



Projet / Project:
**Développement de l'énergie solaire
en Afrique subsaharienne /**
Solar Development in Sub-Saharan Africa

CAMPAGNE DE MESURES SOLAIRES EN AFRIQUE DE L'OUEST /
*SOLAR RESOURCE MEASUREMENT CAMPAIGN IN WEST
AFRICA*

***Rapport d' Installation Station Météorologique
Automatique /***
Automatic weather station installation report

Lossa - Niger / Lossa - Niger

Janvier 2022 / January 2022

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Table des matières / Contents

Table des matières / Contents	2
1 Résumé / Summary	4
2 Description du site / Site description	5
2.1 <i>Emplacement / Location</i>	5
2.2 <i>Environnement et ombrage / Surroundings and shading profile</i>	6
3 Configuration et disposition de la station météorologique automatique / Automatic weather station configuration and layout	7
3.1 <i>Équipement de mesure / Measurement equipment</i>	7
3.2 <i>Disposition de la station / Station layout</i>	8
3.3 <i>Mesures, transmission et analyse des données / Data measurement, transmission and analysis</i>	10
4 Installation et mise en service de la station / Station installation and commissioning	12
4.1 <i>Tâches accomplies et calendrier d'installation / Completed tasks and installation timeline</i> ...12	
5 Liste de contrôle de l'installation / Installation checklist	15
6 Documentation photographique / Photographic documentation	18
7 Procédures de maintenance / Station Maintenance procedures	26
8 Données de mesure / Measurement data	27
9 Certificats d'étalonnage / Calibration certificates	32
9.1 RSI pyranometer (DHI,DNI).....	33
9.2 CMP10 pyranometer (GHI).....	35
9.3 #40C anemometer.....	39
9.4 #200M Wind vane.....	41
9.5 CS106 (PTB110) barometer.....	42

Résumé d'installation et du site / Site and installation summary	
<i>Client / Client:</i>	<i>Système d'Échanges d'Énergie Électrique Ouest Africain (EEEOA) / West African Power Pool (WAPP)</i>
<i>Site / Site:</i>	<i>Sous-station de NIGELEC, Lossa, Niger / NIGELEC substation, Lossa, Niger</i>
<i>Coordonnées / Coordinates :</i>	<i>13.94701°N, 1.57469°E, altitude: 205 m</i>
<i>Type de station / Station type :</i>	<i>Tier2 station météorologique automatique / Tier2 automatic weather station</i>
<i>Date de mise en service / Date of commissioning :</i>	<i>2022-01-22</i>
<i>Démarrage de la campagne de mesure / Start of measurement campaign</i>	<i>2022-01-23</i>
Mise en service / Commissioning	
<i>Installation et mise en service effectuées par</i> Installation and commissioning performed by <i>Date : 22 Janvier 2022/</i> Date : 22 January 2022	<i>Installation sur place / Installation on site :</i> Chaibou Saley <i>Mise en service à distance / Remote commissioning :</i> Pablo Cádiz, CSP Services

1 Résumé / Summary

Dans le cadre du projet "Développement de l'énergie solaire en Afrique subsaharienne, campagne de mesure solaires en Afrique de l'Ouest", une station météorologique automatique (SMA) a été installée au Niger pour la mesure de l'irradiance solaire et d'autres paramètres pertinents pour le développement de projets de centrales solaires. La station a été installée dans la sous-station de la NIGELEC à Lossa.

Le but de cette installation est de collecter deux ans de données de mesure au sol pour la centrale photovoltaïque (PV) à l'échelle du service public prévue à l'endroit décrit. Les paramètres de mesure sont principalement l'irradiation horizontale globale (GHI), l'irradiation normale directe (DNI) et l'irradiation horizontale diffuse (DHI). En outre, sont mesurés la température et l'humidité relative, la pression barométrique, la pluie, la vitesse et la direction du vent, ainsi que le taux d'encrassement des modules PV et le taux de corrosion de différents échantillons métalliques.

Les données de mesure de la station sont transférées à CSPS à intervalles réguliers pour le suivi et le contrôle de la qualité des données. De plus, les données sont disponibles sur un serveur web protégé pour une surveillance et un téléchargement des données en temps réel.

CSPS appliquera des tests quotidiens de qualité des données et enverront les données de mesure finales contrôlées par la qualité à intervalles mensuels aux destinataires définis par le client.

Du personnel sous-traité localement est chargé de l'entretien et du nettoyage des capteurs. La personne responsable était présente le dernier jour de l'installation et a été informée des procédures de maintenance et de nettoyage.

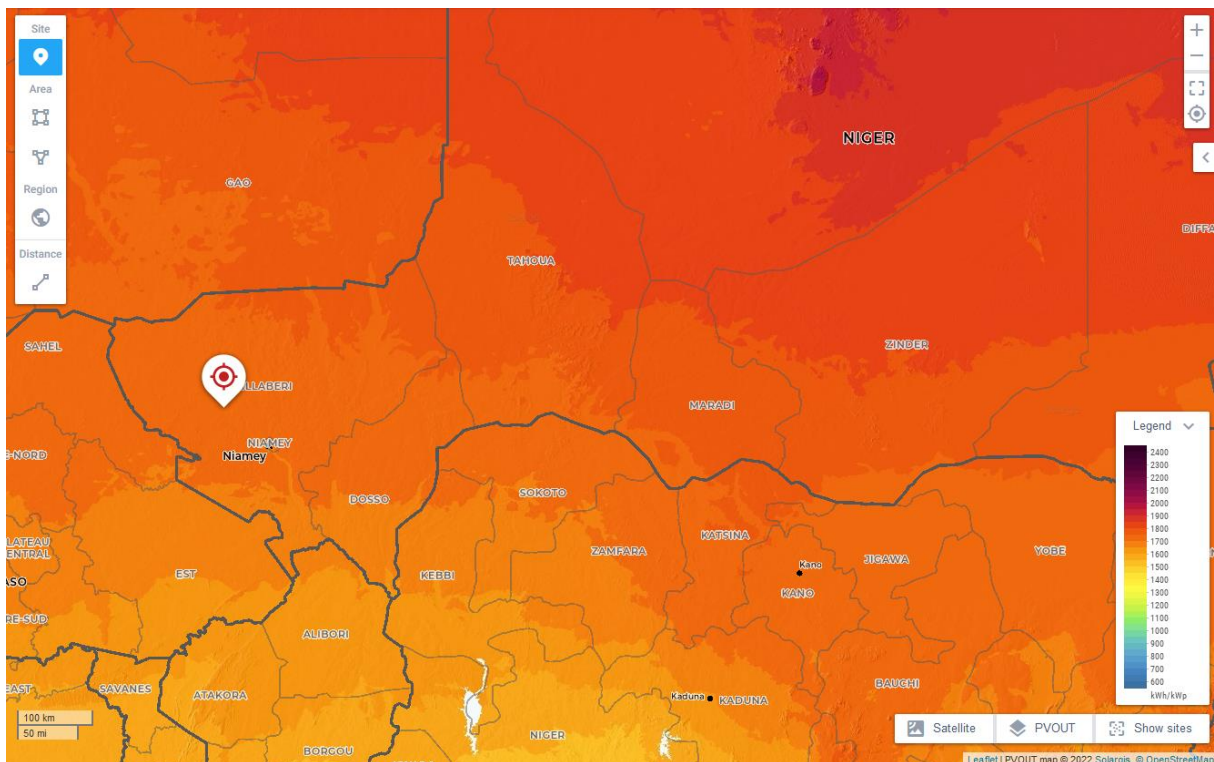


Figure 1: Site de Lossa au Niger (source : globalsolaratlas.info) / Lossa site in Niger.

In the framework of the project "Solar Development in Sub-Saharan Africa, Solar resource measurement campaign in West Africa", an automatic weather station (AWS) was installed in Niger for the measurement of the solar irradiance and other parameters relevant for the development of solar energy power plant projects. The station was installed at the NIGELEC substation in Lossa.

The purpose of this installation is to collect two years of ground measurement data for the planned utility scale photovoltaic (PV) power plant at the described location. Measurement parameters are primarily global horizontal irradiance (GHI), direct normal irradiance (DNI) and diffuse horizontal irradiance (DHI). Further, temperature and relative humidity, barometric pressure, rain, wind speed and

direction as well as the soiling rate on PV modules and the corrosion rate on different metal samples is measured.

Measurement data from the station are transferred to CSPS in regular intervals for data quality monitoring and control. Additionally, the are available on a protected web server for real time data monitoring and download.

CSP Services will apply daily data quality tests and send quality-controlled final measurement data in monthly intervals to the client-defined recipients.

Local subcontracted staff is in charge of the maintenance and sensor cleaning. The responsible person was present on the last day of the installation and was briefed on the maintenance and cleaning procedures.

2 Description du site / Site description

2.1 Emplacement / Location

Site / Site :	Lossa / Lossa
Cordonnées / Coordinates :	13.94701°N, 1.57469°E, altitude: 205 m
Climat / Climate :	Climat désertique chaud / Hot desert climate (Köppen-Geiger Bwh, (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006))

Table 1: Informations de l'emplacement / Location information.



Figure 2: Emplacement dans la sous-station de NIGELEC à Lossa/ Location at the NIGELEC substation in Lossa.

2.2 Environnement et ombrage / Surroundings and shading profile

Les environs immédiats sont plats avec quelques installations à l'ouest et à l'est. Après l'installation de la station météorologique automatique, des photos de l'horizon dans toutes les directions ont été prises à partir de l'emplacement des capteurs d'irradiance et une vue panoramique a été générée à partir de ces photos.

La Figure 3 montre l'image panoramique avec la ligne d'horizon et la course du soleil tout au long de l'année.

The immediate surroundings are flat with some facilities to the west and east. After the installation of the automatic weather station, pictures of the horizon in all directions were taken from the location of the irradiance sensors and a panoramic view was generated from these pictures.

Figure 3 shows the panoramic picture with the horizon line and the sun path throughout the year.



Figure 3: Ligne d'horizon du point de vue du pyromètre et course du soleil tout au long de l'année / Horizon line from the perspective of the pyranometer and sun path throughout the year.

La Figure 4 montre l'analyse de la ligne d'horizon et les occurrences d'ombrage attendues sur les mesures de données d'irradiation. L'analyse montre un champ de vision presque libre pour les capteurs, sauf dans la direction de l'est où certaines installations pourraient causer un peu d'ombre au lever du soleil pendant l'été.

Figure 4 shows the analysis of the horizon line and the expected shading occurrences on the irradiance data measurements. The analysis shows an almost free field of view for the sensors, except in east direction where some facilities might cause some shading at sunrise during the summer.

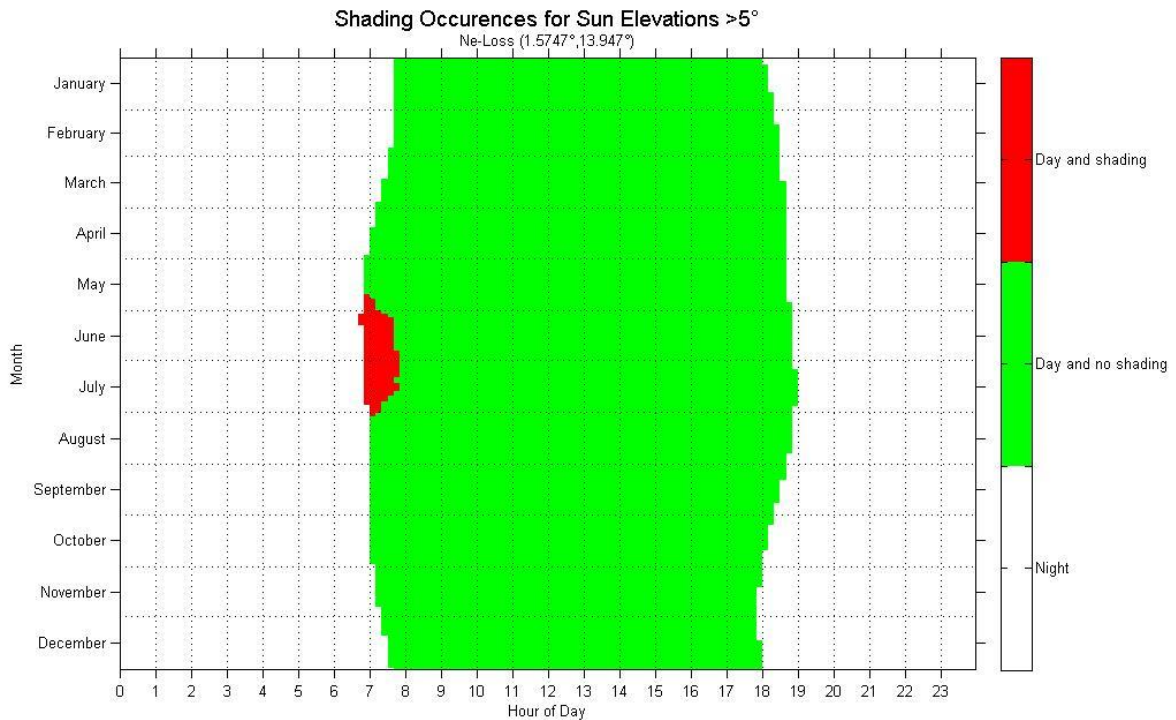


Figure 4: Ombrage pour l'élévation du soleil > 5° / Shading occurrences for sun elevations >5°.

3 Configuration et disposition de la station météorologique automatique / Automatic weather station configuration and layout

Cette section donne une vue d'ensemble de l'équipement installé et des capteurs avec leurs numéros de série respectifs. En outre, un plan de la station météorologique telle qu'elle a été construite est présenté.

This section gives an overview of the installed equipment and sensors with respective serial numbers. Further, a layout drawing of the weather station as built is shown.

3.1 Équipement de mesure / Measurement equipment

Équipement et numéros de série / Equipment and serial numbers		
Station météorologique automatique / Automatic weather station	CSP Services Tier2 / CSP Services Tier2	CSPS.MT.21.226
Boîtier de contrôle / Main control box	CSP Services Tier2 / CSP Services Tier2	CA.21.202.0001
Enregistreur de données / Datalogger	Campbell CR1000X	22464
Modem / Modem	Teltonika RUT240 LTE Router	1110490769
Alimentation électrique / Power supply	Alimentation électrique autonome avec panneaux PV et batterie / Autonomous power supply with PV panels and battery	-

Paramètre mesuré / Measured parameter	Unité / Unit	Type de capteur / Sensor type	Numéro de série / Serial Number
DHI, DNI	W/m ²	CSP Services Rotating Shadowband Irradiometer (installé à 2m du sol) / CSP Services Rotating Shadowband Irradiometer (installed 2m above ground)	DR.20.201.0003 MS.19.201.0006
GHI	W/m ²	Pyranomètre Kipp&Zonen CMP10 (installé à 2m du sol) / Kipp&Zonen CMP10 pyranometer (installed 2m above ground)	210857
Température / Temperature (T)	°C	Capteur de température et d'humidité Hygrovue5 avec écran anti-rayonnement RAD06 (installé à 1,5 m du sol) / Hygrovue5 T/RH sensor with RAD06 radiation shield (installed 1.5m above ground)	E2856
Humidité / Humidity (RH)	%		
Pression barométrique / Barometric pressure (BP)	hPa	Capteur de pression Vaisala PTB110 (CS106) / Vaisala PTB110 (CS106) pressure sensor	S4950666
Précipitations (pluie) / Precipitation (Rain)	mm	Campbell Scientific 52203 (installé à 2m du sol) / Campbell Scientific 52203 (installed 2m above ground)	TB 16364
Vitesse du vent / Wind speed (WS)	m/s	Anémomètre NRG #40C Classe 1 (installé à 10m du sol) / NRG #40C Class 1 anemometer (installed 10m above ground)	179500332899
Direction de vent / Wind direction (WD)	°N	Girouette NRG #200M (installée à 10m du sol) / NRG #200M wind vane (installed 10m above ground)	1007000008939

Paramètre mesuré / Measured parameter	Unité / Unit	Type de capteur / Sensor type	Numéro de série / Serial Number
Taux d'encrassement / Soiling rate	%	CSP Services système de mesure de l'encrassement des services PV / CSP Services PV soiling measurement system	MS.21.201.0026
Taux de corrosion / Corrosion rate	%	Échantillonneur de corrosion Fraunhofer avec 12 échantillons métalliques normalisés d'aluminium, d'acier au carbone, de zinc et de cuivre (trois échantillons de chaque métal) / Fraunhofer corrosion sampler with 12 standardized metal samples of aluminum, carbon steel, zinc and copper (three samples from each metal)	MT.21.226

Informations sur les capteurs et systèmes de mesure sont décrites dans la documentation de spécifications de la station Tier2. Pour les certificats d'étalonnage des capteurs, voir le chapitre 9.

Further information on the listed sensors and measurement systems can be found in the station specification documentation. For calibration certificates of sensors see chapter 9.

3.2 Disposition de la station / Station layout

La disposition la station Tier2 est illustrée dans les figures ci-dessous. Les principaux composants sont la structure de montage avec les capteurs d'irradiance et le mât de mesure du vent avec des capteurs supplémentaires.

The layout of the Tier2 AWS is shown in the figures below. The main components are the mounting structure with the irradiance sensors and the wind mast with additional sensors.

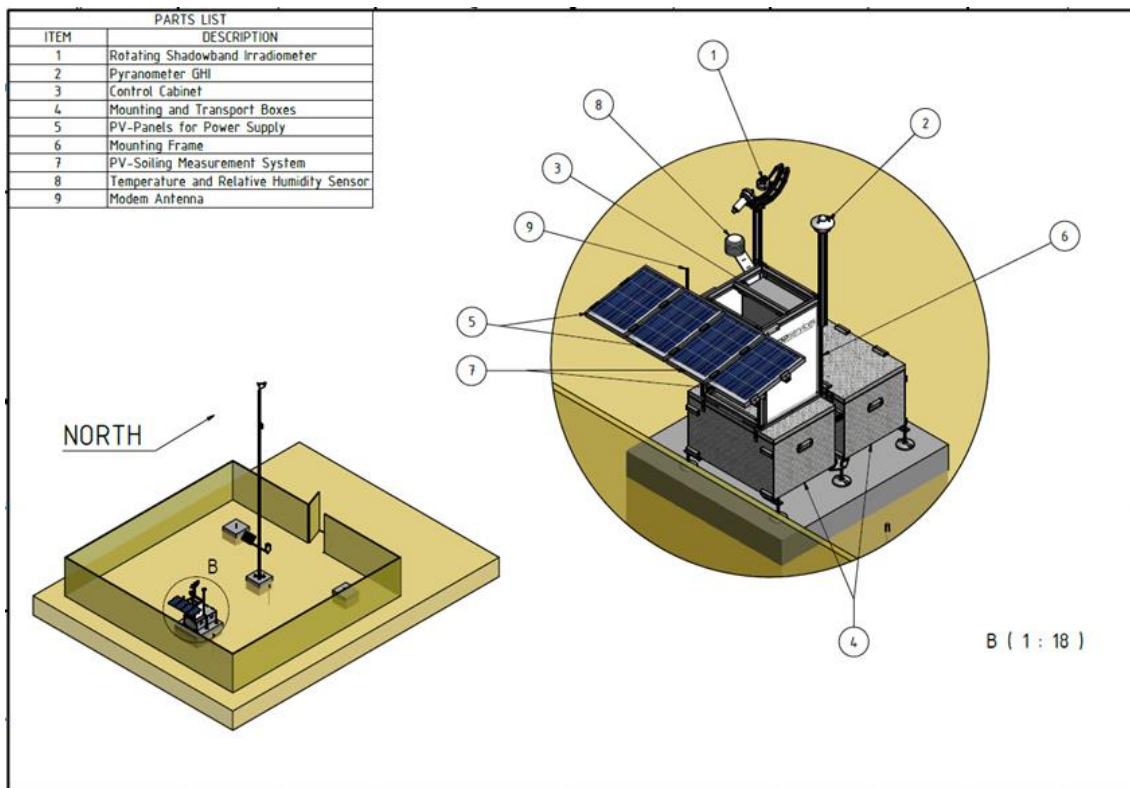


Figure 5: Disposition de la station météorologique automatique Tier2: Capteurs d'irradiance, système de mesure du taux de salissure PV, panneaux PV pour l'alimentation électrique / Tier2 automatic weather station layout: Irradiance sensors, PV soiling rate measurement system, PV panels for power supply.

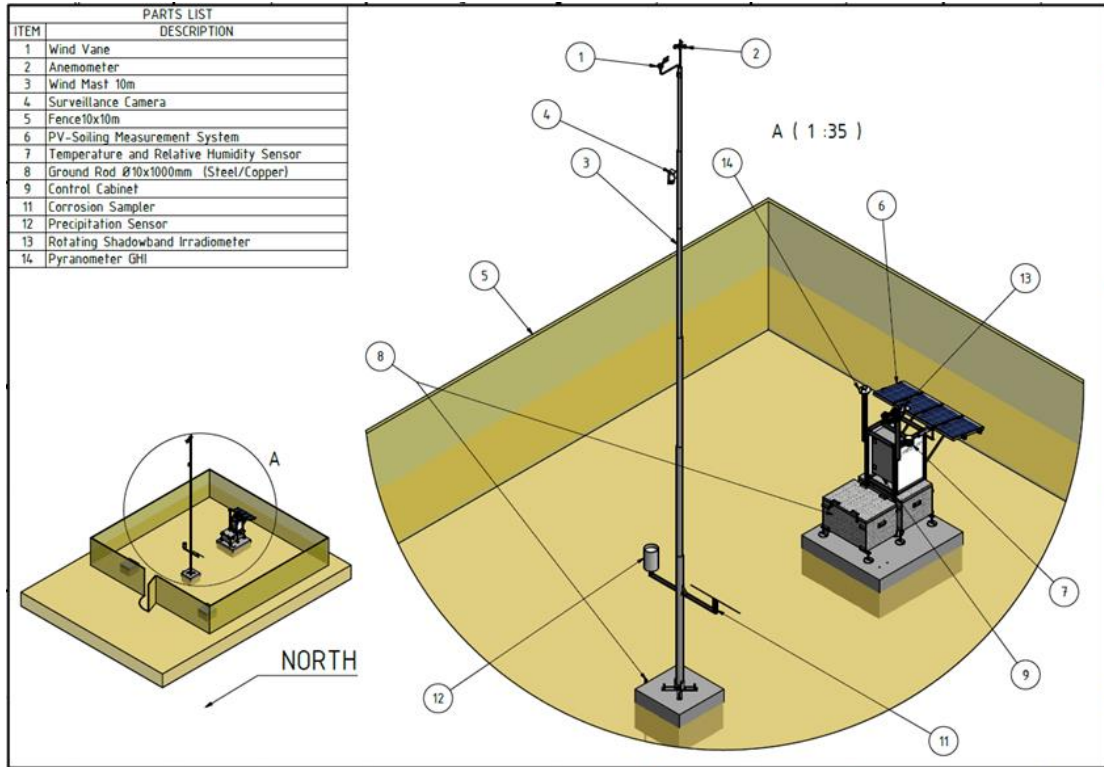


Figure 6: Disposition de la station météorologique automatique Tier2 : détails du mât éolien de mesure et des capteurs de vent / Tier2 automatic weather station layout: wind mast and wind sensors details.

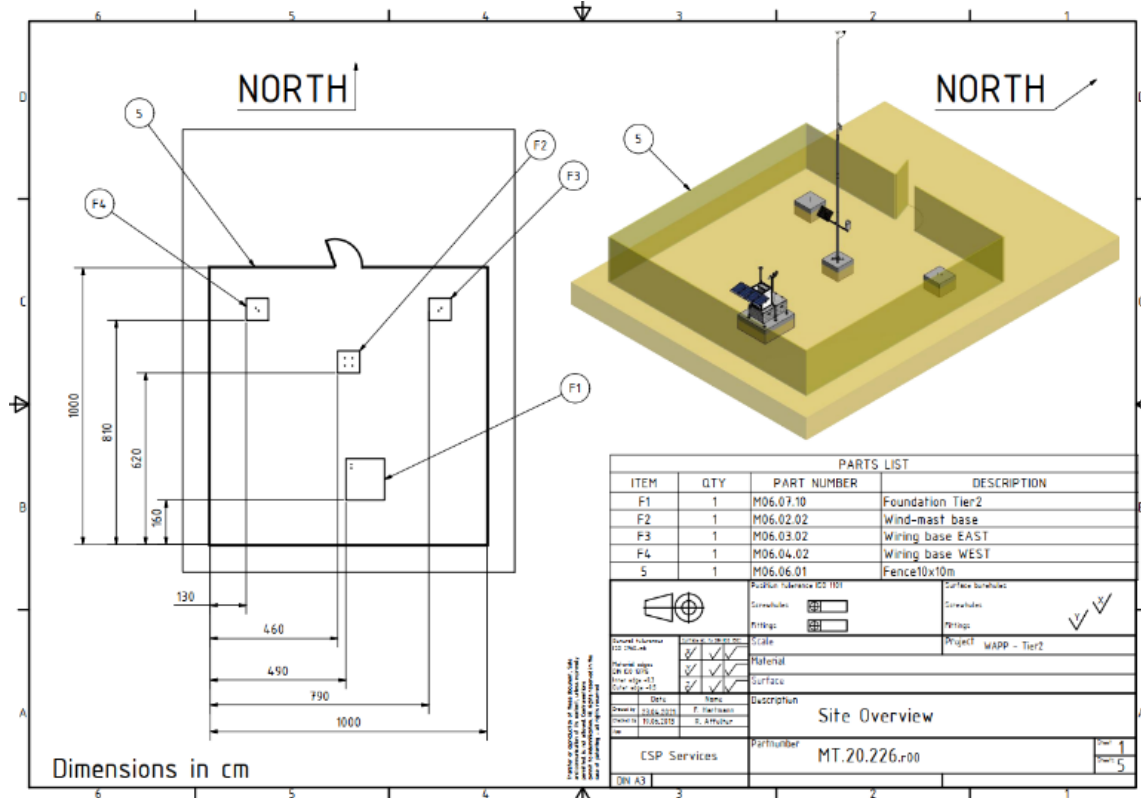


Figure 7: Disposition de la station météorologique automatique Tier2 : détails des fondations / Tier2 automatic weather station layout: foundation detail.

Le mât de mesure du vent est ancré aux fondations de la base de mat et aux fondations des câbles d'haubanage. La station elle-même est fixée à la fondation principale.

Les dimensions et les distances sont indiquées dans les dessins de fondation dans la Figure 7 ci-dessus. La hauteur de la clôture est de 2m. La distance entre le système PV-Soiling et la clôture est d'environ 1.8m.

The wind mast is anchored to the wind mast foundations and guying rope foundations. The station itself is fixed to the main foundation.

The dimensions and distances are shown in the foundation drawings in Figure 7. The height of the fence is 2m. The distance of the PV-Soiling system to the fence is approximately 1.8m.

3.3 Mesures, transmission et analyse des données / Data measurement, transmission and analysis

Les signaux des capteurs sont mesurés à une fréquence de 1 Hz et stockés dans des tables de données moyennes sur 1 minute et 10 minutes dans la mémoire interne de l'enregistreur de données, incluant les valeurs max, min et dév. std.

Les données de mesure sont envoyées aux serveurs de CSPS en temps réel via un routeur 4G LTE avec une carte SIM d'un opérateur local.

Les données de mesure sont envoyées en parallèle au serveur de traitement des données CSPS et au serveur web pour l'accès par le client permettant le téléchargement des données (voir section 7). Elles sont stockées dans la mémoire interne de l'enregistreur de données pendant plus de 3 mois. En cas de problèmes de réseau prolongés, les données peuvent être récupérées après que ceux-ci aient été résolus ou manuellement sur site via un accès USB direct à l'enregistreur de données si nécessaire.

En parallèle avec les données de mesure, les images de la caméra de surveillance sont transmises au serveur CSPS à intervalles réguliers.

L'état de communication du routeur LTE et les paramètres de la configuration mobile (Auto APN) sont illustrés à la Figure 8. L'utilisation des données dépend principalement de la quantité d'images et de vidéos transmises par la caméra et devrait être inférieure à 1 GB/mois en fonctionnement normal.

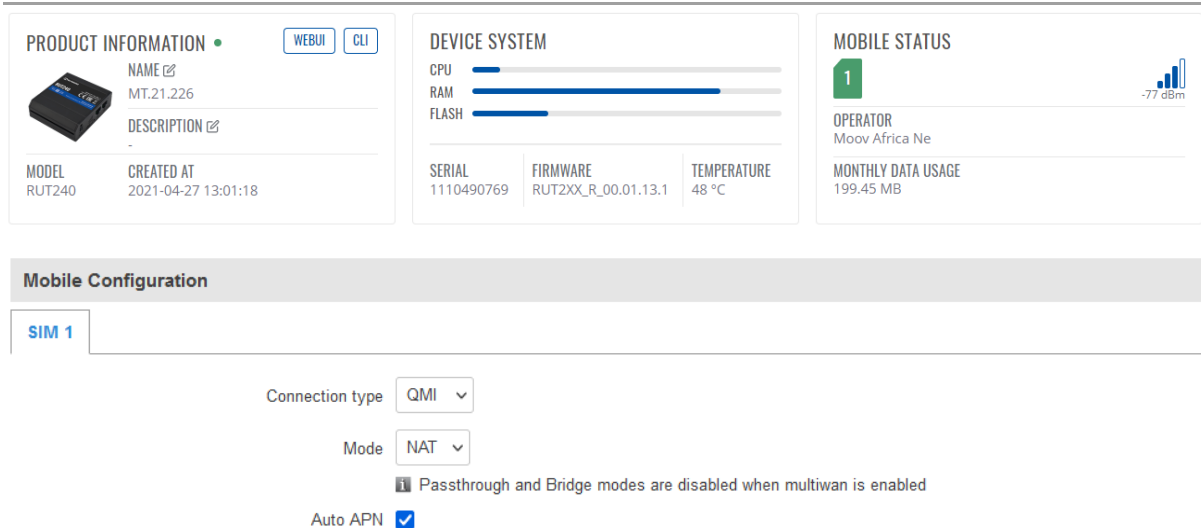
The sensor signals are scanned with a frequency of 1 Hz and stored in 1-minute and 10-minute average data tables in the datalogger's internal memory together with the max, min and StDev values.

The measurement data is sent to the CSPS servers in real time through a 4G LTE router with a SIM card from a local operator.

The measurement data is sent in parallel to the CSPS data processing server and the web server for client access for data monitoring and download (see section 7). It is stored in the internal memory of the datalogger for more than 3 months. In case of prolonged network issues, the data can be retrieved after the network issues have been resolved or manually on site via direct USB access to the datalogger if necessary.

Together with the measurement data, pictures from the surveillance camera are transmitted to the CSPS server in regular intervals.

The communication status of the LTE router and the settings of the mobile configuration (Auto APN) is shown in Figure 8. The data usage depends mainly on the amount of transmitted pictures and videos from the camera and is expected to be less than 1 GB/months during normal operation.



The screenshot displays the router's configuration page, divided into several sections:

- PRODUCT INFORMATION:** Includes fields for NAME (MT.21.226), DESCRIPTION, MODEL (RUT240), and CREATED AT (2021-04-27 13:01:18). Buttons for 'WEBUI' and 'CLI' are visible.
- DEVICE SYSTEM:** Shows resource usage for CPU, RAM, and FLASH. It also lists SERIAL (1110490769), FIRMWARE (RUT2XX_R_00.01.13.1), and TEMPERATURE (48 °C).
- MOBILE STATUS:** Displays signal strength (-77 dBm), OPERATOR (Moov Africa Ne), and MONTHLY DATA USAGE (199.45 MB).
- Mobile Configuration:** A section for SIM 1 with settings for Connection type (QMI), Mode (NAT), and Auto APN (checked). A note states: "Passthrough and Bridge modes are disabled when multiwan is enabled".

Figure 8: État de communication du routeur LTE pour la transmission de données / Communication status of LTE router for data transmission

Pour les procédures de contrôle de la qualité des données, CSPS effectue les tâches suivantes pour assurance de la qualité / contrôle de la qualité (AQ/CQ) des données :

- Téléchargement régulier de données via le réseau de téléphonie mobile (normalement en temps réel).
- Vérification du bon fonctionnement de l'équipement, coordination du personnel de maintenance local.
- Analyse des données, y compris le contrôle de la qualité des données et l'établissement de rapports conformément aux normes internationales.
- Correction des valeurs apparemment erronées et comblement des lacunes (lorsque cela est possible et raisonnable).
- Supervision de la fréquence de maintenance, nettoyage correct du capteur, analyse de l'encrassement du capteur.

For the data quality control procedures, CSPS performs the following tasks for data quality assurance and control (QA/QC):

- Regular data retrieval via mobile phone network (usually in real time).
- Check of correct operation of the equipment, coordination of local maintenance staff.
- Data analysis including data quality screening and reporting according to international standards.
- Correction of apparently erroneous values and gap filling (where possible and reasonable).
- Supervision of maintenance frequency, correct sensor cleaning, analysis of sensor soiling.

4 Installation et mise en service de la station / Station installation and commissioning

L'installation et la mise en service de la station ont été terminés le 2022-01-22. Avant l'installation de la station, le site a été préparé avec des fondations pour l'installation stable et sécurisée de la station météorologique automatique pour la période de la campagne de mesure.

Ce chapitre décrit le calendrier d'installation et les tâches accomplies jusqu'à la mise en service, ainsi qu'une liste de contrôle pour l'achèvement de l'installation et la fonctionnalité de celui-ci.

Une documentation photographique complète du processus d'installation est présentée au chapitre 6.

The station installation and commissioning were completed on 2022-01-22. Before the installation of the station, the site was prepared with foundations for the stable and secure installation of the automatic weather station over the entire measurement period.



This chapter describes the installation timeline and the accomplished tasks up to the commissioning as well as a checklist for the installation completion of the installation and functionality tests of the equipment.



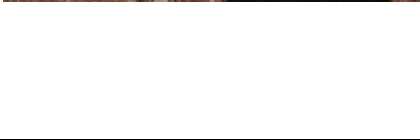

A complete photographic documentation of the installation process is given in chapter 6



4.1 Tâches accomplies et calendrier d'installation / Completed tasks and installation timeline

Les préparatifs du site ont été effectués en septembre 2021 et l'installation de la station en janvier 2022. Le tableau ci-dessous détaille chaque tâche réalisée et son délai d'exécution.

The site preparations were performed in September 2021 and the station installation in January 2022. The table below details each completed task and its completion time.

Date d'achèvement Completion date	Tâche / Task	Photo / Picture
2021-09-24	<p>Détermination de l'emplacement de la station et de la direction du nord. Marquage du périmètre et vérification de l'emplacement et de l'orientation corrects.</p> <p>Determination of the station location and the north direction. Perimeter marked and correct location and orientation verified.</p>	
2021-09-24	<p>Préparation du terrain et des fondations.</p> <p>Preparation of the ground and the foundations.</p>	

Date d'achèvement Completion date	Tâche / Task	Photo / Picture
<p>2021-09-24</p>	<p><i>Mise en place des blocs de ciment et coulage des fondations.</i></p> <p>Positioning of the cement blocks and casting of the foundations.</p>	
<p>2022-01-21</p>	<p><i>Installation de la structure de montage et du boîtier de contrôle des mesures.</i></p> <p>Installation of the mounting structure and measurement control box.</p> <p><i>Installation du système de mesure de l'encrassement des modules PV (PV-S) :</i></p> <ul style="list-style-type: none"> • <i>Structure de montage du panneau PV installée</i> • <i>Panneaux PV à couche mince montés sur la structure, orientation vers le sud</i> • <i>Capteurs de température des panneaux PV installés à l'arrière des panneaux</i> <p>Installation of the PV module soiling measurement system (PV-S):</p> <ul style="list-style-type: none"> • PV panel mounting structure installed • PV thin-film panels mounted on structure, orientation towards south • PV panel temperature sensors installed on panel backsides 	
<p>2022-01-21</p>	<p><i>Installation de la structure de montage et du boîtier de contrôle des mesures.</i></p> <p>Installation and connection of the irradiance and other meteorological sensors.</p>	
<p>2022-01-21</p>	<p><i>Vérification du nivellement et de l'inclinaison de la structure des panneaux PV. Connexion du système de mesure de l'encrassement PV-S et des panneaux d'alimentation.</i></p> <p>Verification of the PV panel structure levelling and inclination. Connection of the PV-S soiling measurement system and the power supply panels.</p>	

Date d'achèvement Completion date	Tâche / Task	Photo / Picture
<p>2022-01-22</p>	<p><i>Installation du mât de 10m avec des capteurs de vitesse et de direction du vent, le capteur de direction du vent étant orienté vers le nord.</i></p> <p>Installation of 10m wind mast with wind speed and wind direction sensors, wind direction sensor oriented towards north</p>	
<p>2022-01-22</p>	<ul style="list-style-type: none"> • <i>Contrôles de fonctionnalité (ingénieurs locaux avec support à distance du personnel de CSPS)</i> • <i>Mise en service de la station (à distance par le personnel de CSPS)</i> • <i>Formation des opérateurs de l'équipe de maintenance sur site (EMS)</i> <ul style="list-style-type: none"> • Functionality checks (local engineers with remote support from CSPS staff) • Commissioning of the station (remotely by CSPS staff) • Operator training for on-site maintenance team (OMT) 	

5 Liste de contrôle de l'installation / Installation checklist

Composant Component	Point de contrôles Work item	Vérifié Checked		Commentaires Comments
		yes	no	
Fondations, clôture Foundations, fence	<i>Fondations correctement préparées</i> Foundations correctly prepared <i>Boulons filetés correctement préparés</i> Threaded bolts correctly prepared <i>Clôture correctement préparée</i> Fence correctly prepared <i>Panneaux de projet attachés</i> Project signs attached	X		(Le périmètre est déjà clôturé) (Perimeter already fenced)
Structure de support avec boîte de contrôle Support structure with Control box	<i>Supports de montage PV ajustés</i> PV mounting supports adjusted <i>Supports de capteurs étendus</i> Sensor mounts extended <i>Nivellement horizontal</i> Horizontally leveled	X		
Câblage, câbles Wiring, cables	<i>Examen visuel</i> Visual examination <i>Fusibles ok</i> Fuses ok <i>Tous les capteurs sont connectés</i> All sensors connected <i>Tous les câbles sont fixés de manière ordonnée</i> All cables orderly fixed	X		
Irradiomètre à bande d'ombre rotative Rotating Shadowband Irradiometer (RSI)	<i>Unité PU avec Licor installé</i> PU Unit with Licor installed <i>Bande d'ombre installée</i> Shadow band installed <i>Mise à niveau horizontal</i> Horizontal leveling <i>Capteurs Licor Clean</i> Licor Sensors Clean <i>Câble connecté au RSI et au boîtier</i> Cable connected to RSI and Box <i>RSI opératif</i> RSI operative	X		
Pyranomètre Pyranometer	<i>Pyranomètre installé</i> Sensors installed <i>Opérabilité des capteurs</i> Operability of sensor <i>Nivellement horizontal</i> Horizontal leveling	X		

SMA Rapport d'installation – Lossa, Niger / AWS installation report – Lossa, Niger

Composant Component	Point de contrôles Work item	Vérifié Checked		Commentaires Comments
		yes	no	
Capteur de pression barométrique	<i>Capteur installé</i> Sensor installed	X		
Barometric Pressure Sensor	<i>Échangeur de pression</i> Pressure exchange vent	X		<i>Installé à l'intérieur du boîtier de contrôle</i> Installed inside main control cabinet
Capteur de précipitations	<i>Capteur installé et mis à niveau</i> Sensor installed and leveled	X		
Precipitation Sensor	<i>Opérabilité des capteurs</i> Operability of sensor	X		
Capteur de température et humidité	<i>Capteur fixé au cadre</i> Sensor fixed to frame	X		
Mât éolien, capteurs de vitesse et de direction du vent	<i>Déploiement mât télescopique</i> Mast extended	X		<i>Extension à une longueur de 10 m</i> Extended to length of 10 m <i>Pour une tige métallique enfoncée dans le sol</i> To metal rod driven into ground
Wind tower, wind speed and direction sensors	<i>Les haubans sont fixés et tendus en toute sécurité</i> Guy wires safely attached and tense	X		
	<i>Câble de mise à la terre connecté</i> Grounding cable connected	X		
	<i>Installation de capteurs de vent</i> Wind sensors installed	X		
	<i>Orientation nord du capteur WD</i> North Orientation of WD sensor	X		
	<i>Câble fixé aux capteurs, à la tour et au boîtier</i> Cable fixed to sensors, tower and box	X		
	<i>Opérabilité des capteurs</i> Operability of sensors	X		
Système de mesure de la salissure des PV	<i>Structure de montage nivelée et alignée au sud</i> Mounting structure leveled and aligned to south	X		<i>18 degrés par rapport à l'horizontale</i> 18 degrees from horizontal
PV soiling measurement system	<i>Panneaux PV installés</i> PV panels installed	X		
	<i>Réglage de l'angle d'inclinaison</i> Inclination angle adjusted	X		
	<i>Capteurs de température du module installés</i> Module temp. sensors installed	X		
	<i>Exploitabilité du système</i> Operability of system	X		
	<i>Panneaux nettoyés</i> Panels cleaned	X		

SMA Rapport d'installation – Lossa, Niger / AWS installation report – Lossa, Niger

Composant Component	Point de contrôles Work item	Vérifié Checked		Commentaires Comments
		yes	no	
LTE router	Carte SIM insérée SIM card inserted	X		Connexion de données au serveur établie Data connection to server established
	Connexion au serveur Server connection	X		Connexion au serveur confirmée Connection to server confirmed
Enregistreur de données Datalogger	Système d'exploitation installé Operation system installed	X		Version: CR1000X Std.05.00
	Corriger les constantes du capteur dans le programme Correct sensor constants in program	X		Comparaison avec les photos des capteurs installés Compared against photographs of installed sensors
	Coordonnées correctes dans le programme Correct coordinates in program	X		Obtenu à partir du GPS Obtained from GPS
	Programme de l'enregistreur de données installé Datalogger program installed	X		Program name: Ne_Loss_2022-01-21-b_str_Enc.CR1X
	Horloge de l'enregistreur de données correcte Datalogger clock correct	X		Heure locale standard, pas d'heure d'été l'heure: UTC +1 Local standard time, no daylight saving time: UTC +1

6 Documentation photographique / Photographic documentation



Figure 9: Clôture et fondation / Fence and foundations



Figure 10 : Fondations du mât du vent / Wind mast foundations



Figure 11: Préparatifs du mât du vent / Wind mast preparations



Figure 12 : Fondations du mât du vent, câble de terre fixé au boulon de terre, tube de protection pour les câbles du mât du vent / Wind mast foundations, ground cable fixed to ground bolt, protective tube for wind mast cables



Figure 13: Marque nord du capteur de direction du vent alignée avec le cantilever de montage et la direction du nord. / Wind direction sensor north mark aligned with mounting cantilever and north direction



Figure 14: Capteurs de vent installés sur le mât du vent / Wind sensors installed on wind mast



Figure 15: Mât du vent installé capteur de direction du vent orienté vers le nord / Wind mast erected; wind direction sensor orientated to North



Figure 16: Pyranomètre CMP10 installé (GHI) / Installed CMP10 pyranometer (GHI)



Figure 17: Numéro de série du pyromètre CMP10 (GHI) / CMP10 pyranometer serial number (GHI)



Figure 18: Mise à niveau du pyromètre CMP10 (GHI) / CMP10 pyranometer leveling (GHI)



Figure 19: RSI installé (GHI,DHI) / Installed RSI (GHI,DHI)



Figure 20: Numéro de série du moteur RSI / RSI motor serial number



Figure 21 : Unité PU avec Licor installé / PU Unit with Licor installed



Figure 22 : Mise à niveau du PU / PU unit leveling



Figure 23: Capteur de pluie et échantillonneur de corrosion / Rain sensor and corrosion sampler



Figure 24: Echantillonneur de corrosion serial number / Corrosion sampler serial number



Figure 25: Numéro de série du capteur de pluie / Rain sensor serial number



Figure 26: Nivellement du capteur de pluie / Rain sensor levelling



Figure 27: Capteur T/RH / T/RH sensor



Figure 28 : Antenne du modem / Modem antenna

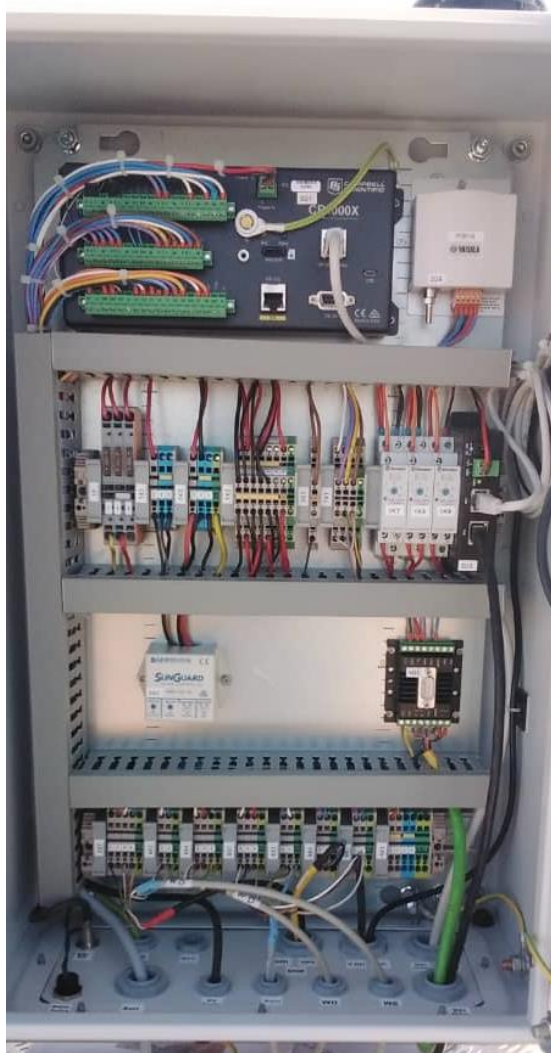


Figure 29: Intérieur du boîtier de contrôle / Control box interior.



Figure 30: Ruteur LTE / LTE router



Figure 31: Assemblage de la structure PV-S + modules et modules d'alimentation / Assembly of PV-S structure + modules. and supply modules



Figure 32: Test du système de PVS (module A) / Test of PVS system (A module)



Figure 33: Structure de support PV-S avec un angle d'inclinaison de 18° vers le sud / PV-S support structure with 18° tilt angle towards South.



Figure 34 : Structure de montage, capteurs et boîtier de contrôle avec le logo WAPP / Mounting structure, sensors and control box with WAPP logo



Figure 35 : Structure de montage, capteurs et boîtier de contrôle / Mounting structure, sensors and control box.



Figure 36 : Installation finale de la station depuis le sud-ouest / Final station installation from southwest



Figure 37 : Installation finale de la station depuis le sud / Final station installation from south

7 Procédures de maintenance / Station Maintenance procedures

La maintenance régulière sur site et le nettoyage des capteurs sont effectués par une équipe de maintenance sur site (EMS) sous contrat local. Les procédures de maintenance et de nettoyage des capteurs ont été définies avant l'installation de la station et un manuel contenant les procédures définies a été fourni à l'EMS. De plus, une formation des opérateurs a été organisée pendant la phase de mise en service de la station. Les capteurs d'irradiation et les panneaux PV du système de mesure de l'encrassement PV-S seront nettoyés conformément au tableau ci-dessous.

(La mesure du taux de salissure avec le système de mesure de la salissure PV-S est basée sur la comparaison entre un module de référence propre (module A) et un module de mesure (module B) qui peut accumuler de la salissure sur sa surface. Le module A est donc nettoyé à chaque visite de l'EMS et le module B est nettoyé une fois par mois pour relancer le cycle de mesure des salissures).

Regular on-site maintenance and sensor cleaning is performed by a locally contracted on-site maintenance team (OMT). The maintenance and sensor cleaning procedures were defined prior to the installation of the station and a manual with the defined procedures was provided to the OMT. Additionally, an operator training was held during the commissioning phase of the station. The irradiance sensors and the PV panels for the PV-S soiling measurement system will be cleaned according to the table below.

(The measurement of the soiling rate with the PV-S soiling measurement system is based on the comparison of a clean reference module (Module A) to a measurement module (Module B) which is allowed to accumulate soiling on its surface. Module A is therefore cleaned upon each visit by the OMT and Module B is cleaned once per month to restart the soiling measurement cycle.)

Capteurs Sensors	Nettoyage Cleaning		Commentaires Comments
	2 x par semaine 2 per week	1 x par mois 1 x per month	
Pyranomètre GHI GHI pyranometer	x		
Pyranomètre RSI RSI pyranometer	x		
Module PV propre (modA) Clean module (Module A)	x		
Module PV sale (modB) Dirty module (Module B)		x	Premier jour de chaque mois First day of the month

Les visites d'entretien programmées pour la maintenance étendue du système sont prévues tous les six mois pendant la durée de la campagne de mesure.

Scheduled maintenance visits for extended system maintenance are planned to be performed every six months for the duration of the measurement campaign.

8 Données de mesure / Measurement data

Les données de mesure sont accessibles sur un serveur web protégé pour un contrôle et un téléchargement des données en temps réel. De plus, CSPS fournira des rapports de données mensuels avec les données de mesure finales de qualité contrôlée. Les graphiques ci-dessous montrent des données exemplaires peu après l'installation.

The measurement data can be accessed on a protected web server for real time data monitoring and download. Additionally, CSPS will provide monthly data reports with the final quality-controlled measurement data. The graphs below show exemplary data shortly after the installation.

Station: Ne-Loss / CSPS.MT.21.226 Type: Tier 2 Station Country: Niger Site: Lossa Time zone: UTC+1 Latitude: 13.94701 °N Longitude: 1.57469 °E Altitude: 205 m	WEST AFRICAN POWER POOL Left-click on date to select begin and end date! 2022-01-23	Rawdata Right-click on table for CSV data export! <table border="1"> <thead> <tr> <th>Timestamp</th> <th>GHI_Avg</th> <th>GHI_Min</th> <th>GHI_Max</th> <th>GHI_Std</th> <th>DNI_Avg</th> <th>DNI_Min</th> <th>DNI_Max</th> <th>DNI_Std</th> <th>DHI_Avg</th> <th>DHI_Min</th> <th>DHI_Max</th> </tr> </thead> <tbody> <tr> <td>2022-01-23 00:01:00</td> <td>-5.68</td> <td>-5.75</td> <td>-5.61</td> <td>0.04</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> </tr> <tr> <td>2022-01-23 00:02:00</td> <td>-5.79</td> <td>-5.83</td> <td>-5.75</td> <td>0.02</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> </tr> <tr> <td>2022-01-23 00:03:00</td> <td>-5.87</td> <td>-5.92</td> <td>-5.82</td> <td>0.03</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> </tr> <tr> <td>2022-01-23 00:04:00</td> <td>-5.97</td> <td>-6.05</td> <td>-5.91</td> <td>0.04</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> </tr> <tr> <td>2022-01-23 00:05:00</td> <td>-6.11</td> <td>-6.18</td> <td>-6.04</td> <td>0.04</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> <td>0.00</td> </tr> </tbody> </table>	Timestamp	GHI_Avg	GHI_Min	GHI_Max	GHI_Std	DNI_Avg	DNI_Min	DNI_Max	DNI_Std	DHI_Avg	DHI_Min	DHI_Max	2022-01-23 00:01:00	-5.68	-5.75	-5.61	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2022-01-23 00:02:00	-5.79	-5.83	-5.75	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2022-01-23 00:03:00	-5.87	-5.92	-5.82	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2022-01-23 00:04:00	-5.97	-6.05	-5.91	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2022-01-23 00:05:00	-6.11	-6.18	-6.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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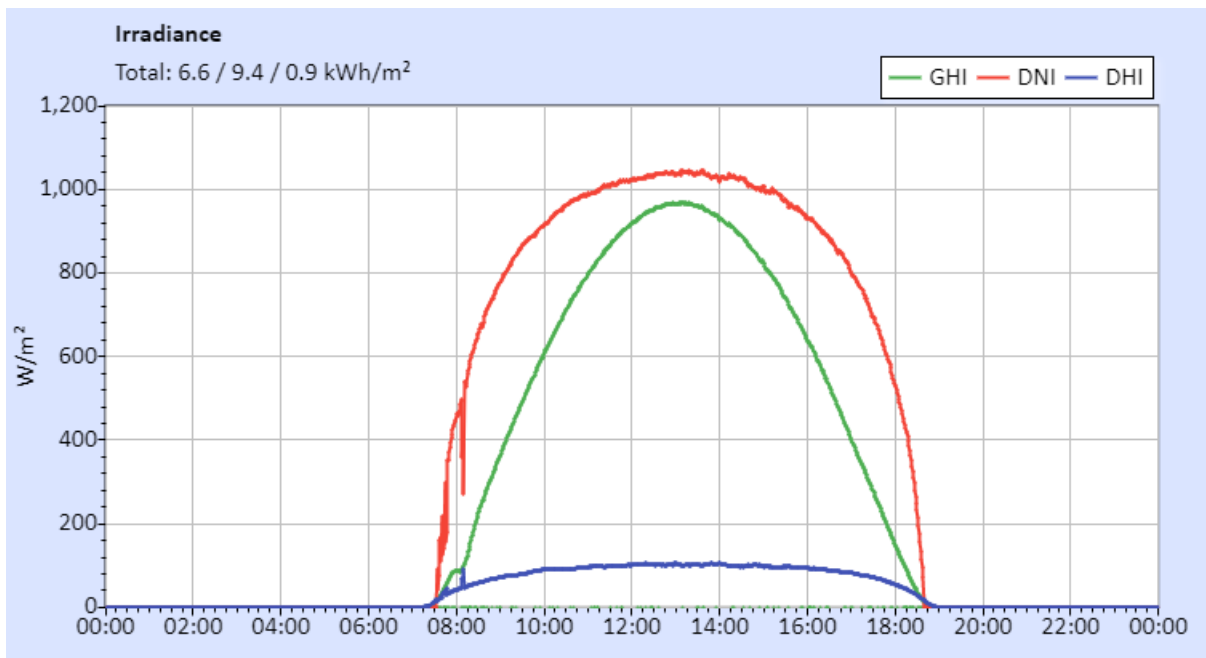


Figure 38 : Irradiance measurement. GHI, DNI and DHI.

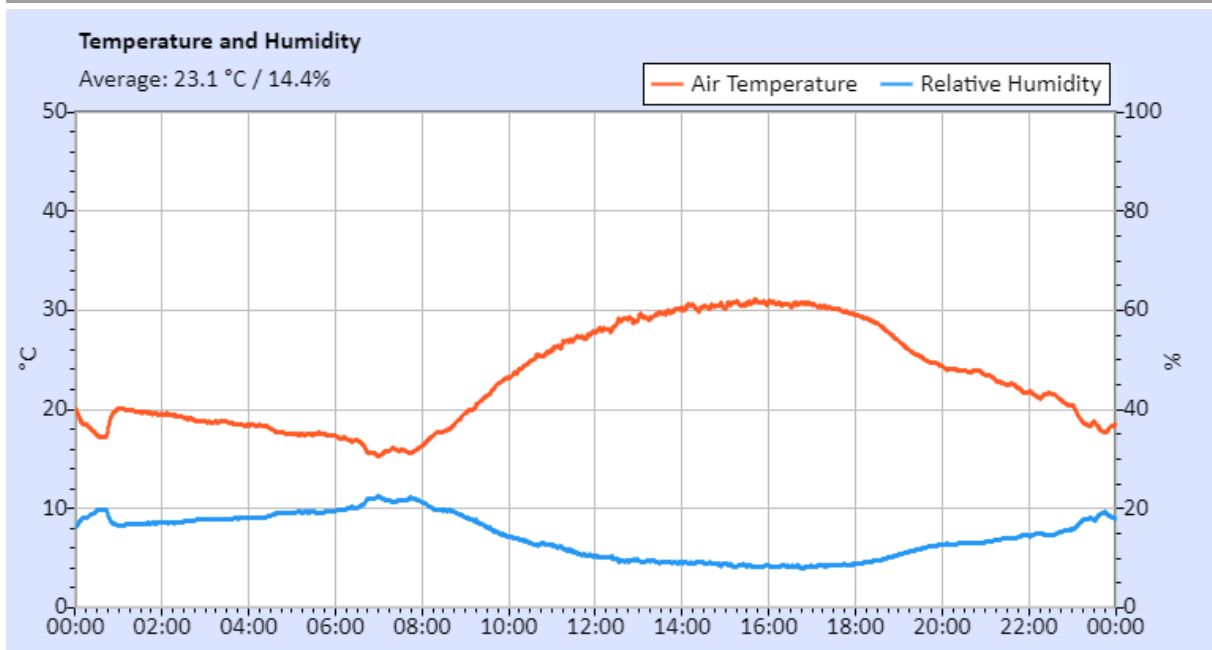


Figure 39 : Temperature and Humidity measurements.

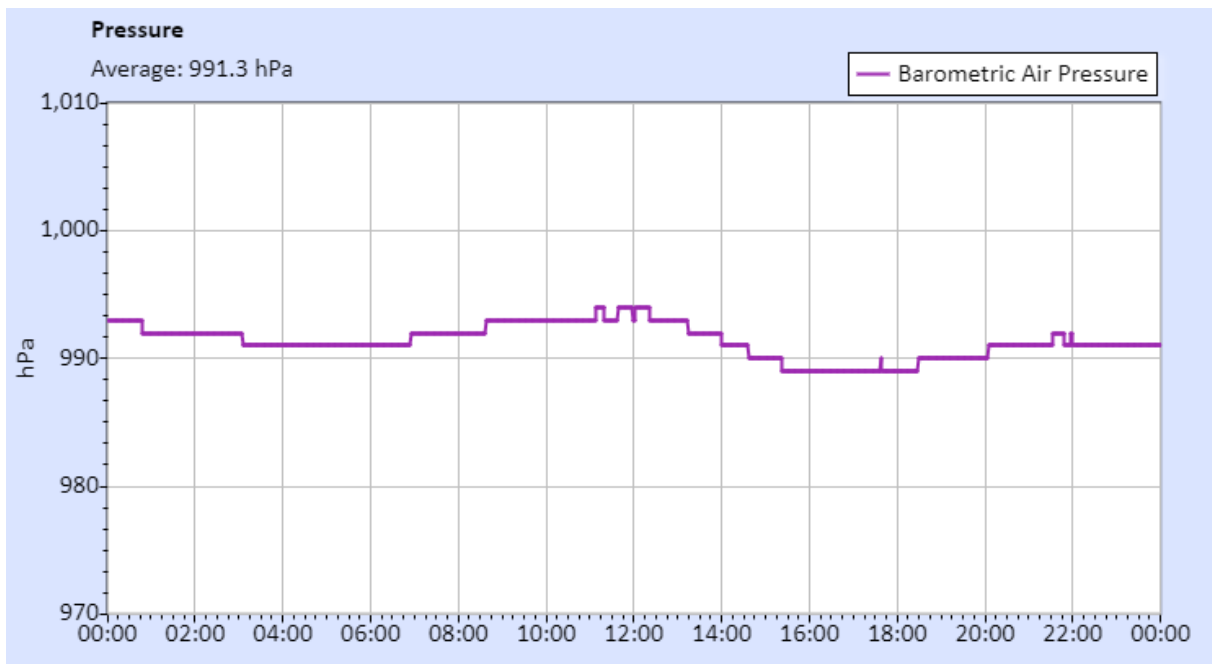


Figure 40 : Barometric air pressure measurement.

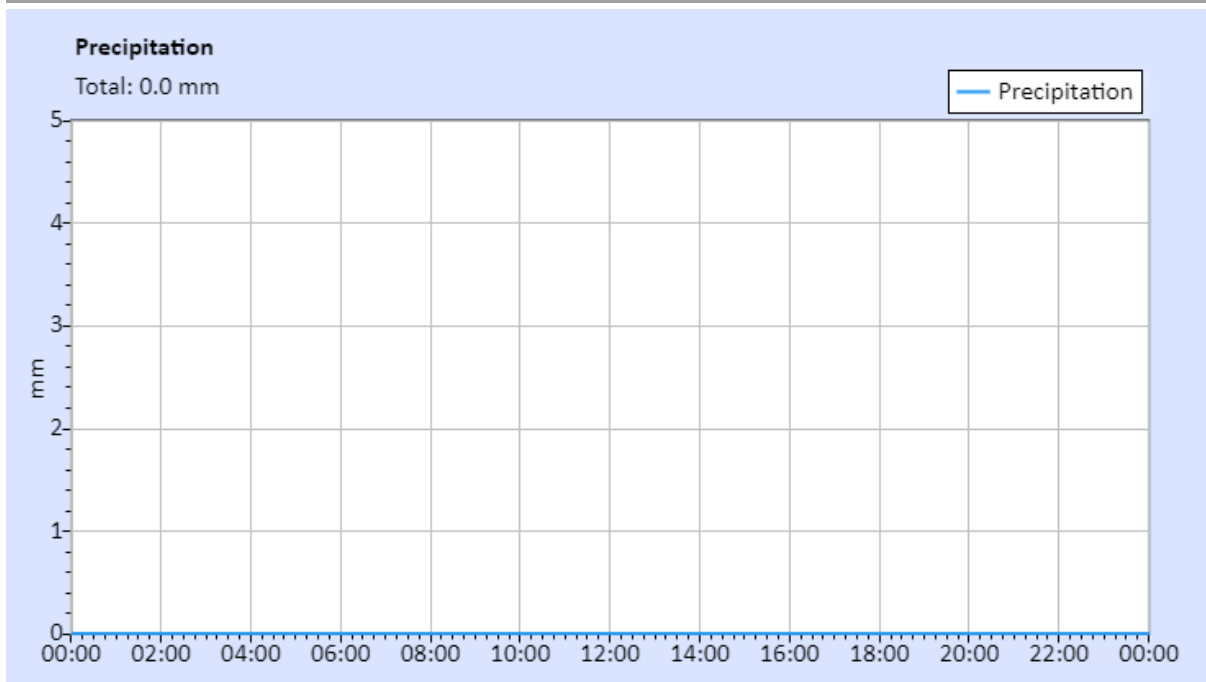


Figure 41 : Precipitation measurement (2021-10-24).

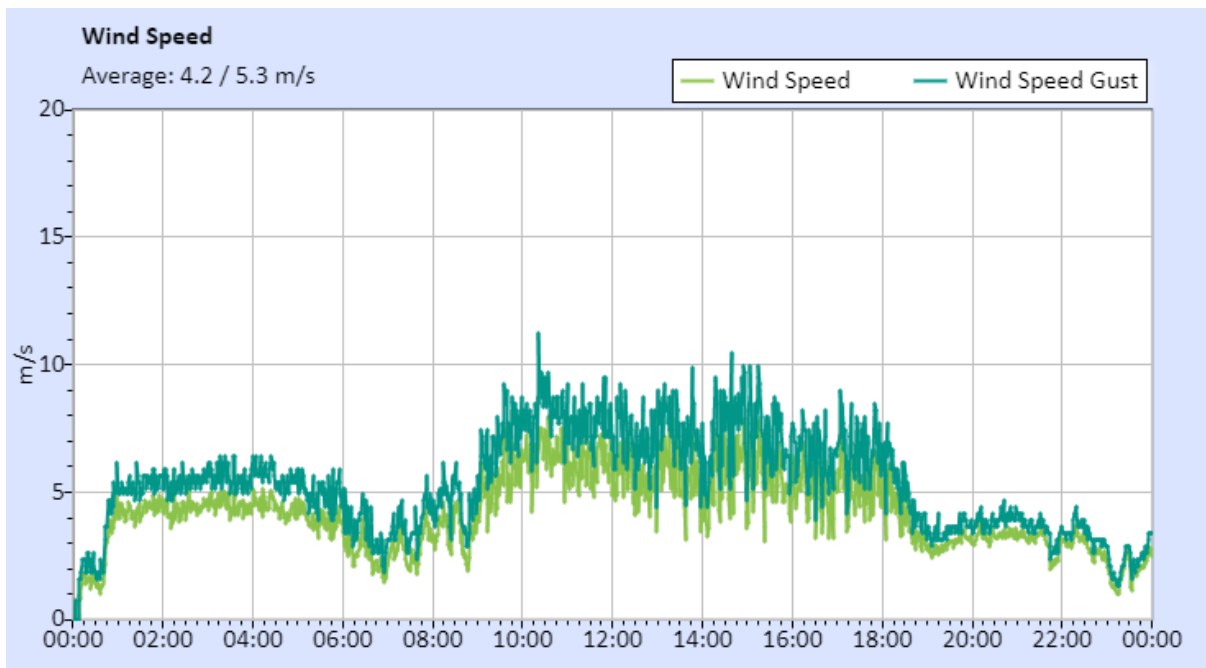


Figure 42 : Wind speed measurement.

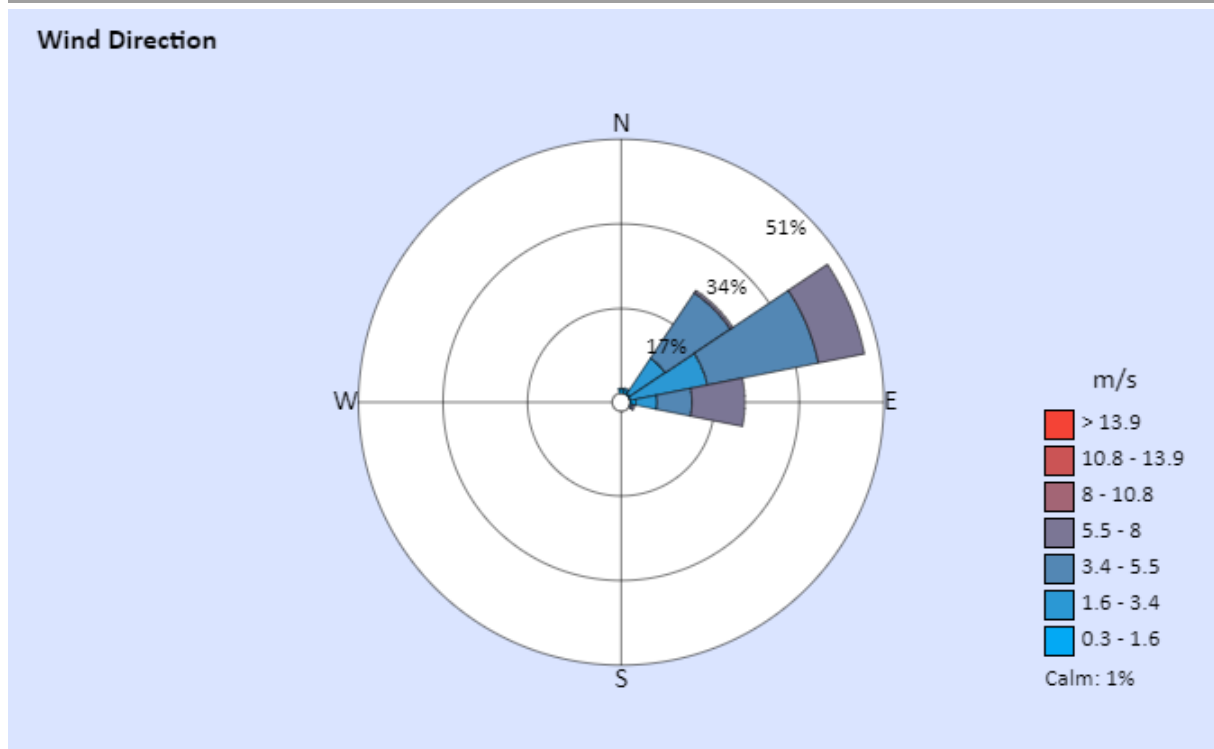


Figure 43 : Wind direction measurement.

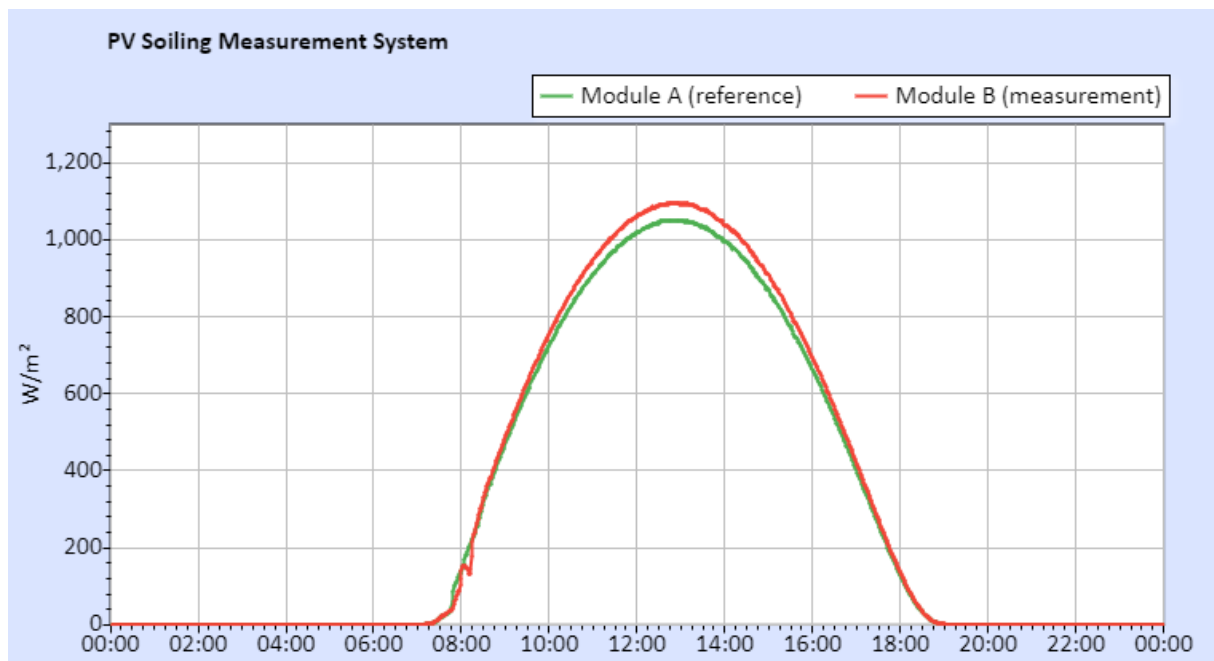


Figure 44 : PV soiling measurements.

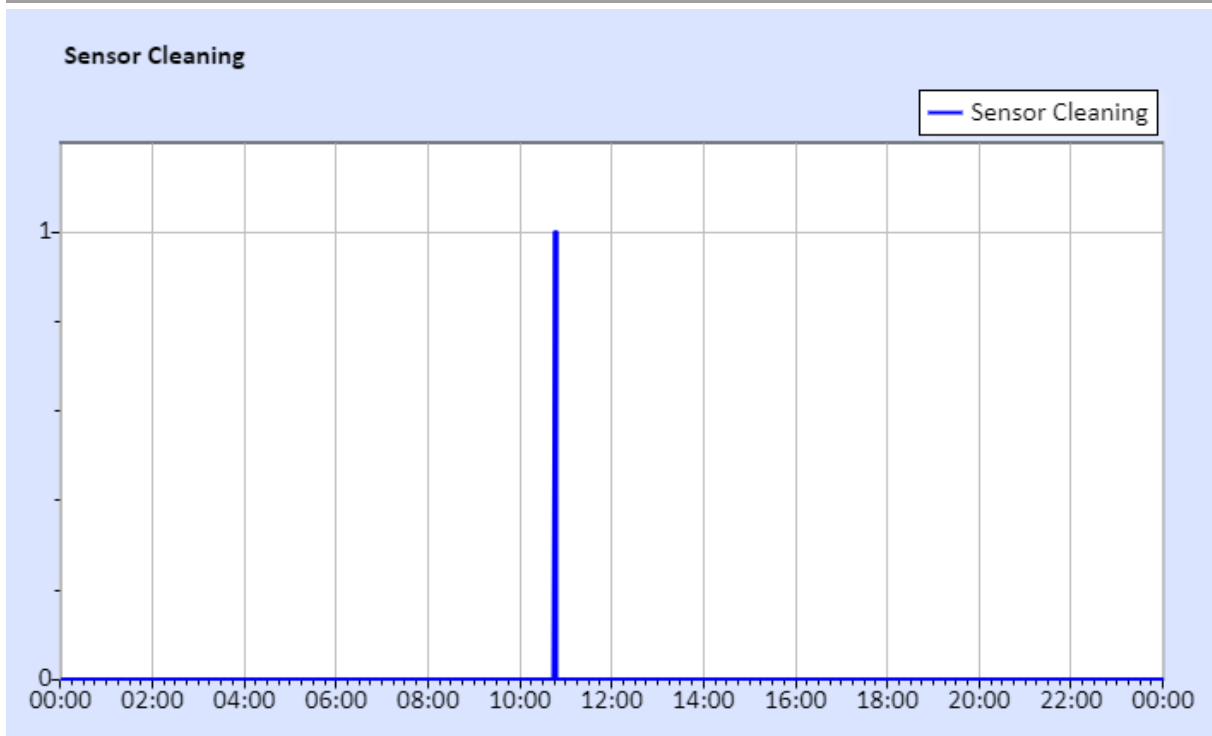


Figure 45 : Sensor cleaning recordings.

9 Certificats d'étalonnage / Calibration certificates

Cette section fournit les certificats d'étalonnage pour chaque capteur. Tous les équipements de mesure sont neufs, non utilisés et incluent les étalonnages d'usine.

À la fin de la première année de mesures, un étalonnage sur le terrain à l'aide d'un pyranomètre de référence (référéncé à la référence radiométrique mondiale établie à Davos, en Suisse) sera effectué à la station de mesure solaire.

This section provides the calibration certificates for each sensor. All measurement equipment is new, unused and includes factory calibrations.

At the end of the first year of measurements, a field calibration using a reference pyranometer (referenced to the World Radiometric Reference established in Davos, Switzerland) will be conducted at the solar measurement station.

Paramètre mesuré Measured parameter	Type de capteur Sensor type	Numéro de série Serial number	Date d'étalonnage Calibration date	Date d'installation Installation date
DHI, DNI	RSI	MS.19.201.0006	2020-03-03	2022-01-22
GHI	Kipp&Zonen CMP10	210857	2021-02-12	2022-01-22
Wind speed (WS)	NRG40C anemometer	179500332899	2020-10-26	2022-01-22
Wind direction (WD)	NRG #200M wind vane	1007000008939	2020-09-12	2022-01-22
Barometric pressure (BP)	Vaisala PTB110 (CS106)	S4950666	2020-12-07	2022-01-22

9.1 RSI pyranometer (DHI,DNI)



Calibration Protocol

For Model: **Twin Rotating Shadowband Irradiometer**

Pyranometer Unit Serial Number: CSPS.MS.19.201.0006
 With pyranometer sensor: LI-COR LI200R PY108329 (primary)
 and LI-COR LI200R PY108330 (secondary)
 Original LI-COR Calibration Constant: 66.72 microamps per 1000 W/m²
 and 67.54 microamps per 1000 W/m²

Correction factors from (DLR2008)

	PY108329	PY108330
Constant Correction Factor	1.037	1.029
Diffuse Correction Factor	1.042	1.038
Root Mean Square Deviation (DNI)	14.9 W/m ²	18.2 W/m ²
Bias (DNI)	-0.9 W/m ²	-0.9 W/m ²
Root Mean Square Deviation (GHI)	6.4 W/m ²	7.0 W/m ²
Bias (GHI)	1.3 W/m ²	1.3 W/m ²

Calibration period: 2019-10-08 to 2020-03-03
 Effective period: 1018 h (GHI) 685 h (DNI) 1018 h (DHI)
 Temporal resolution: 10 min

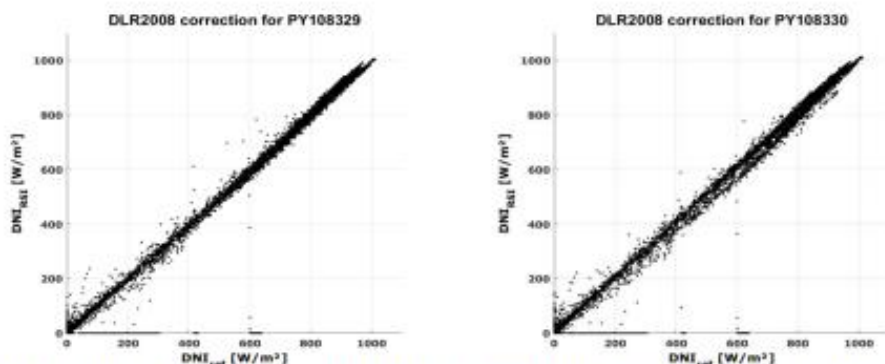


Figure 1: DNI after correction corresponding to chosen function set including calibration constant vs. reference DNI (10-min)

Please consult the detailed description for further information on the calibration process.

Almeria, 12-Jun-2020

i. A. Dr.rer.nat. Natalie Hanrieder

DLR is statutorily represented by its Executive Board. The Executive Board may empower authorized persons to act as its representatives. DLR's head of Legal Department, D-51170 Cologne, provides information on the extent of this empowerment.

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DETAILED DESCRIPTION OF THE RSI SENSOR CALIBRATION PROCEDURE

The RSI irradiation sensor is mounted and operated parallel to the reference DLR meteorological station during a specified period (recommended to be at least one month) at the Plataforma Solar de Almeria in Spain for calibration under real sky conditions.

The Constant Calibration Factor and the Diffuse Correction are determined by comparing the reference direct normal and diffuse horizontal irradiance to corresponding RSI irradiance data as determined with the LI-COR (LI-200) Calibration Constant and including correction functions developed by DLR for RSIs with LI-COR LI200 pyranometers in 2008 (see publications: Geuder, N., Pulvermüller, B., Vorbrugg, O., "Corrections for Rotating Shadowband Pyranometers for Solar Resource Assessment", *Proc. of Solar Energy and Applications, part of SPIE Optics + Photonics, 10-14 August 2008, San Diego, USA*). The RMS deviation of the 10-minute means for DHI is minimized by variation of the thereby determined Diffuse Correction. Then the RMS deviation for the DNI is minimized using the Constant Calibration Factor.

Irradiance data from the RSI and the DLR station is logged as 60 second averages during the entire calibration process. For calibration, only the relevant operation range of solar thermal power plants was considered with DNI > 300 W/m², GHI > 10 W/m², DHI > 10 W/m² and at sun height angles > 5°. Outliers with deviations of more than 25% were not considered.

The following instruments were used during the calibration period:

Manufacturer	Model	Serial Number	Functionality/ Measurand	Calibration/Test remarks		
				constant	by	date
Kipp&Zonen	CMP21	110875	GHI	10.01 $\mu\text{V}/(\text{W}/\text{m}^2)$	DLR	Oct-2015
Kipp&Zonen	CV 2	070990	ventilation unit, GHI			
Kipp&Zonen	CMP21	110869	DHI	9.35 $\mu\text{V}/(\text{W}/\text{m}^2)$	DLR	Oct-2015
Kipp&Zonen	CV 2	070992	ventilation unit, DHI			
Hukseflux	DR03-05	10025	DNI	10.12 $\mu\text{V}/(\text{W}/\text{m}^2)$	DLR	Jun-2016
Campbell Scientific	CS215	E1839	air temp. and rel. humidity		Sensirion	
Campbell Scientific	CS100	3696476	air pressure		setra	Aug-2008
EKO	STR-22G		sun tracking		EKO	
Campbell Scientific	CR1000	7164	data logger for precise sensors			

9.2 CMP10 pyranometer (GHI)



Meteorology Division of OTT HydroMet

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ISO/IEC 17025 CALIBRATION CERTIFICATE

CERTIFICATE NUMBER	022874210857
PYRANOMETER MODEL	CMP 10
SERIAL NUMBER	210857
CALIBRATION DATE	12 February 2021
INSTRUMENT CLASS	ISO 9060, Class A (Sec. Standard)*
CALIBRATION PROCEDURE	ISO 9847 par5.3.2, A3
REFERENCE PYRANOMETER	Kipp & Zonen CMP 21 sn 070114 active from 01 January 2021
REFERENCE PYRANOMETER CALIBRATION PROCEDURE	ISO 9846 par5
CALIBRATION LOCATION	Delft The Netherlands
CUSTOMER	

REMARKS

Delft, The Netherlands, 12 February 2021

J. Mes
J. Mes
(in charge of calibration facility)

F. de Wit
F. de Wit
(in charge of test)

Page: 1 of 2

Kipp & Zonen B.V.
Trade name: OTT HydroMet
Company registered in Delft

Trade register no.: 27239004
VAT no.: NL0055.74.857.B.01
Member of HMEI

EUR payments
Deutsche Bank AG
IBAN: NL70 DEUT 0265 2482 48
BIC: DEUTNL2A

USD payments only
Deutsche Bank AG
IBAN: DE60100701000162416200
BIC: DEUTDEBB101



Meteorology Division of OTT HydroMet

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ISO/IEC 17025 CALIBRATION CERTIFICATE

CERTIFICATE NUMBER 022874210857

Calibration procedure

The indoor calibration procedure is based on a side-by-side comparison with a reference pyranometer under an artificial sun fed by an AC voltage stabiliser. It embodies a 150 W Metal-Halide high-pressure gas discharge lamp and a reflector with a diameter of 16.2 cm. The lamp is positioned 1 m above the pyranometers producing a vertical beam. The reference- and test pyranometer are mounted horizontally on a table, which can rotate. The irradiance at the pyranometers is approximately 500 W/m². During the calibration procedure the reference and test pyranometer are interchanged to correct for any non-homogeneity of the beam. Temperature during calibration: 22 °C ± 2 °C.

Hierarchy of traceability

The measurements have been executed using standards for which the traceability to international standards has been demonstrated towards the RvA.

The reference pyranometer was compared with the sun and sky radiation as source under clear sky conditions using the "alternating sun-and-shade method" ISO 9846 paragraph 5. The measurements were performed in Delft, The Netherlands (latitude: 51.9969°, longitude: 4.3863°, altitude: 10m above sea level). Dates of measurements: 22-24 June 2020.

The receiver surface was pointed directly at the sun using a solar tracker. During the comparisons, the instrument received tilted global radiation intensities from 834 W/m² to 1124 W/m² with a mean of 992 W/m² and tilted diffuse radiation intensities from 83 W/m² to 250 W/m² with a mean of 148 W/m². The ambient temperature ranged from +19.0 °C to +29.9 °C with a mean of +23.9 °C.

The direct radiation on the reference pyranometer as obtained with the alternating-sun-shade method was compared to the DNI measured by the absolute cavity pyrheliometer PMO6 SN 103. The PMO6 is calibrated against the World Standard Group (WSG), maintained at the WRC Davos every International Pyrheliometer Comparison (IPC). WRR factor of PMO6: 0.99787 (from the last IPC-2015).

This calibration proved that the reference pyranometer has been stable and that the original sensitivity 8.37 μV/(W/m²) ± 0.11 μV/(W/m²) is valid and will be applied (see PMOD calibration details). Observed sensitivity differences between the consecutive years are well within the calibration uncertainty.

PMOD calibration details: The reference pyranometer was compared with the sun and sky radiation as source under mainly clear sky conditions using the "continuous sun-and-shade method". The pyranometer was installed horizontally. During the comparisons, the global radiation ranged from 638 W/m² to 1195 W/m² with a mean of 874 W/m². The solar zenith angle varied from 23.5° to 49.8° with a mean of 32.9°. The ambient temperature ranged from +12.6 °C to +26.2 °C with a mean of +23.7 °C. The sensitivity calculation is based on 435 individual measurements. The readings of the WSG are referred to the World Radiometric Reference (WRR). The estimated uncertainty of the WRR relative to SI is ±0.3%. The obtained sensitivity value and its expanded uncertainty (95% level of confidence) are valid for similar conditions and are: 8.37 ± 0.11 μV/W/m². The measurements were performed in Davos (latitude: 46.8143°, longitude: -9.8458°, altitude: 1558 m above sea level). Dates of measurements: 24, 30 June 1, 2 July 2015. Global radiation data were calculated from the direct solar radiation as measured with the absolute cavity pyrheliometer PMO2 (member of the WSG, WRR factor: 0.998623 from the last International Pyrheliometer Comparison, IPC-2015) and from the diffuse radiation as measured with a continuous disk shaded pyranometer Kipp & Zonen CM22 SN 020059 (ventilated with heated air).

SENSITIVITY 9.92 μV/(W/m²) at normal incidence on horizontal pyranometer

UNCERTAINTY 0.14 μV/(W/m²) = 1.44 %

IMPEDANCE 23 ± 1.5 Ω

Justification of total instrument calibration uncertainty

The combined uncertainty of the result of the calibration is the positive "root sum square" of the following components.

1. The expanded uncertainty due to random effects and instrumental errors during the calibration of the reference CMP 21 is ±0.11/8.37 = ±1.31% (k=2). See traceability text.

2. The expanded uncertainty of the transfer procedure (calibration by comparison) is estimated to be ±0.5% (k=2).

3. The estimated uncertainty of the WRR relative to SI: ±0.3% (k=2).

The expanded uncertainty is: $\sqrt{(1.31\% + 0.5\% + 0.3\%)^2} = \pm 1.44\%$ (k=2).

The resistance measurement uncertainties are due to the PXI 4065 uncertainty in the 100 Ω range: 150ppm of range (=15mΩ) the cable resistance (estimated 0.1 Ω) and due to the electrothermal effect the measurement current in the thermal detector of the pyranometer. This was found to be a resistance error of 1.5 Ω, which results in a total resistance uncertainty of $\sqrt{(0.015^2 + 0.1^2 + 1.5^2)} = 1.5 \Omega$ or 5%.

The PXI 4065 is calibrated by National Instruments Hungary, on 7 november 2018 at a temperature of 22.7 °C, under ISO 17025:2005 accreditation. This calibration is traceable to NIST and/or other National Measurement Institutes (NMI's).

The reported expanded uncertainty is based on the standard uncertainty of the measurement multiplied by a coverage factor k, such that the coverage probability corresponds to approximately 95%. The standard uncertainty has been determined in accordance with EA 04/2.

Notice

The calibration certificate supplied with the instrument is valid at the date of first use. Even though the calibration certificate is dated relative to manufacture, or recalibration, the instrument does not undergo any sensitivity changes when kept in the original packing.

* from October 2018 the classification conforms to ISO 9060:2018. Instruments issued before that date conform to ISO 9060:1990.

RvA is member of the European Co-operation for Accreditation (EA) and is one of the signatories to the EA Multilateral Agreement (MLA) and to the ILAC Mutual Recognition Arrangement (MRA) for the mutual recognition of calibration certificates.

Reproduction of the complete certificate is allowed. Parts of the certificate may only be produced with written approval of the calibration laboratory.

This certificate is issued provided that the Raad voor Accreditatie does not assume any liability.

Page: 2 of 2

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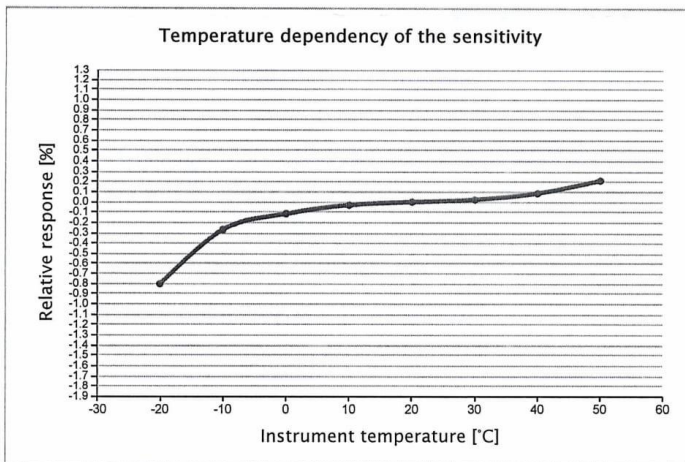
Meteorology Division of OTT HydroMet

Kipp & Zonen B.V. | Delftechpark 36 | 2628 XH Delft | The Netherlands | +31 15 2755 210 | info@kippzonen.com | www.kippzonen.com

MEASUREMENT REPORT PYRANOMETER

Routine measurement of temperature dependency during final inspection

PYRANOMETER TYPE	CMP 10
SERIAL NUMBER	210857
DATE OF MEASUREMENT	21 December 2020
PERFORMED BY	F. de Wit
PROCEDURE	<p>The pyranometer is mounted inside the climate chamber and illuminated with a white light source under normal incidence. A CMP22 pyranometer outside the chamber is used to monitor the lamp stability.</p> <p>The pyranometer is tested over a temperature range from 50 °C down to -20 °C in steps of 10 °C. The relative temperature dependency is plotted below.</p> <p>The measurement uncertainty of this characterisation is $\pm 0.1\%$ (k=2).</p>



Instrument temperature [°C]	Relative response [%]
-20	-0.80
-10	-0.27
0	-0.12
10	-0.03
20	0.00
30	0.02
40	0.08
50	0.21

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MEASUREMENT REPORT PYRANOMETER

Routine measurement of directional error during final inspection

Mean cosine error of each new pyranometer type CMP 10 is measured by a simple routine.

Routine:

The pyranometerbase is placed against the vertical turntable of a goniometer in the parallel (0,5°) beam of a sunsimulator.
Voltage output U(z) is measured for beam incidence (zenith) angles of 0°, 40°, 60°, 70° and 80° coming in over azimuth south (cable pointing to North).
Next the pyranometer output U(-z) is measured for incidence angles of -80°, -70°, -60°, -40° and 0° consequently for azimuth south. The dark signal is measured at the beginning of the routine in the middle and at the end. For each beam incident angle the dark signal is interpolated.

During the CMP 10 measurement cycle, a check is done on the azimuth error at 40° and 70° by measuring voltages for azimuth-directions S, E, N and W. Also at -70° and -40° this azimuth error is measured and the mean of both azimuth measurements cancels out the eventual error in the 0° position.

With the extended procedure at both 40° and -40° and 70° and -70° the specific cosine error for 8 azimuth directions (40° S, W, N and E and 70° E, N, W, S) can be calculated according to formula 1 and verified whether it is within ± 10 W/m².

The applied formula for the relative cosine error is:

$$\frac{(U(z) + U(-z)) - \text{zero}(z)}{2} \cdot \frac{100\%}{\left(\frac{U(0^\circ) + U(0^\circ)}{2} - \text{zero}(z)\right) \cdot \cos(z)} \quad \text{Formula 1.}$$

U(0°) Pyranometer output voltage for normal incidence
U(z) Pyranometer output voltage for angles (z)
Zero(z) Dark signal for angles

Relative cosine error at zenith angle in %

Zenith angle	South	East	North	West
40	-0.23	0.23	0.29	0.00
60	-0.18			
70	0.04	0.74	1.25	0.29
80	-0.18			

Absolute cosine error for 1000 W/m² beam radiation in W/m²

Zenith angle	South	East	North	West
40	-1.73	1.79	2.21	0.04
60	-0.92			
70	0.15	2.52	4.27	0.98
80	-0.32			

PYRANOMETER MODEL: CMP 10

SERIAL NUMBER: 210857

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BIC: DEUTDE33HAN

9.3 #40C anemometer



SOH Wind Engineering LLC

141 Leroy Road · Williston, VT 05495 · USA
Tel 802.316.4368 · Fax 802.735.9106 · www.sohwind.com

CERTIFICATE FOR CALIBRATION OF CUP ANEMOMETER

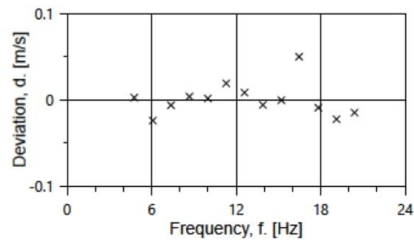
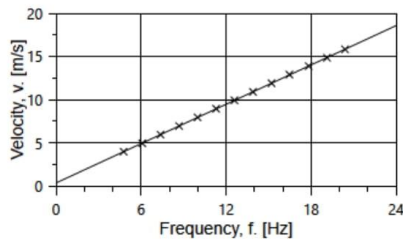
Certificate number: 20.US1.00737 **Date of issue:** October 26, 2020
Type: NRG 40C Anemometer **Serial number:** 179500332899
Manufacturer: NRG Systems Inc, 110 Riggs Road, Hinesburg, VT 05461, USA
Client: NRG Systems Inc, 110 Riggs Road, Hinesburg, VT 05461, USA
Anemometer received: October 20, 2020 **Anemometer calibrated:** October 24, 2020
Calibrated by: MEJ **Procedure:** MEASNET, IEC 61400-12-1:2017 Annex F
Certificate prepared by: EJF **Approved by:** Calibration engineer, EJF

Calibration equation obtained: $v \text{ [m/s]} = 0.75996 \cdot f \text{ [Hz]} + 0.34552$

Standard uncertainty, slope: 0.00150 **Standard uncertainty, offset:** 0.04453
Covariance: -0.0000163 (m/s)²/Hz **Coefficient of correlation:** $\rho = 0.999988$

Absolute maximum deviation: 0.050 m/s at 12.910 m/s
Barometric pressure: 1003.0 hPa **Relative humidity:** 46.0%

Succession	Velocity		Temperature in		Wind velocity, v. [m/s]	Frequency, f. [Hz]	Deviation, d. [m/s]	Uncertainty u _c (k=2) [m/s]
	pressure, q. [Pa]	wind tunnel [°C]	d.p. box [°C]					
1-first	9.27	22.9	26.9		3.973	4.7697	0.002	0.023
13-last	14.38	23.0	26.9		4.948	6.0882	-0.024	0.026
2	20.76	22.9	26.9		5.945	7.3765	-0.006	0.030
12	28.35	23.0	26.9		6.949	8.6845	0.004	0.034
3	37.05	22.8	26.9		7.941	9.9931	0.001	0.038
11	47.01	23.1	26.9		8.949	11.2962	0.019	0.042
4	57.88	22.8	26.9		9.926	12.5960	0.008	0.046
10	69.78	23.1	26.9		10.904	13.9014	-0.006	0.050
5	83.24	22.8	26.9		11.905	15.2112	-0.001	0.055
9	97.80	23.1	26.9		12.910	16.4671	0.050	0.059
6	113.28	22.9	26.9		13.889	17.8337	-0.009	0.063
8	129.52	23.1	26.9		14.856	19.1237	-0.023	0.067
7	147.19	23.0	26.9		15.835	20.4022	-0.015	0.071



AC-1746



Page 1 of 2

EQUIPMENT USED

Serial Number	Description
Njord1	Wind tunnel, blockage factor = 1.0017
2254	Control cup anemometer
-	Mounting tube, D = 12.7 mm
TT003	Summit Electronics, 1XPT100, 0-10V Output, wind tunnel temp.
TT001	Summit Electronics, 1XPT100, 0-10V Output, differential pressure box temp.
DP005	Setra Model 239, 0-1inWC, differential pressure transducer
HY002	Dwyer RHP-2D20, 0-10V Output, humidity transmitter
BP001	Setra Model 278, barometer
PL8	Pitot tube
XB002	Computer Board. 16 bit A/D data acquisition board
Njord1-PC	PC dedicated to data acquisition

The accuracies of all measurements were traceable to the SI through NIST or CIPM recognized NMI's. A real-time analysis module within the data acquisition software detects pulse frequency.



Photo of the wind tunnel setup. The cross-sectional area is 2.5m x 2.5m.

UNCERTAINTIES

The documented uncertainty is the total combined uncertainty at 95% confidence level (k=2) in accordance with EA-4/02. The uncertainty at 10 m/s comply with the requirements in the IEC 61400-12-1:2005 procedure. See Document US.12.01.004 for further details.

COMMENTS

(none)

Certificate number: 20.US1.00737

The results on this certificate relate only to the serial number listed.
All calibrations are done in the "As Found" condition unless otherwise noted.
This certificate must not be reproduced, except in full, without the approval of SOH Wind Engineering LLC

Page 2 of 2

9.4 #200M Wind vane



Factory Calibration

NRG Systems 200M Wind Direction Vane
Serial No. 10070 00008939

Product Description:

Manufacturer	Description	Cal. Date
NRG Systems	200M Wind Direction Vane	12/9/2020

NRG Systems, hereby certifies that the above instrumentation has been calibrated and tested to **meet or exceed** the published specifications. This calibration and testing was performed using instrumentation and standards that are traceable to the **National Institute for Standards and Technology (NIST)**.

Standard Uncertainty of Degree Measurement = ±0.31°

The output (in Deg.) for this 200M sensor is defined by: $\theta = V * Scale\ Factor + Offset$

Criteria	Value	Units
200M Scale Factor	147.6012	Deg./Volt
200M Offset	-1.0606	Deg.

Linearity Results (R^2): 0.99999

Slope (Scale Factor) and Offset Conversion Chart for NRG Systems' Data Loggers.

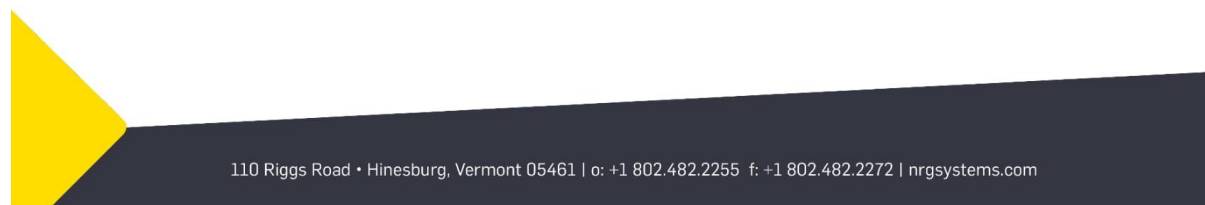
To Scale to...	SymphoniePLUS3 and Older <i>[Symphonie Data Retriever (SDR) software]</i>		SymphoniePRO Data Logger <i>[SymphoniePRO Desktop Application]</i>	
	enter Scale Factor	and enter Offset	enter Scale Factor	and enter Offset
°	0.368	-5.3	147.6012	-1.0606

Procedure: WI-ELE-489

Calibration performed by: sms

Date: 12/9/2020

NRG Systems' management system has been certified to ISO 9001: 2015.



9.5 CS106 (PTB110) barometer



1 (1)
Certificate report no. H47-20500008

CALIBRATION CERTIFICATE

Instrument PTB110 Barometer
Serial number S4950666
Manufacturer Vaisala Oyj, Finland
Calibration date 7th December 2020

This instrument has been calibrated against a Vaisala PTB220 factory working standard. The Vaisala PTB220 is traceable to the National Institute of Standards and Technology (NIST, USA) via Vaisala Measurement Standards Laboratory (MSL). Vaisala MSL has been accredited by FINAS according to ISO/IEC 17025 standard.

At the time of shipment, the instrument described above was within its operating specifications.

Calibration results

Reference pressure hPa	Calculated pressure hPa	Observed voltage Vdc	Correction* hPa	Uncertainty** hPa
510.2	510.2	0.043	0.0	± 0.15
610.0	610.0	0.458	0.0	± 0.15
700.1	700.2	0.834	-0.1	± 0.15
810.1	810.1	1.292	0.0	± 0.15
900.2	900.2	1.668	0.0	± 0.15
1000.0	1000.0	2.083	0.0	± 0.15
1059.8	1059.8	2.333	0.0	± 0.15
1100.0	1100.0	2.500	0.0	± 0.15

*To obtain the true pressure, add the correction to the barometer reading. Interpolated corrections may be used at intermediate readings of the scale of the barometer.

**The calibration uncertainty given at 95 % confidence level, k = 2

Equipment used in calibration

Type	Serial number	Calibration date	Certificate number
HP34970A	EM 12997	2020-03-10	11-9485435-009
PTB220	PA 14018	2020-06-11	K008-D02088

Ambient conditions

Humidity: 34 ± 5 %RH

Temperature: 22 ± 2 °C

Pressure: 1012 ± 20 hPa



Technician

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