

# NETLAKE toolbox for the analysis of high-frequency data from lakes



## Factsheet #2

### Lake Heat Flux Analyzer (LHFA)

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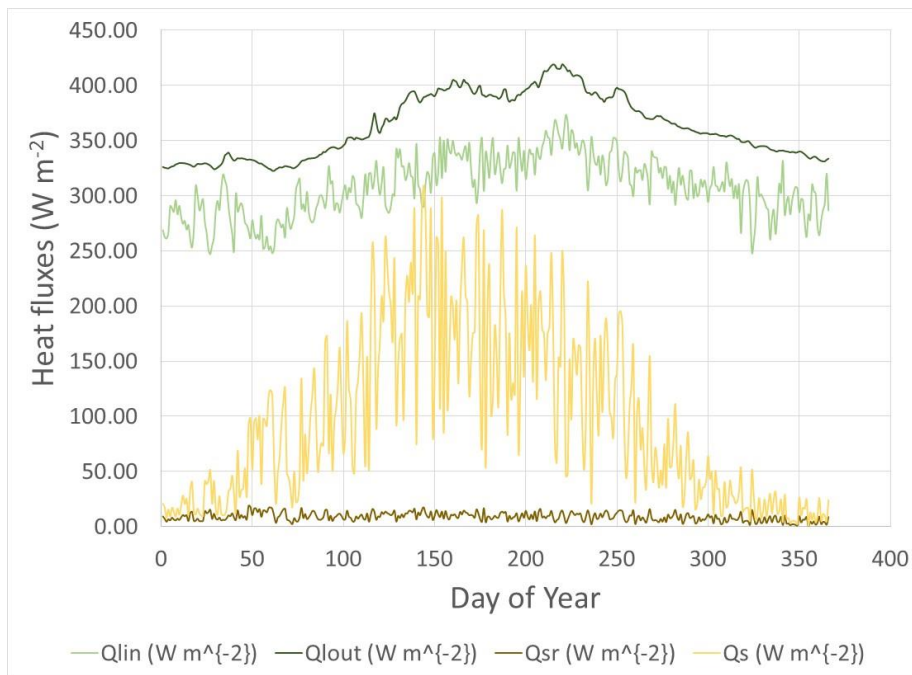
Ian Jones

#### *Objective*

Lake thermal and mixing properties are mainly driven by fluxes of heat and wind mixing at the surface of a lake. There are several different types of heat fluxes. With the right equipment these can be measured, but such equipment can be expensive and requires expertise to deploy. As an alternative to direct measurement most of these fluxes are often calculated with established methods using the meteorological variables commonly measured by automatic lake monitoring stations. These methods can be quite detailed and require some specialist knowledge to execute. The software tool, Lake Heat Flux Analyzer (LHFA), has been written to enable the calculation of these fluxes, and related terms, from standard meteorological variables. It has been specifically written for those using data from high resolution monitoring stations on lakes. The principal fluxes calculated are  $Q_{sr}$ , the reflected short-wave radiation;  $Q_{in}$ , the incoming flux of long-wave radiation;  $Q_{out}$  the outward flux of long-wave radiation;  $Q_h$ , the sensible heat flux, driven by temperature differences between water and the overlying air;  $Q_e$ , the latent heat flux, driven by moisture differences between water and the overlying air; and  $Q_{tot}$ , the total heat flux. In addition, the software calculates transfer coefficients at the measurement height and calculates transfer coefficients, wind speed, relative humidity and air temperature at the standard reference height of 10 m, including their values for a neutral atmosphere approximation. The software tool can also be used if the meteorological data are collected over land, but the results will have some additional inaccuracies.

#### *Specific application*

Some example output for incoming and outgoing long-wave radiation and incoming and reflected short-wave radiation for 2004, calculated from data taken on a monitoring buoy at Esthwaite Water, UK, are shown in Figure 1. These data were calculated using LHFA, downloaded from the web and subsequently read into an excel file.



**Figure 1.** Radiative surface fluxes for Esthwaite Water, UK, 2004.

## Background

The software can be used directly through a web-interface or the Matlab code can be freely downloaded (see link below). Some experience in setting up files and changing formats, specifically the date/time format, is required to utilise the web-version. While the tool can be used without having any prior knowledge of heat fluxes, interpretation of the results does require some understanding of the fluxes.

## Type of data and requirements

The required inputs for LHFA are wind speed, air temperature, relative humidity, surface water temperature and either short-wave radiation or Photosynthetically Active Radiation (PAR), which LHFA will convert to short-wave if necessary. In addition, the measurement heights are required for wind speed, air temperature and relative humidity. Formatting is detailed in the user manual. Note that the formatting must be followed exactly. Example files are provided on the web-page (see link below).

## Basic procedures

The procedure to follow is detailed in the user manual available on the web-page (link below). Only a brief synopsis is given here:

1. Collect and clean high frequency data for wind speed, air temperature, relative humidity, solar radiation and surface water temperature. Note that data must be in numeric Matlab format and missing values denoted by NA will result in an error.

2. Go to the LHFA web-site and reformat data exactly according to the instructions in the user manual and the example datasets, including collecting the data files in a single zipped folder.
3. Either download and use the Matlab version of the code, which can then be executed in Matlab, or upload the zipped data folder to the web-site.
4. Submit file. The program takes a while to run, depending on the size of the dataset and the internet connection.
5. Download the output data.

### *Pitfalls and tips*

- Many different formulae have been developed to calculate heat fluxes. LHFA uses a set of specific established fluxes, but this is not an endorsement that these are the only or the most accurate formulae. Furthermore, the study of air-water fluxes is ongoing and new advances, not captured by this software, are likely to continue.
- Inputting data to the web interface requires very specific formatting. Whilst this formatting is described in detail in the user manual and examples are downloadable from the web-page, it can be frustrating for users to ensure their data are in the exact format required.
- One of the most common reasons for the program to fail is if the date/time is in the incorrect format or if there are strings such as 'missing' in the data. The user should instead leave that particular cell blank or include NaN, which indicates missing data.
- There is no absolute convention for describing the sign of heat fluxes. The LHFA paper describes the direction of fluxes calculated in the software, but, nevertheless, it is still easy for an inexperienced user to get confused over the direction of each of the fluxes.
- The software performs the complex calculations required for determining surface fluxes, but unless users are familiar with typical values, flux directions and meanings of fluxes, misinterpretation of results is easy.
- Any bulk formulae calculations of heat fluxes are subject to error. Results should therefore be interpreted as estimates, rather than exact values.
- Lakes modify the overlying air temperature, relative humidity and wind speed. Fluxes calculated using any land-based measurements will therefore suffer from additional inaccuracy.
- The program searches for consistent times among the different variables, wind speed, air temperature, and so on. Therefore, if the variables have slightly different times (e.g. seconds or minutes), these will not be used in the calculation. Users must ensure consistent times among the variables.

## Further reading

### Key References:

The reference for the paper describing the code and its uses is:

Woolway, R.I., Jones, I.D., Hamilton, D.P., Maberly, S.C., Muraoka, K., Read, J.S., Smyth, R.L., Winslow, L.A. 2015. Automated calculation of surface energy fluxes with high-frequency lake buoy data. *Environmental Modelling and Software* 70: 191–198.

### Other useful references:

For an example of heat fluxes being calculated and used see:

Woolway, R.I., Jones, I.D., Maberly, S.C., Feuchtmayr, H. 2015. A comparison of the diel variability in epilimnetic temperature for five lakes in the English Lake District. *Inland Waters* 5: 139–154.

The sister paper to LHFA for calculating in-lake physics parameters is:

Read, J.S., Hamilton, D.P., Jones, I.D., Muraoka, K., Kroiss, R., Wu, C.H., Gaiser, E. 2011. “Lake Analyzer”: Derivation of lake mixing and stratification indices from high-resolution lake buoy data. *Environmental Modelling and Software* 26: 1325–1336.

For a useful background on lake physics see:

Imberger, J., Patterson J.C. 1990. Physical Limnology. *Advances in Applied Mechanics* 27: 303–475.

## Code

The Matlab version of the software, the web-interface, and the user manual can all be found at: <http://heatfluxanalyzer.gleon.org/>

## Contact details

Ian Jones. Centre for Ecology and Hydrology, UK.

[ianj@ceh.ac.uk](mailto:ianj@ceh.ac.uk)

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