2nd workshop/training course on

EddyUH: a software for eddy covariance flux calculation

Helsinki, 21-25.1.2013

Introduction to the course/workshop

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Where we are: Kumpula Campus
Division of Atmospheric Sciences

- Head: prof. M. Kulmala
- Over 120 scientists and Ph.D. students
- 9 professors
- aerosol- and environmental physics, micrometeorology, chemical meteorology, dynamic and physical meteorology
- National and Nordic Centre of Excellences
Research areas and focus

Focus: Micrometeorology / Measurements and modelling of exchange processes between the atmosphere and different ecosystems

How do we measure EC flux
3D sonic anemometer + fast gas analyzer

High frequency (≥10 Hz) measurements of \( u, v, w, T, \text{CO}_2, \text{H}_2\text{O}, \text{CH}_4, \text{N}_2\text{O} \)…

Open-path IRGA Licor 7500 (CO2 and H2O)
Photos by Sami Haapanala, UH
Eddy covariance technique

- Direct and continuous measurements of net surface exchanges of energy and gases at ecosystem scale.
- Time scale half-hour to interannual.
- Non destructive, non invasive.
- Ecosystem function.

- Only net fluxes.
- Random errors.
- Systematic errors.
- Gaps.
- Flat terrain
UHEL EC flux measurement sites

Siikaneva I
boreal fen

Siikaneva II
boreal bog

Hyytiälä
Scots pine
(SMEAR II)

Lake Kivijärvi

Lake
Valkea-Kotinen

Kumpula Urban
(SMEAR III)

Hotel Torni Urban

Värriö sub-arctic
forest (SMEAR I)
EC sites network in Europe

The situation in Europe

- **1996-1999**: EUROFLUX
  - About 15 sites

- **1999-2002**: MEDEFLU
  - About 10 sites

- **2000-2003**: Carboeuroflux
  - About 35 sites

- **2004-2008**: Carboeurope-IP
  - About 50 sites + 50 not funded

- **2008-2011**: IMECC
  - About 13 sites

- **2009-2012**: ICOS
  - No sites funded

- **2010-2014**: GHG-Europe
  - About 20 sites

Others projects like NitroEurope and CarboExtreme contribute also to support the eddy covariance sites but not as main objective. Regional projects like NECC, Carboitaly, CarboSpain supported also sites.
Eddy covariance sites are world-wide distributed and organized in regional networks

Adapted from D. Papale

www.fluxdata.org
FLUXNET, network of networks

With the aim to connect scientists and promote synthesis studies

Adapted from D. Papale

Growth of FLUXNET
523 Towers as of March 07, 2011

www.fluxdata.org
• Monitoring of concentrations and fluxes of CO$_2$, CH$_4$ and N$_2$O
• Tentative period of operational phase 2014 - 2031
• Head Office to be located in Helsinki
Eddy Covariance: A Practical Guide to Measurement and Data Analysis

Marc Aubinet, Timo Vesala, Dario Papale (Editors)

This highly practical handbook is an authoritative treatment of eddy covariance measurement that will be of keen interest to scientists who are not necessarily specialists in meteorology. The chapters cover measuring fluxes using eddy covariance techniques, from the theory underpinning and system design to data collection, correction, and analysis.

With a state-of-the-art perspective, the authors examine the latest techniques and approaches to data processing and quality control. The chapters provide an overview of measurement problems involved in flux data filtering, analyzing timeseries and gap filling, and labelling. Emphasis is placed on the interpretation of measurement techniques in different environments from forests, grasslands, and wetlands to urban areas, with strategies for data processing, quality control, and statistical analysis. The book also reviews the development of a threedimensional, continuous, and standardized database of flux data, with a focus on the CARBOEurope and FLUXNET databases. The authors discuss the current status of eddy covariance measurements and their future potential in global change research.
1. Flux measurements in urban ecosystems

>>>>> multiple spatio-temporal scale surface heterogeneities
Distribution of the urban flux measurement sites recorded in the Urban Flux Network database (http://www.geoq.ubc.ca/urbanflux/)

<table>
<thead>
<tr>
<th>Climates</th>
<th>Fraction of world population</th>
<th>No of urban flux towers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cities in tropical climates (A)</td>
<td>28%</td>
<td>3</td>
</tr>
<tr>
<td>Cities in arid and semiarid climates (B)</td>
<td>14.5%</td>
<td>3</td>
</tr>
<tr>
<td>Cities in temperate climates (C)</td>
<td>44.6%</td>
<td>40</td>
</tr>
<tr>
<td>Cities in continental climates (D)</td>
<td>12.4%</td>
<td>15</td>
</tr>
<tr>
<td>Cities in polar climates (E)</td>
<td>0.3%</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>61</strong></td>
</tr>
</tbody>
</table>

Source: Fluxnet Newsletter
May 2012
Figure 2 - Number of active urban flux sites active per year (1990-2012) and measured turbulent fluxes. Source of data: Urban Flux Network database (May 2012).
2. Flux measurements in lake ecosystems

- Inland water are important source of carbon (CO2 and CH4) to the atmosphere (Bastviken et al., 2011, *Science*)
- Chamber methods and gas exchange models are often used >>> very large uncertainty.
- Less than 10 papers published on EC CO2 flux.
- Less than 20 papers published on EC energy flux.
- Less than 5 papers published on EC CH4 flux.
EC post-processing software

- EDIRE (University of Edinburgh, UK)
- ALTEDDY (Alterra)
- TK3 (University of Bayreuth, Germany)
- EddySoft (Max-Planck-Institute Jena, Germany)
- Eth-flux (Technical University Zürich, Swiss)
- ECPack * (University of Wageningen)
- ECO 2S* (IMECC-EU Univ. of Tuscia, Italy)
- EddyPro* (www.licor.com)
- EddyUH* (University of Helsinki, Finland)

* = open source
The software **EddyUH**, developed by UHEL/DPAS, includes state-of-art methodologies for EC flux estimates.

### Supported instruments

<table>
<thead>
<tr>
<th>Sonic anemometers</th>
<th>Gill-R2, Gill-R3, Gill-HS, Campbell CSAT3, Metek-USA-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas analyzers</td>
<td>Licor-6262 (CO(_2), H(_2)O), Licor-7000 (CO(_2), H(_2)O), Licor-7500 (CO(_2), H(_2)O), Licor-7200 (CO(_2), H(_2)O), Licor-7700 (CH(_4)), Campbell TGA100 (CH(_4), N(_2)O), Los Gatos –RMT200 (CH(_4)), Picarro G1301-f (CH(_4), CO(_2), H(_2)O), Aerodyne QCLAS (N(_2)O, CO(_2), H(_2)O, CH(_4))</td>
</tr>
</tbody>
</table>

### 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 |
| Coordinate rotation of sonic wind components | 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, Moore et al., 1986); 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 –RMT200 and Aerodyne QCLAS |
Acknowledgements

Nordic Centre of Excellence (NORDFORSK)

- DEFROST (www.ncoe-defrost.org)
- CRAICC (www.atm.helsinki.fi/craicc)

Research Networking Programmes

- TTORCH (www.ttorch.org)
- NORDFROST (www.nateko.lu.se/nordfrost/home.html)