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

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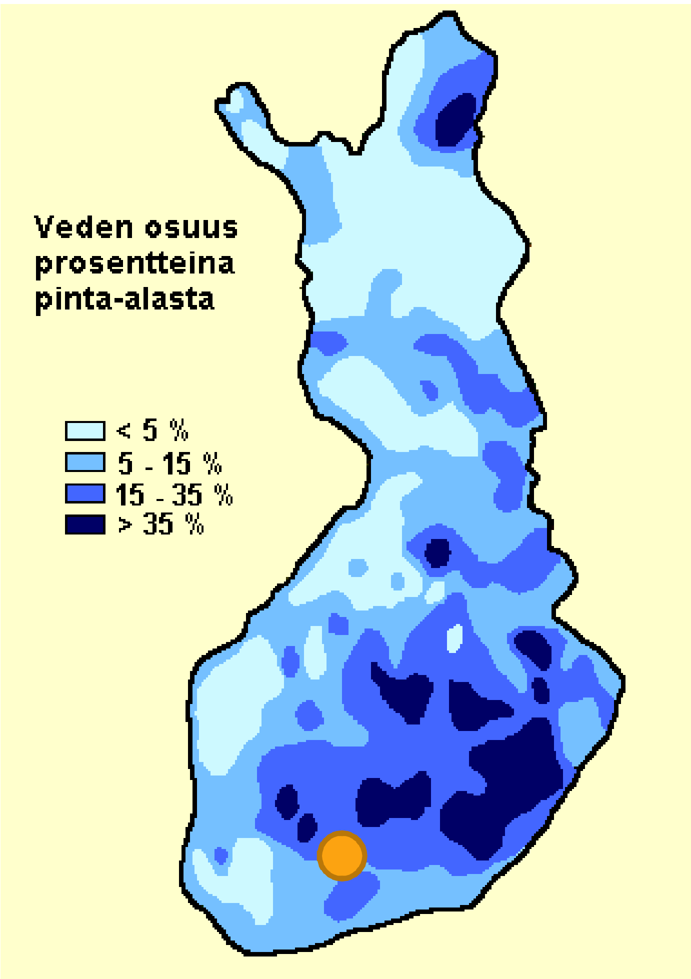
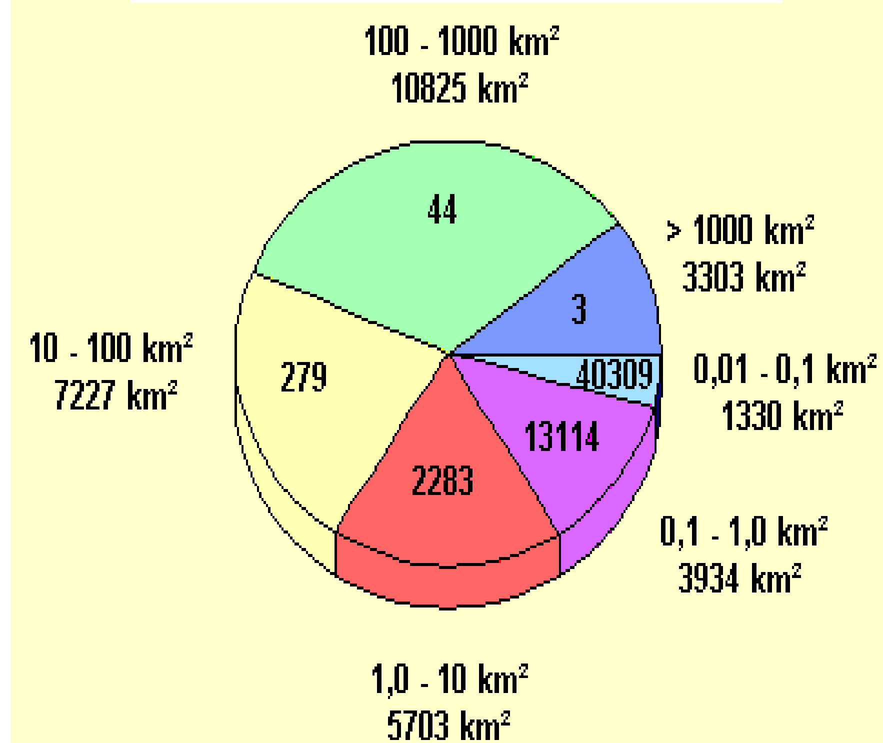
Based on an article submitted to Journal of Geophysical research, revised 27.8.2010: Long-term energy flux measurements and energy balance over a small boreal lake using eddy covariance technique

1. Background

Fraction of water per area



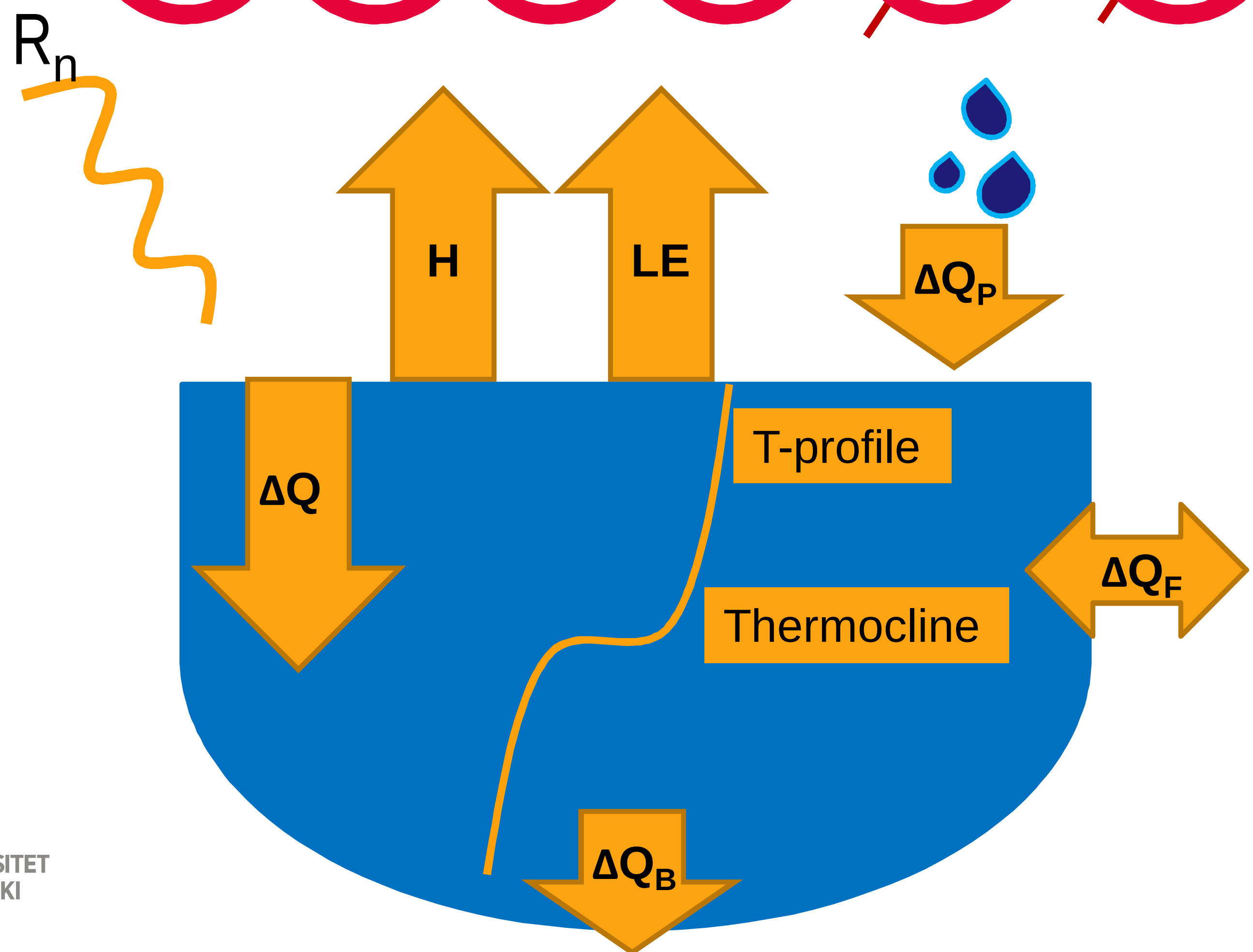
Lakes in size classes



www.enviroment.fi

Lake surface energy balance

$$R_n + \Delta Q = H + LE + \cancel{\Delta Q_B} + \cancel{\Delta Q_F} + \cancel{\Delta Q_P}$$



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

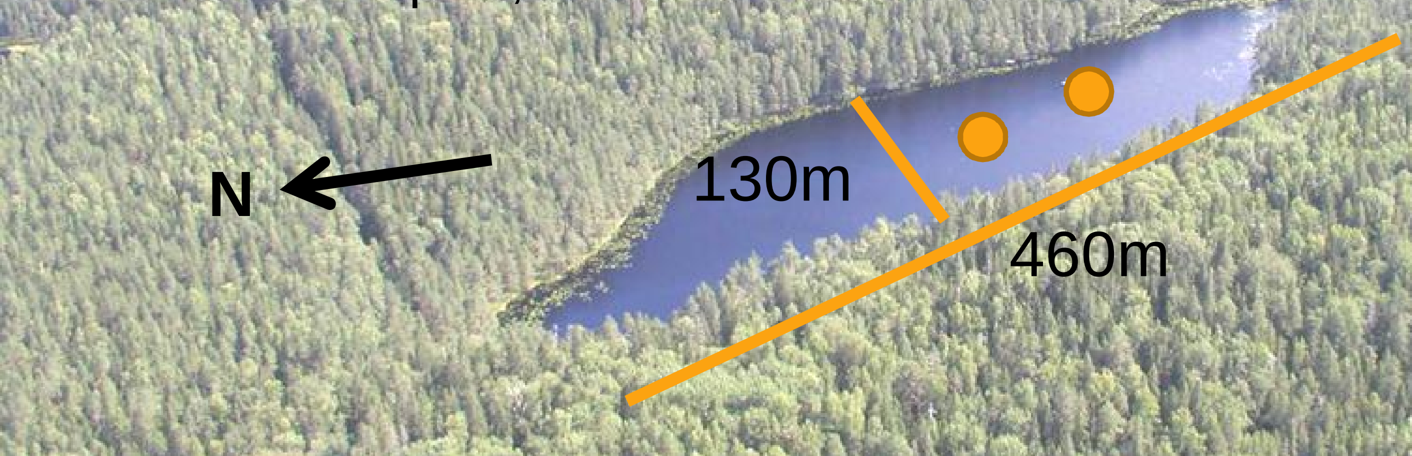
Our aims

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)

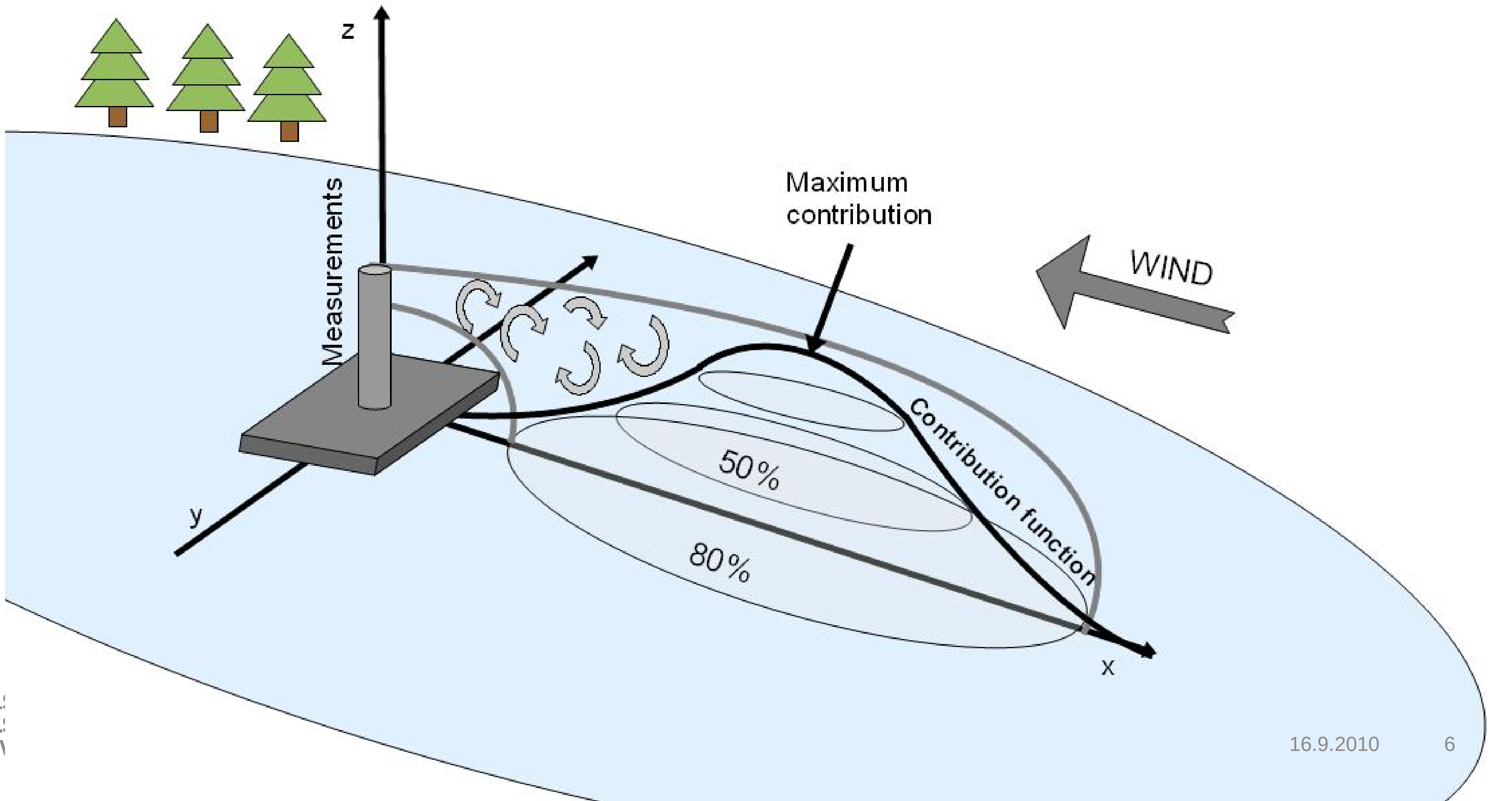
  } 20 Hz data → 60min covariances
- Net radiation: MB-1, Astrodata, Tartu, Estonia
- Near water meteorology
- Water temperature profile → ΔQ
  - 13 depths, 20cm – 4m



- Area 4.1 ha
- Mean depth 2.5 m
- Max depth 6 m
- attenuation coefficient 6.3 m^{-1}

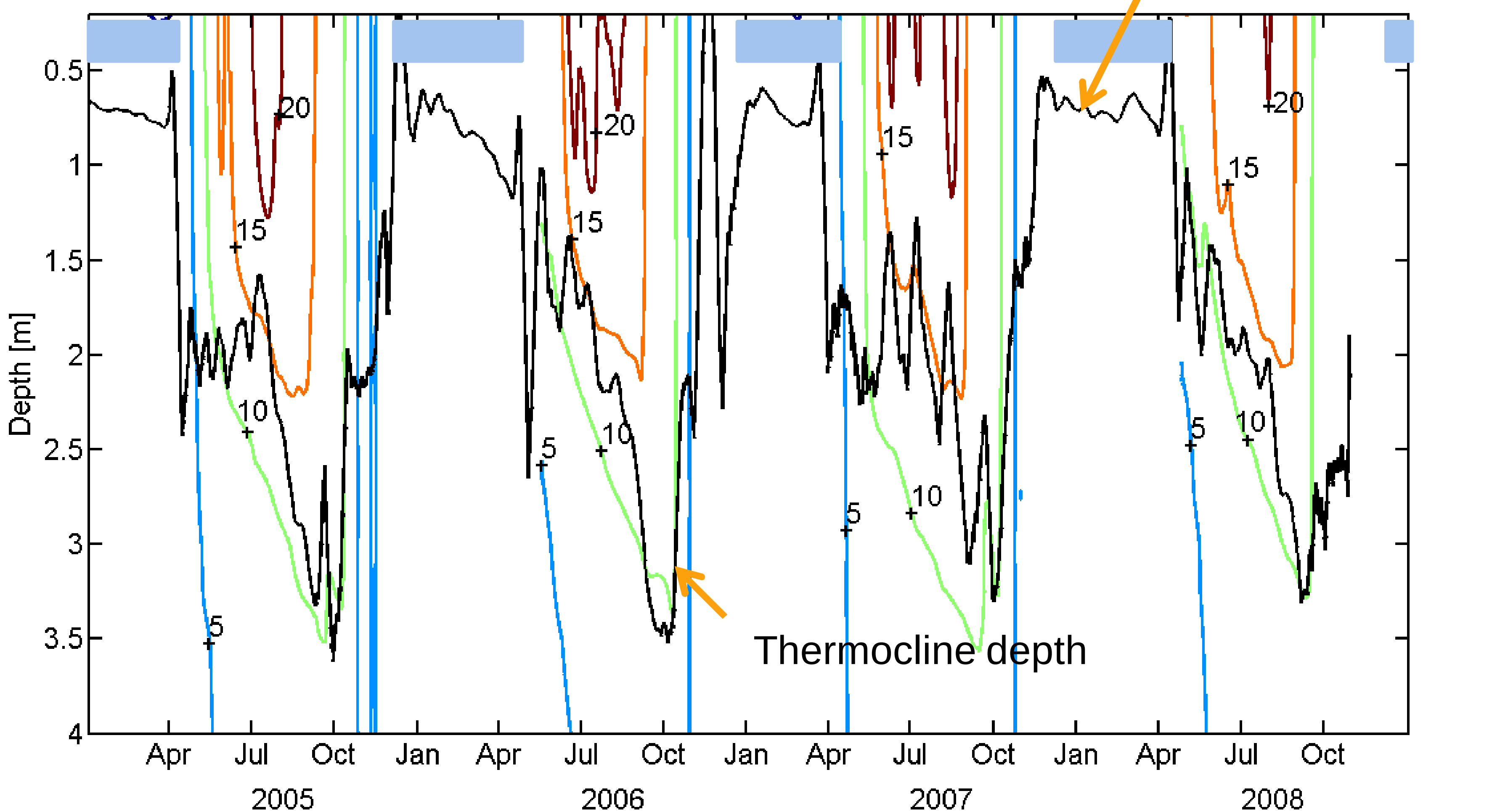
Source areas of the 4 energy fluxes are different

- H & LE: about 50m, source area depends on wind direction, atmospheric stability…
- R_n: 3.6m radius of 80% contribution
- ΔQ: point measurements



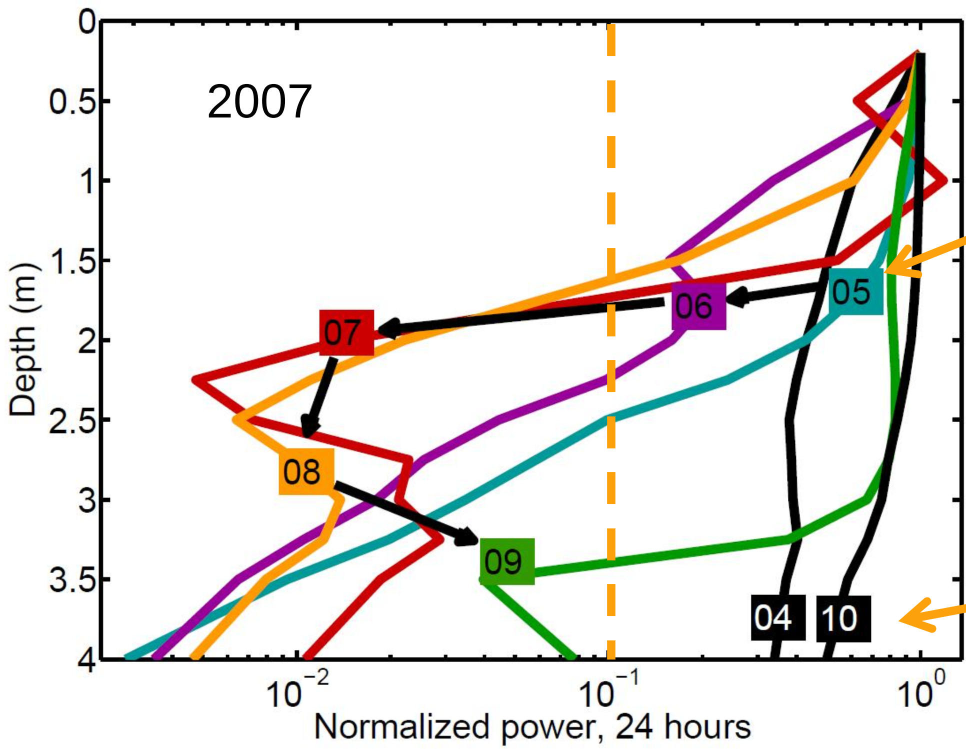
3. Results

Water temperature profile



Does the hypolimnion interact with the atmosphere?

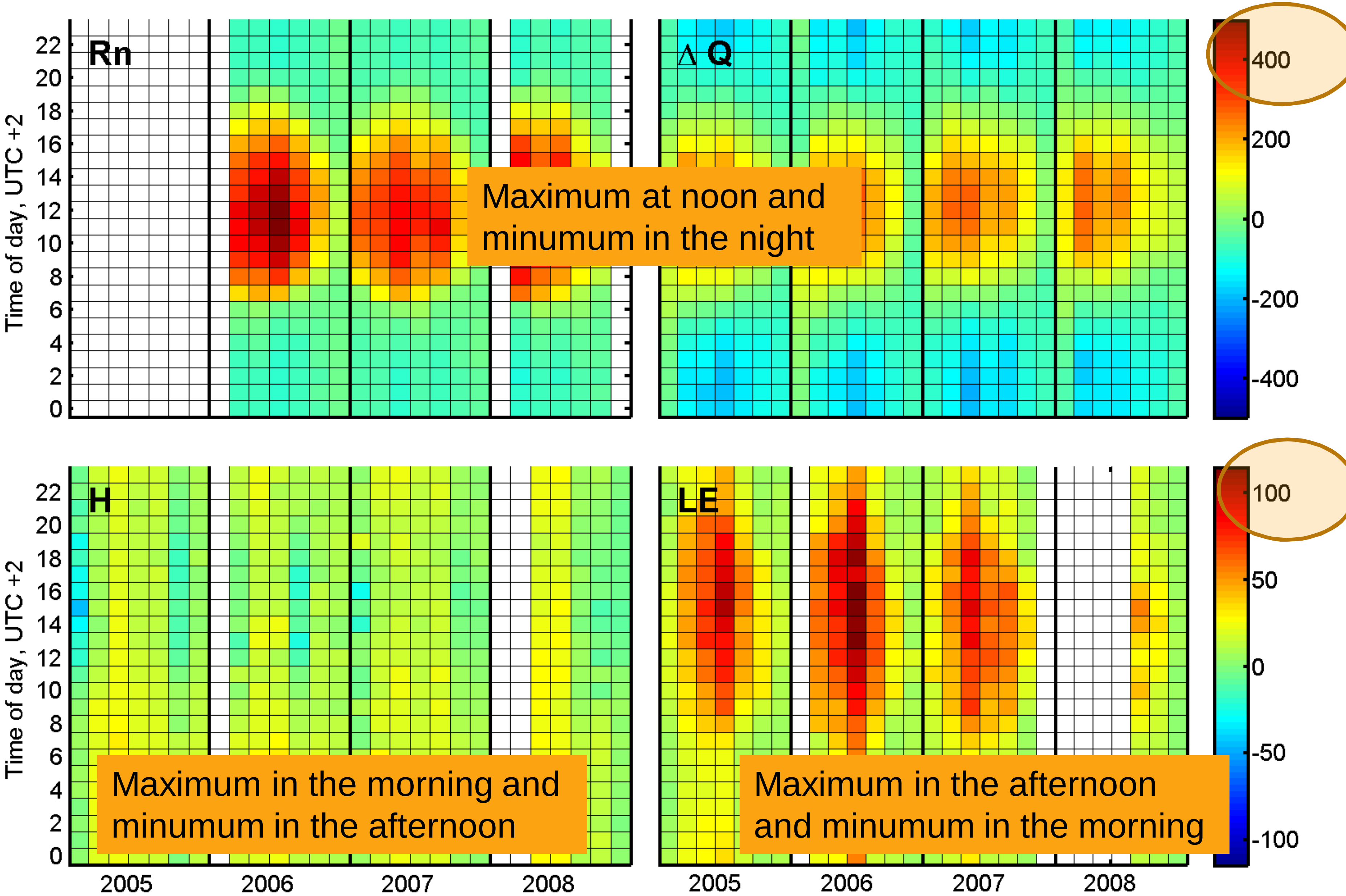
- A FFT applied to water temperature data from 13 depths
- 24h variation power selected
- plotted as a function of depth per each month



Month number shows thermocline depth

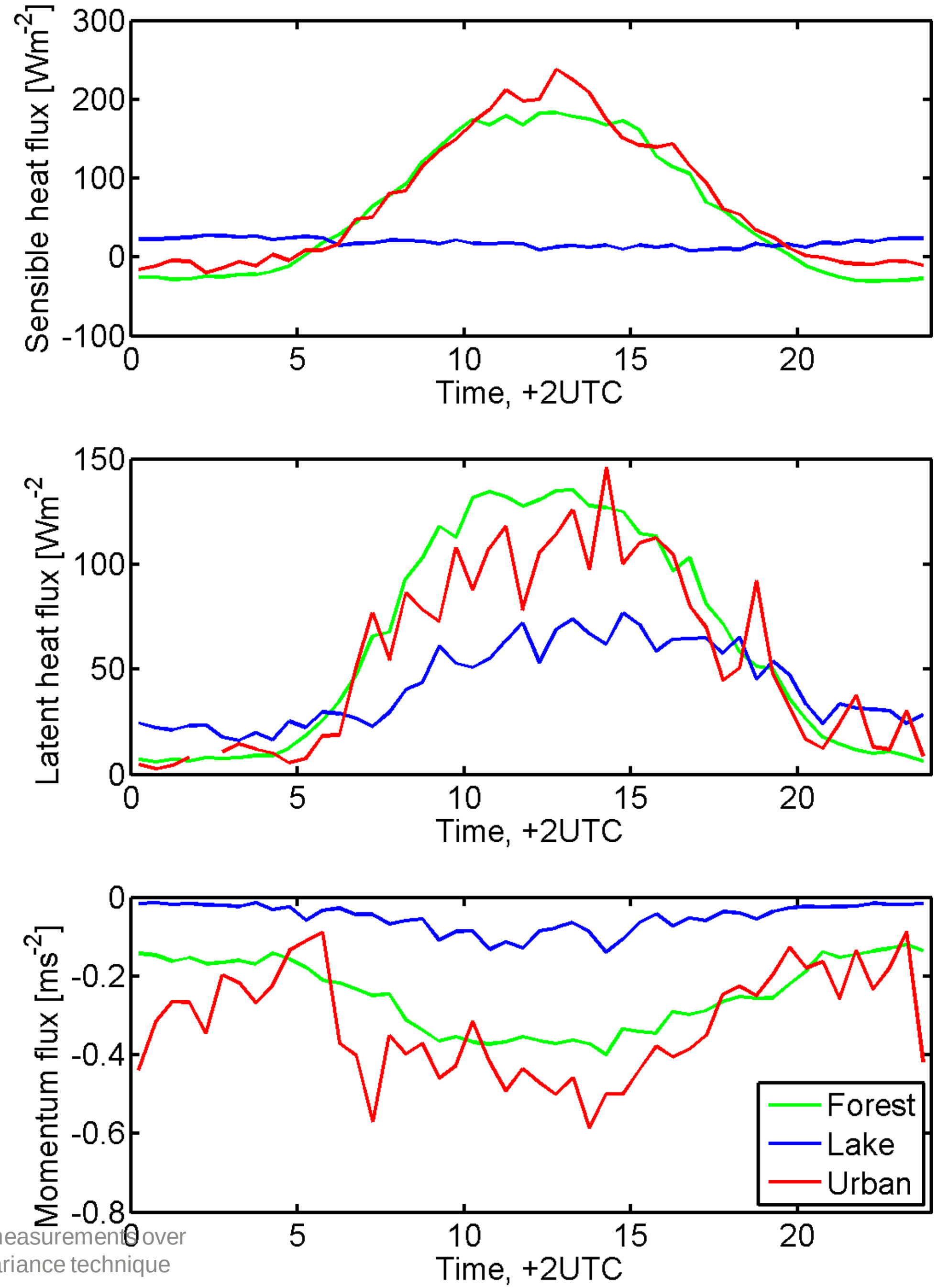
April and October isothermal

Energy fluxes



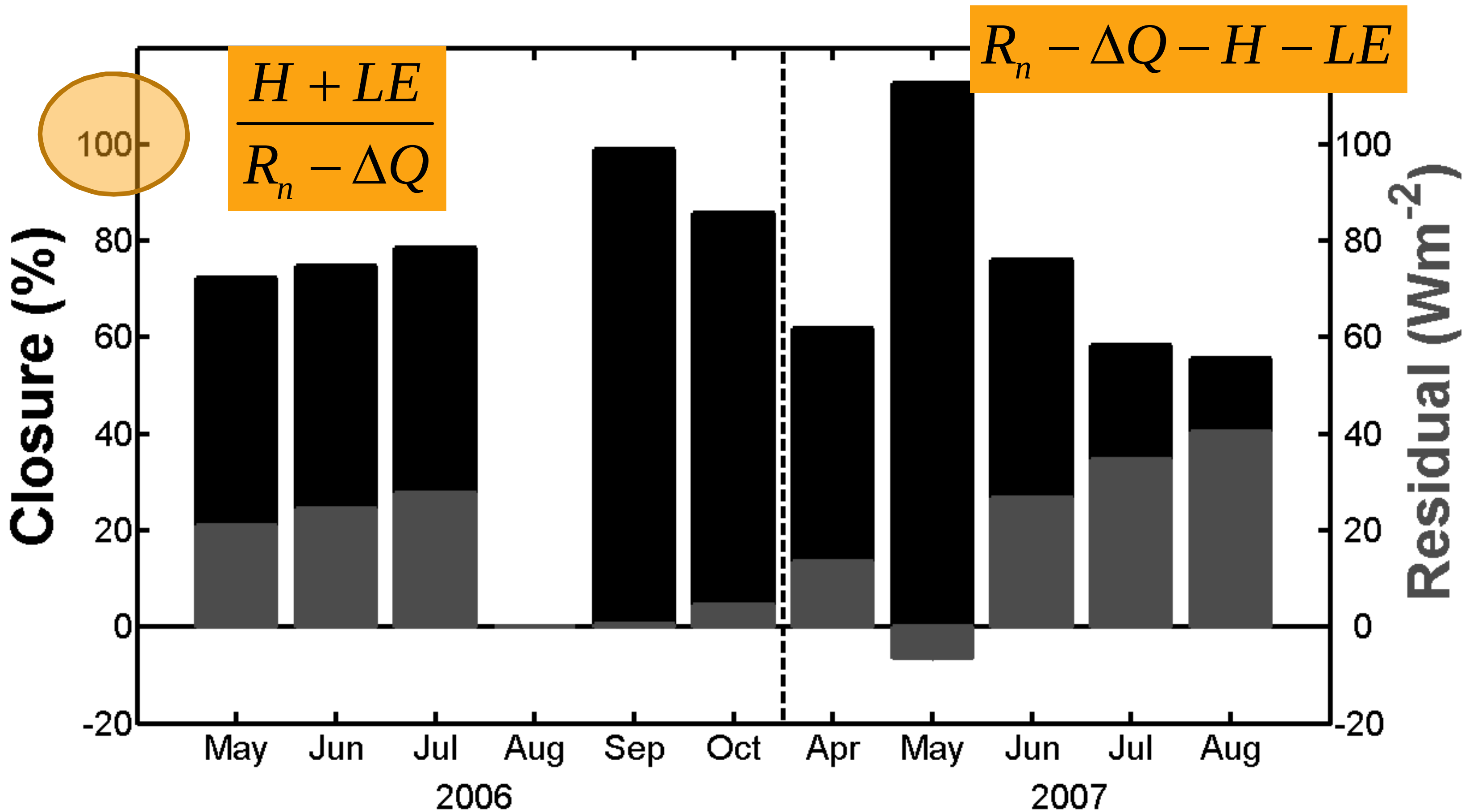
Comparison between measurement sites

Average diurnal course in July 2007



Energy balance closure

Closure comparable to numerous studies from forest sites



4. Conclusions

- Longest data set ever from small lakes

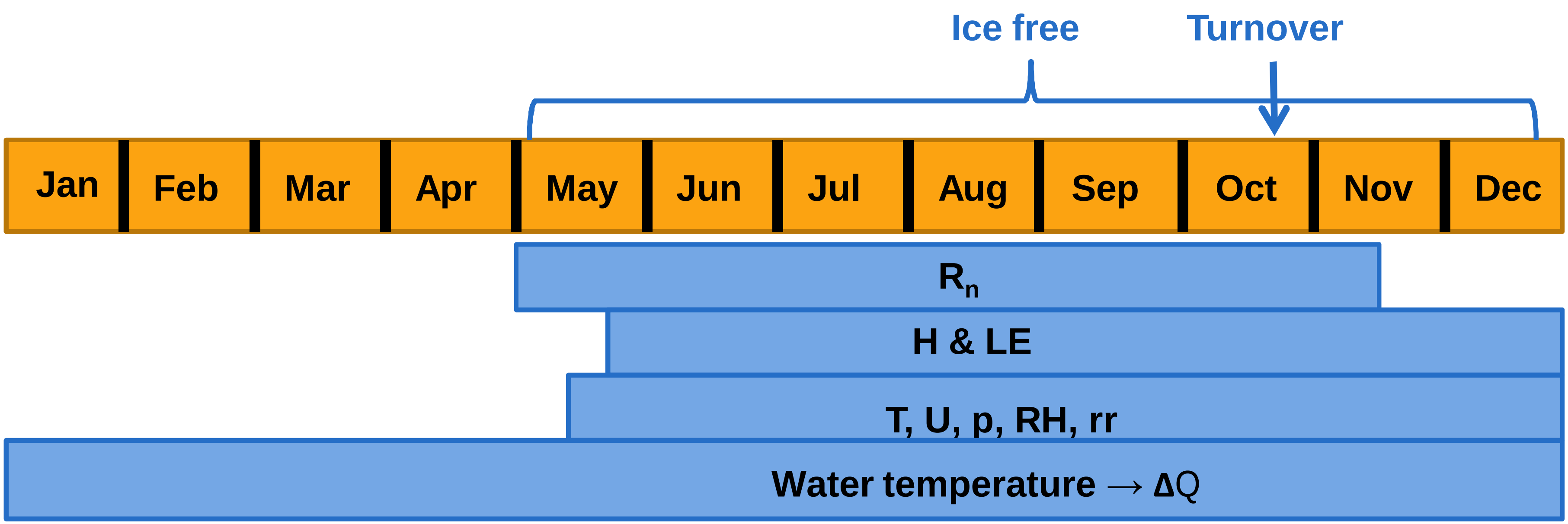
- Energy flux dynamics differ much from those at terrestrial sites
  → should be included in NWPs and climate models
  → data needed from different sized lakes

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

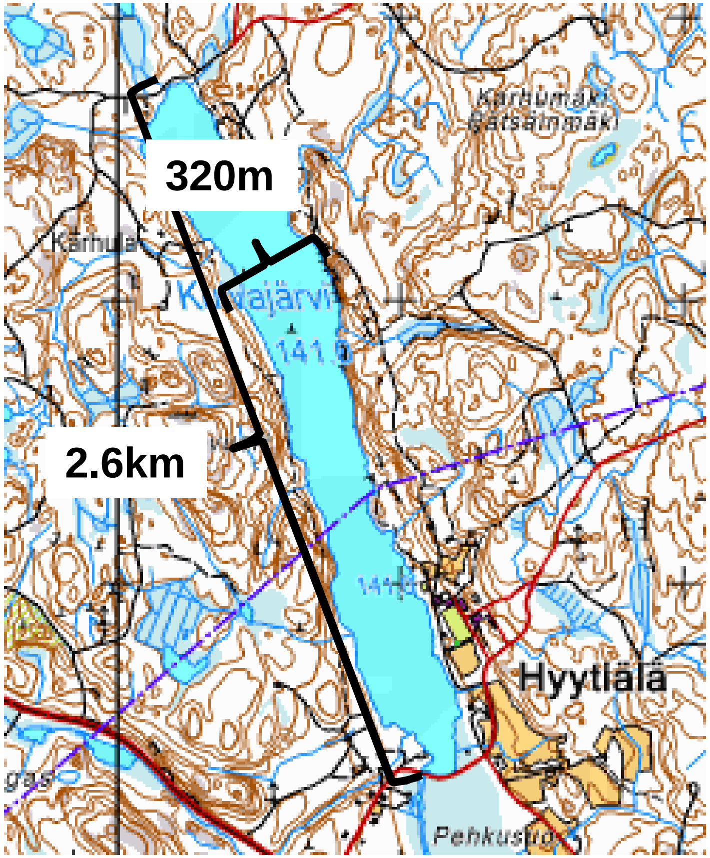
- Hypolimnion not important for energy balance during stratification

5. Potential for model validation?

2006



6. New measurement site



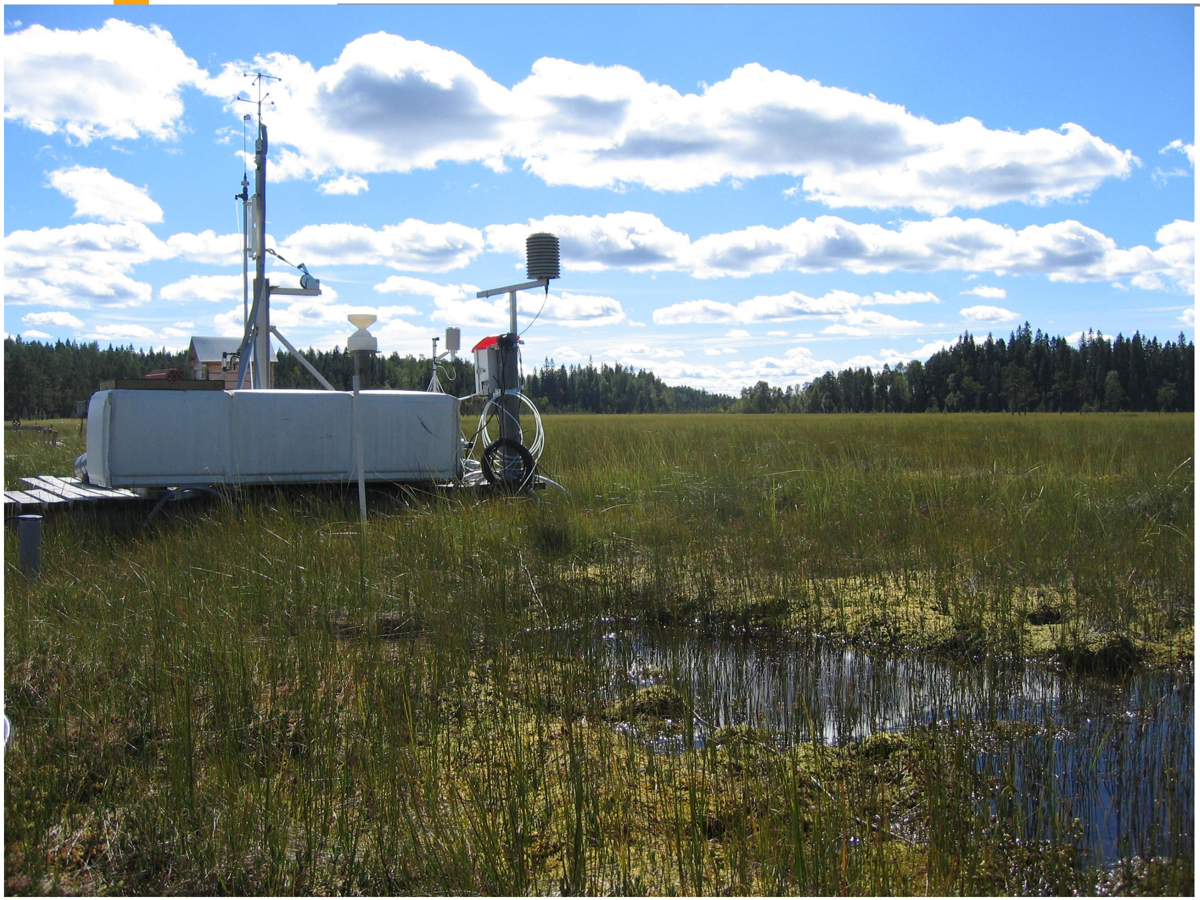
Lake Kuivajärvi, Hyytiälä

61°50'N, 24°16'E

Aug 2009 - Feb 2010
Jul 2010 - now

R_n, ΔQ, H, LE
Meteorology

Measurements also at a fen



61°49.961' N, 24°11.567' E

R_n, ΔQ, H, LE
Meteorology

CO_2 and CH_4 fluxes

See the webpage on the "Contact info" slide for further information


THANKS!

References

Nordbo A., S. Launiainen, I. Mammarella, M. Leppäranta, J. Huotari, A. Ojala and T. Vesala (2010), Long-term energy flux measurements and energy balance over a small boreal lake using eddy covariance technique. *J.Geophys.Res.* Revised on August 27.

Vesala T., J. Huotari, Ü Rannik, T. Suni, S. Smolander, A. Sogachev, S. Launiainen and A. Ojala (2006), Eddy covariance measurements of carbon exchange and latent and sensible heat fluxes over a boreal lake for a full open-water period, *J. Geopys. Res.,* 111 (D11101), doi:10.1029/2005JD006365.

Contact info

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EXTRA SLIDES

Source area analysis of the turbulent fluxes

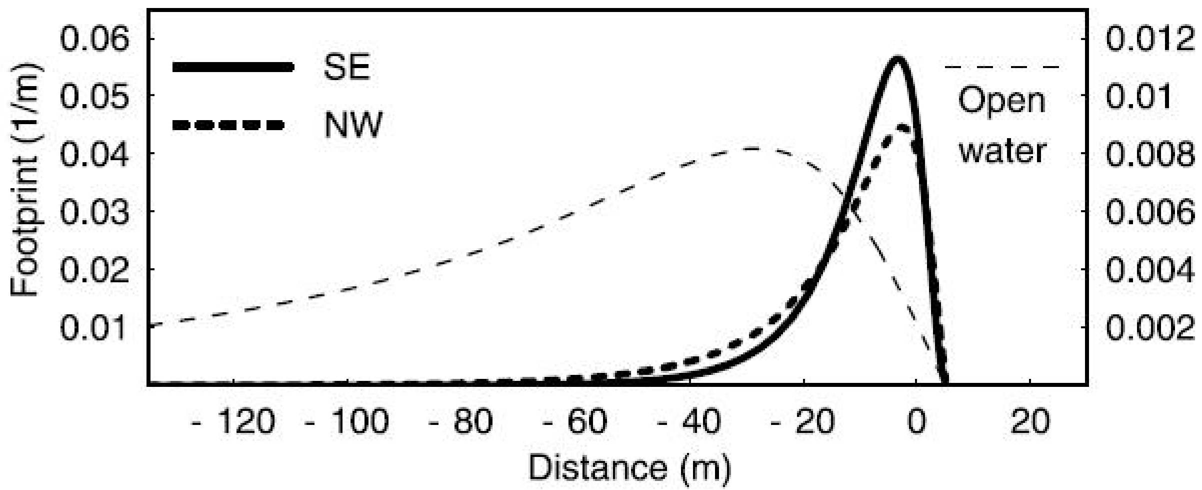
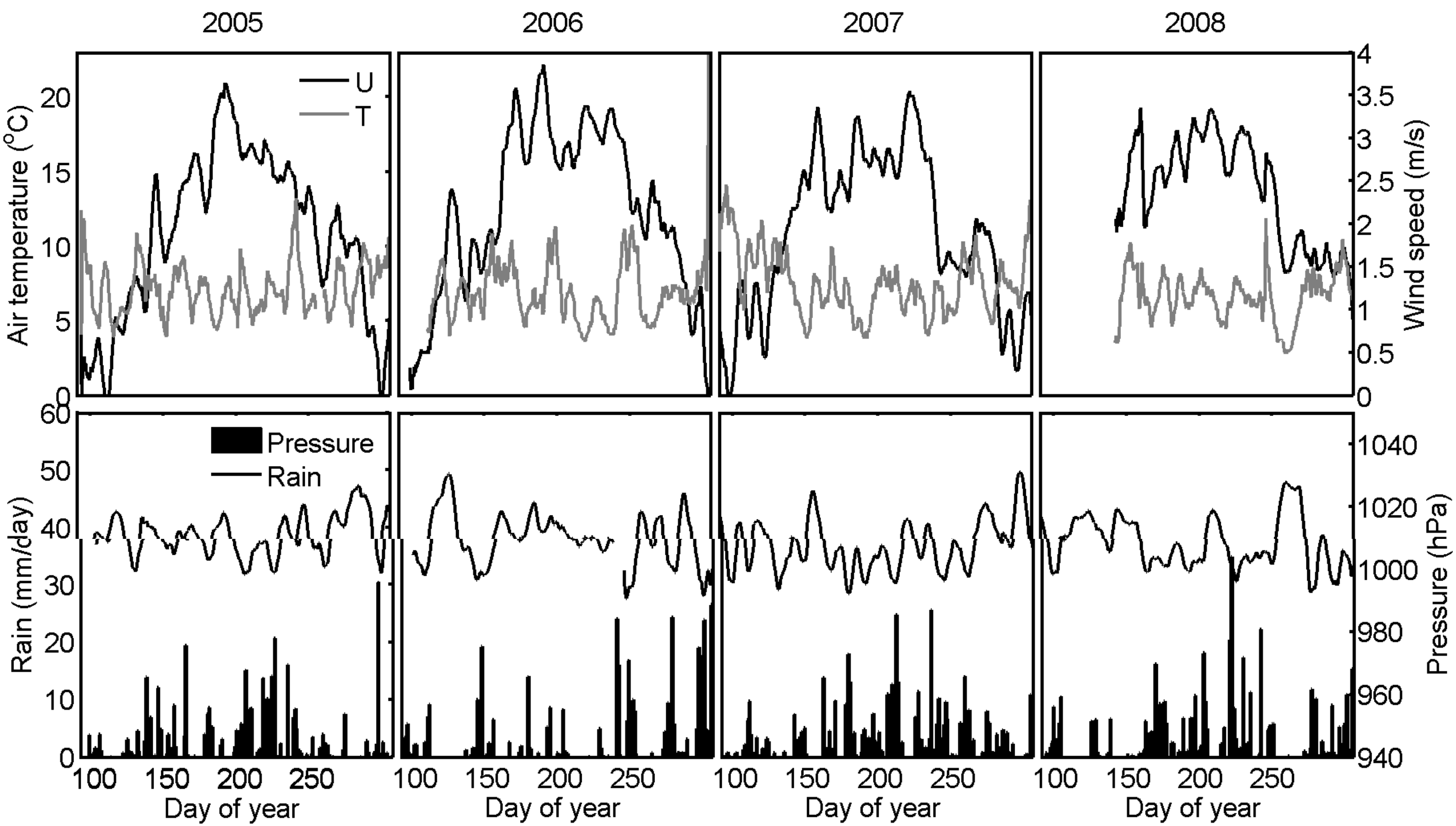


Figure 8. Modeled footprints for the two dominant wind directions along the lake: southeast (SE) and northwest (NE). The distance to the forested shore is 135 m in the SE case and 240 m in the NW case (see Figure 1). For comparison, a footprint for a case of open water body without a nearby forested 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.

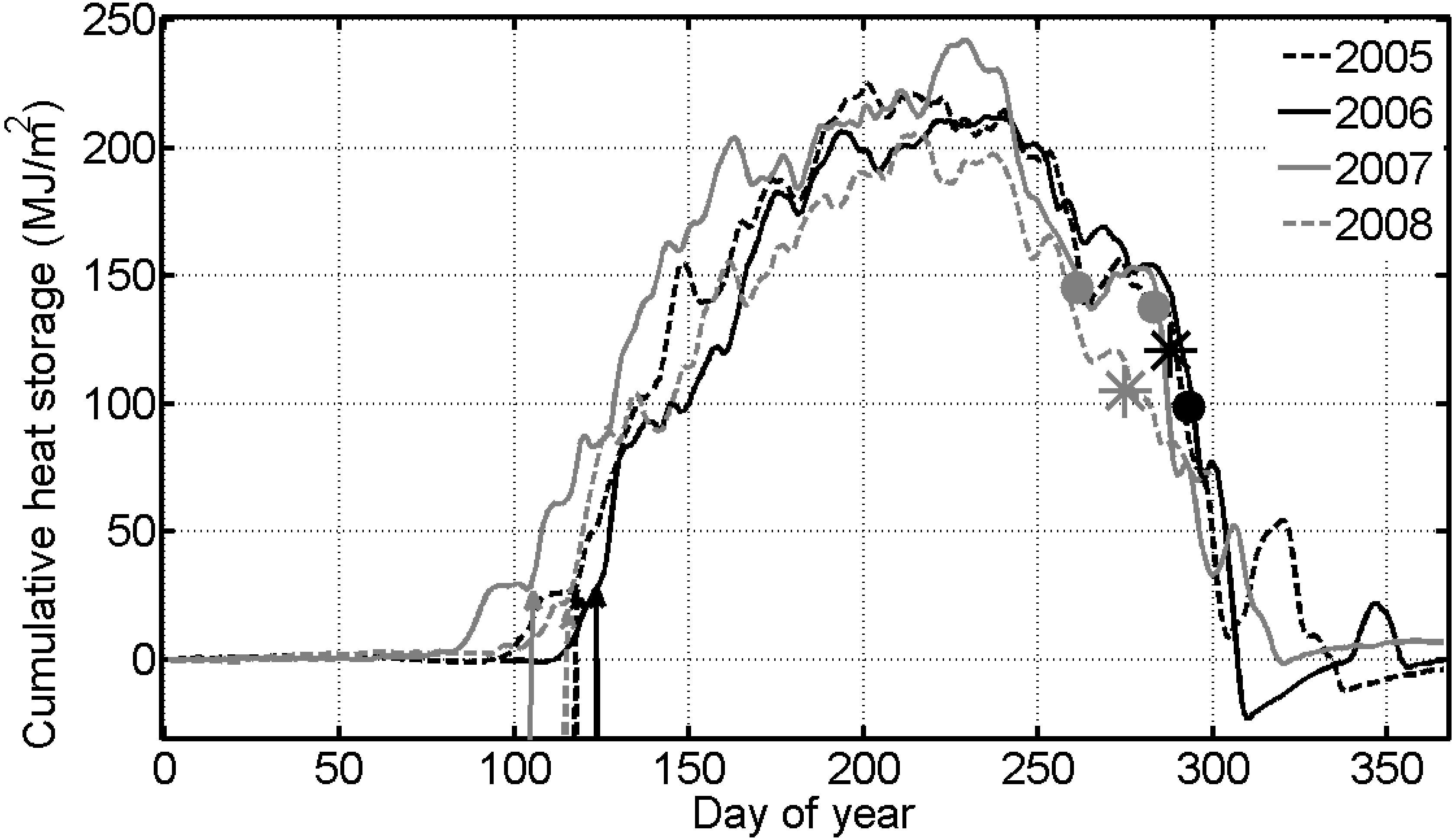
Vesala et al. 2006

Meteorology at Lake Valkea-Kotinen



Nordbo et al. 2010

Cumulative heat storage of the lake



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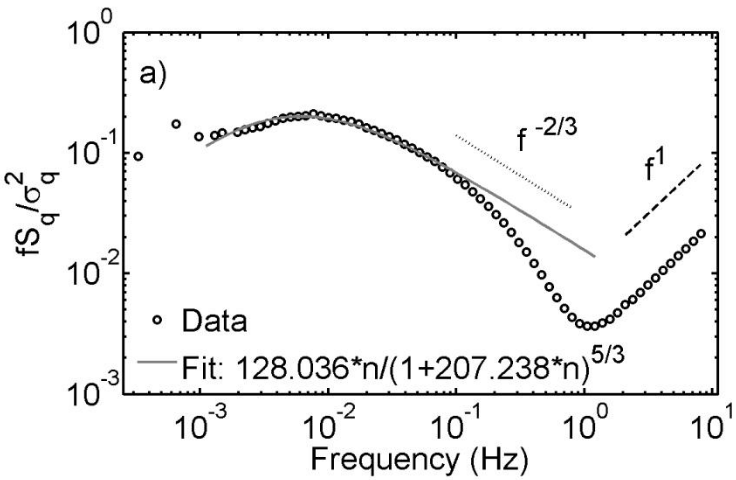
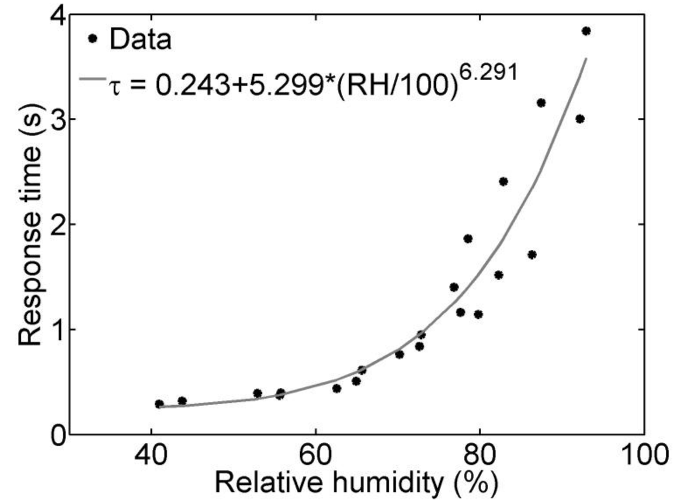
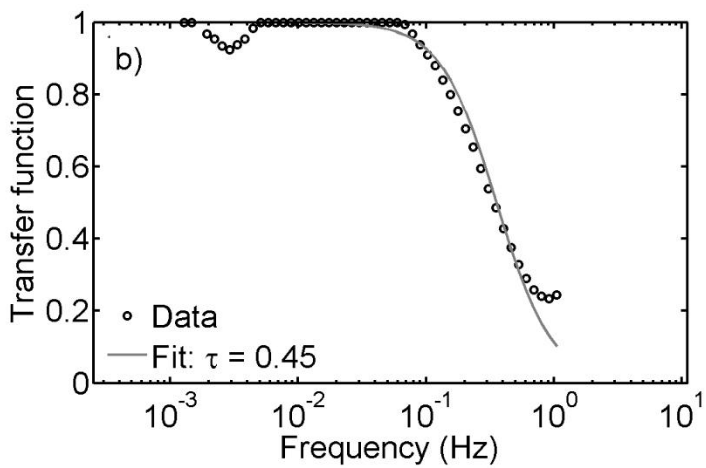
Spectral correction of the water vapor flux







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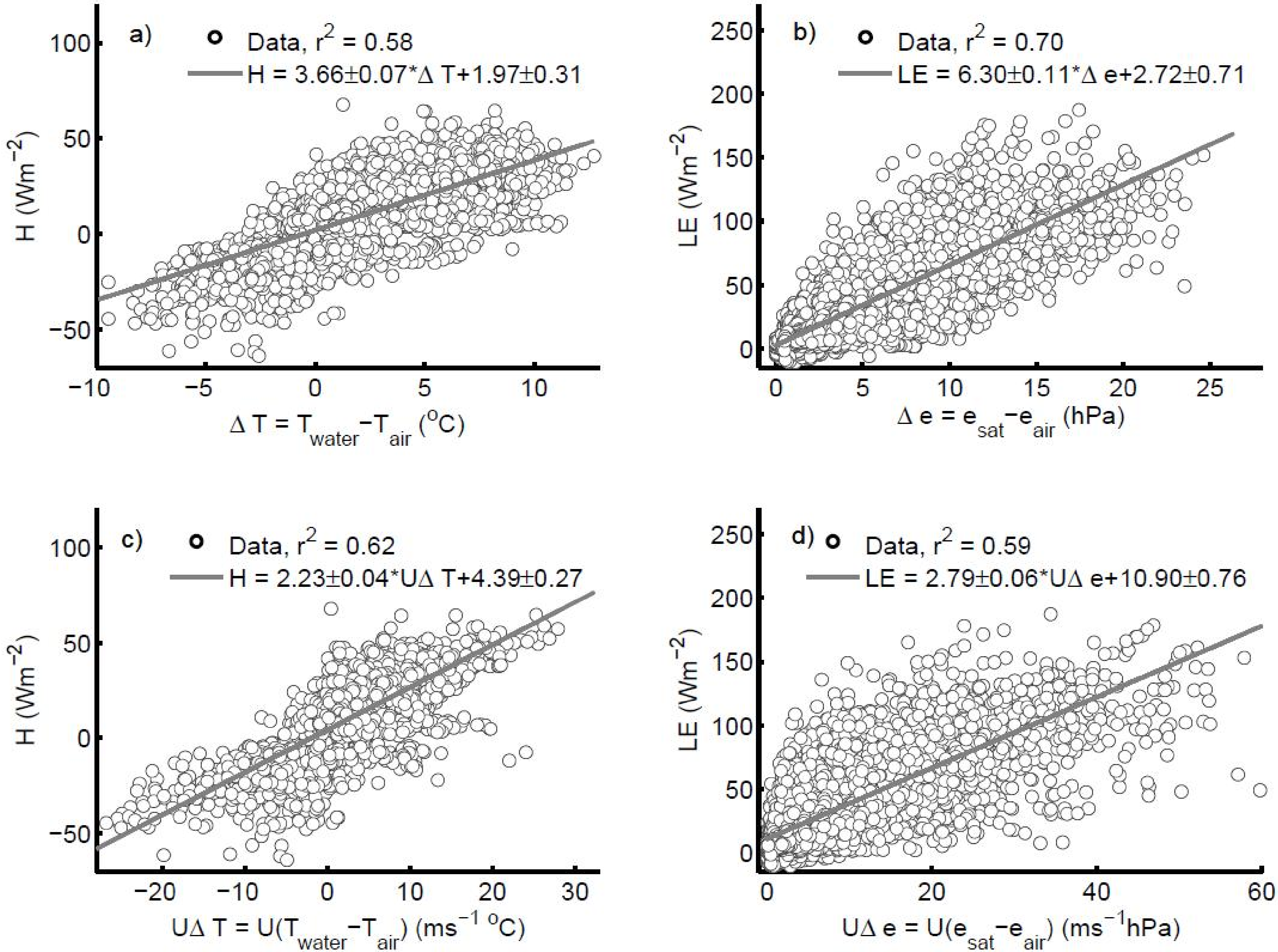
Driving factors of H and LE



Nordbo et al. 2010

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