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Systematic Observations Financing Facility

GBON National Contribution Plan for Mozambique

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Weather and climate data for resilience

GBON National Contribution Plan

Mozambique

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Executive Summary

The Global Basic Observation Network (GBON) National Contribution Plan for the National Institute of National Meteorology (INAM) seeks to give an overview of the status of the existing weather observation network and the infrastructure required for collection and transmission of data nationally and internationally, taking into consideration the (GBON) progressive target towards compliance thereto. The plan does not only consider infrastructure, but also human and institutional capacity requirements. Furthermore, it also articulates the activities required to ensure the sustained operation and maintenance of the national observing network contributing to the Global Basic Observation Network which are pivotal to the development of this plan.

The Plan was developed taking Mozambique's demographic into consideration so as to ensure the setting of realistic targets toward GBON compliance. This plan also seeks to ensure that through the implementation of its proposed activities, INAM will be able to develop the capacity required to generate and internationally exchange GBON observations in a sustainable manner. Furthermore, it will ensure that existing weather observations data gaps nationally are closed to achieve the largest impact on the Numerical Weather Prediction (NWP) models.

The design of the surface- and upper-air observing networks for INAM have an estimated cost of U$ 4 578 898 over a period of 3 (three) years and includes:

- The installation of 6 new Automatic Weather Stations (AWSs), the rehabilitation of 2 AWS to meet the data transfer protocol requirement, as well as the upgrade of the communication/data transmission of all 21 stations.
- Procurement of 4 new upper-air stations reporting twice a day, including repairs and replacement, where needed, and consumables and other running costs.
- Establishment and operation of a regional network for ease of maintenance and calibration with on-going training of staff/personnel to increase the sustainability of the network.
- Repairs and replacement of infrastructure (for example weatherproof building, mains and backup power, water, communications, enclosure for balloon filling, fences for AWS' and AWS stands).
- Training of meteorological personnel from the observations section on maintenance and repair of weather observations instrumentation, quality control of observation data as well as utilisation thereof.

Critical component to the success of the project is Information and Communication Technology (ICT) capability to support data communication from the remote AWS to the Global Telecommunications System (GTS). There is therefore a need for an ICT infrastructure and services design as well as the solutions on data transmission from an observing station nationally, on real-time bases through data management systems and to the GTS. The designed system must have the capability to transmit in Binary Universal Form for the Representation (BUFR) format from the source (AWS) to the GTS.

The above will be achieved through working closely with the World Food Programme (WFP) as the Implementing Entity with years of experience in project management that involves managing international donor funded projects. Furthermore Chapter 1, Article 3(b) and 3(g) of the Internal Regulation of the National Institute of Meteorology can be seen as an enabler as it clearly outlines the mandated activities of INAM which are in line with the objective of SOFF.

Table 1. Summary of the standard practices of the GBON regulations.

SLP: Atmospheric pressure (Sea-level pressure); T: Temperature; H: Humidity; W: Wind; P: Precipitation; SD: Snow depth; SST: Sea surface temperature

GBON requirements per station type	GBON Variables						
	SLP	T	H	W	P	SD	SST
• **Surface land stations** Horizontal resolution[1]: 200km • Observing cycle: 1h • Real-time data exchange to WIS	X	X	X	X	X	X	
• **Upper-air stations operated from land** Horizontal resolution**Error! Bookmark not defined.**[4]: 500km • Vertical resolution: 100m, up to 30 hPa • Observing cycle: twice a day • Real-time data exchange to WIS		X	X	X			
• **Surface marine stations in Exclusive Economic Zones**:[2] 500 km	X						X
• **Upper-air stations operated in Exclusive Economic Zones**:[3] 1000 km • **Vertical resolution:** 100m, up to 30 hPa		X	X	X			

[1] 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.

[2] Although GBON marine stations are not part of the SOFF initial scope, peer advisors are encouraged to analyse this as well, when considered relevant e.g., SIDS, the status of current marine stations for future GBON marine observations investment.

[3] Although GBON marine stations are not part of the initial SOFF scope, the peer advisors are encouraged to analyse this as well, when considered relevant e.g., SIDS, the status of current marine stations for future GBON marine observations investments.

Module 1. National Target toward GBON compliance

The results of the GBON Gap Analysis indicated the need to improve 21 Surface land stations and establish and install 4 new upper-air (radiosonde) stations to meet the GBON standard density requirement and to contribute to the international data exchange of hourly observations and 2 upper-air soundings respectively.
The technical and local assessment of the 21 surface stations, however, indicates the need for the improvement of 15 stations and the installation of 6 new stations.

Table 2. GBON National Contribution Target.

Type of station	Baseline (Results of the GBON National Gap Analysis)				GBON National Contribution Target	
	Target (# of stations)	GBON-compliant stations (#)	Gap		To improve	New
			New	To improve		
Surface	21	0	0	21	15	6
Upper-air	4	0	4	0	0	4

Table 3. Compliance criteria for GBON Surface – land stations

Mark	Name	Description	Criteria
S_{SL} 1	**Monthly Availability (%)**	No. of received monthly reports/ (Days per month * 24) Monthly	**≥ 80%**
S_{SL} 2	**Timeliness (%)**	No. of late reports / (Days per month * 24)	**< 5%**
S_{SL} 3	**Monthly Quality (%)**	No. of rejected monthly reports/ (Days per month * 24)	**< 5%**

Table 4. Compliance criteria for GBON Upper-air – land observing station/platform and SOFF threshold.

Mark	Name	Description	Criteria
S_{UA} 1	**Monthly Availability (%)**	No. of received monthly profile (to 30hPa) reports / (Days per month * 2)	**≥ 80%**
S_{UA} 2	**Vertical Resolution (Y/N)**	Vertical resolution is at least 100 m	**Yes**
S_{UA} 3	**Timeliness (%)**	No. of late reports/ (Days per month *2)	**< 5%**
S_{UA} 4	**Monthly Quality (%)**	No. of rejected monthly reports/ (Days per month*2)	**< 5%**

1.1 National GBON Gap Analysis

Table 5. GBON National Contribution Target. (Confirmed by peer Advisor)

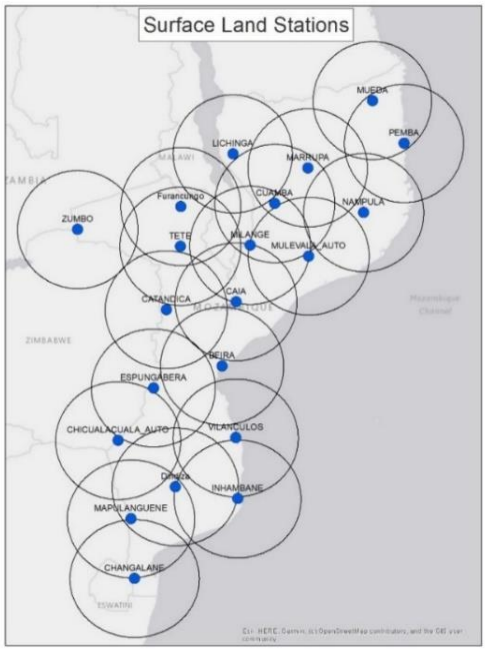
Type of station	Baseline (Results of the GBON National Gap Analysis)			
	Target (# of stations)	GBON-compliant stations (#)	Gap	
			New	To improve
Surface	21	0	0	21
Upper-air	4	0	4	0

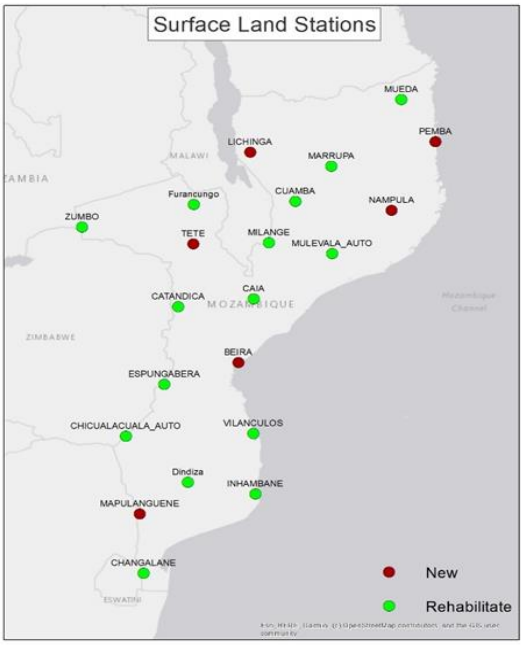
1.2 GBON National Contribution Target

Table 6. Results of the GBON national gap analysis and recommendations on the GBON National Contribution Target

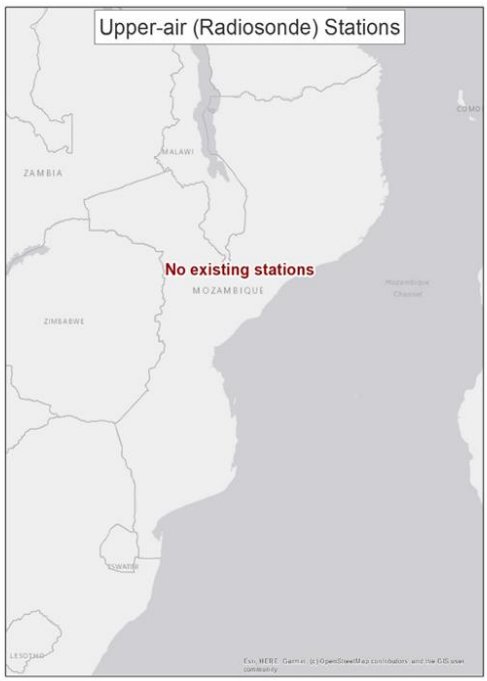
Type of station	Baseline (Results of the GBON National Gap Analysis)				GBON National Contribution Target		GBON Implementation National target based on phased approach (%)						
	Target (# of stations)	GBON-compliant stations (#)	Gap		To improve	New	2023	2024		2025		2026	
			New	To improve			July - December	Jan-June	July - December	Jan-June	July - December	Jan-June	July - December
Surface	21	0	0	21	15	6	25%	25%	50%	75%	≥80%	≥80%	≥80%
Upper-air	4	0	4	0	0	4	n/a	n/a	50%	75%	≥80%	≥80%	≥80%

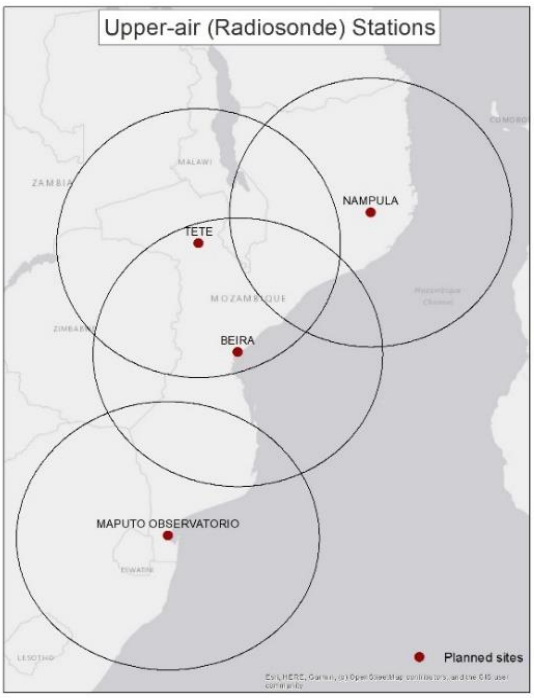
Maps of the surface observing network coverage and indication of required new or to be rehabilitated stations.





Map of the existing upper air observing network and the required new or rehabilitated stations coverage.





Module 2. GBON Business Model and Institutional Development

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

- ***Governmental stakeholders operating and acquiring meteorological observations or with the potential to support GBON;***

  The are several government institutions nationally such as the National Directorate of Water Resource Management under the Ministry of Public Works and Housing and the Ministry of Agriculture who own and operate weather observing stations which are compliant to WMO requirements. Personnel maintaining and managing the said weather stations were trained by the INAM personnel. These government institutions have Memorandums of Understanding (MoUs) with INAM.

- ***Private sector operators providing meteorological observations and data services in the country (for ship-based observations, identify fleet of ships that are government-owned or private and research owned to install instrument packages)***

  Several weather observation stations have been rolled out nationally through partnerships/ funding support from partners with INAM which includes the Japan Cooperation Agency (JICA), World Bank (WB), Food and Agriculture Organization (FAO), Nordic Development Fund (NDF), African Development Bank (ADB), United Nations Development Programme (UNDP) and World Food Programme (WFP). The funding provided was for infrastructure rollout, but no funding for sustainability of the infrastructure, which includes, but is not limited to the provision of spares, accessibility and maintenance of the infrastructure.

  There are potential partners that can contribute to closing GBON gaps nationally should a need for additional stations arise in some areas where INAM have not deployed weather observation stations. They are Maputo National Park and Zinave National Park, both in southern Mozambique.

  Recommendation on how existing and potential partners could contribute to the implementation of the Plan and required activities to materialize the proposed partnerships:

  a. INAM to review the existing MOU with existing partners to include a clause that allows for utilization of their stations to contribute to GBON where necessary, as well as data sharing in line with the WMO universal data policy. Furthermore, to share resources for upgrading maintenance of these stations to be GBON compliant.

  b. INAM to prioritize the development of the National WIGOS implementation plan where all stakeholders owning and operating weather observations infrastructure can be mobilized to contribute to the rollout of the weather infrastructure that will address data needs for all weather-sensitive industries in the country. The said station can be registered to contribute towards GBON compliance within Mozambique.

2.2. Assessment of potential GBON sub-regional collaboration

- Mozambique shares a border with five countries, namely, South Africa, Zimbabwe, Malawi, Eswatini, Tanzania and Zambia. The said countries have been identified as potential sub-regional collaborators for implementation of GBON, especially in closing weather observation gaps along the borders. Through development of Memoranda of Understanding (MoU), with the data sharing as one of the points covered in the MoU, overlapping coverage along the borders can be eliminated. There are several regional organizations / bodies of relevance for implementation of GBON within the sub-region that are leveraged upon for collaboration such as the Southern African Development Community (SADC) Secretariat through its Sub-sectoral Committee on Meteorology (SCOM) and Climate Services Centre (CSC); the Meteorological Association for Southern Africa (MASA), the African Ministerial Community on Meteorology (AMCOMET), which is the body comprising of Ministers responsible for meteorology within the region, Regional WIGOS Centers (RWCs) for Southern and East Africa for data availability and quality, Regional Telecommunication Hub (RTH) - Pretoria for data transmission through the Global Telecommunication System and part of the Global Information System Centre (GISC) for data collection and dissemination to the local and global data collection and producing centers, Regional Instrument Centre (RIC) for maintenance and calibration of observation systems, Regional Training Centers (RTC) for capacity development of Meteorological personnel, just to mention a few.
- South Africa and Tanzania are hosting the RWCs which are operational and in pilot phase and were designated the responsibility to support SADC and East African members in the operation of their weather observation network, in line with the GBON guidelines. Mozambique is one of those members being supported by Regional WIGOS Centre Southern Africa that is hosted by South Africa. Furthermore, there is a Memorandum of Understanding in place between South Africa which can potentially be used as a catalyst towards GBON compliance for Mozambique. Furthermore, South Africa as a RTH and the GISC, which is currently supporting the INAM with data transmission to the GTS. Information and Telecommunications capabilities of South Africa can be leveraged upon to support Mozambique in addressing ICT infrastructure upgrades.
- It is hereby recommended that INAM leverage on regional organizations / bodies of relevance for implementation of GBON within the sub-region, such as (MASA) the Meteorological Association for Southern Africa, (AMCOMET) African Ministerial Community on Meteorology as well as regional Centers to address the GBON requirements within Mozambique. Furthermore, INAM should participation during the development of the Regional WIGOS implementation plan since WIGOS advocated for optimized weather observation coverage and avoidance of duplication of activities regionally.. Existing MoU's with neighboring countries should be reviewed to alignment with WMO Unified Data policy for GBON assigned stations.

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

- The current weather observation infrastructure for INAM is funded through the Mozambique National Government budget. This provided budget covers the entire INAM financial requirement which includes, but is not limited to personnel salaries, maintenance of buildings, communication, travel and accommodation, logistics, maintenance of Weather Observation and Forecasting systems as well as repairs and maintenance of the Information and Technology systems of INAM.
- INAM projected a budget of US $68 628.60 for the current financial year of 2023 for GBON assigned AWS. The projected budget covers preventative maintenance, corrective maintenance, and AWS communication for the 21 AWS allocated for GBON. The budget does not cover spares that are required for the said stations. With inflation, this budget will increase exponentially to US $75 649.13 by year 2 and to US $83 041.84 by year 3. The total projected budget for the medium term is US $227 319.57. This budget further excluded refurbishment of some of the AWS to be GBON compliant and the human capacity requirement to maintain the AWS network operation in accordance with the GBON requirement.
- The "One District, One Weather Station" strategy developed by INAM advocates for decentralization of infrastructure management. Decentralization will minimize reaction time for restoration of non-reporting sites, thus sustaining a high level of data availability which is in line with GBON requirements. There are currently limited human resources for operation and maintenance of the INAM observation infrastructure to meet the GBON requirement. It is highly recommended that, in parallel to the infrastructure deployment plan, a capacity development plan needs to be implemented.
- WIGOS implementation advocates for sharing of resources to minimize duplication. It is recommended that the process to implement WIGOS nationally be initiated to leverage on possible funding from the private sector for the rollout of weather stations that they require which might be co-located with already existing INAM infrastructure. The said funding can then be used to upgrade the existing stations. Partnering with the private sector provides an opportunity to leverage on private sector ability to source required infrastructure faster than the public sector.

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

- The National Institute of Meteorology, abbreviated to INAM, is a public institution of a scientific and technical nature, endowed with legal personality and autonomy to direct meteorological activity at national level, ensuring the inspection and supervision of the operation of the national network of meteorological, agrometeorological, climate and air quality monitoring stations, in collaboration with other State and private entities that operate similar observation networks. **(See Ministerial Diploma No. 67/2016)** for more details.
- INAM developed a national strategy called "A District a Weather Station" aimed at expanding the meteorological observation network to the district level in a phased in approach, targeted for completion by 2030. (See PROGRAM "ONE DISTRICT, ONE WEATHER STATION")

- INAM's Memorandum of Understanding with Agriculture and the Directorate of Water Resources Management make a provision for data access from their Automatic Weather Stations. This provision allows INAM to configure the stations to share data in line with GBON requirements.
- The funding of the infrastructure rolled out through donor funding was not comprehensive as it did not cover the total cost for installation, operation, and maintenance of all observation stations. They were linked to the projects and at the end of the projects, no funding was made available for continuation of maintenance. The Institute of National Meteorological Service is funding the operation of the said stations.

2.5. Review of the national legislation of relevance for GBON

- Chapter 1, Article 3(a) and 3(g) of the Internal Regulation of INAM states " (a) Ensuring the inspection and supervision of the operation of the national network of meteorological, agrometeorological, climate and air quality monitoring stations, in collaboration with other State and private entities that operate similar observation networks" and " (g) Guarantee the observation, transmission, monitoring, archiving and publication of the results of national meteorological and climate observations". The two provisions are more relevant for supporting the operation of the observation networks in line with the GBON requirements. Furthermore, Article (15)(e) of the INAM mandate addresses compliance with the norms and observation methods recommended by the World Meteorology Organization and Article 23 (c) also addresses data communication through the GTS.
- INAM utilizes the approved Regulation Decree no. 79/2022 for Contracting Public Works, Supply of Goods and Provision of Services to the State. As stated in Article 5 of the said regulation, the documents that make up the hiring process public must be written in Portuguese. The Contracting Entity may, simultaneously, disclose the Announcement and Tender Document in Portuguese and in another language, with prevailing documentation having to be in Portuguese.
- The regulation makes provision under Article 8 (b) which reads as follows "(contracting carried out within the scope of projects financed, wholly or substantially, with funds from funding or donations from an official foreign cooperation agency or multilateral financial body, when the adoption of different rules is expressly included as a condition of the respective agreement or contract)."This policy will be the basis for procurement of the required material to upgrade and or install a new station.
- There is an existing Memorandum of Understanding between the World Food Programme and INAM. Within this Memorandum of Understanding is a provision for funds transfer between INAM and WFP. The existing memorandum of understanding between two entities could be considered for accelerating procurement of required equipment to support the SOFF programming of the Institute of the INAM. Furthermore, considering procurement of spares for existing infrastructure, this Memorandum of Understanding can shorten the timeframe for acquisition thereof. The World Food Programme has a dedicated technical department that can be called upon to support large projects such as the upgrading and installation of weather observation infrastructure of INAM.

Module 3. GBON Infrastructure Development

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

The Mozambique National Institute of Meteorology (INAM) operates and maintains 106 Automatic Weather Stations (AWS) deployed nationally as well as 46 manual climate stations. 43 of these AWS are operational but only 14 of these systems transmit data through to the GTS. INAM does not have an operational upper air observing network.

Table 6 below provides the details of the surface- and upper-air observing networks, along with the current station metadata in WMO/OSCAR surface, and an analysis at the time of reports being received at the WMO monitoring centres.

Table 7: Details analysis of the surface- and upper-air observing networks

Network	Current #Stations	OSCAR/Surface		WDQMS
		Declared status	Assessed status	
Surface land	• 106 AWS (43 operational) • 46 Manual synoptic/climate stations	78 Stations • 58 Operational • 20 Closed	78 stations • 4 operational • 26 Partly operational • 2 Silent • 46 Unknown	60 stations • 29 Reporting (>0%) • 31 non-reporting (0%)
Upper-air	0	4 (Planned)	n/a	n/a

The GBON surface and upper air observing network design is based on the WIGOS network design principles and envisage to provide, as best as feasible, a horizontally well distributed network across Mozambique that meets GBON compliance requirements.

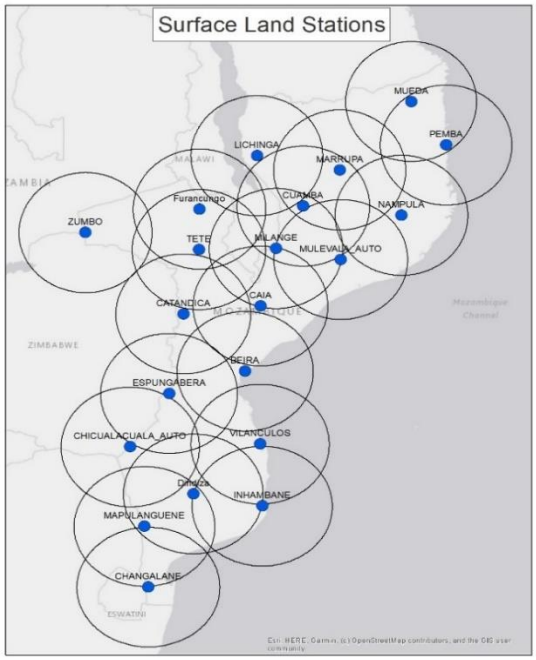
3.1.1 Surface land observing network and observational practices

The global gap analysis developed and provided by WMO to the Institute of National Meteorological Service estimated the need for 20 GBON surface land stations for standard density to meet the horizontal resolution requirement. The results from the GBON national gap analysis conducted in May 2023 however indicates the need for 21 surface land stations to potentially be included in the national GBON network. The additional station will close the gap in the southeastern part of Zambezia province.

Installation of 19 of the 21 automatic weather stations was funded by the Japan Cooperation Agency (JICA), World Bank (WB), Food and Agriculture Organization (FOA), Southern African Development Community (SADC), Nordic Development Fund (NDF), African Development Bank (AfDB), and the United Nations Development Programme (UNDP), respectively. It should however be noted that the funding did not include sustainable operation of the said installations.

It should be noted that INAM currently does not have upper-air stations.

a. Maps of the surface observing network and the list of the required new or rehabilitated stations



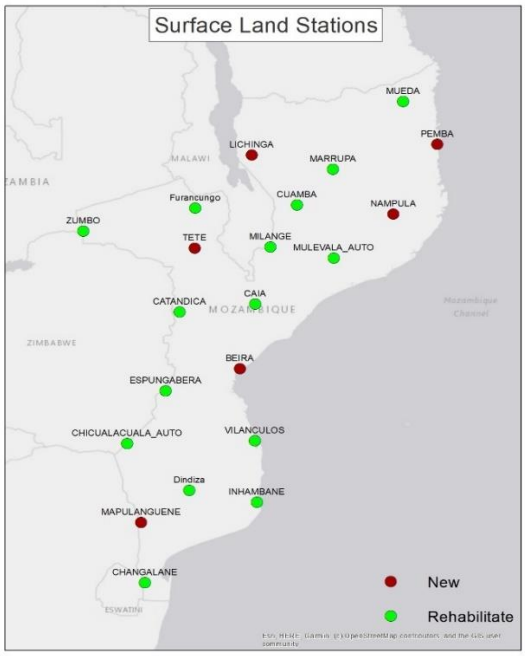


Table 8: List of the new or rehabilitated surface land observing stations.

Station name	WIGOS-ID	Station type (S/UA)	Owner (NMHS/3rd Party)	Funding source	Type	Installation date	Required
BEIRA	0-20000-0-67297	S	NMHS	JICA	AWS	2017	New
CAIA	0-20000-0-67280	S	NMHS	WB	AWS	2019	Rehabilitate
CATANDICA	0-20000-0-67291	S	NMHS	FAO	AWS	2023	Rehabilitate
CHANGALANE	0-20000-0-67346	S	NMHS	FAO	AWS	2022	Rehabilitate
CHICUALACUALA_AUTO	0-20000-0-67303	S	NMHS	FAO	AWS	2022	Rehabilitate
CUAMBA	0-20000-0-67231	S	NMHS	WB	AWS	2019	Rehabilitate
Dindiza	0-20000-0-67309	S	NMHS	WB	AWS	2019	Rehabilitate
ESPUNGABERA	0-20000-0-67301	S	NMHS	FAO	AWS	2023	Rehabilitate
Furancungo	0-20000-0-67225	S	NMHS	FAO	AWS	2023	Rehabilitate
INHAMBANE	0-20000-0-67323	S	NMHS	WB	AWS	2019	Rehabilitate
LICHINGA	0-20000-0-67217	S	NMHS	WB	AWOS	2019	New
MAPULANGUENE	0-20000-0-67331	S	NMHS	SADC	AWS	2020	New
MARRUPA	0-20000-0-67221	S	NMHS	WB	AWS	2019	Rehabilitate
MILANGE	0-20000-0-67260	S	NMHS	BAD	AWS	2019	Rehabilitate
MUEDA	0-20000-0-67201	S	NMHS	FAO	AWS	2022	Rehabilitate
NAMPULA	0-20000-0-67237	S	NMHS	JICA	AWS	2017	New
PEMBA	0-20000-0-67215	S	NMHS	UNDP	AWS	2015	New
TETE	0-20000-0-67261	S	NMHS		Manual		New
VILANCULOS	0-20000-0-67315	S	NMHS	NDF	AWS	2021	Rehabilitate
ZUMBO	0-20000-0-67243	S	NMHS	WB	AWS	2019	Rehabilitate
MULEVALA_AUTO	0-508-0-67281	S	NMHS	INAM	AWS	2023	Rehabilitate

b. List of observation instruments and systems per site

A technical assessment of the 21 surface land stations identified for GBON indicated that 20 of the stations are Automatic Weather Stations and 1 station, Tete, is a manual climate station. It was also found that 7 stations have data loggers with the FTP data transfer protocol whereas 13 stations have the FTP, MQTT and SFTP data transfer protocol, respectively. MQTT and SFTP data transfer protocol are required for the implementation of WIS 2.0.

Table 9: List of observation instruments and systems per site

Station name	Atmospheric Pressure	Air Temperature	Humidity (RH)	Horizontal Wind Direction	Horizontal Wind Speed	Precipitation Amount/ Intensity	Data Logger: Data transfer protocol
BEIRA	✓	✓	✓	✓	✓	✓	*FTP*
CAIA	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
CATANDICA	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
CHANGALANE	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
CHICUALACUALA_AUTO	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
CUAMBA	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
Dindiza	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
ESPUNGABERA	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
Furancungo	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
INHAMBANE	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
LICHINGA	✓	✓	✓	✓	✓	✓	*FTP*
MAPULANGUENE	✓	✓	✓	✓	✓	✓	*FTP*
MARRUPA	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
MILANGE	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
MUEDA	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
NAMPULA	✓	✓	✓	✓	✓	✓	*FTP*
PEMBA	✓	✓	✓	✓	✓	✓	*FTP*
TETE	*X*	*X*	*X*	*X*	*X*	*X*	*Manual*
VILANCULOS	✓	✓	✓	✓	✓	✓	*FTP*
ZUMBO	✓	✓	✓	✓	✓	✓	*FTP, MQTT and SFTP*
MULEVALA_AUTO	✓	✓	✓	✓	✓	✓	*FTP*

Sensors

The technical evaluation of the sensors indicated that none of the 21 stations meet the recommended measurement range for air temperature and precipitation parameters.

Table 10: Sensor Compliance analysis

Station name	Atmospheric Pressure	Air Temperature	Humidity (RH)	Horizontal Wind Direction	Horizontal Wind Speed	Precipitation Amount/ Intensity
	500 – 1080 hPa	-80 °C to +60 °C	0-100 %RH	0-360 degrees	Max: 0-75 m/s Extended: 0-100 m/s	0-500mm/hr
BEIRA	✓	X	✓	✓	✓	X
CAIA	✓	X	✓	✓	✓	X
CATANDICA	✓	X	✓	✓	✓	X
CHANGALANE	✓	X	✓	✓	✓	X
CHICUALACUALA_AUTO	✓	X	✓	✓	✓	X
CUAMBA	✓	X	✓	✓	✓	X
Dindiza	✓	X	✓	✓	✓	X
ESPUNGABERA	✓	X	✓	✓	✓	X
Furancungo	✓	X	✓	✓	✓	X
INHAMBANE	✓	X	✓	✓	✓	X
LICHINGA	✓	X	✓	✓	✓	X
MAPULANGUENE	✓	X	✓	✓	✓	X
MARRUPA	✓	X	✓	✓	✓	X
MILANGE	✓	X	✓	✓	✓	X
MUEDA	✓	X	✓	✓	✓	X
NAMPULA	✓	X	✓	✓	✓	X
PEMBA	✓	X	✓	✓	✓	X
TETE	X	X	X	X	X	X
VILANCULOS	✓	X	✓	✓	✓	X
ZUMBO	✓	X	✓	✓	✓	X
MULEVALA_AUTO	✓	X	✓	✓	✓	X

The air temperature and precipitation sensors will be replaced with sensors that meet GBON requirements during maintenance and break-down response activities.

Other components

The physical assessment of the other components indicated that all surface land stations are using solar power and that the communication technology at all stations needs to be attended to.

Table 11: Other Installed AWS components

Station name	AWS cabinet	Power / mains	Solar panel	Battery	Lightning Protection	Grounding systems	Junction and terminal boxes	Cables, wires, connectors	Communication (Sim cards and airtime, modem etc)
BEIRA	✓	X	X	X	X	✓	X	✓	X
CAIA	✓	X	✓	✓	✓	✓	✓	✓	X
CATANDICA	✓	X	✓	✓	✓	✓	✓	✓	X
CHANGALANE	✓	X	✓	✓	✓	✓	✓	✓	X
CHICUALACUALA_AUTO	✓	X	✓	✓	✓	✓	✓	✓	X
CUAMBA	✓	X	✓	✓	✓	✓	✓	✓	X
Dindiza	✓	X	✓	✓	✓	✓	✓	✓	X

ESPUNGABERA	✓	X	✓	✓	✓	✓	✓	✓	X
Furancungo	✓	X	✓	✓	✓	✓	✓	✓	X
INHAMBANE	✓	X	✓	✓	✓	✓	✓	✓	X
LICHINGA	X	X	X	X	X	X	X	X	X
MAPULANGUENE	X	X	✓	✓	✓	✓	✓	✓	X
MARRUPA	✓	X	✓	✓	✓	✓	✓	✓	X
MILANGE	✓	X	✓	✓	✓	✓	✓	✓	X
MUEDA	✓	X	✓	✓	✓	✓	✓	✓	X
NAMPULA	X	X	X	X	X	X	X	X	X
PEMBA	✓	X	✓	✓	✓	✓	✓	✓	X
TETE	X	X	X	X	X	X	X	X	X
VILANCULOS	✓	X	X	X	✓	✓	X	X	X
ZUMBO	✓	X	✓	✓	✓	✓	✓	✓	X
MULEVALA_AUTO	✓	X	✓	✓	✓	✓	✓	✓	X

Other components will be installed as part of the rehabilitation of existing stations.

Masts, Stands, Fencing and Security

The assessment of the masts, stands, fencing and security indicated the need for the installation of fences at Vilanculos, Zumbo and Mulevala-Auto. There is also a need for solar panel brackets to be installed at all sites for increased security and prevention of vandalism of the stations.

Table 12: Masts, Stands, Fencing and Security

Station name	Wind mast	Temperature/Humidity stand	Rain gauge stand	Fencing	Material for Solar panel bracket (Security)
BEIRA	*x*	*x*	✓	✓	*x*
CAIA	✓	✓	✓	✓	*x*
CATANDICA	✓	✓	✓	✓	*x*
CHANGALANE	✓	✓	✓	✓	*x*
CHICUALACUALA_AUTO	✓	✓	✓	✓	*x*
CUAMBA	✓	✓	✓	✓	*x*
Dindiza	✓	✓	✓	✓	*x*
ESPUNGABERA	✓	✓	✓	✓	*x*
Furancungo	✓	✓	✓	✓	*x*
INHAMBANE	✓	✓	✓	✓	*x*
LICHINGA	*x*	*x*	*x*	✓	*x*
MAPULANGUENE	✓	✓	✓	✓	*x*
MARRUPA	✓	✓	✓	✓	*x*
MILANGE	✓	✓	✓	✓	*x*
MUEDA	✓	✓	✓	✓	*x*
NAMPULA	*x*	✓	✓	✓	*x*
PEMBA	✓	✓	✓	✓	*x*
TETE	*x*	*x*	*x*	✓	*x*
VILANCULOS	✓	✓	✓	*x*	*x*
ZUMBO	✓	✓	✓	*x*	*x*
MULEVALA_AUTO	✓	✓	✓	*x*	*x*

Masts, Stands, Fencing and Security will be installed as part of the rehabilitation of existing stations.

Table 13: Summarised AWS site assessment

GBON New infrastructure

Station name	Type	Installation date	Action required	Comment
BEIRA	AWS	2017	New	Station to be replaced to meet GBON requirements
LICHINGA	AWOS	2019	New	AWOS cannot be configured for hourly data dissemination
MAPULANGUENE	AWS	2020	New	All-in-one station – does not meet GBON requirements
NAMPULA	AWS	2017	New	Station to be replaced to meet GBON requirements
PEMBA	AWS	2015	New	Station to be replaced to meet GBON requirements
TETE	Manual		New	Automation of Manual/Climate station

GBON existing infrastructure

Station name	Type	Installation date	Action required	Comment
CAIA	AWS	2019	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
CATANDICA	AWS	2023	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
CHANGALANE	AWS	2022	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
CHICUALACUALA_AUTO	AWS	2022	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
CUAMBA	AWS	2019	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
Dindiza	AWS	2019	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
ESPUNGABERA	AWS	2023	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
Furancungo	AWS	2023	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
INHAMBANE	AWS	2019	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
MARRUPA	AWS	2019	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
MILANGE	AWS	2019	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
MUEDA	AWS	2022	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
VILANCULOS	AWS	2021	Rehabilitate	Upgrade data logger, wires and cables to meet MQTT/SMTP data transfer protocol, Replace solar panel and battery, Replace junction and terminal boxes, Attend to communication (e.g., data transfer, sim card, airtime), Install a new fence
ZUMBO	AWS	2019	Rehabilitate	Attend to communication (e.g., data transfer, sim card, airtime)
MULEVALA_AUTO	AWS	2023	Rehabilitate	Upgrade data logger, wires and cables to meet MQTT/SMTP data transfer protocol, Attend to communication (e.g., data transfer, sim card, airtime), Install new fence

c. Investments and activities needed for the installation of new stations and the improvement of existing stations.

The technical and local assessment of the 21 GBON surface land stations against the GBON Tender Specifications for AWSs indicates the investments activities needed for the installation of new stations and the improvement of existing stations.

Table 14: AWS sites investment proposal

Activity #	Activity	Quantity	Costing USD ($)
1.	Installation of New AWS	6	107 192
2.	Rehabilitate/modernize/replace data loggers to meet MQTT and SFTP data transfer protocol requirement. Rewiring of AWS required	2	5 560
3.	Upgrade of Air temperature sensors that do not meet required measurement range	15	7 170
4.	Upgrade of precipitation amount/intensity sensors that do not meet required measurement range	15	14 175
5.	Replacement of solar panels	1	135
6.	Replacement of batteries	1	146
7.	Replacement/installation of lightning protection unit	1	150
8.	Replacement of junction and terminal boxes	1	650
9.	Upgrade communication at all sites (sim cards and data/air-time)	21	9508
10.	Replacement/rehabilitation of fences	3	1212
11.	Material to build solar panel brackets as part of the security upgrade (21 stations)		0
12.	Labour accommodation, flight and per diem should external services be required)	4	39051

Other investment related to the surface observation network.

Table 15: Welding equipment for fences, stands and solar panel brackets.

Activity#	Activity	Quantity	Costing USD ($)
1.	Welding machine	1	783
2.	Angle grinder	1	180
3.	Drill	1	180
4.	Bench vice	1	90
5.	Ironwork toolkit	1	680
6.	Pipe wrenches (small, medium, large)	1	150
7.	Mallets (small, medium, large)	1	100
8.	Ear Hammer	1	50

Table 17: Activity Plan for new and rehabilitated surface observing network

#	Activity	Start date	End date	YEAR 1 (2024)				YEAR 2 (2025)				YEAR 3 (2026)			
				JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND
1.	**New GBON surface observing stations**														
1.1	Procurement of new AWSs	2024-01-01	2024-06-30	■	■										
1.2	Site identification, evaluation, and preparation for installation of new stations	2024-07-01	2025-12-31			■	■	■	■	■	■				
1.3	Deployment of 6 new AWSs with fencing and security	2024-07-01	2025-12-31			■	■	■	■	■	■				
2.	**Rehabilitate existing GBON surface observing stations**														
2.1	Procurement of components and peripherals to rehabilitate stations	2024-01-01	2024-06-30	■	■										
2.2	Rehabilitate/modernize/replace data loggers to meet MQTT and SFTP data transfer protocol requirement. Rewiring of AWS required	2024-07-01	2024-12-31			■	■								
2.3	Upgrade communication at all sites (sim cards and data/air-time)	2024-07-01	2024-12-31			■	■	■	■	■	■				
2.4	Site evaluation and deployment/Installation of components, peripherals, fencing and security features	2024-07-01	2025-12-31			■	■	■	■	■	■				
2.5	Upgrade of Air temperature sensors that do not meet required measurement range	2024-07-01	2026-12-31			■	■	■	■	■	■	■	■	■	■
2.6	Upgrade of precipitation amount/intensity sensors that do not meet required measurement range	2024-07-01	2026-12-31			■	■	■	■	■	■	■	■	■	■

d. Observational practices for the surface observing network.

The optimal performance of a surface observing network depends on the skills, training, and competencies of the staff responsible for installation of instruments and communication systems, maintenance of instruments and system performance, fault diagnostics, the repair of faulty instruments and systems and the monitoring of performance of instruments and communication systems.

Equally important is the understanding of meteorological instruments and methods of observations, the site classification for variables, performance of preventative and corrective maintenance on instruments and systems in accordance with Standard Operating Procedures (SOPs) to ensure quality and availability of observations and the calibration of instruments and metadata management.

It is therefore recommended that the INAM staff responsible for the GBON Surface land stations receive training of the installation and management of AWSs. Equally important is the understanding of meteorological instruments and methods of observations, the site classification for variables, performance of preventative and corrective maintenance on instruments and systems in accordance with Standard Operating Procedures (SOPs) to ensure quality and availability of observations and the calibration of instruments and metadata management.

It is therefore recommended that the INAM staff responsible for the GBON Surface land stations receive training of the installation and management of AWSs, fault diagnostics and the repair of faulty instruments and systems.

e. Preliminary maintenance plan for existing and improved new stations, including calibration practices network.

To maintain the quality of meteorological observations made by meteorological stations, at the level of standards established by the World Meteorological Organization (WMO), throughout their lifetime, a maintenance plan for meteorological stations was developed for the INAM GBON surface land stations. The efficiency in the maintenance of the meteorological stations will depend on the existence of qualified technicians, accessories, and maintenance tools, allocated to the Provincial Meteorology Delegations as well as to the Regional Maintenance Centres of INAM.

INAM has been managing the current observations infrastructure to ensure data availability for national and international exchange with limited resources. The country has been impacted negatively by natural forces that rendered accessibility of the surface observation networks difficult. GBON places stringent requirements of data availability and quality which cannot be met with the current resources. It is highly recommended that during this process, capacity to move from point A to point B is enhanced to ensure compliance with GBON requirements. Furthermore, the country is vast and the timeline for restoration of stations is short. The technical capability is currently at the Head Quarters, which is also limited, considering the distance that should be covered to maintain/ repair the observation infrastructure. Calibration of the

test instrument test chambers requires them to be exported, resulting in extended periods without requisite systems to validate the correctness of the field test equipment. Capacity to be able to operate optimally when one chamber is out for calibration needs to be enhanced.

The planned maintenance intervals and activities of INAM is defined for each observing system and individual sensors and components, in accordance with WMO and INAM manuals, guides and SOPs or as recommended by the manufacturers or suppliers.

Preventative and corrective maintenance

The INAM plans to implement a preventative maintenance schedule of 90 days for GBON stations in accordance with their national operations and the available resources. Corrective maintenance activities are performed to fix the technical or communication failures of the GBON stations. It is anticipated to attend to system breakdowns within 5 days to ensure that the station meets the WMO and National monthly data availability performance target.

Currently all maintenance activities are done by the technical team located at the INAM Head Quarters in Maputo with support from a maintenance technician located at Sofala. This plan seeks for the preventative and corrective maintenance to be conducted by the maintenance personnel located at the Provincial offices and the advanced fault diagnostics to be performed by the technologist from the Regional Maintenance Centres. The preventative maintenance may also include field calibration activities.

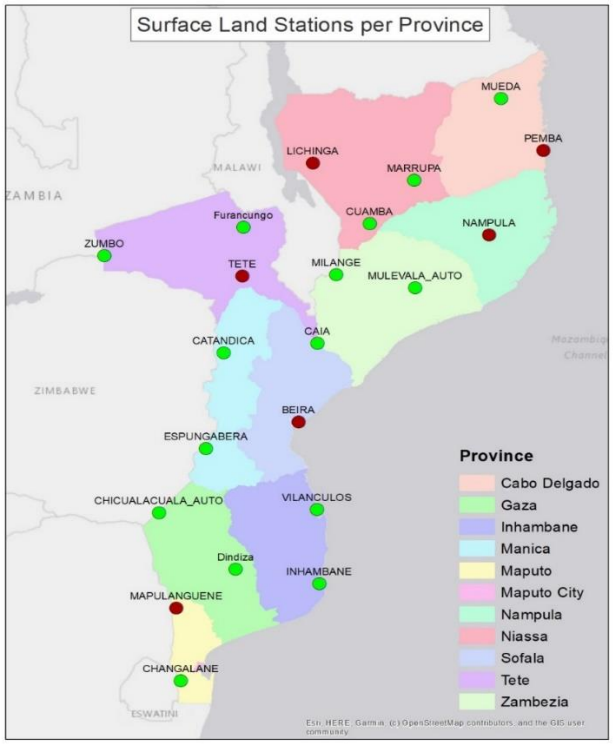


Table: 18: Stations with Regional Maintenance Centre allocation (planned)

Provinces	Stations	Regional Maintenance Centre (Planned)
Cabo Delgado	Mueda	Nampula
	Pemba	Nampula
Gaza	Chicualacuala_Auto	Maputo
	Dindiza	Maputo
Inhambane	Inhambane	Maputo
	Vilanculos	Beira
Manica	Catandica	Beira
	Espungabera	Beira
Maputo/Maputo City	Changalane	Maputo
	Mapulanguene	Maputo
Nampula	Nampula	Nampula
Niassa	Cuamba	Nampula
	Lichinga	Nampula
	Marrupa	Nampula
Sofala	Beira	Beira
	Caia	Beira
Tete	Furancungo	Beira
	Tete	Beira
	Zumbo	Beira
Zambezia	Milange	Nampula
	Mulevala-Auto	Nampula

Table 19: Maintenance type and interval

Maintenance type	Location	Responsible person	Interval (Days)
Preventative maintenance/field calibration	Locally (on-site)	Maintenance technician	90 days
Corrective maintenance	Locally (on-site) Remotely/off-site	Maintenance technician Technologist	Within 5 days

Calibration

There are two types of calibration of measuring instruments of GBON stations, namely laboratory calibration and field calibration with laboratory calibration performed in a laboratory operated in accordance with IEC/ISO 17025. The national or international measurement and traceability standards should be used to perform the required calibrations. Field calibrations are conducted for certain sensors by using the field calibration equipment. All field calibration equipment should be calibrated in a laboratory at defined intervals, for ensuring credible measurements and traceability.

INAM has a laboratory that is equipped with a climate chamber for the calibration of temperature and humidity sensors as well as a calibrator for atmospheric pressure sensor calibrations. It is planned that all laboratory calibration for GBON temperature, humidity and pressure sensors will be performed at the

Maputo Head Office. There is however a need for the calibration and rectification of the laboratory calibrators.

Table 20: Laboratory calibration equipment

Calibrator	Sensors	Date purchased	Date of last calibration	Condition
Climate chamber	Temperature Humidity	10/2015	10/2015	Good
Pressure	Atmospheric pressure	10/2015	10/2015	Good

Table 21: Field Calibration Equipment

Equipment#	Test equipment	Sensors	Quantity
1.	Temperature/Humidity sensor	Temperature/Humidity	6
2.	Radiation shield	For Temperature/humidity sensor	6
3.	Barometric Pressure Transfer standard	Atmospheric pressure	6
4.	Rain gauge field calibration device	Precipitation	
5.	Anemometer drive Propeller torque disc Vane Angle Bench stand Vane Torque gauge	For wind verification	3

Maintenance schedule

The implementation of the maintenance plan is subject to the availability of the field test equipment, transportation, and human resources.

- Year 1 (2024): All field calibrations will be conducted by the Maputo HQ personnel.
- Year 2 (2025) and Year 3 (2026): Maintenance activities will be decentralised to include Beira and Napula as Regional Maintenance Centres. The field calibrations will be conducted by the allocated Regional Maintenance Centre.

The planned maintenance schedule for the GBON surface land stations will be conducted as follows:

Table 22: Maintenance schedule

Stations	YEAR 1 (2024)												YEAR 2 (2025)												YEAR 3 (2026)											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Mueda						M			M			M			N			N			N			N			N			N			N			N
Pemba						M			M			M			N			N			N			N			N			N			N			N
Chicualacuala_Auto						M			M			M			M			M			M			M			M			M			M			M
Dindidza						M			M			M			M			M			M			M			M			M			M			M
Inhambane						M			M			M			M			M			M			M			M			M			M			M
Vilanculos						M			M			M			B			B			B			B			B			B			B			B
Catandica						M			M			M			B			B			B			B			B			B			B			B
Espungabera						M			M			M			B			B			B			B			B			B			B			B
Changalane						M			M			M			M			M			M			M			M			M			M			M
Mapulanguene						M			M			M			M			M			M			M			M			M			M			M
Nampula						M			M			M			N			N			N			N			N			N			N			N
Cuamba						M			M			M			N			N			N			N			N			N			N			N
Lichinga						M			M			M			N			N			N			N			N			N			N			N
Marrupa						M			M			M			N			N			N			N			N			N			N			N
Beira						M			M			M			B			B			B			B			B			B			B			B
Caia						M			M			M			B			B			B			B			B			B			B			B
Furancungo						M			M			M			B			B			B			B			B			B			B			B
Tete						M			M			M			B			B			B			B			B			B			B			B
Zumbo						M			M			M			B			B			B			B			B			B			B			B
Milange						M			M			M			N			N			N			N			N			N			N			N
Mulevala-Auto						M			M			M			N			N			N			N			N			N			N			N

Regional Maintenance Centre: Beira (B), Maputo (M), Nampula (N)

Maintenance cost (USD)

Table 23: Preventative maintenance

Station	Year 1	Year 2	Year 3	Year 4	Year 5	5 Year Total
Mueda	2614	761	837	921	1013	**6145**
Pemba	2457	554	610	671	738	**5030**
Chicualacuala_Auto	544	726	798	878	966	**3911**
Dindidza	371	495	544	598	658	**2667**
Inhambane	486	647	712	783	862	**3490**
Vilanculos	725	624	687	756	831	**3623**
Catandica	1320	477	525	578	635	**3535**
Espungabera	865	600	660	726	799	**3650**
Changalane	106	142	156	172	189	**764**
Mapulanguene	245	327	360	396	436	**1764**
Nampula	2050	0	0	0	0	**2050**
Cuamba	1971	477	525	578	635	**4186**
Lichinga	2323	946	1041	1145	1260	**6715**
Marrupa	2208	793	873	960	1056	**5891**
Beira	1156	0	0	0	0	**1156**
Caia	1358	376	413	454	500	**3101**
Furancungo	775	1033	1136	1250	1375	**5568**
Tete	606	808	889	978	1076	**4357**
Zumbo	1611	1481	1630	1793	1972	**8487**
Milange	1669	792	871	958	1054	**5344**
Mulevala-Auto	1748	470	517	569	626	**3929**
Total	**27207**	**12531**	**13785**	**15164**	**16680**	**85366**

Table 24: Corrective Maintenance (Break-down response)

Station	Year 1	Year 2	Year 3	Year 4	Year 5	5 Year Total
Mueda	784	228	251	276	304	**1844**
Pemba	737	166	183	201	221	**1509**
Chicualacuala_Auto	163	218	239	263	290	**1173**
Dindidza	111	149	163	180	197	**800**
Inhambane	146	194	214	235	258	**1047**
Vilanculos	218	187	206	227	249	**1087**
Catandica	396	143	158	173	191	**1060**
Espungabera	260	180	198	218	240	**1095**
Changalane	32	43	47	51	57	**229**
Mapulanguene	74	98	108	119	131	**529**
Nampula	615	0	0	0	0	**615**
Cuamba	591	143	158	173	191	**1256**
Lichinga	697	284	312	344	378	**2014**
Marrupa	662	238	262	288	317	**1767**
Beira	347	0	0	0	0	**347**
Caia	407	113	124	136	150	**930**
Furancungo	233	310	341	375	412	**1670**
Tete	182	242	267	293	323	**1307**
Zumbo	483	444	489	538	592	**2546**
Milange	501	238	261	287	316	**1603**
Mulevala-Auto	524	141	155	171	188	**1179**
Total	**8162**	**3759**	**4136**	**4549**	**5004**	**25610**

Table 25: Spares for surface land stations

Item	Unit Price (USD)	Quantity p/a	Year 1	Year 2	Year 3	Year 4	Year 5	Total (USD)
Automatic Weather Stations (Spare parts)								
Datalogger (Data Collection Unit)	2780	5	13 900	15290	18072	19879	21867	**89008**
Air temperature and humidity sensor	780	5	3900	4290	4719	5191	5710	**23810**
Radiation Shield with bracket	168	5	840	924	1092	1201	1321	**5379**
Precipitation sensor	384	5	1920	2112	2323	2555	2811	**11721**
Wind Speed Sensor Wind Direction Sensor	993	5	4965	5465	6012	6613	7275	**30330**
Pressure Sensor	2690	5	13450	14795	16275	17903	19693	**82115**
Wind Mast	2069	5	10345	11250	12375	13613	14974	**62556**
Stands (temperature/humidity, precipitation, radiation)	104	5	520	572	629	692	761	**3174**
Solar Power supply – solar module with mountings 12V 50W	105	5	525	578	636	700	770	**3208**
12V 33AH Battery with F11 terminals	141	5	705	776	854	939	1033	**4308**
Power regulator	84	5	420	462	508	559	615	**2563**
16 or 32 Channel Relay Multiplexer	890	5	4450	4895	5385	5924	6516	**27169**
Modem 4G LTE CAT1 Cellular module	575	5	2875	3163	3480	3828	4211	**17557**
Antenna	26	5	130	143	169	186	204	**832**
Other components								
Lightning protection units	10	5	50	55	61	67	73	**305**
Grounding systems	26	5	130	143	157	173	190	**794**
AWS cabinet with mountings and battery holder	262	5	1310	1441	1585	1744	1918	**7997**
Junction and terminal boxes	101	5	505	556	611	672	739	**3083**
Cables, wires, connectors	50	5	250	275	303	333	366	**1526**
Sub Total								**377437**

Maintenance Tools and Test Equipment								
Field test equipment (for sensors and data logger) - travel standard	9000	8	54000	0	0	0	0	**72000**
Office test equipment (for sensors and data logger) – office standard	9000	8	54000	0	0	0	0	**72000**
Tool set for maintenance (Cutter, allen key set, screwdriver, crescent wrench, open ended wrench, wrench set, cable stripper, etc.)	525	4	2100	0	0	0	0	**2100**
Multimeter (travel standard)	350	4	1400	0	0	0	0	**1400**
Multimeter (office standard)	350	4	1400	0	0	0	0	**1400**
Ground Resistance Meter	350	4	1400	0	0	0	0	**1400**
Others								
Oscilloscope	265	4	1060					**1060**
Calibration/recertification of Calibrators	2274	14	31836	35019.6	38522	42374	46611	**194362**
Total								**723159**

Table 26: Activity Plan for maintenance of surface observing network

#	Activity	Start date	End date	YEAR 1 (2024)				YEAR 2 (2025)				YEAR 3 (2026)			
				JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND
1.	**Maintenance of the surface observing stations**														
1.2	Procurement of maintenance tools and test equipment	2024-01-01	2024-06-30												
1.2	Procurement of AWS Spare parts and components	Q1 of Year	Q2 of Year												
1.3	Procurement of Calibration/recalibration services for field test equipment	Q1 of Year	Q2 of Year												
1.4	Procurement of Calibration/recalibration services for Calibrators	Q1 of Year 1 and Year 3	Q1 of Year 1 and Year 3												

f. Technical specifications for new instruments and observing systems for the procurement process.

Table 27: Atmospheric Pressure

ID	Requirement Heading	Requirement
27	Measurement Range	The measurement range must be 500 – 1080 hPa (for both station pressure and mean sea level pressure). [The NMHS may adapt this range in response to expected pressure range for the installation region]
29	Sensor Performance Constant	The instrument time constant, under controlled conditions must be 2s or shorter.
31	Operational Conditions	As a minimum, the equipment installed outdoors must be capable of operating in a Temperature Range [-40 °C to +55 °C], Humidity Range [0-100 %RH, Non-condensing] and Wind Speed up to 50 m/s. Resistance to (vibration) shocks must be included. A NMHS may modify this requirement to meet meteorological conditions normally expected.
508 (and 40)	Achievable Sensor Uncertainty	The sensor uncertainty must be 0.15 hPa or better. For the tendency it must be equal or better than 0.2 hPa. Maximum difference: 0.3 hPa/year [Normal Use]. No more than 0.3 hPa/30 °C temperature change. For the tendency it must be equal or better than 0.2 hPa. Hysteresis less than 0.3 after change of 50 hPa and back again.
42	Static Head	To achieve the required uncertainty of the pressure measurements, a static head should be used. If used, the static head should be located in an open environment, not affected by the proximity of buildings. The supplier should provide documentation specifying any additional uncertainty introduced by the use of their static head.
502	Sensor Type	The sensor/instrument for measuring pressure must be based on an electronic pressure sensor. However, any sensor type compliant with the requirements in this section must be considered.
524	Temperature Correction in Calibration	If the instrument is applying a correction for the ambient air temperature (measured internally or with a separate thermometer), the temperature compensation function should be fully taken into account in the calibration procedure.
28	Reporting Resolution	The resolution of reported measurement and tendency must be 0.1 hPa.
30	Sampling Frequency	The pressure should be sampled at least 4 times over the interval of the sensor time constant. For example, if the sensor time constant is 2 seconds, then there should be a sample at least every 0.5 s.
56	Units	Whatever physical quantity measured; pressure must be presented in/by the instrument/ system in hectopascals (hPa).
32	Calculated Parameters	Averages of all valid samples of pressure must be produced over 1-minute intervals. The 1-minute average must be used as the instantaneous value for pressure.
35	Rate of Change Check	After each signal measurement, the current value should be compared to the preceding one. If the difference between two

		samples is more than 0.3 hPa, the current sample is identified as suspect and is not used for the computation of an average.
38	Stuck Sensor	If over a 60-minute interval the value of 1-minute values of pressure have not changed by 0.1 hPa, then the data should be flagged as suspect for further investigation.
39	Jump Check	If the difference between consecutive 1-minute averages is more than 0.5 hPa, then the data should be flagged as suspect for further investigation. If the difference is more than 2 hPa, then the data should be flagged as erroneous for further investigation.
949	Derived Parameters	The pressure tendency should be determined using the difference between the current pressure measurement, and the pressure values over the previous 3 hours
1015	Derived Parameters 2	The NMHS may request that QFE and QNH be calculated by the sensor, as well as statistics (maximum, minimum, standard deviation) to meet local or Regional Association requirements. These should be outlined here.
1123	Derived Parameters 3	A Mean Sea Level should be determined, and WGS-84/EGM96 be applied to determine the altitude (to which the station pressure relates) with respect to Mean Sea Level

Table 28: Air Temperature

ID	Requirement Heading	Requirement
1	Measurement Range	The measurement range must be -80 °C to +60 °C.
4	Sensor Performance Constant	The instrument time constant under controlled conditions must be 20 s or shorter over the entire operational range. For field measurements in non-actively aspired radiation screens this may not be achievable.
6	Operational Conditions	As a minimum, the equipment installed outdoors must be capable of operating in a Temperature Range [-40 °C to +55 °C], Humidity Range [0-100 %RH, Non-condensing] and Wind Speed up to 50 m/s. Resistance to (vibration) shocks must be included. A NMHS may modify this requirement to meet meteorological conditions normally expected.
25	Sources of Error	The Tendered equipment must demonstrate that the following common sources of error have been adequately compensated for: a) Self heating of the thermometer element b) Inadequate compensation for lead resistance c) Inadequate compensation for non-linearities in the sensor or processing instrument d) Sudden changes in switch contact resistance.
400	Achievable Sensor Uncertainty	The sensor uncertainty must be 0.2 ºC or better.
2	Units	Whatever physical quantity is measured Air Temperature must be presented in/by the instrument/system in degrees Celsius (°C).
3	Reporting Resolution	The resolution of the reported temperature must be 0.1 °C.

5	Sampling Frequency	The air temperature should be sampled at least 4 times over the interval of the sensor time constant. For example, if the sensor time constant is 20 seconds, then there should be a sample at least every 5 seconds,
7	Calculated Parameters	Averages of all valid samples of Air Temperature must be produced over 1-minute intervals. The 1-minute average must be used as the instantaneous value for air temperature.
8	Observation Extremes	The maximum and minimum temperature 1-minute (average) temperature values measured over a 24-hour period must be determined [=daily maximum/minimum]. The time of occurrence must also be stored.
34	Rate of Change Check	After each signal measurement, the current value should be compared to the preceding one. If the difference between two samples is more than 2 °C, the current sample is identified as suspect and is not used for the computation of an average.
36	Jump Check	If the difference between consecutive 1-minute averages (calculated one minute apart) is more than 3 °C, then the data should be flagged as suspect for further investigation. If the difference is more than 10 °C, then the data should be flagged as erroneous for further investigation.
37	Stuck Sensor	If over a 60-minute interval the value 1-minute values of air temperature have not changed by 0.1 °C, then the data should be flagged as suspect for further investigation.
1012	NMHS Calculated Parameters	Additional Air Temperature Statistics should be requested by the NMHS, to meet local or Regional Association requirements. These should be inserted here.

Table 29: Humidity

ID	Requirement Heading	Requirement
69	Sensor Performance Constant	The instrument time constant under controlled conditions must be 40 s or better over the entire operational range. If used for Dewpoint Temperature measurement, then the sensor time constant must be 20 s. For the field measurements in non-actively aspired radiation screens this may not be achievable.
160	Operational Conditions	As a minimum, the equipment installed outdoors must be capable of operating in a Temperature Range [-40 °C to +55 °C], Humidity Range [0-100 %RH, Non-condensing] and Wind Speed up to 50 m/s. Resistance to (vibration) shocks must be included. A NMHS may modify this requirement to meet meteorological conditions normally expected.
475	Sensor Type	The sensor/instrument for measuring RH should be based on an electrical capacitance measurement probes. Sensors for measuring Dew Point directly are usually based on dewpoint mirror. However, any sensor type compliant with the requirements in this section should be considered by the customer.
481	Achievable Sensor Uncertainty	The sensor measurement uncertainty must be better than 3 %RH. If the sensor reports directly a Dew Point Temperature, the sensor uncertainty must be 0.25 °C.
57	Units	Whatever physical quantity is measured, humidity must be presented in/by the instrument/system in %RH.

61	Measurement Range	The maximum measurement range must be 0-100 %RH. If presented as Dew Point Temperature, the maximum temperature range must be -80 °C to +35 °C.
68	Reporting Resolution	The Reporting Resolution for humidity must be 1 %RH (or better). If reported as Dew Point Temperature, the reporting resolution must be 0.1 °C
138	Sampling Frequency	The humidity should be sampled at least 4 times over the interval of the sensor time constant.
139	Calculated Parameters	Averages of all valid samples of humidity must be produced over 1-minute intervals. The 1-minute average must be used as the instantaneous value for relative humidity
141	Rate of Change Check	After each signal measurement, the current value should be compared to the preceding one. If the difference between two samples is more than 5 %RH, the current sample is identified as suspect and is not used for the computation of an average.
142	Jump Check	If the difference between consecutive 1-minute averages if more than 10 %RH, then the data should be flagged as suspect for further investigation. If the difference is more than 15 %RH, the data should be flagged as erroneous for further investigation.
143	Stuck Sensor	if over a 60-minute interval the value of the one-minute values of RH have not changed by 1 %RH and RH < 95 %, then the data should be flagged as suspect for further investigation.
462	Dewpoint Temperature calculations from Air Temperature and RH	If Dewpoint Temperature is calculated from Humidity and Air Temperature, the 1 and 10-minute averages of Dewpoint Temperature should be calculated from the instantaneous Humidity and Air Temperature measurements, after which the averages for Dewpoint Temperature can be calculated. It is not allowed to calculate averages for Dewpoint Temperature from averages of Air Temperature and Humidity.
947	Derived Parameters	If relative humidity is measured, then a Dew Point Temperature should also be calculated, using the formula from the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 4, Annex 4.B.
1014	NMHS Calculated Parameters	Additional Humidity Statistics should be requested by the NMHS, to meet local or Regional Association requirements. These should be inserted here.

Table 30: Horizontal Wind Direction

ID	Requirement Heading	Requirement
71	Sensor Performance Constant	For Mechanical Wind Sensors, the Sensor Damping Ratio must be > 0.3.
157	Operational Conditions	As a minimum, the equipment (and supporting infrastructure) installed outdoors must be capable of operating in a Temperature Range [-40 °C to +55 °C], Humidity Range [0-100 %RH Non-condensing] and Wind Speed up to maximum wind speed required to be observed. Resistance to (vibration) shocks and lightning protection must be included. A NMHS may modify this requirement to meet meteorological conditions normally expected.
650	Sensor Type	The sensor/instrument for measuring WD must be an electrical recording wind direction instrument. The most common

		instruments in use are vanes, combined propeller anemometers/vane and ultrasonic instruments for measuring both wind speed and wind direction. However, any sensor type compliant with the requirements in this section must be considered. [[NMHS may edit if they have a preference for a particular sensor type]]
657	Achievable Sensor Uncertainty	The sensor uncertainty must be 5°.
973	Sampling Frequency	If the sensor is to be used to report wind gust, then wind speed should be sampled at 1 Hz or greater (4 Hz is preferred).
59	Units	Whatever physical quantity measured, Wind Direction must be presented in/by the instrument/system in degrees clockwise from true north.
63	Measurement Range	The maximum measurement range must be 0-360 degrees.
66	Reporting Resolution	The Reporting Resolution for Wind Direction must be 1 degree.
651	Wind Direction Sensor Orientation	Wind direction is defined as and must be reported as the direction from which the wind blows, and it is measured clockwise from geographical north, namely, true north (referred to the World Geodetic System 1984 (WGS-84) and its Earth Geodetic Model 1996 (EGM96)).
654	Practical Range	The maximum measurement range must be 0 – 360°. If two successive samples differ by more than 180°, the difference is decreased by adding or subtracting 360° from the second sample to obtain a wind direction between 0 – 360°.
78	Vector Averaging	Vector averaging should be used for the average values of wind speed and direction.
83	Minimum Data	At least 75% of the wind direction samples should be available to enable the computation of both the 2-minute and 10-minute averages. If insufficient data, the 2-, 10-minute average should be marked as invalid/missing.
87	Stuck Sensor	If the average values of wind direction do not vary by more than 10 degrees over a 60-minute interval, the data should be flagged as suspect for further investigation.

Table 31: Horizontal Wind Speed

ID	Requirement Heading	Requirement
70	Sensor Performance Constant	For a mechanical wind speed sensor, the distance constant must be in the range 2-5 m. [A distant constant is not required for an ultrasonic sensor]
73	Sampling Frequency	If the sensor is to be used to report wind gust, then wind speed should be sampled at 1z or greater (4 Hz is preferred).
158	Operational Conditions	As a minimum, the equipment (and supporting infrastructure) installed outdoors must be capable of operating in a Temperature Range [-40 °C to +55 °C], Humidity Range [0-100 %RH Non-condensing] and Wind Speed up to maximum wind speed required to be observed. Resistance to (vibration) shocks and lightning protection must be included.

		A NMHS may modify this requirement to meet meteorological conditions normally expected.
613	Sensor Type	The sensor/instrument for measuring Wind Speed must be based on an electrical anemometer. The most common instruments in use are cup anemometers, propeller anemometers and ultrasonic anemometers. However, any sensor type compliant with the requirements in this section must be considered.
619	Achievable Sensor Uncertainty	The sensor uncertainty must be 0.5 m/s for Wind Speed ≤ 5 m/s and 10% > 5 m/s.
60	Units	Whatever physical quantity measured, Wind Speed and Wind Gust must be presented in/by the instrument/system in metres per second (m/s).
64	Measurement Range	The maximum measurement range must be 0-75 m/s. In regions of extremely high winds, an extended range of 0-100 m/s should be requested. Wind Gust may reach 150 m/s.
65	Reporting Resolution	The Reporting Resolution for Wind Speed must be 0.5 m/s. The Reporting Resolution for Wind Gust (if measured) must be 0.1 m/s.
72	Calculated Parameters	Averages of all valid wind speed samples over 10-minute intervals must be produced. This 10-minute average must be used as the instantaneous value for wind speed. A standard deviation of wind speed must also be calculated. If the wind sensor is in support of an aerodrome, then an additional 2-minute average must be calculated.
74	Calculated Parameters 2	If an observation of wind gust is required, then this must be the running mean of all valid wind speed samples in a 3-second period.
77	Vector Averaging	Vector averaging should be used for the average values of wind speed and direction.
82	Minimum Data	At least 75% of the wind speed samples should be available to enable the computation of both the 2-minute and 10-minute averages. If insufficient data, the 2-, 10-minute average should be marked as invalid/missing
84	Rate of Change Check	If the difference between a wind speed sample and the preceding one is more than 20 m/s, then the data should be flagged as a suspect for further investigation and not used for the calculation of the average.
85	Jump Check	If the difference between consecutive 2-minute wind speed averages is more than 10m/s the data should be flagged as a suspect for further investigation. If the difference is more than 20m/s it should be flagged as erroneous for further investigation.
86	Stuck Sensor	If the average values of wind speed do not vary by more than 0.5 m/s over a 60-minute interval, the data should be flagged as a suspect for further investigation

Table 32: Precipitation Amount/Intensity

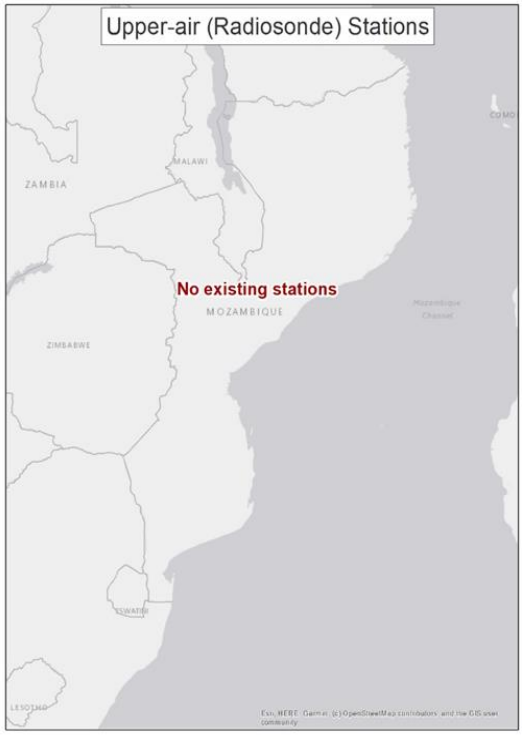
ID	Requirement Heading	Requirement
559	Sensor Type (Intensity)	The sensor/instrument for measuring precipitation intensity must be based on an electronic recording instrument. Any sensor type compliant with the requirements in this section must be considered. The Precipitation Amount and Intensity Sensor should be the same piece of equipment.
110	Collecting Gauge Orifice Area	In case the sensor/instrument for measuring Precipitation is based on collection of precipitation, the area of the collector orifice must be at least 200 cm^2 and no larger than 500 cm^2. The area of the orifice must be known to the nearest 0.5%, and the construction must be such that this area remains constant while the gauge is in normal use. The construction must be such as to minimize wetting areas. The container must also have a narrow entract and be sufficiently protected from radiation to minimize the loss of water by evaporation.
159	Operational Conditions	As a minimum, the equipment (and supporting infrastructure) installed outdoors must be capable of operating in a Temperature Range [-40 °C to +55 °C], Humidity Range [0-100 %RH Non-condensing] and Wind Speed up to maximum wind speed required to be observed. Resistance to (vibration) shocks and lightning protection must be included. A NMHS may modify this requirement to meet meteorological conditions normally expected.
531	Sensor Type	The sensor/instrument for measuring Precipitation must be based on an electronic recording instrument. Any sensor type compliant with the requirements in this section must be considered.
568	Sensor Time Constant (Intensity)	The instrument time constant under controlled conditions must be better than 30 s.
538	Achievable Sensor Uncertainty	The sensor uncertainty must be the larger of 5% or 0.1 mm.
566	Achievable Sensor Uncertainty (Intensity)	The sensor uncertainty must be: • Under constant flow conditions in laboratory: o 5% for > 2 mm/h, o 2% for > 10 mm/h. • In the field: o 5 mm/h, o 5% above 100 mm/h.
541	Heating	If appropriate for local conditions, the precipitation sensor should be equipped with rim heating and funnel heating (tipping bucket). The heating should be controlled by a thermostat and it should be switched on below an ambient temperature of 5 ºC. The heating should avoid snow and ice building up at the rim, and it should melt solid precipitation falling into the funnel. The heating should keep the rim and funnel above 0 ºC, but the heating should be as little as possible to avoid evaporation of the precipitation. For other types of instruments, heating should be offered as required for the local conditions.
58	Units	Whatever physical quantity measured, Precipitation Amount must be presented in/by the instrument/system in millimetres.

561	Units (Intensity)	Precipitation intensity must be presented in mm/hour (based on a 1-minute average).
62	Measurement Range	The maximum measurement range must be 0-500 mm/day. This should be increased to meet local conditions.
562	Measurement Range (Intensity)	The maximum measurement range must be: 0.02 – 2,000 mm/hour.
67	Reporting Resolution	The Reporting Resolution for Precipitation Amount must be 0.1 mm. If reporting daily totals, 0.2 mm should be used. If reporting weekly or monthly totals, 1 mm should be used.
564	Reporting Resolution (Intensity)	The resolution of reported measurement must be: 0.1 mm/hour.
111	Calculated Parameters	The individual measurements are providing the instantaneous readings. The system must calculate/make available amounts over 1 minute, 3 hours and 24 hours.

3.1.2 Upper-air observing network and observational practices

It should be noted that INAM currently does not have any existing operational upper-air stations. The plan is to establish and implement an upper-air network consisting of four new upper-air stations. The stations will perform 2 soundings per day. The sites identified are Beira, Maputo Observatorio, Nampula and Tete.

a. Map of the upper-air observing network and list of the required new or rehabilitated stations



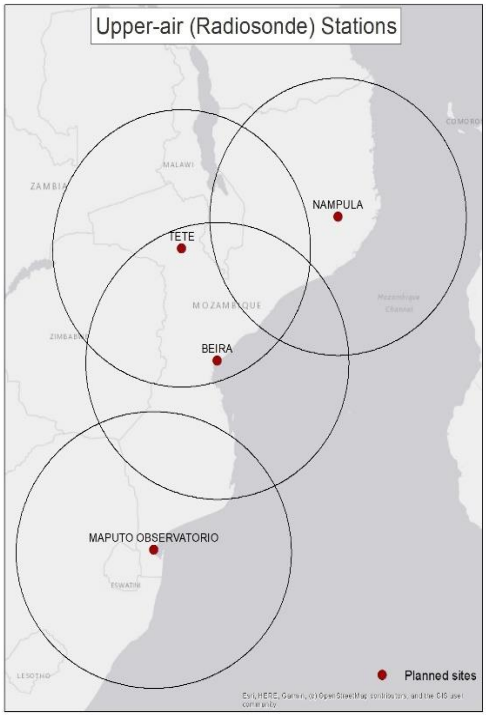


Table: 33: Upper-air reporting cycle and number of soundings per site per annum.

Site/Station name	WIGOS Identifier	Reporting cycle per day	Number of soundings per annum	Required
Beira	0-20000-0-67297	2	732	New
Maputo Observatorio	0-20000-0-67339	2	732	New
Nampula	0-20000-0-67237	2	732	New
Tete	0-20000-0-67261	2	732	New

b. List of observation instruments and systems per site

The technical assessment and local assessment of the planned upper-air sites conducted at the Maputo Observatorio indicated that upper-air ascents were previously conducted at the site as an obsolete hydrogen generator and storage tank were found at the site. Although Beira, Nampula and Tete did not conduct previous upper-air ascents, buildings were identified to be used as balloon rooms.

The plan therefore envisages the rehabilitation of the balloons rooms and the procurement of a hydrogen generation system, ground system and hardware and consumables.

Table 34: Status of upper air sites

Site/Station name	Balloon room (to be rehabilitated)	Hydrogen Generation System	Ground System and Hardware	Consumables
Beira	✓	X	X	X
Maputo Observatorio	✓	X	X	X
Nampula	✓	X	X	X
Tete	✓	X	X	X

c. Investments and activities needed for the installation of new stations and the improvement of existing stations.

The start-up investment and the activities for the establishment and installation of the upper-air network are for the

- Rehabilitation of the balloons rooms/sheds to ensure that the building design is in accordance with national standards and codes of practice concerning the risks presented by explosive gas.
- Lighting, power/mains and water supply, including back-up solutions
- Hydrogen generation systems and helium gas cylinders for back-up
- Ground systems and hardware

- Consumables
- Fire protection (extinguishers and adequate warnings according to national regulations) and first aid kit
- Personal Protective Equipment (PPE) i.e., special garments
- Hydrogen presence detecting tools/ Gas leak detection units.

Table 35: START-UP INVESTMENT AND ACTIVITIES FOR THE ESTABLISHMENT AND INSTALLATION OF THE UPPER-AIR NETWORK

Legend: New (N), R (Rehabilitate), A (Available)				
ITEMS	**BEIRA**	**MAPUTO OBSERVATORIO**	**NAMPULA**	**TETE**
Building/Facilities				
Water and static proof building (Balloon room)	R	R	R	R
Lighting	N	N	N	N
Power/Mains power supply (backup solution)	N	N	N	N
Direct water supply to balloon room	N	N	N	N
Water tank, water pump piping and connectors (back-up)	N	N	N	N
Generator for emergency power supply (back-up)	N	N	N	N
Storage for upper-air consumables	R	R	R	R
Hydrogen Generation System				
Hydrogen generator (0.5 Nm3/hr (20 SCF/hr/500l/hour).	N	N	N	N
Water Purification System with piping, valves, and connectors	N	N	N	N
Hydrogen storage tank with piping, valves, and connectors	N	N	N	N
Balloon fill nozzle with piping and connectors	N	N	N	N
Safety, Health, Environment and Quality (SHEQ)				
Personal Protective Equipment (PPE) i.e., special garments	N	N	N	N
Fire protection (extinguishers and adequate warnings according to national regulations)	N	N	N	N
First aid kit	N	N	N	N
Hydrogen presence detecting tools/ Gas leak detection unit	N	N	N	N
INVESTMENT AND ACTIVITIES FOR THE RUNNING OF THE UPPER-AIR NETWORK				
Ground System and Hardware				
Upper-air ground system	N	N	N	N
Uninterruptable Power Supply (UPS)	N	N	N	N
Desktop computer	N	N	N	N

Network connectivity (network switch and cabling) / mobile network connection	N	N	N	N
Consumables				
Radiosondes	800 p/a	800 p/a	800 p/a	800 p/a
Balloons (350g)	800 p/a	800 p/a	800 p/a	800 p/a
Helium gas as backup (As and when required)	12 bottles p/a	12 bottles p/a	12 bottles p/a	12 bottles p/a
Balloon string				

Table 36: COSTING (USD $)

ITEMS	BEIRA	MAPUTO OBSERVATORIO	NAMPULA	TETE	Total
Building/Facilities					
Water and static proof building (Balloon room)	50 000	50 000	50 000	200000	350 000
Lighting					
Power/Mains power supply (backup solution)					
Direct water supply to balloon room					
Water tank (2000litres), water pump piping and connectors (back-up)	420	420	420	420	1 680
Generator for emergency power supply (back-up)					0
Hydrogen Generation System					
Hydrogen generator (0.5 Nm3/hr (20SCF/hr/500l/hour).	290 000	290 000	290 000	290 000	1 160 000
Water Purification System with piping, valves, and connectors					0
Hydrogen storage tank with piping, valves, and connectors	26 500	26 500	26 500	26 500	106000
Balloon fill nozzle with piping and connectors	0	0	0	0	0
Safety, Health, Environment and Quality (SHEQ) and ATEX regulations					
Personal Protective Equipment (PPE) i.e., special garments	0	0	0	0	0
Fire extinguishers and adequate warnings according to national regulations	0	0	0	0	0
First aid kit	0	0	0	0	0
Hydrogen presence detecting tools/ Gas leak detection unit	0	0	0	0	0
INVESTMENT AND ACTIVITIES FOR THE RUNNING OF THE UPPER-AIR NETWORK					
Ground System, Hardware installation and training					
Upper-air ground system	5 680	5 680	5 680	5 680	22 720
Uninterruptable Power Supply (UPS)					
Desktop computer					

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Ground System, Lease (3300USD per year)	9 900	9 900	9 900	9 900	39 600
Ground System and consumables, Shipping	4 000	4 000	4 000	4 000	16 000
Insurance for shipping	1 950	1 950	1 950	1 950	7 800
Network connectivity (network switch and cabling) / mobile network connection	1200	1200	1200	1200	4800
Total	**379650**	**379650**	**379650**	**379650**	**1802600**

Table 37: Spares and Consumables

Item	Unit Price (USD/Local Currency)	Quantity per annum	Year 1	Year 2	Year 3	Year 4	Year 5	5 Year estimated cost (USD)
Upper Air Observing System (Spare parts and consumables)								
Radiosonde	90	3200	n/a	288 000	316 800	348480	383328	1336608
Balloon	14	3200	n/a	44 800	49 280	54208	59629	207917
Parachute								
Spare parts for hydrogen generator*								
Spare parts for fire extinguishing system*								
Spare parts for ground receiving system (antennas, computers, etc.)*								
Operational Cost (electricity, water, chemicals, data transmission, maintenance of the equipment)			n/a	2 000	2 200	2420	2662	9282
Helium (if used)	395	24	n/a	9 480	10 428	11273	12400	43581
Water purification system*								
Hydrogen detection tool*								
Balloon fill nozzle (piping and connectors)*								
Sub Total			n/a	**344 280**	**378 708**	**416381**	**458019**	**1597388**

***Forms part of the Service Level Agreement with the Service Provider**

Table 38: Activity Plan for the establishment, installation, and operation of upper-air (radiosonde) network

#	Activity	Start date	End date	YEAR 1 (2024)				YEAR 2 (2025)				YEAR 3 (2026)			
				JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND	JFM	AMJ	JAS	OND
1.	**Establishment and installation of the upper-air network**														
1.1	Procurement of services for the environmental impact assessment and rehabilitation of balloon rooms and Maputo, Beira and Nampula	2024-01-01	2024-06-30												
1.2	Procurement of services for the environmental impact assessment and construction of a balloon room at Tete	2024-01-01	2024-06-30												
1.3	Conduct environmental impact assessment, rehabilitation, and construction of the 4 upper-air sites	2024-07-01	2025-06-30												
1.4	Procurement of back-up water supply to balloon rooms	2024-01-01	2024-06-30												
1.5	Installation of back-up water supply at 4 upper-air sites	2024-07-01	2025-06-30												
1.5	Procurement of back-up generator for emergency power supply	2024-01-01	2024-06-30												
1.6	Installation of back-up water supply at 4 upper-air sites	2024-07-01	2025-06-30												
1.7	Procurement for the supply and installation of Hydrogen Generation Systems for 4 upper-air sites	2024-01-01	2024-06-30												
1.8	Installation of Hydrogen Generation Systems at 4 upper-air sites	2024-07-01	2025-06-30												
1.9	Procurement of service for Safety, Health, Environment and Quality (SHEQ)	2024-01-01	2024-06-30												
1.10	Installation of Safety, Health, Environment and Quality (SHEQ)	2024-07-01	2025-06-30												
2.	**Running of Upper-air network**														
2.1	Procurement of Upper-air ground systems and hardware – supply, installation, and maintenance support (lease or purchase) and the supply of upper-air consumables (Radiosondes, balloons, helium gas(back-up)	2024-01-01	2024-06-30												
2.2	Hydrogen Generation System – service and recertification (every 5years)	Q1 of year 5	Q2 of year 5												

d. Observational practices for the upper-air network

INAM currently has 8 Upper-air sounding technicians available with only 4 of the technicians capable of performing daily safety checks and basic maintenance of an upper-air system.

Table 39: Human resources for Upper-air soundings

HUMAN RESOURCES	Beira	Maputo Observatory	Nampula	Tete
Upper-air sounding technicians	2	2	2	2
Technicians for daily safety checks and basic maintenance of upper-air system	2	2	0	0

It is recommended that the 8 upper-air sounding technicians be trained on conducting upper-air soundings, basic upper-air coding and quality control, and system and hydrogen generator checks. OEM training to form part of the tender specification requirements.

The competency requirements to perform a balloon-borne upper-air observation consists of the following prescribed practices and procedures:

- Prepare and deploy balloons and their payload.
    - Balloon shed safety check.
    - Balloon preparation and filling.
    - Instrument ground check.
    - Balloon release.
- Track balloon flight
- Compute ad record upper air and other specialised upper-air observations as required.
- Compute and transmit upper-air observations using prescribed codes and methods.
- Care and handling of instruments.

e. Preliminary maintenance plan for existing and improved new stations, including calibration practices network

The skills, knowledge of the INAM staff is fundamental to the sustainable, effective and efficient operation of the upper-air network, in order to meet the GBON requirements and the adherence to the design principles.

It is recommended that daily safety checks should be done for the balloon room/shed and the hydrogen generating system. Furthermore, regular training, at least every 4 years, should be conducted to ensure that all staff are updated on standards and practices, benefits and requirements for upper-air observations, technology improvements, system maintenance and

quality management. The Hydrogen Generating Systems should also be serviced and recertified at 5-year intervals to ensure to its safety and reliability.

Table 40: Costing for Tank for recertification on Upper Air

Activity	Interval	Cost USD ($)
Daily maintenance and gas leak detection checks	Daily	n/a
Hydrogen Generator Systems - service and recertification	Every 5 years	

f. Technical specifications for new instruments and observing systems for the procurement process

Table 41: Rehabilitation of Upper-air buildings

ID	Requirement Heading	Requirement
	Rehabilitation of 4 balloon rooms/sheds	Refurbishment of the balloon room/shed • Fix building structure. The balloon room should be well ventilated, static and waterproof. • Replace corrugated iron roof. • Replace broken windows • Install flame/spark-proof electric-light fittings inside and outside balloon room/shed. • Install mains power to the building. • Connect water supply to the building. • Installation of fire protection (extinguishers, signs, and alarms) • Installation of complete earthing (grounding) system with all fittings, with the hydrogen equipment and the lightning conductor separately connected to a single earth. Installation must comply with national safety standards. • Provision of first aid kits

1. Environmental Sustainability

Table 42: Environmental Regulatory Compliance

ID	Requirement Heading	Requirement
1-01	General Compliance	The proposed instruments must comply, at a minimum, with recognized European Environmental regulations. Applicable* regulations must apply to the instrument itself, all of its sub-systems, its packaging, and associated consumables. **'Applicable' requires knowledge of the materials and components. Where certain materials, chemicals, and components are used – compliance to regulations controlling their use must be confirmed.*
1-02	Batteries *(example)*	Batteries and Accumulators and Waste Batteries and Accumulators Directive (2006/66EC)
1-03	Packaging *(example)*	Packaging and Packing Waste Directive (1994/62/EC)

1-04	Hazardous Substances *(example)*	RoHS 2 - Restriction of Hazardous Substances Directive (2011/65/EU)
1-05	Chemical Registration *(example)*	REACH – Registration, Evaluation, Authorization, and Restriction of Chemicals (2006/1907/EC)
1-06	Mercury *(example)*	Minamata Convention on Mercury - COP
1-07	Local Jurisdiction	Where recognized regulations, applicable in the jurisdiction where the instrument is installed, are equivalent to or stricter - the local regulation must be applied over the European regulation.

Table 43: Material Use – Instrument

ID	Requirement Heading	Requirement
1-08	Material Identification	The material of each component part of the proposed instrument must be identified by its applicable recognized recycling code.
1-09	Recycled Content	The mass and percent of recycled raw material must be disclosed for each component part made of a homogenous material (coatings excluded).
1-10	Biodegradability	Biodegradable* components in the proposed instrument must be identified. *Biodegradability is defined as >90% of the original material is converted into CO2, water, and minerals by biological processes within 6 months.

Table: 44: **Material Use – Packaging**

ID	Requirement Heading	Requirement
1-11	Material Selection	Where packaging material selection allows, without degradation of the instruments' performance or shelf life, only recyclable materials must be used.
1-12	Material Identification	The material of each packaging element must be identified by its applicable recognized recycling code.
1-13	Biodegradability	Where packaging material selection allows, without degradation of the instruments' performance or shelf life, only biodegradable* materials must be used. *Biodegradability is defined as >90% of the original material is converted into CO2, water, and minerals by biological processes within 6 months.

Table 45: Instrument design

ID	Requirement Heading	Requirement
1-14	Design for Repair	Where instrument performance requirements allow, without degradation of, for example, water intrusion or temperature range, replaceable sub-components and sub-systems of the proposed instruments must be serviceable or replaceable, without the requirement to discard the whole instrument.
1-15	Efficient Packaging	Packaging for the instrument must minimize transport volume and mass wherever possible, without compromising transport durability and equipment performance following long-term storage.
1-16	Recyclability	The instrument design must consider end-of-life disposal and maximize the recyclability of the assembly by facilitating efficient separation of all recyclable materials.

Table 46: Operations and Maintenance

ID	Requirement Heading	Requirement
1-17	Energy Performance	Where feasible, without degradation to the proposed instrument's performance under its specified operating range, the instrument's energy use must be minimized.
1-18	Chemical Disclosure	All chemicals used in the operation, calibration, and maintenance of the proposed instrument must be disclosed and a Material Safety Data Sheet must be provided. Environmentally harmful chemicals must be avoided or minimized where no suitable alternative is available.
1-19	Internal Batteries	Details of the battery or accumulator design, covering, cell type, voltage, capacity, and any necessary safety information must be supplied for the proposed instrument if the design includes a battery or accumulator. Safety information must include instructions for the safe disposal of the battery or accumulator, consistent with local regulations, or the 2006/66/EC directive – whichever is stricter.

1 Documentation, maintenance, and safety

Table 47: Documentation and Training

ID	Requirement Heading	Requirement
2-01	Tender Language	All Tender documents must be in English
2-02	Project/Tender Schedule	The supplier must provide a Project Schedule/Implementation Plan with the offer.
2-03	Documentation	The supplier should provide documentation in electronic format [with permission for the customer to reproduce for internal use] outlining:

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		- basic theory/principles of operation of equipment - step-by-step instructions on the required maintenance and the frequency with which this maintenance is recommended to be performed. - recommended spare parts and test equipment (for maintenance and repair).
2-04	Serial Number	Each instrument must be supplied with a unique serial number.
2-05	Site Drawings	Where the supplier provides Site design, clear site drawings showing the location of cables must be provided to the customer for each site.
2-06	Training	Customer technicians should receive training onsite or at a location designated by the NMHS, on calibration, installation, maintenance, software, QC/inspection [if appropriate], software and operational procedures for the instrument, and on all aspects of the operation of the upper-air systems.

Table 48: Maintenance and Operation

ID	Requirement Heading	Requirement
2-07	Maintenance from a remote location	The control/processing system should support maintenance from a remote location. At least the following functions are supported: • inspection of the real time meteorological observations that are ingested/recorded by the upper-air system • inspection of log records • facilities to change parameter settings and/or station configuration To perform these maintenance functions, a system operator password [or other NMHS determined security] is required.
2-08	Reliability detection of failures	The unavailability of either hardware or software parts that could prevent the execution of the systems' primary function should not go unnoticed.
2-09	Equipment design	The design of equipment and cabinets must facilitate routine inspections.
2-10	Off-line test	The system allows for off-line testing in an isolated environment before and after installation.
2-11	Pre-implementation test	The system allows for testing in the operational environment before implementation, without affecting the operation of the rest of the system.
2-12	Standard components currently in use	It is the customer's policy to maintain uniformity in inspection and maintenance procedures for all meteorological facilities and to keep a minimum level of spare parts. Therefore, it is recommended to consult the list of currently used makes for mechanical, electrical and software components.

		List of component types currently in use by the customer (Item/Manufacturer) PCs [xxx]; Servers [xxx]; Network components [xxx]; Modems [xxx]; Routers [xxx]; Cabinets [xxx]; Rack equipment [xxx] [xxx to be completed by the customer]
2-13	On-line help	The system should provide built-in help facilities which are able to replace user documentation. The online help should be detailed enough to aid a user trained in the general principles of the system.
2-14	Recommended Spare Parts List	The Contractor must submit a Recommended Spare Parts List (RSPL) based upon the Maintenance Conditions as specified in the Maintenance Conditions document and the required availability (MTBF, MTTR) as specified in the Requirement Specifications document. This list must contain spare parts recommended by the Contractor to support/maintain the System and System Components during their respective lifetimes regarding the following: • For consumables the Contractor must recommend an amount of spare parts sufficient for two years for the System and System Components. • For repairable System Components (or modules of the System • Components, if applicable), the Contractor must recommend a number of spares based on the mean time between failure (MTBF) for that specific System Component. • For modules that can only be replaced as a whole in case of malfunctioning, the Contractor must recommend a number of spares based on the lifetime of the System and on the MTBF as provided in the Requirement Specifications document. • The Contractor must make a recommendation for COTS-items.
2-15	Design life for the systems	The system should be designed for a life cycle of at least 10 years.
2-16	Operational hours of system components	Under normal circumstances, system components must perform their primary functions 24 hours a day and 7 days a week.
2-17	Requirements for materials and components	All materials and components furnished must be new and designed to meet the customer's requirements. The supplier has to take into consideration that the installation must not cause any damage to installations and systems.

Table 49: Safety and standards

ID	Requirement Heading	Requirement
2-18	Environment: EMC	Electromagnetic Compatibility (EMC) susceptibility must be according to EC- regulations (or other relevant national or international standards), but special care must be taken to withstand static electric shocks, as well as the use of handheld radio and telephone equipment in the vicinity of the systems.
2-19	Environment: shock and vibration level	The upper-air system should be able to operate in an environment with a shock and vibration level not exceeding 0.1 kB (DIN 4150/ISO 4866).
2-20	Electrical Safety	All installed equipment must comply with applicable local requirements for electrical safety. In the absence of local requirements, IEC 60950-1 is used.
2-21	Electrical regulations	The equipment and installation must conform to the regulations of local authorities. The most common international standards are (latest versions must be applicable): • CE marking • FCC Declaration of Conformity • ISO 9001 : quality management systems and quality assurance • In addition, local standards and regulations apply, the supplier to define which ones are valid for the installation region (latest versions): • Safety regulations for low voltage installations, including supplements and alterations • Lighting conductor installations • Telecommunication colours of cores of cables for use inside buildings and for mounting wires • Telecommunication regulations for wireless (data)communication, use of available frequencies • Factories built low voltage switch gear and control cabinets • Safety transformers • Electrical symbols The supplier must be responsible for the correct application of local standards (latest editions) and regulations necessary to achieve conformity with local legislation. In the absence of local requirements, IEC 60950-1 is used.
2-22	Electromagnetic Compatibility	Installed equipment should have suitable electromagnetic compatibility for operation in the installed environment. In the absence of a local standard, IEC 61326:1997 + A1:1998 + A2:2000 + A3:2003 can be used.
2-23	Regulations	The equipment and installation must conform to the latest editions or regulations of local authorities and the customer.

		The supplier must be responsible for the correct application of valid European/US/applicable standards (latest editions) necessary to achieve conformity with the local legislation on machinery safety. For electrical and control systems particularly, all relevant components, apparatuses, panels, boards, systems and installations, which are part of the scope of work, have to comply with the applicable standards.
2-24	Workmanship Rules	Cabinets are assembled by the supplier. High-qualified workmanship and extreme care should be applied when assembling the equipment. At least the following aspects should reflect this: • All process specification steps should be rigorously followed. • All quality assurance specifications should be rigorously followed. • High-quality soldering with a good reflow, it should be free of excessive solder, pits, and cracks, and is not subjected to mechanical stress. • All cabling should be properly guided and bundled, and attached every 30 cm (no loose cables, no free hanging cables). Unnecessary extra cable loops should be avoided. Cables have always to be installed as close as possible to grounded surfaces. All cable connections in cabinets should be terminated on connector plugs with metal enclosures. The cabling inside cabinets should be routed in an orderly manner in fixed traces and tied up. • The presence of loose cabling over lengths of more than 30 cm is not permitted. • Bolts should be properly torqued and sealed. • All parts should be properly attached by screws, adhesive or brazing (no loose parts). • Painting and coatings should be applied smoothly and with constant thickness, without the presence of drops and non-treated areas. • All equipment should be adequately cleaned and free of dust and dirt. Cabinets, enclosures, and housings should be free of scratches and dents.
2-25	ISO 9001	All suppliers, and their subcontractors were appropriate, should have ISO 9001 certification. Documentary evidence of this certification should be included with the Tender documents.
2-26	Physically disconnection of equipment	When equipment is switched OFF, e.g., by means of a physical ON/OFF switch, the total equipment can be physically disconnected from the power supply. If not so, provisions will be supplied enabling a physical disconnection.
2-27	Minimising risk of injury and damage	The system must be designed in such a way as to prevent the risk of personal injury or system damage.
2-28	Grounding compliance	Grounding must be according to the applicable regulations. The metal frames and casings of the cable runs and the remote-control stations must be bonded together and earthed to the earth bars. The grounding must not be connected to the building earth, but to the installation grounding system as provided by the customer. Armoured cables must only be earthed at the power feeding side.

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2-29	Cable protection for local conditions	The NMHS may specify additional cabling requirements to reflect local climatic/soil conditions or regulations - for example on cabling depth, or protection from humidity or vermin
2-30	Installation protection factor for equipment	Degree of protection between panels and between cable compartments and cabinets should be IP 30. When doors are opened protection should be IP 20. Degree of protection between cable compartment and main bus-bar compartment should be IP 40 after extension. For cabinets and equipment not installed in cabinets, protection should be IP 55.
2-31	Compliance of cables to local standards, regulations and norms	All cables that are used in the systems delivered by the supplier, must comply to local standards, regulations and norms. It is the responsibility of the supplier to find out what local standards, regulations and norms are applicable and that all cables are compliant with these regulations.

Table 50: Site Specification Requirements

ID	Requirement Heading	Requirement
3-01	Infrastructure	The infrastructure to house and operate the upper-air system (i.e. buildings and utilities) are not specified in this document. These details must be provided as general information in the technical specification and the vendors should be requested to confirm compatibility with the offered system and any additional infrastructure and utilities that need to be provided.
3-02	Site location(s)	The geospatial location of the site(s) must be provided in the technical specification, along with any relevant metadata (i.e. station identifier), and a full address for International delivery. BEIRA: Latitude -19.8, Longitude: 34.9 MAPUTO OBSERVATORIO: Latitude: -25.9702, Longitude: 32.5937 NAMPULA : Latitude: -15.1, Longitude: 39.28 TETE: Latitude: -16.1328, Longitude: 33.6064
3-03	Existing equipment	If the upper-air system is expected to be integrated with existing equipment at the site, this needs to be detailed in the technical specification and the vendor requested to confirm compatibility of their system and the provision of any additional components to allow the equipment to be integrated.
3-04	Station sounding schedule	This order is expected to provide a minimum of 60 months of operations, when meeting the minimum requirement of 2 daily soundings per month with measurements of temperature, humidity and wind to at least 30 hPa.
3-05	Delivery	The cost of DAP delivery to the address in 3-02 must be included.
3-06	Packaging	Packaging must be suitable for the international delivery.

4. Meteorological Radiosondes

Table 51 General

ID	Requirement Heading	Requirement
4-01	Radiosonde Intercomparison	The measurement performance of the offered radiosonde must be verifiable by either participation in the latest WMO radiosonde intercomparison, currently China (2010) and/or Germany (2022), or directly referenced to a radiosonde that participated, through an independent report recognized by WMO (INFCOM/Standing Committee on the Measurements, Instrumentation and Traceability (SC-MINT).

Table 52: Temperature Measurement Requirements

ID	Requirement Heading	Requirement
4-02	Temperature Range	The range of temperature capable of being sampled shall not be less than +50 °C to -100 °C.
4-03	Pressure Range	The temperature sensor shall be capable of measuring temperature from 1080 hPa to at least 3 hPa.
4-04	Resolution	The reported resolution shall be 0.1 °C or better.
4-05	Uncertainty	It shall be possible to measure temperatures during ascent with an absolute error of no more than 0.5 °C at all levels.
4-06	Reproducibility	It shall be possible to measure temperatures during the ascent to a reproducibility within: a) 1080 - 100 hPa: 0.2 °C b) 100 - 20 hPa: 0.3 °C c) 20 - 3 hPa: 0.5 °C

Table 53: Relative Humidity Measurement Requirements

ID	Requirement Heading	Requirement
4-07	Humidity Range	The range of relative humidity capable of being sampled shall not be less than 0% to 100% with respect to water.
4-08	Pressure/Temperature Range	The humidity sensor shall be capable of measuring humidity in the temperature range of +50 °C to -100 °C and the pressure range of 1080 hPa to at least 100 hPa.
4-09	Resolution	The reported resolution shall be 1% or better.
4-10	Uncertainty	It shall be possible to measure relative humidity during ascent with an absolute error of no more than 5% at all levels.

Table 54: GPS Derived Pressure Measurement Requirements

ID	Requirement Heading	Requirement
4-11	Pressure Derivation	The radiosonde shall be capable of deriving pressure from GNNS altitude. The manufacturer shall specify how the pressure measurements are calculated.
4-12	Pressure Range	The range of pressure being derived shall be at least 1080 hPa to 3 hPa.
4-13	Resolution	The derived pressure measurements shall have a resolution of at least 0.1hPa.
4-14	Uncertainty	It shall be possible to measure derived pressures during ascent with an absolute error of no more than: a) 1080 - 100 hPa: 1 hPa b) 100 - 3 hPa: 0.6 hPa
4-15	Sampling Rate	The radiosonde shall report GPS derived pressure data with a sampling rate of at least one measurement every 2 seconds.

Table 55: GPS Derived Geopotential Height Measurement Requirements

ID	Requirement Heading	Requirement
4-16	Geopotential Height Derivation	The radiosonde shall be capable of providing geopotential height measurements derived from GNNS measured geometric height. The manufacturer shall specify the method used to convert between geometric and geopotential height.
4-17	Height Range	The range of geopotential height measurements shall be at least 0 - 40 000 m.
4-18	Resolution	The geopotential height measurements shall have a resolution of at least 0.1 m.
4-19	Uncertainty	It shall be possible to measure geopotential height during ascents with an absolute error of no more than 20 m at all levels.
4-20	Sampling Rate	The radiosonde shall report geopotential height data with a sampling rate of at least one measurement every 2 seconds.

Table 56: Wind Measurement Requirements

ID	Requirement Heading	Requirement
4-21	Wind Range	The system shall measure wind by tracking the radiosonde movement using GNNS navigation signals.
4-22	Wind Speed Range	The range of wind speed that can be sensed shall be 0 to at least 120 m/s.
4-23	Wind Direction 360^{o}	The range of wind directions capable of being sensed shall be through the full 360 degrees of azimuth.
4-24	Height Range	Winds shall be reported starting no higher than 100 m up to at least 40 000 m.

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4-25	Resolution of Wind Speed / Orthogonal Wind	Wind speed and orthogonal wind components shall be measured with a resolution of at least 0.1 m/s.
4-26	Resolution of Wind Direction	Wind direction shall be measured with a resolution of at least 1 degree.
4-27	Wind Speed Uncertainty	It shall be possible to measure wind speed with an absolute error of no more than 0.5 m/s at all levels.
4-28	Wind Direction Uncertainty	It shall be possible to measure wind direction with an absolute error of no more than 3 degrees at all levels.
4-29	Sampling Rate - Wind Data	The radiosonde shall report all wind data with a sampling rate of at least one measurement every 2 seconds.

Table 57: Physical Design and Launching Requirements

ID	Requirement Heading	Requirement
Radiosonde Design		
4-30	Weight	The radiosonde weight shall not exceed 400 grams, including battery and un- winder.
4-31	Wind Speed Capability	The radiosonde shall be sufficiently robust to withstand launching in winds gusting up to 35 m/s without damaging the radiosonde sensors.
4-32	Suspension Length	The radiosonde shall deploy to a suspension length of at least 30 m +/- 1 m beneath the balloon after launch.
4-33	Consistency of Configuration of Sensor Boom	The radiosonde shall have temperature and humidity sensors mounted externally on at least one boom, which can be consistently deployed in the same orientation.
4-34	Boom Design - Contamination Mitigation	The supplier shall supply details of the boom design, including any features designed to mitigate against the effects of contamination from moisture, exposure to solar radiation, and exposure to heat from the radiosonde body.
4-35	Shelf Life	Radiosondes supplied should be capable of being stored under recommended conditions for a minimum of 3 years.
4-36	Battery capacity	The sonde should have power capacity to maintain radiosonde operation for at least a total period of up to 30 minutes before launch and 3 hours during flight.
Pre-flight preparation		
4-37	Pre-flight Preparation	It shall be possible for a trained operator to unpack a sonde and complete all ground checks and have the sonde ready for launch within 30 minutes.
4-38	Operation via Single Operator	A system shall require no more than one operator to: prepare and launch the radiosonde, monitor and quality control the data, edit and transmit messages.

ID	Requirement Heading	Requirement
Calibration and Pre-flight		
4-39	Calibration Certification	The sonde shall be delivered calibrated, and calibration data is to be provided with each radiosonde.
4-40	Ground Check	There should be a specified ground check procedure that shall form part of the pre-flight preparation. This shall identify calibration/sensor faults and may be used to modify the calibration parameters used in subsequent data processing.

Table 58: Ground Station Requirements

ID	Requirement Heading	Requirement
4-41	Data	The ground station shall include all items necessary to receive, process, output, archive, and display the data derived from the radiosonde.
4-42	UPS	The ground station shall be supported by an uninterruptable power supply (UPS) and this should be sufficient to operate the system for a period of 60 minutes should the mains power fail.
4-43	Pre-flight Tests	The ground system should be capable of testing the sonde systems prior to launch, ensuring temperature, relative humidity, pressure, and GPS satellite reception are functioning within specification.
4-44	Compliance	The system shall comply with ETSI standard EN 302 054-2 V1.1.1 'Electromagnetic compatibility and Radio spectrum Matters (ERM); Meteorological Aids (Met Aids); Radiosondes to be used in the 400,15 MHz to 406 MHz frequency range with power levels ranging up to 200 mW' and any other statutory requirements as necessary.
4-45	Frequency	The carrier frequency of the transmitted signal shall be operator selectable between 403 MHz and 406 MHz in 100 kHz steps.
4-46	Bandwidth	The modulation bandwidth shall not exceed 100 kHz centred on the carrier frequency.
4-47	Carrier Stability	The carrier frequency shall not drift for any reason during operation, including handling and ground effects at launch, by more than 100 kHz from the selected frequency.
4-48	Effective Radiated Power	This shall not exceed 200 mW.
4-49	Frequency – Reception	The system shall be able to receive and process transmissions within the band 403 to 406 MHz. The reception equipment will be able to sustain satisfactory operations in the presence of transmissions from any other systems in adjacent spectrum bands.
4-50	Slant Ranges / Elevation Angle	The receiving system shall be able to reliably receive data from radiosondes, at slant ranges greater than 200 km from the receiving site, from any direction and any elevation angle equal to, or greater than 5 degrees above the horizon.

ID	Requirement Heading	Requirement
4-51	Telemetry – Direction	The manufacturer shall describe the directionality of the telemetry antennae (i.e. omnidirectional, directional, mechanically steered) and the method used to achieve this directionality.
4-52	Wind Failure	Pressure, temperature, and relative humidity shall still be measured, if the wind measurements fail.
4-53	Raw Data Archive	The data stream including GPS signals as received from the radiosonde, shall be stored by the ground station in a raw data archive.
4-54	Processed Data	The fully processed data archive used to generate the upper air reports for the users, shall include as a minimum pressure, temperature, humidity, geopotential height, wind speed, and direction data.
4-55	Descent Data	The system shall continue to record the variables stated in 5-54 after balloon burst, down to the ground or until the radiosonde signal is lost.

Table 59: Data Processing Software

ID	Requirement Heading	Requirement
4-56	Algorithms & Compensation Methods	The algorithms used to generate the meteorological variables from the engineering variables shall be described fully and be available to the operator of the system at all times, including in any subsequent software updates. Any methods used to compensate for the effects of; solar radiation (temperature and relative humidity), water contamination effects on the sensors (temperature, relative humidity), and the variation in internal temperature of the radiosonde during flight (pressure sensor and sensor references), shall also be described.
4-57	Message Creation	The system shall be capable of manually or automatically creating the following message types: • FM 94 BUFR using templates 3 09 056/3 09 057 at the minimum required vertical resolution (For GBON this is 100m). • FM 94 BUFR using templates 3 09 056/3 09 057 at resolution ≤ 2 s. • FM 94 BUFR using template 3 09 056 to report descent data.
4-58	Message Update	The software to create the message must be able to be upgraded to facilitate new versions of the FM 94 BUFR coding and this must be included as part of the software support to the system.
4-59	Message transmission	It shall be possible to code and send the BUFR message at preselected times/pressures during the sounding.
4-60	Software Functionality	The system shall provide the following facilities: (a) Radiosonde Calibration Data Input - Input of radiosonde calibration data before launch (if necessary).

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		(b) Surface Observation Input - Input of surface observation by operator (c) Launch Detection - Supplier shall also detail how launch is detected by the software.
4-61	Software Updates	The Supplier shall supply details of the frequency of software updates and commit to supply details of any changes to software when a new version is supplied, maintaining a change log detailing all changes, which is to be shared with the operator.

Table 60: Computer and backup power

ID	Requirement Heading	Requirement
4-62	Desktop computer	Bidder to provide a desktop PC with windows operating system and network connectivity to INAM network for each upper air sounding system.
4-63	Backup power	The upper air sounding systems and computers (PC's) must be equipped with backup power (UPS's) for running the whole system during mains power failure for a minimum period of two hours

Table 61: Site Acceptance Test and hand-over of systems for sites

ID	Requirement Heading	Requirement
5-01	Installation test	Bidder must provide all materials required to perform testing of the system during installation / calibration.
	Written confirmation of installation	Bidder must certify in writing for each installation that the system installed has been tested and is fully operational.

Table 62: Maintenance and Support

ID	Requirement Heading	Requirement
6-01	Maintenance	Bidder to provide full maintenance of the equipment during the contract period.

Table 63: Meteorological Balloons

ID	Requirement Heading	Requirement
7-01	Provision	Provision of 800 Meteorological Balloons for Radiosonde soundings per year for period of 3 years to the following sites • BEIRA: Latitude -19.8, Longitude: 34.9 • MAPUTO OBSERVATORIO: Latitude: -25.9702, Longitude: 32.5937 • NAMPULA : Latitude: -15.1, Longitude: 39.28 • TETE: Latitude: -16.1328, Longitude: 33.6064
7-02	Gas Type	Balloons must be suitable for both Hydrogen and Helium.
7-03	Filling Adapter	A balloon filling adapter must be provided with the delivery of first batch of balloon order
7-04	Performance (Burst Height)	Minimum burst height of 30 hPa, when flown under typical conditions, with correct handling and inflation procedures (90% tolerance). Evidence to be provided in tender documents.
7-05	Date Stamp	Date of manufacture must be included with each balloon.
7-06	Evidence of operational use	Evidence that offered product has been used operationally at WMO recognised services/institutes for a period of greater than 1 year. Please provide list of Meteorological Services and/or WIGOS Station identifiers.
7-07	Monitoring	GBON stations will be monitored regularly against the GBON minimum requirements, which include the burst height performance statistics of the balloons. If necessary, these statistics are communicated back to the station operators and/or equipment manufacturers for comment and action.

Table 64: Hydrogen Generation System (HGS)

ID	Requirement Heading	Requirement
8-01	Provision	Provision is for the supply of a hydrogen generator for meteorological applications, storage tanks (replacement or compatible with existing), water purifier (replacement or compatible with existing), UPS and other associated equipment, including the shipment to Maputo Observatorio, Beira, Nampula and Tete, installation on site and training of the observing staff in the ongoing operation and maintenance of the equipment.
8-02	Site	The observation sites are located at the following coordinates: BEIRA: Latitude -19.8, Longitude: 34.9 MAPUTO OBSERVATORIO: Latitude: -25.9702, Longitude: 32.5937

		NAMPULA : Latitude: -15.1, Longitude: 39.28 TETE: Latitude: -16.1328, Longitude: 33.6064 The HGS will be housed at the temperatures in all seasons range from -10 oC to 45 oC. Bidder to confirm the suitability of the proposed solution, to operate in this environment, confirming the dimensions of the equipment to be supplied, and any clearance distances or other dimensions to allow for the safe operation of the equipment and the observing staff involved (Including ATEX regulations). Please indicate pre-installation requirements in terms of site information, preparation, access, etc. The offered system is expected to install a new complete HGS at the 4 stations/sites which is detailed as follows: Hydrogen Generator Storage Tanks Water purification
8-03	Power	The Mains power supply at the site is Mains 220V AC nominal. Please confirm the proposed systems capability to run off this type of power supply. Additionally, please indicate UPS capabilities of the system proposed either as standard, or as costed options. The selected solution will as a minimum require UPS back for 10 to 20-minute outages to allow for system shutdown. The unit must include all recommended power systems necessary for the intended locations. These systems may be integral to the unit or installed externally but they must be supplied with the unit.
8-04	Water Purification	Supply and installation of a complete water purification system at each of the 4 stations/sites. To ensure the system can produce Hydrogen on an on-going basis, despite potentially varying water quality at the site, please confirm the water standard that is necessary to produce hydrogen in the volumes required (see 8-05) and for the application required. Please include in your proposal the solutions to cope with potential low water quality at the site. The unit must include all recommended water conditioning systems necessary for the intended locations. These conditioning systems may be integral to the unit or installed externally but they must be supplied with the unit.
8-05	Hydrogen Generation and Storage	One hydrogen generator for meteorological applications with capacity at least 0.5 Nm3/hr (20 SCF/hr). The Electrolytic generators to acquire must use Polymer electrolyte membrane (PEM) in the electrolysis of water, be sealed, tested, and able to operate 24/7 without interruption of service. Chemical type is not acceptable. The offered system should be compatible with the storage tanks and water purification and should allow the replacement of piping and valves and or storage tanks and water purification in future. The new storage tanks must have sufficient capacity to meet the operational need stated below. They should be made of either stainless steel or galvanized steel interconnected so that any one tank can be removed for

DS

		inspection and testing without impacting the operation of the station. Provide a quote for both types of steel tanks if available. Note: Balloons currently in use are 350 gram Sounding balloons. Currently ascents are 2 per day, but allowance should be made to cover 4 ascents per day for resilience. The storage must be able to fill an additional two balloons in succession to allow for an early balloon burst. Please specify storage capacity (standard, options) and how long it would take to generate the required volume of hydrogen.
8-06	Storage tanks	Supply and installation of a complete storage tank with required piping and valves. The storage tanks need to be able to withstand salty atmosphere (i.e. hot galvanised or similar). They need to have an isolation capability during refilling. They should be able to be drained to enable the removal of oxygen from the system. They also need to be capable of manual handling, as there is no procedure for lifting the equipment making this impractical.
8-07	Maintenance, tools and safety	The tender documents should specify the required maintenance and servicing requirements for the offered system, including any special requirements for storage and handling. The offer should include the necessary tools for the maintenance of the system and safety equipment (i.e. special garments and hydrogen presence detecting tools).
8-08	Evidence of operational use	The operational performance of the offered system (or equivalent) must be verifiable by its use routinely as a component of at least 3 WMO Members national network for a period of more than 1 year. The contact details of the WMO Member must be included within the tender documents so WMO can seek clarification of the system use and their user experiences.

Backup Power supply (Generator and UPS specification)

Table 65: Backup Power supply (Generator and UPS specification

Technical specification	The diesel generator must be at least a 40 KVA low noise/silent diesel generator with a 200lt built-in fuel tank.	4
	The diesel generator must be enclosed in a weatherproof / low noise canopy/housing.	
	An Automatic Transfer Switch (ATS) and Automatic Mains Failure (AMF) must be installed. The controller must have an interface to allow for remote access, monitoring and control of the generator.	
	The installation to include the balancing of the load	
	Fuel tank to be double wall to cater for spillage	
	Ethernet and GSM/GPRS/LTE module/interface for remote access and monitoring	

Other non-technical requirements	- Preparation of site for the installation of the new 40KVA low noise diesel generator with a 200lt build-in fuel storage tank at BEIRA: Latitude -19.8, Longitude: 34.9, MAPUTO OBSERVATORIO: Latitude: -25.9702, Longitude: 32.5937 - NAMPULA : Latitude: -15.1, Longitude: 39.28 and TETE: Latitude: -16.1328, Longitude: 33.6064. - Supply and Installation of a new 40 KVA low noise diesel generator with a 200lt build-in fuel storage tank. - Provide certified diesel generator installation, operations and maintenance training to a team of INAM personnel at the office. - Perform the Diesel Generator site Commissioning and Testing, which shall include the handing over of a complete Site As-Build record. - Provide SAWS with the following upon completion of the installation: ✓ Electrical Certificate of Compliance (CoC) for electrical work conducted during the installation of the new diesel generator. ✓ Diesel Generator Compliance (Mechanical Compliance) Certificate for the mechanical system and installation conducted during the supply and installation.	

Table 66: UPS specification

No.	Description of goods	Qty
1.	Supply, Installation, commissioning and testing of a new 10kVA UPS, 55Kg **Main Features:** ➢ Wide input voltage windows ➢ Expandable back up times ➢ Cold start ➢ Load/battery power meter display ➢ LED/LCD display ➢ Automatic charging in UPS off mode	4
	Input: ➢ Phase: single phase and ground ➢ Voltage range: 220V/230V ➢ Frequency: 45-65Hz	

	➢ Max current: 50A/48A	
	Output: ➢ Phase: single phase and ground ➢ Voltage: 220V/230v ➢ Waveform: ➢ Frequency: 50Hz ➢ Max Current: 50Hz ➢ THD (Linear Load): ➢ Power Factor: ≥ 0.99 ➢ Overload capacity: overload (later go to bypass, automatically resume when load becomes normal) ➢ Short circuit protection: current limit, turn off automatically switch	
	Protection: ➢ Surge protection: IEEEE527B ➢ Noise: FCC.A	
	Communication: ➢ RS232 ➢ Ethernet interface	
	Battery: ➢ Type: 12V/7AH ➢ Maintenance free ➢ Charge current: Standard 1.2A Long run 6A ➢ Charge time: 90% capacity after approx. 8 hours	
	Environment: ➢ Noise: maximum 55db ➢ Temperate: 0 – 40°C ➢ Humidity: 0 – 95%	
	Indication: ➢ LCD: working mode, input and output voltage, input and output frequency, battery voltage, load percentage, UPS inner temperature.	

	➢ LED: low battery, on-line, inverter, bypass, abnormal. 85% efficiency of the whole unit achieved.	
2.	Annual service/maintenance (as and when needed) of the UPS	4
3.	Issuing of an electrical Certificate of Compliance (CoC) for electrical installation performed.	4

Table 67: Backup Power supply (Generator and UPS)

Activities	COST Implications forecast (USD)					
	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Supply, installation and commissioning of four 40kVA silent diesel generator with a 200lt build-in fuel storage tank, including maintenance	30303	16060	16868	6323	6386	**75940**
Supply, Installation, commissioning and testing of a new 10kVA UPS, including maintenance	4798	2368	2508	967	1064	**11705**
TOTAL	**35101**	**18428**	**19376**	**7290**	**7450**	**87645**

3.2 Design of the ICT infrastructure and services

a. Detailed description of the ICT infrastructure and services design

Server room at INAM

The INAM Head Quarters network infrastructure (network cables, switches, and network points), including the server room was renovated/upgraded during 2021/2022 and the project was completed during February 2022, thus no need for a network upgrade in the near future.

Network service providers to INAM are:

1. Vodacom for the Primary link at 20 Mbps
2. MoRENet is the secondary/ backup link at 50 Mbps.
3. MOVITEL is being used for AWS data transmission and currently utilising GSM/GPRS technology.

The following ICT infrastructure is installed in the server room:

- AMBIMETRIC / system (also an / FTP server) which is used for receiving AWS data from automatic (un-manned) weather stations, monitoring and accessing AWS's &

configuring AWS's remotely, dataflow monitoring and & AWS data transfer to the ClimSoft system.

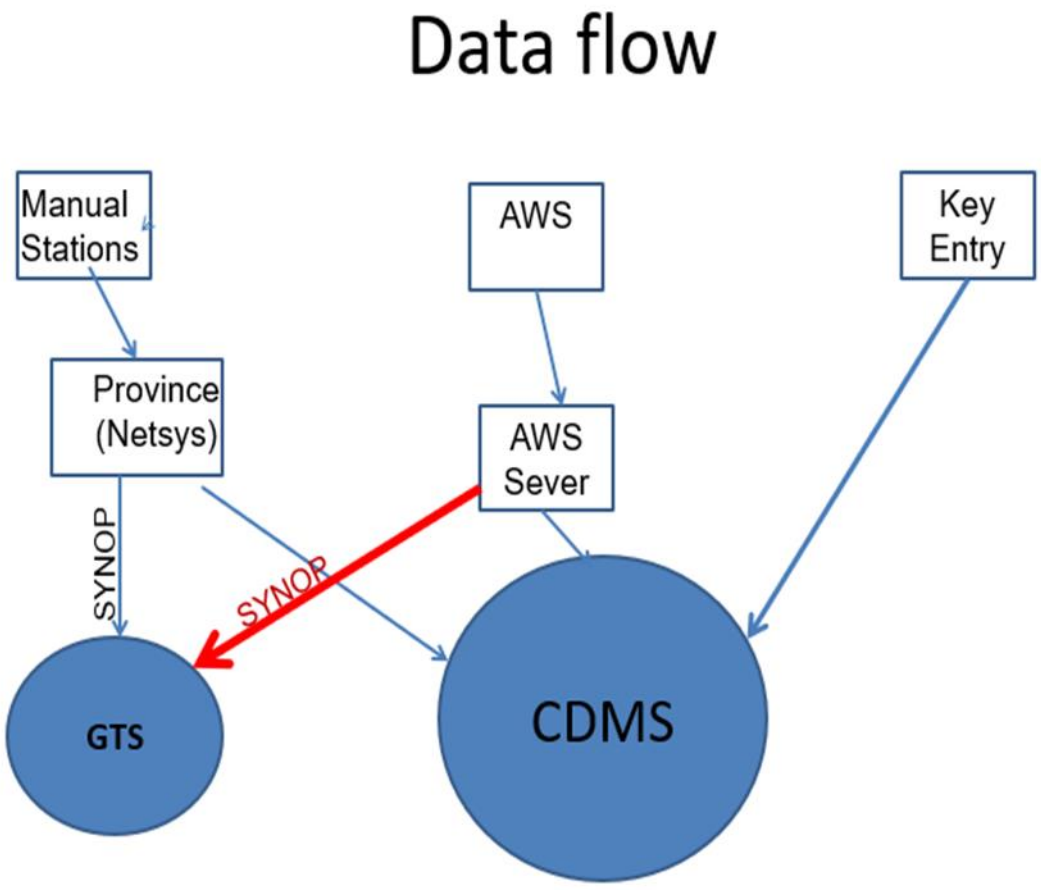
- Data Management System (CDMS) in use is ClimSoft,
- Message Handling System (MHS),
- 2 x HPC servers (provided by Dell),
- Mail server (application in use is Surge mail),
- Diana forecasting workstation server (not fully utilized)
- Web servers (main & aviation). – a web application on the aviation web server, used for compiling and submitting manual synoptic station readings on a 3 hourly basis.
- ClimSA (Climate Station) system was installed recently.

Backup power

- UPS & Generator for server room.
- Generator and UPS for main building.

The Aviation Centre at the airport is on separate network, linked to HQ.

The current data flow at INAM is depicted in the image below.



b. Technical specifications for the data collection system from the observing station to the collection point

The current Automatic Weather Stations network of Institute of National Meteorological Services of Mozambique utilizes GPRS/GSM cell phone technology for Data transfer to the FTP Server at the Head Quarters and from the FTP server to their ClimSoft server (CDMS). Unmanned / automatic stations transmit hourly data, but this data is currently not being distributed to the GTS.

For manual stations, observations are compiled and submitted via a web interface on the Aviation web server and submitted directly to the MHS for distribution to the GTS.

MOVITEL is the service provider being used for Automatic Weather Stations network data transmission because they are the only company that provides cellphone coverage over the whole country, including remote areas.

c. Technical specifications of the data services (compatible with the requirements of WIS 2.0)

The critical component to the success of the GBON implementation is Information and Communication Technology (ICT) capability to support data communication from the remote AWS to the Global Telecommunications System (GTS). There is therefore a need for an ICT infrastructure and services design as well as the solutions on data transmission from an observing station nationally, on real-time bases through data management system and to the GTS. The designed system has the capability to transmitted in Binary Universal Form for the Representation (BUFR) format from the source (AWS) to the GTS.

The requirements for WIS 2.0 are that the AWS should have a data logger that meets data transfer protocols, MQTT and SFTP. Data collected from the station must be converted automatically to generate BUFR reports for WMO international data exchange through GTS and WIS 2.0. Data should be converted to BUFR without any need to be loaded on a database.

INAM SYNOPTIC reports are provided in TAC format. BUFR bulletins are compiled (coder / decoder) on their MHS server and submitted to GTS. There is a mixture of AWS data logger providers such as Campbell Scientific, Vaisala (mostly AWOS), WAGTEC - sponsored by SADC and MESA (Italian company), but these stations are not able to produce SYNOP – they only provide 5-minute data. Currently no hourly data distributed. The only SYNOPS on the GTS are those compiled manually by weather observers, and it is only for main and intermediate synoptic hours.

Recommendation on ICT infrastructure and services design and solutions on data transmission from an observing station to the national real-time data management system and GTS and WIS 2.0, including:

1. Server upgrade needed for MHS Hardware and Software plus training of ICT personnel on Message Handling System for data distribution to GTS until WIS 2.0 in a box can be implemented.
2. Two servers needed for WIS 2.0 in a box implementation.
3. Hardware upgrade needed for AMBIMETRIC (usage - monitoring AWS, FTP, LoggerNet and NESA data logger software) server.
4. At least four laptops with internet connection for maintenance of AWS in the field (preferably rugged laptops) and at least two desktops for monitoring purposes.
5. Four data logger software licences for Loggernet and AWSPlus (Synop generation), respectively.
6. Backup and archiving system needed for all systems.
7. A proper monitoring system needed for network, server, dataflow, and data availability.
8. Data collected from the station must automatically be converted to BUFR for generation of high-resolution report for WMO international data exchange through GTS and WIS 2.0.
9. Data should preferably be transmitted in BUFR format from the source (AWS) without being converted from TAC to BUFR first.
10. WIS 2.0 in a box training and implementation is required as soon as possible and can be conducted via WMO workshop / training.

The implementation of WIS 2.0 in a box requires the procurement and installation of two servers and the installation and rehabilitation of surface observing stations to MQTT/SMTP data transfer protocol which is required for WIS 2.0 Box. Implementation of WIS 2.0 is aimed for December 2024. This projection is based on the funding proposal timelines. Procurement will be initiated as soon as funding is available.

3.3 Design of the ICT infrastructure and services

The proposed design of the INAM ICT infrastructure and services will meet the following requirements:

- Run on general purpose industrial computers and/or cloud service, with latest versions of the OS installed,
- Automatic data files and system processes management,
- Redundancy,
- Remote software installation and upgrade,
- User defined access security, including Data access restricted by authorization,
- Logging of system information and alarm for any technical challenges, with logging retention period, and
- Sustainable and cost effective

Planned maintenance and upgrades will be performed as per the OEM instructions and relevant SOPs will be developed to document system design, implementation, and maintenance as well as the data flow from remote stations to provincial offices and subsequently to the INAM Head Quarters.

Furthermore, the design will ensure the implementation of the WMO Information System 2.0 (WIS 2.0) framework for the international, regional, and national exchange of data in support to the WMO Unified Data policy, the Global Basic Observing Network (GBON).

Discovery and descriptive metadata management

The DMS currently used by INAM makes information on the discovery metadata (discovery, access and retrieval) and interpretation/description or observational metadata. The design of the INAM infrastructure and systems will make provision of the WMO Information System (WIS) metadata and are specified and handled as part of WIS 2.0 in a box. WIGOS metadata for observations from all WIGOS component observing systems are managed through the WMO OSCAR/Surface tools which is updated by the NFP OSCAR/Surface and the metadata editors. The INAM WIS metadata catalogue will be updated as per the metadata catalogue.

Table 68: Meteorological Data Management System

ID	Requirement Heading	Requirement
307(a)	General purpose industrial computers and/or cloud service	The system should use a combination of general-purpose industrial computers and cloud services.
310	Office systems environment	The desktop systems (if part of the project) environment must be the latest stable version of the OS, or equivalent. [The customer should designate a time period (suggestion 5 years) for which the software will guaranteed on the offered OS.]
170	Automatic data files management	The data files or databases should be managed automatically by the system without human intervention.
234	Management of system processes	The MDMS must be able to access system components to perform system management (such as starting and stopping processes, file management, etc.).
323	Redundancy	All aspects of the MDMS should be a redundant system. The redundant systems should have a hot standby relationship. Operation should be taken over within 1 minute. It is preferred to also have a redundant LAN. Cabling should support redundant systems (no plugs have to be changed to make operation of the standby system possible).
348	Software installation from central point	The system must provide facilities for the installation, for making new versions of the software operational and for making new versions of the configurations operational, from a central point, through the MDMS.
296	Access security method	Access authorisation should be based on user identification in combination with a personal password.
169	Logging of system information	Logging of system process and error correction, as provided by the computer operating systems, must be possible. It should be possible to turn this logging on or off by a system administrator. The system administrator can select the relevant system information to be logged (when logging is switched on).
221	Alarm list	All exceptions should generate an alarm that should be presented in an “alarm list”, that should be visible for all MDMS users.

224	Notifications to user	It should be possible to configure the MDMS to send notifications to users in case of exceptions, where all notifications or for particular groups of notifications, are not possible. At least notifications per email should be possible.
971	Logging retention period	The system must retain logged data for a period of [Time period to be determined by the customer, at least 7 days is recommended]. The retention period must be configurable.
293	Data access restricted by authorisation	In order to prevent unauthorised personnel from accessing or damaging information, it is required that authorisation needs to take place. Access to security and privacy sensitive information must be as per login procedure. Access authorisation is to be provided by the supplier, the customer must decide which systems must require login access.
162	Management of configuration parameters for data processing	It must be possible to configure the process of data storage, transactions and processing of the received data sets and/or data reports. Parameters that can be configurable are, for example: • Back-up location • Control data to check the supplied data (files), • Adjustment of the default-priorities • Overview of the waiting queue • Changing manually the default priority settings concerning data processing
235	Access to the MDMS for system management	The MDMS has three types of users with the following access rights: • Technician access rights The technician is responsible for monitoring the technical status of the meteorological equipment. The technician has access rights to view certain displays and to take limited actions such as described in MDMS_014. • Meteorological administrator access rights The meteorological administrator is responsible for meteorological configuration of the AWS and MDMS, the algorithms, the instruments, etc. • System administrator access rights The system administrator is responsible for the technical condition of all computer equipment, data communication equipment, and the ICT configuration of the systems (IP configuration, hardware and software configuration). The system administrator has access rights to all functions within the MDMS, but he should not change the meteorological configuration without approval from the meteorological administrator.

Table 69: Costing: ICT infrastructure requirements

Activities	COST Implications forecast in USD			
	Year 1	Year 2	Year 3	
Message handling System upgrade and configuration (SLA with service provider)	9500	10450	11500	21100
Procurement 2 X MHS servers	20000	N/A	N/A	20000
Procurement, installation, and configuration of Servers for WIS 2.0 (2)	20000	N/A	N/A	20000
Procurement of 3 X Laptops for AWS maintenance	6000	N/A	N/A	6000
Hardware upgrade for AMBIMETRIC (FTP Server)	10000	N/A	N/A	10000
Procurement and installation of the AMBIMETRIC FTP backup	10000	N/A	N/A	10000
Procurement and installation of the ICT monitoring system	3500	N/A	N/A	3500
Storage for backup purposes	30000	5000	5000	40000
Loggernet and AWSPlus licences (4 each)	6800	6800	6800	20400
TOTAL				**155500**

3.4 Environmental and sustainability considerations

The INAM will address the environmental impact of observing technologies as they strive towards GBON compliance. The surface observing networks will be designed, implemented, and operated with the aim of having a sustainable weather and climate observing system.

The upper-air consumables will meet environmental regulatory compliance for batteries, packaging and hazardous substances and mercury with the consideration of biodegradable packaging to be used where possible.

INAM will also consider the use of instruments that have the option for sub-components or sub-systems to be replaced rather than to dispose of the whole instrument. The plan is also to develop a SOP that will guide the re-use of instruments and the elimination of single use plastics or all-in-one sensors. Technologists will also be trained on instrument repair and advance fault diagnostics in support of this initiative.

Module 4: Human capacity development

INAM is a public institution of a scientific and technical nature, endowed with legal personality and autonomy to direct meteorological activity at national level, ensuring the inspection and supervision of the operation of the national network of meteorological, agrometeorological, climate and air quality monitoring stations, in collaboration with other State and private entities that operate similar observation networks. INAM hereby leverage on this mandate to perform its national functions.

The staff complement of INAM is approximately 241 for technical and data management employees based at different offices across Mozambique. 16 of those are technical and technological employees whose capabilities can be enhanced to sustain GBON allocated infrastructure as well as capacity to ensure data exchange through GTS/WIS to the international data centres. 20 of the employees are involved in data capturing and quality control. Some can be unskilled to assist with basic routine maintenance of the GBON assigned infrastructure as well as performance of upper air soundings.

Table 70: Human resources

Province	Human Resources			
	Number of Maintenance Technicians	Number of Technologists	Number of Observers	Number of Data Quality Personnel
Cabo Delgado	0	0	8	1
Gaza	0	0	27	1
Inhambane	0	1	20	1
Manica	0	0	13	1
Maputo	0	0	3	0
Maputo City	6	7	27	11
Nampula	0	0	21	1
Niassa	0	0	14	1
Sofala	1	1	15	1
Tete	0	0	39	1
Zambezia	0	0	18	1

4.1 Assessment of human capacity gaps

- The staff complement as of 2018 for INAM from the Human Resources department which reflects the status on the human capacity maintaining and operating the current weather observations infrastructure was used for this assessment.
- Furthermore, INAM organisational structure (for the Central Office) was shared. Information received suggested that there are similar structures for regional centres in Nampula and Sofala. This information is necessary as it will inform how many Weather Observers, ICT Personnel and Instrumentation Maintenance Personnel will attend to the 21 GBON AWS' and Upper Air Stations as Capacity Building initiatives will focus on them.
- The organogram revealed that the key divisions and departments that will be involved in the GBON programme are the following:
    - Central Observations and Network Services division: Department of Weather Observations
    - Central Infrastructure and Maintenance Services: Information and Communication Technology Department as well as the Maintenance and Calibration Department
    - Human Resources Department's Training Unit
- We were informed that in August 2022, the number of Weather Observers that work across the 10 Provinces (Maputo, Gaza, Inhambane, Sofala, Manica, Tete, Zambezia, Nampula, Niassa and Cabo Delgado). The highest academic level of the Weather Observers was as follows:
    - 0.5% up to Primary school
    - 62 % up to Secondary school, and
    - 24 % up to University Graduate level (although their degrees non-meteorological
    - 14 % from the Gaza Province have not been accounted for as this information was not received.
- Current Weather Observers are trained according WMO Class IV and Class III syllabi. The WMO Executive Council Panels of Experts in Education and Training have since come up with two versions of the Basic Instruction Package for Meteorological Technicians (the latest being the BIP-MT 2022) which set higher standards for the training syllabus for Meteorological Technicians (previously known as Weather Observers). It is highly recommended that those Weather Observers involved with the GBON stations receive updated training, especially because it now includes specialisations (over and above the mandatory modules) such as 'General Meteorological Technician', 'Instrument Technician', 'Specialist Climate-Data Controller', and 'Marine Meteorological Observer' among others.

4.2 Design capacity development activities for technical staff

Personnel responsible for maintenance of the ICT networks as well as observations infrastructure requires upskilling to meet the ever-growing technological enhancement being used for data collections and dissemination. Upper air sounding has not been performed in the country for an extended period. Personnel trained previously to perform this role need refresher training on preparation and deployment of balloons and their payloads. Encoding and transmission of upper-air observations, using prescribed codes and methods is also required to enhance quality control capacity of the NMHS.

It has been noted that there is a Training Unit that resides in the Human Resources Department. In this unit, the Chief of Training utilises staff in the departments of Weather Observations, Aeronautical Observations (Unit), and the Maintenance and Calibration Department to conduct training. This indicates that there are no full-time Trainers, especially since the passing of the Chief of Training recently. There is an opportunity for WMO RTCs to assist in providing refresher meteorological observation training to current Observer Technicians (those with WMO Class IV and Class III qualifications) as well as AWS training to Maintenance Engineers and Instrument Technicians. Training by OEMs should also be considered as part of the roll-out of new infrastructure and technology.

It is recommended that provisions of the "One district one weather station" strategy which outlines future recruitment of required personnel be aligned in this document to attain human capital required for sustained operation of the GBON assigned network.

Surface Land Stations

Table 71: Training requirements for technical personnel

Performance components: install instruments and communication systems
1. Assemble and test instruments before transport to site
2. Transport instruments to site
3. Install instruments and communication systems (including simple site preparation)
4. Coach observing and technical staff in the operation and maintenance of the instruments (including provision of SOPs), standard operating instructions, system manuals, wiring diagrams, and the like
5. Thoroughly test on-site instrument and communications performance, prior to operational cutover
6. Complete site classification for variable(s) concerned, prepare and submit instrument and variable metadata to WIGOS via the Observing Systems Capability Analysis and Review Tool (OSCAR)
7. Switch instrument(s) to operational mode.
Performance components: Maintain instrument and system performance
1. Schedule and carry out preventive maintenance and site inspection following prescribed procedures (for example, change wet bulb wick or recorder charts, clean pyranometer dome or ceilometer window, change anemometer bearings, and carry out preventive maintenance on more sophisticated pieces of equipment such as radars and AWSs as specified in the SOPs)
2. Ensure availability of prescribed spare parts inventories
3. Monitor data availability and the performance of instruments and communications systems

4. Routinely verify correct functioning of instruments, following prescribed procedures
5. Perform on-site calibration checks to ensure that instrument performance is within tolerance, following prescribed procedures
6. Provide guidance and refresher training, remotely, if necessary, to on-site staff, to maintain compliance with prescribed methods of operating the instruments, for making observations and with procedures for the reduction of observations
7. Inspect the exposure of instruments and remove any obstacles nearby, if necessary
8. Record maintenance and site inspection events, calibrations, sensor/instrument replacements in the maintenance log or metadata repository.
Performance components: Diagnose faults
1. Detect abnormality in data acquisition and system operation;
2. Inspect observational instruments, communications systems, power supply facilities and auxiliary infrastructure for faults;
3. Provide guidance, remotely, if necessary, to on-site staff to identify and diagnose minor faults;
4. Record all faults and their occurrence time in a maintenance log or metadata repository
5. If repair is required, order delivery of requisite spare parts.
Performance components: Repair faulty instruments and systems
1. Provide guidance, remotely, if necessary, to on-site staff to repair minor faults;
2. Assess spare parts requirements and ensure availability;
3. Repair faulty components following prescribed procedures and processes;
4. Perform tests after repair to ensure compliance with performance requirements
5. Record repair actions taken and time of resuming data acquisition in a maintenance log or metadata repository.

Upper-air (radiosonde) land stations

Table 72: Training requirements for upper-air sounding personnel

Performance components
Prepare and deploy balloons and their payloads: • Balloon shed safety check. • Balloon preparation and filling. • Instrument ground check. • Balloon release.
Track balloon flight
Compute and record: • Upper-air pressure, temperature, and humidity. • Upper-air wind speed and direction. • Other specialized upper-air observations as required (for example, ozone).
Encode and transmit upper-air observations using prescribed codes and methods.
Knowledge and skill requirements
1. Hydrogen safety and generation
2. Understanding of general meteorology as described in BIP-MT, including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments, and methods of observations;
3. SOPs and prescribed practices for performing upper-air observations
4. On-site instrumentation and systems (including software)
5. Care in handling instruments
6. Accuracy in reading instruments and recording observations;
7. Use of meteorological codes to record observations

Table 73: ESTIMATED CAPACITY DEVELEPMENT FINANCIAL IMPLICATIONS

Activities	COST Implications forecast (in USD)*					
	Year 1	Year 2	Year 3	Year 4	Year 5	Three-year totals
'Instrument Technician' competency training programme (@115,000.00ZAR for a group of up to 5)	5808	7323	7879	8435	8991	38436
'Specialist Climate Data Controller' competency training programme (@80,000.00ZAR for a group of up to 5)	4040	4343	4696	5049	5402	23530
Upper-air training programme (@85,000.00ZAR for a group of up to 5)	4293	4672	5025	5378	5731	25099
Capacity development of the ICT personnel (including Message Handling System for data distribution to GTS)	5088	5667	6246	6843	7415	31259
'Train the Trainers' competency training programme from a WMO recognised RTC (@102,000.00ZAR for a group of up to 5)	5152	5556	6010	6415	6820	29953
'Observing equipment OEM training'**	N/A	N/A	N/A			
TOTAL						148277

***Note 1: above costs do not include travel and accommodation costs**

****Note 2: The OEM training costs could be included in the price of the purchase and installation of the observing equipment if the purchase agreement is set up as such.**

4.3 Design capacity development activities for Senior Management

There is a need for capacity development activities for Senior Management tasked with the management and monitoring of national observation infrastructure, planning for infrastructure rollout, budgeting for resources needed in sustaining the observation network, implementation of WMO related observation recommendations such as the Unified data policy, WIGOS implementation and the others, as well as the importance of collection and quality control of observation data.

It hereby recommended, realising the task of compliance with GBON requirements, Unified WMO data Policy requirements, that refresher training on project management as well as budgeting be considered for the senior management of the INAM.

Table 74: The planned capacity development activities

#	Activity	Cost (USD) Unit price
1.	Capacity development on WMO Standards and Regulations	0
2.	General Management Programme	26000
3.	Women as Leaders	975
4.	Finance for Non-Financial Managers	1120
5.	Project Management for Non-project Managers	945

4.4 CSO consideration and Gender considerations

INAM's observation network has been deployed throughout Mozambique and there is a need for engagement with communities throughout the country with the aim of awareness campaigns on the importance of weather observations infrastructure being enhanced to meet the GBON requirements. This activity should also target private entities that own and operate meteorological stations to sensitise them of the existence of the national observation infrastructure which can be leveraged upon for required data to minimise duplications.

It is recommended that INAM embark on the awareness campaign across the provinces of Mozambique. INAM will be conducting national awareness campaigns to sensitise the communities of the significant role which data collected from the weather observation infrastructure is playing toward climate resilience and food security. During the workshops to be conducted, the specific roles of CSOs in different provinces of Mozambique will be defined. Communities will be adequately informed and involved in the initiative by INAM in close coordination with CSOs. This will aim to translate into better understanding of the initiative at local level, and consequently to a reduction of vandalism of the observation network and improve on data availability.

In terms of gender split in the Weather Observers, ICT and Instrumentation Maintenance personnel groups, the numbers are highly skewed toward a male dominance. To correct this imbalance, INAM need to develop a Gender Equity strategy aligned to the WMO recommendations on gender equity. This strategy will INAM to embark on a decisive recruitment drive that targets young females to join the ranks of the organisation. It is also important to note that INAM has undertaken to engage end users of their services and information products to understand the vulnerabilities of women and girls when designing improved service. This undertaking would have to be unpacked considering the services and products that are provided, and how these can be fine-tuned, to cater for the vulnerabilities of women and girls.

It is recommended that INAM develop a gender equity and equality plan to address existing gaps in women's inclusion and empowerment when it comes to GBON infrastructure management, contributing to an overall improved gender balance within INAM.

Module 5: Risk Management Framework

Table 75: Risk Management Framework

Risk category	Description	Probability	Mitigation action
Contextual risks Risks related to conflicts, safety and political insecurity jeopardizing the delivery of the Readiness phase outputs	There are some insecurity issues in some areas of Cabo Delgado, in the northern tip of the country due to terrorism actions that may jeopardise the delivery installation and operation of the infrastructure	High	1. It is unlikely there will be a need to travel to these areas and avoid travelling to high-risk areas and if required, adopt recognized security measures. 2. Draft a request to WMO to approve exclusion of conflict prone areas such as Cabo Delgado.
	High-impact tropical cyclones affecting Mozambique.	Moderate	Remain vigilant to the risk and alter project activities to minimize the risk.
	Slow procurement process to acquire network required spares to maintain the network (Medium)	Moderate	Utilisation of third party (IE) for acquisition of required observation infrastructure material.
	Vandalism of the deployed infrastructure.	Medium	1. Awareness campaign and sharing of information from the infrastructure, 2. Installation in secure locations.
	Accessibility of selected sites to the deployed infrastructure and maintenance thereof.	Medium	Pre-planning during visitation of the sites taking into consideration the current road infrastructure.
Institutional risks Risks related to the beneficiary country's institutions participation in the	INAM availability of staff resources to fully commit to the readiness phase.	Low	Improve engagement, communication and planning with the PA and IE.

Readiness phase activities	Inadequate Human Capacity to manage and maintain the GBON assigned Network in line with the GBON operational requirements. (Observations and ICT) (High)	High	Capacity Development in line with the national Strategy. (A District a Weather Station)
Programmatic risks Risks related to country ownership of the Readiness phase outputs	Lack of full support from other government agencies and institutions to the benefits of SOFF to the country.	Low	1. The Mozambique government is highly aware of its vulnerability to high-impact weather and is the nominated champion at the African Union. Effective communication of the how SOFF benefits the agenda of all agencies. 2. Legislation updates to support meteorological services nationally

Module 6: Transition to SOFF investment phase

This module involves supporting the beneficiary country and the IE in preparing the Investment phase funding request based on the recommendations provided in the Plan.

Please provide any additional recommendation relevant for the translation of the National Contribution Plan into an Investment Phase Funding Request.

Table 75: SUMMARISED INVESTMENT FUNDING PROPOSAL FOR INAM

	Estimated cost in USD
Item	**Three-year Total**
Surface land observing network	
• **Upgrade of existing AWS**	77722
• **Installation of new AWS**	107192
Upper-air observing network	
• **Buildings and Structures: Balloon rooms (Rehabilitation)**	457184
• **Ground systems and hardware (Installation fee)**	90920
• **Hydrogen Generation Systems**	1645800
• **Consumables**	1597338
• **Backup power (Generator and UPS)**	87645
• **Operation and maintenance (5years)**	0
Calibration and maintenance (AWS)	
• **Spares**	377437
• **Maintenance equipment**	114300
• **Calibration equipment**	194362
• **Machinery and equipment**	2213
• **Travel/Vehicles**	69057
Safety, Health, Environment and Quality (SHEQ)	
• **Fire extinguishers**	0
• **Personal Protective Clothing**	0
• **Gas leak detection unit**	0
Information and Communication Technology and Data Management	
• **Hardware and installation**	95100
• **Storage**	40000
• **Consultation and training**	17000
• **Software Licenses**	20400
Training and Capacity development for staff (Human Resources)	
• **Sounding technicians**	25099
• **Maintenance technicians and technologists**	38436
• **Data staff**	23530
• **IT Staff**	31259
• **Competency training**	29953
• **OHS Requirements**	0
• **TOTAL**	5141947

Summary of GBON National Contribution Plan

Components	Recommended activities
Module 2. GBON business model and institutional development	1. INAM have existing MoU's which can be used to strengthen the working relationship with national Governmental departments such as National Directorate of Water Resource Management under the Ministry of Public Works and Housing as well as the Ministry of Agriculture and private institutions. These MOUs can be reviewed to include clauses that allow for utilization of their weather observations stations to contribute to GBON, where necessary, as well as data sharing in line with the WMO universal data policy.
	2. Private sectors such as Cahora Bassa, Institutions of Higher learning, Açucareira de Mafambisse and Açucareira de Marromeu Sugar factories owns weather observations stations and INAM have existing memorandum of understanding (MoU) with them. INAM to review which can be reviewed to allow for inclusion of additional stations into the national observation network. There is a need to develop program of action aligned to the existing MoU's, which could include sharing of resources for upgrading and maintenance of stations to be GBON compliant.
	3. INAM to prioritize the development of the National WIGOS implementation plan where all stakeholders owning and operating weather observations infrastructure can be mobilized to contribute to the rollout of the weather infrastructure that will address data needs for all weather sensitive industries in the country.
	4. INAM to engage potential partners such as Maputo and Zinave National Parks who own and operate observation weather stations, with the aim of entering MoU's to enhance availability of weather observations infrastructure nationally.
	5. WIGOS implementation advocates for sharing of resources to minimize on duplication. It is recommended that the process to implement WIGOS nationally be initiated to leverage on possible funding from private sector for roll out of weather stations they require which might be co-located with already existing INAM infrastructure. The said funding can then be used to upgrade the existing stations. Partnering with private sector provides an opportunity to leverage on private sector ability to source required infrastructure faster than the public sector.
	6. Mozambique shares its border with five countries, namely, South Africa, Zimbabwe, Malawi, Eswatini, Tanzania and Zambia. The said countries have been identified as potential sub-regional collaborators for implementation of GBON. It is recommended that INAM evaluate existing and or develop MoU's with neighboring countries to included data sharing for GBON assigned stations to close data gaps along the borders and eliminate overlapping coverage along the borders.
	7. INAM to leverage on regional organizations / bodies of relevance for implementation of GBON within the sub-region, such as (MASA) the Meteorological Association for Southern Africa, (AMCOMET) African Ministerial Community on Meteorology as well as regional Centers to address the GBON requirements within Mozambique.

	8. Participate during development of the Regional WIGOS implementation plan to leverage upon WIGOS plan since it advocates for optimized coverage regionally.
	9. The current weather observation infrastructure for INAM is funded through Mozambique National Government budget. The provided budget covers the entire INAM financial requirement which includes, but is not limited to personnel salaries, maintenance of buildings, communication, travel and accommodation, logistics, maintenance of Weather Observation and Forecasting systems as well as repairs and maintenance of the Information and Technology systems of INAM. The projected budget for the current financial year of 68628.60 USD covers preventative maintenance, corrective maintenance, and AWS communication for the 21 AWS allocated for GBON. The budget does not cover spares that are required for the said stations. With inflation, this budget will increase exponentially to 75649.13 USD by year 2 and to 83041.84 USD by year 3. This budget further excluded refurbishment of some of the AWS to be GBON compliant, Human Capacity requirements to maintain the AWS network operation in accordance with the GBON requirement. It is recommended that external funding be made available to sustain the network.
	10. The National Institute of Meteorology, abbreviated to INAM, is a public institution of a scientific and technical nature, endowed with legal personality and autonomy to direct meteorological activity at national level, ensuring the inspection and supervision of the operation of the national network of meteorological, agrometeorological, climate and air quality monitoring stations, in collaboration with other State and private entities that operate similar observation networks. **(See Ministerial Diploma No. 67/2016 supplied with this report)** for more details. INAM to leverage on this mandate during engagements with public and private sector in matters related to observation networks nationally.
	11. INAM developed a national strategy called "A District a Weather Station" aimed at expanding the meteorological observation network to the district level in a phased approach, targeted for completion by 2030 which is not funded. (See **PROGRAM "ONE DISTRICT, ONE WEATHER STATION" supplied with this report**). INAM to use this strategy for deliberation with the government to meets its future weather observation infrastructure needs.
	12. INAM utilizes the approved Regulation Decree no. 79/2022 for Contracting Public Works, Supply of Goods and Provision of Services to the State. As stated in Article 5 of the said regulation, the documents that make up the hiring process public must be written in Portuguese. The Contracting Entity may, simultaneously, disclose the Announcement and Tender Document in Portuguese and in another language, always with the prevailing documentation in Portuguese. It is recommended that this article be considered to facilitate procurement. (**The full document is attached**)
	13. The National Institute of Meteorology, abbreviated to INAM, is a public institution of a scientific and technical nature, endowed with legal

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	personality and autonomy to direct meteorological activity at national level, ensuring the inspection and supervision of the operation of the national network of meteorological, agrometeorological, climate and air quality monitoring stations, in collaboration with other State and private entities that operate similar observation networks. **(See Ministerial Diploma No. 67/2016)** for more details.
	14. INAM developed a national strategy called "A District a Weather Station" aimed at expanding the meteorological observation network to the district level on a phased in approach, targeted for completion by 2030. (**See PROGRAM "ONE DISTRICT, ONE WEATHER STATION**")
	15. Chapter 1, Article 3(b) and 3(g) of the Internal Regulation of INAM state " (a) Ensuring the inspection and supervision of the operation of the national network of meteorological, agrometeorological, climate and air quality monitoring stations, in collaboration with other State and private entities that operate similar observation networks" and " (g) Guarantee the observation, transmission, monitoring, archiving and publication of the results of national meteorological and climate observations". The two provisions are more relevant for supporting the operation of the observation networks in line with the GBON requirements. Furthermore, Article (15)(e) of the INAM mandate address, compliance with the norms and observation methods recommended by the Organization World Meteorology and Article 25(e) also addresses data communication through the GTS .
	16. There is an existing MoU between the World Food Programme (WFP) and INAM. Within this MoU is a provision for funds transfer between INAM and WFP. The existing MoU between two entities could be considered for accelerating procurement of required equipment to support the SOFF programming of the Institute of the INAM. Furthermore, considering procurement of spares for existing infrastructure, this MoU can shorten the timeframe for acquisition thereof. WFP has a dedicated technical department that can be called upon to support large projects such as the upgrading and installation of weather observation infrastructure of INAM.
Module 3. GBON infrastructure development	1. The global gap analysis developed and provided by WMO to The Institute of National Meteorological Service estimated the need for 20 GBON surface land stations for standard density to meet the horizontal resolution requirement. SOFF Peer Advisor GBON National Gap Analysis conducted in May 2023. Recommendation 21 talks to surface land stations to close the national GBON network gaps for Mozambique. The additional stations included will close the gap in the southeastern part of Zambezia province.
	2. Based on the WMO GBON requirements, 15 of the 21 stations assigned as GBON stations meet all WMO sensor specifications and datalogger specifications, but do not meet hourly data transmission requirements. These 15 AWS to be programmed to transmit data on an hourly basis to be fully GBON compliant. The remaining 6 stations need to be

	upgraded or replaced with new stations before GBON compliance can be met.
	3. INAM currently does not have any existing operational upper-air stations. The plan is to establish and implement an upper-air network consisting of four new upper-air stations. The stations will perform 2 soundings per day. The sites identified are Beira, Maputo Observatorio, Nampula and Tete. Action at the upper air sites is to: - a. Rehabilitate the existing balloon building at Beira, Maputo Observatorio and Nampula. b. Leasing of a complete upper air ground receiving system for a period of 5-year, renewable c. Supply of upper-air consumables d. Supply of backup generators for all four sites
	4. ICT infrastructure and services design as well as solutions on data transmission from an observing station to the Meteorological Data Management System be configured to send data to one or more MDMS via a suitable data transfer protocol: MQTT (Message Queue Telemetry Transport) or SFTP (Secure Shell File Transfer Protocol). Redundancy on the system is recommended to have a change over option to allow for minimum disruption in the system.
	5. Data transmission systems can be configured such that Data collected from the automatic Weather stations can be converted automatically to generate BUFR reports for WMO international data exchange through WIS 2.0 or GTS. Conversion to BUFR to take place without any need for data to be loaded on a database.
	6. Procurement of two Servers for implementation of WIS-2.0 in a box, Server software for Message Handling System (MHS), Hardware upgrade for the AMBIMETRIC (usage - monitoring AWS, FTP, LoggerNet, Sonda Web software) server, Procurement of backup and archiving system for all systems and procurement of proper monitoring system needed for network, server, dataflow, and data availability.
	7. The implementation of WIS 2.0 in a box requires the procurement and installation of two servers and the installation and rehabilitation of surface observing stations to MQTT/SMTP data transfer protocol which is required for WIS 2.0 Box. Implementation of WIS 2.0 is aimed for December 2024. This projection is based on the funding proposal timelines. Procurement will be initiated as soon as funding is available.
Module 4. GBON human capacity development	1. Current Weather Observers for INAM are trained according to WMO Class IV and Class III syllabi. The WMO Executive Council Panels of Experts in Education and Training have since come up with two versions of the Basic Instruction Package for Meteorological Technicians (the latest being the BIP-MT 2022) which set higher standards for the training syllabus for Meteorological Technicians (previously known as Weather Observers). It is highly recommended that those Weather Observers involved with the GBON stations receive updated training, especially because it now includes specializations (over and above the mandatory modules) such as 'General Meteorological Technician', 'Instrument Technician', 'Specialist Climate-Data Controller'

	2. Head of Observations is the focal point on WDQMS and is also responsible for management of national observation infrastructure. His roles include planning for infrastructure roll out, budgeting for resources needed in sustaining the observation network, implementation of WMO related observation recommendations such as the Unified data policy, WIGOS implementation and the others, as well as collection and quality control of observation data. It is hereby recommended, realising the task of compliance with GBON requirements, and Unified WMO data Policy requirements, that refresher training on project management, as well as budgeting be considered for the senior management of the INAM.
	3. It is recommended that INAM embark on the awareness campaign across the 11 provinces of Mozambique to build knowledge amongst local communities that may enhance security of the rolled-out infrastructure.
	4. In terms of gender split in the Weather Observers, ICT and Instrumentation Maintenance personnel groups, the numbers are highly skewed toward a male dominance. It is recommended that INAM develop the gender equity plan for the organisation to address gender balance.
Module 5. Risk Management	1. Due to security risk in the Cabo Delgado region, it is recommended that the INAM apply to the WMO for exclusion of this area when addressing GBON compliance for the country. Furthermore, no work be assigned in the high-risk areas.
	2. 2. Due to high level of infrastructure vandalism regionally, to mitigate this risk, installation needs to be on secure locations and awareness campaigns on the importance of the weather observations must be conducted nationally.
	3. Due to slow processes of Governmental procedures for acquisition, the use of private partners to meet stringent timelines of restoration of GBON stations is recommended. Furthermore, maintain a minimum spare part required.
	4. Decentralization of technical capability nationally to be reactive must be prioritized to be short, to minimize on observations network downtime to avoid non-compliance with the GBON requirements in accordance with the One District, One Weather station model.
Module 6. Transition to SOFF investment phase	Collate all the financial requirements as per module 1 to module 6 lead by the implementing entity and compile the project plan for addressing the GBON compliance requirements setting objective targets and reasonable timelines.

Annexes (if any)

Report completion signatures

Peer Advisor signature

Ishaam Abader

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Beneficiary Country signature

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WMO Technical Authority signature