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Monitoring Stream Temperatures—A Guide for Non-Specialists

Chapter 25 of
Section A, Surface-Water Techniques
Book 3, Applications of Hydraulics

Techniques and Methods 3–A25

U.S. Department of the Interior
U.S. Geological Survey

Cover:
Upper left: East Pinnacles Creek looking north along The Pinnacles, Sierra National Forest, California.
Center: Sycan River looking upstream, Fremont National Forest, Oregon.
Lower right: Big Sawmill Creek looking upstream, Arc Dome Wilderness, Toiyabe National Forest, Nevada.
All photographs by Michael Heck, U.S. Geological Survey.

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By Michael P. Heck, Luke D. Schultz, David Hockman-Wert, Eric C. Dinger, and Jason B. Dunham

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Deputy Director
exercising the authority of the Director

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Standard Operating Procedure (SOP) 2—Calibration Check of Data Loggers

Overview

This SOP describes how to determine if data loggers are measuring temperature to the manufacturer's specifications. Thermometers and data loggers calibrated to National Institute of Standards and Technology (NIST) standards are available as a reference during calibration checks. A calibration check should be performed before and after each field installation. A calibration check consists of data loggers recording for 30 minutes in a warm bath, 30 minutes in a cool-down bath, and 30 minutes in a cold bath. This process takes approximately 2 days to complete.

Supplies

- Three coolers (large enough to submerge all data loggers with lots of extra room)
- Crushed ice
- Onset data loggers (U22, Pendant, or TidbiT)
- One NIST-calibrated Onset data logger (use same model as data logger being calibrated: U22, Pendant, or TidbiT)
- 8-in. cable/zip ties (0.095 in. width)
- 10-oz lead fishing weights (one weight per five data loggers)
- Onset Optic USB Base Station
- COUPLER2-A (for Pendant), COUPLER2-C (for U22), or COUPLER2-D (for TidbiT)
- Computer with HOBOware Pro software installed

Procedure—Day 1

1. Fill a cooler about 3/4 full with room temperature water and place in a climate controlled room (stable air temperature). This will be the warm bath.
2. Launch data loggers, including the NIST-calibrated data logger following procedures in SOP 1.
   a. Select a 10 second logging interval.
   b. Set a delayed start to a time the following day to initiate the calibration check. Make sure there is adequate time to set up the cold bath (see step 4).
   c. Create a Calibration Check Worksheet to record basic metrics from the calibration process (fig. 2.1).
   d. Record the serial number and battery voltage at the time of launch on Calibration Check Worksheet.

Serial#	CalibVoltage	CalibDate	CalibMeanWarmDiff	CalibMeanCoolDiff
10768077	3.57	7/26/2016	0.068	0.011
10768078	3.54	7/26/2016	0.057	0.084
10768079	3.57	7/26/2016	0.019	0.000
10768080	3.57	7/26/2016	0.043	0.055

Figure 2.1. Example of a Calibration Check Worksheet.

3. Bundle five data loggers and one 10-oz lead fishing weight together with an 8-in. cable/zip tie (fig. 2.2).

4. Immerse launched and bundled data loggers in the warm bath and let soak overnight with the cooler lid open (fig. 2.3).

Figure 2.2. Photograph showing five Onset U22 data loggers attached to a 10-ounce lead weight with an 8-inch cable/zip tie.

Figure 2.3. Photograph showing four clusters of five Onset U22 data loggers soaking in a warm bath used for a calibration check.

Procedure—Day 2

1. Approximately 3 hours before the data loggers are programmed to start recording, fill two coolers about 3/4 full with crushed ice and add cold water until ice is fully immersed in water.

    a. Close lids and place coolers in the same climate controlled room (stable air temperature). These will be the cool-down and cold baths.

2. Following the delayed start time, begin mixing the water in the warm bath by gently lifting one end of the cooler about 4 in. off the ground.

    a. Repeat this mixing/lifting about every 20 seconds for 30 minutes. The warm calibration check is complete.

3. Remove the bundled data loggers from the warm bath and immerse them in the cool-down bath (one of the two coolers with ice/water mixture) and close the lid.

    a. The cool-down bath is used to decrease the temperature of the data loggers from room temperature to about 0 °C.

    b. Leave the data loggers in the cool-down bath for 30 minutes.

4. Remove the bundled data loggers from the cool-down bath and immerse them in the cold bath.

5. Mix the water in the cold bath by gently lifting one end of the cooler about 4 in. off the ground.

    a. Repeat this mixing/lifting about every 20 seconds for 30 minutes. The cold calibration check is complete.

6. Open HOBOware Pro software and download all the available updates, if prompted (fig. 2.4)

7. Connect the Onset Optic USB base station to the computer using the USB cable and connect a temperature data logger to the base station using the appropriate coupler (see SOP 1—Launching Data Loggers).

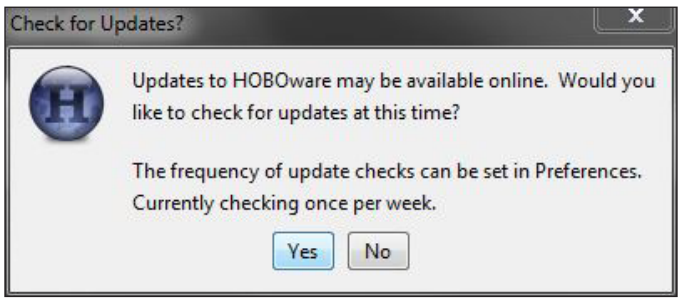


Figure 2.4. Screen capture showing HOBOware Pro **Check for Updates?** dialog box.

8. Readout data from the data logger.

   a. On the HOBOware Pro main screen, click **Device** > **Readout**… (fig. 2.5).

   b. When prompted to stop the data logger, click **Stop** (fig. 2.6).

   c. Create or select a folder in which to store .hobo file, then save the file (fig. 2.7).

   d. The **Plot Setup** dialog box will open (fig. 2.8). To see a graph of the data, click **Plot**, otherwise click **Cancel**.

Figure 2.5. Screen capture showing HOBOware Pro screen capture showing the **Readout**… option under the Device menu.

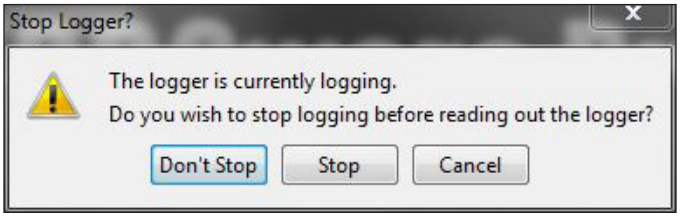


Figure 2.6. Screen capture showing HOBOware Pro **Stop Logger?** dialog.

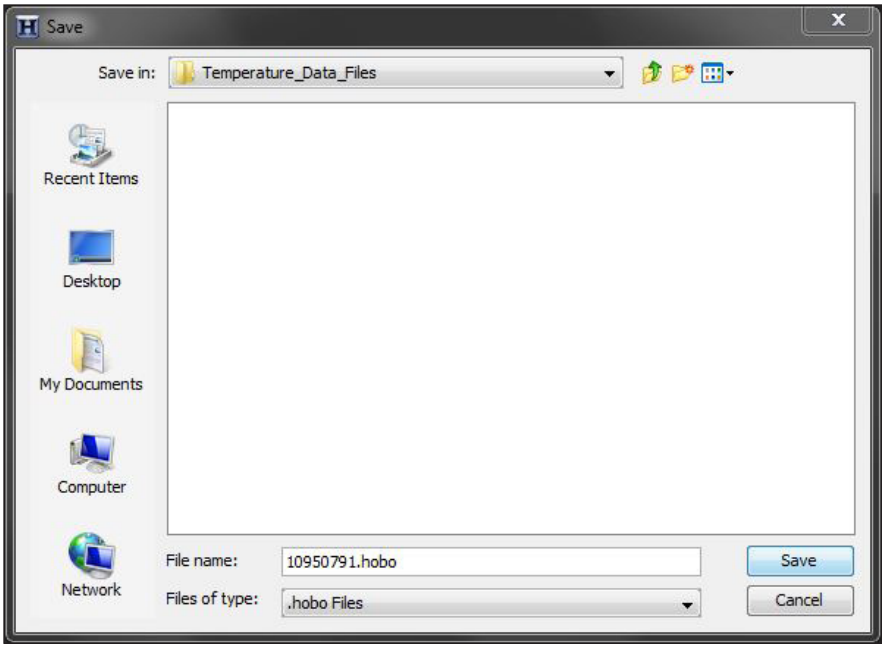


Figure 2.7. Screen capture showing HOBOware Pro **Save** dialog box to determine the location to save a .hobo file.

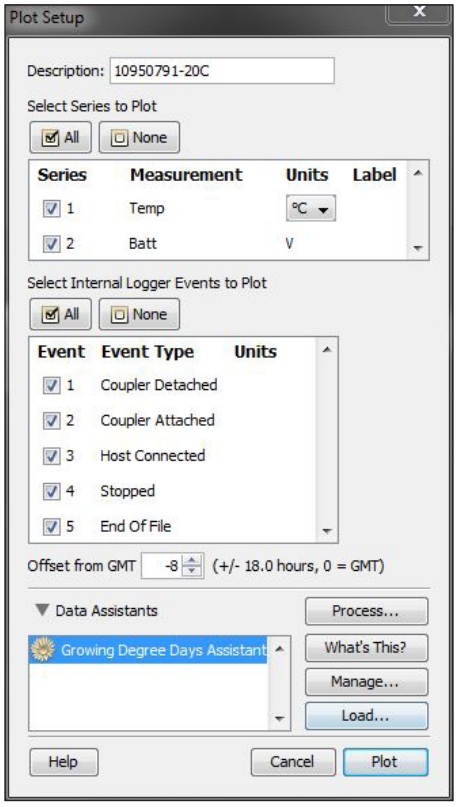


Figure 2.8. Screen capture showing HOBOware Pro **Plot Setup** dialog box.

9. Disconnect the temperature data logger from the base station. After readout, the data logger will be stopped and will remain in that state until it is launched again.

10. Continue to readout data from all data loggers (repeat step 7).

11. After reading out data from all data loggers, export the .hobo files as .csv files.

    a. On the HOBOware Pro main screen, click **Tools** > **Bulk File Export** > **Select Files to Export**... (fig. 2.9).

    b. Browse to the folder where the .hobo files were saved and select all the files, then click **Continue** (fig. 2.10).

    c. In the **Choose Export Folder** dialog box, choose folder where to save the .csv files, then click **Export** (fig. 2.11).

    d. When the bulk file export is complete, click **OK**.

12. Close HOBOware Pro.

13. Open Microsoft Excel or other spreadsheet application and create a blank worksheet.

Figure 2.9. Screen capture showing HOBOware Pro **Select Files to Export**… option under the **Bulk File Export** option, under the **Tools** menu.

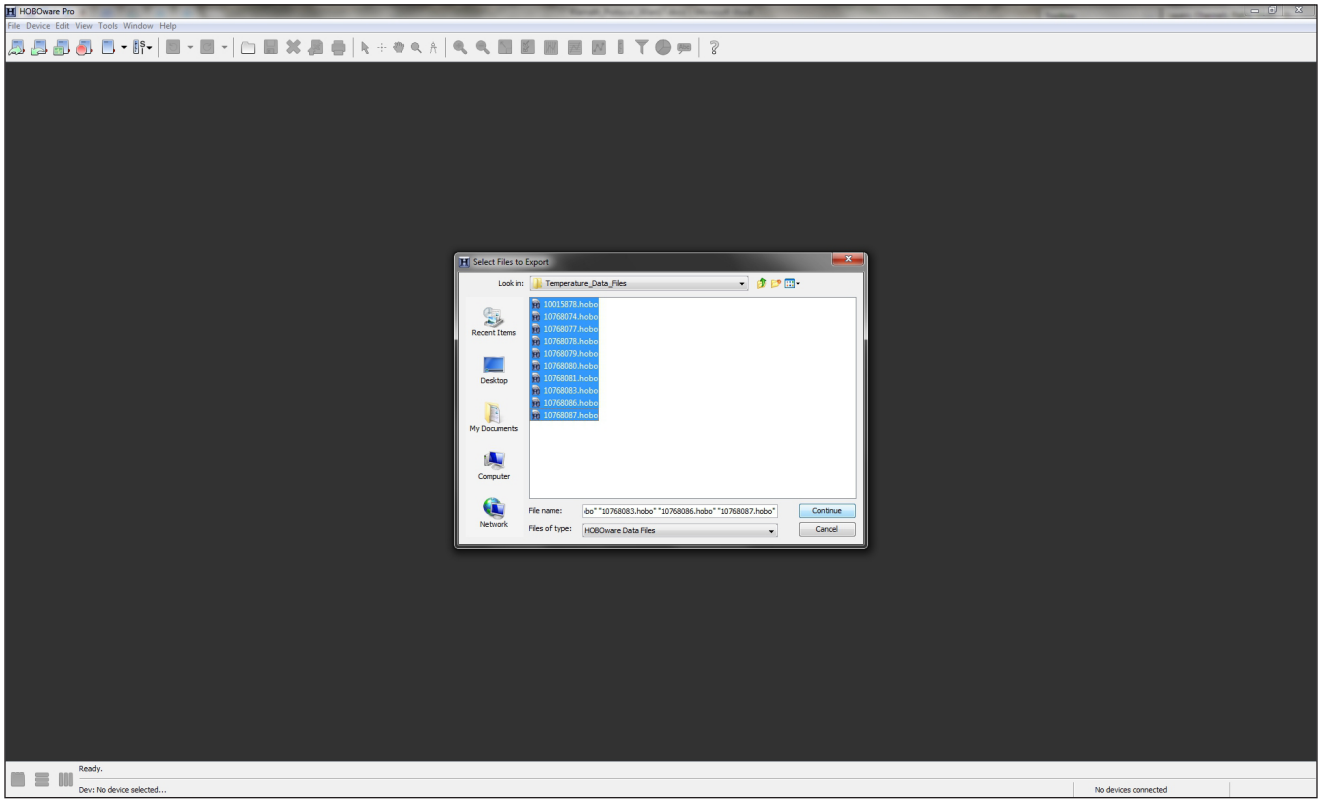


Figure 2.10. Screen capture showing HOBOware Pro **Select Files to Export** dialog box to select .hobo files to export as .csv files.

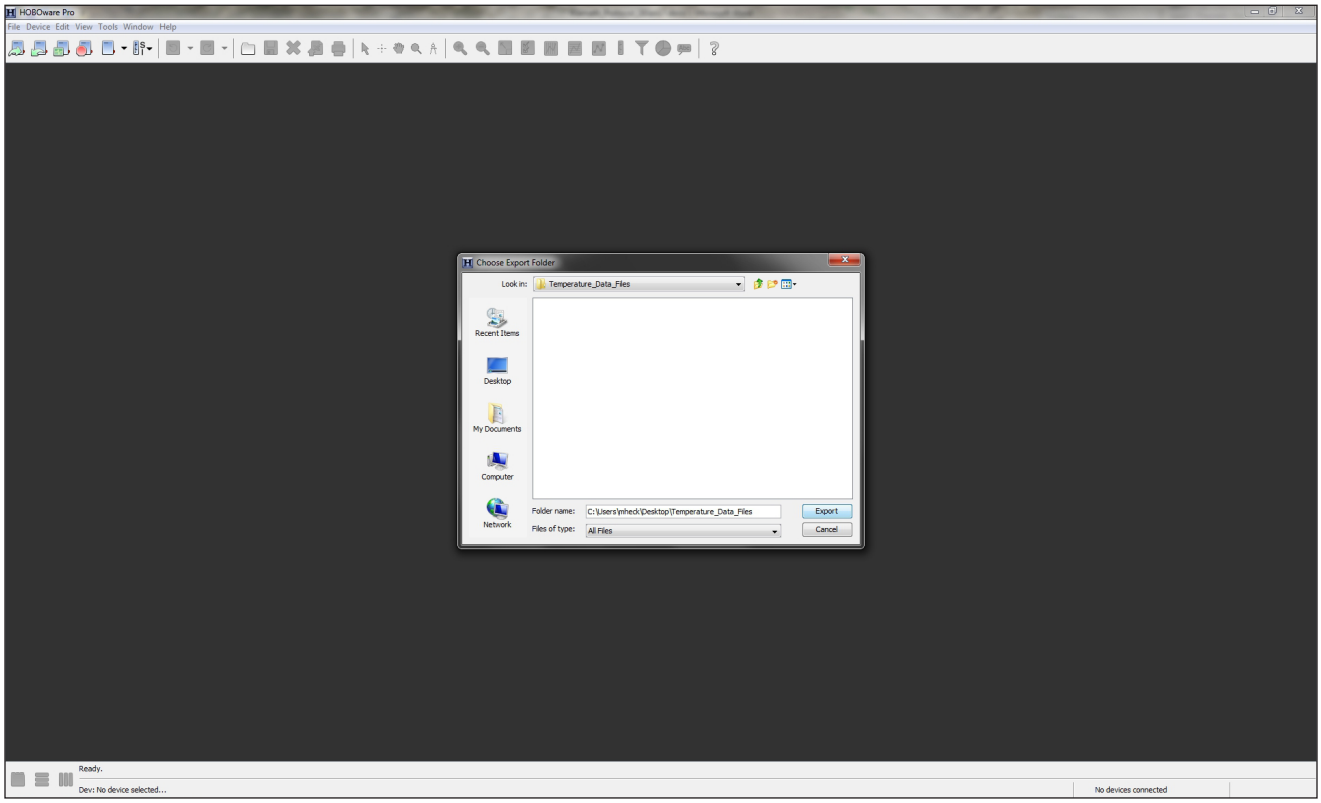


Figure 2.11. Screen capture showing HOBOware Pro **Choose Export Folder** dialog box to determine the location to export .csv files.

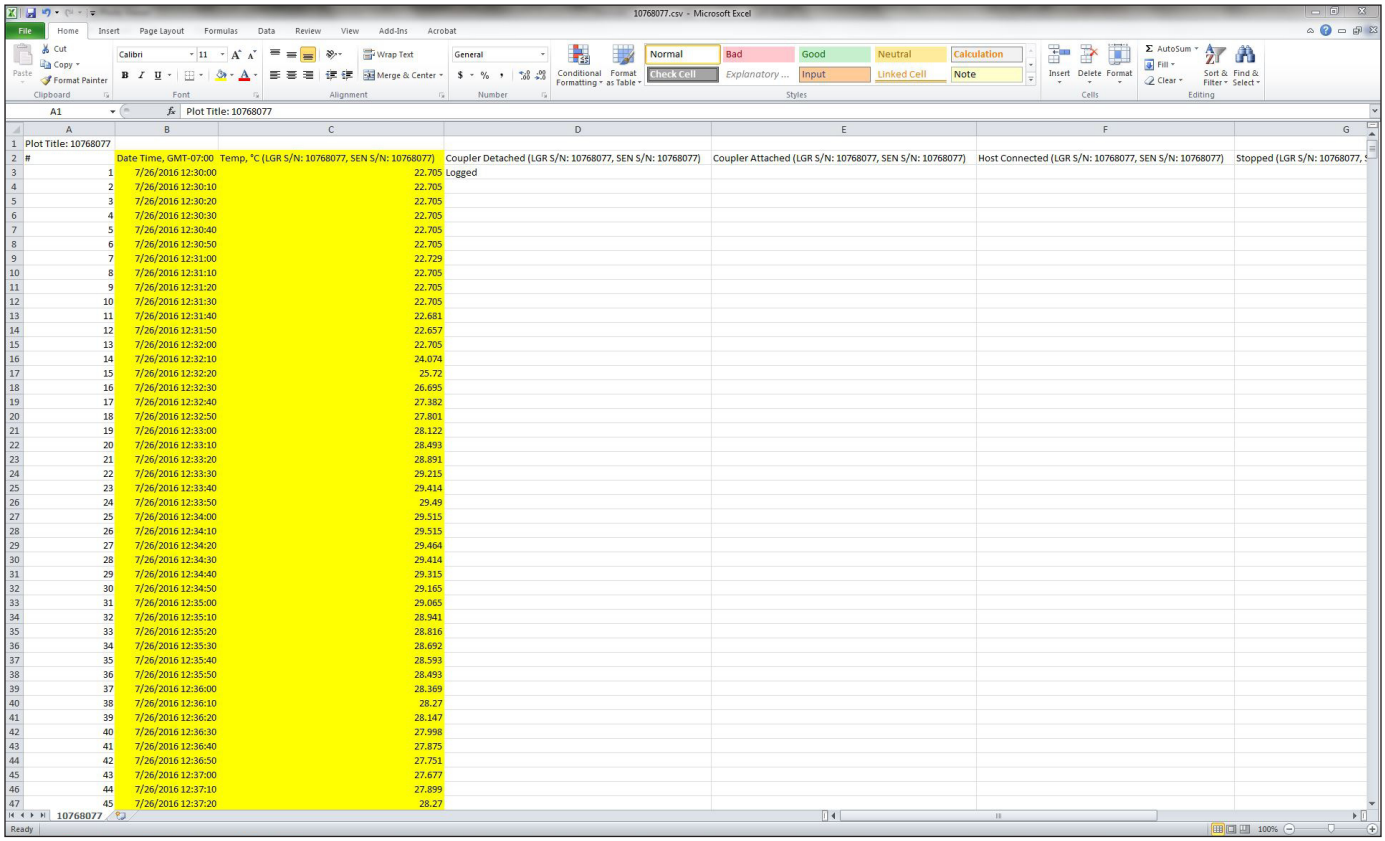
14. Open an exported .csv file, select the Date Time and Temp columns (fig. 2.12), then copy and paste them into columns A-B of the blank worksheet.

15. Continue opening .csv files and copying and pasting the Date Time and Temp columns into C-D, E-F, G-H, and so on (fig. 2.13). The header of the Temp column can be shortened to the data logger serial number (S/N).

16. Create a graph of data logger temperatures over time. Make sure to include the NIST-calibrated data logger temperatures (fig. 2.14).

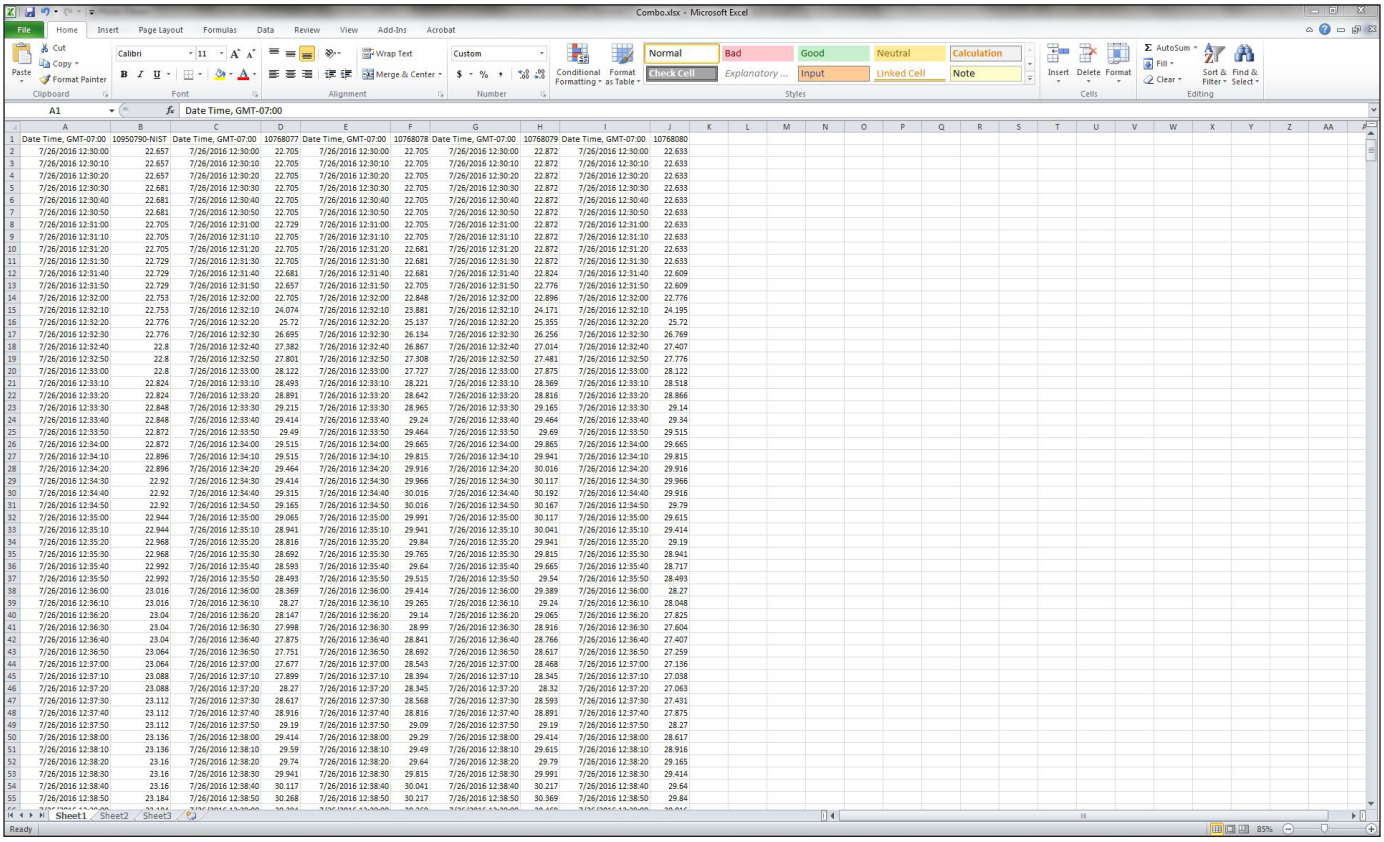
    a. Identify a period during the warm bath of greater than or equal to 15 minutes (90 consecutive records) when data loggers are recording highly consistent temperatures. It is not possible to quantify what "highly consistent" temperatures are because the purpose of the calibration check is to look for data loggers that are dissimilar from one another and the NIST data logger. That comparison needs to be made when all data loggers are recording temperatures in a highly consistent or similar way.

    b. Identify a period during the cold bath of greater than or equal to 15 minutes (90 consecutive records) when data loggers are recording highly consistent temperatures.



	A	B	C	D	E	F	G
1	Plot Title: 10768077						
2	#	Date Time, GMT-07:00	Temp, °C (LGR S/N: 10768077, SEN S/N: 10768077)	Coupler Detached (LGR S/N: 10768077, SEN S/N: 10768077)	Coupler Attached (LGR S/N: 10768077, SEN S/N: 10768077)	Host Connected (LGR S/N: 10768077, SEN S/N: 10768077)	Stopped (LGR S/N: 10768077,
3	1	7/26/2016 12:30:00	22.705	Logged			
4	2	7/26/2016 12:30:10	22.705				
5	3	7/26/2016 12:30:20	22.705				
6	4	7/26/2016 12:30:30	22.705				
7	5	7/26/2016 12:30:40	22.705				
8	6	7/26/2016 12:30:50	22.705				
9	7	7/26/2016 12:31:00	22.729				
10	8	7/26/2016 12:31:10	22.705				
11	9	7/26/2016 12:31:20	22.705				
12	10	7/26/2016 12:31:30	22.705				
13	11	7/26/2016 12:31:40	22.681				
14	12	7/26/2016 12:31:50	22.657				
15	13	7/26/2016 12:32:00	22.705				
16	14	7/26/2016 12:32:10	24.074				
17	15	7/26/2016 12:32:20	25.72				
18	16	7/26/2016 12:32:30	26.695				
19	17	7/26/2016 12:32:40	27.382				
20	18	7/26/2016 12:32:50	27.801				
21	19	7/26/2016 12:33:00	28.122				
22	20	7/26/2016 12:33:10	28.493				
23	21	7/26/2016 12:33:20	28.891				
24	22	7/26/2016 12:33:30	29.215				
25	23	7/26/2016 12:33:40	29.414				
26	24	7/26/2016 12:33:50	29.49				
27	25	7/26/2016 12:34:00	29.515				
28	26	7/26/2016 12:34:10	29.515				
29	27	7/26/2016 12:34:20	29.464				
30	28	7/26/2016 12:34:30	29.414				
31	29	7/26/2016 12:34:40	29.315				
32	30	7/26/2016 12:34:50	29.165				
33	31	7/26/2016 12:35:00	29.065				
34	32	7/26/2016 12:35:10	28.941				
35	33	7/26/2016 12:35:20	28.816				
36	34	7/26/2016 12:35:30	28.692				
37	35	7/26/2016 12:35:40	28.593				
38	36	7/26/2016 12:35:50	28.493				
39	37	7/26/2016 12:36:00	28.369				
40	38	7/26/2016 12:36:10	28.27				
41	39	7/26/2016 12:36:20	28.147				
42	40	7/26/2016 12:36:30	27.998				
43	41	7/26/2016 12:36:40	27.875				
44	42	7/26/2016 12:36:50	27.751				
45	43	7/26/2016 12:37:00	27.677				
46	44	7/26/2016 12:37:10	27.899				
47	45	7/26/2016 12:37:20	28.27				

Figure 2.12. Screen capture showing exported .csv file opened in Microsoft® Excel with the **Date Time** and **Temp** columns highlighted.



Date Time, GMT-07:00	10950790-NIST	Date Time, GMT-07:00	10768077	Date Time, GMT-07:00	10768078	Date Time, GMT-07:00	10768079	Date Time, GMT-07:00	10768080
7/26/2016 12:30:00	22.657	7/26/2016 12:30:00	22.705	7/26/2016 12:30:00	22.705	7/26/2016 12:30:00	22.872	7/26/2016 12:30:00	22.633
7/26/2016 12:30:10	22.657	7/26/2016 12:30:10	22.705	7/26/2016 12:30:10	22.705	7/26/2016 12:30:10	22.872	7/26/2016 12:30:10	22.633
7/26/2016 12:30:20	22.657	7/26/2016 12:30:20	22.705	7/26/2016 12:30:20	22.705	7/26/2016 12:30:20	22.872	7/26/2016 12:30:20	22.633
7/26/2016 12:30:30	22.681	7/26/2016 12:30:30	22.705	7/26/2016 12:30:30	22.705	7/26/2016 12:30:30	22.872	7/26/2016 12:30:30	22.633
7/26/2016 12:30:40	22.681	7/26/2016 12:30:40	22.705	7/26/2016 12:30:40	22.705	7/26/2016 12:30:40	22.872	7/26/2016 12:30:40	22.633
7/26/2016 12:30:50	22.681	7/26/2016 12:30:50	22.705	7/26/2016 12:30:50	22.705	7/26/2016 12:30:50	22.872	7/26/2016 12:30:50	22.633
7/26/2016 12:31:00	22.705	7/26/2016 12:31:00	22.729	7/26/2016 12:31:00	22.705	7/26/2016 12:31:00	22.872	7/26/2016 12:31:00	22.633
7/26/2016 12:31:10	22.705	7/26/2016 12:31:10	22.705	7/26/2016 12:31:10	22.705	7/26/2016 12:31:10	22.872	7/26/2016 12:31:10	22.633
7/26/2016 12:31:20	22.705	7/26/2016 12:31:20	22.705	7/26/2016 12:31:20	22.681	7/26/2016 12:31:20	22.872	7/26/2016 12:31:20	22.633
7/26/2016 12:31:30	22.729	7/26/2016 12:31:30	22.705	7/26/2016 12:31:30	22.681	7/26/2016 12:31:30	22.872	7/26/2016 12:31:30	22.633
7/26/2016 12:31:40	22.729	7/26/2016 12:31:40	22.681	7/26/2016 12:31:40	22.681	7/26/2016 12:31:40	22.824	7/26/2016 12:31:40	22.609
7/26/2016 12:31:50	22.729	7/26/2016 12:31:50	22.657	7/26/2016 12:31:50	22.705	7/26/2016 12:31:50	22.776	7/26/2016 12:31:50	22.609
7/26/2016 12:32:00	22.753	7/26/2016 12:32:00	22.705	7/26/2016 12:32:00	22.848	7/26/2016 12:32:00	22.896	7/26/2016 12:32:00	22.776
7/26/2016 12:32:10	22.753	7/26/2016 12:32:10	24.074	7/26/2016 12:32:10	23.881	7/26/2016 12:32:10	24.171	7/26/2016 12:32:10	24.195
7/26/2016 12:32:20	22.776	7/26/2016 12:32:20	25.72	7/26/2016 12:32:20	25.137	7/26/2016 12:32:20	25.355	7/26/2016 12:32:20	25.72
7/26/2016 12:32:30	22.776	7/26/2016 12:32:30	26.695	7/26/2016 12:32:30	26.134	7/26/2016 12:32:30	26.256	7/26/2016 12:32:30	26.769
7/26/2016 12:32:40	22.8	7/26/2016 12:32:40	27.382	7/26/2016 12:32:40	26.867	7/26/2016 12:32:40	27.014	7/26/2016 12:32:40	27.407
7/26/2016 12:32:50	22.8	7/26/2016 12:32:50	27.801	7/26/2016 12:32:50	27.308	7/26/2016 12:32:50	27.481	7/26/2016 12:32:50	27.776
7/26/2016 12:33:00	22.8	7/26/2016 12:33:00	28.122	7/26/2016 12:33:00	27.727	7/26/2016 12:33:00	27.875	7/26/2016 12:33:00	28.122
7/26/2016 12:33:10	22.824	7/26/2016 12:33:10	28.493	7/26/2016 12:33:10	28.221	7/26/2016 12:33:10	28.369	7/26/2016 12:33:10	28.518
7/26/2016 12:33:20	22.824	7/26/2016 12:33:20	28.891	7/26/2016 12:33:20	28.642	7/26/2016 12:33:20	28.816	7/26/2016 12:33:20	28.866
7/26/2016 12:33:30	22.848	7/26/2016 12:33:30	29.215	7/26/2016 12:33:30	28.965	7/26/2016 12:33:30	29.165	7/26/2016 12:33:30	29.14
7/26/2016 12:33:40	22.848	7/26/2016 12:33:40	29.414	7/26/2016 12:33:40	29.24	7/26/2016 12:33:40	29.464	7/26/2016 12:33:40	29.34
7/26/2016 12:33:50	22.872	7/26/2016 12:33:50	29.49	7/26/2016 12:33:50	29.464	7/26/2016 12:33:50	29.69	7/26/2016 12:33:50	29.515
7/26/2016 12:34:00	22.872	7/26/2016 12:34:00	29.515	7/26/2016 12:34:00	29.665	7/26/2016 12:34:00	29.865	7/26/2016 12:34:00	29.665
7/26/2016 12:34:10	22.896	7/26/2016 12:34:10	29.515	7/26/2016 12:34:10	29.815	7/26/2016 12:34:10	29.941	7/26/2016 12:34:10	29.815
7/26/2016 12:34:20	22.896	7/26/2016 12:34:20	29.464	7/26/2016 12:34:20	29.916	7/26/2016 12:34:20	30.016	7/26/2016 12:34:20	29.916
7/26/2016 12:34:30	22.92	7/26/2016 12:34:30	29.414	7/26/2016 12:34:30	29.966	7/26/2016 12:34:30	30.117	7/26/2016 12:34:30	29.966
7/26/2016 12:34:40	22.92	7/26/2016 12:34:40	29.315	7/26/2016 12:34:40	30.016	7/26/2016 12:34:40	30.192	7/26/2016 12:34:40	29.916
7/26/2016 12:34:50	22.92	7/26/2016 12:34:50	29.165	7/26/2016 12:34:50	30.016	7/26/2016 12:34:50	30.167	7/26/2016 12:34:50	29.79
7/26/2016 12:35:00	22.944	7/26/2016 12:35:00	29.065	7/26/2016 12:35:00	29.991	7/26/2016 12:35:00	30.117	7/26/2016 12:35:00	29.615
7/26/2016 12:35:10	22.944	7/26/2016 12:35:10	28.941	7/26/2016 12:35:10	29.941	7/26/2016 12:35:10	30.041	7/26/2016 12:35:10	29.414
7/26/2016 12:35:20	22.968	7/26/2016 12:35:20	28.816	7/26/2016 12:35:20	29.84	7/26/2016 12:35:20	29.941	7/26/2016 12:35:20	29.19
7/26/2016 12:35:30	22.968	7/26/2016 12:35:30	28.692	7/26/2016 12:35:30	29.765	7/26/2016 12:35:30	29.815	7/26/2016 12:35:30	28.941
7/26/2016 12:35:40	22.992	7/26/2016 12:35:40	28.593	7/26/2016 12:35:40	29.64	7/26/2016 12:35:40	29.665	7/26/2016 12:35:40	28.717
7/26/2016 12:35:50	22.992	7/26/2016 12:35:50	28.493	7/26/2016 12:35:50	29.515	7/26/2016 12:35:50	29.54	7/26/2016 12:35:50	28.493
7/26/2016 12:36:00	23.016	7/26/2016 12:36:00	28.369	7/26/2016 12:36:00	29.414	7/26/2016 12:36:00	29.389	7/26/2016 12:36:00	28.27
7/26/2016 12:36:10	23.016	7/26/2016 12:36:10	28.27	7/26/2016 12:36:10	29.265	7/26/2016 12:36:10	29.24	7/26/2016 12:36:10	28.048
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7/26/2016 12:36:40	23.04	7/26/2016 12:36:40	27.875	7/26/2016 12:36:40	28.841	7/26/2016 12:36:40	28.766	7/26/2016 12:36:40	27.407
7/26/2016 12:36:50	23.064	7/26/2016 12:36:50	27.751	7/26/2016 12:36:50	28.692	7/26/2016 12:36:50	28.617	7/26/2016 12:36:50	27.259
7/26/2016 12:37:00	23.064	7/26/2016 12:37:00	27.677	7/26/2016 12:37:00	28.543	7/26/2016 12:37:00	28.468	7/26/2016 12:37:00	27.136
7/26/2016 12:37:10	23.088	7/26/2016 12:37:10	27.899	7/26/2016 12:37:10	28.394	7/26/2016 12:37:10	28.345	7/26/2016 12:37:10	27.038
7/26/2016 12:37:20	23.088	7/26/2016 12:37:20	28.27	7/26/2016 12:37:20	28.345	7/26/2016 12:37:20	28.32	7/26/2016 12:37:20	27.063
7/26/2016 12:37:30	23.112	7/26/2016 12:37:30	28.617	7/26/2016 12:37:30	28.568	7/26/2016 12:37:30	28.593	7/26/2016 12:37:30	27.431
7/26/2016 12:37:40	23.112	7/26/2016 12:37:40	28.916	7/26/2016 12:37:40	28.816	7/26/2016 12:37:40	28.891	7/26/2016 12:37:40	27.875
7/26/2016 12:37:50	23.112	7/26/2016 12:37:50	29.19	7/26/2016 12:37:50	29.09	7/26/2016 12:37:50	29.19	7/26/2016 12:37:50	28.27
7/26/2016 12:38:00	23.136	7/26/2016 12:38:00	29.414	7/26/2016 12:38:00	29.29	7/26/2016 12:38:00	29.414	7/26/2016 12:38:00	28.617
7/26/2016 12:38:10	23.136	7/26/2016 12:38:10	29.59	7/26/2016 12:38:10	29.49	7/26/2016 12:38:10	29.615	7/26/2016 12:38:10	28.916
7/26/2016 12:38:20	23.16	7/26/2016 12:38:20	29.74	7/26/2016 12:38:20	29.64	7/26/2016 12:38:20	29.79	7/26/2016 12:38:20	29.165
7/26/2016 12:38:30	23.16	7/26/2016 12:38:30	29.941	7/26/2016 12:38:30	29.815	7/26/2016 12:38:30	29.991	7/26/2016 12:38:30	29.414
7/26/2016 12:38:40	23.16	7/26/2016 12:38:40	30.117	7/26/2016 12:38:40	30.041	7/26/2016 12:38:40	30.217	7/26/2016 12:38:40	29.64
7/26/2016 12:38:50	23.184	7/26/2016 12:38:50	30.268	7/26/2016 12:38:50	30.217	7/26/2016 12:38:50	30.369	7/26/2016 12:38:50	29.84

Figure 2.13. Screen capture showing Microsoft® Excel with **Date Time** and **Temp** columns copied from five .csv files and pasted into one worksheet. The **Temp** column headers were shortened to the data logger serial number (S/N).

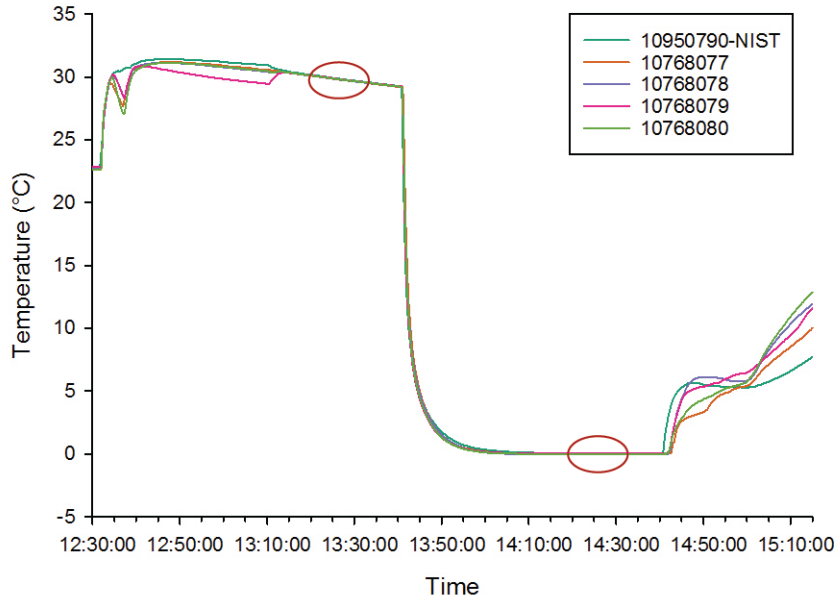

Figure 2.14. Graph showing temperature over time for five Onset U22 data loggers. During this calibration check, data loggers were placed in a warm bath before moving to a cool-down and then a cold bath. Periods of 15 minutes (90 consecutive records) with highly consistent temperatures are highlighted by red ovals.

17. Calculate the mean temperature for each data logger during that period of 90 consecutive records during the warm calibration.

18. Calculate the difference between the mean temperature of the NIST calibrated data logger and mean temperature of each individual data logger.

    a. Record that value under CalibMeanWarmDiff in the Calibration Check Worksheet (fig. 2.1).

19. Calculate the mean temperature for each data logger during that period of 90 consecutive records during the cold calibration.

20. Calculate the difference between the mean temperature of the NIST calibrated data logger and mean temperature of each individual data logger.

    a. Record that value under CalibMeanCoolDiff in the Calibration Check Worksheet (fig. 2.1).

21. Diagnose data loggers with inaccurate measurements by identifying data loggers with a CalibMeanWarmDiff or a CalibMeanCoolDiff that is outside the manufacturer specified tolerance.

    a. Accuracy for Onset U22 and TidbiT data loggers is ±0.21 °C.

    b. Accuracy for Onset Pendant data loggers is ±0.53 °C.

    c. Send inaccurate data loggers back to the manufacturer.

Procedure—Post-Field Installation Calibration Check

1. Perform a calibration check after a data logger has been collected following field installation to check for drift in temperature measurements.

    a. Drift of temperature measurements is when pre- and post-field calibration checks are not equal.

2. Test the accuracy of a data logger following its field installation by performing the same 2-day calibration check as outlined here.

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For more information concerning the research in this report, contact the
Director, Forest and Rangeland Ecosystem Science Center
U.S. Geological Survey
777 NW 9th St., Suite 400
Corvallis, Oregon 97330
https://fresc.usgs.gov

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