Broadband Outdoor Radiometer Calibration (BORCAL) Process for the Atmospheric Radiation Measurement (ARM) Program

Second Edition

Michael Dooraghi, Afshin Andreas, Mark Kutchenreiter, Ibrahim Reda, Martina Stoddard, Manajit Sengupta, and Aron Habte

National Renewable Energy Laboratory

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Technical Report
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Cover Photos by Dennis Schroeder: (clockwise, left to right) NREL 51934, NREL 45897, NREL 42160, NREL 45891, NREL 48097, NREL 46526.

List of Acronyms

AIM	ARM Instrument Management System
ARM	Atmospheric Research Measurement Program
BMS	Baseline Measurement System
BORCAL	Broadband Outdoor Radiometer Calibration
ISO	International Standards Organization
LW	Longwave
MAS	Measurement Assurance Standard
MIDC	Measurement and Instrumentation Data Center
mV	Millivolt
NIP	Normal Incident Pyrheliometer
NPC	NREL Pyrheliometer Comparison
NREL	National Renewable Energy Laboratory
PIR	Precision Infrared Radiometer
PSP	Precision Spectral Pyranometer
RAP-DAQ	Reda Afshin Pete Data Acquisition
RCC	Radiometer Calibration and Characterization
RH	Relative humidity
SGP RCF	Southern Great Plains Radiometer Calibration Facility
SRRL	Solar Radiation Research Laboratory
SW	Shortwave

Executive Summary

The Atmospheric Radiation Measurement (ARM) program maintains a fleet of monitoring stations to aid improved scientific understanding of the basic physics related to the radiative feedback processes in the atmosphere, particularly the interactions between clouds and aerosols. ARM obtains continuous measurements and conducts field campaigns to provide data products that aid in the improvement and further development of climate models. All the measurement campaigns include a suite of solar measurements. The Solar Radiation Research Laboratory at the National Renewable Energy Laboratory supports the ARM program's full suite of stations in a number of ways, including troubleshooting issues that arise as part of the data-quality reviews; managing engineering changes to the standard setup; and providing calibration services and assistance to the full fleet of solar-related instruments, including pyranometers, pyrgeometers, and pyrheliometers as well as the temperature/relative humidity probes, multimeters, and data acquisition systems that are used in the calibrations performed at the Southern Great Plains Radiometer Calibration Facility. This paper discusses all aspects related to supporting the calibration of the instruments in the solar monitoring fleet.

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1 Calibration Process for Radiometers, Multimeters, and Other Instruments

Each year before the Broadband Outdoor Radiometer Calibration (BORCAL) season begins, the Southern Great Plains Radiometer Calibration Facility (SGP RCF) operator and the National Renewable Energy Laboratory (NREL) mentor at the Solar Radiation Research Laboratory (SRRL) should coordinate equipment to ensure that the correct multimeters, radiometers, and meteorological instruments are prepared for use in that year's shortwave (SW) and longwave (LW) BORCAL events. The following sections provide a guide to which instruments are used in each year's SGP BORCAL-SW and BORCAL-LW.

BORCAL sessions are named according to where they were done (NREL or SGP), the type (SW or LW), the year (2018), and the calibration event number for that year. For example, SGP SW BORCAL 2017-02 is the second BORCAL-SW event at the SGP site for 2017. BORCAL-SWs are run during the summer when the sun reaches lower zenith angles (higher sun angles), typically from May to August. BORCAL-LWs are run at night and as a result can be performed year-round. If the last LW BORCAL session of a year does not finish by the end of that year, it will be named based on the year it began.

1.1 References, Controls, and Measurement Assurance Standards

Instruments used for the BORCAL-SW and BORCAL-LW events include the test radiometers along with a set of radiometers that are used for references, controls, and measurement assurance standards (MAS). BORCAL-SW and BORCAL-LW have different numbers of references, controls, and MAS, but the general procedure for their operation is essentially the same. Each year, one set of references and MAS is sent to NREL for calibration and then used the following year at the SGP site. That is, for both the BORCAL-SW and BORCAL-LW, two sets of references and MAS are exchanged each year between NREL and the SGP site and are calibrated at each facility. The set of control instruments is used perpetually in each event at the SGP site and is never sent to NREL. The result of this process is that one set of instruments is calibrated at NREL during even years, and the other is calibrated at NREL during odd years; the same is true at the SGP site. Additionally, for the BORCAL-SWs, two sets of pyrgeometers are used for thermal corrections that are alternatively sent between NREL and the SGP site, like the references and MAS. The instruments described here are kept indoors when not used to minimize sensitivity changes due to exposure. Table 1 and Table 2 list by serial number the references, controls, and MAS used in the SGP BORCAL-SW and BORCAL-LW events and where they should be calibrated for even or odd years.

Once the SGP instruments and multimeters have been sent to the SRRL, it is necessary to verify against this document that the correct instruments have been sent.

The SGP BORCAL-SW includes:

- One set of control instruments. These instruments remain at the SGP site and are calibrated in every BORCAL-SW session. The control instruments include:
    - Six precision spectral pyranometers (PSPs)
    - One normal incident pyrheliometer (NIP).

- Two sets of MAS radiometers. The calibration of these instruments alternates on an annual schedule between the SRRL and the SGP RCF site. That is, one set is calibrated at the SRRL, and the other is calibrated at the SGP site, and they are swapped the next year. The purpose of this process is to ensure consistency between the NREL and SGP calibrations. Note that when the radiometers are at the SGP site, they are calibrated in each calibration session for that BORCAL season; and when they are at the SRRL, they are calibrated in only one session. Each set of MAS instruments includes:
    - Six PSPs
    - One NIP.
- Two reference diffuse pyranometers. These are used in combination with the direct beam irradiance from the cavity to calculate the reference global horizontal irradiance. Prior to the BORCAL-SW 2018-02 event, the reference diffuse irradiance was determined by two Eppley 8-48s. Beginning with the BORCAL-SW 2018-02, the reference diffuse was changed to two Hukseflux SR25s. Each set of diffuse instruments includes:
    - Two SR25s.
- Two sets of precision infrared pyrgeometers (PIRs), which are used to correct for infrared losses. Each set includes:
    - Two Eppley PIRs.

Note that the reference direct beam consists of two AHF Eppley absolute cavity radiometers that are calibrated each year during the NREL Pyrheliometer Comparison (NPC). The control units (digital multimeters) are sent to NREL each year for calibration as described in Section 1.2.

The SGP BORCAL-LW includes:

- One control PIR
- One MAS PIR
- Two reference PIRs.

Table 1. Calibration Schedule for SGP BORCAL-SW radiometers

BORCAL-SW Radiometers				
Type	**Manufacturer**	**Instrument**	**SN**	**Location**
Control units to remain and SGP for all BORCAL events				
Control	Eppley	NIP	31120E6	SGP every year
Control	Eppley	PSP (V)	31099F3	SGP every year
Control	Eppley	PSP (V)	31100F3	SGP every year
Control	Eppley	PSP (V)	31101F3	SGP every year
Control	Eppley	PSP	31152F3	SGP every year
Control	Eppley	PSP	31153F3	SGP every year
Control	Eppley	PSP	31154F3	SGP every year
Set 1 of MAS and references to be exchanged yearly between SGP and SRRL				
MAS	Eppley	NIP	31122E6	SGP odd year/NREL even year
MAS	Eppley	PSP (V)	31149F3	SGP odd year/NREL even year
MAS	Eppley	PSP (V)	31150F3	SGP odd year/NREL even year
MAS	Eppley	PSP (V)	31151F3	SGP odd year/NREL even year
MAS	Eppley	PSP	31158F3	SGP odd year/NREL even year
MAS	Eppley	PSP	31159F3	SGP odd year/NREL even year
MAS	Eppley	PSP	31160F3	SGP odd year/NREL even year
IR correction	Eppley	PIR	29926F3	SGP odd year/NREL even year
IR correction	Eppley	PIR	30696F3	SGP odd year/NREL even year
Reference	Hukseflux	SR-25	2551	SGP odd year/NREL even year (BORCAL-SW-2018-02 and after)
Reference	Hukseflux	SR-25	2552	SGP odd year/NREL even year (BORCAL-SW-2018-02 and after)
Reference	Eppley	8-48	33253	SGP odd year/NREL even year (BORCAL-SW-2018-01 and before)
Reference	Eppley	8-48	33273	SGP odd year/NREL even year (BORCAL-SW-2018-01 and before)
Set 2 of MAS and references to be exchanged yearly between SGP and SRRL				
MAS	Eppley	NIP	31121E6	SGP even year/NREL odd year
MAS	Eppley	PSP	31157F3	SGP even year/NREL odd year
MAS	Eppley	PSP	31156F3	SGP even year/NREL odd year
MAS	Eppley	PSP	31155F3	SGP even year/NREL odd year
MAS	Eppley	PSP (V)	31148F3	SGP even year/NREL odd year
MAS	Eppley	PSP (V)	31147F3	SGP even year/NREL odd year
MAS	Eppley	PSP (V)	31146F3	SGP even year/NREL odd year
IR correction	Eppley	PIR	30170F3	SGP even year/NREL odd year
IR correction	Eppley	PIR	30020F3	SGP even year/NREL odd year
Reference	Hukseflux	SR-25	2549	SGP even year/NREL odd year (BORCAL-SW-2018-02 and after)
Reference	Hukseflux	SR-25	2550	SGP even year/NREL odd year (BORCAL-SW-2018-02 and after)
Reference	Eppley	8-48	32873	SGP even year/NREL odd year (BORCAL-SW-2018-01 and before)
Reference	Eppley	8-48	32872	SGP even year/NREL odd year (BORCAL-SW-2018-01 and before)

Table 2. Calibration Schedule for SGP BORCAL-LW Radiometers

BORCAL-LW Radiometers				
Type	**Eppley**	**Instrument**	**SN**	**Location**
Control unit to remain at SGP for all BORCAL events				
Control	Eppley	PIR	36368F3	SGP every year
Set 1 of MAS and references to be exchanged yearly between SGP and SRRL				
Reference	Eppley	PIR	31206F3	SGP odd year/NREL even year
Reference	Eppley	PIR	31237F3	SGP odd year/NREL even year
MAS	Eppley	PIR	30133F3	SGP odd year/NREL even year
Set 2 of MAS and references to be exchanged yearly between SGP and SRRL				
Reference	Eppley	PIR	29927F3	SGP even year/NREL odd year
Reference	Eppley	PIR	29590F3	SGP even year/NREL odd year
MAS	Eppley	PIR	30132F3	SGP even year/NREL odd year

1.2 Digital Multimeters

Prior to each SGP BORCAL, the digital multimeters are sent to the NREL metrology lab for calibration. The digital multimeters need to be calibrated for use in that year's SGP BORCAL. In late February, the SRRL Atmospheric Research Measurement (ARM) program mentor should remind the SGP Radiometer Calibration Facility (RCF) operator to send the SGP BORCAL multimeters for both LW and SW to NREL in early April so that they can be calibrated and returned to the SGP RCF on time for the first SGP BORCAL-SW event of the year. There are four multimeters in total; the BORCAL-SW and BORCAL-LW use the same four multimeters. When the multimeters have been calibrated at NREL and installed in the SGP RCF BORCAL and before the start of the BORCAL season, the Reda Afshin Pete Data Acquisition (RAP-DAQ) system channel check must be completed (described in Section 2). Table 3 lists the multimeters by serial number, model, and BORCAL type.

Table 3. Calibration Schedule for SGP BORCAL-SW and BORCAL-LW Multimeters

Multimeters			
Manufacturer	**Model**	**SN**	**BORCAL Type**
Agilent	34420A	SG42000596	SW & LW
Agilent	34420A	MY42002863	SW & LW
Agilent	34420A	MY42002864	SW & LW
Agilent	34420A	MY42002866	SW & LW

1.3 Temperature/Relative Humidity Probe

Prior to each SGP BORCAL, a temperature/relative humidity probe is sent to the NREL metrology lab for calibration. The temperature/relative humidity probe is calibrated at NREL for use in that year's SGP BORCAL. Two Vaisala temperature/relative humidity probes are used alternately in the SGP BORCAL from one year to another. Each year, one probe will be sent for calibration for use in that year's SGP BORCAL event, and the other probe will be kept at the SGP site as a spare. The probe should be sent to NREL in early April for calibration along with the four multimeters described in Section 1.2. After calibration at NREL, the probe and meters will be sent back to the SGP RCF on time for the first SGP BORCAL. The probes are kept

indoors when not used. In late February, the SRRL ARM mentor should remind the SGP RCF operator to send the temperature/relative humidity probe (and multimeters) to NREL for calibration in early April. The same temperature/relative humidity probe is used for both the BORCAL-SW and BORCAL-LW events. Table 4 lists the temperature/relative humidity probes by serial number, model, and BORCAL year to be used. In 2016, the schedule swapped for the two probes such that E0710025 was used in 2015 and 2016, resulting in the current schedule shown in Table 4.

Table 4. Calibration Schedule for SGP BORCAL Temperature/Relative Humidity Probe

Temperature/Relative Humidity Probe			
Manufacturer	**Model**	**SN**	**SGP BORCAL Year**
Vaisala	HMP 155T/H	E0710026	Odd years
Vaisala	HMP 155T/H	E0710025	Even years

2 Pre-SGP BORCAL Channel Check

Before the SGP RCF operator can connect any of the instruments to their respective channels on the RAP-DAQ, a channel check for all cables and connectors must be performed. Through this process the noise in the system is quantified by putting a short on each channel. The mV (and ohms on some positions) are read and recorded. This process should be done by two people: one person (the SGP RCF operator) is on the instrument deck at the SGP site with a short, and the other person (the SRRL ARM mentor) is logged into the SGP computer from the SRRL data lab (via remote access through RAmin software). The SRRL ARM mentor calls the SGP RCF operator on a cell phone. The SGP RCF operator then moves the short from one position to the next as instructed by the SRRL ARM mentor. The SRRL ARM mentor logs onto the computer labeled "BORCAL ARM data processing" in the lab. Due to NREL and ARM cyber security requirements, this is the only computer that can be used to access the SGP BORCAL Radiometer Calibration and Characterization (RCC) system. The SRRL ARM mentor should be prepared with the Channel Check Lookup when contacting the SGP RCF operator. This chart is shown in Table 5.

Table 5. RAP-DAQ SW and LW Position and Channel Configuration

Pos-TP	Ch	Pos-C	Ch	Pos-D	Ch	Pos-TP	Ch	Pos-C	Ch	Pos-D	Ch	Pos-TP	Ch	Pos-C	Ch	Pos-D	Ch
1	48	1R	56			**48**	125					**T9**	212				
2	60					**49**	126					**T10**	213				
3	61					**50**	132					**T11**	214				
4	0					**51**	133					**T12**	178	T12R	186		
5	1					**52**	32					**T13**	192	T13R	200		
6	2					**53**	33					**T14**	204				
7	8					**54**	34					**T15**	226				
8	9					**55**	113	55R	121			**T16**	230				
9	10					**56**	114	56R	122			**T17**	236				
10	49	10R	57			**57**	128	57R	136			**T18**	244				
11	50	11R	58			**58**	129	58R	137			**T19**	233				
12	64	12R	72			**59**	141					**T20**	234				
13	65	13R	73			**60**	142					**T21**	241				
14	66	14R	74			**61**	40					**T22**	193	T22R	201		
15	78					**62**	41					**T23**	205				
16	16					**63**	42					**T24**	237				
17	17					**64**	130	64R	138			**T25**	238				
18	18					**65**	144	65R	152			**T26**	245				
19	80	19R	88			**66**	156					**T27**	194	T27R	202		
20	92					**67**	149					**T28**	209	T28R	217		
21	93					**68**	150					**T29**	242				
22	4					**69**	157					**T30**	249				
23	5					**70**	28					**T31**	250				
24	6					**71**	29					**T32**	210	T32R	218		
25	12					**72**	30					**T33**	222				
26	13					**73**	145	73R	153			**T34**	246				
27	14					**74**	146	74R	154			**T35**	253				
28	81	28R	89			**75**	158					**T36**	254				
29	82	29R	90			**76**	164					**T5/1Vt**	7	T5/1Rc	3	T5/1Rd	11
30	208	30Rc	216	30Rd	224	**77**	165					**T5/2Vt**	23	T5/2Rc	19	T5/2Rd	27
31	96	31R	104			**78**	166					**T5/3Vt**	39	T5/3Rc	35	T5/3Rd	43
32	97	32R	105			**79**	36					**T6/1Vt**	55	T6/1Rc	51	T6/1Rd	59
33	109					**80**	37					**T6/2Vt**	71	T6/2Rc	67	T6/2Rd	75
34	20					**81**	38					**T6/3Vt**	87	T6/3Rc	83	T6/3Rd	91
35	21					**82**	160	82R	168			**T7/1Vt**	103	T7/1Rc	99	T7/1Rd	107
36	22					**83**	232	83Rc	240	83Rd	248	**T7/2Vt**	119	T7/2Rc	115	T7/2Rd	123
37	98	37R	106			**84**	161	84R	169			**T7/3Vt**	135	T7/3Rc	131	T7/3Rd	139
38	110					**85**	162	85R	170			**T8/1Vt**	151	T8/1Rc	147	T8/1Rd	155
39	108					**86**	174					**T8/2Vt**	167	T8/2Rc	163	T8/2Rd	171
40	116					**87**	173					**T8/3Vt**	183	T8/3Rc	179	T8/3Rd	187
41	117					**88**	44					**T9/1Vt**	199	T9/1Rc	195	T9/1Rd	203
42	118					**89**	45					**T9/2Vt**	215	T9/2Rc	211	T9/2Rd	219
43	24					**90**	46					**T9/3Vt**	231	T9/3Rc	227	T9/3Rd	235
44	25					**T3**	176	T3R	184			**Temp**	239				
45	26					**T4**	177	T4R	185			**RH**	255				
46	112	46R	120			**T7**	225										
47	124					**T8**	229										

[a] Note: Channel 239 is always used for the Temp probe signal, and Channel 255 is always used for the relative humidity (RH) signal.

2.1 Channel Check Process

The following steps provide a guide for performing the channel check process.

- Log in to the BORCAL ARM data processing computer in the SRRL:
  - Username: rccsgp
  - Password: (See SRRL ARM mentor).
- Double-click the Radmin Viewer 3 shortcut on the desktop:

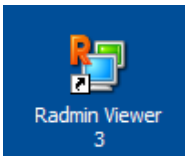


Figure 1. The Radmin Viewer 3 icon is used to access the BORCAL ARM data processing computer from the SRRL.

- Choose menu option: Mode → Full Control.

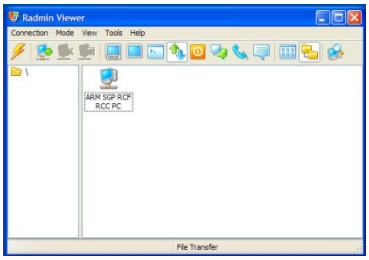


Figure 2. When using Radmin Viewer, choose Full Control from the Mode menu.

- Double-click the ARM SGP RCF RCC PC icon, and log in using the following:
  - Username: sds
  - Password: (See SRRL ARM mentor).
- If it is not already open, double-click the RCC icon to start the RCC:

Figure 3. The RCC icon is used to run the RCC software. (It is located on a remote computer at the SGP.)

- Choose menu option: Acquisition → Channel Check.
- A screen will appear as shown in Figure 4. The upper left corner of the screen is used for initialization.
- In the past, three multimeters were dedicated to SW and 1 multimeter dedicated to LW. After making the upgrades to the LW process to allow for calibration of 35 pyrgeometers at a time (as opposed to 12), all four multimeters are now used for both LW and SW BORCALs, and as a result, the channel check is done once each year.

- To take advantage of the expanded LW capabilities (35 instruments as opposed to 12) it is necessary to use the Y-adapter cables that were built for this purpose. There are 3 types of adapter cables, and Appendix A shows on which positions and channels each type of adapter cable is used.
- BORCAL-LW and BORCAL-SW use the same four control units. Enter 4 in the box labeled "Unit Count." For Units 0, 1, 2 and 3, the DVM should be set to 21, 22, 23 and 1 respectively and the DP should be set to 24, 25, 26 and 4 respectively. The DVM for GPIB Boards is 0 and the DP is 1. These values are all shown in Figure 4.

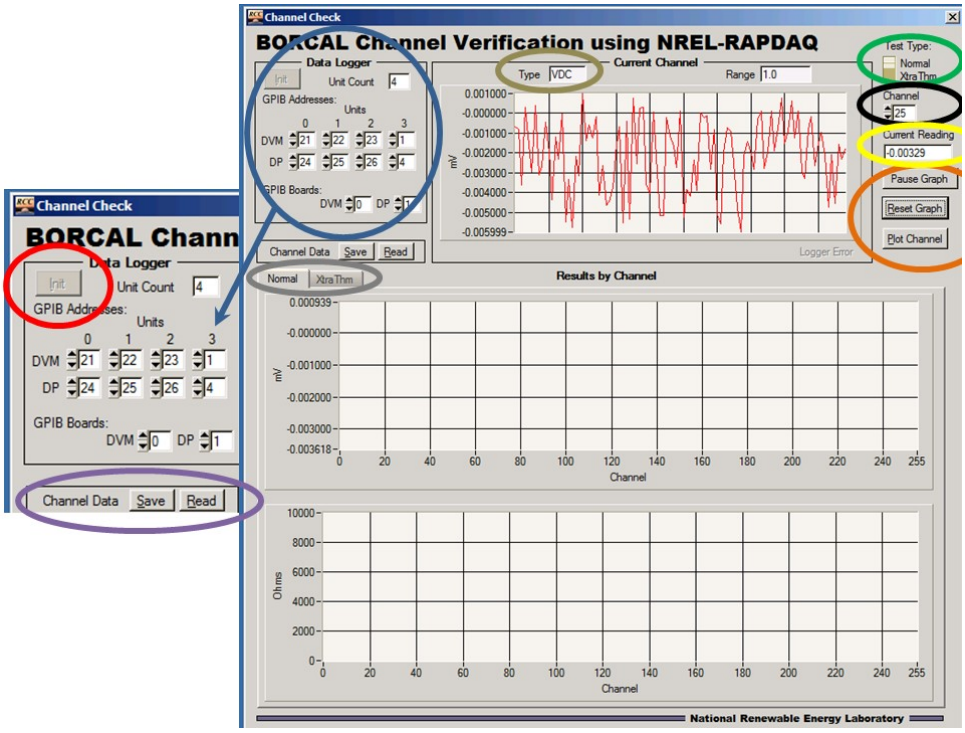


Figure 4. Screenshot of initializing the channel check for BORCAL

- Select the "Init" button, circled in red in Figure 4.
- There are three graphs on the screen (shown in Figure 4). The first, at the top, is titled "Current Channel," and displays the 1-second values from the chosen channel (the channel is chosen from the box circled in black). The second and third graphs are in the lower section, titled "Results by Channel," and they display the average voltage or resistance for each channel when plotted by the user.
- There are two tabs for the bottom two plots shown in Figure 4, one titled Norm and one titled XtraTherm (grey circle).
    - All voltage measurements (those that show "VDC" in the brown circle Figure 4) will be plotted to the "Normal" tab Voltage plot.
    - The two-wire resistance measurements (those that show "RES" in the brown circle Figure 4) that appear on the "Normal" toggle will be plotted to the "Normal" tab resistance plot.

    - The two-wire resistance measurements (those that show "RES" in the brown circle Figure 4) that appear on the "XtraTherm" toggle will be plotted to the "XtraTherm" tab resistance plot.
    - The four-wire resistance measurements (those that show "RES4" in the brown circle Figure 4) for either toggle, will not be used.

- The three buttons shown in the orange circle in Figure 4 allow the user to restart the graph ("Reset Graph"), pause the graph ("Pause Graph"), or plot the average value ("Plot Channel") from the points on the "Current Channel" graph. The average of the values on the "Current Channel" graph is plotted to the associated (voltage or 1 of 2 resistance) plots in the "Results by Channel" section. The first value plotted is only a single point and cannot be seen. Two points are required to make a line that will appear in the graph. When the second voltage or resistance average in any of the three plots is plotted, the line will appear.
- The top right of Figure 4 shows a toggle switch labeled "Normal" and "XtraTherm" (green circle). For each channel, one must plot both the values using the "Normal" toggle and the "XtraTherm" toggle. Note that if the "Type" shown in the brown circle in Figure 4 is "RES4", its values will not be measured and recorded.
- As shown in the top right of Figure 4 in the black circle, the active channel number can be selected by either toggling the arrows or typing within the "Channel" box.
- Each channel has more than one possible purpose: it measures either voltage in mV or resistance in ohms or both.
- The "Current Reading" box below the channel (shown in the yellow circle in Figure 4) displays the millivolts or ohms of that channel. When doing the channel check, the SGP RCF operator will short each channel, and the displayed "Current Reading" will reflect that shorted channel. Shorted voltage channels typically read less than .0005 mV, and shorted resistance channels typically read 1 ohm to 3 ohms. Anomalous readings should be investigated at the time they are discovered by double-checking with the RCF operator for proper set up on the channel. If the anomalous reading is confirmed, it should be recorded and flagged for follow up.
- After selecting a channel and viewing the current readings on the "Current Channel" graph, if a different channel is chosen, the current channel's values will be displayed alongside the previously selected channel. To see only that channel's plotted values, the user will need to choose "Reset Graph" after selecting the new channel.
- When the user has enough data points (only 5–10 are needed as indicated by a limited range of values), click on "Plot Channel," and the average of all the values will be plotted on the "Current Channel" graph. It will be plotted to the appropriate graph depending on whether it is a resistance channel or a voltage channel and if the "XtraTherm" toggle or the "Normal" toggle is chosen.
- If a point is inadvertently plotted with bogus values in its average, then the user should collect a new set of points and plot them, and the program will overwrite the erroneous average for that channel.

- The SGP RCF operator has a 4-pin short for pyranometer/pyrheliometer positions and a 10-pin short for pyrgeometer positions that they will move from one position to another. There may be 1-3 channels associated with each position. The SRRL ARM mentor will need to take readings for each channel at that position on both the "Normal" toggle and the "XtraTherm" toggle. Note that if the "Type" shown in the brown circle in Figure 4 is "RES4", its values will not be measured and recorded. For example:
    - Position 10 is associated with Channel 49 (voltage) and Channel 57 (resistance). When the SRRL ARM mentor finishes Position 9 and asks the SGP RCF operator to move to Position 10, the SRRL ARM mentor will need to measure and plot the values by selecting Channel 37 and plotting the results from the "Normal" tab (not from the XtraTherm" tab because it displays "RES4" in the type) and then by selecting Channel 43 and plotting the results in the same manner (channel 43 also is type "Res4"). Then the SRRL ARM mentor will ask the SGP RCF operator to move to Position 11 (which also has two channels associated with it).
    - Position 61 has one channel associated with it, channel 40. Channel 40 is type "VDC" on the "Normal" toggle and type "RES" on the "XtraTherm" toggle so the SRRL ARM mentor will record measurements for both tabs. Then the SGP RCF operator will move to position 62 which is configured the same way.
- As shown in Table 5, if a position has only a number, then it is for either a PSP or an 8-48. If the position has an 'R' associated with it, then it is a NIP or PSP. If the position has an 'Rc' or 'Rd' associated with it then it is a PIR (resistance of case and resistance of dome). If the position has a 'T' associated with it then it is on a tracker and is likely an 8-48 or a NIP.
- For BORCAL-SW, 90 total positions are on the table, and 40 positions are on trackers 1 through 4. During the channel check process, the SGP RCF operator and the SRRL ARM mentor will move sequentially through the table positions and then through the tracker positions.
- For BORCAL-LW, 15 total positions are on trackers 5 through 9. The SGP RCF operator and the SRRL ARM mentor will move sequentially through the tracker positions. There is room for an additional 24 positions using adapter cables, which allow for the SW positions on the tables to be used for LW calibration positions. Because these cables need SW positions, they can be used only outside of the BORCAL-SW season. Appendix A shows on which positions and channels the various adapter cables can be used.
- Figure 5 shows a current reading of .00035 mV, but there was a period on the "Current Reading" graph when there was a reading out of range, and thus the current channel results are scaled to the bottom of the graph. The user should choose "Reset Graph," which will fix the range issue and provide a proper set of values for averaging and writing to the "Results by Channel" graph.
- While Table 5 shows the positions and channels for all longwave and shortwave channels which aids in performing channel checks, Table 6 and Table 7 show the positions and channels available for SW and LW BORCALS respectively, which may be useful for configuration and troubleshooting.

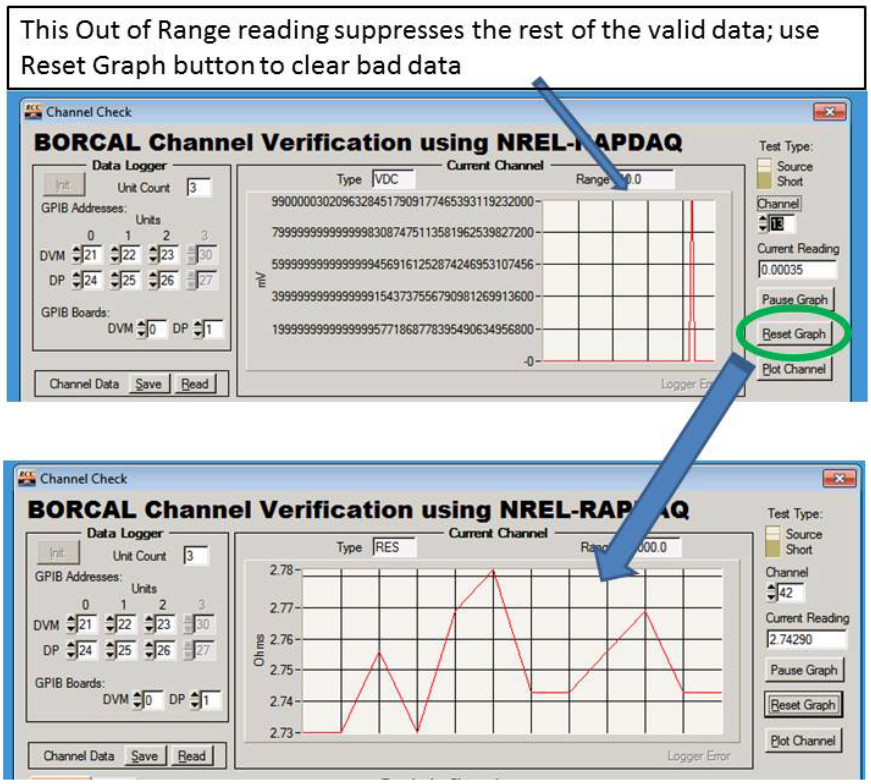


Figure 5. Use the "Reset Graph" function when the value is out of range to avoid plotting bogus averages.

Table 6 RAP-DAQ SW Position and Channel Configuration

Pos-TP	Ch	Pos-C	Ch	Pos-D	Ch	Pos-TP	Ch	Pos-C	Ch	Pos-D	Ch	Pos-TP	Ch	Pos-C	Ch	Pos-D	Ch
1	48	1R	56			**42**	118					**83**	232	83Rc	240	83Rd	248
2	60					**43**	24					**84**	161	84R	169		
3	61					**44**	25					**85**	162	85R	170		
4	0					**45**	26					**86**	174				
5	1					**46**	112	46R	120			**87**	173				
6	2					**47**	124					**88**	44				
7	8					**48**	125					**89**	45				
8	9					**49**	126					**90**	46				
9	10					**50**	132					**T3**	176	T3R	184		
10	49	10R	57			**51**	133					**T4**	177	T4R	185		
11	50	11R	58			**52**	32					**T7**	225				
12	64	12R	72			**53**	33					**T8**	229				
13	65	13R	73			**54**	34					**T9**	212				
14	66	14R	74			**55**	113	55R	121			**T10**	213				
15	78					**56**	114	56R	122			**T11**	214				
16	16					**57**	128	57R	136			**T12**	178	T12R	186		
17	17					**58**	129	58R	137			**T13**	192	T13R	200		
18	18					**59**	141					**T14**	204				
19	80	19R	88			**60**	142					**T15**	226				
20	92					**61**	40					**T16**	230				
21	93					**62**	41					**T17**	236				
22	4					**63**	42					**T18**	244				
23	5					**64**	130	64R	138			**T19**	233				
24	6					**65**	144	65R	152			**T20**	234				
25	12					**66**	156					**T21**	241				
26	13					**67**	149					**T22**	193	T22R	201		
27	14					**68**	150					**T23**	205				
28	81	28R	89			**69**	157					**T24**	237				
29	82	29R	90			**70**	28					**T25**	238				
30	208	30Rc	216	30Rd	224	**71**	29					**T26**	245				
31	96	31R	104			**72**	30					**T27**	194	T27R	202		
32	97	32R	105			**73**	145	73R	153			**T28**	209	T28R	217		
33	109					**74**	146	74R	154			**T29**	242				
34	20					**75**	158					**T30**	249				
35	21					**76**	164					**T31**	250				
36	22					**77**	165					**T32**	210	T32R	218		
37	98	37R	106			**78**	166					**T33**	222				
38	110					**79**	36					**T34**	246				
39	108					**80**	37					**T35**	253				
40	116					**81**	38					**T36**	254				
41	117					**82**	160	82R	168			**Temp**	239				
												RH	255				

Table 7 RAP-DAQ LW Position and Channel Configuration

Pos-TP	Ch	Pos-C	Ch	Pos-D	Ch	Pos-TP	Ch	Pos-C	Ch	Pos-D	Ch
1	48	1R	56	8	9	**82**	160	82R	168	63	42
2	60	4	0	6	2	**83**	232	83Rc	240	83Rd	248
3	61	5	1	7	8	**84**	161	84R	169	85R	170
10	49	10R	57	16	16	**T5/1Vt**	7	T5/1Rc	3	T5/1Rd	11
11	50	11R	58	12R	72	**T5/2Vt**	23	T5/2Rc	19	T5/2Rd	27
13	65	13R	73	14R	74	**T5/3Vt**	39	T5/3Rc	35	T5/3Rd	43
19	80	19R	88	9	10	**T6/1Vt**	55	T6/1Rc	51	T6/1Rd	59
28	81	28R	89	17	17	**T6/2Vt**	71	T6/2Rc	67	T6/2Rd	75
29	82	29R	90	18	18	**T6/3Vt**	87	T6/3Rc	83	T6/3Rd	91
30	208	30Rc	216	30Rd	224	**T7/1Vt**	103	T7/1Rc	99	T7/1Rd	107
31	96	31R	104	32R	105	**T7/2Vt**	119	T7/2Rc	115	T7/2Rd	123
37	98	37R	106	43	24	**T7/3Vt**	135	T7/3Rc	131	T7/3Rd	139
46	112	46R	120	52	32	**T8/1Vt**	151	T8/1Rc	147	T8/1Rd	155
55	113	55R	121	61	40	**T8/2Vt**	167	T8/2Rc	163	T8/2Rd	171
56	114	56R	122	62	41	**T8/3Vt**	183	T8/3Rc	179	T8/3Rd	187
57	128	57R	136	58R	137	**T9/1Vt**	199	T9/1Rc	195	T9/1Rd	203
64	130	64R	138	44	25	**T9/2Vt**	215	T9/2Rc	211	T9/2Rd	219
65	144	65R	152	45	26	**T9/3Vt**	231	T9/3Rc	227	T9/3Rd	235
73	145	73R	153	53	33	**Temp**	239				
74	146	74R	154	54	34	**RH**	255				

2.2 Example Order of Operations

1. The SRRL ARM mentor asks the SGP RCF operator to start at Position 1 on the tables.
2. The SGP RCF operator removes the permanent short on the position, installs the temporary short, and tells the SRRL ARM mentor that the short is connected.
3. The SRRL ARM mentor cross-references the position to the channel per Table 5 and enters the channel in the "Channel" box. Note: in many cases there are multiple channels associated with a position and each channel must be checked on both the "Normal" and "XtraTherm" toggles.
4. As shown in Table 5, for Position 1 the channel is 48. The SRRL ARM mentor enters 48 into the channel box and ensures that the toggle is set to "Normal". Because the "Type" (brown circle Figure 5.) shows "VDC", the SRRL ARM mentor resets the graph (so that the scale is refined to the current readings), allows it to run until 5–10 points are collected, and then chooses "Plot channel."
5. Verify the result plotted in the appropriate "Results by Channel" graph at the lower part of the panel.
6. Move the toggle to "XtraTherm" and because the "Type" shows "RES4" the SRRL ARM Mentor will not record its values (only values of Type "VDC" and RES" will be recorded.
7. If the position also has a resistance channel associated with it (as do positions 10, 11, 12, 13, and others), then the short stays on that position while the SRRL ARM mentor will enter the next channel, reset the graph, collect enough points, and plot the result. Then toggle to the other toggle option and repeat (unless "type" = "RES4"). If the position has

a second resistance channel associated with it (as do 30 and 83), then the SRRL ARM mentor will repeat the same steps for that channel. The positions with three channels are used for the thermal correction pyrgeometers in the SW configuration.

8. When the voltage and any resistances associated with that position have been plotted, the SRRL ARM mentor instructs the SGP RCF operator to go to the next position by specifically telling the SGP RCF operator the position number.
9. After all the table positions are complete, the team will move on to the tracker positions and perform the same set of steps described for the table positions.
10. When all the table and tracker positions have been checked, choose the "Save" button (shown in Figure 4 circled in purple), and save the information to the SGP computer at BORCAL/System check/2018 BORCAL (with correct year). Note that the data may be saved at any point during the process. Further, if the channel check process for some reason needs to be suspended and the system shut down, the data can be saved and then retrieved later using the "Read" button (Figure 4 circled in purple).
11. Reminder notes:
    - The BORCAL-LW and BORCAL-SW data proofs are tested as one setup.
    - Be sure to check the "type" for both toggles for each channel and plot all types that are "VDC" and "RES" and do not record values for "type" of "RES4".
    - The 23 additional LW positions can be used only in the off-BORCAL-SW season (fall and winter). During the SW season, LW calibrations can be done, but only 12 at a time using only tracker locations. This procedure assumes that the channel check is completed prior to the first BORCAL-SW of the season.
    - Once you have completed the channel check, open the file containing the results for the channel check to verify that you have obtained values for all used channels.
    - Be sure to perform both voltage and resistance checks for the positions that contain both.
    - Once the results are saved, inform the NREL BORCAL manager to calculate the system offsets (to be included in the Parameters for Reference Sheet).

3 Pre-SGP BORCAL Configuration Audit Report Checks

Prior to each BORCAL event at the SGP site, SRRL staff will review the rooftop map and the RCC parameters for the reference instruments and compare them to the Session Configuration Audit Report, which represents what is being calibrated and their associated configurations during that SGP BORCAL-SW and BORCAL-LW event.

3.1 Outline

Before the SGP BORCAL session begins and after the SGP RCF operator has completed the sensor configuration, the following procedure must be completed by the SRRL ARM mentor. (The processes for each of these are explained in the following sections.)

- Create the RCC Parameters for Reference Instruments document. (See Section 3.2.)
- Request a rooftop map from the SGP RCF operator. (See Section 3.3.)
- Generate the Session Configuration Audit Report. (See Section 3.4.)
- Compare the Session Configuration Audit Report to the RCC Parameters for Reference Instruments. (See Section 3.5.)
- Compare the Session Configuration Audit Report to the Rooftop Layout provided by the SGP. (See Section 3.6.)
- Make a folder for the BORCAL event that will contain the rooftop map, the RCC parameters for the reference instruments, and the Session Configuration Audit Report. It will also eventually contain any important email correspondences with SGP technicians, notes taken regarding the report, the report itself, and other related documents.

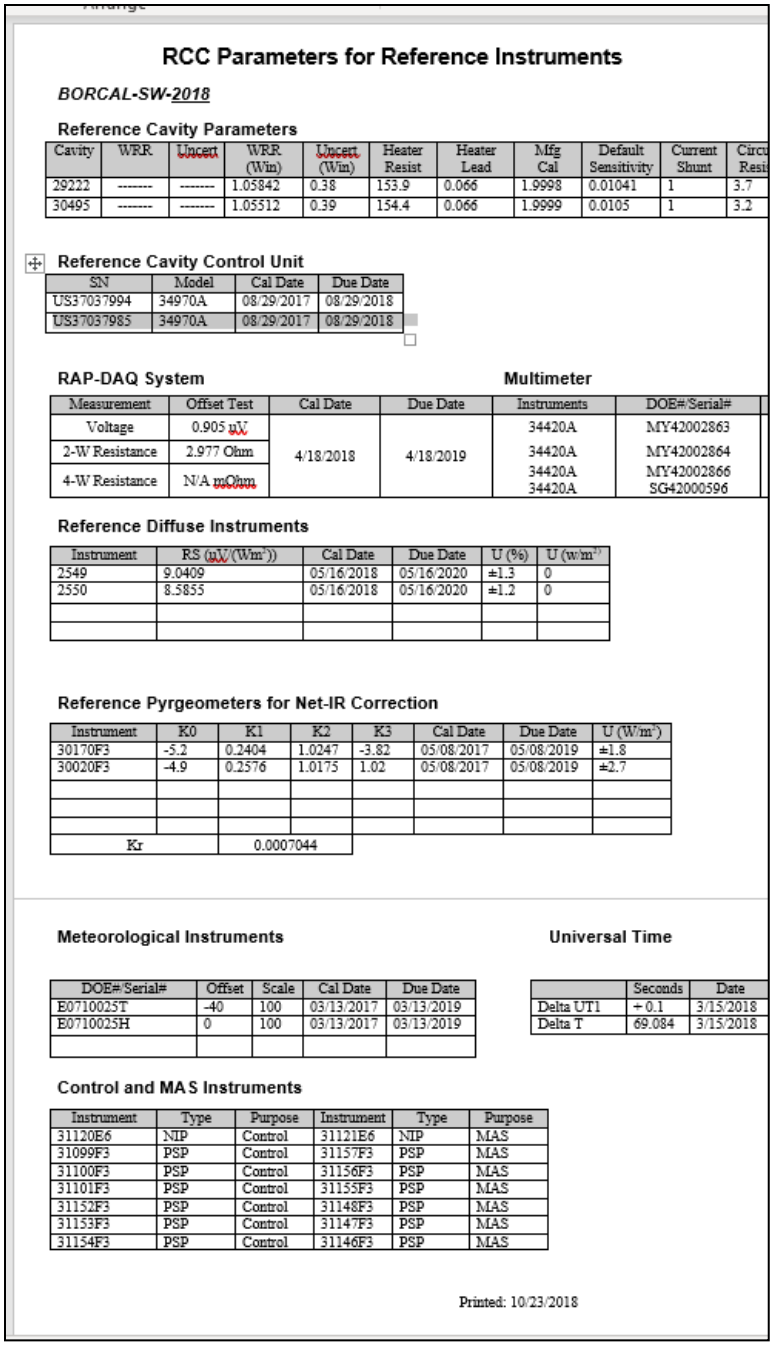
3.2 Create the RCC Parameters for Reference Instruments Document

- This document contains reference instrument serial numbers and other relevant information, and it needs to be updated each year. The same document will be used throughout the year for the various BORCAL events. There will be one RCC Parameters for Reference Instruments for all BORCAL-SW events in a particular year and one for all BORCAL-LW events in a particular year, unless some unexpected change to the reference layout is necessary, such as the failure of a MAS or Control instrument or a change in the time offset.
- If this is the first event of the year, copy the NREL BORCAL RCC Parameters for Reference Instruments template from the following subfolder on the NREL server containing shared files. Choose the LW or the SW template, depending on the intent.
    - NREL\SRRL\AIM\BORCAL_SGP\ARM BORCAL FILES
- Fill the empty template with the correct values for the reference instruments. These are obtained in the following manner:

- Reference cavity parameters (2) (SW): Obtain the values from the NPC report from the previous year.[1]
- Reference pyrgeometers (2) (LW): Request the BORCAL results from the previous BORCAL event from the NREL metrology administrator or check the ARM Instrument Management system (AIM Database). Be sure to use K0 ≠ 0 calibration factors.
- RAP-DAQ system (SW and LW): Request the offset voltage in µV, 2-W resistance in ohms, and 4-wire resistance in milliohms from the metrology lab manager. Note: SGP wiring infrastructure currently does not support 4-wire resistance, so this value is not available. This value is obtained from the channel check described in Section 2.
- RAP-DAQ system—digital multimeters (SW and LW): Request the calibration date and serial number information for the four BORCAL digital multimeters from the NREL metrology administrator.
- Pyrgeometer for NET-IR correction (SW): Request the BORCAL results from the previous BORCAL event from the NREL metrology administrator or obtain from the AIM Database.
- Reference diffuse instruments (SW): Request the BORCAL results from the previous NREL BORCAL event from the NREL metrology administrator or obtain from the AIM Database.
- Metrological instruments (SW and LW): Provide the serial number and request the calibration date from the NREL metrology administrator.
- Universal time (SW and LW): Obtain this from the current SRRL BORCAL RCC Parameters for Reference Instruments document located in this folder (or ask the metrology lab manager). The latest values can also be obtained from the IERS Bulletin-A.[2] The bulletin can also be reached from the metadata link for ΔT on the MIDC BMS.

- If this is not the first event of the year, reprint the RCC Parameters for Reference Instruments from the previous BORCAL-SW or BORCAL-LW event.
- The information is used to cross-check the Session Configuration Audit Report created by the SGP RCF operator.
- The RCC Parameters for Reference Instruments for BORCAL-SW will look like the information shown in Figure 6.

[1] See http://www.nrel.gov/aim/npc.html.
[2] See http://maia.usno.navy.mil/ser7/ser7.dat, where ΔT = 32.184 + (TAI-UTC) - ΔUT1 and ΔUT1 = DUT1.



RCC Parameters for Reference Instruments

BORCAL-SW-2018

Reference Cavity Parameters

Cavity	WRR	Uncert	WRR (Win)	Uncert (Win)	Heater Resist	Heater Lead	Mfg Cal	Default Sensitivity	Current Shunt	Circu Resi
29222	-------	-------	1.05842	0.38	153.9	0.066	1.9998	0.01041	1	3.7
30495	-------	-------	1.05512	0.39	154.4	0.066	1.9999	0.0105	1	3.2

Reference Cavity Control Unit

SN	Model	Cal Date	Due Date
US37037994	34970A	08/29/2017	08/29/2018
US37037985	34970A	08/29/2017	08/29/2018

RAP-DAQ System **Multimeter**

Measurement	Offset Test	Cal Date	Due Date	Instruments	DOE#/Serial#
Voltage	0.905 µV	4/18/2018	4/18/2019	34420A	MY42002863
2-W Resistance	2.977 Ohm			34420A	MY42002864
4-W Resistance	N/A mOhm			34420A 34420A	MY42002866 SG42000596

Reference Diffuse Instruments

Instrument	RS (µV/(Wm²))	Cal Date	Due Date	U (%)	U (w/m²)
2549	9.0409	05/16/2018	05/16/2020	±1.3	0
2550	8.5855	05/16/2018	05/16/2020	±1.2	0

Reference Pyrgeometers for Net-IR Correction

Instrument	K0	K1	K2	K3	Cal Date	Due Date	U (W/m²)
30170F3	-5.2	0.2404	1.0247	-3.82	05/08/2017	05/08/2019	±1.8
30020F3	-4.9	0.2576	1.0175	1.02	05/08/2017	05/08/2019	±2.7
Kr		0.0007044					

Meteorological Instruments

DOE#/Serial#	Offset	Scale	Cal Date	Due Date
E0710025T	-40	100	03/13/2017	03/13/2019
E0710025H	0	100	03/13/2017	03/13/2019

Universal Time

	Seconds	Date
Delta UT1	+ 0.1	3/15/2018
Delta T	69.084	3/15/2018

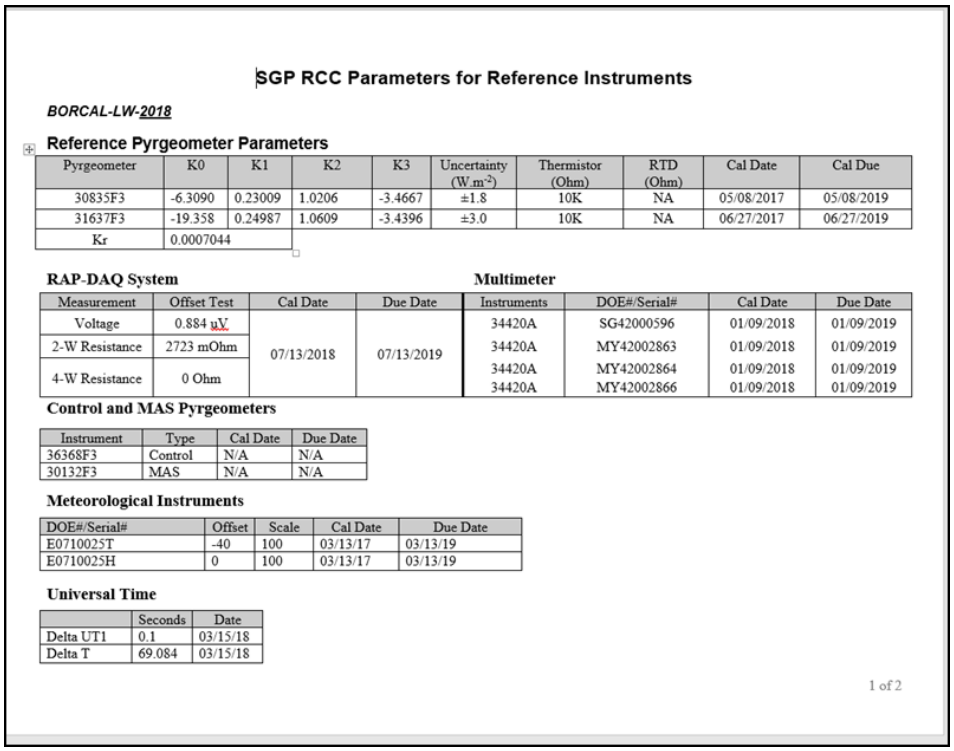
Control and MAS Instruments

Instrument	Type	Purpose	Instrument	Type	Purpose
31120E6	NIP	Control	31121E6	NIP	MAS
31099F3	PSP	Control	31157F3	PSP	MAS
31100F3	PSP	Control	31156F3	PSP	MAS
31101F3	PSP	Control	31155F3	PSP	MAS
31152F3	PSP	Control	31148F3	PSP	MAS
31153F3	PSP	Control	31147F3	PSP	MAS
31154F3	PSP	Control	31146F3	PSP	MAS

Printed: 10/23/2018

Figure 6. RCC Parameters for Reference Instruments (BORCAL-SW)

- The RCC Parameters for Reference Instruments for BORCAL-LW will be in the format shown in Figure 7.



SGP RCC Parameters for Reference Instruments

BORCAL-LW-2018

Reference Pyrgeometer Parameters

Pyrgeometer	K0	K1	K2	K3	Uncertainty ($W.m^{-2}$)	Thermistor (Ohm)	RTD (Ohm)	Cal Date	Cal Due
30835F3	-6.3090	0.23009	1.0206	-3.4667	±1.8	10K	NA	05/08/2017	05/08/2019
31637F3	-19.358	0.24987	1.0609	-3.4396	±3.0	10K	NA	06/27/2017	06/27/2019
Kr	0.0007044								

RAP-DAQ System

Measurement	Offset Test	Cal Date	Due Date
Voltage	0.884 uV	07/13/2018	07/13/2019
2-W Resistance	2723 mOhm		
4-W Resistance	0 Ohm		

Multimeter

Instruments	DOE#/Serial#	Cal Date	Due Date
34420A	SG42000596	01/09/2018	01/09/2019
34420A	MY42002863	01/09/2018	01/09/2019
34420A	MY42002864	01/09/2018	01/09/2019
34420A	MY42002866	01/09/2018	01/09/2019

Control and MAS Pyrgeometers

Instrument	Type	Cal Date	Due Date
36368F3	Control	N/A	N/A
30132F3	MAS	N/A	N/A

Meteorological Instruments

DOE#/Serial#	Offset	Scale	Cal Date	Due Date
E0710025T	-40	100	03/13/17	03/13/19
E0710025H	0	100	03/13/17	03/13/19

Universal Time

	Seconds	Date
Delta UT1	0.1	03/15/18
Delta T	69.084	03/15/18

1 of 2

Figure 7. RCC Parameters for Reference Instruments (BORCAL-LW)

3.3 Request a Rooftop Map from the SGP RCF Operator

- The SGP RCF operator will either fax or email an image of the rooftop map.
- This map shows where instruments are located (by serial number), if they are on a tracker, if they are ventilated, who owns the instrument, and other details.
- For BORCAL-SW, the map will be in the format shown in Figure 8.

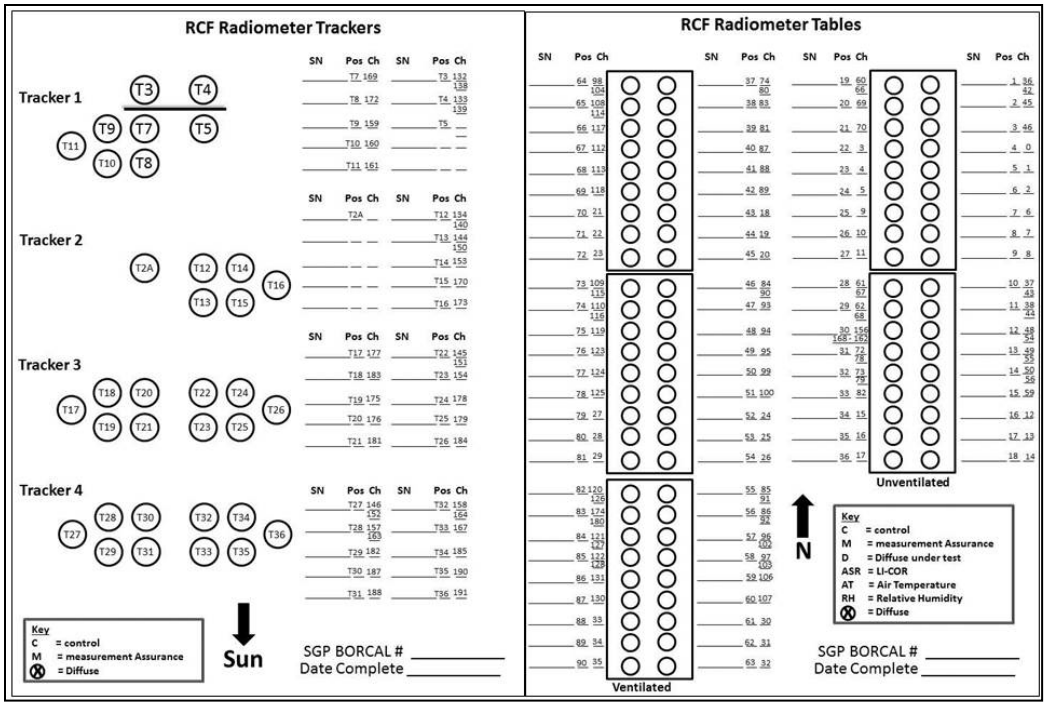


Figure 8. BORCAL-SW tracker and table layout

3.4 Generate the Session Configuration Audit Report

This section outlines the procedure for generating the Session Configuration Audit Report for the BORCAL-SW and BORCAL-LW events. The following screenshots illustrate these steps for a BORCAL-SW event. This is done after the SGP RCF operator has completed entering all the sensors into the RCC configuration.

- Log into the SGP computer as described in Section 2.1.
- From the SGP computer, double-click the RCC icon (shown in Figure 9).

Figure 9. RCC icon

- Select the appropriate RCC event type (BORCAL-SW or BORCAL-LW). Choose the menu option Edit → BORCAL Session, and the screen shown in Figure 10 will be generated.

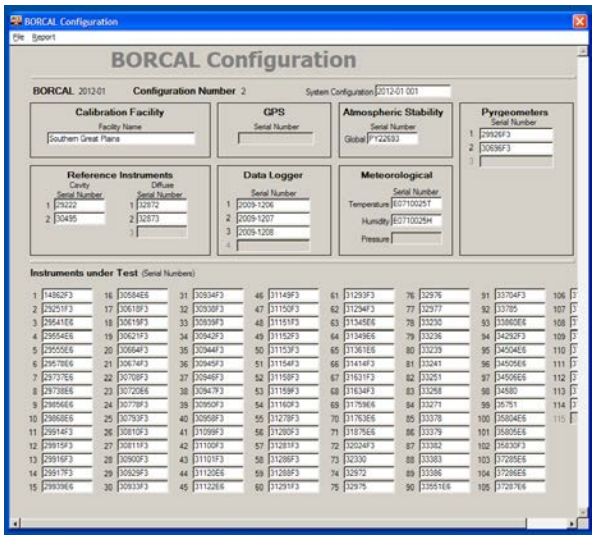


Figure 10. Screenshot of the BORCAL configuration

- Check to ensure that everything on this page looks reasonable (e.g., facility name, BORCAL number, reference instrument serial numbers.).
- From the BORCAL Configuration screen, choose menu option Report → Configuration Audit Report, and a report similar to the screenshot shown in Figure 11 will be generated.

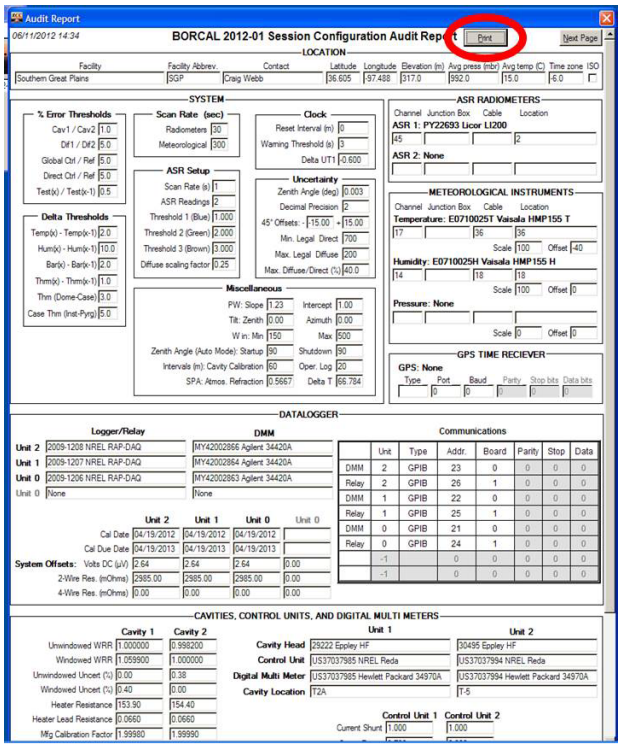


Figure 11. Configuration Audit Report (BORCAL-SW)

- Print report by clicking Print (shown in Figure 11 circled in red).

- Be sure to use the Bullzip PDF printer. The software will not work with other PDF software.
- Close all windows except for RCC. Be sure to leave RCC set to autorun for LW or SW as needed.
- Use the file transfer function of Radmin Viewer 3 to move the newly printed PDF file from the PDF folder (on the SGP computer) to the Initial Configuration Audit folder which is found in both the BORCAL-SW and BORCAL-LW folders on the NREL computer so that it can be printed on an NREL printer. There is a folder in both the BORCAL-SW and BORCAL-LW folders titled "Initial Configuration Audit Reports." Figure 12 shows an example of the file transfer window for a 2018 BORCAL-LW event. Note that there is a folder in both the SW and LW folders called "Initial Configuration Report" that is for moving this initial report.

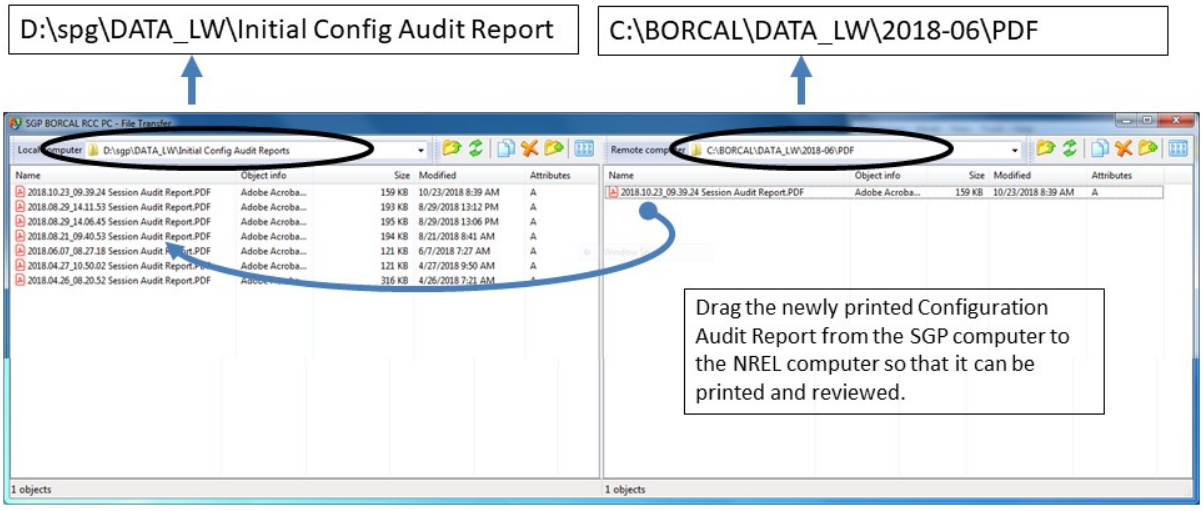


Figure 12. The file transfer window allows the user to move the Session Configuration Audit Report and other files from the SGP computer to the NREL computer.

- Close all windows except for the main RCC window and log off the SGP.
- Locate the Session Configuration Audit Report that was copied onto the NREL computer and print it to the local printer so that it can be used to compare the rooftop layout to the RCC Parameters for References Instruments document.

3.5 Compare the Session Configuration Audit Report to the RCC Parameters for Reference Instruments

Compare the reference instruments on the first two pages of the Session Configuration Audit Report from the SGP to the RCC Parameters for Reference Instruments document from NREL. The RCC Parameters for Reference Instruments will need to be created by the SRRL ARM mentor during the first BORCAL, and this sheet is used to check the rest of the SGP BORCALs that season. (This process is described in Section 3.2.) The BORCAL-SW and BORCAL-LW reference instruments and checks include the two following components.

3.5.1 BORCAL-SW RCC Parameters for Reference Instruments

- Two cavity units
    - Verify that the following values match on each sheet:
    - Unwindowed and windowed World Radiometric Reference
    - Unwindowed and windowed uncertainties
    - Heater and heater lead resistance (This will not change from one event to another.)
    - Manufacturer's calibration factor (This will not change from one event to another.)
    - Default sensitivity
    - Calibration date and calibration due date
    - Current shunt and circuit resistance (This will not change from one event to another.)
- RAP-DAQ system. Verify that the following values match on each sheet:
    - Serial numbers
    - Calibration date and calibration due date
    - System offset volts DC
    - System offset and 2-wire resistance.
- Control and MAS pyrgeometers
    - Serial number
    - Type (Control or MAS).
- Reference pyrgeometers for Net-IR correction. Verify that the following values match on each sheet:
    - Calibration date and calibration due date
    - K0, K1, K2, K3, Kr
    - Uncertainty
    - Note that one should not use the K0 =0 values.
- Reference diffuse instruments. Verify that the following values match on each sheet:
    - Responsivity
    - Calibration date and calibration due date
    - Uncertainty percentage
    - Offset.
- Metrological instruments. Verify that the following values match on each sheet:
    - Serial number

    - Offset
    - Scale
    - Check that the calibration date and due date are current.
- Verify that the delta T and delta UT1 (the time corrections) are correct by cross-referencing the RCC Parameters for Reference Instruments document.

3.5.2 BORCAL-LW RCC Parameters for Reference Instruments

- Two reference pyrgeometers
    - Calibration date and calibration due date
    - K0, K1, K2, K3, Kr
    - Uncertainty
    - Note that one should not use the K0 =0 values.
- RAP-DAQ system. Verify that the following values match on each sheet:
    - Serial numbers
    - Calibration date and calibration due date
    - System offset volts DC
    - System offset 2-wire resistance
    - Note these RAP-DAQ values will all be the same for the LW and SW Parameters for Reference Instruments sheets.
- Control and MAS pyrgeometers
    - Serial number
    - Type (Control or MAS).
- Metrological instruments
    - Serial number
    - Offset
    - Scale
    - Check that calibration date and due date are current.
- Verify that the delta T and delta UT1 (the time corrections) are correct by cross-referencing the RCC Parameters for Reference Instruments document.

3.6 Compare the Session Configuration Audit Report to the Rooftop Layout Provided by the SGP Site

First, verify that the following columns for the individual sensors are filled with correct values:

- Act: This column identifies if an instrument is active. In general, if the instrument is in the BORCAL, then it is active, and all should be checked “Yes.”

- ISO: This column identifies if the sensor is calibrated under International Standards Organization (ISO) standards. This is true for NREL BORCALs, but the SGP site is not ISO certified, so all should be marked as "No."
- AIM:. This column indicates if the data should be stored on the AIM Database. All the instruments should be checked "Yes."
- Vent: Ventilated instruments are used in the downwelling position (SKYGRD), and unventilated instruments are used in upwelling orientation (GNDRAD). LW is always ventilated.
- Sticker: This indicates whether the calibration sticker will have K0 = 0 or K ≠ 0. All test instruments should be "K0 = 0," which is preferred by ARM. Note that the reference PIRs do use K ≠ 0.
- Use: This indicates how the instrument is used. Tot is the total or global horizontal (or diffuse horizontal), PYG is the pyrgeometer or longwave, and DIR is direct normal.
- Kr: This is the fourth coefficient in the series of K factors. At this time, all pyrgeometers should be 7.044 e-4.
- Due: This is how long until the calibration is due again. All instruments should be listed as "12."

Compare the locations and channels of all test and reference instruments as recorded in the Session Configuration Audit Report from the SGP site to the layout and inventory sheets (rooftop maps) provided by the SGP RCF operator. The rooftop maps contain information about the position, channels, and owner for all instruments on the trackers and instrument tables.

Use the following steps for each instrument for both the BORCAL-SW and BORCAL-LW. This is most effective when done by two people.

- Person 1 calls out a serial number from the rooftop map.
- Person 2 finds the serial number on the Session Configuration Audit Report.
- Person 1 calls out the customer, channel, and location and indicates if it is a control or MAS for each instrument.
- Person 2 verifies that those values match the values for the corresponding instrument on the Session Configuration Audit Report. A small check mark is placed by each value as it is verified.
- If any discrepancies are found, they should be marked and noted on the Session Configuration Audit Report.
- Continue this for each instrument until Person 1 has read all the instruments from the rooftop map.
- After all the instruments have been covered, verify that they are checked off on the Session Configuration Audit Report.
- Report any discrepancies to the SGP RCF operator so that they can remedy the finding and update the Session Configuration Audit Report.

Notes:

- BORCAL-SW only: All pyranometers (such as model PSP ending in 'F3') are effective Net-IR corrected instrument and should also be followed by ©.
- BORCAL-SW only: Positions 37–90 are always ventilated instruments unless otherwise noted and positions 1–36 are always unventilated unless otherwise noted.
- BORCAL-SW and BORCAL-LW: If an instrument is a control instrument, it should be followed by ‡.
- BORCAL-SW and BORCAL-LW: The "customer" for the measurement assurance and control instruments is listed as "Calibration System" and should use two channels.
- BORCAL-SW and BORCAL-LW: All instruments should have AIM set to Yes and ISO set to No.
- ISO must also be unchecked on the main page of the Configuration Audit Report (upper right, first page).
- BORCAL-LW: All instruments must be set to Use of PYG; BORCAL-SW: all pyranometers should be TOT, and all pyrheliometers must be DIR.
- BORCAL-LW only: The sticker should be K0 = 0, unless directed otherwise by ARM upper management. (Note that the reference pyrgeometers in LW events and the Net-IR correction pyrgeometers in SW events do not use K0 = 0).
- BORCAL-SW and BORCAL-LW: Ensure that all case and dome temperatures for MAS and Control instruments are configured as their appropriate types (10K for PSPs, NONE for NIPs).

The last pages contain the Effective Net IR corrected instruments. Here the ventilation status of each pyrgeometer is verified using the following steps (BORCAL-SW only):

- Person 1 reads the serial number from the unventilated table (as shown on the rooftop map).
- Person 2 finds the serial number and verifies that the correcting pyrgeometer does not end in a V on the Session Configuration Audit Report (that is, it is not ventilated).
- After all the unventilated instruments on the unventilated table have been covered, verify that there are no instruments remaining on the Session Configuration Audit Report that do not have a 'V.' For example, 29926F3 Eppley PIR-V is a ventilated pyrgeometer, whereas 29457F3 Eppley PIR is unventilated.

Email the SGP RCF operator to inform them of any discrepancies that were found. These include serial numbers that were recorded wrong or sensor channels, positions, or owners that are found to be wrong, etc. After the SGP RCF operator either confirms or denies the findings and any necessary changes have been made to the RCC configuration on the SGP computer, reprint the Session Configuration Audit Report and verify that the changes have been made. Discard the previous Session Configuration Audit Report to avoid using or archiving the wrong document.

After all potential discrepancies have been addressed and the updates to the RCC configuration have been made, inform the SGP RCF operator that the BORCAL session can begin. (Note: Print any important, associated email conversations with the SGP personnel, and put them into the folder for that BORCAL event.) As a sanity check, a test session is typically run to verify normal operation with no unexpected alarm conditions. Unfortunately, because LW only runs at night, SGP personnel do not run the test session and it is recommended that this test session be run through RAdmin. Keep in mind that RCC will force LW to shutdown if the user attempts to run a session during the daytime before solar noon. To prevent shutdown, temporarily change the morning shutdown zenith angle in the BORCAL system configuration to a small value such as 0 degrees. After test session is complete, be sure to restore to the previous value (typically 94 degrees).

4 Post-SGP BORCAL Session Report Screening

For a BORCAL-SW event, the SGP RCF operator will inform the SRRL ARM mentor when they think they have collected enough data to constitute a full day's worth of data (zenith of 70° and less). For a BORCAL-LW event, it is necessary for the SRRL ARM mentor to check daily emails (which are automatically generated through RCC) to check if enough data have been collected. The following sections assume that the BORCAL appears to have enough data and that the SRRL ARM mentor will look over the report and the data to decide whether or not the event can be concluded.

4.1 Determine if Enough Data Have Been Collected

4.1.1 Concluding a BORCAL-SW Event

- To conclude a BORCAL-SW event, confirm that there is clear sky for a full range of zenith from morning to afternoon (at least 70° to 70°).
- This can be accomplished by combining multiple days.
- If multiple days are combined, use the session exclusion function to choose sessions such that there is as little time overlap in the data as possible. Section 4.5.1.1 and Section 4.5.1.2 describes this process.
- If multiple days are chosen, they should be within 3-4 days of each other.

4.1.2 Concluding a BORCAL-LW Event

- To conclude a BORCAL-LW event, confirm that a full range of millivolts have been collected, from 0 mV to approximately -400 mV.
- The maximum negative value will vary slightly with each radiometer.
- It is important to get a range of sky conditions for a BORCAL-LW event. Voltages near 0 are generated under cloudy conditions, and high negative voltages are created under clear skies.
- Other cloud conditions fill in the rest of the range. Figure 13 illustrates an example of a full range of sky conditions.

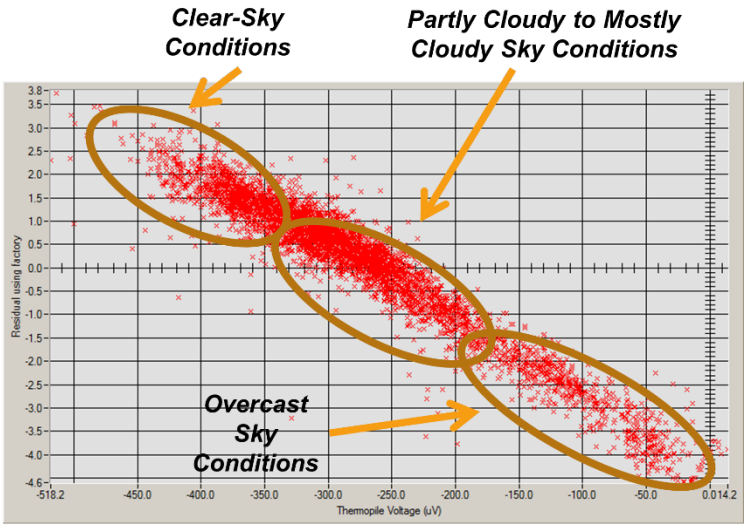


Figure 13. To conclude a BORCAL-LW event, confirm that a full range of sky conditions (mV) have been collected, from clear skies to overcast skies (0 mV to approximately -400 mV voltages). Near 0 mV are generated under cloudy conditions, and high negative voltages are created under clear skies. Other cloud conditions fill in the rest of the range.

4.2 Generate the BORCAL Report

If it is determined that the reference sky conditions are sufficient to conclude the BORCAL event, the results need to be further scrutinized. This involves printing and reviewing the results as follows.

- To view a report, log onto the SGP computer, open the RCC, and choose menu option Generate → Responsivities. (Make sure that the toggle switch is set to the type of BORCAL of interest: LW or SW). See the following figure.

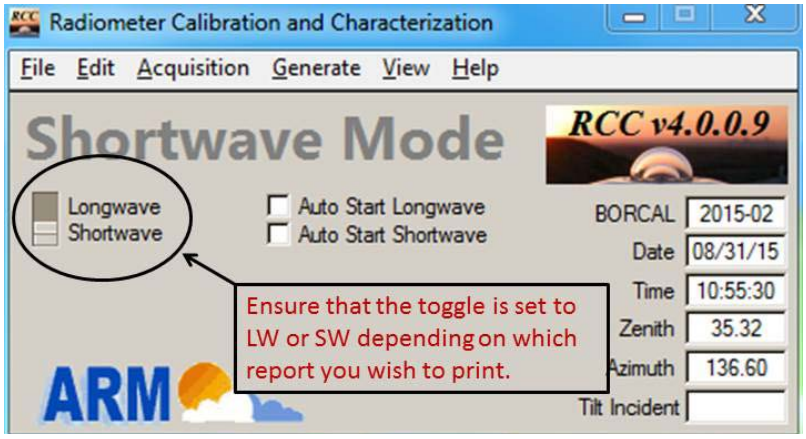


Figure 14. Print the finished report to PDF from the RCC, making note that the correct mode for the RCC has been selected: LW or SW.

- The window shown in Figure 15 will appear after selecting the menu option to generate responsivities. Ensure that all instruments are checked, the correct BORCAL event has been selected, and that the RSR filter is set to blue. Once "Generate" has been selected,

the process will take approximately 10 minutes for a full BORCAL-SW and a shorter time for a BORCAL-LW event.

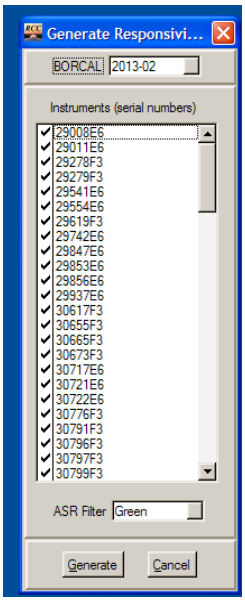


Figure 15. Choose the radiometers for which the responsivities should be generated for the final report. If any radiometers were found to be unleveled or in need of quarantine, they can be excluded from the final report by unchecking them here.

- Then choose menu option Generate → Report → Instrument Results → by BORCAL
- Examine approximately 10 instrument reports to confirm that
    - The dates are correct
    - There are no extreme outliers
    - The recent responsivity does not deviate too far from historical responsivities.
- If the report looks good upon preliminary viewing, contact the SGP RCF operator to let them know that they can cease the BORCAL watch procedures. No instruments should be removed yet, but the watch can stop. This affects only the BORCAL-SW event because the BORCAL-LW event is unmanned and can continue automatically.
- Move all files associated with that event from the SGP computer to the NREL computer where the final report will be generated and examined. This is described in the following.
    a. The first step is to log onto the SRRL computer to access the SGP computer and run "Radmin Viewer 3."
    b. Choose the file transfer option of Radmin Viewer 3 to reveal two Explorer-style windows with the local computer on the left and the SGP remote computer on the right. To transfer files, drag the files from the right (remote computer) to the left (local computer).
    c. On the remote computer navigate to C:\Borcal\DB, and on the local computer navigate to D:\SGP\DB. Find the file titled rcc.mdb. Drag the rcc.mdb file from the remote computer to the local computer. The transfer will take a couple of

minutes. It may be necessary to change the name of the previous RCC database on the NREL computer file so as not to overwrite it.

d. On the remote computer navigate to C:\Borcal\Data_SW\ 2015-02\, and on the local computer navigate to D:\SGP\Data_SW \2015-02\. (Use the correct year and BORCAL event and BORCAL type: LW or SW.)

e. Copy the contents of all of the folders from the remote computer to the local computer by dragging the folders from one to the other.

f. Log off the SGP computer and close the screen.

- After this prescreening, generate the full report as a PDF on the NREL computer; do not print a paper copy. To do this, use the following toolbar access on the RCC: Generate → Report → Full Report. Be sure to choose Bullzip to generate the report and not Foxit or any other PDF creator.

4.3 Review the Full Report

The next step is to look at the whole report, including each instrument's sub-report. The full report begins with the control instruments and the results summary, followed by each instrument's individual calibration certificate. The processes for BORCAL-SW and BORCAL-LW are different from each other, and they are described in the following two sections.

4.3.1 Report Review for BORCAL-SW

- Control instruments
  - All control instruments should be <1% deviation from the most recent historical responsivity and track other similar control instruments.
- Environmental and sky condition plots summary
  - This is at the end of the report, and all plots should be verified as complete and reasonable. Also, verify that there is continuous solar data from morning to evening (<70° zenith).
- Calibration certificate for each sensor
  - Verify that the calibration date and next due date is correct.
  - Verify that there are no outliers. If there are, note the serial number of the sensor and the approximate time of the outlier. This will help filter those outliers later. Outliers only need to be removed when they are so far off the scale that the other data are made indistinguishable due to the large scaling of the graph. Section 4.5.1.2 describes this process.
  - Verify that the responsivity compared to the zenith is symmetric (that is, that the a.m. and p.m. values are not too far off from each other). If it is not symmetric, a sensor might be out of level. Following is an example of a potentially unleveled sensor that should be marked for physical inspection by the SGP BORCAL team to determine if it is not level, there are blemishes on the dome, a radiation shield that is not properly seated, graying of the sensor, etc.

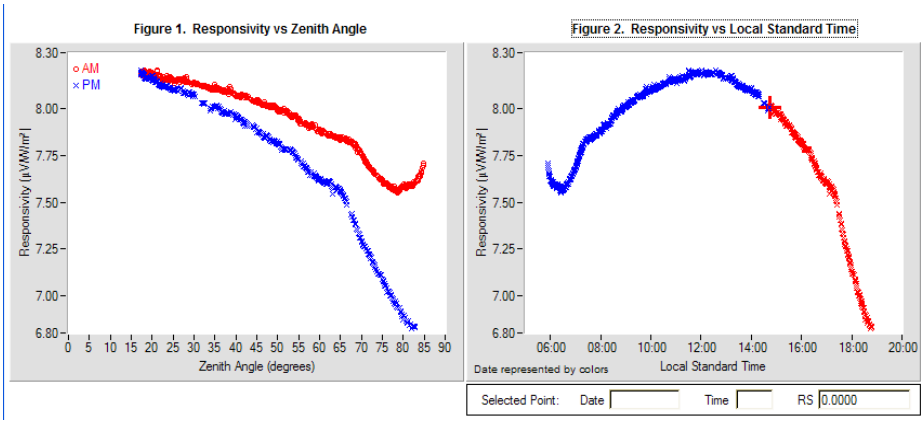


Figure 16. A potentially unleveled sensor

- Note that in most instances fitting the description in the previous point, the sensor will be level and the misalignment of the morning and afternoon zenith data is a true representation of that sensor's responsivity. This is a main reason for the need to calibrate thermopile sensors with their cables pointing to the north.
- Verify that from a historical standpoint the recent responsivity does not vary too much from the last responsivity. Generally, the percent change from the last BORCAL should be within the uncertainty of the instrument.

- Provide the SGP RCF operator with a list of serial numbers for the sensors that are believed to be unleveled or otherwise questionable so that the offending radiometers can be checked. If sensors are found to be unleveled or damaged, the SGP RCF operator will need to re-level and run it in the next BORCAL or put it into quarantine.
- After all the outliers, historical deviations, and potentially unleveled sensors have been noted, it is time to remove the outliers. This is described in Section 4.5.
- If an instrument is found to have a bad calibration, it can be removed from the final report results by the following menu option: Edit → Database → Calibration Data. Then find the instrument by serial number and choose edit. Then change "Valid" to "Invalid."

4.3.2 Report Review for BORCAL-LW

- Control instruments
  - The control instruments for BORCAL-LW will have four K coefficients associated with them as determined from the calibration. The four coefficients should follow these general guidelines:
    - K0: Ranges from 4 to -16 W/m^2
    - K1: Ranges from 0.19 to 0.38 W/m^2
    - K2: Ranges from 0.994 to 1.041 W/m^2
    - K3: Ranges from -2.4 to -6.4 W/m^2.
- Environmental and sky condition plots summary

- This is at the end of the report, and all plots should be verified as complete and reasonable.

- Calibration certificate for each sensor
  - Verify that the calibration date and next due date is correct.
  - Verify that the residuals for the calculated BORCAL-LW for that instrument compared to the reference have two standard deviation bounds that are within ± 1 W/m^2.
  - Verify that the uncertainty falls below 2 W/m^2 – 3 W/m^2.
  - Review the residual plots for each sensor (these are stored in DATAFILES\CALDAT folder for the BORCAL and are emailed daily during a given LW event). Sensors that have been calibrated before should have small residuals (less than approximately ± 4 W/m^2) for all voltages when using the old coefficients. If it is a sensor's first outdoor LW calibration then the residuals will form a line with a slope and the values of the points should not lie more that ± 4 W/m^2 from that line.

4.4 Finding the Manufacturer's Calibration

Note that for any sensors that are in their first BOCAL and thus do not have a previous BORCAL calibration value to compare to, the manufacturer's calibration value can be used. Following are the steps for finding the manufacturer's calibration value.

- From the RCC SGP software, choose Edit → Database → Radiometer Inventory (Pyrgeometer Inventory for BORCAL-LW).

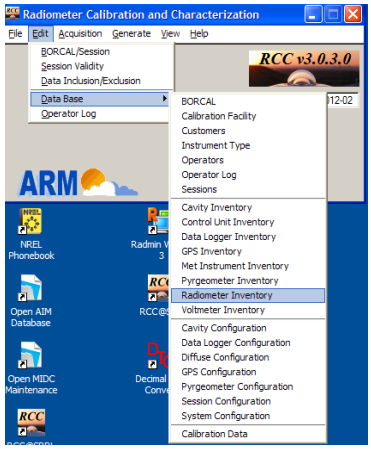


Figure 17. Accessing the BORCAL-SW radiometer inventory to note a radiometer's manufacturer's responsivity

- The screen shown in Figure 18 will appear.

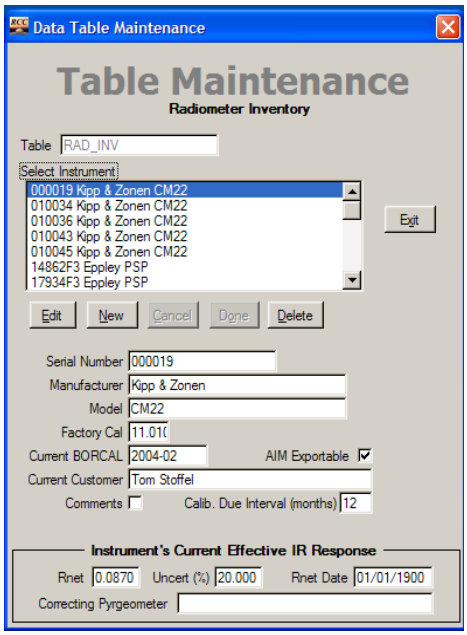


Figure 18. Select the instrument serial number, and its value will be displayed below.

- Find the radiometer in question by typing its serial number, then note the manufacturer's responsivity for that sensor.

4.5 Editing the Sessions and Removing Outlying Data Points

There are two basic methods to remove or include data from the responsivity calculations: **session validity** and **data exclusion**. Use session validity to make large global changes to the sessions that are available for use in the responsivity calculations. This is commonly used to exclude sessions with poor data quality and clear sessions that might overlap other clear sessions on other days. Use data exclusion to remove individual outliers in the data for a single instrument or for a group of instruments within a short time period.

4.5.1 Using Session Exclusion to Remove Data

A BORCAL-SW session consists of a few hours of data or less and might be kept or excluded depending on the clearness and the stability of the sky during the session. BORCAL-LW is different in that a session runs all night long. Full sessions can be excluded for both BORCAL-SW and BORCAL-LW, and the processes are similar for both and discussed in the following two sections.

4.5.1.1 Using Session Exclusion to Remove Data for BORCAL-SW

- The goal is to find a full day's worth of good data (a full zenith range from morning to afternoon of clear, stable sky conditions). During some BORCAL events, all the data will be gathered during a single day. More often, however, data might be used from one morning one day and an afternoon from another or data from three or even more days might be combined. When combining days, there should not be data from the same time of day overlapping each other from different days.

- Open report for any sensor using the following: Generate → Report → Instrument Results → by BORCAL.
- Pick one of the sensors (preferably a PSP because the responsivity curve has a regular shape to it) and click Generate.
- This action will generate a report for the individual sensor. On page two of this report, two graphs show responsivity as a function of time (right) and as a function of zenith (left). These are shown in Figure 19. For this process, the graph on the right is the one of interest: it shows the responsivity as a function of time. Figure 19 shows a calibration report for an individual sensor with no data excluded. There are three days' worth of data represented in the Responsivity vs. Local Standard Time graph in Figure 19: one is shown in red, one in blue, and one in green. Each day will have a separate color.

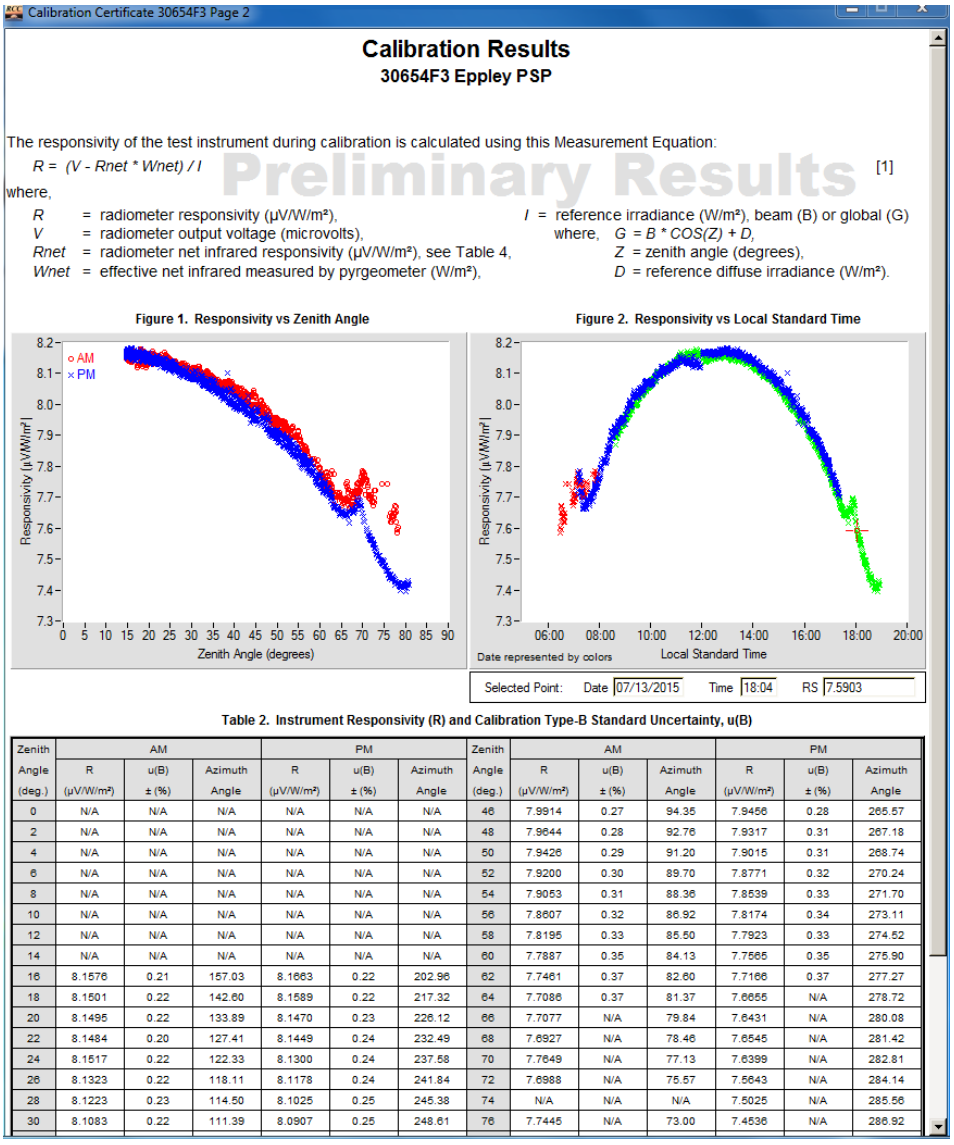


Table 2. Instrument Responsivity (R) and Calibration Type-B Standard Uncertainty, u(B)

Zenith Angle (deg.)	AM R (µV/W/m²)	AM u(B) ± (%)	AM Azimuth Angle	PM R (µV/W/m²)	PM u(B) ± (%)	PM Azimuth Angle	Zenith Angle (deg.)	AM R (µV/W/m²)	AM u(B) ± (%)	AM Azimuth Angle	PM R (µV/W/m²)	PM u(B) ± (%)	PM Azimuth Angle
0	N/A	N/A	N/A	N/A	N/A	N/A	46	7.9914	0.27	94.35	7.9456	0.28	265.57
2	N/A	N/A	N/A	N/A	N/A	N/A	48	7.9644	0.28	92.76	7.9317	0.31	267.18
4	N/A	N/A	N/A	N/A	N/A	N/A	50	7.9426	0.29	91.20	7.9015	0.31	268.74
6	N/A	N/A	N/A	N/A	N/A	N/A	52	7.9200	0.30	89.70	7.8771	0.32	270.24
8	N/A	N/A	N/A	N/A	N/A	N/A	54	7.9053	0.31	88.36	7.8539	0.33	271.70
10	N/A	N/A	N/A	N/A	N/A	N/A	56	7.8607	0.32	86.92	7.8174	0.34	273.11
12	N/A	N/A	N/A	N/A	N/A	N/A	58	7.8195	0.33	85.50	7.7923	0.33	274.52
14	N/A	N/A	N/A	N/A	N/A	N/A	60	7.7887	0.35	84.13	7.7565	0.35	275.90
16	8.1576	0.21	157.03	8.1663	0.22	202.96	62	7.7461	0.37	82.60	7.7166	0.37	277.27
18	8.1501	0.22	142.60	8.1589	0.22	217.32	64	7.7086	0.37	81.37	7.6655	N/A	278.72
20	8.1495	0.22	133.89	8.1470	0.23	226.12	66	7.7077	N/A	79.84	7.6431	N/A	280.08
22	8.1484	0.20	127.41	8.1449	0.24	232.49	68	7.6927	N/A	78.46	7.6545	N/A	281.42
24	8.1517	0.22	122.33	8.1300	0.24	237.58	70	7.7649	N/A	77.13	7.6399	N/A	282.81
26	8.1323	0.22	118.11	8.1178	0.24	241.84	72	7.6988	N/A	75.57	7.5643	N/A	284.14
28	8.1223	0.23	114.50	8.1025	0.25	245.38	74	N/A	N/A	N/A	7.5025	N/A	285.56
30	8.1083	0.22	111.39	8.0907	0.25	248.61	76	7.7445	N/A	73.00	7.4536	N/A	286.92

Figure 19. Page two of the radiometer calibration report for an individual sensor shows the responsivity as a function of time (right) and zenith (left). The right plot (by time) is useful for determining which sessions to exclude and which to include.

- Because the day that is represented by red is so short, is not a smooth function, and is otherwise occurring during the same time of the day as the blue day, the red data can be excluded. Likewise, most of the green or blue day data can be excluded to obtain as much of a full day as possible.
- By clicking on any of the points on the graph, the date and time that the data occurred will be displayed. The red data shown in Figure 19 above is from July 12, the green data is from July 13, and the blue data is from July 14. This example uses the evening of July 13 and all of July 14.
- Open the session Validity window by using the following: Edit → Session Validity. Figure 20 shows this window. By clicking the corresponding session numbers, the data are limited to the days and times discussed above.

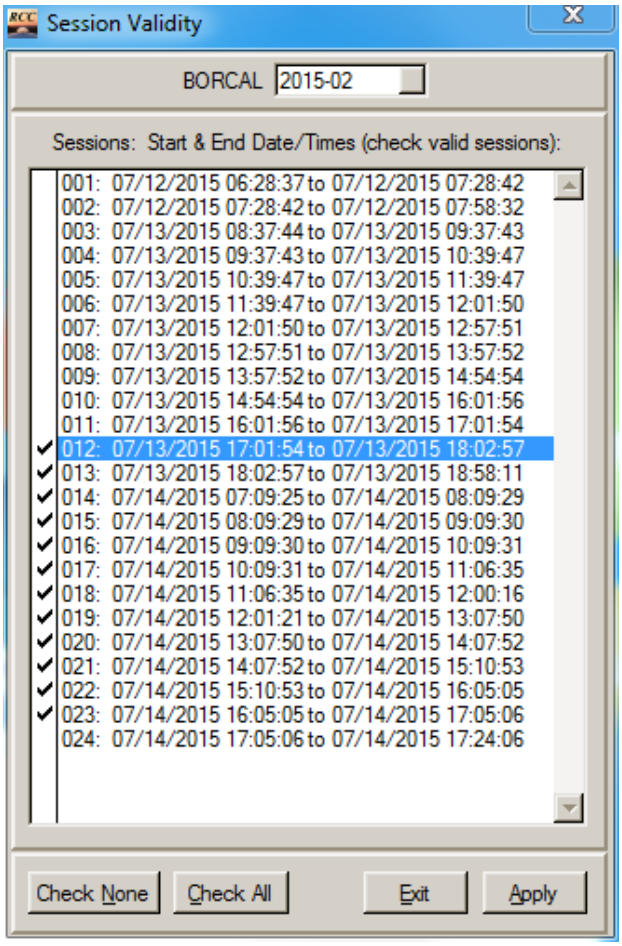


Figure 20. The BORCAL-SW session Validity window from which sessions can be excluded (not checked) or included (checked)

- At this point, review the valid session selection by regenerating the responsivities and subsequently the instrument report and observing whether the changes occurred as expected—that is, there is one continuous set of data covering morning and afternoon from at least 70°.

4.5.1.2 Using Session Exclusion to Remove Data for BORCAL-LW

The process for excluding sessions for BORCAL-LW is very similar to the process for BORCAL-SW. The main differences are the time frame that a session represents and the reason for excluding a session. A session in BORCAL-LW lasts the full night; there is a session for each night. A session should be excluded if it rained that night or was extremely dusty or windy. Because the event occurs at night, many times the conditions might not be known and another source of data will need to be used to determine wind speeds or rain. Figure 21 illustrates a session exclusion screen for BORCAL-LW. Note that each session represents a full day.

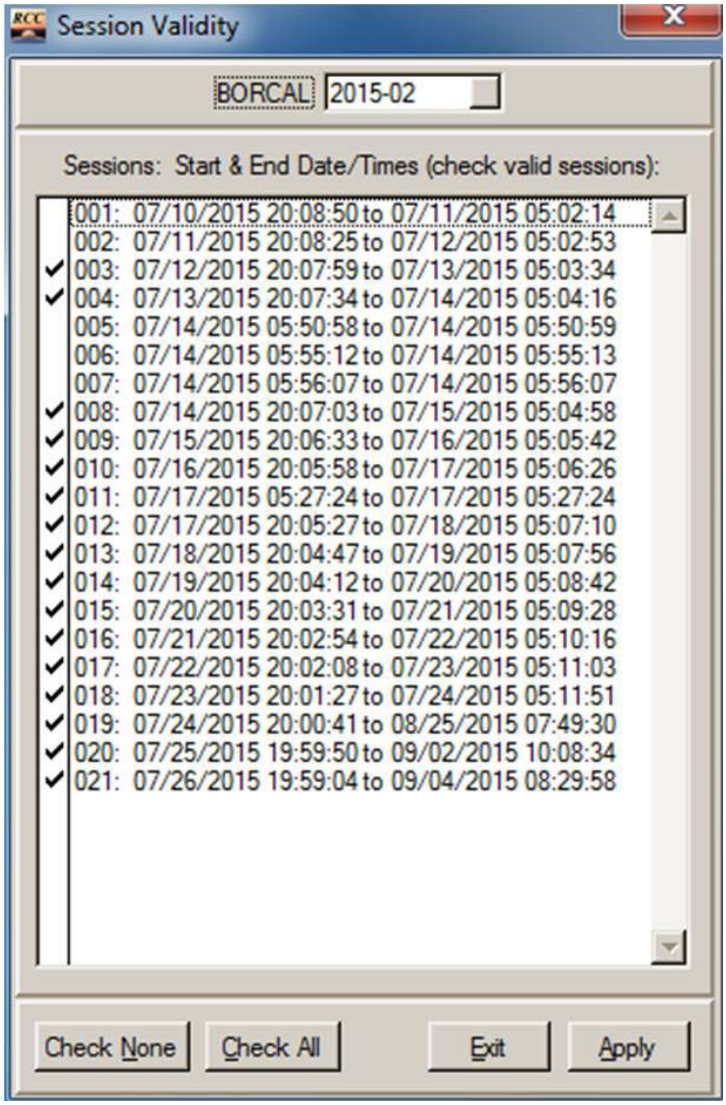


Figure 21. Session exclusion window for BORCAL-LW

4.5.2 Excluding Specific Points for One or More Instruments (BORCAL-SW Only)

In some instances, specific data points might be removed from the valid data range (instead of a full session's worth of data). Examples include:

- When the graph of the responsivity is squished because of a data point that is out of range, specific points for one or some instruments might be excluded.
- If a small cloud passes over the sun disc and causes a blip in the data for all instruments, data during that event might be excluded by applying a global change to a set of data. (Note that even though this affects all sensors, it is not equivalent to a session exclusion because it occurs during a short, limited time.)

When one or more outliers in the data have been noted, these can be removed from all reports by using the RCC Data Inclusion/Exclusion function. Care should be taken when editing data within ±0.3° of 45° zenith angle, as removal of such data can prevent responsivity generation.

- First, note the exact date and time of the outliers. Open the report for any sensor using the following RCC toolbar access: Generate → Report → Instrument Results → by BORCAL. Pick one of the sensors and click Generate.
- When the report is generated, choose page two of the report and click on the outlier(s) in the Responsivity vs. Standard Time graph. Note the date, approximate time, and responsivity of the point.
- Use the following toolbar access: Edit → Data Inclusion/Exclusion. This will open a window containing a grid of squares with sensor serial numbers on the Y axis and hours on the X axis (Figure 22). Double-click the square corresponding to the serial number and hour in question.

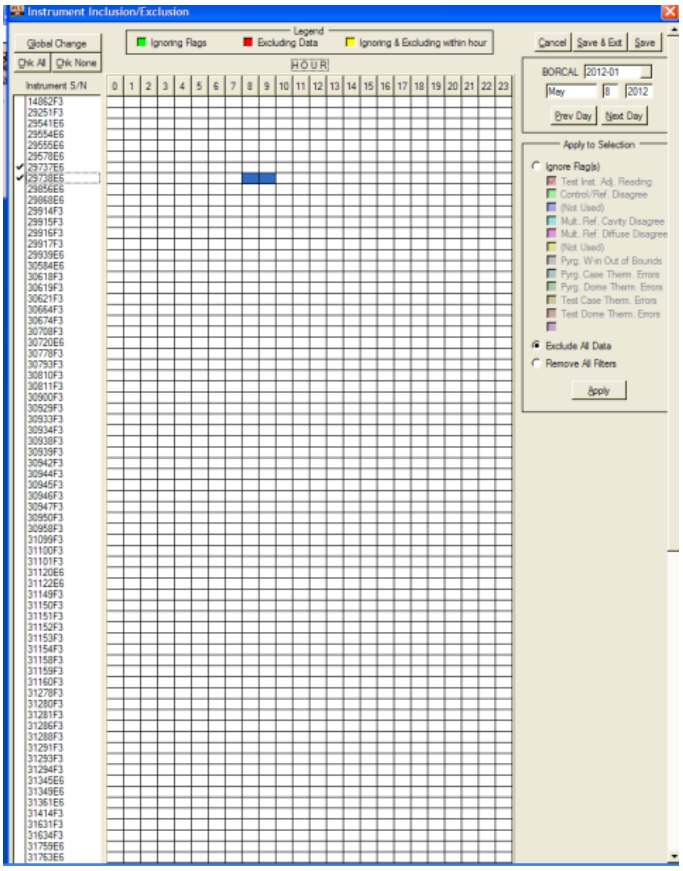


Figure 22. Instrument data inclusion/exclusion window

- A new zoom screen will open with another grid of squares representing the hour chosen (Figure 23). The minute is on the Y axis. The X axis contains two columns: one for the first half minute and one for the second half minute. Choose the square or group of squares that contain the time of the data in question.

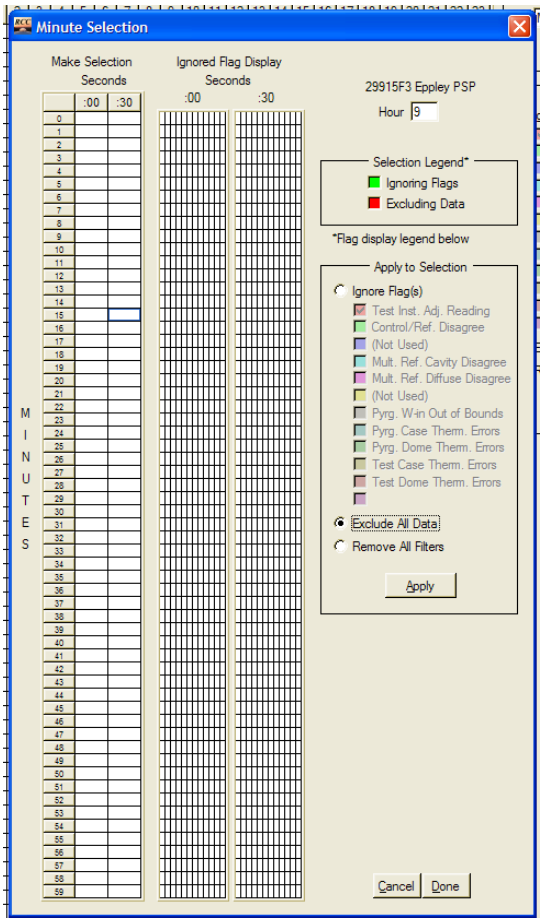


Figure 23. Screenshot of the minute selection

- On the right side of the screen is a list of boxes titled “Apply to Selection.” Here individual flags or all flags can be removed depending on the need. For outlying data points, check the box for “Exclude All Data,” and click “Apply.”
- Save and exit.
- Follow the above steps for each sensor that contains an outlier.
- To make a global change to the data set, click “Chk All” button” or individually click all the boxes corresponding to the sensors that should be changed. Then click the Global Change Button (see Figure 22). Pick the time and date, check “Exclude All Data,” and click “Apply.” To capture all scan groups, remove all data around the outlier for the full 30-second block.

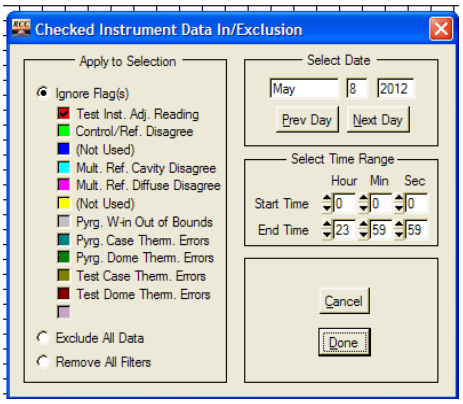


Figure 24. Screenshot of the global change option

- To write the changes to the database, use the following toolbar access: Generate → Responsivities.
- To check that the point has been removed, generate an instrument report (Generate → Report → Instrument Results → by BORCAL), and check the second page to verify that the point or points are missing.
- Finally, regenerate the full report so that it contains the changes made using the following toolbar access: Generate → Report → Full Report. Check that the default values for the front page of the report are correct.
- Thoroughly review the whole report page by page, as described in Section 4.3.

5 Generate Sticker File and Stickers

After the report has been reviewed by the technical manager, the files and data have been transferred to the NREL SGP computer, and responsivities and full report have been regenerated, generate the stickers that will be sent to the SGP RCF operator to be affixed to each instrument. This process will also generate the report and data files The AIM Database will need to be updated with that BORCAL event's report and data.

- From the RCC software on the NREL SGP data-processing computer, ensure that the appropriate BORCAL event type is selected (SW or LW), then choose File → Export → AIM Calibration Stickers.

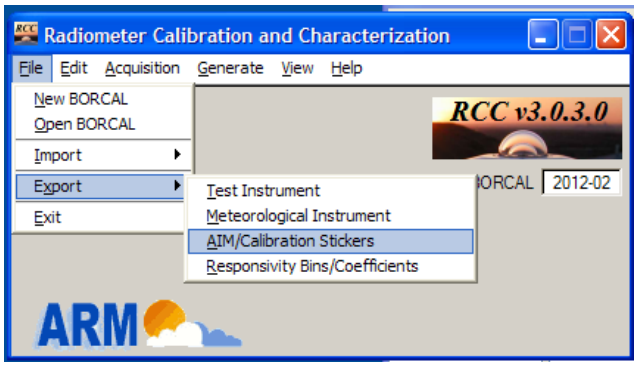


Figure 25. Main menu access to generate sticker files and create files to transfer the BORCAL results to the AIM Database

- This will generate the screen shown in Figure 26.

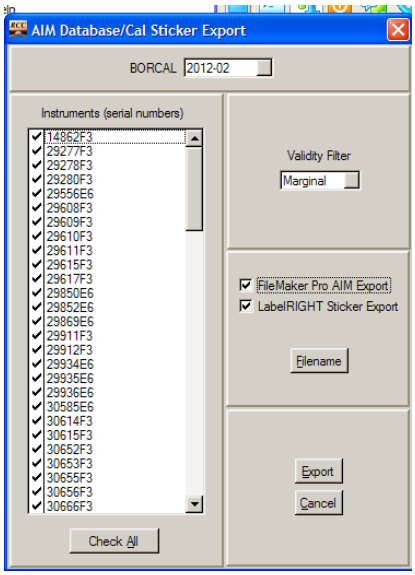


Figure 26. Choose sensors and options for the AIM Database and Sticker Export

- Choose “Check All” unless some instrument calibrations were determined to be bad, in which case you would not check those instruments.
- Ensure that both of the following boxes are checked:
    - FileMaker Pro AIM Export
    - LabelRIGHT Sticker Export.
- Click the filename box and change the default filenames to SGP_LW-2015-02 (using the date and BORCAL event number and type matching the current BORCAL).
- Choose Export.
- This will generate two files (SGP_2015-02.aim.csv and SGP_2015_02.lbl.txt) in the following directory: D:\SGP\Data\2015-02\Export.
- Send these two files to the NREL AIM Database administrator, the NREL metrology administrator, and the SGP RCF operator. Request that the NREL metrology administrator print the sticker file (*.lbl.txt), request a spot check for accuracy after printing, and mail them to the SGP RCF operator for placement on the sensors.
- The *.AIM.csv file will be used by the NREL AIM Database administrator to import the calibration results into the AIM Database.
- Note: For BORCAL-SW, there are various data files (such as 2-degree RS export files) that are automatically transferred to the NREL AIM public website so that they can be accessed via web browser after the NREL AIM Database administrator imports the *.AIM.csv file into the database.

6 Assemble All Related Documentation for Archiving at the SRRL

Assemble a folder of materials to be archived at the SRRL. The folder should contain:

- Black-and-white copy of the SGP BORCAL report (optional)
- Notable findings and all notes regarding the quality-check process
- BORCAL Report QC Checklist
- Session Configuration Audit Report
- RCC Parameters for Reference Instruments

Rooftop map.

Appendix A

Channel Assignments for Dual Connector with Dome using Pins A & B					
Cable	TP/Case Position	TP Channel	Case Channel	Dome Position	Dome Channel
1	37	98	106	43	24
2	64	130	138	44	25
3	65	144	152	45	26
4	46	112	120	52	32
5	73	145	153	53	33
6	74	146	154	54	34
7	55	113	121	61	40
8	56	114	122	62	41
9	82	160	168	63	42
10	1	48	56	8	9
11	19	80	88	9	10
12	10	49	57	16	16
13	28	81	89	17	17
14	29	82	90	18	18

Channel Assignments for Dual Connector with Dome using Pins C & D					
Cable	TP/Case Position	TP Channel	Case Channel	Dome Position	Dome Channel
1	57	128	136	58	137
2	84	161	169	85	170
3	11	50	58	12	72
4	13	65	73	14	74
5	31	96	104	32	105

Channel Assignments for Triple Connector using Pins A & B for each Position						
Cable	TP Position	TP Channel	Case Position	Case Channel	Dome Position	Dome Channel
1	2	60	4	0	6	2
2	3	61	5	1	7	8

BORCAL Report QC Checklist
BORCAL _____

(Initial each step)

Cover Page
- ___ Verify BORCAL event number
- ___ Verify correct calibration facility
- ___ Verity dates for calibration and report
- ___ Disclaimer notice (inside front cover)

Introduction
- ___ Introductory notes, when entered, are present.

Reference and Meteorological Data Plots
- ___ Reference irradiance is reasonable (Note: Separate page for tilt)
- ___ Met plots present and reasonable
- ___ Means reasonable and consistent with data

Control Histories Page
- ___ Current results consistent with instrument histories

Results Summary
- ___ All responsivities look reasonable
- ___ All uncertainties look reasonable
- ___ Spot-check page numbers (first, middle sample, last)
- ___ Ancillary data page number

Certificates
- ___ Reference cavity ID, calibration and due dates (check once)
- ___ Reference diffuse ID, calibration and due dates (check once)
- ___ Calibration date and due date correct (check once)
- ___ Data acquisition dates correct (check once)
- ___ Technician names okay (check once)
- ___ Instrument naming convention (s/n, mfgr, model, spelling)
- ___ Customer matches customer in results summary
- ___ Data plots free of outliers
- ___ Instrument history consistent with past calibrations

BORCAL Notes
- ___ Notes, when entered, are present with correct grammar/spelling

Configuration Audit
- ___ All fields present and reasonable (not present in customer report)

Operator Session Logs
- ___ Present (not present in customer report)

Signatures
- ___ Technical manager

Stickers and AIM Database
- ___ Results summary compared to incoming instrument checklist
- ___ Sticker file compared to RCC database
- ___ Stickers generated and affixed to instruments
- ___ AIM Database updated

BORCAL web page updated
- ___ Full Report (PDF file)
- ___ Refence Irradiance (Text file)

Distribution and Archive
- ___ Certificate sent with all instruments
- ___ Customer reports sent as requested
- ___ Full report archived