

Glaciological Applications of Open Source Photogrammetry

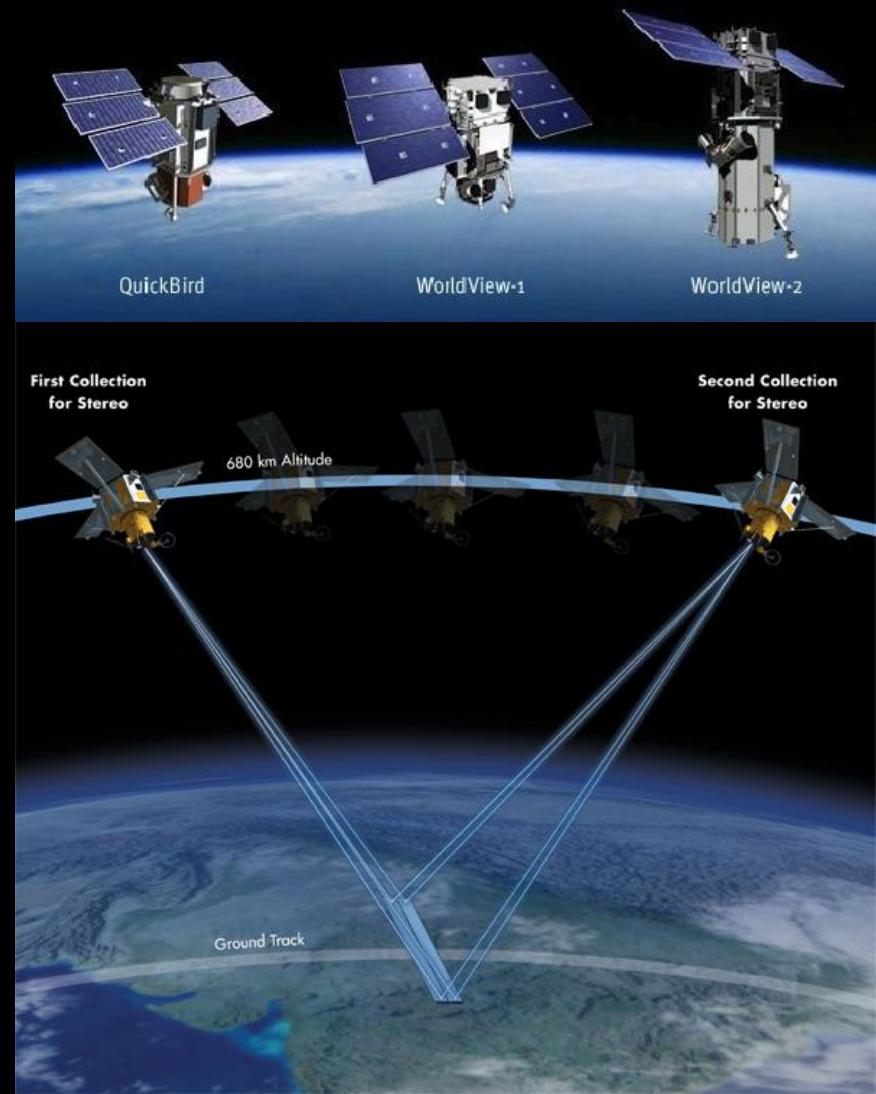
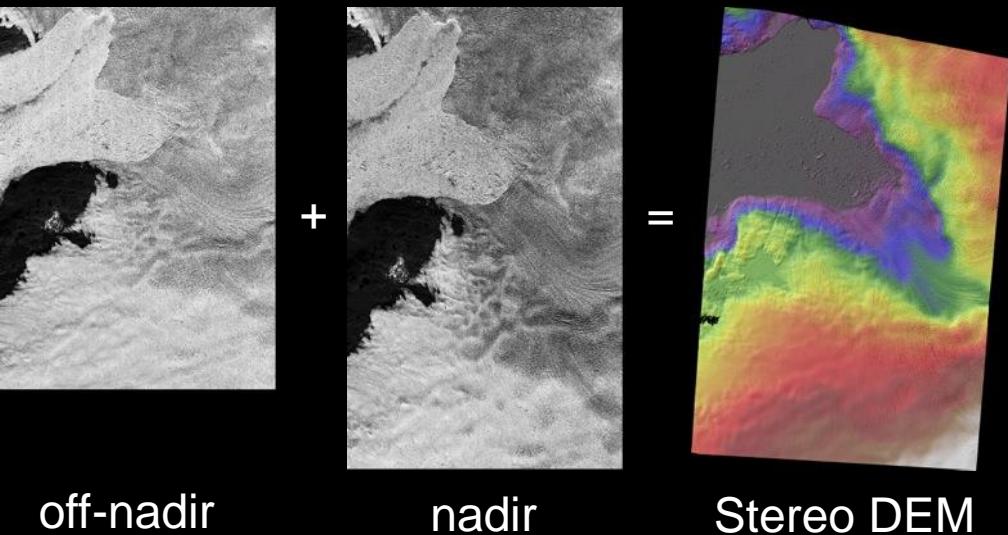
David Shean
University of Washington
Applied Physics Lab, Polar Science Center
CUGOS Fall Fling
October 16, 2013

Outline

- High-resolution Satellite Stereo Imagery
 - Ames Stereo Pipeline
 - Greenland/Antarctica DEM samples
 - Big Data? Bigger Computer
 - Cascades Targeting
- Structure from Motion
 - 2013 oblique aerial surveys
 - Mt. St. Helen's Processing
 - LiDAR vs WV Stereo vs SfM
 - Drones!

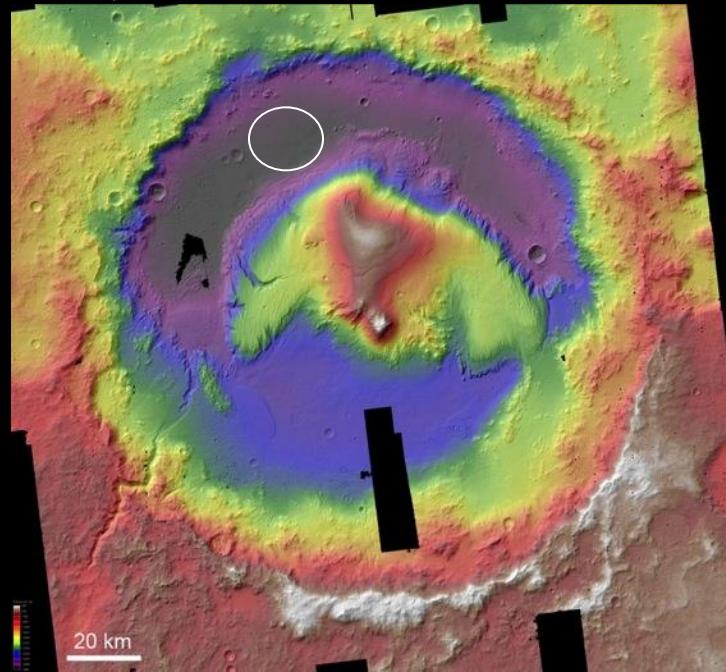
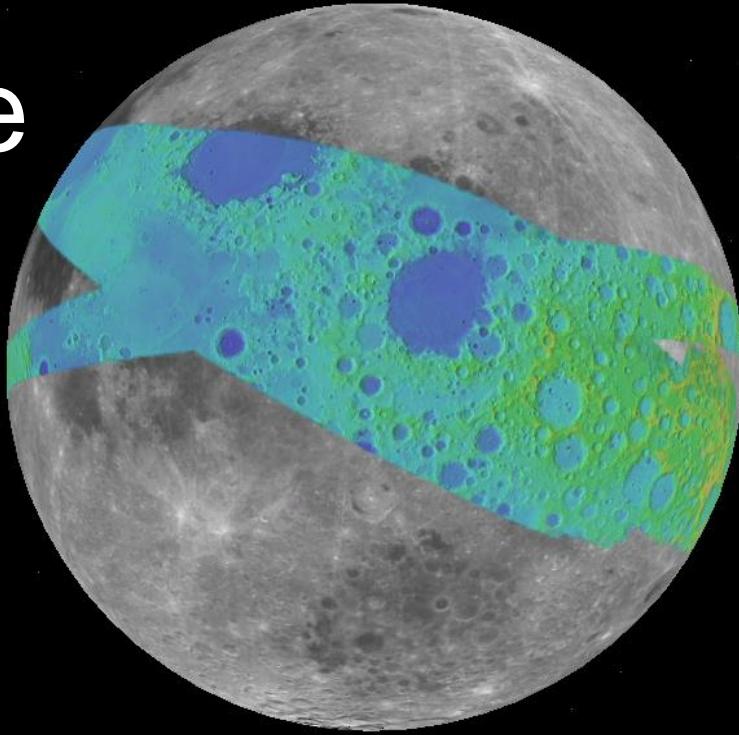
Commercial Satellite Imagery

- DigitalGlobe (+GeoEye)
 - WorldView 1/2, Quickbird, GeoEye 1, IKONOS
 - WorldView 3 (July 2014)
- ~0.5 m/px panchromatic
- ~17 km swath width
- Along-track stereo



Ames Stereo Pipeline

- Automated, open-source, command-line tools
- C++/Python, multithreaded, memory-efficient, scalable
- NASA planetary missions and DigitalGlobe/GeoEye Imagery
- Export DEM grid, las/laz point cloud, orthoimage
- Binaries for Linux/OSX on Ames website (currently down)
- Source available on github



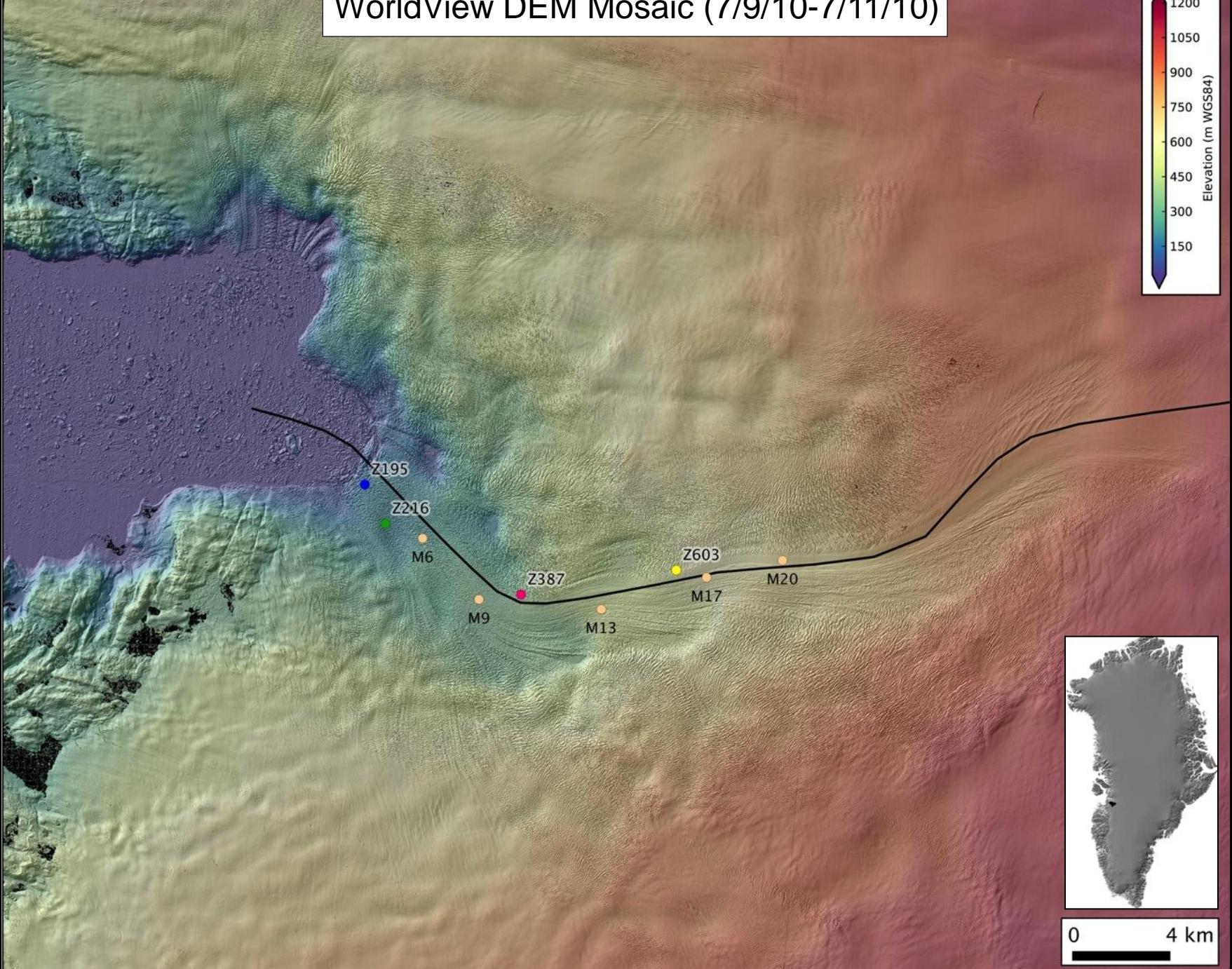
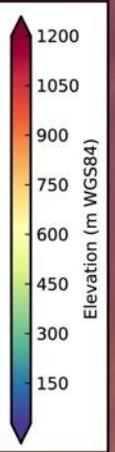
Top: Apollo Metric Camera DEM mosaic

Bottom: Gale Crater, Mars, MRO CTX DEM Mosaic

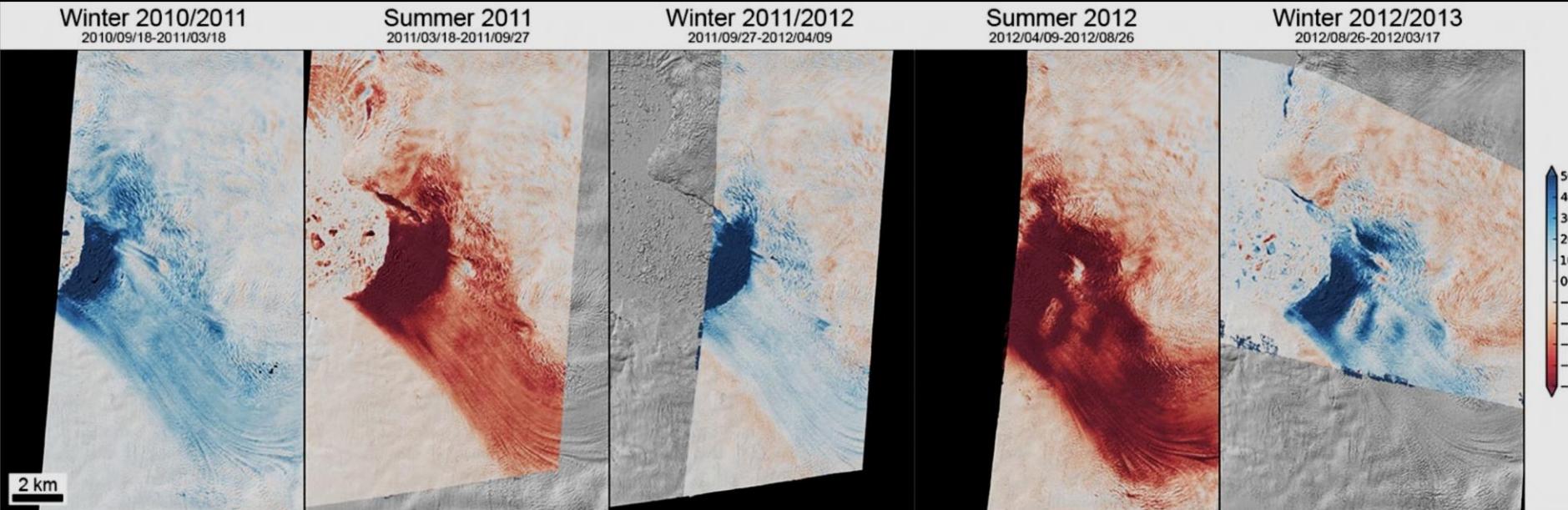
ASP + WorldView FAQ

- Total wall time of ~0.5-24 hours on dedicated 8-core workstation for ~36Kx30K px scene
- DEM posting ~2-4 m/px
- Accuracy:
 - Uncorrected vert/horiz accuracy of ~5 m CE90/LE90 (DigitalGlobe)
 - Corrected/relative accuracy <1 m

WorldView DEM Mosaic (7/9/10-7/11/10)

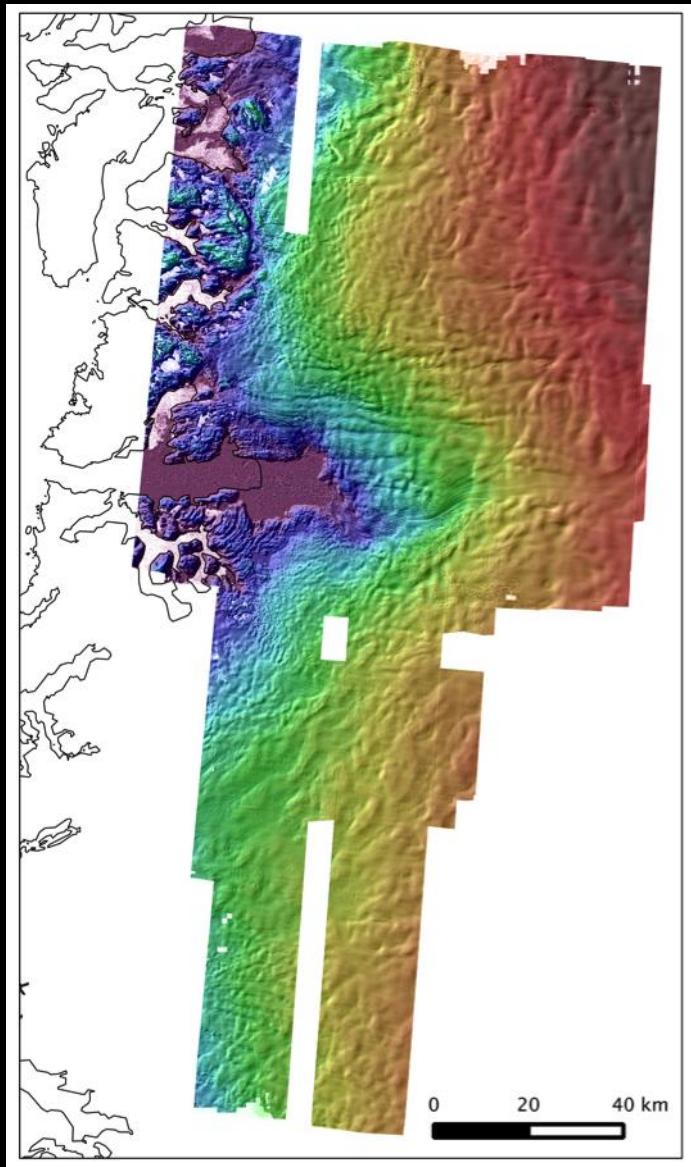


Seasonal Elevation Change

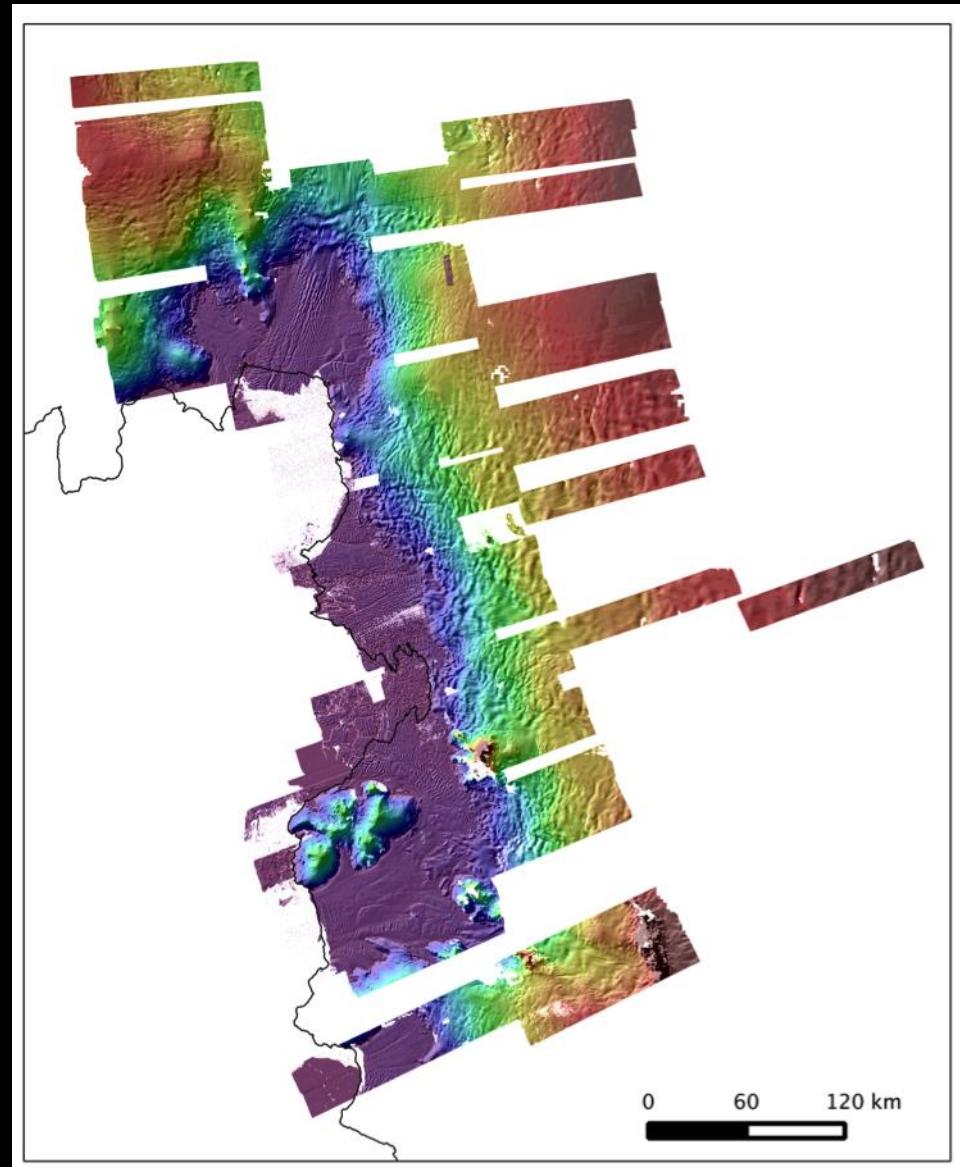


- +10-20 m in winter (~0.3-0.6 km³), front advance
- -30-45 m in summer (~0.9-1.5 km³), front retreat
- Net interannual thinning of -15-20 m/yr

2010-2013 Mosaics

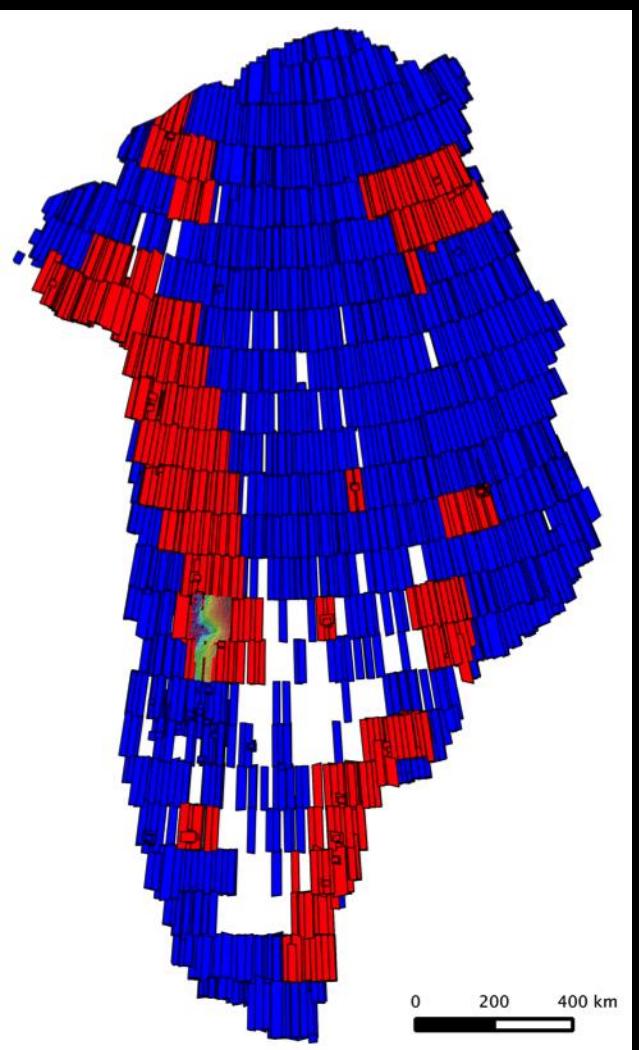


West Greenland (79 pairs)

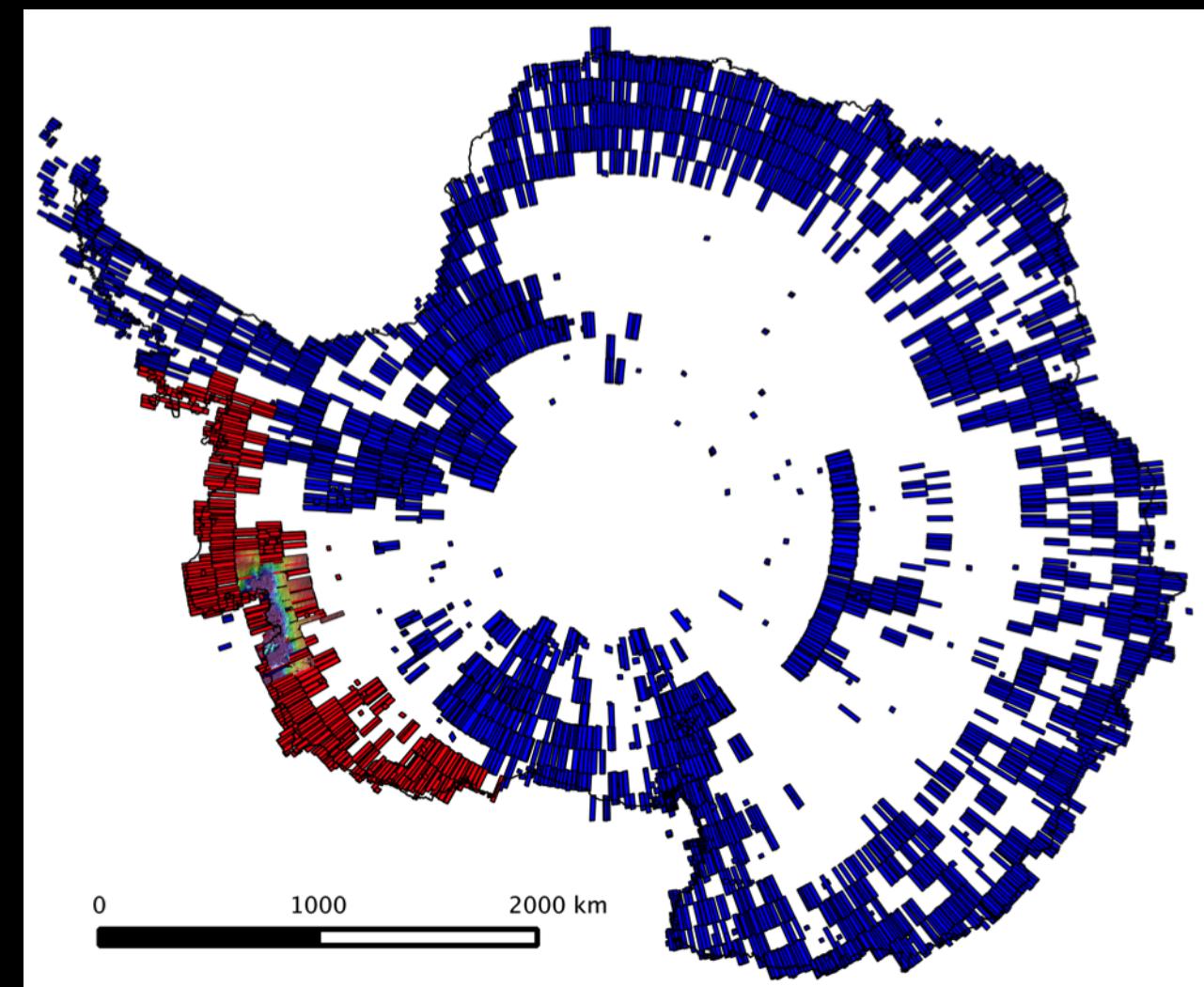


Amundsen Coast, West Antarctica (171 pairs)

New Data Request (red)



1534 pairs



894 pairs

Scaling Up

- NASA Pleiades supercomputer
 - 19th on TOP500 list
 - Total cores: 129,024
 - 1.79 Pflop/s peak
 - “Unlimited” storage (9.3 PB)
- 2012-2013 allocation
 - 86K CPU hours
- 2013-2014 request
 - 2.5M CPU hours

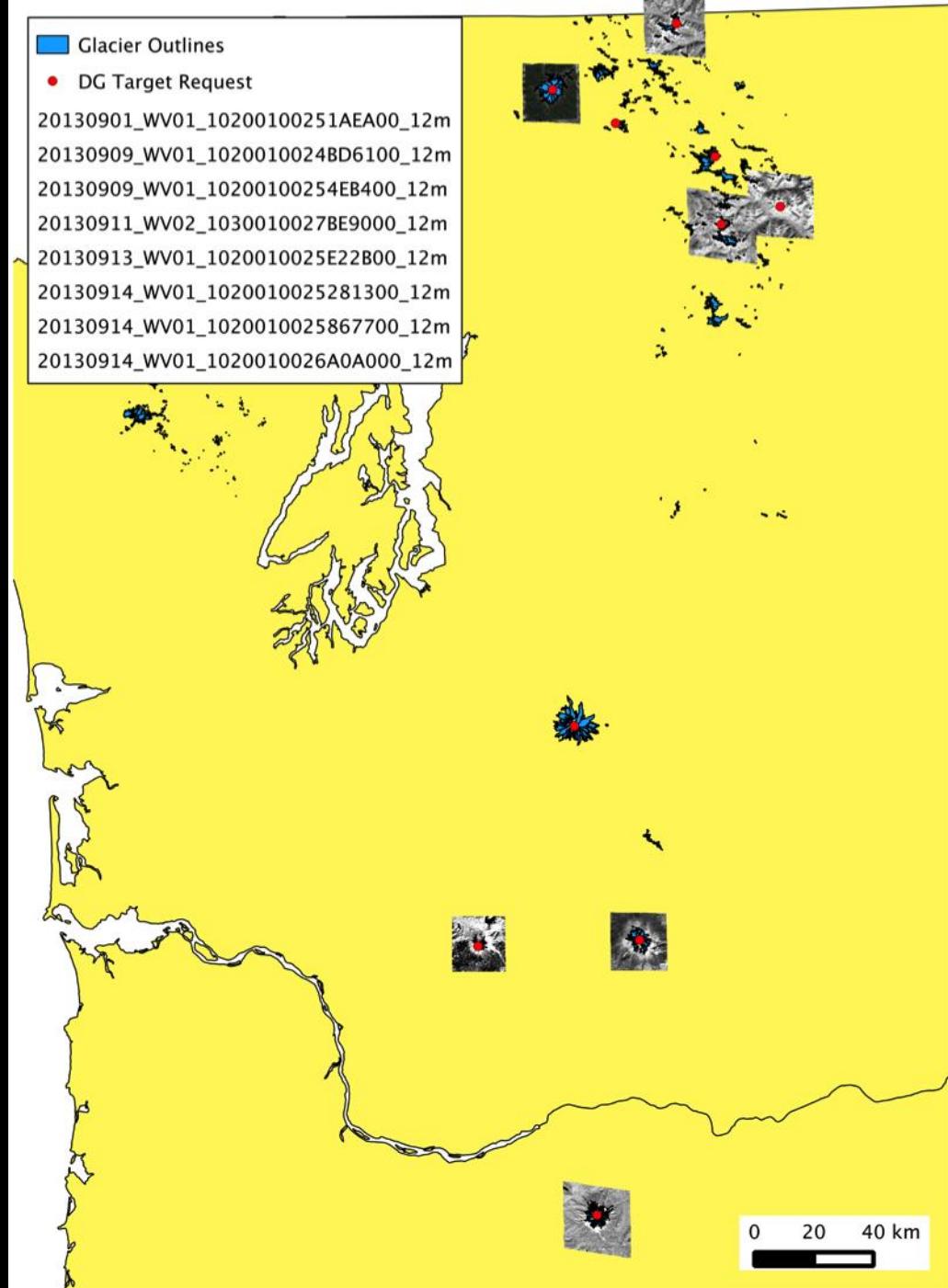


Summary

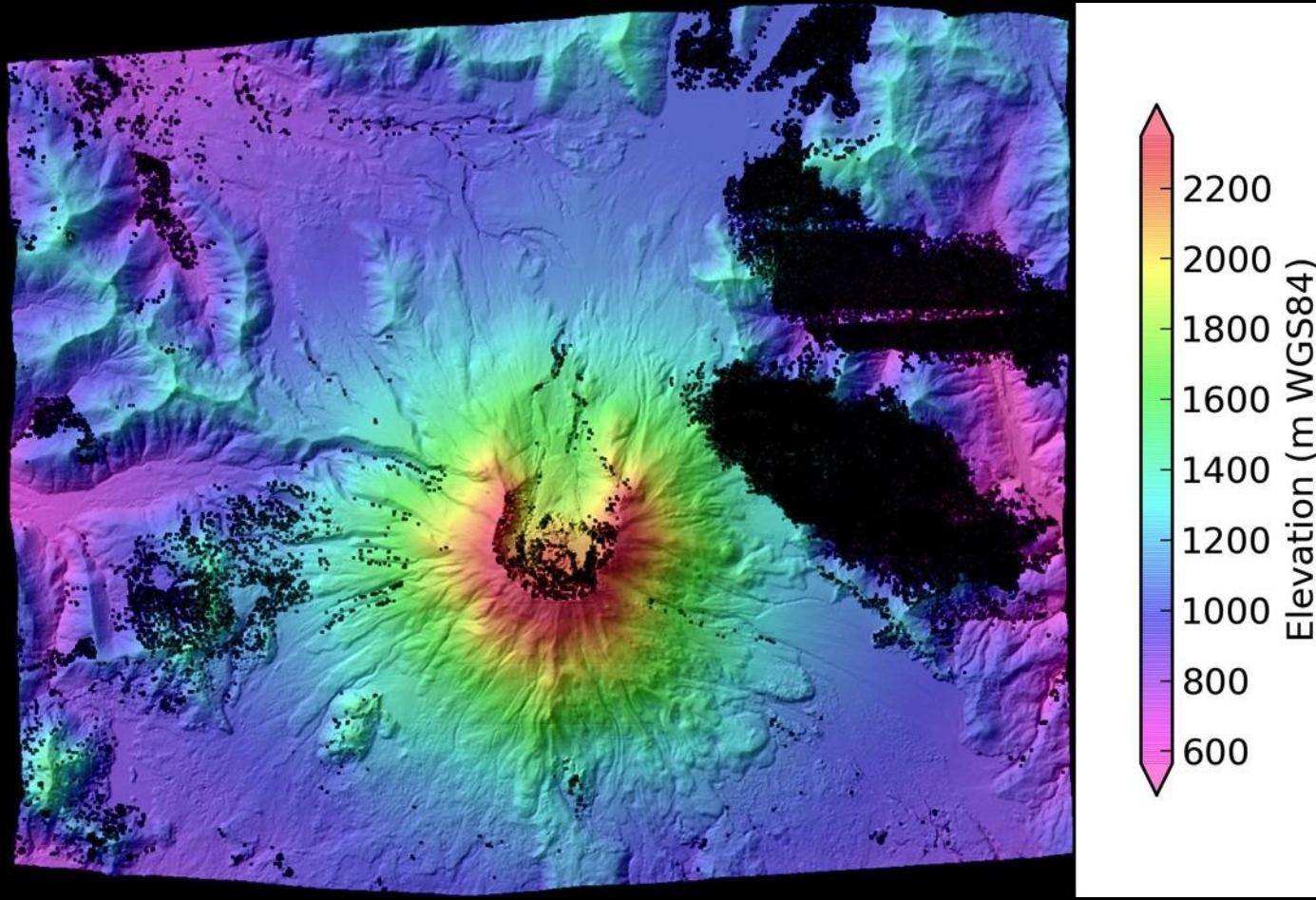
- Ames Stereo Pipeline
 - Automated, open source
 - ~2-4 m/px DEM output for WV-1/2 data
 - <1 m vertical/horizontal accuracy w/ control
- Unprecedented spatial/temporal resolution for studies of ice sheet dynamics/variability
- Preliminary timeseries reveal seasonal/interannual elevation change
- Ongoing development and mass production of detailed timeseries and regional mosaics

Cascades WV Stereo

- October 2012
 - St. Helen's
- September 2013
 - St. Helen's
 - Adams
 - Baker
 - Hood
 - N. Cascades



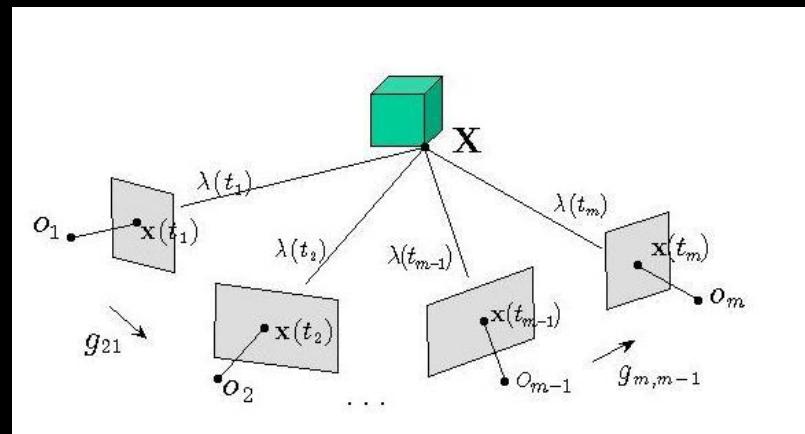
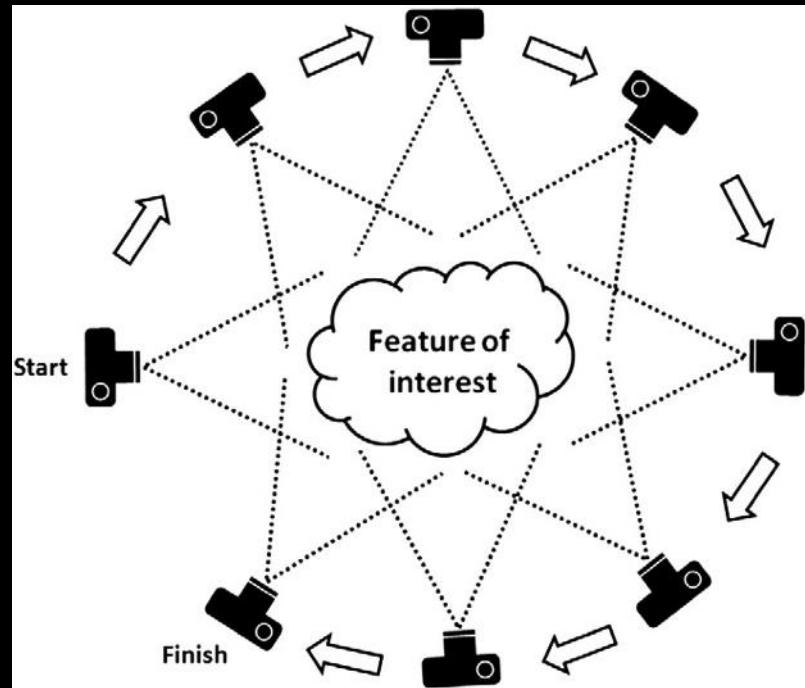
Mt. St. Helen's WV Stereo DEM



10/18/2012

Structure from Motion (SfM)

- 3D info (“structure”) from images with multiple views (“motion”)
- Inexpensive (free!), automated, minimal training required
- Camera calibration, positions, orientations not required
- Absolute scale/orientation from known camera positions (GPS in EXIF header) or ground control
- Minimize occultation
- Pioneered by UW CSE



UW ESS STF Equipment

- Nikon D800 DSLR (36.3 MP, 7360x4912 px)
 - Lenses: 16-35, 50, 85, 28-300 mm
 - GP-1 GPS unit (~5 m accuracy)
- Trimble GeoXH GPS + Hurricane antenna
 - 1 second interval logging
 - ~10-15 cm accuracy
- 12-core processing workstation (W7)
 - ERDAS Imagine + Leica Photogrammetry Suite
 - Agisoft PhotoScanPro
 - Open Source Tools:
 - VisualSFM, Ames Stereo Pipeline, GDAL, QGIS

Oblique Aerial Data Collection

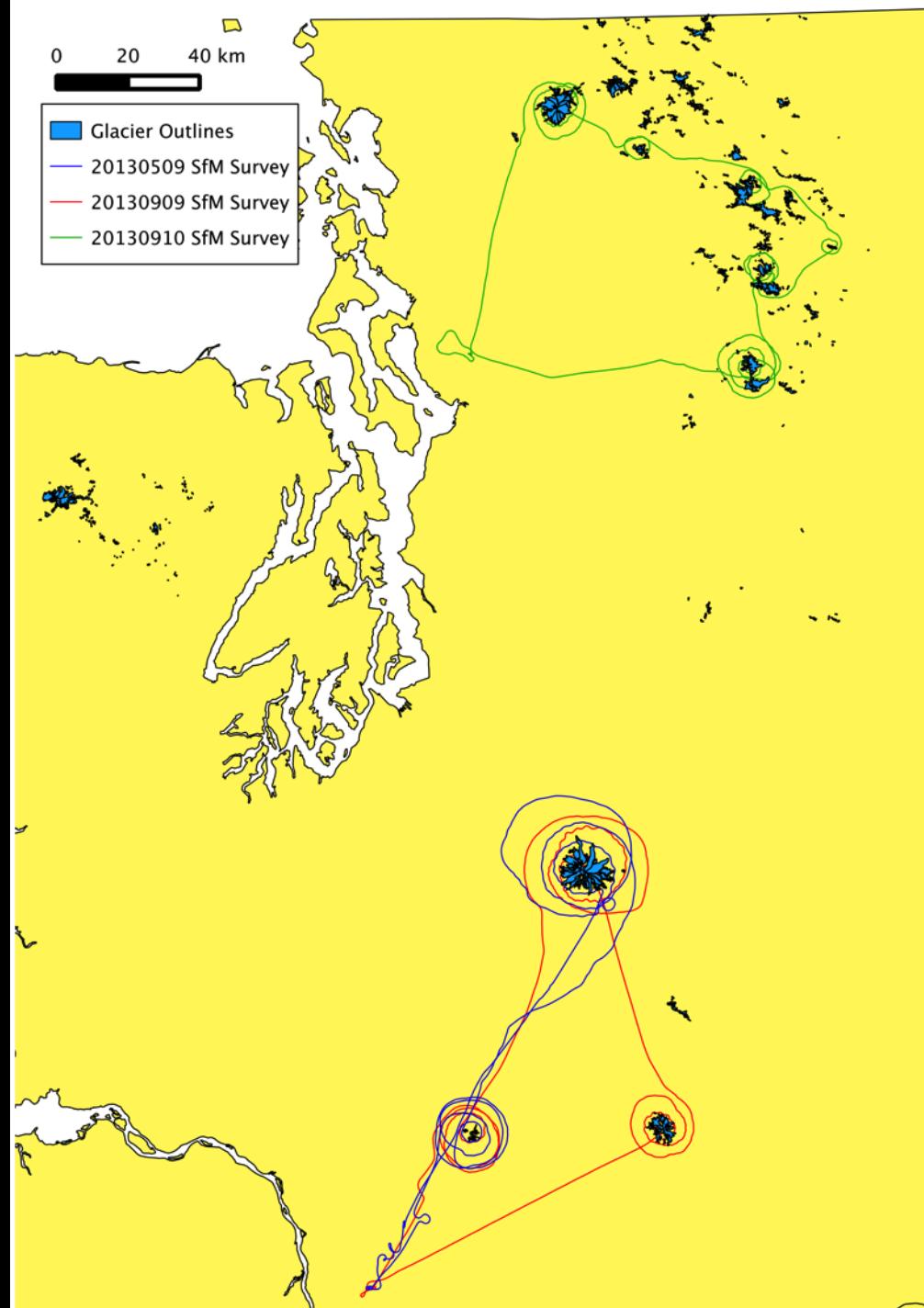
- USGS CVO pilots, Dan Miller and John Pallister
- Van's RV-8 homebuilt tandem aerobatic airplane
- Cost: \$50/hr





2013 SfM Flights

- 5/9/13 (2.5 hr)
 - St. Helen's, Rainier
 - 1080 photos
- 9/9/13 (2.6 hr)
 - St. Helen's, Rainier, Adams
 - 1486 photos
- 9/10/13 (2.6 hr)
 - Baker, N. Cascades, Glacier Peak
 - 1254 photos





Mt. St. Helen's, 9/9/13

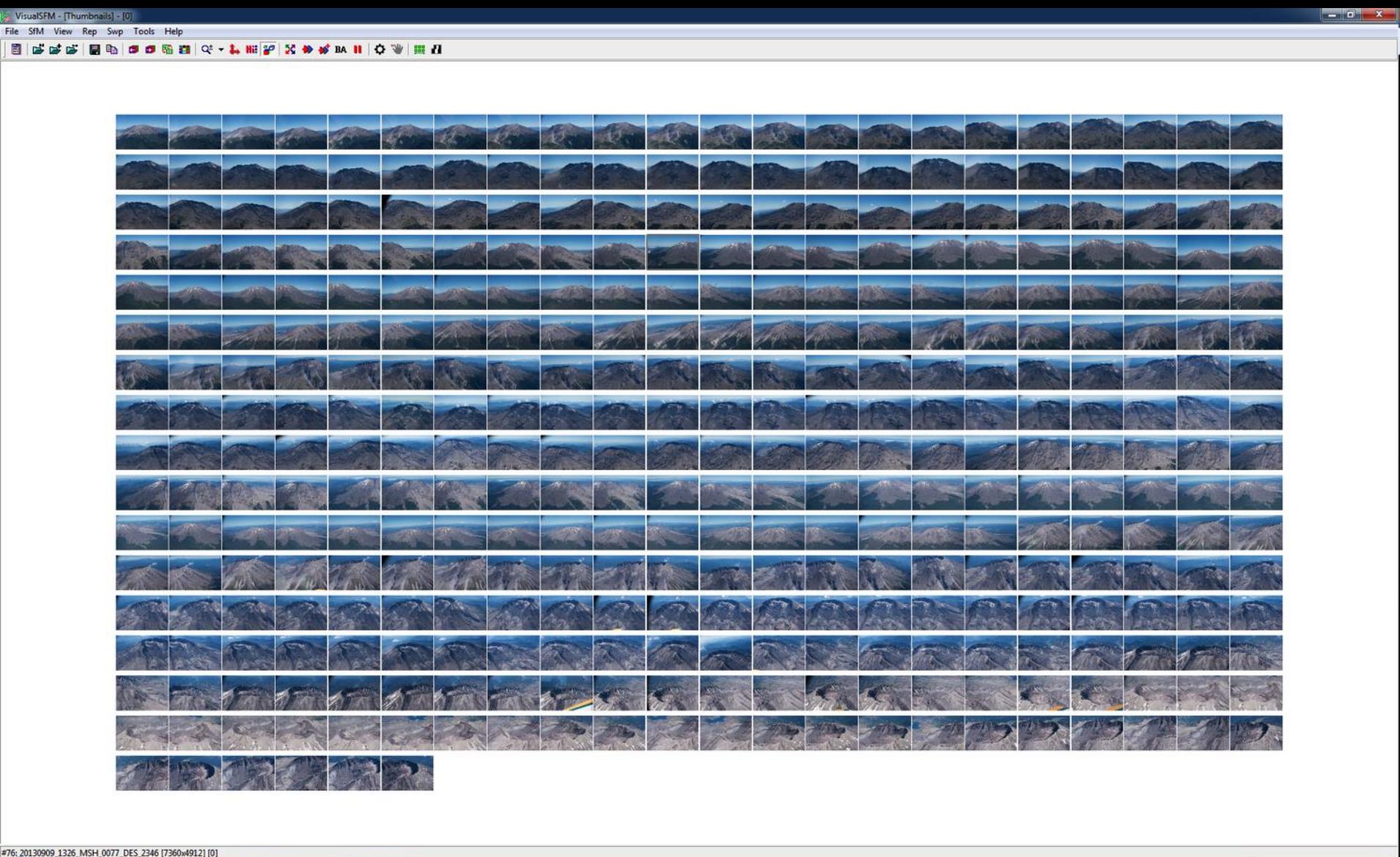
D800, 50 mm f/1.8 lens, f/8, 1/3200, ISO 800

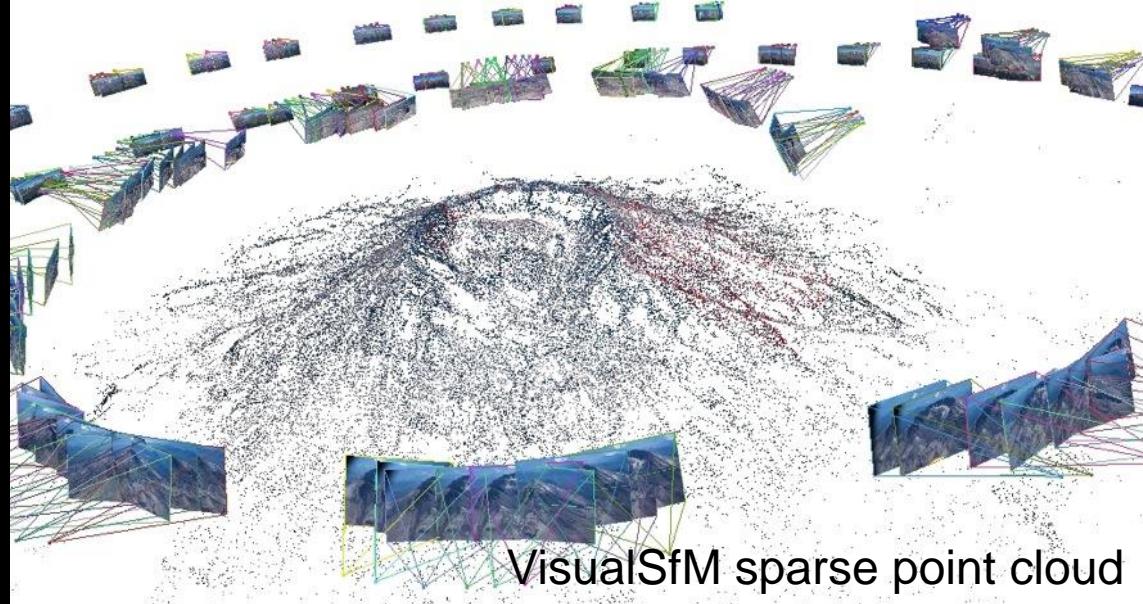


SfM Processing

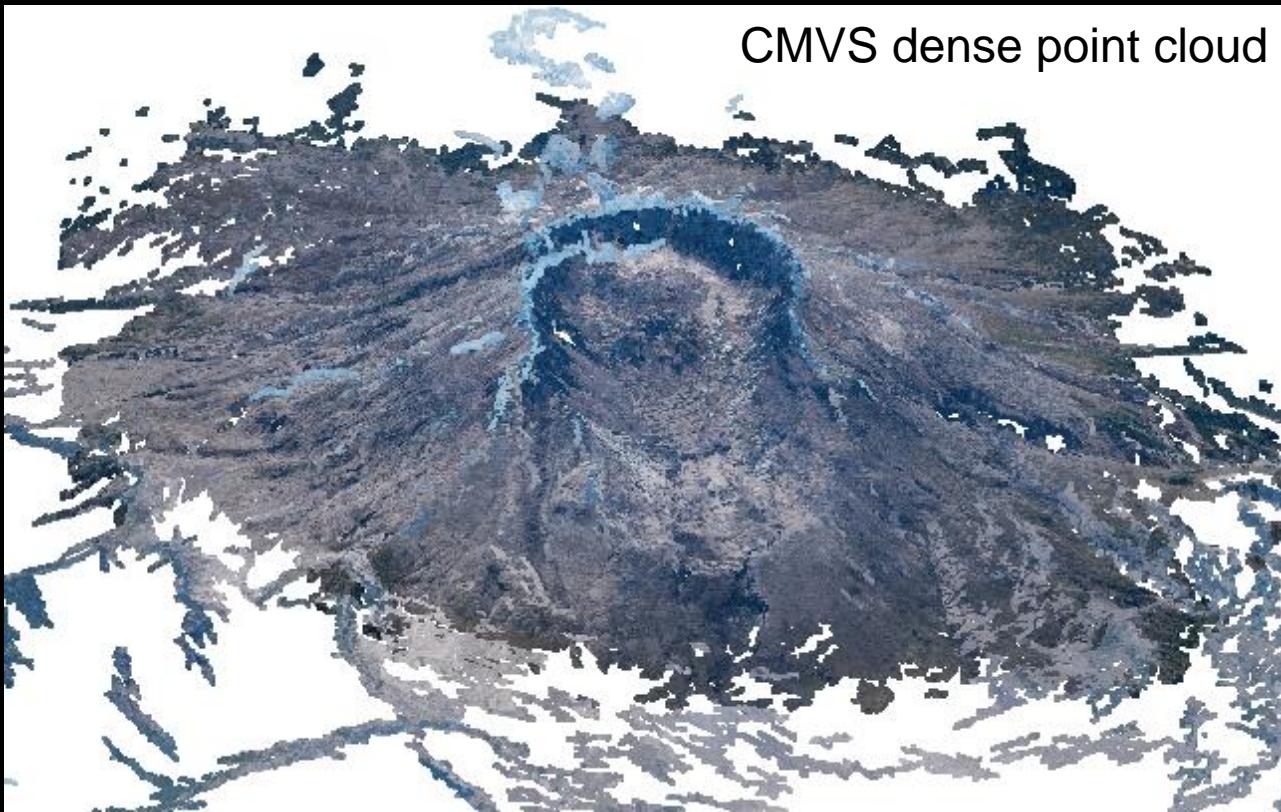
- Agisoft PhotoScan Pro
 - Commercial
 - \$500 academic license
 - Simple workflow
 - Camera calibration utility, integrated control point picker, point cloud editing, geospatial output
- VisualSfM (with CMVS and CMPMVS)
 - Open source
 - Compiling is a challenge, binaries available
 - Limited support, but excellent tutorials available on youtube, online community

20130909 Mt. St. Helen's flight - 358 photos



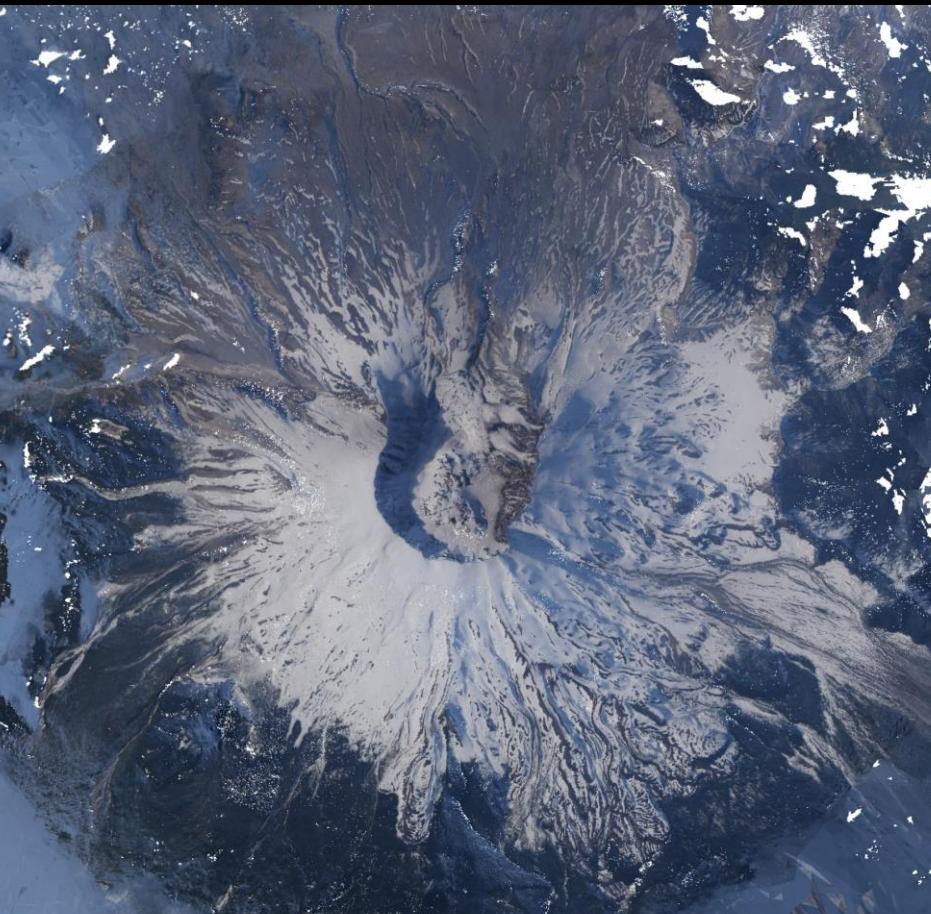


VisualSfM sparse point cloud

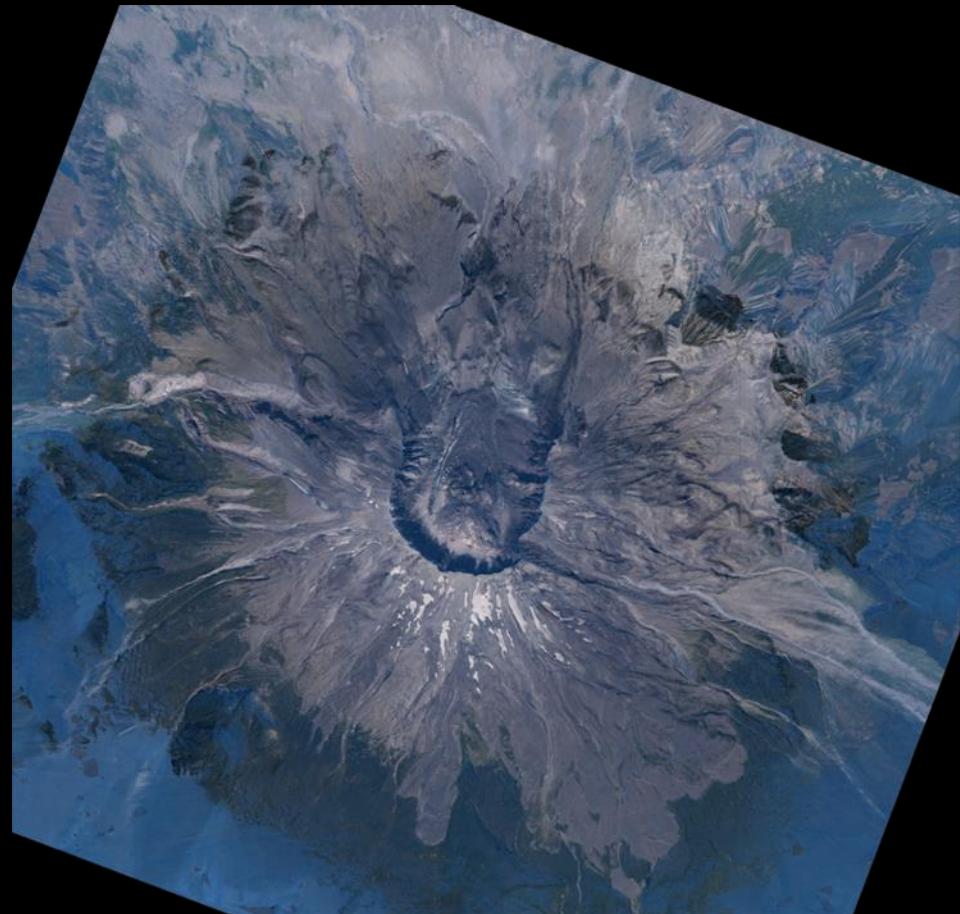


CMVS dense point cloud

Orthophoto Mosaics

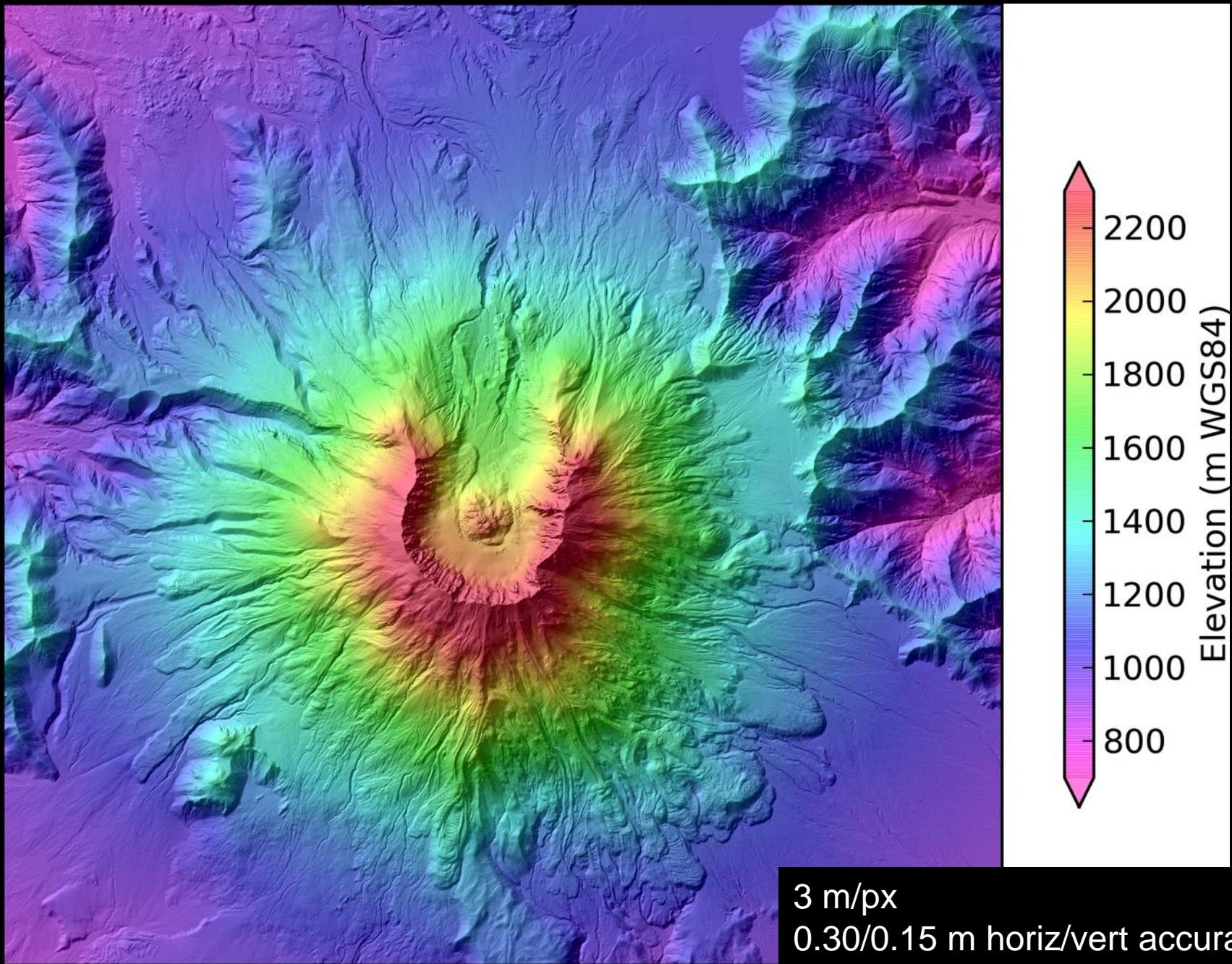


5/9/2013 SfM orthoimage
~0.6 m/px, 270 photos

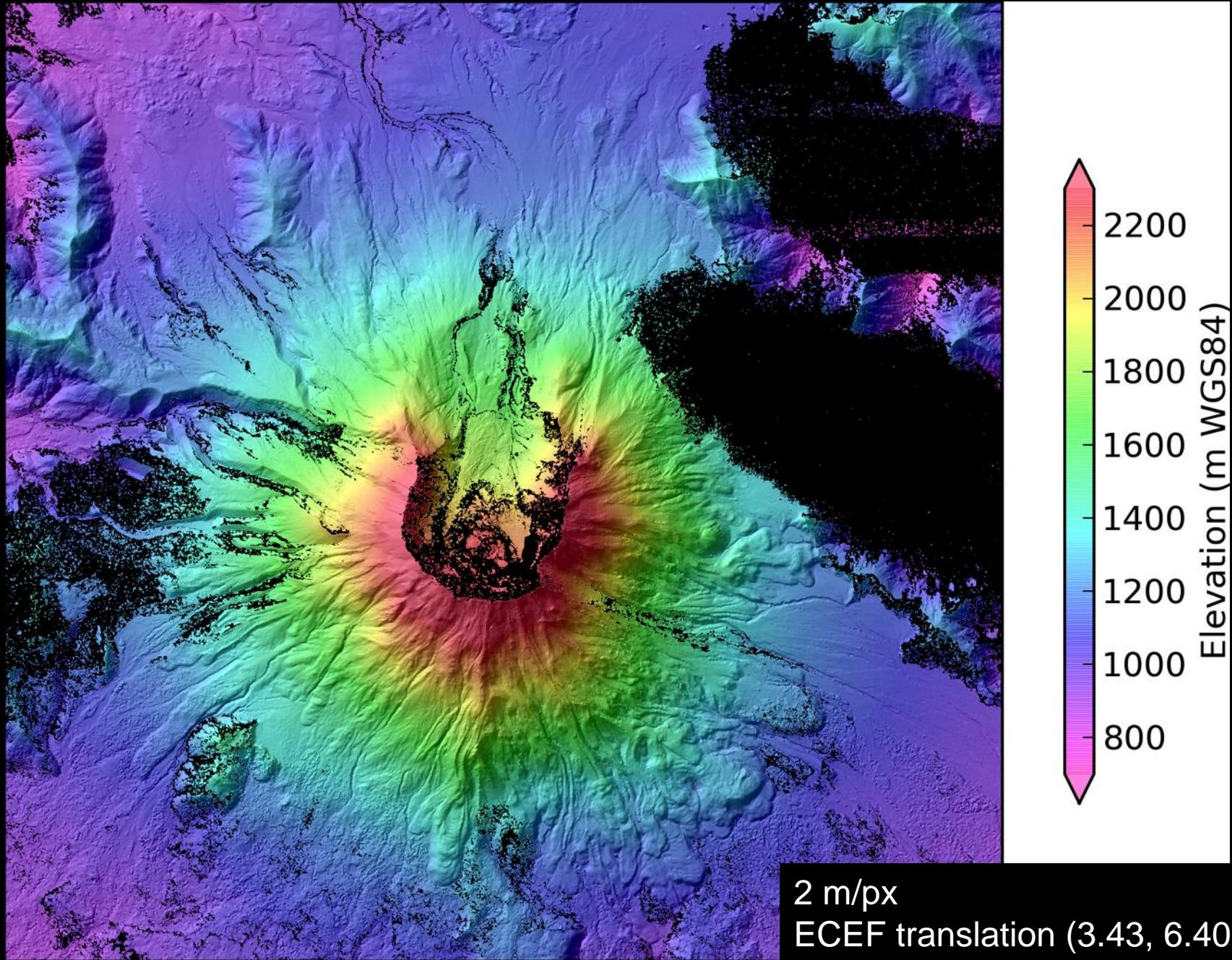


9/9/2013 SfM orthoimage
~0.5 m/px, 357 photos

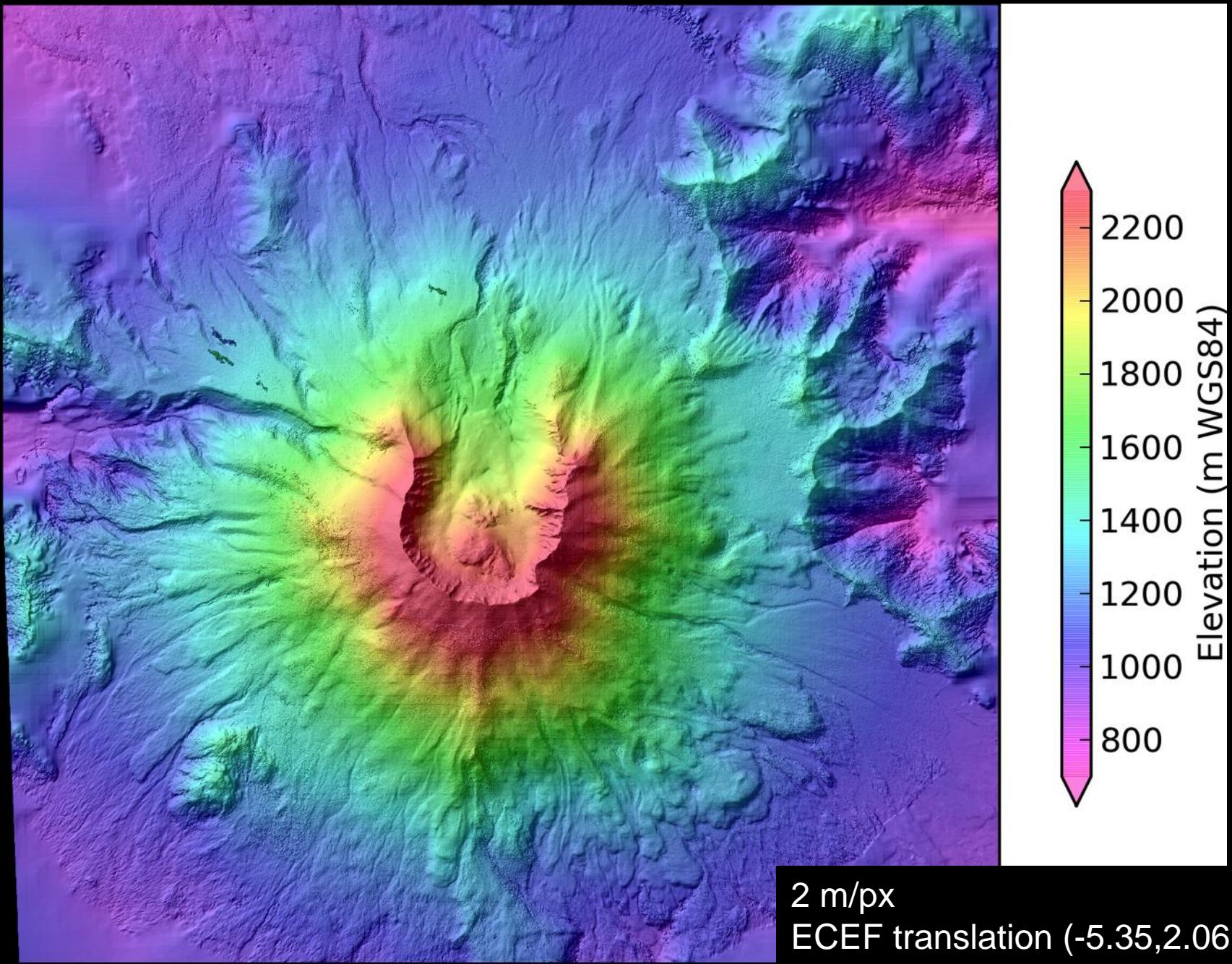
3/15/2004 Bare Earth LiDAR



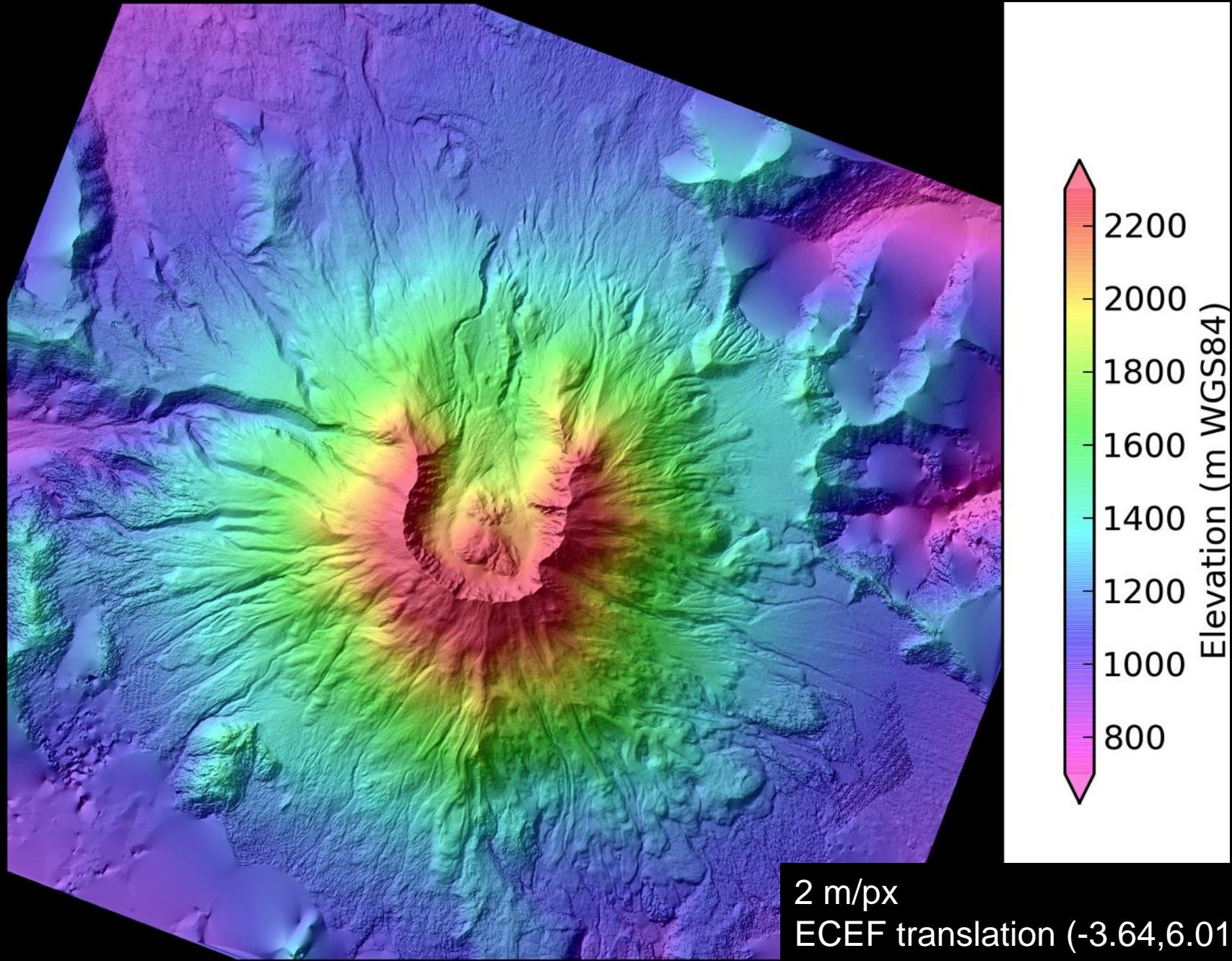
10/18/2012 WorldView-2 Stereo DEM (DRAFT)



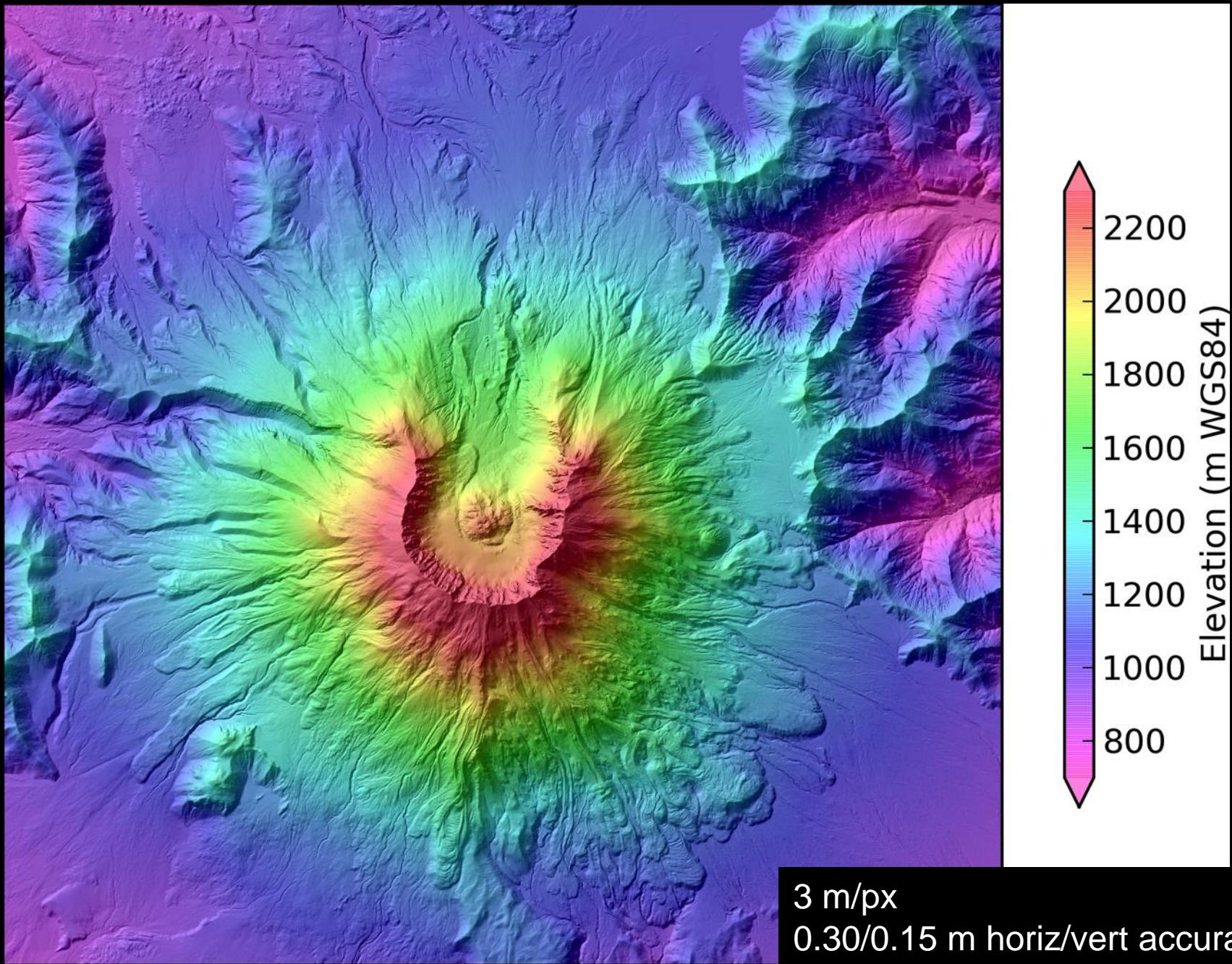
5/12/2013 SfM DEM (DRAFT)



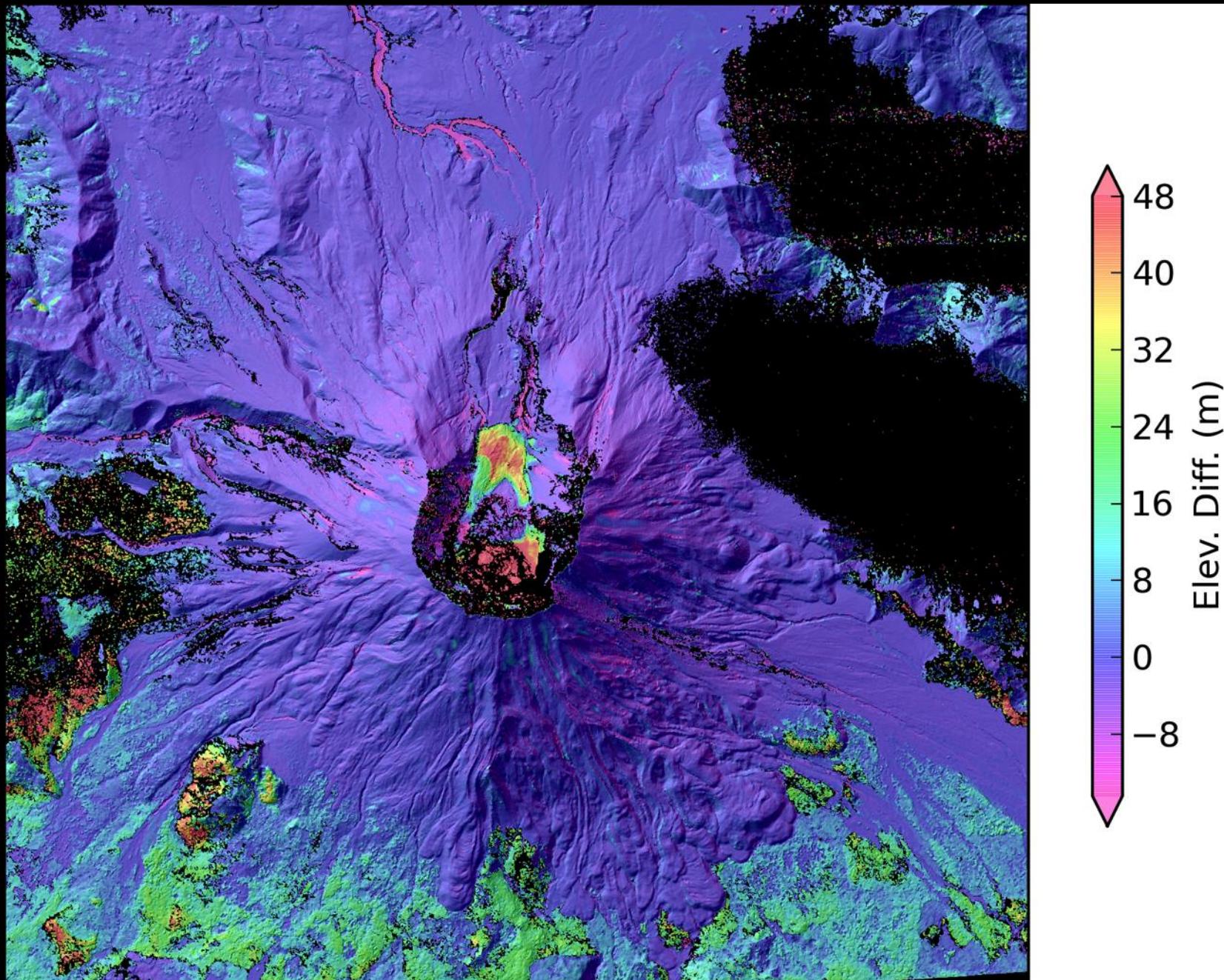
9/9/2013 SfM DEM (DRAFT)



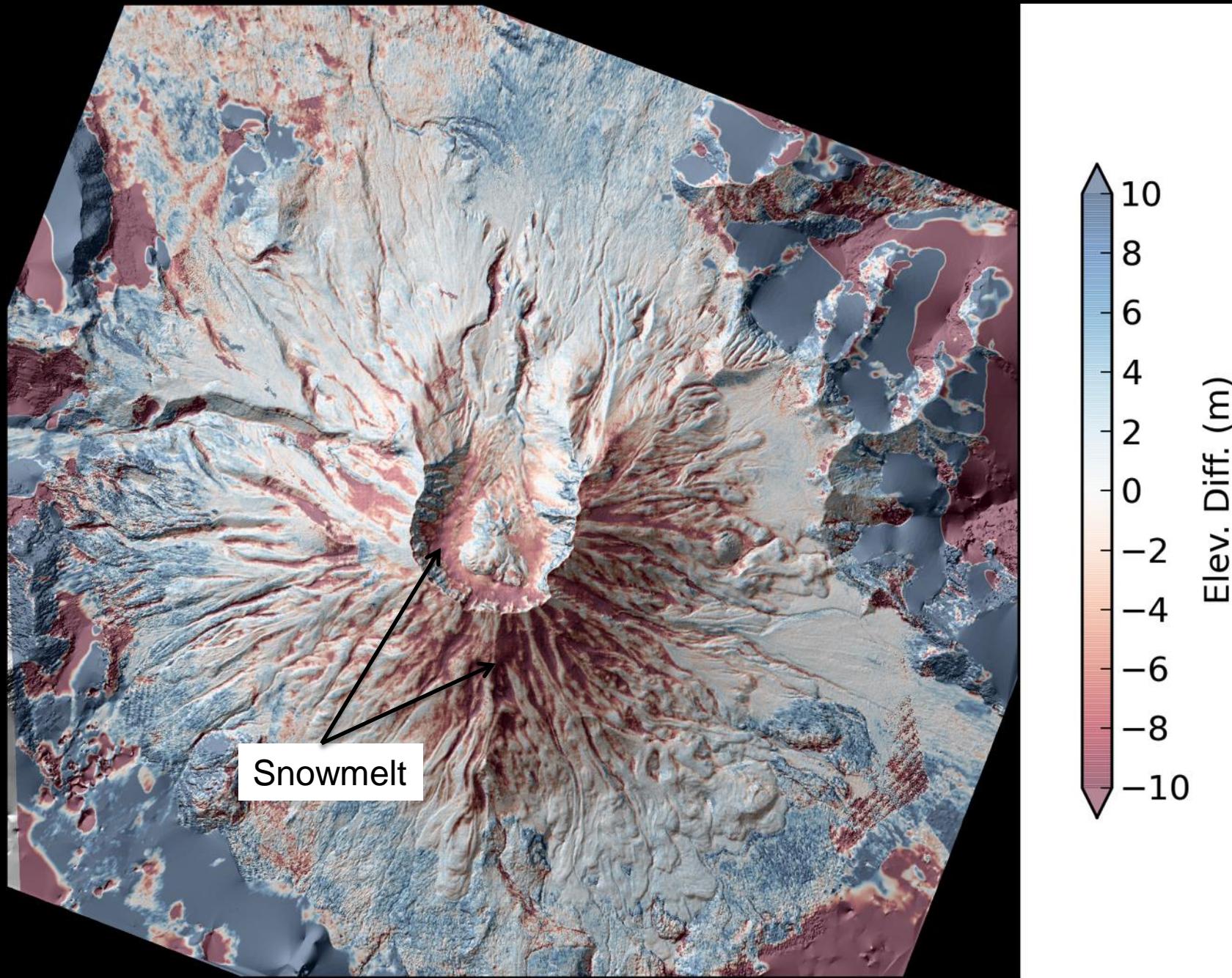
3/15/2004 Bare Earth LiDAR

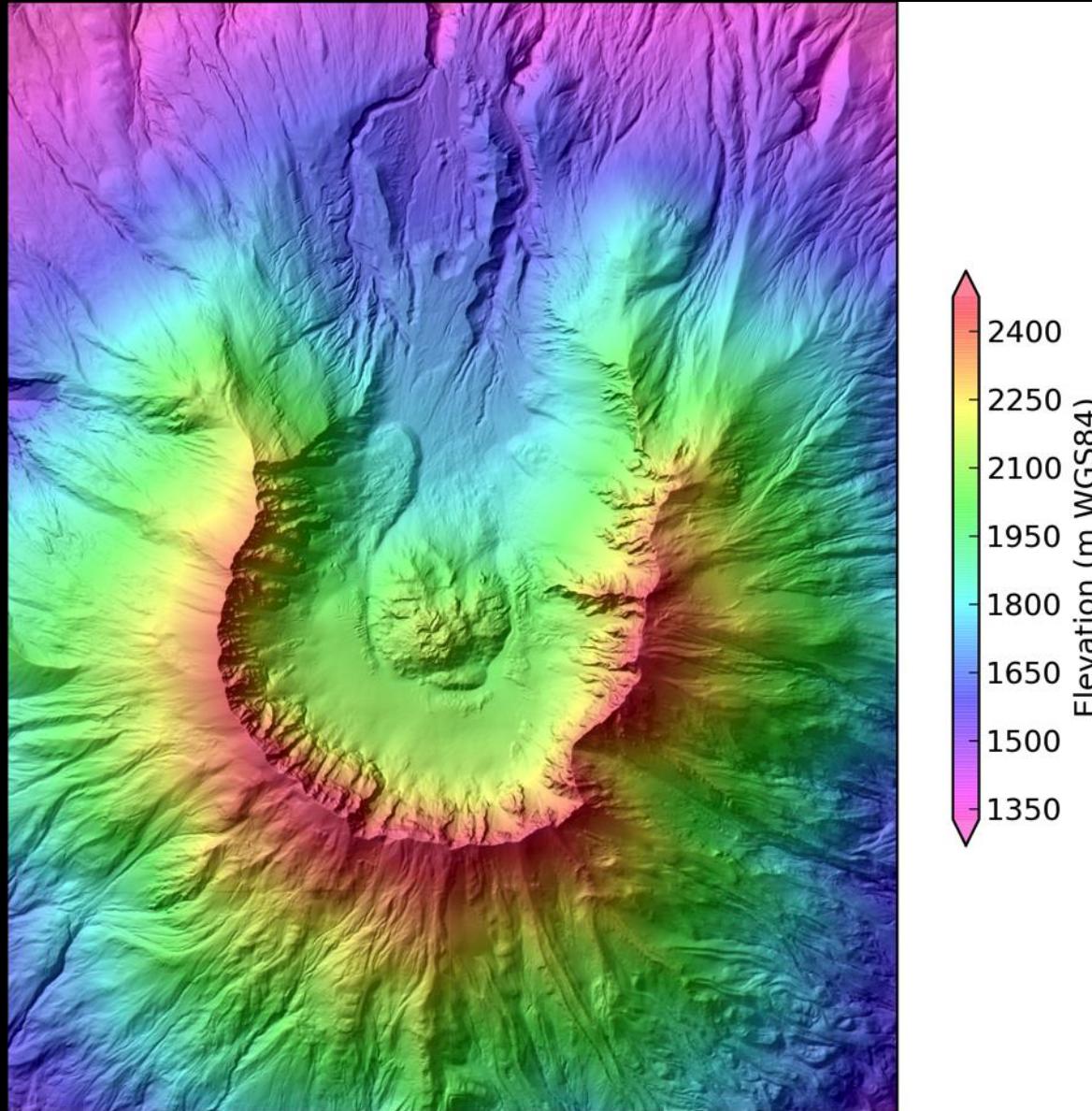


10/18/2012 WV Stereo - 3/15/2004 LiDAR

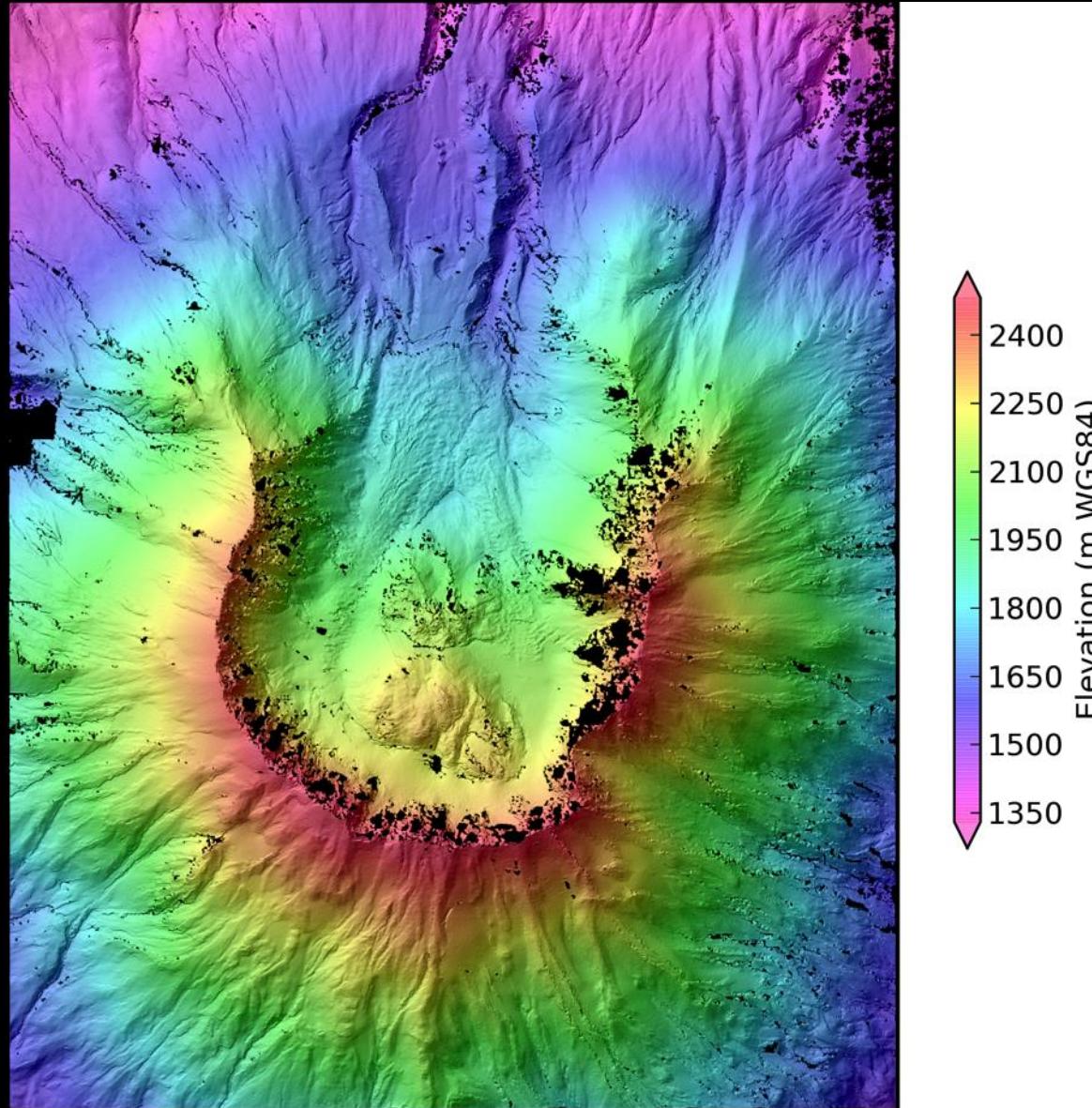


5/12/2013 SfM – 9/9/2013 SfM

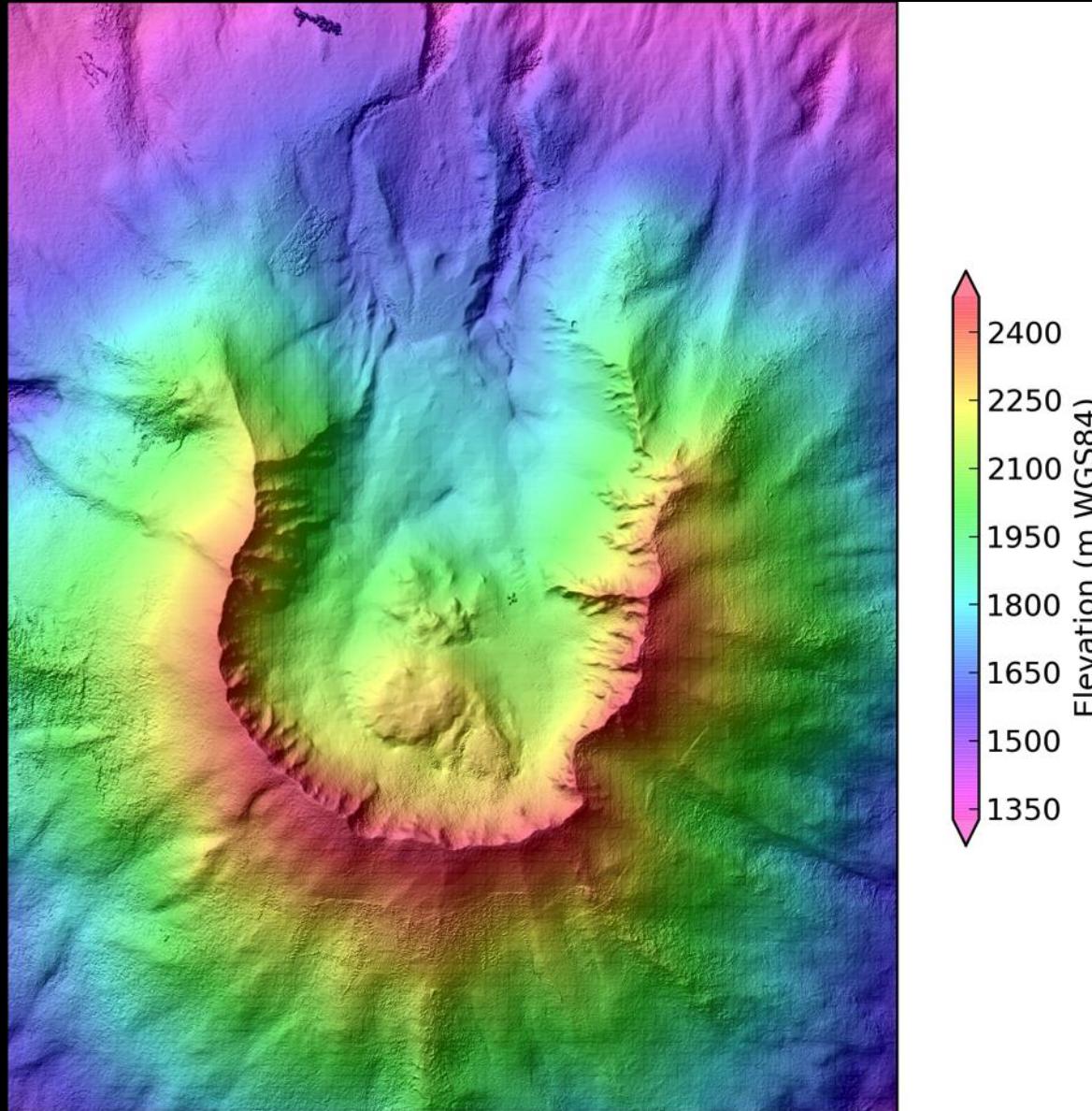




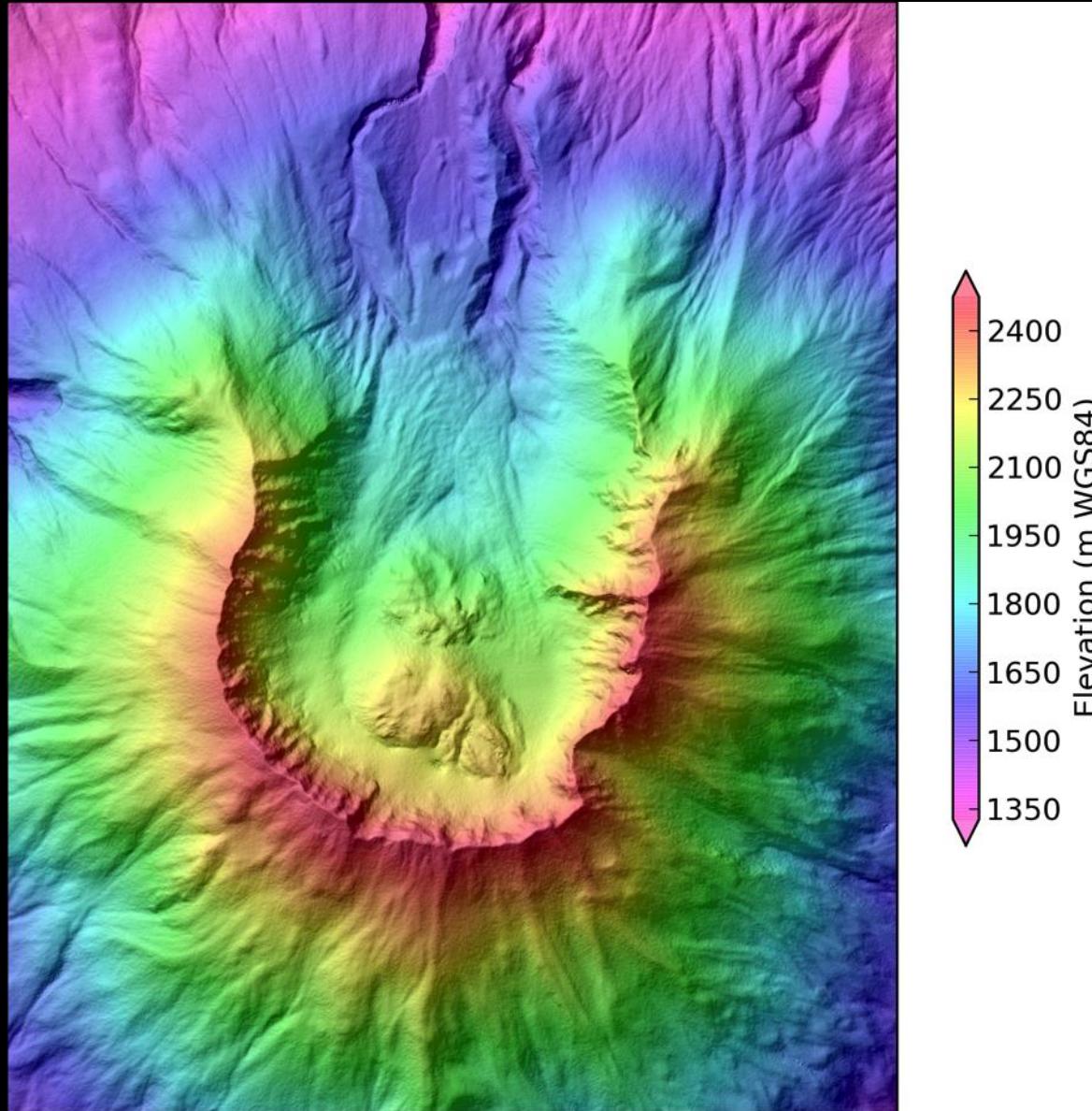
20040315 LiDAR



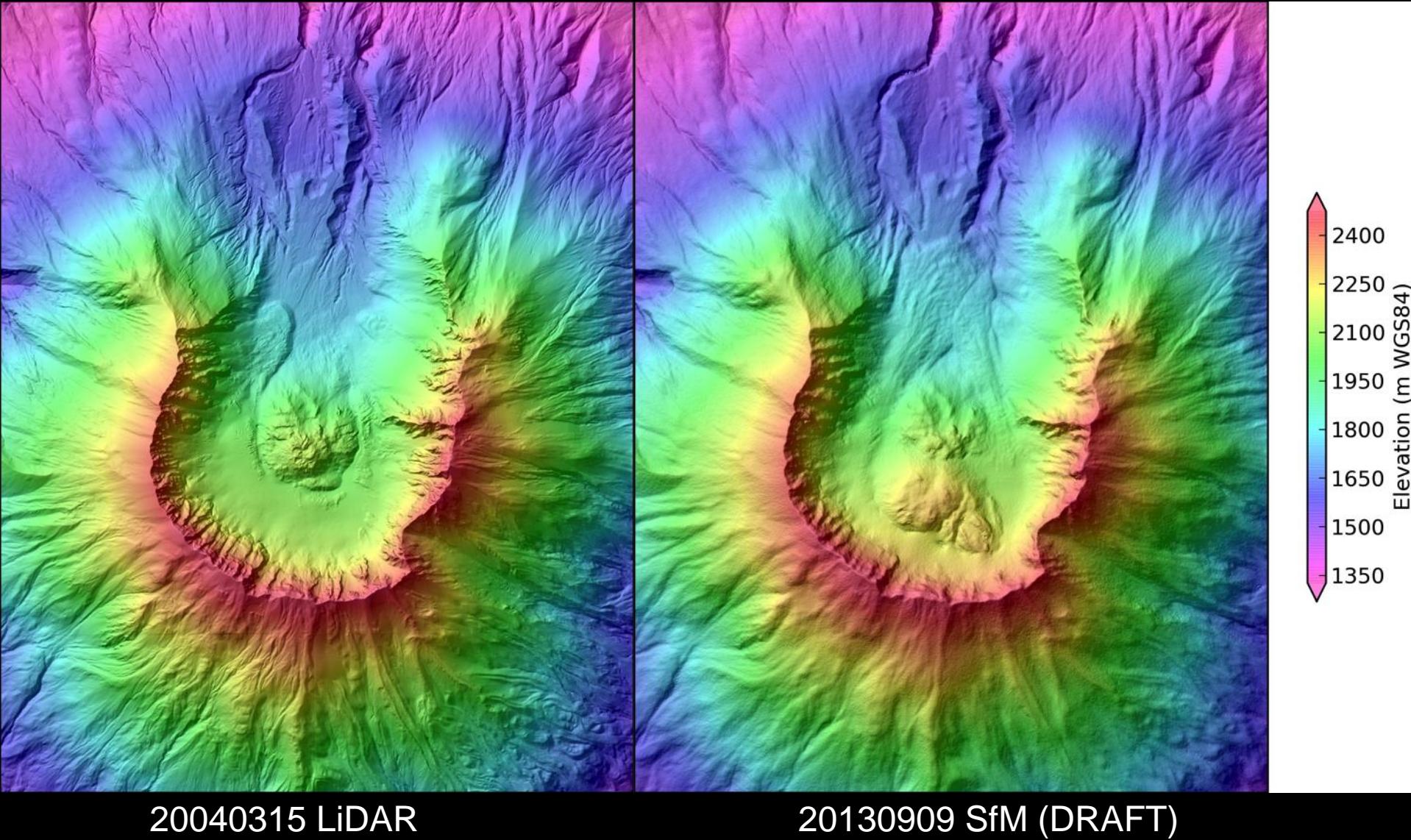
20121018 WV Stereo



20130509 SfM



20130909 SfM



DRONES! (err...UAVs)

- Cheap: ~\$500-1000 for complete setup
- Rapid on-demand deployment
- Repeat surveys in minutes
- Manual control available (FPV video feed)
- Fully autonomous:
 - GPS waypoint navigation
 - OpenPilot Revo or ArduPilot
 - >20 km range, ~30 min flight time
- Payload capacity ~1-2 kg
 - GoPro, Point&Shoot, laser altimeter

Prototype Mapping UAV

- HobbyKing Phantom Flying Wing (1.5 m)
 - “Plug-N-Fly”
 - \$120
- Canon Powershot S100
 - CHDK intervalometer
 - USB trigger RC switch
 - \$200 (ebay)
- OpenPilot Revo/GPS/modem
 - 3-axis gyro
 - 3-axis accelerometer
 - 3-axis magnetometer
 - Barometric pressure sensor
 - \$130 + \$50 + \$20

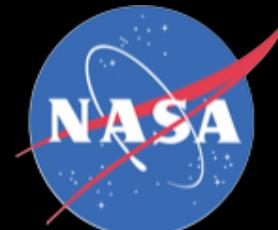


Summary

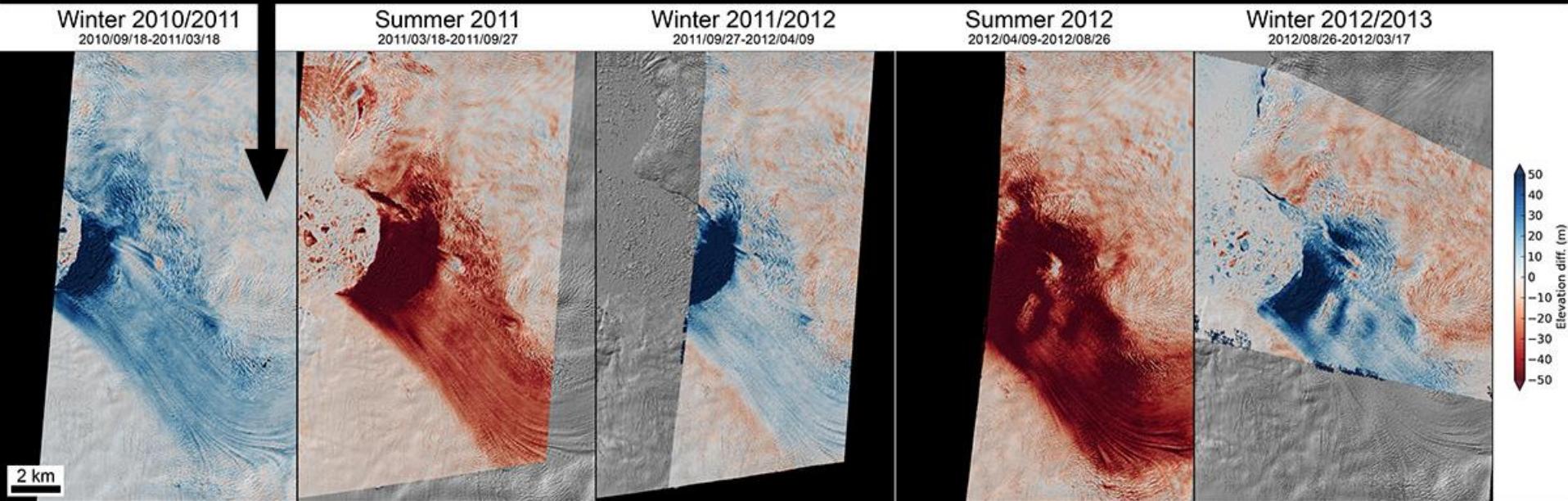
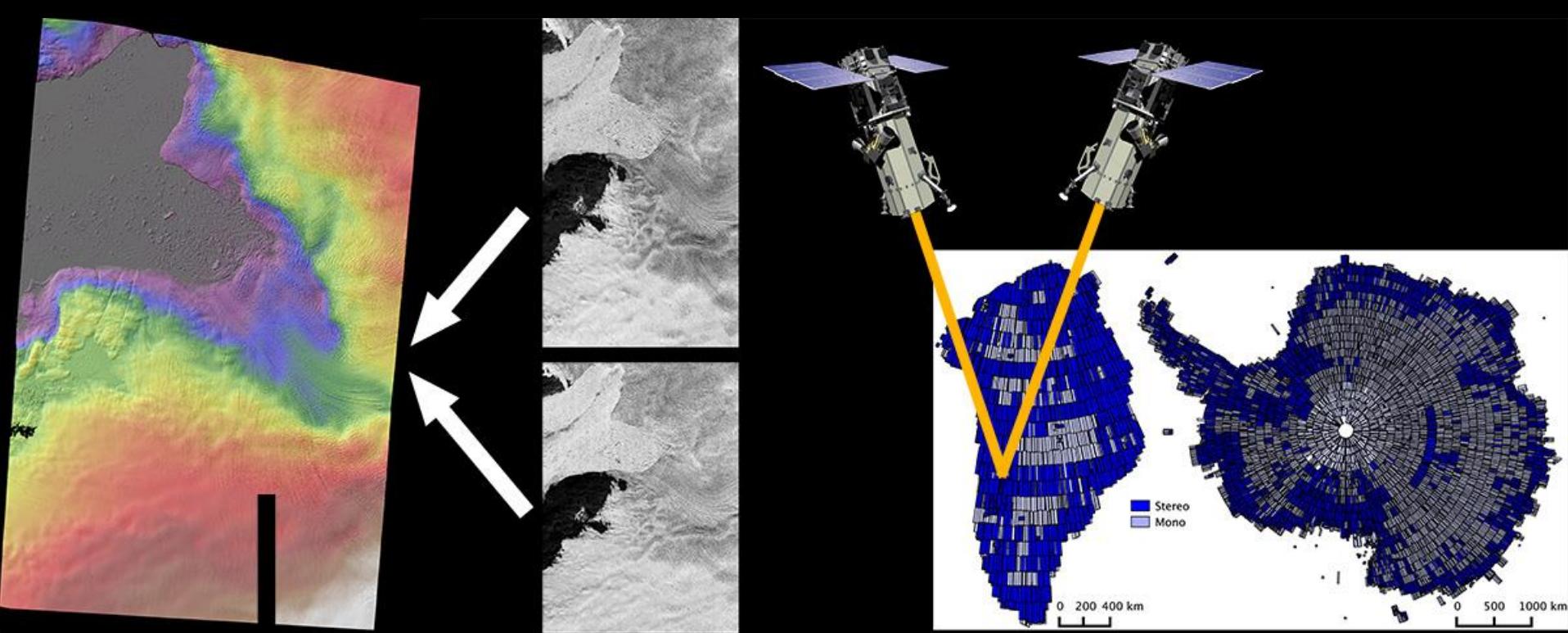
- Open source photogrammetry is here, now!
- Combination of remote sensing platforms (satellite, aerial, RC) offers solutions for range of spatial/temporal requirements
- Cost-effective approaches offer real alternatives to airborne LiDAR, with comparable resolution and accuracy
- It's only going to get cheaper/better.

Acknowledgements

- NASA NESSF program
- UW Student Technology Fee Committee
- Eric Steig, Harvey Greenburg, UW Quaternary Research Center
- Dan Miller, John Pallister, USGS CVO
- Zack Moratto, Oleg Anderson, NASA Ames
- Paul Morin, Claire Porter, Polar Geospatial Center, Univ. of Minnesota
- Ian Joughin, Ben Smith, UW APL
- You (the American taxpayer)



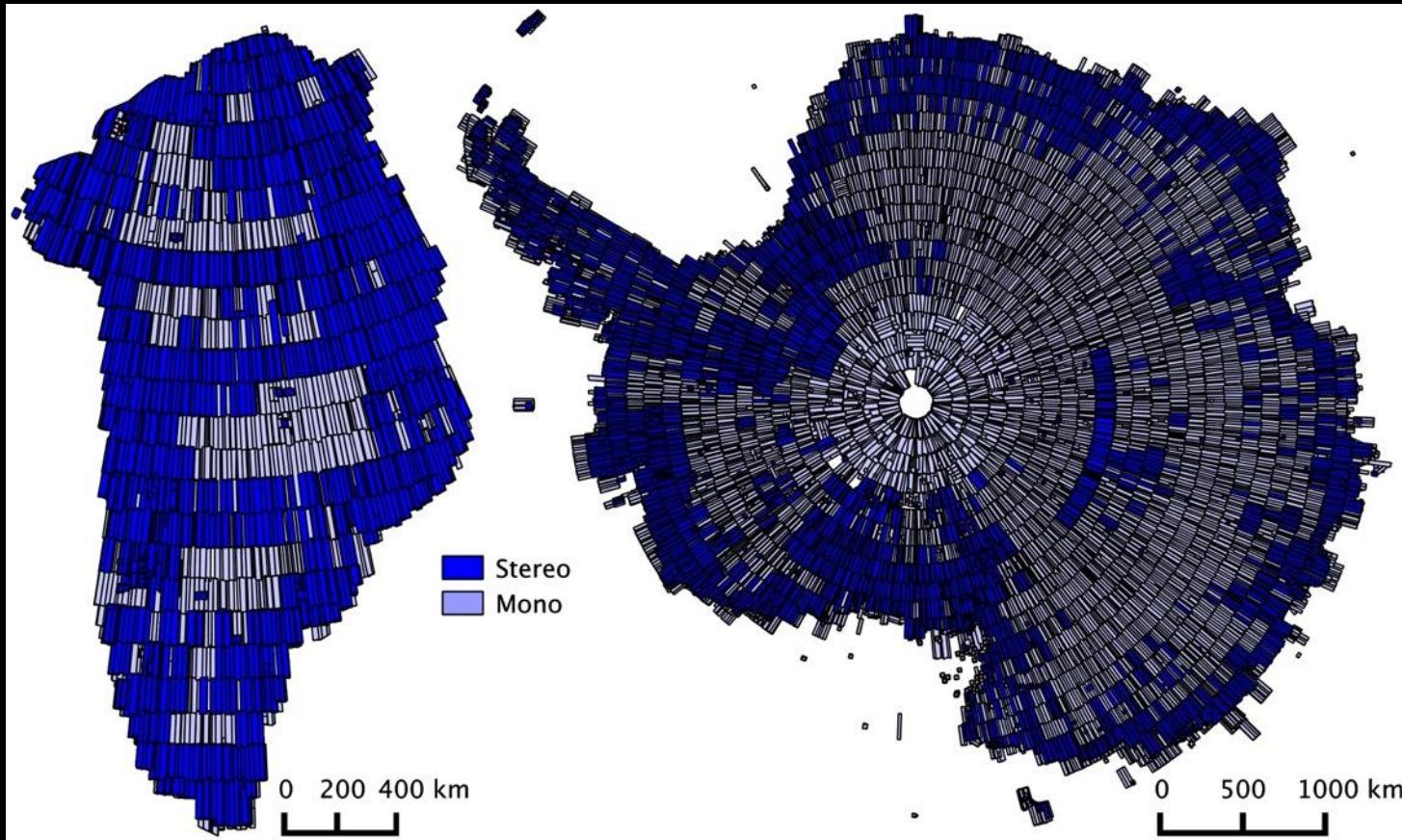
BONUS SLIDES!



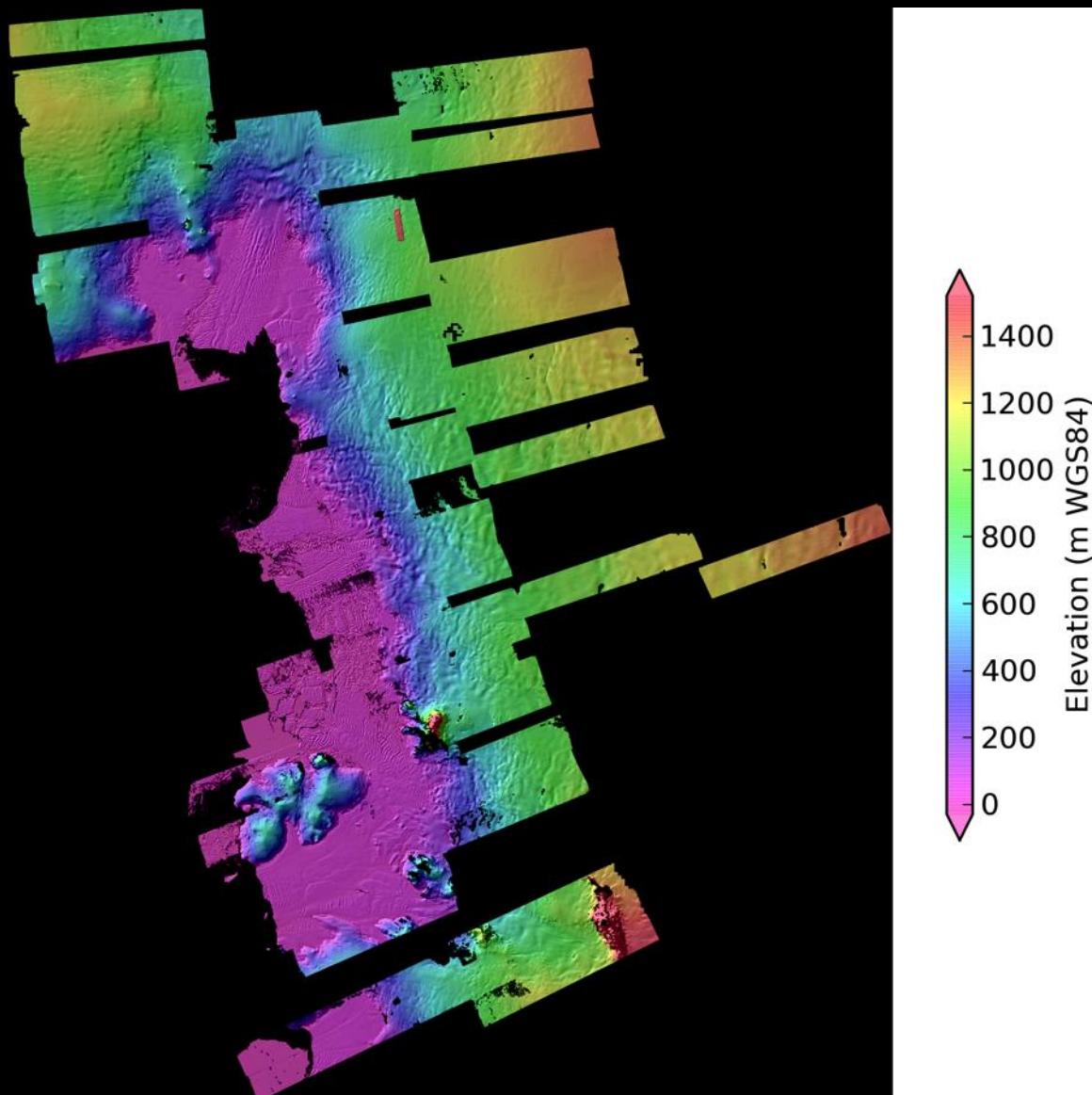
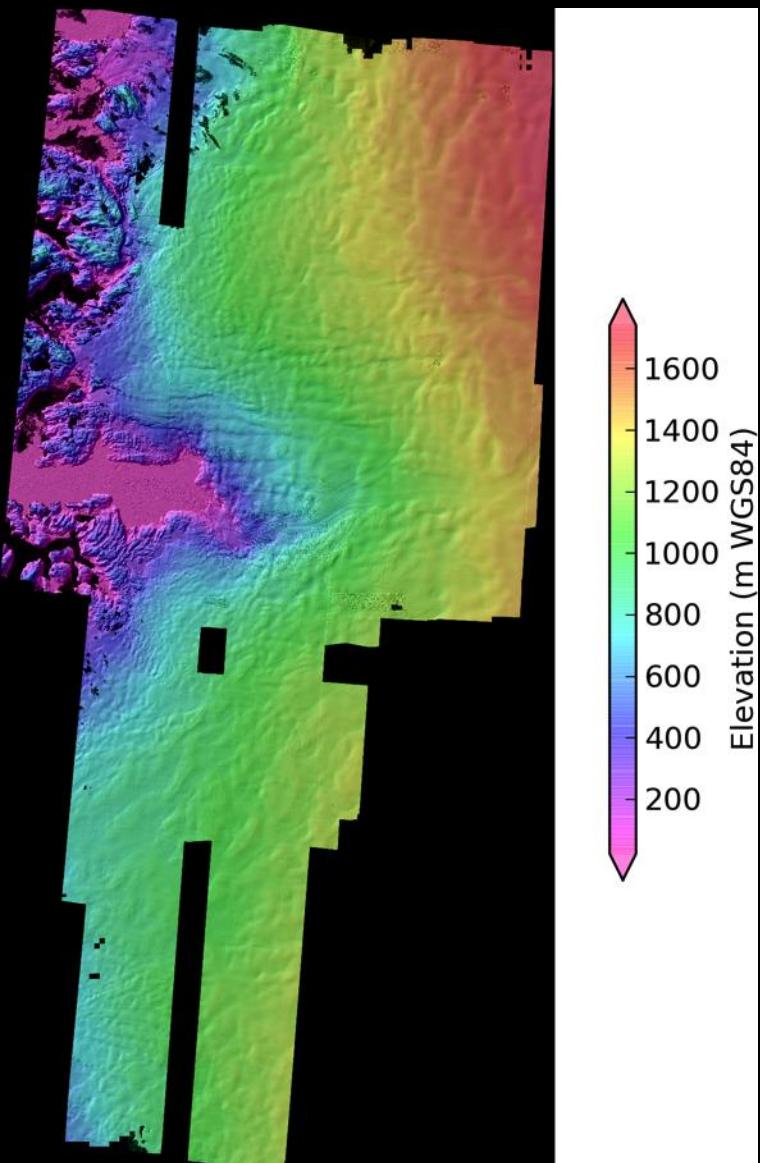
Background

- Surface elevation is one of three key glaciological measurements (velocity, thickness)
- Floating ice is in hydrostatic equilibrium – elevation above sea level is proxy for thickness
- Large outlet glaciers and ice streams display significant seasonal and interannual elevation/velocity change

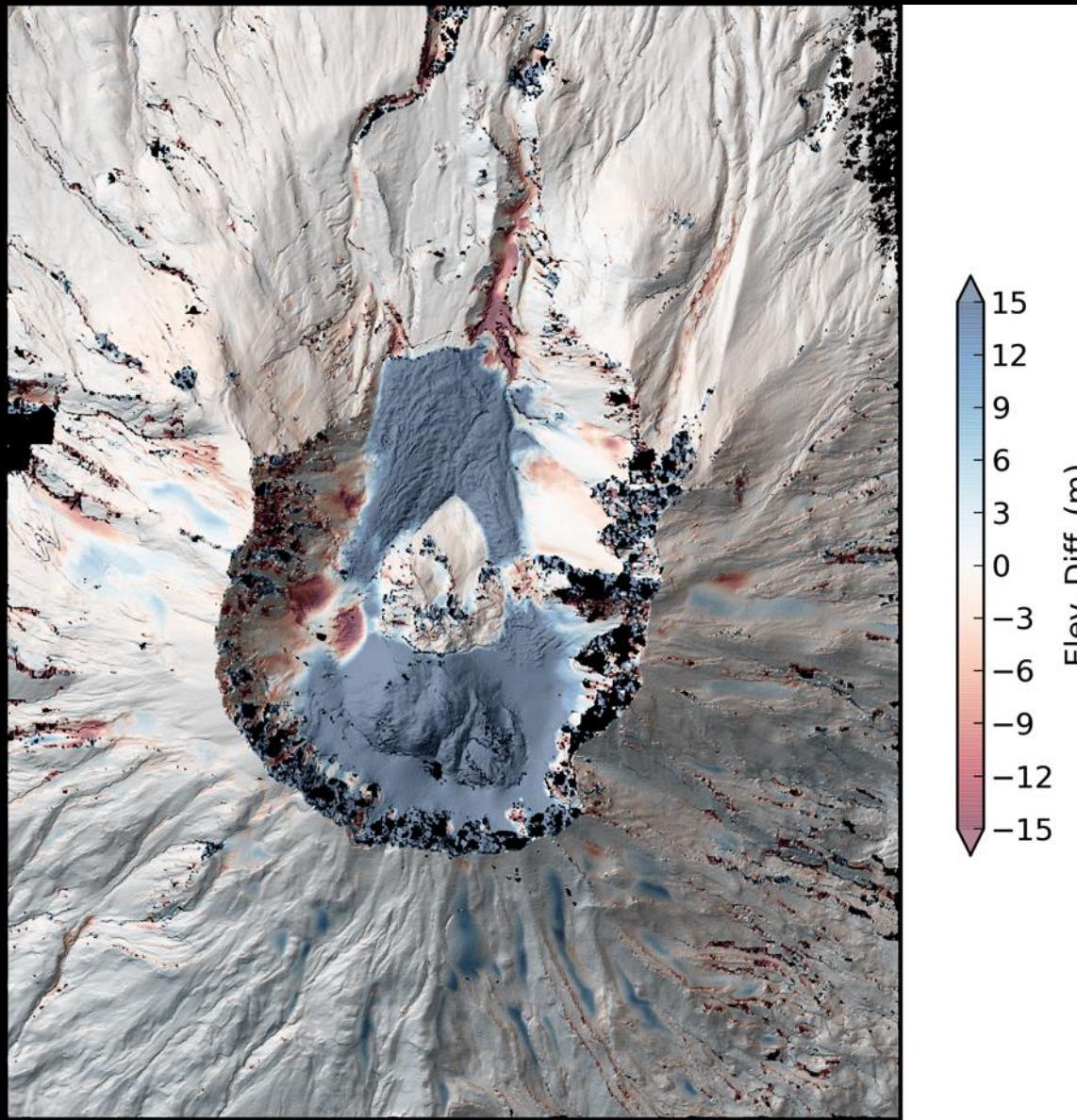
DigitalGlobe Stereo Coverage (3/14/13)



	Mono		Stereo	
	Total	CC<50%	Total	CC<50%
Artic	249887	126922	22683	11422
Greenland	26487	14359	3861	2312
Antarctica	172184	76604	11806	5527

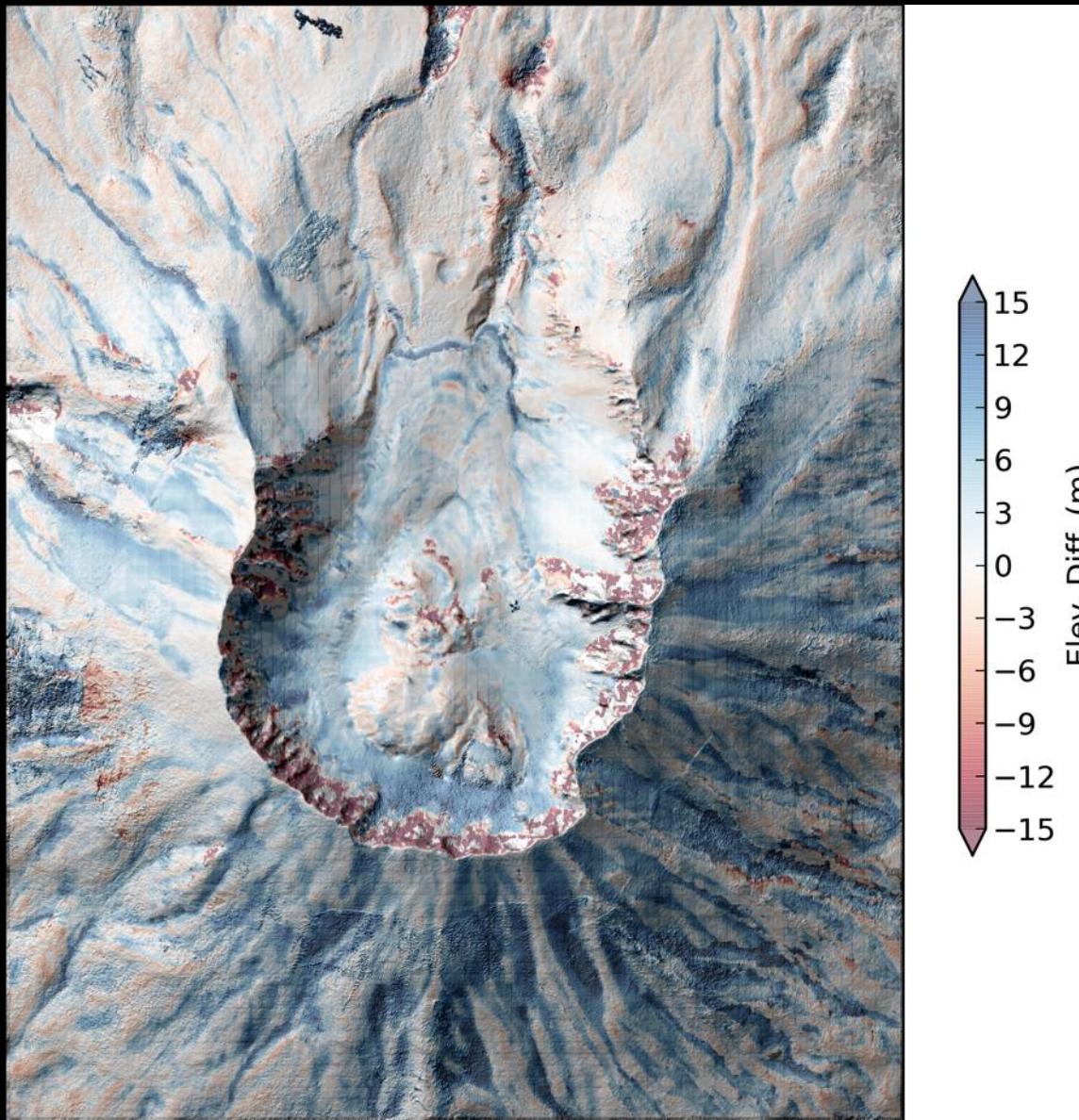


Spring 2004 to Summer 2012



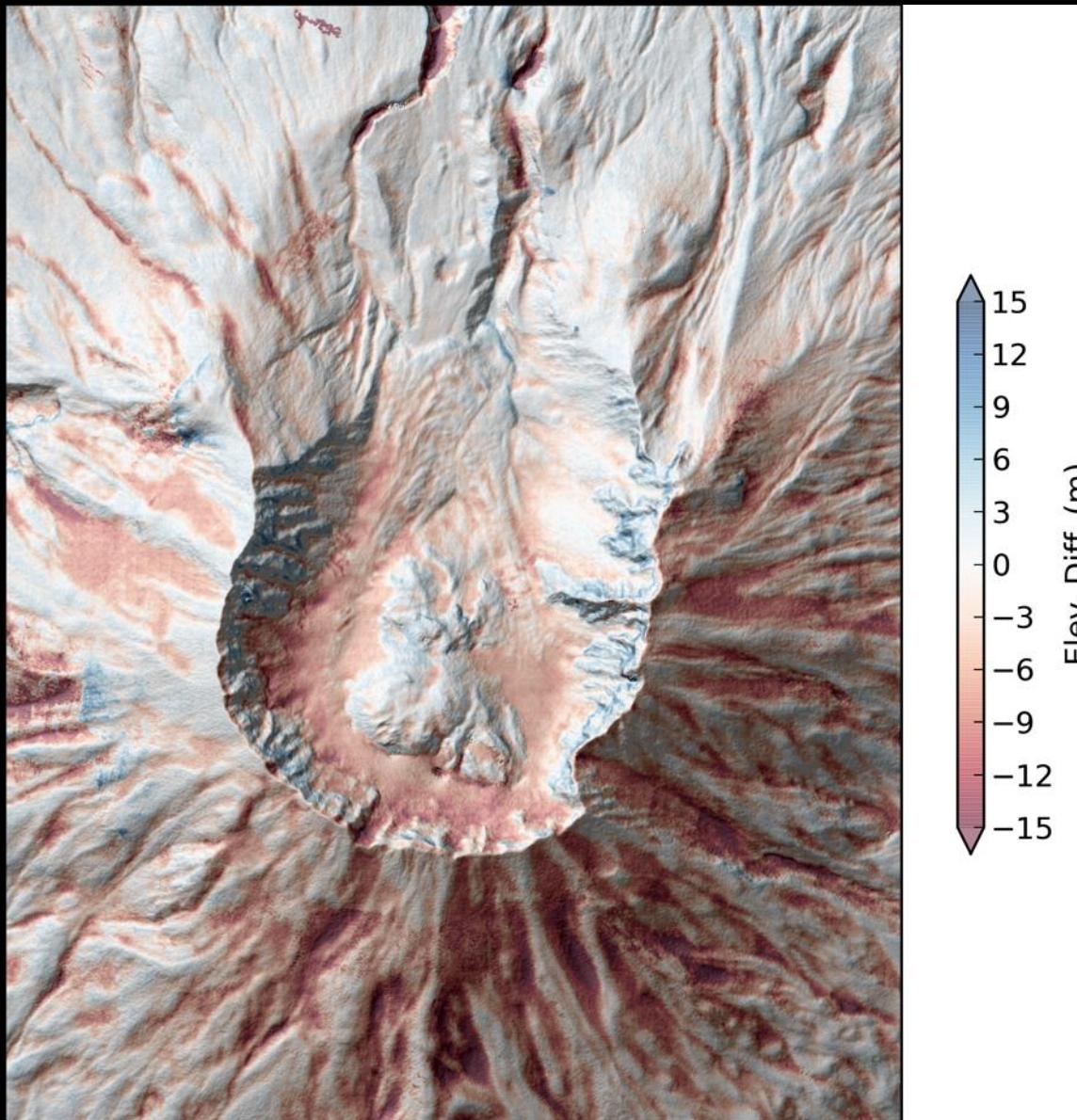
20121018 - 20040318

Summer 2012 to Spring 2013



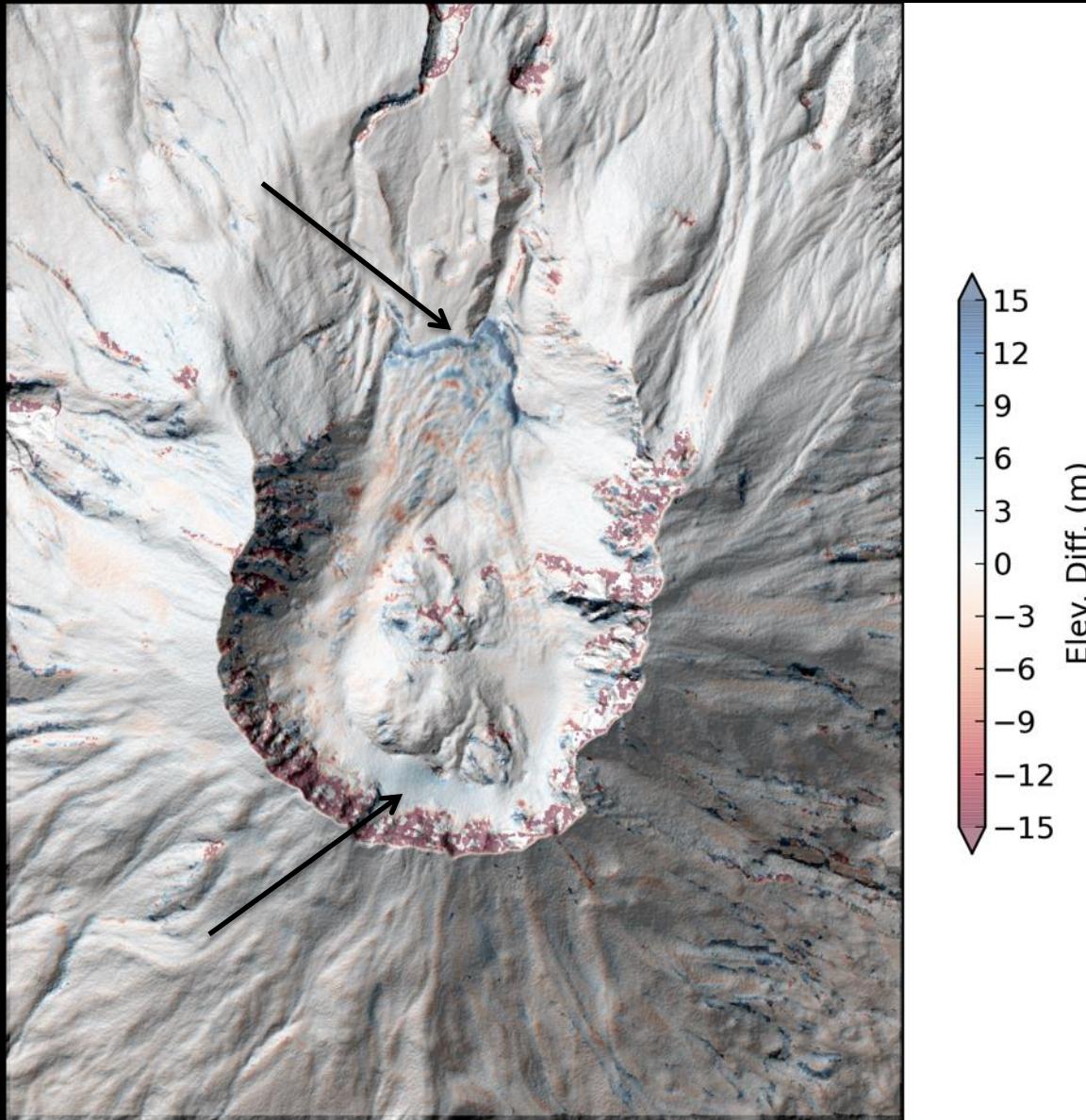
20121018 to 20130509

Spring 2013 to Summer 2013

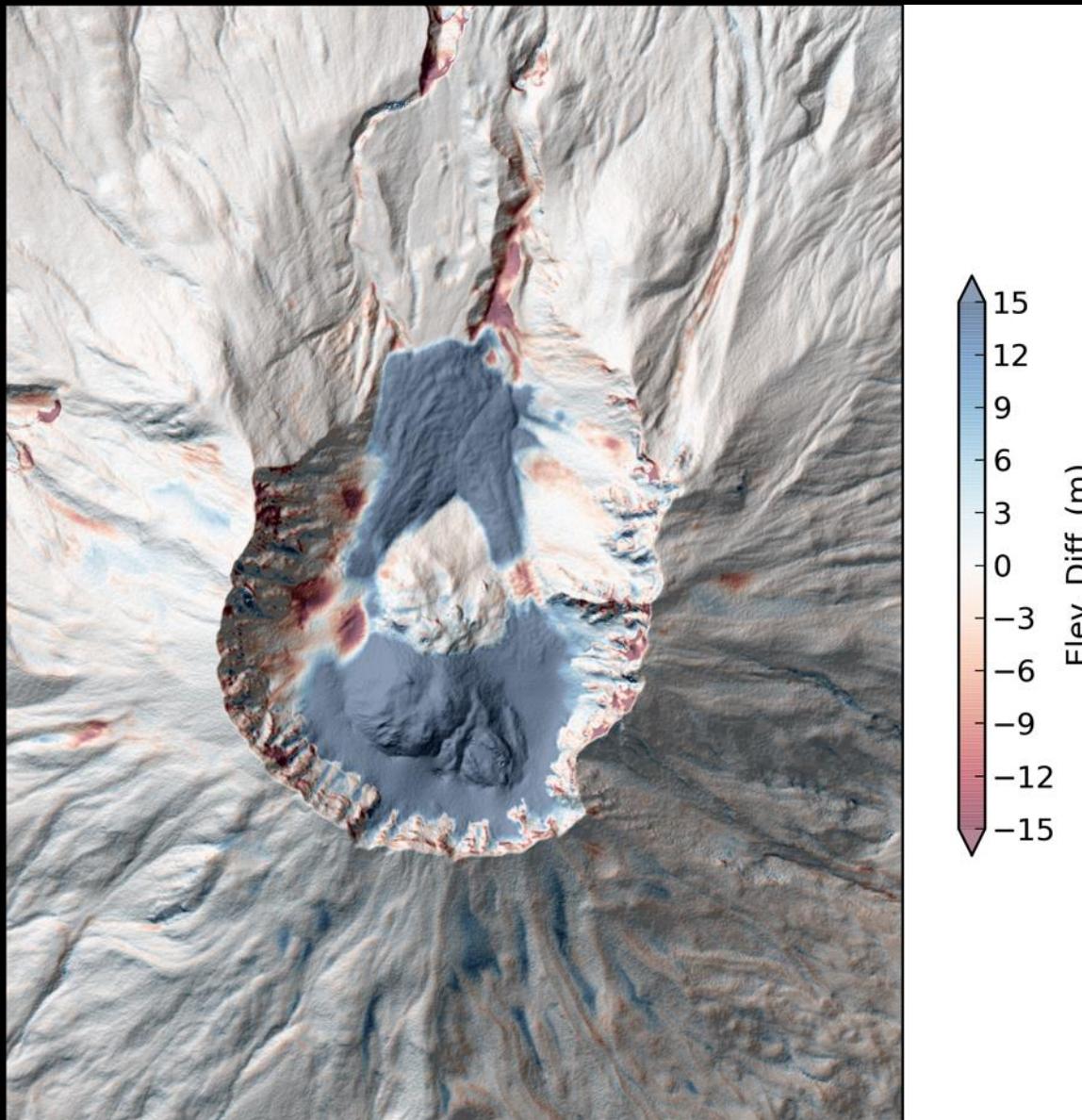


20130909 – 20130509

Summer 2012 to Summer 2013



Spring 2004 to Summer 2013



20130909 - 20040318