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Detection of snow melt using different algorithms in global scale

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Radiometer data I

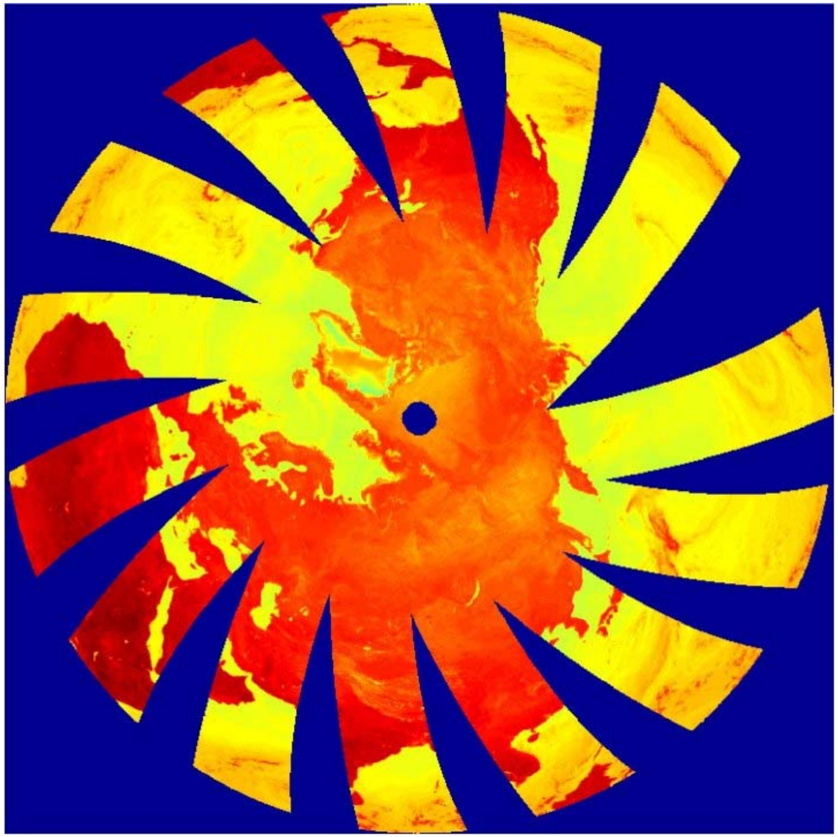
- A complete time series of radiometer data from 1978 to 2007 has been acquired from the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado USA
- For the years 1978-1987 SSMR data from Nimbus 7, 1987-2007 SSM/I data from DMSP D-11 and D-13
- Data is EASE-gridded which means that the projection used is north azimuthal equal-area with a nominal resolution of 25 km x 25 km.
- Geolocation files are provided with the data.
- Sun synchronous orbit -> local time at ascending or descending overpass is almost always the same, descending early morning and ascending late afternoon

Radiometer data II

- SMMR frequencies and true footprint sizes 6.6 GHz v&h, 148 x 95 km, 10.7 GHz v&h 91 x 59 km, 18.0 GHz v&h 55 x 41 km, 21.0 GHz v&h 46 x 30 km, 37.0 GHz v&h 27 x 18 km = **10 channels**
- SMMR swath about 600 km
- SSM/I frequencies and true footprint sizes 19.3 v&h GHz 70x45 km, 22.2 GHz v 60x40 km, 37.0 GHz v&h 38x30 km, 85.5 GHz v&h 16x14 km = **7 channels**
- SSM/I swath about 1400 km
- More data gaps in SMMR due to narrower swath width and turn off periods
- 18/19 GHz and 37 GHz are the most important frequencies for the microwave remote sensing of snow

Example of EASE-Gridded data

- AMSR-E Instrument on Jan 1 2005 18 GHz frequency, vertical linear polarization, ascending node

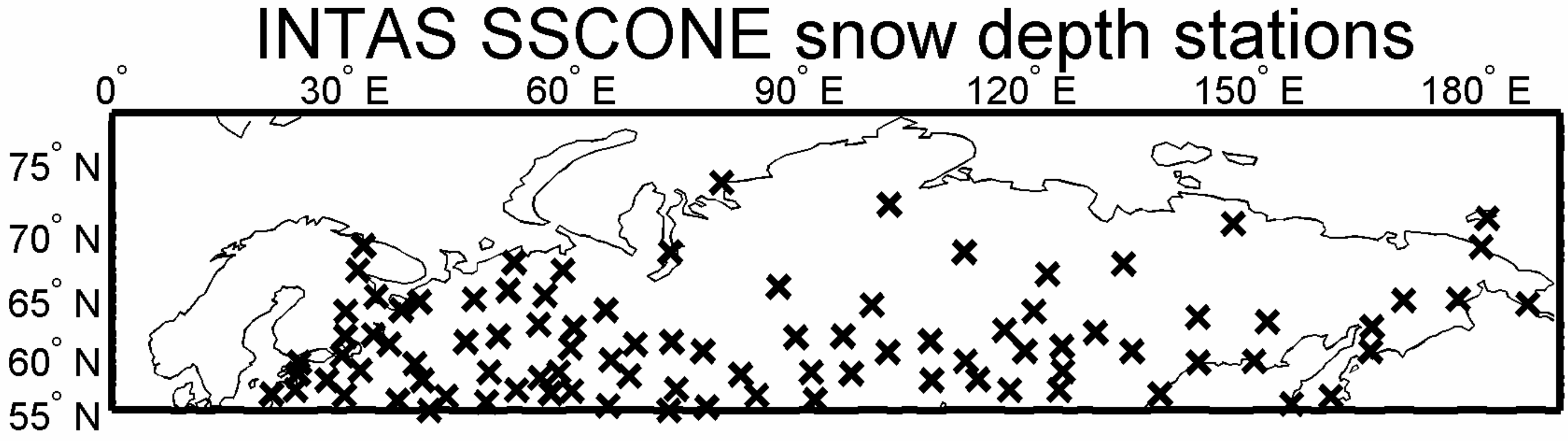


INTAS SSCONE snow cover data I

- INTAS = International Association for the promotion of co-operation with scientists from the New Independent States of the former Soviet Union
- SSCONE = Snow Cover Changes Over Northern Eurasia
- Snow depth data is available from 1888 to 2001 (data exists also for years 2002-2007)
- Locations of stations cover most of the former USSR but the network is rather sparse especially in the case of depth data
- Not all depth stations have necessarily been active in the period of interest

INTAS SSCONE snow cover data II

- There are 223 measurement stations in INTAS SSCONE dataset



INTAS SSCONE snow cover data III

- Dataset contains these parameters: WMO index, year, month, day, snow depth (cm), snow cover data and flag for snow depth data
- In this work the snow melt date is estimated from the flag, the transitions from 0 to either 1 or 2 are detected and the last one in the 180 days period is take into account

Period	Situation	Code (points)
Through of July 1959	No snow	0
	0.1 part of visible area is covered by snow	1
	0.2 part of visible area is covered by snow	2
	...	...
	0.9 part of visible area is covered by snow	9
	Full visible area around of site is covered by snow	10
From August 1959	Less than 0.6 part of visible area is covered by snow	0
	0.5 or more part of visible area is covered by snow	1

Situation	Flag
Value of snow depth is correct	0
Continuous snow melting.(Summer)	1
Temporary snow melting	2
Snow cover absent at site, however there is snow in the vicinity and a state is specified.	3
Snow cover is less than 0.5 cm	4
Observations were not made or value is rejected	9

Algorithms I

- Channel difference algorithm in together with dry snow detection

(T37v-T19v)> -21 K

(T37h-T19v)< -10 K

- Self Organizing Map (SOM) as an unsupervised neural network classificator (input vector, T=[T19v T22v T37v T19h T37h], output one spesific neuron activates == melt)
- Feedforward neural network with backpropagation rule as classificator (input vector, T=[T19v T22v T37v T19h T37h], output snow melt / no snow melt)
- Time series of channel difference T37v-T19v, detection of changes in level

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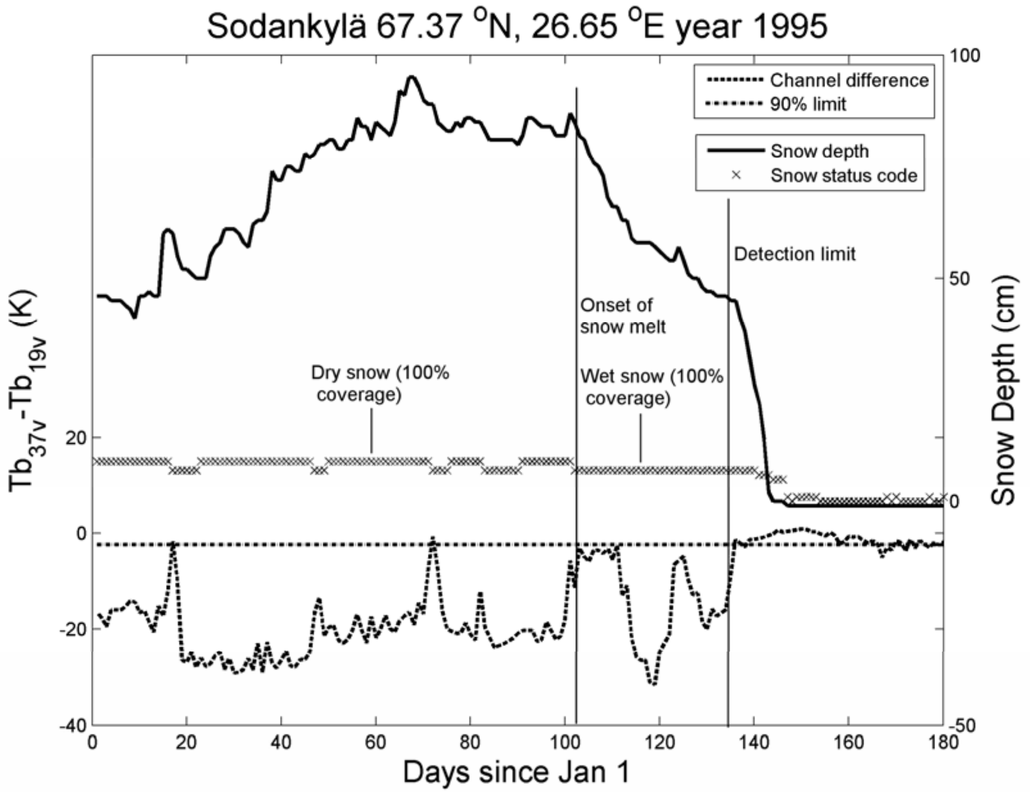
Algorithms II

- Channel difference and neural network examine 24h daily data
- The standard deviation of the error $\varepsilon = t_{int\,as} - t_{estimated}$ is ~ 30 days for channel difference and neural network algorithms
- The std for time series algorithm is ~ 20 days
- Time series analysis can not be used directly on daily basis but well suited for climatological studies
- reference data consists of point observations, how well the single locations represents the 25 km x 25 km pixel?
- The accuracy of reference data? The flag values are qualitative estimates

Time series detection algorithm I

- Example of snow depth (cm), FMI snow status code and T_{37v}-T_{19v} channel difference



Time series detection algorithm II

- Observations in formal notation

$$D(t) = T_{37v}(t) - T_{19v}(t)$$

$$D_{max} = \max\langle D(t_0), D(t_1), \ldots, D(t_N)\rangle$$

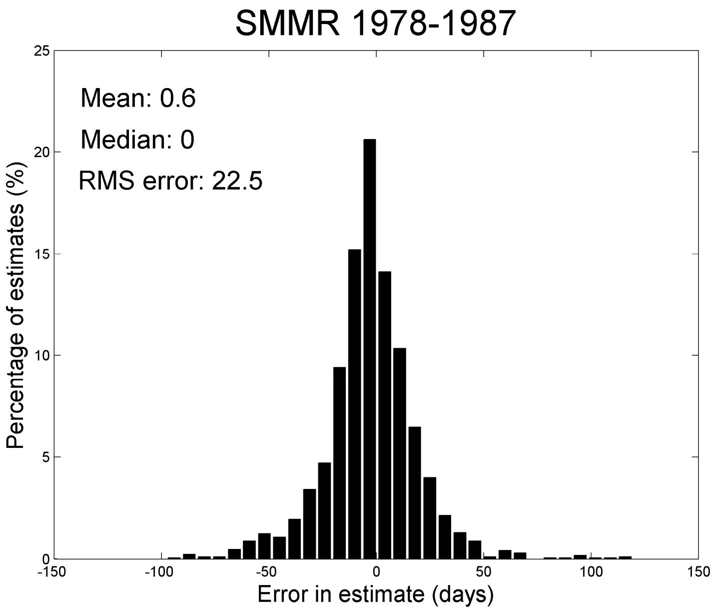
$$D_{min} = \min\langle D(t_0), D(t_1), \ldots, D(t_N)\rangle$$

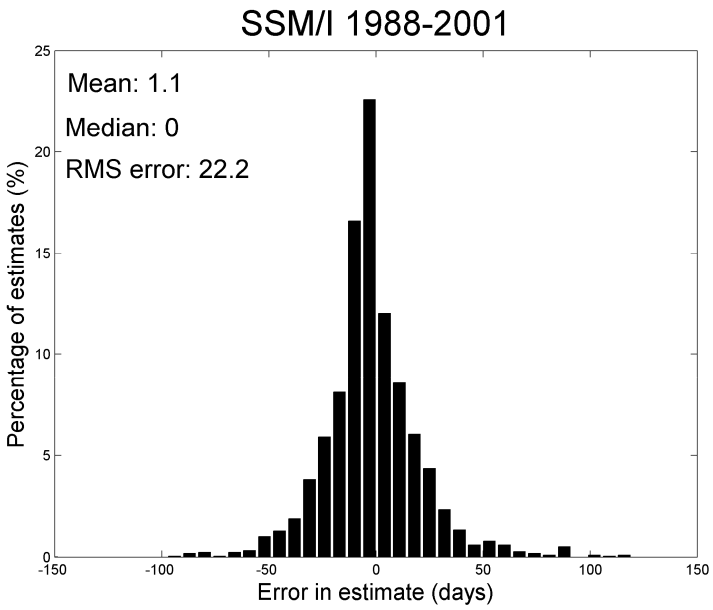
$$\langle D(t)\rangle \geq p \cdot [D_{max} - D_{min}] + D_{min}$$

- D is the channel difference, < > time average, empirically best results are obtained when averaging window is 7-8 days, p is typically 0.9

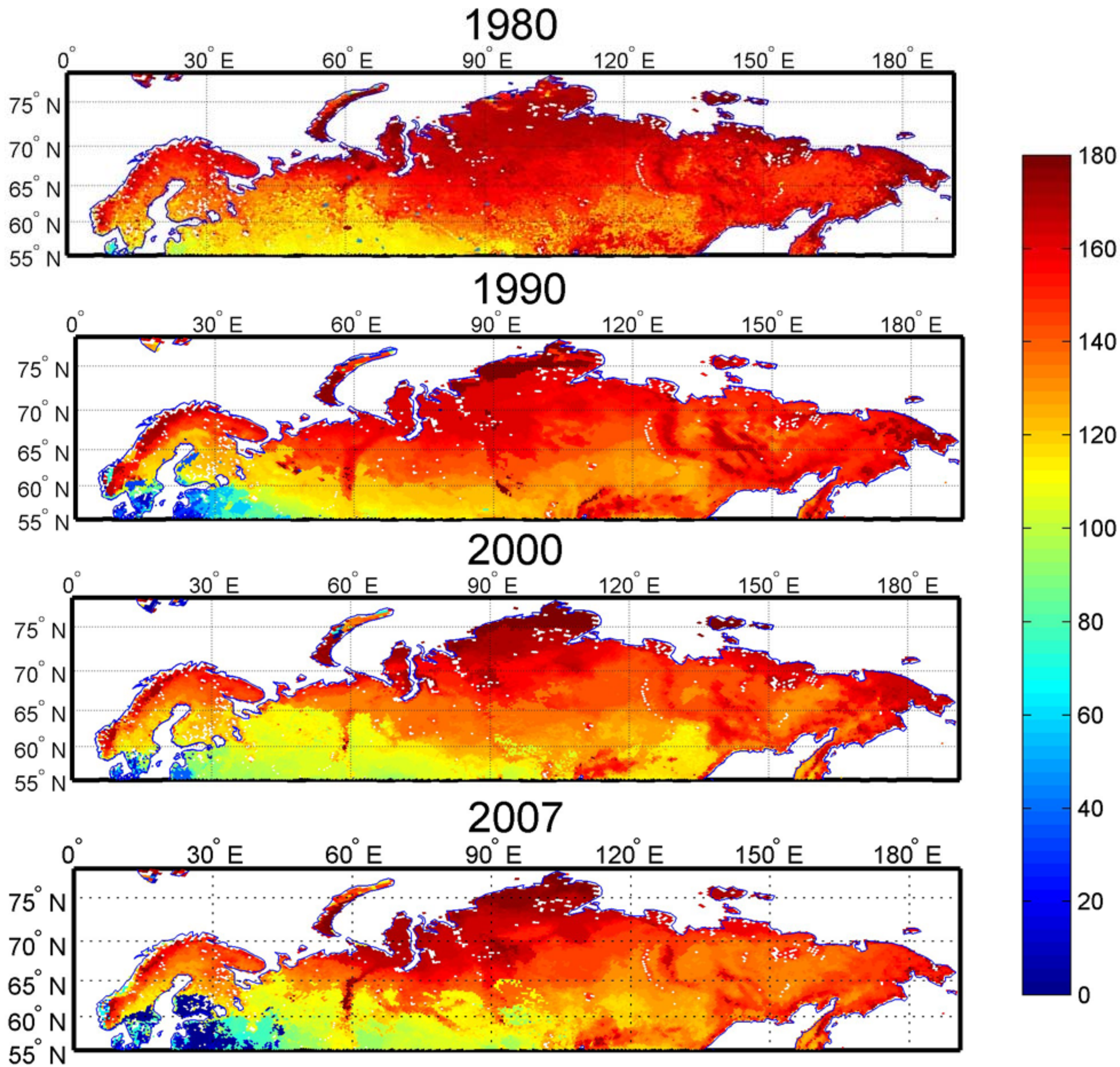
Results I

- Define error $\varepsilon = t_{int\,as} - t_{estimated}$
- 1704 applicable estimates for SMMR and 2205 estimates for SSM/I



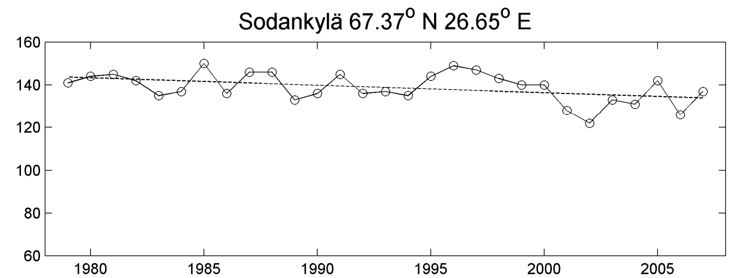


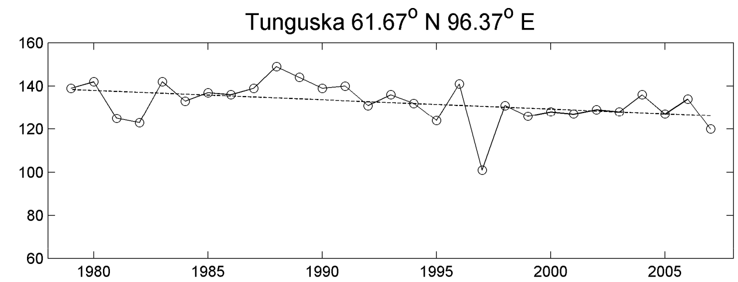
Results II

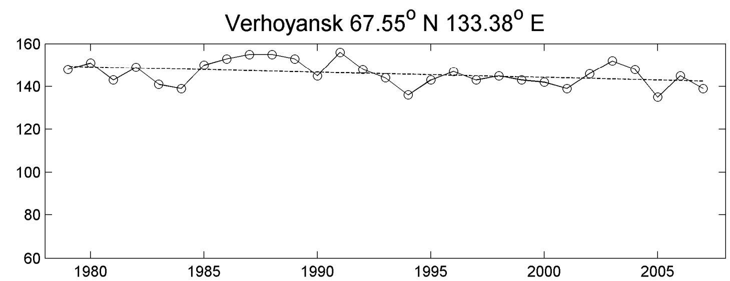

1980
1990
2000
2007
0°
30° E
60° E
90° E
120° E
150° E
180° E
75° N
70° N
65° N
60° N
55° N
180
160
140
120
100
80
60
40
20
0

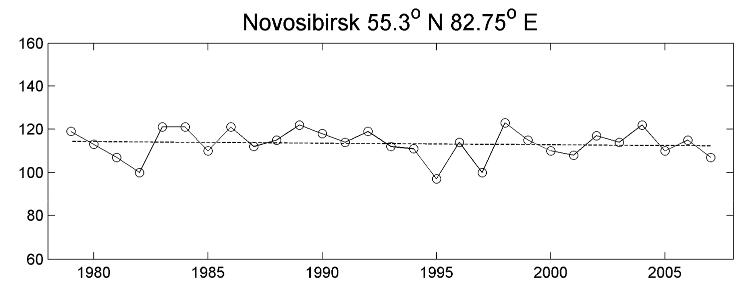
Results III

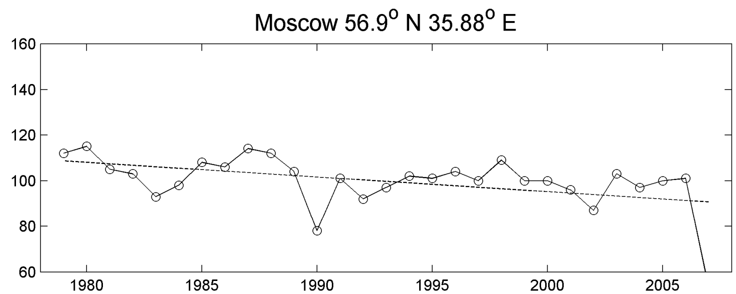
- Slopes: -0.35, -0.24, -0.43, -0.07 and -0.64











Results IV

- Confidence levels (90%,95%) for the slopes

Centre of the circular test area with 250 km radius	Slope	95% confidence level lower bound	95% confidence level upper bound	90% confidence level lower bound	90% confidence level upper bound
Sodankylä	-0,35	-0,64	-0,06	-0,59	-0,11
Verhoyansk	-0,24	-0,49	0,00	-0,45	-0,04
Tunguska	-0,43	-0,83	-0,04	-0,76	-0,10
Novosibirsk	-0,07	-0,39	0,24	-0,33	0,19
Moscow	-0,64	-1,13	-0,15	-1,05	-0,23

- The results are statistically significant!

To do

- Test the effect of different land use categories to the accuracy
- In addition to the snow melt detection detect wet snow cases as well (with improved accuracy)
- Operational aspects
- Integration of the snow melt detection to the continent scale SWE and SD mapping (http://snow.fmi.fi), alpha stage-system running
- Comparison with results from optical instruments (MODIS)
- Using the snow melt data as input to climatological models