NETLAKE

NETLAKE Guidelines for Automatic Monitoring Station Development

Working Group 1: Data Acquisition and Management

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Introduction

NETLAKE guidelines for automatic monitoring station development

Are you interested in setting up some automatic monitoring for a waterbody you are interested in, but do not know where to start? This set of guidelines provides useful information on the practicalities of deploying and maintaining automatic monitoring stations (AMS) in lakes and reservoirs. The guidelines have been developed and reviewed by members of the NETLAKE group who have many years' experience in automatic monitoring. The subject areas were chosen after a NETLAKE member-wide survey, where people were asked about the main stumbling blocks to setting up their AMS. Before you start, you should ask yourself a couple of questions, the answers to which will help you design your AMS and decide on its form and function:

- Why do you want to conduct high frequency monitoring (HFM)?
- How much time and technical support do you have?
- Do you have GPRS coverage?
- Where will you put it?
- What is the bathymetry of the waterbody in question like?
- What depth of water is there?
- What is the prevailing wind direction?
- Will there be security issues?
- Is the water body used for water abstraction?

These factsheets were developed within working group 1 (Data Acquisition and management) of the NETLAKE COST Action (ES1201), supported by COST (European Cooperation in Science and Technology). NETLAKE ran between 2012 and 2016.

NETLAKE guidelines for automated monitoring system development

001 Options for buoy design

Objective

In this factsheet, we describe some of the options that can be used to house an automatic monitoring station (AMS) on a lake.

AMS types

Automatic monitoring stations (AMS) can be divided into two different types:

- Fixed AMS – in which the aquatic monitoring sensors are fixed in position relative to the water surface or relative to the lake bottom using an immobile structure, and meteorological sensors are fixed on a solid structure.
- Floating AMS – in which the monitoring sensors are attached to a floating device that is anchored in position.

Considerations

The selection of station types and configuration depends mainly on the settings of the monitoring location and the design requirements to comply with the monitoring objectives and data quality. Some considerations might be:

Sampling depth	Duration of monitoring (duration of project)
Water depth	Set-up cost
Wind (speed, direction)	Maintenance cost
Wave action	Safety-Security for personnel and equipment
Tidal range (if applicable)	Water activity near the location (i.e. water sports)
Seasonal water levels	Are there existing structures in the location?
Bio-fouling potential	Data transfer possibilities
Site accessibility	Permits
Interference from animals or plants	Concerns from local community or interested parties

Examples of fixed AMS

- **Designed structure** – designed by the user to fulfil the monitoring needs – generally deployed offshore, with sensors placed in a fixed vertical position, sits on and is fixed to the lake bottom (Fig. 1).
- **Existing structure** – where a bridge, island, pier or wall already exist at the monitoring site and the user takes advantage of them to fix the monitoring station – sensors generally placed in a fixed vertical position (Fig. 1). In the case of meteorological measurements, the sensors can be placed on land near to the shore (Fig. 2).
- **On a river bank structure** – located on or close to the river or stream bank – sonde generally placed on an angle to the waterbody monitored
  - **Without equipment shelter** (e.g. anchored pipe)
  - **With equipment shelter** (flow-through and sensor in-situ AMS)

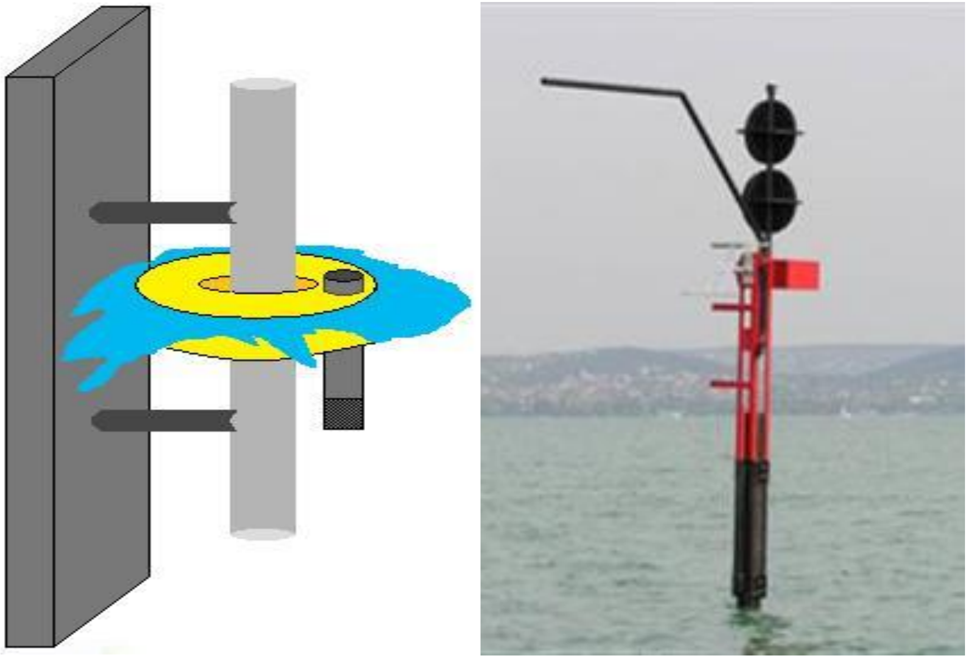

Figure 1. Aquatic fixed automated monitoring systems. Designed structures (left) and fortuitous use of exisiting structures (right) are two options.

Figure 2. A terrestrial fixed automated monitoring system comprising several meteorological sensors.

Examples of floating AMS

- **Buoy** – two basic designs
  - **Surface –** this is the most common design, being relatively simple to procure and deploy (Fig. 3). Most surface AMS are based on the idea of a large float, anchored in two or more places (Fig. 6).
  - **Subsurface -** where you have navigational hazards or security issues, and you don't want the station to be conspicuous, consider anchoring the sensors from the bottom (Fig. 4). This may also be useful where water fluctuations are large, or when issues associated with lake ice want to be avoided. Subsurface moorings are also less affected by surface waves, which can be important when measuring water currents or turbulence.
- **Platform** – when you need a bit more space to enable housing more extensive systems, consider having a larger platform (Fig. 5). These offer protection from the weather and a large workspace, but are harder to moor and may be less resistant to stormy weather than a buoy.

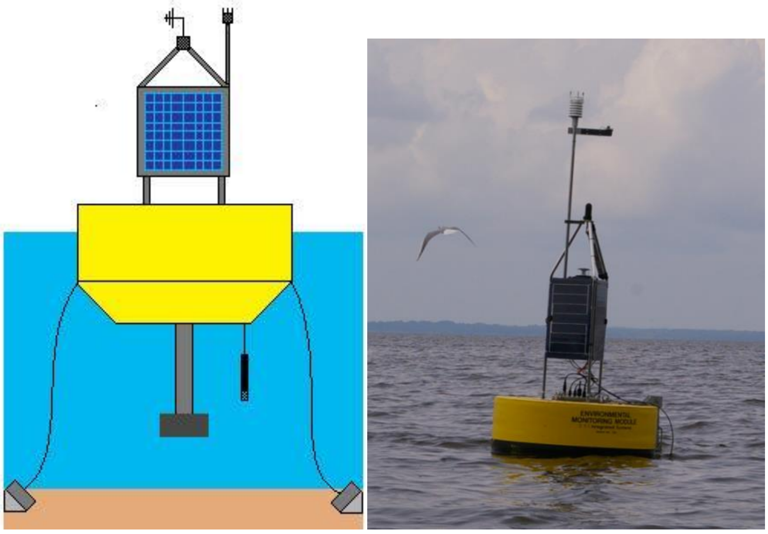

Figure 3. Surface automated monitoring system.

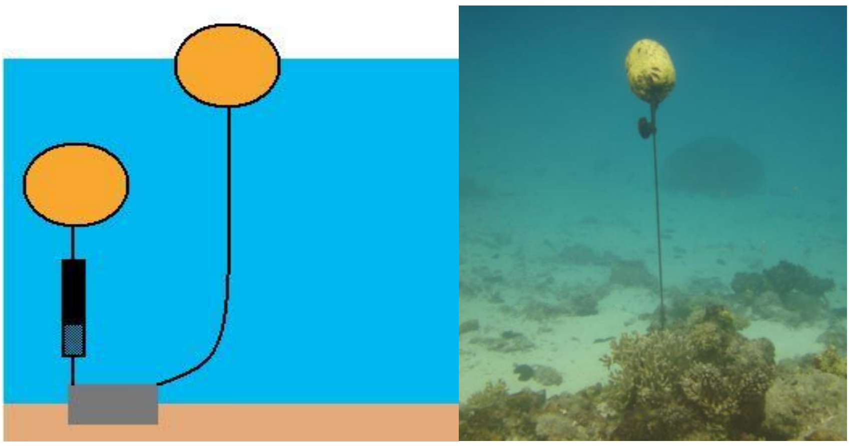

Figure 4. Subsurface automated monitoring system.

Figure 5. Floating platform as an automated monitoring station.

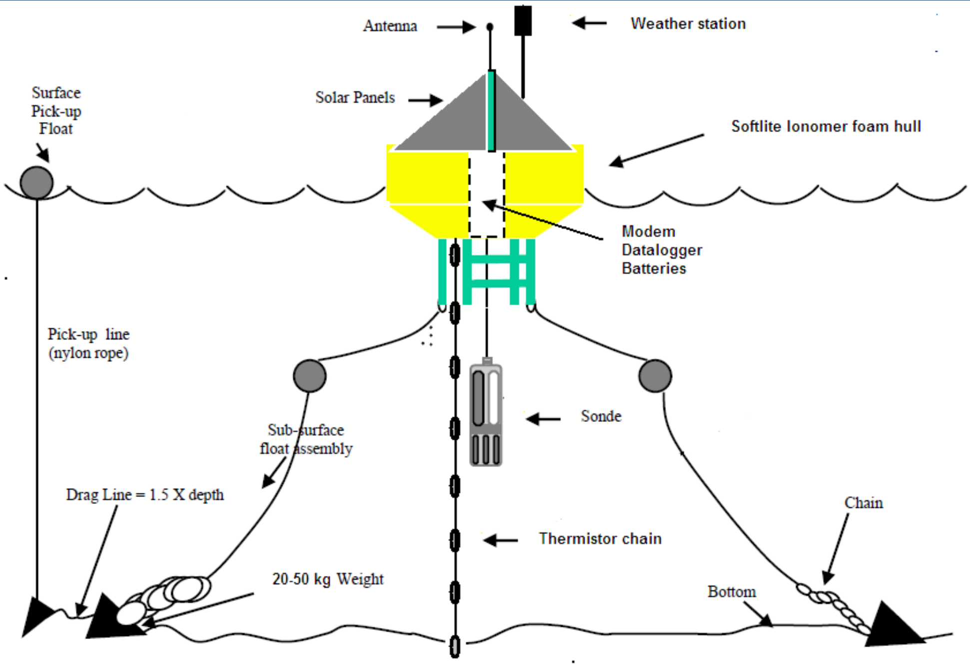

Figure 6. An example of a surface automated monitoring station.

Likely Problems

- Underestimating your water body, and deploying a system that is not suitable for the weather conditions. Bear in mind that, in very extreme conditions, a simple rope and buoy system (potentially subsurface) may be more resilient than a larger station.
- If you are likely to have a problem with birds using the station as a roost, try deterrent devices.
- If you suspect that the station will be prone to vandalism, you should either make it as

inconspicuous as possible (subsurface), or else use a platform design that can have a lock.

More information

http://www.vims.edu/cbnerr/resources/guidelines_shallowwater.php

Suggested citation: Laas, A., Pierson, D., de Eyto, E. and Jennings, E. 2016. Options for buoy design (Factsheet 001). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 2-6. http://eprints.dkit.ie/id/eprint/508

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NETLAKE Guidelines for automated monitoring system development

002 Cost options

Objective

In this factsheet, we describe some of the cost options that will determine your buoy configuration.

Considerations

1. Consider the pros and cons of purchasing a complete system vs individual system components as described below.
2. **Are you bound by public procurement guidelines?** If so, you need to be very clear about your requirements so you can compare like with like in the case of a tendering process.
3. **Data technicians on site?** If not, you might want to include data acquisition and storage in the request for quotes.
4. **Electronic engineers on site**? The advent of open source electronics (e.g. Raspberry Pi) makes it possible for homemade systems to be constructed cheaply, with the right expertise.
5. **Technical support?** Many AMSs contain homemade infrastructures (i.e., monitoring floats, instrument houses), constructed from materials bought in local hardware shops. The feasibility of doing this is determined by the technical know-how in your team
6. **How much do you have to spend?** Useful data can be collected from a variety of stations ranging from single parameter submersible sensors with an in-built data logger to a complete off the shelf monitoring station with a multi-parameter sonde. If you only have a small budget, you can still make inventive use of lower cost instrumentation.
7. **Do you want an off the shelf option?** This can be an easy to use option, with much of the design and engineering options optimized for the specific station design. But perhaps you want to be able to add and subtract sensors, not be locked into the use of sensors from only one manufacturer, and customize your platform according to specific needs? To develop custom configurations using mixed instrumentation you may need to build it piece by piece.
8. **Do you want the data hosted by a private company?** Many monitoring companies offer this, perhaps at a cost. Consider whether you want to have duplicate copies of data on you own servers.
9. **Do you have the IT infrastructure to host the data internally**? This is another option to 8 above, if you have the infrastructure (e.g. a server large enough to store the data), and the technical staff to maintain and archive the data.
10. **Do you want to be able to access the data remotely?** Being able to see real time data has significant advantages (e.g. management use, identification of problems). However, frequent data download can be expensive depending on communication options and data transmission cost. This cost needs to be considered at this stage if it's required.
11. **Are you leaving it in situ long term (i.e. > 6 months)?** If so, you may need a more expensive system, with larger moorings, better weather proofing, powering options etc.
12. **Self-cleaning options** will decrease maintenances costs but may impact on your power supply. In most situations, self-cleaning is a good idea if possible.

13. **Profiling system or just one depth and thermal chain.** Profiling systems provide a picture of the vertical variations in the measured parameters. However, these systems are much more expensive, and their mechanical nature is more prone to failure and therefore, requires a greater level of maintenance. The winch in profiling systems also requires significant power which can limit the frequency of profile measurements. Careful consideration between the costs and advantages of profiling systems versus multiple fixed depth sensors should be considered and are further discussed in AMSD guideline 010: Depth of sensor deployment.

Examples

A low cost option is described in AMSD guideline 003: how to deploy a low cost option.

Costs can be lowered if you have in-house expertise. If you don't have access to this expertise, you may be still be able to save some money by outsourcing all or part of the job, including construction, deployment, data download and storage. This is likely to be higher cost.

Here we provide some examples of costs of individual items, along with complete stations. These are indicative costs only (valid in 2016) and vary according to supplier and country of interest. For up to date costs, please ask for quote directly from several suppliers. We present here a typical price range, but actually, the sky is the limit.

- Data logger: €500-€10000 (and more depending on how many and the type of channels you need).
- Simple standalone temperature logger: €50-100.
- Standalone dissolved oxygen sensor: €1000-8500.
- pH sensor: €600-1500.
- Conductivity sensors : €500-800.
- Fluorometers (chl, turbidity, CDOM etc.): €1500-15000 (or more).
- Multi-parameter sonde: €8000-10000.
- Complete physical structure (buoy, moorings, data logger, solar panels etc.): €13000.
- Profiling winch system: €20000 – 45000.
- Weather station: €1000-2500.
- Batteries: €50-200.
- Solar panels: €100-500.
- GSM or GPRS modem: €100-2000.
- Data download: depends on data transmission costs in your country.

Likely Problems

- Not including maintenance and calibration costs in the initial estimate
- Underestimating the cost of real time data download
- Under-specifying the physical structure and moorings
- Over-specifying the station, and then not checking the quality and using the data that it is capable of producing.

More information

Here are some companies that offer complete solution. For more detailed sensor information, see factsheet AMSD guideline 009: sensor considerations.

http://www.act-us.info/database.php
http://www.observator.com/en/meteo-hydro
https://www.ysi.com/applications/source-raw-drinking-water
http://www.idronaut.it/cms/view
http://www.chelsea.co.uk/environmentalfresh-water
http://pme.com/

Suggested citation: de Eyto, E., Laas, A., Pierson, D. and Jennings, E. 2016. Cost options (Factsheet 002). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 7-9. http://eprints.dkit.ie/id/eprint/509

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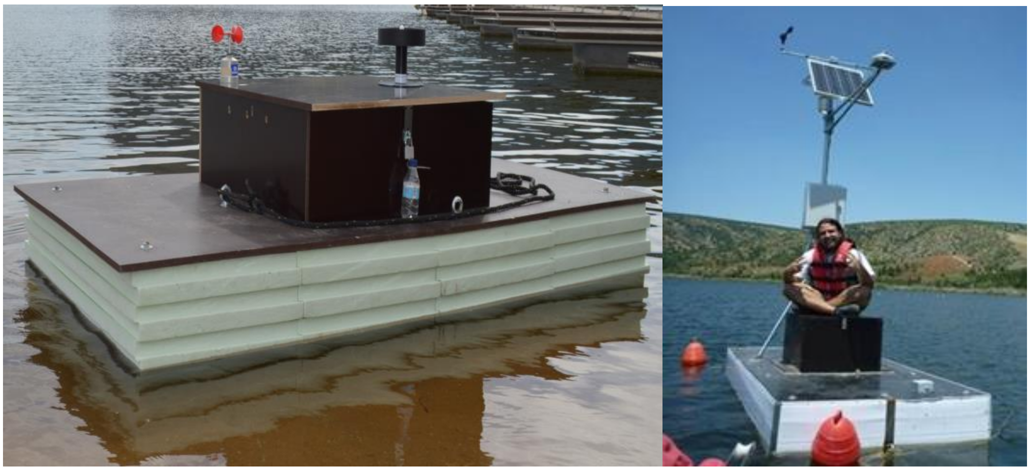
NETLAKE Guidelines for automated monitoring system development

003 How to deploy a low cost option

Objective

In this factsheet, we give an overview of one “low cost” platform system.

Examples



Same low cost platforms in Spain and Turkey.

Materials

- 3 waterproof plywood sheets (width (W) 1250 mm, length (L) 2500 mm, thickness (T) 21mm)
- 3 high density polystyrene foam sheets (W 1000 mm; L 1200 mm; T 200- 300 mm – can also be T 100-150 mm, but then you need 6 pieces and you have to glue them to get thickness needed)
- threaded rod/screw rod (diameter 10 mm) – 3.2 meters
- washers and nuts (for 10mm screw rod) – 32 pieces
- lifting loop nuts (for 100 mm screw rod) – 4 pieces (to connect ropes for anchors)
- waterproof box (1 plywood panel goes to here)
- metal corners (50x50x35x2.0mm) – 12 pieces
- door hinges – 2 pieces (for the box cover)
- glue for polystyrene foam

- screws for wood (max length 2.2mm, thickness need to fit with holes on metal corners and door hinges)
- door hooks (e.g. length 30 cm)
- waterproof padlock
- padlock hasp
- ropes and anchors
- tools (jigsaw, power cutter or grinder for metal, battery drill, spanners, ruler or water level, marker)

Construction guide

1. Cut matching centre holes in the middle of two plywood sheets – this is the hole through which your sensors will go into the lake – the size of the hole depends on your needs (Example picture 1 below).
2. Drill (drill bit diameter 12-14mm) matching holes in 8 places on both plywood panels. These are the holes through which you will insert the screw rods through the sandwich you make of the polystyrene foam plates and plywood panels.
3. Glue the polystyrene foam plates between two plywood sheets (Pic.2).
4. Use a power cutter to cut 8 equal length pieces (eg. 40 cm – depends on the thickness of your platform) of screw rod.
5. Attach the two plywood sheets (polystyrene sheets in between) together with the screw rods, secure with washers and nuts from both side of platform (Pic. 3). The rods should be well in from the corners of the platform and pass through the polystyrene. Use one screw rod on each corner and other four in the centre part of the platform (eg. around the box) to connect and fix the foam plates with plywood on more points.
6. Use lifting loop nuts on those corners and side of platform where you plan to connect your ropes for anchors.
7. Cut off the ends of the screw rod (as short, as you can) on each connection points – to avoid tripping on them when you use your platform on the lake (Pic. 4).
8. Cut the pieces from the third plywood sheet for the instrumentation box – (size of the box depends on your need for your devices; e.g. data logger, battery, connectors, additional cables, etc.).
9. Attach pieces to each other with metal corners and screws.
10. Attach the box on the top of your platform with metal corners and screws.
11. Use door hinges to connect box cover with the walls.
12. Connect the padlock hasp with the cover and front wall.
13. Connect the door hooks inside of the cover panel and side walls – this will help you to hold the cover open if you place your equipment inside of the box or you are working with your platform on the lake (Pic. 5).
14. Think about how you can hold the battery, data logger and other equipment in a stable position within the box (to avoid them moving with wave action) on your platform, if needed?
15. Make some small holes (eg. drill bit 10mm) to the box walls to avoid large temperature or pressure changes in the box.
16. Your new platform is ready to be used (Pic. 6).

Example pictures for constructions

More information

This platform (1.23x2.5m) can easily carry all equipment for water measurements and two people (one on both side) for maintenance.

Bigger platforms (1.5x3m) are more balanced and can carry up to four persons if needed.

If you need any other instructions with this platform you can directly connect Alo Laas (Alo.Laas@emu.ee)

Suggested citation: Laas, A., Pierson, D., de Eyto, E. and Jennings, E. 2016. How to deploy a low cost option (Factsheet 003). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 10-13. http://eprints.dkit.ie/id/eprint/510

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NETLAKE Guidelines for automated monitoring system development

004 How to moor a long term station

Objective

In this factsheet, we describe three examples of how to moor an automatic monitoring station

Considerations

The mooring design depends on:

- Depth of water
- Likely wind speeds and direction
- Longevity of deployment (days or year?)
- The total weight of equipment
- Buoyancy of the platform
- Cost
- Ease of access (how big a boat can you use for the deployment?)

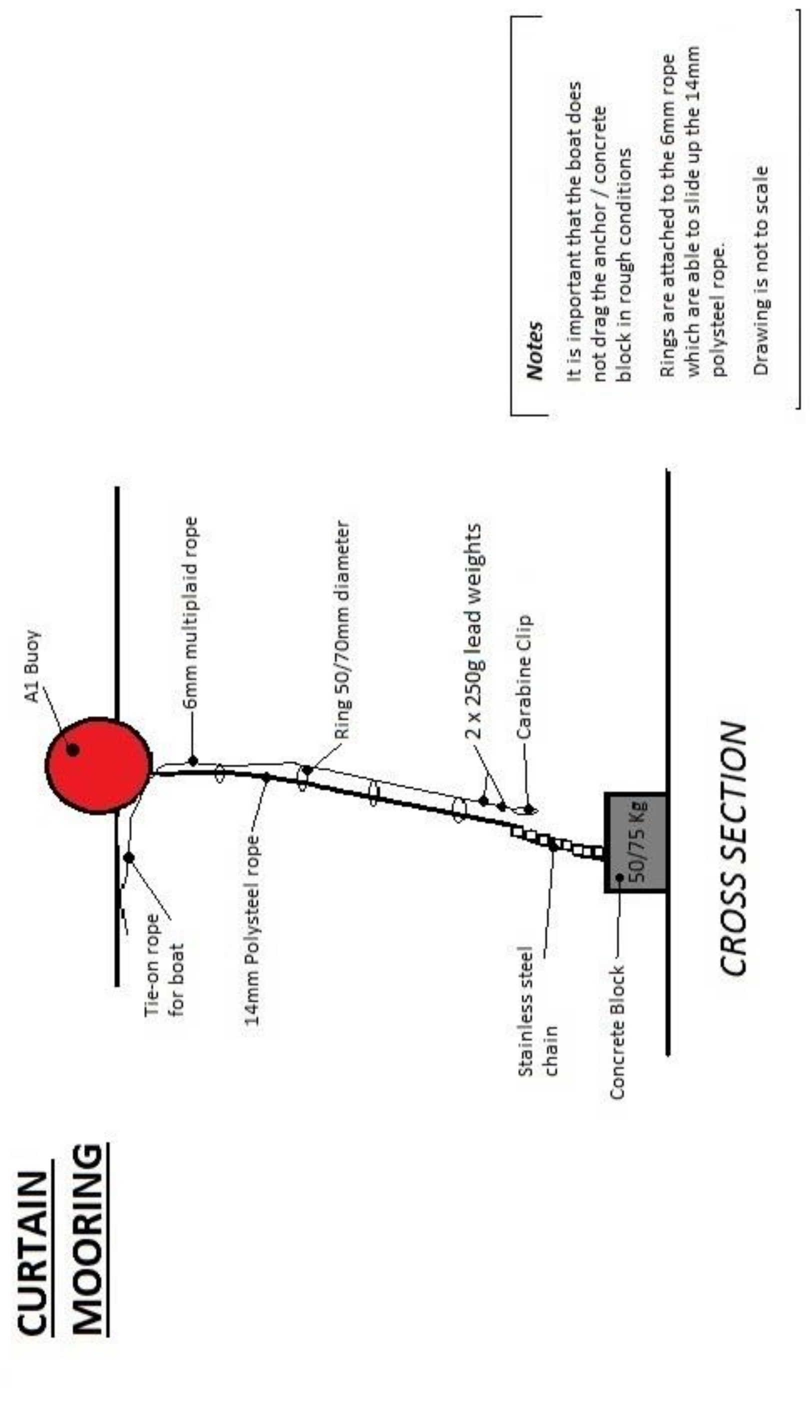
Examples

Three examples are described below, which should be adjusted according to conditions on site.

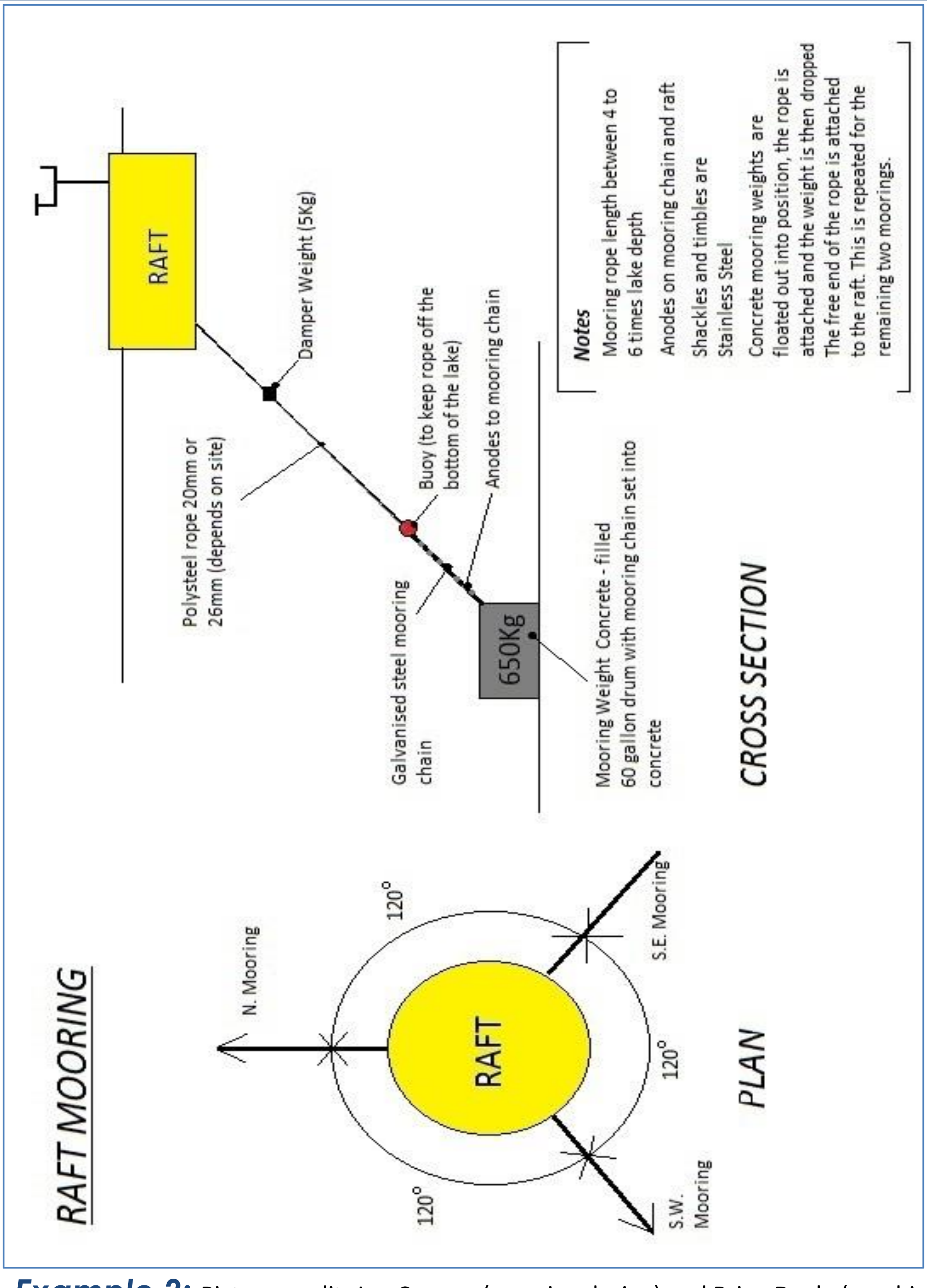
Example 1 is a low cost, single anchor mooring, suitable for deployment of small, lightweight sensors. This set up does not include room for batteries, solar panels etc. This type of mooring is ideal for a string of small temperature or dissolved oxygen sensors such as Onset temperature Tidbits or a PME miniDOT. It is a bottom tensioned line, whereby the small weight at the bottom of the sensor line ensures that the line is vertical at all times. The curtain rings allow the sensor lines to be pulled up and redeployed without tangling around the anchor line.

Example 2 is a more permanent structure for mooring a stable (i.e. not swiveling with the wind) long term platform, fit to hold batteries, sensors, loggers. This example can be seen in operation in Lough Feeagh, Co. Mayo, where a raft has been in place for 20 years. Moorings ropes have been changed periodically in that time. The essential items here are the mooring ropes which need to be several times longer than the maximum depth of water. This allows the anchor chain to lie flat on the lake bottom, and also allows enough slack rope to accommodate varying wind directions. The mooring ropes are connected to the underside of the raft using stainless steel shackles and timbles which can be replaced periodically. This is best done by splicing the mooring rope to make a loop containing a timble (Fig. 1). Sacrificial anodes around the mooring anchors (shaft anodes) can help reduce the amount of corrosion in long term deployments, especially if the waterbody is somewhat saline. Sacrificial anodes are highly active metals that are used to prevent a less active material surface from corroding. Sacrificial anodes are created from a metal alloy with a more negative electrochemical potential than the other metal it will be used to protect.

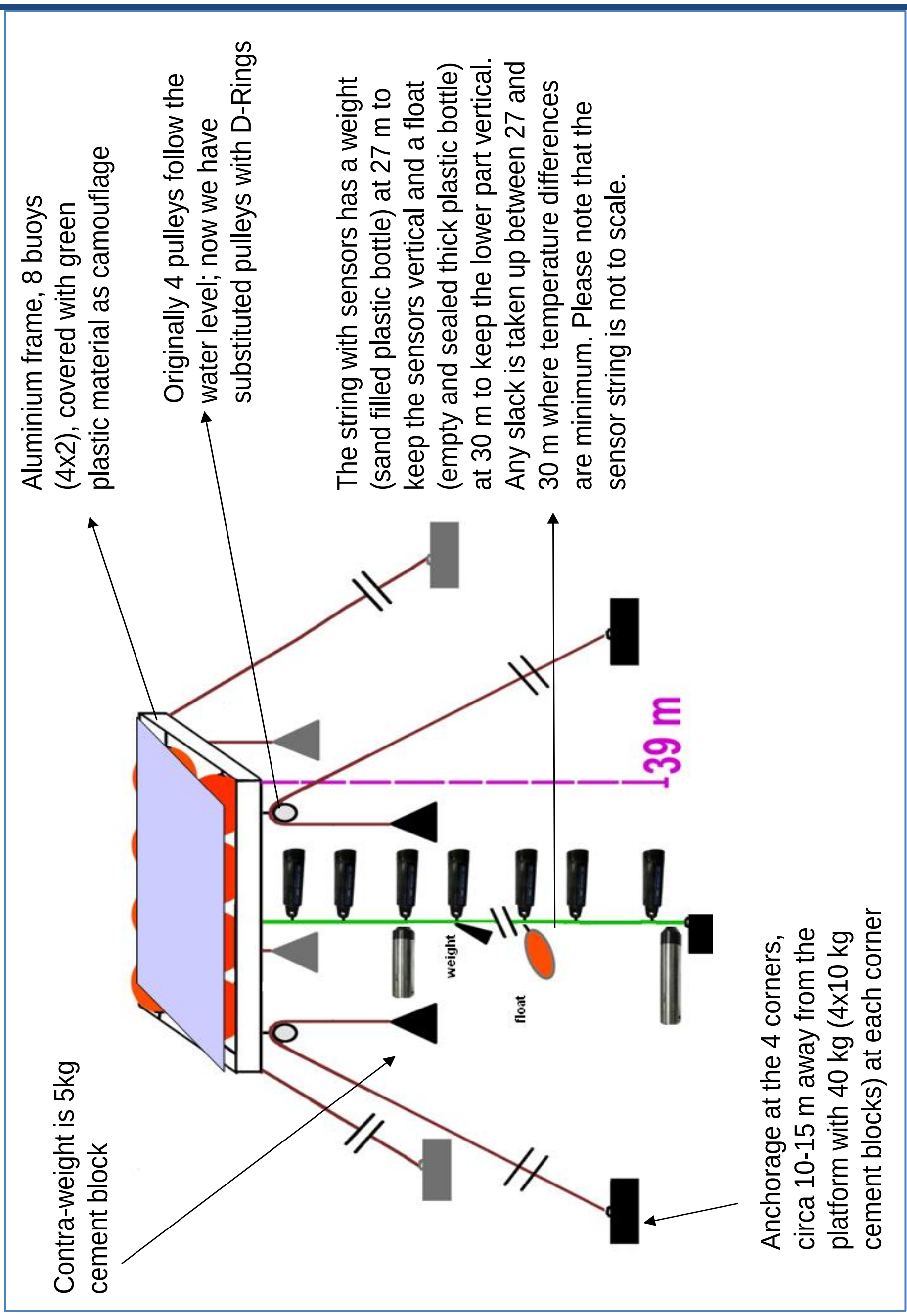
Example 3 is a permanent mooring for a station in a lake with a significant drawdown. This is in operation in Lake Tovel in Northern Italy where water fluctuations in the year are between 2 and 4 metres. However, the moorings needed to be designed for a water drawdown of up to 7m. The contra-weights on each corner ensure that the mooring lines do not become too slack, while still allowing sufficient length to enable the station to rise and fall with changing water levels.



Example 1: Picture credit: Joe Cooney (mooring design) and Brian Doyle (graphics)



Example 2: Picture credit: Joe Cooney (mooring design) and Brian Doyle (graphics)



Example 3: Picture credit: Giovanna Flaim

Likely Problems

- The mooring breaks either at the bottom, top or along the length of rope. The only way to avoid this is to visually check the moorings regularly (at least once a year, if not twice). In the case of a three point mooring, one line is likely to get worn quicker than others, according to the prevailing wind, so check the one under the most amount of pressure.
- You don't have enough slack on the line - this leads to undue pressure on the connectors, and also means that the top buoy may submerge. Plan to do an initial deployment, and a check very soon after. If necessary, lengthen the mooring lines.
- You have too much slack on the line/lines. Here, there is a risk of entanglement (around your boat, or around the sensors). Ropes can be coiled and tightened if necessary, but better to plan on shortening the lines once the deployment has settled in its location.
- The mooring weights are not heavy enough. Try and use the heaviest weight that is practical (e.g. what weight can you bring out in your boat).

More information

http://pme.com/products/lakeesp
http://www.onsetcomp.com/products/data-loggers/utbi-001
http://pme.com/products/minidot
http://burrishoole.marine.ie/Lakes/Feeagh
https://sites.google.com/a/fmach.it/lter-tovel/

See also AMSD factsheet 001, 002 and 003 for more information

Suggested citation: de Eyto, E., Cooney, J., Doyle, B., Flaim, G., Laas, A., Pierson, D. and Jennings, E. 2016. How to moor a long term station (Fachsheet 004). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 14-18. http://eprints.dkit.ie/id/eprint/511

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NETLAKE Guidelines for automated monitoring system development

005 How to cope with lightning

Objective

The purpose of this fact sheet is to provide some practical advice on how to minimize potentially destructive effects of lightning and lightning induced voltage transients.

Considerations

Automated monitoring systems (AMS) used for lake studies can be deployed on both land and water, and are comprised of sensors, data loggers, and can also include telecommunication and power cables. All of these components can be affected by direct lightning strikes and more commonly lightning induced voltage transients. This fact sheet provides some basic information on how to best protect water based and land based systems from lightning.

Nature of the Problem

Lightning is the result of the rising air currents often associated with cumulus clouds. Within these clouds electrical charges develop that lead to electrical discharge within the clouds and also between the cloud and the earth surface (lightning strikes). There are two ways that lightning strikes can affect AMS: 1) a direct strike where the system components (antennas masts etc.) become part of the circuit path between the cloud and ground and 2) Lightning induced voltage transients, where a nearby lightning strike induces voltages into sensors and electrical cabling. This can be considered analogous to an electrical generator where a magnet passing by a coil induces the generated voltage. In the case of lightning the electrostatic discharge (ESD) serves as the magnet, and the sensor, power and communication cables server as the coil. Lightning induced voltage transients are much more common than direct lightning strikes. In our experience at Lake Erken, these occur multiple times each year, while direct strikes have rarely occurred. When long power or communication cables are used another transient problem can arise if a lightning strike leads to a momentary difference in the voltage potential between the two ends of the cable (Fig. 1).

Basics of Protection

Many data loggers are built with lightning and ESD protection circuity, so the first source of information in developing a protection strategy should be to consult the data logger manual for suggestions on grounding and wiring. Protection from direct strikes is achieved by providing a favorable low resistance path that bypasses the monitoring system, so that the strike can pass directly to ground without flowing through the monitoring system. Typically a lightning rod is placed at the highest point of the measurement system above all other sensors and antennas. This is connected to a conductive tower or mast (aluminum) which is in turn connected to a suitable earth ground using a heavy copper wire. The earth ground will be different depending on the application, but generally is a 2-2.5 meter copper/bronze stake driven into the ground or a conductor submersed in the lake water. Protection against direct strikes can be also considered the first line of defense against ESD induced transients. The same system can also be effective in leading ESD around the monitoring system. However ESD transients are also induced in sensor cables. The longer the cable the greater the risk. Long communication and power cables are clearly a risk and require separate ESD transient protection. Additional protection from ESD transients is achieved using a variety of electronic devices. The basic principle behind all of these is that in the presence of a high voltage surge to rapidly (nsec – msec) transfer that surge to system ground, thereby protecting the data logger and sensor. Different surge suppressing components have different response times, voltage and current capacities. Many commercial protection systems make use of multiple components to optimize protection. For example, Campbell Scientific data loggers (i.e., Ref Cr10000 manual) use both gas discharge tubes and Zener diodes as part of the wiring panel transient protection circuitry.

Protection of Water Based Systems

Water based systems are generally less complex to protect than land based systems since they are relatively compact, lack long cables that can induce ESD transients, and since the water serves as the ground. Our general advice on these systems is to use a lightning rod that is approximately 0.5-1.0 meters above any antenna or meteorological instruments, and to connect this to an underwater ground. The data logger ground should also be connected to the same ground using at least a 12 AWG (3.3 mm^2) copper wire. If the data logger itself does not include transient protection circuitry, this could be added to sensors above the water. Underwater sensors are in effect submerged in the ground, so even long cable lengths (i.e. thermistor strings) should be safe. The most complex issue here is developing a good water based ground. There is very little guidance on this issue, the most relevant that can be found is that related to grounding of boats generally in marine systems. A recommendation by the American Boat and Yacht Council (ABYC 2006) is to use an underwater ground plate that is copper or copper alloy that is at least 5 mm thick and having an area of at least 0.1 m^2. There is also some belief that the ESD dissipation will occur along the edges of the copper plate, leading to the suggestion that a long copper strip is more effective than a square plate. At Lake Erken we use a heavy copper wire that goes around the periphery of our float below the water line (Fig 2). This is connected to a common bus that also has connections to our buoy instrument mast and data logger ground. Placing the ground cable around the float prevents entanglement with other sensors.

Protection of land based systems

Land based automated monitoring systems are often used to collect meteorological, water quality and gas flux data from island, near shore, or pier based locations. Island stations are particularly attractive as they can provide in lake measurement sites that are much less affected by ice and do not require the maintenance needed by buoy based systems. Protection from direct lightning strikes is the same as described above for water based systems, with a lightning rod placed above all sensors and antennas, and a connection to earth ground using a heavy copper wire. Development of a good earth ground is critical, and can be difficult especially on islands that are usually mostly rock or from piers. In these cases the typical ground stake can be supplemented or replaced with a water ground. At an island based station in Lake Erken (Fig. 3), we use both a ground stake and a 1m^2 copper plate (following recommendations from the local phone company) submerged underwater as our ground. Both grounds are connected to a common bus to which we also connect meteorological masts and data logger grounds. ESD transients are more problematic on land based sites since instruments tend to be spread out more providing longer cables to collect transients. A useful strategy for land based systems with sensors constrained to a small area is to have multiple ground points, around the perimeter of the instrument area. When connected to a common ground bus this reduces the potential for transient formation. If the system data logger does not have in built transient protection, it is recommended that sensors with leads longer than 3-4 m be protected with some type of transient protection. Sensor manufacturers can offer this as an option, or individual protection devices can be purchased separately. A second ESD transient issue often occurs when the land station is supplied with AC electric power or telecommunication cables. These long cables are highly susceptible to lightning induce voltage transients, and are almost inevitably grounded some distance from the monitoring station. Direct connection of the AC power ground to the local station ground sets up the perfect situation for transients occurring as depicted in example 1. To avoid this the AC line should be protected with a transient protection system, which shorts transients to the local system ground. This is best done by an electrician familiar with installation of transient protection systems. Similar protection is needed for telecommunications cables for example phone lines or lines to short haul modems. However, the issue can be eliminated if fiber optic communications are used.

Examples

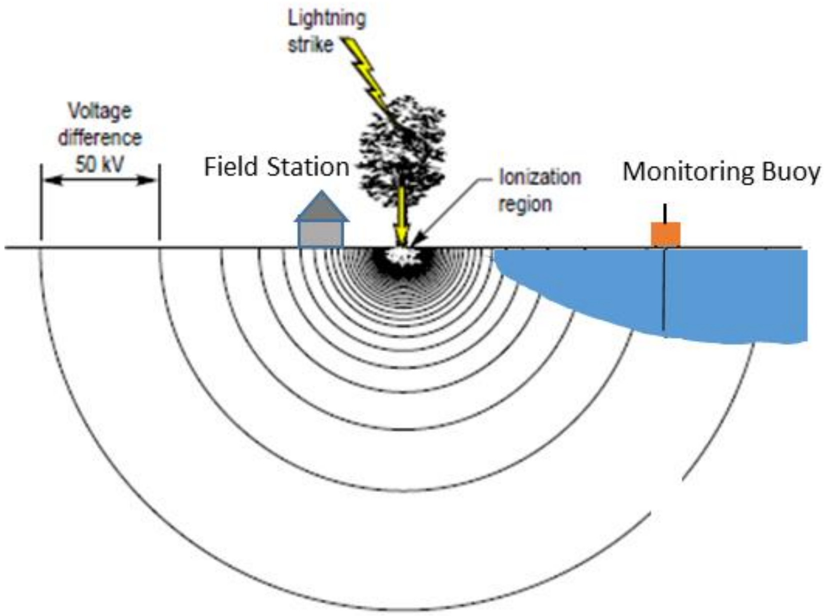

Figure 1. Illustration of the process leading to a large ESD voltage transient. If the monitoring buoy is connected to the field station with a data or power cable the buoy logger and sensors will see and induced transient. Modified from (http://www.slopeindicator.com/instruments/transient-protection.php).

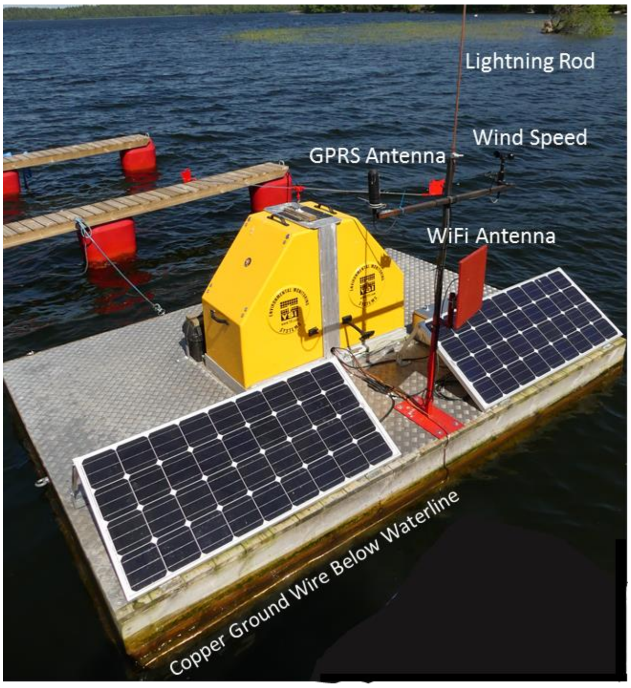

Figure 2. Lightning protection applied to a floating platform used in Lake Erken. Lightning rod is highest point on the platform. Ground wire is approximately 8 cm below the water line.

Figure 3. Lightning Rod protecting Gas flux tower on Malma Island, Lake Erken.

Likely Problems

Potential damage to sensors and data loggers.
Loss of data.

More information

ABYC. 2006. Lightning Protection. Standards and Technical Information Reports for Small Craft. American Boat and Yacht Council (ABYC)
https://en.wikipedia.org/wiki/Surge_protector

Suggested citation: Pierson, D., de Eyto, E., Laas, A., and Jennings, E. 2016. How to cope with lightning (Factsheet 005). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 19-23. http://eprints.dkit.ie/id/eprint/512

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NETLAKE Guidelines for automated monitoring system development

006 Power supply options

Objective

In this factsheet, we describe some of the power supply options for your automated monitoring system (AMS).

Considerations

All AMS require some power to run. At their simplest, this may involve small, standalone sensors with ***internal batteries*** which can be downloaded e.g. at weekly or monthly intervals. Some standalone sensors will have batteries that can contain enough power to run for more than a year even if you measure your parameter at 10 minute frequency.

If you want more capability than standalone sensors, and you need to have a separate data logger then you need to think about power supply. For example, all multiparameter sondes require significant power to run for longer time periods. Some sondes can be powered with internal battery packs, but their capabilities will be in the range of weeks rather than months (depending on measurement frequency). Also some communication options (AMSD 08) can require significant power, especially if continuous communication is required.

Most AMSs will have external power supplies, capable of powering all the sensors, the data logger and the telecommunications. Some AMS have to have navigation lights, so that they are not a navigational hazard.

Solar panels which continuously charge the batteries on AMS are widely used at NETLAKE sites. The number and size of the ***external batteries*** and the charging capabilities of the solar panels will depend on how many sensors you want to run, what measurement frequency you want. Replacing discharged batteries may be needed in winter in northern latitudes. An often neglected drain on power is the telecommunications unit. A winch will also drain power quickly, as will certain sensors (e.g. CO_2 sensors). Careful consideration of the total power requirements will determine what power option is optimal.

How to simply calculate your AMS power consumption? To calculate your power consumption you need to know the amount of power your system uses and the amount of time the system is actively using that power. Most system components will have information on their power usage both when running and in some cases when in a resting stage.

To make these calculations you need to know a few basic computer formulas

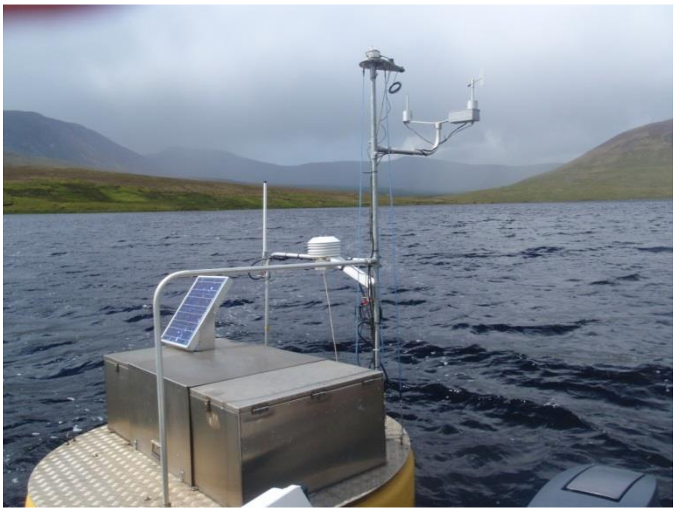
1. Power(watts) = Voltage(volts)*Current(amps)
2. Energy(watt hours) = Power(watts)*Time(hours)

Note that AMS systems often draw low currents in the mA ($A*10^{-3}$) range, so calculated power may be expressed in mW. Battery capacity is often given in amp hours (Ah). This can be converted to energy by multiplying by the battery voltage. A simple example could be a 12 volt winch motor that draws 20 watts when running. To calculate the time the system could be run with a 50 Ah battery one would make the following calculations.

- Time of use = 24 profiles/day * 0.25h/ profile = 6 hours running time / day
- Energy used = 20 watts * 6 hours = 120 watt hours
- Battery capacity used = 120 watt hours/12 volts = 10 Ah
- Running time = 50 Ah /10 Ah/day = 5 days

If you know the station is going to have a high power consumption, a ***cable*** may be more practical if you are within reach of the main supply. However, the efficiency of solar panels has increased while at the same time their price has decreased making them an attractive alternative even in situations of relatively high power consumption. When using solar panels similar power calculations must be made, balancing power usage against the power that can be obtained from the panels for different day lengths and assumed surface light conditions. In this case battery capacity is used to buffer the power obtained from the solar cells and that used by the system.

Examples



Feeagh: 6 X 12 volt 38 amp batteries, charged with one solar panel. This runs a multiparameter sonde, three standalone fluorometers, several meteorological sensors, a Campbell scientific data logger, and real time telecommunication via GPRS. Measurements are taken every two minutes.

Furnace: Same as for Feeagh, but as it has a winch doing four profiles a day, it has a second solar panel to supplement the charging power.

Erken: A YSI profiling system (18 Ah) winch uses two 150 watt solar panels, and a solar regulator that charge three 80 Ah AGM batteries. This provides more than sufficient power for the YSI system, even run long into the autumn when day lengths become much shorter in Sweden. There have been large increases in the effectiveness, and decreases in the costs of solar panels in recent years, so that systems such as the one described above are cost effective solutions to providing relatively large power needs.

Likely Problems

- You don't have enough power.
- The batteries run out before the intended deployment is over.
- The solar panels are not powerful enough.
- There isn't enough sunlight.
- The batteries do not have enough capacity.
- Something is draining power unexpectedly, perhaps because of a short circuit or a wiring issue.

More information

http://www.act-us.info/sensor_list.php?cat=Power%20Supply&type=Hardware

Suggested citation: de Eyto, E., Laas, A., Pierson, D. and Jennings, E. 2016. Power supply options (Factsheet 006). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 24-27. http://eprints.dkit.ie/id/eprint/513

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NETLAKE Guidelines for automated monitoring system development

007 Communication Options

Objective

The purpose of this fact sheet is to provide some advice on the available methods to communicate with and retrieve data from your automated monitoring system.

Considerations

Automated monitoring systems used for lake studies can measure a variety of parameters both above and below water and record these at high frequency. Consequently, large amounts of data can be collected and stored. An important consideration when designing an automated monitoring system is how you will collect and evaluate these data. At the most basic level there is one fundamental choice you will need to make:

- Will you collect your data by physically visiting the monitoring station and manually downloading the data to a computer or memory storage device?
- Or should you develop a method of communicating with your monitoring station that will allow you to collect your data remotely without physically visiting your station?

On-site communication.
The greatest advantage to on-site communication is its simplicity. Furthermore, in the case of standalone submersible logger/sensor systems, this may be the only option available. Depending on the ease of access, the number of loggers, the amount of data to be processed, and other factors, researchers commonly download the data directly in the field without moving the monitoring system, or remove the loggers, download on land, and then later re-deploy the system.

There are various options for downloading data loggers in the field. In the case of stand-alone loggers (i.e. Onset underwater loggers, or RBR solo loggers) data can be transmitted through the water proof housing as light pulses, or in other cases the data is transferred using custom cable that attach to the logger by RS232 or USB connections. Most generic data logging systems such as those produced by Campbell Scientific usually offer the ability to communicate by an RS232 connection which can be made in the field to a laptop computer. Downloading on site can require opening the instrument shelter that contains the data logger in order to make a connection to the logger itself. This can be problematic during rain or rough water conditions. One solution is to use water proof military or oceanographic style connectors so that the RS232 connection can be made through the wall of the instrument shelter/housing (Fig. 1A).

Remote communication
Remote connections allow data collection and monitoring without having to be physically at the site. There are many possible methods of developing a remote connection (see below), all of which are more complex and costly than the direct connection options described above. Despite the issues of cost and complexity there are many advantages to remote communications.

- They allow data to be downloaded more frequently, which in turn allows operators to visually inspect and quality control data, and more rapidly repair failing or fouled sensors

(Fig. 1B).

- They provide the possibility to update data logger programs i.e. to add new measurement intervals or logger processing functions.

- They provide the possibility to interact with the data logger, so that for example the user can switch on high frequency sampling in response to an ongoing event. Or the user can limit the time that power intensive sensors are used in response to reduced battery voltages.

- Finally by collecting the data more frequently data are automatically saved and backed up at a separate location. This can be of great advantage, especially for remote sites which cannot be visited often, or logger deployments, in inherently unstable conditions (i.e. on decaying lake ice).

Options for remote communication

There are many options for remote communication, the one chosen will depend on many factors including station location, power supply options, required communication frequency and cost. While we do not endorse any specific data logger manufacturer, Campbell Scientific does offer a wide variety of data communication options and we therefore, recommend visiting their website to get an overview of what is available. Below is a list of remote communication options.

- ***Short haul modem*** - Use of short haul modems allows a direct RS232 connection using an electrical cable connection over longer distances (up to several km) than would not normally be possible. This can be a reasonable option for loggers located near a lab or field station, and once installed there are no additional communication costs. The disadvantage is the cost and effort of stringing out long communication cables.

- ***Telephone modem*** – If a land line telephone service is available at the data logger sites and a telephone connection can be installed, it is possible that data communication can occur over the telephone network using modems at both the data logger and connecting computer. This is not really an option for buoy systems, but is commonly used for stream side monitoring stations.

- ***GSM (Global System for Mobile Communications) modem*** - Similar to the above option except that logger modem is connected to the GSM mobile phone network. The connecting computer still uses a standard telephone modem. This allows for much greater flexibility since a physical connection between the data logger and telephone network is no longer required. Of course for this to work there must be GSM coverage in the area of deployment, and this can require the use of a high gain antenna pointed in the correct direction. The disadvantage of this option is the costs associated with maintaining a GSM account and for the connection time needed to download the data.

- ***GPRS (General Packet Radio Service) modem*** – This is a mobile communication option that operates on the commercial wireless communications network. It is similar in many ways to the GSM option above, data transfer occurs over different frequencies but often to the same cell tower. A special modem is required for the data logger, however unlike the GSM connection no modem is needed at the receiving computer. Instead the computer connection occurs to an internet address associated with the GPRS account. The advantage of GPRS over GSM is that there are no connection costs and often GPRS provides a faster connection. Communication is possible from any internet connected computer. When purchasing a GPRS account look into the options of obtaining a fixed IP address, rather than a dynamically assigned IP address. The fixed IP address will simplify data communications.

- ***Internet TCP IP connection***. - In cases where a local internet connection is available data loggers can be directly connected to the network using TCP IP protocol. As with any internet connection you will need to assign an IP address, IP gateway and subnet mask to the data logger or its TCP IP interface. And as above, we recommend using a fixed IP address if possible. This is not really an option for buoy based monitoring systems, although it is possible to combine this with a cable based fiber optic or short haul modem connection to a water based logger. The largest advantage to this option is a very high speed connection and low operating cost. For example, at Lake Erken an underwater fiber optic cable has been installed to provide high speed internet access to an island monitoring station from the mainland.

- ***Internet WiFi connection*** – Similar to the above except that TCP IP communications occur over wireless WiFi frequencies, in much the same way as a laptop connects to a WiFi network. This requires a WiFi router that is connected to the data logger, and as above one needs to assign an IP address, IP gateway and subnet mask to the data logger or the router interface. Use of high gain directional antennas can allow reliable WiFi connections over several hundred meter distances. The Lake Erken monitoring system has established a WiFi hot spot on an Island based station that provides WiFi coverage to much of the lake.

- ***Radio Link***. There are a wide variety of options, the choice of which will depend on government regulations, licensing requirements, power requirements and the needed transmission distance. In general radio based solutions transmit data over radio frequencies using transmitters and receivers especially designed for data communications. Transmission occurs over line of sight distances, which can be considerable over water. It is also possible to link stations into a network so that data can be relayed from one monitoring station to another thereby increasing the data transmission distance. Radio linked data transmission is best suited for locations that lack good GSM or GPRS coverage. The disadvantage to radio based communications can be greater power consumption and slower communication speeds.

- ***Satellite link*** – this is an option that can be used for remote locations where none of the above communication methods can be used. Satellite communications are also sometime used over large geographical areas in order to provide a consistent communication protocol that can be applied to the entire region. There are at least four different satellite systems that can be used for data communication. Each will require a specialized communication device, and each will offer different advantages and disadvantages in regards to cost data transmission speed and geographic coverage.

Finally one should also consider the software needed to initiate communication and download the data. When purchasing a data logger system, be sure the logger manufacture provides software that will allows commination using the method that best fits your needs. In the case of power intensive communications such as radio links or cellular modems one may also need to develop logger programs that shuts down the communication device over certain times of the day or in response to declining battery levels.

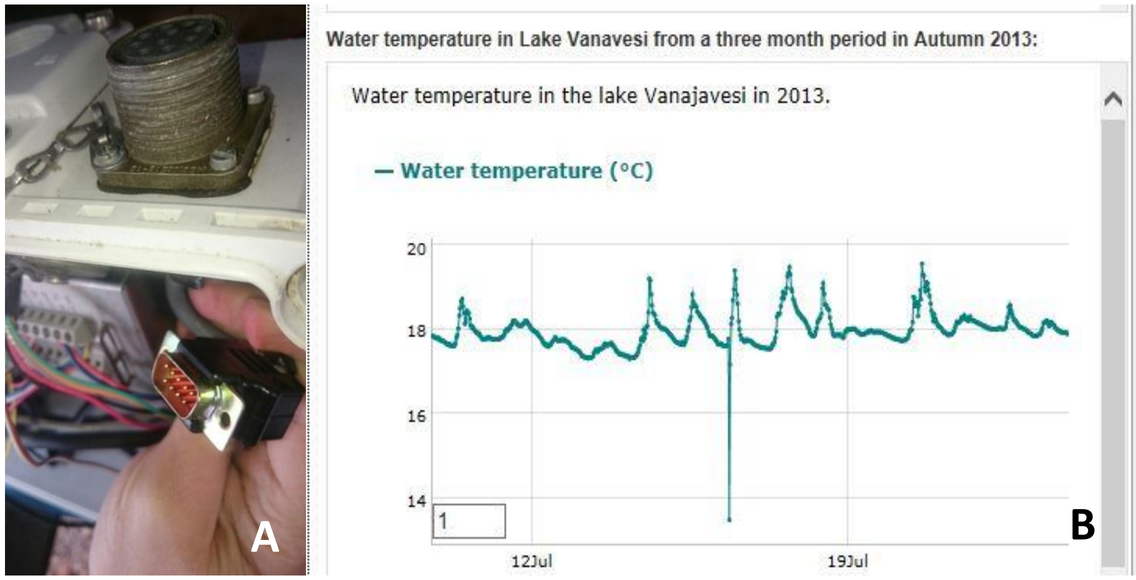

Figure 1. A) Example of using military style connectors to make RS 232 connection through the wall of monitoring system enclosure. B) example of visual quality control system that updated daily following remote communications and data collection. Bad data point can be easily detected.

Likely Problems

- Unreliable communication due to weak radio or cellular signals. This can be improved using high gain omnidirectional or directional antennas

- Complexity in connecting communication equipment and establishing communications. We strongly recommend that you start testing your communication system long before the field season starts. It can take time and many customer support calls to learn how to make the correct electrical connections and set the correct software options needed to establish reliable communications.

- Loss of communications due to power loss. Some communication devices require significant power, in some cases more than the monitoring system itself. If there is a mismatch between the communications power requirements and battery storage and charging rate, the communication system can run down the station power so that the entire system fails. There are several solutions to this: carefully match your power supply to your power needs (AMSD 006); Develop data logger software that will shut down the communication devices over fixed periods of the day or in response to low battery power; use a separate power supply for the communication device.

More information

http://www.onsetcomp.com/
https://rbr-global.com/
https://s.campbellsci.com/documents/us/product-brochures/b_data_retrieval.pdf

Suggested citation: Pierson, D., de Eyto, E., Laas, A., and Jennings, E. 2016. Communication options (Factsheet 007). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 28-32. http://eprints.dkit.ie/id/eprint/514

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NETLAKE Guidelines for automated monitoring system development

008 Weather stations

Objective

In this factsheet, we give an overview of whether you should add a weather station to your platform, which types of weather instruments and stations are available on the market and how to position the weather station on your platform.

Some reasons to add weather measurements to your lake buoy:

1. You don't have a weather station in the locality
2. Your lake is surrounded by obstacles (trees, buildings), meaning that your local land based station does not describe the weather situation on the lake surface adequately.
3. The lake significantly modifies meteorological conditions, such that an on-lake weather station is the only way of capturing meteorological conditions.
4. You want to calculate common metrics for lake physical states. Some of these metrics (Lake Number, Wedderburn number or gas Piston velocity) require lake specific weather data such as wind speed.
5. You want to calculate common metrics for lake biological states, but some metrics require weather data. For example, lake production calculations need global irradiance or PAR measurements.
6. You want to calculate more complex metrics for your lake, requiring weather data other than basic meteorological variables. For example, lake metabolism calculations need wind and irradiance data, while estimates of heat fluxes and evaporation additionally require measurements of air temperature and humidity.
7. You want to study your lake water movements and waves. For this, you need wind speed and direction measurements.

Commonly used weather measurement sensors on lake buoys

When considering the addition of meteorological sensors on your station, there are two main options: either an off the shelf multi-parameter station or a collection of individually specified sensors.

Multi-weather sensors – Are able to measure up to seven of the most essential weather parameters: barometric pressure, humidity, precipitation, temperature, wind speed, wind direction and solar irradiance. Some of them are available with an integrated electronic compass. Most multi-weather sensors are compact, light in weight, require low power for consumption and are compatible with many commonly-used data logging systems.

Individual sensors - some options

Cup anemometer – Cup anemometers are widely used. They are generally well suited to measuring wind speed, tend to be cost attractive in comparison to other types of instruments and are very robust. Cup anemometers are ostensibly adirectional i.e. they should respond identically to winds coming from different directions within the horizontal plane. The cup anemometer is primarily designed to measure the horizontal wind speed, not the magnitude of the horizontal vector.

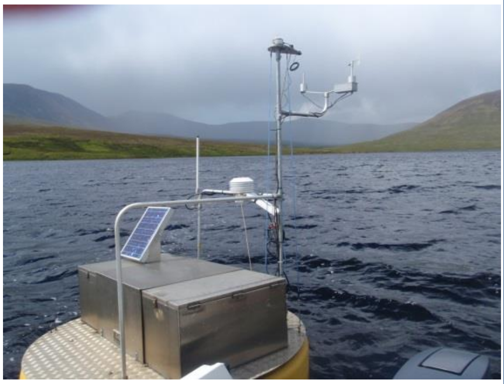
Vane or windmill anemometer – Contrary to the cup anemometer, the axis on the vane anemometer must be parallel to the direction of the wind and therefore horizontal. A vane anemometer combines a propeller and a tail on the same axis to obtain accurate and precise wind speed and direction measurements from the same instrument. In some cases, the speed of the propeller is measured by a counting device and converted to a wind speed output by internal electronic processing. In other cases the propeller shaft turns a magnet which induces a signal in a coil. The frequency of this signal is measured by the data logger and then converted to a wind speed. Wind direction is commonly measured as changes in the resistance of a potentiometer coupled to the wind vane shaft.

Sonic anemometer – Contrary to cup and vane anemometers sonic anemometers use ultrasonic sound waves to measure wind velocity. They measure wind speed based on the time of travel of sonic pulses between pairs of transducers. Sonic anemometers can take measurements with very fine temporal resolution, 20 Hz or better. The lack of moving parts makes them appropriate for long-term use in exposed automated weather stations where the accuracy and reliability of traditional cup-and-vane anemometers are adversely affected by salty air or large amounts of dust. Their main disadvantage is the distortion of the flow itself by the structure supporting the transducers. Since the speed of sound varies with temperature, and is virtually stable with pressure change, sonic anemometers are also used as thermometers.

Solar irradiance sensor - There are two main irradiance sensors which are used in buoy systems: pyranometers and quantum sensors. Pyranometers are designed to measure total solar radiation – the combination of direct and diffuse solar radiation – in the 400 to 2800 nm range. Quantum or PAR sensors measure photosynthetically active radiation. PAR sensors measure light in the wavelength range of about 400 to 700 nm which plants use to drive photosynthesis. PAR sensors measure light as a photon flux density i.e. (moles photons m^{-2} s^{-1}) since photosynthesis is a quantum process, while pyranometers measure the energy of the solar radiation (w m^{-2}). They are not completely comparable as the energy of a photon is wavelength dependent. However, there are a number of simple conversion factors that are based on the average spectral composition of incoming solar radiation.

In addition to wind and light, other possible additions include sensors for barometric pressure, air temperature, precipitation and humidity. As with all AMS, cost will be your main determinant.

Position of weather sensors on your platform



Weather sensors should never be sheltered by other parts of your monitoring system, and are best placed above any other infrastructure (right). Even small PAR sensors shouldn't be close to your wind sensors, because it could cause distortion in the wind speed and direction measurements. At the same time, your irradiance sensor cannot be sheltered by other devices. Many lake mathematical models presume wind speed measurements are taken at 10 meters above the land or water surface. It is possible to correct wind speed measured at one height to wind speed at 10 m with given formulae, but be sure that you know at which height you measure your wind speed!

Considerations

The weather sensor types and configuration to be selected depend mainly on the needs of your research, the monitoring objectives, the required data quality and the available budget. Some sensors are better in accuracy, some need more power, some more frequent calibration while others need to be calibrated less frequently and are therefore better for longer deployment in buoy systems.

Keep in mind that if your platform anchoring lets your system move or rotate you should have your wind direction sensor corrected with an integrated compass.

More information

http://www.act-us.info/sensor_list.php?cat=Meteorological&type=Physical

http://www.skyeinstruments.com/

http://www.windspeed.co.uk/ws/index.html

Suggested citation: Laas, A., Pierson, D., de Eyto, E. and Jennings, E. 2016. Weather stations (Factsheet 008). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 33-36. http://eprints.dkit.ie/id/eprint/515

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NETLAKE Guidelines for automated monitoring system development

009 Sensor considerations

Objective

In this factsheet, we give an overview what sensors are available for high frequency measurements and which are mostly used by NETLAKE monitoring platforms.

NB! This fact sheet contains certain trade names or commercial products only as examples. This should not be considered as an endorsement of any particular product.

Sensors on NETLAKE platforms

The following table gives you an overview about sensors which are currently in use on different NETLAKE platforms. Information has been taken from NETLAKE site posters. We have tried to group sensors under descriptive parameter names.

Weather measurements

Wind speed and direction
Sentry (Campbell, Young)
Combined Wind Sensor Classic (ThiesClima)
Model 05103-5 (RM Young)
Wind Monitor (RM Young)
Wind Sentry (RM Young)

Solar radiation
Star pyranometer (H.I.M.)
Pyranometer (Kipp&Zonen)
Li-200 (Licor)
Starpyranometer 8101 (Logotronic)
Albedometer CMA6 (Kipp&Zonen)
SP-212 (Apogee)

Air temperature and humidity
MP-408 F/T-R (Rotronic)
CD215 (Campbell Scientific)

Air pressure
Micro switch PK8763 (Honeywell / Sommer)

Pecipitation
T-200B (Geonor)

Multi-Weather stations
WXT520 (Vaisala)
MetPak (Gill)
Meteorological station (NESA)
WS-501 (Lufft)

Underwater measurements

Multisonde or CTD
6600V2 (YSI)
6600V2-4 (YSI)
660 OMS V2 (YSI)
RBR Maestro (RBR)
EXO-1 (YSI)
EXO-2 (YSI)
6600V2-M (YSI)
WQM (WetLabs)
DataSonde 5x (Hydrolab)
Ocean seven 316Plus (Idronaut)
DS5X sondes (OTT Hydrometry)
600XLM (YSI)
XR420 (RBR)

Water temp and Thermistors
Semi-conductor 592 C (Sommer)
PT100 2M Thermocouple Probe
HOBO Pendant (Onset)
Minilog (Vemco)
DS1922L (Ibutton)
Thermistor probe (Tiny-Tag)
HOBO TidbiT (Onset)
PT-1000 (AtlasScientific)
Thermocouple
Pt100, RTD (TempCon)

Dissolved oxygen
LDO (HACH)
Digital OPTOD (Ponsel)
miniDOT (PME)
D-opto (ENVCO Global)
DO probe (AtlasScientific)
HOBO U26-001 (Onset)
Optode 4175 (Aanderaa)

cDOM
InSitu Spektralanalysator (GO Systemelectronics)
cDOM fluorometer (Seapoint)
Microflu-cDOM (TriOs)
cDOM fluorometer (WetLabs)

Fluoresence
MicroFlu (Trios)
FluoroProbe (BBE Moldaenke)
TriLux (Chelsea)

Turbidity
ECO NTU (WetLabs)
UniLux (Chelsea)
Transmissometer (WetLabs)

CO_2
Optical CO_2 (AMT Analysenmesstechnik GmbH)
CO_2-sensor (Vaisala)

Conductivity
Conductivity probe K 0.1 probe (AtlasScientific)
Graphite electrode (Honeywell)

pH
Industrial pH probe (AtlasScientific)
Durafet II (Honeywell)

Color
RGB Color detector (AtlasScientific)

Water level
HOBO U20 (Onset)

UV absorbson
ProPS (TriOS)

Underwater light
LI-193 (LiCor)
LI-190 (Licor)

NETLAKE metadatabase

To get more information which sensors are being used for high frequency monitoring, visit the NETLAKE metadatabase at www.netlake.org

More information

http://www.act-us.info/

The Alliance for Coastal Technologies (ACT) is a partnership of research institutions, resource managers, and private sector companies dedicated to fostering the development and adoption of effective and reliable sensors and platforms. ACT hosts a web page where you can find good overviews about different sensors which are used for marine and ocean platforms. Most of them would also be suitable for freshwater research.

Suggested citation: Laas, A., Pierson, D., de Eyto, E. and Jennings, E. 2016. Sensor considerations (Factsheet 009). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 37-39. http://eprints.dkit.ie/id/eprint/516

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NETLAKE Guidelines for automated monitoring system development

010 Depth of sensor deployment

Objective

In this factsheet, we describe some things that need to be considered when deciding what depth you are going to put your sensors at.

Considerations

- **What is the research question**? If this deployment is a long term, sentinel monitoring site, and you want to be able to keep the station running for years, than the simpler the design the better. A single station at the deepest point of the lake with sensors in the epilimnion should capture many of the sentinel indicators. The addition of a fixed thermistor chain will add some vertical resolution to this set up. If it a short-term deployment to answer a very specific research question, the system can be more complicated.

- **Is it a deep lake?** Are conditions at the surface likely to reflect conditions at depth, and do you care? In shallow lakes, two (or more) sondes or sets of sensors may capture some of the vertical variability if that is required for the research. A profiling system with a multiparameter sonde attached to a winch may be required to answer certain questions in a deeper lake.

- **Is there evidence of strong stratification?** If so, then it is more likely that you want sensors at different depths, as conditions may be quite different above and below the metalimnion. You may be interested in knowing what is going on below a very strong permanent stratification, with an anoxic hypolimnion. Alternatively, you may only be interested in the upper layers of the lake where levels of light and primary production will be greatest. An initial deployment of some simple standalone sensors may be useful to determine stratification.

- **Is the lake polymictic?** Data derived from a set of surface sensors will probably not be able to document the frequency and variability of mixing in a polymictic lake with frequent turnovers. Multiple sensors at different depths, or a profiling multiparameter sonde might be needed to adequately characterise the variability of mixing and its effects on lake processes.

- **What is the euphotic depth**? If it's quite shallow, perhaps a single chlorophyll fluorometer in the epilimnion will capture the primary productivity signal quite well. If it is deep or temporally variable, then even several fluorometers may not detect the highest signal and you should start to think about a profiling system.

- **Is there evidence of a deep chlorophyll maximum (DCM)?** If so, and it is moving, then a profiling system may be required to explore the dynamics of the DCM (if that's of interest).

- **Cost considerations.** Multiple sensors and/or a profiling winch all increase the cost. Do you really need them to answer your research question? Can you do some initial exploration and profiles at crucial times of the year to see how much spatial variability there is?

- **Power supply** Multiple sondes or a profiling winch both require more power. If power is limited, restrict your sensor placement according to the research question

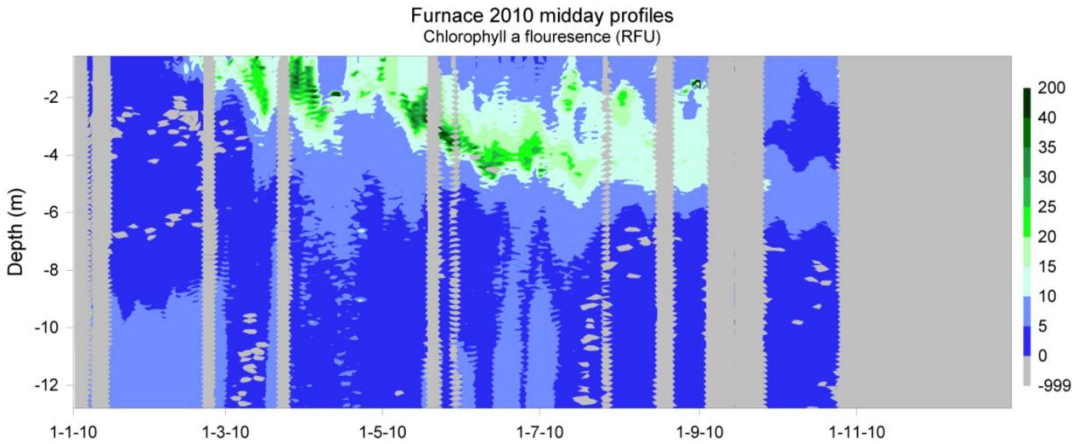
- **Inflow and outflows**: Are these surface or subsurface? Do surface inflows form plumes? Do you have a strong groundwater influence? If it is a reservoir, where are the out-takes? These may all affect the variables you want to measure, and determine where you place your sensors.

- **Data considerations:** The more sensors you have, the more data are going to be gathered. If these are at different depths, it adds complexity to data processing. Do you have the staff time to do this? If not, stick with a simpler system.

Examples

Here are some examples of what can be achieved with sensors at multiple depths.

Example 1: The deep chlorophyll maximum in a stratified lake (Lough Furnace, Ireland), characterized by a chlorophyll sensor on a Hydrolab datasonde S5x connected to a profiling winch, measuring at approximately every 17cm. (Grey areas indicate missing data). Source: Marine Institute Ireland, unpublished data.



Example 2: Metabolism estimates at different depths, in comparison to estimates made with a fixed DO sensor at 1 m (reproduced with permission from Obrador, B., P. A. Staehr, and J. P. C. Christensen. "Vertical patterns of metabolism in three contrasting stratified lakes." Limnology and Oceanography 59.4 (2014): 1228-1240)

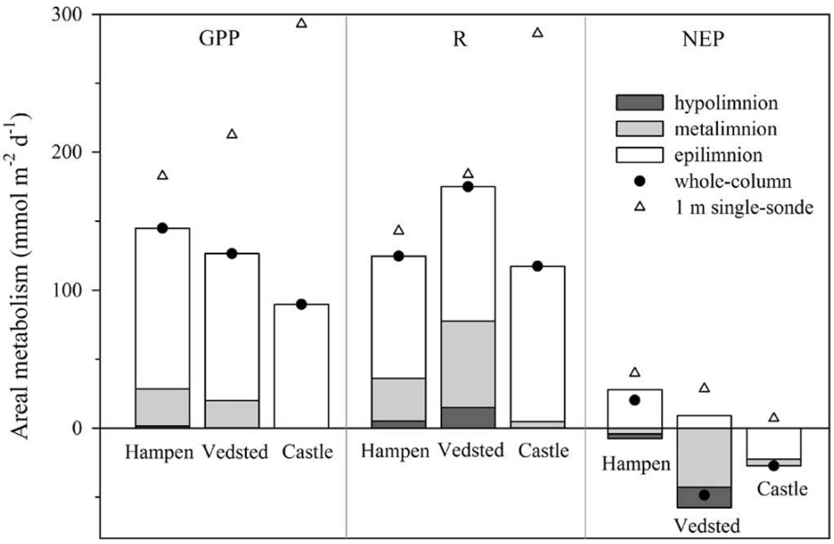
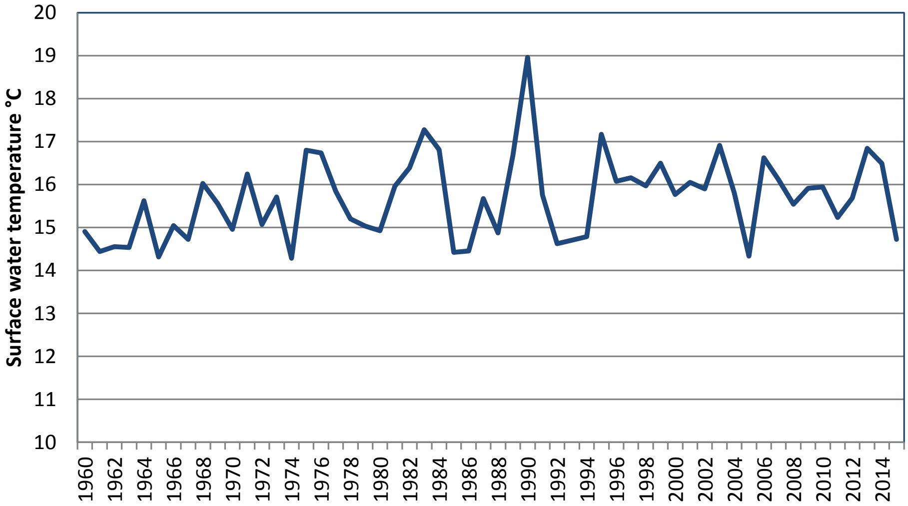


Fig. 4. Mean areal rates (GPP, R, and NEP, in mmol m^{-2} d^{-1}) of the depth layers (bars) and integrated whole-column rates (circles) for the three studied lakes. The estimates derived from single-sonde (1 m depth) measurements are also shown (triangles).

Example 3: Long term summer surface water temperatures of Lough Feeagh Ireland. This example is from a sentinel site, where the primary objective is long term ecological monitoring. In this case, you want to keep the sensors, data acquisition and data collation as foolproof as possible. Source: Marine Institute Ireland, unpublished data.



Likely Problems

While it could be argued that single sensors near the surface are inadequate for monitoring lakes, the reality is that multiple sensors at many depths leads to increased costs and data processing time. Decide what you want to find out, and design the minimum deployment options that will allow you to answer that question.

More information

If you decide you want profiling capability, here are some options:

- ***https://www.ysi.com/File%20Library/Documents/Brochures%20and%20Catalogs/E78-YSI-Vertical-Profiler-Brochure.pdf***
- ***http://www.flydogmarine.com/products/***
- ***http://www.idronaut.it/cms/view/products/monitoring_system/inland_waters/s275***

Suggested citation: de Eyto, E., Laas, A., Pierson, D. and Jennings, E. 2016. Depth of sensor deployment (Factsheet 010). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 40-43. http://eprints.dkit.ie/id/eprint/517

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NETLAKE Guidelines for automated monitoring system development

011 Measurement Frequency

Objective

The purpose of this fact sheet is to provide some advice on the frequency at which data should be measured and saved from automated monitoring stations (AMS).

Considerations

AMS used for lake studies can measure meteorological parameters, water temperature, water chemistry, and indicators of biological processes. All of these vary along a continuum of time scales, which can potentially be studied. Here we provide some guidance on the measurement frequency and storage frequency, based on our collective experience in aquatic monitoring.

Fundamental Considerations

The place to start when designing an automated monitoring strategy is to first define the question(s) that one wishes to answer with data from the AMS, the processes that affect that question, and the time scale(s) over which these processes are expected to vary. The later should set the lower limit on the frequency at which data is collected. As an example, water temperature is a fundamental property of lakes that can affect many other processes, and can therefore be measured at a variety of frequencies. To obtain information on the lake heat budgets or patterns of thermal stratification daily data collection could be sufficient, while to obtain information on levels of water turbulence, measurements need to be made at multiple times per second. While the highest frequency measurements can always be aggregated to longer frequencies, there are costs and tradeoffs that must be made when collecting data at higher frequency. Therefore, measuring at the highest frequency is not always the obvious choice.

Planning for the future

One of the great advantages of AMS is that they provide long-term consistently measured data records. These can be used to evaluate such things as long-term changes in climate or changes in lake inputs. All uses of the data may not be evident when a monitoring station is first established. Future, perhaps unanticipated, use of the data might benefit from storing data at high frequencies. Therefore, despite the sound advice above, there are good reasons to measure at higher frequencies than needed if the costs are not prohibitive. Using the example of Erken Laboratory water temperature, if one was measuring using a temperature sensor chain of 20 sensors and storing data as 4 byte numbers, then one year of daily measurement would only require approximately 30 KB of memory, well below the storage capacity of modern data loggers. When Lake Erken's automated monitoring program first began in 1986, state of the art data loggers had 16 KB of memory, making the storage of too frequent data a real issue. Today however, data storage is typically multiple MB, and it is even possible to store up to 16 GB, a 6 order of magnitude increase in storage capacity. Storing those 20 x 4 byte temperature measurements every 5 min would use about 8.4 MB of storage over an entire year. In most cases there are few reasons to not store the temperature data at frequencies in the minute range: Storage is not limiting; costs are not prohibitive; automated quality control can be just as easily preformed on the higher frequency data. Only the lower frequency data of interest need to be analyzed, but the higher frequency data is always available for future use.

Measurement vs Storage

The frequency of measurements is not necessarily the same as that of data storage. With many data loggers it is possible to measure frequently, and store measurement averages (and/or other statistics) at lower frequencies. In most cases this is a good idea, since averaging high frequency measurements over a longer storage interval generally provides more representative data, but again logger processing should be linked to the questions being asked and the purpose of the monitoring program. The Campbell data loggers in use at Lake Erken measure every second and store mean data values at 5 min, 60 min and 24 hour intervals. In the early days of the monitoring program only the hourly and daily data storage were practical. The 5 min storage interval was added latter as logger memory increased, but the hourly and daily means were retained for the sake of consistency. Today one can consider if it is worth internally processing data in the logger at all. Some advocate storing data at as high a frequency as possible, and preforming all post processing separately from the logger. This has the advantage of providing maximum flexibility in data processing, but can increase data storage and transmission costs. No matter what the choice of internal logger processing it is important that the processing method, or lack of it, is well documented in station metadata descriptions. This information can be very helpful when processing and comparing data from stations run by different institutions - such as data collected across the NETLAKE network.

Limitations on the frequency of measurement and storage

Finally there are properties of the measurement system which will set upper limits on the frequency of measurement. One of the most fundamental properties is the response time of the sensor itself. There is no value in measuring a sensor at a rate that is faster than it can be expected to respond to a change in the environment. Optical sensors such as fluorometers and under water light sensors have nearly instantaneous responses. The response of a temperature sensor is also nearly instantaneous from the electrical point of view, but in practice the response will be slower due to the thermal mass of the sensor itself: large robust sensors will take longer to change temperature than smaller more fragile sensors. Likewise, sensors that rely on the measurement of gradients across a membrane will be dependent on the rates of equilibration across the gradient. Sensor response time will also be related to the steepness of gradient through which the sensor is passing. Luckily in most cases the response time of aquatic sensors is generally faster than the frequency that would need to be measured The response time of most commercial sensors is well documented by their manufactures, and this information should considered when setting the upper limit on measurement frequency. The second limitation on measurement frequency is with the data logger.

While theoretically there are limitations on the frequency of measurement imposed by the data logger electronics, this will rarely be a practical limitation. However, data logger storage capacity, in conjunction with data communications and data transmission capacity can limit the frequency of measurement, and/or the frequency of storage. Going back to the Lake Erken temperature example above of 20 sensors measured at a 5min frequency, but in this case storing the data as higher resolution 8 byte numbers (the equivalent of a single precision floating point value) would require 38.4 KB of data logger storage per day. This is no problem if the data can be collected at daily or weekly intervals, but could become an issue if data can only be collected on a monthly basis. The second potential limitation is data transmission. Knowing that there are 8 bits in a byte the above daily data collection (369 Kbits) would require a data transmission time of 4.5 min/week using a GSM modem with a transmission speed of 9600 Kbits s^{-1} This would not be a prohibitively long transmission time, but GSM connections are not free, and this does illustrate that data transmission rates, can in some cases set limits on the frequency of data storage. In general given the large storage capacity (MB to GB) of modern data loggers it is less likely that on-logger storage will limit measurement storage frequency, and more likely data transmission rates could act as a bottleneck that limits the frequency of data storage.

Likely Problems

- Not properly matching data measurement and collection frequencies to the purpose of the monitoring project.
- Not collecting data that could add to the value of the long term monitoring program at little additional cost.
- Collecting so much data that the project staff are not able to properly analyze and use it

Suggested citation: Pierson, D., de Eyto, E., Laas, A., and Jennings, E. 2016. Measurement frequency (Factsheet 011). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 44-46. http://eprints.dkit.ie/id/eprint/518

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This factsheet is based upon work from the NETLAKE COST Action (ES1201), supported by COST (European Cooperation in Science and Technology).

NETLAKE Guidelines for automated monitoring system development

012 Station Maintenance

Objective

In this factsheet, we describe some of the considerations for maintaining an automatic monitoring station, and how to avoid the "rubbish in, rubbish out" scenario.

Considerations

The value of data collected by automatic sensors is entirely dependent on how the station is maintained, and how carefully the collected data is checked. This is especially true for longer deployments (multiple months to years), but even data from short deployments in eutrophic waters can be affected without careful maintenance.

- **How often can the station be visited?** If visits are going to be infrequent (i.e. lower frequency than monthly), then you are limited on what sensors can be used. Automatic wipers or pressured air cleaning may help here.
- **Do batteries need to be changed?** In northern latitudes, solar panels may not be able to recharge batteries – if you want measurements over winter, batteries may need to be swapped mid-winter.
- **How frequently do sensors need to be cleaned?** This depends on the sensor type, and the lake type. Sensor windows will get dirty in a matter of days or weeks, particularly in the summer. Underwater light sensors are particularly prone to biofouling. Recording of pre and post cleaning results will help define the rate of sensor fouling, and the optimal time between cleanings. Beware of bird fouling on sensors near the surface (or on the surface, such as meteorological instruments).
- **Regular calibration schedule?** It's better to calibrate sensors before problems become obvious if possible, and a routine calibration schedule will help this. E.g. calibrating multiparameter sondes, or individual sensors once a month is probably good practice. Manufacturers should be able to provide details here about regular used calibration. Maintain a log of calibration dates and results, this can be valuable for interpreting data latter on.
- **Calibration against standards:** For proxy sensors, calibration against standards serves two purposes: 1) enables quantification of the parameter of interest and 2) gives the user some idea of sensor drift. For example, calibrate chl fluorometers with serial dilutions of a spinach standard (see below), CDOM sensors with quinine sulphate, nephelometers with a turbidity standard and pH sensors with pH standards.
- **Manufacturer's calibrations:** Some sensors may need regular manufacturer's calibrations (e.g.CO_2, irradiance sensors) at a regular interval. Otherwise, a user calibration may highlight a drift issue, in which case sensors can be sent back to the factory. This can be expensive, and should be factored into your operating budget.
- **Weather conditions:** More applicable to some lakes than others. Check forecasts regularly, be conscious of the prevailing wind, and what is an ideal wind speed and direction for field work. Safety is paramount!
- **Collection of ancillary data to aid interpretation of sensor signals:** Don't rely totally

on sensor information. Use your maintenance visits to collect other data to support the monitoring effort: e.g. Secchi disk and water temperature readings, water samples for chl a extraction, grab samples for turbidity, nutrients, DOC, etc. For stream stations make independent measurements of stage height discharge and water temperature. For meteorological data make an independent measurement of air temperature and a visual check on wind direction. While these measurement may seem unnecessary at the time they can easily be incorporated into your maintenance visits, and they are invaluable for confirming and strengthening patterns shown in the sensor data.

Example

This is the maintenance schedule for the Furnace AWQMS:
http://burrishoole.marine.ie/FurnaceLake.aspx

Item	**Time period**
Check real time data	Once a day
Clean sensors	Every other week
Calibrate multiparameter sonde (DO, conductivity, pH)	Once a month
Take spot samples for comparison with sensor data	Once a month
Visually check moorings	Once a year
Check sensors against a standard (e.g. chl flourometer, CDOM)	Once a year
Software upgrades	Once a year
Strip winch, check and regrease all components	Once a year
Change batteries	As required
Emergency visits	As required

Likely Problems (and solutions)

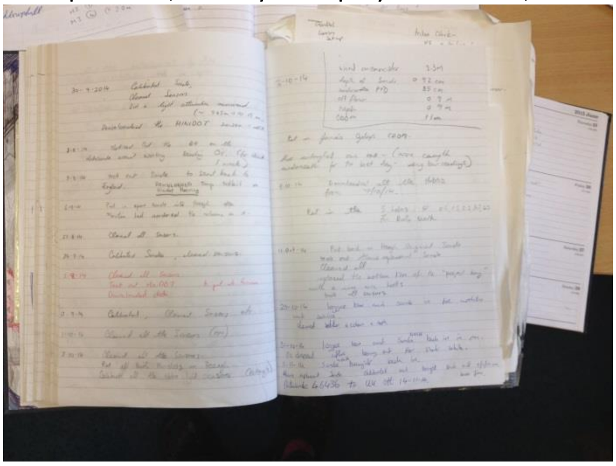
- Power supply goes (batteries flat – especially in winter if they are charged with solar power)
    - add more solar panels, add more batteries, reduce sampling frequency, change batteries more frequently, reduce station power consumption.
- Sensor window is dirty
    - Clean more regularly with cotton buds / brushes
    - Add automatic cleaning (e.g. wipers, pressured air) to your sensors
- Sensor is drifting
    - Manual calibration if possible
    - Return to manufacturer if necessary
- Moorings break
    - Have more than one mooring to prevent total loss of equipment
    - Check mooring regularly
    - Redo moorings with stronger ropes and chains
- Wires leading from sensor to logger wear in one patch (usually when attached with cable ties)
    - Check regularly

- Wrap wires in protective sheath (garden hose) where they are fixed
- Look for the cause of the wear and try an fix wires in a way that prevents wear

- Bad weather means maintenance visits are limited
  - Watch weather forecasts really carefully ☺
- Sensors stop working altogether
  - Return to manufacturer
  - Check battery power – low battery is the most common reason that everything stops working

Top Tips

- Keep a maintenance log where you record EVERYTHING related to the station (maintenance visit, when you notice a problem, when you deployed a sensor, calibration notes)



- Get to know what your data should look like – minimum, maximum etc
- If cost allows, station maintenance is greatly enhanced by having remote data download.
- Take a look at summary data regularly, so that errors can be picked up, and data loss is minimized.

More information

http://www.sigmaaldrich.com/catalog/product/sigma/c5753?lang=en&region=LV (spinach standard)
http://toh.ie/paradigm/ (to manage multiple systems and sensors)

Suggested citation: de Eyto, E., Dillane, M., Laas, A., Pierson, D. and Jennings, E. 2016. Station maintenance (Factsheet 012). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 47-49. http://eprints.dkit.ie/id/eprint/520

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NETLAKE Guidelines for automated monitoring system development

013 What to Do About Ice?

Objective

The purpose of this fact sheet is to provide some practical advice on how to maintain automated monitoring systems (AMS) in lakes or reservoirs which experience a regular period of winter ice cover.

Considerations

For lakes that are regularly frozen in winter, and develop a long-lasting ice cover (greater that 1-2 cm thick), maintaining an AMS becomes more difficult. One is basically left with three alternative strategies for monitoring under ice covered conditions.

- Remove the AMS in the late autumn, and suspend the monitoring program until spring when the AMS can be re-deployed.
- Allow the AMS to become frozen into the lake ice cover, and continue monitoring.
- Deploy an AMS that is completely under water, below the level of the deepest expected ice thickness.

There are advantages and disadvantages to all of these approaches, which we discuss in more detail below.

The first strategy is probably the most common, especially for systems with expensive components, or profiling systems that have cables that regularly move through the water. There is no doubt that an ice bound AMS will often be subject to damage, especially during ice loss. So removal of the buoy during the winter is a reasonable safeguard to minimize instrument damage and maintain a long term monitoring program. It is however unfortunate that this must often be done, since the processes occurring during winter and at the times of the onset and loss of ice are ones that are expected to be strongly affected by climate change (Magnuson et al. 1997). Furthermore despite the best intentions, it is often difficult to re-deploy the buoy just following ice loss, especially on larger lakes where calm weather may be needed. We generally do not recommend removing the anchors, rather we attach a small marker buoy to each anchor rope and hope for the best. In most cases the anchors survive, although they may move. In the rare case that they do disappear they are not too expensive to replace. In cases where the buoy is removed during winter, it may be useful to supplement the monitoring program with a simple underwater deployment as described below.

The second strategy is to just leave the buoy in place during winter and continue measurements. This works well for meteorological measurements made above the water (or ice) surface, and for underwater sensors that are maintained at fixed depths, such as thermistor temperature sensors, oxygen sensors or multisensory sondes. At high latitudes one should consider the power requirements, and battery supply, as low light may limit the effectiveness of solar power systems. Given sufficient power, buoys frozen into the ice cover (Fig. 1) can work as well as during the ice free period. The greatest risk is at the time of ice loss, where in the worst case rapid movements of the lake ice sheet can rip lose anchors, damage submerged sensors, and even tip over the buoy. Such damage almost always occurs with ice loss is associated with a large wind event otherwise known as an ice shove event (Fig. 2). These events are most likely and most severe on large and wind exposed lakes. Overwinter deployment may in some cases be considered a reasonable strategy for small wind sheltered lakes, but there will always be some risk.

The final strategy involves mooring the buoy and sensors below the level of ice formation. This completely protects the sensors, and allows continuous measurements throughout the winter, The main disadvantage to this approach is that it is difficult to maintain telecommunications with the sensors or provide power to the sensors during winter, making this approach most suitable for the deployment of stand-alone logging sensors such as those made by Onset, PME or RBR, or multi-parameter sondes such as those made by YSI or Hydrolab. When using these systems in long under-ice deployments, consideration must be made to account for battery life data storage and measurement frequency. In some cases it has been possible to develop cabled under ice measurements systems which can provide data to an onshore data logger in near real time (Pierson et al. 2011 Example 3), and there are some bottom based profiling systems under development which could also be used under ice cover. The other potential pitfall with underwater deployments is that it can be difficult to find and retrieve the data loggers in the spring, since there is no surface marker buoy. There are several solutions to this. It is of course always good practice to obtain a precise GPS location, and use a brightly colored buoy that can be seen under water. When the deployment is not too far from land a long rope (that sinks) can be attached to the buoy anchor, and then led into land and securely fastened. This can be used to retrieve the buoy in the spring. If far from land a useful strategy is to attach a long bottom line system (Fig. 3) that can be snagged, with a drag hook from a moving boat searching near the known GPS location.

Examples

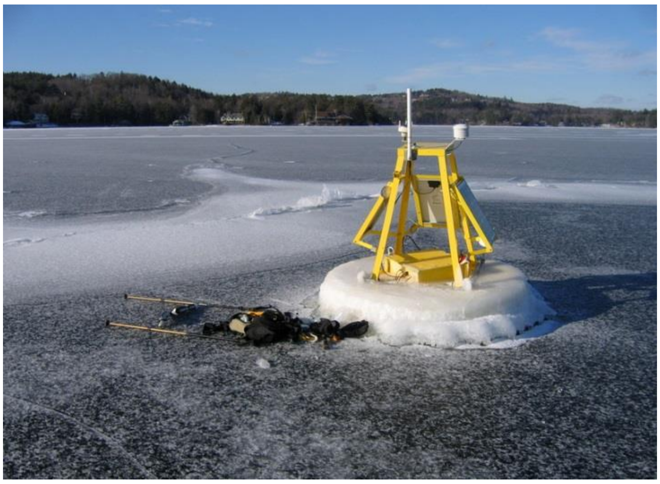

Figure 1. Water quality monitoring buoy frozen into Lake Sunapee N.H. USA. For many winters the buoy performed well, however in one year it was damaged at the time of ice loss. Photo credits: Midge Eliassen

Figure 2. Ice drifts on Lake Võrtsjärv (Estonia). When ice is broken up rapidly in large sheets that are moved by the wind significant AMS damage can be expected. Photo credits: Lea Tuvikene

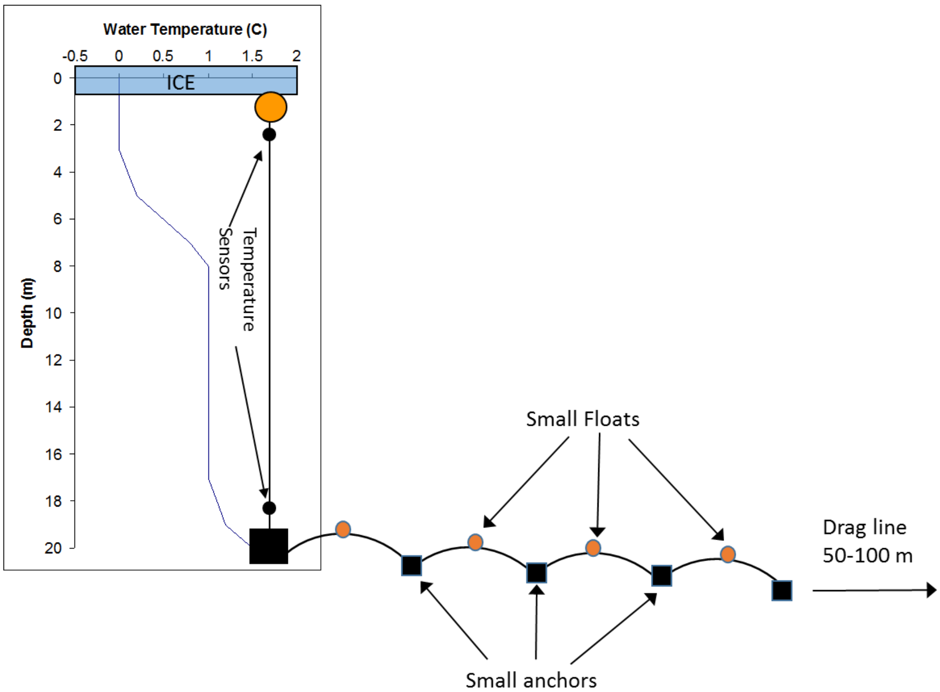

Figure 3. Under-ice temperature sensor deployment, also showing use of a bottom line that can be used with a drag hook to retrieve the system in the Spring. Modified from Pierson et al. (2011)

Likely Problems

Damage to systems frozen into the lake ice cover at the time of ice out.
Difficulty finding systems that are moored completely under water.

More information

Pierson, D. C., G.A. Weyhenmeyer, B. B. L. Arvola, T. K. T. Blenckner, D.M. Livingstone, H. Markensten, G. Marzec, K. Petterson, and K. Weathers. 2011. An automated method to monitor lake ice phenology. Limnology and Oceanography: Methods **9**:74-83.

Magnuson, J. J., K. E. Webster, R. A. Assel, C. J. Bowser, P. J. Dillon, J. G. Eaton, H. E. Evans, E. J. Fee, R. I. Hall, L. R. Mortsch, D. W. Schindler, and F. H. Quinn. 1997. Potential effects of climate changes on aquatic systems: Laurentian Great Lakes and Precambrian Shield Region. Hydrological Processes 11:825-871.

http://www.onsetcomp.com
http://pme.com/
http://www.rbr-global.com/products
https://www.ysi.com/

Suggested citation: Pierson, D., de Eyto, E., Laas, A., and Jennings, E. 2016. What to do about Ice? (Factsheet 013). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 50-53. http://eprints.dkit.ie/id/eprint/519

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NETLAKE Guidelines for automated monitoring system development

014 Security

Objective

In this factsheet, we give an overview of some options for securing your system to avoid accidental lose or damage by storm, people or animals.

Separate NETLAKE guidelines are available on how to securely anchor your station (AMSD guideline 004), protect it from lightening (AMSD guideline 005) and from ice damage (AMSD guideline 013).

Options

Below are some measures you can use to reduce possible damage and data loss

GSM alarm – if your system moves out of your expected operating range, you will get a SMS alert from your system.

GPS tracking – this allows you to track the position of your buoy, and alert you if it has moved from its intended postion.

Birds - Some bird protection devices are available with off the shelf weather stations (right). If you think you could have a bird problem at your site, you can also use homemade scarecrows, flashing objects hanging from a string (e.g. old CDs), or devices designed to scare birds from roosting on sail boats.

Human interference – you have two options here. Either try and hide the station as best you can (underwater, camouflage etc) or else make it very obvious, and appeal to the curious nature of people who may see it. In this case, you can use warning and information signs on the station (left), announcements in local or municipally newspapers and information on your institutional webpage (see below for links). An obvious webcam may act as a deterrent. Another option is to use padlocks to secure expensive items in strong boxes.

Open access to raw data – If you increase the availability of the data you are collecting with your system (line figures in user friendly graphs on your webpage for example), and people can see what parameters are being measured, that may reduce the risk of vandalism. Information signs about online data availability can be added to your platform.

Some examples of Lake data websites

http://burrishoole.marine.ie/FeeaghLake.aspx

https://sites.google.com/a/fmach.it/lter-tovel/

www.aquamonitor.no/langtjern

http://jarveveeb.emu.ee/index_en.html

Suggested citation: Laas, A., Pierson, D., de Eyto, E. and Jennings, E. 2016. Security (Factsheet 014). In: Laas, A., de Eyto, E., Pierson, D. and Jennings, E. (Eds.) *NETLAKE Guidelines for automatic monitoring station development*. Technical report. NETLAKE COST Action ES1201. pp 54-55. http://eprints.dkit.ie/id/eprint/521

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