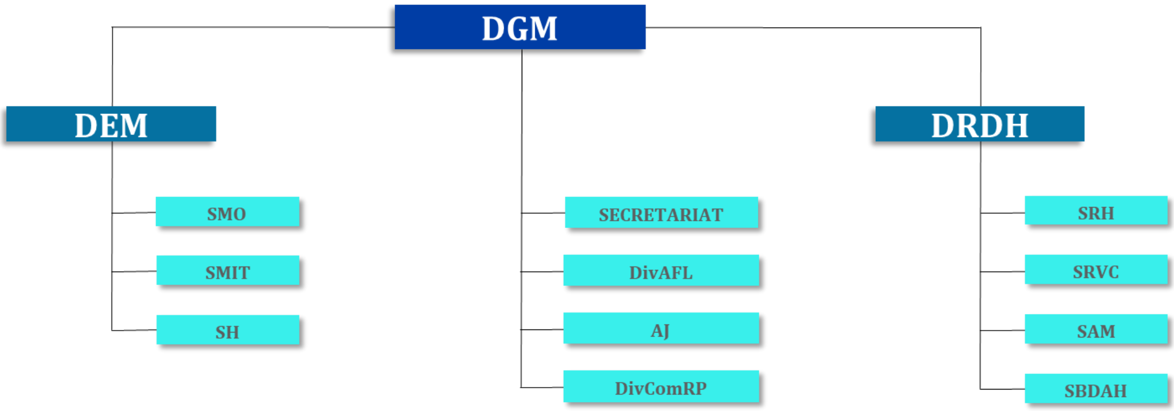


**Figure 2:** Organigram DGM November 2023 (source: DGM, 2023)

DGM operates under the Ministry of Transport and Meteorology and can be considered as a **key government stakeholder** in the implementation of the GBON. DGM operates a legal mandate in accordance with the provisions of Decree No. 62-099 bis of 28 February 1962 establishing the National Meteorological Service of Madagascar. Moreover, it carries out its tasks in accordance with the Law No. 2015-031 relative à la gestion des risques et des catastrophes, décret d'application N°2019-1954 du 28 octobre 2019, which regulates the Multi-Hazard Early Warning System (MHEWS) and defines its responsibilities for all hazards (hazard scale 1-5).

DGM’s mandate is to protect life and property against natural disasters of meteorological and climatic origin. It is responsible for the development and sustainable maintenance of a national hydro-meteorological network, weather analysis and forecasting, and climate services that serves the public interest. However, there are cross-cutting aspects with other sectors, such as agriculture and health, for which DGM provides service products. Additionally, weather forecasting and climate projections are critically vital for decision-making support across the energy, biodiversity, and water sectors.

Close cooperation between the respective ministries or Bureaus (e.g. Bureau National de Coordination des Changement Climatiques, du Carbone et de la Réduction des Emissions dues à la Déforestation et Dégradation des Forêts ou BNCCREDD+ belonging to the Ministry of Environment and Sustainable Development and the Ministry of Agriculture, Livestock and Fisheries) could be beneficial to create synergies and build the capacity needed to implement GBON.

[5] Direction des Exploitations Météorologiques
[6] Direction des Recherches et Développements Hydrométéorologiques

Other bodies under the supervision of the Ministry of Transport and Meteorology are ASECNA and the *National School of Aeronautics and Meteorology* "Ecole Nationale d'Enseignement de l'Aéronautique et de la Météorologie" (ENEAM[7]), with which the DGM already has a close partnership.

ASECNA - Agency for the Safety of Air Navigation in Africa and Madagascar – is an international public body governed by the Dakar Convention revised in 2010, with legal status and financial autonomy. In Madagascar, ASECNA operates four surface stations and two UA stations. All of them are already GBON compliant. ASECNA is currently responsible for the transmission of weather data (their own and data from DGM) to the Global Telecommunication System (GTS). The number of stations operated by ASECNA are included in the national GBON target, which makes ASECNA a crucial partner in the establishment of GBON.

DGM provides meteorological, climatological, hydrological, and environmental services to the Malagasy society and is represented in each of the 23[8] regions of Madagascar by a Regional Meteorological Service supervised by the Regional Directorate of Transport and Meteorology.

This comprises producing and disseminating weather forecasts, warnings, and climate information on various scales, including climate projections in order to mitigate associated risks. Furthermore, tailored customer services and products are provided for the health and agricultural sector, such as two-weekly or monthly agrometeorological bulletins and cropping calendars for millet, maize, ginger, beans, peanuts and rice are provided yearly with detailed recommendation for the timing of cultivation operations such as soil preparation, sowing, fertilization, weeding, bedding and harvesting, for the different regions of Madagascar. This information is available on the website but also disseminated through emails, Facebook and hotline services.

Data are derived from the national observation network comprising 24 synoptic surface observation stations (54% (partly) operational), 36 agro-climatological stations (47% operational) and 2 upper-air stations (100% operational). Furthermore, DGM uses observational data and forecast profiles, numerical weather prediction (NWP) models and satellite imagery, from several meteorological centers for its forecasting activities. The most important sources are the Global Forecast System (GFS), the Hurricane Weather Research and Forecast (HWRF) and the WAVEWATCH III (WW3) of the National Oceanic and Atmospheric Administration of the USA (NOAA), the Integrated Forecast System (IFS) and the Wave Model (WAM) from the European Centre for Medium-Range Weather Forecasts (ECMWF), the Global Deterministic and Met Office Global and Regional Ensemble Prediction System (MOGREPS) from the United Kingdom Met Office (UKMO), LAM AROME-IO[9] from the Tropical Cyclone Centre of La Réunion (RSMC-TC La Réunion) and the Unified Model UM4 from the Regional Specialised Meteorological Centre of South Africa (RSMC Pretoria-SAWS), which are part of the WMO Severe Weather Forecasting Programme (SWFP). The DGM uses a combination of regional and global NWP models, such as the NWP from the WMO Regional and Global Centres with a resolution ranging from 9 km to 0.4 km. On a daily basis DGM runs the Unified Model Weather and Research Forecast NWP with a resolution of 10 km. New forecasts are updated at intervals of 3, 6, and 12 hours.

DGM provides short to medium range weather forecasts based on both deterministic and probabilistic NWP. For the former, the Weather Research and Forecasting (WRF) model is used. Climate outlooks and

[7] Accredited by the WMO, the meteorology courses of ENEAM and École Supérieure Polytechnique d'Antananarivo (ESPA) are further part of the WMO Regional Training Centres (RTCs) based in Madagascar
[8] According to DGM, the number of regions will increase to 26 in the coming years.
[9] limited-area coupled model called **AROME**-Indian Ocean (**AROME-IO**)

seasonal forecasts are done by using the Climate Predictability Tool (CPT), Python CPT tool (PyCPT)[10], Seafords[11] tool, the Climate forecasting tool (CFT)[12] and the Regional Climate Model (REGCM). However, DGM highlights that data storage capacities of the HPC are insufficient.

For short range forecasts, DGM is using the Ensemble Prediction System (EPS) of the ECMWF, the Global Ensemble Forecast System (GEFS) as well as UK's MOGREPS.

Satellite imagery is received directly from EUMETCast[13] and accessed through the EUMETView Web portal. The DGM does not currently operate a weather radar station in Madagascar, but is in dialogue with the African Development Bank (AfDB), the World Bank and the Hydromet IOC project to assess future options in this regard.

Other collaborations with DGM that are of great importance to GBON include the **Trans-African Hydro Meteorological Observatory (TAHMO) and the *Deutsche Gesellschaft für Internationale Zusammenarbeit*[14] - GIZ Madagascar**.

**TAHMO** is working towards the goal to establish a 30 km dens network of hydro-meteorological monitoring stations in sub-Sahara-Africa, using an integrated and sustainable approach. TAHMO collaborates with the **GIZ program PrAda (Project for enhancing adaptation and resilience capacities of rural communities facing climate change)** to create a broader agro-climatological station observation network. This will provide stakeholders in agricultural value chains with a dependable database for informed decision-making. Although these stations do not conform to GBON standards, they will still contribute to the establishment of an observation network that will eventually go beyond the GBON criteria and provide useful additional information. Options for training workshops working on capacity building in quality management, particularly on aspects of station maintenance including field checks for sensor testing facilitated through GIZ and TAHMO should be explored.

Furthermore, TAHMO can provide support for DGM in setting up a connection to the Global Telecommunication System (GTS), which will be replaced by the WMO World Information System (WIS) 2.0. This is a vital aspect in the accomplishment of the GBON requirements, and is therefore of major importance to the SOFF project. Further collaboration holds crucial importance.

There is no private meteorological service operating an observation network in Madagascar that could provide support to the GBON compliance strategy and be approached for cooperation.

Further collaboration with other international organizations or programs involved in related fields, such as climate change and disaster risk, within the country or region is recommended. PACARC[15] (GEF/PNUD), CREWS (WB/GFDRR/WMO/UNDRR), PRRC (WB) and SADC SAWIDRA/SARCIS-DR (EU/AfDB) are potential programs of particular interest. For future collaboration programs, it is recommended to also consider other financing mechanisms such as the GFCS (WMO) or the Green Climate Fund (UN).

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[10] PyCPT is a python interface ad enhancement for the command line version of the IRI-CPT, for seasonal and sub-seasonal skill assessment and forecast experiments; used in the forecast-based financing project of WFP

[11] Seafords is used by the Southwest Indian Ocean Climate Forum

[12] CFT is used by SADC Climate Service Centre Forum

[13] EUMETCast is a method of disseminating various (mainly satellite based) meteorological data operated by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)

[14] German Development Cooperation

[15] PACARC: Projet d'amélioration des capacités d'adaptation et de résilience des communautaés rurales face au changement climatique

Given the diversity of public and private organizations responsible for maintaining a GBON-compliant network, the following main suggestions arise from the information presented earlier:

1. Sustained national budget allocations are critical to strengthening DGM capacity. While the SOFF investment will cover the initial investment for operations and deployment, as well as long-term results-based funding triggered by verified data exchange results monitored globally in real time by the World Meteorological Organisation, it is advisable to develop a national financing plan in parallel, which can guarantee and ensure the sustainable continuation of the observation network to be implemented, even with limited external financial support.

2. In addition, broadening the scope of action and increasing visibility through **capacity building** should be encouraged in order to highlight their role as critical national infrastructure with implications for other sectors such as agriculture, business, health, tourism and energy.

3. Greater attention needs to be given to **involving stakeholders and end users** in order to cater to their needs more effectively.

4. There is currently a **lack of user feedback mechanisms**, which are crucial for service customization. Simultaneously, there is a need for continued efforts to improve the accessibility of the 'last mile' of services. Emphasis must be placed especially on remote regions of the country and marginalized population groups. This matter is presently being tackled primarily by NGOs and other international programs, such as the GIZ PrAda project. In addition to conventional information channels such as radio, TV and social media, the hotline number 321 has also been established, where you can call for weather information and forecasts for agricultural activities. So far, this number is already free for Airtel users, and the price of a normal call for Orange and Telma users. For the latter, the development of partnerships is planned in order to achieve the same service for free with these operators as well. In addition, animators in remote areas will ensure that information reaches the last mile and that people are aware of the services.

5. Close collaboration with the **University of Antananarivo** and regional training centers - in particular**, Ecole Nationale d'Enseignement de l'Aéronautique et de la Météorologie (ENEAM)** and **Ecole Supérieure Polytechnique d'Antananarivo (ESPA)** - is already established and should be further strengthened. An efficient weather service requires employees who are well versed in meteorology. Undertaking an internship or final thesis at DGM is a valuable opportunity to acquire practical expertise. Madagascar has the potential to serve as a regional hub, offering highly skilled professionals to nearby areas or operating as a training center. Increased visibility could provide opportunities for obtaining additional funding.

6. It is crucial to maintain and strengthen the partnership with **TAHMO**, given their responsibility for implementing the WIS 2.0 for DGM. This is essential for establishing the necessary international data exchange required for SOFF. Furthermore, TAHMO holds diverse expertise in setting up cost-effective and low-maintenance weather stations in Sub-Saharan Africa, utilizing various business models to ensure continuous station operation. This valuable experience can be employed to establish a sustainable and effective monitoring network in Madagascar. Although TAHMO has mainly concentrated on establishing agro-meteorological and climatological stations in collaboration with GIZ PrAda, the expertise gained can also be beneficial for a synoptic surface station network. TAHMO can assist the NMHS in the installation and maintenance of meteorological stations and, if required, offers support in improving data transmission and integrating information from different telemetry systems. TAHMO also has experience with compact weather stations, which are inexpensive, low maintenance and robust. But they are measuring all parameters at a height of about two meters and rain gauge orifices

are sub-standard in size. Therefore, the advantages and disadvantages of installing these stations should be discussed in order to extend the observation network. TAHMO is further providing a series of capacity building workshops for the DGM, including planning sessions, coaching and training on station maintenance, computer and server setup, and improvement of critical areas of the data flow system.

## 2.2 Assessment of potential GBON sub-regional collaboration

The southwest Indian Ocean is affected by El Niño/La Niña, Indian Ocean Dipole, Sub Tropical Indian Ocean Dipole phenomena, Monsoon, trade Wind and hazards such as tropical cyclones, drought, extreme rainfall and flooding. Climate change is exacerbating the intensity of these hazards. Therefore, Madagascar, like other island states such as the Seychelles, Mauritius and the Comoros, as well as Mozambique, facing the Indian Ocean, is affected by similar impacts of climate change, sea level rise and hazardous weather events. Regional and sub-regional cooperation enables these countries to improve their early warning capabilities through a regional approach, which allows for the collection of more data for forecasting and the mutual benefit of shared knowledge, experience and resources. Madagascar is therefore a member of various regional alliances such as the Indian Ocean Commission (IOC), the Southern Africa Development Committee (SADC), the Tropical Cyclone Committee (RA I TCC), the Severe Weather Forecasting Programme South Africa (SWFP SA).
Specific projects that have emerged from these regional collaborations and are of interest to GBON are outlined below:

Due to its geographical location, Madagascar is affected by similar impacts of climate change, as are the island states of Seychelles, Mauritius and the Comoros. To address these challenges, the Indian Ocean Commission (IOC) has launched a regional project: "*Building Regional Resilience through Strengthened Meteorological, Hydrological and Climate Services in the Indian Ocean Commission Member Countries"* ***(IOC Hydromet Project)***.

- The project seeks to amplify the capacities of National Meteorological and Hydrological Services (NMHSs) in Comoros, Madagascar, Mauritius, and Seychelles on all fronts of the Global Framework for Climate Services (GFCS) through a regional approach, by creating a Regional Climate Centre Network (RCC-Network). The aim is to address effectively climate-related hazards and institutional capacity gaps which these four nations encounter in comparable ways. This project is focused on three main areas: observations and monitoring, climate services information system, and user interface platform. In order to optimize the observation network, it suggests designing sub-regional networks and forming partnerships with the aim of producing high-quality climate-related products and services. This will include advanced early warning systems for specific user groups. The project's main objective is to bolster the readiness and climate robustness by reinforcing National Meteorological and Hydrological Services, setting up institutional frameworks, encouraging regional collaboration and facilitating knowledge exchange. Collaborative work with PIROI and national partners is underway to try out a community-focused Early Warning System (EWS) to be extended to all four nations.
- The IOC Hydromet project intends to develop an optimized surface observation network and associated Information and Communication Technology (ICT) systems for the South West Indian Ocean Region, aligning with the GBON concept. Therefore, initiating an early exchange between these two projects to leverage synergies regarding information sharing, resource mobilization and project implementation is crucial.
- Over time, the implementation of a Regional Maintenance Center approach could serve as a platform for the DGM to promote the exchange of knowledge and experiences among NHMS

facing similar issues. This presents a valuable opportunity to apply capacity-building programs and explore the beneficial utilization of shared resources. Ideally, the transmitter and receiver characteristics of the UA sondes can be coordinated with the IOC countries so that the data can be received and processed by the other countries when within range.

*CREWS* - Supporting regional cooperation to strengthen seamless operational forecasting and multi hazard early warning systems at national level in the South-West Indian Ocean (The CREWS South West Indian Ocean project)

- In coordination with the Hydromet project detailed above, CREWS aims to enhance the operational forecasting and multi-hazard early warning systems across 5 countries in the SWIO region: Comoros, Madagascar, Mauritius, Seychelles, and Mozambique. The program seeks to strengthen the adaptive capacity and climate resilience of communities and economic sectors in these countries.
- Regional cooperation is critical to ensure optimal use of resources by individual NMHS. Therefore, the support of several Regional Maintenance Centers, such as the centers for tropical cyclones (La Réunion), training (Pretoria) and severe weather forecasting (Pretoria), is expected and additional centers will be set up, including for climate, instrument calibration and data exchange, with direct benefits for forecasting and warning services.
- While the Hydromet project is primarily focusing on enhancing the capacity of the DGM, the CREWS project aims to strengthen the interface between DGM and Bureau National de Gestion de Risques et des Catastrophes (BNGRC) for disaster risk management and CPGU with respect to early warning systems.[16] To ensure that the data collected can be utilized accurately and that the corresponding warning system operates seamlessly and reaches its intended recipients, it is crucial to have constructive collaboration between the bodies mentioned above which is highly pertinent to SOFF.

Madagascar is also part of the **Early Warning for All (EW4All)** initiative, where SOFF is seen as a foundational element and delivery vehicle for the second pillar of the initiative: "Hazard detection, observation, monitoring, analysis and forecasting".
A roadmap for 2024-2027 was developed as a strategic guide to provide government institutions at national and local levels with a structured plan to strengthen a people-centered early warning system in Madagascar through targeted actions and resource allocations. Priority areas for action were identified on the basis of an in-depth gap analysis of the EWS in Madagascar, consisting of surveys, stakeholder consultations and workshops, from which a checklist of minimum core capacities was derived.
The convergence of the two programs aims to achieve the defined outcomes of EW4All by SOFF supporting the improvement of national monitoring systems not only to close the GBON gap in Africa, but also to strengthen national capacities for effective disaster preparedness and early warning systems. An international exchange of GBON data is a key objective.

Furthermore, Madagascar is a beneficiary country of the World Bank Regional Resilience Project for Eastern and Southern Africa. Through this project DGM is expecting 6 new AWS, 6 new automatic Hydrology stations and 1 weather radar.[17]

To date, there is no sub-regional partner providing calibration services that could be collaborated with or that meets the required standards (e.g. RIC Kenya). Furthermore, due to Madagascar's remote location as an island state, outsourcing calibration services would also mean enormous transportation costs, which should also be avoided for the sake of feasibility.

[16] CREWS. South-West_Indian_Ocean_-_CREWS_Proposal_3-final.pdf (South-West_Indian_Ocean_-_CREWS_Proposal_3-final.pdf (ane4bf-datap1.s3-eu-west-1.amazonaws.com)
[17] The World Bank. https://projects.worldbank.org/en/projects-operations/project-detail/P180171

### 2.3. Assessment of a business model to operate and maintain the network

DGM's total budget for 2023 was USD 2.736.619 (12.328.332.000 MGA), fully funded by the government. Operating costs accounted for 3.8% of this amount. In recent years, the available budget has fluctuated greatly, making long-term planning difficult. In 2020 and 2021, the budget was reduced to cover operating costs only, leaving no money for investment. From 2022, both the investment and operating budgets increased. However, the operating budget did not return to pre-2021 levels, resulting in significant gaps in the maintenance of stations. This is primarily due to the difficult accessibility from Antananarivo, as journeys to the stations are often long and arduous due to the poor road infrastructure. In many cases, there is no budget to cover the cost of petrol for these journeys. The shortage of equipment outside of Antananarivo and a lack of qualified personnel for repairs, maintenance, and calibration worsens the issue. In order to achieve and maintain GBON compliance, the initial and operational costs must therefore be covered by SOFF, as DGM does not have the financial resources to do so.

For Madagascar and its specific country context, we propose to apply a fully public business model. This means that full ownership and control of the observing system, operations and services is with the government and therefore with the NMHS. Although there is a private partner involved in operations in Madagascar (ASECNA), data exchange between the two parties is free of charge and a good partnership exists. Therefore, we would still consider it a fully public business model. The private partner's four stations are already GBON compliant and therefore do not require further SOFF support. The remaining 11 stations to be made GBON compliant with the support of SOFF will be fully owned and operated by the NMHS.
Although the public business model carries some risks, we believe that strengthening the public sector is the most sustainable model at this point in time. As described in the CHD, the DGM has a solid organizational structure supporting the chosen business model. There is currently no private service provider that could take over. In addition, most of the actors in the country are from the public sector, with whom close cooperation is explicitly desired (e.g. GIZ, UN, etc.).

In order to become more financially independent of the funds provided by the Ministry, the possibility of a cost recovery mechanism is currently being examined (see Table 2).

The following table shows the risks to be expected with this business model, which should be considered and avoided through respective mitigation measures:

**Table 2:** Risk Assessment public business model

| Risk | Impact | Likelihood/ Mitigation measures |
|---|---|---|
| **Financial risk:**<br>Budget cuts due to change of government or change of priority areas. Restrictions on available resources and recruitment freezes.<br><br>**Risk level:** high | **Major** | **Possible**<br>Uncertainty increased with the elections, new ministry appointments and budget reallocations. However, there is a general trend to be expected towards more budget in the future.<br><br>National Policy on Meteorology of Madagascar has been approved. The next step will be the development of a National Strategy on Meteorology, including the decision on data policy and cost recovery mechanism.<br><br>Financial risk can be reduced when cost recovery mechanism is in place. |

| | | |
|---|---|---|
| **Sustainability:**<br>Appointment to positions and the focus of the NMHS is heavily dependent on the ministry and government formation; no influence on the allocation of positions by the ministry.<br>**Risk level:** low | **Minor** | **Unlikely**<br>NMHS has legal mandate. All directors will be appointed by ministry but all from the Met field. |
| **Market competition:** Potential competition with the private sector and market distortions as a result.<br>**Risk level:** low | **Minor** | **Rare**<br>So far there has been no competition; there is good co-operation and free data exchange with the operating private company. ASECNA is also under the umbrella of the Ministry of Transportation and only responsible for aviation. |
| **Insufficient quality of the services:**<br>Insufficient quality of services due to limited resources.<br>**Risk level:** high | **Major** | **Likely**<br>Despite the current limited resources, there is a certain level of service quality (with room for improvement). Many processes are already underway to improve this. With further resources and capacity development the risk can be greatly minimized. The establishment of four RMC can further contribute in minimizing the risk. |
| **Limited data quality:**<br>limited data quality due to lack of capacities and resources.<br>**Risk level:** high | **Major** | **Likely**<br>It is expected that this risk will be minimized by expanding the monitoring network and building capacity alongside other measures listed in the NCP to meet training needs. |
| **Maintenance of the observation network:**<br>Risk of network inoperability due to lack of maintenance.<br>**Risk level:** high | **Major** | **Likely**<br>Highly dependent on the factors mentioned above, especially available budget and human capacity, can be mitigated by cost covering, proper long-term planning, avoiding risk amplifiers (e.g. remote locations, fragile equipment, insufficient capacity building, etc.). RMC approach can greatly mitigate this risk. |
| **Administrative competence:**<br>The expansion of the network and the establishment of Regional Maintenance Centers increases the area to be managed and therefore the range of tasks and resources required.<br>**Risk level:** low | **Moderate** | **Unlikely**<br>The quality of management also depends heavily on the factors mentioned above, such as budget and capacity building measures. However, the risk of poor or non-existent management can be minimized through good planning, as provided for in the SOFF, which is why the likelihood is expected to be low. Redundancy through RMC reduces the risk of major failure within the network. |

A detailed financial plan will need to be developed as part of the funding request for the investment phase, but should take into account the above-mentioned issues. Furthermore, it should consider the World Bank's estimate of the Total Cost of Ownership, as set out in "Charting a Course for Sustainable Hydrological and Meteorological Observation Networks in Developing Countries" (Grimes et al. 2022), which includes not only procurement costs but also operation and maintenance costs over the lifetime of the equipment. Financial planning must be organized in such a way that the network, including human resources, can be sustained over the long term.

The country's remote location and challenging terrain pose specific challenges for both the procurement and availability of spare parts and the maintenance of stations. It is important to consider additional costs for transport and establishing several spare parts warehouses scattered across the island to avoid long trips (RMC). For Madagascar, it is crucial to consider certain security measures, including avoiding the installation of easily stolen solar panels and limiting all human activity to daylight hours.

Where possible, equipment should be sourced from a limited number of manufacturers that the DGM staff are familiar with or have had a workshop with. Material and resources when available should be sourced locally (e.g. wind tower, fences, civil work etc.).

### 2.4. Assessment of existing national strategies and projects related to observing networks

The DGM has formulated a strategic plan for 2024 that concentrates on its key priority areas including human resources, observation and services, and Quality Management System (QMS). The DGM also aims to modernize the Operational Forecasting Centre to align with international standards and norms, the technical design of which will be undertaken by CREWS experts. This will involve improving the observation network by increasing the number of stations, conducting regular maintenance and renewal, automating processes, and hiring additional staff. Implementing the QMS across the entire value chain and introducing new data flows are also priorities. Furthermore, improving NWP models is a key objective.

After his re-election, the President of the Republic of Madagascar (PRM) published a new General State Policy (PGE- General de l'Etat) for the next 5 years. Climate challenges and environmental protection are among the priorities of this new General State Policy. Therefore, the DGM maintains its long-term goal of installing one synoptic station in each district of Madagascar, going beyond the GBON requirements. In 2023, DGM has received two further stations from the *Project to Support Development in the Menabe and Melaky Regions (AD2M)*[18]. As a result, 90 synoptic stations are left to reach the objective. The GBON-compliant stations under SOFF will be part of these 90 stations, contributing not only to SOFF but also to the PRM-PGE. In order to create a coherent data network, these efforts of the installation of new stations need to be closely coordinated.

Regarding **hydromet projects** active in Madagascar, there has to be mentioned the *Regional Climate Resilience Program for Eastern and Southern Africa Project (RCRP)*[19]. The RCRP is structured as a regional series of projects to address challenges common to the countries of the region (Comoros, Madagascar,

18 The International Fund for Agricultural Development (IFAD); Adaptation for Smallholder Agriculture Programme (ASAP by IFAD); OPEC Fund for International Development (OFID), Government of Madagascar

19 https://documents1.worldbank.org/curated/en/099083023094011434/pdf/P1801710c160a906e0abaa09e50df30f10e.pdf

Mozambique, South Sudan, SADC[20] and ENTRO[21]), while benefiting from a programmatic framework that will enable countries to join at different times and benefit from economies of scale.

The RCPR consist of four key fields of action:

1. Climate and Disasters Risk Management
2. Infrastructure Investments and Sustainable Asset Management for Climate Resilience
3. Adaptive Climate Services for Resilient Communities
4. Project Management

Although the project focuses on improving the management of water-related impacts in Eastern and Southern Africa, the project design shows that there are some areas of action that could allow some overlapping activities to be discussed.
Under the first field of action "Climate and Disasters Risk Management" the following activities are listed:

a) to strengthen the hydrometeorological systems managed by the Direction Générale de la Meteorology,
b) to strengthen the EWS, including the establishment and operationalization of the regional offices of the National Risk and Disaster Management Office and the installation of water resources monitoring networks in the Mandrare basin,
c) to enhance capacity building of concerned entities and elaboration of maintenance and management protocols for water resources monitoring networks, and
d) the operationalization and mobilization of the national disaster fund.

With regard to point a) in particular, it should be clarified which activities are planned in detail and where synergies could possibly arise.

To summarize, partnerships with TAHMO and GIZ are essential for capacity building of staff but also regarding technical aspects of the observation network. In addition, TAHMO is a key partner responsible for the implementation and roll-out of the new GTS system, which will ultimately lead to the implementation of WIS 2.0, thus contributing to the development of a national WIGOS implementation plan, with a particular focus on sustainable knowledge transfer to achieve maximum independence. The CREWS project plays an important role in strengthening the collaboration between DGM and *BNGRC for disaster risk management and CPGU with respect to early warning systems.*

### 2.5. Review of the national legislation of relevance for GBON

By Decree No. 62-099 bis of 28 February 1962, the National Meteorological and Hydrological Service of Madagascar was established immediately after independence in June 1960. It became a general directorate in 2002 and was successively placed under the Office of the Vice Prime Minister in charge of Public Works, the Ministry of Public Works and Meteorology, the Ministry of Transport, Tourism and Meteorology and the Ministry of Transport and Meteorology since 2021. Since then, the DGM also encompasses the Hydrometeorological Research and Development Department and the Meteorological Operations Department. Since 1961 [22] Madagascar is a member of the World Meteorological Organization and DGM's mandate includes:

a) Providing meteorological, climatological, hydrological, and environmental services to the Malagasy society. This comprises producing and disseminating weather forecasts, warnings, and

20 SADC- The Southern African Development Community

21 The Eastern Nile Technical Regional Office (ENTRO) is an intergovernmental partnership of Egypt, Ethiopia, South Sudan, and Sudan

22 https://contacts.wmo.int/all_members/details_all_members/?id=6b6e2cca-816a-e811-a95a-000d3a38cba7

climate information on various scales, including climate projections in order to mitigate associated risks

b) Ensuring the safety and efficiency of air, sea, and land transport.

c) Promoting sustainable use of natural resources to contribute to rapid economic growth.

d) Establishing and maintaining the national meteorological, climatological, and hydrological observation network (collecting, analyzing, and processing observation data); also, in order to enhance resilience to climate variability and change.

e) Providing scientifically-based technical advice on weather, climate, and water-related matters, serving as the authoritative national institution for these issues.

f) Offering climatological services aligned with the National Framework for Climatological Services, delivering tailored information to meet users' needs.

In order to fulfil this mandate, the observation network needs to be expanded and become fully operational, which is why compliance with the GBON is directly linked to it.

There is also close cooperation between the DGM and the BNGRC on disaster risk management and early warning systems. The DGM is officially recognized as the National Warning Authority for Hydrometeorological Hazards in Madagascar, but the Integrated Multi-Hazard Early Warning System (MHEWS) is operated by the BNGRC and the Centre for Studies, Reflection, Monitoring and Guidance[23] (CERVO), its focal point for all warnings and disaster information.
The mandate of the BNGRC is defined in Décret-N-2019-1958-BNGRC. According to Art. 4, it is the central operational structure for risk and disaster management and is therefore responsible for coordinating and implementing the national strategy for risk and disaster management and for managing the National Emergency Fund. According to Art. 5, the actions of the BNGRC must be based on a humanitarian and ecological approach. Art. 6 defines two main tasks:

- Coordination and implementation of the National Strategy for Risk and Disaster Management[24] (SNGRC) by developing and implementing contingency plans and monitoring and evaluating the activities of these various contingency plans throughout the country.
- Mobilization of national and international funds for disaster management activities and provision of funds in the event of disasters, known as the National Contingency Fund.

In its General Policy and National Development Plan (PND 2015-2030), the Malagasy government has emphasized the importance of Disaster Risk Management and Reduction through axis N°5 "Valuing natural capital and strengthening through disaster risks." As a result, a new Law No. 2015-031 of February 12 ,2016 on the National Risk and Disaster Management Policy (PNGRC) has been put in place in order to materialize a new legal framework for GRC. For the implementation of the new PNGRC an update of the SNGRC is required. This update followed an iterative, continuous and participatory process and was carried out by the Emergency Prevention and Management Unit '*Cellule de Prévention et Gestion des Urgences*' (CPGU) and the BNGRC with the support of the United Nations Development Programme (UNDP), resulting in the SNGRC2016-2030.
With regard to GBON, Axis 3.5 of the SNGRC "The organization of data collection is strengthened and operational" is particularly relevant, as it defines the strengthening of the organization and operationalization of information and data collection mechanisms.

[23] Centre d'Etudes, de Réflexion, de Veille et de l'Orientation
[24] Stratégie nationale de gestion des risques et des catastrophes

This SNGRC is attached to the implementing decree of the new Law No. 2015-031 of 12 February 2016 on the National Risk and Disaster Management Policy, which replaces Law No. 2003-010 of 5 September 2003, to which the previous SNGRC was attached. It is in line with the provisions of the new international reference frameworks for Disaster Risk Reduction (DRR), namely the Sendai Framework and the African DRR Strategy.
To reach the vision of "A nation resilient to shocks, protected from all damage, in its social dimension, economic and environmental culture for sustainable development" the strategic focuses are placed on "Greater political commitment to Disaster Risk Management (DRR) and DRR, taking into account the different specificities of the assets and issues involved, to improve resilience", "better governance of DRM/DRR at all levels", "enhances DRM/DRR and coordination capacities of stakeholders", "knowledge management practices for DRM/DRR.[25] A well-functioning meteorological observation network and the capacity to detect weather risks at an early stage and to issue effective warnings are inseparable from these efforts, which is why this national legislation is important for the GBON. Furthermore, Madagascar has a National Climate Change Management Policy (PNLCC, 2021[26]), which also underlines the need to strengthen climate services. In this regard, Madagascar's Climate Change Policy highlight the need to make various parties at all levels responsible for combating climate change, among others through the development of sustainable financing instruments; and promoting research, technology development and transfer, and adaptive management, including the NMHS's capacities as a leading actor in the field of climate research and service.

To summarize, the NMHS has a defined mandate, overarching regulations that emphasize the importance of natural hazard preparedness, disaster risk management and prevention, and climate services, and targets that call on various agencies to act accordingly. It is crucial for these organizations to collaborate effectively, and for the NMHS to be fortified in terms of its capabilities and finances, while receiving further governmental support.

National legislation must be carefully considered in relation to procurement, import and customs procedures. All relevant import and tax regulations, duties and fees will be carefully reviewed by the IE when the procurement list is finalized.

Currently, no import license is required for the items under consideration to be imported into the country, and no customs duties are charged for several countries that are partners with Madagascar in preferential trade blocs. However, as noted above, we recommend that the legislation be reviewed again by the IE once the procurement is in a more advanced stage, as customs duties are subject to annual changes in the range of 5-20%.

[25] BNGRC (2016). National Risk and Disaster Management Strategy 2016-2030 of the Republic of Madagascar, p.10
[26] PNLCC (2021) Politique nationale de lutte contre les changements climatique revisee - republique de madagascar (cbit-madagascar.mg)

# Module 3. GBON Infrastructure Development

### 3.1. Design the surface and upper-air observing network and observational practices

Madagascar has an observation network in place, but it faces limitations due to issues such as insufficient maintenance, restricted capacity, and a sparse supply of spare parts. Table 3 shows the current status of Madagascar's observation network.

**Table 3:** Declared status of the Madagascar observation network

| **Network<br>Current # Stations<br>(self-declared by DGM)** | | **OSCAR[27]/ Surface land station [28]** | | **WDQMS (04.01. 2024/ daily)** |
|---|---|---|---|---|
| | | **Declared status** | **Assessed status[29]** | |
| Surface land | • 4 synoptic AWS (ASECNA)<br>• 20 synoptic (DGM) (AWS & manual; partly or not operational)<br>• 36 agro-climatological (17 operational) | 29 stations<br>• 20 operational<br>• 1 partly operational<br>• 2 non-reporting<br>• 6 closed | 29 stations<br>• 3 operational<br>• 19 partly operational<br>• 7 unknown | 15 stations<br>• 3 reporting (≥80%)<br>• 1 reporting (≥30%)<br>• 10 reporting (<30%)<br>• 1 non-reporting |
| Upper-air | 2 (ASECNA) | n/a | | n/a |

To ensure GBON compliance, it is essential to effectively handle and recognize these constraints while upgrading or replacing non-functional stations, and set up new AWS[30] [31]. Hence, in the process of conceptualizing, strategizing, and budgeting for the network, it is essential to factor in all expenses linked to procurement, operations, encompassing data transfer, communication, maintenance, calibration, field checks and replacement costs. This encompasses indirect expenditures associated with its operations, such as vehicles, transportation for maintenance, ICT, licensing, spare parts, equipment, training, as well as the managerial and administrative workload. It is important to consider the full life cycle of the network, including the life cycle of individual stations in order to guarantee a sustainable approach.

**Regional Maintenance Center (RMC)**

In order to optimize resource utilization through geographical proximity and local expertise, we suggest establishing four RMCs in addition to the headquarters in Antananarivo serving as the central RMC. The proposed sites for the RMCs are Toliara, Farafangana, Mahajanga and Antalaha (see Figure 3). The selection of the sites mentioned is based on several factors:

- Covering an area of sites of (planned) GBON surface stations that are not in the vicinity of the headquarters
- Road connections and existing infrastructure
- Availability of required staff

Each RMC, should serve as maintenance hub for its region and allow for faster responsiveness and better accessibility of the stations distributed over the whole island. It should hold a calibration laboratory,

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[27] Observing Systems Capability Analysis and Review Tool
[28] As of January 2024
[29] OSCAR assessment has been put on stand-by until SOFF implementation
[30] Grimes et al. (2022) provide an overview and guidelines for designing, budgeting and setting up AWS and upper-air systems (Grimes, D. R., Rogers, D. P., Schumann, A., & Day, B. F. (2022). Charting a Course for Sustainable Hydrological and Meteorological Observation Networks in Developing Countries).
[31] AWS must align with the WMO Deliverable 6.1 – GBON Tender Specifications for AWSs

including field check equipment and all essential spare parts for the AWS installed in its administration area, allowing for more maintenance and routine calibration activities. A sufficient amount of spare parts allows for the usage if circulation devices.

Further equipment should include a four-wheel drive vehicle to be mobile and to be able to reach the stations faster than possible from Antananarivo in case of necessary repairs and maintenance; appropriate fuel supplies and budgets should be taken into account. In addition, each RMC should be equipped with a rugged laptop. These are less susceptible to damage from the high humidity and dust, and allow for maintenance activities also under challenging weather conditions. The installation of an air conditioning unit is highly recommended for running the RMCs' calibration labs and can further improve the lifecycle of technical equipment and ensure a safe working environment. In addition, it should be ensured that each RMC has the necessary (office) equipment to guarantee a safe and functional workplace. For a detailed inventory list that every RMC should have, see Appendix 2.2.

The following table shows the staff required at least in each RMC and corresponding qualifications and responsibilities:

**Table 4:** RMC staff requirements

<table>
<tr><th>Function</th><th>Number</th><th>Diploma needed</th><th>Job description/profile</th></tr>
<tr><td>Head of service/<br>Regional Manager</td><td>1</td><td>ENGINEER</td><td>Software/ data transmission<br>Supervision of calibration activities<br>Admin of RMC:<br>(timely procurement of necessary equipment and the maintenance of up-to-date inventory lists, vehicle maintenance and administration, and further administrational tasks.)</td></tr>
<tr><td rowspan="3">Technician<br>1 Station Manager (chef station)</td><td rowspan="3">3/4</td><td rowspan="3">BACHELOR<br>IN ELECTRONICS</td><td>Full installation (civil work and equipment installation)</td></tr>
<tr><td>Maintenance (preventive and curative)</td></tr>
<tr><td>Sensor calibration and field checks</td></tr>
</table>

**Security and safety**

Manual stations in Madagascar have limited operational capacities due to security protocols that only allow daytime operations. Additionally, poor road conditions pose risks for prolonged travel during the day. Given the vast terrain of the country and the need to cover a large area with the observation network, it is advisable to shorten response times while allowing for a more targeted application of regional knowledge on the ground. This can be ensured by the RMC. An additional factor that must be taken into account is the installation of theft-proof equipment at the stations (e.g. climbing defense system on wind towers), as solar panels and other valuable equipment often gets stolen, if they are not securely mounted. In addition, all AWS must be equipped with a Lightening Protection System (LPS). Surge protection for all electrical equipment in the AWS must also be part of the overall lightning protection concept. For all stations in the vicinity of airfields (e.g. Arivonimamo, Ambatondrazaka, Toliara) the installation of appropriate obstruction lights for all elevated structures and red/white marking of the wind towers according to ICAO International Standards and Recommended Practices (see Annex 14 to the Convention on International Civil Aviation, Volume I "Aerodrome Design and Operations") has to be considered.

**Maintenance and calibration**

Maintenance of synoptic and agro-climatological stations is carried out by the Maintenance and Technical Installation Department, known as the "Service de la Maintenance et Installations Techniques (SMIT)". The department's scope of activity includes cleaning, fault detection, sensor and battery replacement, and firmware updates. However, it does not provide sensor repair services. Conducting these operations in remote regions poses a significant challenge because of poor road conditions, exacerbated by certain weather conditions, and limited means and resources for transportation. Further obstacles in upholding the stations entail inadequate provisions of spare parts, insufficient funding and proficiency for automated stations, combined with a lack of clear instructions for staff on cleaning activities and schedules.

The DGM currently only performs limited quality assurance by conducting field checks of sea level pressure, humidity and temperature, as it has only limited access to calibration equipment spare parts to server as circulation devices. To guarantee continuous data collection and transmission, it is therefore crucial to have spare instruments available to replace any defective parts. Meanwhile, faulty instruments can be repaired and reused at another station.

Although the DGM has received calibration equipment through the "*Project to improve the adaptation and resilience capacities of rural communities in the face of climate change*" (PACARC)[32] initiative, the equipment has not been used yet due to a lack of knowledge on how to use these instruments. Further training is therefore necessary for technicians to effectively operate the equipment (see RMC for further details). All RMCs should be equipped with their own set of calibration equipment in order to allow for regional calibration activities. This also applies for a sufficient number of circulation devices in each RMC for routine calibrations (see Appendix 2.3 for a detailed list of calibration equipment).

**Data communication and transmission:**

In some regions, 4G connectivity is prevalent, requiring devices to be adapted accordingly. However, in other areas, reliable statements are not possible at present because the data is currently not transmitted via the mobile network, often due to faulty devices such as Modems. The data is collected using various techniques, including manual or semi-automated methods, and transmitted via various communication channels to ASECNA, where it is entered into the GTS. Therefore, it is necessary to check the network connectivity at these sites in advance to ensure seamless transmission and fulfil GBON/SOFF requirements.

So far only a small proportion of the automated stations are working as expected due to hardware-related failures such as defective modems, broken network cables and defective sensors, as well as numerous software-related difficulties in the transmission processes. Historical dataset storage poses a challenge as not all data is available in digital form yet. In general, numerous interactions are involved in data storage, increasing the risk of human error in databases.

DGM is currently collaborating with TAHMO to enhance the internal data flow of DGM, improve their technical capabilities to manage the transmission, storage, and backup of their meteorological data more effectively, and integrate AWS to the system. The process of digitization of the data has started and is currently in progress with the integration of the data into Climsoft by the Hydrometeorological

[32] Projet d'Amélioration des Capacités d'Adaptation et de Résilience des Communes Rurales face aux Changements Climatiques

Database and Archives Department SBDAH (Service de la Base des Données et des Archives Hydrométéorologiques).
However, there is not yet an adequate backup process in place. To date, only manual backups are performed on a second computer at a different physical location (for more information see Chapter 3.2 and 3.3).

**Network design**

When setting up a synchronized monitoring network, it is of crucial importance to consider the factor of time. Bearing in mind the construction work, transport, logistical challenges, along with the commissioning of the technical components, we recommend a 24-36 month implementation period for eleven synoptic surface stations, one UA station and four RMCs (DGM Headquarters in Antananarivo counts as fifth RMC). In addition, all relevant import and tax regulations, duties and fees must be considered by the implementing entity when finalizing the procurement list.

In general, it is recommended to use a regional strategy for the implementation of the network expansion, to take advantage of geographical benefits. Figure 3 displays a map of the proposed network design. The recommended sites for improving existing synop stations are indicated by the dark blue points. Six stations, namely Mahanoro, Farafangana, Antsohihy, Ranohira, Toliara, and Morombe, will need to be renewed to AWS. Besalampy, Sambava, and Maevatanàna require only construction works, wind tower erections, or solar panel replacements. Please refer to Table 5 for more detailed information. The light blue points represent suggested sites for two new synop stations (Arivonimamo, Ambatondrazaka. The pink triangle indicates the location of two existing UA stations, and the blue triangle presents the suggested site for a new UA station in the north of Madagascar. The two already existing UA stations are operated by ASECNA and do not need any further support from SOFF. The new UA station will be operated by DGM and provided by SOFF. The green pins demonstrate synop stations that are already GBON compliant and are operated by ASECNA. The red star symbol indicates the suggested locations for Regional Maintenance Centers (RMC), while the black star represents the Headquarters in Antananarivo.

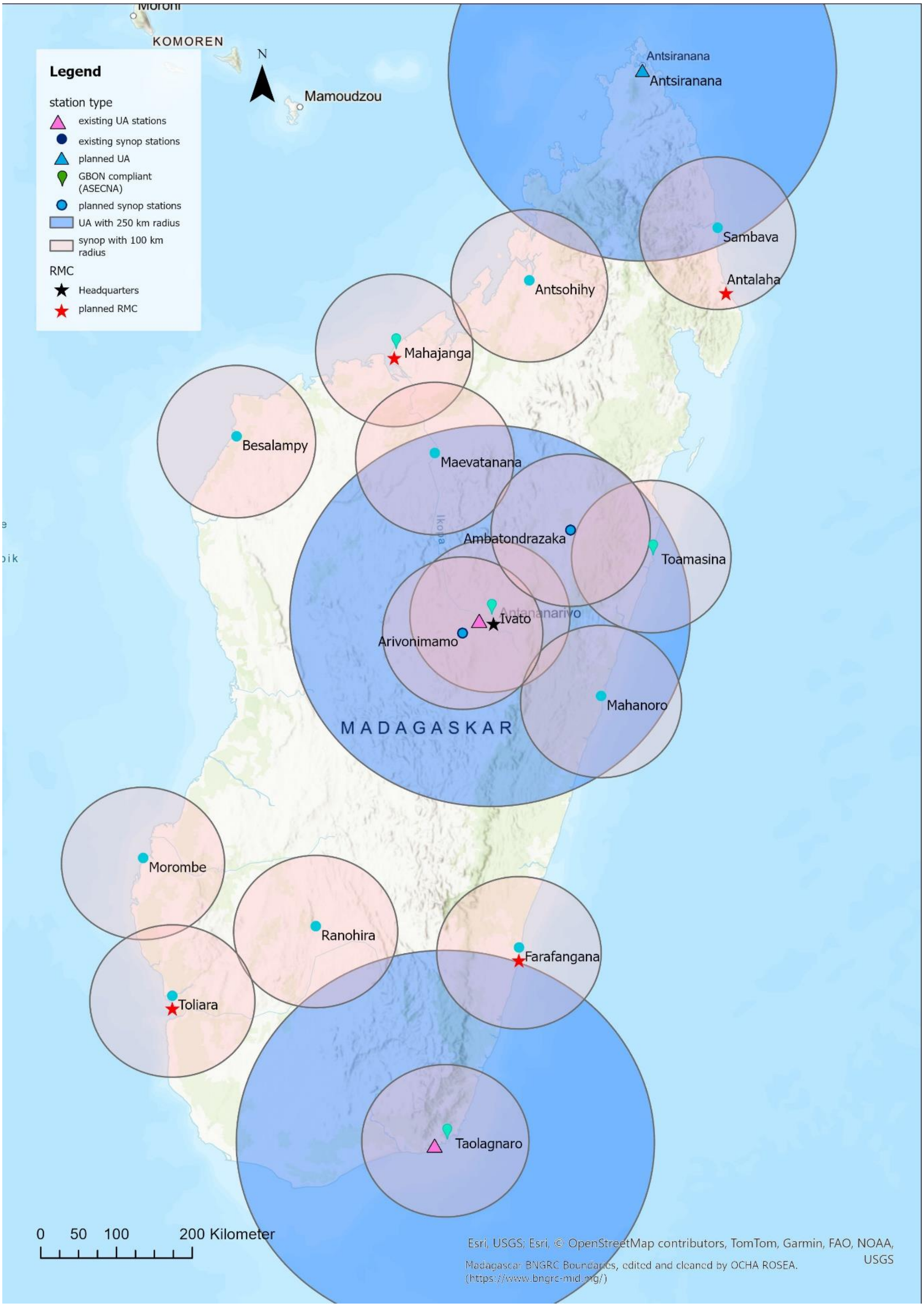


**Figure 3:** Map of planned observation network Madagascar; circles cover a 100km and 250 km radius around the stations (red: synop; blue: UA) (source: own compilation with ArcGis Pro)

As part of the network expansion, it is necessary to develop maintenance and cleaning plans and cover the corresponding training requirements. These tasks can be divided into different levels of complexity. Simpler tasks, such as lawn mowing and emptying/cleaning the rain gauge, can be carried out by less well-trained staff or people from the surrounding region. This training can be carried out internally by DGM employees. The plans and training should be implemented as soon as the stations are installed. Training sessions can be grouped regionally in the respective RMCs.

For more complex maintenance tasks, training sessions should be conducted for designated staff from the DGM's headquarters and RMCs to familiarize them with the (dis)assembling of stations, to enhance their ability to understand the technical components and functions of the various instruments. Consequently, travel allowances, including transportation and hotel stays must be considered in the budget. Additionally, incorporating explanatory videos would be advantageous, allowing for training sessions at the RMCs throughout the year and enabling staff to remain informed of any new developments (see chapter 4.2. Design capacity development activities for technical staff, for detailed training needs assessment).

Continued collaboration with TAHMO and GIZ is recommended for the design and delivery of training courses and the development and provision of training materials such as learning videos and illustrated manuals.

**Implementation Plan**

As mentioned above, the implementation phase (including capacity development described in Chapter 4) is spread over a period of two to three years. The most implementation activities should take place during the dry months (May-October) of the year, as otherwise roads are impassable, construction processes (including drying) can get delayed or impossible, and overall safety is compromised. Due to the size of the country and the partially poor road network, it makes sense to regionally cluster the implementation missions to make use of time and cost resources.

Therefore, a modular implementation strategy is recommended. This involves two teams, each consisting of three technicians and one driver, completing individual installation missions lasting from one week to one month. Ideally, an engineer responsible for the installed stations should attend at least one site installation. After completing a mission and taking a break of several days to weeks, the next mission can be started. This approach allows for better planning of missions based on weather conditions and other external factors. It allows for some flexibility and adaptability in case of unplanned events that may affect the original plan (e.g. delivery delays, illness, weather events, civil works delays, etc.). The installation activities mainly consist of:

- pouring a foundation (incl. 5 drying days); (except from Besalampy, where the foundation is still in good condition);
- deconstruction of old fragile wind masts and erecting of new wind towers [33] (hot-dip galvanized). As wind towers are more stable than simple masts in the event of severe storms or cyclones, the usage of wind towers is recommended. For its installation, tools for the North alignment of wind sensors are required. GPS-based compasses should be preferred since magnetic compasses will be misaligned in the vicinity of large metal structures like the wind towers;
- Wind towers close to an airport (Arivonimamo, Ambatondrazaka) need to be equipped with a red obstruction light (solar powered) and any further requirements concerning frangibility of the tower/fences have to be met;

[33] Based on the WMO Deliverable 6.1 - GBON Tender Specifications for AWS (2022), a lightning protection system (LPS) is essential. For example, Vaisala offers more information on LPS (Vaisala 2021): Safety • DKL201 and DKL202 Installation Guide • Reader • Produkt-Dokumentationsportal (vaisala.com)

- installation of an LPS, including surge protection for all electrical equipment of the AWS;
- installation of new AWS or replacement of defect sensors, including solar panels;
- fencing the area (hot-dip galvanized or plastic coated).

In order to carry out the installation process described below, at least one additional four-wheel drive vehicle must be available. In addition, all equipment and tools must be delivered and available before the mission (e.g. AWS, wind towers, fences, etc.) and civil works must be organized in time.

Table 5 provides an overview of required activities for each station. Next to the station site, the column provides the suggested sequence order to follow. The same color indicates the same team conducting the missions (blue = team 1; green= team 2). The same number but different colors, implies that the two missions are conducted in parallel. The last column estimates the expected time for each mission. As previously suggested, it is recommended to schedule extended breaks of several days to weeks between missions of the same team. Each color block represents a mission that can be adapted to external factors and carried out independently of the other team's mission (other color). Therefore, the implementation schedule of each mission can be adjusted accordingly. Checked cells imply the need for replacement of corresponding sensors/ facilities. The asterisk indicates that the site is located near the coast and is therefore susceptible to salt water exposure, which can lead to premature corrosion of the wind towers. To address this issue, it is recommended that hot-dip galvanized wind towers and fences are selected especially at those sites.

Appendix 2.1 presents a proposed timeline of key activities required to achieve GBON compliance by October 2027. The timeline is intended to provide guidance and indicates when the relevant activities should be completed rather than the exact timeframe in which they should be carried out. This is in line with the proposed modular system to allow for flexibility and adaptability without losing track of the necessary steps.

**Table 5:** AWS implementation overview

| Station site | Sequence of installation | T | H | Wind speed | Wind direction | SLP | P | Tower | Foundation | LPS | Solar panel | Fence | Network (3/4G) | Modem | Server | Sim Card | Logger | AWS | Days of installation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arivonimamo (new) (airport) | 1 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 12 |
| Ambatondrazaka (new) (airport) | 2 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 26 |
| Mahanoro | | x | x | x | x | x | x | x* | x | x | x | x | x | x | x | x | x | x | |
| Farafangana | 3 | x | x | x | x | x | x | x* | x | x | x | x | x | x | x | x | x | x | 19 |
| Antsohihy | 4 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 30 |
| Sambava | | | | | | | | x* | x | x | | x | | | | | | | |
| Ranohira | 4 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | 37 |
| Toliara | | x | x | x | x | x | x | x* | x | x | x | x | x | x | x | x | x | x | |
| Morombe | | x | x | x | x | x | x | x* | x | x | x | x | x | x | x | x | x | x | |
| Maevatanàna, Betsiboka | 5 | | | | | | | x | x | x | | | | | | | | | 27 |
| Besalampy | | | | | | | | | | x | x | x | | | | | | | |

Inspection and maintenance of the AWS need to be conducted regularly on a fixed scheduled and assigned responsibilities. It should be aligned on the WMO Guide "WMO-No. 8: Guide to Instruments and Methods of Observation Volume I –Measurement of Meteorological Variables". It is necessary to plan for a budget that will allow both simple and more complex maintenance work to be carried out at regular intervals. In particular, transport/travelling costs must be considered.

The UA station building process should be initiated with the beginning of the implementation phase and be conducted as a parallel process to the AWS installation. Site training sessions of 2 to 3 days should be covered by the installation site services of the manufacturer. For more details on UA station requirements see the following paragraph on **Upper-air station installation**

The same applies for setting up the RMC. Ideally the RMCs are set up at before or at the same time as the stations in their surrounding are installed, as installation and maintenance trainings should be held in the corresponding RMC. Therefore, we suggest the following sequence order (see Table 6):

**Table 6:** RMC implementation plan

| **Sequence order** | **RMC** | **Construction activities required** | **AWS covered** |
|---|---|---|---|
| 1 | Antananarivo | AC repairment;<br>Equipment | Arivonimamo, Ambatondrazaka, Mahanoro |
| 2 | Farafangana | new 4 room building & garage;<br>Equipment | Farafangana,<br>Ranohira |
| 3 | Toliara | Refurbishment of the existing building (repairs and painting);<br>Equipment | Morombe, Toliara, Ranohira |
| 4 | Antalaha | Refurbishment of the existing building (repairs and painting);<br>Equipment | Sambava, Antsiranana (UA) |
| 5 | Mahajanga | Refurbishment of the existing building (repairs and painting)<br>Building garage<br>Equipment | Besalampy, Maevatanana, Antsohihy |

See Appendix 2.2 for a more detailed list of equipment and resources required in each RMC.

**Surface station installation**

Three out of eleven stations only need some minor technical repairs (e.g. replacing of solar panel in Besalampy, automatization of data transmission, wind tower replacement). In these cases, the existing AWSs will be repaired using corresponding spare parts.

For the remaining eight stations to be replaced by AWS or to be newly installed, it is recommended to use the same manufacturer for all of them, and equip each RMC with all essential spare parts and at least one extra sensor of each type. This will allow for timely repairs of any faulty devices and for the usage of circulation sensors for routine calibrations. Furthermore, it is suggested to work with a manufacturer the DGM is already familiar with the handling, allowing to build on existing experience. For all AWS, an LPS as well a surge protection for all electrical equipment of the AWS needs to be installed.

Air temperature, relative humidity, atmospheric pressure, precipitation amount/intensity, horizontal wind direction and horizontal wind speed are the minimum variables that must be measured to be GBON compliant. Sensors should be selected based on their calibration and maintenance capabilities.

The new sensors/AWS must comply with the WMO Deliverable 6.1. – GBON Tender Specifications for AWS (WMO 2022) but also feature the following attributes:

- The power supply must be provided by solar panels charging an adequate 12 Volt battery. To reduce the risk of theft, it is highly advisable to utilize as few and as small panels as possible, ideally not more than one or two panels with a maximum peak power of less than 100 Watt each. Accordingly, the AWS, including the sensors, must be selected to operate with this limited power supply. Since temperatures below freezing are not to be expected for the stations within the scope of this document, heating is not required. If a sensor should have integrated heaters, there must be an option to deactivate them in order to preserve electrical power.
- The data logger must be able to perform in low power mode, extreme conditions and in remote environments.

  As SOFF encourages the future expansion of the observation network beyond the minimum setup necessary for GBON compliance, the number and variety of logger input channels should not be limited to the ones needed for the basic parameters listed above. To facilitate future additions to the AWS by DGM (e.g. soil temperature, soil moisture or solar radiation sensors) and also possible exchanges of the initial sensors, the logger should offer several analog and digital channels, e.g. 4 to 20 mA, 0 to 20 mA, pulse counting, RS-232, RS-485, RS-422, SDI-12, $I^2C$.

  In addition, the following technical specifications should be covered:

  - state-of-the-art ADC (24-bit) to preserve analog data quality during digitization
  - accurate real-time clock, ideally with automatic correction via GPS
  - local data storage capacity (e.g. microSD) to store station data for at least 30 days

- Automatic data transmission: The AWS has to be equipped with a modem capable of regular and automatic data transmissions via local 3G/4G networks at least once per hour.
- For ease of maintenance and for longer calibration intervals as compared to mechanical instruments an ultrasonic anemometer would be favorable. However, this sensor has to be selected with special regard to its power consumption.
- External display to read measurements directly on the station (without opening the terminal box)
- The use of a static pressure head to reduce the effect of wind on the atmospheric pressure measurements is recommended.

**Upper-air station installation**

The process of installing a UA station varies significantly from that of a synoptic surface station. Therefore, the table only indicates the installation without further details. However, the following section provides a little more detailed description of the measures required. To gain GBON compliance two launches a day are required. For Madagascar, a manual launching UA-system is suggested.

A UA system typically comprises the following components for launching radiosondes (Grimes et al. 2022):

- Radiosonde, an instrument intended to be carried by a balloon through the atmosphere, equipped with devices to measure meteorological variables (pressure, temperature and

humidity) and provided with a radio transmitter for sending this information to the observing station (WMO 2021a). The transmission capacity usually lies at 400 megahertz (MHz) (maximum power: 250 milliwatts or mW) or 1,680 MHz (maximum power: 330 mW). It is crucial to adhere to local regulations.
(Currently, ASECNA operates two UA systems in Madagascar. They use the DFM-17 radiosonde model by *GRAW Radiosondes GmbH & Co. KG);*
- Weather balloon filled with hydrogen to lift and carry the radiosonde;
- Parachute, to avoid uncontrolled radiosonde descent; in addition, the usage of descent data becomes an option if the speed of fall is reduced with a parachute
- Cord to suspend the radiosonde far enough below the balloon to be unaffected by the heated or cooled air flowing over the balloon;
- GPS unit for location tracking and wind speed and direction calculation.

For additional information on environmentally friendly aspects of UA systems, please refer to 3.4. Environmental and sustainability considerations.

In addition, UA systems require a ground station that includes the launch system and associated equipment, as well as receiver units (WMO 2021a):

The launch system consists of:

- Hydrogen generator with a $H_2$ production of 5 $Nm^3/h$ for an average of 2 launches per day and 350 g balloons.
- Hydrogen storage vessel
- Balloon inflation device
- Inflating room (see WMO Guide-NO.8 Vol III, chapter 8 (WMO 2021b) for more information on accurate balloon inflation and launching)
- ATEX[34] compliant building[35] to shelter the hydrogen generator, the hydrogen storage vessel and the inflating room and the electrical room (see Appendix 2.5)

Furthermore, in order to be able to receive, store and process data obtained from the radiosonde, a work station is required as well as a receiver unit. The latter can either be an integrated system or a modular system consisting of:

- Different antennas and radio receiver to receive the radiosonde signals;
- Equipment to decode the radiosonde signals and convert the signals to meteorological units (incl. Software);
- Equipment to present the meteorological measurements to the operator for real-time quality checks and so that the necessary messages can be transmitted to the users as required (incl. Software).
- Uninterruptible power supply (UPS)

### 3.2. Design of the ICT infrastructure and services

A key component of SOFF is not only to improve data collection, but also to improve the international exchange of data. Only through the availability of timely and high-quality data can forecasts and early

[34] Risk of explosive atmospheres | EUR-Lex (europa.eu)
[35] SAGIM is also offering a solution based on a maritime container preconfigured at their premises. In this case, all $H_2$ equipment are installed within the container. Alternatively, a local construction company can be commissioned to build the premises according to the specific requirements.

warning systems be improved and made available to reduce the negative impacts of weather and climate events. ICT infrastructure is therefore essential to ensure the timeliness of data and increase the amount of effectively shared global data.

At the moment, data from DGM surface stations is currently being ingested into Climsoft, but there is no working link between Climsoft and the GTS yet. Data from manual stations is transferred to ASECNA via the TRANSMET server and then to GTS through the MESSIR server. Manual station data is currently ingested into CLIMSOFT using an app by weather observers. A first round of data quality control is conducted when transmitting data to ASECNA. When data is ingested into CLIMSOFT, automated thresholds allow for a second round of data quality control. An additional ticket manager is currently being trained to operate QC. A third quality control takes place when data is ingested into the GTS.

Figure 4 gives a simplified overview of the data flow process in place. A more detailed version can be found in Appendix 2.4.

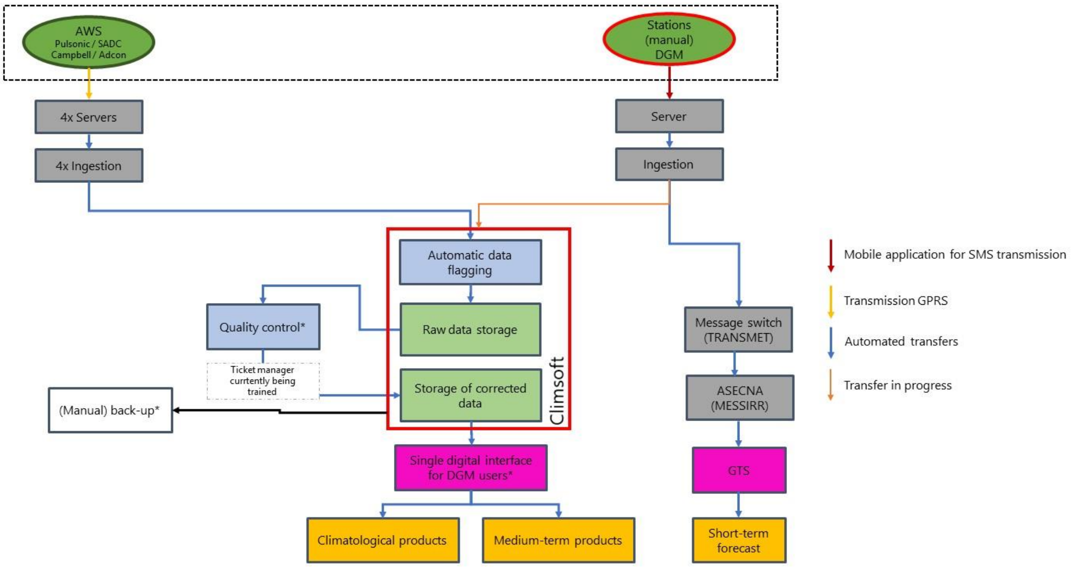


**Figure 4: Data flow (source: DGM, adjusted on discussions 2024)**

Legend:

**AWS**: automatic stations which are managed by DGM and for which also the data goes directly to DGM.

**Stations manual**: manual stations which in the future will be using a mobile app and transmit their data over SMS towards an SMS gateway connected to a server located at DGM.

* follow-up sessions planned by TAHMO

To ensure resilience and continuity of the full data processing chain, a number of actions are required, that are comprised in this report. Briefly summarized, the following aspects are of particular importance:

**Data acquisition** requires working instruments and sensors (outlined in Module 3.1 in the section on surface station installation), achieved by:

- Routine cleaning, preventive and corrective maintenance

- Regular maintenance, sensor testing and calibration activities
- Available spare parts and tools for quick repairments
- For real time data observation options, external display to read measurements directly on the station (without opening the terminal box)
- Data logger with local data storage capacity (e.g. microSD) to store station data for at least 30 days

To ensure resilience and continuity in **data transmission** processes, a working linkage between Climsoft and the GTS/WIS is required to ensure an uninterrupted data processing chain. The link between Climsoft and WIS 2.0 can be set up by TAHMO and staff trained accordingly. However, before this can be implemented, a formal agreement on data sharing needs to be reached between AECNA and DGM. The migration from GTS to WIS 2.0 is planned to be completed by 2030.

Furthermore, the following aspects are needed:

- Back-up system in place (see Module 3.3)
- Power backup through generators and UPS
- Equipped server rooms (Servers, hard drives, AC, etc.)
- Continued capacity building in data transmission and data control mechanisms (Climsoft, RCLIMDEX and CLIMATOL)

For all aspects mentioned above, required training courses need to be provided to suitable employees, to achieve capacity building throughout the value chain (see Module 4.2).

DGM staff have not yet received OSCAR/Surface training, and a national WIGOS implementation plan has not been adopted.

### 3.3. Design the data management system

Data storage and security, availability and retrieval are critical to many downstream processes and are therefore of paramount importance to the NMHS, but also require good management. A good solution is the use of a Climate Data Management System (CDMS), an integrated computer-based system that facilitates the effective archiving, management, analysis, delivery and use of a wide range of integrated climate data. For Madagascar, short-term data, such as observational data, is currently stored and archived using a MySQL database within Climsoft (open source CDMS). Historical data from manned weather stations is currently being imported into the system. Climsoft also provides additional functions such as access and easy retrieval of data via an intranet, retrieval of maps and graphs of weather and/or climate variables, and data export functions, which allows for data processing and product creation. Climsoft further detects flagged data automatically through set thresholds. Quality control of historic data is currently applied through the softwares RCLIMDEX and CLIMATOL. The staff in charge highlighted the need of further capacity building on this topic.

As mentioned before, there is no sufficient back-up system of the data in place yet. Currently the database is kept on the Climsoft server, and is only manually backed-up, by copying the database in csv format onto a second computer. However, this process is not being performed weekly. Additionally, there is no RAID system in place to prevent data loss in the event of a single hard drive failure within the Climsoft server. RAID combines multiple physical drive components into one or more logical units to provide data redundancy while avoiding the loss of important information.

Since country regulations do not allow for cloud-based solutions, as there is no service provider available in Madagascar and data are not allowed to be stored outside of the country borders, we recommend setting up an automatic back-up system between two servers allowing for frequent mirroring of the data as well as geo redundant storage, requiring:

- Extra server (rack/tower)
- UPS
- 5 hard drives (5 TB each, for RAID systems on both servers)

All hardware needs to be suitable for 24/7 operations, possibly at high ambient temperatures (in case of AC failure) and frequent read/write access.

For future data delivery, it is recommended that data should not be sent directly from the station to the WIS 2.0. Since Climsoft already acts as a data control mechanism, the national CDMS should remain interposed to allow for more data control.

Another aspect that is urgently needed in the future is an extended and improved metadata management, necessary to ensure sustainable and seamless information flow and processing. Therefore, it is very important that the installment and maintenance of the planned observation networks is accompanied by an effective and improved meta data management system, as so far not enough variables have been ingested or some aspects have not been relevant so far (e.g. calibration).

The WMO describes two complementary types of metadata that are required (WMO-No. 1192; 2019 edition). Discovery metadata that facilitates the discovery and retrieval of data and helps to find relevant resources more quickly. They contain elements that make it easy to understand when and by which processes the data was or can be accessed.

Descriptive metadata on the other hand provide information about the content and the context of the data, which is essential for further usage and interpretation of the data by users.

The WIGOS Metadata Standards document contains ten categories for descriptive metadata that are considered relevant to facilitate documentation and interpretation. This document can be used as a guide for setting up the new metadata management system.

As a next step, a comprehensive exchange between peer advisors and NMHSs in the investment phase is planned to establish a structured metadata management system. In particular, examples and experiences regarding data structure, databases, station files and inventory, calibration notes, etc. will be discussed, and how these can be adapted to the needs of the NMHS and to what extent they can be implemented. In addition to the identification number, geographical location and station characteristics, it is suggested that the station data be supplemented by photos of the site in all directions and possibly detailed photos of the sensors. Ideally, these photos should be taken at least once a year, e.g. before and after maintenance. The goal is to create a comprehensive and meaningful meta-database of all GBON stations (and beyond).

In addition, the data in Climsoft should also be provided with sufficient discovery metadata to allow quick and easy tracking of processes and to ensure transparency. Ideally, there will be a link between the discovery and descriptive metadata.

### 3.4. Environmental and sustainability considerations

The implementation of RMCs can decrease travel volume, resulting in resource and emission savings. Wherever possible, the advantages of bulk purchasing should be exploited with regional projects (e.g. Hydromet IOC).

Proper handling and repair of the stations can extend the lifespan of the equipment. It is crucial to have well-trained personnel and regional exchange of experience to achieve this. Data from radiosondes can be retrieved and used by multiple NMHSs if coordinated. This maximizes the benefits.

Research is currently being conducted into more environmentally friendly materials for UA stations. One option being considered is the use of blue weather balloons, which are less likely to be accidentally ingested by marine animals. Vaisala is currently piloting more environmentally friendly disposables, which are currently used in Madagascar and various types of cotton string are being tested.

The main changes are:

- Elimination of the white plastic cabinet
- Reduction of the wooden core
- Replacement of the metal screw with a hole in the wooden core
- Replacement of the polyamide string with cotton
- Small latex balloon used for decreasing unwinding speed made from biodegradable material

Furthermore, SAGIM is now offering more ecofriendly hydrogen generators, as no more KOH/Potassium is used.

Additional information regarding options for environmentally friendly radiosondes are provided by the WMO Guide NO.8 (WMO 2021) in the Appendix 12.C., and should be acknowledged in the procurement processes. Some of the main aspects listed in this section are:

- The usage of biodegradable plastics where possible
- Reducing the size/ weight of radiosonde and balloon
- Switching to biodegradable cordage like cotton twine, or polypropylene without UV protection, to reduce entanglement risk to wildlife and allow a more rapid release of radiosonde payloads caught in trees or other structures.
- The usage of natural rubber latex balloons instead of synthetic ones
- The usage of lithium batteries for radiosondes as they present lower environmental impact than others
- The collection and proper disposal of all parts (radiosonde, balloon, cord)

Buying in bulk can decrease the necessity for excessive packaging. The RMC offers a safe storage area for larger shipments, decreasing the frequency of smaller ones. In addition, efficient journey planning is recommended to avoid unnecessary trips, e.g. maintenance trips.

It is further advisable to prioritize local or regional products and producers when delivering resources to the island to reduce resource intensity. Defective devices should be repaired or, where not feasible, used as spare parts for agrometeorological stations. Expertise must also be made available to ensure that the equipment can be repaired and used for a longer period of time, thereby ensuring the sustainable use of resources.

In Madagascar, the entire observation network is powered by solar energy, making efficient use of the country's renewable energy source.

# Module 4. GBON Human Capacity Development Modul

### 4.1. Assessment of human capacity gaps

As of November 2023, DGM employs 224 people, 38% of whom are women, with 11 out of 33 leadership positions held by women. 46.9% of the staff work in the regional offices, the rest in the headquarters in Antananarivo. Only 13% of the staff hold a university degree (Bachelor's or higher), while 22% have completed high school (baccalaureate degree). Three people are holding a PhD (of which two are women) and four further employees are currently enrolled as PhD students. Further 20% hold a Meteorological Engineering Diploma. The majority of employees are aged between 31 and 59 years. The distribution of employees by profession and degree is shown in the following tables (see **Table 7**). The Technical Assistance category is further subdivided into subcategories. Therefore, only the numbers in bold are included in the calculation of the total.

**Table 7:** Distribution of employees by profession/ main field of work (source: DGM)

| **Main Field of Work** | **Central** | **Regional (23 Regions)** | **Sum** |
|---|---|---|---|
| **Accounting** | **5** | **3** | 8 |
| **Administration** | **25** | **13** | 38 |
| **Applied Meteorology** | **3** | | 3 |
| **Archivist** | **3** | | 3 |
| **Communication** | **1** | | 1 |
| **Forecaster** | **4** | | 4 |
| **Director Generale** | **1** | | 1 |
| **Graphic designer** | **1** | | 1 |
| **Hydrology** | **4** | | 4 |
| **Hydrological Station Manager** | **0** | **3** | 3 |
| **Hygienic, Safety and Environment** | **16** | **13** | 29 |
| **IT-Services** | **6** | **1** | 7 |
| **Legislation** | **2** | | 2 |
| **Librarian** | **2** | | 2 |
| **Meteorology** | **10** | **20** | 30 |
| **Planning Officer** | **1** | | 1 |
| **Research** | **7** | | 7 |
| **Technical Assistance** | **19** | **3** | **22** |
| IT-Technician | 1 | | 1 |
| Hydrological Technician | 1 | | 1 |
| Meteorological Technician | 2 | | 2 |
| Others<br>(B.Sc.; FT; Administrative Assistant, Management) | 15 | | 15 |
| **Technical Maintenance** | **9** | **3** | **12** |
| **Weather Station Manager** | | **20** | **20** |
| **Weather Station Observer** | | **26** | **26** |
| | | | |
| **Sum** | **119** | **105** | **224** |

**Table 8:** Overview of employees' qualifications/ degrees (source DGM)

| Degrees | Female | Male | Sum |
|---|---|---|---|
| **Baccalaureate Degree** | 25 | 25 | 50 (21.9%) |
| **Bachelor** | 9 | 8 | 17 (7.6%) |
| **Master** | 4 | 5 | 9 (4%) |
| **PhD** | 2 | 1 | 3 (1.3%) |
| **Meteorological Engineering Diploma** | 9 | 36 | 45 (20.1%) |
| **Meteorological Technician** | 2 | 1 | 3 (1.3%) |
| **IT-Technician** | | 3 | 3 (1.3%) |
| **IT-Engineer** | | 1 | 1 (0.45%) |
| **Hydrological Technician** | | 1 | 1 (0.45%) |
| **Field Training Only** | 21 | 55 | 76 (33.9%) |
| **Administrative Adjoint Diploma** | 5 | 3 | 8 (3.6%) |
| **Administrative Assistant Diploma** | 8 | 3 | 11 (4.9%) |

The University of Antananarivo hosts one of the WMO Regional Professional Training Centres in Meteorology for French-speaking members, which offers licences (Bachelor) and master's degrees in engineering and metrology at the Antananarivo Polytechnic School ESPA. This results in well-trained graduates; for example, all engineers employed by DGM are also graduates of the WMO Regional Professional Training Centre. ESPA-Graduates are given the opportunity to conduct unpaid internships at DGM and write their thesis under DGM's supervision, with some of its staff also teaching at the university.
However, DGM is experiencing a shortage of 200 employees. The cause of this shortfall is not due to a scarcity of university graduates, but rather the implementation of a recruitment freeze in 1990 stemming from government budget constraints. As a result, the employment of university graduates has been restricted. To combat this, DGM has initiated in-field training for its employees to ensure that they can operate as efficiently as possible. At the same time, efforts are being made to deploy graduates to other Indian Ocean Commission (IOC) countries with limited skilled personnel to provide them with a sustainable source of income. Therefore, it is imperative to increase the number of new recruitments or budget items in the state budget.
To ensure effective use of the upgraded observation network, capacity building for employees must be prioritized. The following section outlines necessary training courses to optimally prepare employees for their future tasks and support them in carrying out their activities.

### 4.2. Design capacity development activities for technical staff

A detailed training plan is necessary to cover different areas and levels of expertise, from complex tasks to simple cleaning schedules. Training programs should be planned and executed in a manner that is specific to the target group and developed for each area of activity.

Table 9 gives an overview of the specific training needs that have been analyzed. Training on AWS installation and maintenance, as well as specific training related to UA station, should ideally be conducted promptly after station installation to prevent equipment from sitting idle or being used incorrectly. It is essential that the RMCs in the respective locations are already equipped so that appropriate training can take place there.

**Table 9**: Training on data quality assessment and control (QA/QC) needed.

| Field of Training | Specification | Number of People to be trained<br>Headquarters/ Regional Offices | Comment |
|---|---|---|---|
| **Weather monitoring and Forecasting** | Nowcasting & generation and interpretation of Satellite images and Products | 6/26 | 1 training at HQ<br>2 trainings in North/South |
| | Impact based Forecast and Warning | 50 | Representatives of stakeholders and Met office, Staged training (central & local) |
| | Local forecast | 6/26 | 1 training at HQ<br>2 trainings in regions (North/South) |
| | Marine forecast | 6/13 | 1 training at HQ<br>2 trainings in regions (East and West) |
| **Weather forecasting enabler** | Training course on developing operational tools: coding with Python, Fortran, R, Gmt (Generic Mapping Tool) | 18/26 | 1 training at HQ<br>2 trainings in regions (North/South) |
| **ICT and IT** | PUMA (Preparation for the Use of Meteosat in Africa) station maintenance, installation and configuration of EUMETSAT PUMA software, System installation and update[36] | 4 (HQ)/4 (RMC) | |
| | ODK (open-source mobile data collection platform) installation and configuration for SMS management, use and configuration of SMSEagle | 4 (HQ) | |
| | Virtualization and cloud computing, general principles of Docker installation and configuration | 6/26 | |
| Management of Observation Network<br>**AWS** | **Station installation and maintenance**<br>(preventive and corrective) (technicians and engineers); including safety training for wind tower climbing etc.<br>More details in Table 8 | 7/12 | Cooperation with manufacturers; e.g. Campbell Scientific Africa should be considered where Campbell stations are to be installed. Their services include providing fully functional and |

[36] More information on PUMA can be found here: [pdf_br_cop03_en.pdf (eumetsat.int)]

| | | | |
|---|---|---|---|
| | **Station Operationalization**<br>(Data logger configuration, data transmission) | 2/4 | easy-to-install GBON and SOFF compliant AWS, as well as support in capacity building. Additionally, factory training, installation services, field training, and ongoing support are provided.<br><br>TAHMO for setting up interface between Climsoft and WIS2/GTS |
| | **Field checks, hand helds**<br>Practical training on equipment for field check<br>(list of equipment t.b.c.) | 7/12 | Establish a quality mechanism including field checks for sensor testing (repetitive schedule, inventory list of sensor checks)<br>Establish a ToT approach for engineers to teach technicians to conduct field checks. |
| | **Calibration**<br>Training on calibration equipment<br>(list of equipment t.b.c) | 2/4 | Establish a quality mechanism for calibration equipment (repetitive schedule, inventory list of calibration equipment) |
| Management of Observation Network<br>**UA** | Station installation and maintenance | 1/3 | Hydrogen generator manufacturer |
| | Operation of UA (including security training, launching) | 1/3 | Hydrogen generator manufacturer |
| | Radio sonde operation (software package, etc.) | 1/3 | Sonde manufacturer |
| **Senior Management** | Strategic planning | 10/26 | |
| | Project development and Management | 10/26 | |
| | Leadership and team management | 10/26 | |
| **Database, Data management** | MySQL database | 2/0 | (e.g. TAHMO) |
| | Python programming | 2/0 | |
| | R programming | 2/0 | |
| | Archives digitalization | 2/0 | |
| | Automatic quality control (RCLIMDEX, CLIMATOL) | 2/0 | |
| | Linux | 2/0 | |
| | Application Program Interface (API) | 4/0 | |
| | Webmaster | 4/0 | |
| | Server administration | 4/0 | |

| | | | |
|---|---|---|---|
| **Network management** | Dynamic and static routing of MikroTik routers, port forwarding and setting up firewall systems | 4/0 | |

**Station installation and maintenance**

Training on installation, maintenance, operation, and use of AWS should be divided into different levels of complexity and adapted to the brands dominant in the respective regions and if possible conducted in cooperation with the AWS manufacturers.

Table 10 suggests four different types of trainings for technicians and users (number of trainees to be decided):

**Table 10:** Installation and maintenance training types

<table>
<tr><th>Installation</th><th>Maintenance</th><th>System Operation</th><th>Users</th></tr>
<tr><td>Technical background information on all system components</td><td rowspan="2">Trained to completely install and dismantle all System Components and to perform all maintenance activities</td><td rowspan="2">Training on all diagnostic tools available for the functional maintenance and system management tasks of the system and system components.</td><td rowspan="2">Training on all diagnostic tools available for operational use of the systems and system components</td></tr>
<tr><td>Essential information on the functionality and operation of the system components.</td></tr>
<tr><td>Training shall provide a practical part in which technicians will be trained to completely install and dismantle all System Components.</td><td rowspan="2">Training on all diagnostic tools and mechanical/software tools that are used to facilitate maintenance of the System Components and to monitor the operational status of the System and System Components</td><td rowspan="2">Parts of the configuration of the System for operational purposes shall be realized during and as an essential part of the System Operator Training</td><td></td></tr>
<tr><td>Training on all diagnostic tools available for all System Components</td><td></td></tr>
</table>

For simple tasks, a Training of Trainers (ToT) approach could be considered and carried out internally at the DGM. In addition, it is recommended to explore collaborations with local enterprises to design and develop target-group specific training materials, such as manuals, pictograms or easy-to-understand instructional videos (e.g. explaining cleaning and housekeeping tasks on an AWS plot), translated into the local language/dialect.

**Data transfer and WIS2**

It is critical that data is not only collected and processed at a high level, but also shared in a timely manner with other partners who rely on it for further forecasts and warnings. The World Meteorological Organization (WMO) is therefore continuing to work on faster, inexpensive and more practical data sharing solutions. The WMO Information System's latest version (WIS2) is designed to replace the previous GTS. Therefore, it will also become mandatory for SOFF countries.

Training on data transmission and WIS2 should be developed and delivered in coordination with ASECNA and TAHMO. TAHMO can provide support in the missing linkage between Climsoft and GTS, which will be replaced by WIS2.0. ASECNA is currently investigating the possibility of using the Free and Open Source (FOSS) reference implementation of a WMO WIS2 node, wis2box. The next step will be for DGM and ASECNA to agree on the data sharing process before the link between Climsoft and the GTS/wis2box can be arranged by TAHMO.

### 4.3. Design capacity development activities for senior management

As the observation network expands, so do the management responsibilities. Today good management does not only mean good skills in planning and organizing but managers are also required to function as coach and motivator, allowing their staff to develop, in order to build up human capital within the NMHS.

In order to manage the workload associated with the expanded observation network, we recommend the establishment of a management committee consisting of senior managers from headquarters and the RMCs who communicate regularly. In addition, the support of competent administration and office managers is required to oversee and complete the administrative tasks that arise. Therefore, capacity development activities for the first two years should cover the following basic aspects and should continuously being adapted to meet requirements and further adjusted over the following years.

Training topics for people management:

- Coaching and mentoring;
- Influencing, negotiating and managing conflict;
- Leading a team;
- Motivating a team;
- Managing time;
- Communicating effectively;
- Managing human resources.

Further more advanced senior management skills are:

- Leadership skills, including strategic thinking, decision-making and change management;
- Financial training, financial management and budgeting.;
- Project management training;
- Monitoring and Evaluation (M&E) through the definition of key performance indicators to assess effectiveness of the activities.;
- Strategic planning and regional networking;
- Leadership communication training;
- Technology and digital literacy, to leverage technologies as required.

The management's activities should be based on the strategic objectives and mission of the NMHS, in addition to the administration of the network itself. It is crucial to distribute knowledge and skills to prevent the loss of important functions in case of personnel changes, allowing others to take over.
The training approach and methodology must be realistic and pragmatic and therefore deal with real-life examples, based on a high-level gap analysis and also on the operational side of activities.

### 4.4. Gender and Civil Society Organizations considerations

Madagascar and its population are highly affected and vulnerable to extreme weather events, particularly cyclones, making it the African country at highest risk. The frequency and intensity of these events are increasing due to climate change. Over the past 20 years, Madagascar has experienced a

significant increase in natural disasters, including 35 cyclones, 8 floods, and 5 severe droughts. This has resulted in damages worth $1 billion and has had a major impact on food security, drinking water supply, irrigation, public health systems, environmental management, and overall quality of life. (USAID 2016)[37]
Therefore, it is crucial to decrease people's vulnerability to such events. Early warning systems are essential in facilitating the implementation of appropriate protective measures. This is why meteorological data collection is of utmost importance. To ensure that the information collected and processed, as well as the measures derived from it, reach the civilian population, suitable communication channels and forms are necessary.
Civil society organizations are currently playing a key role as a communication channel, not only to provide people with important information, but also to increase understanding and acceptance of the importance of the observation networks.

GIZ/PrAda is collaborating closely with the Agrometeorological Thematic Group (GTA)[38], led by the Regional Directorate of Agriculture and Livestock (DRAE)[39] and the Regional Meteorological Service (SRM)[40]. The GTA focuses on disseminating and interpreting agrometeorological information products in a format that is understandable for farmers, such as crop calendars and seasonal weather forecasts.
Civil society organizations play a crucial role in disseminating information products and supporting producers in interpreting agrometeorological information. They are particularly important at the district level and are well-positioned to reach the target groups on the ground, so they can support producers in reading and interpreting agrometeorological information products.
By gathering feedback from producers, they make a significant contribution to improving the platform, especially regarding the quality and quantity of agrometeorological information products that are disseminated and the channels used to disseminate information, in order to achieve wider coverage and reach more farmers. Continued close collaboration with the PrAda project is therefore aimed at continuing these efforts during the investment phase and expanding activities in this area.

In Madagascar, where poor infrastructure and remoteness severely limit mobility and accessibility, improved connectivity to the region is crucial. For this reason, the RMC can offer a significant advantage. It allows for faster communication with regional stakeholders in the event of a meteorological event and can also serve as a point of communication (faster response capability, serving as a post-event information point, short-term local information needs).

SOFF is further committed to strengthening gender equality in its activities and a SOFF Gender Action Plan has been launched. The focus of this plan is to ensure adequate gender representation in SOFF's constituent bodies and to promote women's empowerment in collaboration with SOFF peer advisors, SOFF implementing agencies, civil society organizations and beneficiary countries.[41]
Although DGM already has a relatively high percentage of female employees (38%), including leadership positions, gender balance needs to be given special attention, especially in the future employment strategy. Special attention on gender sensitivity will also be given in the design of the training programs as well as to the goal of achieving a minimum participation rate of 50% women in all training courses, where possible.

To create the best possible learning atmosphere, it is important to assess the composition of the training program beforehand, including gender and age divisions, so that questions can be raised freely and openly. It is also important to consider the presence of managers or hierarchical structures, as they can impact the learning environment. All of these issues will be taken into account in the implementation of the training and SOFF activities.

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[37] USAID (2016). Factsheet. CLIMATE CHANGE RISK PROFILE MADAGASCAR.
[38] Groupe thématique agrométéorologique
[39] Direction de l'agriculture et de l'élevage
[40] Service Regional de la Meteorologie
[41] See SOFF Action Report 2023, p. 23 (SOFF Action Report 2023 - Systematic Observations Financing Facility % (un-soff.org)

# Module 5. Risk Management Framework

**Table 11:** Risk Management Framework

| Risk | Description | Probability | Risk mitigation measures |
|---|---|---|---|
| **Contextual risks**<br><br>Risks related to conflicts, safety and political insecurity jeopardizing the delivery of the Implementing phase outputs | Delays in equipment delivery and civil works<br>**Risk level:** high<br>**Impact:** major | **Possible** | • Timely procurement (incl. buffer)<br>• Consideration of applicable import tax, customs etc.<br>• Anticipatory and flexible planning (see Table 5) |
| | Meteorological conditions (e.g. tropical cyclones) that affect the deployment activities by limiting accessibility to sites and constructions as needed<br>**Risk level:** very high (rainy season) / high (dry season)<br>**Impact:** major | **Very likely** in rainy season<br><br>**Possible** Dry season | • Deployment in dry season |
| | Accessibility of the selected locations to the installed infrastructure and their maintenance<br>**Risk level:** very high<br>**Impact:** major | Very likely | The site selection has been decided in accordance to close proximity to settlements and infrastructure. Reducing distances through RMCs, DGM carpooling and fuel budget. |
| **Institutional risks**<br><br>Risks related to the beneficiary country's institutions participation | Insufficient staff resources to manage and maintain the GBON assigned Network in line with the GBON operational requirements. (Observations and ICT)<br>**Risk level:** high<br>**Impact:** major | Likely | • Improving visibility and importance of the NMHS,<br>• Capacity development of the necessary positions,<br>• Personnel restructuring and recruitment |
| | NMHS staff that retire is not replaced due to recruitment freeze.<br>**Risk level:** high<br>**Impact:** major | Likely | • Continuous knowledge transfer to younger staff to replace the retired positions<br>• Insist on recruitment to replace retired staff |

| | | | |
|---|---|---|---|
| **Programmatic risks**<br><br>Risks related to country ownership | After the conclusion of the Investment phase, GBON data are not collected or shared or are shared of insufficient quality<br>**Risk level:** high<br>**Impact:** major | Possible | • High commitment and engagement,<br>• Monetary incentive for regular GBON data exchange,<br>• Proper capacity development,<br>• RMC approach |
| | SOFF-funded investments cause environmental or social impacts<br>**Risk level:** low<br>**Impact:** minor | Unlikely | Keep track of more environmentally friendly alternatives for UA materials (e.g. blue weather balloon, biodegradable cords, etc.) |
| | Vandalism or theft of the deployed Infrastructure<br>**Risk level:** high<br>**Impact:** major | Likely | • To ensure safety, install precautions such as fences and secure anchoring (special screws, spikes, enclosed system).<br>• Proximity to busy places<br>• Awareness campaign on the importance of stations. |
| | Countries cannot make optimal use of data, including accessing or using improved forecasts products from the Global Producing Centers throughout the hydromet value chain<br>**Risk level:** high<br>**Impact:** major | Possible | • Capacity development through appropriate and needs-based training programs;<br>• Adequate work stations<br>• Sufficient internet connection, bandwidth<br>• Electricity supply<br>• Knowledge exchange with other SOFF countries through platforms and forums. |

# Module 6. Transition to SOFF investment phase

The transition to the SOFF investment phase shall be based on the results and recommendations of the Readiness Phase and in particular this National Contribution Plan, which has been prepared in consultation with the beneficiary country and the Implementing Entity. Further detailed information will be provided to the IE by the Peer Advisor and the beneficiary country as required.

# Summary of GBON National Contribution Plan

*Provide summary of GBON National Contribution Plan by filling this table*

| Components | Recommended activities |
|---|---|
| **Module 2.**<br>GBON business model and institutional development | 1. Strengthening the cooperation between governmental bodies and agencies, and universities. |
| | 2. Strengthen and extend the collaboration with regional and sub-regional organizations. |
| | 3. Continue with the fully public business model with full ownership of newly set up GBON stations by NHMS |
| | 4. Consideration of establishing a cost recovery mechanism by NHMS |
| **Module 3.**<br>GBON infrastructure development | 1. Install 2 new AWS |
| | 2. Improve 9 sites with AWS |
| | 3. Install 1 UA |
| | 4. Set up 4 RMC in addition to the HQ (including spare part stock, maintenance workshop, car pool) |
| | 5. Set up WIS 2.0 data transmission |
| | 6. Set up calibration labs and field check procedures |
| **Module 4.**<br>GBON human capacity development | 1. Capacity development on station installation and maintenance |
| | 2. Capacity development on data processing, data transmission, data application, data management |
| | 3. Capacity development on management and leadership |
| | 4. Advocate for further recruitment (incl. gender consideration) |
| **Module 5.**<br>Risk Management | The SOFF Risk Management Framework should be seen as a dynamic instrument, evolving with new risks and mitigation measures. |
| **Module 6.**<br>Transition to SOFF investment phase | Implementation of the recommended action plan to reach and maintain GBON compliance as outlined in the GBON National Contribution Plan. Provide all relevant documents to the Implementing Entity to initiate the transition to the SOFF investment phase. |

# Appendixes

## Appendix 1: List of resources


BNGRC (2016). Stratégie Nationale de Gestion des Risques et des Catastrophes 2016-2030. *https://cdn.climatepolicyradar.org/navigator/MDG/2016/national-disaster-risk-management-strategy-2016-2030_3cd492f8f25e757bbf2f3448630cd4bc.pdf*

CREWS. South-West Indian Ocean Project Proposal. CREWS Project Presentation Note to the Steering Committee. *https://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocrews/s3fs-public/ckeditor/files/South-West_Indian_Ocean_-_CREWS_Proposal_3-final.pdf?OS7oFXrCT0Mp4_qGDppxuSFu3uCFReBB*

Grimes, D. R., Rogers, D. P., Schumann, A., & Day, B. F. (2022). Charting a Course for Sustainable Hydrological and Meteorological Observation Networks in Developing Countries.

ICAO Doc 9157. Aerodrome Design Manual, Part 4 - Visual Aids

ICAO Annex 14. Aerodromes - Volume I, Aerodrome Design and Operations

PNLCC (2021) Politique nationale de lutte contre les changements climatique revisee - republique de Madagascar. *https://cbit-madagascar.mg/wp-content/uploads/PNLCCRevisee_2021.pdf*

The World Bank. Regional Climate Resilience Program for Eastern and Southern Africa Project. *Development Projects: Regional Climate Resilience Program for Eastern and Southern Africa Project - P180171 (worldbank.org)*

USAID (2016). Factsheet. CLIMATE CHANGE RISK PROFILE MADAGASCAR. https://www.climatelinks.org/sites/default/files/asset/document/2016%20CRM%20Factsheet%20Madagascar_use%20this.pdf

Vaisala (2021). Installation Guide. Vaisala Lightning Protection Kits. DKL201 and DKL202. *https://docs.vaisala.com/r/M211785EN-D/en-US/GUID-48BC98AE-67EC-4709-87F9-4D3A8BBCDB53*.

WMO (2019). WIGOS Metadata Standard (WMO-No.1192). 2019 edition. *https://library.wmo.int/viewer/55626/download?file=1192_en.pdf&type=pdf&navigator=1.*

WMO (2021a). Guide to Instruments and Methods of Observation (WMO-NO8.). Volume I – Measurement of Meteorological Variables. World Meteorological Organization WMO. *https://library. wmo. int/index. php.*

WMO (2021b). Guide to Instruments and Methods of Observation (WMO-NO8.). Volume III – Observing Systems. *World Meteorological Organization WMO, URL https://library. wmo. int/index. php.*

WMO (2022). TT-GBON-4. Deliverable 6.1-GBON Tender Specifications for AWSs.

WMO. Madagascar. Details All Members - Public Information · Customer Self-Service (wmo.int)

# Appendix 2: Additional information sheets

**Appendix 2.1** Implementation plan 2025-2027

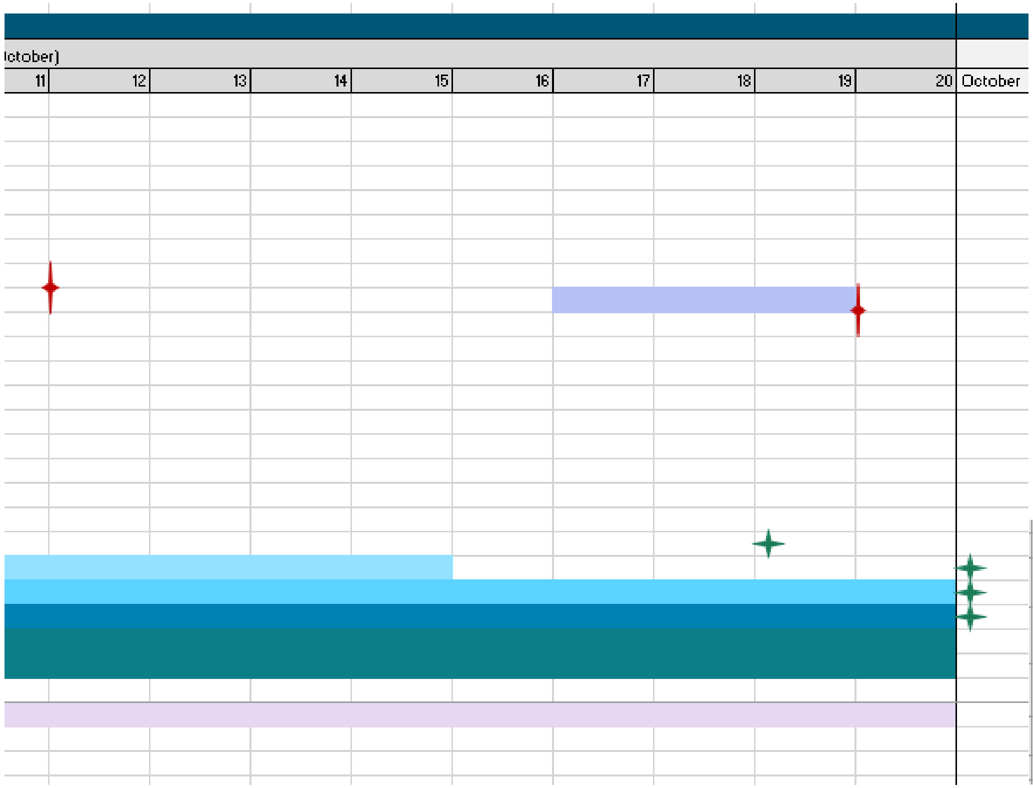
Rainy season 2025

| Implementation Plan | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | February-May 2025 | | | | | | | | | |
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| **Workpackages** | | **Activities** | **Comment** | | | | | | | | | | |
| | 1 | Delivery of Equipment | | | | | | | | | | | |
| | 2 | Organizing Civil work on sites | | | | | | | | | | | |
| **AWS Installation missions** | | | | | | | | | | | | | |
| | 1 | Arivonimamo | | | | | | | | | | | |
| | 3 | Ambatondrazaka<br>Mahanoro | | | | | | | | | | | |
| | 2 | Farafangana | | | | | | | | | | | |
| | 4 | Antsohihy<br>Sambava | | | | | | | | | | | |
| | 5 | Ranohira<br>Toliara<br>Morombe | | | | | | | | | | | |
| | 6 | Maevatanàna<br>Besalampy | | | | | | | | | | | |
| **RMC** | | | | | | | | | | | | | |
| Antananarivo | | Equipment | | | | | | | | | | | |
| Farafangana | | Construction of new building | | | | | | | | | | | |
| Toliara | | Refurbishing | | | | | | | | | | | |
| Antalaha | | Refurbishing | | | | | | | | | | | |
| Mahajanga | | Refurbishing<br>Building garage | | | | | | | | | | | |
| UA | | Building<br>Installation | | | | | | | | | | | |

## Dry period 2025

| Implementation Plan | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Dry Period 2025 (May-October) | | | | | | | | | | | |
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | |
| **Workpackages** | **Activities** | **Comment** | | | | | | | | | | | | |
| 1 | Delivery of Equipment | | | | | | | | | | | | | |
| 2 | Organizing Civil work on sites | | | | | | | | | | | | | |
| **AWS Installation** | | | | | | | | | | | | | | |
| 1 | Arivonimamo | | | | | | | | | | | | | |
| 3 | Ambatondrazaka | | | | | | | | | | | | | |
| | Mahanoro | | | | | | | | | | | | | |
| 2 | Farafangana | | | | | | | | | | | | | |
| 4 | Antsohihy | | | | | | | | | | | | | |
| | Sambava | | | | | | | | | | | | | |
| 5 | Ranohira | | | | | | | | | | | | | |
| | Toliara | | | | | | | | | | | | | |
| | Morombe | | | | | | | | | | | | | |
| 6 | Maevatanàna | | | | | | | | | | | | | |
| | Besalampy | | | | | | | | | | | | | |
| **RMC** | | | | | | | | | | | | | | |
| Antananarivo | Equipment | | | | | | | | | | | | | |
| Farafangana | Construction of new building | | | | | | | | | | | | | |
| Toliara | Refurbishing | | | | | | | | | | | | | |
| Antalaha | Refurbishing | | | | | | | | | | | | | |
| Mahajanga | Refurbishing | | | | | | | | | | | | | |
| | Building garage | | | | | | | | | | | | | |
| UA | Building | | | | | | | | | | | | | |
| | Installation | | | | | | | | | | | | | |

## Dry period 2025 (May-October)




| Milestones: | |
|---|---|
| | A cleaning plan has been developed, cleaning instructions have been carried out, and responsibilities have been assigned. |
| | RMC is operational |
| | UA is operational |
| | 11 AWS are operational and GBON compliant |

# Dry period 2026 (May–October)

| Implementation Plan | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Dry Period 2 | | | | | | | | | | |
| | | | | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| **Workpackages** | | **Activities** | **Comment** | | | | | | | | | | | | | | |
| | 1 | Delivery of Equipment | | | | | | | | | | | | | | | |
| | 2 | Organizing Civil work on sites | | | | | | | | | | | | | | | |
| **AVS Installation** | | | | | | | | | | | | | | | | | |
| | 1 | Arivonimamo | | | | | | | | | | | | | | | |
| | 3 | Ambatondrazaka<br>Mahanoro | | | | | | | | | | | | | | | |
| | 2 | Farafangana | | | | | | | | | | | | | | | |
| | 4 | Antsohihy<br>Sambava | | | | | | | | | | | | | | | |
| | 5 | Ranohira<br>Toliara<br>Morombe | | | | | | | | | | | | | | | |
| | 6 | Maevatanàna<br>Besalampy | | | | | | | | | | | | | | | |
| **RMC** | | | | | | | | | | | | | | | | | |
| Antananarivo | | Equipment | | | | | | | | | | | | | | | |
| Farafangana | | Construction of new building | | | | | | | | | | | | | | | |
| Toliara | | Refurbishing | | | | | | | | | | | | | | | |
| Antalaha | | Refurbishing | | | | | | | | | | | | | | | |
| Mahajanga | | Refurbishing<br>Building garage | | | | | | | | | | | | | | | |

| Dry Period 2026 (May-October) | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |

Dry period 2027 (May-Ocotber)

| Dry Period 2027 (May-October) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

| Milestones: | |
|---|---|
| | A cleaning plan has been developed, cleaning instructions have been carried out, and responsibilities have been assigned. |
| | RMC is operational |
| | UA is operational |
| | 11 AWS are operational and GBON compliant |

Trainings:

Dry period 2025 (May-October)

**Implementation Plan**

| Workpackages | Activities | Comment | 1 | 2 | 3 |
|---|---|---|---|---|---|
| **Trainings** | Concluded | | | | |
| AWS | station installation | engineer | | HQ | |
| | station maintenance | engineer/technicians | | | |
| | station operationalization | engineer/technicians | | | |
| | field checks (hand helds) | engineer/technicians | | | |
| | calibration | engineer/technicians | | | |
| | On-site training | engineer/technicians | | | |

| 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | Farafangana | | | |
| | | HQ | | | | Farafangana |
| | | HQ | | | | Farafangana |
| | | | | | | HQ |

## Rainy season 2025/2026

| Implementation Plan | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Rainy season 2025/2026 (October-May) | | | | | | |
| | | | 1 | 2 | 3 | October | November | December | January | Febraury | March | April |
| **Workpackages** | **Activities** | **Comment** | | | | | | | | | | |
| **Trainings** | Concluded | | | | | | | | | | | |
| AWS | station installation | engineer | | HQ | | | | | | | | |
| | station maintenance | engineer/technicians | | | | | | | | | | |
| | station operationalization | engineer/technicians | | | | | | | | | | |
| | field checks (hand helds) | engineer/technicians | | | | | | | | | | |
| | calibration | engineer/technicians | | | | | | | | | | HQ |
| UA | On site training | engineer/technicians | | | | | | | | | | |
| | Factory training (France) | engineer/technicians | | | | | | | | | | |
| Database, Data management | | IT technicians | | | | | | | | | | |
| Network Management | | IT technicians | | | | | | | | | | |
| ICT and IT | | IT technicians | | | | | | | | | | HQ |
| Senior Management | | t.b.c. | | | | | | | | | | RMC |
| Weather monitoring and Forecasting | Nowcasting & generation and interpretation of Satellite images and Products | t.b.c. | | | | | | | | | | |
| | Impact based Forecast and Warning (stakeholder event) | t.b.c. | | | | | | | | | | |
| | Local forecast | t.b.c. | | | | | | | | | | |
| | Marine forecast | t.b.c. | | | | | | | | | | |
| Weather forecasting enabler | Training course on developing operational tools: coding with python, fortran, R, gmt (generic mapping tool) | t.b.c. | | | | | | | | | | |
| Hydrological Forecasting | | t.b.c. | | | | | | | | | | |

## Dry period 2026 (May-October)

| | Dry Period 2026 (May-October) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| station installation | | Antalaha | Toliara | | | | | | | Mahajanga | | | | | | |
| station maintenance | | | | | | | | | Antalaha/ Toliara | | | | | | | Mahajanga |
| station operationalization | | | | | | | | | Antalaha/ Toliara | | | | | | | Mahajanga |
| field checks (hand helds) | | | | | | | | | Antalaha/ Toliara | | | | | | | Mahajanga |
| Nowcasting & generation and interpretation of Satellite images and Products | | | | | | | | | | | | | | | | HQ |
| Impact based Forecast and Warning (stakeholder event) | | | | | | | | | | | | | | | | HQ |
| Local forecast | | | | | | | | | | | | | | | | HQ |
| Marine forecast | | | | | | | | | | | | | | | | HQ |
| Training course on developing operational tools | | | | | | | | | | | | | | | | HQ |
| Hydrological Forecasting | | | | | | | | | | | | | | | | HQ |

## Rainy season 2026/2027

**Implementation Plan**

| Workpackages | Activities | Comment | Rainy season 2026/2027 (October-May) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | October | November | December | January | Febraury | March | April | 1 | 2 |
| **Trainings** | Concluded | | | | | | | | | | |
| AWS | station installation | engineer | | | | | | | | | |
| | station maintenance | engineer/technicians | | | | | | | | | |
| | station operationalization | engineer/technicians | | | | | | | | | |
| | field checks (hand helds) | engineer/technicians | | | | | | | | | |
| | calibration | engineer/technicians | | | | RMCs | | | | | |
| UA | On site training | engineer/technicians | | | | | | | | | |
| | Factory training (France) | engineer/technicians | | | | | | | | | |
| Database, Data management | | IT technicians | | | | | | | | | |
| Network Management | | IT technicians | | | | | | | RMC | | |
| ICT and IT | | IT technicians | | | | | | | | | |
| Senior Management | | t.b.c. | | | | | | | | | |
| Weather monitoring and Forecasting | Nowcasting & generation and interpretation of Satellite images and Products | t.b.c. | | | | | | | | | |
| | Impact based Forecast and Warning (stakeholder event) | t.b.c. | | | | | | | | | |
| | Local forecast | t.b.c. | | | | | | | | | |
| | Marine forecast | t.b.c. | | | | | | | | | |
| Weather forecasting enabler | Training course on developing operational tools: coding with python, fortran, R, gmt (generic mapping tool) | t.b.c. | | | | | | | | | |
| Hydrological Forecasting | | t.b.c. | | | | | | | | | |

Dry period 2027 (May-October)

**Implementation Plan**

| **Workpackages** | **Activities** | **Comment** |
|---|---|---|
| **Trainings** | Concluded | |
| AWS | station installation | engineer |
| | station maintenance | engineer/technicians |
| | station operationalization | engineer/technicians |
| | field checks (hand helds) | engineer/technicians |
| | calibration | engineer/technicians |
| UA | On site training | engineer/technicians |
| | Factory training (France) | engineer/technicians |
| Database, Data management | | IT technicians |
| Network Management | | IT technicians |
| ICT and IT | | IT technicians |
| Senior Management | | t.b.c. |
| Weather monitoring and Forecasting | Nowcasting & generation and interpretation of Satellite images and Products | t.b.c. |
| | Impact based Forecast and Warning (stakeholder event) | t.b.c. |
| | Local forecast | t.b.c. |
| | Marine forecast | t.b.c. |
| Weather forecasting enabler | Training course on developing operational tools: coding with python, fortran, R, gmt (generic mapping tool) | t.b.c. |
| Hydrological Forecasting | | t.b.c. |

Dry Period 2027 (May-October)

| 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | North | South | | |
| | | | | | | | North | South | | |
| | | | | | | | North | South | | |
| | | | | | | | North | South | | |
| | | | | | | | North | South | | |

**Appendix 2.2** Inventory list of needed equipment for RMCs including the HQ

| Product | Characteristics | QUANTITY per RMC |
|---|---|---|
| **Multi-Tool-Case** | High-quality steel<br>polygonal ratchet wrenches<br>Multi-tooth socket wrenches<br>Screwdrivers and pliers<br>Allen key series<br>Bit sets, wrenches and accessories | 1 |
| **Chisel drill** | Operating voltage 36V<br>Battery capacity 6 AH<br>Striking power 3.2 J<br>Typing rate 0-4500cps/min<br>No-load speed 853 rpm<br>Charger<br>2 concrete drills 1m and 50cm<br>3 spare batteries | 1 |
| **Drill bit** | TE-CX-12/61 R.409202 HILTI | 1 |
| **Drill** | 600W BOSH | 1 |
| **Digital multimeter** | Multifunction (Fluke) | 1 |
| **Rust remover** | Anticorrosion LM40 200ML | 1 |
| **Step ladder** | 6 wooden steps iron structure | 1 |
| **Cold air welding unit** | Power consumption 90 W<br>Temperature range 50°C - 500°C<br>Standby temperature range 50°C -250°C<br>Power consumption 1000 W<br>Temperature stability ±2°C (still air, no load)<br>Blowing 1-120 l/min | 1 |
| **MIG/MAG welding unit** | 3-in1 multi-process welding incl welding protective gear | 1 |

| | | |
|---|---|---|
| **Adjustable Programmable Laboratory Power Supply Linear Transformer Table** | High accuracy 100 mV / 10 mA DC voltage range: 0 - 30V Current range 0 - 20 A<br>Large LED display<br>quick check of active output current and voltage values<br>Overtemperature / overvoltage / overcurrent / overload protection | 2 |
| **Garmin Etrex 32 GPS** | GPS Etrex 32X terrestrial, TFT color display 65.0000, IPX7<br>integrated africa map<br>8GB internal memory<br>compass, barometric altimeter<br>battery life: up to 25 hours | 1 |
| **Compass** | Trigano hiking compass (southern hemisphere) | 1 |
| **Tools for the North alignment of wind sensors** | GPS-based compasses should be preferred since magnetic compasses will be misaligned in the vicinity of large metal structures like the wind towers | 1 |
| **Personal protective equipment (PPE))** | Overall blue night T42 | 3 |
| | Insulating protective glove | 3 |
| | Protective boots | 3 |
| | Fluorescent gloves | 3 |
| | Waterproof set | 3 |
| | Construction helmet | 3 |
| | Safety harness with rope | 3 |

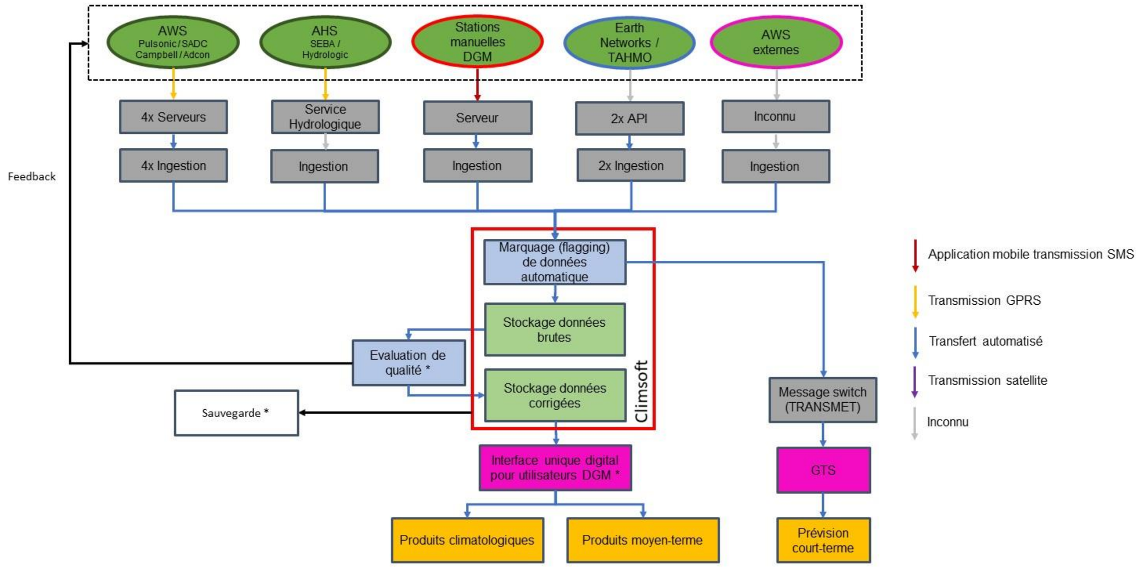
| | | |
|---|---|---|
| **Generator 3500 KT inverter technology** | Single-phase generator<br>Model: soundproofed / inverter<br>Fuel: petrol<br>Speed: 3000 rpm<br>Rated power: 3.5 KVA / 2800 W<br>Sound pressure level (LpA): 65 dB<br>Sound power level (LwA): 90 dB<br>Operating time at 75%: 11 h<br>Consumption (at 75%): 1.1 L/h<br>Tank capacity: 12 L<br>Voltage: 230 V<br>Motor power: 7 HP (hp) / 207 cc cc<br>Maximum power: 3.75 KVA / 3000 W<br><br>+ cable drum (max. power ≥ 3 kV)<br>+ petrol can | 1 |
| **Laptop (e.g. Toughbook)** | water/dust proof, at least IP53 | 1 |
| **Air condition** | Calibration equipment should be stored in in an air-conditioned room to allow for moderate temperatures. Same applies for the server room at the HQ, which is why an additional AC is required at the HQ: | 1 + additional one for HQ |
| **First Aid Kit** | | 1 + additional one for HQ |
| **Climbing protection gear** | Appropriate protective gear for secure climbing of wind tower | 2 |
| **Toyota Land Cruiser Pick-up double cabine** | Gearbox: 5 forward manual gears + 1 reverse<br>Horsepower: 217 hp<br>Fuel tank capacity (130 liters)<br>Average fuel consumption: 12.5l/100km<br>Steel wheels with 225/95R16 (original) tubeless tires<br>Front AIRBAGS (Driver and Passenger)<br>Anti-UV laminated and tinted windscreen<br>Height- and depth-adjustable steering column<br>Seat belts + Front/rear headrests<br>Air conditioning, heating and ventilation<br>Rear spare wheel + car jack and basic tools<br>Fabric interior<br>Integrated cable winch<br>Sand plate | 1 (only for the 4 regions) |

| | | |
|---|---|---|
| | Petrol cans (6x20 Liter)<br>Water tank<br>Cargo straps (ratchet)<br>Options: Tarpaulin roll bar; foglamp, cover<br>First aid kit | |
| **Hard ware** | • Extra server (rack/tower)<br>• UPS<br>• 5 hard drives (5 TB each, for RAID systems on both servers, , capable of 24/7 operations) | Only for HQ |
| **All essential spare parts of AWS and at least one extra sensor of each type** | t.b.c | |
| **Office equipment** | t.b.c. | 1 |

**Appendix 2.3** Calibration Equipment per RMC

| Calibration Equipment | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Products | **Handheld Temperature** | | **Handheld Temperature & Humidity** | | **Manometer** | | **Chilled Mirror Hygrometer (incl. Humidity validator)** | | **Reference Temperature Calibrator** | |
| **RMC** | **in stock** | **further needed** | **in stock** | **further needed** | **in stock** | **further needed** | **in stock** | **further needed** | **in stock** | **further needed** |
| Antananarivo (HQ) | 5 | can be distributed | 0 | 2 | 1 | 0 | 1 | 0 | 1 | 0 |
| Mahajanga | 0 | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| Toliara | 0 | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| Farafangana | 0 | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| Antalaha | 0 | | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| **Sum** | | **0** | | **6** | | **4** | | **4** | | **4** |

## **Appendix 2.4** Data flow DGM (source: DGM)




Different border colors for stations:

Black borders are automatic stations which are managed by DGM and for which also the data goes directly to DGM.

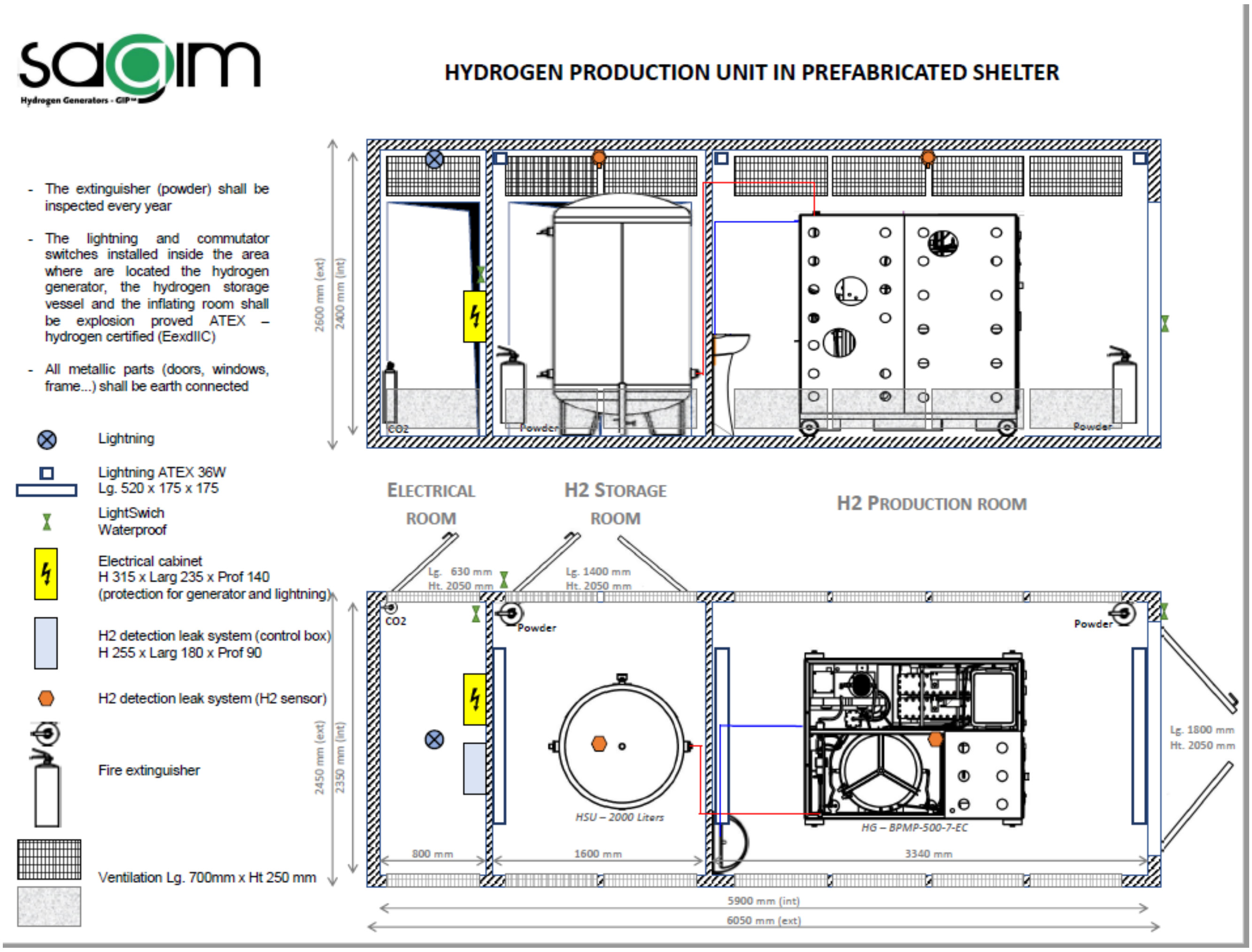
Red border are the manual stations which in the future will be using a mobile app and transmit their data over SMS towards an SMS gateway connected to a server located at DGM.

Blue borders are automatic stations managed by DGM but which transmit their data to external servers. Data will need to be retrieved from these external servers before it can be ingested.

Pink border are fully external AWS. Station is managed and data is received by third parties.

There are some unknown transmissions/flows indicated with grey arrows. The transmissions for Earth Networks and External AWS are unknown and will need to be analyzed in the coming months. Also some parts of data flow for Hydro stations, Degreane stations and external AWS will need to be further analyzed.

**Appendix 2.5** Example of a hydrogen production unit set-up by SAGIM



# Report completion signatures

| |
|---|
| **Peer Advisor signature** |
| **Beneficiary Country signature**<br>…olona RAHOLIJA…<br>Docteur Ingénieur et Météorologue<br>…en Chef de Classe Exceptionnel… |
| **WMO Technical Authority signature** |