A real-time model for terrain and snow trafficability - Reaaliaikainen malli maanpinnan ja lumen kulkukelpoisuudelle

NASA SnowEx 2020, Grand Mesa, CO

Importance of soil

Definition of Terrain Trafficability: Ability of terrain to support vehicle movement without excessive effort or damage.

Key Soil Properties Affecting Trafficability:

- **Moisture Content**: Determines soil strength and cohesion.
- **Soil Texture**: Sand, silt, and clay influence compaction and load-bearing capacity.
- **Compaction and Shear Strength**: Affects the ability to support weight without deformation.
- **Drainage Properties**: Poorly drained soils lead to boggy conditions.

Importance of snow

Factors Influencing Snow Trafficability:

- **Snow Depth**: Deeper snow increases rolling resistance.
- **Density and Compaction**: Packed snow offers better support than fresh powder.
- **Temperature Variability**: Affects snow grain size and hardness.
- **Underlying Terrain**: Soil or rock base under snow changes load distribution.

Data used in present trafficability analysis

- Topographic Database, scale 1:10 000
- Digital Elevation Model 10m, accuracy of elevation data 1.4m

- Stem number per ha, tree diameter 12-25cm (16m)
- Stem number per ha, tree diameter > 25cm (16m)
- Depth to water (DTW) index (2m)

Geological Survey of Finland

- The Superficial deposits of Finland 1:200 000, 1:50 000 and 1:20 000

- Statistical data of soil frost, snow depth and thickness of ice

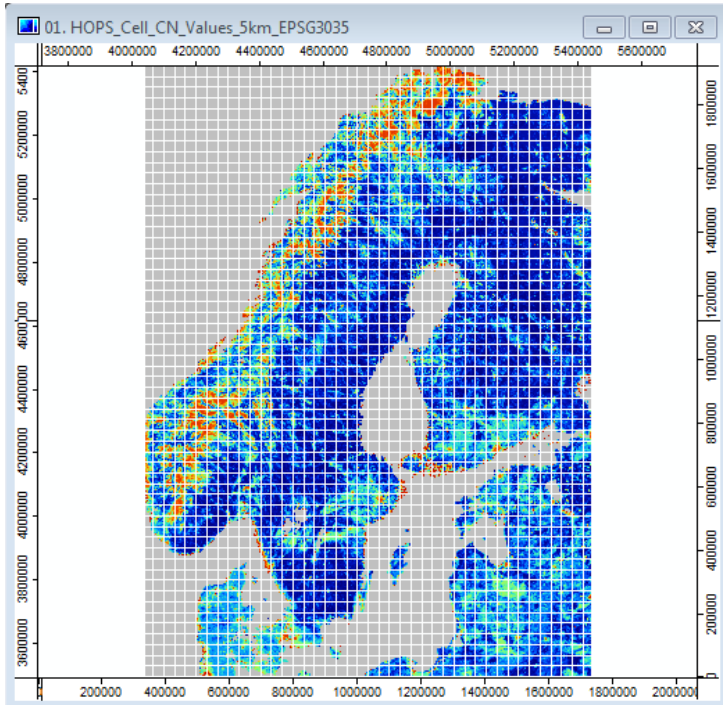
Aims of our project

- To provide dynamic forcing of snow and soil properties for trafficability analysis and forecasts
- 10-km resolution, daily analysis + 60-hour forecast

Paving the way

- Combine a high resolution **snow process model** with a **hydrology model** that simulates soil properties
- Assemble data for validation from 1) Sodankylä supersite 2) operational surveys (snow courses, snow profile observations, soil F/T observations)
- Perform additional measurements on snow structure (winter), soil F/T process (spring and autumn) and soil moisture (summer)
- Perform model runs covering entrire Finland (analysis+forecast)
- Validation against: 1) measurement networks 2) remote sensing

HOPS

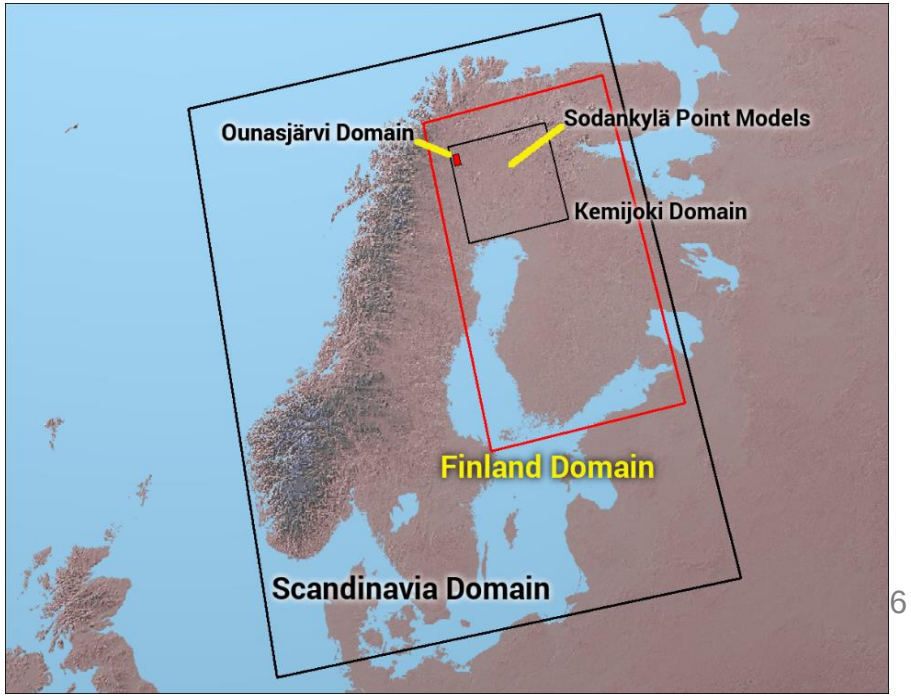


HOPS – current domain:

- Northern Europe, 5 x 5 km
- CRS: ETRS89 / LAEA Europe
- Sub-grid tiles: Organic & Mineral

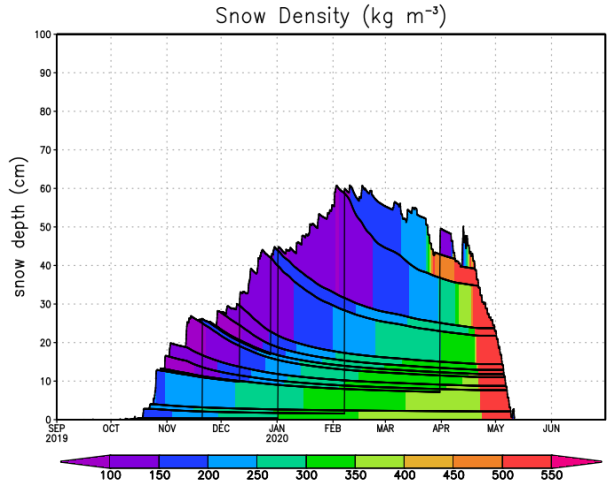
Relevant HOPS output:

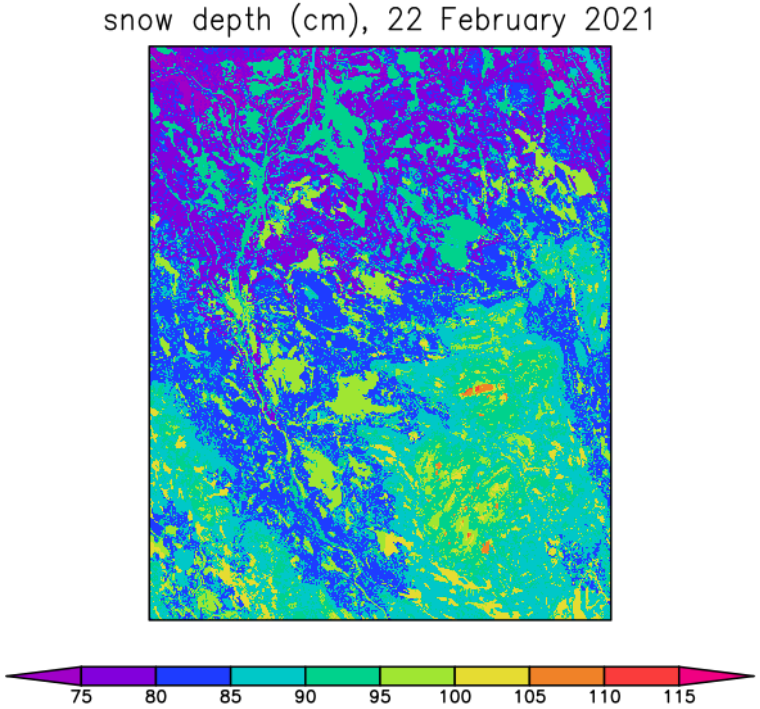
- Soil moisture: top layer (0-30 cm) and root zone (30-200cm)
- Snow depth & snow water equivalent
- Soil temperature at 5 cm, 10 cm, 20 cm and 100 cm
- Nowcasts, 10-day forecasts & ensemble seasonal forecasts



SnowModel: A snow-evolution modeling system

- SnowModel simulates snow distribution and evolution in any environment that experiences snow
- Developed at Colorado State University (CSU) by Glen Liston
- **Inputs**: meteorology, topography and land cover
- **Outputs**: snow depth, density, thermal conductivity, sublimation and runoff



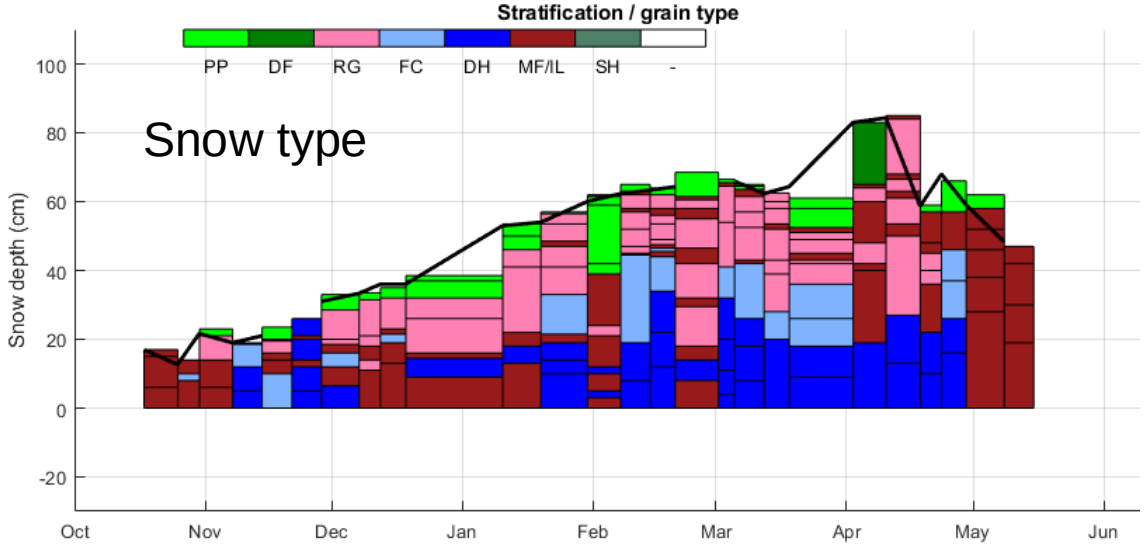


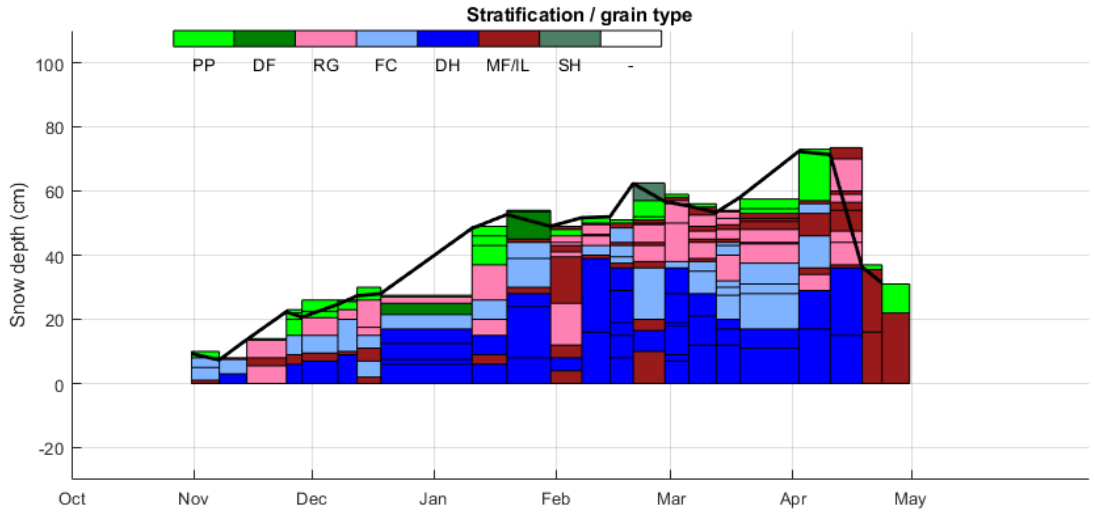
Where we are (first year of two)

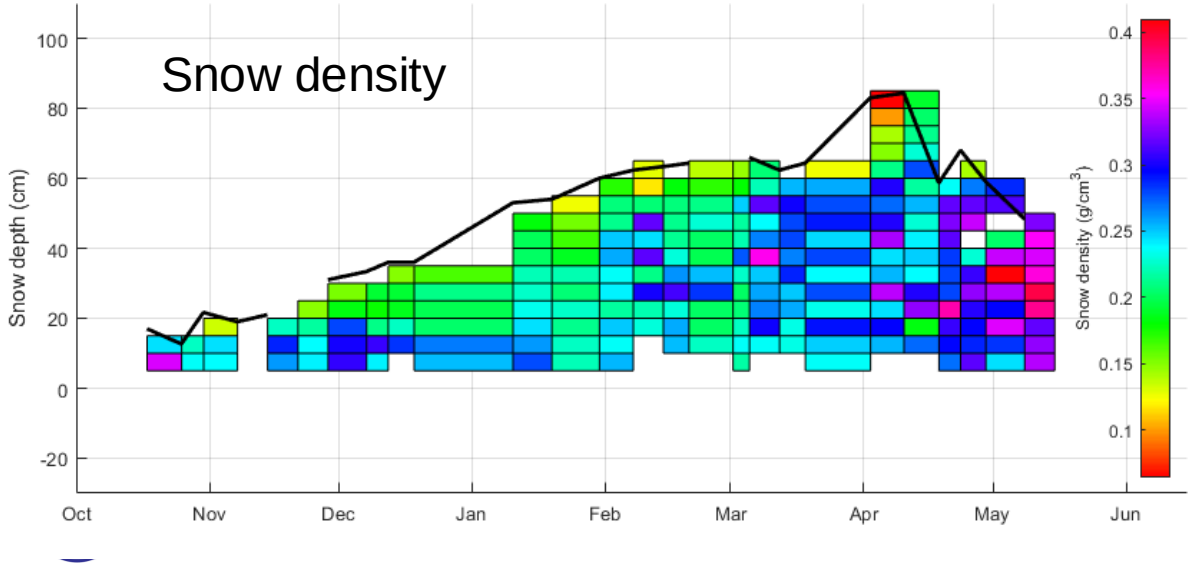
- Campaign observations for snow properties in
  - Sodankylä: weekly observations in boreal forest and wetland
  - Nuorgam: three campaigns; tudra/maritime transition
  - Rovajärvi: one campaign in conjucnction with FDF mobility tests

- Full history of digitized snow course observations obtained from SYKE (~150 sites, monthly observations 1971 onwards)

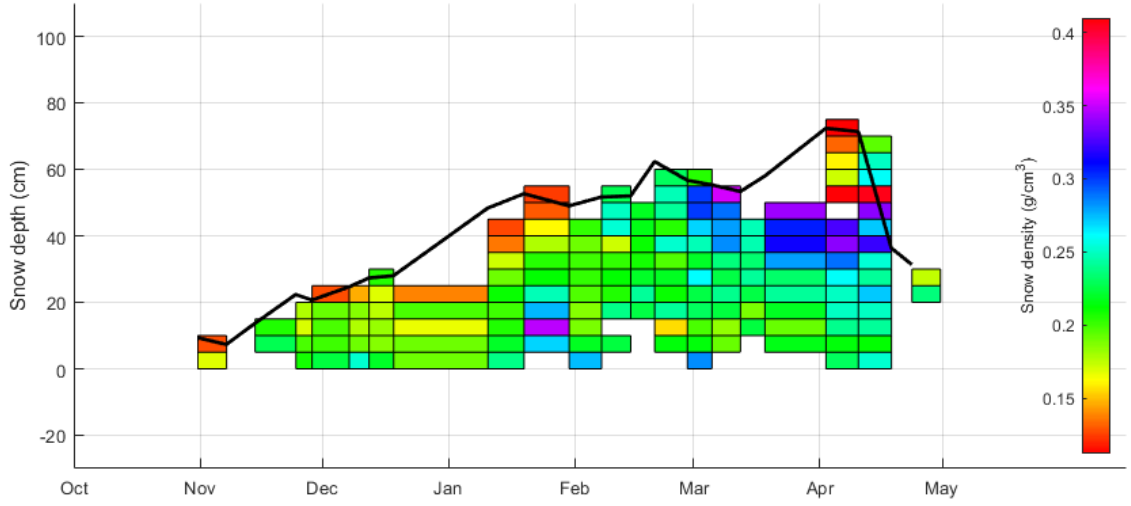
Examples of 2024 snow properties





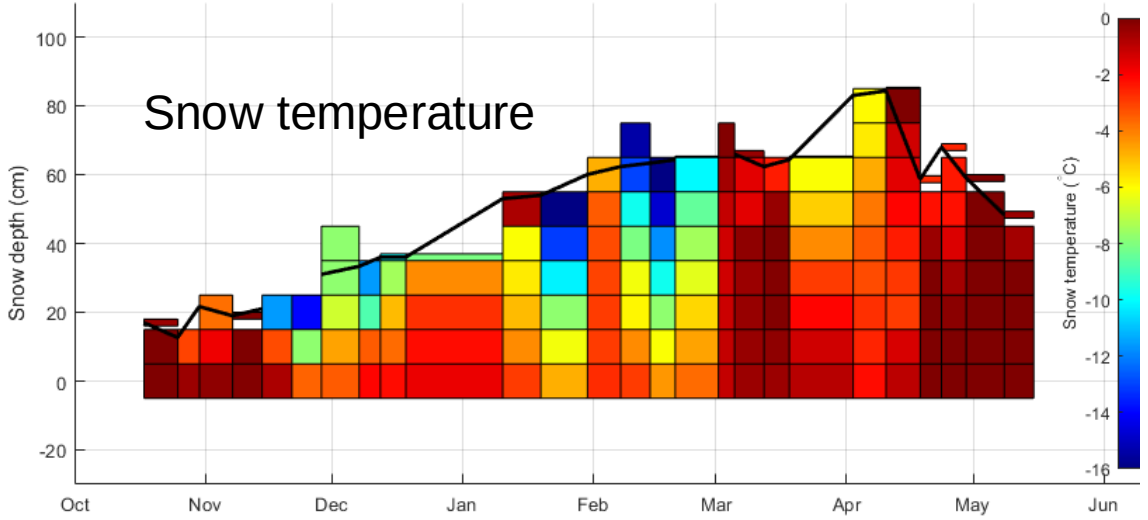


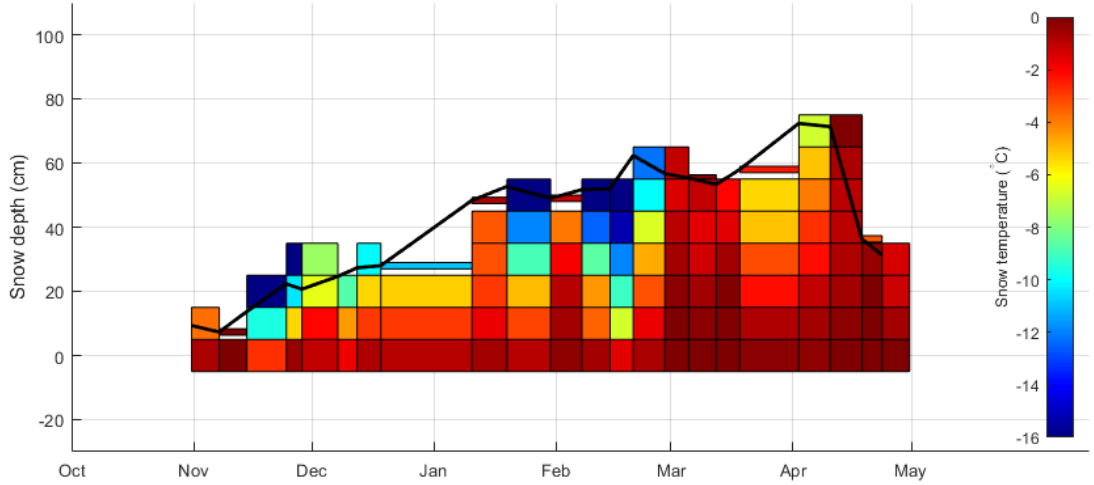
Sodankylä Forest

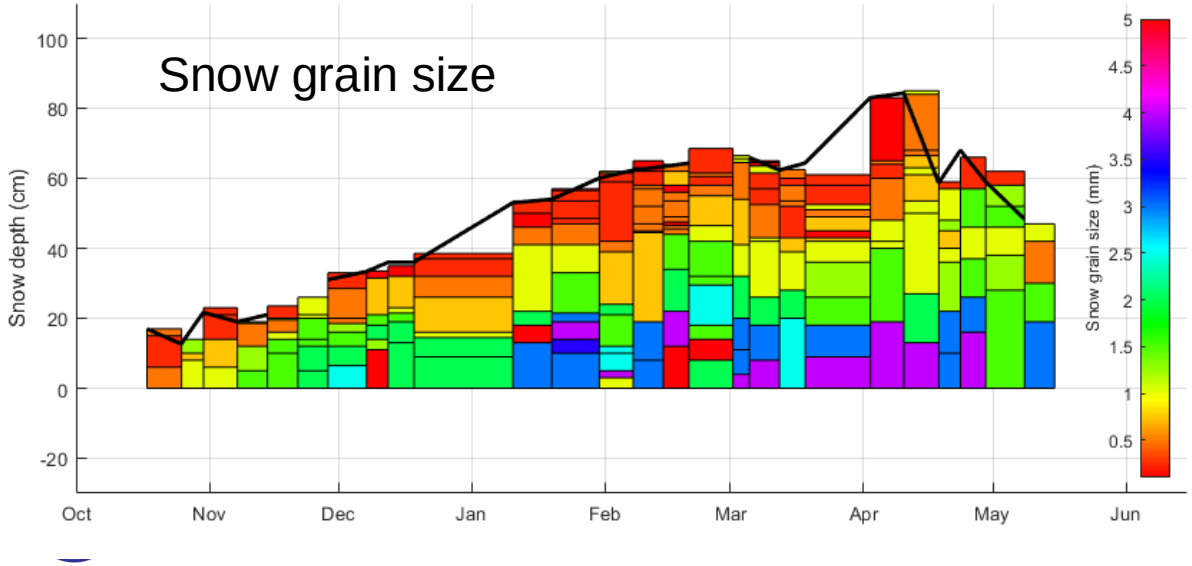


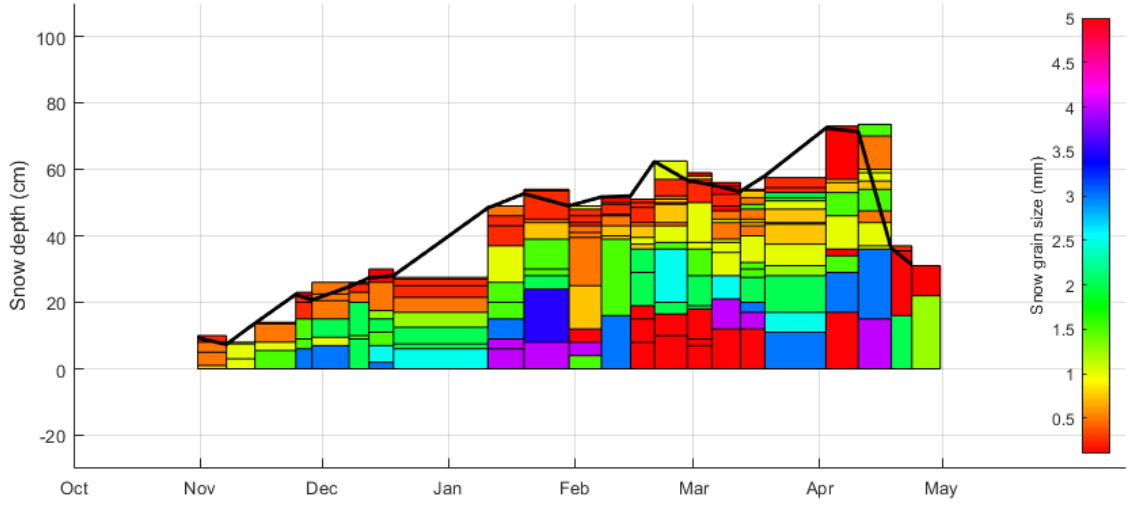
Sodankylä wetland

Examples of 2024 snow properties





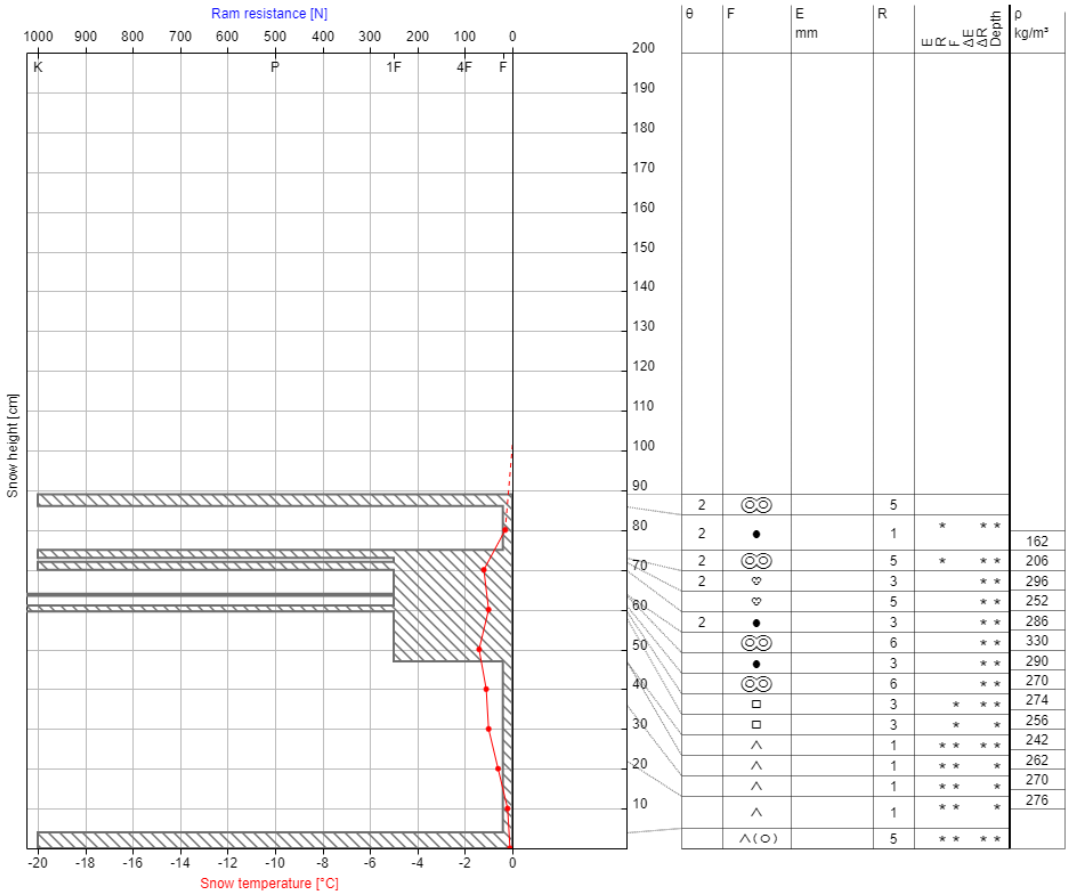




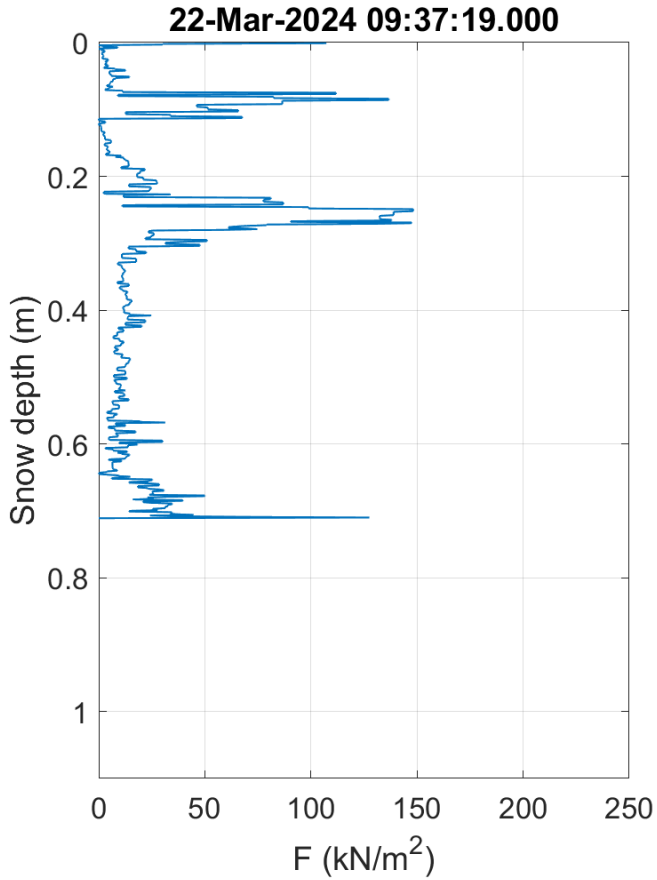
Sodankylä Forest

Sodankylä wetland

Rovajärvi 2024



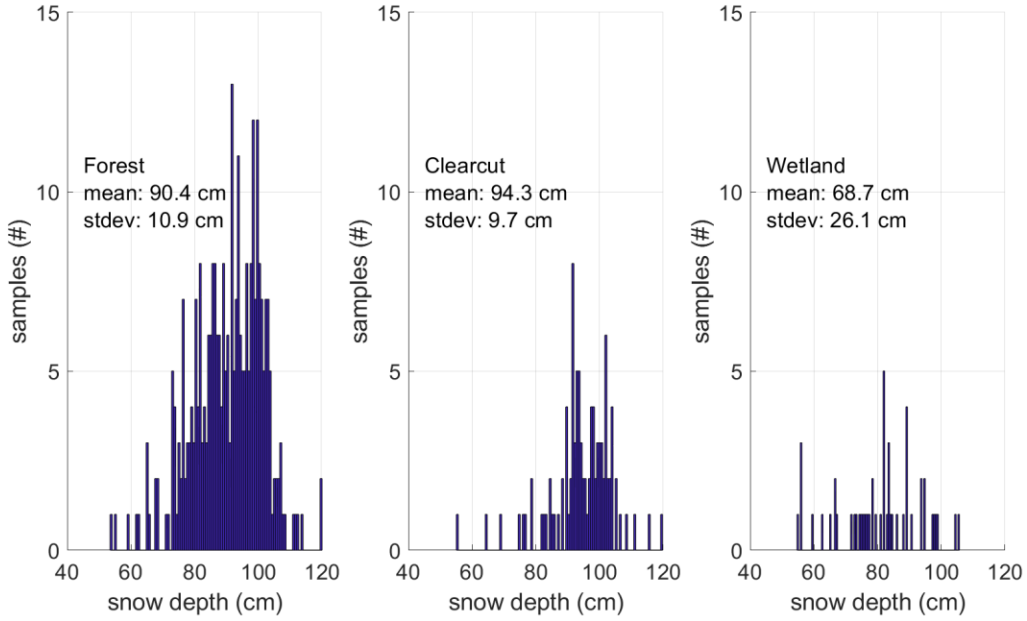
Manual snow profile L242 (Hautavaara).



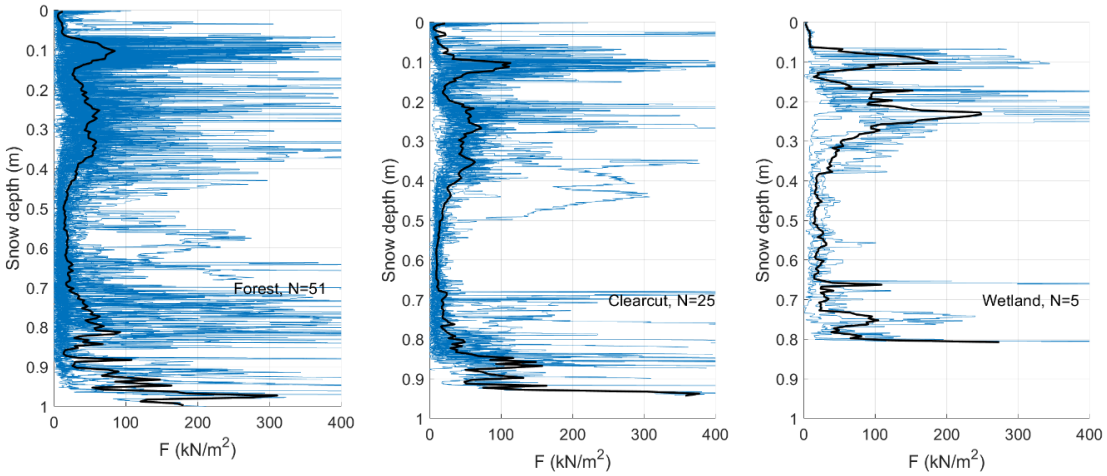
Snow penetration resistance measured using SnowScope at L242 (Hautavaara)

Rovajärvi 2024

- Additional distributed measurements to provide statistical data on snow characteristics
- ~5 km track measured on skis



Snow depth distribution in Hautavaara 22.3.2024



Snow penetration resistance measured with SnowScope, Hautavaara

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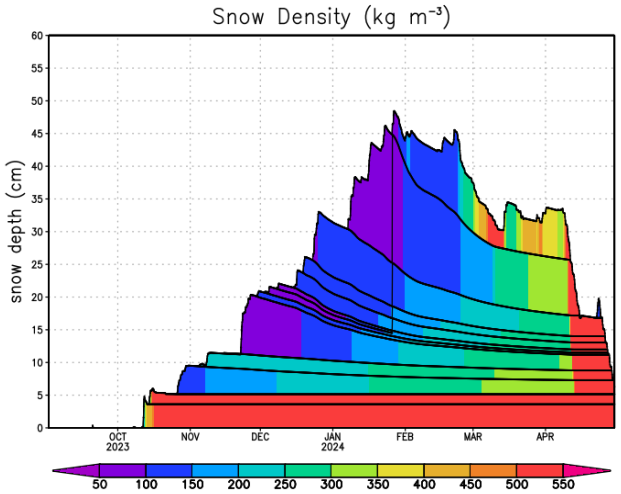
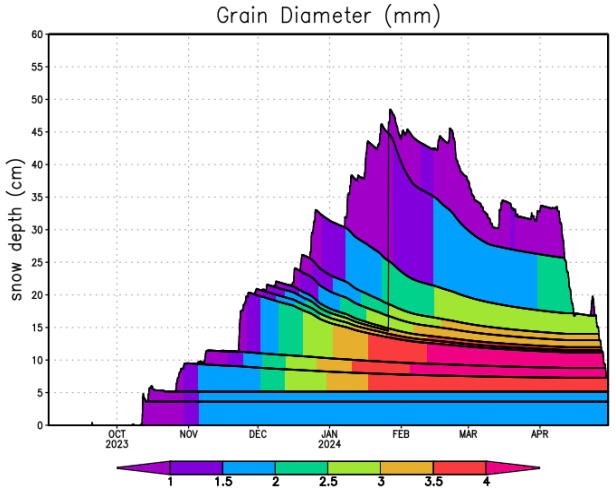
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

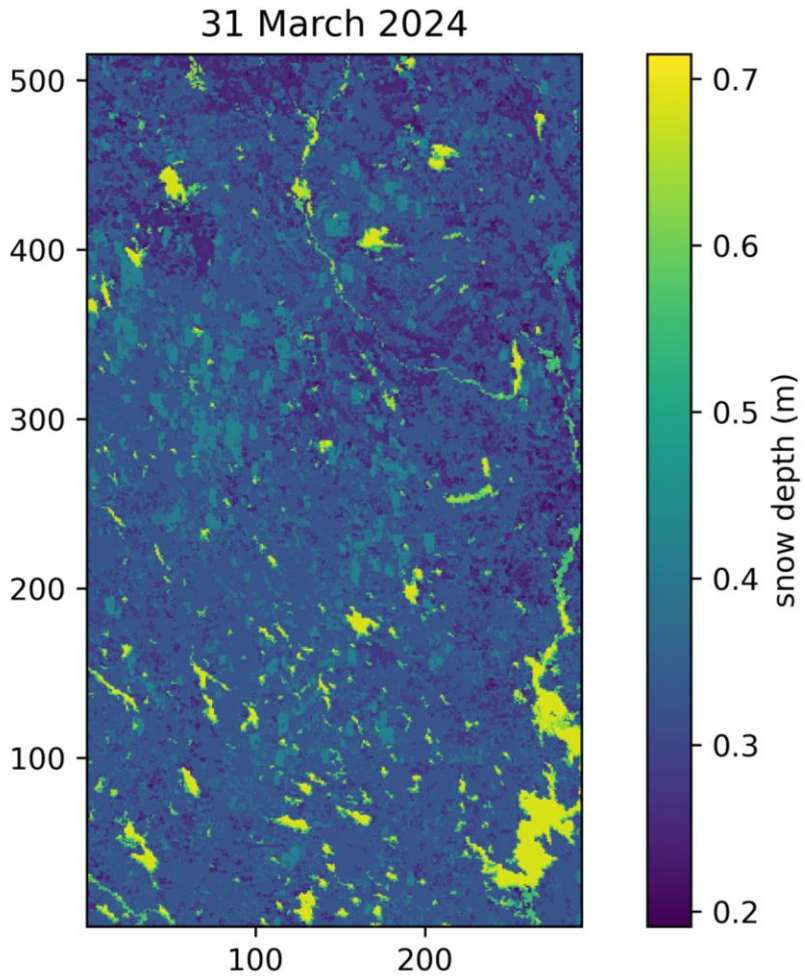
Where we are

- Independent test runs on HOPS and SnowModel underway
- Comparisons to 2024 data will provide first tools for parameterizing models

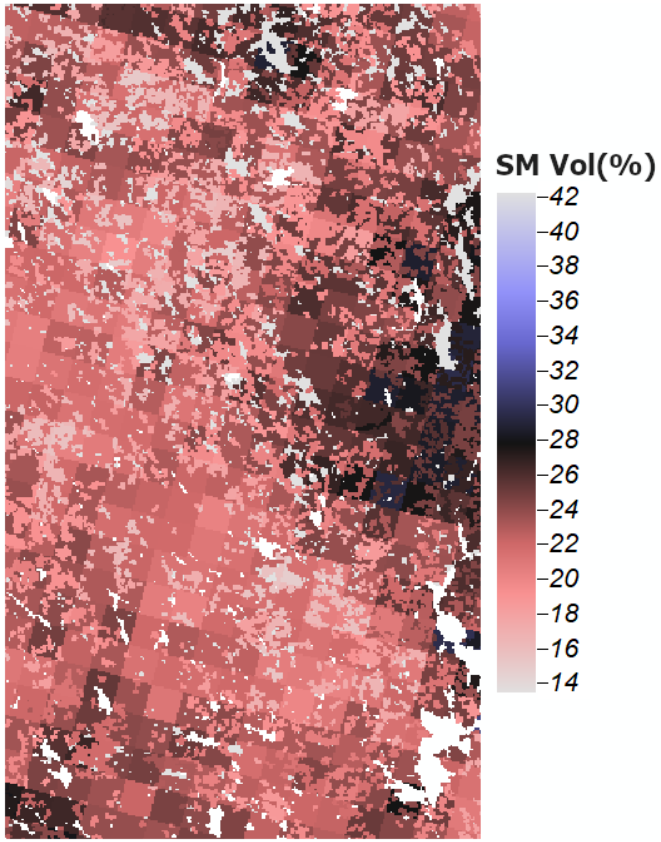
Model runs: SnowModel



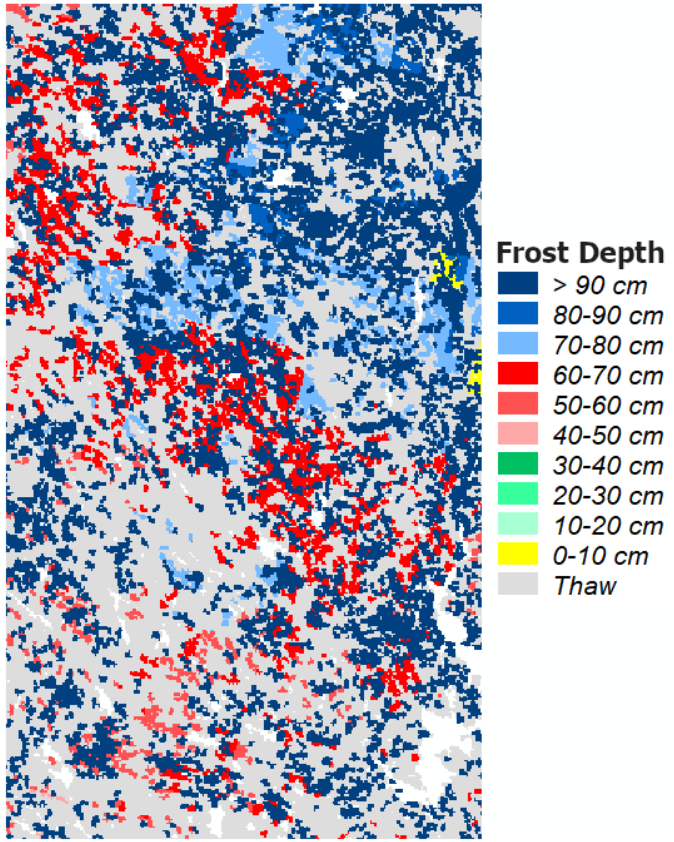




Model runs: HOPS

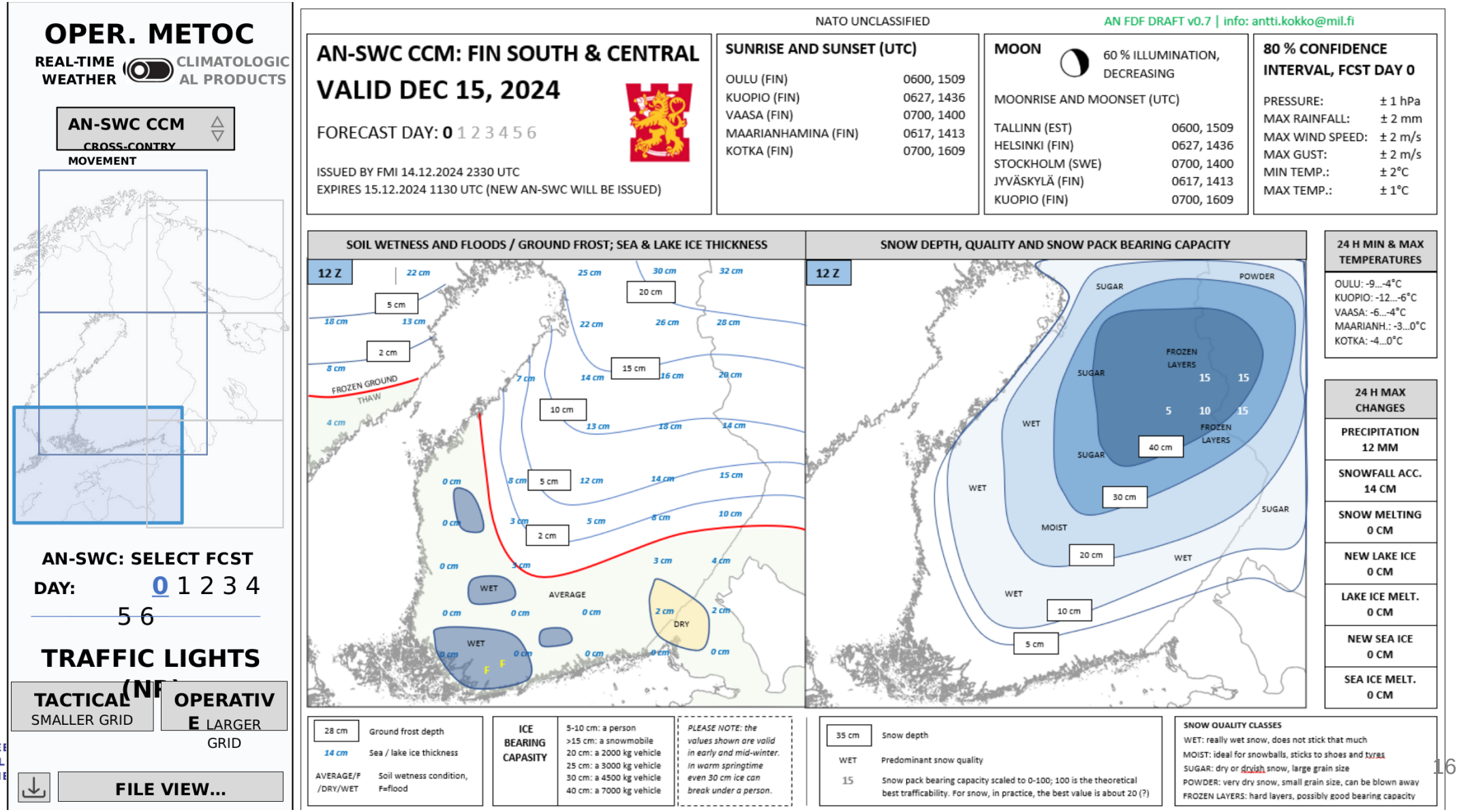


Volumetric Soil Moisture on 31 March 2024



Frost depth on 31 March 2024

An example


OPER. METOC
REAL-TIME WEATHER
CLIMATOLOGICAL PRODUCTS
AN-SWC CCM
CROSS-CONTRY MOVEMENT
AN-SWC: SELECT FCST DAY: 0 1 2 3 4 5 6
TRAFFIC LIGHTS (NR)
TACTICAL SMALLER GRID
OPERATIVE LARGER GRID
FILE VIEW...
NATO UNCLASSIFIED
AN FDF DRAFT v0.7 | info: antti.kokko@mil.fi
AN-SWC CCM: FIN SOUTH & CENTRAL
VALID DEC 15, 2024
FORECAST DAY: 0 1 2 3 4 5 6
ISSUED BY FMI 14.12.2024 2330 UTC
EXPIRES 15.12.2024 1130 UTC (NEW AN-SWC WILL BE ISSUED)
SUNRISE AND SUNSET (UTC)
OULU (FIN) 0600, 1509
KUOPIO (FIN) 0627, 1436
VAASA (FIN) 0700, 1400
MAARIANHAMINA (FIN) 0617, 1413
KOTKA (FIN) 0700, 1609
MOON
60 % ILLUMINATION, DECREASING
MOONRISE AND MOONSET (UTC)
TALLINN (EST) 0600, 1509
HELSINKI (FIN) 0627, 1436
STOCKHOLM (SWE) 0700, 1400
JYVÄSKYLÄ (FIN) 0617, 1413
KUOPIO (FIN) 0700, 1609
80 % CONFIDENCE INTERVAL, FCST DAY 0
PRESSURE: ± 1 hPa
MAX RAINFALL: ± 2 mm
MAX WIND SPEED: ± 2 m/s
MAX GUST: ± 2 m/s
MIN TEMP.: ± 2°C
MAX TEMP.: ± 1°C
SOIL WETNESS AND FLOODS / GROUND FROST; SEA & LAKE ICE THICKNESS
SNOW DEPTH, QUALITY AND SNOW PACK BEARING CAPACITY
12 Z
FROZEN GROUND
THAW
WET
AVERAGE
DRY
SUGAR
POWDER
FROZEN LAYERS
MOIST
24 H MIN & MAX TEMPERATURES
OULU: -9...-4°C
KUOPIO: -12...-6°C
VAASA: -6...-4°C
MAARIANH.: -3...0°C
KOTKA: -4...0°C
24 H MAX CHANGES
PRECIPITATION 12 MM
SNOWFALL ACC. 14 CM
SNOW MELTING 0 CM
NEW LAKE ICE 0 CM
LAKE ICE MELT. 0 CM
NEW SEA ICE 0 CM
SEA ICE MELT. 0 CM
28 cm Ground frost depth
14 cm Sea / lake ice thickness
AVERAGE/F /DRY/WET Soil wetness condition, F=flood
ICE BEARING CAPASITY
5-10 cm: a person
>15 cm: a snowmobile
20 cm: a 2000 kg vehicle
25 cm: a 3000 kg vehicle
30 cm: a 4500 kg vehicle
40 cm: a 7000 kg vehicle
PLEASE NOTE: the values shown are valid in early and mid-winter. In warm springtime even 30 cm ice can break under a person.
35 cm Snow depth
WET Predominant snow quality
15 Snow pack bearing capacity scaled to 0-100; 100 is the theoretical best trafficability. For snow, in practice, the best value is about 20 (?)
SNOW QUALITY CLASSES
WET: really wet snow, does not stick that much
MOIST: ideal for snowballs, sticks to shoes and tyres
SUGAR: dry or drvish snow, large grain size
POWDER: very dry snow, small grain size, can be blown away
FROZEN LAYERS: hard layers, possibly good bearing capacity

Thank you!