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SNOWCARBO

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Table of contents

1 Summary of project scope and objectives

The main objective of the SnowCarbo project was to implement and demonstrate a new innovative approach for the net carbon balance mapping in the northern Eurasian region combining of different information sources describing snow evolution, phenology, land cover, CO2 fluxes and concentrations. The implemented method combines local in situ observations and global Earth observation (satellite) data together with land cover class information in a new way. The annual maps of carbon balance produced by SnowCarbo can be used to aid the definition of the European and national adaptation strategies to climate change impacts and to support the formulation of the environmental legislation and regulations.

In SnowCarbo project, net carbon balance maps was provided for national and international organizations and policy makers responsible for 1) climate change investigations 2) inventory of greenhouse gases and 3) international agreements, their implementation and reporting in Finland. The primary stakeholders of the project in Finland include:

- Ministry of Transport and Communications (governing body of FMI)
    - CO_2 net balance information highly relevant for future traffic regulations
- Ministry of Environment (governing body of SYKE)
    - Project results highly relevant for the implementation of national environmental policy
- Statistics Finland
    - Greenhouse gases (GHG) reporting
- Ministry of Agriculture and Forestry
    - CO_2 net balance of forest holdings highly relevant for the national forestry policy, future regulations, and the development of environmentally sustainable forestry industry.
- Finnish Forest Research Institute (METLA)
    - Methods for calculation of GHG balances of forests
- Agrifood Research Finland (MTT)
    - Methods for calculation of GHG balances of agricultural land

For the European Comission the project results are important concerning Green Paper follow up (adaption policy development) and European Climate Change Programme II (ECCP). The products of SnowCarbo project will also support a number of international environmental monitoring activities, such as Arctic Monitoring and Assessment Programme (AMAP) and Sustained Arctic Observing Networks (SAON) initiative of the Arctic Council, and Global Atmosphere Watch (GAW) programme of the World Meteorological Organization (WMO).

In SnowCarbo project a new innovative approach was implemented and demonstrated. A new innovative approach to net carbon balance mapping is based on a combination of different information sources describing snow evolution, phenology, land cover, CO_2 fluxes and concentrations. The information sources include in situ observations and Earth observation (satellite) data. Dedicated models for different land cover classes were applied to describe carbon uptake and respiration.

List of SnowCarbo project key objectives:

- To provide accurate map information on net carbon balance in boreal forest zone in order to assess the real levels of carbon sinks and sources for future climate controlling treaties and policy making

- To provide and demonstrate methodologies to extract anthropogenic influence from natural background CO_2 sources in order to enable the development new legislative means for CO_2 regulation. These methodologies include the use of Earth observation data as a comprehensive data source (together with models and in situ data).

- To provide information for the future needs required in situ, Earth observation and land cover data needs of continental scale carbon balance mapping/monitoring (focusing on northern areas)

2 Methodology and key results

Methodology

A modelling framework predicting present day land ecosystem CO_2 balance for Nordic countries and surroundings (i.e. for Northern Europe) was developed. The modelling framework consists of regional climate model REMO and land surface model JSBACH accounting for photosynthesis. In the framework of this project a method of coupling between the climate model REMO and the land surface model JSBACH (Figure 1) was implemented and tested: 1) the first step is a REMO-run to determine fine scale regional climatic variables such as air temperature, surface pressure, radiation and precipitation; 2) in the second step the JSBACH model is forced with the climatic variables to produce the land vegetation CO_2 exchange rate; and 3) as final step the exchange rate together with mapped data for anthropogenic and ocean CO_2 sources the REMO is driven in a version distributing the tracers to the atmosphere inside the model domain. Both REMO and JSBACH use model specific surface parameter fields (i.e. surface maps or surface libraries) that were modified with data from various actions of this project.

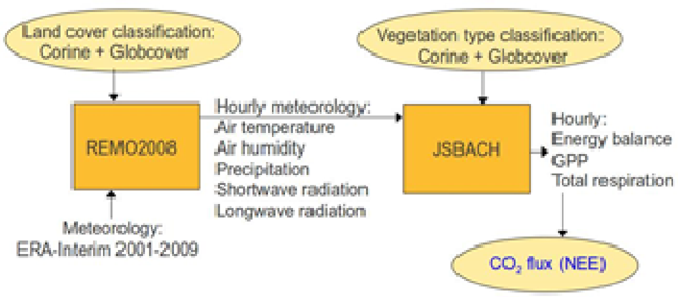

Figure 1: Modelling framework showing the one-way coupling between the models. JSBACH does not feedback to REMO.

Key results

1. Digital carbon balance maps covering years from 2001 to 2009

Digital carbon balance maps covering years from 2001 to 2009 were produced shown in Figure 2. The maps of highest degree of detail have been produced with the land cover based on the National Corine data. These maps are available for the scientific community by demand. For public, monthly and yearly the CO_2 balance mapped data have been transformed into non-rotated latitude-longitude grid. The data is accessible via Erdas Apollo database. Furthermore, a table of monthly and yearly CO_2 balance values for Finland have been produced for comparison with the National GHG inventories.

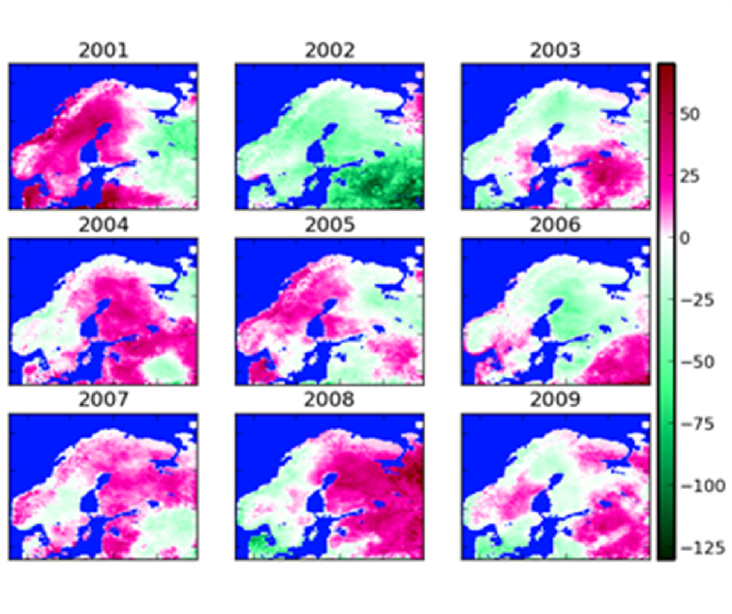

Figure 2: Yearly CO_2 balance of years 2001-2009 in the original model grid with the resolution of 0.167 degrees. Ecosystem sources of CO_2 are indicated in red and sinks in green. The values are given in terms of grams of carbon per area (g(C)/m^2).

2. Extraction of carbon balance-related indicative features

Time-series of Snow Covered Area (SCA) and Normalized Difference Vegetation Index (NDVI) were produced from Moderate Resolution Imaging Spectroradiometer (MODIS) observations, describing the status of snow cover and vegetation, both of which are important components in the carbon exchange between atmosphere and soil and vegetation. In addition, also Normalized Difference Water Index (NDWI) was calculated, as it was shown to be a good indicator for the greening-up in the boreal region. Cloud masking was applied to SCA, NDVI and NDWI products and daily composites were calculated.

Filtered and interpolated time-series were used to extract features indicating important changes in the carbon exchange, namely:

a) Beginning of growing season (shown in Figure 3),

b) Seasonal vegetation peak and

c) End of growing season.

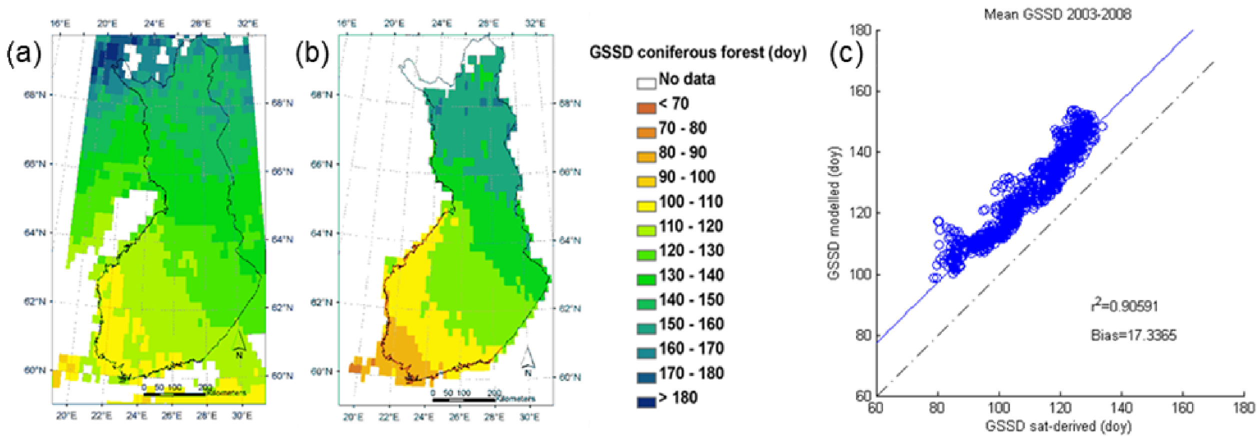

Figure 3: Mean GSSD(Growing Season Start Day) from modelling data (a) and from satellite data (b) and scatter-plot from the estimates from the area of Finland (c) shows good correlation between the two datasets, but with a systematic bias.

The effects of land cover data on the modelling results were investigated in Finland in two ways during the project. First the effects of land cover on the modelled snow cover produced by the REMO- model, which influenced the local climate used for modelling the carbon balance. The increase in other land cover/land use types from the USGS land cover to the combination land cover seemed to increase the snow depth in general (Figure 4). The changes were most pronounced in the areas where the land cover was changed from forest types (evergreen deciduous, which does not really exist in Finland and coniferous) were changed to wetlands. The surface energy balance changes between different land cover types and therefore affects the snow melt rate.

The carbon balance results show that the coniferous forests have a significant role in the carbon balance of Northern- latitudes (Figure 5). The USGS classification over estimates the amount of coniferous forests and therefore produces on average a net-sink for the annual carbon balance. Using the improved land cover data, the Scandinavia and Finland stay close to zero balance, but the Baltic countries, Western-Russia and Belarus, display as annual sources of carbon-dioxide, the main differences between the two datasets in these areas being the over estimation of coniferous forests in areas of summer-green vegetation by USGS classification.

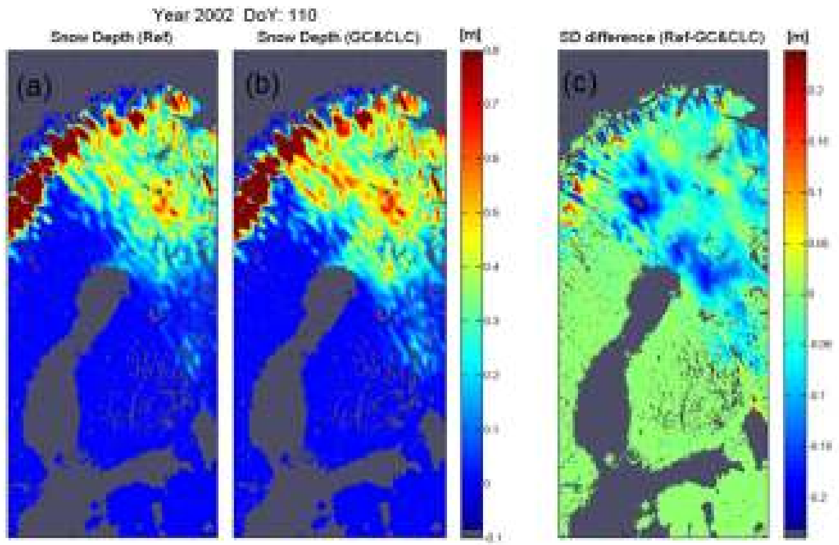

Figure 4: Example of the effect of land cover on model parameters. (a)Snow cover from REMO-model run with USGS land cover and (b)with the combination land cover (Finnish National CORINE-land cover, European CORINE land cover and GlobCover) (c) and the difference in snow depth.

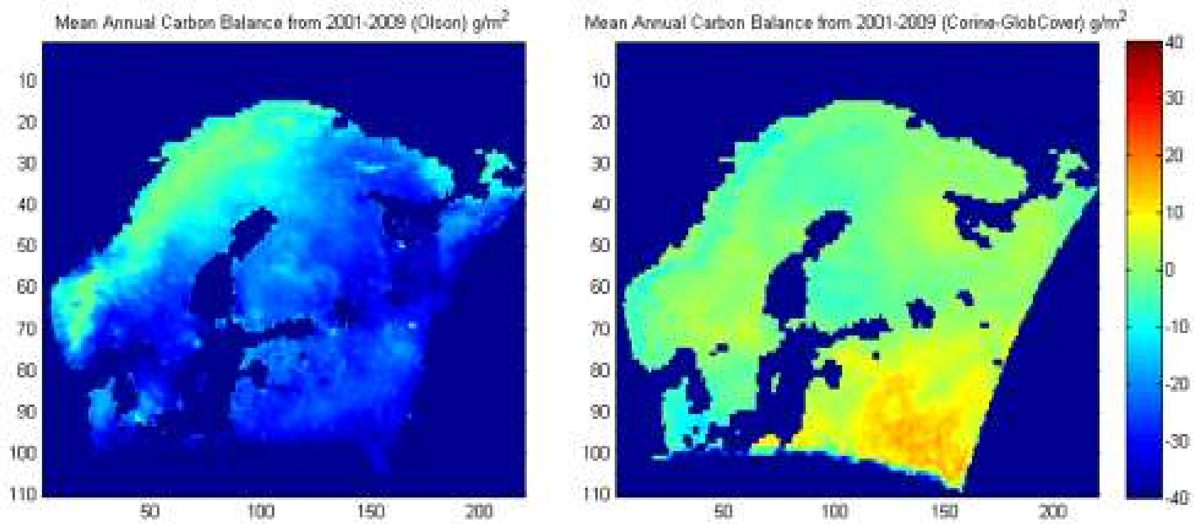

Figure 5: Carbon balance estimates with two different land cover datasets from 2001-2009. USGS land cover data (left) and Corine-GlobCover combination dataset (right).

3. Northern-Eurasian land cover information

Land cover classification give the spatial distribution of land cover types and surface parameters allocated for each land cover. These characterize each land cover category used by the models. Several sets of gridded land cover maps were produced in different resolutions (scales) and geographical coverage:

1. Detailed (local) land cover information covering intensive in-situ monitoring areas (flux stations in northern Finland) were produced using satellite data (IRS P6 LISSIII, SPOT 4 XS, LANDSAT 5 TM, KOMPSAT 2) together with ancillary GIS and in-situ data. Employed methods included estimation of land cover variables using rule-based predictive models. Additionally Finnish national CORINE land cover databases were utilized.
2. In standard model versions the surface cover data is a global 1km resolution land cover dataset based on Olson ecosystem classification. Since Olsson data do not describe Nordic land cover properly, alternative land cover information was produced. Different revised land cover data sets recoded into Olsson nomenclature were produced and delivered covering the modelling window in Scandinavia and surrounding areas. Following data were utilized:
    a) GlobCover (regional version 2.2)
    b) European Corine Land Cover (CLC2006)
    c) National Corine Land cover (CLC2000 and CLC2006)
    d) Clusters of MODIS products (MOD15 Leaf Area Index and MCD43 Albedo)

When considering feasibility of land cover information for carbon balance modeling in terms of thematic accuracy of data, European and national version of Corine Land Cover 2006 should be used as input data source for land cover information over Scandinavia. In the areas where CORINE land cover data does not exist (territory of Russia) GlobCover can be used. These data describes well the spatial distribution of land cover categories in Nordic areas. Combination of CORINE land cover and GlobCover data was produced covering the modelling window in Nordic areas and these data were used to replace the old Olsson land cover data original used by the models (see Figure 6).

Figure 6: Combination of CORINE Land Cover 2006 and GlobCover

3 Benefits and impacts on the results

Climate change indicators are simple ways of presenting difficult information to the public. In order to map the climate change indicators related to boreal ecosystems, we must use modeling tools. The models will enable projections to the future. The magnitude of climate change is dependent on the atmospheric load of the two most important greenhouse gases, carbon dioxide and methane. The terrestrial biosphere plays an important role in the global carbon balance, and boreal forests and peatlands are an important part of the global carbon cycle. Global carbon balance of the terrestrial ecosystems is known in an accuracy of about +-35% based on atmospheric concentration increase and versatile use of other observational and modeling methods. The uncertainty increases in the regional level, and obtaining accurate figures of country based carbon balances and their future development is a challenge.

To obtain reliable regional carbon balance estimates and accurately predict their future development, spatial coverage of observations should be increased and models calibrated with observations referring to the target region. To interpret and evaluate the results we need knowledge of the regions studied and their specific features. Thus, the contribution of the northern regions to the global carbon balance requires input from researchers who have first-hand knowledge on the climatological conditions and carbon cycling in the boreal zone. In regional modelling it is essential to have up-to-date high-resolution land cover maps and to use vegetation types which correctly correspond to land cover classes. Regional uncoupled models such as developed in SnowCarbo project are important to efficiently develop the processes and scaling approaches. Using regional approach, extreme weather events and their effects and importance on the regional carbon balances can be better quantified.

Main expected longer term benefit from SnowCarbo project is a tool applicable for assessing the impacts of climate change on the land vegetation CO_2 balances for Nordic countries and surroundings. SnowCarbo project provides a tool to assess natural and potential natural CO_2 source and sink strengths. The tool can be also applied in assessing changes of sources and sinks due to land use change or under climate deviating from present.

SnowCarbo project results will make a contribution to GEOSS (The Global Earth Observation System of Systems) and thereby also to (environmental) policies of the European Union. GEOSS addresses 9 areas of critical importance to people and society (www.earthobservations.org/geoss.shtml). Other long-term benefits are

4. Increase of knowledge about carbon balances and their projected changes for boreal areas
5. Benefit to global model-based assessments of the GHG balances especially wetlands (44% of global wetlands occur in Northern latitudes).

The modeling framework, implemented in SnowCarbo- project, can be used to produce information to support national and international climate policy making and monitoring. The central international conventions and programs in European level, which can utilize the results, are:

- Updating and publishing greenhouse gas inventories (including carbon dioxide) on regular bases to UNFCCC (United Nations Framework Convention on Climate Change),
- **DG CLIMA:** The accounting of greenhouse gas emissions in all sectors of society (e.g. forestry and agriculture) and building mechanisms for restricting emissions,
- **DG ENV:** Imposing emission limits, regulation of emission trade and monitoring of emissions need comprehensive emission accounting and reporting

- **DG ENER:** Emission trade related to energy production; Research and development aiming at reduction of carbon dioxide emissions
- **DG MOVE:** Program for reduction of emissions from land and sea traffic