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Preliminary methodology report

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LIFE+ PROJECT NAME or Acronym

Climate change indicators and vulnerability of boreal zone applying innovative observation and modelling techniques

Data Project

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1. Methodology on JSBACH Model

The soil component is important in modeling energy, water and carbon balances as it regulates the water reservoir essential for optimal plant functioning, as well as a large carbon storage responsible for the majority of respiration flux to the atmosphere. Furthermore, properties of soil properties influence the surface conditions like length of snow period and droughts. Traditionally models have used a 1 layer ‘bucket’ model for soil water whereas novel descriptions include several layers. There, for example, the soil moisture content is expressed as a profile instead of single value, enabling sophisticated descriptions of e.g. water levels in soil and freezing of soil layers. We have already taken into use and is currently testing a new 5-layer soil module in JSBACH model replacing the old 1 layer module. The model results have been compared to latent heat flux observations at Sodankylä (fig. 1). The new module is able to produce more realistically the annual cycle of evapotranspiration. Further testing including implementation of Finland validated distribution of soil property values for peatlands and mineral soils (field capacities, porosities etc.), and checking the status of soil variables is taking place. Further, regional evaporation and transpiration rates will be studied and transpiration results will be connected to CO2 uptake, enabling investigation of regional water use efficiency (WUE) values. Regulation of CO2 uptake by loss of water through stomata and available soil water and their practical implementation in models is still an open issue. Here, schemes including different conductance formulations will be experimented and results will be compared to flux observations.

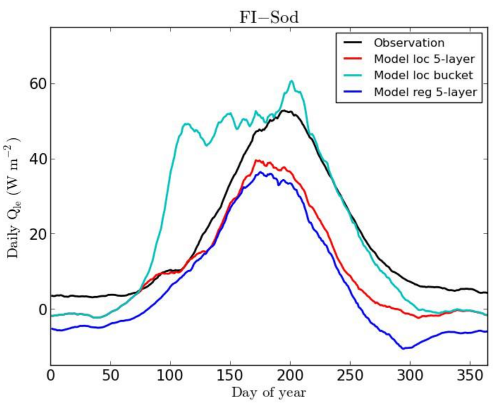

Fig. 1. Latent heat flux at Sodankylä, averaged over years 2001-2008, with the so-called bucket model and 5-layer model.

JSBACH includes two options for soil carbon modules, new YASSO with six carbon pools: four fast decomposing pools separated according to solubility of decomposing material, one pool for slowly decomposing coarse woody litter and one very slow pool for humus, and old CBALANCE with two pools for fast and slow decomposition rates. CBALANCE was used for example in previous SNOWCARBO Life+ project. New YASSO version has now been taken into use and the results will be compared to old CBALANCE module at local and regional level and against empirical evidence on soil carbon content. Preliminary results are shown in Fig. 2 for Sodankylä. According to earlier global scale studies, YASSO releases more carbon into atmosphere and has smaller carbon storages in soil, which globally is better in line with observations (Thum et al., 2011).

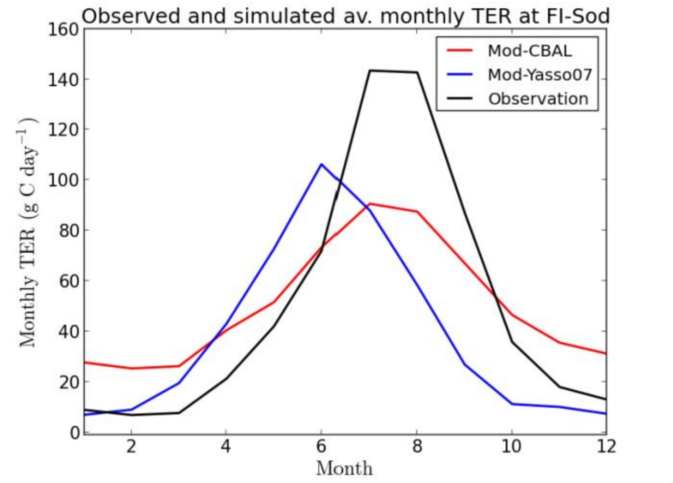

Fig. 2. Annual monthly cycle of Total Ecosystem Respiration (TER) averaged for years 2001-2008 at Sodankylä in: observation (in black), CBALANCE original version (in blue) and Yasso07 (in blue). TER includes heterotrophic (same as variable 'soil respiration' is JSBACH model) and autotrophic respiration.

2. Parameterization of JSBACH model

It is important to obtain information of which model parameters can be constrained by observations, what are their most probable values in local and regional scales, and which parameters are in key position regarding the carbon and water balance uncertainty estimations. We have initialized JSBACH hydrological parameter estimation using statistical Monte Carlo (MC) methods. The first step is to implement a computing scheme for MC simulation runs, and then optimize a parameter set against Hyytiälä latent heat flux data. The first trial set will include mainly soil parameters. Currently JSBACH can produce estimates of the annual cycle of leaf area index (LAI). Alternatively, the maximum LAI value or full LAI annual cycle can be assimilated from an independent data source. The option to assimilate remotely sensed LAI for model use will be examined, as well as optimizing the phenology parameters producing the annual development of LAI in JSBACH. Further, if the LAI constraint is not sufficient, assimilation of soil moisture observations to JSBACH will be investigated. The parameter optimization exercise will be broadened to multiple sites and regional scales, where possibility to use river run-offs as diagnostic variable will be investigated.

Time series of webcam images will be examined and their potential in calibrating the model phenology parameters will be studied. The images show onset of spring through greening of the landscape as well as close up imaging of bud burst and shoot growth. Discoloration and shedding of the leaves during autumn will as well be detected. The potential of calibrating both coniferous and deciduous canopy, as well as understory vegetation phenological descriptions will be investigated. The seasonality of photosynthesis parameters will be implemented by using empirical relations between chlorophyll fluorescence and temperature. Series of manual active fluorescence (Fv/Fm) measurements has already been made at Sodankylä pine forest during several growing seasons, and the results show a clear seasonal variation in Fv/Fm signal (Fig. 3) and response to e.g. night frosts. The results will be used in building a relationship between temperature and Fv/Fm and it will be further utilized in improving the temperature dependence of model photosynthesis parameter Vcmax during cold stress.

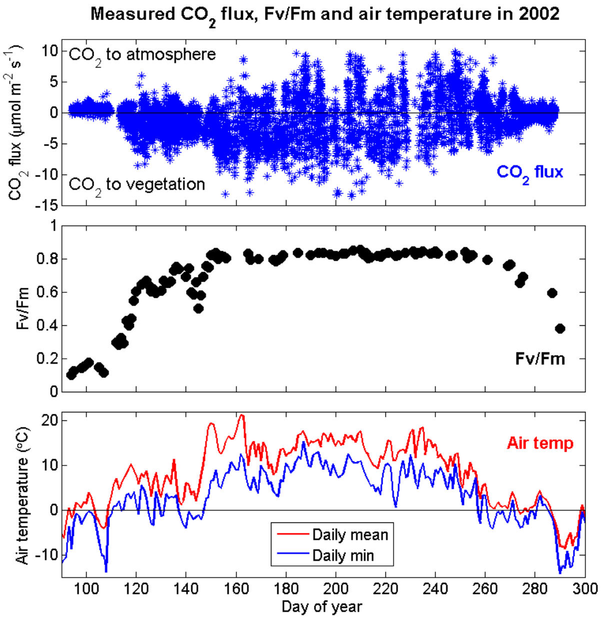

Fig. 3. Measured CO2 flux, Fv/Fm and air temperature in Sodankylä, year 2002

In northern latitudes the seasonality of the snow cover impacts the surface temperature and albedo. In the models the surface atmosphere interaction is impaired by the treatment of the surface temperature. While subgrid scale albedo parameterization makes use of fractional description of the snowcover, the fractional manifestation of the surface properties is not accounted for in grid-scale surface temperature, who start rising too late in the spring because too much energy is consumed in melting snow. This poorly presented sub-grid scale process in turn modulates e.g. the permafrost pattern. EO and ground based observations of albedo and snow cover will be compared to model results and used in assessing the sub-grid scale land use heterogeneity effects.

3. JSBACH methane emission model

JSBACH methane emission module is under development and the first version has already been compared to Siikaneva flux measurements (fig. 4). The methane emission module includes description of methane production, oxidation and transport processes in several soil layers with a distribution of plant roots. Transport processes include diffusion in water filled soil, air filled soil, through roots and sedges, ebullition as well as transport of oxygen for methane oxidation. The methane emission module obtains input from soil carbon module including amount of carbon substrates available for methane formation. The new JSBACH PeatBalance soil module has been implemented and used in estimating carbon accumulation in peat soil. It has carbon pools separately for acrotelm and catotelm. Litter and exudate pools have also been implemented during current year. Methane emission model and PeatBalance model parameters will be calibrated against available wetland eddy flux and chamber measurements.

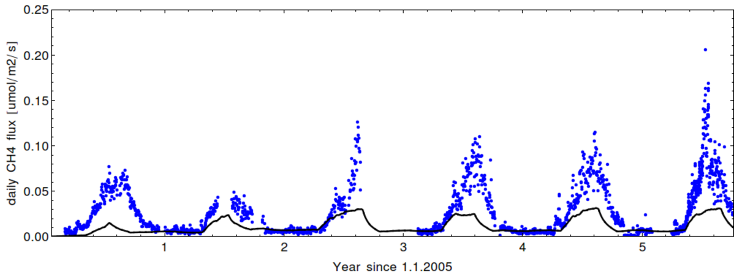

Fig. 4. Measured (blue dots) and modelled (black line) CH4 flux at Siikaneva wetland.

Climate change indicators will be extracted from current day model results before and after new module implementations and calibrations are ready. Some indicators like those concerning drought and flooding are not directly obtained from model results, but require definition of conditions when the indicator is active. At current, climate change indicator related to drought is being extracted from the existing JSBACH model results using alternative procedures suggested in literature, related to soil moisture results as well as temperature and precipitation data. Vegetation active period will also be extracted from the model results during last 30 years and compared to remote sensing and flux observations using methods presented in Böttcher et al., 2014.

4. Calibration of PreLes model parameters

We have calibrated PreLes model parameters related to photosynthesis and transpiration against eddy-site flux measurements from 10 sites in Finland and Sweden, as had already been done previously using Hyytiälä and Sodankylä GPP and evapotranspiration results. The calibration was made for site specific parameters as well as for all sites combined. The results showed that parameters are largely transferable between sites (Fig. 5). We will now extend this analysis specifically to peatland sites, including methane flux as well, to assess the generality of the model for peatlands also. PreLes will be connected with the soil carbon model Yasso through a forest growth model CROBAS simulating leaf area, litter production etc. This work has been initiated already. The result will provide information about all carbon fluxes on a daily basis and can be run with LAI products and compared with JSBACH results. We will further include deciduous phenology and within season conifer LAI dynamics using existing models and data (cameras, shoot growth, sapflow measurements). We will assess the needs to develop the soil water module in PreLes model system.

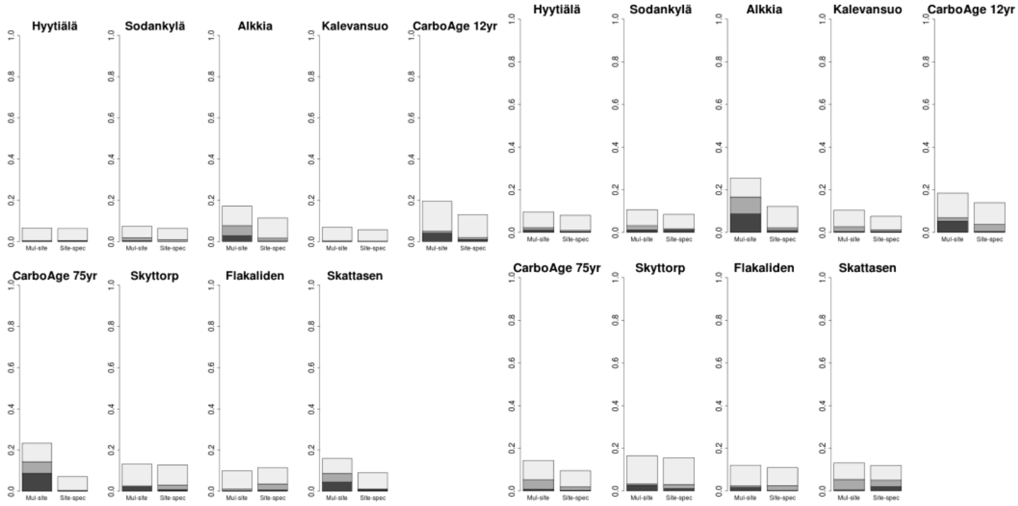

Fig. 5. GPP (left) and ET (right) model-data mismatch according to multi-site vs. single site parametrisations.

5. References

Böttcher K, Markkanen T, Thum T, Aalto T, Mattila O-P, Arslan A.N., Aurela M., Kolari P., Pulliainen J Evaluating land surface model estimates of start of the growing season in boreal regions by satellite data (submitted manuscript)

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