

Lake Taihu water quality monitoring station: Technical Manual

CBER Report 83

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1. Introduction

The Lake Taihu monitoring station was constructed over September and October 2007. It is intended to provide real-time, internet accessible data for the water quality and meteorology of Lake Taihu, as well as contributing to the Global Lakes Ecological Observatory Network (www.gleon.org).

The system was commissioned by the Nanjing Institute of Geography and Limnology, Chinese academy of Sciences, and designed and built by Chris McBride and Professor David Hamilton of Waikato University, New Zealand, with direction from Associate Professor Guangwei Zhu, and Dr. Liancong Luo (NIGLAS).

A range of high quality environmental sensors have been used in order to provide reliable and accurate observations of the climate and limnology at Taihu. The sensors were chosen for their accuracy and long-term stability, however, as with any sensor-based monitoring, regular maintenance and calibration of the sensors is essential for the collection of accurate and precise data over long time periods.

This manual is intended to provide background information about the function and configuration of the monitoring system, and to act as a step-by-step guide for the proper cleaning and calibration of the sensors.

2. Overview

The monitoring station can be operated either from the Taihu field station pier (as in the initial October 2007 installation, Figure 1), or as the monitoring buoy for use in other regions of the lake (Figure 2).

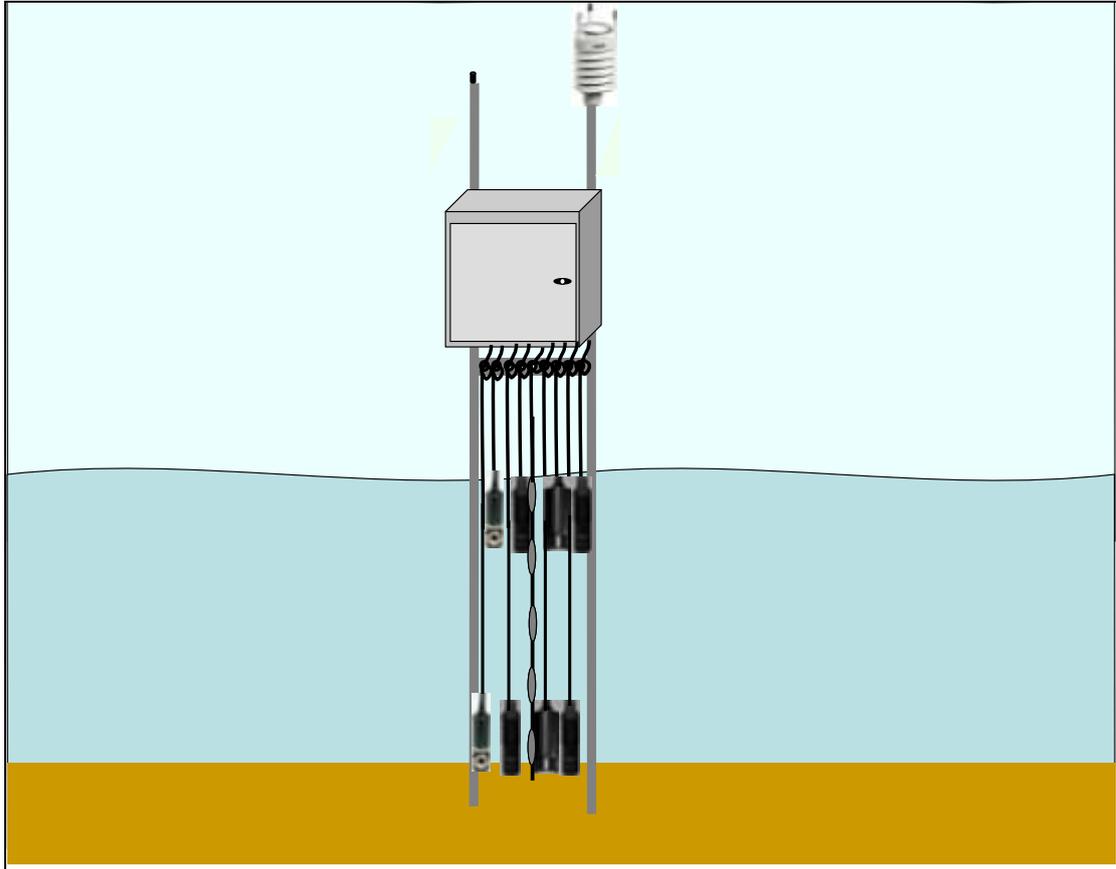


Figure 1. Sensors deployed from the Taihu station pier.

The surface sensors are attached to a float, so that they take measurements from just below the surface water, regardless of the lake level. The thermistor (temperature sensor) string is attached to a separate rope which is anchored at the bottom. Keeping this rope tight will give temperature measurements from accurate depths. The deep sensors are attached to a separate line and mounted on a disc to keep them level. The height of the sensors from the bottom of the lake can be altered by the user, and may be changed depending on the research question being investigated.

In the stationary (pier) installation, power is supplied to the system by a UPS and AC to 12V DC voltage converter. When the system is installed on the buoy, power is supplied by a 60W solar panel, with a 50AH sealed lead-acid battery for reserve power.



Figure 2. The monitoring buoy (without sensors installed).

2.1 Sensors

The Taihu system contains sensors for many water quality and meteorological variables (Table 1). These sensors have been chosen from many types available, for their low power consumption, accuracy, long-term stability, and cost effectiveness.

Table 1. Sensor types used for the Taihu monitoring station.

Sensor	Variable	Depths (m)
Nexsens “TS110” thermistor string	Water temperature	0, 0.5, 1, 1.5, 2, 2.5
Zebra-tech “D-opto”	Dissolved oxygen (ppm & % saturation), water temperature	0, bottom
Seapoint chlorophyll fluorometer	chlorophyll <i>a</i>	0, bottom
Seapoint turbidity fluorometer	Turbidity	0, bottom
INW “TempHion T2”	pH	0, bottom
Vaisala WXT510	Air temperature, relative humidity, wind speed, wind direction, barometric pressure, rainfall, hail.	n/a
Apogee pyranometer	Solar (short-wave) radiation	n/a

2.2 Power and data management

All the electronic components of the system are contained within a weatherproof stainless steel case. The case is resistant to heavy weather and splashing, but is *not* submersible. Cables enter the case through watertight cable glands. Each sensor is connected to a circuit board within the case, and in turn connected to the datalogger for the measurement and storage of the data (Figure3).

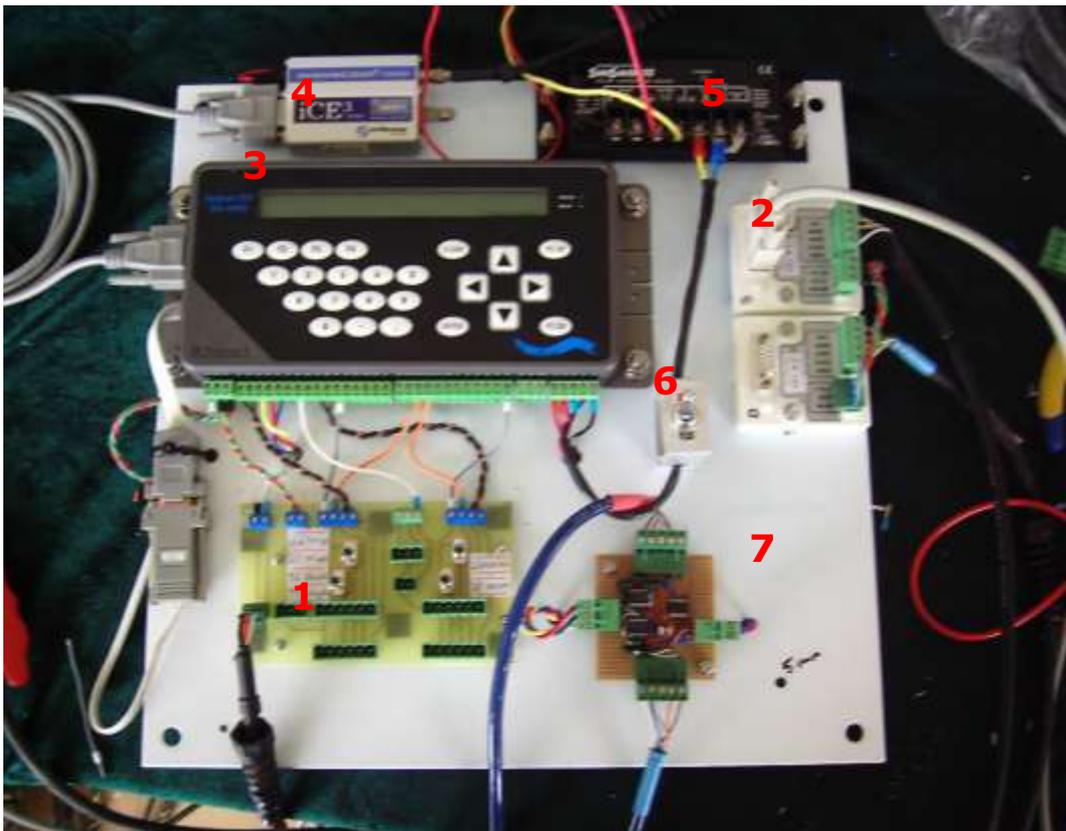


Figure 3. Components of the electronics case.

1. Sensor connection circuit board
2. D-opto connection boards
3. Datalogger: iQuest DS-4483 datalogger
4. GPRS modem: iQuest iCE³ cellular modem
5. Solar power regulator: SunSaver SS-10 12V
6. System power switch
7. TempHion T2 voltage converte.

Circuit board

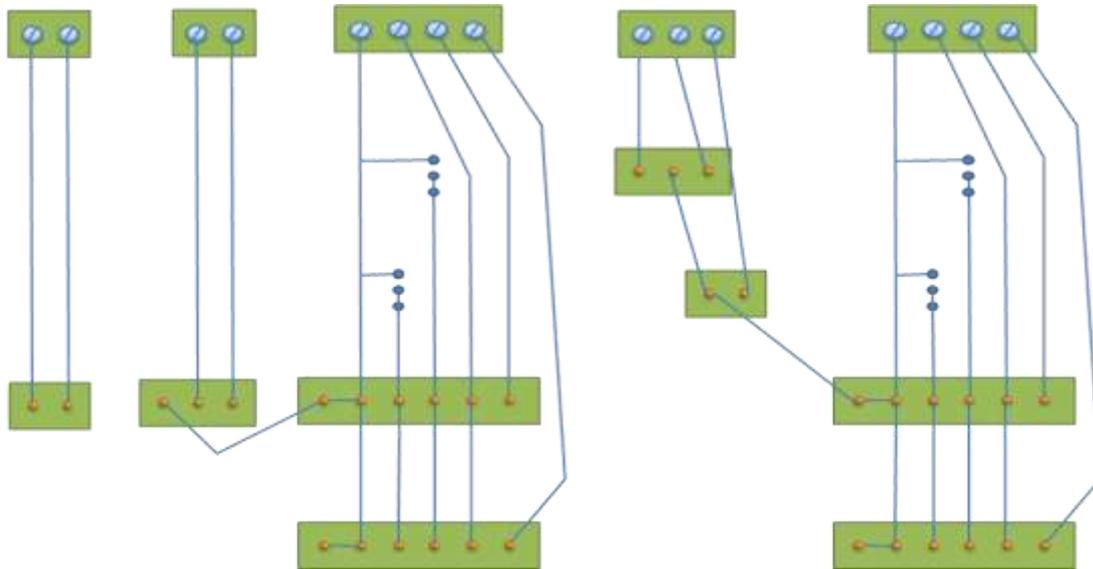


Figure 4. Correct wiring for the installation of the sensors. If any changes or repairs are required to the wiring, care must be taken to ensure the signal paths are correct before the power to the sensors is switched on, or damage to the sensors could result. Note that the red wires on the chlorophyll and turbidity sensors are not connected to the 6-pin plug. This is in order to set the gain of the instrument. See the Seapoint manuals (Appendix 2 and 3) or section 3 for more information.

Power consumption

Table 2. Theoretical power consumption for the Taihu monitoring station.

Item	Mode	Volts	mAmps	Watts	Hours	Number of sensors	Subtotal (Watt hours)
iQuest DS-4483 datalogger	Sleep	12	20	0.24	23.5	1	5.64
	Active	12	80	0.96	0.5	1	0.48
iCE cube cellular modem		12	20	0.24	24.0	1	5.76
Seapoint chl a fluorometer	Standby	12	1	0.01	23.9	2	0.57
	Active	12	15	0.18	0.2	2	0.05
Seapoint turbidity fluorometer		12	1	0.01	23.9	2	0.57
		12	6	0.07	0.2	2	0.02
D-opto	Standby	12	12	0.14	0.2	2	0.04
	Active	12	0.2	0.00	23.9	2	0.11
Nexsens thermistor string		12		0.00	24.0	1	0.00
TempHion T2		12	2.3	0.03	24.0	2	1.32
Appogee pyranometer		n/a	0	0.00	24.0	1	0.00
Vaisa WXT510		12	3	0.04	24.0	1	0.86
Total				160.5			15.44688

2.3 Basic operation of the monitoring system

Datalogger

The logger stores data internally and also transmits data every 10 minutes via the GPRS modem, to the iQuest “HydroTel” database system. The data is then made accessible on the internet at the website:

<https://data.iquest.co.nz/hydrotel>

Please contact Assoc. Prof. Guangwei Zhu, or Dr. Liancong Luo (NIGLAS) to acquire a username and password in order to view the data. An archive of the data will also be routinely sent to NIGLAS as a backup to the Hydrotel system.

Operation of the iQuest DS-4483 datalogger and iLink software

Proper calibration and configuration of the Taihu station requires a basic knowledge of how to operate the datalogger and configuration software (iLink). The appropriate manuals are available in electronic form; however, the following provides instructions for the basic use of the datalogger and iLink.

Installing iLink

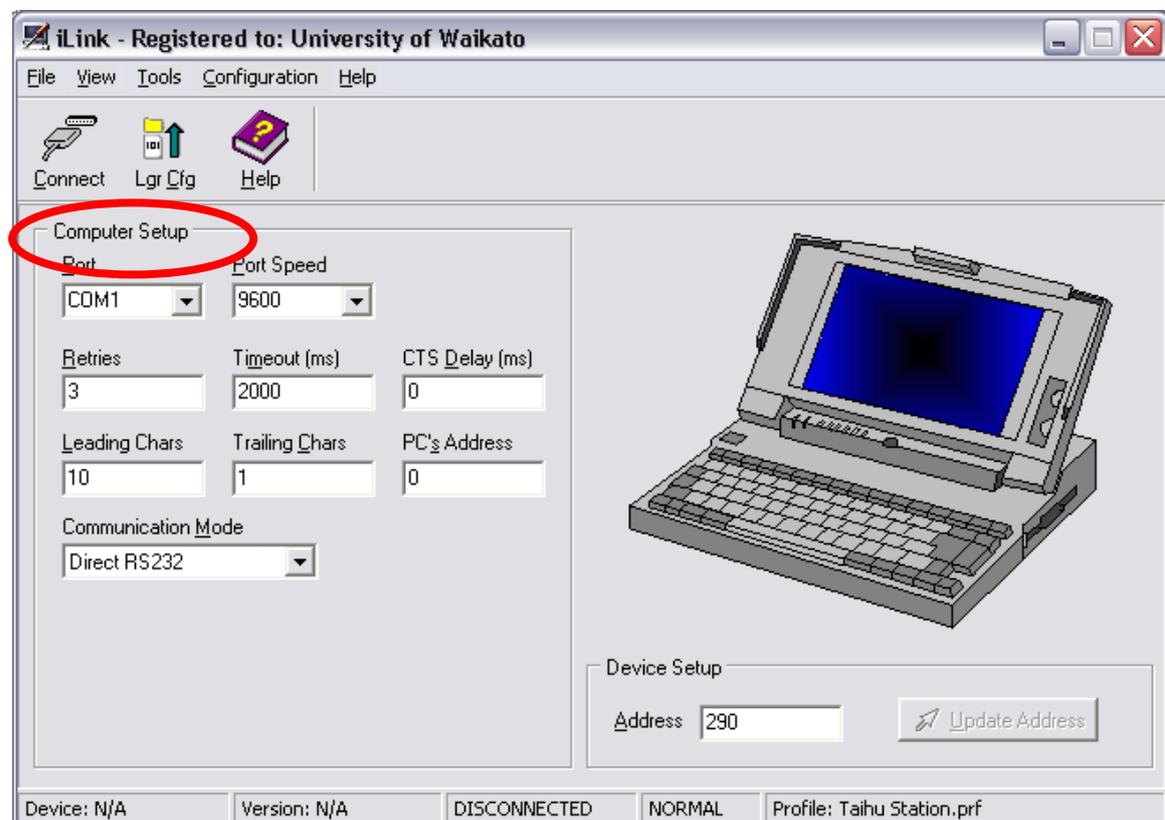
Insert the iLink software installation CD, follow the instructions to install iLink under the Program files folder. Please contact Assoc. Prof. Guangwei Zhu for a registration code if required.

In order to pre-load the Taihu station configuration, two files must be copied into separate folders under the iLink menu.

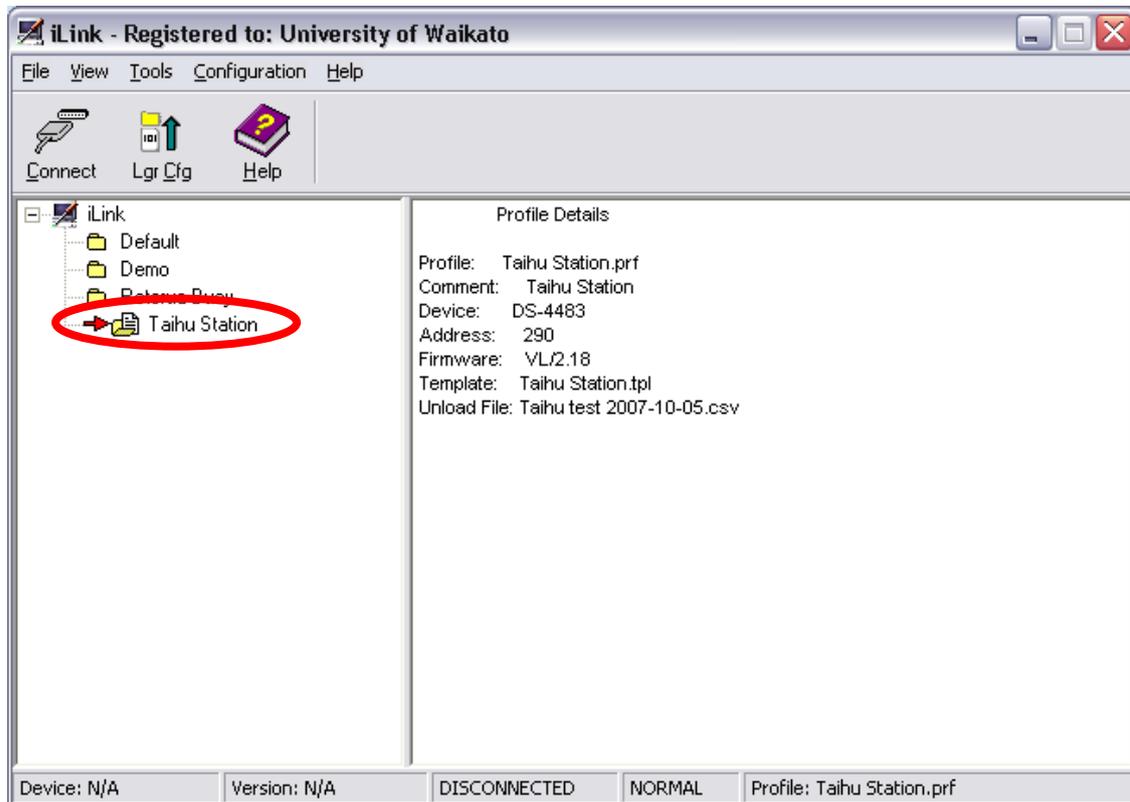
1. The file “Taihu station.prf” must be copied into the folder:
[C://Program files/iQuest \(NZ\) Ltd/iLink/Profiles](C://Program files/iQuest (NZ) Ltd/iLink/Profiles)
2. The file “Taihu station.tpl” must be copied into the folder:
[C://Program files/iQuest \(NZ\) Ltd/iLink/Profiles](C://Program files/iQuest (NZ) Ltd/iLink/Profiles)

After the files are copied, open iLink. The Taihu station should be listed on the left. The Taihu datalogger is configured to communicate over com port 1. If your serial cable is not configured to use com1, use the Windows control panel to change to com1.

Alternatively, the com port used by the logger can be changed by clicking the “Configuration” menu and choosing “communications”.



Now that your com port settings are correct, select Taihu station at the left (so that it has a red arrow as in the picture below) then press the “Connect” button.



If the logger successfully connects to the computer, you will be taken through to the logger information screen:

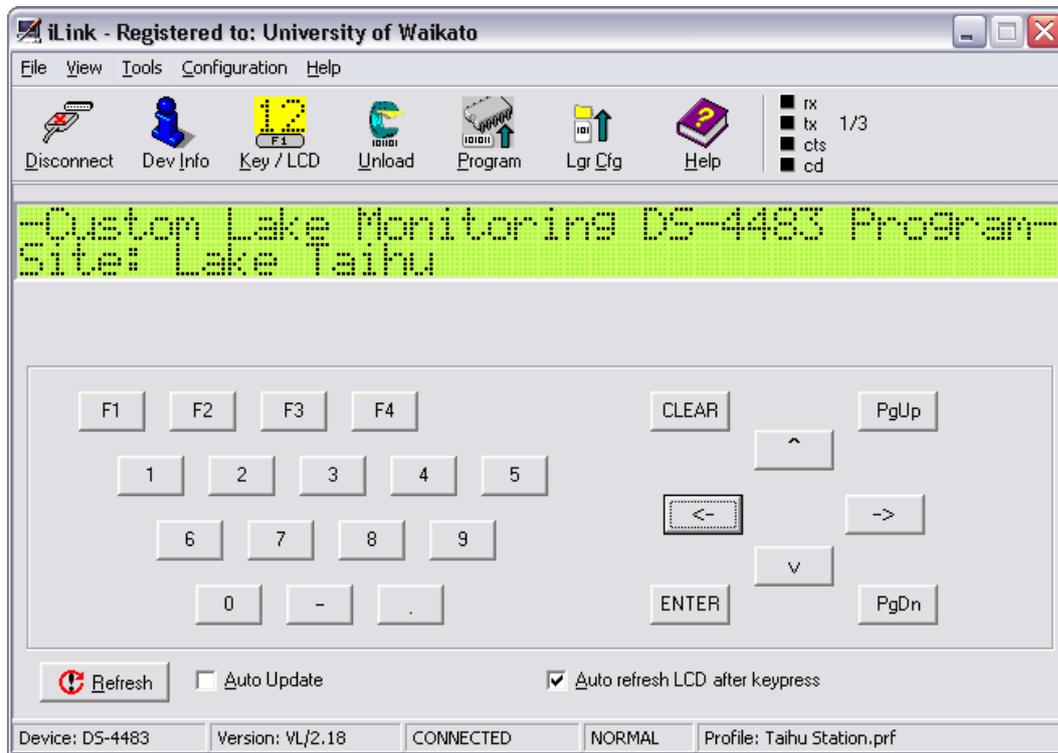


1. Sync: Pressing this button will synchronise (match) the clock of the datalogger to the clock of the computer.

2. Disconnect: disconnects the computer from the datalogger.

3. Dev Info: This is the main screen (shown above). It displays basic information about the datalogger, such as the clock time, memory, battery volts etc.

4. Key/LCD: This enables the user to view information from the logger on the computer, and to control the display of the logger using the computer.

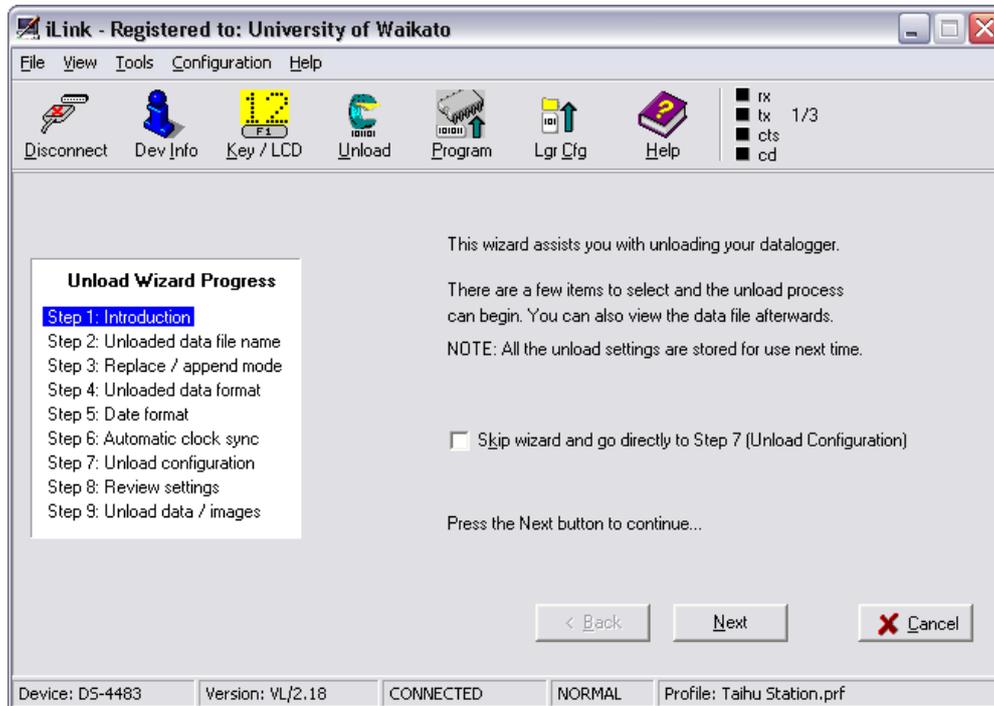


The arrow buttons can be used to scroll through the data from the different sensors.

5. Unload: This button can be used to retrieve data from the logger when the internet database is not available.

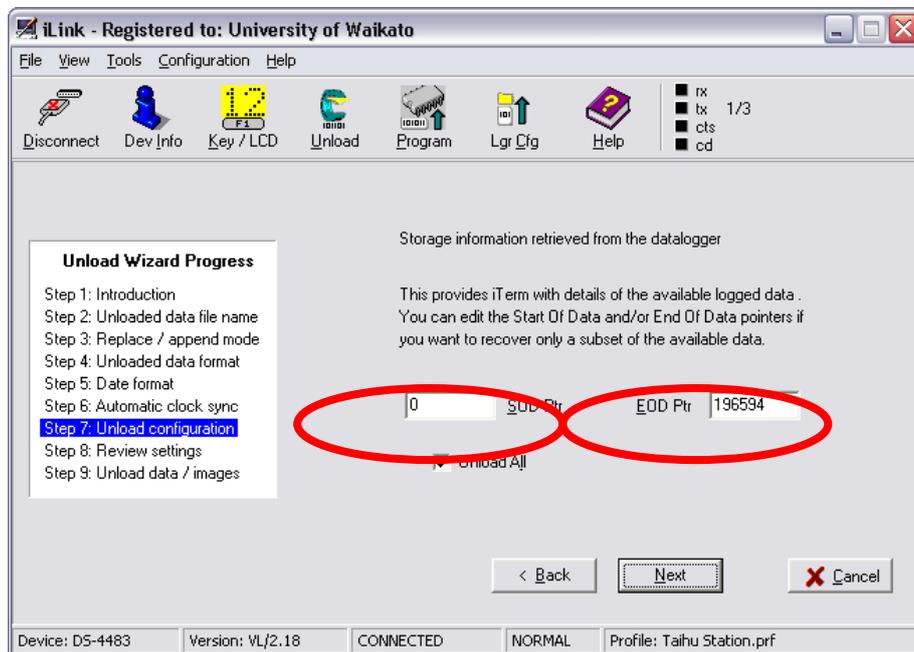
Unloading data from the logger

Click the “Unload” button.

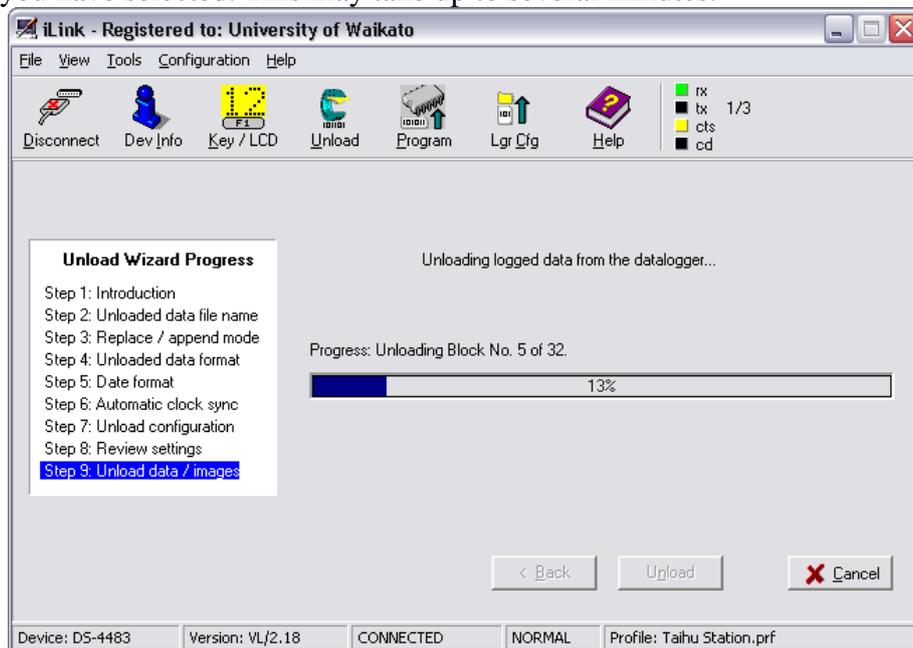


1. Follow the wizard to unload the data: click next.
2. Choose a file name for the unloaded data. Also choose the location where you want the data saved. Click next.
3. Choose replace if you want to overwrite any old datafiles with the same name. Choose append if you only want to add new data to the old file. Click next.
4. Choose Table: your data will be saved as a “.csv” file, which will open in MS Excel. Click next.
5. Select the date format you require. Click next.
6. Do not tick the auto sync box unless you wish to change the datalogger clock to match your computer. Click next. iLink will now retrieve the sensor information.

- You can now choose to download all the data, or to download only a selection by changing the Start of Data (SOD) and End of Data (EOD) points.



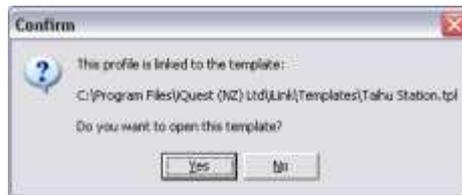
- Check your settings and press unload. The computer will now retrieve the data you have selected. This may take up to several minutes.



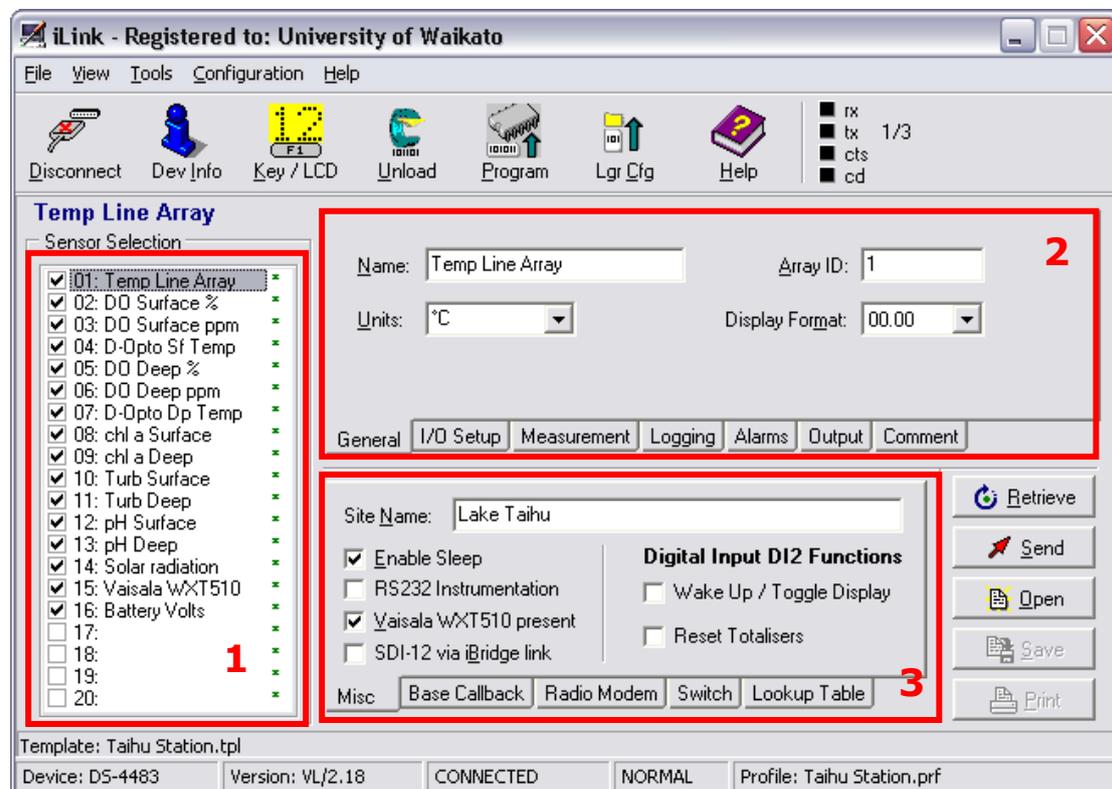
- Your data should open in MS Excel automatically. You can now save it as a .xls file.

6. Program: This page can be used to load specialised programs that control complex sensors (for example the thermistor string). *It should not be altered or used without special instruction being given.*

7. Lgr Cfg (Logger Configuration): This will be the most useful page for the routine calibration of the sensors. Click on the Lgr Cfg button.



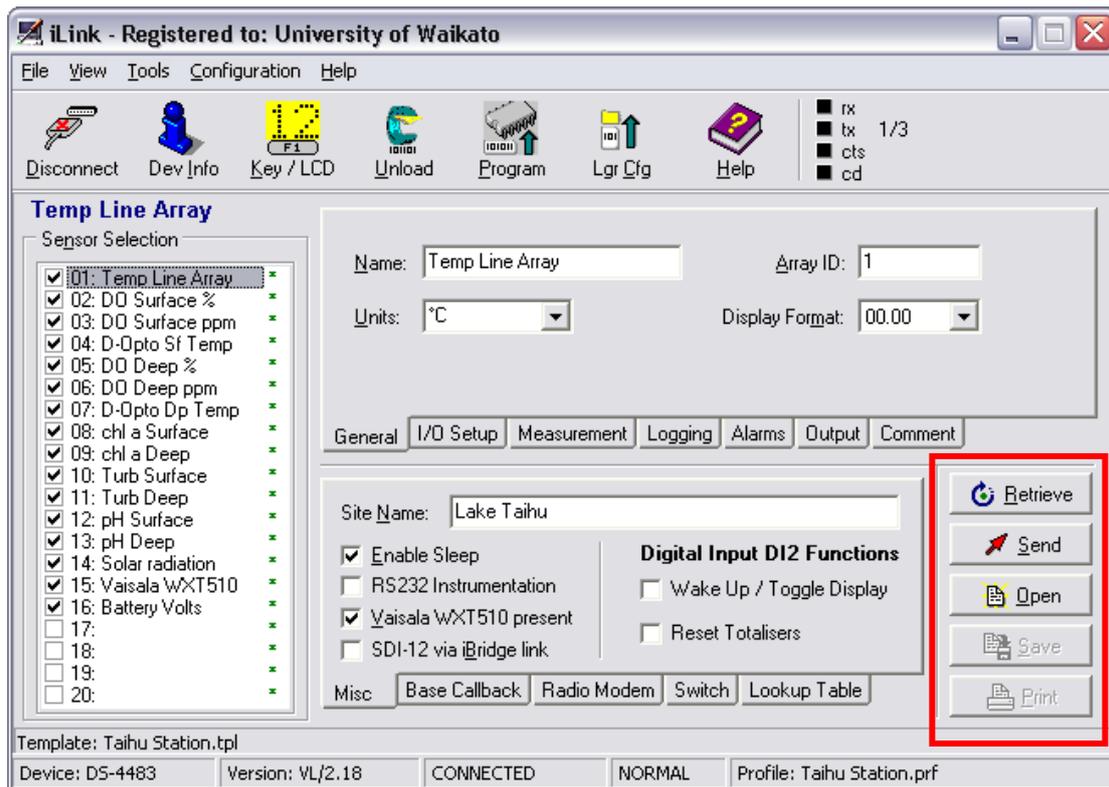
Click "Yes" to load the template, which should look like this:



- Area 1: shows all the sensors which are configured on the logger. When the box to the left of the sensor is ticked, the sensor is active. If unticked, the sensor is disabled.

-Area 2: Stores all information specific to each sensor. The measurement tab is particularly useful for calibrating the sensors. Please see the Section 3 for information on how to calibrate each sensor.

-Area 3: Shows communications settings and should not be altered, unless under specific instructions.



- Retrieve: Pressing this button will retrieve and load all the settings from the logger.
- Send: This will send the settings made on the computer to the datalogger. If you have made changes (for example to a calibration offset and multiplier), you must press “send” before they will take effect.
- Open: Can be used to open a new template. This button should not be used for operating the Taihu station.
- Save: After making changes and sending them to the logger, it is important to save the new settings on the computer. This way, both logger and computer should have the same settings saved before you disconnect them from each other.
- Print: This should not be needed.

iCE³ GPRS modem

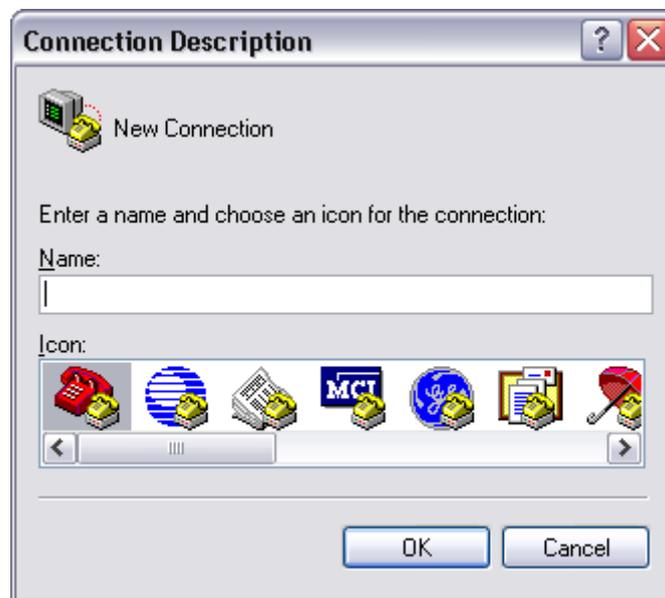
Configuring the modem

The iQuest iCE³ GPRS modem is configured correctly to transmit data from the datalogger every 10 minutes to the HydroTel database. It should not require any maintenance.

However, if for any reason the modem appears to stop communicating with the database, the following troubleshooting guide should help to diagnose the problem.

Problem: *No new data is being transmitted to the internet.*

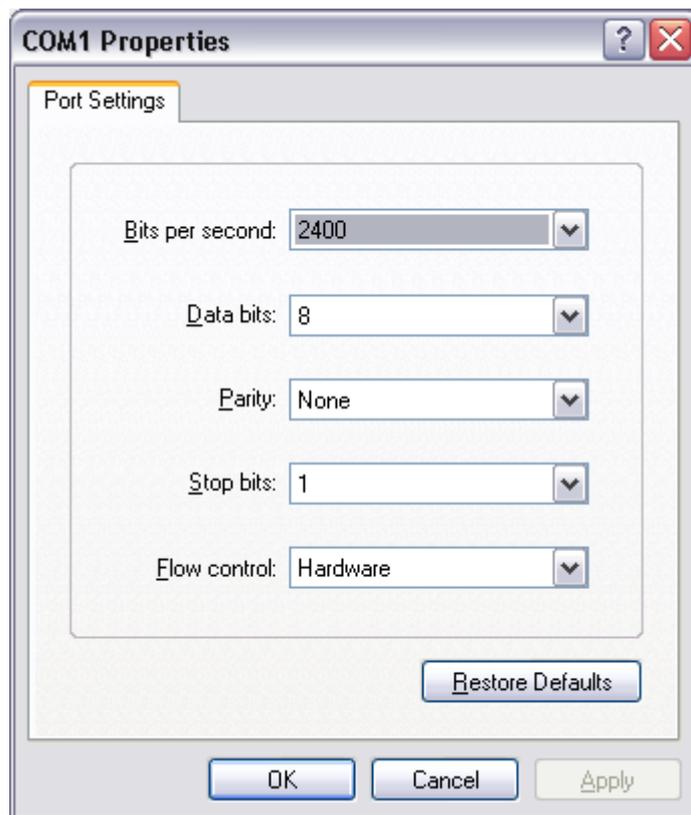
1. Wait for a few hours, to see if any new data appears. Occasionally there will be short outages of the iQuest servers while maintenance or upgrades are being performed. If you wish to check this, contact Chris McBride (University of Waikato, see appendix for contact details).
2. Check the blue LED light of the modem. When idle, it will flash once every few seconds. When trying to connect to GPRS, the modem will quickly flash twice every few seconds. If the modem goes for >10 minutes without changing to the double flash pattern, it is not trying to go online and there may be a configuration problem.
3. Unplug the modem from the datalogger, and connect your computer to the modem cable using your serial adapter. In Windows, click [Start>Programs>Accessories>Communication>Hyperterminal](#).



Name the connection (e.g. “Taihu modem”)

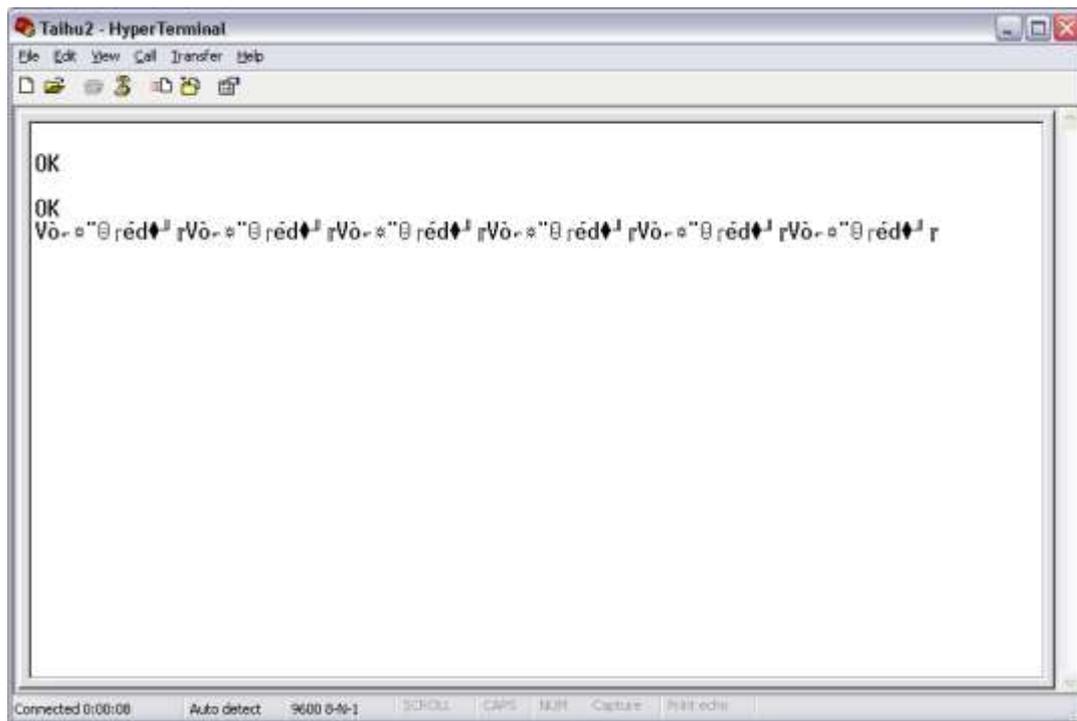


From the drop down menu at the bottom, select com1.



Change “Bits per second” to 9600. Change “Flow control” to “None”. Click OK.

You should see a window like this:



The mixed symbols (e.g. V•© " " Ú, etc) simply means the modem is trying to connect to the database. If it isn't trying to connect you will not see any symbols.

Try typing "at". If no characters appear, you must take the modem offline by holding down shift and pressing the + key 3 times.

You should now be able to check the settings of the modem by typing the command:
at^idas?

Here is how the settings should be:

```
OK
^IAPN: "cmnet" ← GPRS network
^IDFC: 0
^IDTO: 20 ← IDTO should be 20
^IHDT: 0 (Normal)
^IHPS: 9600,"8N1"
^IIPA: 1,"0.0.0.0","255.255.255.255"
^IIPA: 2,"0.0.0.0","255.255.255.255"
^IIPA: 3,"0.0.0.0","255.255.255.255"
^IIPA: 4,"0.0.0.0","255.255.255.255"
^IIPA: 5,"0.0.0.0","255.255.255.255"
^IIP: "10.143.169.223" ← This is the cmnet IP address, and will change every time the
modem connects
^IPTI: 120 ← IPTI should be 120
^IPWD: "guest" ← This is the cmnet password, should be "guest"
^IRIP: "203.190.210.84",7780 ← This is the Quest IP address, and should be set to the numbers
Shown here
^IRTS: 1
^ISDA: 290 ← Should be 290
^ISNO: AE0-0217 ← Modem serial number
^IUID: "guest" ← This is the cmnet userID, should be "guest"
^IVER: 1.15
OK
-
```

If the settings you see are different to those above, you need to re-configure the modem with the above settings. To change a setting type:

`at^(four letter code)=(new value)`
e.g. `at^iapn="cmnet"`

To check that the settings have been applied, type:

`at^(four letter code)?`
e.g. `at^iapn?`

Change all the necessary settings until your settings match those shown above.

Type : `at^iace=2`

This will make sure the modem is set to go online with a dynamic IP address.

Close Hyperterminal (save the connection for future use) and re-connect the modem to the datalogger. Data should now transmit.

If you are still having problems, please contact Chris McBride (University of Waikato, New Zealand).

Changing the frequency of data transmission

Connect to the modem using Hyperterminal, as described in the above section.

Take the modem offline by holding down the shift key and pressing the + key three times quickly.

Type: `at^iacs?`

You should see something like:



```
Taihu modem - HyperTerminal
File Edit View Call Transfer Help
at^iacs?
^IACS: 0,2359,180,10,0
OK
```

The 3rd and fourth numbers represent the number of seconds the modem stays online for, and the number of minutes between data transmission. To change the frequency, type:

`at^iacs=0000,2359,(seconds online),(minutes between),0`

e.g. `at^iacs=0000,2359,300,20,0` would put the modem online for 300 secs (6 mins) every 20 minutes.

You can check your new settings by typing: `at^iacs?`

3. Maintenance

Buoy: Battery

The battery used for the Taihu station should be a 12-volt, sealed lead-acid battery (also called a “gel cell”) with a capacity of 40 amp hours or greater. This type of battery does not require regular maintenance. It is, however, important not to let the battery drain to <11.5 volts, as this will damage the capacity of the battery to re-charge.

Pier: UPS and voltage converter

The UPS and voltage converter supply continuous DC power to the monitoring system. The trimpot on the voltage converter should be set to supply ~12.5V DC at the datalogger. Take care that the connections at the UPS and voltage converter cannot short-circuit.

Vaisala WXT510 weather station

The Vaisala weather station is considered stable and should not require regular maintenance. Refer to the manual (appendix 4) for more information.

Apogee Pyranometer

The Apogee pyranometer is factory calibrated. The effect of temperature on the sensor output is minimal (<1% between 5 and 40°C). The output of all radiation sensors tends to decrease over time as the detector ages. The average decrease of the Apogee sensor is 1 to 2 % per year. Do not attempt recalibration without a radiation standard. Apogee recommends that you send your sensors in every 3 years for recalibration. See the manual (appendix 6) for more details.

Nexsens TS110 thermistor string

The TS110 thermistor string has a stable output and should not require regular maintenance. If a thickIf desired, the sensor may be returned to the factory every three years to check the accuracy of the thermistors.

Seapoint chlorophyll and turbidity fluorometers

These sensors are very stable. According to the manual, the lamp intensity would reduce by 10% after 5000 hours use. The fluorometer lamps are configured to be in operation less than 100 hours per year (10 seconds operation every 15 minutes). Theoretically, this results in a decrease of ~0.2% per year.

The most likely cause of error with these fluorometers is bio-fouling. The optical windows of the sensors should be regularly checked for algal growth and snails. If bio-foul is present, clean the windows with a soft, non-abrasive pad, such as those supplied with the D-opto sensors. Do not touch the optical windows with your fingers.

It is important to remember that fluorometers provide only a millivolt response. Various algae and partical types, as well as intense sunlight, will cause differing responses from these instruments. It is important to collect regular water samples for solvent extraction chlorophyll lab analysis for comparison.

Background information

These sensors produce an output of 0-5 volts. Each sensor has four gain (sensitivity) settings, which are set using the green and red wires of the cable. Hardwiring the gain does not require an external voltage source. *To hardwire a line to +5V, simply leave it open, which allows an internal pull-up to hold it at +5 VDC. To set a line to 0V, tie it to the power ground.*

Cable colour codes

white: Power Ground
black: Signal Output
blue: Signal Ground
orange: Power In
green: Gain Control A
red: Gain Control B

Table 3. Wiring configuration for setting gain for the Seapoint fluorometers.

Green	Red	Gain	Range	Multiplier	
<i>Chlorophyll</i>					
0 V	0 V	1X	0.033	300 µg/l	60
0 V	+5 V	3X	0.1	100 µg/l	20
+5 V	0 V	10X	0.33	30 µg/l	6
+5 V	+5 V	30X	1 V	10 µg/l	2
<i>Turbidity</i>					
0 V	0 V	1X	0.033	n/a	
0 V	+5 V	5X	0.1	500 FTU	100
+5 V	0 V	20X	0.33	125 FTU	25
+5 V	+5 V	100X	1 V	25 FTU	5

The range of the instruments has been set to reflect the expected ranges observed in Taihu. For chlorophyll *a*, the gain has been set at 3x, and at 5x for turbidity. It is important to remember that without calibration to lake water, the response of the fluorometers is a voltage only. Therefore, a change in gain is only required if:

- the fluorometer is “peaking” i.e. frequently returning the maximum (equivalent to 5V) response, or
- the range of values observed are within the lower region (equivalent to 0-1V) of the sensor’s output.

If a change in the gain settings is required, simply connect the appropriate coloured cable to the 6-pin connector at the end of the sensor cable. This will tie it to the ground circuit of the datalogger.

It is not advised to calibrate the fluorometers using the datalogger coefficients! Rather, collect water samples for lab analysis, and if desired calibrate during post-analysis of the data.

D-opto dissolved oxygen sensors

Compared to other types of dissolved oxygen sensors, the D-opto sensors are extremely stable. They may require re-calibration every 1-2 months, however, they can remain stable for much longer periods.

The most likely cause of error with these sensors is bio-fouling. The optical windows of the sensors should be regularly checked for algal growth or snails. If bio-foul is present, clean the windows with a soft, non-abrasive pad, such as those supplied with the D-opto. Do not touch the optical windows with your fingers.

Calibrating D-opto sensors

Materials required

Bucket of water

Oxygen pump

Sodium Sulfite (if two-point calibration is needed).

Calibration process:

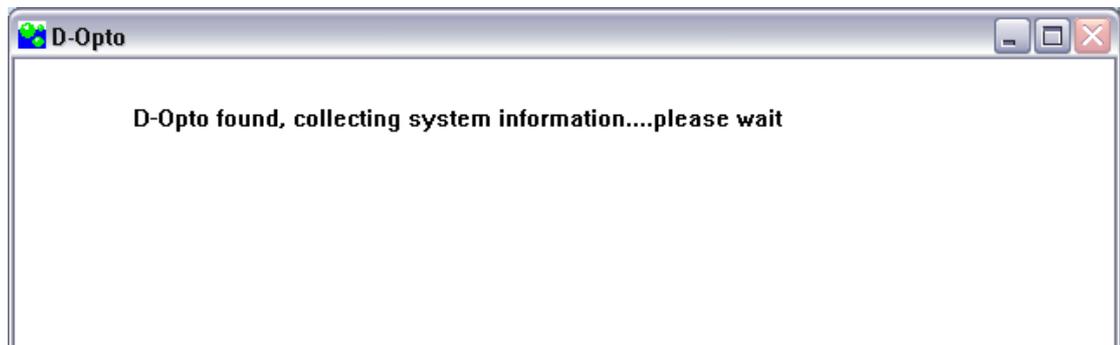
Calibrating the D-opto sensors is relatively easy, and does not require the use of iLink.

1. The D-opto connector boards (Fig. 3) have a available DB-9 port (9-pin serial connector). Connect your computer to this port using the serial cable, and open the D-opto sensor software (“DoptoCom”). Select the correct com port (and SDI-12 address if required) for communication and connect to the sensor.

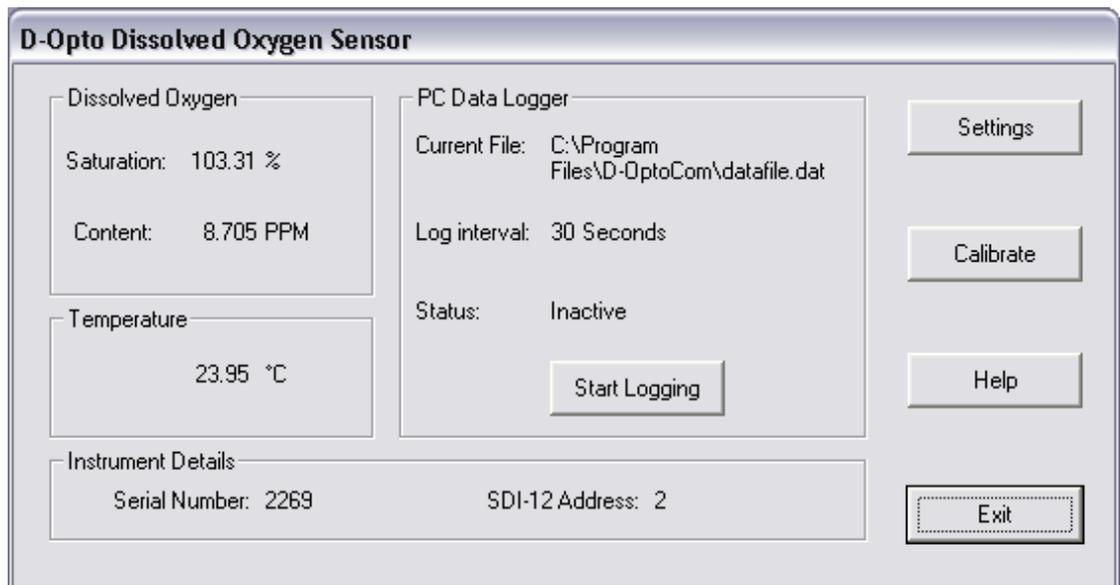
Surface sensor: SDI-12 address **1**

Deep sensor: SDI-12 address **2**

You should see the following screens:



Then...

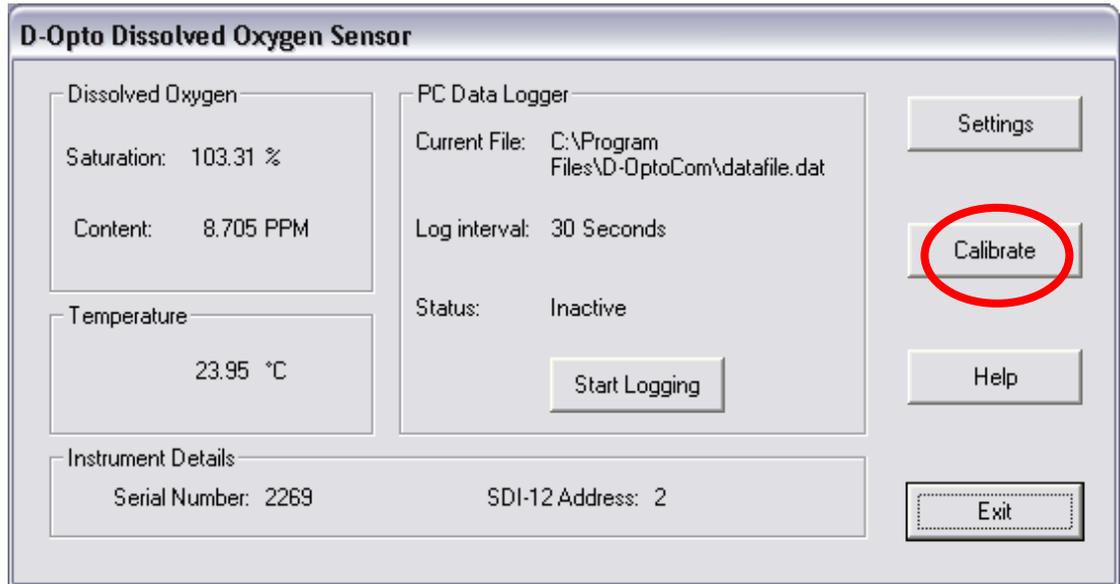


2. Fill a bucket with clean water (**not** lake water if possible) and use the air pump to aerate the water to saturation (at least 10 minutes). Check that the optical window is free of biofoul (if not then clean it with a soft, non-abrasive sponge) and place the sensor in the bucket. Allow the sensor to attain a stable reading.

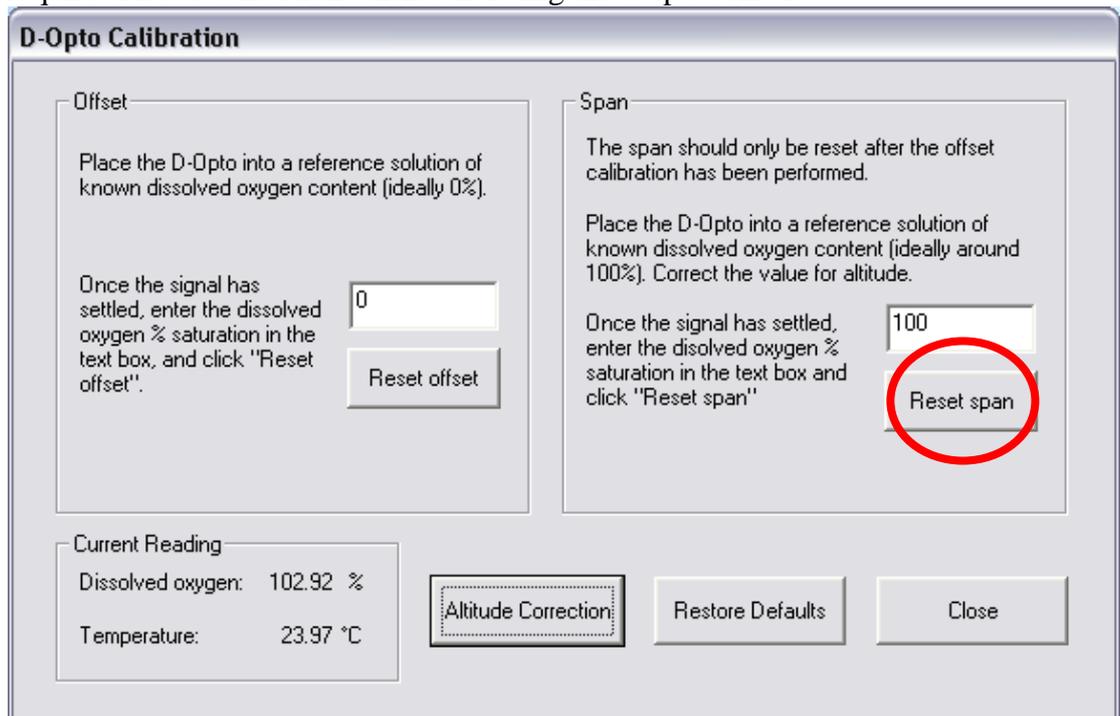


Optical window

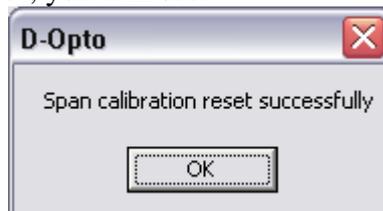
3. Click the “calibrate button”.



4. Once the reading from the sensor is stable, click the “reset span” button. This will re-calibrate the d-opto at 100% saturation. The Taihu station does not require altitude correction when calibrating the d-opto sensors.



5. If the calibration is successful, you will see:



6. If you wish to perform a 2-point calibration: place a teaspoon of Sodium Sulfite in a small bucket of water and stir. This should consume all oxygen in the water within about 5 minutes. Place the sensor into the de-oxygenated water, allow the reading to stabilise, and then press “reset offset”. This will recalibrate the d-opto for 0% saturation.

7.

D-Opto Calibration

Offset

Place the D-Opto into a reference solution of known dissolved oxygen content (ideally 0%).

Once the signal has settled, enter the dissolved oxygen % saturation in the text box, and click "Reset offset".

0

Reset offset

Span

The span should only be reset after the offset calibration has been performed.

Place the D-Opto into a reference solution of known dissolved oxygen content (ideally around 100%). Correct the value for altitude.

Once the signal has settled, enter the dissolved oxygen % saturation in the text box and click "Reset span"

100

Reset span

Current Reading

Dissolved oxygen: 102.92 %

Temperature: 23.97 °C

Altitude Correction

Restore Defaults

Close

Resetting the offset using this method should be required less often than the 100% calibration. After a few months of testing, it should be clear how often calibration must be performed.

TempHion T2 pH sensors



The TempHion pH sensors have a “reference electrode” (underneath the white cap) and a “sensing electrode” (the glass hemisphere set into the steel case). The reference electrode should be filled with reference solution. The sensing electrode is exposed to the lake water. The T2 sensor also has a thermistor (temperature sensor), however, this is not used for the Taihu station. The following is a guide to the maintenance and calibration of the pH sensors. Please read the manual for more detailed information into the operation of the pH sensors.

Calibrating the T2 Sensors

Replacing the reference solution

Every 1-3 months, it will be necessary to replace the reference solution of the T2 sensors.

1. Unscrew the white cap and empty the old solution. Thoroughly rinse the electrode, and the inside of the cap with distilled water, and allow them both to dry completely.
2. Place 12-15 drops of fresh reference solution (no more than 15 drops) into the white cap. Holding the sensor and cap upright, screw the white cap back onto the end of the sensor. As the cap becomes tight, reference solution should spill over the top of the cap. Screw the cap on firmly, but do not over-tighten.
3. *Wash your hands if they have come into contact with the reference solution.*

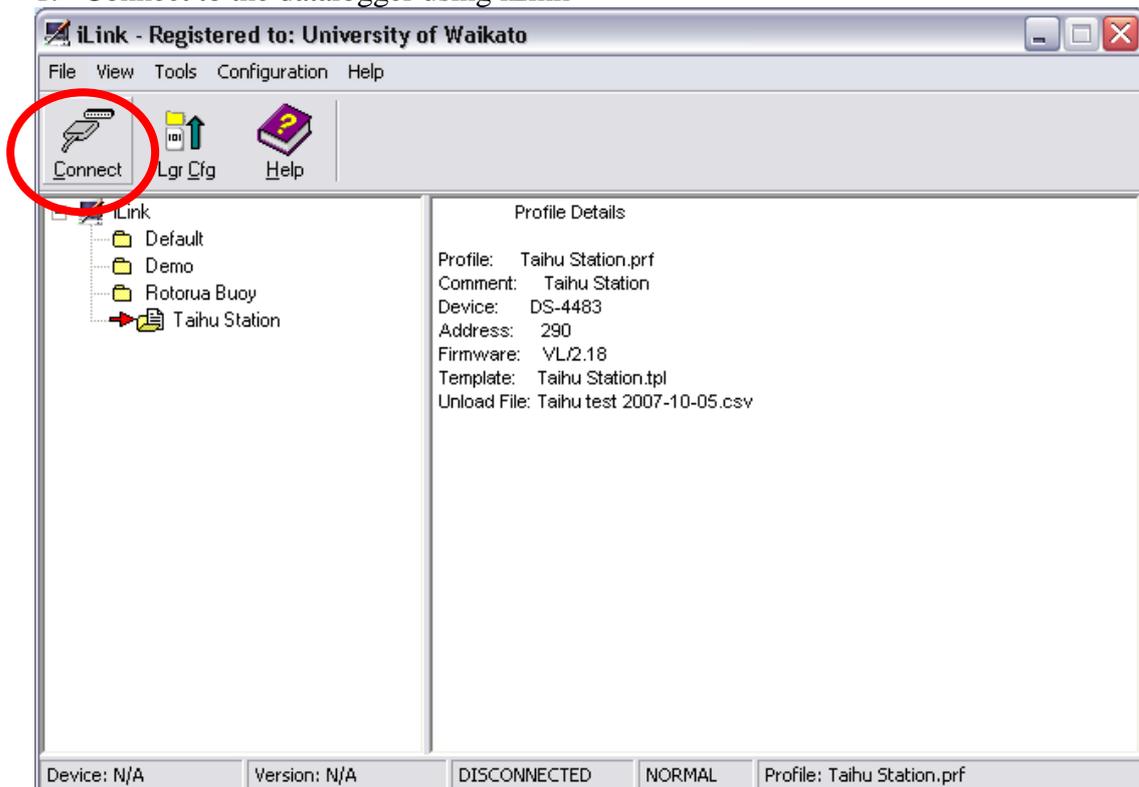
Calibrating the T2 sensors

Materials required:

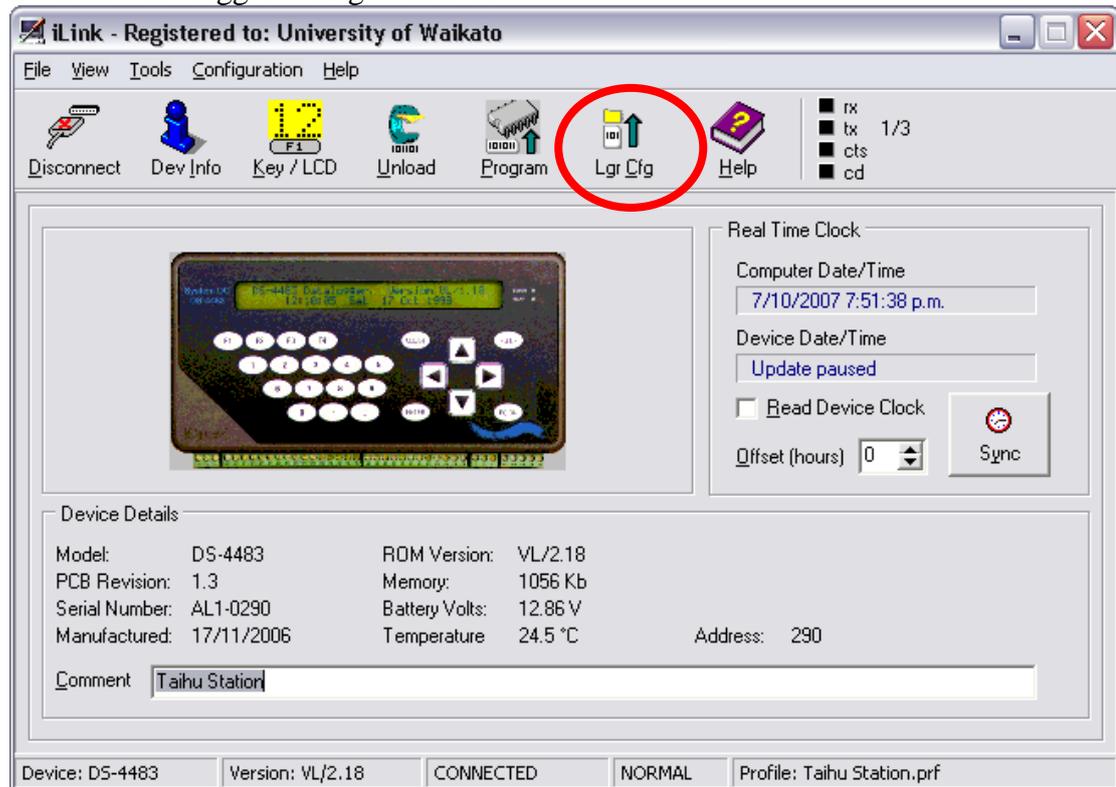
- pH buffer solutions: Two or three pH buffer solutions than cover the range of pH likely to be observed in Lake Taihu (i.e. ~pH5 – pH10)
- A squirt bottle of distilled water
- Cylinders in which to place the buffer solutions

Calibration process

1. Connect to the datalogger using iLink

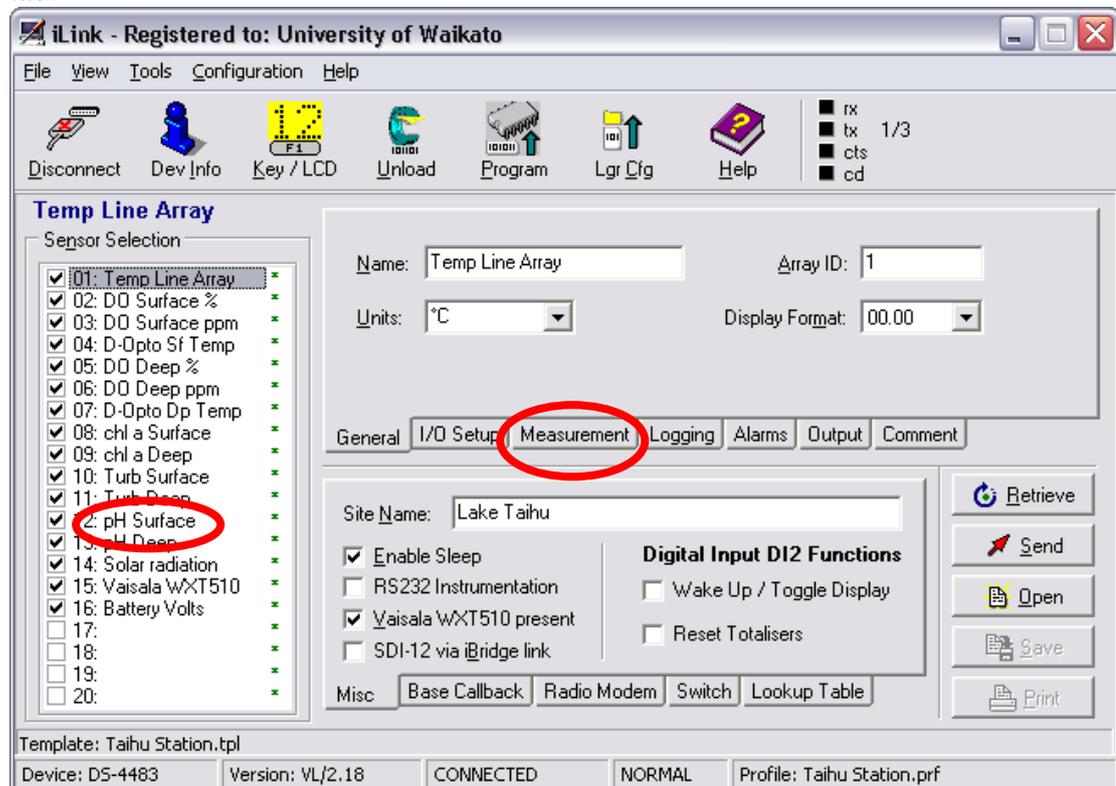


2. Select the logger configuration tab

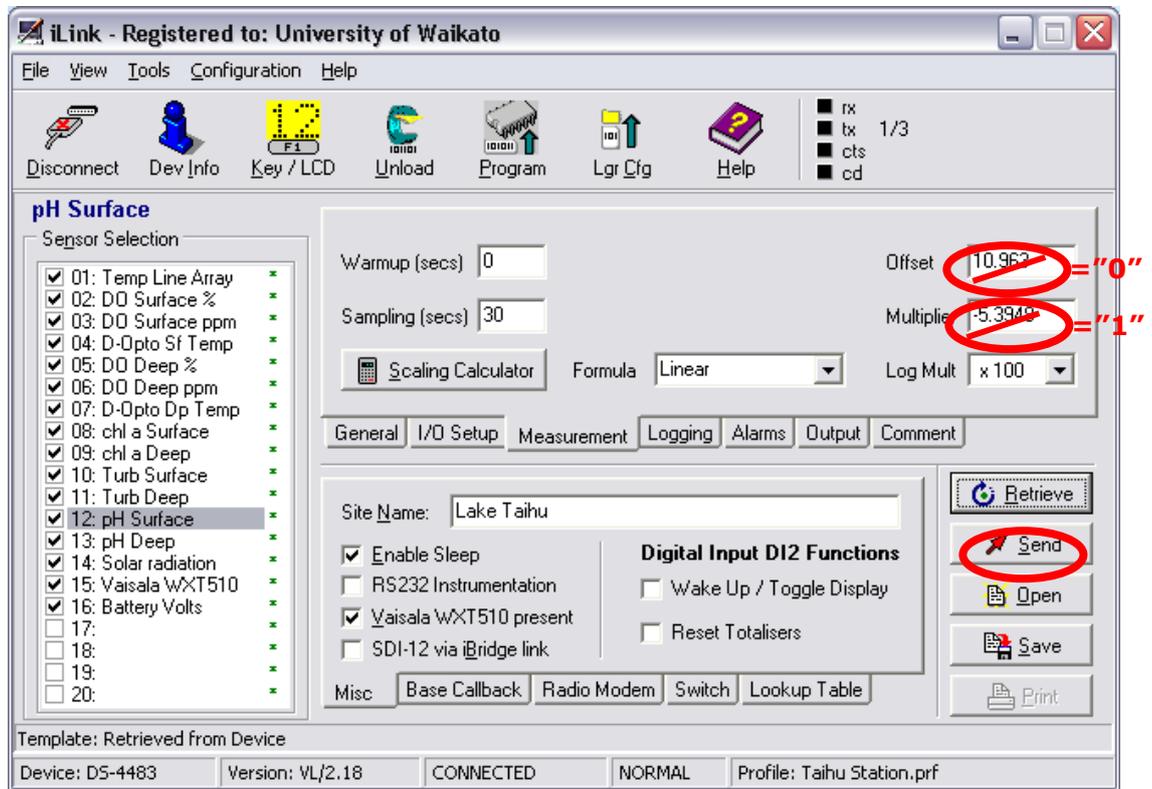


Click "Yes" to open the template file for Taihu station.

3. Select the appropriate sensor at the left hand side and select the measurement tab.



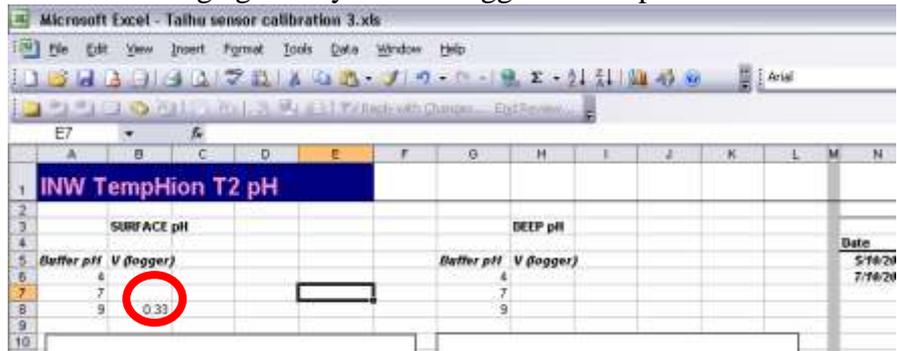
- Replace the offset value with 0. Replace the multiplier value with 1. Next, click send. This removes the previous calibration so that the logger will display the actual voltage signal from the sensor.



- Rinse the sensor with distilled water. Then rinse the sensor with the highest pH buffer solution you will use (i.e. if using pH 4, 7 and 10 solutions, use pH10 first).
- Fill one of the cylinders with the same value pH buffer solution, and immerse the sensor, making sure that there is enough solution to cover the sensing electrode. Allow the reading to stabilise.
- Open the Excel spreadsheet “Taihu sensor calibration.xls”, and select the “pH” tab. Enter the values of pH buffer solution you are using under the heading “Buffer pH”.

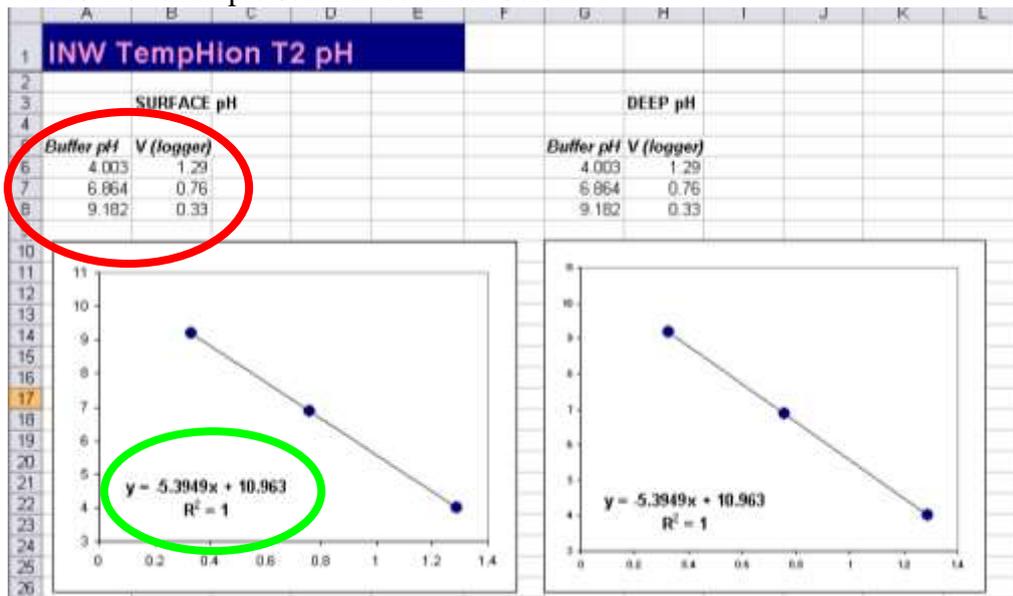
INW TempHion T2 pH									
SURFACE pH					DEEP pH				
Buffer pH (logger)					Buffer pH (logger)				
	4					4			
	7					7			
	9					9			

- Enter the voltage given by the datalogger for the pH buffer solution.



- Remove the sensor from the buffer solution. Rinse it with distilled water, and then rinse with the next highest pH buffer solution. Place the sensor in a cylinder of the new pH buffer, allow the reading to stabilise, and then enter the voltage observed into the spreadsheet. Repeat this process for the last pH buffer value (i.e. the lowest pH buffer solution). If you are using the same cylinder, be sure to rinse in between uses with both distilled water and some pH buffer of the value about to be tested.

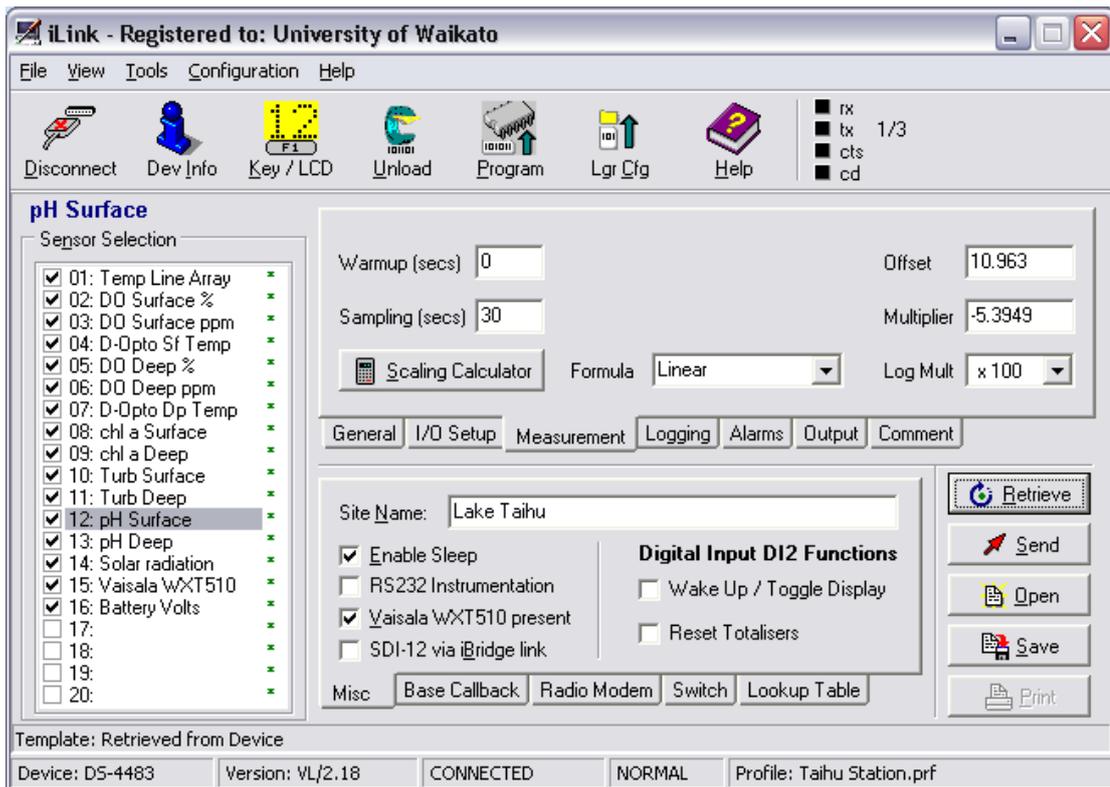
You should now have three voltage results for three different buffer pH values. For example see the red circle below:



The spreadsheet will automatically plot the calibration and give a regression equation. This equation provides the offset and multiplier to be applied to the datalogger (green circle).

- The offset is the intercept (in this example, 10.963)
- The multiplier is the slope, (in this case, -5.3949)

- In iLink, return to the “Measurement” tab, and enter the new offset and multiplier. Click “send”. This will update the information stored on the logger. Click “save” so that the changes are also stored in the iLink template file on the computer.



11. Repeat the process for the other pH sensor (alternatively, you may wish to calibrate both sensors at the same time, using two cylinders of buffer pH solutions).

4. Conclusion

With regular maintenance and calibration, the Taihu monitoring station should provide many years of reliable data on the water quality and meteorology of Lake Taihu.

If you have any questions regarding the operation or maintenance of any of the electronics or sensors, please contact one of the people listed as contacts in Appendix 1.

5. Appendices

1. Contact details for more information or technical assistance with the Taihu Station.
2. D-opto dissolved oxygen sensor manual
3. Seapoint chlorophyll fluorometer manual
4. Seapoint turbidity sensor manual
5. Vaisala WXT510 manual
6. iQuest DS-4483 manual
7. Apogee pyranometer manual
8. Nexsens TS110 thermistor string manual
9. Documentation CD copy

Appendix 1. Contact details for assistance

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