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EddyUH: an advanced software for Eddy Covariance flux calculations

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Background

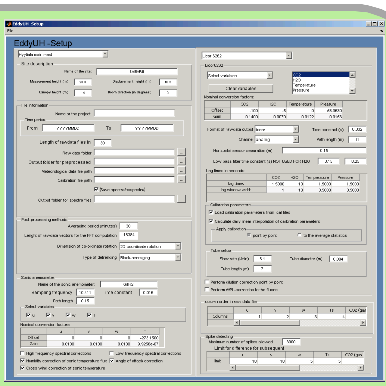
Eddy Covariance (EC) is a mathematically complex technique that analyzes high-frequency wind and scalar atmospheric data series (often called "raw data"), which are usually saved in hard drive devices for post-processing and final estimations of turbulent flux values. Although in the past several years great efforts of the EC flux community have led to a standard methodology (Aubinet et al., 2000) for post-processing steps (at least for CO_2 and energy fluxes), the harmonization of post-processing is quite difficult, since most of the required steps and corrections are site- and instrument (gas analyser and sonic anemometer) specific. Systematic differences in EC flux estimates strongly depend on the selection, application and order of processing steps (Mauder et al., 2008). With this in mind we recently developed a new post-processor for EC measurements, EddyUH, which can be used in processing data from any site with any instrument setting. It includes the most updated corrections and methods for EC flux estimations. With this software the user can determine fluxes of various scalars from high frequency data series, including not just the usually measured scalars (temperature, H_2O and CO_2) but also for instance methane and nitrous oxide. EddyUH is written in MATLAB and includes a graphical user interface.

Main features of EddyUH

Supported instruments	
Sonic anemometers	Gill-R2, Gill-R3, Gill-HS, Campbell CSAT3, Metek-USA-1
Gas analyzers	Licor-6262 (CO_2, H_2O), Licor-7000 (CO_2, H_2O), Licor-7500 (CO_2, H_2O), Licor-7200 (CO_2, H_2O), Licor-7700 (CH_4), Campbell TGA100 (CH_4, N_2O), Los Gatos –RMT200 (CH_4), Picarro G1301-*f* (CH_4, CO_2, H_2O), Aerodyne QCLAS (N_2O, CO_2, H_2O, CH_4), Unisearch Associates Inc. LOZ-3 (O3) , CPC (particle number concentration)
Implemented methods/corrections	
Raw data level	Units conversion and Calibration; Spike detection; Cross-wind correction (Liu et al., 2001); Dilution correction point by point; Angle of attack correction (Nakai et al., 2006); Block averaging, linear detrending and autoregressive running mean filter; Time lag estimation
Wind coordinate rotation	Planar fit (Wilczak et al., 2001); Streamwise rotation (1D, 2D or 3D) according to McMillen (1988)
Quality statistics	Skewness, kurtosis, flux non-stationarity, random flux error, flux intermittency
High frequency loss	Theoretical (Moncrieff et al., 1987); Empirical estimation of the transfer function (Aubinet et al., 2000; Mammarella et al., 2009)
Low frequency loss	According to Rannik (1999)
Humidity corr to sensible heat flux	According to Schotanus et al. (1983)
WPL correction	Based on Webb et al.(1980), Ibrom et al.(2007) for closed-path GA, additional cross-talk correction for Licor-7700, Los Gatos -FMA and Aerodyne QCLAS

1. EddyUH Project Setup

The first step is to create a project setup-file. It can be done by using a graphical interface called EddyUH-Setup, which allows the user to upload all relevant information concerning the site, the EC system configuration, and the related methods and corrections to be used. The file is used as an input in other packages or modules.

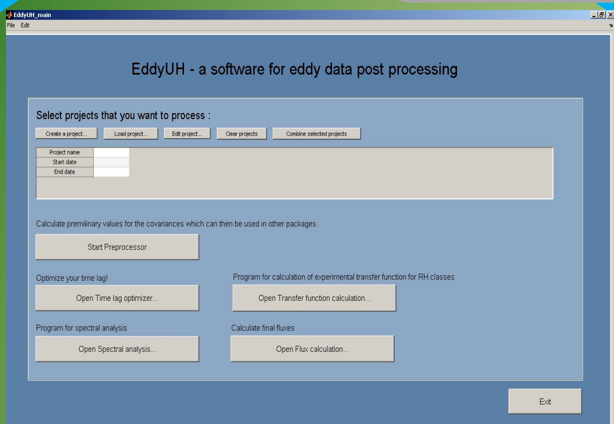


2. EddyUH_Preprocessor

It performs several operations on the EC raw data. The module needs ancillary information passed as input from the project file. The outputs are wind and gas raw signals statistics (mean, standard deviation, co-variance, skewness, kurtosis), spectra and co-spectra for each raw data file, time lag estimates, quality statistics parameters (flux non-stationarity, flux intermittency, random flux error). All these data are saved in monthly binary files, and then used by other modules. With this kind of preliminary values for the fluxes it is possible to separate time lag optimisation and transfer function calculation from final flux calculation and therefore the time consuming flux calculation can be done faster.

3. Time lag optimisation

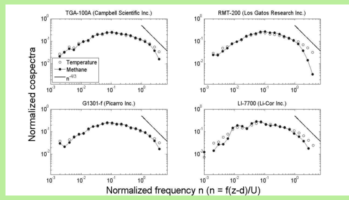
Closed-path gas analysers inflict a time lag between concentration and wind speed measurements due to the sampling tube. For water vapour this lag depends on relative humidity (Ibrom et al., 2007). With this package the dependence is approximated and the result is used in flux calculation package. Moreover several statistical and visual tools allow the user to optimize the time lag windows, which were used in the *EddyUH_Preprocessor* and to validate the estimated values of the time lag.



The main interface of the software

4. Spectral analysis

Spectra–files created in *EddyUH_Preprocessor* are used. The user can perform several analyses using spectral data e.g. ogive and spectral similarity. In addition spectral models used in spectral corrections of fluxes can be determined. Tools to calculate turbulent parameters like the integral time scale of turbulence and the dissipation of turbulent kinetic energy are also available.

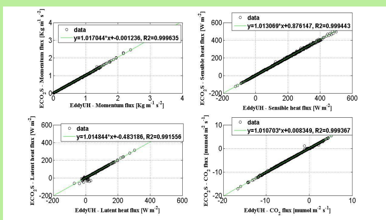


(from Peltola et al. (2011) FcoE presentation)

6. Final fluxes

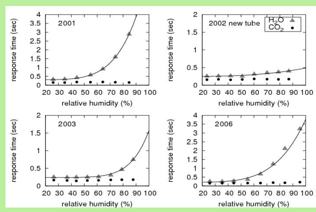
Final estimates for the surface fluxes are calculated from raw data using post-processing methods described in setup-file and information gathered from other packages. It uses the outputs and the information from all the other modules and performs remaining relevant corrections to the fluxes. An automatic and visual quality screening of the fluxes is also performed at this stage. For each processed month the outputs are then saved in two ascii files, one containing the full dataset (not only the corrected fluxes), and another one having a user defined format.

The new software was validated against the Eddy Covariance Community software (ECO_2S), recently developed within the IMECC-EU project (http://gaia.agraria.unitus.it/eco2s/). The software intercomparison was performed using one month of raw data, measured at the SMEAR II station, Hyytiälä, Finland.



5. Transfer function calculation

Signal related to high frequency fluctuations is damped because of various reasons. With this package transfer function related to low pass filtering effect is determined assuming scalar similarity. In addition effects of relative humidity and wind direction are examined. lets the user to empirically estimate the low pass filter time constant of the EC system, by using the previously estimated co-spectral data. For water vapour fluxes, measured by a closed path EC system, the analysis is performed on different classes of relative humidity (RH). Then the H_2O time constant is parameterized as a function of RH following the method of Mammarella et al. (2009). The estimated time constants are then used in the *EddyUH_Flux calculation* module in order to perform the spectral correction to the final flux values.



Relationship between the low pass filter time constant for water vapour and the relative humidity estimated for several years (triangles). EC data were measured above a Scots Pine forest in Hyytiälä, Finland.

Acknowledgements

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