The SMEAR: integrated research infrastructure concept and insights in its potential

(Drought in boreal evergreen forest?)

Jaana Bäck

Institute for Atmospheric and Earth System Research (INAR), University of Helsinki, Finland

Professor in forest-atmosphere interactions

Coordinator of eLTER PLUS (EU grant of 10 M€ for 2020-2025)

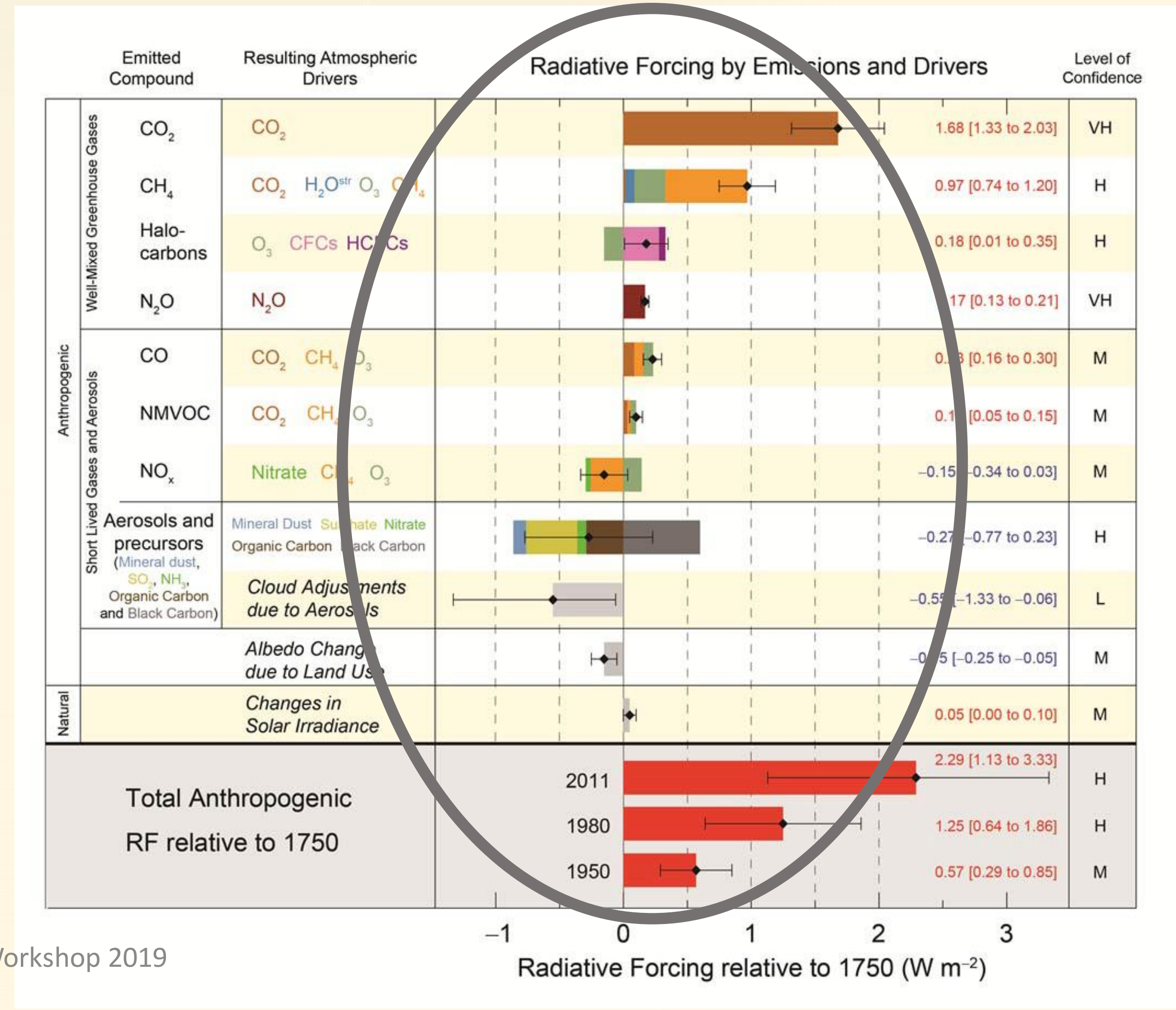
INTEGRATED APPROACH is urgently needed

Current observations (see IPCC 2013) are fragmented:

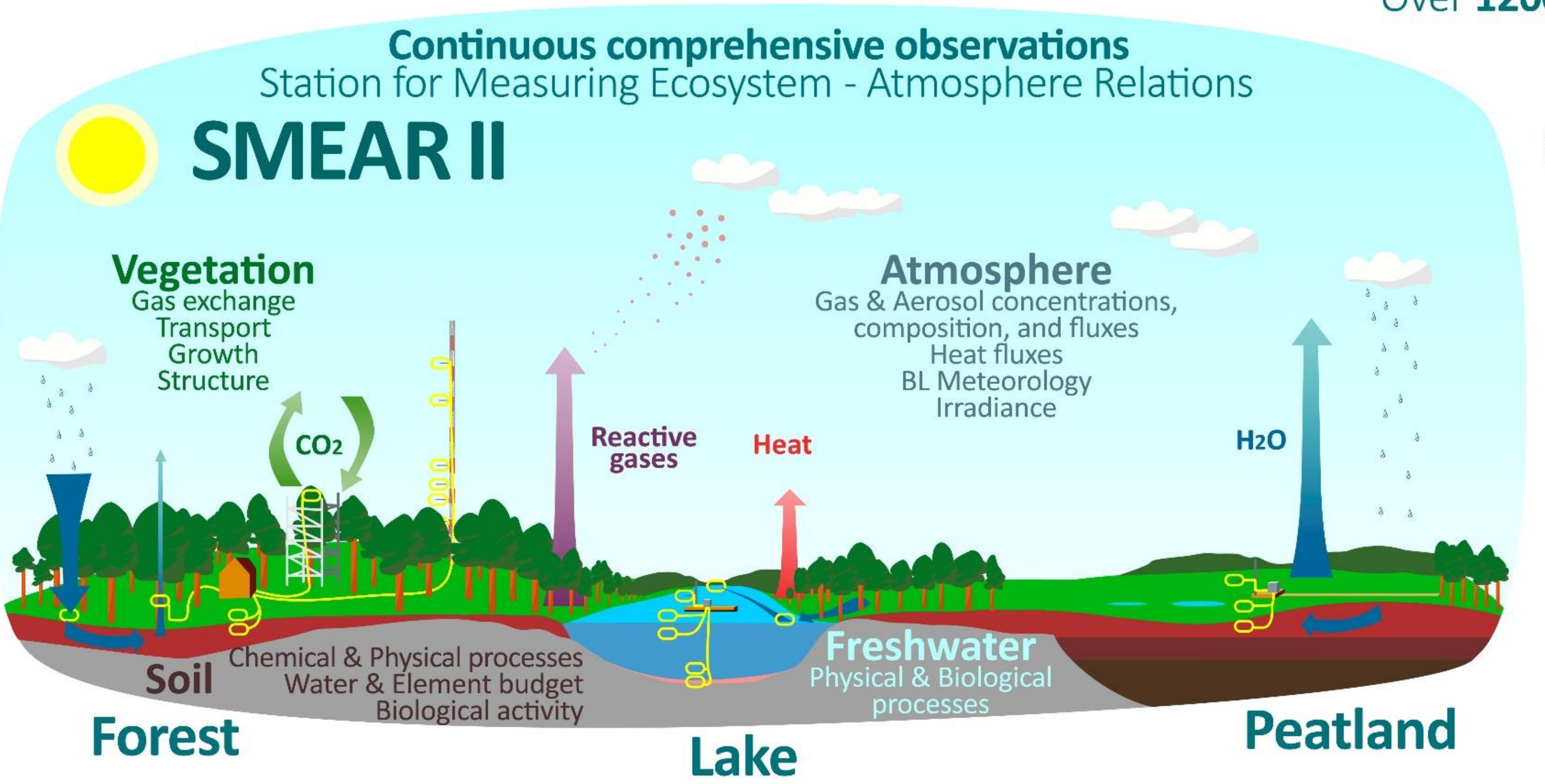
1) Greenhouse gases
2) Aerosols
3) Air quality
4) Ecosystems
5) Climate
6) Soils …

Future aspiration: **Integrated approach**

- **To understand feedbacks**
- **To reduce uncertainties**
- **To mitigate and adapt effectively**



CONTINUOUS COMPREHENSIVE OBSERVATIONS
’SMEAR CONCEPT’



Over **1200** different variables

Flagship site for integration: combines all IPCC components.

Contributes to :

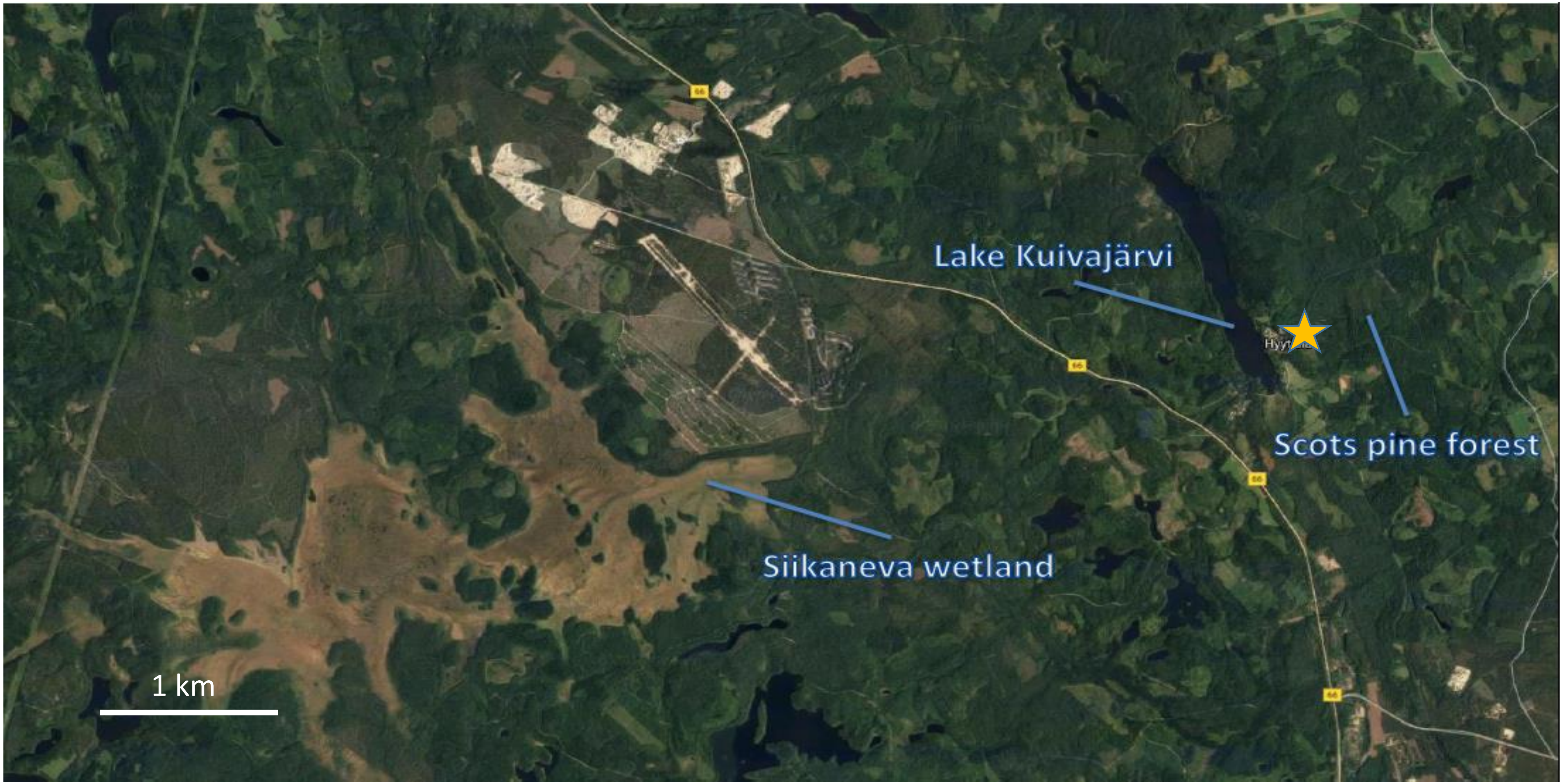
- ACTRIS
- ICOS Integrated Carbon Observation System
- AnaEE Analysis and Experimentation on Ecosystems
- eLTER
- Pan-Eurasian Experiment PEEX
- World Meteorological Organisation

SMEAR network with 7+ stations:

SMEAR = Stations for Measuring Ecosystem-Atmosphere Relations

SMEAR I; subarctic forest, protected nature reserve, Värriö
(ICOS, eLTER, AnaEE, ACTRIS, INTERACT)
SMEAR II; boreal forest, rural site, Hyytiälä
(ICOS, eLTER, AnaEE, ACTRIS, INTERACT)
SMEAR III; urban site, Helsinki
(ICOS, ACTRIS)
SMEAR IV; urban/boreal forest, Kuopio
(ICOS, AnaEE, ACTRIS)

SMEAR-Estonia; hemiboreal forest, Järvselja
SMEAR-China; urban, subtropical: Nanjing; Beijing; Shanghai
SMEAR S-Africa; semi-arid savanna; Welgegund


Lake Kuivajärvi
Scots pine forest
Siikaneva wetland
1 km

- **Value of the SMEAR-II flagship station > 10 M€**
- **Maintenance 0.5-1 M€ / year**

Photos Juho Aalto

ATMO-SPHERE

aerosols, atmospheric chemistry and physics, cloud microphysics, boundary layer micrometeorology, irradiance, deposition



BIO-SPHERE

gas exchange, water and nutrient flows, biomass growth, canopy structure, energy capture and use



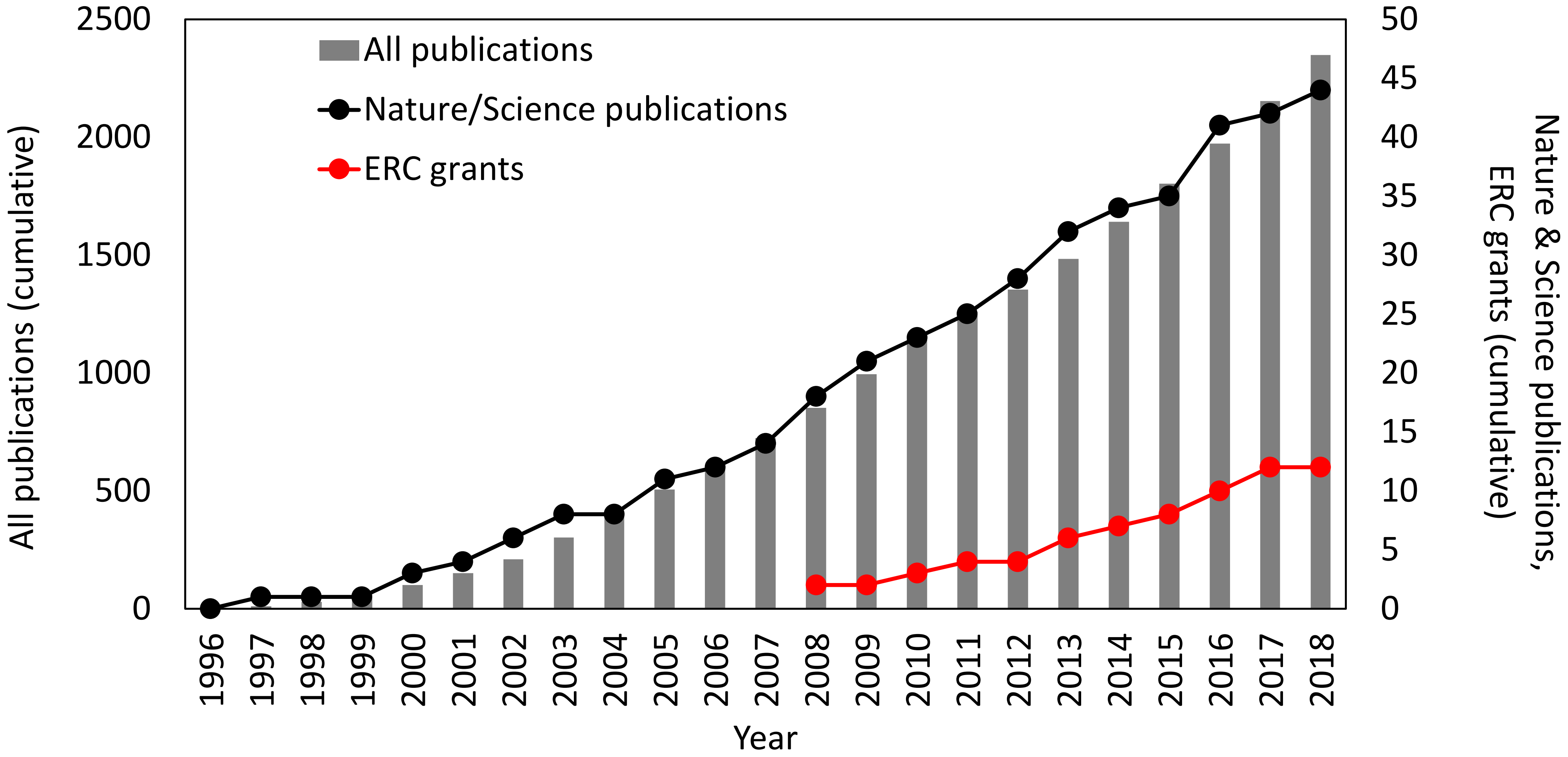
LITO-SPHERE

water and nutrient concentrations and uptake, profiles of temperature and moisture, gas exchange, root growth, microbial processes


HYDRO-SPHERE

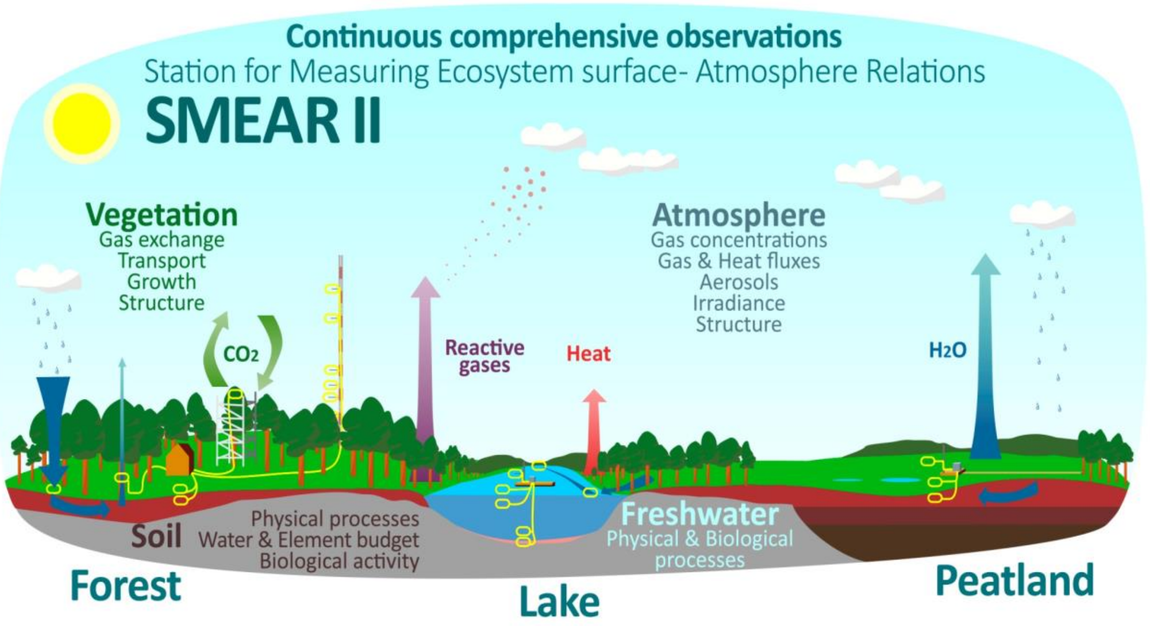
gas and energy exchange, gas concentrations, dissolved org/inorg. carbon, phytoplankton biomass and composition, lateral fluxes, meteorology, catchment processes


Scientific impact



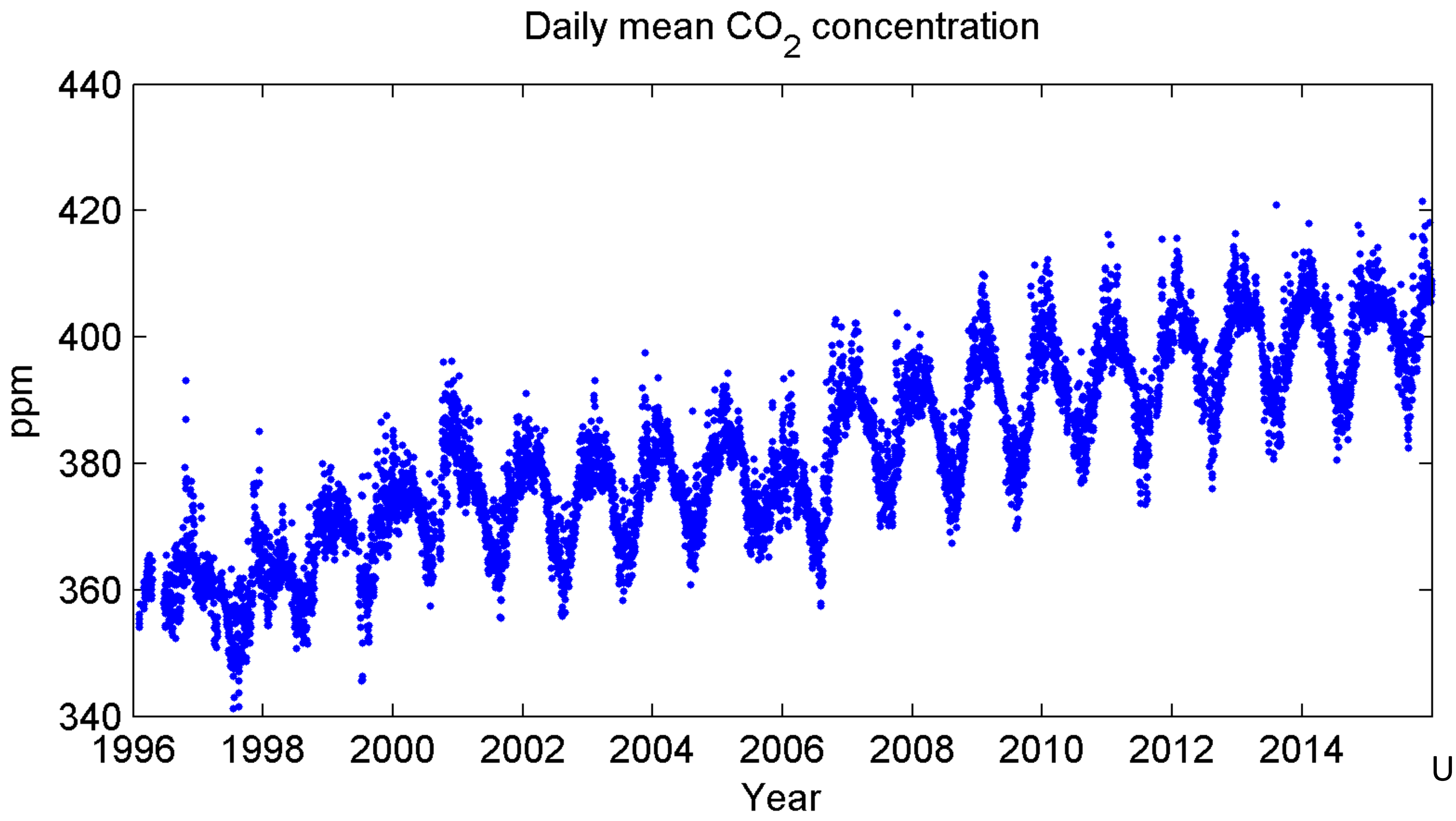
Continuous comprehensive measurements : powerful tool

- **Trends** in measured concentrations and fluxes, statistics (temporal and spatial variability)
- **Process** dynamics and partitioning
- **Feedbacks** between processes and compartments
  - Soil-forest-atmosphere
  - Forest-soil-streams-lake
  - Atmosphere-forest-soil



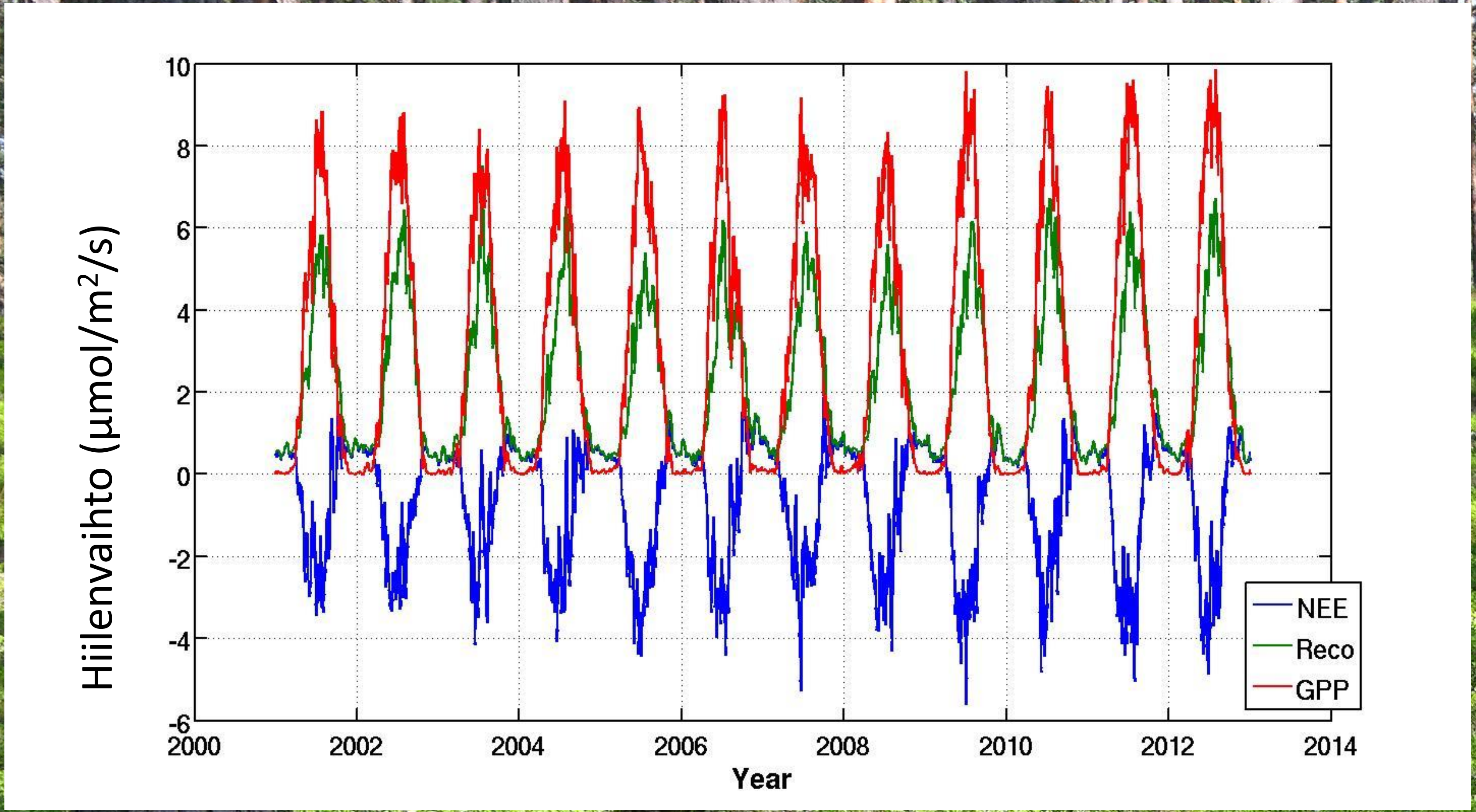
CO_2 concentration

Trends



Unpublished results

Trends



Carbon sink in a boreal forest

Unpublished results

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

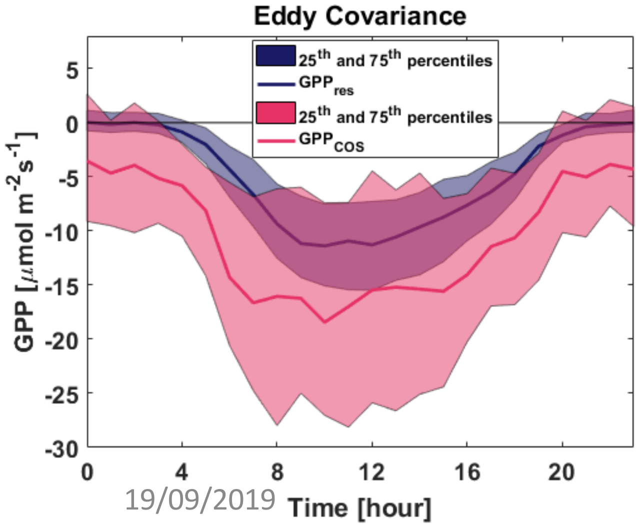
Processes

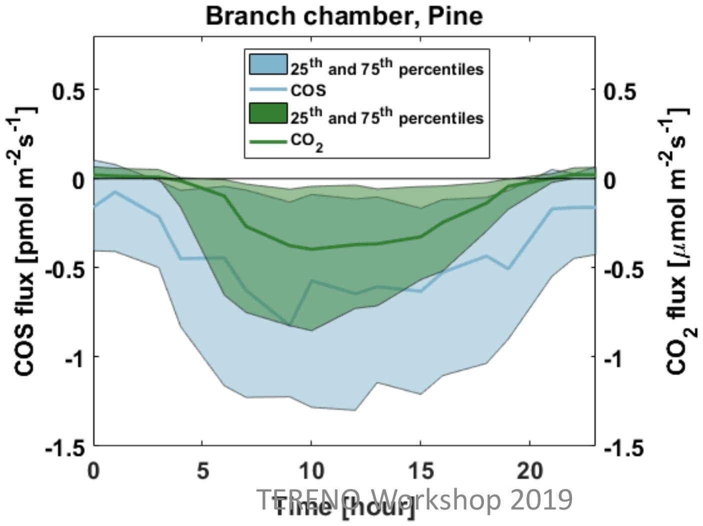
- COS is taken up by plants via same pathway as CO_2 during photosynthesis
- COS may be used as a proxy for gross primary productivity GPP (photosynthesis)

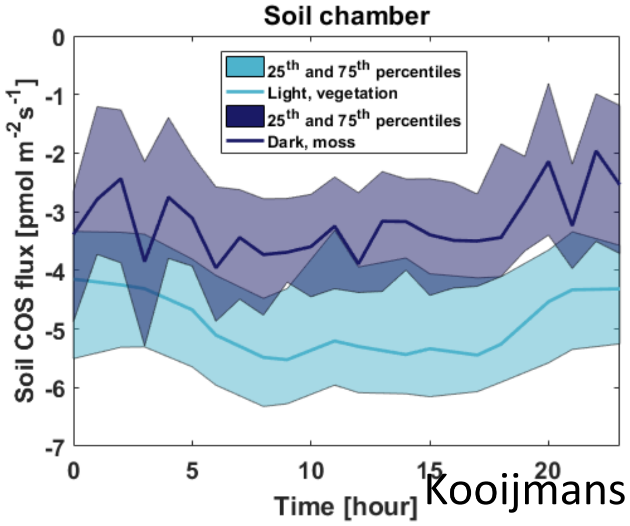
$$GPP = \frac{F_{COS}}{LRU}\frac{[CO_2]}{[COS]}$$

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



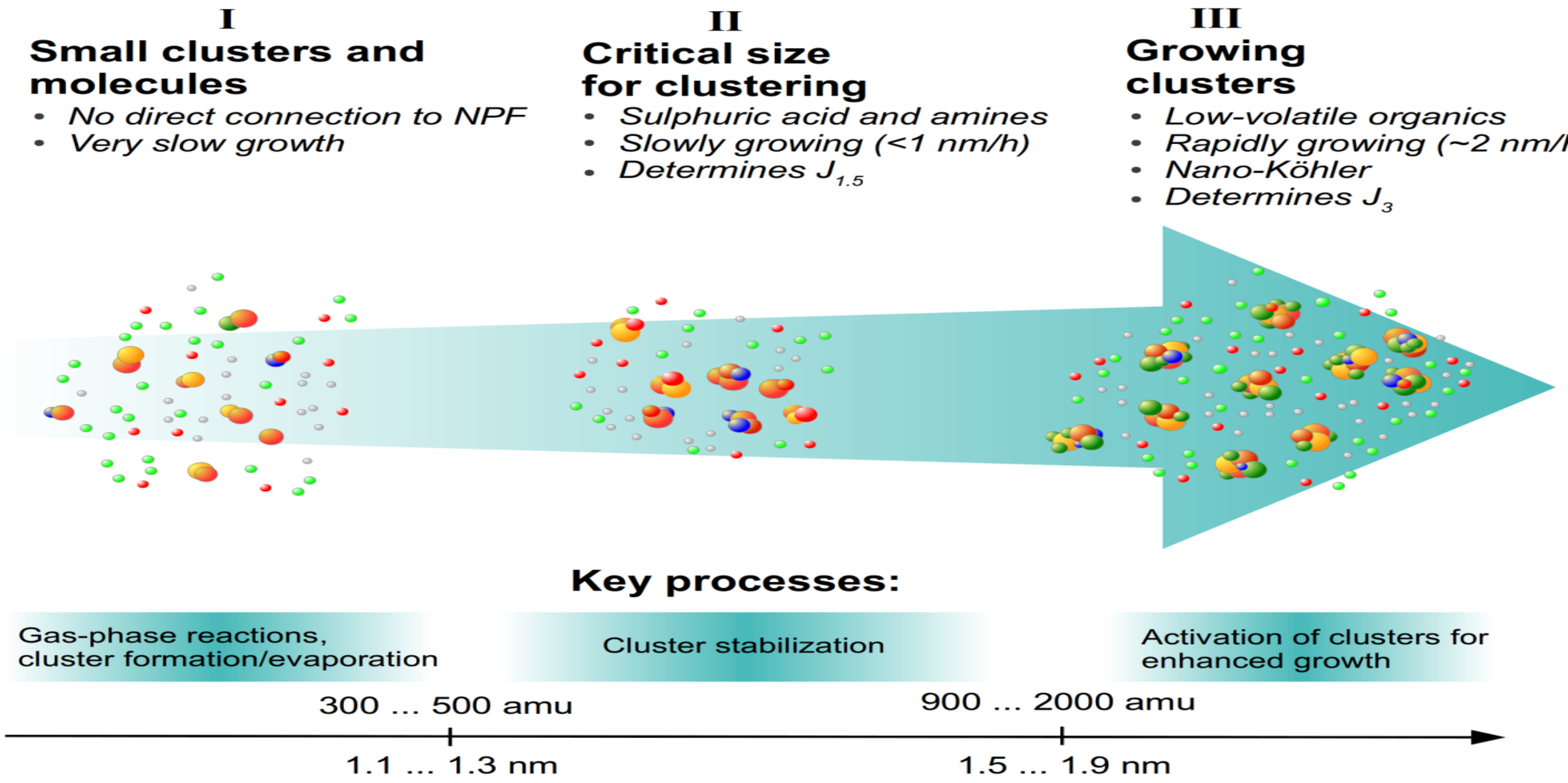




Kooijmans et al 2018, Erkkilä et al 2018

Processes

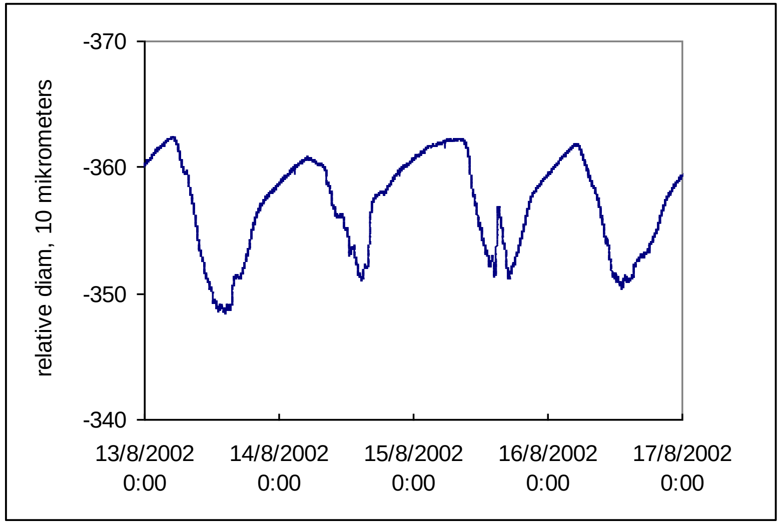
Atmospheric nucleation / clustering

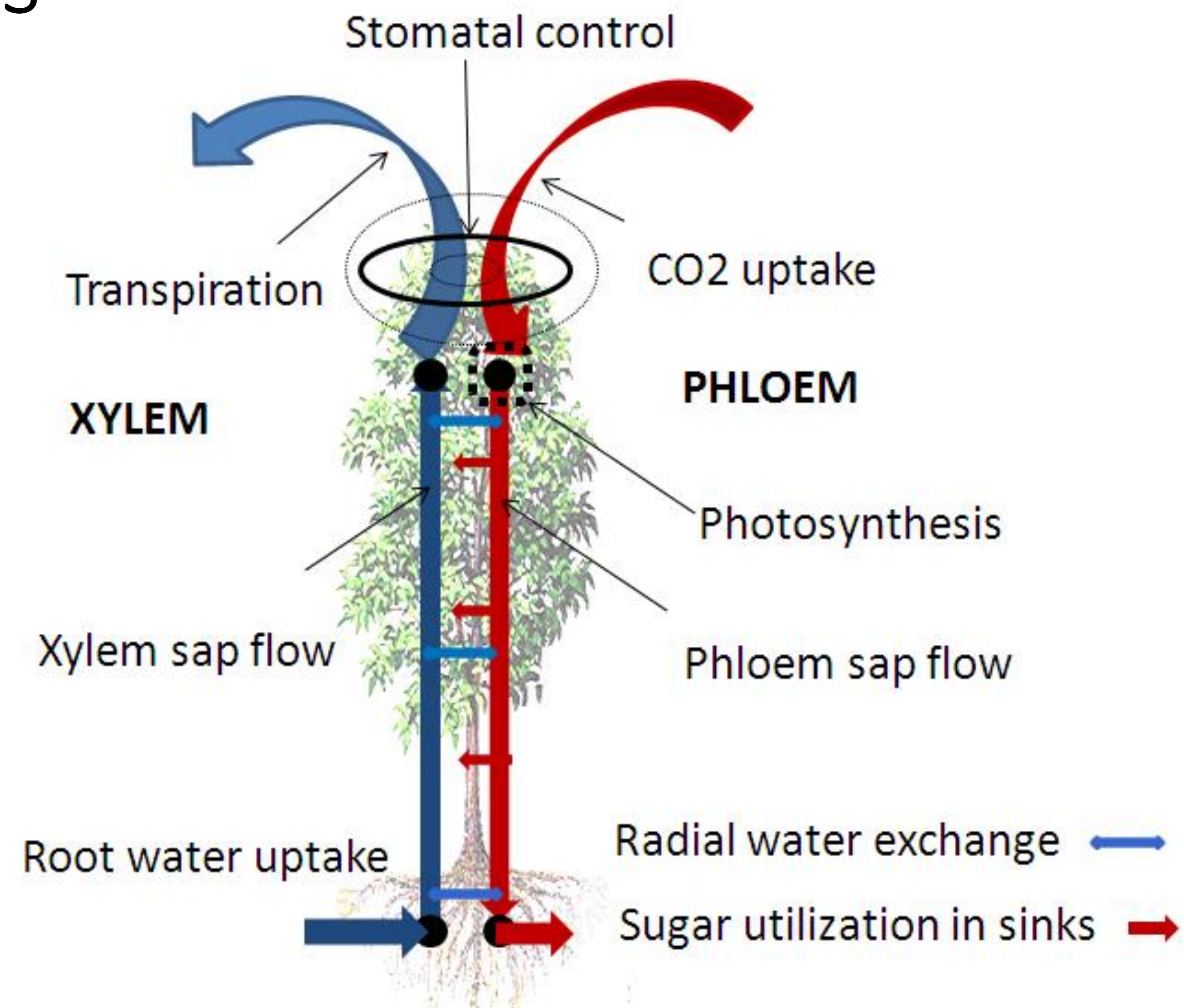


Kulmala et al., Science, 2013

Processes

Model-data linkages





Nikinmaa et al 2012, Hölttä et al 2016, 2018, Chan et al 2016, Dewar et al 2018

Experimentation

nature COMMUNICATIONS

Processes

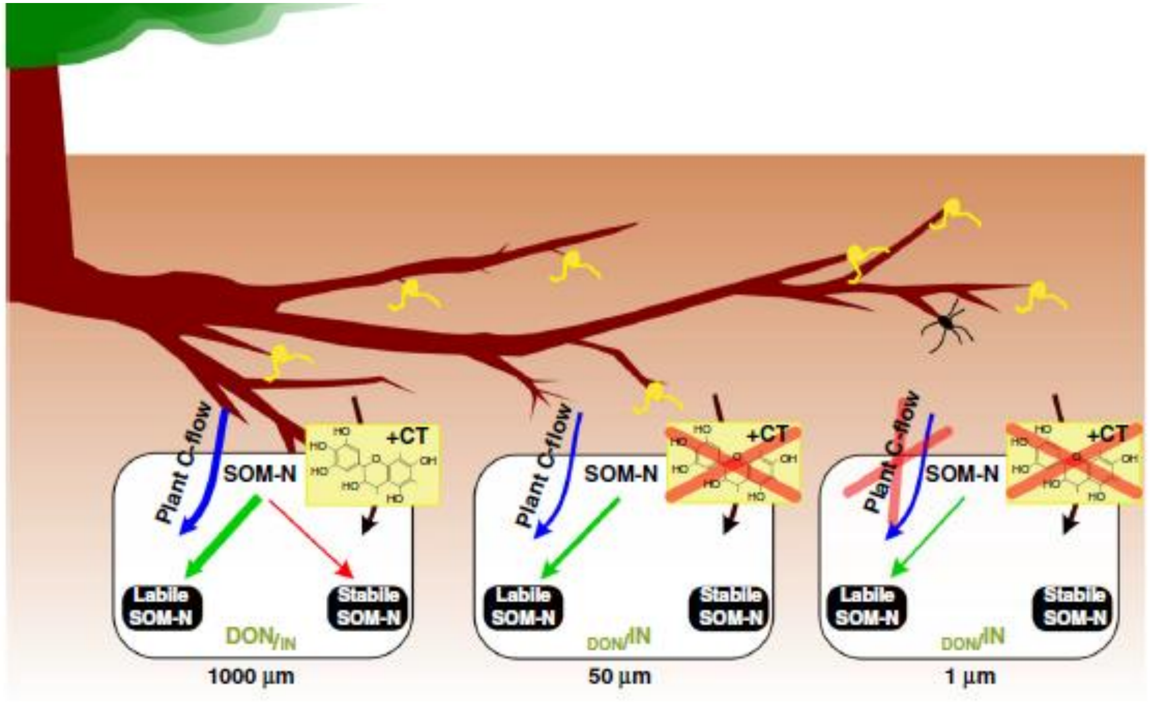
ARTICLE

https://doi.org/10.1038/s41467-019-11993-1 OPEN

Plant roots increase both decomposition and stable organic matter formation in boreal forest soil

Bartosz Adamczyk[1,2,3,4], Outi-Maaria Sietiö[2,3], Petra Straková[4,5], Judith Prommer[6], Birgit Wild[6,7,8,9], Marleena Hagner[10], Mari Pihlatie[1,2,11], Hannu Fritze[4], Andreas Richter[6] & Jussi Heinonsalo[1,2,3,12]

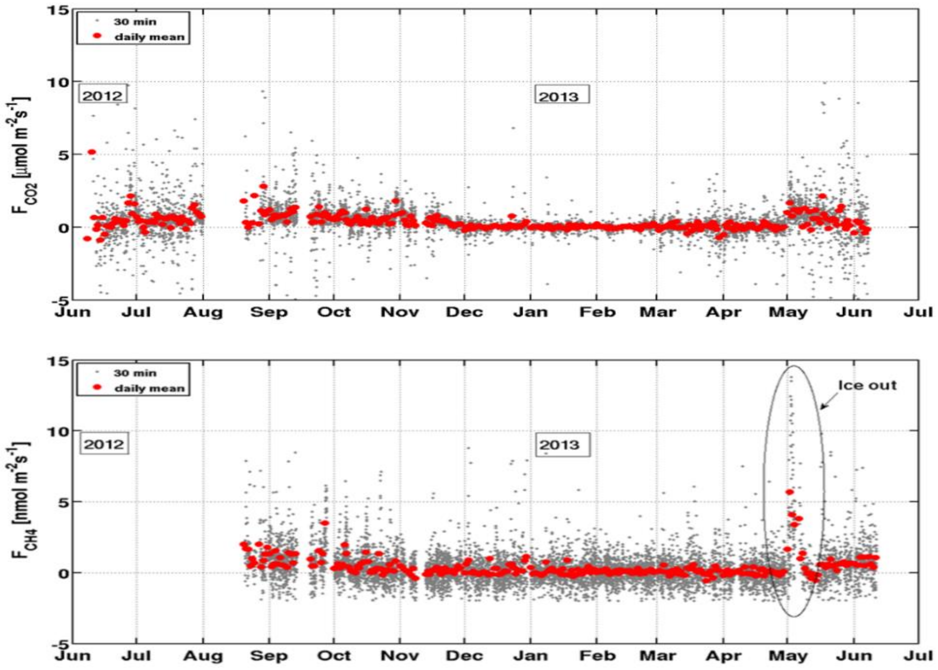
- Presence of roots accelerates decomposition and builds up a stable SOM-N pool
- Root exclusion leads to inorganic soil N economy, decreased decomposition rates and reduced stable SOM-N build-up

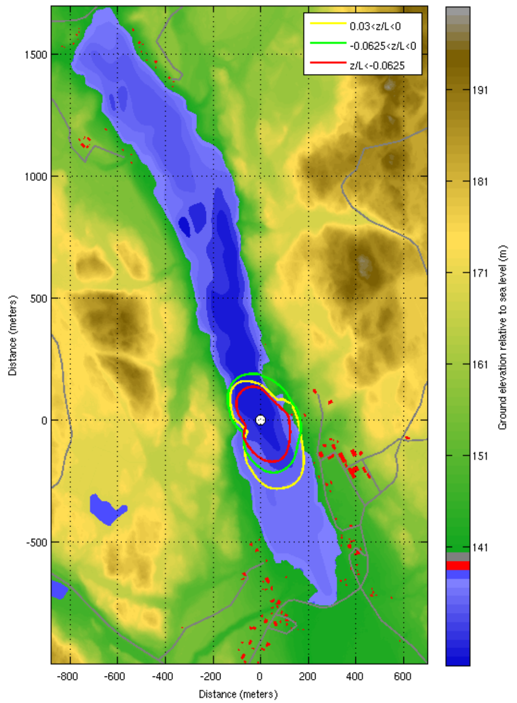


Adamczyck et al 2019

Lake Kuivajärvi-forest-wetland comparison of annual balances

Feedbacks





Longest flux data on the lake in the world

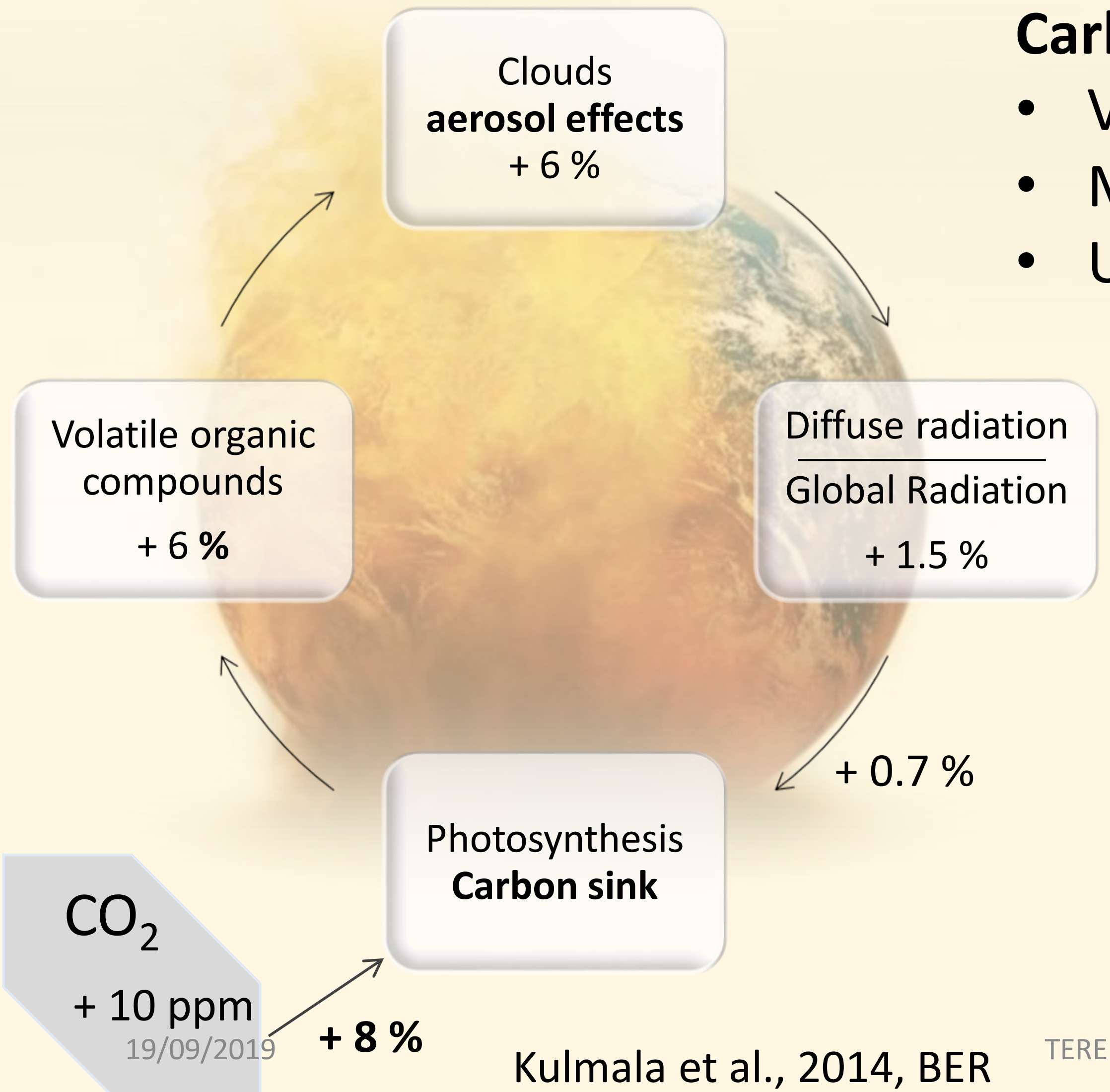
	Lake	Pine forest	Fen
CO2	**+116**	-280	-51
CH4	0.2	NA	10

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

(Mammarella et al., JGR)

THE potential of integration (SMEAR CONCEPT): GLOBAL COMPREHENSIVE FEEDBACK ANALYSIS

Feedbacks

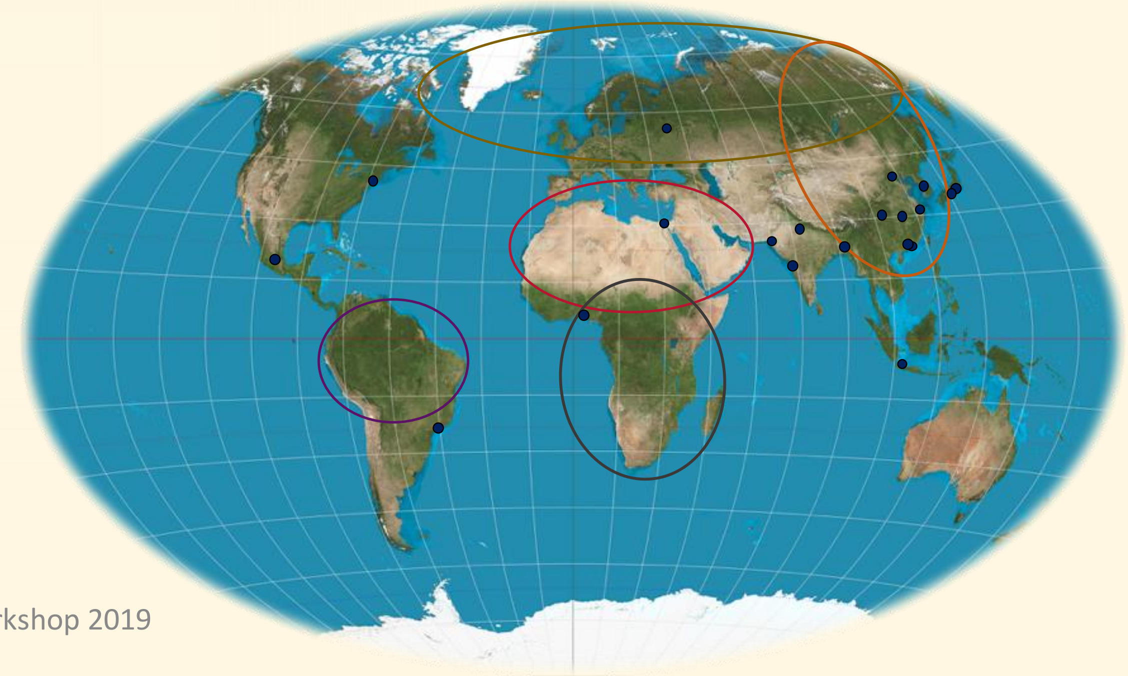


Kulmala et al., 2014, BER

CarbonSink+

- VOCs, Aerosols, clouds, precipitation
- Max 1.8 x carbon sink (Hyytiälä / SMEAR II results)
- Uncertainties

  => observations / models



Second, to foster creativity, we plan to support people who want to work in new areas — especially young researchers setting up their own labs. Most scientists do their most creative work at this early stage of their careers. But — understandably — it's often hard to obtain funding unless you can demonstrate expertise in a particular area. The Chan Zuckerberg Initiative could fill a niche by taking on more risks than other funders. That risk is worthwhile if it brings people into biomedical areas in which the need is great but current research is narrowly directed. Unfortunately, disease-relevant fields can be some of the hardest to break into for someone with a new idea or approach. Certain disease foundations, such as the Hereditary Disease Foundation for Huntington's disease or the Simons Foundation Autism Research Initiative, have done this well in the past. But we think that there is room to scale up this model to many other biomedical problems.

Finally, on openness. We believe that research advances when people build on each others' work. So our principles include making data, protocols, reagents and code freely available for other scientists to use. As an example of this approach, the HCA has committed to making its reference data publicly available after quality-control checks. Indeed, the Chan Zuckerberg Initiative engineering team and our HCA collaborators are building all of the software for the 'data coordination' arm of the project on the open-source platform Github.

We're also supporting external groups that share these values and goals. For instance, we're funding bioRxiv, the largest and fastest-growing preprint repository for the biological sciences — and a leader in bringing biology towards the level of sharing that's expected in the physical and computer sciences.

The Chan Zuckerberg Initiative is just starting, and we have a lot to learn. But I've been lucky to work in areas in which the free exchange of ideas and results is the norm. In my experience, such an approach creates the most dynamic fields. Now I have the chance to lead a new funding venture, and to explore whether openness or dynamism comes first. After all, as scientists we do experiments; as funders, we can do experiments too. ■

Cori Bargmann *is president of science at the Chan Zuckerberg Initiative in Palo Alto, California; and professor of genetics, neuroscience and behaviour at the Rockefeller University, New York, USA.*
e-mail: science@chanzuckerberg.com

JUHO AALTO

An enclosure for measuring gas exchange between plants and the atmosphere at a station in Finland.

Build a global Earth observatory

Markku Kulmala calls for continuous, comprehensive monitoring of interactions between the planet's surface and atmosphere.

Climate change. Water and food security. Urban air pollution. These environmental grand challenges are all linked, yet each is studied separately.

Interactions between Earth's surface and the atmosphere influence climate, air quality and water cycles. Changes in one affect the others. For example, increasing carbon dioxide enhances photosynthesis. As they grow, plants withdraw greenhouse gases from the atmosphere, but they also release volatile organic compounds such as monoterpenes. These speed up the formation of aerosol particles, which reflect sunlight back into space. Our actions — such as emission-control policies, urbanization and forestry — also affect the atmosphere, land and seas[1–5].

Satellites and stations on the ground track greenhouse gases, ecosystem responses, particulate matter or ozone independently of each other. Coupled observations are occasionally performed, but in intensive bouts. Vast areas of the globe — including Africa, eastern Eurasia and South America — are barely sampled.

The result is a cacophony of information that yields little insight. It is like trying to forecast weather in November with spotty measurements of rain, wind, temperature or pressure from June.

The answer is a global Earth observatory — 1,000 or more well-equipped ground stations around the world that track environments and key ecosystems fully and continuously. Data from these stations would be linked to data from satellite-based remote sensing, laboratory experiments and computer models.

Researchers could find new mechanisms and feedback loops[6] in this coherent data set. Policymakers could test policies and their impacts. Companies could develop environmental services. Early warnings could be provided for extreme weather, and quick responses initiated during and just after chemical accidents.

A global observatory has been discussed for more than a decade, but is only now feasible[7]. Instruments have matured; for example, today's mass spectrometers ▶

Needed: A Global Earth Observatory and hierarchical in-situ station network as proposed by eLTER

1. Flagship sites

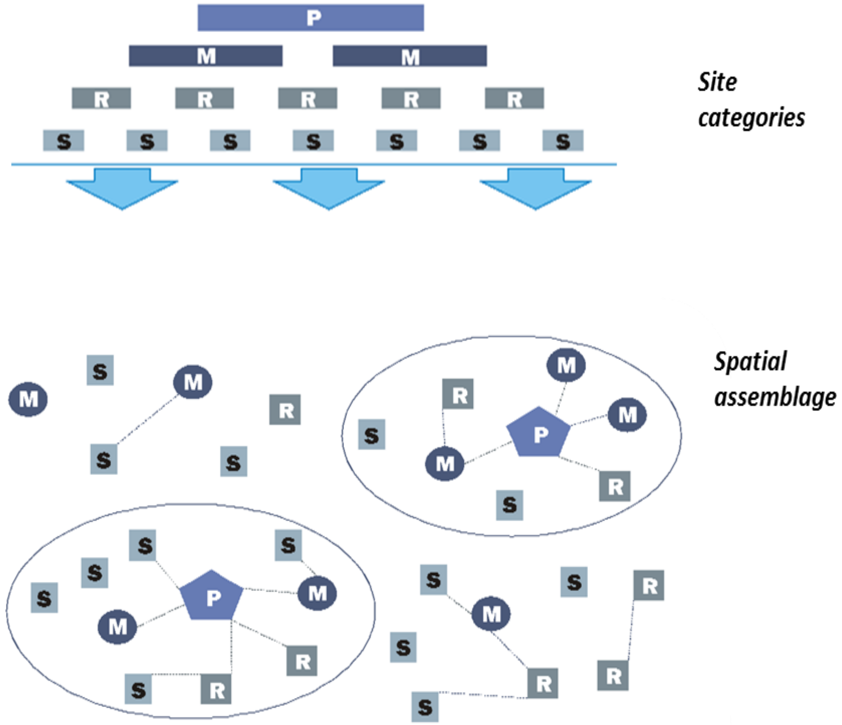
- comprehensive measurement strategy in different domains, co-location
- process studies, experimentation, long-term observations
- high cost, extensive services
- E.g. SMEAR, TERENO

2. Advanced sites

- E.g. Fluxnet, LTER regular, GAW stations
- average cost, comprehensive in some measurement type or services

3. Basic sites

- e.g. weather stations, ICP –Forest-Waters-IM sites
- low cost, providing ‘background’ data



❑ Hierarchical network is able to tackle problems related to large spatial scales, heterogeneity of ecosystems and their complexity in landscape

❑ A dense network of the Advanced and Basic stations allows application and up-scaling of the results obtained from Flagship stations to the global level

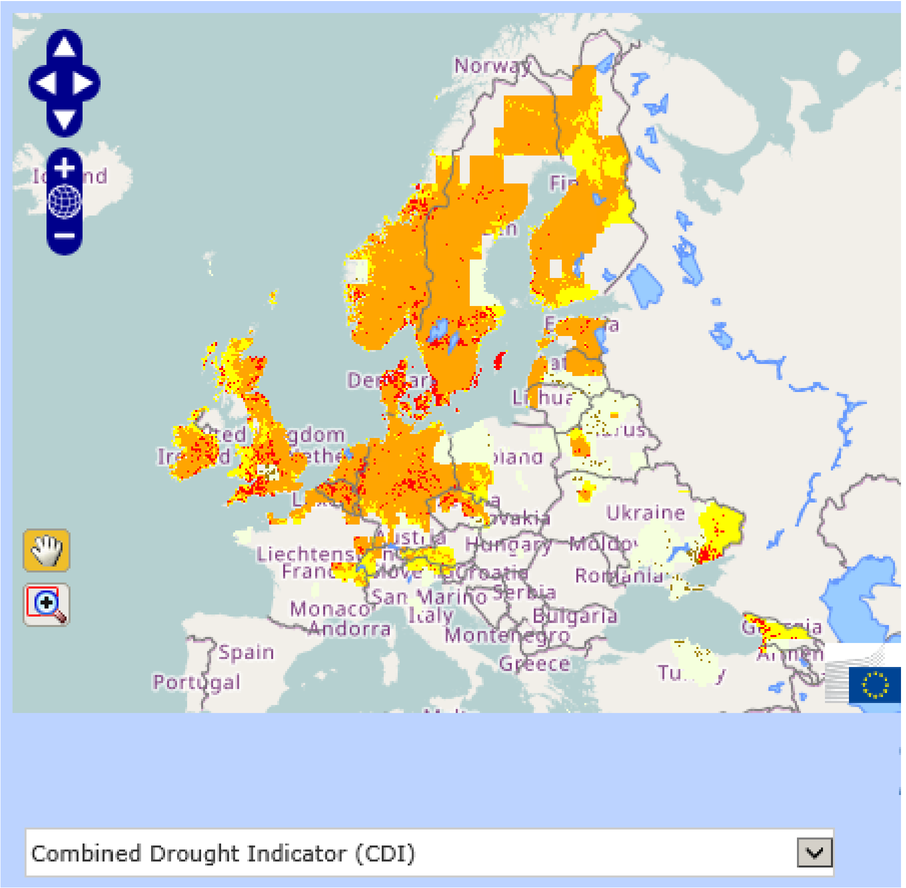
❑ Co-location of RI’s in advanced and flagship sites crucial to provide enough integration!

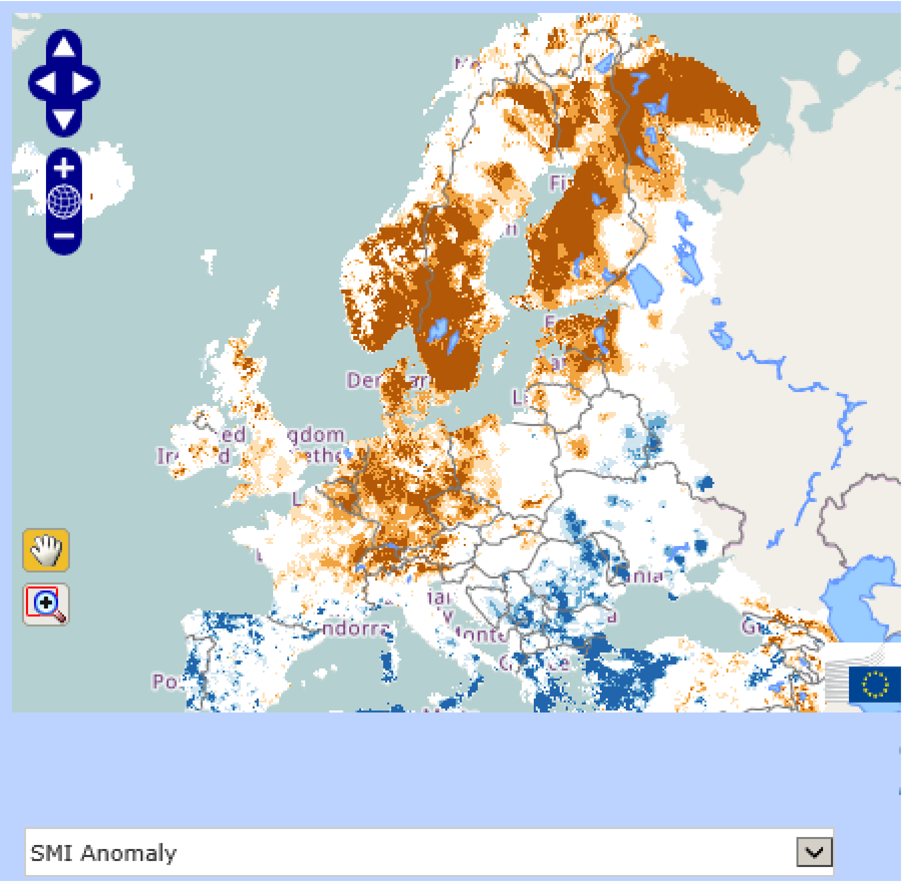
eLTER Research Infrastructure

Autumn school 2018: addressing the droughts as example of a data integration

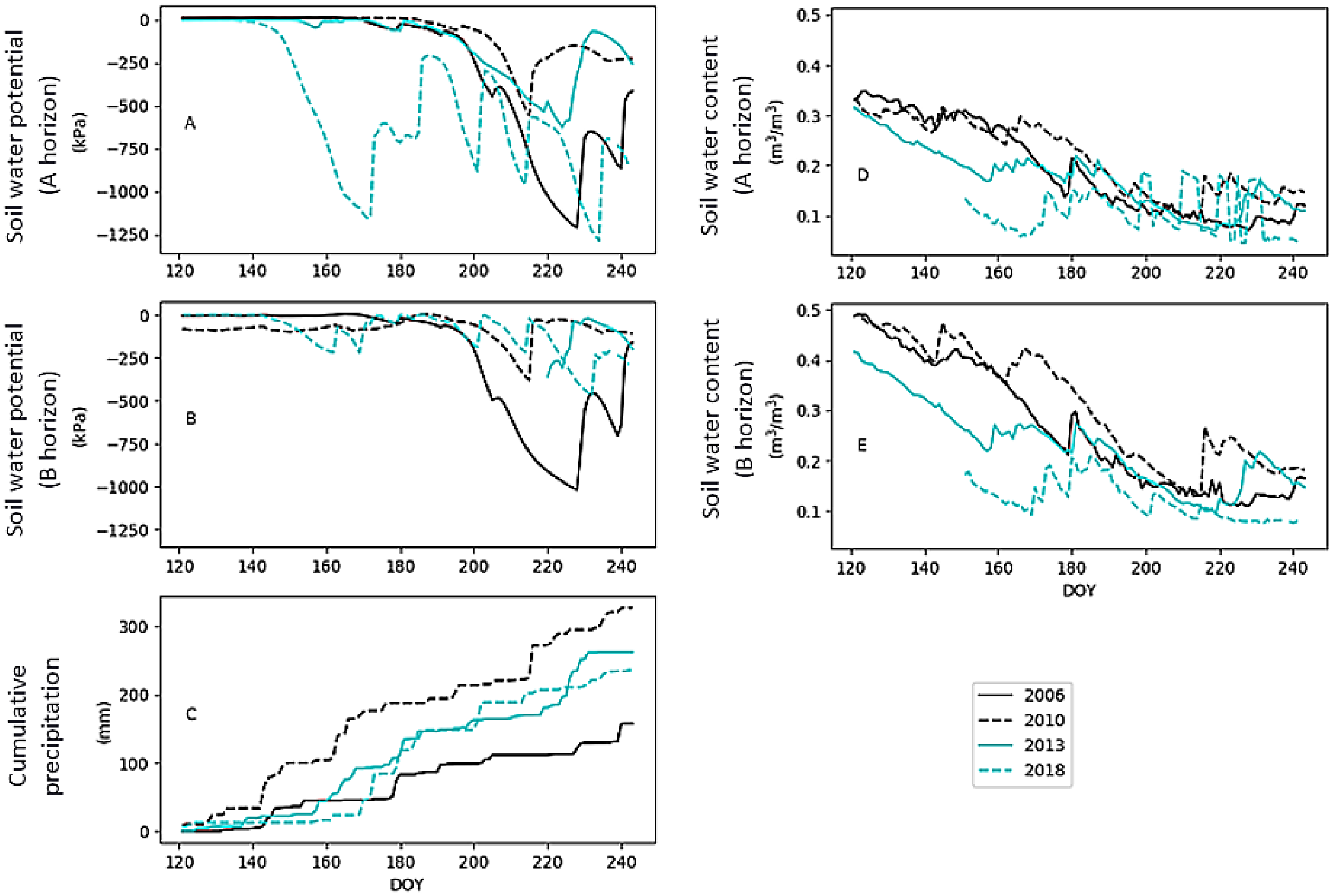
Drought

The 2018 summer drought in Europe; maps from August 2018 (source: European Drought Observatory)



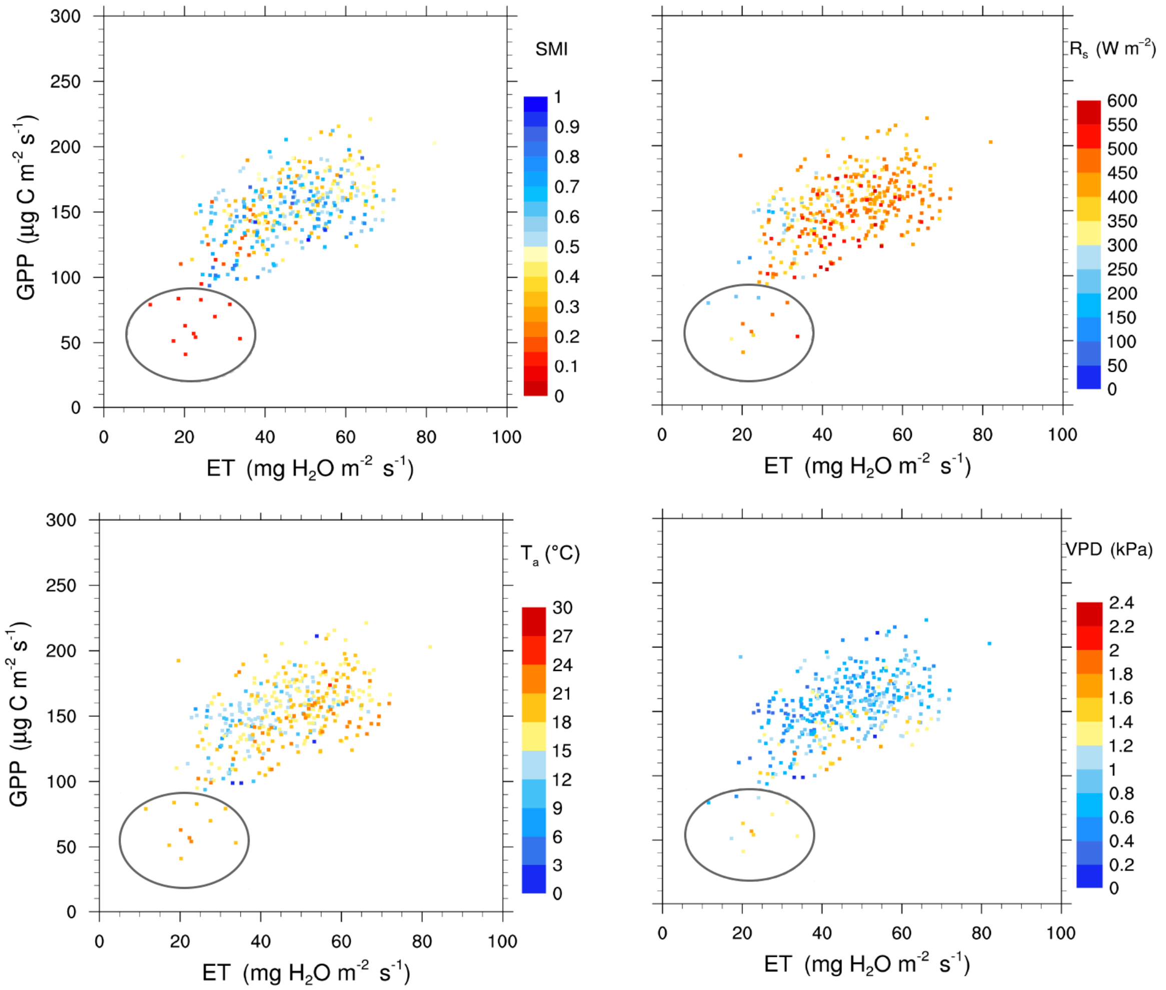


Soil water potential



Unpublished results

Daytime averaged GPP and evapotranspiration 1999-2009



Gao et al 2017