DRONES – drone observational network for snow water storage monitoring

DRONES was financed by the Swedish Energy Agency call HåVa (Sustainable Hydropower) 2021/09-2024/08.

Participants
Björn Norell: *Vattenregleringsföretagen*; Daniel Wennerberg, David Gustafsson, Ilaria Clemenzi, Viktor Fagerström: *SMHI*; Franziska Pezzei, Jie Zhang, Karuna Sah, Rickard Pettersson; Veijo Pohjola: *Uppsala universitet.*

DRONES objectives

1) Assess how remotely sensed snow data best assist sustainable hydropower production.

2) Investigate how dense the distribution of observational coverage of SWE in space and time need to be in a given catchment to optimize the prognostics of filling rates into a water magazine.

3) Test different methodologies to assess which method has the ”best bang of the buck” in respect of outcome vs. the need of advanced expert knowledge.

4) To offer a road map of how an optimal methodology can be operationalized for industrial hydropwer applications.

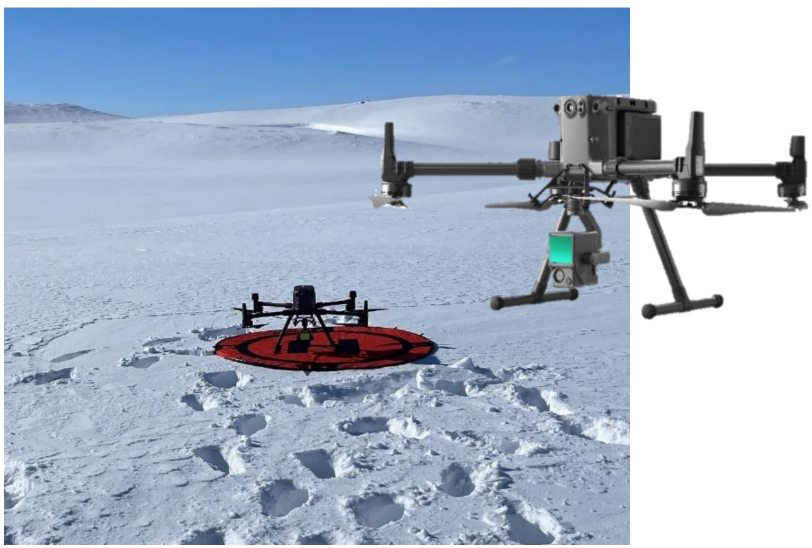
outline

Part I – Drone operations and snowdepth observations 2023 (Veijo Pohjola)

Part II – How to operationalize drone surveys, operations 2024 & snow hydrological modelling (David Gustafsson)

machinery

- DJI Matrice M300
- L1 LIDAR sensor
- RTK



- Deltaquad pro fixed wing (VTOL)
- Sony A7R mark III photogrammetry camera
- PPK

UPPSALA UNIVERSITET

selection

Our objective is to select catchments for our study that are different and such make ur results applicable for different types of mountain catchments, using:

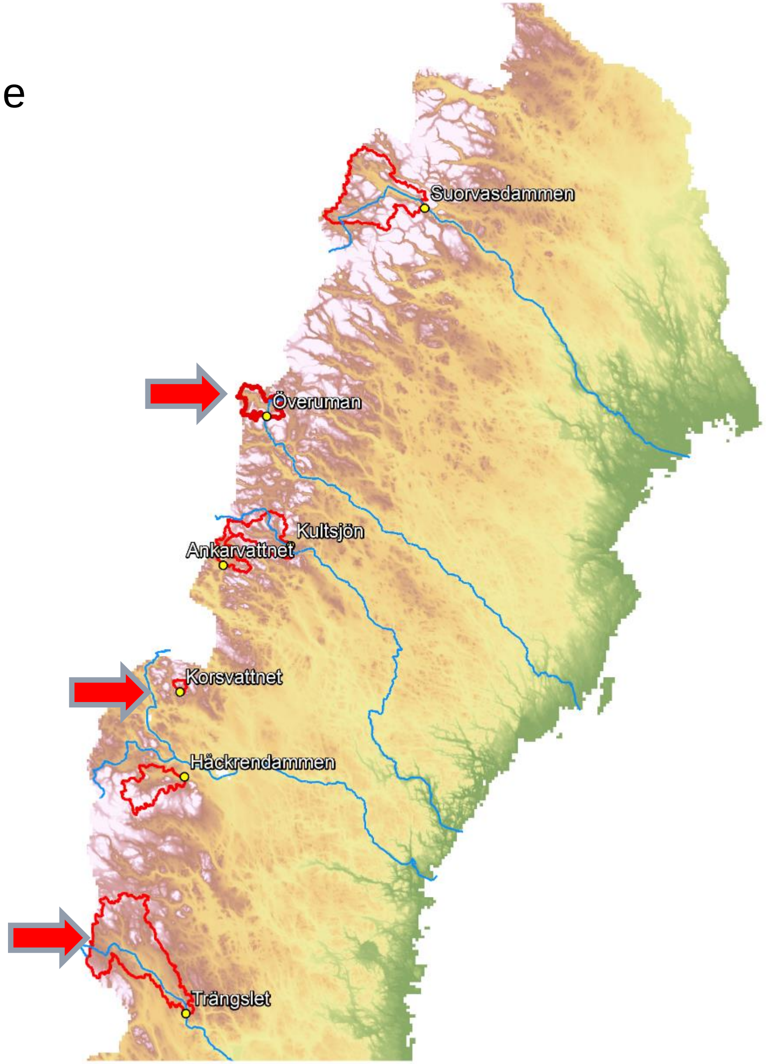
- Hypsometry
- Aspect
- Vegetation (coverage and type)

Other important aspects were:

- Industrial infrastructure and data availability
- Accessability

From our seven options our choice was:

- Korsvattnet
- Trängslet
- Överuman

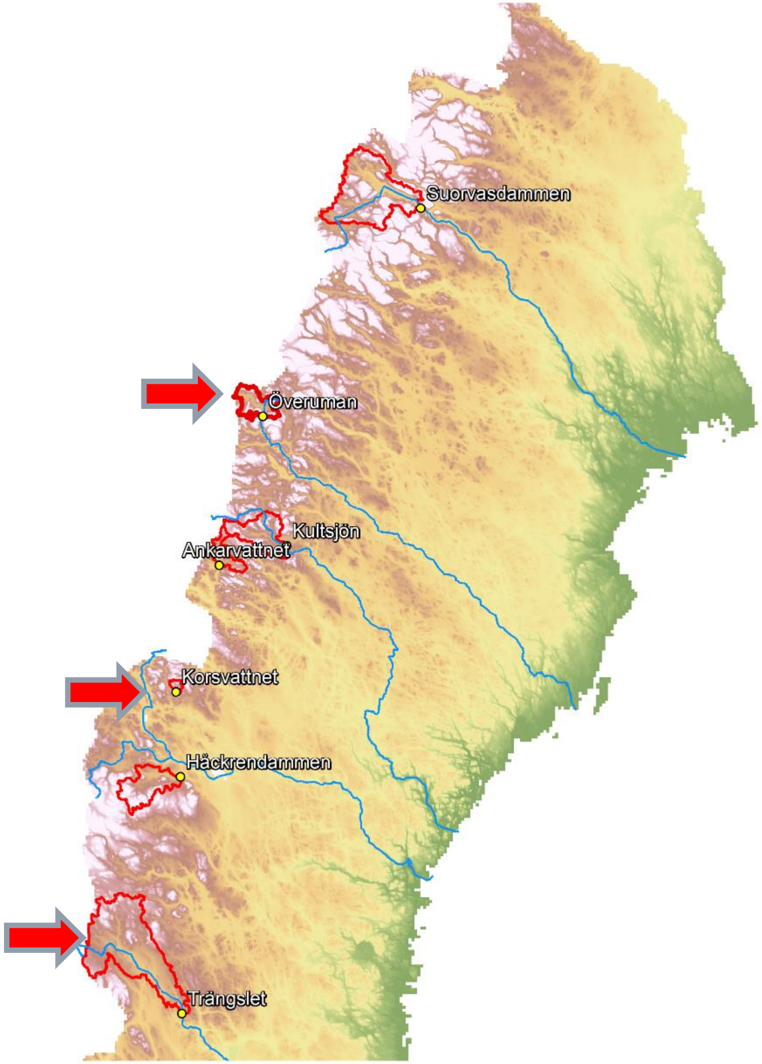


Auxilliary data exists from Luleälven and Ångermanälven.

droned areas

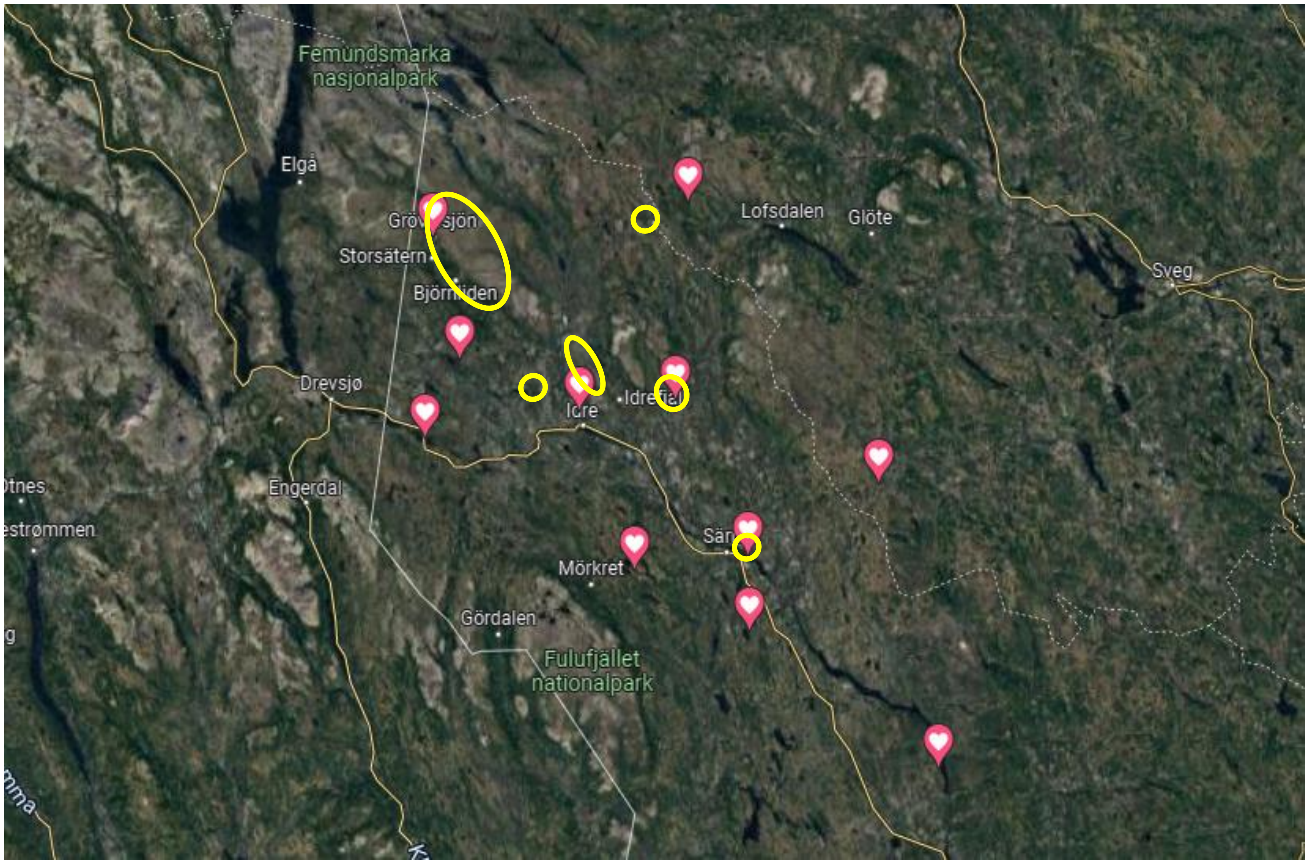
DRONES field work 2023

- Korsvattnet: 1-5 March, ~0.5 km^2
- Trängslet: 6-10 March, ~2 km^2
- Överuman: 20-25 March, ~4.5 km^2



Planning SWE measurements in the Trängslet/Österdalälven catchment

UPPSALA UNIVERSITET



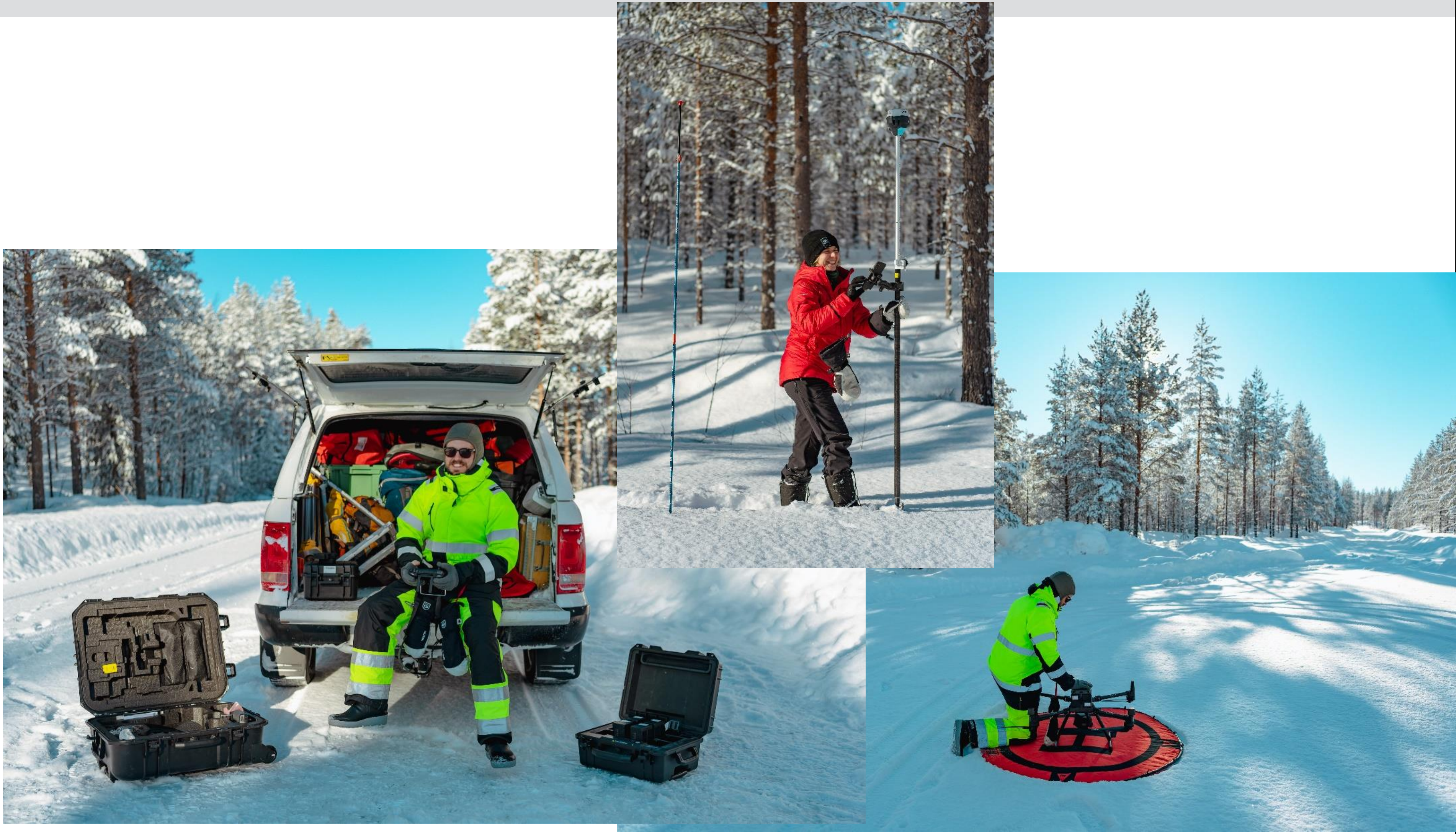
SWE measurement points in the Trängslet catchment 2014-2024 by Vattenregleringsföretagen/Fortum

Planned SWE drone missions in the Trängslet catchment 2023 by DRONES

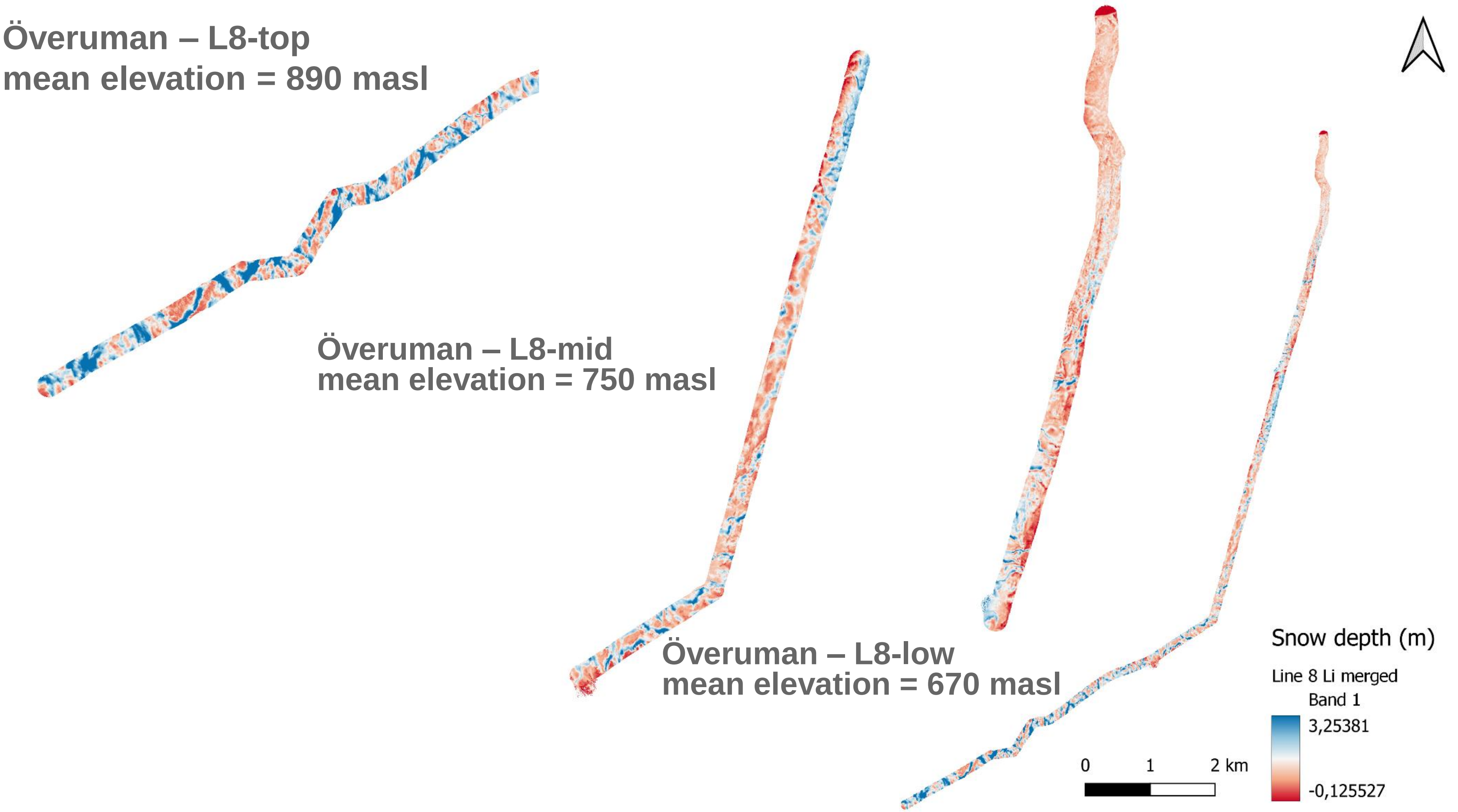
example of flight area: Idre

UPPSALA
UNIVERSITET

example of set-up: Foskdalsvallen

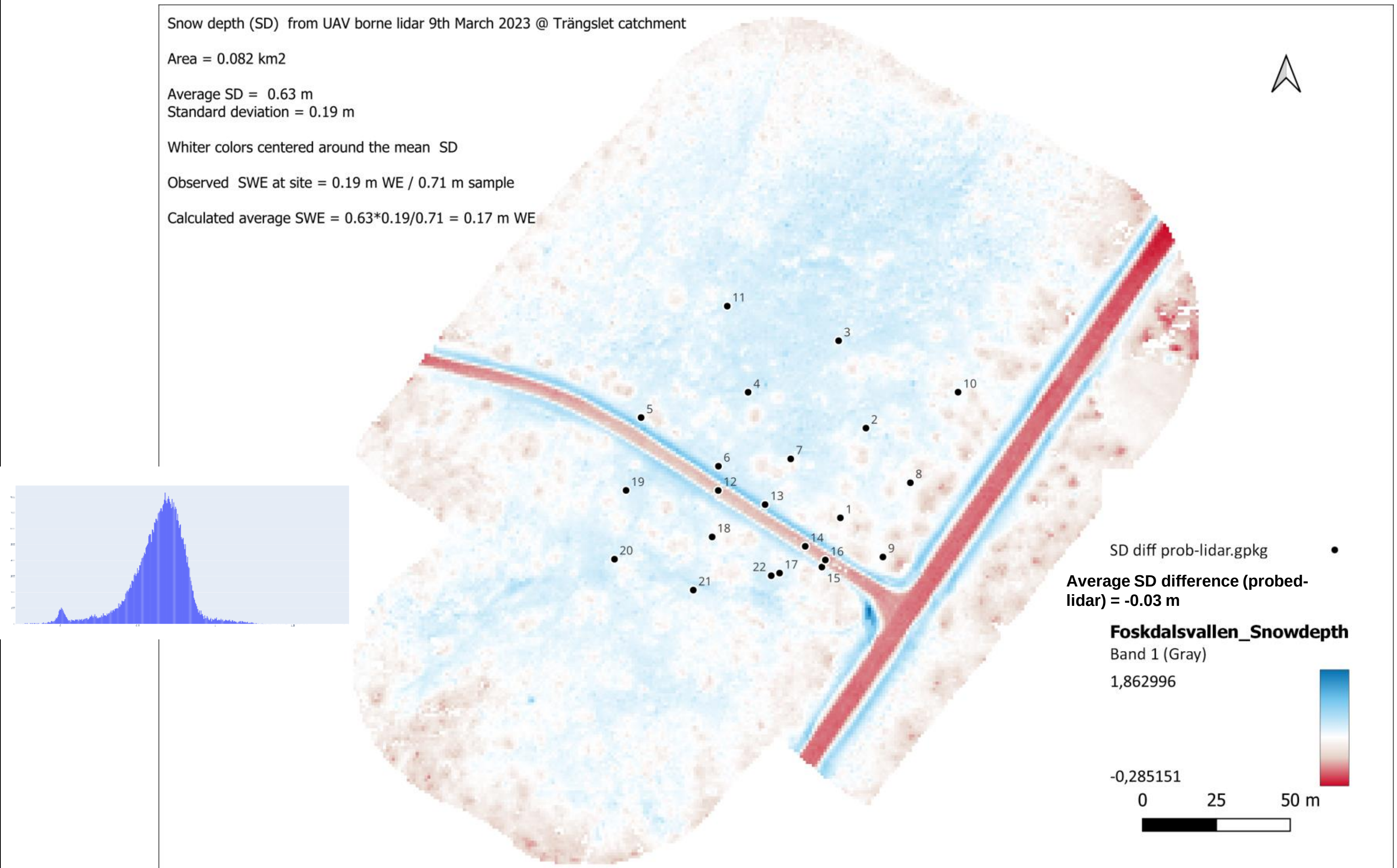


example of data: lidar Överuman



UPPSALA UNIVERSITET

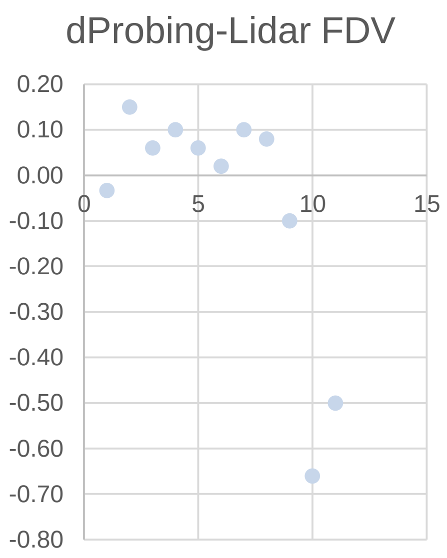
snow depth: Foskdalsvallen



UPPSALA UNIVERSITET

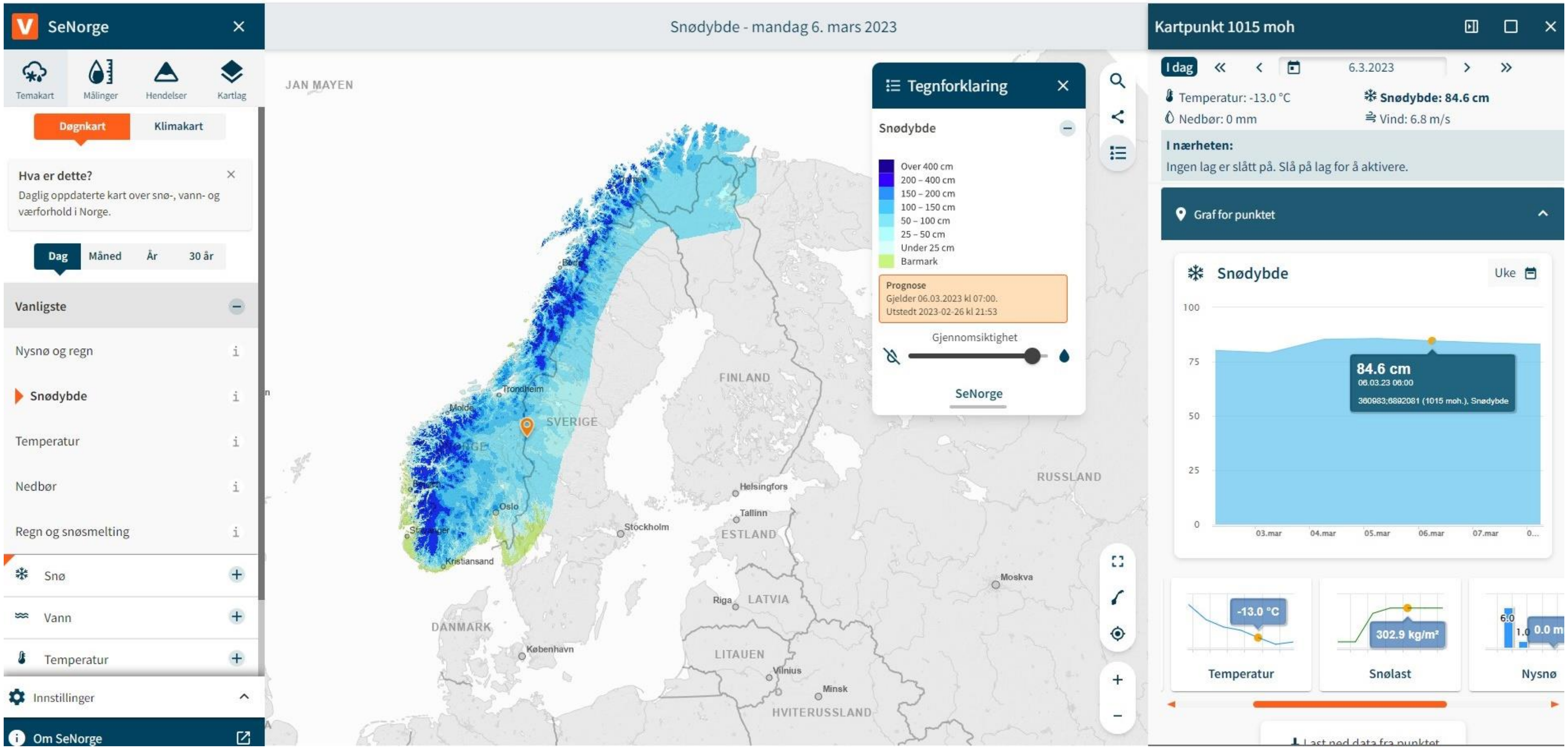
snow depth: validation

site	dPr-Li	n
FDV	-0.03	17
SDV	0.15	13
GRV1-HÄV	0.06	14
GRV2-LÖV	0.1	9
HMS	0.06	8
HMF1	0.02	9
HMF2	0.1	14
SÄR	0.08	7
ÖUMN-L5	-0.1	13
ÖUMN-L8 li	-0.66	19
ÖUMN-L8 Ph	-0.5	8
average	-0.07	12
average - ÖUMN L8	0.05	12



UPPSALA UNIVERSITET

seNorge.no snowmodel



Daily maps of snow conditions have been produced in Norway with the seNorge snow model since 2004.The seNorge snow model operates with 1 × 1 km resolution, uses gridded observations of daily temperature and precipitation from Met.no as its input forcing, and simulates, among others, snow water equivalent (SWE), snow depth (SD), and the snow bulk density (Salorata, 2012).

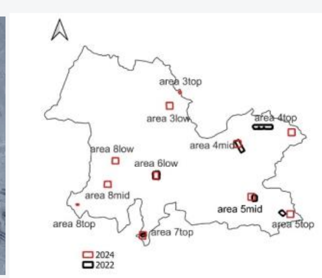
Part II

How to operationalize drone snow surveys & apply drone data in snow hydrological modelling

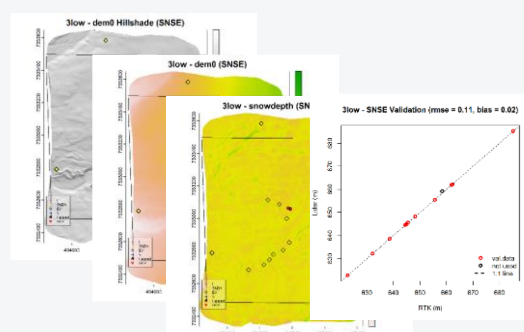
- Results of pre-operational test 2024

From research
to
Efficient data production

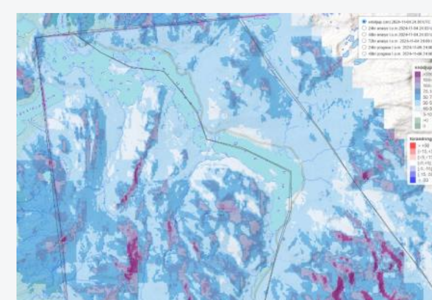
Optimize field workflow & spatial coverage



Automate data processing & quality control



Extrapolate data through model application



Optimization of survey design and workflow

Criteria for survey design and workflow:

- Different elevations, aspect, vegetation
- Consistent locations between years
- Ground truth data (depth, density, elevation)

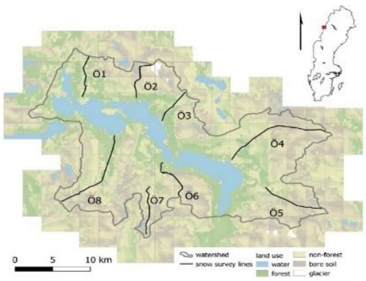
- Safety, accessibility, personel costs
- Line-of-sight surveys
- Battery duration / re-charge capacity
- Weather conditions

- RTK / mobile coverage vs. base station

- Maximize flight-time and minimize time for all other activities

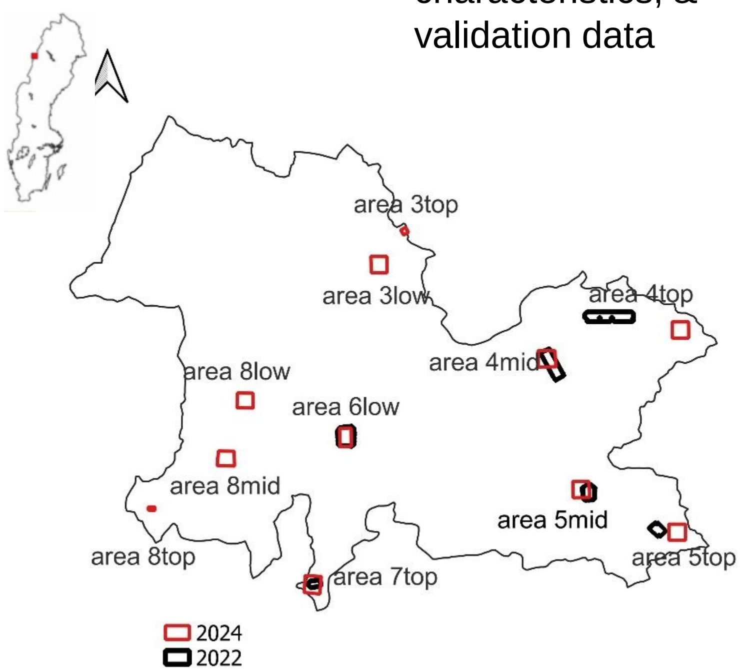
DRONES surveys in Överuman
2022: 6 survey areas, 3 persons
2023: 11 areas (7 fails) 5 persons
2024: 11 areas 2 persons

~1 week (7 days) incl. travel



Survey areas were distributed along existing GPR lines:

Know access routes & representation of topographical characteristics, & validation data



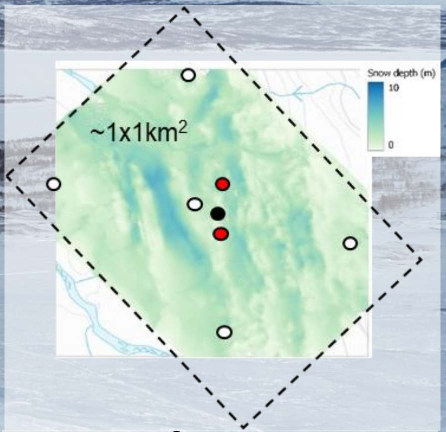
Field setup / workflow

drone pilot (unpacking / setup / flying / packing)

co-pilot (unpacking / ground control points / snow depth / density validation)

Equipment

- DJI M300, L1 LIDAR, RTK
- Handheld RTK-unit (snow surface elevation)
- Snow probes (depth)
- Snow tube (density)



~1x1 km² surveys:

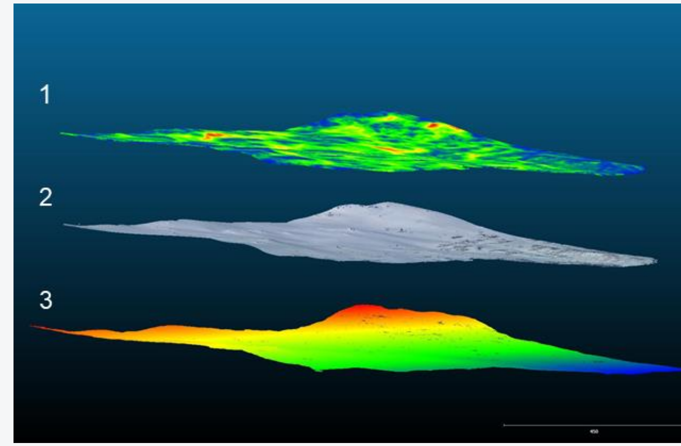
- Take-off (black dot)
- Lidar targets (red dot)
- Surface elevation, Snow depth/density (white dot)

efficient packing
battery charging

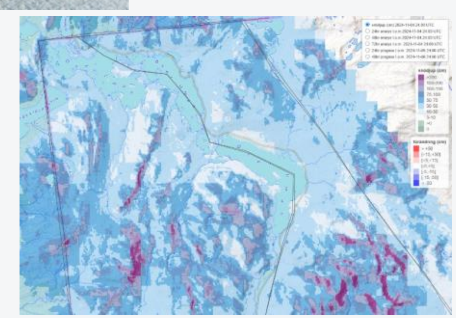
satellite internet for stable RTK

Drone data processing principle

- Lidar raw data = point cloud (xyz) surface reflections
- Rasterization of point cloud ➔ surface elevation DEM
- snow depth = snowsurface_dem – snowfree_dem*
- snowfree_dem = Lantmäteriets* Höjddata (1m)



- Correction of systematic errors and validation using manual snow depth and RTK elevation measurements
- Snow water equivalent, and extrapolation to entire catchment using snow density measurements and/or modelling tools

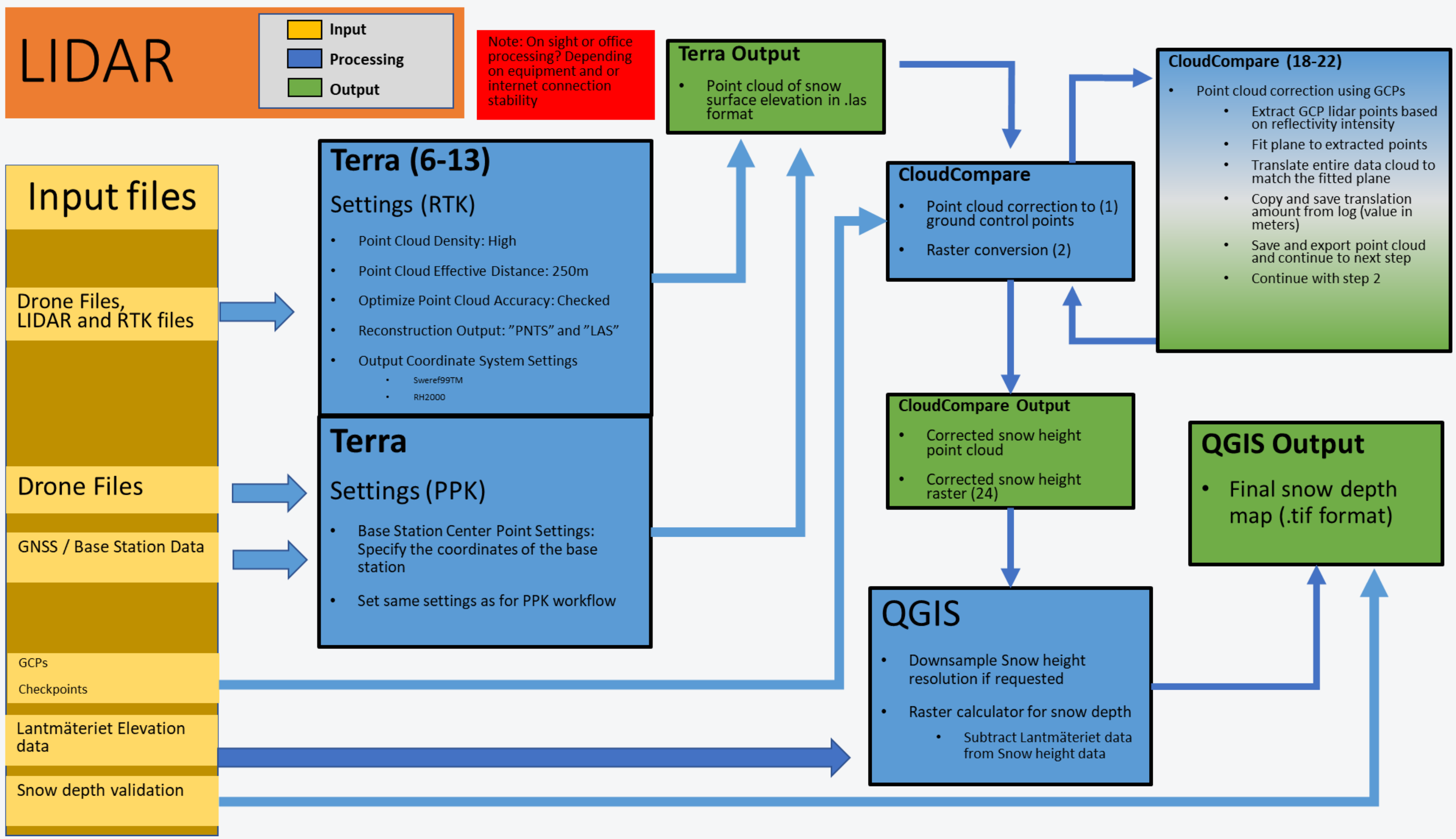


*The Swedish Mapping, Cadastral and Land Registration Authority

Manual processing workflow

SMHI

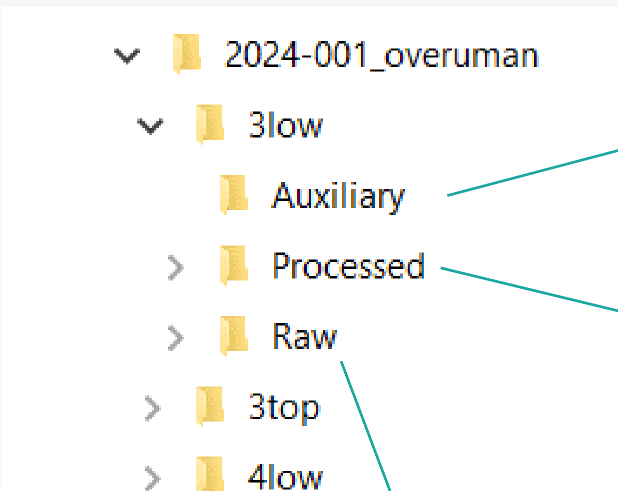
- Many input/output files, intermediate outputs, software tools
- Time-consumption/quality depending on experience
- Potential lack of transparency / re-producability



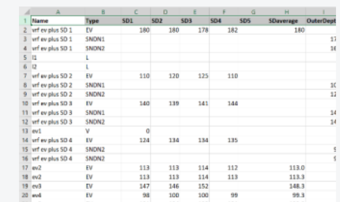
Operational processing workflow

1. Systematic organization of input/output data

Sub-folders for each survey area:

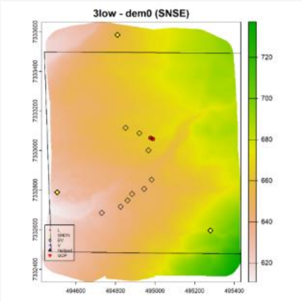


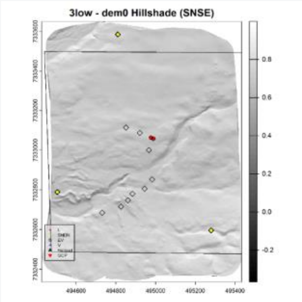
Auxiliary - Ground control data:
(RTK, snow depth, density)

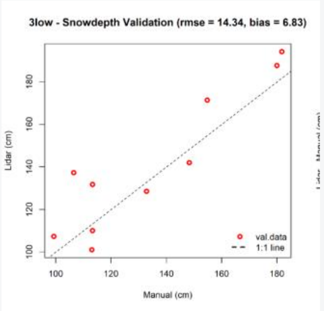


Processed data:

- Intermediate and final data and validation products
- Quicklook images for efficient verification







’Raw’ drone data:

- DJI-closed format (from survey)
- Open format (extracted in ’Terra’)
- Partly black-box

SMHI

Operational processing workflow

2. Reduce manual data preparation >> Automatic processing where possible

Terra

Raw

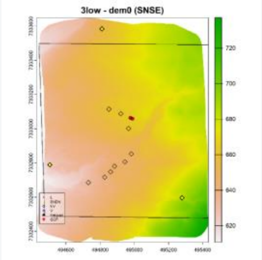
PPK, Text to spread sheet, etc

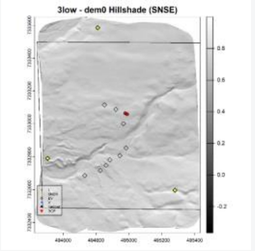
Aux

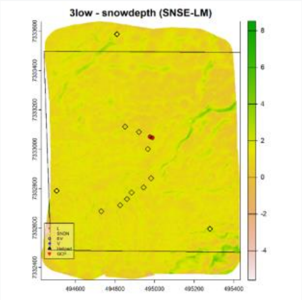
'snowlidR'
automatic processing using R and lidR:

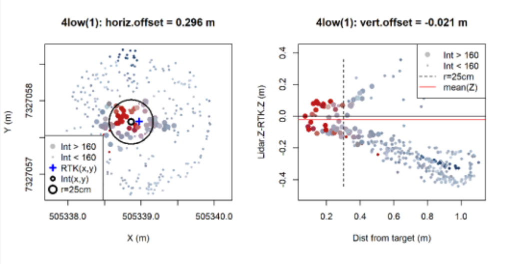
1. ground classification
2. pc to surface DEM
3. reference DEM
4. snow depth DEM
5. offset adjustment
6. validation

Proc







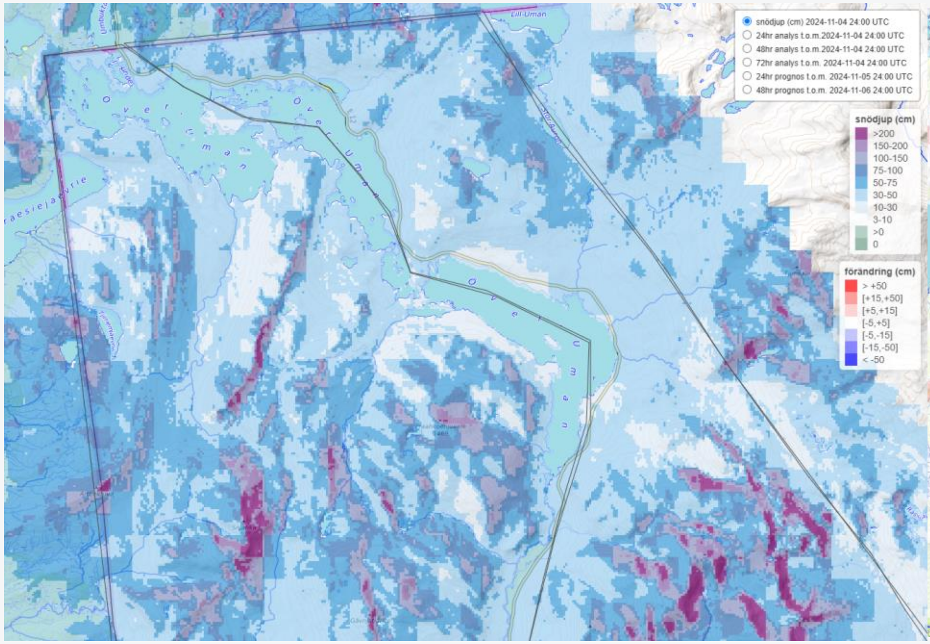


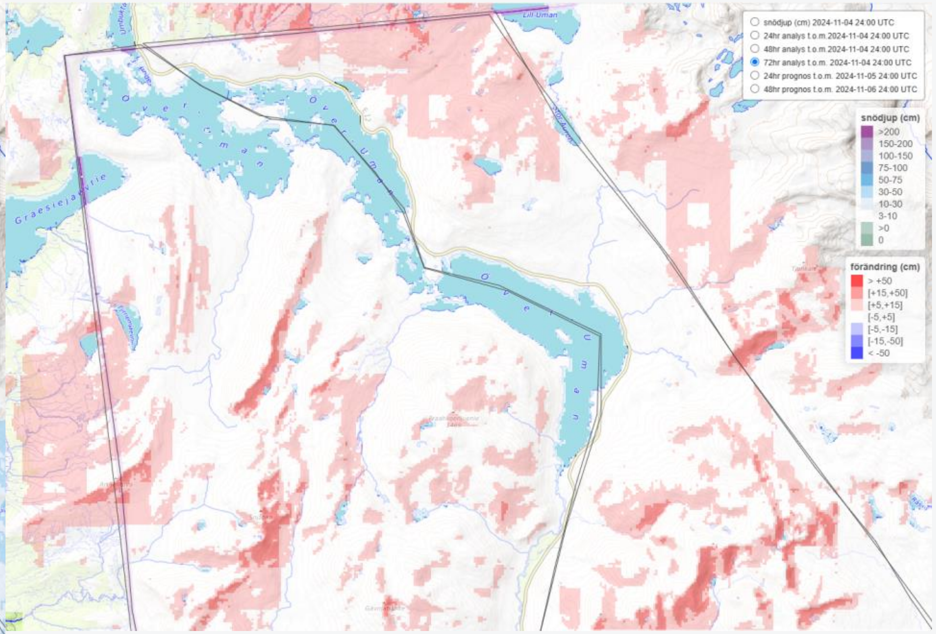
Field work | **Input preparation** | **Snow product generation**

Snow modelling informed by drone data

HYPE Snow distribution model developed in SNODDAS (Clemenzi et al, 2023) is further developed using the drone snow data.

- wind speed impact and explicit drift of old/new snow
- developed also for Naturvårdsverkets avalanche risk forecast unit





Conclusions & Outlook

SMHI

- 4-5 years trial and error converging towards efficient field workflows:
  - 2 persons is optimal for the drone survey itself
  - 2 more simplifies validation, remote area access, security, logistics etc

  - Weather challanges requires flexible planning, eg. last minute delay/extension of field trips

- Drone surveys provided additional information compared to traditional line surveys and point observations.

- Work to improve the snow models with the new data is still in progress