2nd October 2024

Systematic Observations Financing Facility

GBON National Contribution Plan of Zambia

Systematic Observations Financing Facility

Weather and climate data for resilience

GBON National Contribution Plan

Zambia

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Table of contents

Module 1. National Target toward GBON Compliance

Table 1. GBON National Contribution Target

Type of station	WMO GBON Global Gap Analysis, June 2023				GBON National Contribution Target	
	Target	Reporting	Gap		To improve	New
			To improve	New		
	[# of stations]				[# of stations]	
Surface	19	0	19	0	21	0
Upper-air	4	0	4	0	0	4
Marine	*when applicable					

Figure 1 illustrates proposed 21 GBON sites with 100km radius circle indicated and Figure 2 illustrates the proposed upper air station with a 250km radius circle.

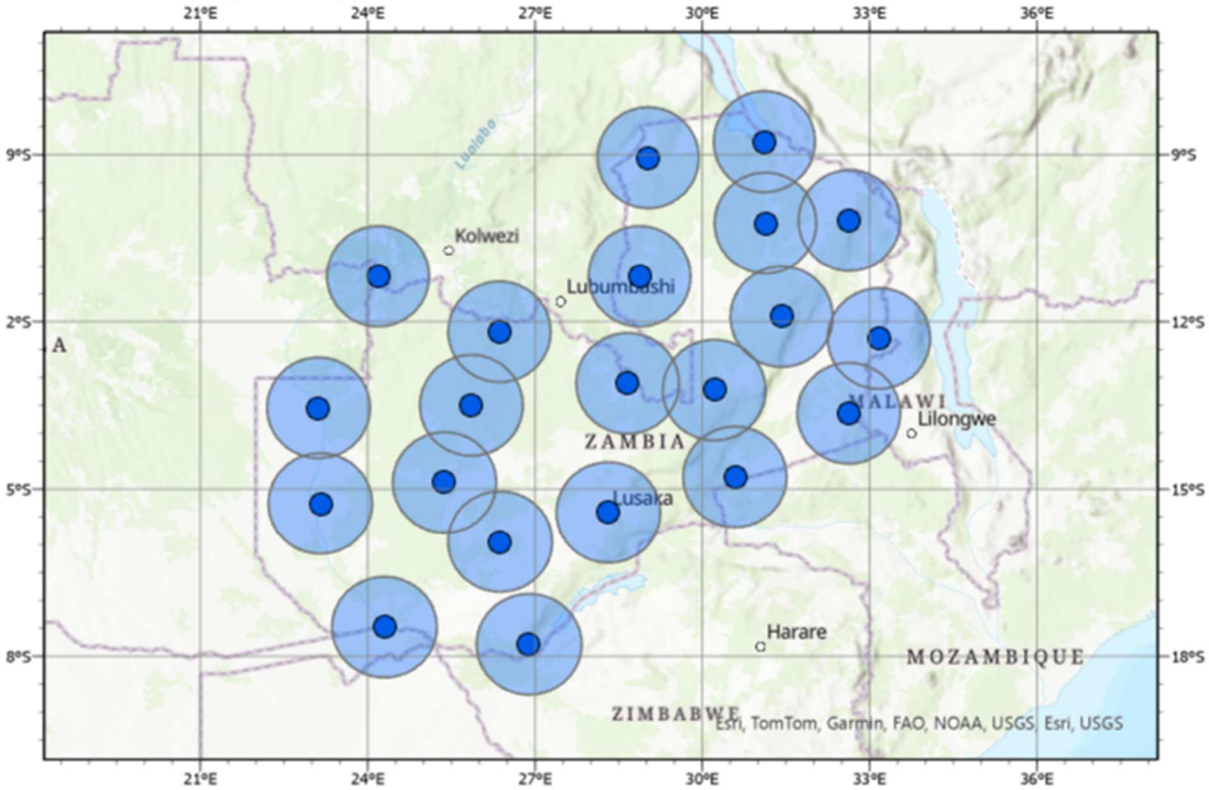

Figure 1 Proposed 21 GBON Surface Stations with 100km circles

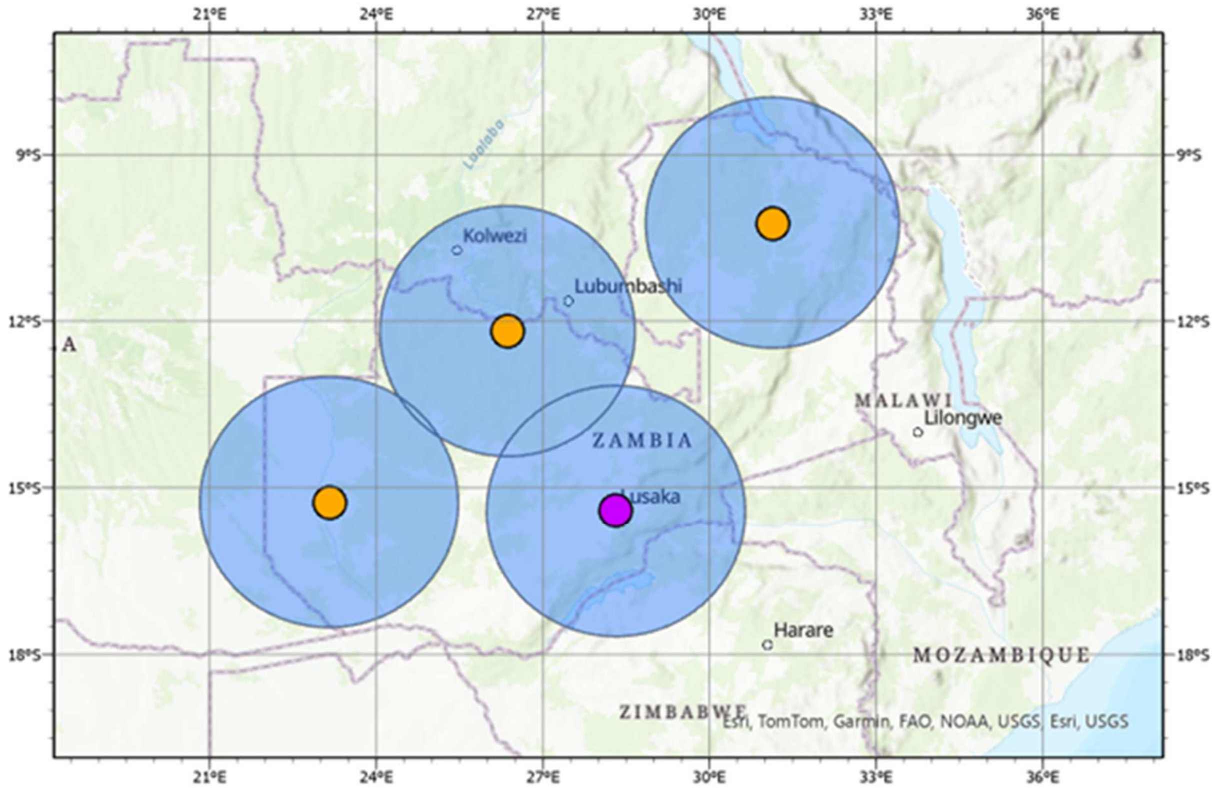

Figure 2 Proposed GBON Upper Air Station with 250km circle

Module 2. GBON Business Model and Institutional Development

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

- *Identified governmental stakeholders operating and acquiring meteorological observations or with the potential to support GBON*
- *Identified private sector operators providing meteorological observations and data services in the country*
- *Recommendation on how they could contribute to the implementation of the plan and required activities to materialize the proposed partnerships:*
    a. *Existing partners and relationships;*
    b. *Potential new partners and collaborators and their role*

During the assessment visit, the peer advisor team, together with the Zambia Meteorological Department and the implementing entity spoke to a wide range of government stakeholders regarding the role of ZMD in making weather and climate observations and enquired whether there were supporting observation networks that would complement those made by ZMD. Government departments that operate observing networks include:

- Ministry of Agriculture
- Ministry of Water Resources (WARMA)

ZMD does cooperate with the Zambia Civil Aviation Authority regarding the operation of both observation stations and provision of weather services at several airports around the country. This includes sites where Automatic Weather Stations have been installed. These sites are favourable for selection as GBON stations where this is possible, as there is high security and good communication availability. Airport sites also tend to be well exposed.

Another key government department that ZMD cooperates with is Defence. ZMD headquarters is located at Lusaka City Airport and manual observations here, are already made by a team that is jointly managed by the Zambian Air Force. Whilst it is recommended that GBON surface stations are AWS sites and not manual sites, so that the frequency requirements can be met, the military staff that are available at Lusaka City Airport can be trained to conduct radiosonde launches. It is understood that this team is adaptable and as they are military personnel extending hours to cover night shift requirements is not considered an issue. The other key advantage of locating the radiosonde station at this location in Lusaka is that the site is very secure.

Recommendation 2(1): ZMD makes a formal arrangement with Zambia Air Force to utilise the military staff that work with them at Lusaka City Airport in order to sustain the radiosonde launches at the frequency required by GBON.

ZMD are also exploring collaboration with the Zambia Metrology Agency, who may be able to provide instrument calibration facilities to support AWS operations.

Whilst ZMD and the assessment team are aware of several commercial farms and mining companies that are operating Automatic Weather Stations around the country, it is not recommended that these are directly used for GBON. This is because, as referenced in 2.4, there has been significant investment in provision of AWSs at ZMD in recent years and it is felt that it will be most efficient to share data from these sites for GBON purposes.

An important aspect that was highlighted by ZMD staff was availability of transport to remote sites in order to maintain the observing network. One suggestion that was made was that World Food Programme, as SOFF Implementing Entity for Zambia, might be able to provide logistical support to ZMD over the investment and compliance phases. This could be an efficient way for ZMD to access vehicles across the country.

Recommendation 2(2): It is recommended that ZMD establish a MOU with WFP to provide logistical support for remote site visits as part of the SOFF investment and compliance phases.

2.2 Assessment of potential GBON sub-regional collaboration

- *Identified neighbouring countries and regional organizations of relevance for potential sub-regional collaboration*
- *Recommendations for potential optimization of the observing network through sub-regional network design and other sub-regional collaboration for the implementation of the Plan*

The Meteorological Association of Southern Africa (MASA) provide an opportunity for collaborative activity in terms of training, maintenance of equipment and calibration. The WMO designated regional training centre (RTC) is based at South Africa Weather Services in Pretoria. This may provide an opportunity for collaborative training across the range of disciplines required by GBON.

It also makes sense to explore economies of scale with respect to the provision of WIS2.0 capability. ZMD are currently working with WMO on a WIS2.0 pilot which is providing a capability through which they can share data from AWSs with the international community. As a common functionality will be required across many (or all) SOFF countries, it may make sense if this is coordinated more centrally either on a regional, or global basis.

The GBON-WMO Gap Analysis identifies the need for 4 upper air stations in Zambia. Our focus through this investment phase is on establishing one station (in Lusaka), if surrounding countries are also successful in establishing and sustaining some upper air measurements, it may be possible to review the overall requirement for additional stations in Zambia.

2.3 Assessment of the most effective business model to support network operations

- *Assessment of the current funding sources, budget allocations and financial status related to operations of the NMHS observing network*
- *Recommendation on a business model for public-private collaboration for the implementation of the Plan, based on the SOFF private sector business models, including:*
    a. *Recommendation on NMHS business model to operate and maintain the GBON infrastructure, considering arrangements for SOFF financial support during the Compliance phase*
    b. *Identify potential private sector operators depending on the proposed business model*
    c. *Develop a financial plan for operating the modernized infrastructure, including considerations on the total cost of ownership*

The observing network in Zambia is currently funded by a combination of government grants, and donations from international organizations and climate projects. The ZMD currently have a regular budget from government of approximately USD $80,000 for the maintenance of their network. The budget allocations and financial status of the network vary depending on the availability and reliability of these sources, which may not be sufficient or sustainable to support the operations and maintenance of the GBON infrastructure.

It is recommended that the observation network in Zambia that supplies GBON continues to be publicly owned. At the same time, there is an opportunity to continue to develop a commercial partnership to sustain the surface and upper-air to GBON standards. In recent years, both SCRALA and TRALARD projects to install AWS networks in Zambia have chosen Campbell Scientific as the supplier of AWS technology. The TRALARD project is still being delivered and ZMD staff have built good working relationships with members of the Campbell Scientific Team.

Recommendation 2(3): An ongoing service agreement is established between ZMD and Campbell Scientific to help maintain the network of GBON Surface Stations. A similar agreement should also be established with the supplier of radiosonde system and hydrogen generator. This could deliver significant value in both maintaining the network, but also continuing to develop the capacity of the ZMD staff over an extended period through the investment and compliance phases of SOFF.

Recommendation 2(4): Review the ZMD strategic plan to ensure that stakeholder management is strengthened in order to enable ZMD to highlight the importance of the GBON network to government stakeholders.

2.4 Assessment of existing national strategies and projects for developing and improving observing networks

- *Review of the national strategies for developing and improving observing networks*
- *Review of existing or planned hydromet development projects related to GBON*
- *Recommendation on activities to ensure consistency and complementarity of current and planned national investments and activities of relevance for GBON*

The main focus of ZMD has been developing their network of AWS through a number of development funded projects. The most recent and significant is TRALARD which is being delivered through World Bank funding. This project will deliver 120 AWS across Zambia – this includes an AWS in each of the administrative districts. The focus of this project is on improving the information available to farmers and agricultural organisations across Zambia.
Previous initiatives, such as SCRALA have also invested significantly in AWS capability. This means that AWS hardware does not need to be a focus of SOFF investment.

At the same time, the challenge that is presented by these initiatives is in how these capabilities can be sustained. Maintaining, calibrating, funding telecommunications, securing more than 150 Campbell Scientific AWS stations will be a challenge for any National Meteorological Service. It requires a team of engineers, well designed processes, a sustainable source of spares and the ability for engineers to travel to remote sites. Possibly the greatest challenge that all National Met Services face is in maintaining the security of sites. AWSs contain solar panels and batteries that are attractive and valuable to people who may not appreciate the importance of the observations. Consequently, they have a habit of growing legs. The risk associated with having so many AWSs in Zambia is that human resources and spares will be spread thinly and will not be sufficient to maintain all 150 sites.

Recommendation 2(5): ZMD incorporates a strategy for tiering their stations within their SOPs. This should identify the 21 GBON stations, and a handful of other priority sites, as tier 1, and resources should be focussed accordingly.

2.5 Review of the national legislation of relevance for GBON

- *Review of national legislation related to responsibility for measuring and providing weather observations related to GBON*
- *Review of the legislation related to procurement, importation and customs processes of relevance for the proposed Plan's activities and investments*
- *Recommendation on how to address any constraints related to the national legislation required to implement GBON*

There are no direct laws that govern meteorology in Zambia. However, the mandate and functions of meteorological services is assigned through a government gazette, which is a legal instrument, to the Ministry of Green Economy and Environment (MGEE).

There seems to be good collaboration between ZMD and other key departments within Zambia, so we do not consider a review of the legislation relating to ZMD to be a priority for the delivery of the SOFF.

The list below identifies the key national partners from government, private sector, and academia:

- Disaster Management and Mitigation Unit (DMMU)
- Ministry of Agriculture (MoA)
- Water Resources Management Authority (WARMA)
- Ministry of Energy
- ZESCO Limited
- Zambezi River Authority (ZRA)
- University of Zambia (UNZA)
- Copperbelt University (CBU)
- Mulungushi University (MU)

For the TRALARD Project the MGEE facilitates the local regulatory requirement of procurement, and the project submits to the World Bank for No objection to proceed to award any contract after the Ministry of Justice approval. The SOFF procurement can be done through WFP in the same way.

Module 3. Infrastructure Development

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

- *Recommendation on a harmonized observing network design, including siting and instrumentation of new and improved stations, including*
  - a. *A map of observing network distribution and a list of the required new or rehabilitated GBON stations;*
  - b. *A list of observation instruments and systems per site; and*
  - c. *Investments and activities needed for the installation of new stations and the improvement of existing stations*
- *Observational practices defined per network*
- *Preliminary maintenance plan for existing and improved/new stations, including calibration practices*
- *Technical specification for new instruments and observing systems for the procurement process*

GBON Surface network

Establishing 21 GBON surface stations has been recommended through the Gap Analysis. The list of these stations is given in ANNEX A and a map showing these stations is given in Figure 3.

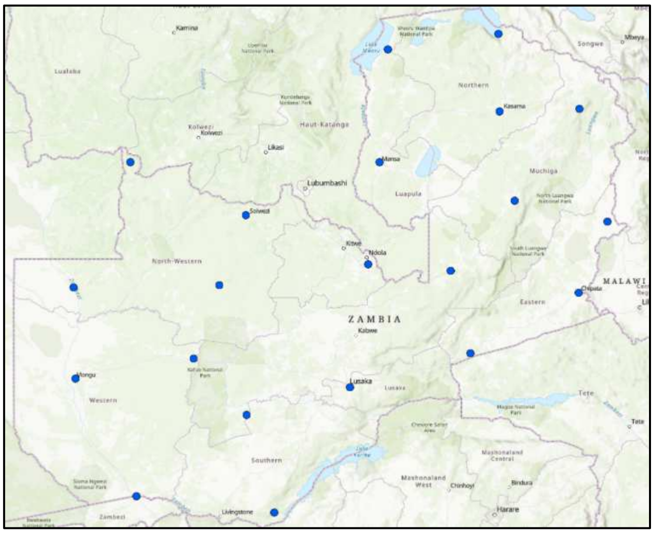

Figure 3: Proposed GBON Surface Network

These stations have been chosen through discussion between the peer advisory team and staff at ZMD to reflect the following design characteristics:

i. The distribution of the stations meets the GBON requirement for horizontal spatial resolution of 200km. A couple of additional stations were identified through the gap analysis (taking the total number of stations recommended from 19 to 21). An additional site at Kasempa helps to improve the coverage across central parts of Zambia. An additional site at Kasama is important as this location is also being proposed as a radiosonde site and it makes sense from a scientific and operational perspective to have surface and upper-air measurements collocated.

ii. The stations selected all have Campbell Scientific Automatic Weather Stations installed, or being installed, as part of the SCRALA, or TRALARD, Projects. To achieve compliance, all of the GBON designations in Zambia will be transferred away from manual sites to AWSs. To keep maintenance as simple as possible the network used for GBON should be homogenous, for this reason none of the older ADCON AWSs will be selected as GBON stations.

iii. The sites chosen are located at airfields, schools and other government owned locations that are considered secure, and this is probably the most important consideration.

iv. The sites all have good mobile phone coverage. ZMD has agreement with national mobile telecoms provider MTN, who provide mobile SIM cards that enable the Campbell Scientific AWSs easy connection to the internet for less than USD $2 per month for transfer of the 90MB of data required. The Campbell Scientific AWSs are able to communicate via satellite and some of TRALARD stations have been installed at locations where this is the only available communications mechanism. As this significantly increases telecoms costs, and also to ensure homogeneity of the network, only sites where good MTN coverage is available will be used for GBON.

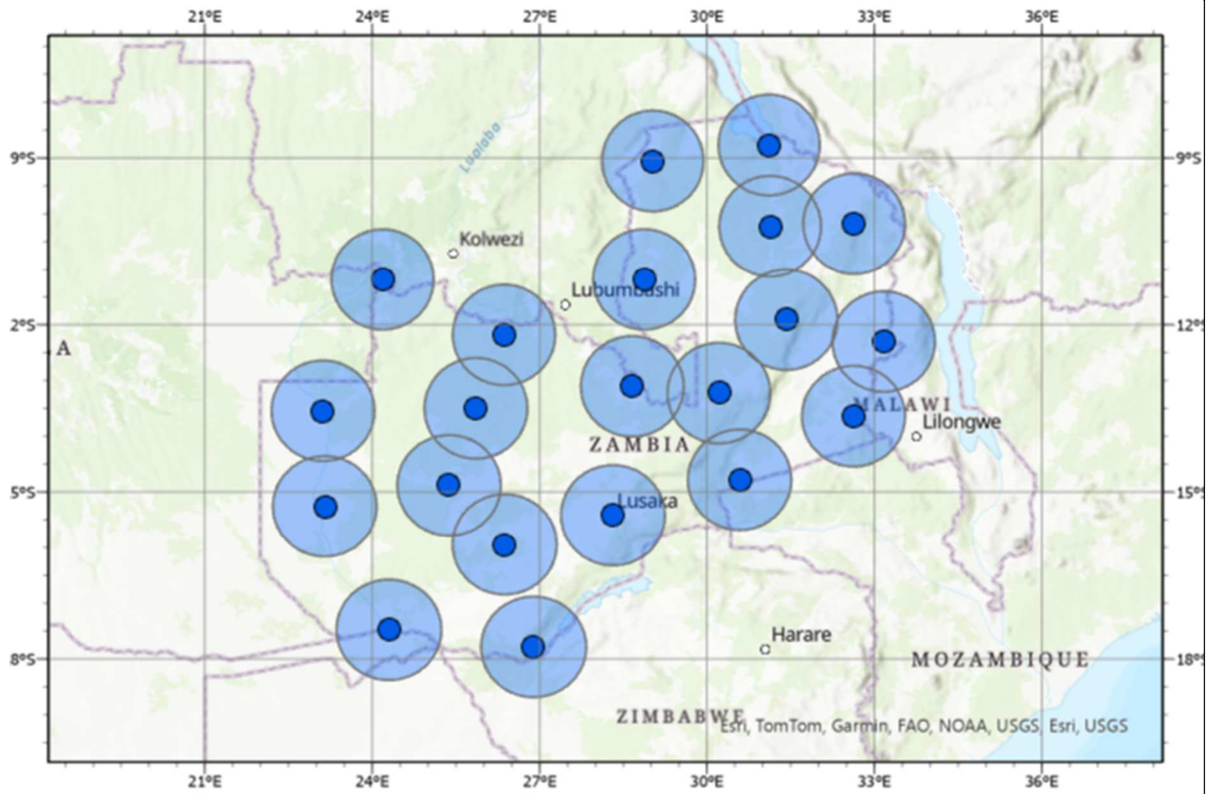

Figure 4 - ***Proposed GBON surface observation network showing 100km radius spatial threshold in blue***

Recommendation 3(1): Only sites with Campbell Scientific AWSs installed, good security, and good MTN network coverage should be designated as GBON. Existing manual stations should continue to report to GTS, however all GBON sites should be redesignated to the AWS.

The technical specification for the Campbell Scientific AWSs which will be used for Zambia's GBON network is given at ANNEX B. In addition the stations must meet the technical specifications set out in TT-GBON approved technical specifications (TT-GBON approved material | World Meteorological Organization (wmo.int)) 6.1 – GBON Tender Specifications for AWS and 6.2 – Requirement document to be used as input to tender specifications for radiosonde-related procurements. In line with the GBON requirements and to specifications outlined in WMO No. 8, these measure Sea level pressure, Temperature, Humidity, Wind and Precipitation. The stations do not measure snow depth as this is not a priority in tropical Zambia.

As there has been such a huge investment in AWS in Zambia in recent years, provision of this infrastructure is not a priority for SOFF investment. There is a requirement to make sure that ZMD has adequate access to spares throughout the delivery phase of SOFF and this will be factored into a service agreement with Campbell Scientific – see **Recommendation 2 (3).**

Outline Maintenance Plan for GBON Surface Stations

It is suggested that maintenance of the stations is structured around four service hubs which have already been proposed under TRALARD. These correspond to the proposed locations of the upper air stations of Lusaka, Mongu, Kasama and Solwezi. There are already small teams of staff (between 4-6 people) centred at each of these locations. Whilst these staff are currently focussed on making manual observations, they could take on routine maintenance tasks such as site inspections, housekeeping, QC and calibration checks, and replacing failing components.

In line with international best practice, a four stage maintenance process is proposed for the GBON surface stations. This is illustrated in Figure 5.

The maintenance plan comprises the following elements:

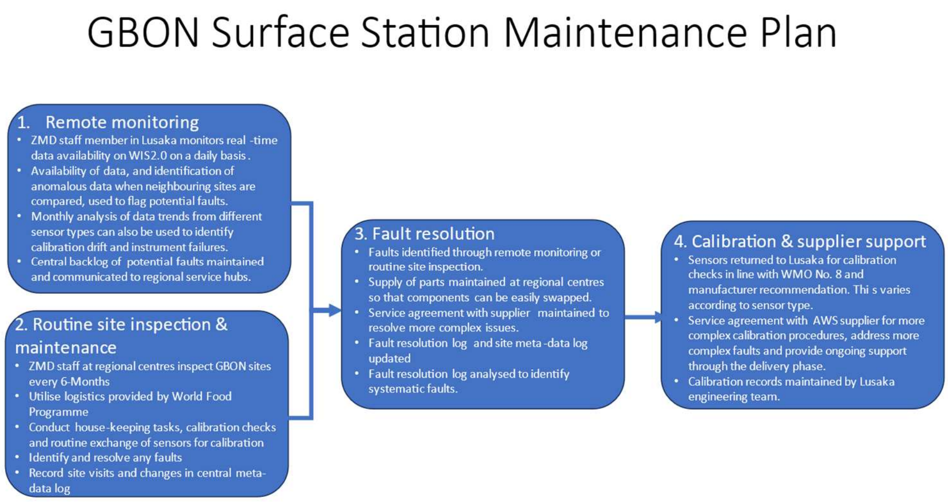

Figure 5 Proposed GBON surface station maintenance plan

1. Remote monitoring

Remote monitoring will be conducted by the ZMD Operations and Engineering Services team in Lusaka. They will check the availability of data on the WIS2.0 box as well as on their central database which has been provided by Campbell Scientific. They will also regularly check data from neighbouring sites to spot anomalous data in real-time. Monthly statistical analysis will identify trends in the data over time that could indicate calibration drift, or complete sensor failure.

The Operations and Engineering team will maintain a backlog of potential faults which will be communicated to regional maintenance hubs. This will be updated once potential faults have been investigated and resolved. In this way any systematic faults across the network can be identified and addressed.

2. Routine site inspection & Maintenance

ZMD teams at regional maintenance hubs in Lusaka, Mongu, Kasama and Solwezi will be responsible for conducting routine inspection & maintenance, as well as fault resolution site visits. It is expected that each site will be visited at least once every 6-months. During these visits, routine tasks such as grass cutting will be undertaken. The team will also conduct calibration checks during each visit and carry spares so that sensors and other hardware (e.g. solar panels, batteries and loggers) can be exchanged if they are found to be out of tolerance. Sensors will also be rotated during these visits so that they can be sent back to Lusaka for more thorough calibration testing against known standards. A central maintenance log will be updated and any changes to meta-data recorded as part of each visit. However, for outstanding maintenance and repair faults that will not be resolved by the regional maintenance teams will be resolved by the Lusaka Operations and Engineering Services team.

3. Fault resolution
If a potential fault at a station has been identified, the Lusaka Operations and Engineering Services team will direct staff at the regional maintenance hubs to undertake a fault resolution visit. These visits will take priority over routine maintenance visits in order to maintain GBON compliance on data availability. It is expected that most faults will be resolved by the team swapping out a component at a site with a spare. It is expected that during a fault resolution visit, the regional team will also conduct routine site inspection and maintenance of the site (in line with point 2. above).

4. Calibration & supplier support
Faulty sensors, or sensors that require calibration, will be rotated out of sites and back to Lusaka for calibration. ZMD is exploring a collaboration with the Zambia Metrology Agency (ZMA) to provide traceable calibration for key parameters. It is expected that some instruments will need to be either directly replaced or calibrated through an ongoing relationship with the AWS supplier (Campbell Scientific). As per recommendation 2(3), an ongoing service agreement with Campbell Scientific would enable this process. It would also provide 3rd line support to ZMD staff in maintaining the network and in dealing with more complex issues. It would also be expected that this agreement would provide training throughout the SOFF investment and compliance phases, so that ZMD staff continually increase their capacity and skill.

Recommendation 3(2): Regional maintenance hubs are established (in line with the approach already being proposed under TRALARD) and the maintenance and calibration plan proposed is adopted.

GBON Upper Air Network

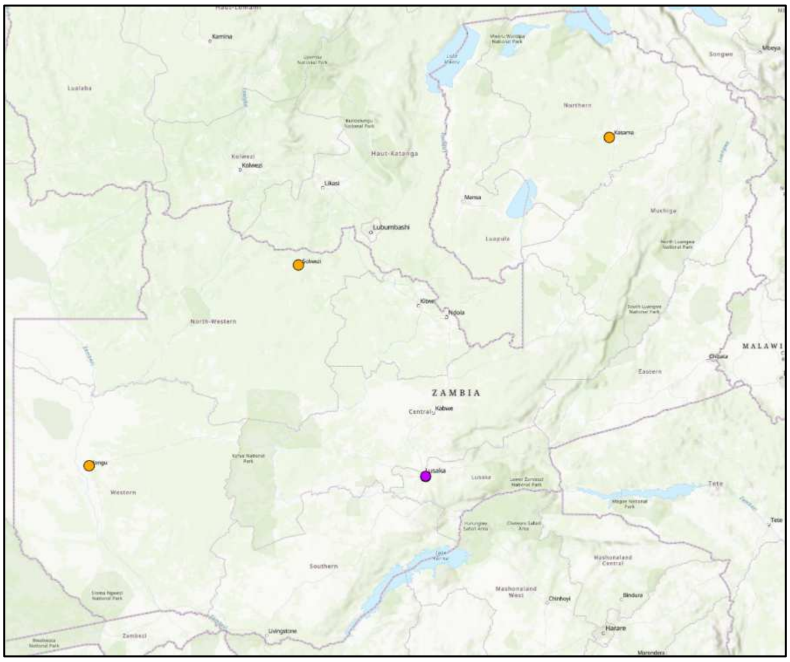

Figure 6: Proposed GBON Upper Air sites (note it is proposed only Lusaka is taken forward through the initial SOFF investment phase)

As explained in the gap analysis, it is recommended that ZMD focus on establishing one GBON Upper Air station, at Lusaka City Airport, over the investment period. It is then suggested that this network can be extended to meet the requirement for a further three upper air stations needed for full GBON compliance. A map of the initial proposed sites is given at Figure 6. Note that whilst sites at Lusaka (Capital City of Zambia), Mongu (Provincial Capital Western Province), Kasama (Provincial Capital Northern Province) and Mwinilunga (A remote town in North-Western Province close to the borders with Angola and DRC) were originally proposed as GBON upper air stations, it is recommended that the proposed Mwinilunga site is moved to Solwezi, the provincial capital of North-Western Province. This is because of a variety of factors: Solwezi has a team of proficient staff; the Met Department has a secure airport site that would be suitable for balloon launches; and Solwezi is also accessible via sealed roads and during the rainy season for deliveries of consumables.

The network should only be extended if the initial station at Lusaka can be sustainably operated for a period of at least 2 years. It is noted that it would be a significant step forward, and an incredible achievement, if just one upper air station were established and sustained in Zambia that met GBON requirements.

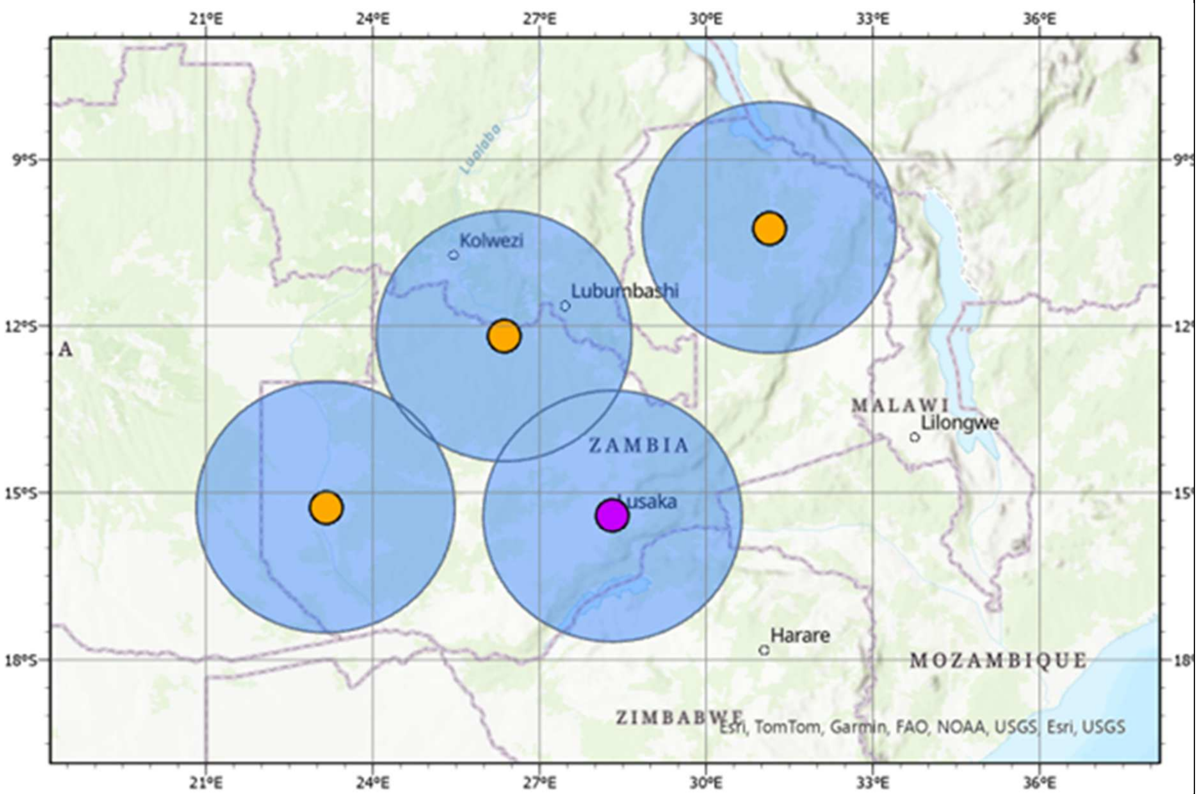

Figure 7 - ***Proposed final GBON upper air network showing 250km radius threshold in blue***

Recommendation 3(3): SOFF funding is initially focussed on establishing one GBON compliant upper air site at Lusaka City Airport (ZMD HQ). Any further investment will be contingent on these observations being sustained for a period of 2-years.

Several manufacturers offer radiosonde systems which meet GBON specification, as laid out in WMO No. 8 and GBON requirements. These include MODEM, Vaisala, Graw, Intermet and Meisi. Both manual and auto-sonde solutions have been considered by ZMD and the peer advisor team. Given the availability of military personnel at Lusaka City Airport who are already embedded within the ZMD team, and available for launches at both 12 and 00 UTC, it is proposed that a manual radiosonde system is installed at this location. Given the smaller numbers of staff available at the other proposed sites, auto-sonde may offer a better solution at these locations (these will not be specified in the initial SOFF funding proposal).

For resilience it is recommended that two radiosonde ground systems are purchased and installed at the Lusaka City Airport observing office. These should be used alternately to make sure that both systems are maintained in good working order. It is recommended that an extended service agreement is maintained with the supplier throughout the SOFF compliance phase so that any issues with the systems can be quickly resolved – see **Recommendation 2(3)**. This makes sense as the supplier will also be required to maintain a supply of consumables (sondes and balloons) throughout this period.

It is suggested that the radiosonde ground station is connected to the internet via a mobile phone modem. This is a cheap way of ensuring resilience. It is also recommended that backup power supply is provisioned within the procurement to account for temporary power outages.

It is also necessary to procure a supply of hydrogen to support radiosonde operations. The peer advisory team has considered two options for this provision, installation of a hydrogen generator and the ongoing supply of hydrogen from a third party. Having reviewed the two options it has been determined that it would be most reliable to install a hydrogen generator on site at Lusaka City Airport. These can be supplied and installed in a shipping container for ease of installation, security and safety of operations.

Recommendation 3(4): Two manual radiosonde ground stations and a self-contained hydrogen generator are procured and operationalised for Lusaka City Airport as part of the SOFF Investment Phase. This should include provision for backup power and mobile telecommunications.

Outline maintenance plan for Upper-Air station
There is only limited maintenance required for a manual radiosonde station. This is because the system is reliant on consumable sondes, which are systematically tested before launch against the ground system. SOPs will be established with the operators to routinely cross check the ground system against the AWS measurements at that location. It is recommended that a service agreement is established with the radiosonde supplier as part of the procurement, this will provide third line support in the event of ground system failure – see **Recommendation 2(3)**. Further resilience will be built into the system through the procurement of two ground systems that will be used alternately.

Hydrogen generators typically require servicing every 2-3 years by a supplier engineer. Hydrogen generation will be undertaken by the Operations and Engineering Services Team in Lusaka, as well as routine maintenance tasks on the generator.

Recommendation 3(5): The peer advisor will work with ZMD to develop Standard Operating Procedures to support the monitoring, maintenance and calibration of the GBON surface and upper-air stations and develop maintenance, calibration and meta-data logs required to provide quality assurance of observations in line with GBON standards.

3.2 Design of the ICT infrastructure and services

- *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*
  a. *Detailed description of the ICT infrastructure and services design*
  b. *Technical specifications for the data collection system from the observing station to the collection point*

c. *Technical specifications of the data services (compatible with the requirements of WIS 2.0)*
d. *Detailed description of the measures to ensure resilience and continuity of the full data processing chain*

GBON Surface Component

Under the SCRALA and TRALARD projects an IT infrastructure has been established for the collection and management of data from Campbell Scientific AWS stations. ZMD are also taking part in a WMO pilot of "WIS2.0 in a box". Through this pilot some of the Campbell Scientific AWSs are already sharing data into the WMO cloud and this is technically available to the WMO community via WIS2.0. Figure 8 illustrates the data currently available via Zambia's WIS2.0 in a box pilot. The live WIS2.0 data can be viewed at this link: https://zmdwis2box.mgee.gov.zm/urn:x-wmo:md:zmb:zambia_met_service:surface-weather-observations.

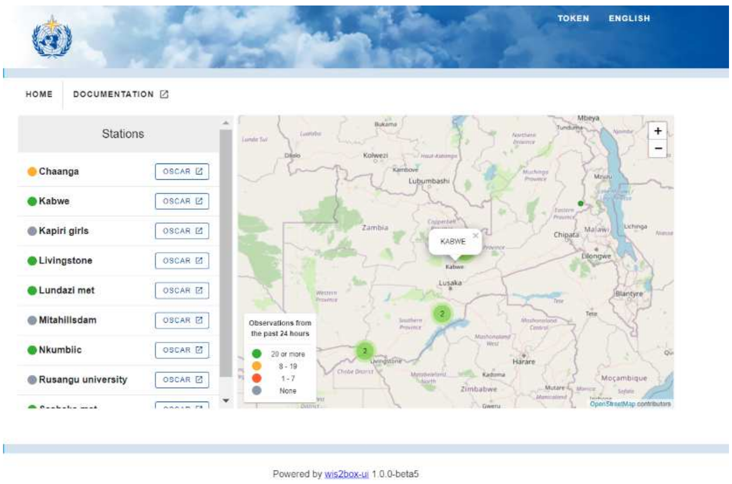

Figure 8: Zambia WIS2.0 in a box

There seems to be an issue at the moment with the visibility of data to other members of the WMO community. This seems to be linked to the current configuration of WIS2.0, rather than a configuration error associated with ZMD/Campbell Scientific.

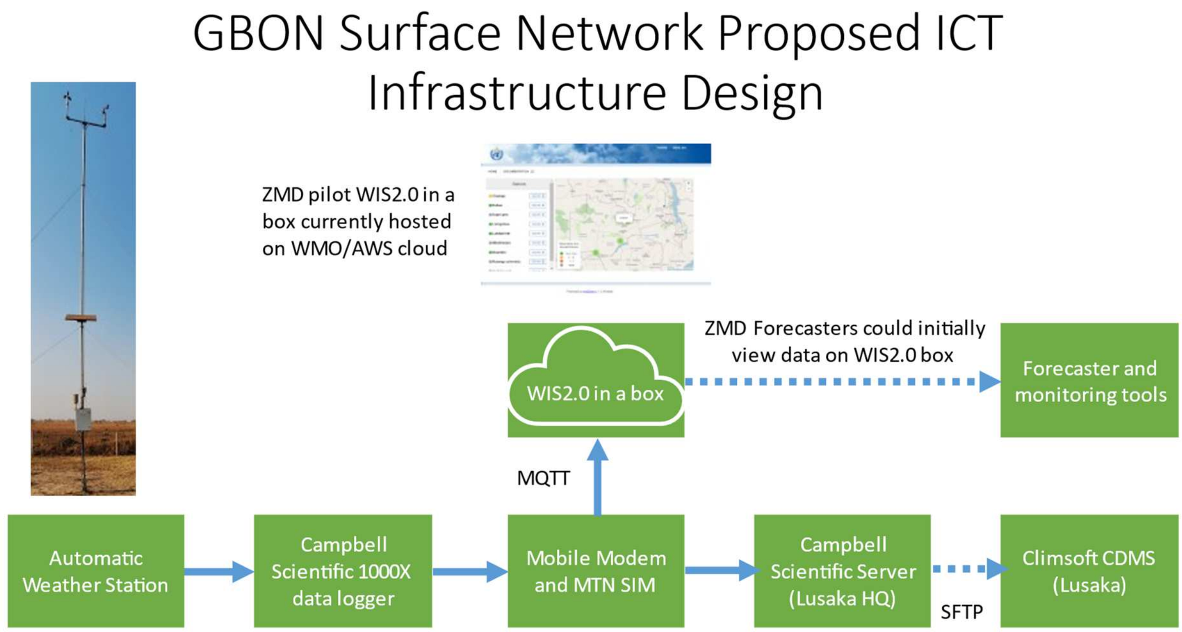

Figure 9: Proposed BGON Surface Network ICT Design

Figure 9 illustrates the ICT design for the surface network component. The data architecture appears to be a very elegant and efficient solution, as the AWSs can transmit directly to the WIS2.0 cloud via MQTT protocol, as well a central database that is hosted at the ZMD headquarters in

Lusaka. All of the stations proposed for GBON are powered by a solar panel and battery, connected via an MTN mobile phone modem, and are sited in locations where there is reliable MTN network coverage. This means that the infrastructure is resilient as the provision of the data to WIS2.0 is not reliant on internet connectivity to and from Lusaka, maintenance of the server and database at Headquarters, or power supply issues.

The WMO WIS2.0 in a box team who are managing the pilot have identified a couple of issues pertaining to the sustainability of the solution:

i. The data configuration to WIS2.0 is currently being led by Campbell Scientific. There is a capacity gap for ZMD to develop and maintain their technical capabilities to maintain the WIS2.0 in a box.
ii. Currently cloud costs are being met through an agreement that WMO has with Amazon Web Services. Future costs will need to be factored into the SOFF proposal.
iii. The ongoing development and support of the WIS2.0 in a box capability is currently reliant on a very small team within WMO. If this is likely to be used by many countries in the delivery of the SOFF, it will require a sustained investment on a regional, or global basis.

Recommendation 3(6): SOFF Investment builds upon the WMO WIS2.0 in a box pilot. The capacity of ZMD staff should be increased to ensure that the capability exists to maintain the WIS2.0.

Recommendation 3(7): SOFF considers whether centralised funding should be provided to support WIS2.0 in a box to sustain and grow this capability either on a global, or regional basis. As this could realise economies of scale in terms of cloud computing costs as well as availability of technical resources.

GBON Upper-Air Component

Figure 10 illustrates the IT infrastructure required for operation of the manual GBON radiosonde station in Lusaka. Much of the capability required can be provided “out of the box” by a radiosonde supplier. Note that radiosonde ground systems can be configured to send data in many ways. This will help to make sure that the profile data is shared effectively with GTS/WIS2.0 as well as forecasters in Zambia. For example, the profiles can be packaged in BUFR and shared via email to the South Africa GTS gateway if it is not immediately possible to share the data via MQTT and the WIS2.0 in a box. Likewise, automatically sharing images of Skew-T diagrams or Tephigrams with forecasters via email, or even What’s App groups, might be an effective method to make sure that the best use of the data can be made without significant investment in downstream tools and systems.

Like the AWSs, it is suggested that the radiosonde ground station PC should be connected to the internet via a mobile phone modem. This is because internet at Lusaka HQ is intermittent and often has poor connectivity.

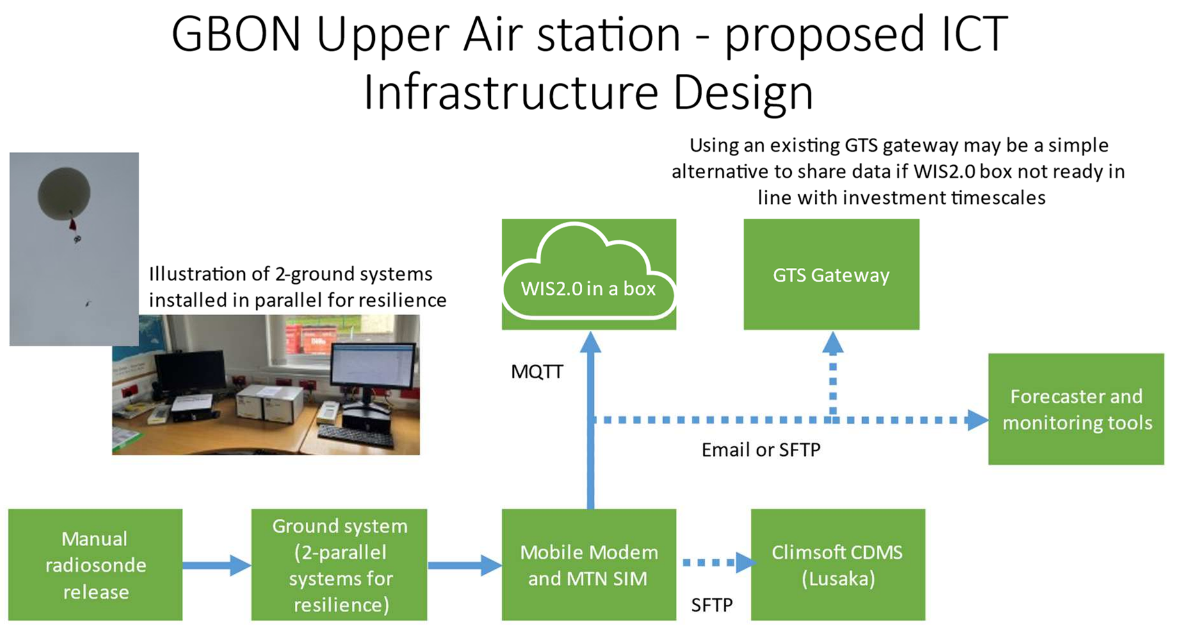

Figure 10: Upper air station - proposed ICT infrastructure design

3.3 Design the data management system

- *Recommendation on requirements for a data management system aimed to provide access to data used by operational applications on a real-time basis and the capability to deliver data to a Climate Data Management System (CDMS) for long-term archiving purposes. The system should provide:*
  - a. *Short-term data storage and access through the services and protocols required by applications for national and international operational activities*
  - b. *Acquisition of data to and from WIS/GTS, WIS 2.0 and other national or international sources required for operational activities*
  - c. *Data delivery to the national CDMS*
  - d. *Discovery and descriptive metadata management*
  - e. *Monitoring of data, processing and services*

Much of the design for data management system for GBON Networks in Zambia has been described in section 3.2. As part of the SCRALA and TRALARD projects Campbell Scientific has installed server capacity in Lusaka that collects and enables the management of the data from the AWSs. Long term storage and supply of the data to third party customers will be provided through the National Climate Centre in Lusaka. ZMD moved across to Climsoft for their CDMS in December 2022. Since then the National Climate Centre team have been working on building their electronic record from the manual observing sites in Zambia. Whilst the server with the AWS site data sits down the corridor from the climate team, the Climsoft CDMS has yet to be configured to collect the data from the AWSs.

The WMO Open CDMS initiative is seeking to establish CDMS capability that will sit alongside WIS2.0 in a box within cloud architecture. This could simplify the data management system, but

would make it even more important that ZMD have access to staff, or partner resource, who are proficient at configuring and managing cloud databases. A Corobor communication system is the current mechanism that enables the sharing of manual observations to the GTS and is also the route through which observations, and other products, are received from the GTS and used for forecasting. **Recommendation 3(9):** Explore simple systems and options to provide access to WIS2.0 data, including data from other countries, for use by forecasters and climatologists at ZMD.
3.4 Environmental and sustainability considerations · • *Recommend pragmatic approaches and measures for environmentally responsible design and evolution of the national networks to achieve GBON requirements, including: a. Development and use of specifications that consider environmental sustainability for procurement of measurement instrument equipment to meet the GBON requirements* • *b. Integration of sustainability considerations for the management of operations of GBON stations, including installation, calibration, and maintenance* • *c. Careful material selection for the development, shipping and day-to-day operations of GBON stations, with a focus on developing and using reusable instruments and sustainable methods of observation (e.g., elimination of single-use plastics).*
Environmental and sustainability considerations Environmental and sustainability considerations should be incorporated into the procurement process as part of the specifications including the use of reusable instruments where possible and sustainable methods of observation. Surface instruments should be reusable where appropriate and consideration of the environmental and sustainability impacts of maintenance (including associated travel) will be made as part of the SOP for maintenance and calibration in collaboration with the peer advisor. Similarly, consideration of the use of biodegradable materials for upper air observations should be made where possible as well as the environmental impact of shipping methods and materials including, for example, the elimination of single-use plastics. In addition, the operation of the upper air station by staff routinely located on site will reduce unnecessary travel. Local generation of hydrogen, as opposed to sourcing and importing the gas externally will contribute to the environmental sustainability of the station.

Module 4. GBON Human Capacity Development Module

4.1 Assessment of human capacity gaps

- *A summary of staff skills, education levels, and capacity gaps for technicians, experts, and management, including gender balance and gender opportunities*

The Zambia Meteorological Department (ZMD) are a department of the Government of Zambia and are part of the Ministry of Green Economy and Environment (MGEE). They have both national and international responsibilities, covering a diverse range of activities. These include making GBON and ICAO compliant observations, provision of forecast and warning services to the public and relevant government agencies, provision of seasonal forecasts, and climate services on behalf of Zambia. Zambia is a vast country and this poses a significant responsibility that requires ZMD to have commensurate skilled staff. ZMD currently employs 205 staff and are organised as shown in the organisation chart – see Figure 11 below.

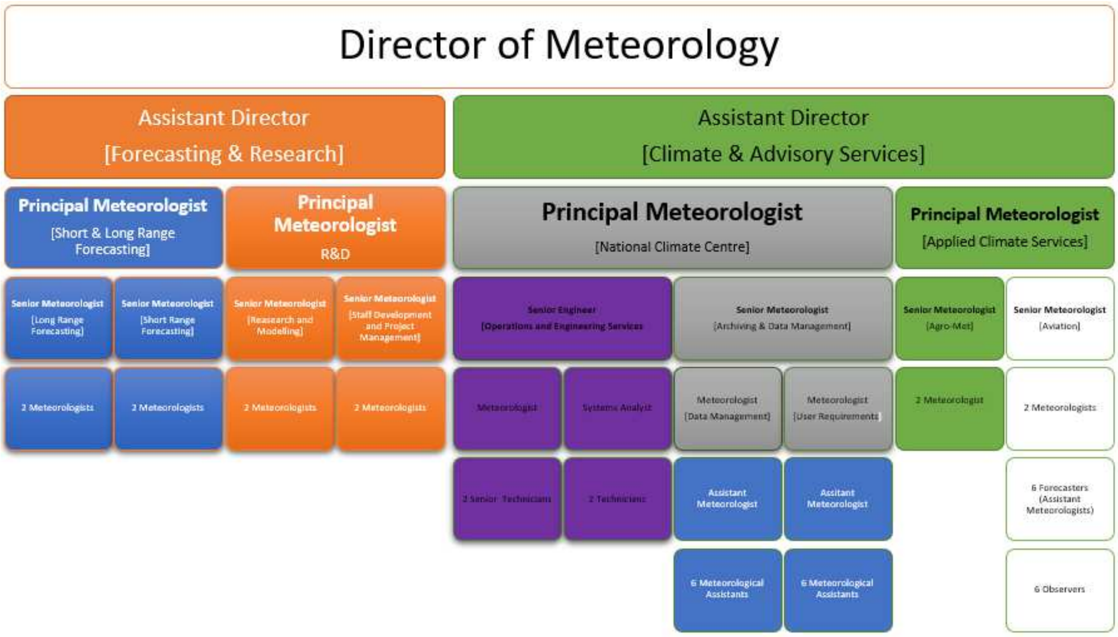

Figure 11: ZMD Organisational Chart

ZMD staff has a diverse range of educational qualifications. The majority (58%) hold certificates, while 20% have earned degrees, and 10% have obtained master's degrees. Capacity gaps are identified in sections 4.2 and 4.3, and recommendations to fill these gaps gave been made.

4.2 Design capacity development activities for technical staff

- **Recommendation on training activities and recruitment for technical staff in**
  a. Instrument and station maintenance at site;
  b. Calibration and maintenance at the workshop;
  c. Network monitoring; and
  d. ICT system operations

For the Surface GBON component, it is suggested that ongoing training of remote and HQ staff on the maintenance of sites is delivered through a service agreement with Campbell Scientific, or one of their delivery partners. This training would also include field and lab calibration as well as training on relevant IT systems. It is also suggested that a similar supplier agreement is reached for technical training in the operation of the proposed radiosonde station in Lusaka.

Further to this there is a requirement to train staff on developing Standard Operating Procedures for site maintenance, network monitoring, quality management, calibration procedures, etc. Whilst these could be delivered via a third party consultant, it is perhaps these aspects that would be most valuably delivered by a peer advisor from another NMHS. It is recommended that this is built into the funding proposal. This is covered under recommendation 3(5).

It is evident that there are a number of capacity gaps within the ZMD staff. In particular it is recommended that ZMD are able to recruit staff members to support the configuration and maintenance of WIS2.0 in a box capability. These staff would need to be technically capable to configure cloud based IT systems.

Recommendation 4(1): Recruit 2 new staff members and train existing staff within the Operations and Engineering Services team to configure and manage Zambia's WIS2.0 in a box capability.

4.3 Design capacity development activities for senior management

- ***Recommendation on training activities and recruitment for management in***
  - a. *Strategic and financial planning; and*
  - b. *Project management*

ZMD have a broad and diverse range of responsibilities, and as awareness of the climate crisis increases, demand for more services from them is also increasing. Whilst there have been several initiatives to increase the physical and technical capacity of ZMD over the years, there has been very little investment in the management and leadership of the organisation. It is generally assumed that this capacity pre-exists, but typically adds burden to ZMD management and puts the SOFF investments at risk.

To manage this situation requires a range of interventions that will rapidly satisfy the needs in an effective and sustainable manner. The first recommendation is to refresh the ZMD Strategic and Operational plans. These activities will clearly identify the high priority needs and provide the evidence to government and investors. Thereafter, it is recommended to provide development in two forms. Firstly, through off-the-shelf training packages, such as Management and Leadership training, Managing Successful Projects training, Financial Management and Human Resource Management training. Secondly, through practical implementation of ZMD Observation Strategy and translation into operational plans with the peer advisor to deliver GBON compliance. Outputs will include the development of standard operating procedures for quality assurance, maintenance, and sustainability, and their adoption into a Quality Management System (QMS).

In recognition of the existing and excessive tasking on ZMD, it is recommended that a project officer/unit is established and recruited. This post(s) will be responsible for the effective introduction of all SOFF funded outputs to ZMD. As the project approaches it end, this post will be evolved to have more stakeholder engagement responsibilities and ensure sustainability of the GBON is maintained.

Recommendation 4(2): Strategic and project management training is procured for senior managers across ZMD.

Recommendation 4(3): ZMD senior managers to refresh the ZMD strategy and operational plans, with support from the peer advisor, to ensure that the training received translates into actionable plans for the execution of SOFF investments.

Recommendation 4(4): Recruit a project manager to oversee SOFF investment phase and to engage with government and donor community to sustain GBON network in medium/long term.

4.4 Gender and CSOs considerations

- *Recommendations on activities, consultations, and areas of collaboration for the implementation of the Plan to ensure active CSOs participation and promotion of gender balance and gender opportunities*

ZMD recognises the importance of Gender, Equality and Social Inclusion (GESI) and the crucial role of the department to address the issues of GESI and support people and communities disproportionately impacted by extreme weather, seasonal events and climate change. They recognise the need to proactively support women, girls and marginalised people who are more likely to be negatively affected by the impacts of a climate and weather-related extreme events. It is recommended that ZMD undertake Gender, Equality and Social Inclusion (GESI) training as part of a broader activity to ensure GESI is mainstreamed in their working practices. In addition, the following guidelines WISER GESI Minimum Standards should be followed and adhered to on all SOFF activities:

1. Is there a GESI context analysis to inform programming which identifies:
   i. Barriers and enablers to people of different gender, ages and ability, social economic constraints, or marginalised groups accessing project services.
   ii. The risks of project activities which might negatively impact GESI and how to mitigate such risks?
2. Can people of different gender, ages and ability, social economic constraints, or marginalised groups with differing abilities meaningfully participate in the design, implementation and MEL of the project, so they can build individual agency, change gender and group relations, transform systems and structures
3. How does the project contribute to the gender equity, protection, and longer term empowerment of different genders, ages and ability, social economic constraints, or marginalised people?
4. Is there a plan for building the capacity of local partners on GESI using these Minimum Standards and GESI upskilling?
5. Does the MEL system enable analysis of GESI issues and does the project Logframe or results framework integrate qualitative and quantitative:
   i. Gender and social inclusion targets, that capture evidence of leadership, empowerment and meaningful participation in decision-making?
   ii. Sex, age, and differing ability disaggregated data and account for intracommunity diversity and complexity?

There was no formal gender assessment of ZMD undertaken during the readiness phase, so it is recommended that they conduct a self-gender assessment of their institution and include insights to their modernisation plans. During the SOFF Investment Phase, and any further modernisation, recruitment and training should follow these guidelines:

- Women should represent at least 50 % of all participants in SOFF-related and supported training
- Women should represent at least 50 % of all participants in SOFF consultations, planning workshops, etc.
- Women should represent at least 50 % of staff for operating and maintaining GBON stations
- Women should represent at least 50 % of decision-making and project management positions where applicable

It is also recognized that engagement with civil society is an important factor, to raise awareness of ZMD and the observation sites and how they play an important role in the value-chain that provides high-impact weather information, especially to women and girls. Many of the GBON sites proposed in Zambia are in secure locations, but it’s not always the case. The less secure sites will require cooperation with CSOs. It is recommended that a consultation and awareness raising event is held with CSOs to engage with this sector, including those focused on women’s empowerment, to mitigate against the risk of theft and vandalism.

Recommendation 4(5): Senior Leaders should all receive Gender Equality and Social Inclusion training before sensitisation training is rolled out to all staff at ZMD.

Recommendation 4(6): Commission a formal gender assessment of ZMD.

Recommendation: 4(7): Commission a Civil Society Organisation engagement workshop with external facilitator to build understanding of the importance of weather and climate information amongst communities who are hosting AWS sites.

Module 5. Risk Management Framework

5.1 Assess the risks of the observing network and propose mitigation measures

The primary risks to the observation network are set out in the risk register below. This risk register should be owned and maintained by the Director of ZMD and updated on a quarterly basis.

Operational risks to the observations network						
Risk description	**Impact description**	**Impact level**	**Probability level**	**Priority level**	**Mitigation**	**Owner**
Security of AWS and radiosonde sites	Network cannot be maintained due to theft or damage of equipment	High	High	High	- Utilise sites that are most secure (i.e. airports, schools and public offices) - Security of sites has been designed in. - Education of local people and sharing of data as a public resource.	
Maintaining supply of consumables and spares	Reliant on the continued supply of radiosondes, balloon, etc as well as spares for AWSs, ground station and hydrogen generator	High	High	High	- Maintain ongoing service agreements with suppliers. - Keep stock of spares at each of the regional hubs. - Install 2 radiosonde ground systems - Have back up plan to procure local hydrogen should generator fail.	
Access to sites for maintenance visits	Staff are unable to access sites due to lack of transport, or flooding.	High	High	High	- Work with WFP to provide logistics to transport staff to remote locations - Acquire service/maintenance regional vehicles with support from WFP for emergency fault repairs.	
Installation of 150 AWS sites diverts attention away from GBON 21 stations.	Demands on ZMD to maintain 150 weather stations mean that quality of GBON stations is not high enough – i.e. resources are stretched too thinly.	High	High	High	- Adopt a tiered approach to network management, prioritising GBON 21 and a few other key stations over all other requirements.	

Insufficient trained resource to configure data systems	Data is unavailable via WIS2.0 because staff do not have the capability to configure the required systems	High	High	High	- Recruit new resource to support the team. - Ensure ongoing service agreement with suppliers covers configuration of WIS2.0 system. - Encourage SOFF to invest in global, or regional, support mechanisms for WIS2.0 in a box.	
Hardware failure	Inability to provide the full GBON compliant observations to GTS/WIS2	Medium	Very High	High	- Adequate funding, skills and planning to manage the network. Resilience and redundancy measures to be included in network design and operational plans / SOPs.	
Inability to access staff to maintain radiosonde launches	Staff are not willing or able to work shift patterns to ensure 12 and 00 UTC radiosonde launches	Low	High	Medium	- Utilise military personnel available to ZMD at Lusaka City Airport. - Consider autosonde as an alternate option should investment in other locations proceed.	
Retention of staff following training	Staff leave ZMD once they have received training.	Medium	Medium	Medium	- Ensure that staff are suitably motivated by their work and understand its global importance. - Access additional funding to incentivise key staff. - Maintain supplier service agreements, and peer advisor engagement, to ensure ongoing support and training for new staff.	

Module 6. Transition to SOFF investment phase

It is recommended that, on approval of the Investment Phase Funding Request, a workshop including the Zambia Met Department, World Food Programme and Met Office is arranged to review the outputs of the readiness phase and discuss the transition to the investment phase. The regular project meetings undertaken in the readiness phase should continue under the coordination of the WFP and should include the peer advisor wherever necessary.

Summary of GBON National Contribution Plan

Provide summary of GBON National Contribution Plan by filling this table

Components	Recommended activities	Related outputs and technical details
Module 2. GBON business model and institutional development	2(1) ZMD makes a formal arrangement with Zambia Air Force to utilise the military staff that work with them at Lusaka City Airport in order to sustain the radiosonde launches at the frequency required by GBON.	Section 2.1
	2(2) It is recommended that ZMD establish a MOU with WFP to provide logistical support for remote site visits as part of the SOFF investment and compliance phases.	Section 2.1
	2(3) An ongoing service agreement is established between ZMD and Campbell Scientific to help maintain the network of GBON Stations. A similar agreement should also be established with the supplier of radiosonde system and hydrogen generator.	Section 2.3
	2(4) Review the ZMD strategic plan to ensure that stakeholder management is strengthened in order to enable ZMD to highlight the importance of the GBON network to government stakeholders.	Section 2.3
	2(5) ZMD incorporates a strategy for tiering their stations within their SOPs. This should identify the 21 GBON stations and a handful of other priority sites, as tier 1, and resources should be focussed accordingly.	Section 2.4
Module 3. GBON infrastructure development	3(1): Only sites with Campbell Scientific AWSs installed, good security, and good MTN network coverage should be designated as GBON. Existing manual stations should continue to report to GTS, however all GBON sites should be redesignated to the AWS.	Section 3.1
	3(2): Regional maintenance hubs are established (in line with approach already being proposed under TRALARD) and the maintenance and calibration plan proposed is adopted.	Section 3.1
	3(3): SOFF funding is initially focussed on establishing one GBON compliant upper air site at Lusaka City Airport (ZMD HQ). Any further investment will be contingent on these	Section 3.1

	observations being sustained for a period of 2-years.	
	3(4): Two manual radiosonde ground stations and a self contained hydrogen generator are procured and operationalised for Lusaka City Airport as part of the SOFF Investment Phase. This should include provision for backup power and mobile telecommunications.	Section 3.1
	3(5): The peer advisor will work with ZMD to develop Standard Operating Procedures to support the maintenance and calibration of the GBON surface and upper-air stations and develop maintenance, calibration and meta-data logs required to provide quality assurance of observations in line with GBON standards.	Section 3.1
	3(6): SOFF Investment builds upon the capabilities that have already been developed by SCRALA/TRALARD projects, as well as the WMO WIS2.0 in a box pilot.	Section 3.2
	3(7): SOFF considers whether centralised funding should be provided to support WIS2.0 in a box to sustain and grow this capability either on a global, or regional basis. As this could realise economies of scale in terms of cloud computing costs as well as availability of technical resources.	Section 3.2
	3(9): Explore simple systems and options to provide access to WIS2.0 data, including data from other countries, for use by forecasters and climatologists at ZMD.	Section 3.3
Module 4. GBON human capacity development	**4(1):** Recruit 2 new staff members and train existing staff within the Operations and Engineering Services team to configure and manage Zambia's WIS2.0 in a box capability.	Section 4.2
	Recommendation 4(2): Strategic and project management training is procured for senior managers across ZMD.	Section 4.3
	Recommendation 4(3): ZMD senior managers to refresh the ZMD strategy and operational plans, with support from the peer advisor, to ensure that the training received translates into actionable plans for the execution of SOFF investments.	Section 4.3

	Recommendation 4(4): Recruit a project manager to oversee SOFF investment phase and to engage with government and donor community to sustain GBON network in medium/long term.	Section 4.3
	Recommendation 4(5): Senior Leaders should all receive Gender Equality and Social Inclusion training before sensitisation training is rolled out to all staff at ZMD.	Section 4.4
	Recommendation 4(6): Commission a formal gender assessment of ZMD.	Section 4.4
	Recommendation: 4(7): Commission a Civil Society Organisation engagement workshop with external facilitator to build understanding of the importance of weather and climate information amongst communities who are hosting AWS sites.	Section 4.4
Module 5. Risk Management	All risk management actions are covered in the recommendations above.	
Module 6. Transition to SOFF investment phase	Recommendation 6(1): Hold an event between ZMD, WFP, Peer Advisor and other stakeholders to review outputs of investment phase funding request to enable effective transition to investment phase.	Section 6

Report completion signatures

Peer Advisor signature Helen Bye - Head of International Engagement Met Office 30/09/2024
Beneficiary Country signature **Edson Nkonde** **Director of Meteorology** **Permanent Representative of Zambia with WMO** 27 September 2024
WMO Technical Authority signature

ANNEX A: List of proposed Surface and Upper Air Stations

No	PROV	DISTRICT	STATION NAME	WIGOS Station ID	Latitude	Longitude	Type
1	Western	Sesheke	Sesheke MET	0-894-2-WESS001	-17.4771	24.3015	Surface
2	Western	Nkeyema	Nkeyema Secondary School	0-894-2-WEKY001	-14.8772	25.3805	Surface
3	Southern	Livingstone	Hillcrest Secondary School	0-894-2-SOLI001	-17.8326	25.8572	Surface
4	Southern	Namwala	Moobola primary School	0-894-2-SONW001	-15.9394	26.3780	Surface
5	Central	Serenje	Serenje MET	0-894-2-CESR001	-13.2190	30.2201	Surface
6	Copperbelt	Ndola	Fatima Girls Secondary	0-894-2-COND002	-13.0986	28.6656	Surface
7	North-western	Solwezi	Solwezi MET	0-894-2-NSWO001	-12.1709	26.3656	Surface & Potential Upper Air
8	North-western	Mwinilunga	Lumwana West Day Secondary	0-894-2-NWMN002	-11.8225	25.2608	Surface
9	North-western	Zambezi	Zambezi MET	0-894-2-NWZA001	-13.5358	23.1193	Surface
10	Luapula	Chiengi	Mununga Secondary	0-894-2-LPCE002	-9.0462	29.0349	Surface
11	Northern	Mpulungu	Mpulungu Harbour	0-894-2-NRML002	-8.7644	31.1045	Surface
12	Muchinga	Mpika	Katibunga Day Secondary School	0-894-2-MUMK002	-11.9005	31.4300	Surface
13	Muchinga	Isoka	Isoka MET	0-894-2-MUIO001	-10.1725	32.6470	Surface
14	Eastern	Lundazi	Lundazi MET	0-894-2-ESLN001	-12.2915	33.1761	Surface
15	Lusaka	Lusaka	Lusaka City Airport	0-894-2-LSLU002	-15.4163	28.3207	Surface & Upper Air
16	Eastern	Nyimba	Kacholola	0-894-2-ESNY001	-14.7761	30.5908	Surface
17	Western	Mongu	Mongu	0-894-2-WEMO001	-15.2540	23.1507	Surface & Potential Upper Air

18	Luapula	Mansa	Mansa	0-894-2-LPMA001	-11.1745	28.8800	Surface
19	Eastern	Chipata	Chipata	0-894-2-ESCP001	-13.6340	32.6344	Surface
20	N.Western	Kasempa	Mukinge girls sec	0-894-2-NWKE002	-13.4913	25.8619	Surface
21	Northern	Kasama	Kasama Met	0-894-2-NRKS002	-10.2176	31.1383	Surface & Potential Upper Air

ANNEX B: SPECIFICATIONS FOR CAMPBELL SCIENTIFIC AUTOMATIC WEATHER STATION SENSORS

	Parameter	Sensor	Sensor Details
1	Temperature/Relative Humidity	Vaisala HMP 155	• Sensor Pt100 RTD element, Class F 0.1 IEC 60751 • Observation range −80 … +60 °C (−112 … +140 °F) • Response time for additional temperature probe in 3 m/s (7 mph) air flow 63 %: < 20 s 90 %: < 35 s • Operating humidity 0 … 100 %RH • IP rating IP66
2	Air Pressure	Vaisala PTB330	• Pressure range 500 … 1100 hPa, 50 … 1100 hPa • Operating temperature −40 … +60 °C (−40 … +140 °F) • Operating temperature with local display 0 … +60 °C (+32 … +140 °F) IP rating IP66
3	Wind Direction	Thies Clima 4.3129.10.712	• Measurement range 0 ... 360° (0 Ohm in the North point) • Resolution 0.5° • Accuracy ± 2°
4	Wind Speed	Thies Clima (First Class) 4.3352.10.000	• Measurement range 0 ... 75 m/s • Accurancy < 1 % of meas. value (0.3 ... 50 m/s) or < ±0.2 m/s • IP 55
5	Rainfall	Texas Electronics Model 525	• Sensor TypeTipping bucket with magnetic reed switch • Operating Temperature Range - 0° to 50°C • Resolution =1 tipVolume per Tip4.73 ml/tip (0.16 fl. oz/tip) • Rainfall per Tip = 0.254 mm (0.01 in.) • Measurement Uncertainty1.0% up to 50 mm/h (2 in./h) • Orifice Diameter15.4 cm (6.06 in.)
6	Global Radiation	Kipp & Zonen SMP6-V	• **Spectral range (50% points)**285 to 2800 nm • **Response time (63%)**< 1.5 s • **Response time (95%)**< 12 s • **Zero offset A**< ±8 W/m² • **Zero offset B**< ±2 W/m² • **Directional response (up to 80° with 1000 W/m² beam)**< ±15 W/m² • **Temperature response (-10 to +40°C)**< ±2 % • **Temperature response (-40 to +70°C)**< ±4 %

7	Leaf Weatness	Campbell Scientific P/N-5259-02	Resistance at Wet/Dry Transition 1. Normally 50 and 200 kohm (uncoated sensor) 2. Normally 20 to 1000 kohm (coated sensor) • Operating Temperature Range 0° to 100°C • Short-Term Survivability Temperature Range -40° to +150°C
8	Soil Temperature & Moisture	Campbell Scientfic SoilVUE10 TDR	• Measurements MadeVolumetric water content (VWC), permittivity, electrical conductivity (EC), and temperature • Operating Temperature Range -40° to +60°C • 1m depth (5, 10, 20, 30, 40, 50, 60, 75, and 100 cm) **Electrical Conductivity** • Range0 to 10 dS/m • Accuracy: ±2% (0 to 2.5 dS/m), ±5% (full range) **Relative Dielectric Permittivity** • Range1 to 80 • Accuracy ±1 permittivity unit (between 4 and 42 permittivity) **Volumetric Water Content** • Range0 to 100% • Water Content Accuracy±1.5% typical with most soils Soils with high organic matter (> 12% soil organic carbon) or high clay content (> 45% clay) may need a soil-specific calibration due to the dispersive nature of these materials. **Soil Temperature** • Accuracy± 0.15°C (between -30° and +40°C)