Biosphere-atmosphere interactions

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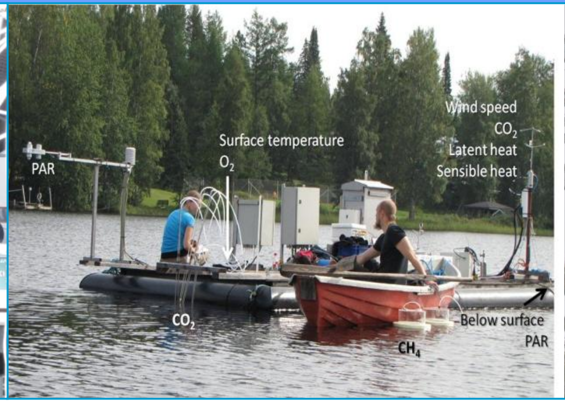
Biosphere-atmosphere interactions



The group activities focus on

1) micrometeorological methods for estimating fluxes of energy, GHGs and other tracer gases.

2) surface exchange processes in different natural ecosystems.

3) models ⟷ observations

The vision of ICOS

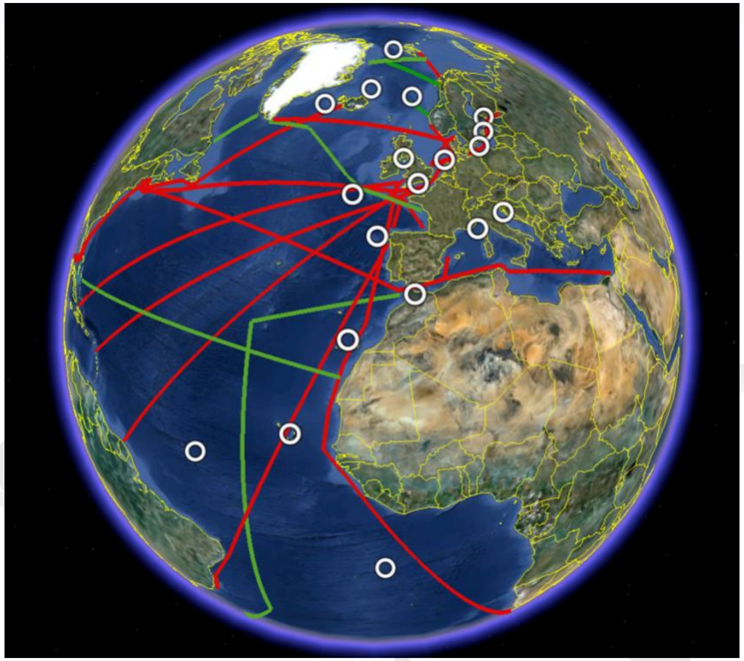
- fundamental understanding of carbon cycle, greenhouse gas budgets and pertubations and underlying processes,
- ability to predict future changes,
- verify the effectiveness of policies aiming to reduce greenhouse gas emissions,
- technical and scientific innovation,
- education and capacity building.

The ICOS station network today

Atmosphere

Ecosystems

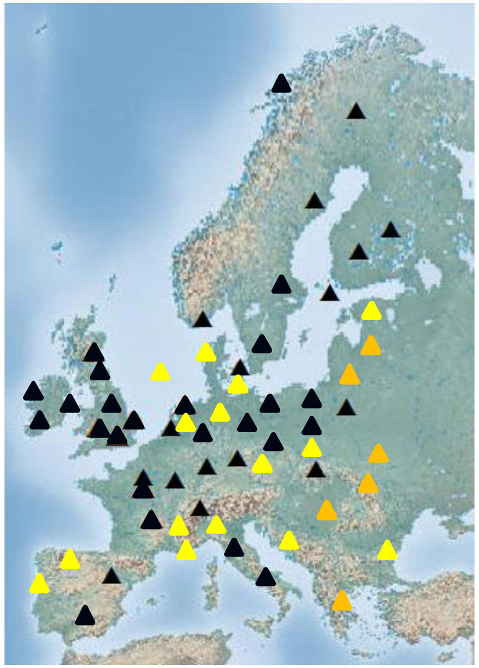
Oceans



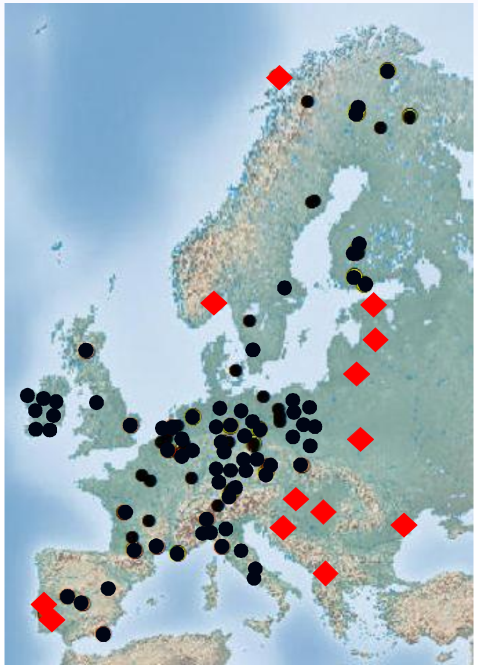
Werner Kutsch

….and anticipated ICOS station network 2020

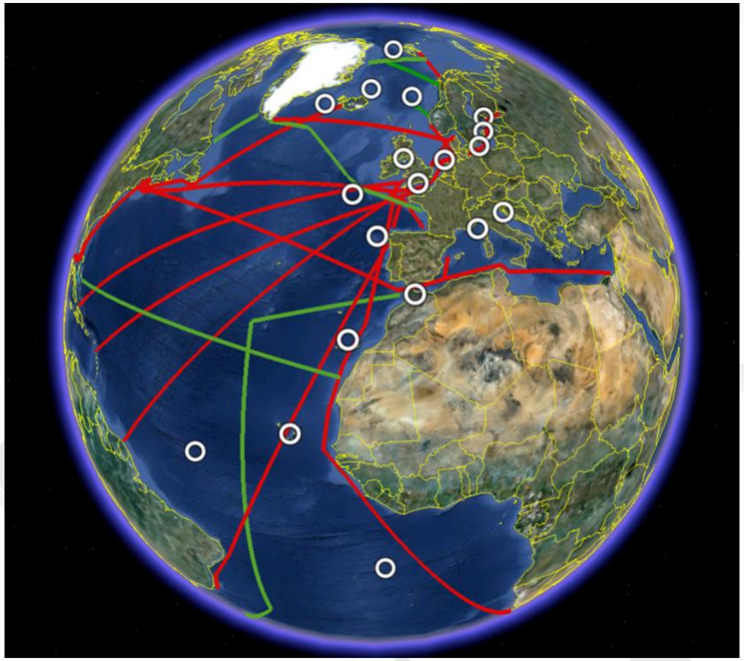
Atmosphere



Ecosystems



Oceans



Werner Kutsch

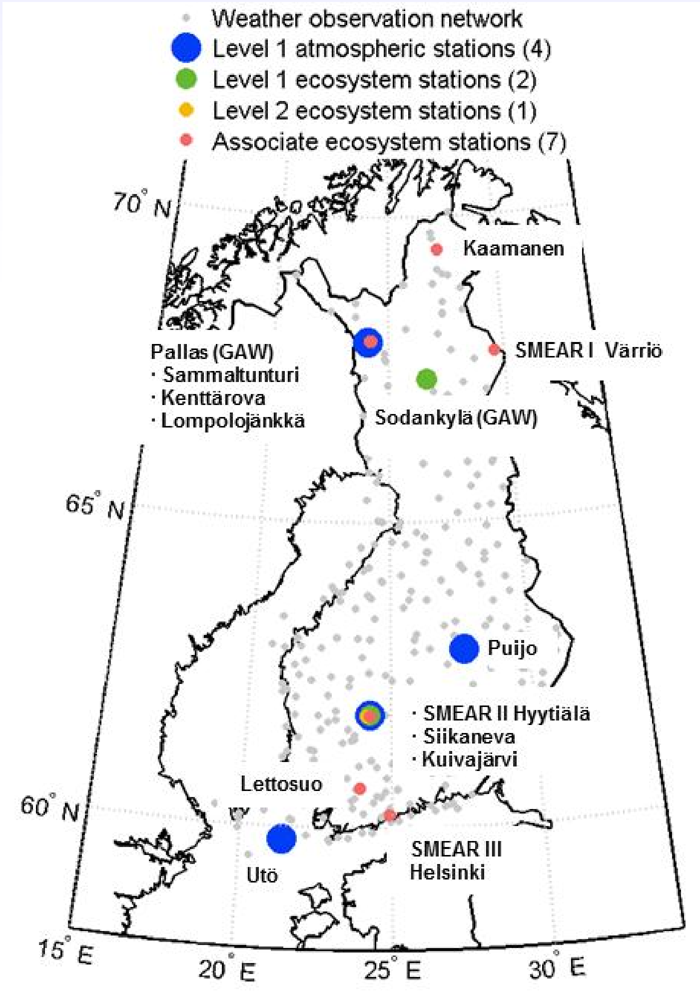
Flux Tower Stations

Siikaneva I

Siikaneva II

SMEAR II

Kuivajärvi



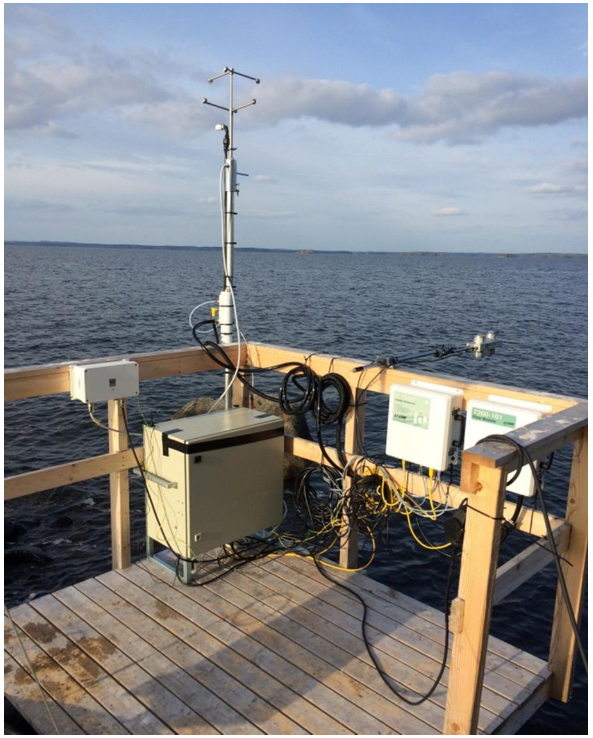
ICOS-FINLAND Station Network

Värriö sub-arctic forest (SMEAR I)

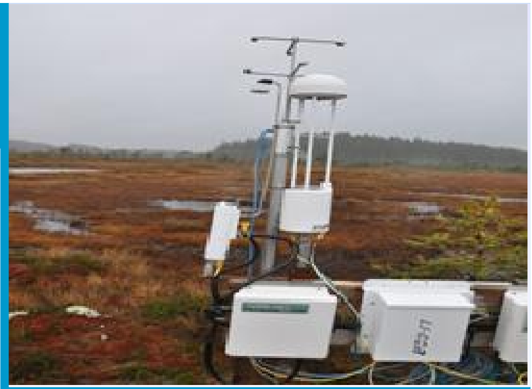
Two New Flux Towers

Lake Vanajanselkä (Finland)

Mukhrino wetland
(Western Siberia)

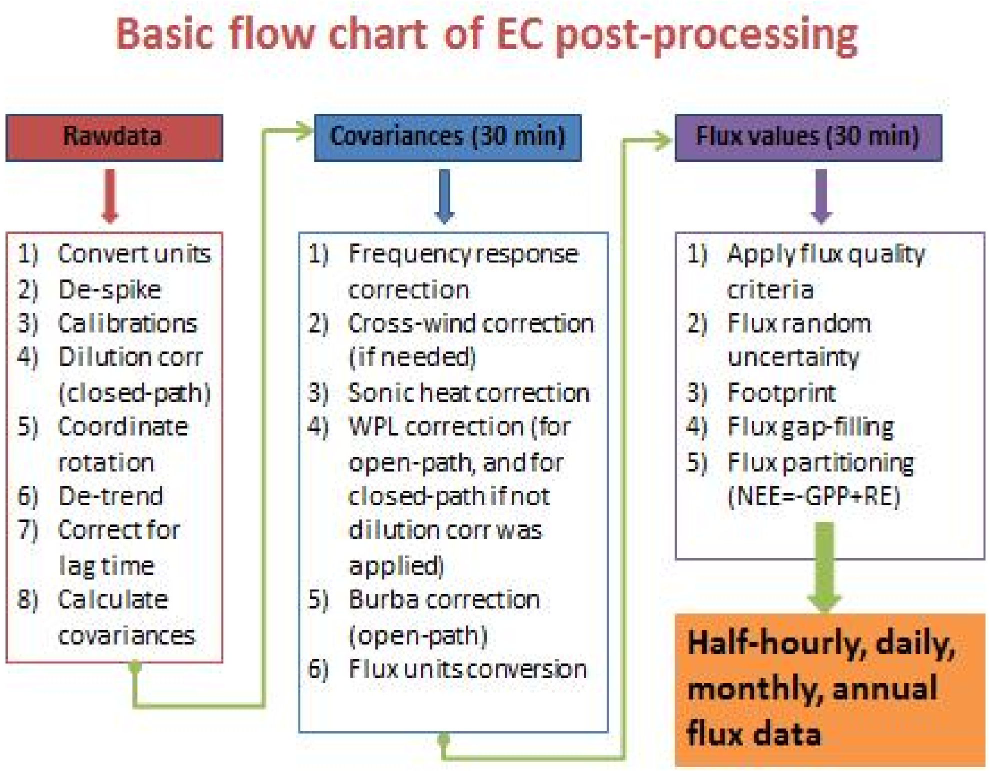


Eddy covariance



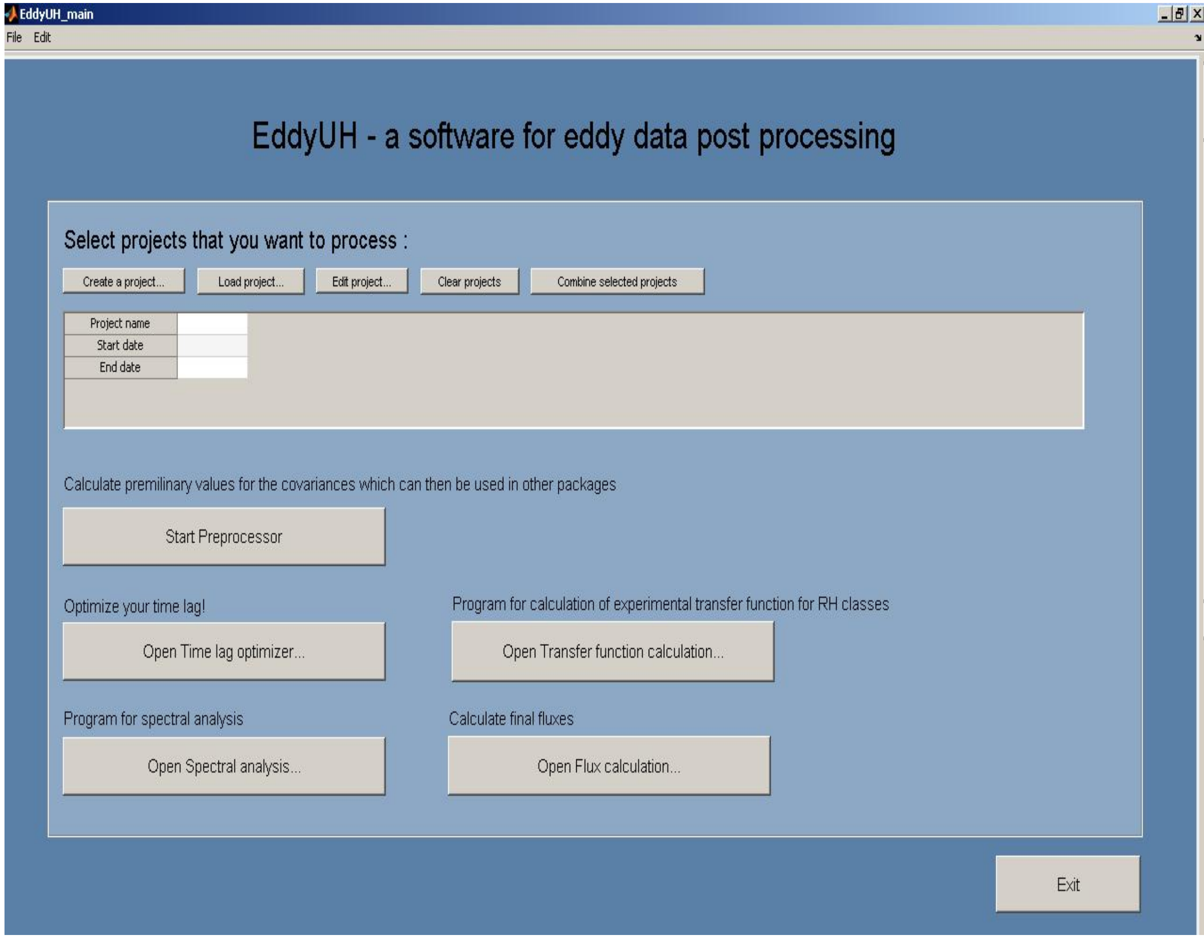
- Direct and continuous measurements of net surface exchanges of energy and gases at ecosystem scale
- Time scale half-hour to inter-annual
- Non destructive, non invasive

- Only net fluxes
- Random errors
- Systematic errors
- Data gaps
- Data processing



EddyUH
(www.atm.helsinki.fi/Eddy_Covariance)

Over 150 external users worldwide.



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 QCL (N_2O, CO_2, H_2O, CH_4 , COS)

Towards a standard protocol for EC flux measurements of CH_4 and N_2O

Aim:

Evaluation of performance and flux uncertainty of state of art CH_4 and N_2O gas analysers for EC flux measurements.

How:

Four international inter-comparison field campaigns during the past three years.

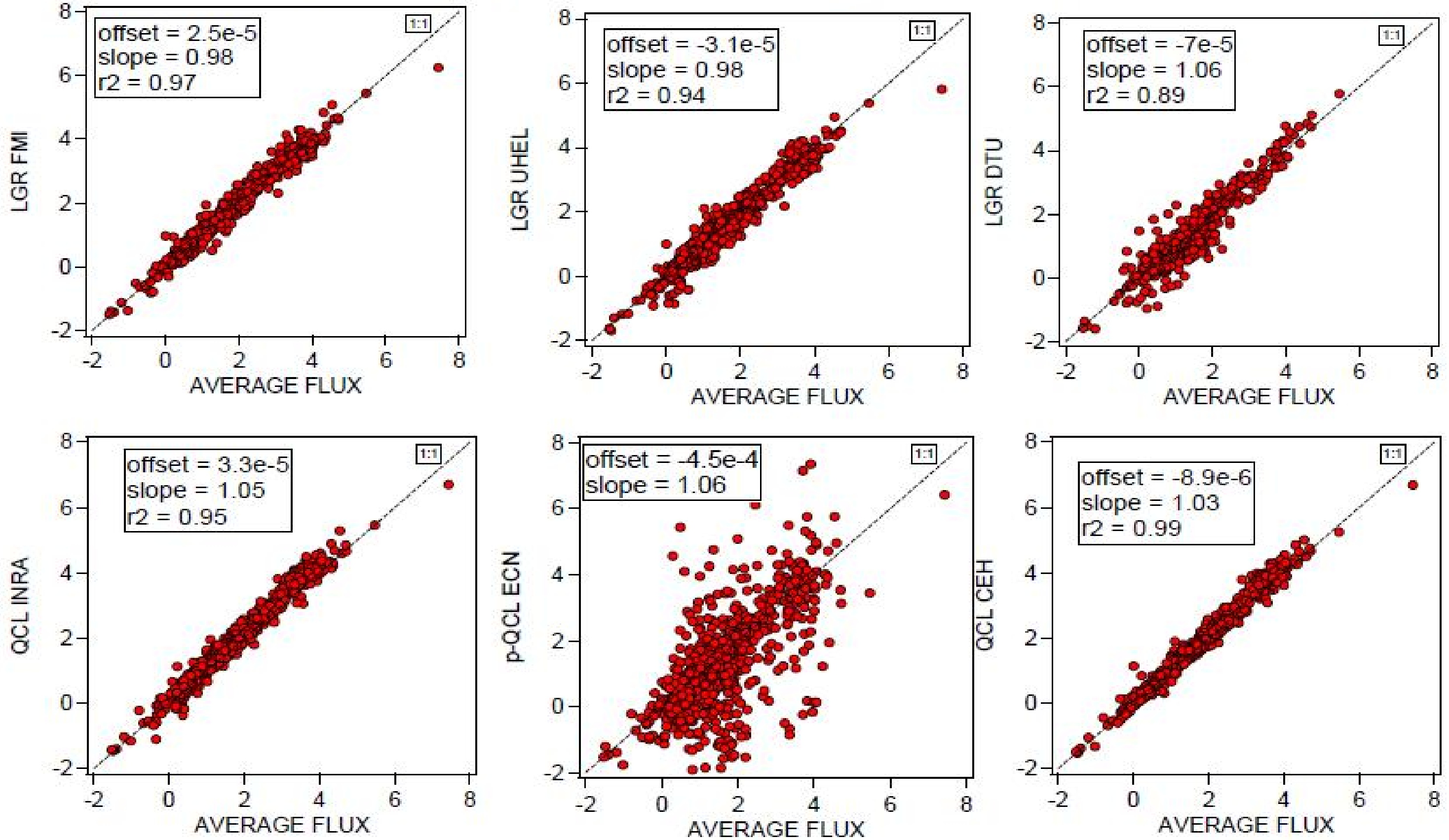
Results are currently used for development of ICOS measurement protocols for CH_4 and N_2O fluxes.

Peltola et al., 2013, Biogeosciences; Rannik et al., 2015, Biogeosciences; Peltola et al., 2014, Biogeosciences

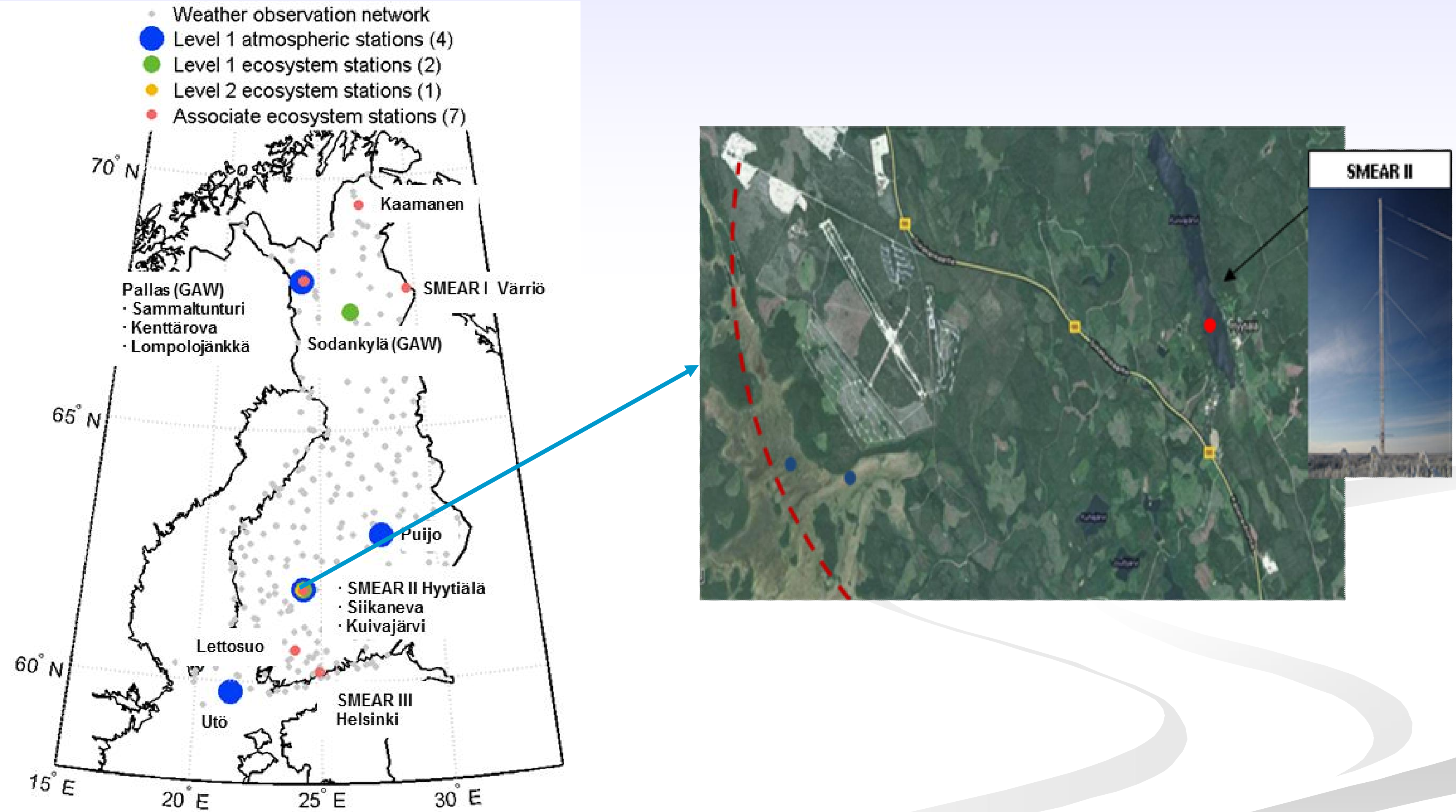
N_2O Fluxes Field Campaign at Easter Bush (Edinburg, Scotland) , grass field, June 2013

Comparison of fluxes *[nmol / m² s]* with average

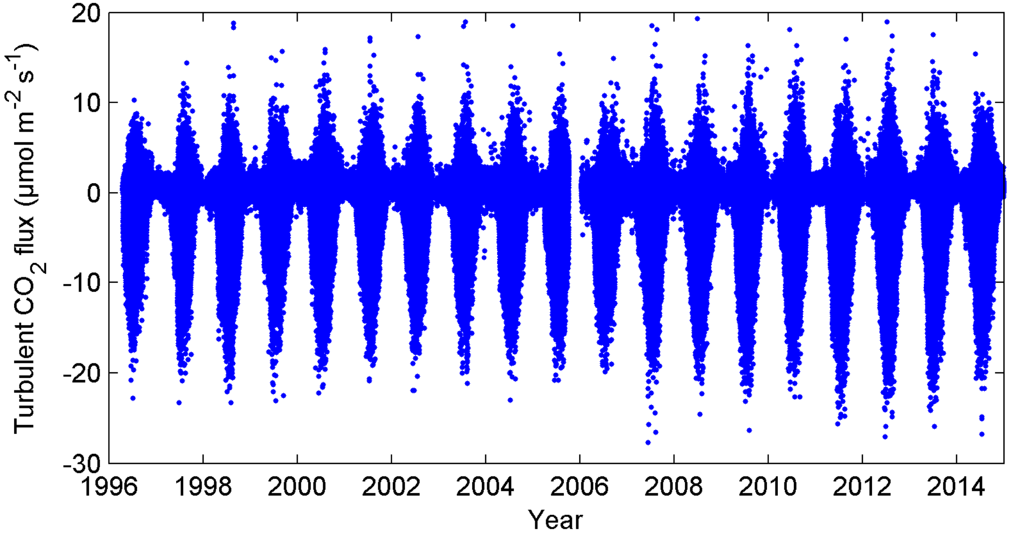
Each sensor (Y axes) against the “average sensor” (X axes)

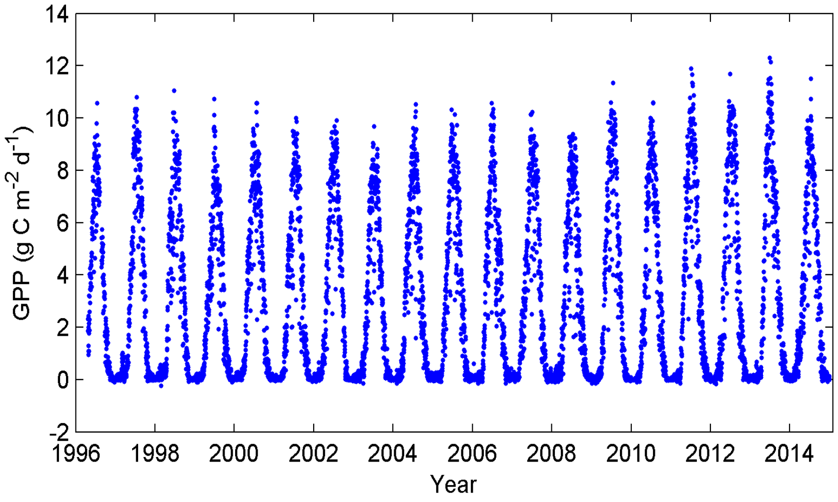


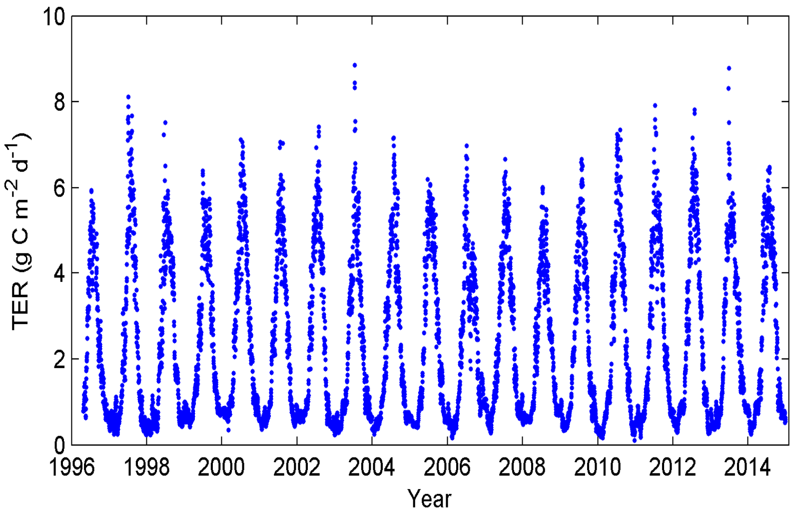
Famulari et al, manuscript


Weather observation network
Level 1 atmospheric stations (4)
Level 1 ecosystem stations (2)
Level 2 ecosystem stations (1)
Associate ecosystem stations (7)
70° N
65° N
60° N
15° E
20° E
25° E
30° E
Kaamanen
SMEAR I Värriö
Pallas (GAW)
· Sammaltunturi
· Kenttärova
· Lompolojänkkä
Sodankylä (GAW)
Puijo
· SMEAR II Hyytiälä
· Siikaneva
· Kuivajärvi
Lettosuo
Utö
SMEAR III
Helsinki
SMEAR II

Long term CO_2 flux measurements at SMEAR II (forest site)



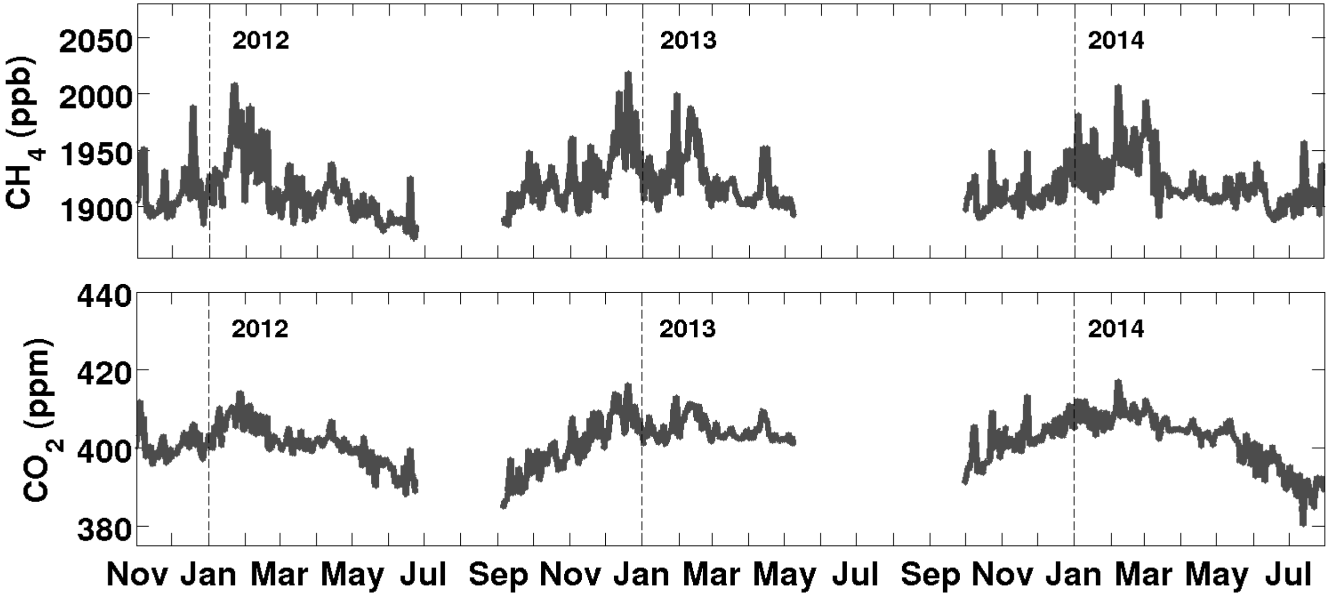




Tall tower concentration measurements of CH_4 and CO_2 at SMEAR II (forest)

High precision measurements done at 16, 67 and 125 m with Picarro G1301.

.



CH4 Flux

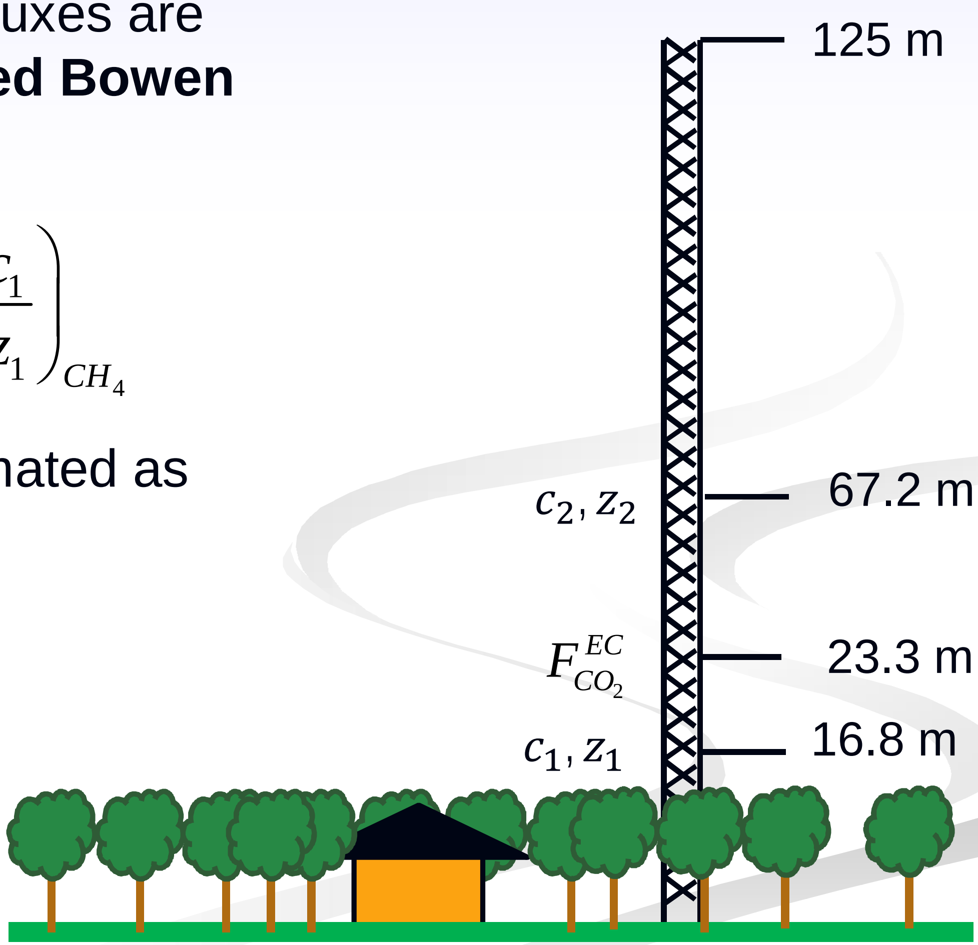
Landscape scale methane fluxes are calculated using the **modified Bowen ratio method**

$$F_{CH_4} = K\left(\frac{\partial c}{\partial z}\right)_{CH_4} \approx K\left(\frac{c_2 - c_1}{z_2 - z_1}\right)_{CH_4}$$

where eddy diffusivity K is estimated as

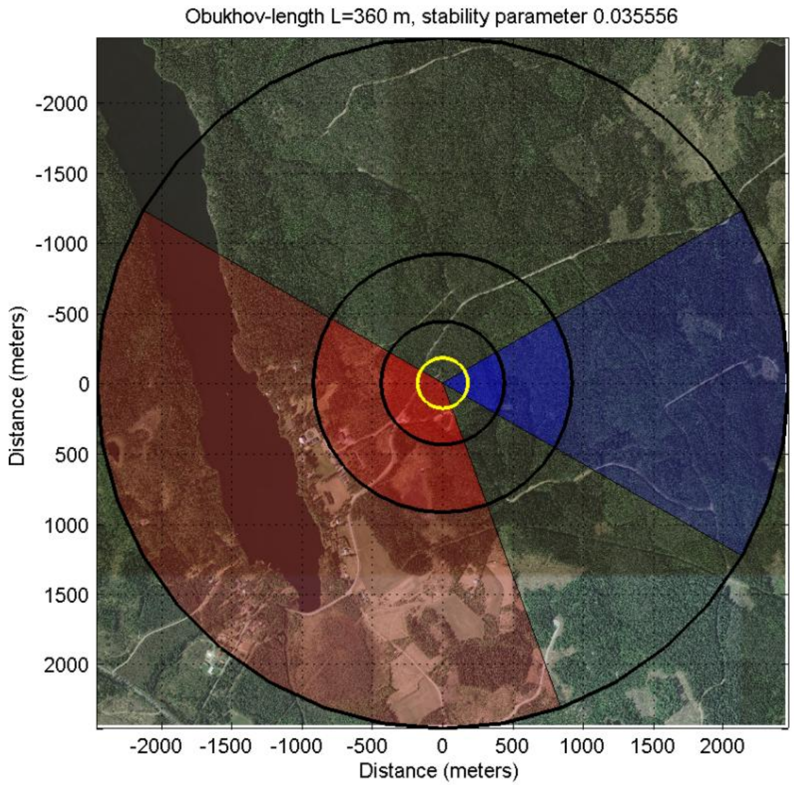
$$K = \frac{F^{EC}_{CO_2}}{\left(\frac{c_2 - c_1}{z_2 - z_1}\right)_{CO_2}}$$

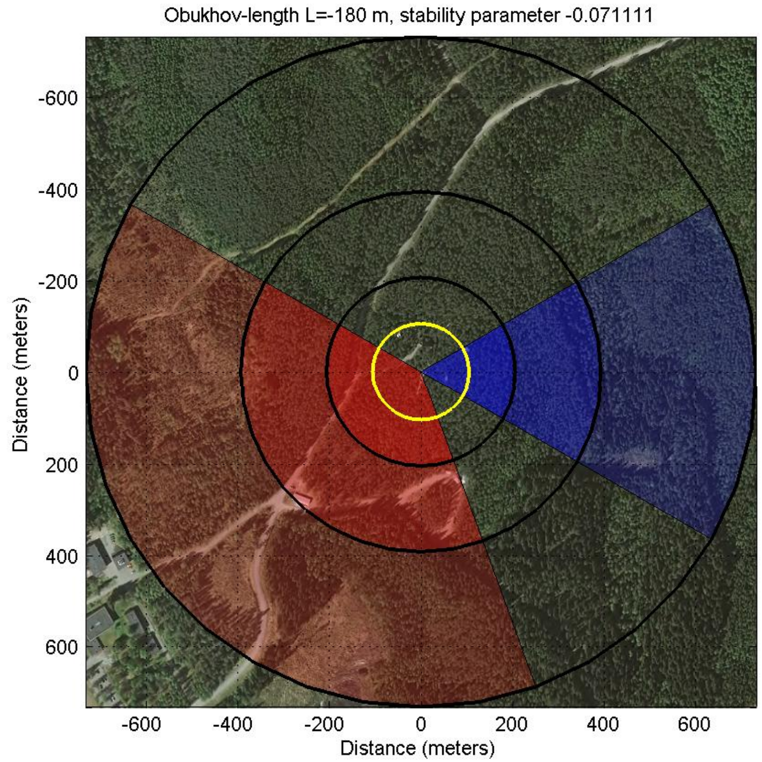
Assumptions:
- Scalar similarity
- EC-flux and gradient have the same source area



CH4 Flux

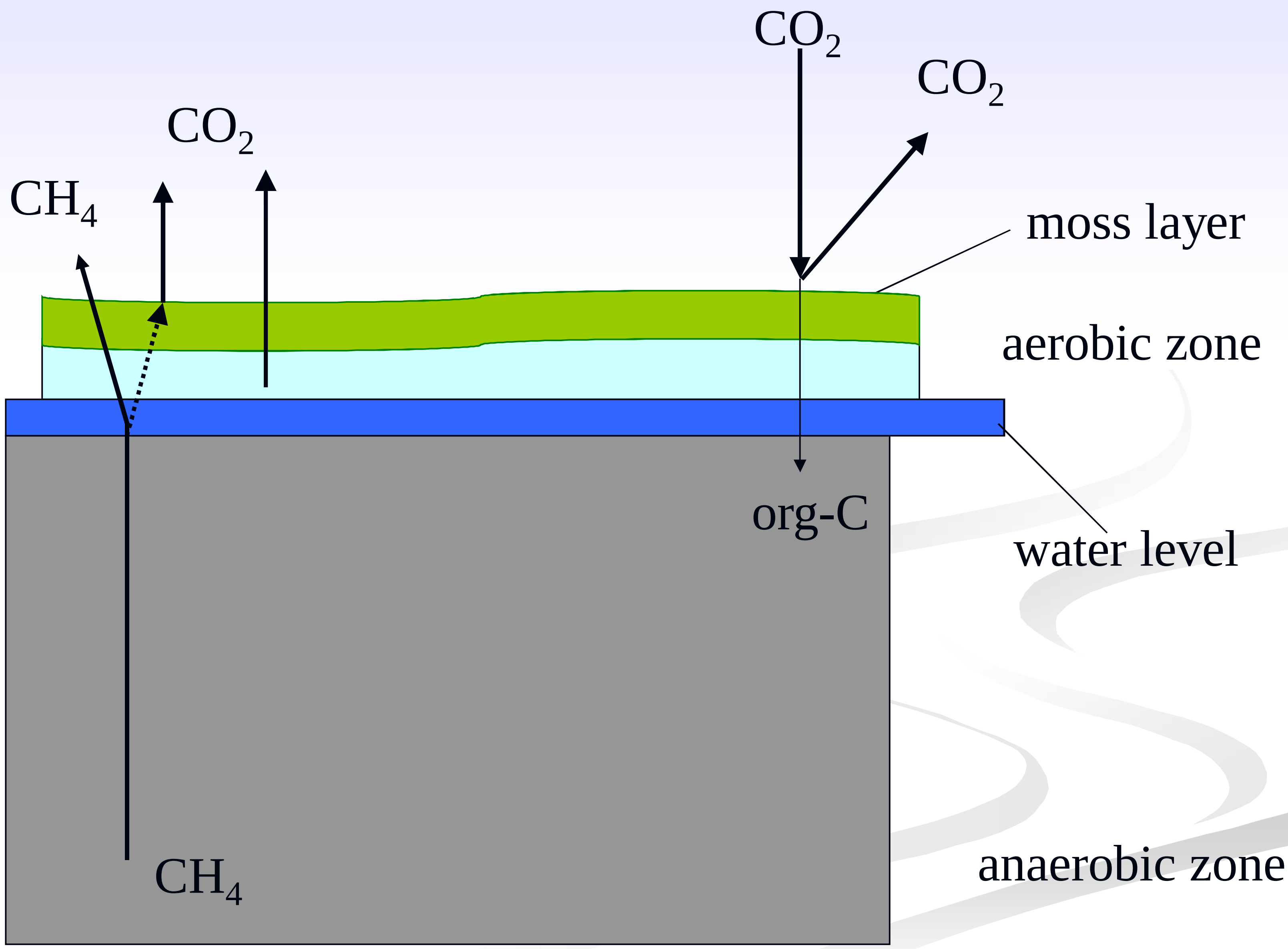
Flux Footprint analysis



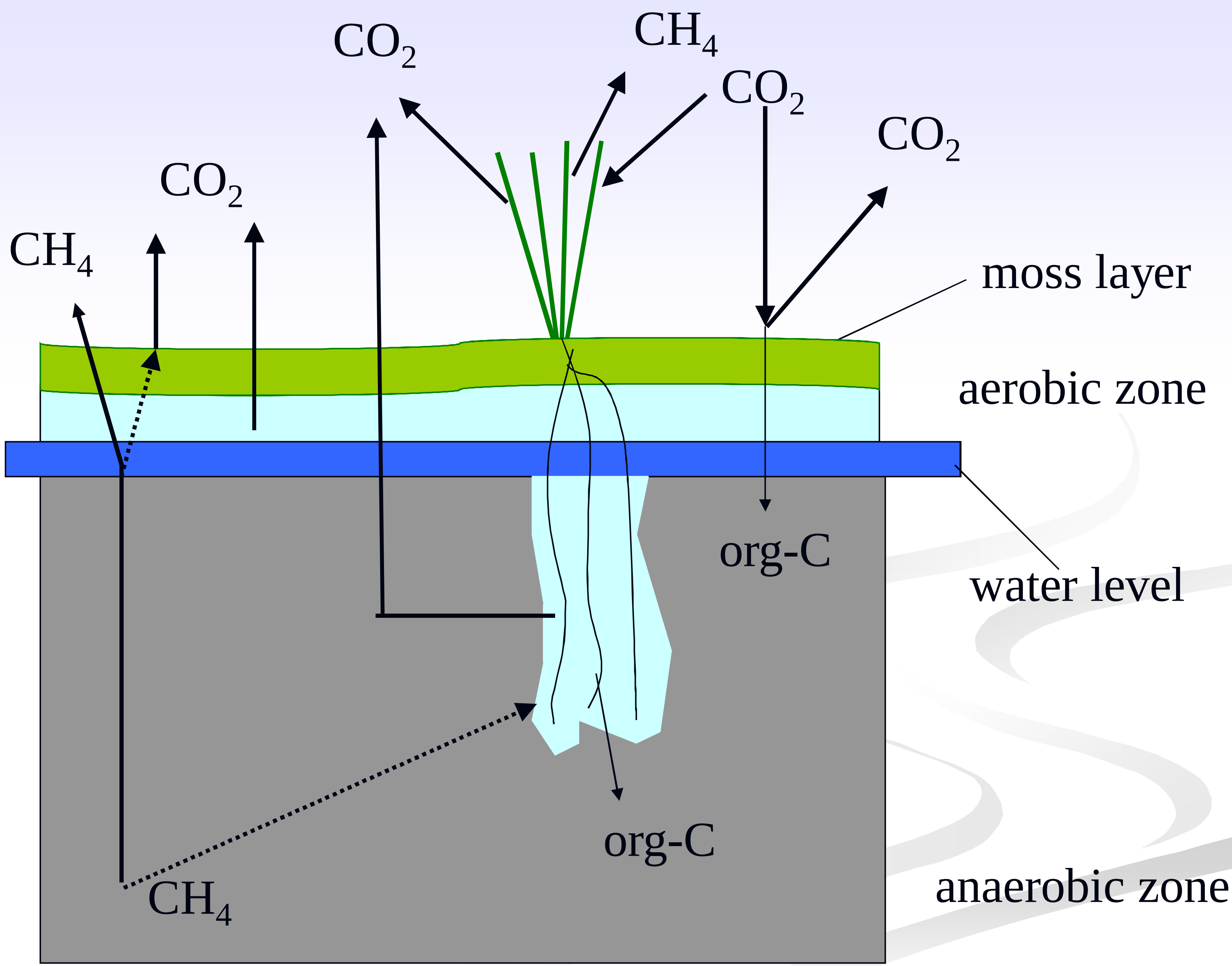


Tall tower fluxes are compared to the up-scaled fluxes measured at small scales (top-down vs bottom-up approach).

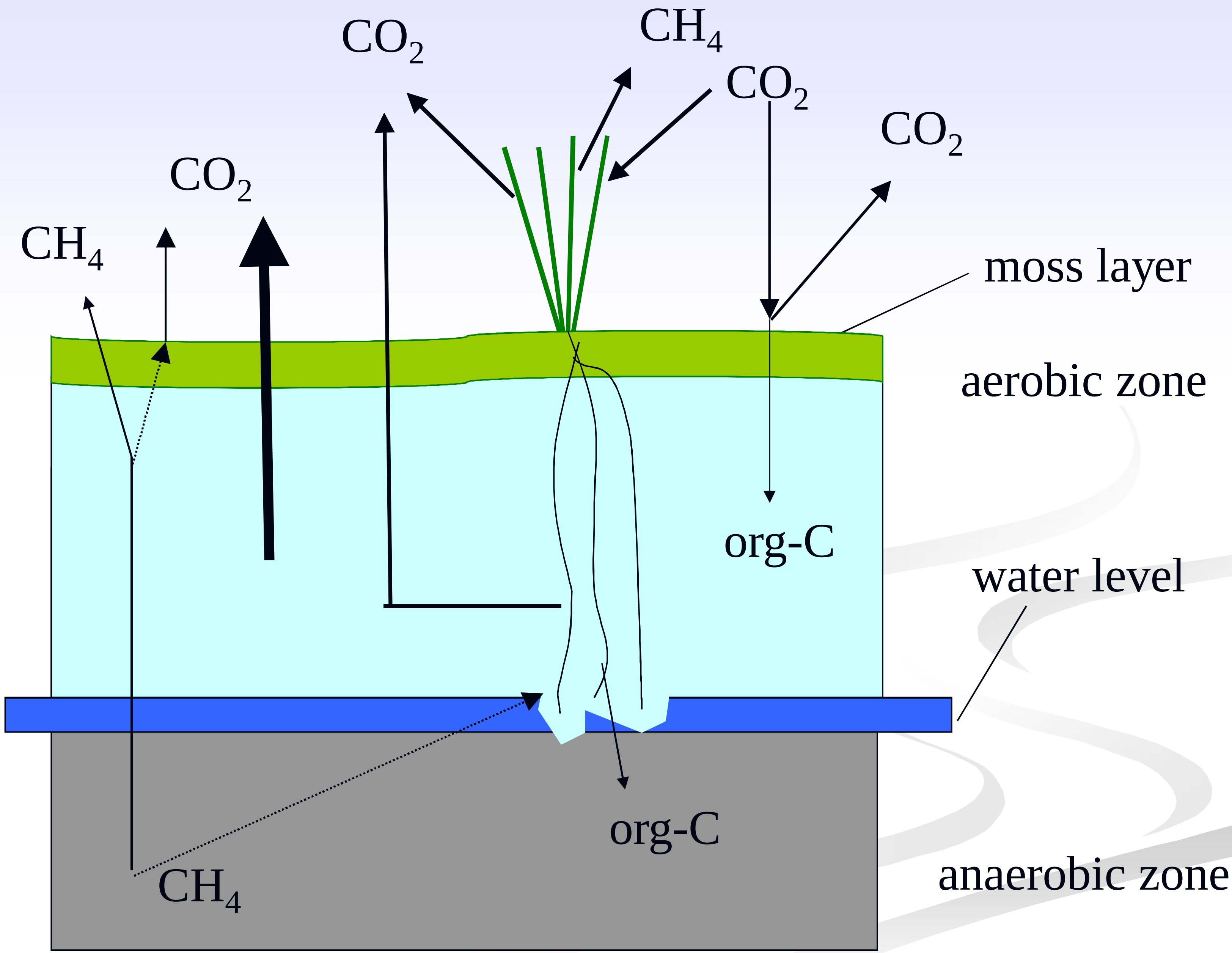
Wetland and Methane (CH_4)


CO2
CO2
CO2
CH4
moss layer
aerobic zone
water level
org-C
anaerobic zone
CH4

T. Riutta



CO_2
CH_4
CO_2
CO_2
CO_2
CH_4
moss layer
aerobic zone
water level
org-C
org-C
CH_4
anaerobic zone

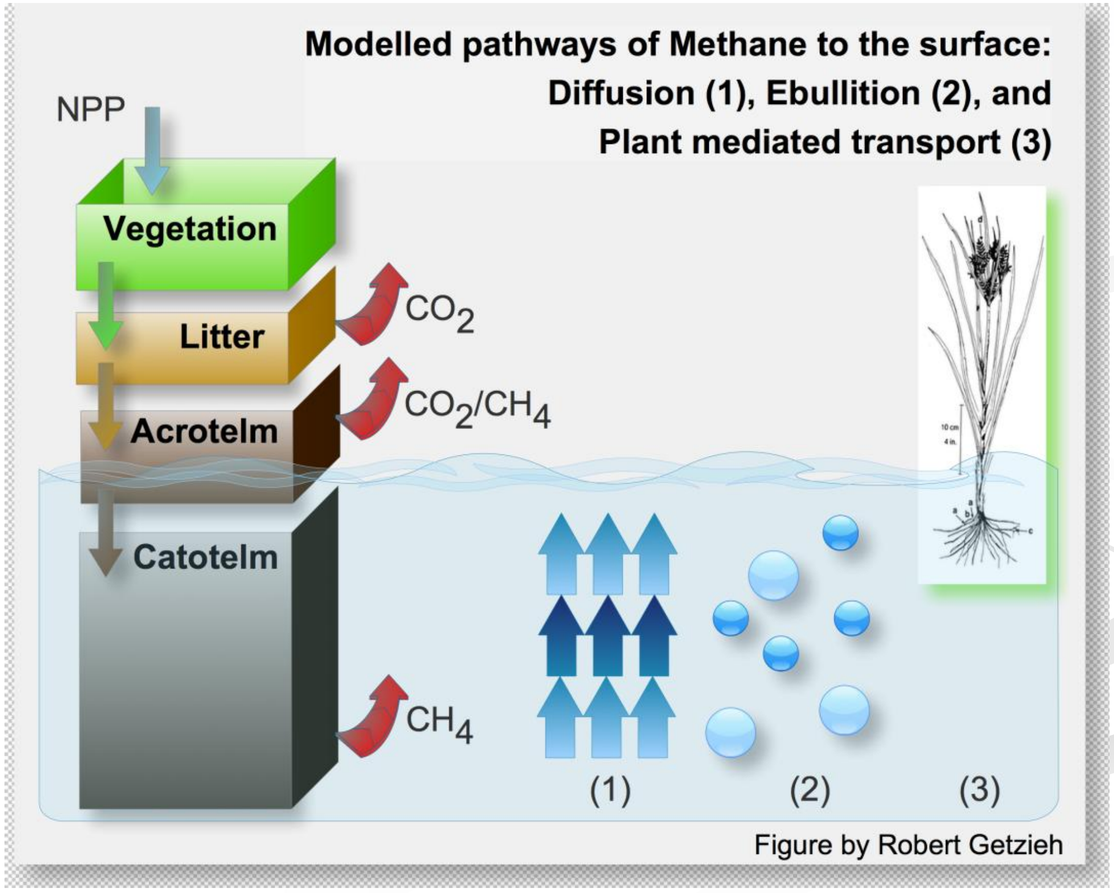


CO2
CH4
CO2
CO2
CO2
CH4
moss layer
aerobic zone
org-C
water level
org-C
CH4
anaerobic zone

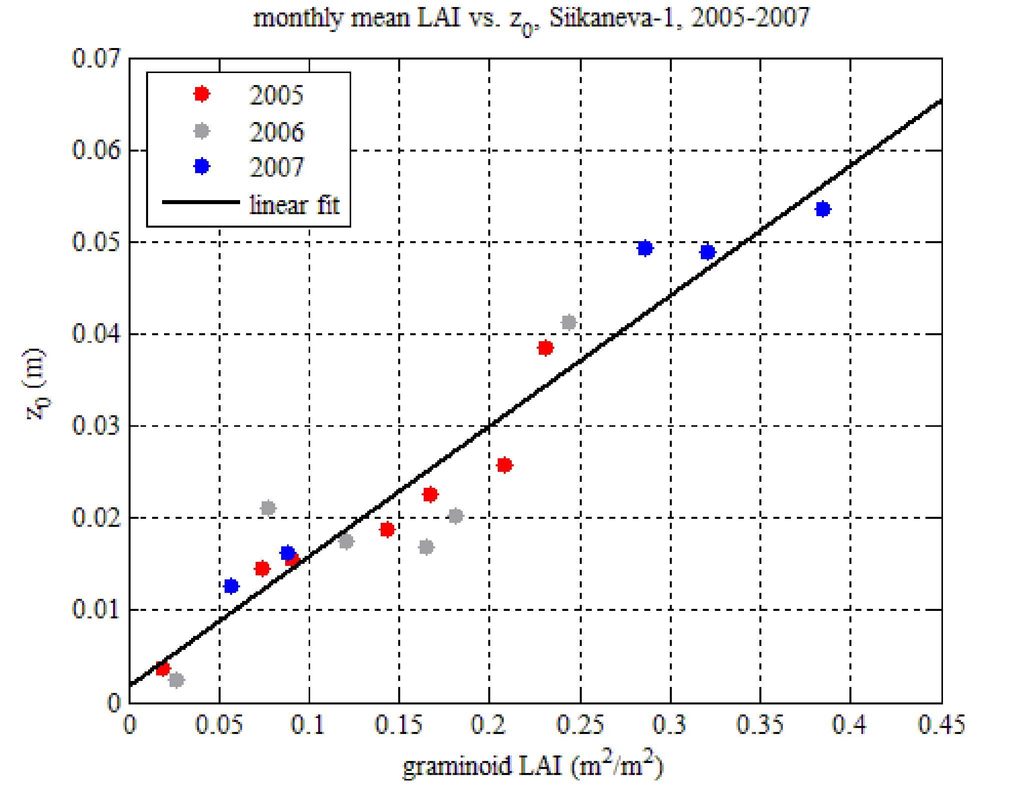
• Methane production and oxidation

• (Diffusive) transport in peat and plants

• Bubble formation (heterogeneous nucleation?) and release to the atmosphere

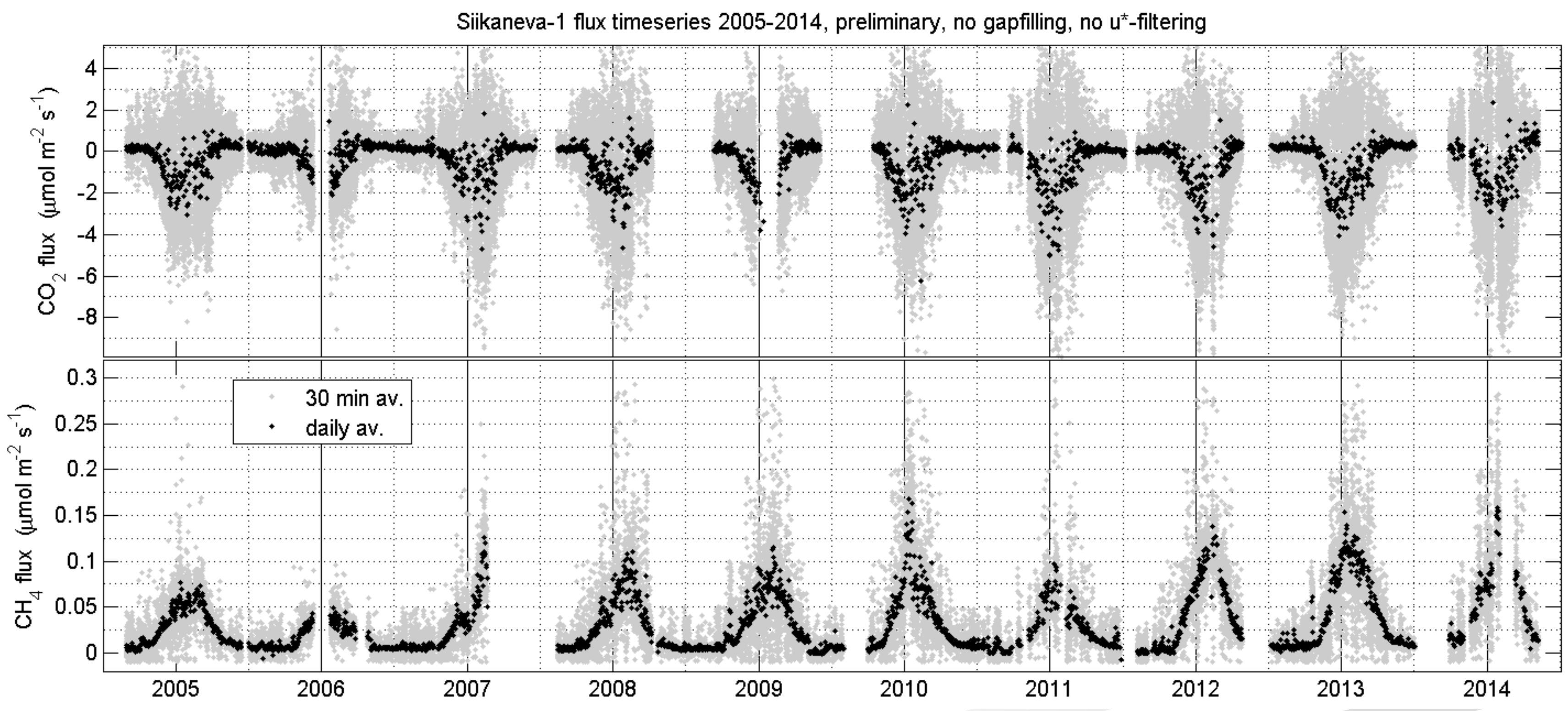


Graminoid leaf area index explains the roughness length parameter



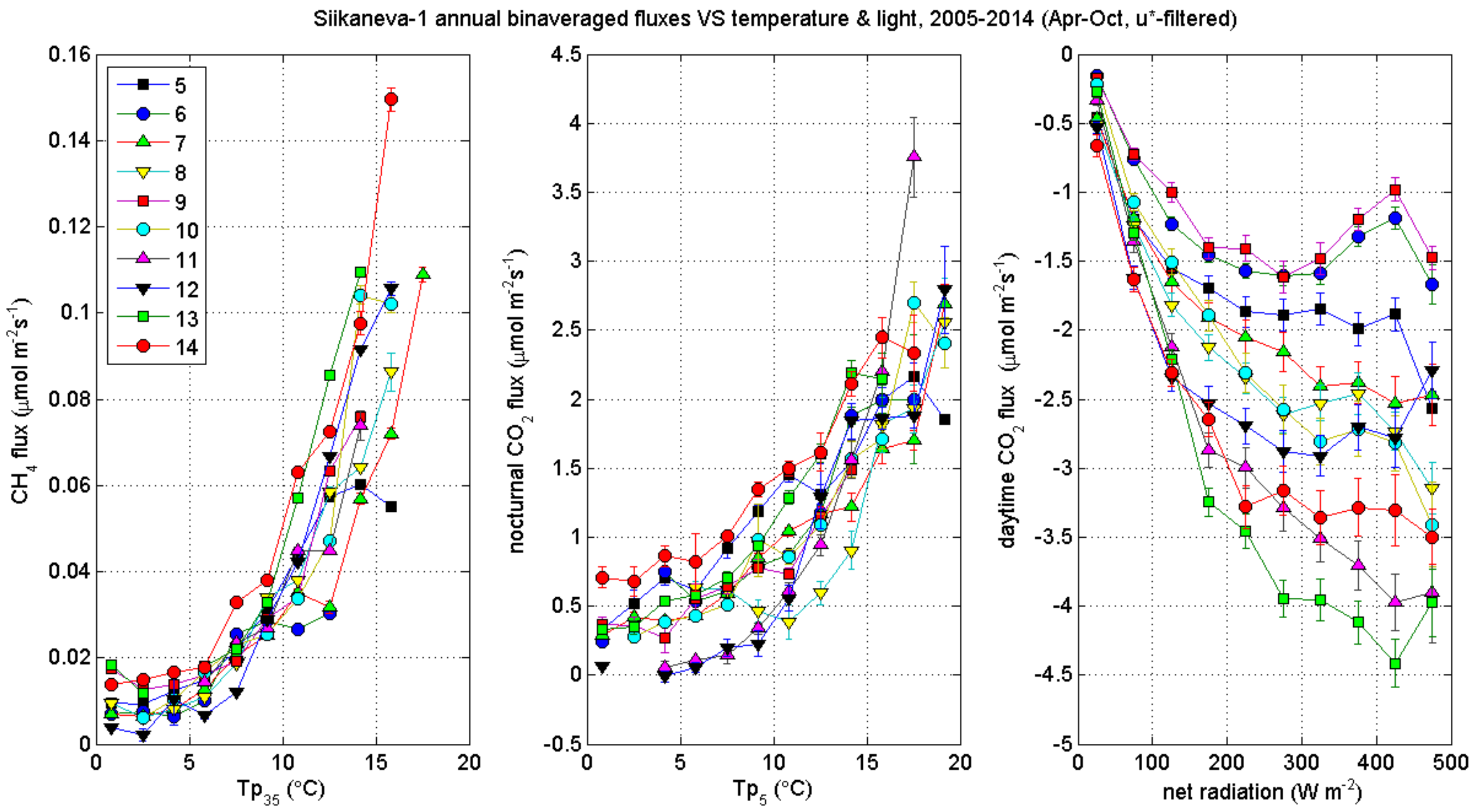
Pavel Alekseychik

10 years of CH4 and CO2 measurements at the Siikaneva-1 fen site



Pavel Alekseychik

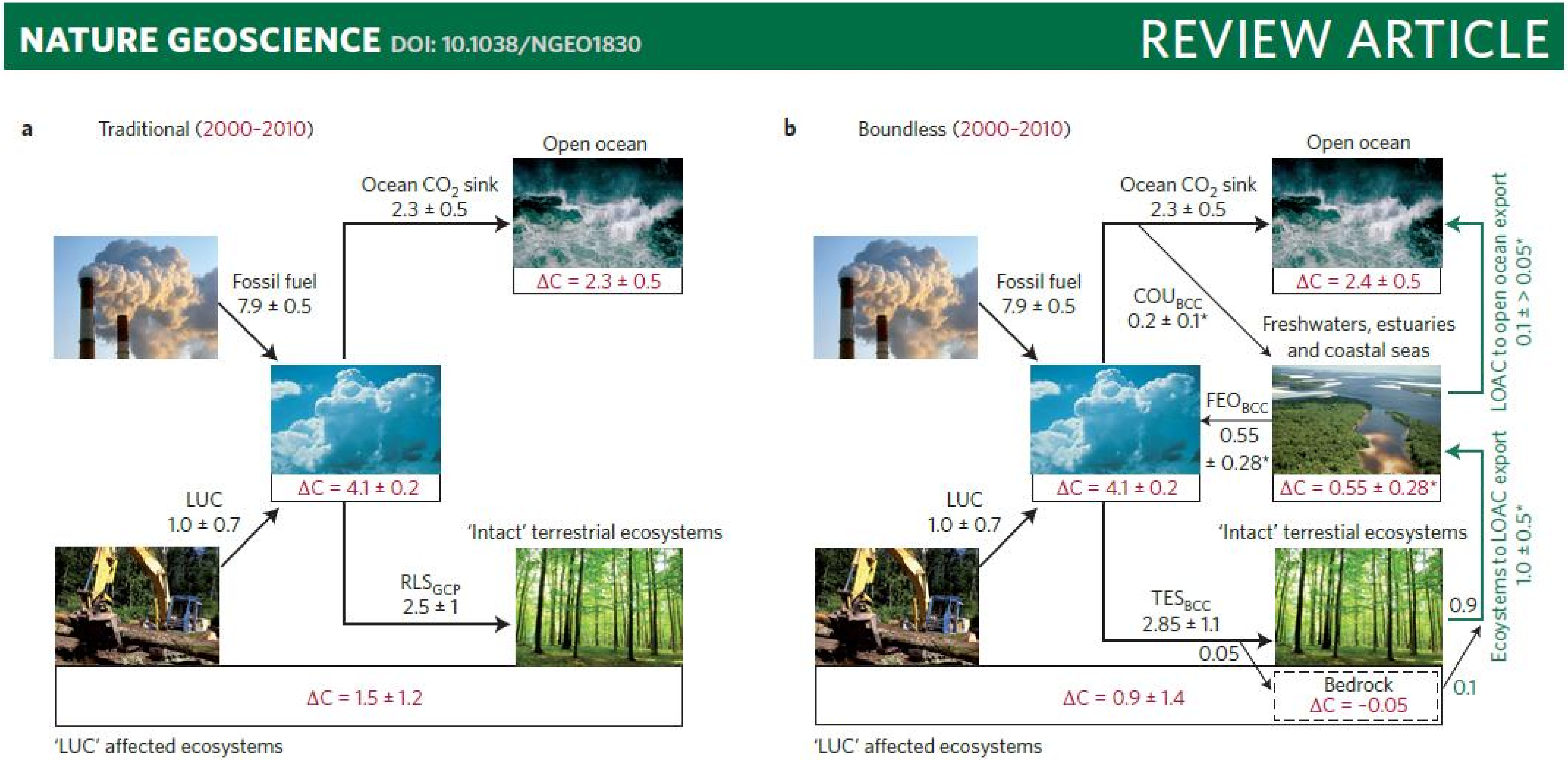
Year-specific temperature and light response curves, Siikaneva-1 fen



Pavel Alekseychik

LAKES

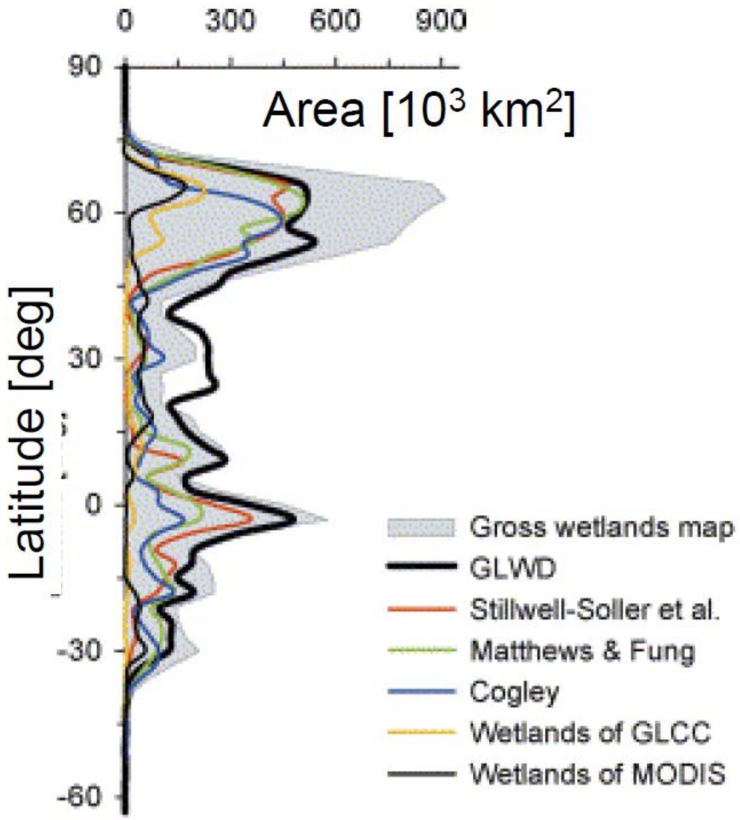
Freshwaters in global carbon cycle



Regnier et al. 2013

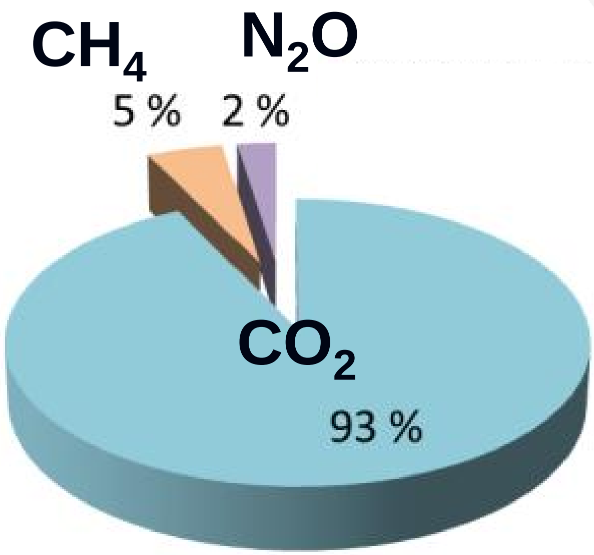
GHG efflux from lakes

Global distribution of lakes and wetlands



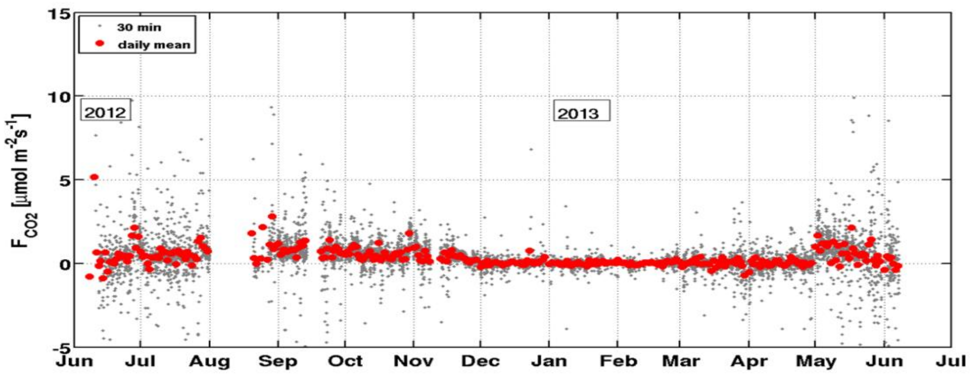
Lehner & Döll (2004) J. Hydrology 296 1-22

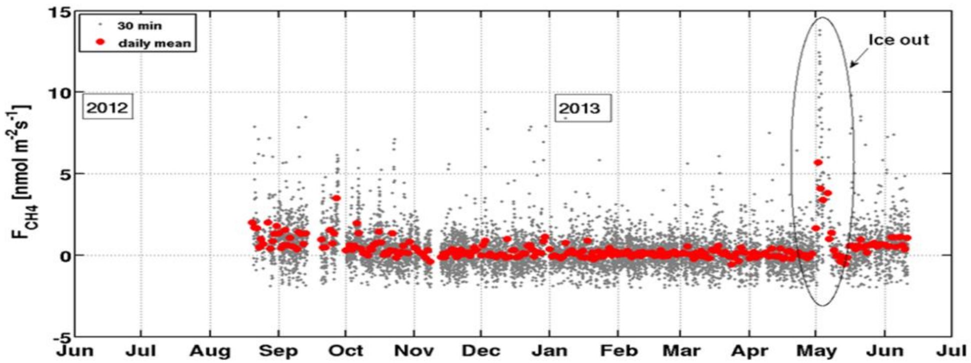
The relative portion of each GHG from the total efflux when weighed by respective global warming potentials (Lake Kuivajärvi 2012)

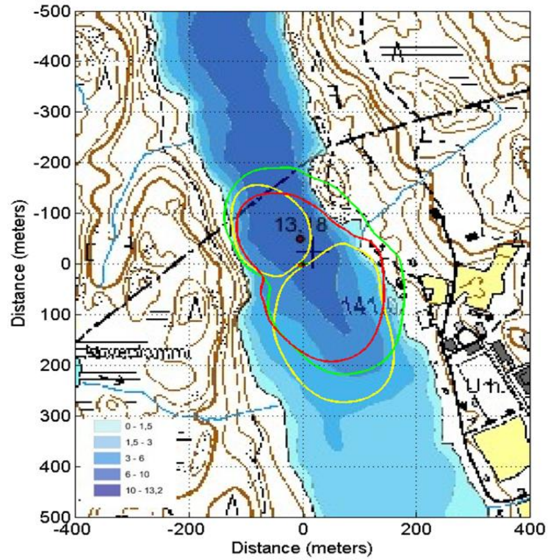


Miettinen, H. *et al.* 2014. Bor. Env. Res., 20, ISSN 1797-2469.

LONG TERM EC MEASUREMENTS OF CARBON DIOXIDE AND METHANE FLUXES OVER LAKE KUIVAJÄRVI





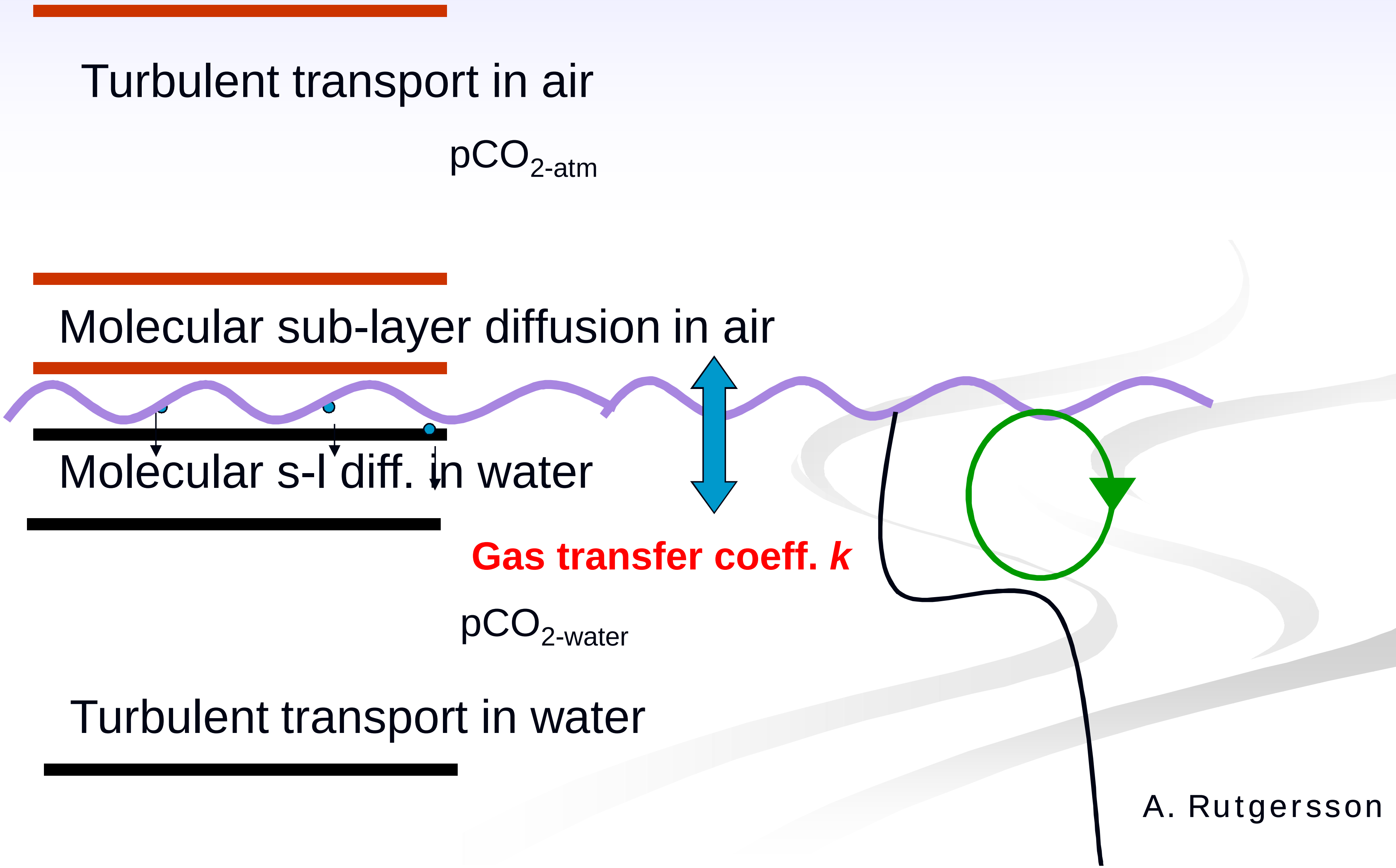


	Kuivajärvi (Lake)	SMEAR II (Scots Pine Forest)	Siikaneva (Wetland)
CO2	+116	-280	-51
CH4	0.2	NA	10

Annual budget (gC m^{-2}) comparison(June 2012–June 2013)

(Mammarella et al., JGR, subm)

Physical bottleneck for gas transfer

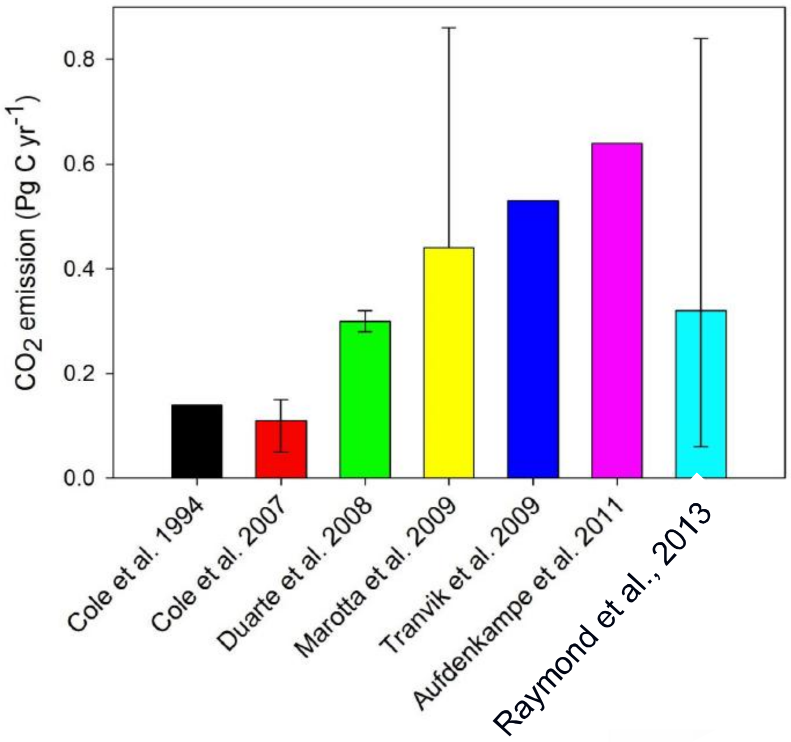


A. Rutgersson

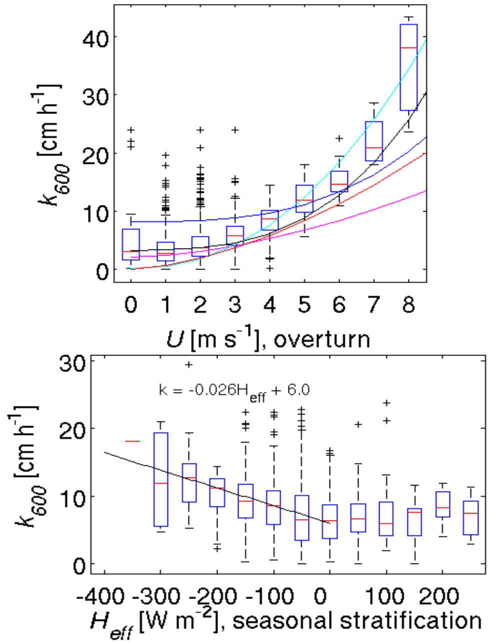
Gas exchange (diffusive flux)

$F_{CO2} = k\,K_0(pCO2_w - pCO2_a)$

Global CO_2 emission from lakes/reservoirs



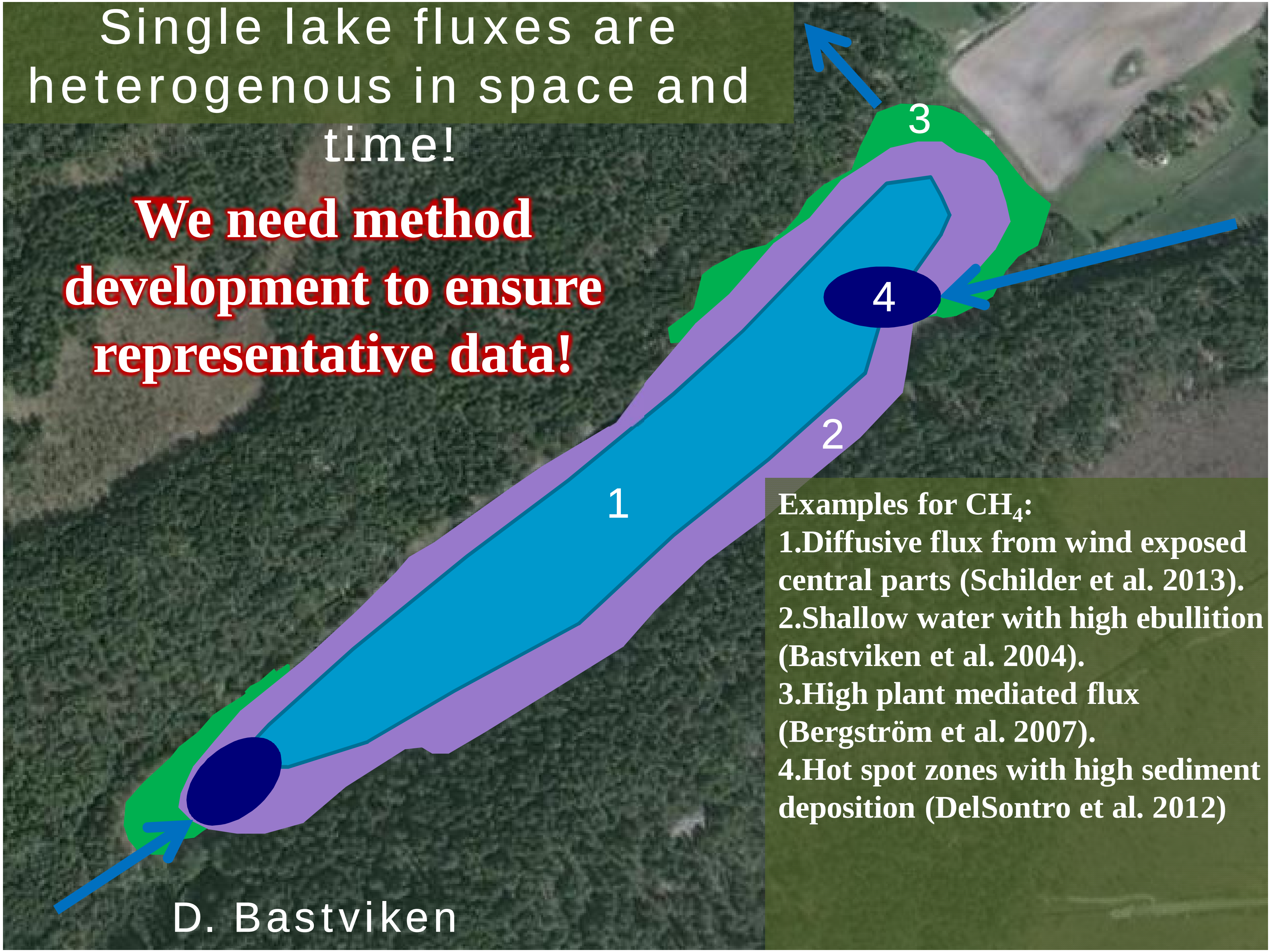
Measured *k* from Lake Kuivajärvi



Heiskanen et al, 2014, Tellus B

Single lake fluxes are heterogenous in space and time!

We need method development to ensure representative data!

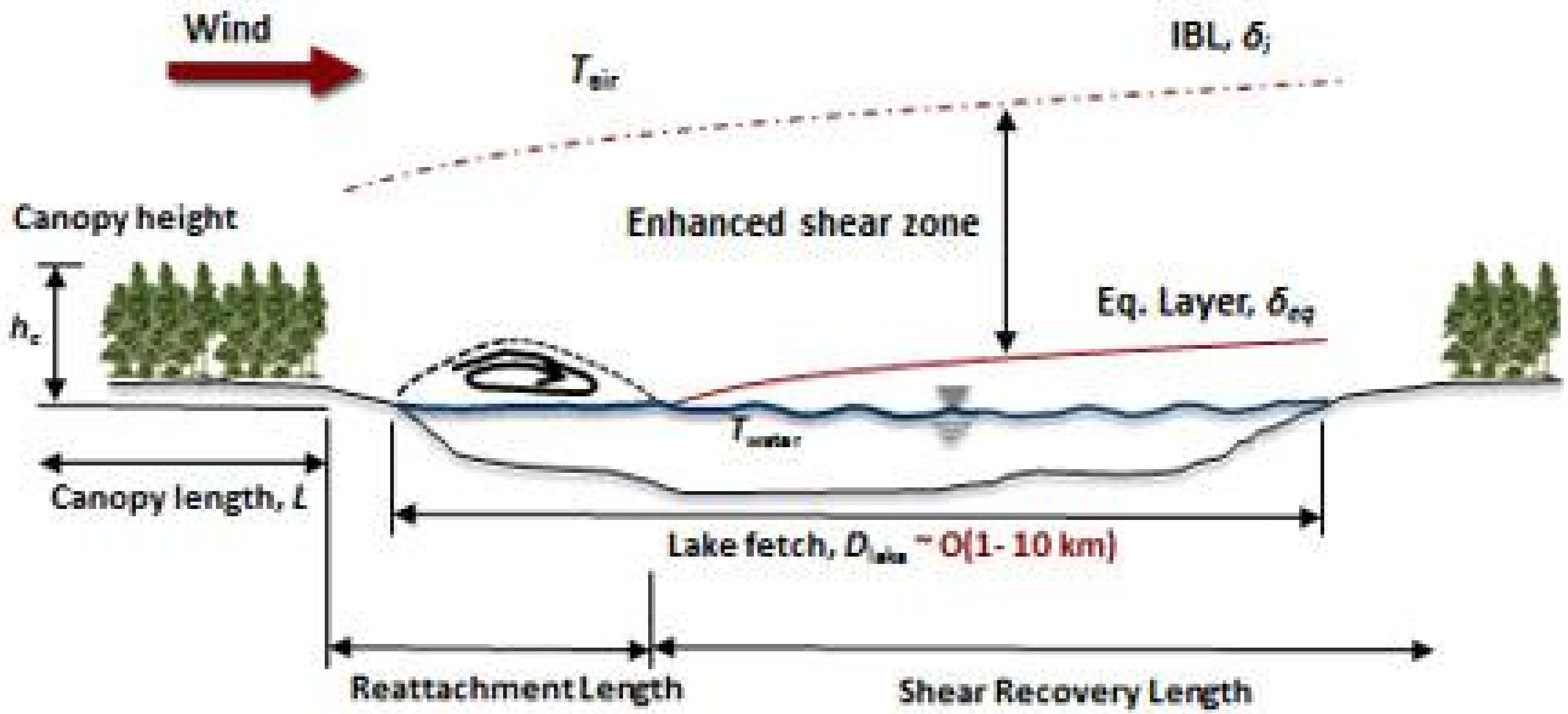


Examples for CH_4:

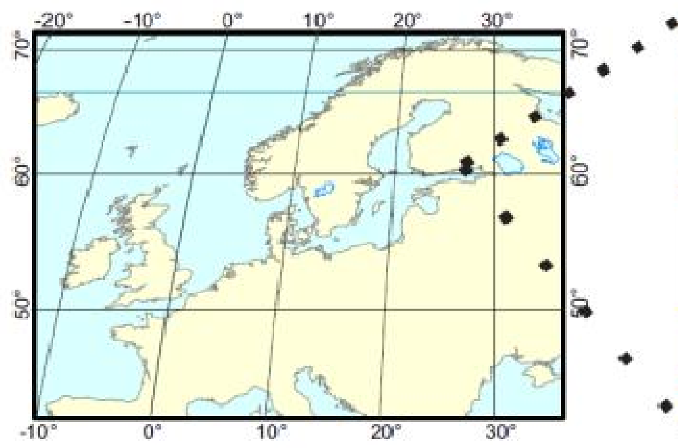
1. **Diffusive flux from wind exposed central parts (Schilder et al. 2013).**
2. **Shallow water with high ebullition (Bastviken et al. 2004).**
3. **High plant mediated flux (Bergström et al. 2007).**
4. **Hot spot zones with high sediment deposition (DelSontro et al. 2012)**

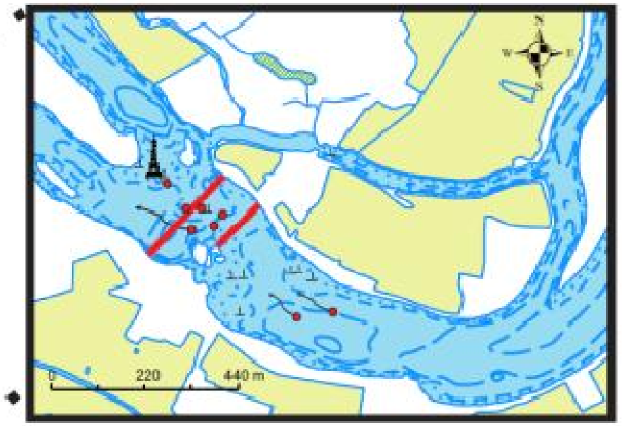
D. Bastviken

Small vs. large lakes: EC footprints (source areas), advection and wind shear vs. convection (*k)*



Markfort et al., 2014, Env. Fluid Mech.





EC over rivers

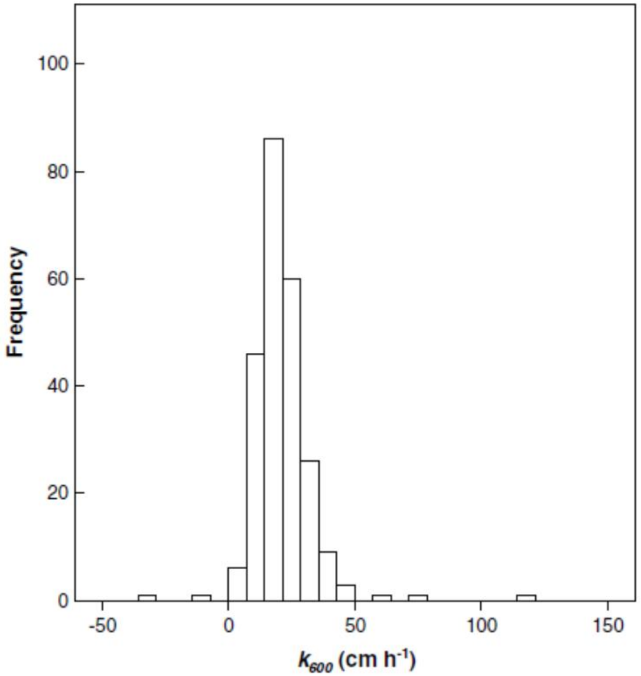
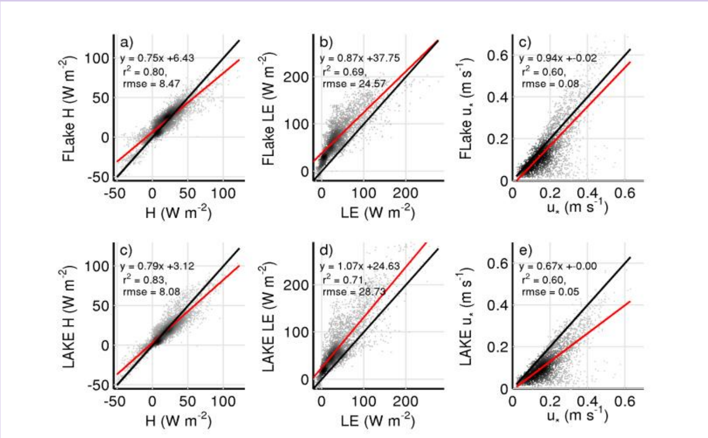


Figure 2. Frequency distribution of normalized gas transfer velocity k_{600} (cm h^{-1}). The mean is 20.8 (±12.5 standard deviation) cm h^{-1} (N=241).

Huotari et al., JGR, 2013

Observation ⟶ Model validation

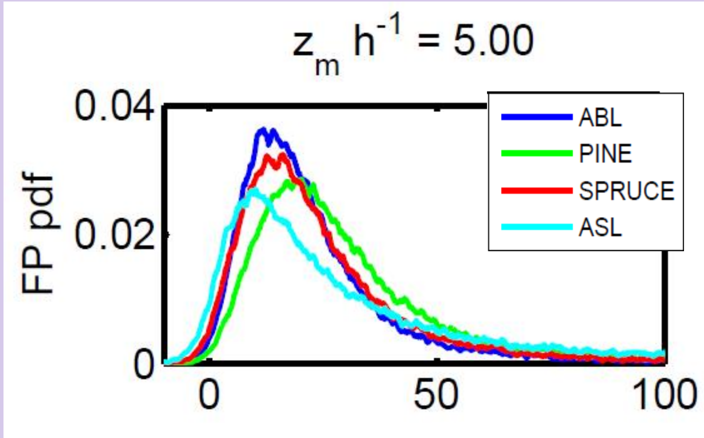
Lake model



(Heiskanen et al., JGR, subm)

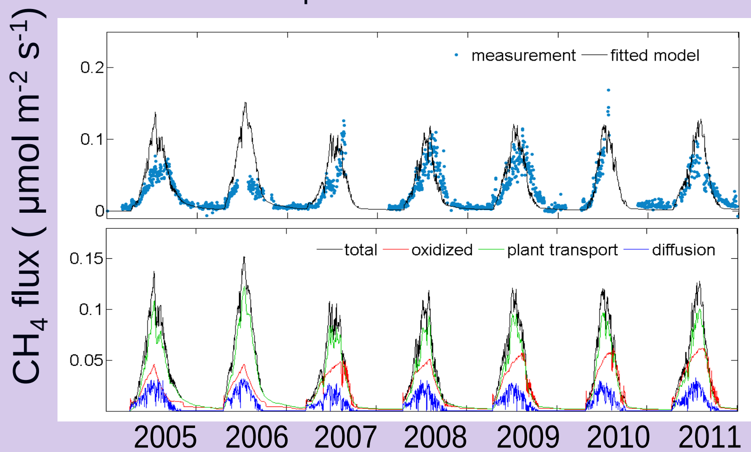
Model ⟶ Data interpretation

Flux footprint model for tall towers



(Rannik et al., in preparation)

Wetland CH_4 emission sub-model



(Raivonen et al.)

LES model for small lake

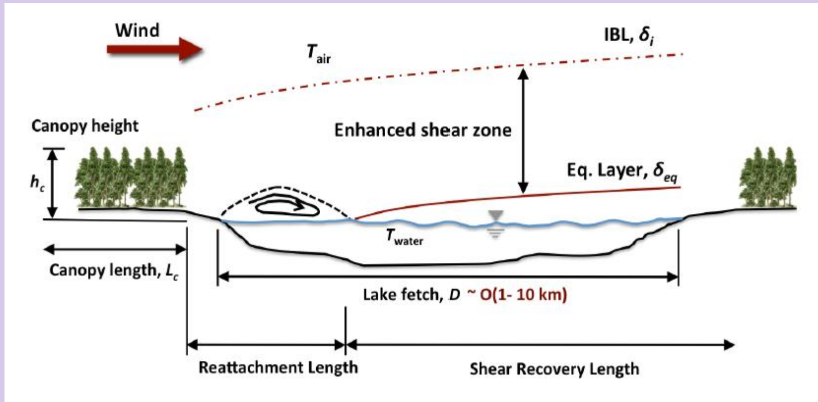


FIG. 2: Schematic of flow transition from a tall canopy to a small lake

(A. Glazunov, Moscow State University)

Thanks for your attention