Station Information Report

Solar and Meteorological Station

World Bank – Soroti, Uganda

Revision	Date	Author	Checked	Approved	Comments
Rev 0	01 Apr 2020	H. Bester	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:

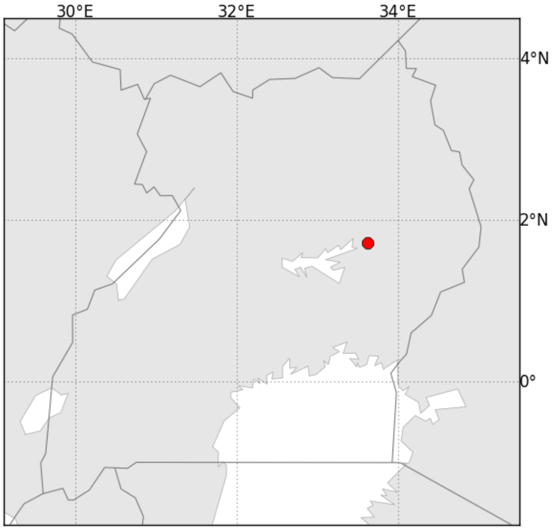
- An inception mission which involves visiting the proposed site locations and selecting the optimal location for the measurement equipment. The outcome of this inception mission is this implementation plan where sites and stations tiers are proposed;
- Providing high quality measuring equipment for 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 including security fence.
Commissioning date	24 January 2020
Planned decommissioning date	24 January 2022
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: Job Kahororo Email: job.kahororo@uetcl.com Telephone: +256 772 360 185
Site location	Located in the town of Soroti, 194km northeast from Kampala, Uganda. Site is situated on Soroti Airport premises. 
Access	Approaching Soroti from the east on Mbale-Soroti road, head to town centre. Turn right at Moroto road and head north for 440 m. Turn right onto Elangot road and head east for 230 m. Enter Soroti Airport gate and continue north for 330m and turn right when reaching tarmac. Head east for 200 m and drive around left side of hangar. Drive northeast for 250 m, the station is located south of existing weather station.
Coordinates	01° 43' 27.66" N, 33° 37' 19.55" E (1.724351, 33.622098)
Elevation	1128 m AMSL
Time zone (local and data logger)	GMT+3 local time zone
Name and contact details of on-site contact person(s)	Name: Omoding Joseph Cell: +256 075 680 9408

3 Map of area

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

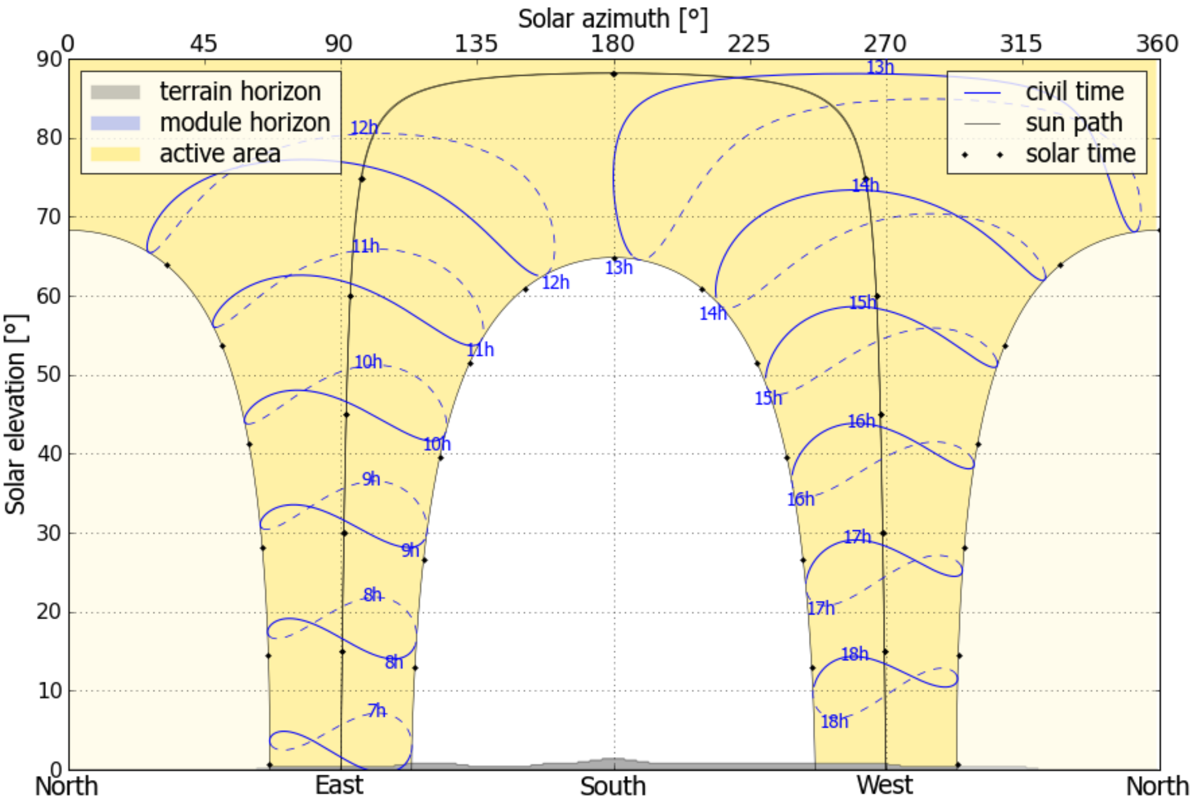


Figure 2: Terrain horizon and day length (Source: Solargis)

4 Site layout

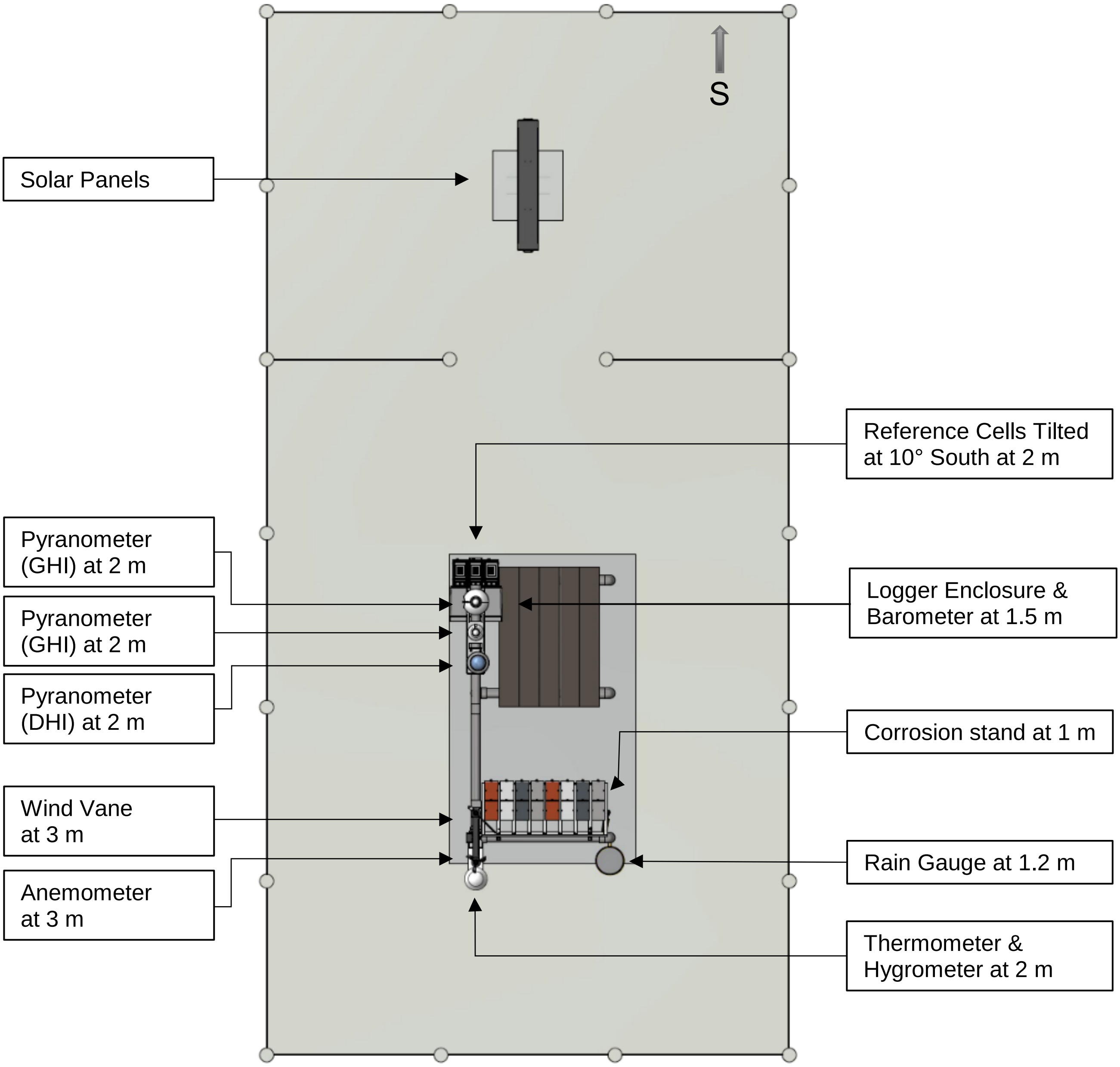


Figure 3: Site Layout (plan view)

Figure 4: Site Layout (perspective view)

5 Instrument list, serial numbers and multipliers

Instrument (Measurement)	Make and Model	Serial Number	Variable Name (Program)	Multiplier
Pyranometer (GHI)	Kipp & Zonen CMP 10	163400	GHI_1	8.83 µV/W/m²
Pyranometer (GHI)	Kipp & Zonen CMP 10	163401	GHI_2	9.55 µV/W/m²
Pyranometer (DHI)	Delta-T SPN 1	A2060	DHI_SPN1	1
Reference Cell Clean	Ingenieurbüro Si-mV-85-A	85-00205-17-19350097	RefCellClean	57.93 µV/W/m²
Reference Cell Monthly	Ingenieurbüro Si-mV-85-A	85-00205-17-19350098	RefCellMonthly	57.73 µV/W/m²
Reference Cell Dirty	Ingenieurbüro Si-mV-85-A	85-00205-17-19350099	RefCellDirty	57.62 µV/W/m²
3-Cup Anemometer (Wind speed)	Met One 014A	W14201	WSpd	0.447 Offset 0.8 Slope
Wind Vane (Wind Direction)	Met One 024A	W12324	WDir	0 Offset 738.9744 Slope
Temperature Sensor (Ambient Temperature)	Campbell Scientific CS215	E12908	Temp	1
Relative humidity Sensor (Relative Humidity)	Campbell Scientific CS215	E12908	RH	1
Barometer (Atmospheric Pressure)	Vaisala PTB110	L0440025	BP	500 offset 0.24 slope
Rain Gauge (Rain)	Texas Electronics TR-525I	53614-1112	Rain	0.2 mm/tip
Corrosion Plate	**Make**	**Sample**	**Position (Column, Row)**	**Mass (g)**
Mild Steel plate (Corrosion Testing)	Orytech Mild Steel	H1	C6, R1	130.9460
		H2	C6, R2	168.4528
		G5	C2, R1	137.9573
		G6	C2, R2	130.1460
Galvanised (Zinc) plate (Corrosion Testing)	Orytech H.D. Galvanised (Zinc)	H1	C4, R1	79.7632
		H2	C4, R2	80.3417
		G5	C8, R1	79.8237
		G6	C8, R2	80.9457
Copper plate (Corrosion Testing)	Orytech Copper	H1	C3, R1	81.7433
		H2	C3, R2	83.1200
		G5	C7, R1	81.2713
		G6	C7, R2	81.9600
Aluminium plate (Corrosion Testing)	Orytech Aluminium	H1	C5, R1	37.3991
		H2	C5, R2	37.3133
		G5	C1, R1	37.2259
		G6	C1, R2	36.3331

6 Supporting hardware and communication peripherals

Data Logger	Campbell CR1000 (OS:Std.32.03)
Communication	RS232 (115200) TCP/IP
Pakbus Address	777
Password Set	None
Modem and Antenna	Maestro M100 3G modem with Poynting antenna
Network Details	Service provider: Airtel Phone number: (256) 753 115500
Modem Power Control	SW12V
Data Logger Clock	GMT+3
Main Battery	2 x 12 V / 24 Ah
Solar Panel(s)	2 x 25 W
Charge Controller	2 x CPL Research (10 A)

7 Data logger wiring

E.Africa Wiring Diagram
November 2019

Logger Port	Accessories	Connection	Instrument Cable	Function	Reading	Instrument
		1H	White	Signal +	GHI1	SR20
		1L	Green	Signal -		
		AGB	Black	Shield		
	Relay 1 NO		Yellow	Heater +		
		GB	Brown	Heater -		
VX3	10kΩ 0.1% Resistor	SE3	Pink	Temp +		
			Red	Temp +		
		AG1	Grey	Temp -		
			Blue	Temp -		
		3H	White / Red	Signal +	GHI2	SR20 / CMP
		3L	Green / Blue	Signal -		
		AGB	Black	GND		
C8	Relay 1 NO		Yellow	Heater +		
		GB		Heater -		
VX1	10kΩ 0.1% Resistor	SE4	Red	Temp +		
		AG2	Blue	Temp -		
		5H	White	GHI +	DHI	SPN1
		6H	Brown	DHI +		
		5L	Green	Signal -		
		6L				
		GB	Grey	0 V		
		PB	Pink	12 V		
	Relay 1 NO		Red	Heater +		
		GB	Blue	Heater -		
		AGB	Clear	GND		
		NC	Yellow	Sun		
		PB	Red	12 V	Temp & RH	CS215
		C1	Green	Signal +		
		GB	White	0 V		
		GB	Black	0 V		
		AGB	Clear	GND		
		SE13	Red	Signal +	Clean	Ref cell
		AG6	Blue	Signal -		
		AGB	Black	GND		
		SE14	Red	Signal +	Monthly	Ref cell
		AG7	Blue	Signal -		
		AGB	Black	GND		
		SE15	Red	Signal +	Dirty	Ref cell
		AG7	Blue	Signal -		
		AGB	Black	GND		
		VX2	Black	Excitation	WD	024A
		SE16	Red	Signal +		
		AG8	White	Signal -		
		AGB	Clear	GND		
		P1	Black	Signal +	WS	014A
		AG	White	Signal -		
		AGB	Clear	GND		

		P2	Black	Signal +	Rain	TE525
		AG	White	Signal -		
		AGB	Clear	GND		
5V	10kΩ Resistor	C2	Red	Signal +	Clean	Clean Button
		C5	Green	Light +		
		C3	Blue	Signal -		
		AGB	Clear	GND		
5V	10kΩ Resistor	C4	Yellow	Signal +	Monthly	Monthly Button
		C5	Green	Light +		
		C3	Blue	Signal -		
		AGB	Clear	GND		
5V	10kΩ Resistor	C6	Red	Signal +	Gate	Switch
		G	Blue	Signal -		
		AGB	Clear	GND		
		SE4	Blue/Brown	Signal +	Pressure	PTB110
		PB	Red	12V		
		C7	Green	Signal +		
		GB	Black	Signal -		
		AG	Yellow/White	GND		
		AGB	Clear	GND		

8 Power circuit diagram

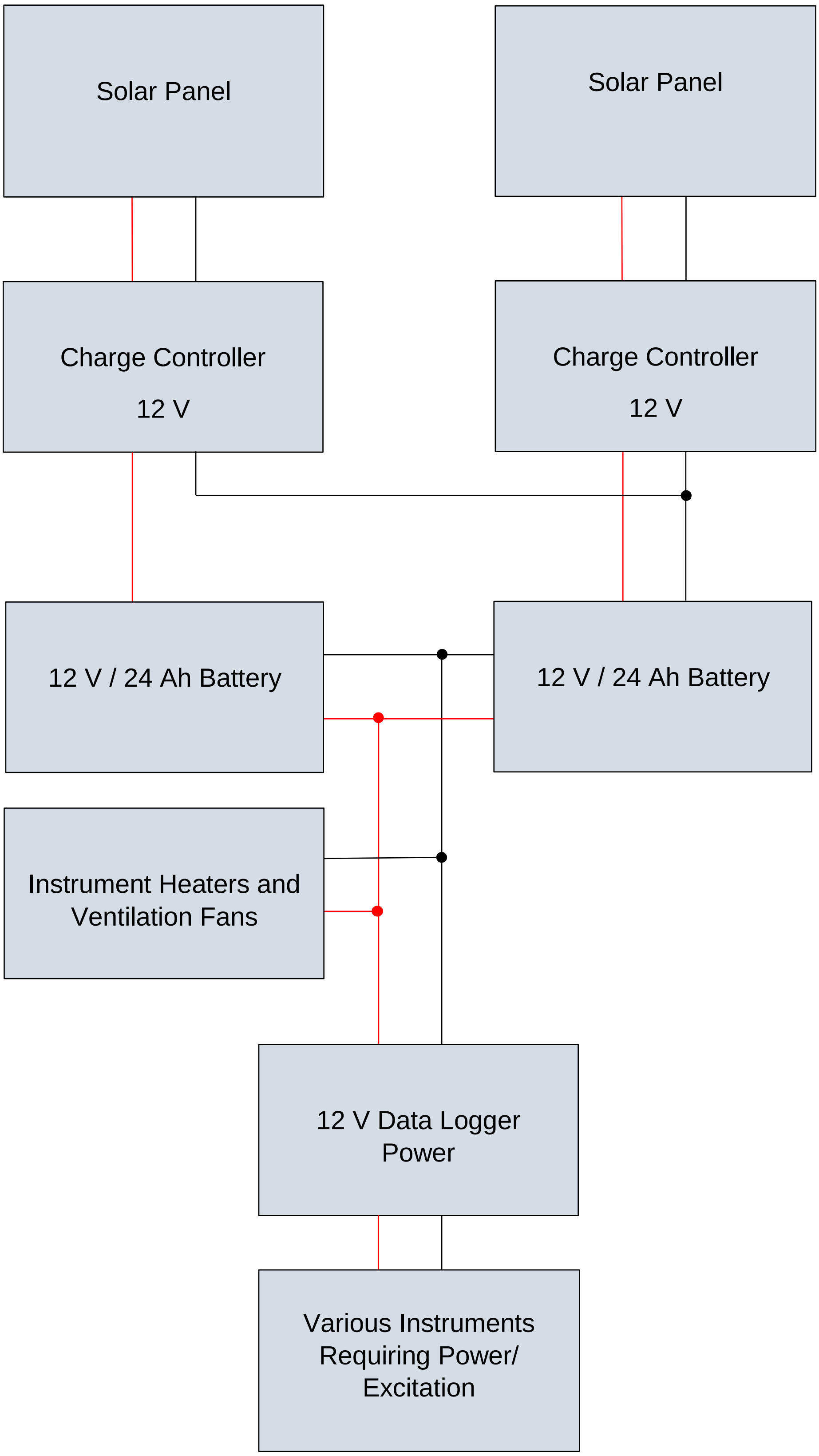


Figure 5: The DC power circuit

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 6: Station Summary

Figure 7: GHI (1) Pyranometer Installation

Figure 8: GHI (2) Pyranometer Installation

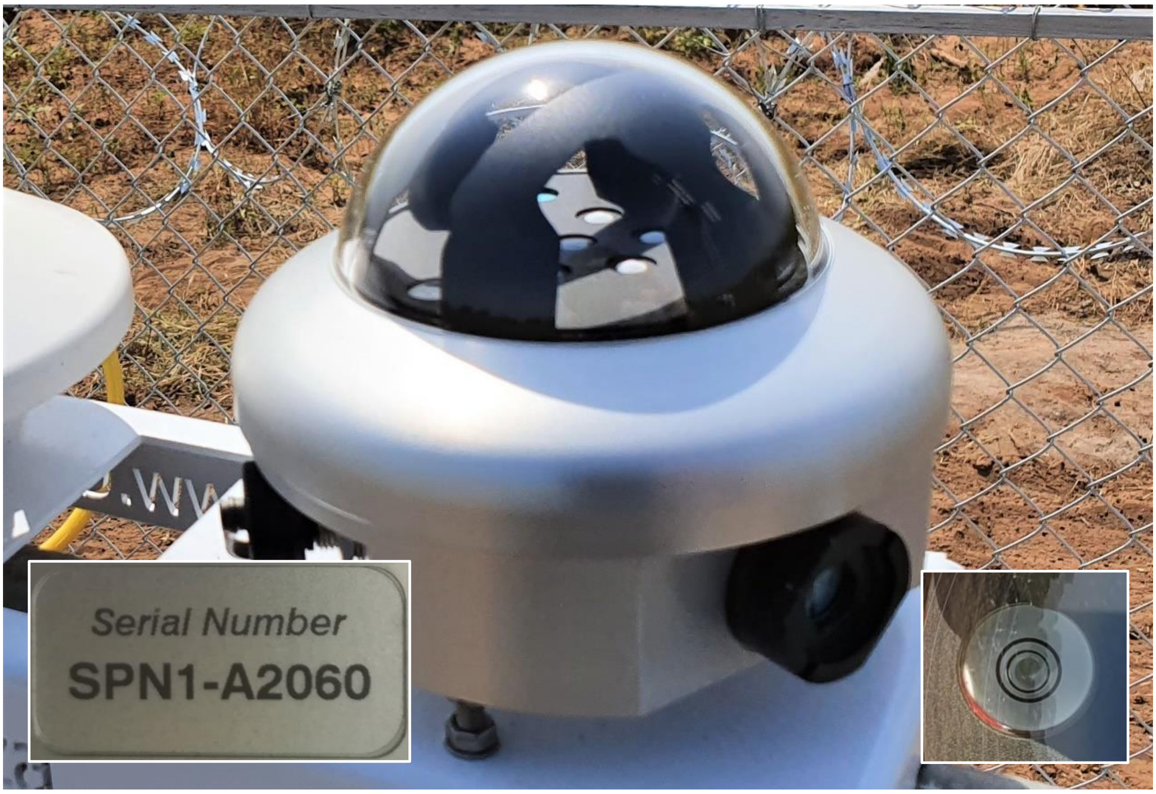


Figure 9: DHI Pyranometer Installation

Figure 10: Wind instruments at 3 m

Figure 11: Thermometer and Hygrometer at 2 m

Figure 12: Corrosion Test Stand

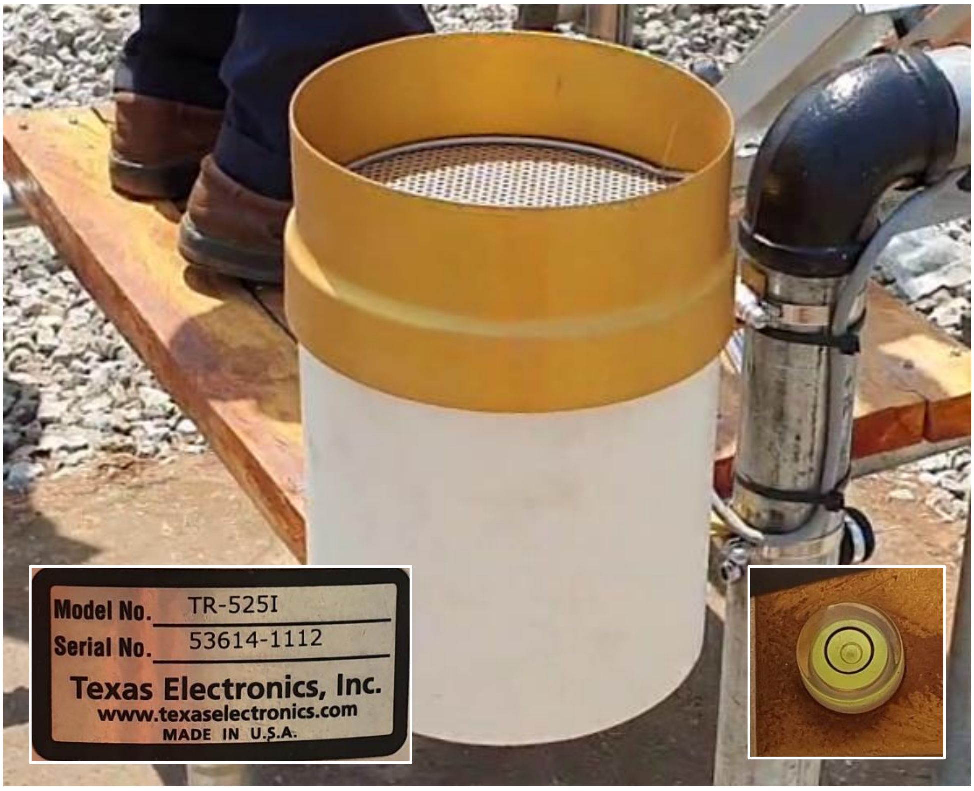


Figure 13: Rain Gauge

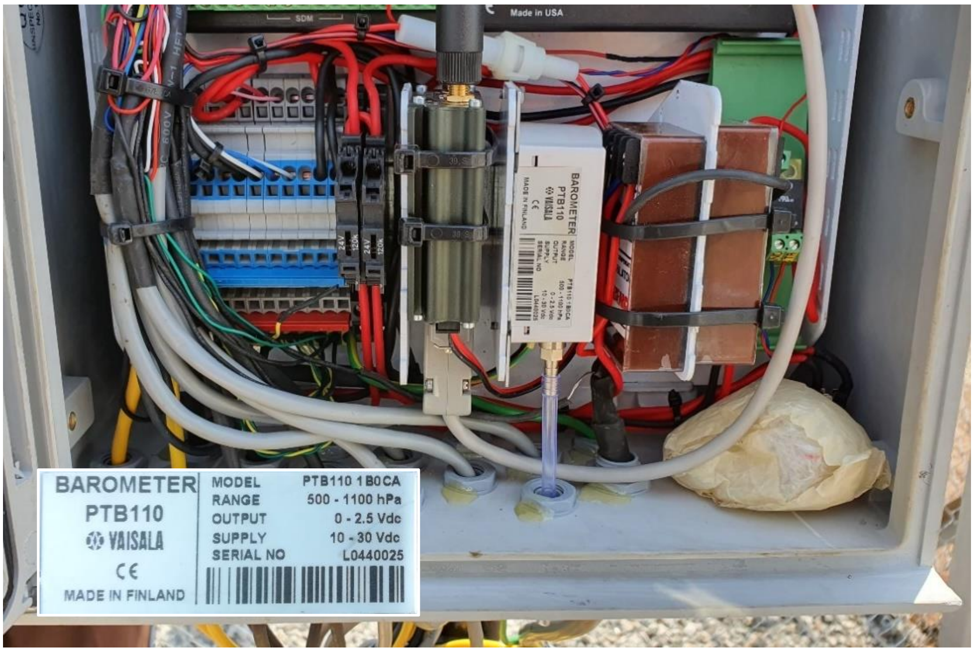


Figure 14: Barometer

Figure 15: Reference Cells at 10° South

Figure 16: Solar Panel

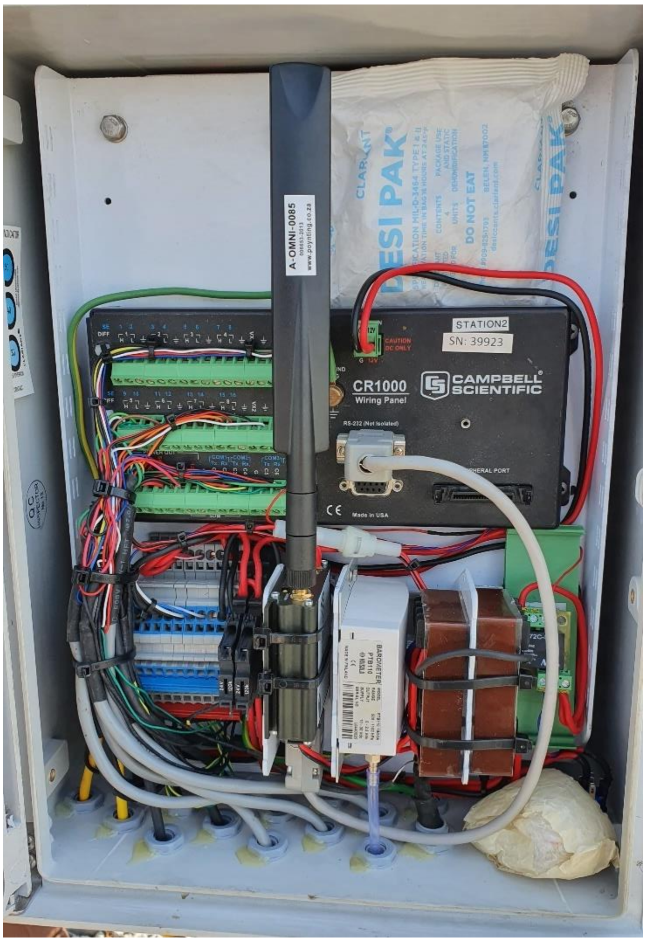


Figure 17: Logger Enclosure

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 18: 0/360 Degrees (North)

Figure 19: 30 Degrees

Figure 20: 60 Degrees

Figure 21: 90 Degrees (East)

Figure 22: 120 Degrees

Figure 23: 150 Degrees

Figure 24: 180 Degrees (South)

Figure 25: 210 Degrees

Figure 26: 240 Degrees

Figure 27: 270 Degrees (West)

Figure 28: 300 Degrees

Figure 29: 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 30: 0/360 Degrees (From North)

Figure 31: 30 Degrees

Figure 32: 60 Degrees

Figure 33: 90 Degrees (From East)

Figure 34: 120 Degrees

Figure 35: 150 Degrees

Figure 36: 180 Degrees (From South)

Figure 37: 210 Degrees

Figure 38: 240 Degrees

Figure 39: 270 Degrees (From West)

Figure 40: 300 Degrees

Figure 41: 330 Degrees

12 Calibration Certificates

Calibration Certificate

GeoSUN AFRICA

Pyranometer ISO 9847 Calibration — Certificate Number: GSACA-0885

Calibrated Instrument

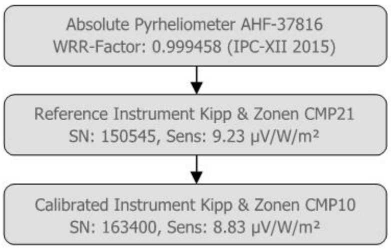
Instrument:	Pyranometer	Calibration Date:	06 November 2019
Manufacturer:	Kipp & Zonen	Serial Number:	163400
Model:	CMP10	New Sensitivity:	8.83 μV/W/m²
ISO 9060:1990 Class:	Secondary Standard		

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 Kipp & Zonen CMP21 pyranometer (SN 150545). The instrument was calibrated on 17 April 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 ±0.47%.
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 $\sqrt{(0.47^2 + 0.5^2 + 1^2)} = \pm 1.21\%$.

Calibration Environment, Results and Instrument Status

The calibration was performed at latitude -33.96543°, longitude 18.83626° and altitude 134 m AMSL and was concluded on 06 November 2019 at 10:36. 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:	Good

Calibration Environment -	Average [Range]
Irradiation:	444 [444 - 445] W/m²
Ambient Temperature:	24.4 [24.2 - 24.6] ºC
Reference Instrument Temp.:	24.1 [23.9 - 24.3] ºC

Original	Calibration
Original Sensitivity:	9.02 μV/W/m²
Original Calib. Date:	06 December 2016

Calibration	Results
New Sensitivity:	8.82968 μV/W/m²
Sensitivity Standard Deviation (σ_{n-1}):	0.00337 μV/W/m²
Calibration Uncertainty (k = 2):	±0.1071 μV/W/m² (±1.21%)
Data Quantity :	4 Series, 16 Samples
Next Calibration:	November 2020

Calibrated by:
W.C. Engelbrecht

Authorised by:
M.L. de Jager

ISO 9001:2015 REGISTERED COMPANY

GeoSUN Africa (Pty) Ltd
Unit 1, CS Africa Building, 1 Meson Street, Techno Park, Stellenbosch, South Africa
info@geosun.co.za, www.geosun.co.za,+27 21 882 8354

V2019/07/16
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End of certificate

Calibration Certificate

GeoSUN AFRICA

Pyranometer ISO 9847 Calibration Certificate Number: GSACA-0886

Calibrated Instrument

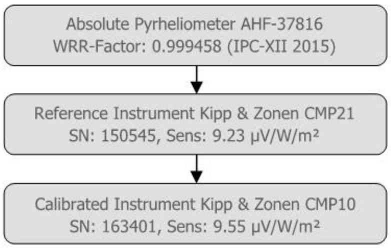
Instrument:	Pyranometer
Manufacturer:	Kipp & Zonen
Model:	CMP10
ISO 9060:1990 Class:	Secondary Standard
Calibration Date:	06 November 2019
Serial Number:	163401
New Sensitivity:	9.55 μV/W/m^2

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 Kipp & Zonen CMP21 pyranometer (SN 150545). The instrument was calibrated on 17 April 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 ±0.47%.
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 $\sqrt{(0.47^2 + 0.5^2 + 1^2)} = \pm 1.21\%$.

Calibration Environment, Results and Instrument Status

The calibration was performed at latitude -33.96543°, longitude 18.83626° and altitude 134 m AMSL and was concluded on 06 November 2019 at 10:51. 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:	Good

Calibration Environment -	**Average [Range]**
Irradiation:	445 [444 - 445] W/m^2
Ambient Temperature:	24.9 [24.7 - 25.0] ºC
Reference Instrument Temp.:	24.8 [24.6 - 25.0] ºC

Original	**Calibration**
Original Sensitivity:	9.72 μV/W/m^2
Original Calib. Date:	06 December 2016

Calibration	**Results**
New Sensitivity:	9.55314 μV/W/m^2
Sensitivity Standard Deviation (σ_{n-1}):	0.00143 μV/W/m^2
Calibration Uncertainty (k = 2):	±0.1159 μV/W/m^2 (±1.21%)
Data Quantity :	4 Series, 16 Samples
Next Calibration:	November 2020

Calibrated by:
W.C. Engelbrecht

Authorised by:
M.L. de Jager

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End of certificate

Delta-T Devices Ltd

SPN1 Sunshine Pyranometer

Calibration Certificate

This is to certify that the Sunshine Pyranometer type SPN1 identified below has been calibrated in accordance with Delta-T Devices Ltd standard production procedures and conforms to the specifications as detailed.

Serial Number	SPN1 – A2060
Date	24/09/19
Authorised Signature	

We recommend that this instrument is recalibrated every 2 years.

Traceability

The SPN1 is calibrated under a uniform light source which simulates the solar spectrum, against a transfer standard SPN1. The transfer standard is calibrated outdoors against a Kipp & Zonen CM21 secondary standard pyranometer (calibration traceable to the World Radiometric Reference), with solar tracker and shading disk for diffuse measurement.

Accuracy, Total (Global) and Diffuse radiation

When correctly calibrated, the expected accuracy is given in the table below. The figures give 95% confidence limits, i.e. 95% of individual readings will be within the stated limits under normal climatic conditions.

Overall accuracy:	±5% daily integrals ±5% ±10 $W.m^{-2}$ hourly averages ±8% ±10 $W.m^{-2}$ individual readings
Range	0 to >2000 $W.m^{-2}$
Analogue output sensitivity	1mV = 1 $W.m^{-2}$

Delta-T Devices Ltd
130 Low Road, Burwell, Cambridge, CB25 0EJ, UK
Tel: +44 1638 742922 Fax: +44 1638 743155
email: sales@delta-t.co.uk web: www.delta-t.co.uk

INGENIEURBÜRO
Mencke & Tegtmeyer GmbH
Meßgeräte für die Solartechnik
Schwarzer Weg 43A
31789 Hameln, Germany
www.ib-mut.de

Calibration Certificate Silicon Irradiance Sensor

Sensor Type: **Si-mV-85-A**
Serial No.: **85-00205-17-19350097**
Comment:

Irradiance Calibration with Artificial Light in Comparison to a Reference Cell

Calibrated by: **Huhnstock-Breuer**
Date / Time: **28.08.2019** **13:52**

	Type	Calibration µV/W/m²	Temperature Coefficient 1/°C	Output mV	Temperature °C	**Irradiance[1)] W/m²**
Reference Cell	Si-Ref mono PTB-1	56,51	0,00067	56,953	30,76	**1004,0**
	Type	Irradiance W/m²	Correction Factor [3)]	Output mV	Temperature °C	Calibration µV/W/m²
Test Object	Si-mV-85-A	1004,0	0,995783	58,402	31,05	**57,93**

Test Equipment Irradiance Calibration

Manufacturer	Type	Serial No.	Calibration Certificate	Trace
Ingenieurbüro Mencke & Tegtmeyer GmbH	Si-Ref mono PTB-1	02-20002-05-15309999	47109-PTB-18	PTB
Gantner Instruments	IDL100	191667	098220-02 D-K-15019-01-00	DKD
	ISM111	078743	098221-02 D-K-15019-01-00	DKD
OMEGA Engineering	IN510	9894	./.	./.

$$^{1)}Irradiance = \frac{Output * 1000}{Calibration * (1 + Temperature\ Coefficient * (Temperature - 25))}$$

$$^{2)}Calibration = \frac{Output * 1000 * Correction\ Factor}{Irradiance}$$

[3)] Individual calculated for each Calibration Process, must not be used for Outdoor Application.

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Sensor Type: **Si-mV-85-A**
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Reference Cell	Si-Ref mono PTB-1	56,51	0,00067	56,953	30,76	**1004,0**
	Type	Irradiance W/m²	Correction Factor [3]	Output mV	Temperature °C	Calibration µV/W/m²
Test Object	Si-mV-85-A	1004,0	0,995956	58,192	30,8	**57,73**

Test Equipment Irradiance Calibration

Manufacturer	Type	Serial No.	Calibration Certificate	Trace
Ingenieurbüro Mencke & Tegtmeyer GmbH	Si-Ref mono PTB-1	02-20002-05-15309999	47109-PTB-18	PTB
Gantner Instruments	IDL100	191667	098220-02 D-K-15019-01-00	DKD
	ISM111	078743	098221-02 D-K-15019-01-00	DKD
OMEGA Engineering	IN510	9894	./.	./.

$$^{1)}Irradiance = \frac{Output * 1000}{Calibration * (1 + Temperature\ Coefficient * (Temperature - 25))}$$

$$^{2)}Calibration = \frac{Output * 1000 * Correction\ Factor}{Irradiance}$$

[3] Individual calculated for each Calibration Process, must not be used for Outdoor Application.

INGENIEURBÜRO
Mencke & Tegtmeyer GmbH
Meßgeräte für die Solartechnik
Schwarzer Weg 43A
31789 Hameln, Germany
www.ib-mut.de

Calibration Certificate Silicon Irradiance Sensor

Sensor Type: **Si-mV-85-A**
Serial No.: **85-00205-17-19350099**
Comment:

Irradiance Calibration with Artificial Light in Comparison to a Reference Cell

Calibrated by: **Huhnstock-Breuer**
Date / Time: **28.08.2019** **13:53**

	Type	Calibration µV/W/m²	Temperature Coefficient 1/°C	Output mV	Temperature °C	**Irradiance[1)] W/m²**
Reference Cell	Si-Ref mono PTB-1	56,51	0,00067	56,953	30,76	**1004,0**

	Type	Irradiance W/m²	Correction Factor [3)]	Output mV	Temperature °C	Calibration µV/W/m²
Test Object	Si-mV-85-A	1004,0	0,995956	58,088	30,8	**57,62**

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Calibration Certificate

ISO 9001 Meteorological Calibration Calibration Number: GSACM-0061

Station Name: Soroti Meteorological Station Calibration Date: 22 November 2019
Location: -33.965447°, 18.8361658° Ambient conditions: 25 - 29 °C; 39 - 40 % RH

Test Instrument	Parameter	Reference Reading	Test Reading	Uncertainty (±)* Instr.	Absolute
Campbell Scientific Model CS215 SN E12908	Ambient Temperature	0.5 °C 46.6 °C	0.0 °C 46.9 °C	0.9 °C	1.9 °C
Campbell Scientific Model CS215 SN E12908	Relative Humidity At 29°C → At 29°C →	21.9 % RH 70.1 % RH	21.7 %RH 70.9 % RH	2 % RH	5.6 % RH
Vaisala PTB110 SN L0440025	Barometric Pressure	702.2 hPa 807.1 hPa 901.8 hPa 996.3 hPa	702.5 hPa 806.1 hPa 901.2 hPa 996.2 hPa	1.5 hPa	2.7 hPa
Met One 014A W14201	Wind Speed $m/s = (rpm \times 0.02667) + 0.447$ 200 rpm → 400 rpm → 800 rpm → 1 800 rpm → 2 400 rpm → 3 000 rpm →	5.8 m/s 11.1 m/s 21.8 m/s 48.4 m/s 64.4 m/s 80.4 m/s	5.6 m/s 11.2 m/s 21.6 m/s 48.4 m/s 64.4 m/s 80.4 m/s	1 m/s	1.0 m/s
Met One 024A W12324	Wind direction	North East South West	0 ° 90 ° 180 ° 270 °	5 °	10 °
Texas TR525I SN 53614-1112	Precipitation $Tips = \frac{ml}{4.73\ ml/Tip}$	250 ml 52 Tips	52 Tips	7.5 ml 1 Tip	11.5 ml 2 Tips

Comments: The rain gauge sensitivity was adjusted.

Reference Instruments

Parameter	Reference Instrument	Serial Number	Traceability	Calibration Date	Uncertainty (±) Instr.	Expanded*	
Temperature	Campbell Scientific 109	15553-29	South African National Standard (NMISA)	05-Sep-19	0.01	1.02	°C
Relative Humidity	Rotronic HC2A-SH	20261232	Swiss National Standard (Rotronic)	03-Sep-19	1.1	3.6	% RH
Barometric Pressure	Vaisala PTB110	L2850725	South African National Standard (Inteltronics)	09-Sep-19	0.2	1.2	hPa
Precipitation	Glassco Measuring Cyl.	05.15/2028	Indian National Standard (Glassco)	19-Sep-19	3	4.02	ml
Wind Speed	Young 18802 Drive	4664	South African National Standard (LabCom)	28-Aug-19	2	3	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

ISO 9001:2015

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