A Network of High-Frequency Sensors Helps Protect the Future of Fresh Water Lakes

The Need for High Frequency Lake Monitoring

Lakes across the world are often in areas of outstanding natural beauty, enriching the landscape and our lives with their serene environments. They also provide the highly important economic functions in the supply of water, food, energy, flood control, and recreation. Often, they also support a tourist industry with major local economic benefits; for example 15 million people sample the delights of the English Lake District each year.

" Currently, for example, cyanobacterial blooms are widespread in many lakes around the world and since they are potentially toxic to livestock, pets and humans their occurrence severely restricts the use to which the lake and the lake water can be put. "

During the early part of the 20th century, many lakes in Western Europe and elsewhere were affected by raw sewage and fertiliser run-off from agriculture, degrading the economic benefits they provided and causing severe ecological damage and loss of species. Subsequent improvements in waste water management and farming practises have started to reverse these effects, but rates of recovery are low and other environmental pressures such as those caused by climate change, invasion of non-native species, water abstraction and atmospheric deposition have added further pressures. Currently, for example, cyanobacterial blooms are widespread in many lakes around the world and since they are potentially toxic to livestock, pets and humans their occurrence severely restricts the use to which the lake and the lake water can be put.

High frequency data are needed to understand how the different environmental pressures affect lakes and to forecast future responses. This is because lake condition can change rapidly, since the generation time of the largely microbial populations that control ecological structure and function is very short, of the order of days or less. Equally importantly, lakes are strongly influenced by short-term weather events, such as a storm or a flood, or a period of hot weather.

The UKLEON (United Kingdom Lake Ecological Observatory Network http://www.ceh.ac.uk/sci_programmes/water/uk-lake-ecological-observatory-network.html) project has developed an innovative sensing system exploiting new technology in sensors, data-loggers, computing and telemetry to collect high frequency ecological data automatically from remote sites. This not only provides a huge advantage for scientific research, but also has the potential to provide environmental managers or water companies with up-to-date information.

light and dissolved oxygen; the latter variable is measured using fluorescence which is much more reliable and stable than the electro-chemical technology used previously.

An automatic water quality monitoring station on Blelham Tarn.

The concentrations of the biological pigments chorophyll a (the green pigment in all photosynthetic algae and plants) and phycocyanin (a blue pigment that is specific to cyanobacteria or blue-green algae) are also measured using fluorescence. In addition, a sensor designed to measure carbon dioxide in air has been modified by the addition of a water-proof but carbon dioxide-permeable membrane so that it measures carbon dioxide in water.

Finally, there is an underwater light sensor to measure the light in water in comparison to a similar sensor just above the water surface. Bio-fouling of the sensors, especially in productive sites, has been largely overcome with automatic wipers to remove biofilm. Each AWQMS is powered by lead-acid batteries with most of the power in the summer provided by two solar panels.

The Network and Monitoring System

A network of automatic water quality monitoring stations (AWQMS) has recently been deployed across eleven lakes in the UK, including sites in England (5), Scotland (3), Wales (2) and Northern Ireland (1). The sites cover a very large variety of lake types and sizes; ranging from unproductive to productive, small to large, shallow to deep and lowland to upland.

Each AWQMS is equipped with a meteorological station to record local weather. Underwater, there is a chain of platinum resistance thermometers measuring temperature at a range of depths. Sub-surface, several sondes measure temperature, conductivity, pH, carbon dioxide, underwater

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Scotland
Loch Lomond (Glasgow)
Loch Leven (CEH)
Round Loch of Glenhead (UCL)

Northern Ireland
Lough Erne (AFBI)

England
Bassenthwaite Lake (CEH)
Blelham Tarn (CEH)
Esthwaite Water (CEH
Windermere (CEH)
Rostherne Mere (Loughborough)

Wales
Llyn Conwy (CEH)
Llyn Tegid (NRW)

The location of the eleven UKLEON monitoring stations. Organisations responsible for each station are shown in parentheses.

Surface water temperature
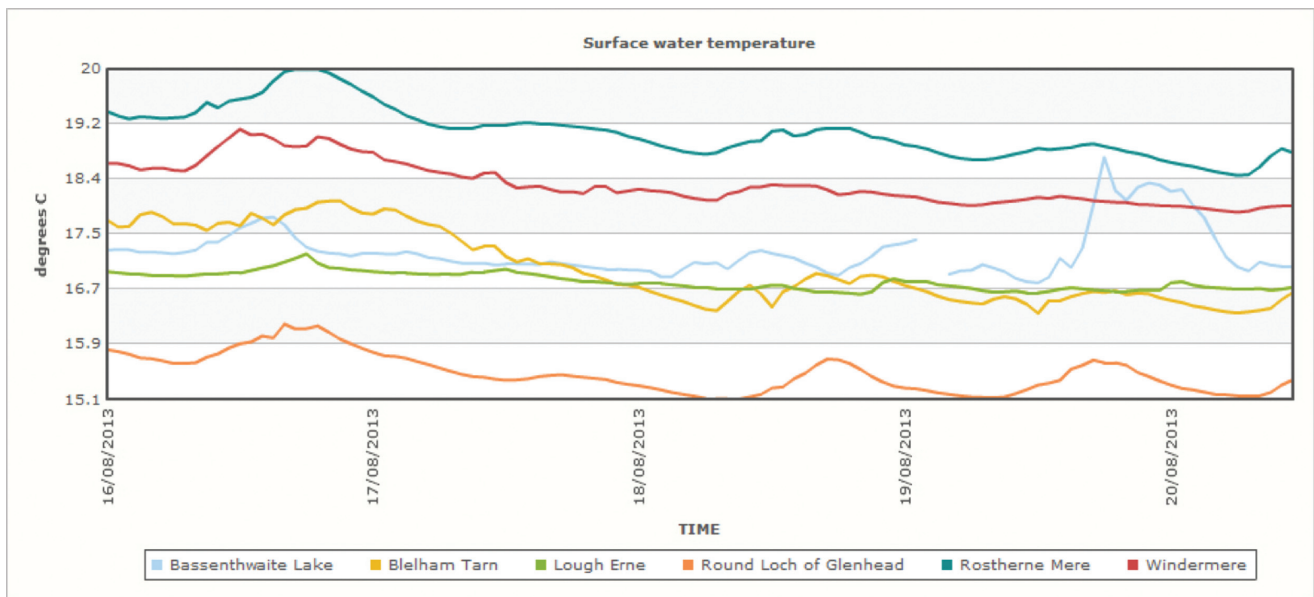
Example of real-time data made available on the internet (http://data.ecn.ac.uk/ukleon/results.asp).

Hydrolab multiparamater water quality instrument courtesy of OTT Hydrometry Ltd. The rotating cleaning brush is visible to the right

Early Data and Results

A web-site has been set-up where anyone can view the data in real-time or for past periods. A particular site or variable of interest can be selected and variables (water temperature or solar radiation for example) can be compared across the network of sites.

A simple interface allowing the different partners in the project to download and work on the data is nearly completed, allowing the three scientific demonstration projects to be progressed further:

• Real-time forecasting of algal blooms

• The effect of meteorology on the fate of carbon within lakes

• The level of regional coherence in sub-seasonal timescales.

Each AWQMS records around 30 different variables every 4 minutes, producing about 43.4 million data points annually from across the entire network. This creates a technological challenge in how to handle, quality control, and make use of this mass of data. Our approach has been to produce a bespoke piece of data loading software (UKLOADER) that automatically collects the information sent from each buoy by telemetry, and loads it into an Oracle database held at CEH Lancaster. The database implements a simple form of quality control by applying 'flags' to the data when, for example, data exceeds a reasonable range, where there is a known problem such as low battery voltage, or where sondes have been serviced and maintained at that particular time. No data are discarded, so a user can decide how best to deal with potential data

issues. Furthermore, many users will not need or wish to deal with the very high resolution data, so the database also automatically produces hourly and daily averages for all variables.

UKLEON Project Partners & Funders

UKLEON is funded as part of the Natural Environment Research Council's Sensor Network Programme. It is led from the NERC Centre for Ecology & Hydrology (CEH) in collaboration with the Universities of Glasgow, Lancaster, Loughborough and University College London and also with Natural Resources Wales. A substantial additional input of time and expertise has been contributed by staff from the UK Astronomy Technology Centre (UKATC) with expertise in handling large volumes of data. Two UK companies are also heavily involved in providing off-the shelf and bespoke equipment for the project: OTT Hydrometry Ltd and Lakeland Instrumentation Ltd. OTT Hydrometry are contributing further by funding a PhD as part of the project.

Bassenthwaite Lake, Cumbria (photo: IJ Winfield).

Collaboration

UKLEON is contributing to the NERC Consortium Grant GloboLakes (http://www.globolakes.ac.uk), that is investigating the state of lakes and their response to climatic and other environmental drivers of change at a global scale using satellite data; the COST action NETLAKE that is building a network of AWQMS around Europe (https://www.dkit.ie/netlake); and a project led from the USA, GLEON (Global Lake Ecological Observatory Network), that is building a global network of lake AWQMS (http://www.gleon.org).

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