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Soil-vegetation-atmosphere (SVAT) models for estimating climate change effects on boreal ecosystems

Tuula Aalto (FMI), Leif Backman (FMI), Yao Gao (FMI), Tiina Markkanen (FMI), Francesco Minunno (UHEL), Annikki Mäkelä (UHEL), Jarmo Mäkelä (FMI), Mikko Peltoniemi (LUKE), Maarit Raivonen (UHEL), Jouni Susiluoto (FMI), Tea Thum (FMI)
+ Data experts from SYKE, LUKE, UHEL and FMI

- **Aim:** To produce reliable estimates of northern land ecosystem responses to environmental drivers in the current climate and for use in future climate projections

- **Methods:** Apply two up-to-date SVAT models, calibrated using in situ and EO data on boreal ecosystem seasonal dynamics, forest carbon exchange, hydrology, soil carbon and wetlands

LifeMonimet LIFE12 ENV/FI/000409
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SYKE
HELSINGIN YLIOPISTO HELSINGFORS UNIVERSITET UNIVERSITY OF HELSINKI
Life

Models

Meteorological variables
- Time resolution 1 hour – 1 day
- CO2 concentration, SW and LW radiation, wind speed, precipitation, air temperature, pressure and humidity

Vegetation and soil properties
- E.g. plant functional type, leaf area, cover fraction, soil type, field capacity

SVAT model

Carbon fluxes and storages (soil and biomass)

Energy fluxes

Water fluxes and storages (incl. snow)

JSBACH

Land ecosystem model

Carbon and energy balances of the whole landscape

Dynamic or prescribed vegetation

PREBAS

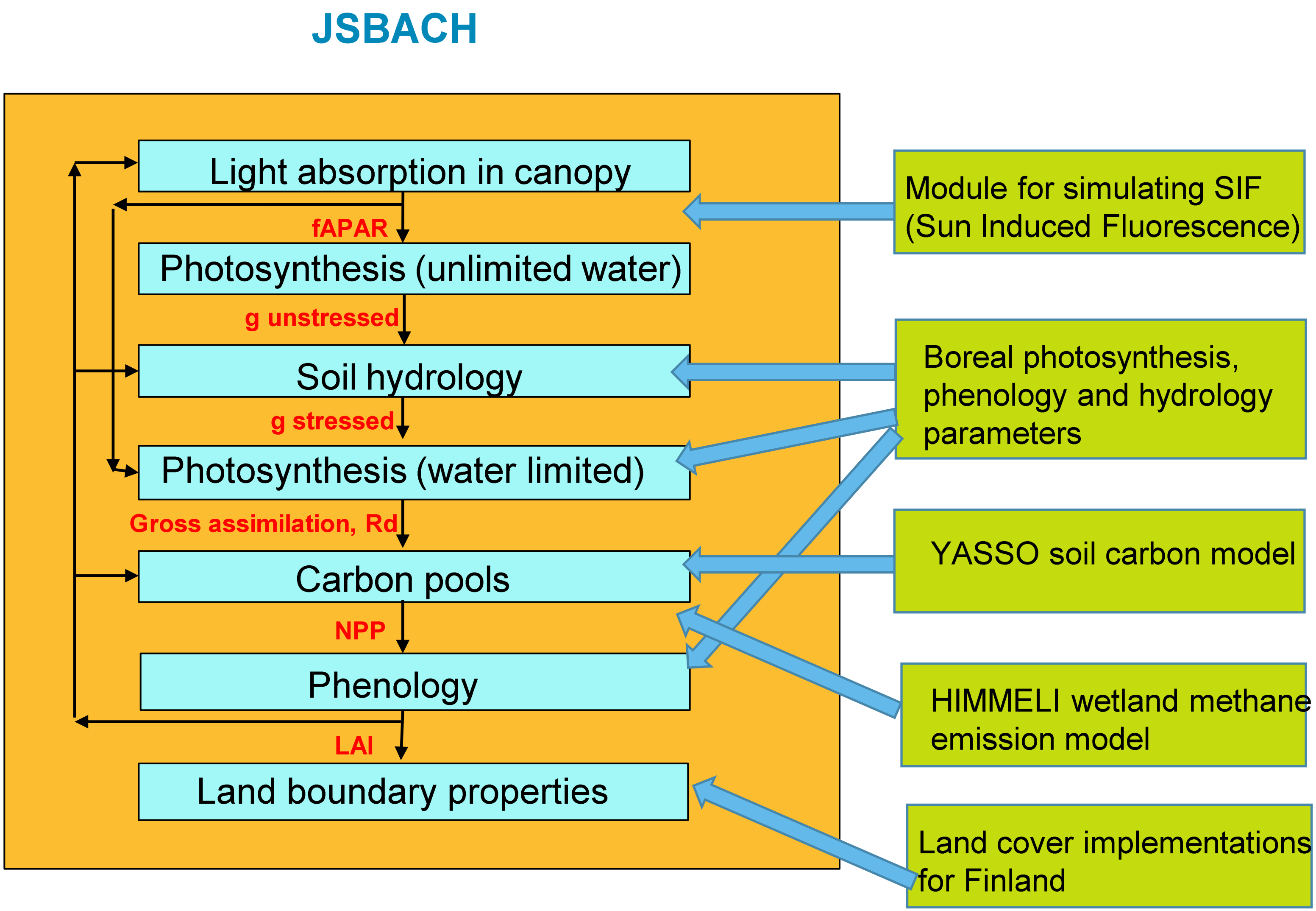
Semi-empirical stand flux model

Canopy values from stand properties.

Stand growth model based on carbon acquisition and allocation in trees.

Both use the Finnish soil carbon model YASSO

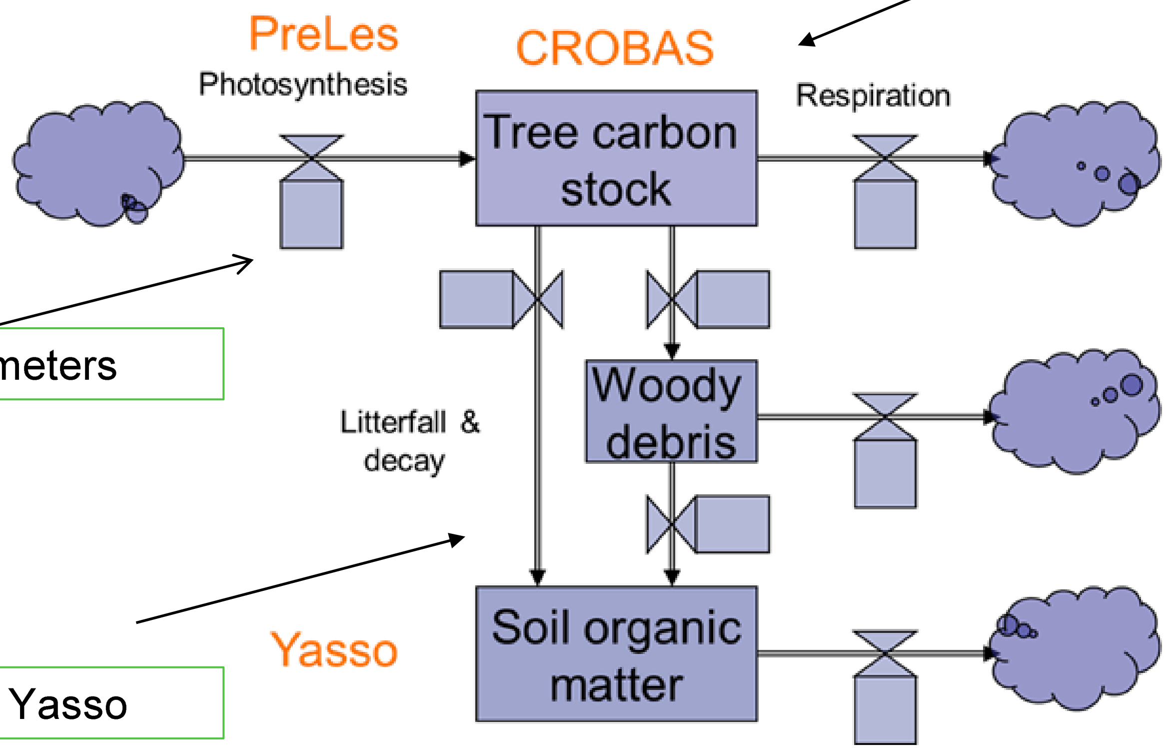
Model developments



Model developments

PREBAS

Full parameterisation



Boreal parameters

Linkage with Yasso

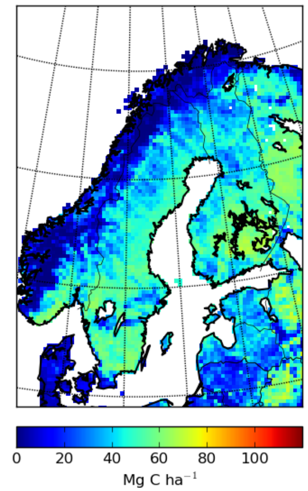
Forest management

Results / JSBACH

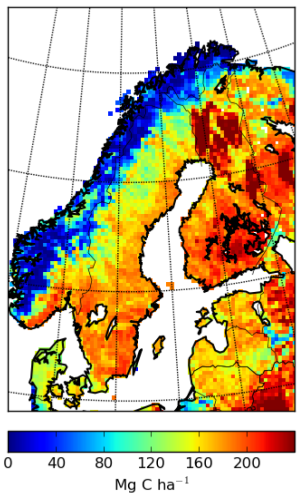
- New soil hydrology scheme: Improved soil moisture and evapotranspiration -> implications for e.g. drought & run-offs
- New soil carbon module Yasso: Improved soil carbon content estimates -> implications for soil respiration
- New methane module HIMMELI -> Enables estimates of wetland methane emissions
- Boreal forest parameter optimisation using flux data: Improved gross primary production and evapotranspiration -> implications for CO_2 uptake and drought
- Forest seasonality: New model descriptions and parameter optimisation using flux and EO data -> implications to vegetation active period and CO_2 balance

Results / JSBACH

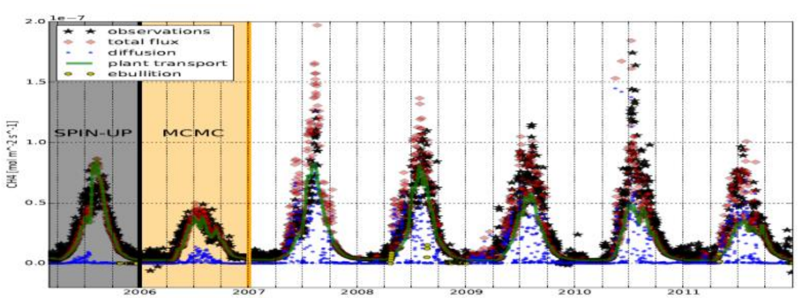
Soil C pools (Mg(C)/ha)	Cbalance	Yasso
North	181	33
Middle	202	44
South	199	52



YASSO



CBALANCE

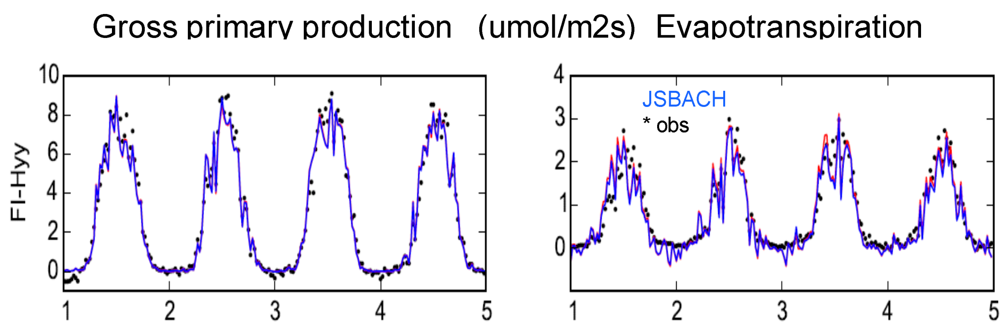


Siikaneva CH_4 fluxes

CH4 emission (gCH4/m2/yr)	Default parameters	Optimised parameters (Siikaneva)	Flux observa tions
Siikaneva 2005-2011	11.9	12.6	12.4
Lompolojänkkä 2006-2010	44.0	34.8	27.3

Susiluoto et al., GMDD 2017, Raivonen et al., GMDD 2017

Results / JSBACH



Model parameter optimisation with Bayesian methods using GPP and ET from boreal sites:

CA - QUEBEC
CA – SASKATCHEWAN S
FI – HYYTIÄLÄ
FI - KENTTÄROVA
FI - SODANKYLÄ
RU – FYODOROVSKOYE
CA – SASKATCHEWAN P
US – POKER FLAT
FI – LETTOSUO
RU – ZOTINO

CAL

VAL

	GPP				ET			
	multi-site		site-specific		multi-site		site-specific	
	R^2	slope	R^2	slope	R^2	slope	R^2	slope
CA-Sas	0.83	1.11	0.83	0.96	0.52	0.73	0.52	0.69
CA-Que	0.75	0.81	0.74	0.87	0.49	0.61	0.49	0.67
FI-Hyy	0.83	0.95	0.83	0.95	0.53	0.65	0.53	0.70
FI-Ken	0.78	0.82	0.79	0.9	0.4	0.64	0.45	0.57
FI-Sod	0.83	1.11	0.83	0.96	0.52	0.73	0.52	0.69
RU- Fyo	0.75	0.81	0.74	0.87	0.49	0.61	0.49	0.67

Mäkelä et al., NPG 2016, Gao et al., HESS 2016

Seasonality

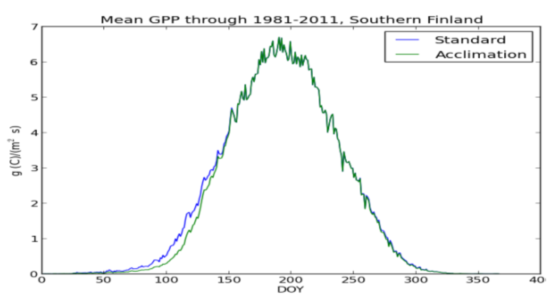
Model calibrations:

- Phenology parameter optimisation:
  - Coniferous forest from the Bayesian approach utilising flux data
  - Deciduous forest from EO data (tuning threshold temperature of budburst)

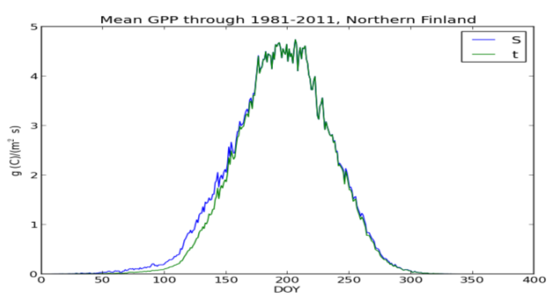
Böttcher et al., RS 2016

- Parametrisation for state of acclimation (S):
  - Drawdown of carbon uptake after cold spells, applied in the model via temperature memory effect

Southern Finland



Northern Finland



30-yr average daily GPP over the calendar year
for standard JSBACH and JSBACH with S

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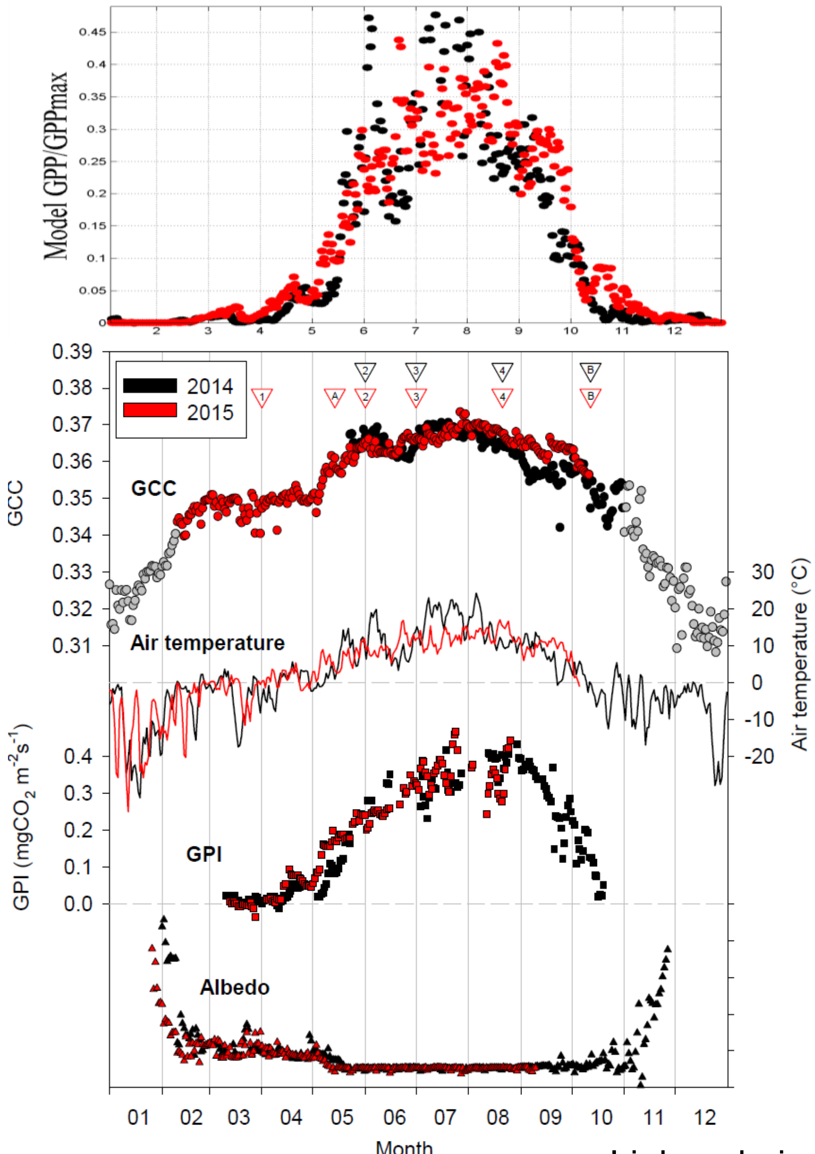
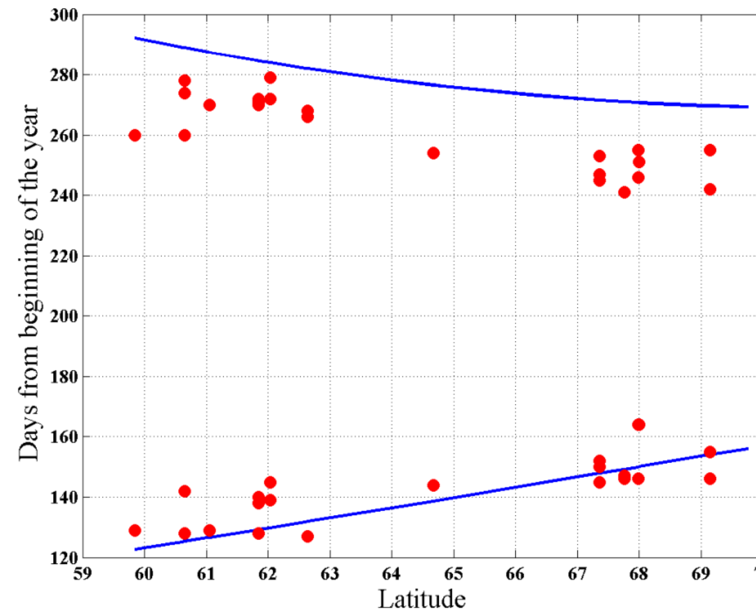
Seasonality: Webcams

Sodankylä





Linkosalmi et al GI 2016

Start and end of season

- JSBACH
- Webcam birch observations, years 2014 – 2016

Results / PREBAS

- New calibration of PRELES using flux data: Improved gross primary production and evapotranspiration -> implications for CO_2 uptake and water balance

- New forest growth and carbon allocation CROBAS: Enables estimates of forest growth

- New soil carbon module Yasso: Enables estimates of soil carbon content -> implications for soil respiration

- Calibration of PREBAS using data from Norway spruce, Scots pine and Silver birch Finnish forest: -> Improved estimates of CO_2 uptake, forest development and carbon balance

- Implementation of management practices: -> implications for CO_2 uptake and soil carbon balance

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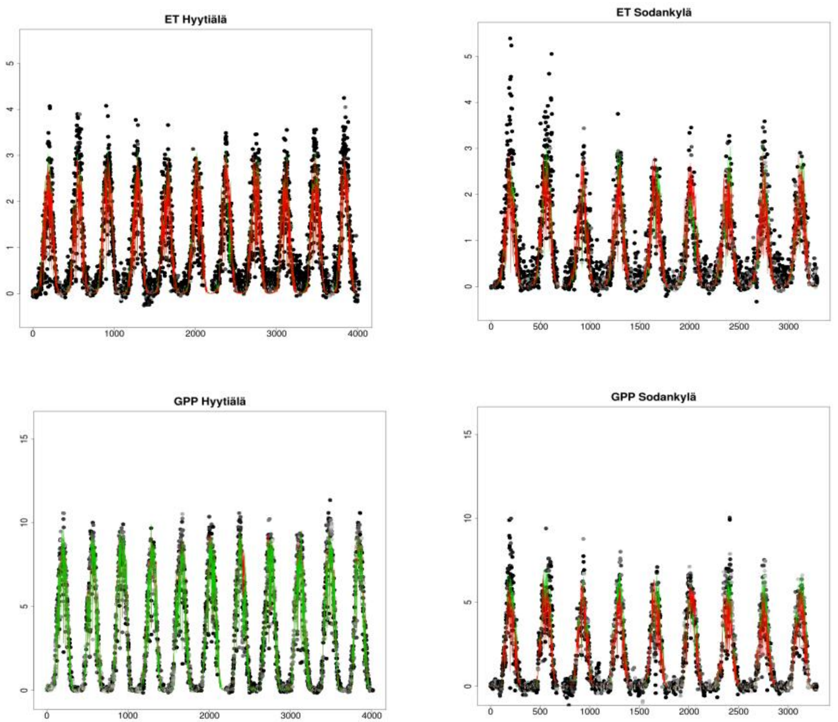
Results / PREBAS

Site specific vs multi-site calibration
Improving CO2 uptake estimates at regional scale

Model – data mismatch

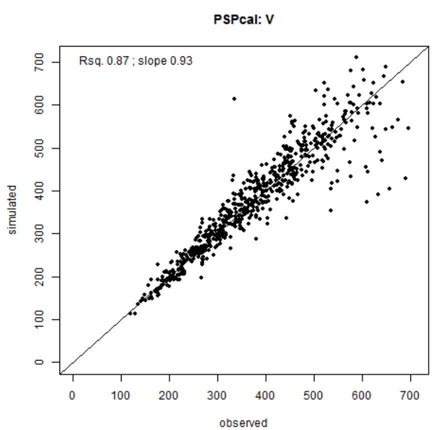
	ET				GPP			
	Multi-site		Site-specific		Multi-site		Site-specific	
	R2	Slope	R2	Slope	R2	slope	R2	slope
Hyytiälä	0.88	0.90	0.89	0.91	0.95	0.97	0.96	0.96
Sodankylä	0.75	0.78	0.80	0.81	0.89	0.81	0.91	0.89
Alkkia	0.83	**0.63**	0.85	0.88	0.89	0.78	0.89	0.88
Kalevansuo	0.91	0.88	0.91	0.89	0.95	0.96	0.95	0.96
CarboAge 12yr	0.71	0.78	0.75	0.71	0.72	0.74	0.84	0.87
CarboAge 75yr	0.88	0.81	0.92	0.89	0.93	1.06	0.95	0.98
Skyttorp	0.72	0.85	0.72	0.80	0.81	0.84	0.81	0.86
Flakaliden	**0.69**	0.86	0.72	0.79	**0.62**	0.76	**0.67**	**0.60**
Skattasen	0.89	0.73	0.90	0.88	0.91	0.78	0.91	0.92
Norunda	0.81	0.88	0.85	0.86	0.90	0.99	0.90	0.92

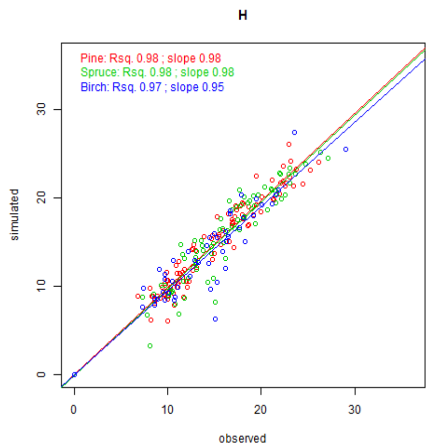


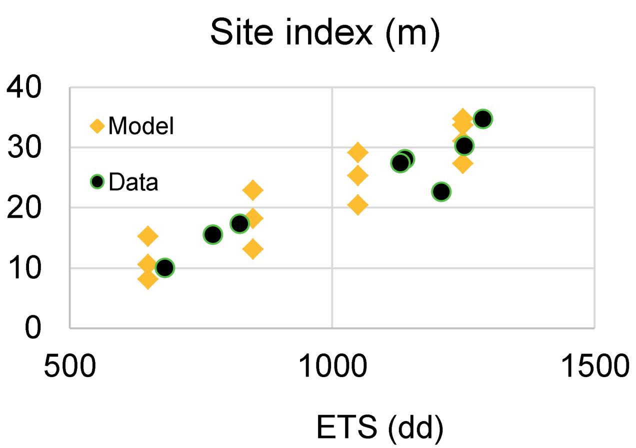
Minunno et al., EM 2016

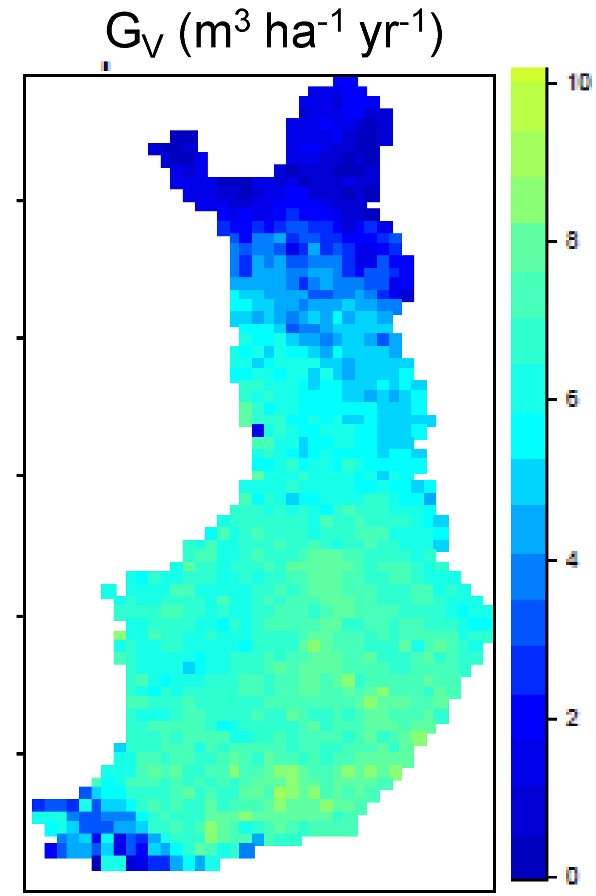
Results / PREBAS

CROBAS calibration for forest stands in Finland
Estimating forest growth and forest carbon stocks









Results of stem growth correspond to statistics

- Mäkelä et al. 2016 FORECO

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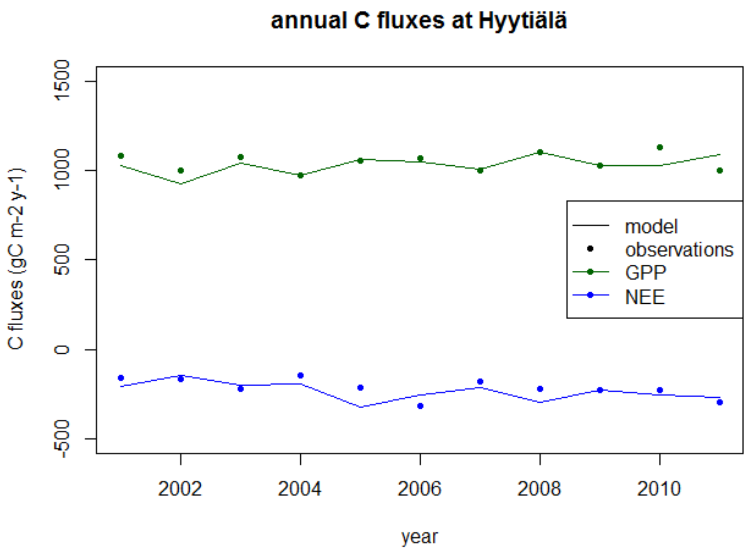
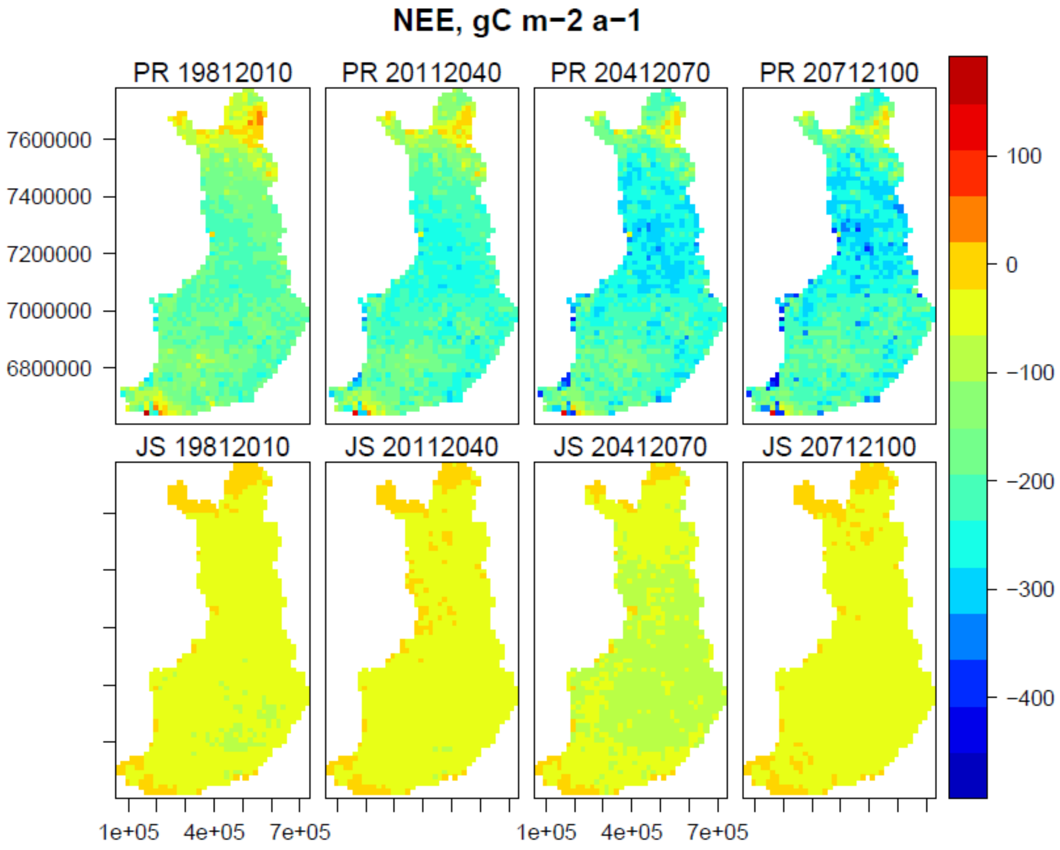
Results / PREBAS

NEE in Finland





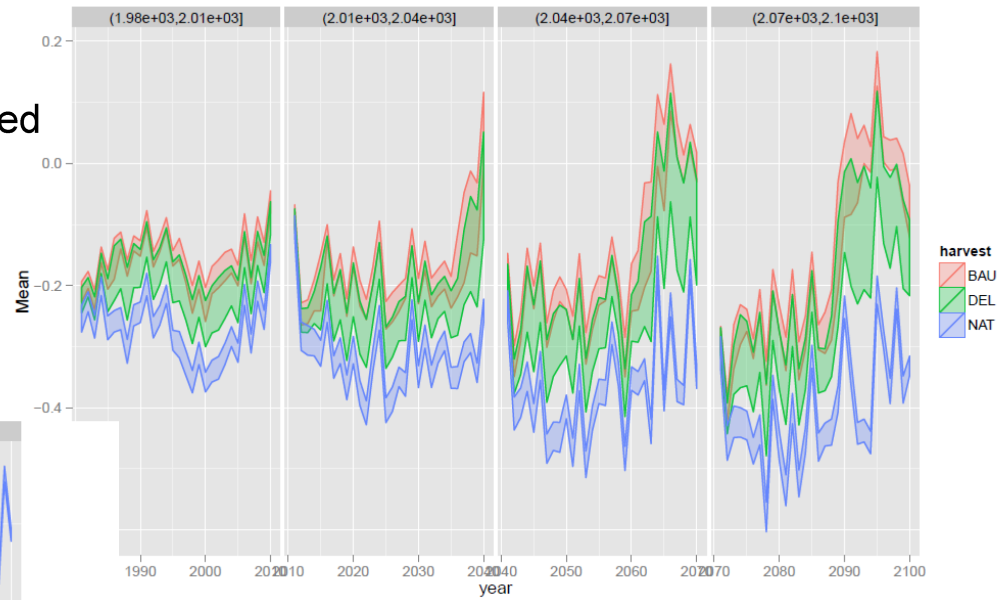
Thanks to the YASSO module We were able to complete the carbon balance and estimating NEE and soil C

Results / PREBAS

The impact of management roules on the carbon balance of forests

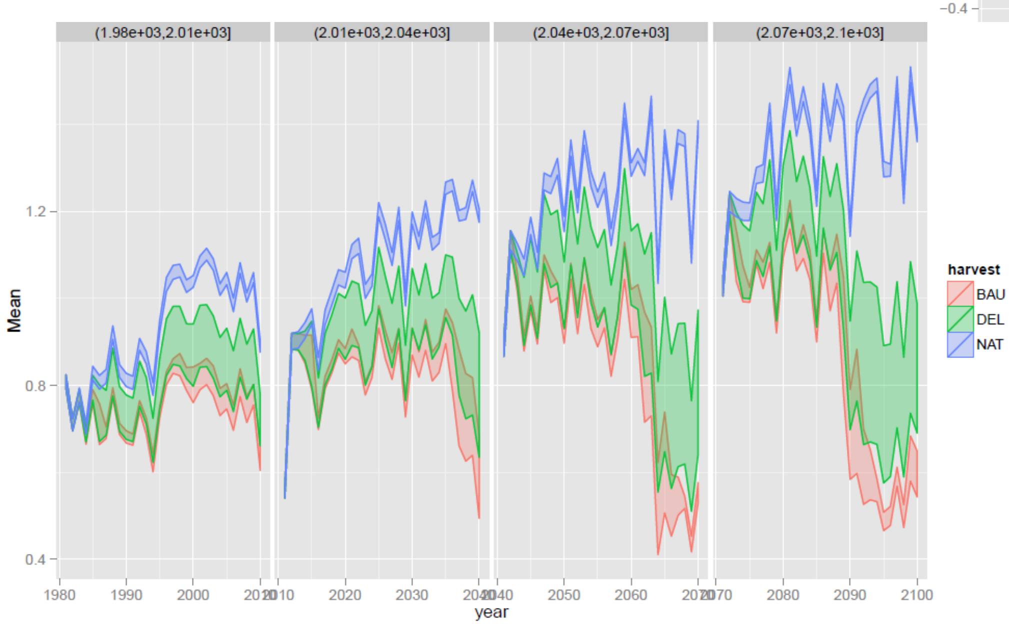
Harvest scenarios/rules/assumptions:

- BAU, harvest @ dbh 24-30 & Age 60-100
- DEL: Aims at near term C sink increase: Increased harvest dbh (@36cm @30% prob)
- NAT: Reference, no harvests



NEE

GPP



Conclusions

- New model components, parametrisations and optimised parameter values were applied to two SVAT models, JSBACH and PREBAS
- Using the calibrated models, we are able to better estimate the northern land ecosystem responses to environmental drivers and different management routines (PREBAS)
- Work needs to be continued regarding e.g. vegetation phenology, non-forest PFTs (e.g. crops, wetland vegetation), peatland hydrology, peat accumulation, methane emissions and respiration components
- The calibrated models were used in future predictions and their uncertainty estimates –> coming next