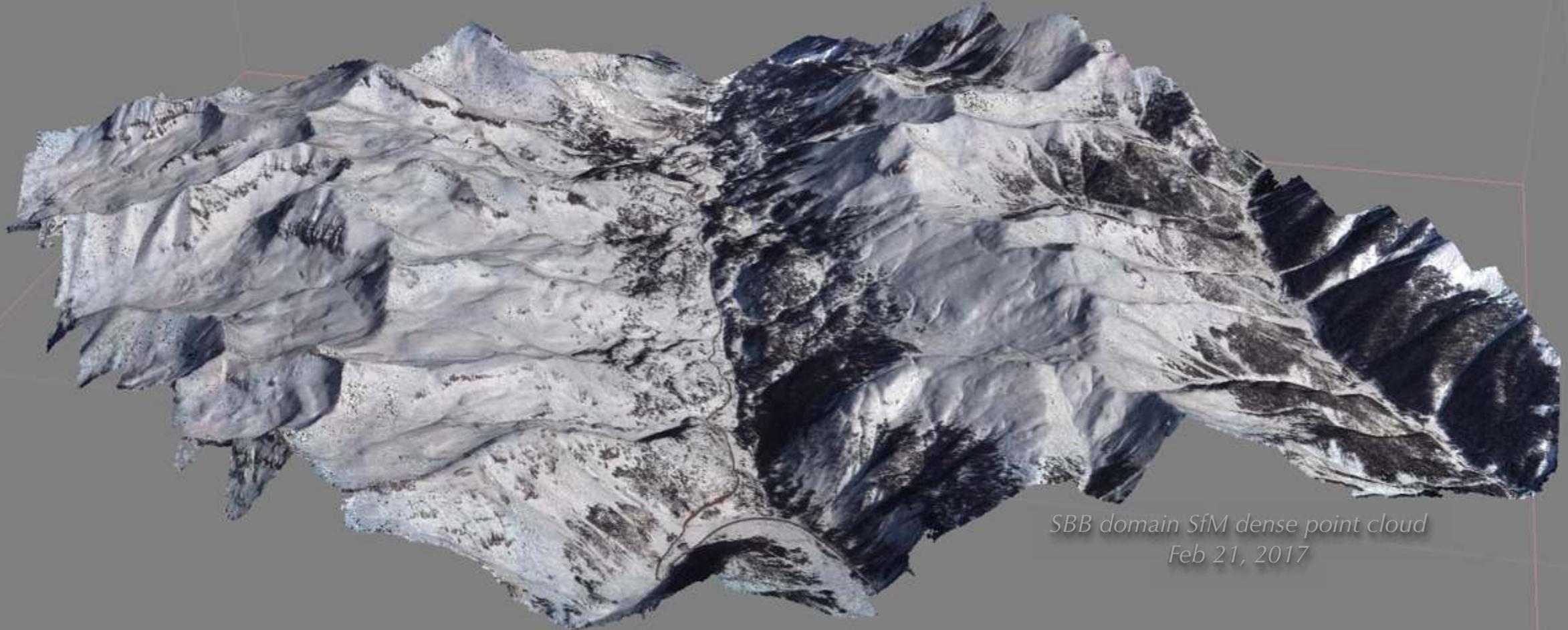


Applying Structure-from-Motion to Airborne Snow Observatory imagery from SnowEx Year 1 to build high resolution surface models



*SBB domain SfM dense point cloud
Feb 21, 2017*



S. McKenzie Skiles¹, Jeremy Andreini², and Steven Clark¹

¹ Department of Geography, University of Utah

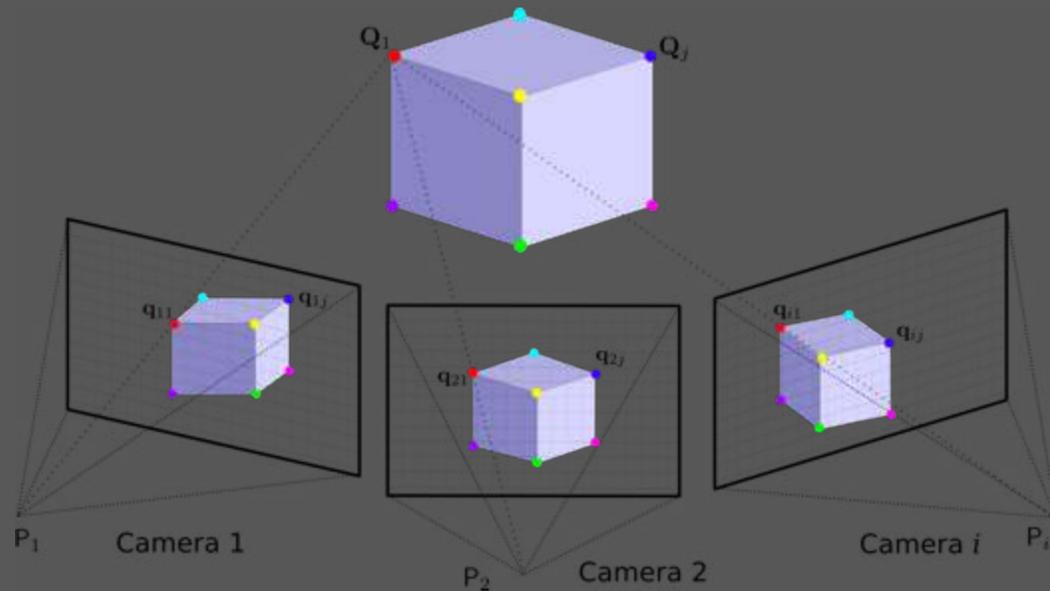
² Department of Earth Science, Utah Valley University



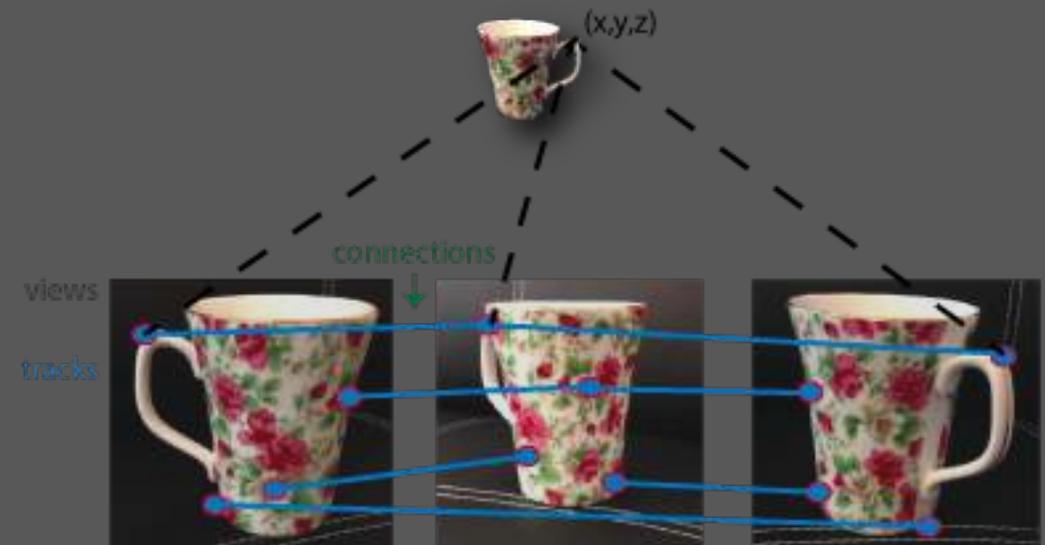
Background

- Structure from Motion

- A photogrammetric method that uses overlapping 2d images to estimate the 3d structure of an area or object



Julien Michot



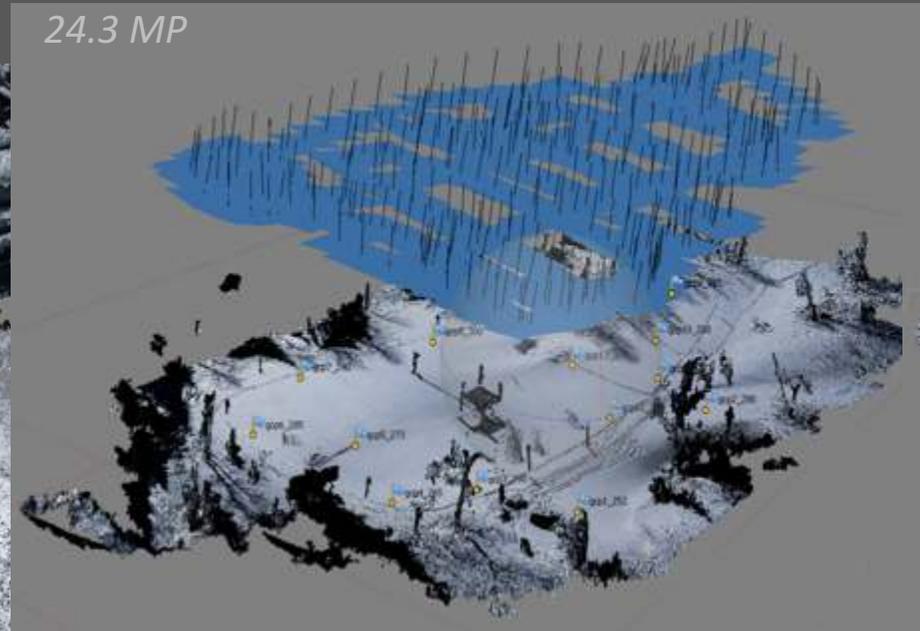
Mathworks

Background

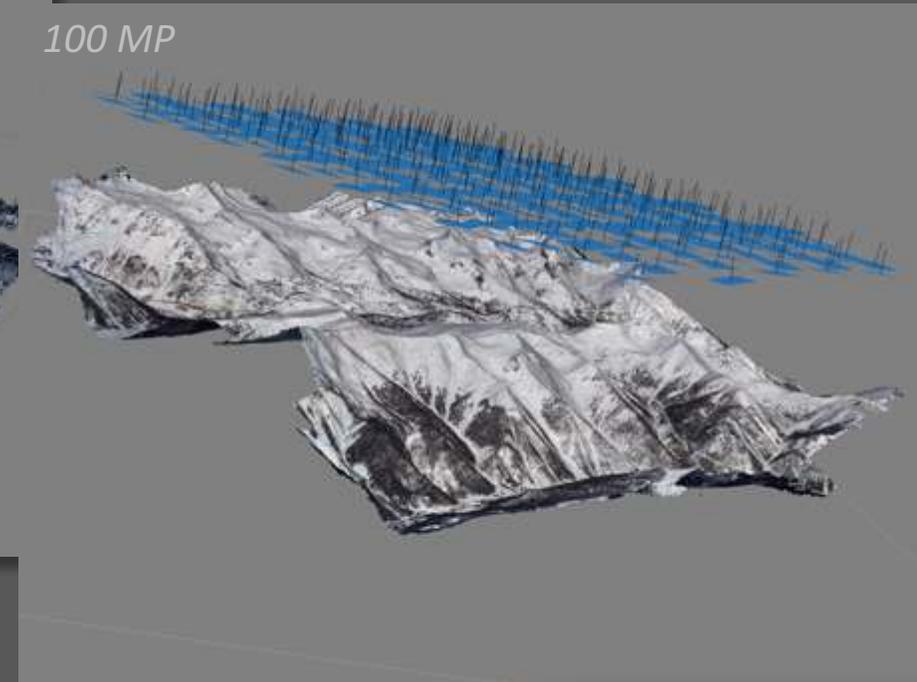
- Structure from Motion
 - Flexible and scalable depending on desired target, camera functionality, and platform



*Fire Hydrant: ~20 pictures
(person + smartphone)*



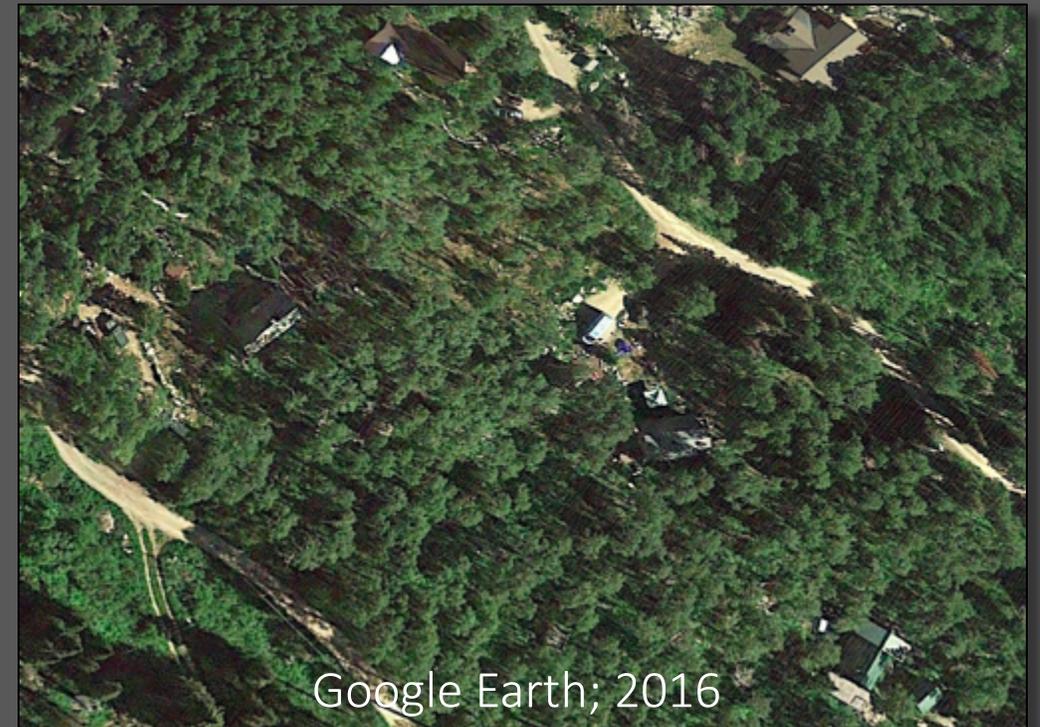
*Atwater Study Plot: ~100 pictures
(DJI Phantom 2 + Sony A5100)*



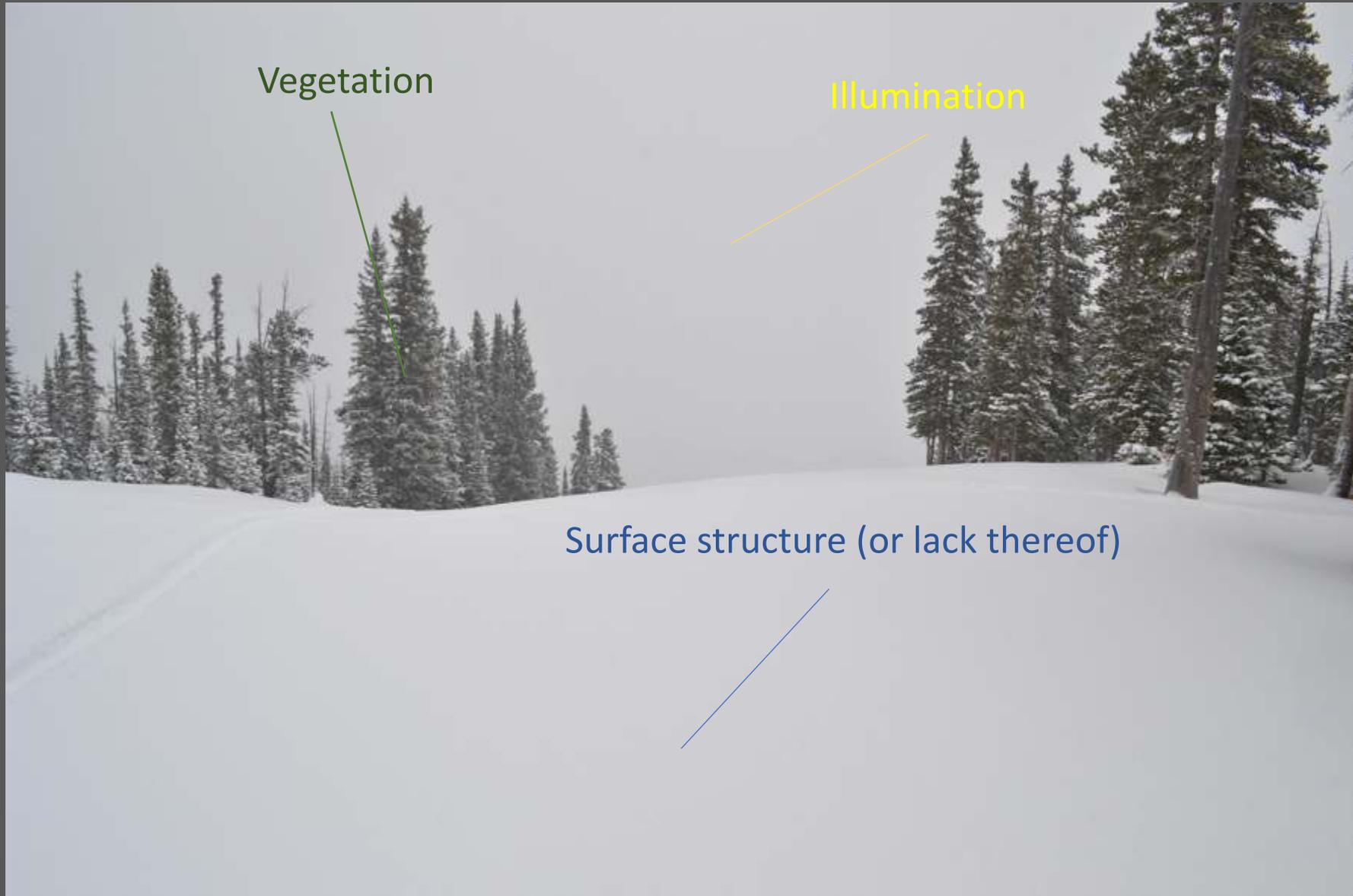
*Senator Beck Basin Domain: ~350 pictures
(King Air A90 + Phase One A/S iXU180-R)*

SfM and Snow: Motivation

- Same concept as differential mapping with lidar
 - Low cost and effective (lidar is expensive, cameras are cheap)
- Rapidly advancing UAV technology
- High resolution lidar from space vs high resolution imagery from space

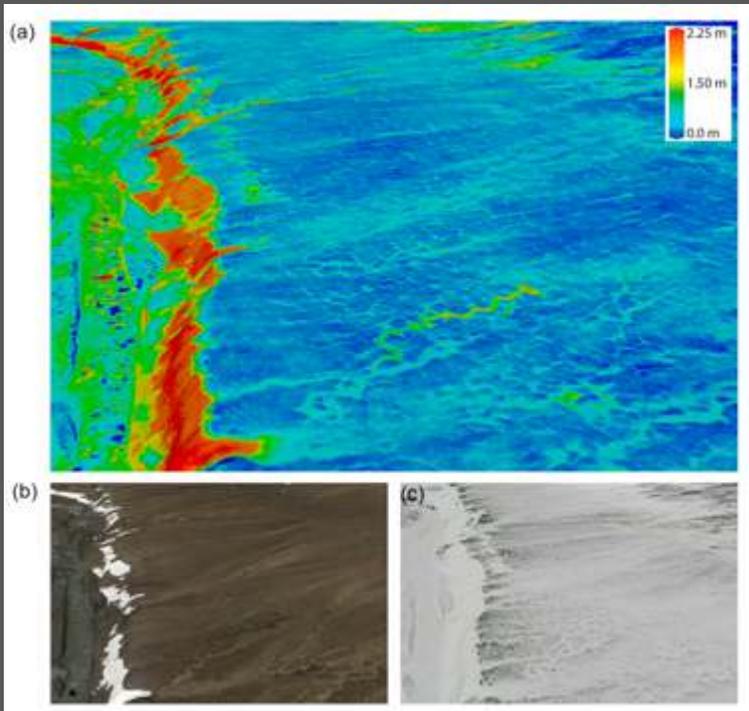


SfM and Snow: Challenges

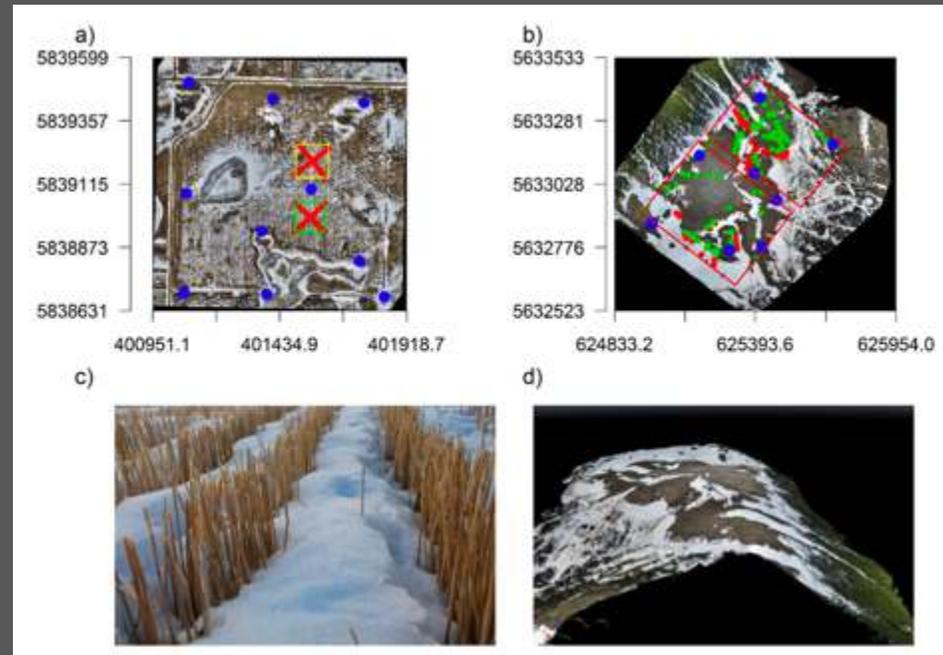


SfM and Snow/Ice: Previous Work

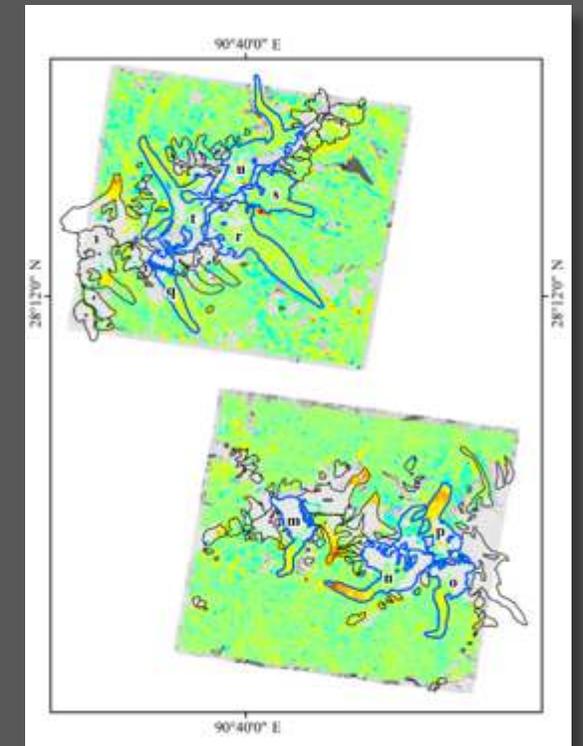
AK Arctic, manned: *Nolan et al., 2015*



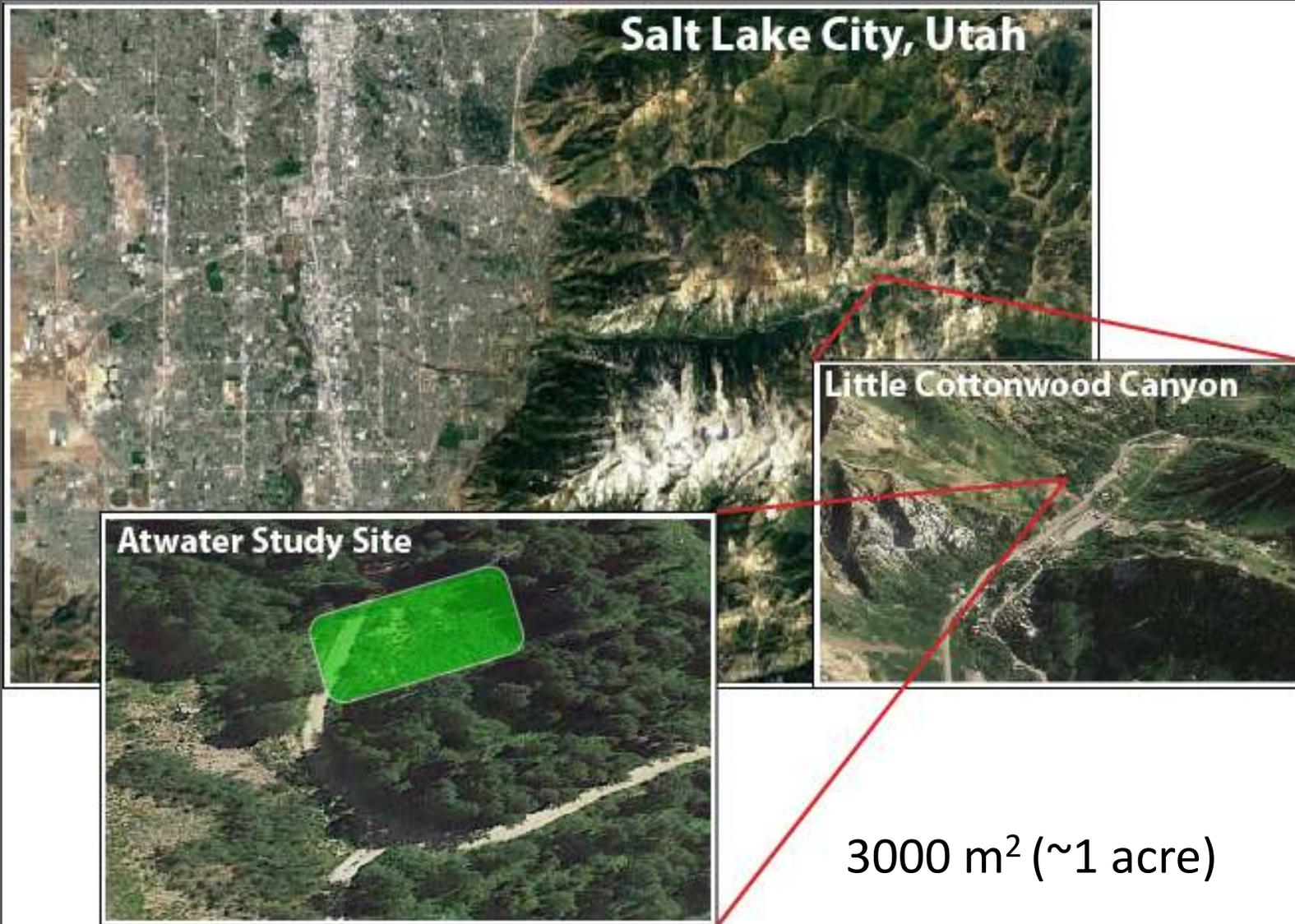
Canadian prairies and mountains, unmanned: *Harder et al., 2016*



Himalaya glaciers, spy imagery & ASTER: *Maurer et al., 2016*



Case Study: Atwater Study Plot, LCC, UT



Case Study: Atwater Study Plot, LCC, UT



3000 m² (~1 acre)



Case Study: Atwater Study Plot, LCC, UT



Ground control point locations

Case Study: Atwater Study Plot, LCC, UT

NGB Camera



RGB Camera



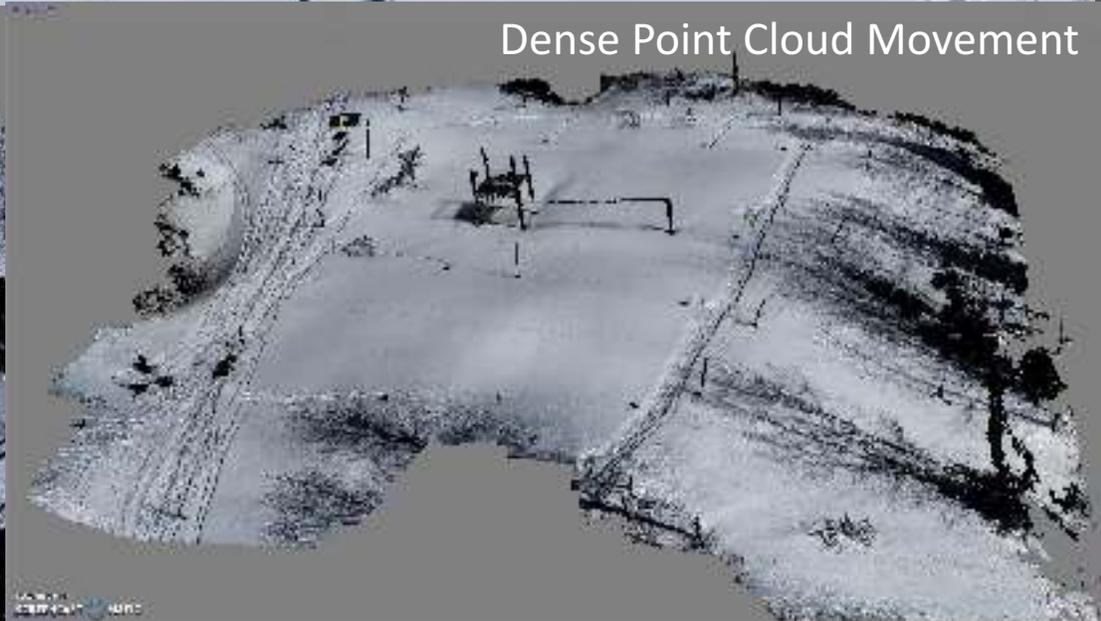
Sparse Point Cloud



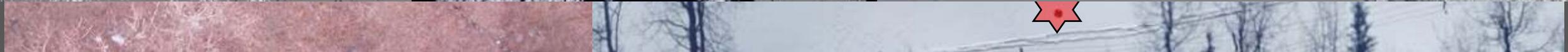
Dense Point Cloud



Dense Point Cloud Movement



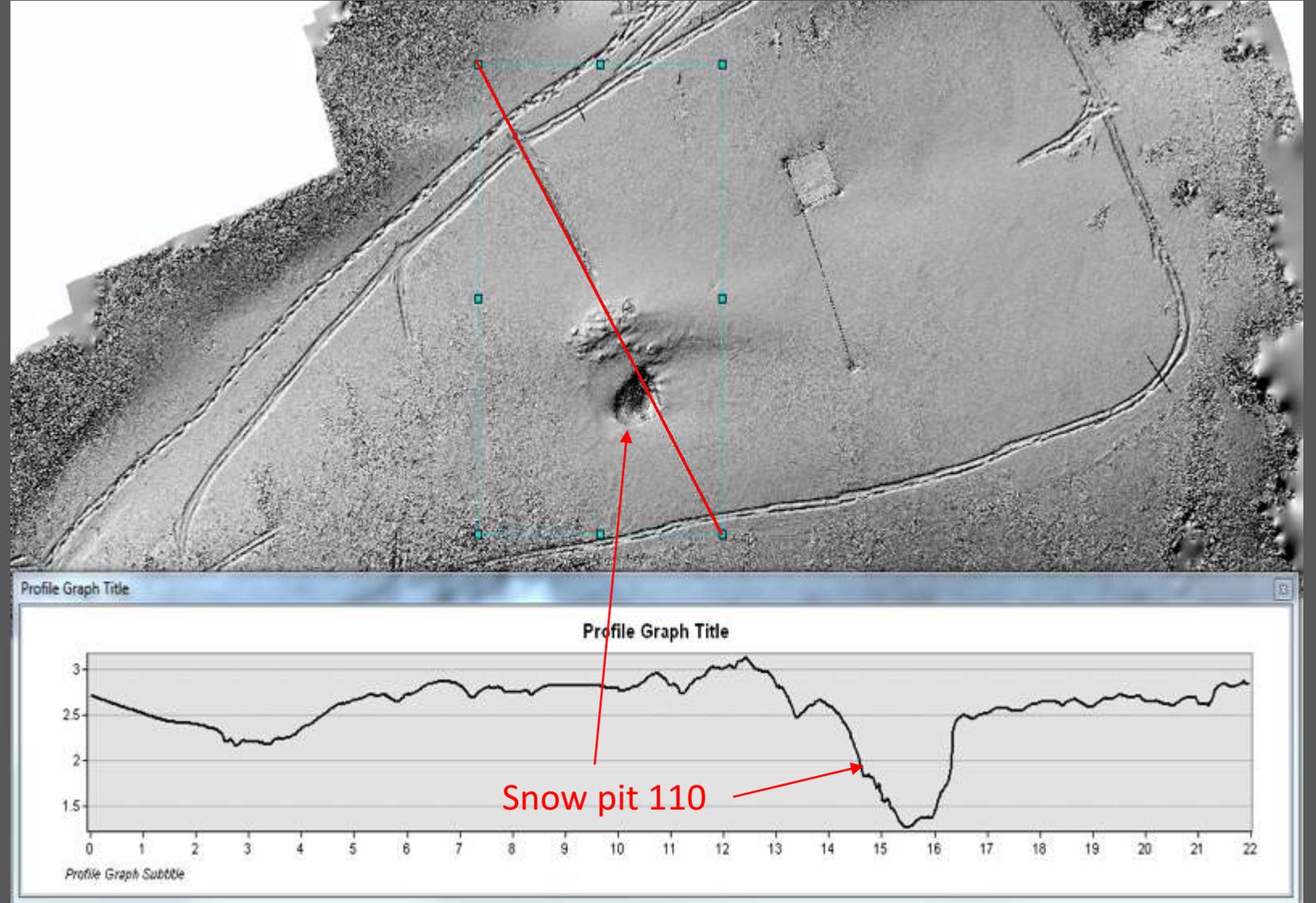
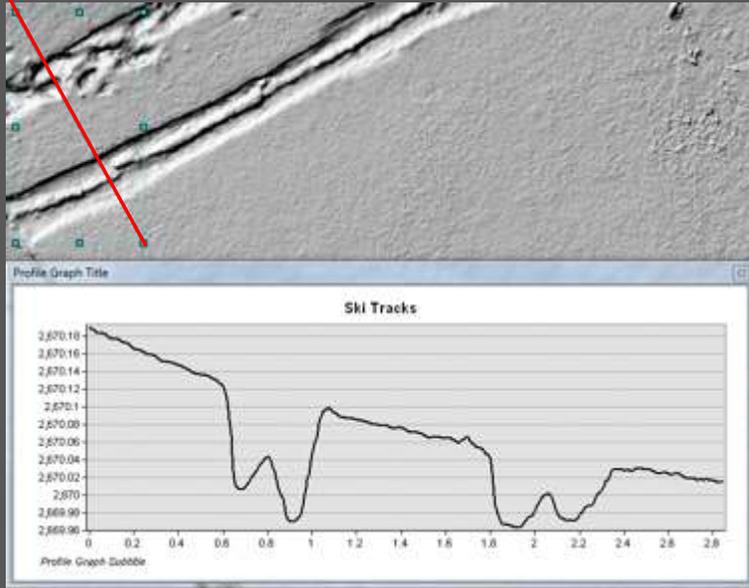
Ground control point locations



Case Study: Atwater Study Plot, LCC, UT

- Elevation Profile across the DSM March 7th, 2017

Elevation profile across ski tracks



Case Study: Atwater Study Plot, LCC, UT

Orthophoto
March 7th, 2017

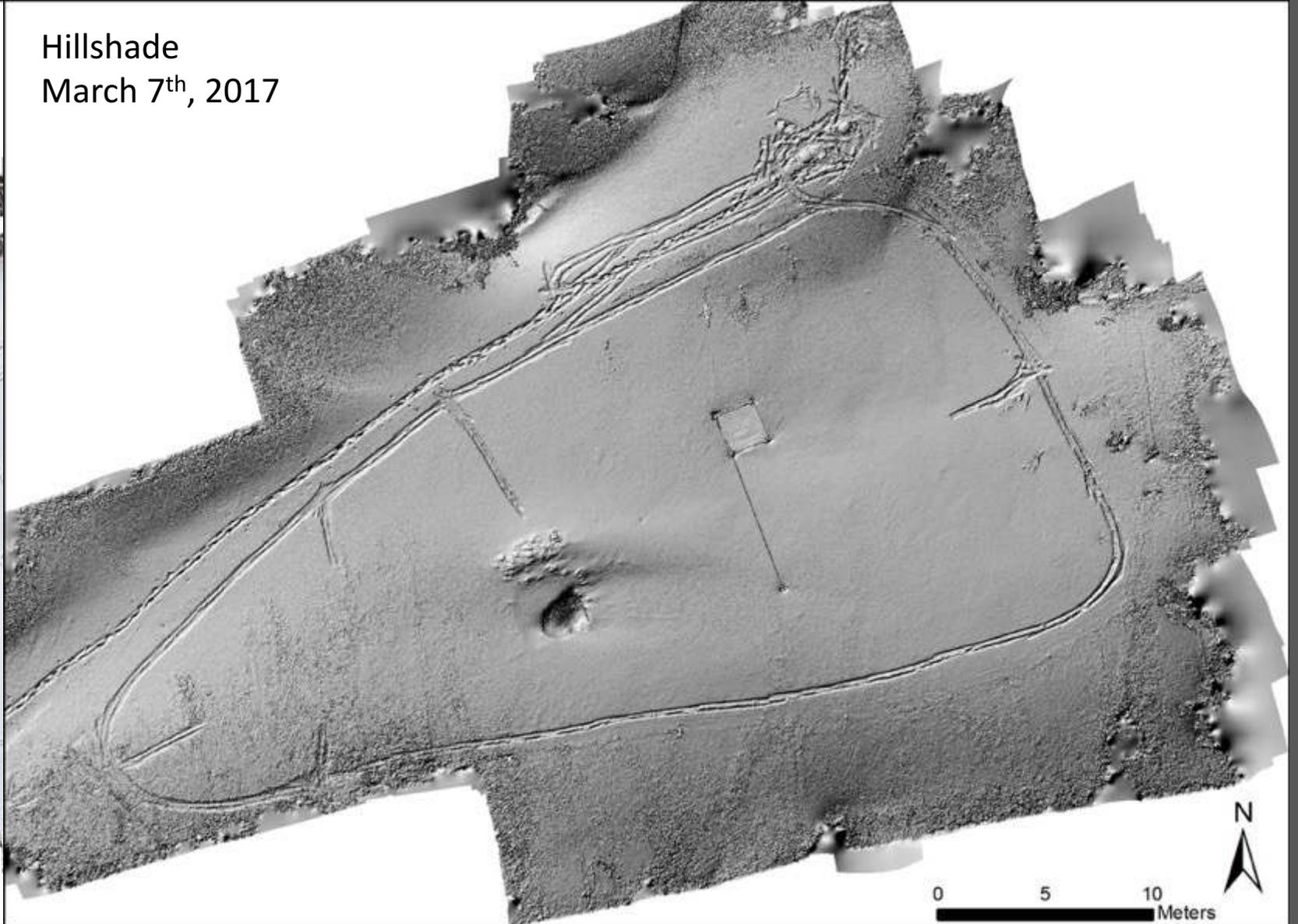


Case Study: Atwater Study Plot, LCC, UT

Orthophoto
March 7th, 2017



Hillshade
March 7th, 2017

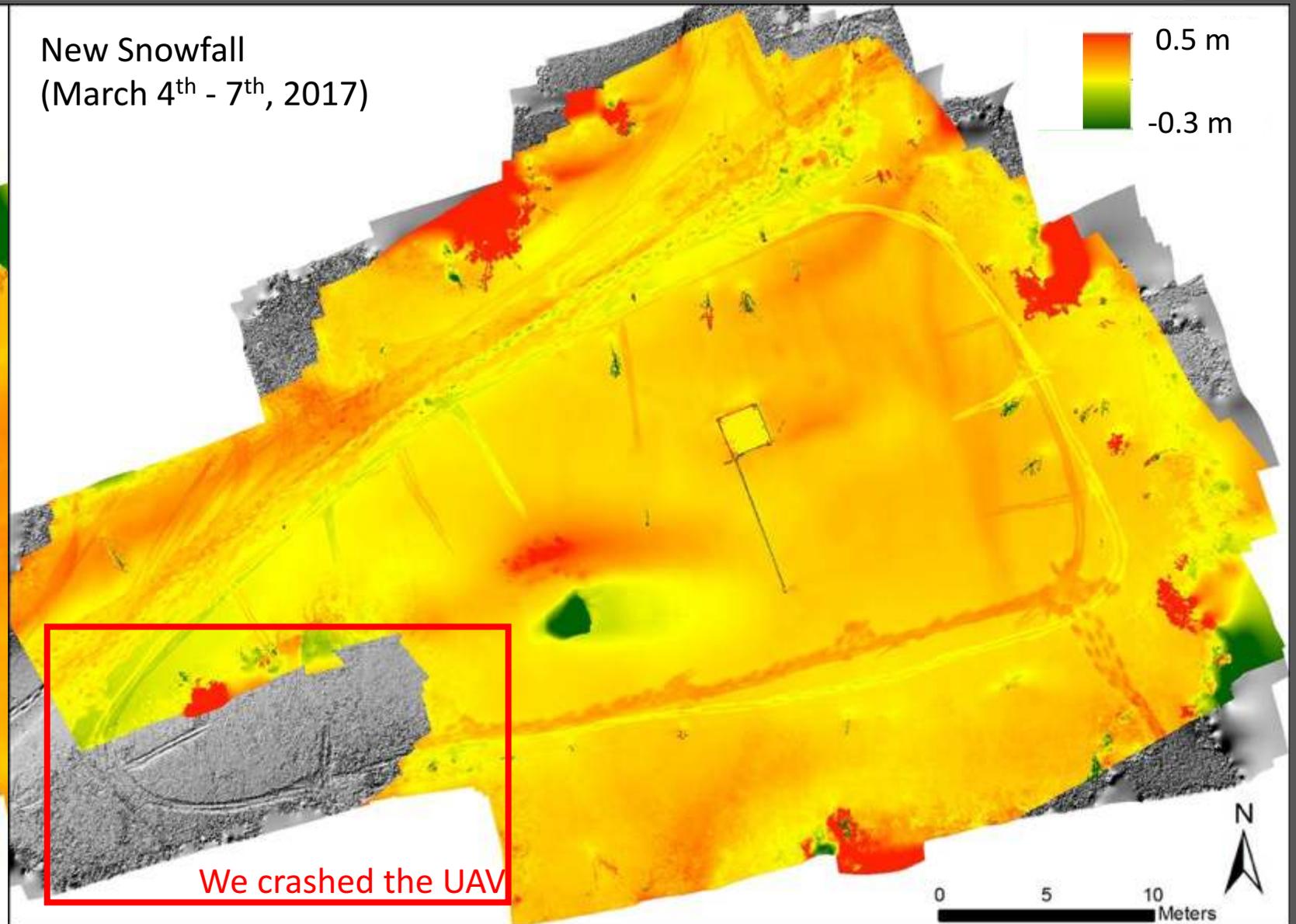


Case Study: Atwater Study Plot, LCC, UT

Total Snow Depth
March 7th, 2017

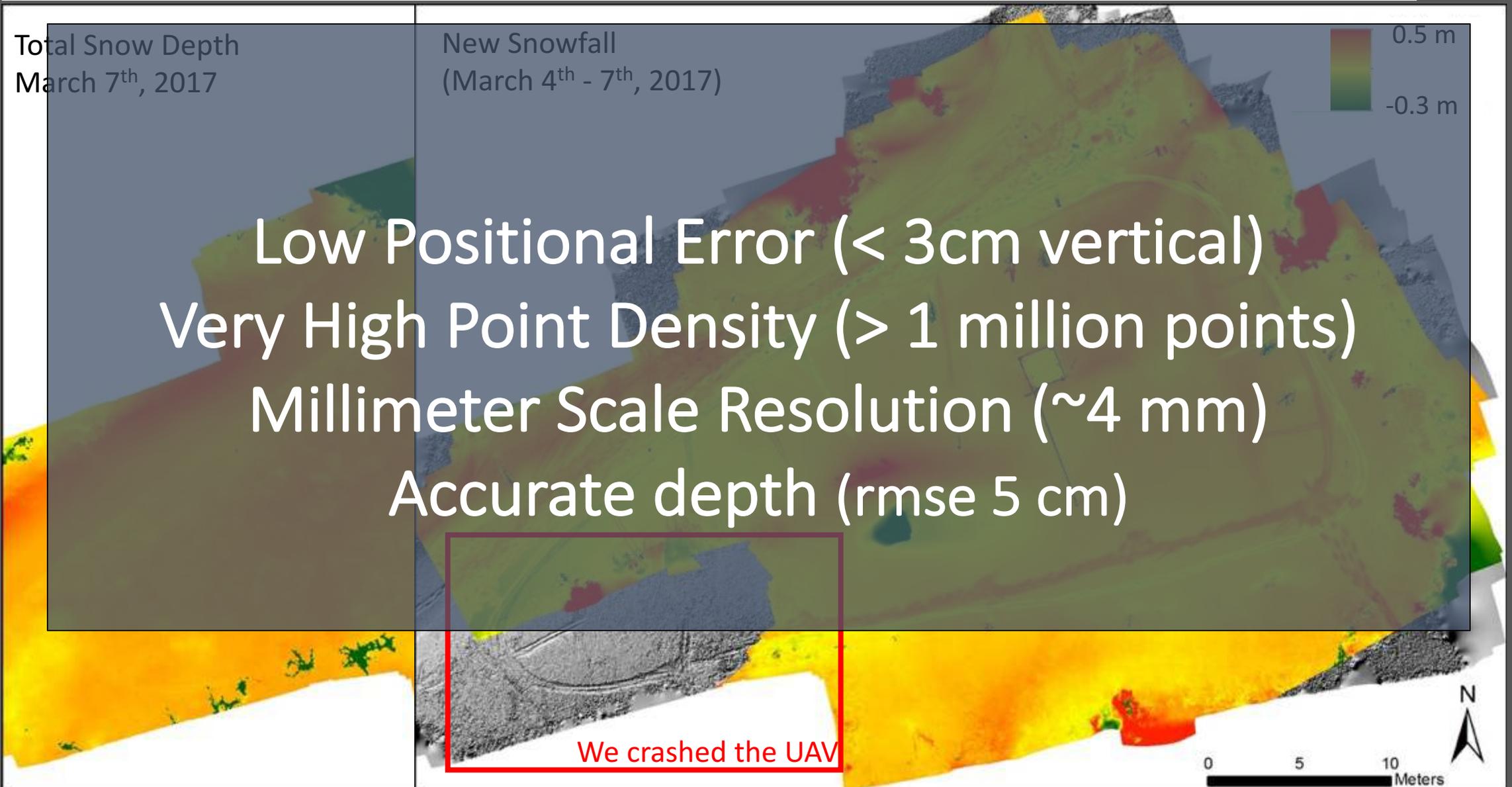


New Snowfall
(March 4th - 7th, 2017)



We crashed the UAV

Case Study: Atwater Study Plot, LCC, UT



Scaling Up: ASO and SfM

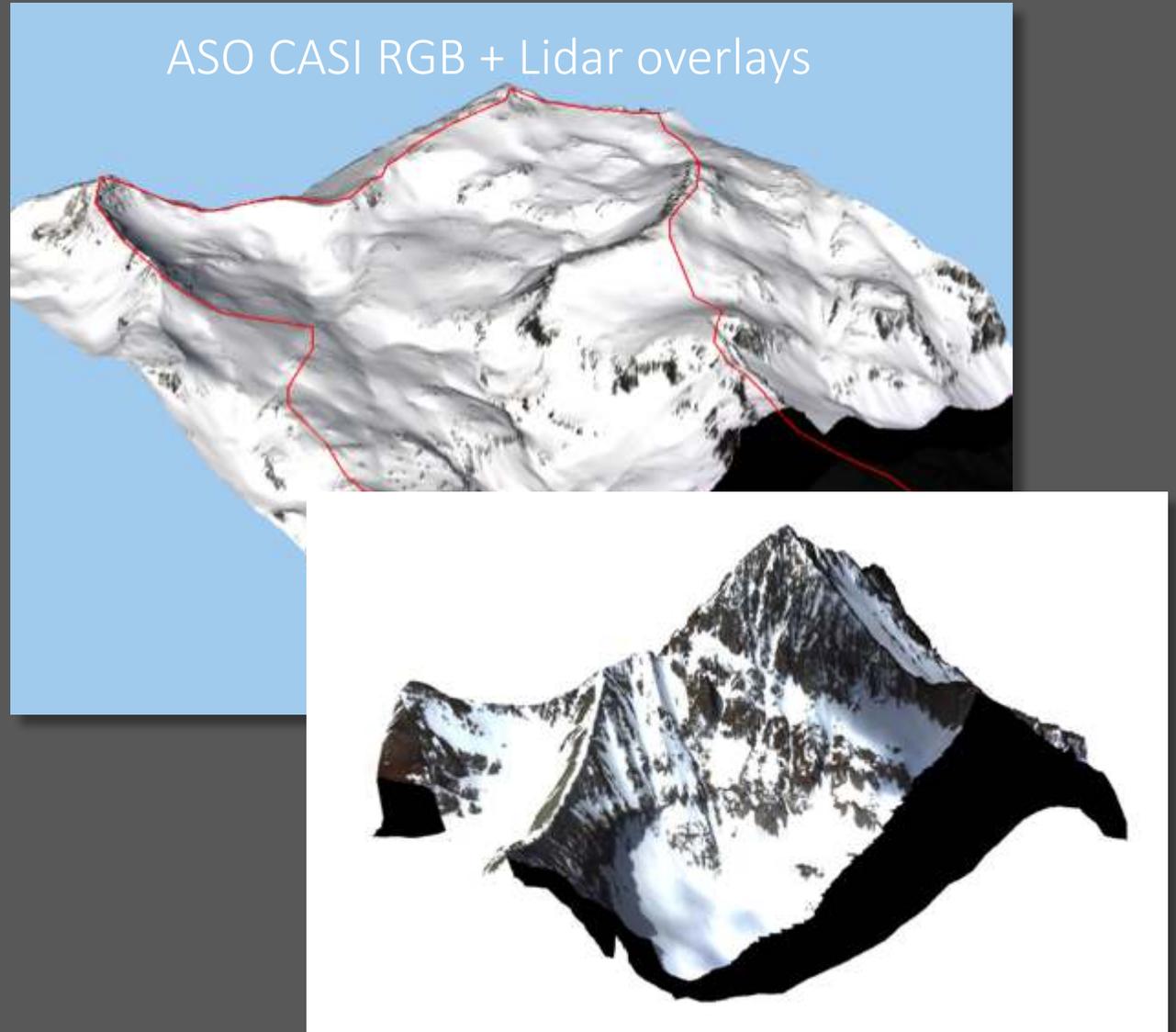
- Plot scale → watershed scale
(e.g. 1 acre to 1000 acres)
- RGB camera integrated with lidar unit (separate from CASI imaging spectrometer)
- Because flight lines are optimized for the CASI there is sidelap built in
- Acquisition timing is manually set, so frontlap can be optimized

video

video

Scaling Up: ASO and SfM

- Status quo for ASO: snow depth from lidar, RGB/classification/albedo (++) from imaging spectrometer
- The integrated Phase One medium format 100 mp RGB is intended to colorize the point cloud
- Here, I show you can also use the imagery to build DSMs via SfM



Surface Model: SBB 2/16



- Image tie points,
100 images
- 12 sec acq rate



Surface Model: SBB 2/16



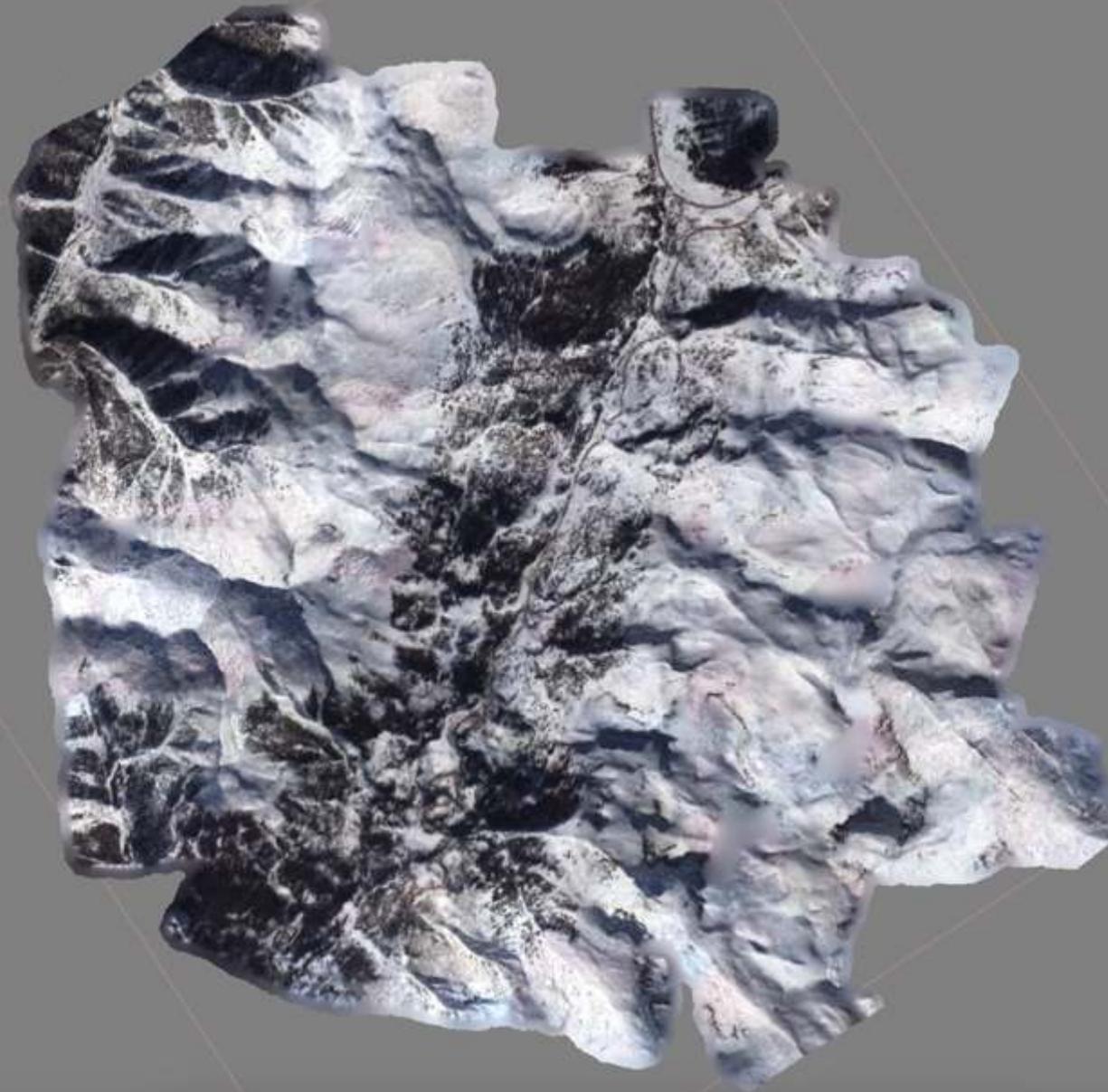
- Dense cloud, > 7 million points



Surface Model: SBB 2/16



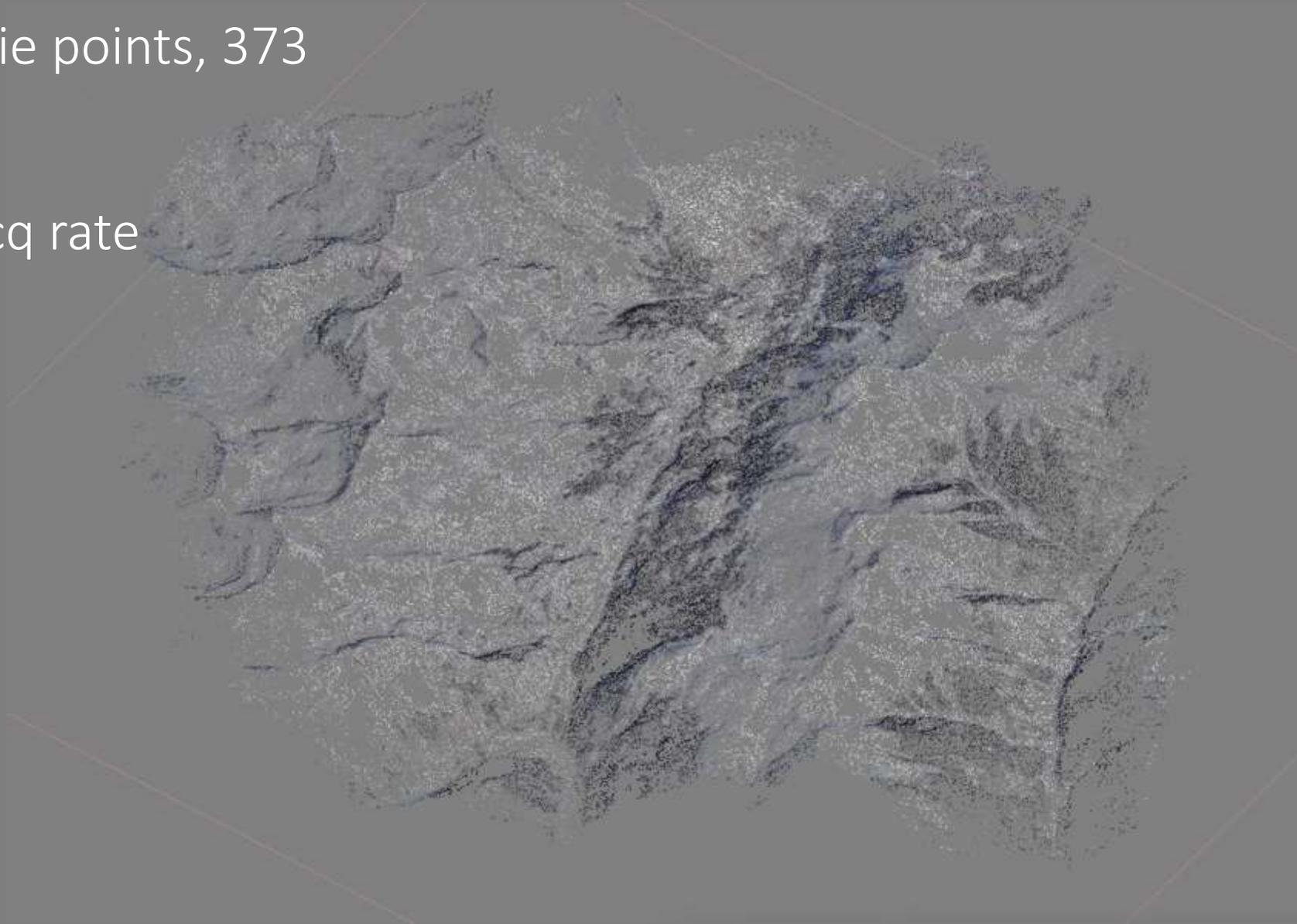
- 3d model
- Orthophoto



Surface Model: SBB 2/21



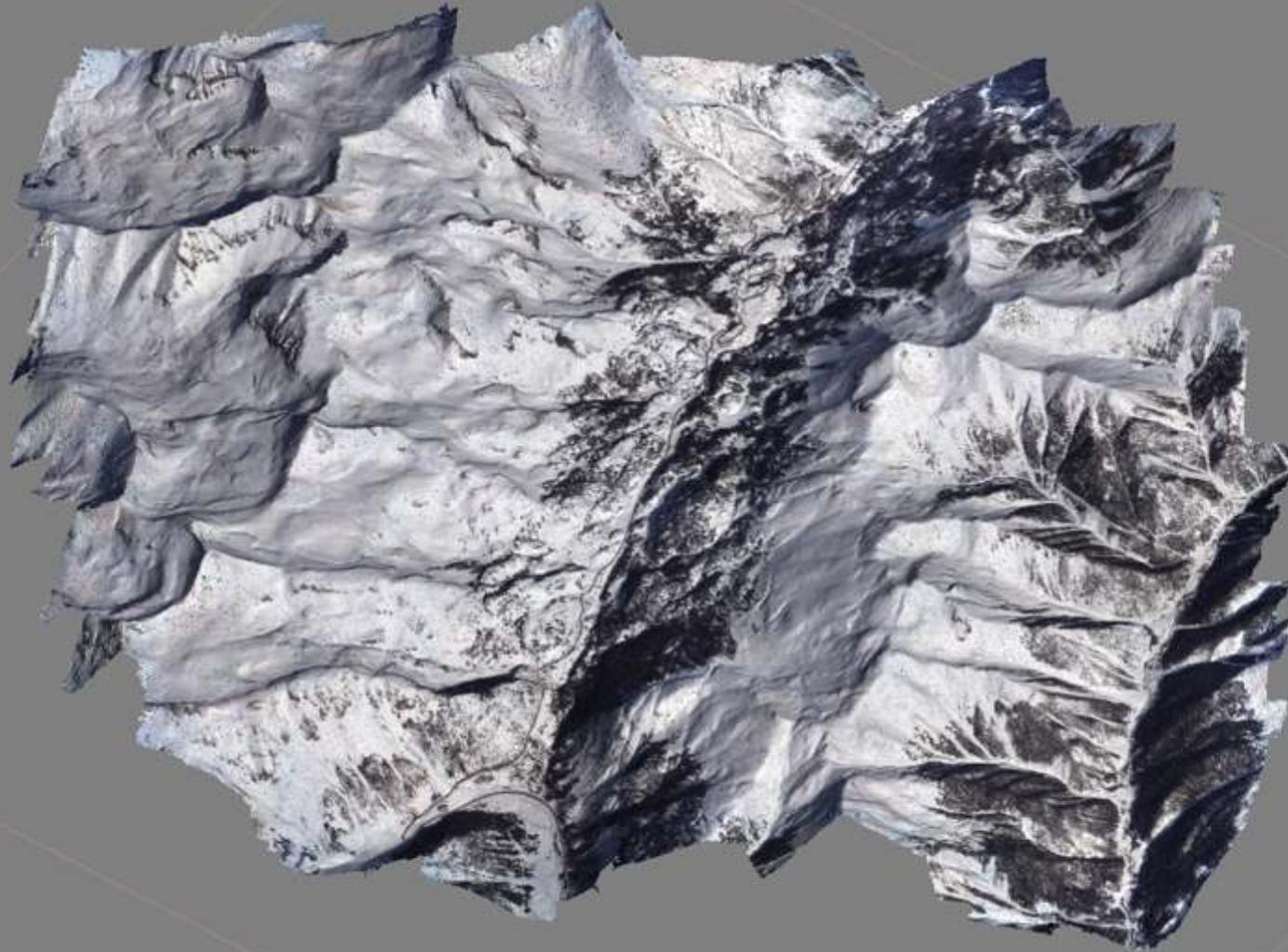
- Image tie points, 373 images
- 5 sec acq rate



Surface Model: SBB 2/21



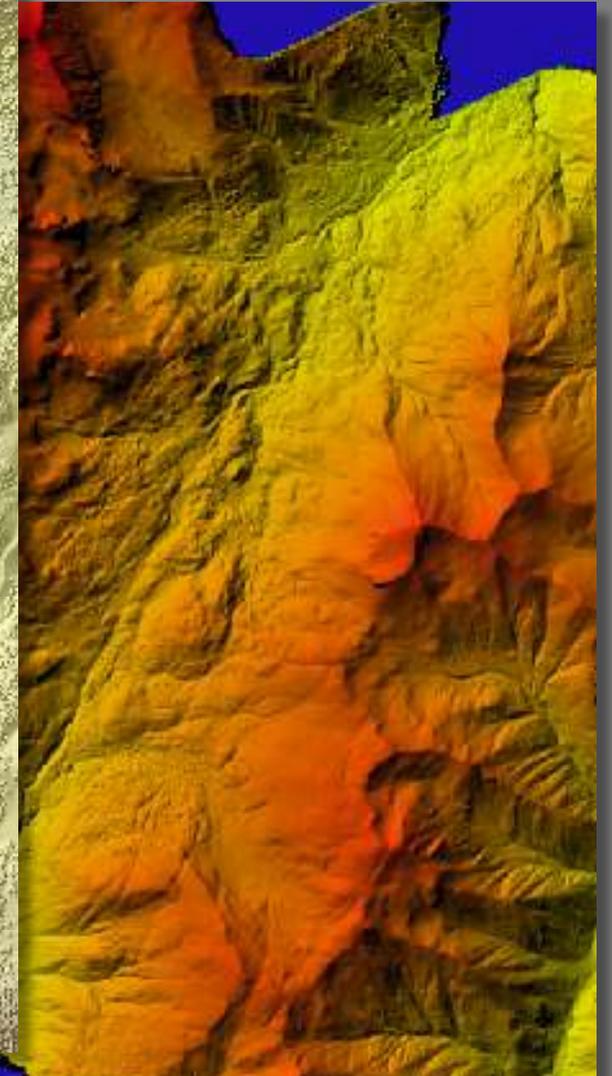
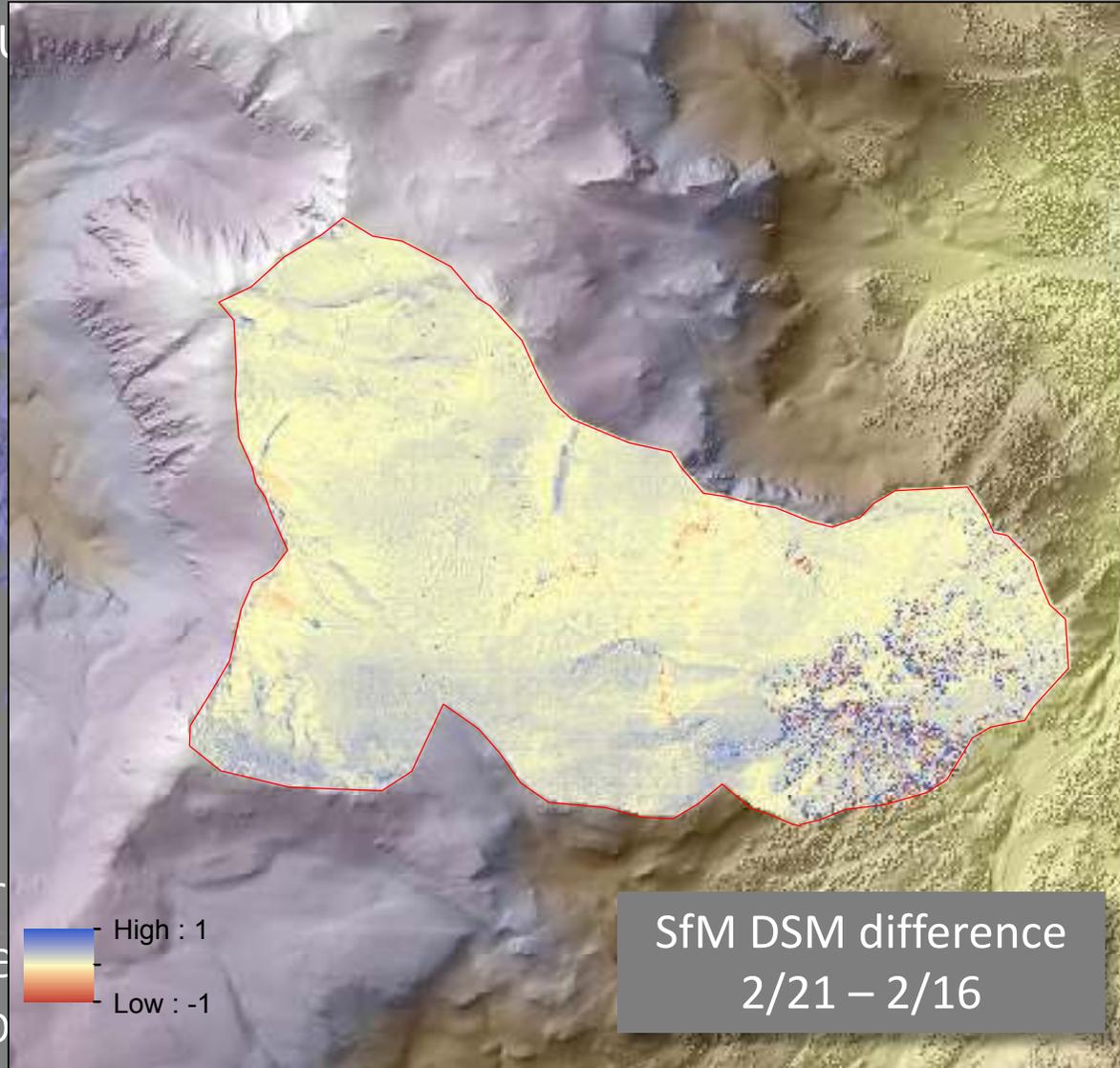
- Dense cloud,
>14 million
points



Surface Model: SBB 2/21



- < 0.5 m resolution
DSM

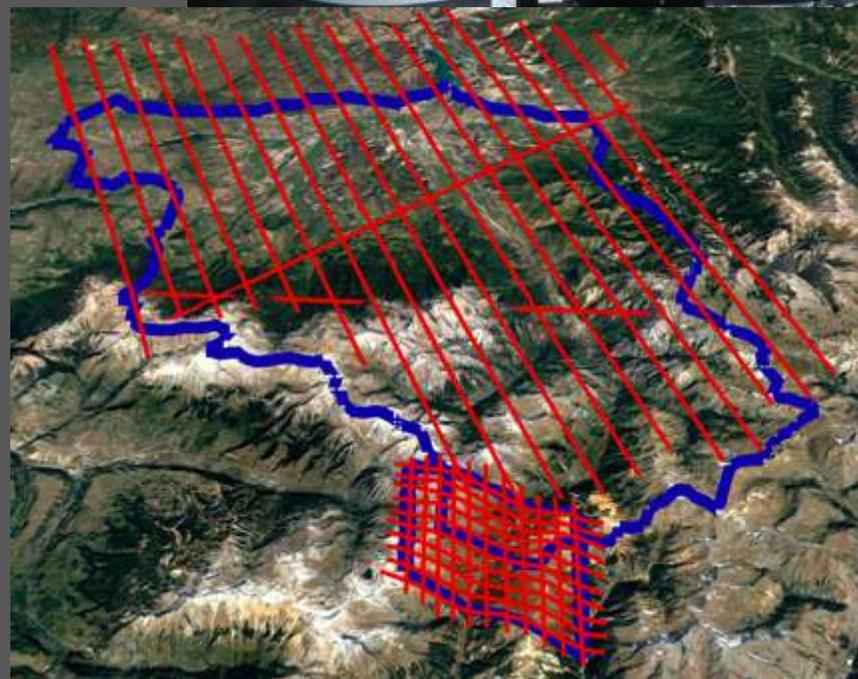
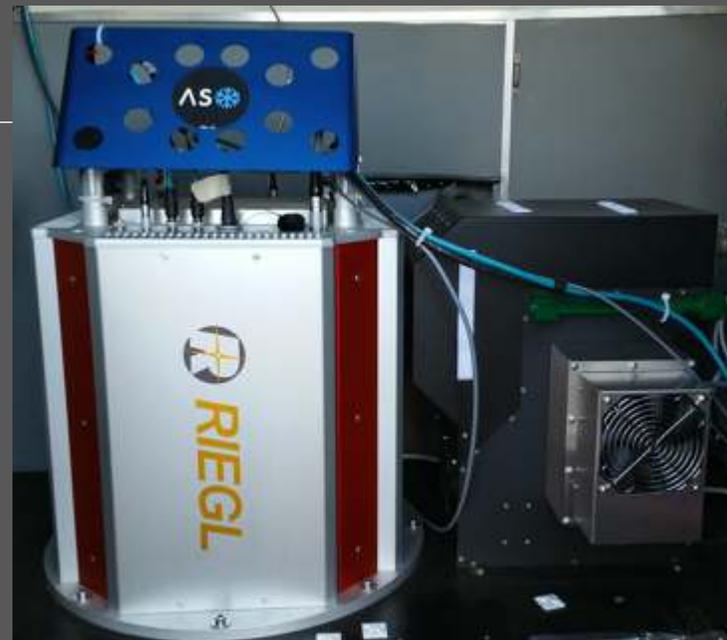


- Coming soon! Comparison of ASO dem, SfM snow depth, validation of snow depth ASO & ground measurements

3 km yellow

Caveats

- Cameras are cheap, but this camera is built into the ASO lidar unit, and therefore takes advantage of the IMU for orthorectification (for snow depth positional accuracy is paramount!)
- For SnowEx ASO was collecting in high resolution mode- flying closer to the surface and with flight lines spaced closer together- under normal operating procedure the dense point clouds might not be quite this dense (more testing to come in the Tuolumne)



Looking Forward: Do we need lidar?



- Yes.
- SfM has some important limitations, namely vegetation and acquisition restriction to daylight hours (unknown density → SWE)
- There is great promise is combining SfM and lidar to improve point cloud density (and fill in for each other if one fails) and produce sharp colorized point clouds at higher resolution than combining the lidar and imaging spectrometer RGB
- It depends.
- If you are interested in differential snow depth mapping outside of areas with dense canopy, SfM is a great alternative to lidar
- Spaceborne capabilities of imagery vs. lidar

Questions?



*Grand Mesa domain SfM dense point cloud
Feb 21, 2017*



???

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