New Broadband Pyranometers and Progress on the LW And SW Standards

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1. NREL
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ARM/ASR

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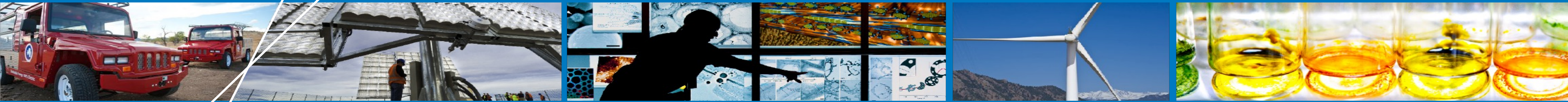
World Radiometric Reference and World InfraRed Standard Group Scale Change Update



The Atmospheric Radiation Measurement (ARM)/Atmospheric System Research (ASR) Joint User Facility/Principal Investigator Meeting Aug 7-10, 2023

by

Ibrahim Reda, Manajit Sengupta, Aron Habte

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Solar Irradiance Scale Change

The World Radiometric Reference (WRR) is an artefact-based reference for terrestrial Direct Solar Irradiance (DSI) measurements. The WRR is defined by the average of currently six solar absolute radiometers belonging to the World Standard Group (WSG) located at the Physikalisch Meteorologisches Observatorium Davos and World Radiation Center (PMOD/WRC), Switzerland.

Historic scale comparisons have shown good agreement between the WRR and SI standards for radiant power and area (length). More recent intercomparisons, which have utilized improved laboratory facilities, revealed a significant scale difference of about -0.3% of the SI scale being lower relative to the WRR scale. The idea is to replace the WSG with the Cryogenic Solar Absolute Radiometer (CSAR) in future. CSAR aims for resolving the scale difference issue by providing a direct traceability of DSI measurements to the SI scale. Furthermore, CSAR aims to reduce the overall uncertainty of DSI measurements from 0.3% to 0.01%. CSAR is the world's first cryogenic absolute radiometer for terrestrial solar irradiance measurements and was developed and built by the National Physical Laboratory in London (NPL), the PMOD/WRC and the Federal Institute of Metrology (METAS) in Bern, Switzerland.

Direct Solar Irradiance measurements with a Cryogenic Solar Absolute Radiometer, RADIATION PROCESSES IN THE ATMOSPHERE AND OCEAN (IRS2016): Proceedings of the International Radiation Symposium (IRC/IAMAS), 16–22 April 2016, Auckland, New Zealand

Atmospheric Longwave Irradiance Scale Change

Historical atmospheric longwave irradiance data sets with traceability to the International System of Units (SI) are essential for renewable energy and atmospheric science research and applications. To date, all pyrgeometers used to measure the irradiance are traceable to the interim World Infrared Standard Group (WISG), not to SI units. In 2013, the Absolute Cavity Pyrgeometer (ACP) (Reda et al. 2012) was developed at the National Renewable Energy Laboratory (NREL) to measure the atmospheric longwave irradiance. The ACP has been compared against the InfraRed Integrating Sphere (IRIS), developed by the PhysikalischMeteorologisches Observatorium Davos/World Radiation Center (PMOD/WRC) (Gröbner 2012). The ACP and the IRIS are absolute instruments traceable to SI units through the International Temperature Scale of 1990. Results of six comparisons between the ACP and the IRIS at different locations have shown that the irradiance measured by WISG pyrgeometers underestimates clear-sky atmospheric longwave irradiance by ~5 W/m^2 (Gröbner et al. 2014); therefore, once the world reference is established with traceability to SI units, the historical ASR/ARM data would be corrected using this published article ”*A Procedure to Correct the Historical Atmospheric Longwave Irradiance Data When the World Reference Is Established with Respect to the International System of Units”*

Reda, I., Andreas, A., & Gotseff, P. (2022). A Procedure to Correct the Historical Atmospheric Longwave Irradiance Data When the World Reference Is Established with Respect to the International System of Units. European Journal of Applied Sciences, 10(2). 274- 281

Surface Broadband Radiometer replacements

ENG0004176

Current status:

- SGP -2023-01 SW & LW BORCAL ➔ 50 SR20s and 15 DR20s
- SGP -2023-02 SW BORCAL ➔ 20 SR20s
- Deployment sequence of new Hukseflux radiometers as provided by Jennifer Comstock - RCF, SGP CF,NSA, ENA, AMF1, AMF2, AMF3 then EFs will follow in the second year.

Overview

- Characterization of new radiometers
  - IR loss correction
  - Temperature response
  - Directional response
- Station reconfiguration status
- Discussion

IR Loss Correction Analysis Using Old and New Radiometers from three stations

- Using NREL and QCRAD correction methods

The responsivity (R, µV/W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$R = (V - Rnet * Wnet) / I \qquad [1]$$

where,

V = radiometer output voltage (microvolts),

$Rnet$ = radiometer net infrared responsivity (µV/W/m²), see Table 4,

$Wnet$ = effective net infrared measured by pyrgeometer (W/m²),

= $Win - Wout$ = $Win - \sigma * Tc^4$

where, Win = incoming infrared (W/m²), σ = 5.6704e-8 W·m-2·K-4,

Tc = case temperature of pyrgeometer (K).

I = reference irradiance (W/m²), beam (B) or global (G)

where, $G = B * COS(Z) + D$,

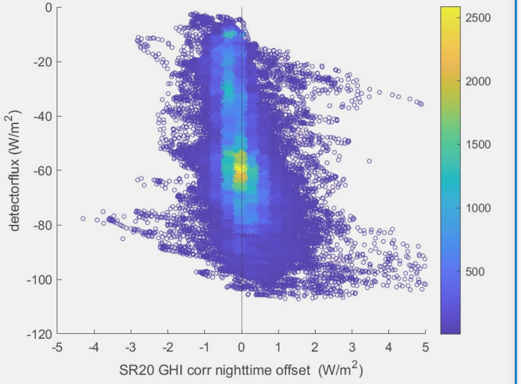
Z = zenith angle (degrees),

D = reference diffuse irradiance (W/m²).

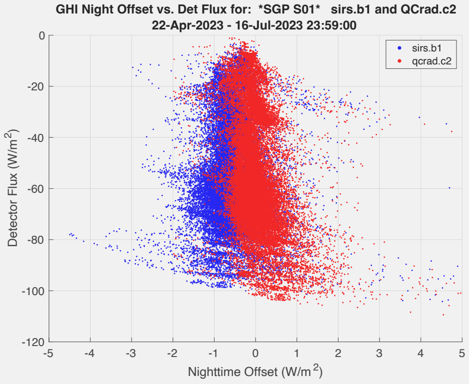
ARM S01 (4/22/2023 -7/16/2023) (SR20s)

Corrected GHI for thermal offset

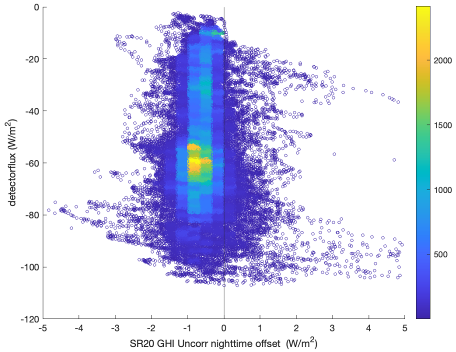
NREL method



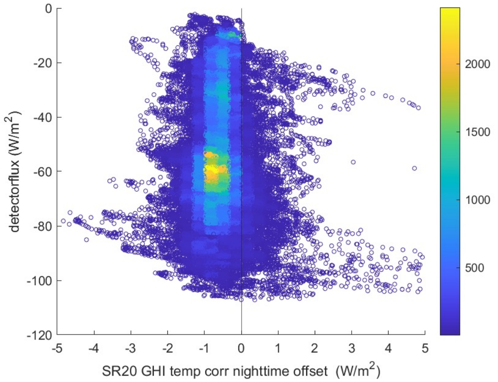
QCRAD method



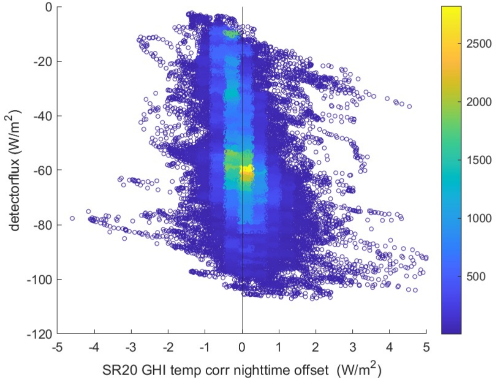
Uncorrected GHI for thermal offset & temp.



Corrected GHI for ~~thermal offset &~~ temp.

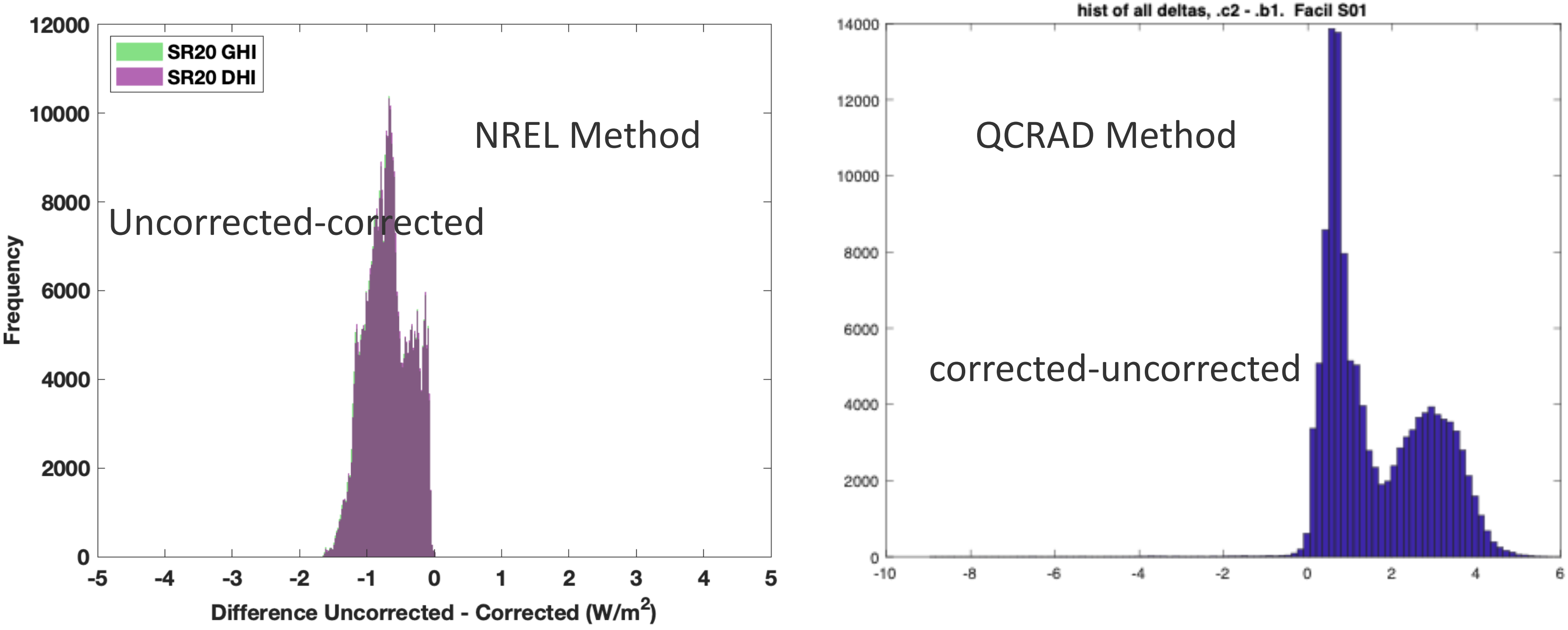


Corrected GHI for thermal offset & temp.



Nighttime offset analysis using NREL and QCRAD method. Both methods provide similar result (plots inside the box –left side).

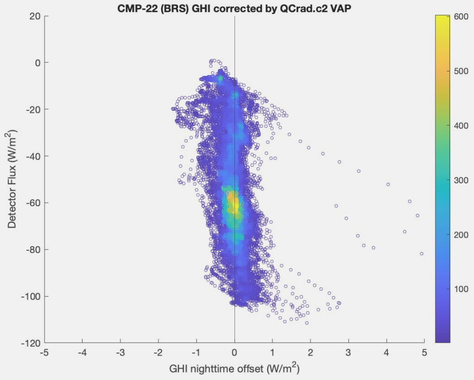
SR20 (S01) –IR corrected (day and night data)



QCRAD appears to make larger corrections to all dataset (day and night) as compared to the NREL method. I think this could be the wet and dry correction that was developed for the QCRAD.

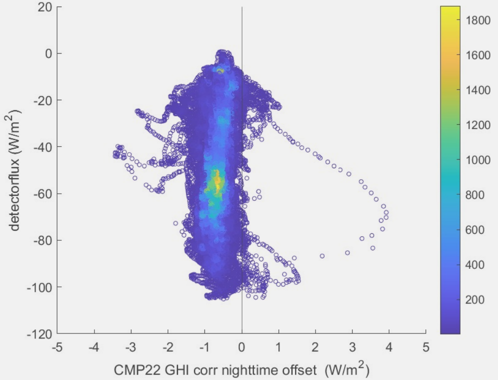
ARM S01 (4/22/2023 -7/16/2023) (CMP22)

QCRAD method

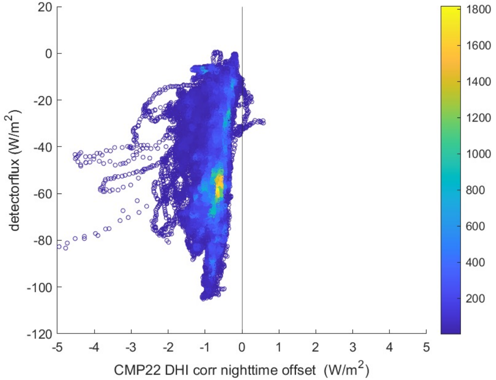


NREL method

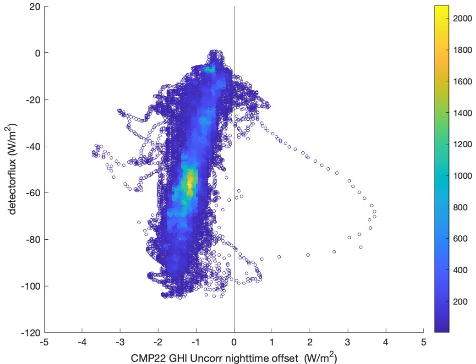
CMP22 GHI corrected for thermal offset



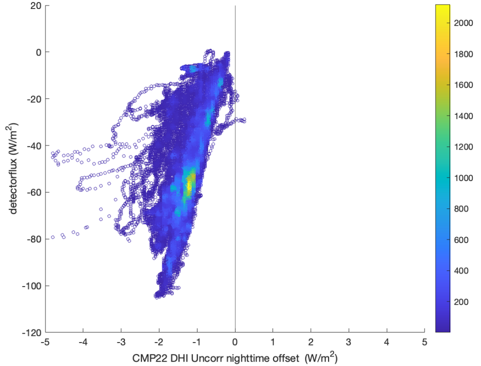
CMP22 DHI corrected for thermal offset



CMP22 GHI uncorrected for thermal offset

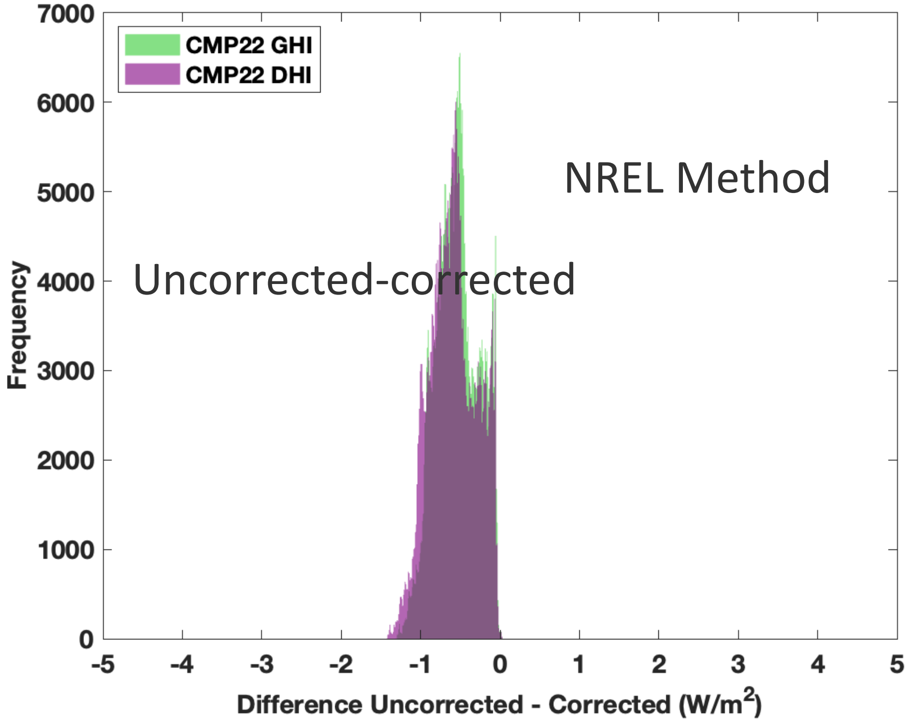


CMP22 DHI uncorrected for thermal offset



The nighttime offset correction using QCRAD and NREL method is similar

CMP22 (BRS) – day and night data



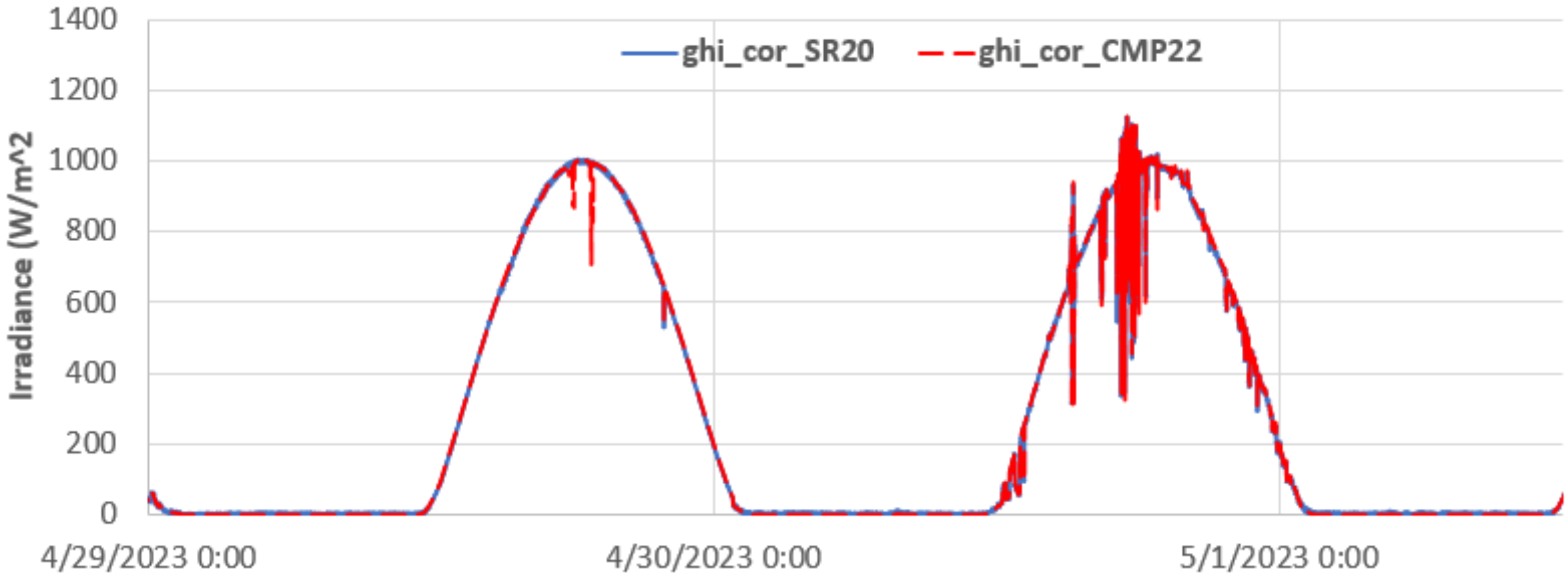
NREL Method

Uncorrected-corrected

QCRAD Method

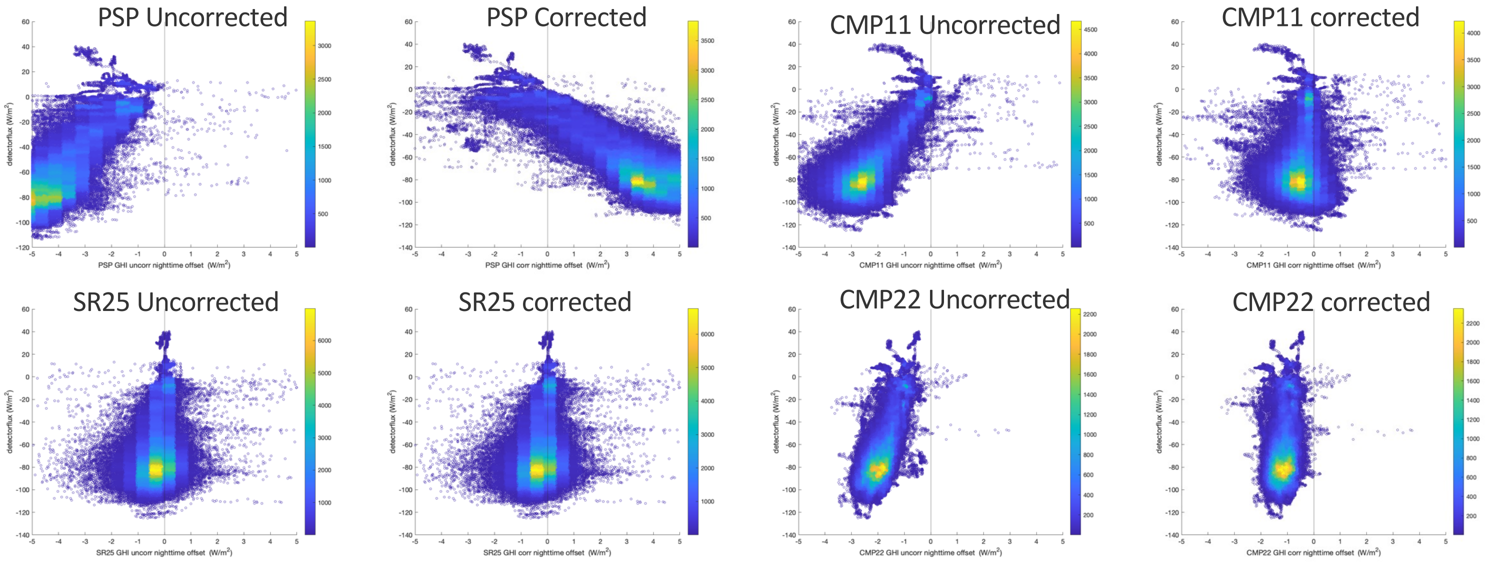
corrected-uncorrected

Difference between SR20 and CMP22 after correction



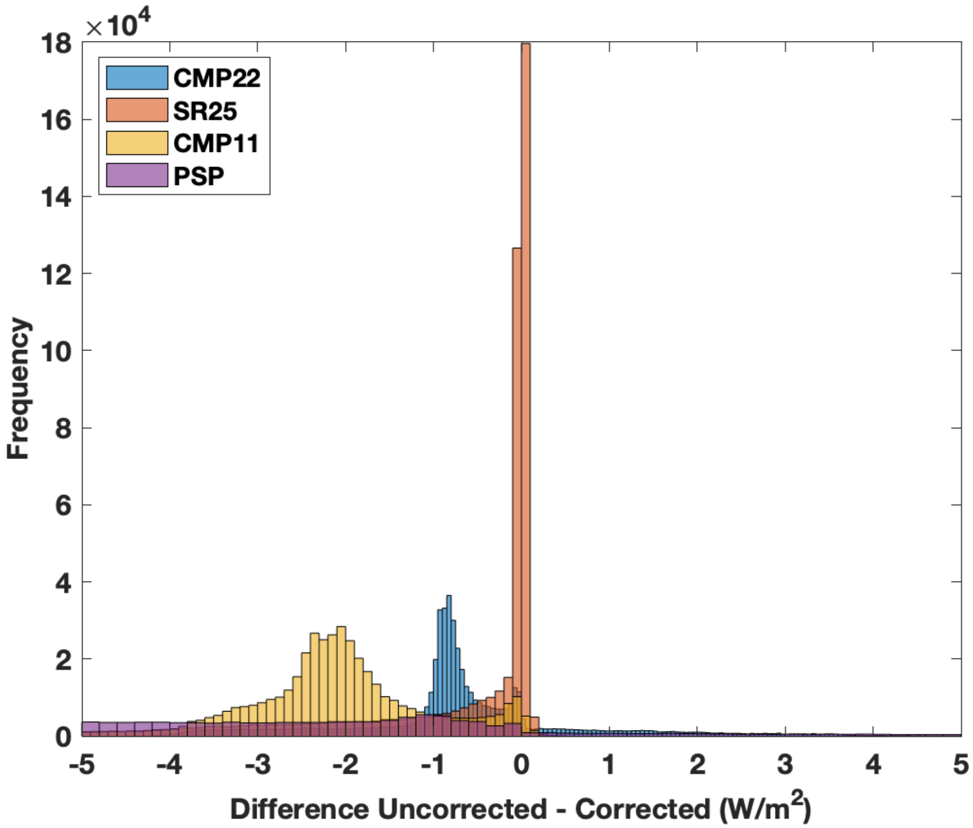
NREL SRRL (1/1/2022 -1/31/2022)

thermal offset correction



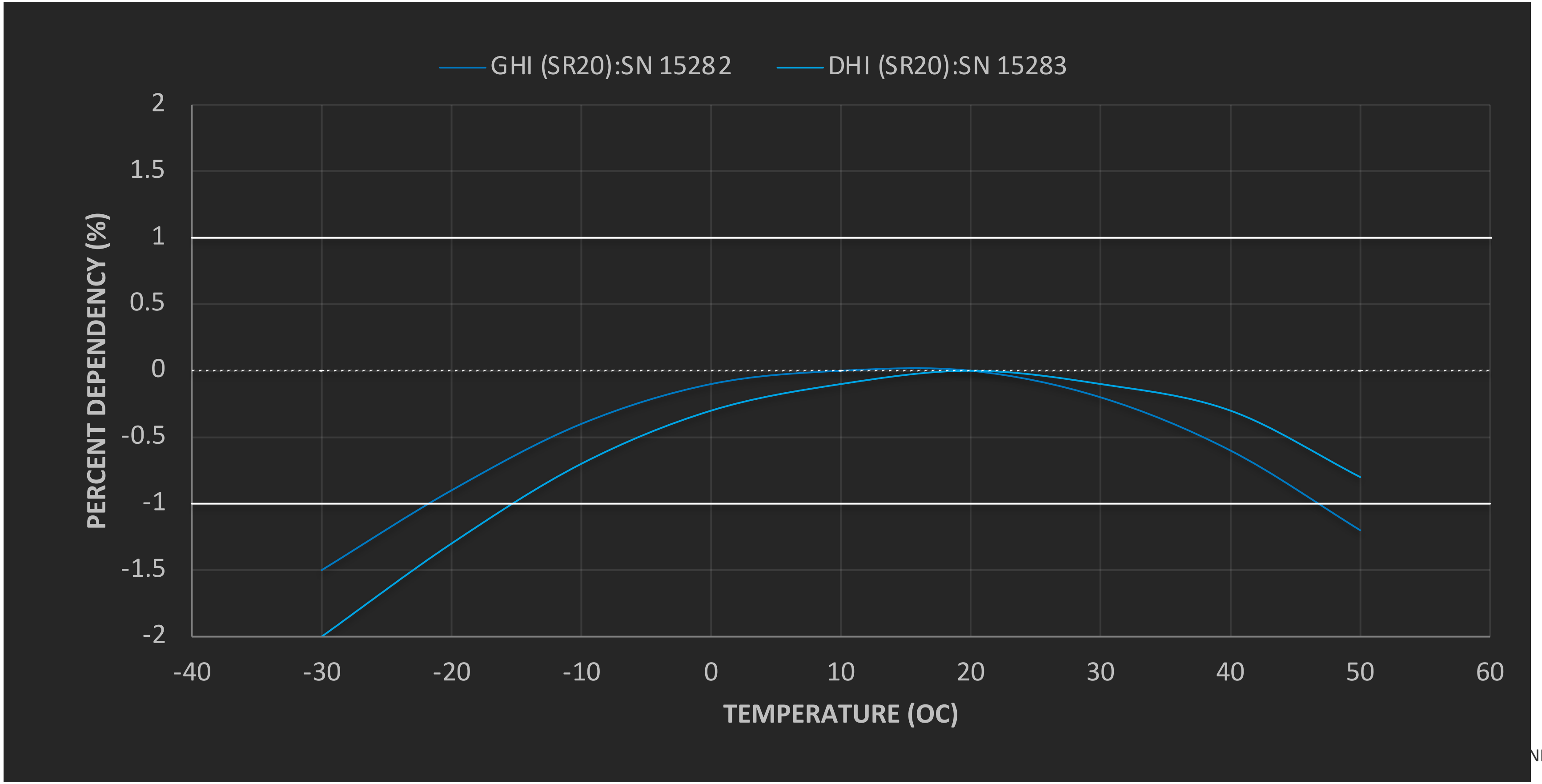
Nighttime thermal offset correction using NREL method for various radiometers.

NREL SRRL

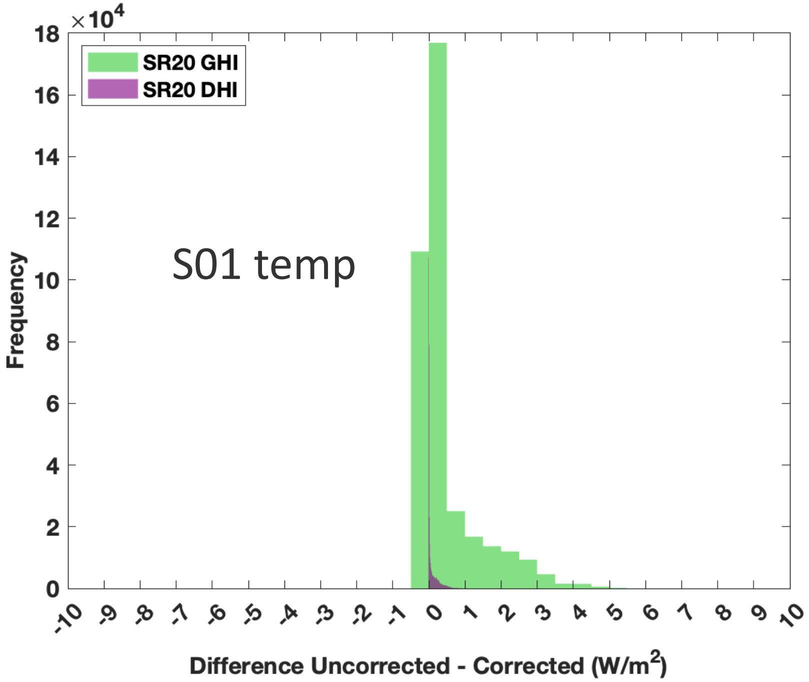


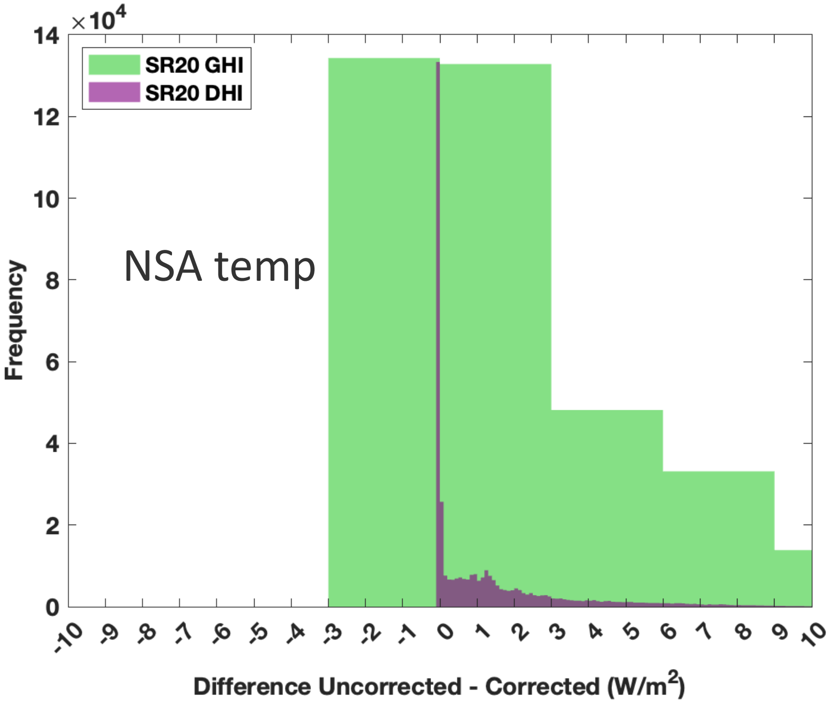
Day and nighttime thermal offset correction using NREL method for various radiometers.

SR20s Temperature response



SR20 (S01) –only Temperature response correction

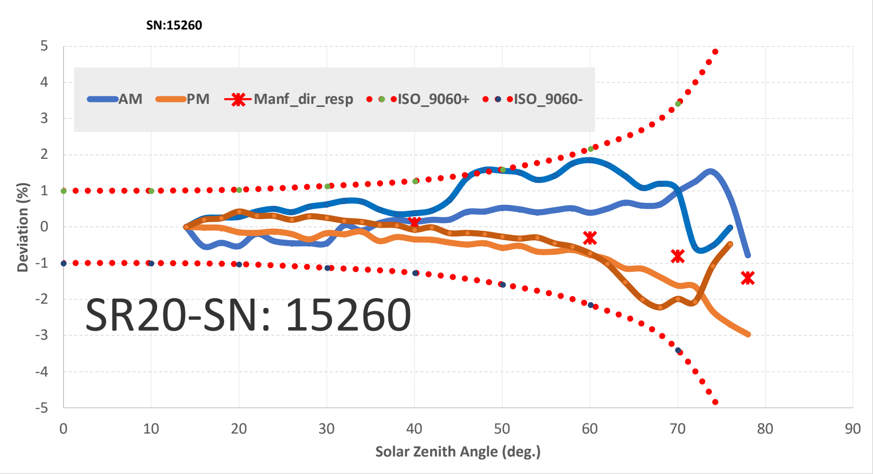


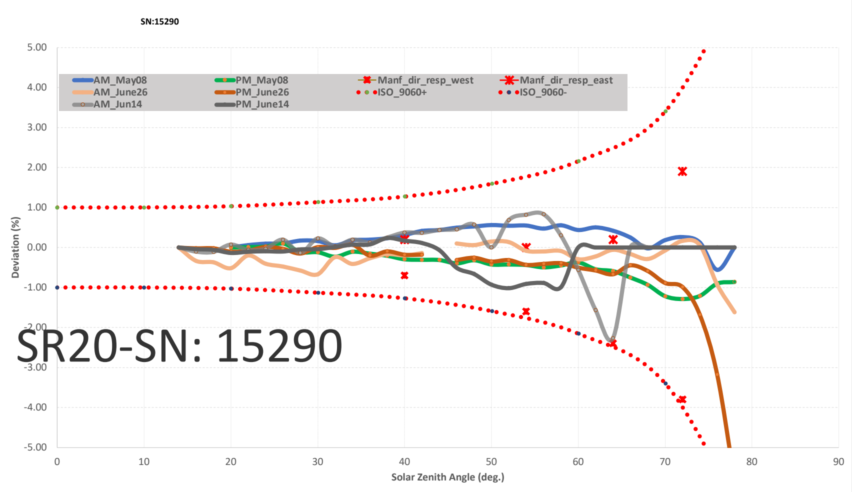


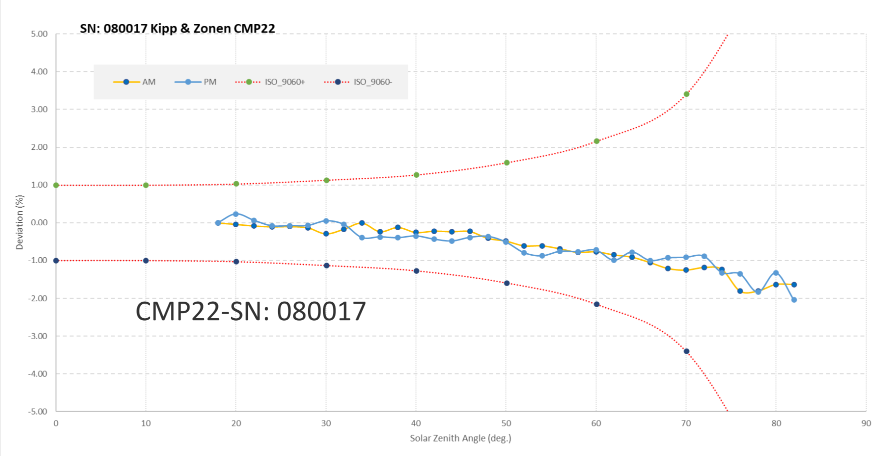
Temperature response correction is relatively significant compared to thermal offset correction

Directional response of newer radiometers

Directional response of CMP22 and SR20







Summary

- The IR correction is relatively small for the SR20s as compared to PSPs
- Relatively temperature response correction is more significant/important than the IR loss correction for the SR20s radiometers.
- Investigating directional response and correction methodologies in the future could be of importance.

Split SIRS into SKYRAD and GNDRAD

ENG0004406

Stations reconfiguration status (ENG 0004406)

- Since 1994 Skyrad and Gndrad have been separate systems as well as independent of SIRS. This ENG is proposed to discuss absorbing Skyrad and Gndrad into the SIRS datastream. This leaves only one broadband radiometric data stream to lessen confusion among data end users. This would create a discontinuity in the datasets but lessen development time and number of separate ingests as well as integration of new QC or VAP products.

Plan forward:

- SKYRAD/GNDRAD systems into one on hardware system.
- Merge data products (SKYRAD/GNDRAD) into a single SIRS datastream and hide the SKYRAD/GNDRAD datastreams from users to limit confusion.
- Reprocess all the historical data to produce the consistent SIRS datastream and hide the old SKYRAD/GNDRAD datastreams.

For the sake of consistency and to enable future flexibility, the SGP SIRS would have a second logger added when the new radiometers are installed and would follow the SKYRAD/GNDRAD set up.

- The mentors will have to work with site operations to either use the MET enclosure, if there's room, or put in a new enclosure at the base of the GND measurements and modify the cable to reduce distance.
- Site ops will also have to run a new ethernet cable most likely.
- The mentors will need to review the PMs at SGP and update accordingly.

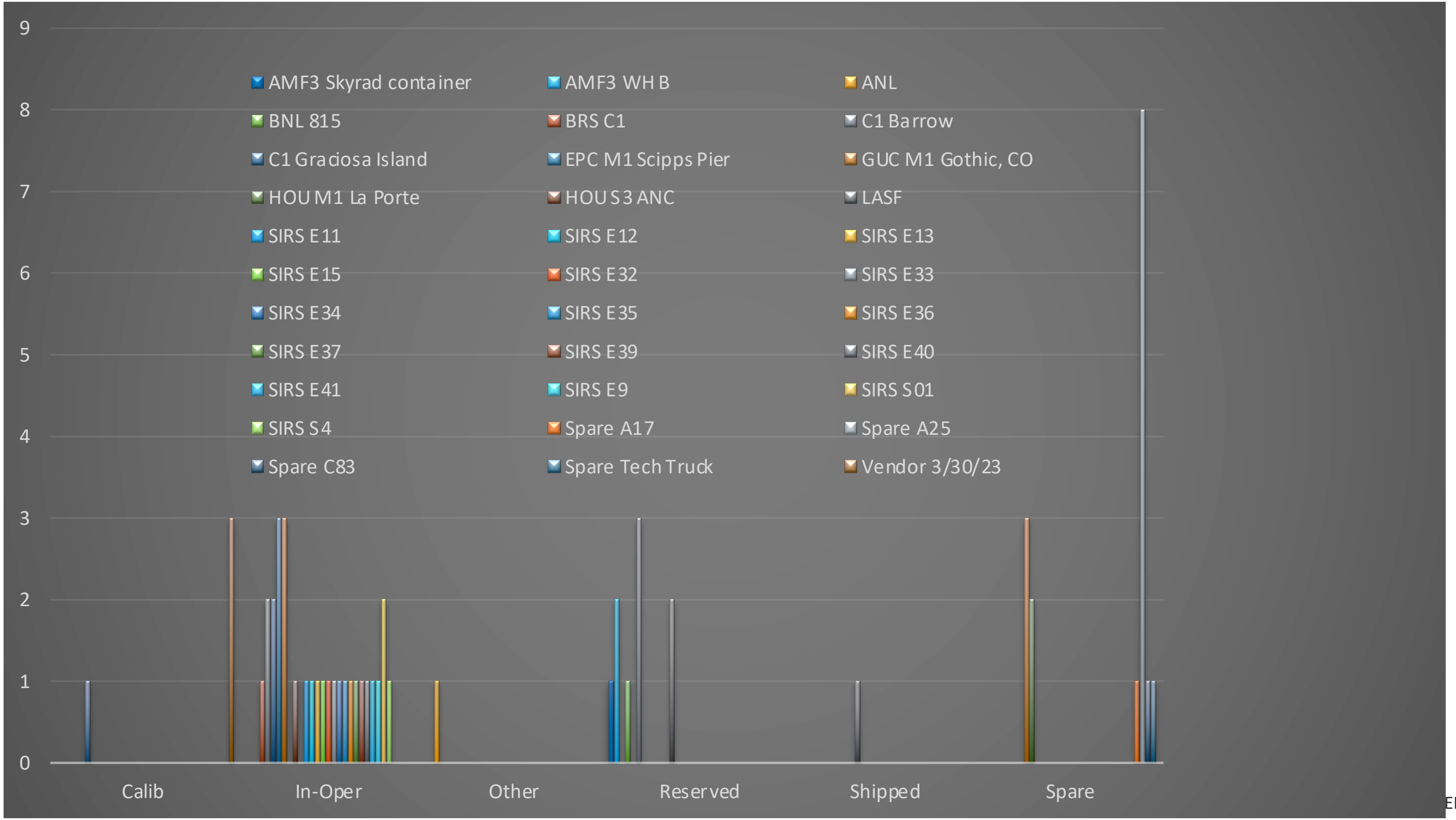
The mentors will add the new loggers to the procurement plan for the FY24 radiometer purchases.

For the INST process @Richard Cederwall @Maggie Davis @David Swank @Robert Records @Brian Ermold we will still submit these as SIRS INSTs but it is expected that metadata, collections, and ingest will need to be set up under that one INST for the SKYRAD/GNDRAD and SIRS.

Stations reconfiguration (ENG 0004406)

CONFIGURATION OPTIONS AND COMMENTS	
Single Radiometer Configuration Options:	**Comments:**
Action Item 1: Convert SIRS sites to use CR3000 and CR1000X/CR3000. 1) S01: 2 CR3000 are now using 2) Chris and James will check if there is CR1000x available to swap the gndrad CR3000. Note: 5 able CR1000x are available. Programs: Skyrad and gndrad is almost ready then data piping to SIRS format will follow	- CR1000x for Gndrad and CR3000 for Skyrad

CR3000 dataloggers (Under SGP inventory only)



Additional points for discussion

- Collecting 1-second data
- DR20s cable issue
- Ventilator adapters
- Data logger program (Skyrad and gndrad)
- Temperature response values for new radiometers - accessibility
- New Solar tracker procurement ???
- Indoor calibration capability???

Thank You!

www.nrel.gov

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