HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

EC FLUXES: BASIC CONCEPTS AND BACKGROUND

Timo Vesala (thanks to e.g. Samuli Launiainen
and Ivan Mammarella)

Scales of meteorological processes:

- Synoptic scale, ~ 1000 km (weather predictions, ~ day)
- Mesoscale, ~ 100 km (land-sea breeze, ~ hours)
- Microscale, ~ 1 mm – 1 km; ~ seconds - hour

1. Big issues and motivation trial

2. Concept of flux

3. C and water cycles and flux towers

4. Methane and wetlands

5. Lakes

6. Urban surface

7. N and reactive gases

8. ICOS (Integrated Carbon Observation System) and versatile field stations

Fate of Anthropogenic CO_2 Emissions (2010)

9.1±0.5 PgC y^{-1}

+

0.9±0.7 PgC y^{-1}

5.0±0.2 PgC y^{-1}

50%

2.6±1.0 PgC y^{-1}

26%

Calculated as the residual
of all other flux components

24%

2.4±0.5 PgC y^{-1}

Average of 5 models

Global Carbon Project 2010; Updated from Le Quéré et al. 2009, Nature Geoscience; Canadell et al. 2007, PNAS

nature geoscience

REVIEW ARTICLE

PUBLISHED ONLINE: 25 JULY 2010 | DOI: 10.1038/NGEO905

Terrestrial biogeochemical feedbacks in the climate system

A. Arneth[1,2*], S. P. Harrison[3,4], S. Zaehle[5], K. Tsigaridis[6,7], S. Menon[8], P. J. Bartlein[9], J. Feichter[10], A. Korhola[11], M. Kulmala[2], D. O'Donnell[10], G. Schurgers[1], S. Sorvari[2] and T. Vesala[2]

• Total positive radiative forcing comparable in magnitude to other physical forcings/feedbacks

• Understanding of these very low (e.g. nitrogen cycle stimulation or limitation of C sequestration)

Forests in Flux

REVIEW

Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests

Gordon B. Bonan

serving as a control to compare against another simulation with altered vegetation, demonstrate an ecological influence on climate.

Atmospheric models require fluxes of energy, moisture, and momentum at the land surface as boundary conditions to solve numerical equations of atmospheric physics and dynamics. The first generation of land surface parameterizations developed in the late 1960s and 1970s used bulk aerodynamic formulations of energy exchange without explicitly representing vegetation [supporting online material (SOM)]. Soil water

Science 320, 1444 (2008)

- Physical, chemical and biological processes affect the climate (energy, hydrology and atmospheric composition)

- Complex and non-linear interactions can damp and enhance anthropogenic changes

- Forests act as carbon sinks and feedbacks can increase or decrease this climate forcing

- Transpiration of tropical forests cools and the darkness of boreal forests (albedo) warms

- Net effects are not known

CONCEPT OF FLUX

MASS TRANSPORT BETWEEN THE ATMOSPHERE AND ECOSYSTEMS

Material produced or absorbed by the biological sink is either stored in the air or transported away

Transport by

- Turbulence (eddies)
- Advection (bulk flow)

What is a vertical flux?

- **Vertical flux (density!) is defined as the amount of material transported vertically per unit area per unit time**
- Typical units:

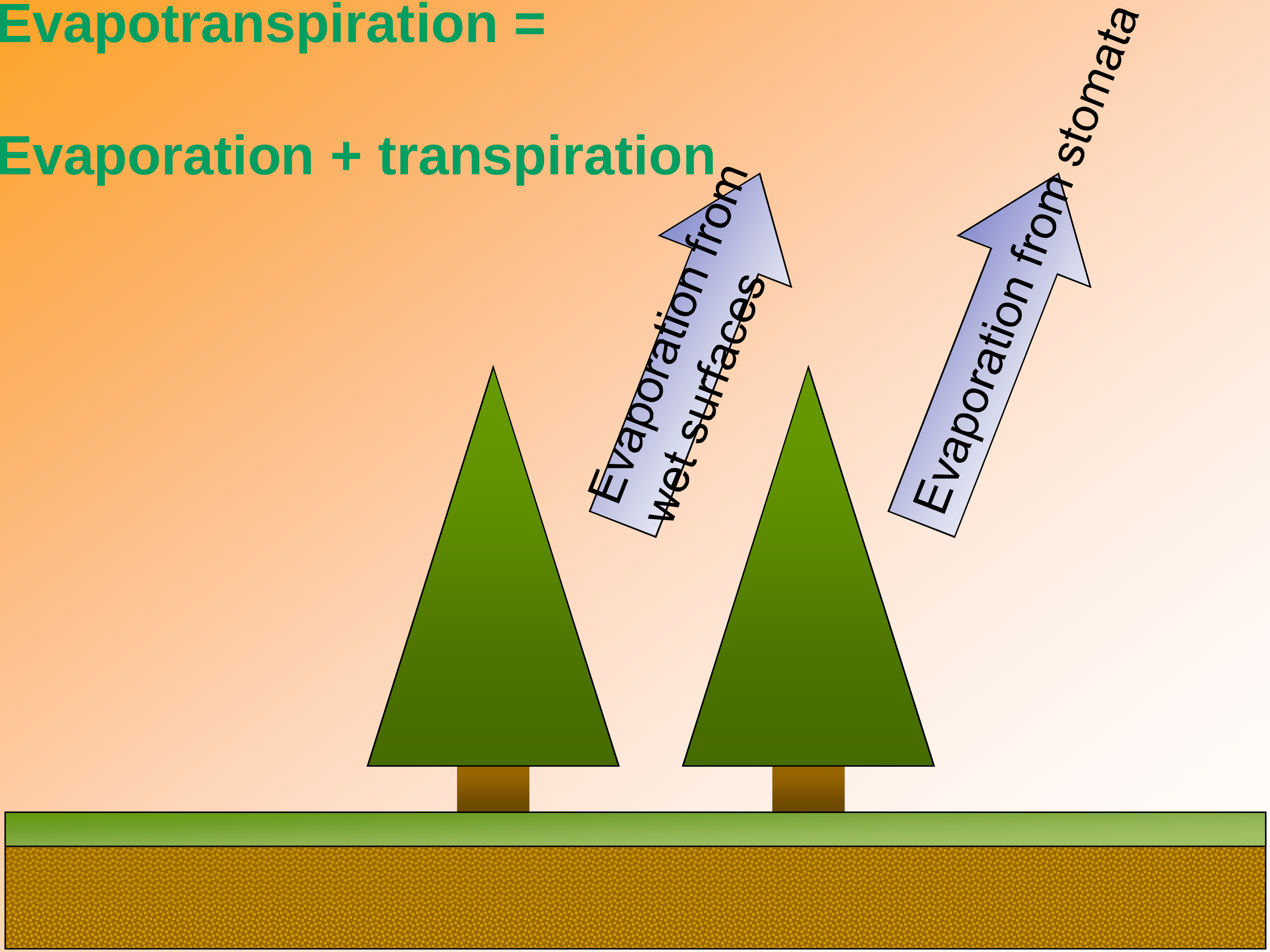
μmol m^{-2} s^{-1}	**CO_2, plant physiologists**
μg m^{-2} s^{-1}	pollution community
mg m^{-2} hr^{-1}	chambers, VOC
ppb m s^{-1}	chemists' units
# cm^{-2} s^{-1}	particle number fluxes
μeq m^{-2} s^{-1}	comparisons, acidity
kg ha^{-1} yr^{-1} or g m^{-2} yr^{-1}	**annual budgets CO_2, N**
W m^{-2}	**sensible and latent heat fluxes**

E. Nemitz

C and WATER CYCLES and FLUX TOWERS

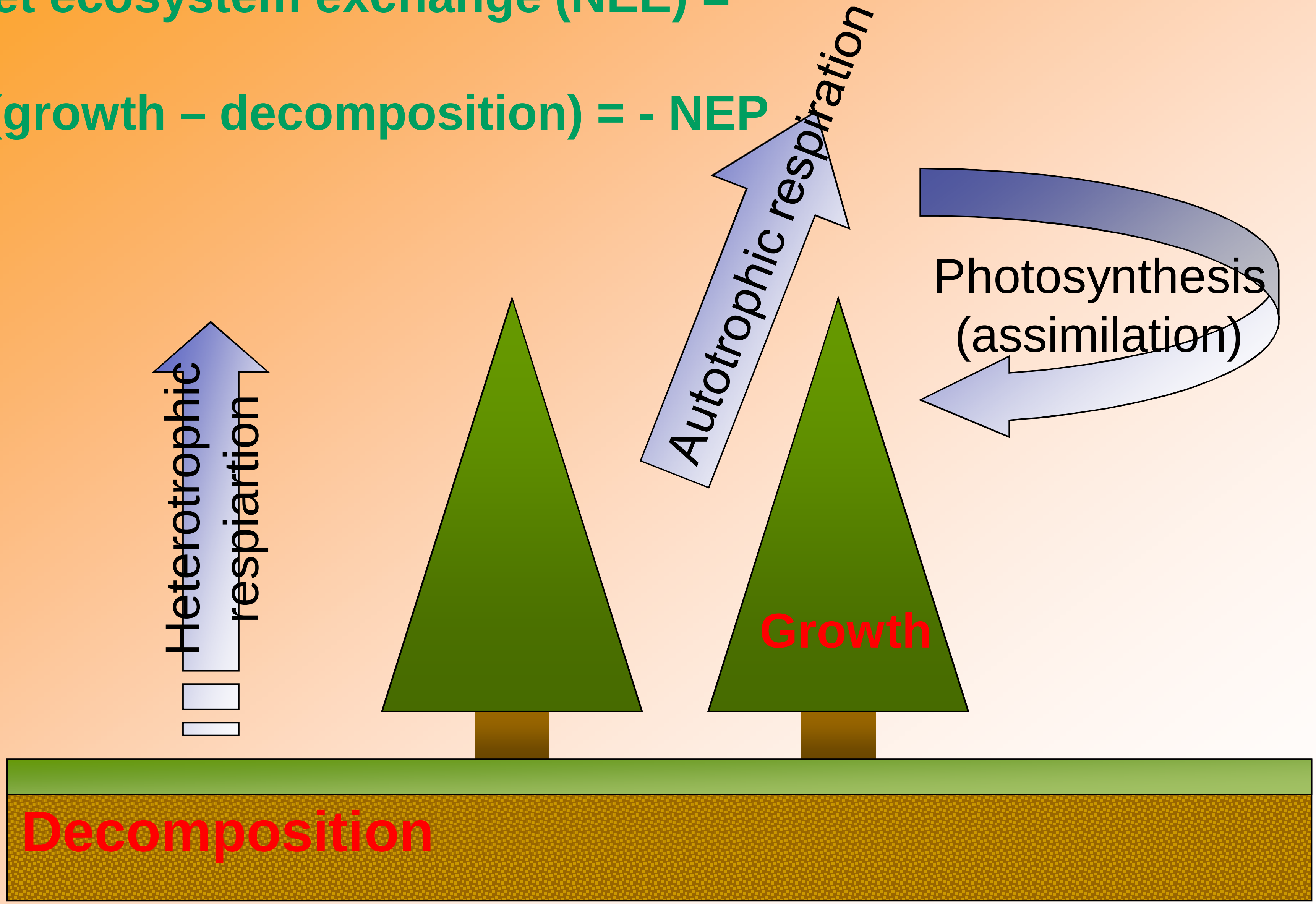
Evapotranspiration =

Evaporation + transpiration

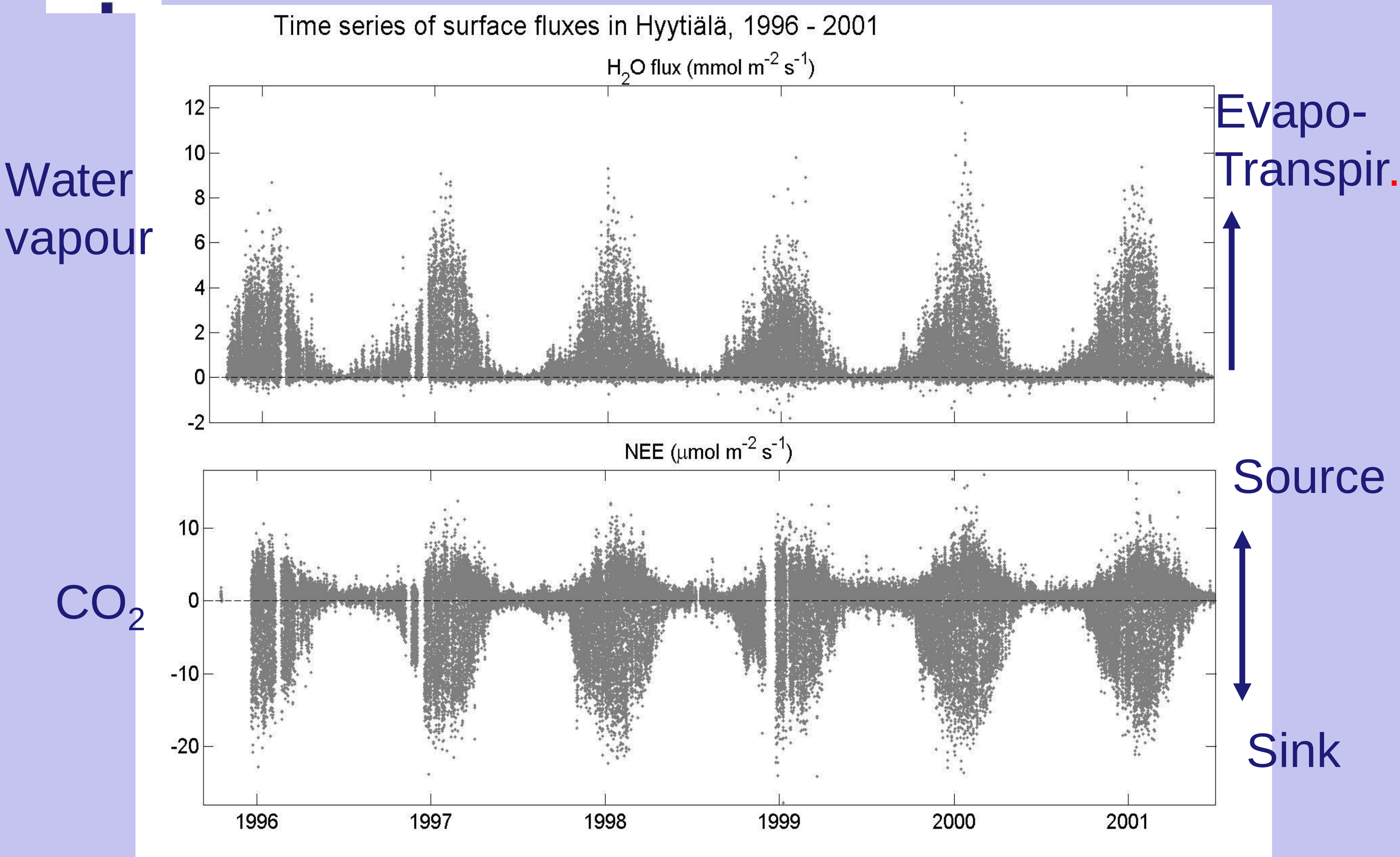


Net ecosystem exchange (NEE) =

- (growth – decomposition) = - NEP



Water vapour and CO_2 exchange in Hyytiälä (40-year-old pine)



Forest site
Hyytiälä 2002-2008

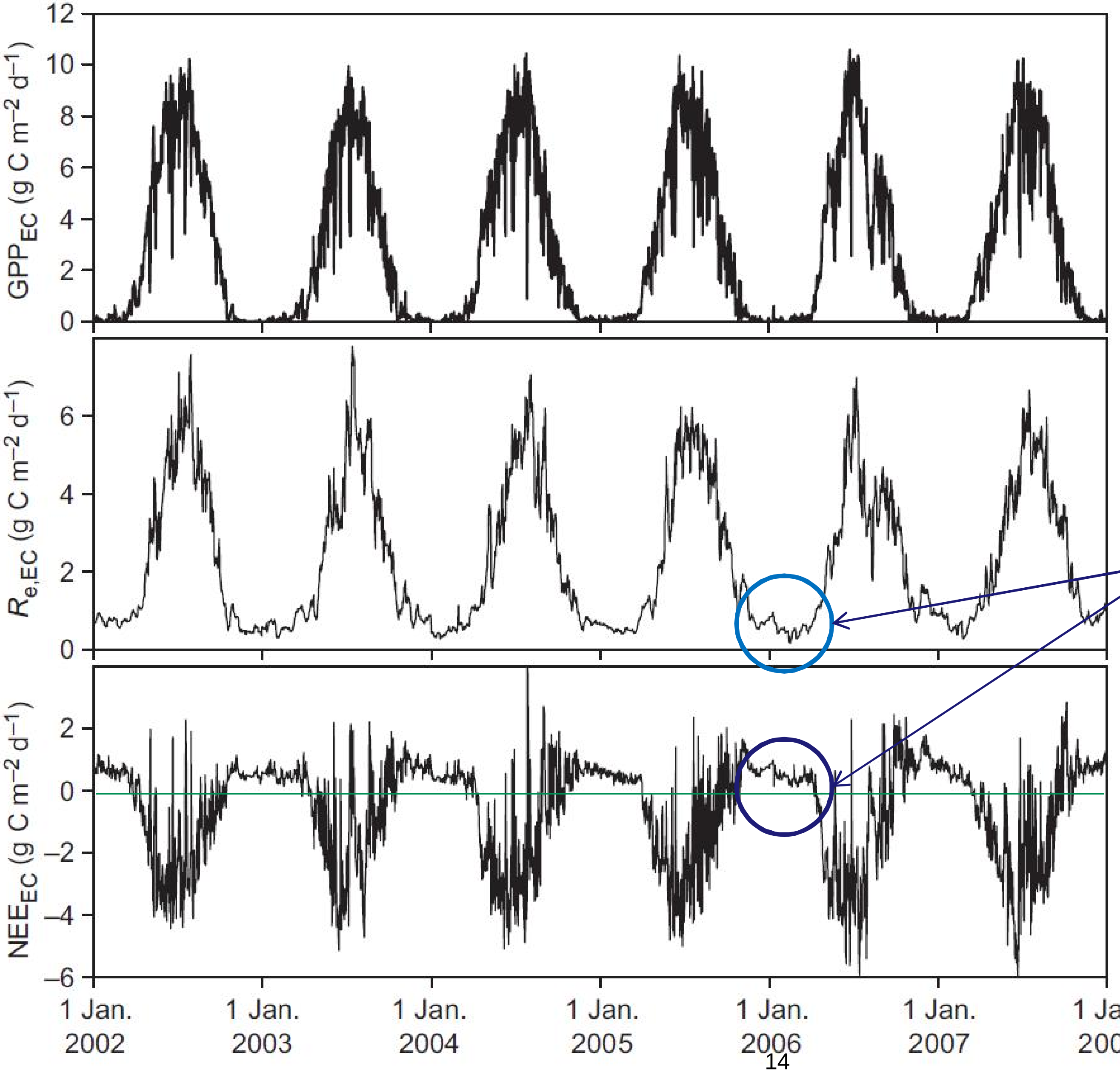


Fig. 4. Seasonal courses of daily photosynthetic production (GPP$_{EC}$), ecosystem respiration ($R_{e,EC}$) and net ecosystem exchange (NEE$_{EC}$) from eddy covariance in 2002–2007. Positive NEE indicates loss of carbon from the ecosystem, negative NEE uptake by the ecosystem.

Kolari et al. 2009

Hyytiälä energy fluxes

EC

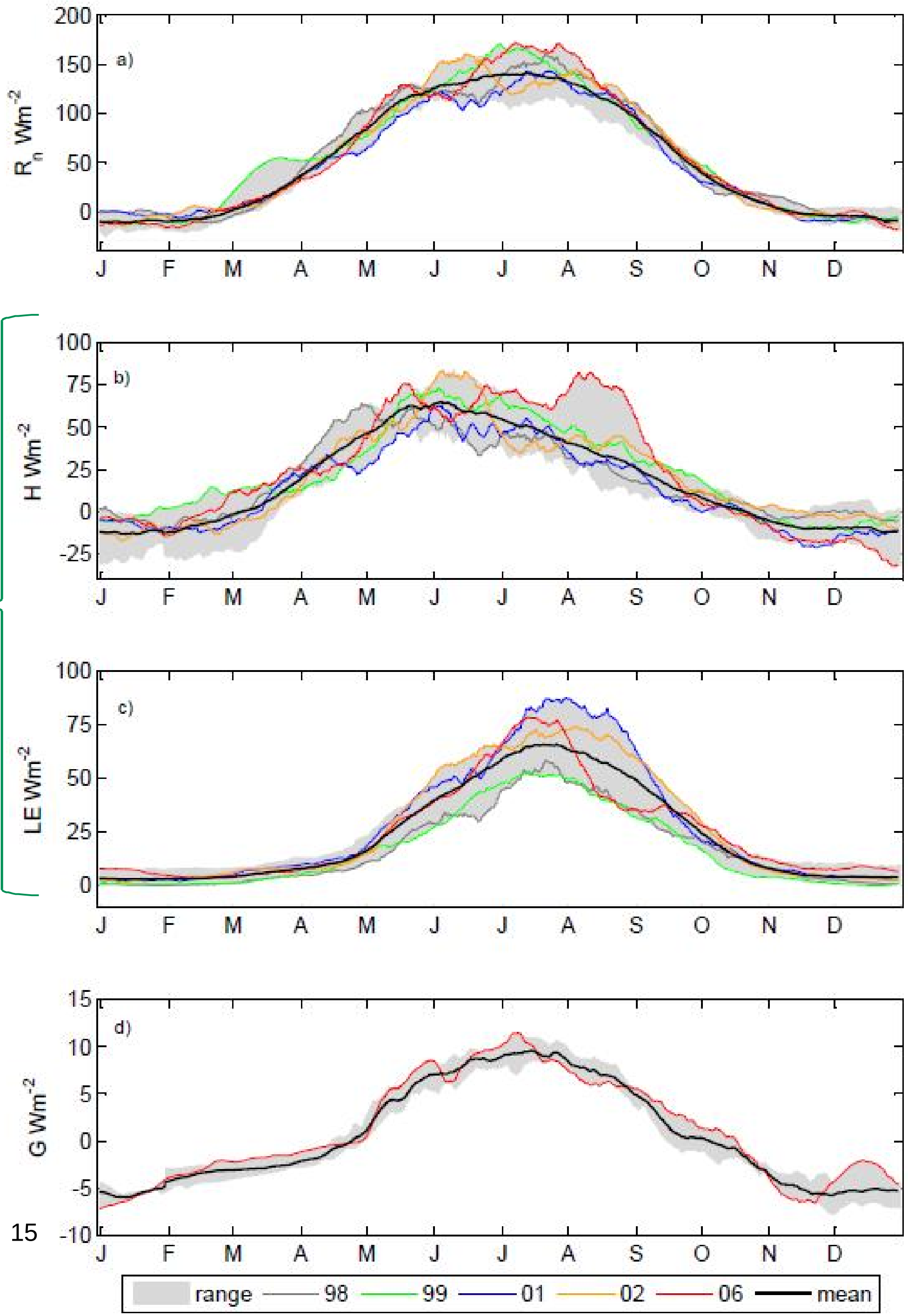
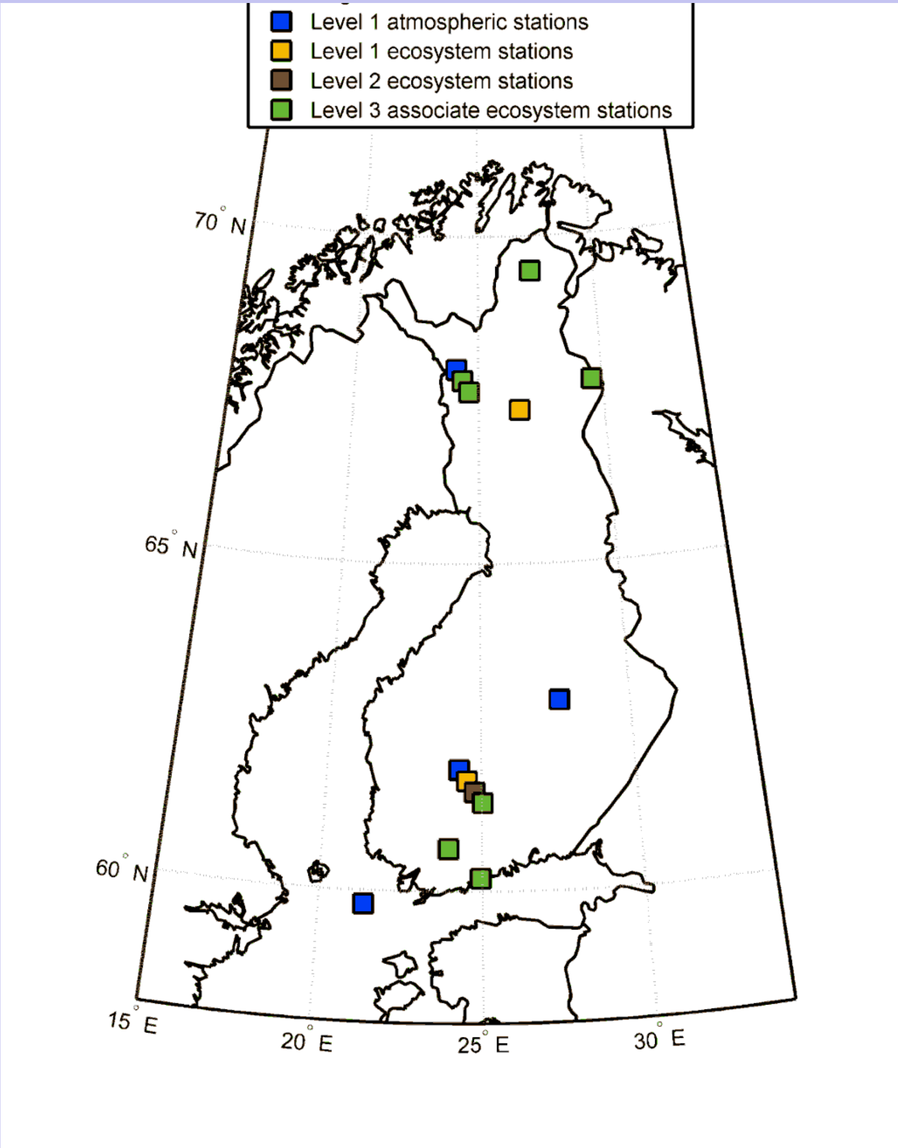


Fig. 3. Seasonal course of main energy balance terms: **(a)** net radiation (R_n), **(b)** sensible heat flux (H), **(c)** latent heat flux (LE) and **(d)** heat flux into the soil (G). All data are 30-day running means. The grey area corresponds to the variability range of the 30-day running means during 1998–2008 while the average is given by the thick black line. G was not explicitly measured before year 2006. The R_n and G are defined positive downwards while the sign convention is opposite for H and LE.

Launiainen et al. 2010



Long-term stations in Finland

LEVEL 1

SMEAR II Hyytiälä (**forest**)
Sodankylä (**forest**)

LEVEL2

SMEAR II Siikaneva (**wetland**)

LEVEL 3

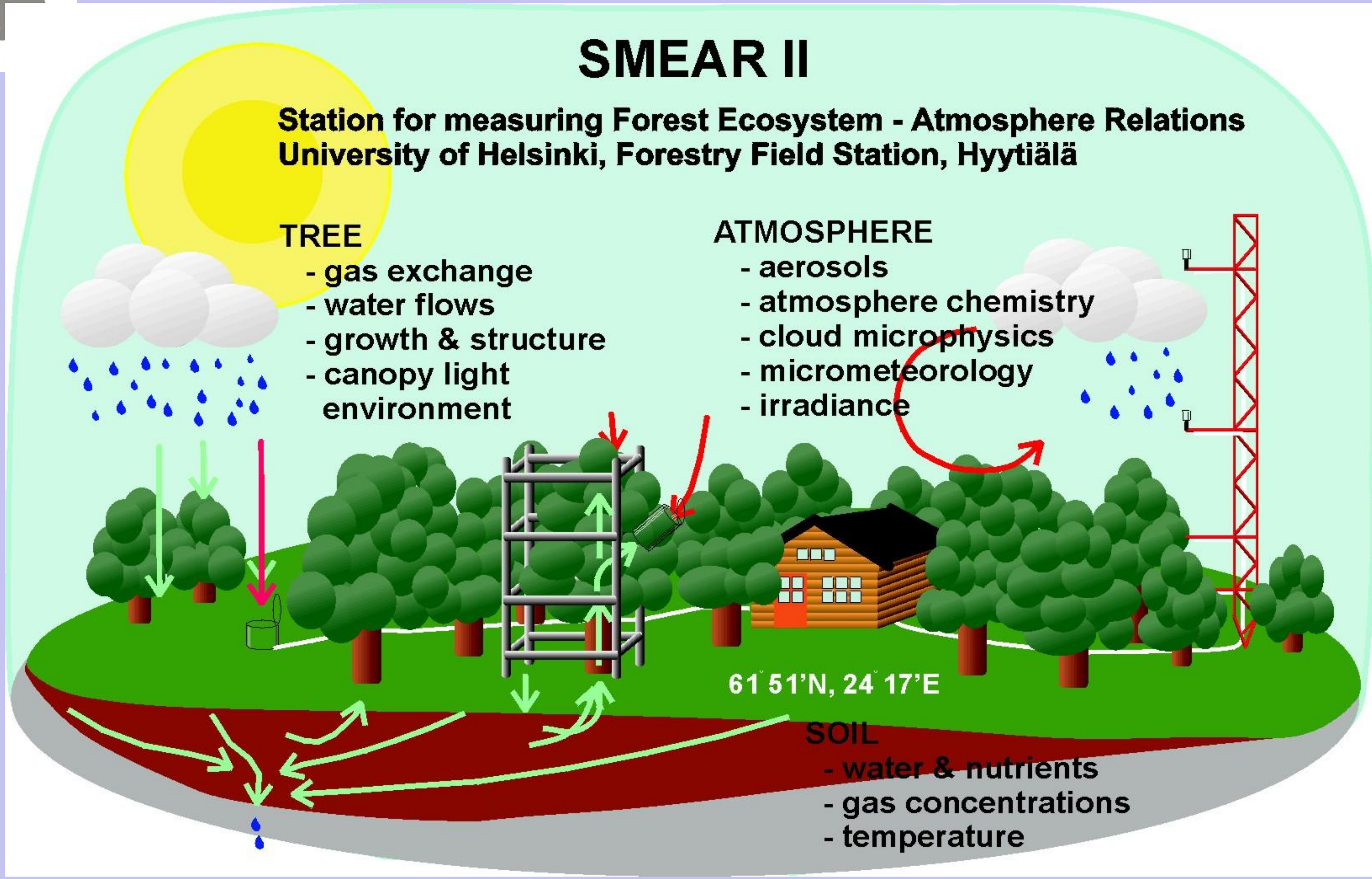
Lompolojänkkä (**wetland**)
SMEAR I Värriö (**forest**)
SMEAR III Helsinki (**urban)**
Lettosuo (**wetland**)
Kaamanen (**wetland)**
Kenttärova (**forest)**
Kuivajärvi (**lake)**

LaThuile Fluxnet Workshop, Feb. 2007

- New Gap-Filled, Qa/Qc Dataset
- 250 Sites; 930 Site-years of Data
- www.fluxdata.org

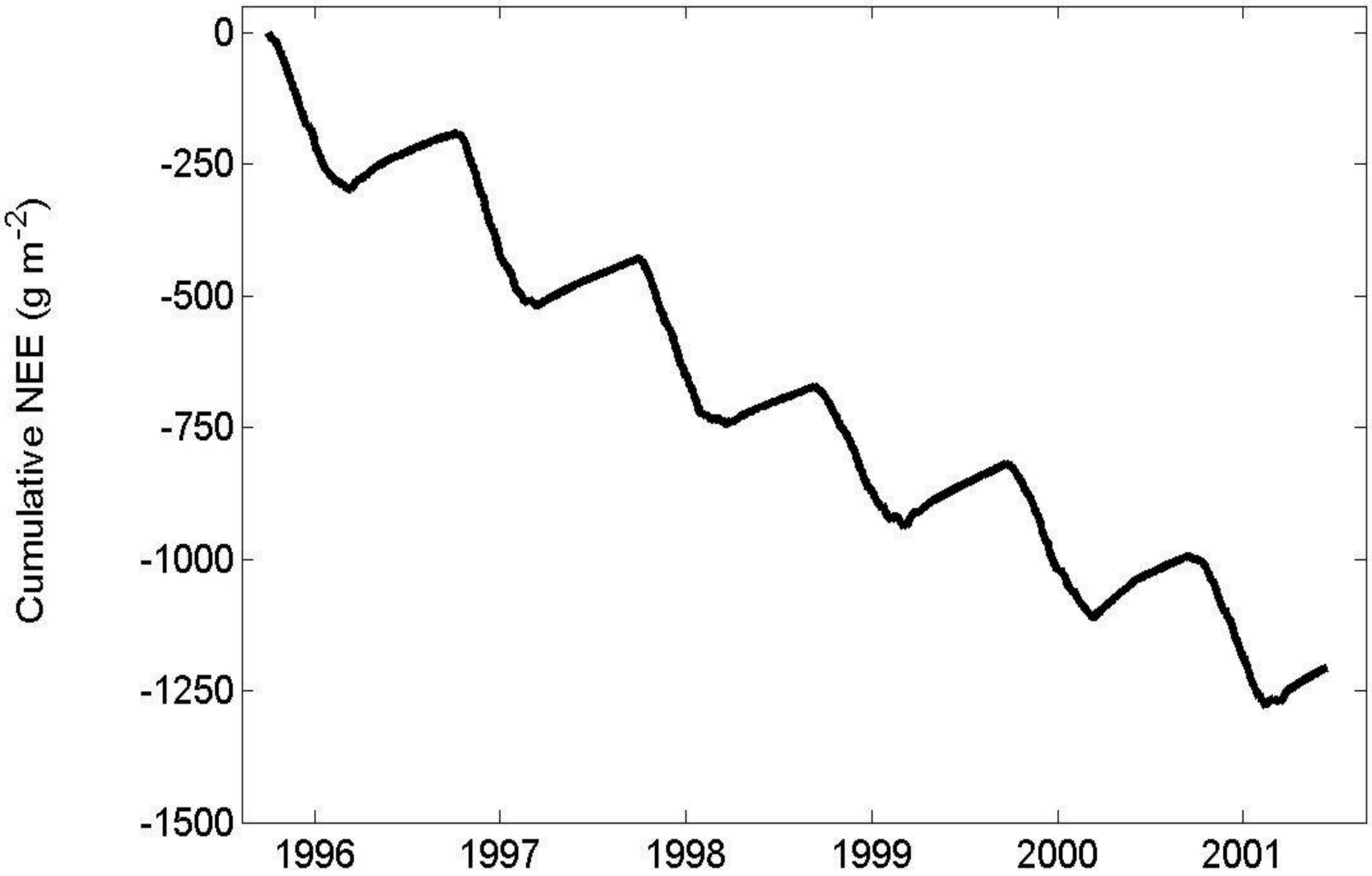
CORE VARIABLES CONTINUOUS	CORE VARIABLES DAILY TO MONTHLY	CORE VARIABLES YEARLY
CO_2, H_2O and energy fluxes	Leaf Area Index (LAI)	above ground biomass by laser technology
soil heat flux	soil respiration (automatic chambers technique);	soil carbon
high precision CO_2 concentration vertical profile	CH_4, N_2O by automatic chambers	stem diameter
net radiation	plant respiration (chamber technique)	above-ground Net Primary Production (NPP)
incoming/reflected/diffuse global radiation	phenology	litter fall
incoming/outgoing longwave radiation		C and N import and export on managed sites
Albedo		bulk N deposition
incoming/reflected Photosynthetic Active Radiation (PAR)		leaf N content
Spectral reflectance in selected wavelength		soil water N content
relative humidity		land-use history
temperature vertical profile		managements and natural disturbances
soil temperature and water content profile		
wind speed and direction		
air pressure		
canopy temperature		
precipitation, through-fall, ground water level, snow depth		
sap flow		

Table 3: List of mandatory variables for ICOS-Ecosystem Station-L1



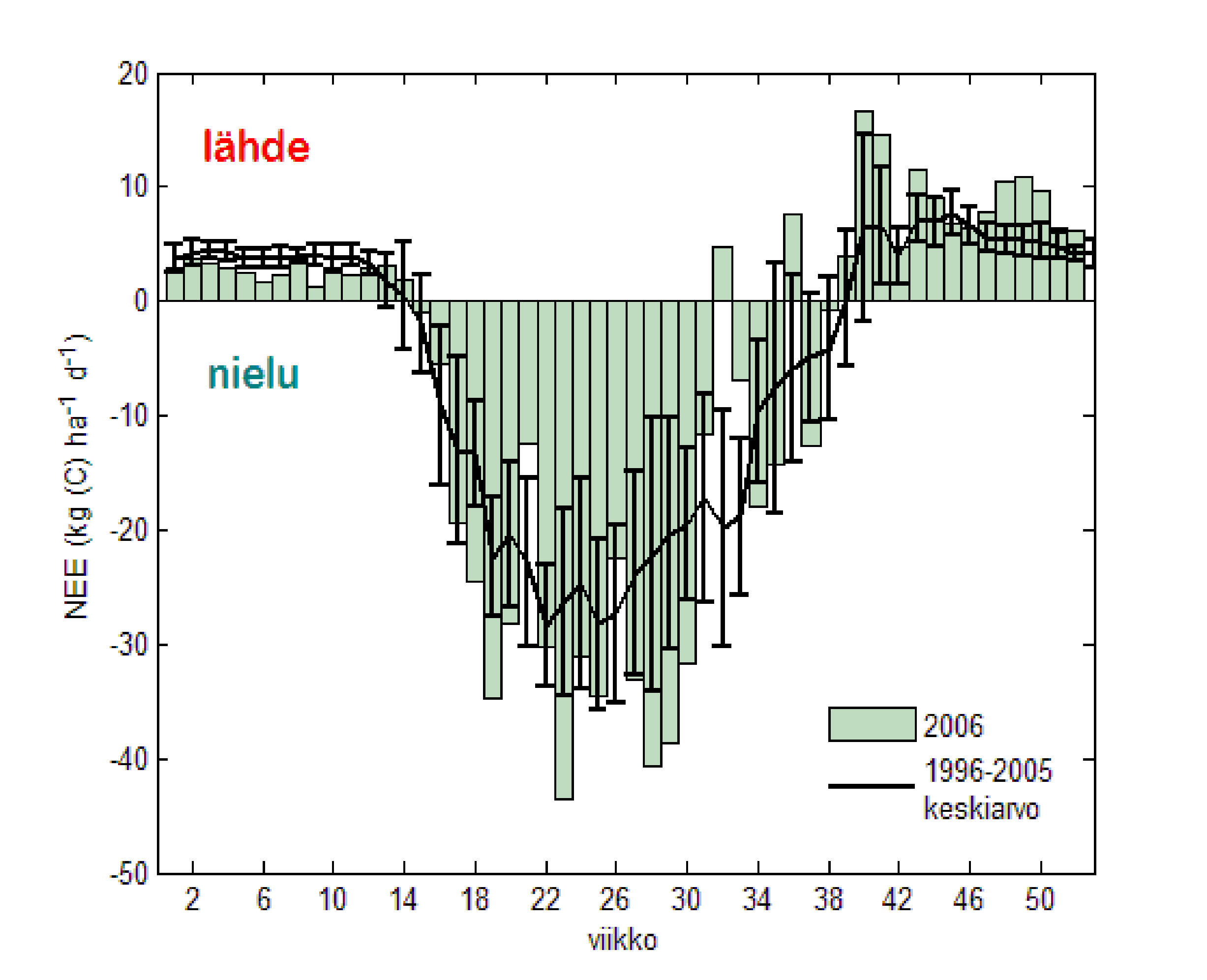
SMEAR II = Hyytiälä

Gap-filled carbon balance (Hyytiälä Scots pine)



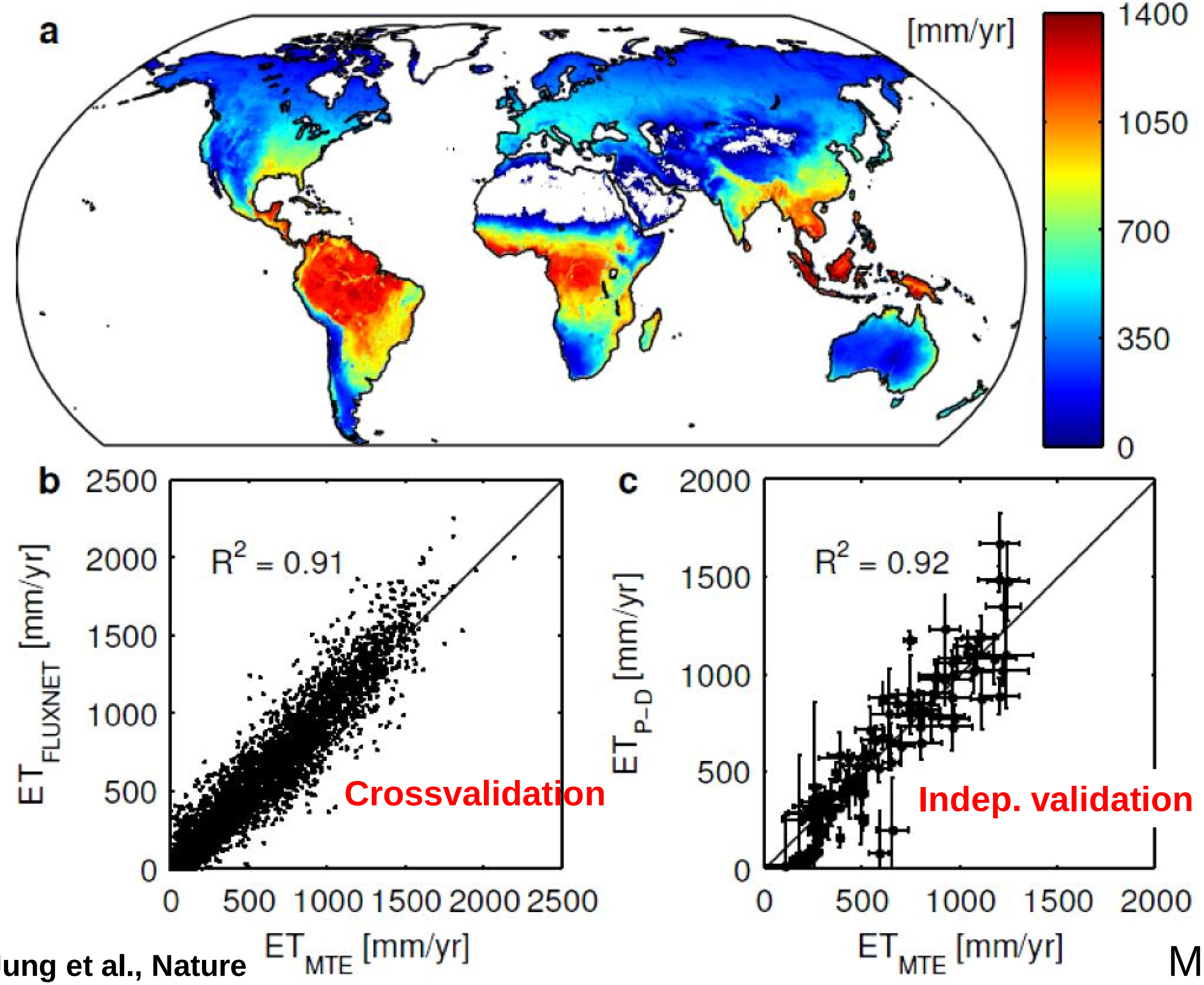
g per m^2 = 10 kg per ha

Weekly average NEE, pine forest, Hyytiälä



S. Launiainen

Global evapotranspiration (ET): ca. 65 Eg yr^{-1}



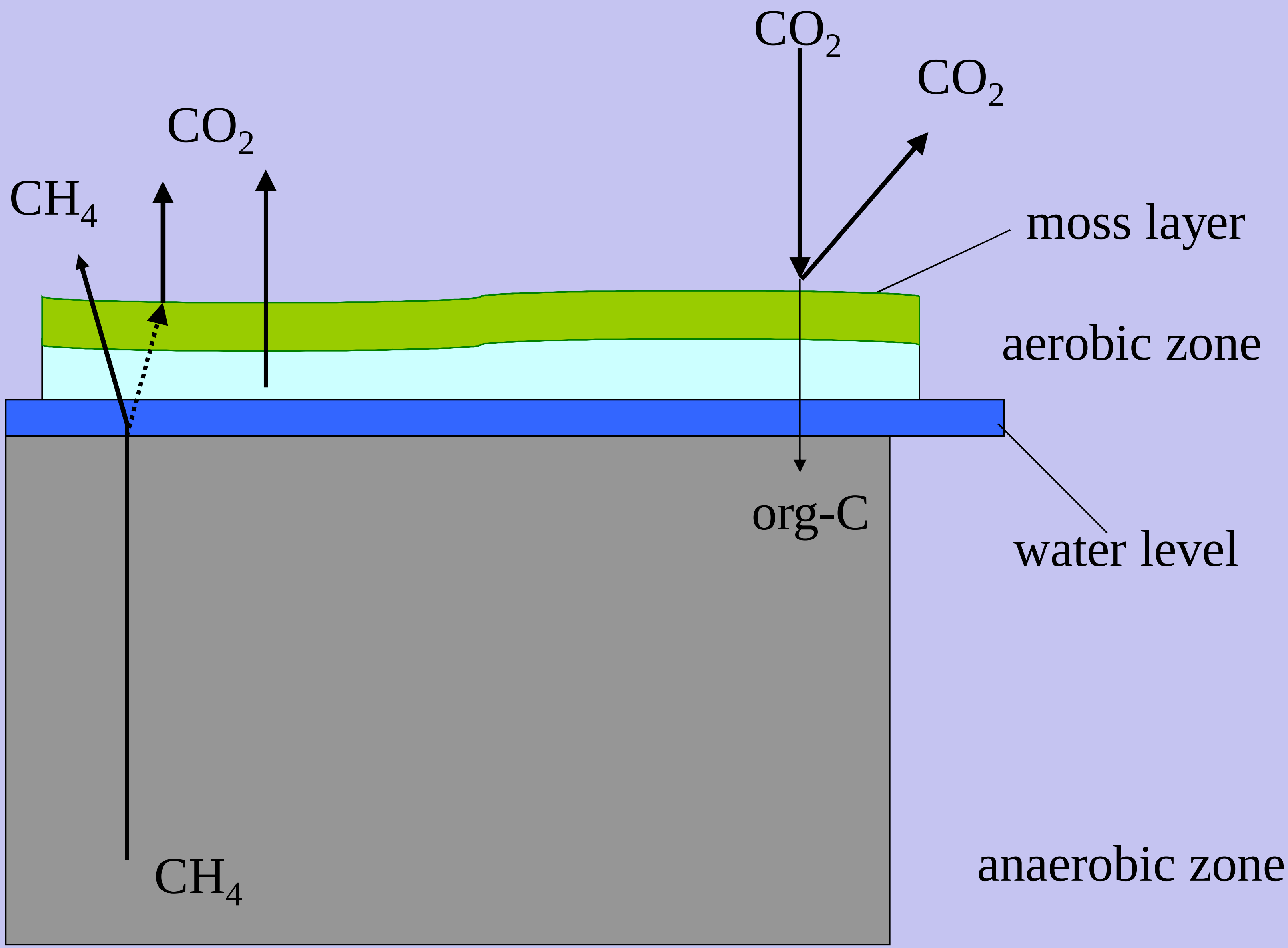
Jung et al., Nature

M. Reichstein

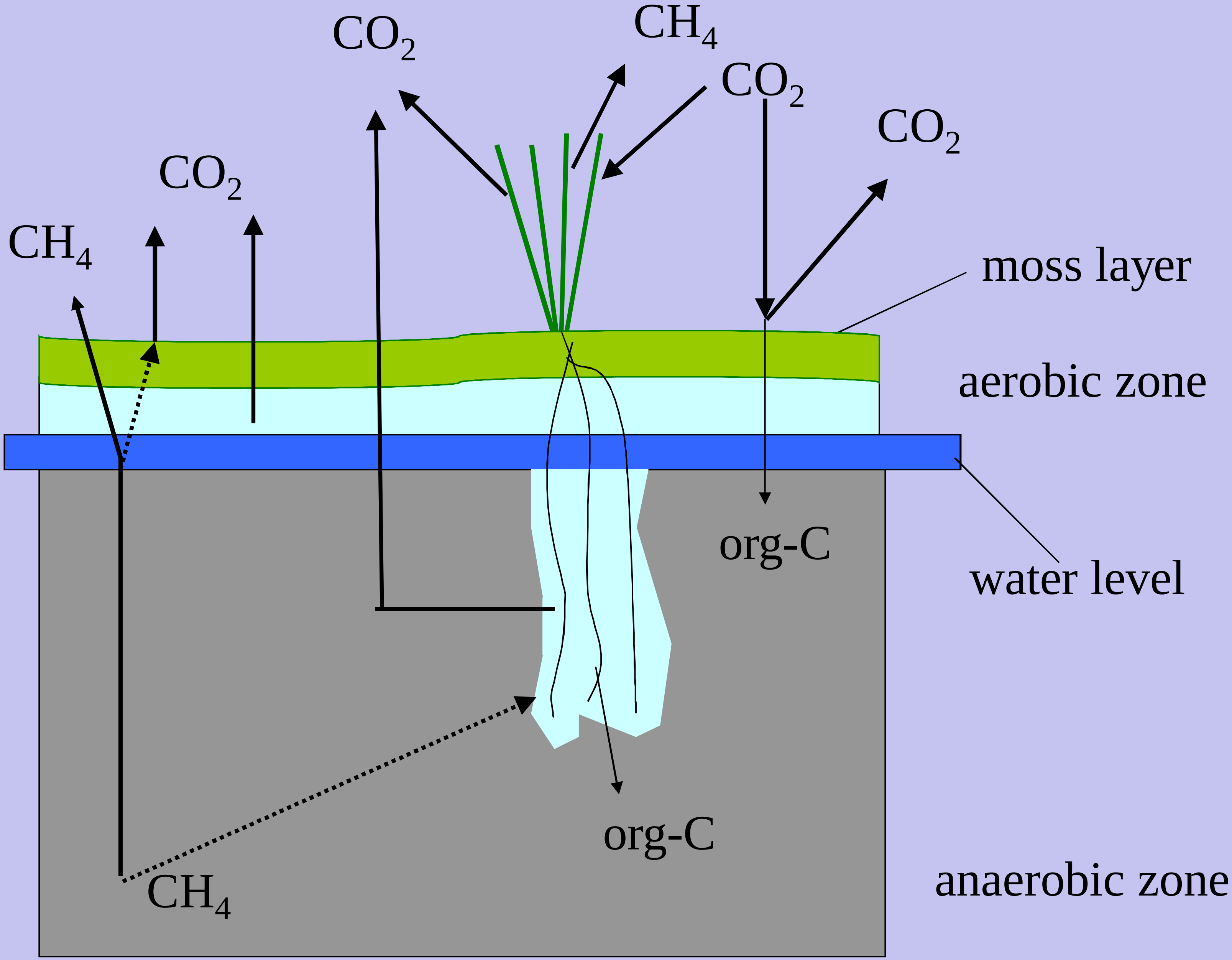
METHANE and WETLANDS

Methane (CH_4)

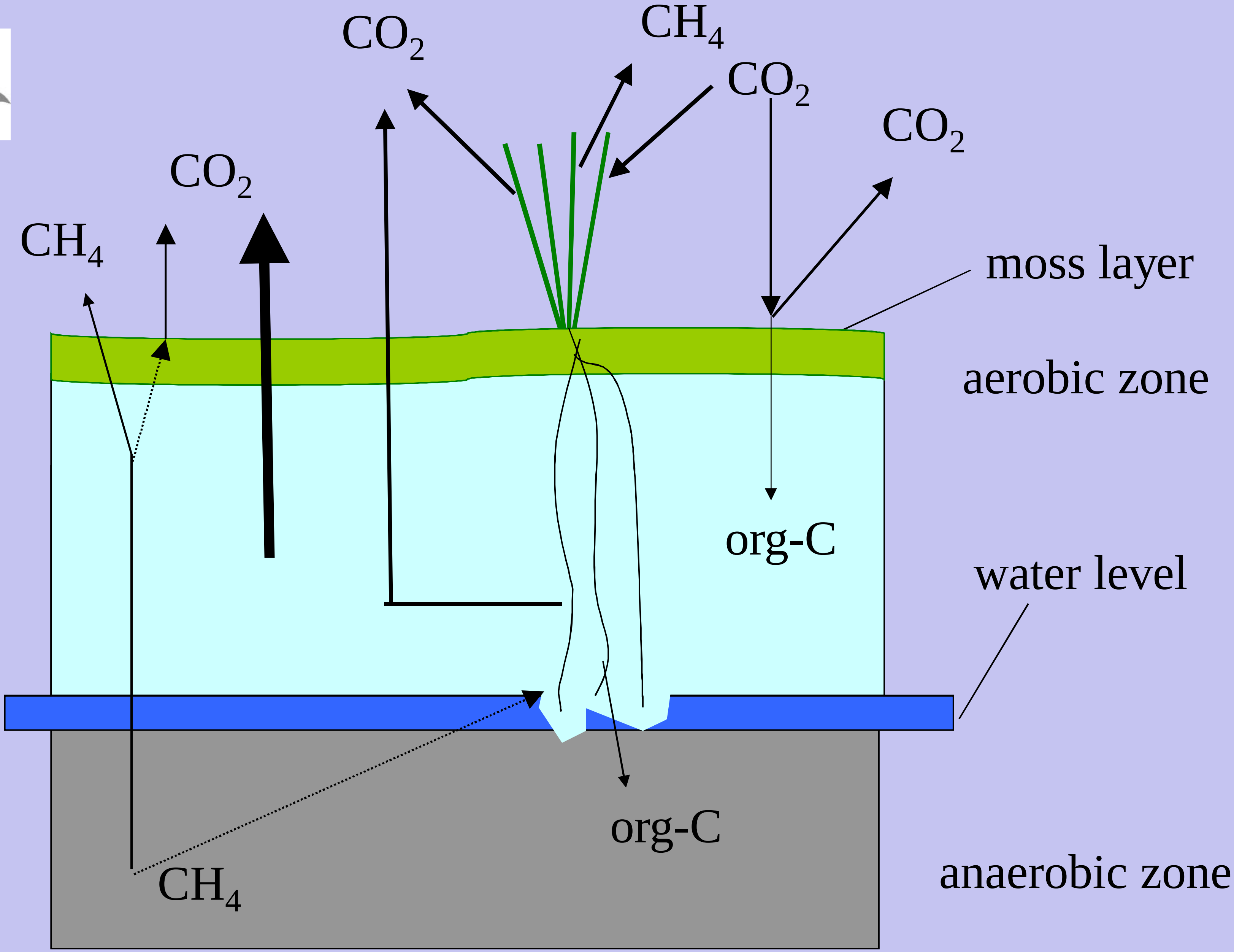
Siikaneva fen,
Hyytiälä satellite site,
Southern Finland



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



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

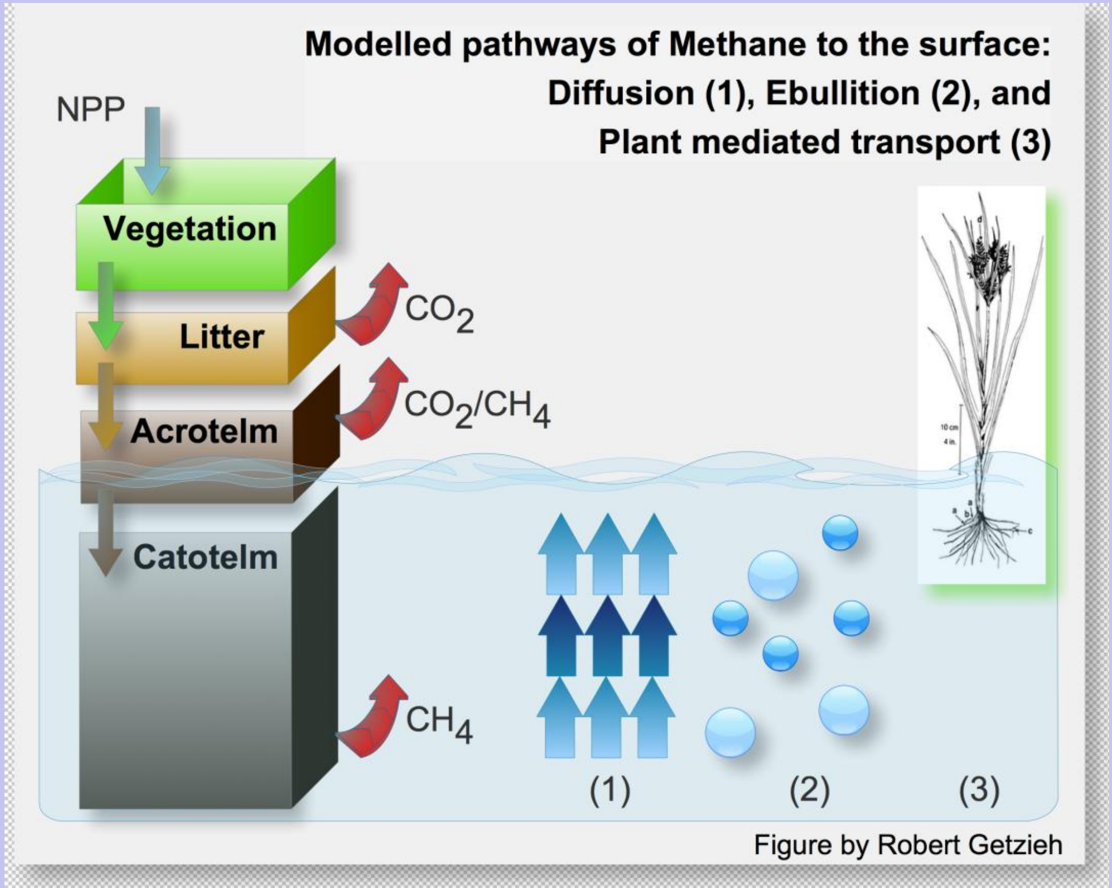


CO_2
CH_4
CO_2
CO_2
CO_2
CH_4
moss layer
aerobic zone
org-C
water level
org-C
CH_4
anaerobic zone

• Methane production and oxidation

• (Diffusive) transport in peat and plants

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



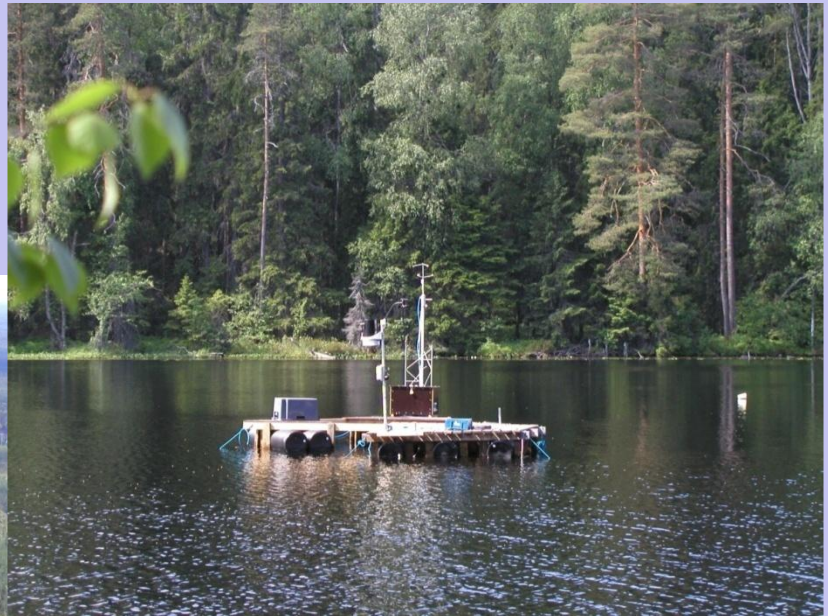
Carbon balance of Siikaneva fen, about 1/5 of that for Hyytiälä forest

	gC m^{-2} a^{-1}
CO_2 2005	- 51
CH_4 2005-2006	10
Total C	41

J. Rinne

LAKES

Lake Valkea-Kotinen, Southern Finland



A. Ojala

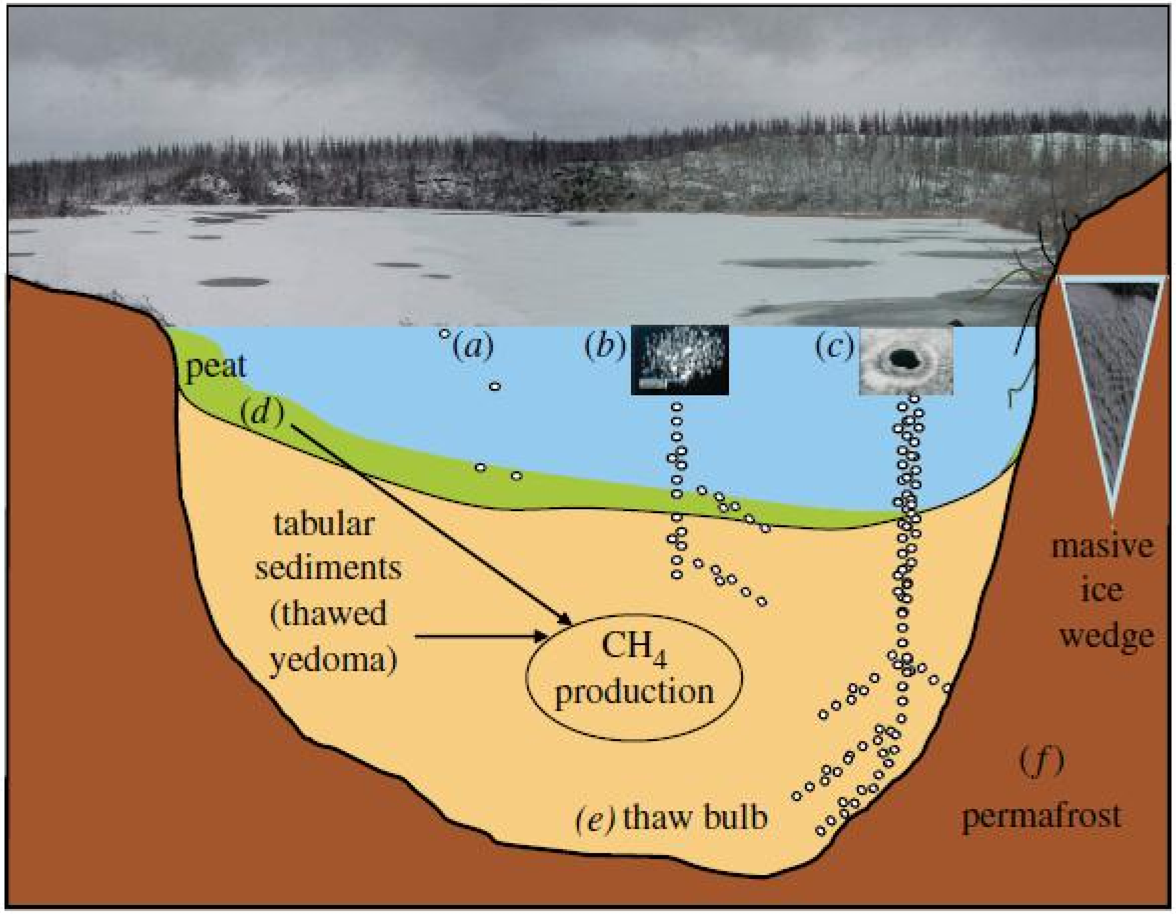
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

Phil. Trans. R. Soc. A (2007) 365, 1657–1676
doi:10.1098/rsta.2007.2036
Published online 18 May 2007

Methane bubbling from northern lakes: present and future contributions to the global methane budget

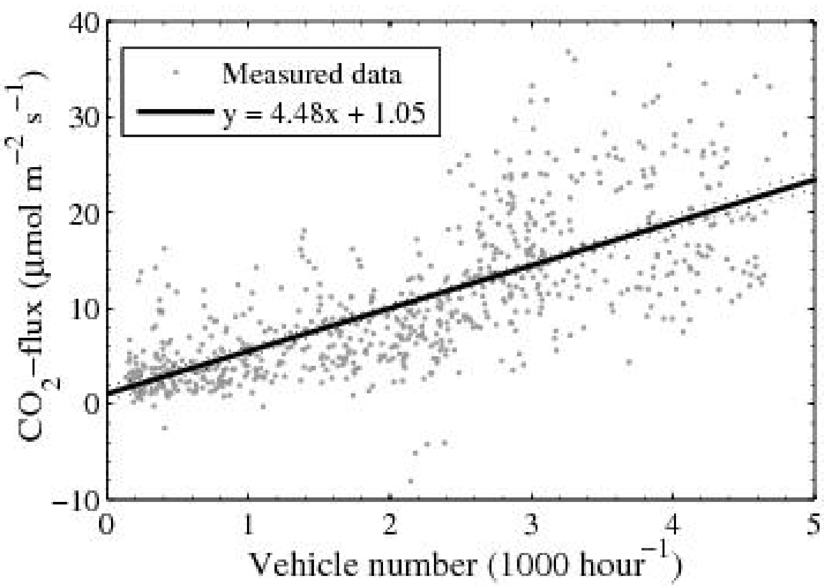
By Katey M. Walter[1,*], Laurence C. Smith[2] and F. Stuart Chapin III[1]

Methane bubbling from northern lakes

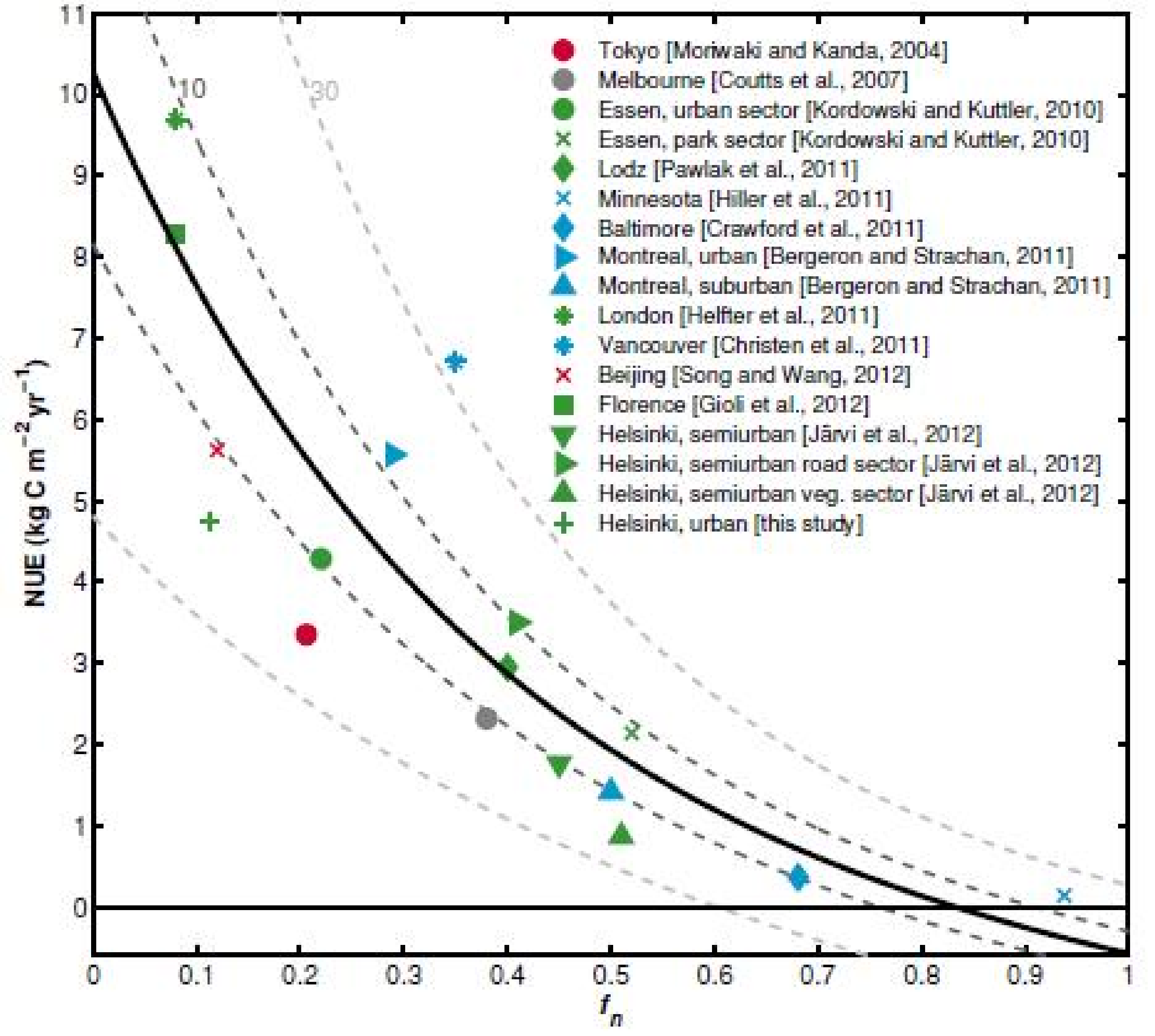


URBAN SURFACE

CO2 flux and traffic density in Kumpula Campus



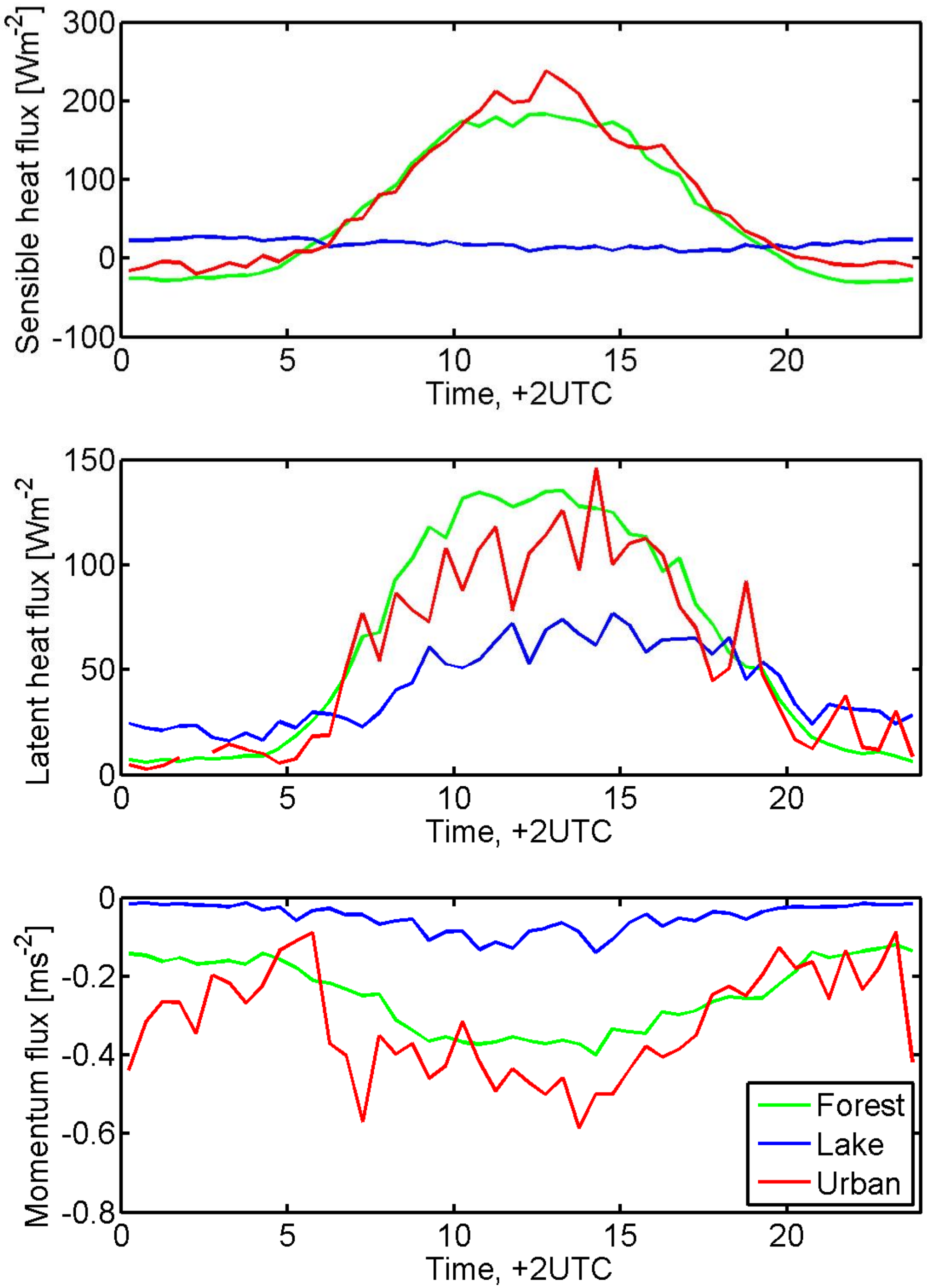
Meta-analysis of Net Urban Exchange vs. vegetation land-use fraction



Nordbo et al., GRL

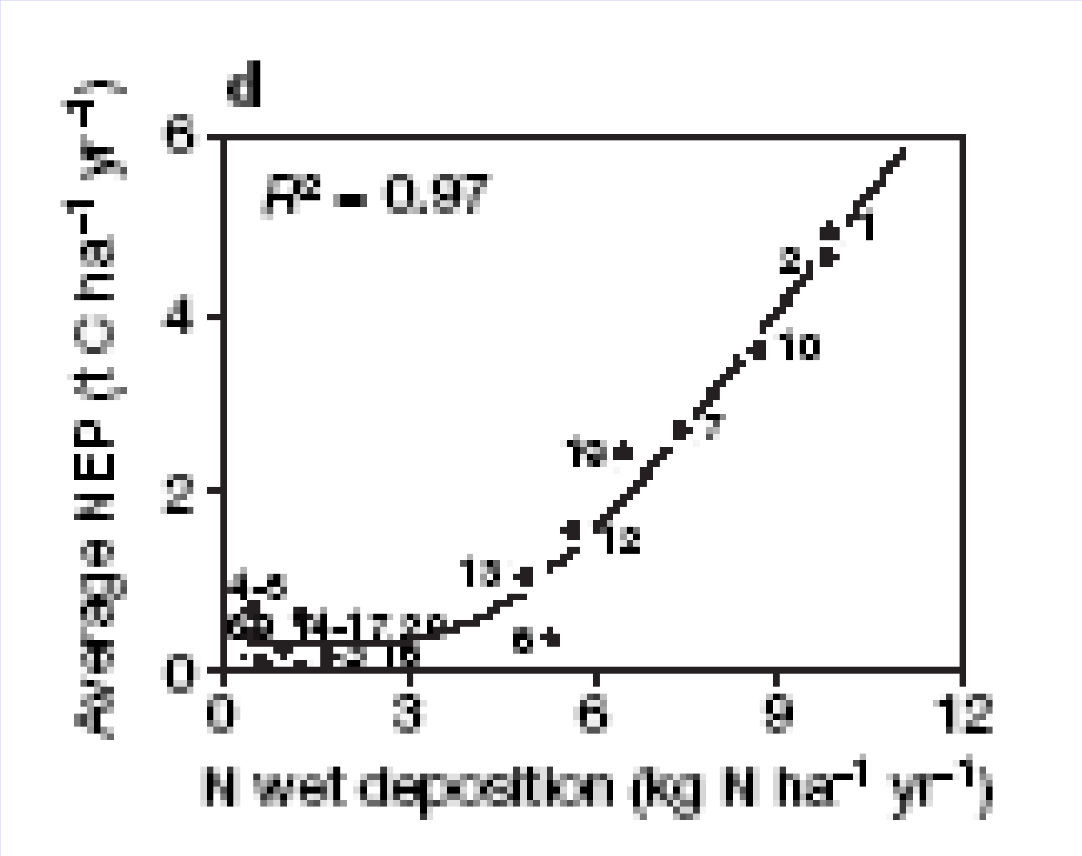
Comparison of 3 different surfaces

Average diurnal courses in June 2009



N

Published in Nature….although everybody knows….



Mangani et al.

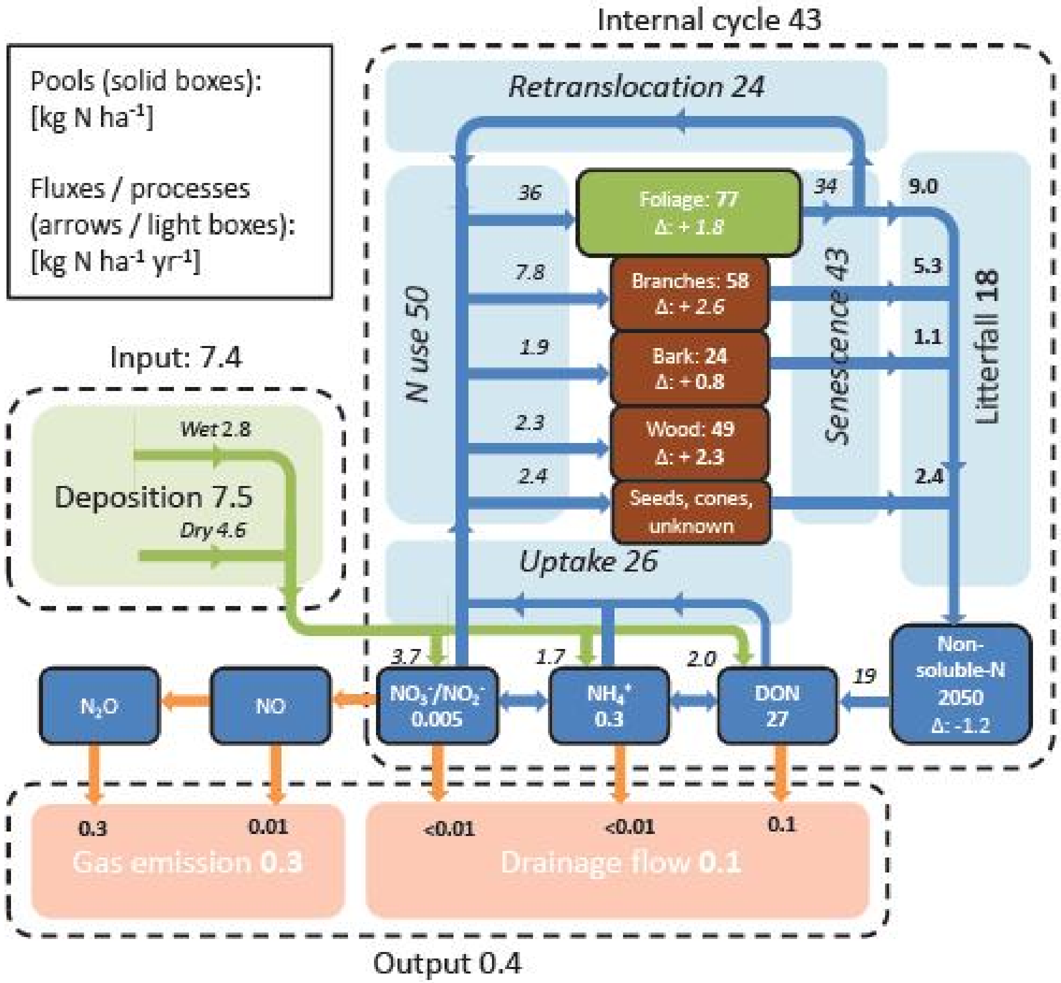
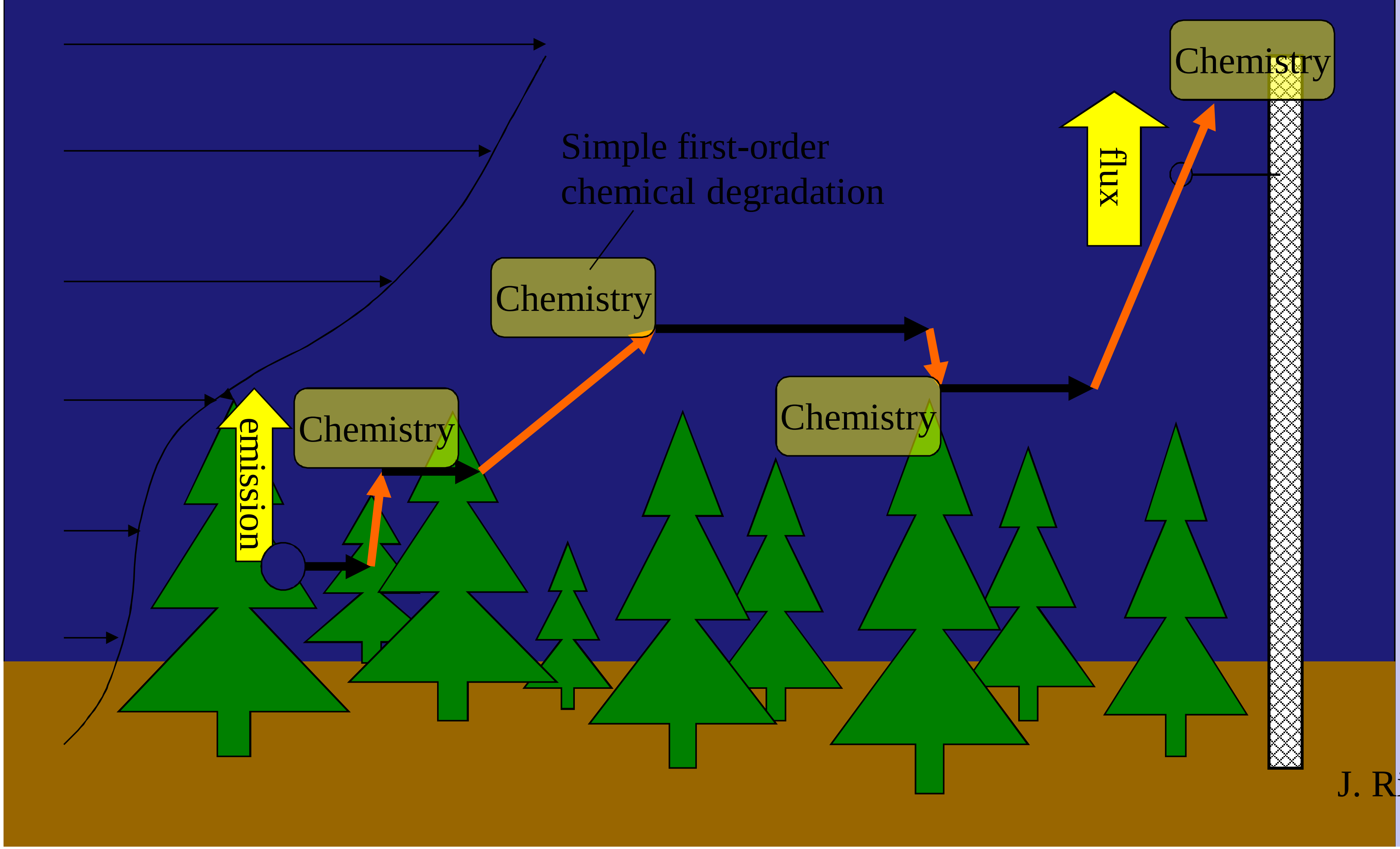


Fig. 4. Flow chart of nitrogen cycling in Hyytiälä Scots pine forest. The solid boxes are pools and arrows are fluxes. The light boxes overlapping the arrows are processes. The numbers at light boxes are total fluxes of the processes. Inputs, outputs and internal cycling of nitrogen are separated by dashed line and arrows (processes) are colored accordingly. The values originating from direct measurements are in bold. Values which are considered indirect measurements or which are otherwise more uncertain, are in italics.

Korhonen et al., Biogeosci. Disc.

From canopy emission to above canopy fluxes



J. Rinne

- Monitoring of concentrations and fluxes of CO_2, CH_4 and N_2O
- Tentative ending year 2031
- Head Office to be located in Helsinki, Kumpula

What is ICOS ?

- A world-class infrastructure to quantify and understand **greenhouse gas concentrations and fluxes**
- **Long-term** measurements at **network** of sites
  - ~ 40 backbone ecosystem flux sites
  - ~ 40 atmospheric concentration sites
  - ~ 10 ocean ship-lines
  - The performance of the ensemble will be greater than the sum of each national network
- Scale: **Europe** and key regions of interest for Europe
- Large implications for **climate policy**

Marjut Kaukolehto, Sanna Sorvari

Objectives of ICOS

- ✓ To establish an integrated long-term research infrastructure to understand the biogeochemical cycles of greenhouse gases
- ✓ To determine regional GHG fluxes from observations and attribute these to processes
- ✓ To enable early detection of surprises
- ✓ To provide regional carbon budgets for policy support
- ✓ To provide access and services for data and data products

The Network - high quality long-term observations

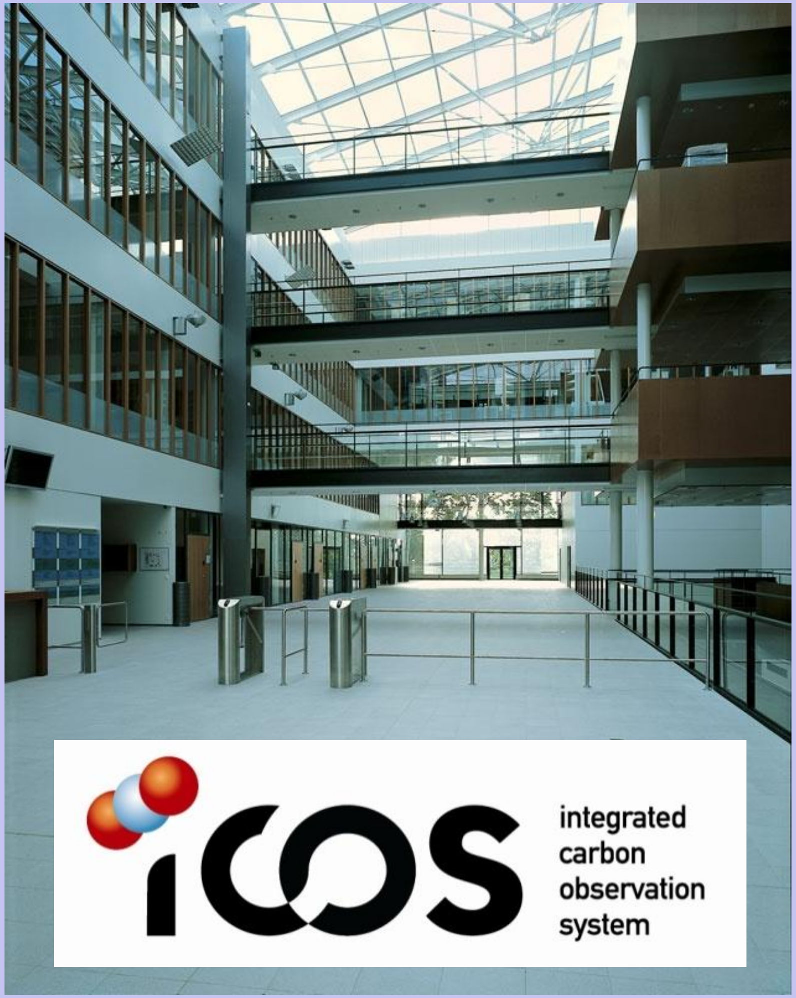
- ✓ Same sensors deployed at all stations
- ✓ Centralized and near real time data processing
- ✓ Standards compatible with international systems (WMO etc.)
- ✓ Backbone data for operational flux modelling

Towards ICOS

- ✓ **Preparatory phase project** (EC funded, 2008- 2013; start constructions)

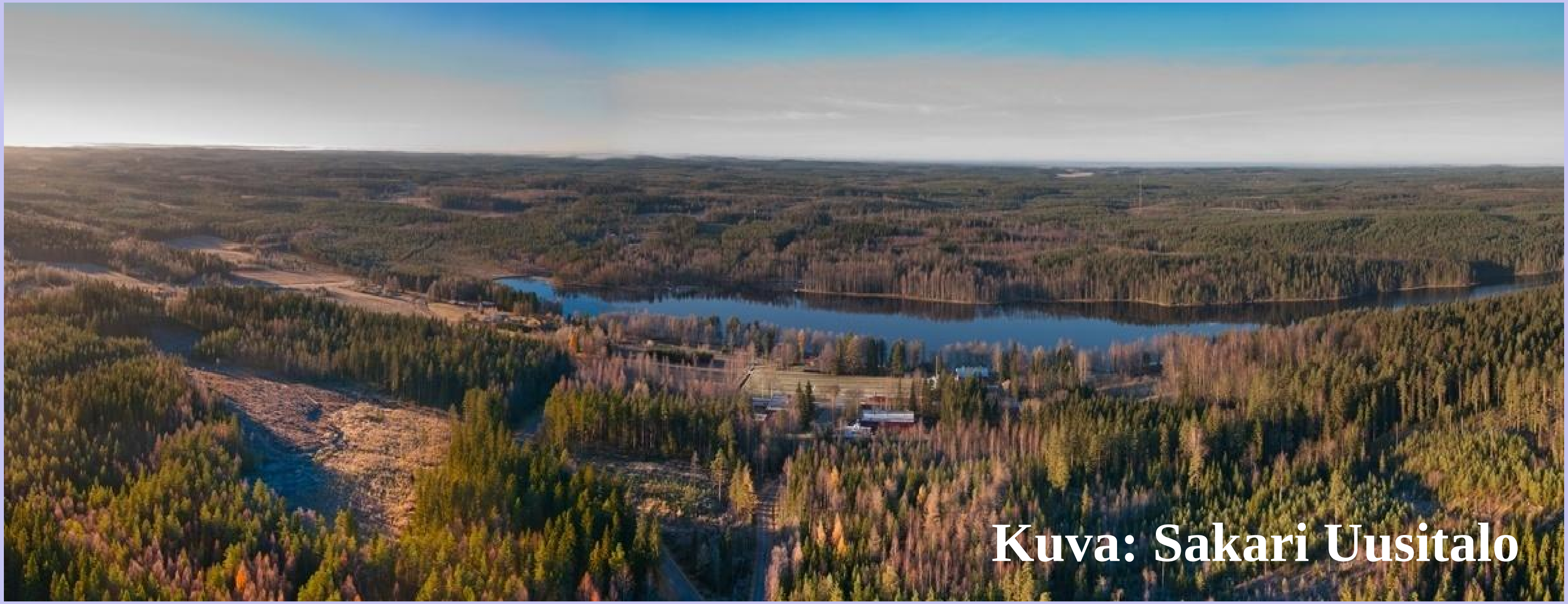
- ✓ **Set-up phase** (constructions, negotiations)

- ✓ **ICOS established** (operational 2014)



You, the researhers/students, are the end-users of the data; you can also actively affect how well the data is used

Remember that the whole ICOS-Europe is available



“**FLUXNET is probably the largest geophysical experiment in Earth and the application and potential information contained in the collected data goes beyond the individual sites**.” D. Papale

“**Astrophysicists have Hubble, nuclear physicists have CERN, biogeochemists have FLUXNET**”.
a reviewer of Nature paper (Valentini et al., 2000)

http://daac.ornl.gov/FLUXNET/fluxnet.html