FRESHWATER CENTRE

Ground frost variation in Finland 1981- 2010

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The 6th seminar on snow on the day of Pyry 2.11.2015

COST ES1404

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Ground frost monitoring

- measured by the Finnish Environment Institute and its prior organizations at some locations since the 1920's

  - 5 or 15 day interval
- a more extensive network since the 1960's
- the present network consists of approx. 40 stations

  - situated across the country, and

  -represent a variety of climatic conditions in different soil, forest and mire terrains.
- the stations + ground frost observations at the gw sites + small catchments areas sites = approx. 700 measuring sites
- the stations measurements represent results from naturally occurring ground frost and snow cover

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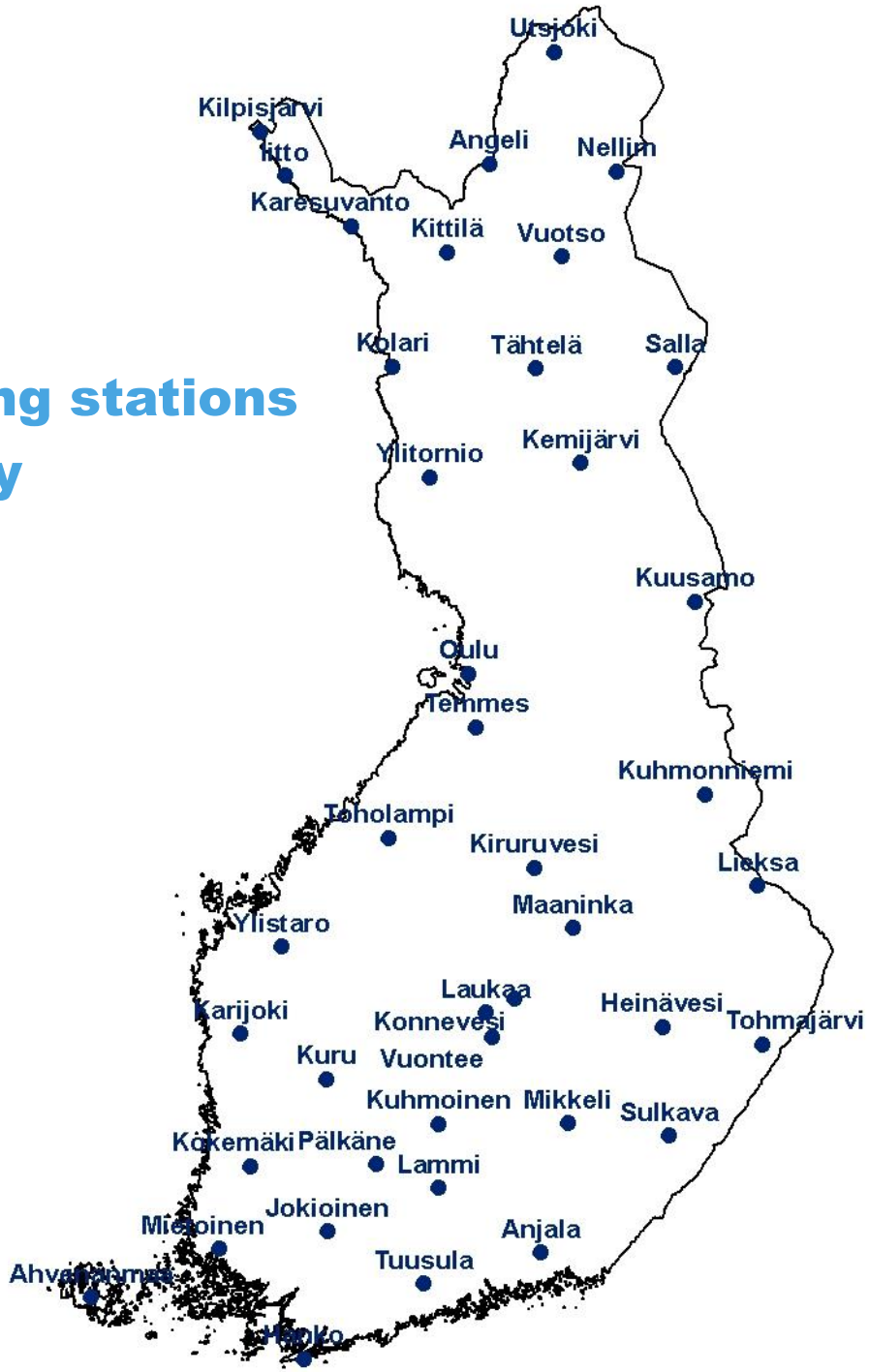
Ground frost monitoring stations reviewed for this study



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Measurements

- different methods throughout the 20th century
- methylene blue tubes since the 1970's

  - the results are more comparable
- measurements: 6,16 and 26th day of the winter months + denser observations when ground frost is thawing (1,11, 21)
- ground frost levels (depth and surface thaw), snow cover thickness
- accuracy ± 5 cm
- measuring points at the stations (if possible):

  2 in open areas, 2 in forested areas, 1 in a mire

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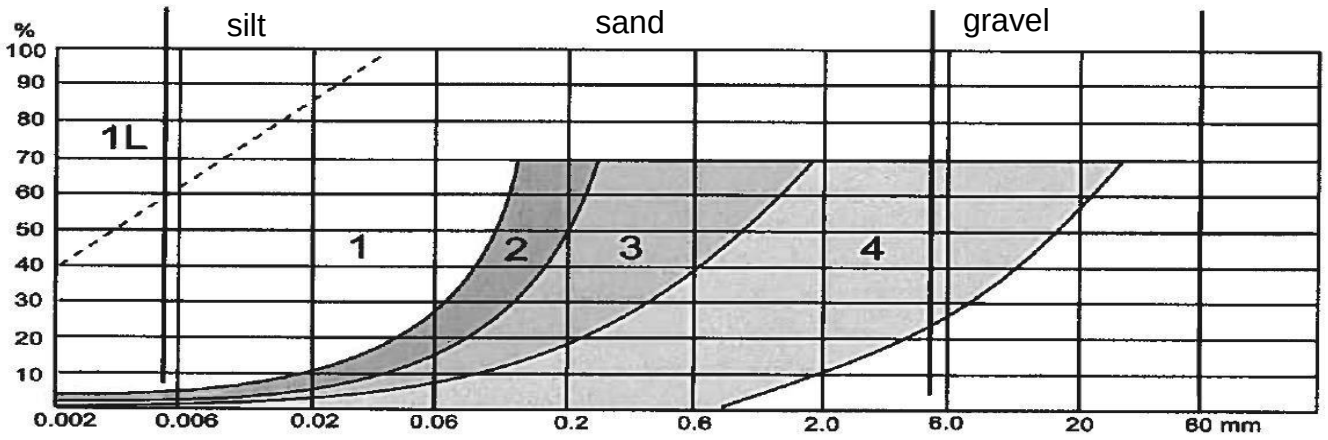
Factors which effect frost depth

- snow depth (major factor)
- frost sum (major factor)
- soil type
- soil moisture
- groundwater level
- vegetation (especially the tree stand)
- the terrain in general (wind)



(Salonen et al.2002, edited)

1= frost-lifting (1L= massive ground frost)
2= frost-lifting if the capillary rise is >1 m
3,4= not frost heaving

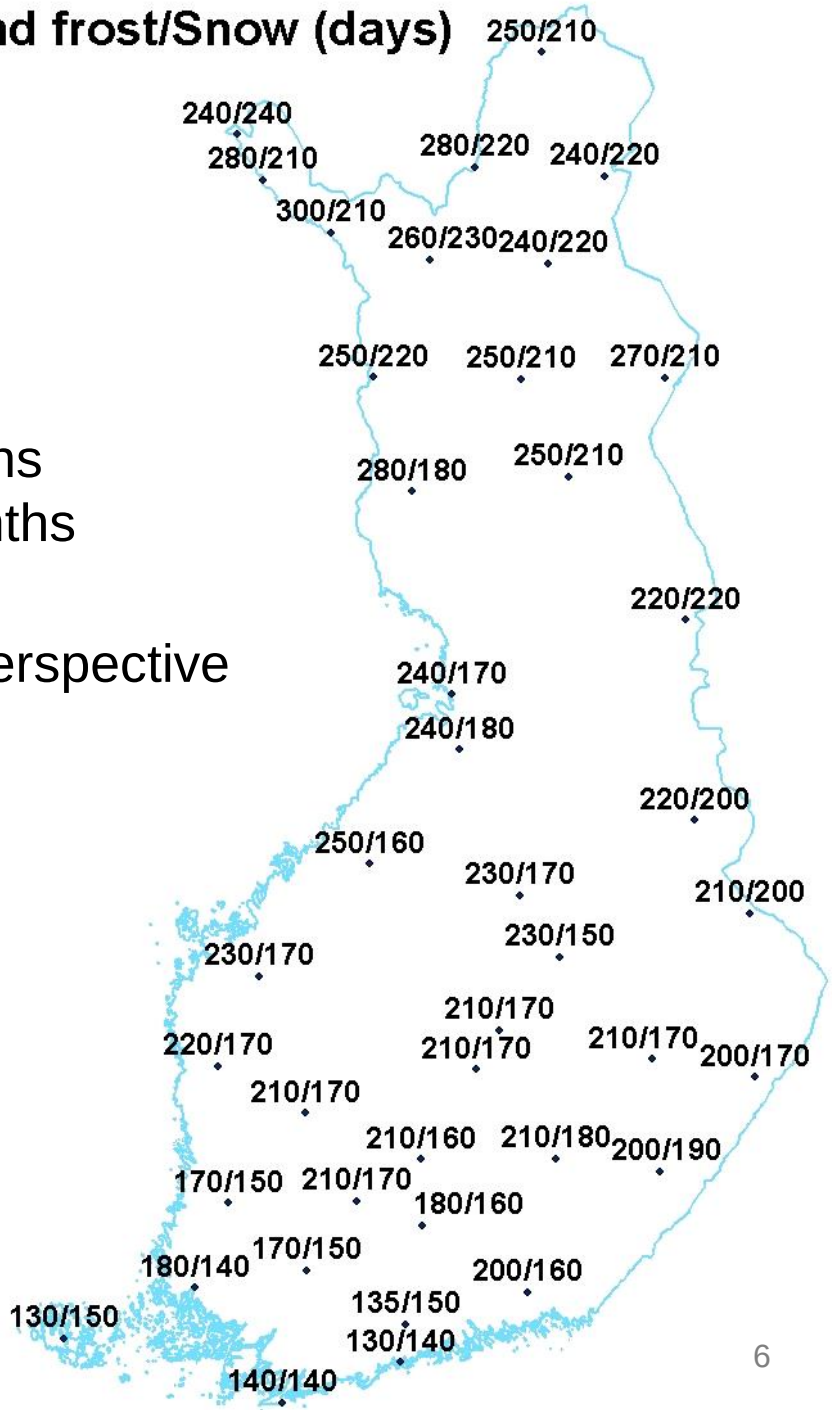
Ground frost period

- 4- 8 months

  Coastal areas 0-4 months
  Central Finland 4-5 months
  Lapland 6-8 months

- relatively long in European perspective

- measurement data from 1981-2010



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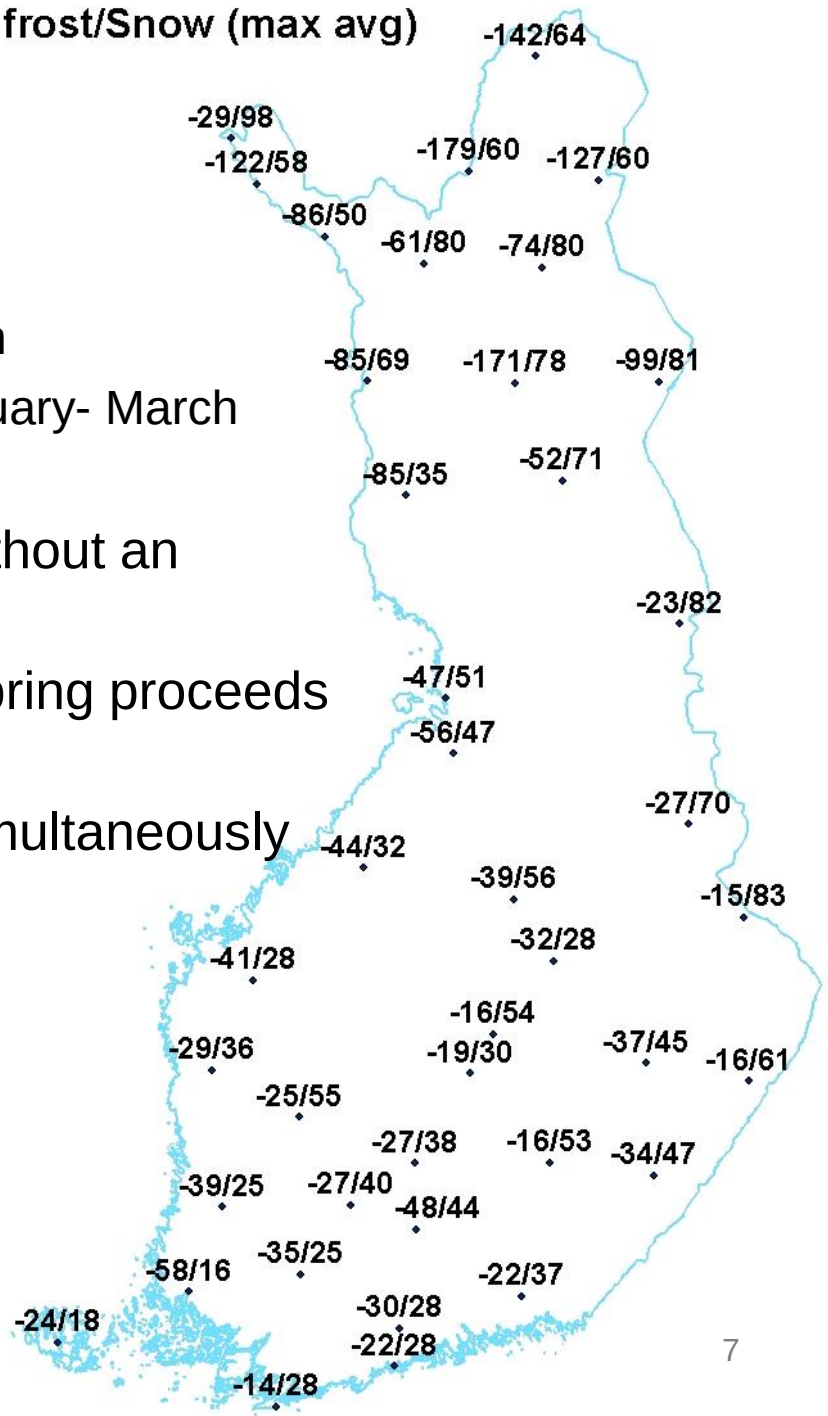
Ground frost thickness

- varies between 0 – 200 cm
- maximum ground frost depths occur in
  - southern and central areas: February- March
  - northern parts: late March
- ground frost penetrates deeper without an isolating snow cover
- thawing rate dependant on how spring proceeds yearly
- thaws from surface and bottom simultaneously

- measurement data from 1981-2010



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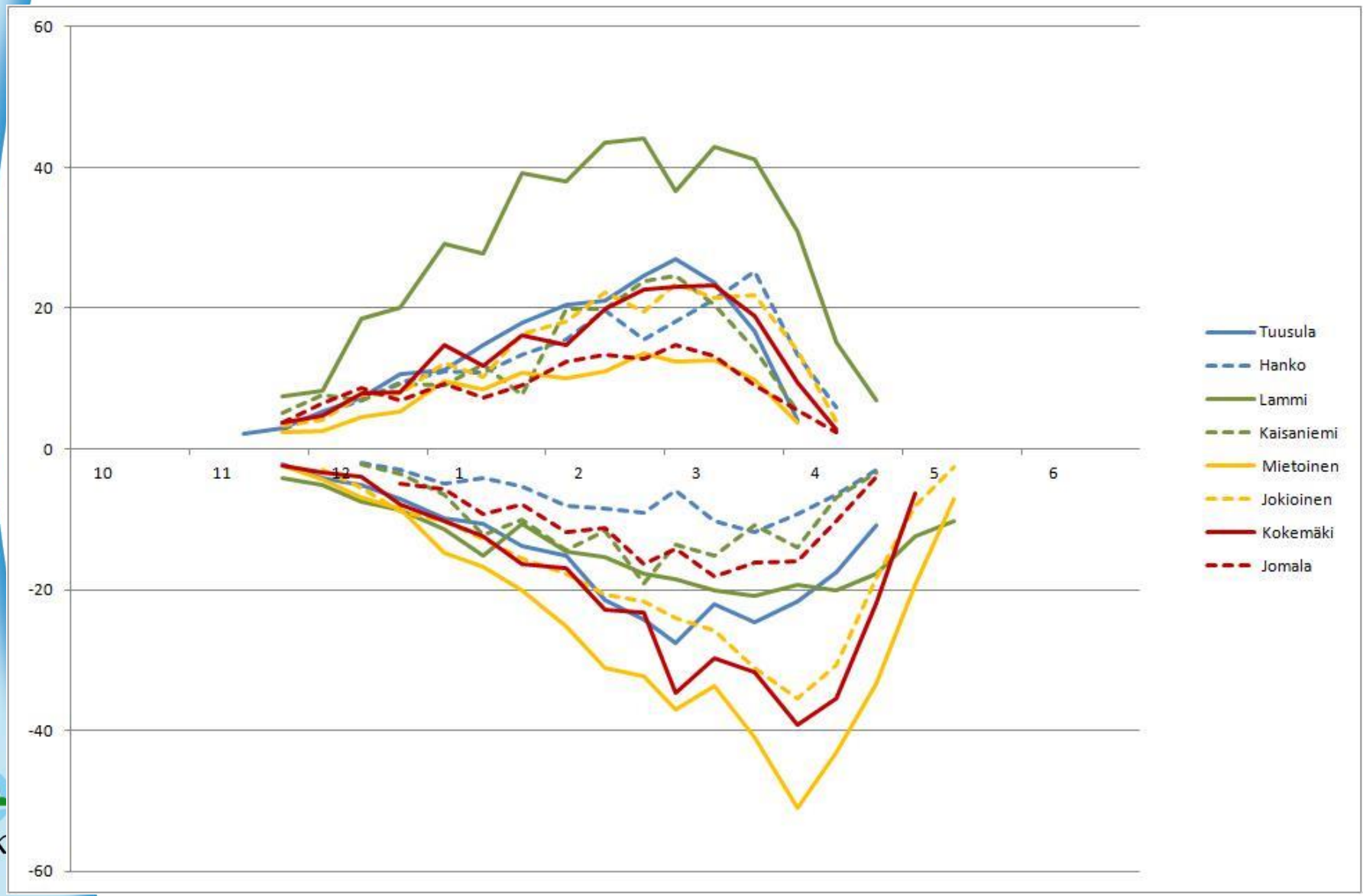
OPEN AREAS – Southern Finland
avg max ground frost and avg snow cover 1981-2010



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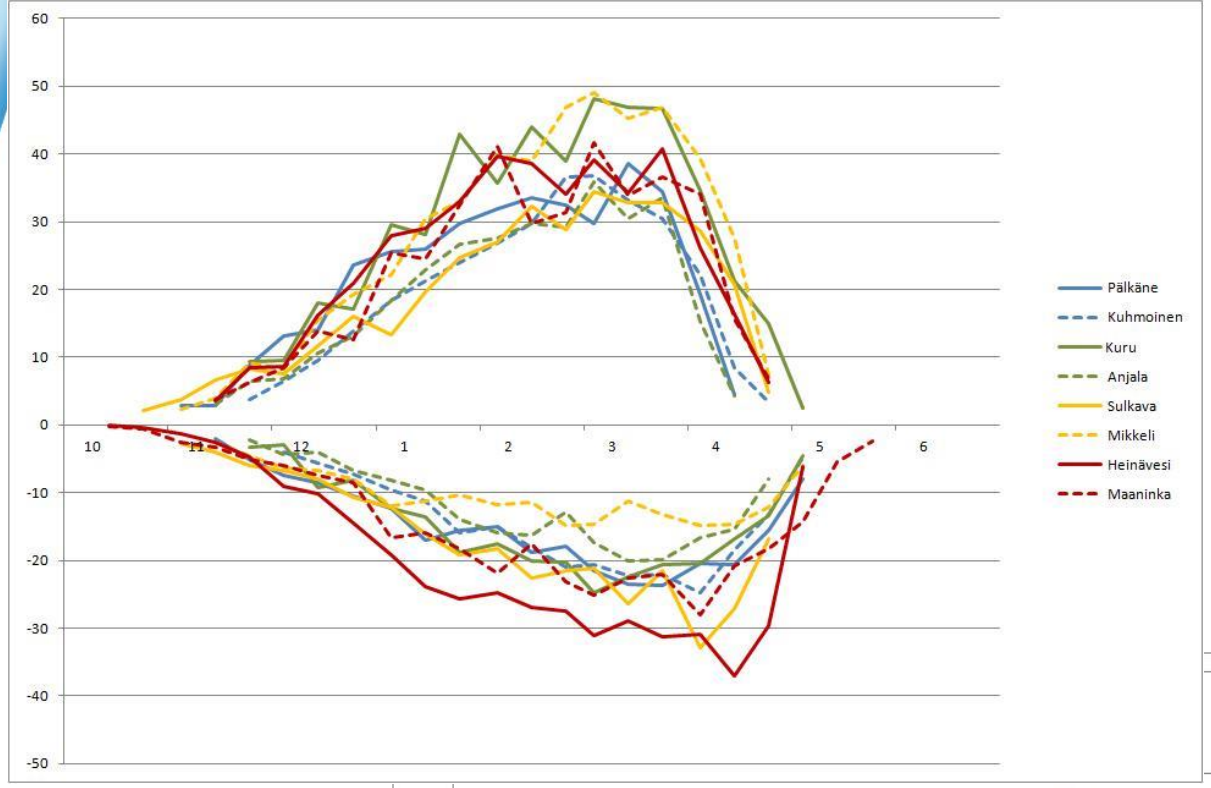
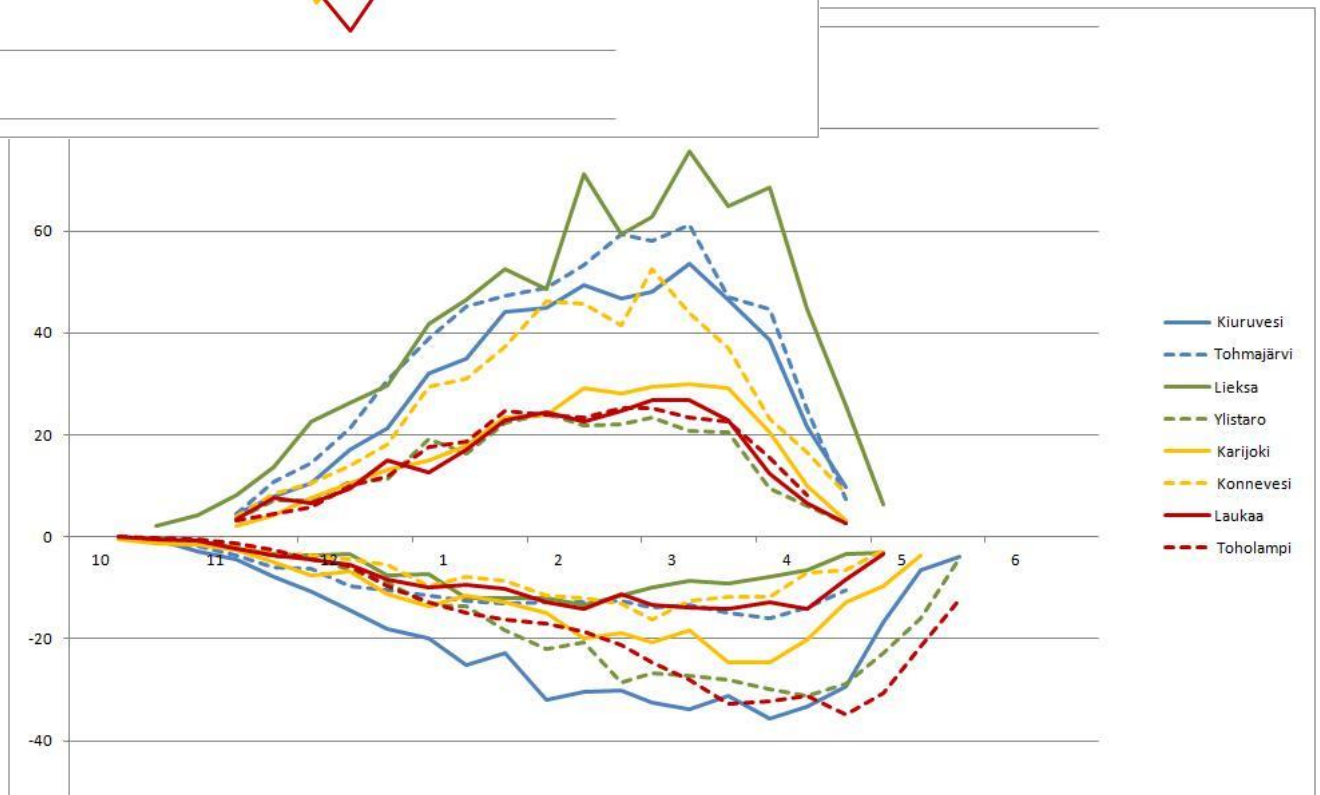
OPEN AREAS - Central and Eastern Finland

avg max ground frost and avg snow cover 1981-2010





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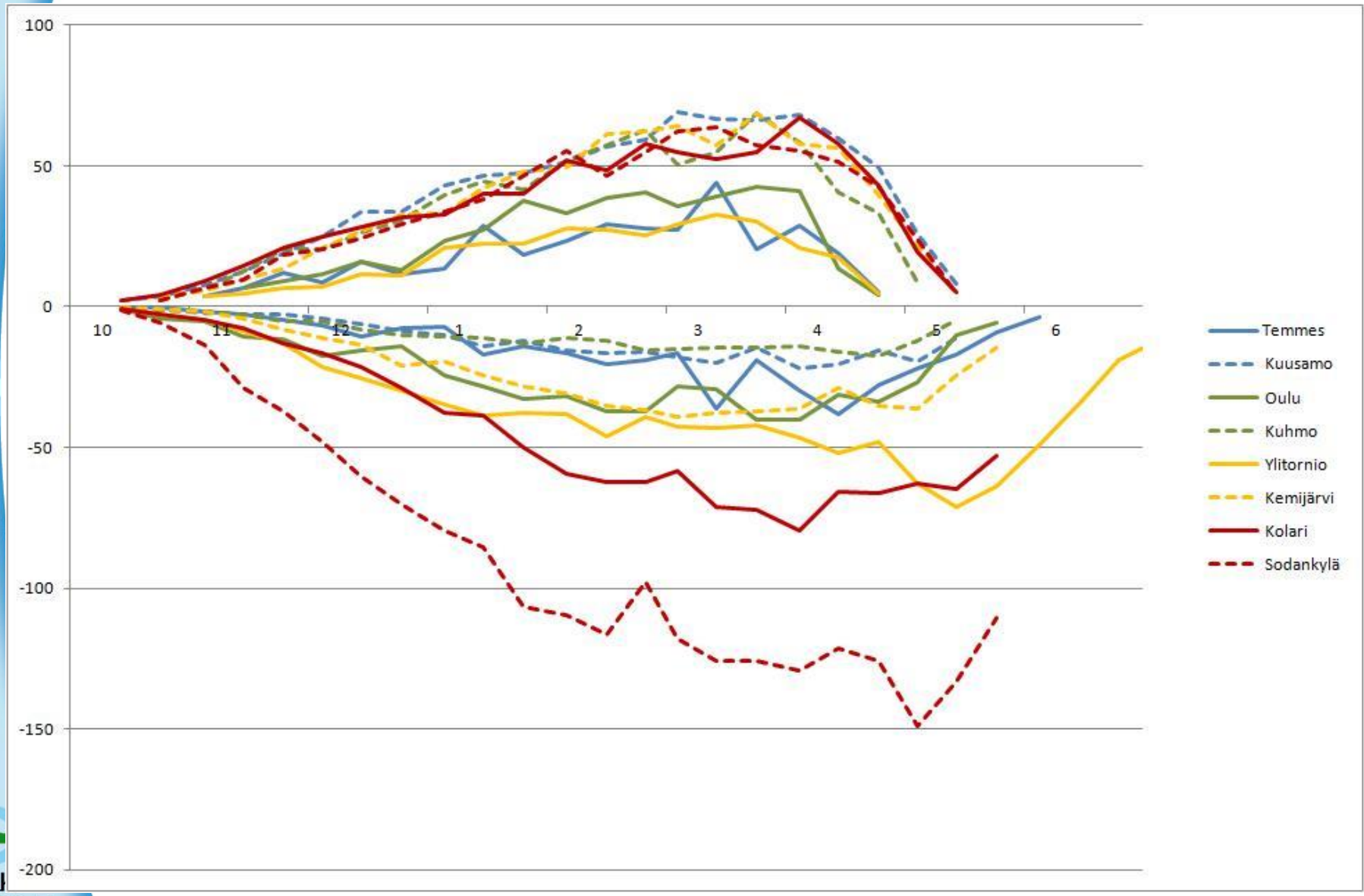
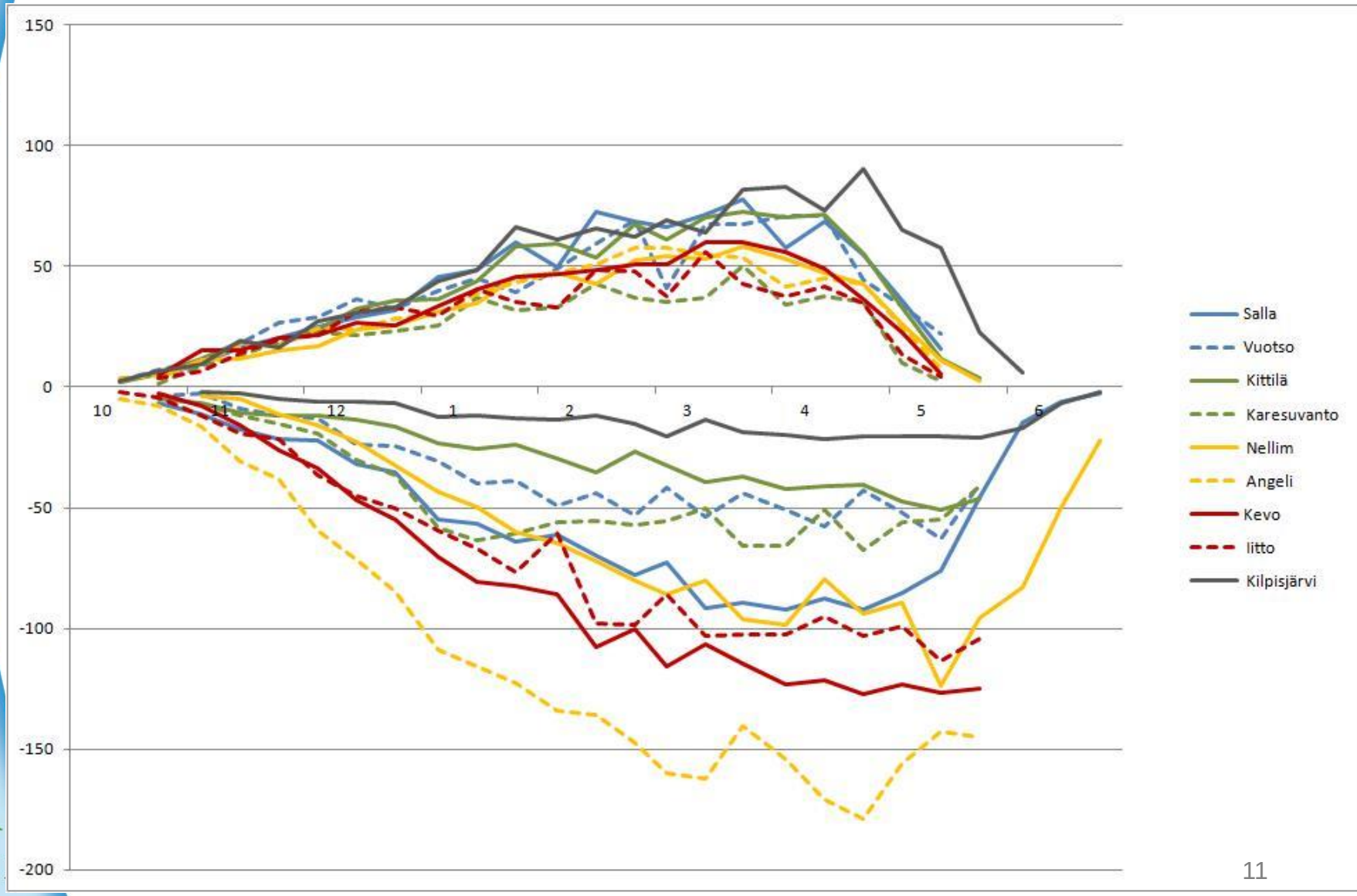
OPEN AREAS – Ostrobothina and Southern Lapland

avg max ground frost and avg snow cover 1981-2010



OPEN AREAS - Lapland

avg max ground frost and avg snow cover 1981-2010 (except for Kilpisjärvi)



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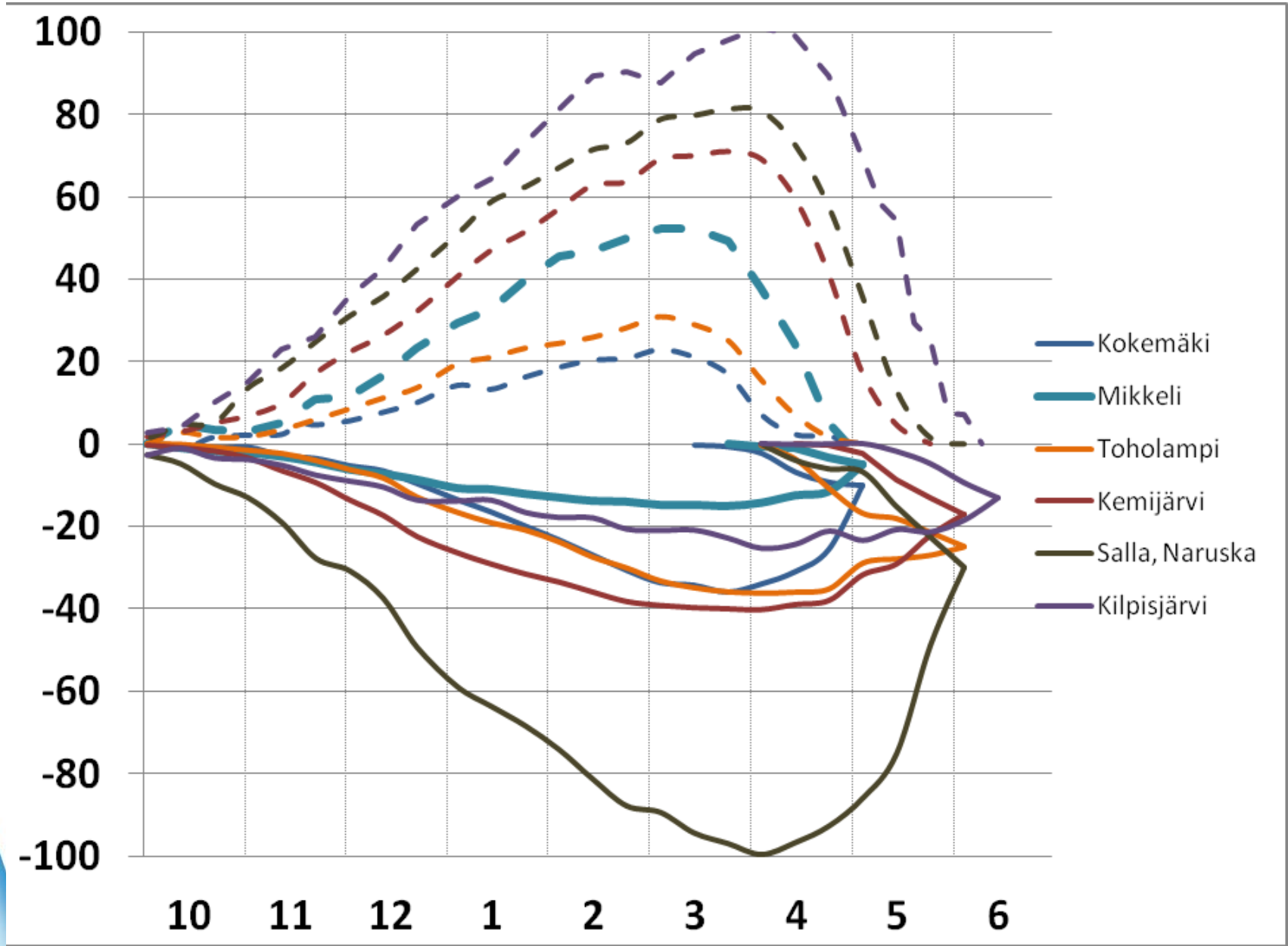
GENERAL OVERVIEW
avg max ground frost and avg snow cover 1981-2010



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Regional variation

- southwestern and coastal regions of Finland:
  -usually more ground frost than the eastern and northern regions
- caused by differences in snowfall periods and geographical differences

- ground frost forms quite similarly in 2/3 of Finland

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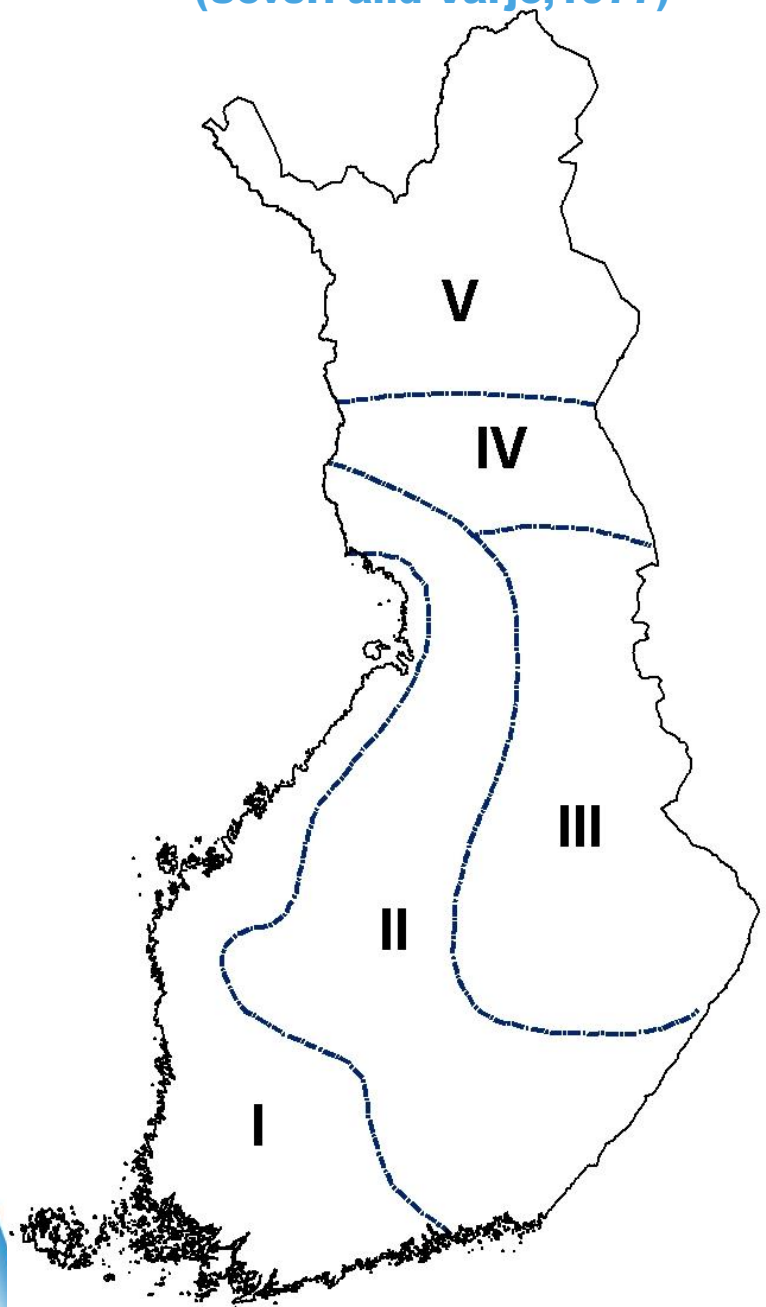
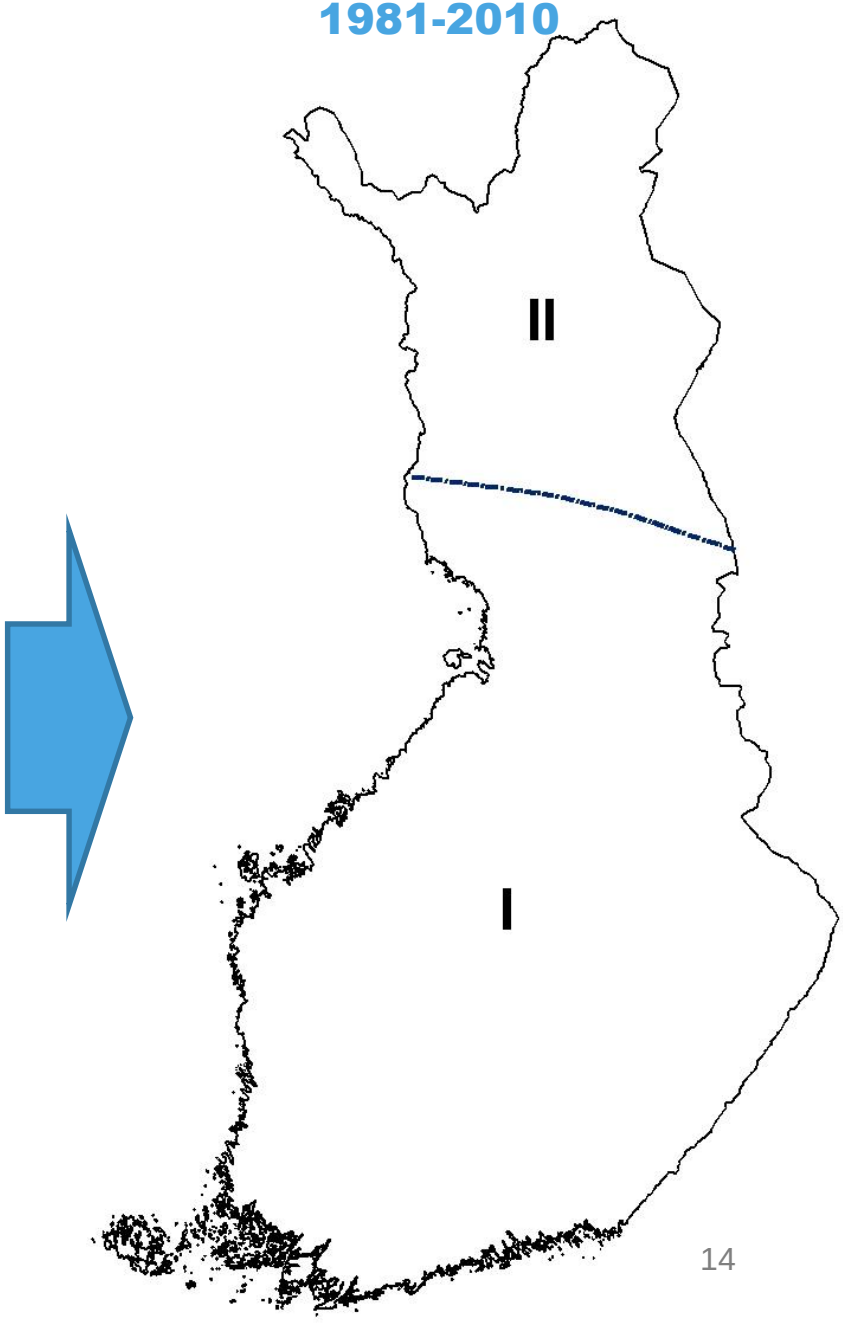
Ground frost regimes according to results from 1955-1975 (Soveri and Varjo,1977)



Ground frost regimes based on monitoring during 1981-2010



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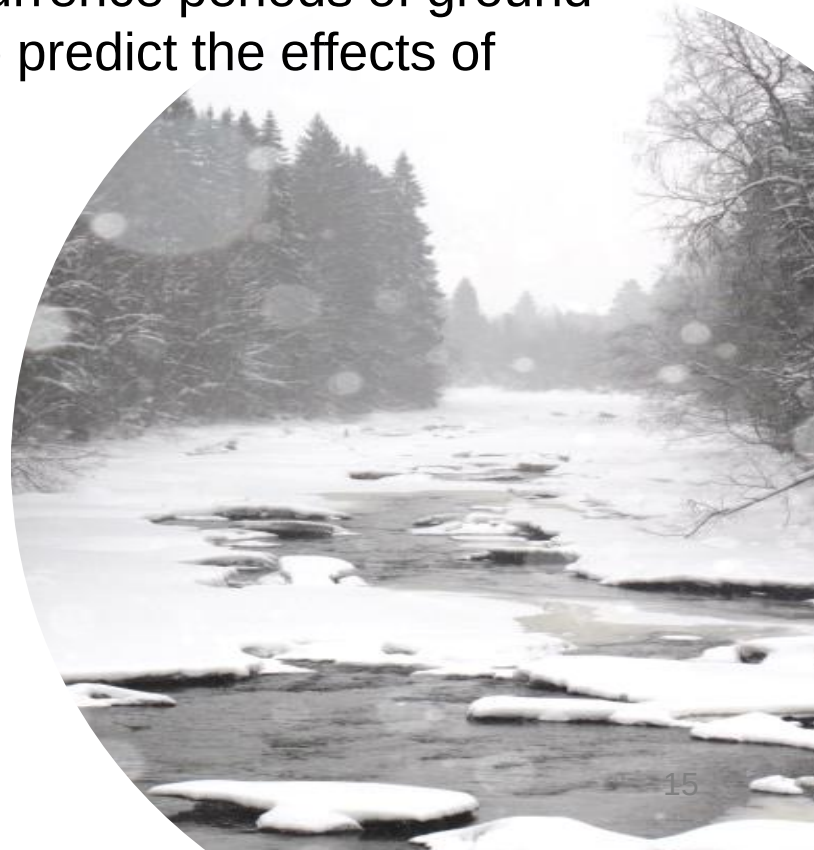
Future occurence

- winters are anticipated to become substantially milder during this century
- snow cover will become thinner especially in the southern and central parts of the country
- the changes in the depth and occurrence periods of ground frost during the past 50 years help predict the effects of climate change in the future



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The decrease or disappearance of ground frost

ASSETS

- longer growth period
  - eased waterflow for plants in spring
- no frost heave
  - huge savings in e.g. road maintenance
- all-year recharge of groundwater
- farming fields spring work eased
  -frost heave does not lift rocks

CONSTRAINTS

- increased winter storm damages
  - storms and crown snow loads may topple trees when roots rise easily from moist and soft ground
- complications and financial losses in forestry
  - felling and log transportation impossible if the ground does not bear the loads of heavy vehicles
  - decreased logging areas
- reworking fields more arduous
  - ground frost crumbles clay lands

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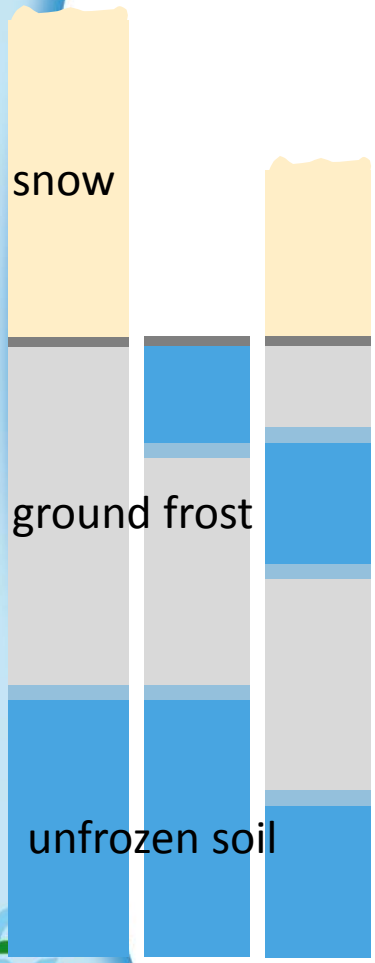
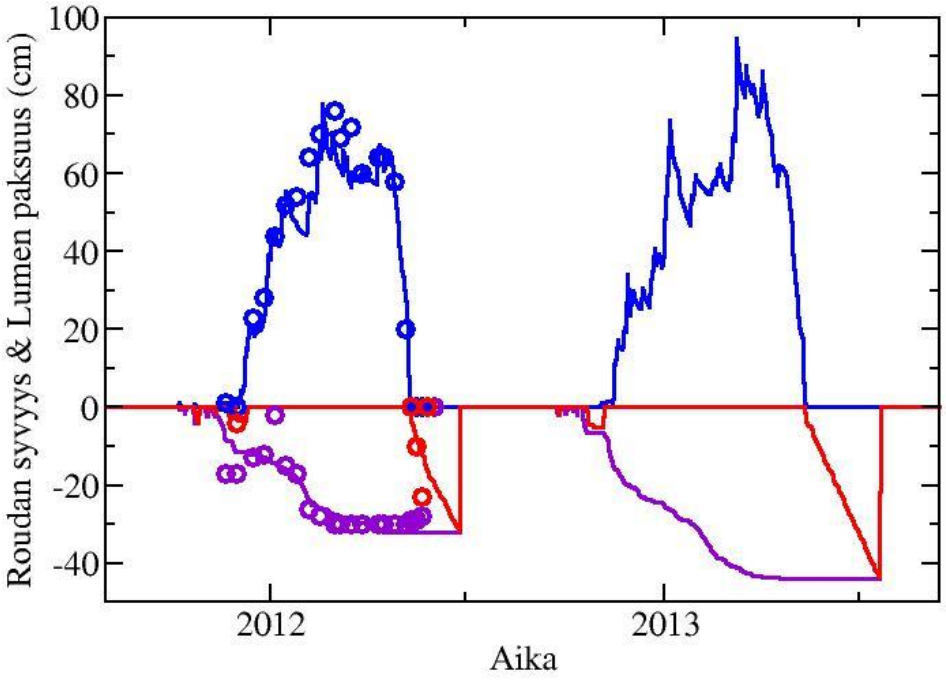
Ground frost modelling

- Ground frost model will be included in the operative forecast model
- Different forest types (open area, forest, swamp) considered individually accounted
- Possibility of having several ground frost/unfrozen layers

- Simple model:
  - all heat energy will be used for thaw/freezing
  - Parameters describing the heat conductivity of soil will be calibrated



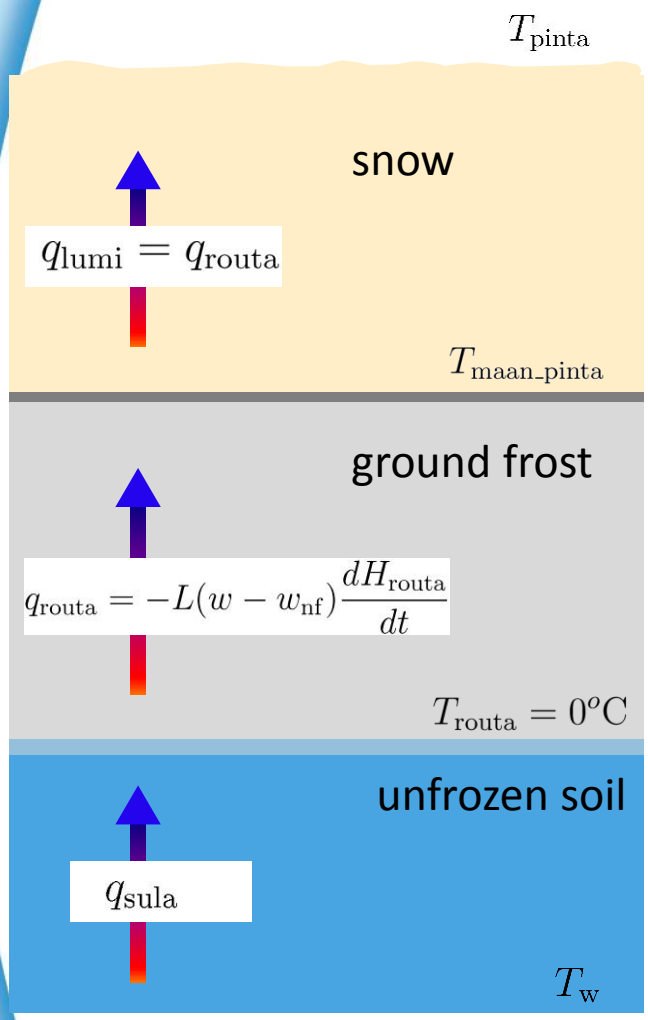


Example:
Ylitornio Meltosjärvi
(swamp)
(preliminary results)

Snow cover depth
Ground frost depth
Unfrozen soil

Slide courtesy of Vesa Kolhinen/SYKE

Modelling ground frost – a closer look



Equation for heat conduction:

$$q = -k\frac{dT}{dz}, \quad C \approx 0$$

Growth of the frost layer:

$$H_{\text{routa,t+}\Delta\text{t}} = -\frac{k_{\text{routa}}}{k_{\text{lumi}}}H_{\text{lumi}} + \sqrt{\left(\frac{k_{\text{routa}}}{k_{\text{lumi}}}H_{\text{lumi}} + H_{\text{routa,t}}\right)^2 - \frac{2k_{\text{routa}}T_{\text{pinta}}\Delta t}{L(w - w_{\text{nf}})}}$$

Correspondingly: growth of the melt soil:

q_{sula}

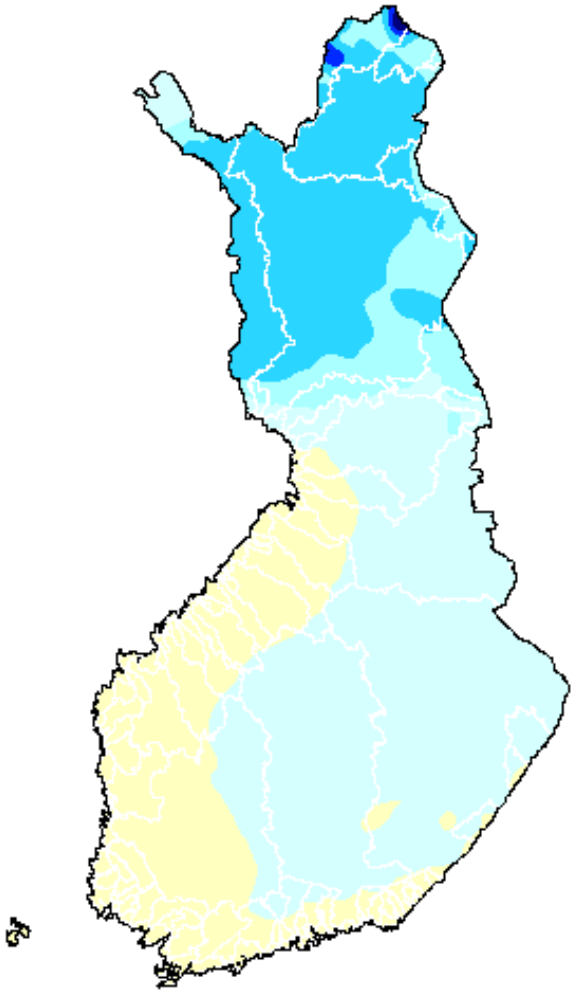
$$H_{\text{sula,t+}\Delta\text{t}} = \sqrt{(H_{\text{sula,t}})^2 - \frac{2k_{\text{sula}}T_{\text{pinta}}\Delta t}{L(w - w_{\text{nf}})}}$$

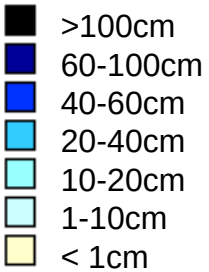
Heat conductivity ($k_{\text{lumi}}, k_{\text{sula}}, k_{\text{routa}}$) depends on temperature, soil type, humidity, snow density and snow microstructure. The model utilizes simplified formulae combined fit parameters to be fitted to data.

Ground frost model:Paula Havu/SYKE, slide courtesy of Vesa Kolhinen/SYKE

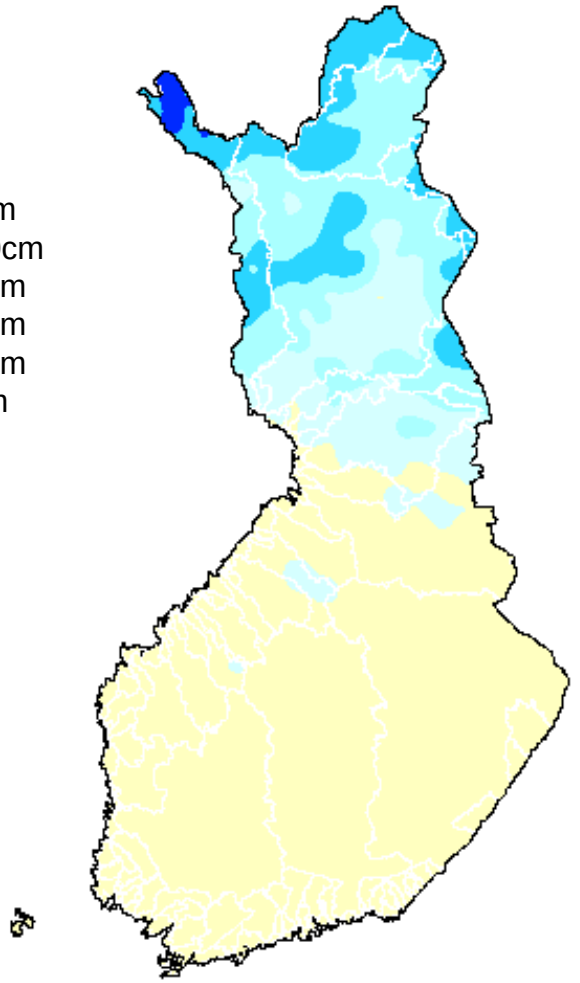
Ground frost and snow modelling: maps

Ground frost depth





Snow cover thickness



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