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LIFE+ PROJECT NAME or Acronym

SNOWCARBO

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List of abbreviations

FMI	Finnish Meteorological Institute
MPI-M	Max Planck Institute on Meteorology, Hamburg
JSBACH	Jena Scheme for Biosphere-Atmosphere (model describing biosphere-atmosphere interaction)
REMO	Regional climate model
REMOTracer	REMO capable of transporting CO2
EC	Eddy covariance method to determine matter (e.g. CO2) and energy exchange
NEE	Net ecosystem exchange of CO2 in between the atmosphere and a ecosystem

1 Introduction

This action focuses on demonstration of carbon balance assessment methodology by applying information from actions A9, A3 and A4 as reference data. The modeling tasks consist of the climate model REMO runs in the two running modes (a *climate run* that is initialized in the beginning of each run and a *forecast run* that is initialized daily, see the "1st report on methodology" of A6 for a more thorough description of the modes) and consequent offline JSBACH and REMOTracer model runs with various initial and boundary data. Target years span from 2001 to 2011 and the domain covers Northern Europe, i.e. Nordic countries (except for Island) and Baltic countries. The demonstration of the modeling framework consists of sensitivity analysis among the different modeling schemes and comparison to observation data of different climate related variables. The selection of the most suitable modeling framework for producing the present day CO2 balance will include comparison to the in situ data of A4 and phenology data from A3. In this document the intended evaluations of some central variables are discussed with outline of the methods. Additionally, some preliminary evaluation results are shown. The demonstration approaches eventually taken will be reported in detail in the next demonstration report.

2 Objective

While the principle product of the modeling framework is the regional CO2 balance estimate, a few other predicted variables can be assessed against the wide observation data set available for the project. Assessment of the variables that can be considered as by-products from the CO2 balance point of view, is important in order to find out the strengths and weaknesses of the overall modeling framework.

The predicted variables that will be evaluated include the central climatic variables such as temperature and precipitation as well as other variables relevant for water balance. In general, the variables related to the surface energy balance reveal fundamental features of model performance and thus they play an important role in assessment of the model performance. In addition to comparison with the observation data, the differences in the predictions of both models – REMO and JSBACH - have to be explored. In the evaluation, the areal differencies in model predictions are first visually recognized. In order to evaluate the influence of improved land cover data sets, both REMO and JSBACH predictions with different surface data will be compared. All in all, the model evaluation consists of model intra-comparison, model inter-comparison and comparison to the observations. This division in to the three comparison categories is given in order to organize the process of testing the models. The definition of the classes is given in the "1st report on methodology" as well as in the chapter below.

3 Approaches

Various model simulations calculated for a certain period of time may deviate from eachother 1) due to differences in the running set up, 2) due to differences in the boundary and initial conditions and 3) due to differences in the process descriptions in the applied models. The first case will occur for instance in between the REMO forecast and climate runs, the second case will hold when the land cover data or the driving meteorological fields are varied, and the third case holds for differences in between REMO and JSBACH which both predict independently a set of variables related to surface processes, such as latent heat flux or snow depth.

The reference data suitable for the evaluation will depend on the causes of deviations and the goals of the evaluation. Thus in the "1st report on methodology" we defined three different evaluation approaches to be applied in the assessment of the performance of the modeling framework. These are 1) model intra-comparison that is performed among the results achieved with different boundary conditions (e.g. various land cover data) by a single model in a certain running mode; 2) model inter-comparison that is comparison between the common variables predicted independently by both REMO and JSBACH and 3) comparison to the observations.

3.1 Spatial scale of the evaluations

The first two comparison methods can be performed simultaneously for the whole model domain whereas the target area of the last method depends on the nature of the reference data. Depending on the preliminary results, the investigations with the first two methods can be zoomed in on to the areas of most deviations. In areal comparison the primary method is visual assessment of the areas of largest differences. Areal averages of various resolution will be exploited in determining the spatial scales of the deviations.

The above mentioned measures can be used also in the comparison to the observations whenever the observation can be transformed into the spatial grid respective to that of the model results. However, when site wise data such as EC flux data from A4 is used as a reference, the most relevant model results have to be selected with care. In the case of REMO results, it can be considered whether the grid cell where the measurements are located is the most representative for the the vegetation cover that the EC device observes or whether another nearby grid cell would be more suitable regarding the surface characteristics. In the JSBACH model case it can be also considered whether all the four tiles of a grid cell should be included or only the one matching with the dominant land cover of the flux site. As a default approach an average of the nine adjacent model grid cells closest to the measurement location are used in comparison to site-wise data.

3.2 Temporal scale of the evaluations

Time averages of different scales - i.e. daily, weekly, monthly and yearly - will be applied in processing and reporting the results. The time resolution of the model evaluations will be decided for each case separately according to preliminary tests. The data storage requirements have to be taken into account in decision making. However, because CO2 exchange rate has several distinct cycles, such as the daily cycle due to PAR irradiance and the yearly cycle due to temperature and radiation, the averaging windows for the model evaluation have to be adjusted so as to capture the time scales each reference is sensitive to.

3.3 Application of a site specific model version

In order to perform site specific system evaluation, a site wise JSBACH model will be adopted and run for Hyytiälä and Sodankylä Scots pine sites. The model version suited for driving with standard flux site data of half hourly time step and with half hourly output is currently developed in Max Planck Institute for Biogeochemistry, Jena. A version is available for the FMI personnel from the beginning of the year 2011 and its implementation and testing will be started immediately. Site wise evaluation will provide information on the model performance under the particular weather situations that occurred at the location of the flux tower. Consequently the result is better comparable to the flux data. Especially, the site specific characteristics of vegetation and soil properties will be easier adopted in the modeling and thus the features due to process description will be easier distinguished from the features due to parameterization.

Application of the site wise version is however conditional as it depends on the reliability of the newly developed model version. The methodology for site wise evaluation and its implications to the regional level will be reported in detail in the actual Demonstration Report of this action that is due to in November 2011.

4 Reference data

In the following the various types of reference data are explained separately with discussion on their characteristic features to be considered in model evaluation.

4.1 Regional data

Regionally the performance of the vegetation model will be evaluated against phenological data, such as NDVI from satellites A3 or in situ data set for phenology A5. In the case of for instance bud burst or NDVI there is no identical variable predicted by the model but variables closely related, such as LAI (leaf area index) or GPP (gross primary production) will be used instead. Some variables, such as soil moisture, are both among the in situ phenological data and predicted by the model. In such a case, however, it is crucial to make sure that the definitions of the two variables do match. Often, in order to avoid offsets due to deviating specifications, the phase of the data series rather than the absolute magnitudes of the variables should be observed. In this case composite time series of selected domain sub-areas do reveal the phase differences between variables.
The required time averaging window will be set to agree the time resolution of the reference data. During spring and autumn the time averaging window should be set as narrow as possible in order to capture rapid changes in the state of the vegetation.

4.2 In situ data

We will use CO2 net ecosystem exchange (NEE) data of CARBOEUROFLUX sites that belong to FLUXNET network and atmospheric CO2 concentration data from Pallas GAW site (see reports of A4). As the data is processed by methods developed in the frameworks of the international specialized networks, there is no need to develop a new methodology for data processing. However, data needs to be selected according to various environmental and meteorological phenomena in order to assure its representativeness.
This task also will be as far as possible covered by the existing flagging and other support information provided with the standard data forms. For instance some footprint analysis exists for flux sites and certain CO2 concentration data are attached with basic tracer information on the origin of the air mass.
Concentration data represents a large area horizontally but the most representative vertical model level has to be determined. In both cases the complications due to special meteorological situations have to be carefully considered.

4.2.1 Flux site data

The focus of this action is the direct evaluation of the CO2 exchange measures – fluxes and concentrations – will be carried out against in situ data (A4). In this case there is one to one correspondence between the definitions of the measured variables and their modeled counterparts. However, there are certain conditions which have to be fulfilled. Especially flux signal is of so local nature that its representativeness for the model results has to be carefully considered and the most suitable grid cell for comparison has to be selected before evaluation of model performance against flux data (see also the general discussion on the spatial scale of the evaluations above). This is due to fact that some other grid cell may be more representative for species distribution wise for the fetch of the measurement.
In addition to the CO2 flux data, from the eddy covariance (EC) sites there is local data available on the counterparts of surface energy balance who can be separately evaluated

against the model. Moreover, the other flux variables can be utilized in recognition the grid cell of best representativeness for the land use type of interest.

4.2.2 CO2 background concentration data

For the validation of CO2 concentration the model result of the grid cell where Sammaltunturi is located – together with the data of adjacent grid cells - will be extracted from the data series and compared to the measured time series.
Concentration data represents a large area horizontally but the most representative vertical model level has to be determined. As default value the lowermost vertical grid level will be used for comparison. However, for the final decision various options will have to be explored. We may have to develop various criteria under which modeled and measured meteorological conditions the comparison is feasible.

4.3 Forest inventory data

In national level the CO2 balance predictions will be compared to the national forest inventory data. In this case there is no identical variables directly available from the the model and from inventories. However GPP can be used as indicator of tree growth and year to year variations of inventory data can be compared with year to year variation of modeled GPP. This comparison will be done in co-operation with Finnish Forest Research Institute (Metla) who is the national inventory data provider. Furthermore Metla does work on process modeling of GPP estimates. Comparison of the results of Metla's and our modeling frameworks will be carried out in the later stages of the project.

5 Improving boundary data

Te below discussed approach to modify a snow depth boundary can be applied to any independently observed REMO boundary variable that can be transformed into REMO grid. As the snow depth is a central variable in this project that will be adjusted with the data from the measurements, the sequence of production runs will be adjusted according to the results of A9. In order to keep the weather of the target years of the project as close to the observed as possible, the production runs will be performed in forecast mode (See The 1st Progress report on methodology of A6). In forecast mode the snow depth is very close to its daily initial value. The reference snow depth data, i.e. that resulting from climate and forecast runs from REMO and the JSBACH predicted with the standard land cover, is first evaluated in A9. Already A9 has revealed certain deficiencies in the boundary data. Thus the final planning of the production runs will be planned in close co-operation in between A9 and A8. In the actual production runs the models will be nudged with snow depth data provided by A9. In REMO the substitute data will be written into the boundary data fields. In JSBACH case application of external data source is more complicated, because certain quantities, such as snow depth, are internal variables of the model. Adoption of external data can be most easily carried out by a cold start whenever model predictions and observations deviate too much from each-other. However, the levels of storage variables have to be carried through the subsequent cold starts.

6 Downscaling the model results

As there is lower limit for climate model runs with REMO (the resolution of JSBACH matches with that of REMO) the intended estimation of CO2 balance for different resolutions will not be directly modeled. Instead the downscaling of the predicted CO2 balance can be done by allocating the different land cover types of the various maps with the yearly CO2 balances of the nearby areas of the respective plant functional type.

7 Run settings

REMO model have been run for the pre-existing climate data series, i.e. for years 2001-2007, in climate and forecast modes. The results by both modes will be checked for any distortion due to relatively dense model grid and the need of double nesting is estimated accordingly. Even though the forecast mode with daily ignitions from the observed data is presumably the climate modeling approach to be applied in this project, the comparison with climate mode runs is expected to provide insight in strengths and weaknesses of both approaches.

REMO model is run with three different land use data – the original Olson data set, GlobCover and Corine (CLC)+GlobCover land cover classifications from WP11. The differences in energy balance partitioning due to different surface parameter maps will be assessed (see Figures 1 and 2). Unfortunately a decisive selection of the most suitable land cover data is handicapped due to the local nature of the energy balance data from the flux sites. Thus, further modeling steps will be carried for several newly implemented land cover classifications.
Furthermore, the allocation of forest ratio and vegetation ratio will be restored because according to the refined maps the increased values are too high. Additionally, the importance of the applied land use will be estimated by repeating the calculations for a purely artificial land cover map consisting solely of a class Boreal coniferous forest.

The initial JSBACH runs subsequent to the REMO simulations were carried out with the standard version of the stand alone JSBACH who requires the input in daily time step. For this aim the forcing data was extracted from hourly weather data series (A6). Another important preparation for this aim was the production of suitable land cover maps that are consistent with the respective data set from REMO runs. Point-wise evaluation of the produced 2D maps of CO2 fluxes will be carried out against the data from several flux sites located in the domain.

At the stage when a fully coupled REMO-JSBACH model, that is presently developed in MPI-M, Hamburg, exists and is available for the Snowcarbo project all the runs will be repeated and the benefits gained with the two-way coupling scheme over the one-way coupled set up will be estimated in terms of the degree of energy balance closure. Consequently, the basic comparison between modeled and measured fluxes will be carried out.

Design of the runs utilizing observed snow cover characteristics will be started when the results obtained from comparisons between measurements and modeled values exist (A9). A preliminary plan is to substitute the snow water equivalent of the initial and boundary data with the respective EO data. Subsequently the impact of the change to the flux estimates will be assessed.

The final step of each complete model sequence is the second REMO run in a mode that transport the CO2 tracers producing concentration field due to surface sources within the domain. The results of this modeling step are consequently compared with CO2 concentration data obtained from Pallas GAW station (see In situ data document 31/12/2009). Even though this variable is expected to be the most uncertain the phase of the yearly cycle will provide a reference for timing of ecosystem functioning.

7.1 Model spin-ups

Required spin-up procedures for both JSBACH and REMO are taken either offline (e.g

CBALONE) or as a part of each production run. The purpose of these spin-ups is to ensure the correct base stages of storage variables, on the one hand, and well developed circulation of the atmosphere, on the other hand.
The required spin-up procedures and their purpose is listed in the table below.

Module/model	Variables adjusted	Duration	Spin-up type
REMO2008	Soil water, atmospheric circulation	1 year in climate run 6 hours in forecast run	online
REMOTracer	Soil water, atmospheric circulation	6 hours	online
JSBACH (including CBALANCE)	Soil water, short term carbon storages	1 (or couple of) year(s)	online
CBALONE	Carbon storages	Up to 1000 years	offline

All the various spin-ups are implemented in A6. However, their reliability is still to be assessed. The main problem foreseen is the realistic allocation of the soil carbon storages as present day land cover maps will be used in the spin-up. Possible solutions include averaging of the storages over larger areas, tuning of the storages according to literature values, and adoption another soil carbon model (Yasso by Jari Liski from SYKE) that is better suited for North-European ecosystems.
Whether the spin-up procedure adopted for generating different soil carbon pools is appropriate for the purposes of this study will be assessed by studying the soil respirations estimated for the flux sites. At simplest the evaluation is a relatively simple comparison in between the average of the total ecosystem respiration estimated from night time flux measurements and its modeled counterpart over a suitable period of time which may extend from seasons to the length of whole period. In a more thorough analysis the temperature responses and occurrence and timing of various spells and inflexion points in the data series should be explored.

8 Preliminary results

The first REMO climate runs were carried out for years 2001-2006. The resolution was 0.167° and the ECMWF-analysis data was used as boundary (see the "1st report on methodology" of A6 for the details on model domain and reports of A4 for details on boundary data). A sensitivity study was performed for two preliminary revised land cover data sets from A11. These were Globcover and a hybrid of a Finnish Corine land cover and Globcover (see reports of A11 for details).
The land cover data is unambiguously related to following parameters: background surface albedo, fractional vegetation cover, leaf area index (LAI), forest ratio, roughness length, and water holding capacity. The surface data is aggregated into surface maps of the size and resolution of the prospective domain. For most of the parameters the preprocessing steps consist of weighed areal averaging. In the North-European areas the aggregation of two parameters - soil field capacity and forest ratio - is modified to account for region specific vegetation and soil features.
Visual inspections revealed that surface property maps change considerably (see reports of A11 for details) when the new land cover data are applied. Field capacity is typically high in wide areas of forested wet lands in Finnish and Swedish Lapland, where the land cover is boreal coniferous forest whose allocated soil field capacity is 0.21 that is too low for the

soils. Thus the value is overwritten with a constant value of 0.71 according to the distribution of class 15 of the FAO/Unesco soil type dataset. The fractional vegetation cover of the land cover class boreal coniferous forest is increased from 0.52 to 0.91 in Scandinavia.

The influence of above described difference in land surface properties on the REMO predictions was further visually inspected at seasonal scale. Some exemplary results about the impacts on the surface energy balance are shown and briefly discussed below. Since these preliminary runs the allocation of the land cover types of the renewed land cover maps were revised. The revision was partly based on the findings presented here.

In spring the sensible heat fluxes (Fig 7.1.) estimated using the revised land cover classifications show in Globcover case higher fluxes from the surface at areas of higher field capacities used to derive heat conductivity and heat capacity. In FinnishCLC+Globcover case the effect of maximum soil water capacity is pronounced in Norther Finland where actually the state borders are visible. This is due to the fact that in the hybrid of Finnish Corine land cover and Globcover the classification followed the state borders.

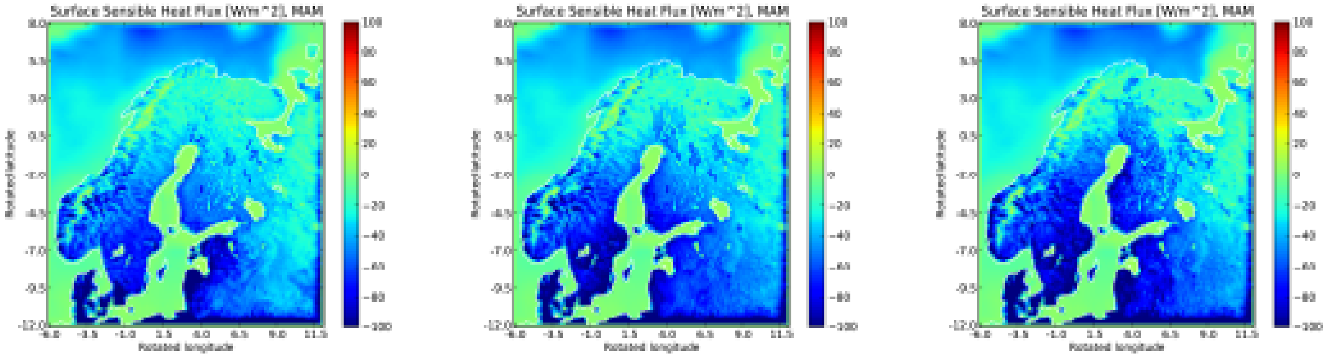

Figure 7.1. The sensible heat fluxes in spring 2003 estimated using the revised land cover classifications. From left to right: the standard Olson land cover, Globcover and a hybrid of a Finnish Corine land cover and Globcover.

In autumn the latent heat fluxes (Fig 7.2.) estimated with modified land covers are slightly smaller than those derived with the REMO standard land cover in most land areas within the domain.

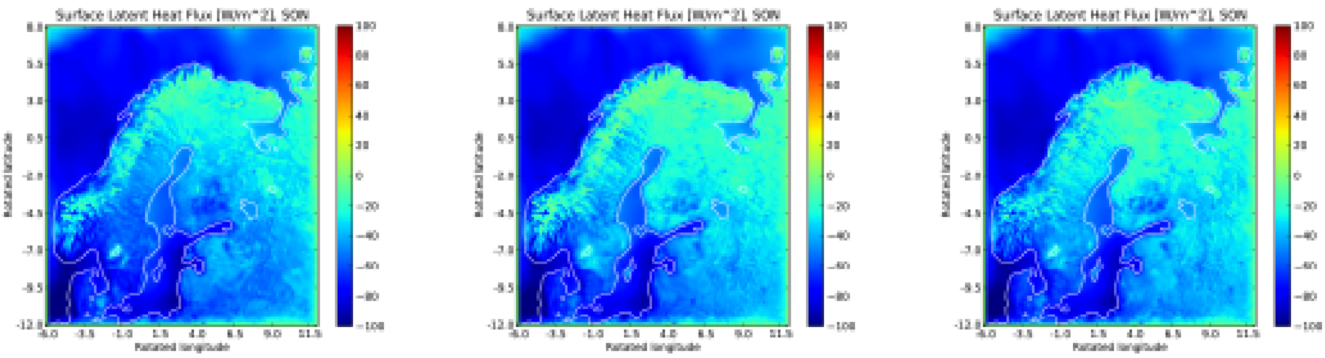

Figure 7.2. The latent heat fluxes in spring 2003 estimated using the revised land cover classifications. See the Figure 7.1. for the order of the land cover data.

In summer the Bowen ratios are close to zero or have small positive values (Fig 7.3.). The modified land covers show slightly higher values at most of the Scandinavia. The Clobcover classification shows especially high values in Scandinavian mountain range. This is probably due to allocation of the Clobcover class 150, that is prevailing at mountain areas, with the Olson class Cold grassland. In the case of FinnishCLC+Globcover the Bowen ratio has higher values at the areas of lower than average field capacities.

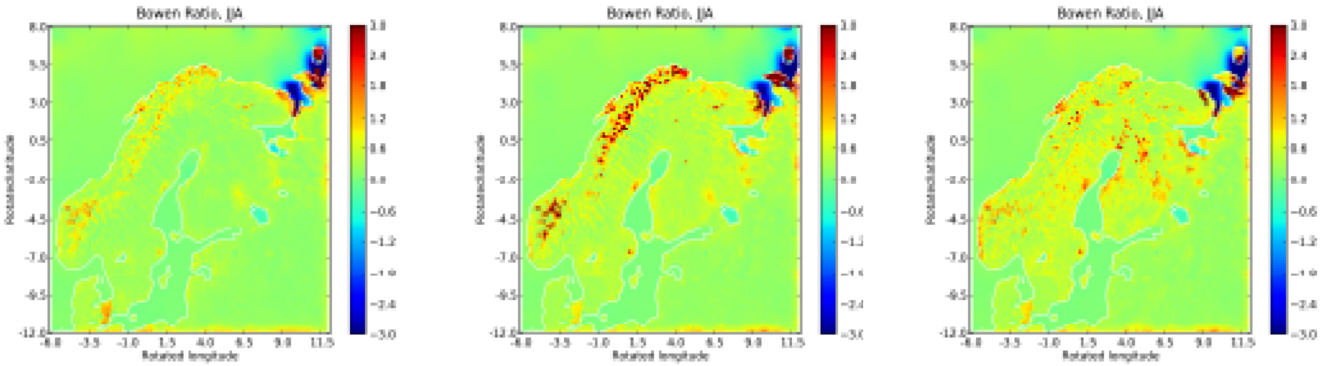

Figure 7.3. Bowen ratios in spring 2003 estimated using the revised land cover classifications. See the Figure 7.1. for the order of the land cover data.

In overall the preliminary REMO climate runs reveal some distortion of the variable fields at the domain boundaries (see e.g. Fig 7.1.). This is an expected effect due to adaption of the atmospheric circulation to the boundary fields at the boundaries. The effect is not crucial for our aims as the border areas can be extracted from further evaluations and for instance, no flux site is located at the areas of most edge effect.

The first evaluation runs with offline REMO-JSBACH runs revealed several central properties of the modeling framework. For these trials REMO was run in the forecast mode with daily cold start and a spin up of six hours. The daily averaged climatic drivers for JSBACH were derived from hourly REMO output. Constant values were used for soil carbon pools throughout the domain.
In comparison to the NEE from Sodankylä site (Fig 7.4.) only one model grid cell was extracted for a comparison of the time series. The timing of the spring awakening as well as summer time peak NEE and the increase of ecosystem respiration in the summer were well captured. However, a major problem was also revealed – during cloudy days the NEE is too low. Improvement of this feature is the principal task of the A6 at the moment.

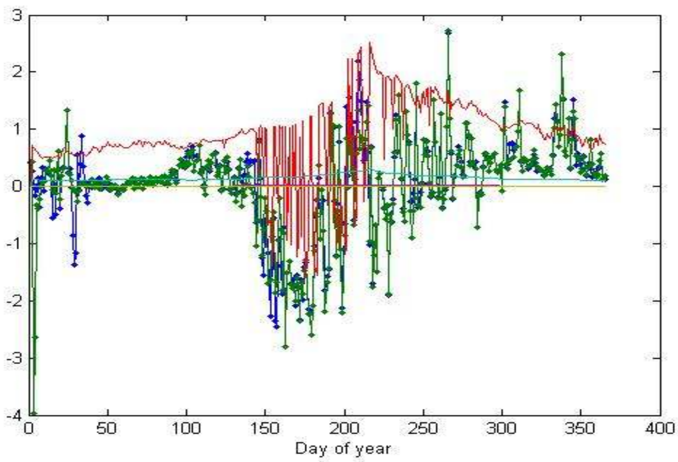

Figure 7.4. Daily NEE measured at Sodankylä site in 2003 (green and blue standing for two different gap filling methods required to complete the data series) and modeled with JSBACH (red shades standing for the four tiles within the selected grid cell).