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FINNISH METEOROLOGICAL INSTITUTE

Terrain trafficability based on physical snow and soil models

MATINE research seminar

19.11.2025 **Ioanna Merkouriadi**

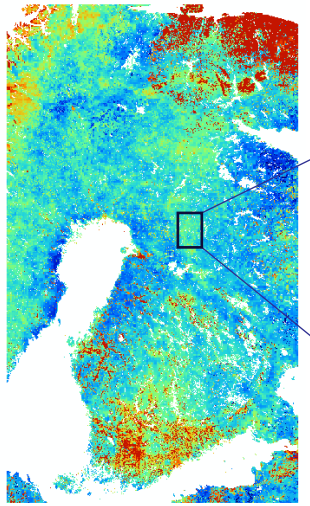
Dynamic forcing for cross-country mobility (CCM) analyses and forecasts

Goals:

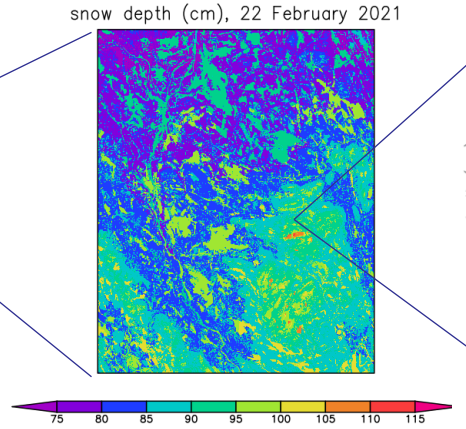
- Dynamic forcing for cross-country mobility:
  - Soil conditions: soil moisture, soil temperature etc.
  - Snow conditions: snow depth, snow density, snow wetness etc.
  - Lake and sea ice: ice extent, ice thickness
- 10 x 10 km scalable grid
- Analysis every 12 hours and +7 day forecast

Methods:

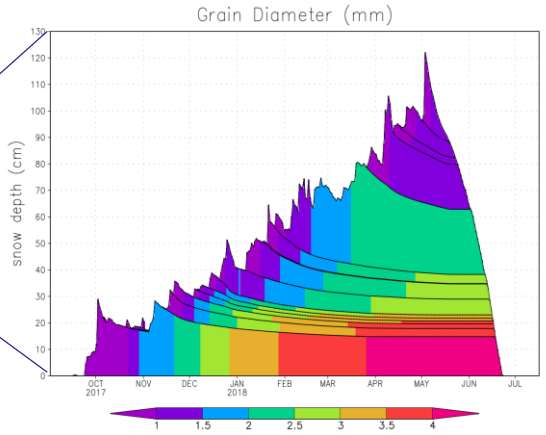
- Combination of hydrological model HOPS and a physical snow evolution model (SnowModel)
- Interface with present FDF CCM analysis



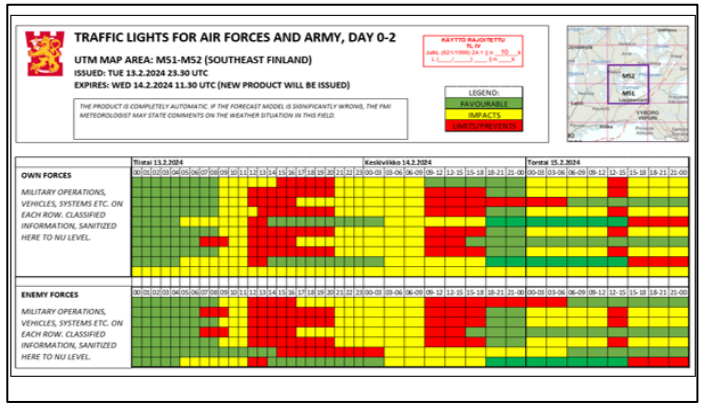
Soil moisture and temperature (HOPS)



Snow redistribution (SnowModel)



Layered snow properties (SnowModel)



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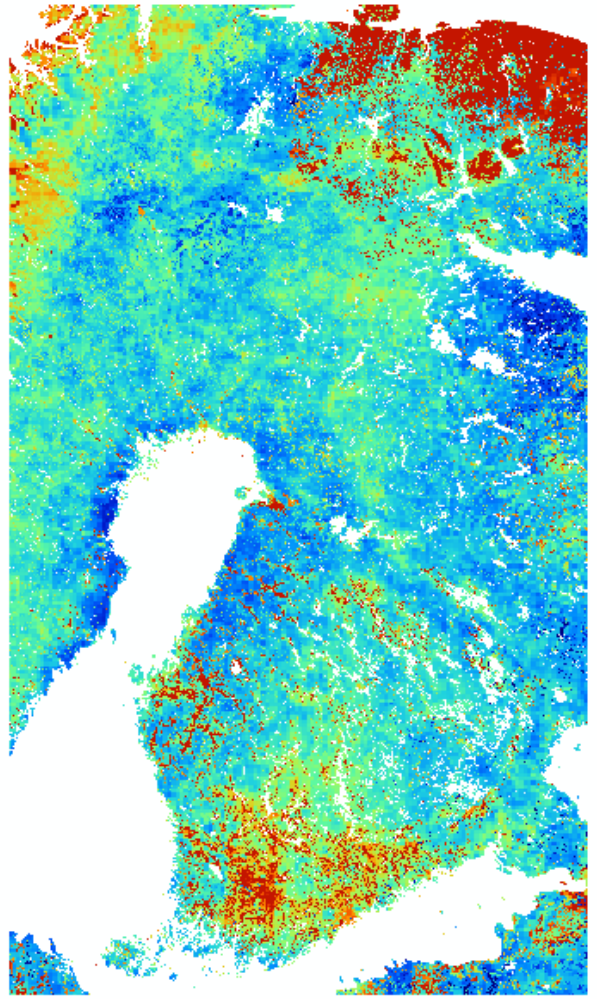
The models

- Hydrological Prediction System (**HOPS**): Runs operationally in FMI, used to forecast soil moisture, soil freeze/thaw states, snow depth

- **SnowModel**: a spatially distributed, snow evolution modeling system. Does not run operationally (yet)

HOPS

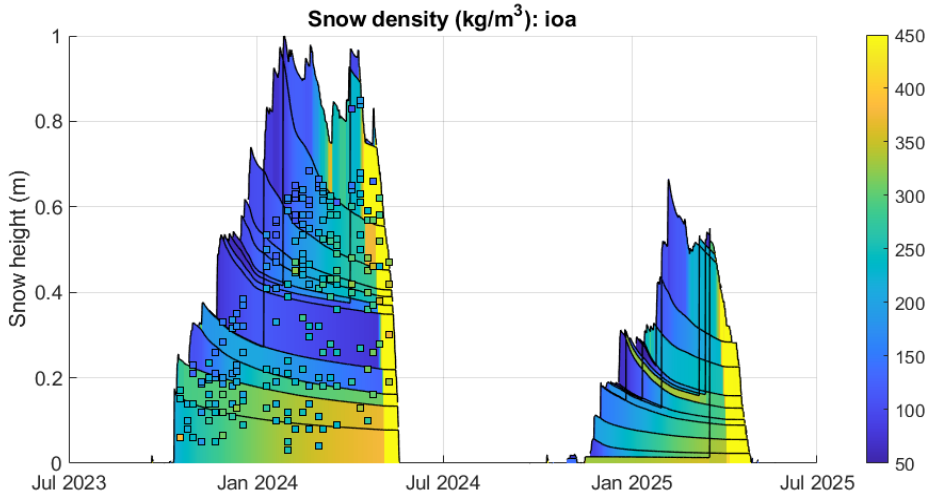
- HOPS v2.0.1 Running Operationally Daily
  - Soil Moisture
  - Soil Temperature -> Derived Soil Frost Depth
  - Snow (SWE and snow depth)
  - 24h Temporal Resolution, 10 Day Forecasts



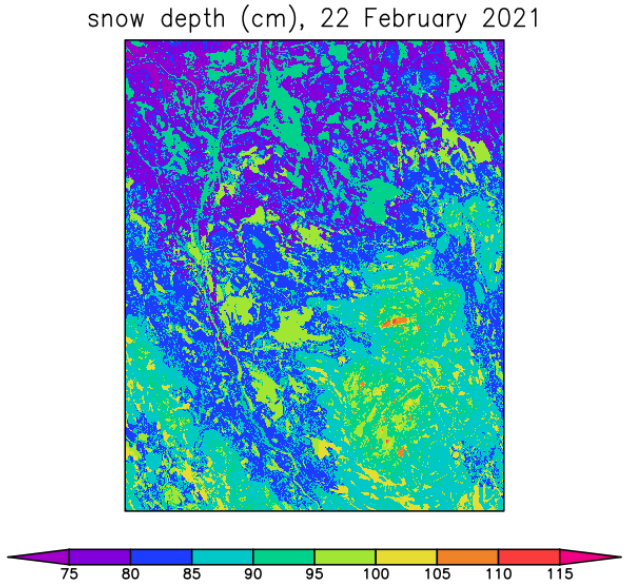
Volumetric Soil Moisture 03.10.2024

SnowModel

- 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, wetness, sublimation and runoff

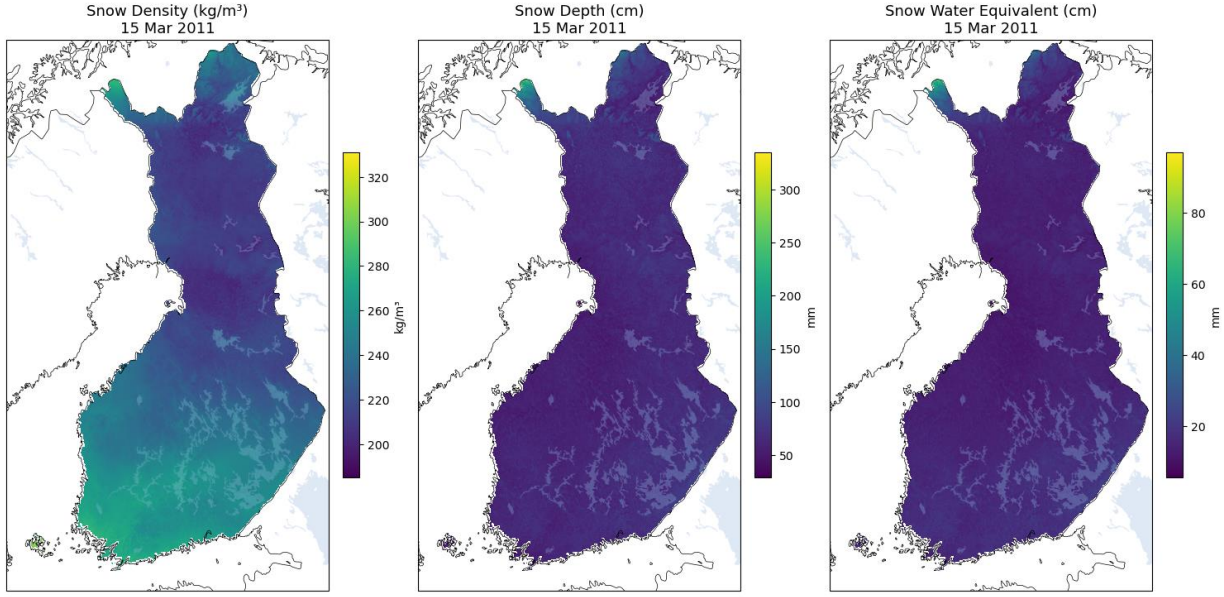


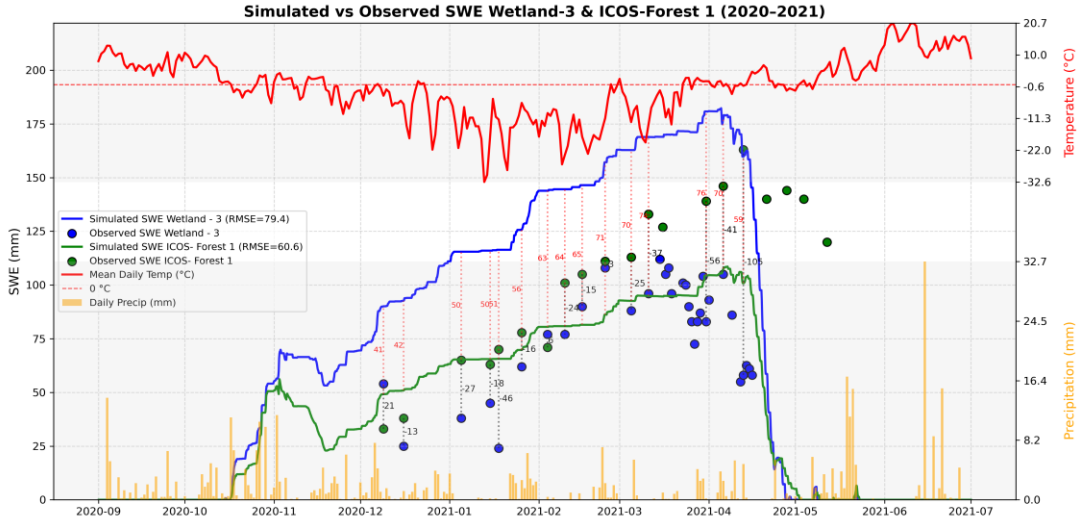
Dr. Glen Liston, CSU



SnowModel ongoing work

- Adapting SnowModel to Finnish climate and land cover conditions, using campaign observations of snow properties
  - **Sodankylä**: weekly observations in boreal forest and wetland
  - **Nuorgam**: three campaigns; tudra/maritime transition
  - **Saariselkä**: one campaign; tundra
  - **Rovajärvi**: two campaigns in conjunction with FDF mobility tests
- Assimilating SnowModel with long historical snow course observations obtained from SYKE (~150 sites, monthly observations 1971 onwards)
- Replacing snow component of HOPS with SnowModel





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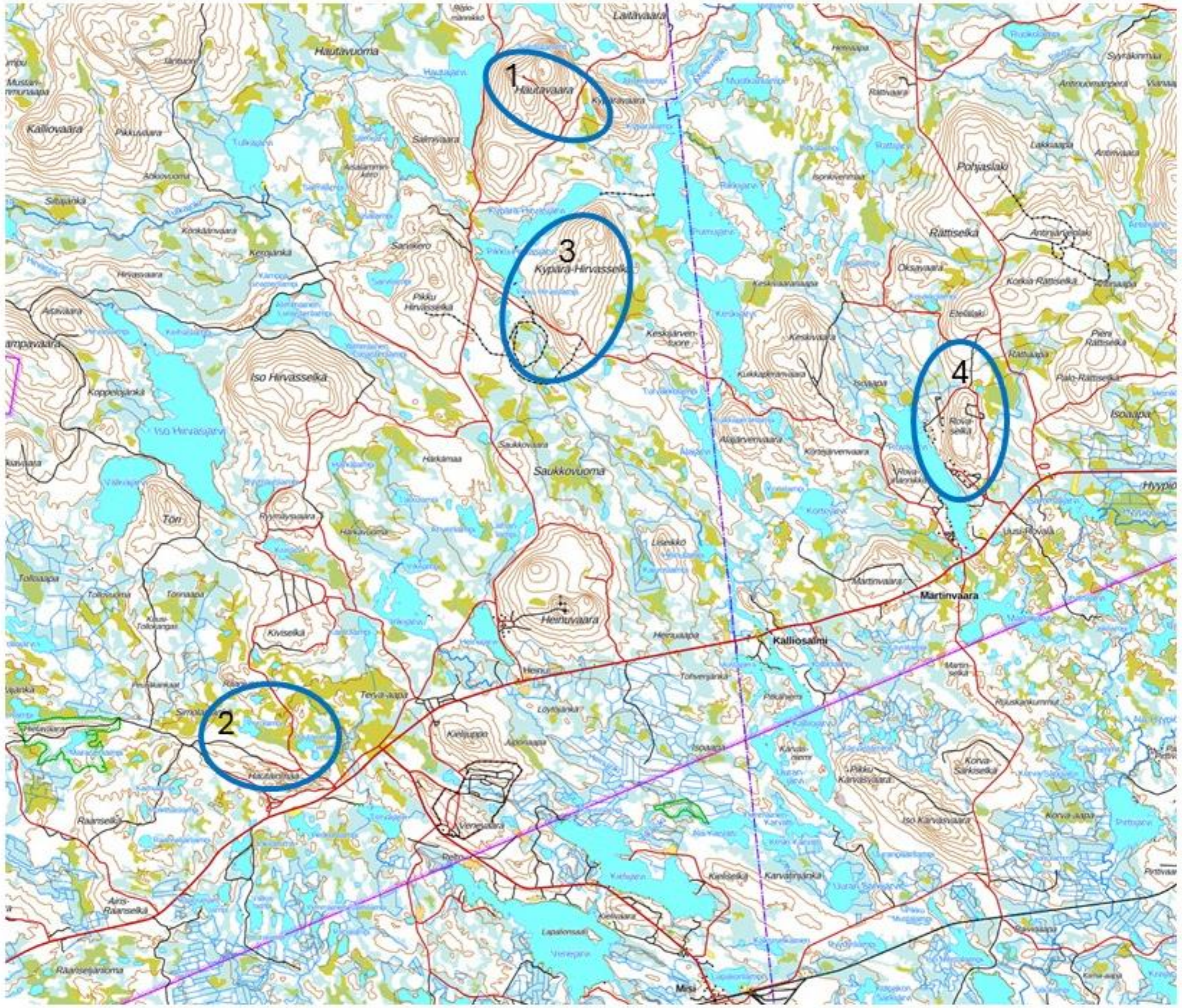
Rovajärvi 2024-2025

- Measurement campaigns for snow conditions in conjunction with mobility tests
- Variable topography and surface types
- 22.-23.3.2024, Areas 1 & 2:
  - 6 snow profiles
  - > 900 samples of snow depth
  - 15 samples of bulk SWE/snow density
  - High-resolution measurements of snow penetration resistance
  - Average snow depth: 82 cm
- 25.-28.3.2025, Areas 1 - 4:
  - 14 snow profiles
  - > 3000 samples of snow depth
  - 43 samples of bulk SWE/snow density
  - Average snow depth: 51 cm



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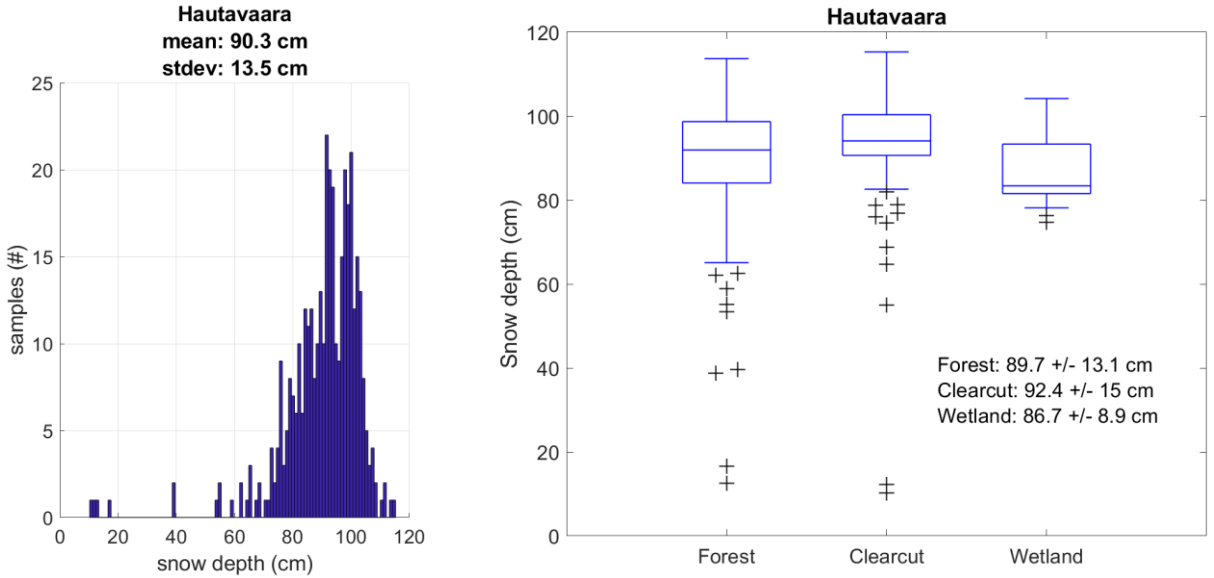
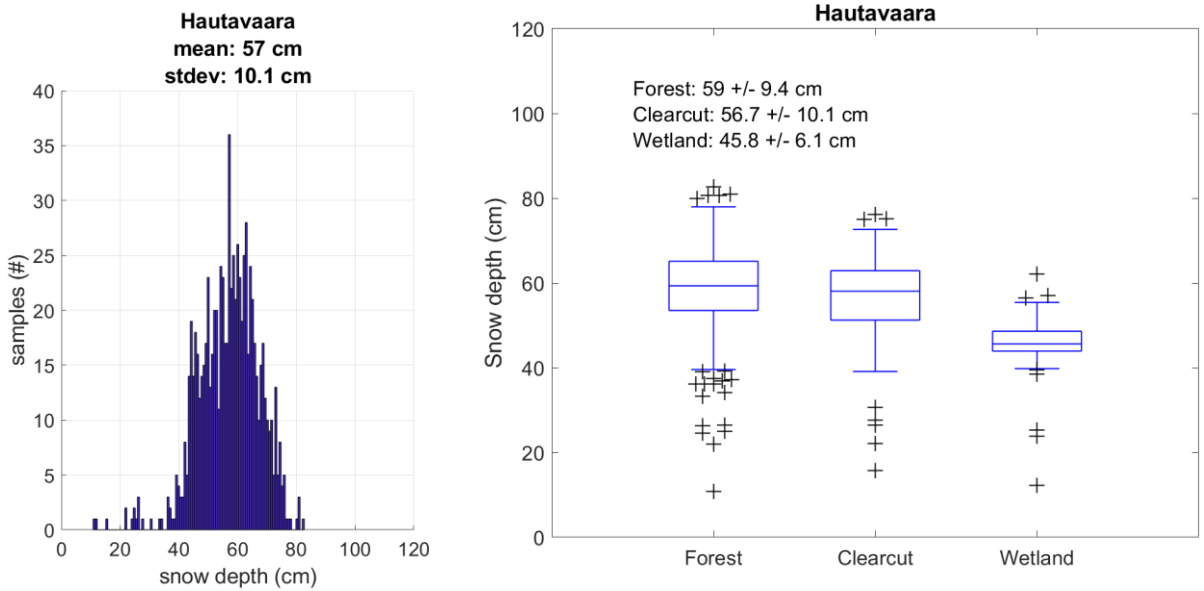


Area 1 (Hautavaara) snow depth distribution March 2024



Area 1 (Hautavaara) snow depth distribution , March 2025

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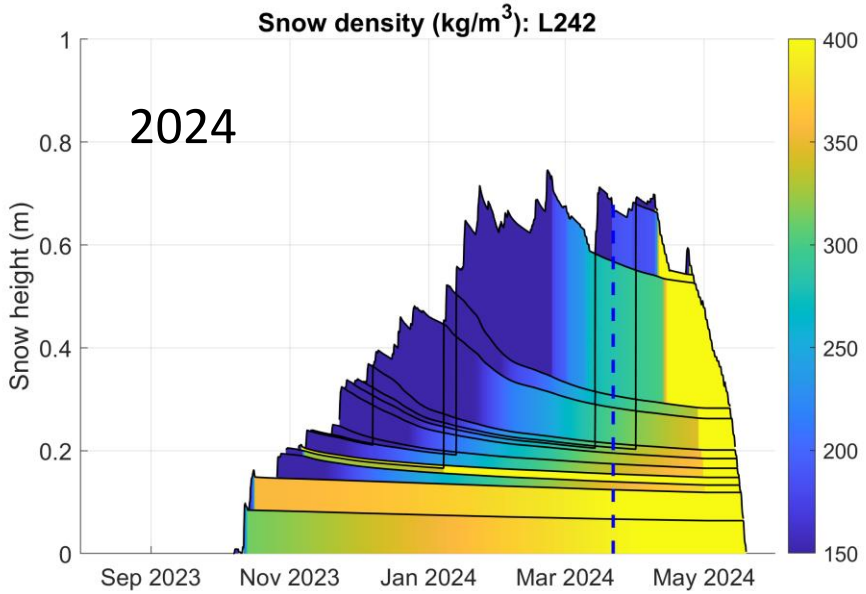
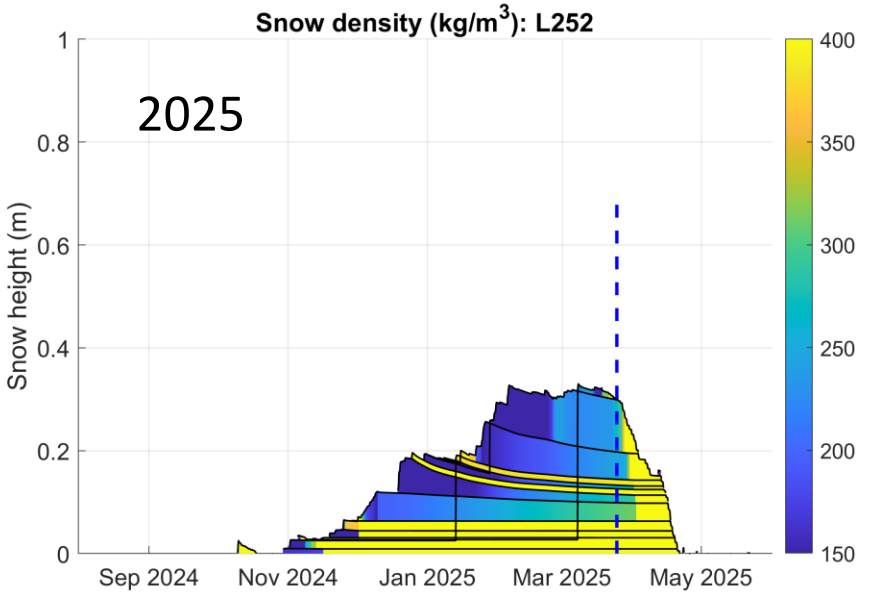
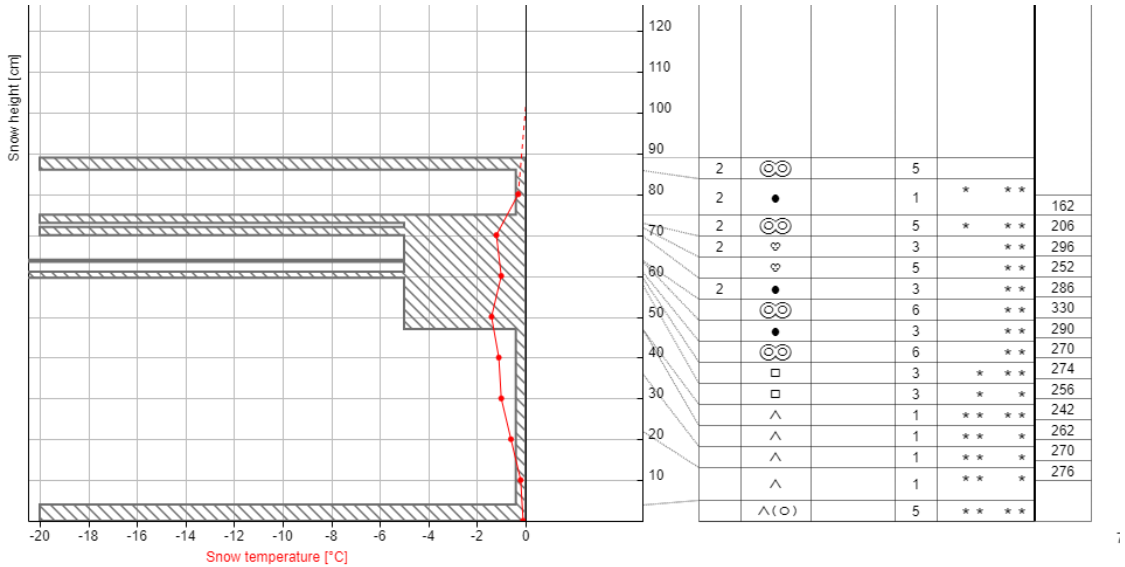
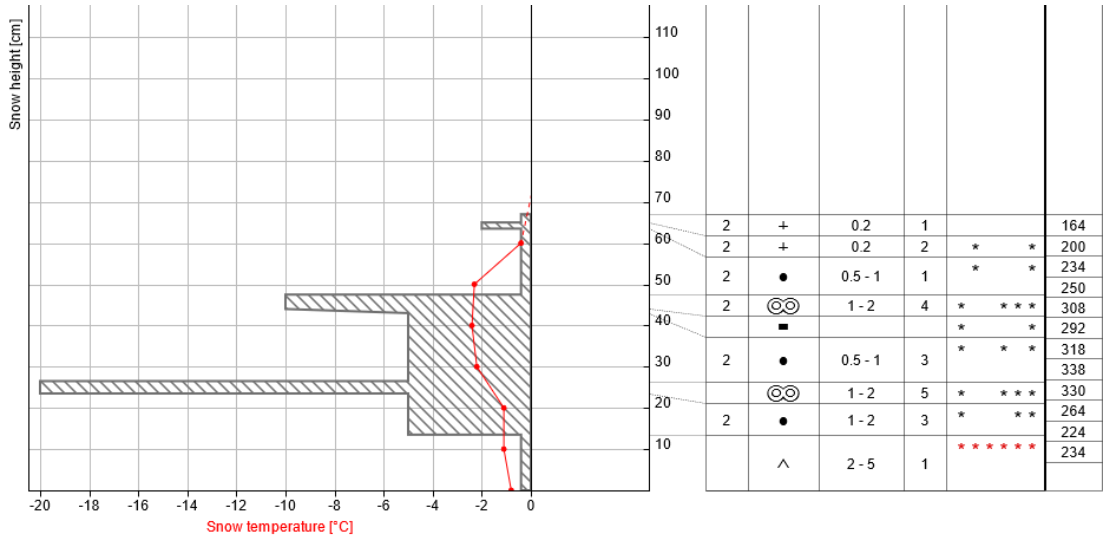
SnowModel simulations: point L243, Area 1

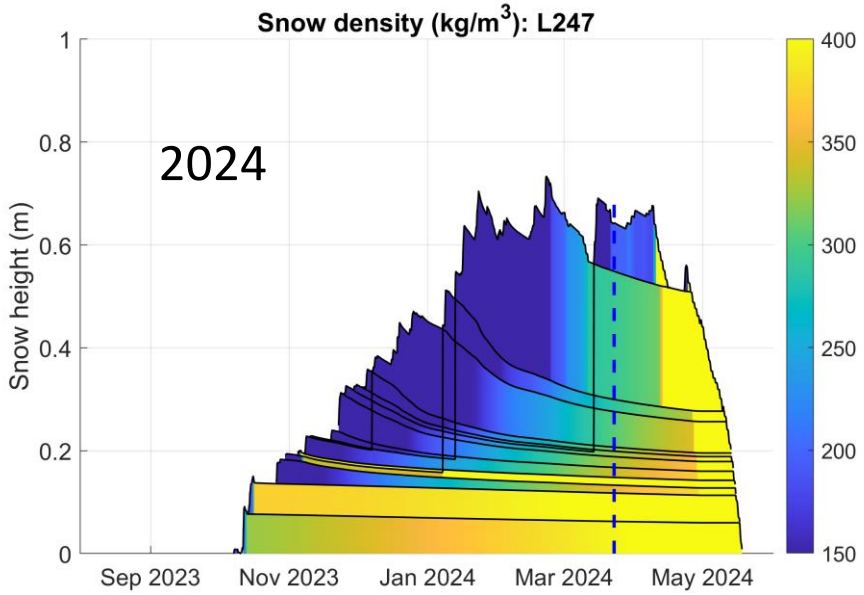


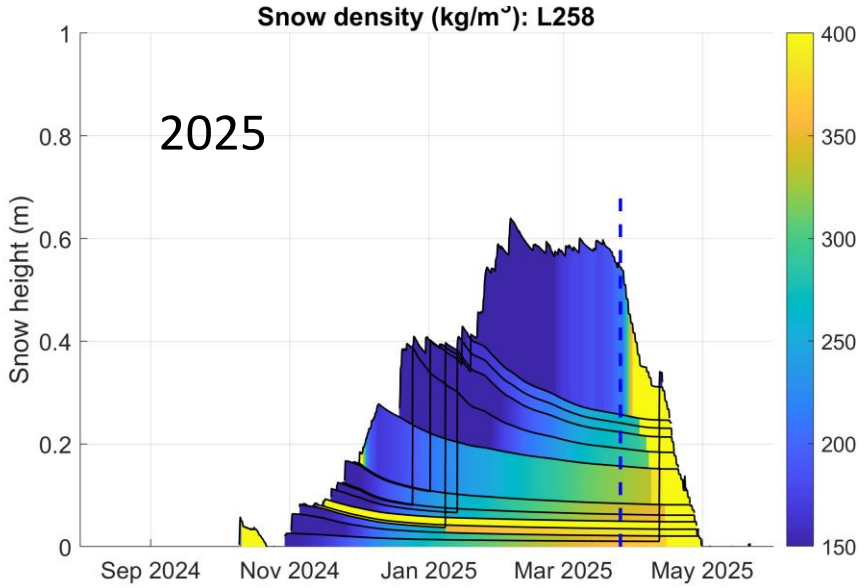


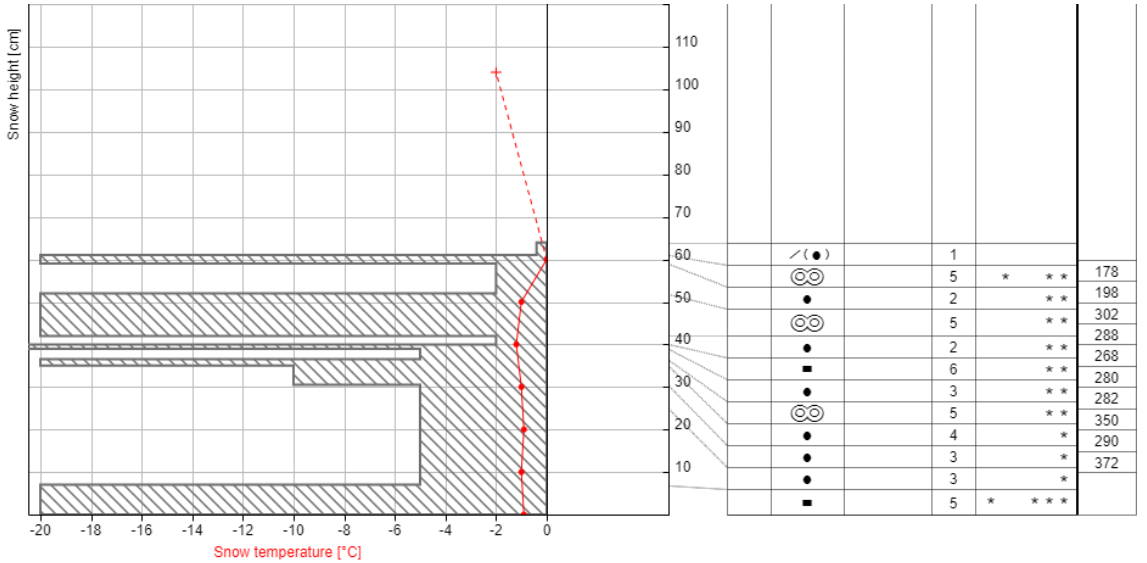


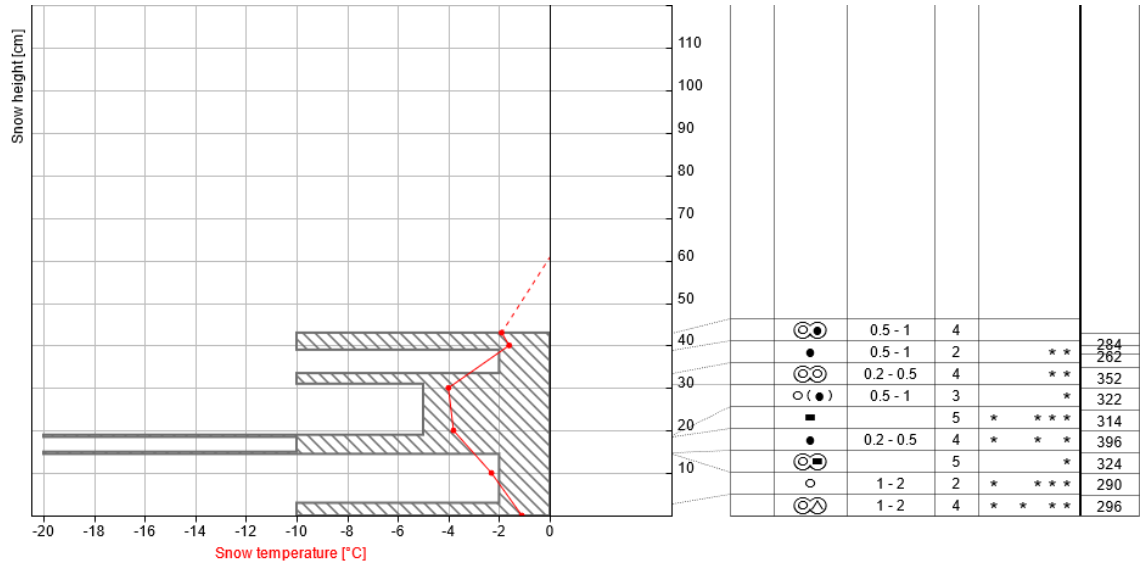


SnowModel simulations: point L247, Area 2



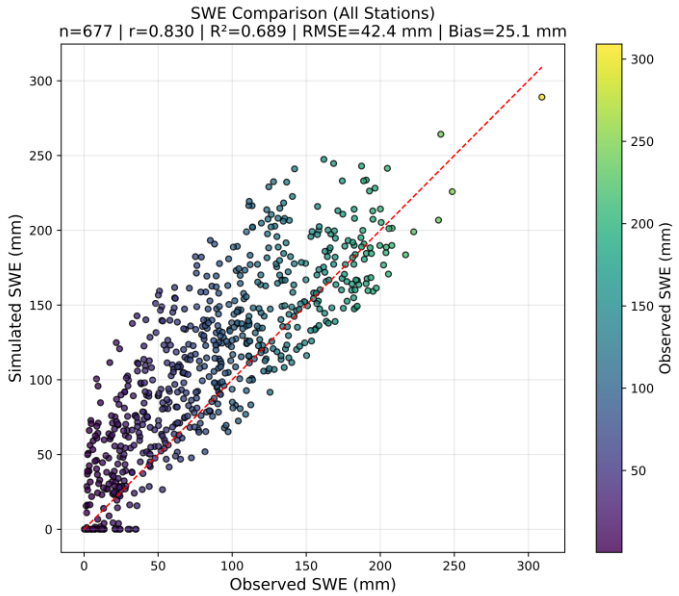


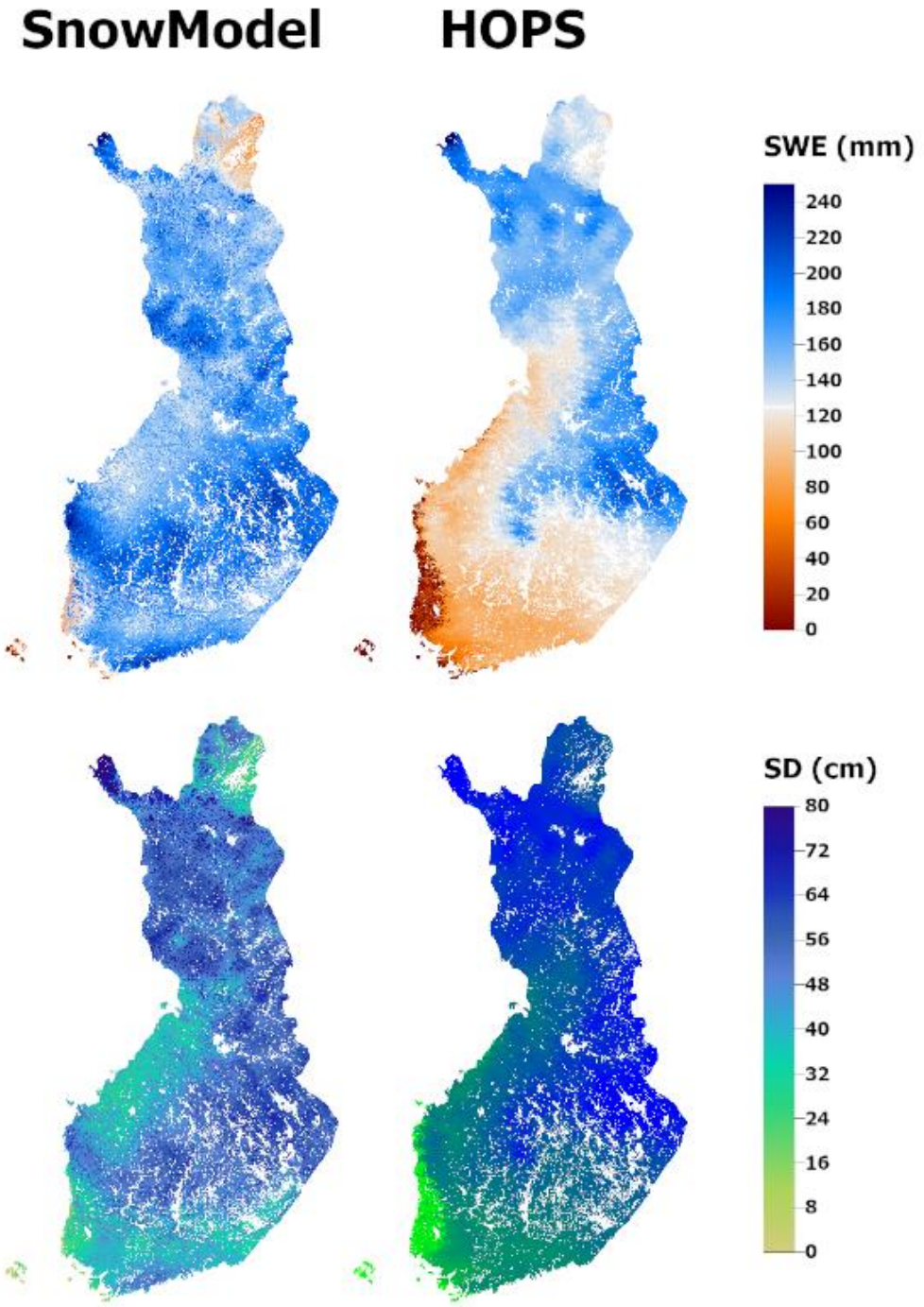




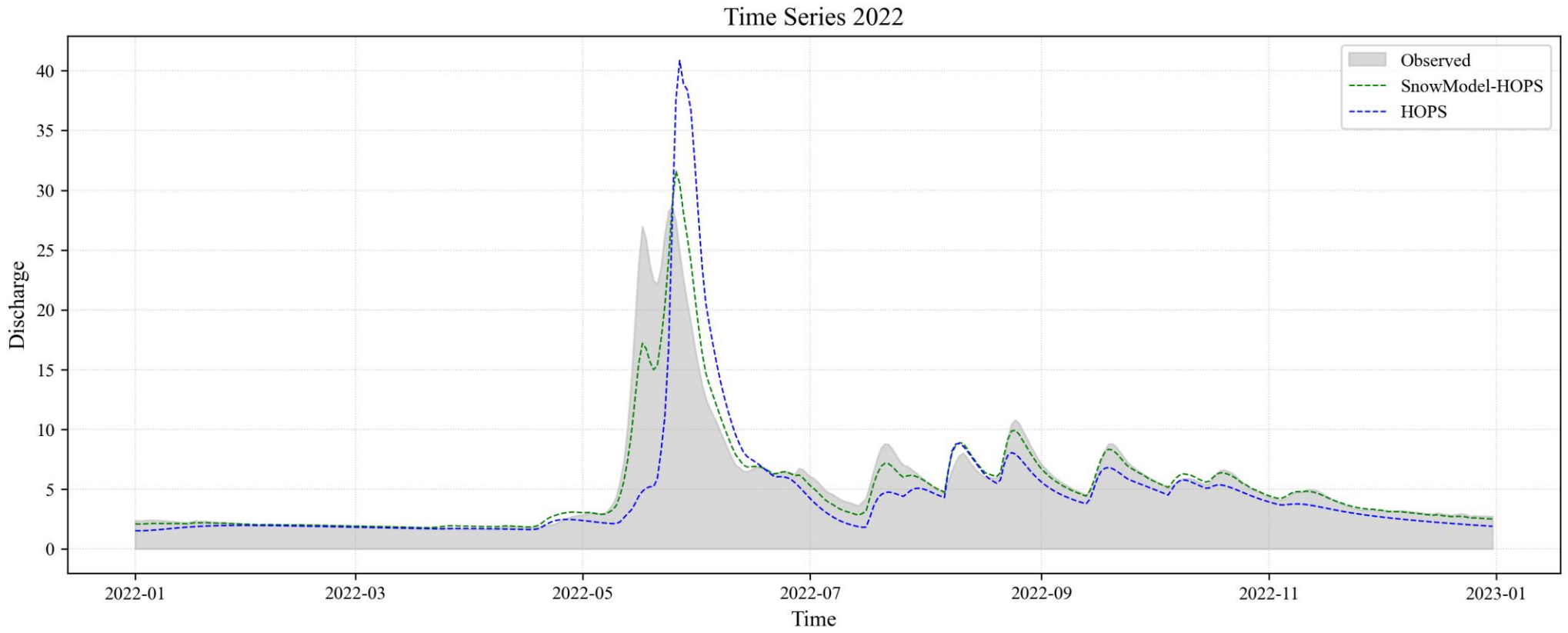
HOPS vs. SnowModel snow

- Snow depth is derived from SWE and density of the snowpack
- Density in HOPS is constant
- Density in SnowModel is dynamic, it evolves during the snow season due to compaction



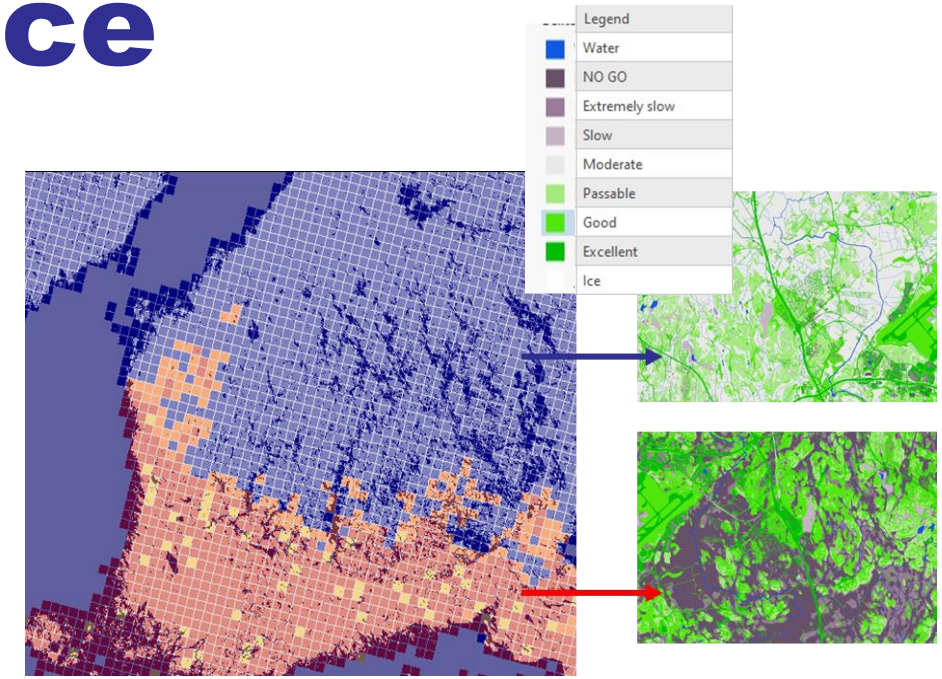


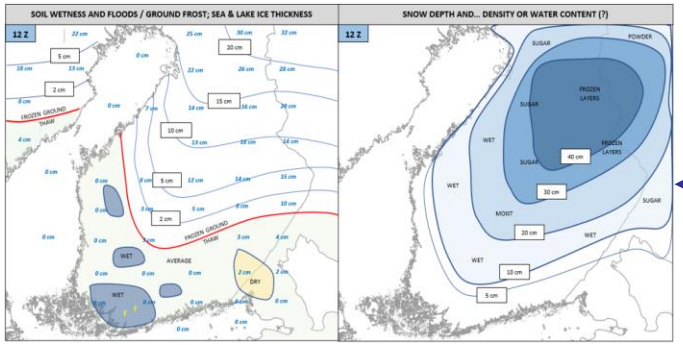
SnowModel improved HOPS discharge at Ounasjärvi 2019-2024

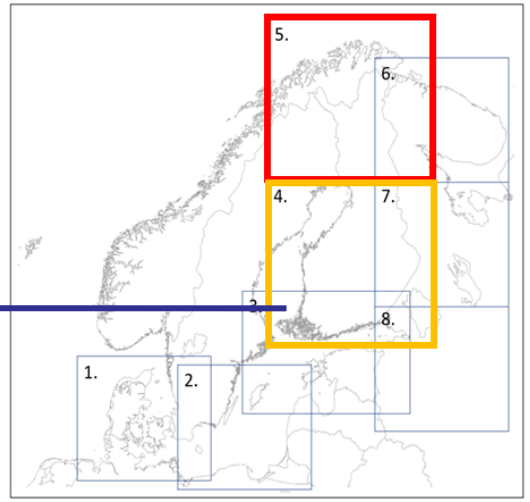


CCM Conditions Service

- Three types of CCM condition information and forecasts will be operationally provided
  - **GEOC General** 10x10 km CCM season (ESRI shape files):
    - Winter, Spring, Summer, Autumn
    - Based on soil moisture, soil frost/thaw states and predefined thresholds
  - **GEOC Auxiliary** 10x10 km information (ESRI shape files):
    - Snow conditions
    - Soil frost/thaw depths
  - **METOC Thematic** large-scale situational information and forecasts as printable maps (.pdf / .png)
  - Map A (Soil Conditions):
    - Soil ”wetness”: Dry, Wet, Muddy
    - Soil frost depth
  - Map B (Snow and Ice):
    - Snow depth
    - Lake ice depth
    - Sea ice depth







Kiitos!