COUNTRY HYDROMET DIAGNOSTICS

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

Cabo Verde Report

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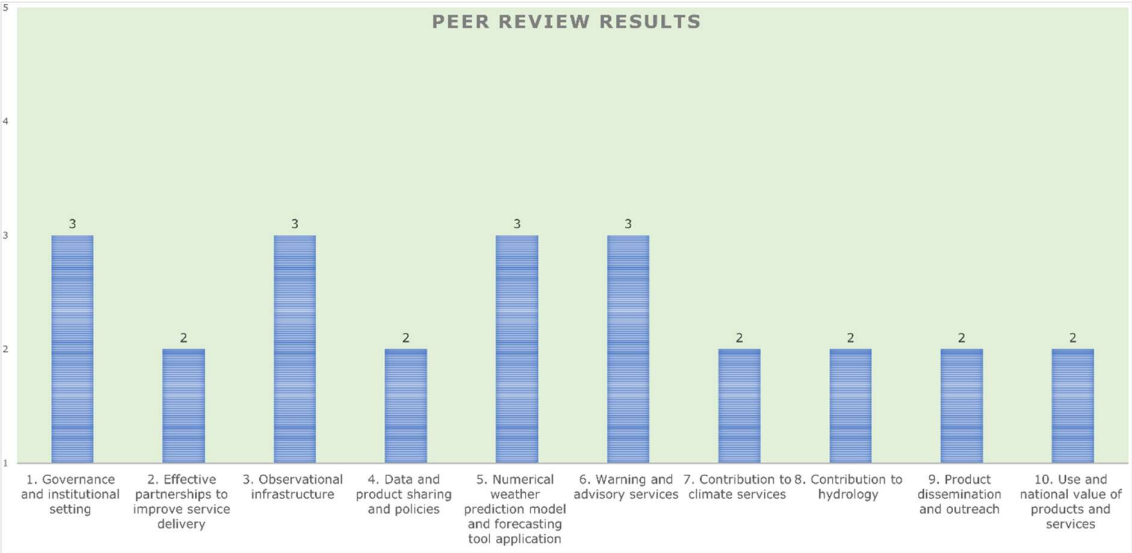
Table of Contents

Executive summary

Overview of Maturity Levels

A bar graph and table overview summarizing the peer-review scores for Cabo Verde is shown below in Figure 1. The element scoring criteria, defined in the CHD guidelines and provided by WMO were used to jointly assess the maturity levels by the peer-advisor and beneficiary. Cabo Verde obtains currently Maturity Level scores between 2 and 3, for the ten value chain elements.



Element	Maturity level score
1. Governance and institutional setting	3
2. Effective partnerships to improve service delivery	2
3. Observational infrastructure	3
4. Data and product sharing and policies	2
5. Numerical weather prediction and forecasting tool application	3
6. Warning and advisory services	3
7. Contribution to climate services	2
8. Contribution to hydrology	2
9. Product dissemination and outreach	2
10. Use and national value of products and services	2

Figure 1: Graph and table with Maturity Levels for Cabo Verde (assessed Jul-Sep, 2023)

The maturity levels of some elements such as effective partnership building (2), data and product sharing (4) and product dissemination and outreach (9) can be elevated with relatively little efforts, implementing suggested key recommendations (see below).

For certain early warning related value chain elements i.e., governance (1), warning services (6) and hydrology (8), issues in national governance structure and accountability were detected and persist. Not only legal frameworks, but comprehensive and operational mandates for national key players in the system need to be resolved for early warning of natural hazards. This refers also to early warning for hydrological risks i.e., flash floods and related hazards.

Financial challenges and staff capacity are currently impeding INMG from effectively fulfilling all its roles at the national, regional and international levels. Financial dependency from aviation authorities does not easily permit INMG to diversify its services to other economic sectors (agriculture, health, environment, tourism). Limited funds hinder staff capacity development and recruitment, station infrastructure and instrument maintenance across the nine inhabited islands. Appropriate solutions including servicing the private sector (e.g., energy, water, tourism utilities), including building of secure public - private partnerships are required to resolve certain financial constraints. We refer to the next paragraph for further key recommendations, organized per element of the Hydromet value chain.

Gaps, Urgent Needs and Key Recommendations

In the Table below, we present the needs and key recommendations for the different gaps, identified for the ten elements of the Hydromet value chain of Cabo Verde. The recommendations are ordered according to the 10 elements.

Element of Value Cycle	**Key recommendations**
Element 1: Governance and Institutional Settings	- Consider reviewing the regulations and decree(s) to better identify the role and responsibilities and increase the visibility of the organization, serving <u>all</u> economic sectors, public and private stakeholders; (see also MHEWS in element 6) - Consider developing services for the private sector, using activity-based service level agreements and pricing; - Seek more (personal and core) budget to: - train or hire new staff to efficiently ensure maintenance of the observation networks on the different islands (incl. other costs for transportation, equipment repair, renewals, calibration); - hire more ICT dedicated expertise (including FOSS knowledge) in data management for meteorological applications, web design, network security, including open-source software applications and computing languages.

Element 2: Effective Partnerships to Improve Service delivery	- Consider establishing an Advisory Committee of partners, incl. international experts as a systematic consultation mechanism for efficient multi-sector service delivery; - Continue building on partnerships with peer-advisor KNMI (Netherlands) and others in the area of technical expertise and advice (scientific, commercialization,); - Engage in medium- to long-term human Capacity Development, scientific cooperation and training trajectories for staff with selected international partners and experts
Element 3: Observation Infrastructure	- Strive to make more AWS station data available on GTS and WIS2.0 and compliant to WMO standards; - In view of the extended EEZ (Exclusive Economic Zone) vs. land area, consider to engage in using satellite observations, merged with land surface and marine buoy data in day-to-day meteorological practice for a> EEZ coverage of i.e., sea surface temperature, surface winds, wave heights, coastal water quality; and also applicable to b> rainfall forecasting and estimation; c> water & food security monitoring and d> weather hazard early warning; - Engage with int'l partners and experts to build more human capacity in satellite data use for meteorological applications; - Include dissemination of satellite information in weather bulletins (see element 4 and 9); - Consider and investigate the option to install and deploy marine buoys to increase monitoring capacity of marine meteorological conditions, in cooperation with regional or other partners;
Element 4: Data and Product Sharing and Policies	- Consider developing and implementing a data sharing policy and mechanism (with urgency); - Seek faster digitalization of paper archived long-term historical climate data (e.g. using ClimSoft v4) for sharing and facilitating building of Climate Services; - Consider establishing a direct link with the WMO Global Information System Centre (GISC) at the DGM Casablanca / Morocco, for sharing and accessing data from international communities;
Element 5: Numerical Model and Forecasting applications	- Engage in partnerships with NWP expertise centers (or country NMHS) to produce higher resolution NWP model outputs for local applications (including marine); - Arrange for continuous support and (forecaster) staff capacity development in NWP (e.g., current CPTEC or other NWP tools); - Consider access to the WMO Regional Centre for severe weather forecasting in Dakar (Senegal) and investigate the benefits of the cascading forecast process;

Element 6: Early warning and advisory services	- Review and better define mandates and responsibilities concerning Multi Hazard Early Warning Services (MHEWS) and hydrometeorological risks and hazards with national stakeholders and lay down in official legal document(s); - Consider contributing (with urgency) to implementing the MHEWS (e.g. SINAGRED), with partners (i.e., civil protection, water agency, coast guard, municipalities, public health, etc.); - Consider contributing to a pilot flash flood stream gauging monitoring station with the NHS (National Water Agency), using INMG expertise (data communication, station setup);
Element 7: Contribution to Climate Services	- Develop and produce tailored climate products and services to key economic sectors (tourism, transports, agriculture, forestry, health and water) through engagement in projects and/or using activity-based costing and pricing; - Engage in capacity development and training in climate data analysis (e.g., time series statistics) and CS building using FOSS[1] tools; - increase staff capacities (and numbers) in use of FOSS computing and ICT tools (or hire new staff);
Element 8: Contribution to Hydrology	- Seek to establish a data-sharing mechanism for hydrometeorological data with the NHS; - Consider co-developing a pilot project (led by the NHS) for implementing a flash flood monitoring EWS, in a flood risk prone urban area (e.g., Praia, Mindelo, San Nicolau, etc.); - Develop a/o hire more human capacity in watershed hydrological (rainfall-runoff) modelling and assessment through training (for both NHS and NMS);
Element 9: Product dissemination and outreach	- Develop a dedicated website and platform for (registered users) data access and dissemination to stakeholders and public; - Consider putting in place an outreach program to raise awareness of INMG products and services and to increase visibility and public awareness for weather and climate issues - Progress with the cell phone App, with INMG weather bulletins in Cape Verdean "kriolo" language, for reaching out to remote communities, elderly and other CSO;
Element 10: Use of National Products and Values	- Increase engagement on a more regular basis with stakeholders incl. NGOs, private sector, international institutions, CSO to improve use of products (valorisation of meteorological data);

[1] FOSS Free and Open-Source software (e.g., Python, R, Jupyter, ClimSoft, see also WIS2.0)

Chapter 1: General information

Short country profile

Cabo Verde, a lower middle-income country and Atlantic SIDS is discussed in this report. In Cabo Verde, Meteorological Services are provided by the "Instituto Nacional de Meteorologia & Geofysica" (INMG)[2]. Hydrology and water resources services are taken care by the National Agency of Water & Sanitation (ANAS)[3].

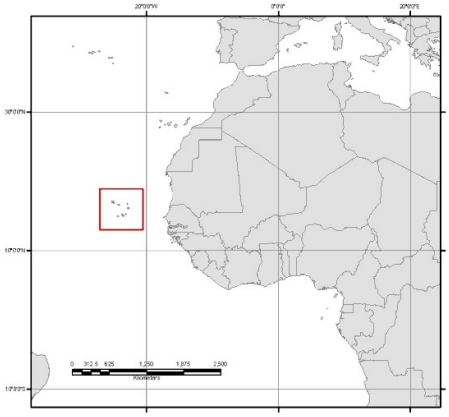


Figure 2: Location of Cabo Verde in the Central-east Atlantic Ocean

Cabo Verde is an archipelago of 10 islands (land area 4,039. km^2) in the Central East Atlantic Ocean, between latitudes 14.50 – 17.50 North and longitudes 22.50 to 25.50 West (see Fig. 1). Population is estimated approx. 598,683 (2023)[4] on 9 inhabited islands. Size of the inhabited islands range from a mere 22 km^2 for Sal Island to near 1,000. km^2 for the most populated Santiago Island.

Natural Hazards & Disaster Risk Profile

The islands are of volcanic origin and the more western are mountainous with steep topography. This culminates in Fogo Island (max m.a.sl. 2,830. m), considered an active stratovolcano, last eruption (Dec. 2014 – Feb, 2015). Their unique location around the 15-17N latitudes and Atlantic Ocean position, 500-km west of the African continent and Sahara Desert, makes the country susceptible to various extreme weather hazards like consecutive low rainfall years and prolonged droughts, Sahara dust storms and strong winds. But also, heavy Atlantic cyclonic rainfall during the summer monsoon occurs, leading to local flash flooding, landslides, posing important risks to urban populations and road infrastructure. These hurricane-type depressions (e.g., hurricane Fred Aug, 28 – Sep 01, 2015) also induce strong winds, sea swells and serious risks to the maritime sector (inter-island passenger and freight transport, fisheries, leisure and tourism).

Figure 3: Cloud free satellite view of Cabo Verde archipelago

Fisheries, maritime trade, rainfed and small-scale irrigated agriculture are the main livelihoods, although agriculture is impeded due to limited availability of freshwater and low unreliable rainfall. Since several years, the tourism sector is developing rapidly and is becoming one of the backbones of the economy on several islands (e.g., Ilha do Sal, Boa

[2] INMG: National Institute of Meteorology and Geophysics (also named NMS: Nat. Meteorological Service)
[3] National Hydrological Services are since 2013-07-31, with the National Water & Sanitation Agency (ANAS).
[4] Source: UN World Population Prospects https://population.un.org/wpp/

Vista, Santo Antão). Part of the economy of the country is also sustained by an important Cabo Verdean diaspora, living abroad after historical emigration. This was mostly caused by recurrent historical long-term droughts leading to famines[5] and forcing especially rural populations to seek their livelihood abroad.

Despite its insignificant contribution to global warming, Cabo Verde is suffering heavily from its consequences, and is paying an overly expensive bill for climate change. Cabo Verde therefore needs strong partnerships and sustainable interventions with clear impact on strengthening the country's institutional capacities. The hydrometeorological sector overseeing weather and climate observations and data plays a crucial role in hydrometeorological service provision to the local society and the global community.

CHD methodology

The Country Hydromet Diagnostics responds to the need for a standardized, integrated and operational tool and approach for diagnosing National Meteorological Services, their operating environment, and their contribution to high-quality weather, climate, hydrological and environmental information services and warnings. The CHD is an umbrella tool that draws on and adds value to existing WMO assessment material by synthesizing existing approaches and data into an easily interpretable form, validating the information provided by WMO Members through a peer review process, and obtaining missing information.

The Diagnostics aims at informing policy and investment decision-making, in particular guiding investments of the members of the Alliance for Hydromet Development. The Alliance brings together major development and climate finance partners behind a joint commitment to strengthen developing country Hydromet capacity. Through the Diagnostics, developing countries are expected to benefit from better targeted and aligned financial and technical support. The Country Hydromet Diagnostics is based on the ten most critical elements of the Hydromet value cycle, grouped under four categories – enablers, observation and data processing system, service and product production and dissemination, and user and stakeholder interaction.

Country information available in WMO database and answers provided by NMHS focal points to a questionnaire developed based on the indicators of the CHD have been used as first source information to prepare this report. Various reports related to Cabo Verde meteorological and Hydromet capacities have also been used for information of interest in this peer review process. However, it may be mentioned that the main focus of this report is on the NMS. This report present review of each of the ten most critical elements of the Hydromet value cycles based on the information mentioned above and rate each of them with a Maturity level score (based on the assessment of the indicators). At the end, recommendations of the reviewers to help lift up the rating of the maturity level in respect of these critical elements have been listed.

[5] Antonio Carreira, 1977. Cabo Verde. Aspectos Sociais. Secas e fomos do século XX. Bibl. Ulmeiro n.9, Lisbon.

Chapter 2: Country Hydromet Diagnostics

Element 1: Governance and institutional setting

In Cabo Verde, national meteorological services (NMS) are provided by the National Institute of Meteorology & Geophysics or INMG[6]. The Service resorts under the Ministry of Agriculture & Environment (MAA). Hydrological Services are provided by the National Agency of Water & Sanitation (ANAS). The National Civil Protection Service & Fire Brigade (SNPCB) has an important role in disaster risk management. Next to weather and climate, INMG also is legally mandated and monitors geo-hazards, related to volcanic and seismic activity.

1.1 The legislative act regulating the national meteorological service and institution is government resolution 24/2000 of August, 21 2000, creating the INMG. Some other follow-up legal decrees, approving the statutes of the INMG are DR. n07/2000 (28-08-2000) and DR 13/2009 (20-07-2009). The legal status the INMG is a Public Government institution.

The mandate and primary areas of responsibility are meteorology in general, meteorology for aviation and the maritime sector, the national authority for meteorological observations for other purposes, climatology and geophysics. A shared area of responsibility is air quality monitoring, together with the Directorate General of Environment (DGA) of the Ministry of Agriculture & Environment (MAA).

A legal framework (Government Resolution n°114/Oct, 20 2018) defining the National Strategy on Disaster Risk Management (DRM) including Multi Hazard Early Warning, emergency preparedness and rapid response was established in 2018. This document describes also the contours of an operational National System of DRM (SINAGRED) and establishment of EOCs (Emergency Operations Centers). Notwithstanding initiatives taken by e.g., the Civil Protection Service & Fire Brigade (SNPCB), the AAC (Civil Aviation Agency) and other institutions, operational Multi-Hazard Early Warning System (MHEWS) mechanisms are still under development. Limited human resource capacity for handling advanced risk analysis and monitoring systems and coordination of emergency operations among multiple stakeholders can be mentioned as explanatory key elements.

1.2 INMG uses 4-year Strategic Plans (e.g., 2019-2022) and is currently issuing the 2023-2026 version. The main priority of the new Strategic Plan is to increase the weather and climate information and early warnings (incl. seismic and geohazards) coverage to >70% of the national territory and remote rural populations. INMG reports annually on progress related to implementation of the plan to higher authorities. It uses an annual planning agenda schedule to manage its work processes.

1.3 The annual budget is 179.658.950,00 CVE and equivalent to 1,629,411. EUR. 73.7% of the budget is used for the staff payroll.

[6] INMG: "Instituto Nacional de Meteorologia e Geofísica"

INMG does not depend on international donor aid a/o projects for the main annual operations budget. The aviation and aeronautical weather services cover 74.4% of the annual budget. Direct government funding is 8.8%. Private revenues amount to only 0.33%. The overall budget shows a slight decrease in the recent (3-5) years.

Significant station equipment and instrument deployments are funded through national and cooperation projects related to different sectors (security, agriculture, maritime, environment and others).

1.4 The human resources base of INMG consists in total of 62 staff (June, 2023). The staff gender ratio is 30 females to 32 males.

1.5 Staff competence frameworks are in the design stage (nearing completion). Currently, there is no formal training policy and no specific institutional arrangements for capacity development. Staff uses African Regional centres (e.g., Agrhymet - Niamey), Latin American (e.g., CPTEC, Brazil) and/or European, Asian or other institutions globally according specific training needs.

1.6 INMG supports and collaborates in international "Hydromet" type of projects and works with several international cooperation partners (see paragraph 2.2), but has no own track record and human resource capacity available for leading or conducting larger international funded R&D projects. An example is collaboration in NASA's extension of the African Monsoon Multidisciplinary Analysis project, NAMMA, researching on African Easterly atmospheric waves, tropical cyclogenesis and Atlantic hurricane development (see Annex 4 with literature references).

Summary score and recommendations for Element 1

Based on the above, **a Maturity Level 3 was given to the Governance and Institutional Settings** of the Hydromet value chain for INMG. This score is due mainly to an important (~74%) budget dependency from one aeronautical funding agency (ASA). The current budget does not easily support development of other operational activities, including e.g., weather and climate research and the expansion of the other functional observation networks, related to maritime, agrometeorology, climate and other e.g., MHEWS purposes. This can be enhanced if INMG can develop new strategies with (e.g., public-private partnerships), government authorities and various partners supporting the full weather and climate observation chain, including capacity development.

Element 2: Effective partnerships to improve service delivery

2.1. INMG has official government partnerships with the Agricultural (DGASP, INIDA), water (ANAS), health (INSP) and environmental (DGA) sectors, aviation (ASA) and the Civil Protection services (SNPCB).

2.2. INMG has a formal collaboration protocol with ASA on the operation and maintenance of the airport AWOS (Aviation Weather Observation Systems) in place for aviation.

There are currently no formal agreements between public and private sector weather observation data collection initiatives or processes.

There is active collaboration with academia and the following research institutions: University of Cabo Verde (UNiCV) and international Institutions such as York University (UK), Max-Planck-Institute for Biogeochemistry, Jena (MPI-BGC) and Leibniz Institute for Tropospheric Research, Leipzig (TROPOS)- Germany; IPMA(Portugal), CPTEC(Brazil); the KNMI (The Netherlands); University of Barcelona, Catalunya/Spain; University of Lille (France). We refer also to the Cabo Verde Observation Infrastructure, managed by INMG (Annex 3).

INMG does not receive national government funding for research activities. All research is derived from and linked to international funded cooperation projects and operations.

There are currently no legal provisions for private sector participation in the delivery of meteorological and climate information. There is no consultative platform in place. There is an increasing trend for meteorological service provision to the private sector (i.e., requests from private utility companies such as e.g., the water supply & treatment APP or "Aguas de Ponta Preta", operating on Ilha do Sal and Santo Antão and other parties).

2.3. One effective partnership with the international climate community is the collaboration with German and UK institutions for operation of the Cabo Verde Global Atmospheric Observatory (CVAO) station in Calhau (WMO GAW Station) on San Vicente Island. This CVAO operates since 2007 on a continuous basis as a global (oceanic) GHG measurement site and other atmospheric constituents (e.g., dust particles, aerosol composition, global long range Mercury monitoring campaign, etc.). The CVAO does atmosphere (air chemical composition, particles) samplings and measurements for various international partners e.g., IMAU, Utrecht, the Netherlands.

The AWS network has been enhanced with the funding support of the European Union (EU) through REFLOR-CV project (implementation entity FAO). The maritime (and harbor) AWS observation network (MARINENET) has been enhanced with funding support from Spain (WMO regional cooperation).

2.4. INMG is working with international partners (KNMI) to improve and rescue its historical analogue (paper) long-term climate database (using Climsoft4). First meteorological observations in Cabo Verde were made in 1883, Mindelo, related to international harbour activities. INMG also works with the KNMI (NL) and CPTEC (Brazil) on capacitating staff in weather prediction and (seasonal forecast) modelling, using e.g., the Eta NWP model from CPTEC.

Summary score, recommendations, and comments for Element 2

The INMG is an appreciated host and works with several partners in weather and climate. The INMG does not have a leadership role (yet), including overseeing financing initiatives, in most

joint efforts in this respect. **A Maturity Level 2 was therefore given to this Element 2: Effective Partnerships.** To lift this score further up, INMG should engage further with national and international stakeholders and interested parties, and see to take up a more (co-)leading role in the activities. This however requires human resources capacity development trajectories for (new) and current INMG staff, co-leading future joint cooperations. Engagement with international institutions and/or private partners can be considered essential in this aspect.

Element 3: Observational Infrastructure

3.1. The main observational core infrastructure of INMG with real time global data communication, consists currently of only 3 Synoptic aeronautical AWOS stations and one Upper-Air Station facility (Fig.4). The synoptic stations are listed in WMO OSCAR/Surface and report to the WMO GTS. The UAS is currently not reporting. The Synoptic station spatial resolution (150 to 200-km) and station distribution was historically derived from international aviation and maritime transportation needs and coastal zones activities (fisheries, tourism and rescue). The current station distribution approaches the GBON resolution requirement.

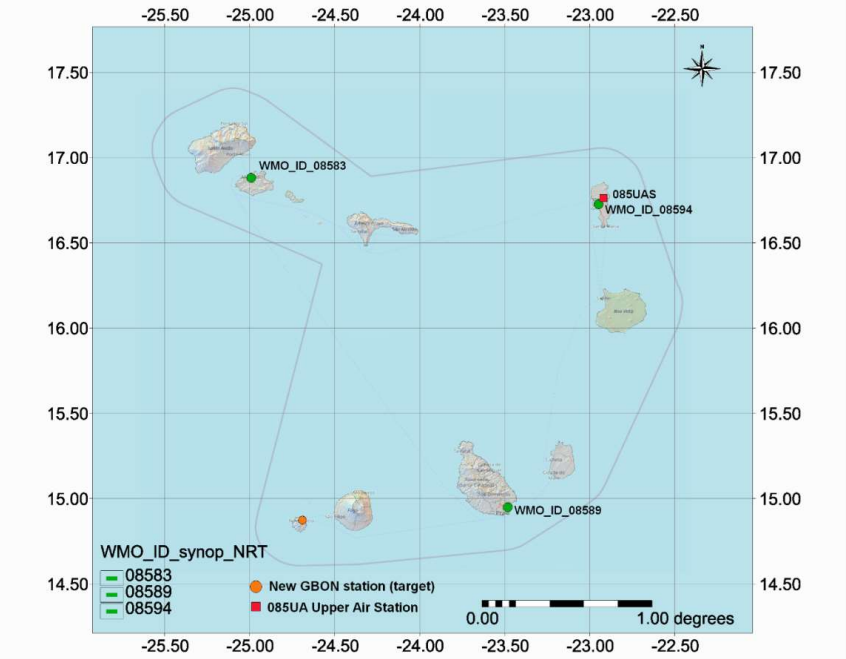


Figure 4: Current (2023) WMO-ID synoptic reporting stations – Cabo Verde (and new target station)

INMG also operates a network of 32 AWS, distributed across the archipelago and shown in Fig.5. The AWS serve different purposes (see Figure 4). Data are not shared in the GTS, but stored on a national data server (on Ilha do Sal).

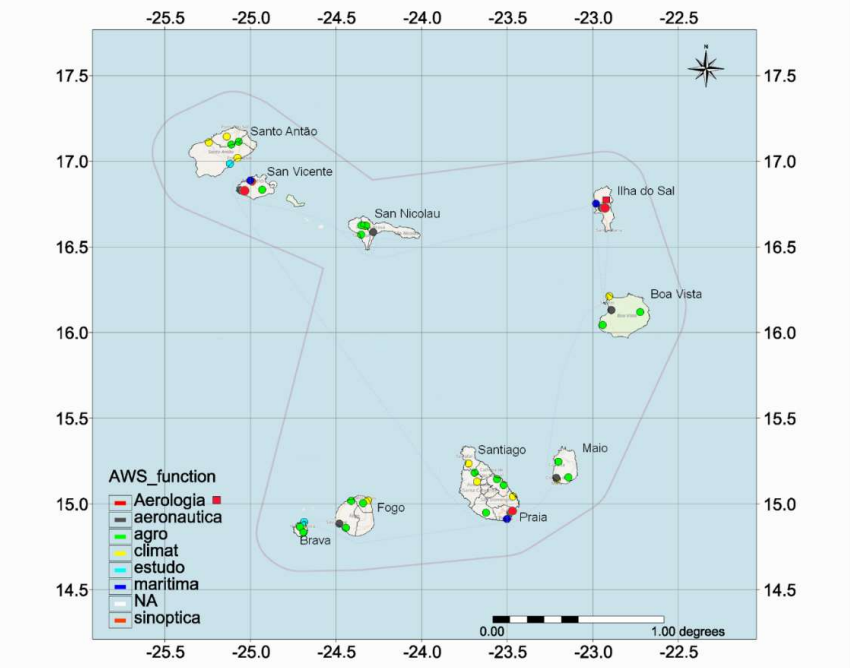


Figure 5: AWS observation network infrastructure of Cabo Verde (2023)

3.2. INMG does not use additional surface data for short-term (<12-48-hr) early warning purposes. It uses EUMETSAT near real time Meteosat (MSG) 3-km resolution - 15-minute time frequency satellite observations and products derived with MESSIR SAT and PUMA data reception systems. Global weather forecast model outputs (i.e., ECMWF (EU), GFS (US-NOAA) and ICON (DWD), retrieved from internet sources are routinely employed in the forecasts. There are no Doppler weather Radar systems on Cabo Verde deployed by INMG.

3.3. Although INMG staff applies quality criteria for deployment, maintenance and quality assurance of equipment and instruments, there are no formal SOPs and/or a national WIGOS governance mechanism in place. Two staff are trained in OSCAR. There is not yet a national process in place for quality issues and information, received from WIGOS and the WMO-GDQMS.

3.4 INMG puts efforts to follow scientific trends in new station and sensor deployment (e.g., sonic anemometers, air quality sensors, etc.), auto energy sufficiency using solar power and low energy (e.g., Loran, IoT) data communication. Operational budget for station maintenance (incl. field instrument re-calibration) is however very high due to the dispersed islands, requiring inter-island staff travel. We refer to the GBON National Contribution Plan for more information. There is currently no national WIGOS implementation plan in place.

3.5. Most (estimate >90%) surface meteorological observations depend on AWS techniques and data communication protocols. The main aeronautical (international airport) station SYNOP reports are transmitted using the ICAO AFTN (Automated Fixed Telecommunication Network) and transferred manually to WMO (Casablanca DGM node, Maroc) using a WIS2.0 - DGM web-based connection. Other AWS data are communicated to the national meteorological data centre (Ilha do Sal) server through GSM/GPRS

communication. Currently, Cabo Verde has only two manual or MWS Class A type stations in operation out of a total 32 AWS+ 2 MWS network (see Annex 4 for more info).

Summary score, recommendations, and comments for Element 3

A Maturity Level 3 was assessed for the Observational Infrastructure. INMG has currently a moderately extended network, but showing gaps with respect to WMO regulations and guidance, and with some data quality and reporting issues.

The maturity level could be increased when more functional AWS are shared through the GTS (WIS2.0). The further development of the current integrated system for data reception, monitoring, storage, quality control and management of weather and climate data is also required.

INMG should further work to fulfil its SOP requirements in line with WMO standards. The accessibility and maintenance of more remote and older observation sites, incl. calibration and maintenance are also an issue which should be planned on a medium, long-term basis, incl. financial and human resources issues, related to network operation.

Element 4: Data and product sharing and policies

4.1. Currently, three airport stations are reporting (partially GBON compliant) to the global community (e.g., GSOD global meteorological database). One long-standing Upper-Air sounding facility is present on Sal Island but stopped reporting since 2018. There is also one GAW or Global Atmospheric Watch facility, measuring and reporting on GHG, other trace gases and atmospheric constituents on São Vicente Island. 6-hourly aeronautic SYNOP (and 3-hourly intermediates for Ilha do Sal airport) data are now experimentally exchanged using WIS2.0 and send on a 24/7/365 basis to the DGM (Casablanca, Maroc) WMO regional data centre using a web-based manual protocol (WIS2-DGM).

4.2. There is no formal data sharing policy in place at present by INMG for sharing other station data generated by the service. Data are provided upon request to inquiring users (at a minor cost for the private and commercial sector). Data are freely provided to government services and higher education institutions.

There is no national WIGOS partnership agreement in place for integration and open-sharing of observations from NMS and non-NMS sources. There currently exist no data policies and practices for sharing observation data.

4.3. Near real time access to WMO data and products, and also weather model and satellite data from other international sources data is reliable. INMG uses EUMETSAT data reception (Ilha do Sal only) and analysis products provided by the MESSIR SAT (Corobor/Campbell Sc. Inc.) and PUMA systems. Access to global weather forecast models is used by the forecasting group, using reliable internet sources (e.g., NOAA, ECMWF, CPTEC, EUMETSAT, EU Copernicus).

Cabo Verde requires a high spatial resolution (~< 10km or ~<0.1deg) of forecast model output for being useful on and around the islands. Strong wind effects and island topographic impacts can be seen in model outputs (when the CV islands are parameterized in an NWP model!) and on satellite imagery (e.g., "von Karman" streets in the trade wind season, etc.). INMG is currently gaining experience with the CPTEC Eta global (regional) forecasting model. Satellite data (e.g., the current MSG at 3-km 15-min and the new upcoming MTG or Meteosat Third Generation (2-km) and polar orbiting Metop EPS (1-km to 0.5 km in the near future) offer interesting opportunities to use medium-high spatial resolution and sufficiently high time frequency (15') information for weather prediction.

Summary score, recommendations, and comments for Element 4

A Maturity Level of two (2) was assessed for the Data and Products Sharing and Policies element. Currently, only a very limited amount of station data is shared to the WMO-GTS or WIS2.0 and global community. Only 3 airport AWOS releasing 6-hr synoptic data and daily means (GSOD database) are available. We note that also METAR data (hourly meteorological airport reports) can be traced on global aviation data servers.

The maturity level can be lifted up if a proper data sharing policy is set up by INMG, incl. technical aspects of AWS data communication and adoption of the WIS2.0 protocols, in parallel with the current ICAO - AFTN data protocols for aviation purposes.

The set-up of a web-based platform for dissemination of data and information to interested parties and public is also considered essential, next to the WIS2.0 two-way data sharing, and will further enhance and increase weather and climate analysis and research efforts, by national and international education and research a/o private partners.

Element 5: Numerical weather prediction and forecasting tool application

5.1. INMG uses near real time internet access to various global weather forecasting model outputs (ECMWF/EU, GFS/NOAA, ICON/DWD) together with satellite data products and information generated by the PUMA and MESSIR SAT systems for forecasting. Data types used range from textual information to weather charts and gridded data.

5.2. Through cooperation with KNMI and CPTEC (Brazil), INMG runs (experimental phase) the Eta model http://etamodel.cptec.inpe.br/history/ . It was tested in a seasonal forecast mode. INMG is now experimenting with daily predictions. The model is run internally on a local computing server (Ilha do Sal), but with relatively limited capacity. Current human expertise is still limited (2 persons). Being aware of the SIDS nature of Cabo Verde, with relatively limited computing and science capacity or number of human resources, INMG envisages cooperation and engagement with NWP expertise partners and other country NMHS for advancing the use of high-resolution NWP models for operational purposes.

The INMG weather prediction unit further uses and analyses real time information from Regional and Global NWP, climate prediction centers and WMO GTS data. This are internet based (near) real time data and information sources (e.g., the ECMWF 9-km model).

Cabo Verde being an archipelago with 9 dispersed inhabited islands, NWP model resolution is an important issue. The 0.2 degree or 22-km resolution of the standard global GFS (NOAA) model without island parameterization or data assimilation has poor a weather prediction capacity across the archipelago (pers.comm. forecasting group INMG).

The Eta model (CPTEC, Brazil) is run by the INMG currently on a seasonal forecasting basis. Experimental work is on-going using daily or 10-daily lead times, using appropriate resolution (~10km) and including physical parameterization of the different islands.

5.3. There are currently no probabilistic forecasts, derived from e.g., ensemble predictions generated by INMG. This requires human resource and capacity development in first place.

Summary score, recommendations, and comments for Element 5

The Maturity Level for Element 5: Numerical Weather Prediction and Forecasting is assessed as Level 3. Prediction based mostly on model guidance from external and limited internal sources (without data assimilation) and remotely sensed products in the form of maps, figures and digital data and cover nowcasting, short and medium forecast time ranges.

Further lifting of maturity level requires capacity development and international long-term cooperation with NWP expertise centers (a/o countries) in the first place, as few staff is trained or has experience with numerical weather prediction models. Next to capacitating national staff, INMG seeks further engagement with regional a/o other NWP expertise partners for co-producing high resolution NWP model outputs for the archipelago.

Element 6: Warning and Advisory Services

6.1. For Early Warning Services (EWS) and DRR (Disaster Risk Reduction), there is a national committee (CNPC) composed of ministries, agencies and other stakeholders that coordinate Emergency Preparedness, Disaster Risk Management & Reduction activities at the national to local levels. The National Service for Civil Protection & Fire Brigade (SNPCB), has a lead role in this committee, and INMG is entire partner for meteorological, seismic and volcanic hazards.

A legal framework for MHEWS has been established in 2018. Full operationalization of the National System for Disaster Risk Management and Mitigation (SINAGRED) is however currently not yet achieved and under development among stakeholders (see references). We refer to also to 1.1.

INMG has an 24/7/365 weather alert service covering all weather-related hazards: tropical waves and associated convection, extreme rainfall, winds and hurricanes, dust storms, sea swells or high seas. Lead times are 48-hrs to minimum 12-24-hrs.

INMG also alerts for seismic and volcanic hazards on a 24/7/365 basis, using its seismic and air quality monitoring station networks.

6.2. Hydrometeorological hazards monitored by INMG include: drought and extreme dry spells, dust storms, high seas and sea swells, coastal flooding, tropical waves, convection and thunderstorms, hurricanes, volcanic ash clouds and strong winds.

INMG releases early warnings (monsoonal depressions, tropical waves and associated convection, heavy rainfall and strong wind alerts, high seas, dust storms) via the standard national communication channels. It cooperates with its national partners (civil protection services, water agency and municipalities) in this respect. These weather-related warning service has a good local public reach but also relies much on informal engagement with relevant institutions, including disaster management agencies.

With respect to preparedness and rapid emergency response to meteorological early warnings, recent history (e.g., hurricane Fred, Sep. 2015; Praia flashflood, Sep, 2021 and more) shows that more rapid response coordination mechanisms (between local municipalities and inter-government agencies) need to be put in place. For geohazards (slope failure, earthquakes), and water-related hazards (flash floods), detailed risk mapping (zonation) should be taken up, especially in vulnerable areas such as certain urban, peri-urban zones and catchments.

In Cabo Verde, there is currently no flashflood observation system and no streamflow gauging stations are operational. This rapid diagnostic indicated that the legal foundation and framework for this hydrological hazard is still poorly resolved, and requires more attention by governmental stakeholders (ANAS, SNPCB, INMG and municipalities).

INMG main office (Sal RS or "Radio Sondagem", Espargos) on Ilha do Sal and near the airport is a recognized international Tropical Cyclone Advisory Center (TCAC).

6.3. The NMS does not have an established mechanism for the co-design and/or co-production of tailored products and services. For aviation safety, INMG functions as a "tropical cyclone advisory center" (TCAC). There are currently no common alerting procedures (CAP) format in place with partner government or non-governmental organizations.

Summary score, recommendations, and comments for Element 6

The Early Warning and Advisory Service Element was given a Maturity Level-3, conform the CHD evaluation specifications. Weather-related warning service is in place but still not with a full public reach. Informal engagement with relevant institutions, including disaster management agencies is still the common practice, but progress is being made.

A legal basis and National Strategy on Disaster Risk Management exists. A fully functional Multi Hazard Early Warning System (MHEWS), Common Alerting Procedures (CAP), and

operational EOCs (emergency operations centers) are still under development with the concerned government authorities, local entities (i.e., municipalities), CSO's and NGO's.

Element 7: Contribution to Climate Services

7.1. INMG has a basic but limited capacity and is involved in national governance mechanisms for Climate Services (CS), which enable it to contribute to national adaptation planning. The National Climate Service contribution agenda is coordinated by the Directorate General of Environment (DGA/MAA), overseen by the National Climate Council (CNC). INMG has the basic system capacity (observation networks and data) that allows it to contribute to CS building and provide climate information to national and international authorities and interested parties.

The mechanisms, tools and climate data bases that allow climate services users and providers to interact, to ensure co-production and tailoring of services for decision support and feedback, are however rated basic at this moment. Human resource capacity development is considered an important issue for improving CS contributions by INMG.

The Directorate General of Environment (DGA/MAA) is the government entity coordinating the Climate Services and Adaptation domain. It works together with multiple national stakeholders and international and financing entities. INMG supports CS processes with weather and climate data supply and analysis and other relevant information.

Summary score, recommendations, and comments for Element 7

The **Maturity score for this Element was rated at Level two (2), which is Basic Capacity for Climate Service Production.**

INMG has a basic data infrastructure, but a limited human resource base to respond to requests for climate data products and Climate Services. INMG disposes of very long meteorological data time series (first obs. in year 1885 in Mindelo; Praia: year 1926), which can lead to very valuable contributions to climate change research and development of climate services. Many data are however still in analogue (paper) format and require urgent data rescue (digitalization).

INMG should develop more human capacity to generate sector specific products using freely available climate data and model products from various regional and global operational and research climate centers to provide improved weather and climate services.

Referring to Element 4 on Data Sharing, INMG could set-up partnerships with international institutions to cooperate and jointly develop CS, relevant to global change and current world climate issues. Easy two-way data sharing (e.g., WIS2.0) is essential for success of such operations.

Element 8: Contribution to Hydrology

8.1. The National Agency of Water & Sanitation (ANAS) is since its inception (Government Decree of 2013-07-31), the main entity for "Hydrology and Water Services" in Cabo Verde. It is supported by a National Council for Water & Sanitation (CNAS). ANAS is responsible for the following fields of operational hydrology: (a) collection and management of hydrological data, (b) water resources assessment and (c) water supply and sanitation services. It operates with public and private water utility partners in this respect.

The focus of ANAS lies strongly on groundwater resources assessment, water supply and sanitation. Groundwater constitutes the only land-based freshwater resource of Cabo Verde, next to desalinization of seawater. There are almost no surface water resources, except some small seasonal reservoir impoundments, upstream a number (9) of small dams, operated by the DGASP/MAA. Eventual surface runoff water in streams and alluvial river channels is highly ephemeral and of very short duration (< 3 to 24-hour flash flood regime). It occurs only after high intensity precipitation (P=>50 mm) hits the islands and respective catchments.

There are historical streamflow observations (gauging weirs, peak runoff and base flow data, runoff plots) on surface runoff from the period 1978 to 1995, available for a few catchments (Ribeira Seca, Ribeira San Felipe watersheds) on Santiago Island. These hydrological observations were realized in the framework of WMO Agrhymet and FAO projects during that period.

8.2. There is currently no surface water or streamflow monitoring infrastructure in operation, and consequently no Standard Operation Procedure (SOP) is in place. Any information exchange is done on an ad-hoc request basis. ANAS has an important hydrogeological groundwater database, but this is only partially related to flash flood risks and early warning.

8.3. On request, NMS provides meteorological data and information to the services linked to Hydrology and Water Resources (ANAS). There is currently no operational and real-time data sharing mechanism in place. Standard hydrometeorological data products (e.g., quantitative precipitation estimates or QPE's), according the requirements of the hydrological and agricultural communities, are generated and disseminated afterwards via agrometeorological bulletins on the INMG webpages.

8.4 ANAS has several national and international cooperation projects, but mostly related to groundwater resources, water supply, sanitation infrastructure and water management.

Summary score, recommendations, and comments for Element 8

A Maturity Score Level-2 was assessed for Element 8: Contribution to Hydrology. The INMG delivers meteorological information for hydrology and water resources management on an ad-hoc basis, and also for early warning of hydrologic risks and potential disasters i.e., flash floods. It cooperates here with the Agency for Water & Sanitation (ANAS), mandated to cover national water and hydrology matters and the Civil Protection Service (SNPCB).

The water agency (ANAS) strongly focuses on water supply and sanitation, using groundwater resources and seawater (desalinization). It cooperates with water utility partners (e.g., APP, AdS, (see Annex 1 for abbreviations) on several islands.

Currently, there is no operational stream gauging monitoring network, which could be considered essential for early warning for flash flooding in a number of watersheds, draining through flood risk-prone urban centres (i.e., Praia capital, Ribeira Brava on San Nicolau, etc.).

INMG and ANAS should engage in setting-up an essential hydrometric monitoring and early warning gauge network in "high-risk" ephemeral stream courses, draining through the main urban centres. Flash floods (with very short lead times) and accompanied with sediment density flows, present a serious risk to populations and infrastructure in case of extreme hydrologic (i.e., hurricane) hazard in a number of catchments and populated areas.

In this respect, hydrological risk and hazard zonation focusing on flash flood prone urban a/o inhabited areas remains an essential gap, and mapping is requested by e.g., the territorial planning and cadastre institute (INGT) and municipalities. It is highly recommended to continue with more detailed hydrologic assessments, initiated by a former Multi Hazard Disaster Risk Management (DRM) screening project (2009-2014), implemented by the PNUD.

Element 9: Product dissemination and outreach

9.1. INMG uses its internet website, social media and national television (weather bulletin) to communicate about the weather, issue alert warnings etc. and inform the public. The webpages contain various pages, ranging from the actual weather, 24-hour forecast, 10-day predictions, maritime and agrometeorological information. A Facebook page is also available as social media. It uses standard communication data technologies, but access speed is fair. A cell phone application (App) to improve dissemination of its weather bulletins including weather alert messages, is currently under development (by INMG).

9.2. There is no standard procedure for education and awareness building – weather and climate literacy – although INMG gives (upon request) regular outreach demonstrations of weather observation to school grade children and young adults. INMG has engaged in a cooperation with LUXDEV and international partners to stimulate "weather and climate literacy".

INMG is also involved in air quality monitoring and manages a test pilot air quality observation network (6 stations), distributed across the islands, incl. near the Fogo volcano and urban centres. This network is managed in cooperation with the DGA/MAA.

9.3. The cell phone App under development also aims to better reach remote communities, youth and elderly populations. INMG and the DGA also conduct outreach on respectively weather stations, observations and climate change. ANAS is active in outreach related to water provision, water quality and sanitation.

Summary score, recommendations, and comments for Element 9

Considering the above, **the Maturity level for Element 9: Product dissemination and outreach is assessed at Level 2.** This means standard communication channels (radio, TV, newspapers incl. on-line) and a dedicated website is used to disseminate forecasts and information to the population and the different economic sectors.

Further improvement in the maturity level can be by making the website still more informative, increasing services to more sectors like tourism and health using e.g., cell phone Apps, and conducting more awareness and capacity building events with the user community.

Element 10: Use and national value of products and services

10.1. INMG does not possess a formalized platform to engage with users or co-design improved services. INMG is usually not the main organizer/convener of the dialogue between sectors, but actively engages in multi-sectoral debate concerning weather and climate, incl. services.

10.2. INMG conducts multi-user and stakeholder surveys in the framework of its 4-year Strategy report updates. Specific surveys (for potential client needs, communities) are done as work processes by the service.

10.3. Quality Management Processes and Services (QMS) are implemented, e.g., for meeting the requirements for international navigation and aviation. QMS are according the ISO9001:2015 standard. The implementation project deadline (for aviation) is 2024.

For meteorological data and services for other purposes, INMG has a partial coverage for implementing QM processes within the service. There is currently no QMS for maritime services.

Summary score, recommendations, and comments for Element 10

The Maturity Level of this element 10: is assessed as Level 2. Service development draws much on informal stakeholder input and feedback. There is regular interaction with national stakeholders when extreme weather (i.e., dust storms, high seas, monsoonal rainfalls) occurs across the archipelago.

The maturity level can be lifted by setting a mechanism for more regular interaction including collection of feedback from stakeholders for co-design and co-production of user specific products. Joint product and service development for the various stakeholders and interested parties (see Annex 3) would be a strong asset for INMG's role in society and also in the international arena.

ANNEXES

Annex 1: List of abbreviations and acronyms

AAC	Civil Aviation Agency
APP, AdS	Águas de Ponta Preta, Águas de Santiago (water utilities, Co)
ANAS	National Agency for Water & Sanitation
ASA	Airports & Air traffic Safety Agency
AWOS	Aviation Weather Observing Systems
AWS	Automated Weather Station
GBON	Global Basic Observation Network – WMO
CNPC	National Council for Civil Protection
CV	Cabo Verde
CPTEC	"Centro de Previsão do Tempo & Clima" (Brasil)
CSO	Civil Society Organization
DGA	Directorate General for Environment
DGASP	Directorate General for Agriculture, Forestry and Livestock
DRM	Disaster Risk Management a/o Risk Reduction (DRR)
ECMWF	European Centre for Midterm Weather Forecasting
ECOWAS	Economic Commission for West African States
EU	European Union
EUMETSAT	European Meteorological Satellite Agency
EUMETCast	Eumetsat multiCast data dissemination Service
FAO	Food & Agricultural Organization (UN)
FOSS	Free and Open-Source Software
GFS	Global Forecasting System (US/NOAA)
GSOD	Global Summary of Day meteorological database (WMO Res.41)
ICAO	International Civil Aviation Organization
INIDA	National Institute for Agricultural Development & Research
INGT	National Institute for Territorial (Land) Management
INMG	National Institute of Meteorology and Geophysics
INSP	National Institute for Public Health
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
MIOTH	Ministry of Infrastructure, Territorial Planning & Housing
NHS	National Hydrological Service
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
SINAGRED	National System for Natural Risks and Disaster Management
SNPCB	National Service for Civil Protection and Fire Brigades
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
UNICEF	United Nations Children's Fund
UNICV	(Public) University of Cabo Verde
WIGOS	WMO Integrated Global Observing System
WIS2	WMO Information System 2.0
WMO	World Meteorological Organization
WHO	World Health Organization

Annex 2: List of References & Information supplied through WMO

The data inventory and review sheet supplied by WMO was used as a peer-review assistance tool developed to standardize the review process by providing WMO Monitoring System data in an organized way. A digital copy of the sheet was provided to peer advisors (June, 2023) with beneficiary country data organized across the CHD elements, indicators, WMO Data, Suggested Additional Data, Peer-Advisory Score, and Comment Sections.

For this CHD production, multiple WMO webpages, related to the observation infrastructure, data streams and the SOFF process were reviewed. The https://alliancehydromet.org pages and information was also used to disseminate the purpose of the CHD country diagnostic to the INMG service staff and stakeholders. This included also the PowerPoints. We refer further to the list of references below.

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WMO EW4All Rapid Assessment for Pillar-2 (2023)
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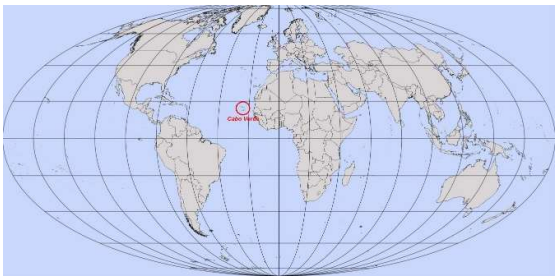
Annex 3: Analysis of consulted stakeholders and interests

Socio-economic sector	List of institutions and other entities	Strategy or activity of entity (a/o references)	#	Projects a/o proposed cooperation activities (services, products, agreements, etc.)
AGRICULTURE & FOOD SECURITY	**INIDA** (Instituto Nacional de Investigação e Desenvolvimento Agrário)	INIDA mentions various cooperation activities with INMG in its strategic plan - see https://maa.gov.cv/index.php/maa/organograma/institutos-e-agencias/inida	1	Cooperation in the field of drought monitoring related to agriculture and land degradation, soil & water conservation; use of Reflor agrometeorological station network data (temp, RH, winds, pressure, radiation, rainfall, soil moisture, soil temperatures)
	DGASP - Direção Geral da Agricultura, Silvicultura e Pecuária	DGASP oversees the national agricultural, forest and animal husbandry production and farming sector of Cabo Verde	2	Resilience Project (development of a smartphone App or INMG webpage application for agriculture with e.g., agrometeorological information on rainfall, cumulative totals and advice for seeding (rainfed agriculture)
	POSER - Programa de Promoção de Oportunidades Socio Económicas Rurais		3	POSER requires more easy access to (local) meteorological data and climate information its promotion activities in rural areas
PUBLIC HEALTH	**INSP** Instituto Nacional de Saúde Pública	INSP has its strategic plan on https://insp.gov.cv/wp-content/uploads/2022/11/Plano-Estrategico-2019-2021-INSP-MSSS_compressed.pdf	4	Seeks more close collaboration for assessing meteorological impacts on public health, air quality and environmental health; data on air temperatures, humidity, rainfall, winds, for e.g., vector-borne diseases, analysis of outbreaks e.g., SARS-Cov2, etc.
CIVIL PROTECTION	**SNPCB** - Serviço Nacional de Proteção Civil e Bombeiros	SNPCB has a strategic plan, and is responsible for civil protection during extreme weather, alerts, volcanic activity, etc.	5	Establishment of coordination and collaboration agreements to strengthen the provision of disaster management and early warning services to the transport sector, promotion and animation of workshops/conferences for user/beneficiary groups and implementation of an integrated early warning system.
WATER & SANITATION	**ANAS** - Agência Nacional de Água e Saneamento	The Strategic Plan of ANAS can be found at https://www.anas.gov.cv/index.php/apresentacao/quem-somos	6	Interested to join forces for setting a hydrometric network of surface water (flash flood and base flow monitoring in major catchments with potential hydrologic risk and hazard for populations.

WATER & SANITATION	**ANAS** - Agência Nacional de Água e Saneamento			
			7	Set-up and automatization of stream flow monitoring stations equipped with convenient data storage and easy dissemination
			8	Adapted surface weirs to hydraulic regime (supercritical) and sediment/bed load transports
			9	Set-up of a flash flood monitoring and early warning system
			10	Cooperation on hydrometeorological data analysis for water balance calculations, estimation of water retention in the small reservoirs (dams); estimation of groundwater recharge in alluvial plains
	APP - Águas de Ponta Preta	Private service Company in water supply & sanitation (Sal, Santo Antao Islands)	11	Installation of meteorological stations (type AWS) on the water supply and sanitation plants and installations of APP
TOURISM	**CT** - Câmara do Turismo de Cabo Verde	More easy local weather info access for day-to-day activities, including events (free air), with also tourist groups, etc.	12	Elaboration of a protocol of collaboration with several themes: one of them, very important, will be the training of partners in the Tourism sector (service providers, tour guides, journalists, etc.); give more literacy and competences on weather and climate of Cabo Verde
	ITCV - Instituto do Turismo de Cabo Verde		13	Integration of INMG info in the National Information and Management System of Tourism
			14	Collaboration with information provision for the Tourist Observatory
			15	Collaboration in information provision for tourist projects, hiking, stages of championships and world events, which take place in Cabo Verde, fairs, galas, etc.
MARITIME SECTOR	**IMP** - Instituto Marítimo Portuário	www.imp.cv	17	Collaboration in information provision for projects and national nautical sports & championships, stages of championships and world events, which take place in Cabo Verde, (ref. recent Global Ocean Regata Mindelo harbor) etc.
	IMAR - Instituto do Mar		18	

EDUCATION & RESEARCH	**UniCV** - Universidade de Cabo Verde	to enhance the educational process, with greater integration of knowledge of weather and climate in various curricula; support school competitions and other major events, many of them outdoors with meteorological information	19	Collaboration in the preparation and execution of projects for large-scale events such as the Professions Fair, and introduction to meteorology incl. education practical laboratory activities, study visits, knowledge of weather data collection tools, etc.
			20	The partnership can be based on knowledge education exchange, as well as take advantage of the various aspects and skills already acquired by UniCV, for example, in audits, QMS, data protection and sharing, research
			21	Another cooperation project is the Dust Risk project, executed with TROPOS (an Atmospheric Investigation Centre in Germany).
	CVAO - Cabo Verde Atmospheric Observatory	International third-party research station WMO GAW-CVO	22	Continuation of the current long-term cooperation with international partners, researcher training,
	OSCM - Ocean Science Centre Mindelo	International third-party research Centre	23	Exploring cooperation potential in marine area (weather monitoring and sea surface monitoring e.g., with meteorological satellites)
LOCAL ADMINISTRATION	**ANMCV** - Associação Nacional dos Municípios de Cabo Verde	Meteorological information is essential for the implementation of municipal policies in various socio-economic fields and activities	24	Collaboration in the preparation and execution of projects of national championships of various sports modalities, musical and cultural festivals, etc.); easy data platform and real time information
AVIATION SECTOR	**ASA** - Aeroportos e Segurança Aérea	ASA will from July 13, 2023 unfold in a national Company that will deal with the area of Air Navigation and CVA - Cabo Verde Airports, which by concession to the Vinci group, will manage the airport infrastructures of the archipelago.	25	Next to INMGs current role in operation of the AWOS (Automated weather observation systems) of the airports, also another cooperation area: QMS (Quality Management System)
	AAC - Agência da Aviação Civil		26	Collaboration in the area of Air Navigation and airport infrastructures of the archipelago.

Annex 4: Cabo Verde Weather, Atmosphere, Air and Climate Observation Infrastructure



The weather, atmosphere, air and climate observation infrastructure and networks of Cabo Verde, managed[7] by INMG, consists currently (6/2023) of:

- 32 Automatic Weather Stations (AWS),
- 2 Manual weather Class A stations
- 1 Upper Air Station and troposphere sounding facility
- Precipitation gauge network (~ 250 totalizing manual rain gauges)
- Air quality monitoring network (6 locations, incl. mobile stations)
- An International - third party - long term Cape Verde Atmospheric Observatory (GAW - CVAO)
- 1 atmospheric Aerosol spectral sun-photometer (long-term) station

The INMG also operates 2 meteorological satellite receiving systems using EUMETCAST near real time data reception for weather monitoring and prediction purposes:

- One (1) MESSIR-SAT and one (1) PUMA-MESA data reception station

The following Earth-related Observation infrastructure is also operated by the INMG:

- 20 seismic monitoring stations (geophysical hazard monitoring network)
- 1 Earth Magnetic Field monitoring station (with int'l cooperation);

In Cabo Verde, there is also an international third-party Atlantic Ocean Observatory[8].

Hereafter, some succinct details of the different stations is given.

[7] The GAW – CVAO is managed by the int'l partners (UK, Germany) jointly with INMG – Cabo Verde
[8] The Ocean Observatory is managed by int'l partners (Germany) in cooperation with INM (Instituto Nacional do Mar)

Automated Weather Station (AWS) network

Figure 1 below shows the distribution of the Automated Weather Station network across the archipelago.

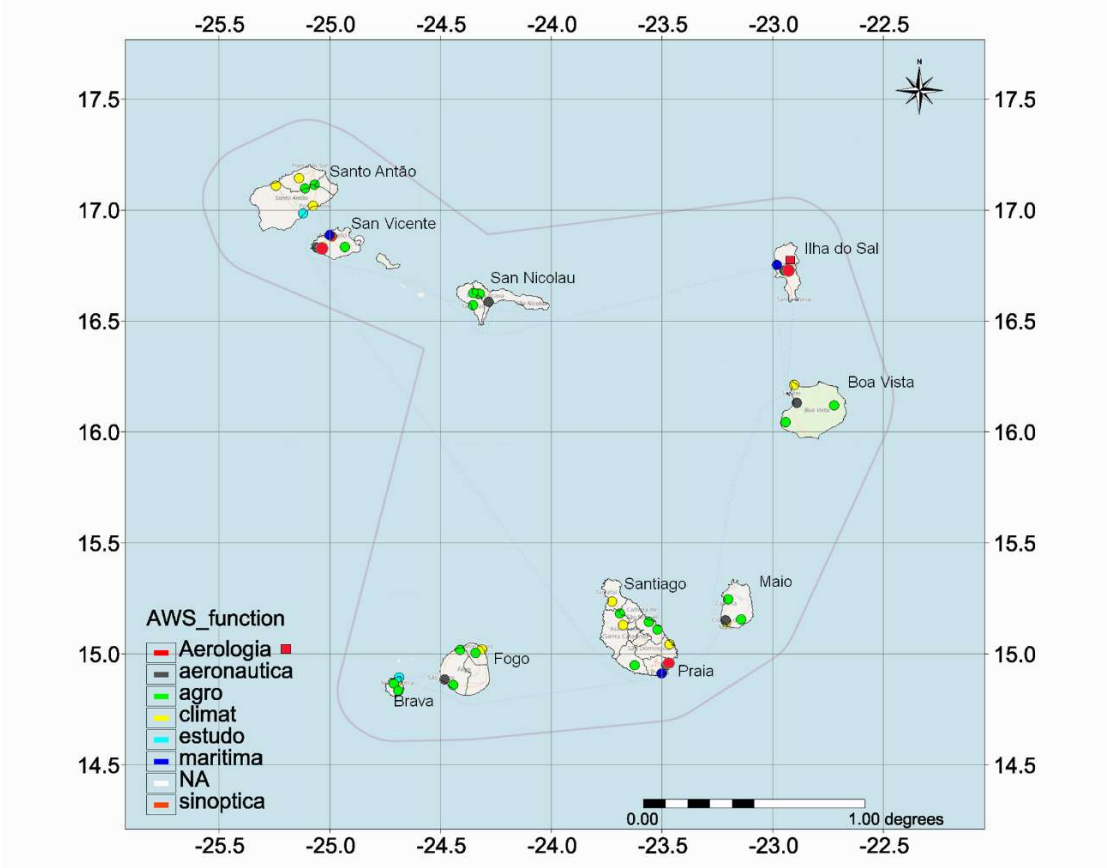


Figure 1[9]: Automated Weather Station network incl. function - Cabo Verde (6/2023)

The AWS network serves different purposes as can be seen from the Figure 1 legend. Most stations are connected via a GSM or GPRS communication protocol service to a central data server at INMG Headquarters on Ilha do Sal. The data collection and storage system uses Campbell Scientific data software. Stations use also on-site station temporary storage (e.g., using mostly Campbell CR-800 data loggers or other Sutron Xpert, etc.). The data server also monitors the station functioning and data collection process. Data are made available to staff via NextCloud, a suite of client-server software for creating and using file hosting services. Next Cloud provides functionality similar to Dropbox, Google Drive, etc.

[9] Figure source data: INMG_station_table.xls; arquipelago.shp; SRTM_DEM; OpenStreetMap; FOSS software: ILWISv3.86 © ITC, Irfanview v4.36

Aeronautical AWS network

In order to cover international air (passenger and freight) transport and regular local flights to several islands (7 out of 9 islands having airports), INMG operates 7 ICAO coded aeronautical stations for the ASA[10]. Four airports manage international air traffic and 3 smaller airports serve domestic travel and air transport. In relation to the GBON requirements, currently 3 aeronautical (ICAO and WMO_ID coded) stations (at the main international airports: Amilcar Cabral on Ilha do Sal, São Pedro on San Vicente Island and Praia on Santiago Island), issue 3-hourly to 6-hourly SYNOP messages[11], and hourly METAR/TAF reports for aviation purposes. This system uses the AFTN[12] or Aeronautical Fixed Telecommunication Network (ICAO) protocols for data communication. Ilha do Sal airport is an ICAO AFTN Communication Centre and the other two stations are considered AFTN stations, sending data via Sal. Boa Vista International airport also issues METAR/TAF reports.

Aeronautical - Synoptic AWS

Three aeronautical AWS stations, also mentioned above with WMO-IDs: 08594, 08583, 08589, are also classified as Synoptic stations. The SYNOP and METAR/TAF message data from these 3 international airports can be easily traced on international data gateways and webpages e.g., the NOAA SYNOP data gateway, the NOAA/NWS https://www.aviationweather.gov/, and other international data servers.

Maritime AWS network

INMG operates three MARINMET stations operating in the 3 main international harbors (Palmeira, Mindelo and Praia). These weather stations (manufacturer: SUTRON/Ott Hydrometry/Hach Inc.) are also equipped with a tidal and wave height gauging system MIROS SM-140. Data transmission is also via GPRS through Sal Headquarters. Data are available for INMG on NextCloud.

Fig. 2: Maritime AWS of Mindelo harbor on San Vicente Island; type Sutron

Agrometeorological AWS network

INMG operates 18 AWS, dedicated to support weather and climate monitoring for the agricultural, (re)forestation sector of the Ministry of Agriculture & Environment and rural communities. The newer stations (e.g., 14 AWS of the Reflor project; funding/EU, IE/PNUD, FAO, 2020; Manuf.: Campbell Stokes Inc.) record all six weather variables (incl. direct/diffuse radiation) at 10-min intervals, and include soil temperature and moisture sensors at 3 soil depths. Data are transferred via GPRS to INMG HQs and also managed/accessible via a web-based AmbiDS Data System by INMG staff.

[10] ASA: Agency of Airports and Air Traffic Control & Security
[11] The 4 main (UTC 00:00-06:00-12:00-18:00) and 4 intermediates (UTC 03:00-09:00-15:00-21:00)
[12] AFTN: Aeronautical Fixed Telecommunication Network (ref. ICAO)

Fig. 3: Agrometeorological AWS (Madeiral, San Vicente; type Campbell Sc.)

Climatic AWS network

INMG operates several older (>10-15 years operation) medium-term observation stations across the islands. These stations monitor a variable number of weather parameters (Temperature, Humidity, Precipitation, Wind). Not all stations are equipped with solar Radiation and atmospheric Pressure sensors. We note that a number of the older stations, especially in remote locations are not fully operational anymore a/o defunct, and require servicing or taking out of operation.

Precipitation Gauge Network

Next to its AWS network, INMG also oversees a large number (~ 250) of manually-operated rain gauges, in order to capture the extremely high local variability in rainfall during the monsoon season (~ 15-July to 15-October). Due to the mountainous nature of several islands, a strong orographic effect of precipitation is noted during precipitation events[13]. Rainfall information is typically used by the agricultural sector and also by the civil protection services (in case of extreme precipitation alerts). These manual rain gauges operate usually only in the rainfall season (July-October), except on North Westerly San Antão island, where at higher elevations (> 1,000 m.a.s.l.), low precipitations (Jan-Mar) may be measured related to North Central Atlantic atmospheric weather phenomena. Observers receive a small gratification for their monitoring task from INMG. Instrument maintenance, data collection and quality control however remain issues for maintaining this extended local manual rain gauge network.

Figure 4: Manual 400 cm^2 totalizing rain gauge; type Precis Mécanique

Aerology – Upper Air Station (UAS)

Ilha do Sal (Sal) has an Upper-Air Sounding facility, in operation since the 1960s, and which was functional until quite recently (2018). It is currently out of operation, due to equipment age issues e.g., Hydrogen (H_2) production electrolyzer (very old equipment to be renewed), but also financial funding of the atmospheric sounding observations. In the past, the Agency for Airports and Air Traffic Control and Security (ASA) co-financed the troposphere soundings (e.g., ~ 400 per year), but this financing has stopped since several years. Also new meteorology staff needs training in UAS observation practices.

Fig. 5: (very) old/defunct H_2 generator at the UAS sounding facility, Espargos, Ilha do Sal

[13] See references (J.Sanchez, C.Mannaerts et al, 2012)

Satellite-based observation and weather monitoring systems

Fig. 6: C-band satellite reception (Eumetcast) at Espargos, Ilha do Sal

With respect to near real time weather (and climate) observations, INMG also operates two satellite-based observation systems: an (older) PUMA/MESA type station and a MESSIR-SAT station, using satellite and WMO weather and model data transmission through the EUMETCast Tellicast near real time data distribution system from EUMETSAT. These systems permit to receive several meteorological and other satellite data in near real time, incl. WMO GTS data streams. Data are used by the weather forecast unit of INMG.

Air Quality Observation Network

INMG is currently cooperating with the Directorate General of Environment (of the MAA), and international partners in air quality monitoring. Currently, several test pilots on urban air quality monitoring are conducted in several locations incl. the capital, Praia city. Air quality monitoring related to volcanic hazard (Fogo Island) is also conducted.

Fig. 7: Air quality monitoring in Cova Figueira, Fogo, used by INMG (near the Fogo stratovolcano)

Geophysical Seismic Observation Network

Fig. 8: Seismic real time monitoring facility – INMG San Vicente

Next to its weather and climate observation networks, INMG also operates a geophysical seismic observation facility, with 20 seismometers operating across the different islands. The more westerly islands (Santo Antao, Fogo, Brava) register more seismic activity, which requires careful monitoring, due to an active (status) stratovolcano on Fogo Island (last eruption Dec, 2014-, Feb, 2015) and active geological faults or seismic activity on Brava and Santo Antão. The seismometer network is monitored remotely from the INMG – Mindelo office by a geophysical expert and INMG staff. At the time of revision of this report (Sep-Nov, 2023), seismic activity (Richter scale > 4) was registered on Brava Island by INMG, including alert warning and emergency support actions by SNPCB.

International - third-party - atmospheric and earth observation infrastructure

INMG also oversees and co-manages with international cooperation partners several other important observations related to global earth and atmospheric, weather and climate change sciences.

Cape Verde Atmospheric Observatory (CVAO)[14]

A Global Atmospheric Watch (WMO-GAW) Observation facility is operating in Cabo Verde since 2007 on a continuous basis, and more specifically at Calhau, the most eastern point of San Vicente Island. This station is the result of a joint international cooperation of INMG and international researchers and institutions, Max-Planck-Institute for Biogeochemistry, Jena (MPI-BGC), Leibniz Institute for Tropospheric Research, Leipzig (TROPOS), both from Germany, and University of York (UoY), acting on behalf of and under contract from the UK National Centre for Atmospheric Science (NCAS). This global environmental air monitoring tower station (GHG, Ozone, dust, long range atmospheric contaminant transports (Hg), etc.) is listed in the OSCAR database Cabo Verde. The research at this station has led to important findings on atmosphere – ocean interactions, related to Ozone and GHGs and also long-range transport of dust particles and behavior of aerosols.

Fig. 9: Cape Verde Atmospheric Observatory, Calhau, San Vicente (pls. read important footnote)

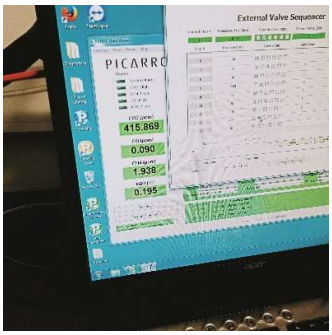


Fig. 10: Measuring Green House Gases @ CVAO Calhau

Other international third-party Observations

Next to the CVAO, we can also mention:

- an Earth Magnetic Field Observation Facility, in cooperation with Univ. of Catalúnia (Spain);

- a CIMEL atmospheric (aerosol) spectral sun photometer, linked to the Global Aerosol Robotic Network, in cooperation with the University of Lille (France), operating more than 20-years;

These last two instruments are located on Ilha do Sal (INMG Head office), at Espargos and at proximity of Sal International airport. Data of this last instrument can be obtained from the Global Aerosol Robotic Network webpage or https://aeronet.gsfc.nasa.gov/ . This last line illustrates the beneficial effect of engaging with the int'l (global) research community for gathering long-term surface and atmospheric observation data on SIDS regions.

[14] Please note that the "rusty" corrosion outside look of the container labs at the near ocean Calhau CVAO, is caused corrosive sea aerosols. Painting would influence the very sensitive air/atmosphere gas and other constituent measurements by the inside measuring equipment's i.e., gas chromatograph - mass spectrometers and other instruments, and contaminate the long time series. It was therefore decided not to paint the containers regularly by the lead scientists (personal comm. of Mr.Mendes, local CVAO lead staff)