Systematic Observations Financing Facility

23 April, 2024

GBON National Gap Analysis

São Tomé and Príncipe

Systematic Observation Financing Facility

Weather and climate data for resilience

WEATHER CLIMATE WATER

Screening of the National Gap Analysis (NGA) of Sao Tome and Principe

WMO Technical Authority screens the GBON National Gap Analysis to ensure consistency with the GBON regulations and provides feedback for revisions as needed. *The screening of the NGA is conducted according to the SOFF Operational Guidance Handbook, version: 04.07.2023 and the provisions in Decision 5.7 of the SOFF Steering Committee.*

Following iterations with peer advisor and beneficiary country, WMO Technical Authority confirms that the National Gap Analysis is consistent with GBON regulations. While the WMO GBON Global Gap Analysis identified the need for 1 surface stations 1 upper air stations over land to meet the GBON horizontal requirement, the **WMO Technical Authority confirms the NGA results which indicate the need for 2 surface land stations and 1 upper station based on specific national circumstances.**

Date:17 October 2024

Signature:

Albert Fischer

Director, WIGOS Branch, Infrastructure Department, WMO

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GBON National Gap Analysis

Republic of São Tomé and Príncipe

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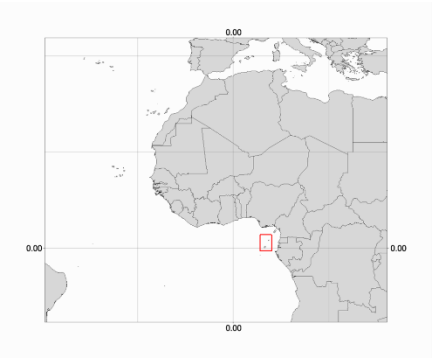
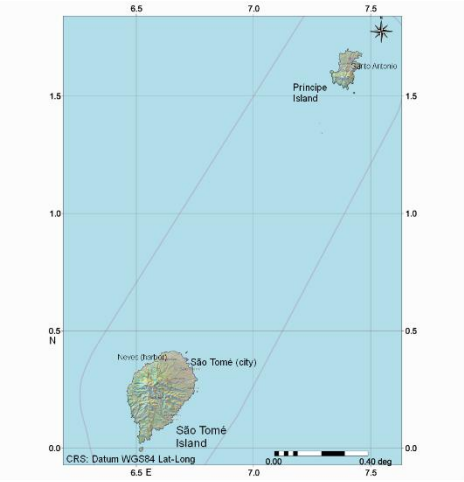
WMO Technical Authority	WMO

Preface: short country info



Location: Central East Atlantic; Lat 0.5S -1.5 N - Lon 5.0-6.5 E
Land area: Archipelago, 2 main inhabited islands: 1,001. km^2
Exclusive Economic Zone Ocean area: 161,000. km^2
Geology/topo: volcanic, mountainous: Max.elev.:2,024.m.a.s.l.
Population #: ~201,000.[1] to ~227,360.[2] estimates (2023)
Climate: Humid tropical. Köppen-Geiger Am classification.
Seasons: rainfall season(s) from September to May; drier period "Gravana" from June to August
Mean annual air temperatures[3,4] : avg 24.8C, min 21.7C, max 29.5C
Mean annual rainfall[4]: 2,200. mm/yr^2 with from ~>1,000 mm/yr on Northern coast of São Tomé Island to ~5,000. mm/yr at higher elevations in the South Western region of ST.



As a Small Island Development State (SIDS), STP faces particular challenges with respect to weather and climate. Lying on the equator in the West African Gulf of Guinea, STP is particularly vulnerable to extreme tropical weather phenomena i.e., massive convection, tropical storms with high winds and rainfall, presenting serious challenges to coastal areas, populations and management of its natural land and marine resources[4] [5].

Despite its insignificant contribution for global warming, São Tomé and Príncipe is suffering heavily from its consequences, and is paying an overly expensive bill for climate change. São Tomé & Príncipe 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 service provision to the local society and the global community.

It is important for governments and organizations to invest in modernizing and strengthening the hydrometeorological sector in the country to ensure that essential information is made available in a timely and accurate manner, helping to protect lives, property, and the environment.

[1] Source: UN World Population Prospects https://population.un.org/wpp/ (Jan, 2024)
[2] Source: https://dadosmundiais.com (Mar, 2024)
[3] Source: CRU v4.06 global observed climate database from Climate Research Unit, University of East Anglia, UK (Fev, 2024)
[4] https://www.un.org/ohrlls/content/about-small-island-developing-states. UN Office of the High Representative for LDC and Small Island Development States - SIDS. (web portal visited Jan, 2024)
[5] https://climateknowledgeportal.worldbank.org/country/sao-tome-and-principe/climate-data-historical

1. Country information from the GBON Global Gap Analysis

Within the implementation of the new GBON or Global Basic Observation Network of WMO, the following information in Table 1 was provided by WMO to São Tomé & Príncipe (Jun, 2023)[6]. Using the new GBON target coverage and reporting requirements (e.g. 6-variables; hourly reporting cycle, use of WIS2.0), an initial gap was identified based on the WGDQMS or WMO Global Data Quality Monitoring System screening of São Tomé & Príncipe. In combination with the new WIGOS, GBON, i.e., WIS2.0 information system reporting requirements, setup by WMO (end 2021), this information is considered realistic.

This GBON Gap Analysis Report suits the purpose to investigate the current reporting status and reply (as country) to this initial GBON country assessment.

A. GBON horizontal resolution requirements	B. Target	C. Reporting	D. Gap total	E. Gap improve	F. Gap new
Surface stations Horizontal resolution: 200km	**1**	**0**	**1**	**1**	**0**
Upper-air stations Horizontal resolution: 500km	**1**	**0**	**1**	**0**	**1**

Table 1. WMO GBON Global Gap Analysis (June, 2023)

1.1 Surface station horizontal resolution requirement

For evaluating the 200-km spatial GBON station resolution requirement, we spatially plotted the São Tomé and Príncipe land area on a 200 km resolution grid in Figure 1. Figure 1 confirms the initial GBON station target, but also illustrates the large marine/ocean coverage compared to the land surface. We added the 2 current WMO OSCAR WMO-ID registered synoptic stations. The EPSG:32672 Coordinate Reference System (CRS) and metric UTM (Universal Transverse Mercator) projection, using UTM Zone 32 North was used for analyzing the 200-km grid requirement.

[6] WMO document Ref. /2022/I/WIGOS/ONM/GBON.

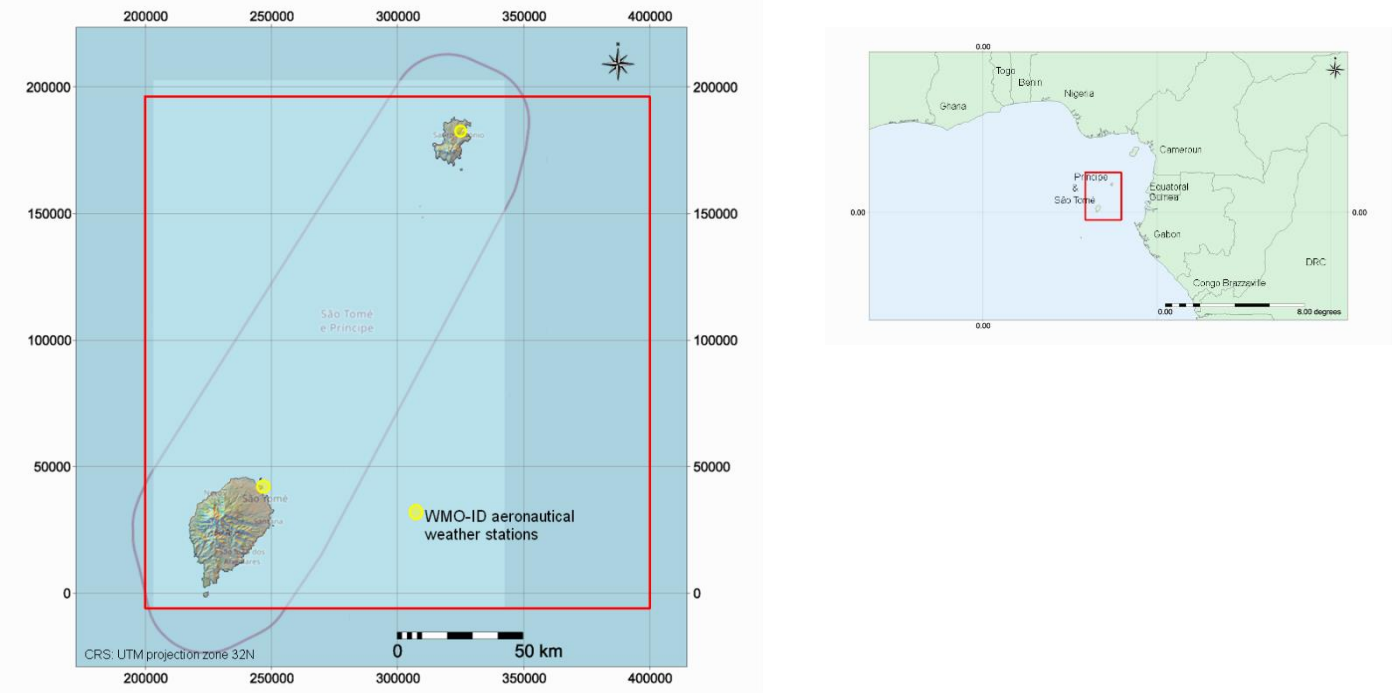


Figure 1: São Tomé and Príncipe in a 200-km UTM projected grid resolution (with WMO_ID Synoptic aeronautical station, registered in WMO-OSCAR).

1.3 WMO Country Information available on WIGOS: OSCAR, WGDQMS and GBON

Before initiating the Gap analysis, we reviewed (June, 2023) the information available about São Tomé & Príncipe in the WMO – WIGOS i.e., OSCAR, WGDQMS and GBON global database systems.

São Tomé and Príncipe *stations in WMO-OSCAR*

STP has two (2) stations registered in the WMO-OSCAR https://oscar.wmo.int/surface/ global observation inventory database. The assessed reporting status is currently for all: "partly operational" based on a WMO – OSCAR status check: 2024-01-30 (Webpages accessed in period Jan, 30 to Feb, 07 2024). Reporting stations (partly according WMO – OSCAR and WDQMS evaluations) are: São Tomé international airport and Príncipe airport.

São Tomé and Príncipe *stations in WMO-WGDQMS*

In the WMO-WDQMS or WIGOS Data Quality Monitoring System, on https://wdqms.wmo.int the % available data reports for the two (2) SYNOP stations are variable, pending weather variable

data (SLP,TMP,RH, W, PCP, etc.) checked. In general an orange score[7] is seen for STP, but this is quite variable according the days and periods of observation (from black: no data to red (data <30%) and orange (>30% ; availability issues).

São Tomé and Príncipe *stations in the WMO-GBON Visualization Tool*

In January 2024, there is no STP (as country) and GBON stations in the WMO GBON visualization Tool https://community.wmo.int/en/global-basic-observing-network-gbon-station-visualisation-web-tool .

We recommend strongly that the WMO Focal Point of INM or another designated person updates the WMO OSCAR and GBON station registrations and metadata, and contacts WMO for adding STP and the stations in the GBON global visualization tool (see also Identified rapid actions paragraph 3.3 at end).

2. Analysis of existing GBON stations and their status against GBON requirements

Following the WMO GBON gap analysis inventory requirements, we made an assessment of the GBON existing stations (inventory date: Jan, 2024) in Tables 2 and 3. We refer to the footnotes and textual comments for explanation on the numbers in Table 2.

GBON Requirements	Existing observation stations (# of stations)			
	NMHS network		Third-party network	
	Reporting	Improve	Reporting	Improve
Surface stations Horizontal resolution: 200km Variables: SLP, T, H, W, P, SD	**0**	**1**	**0**	**0**
Upper-air stations Horizontal resolution: 500km Vertical resolution: 100m, up to 30 hPa - Variables: T, H, W	**0**	**1**	**0**	**0**

Table 2. Assessment of existent stations according operational status and network ownership

INM also oversees and manages other weather stations and observation networks, delegated by other projects and sectors[8]. It's network is therefore made up of several sub-networks, serving

[7] WMO WGDQMS Red or Orange score : <30% or >30% data availability.

[8] Examples are the SAP ("Sistema de Alerte Prévio" project, IE/UNDP) and the regional WACA or "Western Africa Coastal Area Management" Program, WorldBank / GFDRR, by the Directorate General of Environment (Min.of Environment), Directorate General of Natural Resources and Energy (DGRNE) and INA (National Water Institute).

different monitoring purposes i.e., aviation, maritime, agrometeorology and climate. In Annex 1, a short overview of the main weather observation infrastructure of STP is given.

2.1 Status summary of the existing reporting weather stations

Among the surface weather stations, currently one operates on a 24/7 manned basis and issues SYNOP standard reports to the WMO GTS via the WMO RTH Congo Brazzaville. The reporting cycle is variable, ranging from 1-, 3- to 6-hr and longer, pending the days, for São Tomé airport WMO-ID 61931. Príncipe airport WMO-ID 61934 has issues for sending complete SYNOP messages. We note that hourly METAR or Meteorological Airport Reports and TAF or Terminal Aerodrome Forecasts are also issued from these 2 airport stations. WMO-ID 61931 METAR/TAF reports can be found on accessible international global "current aviation weather" data servers. METAR data of Príncipe airport (WMO station code 61934) are not traceable. All other AWS recorded observation data of São Tomé and Príncipe are transmitted to the INM main data server using GPRS / GSM transmission protocols.

2.2 Reporting frequency of meteorological variables

In Table 3, the status of the existing stations is analysed in terms of the GBON variables and international reporting cycle requirements. The (manual) reporting frequency of the earmarked GBON stations is currently irregular. Verification on the WIGOS WGDQMS (Surface Data Monitoring System) leads to irregular 6-hour data reception by WMO. MESSIR Net/Com software is used for sending messages to the Congo Brazzaville RTH. Príncipe Island airport WMO-ID 61934 is also transmitting SYNOP data. Data communication issues (irregular reporting frequency) from STP to the global international network are in general noted on global SYNOP and METAR / TAF weather data gateways (check periods: Oct-Nov, 2023 and Jan-Feb, 2024)

Station name	Station type (S/UA)	Owner NMS/third-party)	Funding source	GBON variable measured ****						Report cycle (hr)	GBON Compliance (Y/N)
				SLP	T	H	W	P	SD		
São Tomé	Surface	INM	INM	x	x	x	x	x	-	6-hr [9]	N
Príncipe	Surface	INM	INM	x	x	x	x	x	-	12-hr[10]	N
São Tomé	UA**	INM	INM		-	-	-			(-)	N

** currently non existing (only old premises, building near main INM office)

Table 3. Assessment of current GBON stations per station characteristics.

[9] Current reporting frequency for SYNOP aeronautical station data is variable

[10] Idem: irregular frequency a/o incomplete SYNOP message sending from Príncipe airport.

3. Results of the GBON National Gap Analysis

The results of the Gap Analysys steps 1 and 2 are summarized in Table 4. From Table 4, we observe that currently no station fully complies with the GBON requirements. We give remarks and considerations on the reported gap analysis results of Table 4 and GBON compliance below. The GBON National Contribution Plan will outline more details on the next steps.

GBON requirements	Target (# of stations)	GBON Compliant stations (#)	Stations gap	
			New	Improved
Surface stations • **Horizontal resolution**: 200km • **Variables**: SLP, T, H, W, P, SD • Observation cycle: 1h	**1**	**0**	**0**	**2**[11]
Upper-air stations • **Horizontal resolution**: 500km • **Vertical** resolution: 100m, up to 30 hpa **Variables**: T, H, W • **Reporting cycle**: twice a day	**1**	**0**	**1**	**0**

Table 4. Results of the GBON National Gap Analysis

SLP: Sea-level pressure; T: Temperature; H: Humidity; W: wind; P: Precipitation; SD: Snow depth

3.1 Number of target stations – Claim for exemption

The first rough estimate made in the global gap analysis was one station for the whole country. Based on our more detailed analysis presented in this report we would strongly recommend to install two GBON stations i.e., one on São Tomé and one on Príncipe Island.

We recommend a GBON Surface station on both islands because of the specific geographical locations (i.e., 170-km apart) and climatological characteristics of São Tomé on one hand and Príncipe on the other hand. Both islands have important resident populations and economies.

Furthermore as GBON observations are the basis in the chain for EW4all, it is important to have observations on both islands to support local communities. In addition, it is challenging to represent the local climate in all detail of these small islands in global NWP. For local decision

[11] São Tomé & Príncipe will seek a Target of (two) 2 Surface AWS and (one) 1 UAS as compared to the original (WMO June 2023) GBON global gap analysis. The rationale is outlined in paragraph 3.1 and further described in the GBON National Contribution Plan. Figure 2 shows the AWS (2) and UAS (1) location map, with indicative station coverage radius, according GBON 500-km for AWS / SIDS and 1000-km for UAS.

making and (impact) modelling it will be necessary to have observations from São Tomé as well as Principe Island.

The National Meteorological Service (INM) stresses the importance of an operational and GBON compliant Surface station on Príncipe Island . The distance between Príncipe and São Tomé Islands (~170-km), and the additional early warning function of this station, justify this observation (Figure 2). Occurrence of extreme weather (e.g. large convection, tropical thunderstorms) on São Tomé Island not necessarily means alert warning on Príncipe Island and vice versa.

WMO also recommends a gap fill of the old (since long not operating) Upper-Air Station (UAS) facility present at INM near São Tomé airport. INM is keen to re-activate the UAS soundings. The facility requires total renewal, including meteorologist and observer staff training in UA soundings and operation of semi- or automated UAS systems (ref. the GBON National Contributing Plan).

We added the stations on the GBON AWS en UAS station map in Figure 2, including the station potential areal coverage extend. The extend is shown as diameter: 500-km for Surface AWS; 1000-km for UAS. We refer further to the GBON National Contribution Plan report for more information.

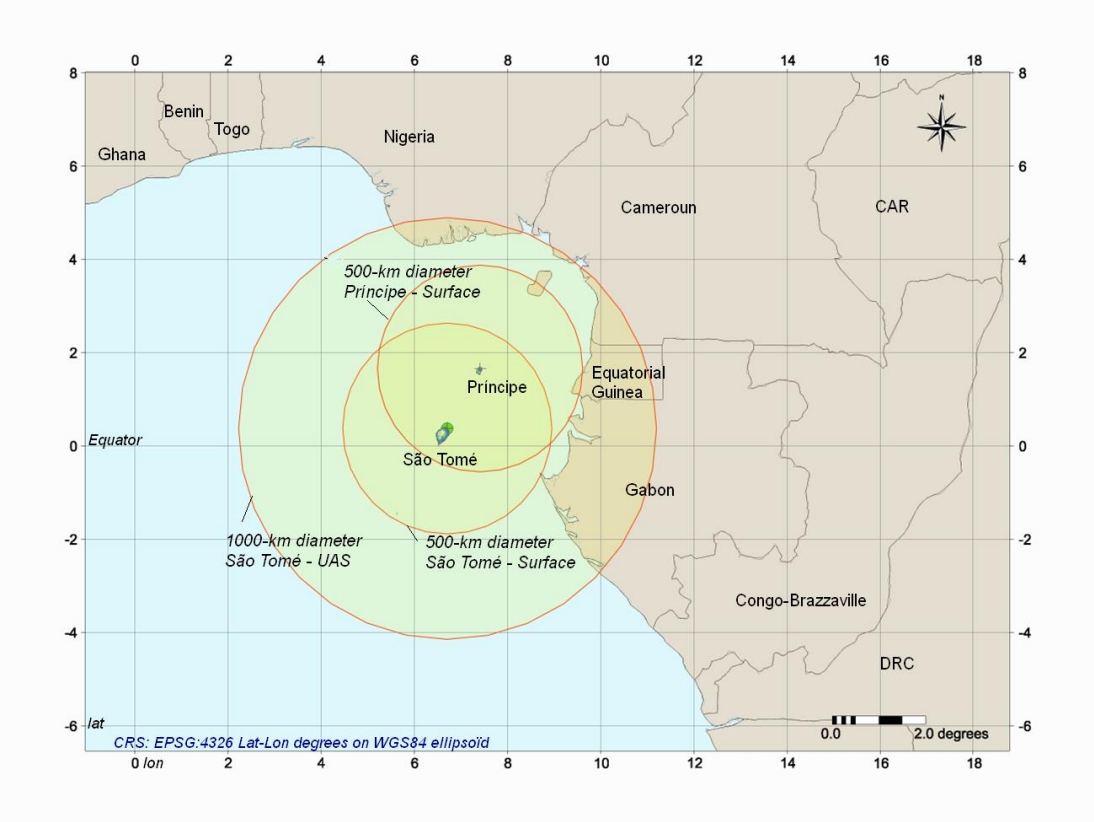


Figure 2: Map of the two (2) GBON Surface and one (1) UAS target stations of the Republic of São Tomé and Príncipe (incl. views of indicative coverage extent)

3.2 Reporting frequency and cycle

STP currently relies entirely on two aeronautical synoptic stations (São Tomé international airport and Príncipe airport) for real time weather data communication, in first place to the aviation sector. SYNOP data are reported (with data gaps), manually by national INM weather observer and forecaster staff from São Tomé international airport station WMO-ID 61931. The international airport stations are manned 24/7. The WIGOS WGDQMS indicates data gaps, also found by our other independent checks (period Oct/Nov, 2023 - Jan/Feb, 2024) on international aviation weather data gateways.

3.3 Identified rapid actions to meet GBON requirements

Hereafter, a number of rapid interventions are already proposed, anticipating GBON National Contribution Plan and Investment Request approval.

- The peer-advisor has recommended the WMO Oscar Focal Point of STP to contact WMO -> to add STP country and GBON stations in the GBON visualization. If a language barrier would exist (Portuguese speaking only), local support should be asked for this rapid action.

- Verify SYNOP data communication (from the two airport AWS) to the WMO RTH Congo Brazzaville and WMO GTS, and ingestion in the WMO-GQDBMS. INM could inspect its software (MESSIR-COM/NET) message switching system and/or hardware components, incl. communication infrastructure (network: access point, switches, routers, etc.) and its SOP (Standard Operation Protocols) for its personnel in this respect.

- Initiate WIS2.0 Data Communication Capacity Development

  Hourly data communication in the new WMO WIS2.0 communication system, will require automated data transmission protocols, to be implemented by INM. Manually sending hourly data on a continuous basis e.g., "SYNOP – horaire in MESSIR-COM" remains cumbersome and rather unfeasible (e.g., change of aviation weather personnel work shifts, etc.). An important gap here is staff capapcity for operating WIS2.0-in-box. The staff of INM is yet not (at all) knowledgeable in the WIS2.0 data protocols, software tools and coding language (i.e., Python v3). An urgent need for capacity development by preference in a bilingual format (English/Portuguese) is therefore present. Learning of these new Free and Open Source (FOSS) data communication environments (i.e. Python) will require a capacity development traject (e.g. continuing support by peer-advisor a/o other education or training partners). We can propose regional Atlantic SIDS training for the purpose (in bilingual formats EN/Pt…), as a language barrier was noted during the Readiness phase on-site visit by the peer-advisor and consultant (end Jan/Feb 2024).

4. Report completion signatures

Peer Advisor signature

Rubert Konijn
KNMI Strategic Business Manager Climate

WMO Technical Authority screening remarks and signature

Beneficiary Country remarks and signature

Annex 1: Succint overview of the weather and climate observation station infrastructure of STP

Synoptic stations

Currently, two airport weather observation stations with WMO-IDs: 61931 (Sao Tomé), 61934 (Principe) are classified as Synoptic Aeronautical AWS (see Figure 3). They are owned and operated by INM for ENASA[12]. These manned stations operate on a continuous 24/7 basis, with Metar/Taf observations made on a hourly basis, serving aeronautical purposes. METAR/TAF hourly messages of WMO-ID 61931 can be traced on aviation weather data gateways and international data servers. SYNOP messages from São Tomé airport are send, but with irregular frequency[13] to the Congo Brazzavile WMO RTH. Príncipe airport has issues in sending SYNOP and METAR/TAF data to international data gateways (i.e., empty Synop strings received e.g., "AAXX 12154 61934 NILL ==").

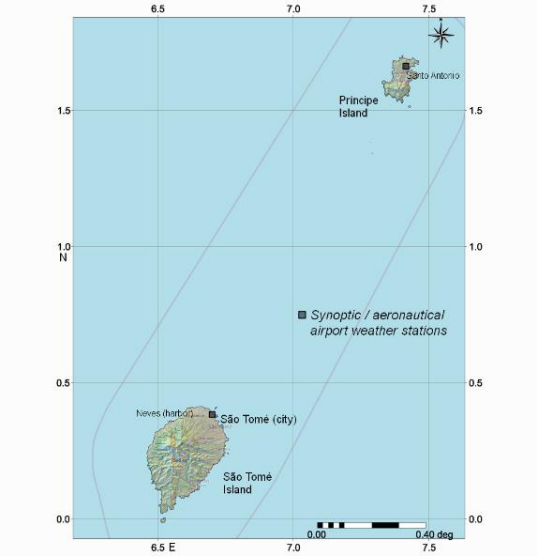


Figure 3: Synoptic - Aeronautical stations of STP

Aeronautical stations

The airport stations all are ICAO coded (FPST for São Tomé and FPPR for Príncipe airport). The airport AWS use VHF radio communication to send data to the airport (ENASA) aviation meteorology and daily weather prediction section (manned by INM). The data are further send to the WMO RTH or Regional Telecommunication Hub in Congo Brazzaville. The ICAO's AMHS Aeronautic Message Handling System and Authormated Fixed Telecommunication Network is also used to transmit messages for aviation.

Climate AWS stations

Next to its 2 aeronautical stations, INM operates (survey data Jan, 2024) in total 16 other AWS, dedicated to support weather and climate monitoring for other socio-economic sectors and purposes (Figure 4).

Seven (7) AWS were set-up in 2016 in the framework of "SAP", a Hydromet Early Warning System project (see footnote 14) across the two islands (4 on São Tomé, 3 on Príncipe). These stations monitor a variable number of weather parameters (Temperature, Humidity, Precipitation, Wind, Surface Level Pressure, Radiation). Two (2) other AWS are in operation since 2011 on São Tomé.

[12] ENASA: " Empresa Nacional dos Aeroportos & Segurança Aerea

[13] Synop data availability checks on global data gateways (dates: Jan 30 and Feb, 05, 06 and 10, 2024; by cm)

In the framework of the regional WACA or Western Africa Coastal Area Management program (Worldbank/GFDRR), nine (9) AWS were recently (2023) installed or recovered and are operational. Two WACA AWS stations also serve maritime purposes (Ana Chaves and Neves harbors). The two main airport AWOS are also included in this project (renewal, instrument replacement, etc.).

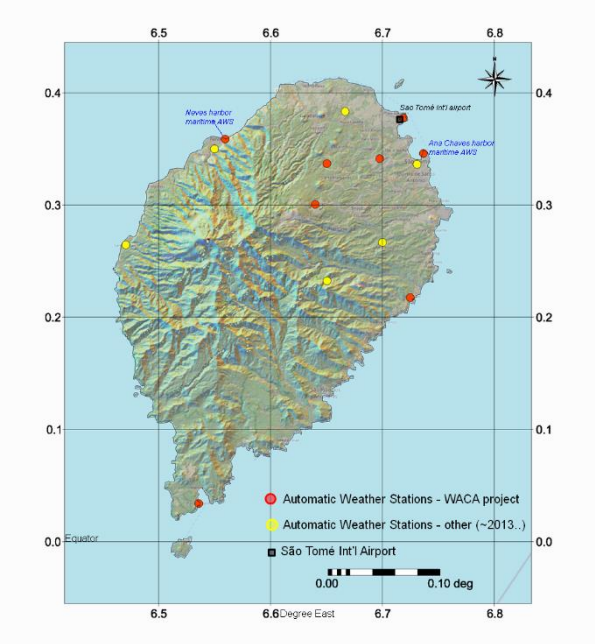
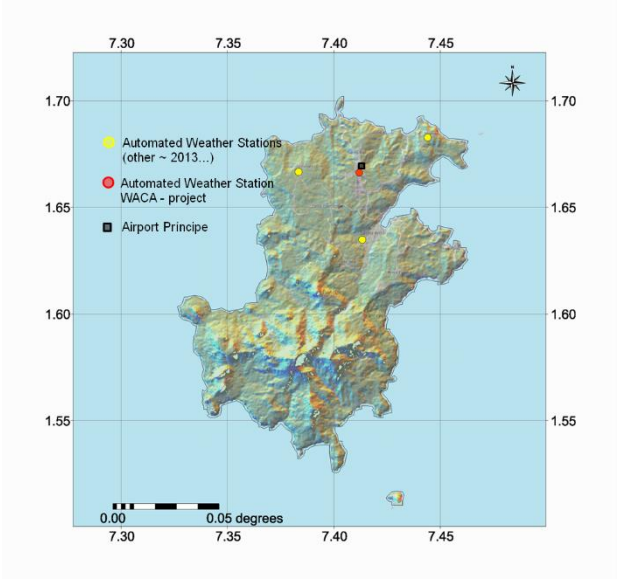


Figure 4a-b: Automated weather station (AWS) network of STP

Aeronautical stations communicate through VHF to the ENASA / INM meteorology section. Other station data are transferred via GPRS to INM and managed using a cloud-based Data Storage System (AmbiDS © Ambimetric, Pt).

Maritime AWS stations

INM operates two (2) maritime AWS stations operating in the 2 main international harbors, Ana Chaves and Neves on São Tomé. These weather stations are also equipped with a tidal gauge. NRT data transmission is via GPRS to the INM Headquarters data server.



Aerology – Upper Air Station (UAS)

The INM Head Office at São Tomé airport has an old (defunct) Upper-Air Sounding site (only old building remnants leftover), functional until the mid 1970's.

AWS linked to Hydrometrical network

The Directorate General of Natural Resources and Energy, resorting under the Ministry of Environment, manages a number of automated streamflow gauging stations, in the framework of flash flood Early Warning and for other hydrologicalpurposes (river flow monitoring)[14].

[14] Hydrometrical & AWS stations were setup in the framework of the SAP (Sistema de Alerte Previa) project (2016), implemented by UNDP with international partners and C^{o} (e.g., ADASA, Spain and others).

These stations (see Figure 5) are also equipped with AWSs. Stations and data are managed by the DGRNE and INA, but also INM receives available data (via GPRS). This network is in operation since 2016, but requires recovery[15]. Also on Príncipe, a hydrometric station is planned.

Third-party weather observations

A few private companies (e.g., AgriPalma C^{o} with oil palm plantations in the South of São Tomé Island) also engage in a local weather monitoring using own AWS. They are not linked to the INM.

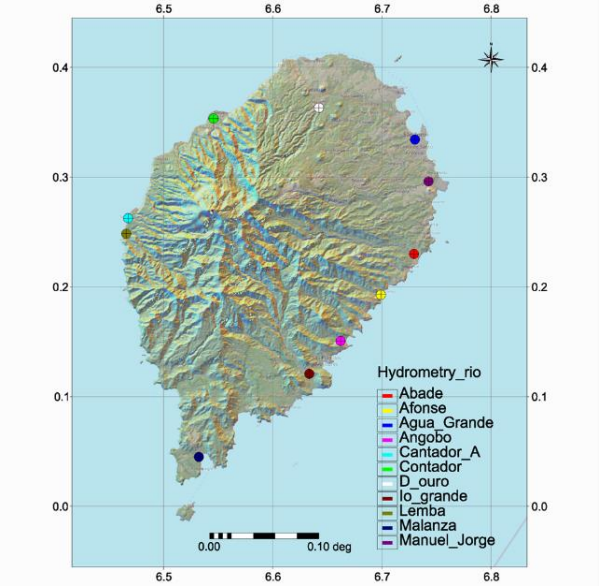


Figure 5: Hydrometric station network of STP

[15] Station recovery efforts are in planning through the WACA+ (project extension)