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1st summary report of snow data

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LIFE+ PROJECT NAME or Acronym

Climate change indicators and vulnerability of boreal zone applying innovative observation and modelling techniques

Data Project

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Data Beneficiary

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List of abbreviations

FMI	Finnish Meteorological Institute
e-code	A code from FMI weather station network describing the snow conditions in the surroundings.
FSC	Fractional Snow Cover
SYKE	Finnish Environment Institute
WMO	World Meteorological Organization

1 Summary

This document provides a general description of the *in situ* observations used in the calibration and validation of snow cover extent (2011-2013). The *in situ* dataset includes the observations on snow patchiness made at the snow courses by the Finnish Environment Institute SYKE (starting from 1950s) and the snow e-code observations from FMI weather stations.

2 Data

2.1 Snow courses

Ground reference data feasible for evaluation of fractional snow cover (FSC) retrievals is often relatively difficult to obtain. This is because FSC is typically registered by human observers. Moreover, fractional snow typically varies rather widely in space and time, and therefore single point observations are not necessarily representative of the local spatial variation. This representation also depends on the landscape character and other prevailing conditions. The observations should be conducted over an area corresponding to the pixel size of the applied satellite sensor, and the timing should match the satellite overpass at least so that no major changes in snow cover occur. The snow course network governed by the Finnish Environment Institute (SYKE) has a heritage from the beginning of the 20th century. The network consists of ~160 courses which are visited on a monthly basis. A snow course is a 2-4 km long transect passing through different landscapes; the observer registers the snow information typically at 80 locations along the transect. The observations include snow depth (SD, measured with a stick), snow density (measured with a snow tube) and fraction (%) of snow-free ground (visually estimated for an area within a 25 m radius of the observer's location). Hence, FSC=100%−Fraction of snow-free ground. The map of the Finnish snow courses and the trail of a snow course plotted over a digital photograph are shown in Fig. 1.

Note: the four squares shown in the Fig 1 (right) correspond to 1×1 km^2 snow product pixels that cover the course; at least these pixels should be used when comparing the snow product against the in situ observations along the course. Also a larger window (e.g. 3×3 product pixels) can be used. In either case, an average of the selected product pixels is taken and compared with the average FSC calculated from the observations along the snow course.

Proper *in situ* observations are particularly difficult to obtain when only trace amounts of snow are present. In a scale of a pixel, these easily remain unnoticed by human observers if only several samples are taken at ground level. The route of each snow course maintained by SYKE is individually planned so that it should represent a locality of a few square kilometres. The trail goes through different landscapes in order to catch the differences in snow conditions; the information of the prevailing landscape is assigned to each measurement location. The landscapes are: pine forest, spruce forest, mixed forest, broad-leaf forest, forest opening and open bog.

Table 1 Measurements performed at each snow course.

Parameter	Description	# meas./site	Unit
Snow depth	- at least 10 for each land cover type	50 or 80	cm
Snow patchiness	- the % terrain covered by snow	50 or 80	%
	- at least 10 for each land cover type		
Snow water equivalent	- the water content/m^2 if the snow pack would be melted	10 or 8	[mm] w.e.
	- at least 1 for each land cover type		
Snow density	- at least 1 for each land cover type	10 or 8	kg/m^3

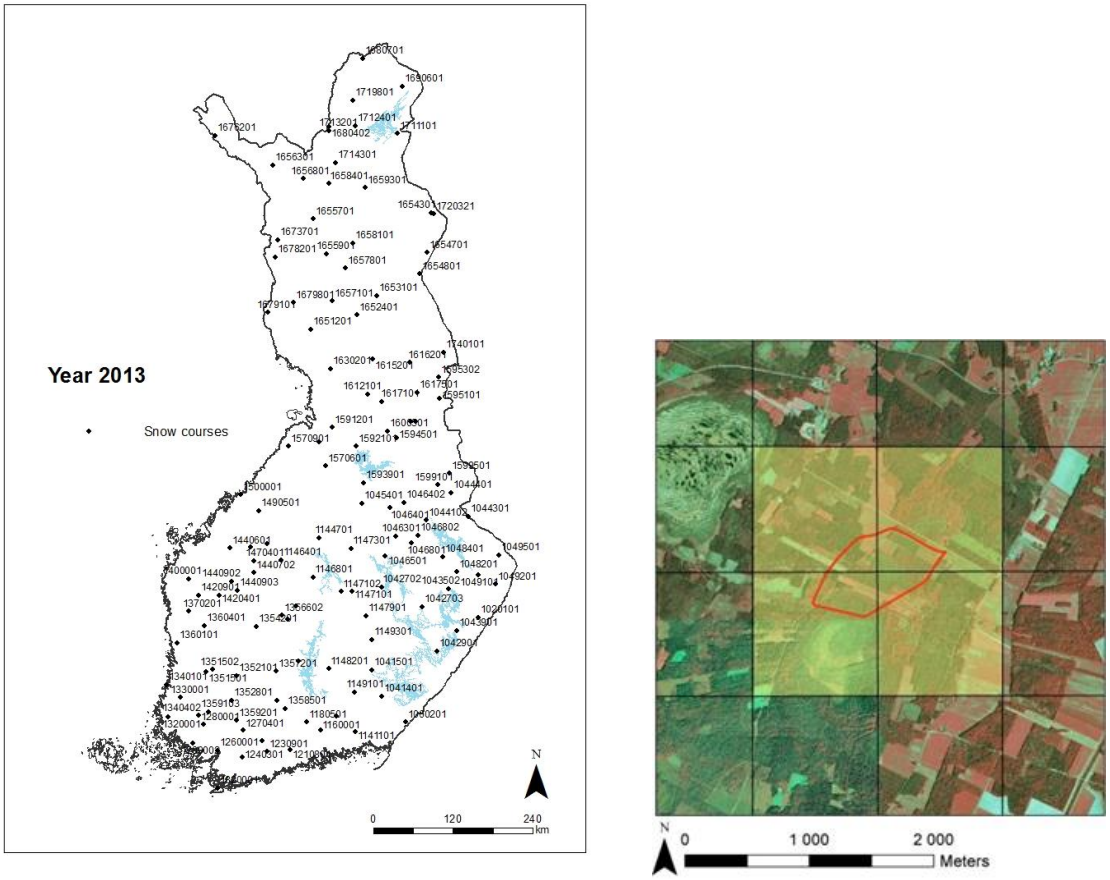

Figure 1. Left: Location of active snow courses in 2013, Right: an example of the route of a snow course.

Actions related to the snow course data:

Snow course observation are extracted from hydrological data bases in SYKE and further processed to allow comparisons with satellite observations related to snow properties. The following data fields are retained in the final Excel-file: *1. Snow course ID,* 2. *coordinates (lat,long) in WGS-84 system, 3. Date of observation, 4. Snow depth, 5. Patchiness, 6. Landcover type.* The landcover-specific average values are also calculated and provided as separate Matlab-tables, so that one table is created for each individual snow course visit.

For five selected snow courses around Sodankylä-Pallas area a historical time series has been processed and is available for the last 30 years period.

2.2 Weather station e-codes

The weather station network of the Finnish Meteorological Institute (FMI) in Finland consists of ~250 stations, where observations on snow depth (point-wise) and snow coverage (within the range of vision) are made on a daily basis. Figure 2 presents the locations of the weather stations. Snow coverage is described with a particular e-code following the definitions presented by the World Meteorological Organization (WMO), see Table 2. Observations of

snow coverage were discontinued at many of the stations in 2009 due to the automation of observing protocols, but in many stations it is still recorded.

Table 2 Description of e-codes.

E-code	Description
0	Dry snow free terrain, vegetation can be covered by moisture from dew or fog.
1	Wet snow free terrain.
2	Snow free terrain with water ponds.
3	Terrain frosted or covered with surface ice.
4	Open terrain snow free, some snow in forested areas.
5	Snow covering over 0%, but less than 50% of the terrain.
6	Wet or re-frozen snow covering over 50% but less than 100% of the terrain.
7	Wet or re-frozen snow covering 100% of the terrain.
8	Dry, loose snow covering over 50%, but less than 100% of the terrain.
9	Dry, loose snow covering 100% of the terrain.

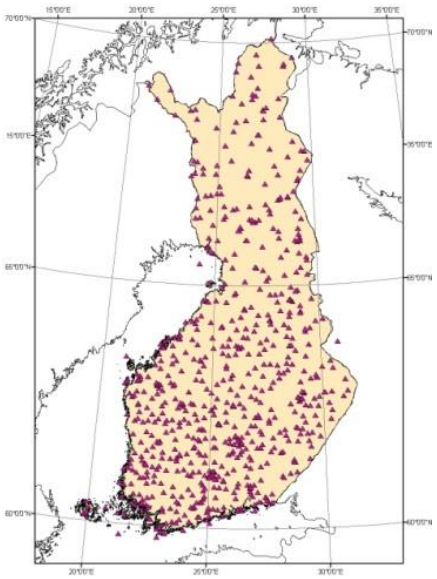

Figure 2 FMI weather stations with e-code observation.

Although expected to represent the average snow conditions in the locality, the snow observations may introduce a bias towards less snow than is actually present in the surrounding area, corresponding e.g. to a pixel of a satellite image. This is because each weather station is located in an open area, where snow typically disappears earlier than in forest areas. In order to evaluate how well the point-wise observation applies to a larger surrounding area, the correspondence between the e-code and the nearby same day's snow course FSC – providing a better spatial distribution – was analysed and found to be reasonable. This correspondence is considered to be an indication of spatial representativeness of point-wise observations in the scale of pixel-size of the Earth-observation imagery used in Monimet-project. Figure 3 presents the results of the analysis. The spatial representativeness is further supported by the good correlation between snow depth observations, again from the weather stations and snow courses within a distance of <4 km for data from years 1991-2008.

The correlation coefficient is 0.94, with a root mean squared (RMS) difference of 10.1 cm, indicating that for snow depth, point-wise observations also represent the snow conditions in a larger spatial domain.

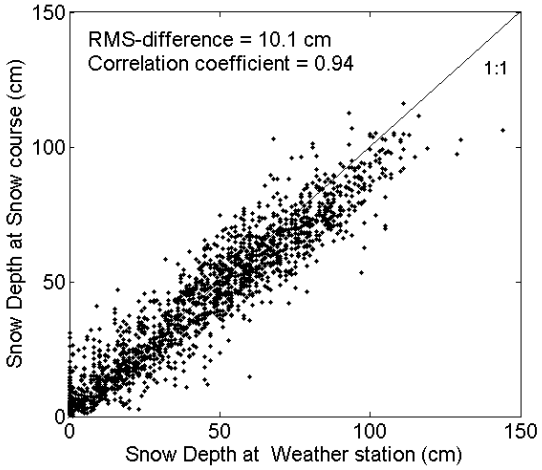

Figure 3. Correspondence of snow depth from weather stations and from snow courses.

For comparing the e-code and the snow product, a product pixel centered nearest to the station location is identified. FSC from this one pixel or from a larger window (e.g. average FSC from 3×3 pixels) can be employed in the comparisons.

Action related to weather station data:

E-code observations have been extracted from FMI data bases and processed for the comparison with satellite observations on snow cover. The data fields retained in the final Excel-file are the following: 1. *coordinates (lat,long) in WGS-84 system, 2. Date of observation, 3. Snow depth, 4. e-code.*