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Land Cover Data Needs for Carbon Balance Mapping

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Action 11 – Evaluation of required North-Eurasian land cover information

LIFE+ PROJECT NAME or Acronym

SNOWCARBO

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Table of contents

List of abbreviations

CLC	CORINE land cover
CORINE	Coordinated
COSMOS	Community Earth System Models (network for earth system modelling)
DEM	Digital elevation model
ECHAM5	European Centre Hamburg Model (global circulation model, atmosphere)
ENVISAT	Environmental satellite
IMAGE2000	Satellite image database for pan-European image coverage for 2000 (±1y)
JSBACH	Jena Scheme for Biosphere-Atmosphere (model describing biosphere-atmosphere interaction)
LAI	Lead area index
LSP	Land surface parameter
MERIS	Medium resolution imaging satellite
NDVI	Normalized difference vegetation index
NLS	National Land Survey
REMO	Regional climate model
SYKE	Finnish Environment Institute
TOA	Top of the atmosphere
USGS	United States Geological Survey

1 Introduction

This report describes the models used in carbon balance modelling in SnowCarbo-project, their needs concerning spatial data and preliminary plan how to fulfil them. This plan will be modified according to modelling experiences.

2 Models at Finnish Meteorological Institute

Carbon balance modelling at Finnish Meteorological Institute is based on COSMOS model family developed at Max-Planck-Institut. They are used to simulate past, present and future climates over wide range of spatial resolution. Their applications include weather forecasting, analyzing the climate system and projecting climate change. Physical core of these models is Navier-Stokes equation on a rotating sphere with consideration of various energy sources, such as radiation or latent heat, by means of inclusion of appropriate thermodynamic terms. These equations are derived for suitable temporal and spatial resolution using initial and boundary conditions representative for the actual research problem. Atmosphere model ECHAM5 (Roeckner et.al., 2003), regional model REMO (Majewski, 1991, Jacob, 2001) and a biosphere model JSBACH (Raddatz el.al., 2007) are used in this work.

2.1 ECHAM5

The ECHAM (Roeckner, 2003) Global Circulation Model (GCM) has its original roots in global forecast models developed at European Centre for Medium-Range Weather Forecasts (ECMWF). This model has been modified for climate research, and its development continued to the current cycle ECHAM5. ECHAM is a comprehensive general circulation model of the atmosphere. The model is typically driven with sea surface temperature and does not consequently predict actual weather conditions.

ECHAM requires properties of some atmospheric gases, land cover type map, orography and monthly varying parameters like surface albedo, snow depth, leaf area index, vegetation ratio and temperature as inputs.

2.2 REMO

REMO (Majewski, 1991, Jacob, 2001) is a regional model suitable for climate modelling and weather forecasting. It can be driven in climate mode and in forecast mode which differ for their requirements of boundary data and slightly for their ability to repeat actual weather conditions. As the model does not presently consider ecosystem processes, the ecosystem module of the global model is supposed to be adapted to the model in the framework of this project.

Surface characteristics which are constant over time are orography, surface roughness length, land-sea mask and field capacity. Monthly varying parameters are surface background albedo, vegetation fraction and leaf area index (LAI). From version 5.1 on REMO uses a fractional surface coverage i.e. each grid box can contain a land, a water and a sea ice fraction. The

large scale forcing fields are prognostic atmospheric variables and prognostic surface variables like surface temperature, soil temperatures, soil wetness and snow depth

In standard model versions the vegetation cover data is a global 1km resolution land cover dataset by Hagemann (Hagemann et.al., 1999, Hagemann, 2002) based on Olson ecosystem classification (Olson, 1994a, 1994b). ECHAM uses also same data. This land cover class 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.

2.3 JSBACH

JSBACH (Raddatz et.al., 2007) is soil and vegetation model of ECHAM5 and REMO. Vegetation has been divided into 14 classes and each class has its own set of parameters. Values for parameters are estimated using remote sensing and map data, or values are taken from literature. These parameters include general land cover map, various parameters describing vegetation details like agriculture, height and roughness, amount of carbon in vegetation and albedo of vegetation and snow

3 Information for models

Both ECHAM5 and REMO use land surface parameter (LSP) dataset (Hagemann, 1999, Hagemann, 2002) based on Olson ecosystem classification (Olson, 1994a, 1994b) as land cover and use map. Its spatial resolution is about 1 km, consists of more than 80 classes and each class has a set of parameters describing class better. These parameters are background surface albedo α_s, surface roughness length due to vegetation $z_{0,veg}$, fractional vegetation cover c_v and leaf area index LAI for the growing (g) and dormancy season (d), forest ratio c_f, plant-available soil water holding capacity W_{ava}, and volumetric wilting point f_{pwp}. Vegetation model JSBACH has its own set of classes and parameters.

SYKE has more detailed information concerning land cover and use, as well as for soil than LSP dataset. This data is used to modify LSP land cover and use map by including more classes describing study area better and determining proper parameters for these classes.

3.1 Land cover for Finland and surrounding territory

Corine land cover classification is pan-European project aimed at gathering information relating to the environment on certain priority topics for the European Union (Land cover, Coastal Erosion, Biotopes etc). CORINE land cover (CLC) classification is produced using satellite images. The mapping scale is 1:100 000 and mapping accuracy is at least 100 m. The minimum mapping unit is 25 hectares and minimum width of units is 100 m. Only area elements are classified. The classification nomenclature is hierarchical and contains five classes at the first level, 15 classes at the second level and 44 classes at the third level. There can also be national level 4 classes. Originally, the CLC classification was performed as visual interpretation of hardcopy printout of satellite images by overlaying a transparency on

the printout, drawing polygons to transparency and digitizing drawn polygons (Törmä et.al., 2004).

Finnish national CLC classification is a combination existing digital map data and land cover interpretation based on IMAGE2000. The land cover interpretation is performed by estimating various variables describing tree and vegetation cover for each image pixel and thresholding these to CLC classes. CLC classes related to land use are created by recoding digital map data to CLC classes and in some cases updating them with satellite images. The result is a raster database with a resolution of 25 m by 25 m (Fi25m), including additional raster datasets describing the origin and date of data in each pixel (Törmä et.al., 2004).

New version of Corine classification, CLC2006 (Haakana et.al., 2008), is currently in production. Production is made as with CLC2000, except some databases are more up-to-date and of better quality. Main difference is classification of Lapland, which is based on decision tree classifier and better use of GIS-data. Also, there are more national classes, like coniferous forests that are divided to pine and spruce forests. This Lapland classification whose test version is presented in chapter 3 can be applied to climate models.

Information concerning soil (mineral soil, peat soil, rock) in Finnish Territory is based on Topographic database produced by National Land Survey. It is based on interpretation and stereomapping of aerial images and comparable to maps on scale 1:5 000 - 1:10 000 (Härmä at.al., 2005).

Global land cover classification GlobCover is used for areas outside Finnish territory. The GlobCover products are based on ENVISAT's Medium Resolution Imaging Spectrometer (MERIS) Level 1B data acquired in Full Resolution mode with a spatial resolution of 300 meters. For the generation of the Level 1B data, the raw data acquisitions have been geometrically corrected and resampled on a path-oriented grid, with pixel values having been calibrated to match the Top Of Atmosphere (TOA) radiance. Then, cloud and snow detection is made to images, they are mosaiced and mosaics classified. Different geographical regions can have their own more detailed classes (Bicheron et.al., 2008).

4 Derivation of parameters of land cover classes from EO data

Background surface albedo α_s is defined as the ability of land surface to reflect the incoming solar radiation of snow free areas (Hagemann et.al., 1999). It can be derived from Meteosat surface albedo. The Meteosat Surface Albedo product contains estimates of surface albedo acquired under direct and perfectly diffuse illumination conditions which are used to estimate the actual surface albedo (Pinty et.al., 2005).

Surface roughness length due to vegetation $z_{0,veg}$ is a measure of the roughness of the surface used to describe processes in the surface boundary layer (Hagemann et.al., 1999). This parameter depends on tree density which is described using LAI and stand height.

Fractional vegetation cover c_v indicates the fractional area covered by plants within a gridbox which are able to modify evapotranspiration by their stomata (Hagemann et.al., 1999). Parameter can be estimated from MODIS NDVI time-series using locally developed model (Törmä et.al., 2007) or geoland2-project (geoland2, 2009) product BP-1 or -10. Drawback of

the first option is that it underestimates the fraction of vegetation and the second that the products are not available for year 2009 except 4 drainage basins in Finland and Sweden.

Leaf area index *LAI* for the growing (*g*) and dormancy season (*d*) is defined as the ratio of the leaf area to its projected area on the ground. It can be estimated from MODIS time-series.

Forest ratio c_f is defined as the fractional cover of trees (Hagemann et.al., 1999). This parameter is estimated using Finnish national Corine Land Cover 2000 or CLC2000 tree crown cover estimate in Finland and GlobCover in other areas. Also, forest transmissivity which is estimated for snow mapping purposes at SYKE could be used.

Plant-available soil water holding capacity W_{ava} is defined as the maximum amount of water that plants may extract from the soil before they start to wilt (Hagemann et.al., 1999). It is estimated using land cover from Corine or ClobCover and soil information (mineral soil / peat soil / rocks) from Topographic database of National Land Survey. Unfortunately, soil information does not exist outside Finland so original USGS data will be used.

Volumetric wilting point f_{pwp}. Is computed from plant-available soil water holding capacity and field capacity (Hagemann et.al., 1999). Estimated using land cover from Corine or ClobCover and soil information (mineral soil / peat soil / rocks) from Topographic database of National Land Survey. Unfortunately, soil information does not exist outside Finland so original USGS data will be used.

4.1 Other paramerers

Space-borne microwave radiometers could also be used to acquire information about soil wetness and snow depth. Drawback is that spatial resolution is quite poor, some kilometers or worse. SYKE produces estimates for Sea Surface Temperature for Baltic Sea (Sea Surface, 2009), global MODIS-product MOD28 (Brown and Minnett, 1999) could be used for other areas.

4.2 Other spatial data

DEM is used to define orographic variables. The best alternatives are NLS-DEM (Härmä et.al., 2005), raster with 25m pixel covering Finland, which is produced by Finnish National Land Survey and Aster-DEM (Aster, 2009) which is based on data acquired by Aster instrument, and is raster with 30 m pixel, covering the Earth's surface between 83N and 83S latitudes.

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