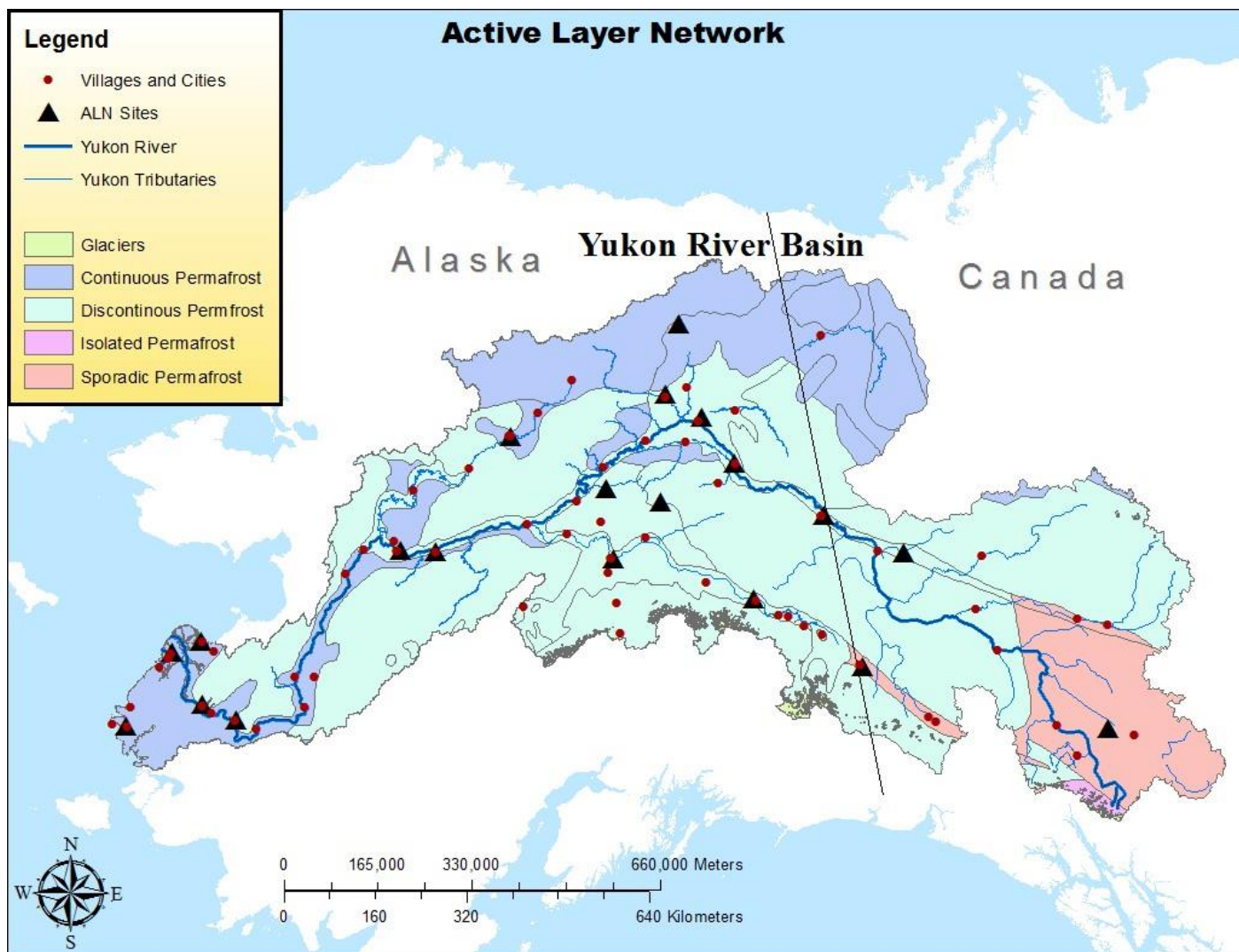


# The Active Layer Network Field Manual

**Yukon River Inter-Tribal Watershed Council**  
**US Geological Survey**  
**Fall 2020**



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## ***Overview***

This manual is a reference tool for technicians participating in the Active Layer Network (ALN) under Yukon River Inter-Tribal Watershed Council - US Geological Survey (YRITWC-USGS) protocols. These protocols were adapted and modified from the Circumpolar Active Layer Monitoring (CALM) protocols, which can be found at: <http://www.gwu.edu/~calm/> and through communication with Dr. Romanovsky and Dr. Yoshikawa of the University of Alaska, Fairbanks. Throughout the manual key points will be noted with special characters and text boxes in the body of the text. This will highlight essential material, as well as give resources for additional research.

## ***Acknowledgements***

Special thanks and recognition are given to Dr. Vladimir Romanovsky and Dr. Kenji Yoshikawa of the University Alaska Fairbanks, for their informative expertise and the time they took to share their experiences and advice with us throughout the initiation of this project. Recognition is also given to Paul F. Schuster of the US Geological Survey for his long-time technical assistance and friendship to the Yukon River Inter-Tribal Watershed Council. And finally, the dedicated YRITWC Indigenous Observation Network (ION) field technicians and environmental coordinators that enable the science department to efficiently engage local participation in the ALN study and successfully complete the installations at selected grid sites across the basin. Thank you!





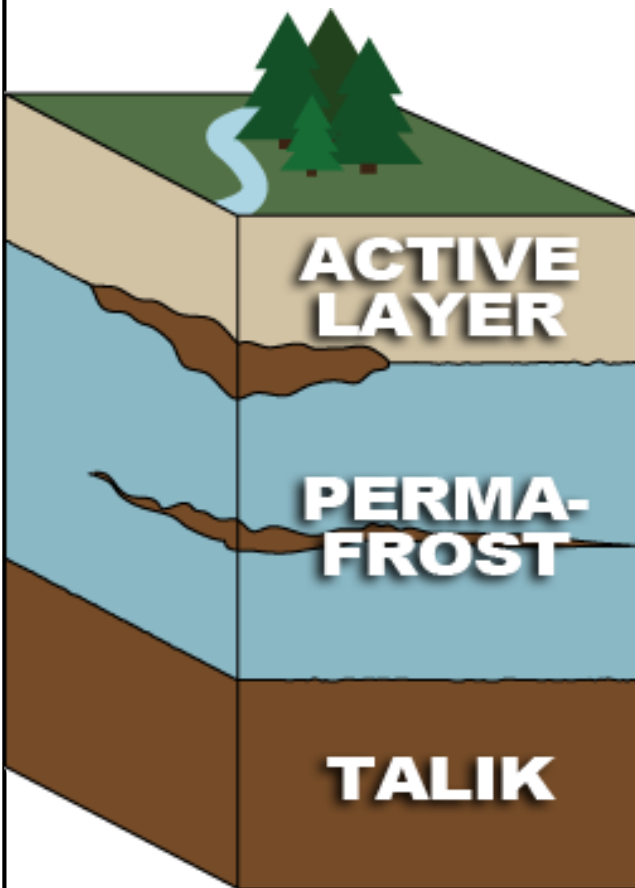


## ***Introduction***

Thank you for becoming part of the Active Layer Network! This manual is intended to be a guide and reference for Tribal Environmental Coordinators and technicians to complete the necessary steps in order to monitor the active layer in their community.

## ***Background***

The Active Layer Network (ALN) began in 2009 as a cooperative project between the Yukon River Inter-Tribal Watershed Council (YRITWC) and the US Geological Survey (USGS). The active layer is the layer of soil above the permanently frozen ground (permafrost) that thaws during the summer months and begins freezing again in autumn. By measuring the depth of the active layer in late summer, at the time of maximum thaw, we are better able to understand the effects of a warming climate on permafrost.



**Permafrost is permanently frozen soil, which stays frozen at least two consecutive years.**

**Permafrost comprises 24% of the land in the Northern Hemisphere.**

**The active layer is the layer of soil above the permafrost, which thaws and freezes with the seasons.**

**Talik is permanently unfrozen ground usually found beneath bodies of water.**

## ***Site Selection***

ALN sites were chosen based on the following criteria: presence of permafrost, distribution within the YRB, existing YRITWC-USGS relationships with communities, and feasibility of USGS-YRITWC staff travel within the limited time frame of the end of August and beginning of September.

## ***Why Monitor the Active Layer?***

Numerous studies indicate that permafrost is thawing and the active layer is deepening (Jorgenson and others, 2006; Romanovsky and others, 2008; Frey and McClelland, 2009). Permafrost thaw will likely lead to changes in groundwater flows (Walvoord and Striegl, 2007) and the quantity and quality of the rivers, streams, and lakes (Striegl and others, 2005, 2007). Moreover, systematic changes in the thickness of the active layer may have profound effects on the fluctuation of greenhouse gases, human infrastructure, and land- scape processes in cold regions. It is critical, therefore, that observation and analysis continue over a period of decades to assess trends and detect cumulative long-term change.

**Permafrost stores massive amounts of carbon, a source of greenhouse gases. As permafrost thaws it releases the stored carbon in the form of carbon dioxide and methane. In addition, permafrost is structurally important. The thawing of permafrost has been known to cause erosion, disappearance of lakes, landslides, and ground subsidence.**



Drunken houses: buildings slump together as the permafrost beneath them thaws in Yukon, Canada. Photo: Bryan and Cherry Alexander Photography (<http://www.newint.org/features/2009/07/01/arctic-climate/>)



One of the consequences of thawing permafrost is the phenomenon of "drunken trees". As the ice in the permafrost thaws, support for the root system of the trees disappears.

([http://www.sciencepoles.org/multimedia/picture\\_gallery\\_detail/the\\_current\\_state\\_of\\_permafrost/8/](http://www.sciencepoles.org/multimedia/picture_gallery_detail/the_current_state_of_permafrost/8/))



## Methods

In order to monitor the active layer, two different types of measurements are made: manual measurement of the depth of the active layer and measurements made by sensors that were installed when the ALN was initiated in 2009. Each ALN site consists of a 50-meter by 50-meter grid, an air temperature sensor mounted on a stake or tree, 2 buried soil moisture sensors, 2 buried soil temperature sensors and a data logger all of which are at the center of the grid. The following sections will describe how to make the manual measurements and download the data collected by the sensors and stored in the data logger.



## Manual Measurements

Measurements of the active layer are taken every 5 meters and recorded on the provided field sheet (an example of the field sheet is provided on the next page). The distance between measurements is determined using a 100-meter tape measure stretched along the grid.



- **Stringing the Tape Measure:** Begin at Northwest (NW) corner of the grid using the known GPS coordinates (GPS coordinates can be found in the appendix) and wooden stake as a visual aid (at some sites the stakes may have fallen due to weather conditions). While one person holds the tape measure steady at the NW corner, the other person walks in a straight line directly South, pulling the tape measure and using a compass as a guide to ensure the line is straight, until reaching the 50 M mark on the tape measure. You should now be at the Southwest (SW) corner of the grid, if there is not a stake there install one.



# Field sheet example

RESEARCHERS: Edda Mutter  
 SITE: ALN-EAA DATE: 9-8-201

NW  
 Lat: 64.77802  
 Long: 141.10866

NE  
 Lat: 64.77890  
 Long: 141.10893

NORTHING →  
 ↑  
 ↓  
 RR = Rock

X	X	X	X	X	X	X	X	X	X	X
85	73	75	54	69	59	61	50	54	57	52
X	X	X	X	X	X	X	X	X	X	X
59	71	61	55	58	47	51	57	57	55	57
X	X	X	X	X	X	X	X	X	X	X
56	70	66	62	59	45	44	48	44	59	62
X	X	X	X	X	X	X	X	X	X	X
75	56	53	58	54	34	43	47	48	52	58
X	X	X	X	X	X	X	X	X	X	X
50	46	43	58	47	45	35	50	57	42	52
X	X	X	X	X	X	X	X	X	X	X
37	46	43	43	46	48	42	41	22	22	52
X	X	X	X	X	X	X	X	X	X	X
53	22	22	63	84	73	54	58	62	22	38
X	X	X	X	X	X	X	X	X	X	X
53	45	65	32	63	22	22	22	22	44	52
X	X	X	X	X	X	X	X	X	X	X
22	62	45	22	54	56	31	39	22	22	62
X	X	X	X	X	X	X	X	X	X	X
22	68	22	54	22	22	64	22	22	22	68
X	X	X	X	X	X	X	X	X	X	X
22	70	68	56	58	62	52	48	50	42	52

SW  
 Lat: 64.77763  
 Long: 141.10888

EASTING →

SE  
 Lat: 64.77853  
 Long: 141.10899

Northing (degrees): 370° Easting(degrees): 80°

Sum: \_\_\_\_\_ Max: \_\_\_\_\_ Min: \_\_\_\_\_  
 N: \_\_\_\_\_ Mean: \_\_\_\_\_ Std. Dev: \_\_\_\_\_

GPS coordinates for center of grid/location of instruments

Lat: 64.77775  
 Long: 141.12952



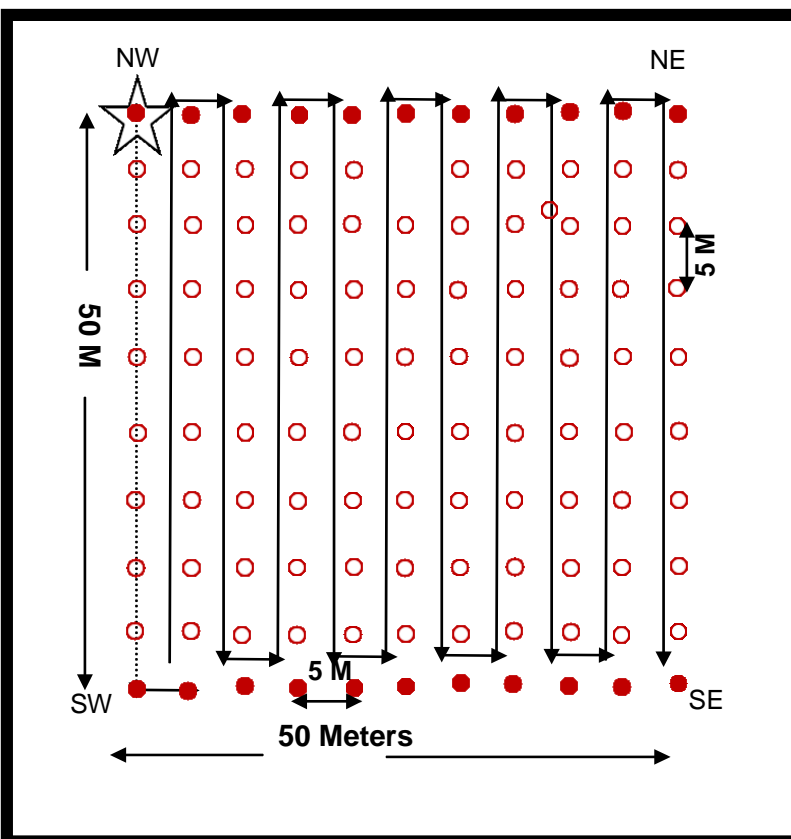
- **Making the manual measurements:** The measurements are made with a metal rod that has a pointed end and T-handle grip. The metal rod is calibrated with various lines up to 1.2 meters (M). Triple lines indicate 10 centimeters (cm), double lines indicate 5 cm and single lines indicate 1 cm (see picture below).

### Calibrated metal rod



1. Begin at the Northwest (NW) corner and walk along the line you made with the tape measure. Every 5 M push the metal rod into the ground until hitting permafrost (this has a distinct feel that you will learn to recognize and distinguish from rocks as you make more measurements). To minimize the questionable influence of tussocks on the measurement, measurements should be taken at the lowest surface level within about a foot of the designated point.
2. Note the point at which the metal rod is level with the ground by marking it with your hand as you pull the rod out of the ground. Use the calibrated lines on the rod to calculate the depth and record this number on the fieldsheet.
3. Once you have completed the first row of measurements each person holds an end of the tape measure and together move the tape measure directly east 5 meters to string the next line you will measure.
4. Continue making measurements every 5 meters down the tape measure and moving the tape measure 5 meters to the east once each row is completed. Continue this process until you reach the Southeast corner and all 121 measurements are made (see diagram). It is best to do this as a team with one person making the measurements as another records them.

- ⇒ Start at the NW
- ⇒ Measure and record every 5 meters along the ○ row and between rows ●
- ⇒ Place stakes marking the North and South perimeters of the grid ●



## ***Downloading the sensor data***

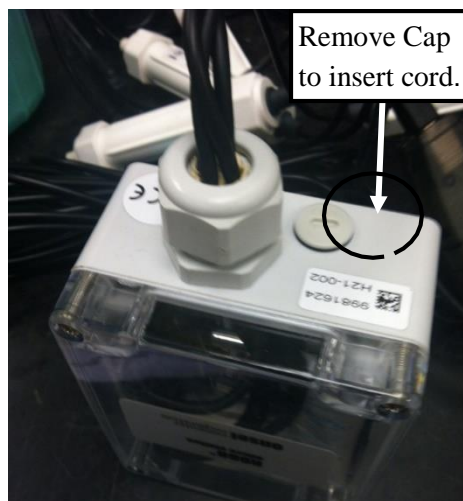
The air temperature sensors and soil moisture/temperature sensor data must be downloaded from the data logger and the air temperature sensor itself.

- **Downloading the soil data:**

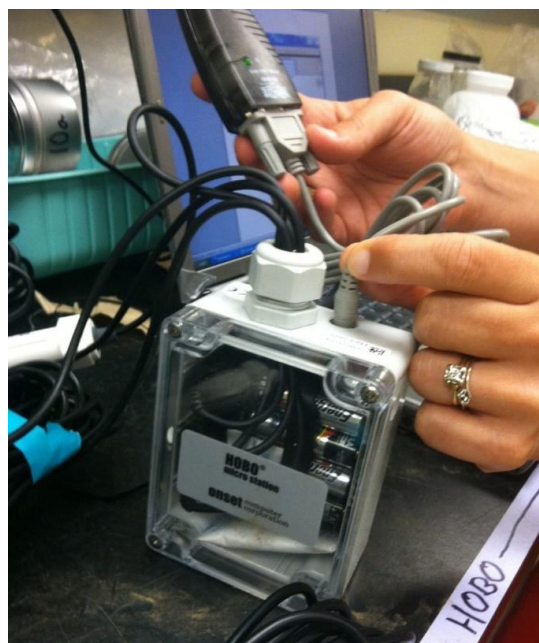
To download the data from the soil sensors an adaptor, USB cord, and VGA cord must be attached to the laptop computer and data logger or a data shuttle must be used.

⇒ To use the adaptor and cords follow the steps below. If you are using a data shuttle skip ahead to page 15 to find instructions on how to use the data shuttle to download the soil data.

1. Insert USB cord into adaptor and laptop, connecting the two.
2. Next, attach VGA cord into the other end of the adaptor and into the data logger.
3. The data logger and laptop computer should now be connected.

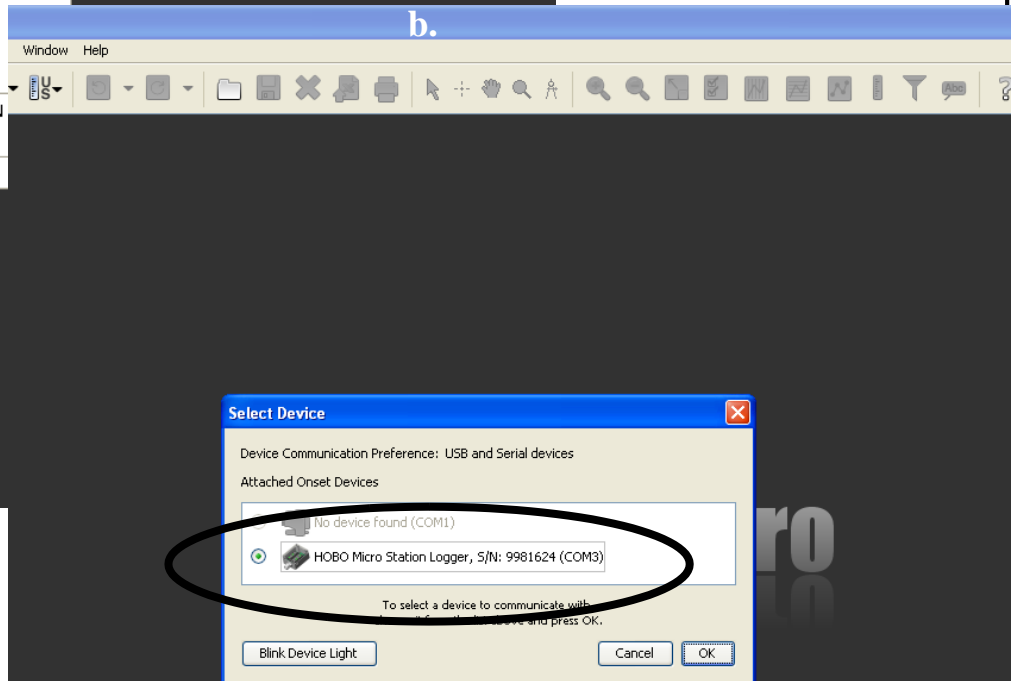
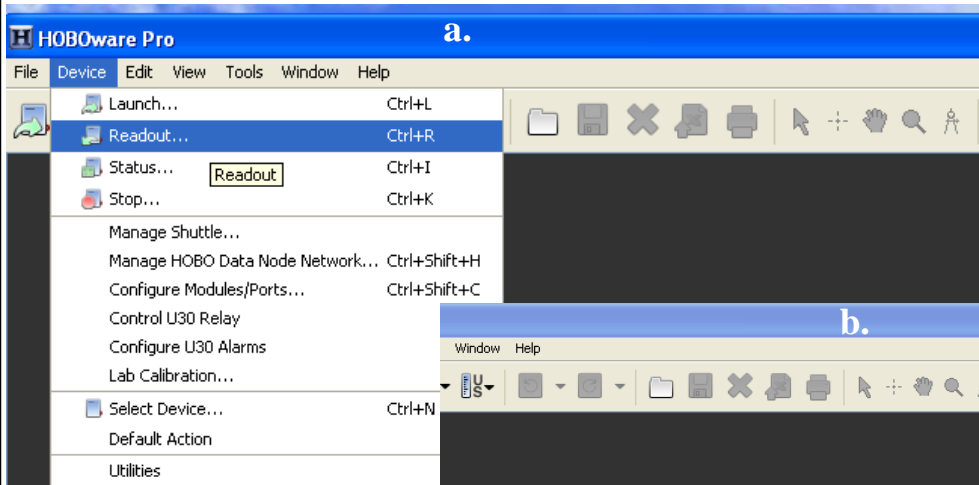


4. Once the data logger and computer are connected open the HOBOWare pro software on the laptop computer.

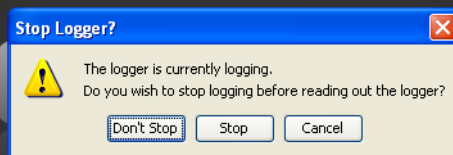




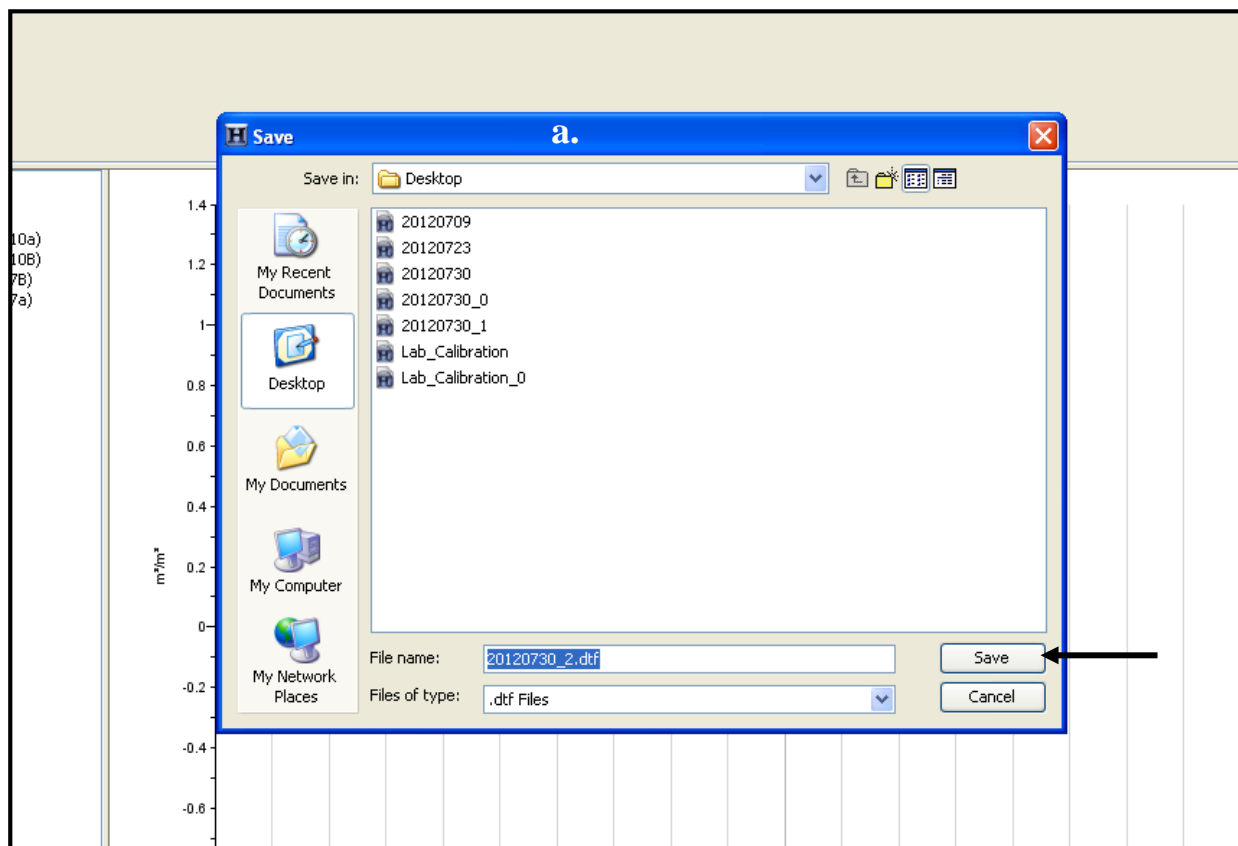
5. Navigate to the “Device” tab on the toolbar and choose “Readout...” from the dropdown menu (a).
6. After you click “Readout...” the program will ask you to select your device (b). Select –HOBO Micro Station Logger and click “OK”.
7. Once the logger is selected the program will ask you if you want to stop the logger, select “Stop” (c).



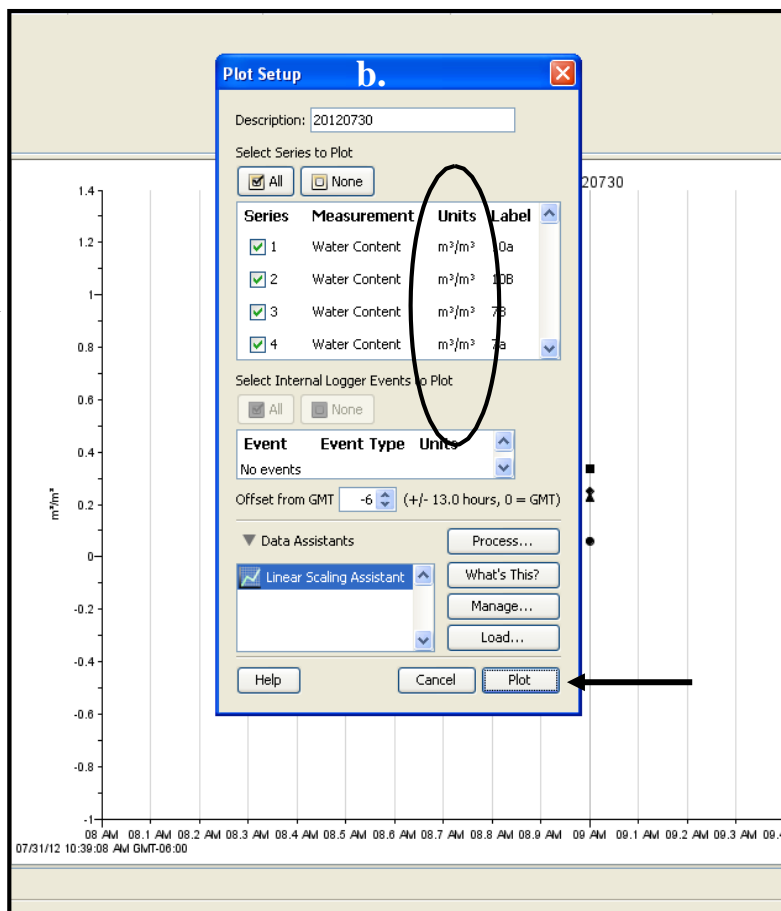
**c.**



8. Once the logger has been stopped you will be prompted to save the file (a). Give the file a name, for example the site name and date (Eagle08302020) and select “Save”.

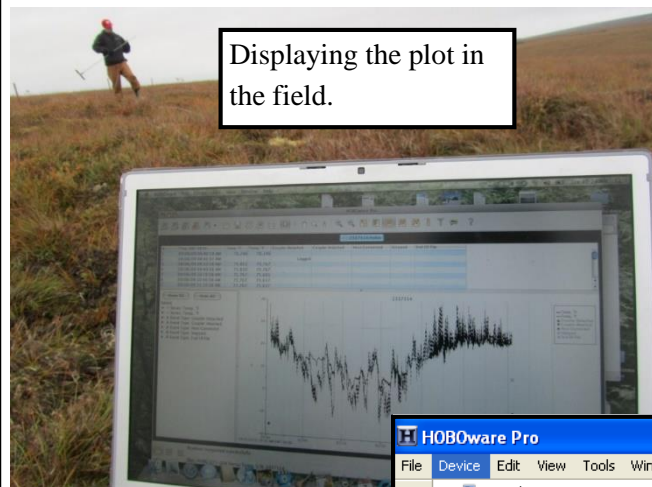


9. Next, you will be asked what units to display the plot in (b). In the example provided only moisture (“Water Content”) sensors are being plotted, you will be plotting both the moisture and temperature sensors. The moisture sensors should always be displayed in  $\text{m}^3/\text{m}^3$ , the temperature should be displayed in  $^\circ\text{C}$ . Once the units are correct, click “Plot”.

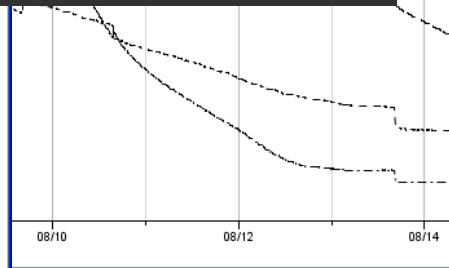
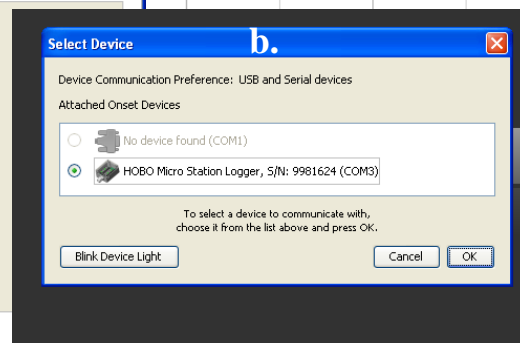
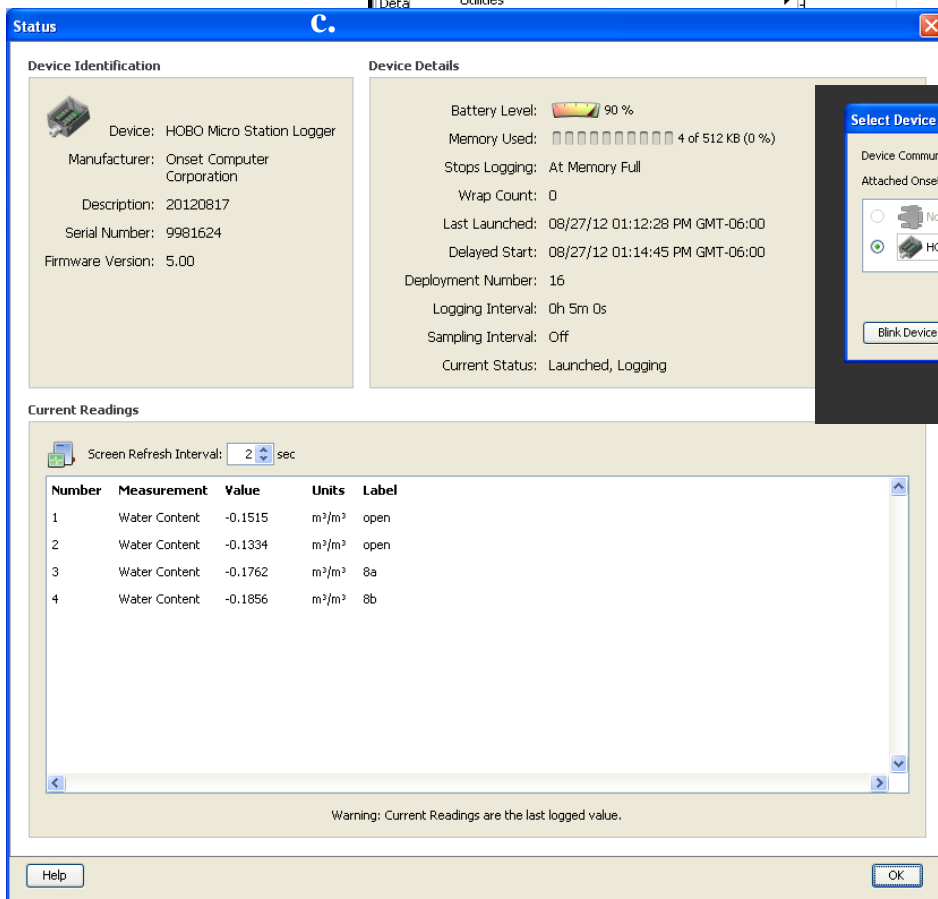
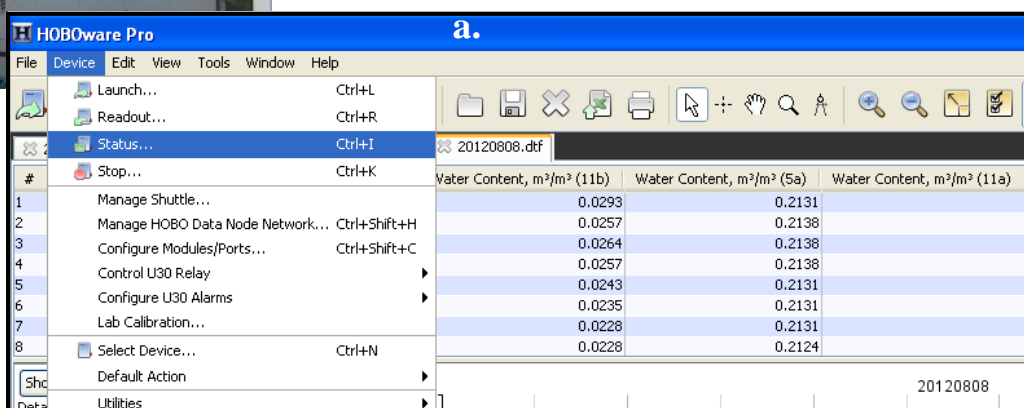




10. The plot should now be displayed. Look at the plot and see when the last entry was made, if it was before today's date make a note of that, something may have happened during the year causing the logger to stop recording (such as too much moisture in the logger box). Also, check to see that the temperature and moisture went up and down the way you would expect with the season.

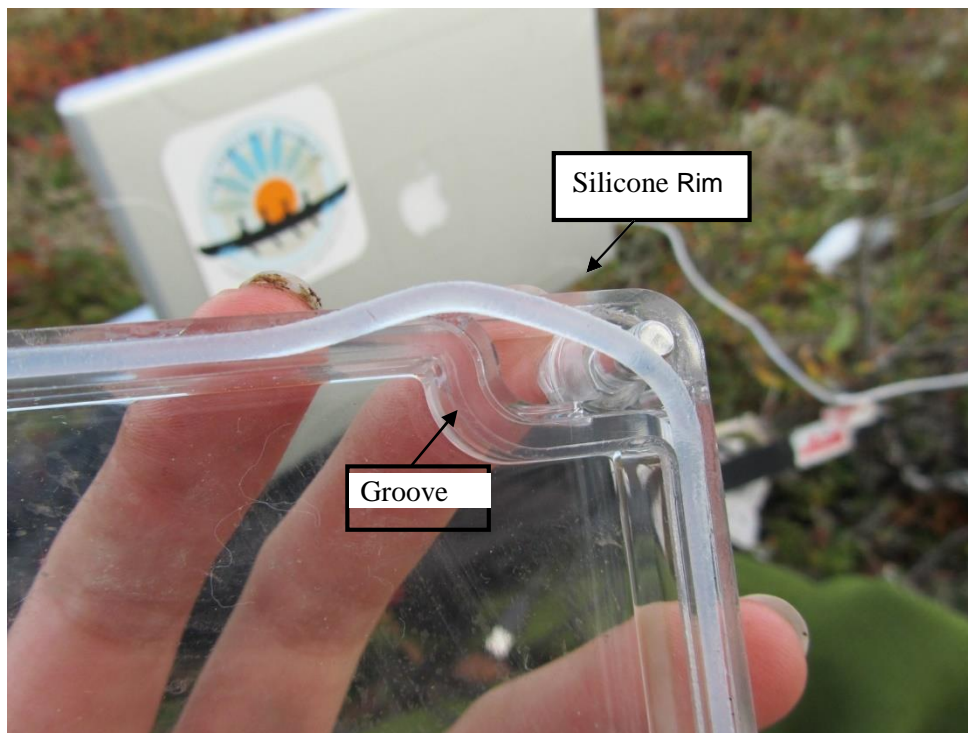


11. Next check that the sensors are functioning properly. Navigate to “Device” on the toolbar and choose –Status from the dropdown menu (a.). A new box will appear asking you to choose your device. Select the HOBO Micro Station Logger (b.). A new box with information about the data logger and the sensors will appear (c.). If everything looks fine, click “OK”. If there is a problem with any of the sensors let the YRITWC know.





12. After the plot has been saved and the status of the logger and sensors checked, the batteries in the logger must be changed and the logger checked for damage. To change the batteries, remove the clear plastic top of the data logger by unscrewing the screws. Remove the black arm holding the batteries in place. Remove the old batteries and install the new batteries. Place the black arm over the new batteries and screw the top back on the logger ensuring that the silicone rim seals tight. It is very important that the silicone rim seals tight so that moisture is kept out of the logger. If the data plot ended unexpectedly before today's date, there may be some damage to the logger and it may need to be replaced. See page 16 for instructions on how to replace the logger.

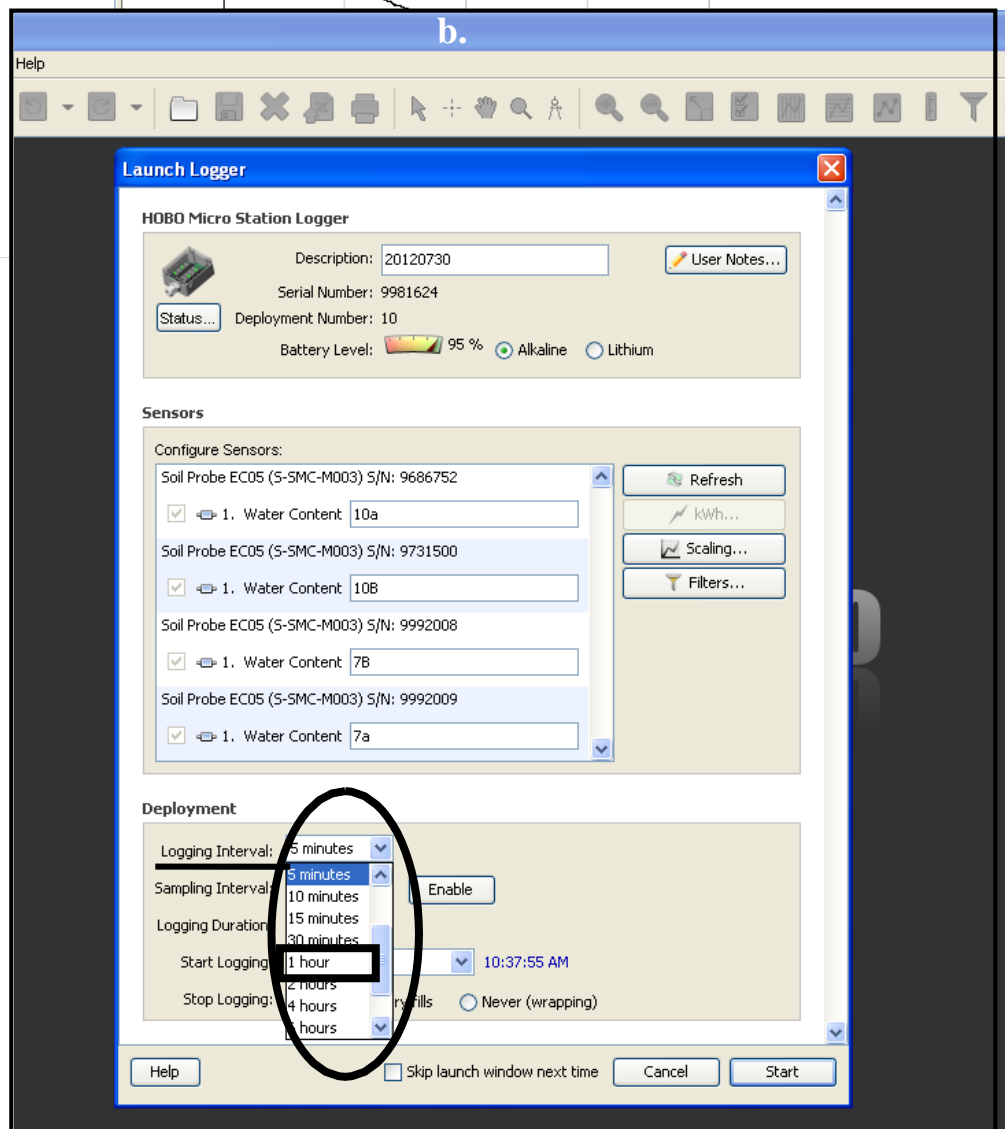
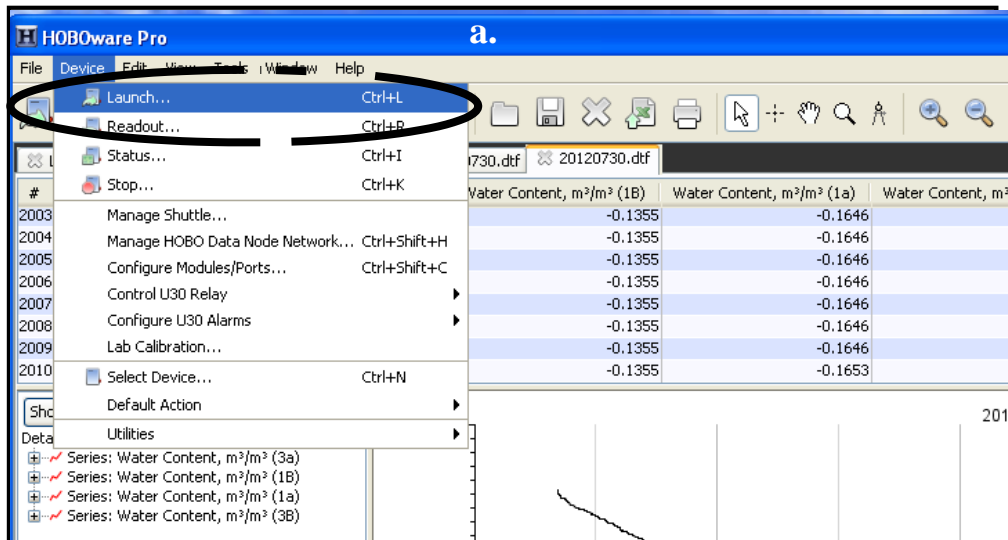


This silicone rim has moved out of place and needs to be pushed back into the groove around the top to seal moisture out.



13. After the batteries have been changed and the data logger has been deemed functional (or has been replaced, directions on how to replace the logger can be found on page 18) it must be re-launched. To do this re-insert the USB cord if it has been removed. Choose “Device” from the toolbar and select “launch” (a).

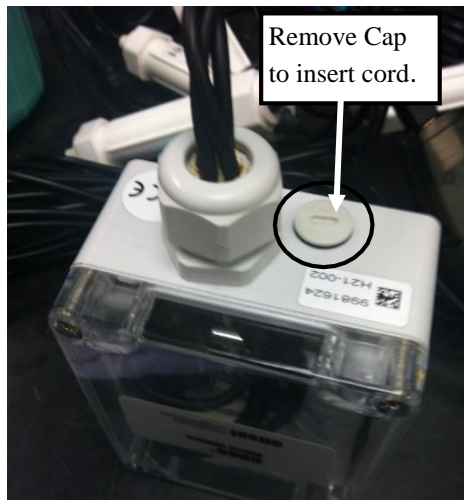
A new box will pop up, check to ensure that data is set to collect every 1 hour under “logging interval” (if it is set to a different time, choose 1 hour from the dropdown menu) and then click “Start” (b).



- **Using a data shuttle to download the soil sensor data:**

1. Plug the data logger into the shuttle and turn on the shuttle (see pictures below).

Data Shuttle and Cords



2. Follow prompts on the shuttle screen.

- After turning the shuttle on the screen should read:

(Y) Find Device

(N) Shuttle info

Push the yes button on the shuttle to find the data logger (“Device”)

- The next screen should say:

Hobo is logging

Push the yes button (next).

- The next screen should read:

Sensors found:4

Show sensors?

Push the yes button to display the sensors and ensure they are all working properly. Scroll through the sensors by pushing the yes (next) button until you reach the screen displaying:

Sensors found: 4

Repeat sensors?

Unless you would like to scroll through the sensors again, push the no button.

- The next screen should read:

Read Out HOBO?

HOBO is logging

Push yes to offload the data from the logger onto the shuttle.



- The next screen will display:  
offloading
- When all of the data has been offloaded onto the shuttle the screen will display:  
Offload Complete  
Restart HOB0?

Push the yes button to restart the data logger.

- The shuttle will ask you to confirm this by displaying:  
Are you sure?

Push the yes button to confirm that you would like to restart the data logger.

- After you confirm this the shuttle will display:  
Change Battery?  
Stopped, Bat: %

Push the yes button if the battery needs to be changed and no if it does not.

- If you select yes the next screen will say:  
Change Battery Now,  
Then push Y

Change the batteries in the data logger and then push the yes button.

- The shuttle will then ask you again if you want to show the sensors:  
Show sensors

Push no

- The data logger will now be re-launched and the screen will display:  
HOB0 launched  
Remove Device(s)

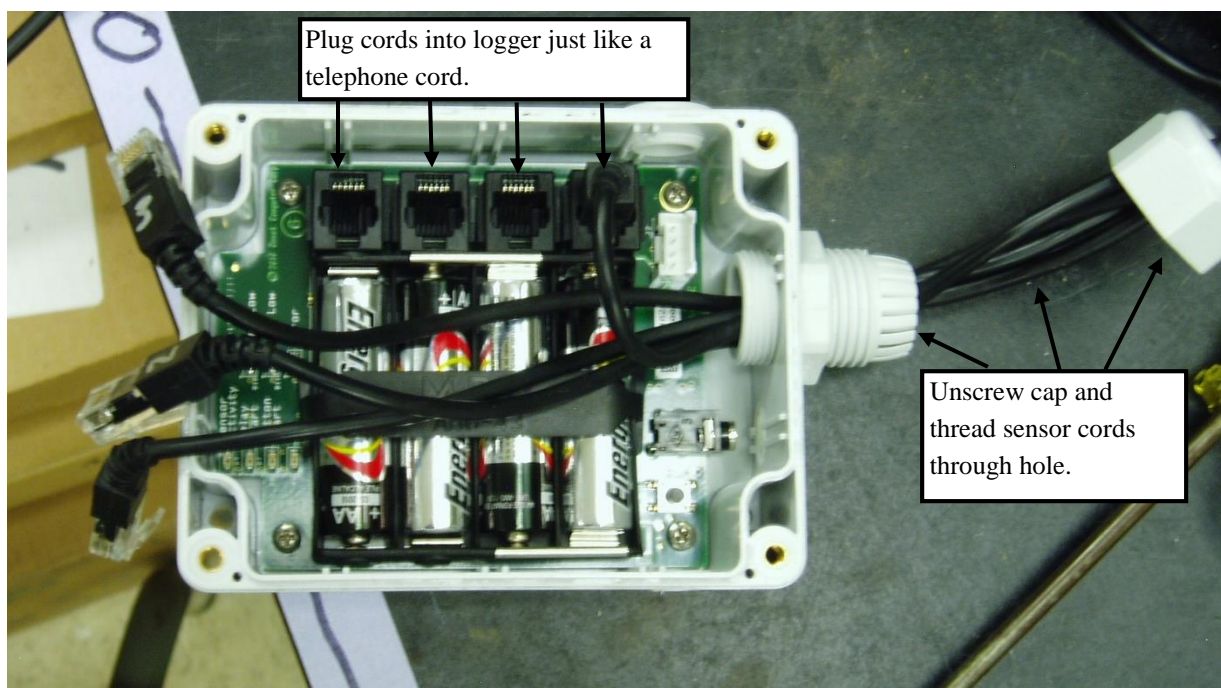
You can now remove the cord from the data logger and the shuttle.

3. When you return to your computer use the USB cord to download the data from the shuttle onto your personal computer.

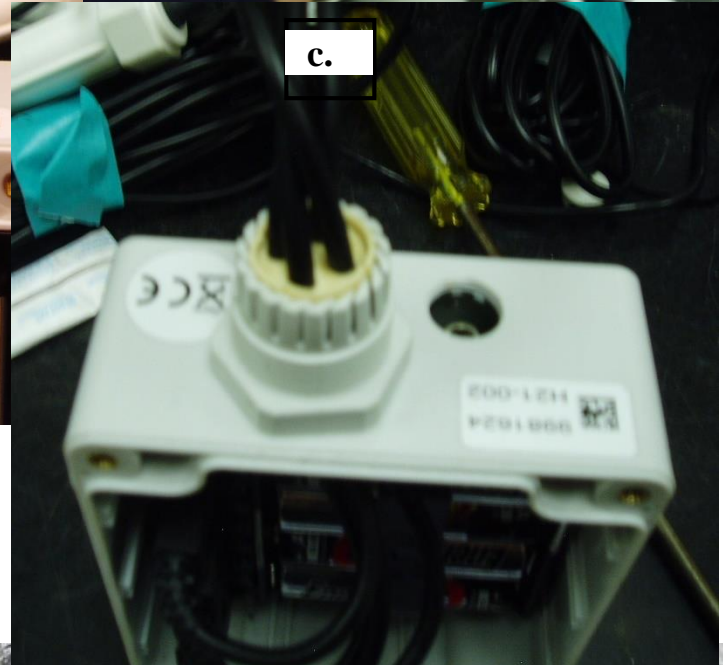
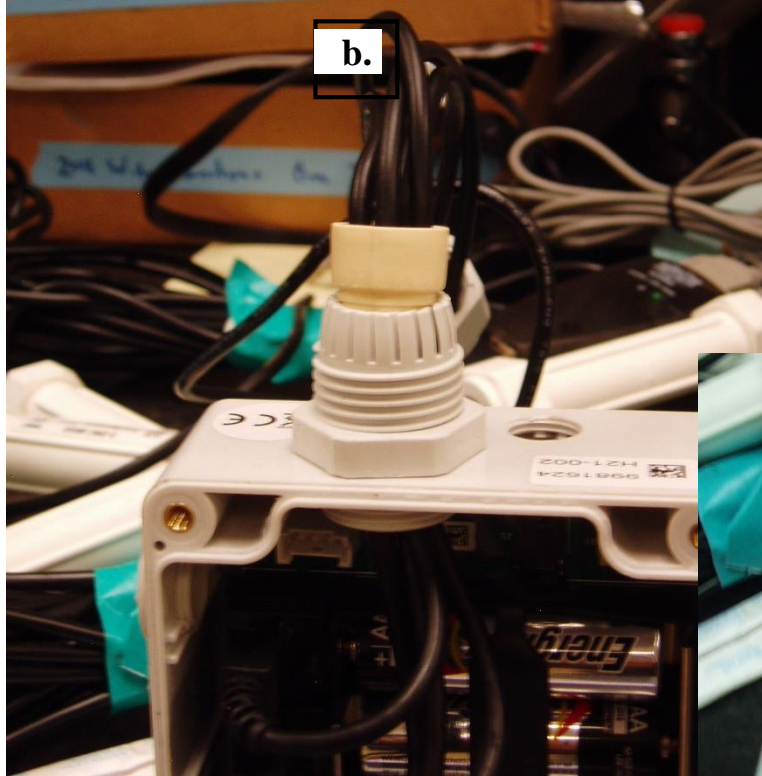
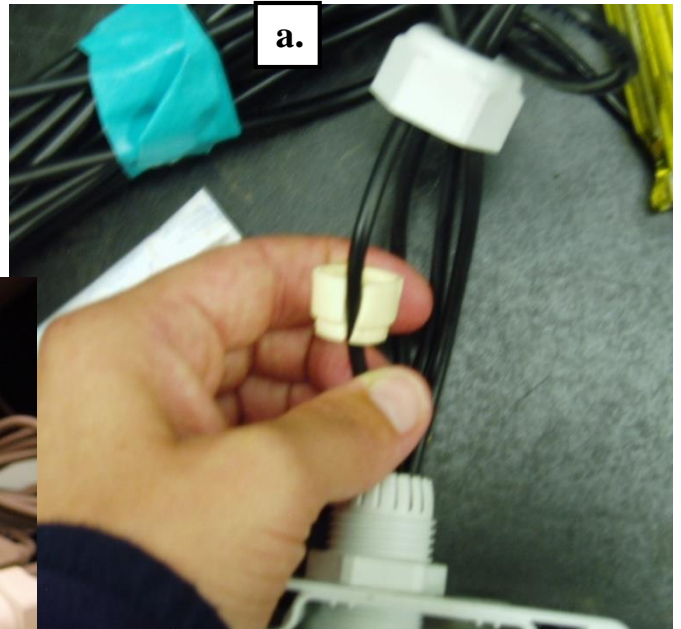
- **Replacing the data logger:**

If the data logger has been damaged over the course of the year because too much moisture has gotten inside or for any other reason, then it must be replaced.

1. Open the box that the data logger is in. Inside you should find the logger itself, four AA batteries, screws, a white rubber gasket, silicone gel, and desiccant packs (see picture to the right).
2. First, take off the clear plastic lid. Install the batteries and place the black arm over them to secure the batteries in place.
3. Next, unscrew the white cap on the end of the logger. The sensor cables will be threaded through the white rubber gasket and then the gasket will be pushed into this hole.
4. Remove the sensors from the original damaged logger making a note of the serial number so that you know which sensor is the deep versus the shallow sensor for both temperature and moisture. This information is also in the appendix if you need to refer back to it (you will need to enter this data when launching the logger).
5. After removing the sensors from the damaged logger thread them through the hole and install them into the logger. The sensors cords plug into the logger just like a telephone cord. While installing them keep track of which sensor (deep/shallow; temperature/moisture) is going into which plug so that this information is correctly entered into the software when re-launching the logger.



6. Once the sensor cables are threaded through the hole they can be pushed into the rubber gasket (a.) and the gasket can then be pushed into the hole (b). Once the gasket is firmly placed in the hole (c.) the cap can be screwed back on. It is critical that the gasket is firmly in place as this will keep moisture out.



7. Next place the desiccants into the logger. Open the silicone gel and spread a layer around the rim of the logger.

8. Screw the clear plastic top tightly onto the logger.



Spread silicone gel around rim of logger.

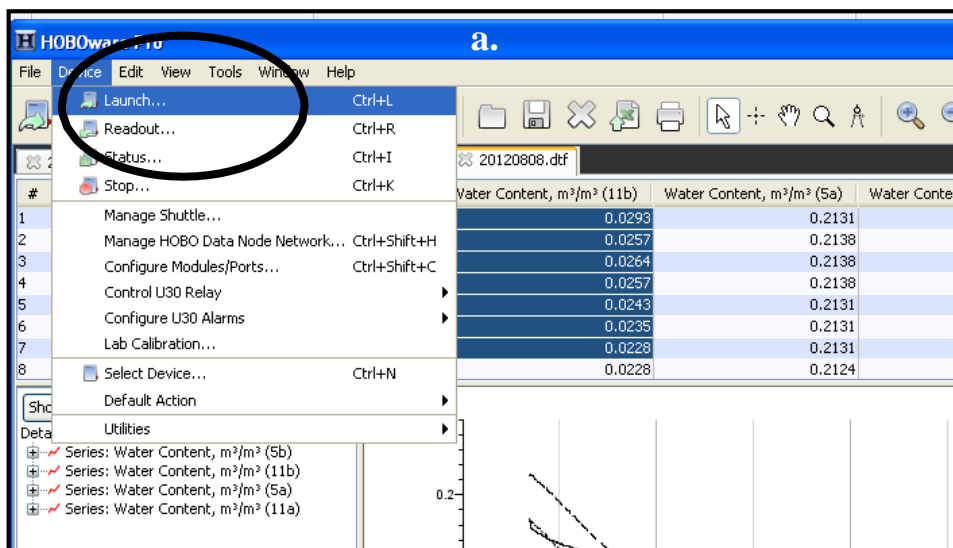


- **Launching the newly installed data logger:**

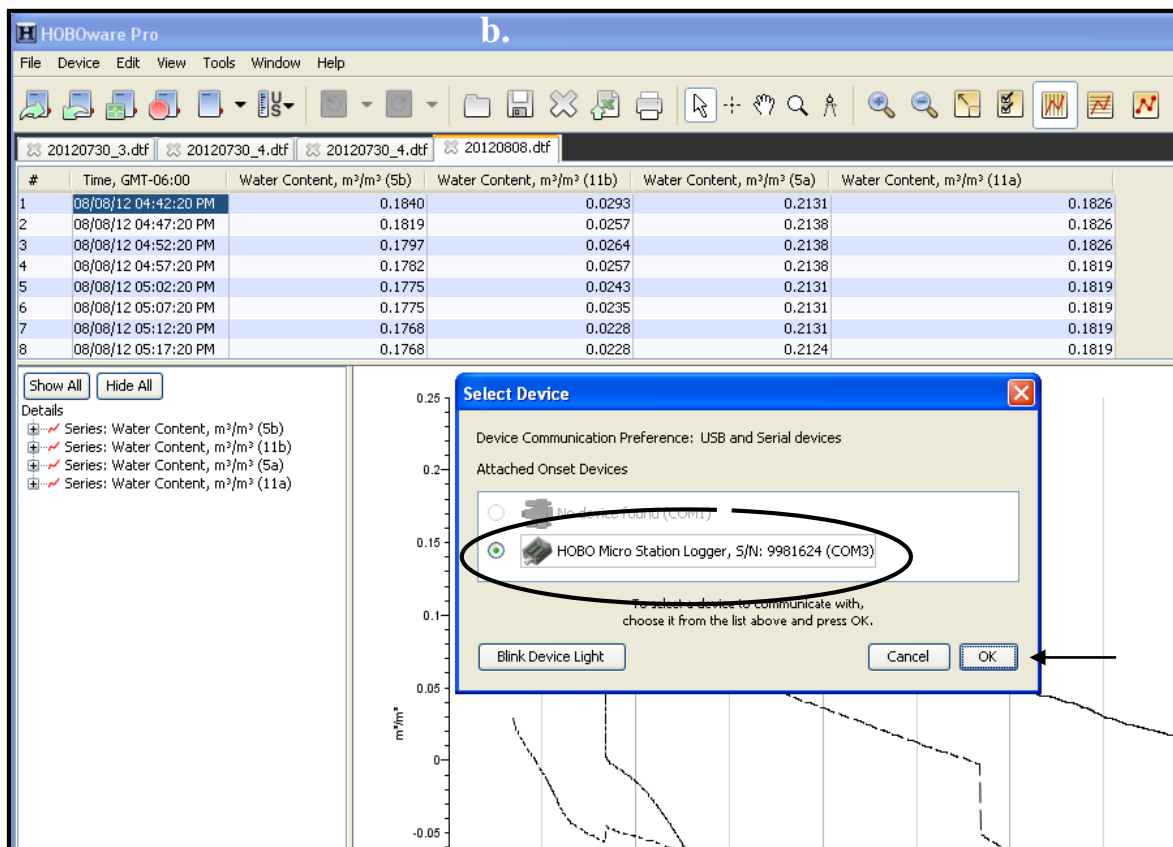
Once the data logger has been installed it must be launched so that it may begin collecting data again.

1. Open the HOBOWare pro software on the laptop computer if it has been closed and ensure that the logger and laptop are connected via the cables and adaptor as previously discussed (see page 10).

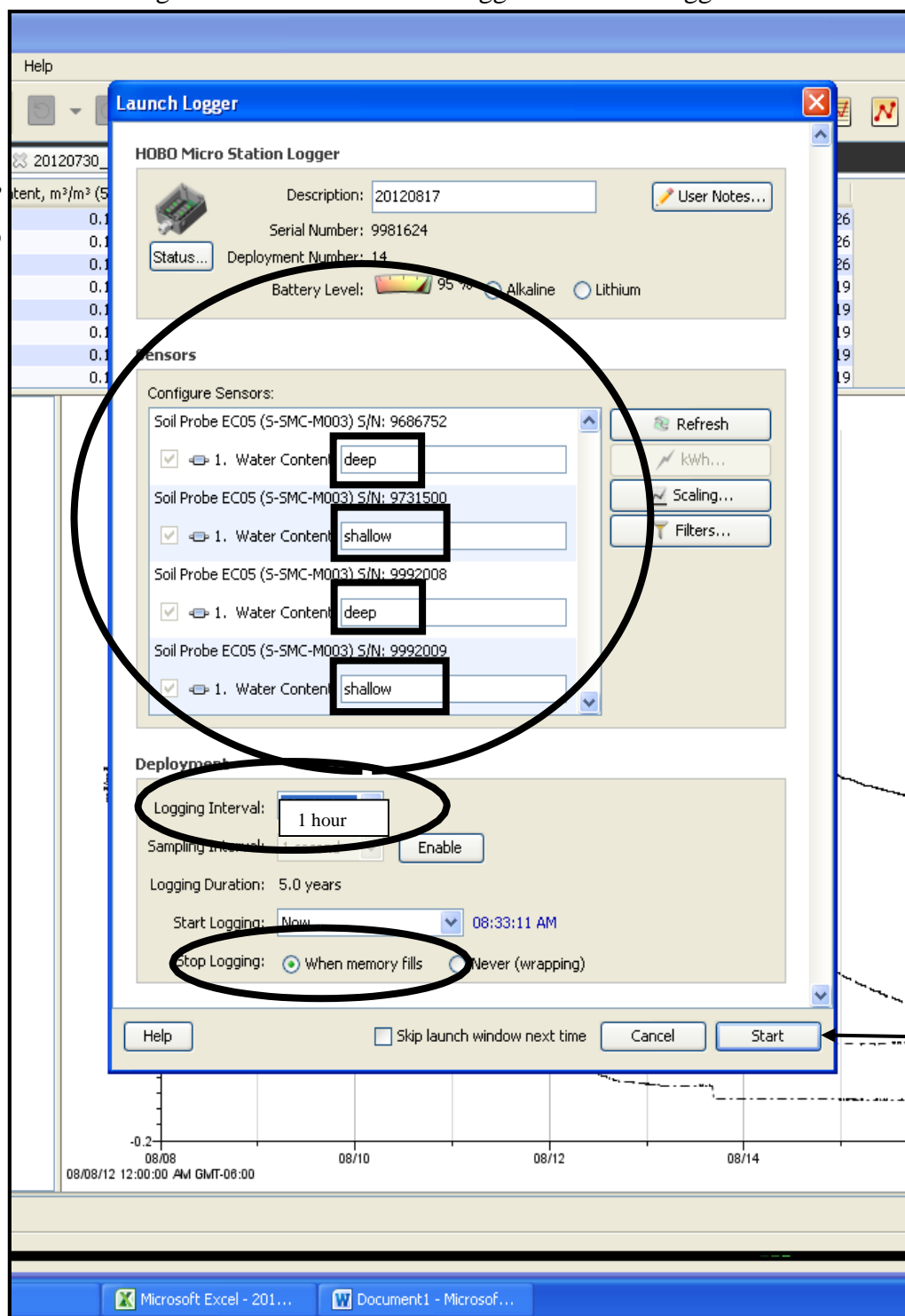
2. Click on the “Device” tab on the toolbar to open the dropdown menu and then choose “Launch...” (a.).



3. A box will appear asking you to choose your device (b.). Select “HOBO” Micro Station Logger and ensure that the serial number (S/N) matches that of the newly installed logger. Click “OK”.



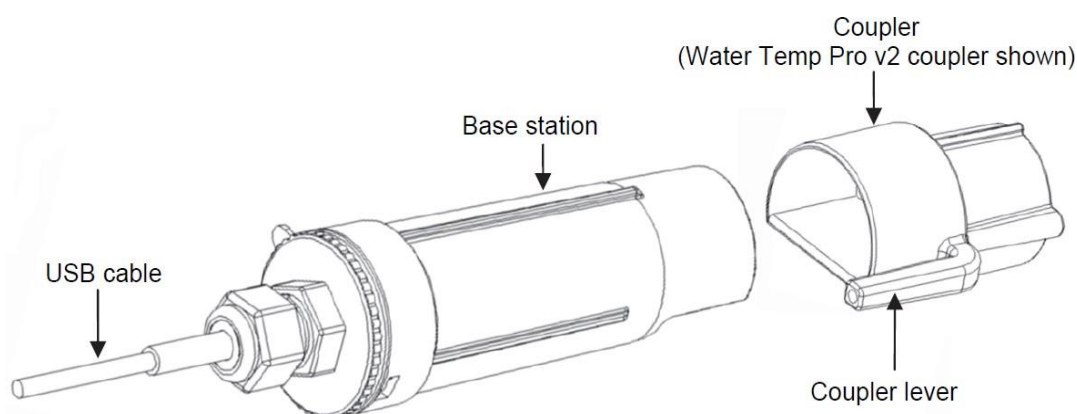
4. Once you click “OK” a new box will appear (“Launch Logger”). In this box you will need to enter information about the sensors before you can launch the logger. In the “Sensors” box information will be displayed about each of the four sensors. In the example provided below all sensors are moisture sensors (water content) you should have two moisture (water content) sensors and two temperature sensors. The serial numbers (S/N) should be displayed for each sensor as well as the type of sensor it is. In the text box you will enter whether each sensor is a deep or shallow sensor based on their serial numbers and the information you noted before when switching the sensors from the old logger to the new logger.
5. Next check the logging interval and ensure it is set to collect data every 1 hour. Also check that “When memory fills” is selected for “Stop Logging”.
6. You are now ready to launch the logger. Click “Start”.



- **Downloading the air temperature data:** The air temperature sensor also has a special USB cord and adaptor that must be connected to the sensor and the laptop in the field.

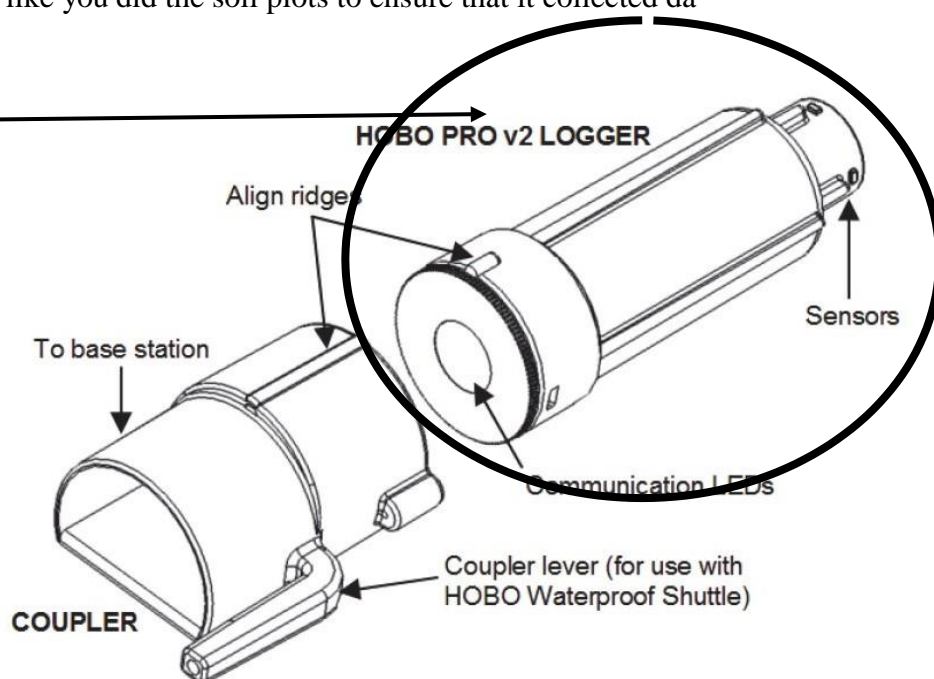


1. If it is not already open, open the HOBOWare software on your computer.
2. Plug the USB connector on the base station into an available USB port on your computer.
3. Firmly insert the optical end of the base station into the D-shaped end of the coupler (see picture below).
4. Insert the logger into the coupler. The base station's LED will illuminate when the logger is able to communicate with the computer. If the logger is not aligned properly, or if the coupler is not seated firmly on the base station, the logger and the Optic USB Base Station will be unable to communicate.



Check the air temperature plot just like you did the soil plots to ensure that it collected data

This is what the air temperature logger and sensor look like.

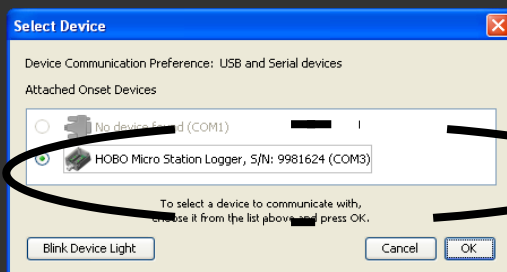
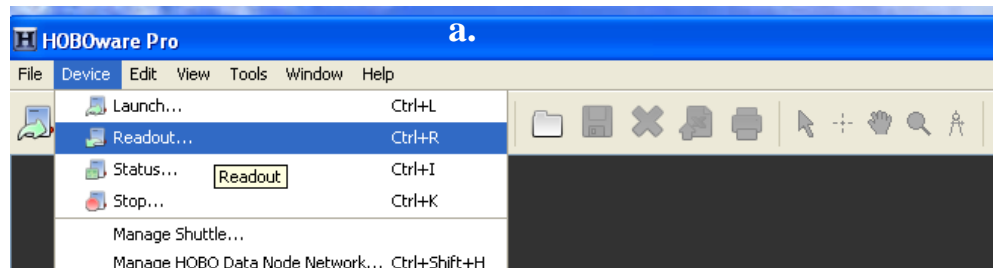






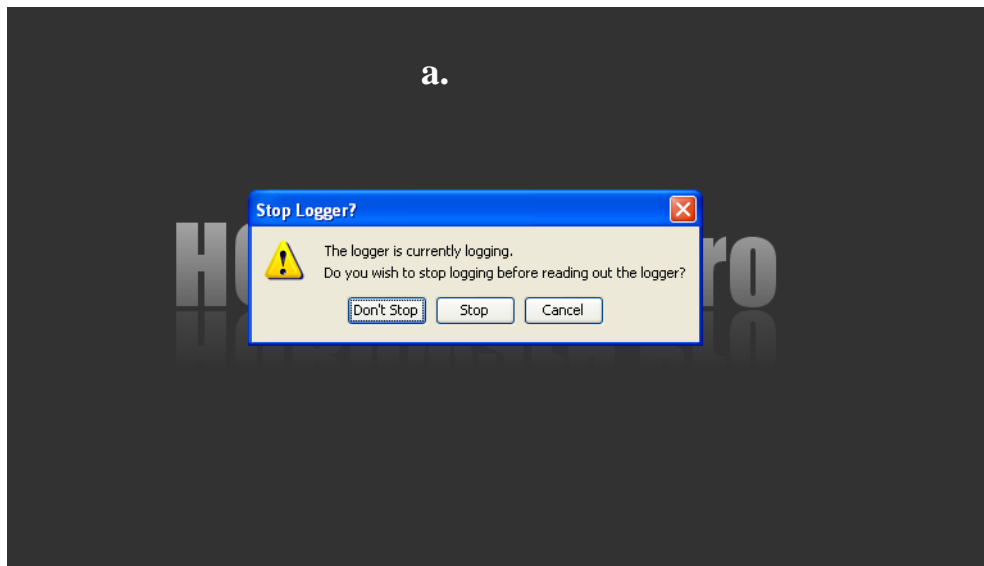
5. When the logger is recognized by HOBOWare, the right side of the status bar at the bottom of the HOBOWare window will update to reflect the number of loggers connected (if you are connected a base station/coupler or logger that has never been connected to this computer before, it may take some time for the computer to detect the new hardware and report that it has been connected successfully. One or more messages will appear, indicating that new hardware has been found. You may also hear a chime. You may be prompted to reboot your computer; this is not necessary).

6. Next you will readout the data just like you did for the soil sensors. Click –Device| in the HOBOWare toolbar and choose “Readout” from the dropdown menu (a.). Next you will select the device just as you did for the Micro Station Logger (b.)

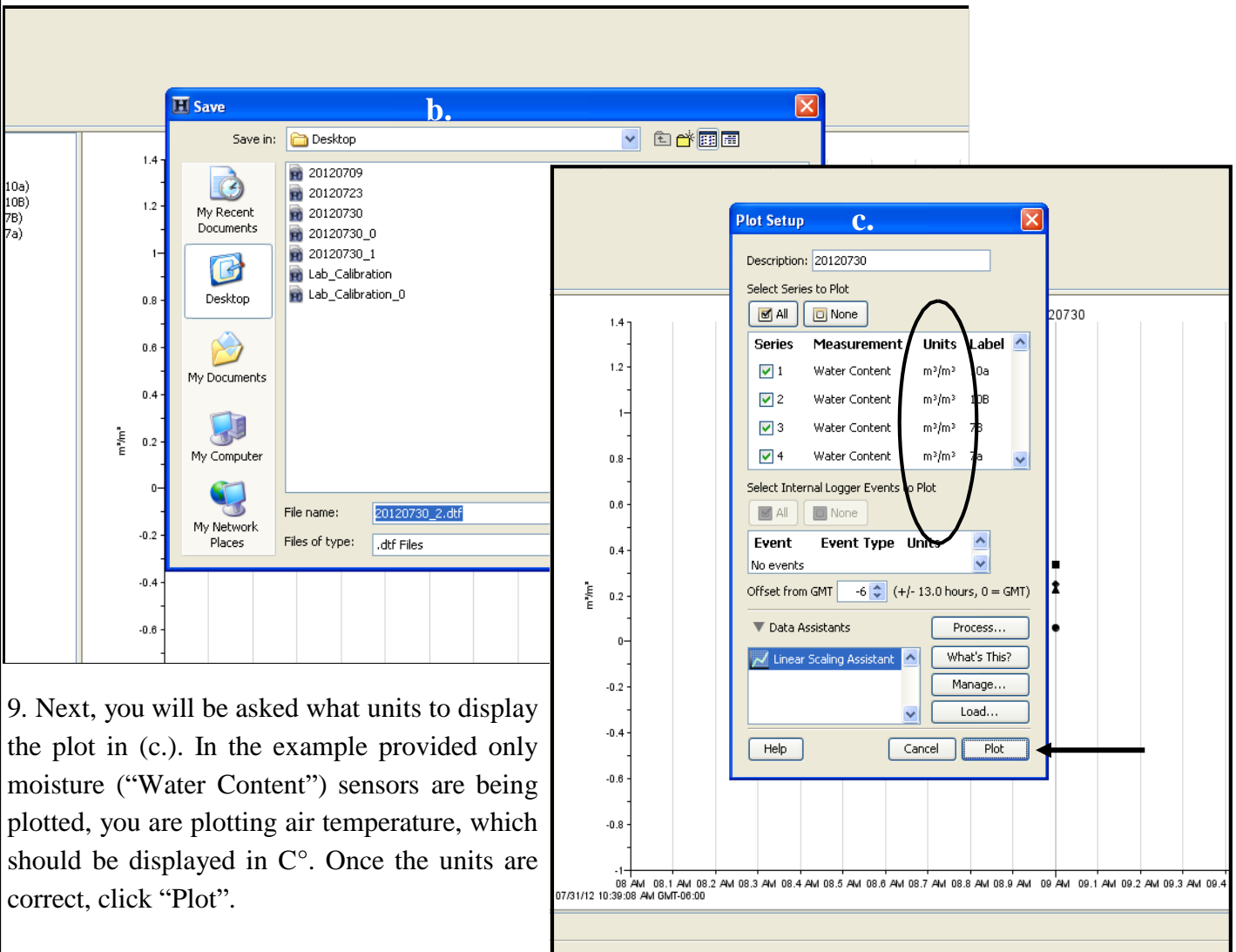


This will now display the air temperature logger and corresponding serial number (S/N).

7. Next the software will ask you if you want to stop the logger. Select —Stop! (a.).



8. Once the logger has been stopped you will be prompted to save the file (b.). Give the file a name, for example the site name and date as well as the word 'air' (Eagle08302012air) to distinguish it from the soil data and select “Save”.



9. Next, you will be asked what units to display the plot in (c.). In the example provided only moisture (“Water Content”) sensors are being plotted, you are plotting air temperature, which should be displayed in C°. Once the units are correct, click “Plot”.

10. The plot should now be displayed. Look at the plot and see when the last entry was made, if it was before today's date make a note of that, something may have happened during the year causing the logger to stop recording. Also, check to see that the temperature and went up and down the way you would expect with the seasons

11. Next check that the sensor is functioning properly. Navigate to "Device" on the toolbar again and choose "Status" from the dropdown menu (a.). A new box will appear asking you to choose your device. Select the air temperature logger just as you did to readout the data (b.). A new box with information about the logger and sensor will appear (c.). If everything looks fine, click "OK". If there is a problem with any of the sensors let the YRITWC know.

**a.**

**b.**

**c.**

**Device Identification**

Device: HOBO Micro Station Logger  
 Manufacturer: Onset Computer Corporation  
 Description: 20120817  
 Serial Number: 9981624  
 Firmware Version: 5.00

**Device Details**

Battery Level: 90 %  
 Memory Used: 4 of 512 KB (0 %)  
 Stops Logging: At Memory Full  
 Wrap Count: 0  
 Last Launched: 08/27/12 01:12:28 PM GMT-06:00  
 Delayed Start: 08/27/12 01:14:45 PM GMT-06:00  
 Deployment Number: 16  
 Logging Interval: 0h 5m 0s  
 Sampling Interval: Off  
 Current Status: Launched, Logging

**Current Readings**

Screen Refresh Interval: 2 sec

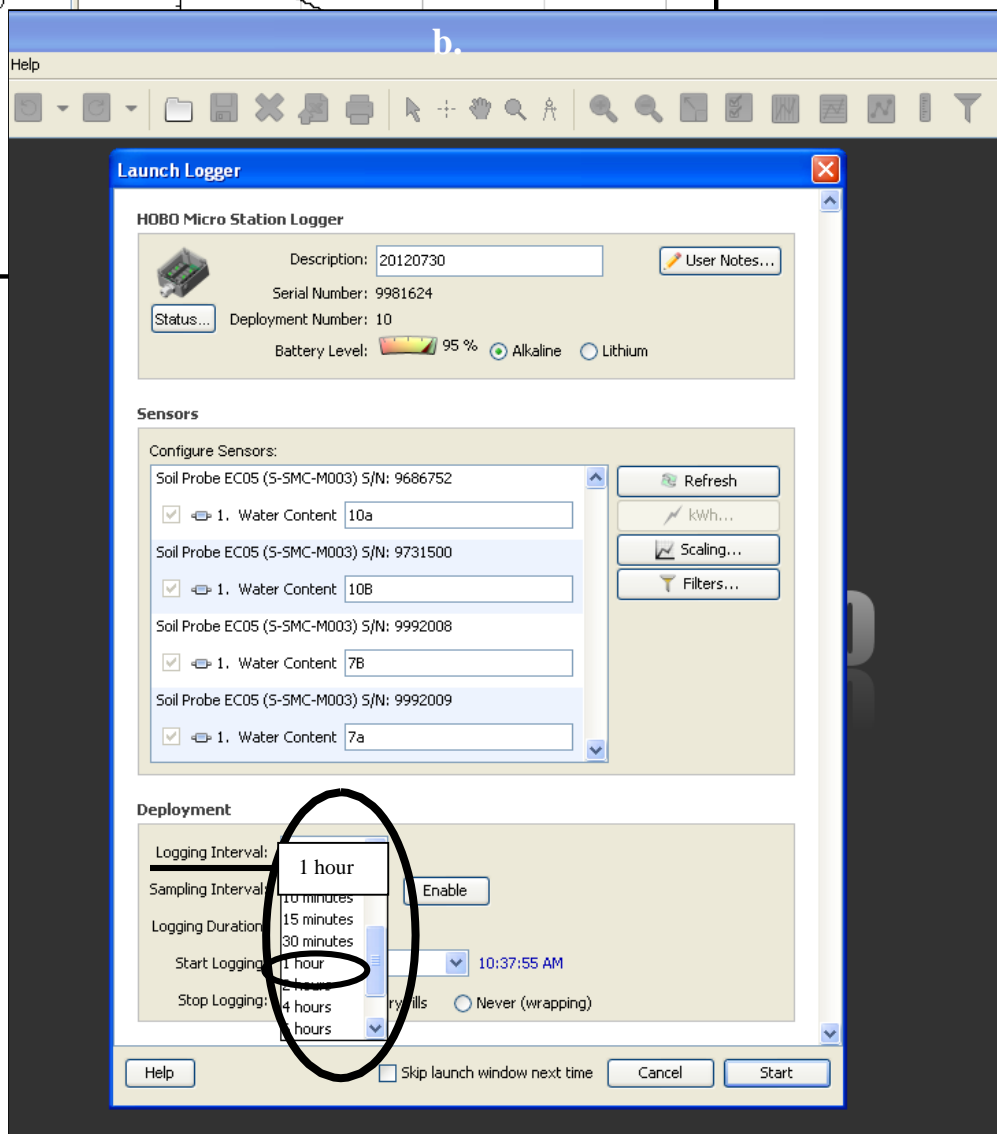
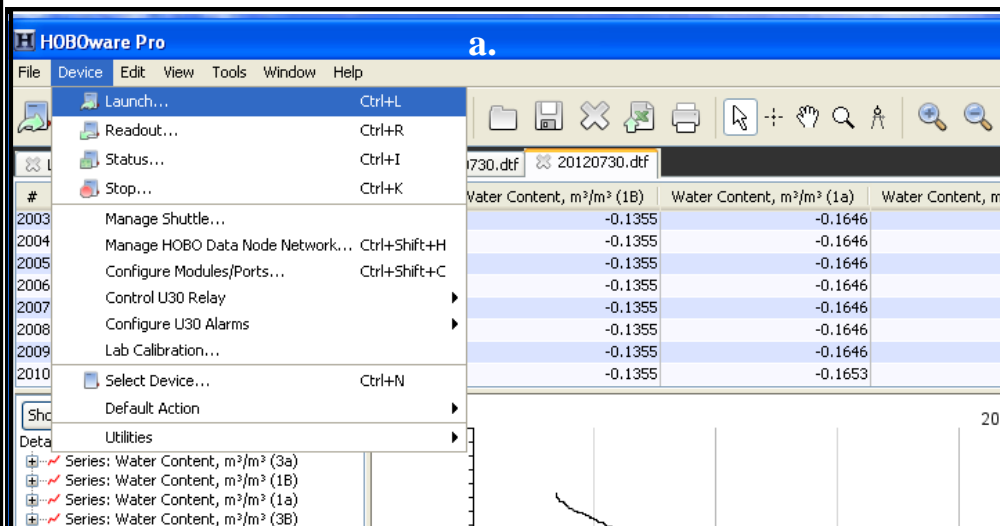
Number	Measurement	Value	Units	Label
1	Water Content	-0.1515	m <sup>3</sup> /m <sup>3</sup>	open
2	Water Content	-0.1334	m <sup>3</sup> /m <sup>3</sup>	open
3	Water Content	-0.1762	m <sup>3</sup> /m <sup>3</sup>	8a
4	Water Content	-0.1856	m <sup>3</sup> /m <sup>3</sup>	8b

Warning: Current Readings are the last logged value.

Help OK



12. Once the status of the logger and air temperature sensor have been checked and judged fine, the logger and sensor must be re-launched. To do this re-insert the USB cord if it has been removed and ensure that HOBOWare is open. Choose “Device” from the toolbar and select “launch” (a). A new box will pop up, check to ensure that data is set to collect every 1 hour under “logging interval” (if it is set to a different time, choose 1 hour from the dropdown menu) and then click “Start” (b).



## ***Appendix A: Sensor serial numbers***

### **Hughes**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	20614910
Soil Moisture, Shallow	20614905
Soil Temperature, Deep	9819072
Soil Temperature, Shallow	2407256

### **Hess Creek**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	
Soil Moisture, Shallow	
Soil Temperature, Deep	
Soil Temperature, Shallow	

### **Nenana**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	9781836
Soil Moisture, Shallow	9781838
Soil Temperature, Deep	9775075
Soil Temperature, Shallow	9756524

### **Arctic Village**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	9781842
Soil Moisture, Shallow	9781839
Soil Temperature, Deep	9775072
Soil Temperature, Shallow	9775069

### **Galena**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	2401307
Soil Moisture, Shallow	2401324
Soil Temperature, Deep	2407262
Soil Temperature, Shallow	2407267

### **Allakaket**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	2401331
Soil Moisture, Shallow	2401330
Soil Temperature, Deep	2407298
Soil Temperature, Shallow	2407281

### **Eagle**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	2401315
Soil Moisture, Shallow	2401318
Soil Temperature, Deep	2407291
Soil Temperature, Shallow	2407292

### **Kotlik**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	2412083
Soil Moisture, Shallow	2401336
Soil Temperature, Deep	2407280
Soil Temperature, Shallow	2407269

## *Appendix A: Sensor serial numbers*

### **Chevak**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	2401313
Soil Moisture, Shallow	241312
Soil Temperature, Deep	2407254
Soil Temperature, Shallow	2407253

### **Nome Creek**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	2412088
Soil Moisture, Shallow	2401321
Soil Temperature, Deep	2407263
Soil Temperature, Shallow	2337316

### **Circle**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	2401305
Soil Moisture, Shallow	2401333
Soil Temperature, Deep	2407258
Soil Temperature, Shallow	2407285

### **St. Mary's**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	
Soil Moisture, Shallow	
Soil Temperature, Deep	
Soil Temperature, Shallow	

### **Emmonak**

<b>Type of sensor:</b>	<b>Serial Number:</b>
Soil Moisture, Deep	2412084
Soil Moisture, Shallow	2412085
Soil Temperature, Deep	2407268
Soil Temperature, Shallow	2407289



## ***Appendix B: GPS coordinates***

### **Hughes**

#### **Northwest (NW) corner**

Latitude	66.042167
Longitude	154.219877

#### **Northeast (NE) corner**

Latitude	66.042121
Longitude	154.218832

#### **Southwest (SW) corner**

Latitude	66.041780
Longitude	154.210285

#### **Southeast (SE) corner**

Latitude	66.041711
Longitude	154.219262

### **Hess Creek**

#### **Northwest (NW) corner**

Latitude	65.657133
Longitude	149.085571

#### **Northeast (NE) corner**

Latitude	65.657731
Longitude	149.08442

#### **Southwest (SW) corner**

Latitude	65.656576
Longitude	149.084519

#### **Southeast (SE) corner**

Latitude	65.657229
Longitude	149.082683

### **Nenana**

#### **Northwest (NW) corner**

Latitude	64.55446
Longitude	149.08344

#### **Northeast (NE) corner**

Latitude	64.55443
Longitude	149.08252

#### **Southwest (SW) corner**

Latitude	64.55403
Longitude	149.08359

#### **Southeast (SE) corner**

Latitude	64.55405
Longitude	149.08258

### **Arctic Village**

#### **Northwest (NW) corner**

Latitude	68.13013
Longitude	145.54066

#### **Northeast (NE) corner**

Latitude	68.12997
Longitude	145.53976

#### **Southwest (SW) corner**

Latitude	68.12970
Longitude	145.54106

#### **Southeast (SE) corner**

Latitude	68.12959
Longitude	145.54015

## ***Appendix b***

### **Galena**

#### **Northwest (NW) corner**

Latitude 64.44077

Longitude 156.4705

#### **Northeast (NE) corner**

Latitude 64.44071

Longitude 156.46993

#### **Southwest (SW) corner**

Latitude 64.44052

Longitude 156.47071

#### **Southeast (SE) corner**

Latitude 64.44048

Longitude 156.47017

### **Allakaket**

#### **Northwest (NW) corner**

Latitude 66.54517

Longitude 152.64592

#### **Northeast (NE) corner**

Latitude 66.54498

Longitude 152.64493

#### **Southwest (SW) corner**

Latitude 66.54478

Longitude 152.64601

#### **Southeast (SE) corner**

Latitude 66.54462

Longitude 152.64510

### **Eagle**

#### **Northwest (NW) corner**

Latitude 64.77802

Longitude 141.10971

#### **Northeast (NE) corner**

Latitude 64.77787

Longitude 141.10887

#### **Southwest (SW) corner**

Latitude 64.77767

Longitude 141.10991

#### **Southeast (SE) corner**

Latitude 64.77757

Longitude 141.10899

### **Kotlik**

#### **Northwest (NW) corner**

Latitude 63.02161

Longitude 163.56075

#### **Northeast (NE) corner**

Latitude 63.02134

Longitude 163.56018

#### **Southwest (SW) corner**

Latitude 63.02132

Longitude 163.56139

#### **Southeast (SE) corner**

Latitude 63.02102

Longitude 163.56075

## ***Appendix b***

### **Circle**

#### **Northwest (NW) corner**

Latitude 65.82838  
Longitude 144.07895

#### **Northeast (NE) corner**

Latitude 65.82838  
Longitude 144.07803

#### **Southwest (SW) corner**

Latitude 65.82796  
Longitude 144.07896

#### **Southeast (SE) corner**

Latitude 65.82796  
Longitude 144.07802

### **St. Mary's**

#### **Northwest (NW) corner**

Latitude 64.77802  
Longitude 141.10966

#### **Northeast (NE) corner**

Latitude 64.77790  
Longitude 141.10883

#### **Southwest (SW) corner**

Latitude 64.77763  
Longitude 141.10989

#### **Southeast (SE) corner**

Latitude 64.17853  
Longitude 141.10899

### **Chevak**

#### **Northwest (NW) corner**

Latitude 61.52816  
Longitude 165.61809

#### **Northeast (NE) corner**

Latitude 61.52804  
Longitude 165.61717

#### **Southwest (SW) corner**

Latitude 61.52780  
Longitude 165.61853

#### **Southeast (SE) corner**

Latitude 61.32765  
Longitude 165.61850

### **Nome Creek**

#### **Northwest (NW) corner**

Latitude 65.370209  
Longitude 147.061329

#### **Northeast (NE) corner**

Latitude 65.369907  
Longitude 147.060445

#### **Southwest (SW) corner**

Latitude 65.369698  
Longitude 147.061409

#### **Southeast (SE) corner**

Latitude 65.369637  
Longitude 147.060528

## ***Appendix b***

### **Emmonak**

#### **Northwest (NW) corner**

Latitude 62.78509  
Longitude 164.52637

#### **Northeast (NE) corner**

Latitude 62.78484  
Longitude 164.52551

#### **Southwest (SW) corner**

Latitude 62.79472  
Longitude 164.52667

#### **Southeast (SE) corner**

Latitude 62.78443  
Longitude 164.52603

#### **Northwest (NW) corner**

Latitude  
Longitude

#### **Northeast (NE) corner**

Latitude  
Longitude

#### **Southwest (SW) corner**

Latitude  
Longitude

#### **Southeast (SE) corner**

Latitude  
Longitude

#### **Northwest (NW) corner**

Latitude  
Longitude

#### **Northeast (NE) corner**

Latitude  
Longitude

#### **Southwest (SW) corner**

Latitude  
Longitude

#### **Southeast (SE) corner**

Latitude  
Longitude



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