SMEAR – ecosystem measurements (part2)

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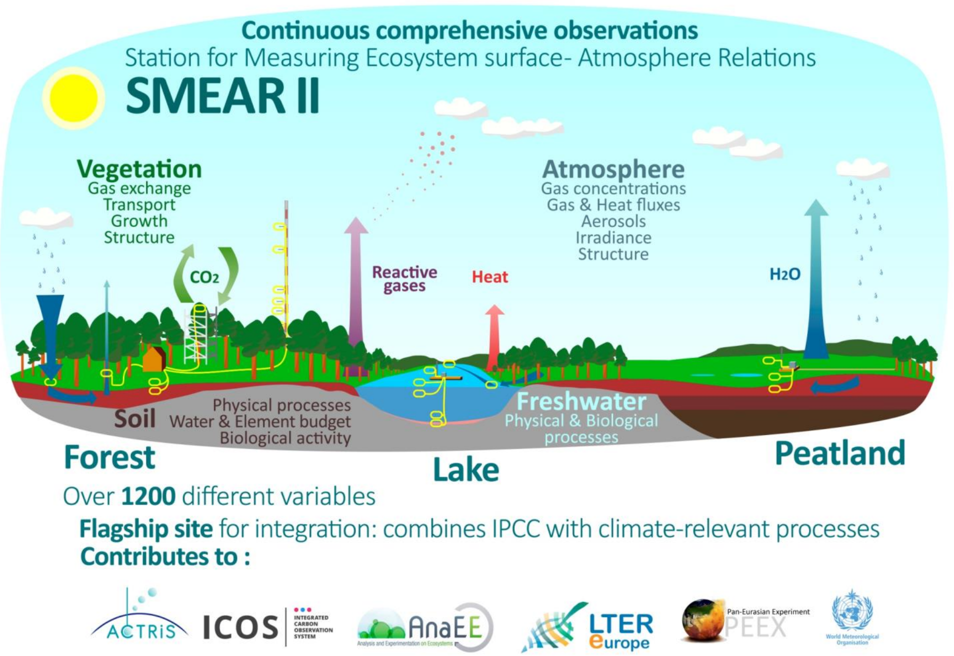
Important ecological research questions at SMEAR II



- **How ecosystems are affected by climate**
  - Natural variation (abiotic and biotic interactions)
  - Changing climate
- **How ecosystems influence climate**
  - Cycling carbon, nitrogen and water
  - Exchanging reactive compounds and aerosols
  - Energy balance

Fundamental concepts directing the ecosystem measurements at SMEAR stations

1. **Mass, energy and momentum** are being conserved
2. **Metabolic, physical and chemical processes** convert material and energy into other forms at molecular levels
3. These processes generate **concentration, temperature and pressure differences**
4. Concentration, temperature and pressure differences give rise to **material and energy flows and structure of the system**
5. The flows change the material and energy pools in the atmosphere, vegetation, soil and water

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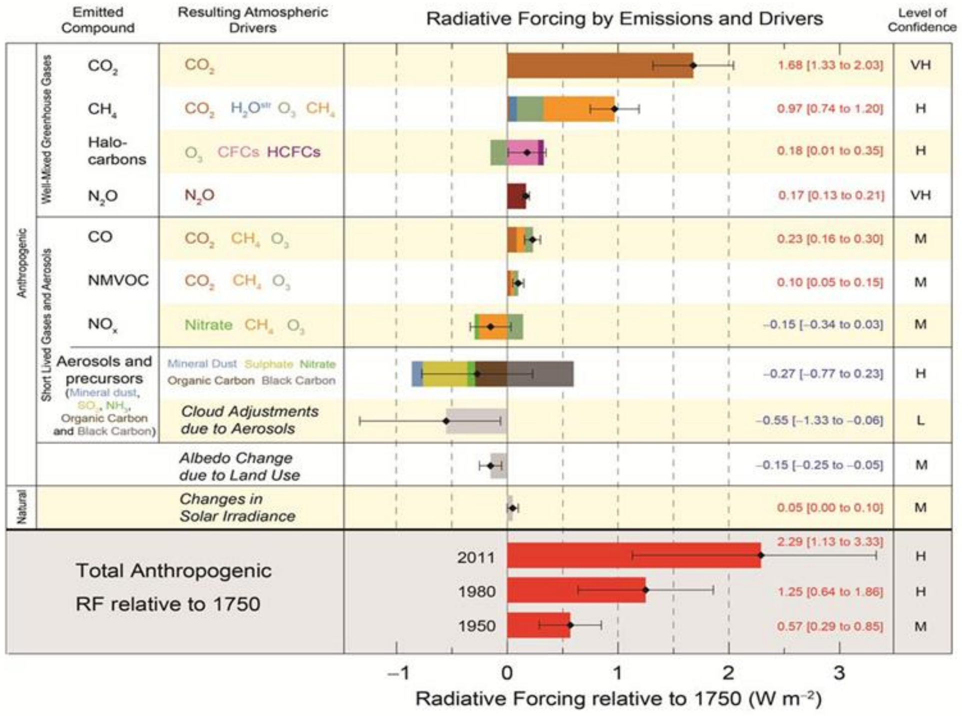
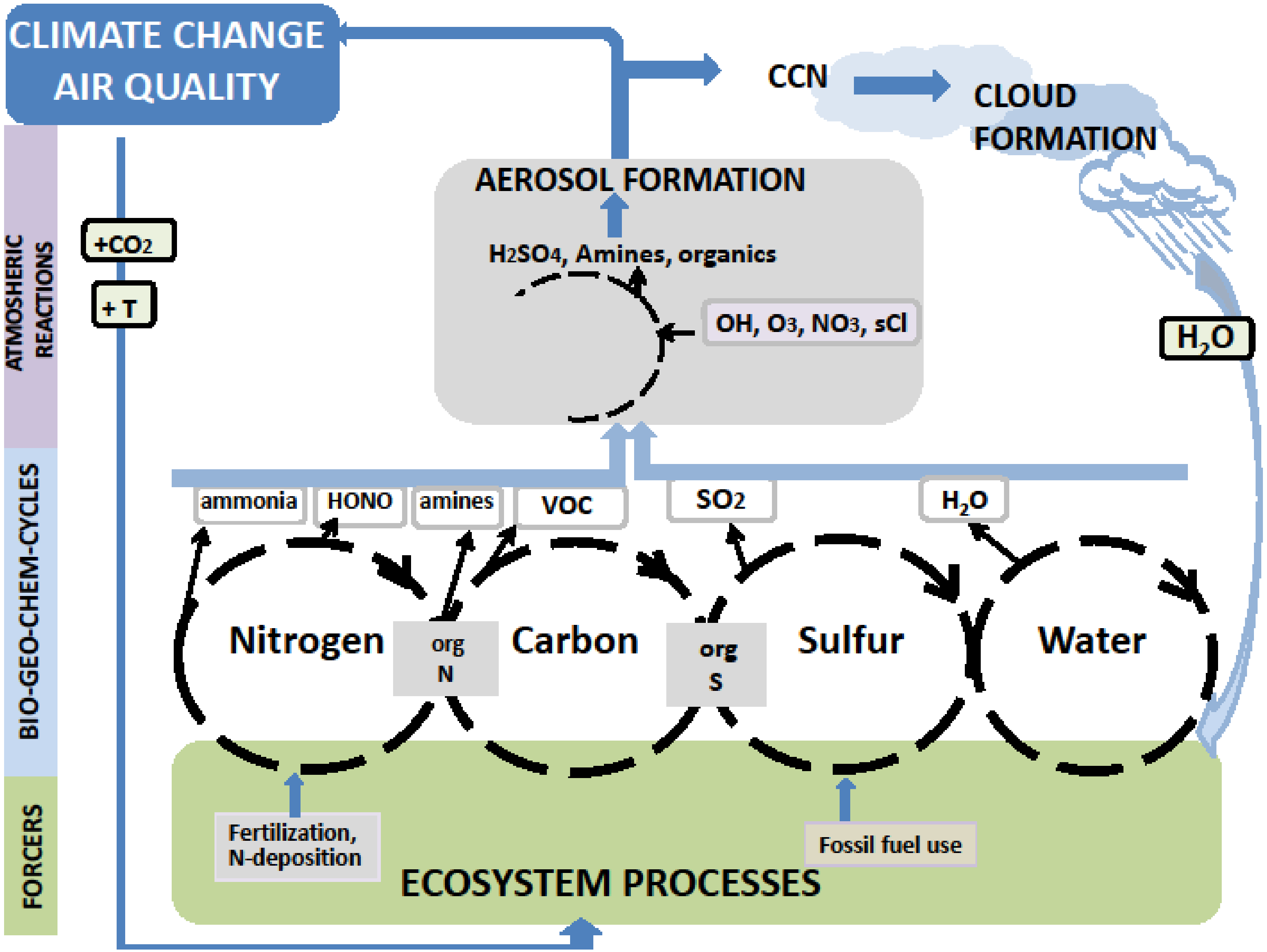
6. **Scaling up:** Material and energy flows combine molecular phenomena to the behavior of larger-scale system
7. **Feedbacks** → responses at global level

CHALLENGE: QUANTIFY THE CLIMATE-RELEVANT PROCESSES AND COMPONENTS

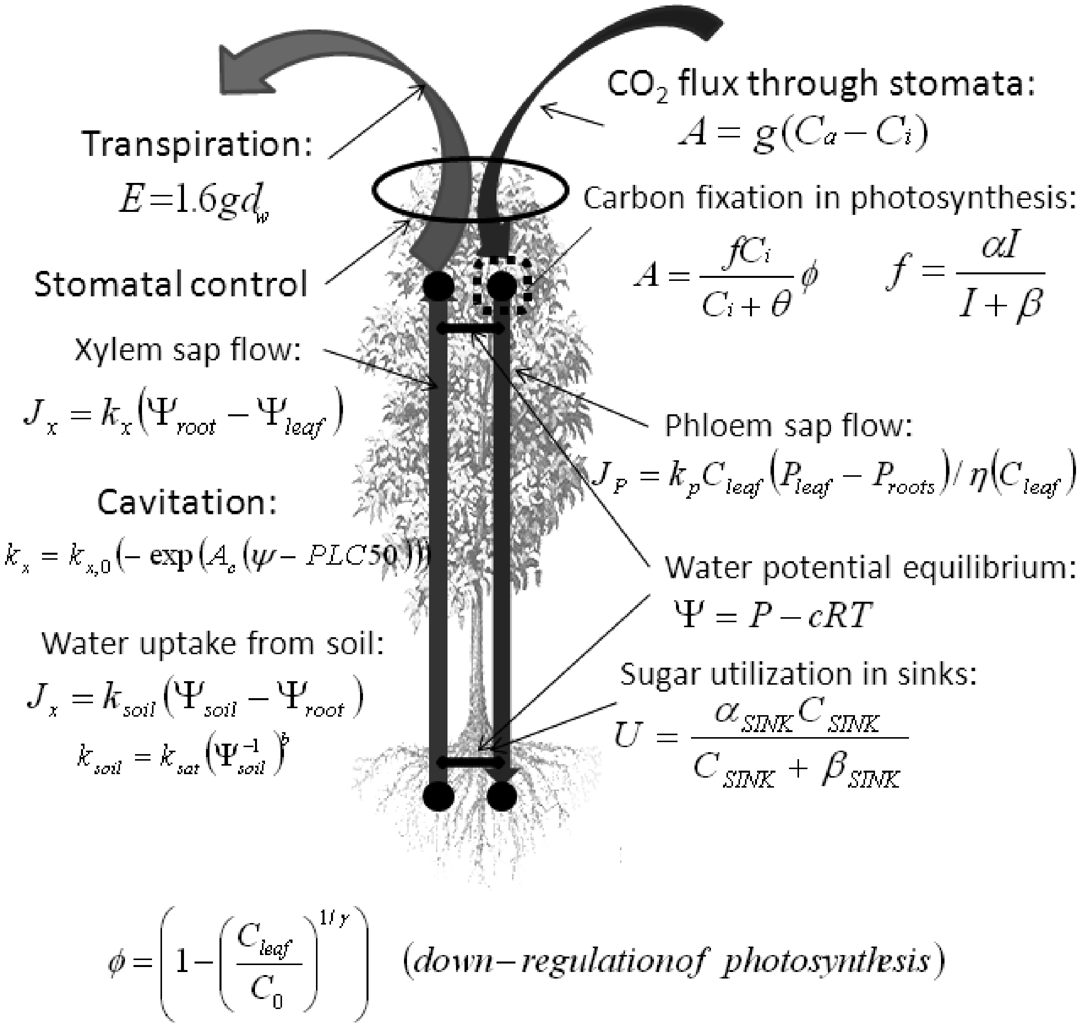


INTERLINKED PROCESSES AND FEEDBACKS

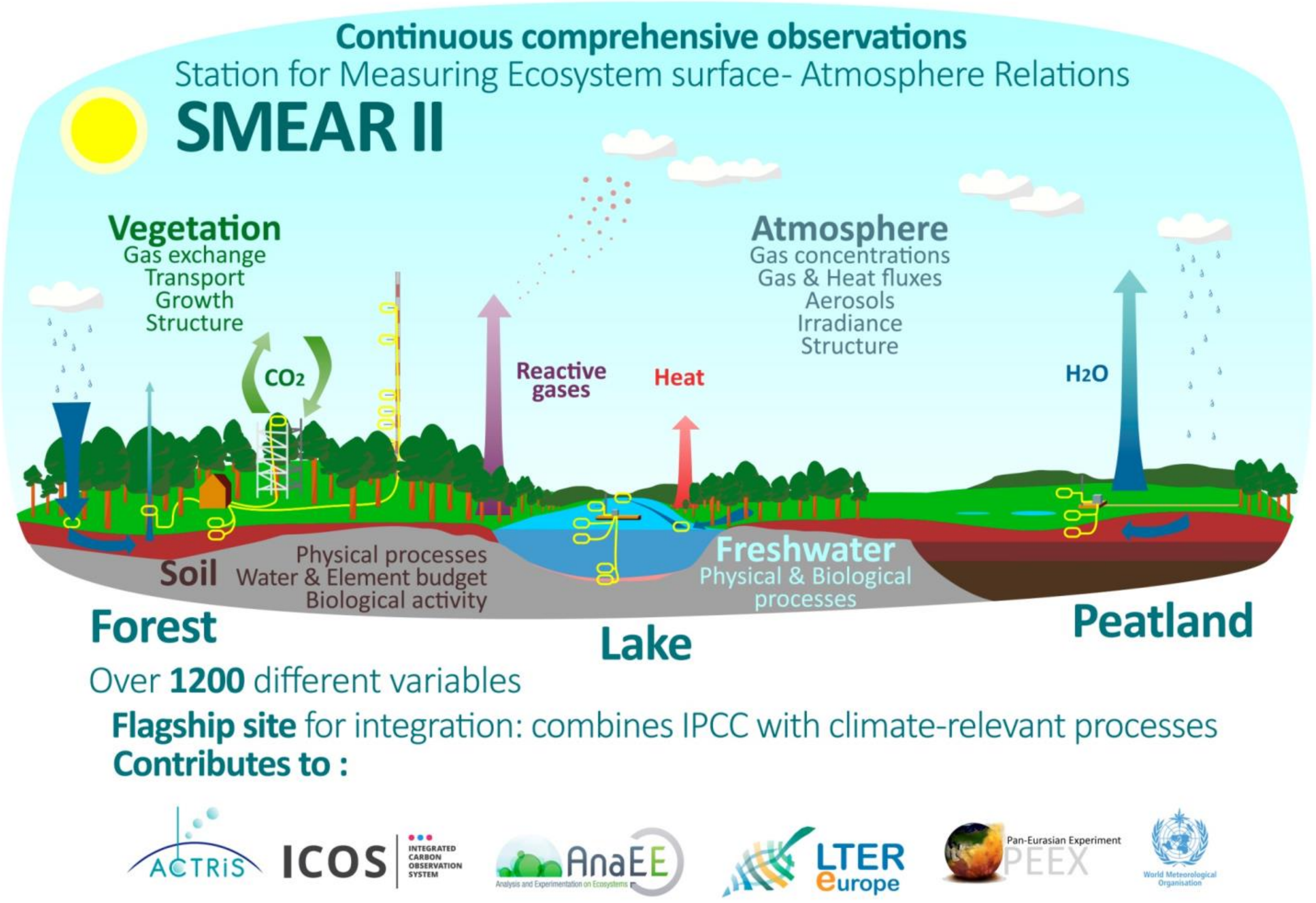


Ecosystem processes approach

- **Continuous, high-resolution measurements of ecosystem properties and functions related to biogeochemical cycles**
- **Quantitative and comprehensive physical, ecological and physiological understanding**
- **Modelling**
    - process description and understanding
    - long term dynamics
    - upscaling
- **Manipulation experiments**
- **Laboratory experiments**



Small scale measurements on different ecosystem compartments

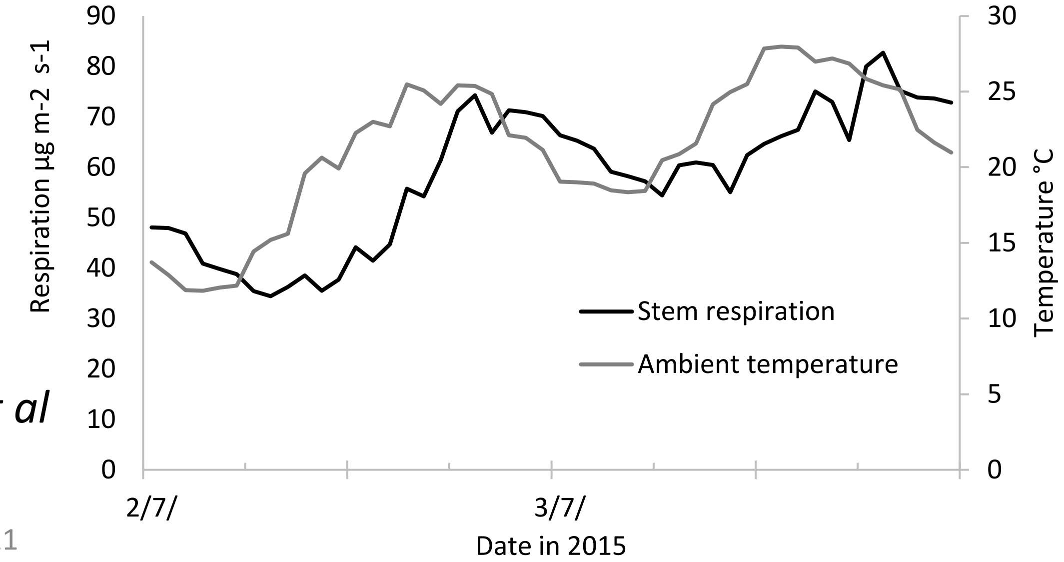


Gas exchange measurements with **stem enclosures**

- Tree stems release CO_2 (respire) and H_2O (transpire) depending on the prevailing environmental factors. They also exchage VOCs with the atmosphere.

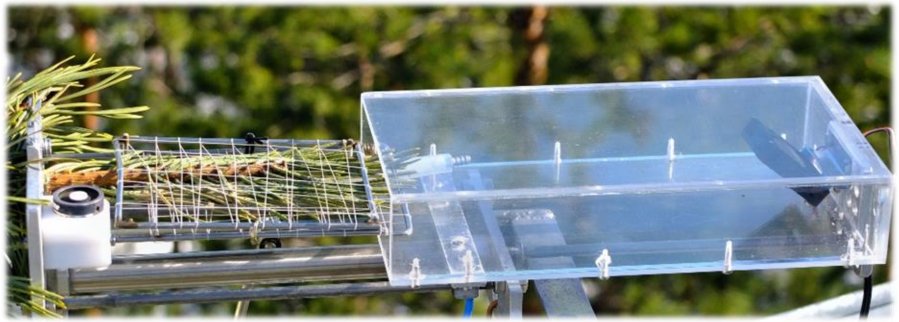
- The CO_2 and H_2O exchange of stems is monitored continuously with enclosures tightened around stems and connected to a gas exchange measurement system including gas analysers.

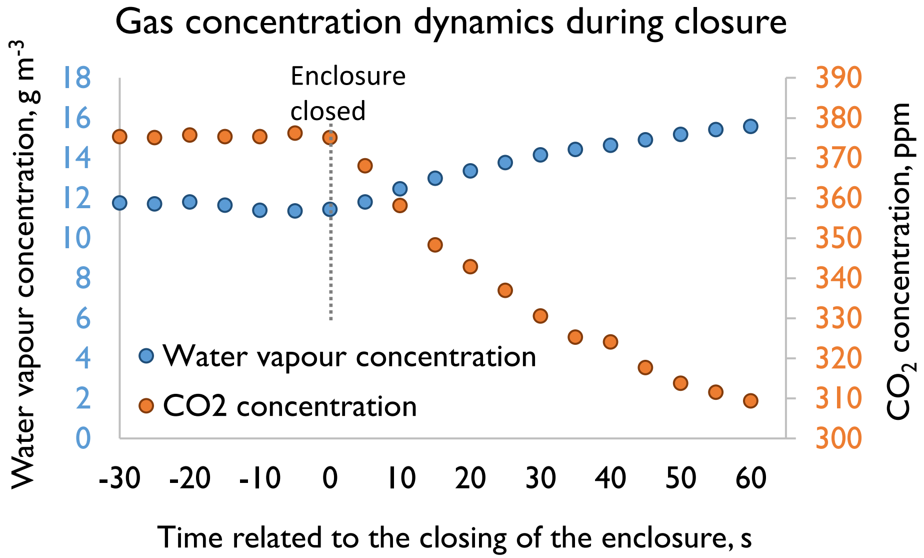
Lintunen et al



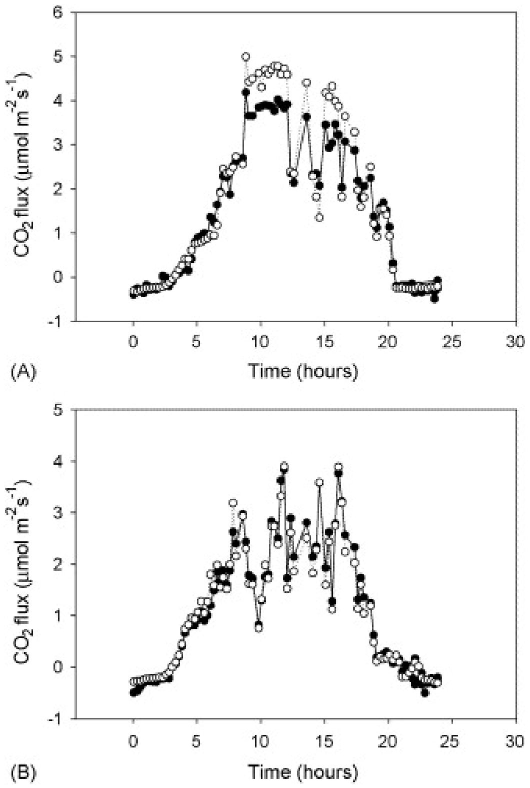
The CO_2 exchange of upper canopy pine stem and ambient air temperature during two days in summer 2015. The higher temperature, the higher stem respiration.

Gas exchange measurements with **shoot enclosures**





- Photosynthetic capacity as well as other metabolic activity is seasonally controlled by environmental factors, such as temperature and light (Kolari et al. 2014).



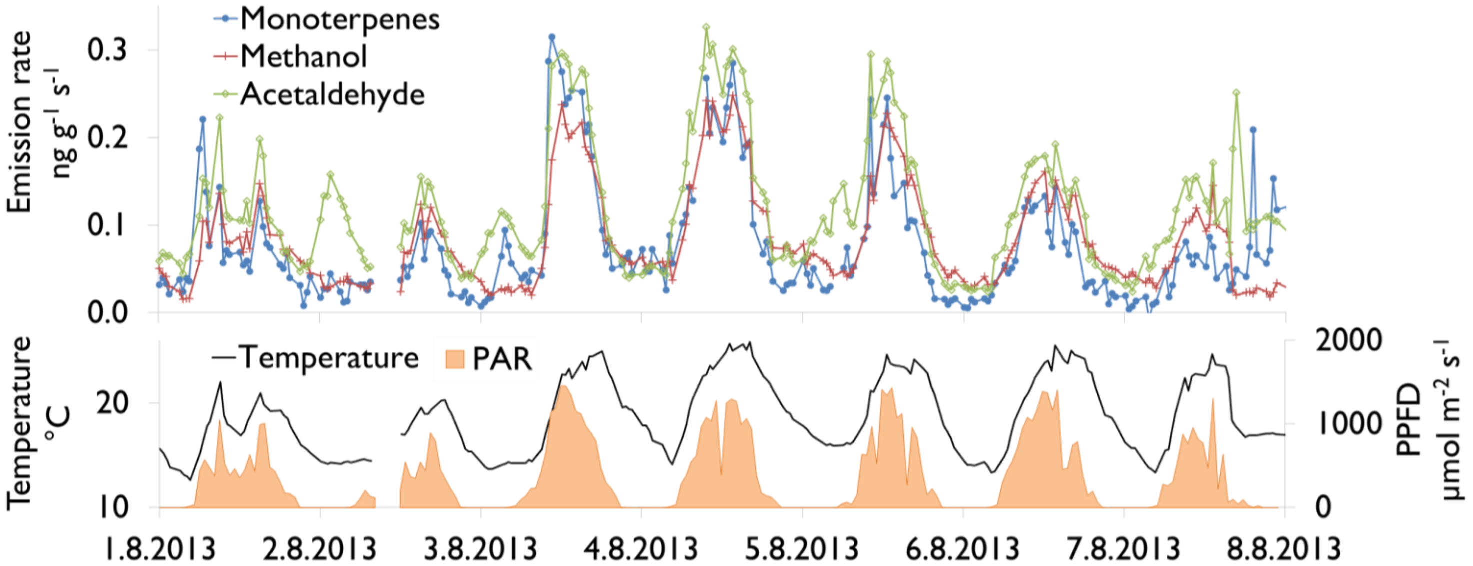
Aalto, Bäck et al

CO2 exchange during two days in summer 2001. Filled circles represent the measured CO2 exchange rate, open circles represent a photosynthesis model based on optimum stomatal control (Mäkelä et al. 2006, Hari & Mäkelä 2003).

Hari & Mäkelä 2003. *Tree Physiol,* 23: 145-155.
Kolari et al. 2014. *Front Plant Sci,* 5.
Mäkelä et al. 2006. *Agr Forest Meteorol,* 139: 382-398.

VOC emission measurements with **shoot enclosures**

- Emissions of several VOCs, such as monoterpenes, methanol and acetaldehyde, show strong seasonal pattern, controlled both prevailing environmental conditions and seasonal effects such as new biomass growth, photosynthesis recovery or senescense (Aalto et al. 2014, 2015).

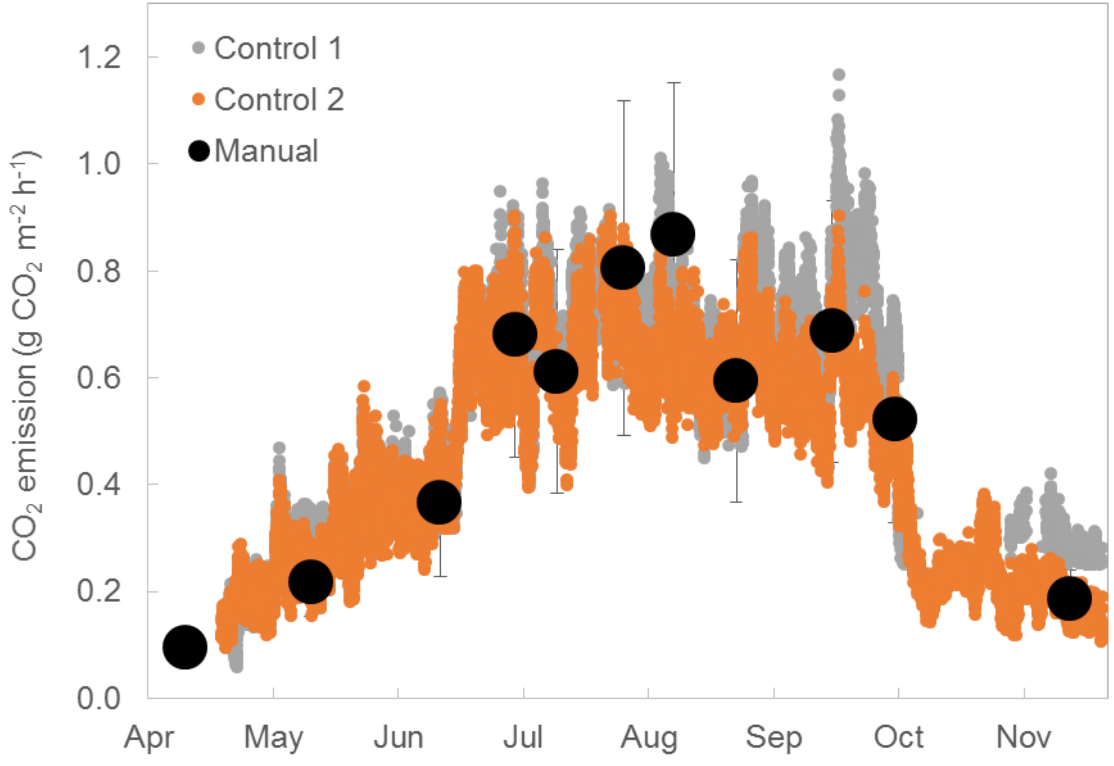


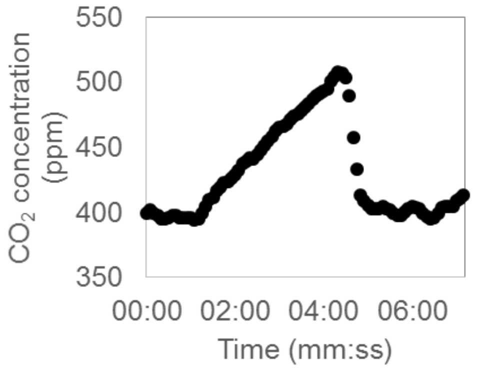
An example of continuous VOC emission rate measured from Scots pine shoot.

Aalto et al. 2014. *Biogeosci*, 11: 1331-1344.
Aalto et al. 2015. *Plant Cell Environ*, 38: 2299-2312.
Aaltonen et al. 2013. *Plant Soil*, 369: 241-256.
Vanhatalo et al. 2015. *Biogeosci*, 12: 5353-5363.

Automated measurements with **soil enclosures**

- Forest floor is a key source of CO_2 in boreal forests, and climate change will likely modify the seasonal variation and strength of the soil respiration, as well as affect other sources of trace gases from soil.
- Understanding processes maintaining the sources plays central role in predicting the future trace gas fluxes from soil.





CO2 concentration change inside the soil chamber during one closure.

Ryhti et al

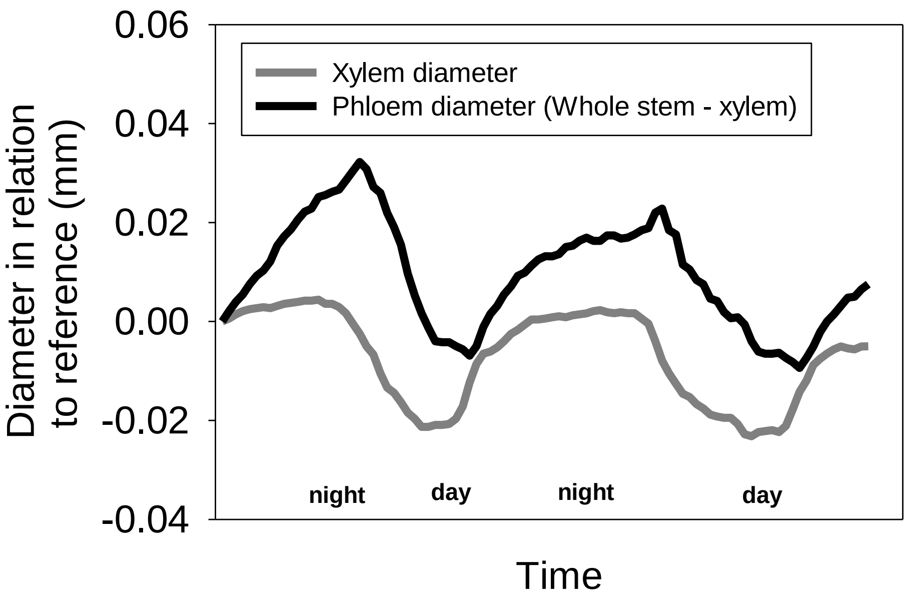
Forest floor CO_2 flux from control plots in 2015 compared with manually conducted measurements (14 plots)

Point dendrometers

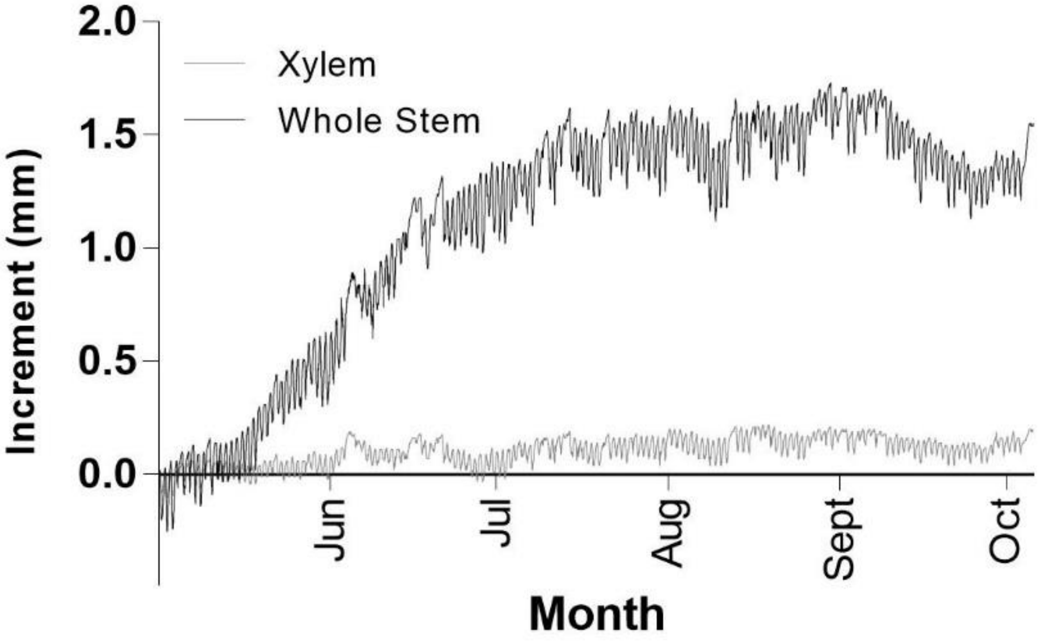
- xylem and whole stem water relations
- cambial growth
- changes in osmotic concentration of living cells in the xylem

Point dendrometers in SMEAR II

Diurnal dynamics



Annual dynamics

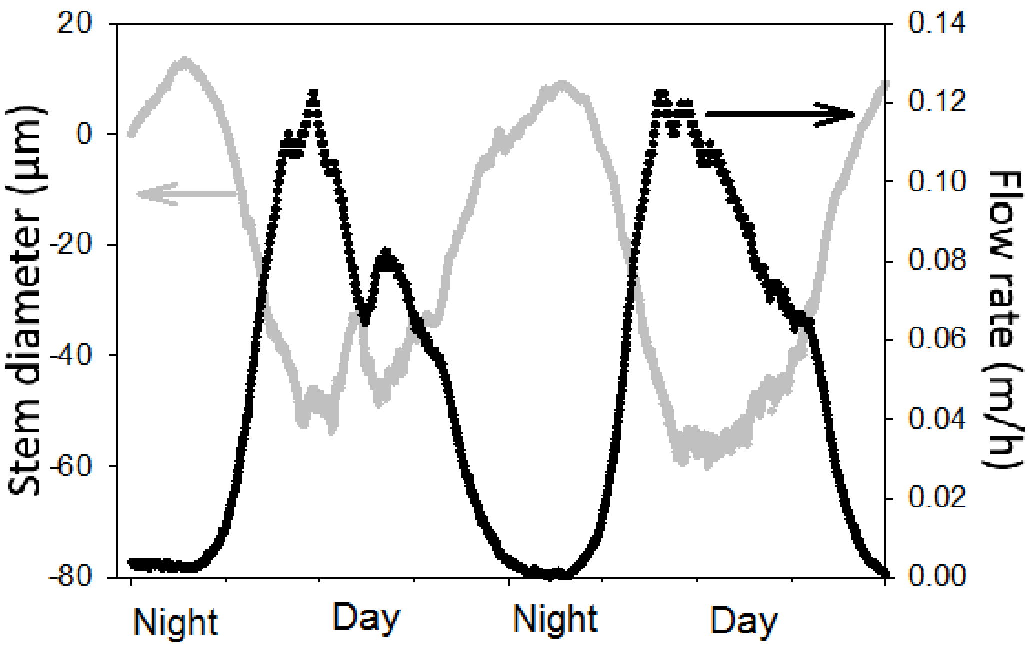


Salmon et al

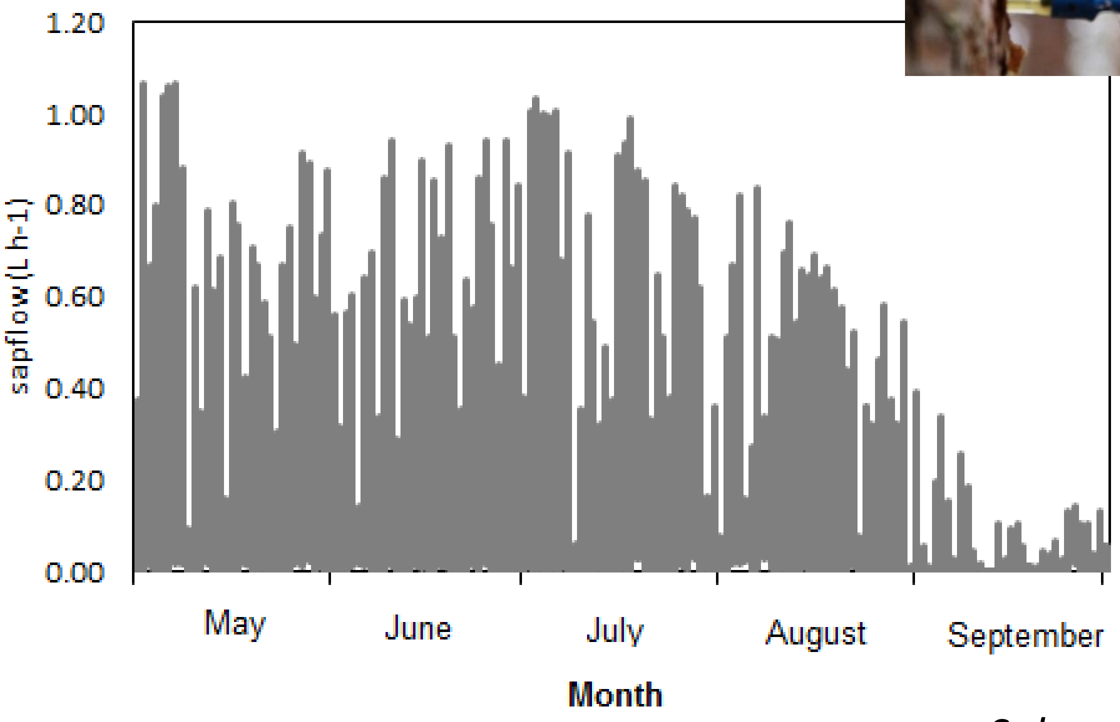
Sap flow

- for measuring xylem sap flow and tree water use dynamics
- Nighttime: swelling, Daytime: shrinking of stems

Diurnal dynamics:

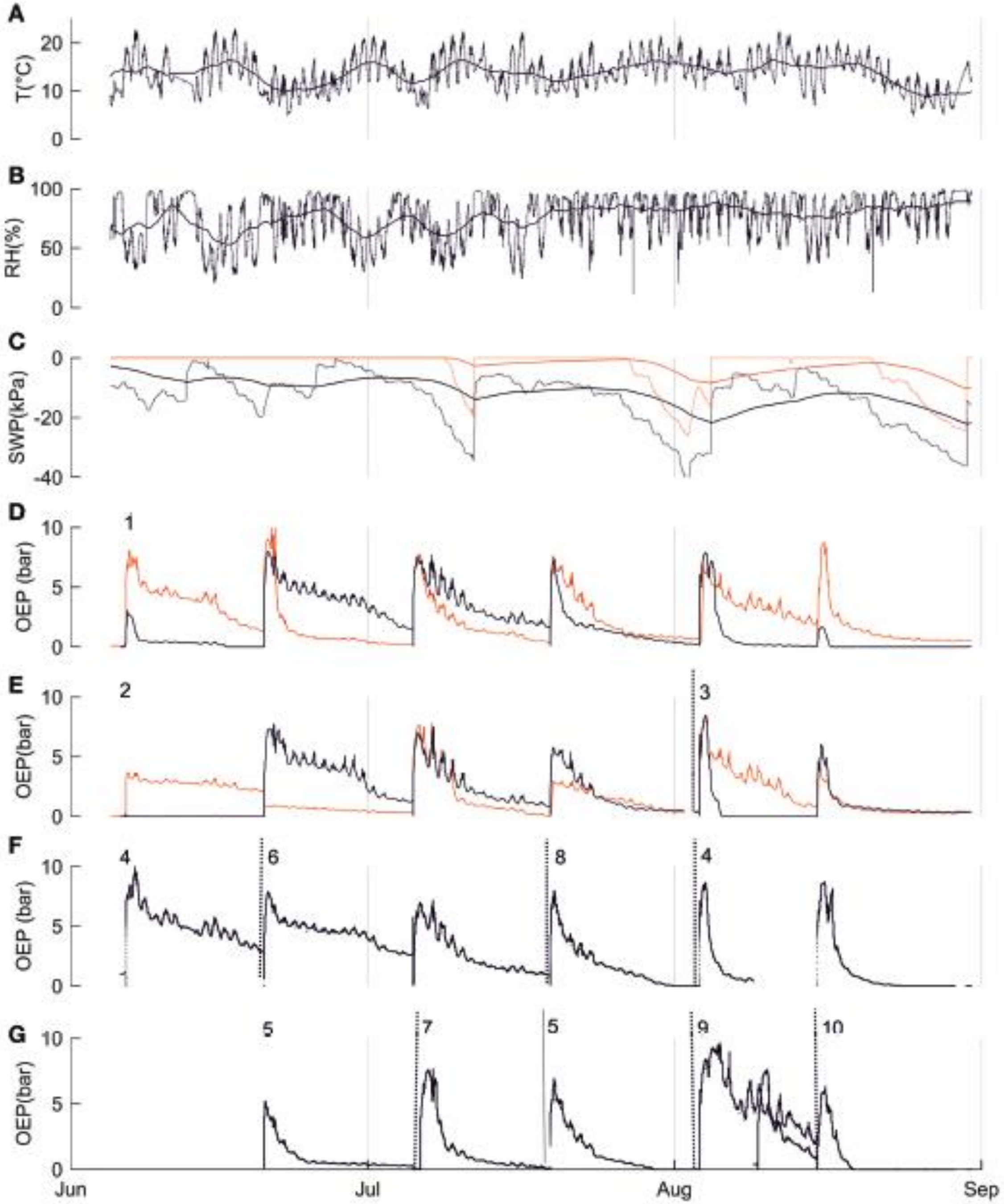


Annual dynamics:



Salmon et al

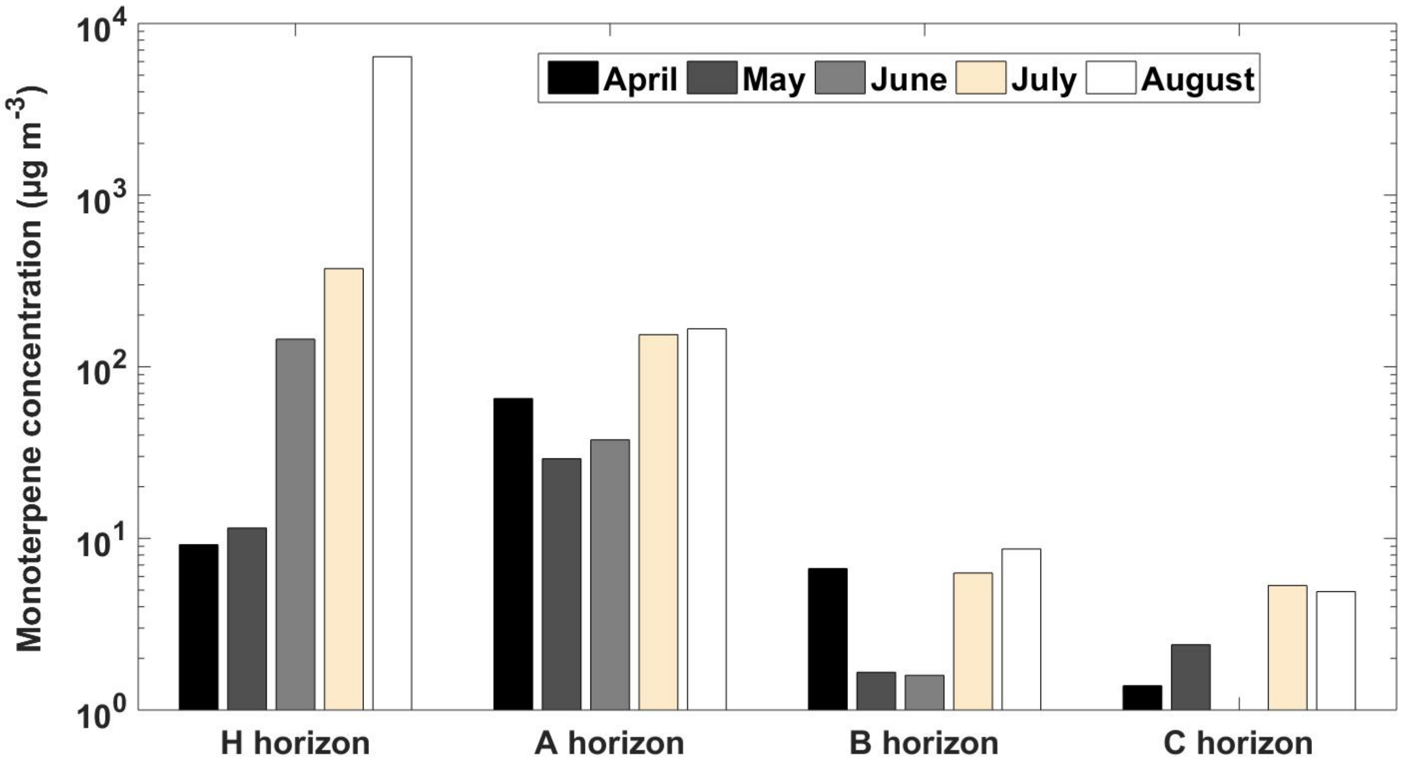
Stem oleoresin pressure

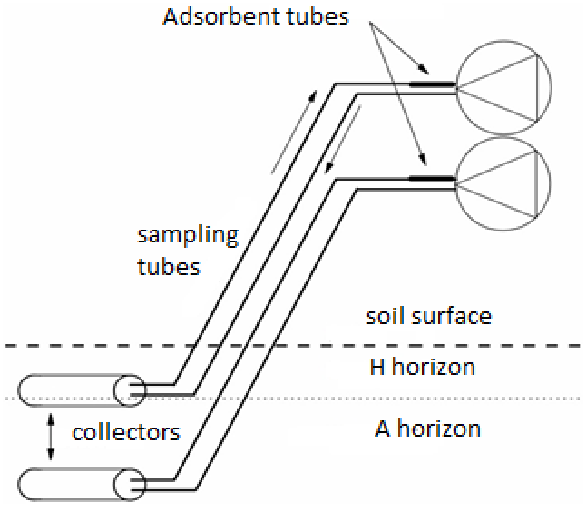


- Resin pressure over the growing season positively connected to SWP
  - thermal expansion of resin and changes in bubble volume due to changes in gas solubility
- T main driver at the diurnal scale

Rissanen et al

VOC PRODUCTION IN BOREAL FOREST SOIL



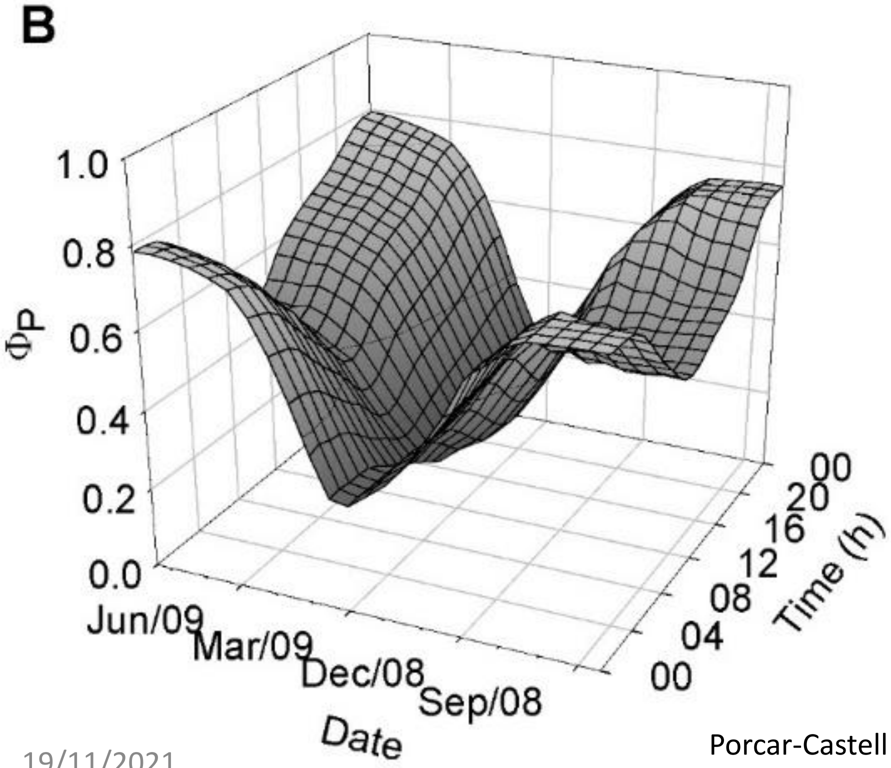


- Concentrations were highest in organic layer, containing fresh monoterpene-rich litter from trees.
- Biological processes i.e. litter decomposition produces highest monoterpene concentrations during fall.

Mäki et al

Long-Term leaf-level (PAM) Fluorescence Measurements

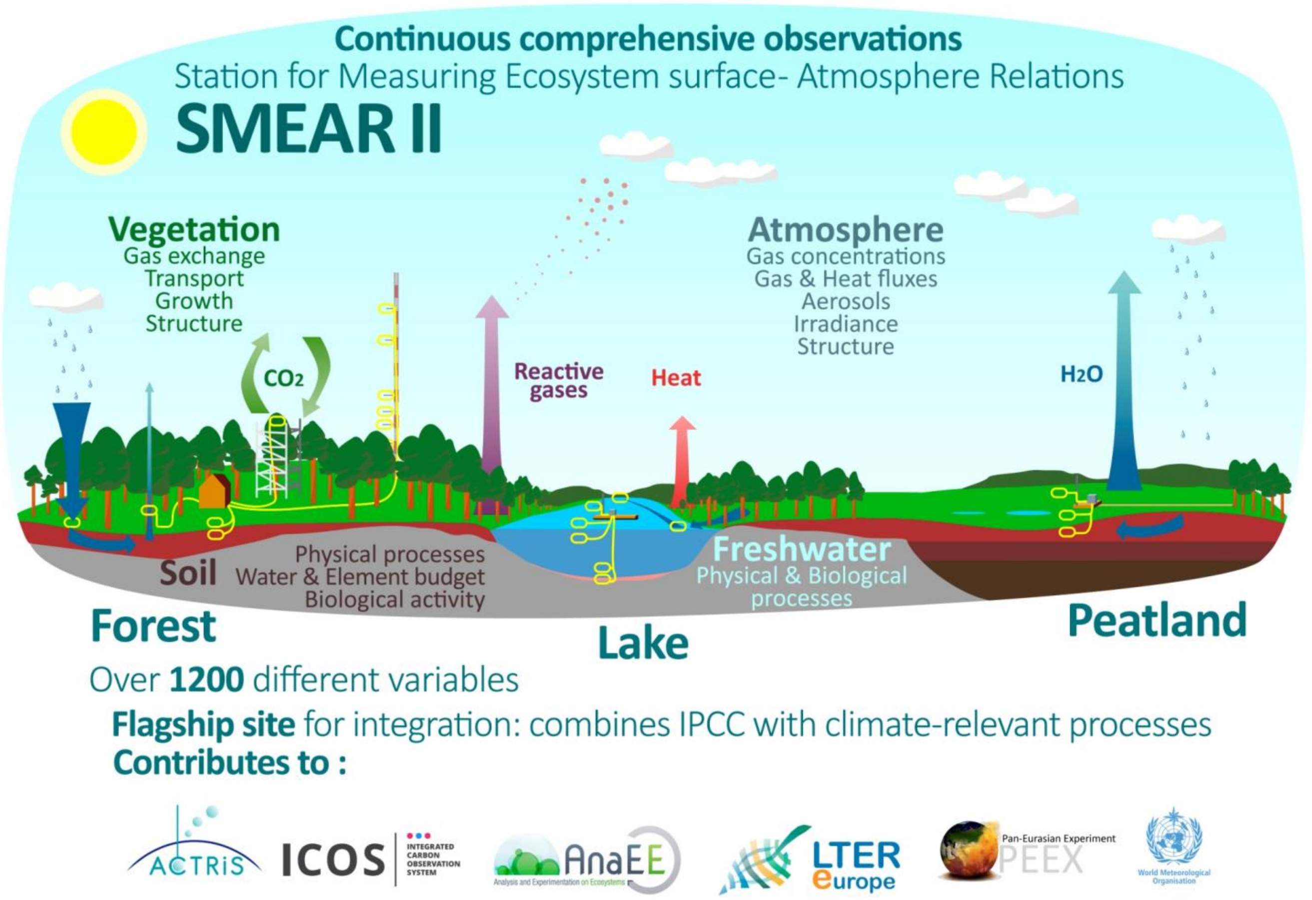
Portable pulse amplitute modulated (PAM) fluorometer systems can be used to estimate the efficiency of photosynthesis and its temporal dynamics using the quantum yield of photosystem II.



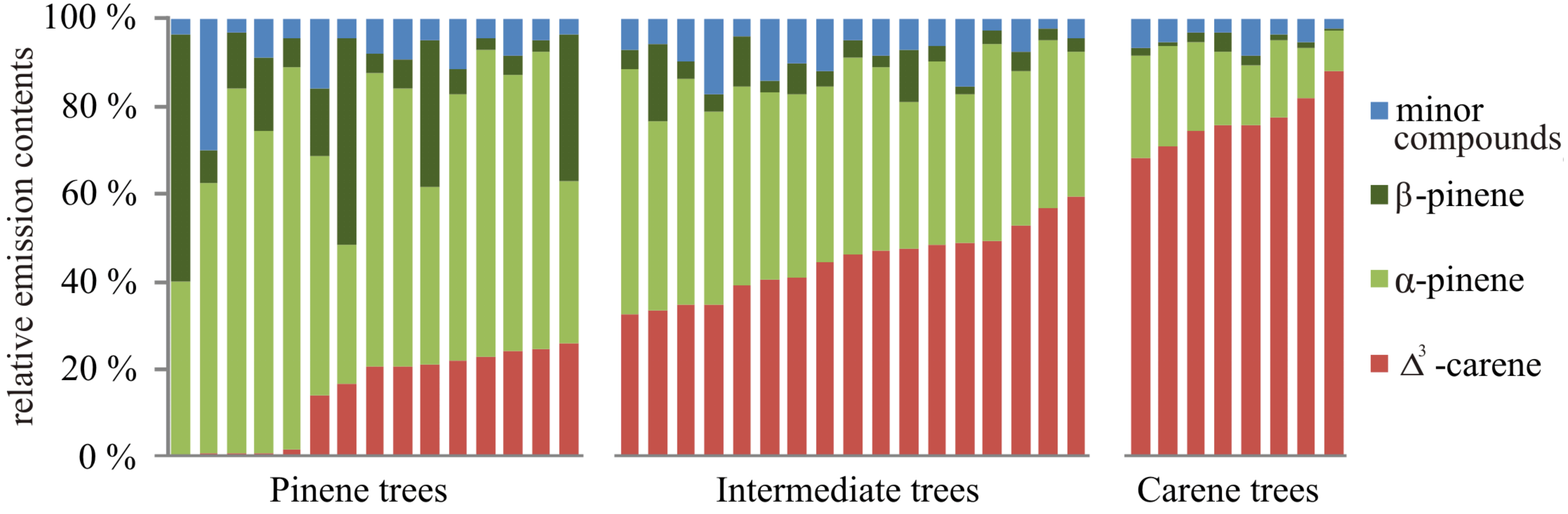
Porcar-Castell et al

Porcar-Castell A 2011. Physiologia Plantarum 143: 139–153. 2011

Stand scale measurements aggregating the small scale observations

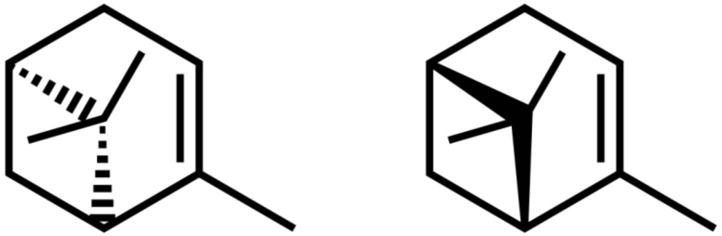


MONOTERPENES: chemodiversity in pine forest



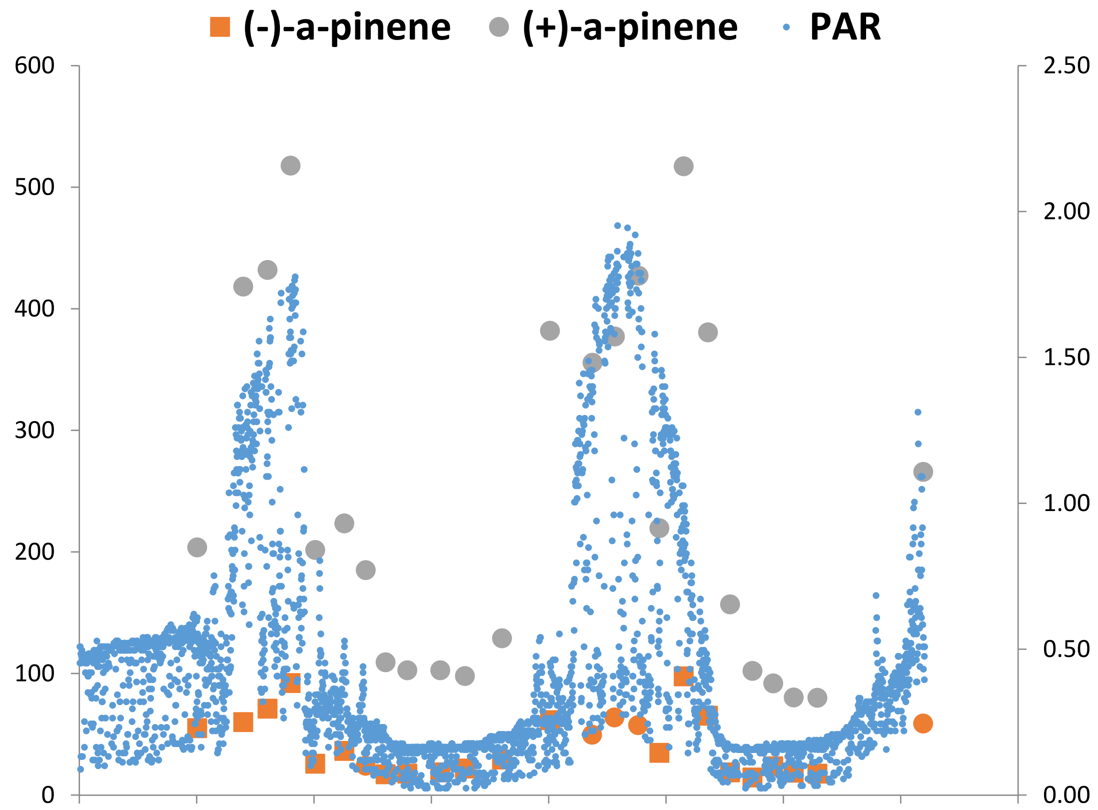
Bäck et al (2012) Biogeosciences 9: 689–702

Atmospheric chemistry affected by chemodiversity



(+)-α-pinene (−)-α-pinene

- The enantiomers can have very different emission patterns and reactivities
- Probably related to their roles in protection against herbivores?



Yassaa et al 2012

Soil, branch and ecosystem scale fluxes of carbonyl sulfide (COS)

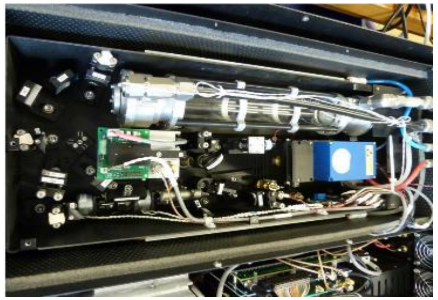
- COS is taken up by plants via same pathway as CO_2 during photosynthesis
- COS may be used as a proxy for gross primary productivity GPP (photosynthesis)

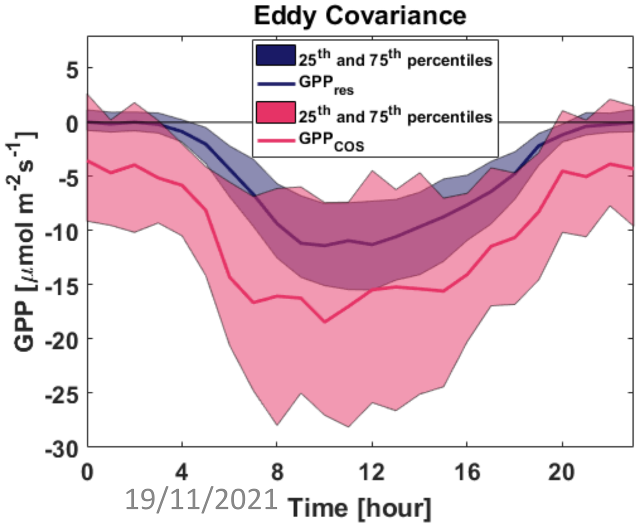
$$GPP = \frac{F_{COS}}{LRU}\frac{[CO_2]}{[COS]}$$

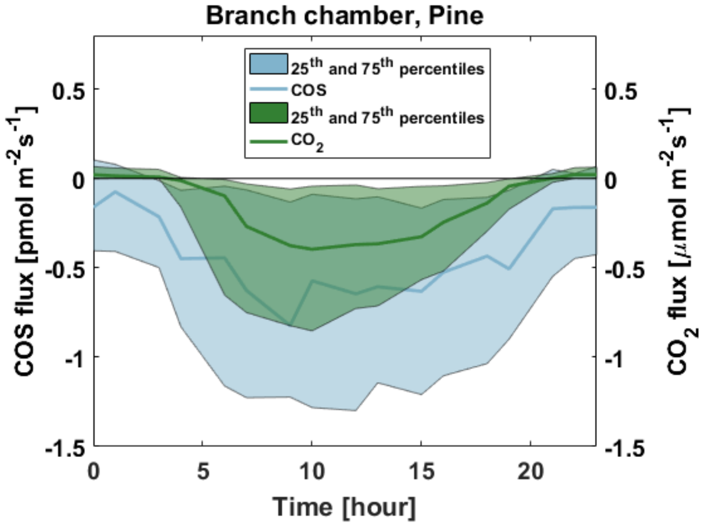
LRU = Leaf-scale Relative Uptake

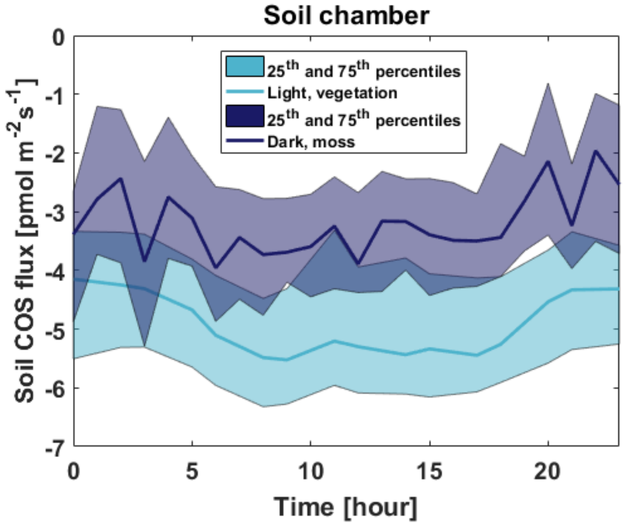
- Ecosystem and branch COS and CO_2 fluxes follow the same diurnal cycle
- Offset in observed GPP could be explained by negative soil COS fluxes or incomplete closure of stomata during nighttime

Kohonen et al

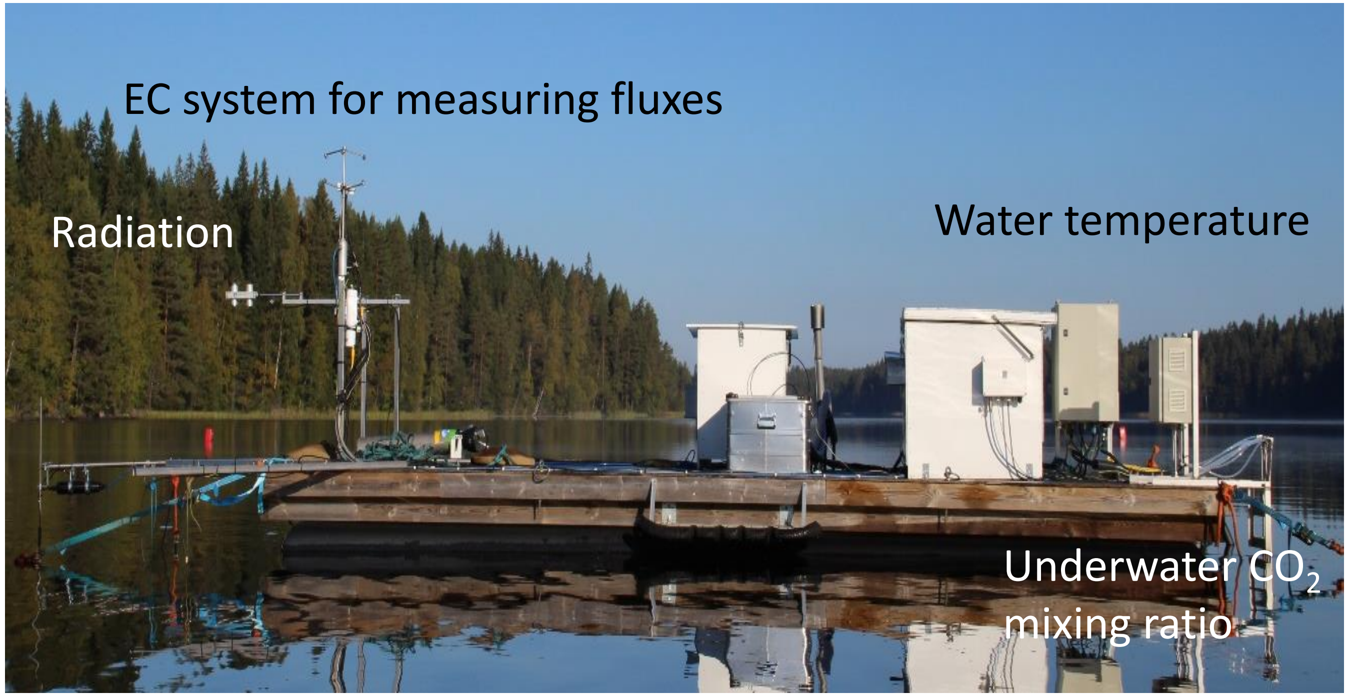


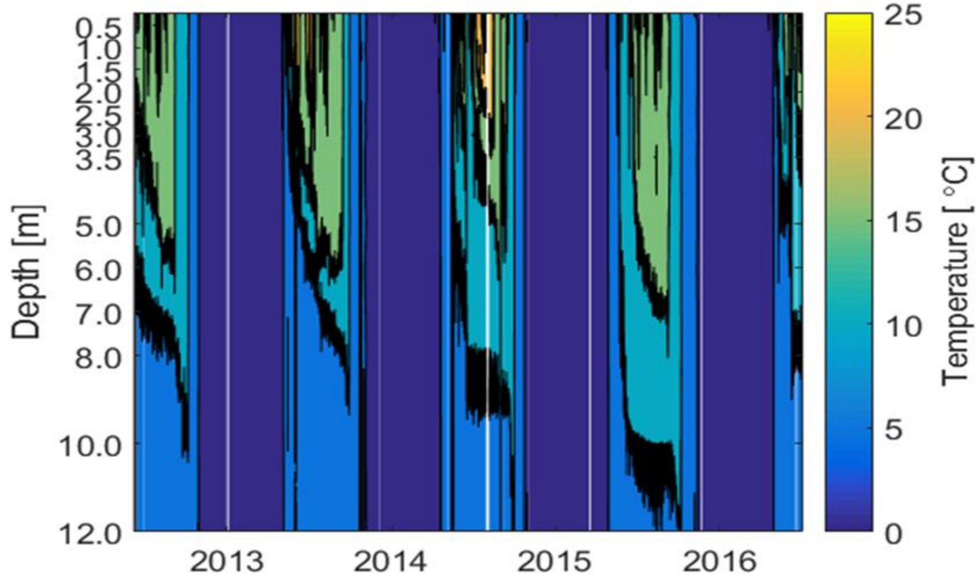


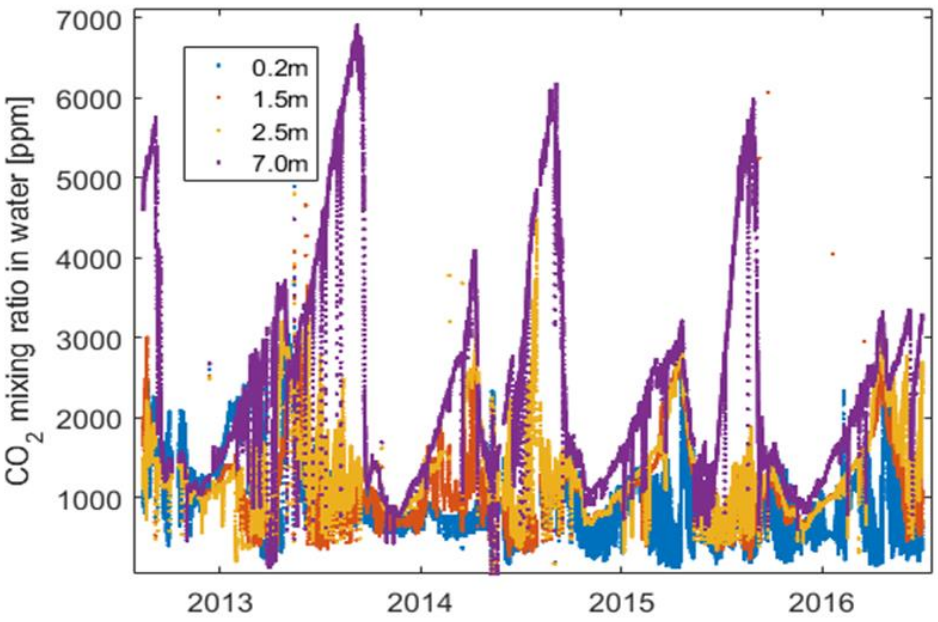




Lake platform for measuring lacustrine fluxes

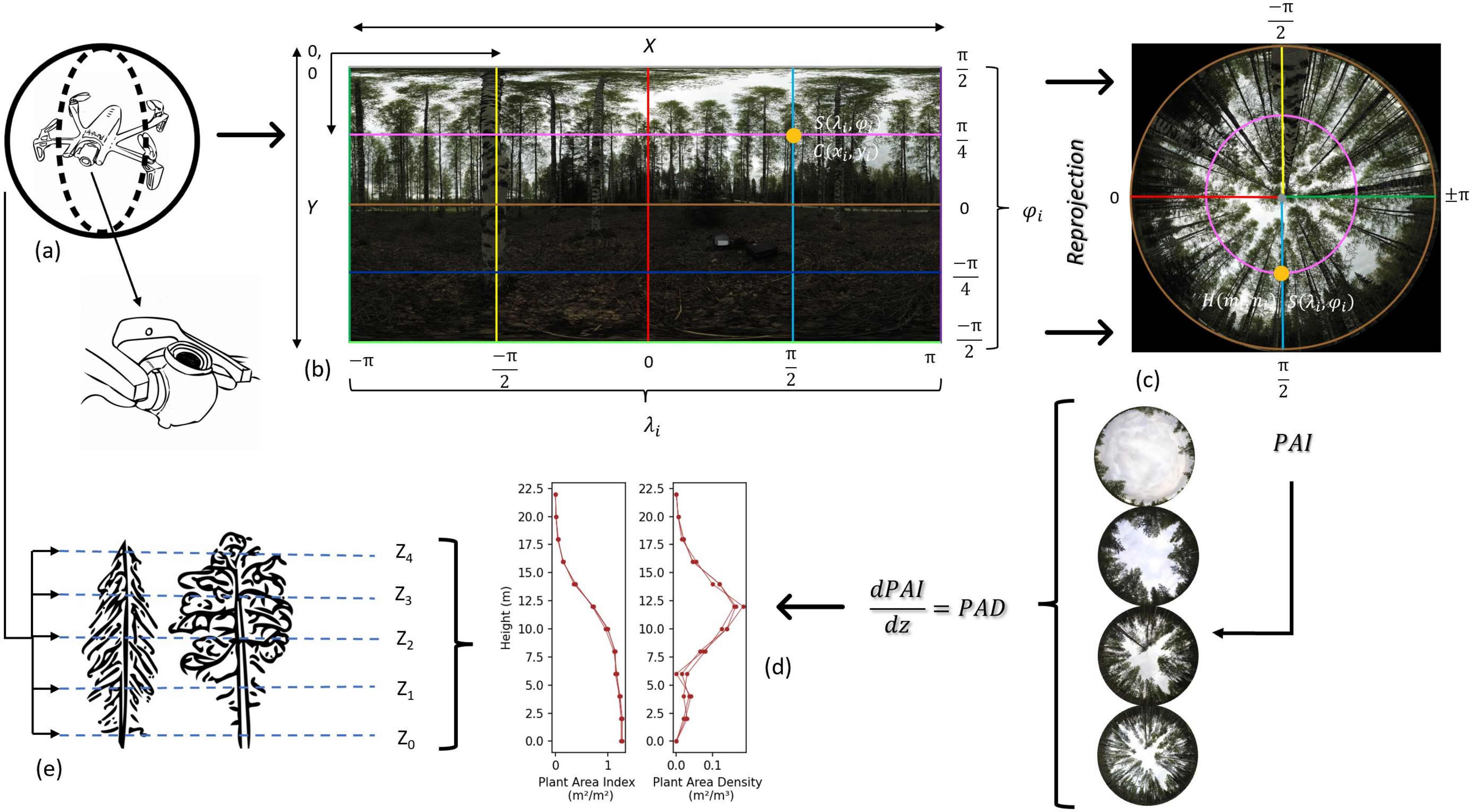






Mammarella et al

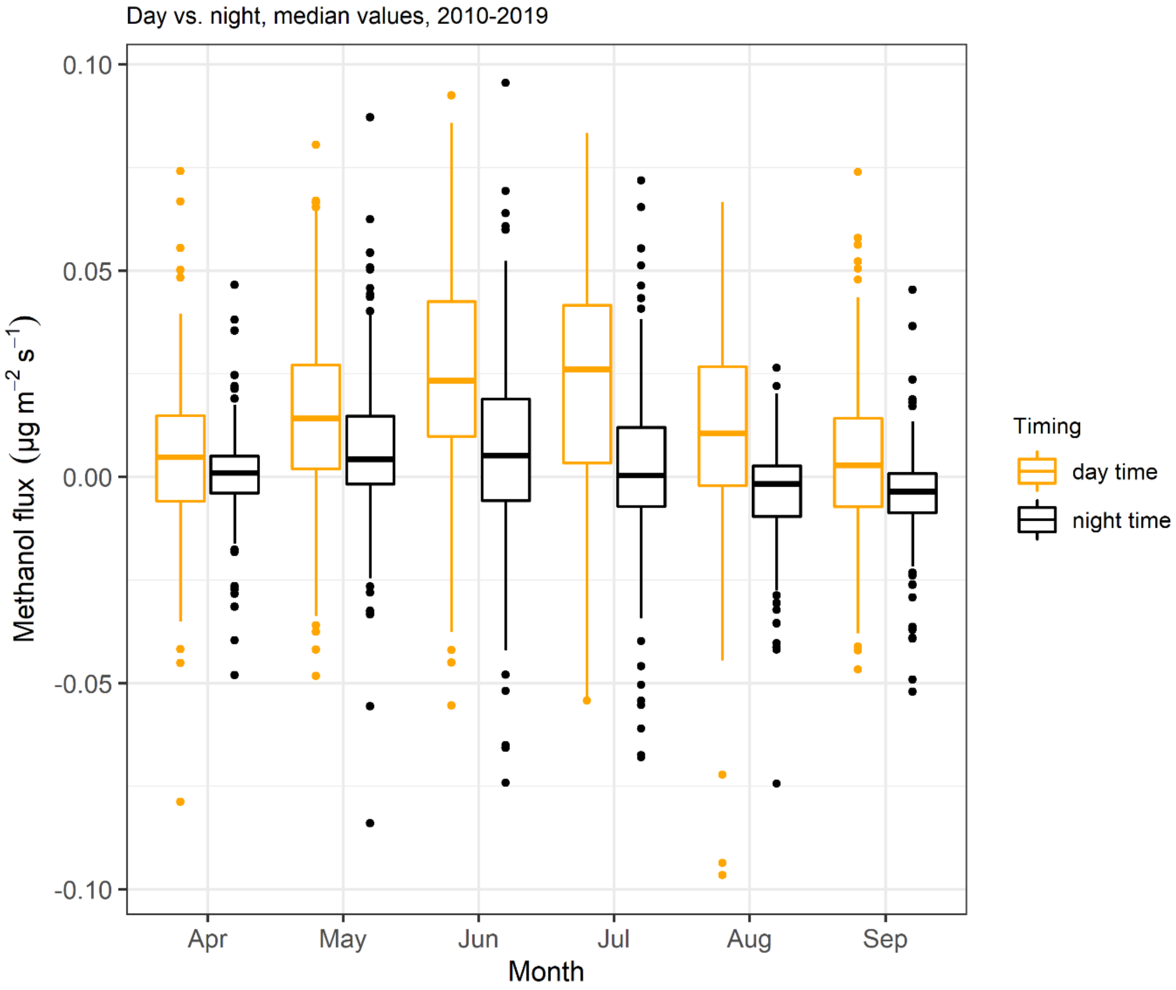
Estimating canopy properties with drones



Ribas Costa, Atherton et al

Top-down: Atmospheric concentrations

- Tower profiles
  - Concentrations
  - Flux methods (EC, disjunct EC, gradient)
    - Emission or deposition



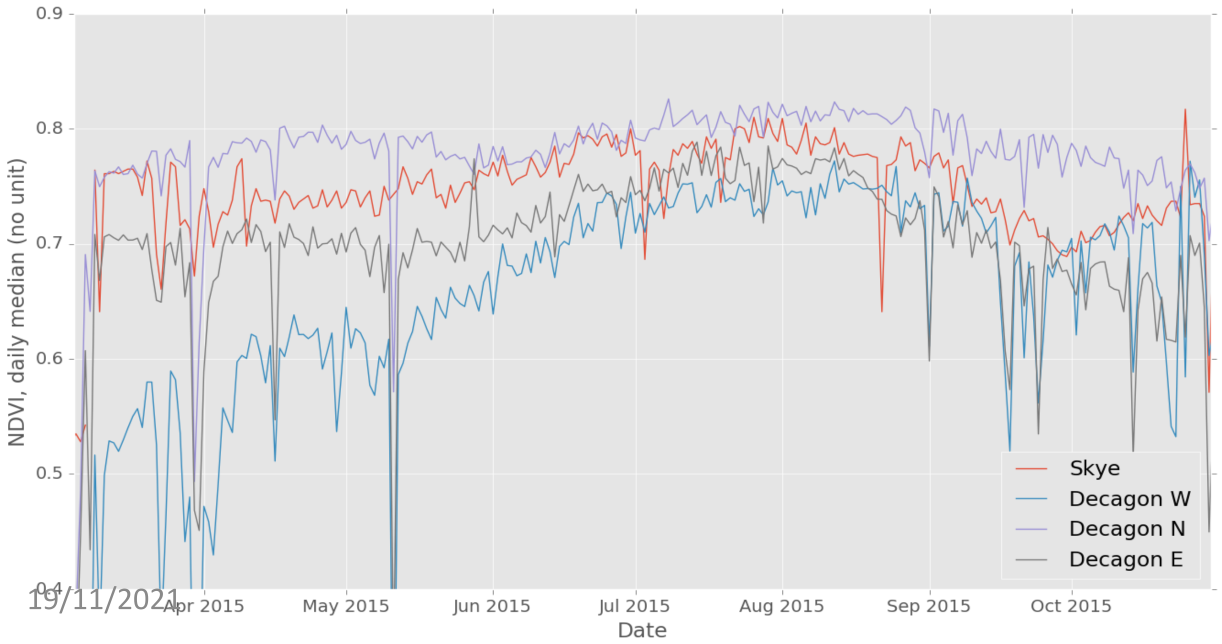
Bäck et al manuscript

Above Canopy Spectral Measurements

Reflectance-based Vegetation Indices are indicators of canopy and understory growth and phenology. Measurements can also be used to validate satellite data.

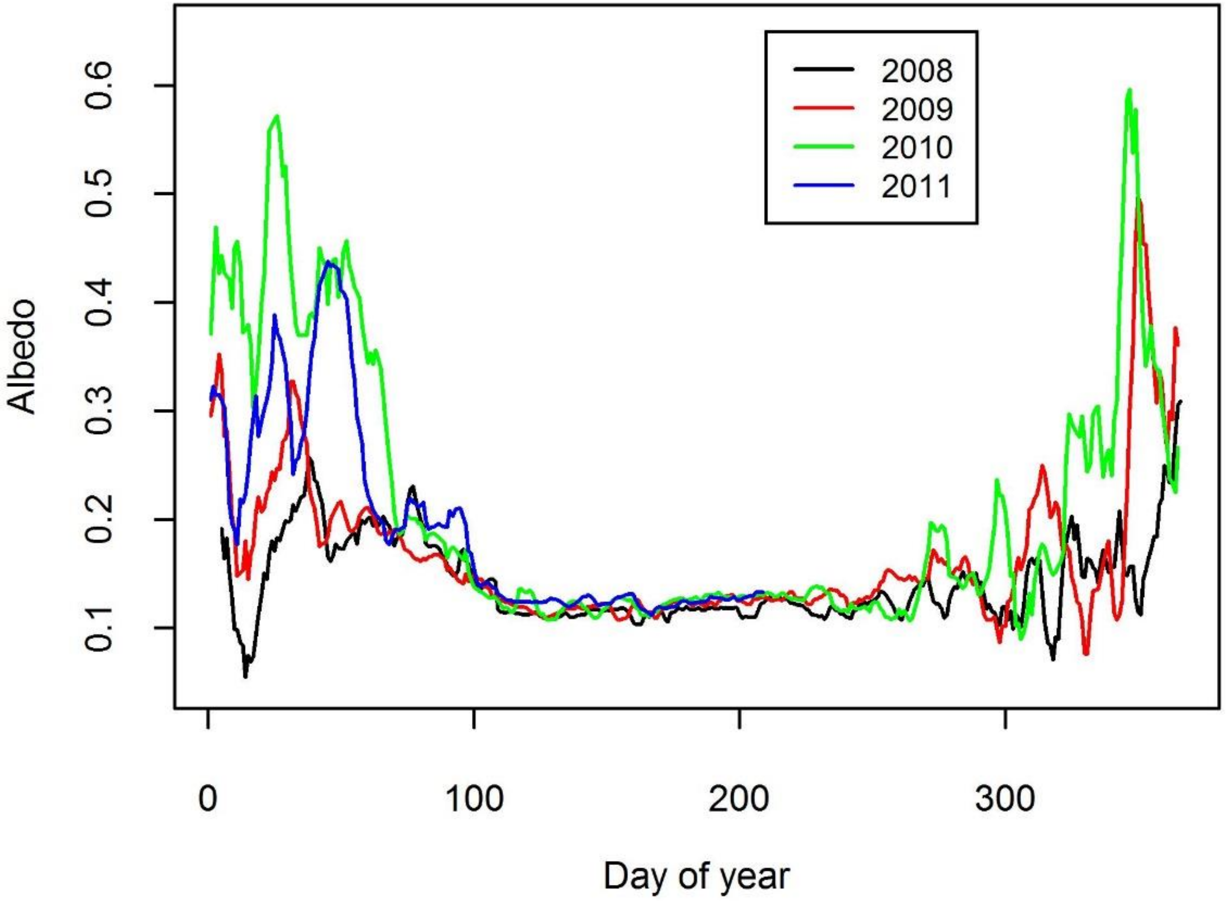
Above Decagon PRI and NDVI spectral sensors

Porcar-Castell et al



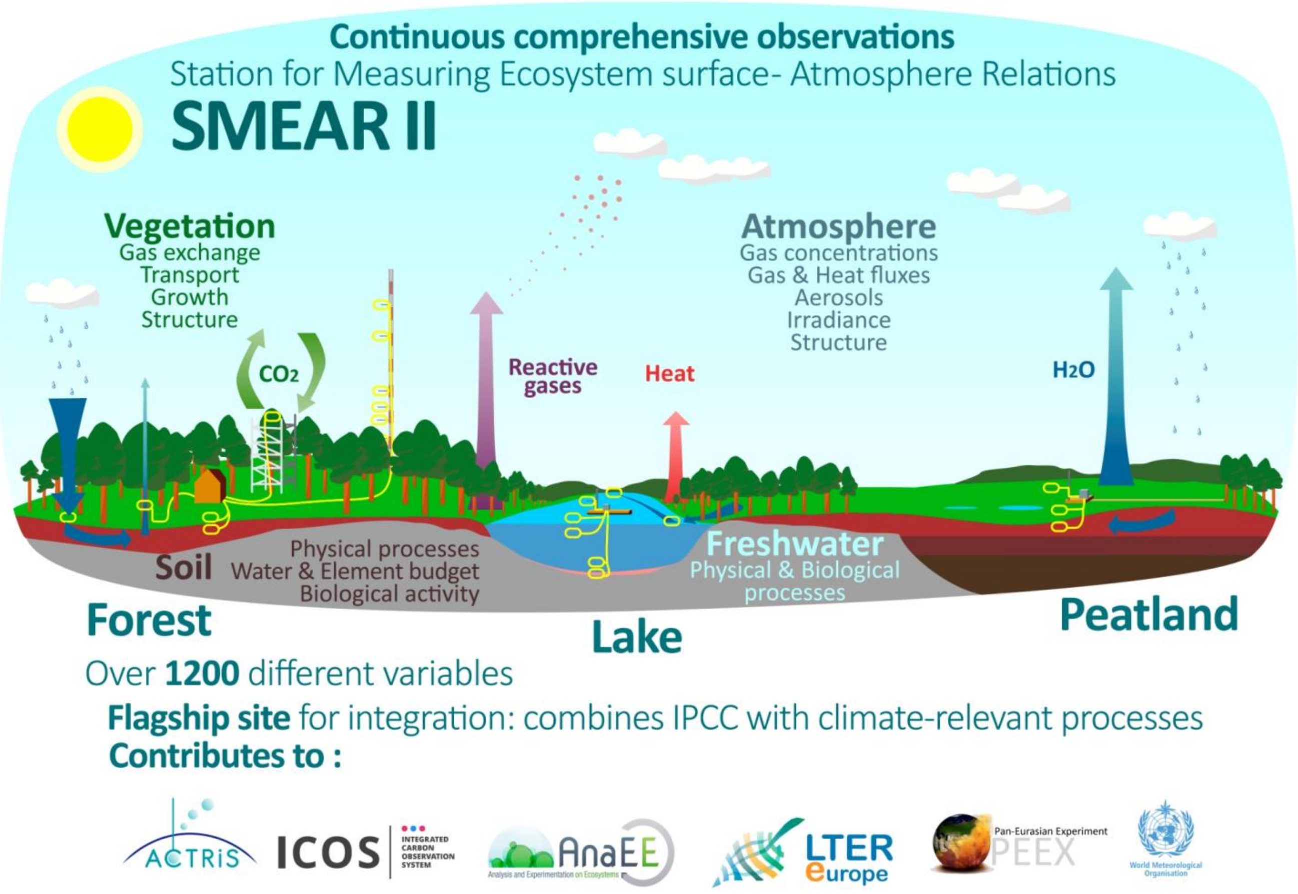
Left Daily median NDVI from multi-view sensors

Albedo in a boreal forest: wintertime is important



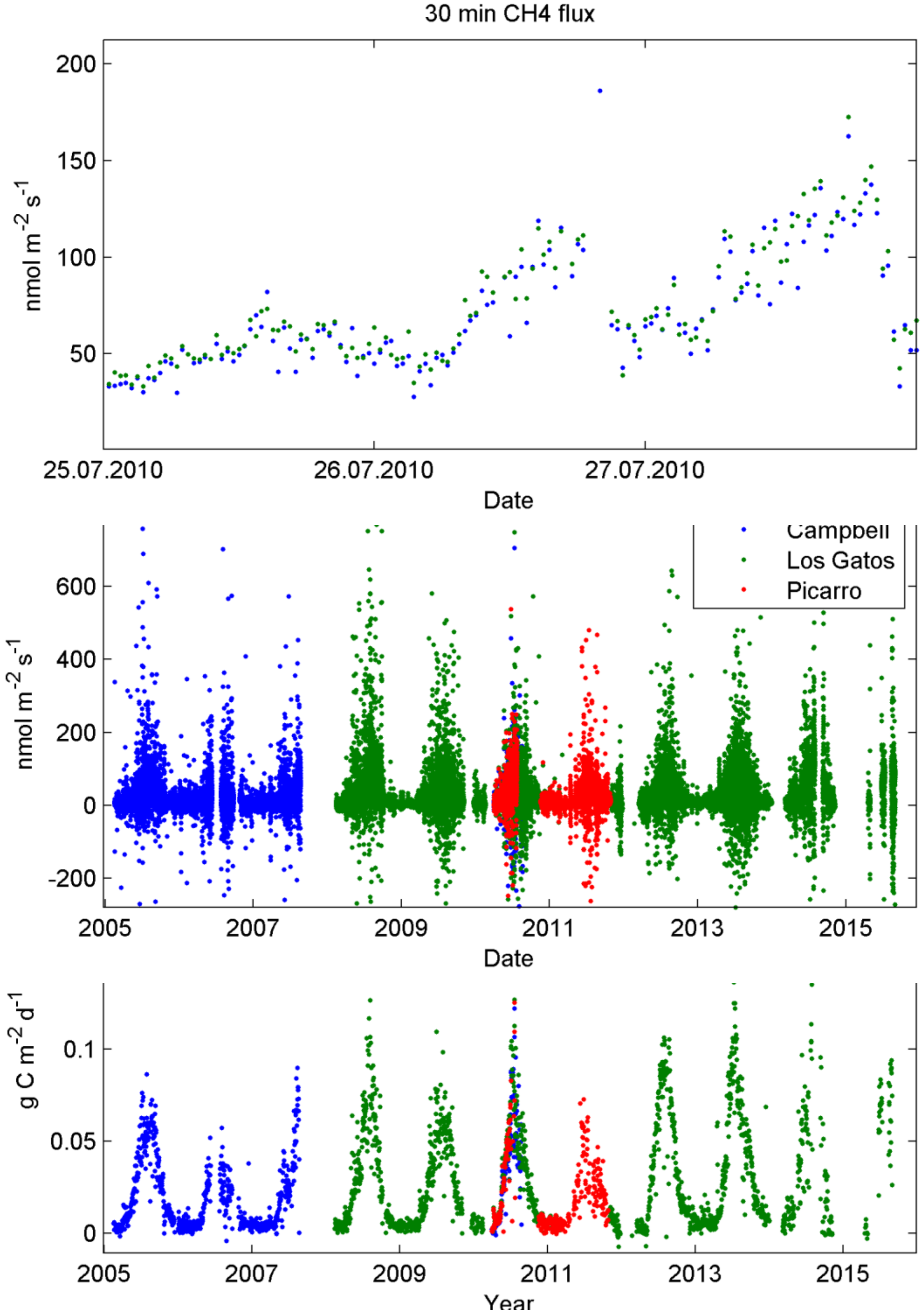
Kuusinen et al 2014

Other greenhouse gases



CH_4 flux from peatland

- Weak diel variability, plot shows increase in CH_4 efflux with peat warming up during 3 example days
- Strong annual cycle
  - peat temperature
  - water table depth
  - vegetation productivity
- The site is source of CH_4



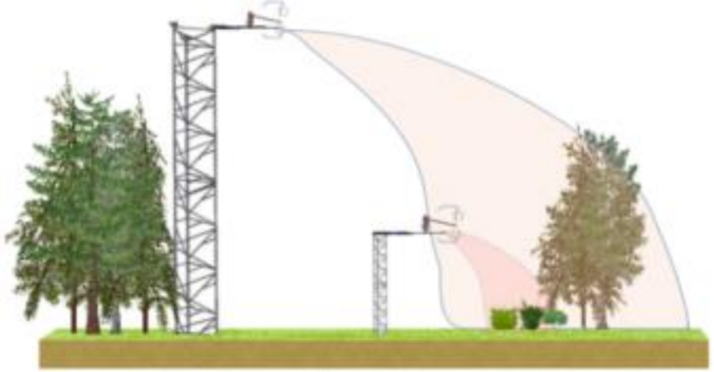
Kolari et al

Human impact on ecosystems

Forest management affects the C fluxes

- Small trees around the measurement station were removed in 2019
- The main thinning was conducted in Jan-Feb 2020.
- Totally ca. 40% of basal area was removed.
- EC fluxes have been monitored at 2.4 m and 27 m above the ground.
    - The EC set up at 27 m provide info at ecosystem level
    - The EC set up 2.4 m provide info about ground vegetation and soil.

Removed trunks (March 2020)



EC setups

Subcanopy EC setup after thinning (March 2020).
Trunks with diameter less than 6 cm left in the field.

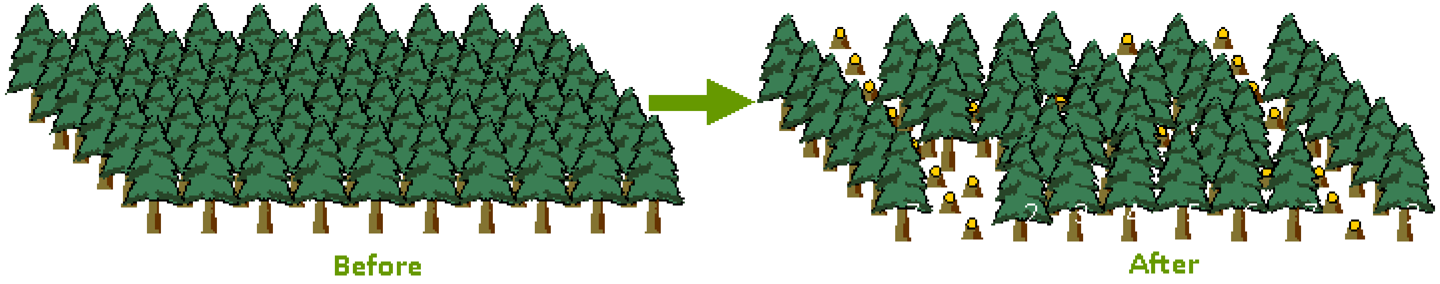
Toprak Aslan et al

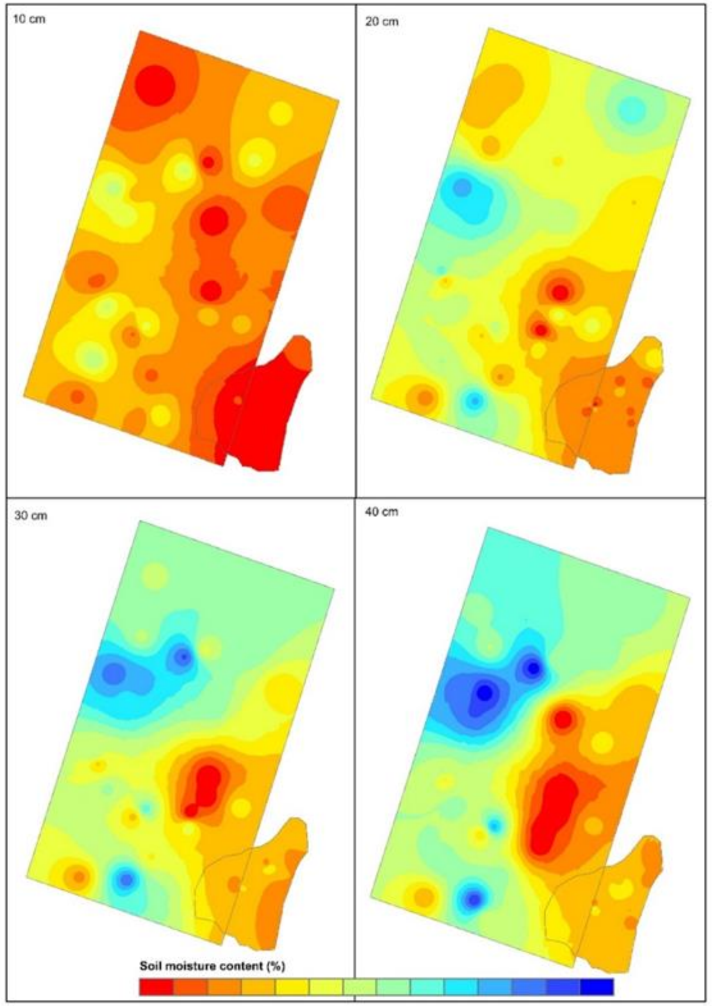
Effect of forest management on tree physiology and tree-soil interactions

Thinning → soil moisture content increases & more light penetrates the canopy etc.

→affects tree physiology & growth and soil processes

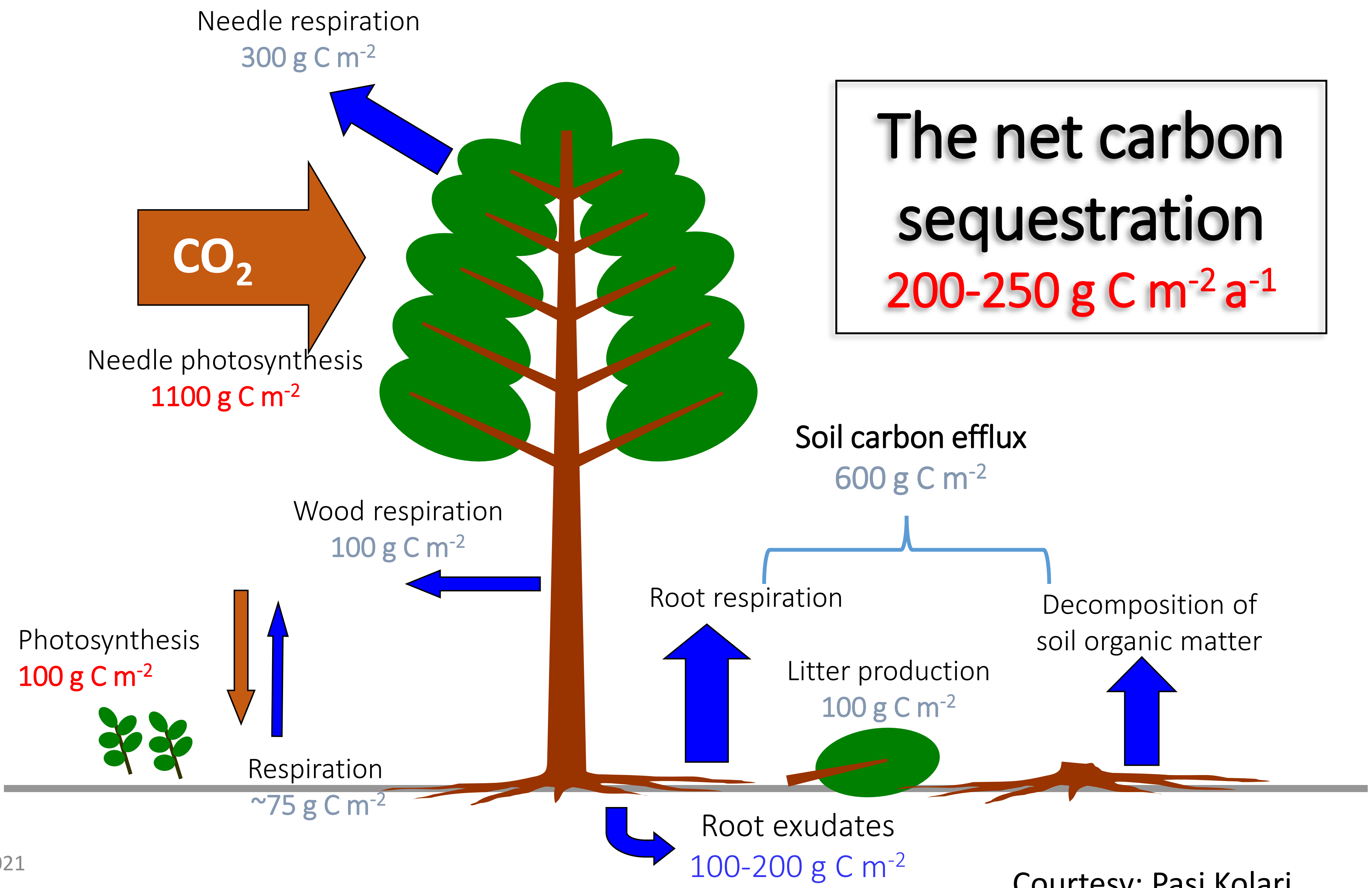
→affects forest carbon balance





De Alzamora et al

CARBON budget



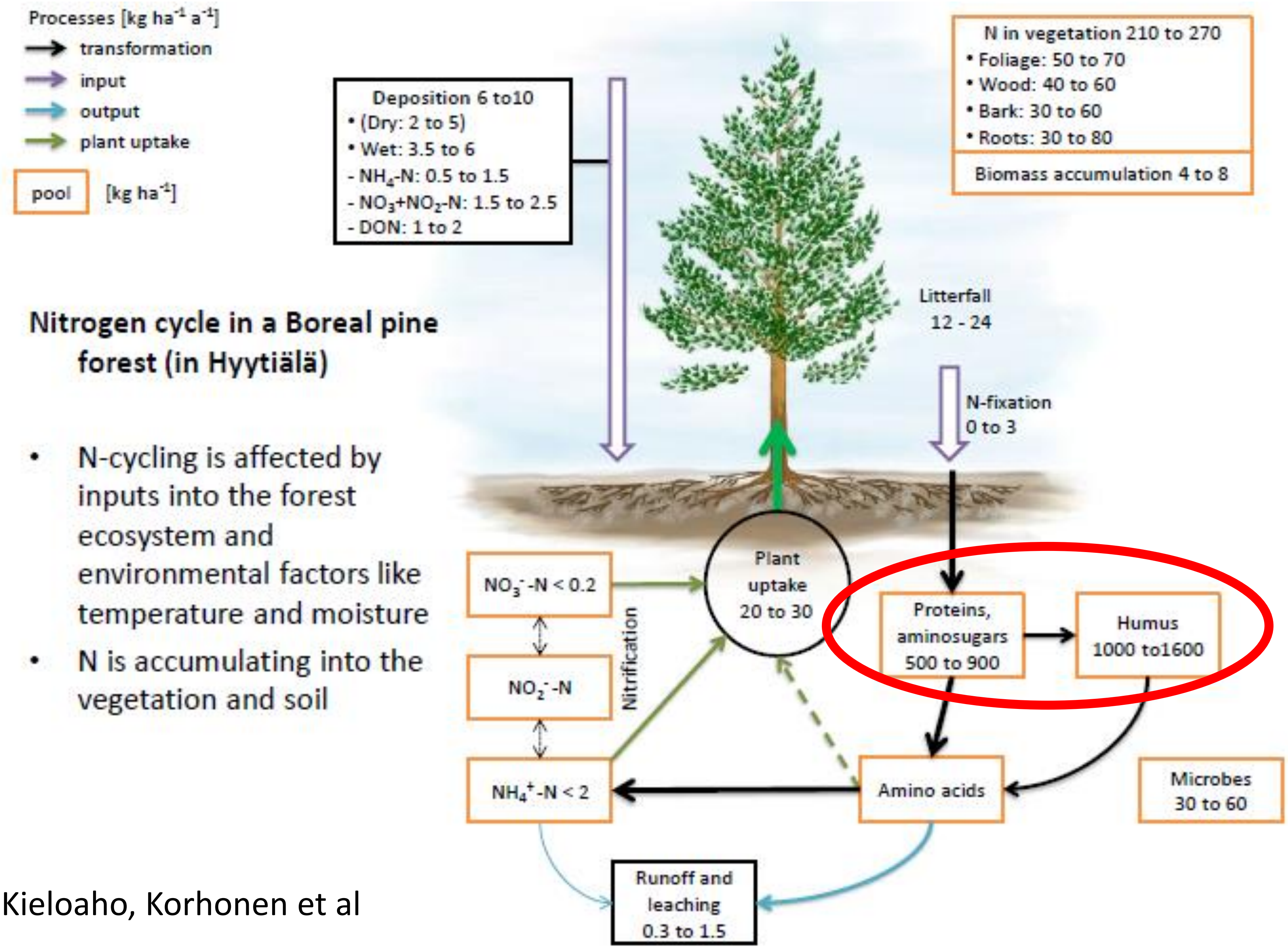
The net carbon sequestration
$200\text{-}250$ g C m^{-2} a^{-1}

Courtesy: Pasi Kolari

NITROGEN budget

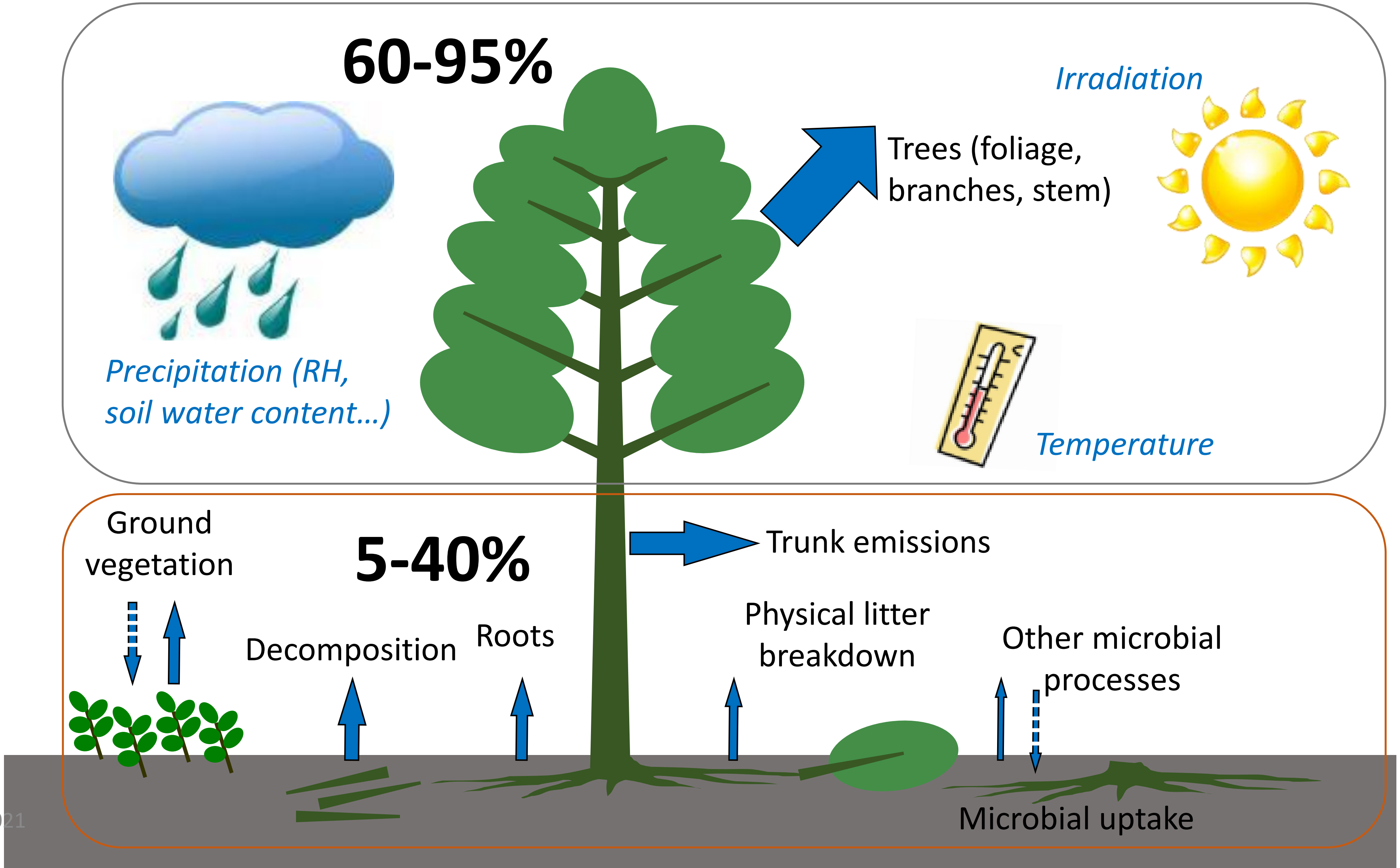
Nitrogen cycle in a Boreal pine forest (in Hyytiälä)

- N-cycling is affected by inputs into the forest ecosystem and environmental factors like temperature and moisture
- N is accumulating into the vegetation and soil



Kieloaho, Korhonen et al

BVOC budget


60-95%
Irradiation
Trees (foliage, branches, stem)
Precipitation (RH, soil water content…)
Temperature
Ground vegetation
5-40%
Trunk emissions
Decomposition
Roots
Physical litter breakdown
Other microbial processes
Microbial uptake