LIFE Project Number

ENV/FIN/000133

Preliminary Demonstration Report

Reporting Date

30/11/2010

Action

Action 9 – Demonstration and validation of EO services (SYKE)

LIFE+ PROJECT NAME or Acronym

SNOWCARBO

Author

Name Beneficiary	Finnish Environment Institute (SYKE)
Contact person	Sari Metsämäki
Postal address	P.O.Box 140 (Mechelininkatu 34a), 00251 Helsinki
Telephone	+358 40 534 3856
Fax:	+358-9-5490 2690
E-mail	sari.metsamaki@ymparisto.fi
Project Website	http://snowcarbo.fmi.fi

Table of Contents

List of key-words and abbreviations

AMSR-E	The Advanced Microwave Scanning Radiometer for EOS
ECMWF	The European Centre for Medium-Range Weather Forecasts
ENVIMON	Processing software for satellite images
FMI	Finnish Meteorological Institute
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
REMO	Regional Climate Model
SWE	Snow Water Equivalent
SYKE	Finnish Environment Institute

1 Summary

This document describes the preliminary results from work concerning the demonstration of using Earth-observation data in Carbon modelling.

2 Data sources

REMO Regional climate model

The regional climate model REMO can be run in *climate* and *forecast* modes. In the climate mode the model is constrained once in ignition of the simulation with initial 3d meteorological and tracer fields and after that it is only forced from domain boundaries while the climate and tracer concentrations within the domain are estimated by the model. In the forecast mode the model is continuously forced with the boundary data with typically daily ignition and a spin up of couple of hours. Because the spin up period is rejected, the daily runs overlap for a duration of the spin up. A run in forecast mode follows closer to the boundary data than a run in climate mode. Thus, as Snowcarbo aims at simulating actual climate, the forecast mode is used for production runs. However, for evaluation of model performance, a climate run is performed as well. In order to demonstrate the benefits of using remote sensing data in the modeling, particularly snow output from REMO has been investigated.

ECMWF data

ECMWF (The European Centre for Medium-Range Weather Forecasts) operational data is used for boundaries and initial fields of meteorology for REMO runs. The data is based on synoptic weather station data all over Europe, including the stations operated by FMI. In SnowCarbo, Snow Water Equivalent (SWE) data by ECMWF serves as "stand alone" as well, since they are compared with remotely sensing snow information data.

Land cover data

REMO use Olson ecosystem classification for their land cover information. It has 94 classes and each class has own set of parameters describing the surface characteristics of each class and used by the models (Olson, 1994). When compared to Finnish national Corine Land Cover (Haakana et al., 2008), the proportion of coniferous forests is larger in Olson and the proportion of other land cover types smaller. Due to large pixel size, the dominant land cover type is emphasized. Parameter forest ratio and LAI of Olson classification were studied further. It was noticed that usually the forest ratios of classes were quite much higher than forest crown cover estimates computed from high resolution satellite images. Also LAI for Olson forest classes were higher than estimated using high resolution LAI maps produced in Valeri project.

Different revised land cover data sets recoded into Olsson nomenclature were produced covering the modelling window in Scandinavia and surrounding areas. The land cover classes were retrieved using:

1. GlobCover
2. European Corine Land Cover were available and Globcover elsewere
3. National Corine Land cover within Finland, European Corine Land Cover where available and Globcover elsewhere
4. MODIS products

When considering thematic accuracy of data, European and national version of Corine Land Cover should be used as input data source for land cover information over Scandinavia. However the feasibility of enhanced land cover information in models will be evaluated by comparing model outputs with in-situ carbon fluxes and EO based observations. More details of derived alternative land cover data sets can be found in the report of action 11 – "Evaluation of required North-Eurasian land cover information" (date 20/11/2010).

Snow water equivalent from Earth observation data

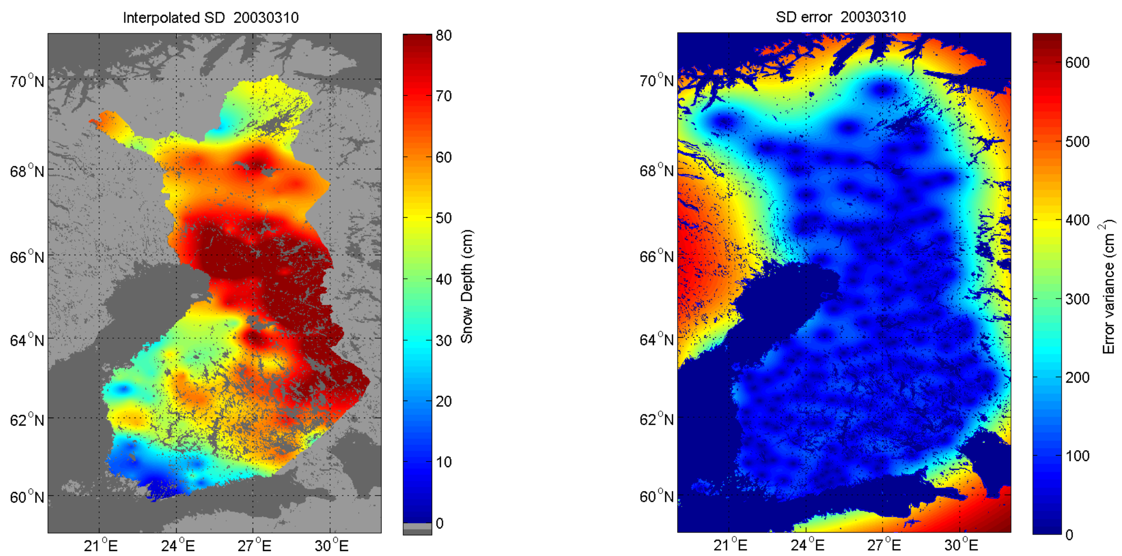
The snow water equivalent (SWE) estimations are derived from microwave radiometer data and weather station snow depth measurements. The microwave data consists of AMSR-E instrument L2A data of 18.7 and 36.5 GHz bands. The weather station data consists of snow depth measurements of the Finnish weather stations (around 150). Also a forest stem volume map of Finland is used.
A statistical inversion method is used to derive the SWE. It uses a microwave snow emission model to fit the observed brightness temperature values to modelled values using the snow grain size as a fitting parameter. The snow depth measurements of weather stations are used to calibrate the model in those known points. The method is described in detail in Pulliainen (2006).

Satellite-derived start of season

Start of growing season for coniferous forest in Finland was calculated for the years 2003-2007 using the methodology developed in action 7 (see deliverable "Progress report on extracted features (2001-2008)"). The beginning of photosynthetic activity determined at CO_2 flux measurement sites (Suni *et al.*, 2003; Thum *et al.*, 2009) was used as reference date for the definition of start of growing season. Start of growing season was determined for each MODIS pixel (resolution of 0.0025 degrees) with a fraction of coniferous forest above 90 %. Results were aggregated to a pixel size of 0.025 x 0.025 degrees for visualization.

In-situ data

The *in situ*-data consist of Weather station observations on Snow depth. A comprehensive network of ~¨200 weather stations operated by the Finnish Meteorological Institute (FMI) provides mostly automated measurements of Snow Depth (SD) on daily basis. The in situ data includes not only these individual point-wise observations, but also continuous SD fields generated from those observations using Krieging interpolation method. Figure 1 shows an example of interpolated SD-field for a certain date (left); the Krieging method also proved error estimated for interpolation based on the spatial variance and spatial distribution density of pint-wise observations (right).



SYKE
ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Figure 1. Snow Depth map interpolated from in situ measurements at weather stations (right), errors generated by interpolation method, small error indicate presence of in situ observation (right).

3 Methodology

The effect of land use data to REMO was assessed by comparing the Snow depth provided by REMO (climate mode) when two different land cover data were use. These are

1) Olson -hereby referred as reference
2) Combined GlobCover and Corine Land Cover data - hereby referred as GC&CLC.

At this stage, snow depth was chosen to be a good indicator of REMO performance as it is one of the key parameters assessed by the means of remote sensing. With REMO, daily snow depth was calculated for years 2002, 2003 and 2006. As a result, two sets of SD time series was obtained, one set for both Land cover data. Figure 2 shows a subset of SD time series of 2002, provided by REMO using Reference Land Use data.

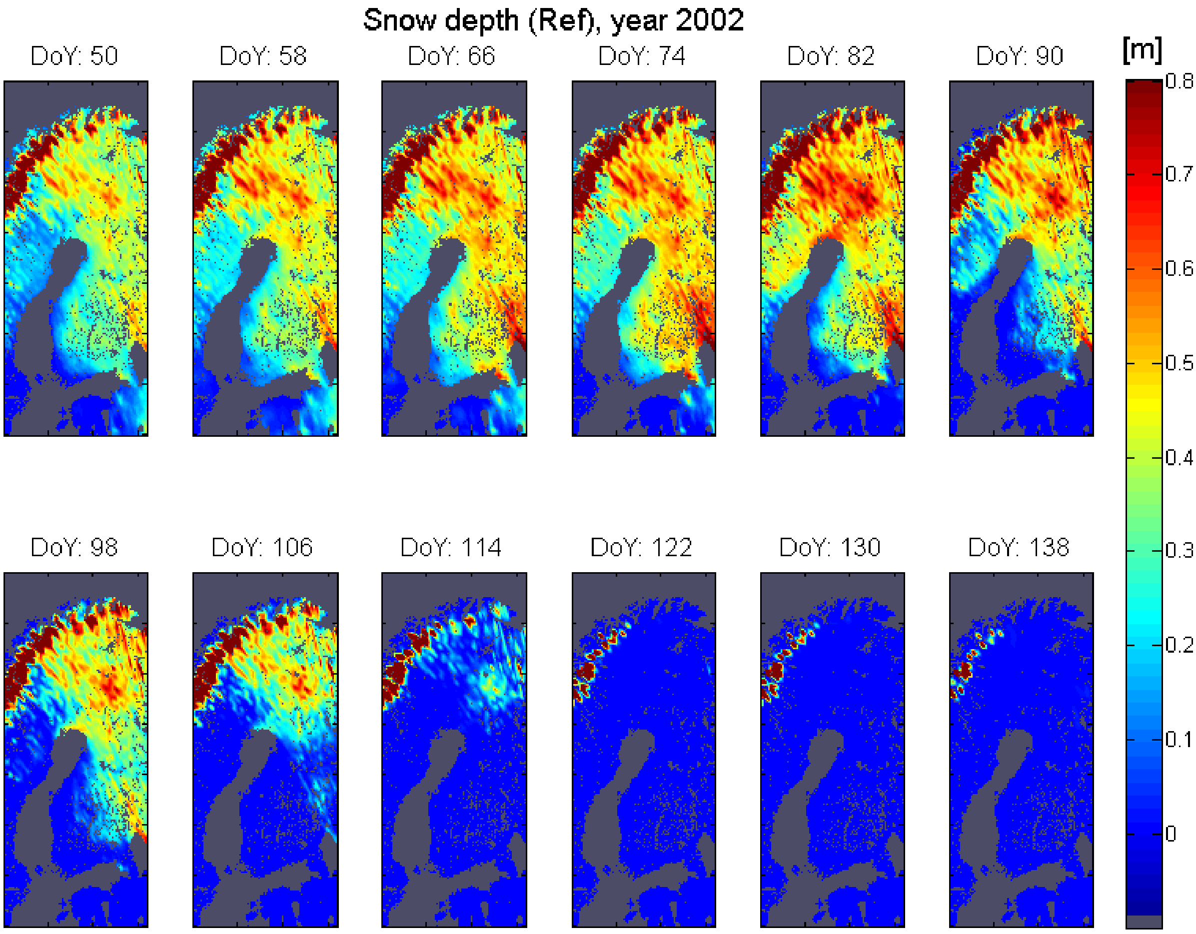


Figure 2. Subset of time series of Snow Depth provided by REMO.

For each year, a difference between gained SD-data was calculated. The resulting difference maps show the areas where the effect of Land Cover data is prominent and, on the other hand, which areas are almost insensitive to land Cover data. Figure 3 shows an example on Day 110 (April 10th) of 2002:

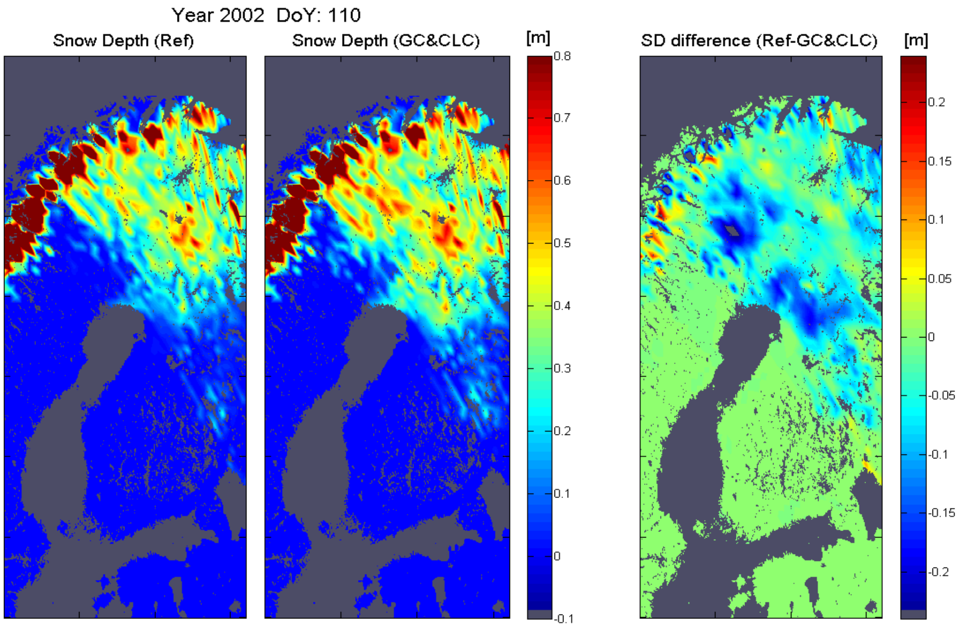


Figure 3. Example of Snow depth maps by $REMO_{ref}$, $REMO_{GC\&CLC}$ and their difference.

By investigating the differences between Snow Depth provided by different REMO runs, we can locate the areas where the change in land cover type alters REMO snow output the most. This information can be linked to REMO surface parameters calculated from land cover data, e.g. to surface albedo or to forest coverage. Hence, we try to find a surface parameter which mostly affects the snow depth calculations. As these surface parameters can be derived by means of remote sensing, these experiments guide us in later attempts to feed REMO (forecast mode) with remotely sensed data on forest fraction and on surface albedo.

REMO Snow depth was also compared to in situ measurements in order to have an overview of model performance.

REMO forecast mode uses ECMWF snow data as one the input fields. It is therefore relevant to investigate if snow data can be replaced or improved by means of remote sensing. This work started with comparisons between ECMWF SWE-field (converted to Snow Depth) and SWE field derived from observations by AMSR-E microwave radiometer onboard NASA/Aqua satellite.

Spatial and temporal patterns in start of growing season

Spring phenology is one important factor influencing the carbon balance of boreal ecosystems (Richardson *et al.*, 2009) and therefore accurate information related to spring phenology is important for studies of the regional carbon budget. The beginning of photosynthetic activity (referred here as start of growing season) in an ecosystem can be determined from in situ measurements of the CO_2 fluxes with the eddy covariance technique at local sites. These measurements are only available at very few locations and thus it is important to spatialize the information provided by these sites. Therefore, satellite-derived NDVI time-series were used for the determination of start of growing season of coniferous forest using a method which was calibrated with in situ data (see deliverable action 7 "Progress report on extracted features (2001-2008)").
Spatial distribution of the start of growing season of coniferous forest in Finland for different years will be shown in section Virhe. Viitteen lähdettä ei löytynyt.. These are preliminary results, which will be investigated further. Spatial patterns in different years will be compared to modeled start of season at a later stage (not shown in this report).

Furthermore, it is important that interannual changes and anomalies of the event, which are observed at measurement sites, can also be described using satellite data. Therefore, the deviation of timing of start of season in a year from average occurrence of the event (period of 9 years) will be compared for satellite-derived and in situ date in section 4.3.

4 Results

4.1 Effect of land use data to REMO

The results indicate that REMO snow depth is dependent on land cover data employed. The magnitude of the effect varies with the model grid cell location and the modeling year (i.e. boundary data). However, regardless of year, $REMO_{ref}$ provides smaller SD for certain areas in Finland (i.e. difference is negative). Figure 4 shows some statistical features for difference SD_{ref}, - $SD_{GC\&CLC}$ calculated for each pixel from the daily modeled SD-values throughout the snow seasons 2002 and 2006 (February to May). It is evident that in both years, there are about the same regions where the magnitude of SD difference is clearly larger that in average, indicating that in theses areas, the land cover type strongly affects the SD calculations. However, since a climate model is in concern, it is more pertinent to investigate multiyear statistics instead of individual year. This work is under progress.

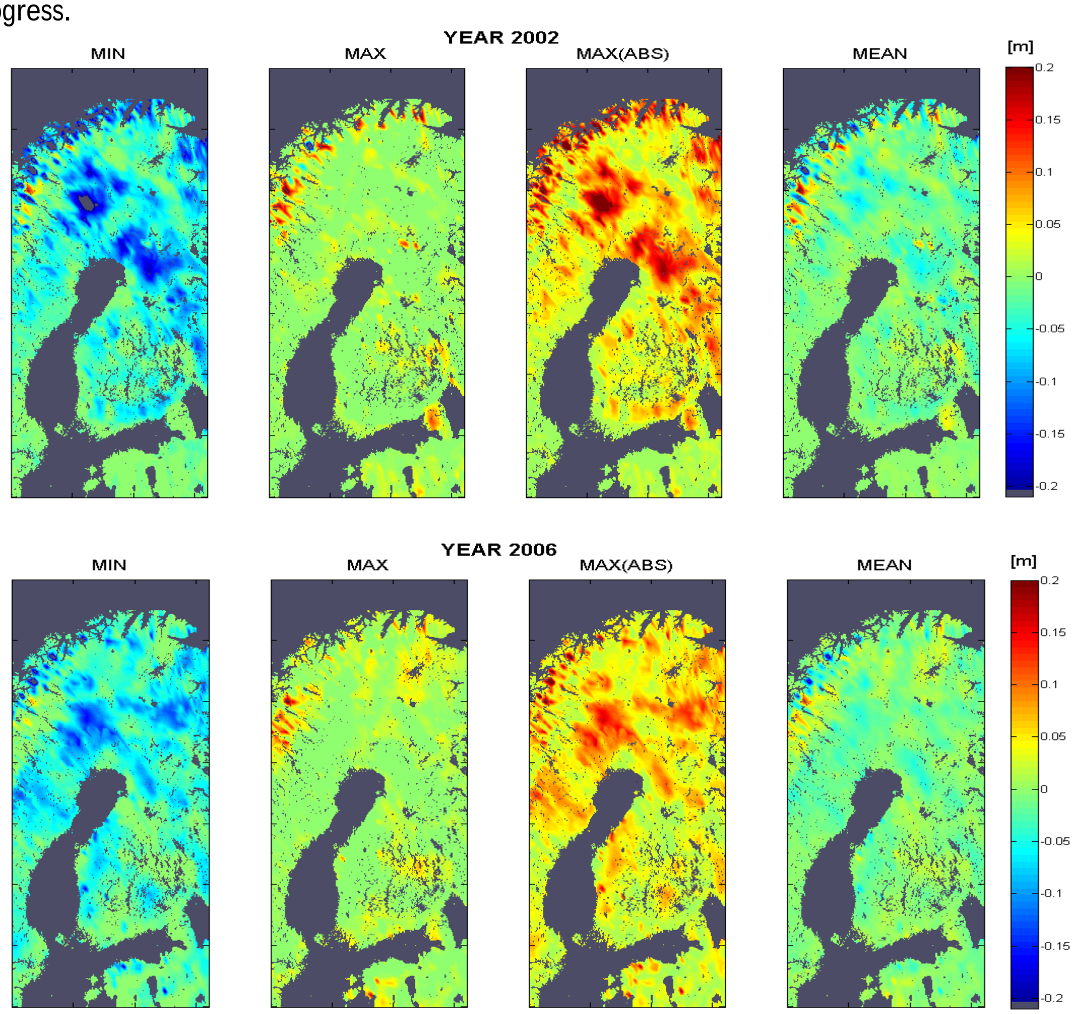


Figure 4. Main statistical features of SD difference (ref-CG&CLC) for years 2002 and 2006.

The comparison of REMO-modelled snow depth against *in situ* snow depth was carried out for several points of interest in Finland. Grid cell overlaying phenology stations were selected for further analysis. Figure 5 shows the results for three of the stations; the REMO SD relatively well follows the ground truth. However, in some locations, REMO seems to melt the snow too fast, so that SD of zero is reached too early. Still, as the actual output of REMO is Snow water equivalent and we use a constant snow density to convert it to snow depth, the results cannot be treated as absolute but only indicative measures of REMO performance.

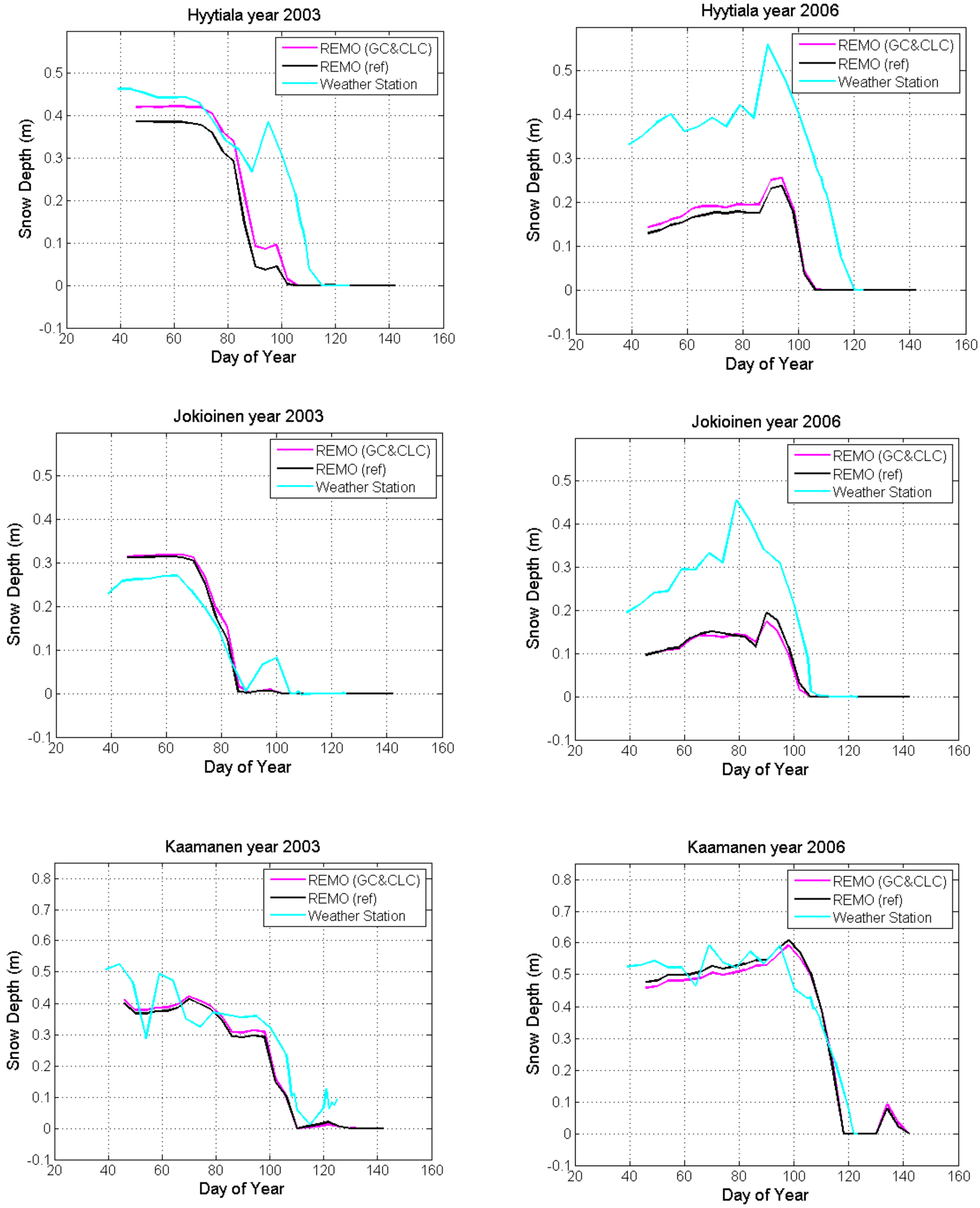


Figure 5. Time series of REMO Snow depth and *in situ* snow depth for some fenological stations.

4.2 Comparison of ECMWF snow data and remote sensing snow data

The ECMWF SWE-fields were compared against SWE data derived from AMSR-E observations processed by SYKE. Additionally, both these were compared with interpolated snow field from in situ *in situ* measurements. Analysis for years 2001-2004 indicate clear discrepancies between ECMWF data and remote sensing data. Figures 6 and 7 show a subset of the comparison data for years 2003 and 2004, representing the typical tendency. It is evident that ECMWF fails in catching the meting snow later in the season, particularly in eastern Finland. Since remote sensing data strongly correlates with *in situ* observations (this is because the applied algorithm assimilated in situ data and AMSR-E data with a strong weight on *in situ* observations), it can be deduced that remote sensing data is closer to real situation. Therefore, using remote sensing data instead of ECMWF should improve REMO performance and consequently, the carbon mapping of JSBACH. It is recommended that trials of using remote sensing SWE as model input should be made. This work is under progress.

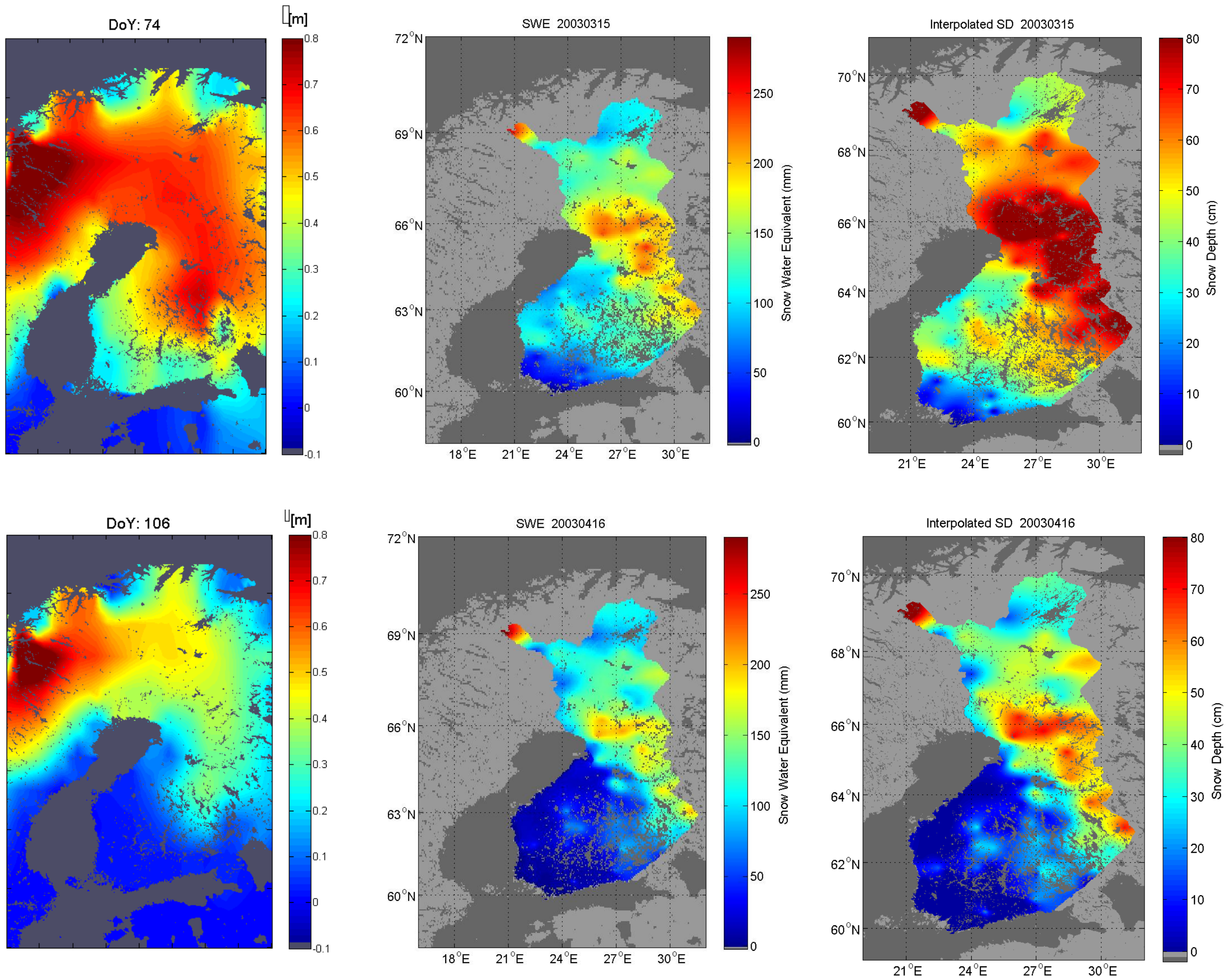


Figure 6. Snow depth by ECMFW (left), Snow depth from AMSR-E data (middle,)Snow depth interpolated from Finnish Weather station data (right) for two days: March 15th 2003 and April 16th 2003.

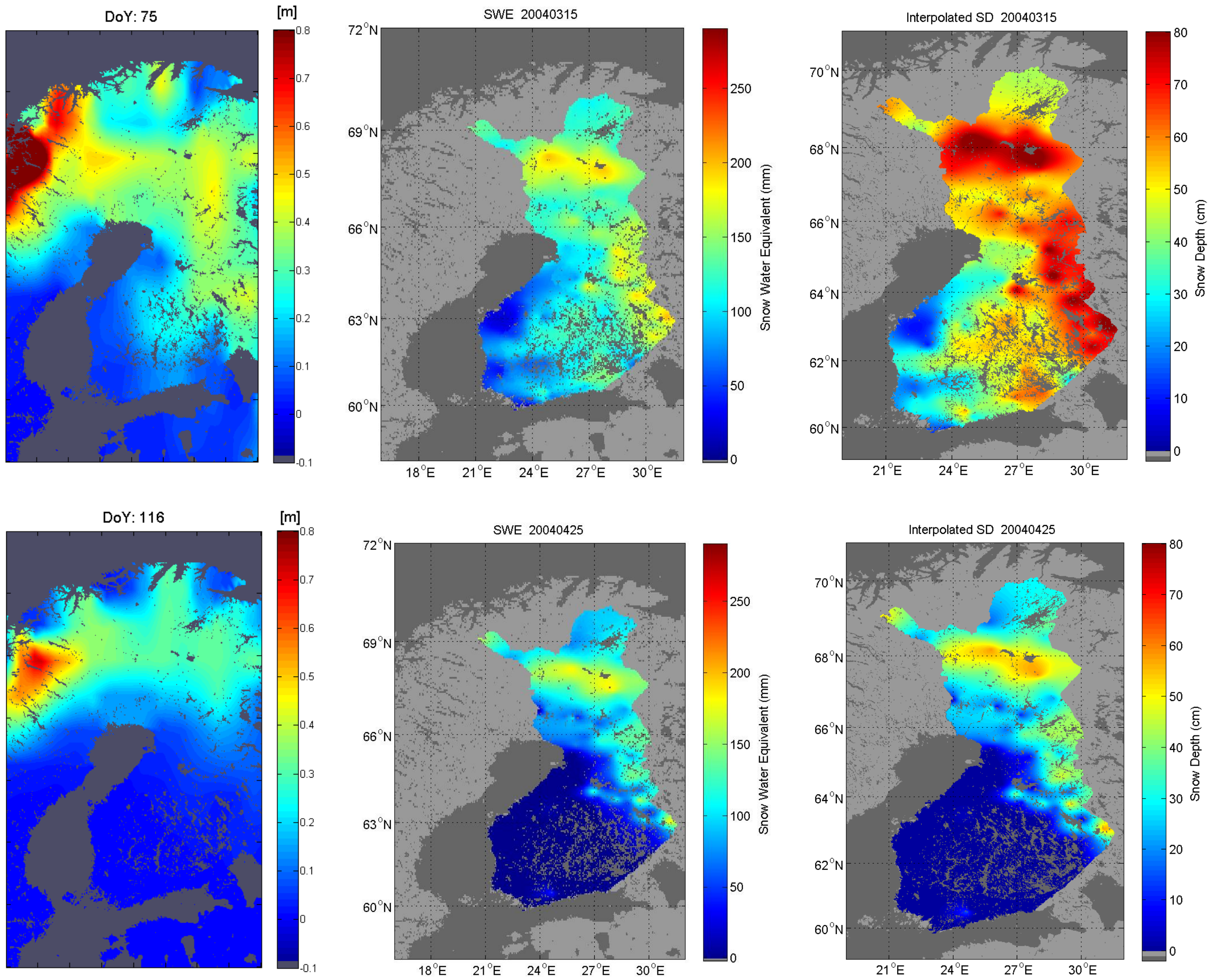
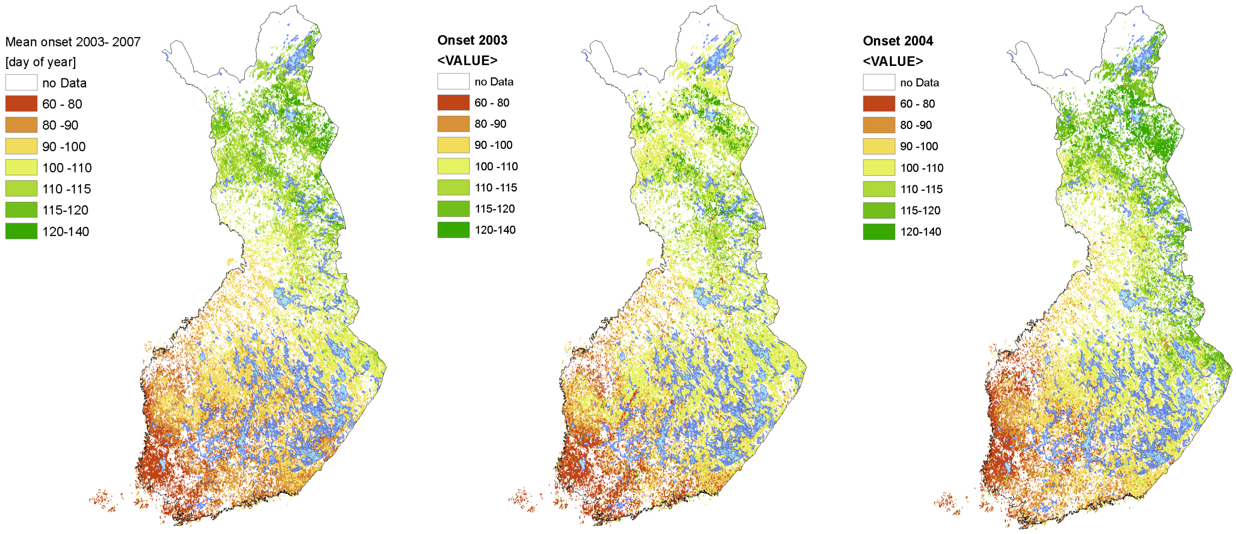


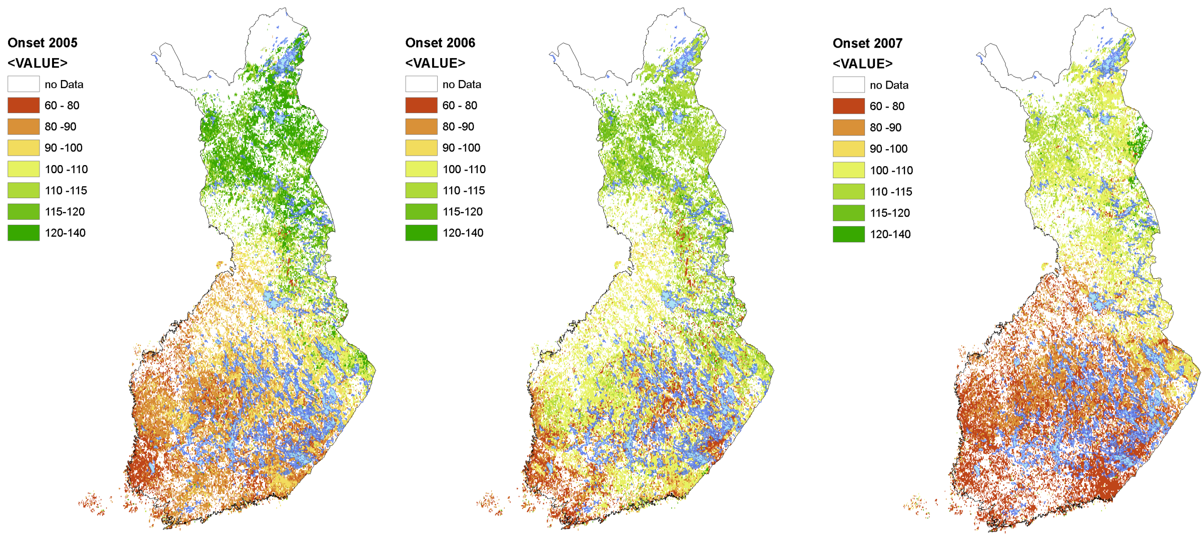
Figure 7. Snow depth by ECMFW (left), Snow water equivalent from AMSR-E data (middle,)Snow depth interpolated from Finnish Weather station data (right) for two days: March 15th 2003 and April 24th 2004.

4.3 Start of growing season of coniferous forest in Finland

The following figures show the beginning of growing season of coniferous forest for different years in Finland and the mean onset for the 5-years period from 2003-2007.
Satellite-derived start of season shows an average onset values in the range from day 60 -80 for the southwestern part of Finland and a spatial trend to later onset towards the North following the climate gradient.



a) b) c)



d) e) f)

Figure 6. Start of growing season [day of year] of coniferous forest for different years (b –f) in Finland and mean value for start of season for period 2003 – 2007 (a).

Interannual changes in start of growing season

Interannual changes in the beginning of growing season (compared to the mean value of 9 years) for station Sodankylä and Hyytiäla are given in figure 7 and 8, showing both in situ observations and satellite-derived onset. Interannual changes are depicted as deviation from the mean value of the observation period. Negative values indicate earlier onset as in average and positive values indicate later onset than the average year. Satellite-derived start of season follows similar behavior as described by in situ observations, for example the onset of growing season in Hyytiälä occurred earlier (~15 days) in 2007 compared to the average of the 2001-2009 period. Satellite observations (figure 6 e and 9) indicate early onset for 2007 for the whole Southern part of Finland. Note, that base period for calculation of the mean onset date from satellite data was only 5 years.
Late start of season (compared to mean of years 2001-2010) was observed for station Sodankylä for the year 2010.

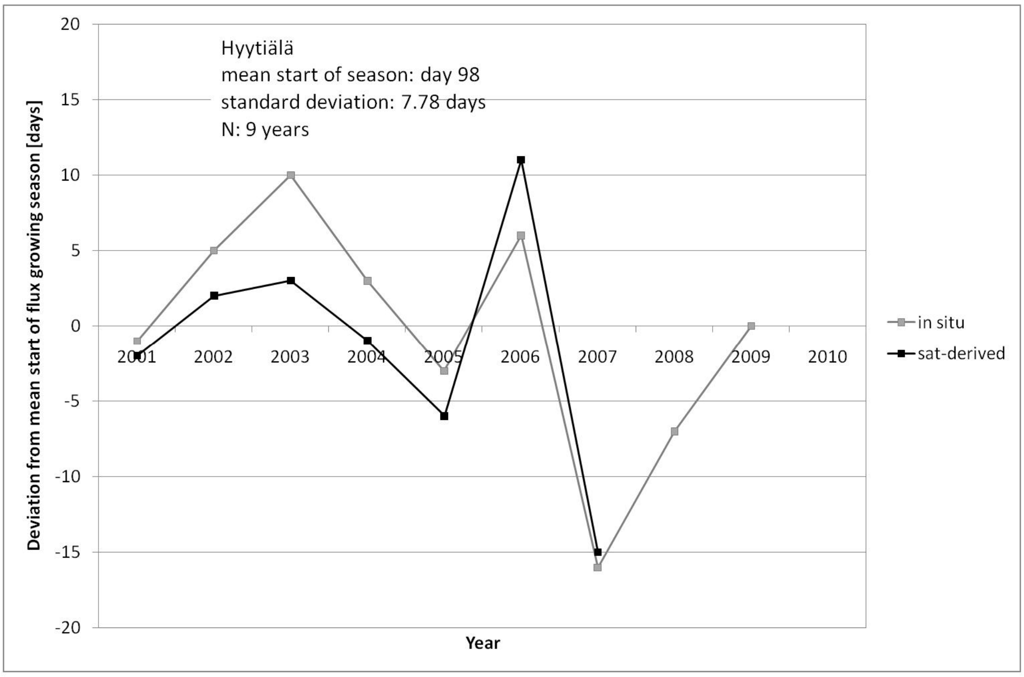


Figure 7. Deviation from mean for in situ and satellite-derived start of season at station Hyytiälä for years 2001 – 2009.

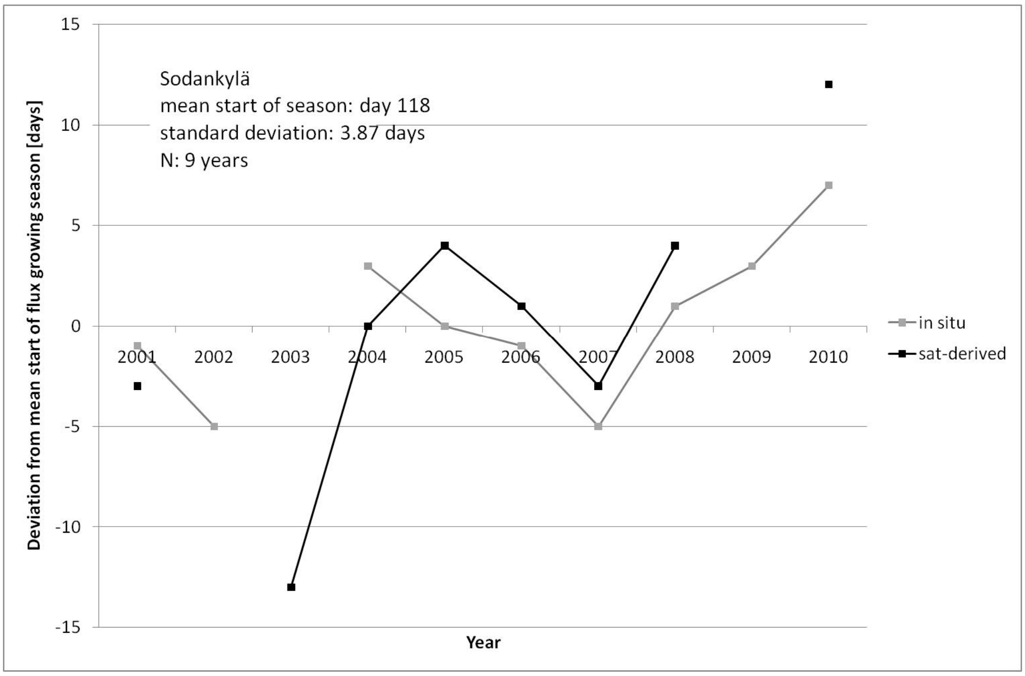


Figure 8. Deviation from mean [day] for in situ and satellite-derived start of season at station Sodankylä for years 2001 – 2010.

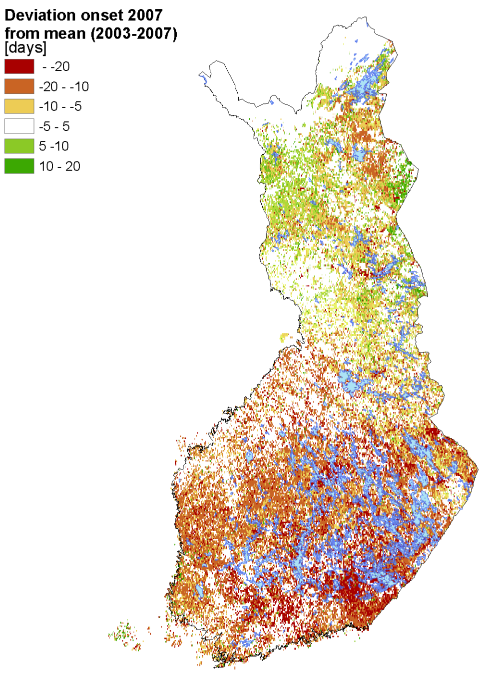


Figure 9. Deviation of start of growing season for year 2007 from mean onset day (years 2003 – 2007).

5 Summary

Haakana, M., Hatunen, S., Härmä, P., Kallio, M., Katila, M., Kiiski, T., Mäkisara, K., Peräsaari, J., Piepponen, H., Repo, R., Teiniranta, R., Tomppo, E., Törmä, M., 2008 "Finnish CORINE 2006 -project: determining changes in land cover in Finland between 2000 and 2006." *SPIE Europe Remote Sensing congress* 2008.

Olson, J.S., 1994 [Global ecosystem framework-definitions.] *USGS EROS Data Centre Internal Report, Sioux Falls SD* (1994).

Pulliainen, J. 2006. Mapping of snow water equivalent and snow depth in boreal and sub-arctic zones by assimilating space-borne microwave radiometer data and ground-based observations. *Remote Sensing of Environment*. 101(2): 257-269.

Richardson, A.D., Hollinger, D.Y., Dail, D.B., Lee, J.T., Munger, J.W., O'keefe, J., 2009. Influence of spring phenology on seasonal and annual carbon balance in two contrasting New England forests. *Tree Physiol* 29, 321-331.

Suni, T., Berninger, F., Vesala, T., Markkanen, T., Hari, P., Mäkelä, A., Ilvesniemi, H., Hänninen, H., Nikinmaa, E., Huttula, T., Laurila, T., Aurela, M., Grelle, A., Lindroth, A., Arneth, A., Shibistova, O., Lloyd, J., 2003. Air temperature triggers the recovery of evergreen boreal forest photosynthesis in spring. *Global Change Biology 9,* 1410-1426.

Thum, T., Aalto, T., Laurila, T., Aurela, M., Hatakka, J., Lindroth, A., Vesala, T., 2009. Spring initiation and autumn cessation of boreal coniferous forest CO2 exchange assessed by meteorological and biological variables. *Tellus B 61*, 701-717.