Vulnerability Assessment of ecosystem services for Climate Change Impacts and Adaptation (VACCIA)

Action 2: Derivation of GMES-related remote sensing data

Deliverable 2: Filtered and Interpolated Time-series

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CONTENT

Filtered Time-series of phenology and snow coverage

Length of the period between the end of melting period and start of the green vegetation growth is especially interesting for the catchment area modelers. During this period, the soil is vulnerable for the erosion and nutrient leaching to the water systems. Remote sensing allows unceasing observation of snow melting and changes green vegetation growth over extensive spatial coverage. Furthermore, the seasonal monitoring can be extended to different land use classes by using EO based land cover information. This allows, for example, the comparison of seasonal dynamics between coniferous forests and agricultural areas in catchments located in different parts of Finland or Europe. It is clear that cloud cover and atmosphere originated disturbances together with the relatively coarse spatial resolution of the original data causes gaps and inaccuracies in the time series. However, even from a noisy time series or from one with significant gaps, indicative information can be extracted by interpretation of models fitted to the filtered time series.

This second deliverable of VACCIA Action 2 (Remote Sensing) include filtered and interpolated/modeled time series of green vegetation rising (expressed with NDVI-index) and snow melt (SCA) from the years 2001-2008. Earth observation based time series were extracted for 5 different FinLTSER-site areas of interest (AOI) and separated to major land cover classes (agricultural areas, coniferous forests, broad leaved forests, mixed forests and peat land areas) (see first deliverable of VACCIA Action 2). Outlier methods were filtered with standard methods and modeling was performed for the snow melt event and start of the growing season for each of the AOIs and land cover types. Aim was to provide information on the seasonal dynamics in these ecosystems. This was specifically under interest for the project actions 7, 8, 10 and 12.

Areas on interests for NDVI and SCA time-series

Time-series of NDVI and SCA from the years 2001-2008 were generated for five drainage basins of different size in Finland (Figure 1). Time series were generated for the areas of interest of FinLTER-sites of Lammi (Action 8), Lake Päijänne (Action 10), Lepsämänjoki agricultural (Action 7) and Northern LTSER (Action 12). Figure 1. shows the location of different areas of interest and general descriptions from these areas are added to Table 1.
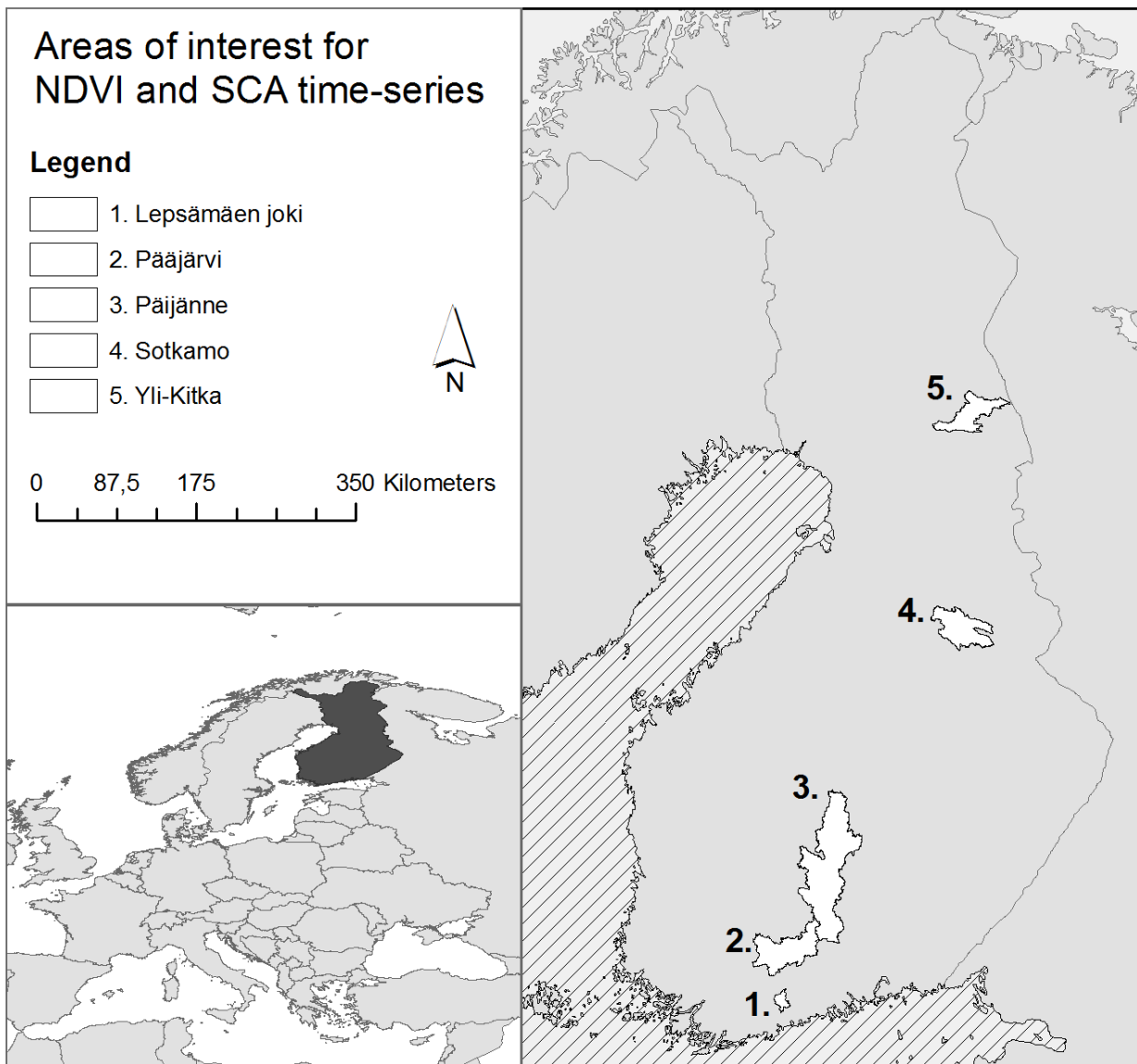
Figure 1. Areas of interest for NDVI and SCA time-series.

Table 1. Areas of interest descriptions

Area	Area of Interest	Total area (km2)	VACCIA action	FinLTSER -site
Pääjärvi	1st order DB	3621	8	Lammi
Päijänne	1st order DB	9286	10	Lake Päijänne
Lepsämäenjoki	2nd order DB	347	7	LAWA
Yli-Kitka	2nd order DB	2856	12	Northern
Sotkamo	Four second order DBs	3291	12	Northern

Areas of interest were defined using vector GIS data. This data was automatically applied when extracting time-series of NDVI and SCA-estimates from different land cover types. Corine Land Cover classification was used to differentiate the land cover classes (Härmä et al. 2004). Maps from the areas of interest with general land cover classification are

presented in Figure 2. Each observation in time-series is a mean value from the applicable pixels of each land cover class. Estimation of NDVI and SCA is done in different spatial resolutions (250m and 500m, respectively) and therefore the number of pixels, i.e. sample size, varies according to the spatial resolution and land cover type fragmentation in areas of interest (table 2).
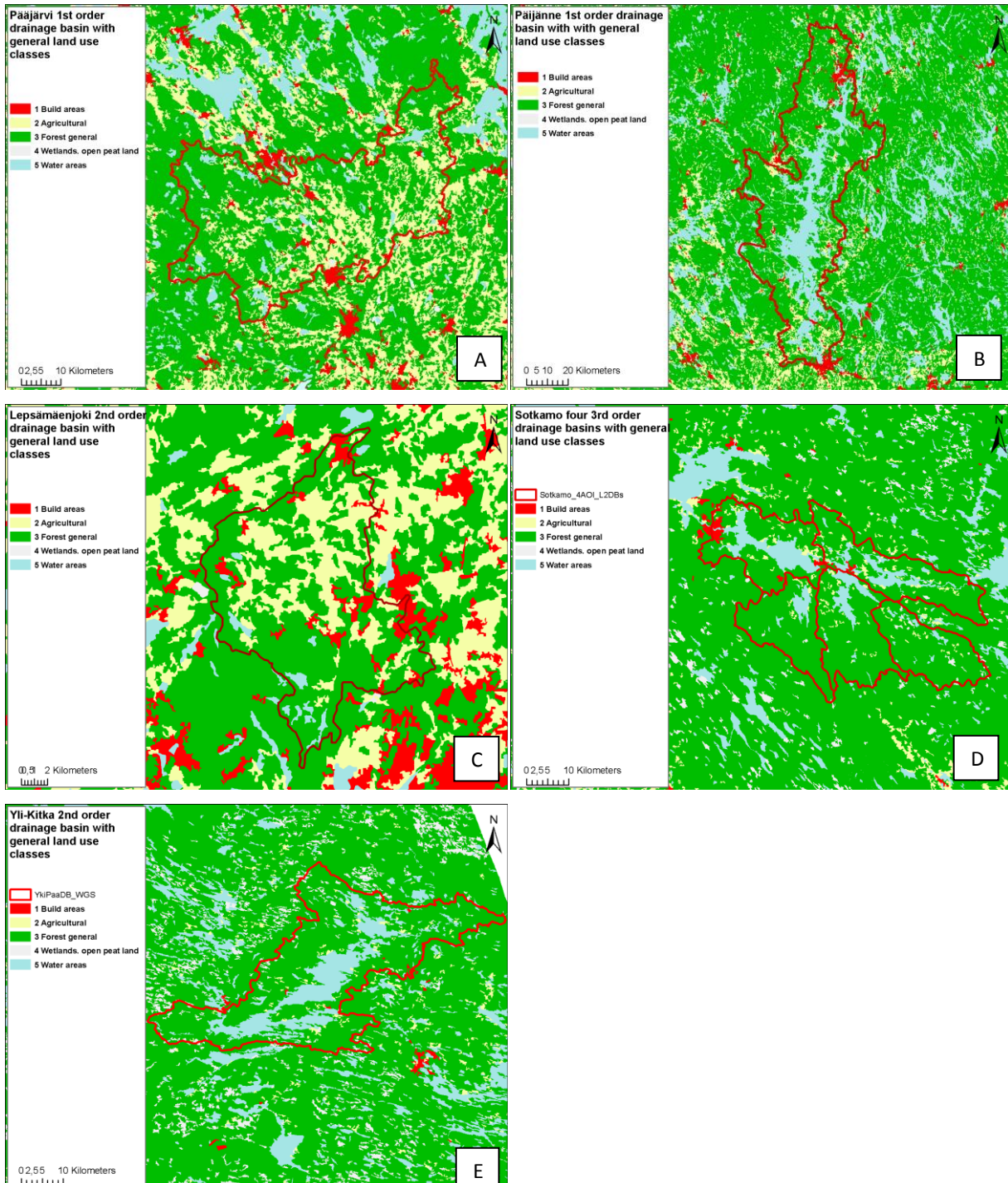

Figure 2. General land use in areas of interest (marked with polgygons in maps) for NDVI and SCA time series. Lake Pääjärvi 1st order drainage basin (A), Lake Päijänne 1st order drainage basin (B), River Lepsämäen joki 2nd order drainage basin (C), four 3rd order drainage basin in Sotkamo area (D) and Lake Yli-Kitka 2nd order drainage basin.

Table 2. Amount of pixels with different land use class in areas of interest in 250 meter resolution (NDVI) and 500 meter resolution (SCA)

Area of Interest	# of pixels in agricultural areas in 250m/500m resolution	# of pixels in coniferous in forests areas 250m/500m resolution	# of pixels in broad leaved in forest areas 250m/500m resolution	# of pixels in mixed forest areas in 250m/500m resolution	# of pixels in Open peat land areas in 250m/500m resolution
Pääjärvi	3915/835	3496/734	49/12	803/137	110/32
Päijänne	1626/317	6687/1380	185/19	2793/461	105/25
Lepsämäenjoki	470/100	330/60	2/0	92/15	0/0
Yli-Kitka	26/4	2819/575	5/1	860/133	127/28
Sotkamo	148/28	2139/458	5/0	2456/419	80/13

METHODS

Description of the methods and data sets used to the derive EO based time series are provided in the 1st deliverable of Action 2. The general process flow from raw satellite data to interpreted time series results are presented in figures 3A and 3B.
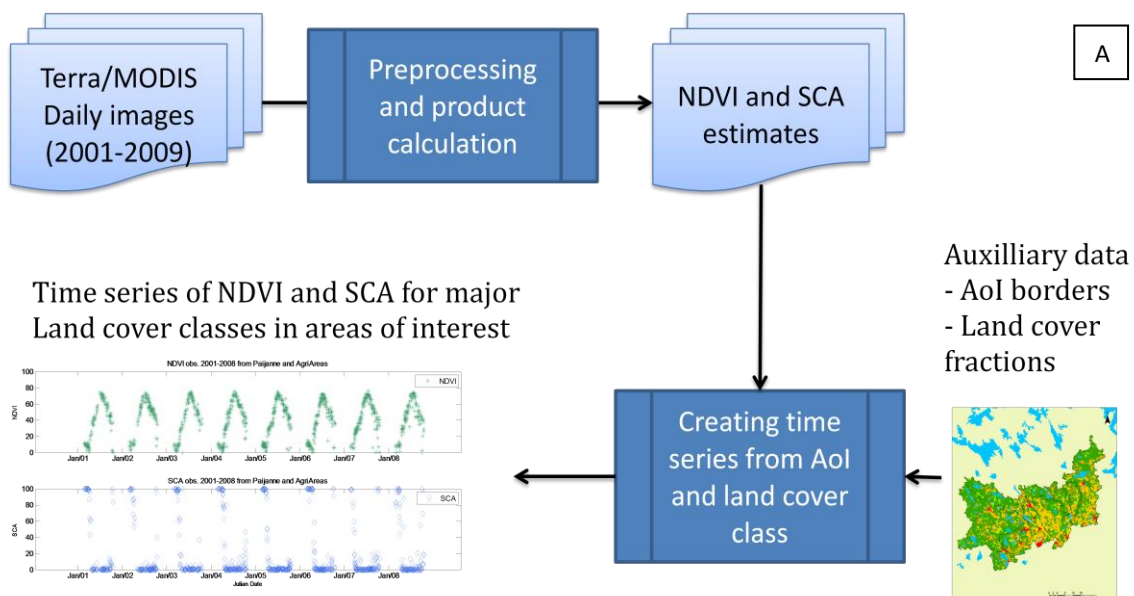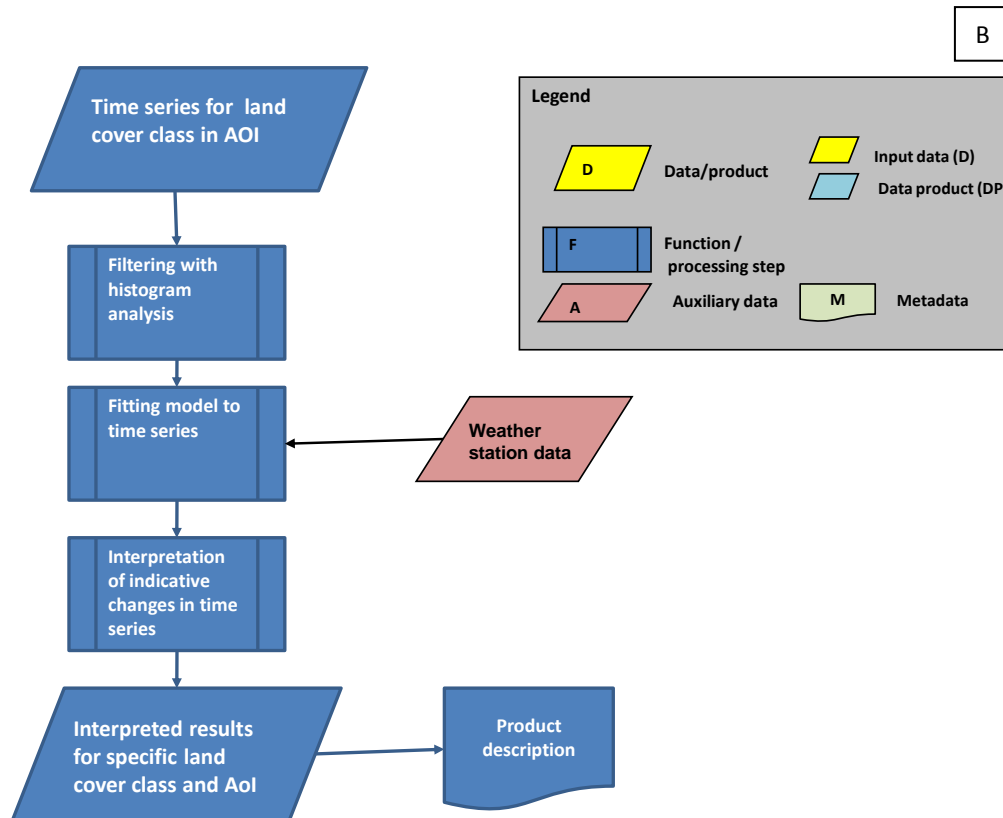
Figure 3. General process flow description for deriving time-series of NDVI and SCA from years 2001-2008 (A), the process flow for filtering, modeling and interpretation of time series (B).

TIME SERIES FILTERING

All time series of SCA and NDVI were filtered with the same method. Every observation in time series is a daily mean value from a set of observations from the same land cover type. Filtering was performed by eliminating observations i.e. pixels with values outside of two times the standard deviation around the mean of each set of observations. The number of observations, i.e. pixels with SCA or NDVI value, needed to exceed 10 in order to allow the calculation.

MODELING OF THE NDVI AND SCA TIME SERIES

Time series functions were fitted to the extracted and filtered snow cover and NDVI observations. Synoptic weather station data was used as auxiliary information to help to parameterize the models.

MODELING OF NDVI TIME SERIES

Gaussian, or similarly behaving sigmoidal, functions are often used to model phenological NDVI observations (e.g. Jönsson & Eklundh, 2002; Soudani et al., 2008). We used Gaussian function (Eq. 1) that was fitted to the NDVI time series from the drainage basins from the years 2001-2008.

$$fNDVI(t) = (1 - \exp(-\frac{t^2}{(r^2 * a)})) + n \qquad \text{eq. 1}$$

where, t is the time in days, r is time period in days during the change occurs, n is the NDVI or SCA value where time series starts change, *a* is the constant value. We used a = 1/3 according to (Chiles&Delfiner 1999). These three parameters that define the shapes for the gaussian models were chosen semi-empirically. First estimates for the parameter values were generated by minimizing the gaussian function in relation to the NDVI observations. Model performance was then visually checked and if needed, the parameter values were further adjusted to get the best possible fit. Weather station data of air temperature and snow cover was used as auxiliary data in manual fitting. Example of a fitted model and used weather station data are presented in the figure 4.
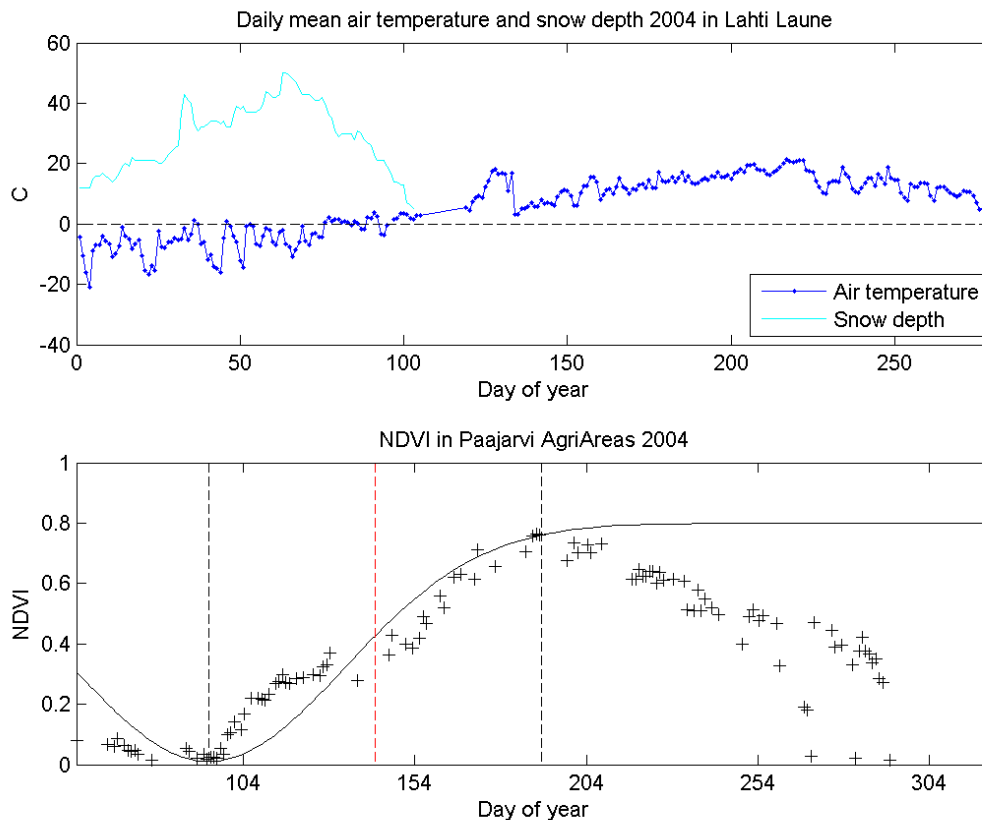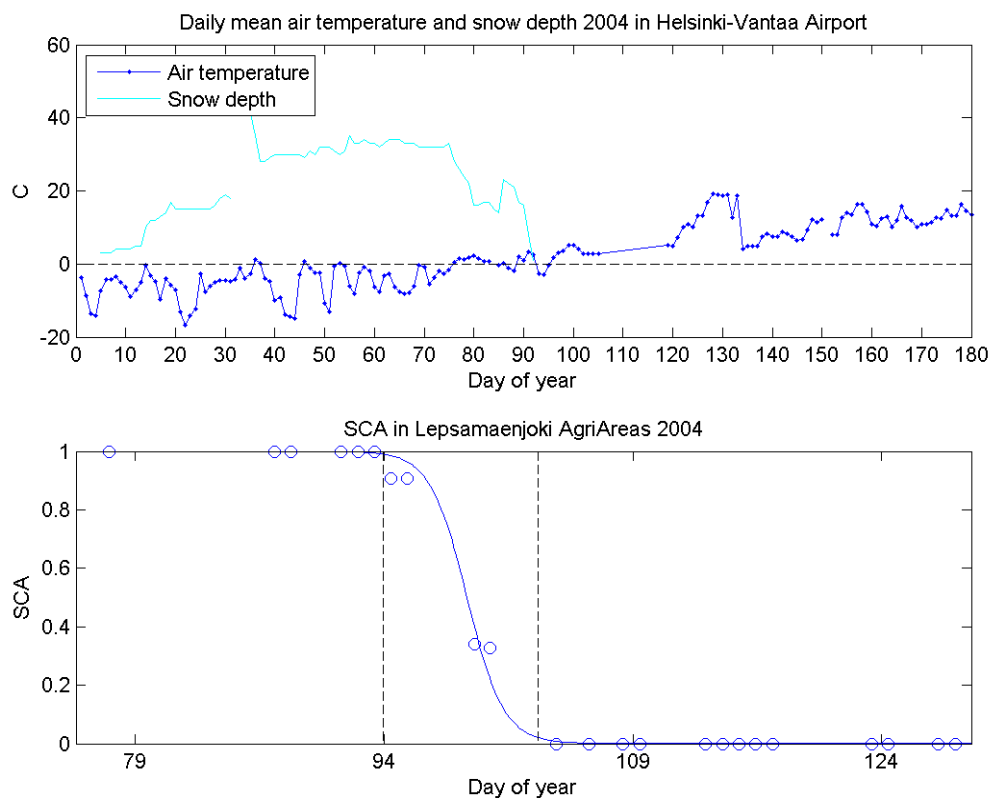

Figure 4. In the upper time series are shown the snow depth (solid line) and air temperature (dotted line) from the nearest weather station from the area of interest. In the time series below are EO based and filtered NDVI observations (crosses), fitted Gaussian model (solid line) and estimated interpretations from the NDVI model: minimum and maximum of NDVI (vertical and black dashed lines) and estimated green vegetation on set (dashed red line in the middle).

MODELING OF SCA TIME SERIES
Similar time series analysis for the snow covered area was not found in the literature. Melting of snow is a variable process where melting is constantly suspended by colder periods and also falls of new snow. Melting itself, however, proceeds undeniable against the summer and the recession of snow coverage often follows a recurrent pattern. At the early stages of melting, accumulated layers of snow starts to recess slowly. This is followed by a rapid drop in snow coverage, when the daily mean temperature starts stay above zero. Recession in SCA is, however, constantly interrupted by colder periods and new snow fall, but these thin layers often melt quickly during the next warmer

period. At the end of the melting period, the remaining snow hangs on the colder microclimates typically occurring in areas with icy soil or dense forests. This reasoning encouraged us to fit a sigmoidial function SCA time series (eq. 2.).

$$fSCA(t) = \frac{1}{1+\exp(\frac{a-t}{b})} \qquad\qquad \text{eq. 2}$$

Where *a* determines the position of inflection point i.e. the date where the melting rate starts to decrease after a faster drop, and *b* gives the rate of change. Temperature and snow dept data from the synoptic weather stations within or close to the AOI were used as auxiliary data to help in the parametrization of the models. The start and end of the melting period were then determined by using threshold values of 99% and 2%, respectively, to the SCA model. Example of model fitting to SCA time series is provided in figure 5.

Figure 5. In the upper time series are show the snow depth (solid line) and air temperature (dotted line) from the nearest weather station from the area of interest. In the time series below are EO based and filtered SCA observations (circles), fitted sigmoidal model (solid line) and estimated interpretations from the SCA model: start and end of the melting period (vertical and black dashed lines).

RESULTS

NDVI and SCA time series for years 2001-2008 are separated under different areas of interest and land cover classes in following sub-sections. Results are provided to only those areas and land cover types from which time series could be derived for both of the EO applications.

Figure 1. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Agricultural areas and year 2001
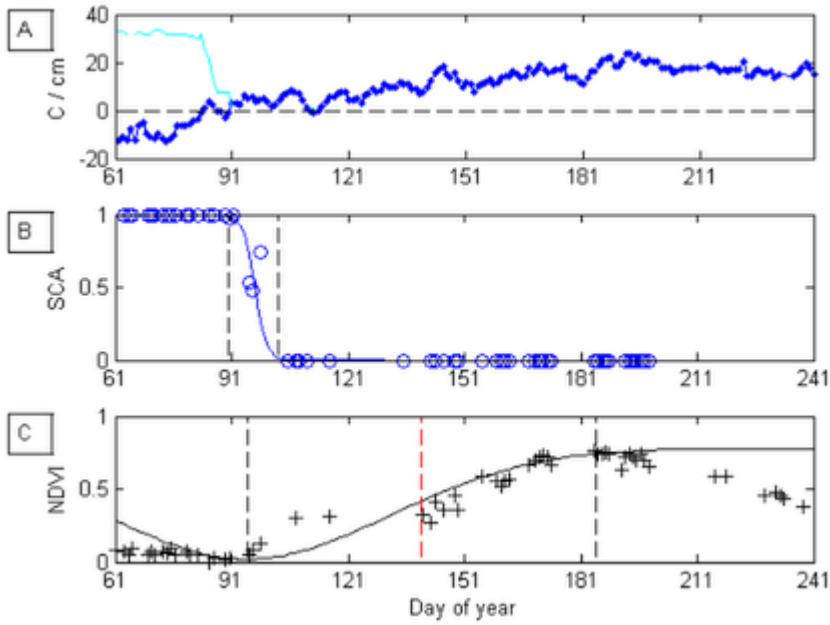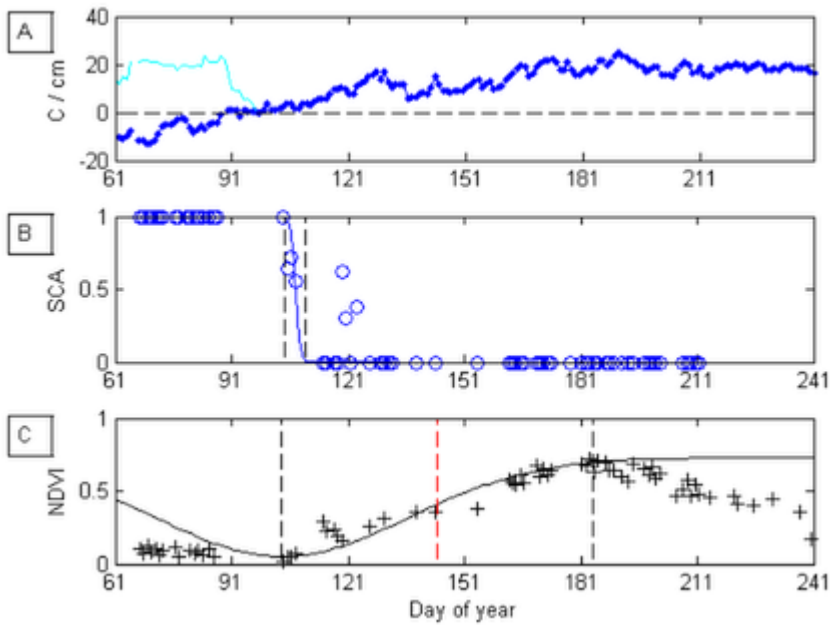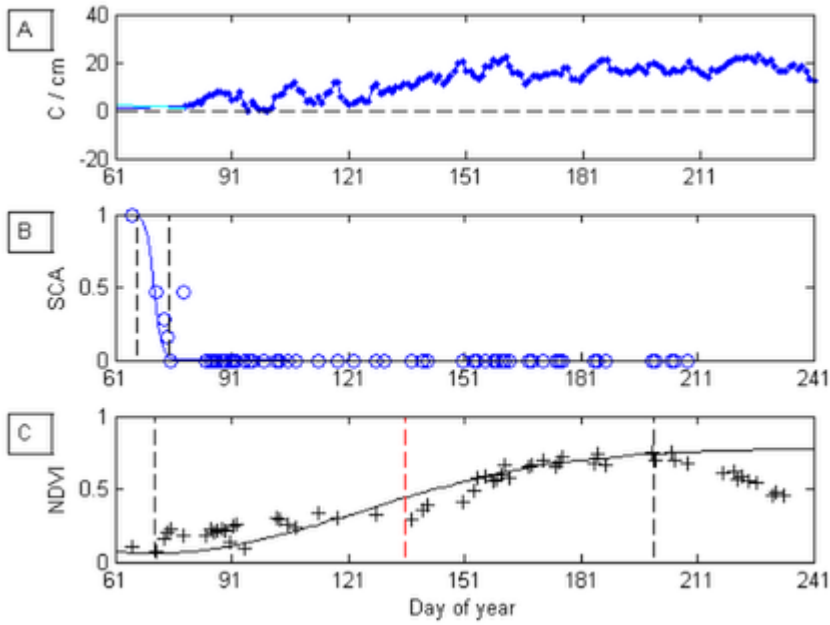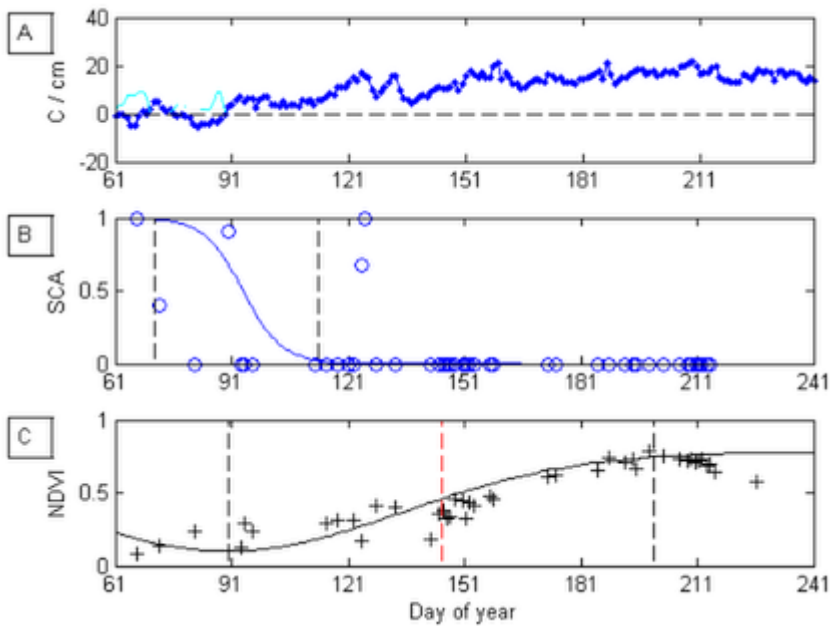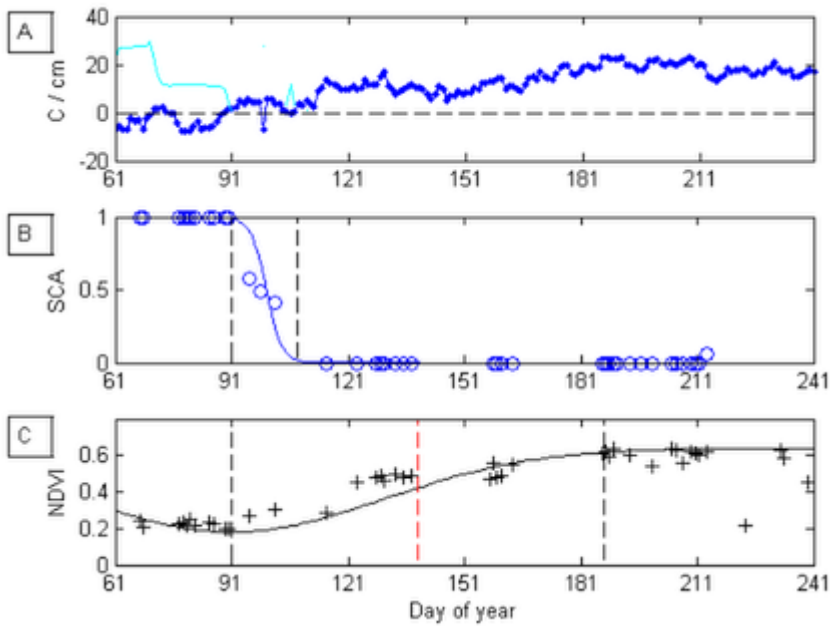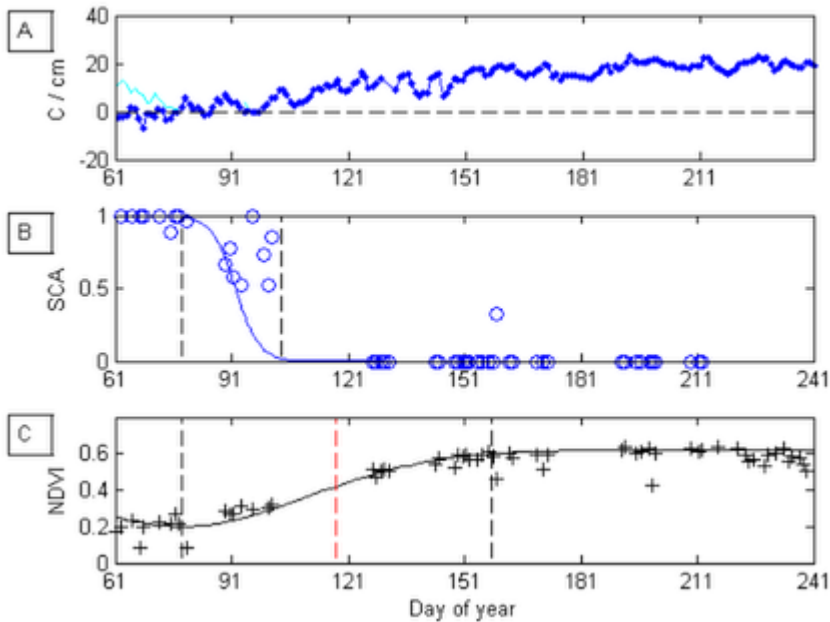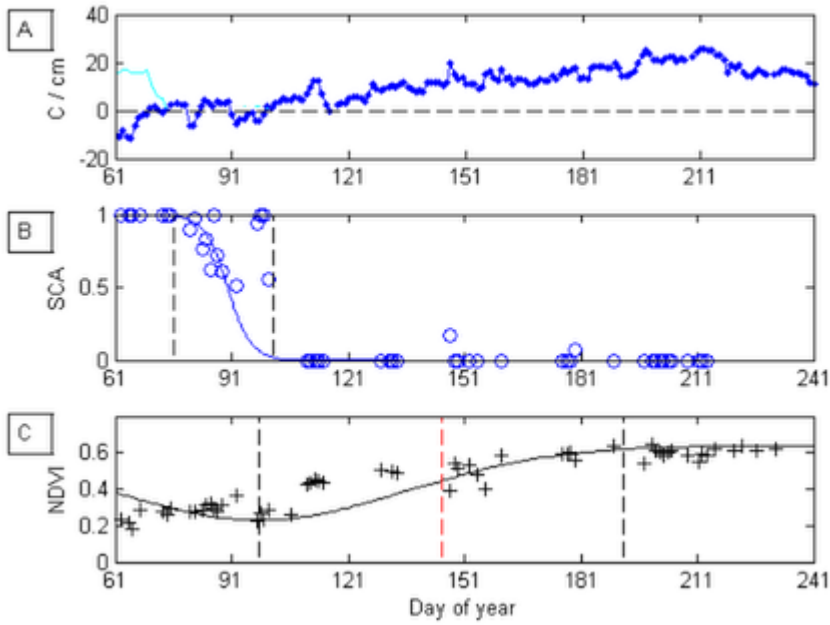

Figure 2. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Agricultural areas and year 2002
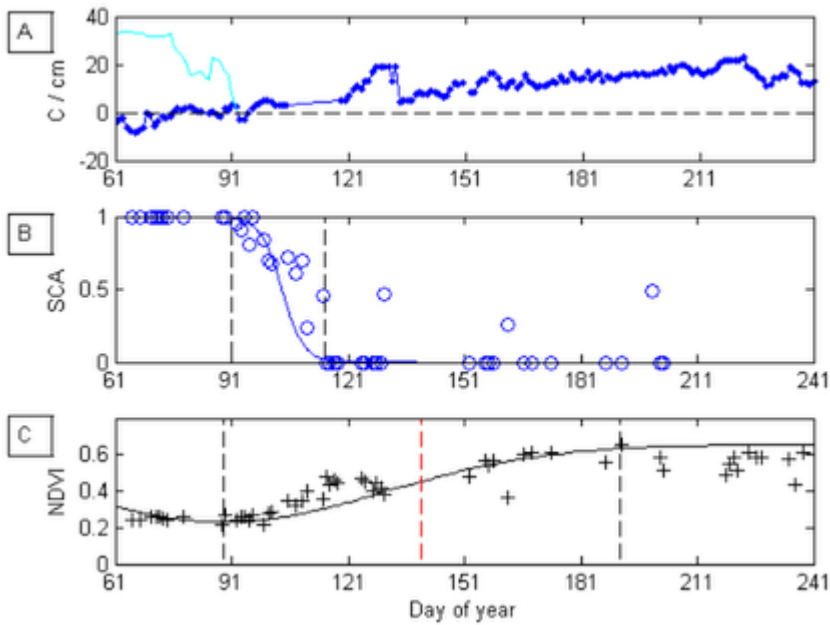
Figure 3. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Agricultural areas and year 2003
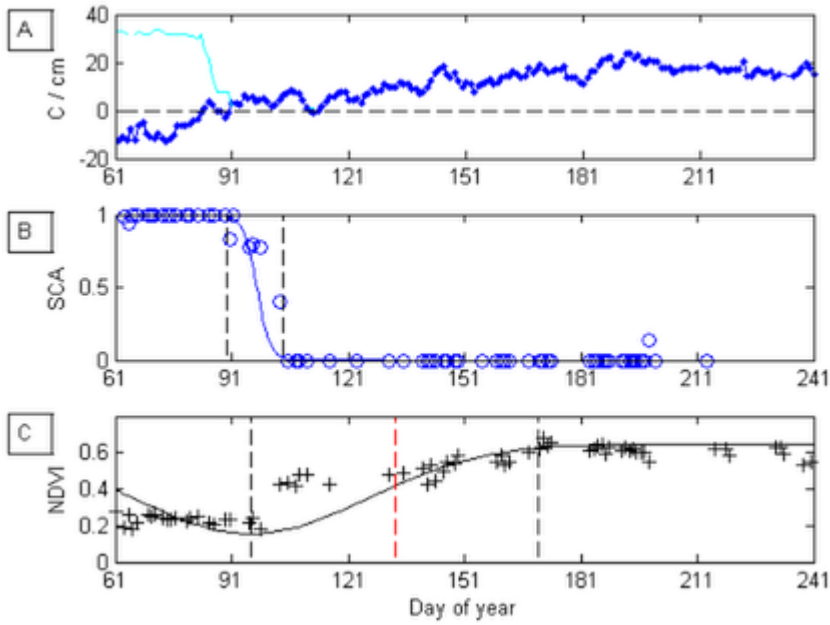

Figure 4. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Agricultural areas and year 2004
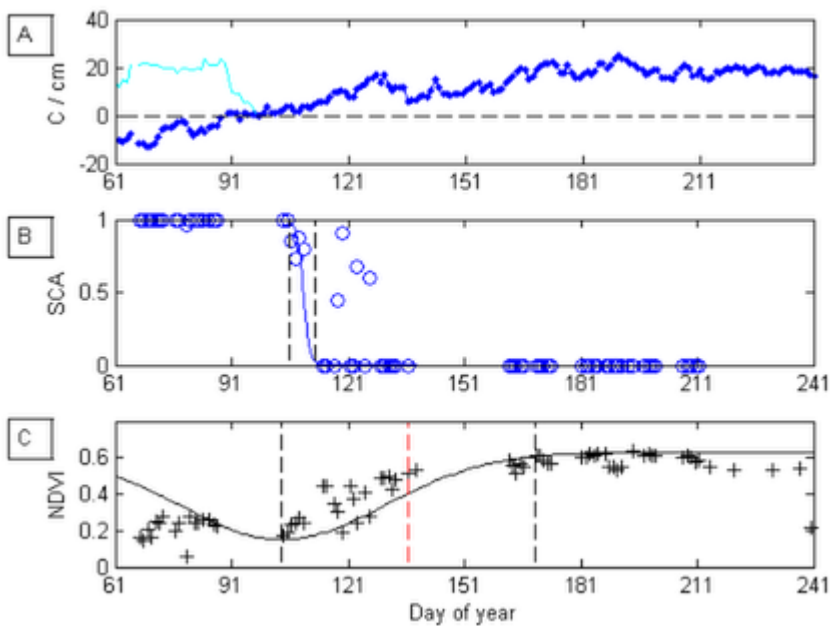
Figure 5. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Agricultural areas and year 2005
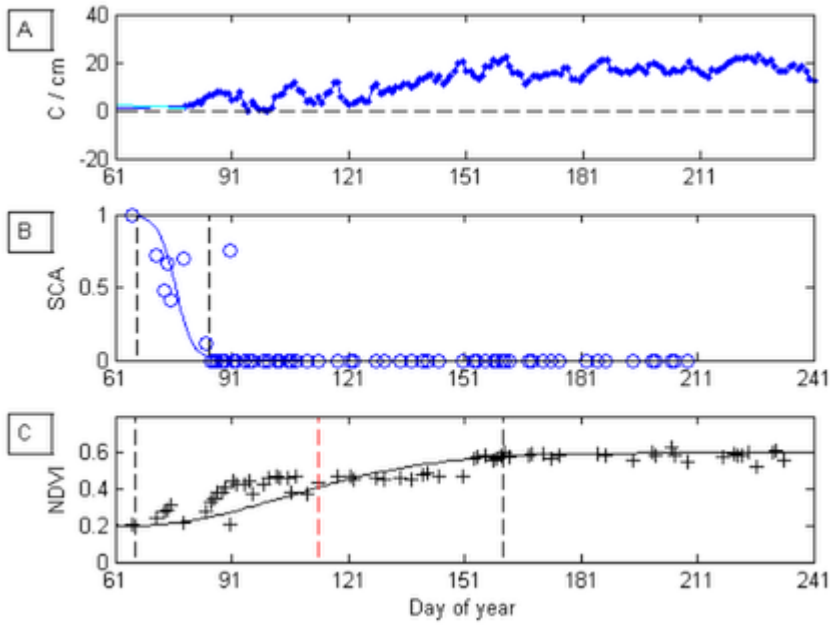

Figure 6. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Agricultural areas and year 2006
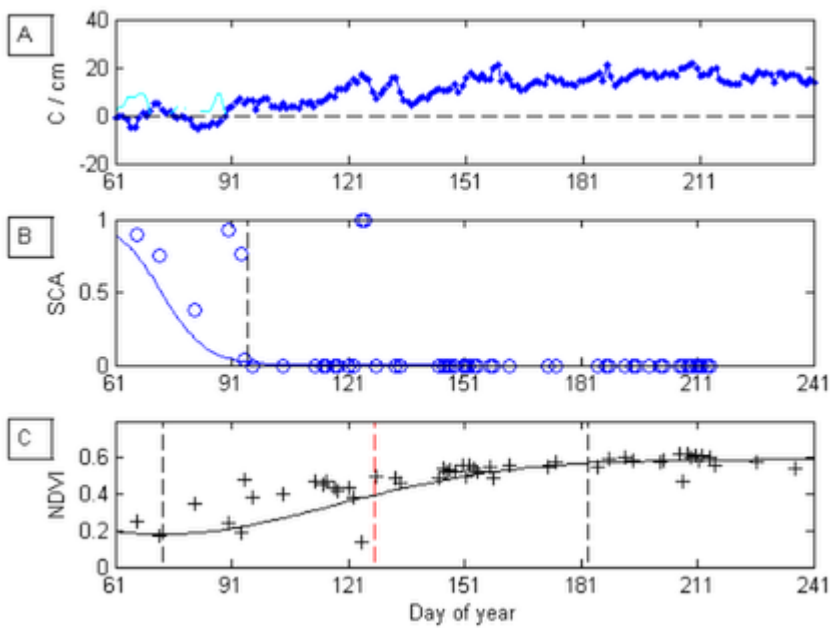
Figure 7. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Agricultural areas and year 2007
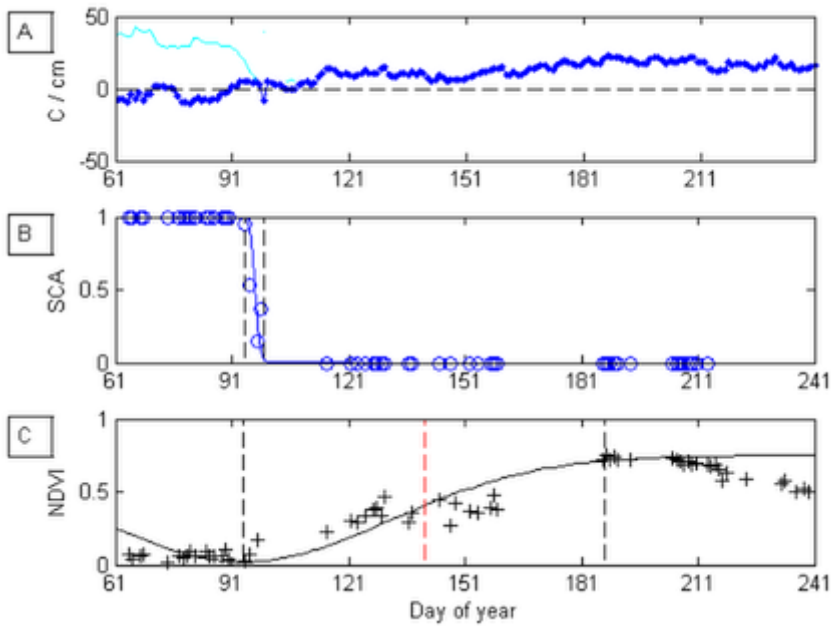

Figure 8. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Agricultural areas and year 2008
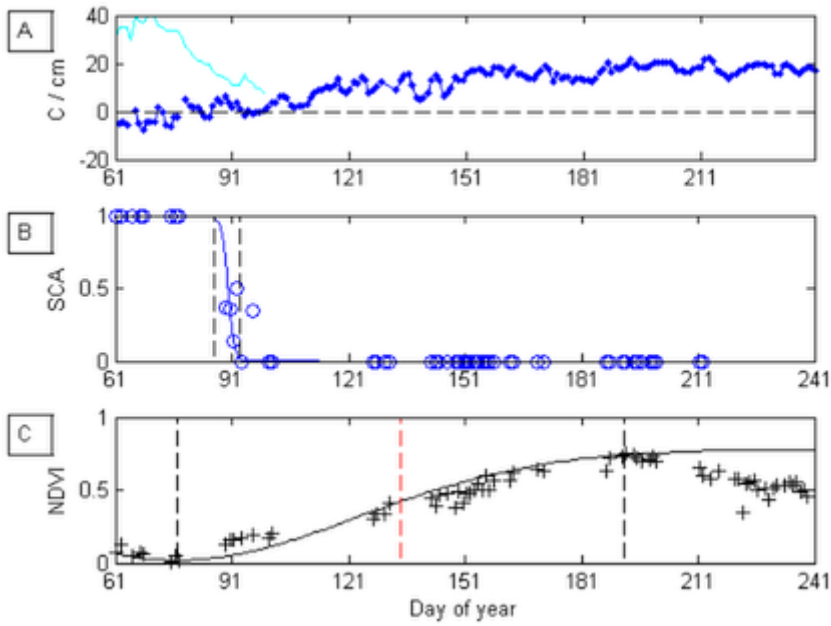
Figure 9. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Coniferous forests and year 2001

Figure 10. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Coniferous forests and year 2002
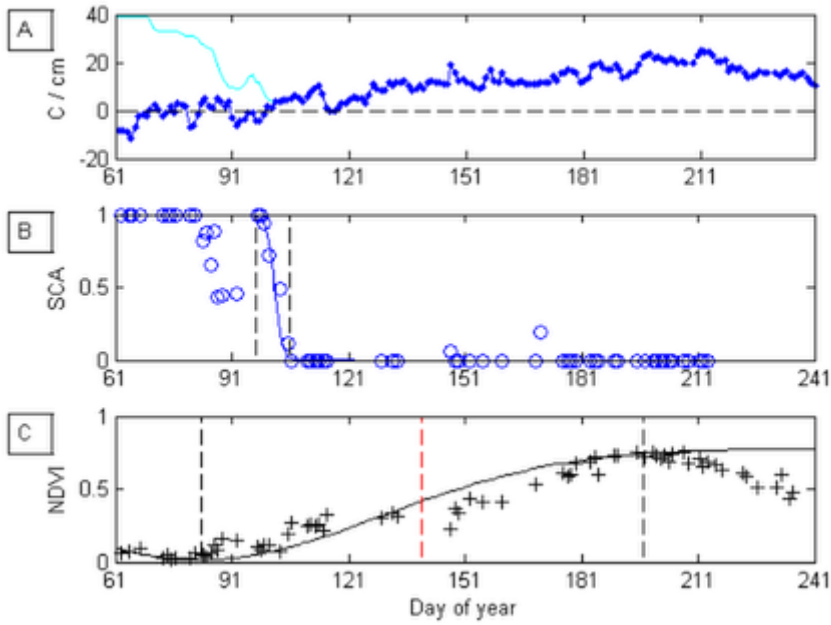
Figure 11. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Coniferous forests and year 2003
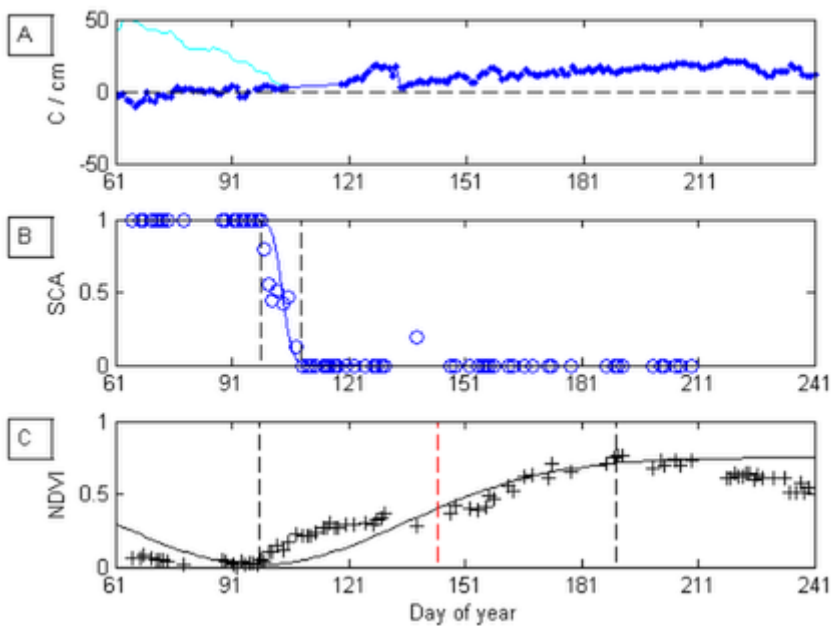

Figure 12. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Coniferous forests and year 2004
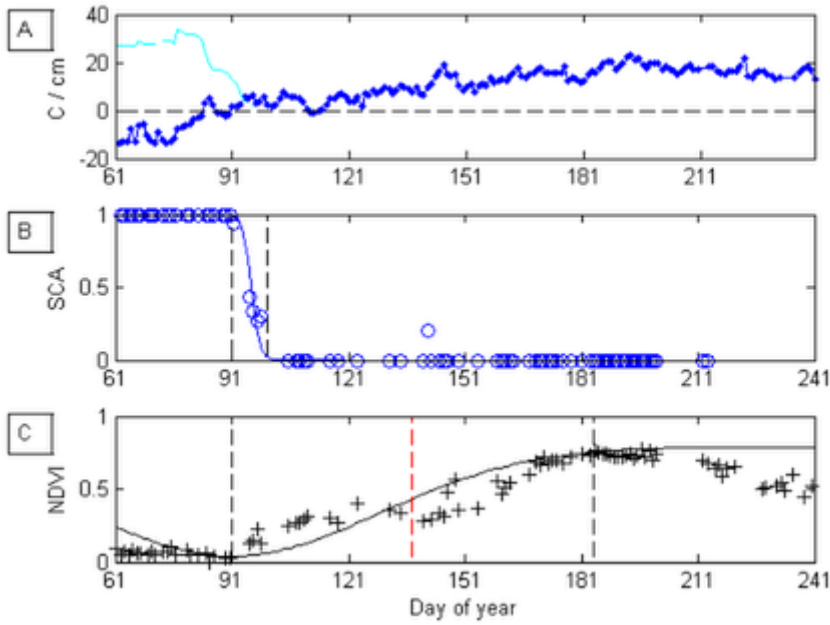
Figure 13. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Coniferous forests and year 2005
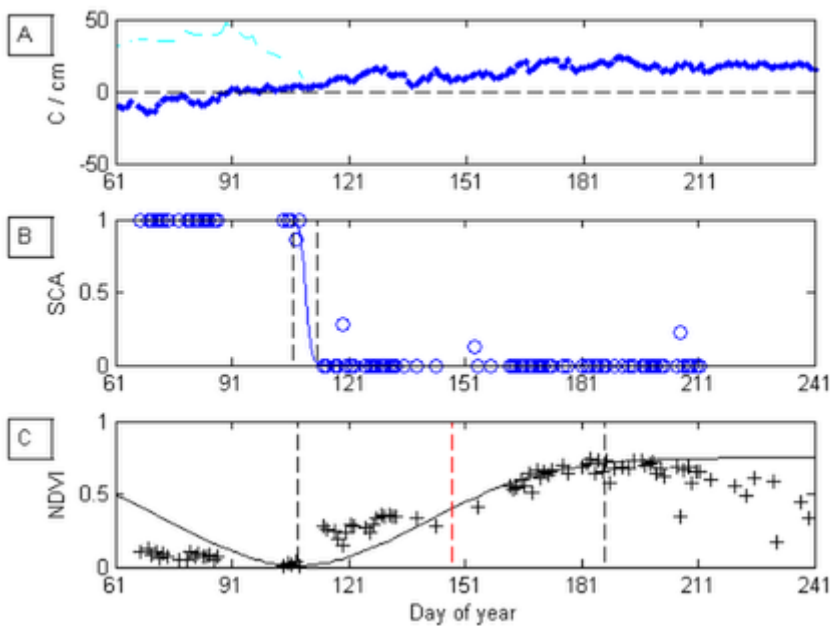

Figure 14. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Coniferous forests and year 2006
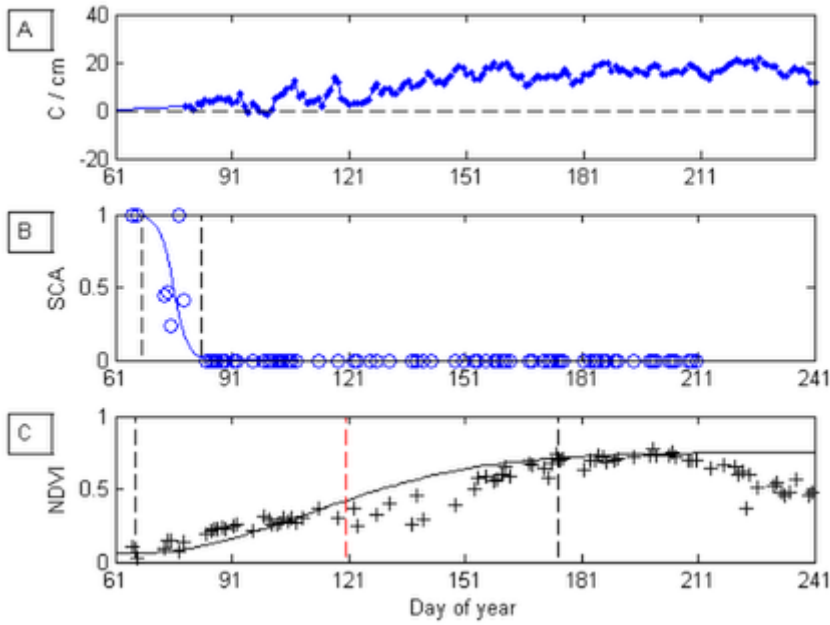
Figure 15. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Coniferous forests and year 2007

Figure 16. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Lepsamaenjoki Coniferous forests and year 2008

Figure 1. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Agricultural areas and year 2001
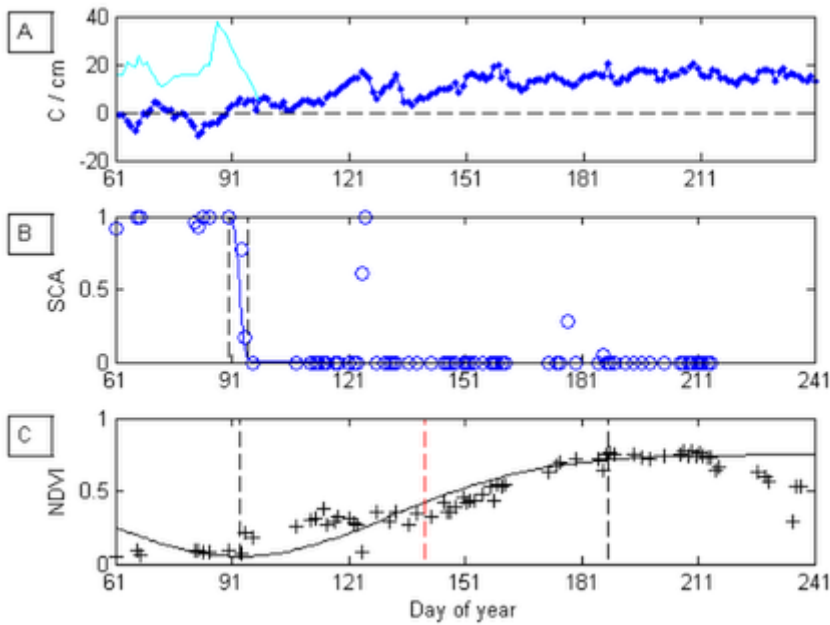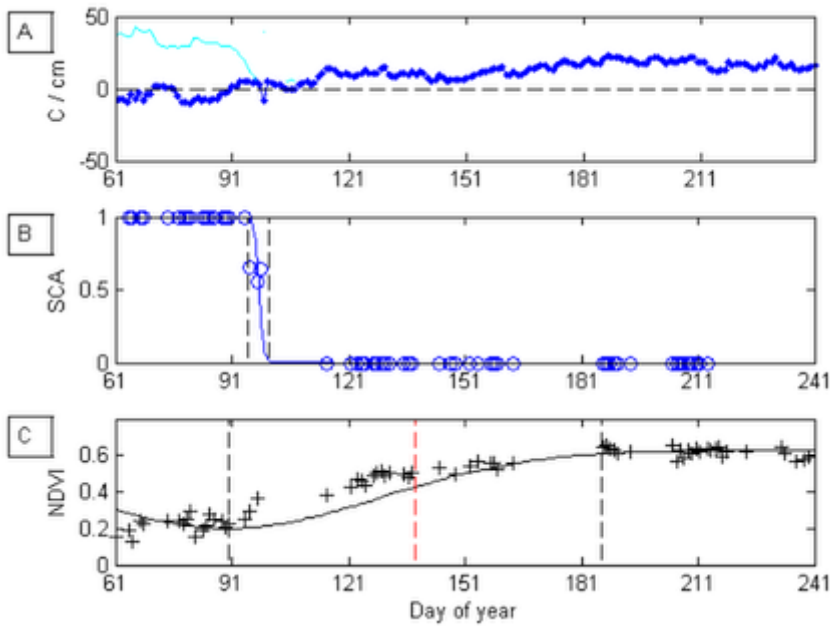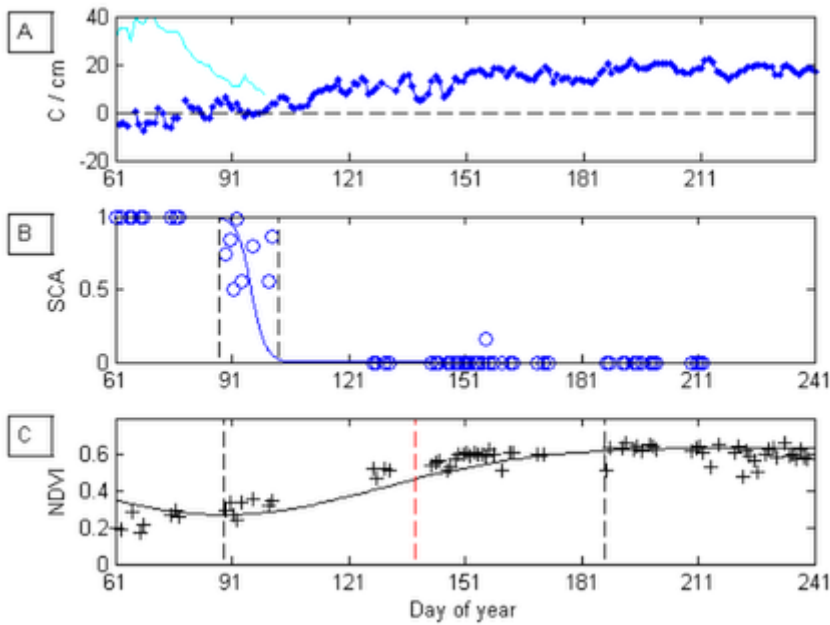

Figure 2. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Agricultural areas and year 2002
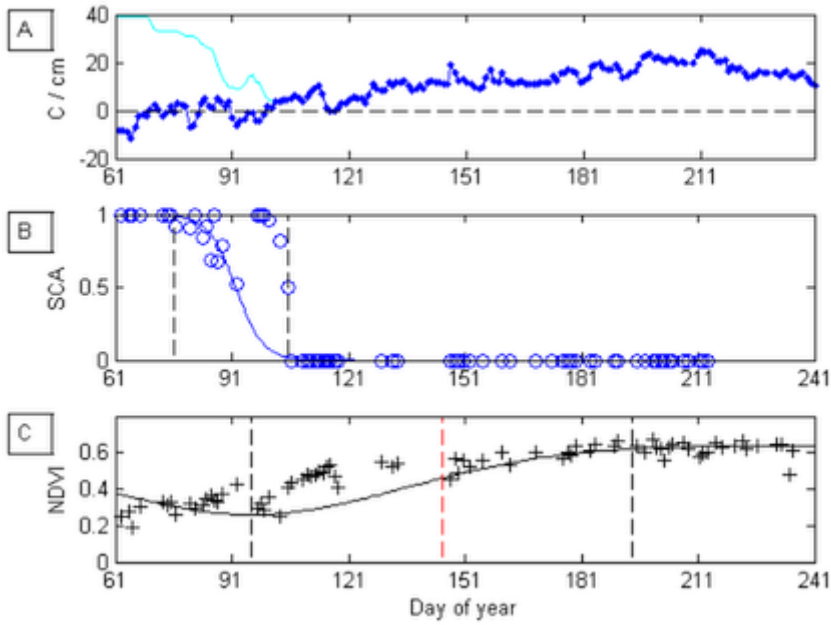
Figure 3. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Agricultural areas and year 2003

Figure 4. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Agricultural areas and year 2004
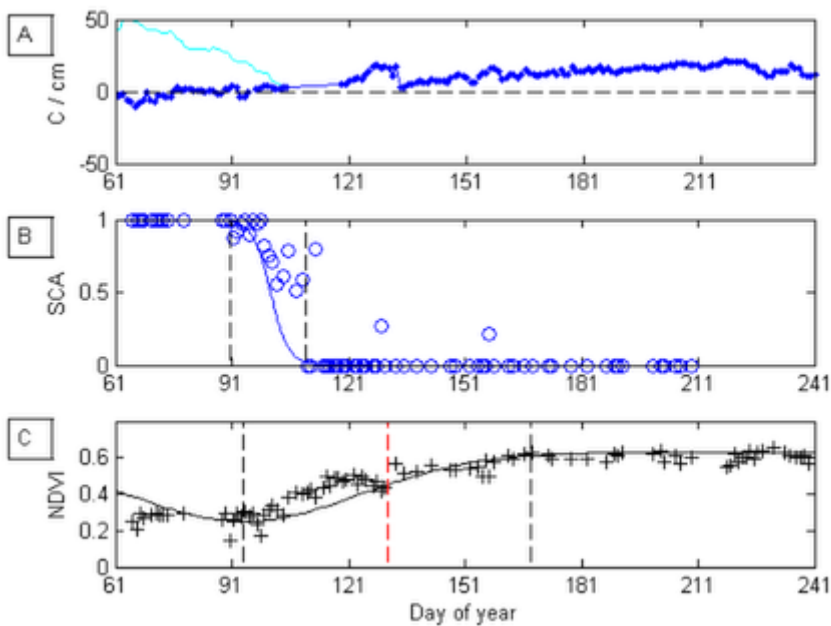
Figure 5. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Agricultural areas and year 2005
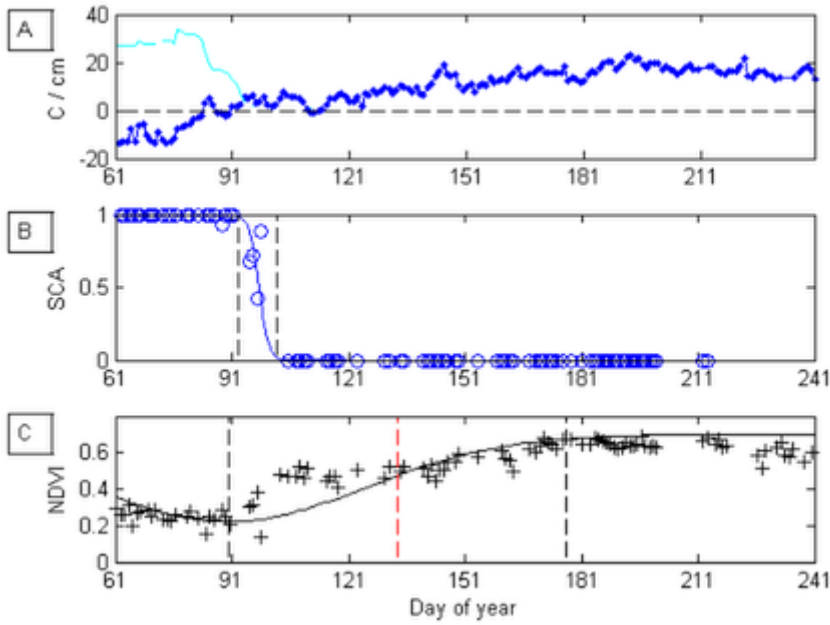

Figure 6. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Agricultural areas and year 2006
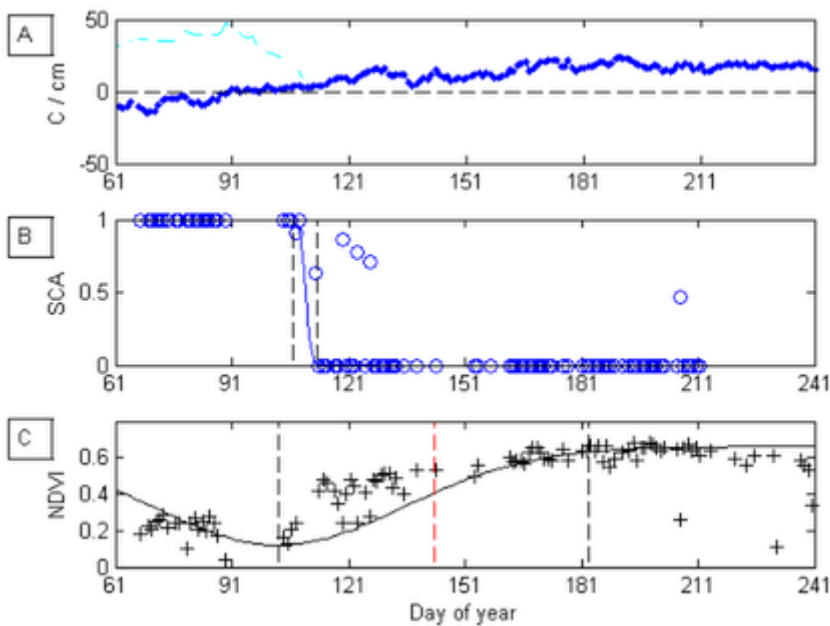
Figure 7. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Agricultural areas and year 2007

Figure 8. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Agricultural areas and year 2008

Figure 9. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Coniferous forests and year 2001
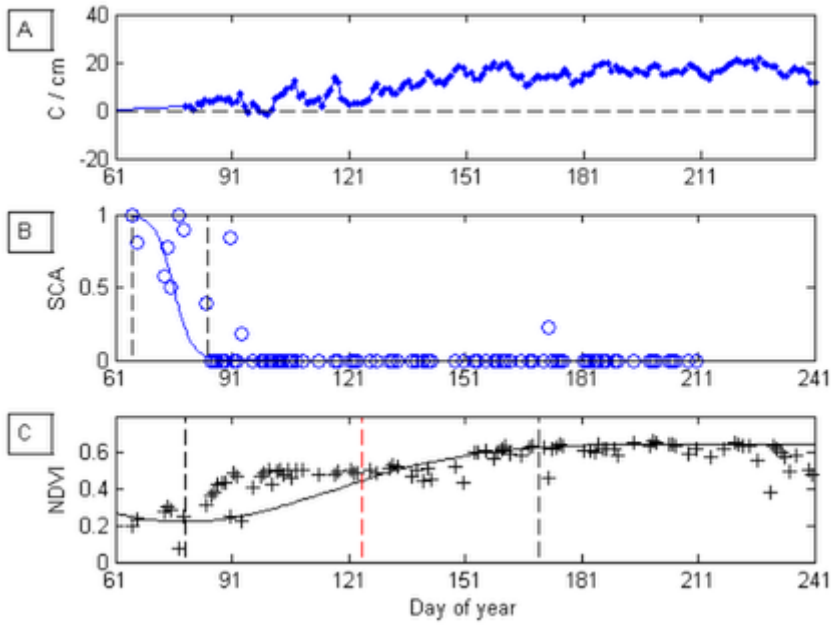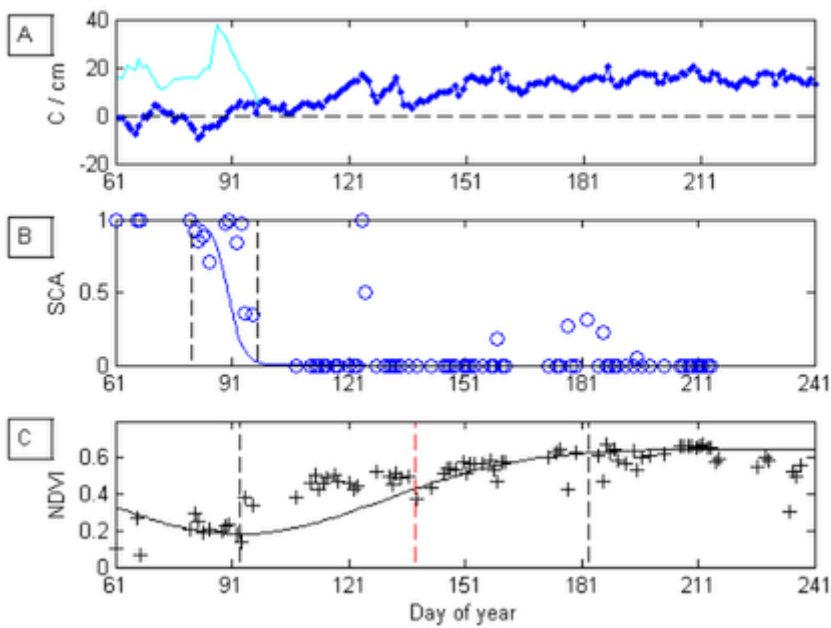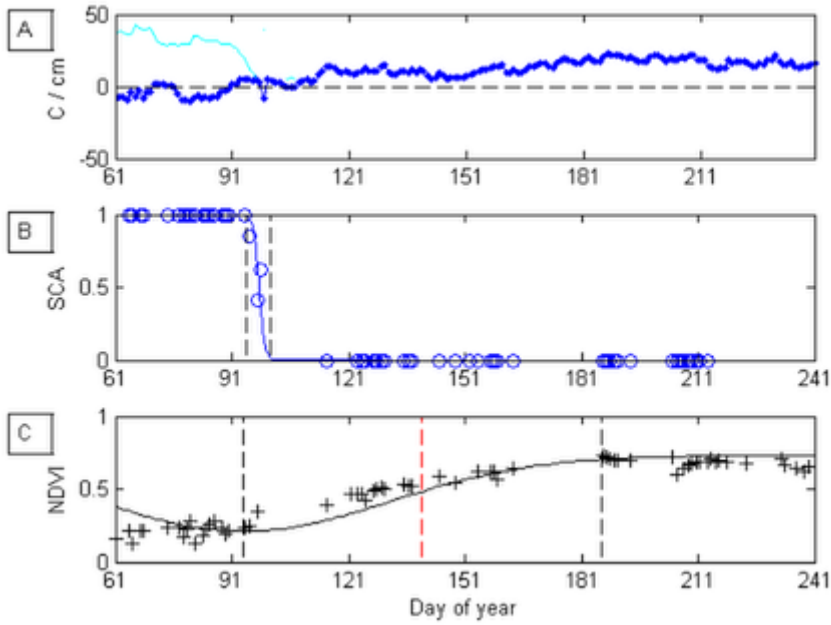

Figure 10. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Coniferous forests and year 2002
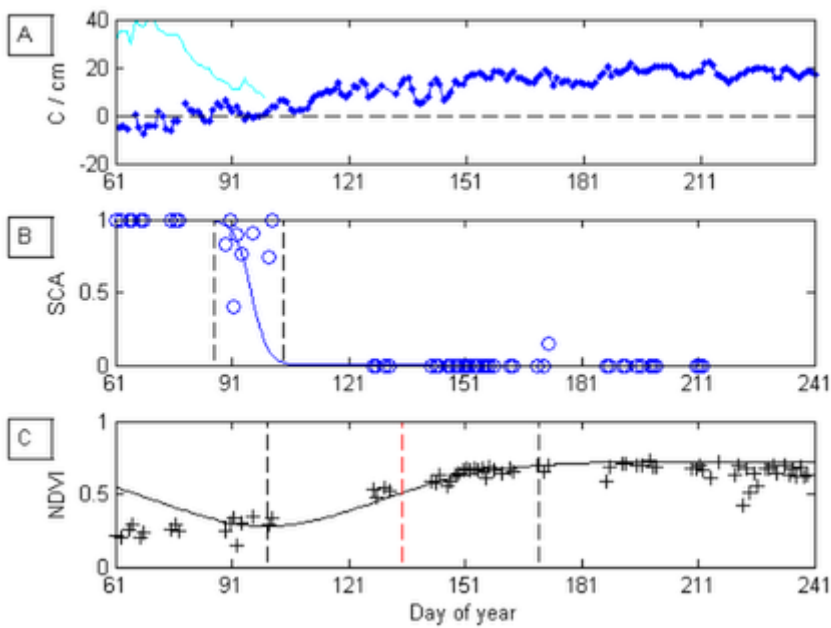
Figure 11. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby
weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi
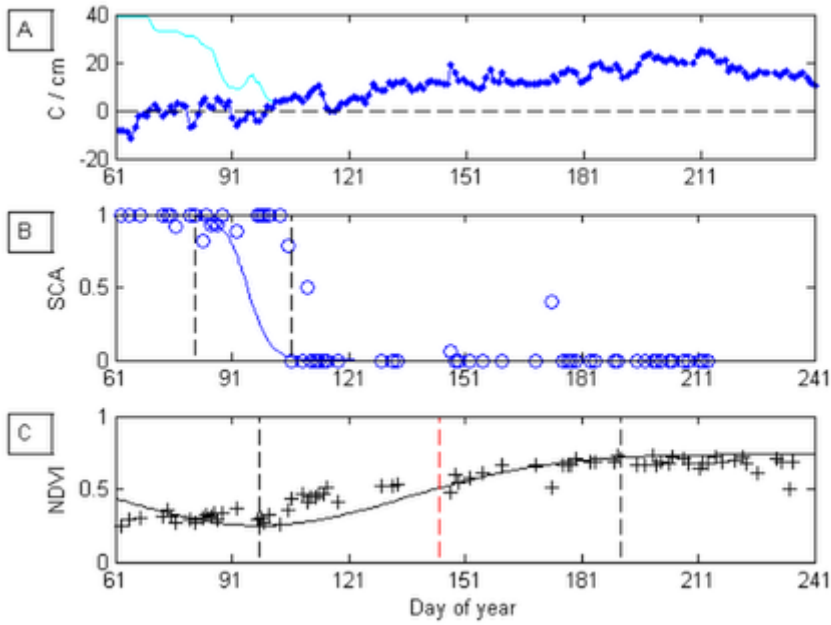Coniferous forests and year 2003

Figure 12. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby
weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi
Coniferous forests and year 2004

Figure 13. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Coniferous forests and year 2005
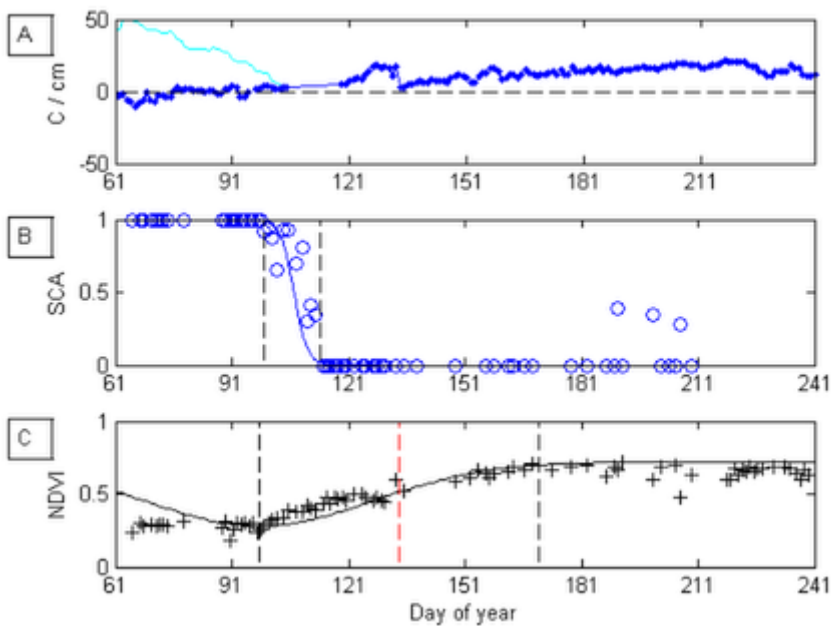

Figure 14. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Coniferous forests and year 2006
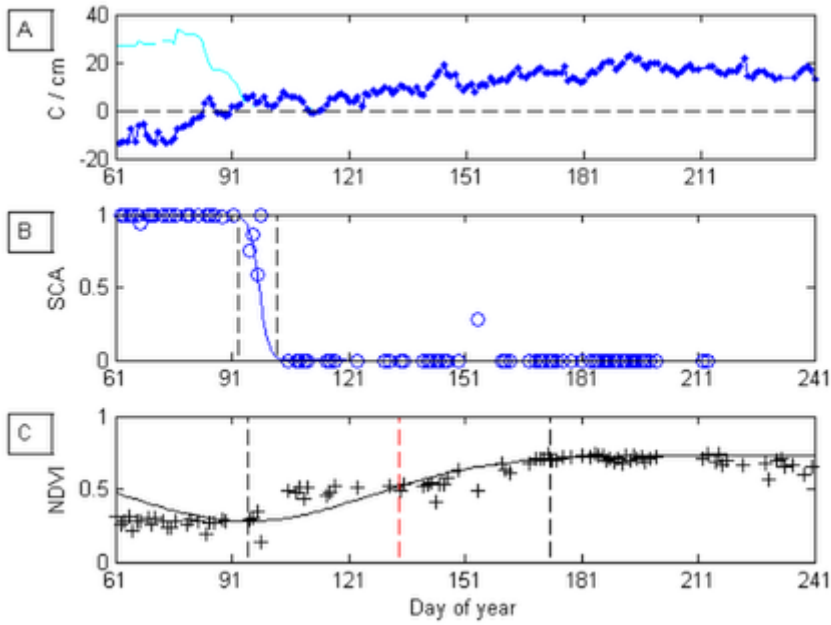
Figure 15. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Coniferous forests and year 2007

Figure 16. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Coniferous forests and year 2008

LAKE PÄÄJÄRVI, MIXED FORESTS

Figure 1. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Mixed forests and year 2001
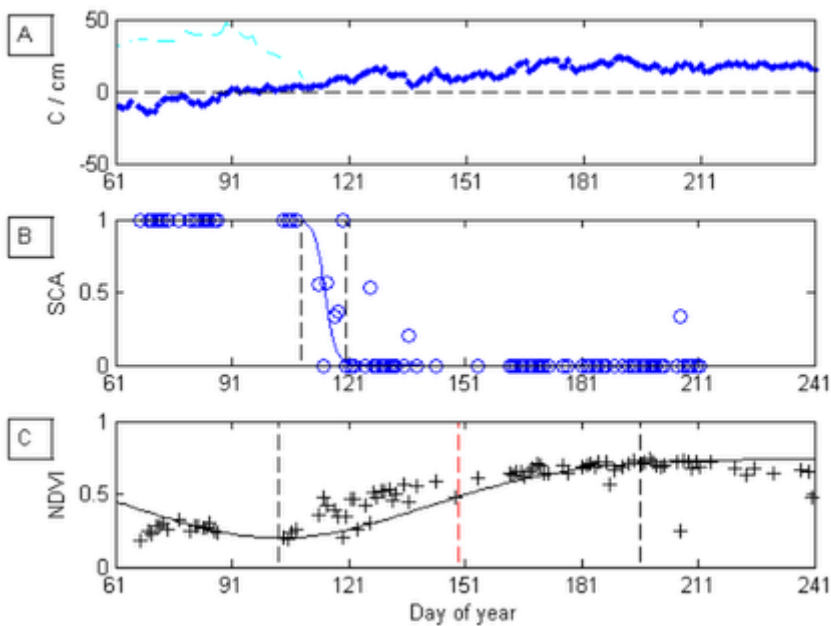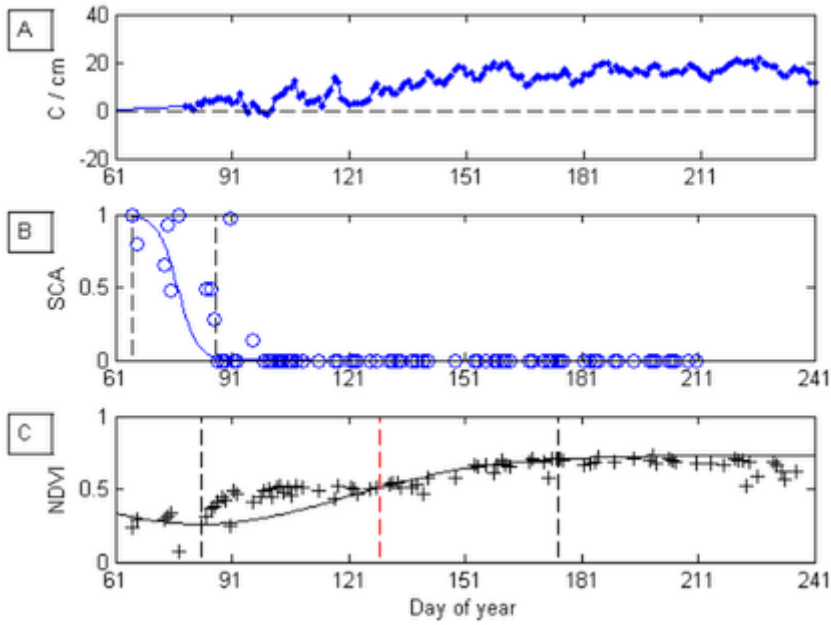

Figure 2. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Mixed forests and year 2002
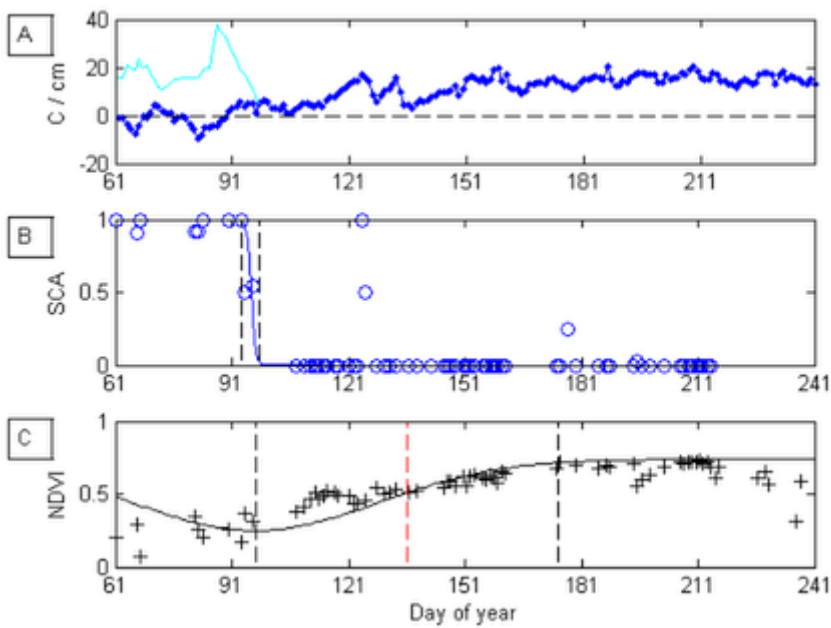
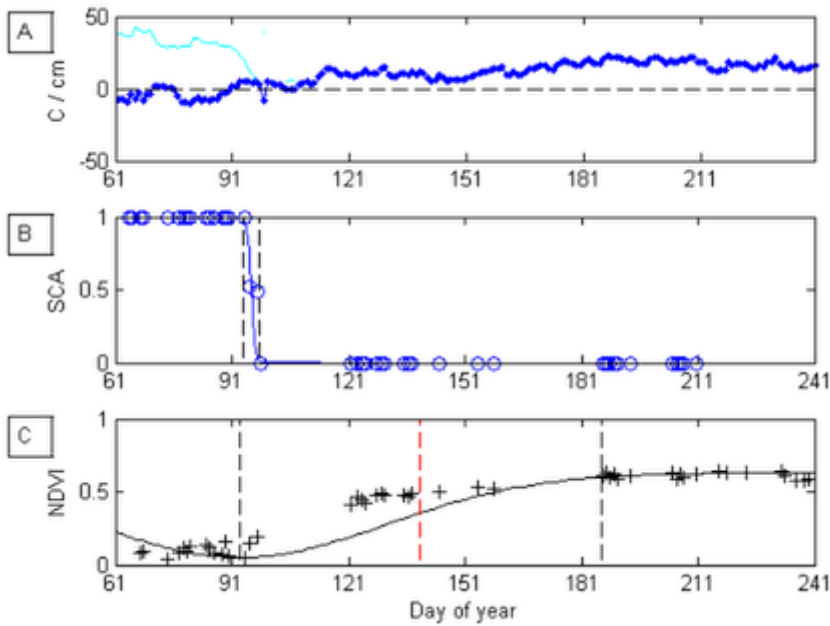Figure 3. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Mixed forests and year 2003
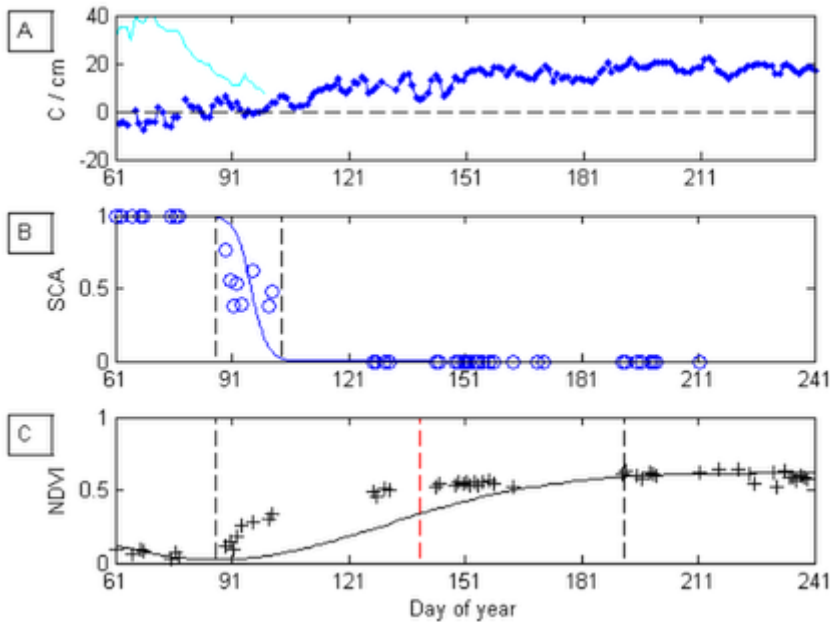

Figure 4. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Mixed forests and year 2004
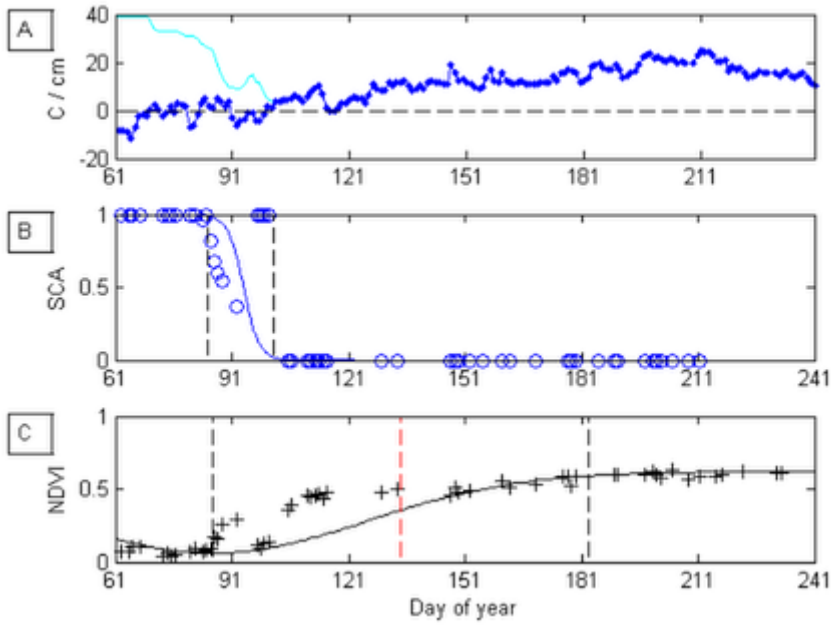
Figure 5. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Mixed forests and year 2005

Figure 6. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Mixed forests and year 2006
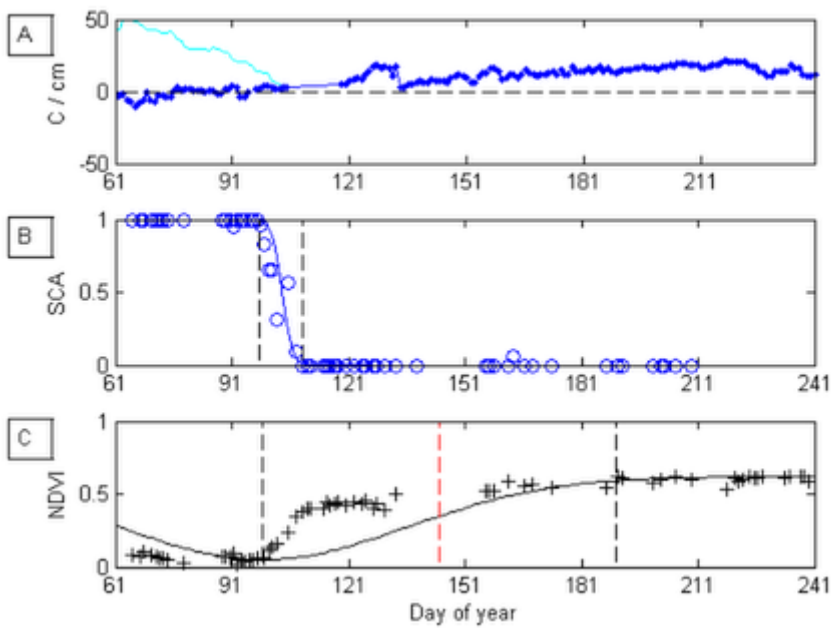
Figure 7. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Mixed forests and year 2007

Figure 8. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Mixed forests and year 2008

Figure 17. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Peatland areas and year 2001
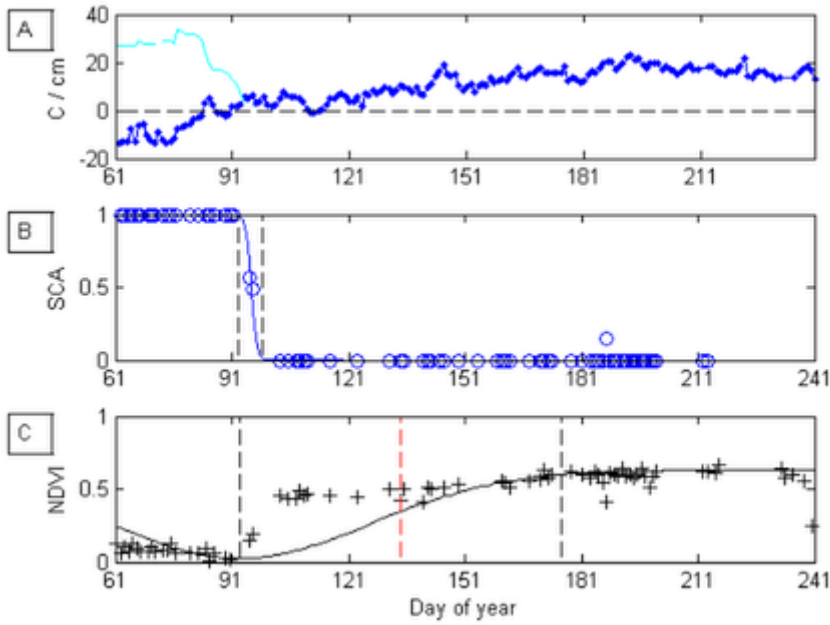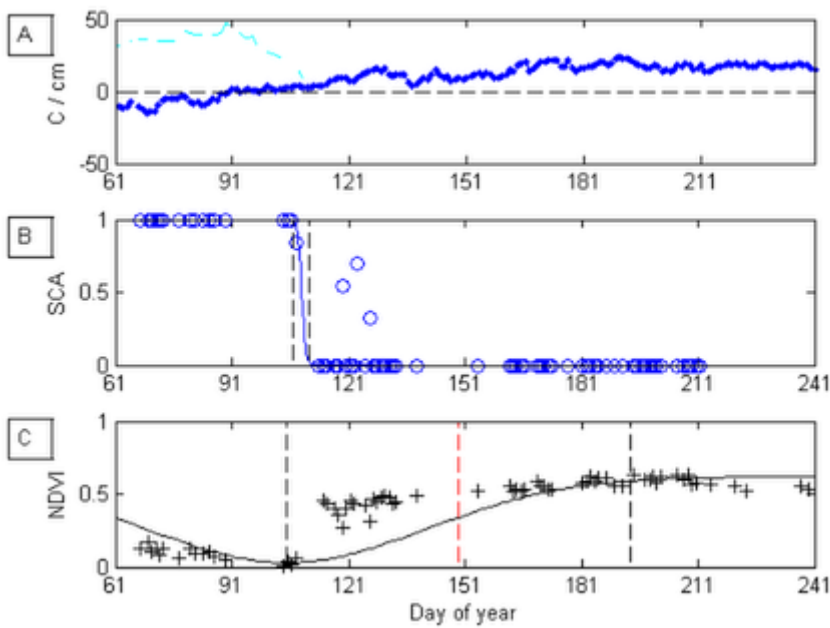

Figure 18. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Peatland areas and year 2002
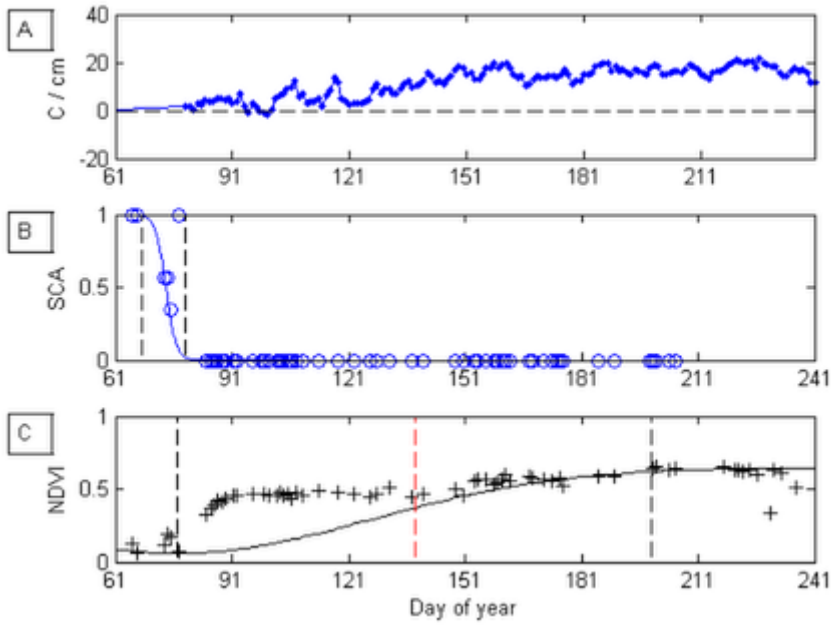
Figure 19. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Peatland areas and year 2003
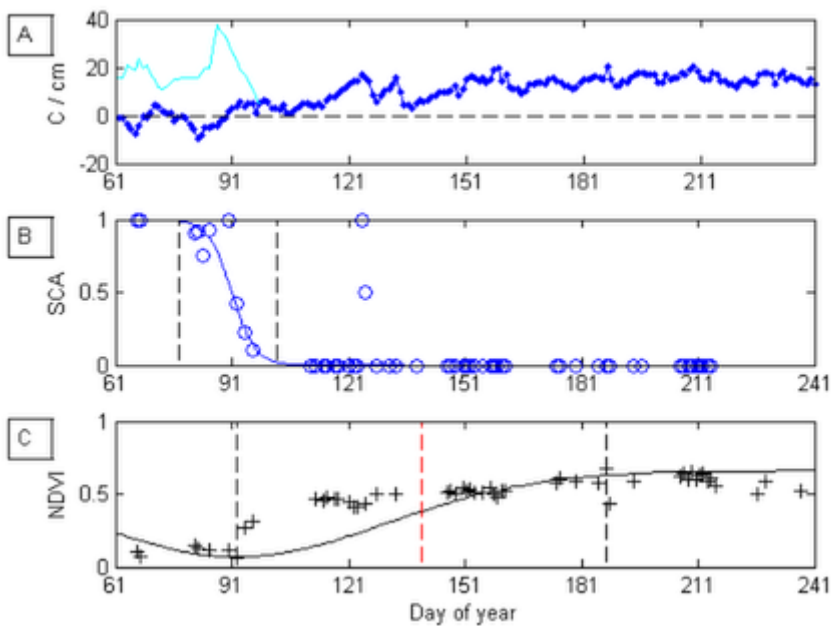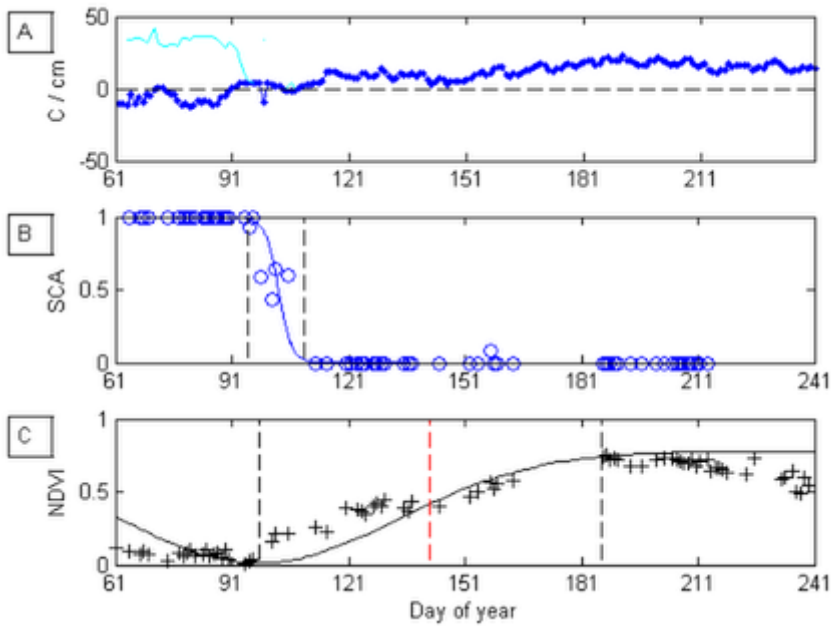

Figure 20. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Peatland areas and year 2004
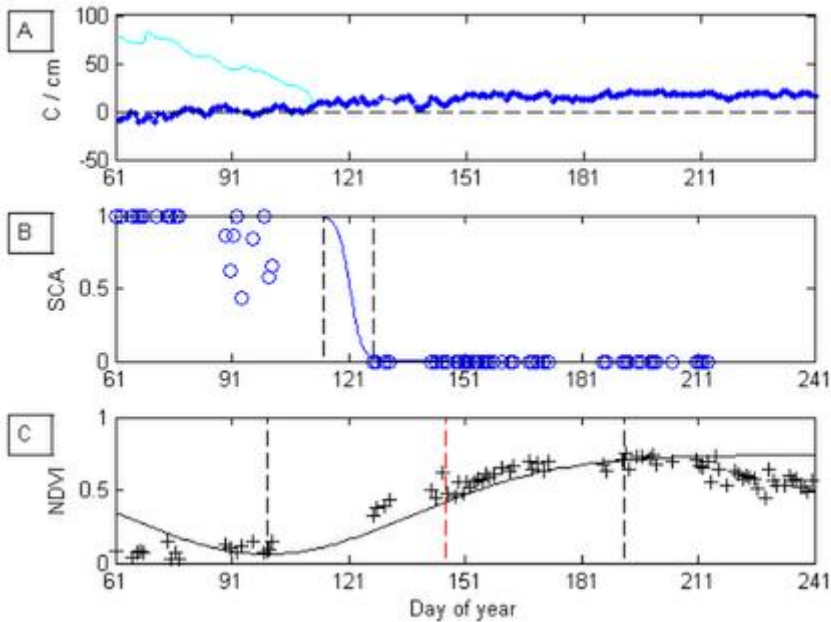
Figure 21. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Peatland areas and year 2005
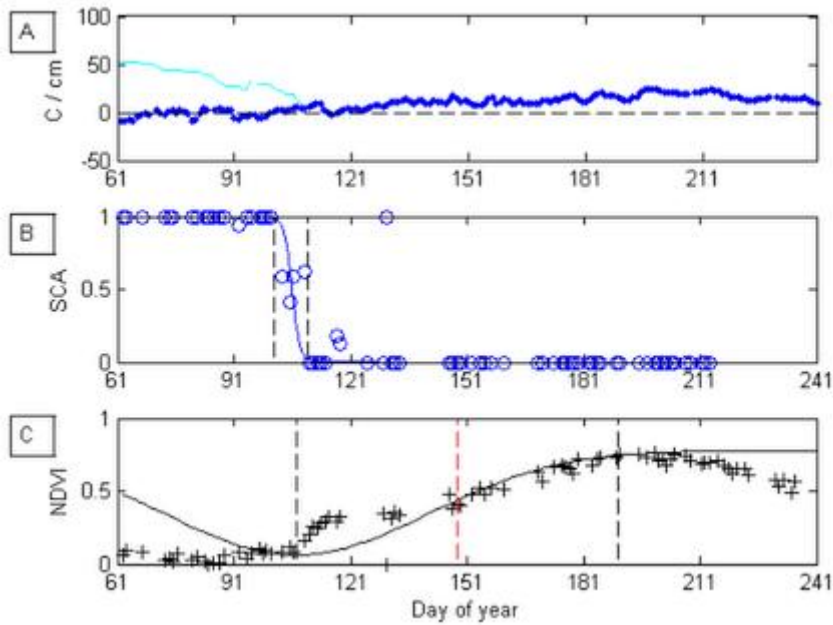

Figure 22. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Peatland areas and year 2006

Figure 23. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Peatland areas and year 2007

Figure 24. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paajarvi Peatland areas and year 2008

Figure 1. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Agricultural areas and year 2001
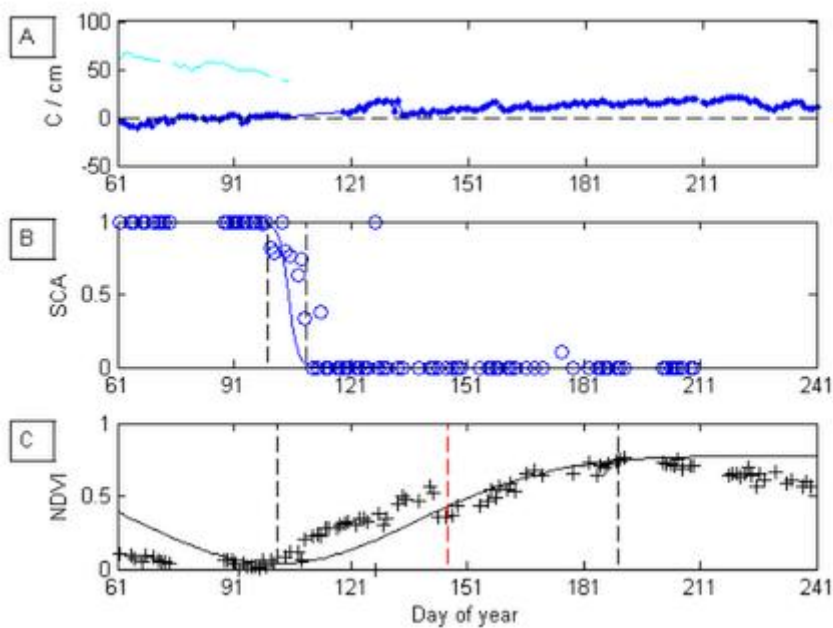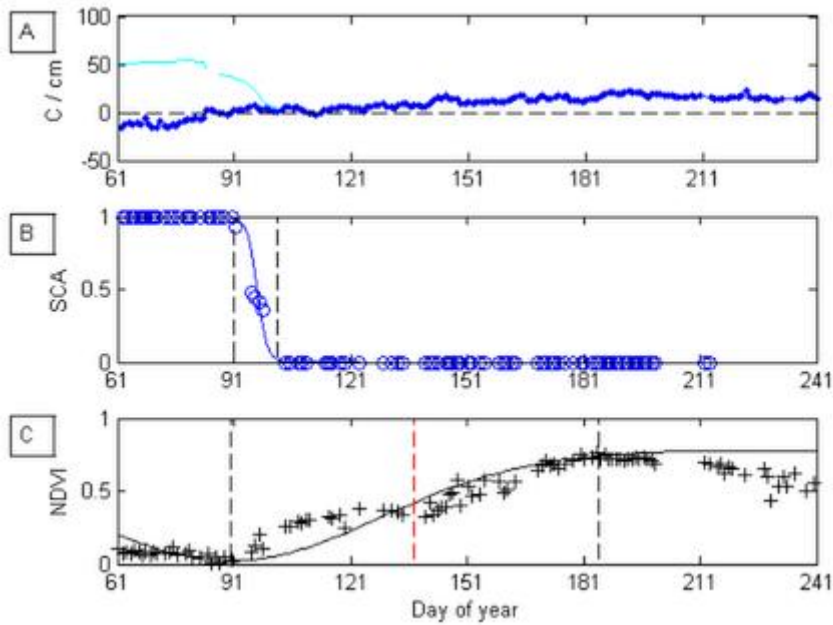

Figure 2. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Agricultural areas and year 2002
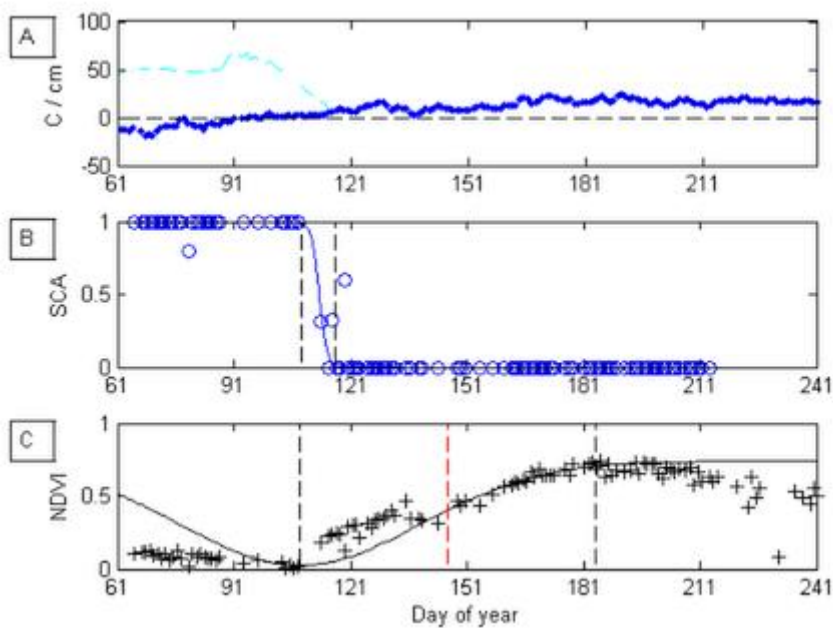
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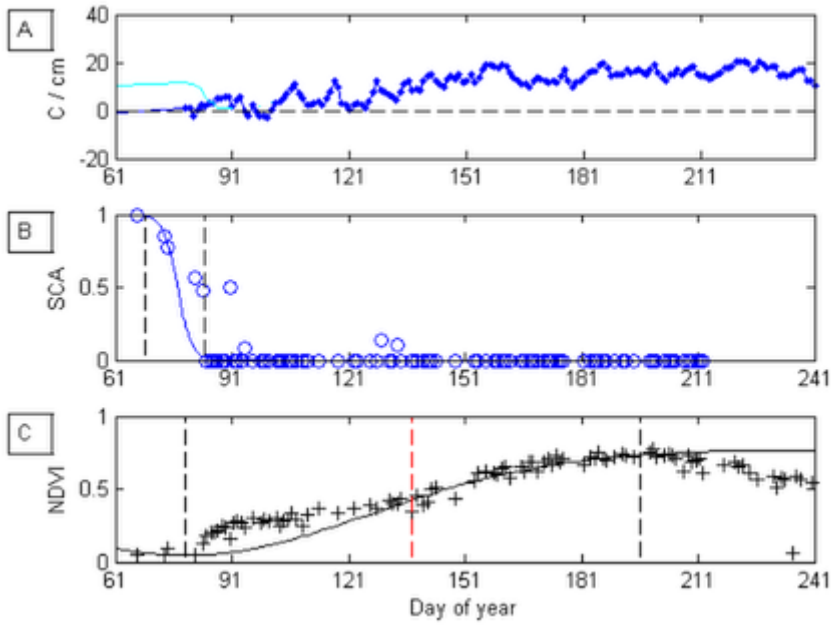

Figure 4. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Agricultural areas and year 2004
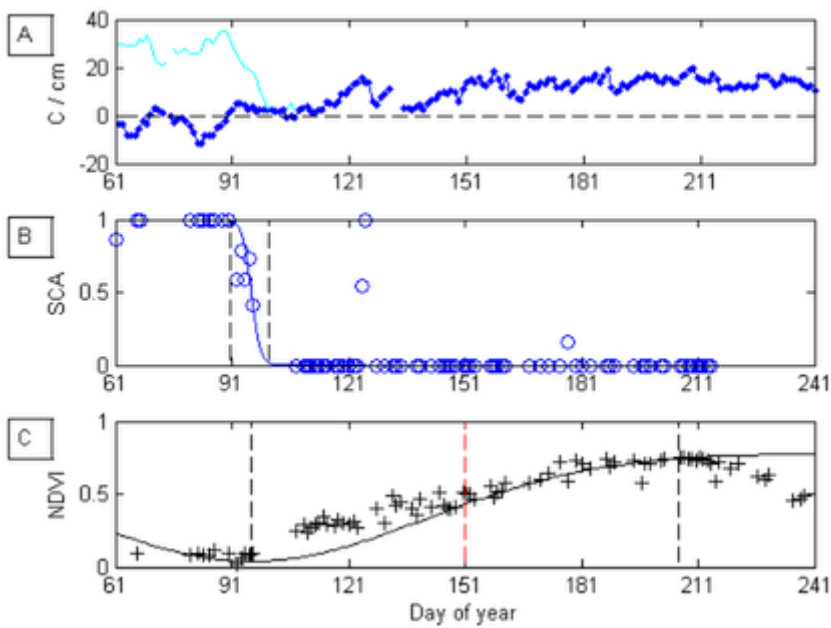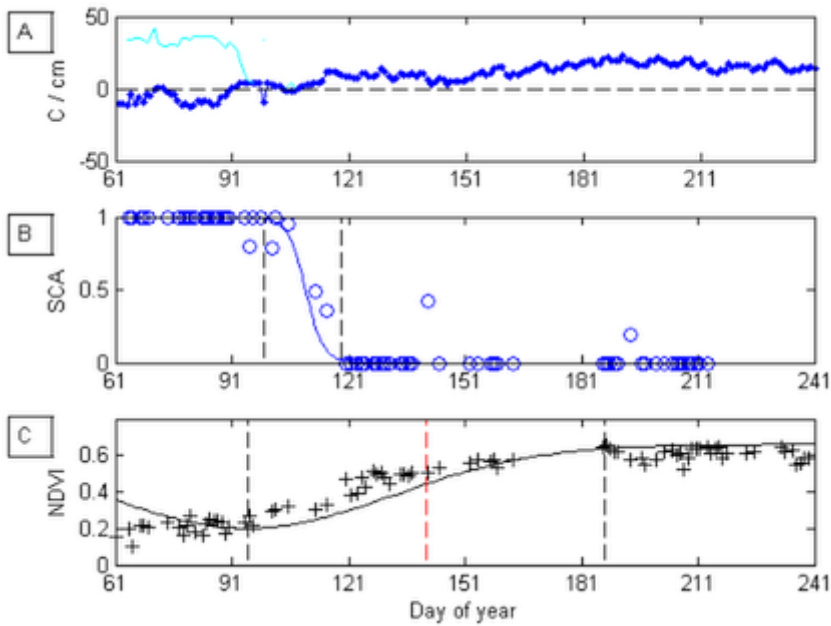
Figure 5. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Agricultural areas and year 2005
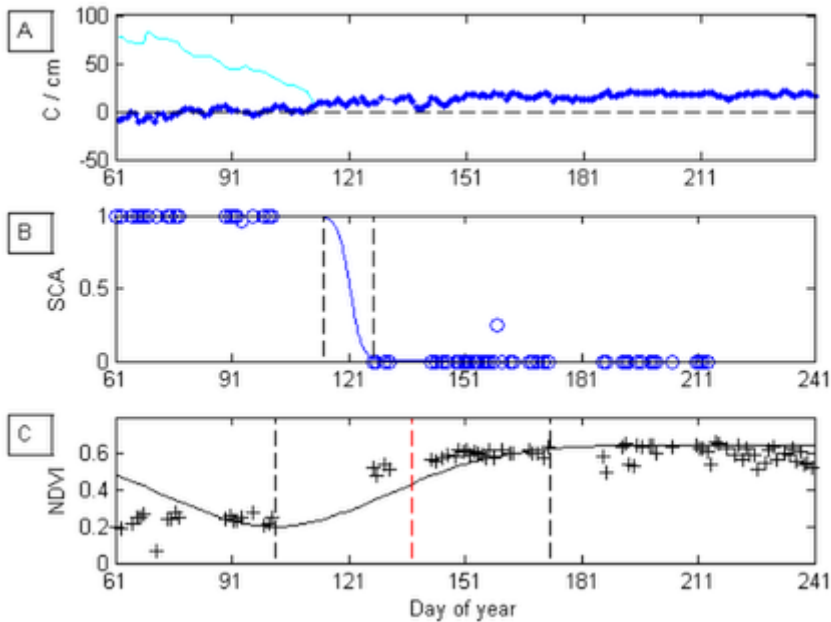

Figure 6. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Agricultural areas and year 2006

Figure 7. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Agricultural areas and year 2007

Figure 8. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Agricultural areas and year 2008

Figure 9. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Coniferous forests and year 2001
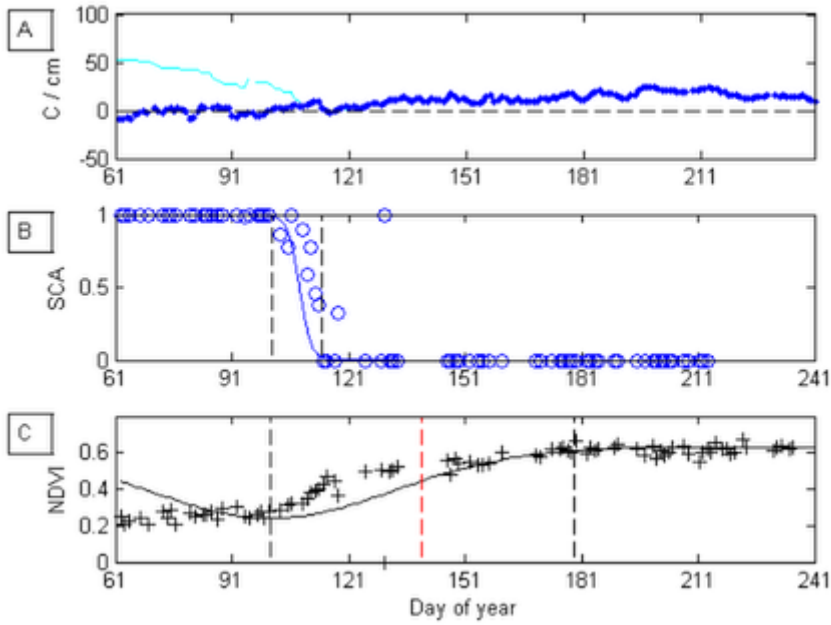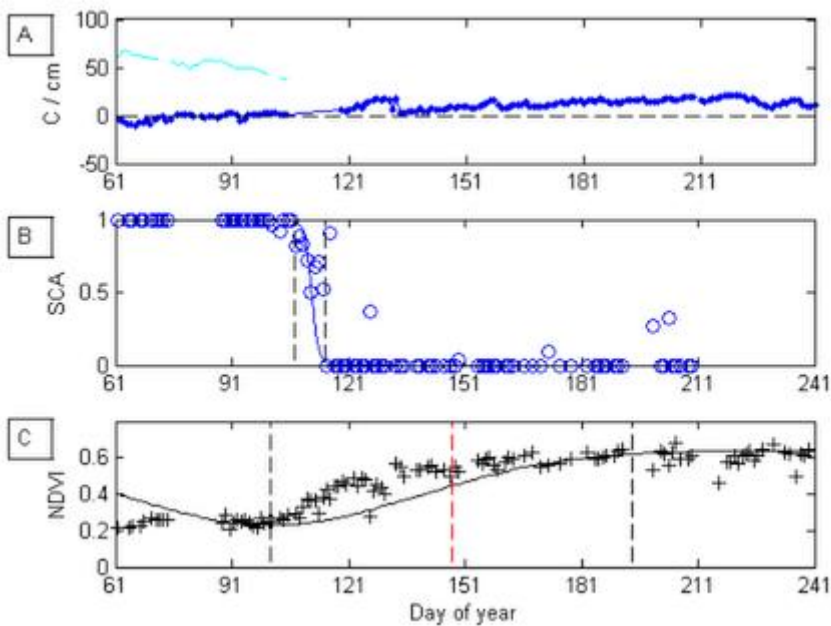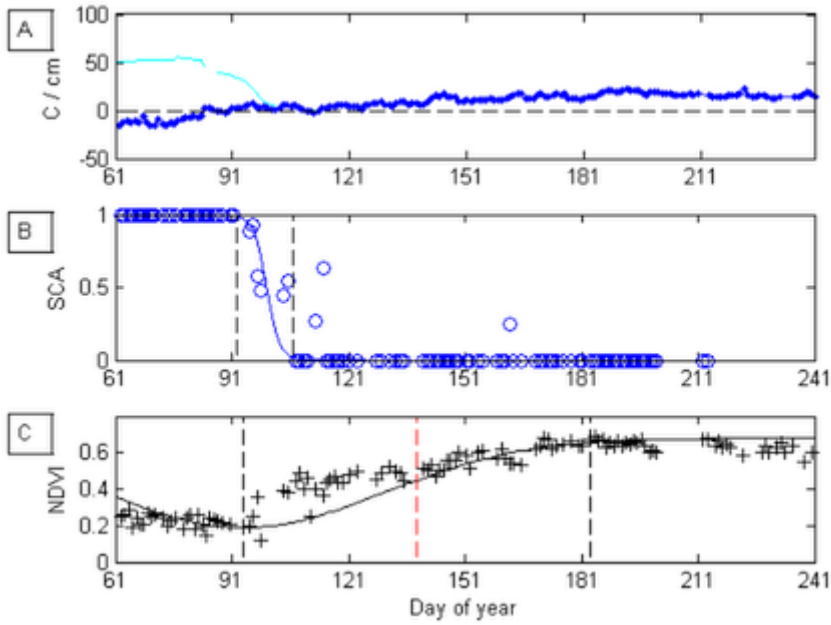

Figure 10. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Coniferous forests and year 2002
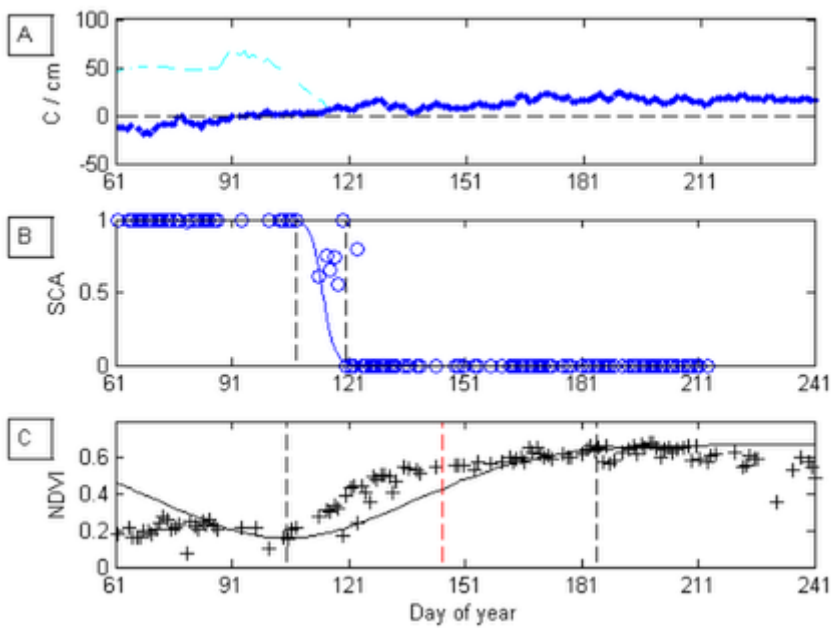
Figure 11. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Coniferous forests and year 2003

Figure 12. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Coniferous forests and year 2004
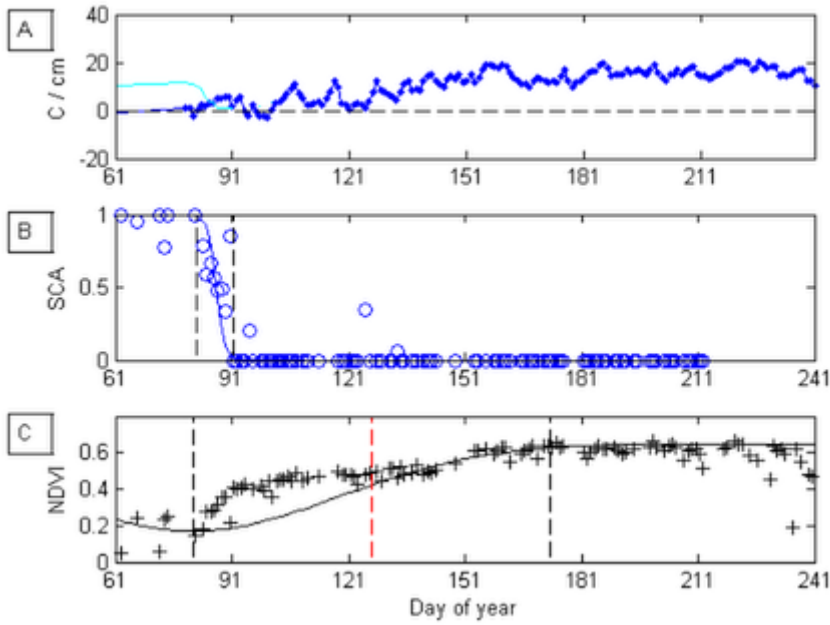
Figure 13. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Coniferous forests and year 2005
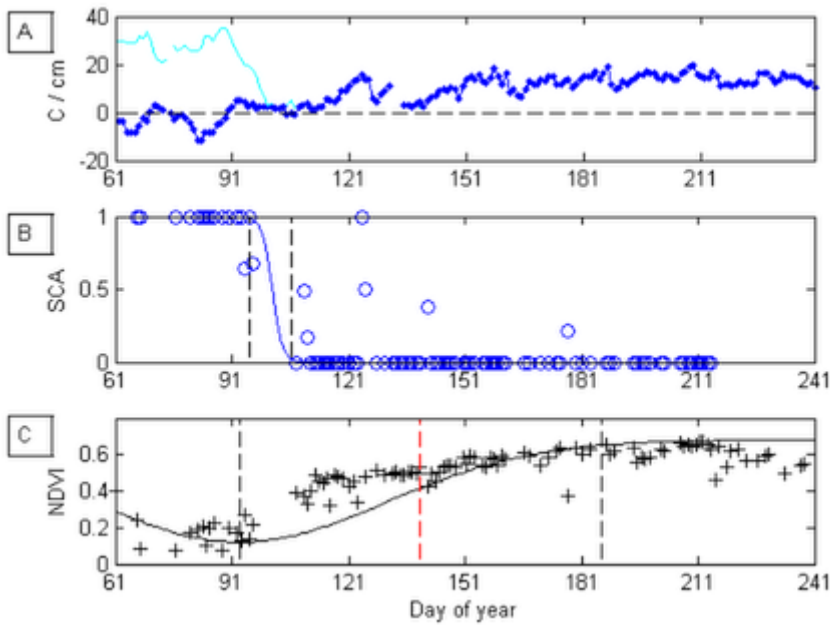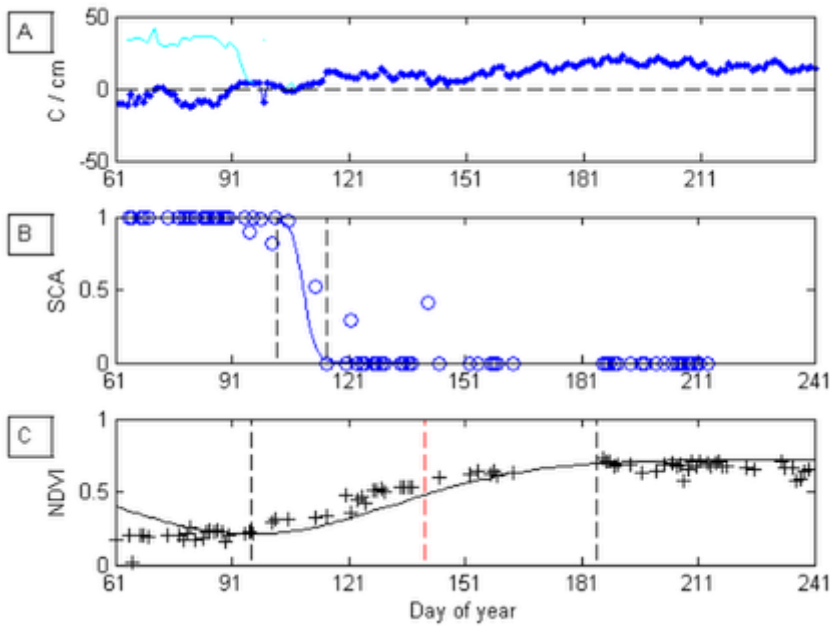

Figure 14. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Coniferous forests and year 2006

Figure 15. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Coniferous forests and year 2007

Figure 16. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Coniferous forests and year 2008

Figure 17. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Mixed forests and year 2001
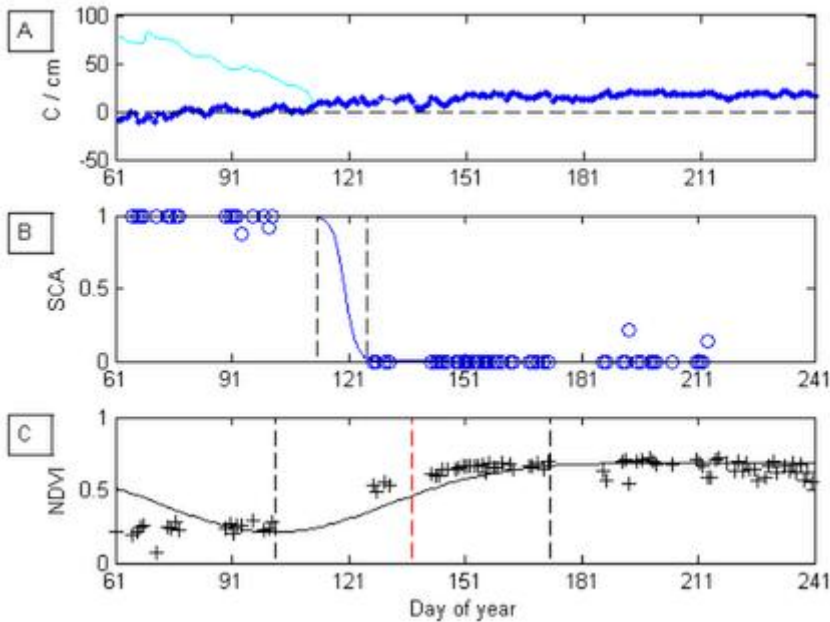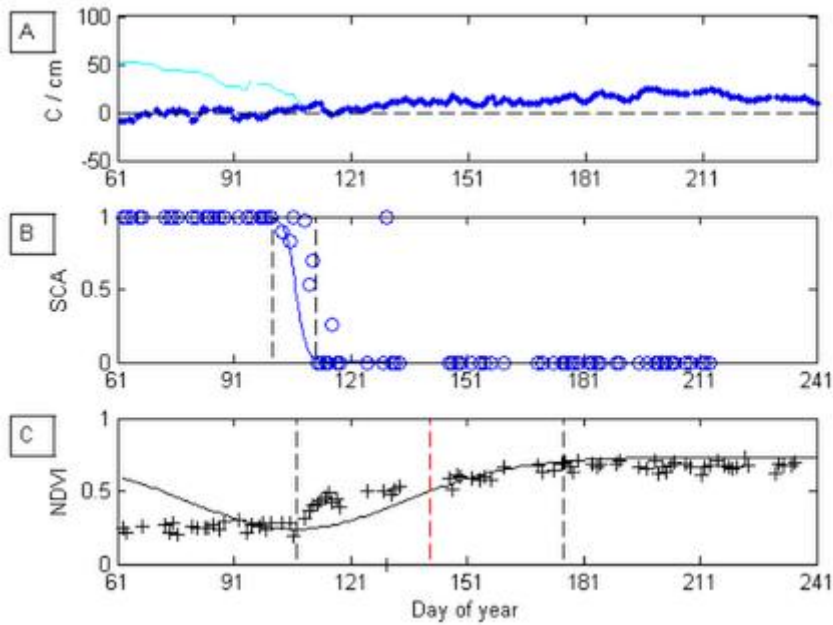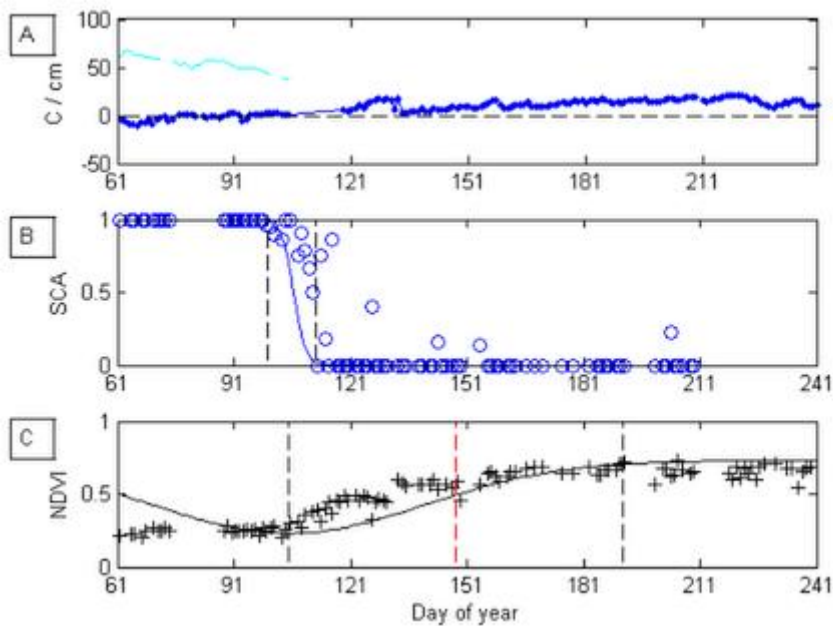

Figure 18. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Mixed forests and year 2002
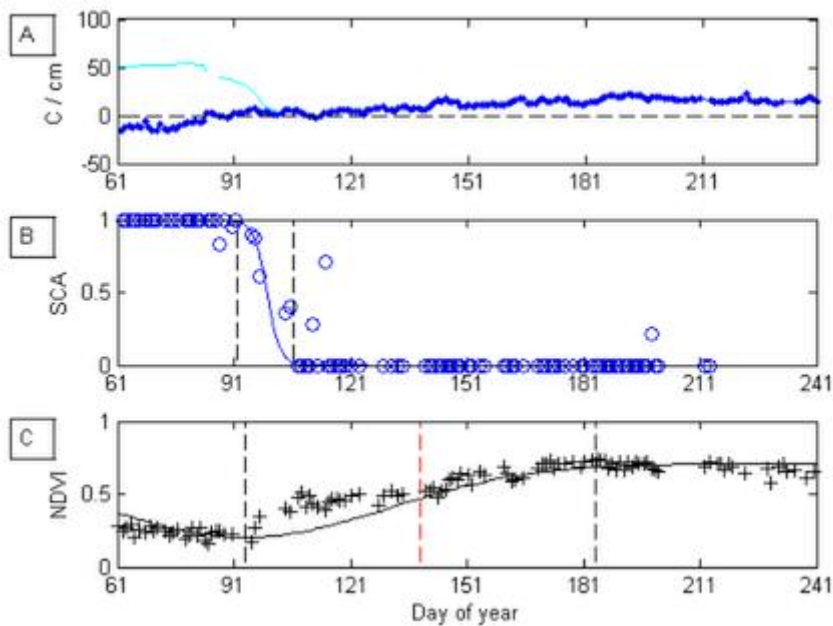
Figure 19. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Mixed forests and year 2003

Figure 20. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Mixed forests and year 2004
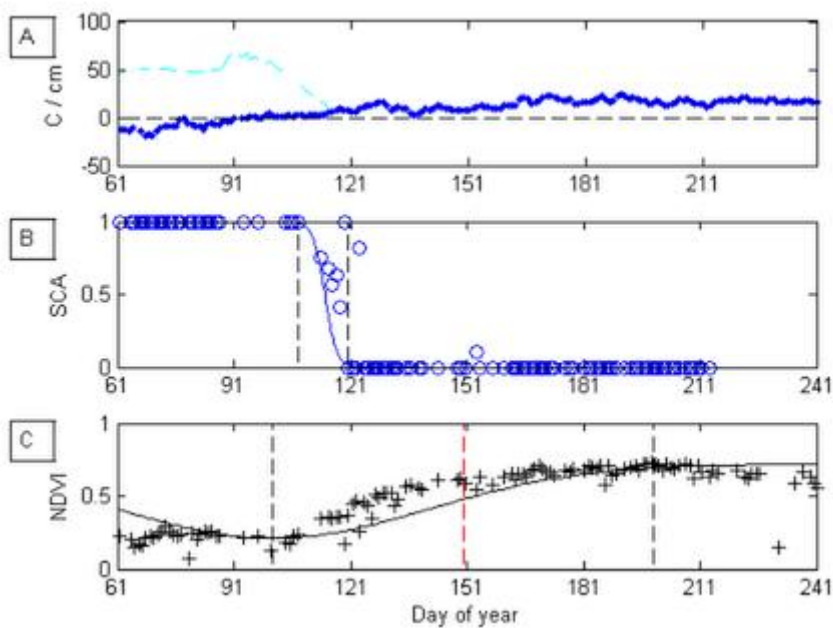
Figure 21. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Mixed forests and year 2005
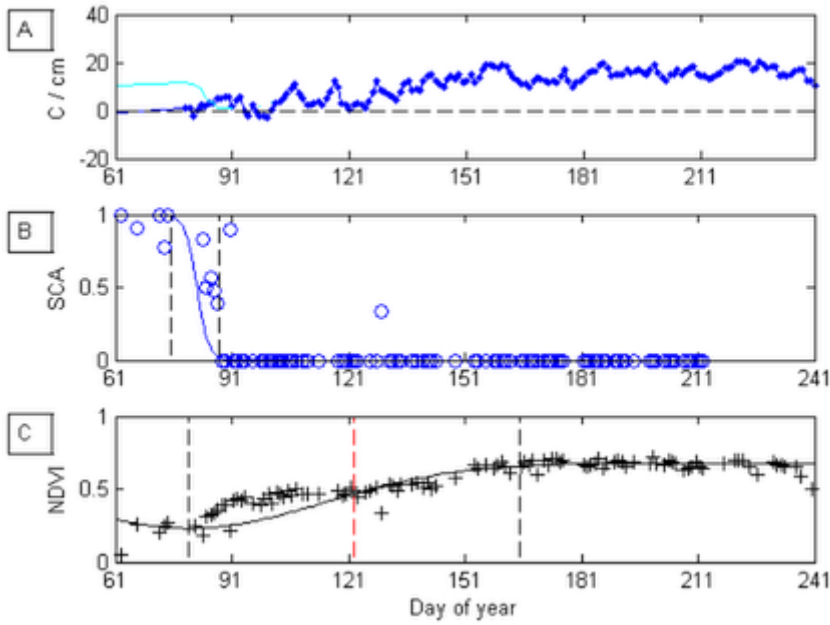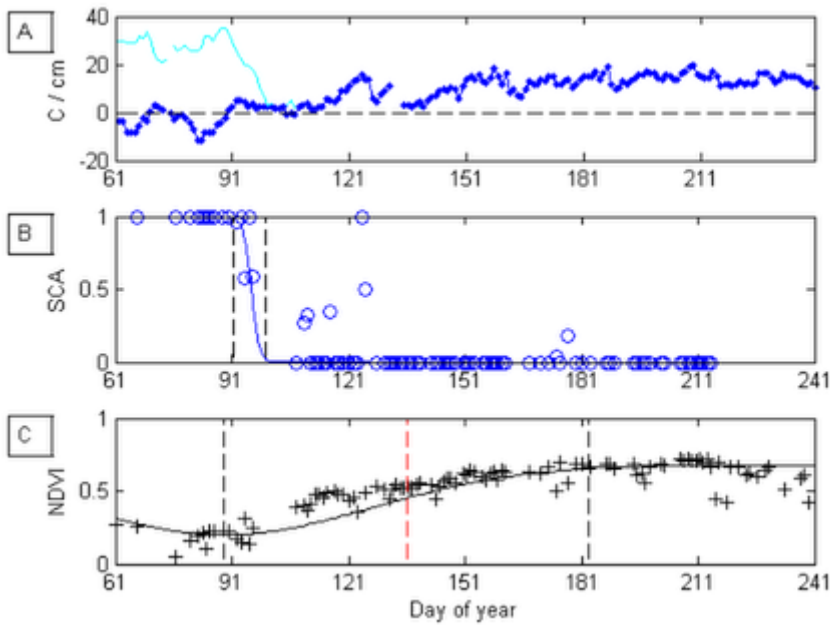

Figure 22. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Mixed forests and year 2006
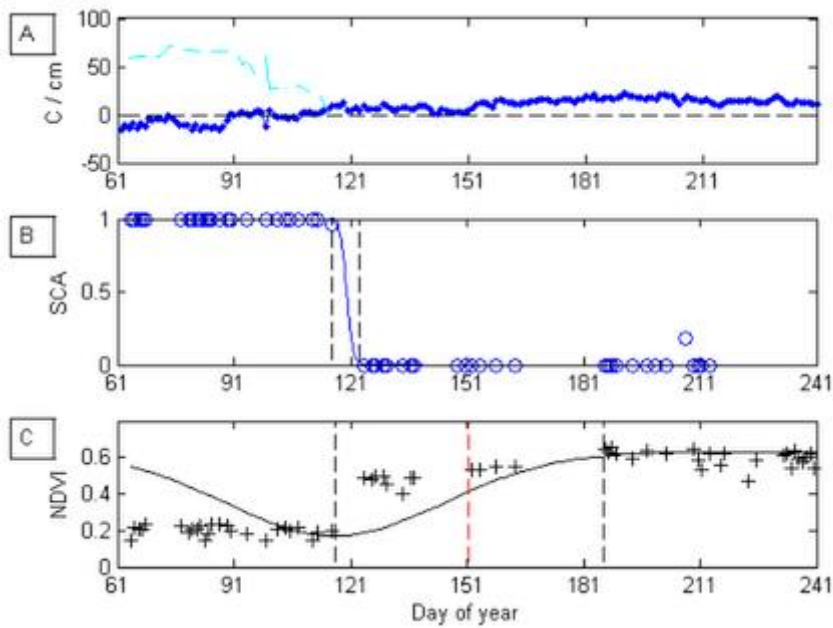
Figure 23. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Mixed forests and year 2007

Figure 24. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Paijanne Mixed forests and year 2008

Figure 1. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Coniferous forests and year 2001
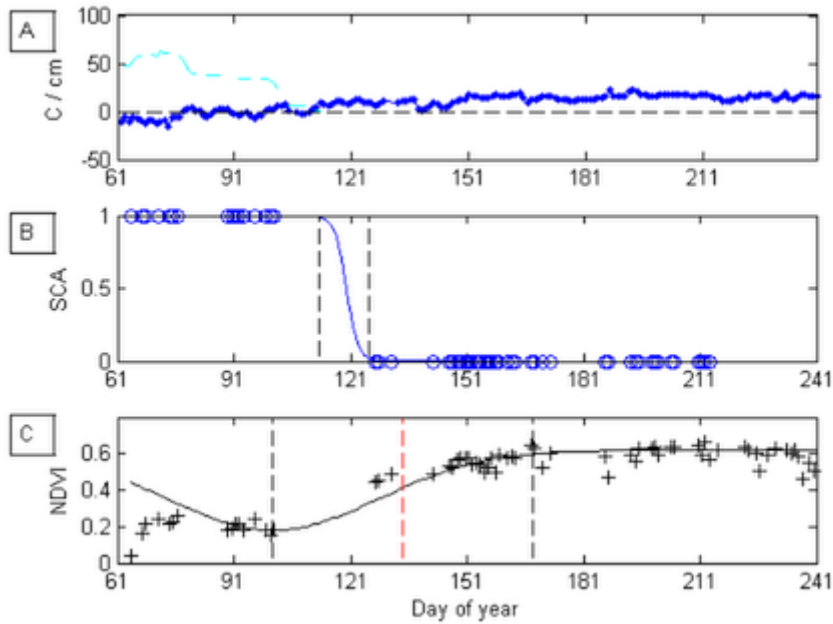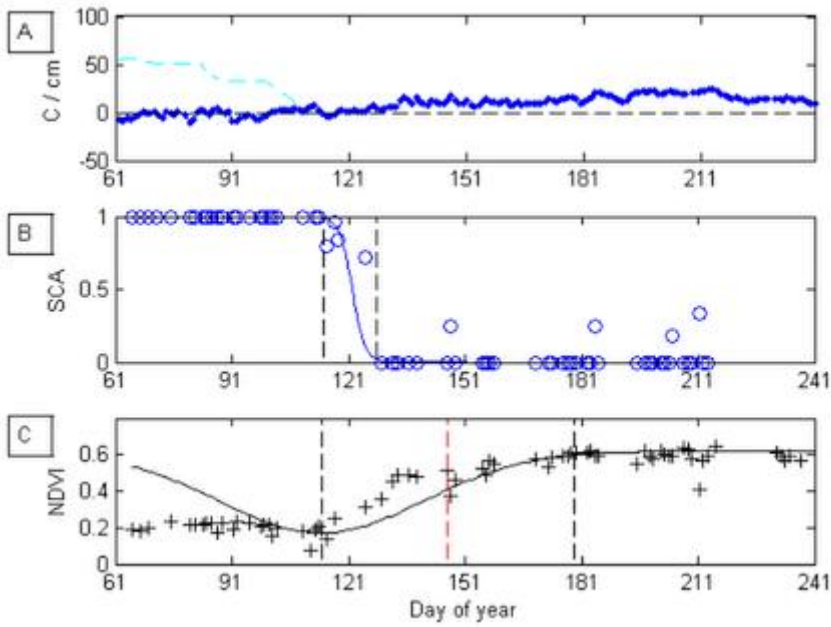

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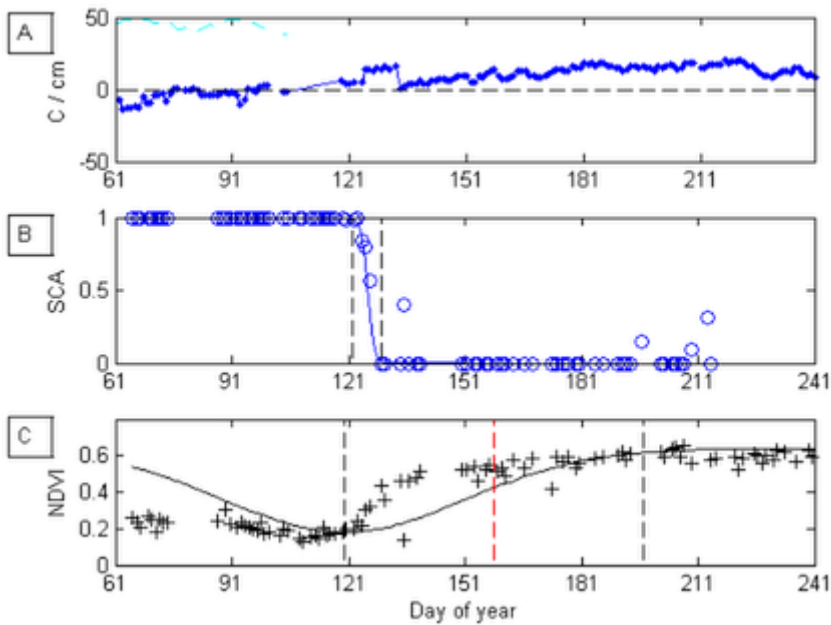
Figure 3. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Coniferous forests and year 2003

Figure 4. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Coniferous forests and year 2004
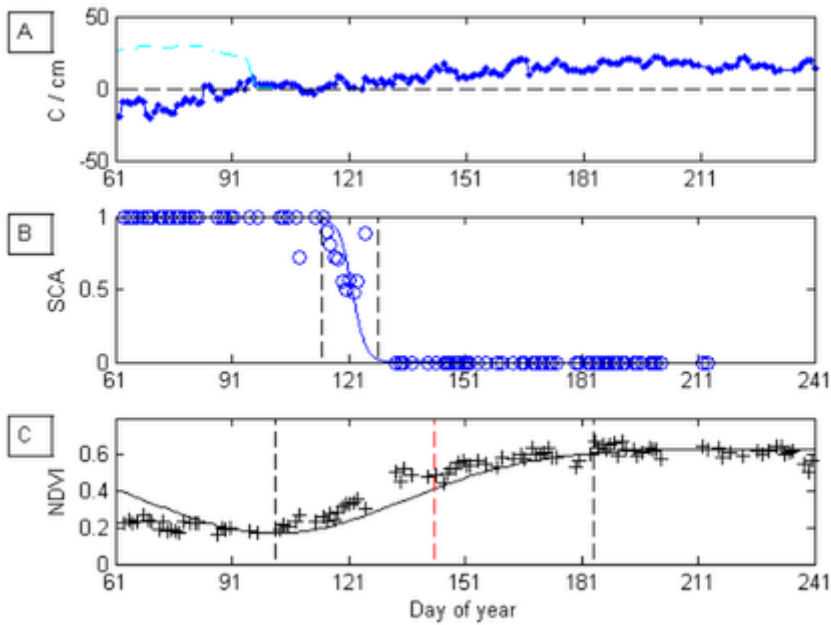
Figure 5. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Coniferous forests and year 2005
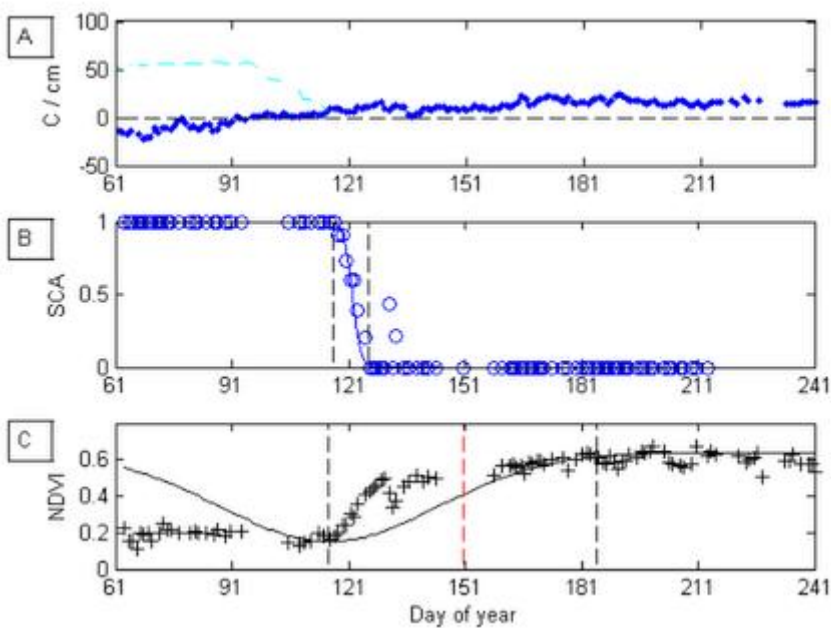

Figure 6. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Coniferous forests and year 2006
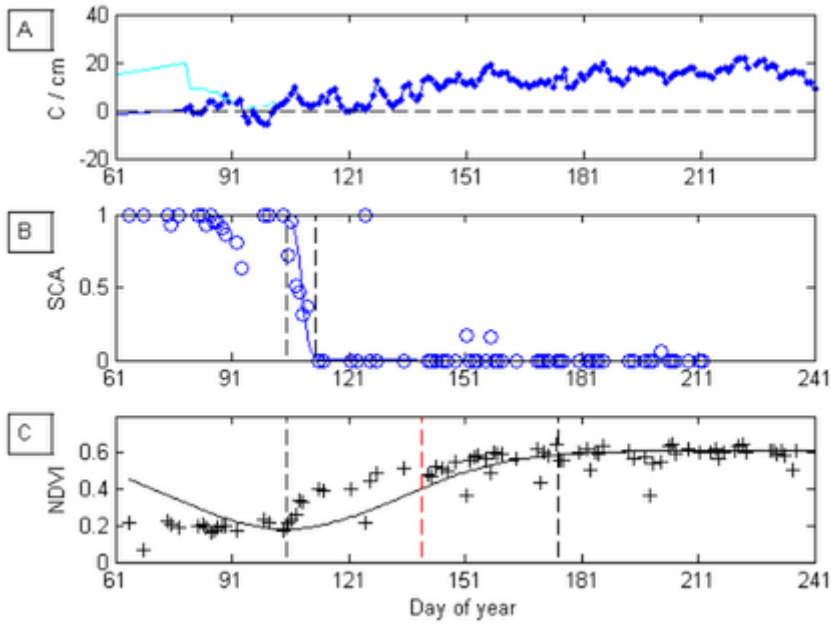
Figure 7. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Coniferous forests and year 2007
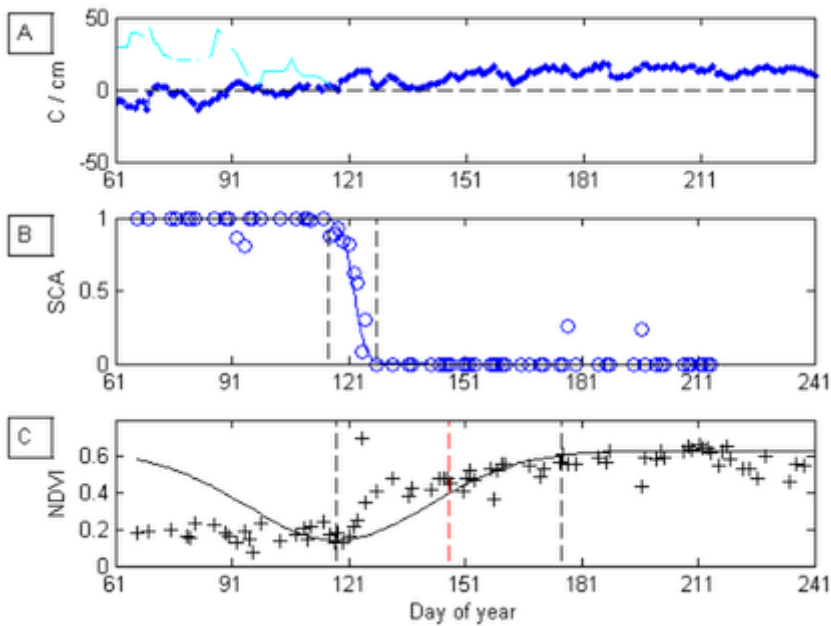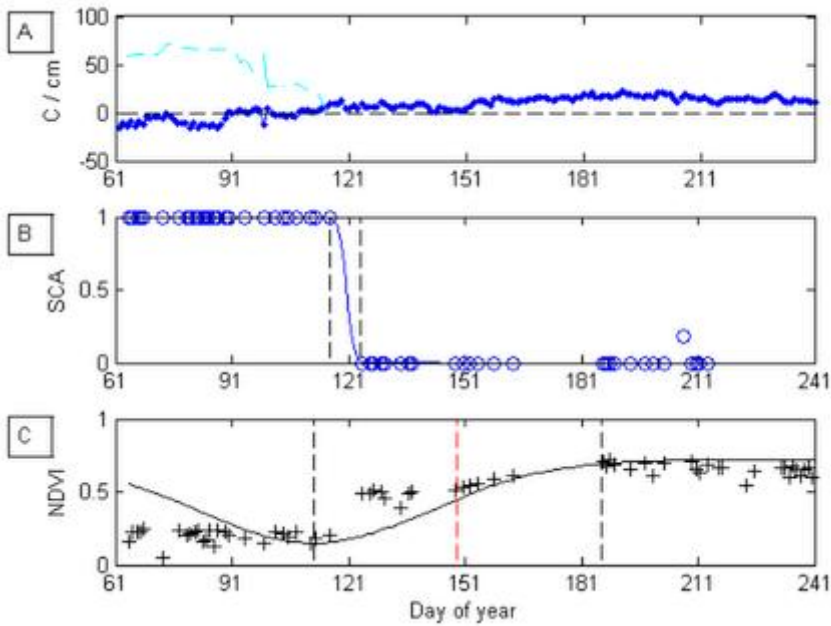

Figure 8. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Coniferous forests and year 2008

Figure 9. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Mixed forests and year 2001
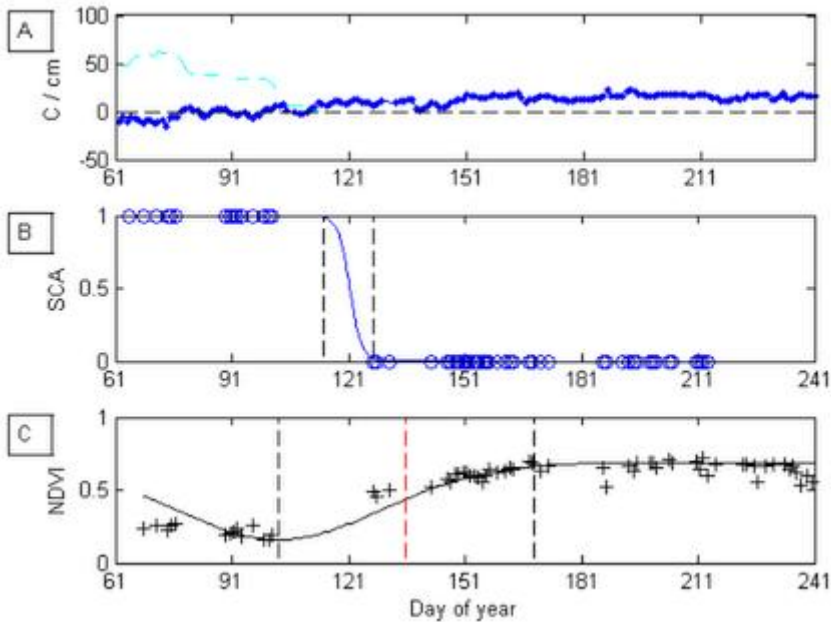

Figure 10. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Mixed forests and year 2002
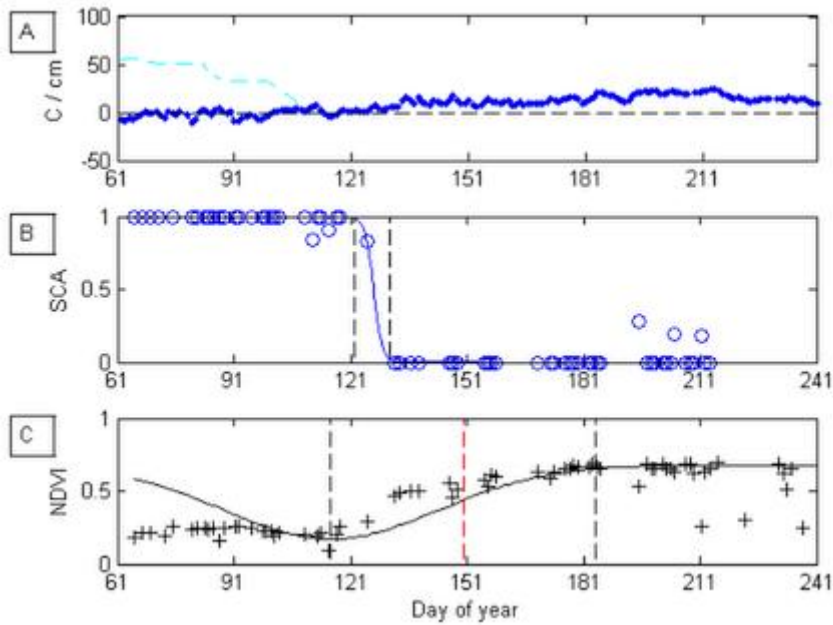
Figure 11. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby
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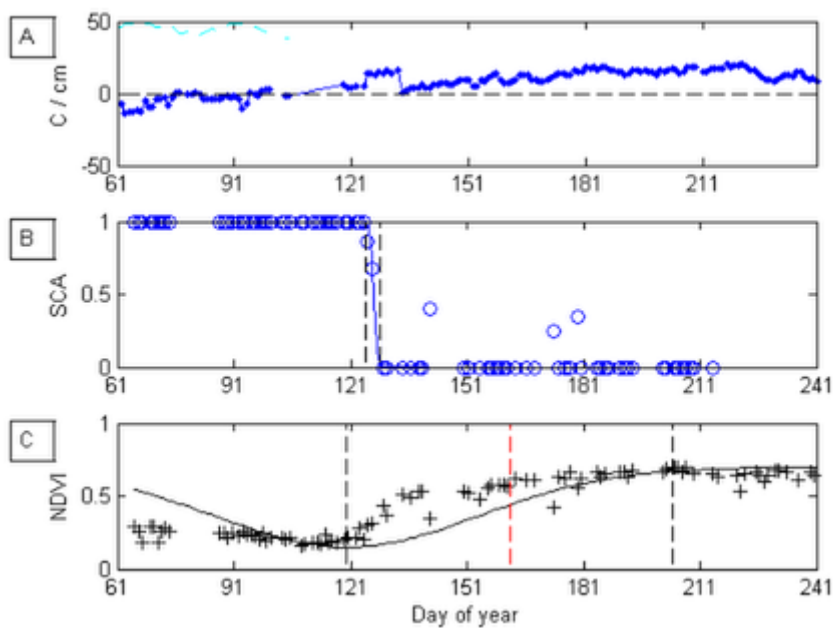forests and year 2003

Figure 12. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby
weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Mixed
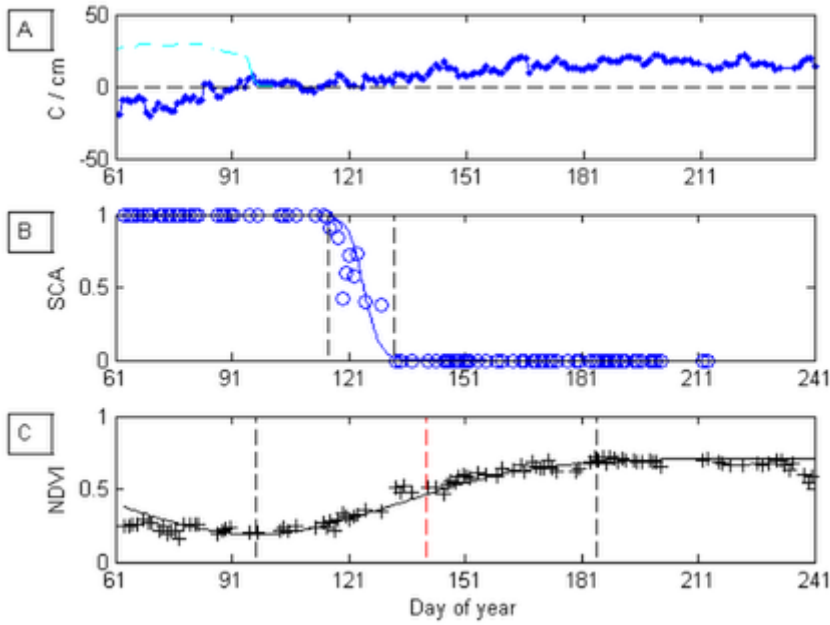forests and year 2004

Figure 13. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Mixed forests and year 2005
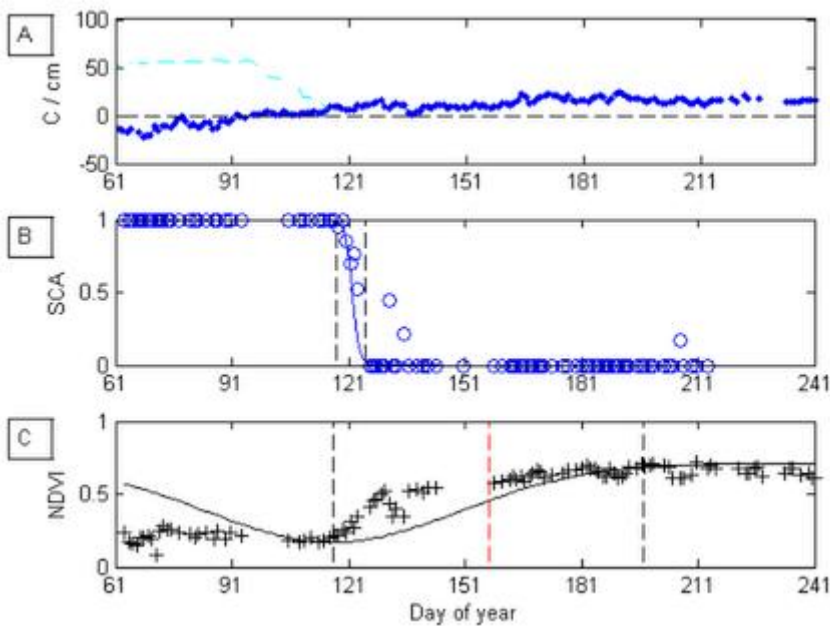

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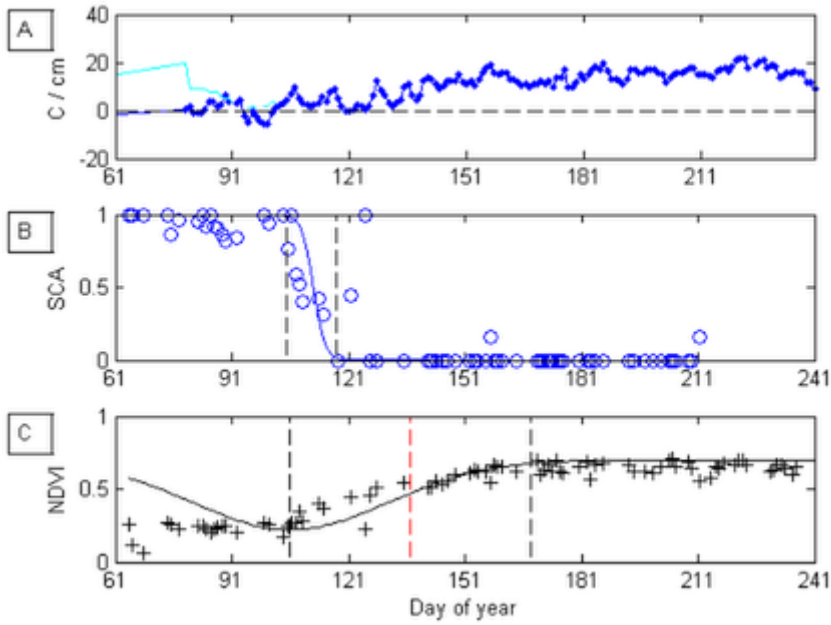
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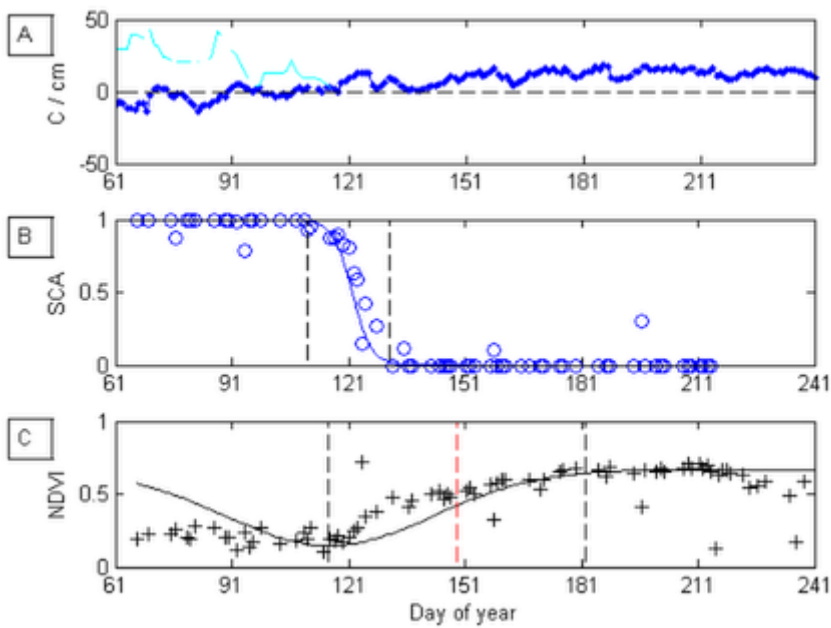

Figure 16. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Sotkamo Mixed forests and year 2008

Figure 1. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Coniferous forests and year 2001
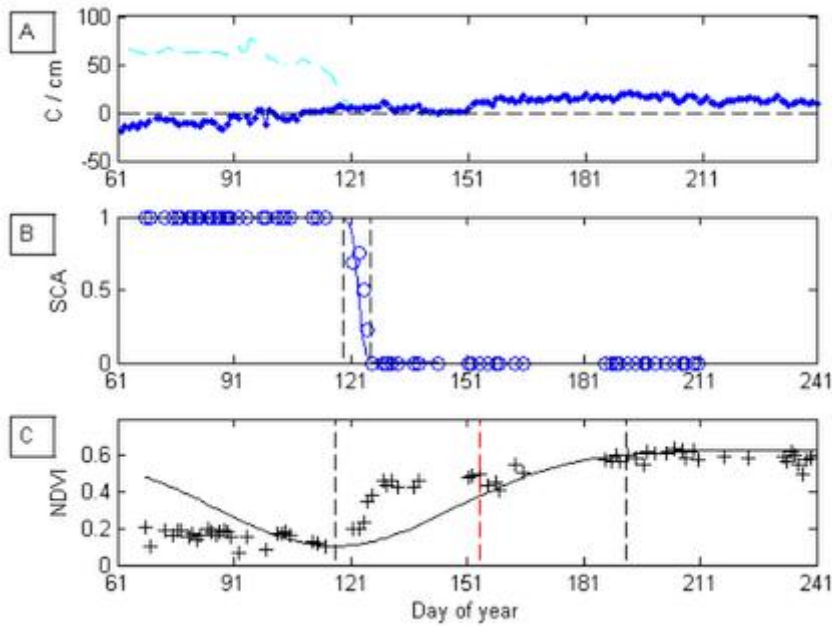

Figure 2. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Coniferous forests and year 2002
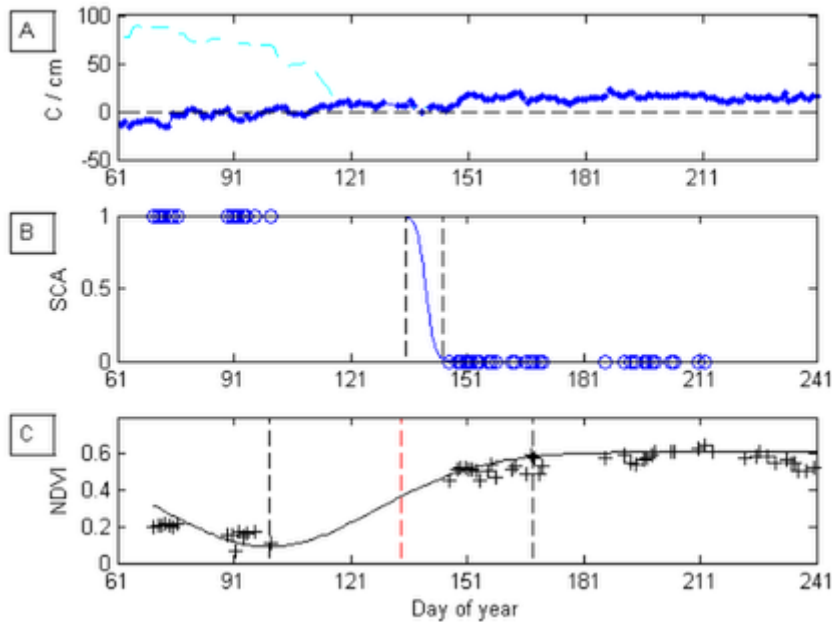
Figure 3. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Coniferous forests and year 2003

Figure 4. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Coniferous forests and year 2004
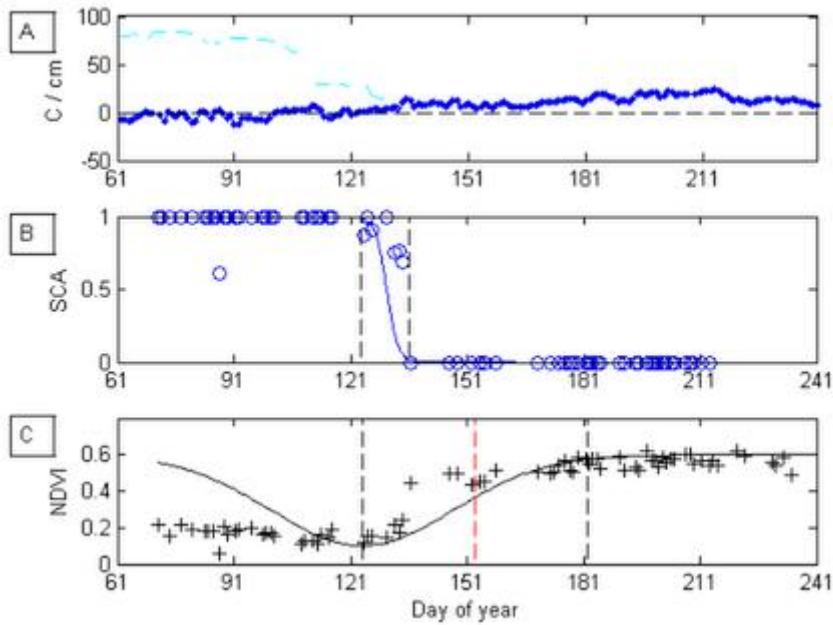
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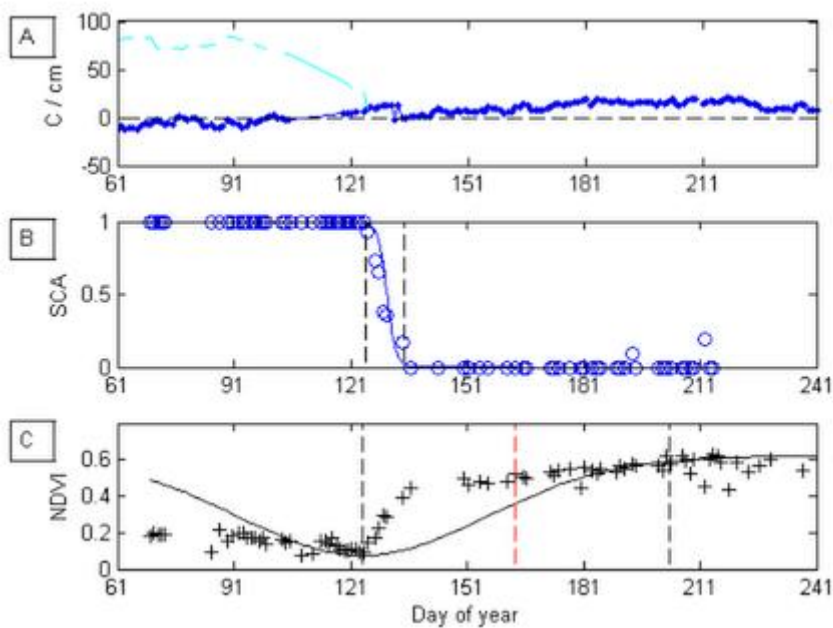

Figure 6. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Coniferous forests and year 2006
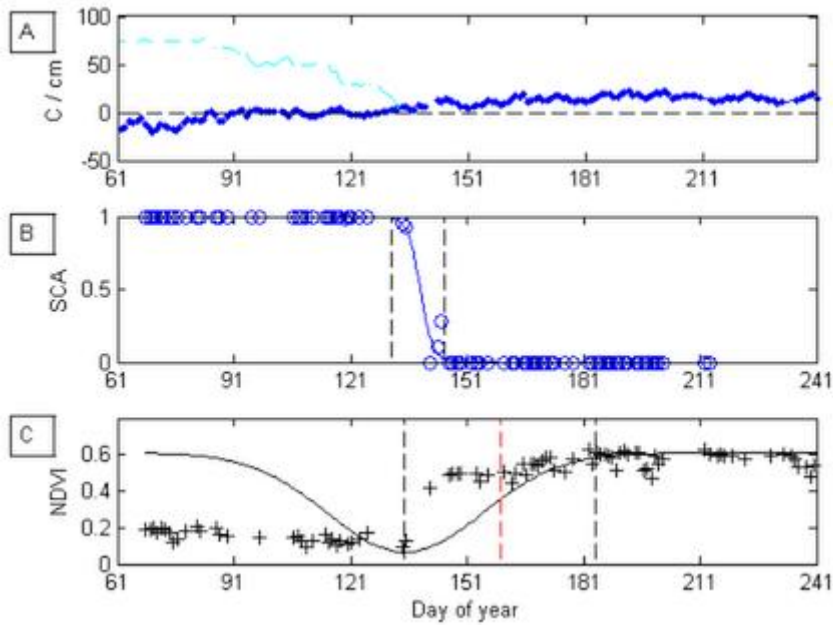
Figure 7. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby
weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka
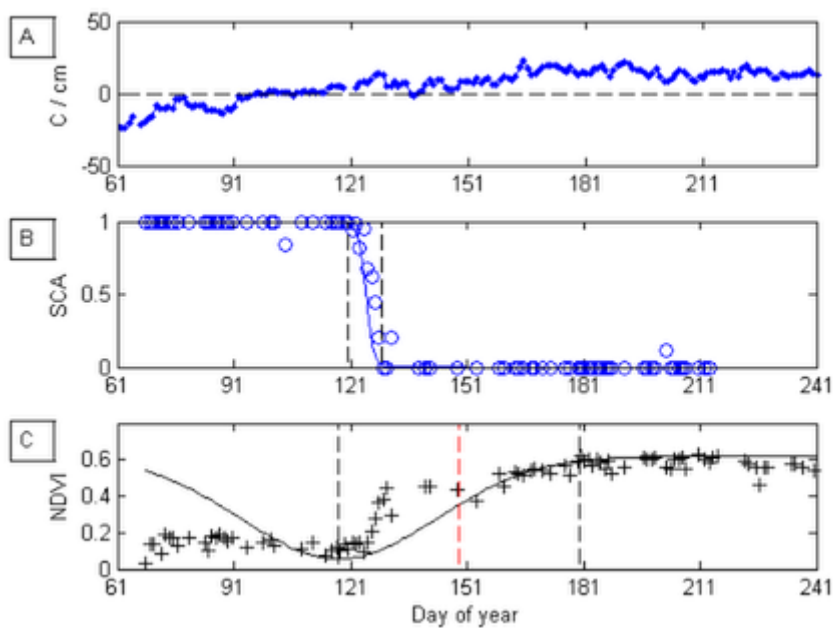Coniferous forests and year 2007

Figure 8. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Coniferous forests and year 2008
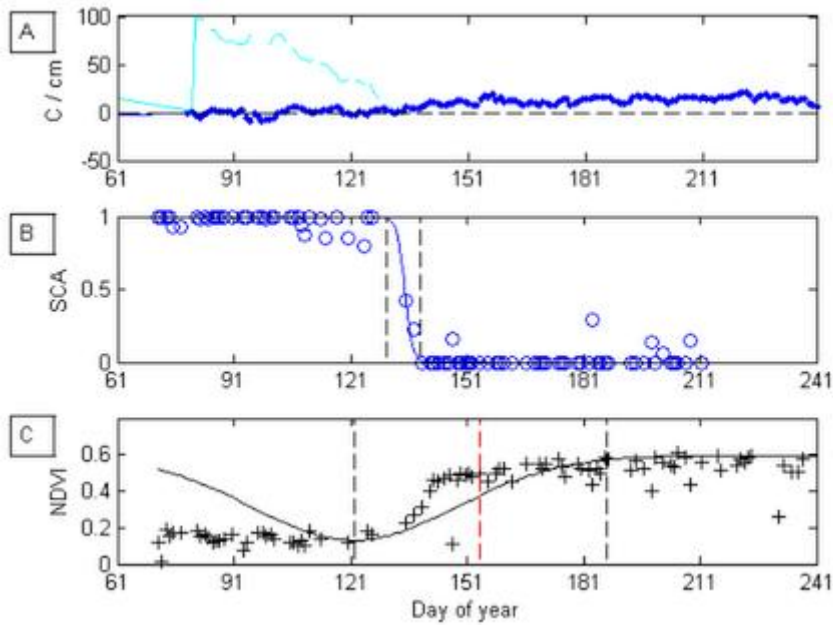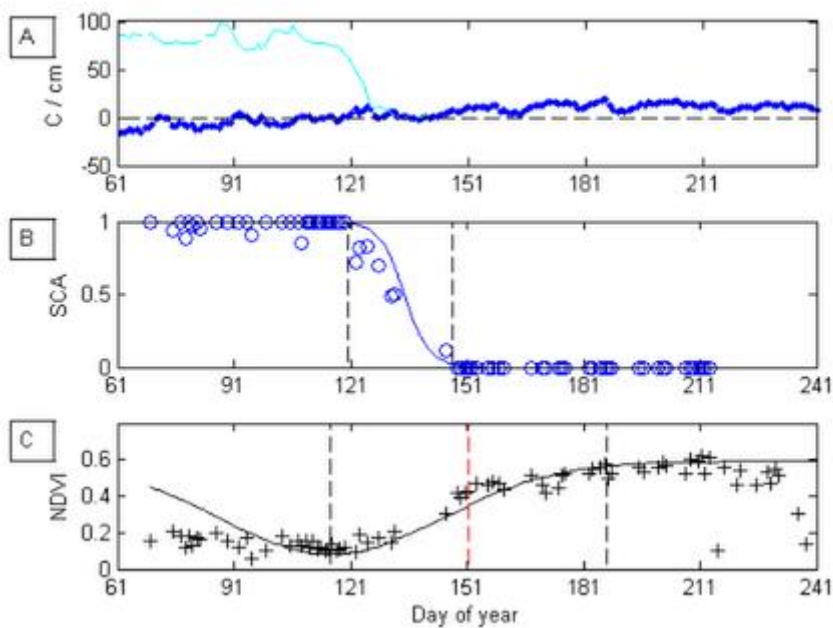
Figure 9. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Mixed forests and year 2001

Figure 10. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Mixed forests and year 2002
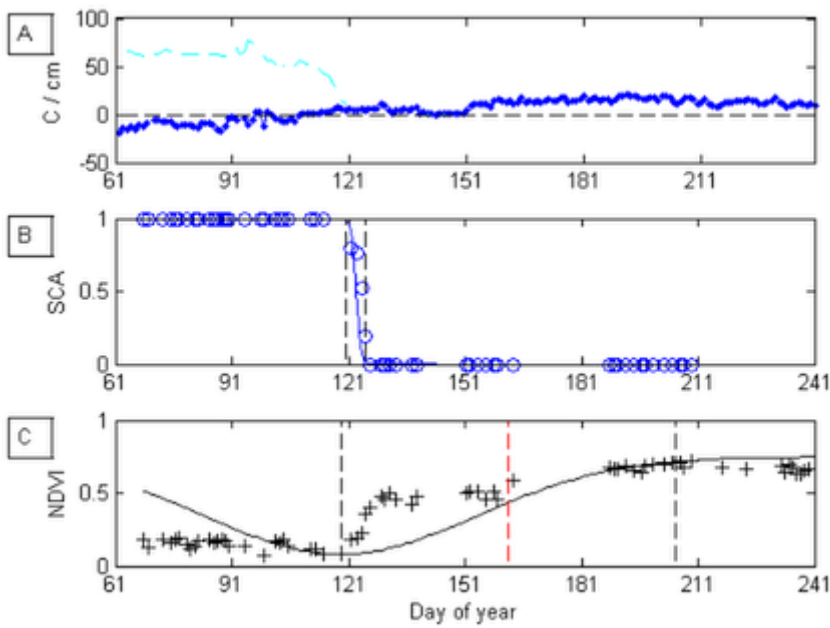
Figure 11. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Mixed forests and year 2003
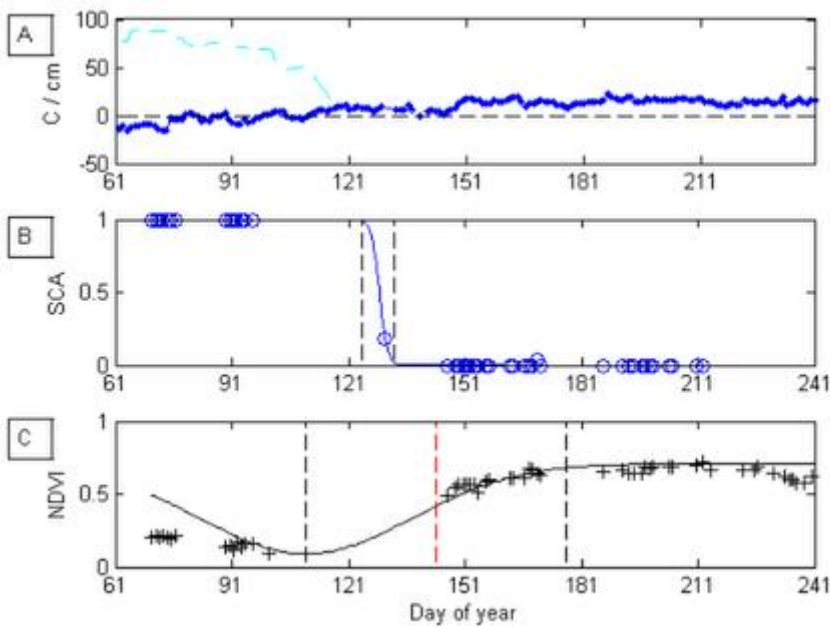

Figure 12. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Mixed forests and year 2004

Figure 13. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Mixed forests and year 2005
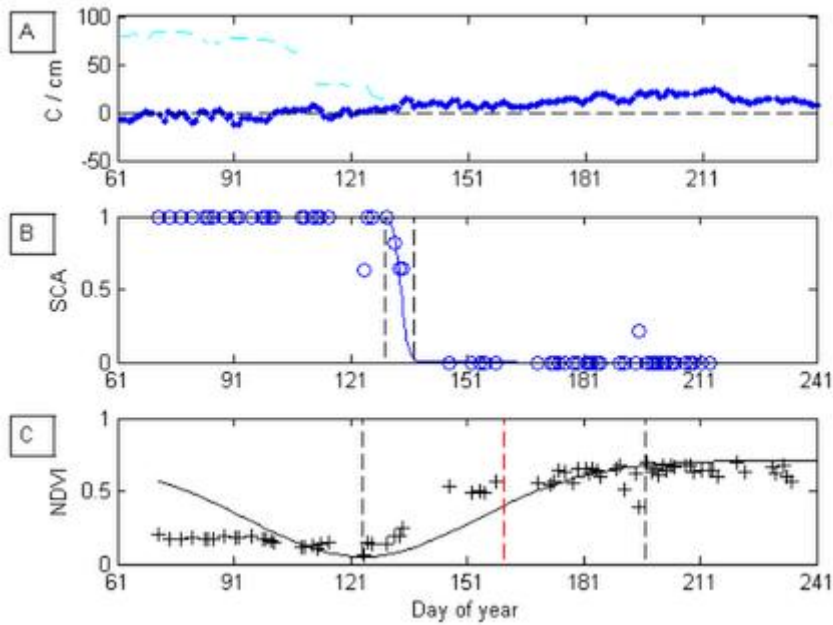

Figure 14. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Mixed forests and year 2006
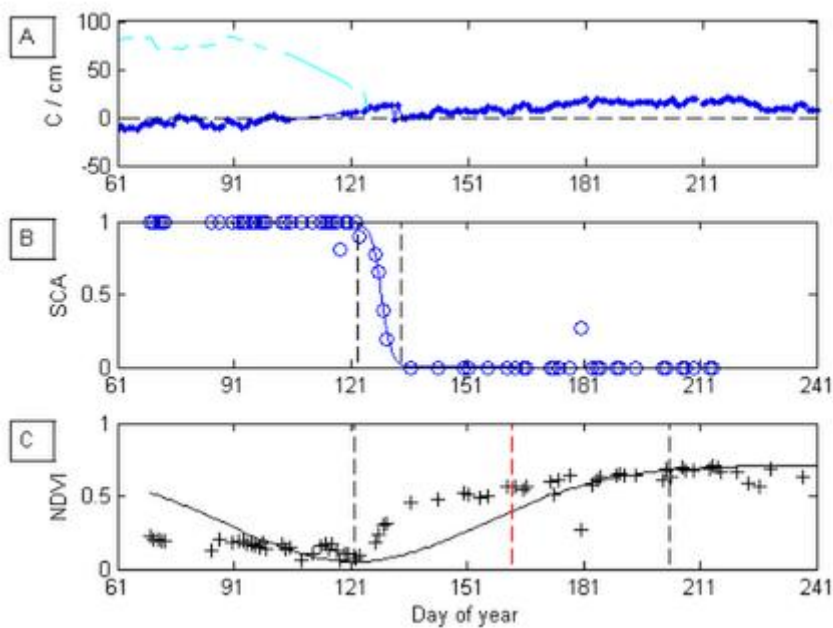
Figure 15. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Mixed forests and year 2007
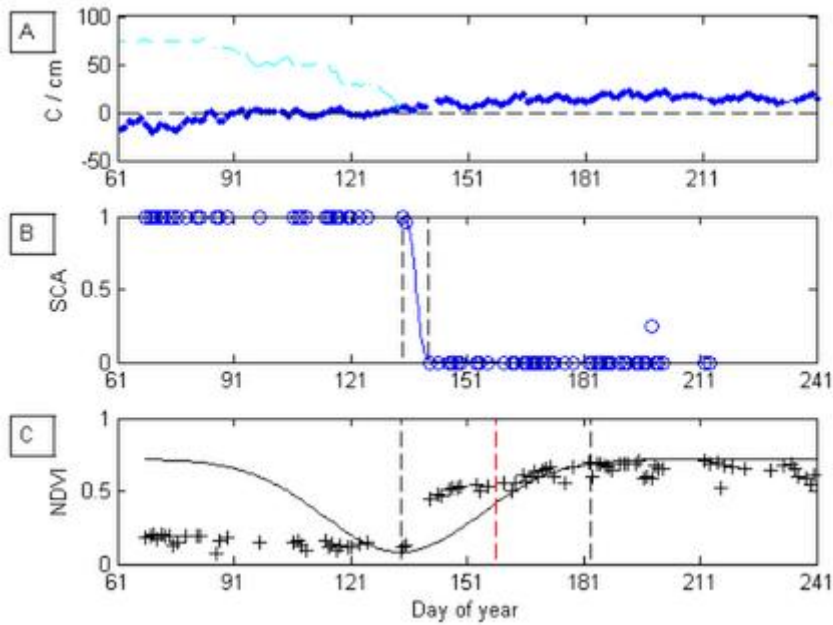

Figure 16. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Mixed forests and year 2008
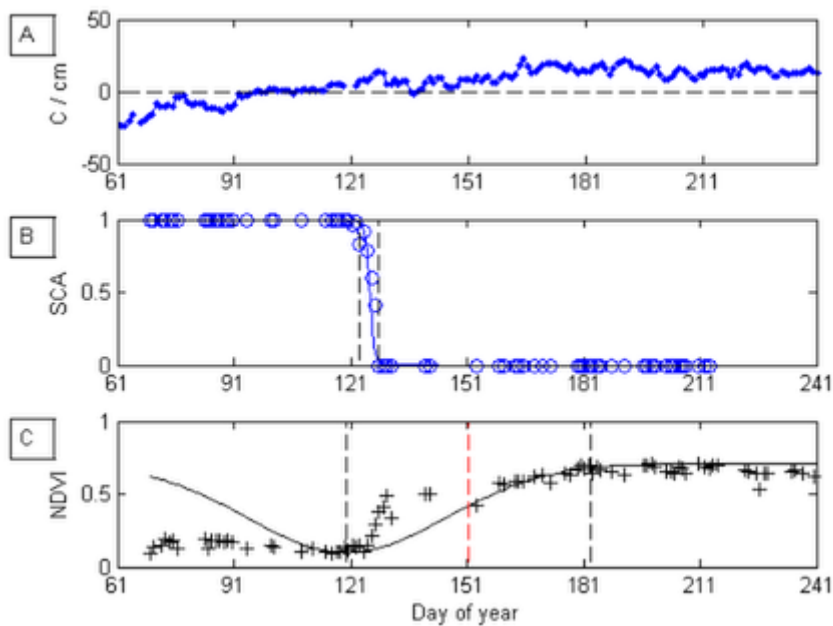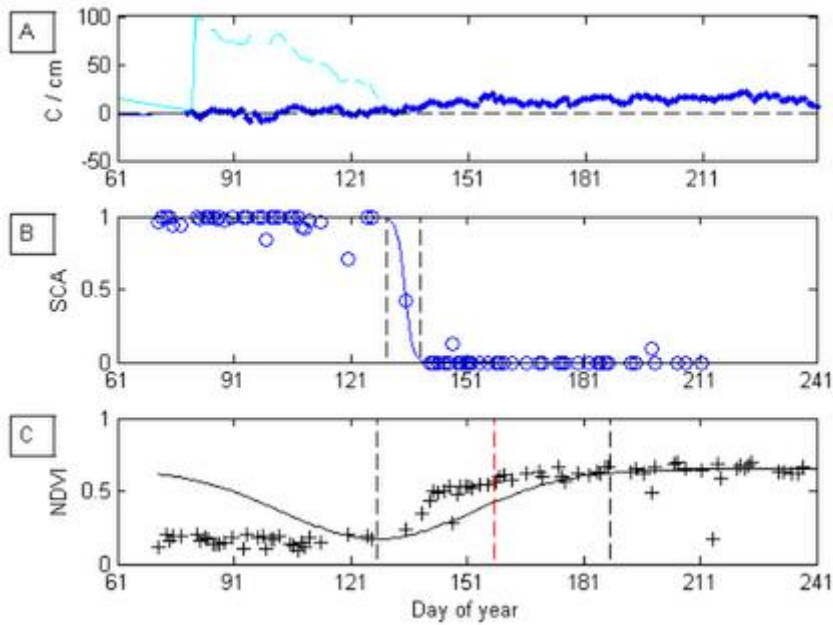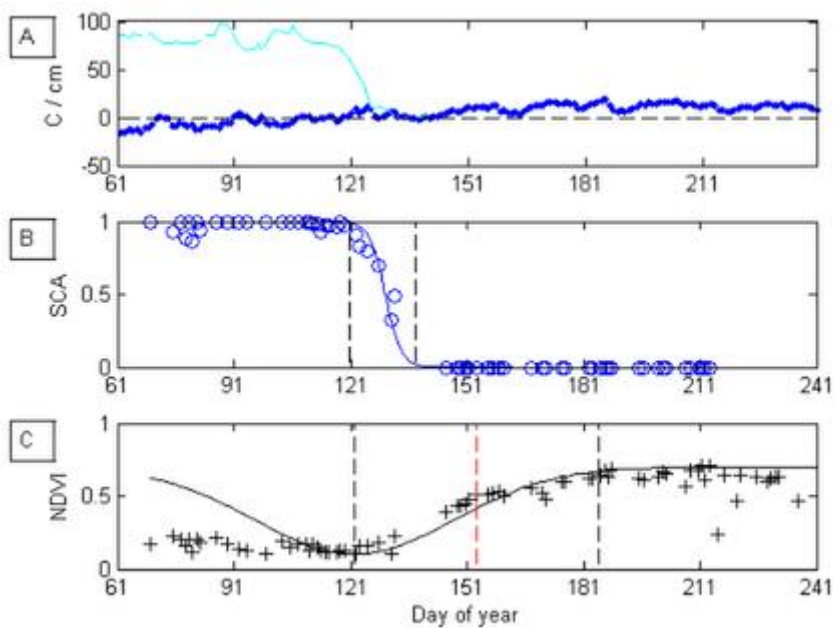
Figure 17. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Peatland areas and year 2001

Figure 18. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Peatland areas and year 2002

Figure 19. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Peatland areas and year 2003
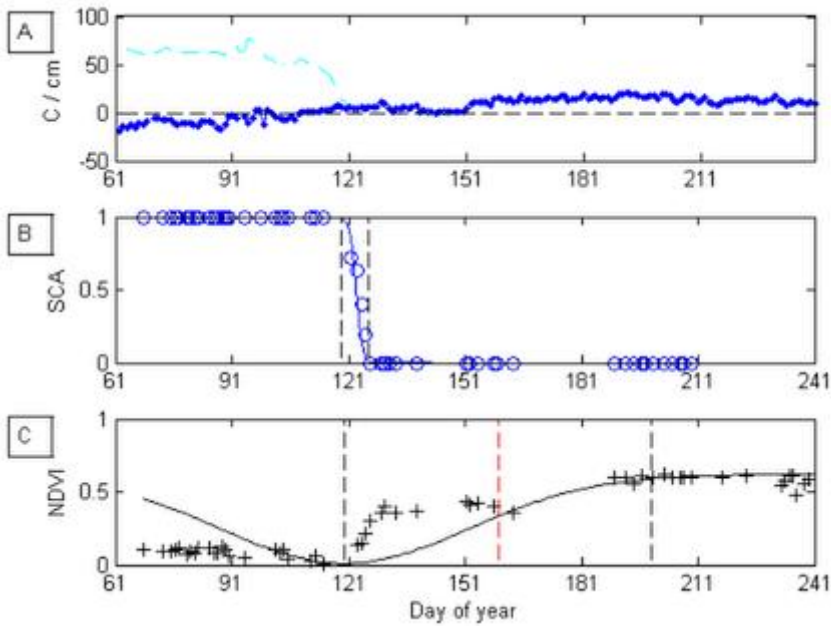

Figure 20. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Peatland areas and year 2004

Figure 21. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Peatland areas and year 2005
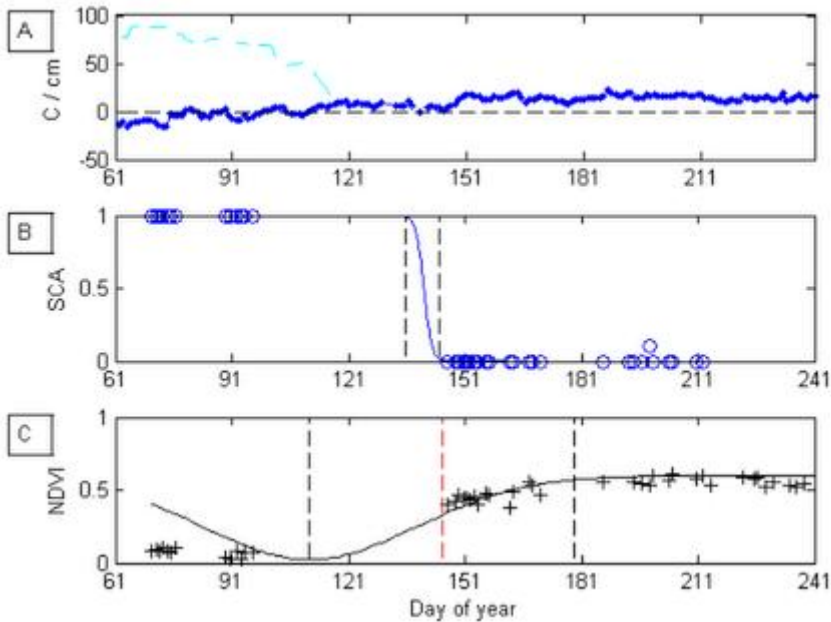

Figure 22. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Peatland areas and year 2006
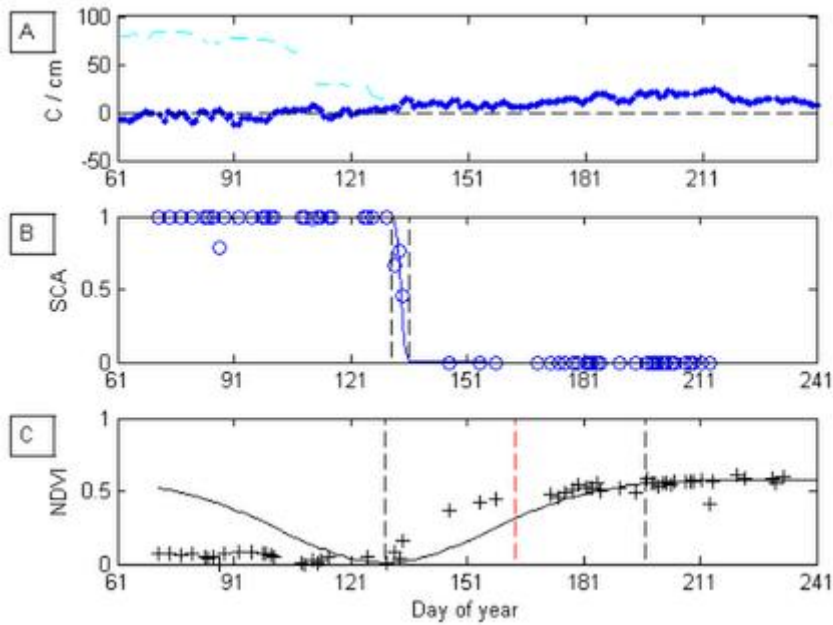
Figure 23. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Peatland areas and year 2007
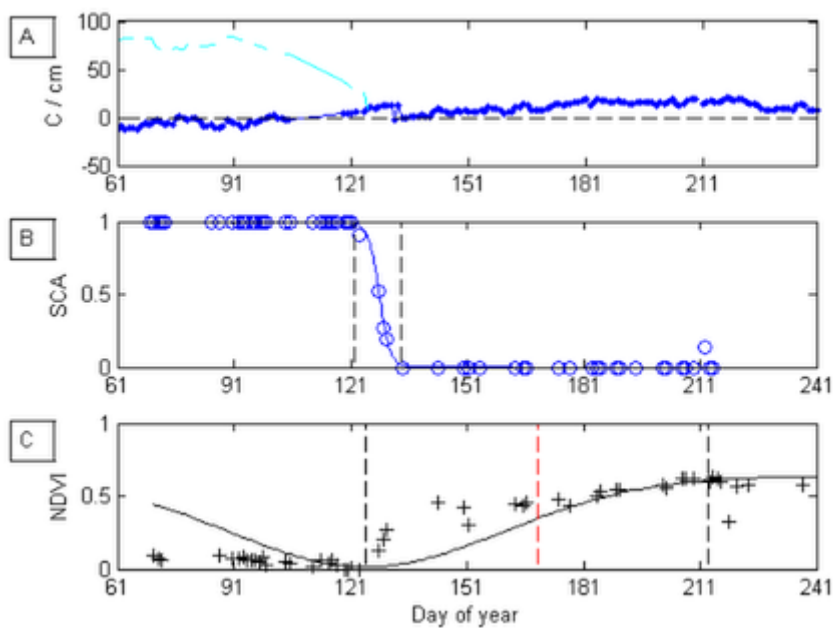

Figure 24. Air temperature (blue line with dots) and snow depth (solid cyan line) from the nearby weatherstation (A). Filtered and modelled SCA (B) and NDVI (C) time series from the Yli-Kitka Peatland areas and year 2008
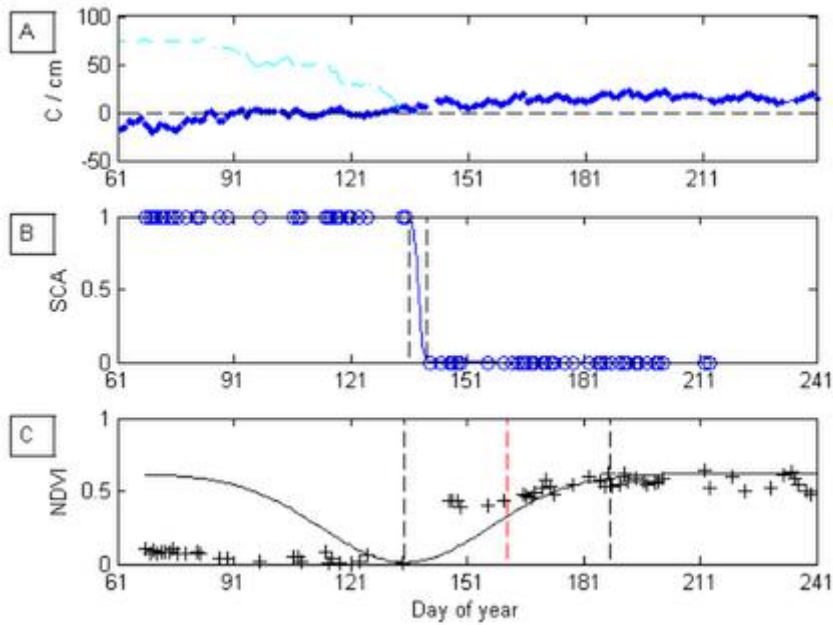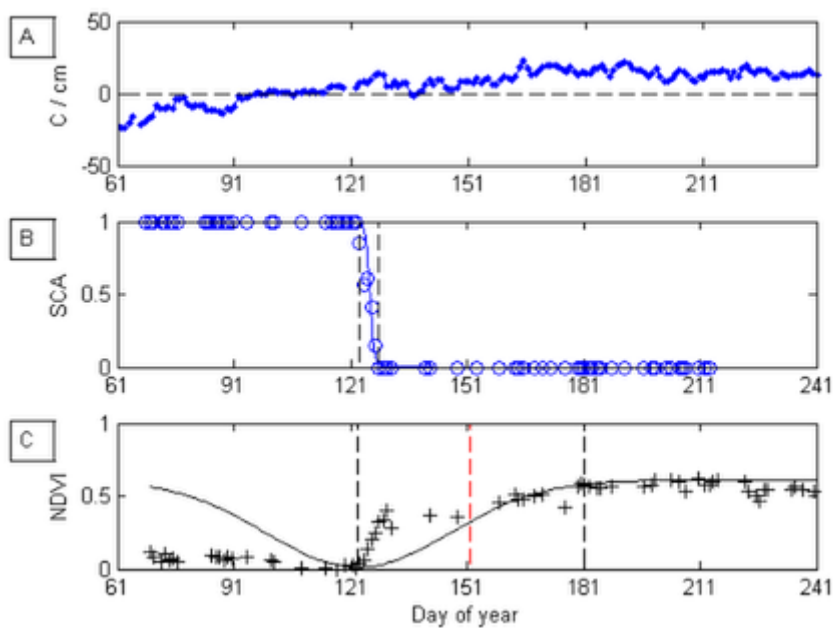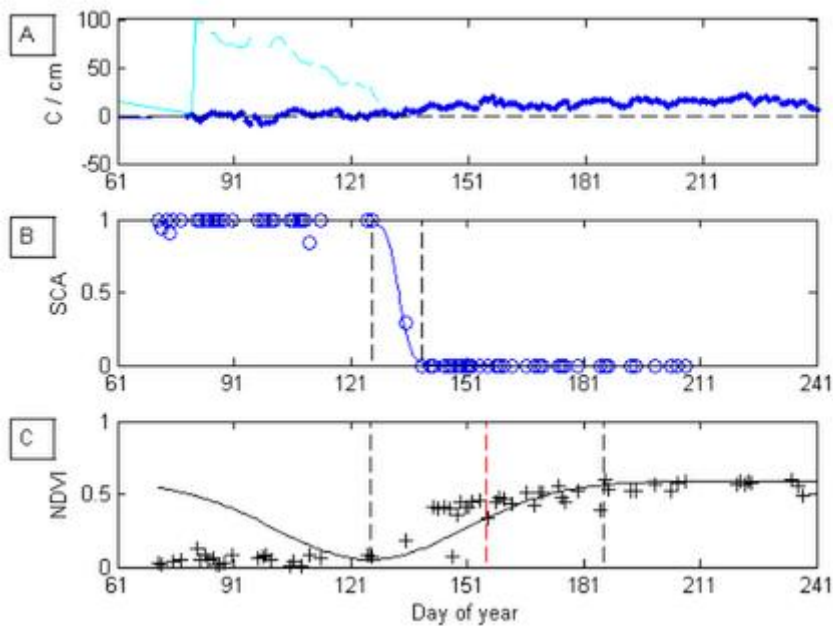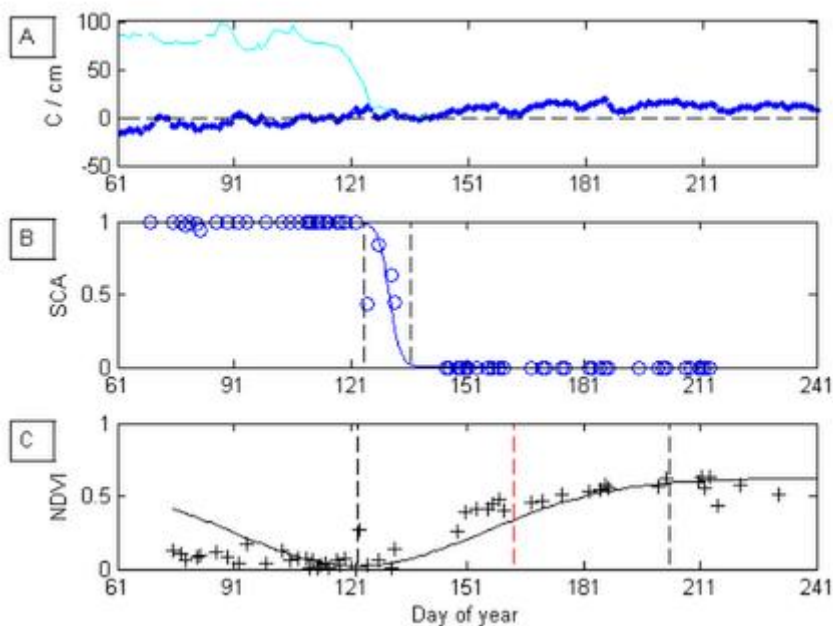
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