Unmanned aerial vehicle remote sensing of snow: improving snowmelt prediction

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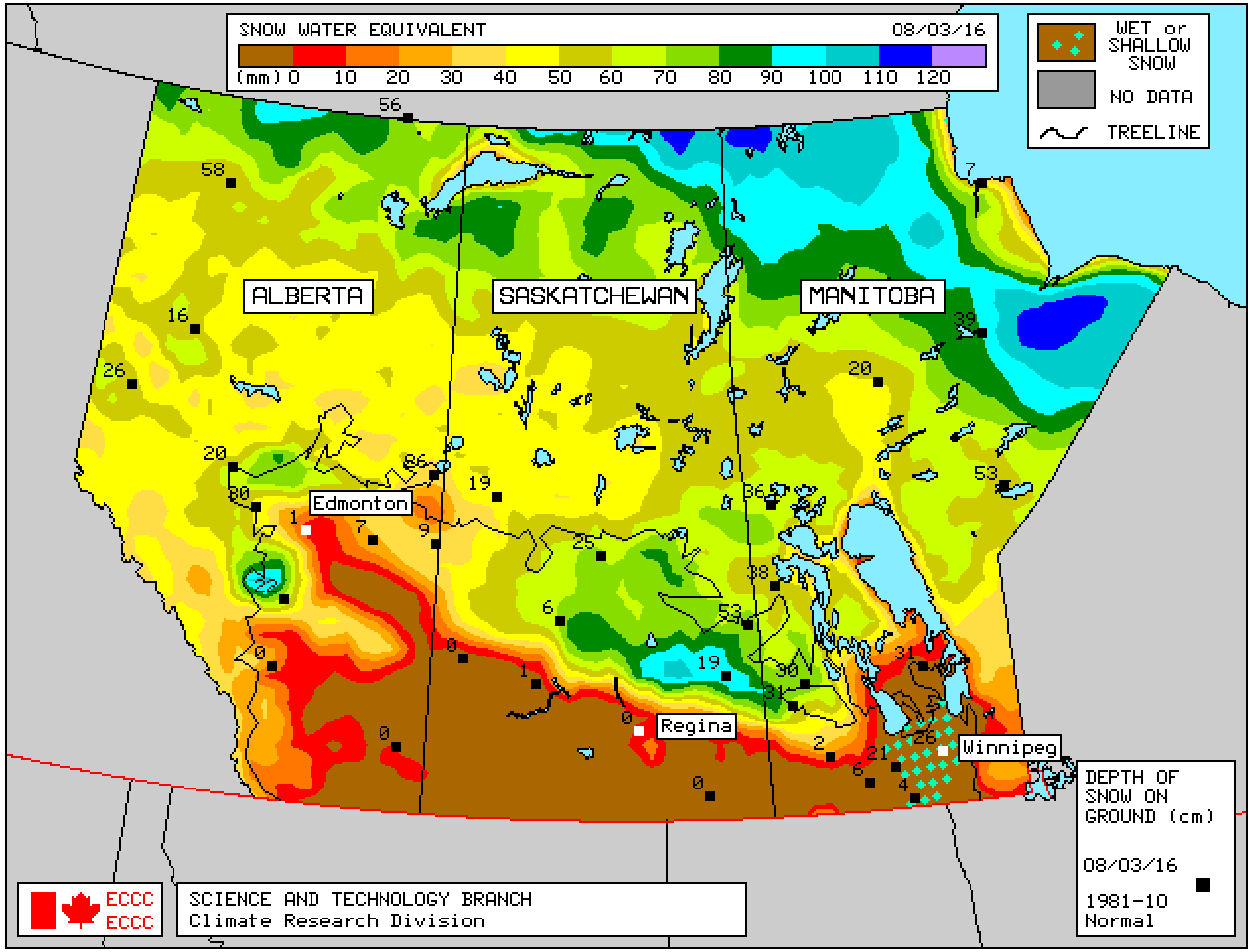
Why do we want to improve snow melt predictions?

- Snowmelt is often the most important hydrologic event in on the Prairies
  - snow melt = runoff + infiltration
  - agriculturally significant
    - for every 25mm of water over a base requirement wheat yield increased by 3.5-6 bu/acre
- Hydrologic models struggle with representing thin, patchy snowcover
- Snow is traditionally quantified with snow surveys

Research Gap

- To improve the understanding of prairie snowmelt high spatio-temporal resolution data of snow depth and extent is needed
- Remote sensing struggles to capture snow depth and water equivalent
- Snow covered area can be measured, but:
    - Satellite imagery cannot observe:
        - Small scale heterogeneity
        - Rapid changes during melt
    - Repeat aerial imagery costs are prohibitive



Unmanned Aerial Vehicles

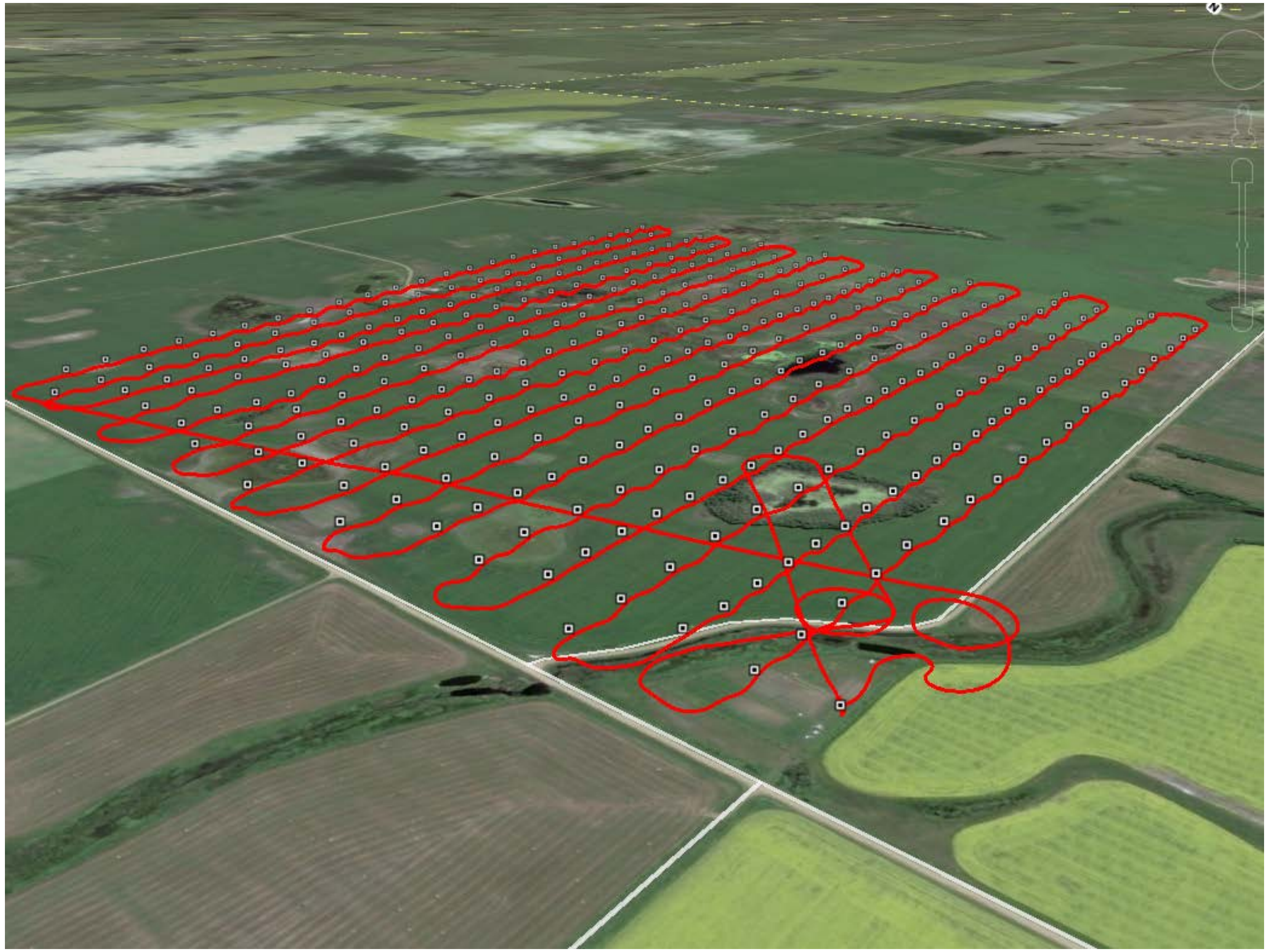
- Come in all shapes and sizes
- Can carry variety of sensors
  - commonly RGB camera
  - NIR
  - thermal
  - ……….
- Deploy on demand
- Can fly under cloud cover
- Subject to regulations which are still evolving

Objectives

To assess the utility of Unmanned Aerial Vehicles (UAVs) to quantify and improve the prediction of Prairie snowmelt

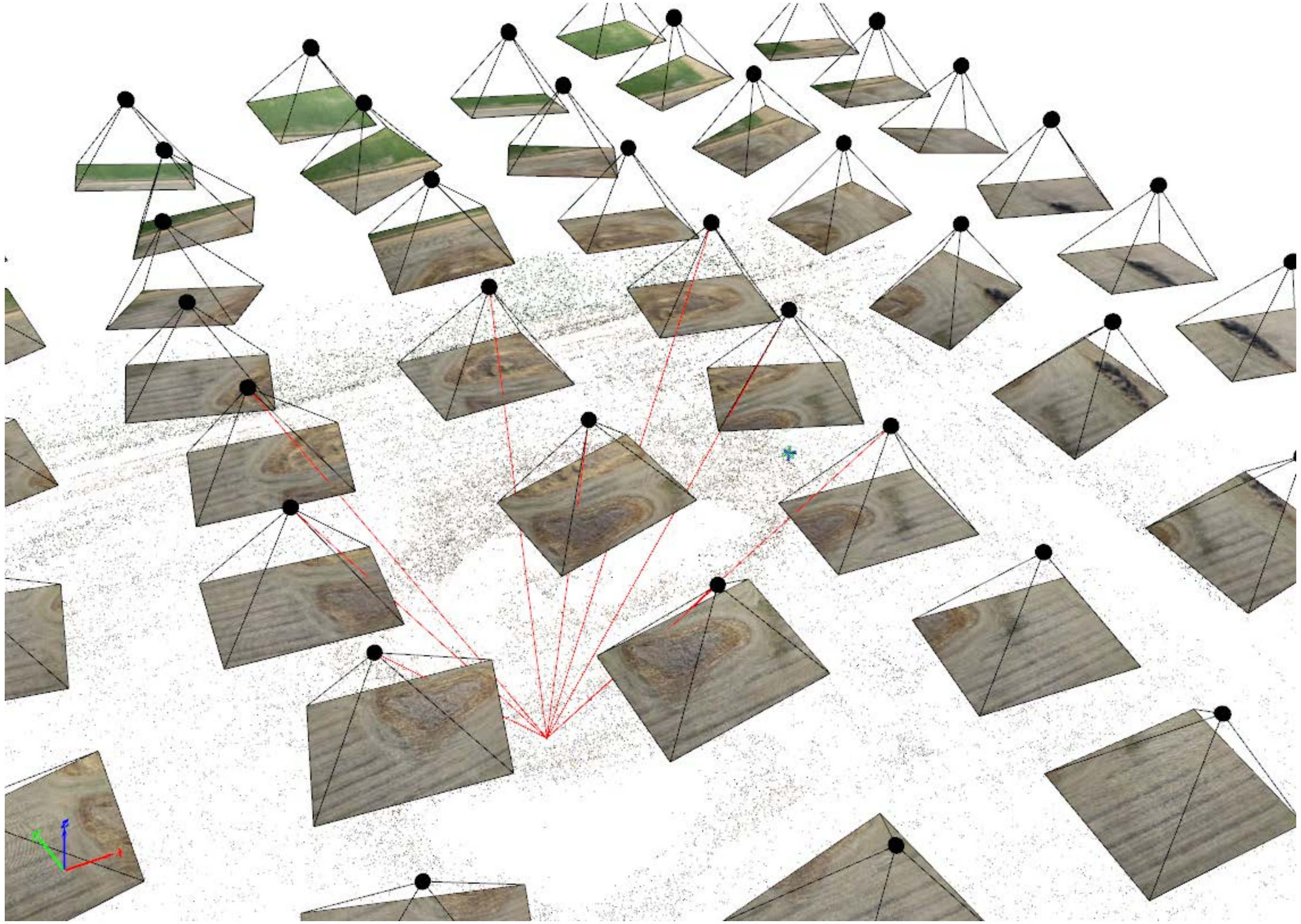
Sensefly Ebee RTK

- Autonomous platform
- Can cover a quarter section in <40 minutes
- Images are geotagged at an accuracy of <2.5cm



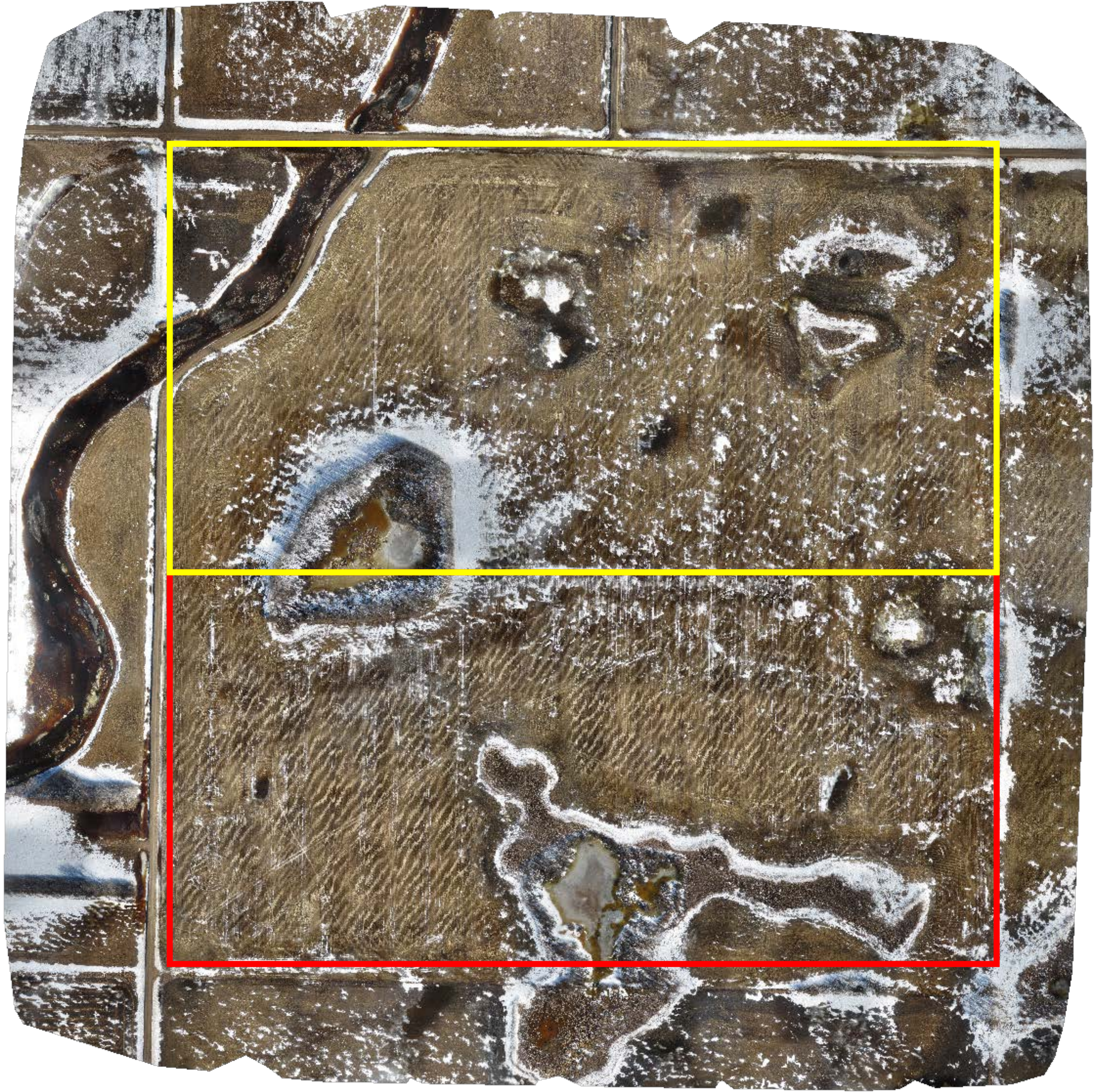
Structure from Motion (SfM)

- SfM resolves 3D structure from 2D images
- Produces a point cloud from the identification and triangulation of common features from multiple images
- Georeferenced orthomosaics and Digital Surface Models (DSMs) are generated if :
  - camera locations are known
  - locations of features in images are known

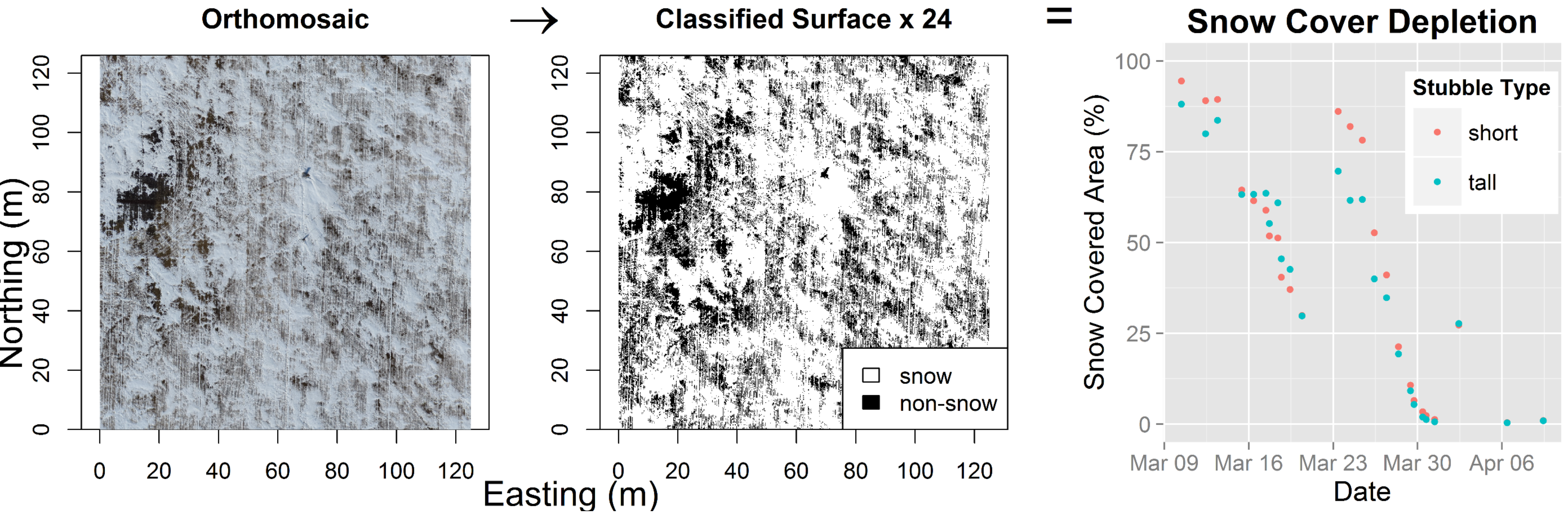


Site

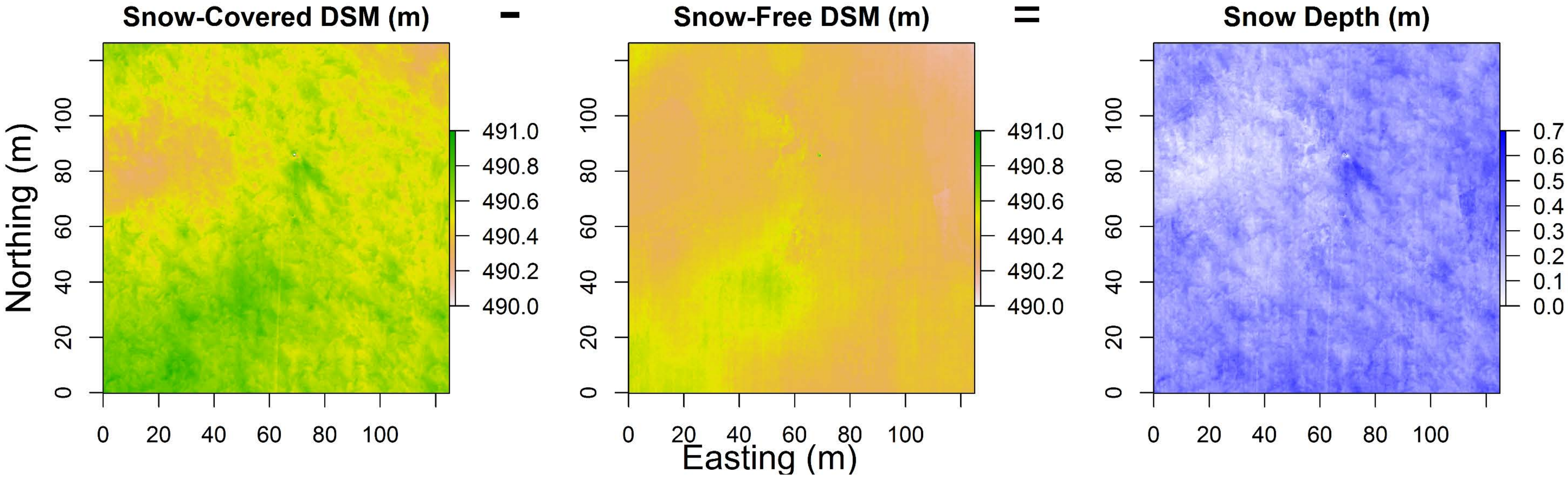
- Wheat field near Rosthern, SK
- Short (15cm) and tall (35cm) standing wheat stubble
- Flat terrain with significant blowing snow redistribution



Snow Covered Area



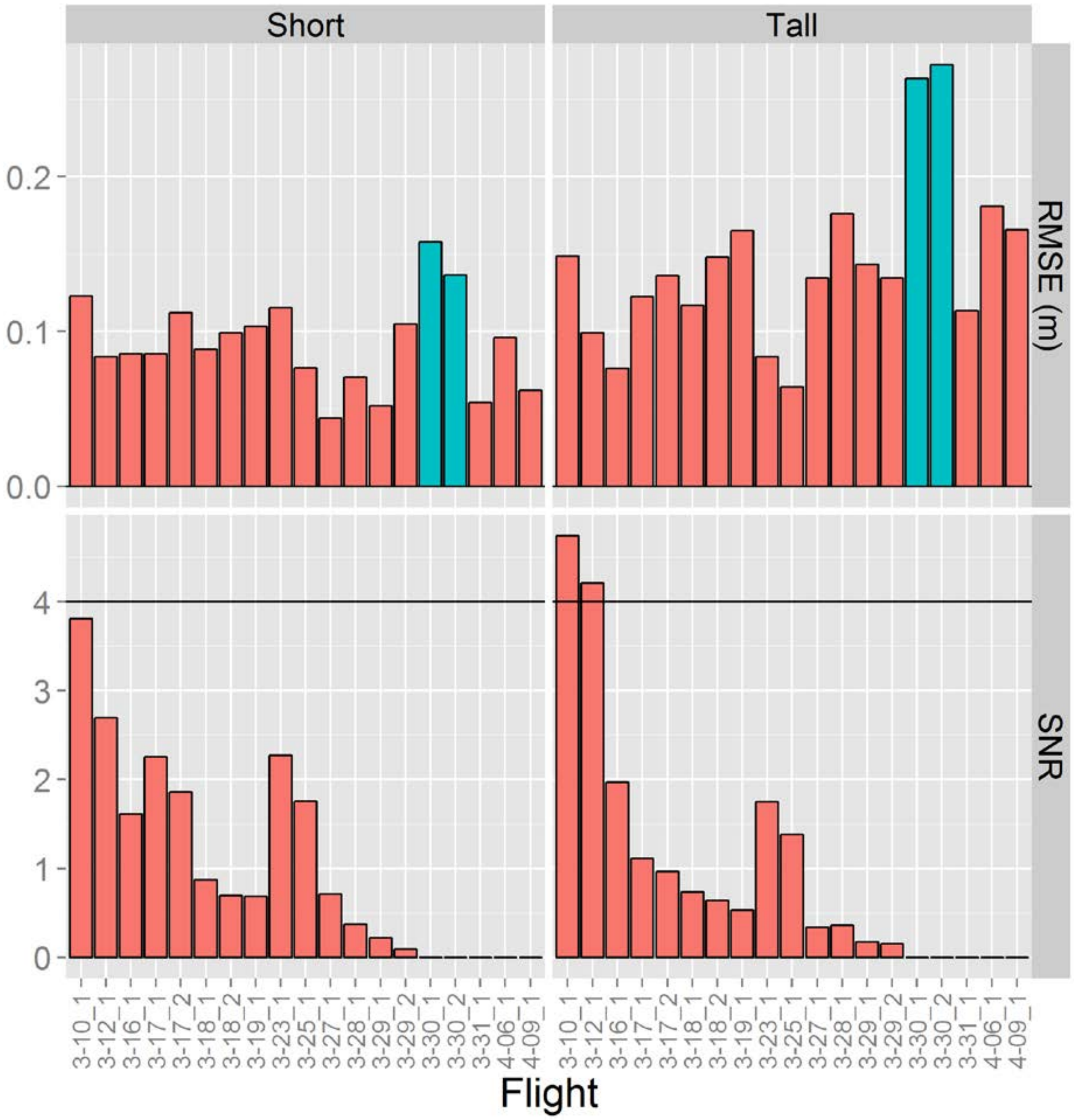
Snow Depth



Snow-Covered DSM (m)
-
Snow-Free DSM (m)
=
Snow Depth (m)
Northing (m)
Easting (m)
0
20
40
60
80
100
491.0
490.8
490.6
490.4
490.2
490.0
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

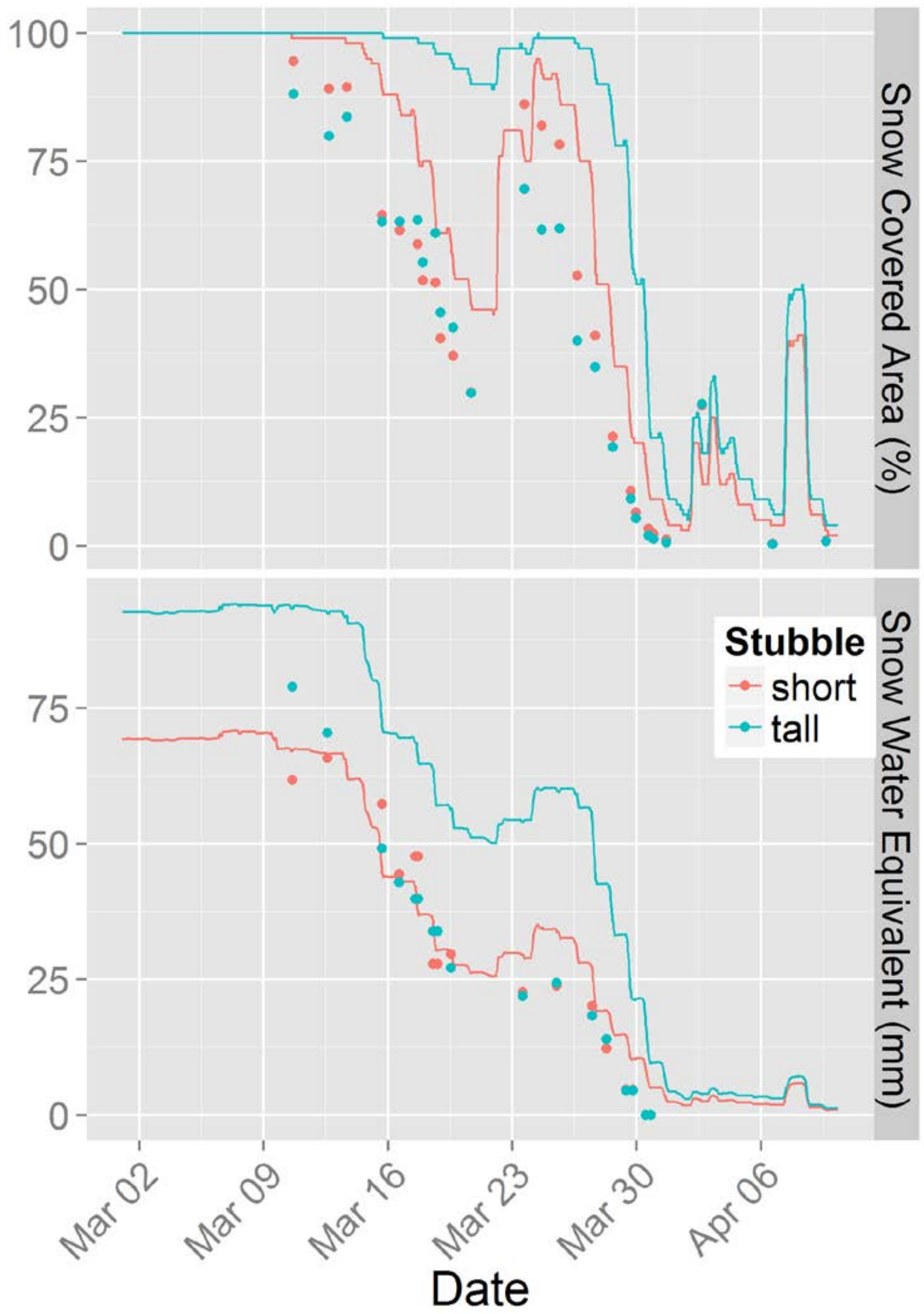
Accuracy of Snow Depth Estimation

- Accuracy assessed w.r.t. manual snow depth observations
- Vertical accuracy with SfM is theoretically 2x the horizontal resolution
  - Actual RMSE < 15cm
- Signal-to-Nosie ratio suggests only peak snow depths can be reliably measured



Modelling Snowmelt

- Three Source Area Model (3SOM): represents snowmelt of a heterogeneous surface (snow, vegetation and bare ground)
- Inputs include:
  - Pre-melt snow depth standard deviation and mean
  - Peak snow density
  - Vegetation distribution
  - Hourly meteorological data
- 3SOM assessed against UAV derived SCA and snow survey observed snow water equivalent (SWE)
  - Tall stubble confounds assessment of modelled SCA and SWE



Conclusions

- UAVs can:
  - Quantify snow-covered area in presence of exposed vegetation at a resolution previously impossible
  - Measure snow depth distribution prior to melt
- UAVs cannot:
  - Measure the spatial variability of snowmelt in shallow snow with exposed vegetation
- UAV derived snow depth properties can be used to improve the modeling of snow melt
  - 3SOM modelling identifies a deficiency with respect to tall stubble representation

Why does this matter to a soils and crops crowd?

- Snowmelt water is crucial for crop production
- Previously unable to obtain high resolution spatially distributed snow depth data

The challenge:

- Can the spatial distribution of snow and snowmelt be related to variables relevant to crop growth?
- Could this information be leveraged in precision ag systems to improve crop production?