23.01.2024

GBON National Contribution Plan

Cabo Verde

Systematic Observation Financing Facility

Weather and climate data for resilience

GBON National Contribution Plan - Cabo Verde

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Module 1 National Target toward GBON compliance

1.1 Summary of the GBON National Gap Analysis

The results of the GBON National Gap Analysis (NGA) indicated the need to improve 3 land surface AWS and install 1 new one to meet the GBON standard 200-km spatial grid resolution and density. One (1) Upper-air sounding station at Ilha do Sal needs to be improved (see Figure 1). Table 1 summarizes the NGA GBON compliance gaps, and also includes the GBON National Target (see section 1.2).

GBON requirements	Target # of stations	GBON Compliant stations #	Stations gap		GBON National Contribution Target	
			New	Improve	New	Improve
Surface AWS	4	0	1	3	1	3
Upper-Air UAS	1	0	0	1	0	1
Marine stations	[1]when applicable					

Table 1: National Gap Analysis – Cabo Verde (Jun, 2023)

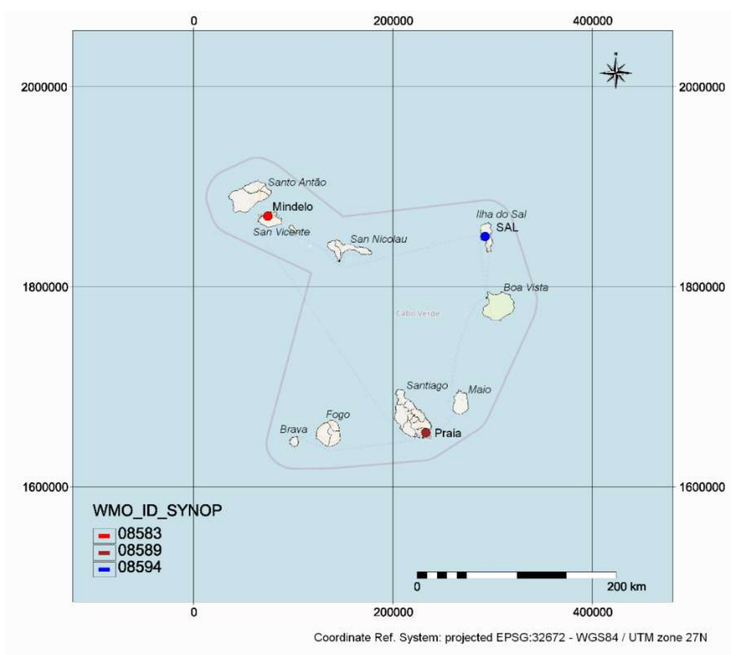

Figure 1: Current WIGOS_ID GTS reporting AWOS stations at int'l airports (Sal, Praia, Mindelo)

Some more details of the GBON Gap Analysis are given below.

[1] To add

1.1.1 Surface Observations

1.1.1.1 Spatial Resolution

Figure 1 illustrates the Cape Verde archipelago, projected in a UTM (Universal Transverse Mercator) coordinate system, permitting to evaluate the metric 200-km grid resolution and GBON requirement. The 4-station requirement, corresponding to four 200-km grids, recommended by the WMO in their Initial GBON Gap Analysis document for Cabo Verde can be observed (Figure 2). A spatial coverage gap of 1 grid (or 1 station) can be observed. Currently, the Cabo Verde station distribution meets 3 target grids, with three WMO-ID indicated stations responding currently via the WMO GTS system. The full 4-grid target can be met by adding one GBON compliant station in the South West grid e.g., Brava Island.

1.1.1.2 Temporal Resolution

The current earmarked GBON AWS of Cabo Verde do not comply (yet) with the hourly data communication standard (for the 6 weather variables) and do not use the WIS2.0 communication protocol, required by GBON. We refer to the Gap Analysis report for more details. At this moment, 3-hourly (WMO_ID 08594) and 6-hourly (WMO_IDs 08593 and 08589) SYNOP messages are communicated by these three synoptic stations, mainly used for aeronautical purposes. A WIS2.0 node for automated hourly data communication is not fully installed yet. Data are currently transferred to the WIS2.0 system via a small WIS2.0-DGM Morocco web interface and manual protocol.

1.1.2 Upper Air Observations

Cabo Verde has one Upper Air Sounding facility on Sal Island, at the INMG Head Quarters, near Amilcar Cabral Int'l airport (see Figure 2). This UAS has been operating since the 1960's until 2018 on a regular basis. The sounding station is currently out-of-operation and was assessed as a present GBON gap.

1.2 National Target toward GBON Compliance

Table 1 (Right Collums) also show the GBON National Contribution Target of Cabo Verde. In order to meet GBON compliance, Cabo Verde requires to lift the GBON gaps, mentioned above.

The NMS has therefore set and recommends the following national targets:

- **Spatial Coverage of Surface Observations:** Rehabilitate 3 AWS stations and install one (1) additional new GBON compliant AWS, in the South western region e.g., Brava Island in order to meet the GBON spatial coverage requirement (four 200-km surface grids covering the land surface; see also Figure 2);

- **Data Communication:** Install a full WIS2.0 communication node and link in real time to the new WMO data communication system, using FOSS based data protocols; train service ICT and observer staff in FOSS based data transmission and exchange.

- **Temporal Data Requirement of Surface Observations:** link the GBON earmarked stations to the WIS2.0 system, and also meet the near real time hourly GBON temporal (hourly) data requirement for the six reporting variables;

- **Upper Air Observations***:* Re-furbish the existing Upper Air Sounding facility on Sal Island and retake the sounding practices (twice daily) to meet the GBON requirement.

A phased approach is proposed to meet progressively the four main targets. In the next modules, the different aspects on how to implement the GBON targets are discussed.

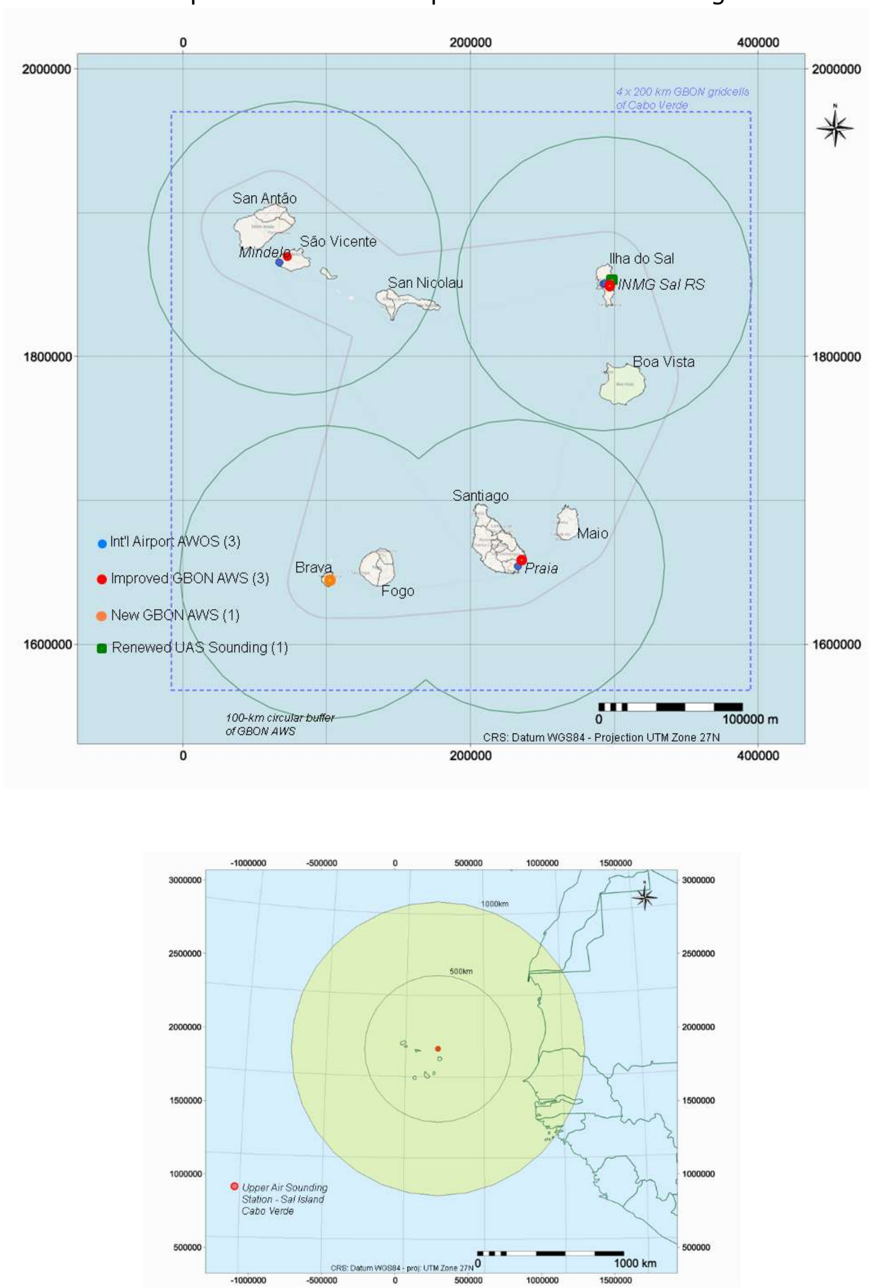

Figure 2: GBON National Target and Contribution of Cabo Verde (4 AWS + 1 UAS)

Module 2 GBON business model and institutional development

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

In Cabo Verde, the National Meteorological Service is by legal Decree (Regular Decree nº 13/2009 of June, 20), currently the only operator and authorized government institution, acquiring meteorological observations a/o with potential to support GBON. In this respect, it collaborates closely with the ASA[2] for providing Aeronautical Meteorological Services.

An exception in third-party weather and atmospheric observations and data gathering are int'l research partners (from UK and Germany) operating jointly with INMG, the WMO Global Atmospheric Watch or GAW-CVAO facility at Calhau on San Vicente Island. This Observatory is operating continuously since early 2007. This facility, next to air component analysis also operates a weather station.

The INMG also cooperates with several international partners in meteorology and climate services. With the CPTEC (Brazil) and the KNMI from the Netherlands, it is cooperating in the areas of Numerical Weather Prediction (NWP), Climate Data Management Systems (incl. data rescue of historical analogue data) and climate research (e.g., sea-level rise). With IPMA (Portugal), it cooperates in capacity development for aviation meteorology for aeronautical purposes. It cooperates in regional an EU-funded initiative for Macaronesia, representing the Acores Islands, the Canary Islands and Cabo Verde. It works on the operationalization of a National Framework for Climate Services with funding from Luxemburg (LuxDev). INMG also cooperates with American University partners, NOAA and NASA and also the UK on atmospheric research related to Atlantic hurricanes (e.g., NAMMA campaign, etc.).

At this stage, no private sector operators were identified which provide meteorological observations and data services in the country. Several private entities e.g., water supply & sanitation Co APP, AdS and the tourism / hotel sector however show interest in collaborative weather observations.

It is therefore recommended to further develop an operational and financial strategy to build sustainable partnerships with private Co a/o other Gvt. agencies, using e.g., public-private partnership or other business models. First initiatives have been taken (ref. 2.3). INMG proposes to organize two stakeholder engagement workshops, to which public and private sector potential partners will be invited to discuss and elaborate on business models, 3P[3] and opportunities in the SIDS country setting of Cabo Verde. The Table 2.1 below shows the investment requirement for this business development and institutional development action (workshop costs). For facilitating participation of all partners, INMG proposes to keep two workshops ("Barlavento" and "Sotavento" island regions).

[2] ASA : Agency of Air Navigation and Safety – Cabo Verde

[3] 3P: Public – Private - Partnerships

Table 2.1: Investment proposal for stakeholder and private partner engagement

Item #	Item/Activity	Location (suggested)	Cost estimate (USD)
1	Stakeholder and private sector engagement workshop (1)	Mindelo, São Vicente	
2	Stakeholder and private sector engagement workshop (2)	Praia, Santiago	
		Total	See IFR [4]

Although INMG is currently working on a strategy for private sector engagement in meteorological services (e.g., station maintenance, weather bulletin dissemination), it is also requesting any further support from SOFF and peer-advisor in this aspect.

2.2 Assessment of potential GBON sub-regional collaboration

Cabo Verde has currently (2023) no immediate direct cooperation in joint meteorological observations anymore with NMS of neighbouring countries i.e., Senegal, Mauritania and Guinee-Bissau. There existed (~ 2013-2018) a regional WMO cooperation project (MARINMET), funded by AEMET (Spain), related to marine (harbour) meteorological observations. This project was suspended due to the SARS-CoV19 pandemic (3/2020-2021). This collaboration with AEMET has resulted practically in 3 marine harbour AWS (see Figure 3), including tidal and wave observations.

It is recommended to re-initiate this type of collaborative maritime observation projects with neighbouring countries, with e.g., adjoining EEZ (Extended Economic Marine Zones) and support of international knowledge partners. As potential collaboration with direct neighbouring countries, INMG considers a marine observation network as important to explore further.

INMG is also cooperating in an ECOWAS region project "Intra ACP-ClimSA", performing a diagnostic on meteorological observations and data collection in the CILLS/ECOWAS region countries. This project also includes adaptation of an Agrometeorological model (FAO-AquaCrop) to better monitor and predict agricultural crop yields in Cabo Verde. Cabo Verde has quite particular agro-hydro-meteorological conditions, compared to the continental West-African mainland. It cooperates here regionally with the Agrhymet Centre (Niamey, Niger). INMG also has regional project-based cooperation with "Macaronesia"[5] (PLANCLIMAC, MACCLIMA), focusing on meteorological observation network support and sustainability, including monitoring of climate risks in coastal zones.

For increasing (staff) mobility, engagement and fostering regional collaboration, related to GBON and SOFF, INMG requests some mobility funds for participation in e.g., regional meetings, partner study visits (e.g., Morocco, Senegal, Guinee Bissau, São Tomé & Principe, etc.). Study visits to the National DGM Morocco will be organized for instrument and calibration, data exchange and data management, noting that the DGM Morocco serves

[4] For budget estimates, we refer to the SOFF Investment Phase Funding Request or IFR (elaborated jointly by the IE, peer-advisor and beneficiary)

[5] "Macaronesia" consists of the Central East Atlantic Island archipelagos of the Azores, Madeira (Portugal), the Canary Islands (Spain) and Cabo Verde.

as a WMO RIC (Regional Instrument Centre), RWC (Regional WIGOS Centre) and GISC. Table 2.2 summarises the investment requirement for these activities.

Table 2.2: Investment proposal for engagement (mobility) in regional collaboration

Item #	Item/Activity	Locations	Cost estimate (USD)
1	Mobility fund (5-yr ~ 15,000.USD p.a.) for participation and exchange in SOFF, GBON regional a/o other activities	Various	See IFR[4]

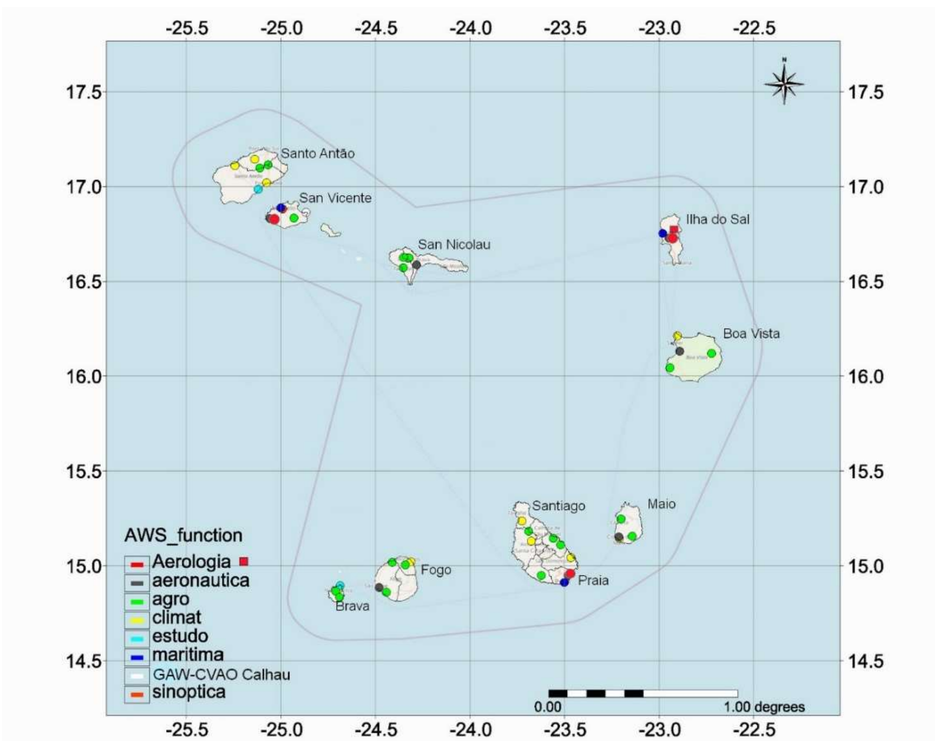

Figure 3: AWS infrastructure and station functions of Cabo Verde

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

Until present, INMG has secured the operation and maintenance of its meteorological and other (i.e., seismic) observation network. Figure 3 for illustrates the current AWS network and function in Cabo Verde.

The INMG has recently elaborated a new Strategic Plan (2023-2026) and is investigating the option, incl. securing financial conditions, for outsourcing meteorological station maintenance and management on a service contract basis to a private partner, or using a public-private partner contract model or similar. The maintenance of the GBON station network can also be part of this outsourcing process.

INMG has a defined but limited allocation within its annual budget for basic maintenance of its observation network. This is however insufficient to allow regular (e.g., 90-day full inspection and preventive maintenance incl. small repairs) of its AWS, distributed across the islands. It is currently not able to implement all required interventions, such replacement of instruments reaching their end-of-lifetime (instrument lifecycle management). Limited own generated funds (e.g., data provision) and very limited government contributions are used for the purpose. Therefore, INMG is now actively engaging with cooperation (service level agreements) with available private partners (i.e., Water Utilities e.g. APP, AdS[6]), to manage its network (location safety issues, daily function check i.e., solar power supply, wiring connections, cleaning) in exchange in weather observation data.

This new business model and management process is under further development (business model, maintenance requirements and protocols, terms of reference, funding issues, availability of potential partner and private sector operators, required qualifications, responsibility and liabilities, risk management, etc.).

INMG is also building up experience in outsourcing preventive maintenance, especially for its AWS located on islands, without resident meteorological human resources. This is done in order to reduce regular and expensive inter-island displacement of staff. It uses a service level agreement or contract concept for these services, and engages official partners e.g., municipalities, but also caters for private sector (e.g., farm companies).

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

For the existing and future National strategy on improving observation networks, we refer to the new Strategic Plan update 2023-2026, to be published soon. We also point to paragraph 2.3. above for the new business approach (under development) for improving station maintenance and operations. The new Strategic Plan (2023-2026) of INMG, is based on 5 strategic pillars[7]. Pillar four refers to improvement of the observation infrastructure, data communication and information technologies. A financial investment of 218,182 €. is foreseen for this strategy element. Using this own and SOFF investments, it will strive to harmonize observation procedures in its networks, focusing on instrument O&M, data communication using WIS2.0 and data quality and control procedures.

Also referring to regional cooperation actions (see 2.2), INMG now is increasing its agro-hydro-meteorological AWS network within the REFLOR-CV project, using EU funding and implementation by FAO[8]. INMG will strive to apply GBON technical criteria, including WIS2.0 data communication, to manage this important national observation system, serving the agricultural, water & food security and environment sectors. The proposed

[6] APP: "Aguas de Ponta Preta" water utility companies (operating on Sal and Santo Antão Islands) AdS: "Aguas de Santiago" water utility operating on Santiago Island.
[7] INMG Strategic Plan (2023-2026) is awaiting final Ministerial approval (signature), before final publication – Jan, 23 2024
[8] REFLOR-CV: Re-enforcement of Climate Adaptation & Resilience Capacity of the Reforestation sector of Cabo Verde project 2020-2024 (funding European Union / IE. FAO)

GBON network of Cabo Verde complements the planned national investments with respect to meteorological observations. Only the marine meteorological observations are currently not included in this stage of the process.

2.5 Review of the national legislation of relevance for GBON

The current national legislation and regulations on meteorological observations are adequate with respect of implementing GBON, also with respect to compliance and operations. INMG remains the prime national authority in meteorology, with autonomous administrative and financial authority (Regular Government Decree n°13/2009, July 20, 2009). The NMS is allowed (by law) to contract external services from private sector a/o other entities to support the observation process chain (e.g., for station maintenance or another work process). In this sense, for example, the Telecommunication provider (CV-Telecom), providing optical glass Fiber FTTH network communication protocols for the int'l airport stations, can be seen as an (important) external service provider to INMG.
There are no special legal requirements (or customs constraints) related to importing meteorological instruments and related equipment's. Cabo Verde has a concrete legal framework and laws concerning public procurements. Procurement and acquisition processes (for services, equipment's, etc.) by INMG are formally implemented according these laws (Law n°88/VIII/2015).

Module 3: Infrastructure Development

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

The Cabo Verde Institute of Meteorology & Geophysics (INMG) operates and maintains a substantial number of Automated Surface weather stations (AWS) and a few manual stations (MWS). INMG operated a long-term Upper-Air sounding station until 2018. The weather station network serves various purposes (aviation, maritime, agrometeorology, climate) as indicated in Figure 2.

The NGA indicated that three (3) GBON synoptic stations need to be improved or renewed and requires the installation of 1 new synoptic AWS to meet the GBON areal coverage (4 x 200-km grids) in the south-western Island of Brava (see map in Figure 2).

Table 3.1: List of current WMO - WIGOS registered Surface airport weather stations

Station Name	WIGOS_ID	ICAO	Owner	Type	Lat	Lon
Sal (CV)	08594	GVAC	ASA[9]	AWOS[10]	16.72694N	22.94750W
Mindelo (CV)	08583	GVSV	ASA	AWOS	16.83139N	25.05917W
Praia (CV)	08589	GVNP	ASA	AWOS	14.94917N	23.48250W

[9] ASA: Agency of Air Navigation & Safety – Cabo Verde
[10] AWOS : Aviation Weather Observing System

The three (3) current GBON synoptic weather stations are in operational condition, serving aviation weather purposes and air safety. However, they are not compliant with GBON due a gap in data transmission frequency and automated data delivery to the new WIS2.0 system. The hourly data transmission requirement cannot be met in the current AFTN network settings and ownership conditions of the airport AWOS. This will also remain in the future. We therefore recommend to keep using these three surface stations during the first SOFF phases (Readiness & Investment) as is, and invest in the improvement of three (3) AWS, owned and entirely managed by the INMG. The new GBON surface infrastructure will also meet the GBON spatial grid coverage (as proposed in the NGA). This GBON surface infrastructure will be located at the three (3) main INMG offices on Sal Island (Espargos), San Vicente (Mindelo) and on Santiago Island (near Praia). The current 3 GBON synoptic (non-fully compliant) airport stations will be phased out from GBON and replaced by the INMG GBON stations at the end of the investment phase (once fully operational). The fourth (4) additional new station will be installed to fill the geographical gap in the South-western part of Cabo Verde. Table 3.2 lists the 4 GBON surface stations required and to be improved or set-up in Cabo Verde.

Table 3.2: List of “to be improved and new” GBON Surface stations

Station Name	WIGOS_ID	Owner	Type	Lat	Lon	Required
Sal - R/S Sede		INMG	AWS	16.7313N	22.9353W	improve
Mindelo – DSV		INMG	AWS	16.8807N	24.9905W	improve
Praia – SF		INMG	AWS	14.9670N	23.5301W	improve
Brava		INMG	AWS	14.8766N	24.6970W	new

Technical specifications by the GBON task team will be utilized when supporting the IE in preparing tender documents during the investment phase.

- **A map of observing network distribution and a list of the required new or rehabilitated GBON stations**

Figure 3 and 4 show the projected GBON surface station infrastructure and the current aeronautical aviation weather observing systems at the main int’l airports.

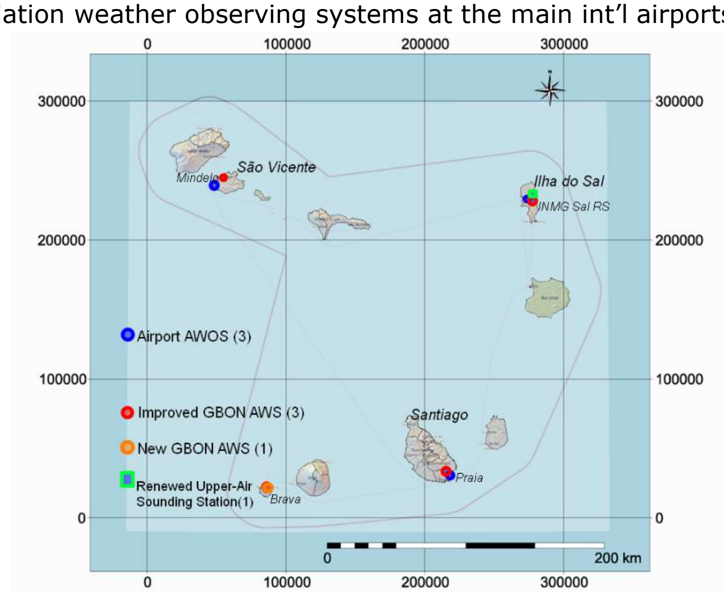

Figure 4: GBON Target Contribution Cabo Verde

A list of observation instruments and systems per site

The AWS will be equipped with instruments according WMO technical specifications and recommendations for Tender of equipment's. Table 3.3 lists the hourly observations which will be made from the four (4) stations and communication protocols.

Table 3.3 list of observations (variables) per site

Station Name	SLP	T	RH	Ws	Wd	P	Comm. protocol
Sal (RS)	✓	✓	✓	✓	✓	✓	HTTP/MQTT
Mindelo (DSV)	✓	✓	✓	✓	✓	✓	HTTP/MQTT
Praia (S.F)	✓	✓	✓	✓	✓	✓	HTTP/MQTT
Brava	✓	✓	✓	✓	✓	✓	HTTP/MQTT

- **Investments and activities needed for the installation of new and improvement of existing surface stations**

Based on the NGA and further discussions with the SOFF secretariat, peer-advisor and other exchanges, the SOFF project executive team (INMG, KNMI supported by local consultant) is recommending the following initial investments for INMG to produce GBON compliant observations.

As explained before, the INMG recommends to improve the current GBON network by rehabilitating existing and/or installing new AWS, meeting the areal GBON coverage and data frequency requirements. The improved GBON stations on Ilha do Sal and San Vicente (Mindelo) do not need siting, as they will be set-up and/or improve existing AWS on existing station locations: SAL INMG HQs and Mindelo INMG office. The GBON station on Santiago Island is projected near the INMG office (Praia/Achada San Felipe) facilities. This location also requires protective fencing and rehabilitation works. The installation of the entirely new GBON station on Brava Island will require the full process chain of siting and also require the station equipment's as specified in the table 3.4. Table 3.5 shows the required investments for setting up new GBON AWS on Brava. It is therefore recommended to invest in the following equipment's for the GBON surface stations.

Table 3.4: Equipment requirement for the AWS (stations) to meet GBON compliance

Required AWS components	GBON station Locations				Spare
Instrument/equipment	Sal RS	Mindelo DSV	Praia SF	Brava	
Air Temp / Humidity sensor	✓	✓	✓	✓	✓
Radiation shield	✓	✓	✓	✓	✓
Wind speed - direction sensor	✓	✓	✓	✓	✓
Pressure sensor	✓	✓	✓	✓	✓
Precipitation sensor	✓	✓	✓	✓	✓
Wind mast & stands	✓	✓	✓	✓	✓
Solar power supply	✓	✓	✓	✓	✓
Power regulator/multiplexer	✓	✓	✓	✓	✓
Data logger	✓	✓	✓	✓	✓

Data comm. modem, antenna	✓	✓	✓	✓	✓
Lighting protection	✓	✓	✓	✓	✓
AWS cabinet; junctions,	✓	✓	✓	✓	✓
Cables, wiring, connectors	✓	✓	✓	✓	✓
Protective fencing	0	0	✓	✓	0

We considered a quantity of 4 instruments plus one additional spare (as normally one invests in 130% on instrument networks). We included one spare of each instrument for the 4 locations. Verification (July 2023) of the GBON earmarked stations and locations leads to the following investment requirement for the surface AWS (3) rehabilitation:

Table 3.5: AWS sites (improve/upgrade) investment proposal and initial cost estimate[11]

Activity #	Action required	Quantity	Cost estimate (USD)
1	Rehabilitate or upgrade data loggers to meet MTQQ & SFTP transfer protocol requirement	3	[12] See IFR
2.	Upgrade air temp/humidity sensors incl. radiation shields (not meeting requirement measurement range)	3	
3.	Upgrade precipitation sensors (not meeting requirement measurement range)	3	
4.	Upgrade wind speed & direction sensors (not meeting requirement measurement range)	3	
5.	Verify a/o upgrade atmospheric pressure sensors (not meeting requirement measurement range)	3	
6.	Replace solar panels, batteries, power regulator, multiplexer, and security materials	3	
7.	Verify / replace lightning protection unit and cables/earth	3	
8.	Upgrade communication at all sites (modem, antenna, sim cards,)	3	
9.	AWS cabinet and mountings	3	
10.	Cables, wires, junctions, terminal boxes…	3	
11.	Labour, transportation (flights), Dsa for external support, where required	3	
12.	Field installation cost (incl. inter-island travel, etc.)	3	
13.	Int'l Transport (air freight) of equipment goods	3	
14.	Import duties, customs clearance cost	3	
15.	Operation & Maintenance of GBON AWS (3) 7,000. p.a. * 5-years * 3 AWS	3	
		Total	[7] see IFR

[11] TT-GBON approved material | World Meteorological Organization (wmo.int)

[12] For budget estimates, we refer to the SOFF Investment Phase Funding Request or IFR (elaborated by the IE, with the peer-advisor and beneficiary)

INMG will follow TT-GBON Task Team WMO Tender specifications during the investment phase and procurement phase of all equipment's, with support from the peer-advisor a/o others. Power will be supplied using renewable solar energy technology (currently already in practice in Cabo Verde). GBON station security of at least three GBON AWS can be assured (INMG office and station grounds; ref. also Module 5: Risk Management). For the new GBON AWS to be set-up on Brava Island, special measures will be taken into account and also negotiated (e.g., local service level agreement) with local authorities or present stakeholders.

Table 3.6: Activities and investments required for installing new AWS on Brava Island

#	Activity	Cost estimate (USD)
Site selection, preparation and station installation		
1	Site prospection (staff/inter island travel)	
2	Station Installation (staff costs; 2-wks; 2p; interisland)	
3	Site ground preparation works (labour, equipment hires, ….)	
4	Protective fencing and construction materials	
Instruments and Equipment's		
5	AWS instrumentation (see table 3.4) & O&M	
6	Int'l Equipment transport	
7	Local equipment transportation cost (Sal to Brava Island)	
8	Import duties, customs clearance;	
Human Capacity Development element (observer) -> see Module 4		
9	(resident) meteorological observer trainings WMO BIP-MT 2022 updates in (5-year period)	
10	Local technical assistance service contract (5-yr @ 9,800 p.a.)	
11	Local expenditures, communication costs, (5-yr @ 600 p.a).	
	Total	[13] See IFR

- **One improved (renewed) Upper-Air Sounding station**

Information on the atmospheric state (temp, humidity, pressure, horizontal wind) in the vertical profile is critically important for initializing weather forecast models and also for air navigation safety purposes. The Atlantic UAS facility on Ilha do Sal (CV) was operational since the late 1960's until 2018. It served air navigation safety in the large east Atlantic Flight Information Region (FIR-Ilha do Sal) and also was used during several research campaigns, related to Atlantic hurricane research and West-African Monsoon analysis and study projects. This location was and can provide crucial information on tropical depressions in this region and monitoring of Atlantic hurricane track development.
A full rehabilitation and operationalization of the UA sounding facility on Ilha do Sal (Espargos station) was recommended in the NGA report and is also required. This facility is located at proximity (approx. 1,400-m east of Sal int'l airport station). The historical radio sounding data used the same WIGOS_ID 08594 and ICAO GVAC airport code.

[13] For budget estimates, we refer to the SOFF Investment Phase Funding Request or IFR (elaborated by the IE, with the peer-advisor and beneficiary)

Table 3.7: List of the Upper-air Sounding station

Station Name	WIGOS_ID	Lat	Lon	Upper-air	Required
Sal (CV)	08594	16.73146N	22.93077W	UAS	Renew

Based on recommendation by the peer-advisor, the current semi-automated Upper Air Observatory will be fully rehabilitated and made operational. sounding Semi-automated UAS require more human resource manpower (balloon launching and monitoring twice daily), but also permits Cabo Verde to further develop its human resource capacity in meteorology. Renovation and construction work on the current UAS site will also be required, including implementation of safety measures (gas storage etc.), related to UAS operation. The technical and local assessment (July 2023) of the Upper-air site (Espargos, Sal) conducted in July 2023, indicated that upper air ascents were previously conducted (since late 1960's until 2018) at regular intervals. However, an obsolete H_2 generator and storage tank were found. The plan therefore envisages the rehabilitation of the balloon room and procurement of a H_2 generator, a ground monitoring system and consumables. Also, training will be included (ref. Module 4).

Table 3.8: Investment requirement for the UAS rehabilitation - Ilha do Sal

UAS station	Balloon room rehabilitation	Hydrogen generator	Ground system hard-/software	Consumables
Sal (R/S Sede)	✓	✓	✓	✓

The start-up investment and activities needed for the rehabilitation of the UAS site are:

- Rehabilitation works on balloon room/building in accordance with int'l standards and code of practice (incl. Safety regulations)
- H_2 generator and storage; Helium gas cylinders (for back-up)
- Ground system hardware/software
- Consumables (radiosondes, balloons, strings, etc.)

Table 3.9 gives the investment requirement and an indicative cost estimate of the UAS upgrade

#	Item/activity	Quantity	Unit price	Cost estimate (USD)
1	Rehabilitation works UAS building	1 Sal RS	--	
2	H_2 hydrogen generator & storage	1		
3	H_2 hydrogen storage tank, piping, valves,	1		
4	Ground monitoring system hard-/software - Upper-air Ground System - UPS and Desktop PC	1		
5	Ground System lease contract for 5-years	1 (5-yr)		
6	Consumables: Balloons	400 p.a. for 5-yrs		
7	Consumables (radiosondes)	400 p.a. for 5-yrs		

7	Helium gas cylinder (backup)	1 per yr		
8	Shipping and transportation (to Sal)	Per shipment		
9	Import duties, customs clearance	Per import		
			Total	See IFR [14]

For the re-activation of the UAS site on Ilha do Sal, there is also an investment requirement for human capacity (Upper-air sounding qualified technical assistance). We added the investment requirement for human capacity in Upper-air sounding qualified personnel in the Table 3.10. We further refer to Module 4 for more details on the required UAS personnel qualification and capacity development.

Table 3.10: Investment Requirement for (new) Upper-air Sounding technical assistance

Technical assistance Investment cost for UAS operations (5-yr)				
Item #	Qualification	# staff	Annual cost (USD)	5-yr cost (USD)
1.	technical assistance UAS: Qualified in meteorology & UAS	1	15,000. p.a. @ +5% p.a.*	
2.	Meteorological Technician (UAS qualified)	2	2x10,000. p.a. @ +5% p.a.	
			Total	See IFR [15]

(* annual cost increases, inflation, etc. over 5-year period)

The annual (up to 5-year) operational costs for the UAS station should also be estimated based on established guidelines and country specific conditions. This includes e.g., technicians local transport to/from site (on a two-per-day/night 365/24 basis).

- **Observational practices defined per network**

The performance of the surface observation network depends on the skills, and competencies of the staff responsible for the installation and operation of the station instruments and communication systems. The operation of the GBON AWS and sounding station requires a robust process including preventive a/o corrective maintenance and SOPs (Standard Operation Procedures). The beneficiary has already a long history in making weather observations and maintaining meteorological instruments. A detailed Protocol for observations, especially for the aviation (aeronautical) sector is available and used by the observers. The airport stations are 24/7 manned stations (ref. SYNOP code).
For the GBON stations, the INMG will invest in preparing a new special SOP protocol, including data transmission (to WIS2.0) processes.

The peer-advisor will further support in developing operation procedures for the observing systems, related to GBON. An additional challenge is the new data communication and WIS2.0 transfer protocols now in use by WMO. For operating the renewed upper-air sounding facility, a support training program will be defined and developed, and new UAS operations staff to be recruited.

[14] See Investment Phase Funding Request (IFR)
[15] See Investment Phase Funding Request

- **Preliminary maintenance plan for existing and improved/new stations, including calibration practices**

INMG plans to use a preventive maintenance schedule of 90 days for GBON earmarked stations, as is done now for the current airport weather station network undergoing a 90-day interval full inspection. Corrective maintenance activities should be performed to fix technical or communication failures. It is anticipated (due to the close locations of the GBOM AWS to the main INMG offices) to attend system breakdowns within 24/48-hours for at least 3 GBON AWS and within 5-days for the Brava AWS. Current maintenance activities are done by the technical staff located at Ilha do Sal, Mindelo and Praia offices. Corrective maintenance may also require and include field re-calibration of instruments.

Calibration

The INMG staff executes field calibration of instruments when anomalies a/o mal-functioning is detected. When required, instruments can be sent for inspection and (re-)calibration to the DGM (Morocco) being the WMO RIC or Regional Instrument Centre or IPMA (Portugal). For language issues a/o eventual trainings, the Portuguese national weather service could be useful. The equipment manufacturers will also be involved in designing an equipment maintenance and (re) calibration programs. We also recommend to cooperate closely with the peer-advisor on maintenance and calibration aspects where needed. INMG recommends to invest in the following field calibration equipment, required for improving operations and maintenance of weather field instruments

Table 3.11: Field calibration equipment requirement

#	Field Calibration Test equipment	Sensors	Quantity
1	Temp/humidity sensor with rad. shield	Temp/humidity	2
2	Barometric Pres. Transfer standard	Atmospheric pressure	2
3	Rain gauge calibration device	Precipitation calibration	2
4	Prop.torque, etc.	Wind verification	2

INMG also recommends to equip a small laboratory with a small climate chamber for the calibration of temperature and humidity sensors as well as for atmospheric pressure calibrations. It is projected that all future laboratory calibration for GBON temperature, humidity and atmospheric pressure sensors will be performed at INMG Head Office (Espargos, Sal RS).

Table 3.12: Laboratory calibration equipment requirement

#	Calibrator	Sensors	quantity
1	Climate Chamber	Temp/humidity	1
2	Atmospheric Pressure	Atmospheric pressure	1

This leads to the following investment requirement for Field and small laboratory calibration and test equipment's.

Table 3.13: Investment requirement for field and small laboratory calibration equipment's

Item	Quantity	Unit price	Cost estimate (USD)

Field calibration and test equipment	2		
Laboratory equipment	2		
Toolset (travel standard), multi-meter, oscilloscope.	2		
Recertification cost of calibrators	2		
		Total	See IFR [16]

For instrument calibration issues, INMG will also seek cooperation with WMO-RIC centres (e.g., DGM/Morocco) a/o peer-advisor for further support.

- **Technical specification for new instruments and observing systems for the procurement process**

We already added our instrument requirements in section and Tables above.

3.2 Design of the ICT infrastructure and services

a. Description of the ICT infrastructure and services design

The INMG Head Quarters at Espargos (Ilha do Sal) accommodates the national network infrastructure (network main server, switches, cables, etc.) for storing and dissemination weather and climate data of Cabo Verde. The main data server room currently operates on

Figure 5: Mainframe Computer INMG at Sal RS

Public network service providers to INMG are CV-Telecom -> Primary Link (250 Mbps)
INMG oversees different weather data acquisition flows, related to airport navigation and safety but also other monitoring networks (agrometeorological AWS, seismic stations).

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

[16] See Investment Phase Funding Request

The int’l airport weather data and air navigation services use a separate network and the NetSYS hard/software system for providing weather forecasts and air navigation information to pilots, incl. message handling (MHS). The communication system uses GRE tunnel routing and optical Fiber technology (FTTH) for data transmission.
AWS (unmanned weather stations) data transmission is currently achieved using GSM/GPRS technology via a national telecom provider CV-Telecom. The AWS use typically own data loggers (e.g., Campbell CR1000X and modems). Incoming station data (10’ or longer time intervals) are centrally stored and managed using Campbell Loggernet software. This permits to monitor station functioning, data reception and also to do initial quality checks (anomalies). Recently and in the framework of the REFLOR[17] project, AmbiDS[18], a web-based environmental (incl. weather) data collection and monitoring system, based on remote cloud-based ftp-server storage, was also installed for the new agrometeorological AWS station network. For its unmanned AWS network, INMG uses GSM/GPRS communication protocols and the national CV-Telecom cell phone communication provider.

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

Currently, INMG is using an IO-WIS2.0 web-application (MINIO console) after advice and instructions received from DGM – Morocco to manually transfer and convert SYNOP messages data to the WIS2.0 main RA1 node in Morocco. Airport weather observation staff (Sal airport and main node) perform this process manually (every 3 to 6-hours) to transfer the standard SYNOP messages from the three Sal, Mindelo and Praia WIGOS_ID airport stations to the WIS2.0. A basic WIS2.0 node is therefore currently present on Ilha do Sal. However, except from inputting (sending SYNOP), there is no staff capacity for operating the WIS2.0-in-the box FOSS free and open software system and tailoring this to their own needs and compliance requirements of WMO GBON. We further refer to Module 4 on Human Capacity Development in this respect. INMG will be fully hosting the national WIS2.0 node facility.

d. Detailed description of the measures to ensure resilience and continuity of the full data processing chain

Meteorological data acquisition (sub-hourly) is achieved in Cabo Verde at several station locations and islands for a variety of purposes (aviation, maritime, agriculture, civil protection, environment, etc.). Aviation weather services use a separate network for communications i.e., the AFTN[19] (ref. ICAO). Synoptic aviation weather station data (main 6-hour and 3-hourly intermediate messages from the three main int’l airports) are also communicated to the WMO – GTS. As measures of resilience in data continuity, INMG recommends to upgrade the main data storage facility including software updates and a full-fledged installation of the WIS2.0 node on Ilha do Sal, Espargos INMG main office.

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[17] REFLOR-CV: Re-enforcement of Climate Adaptation & Resilience Capacity of the Reforestation sector of Cabo Verde project 2020-2024 (funding European Union / IE. FAO)
[18] AmbiDS: Web-based environmental data management application (©Ambimetric, Pt)
[19] AFTN: Automated Fixed Telecommunication Network (ref. ICAO: Int’l Civil Aviation Organization)

A capacity development (training) program needs to be conducted with urgency to roll-out the use of WIS2.0-in-the-box and integrate this in the current data flow and weather and climate data management systems of INMG. It is recommended to use a bi-lingual (English/Portuguese) training. It can be envisaged to have a regional or Atlantic SIDS training course or program e.g., from Ilha do Sal, CV.

3.3 Design of the Climate Data Management System

a. Short-term data storage and access through the services and protocols required by applications for national and international operational activities

Currently, INMG is storing its incoming station data on its main data server. Data are made disponible to INMG staff through NEXTCLOUD[20], a cloud-based data storage and back-up solution. INMG has also started using CLIMSoft v4. as a Climate Database Management System, with the support from the peer-advisor. Next to ClimSoft v.4, it is storing its data in a relational database, which can be accessed using MySQL and PostpreSQL querying and software interfaces such as Clarity. These applications for now are INMG staff dependent, and not generalized in the service.

b. Acquisition of data to and from WIS/GTS, WIS 2.0 and other national or international sources required for operational activities

INMG is now operating a web-based WIS2.0 application (MINIO console), received from the DGM (Morocco), to manually transfer the 3 airport synoptic station data (3-hr, 6-hr UTC) to the WIS2.0. Sending of standard synoptic data to the WMO-GTS is done by the Message Handling System of the three (3) aeronautical and int'l airport stations using Netsys. There is currently a capacity gap to acquire or supply other data to WIS2.0 system (see also Module 4).

c. Data delivery to the national CDMS

INMG stores incoming weather station data on its mainframe computer at INMG Headquarters (Ilha do Sal). Data can be queried by some INMG staff using MySQL relational database protocols. INMG has initiated and is using the CLIMSoft v.4+ CDMS for recovery of historical and further development of its climate database. Important data rescue efforts are still required here, requiring staff capacity a/o hiring of skilled personnel.
With the peer reviewer is has already engaged in a data rescue initiative using CLIMSoft v.4, for digitally archiving its large (long-term) analogue (paper format) weather and climate data. However, this project lacks manpower. It is envisaged that once the GBON compliance phase has been reached, real-time weather observations from:

- GBON stations (4 AWS)
- Upper-Air sounding station (Ilha do Sal)
- Airport synoptic weather observations (3)

will be available via the WIS2.0 node for further use, applying the WMO resolution #40 on (re-)use of weather station data by third parties.

[20] NEXTCLOUD: cloud-based data storage and hosting application and system (ref. nextcloud.com)

d. Discovery and descriptive metadata management

INMG is intending but will seek technical support and advice to set-up a data dissemination system (web-based data platform). This will permit registered users to access weather and climate information and also foster national and int'l exchange in weather and climate data use and applications. For the process of metadata production and management (e.g., in netCDF, BUFR, GRIB2 and other data formats), training of staff is further required (see Module 4). The Tables 3.14 and 3.15 contains the INMG recommendation for hard- and software computer upgrade (improvements required for meeting future GBON compliant data communication. It is also advised to hire consultant service with respect to data management, networks, CDMS and set-up of the data dissemination platform.

Table 3.14: Requirement for advisory service for ICT and data management

#	Advisory service (short term consultant)	Activities	Cost estimate (USD)
1	Hard-, software, network engineering Incl. Open Source software solutions	Review of current practices, recommendation; including FOSS use; (travel, dsa, fee)	
		Total	See IFR [21]

Table 3.15: Computer hardware investment requirement estimate

#	Computer & communication (ICT) Equipment	Quantity	Description / specifications	Cost estimate (USD)
1	e.g., Dell PowerEdge Rack Server, HP or similar types,…	1		
2	Router e.g. CISCO ER 4331 or similar	1		
3	Network access point e.g. Cisco	1		
4	Network switch e.g. Cisco	1		
5	PC (e.g. Dell OptiPlex, HP or other..)	6		
6	Monitor e.g. EIZO EV2556 24" Full HD	6		
7	Tablets (field data collection)	6		
8	NAS storage (Synology or) 24 TB	1		
9	Smart UPS 3kVA	1		
10	UPS 700VA	6		
11	Cables, wiring,	-		
12	WLAN-USB e.g., TpLink	6		
13	Scanner e.g. Epson Perfection V550 Photo	1		
14	Printer e.g. HP ColorLaserjet CP5525dn	1		
15	HP color cartridges	3x4		
16	Int'l transport (e.g., air freight)	-		
17	Customs clearing, import duties,	-		
			Total	See IFR [22]

[21] See Investment Phase Funding Request
[22] See Investment Phase Funding Request

Table 3.16: Software upgrade/improvement investment requirements

#	Software	Use/location	Location	Coast estimate (USD)
1	Campbell Loggernet version upgrade	Central incoming station data monitor (Sal RS)	Sal RS	
2	UAS Ground System	Upper-Air Sounding	Sal RS	
3	MS Windows OS 6-pack	Generic new PCs	Sal RS	
4	Miscellaneous i.e., malware scanners, (5-yr licence fee, etc.	--	--	
	Total			See IFR [23]

3.4 Environmental sustainability considerations

INMG will strive to minimizing the environmental impact of observing technologies as they also 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 systems. The upper-air consumables will meet environmental regulatory compliance for batteries, packaging and hazardous substances with the consideration of biodegradable packaging to be used where possible.

INMG 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 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. Further sustainability specific considerations include at least:

Upper-air sounding station: The GBON compliant sounding system (despite of being fully or semi-automatic) is recommended to be located at a site where permanent staff works daily. This is the case in Cabo Verde (at INMG Headquarters, near Ilha do Sal Int'l airport). This will decrease unnecessary long staff displacements and burdening financial implications. Regular (i.e., quasi permanent) attention can be assured. The tender process will also emphasize quality criteria related to composability in material selection where applicable. The investment in sounding system is made for 20-30 years, and thus, care must be taken to ensure that annual maintenance is ensured throughout its lifecycle. This has high financial cost implication for the operation, especially in the case of fully automatic sounding systems. Generation of hydrogen, needed by balloons, locally at the station will make the operation more environmentally sustainable. Proton-Exchange-Membrane

[23] See Investment Phase Funding Request

technology i.e., a PEM based Hydrogen (H_2) electrolysis and production system will be employed [24]). INMG is also developing a plan to fully supply power to the UAS facility using solar technology.

AWS: The GBON compliant AWS is recommended to improve (where needed) existing AWS with civil infrastructure (e.g., electricity, wind mast, etc.) that is reusable or has environment friendly maintenance. With scheduled preventive maintenance and calibration, the lifecycle of sensors will be lengthened as long as appropriate. Solar renewable energy will be used (and in several cases is already used for AWS power supply in Cabo Verde) as appropriate.

Module 4: Human Capacity Development

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 current actual staff numbers including their function of the INMG (NMS) is shown in Table 4.1 below

Staff functions	**Numbers**	Women	Male/men
Senior Management	3	2	1
Meteorology / oceanography	9	4	5
Meteorological technician	6	2	4
Hydrology	1	0	1
Climate Services / Air Quality	2	0	2
Agrohydrometeorology	6	1	5
ICT Technology	5	0	4
Weather Observer	36	21	15
Geophysics	1	0	1
Administration staff	6	6	0
Total (staff) and Gender	74	36	38

In the context of the rapid economic and social development pace of Cabo Verde in the last decades, the INMG is aiming at a human capacity growth scenario, for developing and delivering more weather and climate services to the public and private sector (e.g., early warning, tourism, environment). Table 4.2 shows the desired situation and future needs for human resources related to the weather and climate sector and science. In view of the current global warming threats and associated climate issues, these numbers are realistic.

Table 4.2: Desired human resource capacity (by INMG)

Staff functions	Actual Numbers	Recommended	Desired

[24] PEM-based H_2 electrolysis equipment for UAS balloon filling

Meteorology	9	+ 6	15
Hydrology/oceanography	1	+ 2	3
Climate Services / Air quality	2	+ 3	5
Agro-hydrometeorology	6	+ 1	7
ICT specialists	5	+ 4	9
Weather Observer / Meteorological Technician	36	+ 10	46
Geophysics	1	+ 2	3

The meteorologists, oceanographer, agrometeorologists and geophysics staff followed academic degree training abroad in various countries and universities. This ranges from countries in Eastern and Western Europe and Latin America (e.g., Brazil) to Asia (P.R.China). Several INMG staff followed degree training in African Centres such as EAMAC and AGRHYMET (Niamey) and short trainings in ACMAD application centres. Aviation meteorologists also follow ICAO linked trainings in regional centres (e.g., Dakar) and training from Portugal (IPMA).

Current Weather Observers, now called Meteorological Technicians, are trained locally according WMO Class IV and Class III syllabi. It is highly recommended that those Technicians involved in the GBON stations receive updated training, especially because the WMO updated Basic Instruction Package (BIP-MT 2022) sets higher standards for the training requirements for Weather Observers.
For Cabo Verde and SIDS in general, Marine Meteorological Observers should also be trained amongst others. These specializations are included in the recent BIP-MT 2022.
Furthermore, attention should be given at ToT (Training of Trainers) issues, and regular updating and refreshing of current trainer staff. The WMO Regional Training Centres (RTC) EAMAC for meteorology and AGRHYMET (agro-hydro-meteorology) in Niamey, play an important role here. A recent capacity gap for many INMG staff is the management of the newly introduced WIS2.0 by WMO (2021). The new information system uses FOSS (Free and Open-Source Software) tools and the upper-level computing language (Python v.3). Where the use of Linux (e.g., Ubuntu) Operation Systems is very common by meteorologists, using a/o adapting python code used by the WIS2Box requires dedicated training in use of OS-ware as for example the Github and new IoT communication tools such as MQTT, based on very low power consumption (Loran) technology. The WIS2Box is the Reference implementation of the WMO-WIS2 Node.

4.2 Design capacity development activities for technical staff

- **Recommendation on training activities and recruitment for technical staff in**

  a. Instrument, calibration and station maintenance

For the training of technical personnel directly related to the GBON surface stations, the training requirements can be summarized as follows in Table 4,3

Table 4.3: Training requirements for technical staff (O&M Surface stations)

Performance component: Install instruments and communication systems

1.	Assemble and test instruments before transport to site
2.	Transport and install instruments and communication systems
3.	Coach observer staff in O&M of new instruments incl. use of SOPs
4.	Test performance, prior to operationalization
5.	Complete site classification for observed variables,
6.	Prepare metadata submission to WIGOS via OSCAR (and PoC)
Performance component: Maintain and control system performance	
7.	Schedule and conduct preventive maintenance; ensure spare parts; check inventory
8.	Monitor data availability and communication
9.	Verify correct instrument functioning
10.	Provide guidance to Observers and conduct refresher training
11.	Record maintenance checks, on-site events, calibrations, replacements in station log
Performance component: Diagnose Faults	
12.	Detect abnormalities in data acquisition
13.	Check cabling, wiring, power supply,…
14.	Record faults in maintenance log
Performance component: Repair faulty instruments and comm.systems	
15.	Requisite spare parts
16.	Repair according SOPs and processes
17.	Perform tests after repair to ensure compliance with performance requirements
18.	Record repair actions

b. Upper-air station capacity development training needs

For the Upper-Air Station operations and maintenance, the training requirements are summarized in Table 4.4

Table 4.4: Training requirements for UAS O&M

Performance chain components	
1.	Prepare and deploy balloon and payload - Carry out Balloon room safety check - Prepare and fill balloon - Instrument ground check - Release balloon
2.	Track balloon flight - Compute and record; upper-air pressure, temp, humidity, wind speed & direction - Carry other (special) observations as required (e.g. Ozone)
3.	Encode and transmit upper-air observation data using prescribed codes and protocols
Knowledge and skills requirement	
4.	H_2 (hydrogen gas) safety and generation
5.	Understanding of basic meteorology (ref. WMO BIP-MT) and Upper-Air meteorological sounding obs.
6.	SOPs and prescribed practice of Upper-air radio sounding observations

7.	On-site instrument care and use of tracking software

For manning the Upper-air Sounding facility, recruitment of a meteorologist and two meteorological technicians and capacity development is a requirement for successful future operation of the site. Some experienced staff in UA soundings is since then retired, and was not replaced due to the non-functioning (since 2018) of the sounding station. This presents also a long-term personnel investment.

- **c. ICT and Data Communication capacity development requirements**

The ICT and the data communication technology component plays an important role in O&M (operation and maintenance) of the GBON surface and UA sounding. Here new WIS2.0 communication technology will be applied and training is required for improved understanding and use of this FOSS-based data communication. The WIS2Box communication (via HTTP/MQTT) differs from the MHS (Message Handing System) to WMO-GTS. Tables 4.5. and 4.6 summarize the training requirement for data communication. It can be seen as essential that the ICT lead personnel of INMG (managing data communication and transmissions) obtains skills and training in the use of Python computing language. This open source upper-level language is relatively easy to understand but basic training in running and adapting python code in a Linux Ubuntu environment is essential. Below in Table 4.5, training requirements are shown:

Table 4.5: Training requirement for ICT and Data Communication (Python OS computing language training)

Performance component: basic Python computing	
1.	Installing Python v3.10 or higher (use of virtual environment versus hard paths)
2.	Updating and checking packages and libraries (e.g., main libs and site-packages)
3.	Running Python from command line; via IDLE interface; calling python
4.	Basic Python: Creating and running small python code
5.	Basic Python: variables, strings, numbers and math; functions, loops;
6.	Basic Python: Debugging code; ..

In the Table 4.6 below, the training requirements for use and set-up of a WIS2.0-Node are summarized. This training requirements applies to ICT personnel and senior meteorologists requiring full understanding of the data communication setup and protocols of the WOM WIS2.0. This can apply to te weather and climate database related staff of INMG and researchers. Technical Observer staff can be trained only for e.g., data inputs (using the MINIO widget interface) in case needed for manual data transmission (as currently done). The WIS2.0-Node is to be configured for automated data ingestion (due to the hourly GBON data communication requirement). These options can be set by trained ICT staff.

Table 4.6: WIS2-in-the-Box training requirements (for ICT staff a/o dedicated meteorologists e.g., database managers)

Performance component: install and operate WIS2-in-the-Box	
1.	Acquire knowledge of WIS2box @ WMO https://docs.wis2box.wis.wmo.int/en/1.0b5/
2.	Acquire knowledge in use of Github FOSS repository

3.	Installing (and updating) the WIS2box components (requires Python knowledge)
4.	Configuration and administration; authentication and access building
5.	Data ingestion setup
6.	Public service setup
7.	Downloading data from WIS2

- d**. Climate Database Management training requirements**

The INMG staff (databases) is using relational database concepts (MySQL, PostgreSQL with CLARITY) to query and organize its current weather and climate data. The open source CLIMSoft v4. Database, also supported by WMO, was also introduced by the peer reviewer, to support its data rescue (digitalization of historical analogue data) efforts. It is recommended to further support these CDMS efforts using capacity development in this field. This database activities will be streamlined with the WMO WIS2.0 data exchanges in the future (after full operationalization of the WIS2.0-Node, and once the staff is capacitated in the WIS2.0. The training requirement on databases can be geared towards two training packages. The first is geared in getting support and capacity in managing and working with an open source geospatial (station time series data) using relational database concepts and statistical tools.

Table 4.7: Training requirements for Climate Database Management & Development (1)

Performance component: concepts of web-based geospatial and relational databases	
1.	Geospatial aspects of meteorological data; coordinate reference systems, map projections and datums; accuracy assessment; issues with use of small mapping software's;
2.	Meteorological data formats: grib2, bufr4, netCDF, geojson, csv, geotiff and others
2.	Open-Source basic GIS geospatial mapping concepts (data applied to Cabo Verde)
3.	Setting up a geospatial – temporal (AWS station) data base
4.	Relational database querying (using PostGreSQL, MySQL)
5.	Data communication with WMO-WIS2.0

For further rapid-pace development of its data rescue efforts (digitalization of historical analogue data), INMG also requires training and support in ClimSoft v4. and obtain knowledge in relational database and web-based technologies. We note that R-coding (language) training is required to fully use the functionality of ClimSoft for data analysis. We therefore recommend the following items for capacity development in this respect:

Table 4.8: Training requirements for Climate Database Management and Development (2)

Performance component: ClimSoft training for historical data rescue and climate data analysis	
1.	Install/setup Climsoft_v4+; user assign;
2.	Ingestion of historical (analogue) climate records
3.	Management of current AWS data
4.	Message encoding/handling and comm. with WMO-WIS2
5.	Basic R-code (language) introduction (e.g., RStudio)
6.	Climate data analysis procedures (using R-instat)

7.	Building Climate Services from data services

Capacity Development requirements and cost estimate for meteorological technicians, ICT information technology and climate database development & management

In summary, we summarized the capacity development training programs and estimated the financial implications in the summary Table below. The trainings may be organized as face-2-face events and locations to be decided. The trainings can be in any other country of choice (Portugal, Netherlands, Niger, others) or can also be conducted in Cabo Verde e.g., Ilha do Sal or any other selected place (Mindelo, Praia). It is generally assumed that trainings are conducted in a hybrid mode, with e.g., a face-2-face component and also an on-line follow-up using an e-learning platform and adequate knowledge exchange model and process.

Table 4.9: Summary of Capacity Development activities for Meteorological Technician, ICT data communication and climate databases (including initial cost estimate)

#	Capacity Development Activities	Short Description	Mode face-2-face on-line; hybrid;	Cost estimate (USD)
1	Meteo Technician Station O&M Training program	Number: 4 trainings Trainer org.: WMO RTC Locations: 2 in CV; 2 trainings abroad; #staff: 5 in CV; abroad (2)	tbd	
2	Upper-Air Sounding Station Training Program	Number: (2) Yr 1 and yr 2 Trainer org.: KNMI, tbd… Location: NL (KNMI?) or… Duration: 1-wk; tbd # staff: 5	tbd	
3	ToT competence training (from WMO-RTC)	Number: (2) Year 1 and 3 Trainer org.: WMO-RTC Location: Niamey Duration: tbd # staff: 3	tbs	
4	ICT & Data Communication Training (1) Basic Python	Number: (2) Year 1, 2 Trainer org.: NL or tbd Location: on-site Sal Duration : 1-wk ; # staff: 10	Face-to-face with on-line follow-up	
5	ICT & Data Communication Training (2) WMO - WIS2.0 Box	Number: (2) Year 1, 2 Trainer org.: WMO affiliated or tbd; Location : on-site (Sal) Duration : 1-wk # staff: 10	Face-to-face with on-line follow-up	

6	CDMS Concepts of Geospatial & relational Databases	Number: (2) Year 1 and 2 Trainer org.: NL (ITC); tbd Location: Sal RS Duration: 1-wk # staff: 10	Face-to-face with on-line follow-up	
7	CDMS ClimSoft v.4 Data Rescue and climate data analysis (using R)	Number: (2) Year 1 and 3 Trainer org.: KNMI/ITC or Climsoft network orgs.; Location: Sal, Mindelo, Praia, tbd Duration: 1-wk # staff: 10	Face-to-face with on-line follow-up	
			Total	See IFR [25]

Recommendations on other (hydro)meteorological Capacity Development activities

As an island state (SIDS), Cabo Verde has no immediate land-based neighbours and surface observation network. It has a very extended marine EEZ of 808,000. Km^2, compared to a 4,033. Km^2 land area. INMG currently uses (standard) global NWP model outputs and satellite observations in its weather forecasting processes. It considers NWP outputs and satellite observations as an essential complement to surface observations for predicting the weather across the islands and region. For risk mitigation purposes (e.g., extreme weather events a/o anomalies), knowledge on NWP models and interpretation of meteorological and other satellite data is essential. INMG therefore also recommends to further develop capacities related to NWP and satellite meteorology.

a. NWP training and staff development

INMG requires more skilled staff in NWP and using global and regionalized prediction models and outputs. So, we also propose to have trainings and support in:

- Eta model (CPTEC) training;
- Feasibility study on application of higher NWP model resolutions to Cabo Verde;
- SWAN sea state model (and coastal waters)

Earmarked support partners here are CPTEC (Brazil) for the Eta model, and IPMA with KNMI for the UKMET, WRF and SWAN models. INMG recommends and proposes to organize a workshop and study (exchange) visits for its staff to regional countries (e.g., Morocco) and also expertise centres and peer-advisor (KNMI, IPMA, etc.).

In Table 4.9, we summarize the capacity development requirement for NWP models

Capacity Development in NWP	suggested expertise partners, cooperation

[25] See Investment Phase Funding Request

1	Regional workshop on use of NWP models and applicability of higher resolution models to Cabo Verde (and SIDS)	KNMI, CPTEC, IPMA, DGM, other
2	Staff mobility (and study visits) to NWP centres, countries	KNMI, CPTEC, IPMA, DGM

The capacity development requirement in NWP (Numerical Weather Prediction) leads to the following investment requirement and initial cost estimate

Table 4.10: Capacity development requirement in NWP (including initial cost estimate)

Activity #	CD activity Description	Location	Cost estimate (USD)
1	Regional workshop	Sal Island (tbd)	
2	Staff mobility, study visits for NWP	KNMI, CPTEC,…	
		Total	See IFR [26]

b. Satellite Meteorology Applications for SIDS Capacity Development

It remains no doubt that meteorological and environmental satellite observations play an important role in obtaining meteorological information (e.g., winds, wave heights, sea temperatures) of the state of the EEZ, ocean and coastal zones. INMG also wants therefore to develop human resource capacities in using satellite data sources (including near real time e.g., Meteosat MSG and new MTG) for deriving weather parameters and information on the state of seas/ocean, early warning of extreme events. This includes and focuses also on assimilation and merging of surface observations with satellite information.

INMG proposes to organize a workshop, incl., Atlantic SIDS. In Table 4.11, we summarize capacity development activities in satellite meteorology and applications for Atlantic SIDS, recommended by INMG.

Table 4.11: Capacity development requirement in Satellite Meteorology for SIDS (and initial cost estimate)

Activity #	CD activity Description Short courses	Location	Cost estimate (USD)
1	Regional workshop on hydrometeorological satellite applications for SIDS (incl. satellite – surface data merging)	Cabo Verde; Sal, Mindelo, Praia; tbd	
2	Study visits for INMG staff (mobility)	Satellite expertise (training) centres e.g., (ITC(NL), INPE (Br)..	
		Total	See IFR [27]

[26] See Investment Phase Funding Request
[27] See Investment Phase Funding Request

The higher cost for these regional short training events is due to the participation cost of persons from e.g., Sao Tome & Principe and/or other countries.

- **For NHS: Hydrometeorological early warning (flash floods, geo-hazards)**

Related to Multi Hazard Early Warning and especially potential flood hazard and risks around urban centres in Cabo Verde, it would be useful to also include hydrological monitoring/modelling. This would be with ANAS, UniCV, SNPCB, or any other Cabo Verdean concerned institution. Training in Hydrologic modelling (for flash floods risk & hazards) could be envisaged.

4.3 Design capacity development activities for senior management

- **Recommendation on training activities and recruitment for management in**

   a. Strategic and financial planning;

INMG proposes a number of work visits of senior management staff to advanced NMS (e.g., KNMI, IPMA and others), for exploring further personnel and knowledge exchanges and elaboration of other cooperation activities.

   b. Project management

For daily management of the SOFF / GBON project, INMG requests the need to hire two project management staff @ 15,000. USD per person per year (with 5% annual increase, for inflation, salary increase, etc.).

Related to project management and dissemination of weather information, communication and presentation skills (of e.g. extreme event early warnings and weather information) short trainings are also requested. We assumed here an investment cost of 15,000 USD (for travel related costs).

This leads to the following Investment requirement for project management and Senior Staff CD.

Table 4.12: Investment requirement estimate for SOFF-GBON project mgt and senior staff Capacity Development

Capacity Development in NWP		Cost estimate (USD)
1	2 mgt. staff salary cost @ 15,000. USD p.a. per person with @+5% annual increase (inflation correction, salary increase, etc.)	
2	Senior mgt. staff CD and mobility	
	Total	See IFR [28]

[28] See Investment Phase Funding Request

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**

Gender issues

Climate change and extreme weather events are not gender neutral, but they affect women, girls, men, and boys differently[29],[30]. This is due to socioeconomic circumstances, cultural beliefs or traditions that can all contribute to inequality, resulting in women being put in situations of disadvantage when disasters strike. Therefore, it is important that in the pre-disaster context, those who likely will be the most affected by crisis, are also included in the preparedness process. This includes having equal access on political, social, and economic levels as well as being able to participate in decision making. Not only is it fair, that population is equally engaged in climate change adaptation and resilience building, but there is also substantial evidence that shows that women are often the most resilient members of society and the powerful agents of change in the event of a disaster. They also have historic coping mechanisms that can be of use when designing and tailoring local grass-root level early warning systems or other climate change adaptation services and activities.

Although inclusion and participation of women in work processes at all levels at INMG (and Cabo Verde in general) is very high, and approaches a 50-50 gender ratio, INMG will further implement the WMO guidelines[31] and follow its Gender Action Plan in this respect.

INMG its gender balance includes senior management and decision role positions. We refer to the current chief administrator council of INMG consisting of (one male and two female).

INMG recommends the following gender-related actions to further promote and empower women in weather observations, climate services and the SOFF process. In all foreseen and recommended capacity development actions (Module 4), participation of female personnel and gender equality will be actively pursued. This includes women participation in international exchanges, training and study visits e.g. at WMO-RIC, peer-advisor a/o other centres.

In its recruitment process for services and personnel, INMG will actively see to attract women, and respect e.g., gender 50:50 threshold. Women's participation will also be promoted (e.g., using where needed local sensibilization mini-workshops) in the work area of "improving observing networks" (see sections 2.3 and 2.4). Here INMG is relying on local (island resident) governmental or private partners, for service agreements or contracts. INMG also foresees and will further pursue empowerment of women from CSO's in the participatory 'Triple Sensor' observation approach and information gathering chain (see next section: CSO participation and inclusion).

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[29] https://www.undp.org/publications/gender-adaptation-and-disaster-risk-reduction

[30] https://wmo.int/site/wmo-and-early-warnings-all-initiative

[31] WMO Gender Action Plan

CSO participation and inclusion

Concerning CSO participation and inclusion in weather and climate monitoring, INMG recommends and proposes to engage CSOs using a Triple Sensor approach. The idea of this approach was born in the framework of an EU-FP7 project AfriAlliance. We refer to a small demo on *http://afrialliance.itc.utwente.nl/triplesensor/ and illustration in Annex 1.* A succinct explanation of the approach is explained below:

" In Triple sensing, we gather and compare information gathered by different observers or users i.e., in this case 1> citizens (read local urban or rural communities CSO), 2> data from the NMS AWS network and 3> satellites or NWP models, to get the most reliable information on the weather variable (for example rainfall, or temperatures, humidity, etc.) for the location. An advanced statistical Triple collocation algorithm (see ref. in Annex 1) is used for the evaluation.

A selected number (e.g., 30 or more conform funding) of citizens (CSOs e.g., (to be selected e.g., local health posts, rural communities, local schools, urban..) will be supplied with low-cost meteorological automated stations and encouraged (trained) to observe and report. This information will be compared with the official national AWS network and also NWP model a/o satellite data. In the end we can evaluate who is the most reliable and also derive the best (combined collocated estimate), and organize CSO inclusion events related to weather and climate observations". Statistical triple collocation of observations is used as statistical evaluation method (ref. see Annex 1).

The recommendation (to be further discussed and elaborated) is to cooperate closely with Ministry of Health and the Directorate General of Environment, due to the increased attention of health and heat waves and related weather phenomena in Cabo Verde. The local "health posts", distributed across the islands could e.g., be used as citizen observation sites, among others (e.g., local schools or other CSO willing to cooperate). We propose to monitor both surface temperature and rainfall.

In order to further develop the strategy and upscale this CSO inclusion using a triple sensing approach, we propose and recommend an investment for stakeholder consultation and mobilization for developing this original weather monitoring strategy with partners. The investment includes a workshop where different CSO's and other stakeholders will be invited.

Table 4.13: Investment requirement estimate for CSO engagement

Activity #	CD activity Description Short courses	Location	Cost estimate (USD)
1	Consultations and mobilization of CSO inclusion in weather & climate observation, using Triple Sensing	Cabo Verde; CSOs, stakeholders, various locations	
2	(Stakeholder) Workshop on CSO inclusion in weather and climate	Praia, Cabo Verde	
		Total	See IFR [32]

[32] See Investment Phase Funding Request

Module 5: Risk Management

WMO recommends its members to establish a Quality Management System (QMS) to ensure that customer and end-user requirements are met (WMO n°. 1100). INMG is currently involved in an ISO9001:2015 certification project for implementing a Quality Management System process for its aeronautical (airport) weather services (AERO MET). This contains the use of comprehensive risk matrixes for AWS and ICT operation and maintenance, contingency plans and more.

The main finding and recommendation of the peer-advisor is to further develop and adopt risk-based thinking within the organization for the various work processes, ranging from station observations, operations & maintenance to data processing, communication (ICT) and database management. It also recommends INMG to give additional attention to risks related to the operation of its other AWS networks (i.e., maritime, agrometeorology, research, environment) next to the aeronautical, and in the near future also 3rd party operators. Their role in the value chain of observation will most probably become more important, but should be monitored using appropriate QMS by INMG. Risk management should also be applied to the upper-air radio sounding station operations, as this activity was discontinued (since 2018).

Recommendations for risk management during the SOFF Investment period and operational period

As stated in the SOFF Operations Manual 21, the risk mitigation procedures of the IE will be relied upon for SOFF implementation during the Investment phase. The Operational phase is supported by the risk mitigation procedures of beneficiary. The following Table 5.1 summarizes overarching key risks for investment and operation phase to be carefully considered and handled by IE, beneficiary and peer adviser. We distinguished among the following risk categories:

- Contextual: risks related to conflicts, safety, political stability, regional weather, jeopardizing the delivery of the Readiness and Investment phase outputs
- Institutional: risks related to the beneficiary country's institutions participation in the Readiness and Investment phases
- Programmatic: risks related to the country ownership of the Readiness phase outputs and transition to investment and operations.

Table 5.1: Risk management framework for SOFF - Cabo Verde.

Risk category / description	Probability	Mitigation action	Monitoring & evaluation
Contextual - Geography (insecure areas) - Site Accessibility issues	 Very low Low	 No GBON site is considered insecure; No action required 3 out of 4 GBON AWS & UAS (at INMG	 NMS to monitor conceptual risks; Remote (new) Brava Island GBON AWS and extreme weather impacts (e.g.,

- Weather Extremes: hurricanes, Sahara dust storms	Medium	main/regional offices); one remote island station (Brava) requiring special attention; Weather-proof; regular AWS control, maintenance required;	Sahara dust storms) requiring special attention on station / instrument operations
Institutional - Staff availability for implementation (AWS, ICT, DB) - Inadequate Human Capacity - Slow procurement of equipment a/o technical capacity issues - Slow implementation of installation - Slow implementation of training & CD activities - Retaining of staff & competences - Slow implementation of data sharing and dissemination	Medium Medium Low/Med Low/Medium Low/medium Low/med Medium	Relatively limited staff # available (SIDS issue) especially for ICT work; Staff training & new recruitment required (young professionals….) Support/advice required for certain equipment's e.g., hpc, uas,… Train a/o hire additional workforces to support station installation; … Develop fast-track process, especially for ICT, WIS2.0, DB related trainings; Implement staff policy, and NMS to take corrective actions; NMS to implement staff development policy; Develop fast-track capacity development for ICT & databases	INMG management to monitor and take measures where required IE, peer-advisor, beneficiary country jointly monitor progress Idem; IE, peer-advisor and NMS jointly monitor progress Country beneficiary (NMS) takes NMS to monitor and take appropriate action
Programmatic - Decrease in funding support for operations - Lack of support from other Government agencies, incl. central	Medium/High Low/Medium	IE and NMS management are responsible for taking actions to secure (nat./int'l) funds NMS uses sufficient communication to persuade gvt. And others;Cabo Verde gvt. has weather and climate high in agenda;	IE and NMS management are responsible for monitoring NMS with support of IE monitors gvt. and partners interests,

Continuation and extending the QMS insurance and certification processes (currently done for the aeronautical station infrastructure, is recommended. We therefore also propose to invest in this important QA/QC process. Again, we propose international exchange (incl. expertise and knowledge) and continued engagement of INMG staff in this process. Table 5.2 summarizes the investment requirement for QMS

Table 5.2: Investment requirement for Quality Management Systems engagement

Activity #	CD activity Description Short courses	Location	Cost estimate (U$)
1	Workshop (expertise exchange)	Cabo Verde (Sal)	
2	Staff study visits, participation and collaboration with int'l, countries, QMS expertise centres or private C°	Tbd (5-year period)	
		Total	See IFR [33]

Module 6. Transition to SOFF investment phase

The transition to SOFF investment phase is recommended to carry out by following the Gap Analysis and National Contribution plan (this document). The peer adviser, IE and beneficiary have together filled in funding request for SOFF implementation phase. This supports the best coordination in the transition phase.

Summary of the GBON National Contribution Plan

Components	Recommended activities
Module 2: GBON Business development and private sector engagement	The financial status of INMG to carry out GBON compliant operations consists currently of limited governmental budget funding and foreseen financial support from UNEP (IE) for station maintenance. Important other funding of INMG is related to its operations for the aviation weather and aeronautical sector, and int'l cooperation projects. INMG is currently analyzing business models and opportunities for public-private partnerships. The organization is now active in partnering with Government entities, academia as well as with int'l weather and climate research institutions. There is room for further enhancing and widen partnerships nationally and internationally to ensure GBON compliance throughout the value chain of observation. Especially service agreements with private sector operators or entities are seen as a vehicle for co-funding and sustaining meteorological operations and services.
Module 3: GBON Infrastructure development	Following WMO and SOFF guidance, INMG will improve current its AWS, UAS and set-up new GBON compliant observation infrastructure, with subsequent WIS2.0 data communication.

[33] See Investment Phase Funding Request

	Through engagement with SOFF, peer-advisor, other country NMHS and regional partners, it aims to set-up a monitoring and evaluation chain, starting from station operations, communication, calibration, maintenance and data QA/QC (Quality Assessment and Control).
Module 4: GBON Capacity Development	The gap in capacity in INMG is in specific job or task related fields, ranging from instrument maintenance, calibration and automated data transfer and handling using the newer WIS2.0 open free and source-based software ICT and data technology. Also rescue of important long-term historical climate data including quality control requires more human capacity and solutions. INMG also will enhance its institutional CD planning to avoid e.g., staff turnover and loss of competences. As a SIDS, Cabo Verde requires continuous competence building not only in land surface observations, but also in marine and satellite-based weather monitoring. It therefore also seeks to engage with expertise partners in NWP and satellite meteorology, especially for risk mitigation related to more extreme weather events.
Module 5: Risk Management	Following WMO advice[34], INMG is currently working on an ISO9001:2015 QMS focusing on the operational chain of its aviation weather observing systems and data. Extending this quality insurance to its other monitoring operations and staff development in QMS is recommended. Further, a number of key risks and mitigation measures are given.
Module 6: Transition to GBON Investment phase	The transition to the Investment phase is recommended to carry out the NGA and NCP (this document). The peer-advisor, IE and beneficiary have together prepared the funding request for the investment phase.

The summary tables 6.1 a-d below summarise the investment requirement estimates for all elements (Modules) of this GBON National Contribution Plan. For financial figures, we refer to the SOFF Investment Phase Funding Request.

Table 6.1a: Investment requirement estimate for business development and engagement of private sector in meteorological services of Cabo Verde.

Item #	Item/Activity	Locations	Cost estimate U$
1	Business development and Private sector engagement workshops (2)	Mindelo, Praia	
2	Mobility fund for participation and exchange in SOFF, GBON regional a/o other activities	São Tomé & Principe, etc.	
		total	See IFR [35]

Table 6.1b: Investment requirement estimate for Infrastructure Development

[34] WMO Publication n° 1100.
[35] See Investment Phase Funding Request

#	Activity or equipment investment (see also Tables in report)	Cost estimate
1	Table 3.5: GBON AWS station (3) upgrade, O&M (5-yr)	
2	Table 3.6: New GBON AWS +site setup+ technical assistance (5-yr)	
3	Table 3.9: Upper-Air Station renewal (5-yr)	
4	Tabe 3.10: UAS technical assistance (1 meteo + 2 meteo-tech) 5-yr	
5	Table 3.13: Field & small laboratory calibration equipment	
6	Table 3.14: Technical Advisory service for ICT & OS-ware	
7	Table 3.15: Computer hardware (server, databases,…)	
8	Table 3.16: Software's	
9	Operational costs 4 GBON AWS (annual @ 5-years)	
10	Operational costs 1 UAS (annual @ 5-years)	
	Total	See IFR [26]

Table 6.1c Investment requirement estimate for Capacity Development

	Training – capacity building activity	Cost estimate
1	Table 4.9: Short training courses for a> Meteorological technicians, b>ToT, c> ICT data communication and d> Climate Databases	
2	Table 4.10 Regional workshop and study exchange visits for NWP (focus SIDS)	
3	Table 4.11: Regional workshop on merging satellite with surface weather data and study / exchange visits (focus Atlantic SIDS)	
6	Table 4.12: SOFF GBON Project Management & CD incl. strategy development for senior management	
7	Table 4.13: CSO inclusion (consultations & mobilization workshop)	
	Total	See IFR[26]

Table 6.1d SOFF Investment requirement estimate of Cabo Verde (summary)

	Activity / module	Cost estimate U$
1	Institutional & Business development & Private sector engagement	
2	Infrastructure Development	
3	Capacity Development	
4	Risk Management	
	Total	See IFR[26]

7. Report completion signatures

Peer Advisor signature

Dr. Gé Verver
Royal Netherlands Meteorological Institute (KNMI)

Beneficiary Country remarks and signature

Ester Araújo de Brito
Executive Administrator of the Cabo Verde Institute National of Meteorology and Geophysics, and SOFF Focal Point

WMO Technical Authority screening remarks and signature

Annex 1: Demo web App on Triple Sensor Collocation

Please visit a small demo on *http://afrialliance.itc.utwente.nl/triplesensor/*. Reference.: EU Horizon Afrialliance project (2016-2021) and document resource[36].

Triple Sensor Collocation demo – AfriAlliance project

Triple Sensor Collocation can be used to validate 3 independent observations at a location, when the error-free true value is not known. With this you can judge, which water or climate observation, i.e. your citizen observation, conventional station data or a remotely sensed satellite look-up is most reliable.

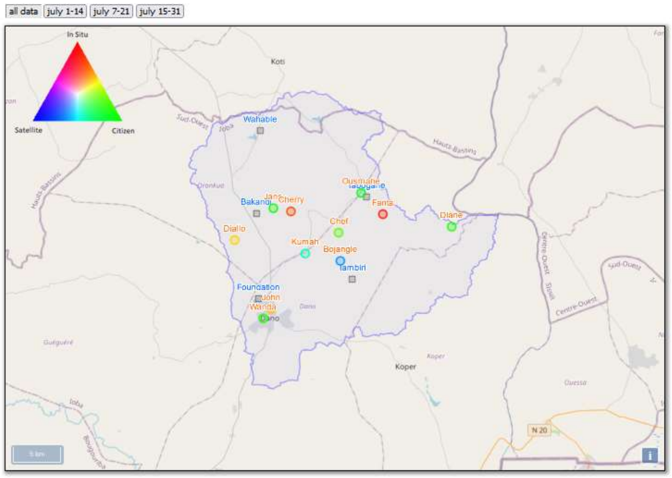
Stockholm Demo Use case: rainfall at the Dano area

The Afrialliance web-demo illustrates the technique for rainfall observations (July 2015) near Dano in Southwest Burkina Faso, a research area of West African Afrialliance partner WASCAL. Citizen locations were extracted from the Open access WPDx or Water Point Database. Citizen names were adapted (privacy) and rain data were generated for demo purposes. Observed meteorological station data were obtained from WASCAL.org and CHIRPS2 was used as open access satellite precipitation. This AA demonstration package is under development and will also be available on-line via the AA project portal www.afrialliance.org

Run the Demo

Change the observation period and view which data source is most reliable in that period (compare the color of the symbols to the color triangle legend). Scroll map and move mouse pointer over Citizen location(s) for evaluation statistics.

all data | july 1-14 | july 7-21 | july 15-31



Method and references

Method and references

The method is based on statistical covariance analysis on three independent data sources and yields the errors (RMSE) and correlations and permits to rank the dataset reliability.

McColl, K. & Vogelzang, J., Konings, A., Entekhabi, D., Piles, M. & Stoffelen, A. (2014). Extended Triple Collocation: estimating errors and correlation coefficients with respect to an unknown target. Geophysical Research Letters. 10.1002/2014GL061322. [link]

Mannaerts, C.M., Maathuis, B., Wehn, U., Gerrets, T., Riedstra, H., Becht, R. and Lemmens, R. (2017) - Afrialliance Project Report Deliverable 4.4: Constraints and Opportunities for Water Resources Monitoring & Forecasting using the Triple Sensor approach. Available here [link]

Data sources: Wascal (2018) http://www.wascal.org ; Chirps (2018) http://chg.geog.ucsb.edu/data/ ; WPDx (2018) http://www.waterpointdata.org

About: Demo-app developed for Afrialliance by consortium partner ITC (Faculty of Geo-information Sciences & Earth Observation, Department of Water Resources, UTwente). For more information, pls. contact C. Mannaerts c.m.m.mannaerts@utwente.nl, V. Retsios v.retsios@utwente.nl and R. Lemmens r.l.g.lemmens@utwente.nl .

The Afrialliance project has received funding from the EU H2020 program under grant agreement No. 689162. For more project info, pls. contact Uta Wehn u.wehn@un-ihe.org .

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[36] Literature reference: Mannaerts, C.M. et al (2017) – Afrialliance Project Report Deliverable 4.4: **Constraints and Opportunities for Water Resources Monitoring & Forecasting using a Triple Sensor approach**. (see https://afrialliance.org/knowledge-hub/afrialliance-geodata-portal/afrialliance-triple-sensor-approach or available on-request from cmannaerts55@gmail.com

Annex 2: List of Abbreviations

AAC	Civil Aviation Agency (CV)
ACMAD	African Centre for Meteorological Application Development
ANAS	National Agency for Water & Sanitation (CV)
ASA	Agency of Air Navigation & Safety (CV)
AWOS	Aviation Weather Observing Systems
AWS	Automated Weather Station
GBON	Global Basic Observation Network – WMO
CV	Cabo Verde
CPTEC	"Centro de Previsão do Tempo & Clima" (Brasil)
CSO	Civil Society Organization
DGA	Directorate General for Environment (Cabo Verde)
DRM	Disaster Risk Management a/o Risk Reduction (DRR)
ECMWF	European Centre for Medium-Range Weather Forecasting
EU	European Union
EUMETSAT	European Meteorological Satellite Agency
FAO	Food & Agricultural Organization (UN)
FOSS	Free and Open-Source Software
FTTH	Fiber to the House (optical fiber communication tech)
GFS	Global Forecasting System (US/NOAA)
GSM/GPRS	Global System for Mobile Communication / General package Radio Service
GSOD	Global Summary Of Day meteorological database (WMO Res.40)
ICAO	International Civil Aviation Organization
INMG	National Institute of Meteorology and Geophysics
INSP	National Institute for Public Health
IPMA	Portuguese Institute for Sea and Atmosphere
KNMI	Royal Netherlands Meteorological Institute
LUXDEV	Luxemburg Development Cooperation Agency
MAA	Ministry of Agriculture & Environment
METAR	Meteorological Airport Reports (used for aviation)
MHEWS	Multi Hazard Early Warning Systems
NMS	National Meteorological Service
NOAA	National Oceanic and Atmospheric Administration (USA)
NWP	Numerical Weather Prediction
NGO	Non-Governmental Organization
OSCAR	Observing Systems Capability Analysis Reviewing Tool - WMO
SIDS	Small Island Development States
SOFF	Systematic Observations Financing Facility
SYNOP	Synoptic coded weather station messages
UN	United Nations
UNDP/PNUD	United Nations Development Program
UNEP	United Nations Environment Program
UniCV	(Public) University of Cabo Verde
WIGOS	WMO Integrated Global Observing System
WIS2.0	WMO Information System 2.0