MEASURING AND MODELLING THE DYNAMIC RESPONSE OF REMOTE MOUNTAIN LAKE ECOSYSTEMS TO ENVIRONMENTAL CHANGE

A programme of **MO**untain **LA**ke **R**esearch

MOLAR

CLIMATOLOGY AND METEOROLOGY

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Climatology and Meteorology

1. Automatic Weather Stations

1.1 Location and Installation

Weather stations should be installed as close to the lakes as is practically possible, preferably directly at the lake shore. The mast must be well-anchored and sufficiently robust for the conditions likely to be encountered at each site (e.g. highwinds and lateral snow pressure). It may be necessary to bolt the mast to a cement foundation or to a rock base. If a large permanently-moored raft is being used for other sampling, the weather station might be able to be mounted on the raft (this may also reduce security problems). Weather stations should in general be installed on flat land well away from obstructions affecting the wind field (e.g. cliffs, trees), and the site chosen should be as representative of the lake as possible. This is particularly difficult to achieve in the case of radiation measurements made at mountain lakes subject to varying amounts of shade from the surrounding topography.

To obtain an estimate of geomorphological wind sheltering, please measure the vertical angle of the topographical horizon (with a clinometer) at the 16 points of the compass N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW and NNW. These measurements should be made twice: once at the centre of the lake surface (not necessarily identical with the deepest point of the lake) and once, for comparison purposes, at the weather station itself.Please also take one or two photographs of the weather station in situ to show the character of the surroundings.

Each site operator should take appropriate measures to ensure the security of the weather station. The measures necessary will have to be decided by the site operator basedon his/her local knowledge. At the very least, warning notices should be posted.

1.2 Meteorological Variables

The following meteorological variables should be measured at all weather stations situated at Work Package 3 sites:

Air temperature (point values, every 30 minutes)
Relative humidity (30 minute mean values)
Wind speed (30 minute mean values)
Wind direction (point values, every 30 minutes)
Short-wave (solar) radiation (30 minute mean values)
Long-wave (infra-red) radiation (30 minute mean values)
Air pressure (point values, every 30 minutes)
Precipitation (daily mean values, 07.00h - 07.00h)

The data logger should be set to measure on the hour and on the half-hour to facilitate comparison with data from other meteorological stations. However, 30 minutes should be looked upon as the coarsest sampling interval; if data can be measured at higher resolution (e.g. at intervals of 15 or 10 min), this is of coursebetter. If a thermistor chain is installed in the lake, the weather station and thermistor chain data should, if possible, be measured simultaneously. The radiation measurements are not necessary at Work Package 2 sites. Modern data loggers should allow storage of half-hourly output data from, say, 10 sensors over a period of as much as six months (86,400 data points plus date and time) without any problem. Before being sent on from each site, the raw meteorological data must be calibrated according to the instructions of the manufacturer; uncalibrated data are not useable.

At sites where there are no plans to install a thermistor chain for the automatic monitoring of the lake temperature profile, it would be very useful if at least one temperatu re sensor measuring lake surface water temperature (at 10-30 cm below the lake surface) could be integrated into the weather station. This would allow us at least i) to relate surface water temperature to air temperature empirically, and ii) to calculate the infra-red radiation leaving the lake surface (necessary for modelling the lake heat balance).

Wind speed and direction measurements should be made 10 m above ground level (the standard meteorological height for wind measurements). This can be reduced to, say, 5 m, if it is not practicable to use a 10 m mast, since the logarithmic form of the wind speed profile means that the difference is usually relatively small between 5 and 10 m._At heights lower than 5 m, however, especially in mountainous terrain, roughness elements are likely to have a substantial effect on the wind speed. If wind measurements are being made on a raft in the lake, it would be valuable to make two simultaneous sets of wind speed measurements (say at 10 m and 3 m), which would allow the wind speed_drag coefficient over water to be determined (there is little point in doing this over land for our purposes). Make sure from the firm supplying the weather station that the anemometer will function properly in winter (problems frequently arise with snow in the cups and freezing up, for instance).

Variables other than wind speed and direction can be measured at heights much lower than 10 m; however, please make sure the sensors are mounted high enough so that they are always well above the maximum possible height of snow cover. Air temperature andrelative humidity sensors should have ventilated radiation shields. The heights of the sensors above ground level and above the surface of the lake should be noted.

If additional sensors and spare channels are available, site operators maywish to duplicate some measurements i) in case of possible malfunction of one sensor; and ii) to obtain an estimate of horizontal variability (precipitation, for instance, is very heterogeneous spatially: the possibility of using several precipitation gauges distributed over an area might therefore be worth considering, especially at Work Package 2 sites: see below).

Most practical problems with the weather station are likely to occur in winter. Anemometers ice up, snow covers the radiation gauges, the electronics become unreliable, batteries lose power, etc. etc.Measuring precipitation in winter is definitely a problem. Continuous automatic recording of precipitation using a standard unheated gauge is only feasible when the air temperature is above zero.However, heating the precipitation gauge requires a large amount of power and drains batteries rapidly, and so will not be possible at most MOLAR sites. Another possible solutionto this problem involves the use of special automatic precipitation gauges containing anti-freeze, but such sensors tend to be expensive. Thus, in general, continuous precipitation measurements will not be available in winter. Precipitation estimates at most stations during a large part of the year will therefore have to be based on totalisator-type gauges (containing a measured amount ofanti-freeze to melt snow falling into the totalisator before it is blown out again by the wind, and possibly a thin layer of oil to reduce evaporation; contact your national meteorological office for advice on this).Because precipitation tends to be spatially very heterogeneous, if possible several totalisators should be set up at different points within the lake catchment area to give an idea of the spatial variation present.This may not be feasible for reasons of cost (totalisators are not cheap), but even normal large buckets containing a measured amount of anti-freeze, fixed on a platform about 2 m above ground, and distributed around the catchment area, would be better than nothing for this purpose.

Radiation measurements in winter are also a problem, since the sensors are sometimes covered with snow, which may or may not then be blown off by the wind. One possible solution to the this problem might be to use two sensors, one receiving direct radiation, the other receiving radiation reflected upwards from the snow on the ground. However, the problem of winter measurements is less serious than it seems, since meteorological effects on a lake are much less important during periods of ice cover than otherwise.

At some sites, a permanent meteorological station belonging to some other organisation already exists within about five kilometres from the site. In this case, if the data can be made available to us, it may not beconsidered necessary to install a weather station, or it may only be necessary to install a cut-down version. Assuming all necessary meteorological variables are measured at the permanent station, such a cut-down version should at least measure wind speed and direction, precipitation and air temperature.

Calibrated data from the meteorological stations, as Excel tables or in ASCII format, should be sent in the first instance by e-mail to:

Dr. David M. Livingstone
Dept. of Environmental Physics, EAWAG
Ueberlandstrasse 133
CH-8600 Dübendorf
Switzerland
e-mail: living@eawag.ch

Variables should either be listed (i) in separate files or (ii) in table form, with one variable to a column, and with only one delimiter (tab, space or comma) between columns. Please send enough accompanying documentation to allow the data to be interpreted (e.g. starting date and time; ending date and time; measuring intervals; exact location of station; height of sensors above ground level, above lake surface level and above sea level; any information on sensor or data logger malfunctioning or otherpossible sources of bad data; the order in which the variables are tabulated and the units in which they are given).

2. Existing Meteorological Stations

A map illustrating the locations and elevations above sea level of all permanent meteorological stations within about 200 km of the MOLAR sites, with a list of the data available from these stations is requested, along withanswers to the following questions:

2.1 Data

a. Which meteorological variables have been measured (e.g. air temperature, precipitation, global radiation...)?
b. For which time period do the measurements exist (e.g. 1963-1989).
c. Are the data available free, or at reproduction cost, to researchers?
d. What is the sampling interval (10 min, hourly, daily means, monthly means...)?
e. Do you know of any really long data series (going back to, say, 1800 A.D.) from a station in your country which we may not be aware of (even if the station is situated far from the MOLAR sites)?
f. Do you know of any data series from particularly high e levations in your country (even short series)?

2.2 Researchers

Do you know the name and address of any local research workers interested in climatology that we might contact to find out more about climate data from your country?

Please send information on existing meteorological stations to:
Dr. Roy Thompson
Dept. of Geology and Geophysics, University of Edinburgh
King's Buildings, West Mains Road
Edinburgh
Scotland
e-mail: egph08@castle.edinburgh.ac.uk

3. Data on Lake Ice Cover

3.1 MOLAR sites

Any information on the ice cover of the MOLAR lakes which may be obtained during the sampling program is requested. This information includes i) date of freeze-up (defined as the first date on which the lake is completely covered with ice); ii) date of break-up (defined as the first date on which the lake is completely ice-free); iii) thickness of ice at the sampling hole.

3.2 Other Lakes

Information on the dates of freeze-up and break-up of any other lakes in your area is also requested, especially if long series of such data already exist. An effort should be made to discover if any long series of observations of freeze-up and break-up exist.

Please send information on lake ice cover to:
Dr. David M. Livingstone
Dept. of Environmental Physics, EAWAG
Ueberlandstrasse 133
CH-8600 Dübendorf
Switzerland
e-mail: living@eawag.ch