Station Information Report

Solar and Meteorological Station

World Bank – University of Dar Es Salaam, Tanzania

Revision	Date	Author	Checked	Approved	Comments
Rev 0	15 Dec 2020	M.D. Johnstone	J. van Jaarsveldt	M. de Jager	First Issue
Rev 1					
Rev 2					

Contents

1 Introduction

NOTE: This project occurred during the COVID19 pandemic outbreak. Any impact on the data quality as a result of the pandemic will be recorded in the monthly quality feedback report alongside other noteworthy events for the affected month.

The World Bank initiated a project with funding from the Energy Sector Management Assistance Program (ESMAP) to, amongst others, support the East African Power Pool (EAPP) in doing renewable energy resource assessments. The focus for this particular section of the project is to get high quality bankable irradiance measurements, high quality supporting meteorological measurements and to promote the awareness of the resource potential of solar energy.

The project is orientated around sites considered for large-scale solar power plant development in the near future. The on-site measured data generated from this project for the applicable term is to be used in conjunction with overlapping and historic satellite derived data for the same location in order to generate a bankable data set, subsequently providing enhanced data accuracy for locations where there may be substantial project investments. The data complements the global resource data available for free via the Global Solar Atlas (https://globalsolaratlas.info).

GeoSUN Africa has been awarded the contract to execute the on-site measurement related aspects of the project. The assignment for GeoSUN Africa is the following:

- An inception mission which involves visiting the proposed site locations and selecting the optimal location for the measurement equipment. The outcome of this inception mission is this implementation plan where sites and stations tiers are proposed;
- Providing high quality measuring equipment for each site, in line with the technical specifications;
- Installation of measurement equipment as well as subsequent Site Installation Report and photographs for each site;
- Hosting and providing two years of high quality, ‘bankable’ meteorological data relevant for solar resource assessment and project development, including upload to an ‘open data’ platform for public dissemination;
- Ensuring maintenance, security, local cleaning/caretaking, and mitigation against extreme weather events and corrosion;
- Ensuring strong local involvement and capacity building at all stages of the measurement campaign;
- Decommissioning of all sites at the end of the measurement campaign, unless separate arrangements are made with one or more host institutions to continue with measurements outside of this assignment/contract.

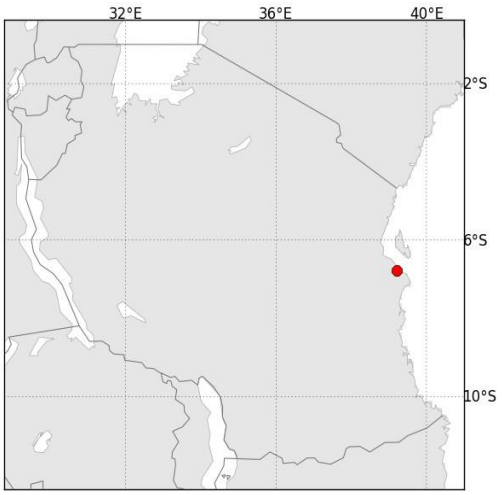
This document acts as the Site Installation Report which follows the commissioning of the site, outlining the site location, site characteristics, technical specifications, calibration procedures, and all other relevant information to allow data users to fully understand the site and ensure the bankability of the measurement data. The Site Installation Report is contains photographs of the site and the surrounding terrain.

The measurement data from the site will be continuously transferred to GeoSUN’s central data repository, and shall then be transferred to the World Bank on a monthly basis in both raw and

quality controlled formats according to the specifications developed by ESMAP. This data will be delivered via an online file sharing platform one month in arears. Site Measurement Reports will accompany the delivery of monthly data, and shall detail any issues with the site or equipment, field calibration procedure, and any notable conclusions or results. The World Bank and key client counterparts shall also be provided with access to the vendor's data repository or monitoring platform for real-time analysis.

The assignment shall be deemed completed once two years of concurrent data is delivered in compliance with the minimum data recovery rates specified. At this point the vendor shall decommission each site and remove the solar measurement equipment, unless alternative arrangements outside the scope of this assignment/contract are made and endorsed by the relevant client/host agency.

2 Station Summary

Work performed	Installation and commissioning of solar and meteorological measurement station.
Commissioning date	28 November 2020
Client	World Bank
Client contact person and contact details	Name: Abdul Rahim Jalloh Email: Abduljay@gmail.com Telephone: + 1 301 825 1628 Name: Chiara Rogate Email: crogate@worldbank.org Telephone: +1 202 250 0568 Name: Brenda Kazimili Email: bkazimili@gmail.com Telephone: +255 754 299 620
Site location	Installed on the Roof of the physics building of the university of Dar es Salaam, Tanzania. 
Access	From USDM Post office, head West on University road for approximately 500 m then turn left. Continue for 250 m then your destination will be on your left.
Coordinates	06° 46' 51.18" S, 39° 12' 13.58" E (-6.78088297128,39.2037733112)
Elevation	93 m AMSL
Time zone (local and data logger)	GMT +3 local time zone
Name and contact details of on-site contact person(s)	Name: Brenda Kazimili Cell: +255 754 299 620

3 Map of area

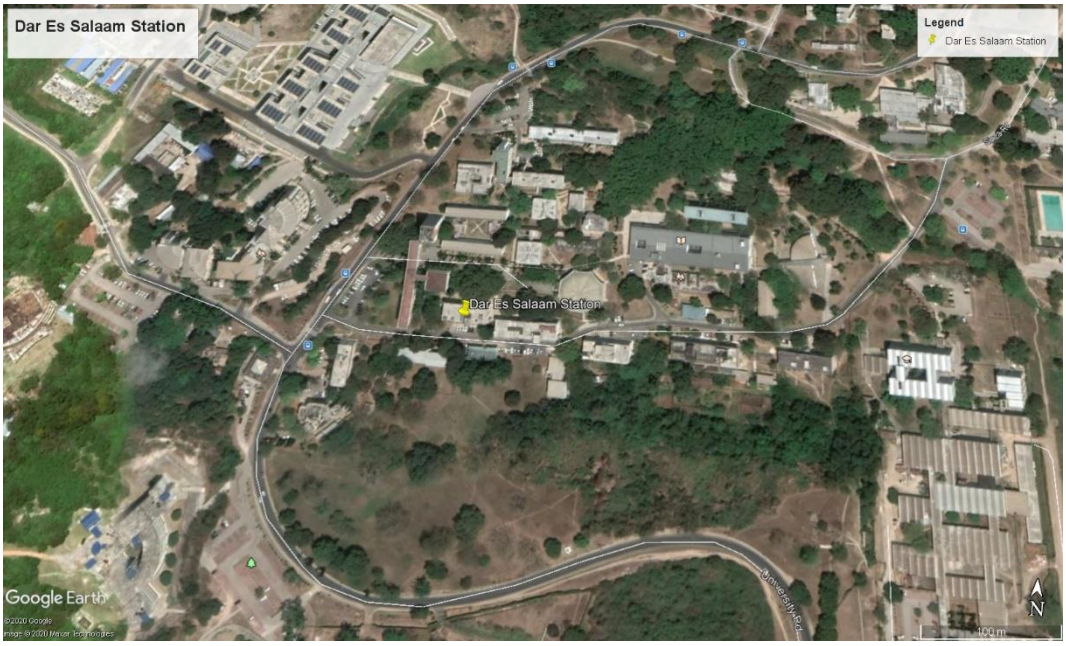


Figure 1: Map of the surrounding area (Source: Google Earth)

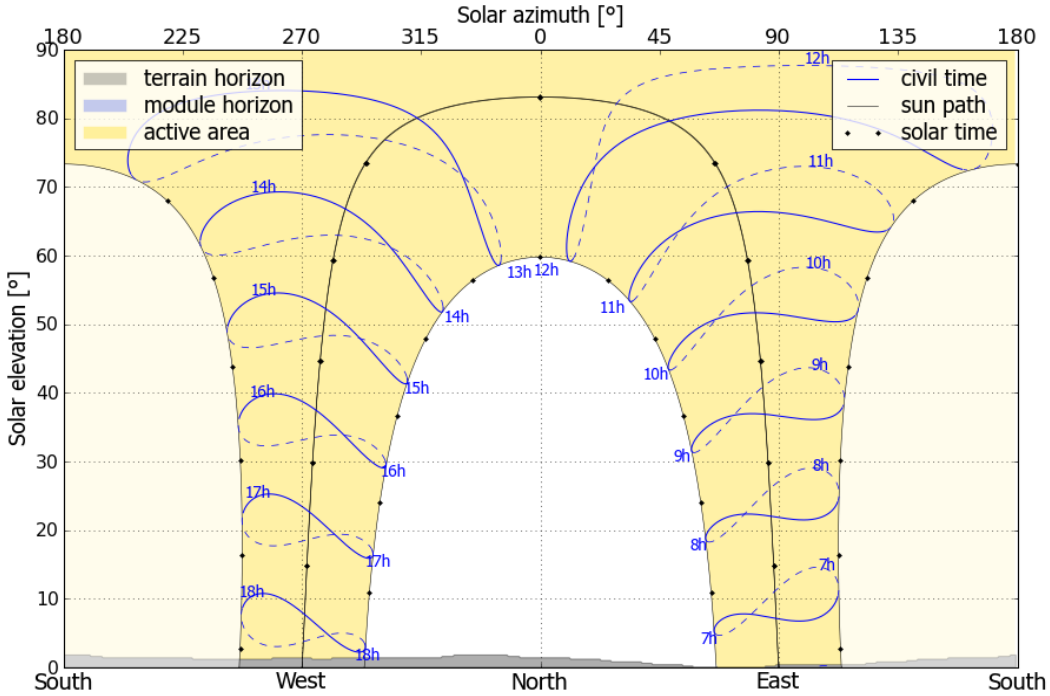


Figure 2: Terrain horizon and day length (Source: Solargis)

4 Site layout

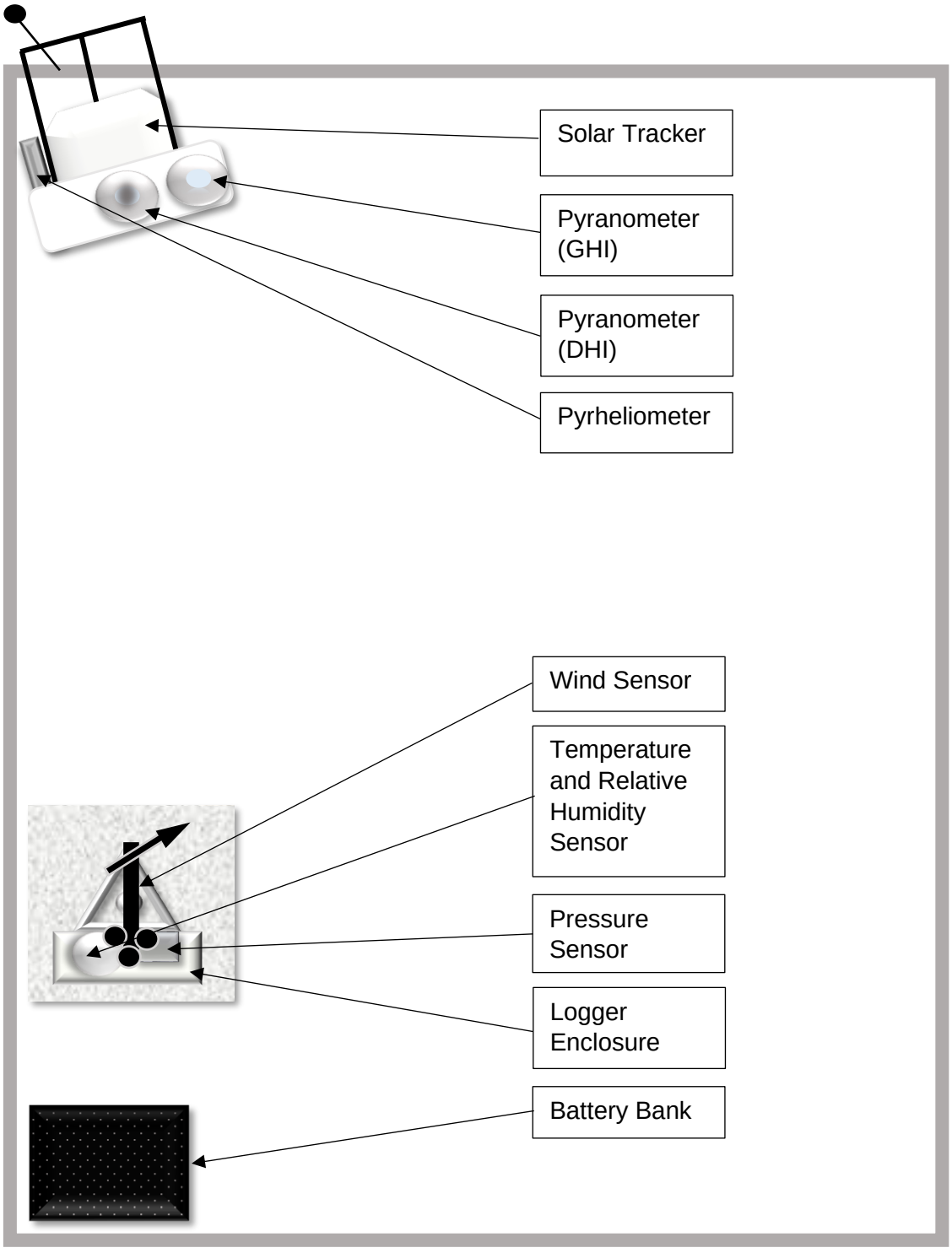


Figure 3: Station Layout (Top View)

5 Instrument list, serial numbers and multipliers

Instrument (Measurement)	Make and Model	Serial Number	Variable Name (Program)	Multiplier
Pyrheliometer (DNI)	Hukseflux DR02	8362	DNI	9.84 µV/W/m^2
Pyranometer (GHI)	Hukseflux SR20-T2	3685	GHI_1	12.40 µV/W/m^2
Pyranometer (DHI)	Hukseflux SR20-T2	3681	DHI	11.43 µV/W/m^2
3-Cup Anemometer (Wind speed)	RM Young 03002	013394	WSpd	0.2 Offset 0.75 Slope
Wind Vane (Wind Direction)	RM Young 03002	013394	WDir	0 Offset 352 Slope
Temperature Sensor (Ambient Temperature)	Geonica STH-S331	0313	Temp	-40 offset 0.1 slope
Relative humidity Sensor (Relative Humidity)	Geonica STH-S331	0313	RH	-40 offset 0.1 slope
Barometer (Atmospheric Pressure)	Vaisala PTB110	J5150002	BP	500 offset 0.24 slope
Sun Tracker	Kipp & Zonen Solys 2	150172	N/A	N/A

6 Supporting hardware and communication peripherals

Data Logger	Campbell CR1000 (OS: Std.31.08)
Communication	RS232 (115200) TCP/IP
Ethernet	Campbell NL115 Ethernet Module with Additional Memory card
Pakbus Address	789
Password Set	None
Modem and Antenna	Maestro M100 3G modem with Poynting antenna
Network Details	Service provider: TTCL, Tanzania Phone number: +255 73 431 3061
Modem Power Control	SW12V
Data Logger Clock	GMT+3
Main Battery	2 x 12 V / 100 Ah
Secondary Battery	1 x 12 V / 7 Ah
Battery Charger	Mean Well 24 V Charger
Voltage Regulator	Mean Well 12 V Regulator and 12 V Charger

7 Data logger wiring

World Bank Dar Wiring Diagram October 2020 - CR1000						
Logger Port	**Din-rail Terminal**	**Connection**	**Instrument Cable**	**Function**	**Reading**	**Instrument**
Jumper between 1L and AG	1	1H	Yellow	Signal +	DNI	DR02
	2	1L	Green	Signal -		
	3	AG	Clear	Shield		
Jumper between 2L and AG	4	2H	White	Signal +	GHI	SR20-T2
	5	2L	Green	Signal -		
	6	AG	Clear	GND		
C4 - Heater Relay	H1+	NO1	Yellow	Heater+		
	H1-	G	Brown	Heater-		
VX2 10kOhm	T1+	6L	Red, Purple	Temp+		
	T1-	AG	Black,Blue	Temp-		
Jumper between 3L and AG	7	3H	White	Signal +	DHI	SR20-T2
	8	3L	Green	Signal -		
	9	AG	Clear	GND		
C4 - Heater Relay	H2+	NO2	Yellow	Heater+		
	H2-	G	Brown	Heater-		
VX2 10kOhm	T2+	8H	Red, Purple	Temp+		
	T2-	AG	Black,Blue	Temp-		
	10	4H	Green	Signal +	Wind	RM Young 03002
	11	P1	Red	Signal +		
	12	VX1	Blue	Excitation		
	13	AG	White,Black	GND		
	14	AG	Clear	Signal -		
	15	NC	Green	Ref	Pressure	Vaisala PTB110
	16	AG	Clear	GND		
	17	4L	Yellow	Vout+		
	21	12V	Red	12V		
	19	G	Blue	GND		
	24	7H	Blue	Temp	Temp & RH	Rotronic
	25	7L	Red	RH		
	29	AG	Clear,Black,White	AG		
	31	VX3	Green	Excitation		
	32	5V	Brown	Power		
	33	AG	Black,Purple	GND		
	36	G	Green	Signal +	Clean	Clean Button
	39	C5	Yellow	Light +		
C5-Pushbutton Relay	43	G	Blue	Signal -		
NO1-12V	44	NO1	Red	GND		
		8L	Green	Signal +	BAT24	Battery 24V Measurement
		24V+	White	BAT24		
		G	Yellow	GND		
		24V-	Black	BAT24		

8 Power circuit diagram

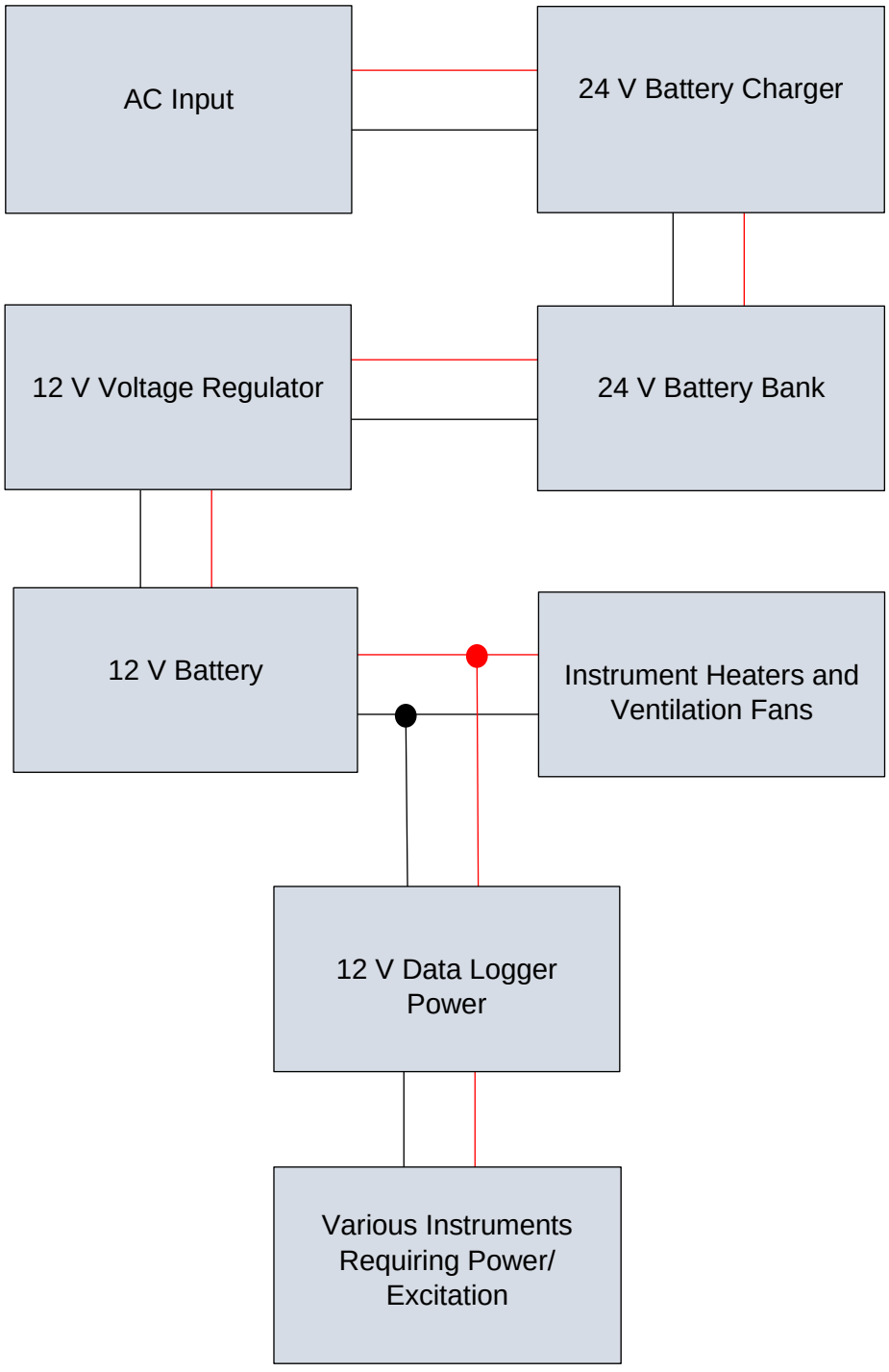


Figure 6: The power circuit

9 Detail Photographs

This section showcases details of the installation, including the main station components. Records are shown of instrument makes, models and serial numbers, as well as the installation levels and orientation where applicable.

Figure 7: Station Summary

Figure 8: GHI (1) Pyranometer Installation

Figure 9: DHI Pyranometer Installation

Figure 10: DNI Pyrheliometer Installation

Figure 11: Wind instruments at 3 m

Figure 12: Thermometer and Hygrometer at 2 m

Figure 13: Barometer

Figure 14: Logger Enclosure

10 Terrain Photographs

Obstacles protruding higher than the horizon as viewed from the solar instruments will affect lower solar elevation readings if they fall within the sun path as depicted in Figure 2. The pictures in this section shows the terrain surrounding the station at the time of installation, giving an indication of near or far shading influences on the station.

Figure 15: 0/360 Degrees (North)

Figure 16: 30 Degrees

Figure 17: 60 Degrees

Figure 18: 90 Degrees (East)

Figure 19: 120 Degrees

Figure 20: 150 Degrees

Figure 21: 180 Degrees (South)

Figure 22: 210 Degrees

Figure 23: 240 Degrees

Figure 24: 270 Degrees (West)

Figure 25: 300 Degrees

Figure 26: 330 Degrees

11 Station Photographs

This section indicates the station within the surrounding terrain to give an overall view thereof, as well as provide additional context to the possible near and far shading influences.

Figure 27: 30 Degrees

Figure 28: 150 Degrees

12 Calibration Certificates

Calibration Certificate

GeoSUN AFRICA

Pyrheliometer ISO 9059 Calibration Calibration Number: GSACH-0082

Calibrated Instrument

Instrument: Pyrheliometer
Manufacturer: Hukseflux
Model: DR02
ISO 9060:1990 Class: First Class

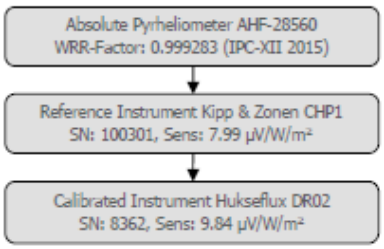
Calibration Date: 05 October 2020
Serial Number: 8362
New Sensitivity: 9.84 µV/W/m²

Calibration Methodology

GeoSUN performed an outdoor calibration through exposure of both the calibrated instrument (instrument under test) and a reference instrument with the sun and sky radiation as the source and comparing the sensor outputs. The instruments were installed on a common solar tracker and regularly checked to ensure that it remained clean and aligned for the duration of the reference data being collected. The calibration was performed in accordance with the ISO 9059 (1990) standard.

Reference Instrument and its Traceability

The reference instrument is a Kipp & Zonen CHP1 pyheliometer (SN 100301). The instrument was calibrated on 13 November 2019 at ISO-CAL North America against absolute cavity radiometer AHF–28560 which successfully participated at IPC-XII with the World Standard Group of radiometers. The location of ISO-CAL is at 20th street, Phoenix, Arizona in the USA at latitude 33.8176944°, longitude -112.0396083° and altitude 570 m AMSL. The reference instrument was calibrated at normal incidence with the sun and sky radiation as the source using the "alternating sun-and-shade method". The readings are referenced to the World Radiometric Reference (WRR) as stated in the WMO Technical Regulations, originally with an SI relative uncertainty estimated at ±0.3%. The diagram on the right shows the traceability hierarchy.



Absolute Uncertainty

The absolute uncertainty is the combined result of two uncertainties namely:
1) The expanded uncertainty during calibration of the reference instrument, given as ±0.43%.
2) The expanded uncertainty of the transfer procedure (calibration by comparison), estimated by scientific judgement as ±0.50%.
The combined expanded uncertainty is the root sum of the squares, resulting in $\sqrt{(0.43^2 + 0.50^2)} = \pm 0.66\%$.

Calibration Environment, Results and Instrument Status

The calibrated instrument underwent various inspections. A calibration was done using the measured output of the test instrument, of which the calibration environment and results are stated below. The standard deviation of the result is acceptable. Although the manufacturer specifies a calibration interval of two years, considering the operating conditions GeoSUN recommends an annual calibration.

Instrument	Status
Window:	Good
Desiccant Status:	Replaced
Desiccant Cartridge:	Good

Calibration Environment -	Average [Range]
Irradiation:	901 [816 - 953] W/m²
Ambient Temperature:	24.3 [20.5 - 27.8] °C
Solar Elevation:	52.0 [35.0 - 61.4] °
Linke Turbidity Factor:	2.3 [1.7 - 3.5]
Wind Speed:	1.3 [0.0 - 4.7] m/s

Previous	Calibration
Previous Sensitivity:	9.66 µV/W/m²
Previous Calib. Date:	25 Feb 2015

Calibration	Results
New Sensitivity (Avg. of 21 Series Over 1 Day):	9.83515 µV/W/m²
Sensitivity Standard Deviation (σ_{n-1}):	0.01137 µV/W/m²
Calibration Uncertainty:	±0.1178 µV/W/m² (±0.66%)
Next Calibration:	Oct 2021

Calibrated by: J.J. Terblanche

Approved by: M.L. de Jager

ISO 9001:2015

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2020/09/11

Calibration Certificate

GeoSUN AFRICA

Pyranometer ISO 9847 Calibration Certificate Number: GSACA-1267

Calibrated Instrument

Instrument: Pyranometer
Manufacturer: Hukseflux
Model: SR20-T2
ISO 9060:1990 Class: Secondary Standard

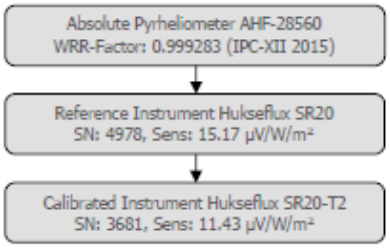
Calibration Date: 21 October 2020
Serial Number: 3681
New Sensitivity: 11.43 µV/W/m²

Calibration Methodology

GeoSUN performed an indoor calibration through exposure of both the calibrated instrument (instrument under test) and a reference instrument to an artificial light as radiation source and comparing the sensor outputs. The instruments were installed on a common horizontal base and regularly checked to ensure that it remained clean and level for the duration of the reference data being collected. The calibration was performed in accordance with the ISO 9847 (1992) standard, procedure type IIc.

Reference Instrument and its Traceability

The reference instrument is a Hukseflux SR20 pyranometer (SN 4978). The instrument was calibrated on 12 November 2019 at ISO-CAL North America against absolute cavity radiometer AHF-28560 which successfully participated at IPC-XII with the World Standard Group of radiometers. The location of ISO-CAL is at 20th street, Phoenix, Arizona in the USA at latitude 33.8176944°, longitude -112.0396083° and altitude 570 m AMSL. The reference instrument was calibrated at normal incidence with the sun and sky radiation as the source using the "alternating sun-and-shade method". The readings are referenced to the World Radiometric Reference (WRR) as stated in the WMO Technical Regulations, originally with an SI relative uncertainty estimated at ±0.3%. The diagram on the right shows the traceability hierarchy.



Absolute Uncertainty

The absolute uncertainty is the combined result of three uncertainties namely:

1) The expanded uncertainty during calibration of the reference instrument, given as ±0.44%.
2) The uncertainty in the correction of directional errors (cosine errors), estimated by scientific judgement as ±0.5%.
3) The expanded uncertainty of the transfer procedure (calibration by comparison), estimated by scientific judgement as ±1%.

The combined expanded uncertainty is the root sum of the squares, resulting in $\sqrt{(0.44^2 + 0.5^2 + 1^2)} = \pm 1.20\%$.

Calibration Environment, Results and Instrument Status

The calibration was performed at latitude -33.96521°, longitude 18.84092° and altitude 124 m AMSL and was concluded on 21 October 2020 at 13:37. A calibration was done using the measured output of the test instrument, of which the calibration environment and results are stated below. The measurement results recorded in this certificate were correct at the time of calibration. The subsequent accuracy will depend on factors such as care, handling and frequency of use. The calibration certificate or report may not be reproduced except in full, without the written approval of the laboratory. Considering the operating conditions and the IEC 61724-1:2017 standard requirements, GeoSUN recommends an annual calibration.

Instrument	Status
Bubble Level:	Good
Dome:	Abrasions present but fit for use
Desiccant:	Replaced

Calibration Environment -	Average [Range]
Irradiation:	471 [470 - 473] W/m²
Ambient Temperature:	22.6 [22.2 - 22.9] ºC
Reference Instrument Temp.:	22.5 [22.2 - 22.7] ºC

Original	Calibration
Original Sensitivity:	11.11 µV/W/m²
Original Calib. Date:	02 April 2015

Calibration	Results
New Sensitivity:	11.43243 µV/W/m²
Sensitivity Standard Deviation (σ_{n-1}):	0.00277 µV/W/m²
Calibration Uncertainty (k = 2):	±0.1374 µV/W/m² (±1.20%)
Data Quantity :	4 Series, 16 Samples
Next Calibration:	October 2021

Calibrated by: J. van Jaarsveldt

Authorised by: M.L. de Jager

ISO 9001:2015

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Calibration Certificate

GeoSUN AFRICA

Pyranometer ISO 9847 Calibration Certificate Number: GSACA-1268

Calibrated Instrument

Instrument: Pyranometer
Manufacturer: Hukseflux
Model: SR20-T2
ISO 9060:1990 Class: Secondary Standard

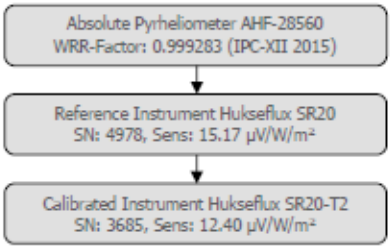
Calibration Date: 21 October 2020
Serial Number: 3685
New Sensitivity: 12.40 µV/W/m²

Calibration Methodology

GeoSUN performed an indoor calibration through exposure of both the calibrated instrument (instrument under test) and a reference instrument to an artificial light as radiation source and comparing the sensor outputs. The instruments were installed on a common horizontal base and regularly checked to ensure that it remained clean and level for the duration of the reference data being collected. The calibration was performed in accordance with the ISO 9847 (1992) standard, procedure type IIc.

Reference Instrument and its Traceability

The reference instrument is a Hukseflux SR20 pyranometer (SN 4978). The instrument was calibrated on 12 November 2019 at ISO-CAL North America against absolute cavity radiometer AHF-28560 which successfully participated at IPC-XII with the World Standard Group of radiometers. The location of ISO-CAL is at 20th street, Phoenix, Arizona in the USA at latitude 33.8176944°, longitude -112.0396083° and altitude 570 m AMSL. The reference instrument was calibrated at normal incidence with the sun and sky radiation as the source using the "alternating sun-and-shade method". The readings are referenced to the World Radiometric Reference (WRR) as stated in the WMO Technical Regulations, originally with an SI relative uncertainty estimated at ±0.3%. The diagram on the right shows the traceability hierarchy.



Absolute Uncertainty

The absolute uncertainty is the combined result of three uncertainties namely:
1) The expanded uncertainty during calibration of the reference instrument, given as ±0.44%.
2) The uncertainty in the correction of directional errors (cosine errors), estimated by scientific judgement as ±0.5%.
3) The expanded uncertainty of the transfer procedure (calibration by comparison), estimated by scientific judgement as ±1%.

The combined expanded uncertainty is the root sum of the squares, resulting in $\sqrt{(0.44^2 + 0.5^2 + 1^2)} = \pm 1.20\%$.

Calibration Environment, Results and Instrument Status

The calibration was performed at latitude -33.96521°, longitude 18.84092° and altitude 124 m AMSL and was concluded on 21 October 2020 at 14:27. A calibration was done using the measured output of the test instrument, of which the calibration environment and results are stated below. The measurement results recorded in this certificate were correct at the time of calibration. The subsequent accuracy will depend on factors such as care, handling and frequency of use. The calibration certificate or report may not be reproduced except in full, without the written approval of the laboratory. Considering the operating conditions and the IEC 61724-1:2017 standard requirements, GeoSUN recommends an annual calibration.

Instrument	Status
Bubble Level:	Good
Dome:	Abrasions present but fit for use
Desiccant:	Replaced

Calibration Environment -	Average [Range]
Irradiation:	468 [468 - 469] W/m²
Ambient Temperature:	22.1 [21.9 - 22.2] °C
Reference Instrument Temp.:	21.8 [21.7 - 22.0] °C

Original	Calibration
Original Sensitivity:	12.13 µV/W/m²
Original Calib. Date:	02 April 2015

Calibration	Results
New Sensitivity:	12.39972 µV/W/m²
Sensitivity Standard Deviation (σ_{n-1}):	0.00428 µV/W/m²
Calibration Uncertainty (k = 2):	±0.149 µV/W/m² (±1.20%)
Data Quantity :	4 Series, 16 Samples
Next Calibration:	October 2021

Calibrated by: J. van Jaarsveldt

Authorised by: M.L. de Jager

ISO 9001:2015

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V2020/10/06
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End of certificate

Calibration Certificate

ISO 9001 Meteorological Calibration — Calibration Number: GSACM-0144

Station Name: Dar es Salaam Pressure Sensor
Location: -33.965129°, 18.840923°

Calibration Date: 11-Dec-2020
Ambient conditions: 22°C; 62% RH

Test Instrument	Parameter	Reference Reading	Test Reading	Uncertainty (±)* Instr.	Uncertainty (±)* Absolute
Vaisala PTB110 SN J5150002	Barometric Pressure	700.5 hPa 800.2 hPa 900.4 hPa 1000.3 hPa	700.7 hPa 800.2 hPa 900.6 hPa 1000.7 hPa	1.5 hPa	2.9 hPa

Comments: None.

Reference Instruments

Parameter	Reference Instrument	Serial Number	Traceability	Calibration Date	Uncertainty (±) Instr.	Uncertainty (±) Expanded*
Temperature	Campbell Scientific 109	15553-29	South African National Standard (NMISA)	22-Oct-20	0.01	1.02 °C
Relative Humidity	Rotronic HC2A-SH	20261232	South African National Standard (NMISA)	16-Oct-20	1.7	4.2 % RH
Barometric Pressure	Vaisala PTB110	L2850725	South African National Standard (NMISA)	07-Oct-20	0.401	1.401 hPa
Precipitation	Young 52260 Calibrator	M18-05	South African National Standard (NMISA)	16-Oct-20	3	4.02 ml
Wind Speed	Young 18802 Drive	4664	South African National Standard (NMISA)	05-Oct-20	3	4 rpm

** Expanded uncertainty includes the reference's accuracy and calibration uncertainty, and this calibration's transfer uncertainty. Absolute calibration uncertainty includes the test instrument accuracy. Although the test instrument increment resolution can have an effect on the uncertainty, it is not taken into account.*

Calibration Methodology

Temperature:	Reference and test instruments were sealed and submerged in warm and cold water sources for respective measurements.
Relative Humidity:	Reference and test instruments were tested in a low humidity chamber and at ambient conditions.
Barometric Pressure:	Reference and test instruments were connected to a closed pressure system and different pressures were induced.
Precipitation:	A set volume of water was poured through the rain gauge at an acceptable flow rate and the amount of tips were counted.
Wind Speed:	A drive was coupled to the anemometer shaft, set rotational speeds were applied and wind speed recorded.
Wind Direction:	The wind vane was handheld at roughly 90° increment angles while angle outputs were recorded.

Calibrated by: W.C. Engelbrecht

Approved by: M.L. de Jager

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2018/06/16