Long-term energy flux measurements over a small boreal lake using eddy covariance technique

2nd Workshop on Parameterization of Lakes in Numerical Weather Prediction and Climate Modelling


Based on an article submitted to Journal of Geophysical research, revised 27.8.2010: Long-term energy flux measurements and energy balance over a small boreal lake using eddy covariance technique
1. Background

Fraction of water per area

Lakes in size classes

<table>
<thead>
<tr>
<th>Size Class</th>
<th>Count</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01 - 0.1 km²</td>
<td>40309</td>
<td>3303 km²</td>
</tr>
<tr>
<td>0.1 - 1.0 km²</td>
<td>13114</td>
<td>1330 km²</td>
</tr>
<tr>
<td>1.0 - 10 km²</td>
<td>279</td>
<td>5703 km²</td>
</tr>
<tr>
<td>10 - 100 km²</td>
<td>2283</td>
<td>7227 km²</td>
</tr>
<tr>
<td>100 - 1000 km²</td>
<td>44</td>
<td>10825 km²</td>
</tr>
<tr>
<td>&gt; 1000 km²</td>
<td>3</td>
<td>&gt; 1000 km²</td>
</tr>
</tbody>
</table>

Veden osuus prosentteina pinta-alasta
Lake surface energy balance

\[ R_n - \Delta Q = H - LE + \Delta Q_B + \Delta Q_F + \Delta Q_P \]
Motivation

- Lakes described very crudely in weather prediction models
  - Increasing resolution enables small lakes to be taken into account
  - Measurements for evaluation data needed
- Lake ecology: thermal structure, gas exchange (CO$_2$, CH$_4$…)
- Energy balance closure in EC measurements

Our aims

1. Detailed information on the thermal structure of a small boreal lake
2. Determine the energy closure of the lake with its components and their driving factors
3. Provide data for model evaluation
2. Measurements

- Raft on Lake Valkea-Kotinen, Lammi (61°24'N, 25°03'E)
- Open-water periods 2005-2008
- Eddy covariance measurements → H & LE
  - sonic anemometer (Metek USA-1)
  - closed-path IR gas analyzer (LI 7000)
- Net radiation: MB-1, Astrodata, Tartu, Estonia
- Near water meteorology
- Water temperature profile → ΔQ
  - 13 depths, 20cm – 4m

Area 4.1 ha
- Mean depth 2.5 m
- Max depth 6 m
- attenuation coefficient 6.3 m⁻¹
Source areas of the 4 energy fluxes are different
- H & LE: about 50m, source area depends on wind direction, atmospheric stability…
- $R_n$: 3.6m radius of 80% contribution
- $\Delta Q$: point measurements
3. Results

Water temperature profile

Thermocline depth

Inverse stratification
Does the hypolimnion interact with the atmosphere?

- A FFT applied to water temperature data from 13 depths
- 24h variation power selected
- plotted as a function of depth per each month

2007

Month number shows thermocline depth

April and October isothermal
Energy fluxes

Maximum at noon and minimum in the night

Maximum in the morning and minimum in the afternoon

Maximum in the afternoon and minimum in the morning
Comparison between measurement sites

Average diurnal course in July 2007
Energy balance closure

Closure comparable to numerous studies from forest sites

\[
\frac{H + LE}{R_n - \Delta Q}
\]

\[
R_n - \Delta Q - H - LE
\]
4. Conclusions

- Longest data set ever from small lakes

- Energy flux dynamics differ much from those at terrestrial sites
  → should be included in NWPs and climate models
  → data needed from different sized lakes

- An inexplicable unclosed energy balance also at a lake site (as other sites, too)

- Hypolimnion not important for energy balance during stratification
5. Potential for model validation?

2006

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Ice free

Turnover

$R_n$

H & LE

T, U, p, RH, rr

Water temperature $\rightarrow \Delta Q$
6. New measurement site

Lake Kuivajärvi, Hyytiälä
61°50'N, 24°16'E
Aug 2009 - Feb 2010
Jul 2010 - now
$R_n, \Delta Q, H, LE$
Meteorology
Measurements also at a fen

61°49.961’ N, 24°11.567’ E

R_n, ΔQ, H, LE
Meteorology

CO₂ and CH₄ fluxes

See the webpage on the "Contact info" slide for further information
THANKS!
References


Contact info

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Source area analysis of the turbulent fluxes

Figure 8. Modeled footprints for the two dominant wind directions along the lake: southeast (SE) and northwest (NW). The distance to the forested shore is 135 m in the SE case and 240 m in the NW case (see Figure 1). For comparison, a footprint for a case of open water body without a nearby forested shore is also presented (note 5 times larger scale for the open-water footprint presented on left axis). The measurement height is 1.5 m.

Vesala et al. 2006
Meteorology at Lake Valkea-Kotinen

Nordbo et al. 2010
Cumulative heat storage of the lake

Nordbo et al. 2010
Spectral correction of the water vapor flux

Nordbo et al. 2010
Driving factors of H and LE

Nordbo et al. 2010