High-res, 4D Topography from satellite/airborne/UAS imagery: Ice Sheets to Volcanoes

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EARTH & SPACE SCIENCES
UNIVERSITY of WASHINGTON
College of the Environment

Outline

- Commercial Stereo examples:
  - Ice sheets
  - Cascades
- Oblique Aerial Surveys
- sUAS
  - Keechelus Lake test
  - Easton Glacier surveys
- Future plans and potential projects

Who am I?

- 4^{th} year PhD student in Dept. of Earth and Space Sciences, RA at APL
- Started out in CE at Brown, distracted by pictures of Mars
- Worked for MSSS – Mars Reconnaissance Orbiter, Mars Science Laboratory
- Remote sensing – ideal combination of science and engineering (hardware/software)

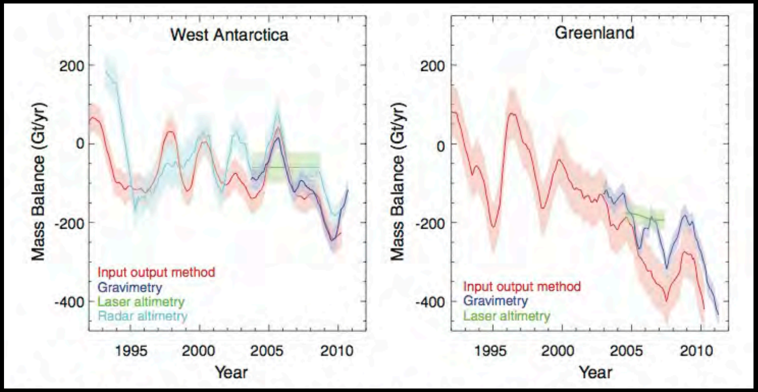
Motivation

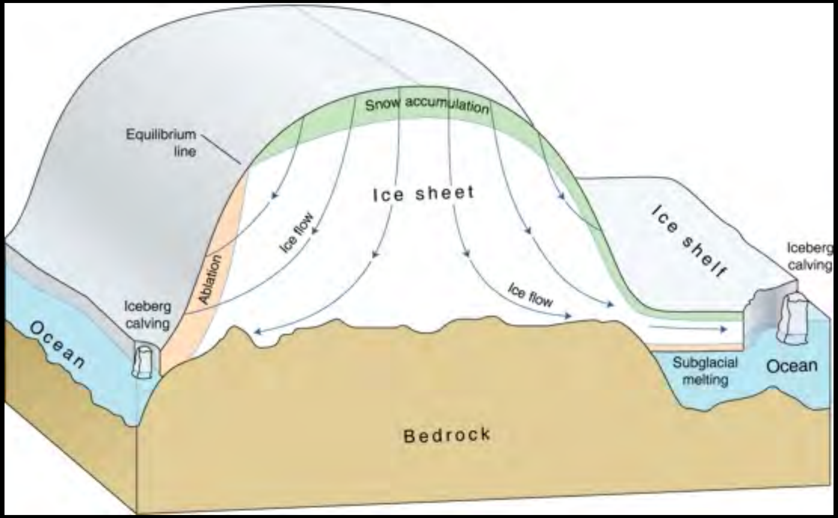
Repeat, high-resolution measurements of surface topography capture ice loss/gain and characterize the processes driving observed change.

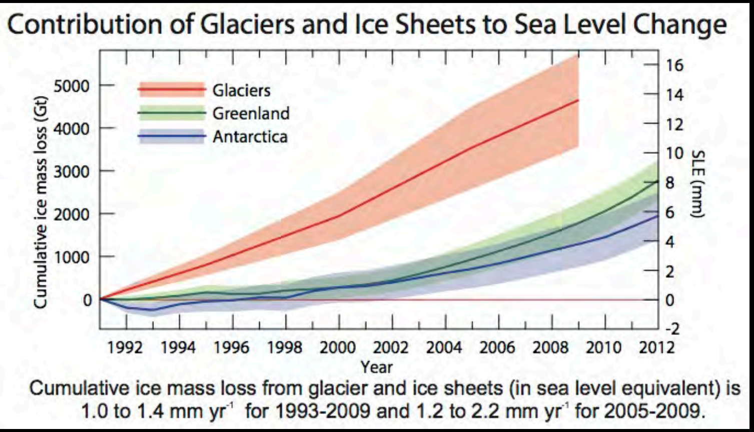
- Ice sheets – sea level rise
- Mountain glaciers – regional climate change
- Seasonal snowpack – water resources, avalanche hazards

Ice Sheet Mass Balance

- Two components:
  - Input: precipitation
  - Output: melting, discharge (calving)
- Increasing net mass loss from 1992-present
- Implications for 21st Century sea level rise



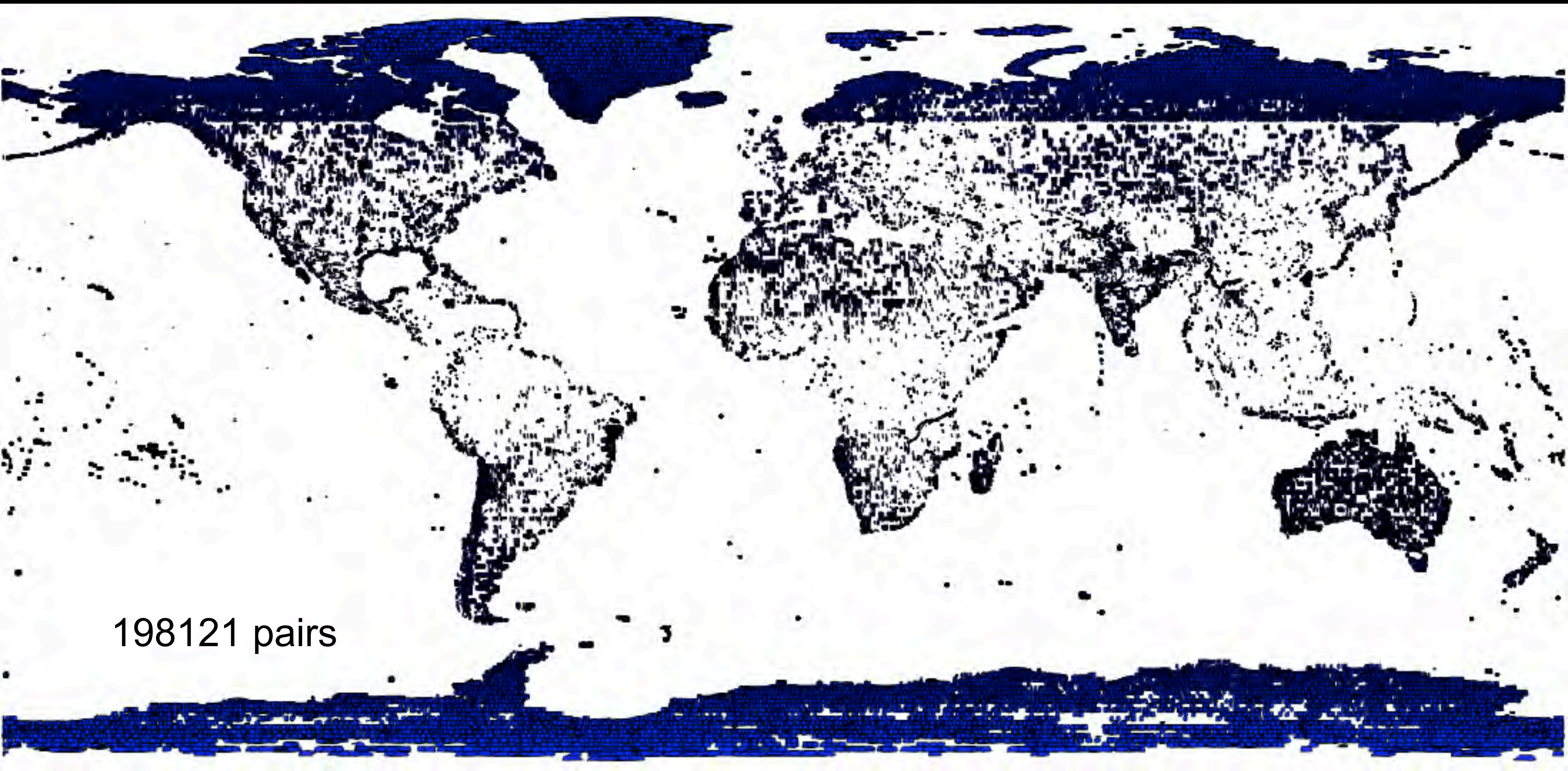




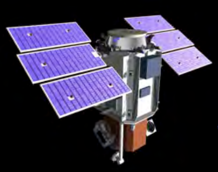
http://www.solcomhouse.com/icecap.htm

Shepherd et al. (2012); IPCC AR5 (2014)

DigitalGlobe Stereo Archive – 10/8/2014




Ikonos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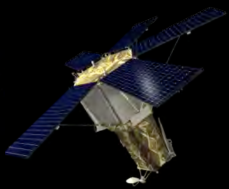
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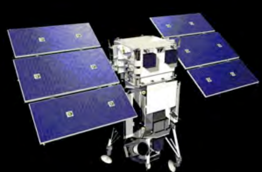
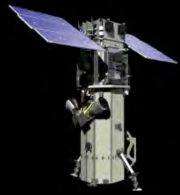
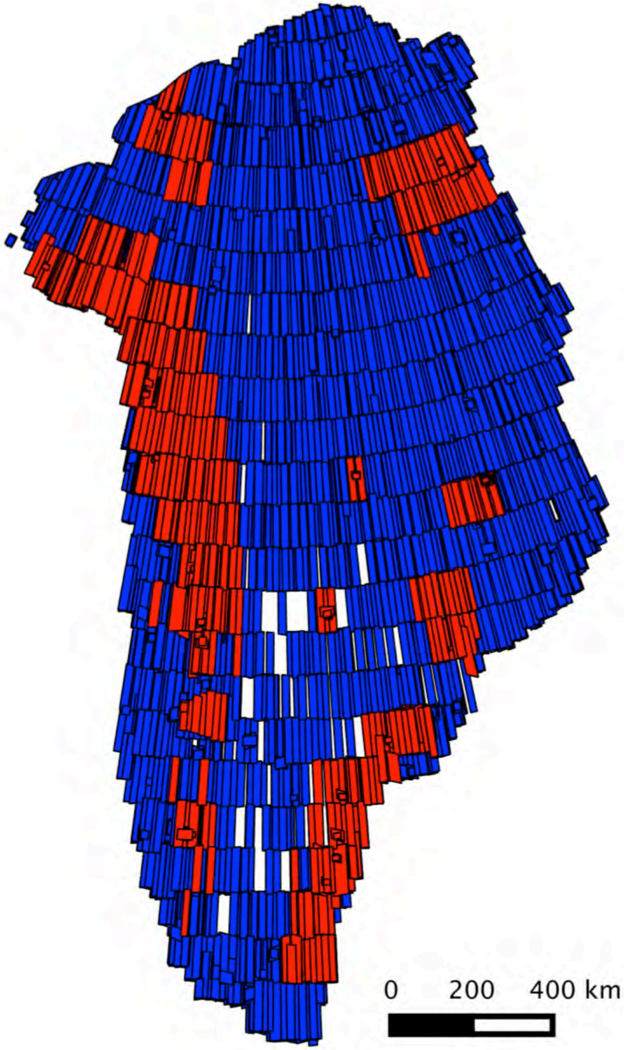
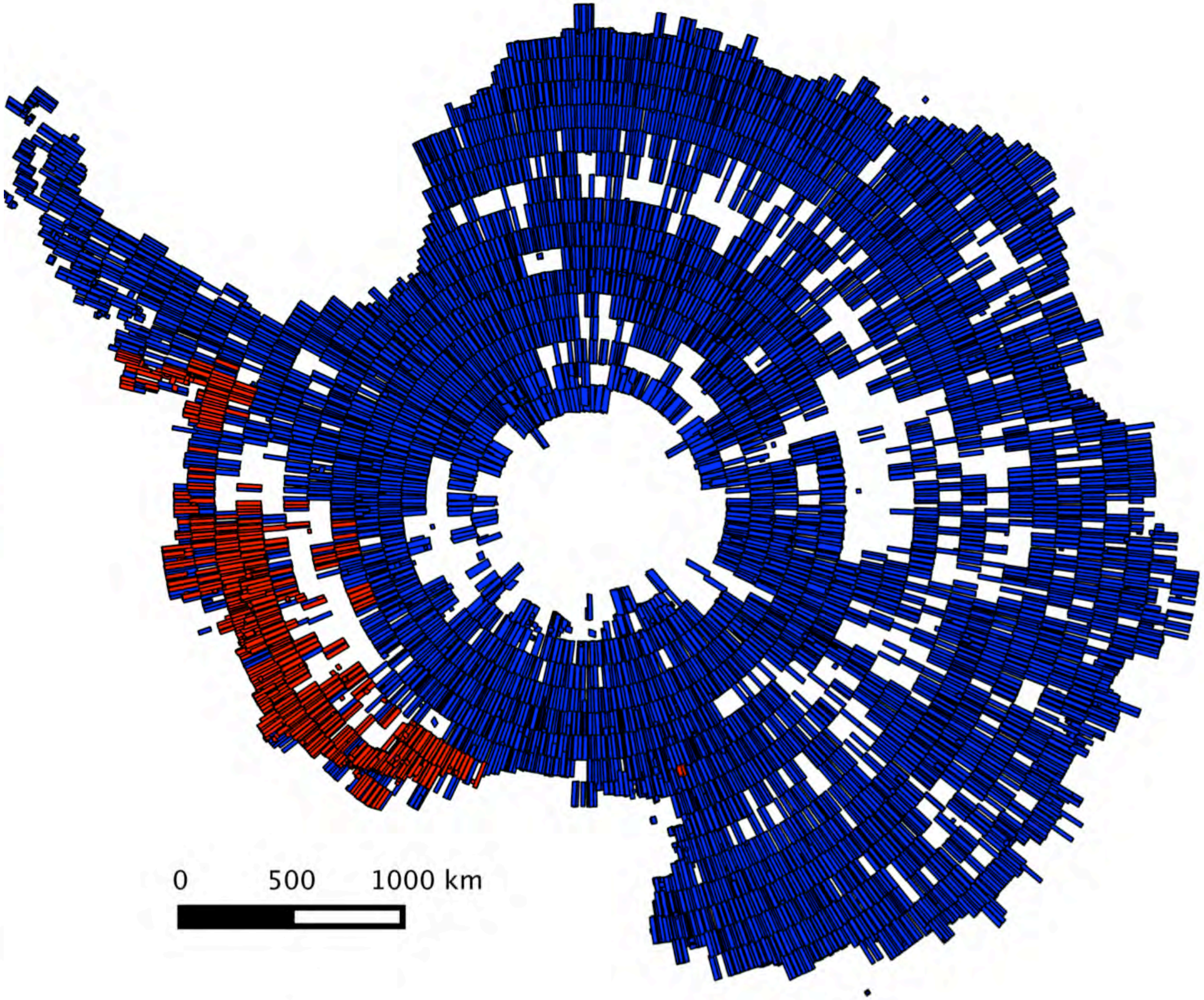

WorldView-1


WorldView-2


WorldView-3

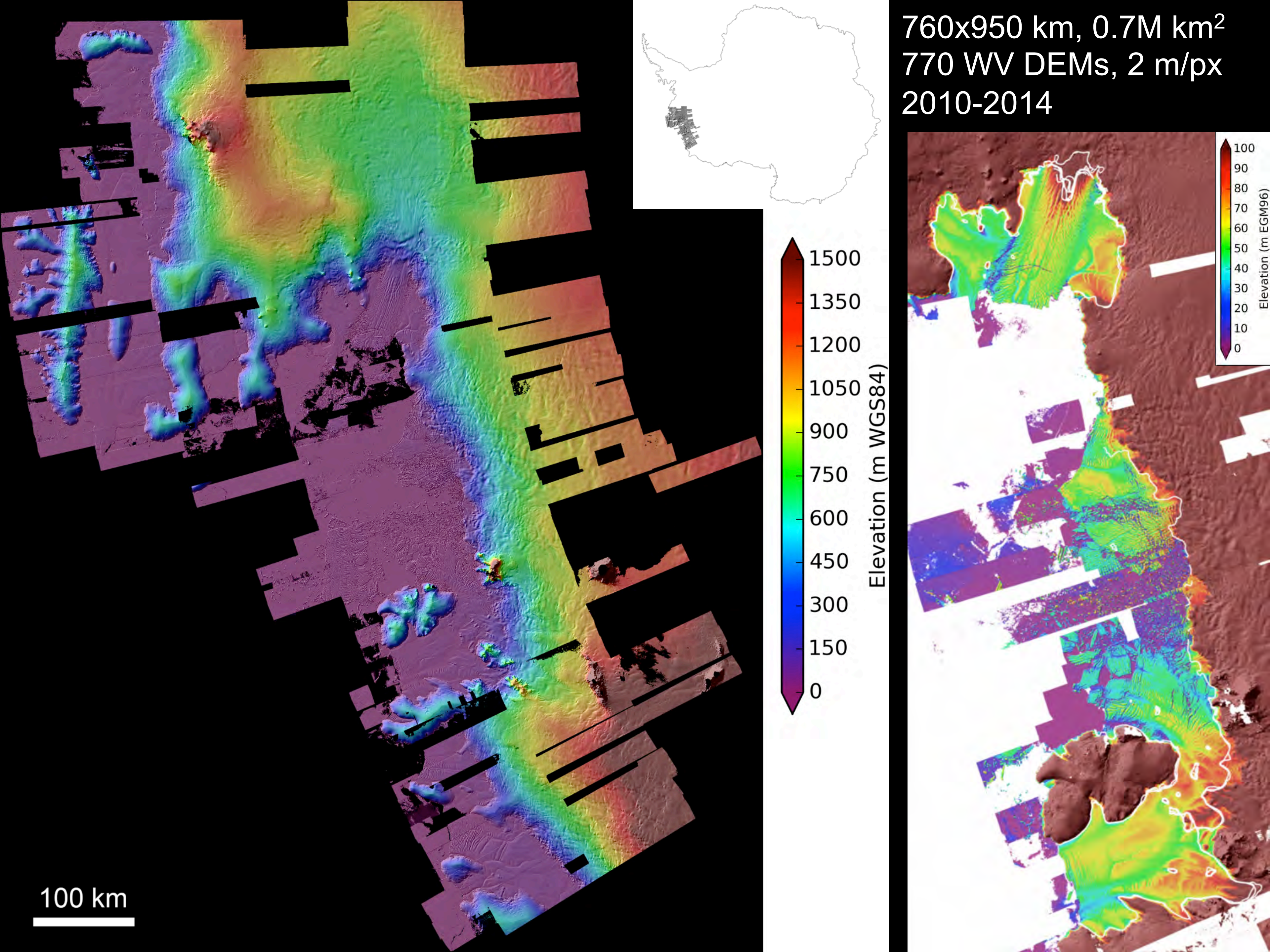
Polar Stereo Coverage as of 9/7/2014

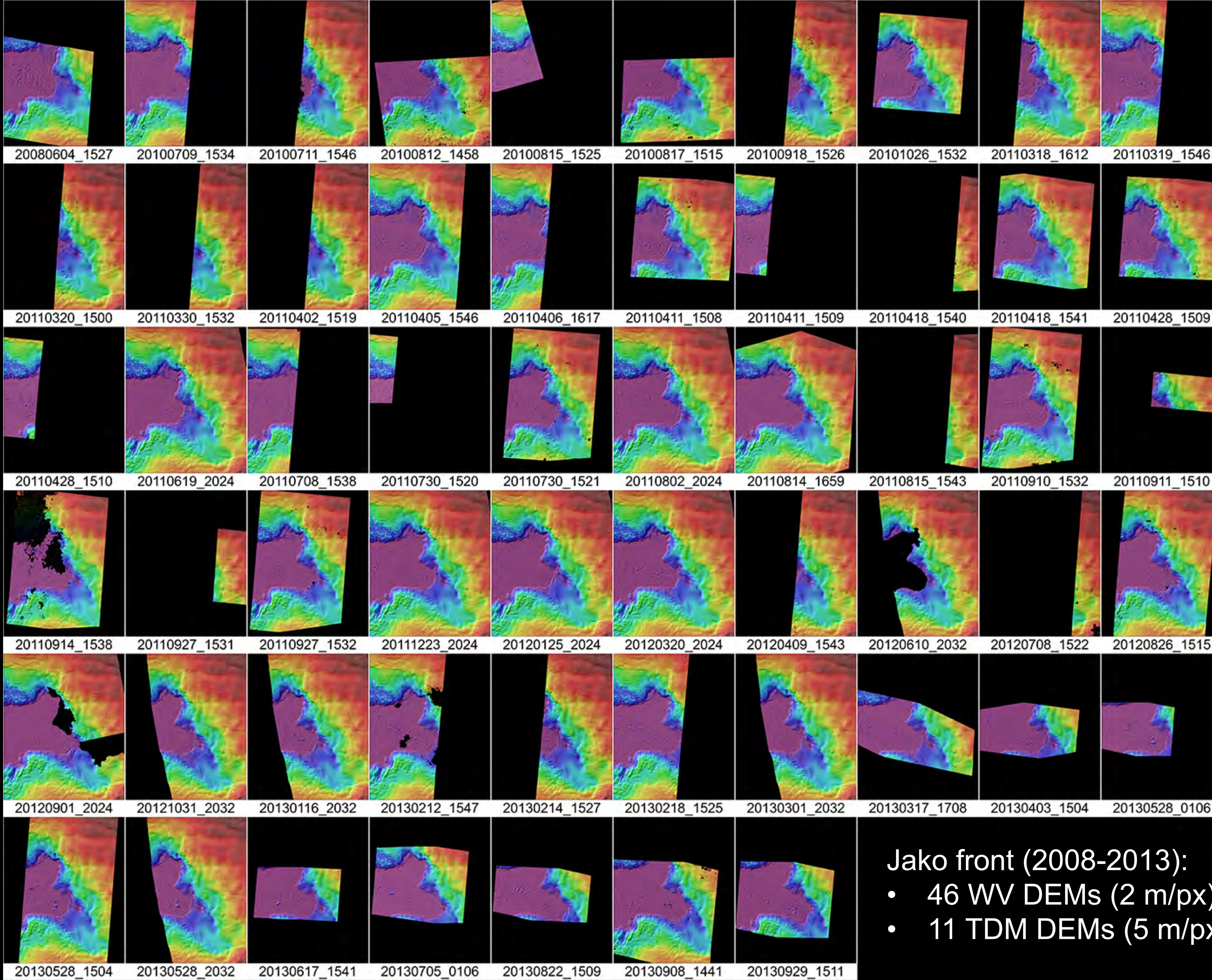




9933 pairs

20006 pairs

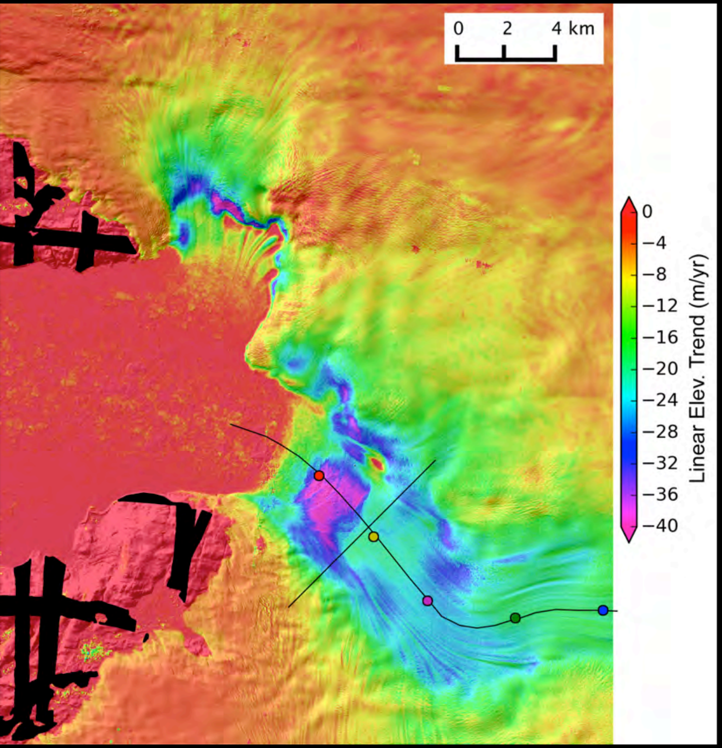

760x950 km, 0.7M km^2
770 WV DEMs, 2 m/px
2010-2014
100 km
1500
1350
1200
1050
900
750
600
450
300
150
0
Elevation (m WGS84)
100
90
80
70
60
50
40
30
20
10
0
Elevation (m EGM96)

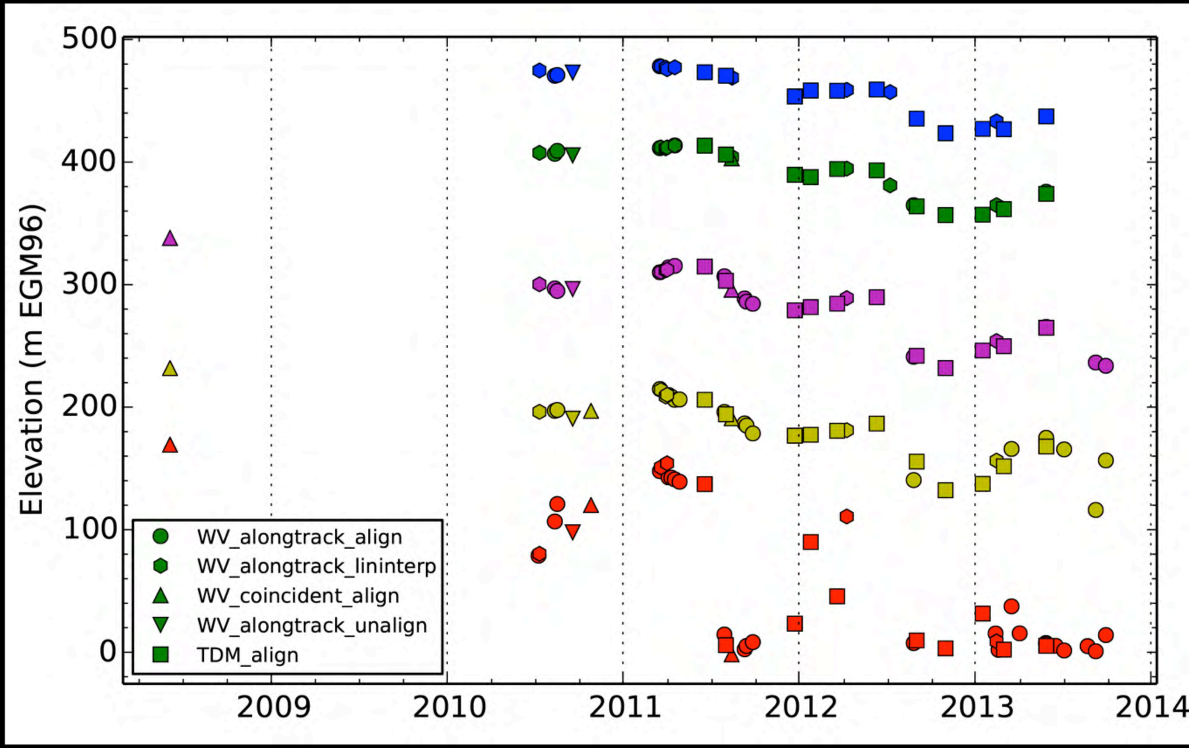


Jako front (2008-2013):

- 46 WV DEMs (2 m/px)
- 11 TDM DEMs (5 m/px)

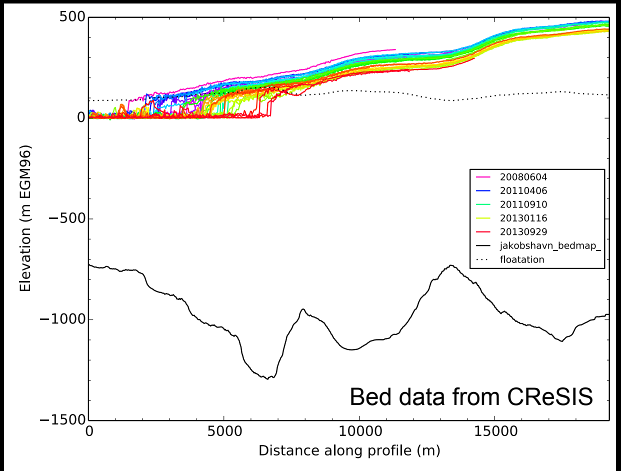
Interannual/Seasonal Variability



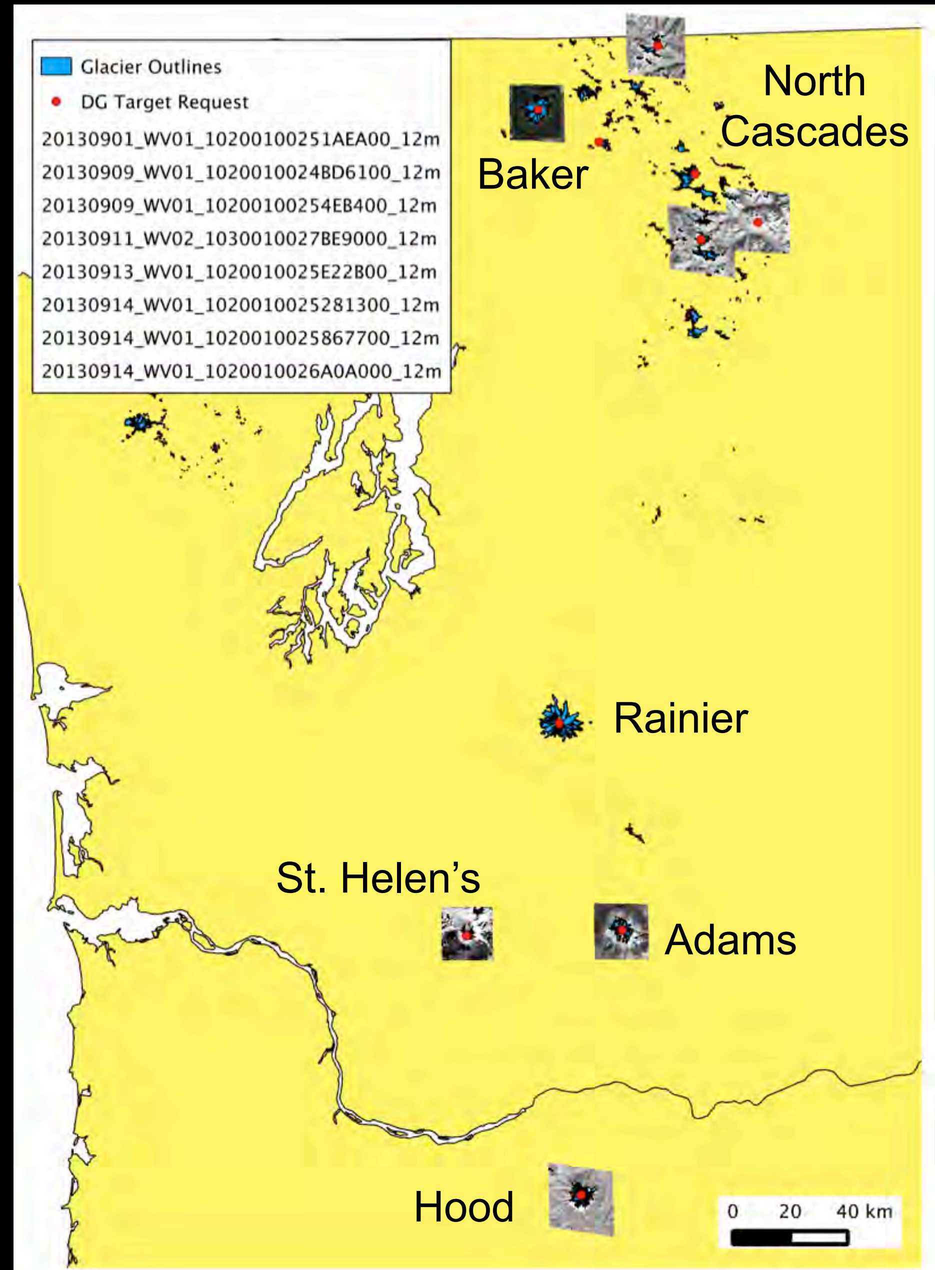


2008-2013: 57 high-res DEMs

- Interannual trend
  - Thinning over land-terminating ice: -2 to -4 m/yr (SMB)
  - Thinning over trunk: -15 to -40 m/yr
- Seasonal cycle
  - Summer thinning of -30 to -50 m
  - Winter thickening of +10 to +15 m

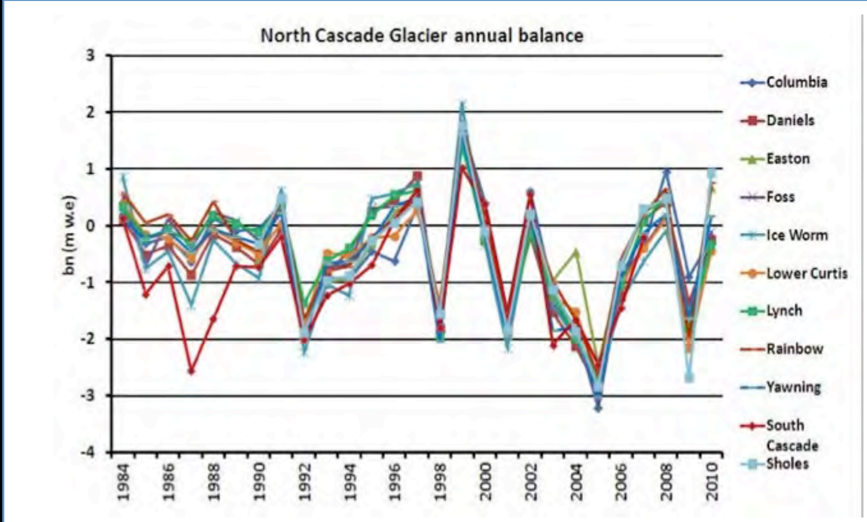


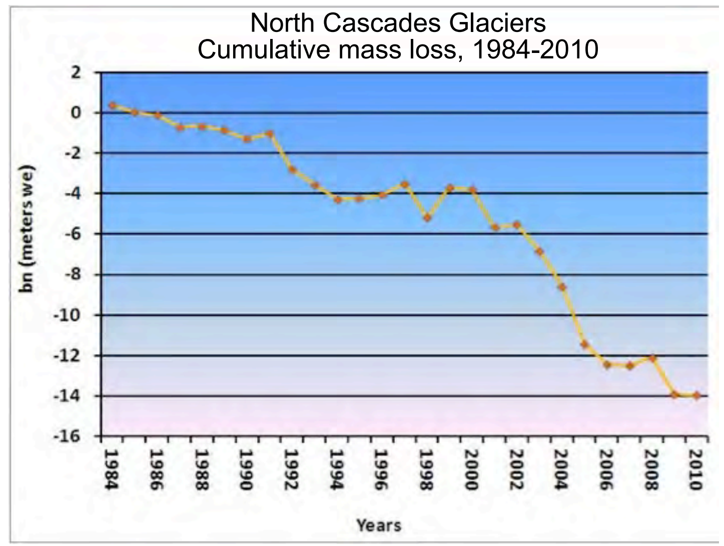
2012/2013 Cascades Stereo Acquisitions



Motivation

- Mountain glaciers are natural laboratories for studying fundamental glacial processes (e.g. subglacial drainage system evolution)
- Mt. St. Helen's – unique opportunity to study the birth and evolution of a glacier
- Long-term mass balance measurements provide valuable regional climate data
- Cascade glaciers currently in a state of disequilibrium
- Hazards – outburst floods, lahars, etc.

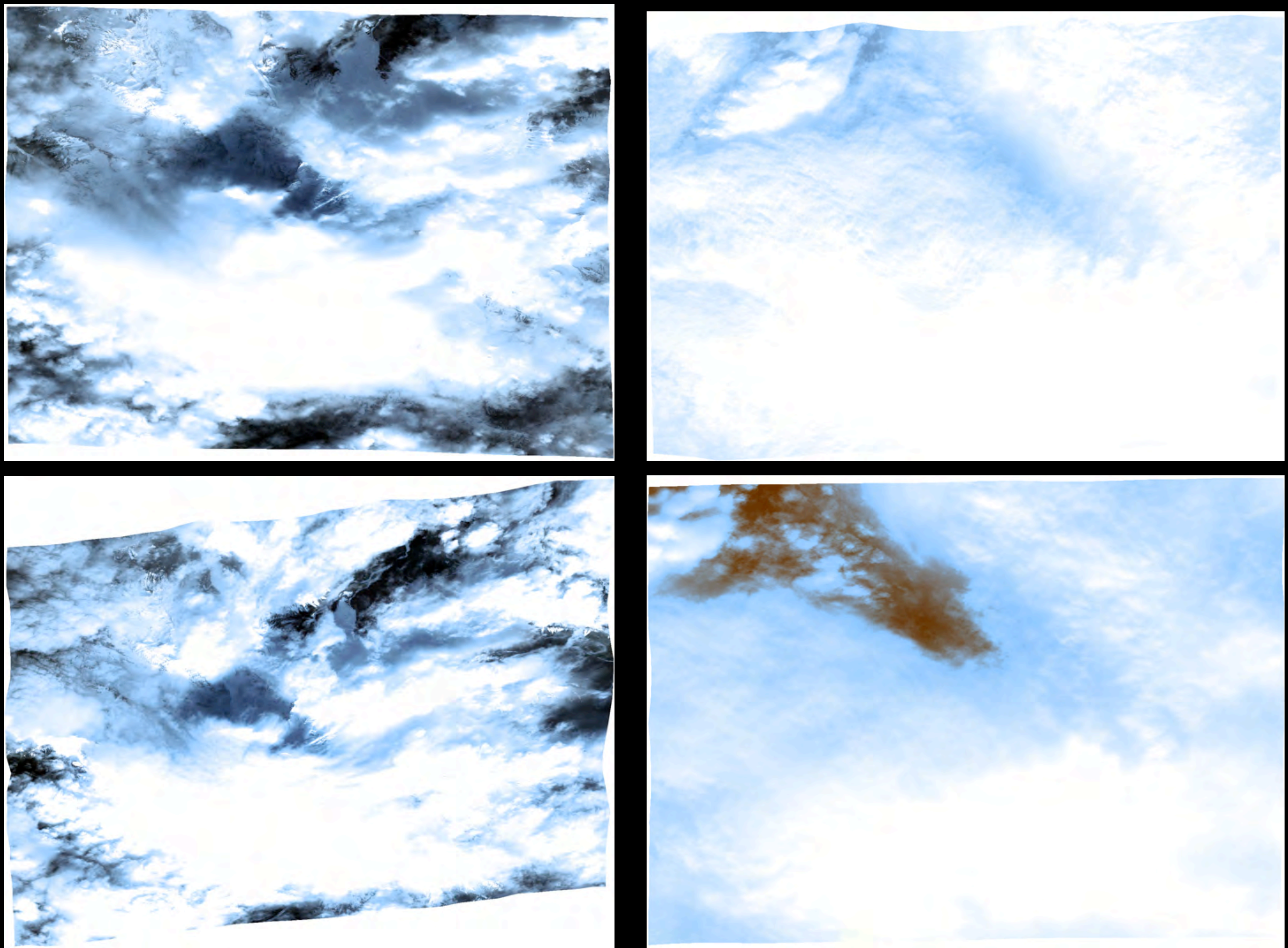




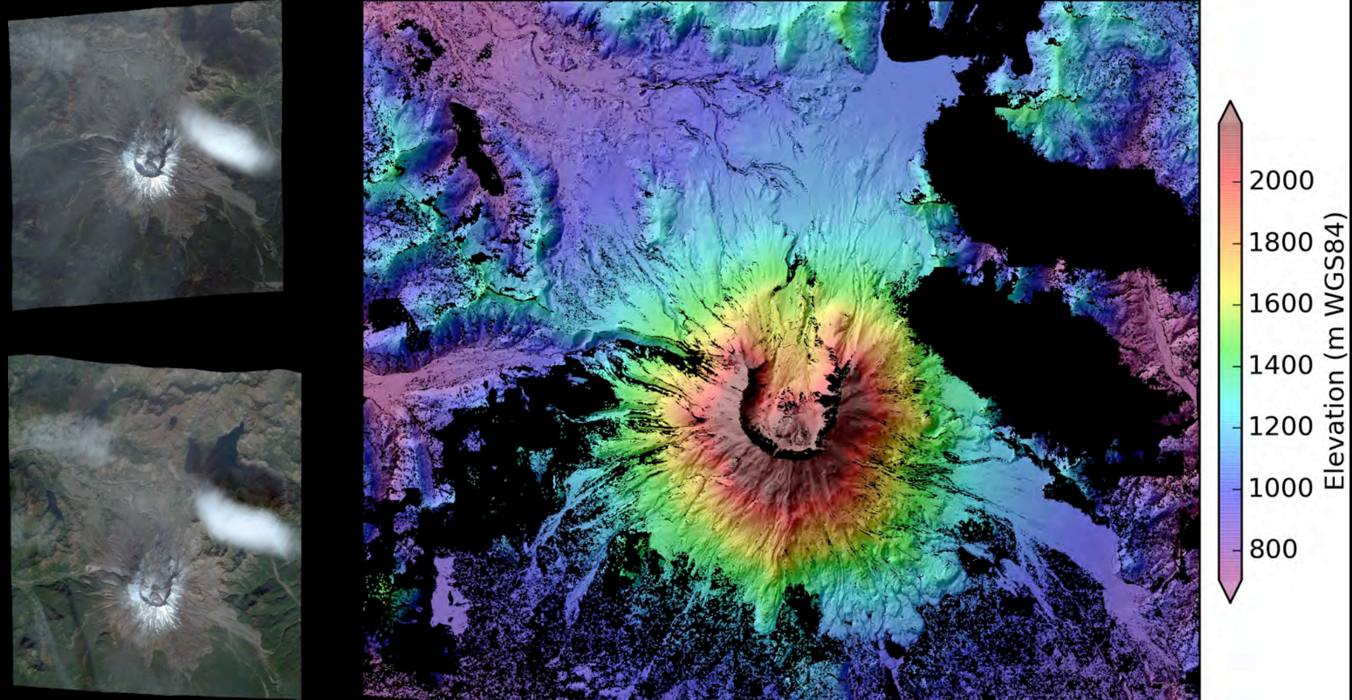
NORTH CASCADE GLACIER CLIMATE PROJECT
http://www.nichols.edu/departments/glacier/

10/23/2012

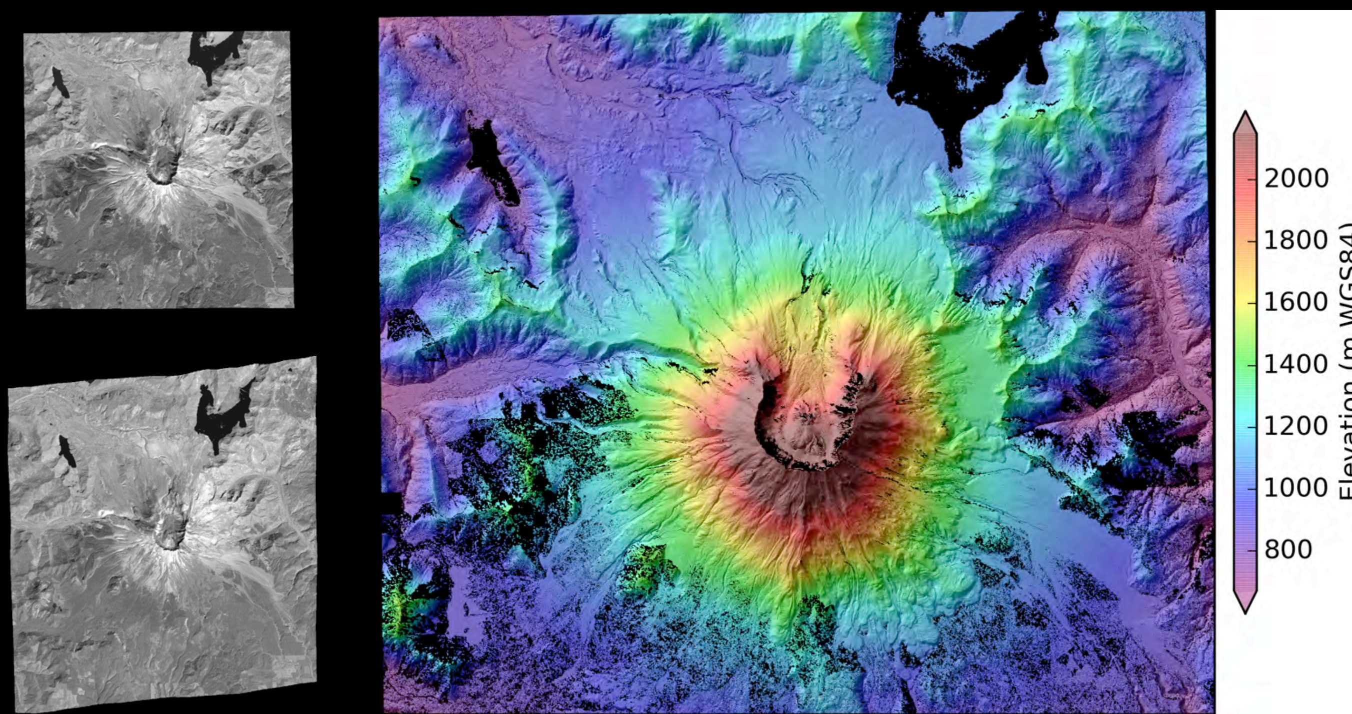
10/26/2012

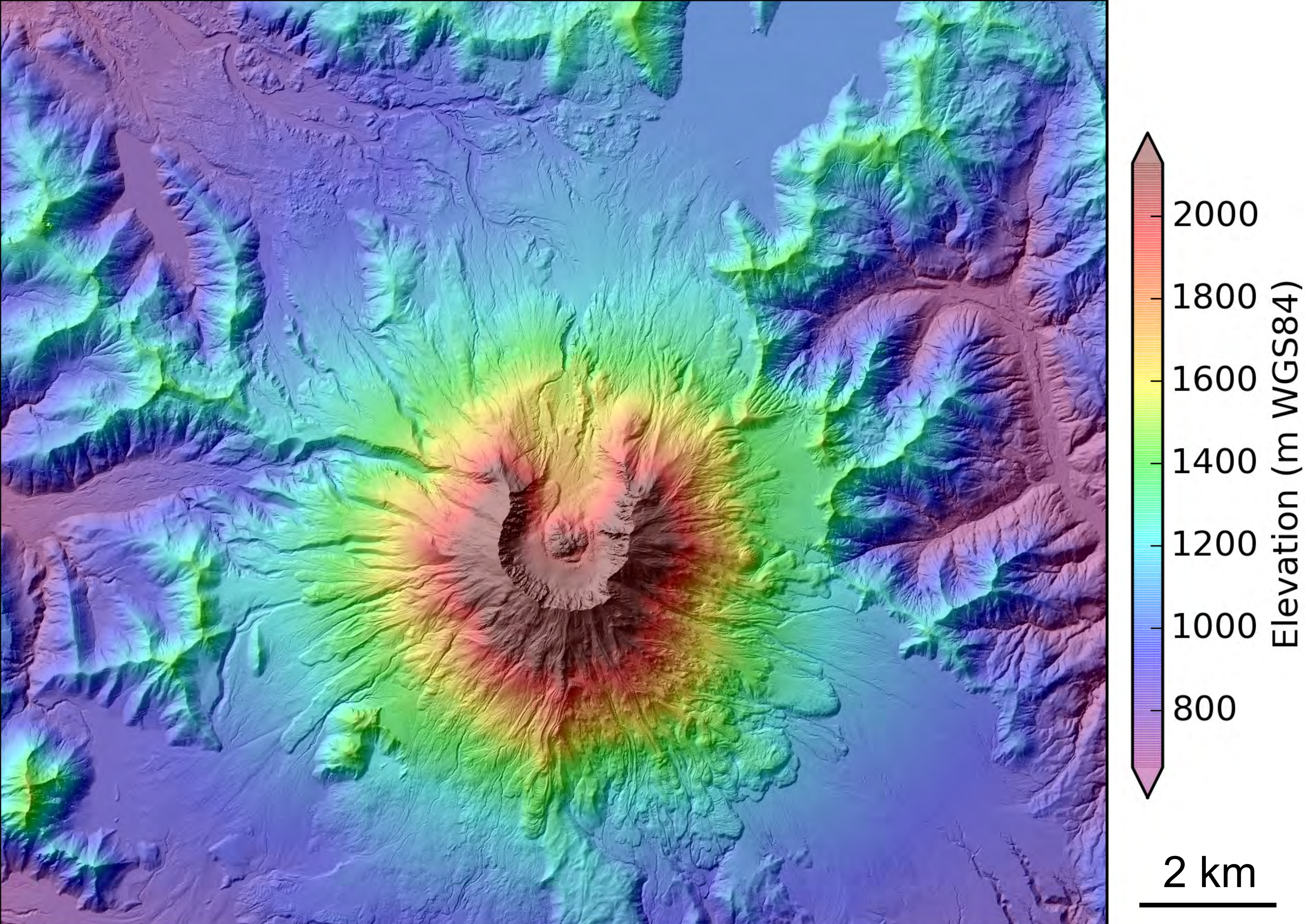


2012-10-18

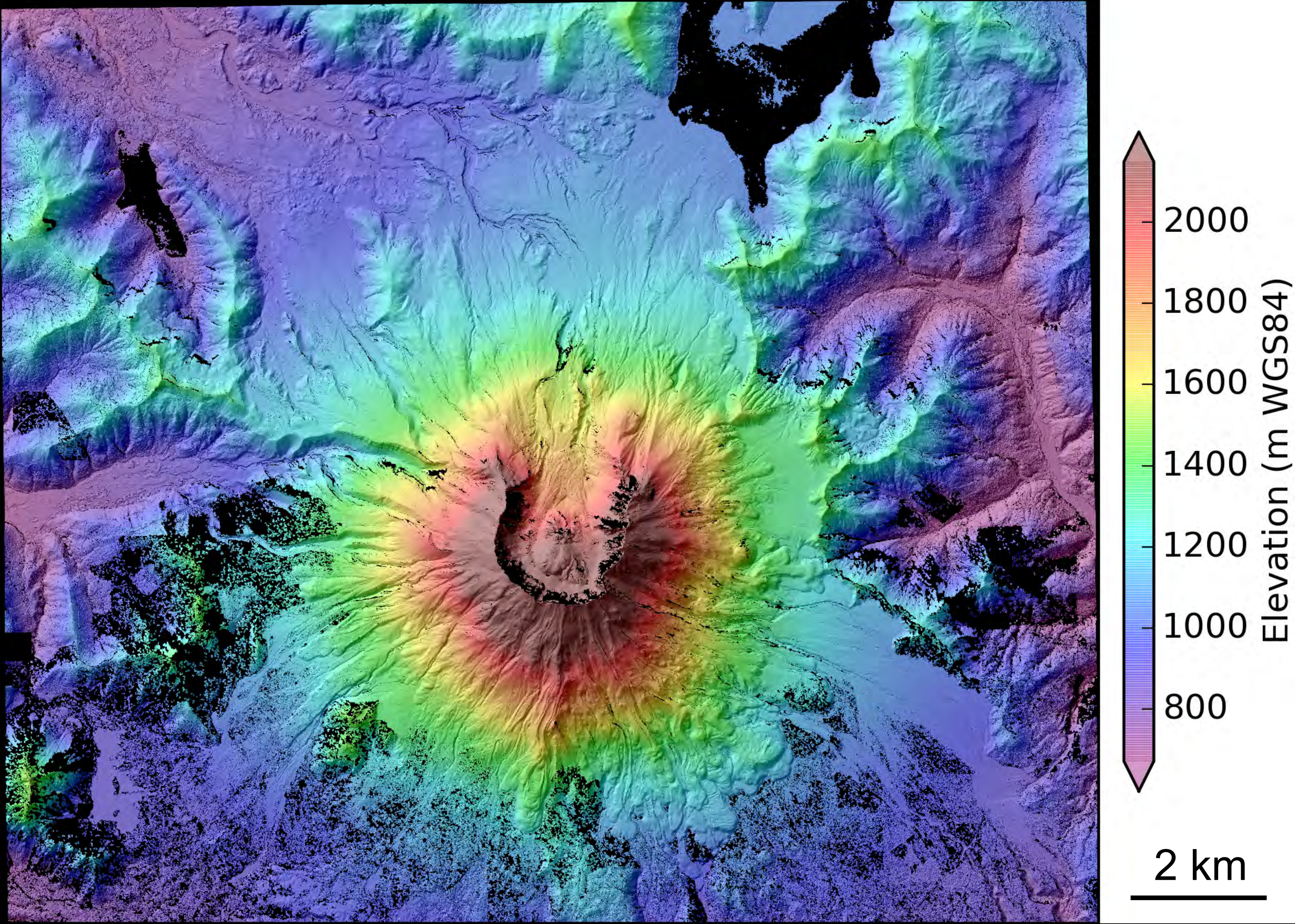


2013-09-09

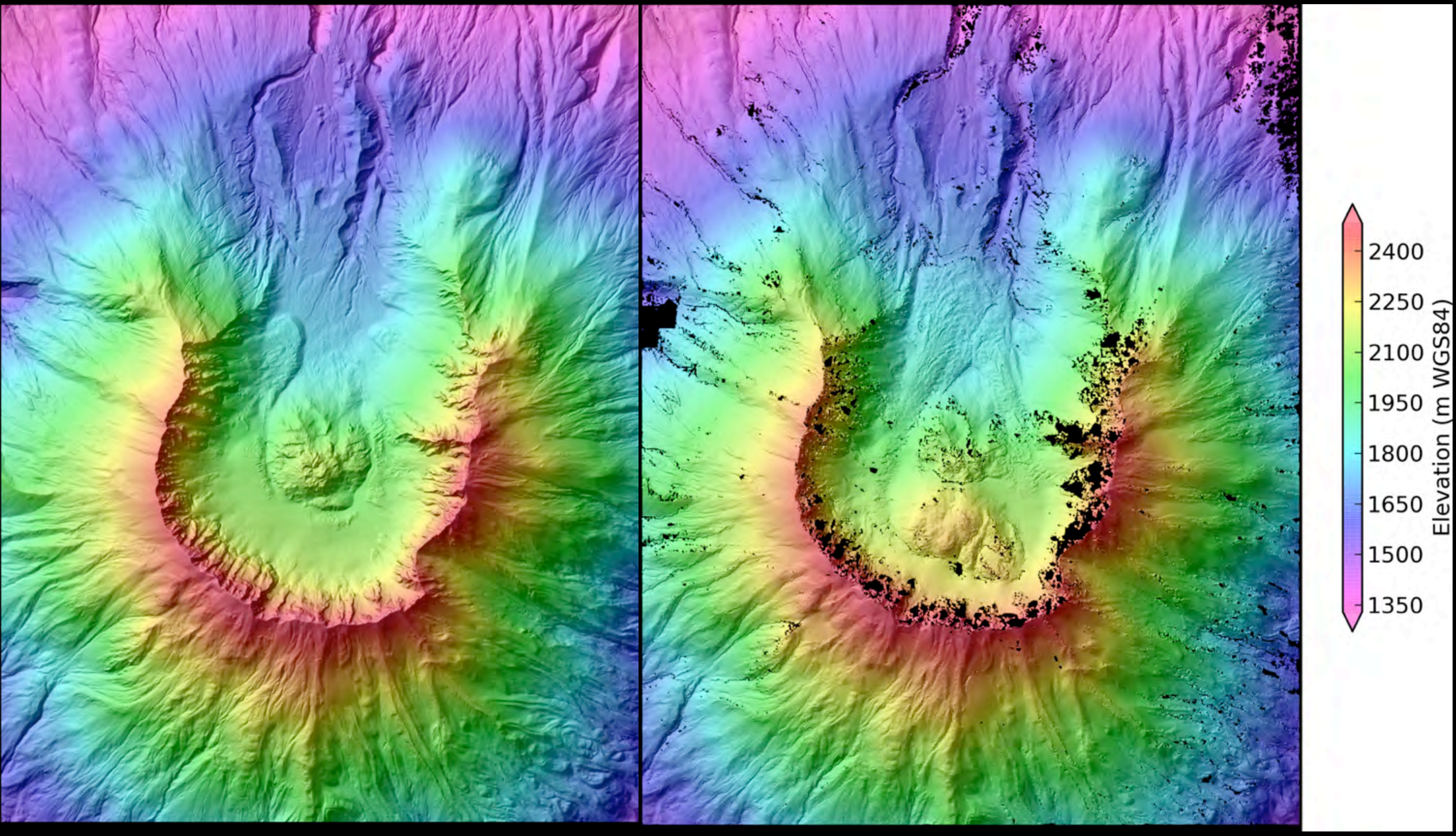




Bare Earth LiDAR, 9/20/2003

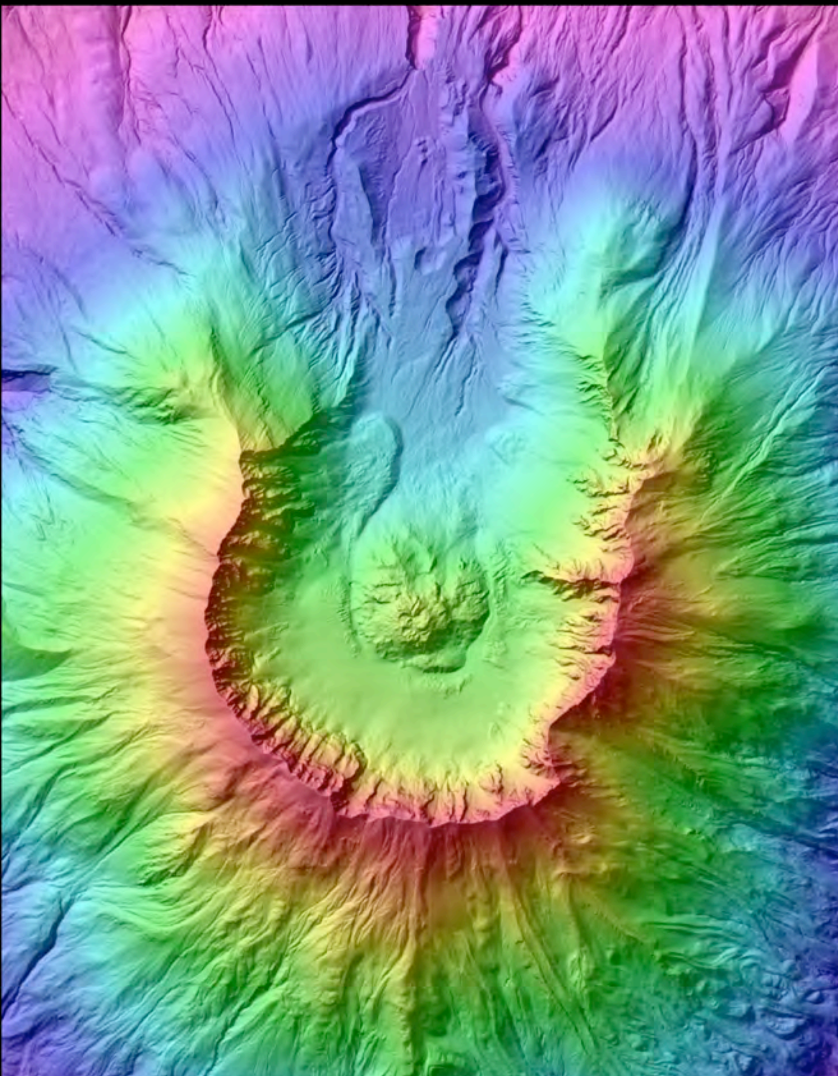


WV Stereo DEM, 9/9/2013

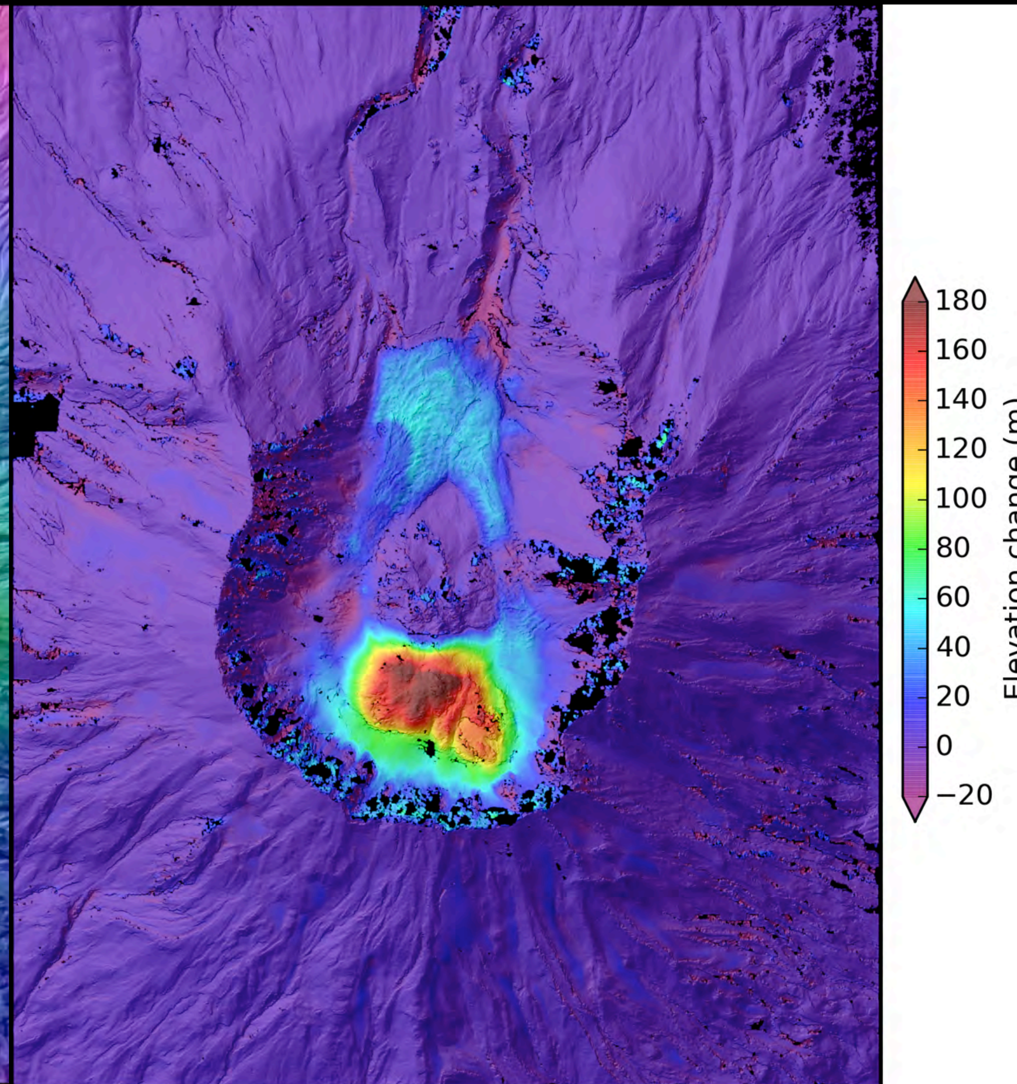


2003-09-20 LiDAR

2012-10-18 WV Stereo

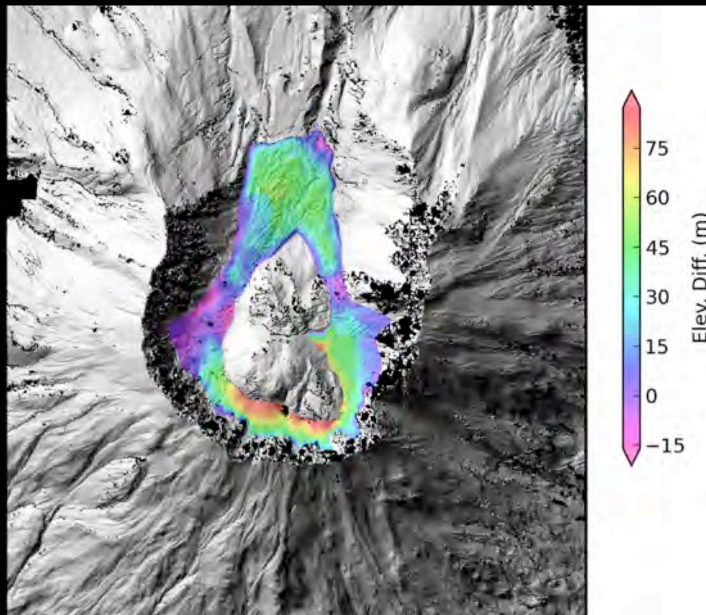


2003-09-20 LiDAR

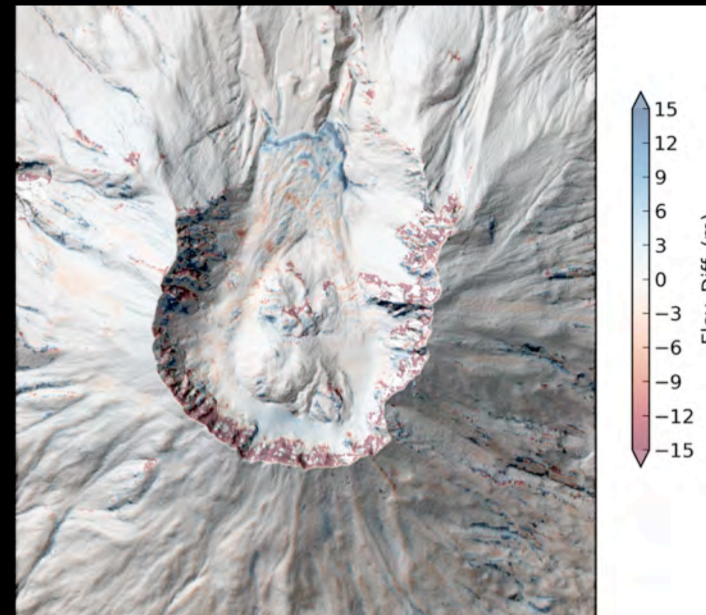


2012-10-18 – 2003-09-20

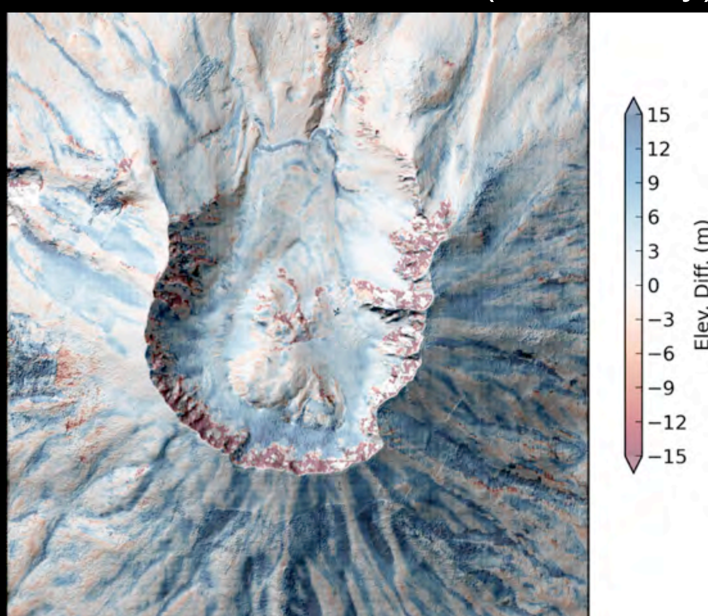
10-year glacier volume: +4.1x10^7 m^3



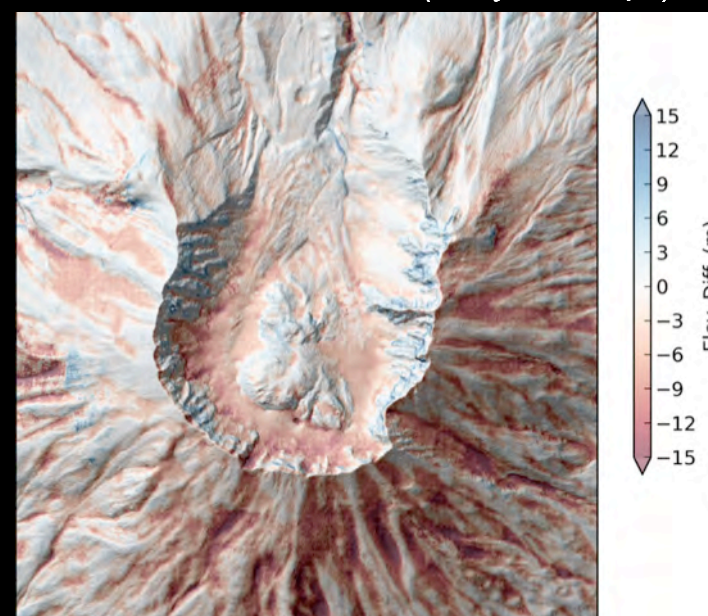
1-year glacier advance: ~40-70 m/yr



2013 winter accumulation (Oct to May)

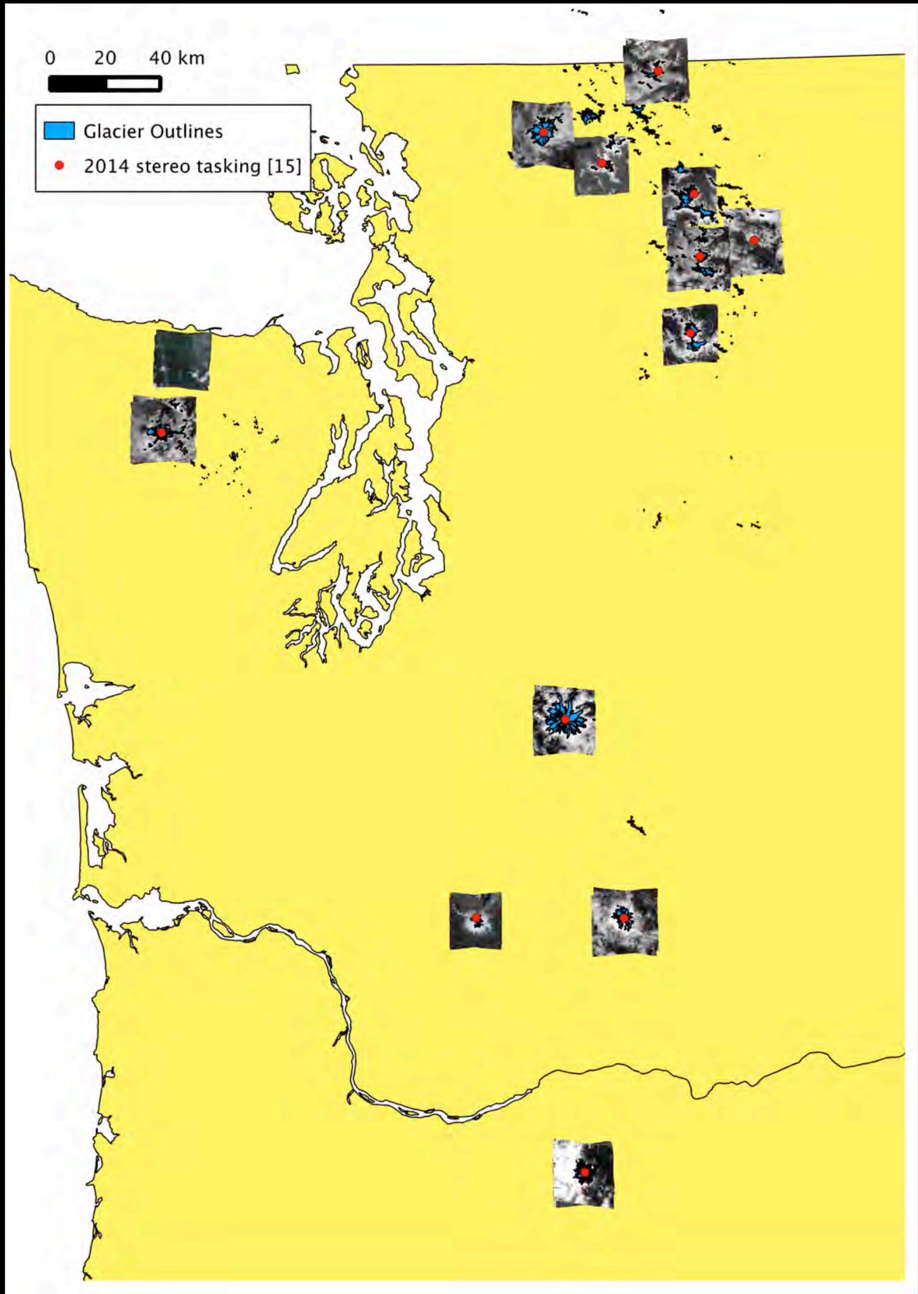


2013 summer melt (May to Sept)



Spring 2014 Cascades Stereo Acquisitions

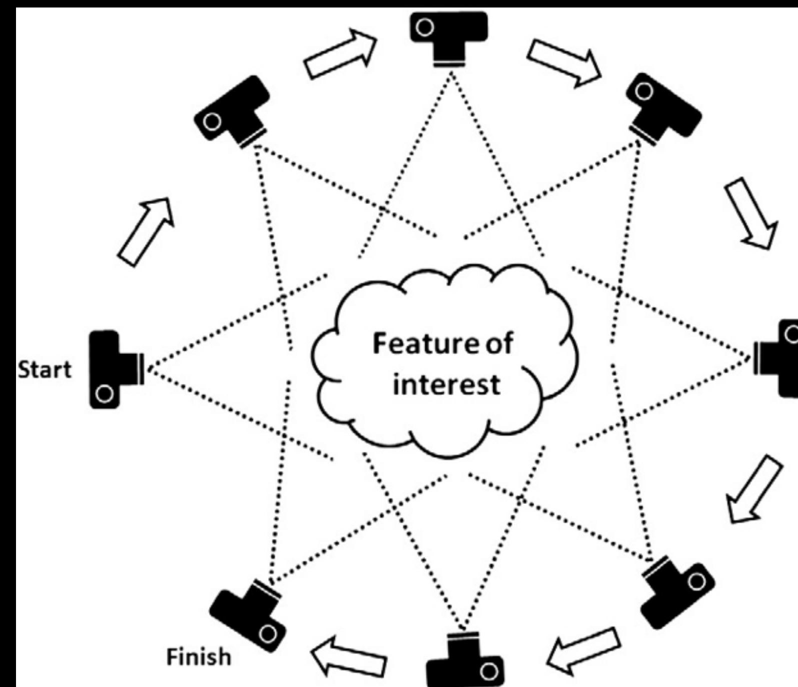
- 12 targets
- April/May (max snow)
  - 30 acquisitions
  - Most targets >2x
  - Some ~30-50% cloudy
- Sept/Oct (min snow)
  - Shooting now
- Rainier: monthly stereo

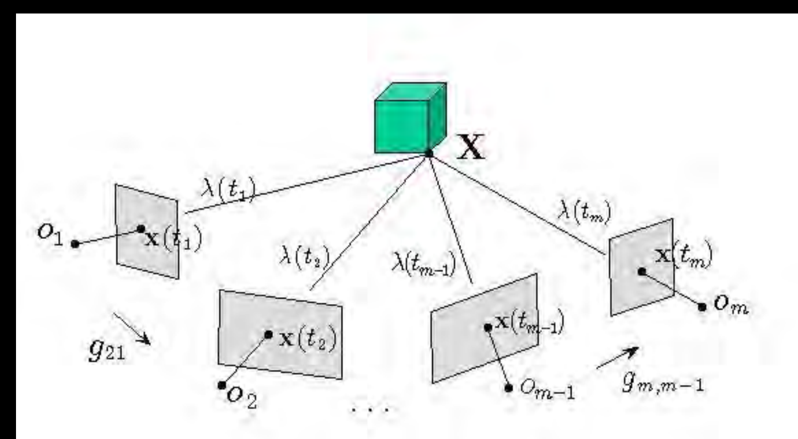


Oblique Aerial Surveys

Structure from Motion (SfM)

- 3D info ("structure") from multiple viewpoints ("motion")
- Minimize occlusion
- Consumer cameras
- Automated software, minimal training required
- Scale/orientation from known camera positions (GPS) or ground control
- Pioneered by UW CSE





ESS STF Photogrammetry Gear

Nikon D800
36.3 MP (7360x4912 px)

Nikon D90
12 MP

GeoXH + Hurricane antenna
~10-15 cm accuracy

50 mm

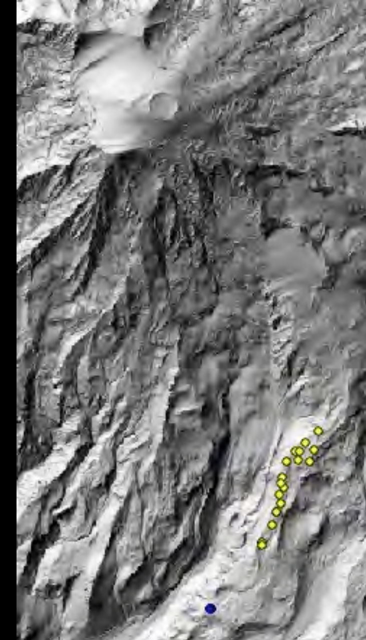
16-35 mm

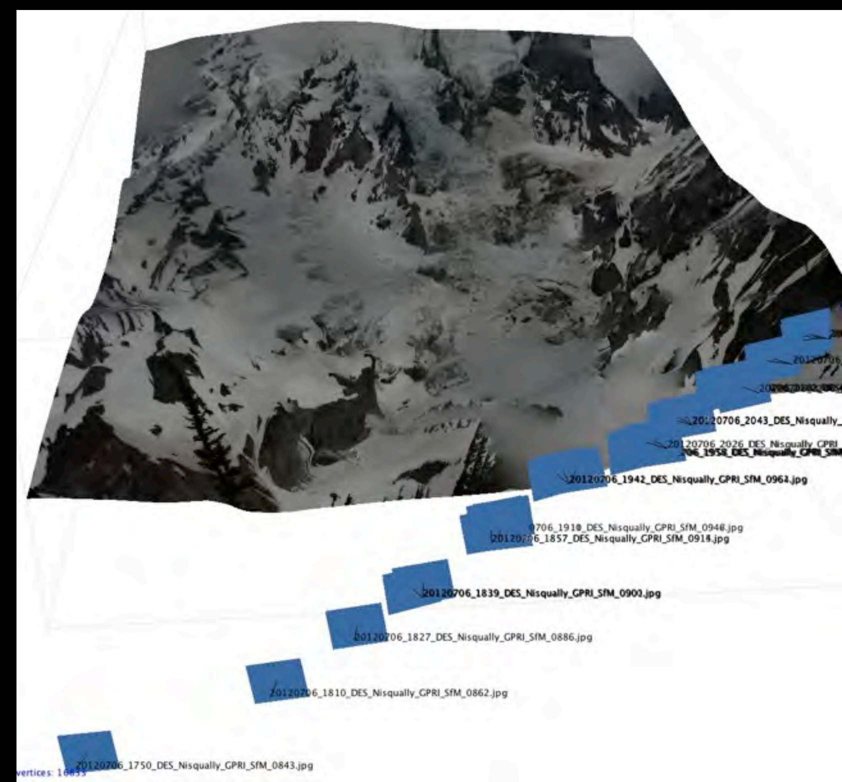
85 mm

28-300 mm

Nikon GP-1 GPS
~5 m accuracy

Nisqually Glacier, Mt. Rainier
Ground-based SfM Survey
July 2012



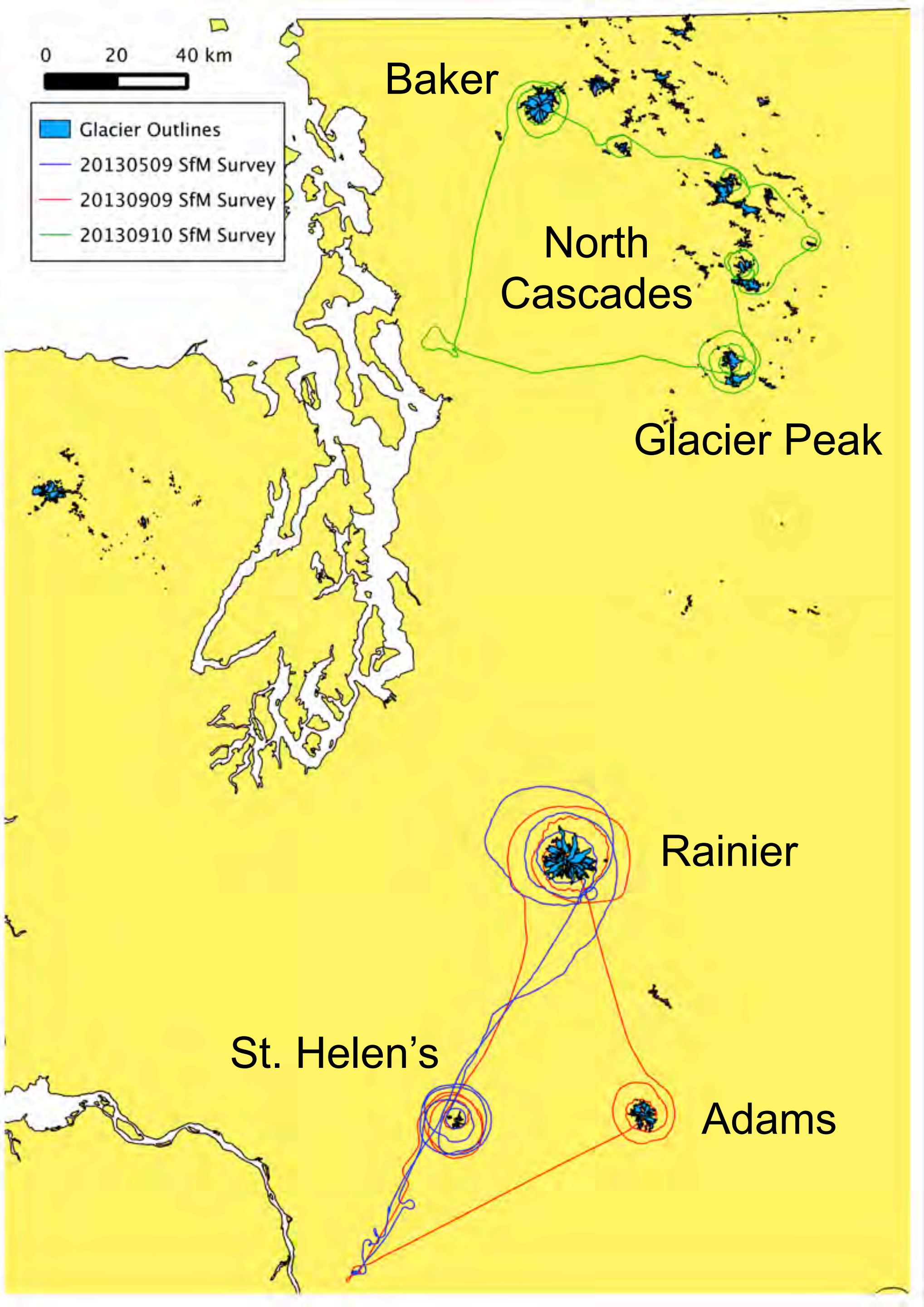


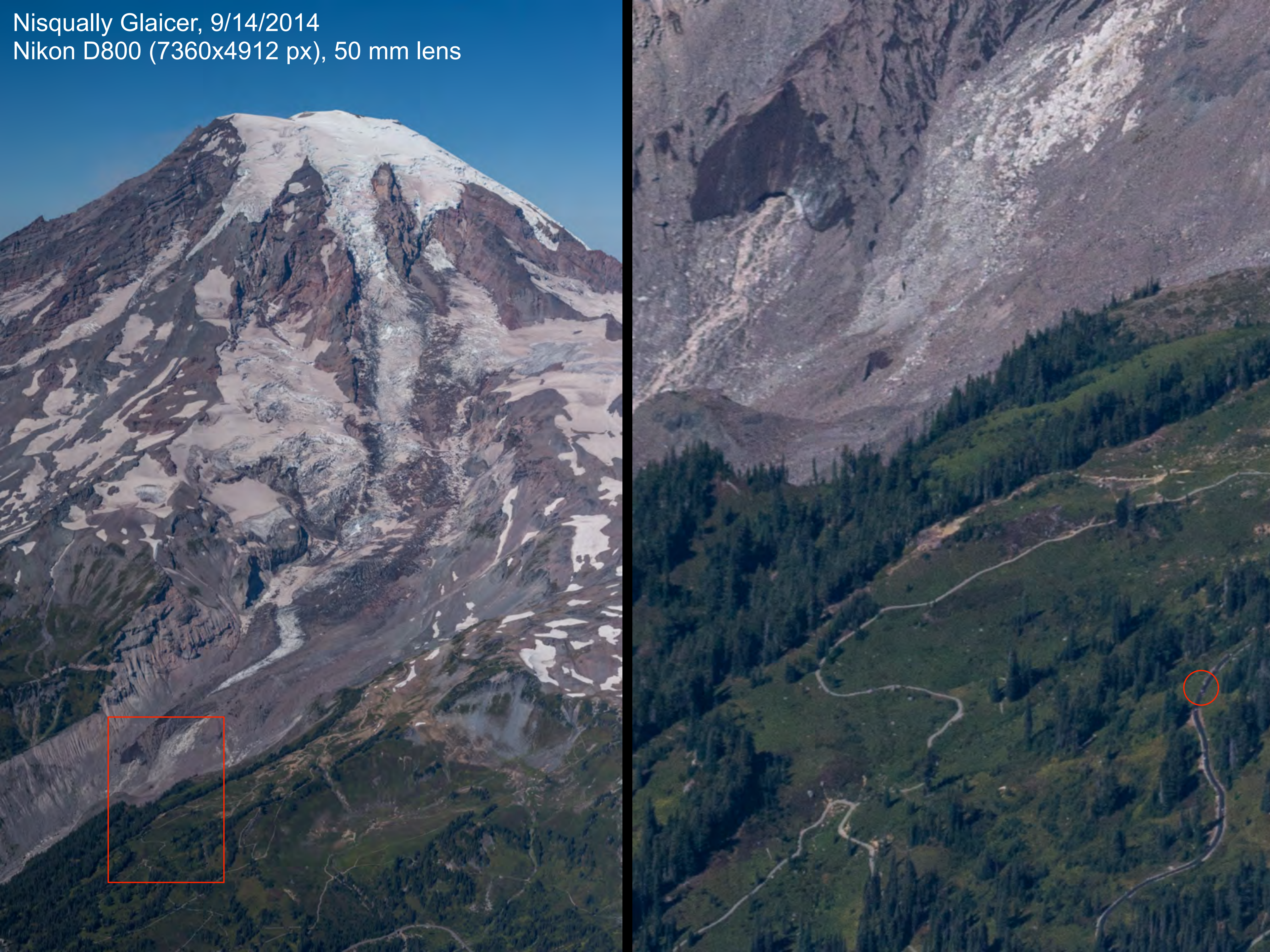

Trimble


MENTAL

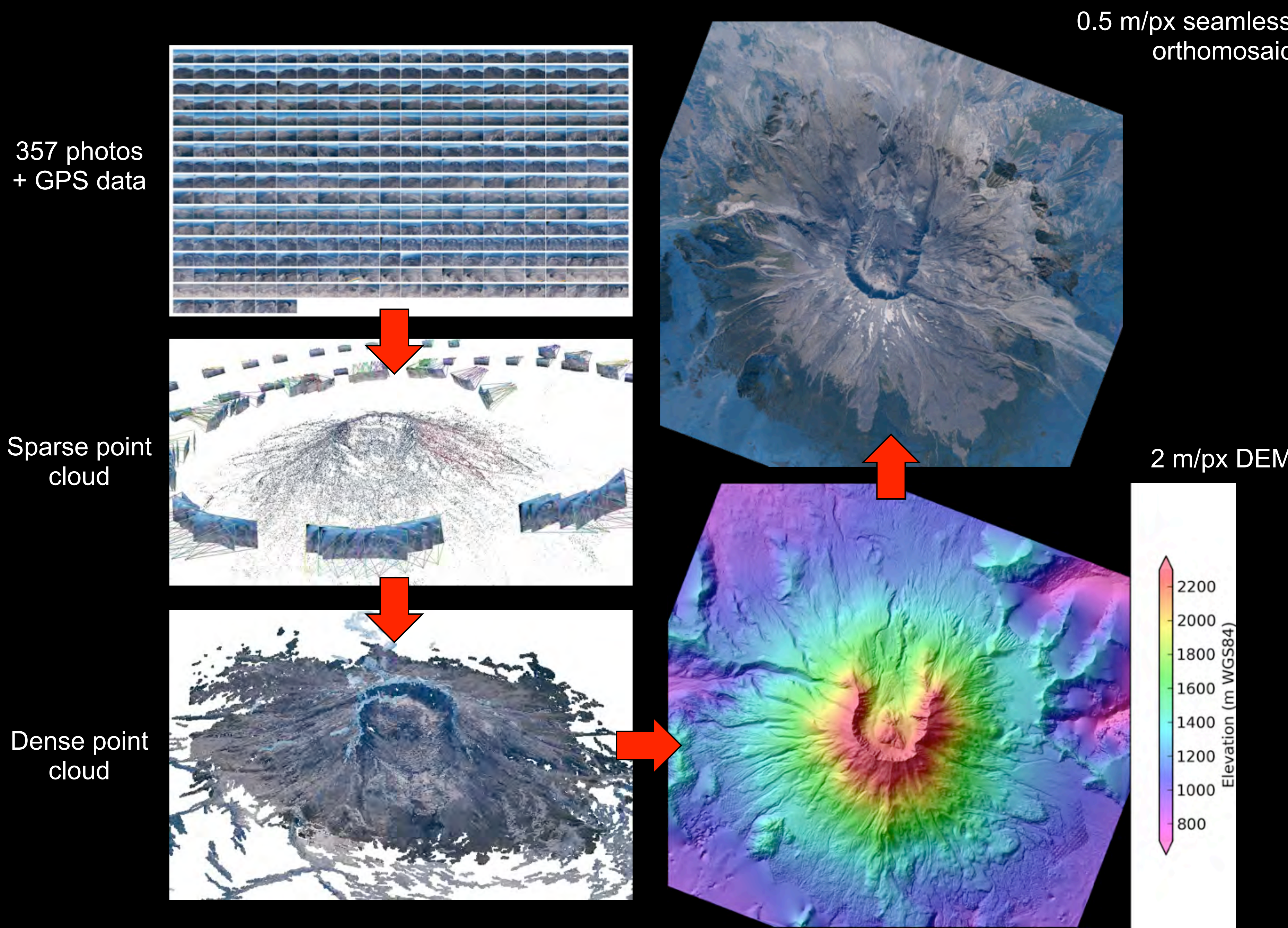
2013 Oblique Aerial Surveys

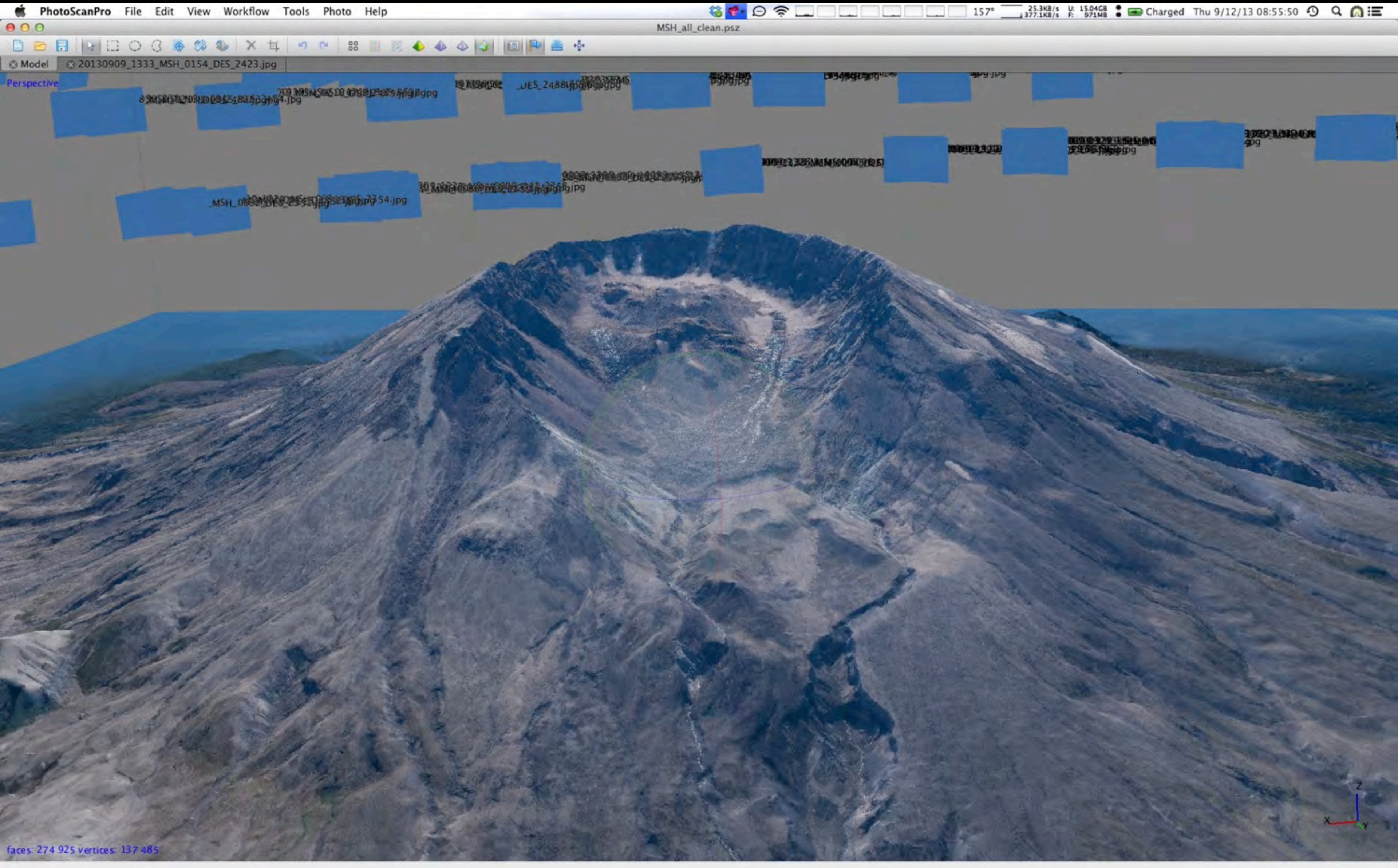
- 3 flights, 2.5 hr each
- $50/hr shared costs
- 2-3 passes
- 5000-15500' altitude




Nisqually Glaicer, 9/14/2014
Nikon D800 (7360x4912 px), 50 mm lens

Structure from Motion Workflow




PhotoScanPro File Edit View Workflow Tools Photo Help
157°
Charged
Thu 9/12/13 08:55:50
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Model
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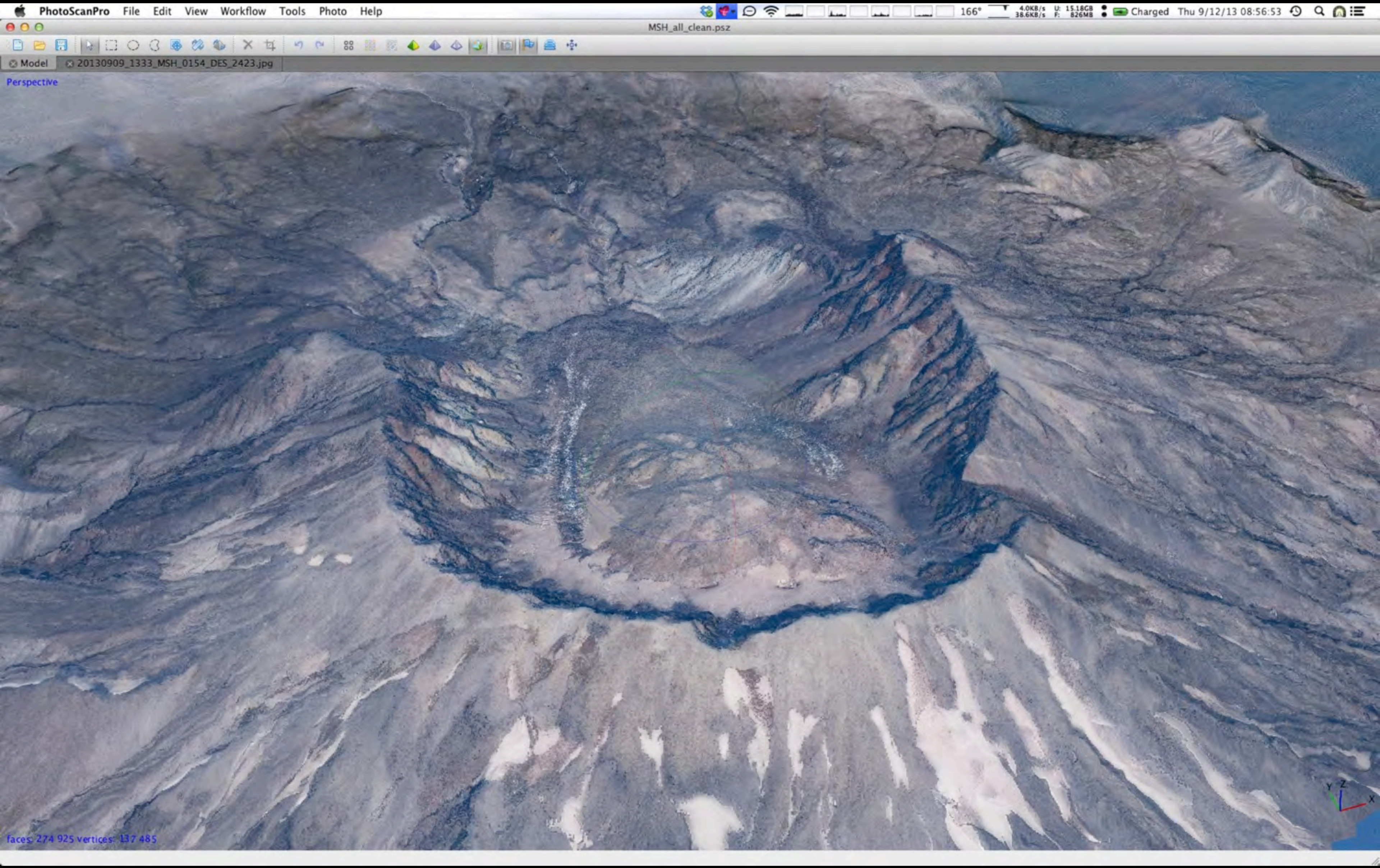
Perspective
faces: 274 925 vertices: 137 485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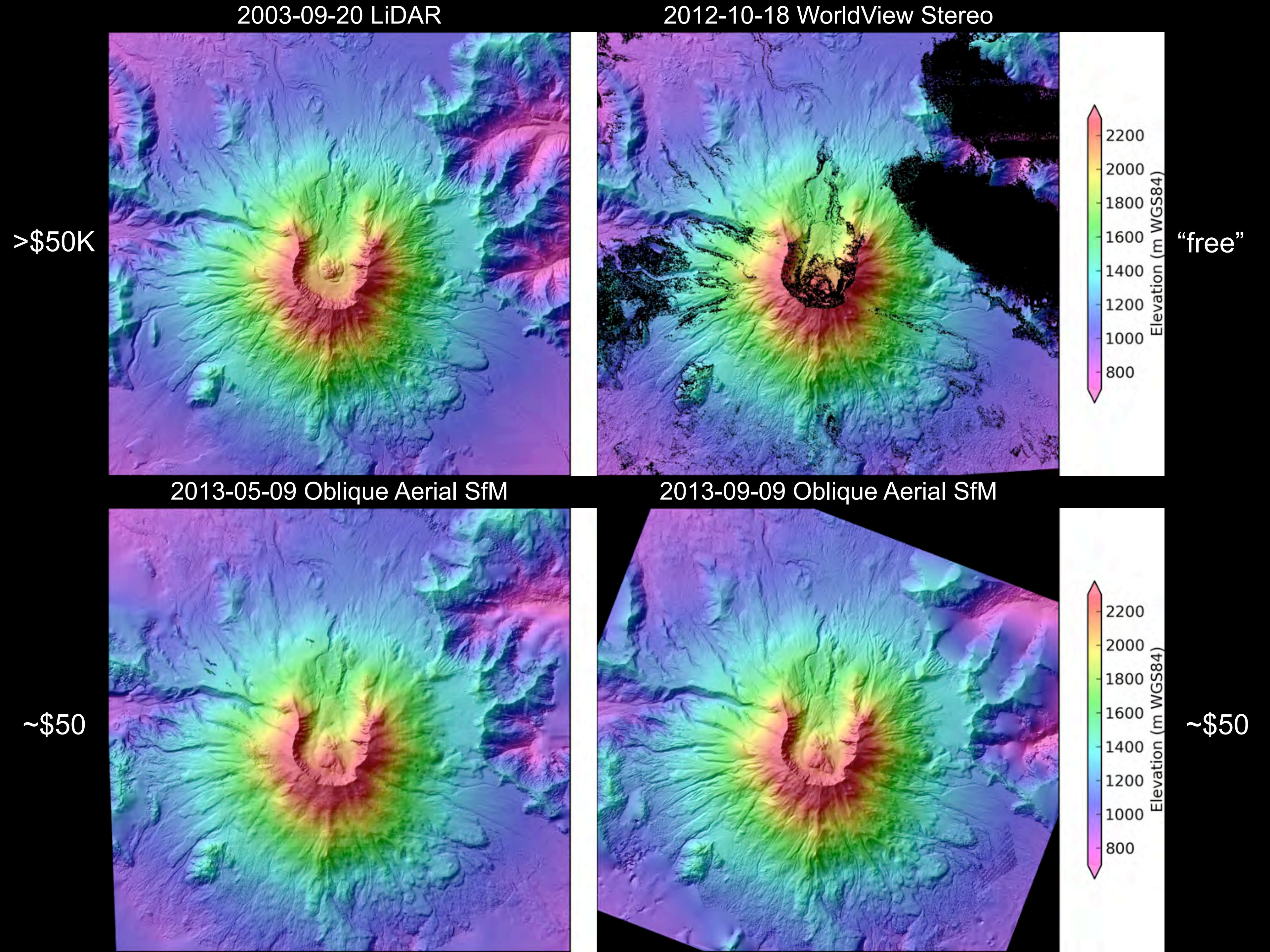
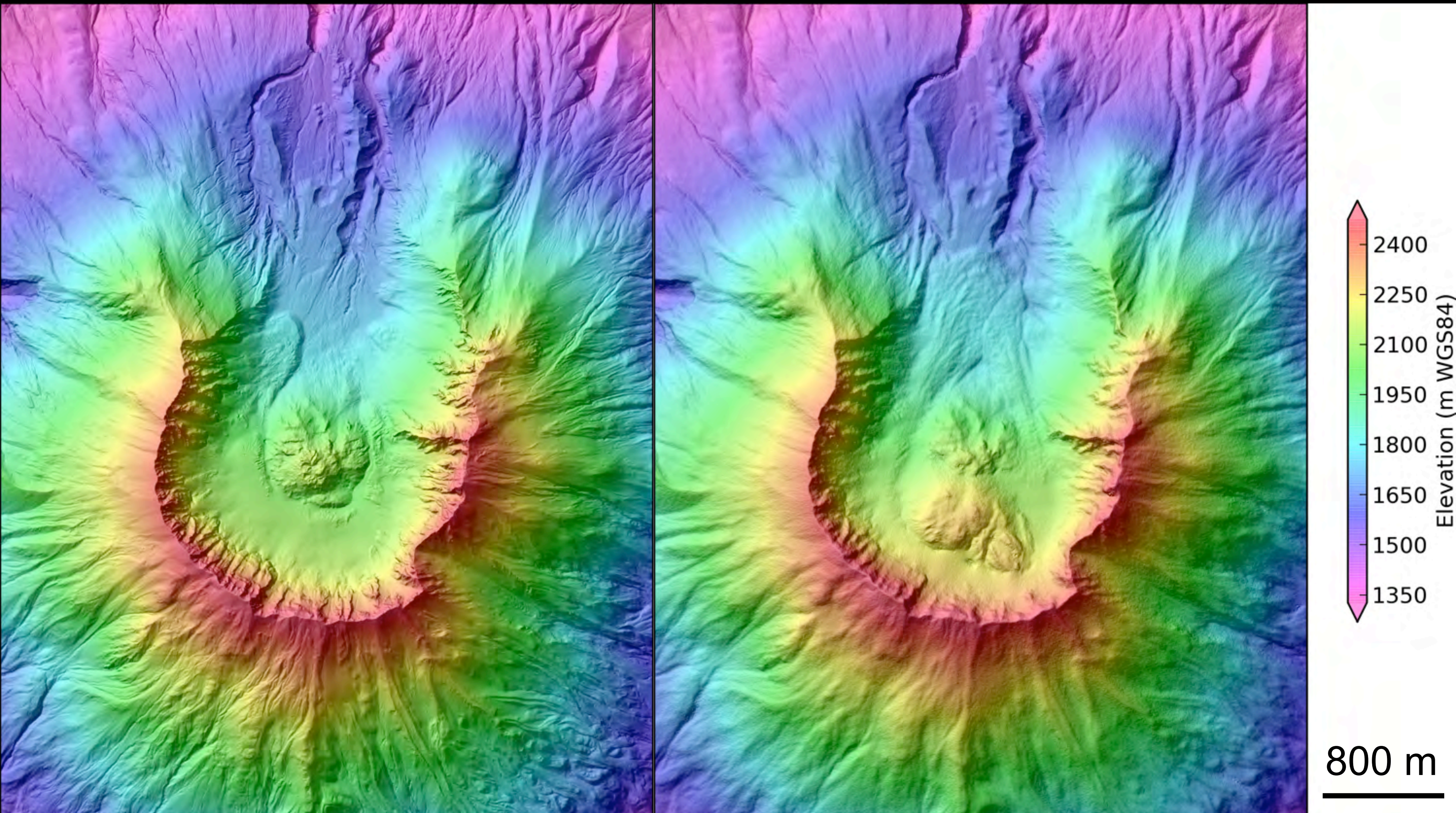
Perspective
faces: 274 925 vertices: 137 485

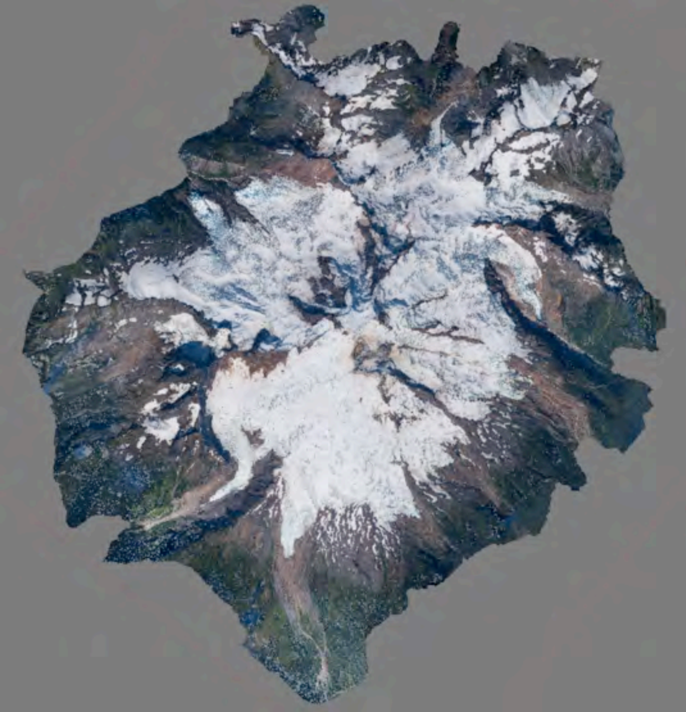

2003-09-20 LiDAR
2012-10-18 WorldView Stereo
>$50K
"free"
2013-05-09 Oblique Aerial SfM
2013-09-09 Oblique Aerial SfM
~$50
~$50
Elevation (m WGS84)
2200
2000
1800
1600
1400
1200
1000
800

2003-09-20 LiDAR

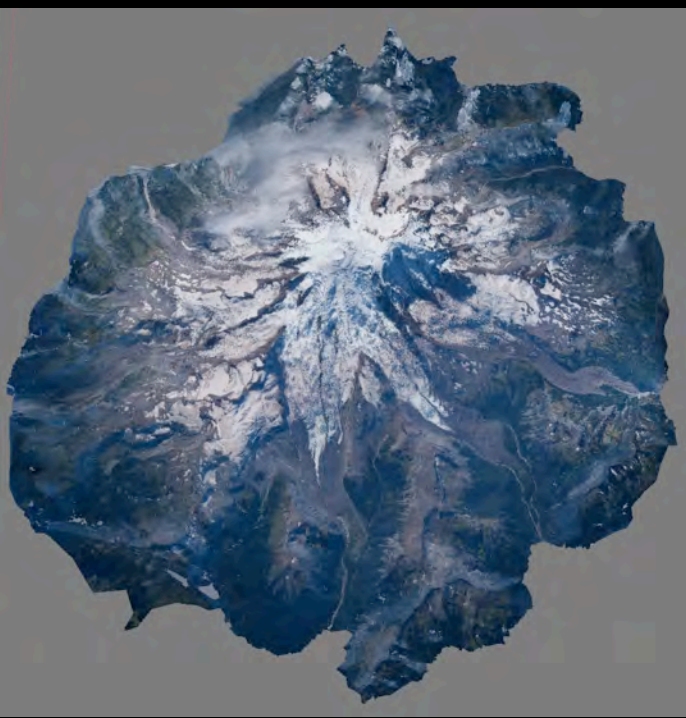
2013-09-09 Oblique Aerial SfM



(“medium” quality)



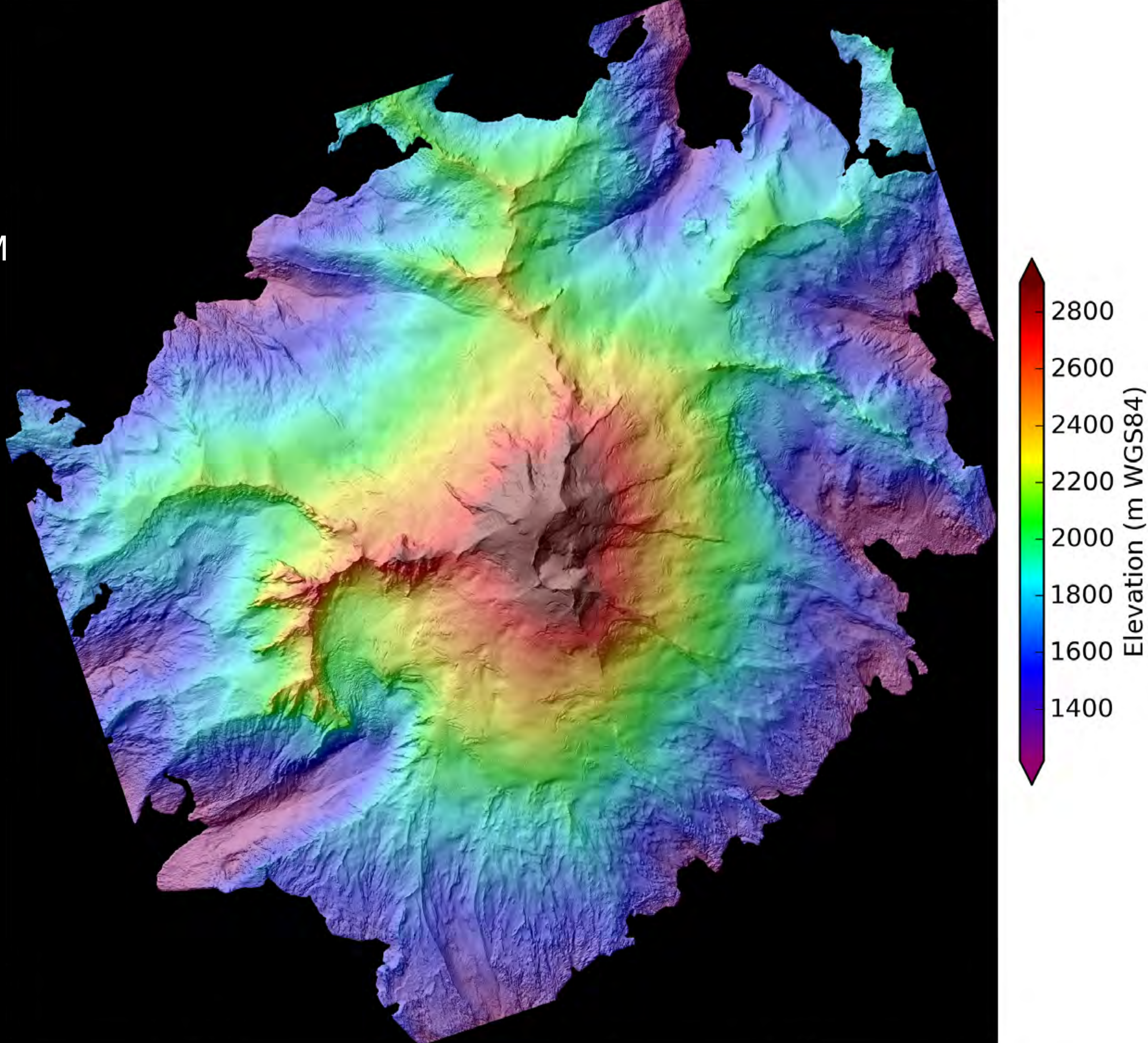
Mt. Baker, 9/10/13, 506 photos, 0.32 m/px, 109 km^2



Mt. Rainier, 9/9/13, 695 photos, 0.65 m/px, 362 km^2

Tait Russell,
UW ESS Senior

9/10/2013
Mt. Baker
3 passes
508 photos
50 mm lens
1.3 m/px DEM



sUAS

Mapping landslide displacements using Structure from Motion (SfM) and image correlation of multi-temporal UAV photography

Progress in Physical Geography
1–20

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Utrecht University, The Netherlands

Darren Turner
University of Tasmania, Australia

Figure 3. The remote controlled UAV OktoKopter equipped with digital camera and GPS.

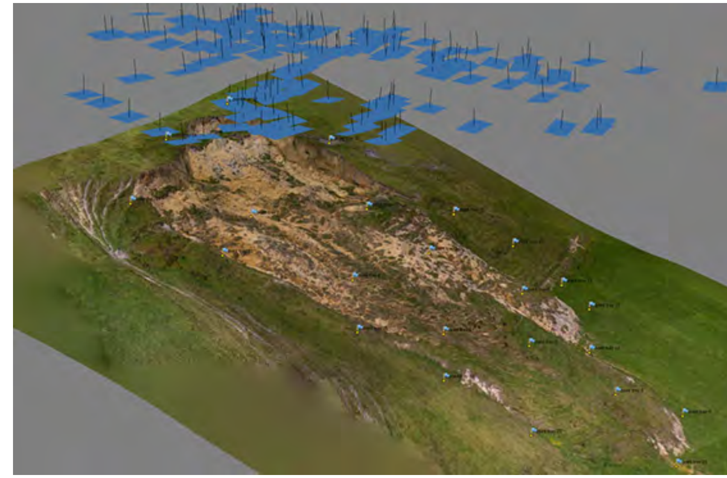

Figure 4. Perspective view of the texture-mapped 3D surface acquired on 10 November 2011. The blue squares over the landslide show the camera positions and orientations during image acquisition by the UAV. The numbered flags on the landslide show the positions of the ground control points used for the bundle adjustment.

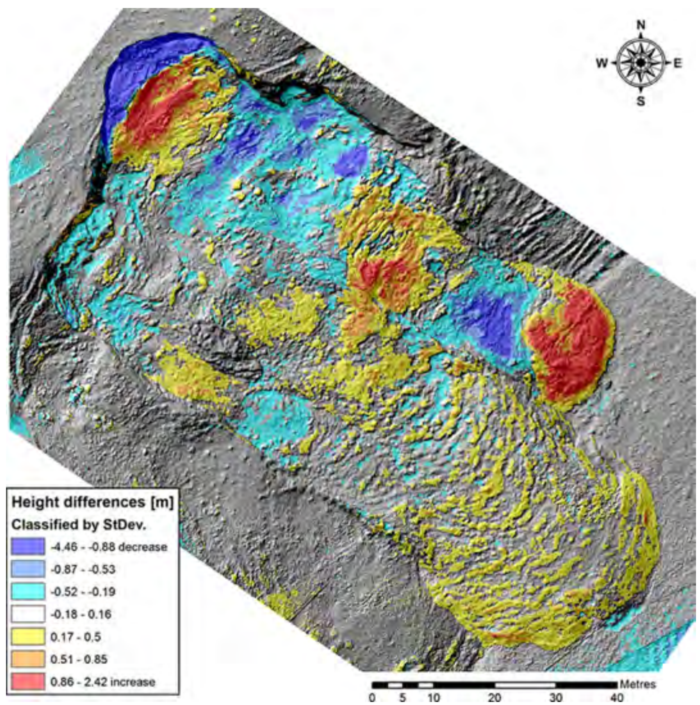

Figure 6. Difference between the 1 cm DEMs of 19 July 2011 and 10 November 2011 illustrating the surface changes and as such the dynamics of the landslide. Note the significant retreat of the main scarp and the expansion of the toes.

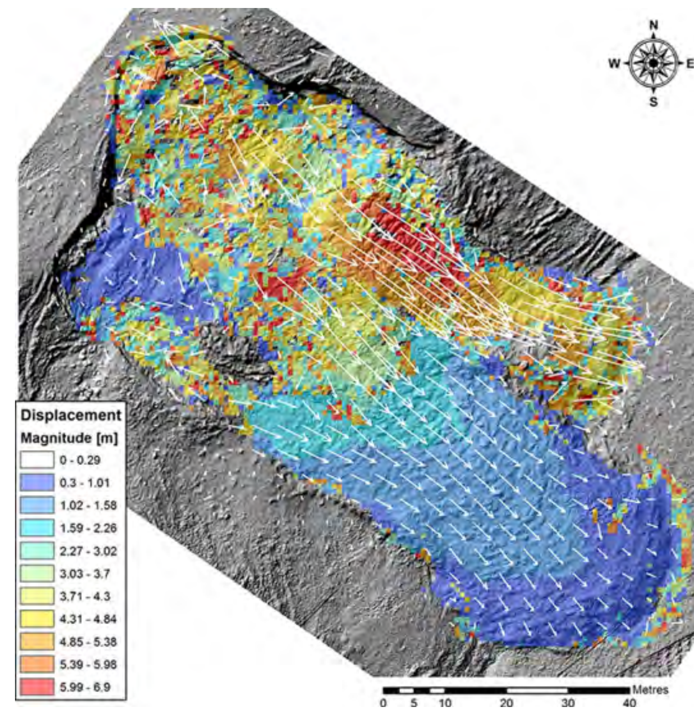

Figure 7. Displacement of the Home Hill landslide between 19 July 2011 and 10 November 2011 using the COSI-Corr algorithm. The white vectors indicate displacement directions and the coloured layer illustrate the combined magnitude of displacements in the N–S and E–W directions.

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Contents lists available at ScienceDirect

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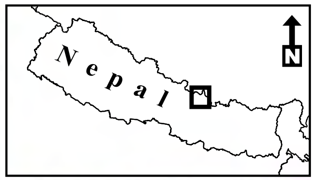
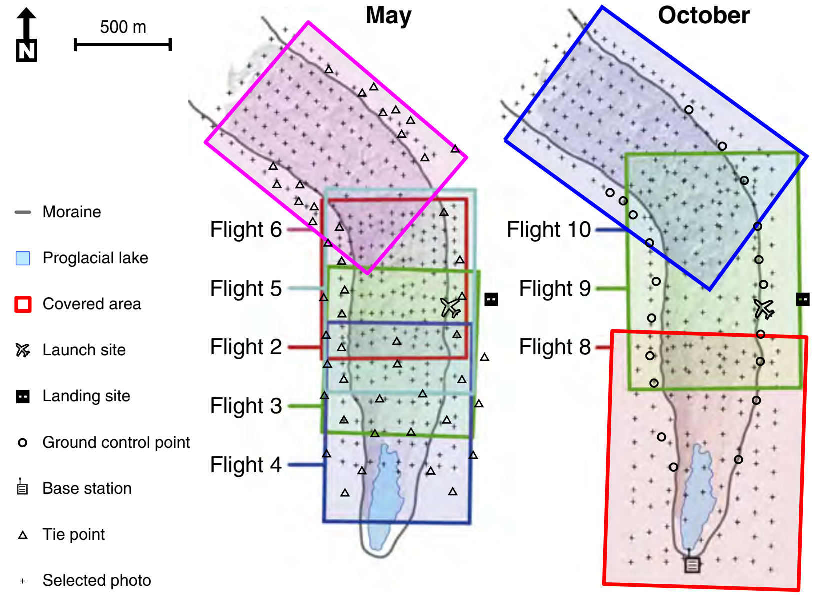
journal homepage: www.elsevier.com/locate/rse

High-resolution monitoring of Himalayan glacier dynamics using unmanned aerial vehicles

W.W. Immerzeel [a,b,c,*], P.D.A. Kraaijenbrink [a], J.M. Shea [b], A.B. Shrestha [b], F. Pellicciotti [b,c], M.F.P. Bierkens [a], S.M. de Jong [a]





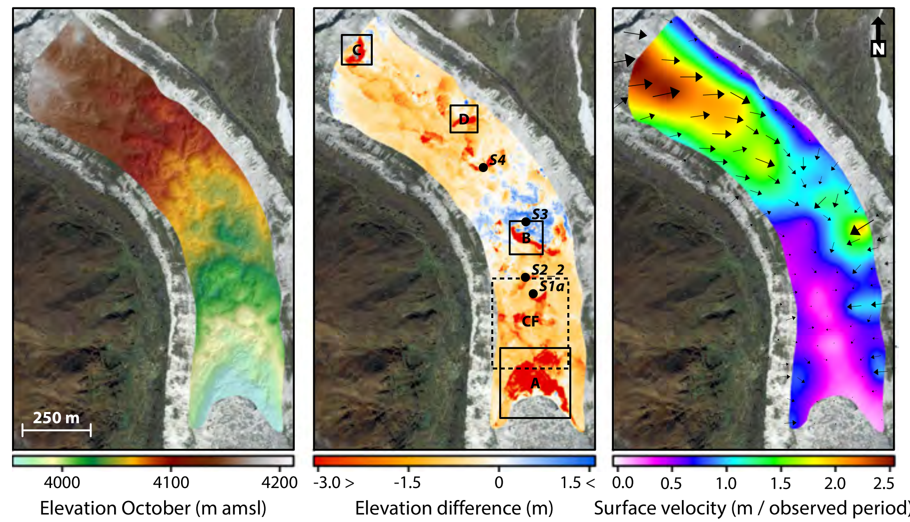


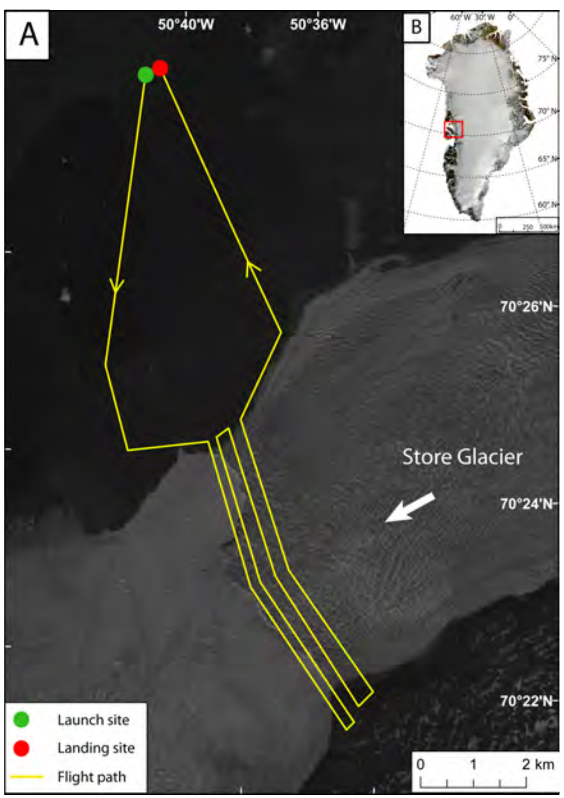
Fig. 5. Digital elevation model in October 2013 (left panel), changes in elevation between May and October 2013 (middle panel), and the derived surface velocity and direction of flow (right panel). The middle panel shows the locations of the ablation stakes and the extents of the panels of Fig. 7 (solid boxes) as well as the extent in Fig. 8 (dashed box).

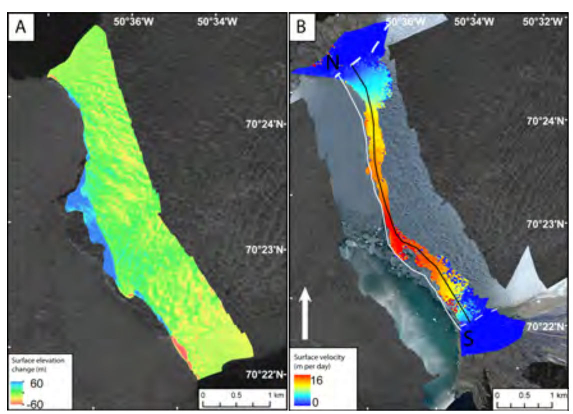
The Cryosphere Discuss., 8, 2243–2275, 2014
www.the-cryosphere-discuss.net/8/2243/2014/
doi:10.5194/tcd-8-2243-2014

The Cryosphere
Discussions
Open Access

Repeat UAV photogrammetry to assess calving front dynamics at a large outlet glacier draining the Greenland Ice Sheet

J. C. Ryan[1], A. L. Hubbard[1], J. Todd[2], J. R. Carr[1], J. E. Box[3], P. Christoffersen[2], T. O. Holt[1], and N. Snooke[4]





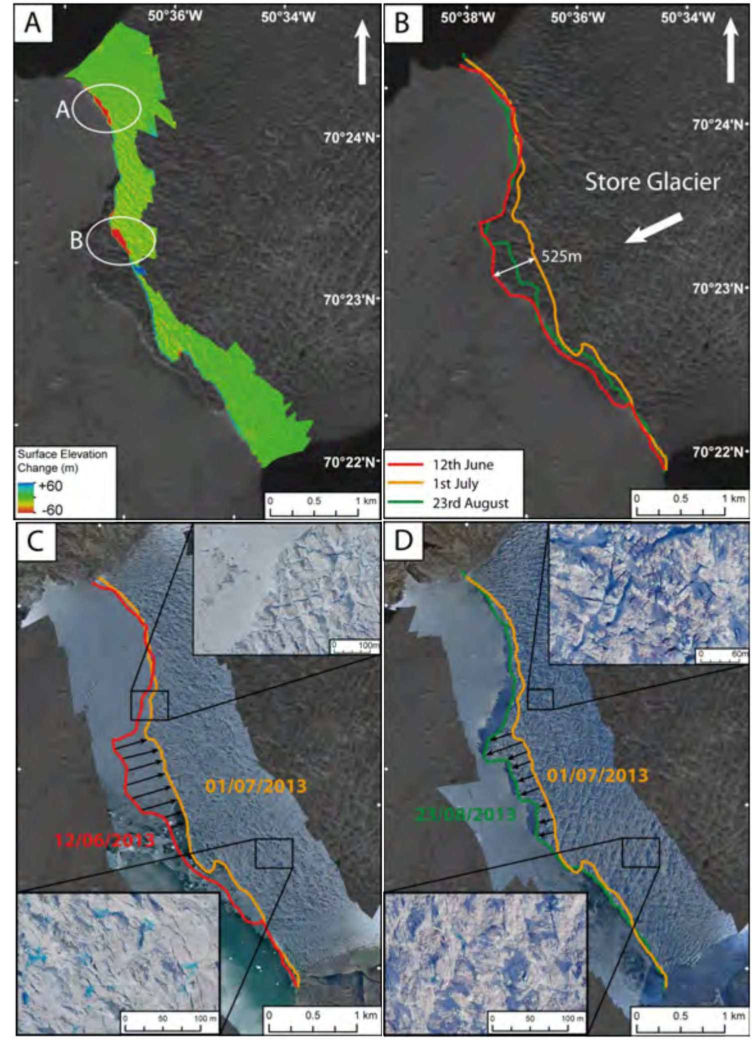


Fig. 3. (A) Surface elevation difference between two DEMs collected on the 1 July and 2 July. Red areas show elevation loss whilst blue areas show elevation gain. White circles highlight the calving events that occurred between the two UAV surveys. **(B)** The position of the calving front of Store Glacier during the summer of 2013. **(C)** Calving front retreat observed between 12 June and 1 July. Inset is an orthorectified image of the water-filled crevasses observed on 1 July with a pixel resolution of 30 cm. **(D)** Calving front advance observed between 1 July and 23 August. Inset is an orthorectified image showing water-filled crevasses observed on 23 August. The coverage and size of water-filled crevasses is smaller.

Commercial Options

- Aeromao Aeromapper (~$10K)
- Trimble UX5 (likely $50-100K)
- senseFly eBee ~$20K
- Aeryon Scout Quad (~$100K)
- Aibot X6 (likely $50K)

Aero-M

The Aero-M is an all-in-one solution for creating high-resolution visual-spectrum aerial maps. The fixed-wing platform offers incredible endurance and scope of coverage, with 40 minutes of flight time and up to 250 acres of coverage area. It's the perfect platform for regularly acquiring highly detailed and actionable data for large-scale operations such as farming, construction and conservation, as well as search and rescue and emergency response. We've chosen a lightweight and robust foam frame, which translates to less risk and cost per flight and multiplies the cost-effectiveness of our platform.

The Aero-M package includes a Canon SX260 high-resolution 12 MP camera and the powerful image processing tool, Pix4Dmapper 3DR Edition software, to create highly accurate, georeferenced and orthorectified mosaics.

Price: $5400

Includes: Aircraft, transmitter, two batteries, spare parts, high-resolution camera, hard case

Software Included: Pix4Dmapper LT 3DR Edition

Options: Ground station frequency (413 or 915), FPV (optional), upgrade to Pix4Dmapper Pro 3DR Edition (optional), extra batteries (optional)

Autopilot: Pixhawk autopilot system

Flight time: 40 min*

Area coverage: 250 acres*

Map ground resolution: 2 inches per pixel (5 cm per pixel)*

Orthomosaic accuracy: 3-16 ft (1-5 m)

Buy Now ›

X8-M

The X8-M is the perfect tool for creating high-resolution visual-spectrum aerial maps. The platform offers low-flying and high accuracy mapping, with a fully redundant propulsion system for increased reliability. Easy to fly and simple to operate, the X8-M can take off and land even in the tightest areas, which makes the vehicle compatible with just about any type of terrain. And because the X8-M can fly at low altitudes and at slow speeds, it can capture images with a level of detail and precision that's impossible to acquire with manned flights or satellite imagery.

The X8-M package includes a Canon SX260 high-resolution 12 MP camera and the powerful image processing tool, Pix4Dmapper LT 3DR Edition software, to create highly accurate, georeferenced and orthorectified mosaics.

Price: $5400

Includes: Aircraft, transmitter, two batteries, spare parts, camera, hard case

Software Included: Pix4Dmapper LT 3DR Edition

Options: Ground station frequency (413 or 915), FPV (optional), upgrade to Pix4Dmapper Pro 3DR Edition (optional), extra batteries (optional)

Autopilot: Pixhawk autopilot system

Flight time: 14 min*

Area coverage: 25 acres*

Map ground resolution: .7 inches per pixel (2 cm per pixel)*

Orthomosaic accuracy: 3-16 ft (1-5 m)

Buy Now ›

DIY UAVs

Hobby airframe ($100)

+

Autopilot + GPS ($280)

+

Sensors ($200-400)

- Cheap: ~$500-1000 total
- On-demand, repeat surveys in minutes
- Manual or autonomous navigation
- Low altitude (<400’) = high-resolution (cm/px)
- ~1-100 km range, ~0.1-2.0 hr flight time

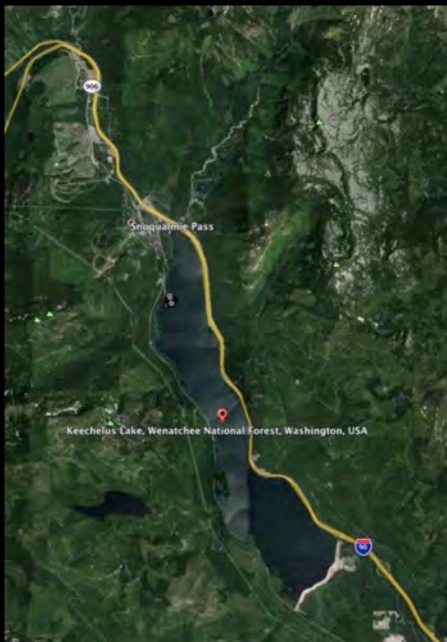
2014 Prototypes

$200 quadcopter

$150 fixed wing

$150 flying wing

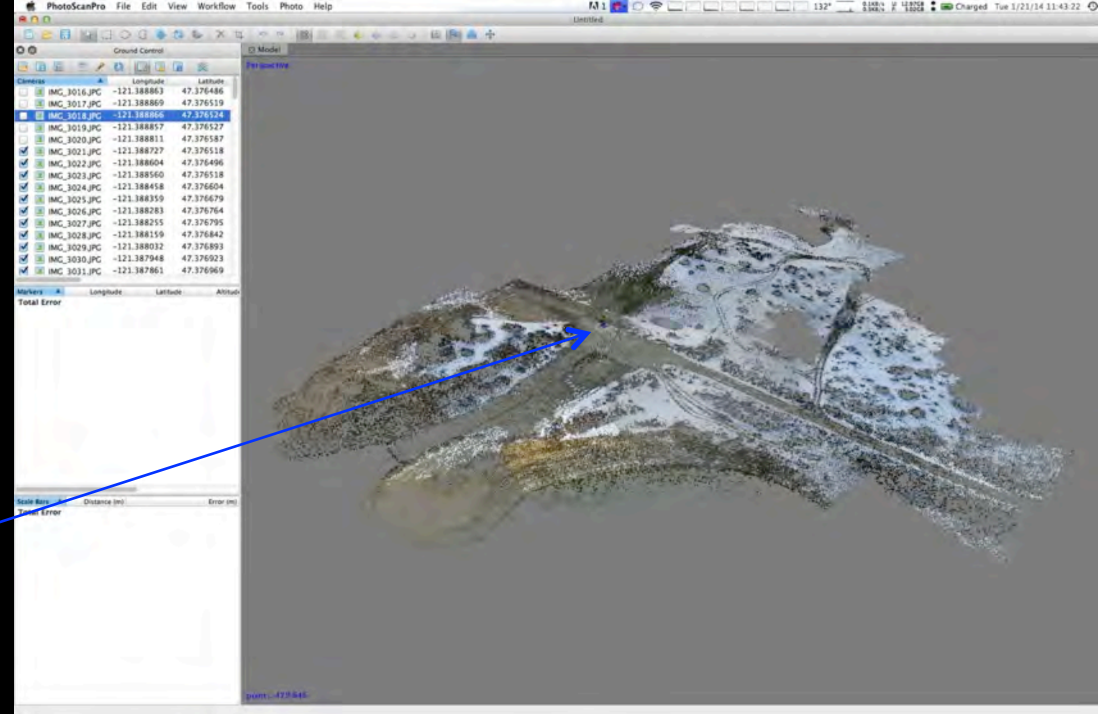
Keechelas Lake Pilot Study

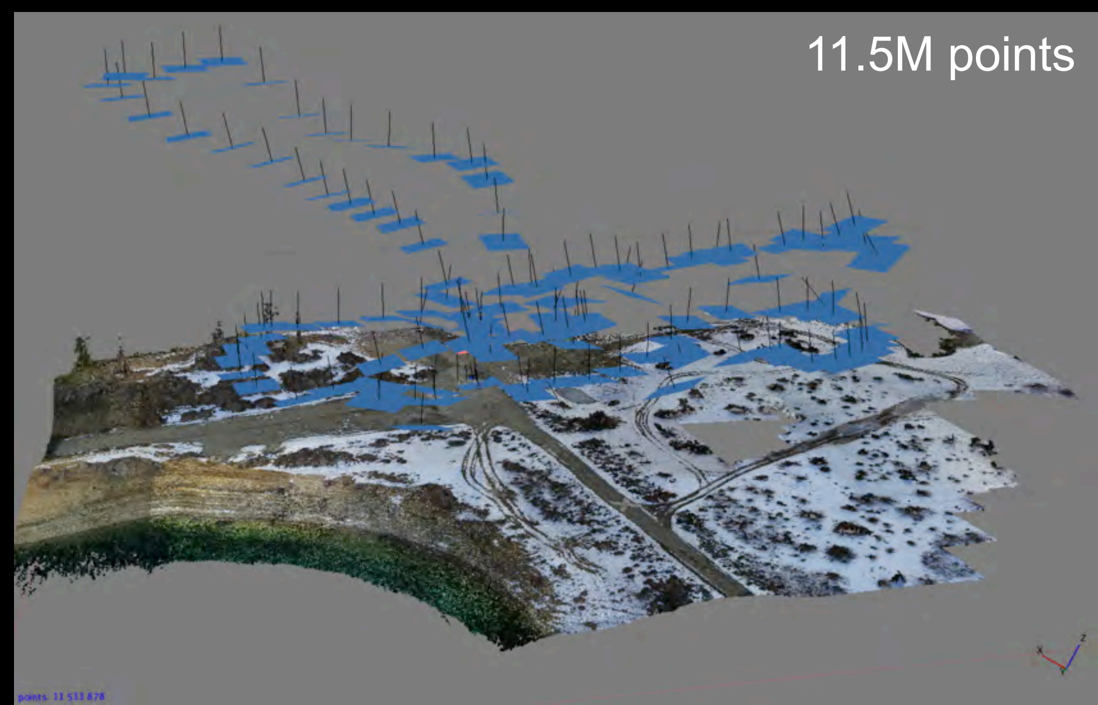


Blade 350 QX Quadcopter

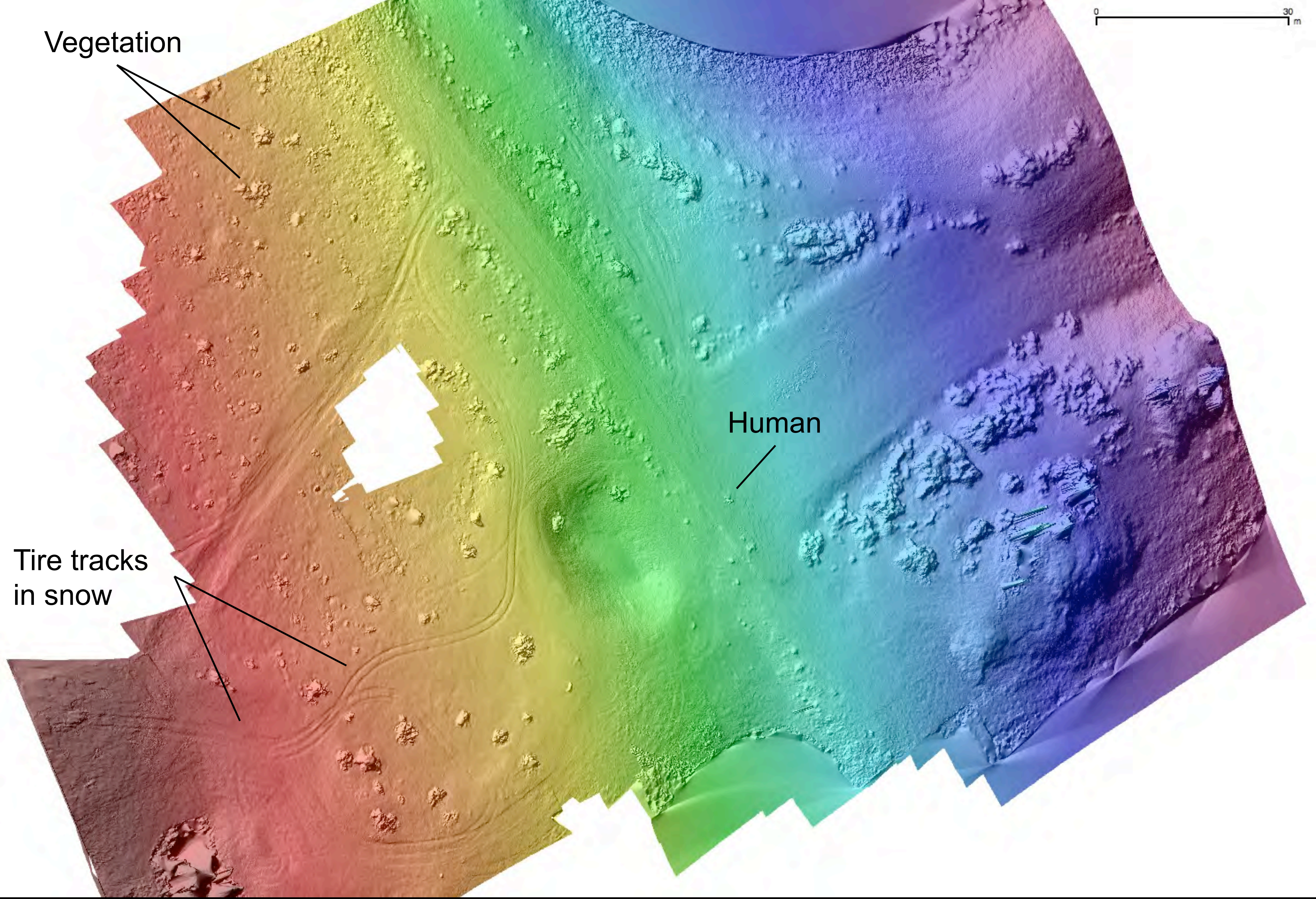
+

11 MP Canon S100

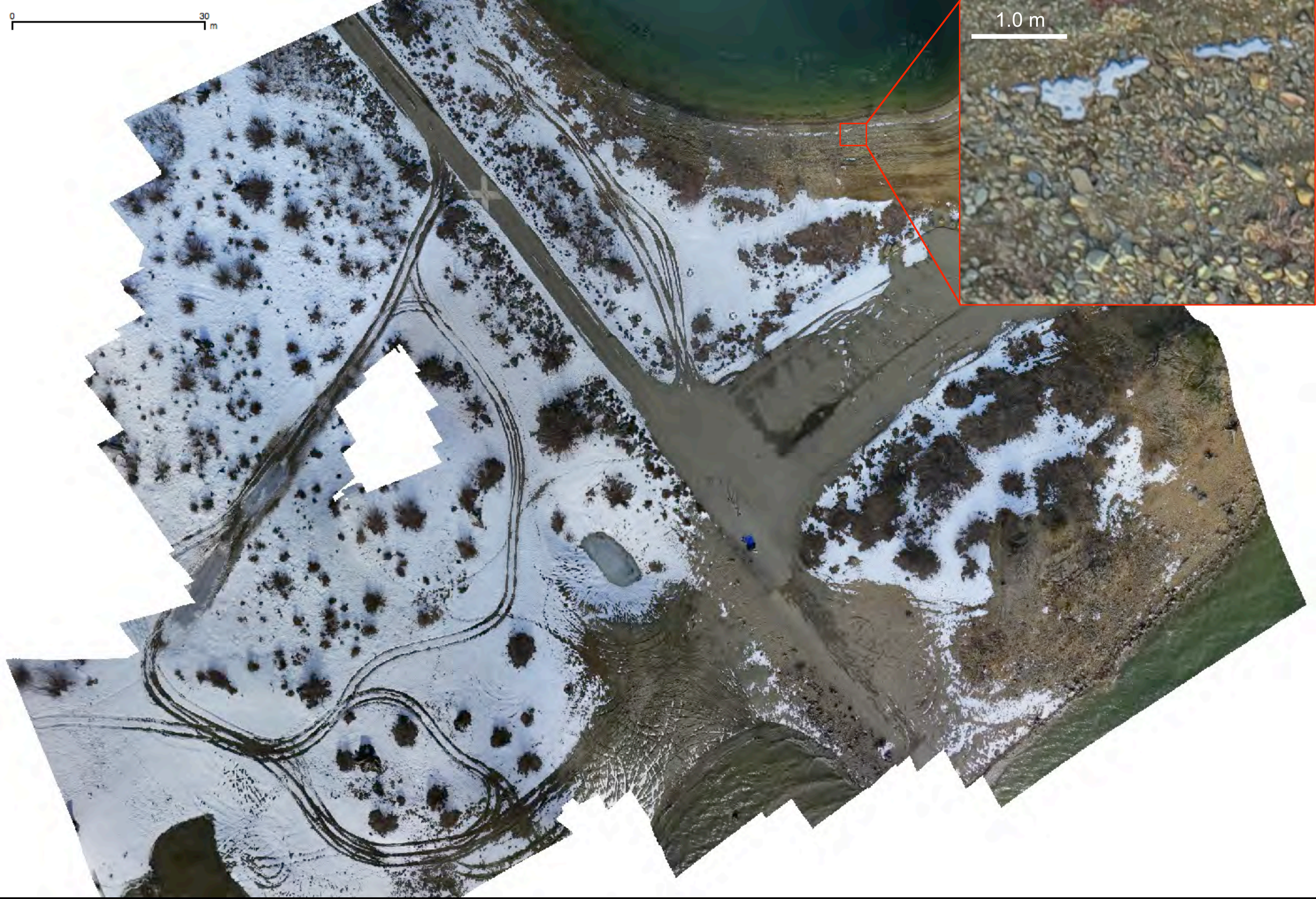




- ~5 minute manual flight
- ~120 images



~200x200 m, ~5 cm/px topography



~200x200 m, ~1 cm/px image mosaic

Lower Easton Glacier Survey

- August 8, 2014
- Pilot study for UAV SfM survey in alpine/glacial environment
- Mount Baker Recreational Area
- 6 volunteers
- TBS Discovery quadcopter
- Seven ~6-8 min flights
- Manual control
- Sony NEX-5N w/ 20 mm lens
- Pixhawk4 GPS/IMU/telemetry
- 650 Images

The Quad


NEX-5 survey camera
Telemetry Tx


FPV video Tx
RC Rx
Pixhawk4
NAZA flight controller GPS
Pixhawk4 GPS/compass
Pilot’s camera

The Crew

Spotter #1
Long-range video antenna

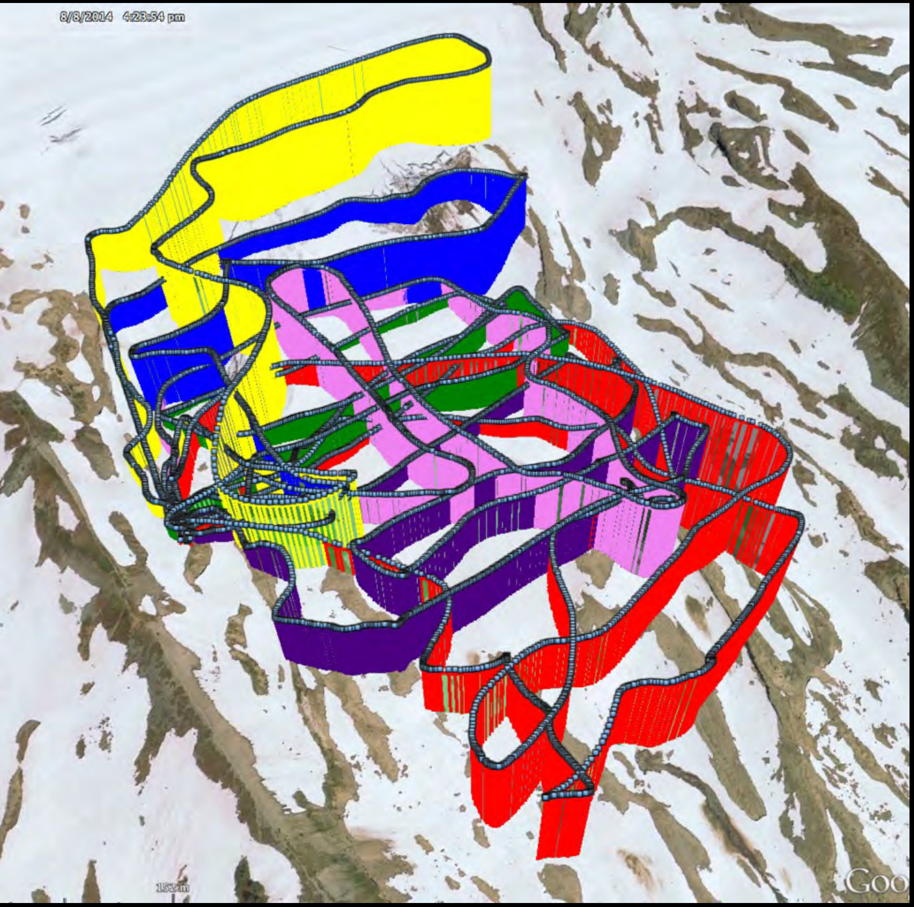
Spotter #3
Monitoring OSD feed

Pilot

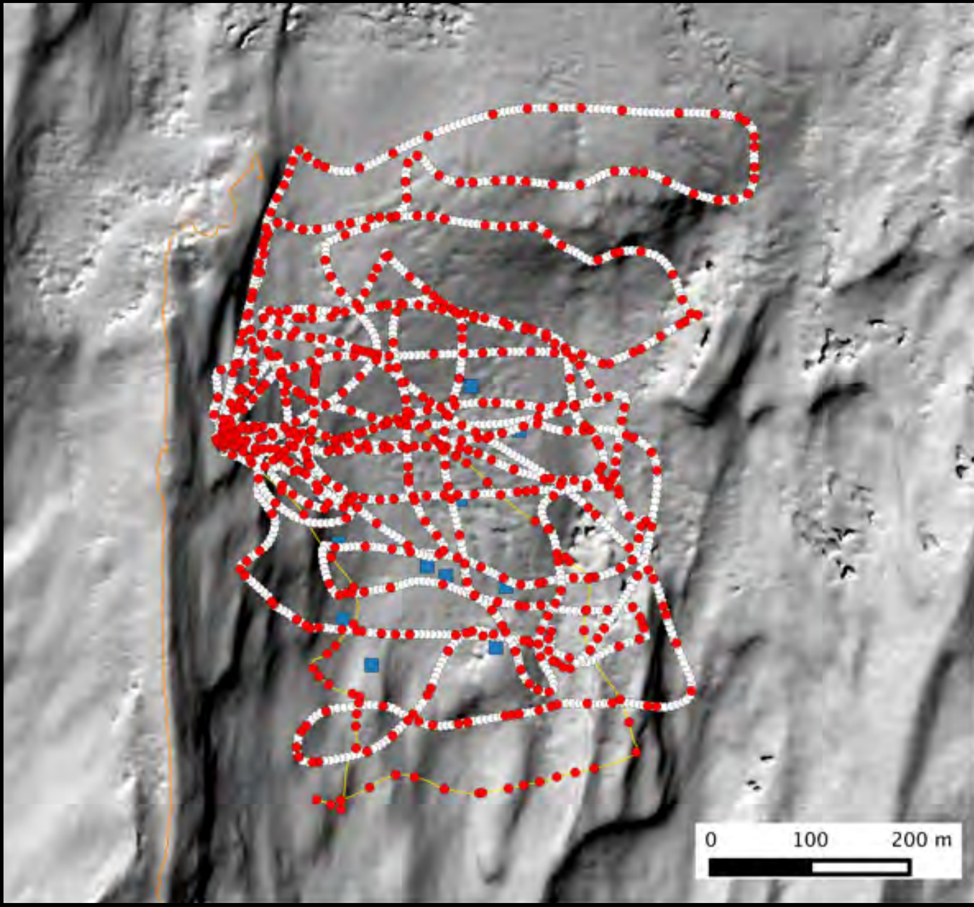
Telemetry link
(real-time position on map, battery voltage, etc.)

Spotter #2
(binoculars)

GPS/Camera Logs



3D view of data collection flights



White: camera trigger fired
Red: photo locations (delays due to poor camera/trigger tuning)
Blue: ground control points

Photo from Sony NEX-5N: 16MP, 4912 × 3264

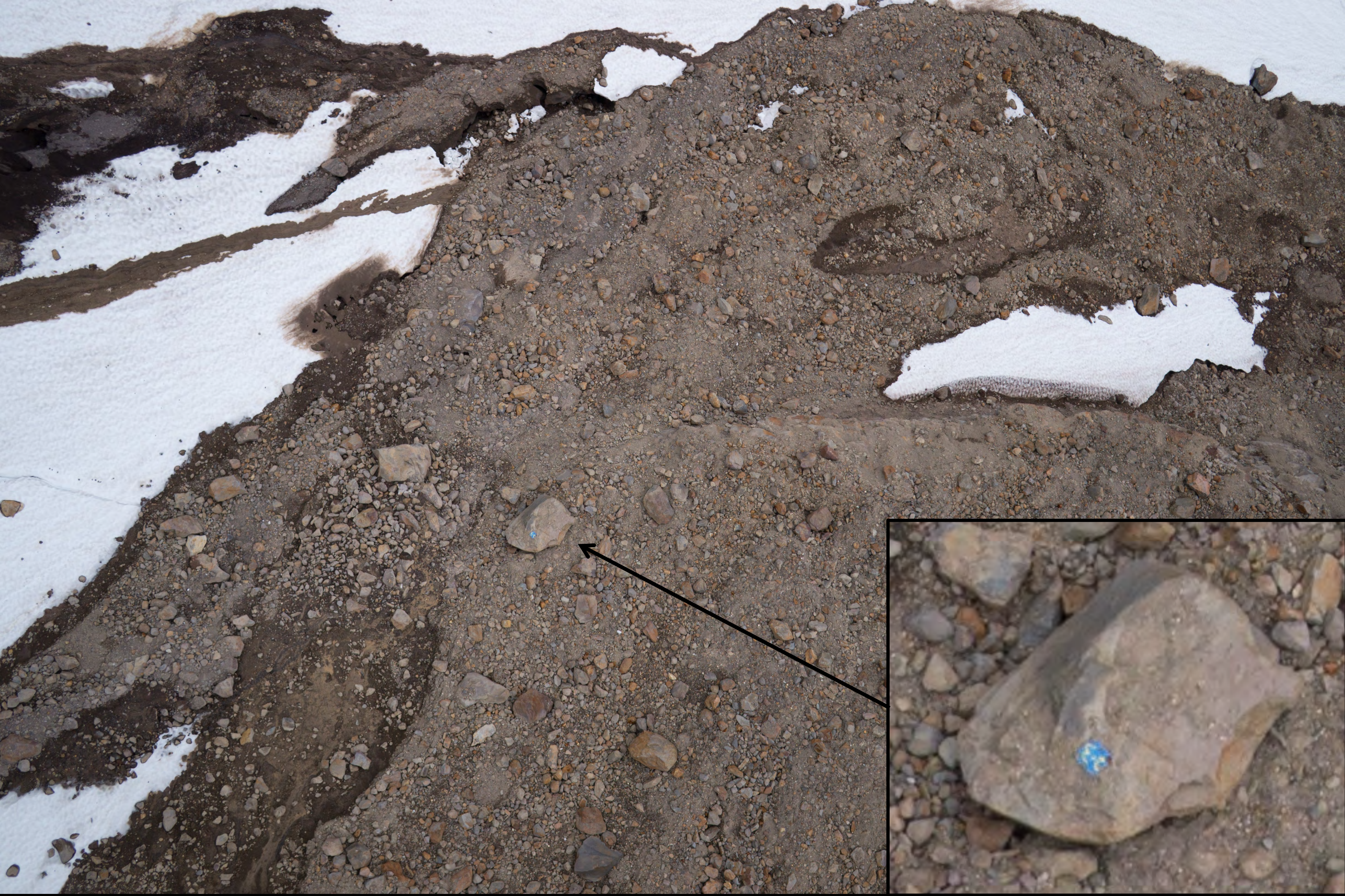
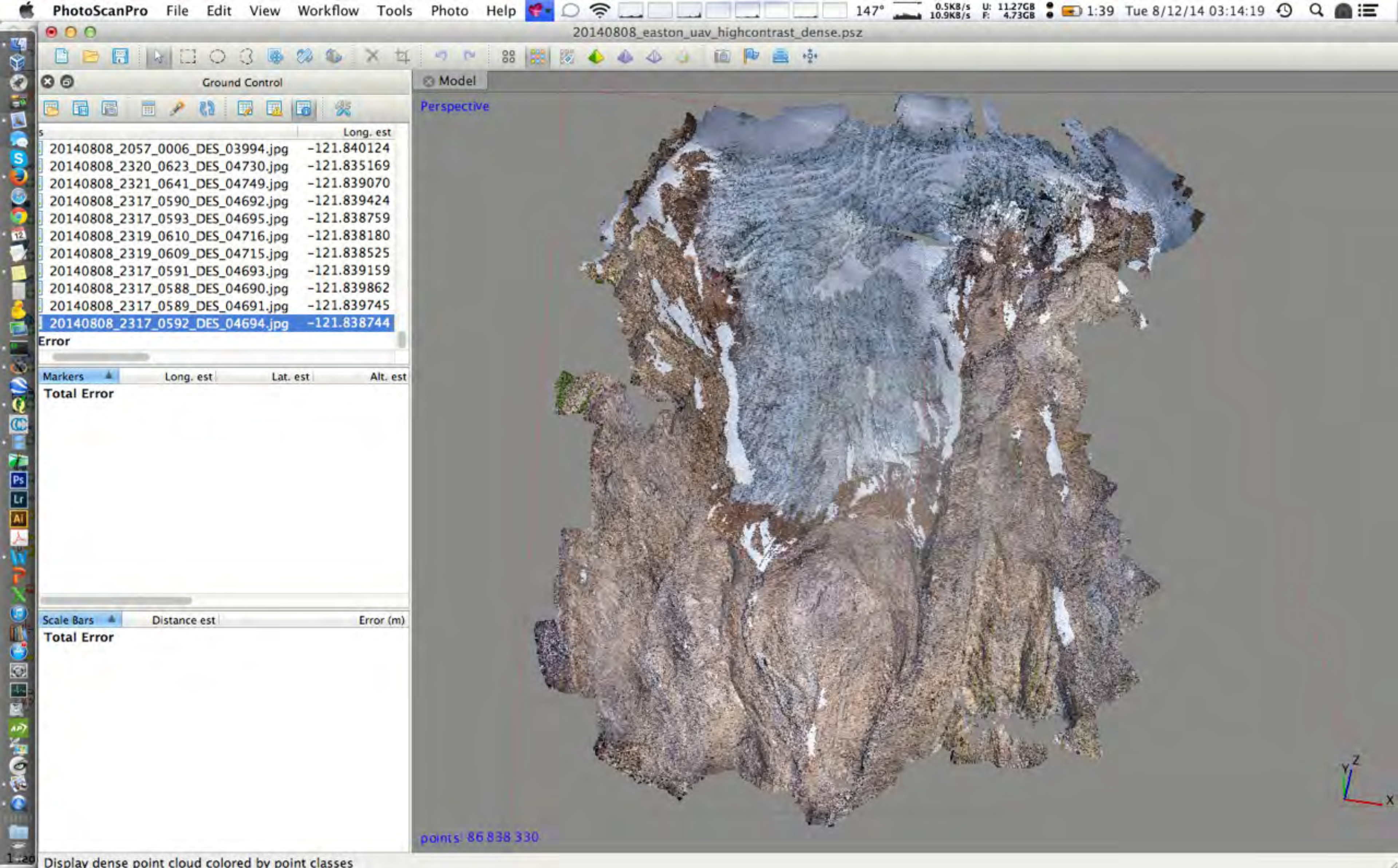
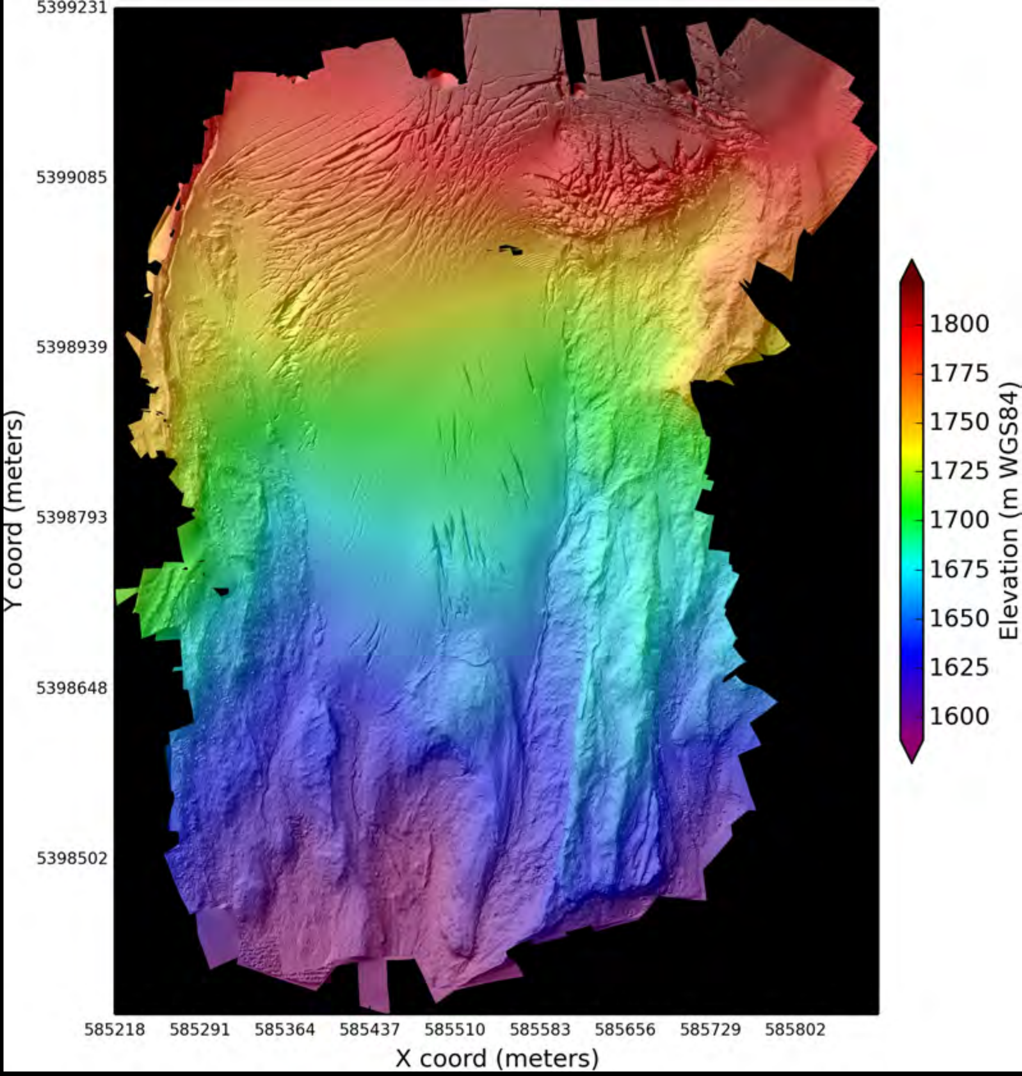


Photo from Sony NEX-5N: 16MP, 4912 × 3264

GCP #23 (~1’x1’ tarp)



Dense Point Cloud ("medium" quality): 87 million points, ~67 pts/m^2



~2 cm/px orthomosaic

~7 cm/px gridded DEM
670 x 845 m

Survey Data

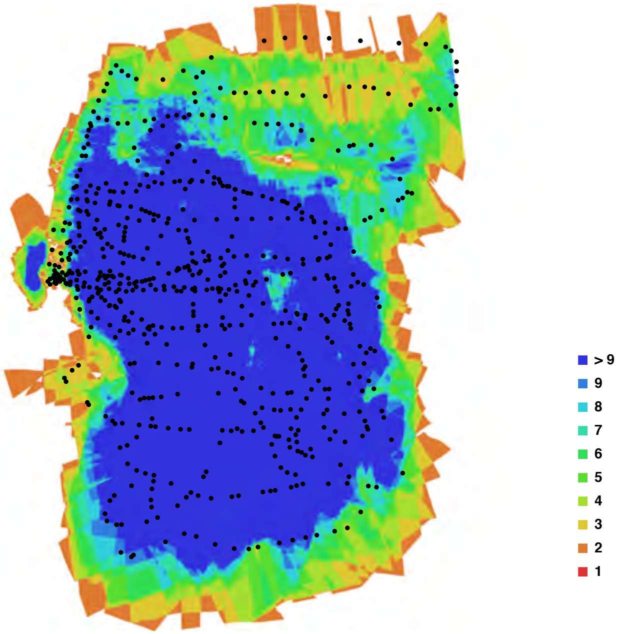


Fig. 1. Camera locations and image overlap.

Number of images:	650	Camera stations:	647
Flying altitude:	83.3726 m	Tie-points:	3454877
Ground resolution:	0.0181417 m/pix	Projections:	11291307
Coverage area:	0.386591 sq km	Error:	0.638477 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
NEX-5N (20 mm)	4912 x 3264	20 mm	4.76384 x 4.76384 um	No
NEX-5N (20 mm)	3264 x 4912	20 mm	4.76384 x 4.76384 um	No

Table. 1. Cameras.

XY DGPS GCP Accuracy: 0.23 m

Z DGPS GCP Accuracy: 0.57 m

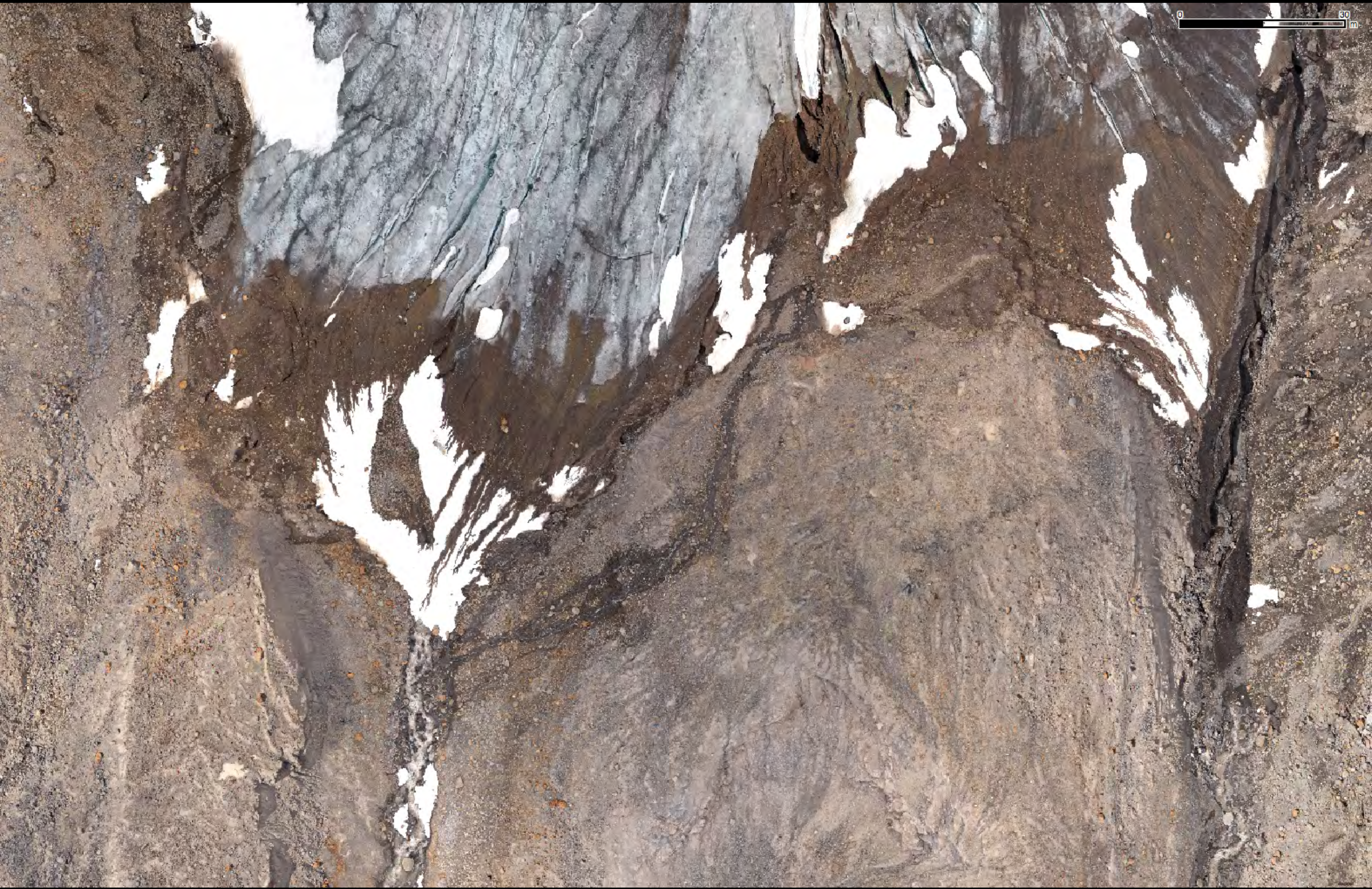
Mean GCP Accuracy: 0.4 m

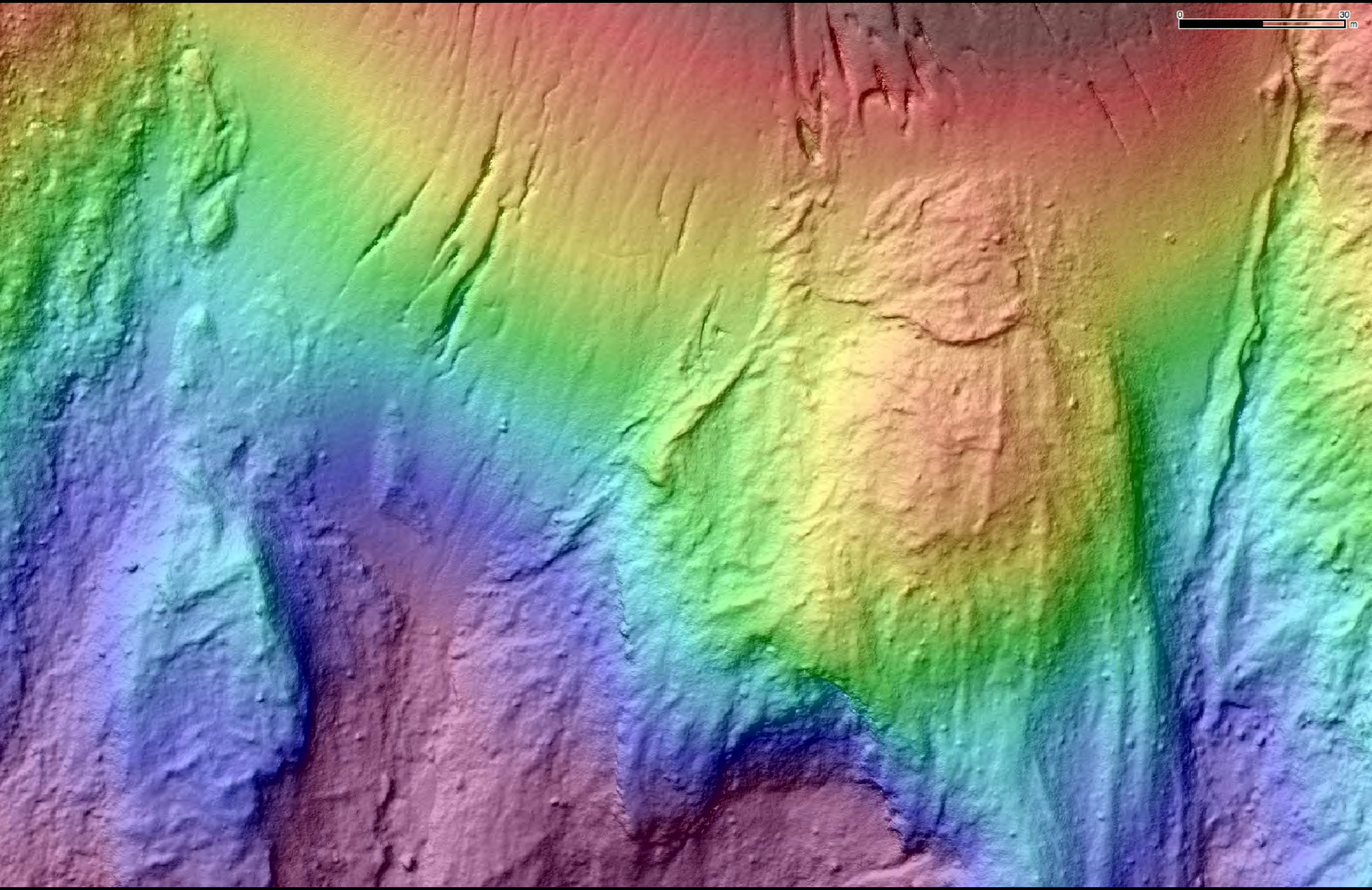
Ground Control Points

Fig. 3. GCP locations.

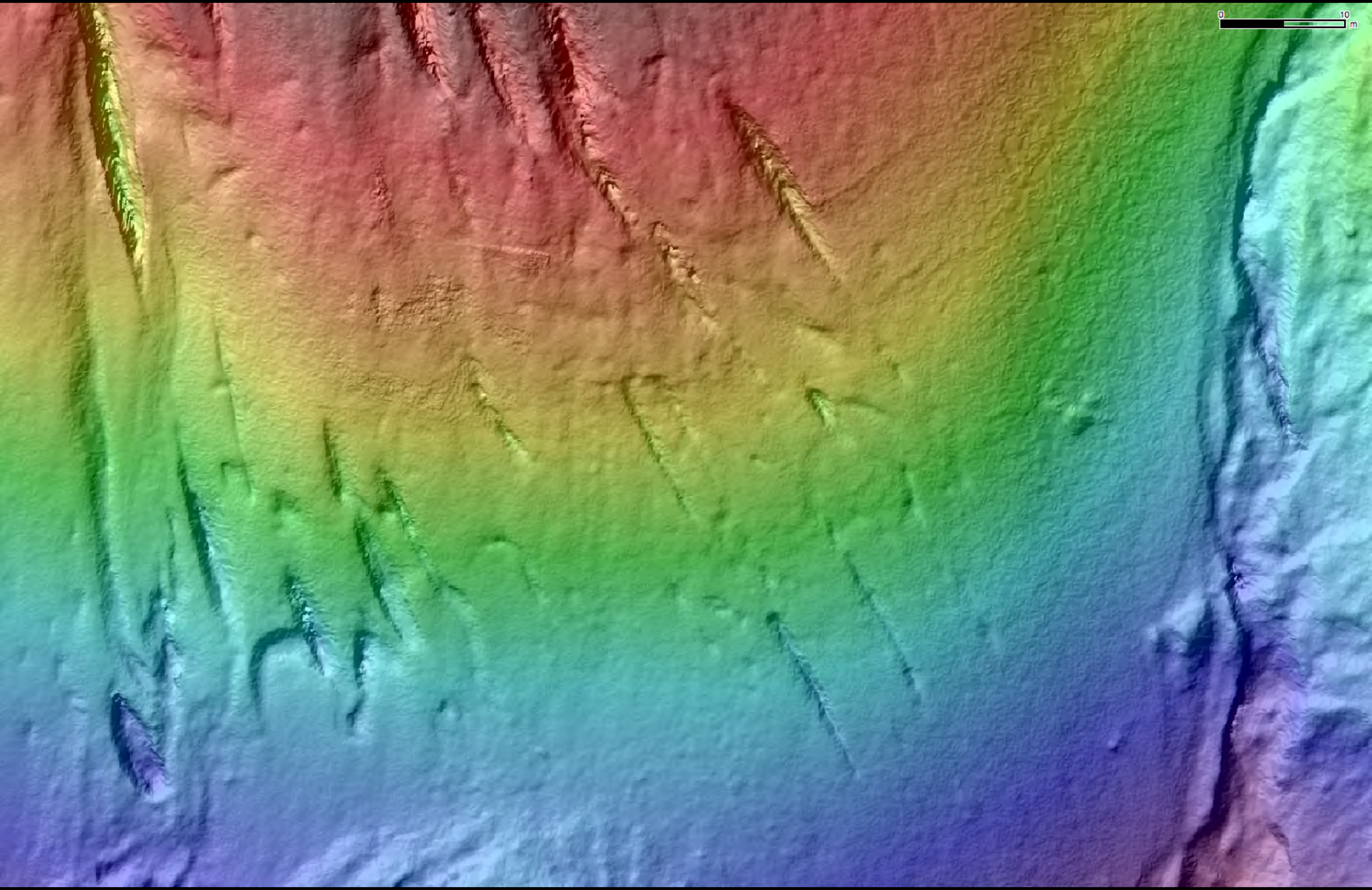
Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
"18"	-0.026827	-0.079396	0.020702	0.086325	25	0.653026
"19"	-0.091175	0.154022	0.361635	0.403504	7	0.437484
"20"	-0.053616	0.107871	0.031633	0.124545	19	0.643432
"21"	-0.053181	-0.203439	-0.124711	0.244476	6	0.462409
"22"	-0.122229	0.077414	0.364699	0.392350	11	0.504958
"23"	-0.056148	0.110814	-0.016464	0.125313	25	0.629273
"24"	0.063892	0.012594	0.215516	0.225140	18	0.517765
"4"	0.160812	0.258720	-0.388699	0.493846	18	0.560542
"5"	-0.050714	0.244829	0.597209	0.647435	18	0.553953
"6"	0.352618	-0.668041	-0.425768	0.867120	19	0.612902
"7"	-0.097480	-0.123188	0.101759	0.187170	21	1.426543
"8"	-0.059191	0.097379	-0.156388	0.193503	15	0.901427
Total	**0.129964**	**0.241401**	**0.295990**	**0.403454**	**202**	**0.744353**

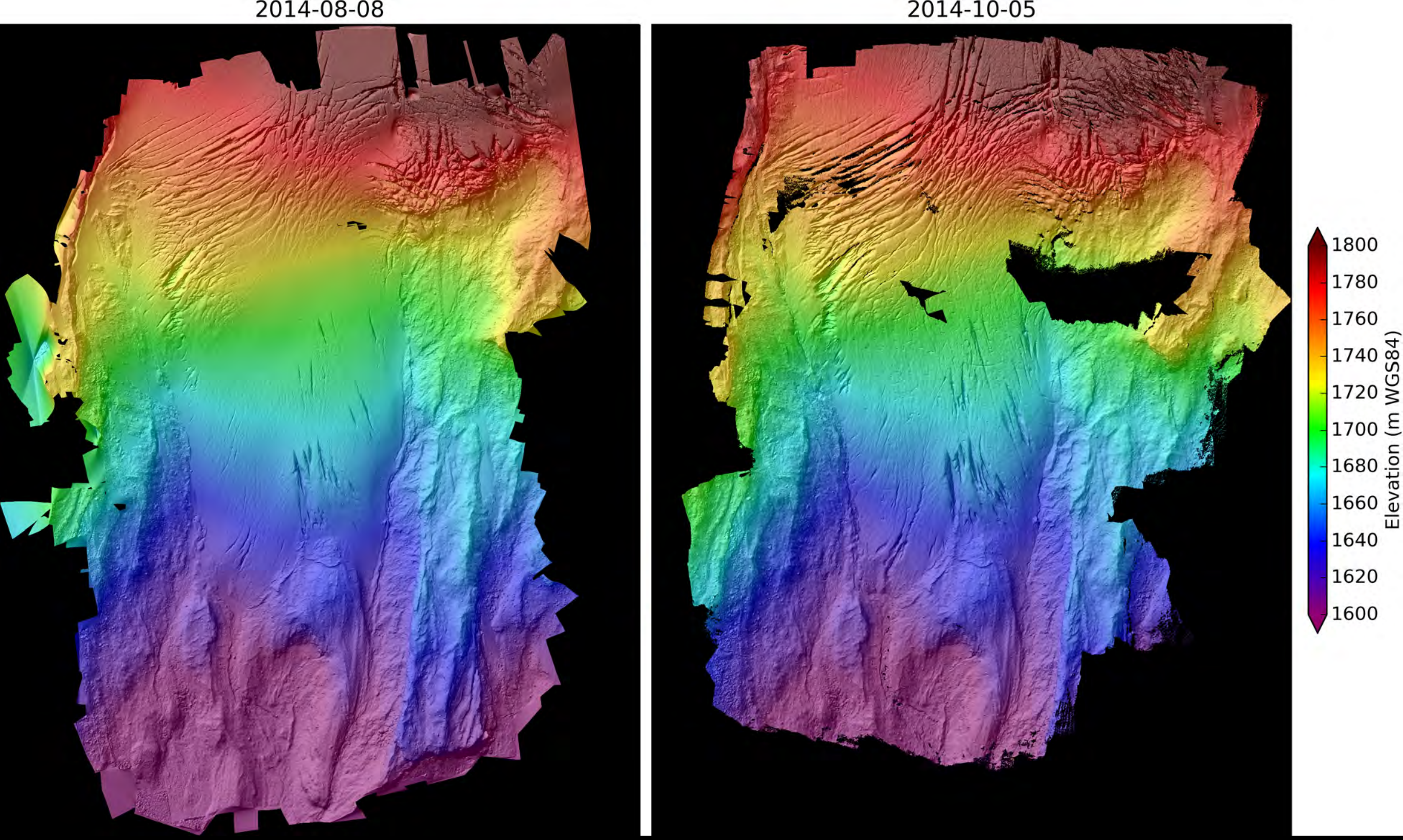
Table. 3. Control points.


0
30
m

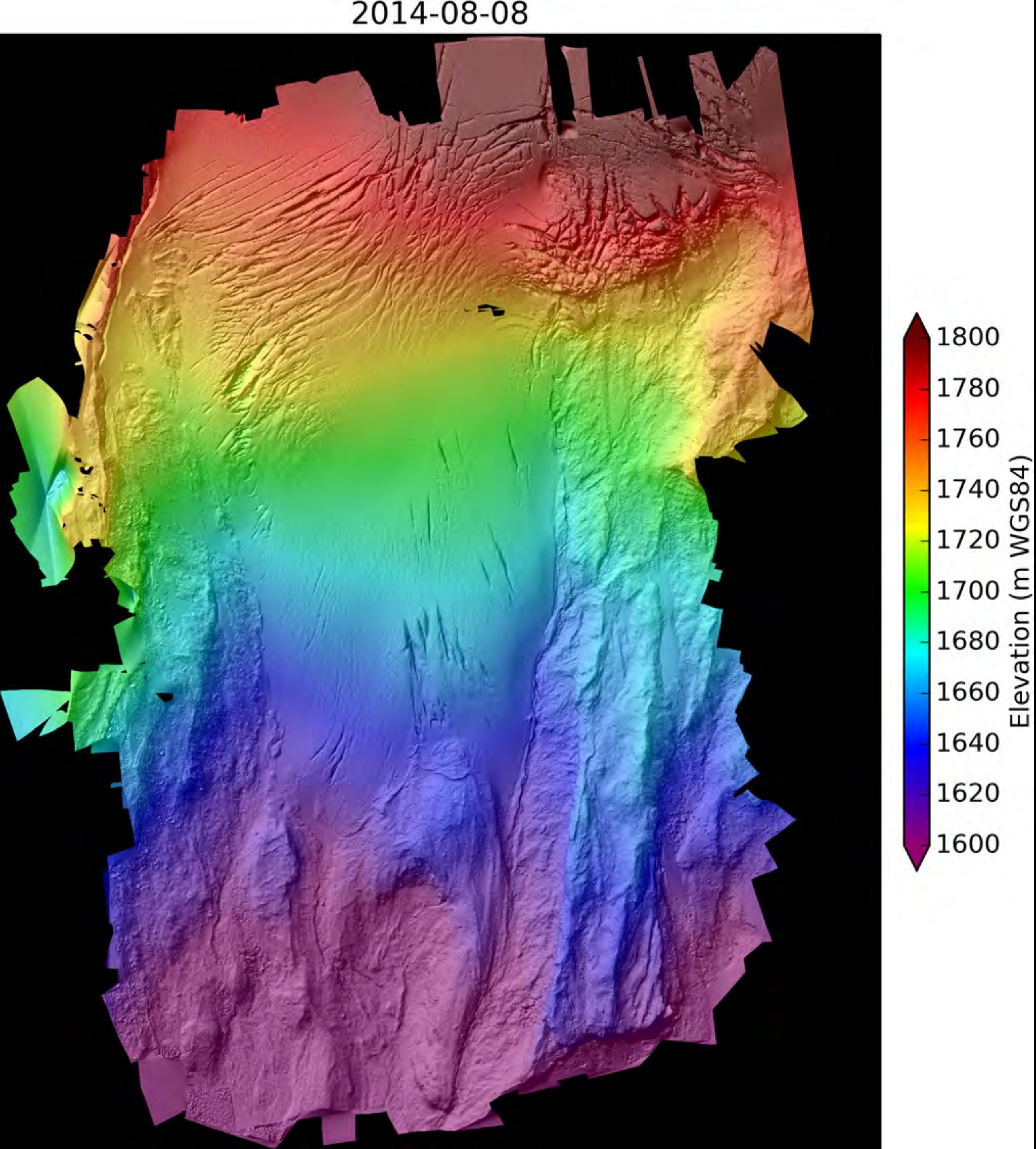

0
30
m


0
10
m

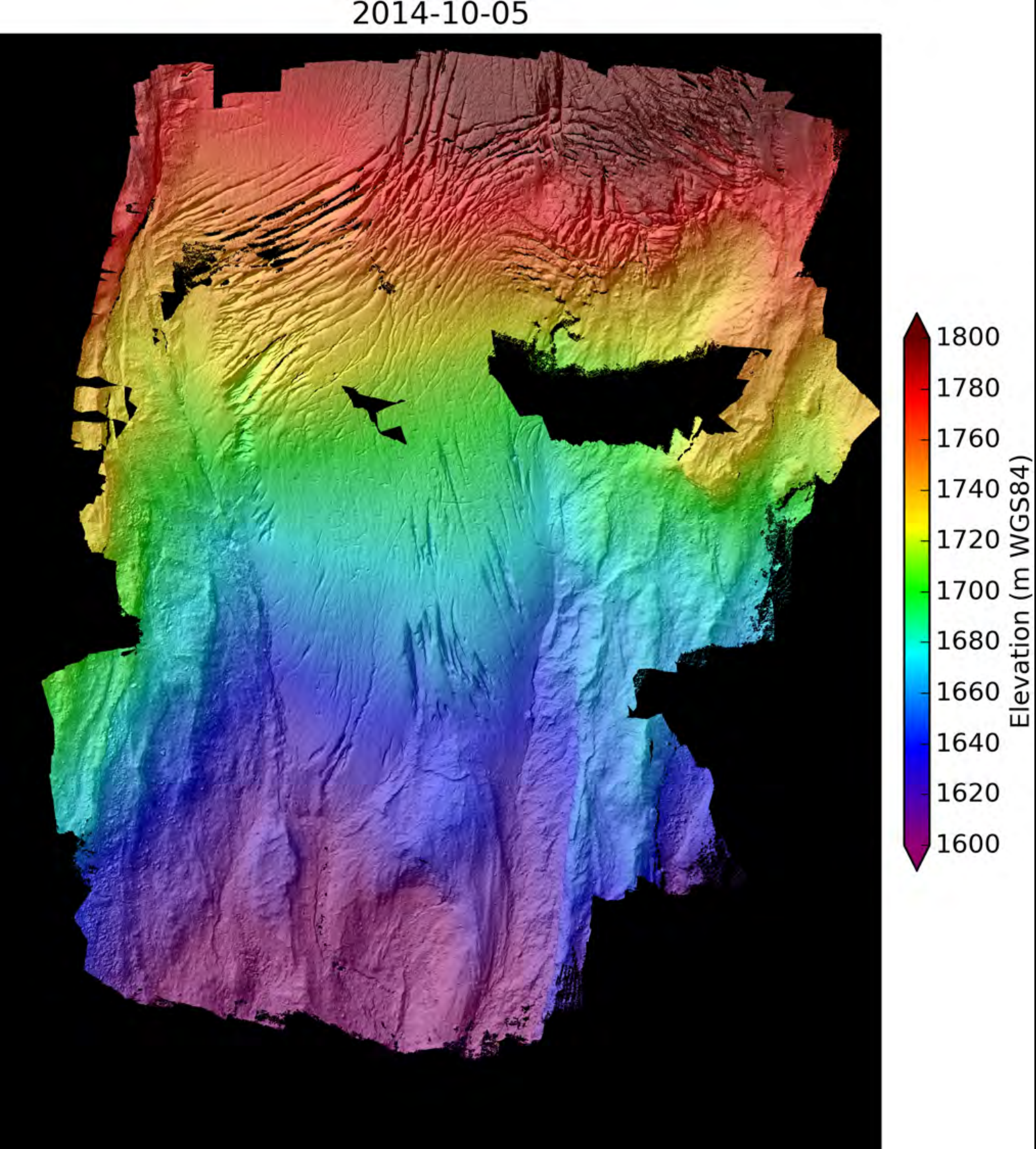

0
10
m



2014-08-08
2014-10-05
1800
1780
1760
1740
1720
1700
1680
1660
1640
1620
1600
Elevation (m WGS84)

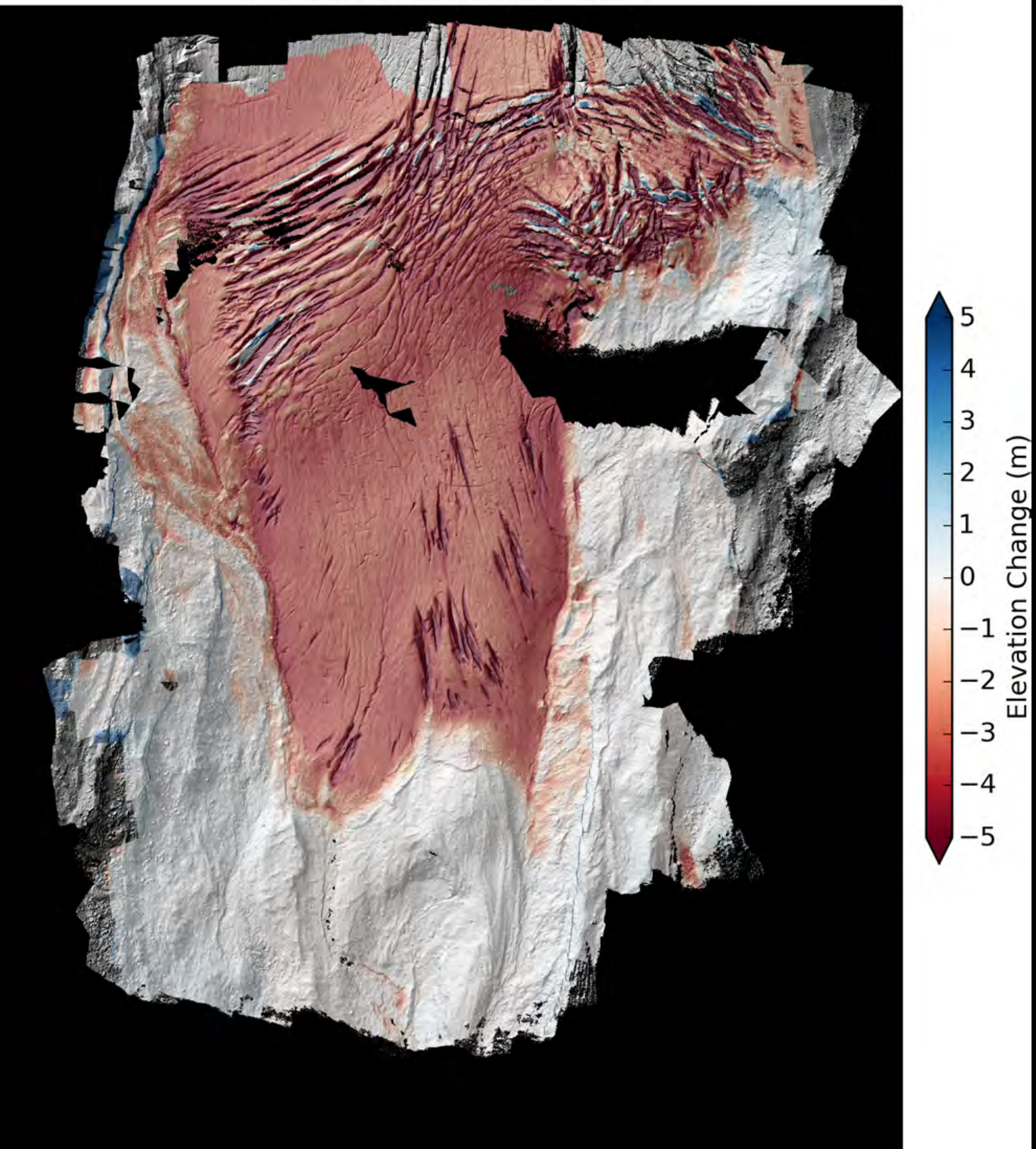


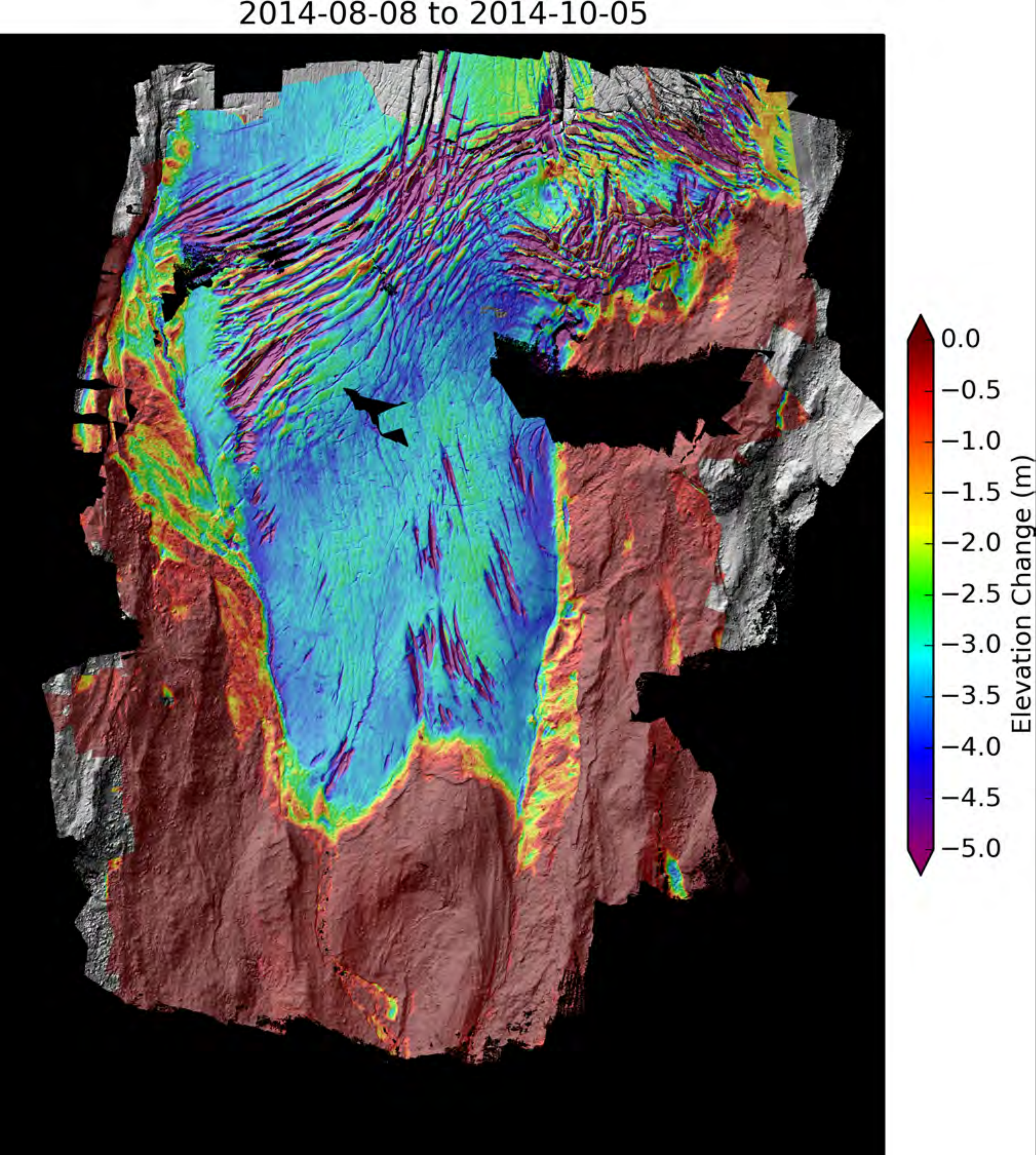
8/8/14 DEM
7 cm/px
615 x 845 m
~0.4 m accuracy



10/5/14 DEM
7 cm/px
684 x 827 m

2014-08-08 to 2014-10-05





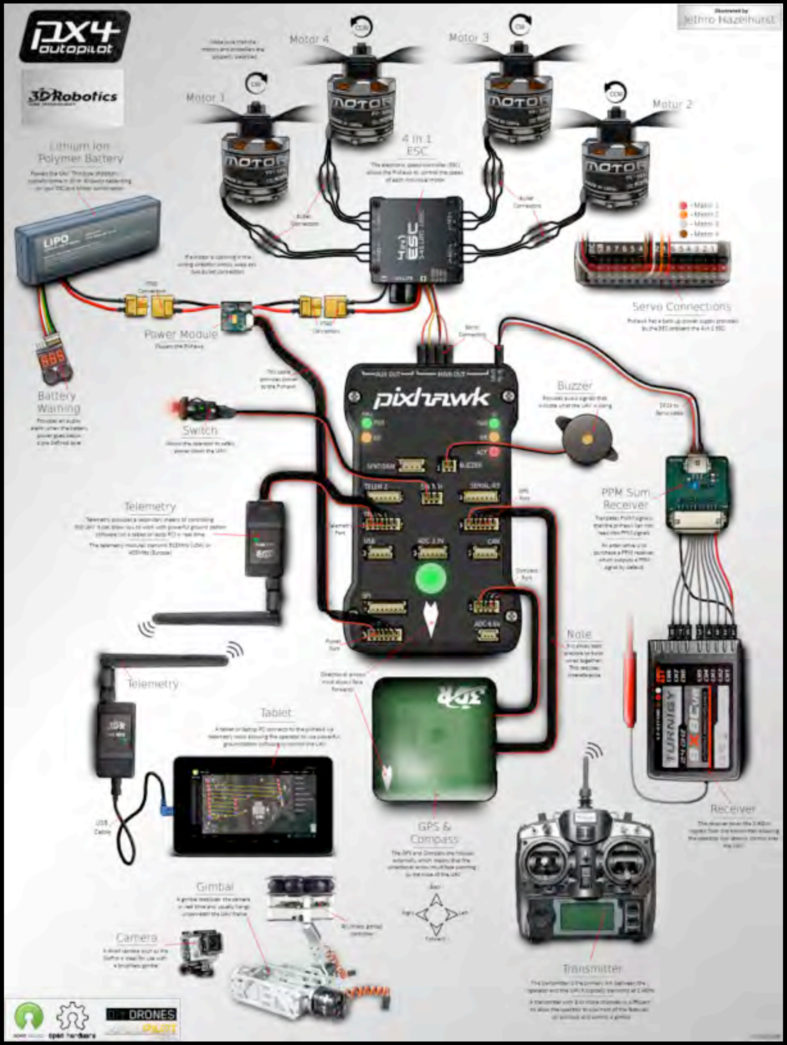
Easton Glacier
Late summer change:

- ~3 m exposed ice loss
- Crevasse expansion
- Stream network evolution
- Buried ice loss

Now what?

- Near Term Goals
  - Winter 2014/2015: Continue testing platform with waypoint grid navigation
  - April/May 2015: WA snowpack surveys
  - Sept/Oct 2015: WA glacier surveys
- Long Term Goals
  - Mt. Rainier National Park
  - Greenland outlet glacier calving dynamics
  - Antarctic ice shelf surveys, melt rates

Open Source Autopilot Systems (~$200-300)



http://3drobotics.com/

GPS waypoint navigation & camera triggering

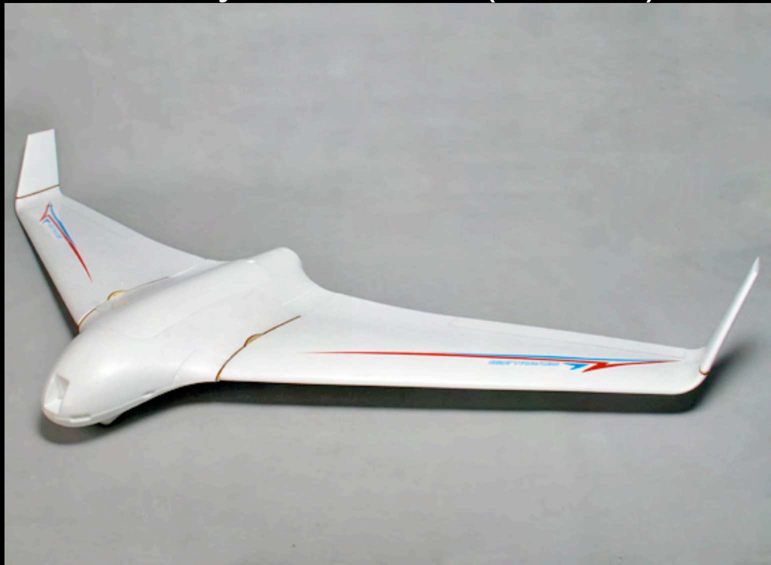
Potential Projects

- Fixed wing
  - Autonomous waypoint navigation
  - Range >10km
  - Payload ~0.5 kg
- Endurance multi-rotor
  - >15 minute flight time
  - Autonomous waypoint navigation
  - 2-axis gimbal for ~0.5-1 kg payload (camera or small LiDAR)
- RTK DGPS
- Open Source SfM pipeline

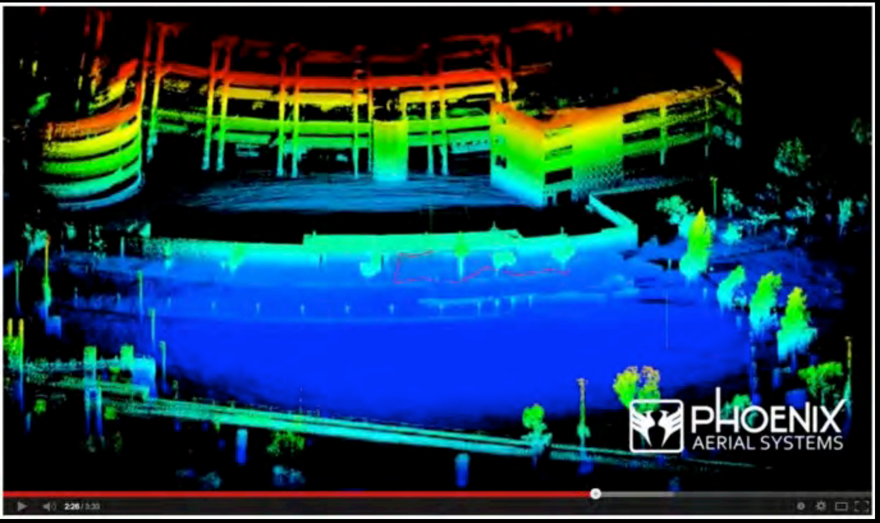
DJI Spreading Wings S900

Skywalker 1900 (1.9 m)

Skywalker X-8 (2.12 m)



The Future (LiDAR)



http://www.phoenix-aerial.com/

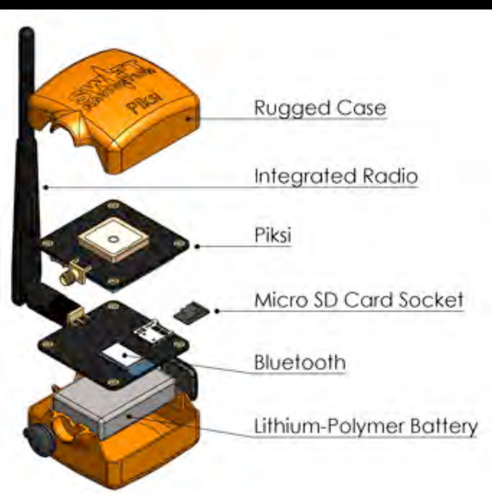
http://www.velodynelidar.com

- ~100 m range
- 0.6 kg
- 300 KHz pulse repetition rate
- $8000

Piksi RTK GPS

~4 cm post-processed accuracy
Open source processing software
Fast (50 Hz) position/velocity/time updates

Shipping April 2014:
$525 each
$975 for RTK setup (2x GPS, radio link)



https://www.kickstarter.com/projects/swiftnav/piksi-the-rtk-gps-receiver

Challenges

- Landing in mountainous terrain
  - VTOL, parachute?
- Flying at >5000’ MSL
- Steep topography
- Wind

Thank you!

Pigeon “drones”, ca. 1909

- David Shean (dshean@uw.edu)
  - Dept. of Earth and Space Sciences
  - Polar Science Center, Applied Physics Lab

- Growing user group at UW. Join us!
  - Help design, build, fly, process/analyze data

- Acknowledgements:
  - UW Quaternary Research Center
  - UW Student Technology Fee Committee
  - Gregg Petrie and Pat Heasler, ESS donors

Applications

- Repeat surveys for dynamic targets:
  - Glaciology (dynamics, mass balance, snowpack evolution)
  - Landslides (rapid response, monitoring)
  - Volcanism (dome growth, gas sampling)
  - Coastal erosion
  - Tectonics (fault displacement)
  - Atmospheric data collection (T, pressure, position)
- Single surveys for static targets:
  - Geologic mapping (outcrop or map-plane)
  - Volcanic conduits

Goals for MORA Ice/Snow

- Interannual volume/mass change
  - Long-term records
- Mass balance
  - Spatial distribution and magnitude
  - Winter accumulation, summer ablation, net balance
  - Redistribution of snow (avalanches, wind)
- Ice dynamics
  - Surging or wave propagation?
  - Sliding vs. deformation
- Hazards
  - Subglacial volanic activity
  - Subglacial lake filling

Other MORA Applications

- Hazards
  - Subglacial volcanic activity
  - Subglacial reservoir filling/draining
  - Avalanches, slope stability
- Lake levels
- Canopy height and evolution, biomass
- River morphology, erosion/deposition
- Infrastructure (roads, buildings)

change is in the air
ASPRS UAS Technical Demonstration and Symposium
October 21-22, Reno, NV

ASPRS UAS Technical Demonstration and Symposium – October 21-22, Reno, Nevada

About the Conference

The ASPRS Northern California Region is hosting a 2-day symposium on unmanned aircraft systems (UAS) in Reno, NV on October 21-22, 2014. The purpose of the event is to assemble academia, UAS developers, survey and mapping companies, government agencies, and UAS enthusiasts, to share information, showcase new technologies and demonstrate UAS systems in action (in flight). The event will be held at the ASPRS Turf Farm UAS Mapping Calibration Test Site, as well as at a symposium hotel in downtown Reno. The mission of the event is to advance knowledge and improve the understanding of UAS technologies and their safe and efficient introduction into our national airspace, government programs and business.

View Promo Flyer

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CONFERENCE REGISTRATION
Click to Register

SPONSORS

The AeroMapper family of UAVs:

For the developer, the integrator, the researcher or the mapping professional: The AeroMapper UAV is a versatile and affordable UAV designed for remote sensing and mapping applications. Features a high performance aerodynamic design with a modular Payload bay with lots of room for electronics, sensors and cameras. Built to last, it is made in reinforced carbon fiber.

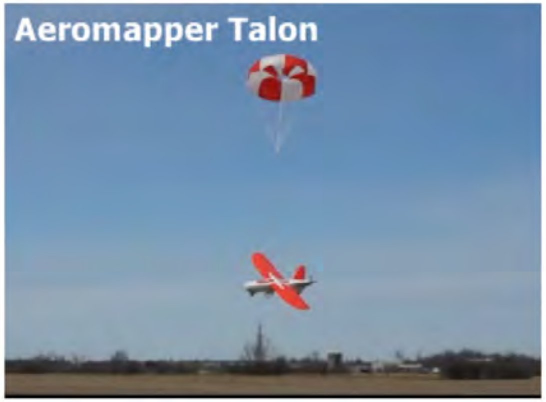
Systems are delivered Ready to Fly, with fully autonomous capabilities, with parachute landing system and fully detailed instructions & User Manual. Trainings are also available. We can customize the UAvs for your particular appliaction.

We currently offer the **Aeromapper EV2** and the **Aeromapper Talon UAV**.

NEW! **The Aeromapper 300**, a working horse with 1.5 hrs of flight endurance carrying a 24mp or 36mp survey grade sensor with top of the line optics for mapping.

NEW!: an ever-growing variety of sensors with hot-swappable capabilities for the Aeromapper EV2 and Aeromapper 300 is already available. **One airframe + multiple sensors = unlimited number of applications!**

Our Aeromappers are being used by private companies, Universities and even Government agencies in more than 25 countries!



National Park Service Press Release

For Immediate Release: June 20, 2014

Contact(s): Jeffrey Olson, 202-208-6843
April Slayton, 202-208-6843

Unmanned Aircraft to be Prohibited in America's National Parks

Visitor safety and park resources concerns prompt policy directive

WASHINGTON – National Park Service Director Jonathan B. Jarvis today signed a policy memorandum that directs superintendents nationwide to prohibit launching, landing, or operating unmanned aircraft on lands and waters administered by the National Park Service.

"We embrace many activities in national parks because they enhance visitor experiences with the iconic natural, historic and cultural landscapes in our care," Jarvis said. "However, we have serious concerns about the negative impact that flying unmanned aircraft is having in parks, so we are prohibiting their use until we can determine the most appropriate policy that will protect park resources and provide all visitors with a rich experience."

Unmanned aircraft have already been prohibited at several national parks. These parks initiated bans after noise and nuisance complaints from park visitors, an incident in which park wildlife were harassed, and park visitor safety concerns.

Last September, an unmanned aircraft flew above evening visitors seated in the Mount Rushmore National Memorial Amphitheater. Park rangers concerned for visitors' safety confiscated the unmanned aircraft.

In April, visitors at Grand Canyon National Park gathered for a quiet sunset, which was interrupted by a loud unmanned aircraft flying back and forth and eventually crashing in the canyon. Later in the month, volunteers at Zion National Park witnessed an unmanned aircraft disturb a herd of bighorn sheep, reportedly separating adults from young animals.

The policy memorandum directs park superintendents to take a number of steps to exclude unmanned aircraft from national parks. The steps include drafting a written justification for the action, ensuring compliance with applicable laws, and providing public notice of the action.

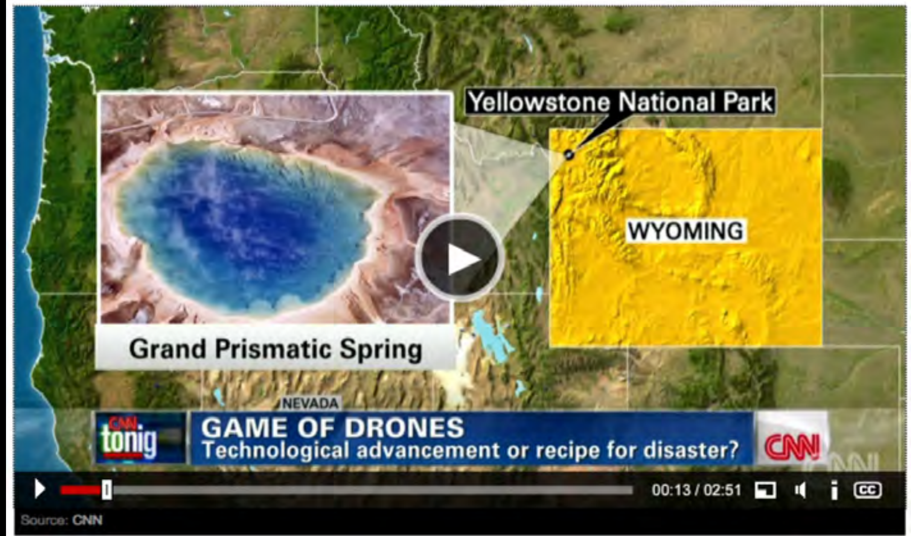
The memorandum does not affect the primary jurisdiction of the Federal Aviation Administration over the National Airspace System.

The policy memorandum is a temporary measure. Jarvis said the next step will be to propose a Servicewide regulation regarding unmanned aircraft. That process can take considerable time, depending on the complexity of the rule, and includes public notice of the proposed regulation and opportunity for public comment.

The policy memo directs superintendents to use their existing authority within the Code of Federal Regulations to prohibit the use of unmanned aircraft, and to include that prohibition in the park's compendium, a set of park-specific regulations.

All permits previously issued for unmanned aircraft will be suspended until reviewed and approved by the associate director of the National Park Service's Visitor and Resource Protection directorate. The associate director must approve any new special use permits authorizing the use of unmanned aircraft. Superintendents who have previously authorized the use of model aircraft for hobbyist or recreational use may allow such use to continue.

The National Park Service may use unmanned aircraft for administrative purposes such as search and rescue, fire operations and scientific study. These uses must also be approved by the associate director for Visitor and Resource Protection.



- MORA status?
- Research permits?
- Priorities?