COUNTRY HYDROMET DIAGNOSTICS

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

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Madagascar Peer Review Report

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List of Abbreviations

AfDB	African Development Bank
AMHEWAS	Africa Multi-hazard Early Warning and Action System
APIPA	Autorité pour la Protection contre l'Inondation de la Plaine d'Antananarivo
ASECNA	l'Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar
AWS	Automatic Weather Stations
BNCCC	Bureau National de Coordination des Changement Climatiques
BNGRC	Bureau National de Gestion des Risques et des Catastrophes
CAP	Common Alerting Protocol
CERVO	Centre d'Etudes, de Réflexion, de Veille et de l'Orientation
CIRAE	Circonscription régionale de l'agriculture et de l'élevage
CFT	Climate Forecasting Tool
CPT	Climate Predictability Tool
CRIC	Comité de Réflexion des Intervenants aux Catastrophes
DEM	Direction des Exploitations Météorologiques
DGM	Direction Générale de la Météorologie
DMA	Direction de la Météorologie Appliquée
DRDH	Direction des Recherches et Développements Hydrométéorologiques
ECMWF	European Centre for Medium-Range Weather Forecasts
ENEAM	Ecole Nationale d'Enseignement de l'Aéronautique et de la Météorologie Antananarivo - RTC Madagascar
EPS	Ensemble Prediction System
ESPA	Ecole Supérieure Polytechnique d'Antananarivo - RTC Madagascar
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
GDP	Gross Domestic Product
GFS	Global Forecast System
GEFS	Global Ensemble Forecast System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HPC	High Performance Computer
HWRF	Hurricane Weather Research and Forecasting model
ICAO	International Civil Aviation Organization
IE	Implementing Entity

IFS	Integrated Forecasting System
IPCC	Intergovernmental Panel on Climate Change
IOC	Indian Ocean Commission
GBON	Global Basic Observation Network
LAM	Limited Area Model
METAR	Meteorological Aerodrome Report (Aviation Routine Weather Report)
MGA	Malagasy ariary
MHEWS	Multi-Hazard Early Warning System
MTM	Ministère des Transports et de la Météorologie de Madagascar (Ministry of Transport and Meteorology of Madagascar
MOGREPS	Met Office Global and Regional Ensemble Prediction System
MOS	Model Output Statistics
NAPS	National Adaptation Plans
NFCS	National Framework for Climate Services
NMHS	National Meteorological and Hydrological Services
NWP	Numerical Weather Prediction
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
PrAda	Projet Adaptation des chaînes de valeur agricoles au changement climatique
PRCCC	Programme de Renforcement des conditions et capacités d'adaptation durable au changement climatique
QMS	Quality Management System
REGCM	Regional Climate Model
RSMC	Regional Specialised Meteorological Centre
SARC	Strengthening Climate Resilience Department
SCAA	Mitigation Coordination Department
SCAT	Cross-cutting Activities Coordination Department
SDFC	Climate Finance Development Unit
SEB	Social and Economic Benefits
SOFF	Systematic Observations Financing Facility
SPECI	Aerodrome special meteorological report
SWFP	WMO Severe Weather Forecasting Programme
TAHMO	Trans-African Hydro-Meteorological Observatory

UKMO	United Kingdom Meteorological Office
USD	United States dollar
WAM	Wave Model
WDQMS	WIGOS Data Quality Monitoring System
WFP	World Food Programme
WIGOS	WMO Integrated Global Observing System
WIS	WMO Information System
WW3	WAVEWATCH III

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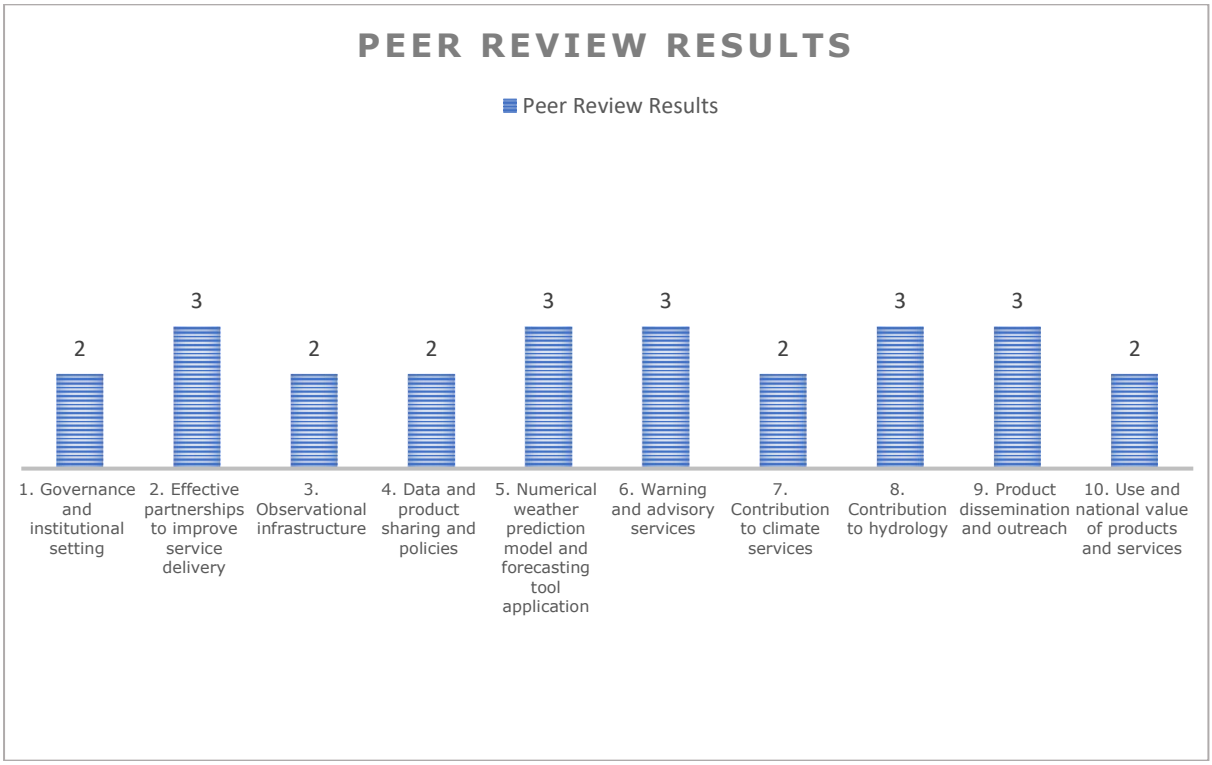
Executive Summary

The Maturity Levels (1-5) based on the results of Country Hydromet Diagnostics (CHD) inventory and review sheet, have been assessed as follows:



The primary assessment of the status of these ten elements took place during the first country mission to Madagascar in April 2023. This enabled us, as peer advisors, to gain a deeper understanding of the structures and activities of the Direction Générale de la Météorologie (DGM), which, together with the Directorate of Operational Meteorology and the Directorate of Hydrometeorological Research and Development, forms the National Meteorological and Hydrological Service (NMHS) of Madagascar. The information obtained was then reviewed in follow-up meetings, and superficial information on the review sheet was supplemented with more detailed information.

Through this constant exchange with the NMHS of Madagascar, we were able to get to know an extremely ambitious NHMS with clear goals and ideas. At the same time, it became clear what challenges they face in implementing these ideas. As it turned out, these are very often structural and institutional limitations that prevent DGM from using its potential more widely. The main constraints that were identified, along with the most pressing needs and the resulting recommendations, are briefly summarized in the following section.

Governmental and institutional strengthening:

DGM experiences severe institutional constraints that impede its ability to implement planned activities, mostly due to budget limitations derived from the government's fluctuating budget in recent years. As a result, planning for future activities is challenging and there is an inadequate budget allocation to hire the required number of personnel. Furthermore, financial resources are lacking to meet its mandate, as there are insufficient funds to undertake tasks in accordance with standards or to update and maintain the necessary technical equipment.

Capacity building activities could further enhance the NMHS's ability to expand its skills and thus its scope of action. This could further increase the importance of the NHMS, both nationally and internationally, and thus attract more attention in international projects to enable budget reallocations that would benefit the NMHS, and further international projects that work with and support the NMHS.

User engagement and stakeholder management:

Quality management is still poor. In particular, there are still significant shortcomings in user feedback loops, which are essential to better address user needs and ensure that products and services, as well as important warnings, actually reach users. Expansion of the 'last mile' is urgently required to extend the reach of such provisions. Simultaneously, there is a lack of research on the social and economic benefits (SEB) provided by weather, climate and hydrological services. These could provide a significant foundation for budgetary increments by the government and other stakeholders, to further invest in the NHMS as a sustainable investment in the country's economic future.

In conclusion, the Peer Review showed that half of the 10 critical elements have only reached a basic level of maturity, while the other half is already at an intermediate level. However, it is evident that the NMHS has well-defined objectives and strategies to broaden its monitoring network, exceeding the GBON criteria. DGM has shown a high level of ambition and motivation for further development.

In addition, thanks to good cooperation with the University of Antananarivo and the WMO Regional Training Centres (Ecole Nationale d'Enseignement de l'Aéronautique et de la Météorologie (ENEAM) and Madagascar Ecole Supérieure Polytechnique d'Antananarivo (ESPA)) based there, Madagascar has well-trained meteorologists and technicians. It is crucial to support DGM in its endeavors by allocating adequate resources for recruiting well-trained graduates and being an attractive employer, and to ensure that this is not constrained by a lack of resources.

Chapter 1: General information

Introduction

The Country Hydromet Diagnostics (CHD) is a key tool for identifying areas within the hydromet value chain that require additional attention and support. By integrating ten critical elements and applying a peer review approach, the CHD assesses the maturity of hydromet services. The aim is to improve global hydrometeorological capabilities, provide more accurate forecasts, reduce the number of deaths from natural disasters and efficiently target investments. Developed by the Alliance for Hydromet Development in collaboration with 16 countries, the CHD is now operational as part of the Systematic Observations Financing Facility (SOFF) program to promote cooperation between the meteorological services of partner and participating countries.

Madagascar, the fourth-largest island in the world, is situated off the south-eastern coast of Africa, covering an area of 592,800 km². The country's diverse terrain includes a narrow coastal plain, a high plateau, mountainous regions in the center, and low plateaus and plains in the western part of the island. With a population of 28,812,190 people, Madagascar experiences varied climates, ranging from tropical conditions on the coast (Af, Am, Aw), arid climates in the south (BSh), to temperate zones (Cwa, Cwb, Cfa, Cfb) further inland (see Figure 1).

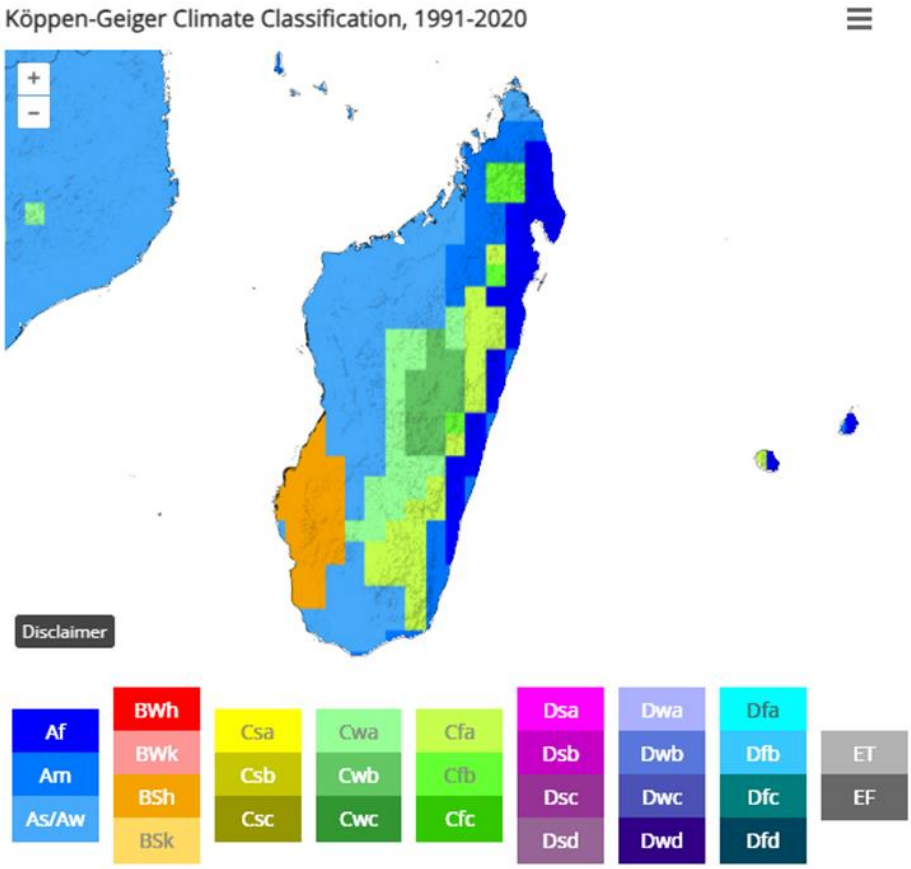


Figure 1: Köppen-Geiger climate classification map for Madagascar 1991-2020 (source: https://climateknowledgeportal.worldbank.org/country/madagascar)

By Decree No. 62-099 bis of 28 February 1962, the National Meteorological 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 1960[1] Madagascar is a member of the World Meteorological Organization and the NMHS's main tasks include:

a) Providing meteorological, climatological, hydrological, and environmental services to the Malagasy society. This comprises producing and disseminating weather forecasts, warnings, and 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 Climate Services, delivering tailored information to meet users' requirements

CHD methodology

The CHD was developed on the basis of a WMO questionnaire, which was initially completed by the Malagasy National Meteorological and Hydrological Service (DGM). The subsequent peer review was conducted in close collaboration between the DGM and the peer advisory NMHS DWD with additional input. In addition, a weekly meeting was established with all parties involved (NMHS, Implementing Entity and other stakeholders) to discuss relevant details on the ten elements of the CHD. The following report summarizes the main findings and assigns the level of maturity achieved by the DGM to each of the ten elements of the CHD.

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

Chapter 2: Country Hydromet Diagnostics

Element 1: Governance and institutional setting

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

In the Republic of Madagascar, the National Meteorological and Hydrological Services are carried out by the Direction Générale de la Météorologie (DGM) under the Ministry of Transport and Meteorology, together with the Directorate of Operational Meteorology (DEM) and the Directorate of Hydrometeorological Research and Development (DRDH) and 23 Regional Meteorological Services.

DGM operates in accordance with the provisions of Decree No. 62-099 bis of 28 February 1962 establishing the National Meteorological Service of Madagascar. It also carries out its functions 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. The DGM is officially recognized as the national warning authority for hydrometeorological hazards in Madagascar.

DGM's mandate is to protect life and property through the development of a national hydro-meteorological network, weather analysis and forecasting, and the provision of climate services. Although DGM is not the national aeronautical meteorological authority as defined in ICAO Annex 3, it is responsible for providing meteorological information to 15 airports. Air quality and agrometeorology are also part of its mandate.

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

DGM has identified the following strategic priorities for the next years:

- Modernization of the operational forecasting center to meet international standards and norms at central level and at all the 23 regional forecasting units;
- Improvement of its observation network (number of stations covering the area, regular maintenance, renewal and automation, number of staff to be recruited);
- Implementation of the quality management system for the whole value chain;
- Implementation of a new data flow;
- Improvement of the numerical weather prediction models.

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

DGM's total budget for 2023 was USD 2.736.619[2] (12.328.332.000 MGA), fully funded by the government. Operating costs accounted for 3.8% of this. 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 again, but the operating budget did not return to pre-2021 levels. As a result, there are major gaps in station maintenance (building and equipment), mainly because there is no money to pay for petrol to get to the stations, to take the equipment to the laboratory for calibration, limited budget to buy the spare parts when available for purchase, unavailable spare parts or limited skilled staff. Moreover, there is also a lack of spare parts for calibration. According

[2] Exchange rate as of 15 November 2023

to DGM, it is estimated that at least five times the total budget available in 2023 would be needed for the NMHS to fulfil its responsibilities.

DGM has extensive experience with internationally funded projects (Annex 2). Such collaborations are crucial for the further development of its institutional and human capacity.

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

Today, DGM employs 224 people, 38% of whom are women, with 11 out of 33 leadership positions held by women. 46.9% of the staff works in the regional offices, the rest in the headquarters in Antananarivo. 22% of the staff have a Baccalaureate degree, while only 13% have a Bachelor Degree or higher. 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 1 and Table 2).

Table 1: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 (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 2: Distribution of employees by degree (source: DGM)

Degrees	**Female**	**Male**	**Sum**
Baccalaureate Degree	25	25	49 (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%)

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

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 meteorology at the *Antananarivo Polytechnic School* (ESPA - École Supérieure Polytechnique d'Antananarivo). 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. The difficulty is therefore not in finding suitable staff, but in replacing retiring staff, as funding for the continuation of these posts is often cut by the Ministry. At present, there is a deficit of 200 employees at the DGM, with an additional 14 serving voluntarily. This is a result of the recruitment freeze that has been imposed since 1990 due to government budget constraints, which prevents the employment of university graduates. In response, the DGM has trained its staff through in-field training in order to be as operational as possible.

Efforts are being made to dispatch skilled workers to other Indian Ocean Commission (IOC) countries with limited qualified personnel, establishing an opportunity for them to earn a sustainable source of income. Therefore, it is imperative to increase the number of new recruitments or budget items in the state budget.

Summary score and recommendations for Element 1

In summary, the DGM operates on the basis of a solid legal and regulatory mandate with clear objectives and strategic priorities. This allows it to almost reach a Maturity Level of 3. However, the capacities of the DGM are not yet sufficient to close the operational gaps. The main challenge in relation to Element 1 continues to be the lack of state resources to hire well qualified staff in line with their qualifications, to recruit more highly qualified staff and to provide them with the necessary resources to do their job well. The lack of fuel and spare parts for repairs has resulted in many synoptic stations being out of service in recent years.

The negotiations that are already taking place with the Ministry need to be continued in order to put an end to the recruitment freeze. The recent elections could help these negotiations. In addition, the importance and benefits of the work of the DGM must continue to be emphasized. With regard to fuel and spare parts, a regional approach and a mobility concept should be considered. The **Maturity Level** for Element 1 is therefore still set at **2**.

Element 2: Effective partnerships to improve service delivery

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

The DGM has several partnerships at national level, both with government institutions and with the private sector. These include the Ministry of Health, the Ministry of Agriculture and the *National Centre for Applied Research in Rural Development* "Centre National de Recherche Appliquée au Développement Rural" (FOFICA/CENRADERU) under the responsibility of the Ministry of Higher Education and Scientific Research. DGM also has a formal agreement for monitoring data with the mining company based in Ambatovy. As the plant is exposed to cyclones on an annual basis, weather data and risk management are of vital importance.

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

There are also a number of collaborations with national and international academic and research institutions, including the University of Antananarivo, the International Research Institute for Climate and Society at Columbia University, the University of Princeton, the University of Reading, the University of La Réunion and the University of Witwatersrand (Wits) in Johannesburg.

DGM also maintains a good partnership and close cooperation with the Agency for the Safety of Air Navigation in Africa and Madagascar (ASECNA), an international public body governed by the Dakar Convention revised in 2010, with legal status and financial autonomy. In Madagascar, ASECNA operates four surface land weather stations and two upper air stations, all of them already GBON compliant. ASECNA is currently responsible for the transmission of weather data (their own and data from DGM) to the GTS and has their own in-house calibration laboratory. 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.

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

The Trans-African Hydro-Meteorological Observatory (TAHMO) is working towards the goal of establishing a 30 km dense network of hydro-meteorological monitoring stations in sub-Saharan Africa, using an integrated and sustainable approach. TAHMO is working with the GIZ program PrAda (Project for enhancing adaptation and resilience capacities of rural communities facing climate change) to establish a broader agro-climatological observation network. In collaboration with the DGM, these projects aim to make weather and climate data available to stakeholders in the agricultural value chain to enable them to make informed decisions. The DGM has also signed MOUs with the Projet de Développement des Régions Menabe et Melaky (AD2M project) in order to install new observation stations and improve the observation network. The DGM has an essential role to play in providing seasonal forecasts. These are essential for advising on adaptation to climate change and responding to slow-onset and longer-term changes (e.g. testing drought-resistant crop varieties, investing in trees and saplings that could provide more soil nutrients). In turn, the project aims to strengthen the capacity of the DGM through the provision of technical equipment and training workshops. Furthermore, TAHMO is currently setting up a Global Telecommunication System (GTS) for the DGM according to the World Information System (WIS) 2.0 standards of the WMO. 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 therefore a crucial importance.

Under the initiative of the DGM, the Decree N° 2015-1548 portant création et organisation du Comité Pluridisciplinaire de Pilotage du Cadre National pour les Services Climatiques - establishing and organizing the Multidisciplinary Steering Committee for the National Framework for Climate Services - (CNSC), was published on February 8th, 2016.

The committee is placed under the supervision of the institution in charge of Meteorology (Article 2). It is chaired by the Permanent Representative of Madagascar with the World Meteorological Organization who is also the acting Director General of Madagascar National Meteorological and Hydrological Service (Article 5)

The mission of the CNSC Multidisciplinary Steering Committee is to (Article 3):

- operationalize the CNSC in Madagascar through an action plan

- make decisions on the issues identified in the implementation of the CNSC

- guide and supervise the activities of the CNSC in an overall manner

- defend at all levels the value and necessity of Climate Services to the country's adaptation to climate variability and change and its sustainable development as well as the investment needs to have products, information and good quality climate services.

However, the committee is currently non-operational due to frequent changes in the government. This is because the committee requires ministers to be nominated in order for it to be operational. As a result, with each new government, new ministers must be nominated. The action plan submitted by the previous government must be updated again with the new committee members. A focal point for climate issues has already been established but still requires formalization.

At the international level, the DGM is involved in Madagascar's cooperation with intergovernmental organizations such as the Indian Ocean Commission (IOC). The IOC focuses on environmental management and conservation, including the needs of growing island states, adaptation to the effects of climate change, food security and public health, through cooperation among its member and observer states. In this regard, the IOC Hydromet project - Building Regional Resilience through Strengthened Meteorological, Hydrological and Climate Services in the Indian Ocean Commission (IOC) Member Countries – is about to be implemented and will help to improve the capabilities of NMHS in the four countries Comoros, Seychelles, Mauritius and Madagascar. Discussions are currently taking place on possible synergies with the SOFF project.

Other collaborations include the Southern African Development Community (SADC). The DGM has received Automatic Weather Stations (AWS), a high-performance computer (HPC), computers, software and training through various SADC projects such as the SARCIS-DR project and the CLISMA project.

UN organizations including the UN Development Programme (UNDP), the World Food Programme (WFP), and the UN Educational, Scientific and Cultural Organization (UNESCO) partner with the DGM to implement their projects, often focusing on the provision of climate services in their respective project areas. For instance, the WFP collaborates with DGM in the implementation of the WFP's Forecast-based Financing (FbF) program. In this context, DGM plays a crucial role in providing state-of-the-art sub seasonal to seasonal (S2S) forecasting services tailored to the specific project regions.

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

Furthermore, the UNDP has allocated funding to support DGM's initiatives through the PACARC/UNDP/GEF project. As a result, DGM has been able to undertake various activities, including the formulation of a preliminary draft of the National Meteorological Policy, as well as the installation of AWS and hydrological monitoring stations, maintenance equipment and a four-wheel drive vehicle for field maintenance operations. In addition, UNESCO is primarily engaged in training DGM personnel in the field of hydrology, contributing to the enhancement of the organization's technical capacity.

Summary score and recommendations for Element 2

The **Maturity Level** for Element 2 'Effective partnerships to improve service delivery' is set at **3**. There are a number of effective partnerships and collaborations with promising projects. However, the establishment of sustainable and self-determined funding mechanisms remains a challenge and needs to be further enhanced.

Element 3: Observational infrastructure

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

The current **observation network in Madagascar consists of:**

- 24 synoptic surface observation stations (20 operated by DGM and 4 by ASECNA)
- 2 upper-air stations (ASECNA)
- 36 agro-climatological stations, all automated

In recent years, 85.71% of the observation network has been automated. However, not all automated stations are automatically connected to the GTS. Where this is not yet the case, data is sent from the station to the DGM, which in turn forwards it to ASECNA. ASECNA then transfers the data in the GTS so that it is available in the WDQMS. To date, there are 4 GBON compliant surface stations directly connected to the server and operated by ASECNA. The same applies to the two radio sounding stations in the country.

Stations directly connected to the server report hourly, and data to be read manually and transmitted via phone is reported every three hours. In Madagascar, however, the latter transmission frequency is limited to daytime hours, as the security situation does not permit operation after dark.

3.2. Additional observations used for nowcasting and specialized purposes.

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. So far, data are collected through numerous methods (manual, semi-automatic and automatic) and communicated via different communication channels to ASECNA from where the data is entered into the GTS. The range of methods utilized necessitates diverse procedures to analyze the data, leading to increased transaction costs that further strain an already tight budget. Furthermore, the issues are compounded by the fact that 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. But, the process of digitization of the data has started and is currently in progress with the integration of the data into Climsoft by SBDAH, also in order to establish an automatic backup, reducing the risk of unrecoverable loss in the event of hardware-related incidents.

Furthermore, it is currently discussed between TAHMO, DGM and ASECNA to establish an own GTS for DGM, or at the very least, the creation of an additional backup system. The migration from GTS to WIS2.0 is planned once WIS2.0 becomes fully operational. So far, no national WIGOS implementation plan has been adopted yet. DGM staff have not yet received OSCAR/Surface training.

During the last 5 years,

- 1 automated synoptic station has been installed through the PrAda project[3]

[3] the station got struck by lightning in October 2023 and is no longer operational)

- 1 automated synoptic station and 30 agro-climatological stations have been installed through the PRCCC[4] project initiated by GIZ/EU (2 out of 30 agro-climatological stations are no more operational).
- 2 automated synoptic stations, 5 agro-climatological stations and 4 hydrological stations were donated to DGM through PACARC[5] project financed by UNDP/GEF. The 2 synoptic and 5 agro-climatological stations are not operational because of power supply and data transmission problem. The 4 hydrological stations are not yet installed.
- 4 automated synoptic stations have been installed through the SADC/SARCIS-DR project.

The following table gives an overview of the operational status of the different stations:

Table 3: Status of the surface observation network DGM, Nov 2023

Station type	**total**	**operational**	**partly operational** (not all variables measured)	**not operational**
Synoptic	**24**	13 (54.2%) (4 manuals/ 9 AWS)	5 (20.8%) (5 manuals)	6 (25%) (3 manuals/ 3 AWS)
Agro-climatological	**36**	17 (47.2%)	5 (13.9)	14 (38.9%)

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

Overall, the surface observation network is diverse in terms of equipment and manufacturers, having been set up under different projects, not always considering the given infrastructure conditions. In some cases, this can lead to insufficient power supply for the installed instruments and sensors and the stations become inoperable.

Furthermore, the lack of uniformity makes maintenance even more difficult, as both knowledge and spare parts are required for different systems, and compatibility between equipment is not necessarily guaranteed.

Although ASECNA has an in-house calibration laboratory, the DGM is unable to carry out its calibrations there due to a lack of transport facilities and spare equipment. Calibration for wind speed and direction also poses a challenge for ASECNA, since their laboratory lacks a wind tunnel. While the DGM has received calibration equipment from the PACARC initiative, further training is necessary for technicians to use the equipment effectively. Field checks are operated for parts for the variables (sea level pressure, humidity, and temperature) but geographical coverage is proving difficulty. Field checks for wind remain difficult, but opportunities for precipitation should be further explored as they are easier to implement.

Data quality is therefore mostly limited to factory standards as only limited additional downstream quality control procedures can be applied to check the validity of the data (and discard it if necessary) or to detect technical problems at the station (equipment drift, power failure, data communication).

Generally, manual stations are better maintained due to their proximity to operators. Nevertheless, manual stations face other problems, such as restrictions on operation

[4] PRCCC - Programme de Renforcement des conditions et capacités d'adaptation durable au changement climatique

[5] PACARC - Amélioration des capacités d'adaptation et de résilience au changement climatique

outside daylight hours or manual wind measurements during storms, which would be too dangerous. Additionally, some instruments are damaged or non-compliant with regulations (e.g. mercury thermometers). Wind sensors were non-operational at the majority of stations during the first country mission in April 2023.

3.4. Implementation of sustainable newer approaches to observations.

Overall, the DGM already measures a number of variables to better predict hazards. In addition, the DGM receives data from the *Antananarivo Flood Protection Authority* "Autorité pour la Protection contre l'Inondation de la Plaine d'Antananarivo (APIPA)" to provide nowcasting data on riverine floods. However, it is emphasized that the following variables need to be measured in order to improve forecasts and make early warning systems useful:

- Tropical cyclone: Radar data and lightning data;
- Drought/Dry spell: High resolution of rainfall data and soil moisture;
- Riverine Floods: Temperature and solar radiation;
- Wild land fire/Forest fire: soil moisture; high resolution satellite data;
- Hail: lightning

Nevertheless, there is not only a lack of sufficient surface observation networks, upper air and hydrological observation networks, weather radar and lightning observation stations, but also a lack of materials, trained personnel, training and financial resources.

Summary score and recommendations for Element 3

In summary, Madagascar has already laid a good basis for further development of the observation network. There is already a basic infrastructure of stations which to build on, even if some of them are not operational at this stage. With the DGM, Madagascar also has a well-organized and well-functioning national hydro-meteorological service (NMHS), which mainly lacks operational resources but already has well-trained staff who can fill many gaps with appropriate training. DGM's ambitions to expand the network beyond SOFF to have at least one station in every district of the country for comprehensive coverage is yet another example of the extraordinary motivation of the NMHS.

However, as there are still significant gaps that limit the functioning of the observation network, in particular with regard to maintenance and data quality management, the **Maturity Level** for Element 3 is **2**.

Element 4: Data and product sharing and policies

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

A good overview of the observation network currently operated by the DGM has been given in the previous section. Currently, 15 surface stations are linked to the GTS. Only 4 stations reach the 80% threshold to be GBON compliant (operated by ASECNA). A further 8 stations have data availability below 30% and 3 stations are completely disconnected. Two radio sounding stations are currently in operation (ASECNA) but one more is planned. On the basis of this network, the DGM has selected the most promising sites for stations to be upgraded to meet future GBON requirements and two suitable sites for the installation of new stations.

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

Observation data are currently stored and archived using CLIMSOFT, a Climate Data Management System (CDMS), and a real time data transmission system for Automatic Weather Stations.

Historical data from manned weather stations are currently being imported into CLIMSOFT. In addition, CDMS offers additional features, which include accessing data via Intranet, retrieving maps and graphs of weather and/or climate variables, as well as data export functions.

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

In addition, the DGM has an agreement with APIPA for the exchange of riverine flood data in Antananarivo to produce data products relevant to this hazard. Further monitoring for tropical cyclones and hail is done using satellite data from EUMETSAT (MESA-PROJECT)[6]. Three out of four operational DGM weather forecasters have been trained in the use and interpretation of satellite imagery and products. These trainings were conducted by EUMETSAT in cooperation with its Centers of Excellence (Casablanca, Pretoria, Nairobi, Niger and Senegal) and mainly covered the use of products and images in forecasting processes and extreme weather monitoring.

To date, GBON-compliant data exchange has been very limited, mainly due to a lack of resources, technology as well as a lack of capacity building for staff, a shortage of spare parts and repair expertise. In addition to insufficiently equipped stations, there is also a lack of resources at the headquarters, e.g. resulting in an unstable internet connection due to budgetary problems and only one available forecasting station. The transportation and logistics situation in Madagascar present a multitude of challenges. High petrol prices and inadequate road infrastructure, which is also subject to weather and seasonal variations, contribute to significant difficulties in station accessibility and prompt response.

Summary score and recommendations for Element 4

Consequently, DGM has indicated a need for four regional maintenance centers and upgrading transportation options to individual stations. This will also enable on-site utilization of locally adapted and anchored knowledge regarding the stations. Therefore, despite the progress that has been made, the **Maturity Level** given for **Element 4 is 2**.

[6] Satellite data accessed via PUMA & Internet; Communication system used: SATCOM Direct Reception

Element 5: Numerical model and forecasting tool application

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

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 GFS, HWRF and WW3 of the National Oceanic and Atmospheric Administration (NOAA) of the USA, IFS and WAM from the European Centre for Medium-Range Weather Forecasts (ECMWF), the Global Deterministic model and MOGREPS from the United Kingdom Met Office (UKMO); LAM AROME-IO from the Tropical Cyclone Centre of La Réunion (RSMC-TC La Reunion) 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).

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

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, combined with a Limited Area Model (LAM). New forecasts are updated at intervals of 3, 6, and 12 hours.

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

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 seasonal forecasts are done by using the Climate Predictability Tool (CPT), Python CPT tool (PyCPT)[7], Seafords[8] tool, the Climate forecasting tool (CFT)[9] and the Regional Climate Model (REGCM). However, DGM highlights that data storage capacities of their 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 Met Office's Global and Regional Ensemble Prediction System (MOGREPS).

Satellite imagery is received directly from EUMETCAST 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 AfDB to assess future options in this regard.

DGM highlights, that the level of access to products provided by global and regional centers has improved in the last two years and its staff does have the capacities to post-process NWP. However, it is mentioned that additional training is required in order to improve these activities, especially in terms of Model Output Statistics (MOS) and bias corrections.

Summary score and recommendations for Element 5

In summary, forecasts are based mainly on model guidance from external sources and to a limited extent from internal sources. In addition, remote sensing products are used as an additional source of information. Therefore, **Element 5** is assessed at a **Maturity Level of 3.** Although climate outlooks and seasonal forecasts are already produced and there are staff trained in NWP post-processing, these skills are still limited and further training is needed to bring them up to level 4.

[7] PyCPT is the tool developed by the International Research Institute for Climate and Society (IRI) of the Columbia Climate School; used in the forecast-based financing project of WFP
[8] Seafords is used by the Southwest Indian Ocean Climate Forum
[9] CFT is used by SADC Climate Service Centre Forum

Element 6: Warning and advisory services

6.1. Warning and alert service cover 24/7.

The DGM is officially recognized as the National Warning Authority for Hydrometeorological Hazards in Madagascar and an Integrated Multi-Hazard Early Warning System (MHEWS) is operated through the Bureau National de Gestion des Risques et des Catastrophes (BNGRC) under the Centre d'études, de réflexion, de veille et d'orientation (CERVO), its focal point for all warnings and disaster information.

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

The DGM issues severe weather warnings, as well as cascade effects related to cyclones and floods, for hazardous weather events relevant and expected in Madagascar, with a maximum lead time of five days and a minimum lead time of a few hours. In addition, the Common Alerting Protocol (CAP) is operational in Madagascar and warnings are illustrated using color codes for hazard exposure and vulnerability. DGM also provides hazard risk maps to the BNGRC. Guidance products provided by the RSMCs are used for tropical cyclones, drought and hail, and a warning and forecast archiving system is in place for cyclones, heavy rain, high waves, strong winds and floods. Standard operating procedures for tropical cyclones are contained in the Early Warning System Manual and the National Contingency Plan.

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

Weather warnings, such as heavy rains, strong winds, heavy waves, are issued by the Met Office and disseminated both by the DGM itself via email and website, and by the BNGRC and other partners to the last mile via mobile phone, TV, radio, newspaper and social media channels. DGM warnings also include recommendations for action in the event of hazards. These include, for example, the relocation of people due to coastal submersion and river flooding, and the prohibition of marine navigation and fishing at sea and in rivers. However, due to a lack of personnel, the monitoring activities are not carried out around the clock, but only during tropical cyclones.

Cyclone and tsunami warnings are transmitted directly from DGM to CERVO. Cyclone warnings are updated every 6 to 3 hours at longer distances and every hour at shorter distances.

The DGM does not yet have sufficient software tools to provide fully impact-based forecasts and warnings, but is in the process of incorporating at least possible general impacts into its warnings. Hazard-specific impact models are not used either, but their forecasters have been introduced to this as part of their tropical cyclone and Severe Weather Forecasting Demonstration Project training.

Post-disaster analysis is conducted and provided by the BNGRC. The African Centre for Meteorological Application for Development (ACMAD) and the Africa Multi-hazard Early Warning and Action System (AMHEWAS) Situation Room provide information on predicted impacts. The verification of the warning system is mainly done by the DGM together with the BNGRC and other NGO and private sector stakeholders, during cyclone events. Further performance evaluation of the NMHS and MHEWS is only done internally; external user feedback mechanisms are not in place. The results of the internal feedback rounds are incorporated into the annual work plan. In addition, simulation exercises are carried out

annually by the BNGRC/ Directorate of Applied Meteorology (DMA). In terms of a fail-safe system however, the only back-up system in place is a generator to cover power outages.

Summary score and recommendations for Element 6

Madagascar has a warning system for primary hazards in place that is following standard procedures and protocol, facilitated by the BNGRC and its subordinated commissions. In case of a probability of an event the Comité de Réflexion des Intervenants aux Catastrophes (CRIC) is activated, a platform to support coordination of actors in case of an emergency. However, there are still shortcomings in the dissemination of warnings, especially in the last mile, which is why the public reach of weather warnings is still considered moderate. Taking this into account, together with the lack of impact-based warning services, we have concluded that Element 6 has a **Maturity Level of 3.** Therefore, more attention needs to be paid in developing a far-reaching warning system that can also reach remote locations. Software capabilities must also be improved to allow for impact-based forecasts and warnings, and a stronger fail-safe system must be put in place.

Element 7: Contribution to Climate Services

According to the IPCC's Sixth Assessment Report, Madagascar will face significant climate change impacts by the mid-21st century if global warming is at least 2 °C. The regional projections for Madagascar show an observed increase in aridity; a projected increase in meteorological droughts with a warming of 1.5 °C or more, with increasing probability at higher global warming levels (GWL). There is also expected to be an increase in agricultural and environmental droughts, particularly at higher levels of warming; a projected increase in heavy rainfall and pluvial flooding; a projected increase in the mean wind speed of tropical cyclones and associated heavy rainfall; and a projected increase in the proportion of category 4-5 tropical cyclones[10] is expected.

Madagascar's economy is heavily dependent on agriculture (22.4% of GDP) and services, particularly tourism (48% of GDP). Both sectors are highly vulnerable to the expected impacts of climate change, threatening the livelihoods of a large number of people. Climate services that support people and climate-sensitive sectors in the adaptation and mitigation of climate change are therefore of major importance.

7.1. Contribution to climate services according to the established capacity for the provision of climate services.

In Madagascar, the BNCCC, which reports to the Ministry of the Environment and Sustainable Development, is the main body responsible for climate change adaptation. The BNCCC is in turn divided into several departments: Adaptation and Strengthening Climate Resilience Department (SARC); Mitigation Coordination Department (SCAA); Cross-cutting Activities Coordination Department (SCAT); Climate Finance Development Unit (SDFC).

Furthermore, there is a multi-disciplinary committee in place, that is in charge of implementing the National Framework for Climate Services (NFCS). The NFCS aims to facilitate cross-sectoral coordination to develop measures based on specific national circumstances and capabilities as well as relevant scientific data. It complements the National Adaptation Plans (NAPs) in adapting to climate impacts in the medium and long term by assessing vulnerability to climate change and identifying adaptation strategies. The NFCS aims to improve the understanding of climate and its impacts, and to develop planning and implementation capacity for adaptation in climate-sensitive sectors.

Madagascar has currently reached Step 5 of the NFCS implementation status: that means the NFCS has been launched, the country is in the process of implementing the National Action Plan for Climate Services and is conducting rigorous monitoring and evaluation.

With the establishment of working groups on climate and health, a strategic and technical committee on the cropping calendar and a reflection committee of disaster risk stakeholders, several bodies have been created to provide a mechanism for interaction between users and providers of climate services. The aim is to involve all stakeholders and facilitate decision-making. So far, decision support products and services are provided for the health sector, energy sector, biodiversity sector, water and agricultural sector. However, as of today, no monitoring and evaluation of the socio-economic benefits generated through these services has been done.

In summary, Madagascar is part of regional and global institutions working on climate change adaptation and impacts (IOC; SADC), in addition to government agencies working on climate change adaptation strategies.

[10] IPCC-AR6-WGI: Regional Factsheet Africa (2021): https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Africa.pdf

Besides the daily, weekly and two-weekly weather forecasts, DGM also provides climate projections, the seasonal forecasts and the climate outlook from October to April when Madagascar is entering to the hot and humid season and the cyclonic season. Furthermore, sector-specific climate services for the 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 service. However, these services often do not reach farmers in rural areas who are either not aware of these services or do not have the necessary devices to access these services. These information dissemination deficits, also known as the "last mile" or "grassroots problem", are currently being addressed by the GIZ project PrAda. Through local multipliers more people are supposed to become aware of the different services in place. User surveys are in the planning in order to better adopt the services to the needs.

Data is stored on hard copies as well as digitally archived to allow long time series analytics. Digital data is accessible via a digital tool called "Maproom", an interactive web application that contains a collection of maps and other figures that monitor current and recent weather conditions, as well as forecasts. It allows for making analyzes between climatic conditions and sectors of activity, including agriculture, health and hydrology. Maps and figures can be adjusted and are linked to original Météo Madagascar data.

Summary score and recommendations for Element 7

However, the capacity of the DGM hardly goes beyond the provision of observation networks, data and data management, monitoring and forecasting systems that enable the production and provision of climate information and services at a basic level.

The DGM's ability to provide more advanced climate services is severely constrained by staff shortages, a very limited operational observing network and a lack of available resources (as mentioned in Element 1-4). For these reasons, the **Maturity Level** of **Element 7 is 2**, and particular attention should be paid to these issues in order to achieve a higher level.

Element 8: Contribution to hydrology

In recent years, Madagascar has experienced the most severe and prolonged droughts in four decades. In a country like Madagascar, whose population is so heavily dependent on rainfed agriculture, droughts in combination with continuous environmental degradation have a catastrophic impact on people's livelihoods. Crop failures have led to major famines in the country.[11]

8.1. Data sharing agreements on hydrological data

Hydrology and water resources management are therefore of great importance to Madagascar and fall within the remit of the NMHS. In the DGM, the hydrological services and the observation network are combined in one department and the collection of hydrological data, hydrological forecasting and the assessment of water resources thus lies within their responsibility. For the city of Antananarivo, the collection of hydrological data is coordinated jointly with APIPA. At the moment there are three out of nine operational Automatic Hydrological Stations, observing water levels and rainfall.

Through the Projet Régional de Résilience Climatique (PRRC) of the World Bank, seven new stations are expected to be installed in four regions:

- ANOSY (River Mandrare),
- ATSIMO ATSINANANA (River Manampatrana/Farafangana),
- FITOVINANY (River Matitanana/Vohipeno),
- VATOVAVY (River Mananjary).

The generated data are archived and digitalized dating back to the 1950s.

Forecasts mainly concern river flooding during an adverse weather event, such as a cyclone. The respective warnings are issued in the same way as the weather warnings. The DGM also works closely with the BNGRC to coordinate flood management and disaster risk reduction, all of which are outlined in the National Contingency Plan.

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

A cooperation with the United Nations Industrial Development Organization in 2020/2021 allowed the calculation of low flows for the estimation of electricity output for the Vatovavy Fitovinany region.

Summary score and recommendations for Element 8

As mentioned above the hydrological service and meteorological service of Madagascar are under the same mandate and combined within the DGM. Therefore, there is a high-level of data sharing through a well-established interplay between the different directorates. However, the monitoring capacities still need to be expanded, especially regarding rivers catchments prone to floods near main urbanized areas (Nosy Be and Antsinanana in the North as tourism areas, Mahajunga and Morondava and Toliara on the West coast, and Taomasina on the East coast).

The **Maturity Level for Element 8 is 3.**

[11] https://earthobservatory.nasa.gov/images/148636/drought-in-madagascar; Madagascar: Severe drought could spur world's first climate change famine | UN News

Element 9: Product dissemination and outreach

9.1. Channels used for user-centred communication and ability to support those channels

DGM has launched a new and very comprehensive website with daily weather forecasts and warnings in Malagasy. DGM has its own TV studio where daily weather forecasts are recorded in-house in very good quality. Up-to-date weather forecasts and severe weather warnings are not only available to the public on the website and on Youtube, but are also broadcast on television, radio, in the newspaper and by email. Telephone users can also dial 321 to listen to the crop calendar and related advisories. Calls are 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, DGM launched a mobile application for Android devices in March 2022, which includes the daily weather forecast, other forecasts such as the agro-meteorological bulletin and the temperature and wind map. It also provides hurricane alerts and warnings of dangerous phenomena as well as information on marine bulletins for coastal waters and high sea, site specific forecast for wave and swell parameters (significant wave heights, primary swell period and direction, surface wind speeds).

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

Measures to ensure that more information reaches marginalized groups are mainly taken and implemented by NGOs and other projects such as GIZ's PrAda project, and are still in the process of being established.

Summary score and recommendations for Element 9

Due to its good quality TV studio, which allows weather forecasts and warnings to be made available to the general public through various channels, and a very informative and well-maintained website, the **Maturity Level for Element 9 is 3**. Social media platforms could be improved and further capacity development in the area of awareness raising would need to be improved to reach the next level.

Element 10: Use and national value of products and services

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

As already mentioned in the previous elements, Madagascar's NMHS provides and disseminates weather products and services on several platforms (e.g. website, mobile web application, TV, radio, email and newspaper). Furthermore, it is engaged in the multi-disciplinary committee for the implementation of the NFCS and is a member of the National Council for Disaster Risk Management. The multi-sectoral consultative platform on agriculture meets once a year, and on disaster risk reduction on request. Tailored customer services and products are provided for the health and agricultural sector. These include a crop calendar, which is based on the seasonal forecast and provides the outlook on planting and harvesting dates for different crops.

The climate and health bulletins are also based on seasonal forecasts and give the probability of the incidence of climate sensitive diseases for epidemiological surveillance (e.g. plague, malaria, diarrhea, respiratory infection etc.).

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

To date, there have been no studies on the social and economic benefits (SEB) of weather, climate and hydrological services. However, satisfaction surveys on crop calendars are conducted and the accuracy and timeliness of NMHS services are regularly monitored and reported.

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

With regard to aviation services, Aeronautical Meteorological Stations (AMS) are operated with local routine observations made at aerodromes and reported via METAR (METeorological Aerodrome Report) or SPECI (Aerodrome Special Meteorological Report). An Integrated Quality Management System has so far only been implemented by ASECNA for international air traffic control, but a schedule of 3 years is foreseen to fully implement the QMS for international air traffic control and early warning.

Summary score and recommendations for Element 10

In summary, the DGM already provides tailor-made services to the agriculture and health sectors, platforms are in place for regular cross-sector dialogue, and there is a good partnership with ASECNA, providing Aviation Services.

Yet there are still significant gaps in the QMS of NMHS and in surveys of the social and economic benefits of weather services that have not yet been conducted. Accordingly, there is a lack of user feedback on these services. Such feedback results would certainly be of great importance for the continuous development of the services, also in order to be able to offer further adapted services. On the basis of this assessment, **a Maturity Level of 2** is assigned to **Element 10**.

Annexes

Annex 1: Consultations

The Data Inventory and Review Sheet and the CHD EW4All Data Inventory and Review Sheet for Madagascar served as questionnaires. It was completed by the DWD-SOFF team together with selected DGM staff during the first country visit in April 2023. Subsequently, based on the information gathered, further details were discussed in a series of online meetings, in consultation with the experts listed below:

Direction Générale de la Météorologie (DGM):

- Nirivololona Raholijao (Director General)
- Miora Linah Rakotonirina (Head of Maintenance and Technical Installation Service)
- Herinjanahary Ralaiarinoro (Head of the Hydrology Department)

Deutscher Wetterdienst (DWD):

- Dr. Carmen Emmel (Member of Division Measurement Technology, DWD representative at the WMO)
- Dr. Jan Lenkeit (Head of Section Sensor Introduction and Testing)
- Carolin Müller (Peer Advisor SOFF)

GIZ PrAda:

- Lena Klockemann (GIZ PrAda; former head of the PrAda project)
- Tantely Andriambololona (GIZ; Technical Advisor in AgroMeteorology and Seed Production, Component resilient production System, Adaptation of agricultural value chains to climate change project (PrAda)
- Mandresy Razafimaharo (GIZ; Technical Advisor in Climatological Services and Sustainable Fisheries, Component resilient production system, Adaptation of agricultural value chains to climate change project (PrAda)

TAHMO:

- Frank Ohene Annor (CEO)

Annex 2: Urgent needs reported

The summary at the end of each element provides a good overview of the gaps identified and the actions required. The following section provides a condensed summary of the most urgent needs identified throughout all the elements:

1. **Lack of financial resources:** It is crucial that the governmental recruitment freeze be lifted and resources be made available from the ministry to recruit well-qualified staff and provide them with necessary resources. Therefore, it is important to maintain a good dialogue. There is a need for further research into the social and economic benefits of weather, climate and hydrological services. To attract more attention and secure budgetary resources, it is crucial to clearly communicate and display these results.

2. **Maintenance and operation:** To meet the requirements of GBON, the surface and upper air network must be upgraded and modernized, as described in the National Contribution Plan. This includes developing maintenance and operation capacities, such as station maintenance, improved ICT infrastructure, and data management and back-up. The NMHS has indicated a need for four regional maintenance centers and upgraded transportation options to sustainably operate and maintain the observation network. These regional centers are to be equipped with necessary spare parts and tools to enable faster repair and maintenance operations, as stations can be reached more quickly and more trained personnel are available in the regions.

3. **Capacity Development:** The assessment of the 10 elements highlighted the need for increased capacity building of staff in various areas of action. Capacity building should be based on an evaluation of training needs, followed by the design and implementation of an appropriate training program.

4. **Quality Management:** There are still significant shortcomings in quality management, particularly in user feedback loops. These are essential to better respond to user needs and ensure that products, services, and important alerts are disseminated as intended. Therefore, more user surveys and process controls need to be carried out, and work processes adapted accordingly.

5. **Warning Service:** Special attention should be given to further expanding the warning system, particularly to ensure that warnings are also received in remote regions.

Annex 3: List of Hydromet Projects and Partners (last 5 years)

Project name	Objectives	Donors/ Organizations/ Agencies
PRCCC: Programme de Renforcement des conditions et capacités d'adaptation durable au changement climatique	This project aims to develop mechanisms for adapting to climate change effects in order to adopt a strategy to deal with change, strengthen the legal and institutional framework, and promote the adequate integration of adaptation and mitigation measures in municipality development.	GIZ/EU
PACARC: Projet d'Amélioration des Capacités d'Adaptation et de Résilience des Communes Rurales face aux Changements Climatiques	The objective of the project is to increase the implementation of climate change adaptation practices and reduce the vulnerability of the target communities.	GEF/PNUD
PRADA: Projet d'adaptation des chaines de valeur agricole au changement climatique	To strengthen the performance capacity of stakeholders involved in agricultural value chains particularly affected by climate change.	GIZ
CREWS: Climate Risk and Early Warning Systems	CREWS's overall objective is to substantially reduce disaster mortality by 2030 and to significantly increase access to early warnings and risk information in LDCs and SIDS (Sendai Framework for DRR Target A and Target G)	World Bank/ GFDRR/ WMO/ UNDRR
PRRC: Projet régional de résilience climatique	The Regional Climate Resilience Programme (RCRP) is structured as a regional series of projects (SOPs) to address challenges common to the countries of the region, while benefiting from a programmatic framework that will enable countries to join at different times and benefit from economies of scale. The five components of the RCRP are: (i) Climate Risk and Financing, (ii) Infrastructure Investments and Asset Management for Climate Resilience, (iii) Adaptive Social Protection for Resilient Communities, (iv) Project Management, and (v) a Conditional Emergency Response Component (CERC).	World Bank
SOFF WMO: Systematic Observation Financing Facility/ Early Warnings for All	Contribute to strengthening climate adaptation and resilient development through improved weather forecasts, early warning systems and climate information services. Ensure that by the end of 2027, everyone on Earth is protected from dangerous weather, water or climate events through life-saving early warning systems.	WMO/ UNDP/ UNEP/ UN Multi-Partner Trust Fund Office
SADC SAWIDRA/SARCIS-DR Southern African Regional Climate Information Services for Disaster Resilience Development (SARCIS-DR) Project	Aims to improve the core capacities of national and regional climate centres (RCC) to meet the needs of Disaster Risk Management (DRM) agencies and socio-economic sectors for effective use of weather and climate services and	EU/AfDB

	community-focused and real-time early warning systems (EWS).	

Annex 4: Information supplied through WMO

- WMO Global GBON gap Analysis
- WMO WIGOS Data Quality Monitoring System
- WMO EW4All Rapid Assessment for Pillar-2

Annex 5: List of materials used

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

DECRET N° 2015-1548 Portant création et organisation du Comité Pluridisciplinaire de Pilotage du Cadre National pour les Services Climatologiques (CNSC).

IPCC-AR6-WGI: Regional Factsheet Africa (2021). Regional Fact Sheet Africa (ipcc.ch)

Köppen-Geiger climate classification map for Madagascar 1991-2020

Meteo Madagascar A propos de Météo - Météo Madagascar (meteomadagascar.mg)

Nasa Earth Observatory Drought in Madagascar

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

PRADA Projet d'adaptation des chaines de valeur agricole au changement climatique

PRCCC Programme de Renforcement des conditions et capacités d'adaptation durable au changement climatique

Renforcement des Systemes d'Alerte Precoce Plan d'action Pays Pilier 2 – Madagascar, 2024-2027

RCRP: The Regional Climate Resilience Programme

SADC SAWIDRA/SARCIS-DR Southern African Regional Climate Information Services for Disaster Resilience Development (SARCIS-DR) Project

SOFF WMO Systematic Observation Financing Facility/ Early Warnings for All

The World Bank Group Madagascar - Summary | Climate Change Knowledge Portal (worldbank.org)

United Nations UN News Madagascar Severe drought could spur world's first climate change famine

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