Geomorphologic Mapping by Airborne Laser Scanning in Southern Victoria Land

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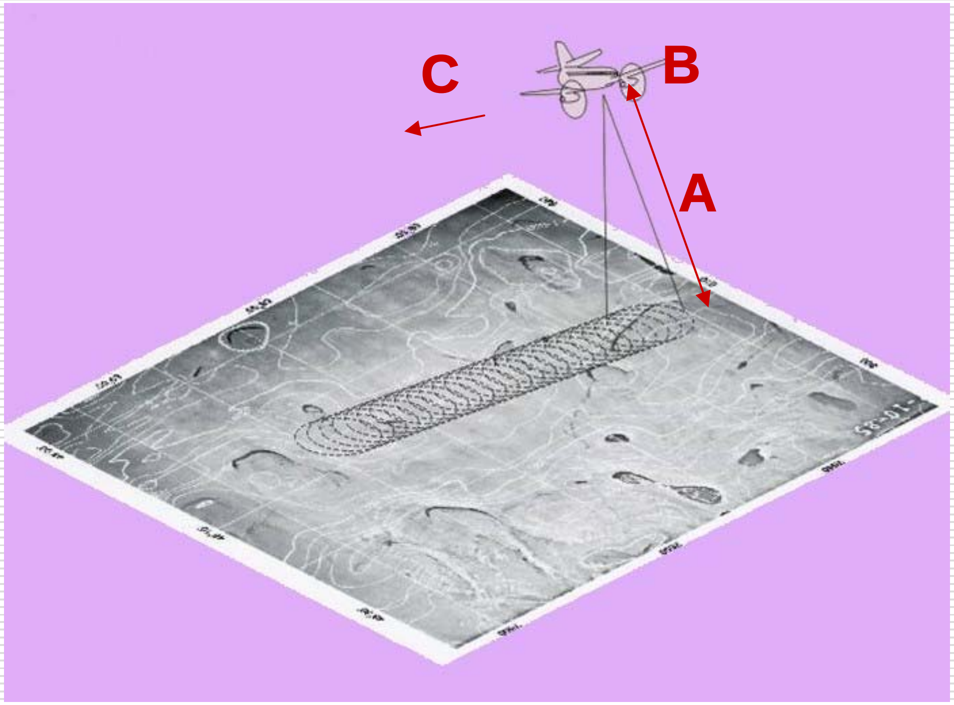
Outline

- Overview on laser mapping
- NASA's Airborne Topographic Mapping (ATM) system
- ATM survey of Dry Valley
- Examples of geomorphologic mapping with laser altimetry
  - Glacial geomorphology
  - Volcanic cones
  - Tectonics
- Note: no agreement about the name of the technique, both laser altimetry and scanning is used

Principles of laser altimetry

- A. Distance between sensor and ground is determined from measurement of laser travel time
- B. Position of sensor is measured by differential GPS
- C. Attitude of sensor is measured by Inertial Navigation System (INS)
- A, B and C are combined with calibration values and correction factors to compute the position of the 'laser point' in a global reference system
- Result is a set 3D points
- For mapping applications grids are computed



Why using LIDAR for cryosphere research?

- Airborne and satellite laser is ideal for polar and alpine research, because
  - fresh snow is nearly ideal, bright Lambertian reflector
  - laser scanning provides simultaneously synoptic coverage, high spatial resolution and spatial accuracy
  - laser systems can map featureless terrain – problem for photogrammetry
  - laser systems have small footprint – problem for radar systems

History and state-of-art

- The beginning: NASA has started a systematic mapping program in Greenland in the early 1990s
- Current status: Laser is applied routinely for mass balance and ice dynamics studies over ice sheets and mountain glaciers
- New sensors: NASA has launched the Ice, Cloud and land Elevation Satellite (ICESat) on January 12, 2003. The sole sensor of the satellite is the Geoscience Laser Altimetry System (GLAS), NASA's first terrestrial laser altimetry satellite mission. The program is in calibration/validation phase
- New applications: first surveys for glacial geomorphology

Dry Valley airborne laser altimetry survey

- Goals:
  - obtain precise elevations the ICESat cal/val
  - assess the use of airborne laser for Antarctic mapping purposes
- Joint project of NASA/NSF/USGS
- Data acquisition:
  - Sensor: NASA's Airborne Topopgraphic Mapper (ATM) conical laser scanning system
  - Survey: December 2001
  - Results: coverage of selected site with an average laser point density is 0.1 – 0.5 point/m^2

Why did we select Dry Valleys as ICESat calibration site?

•Small annual and interanual variability

•no vegetation, minimal snow/ice cover

•Minimal cloud cover

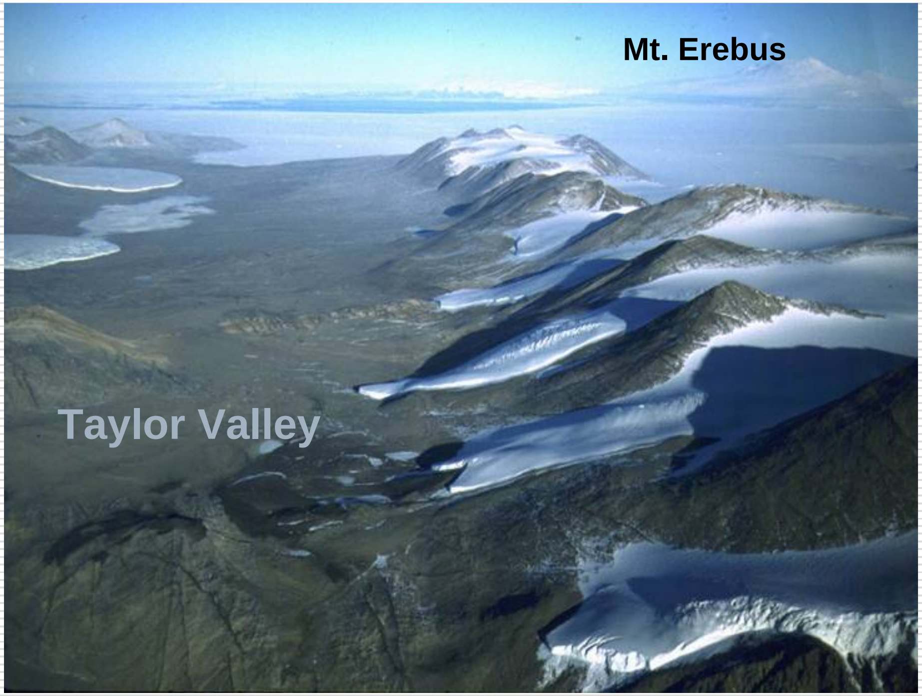
•Smooth surface at the scale of the ICESat footprint

•Diverse topography (slope)

•High ICESat track density

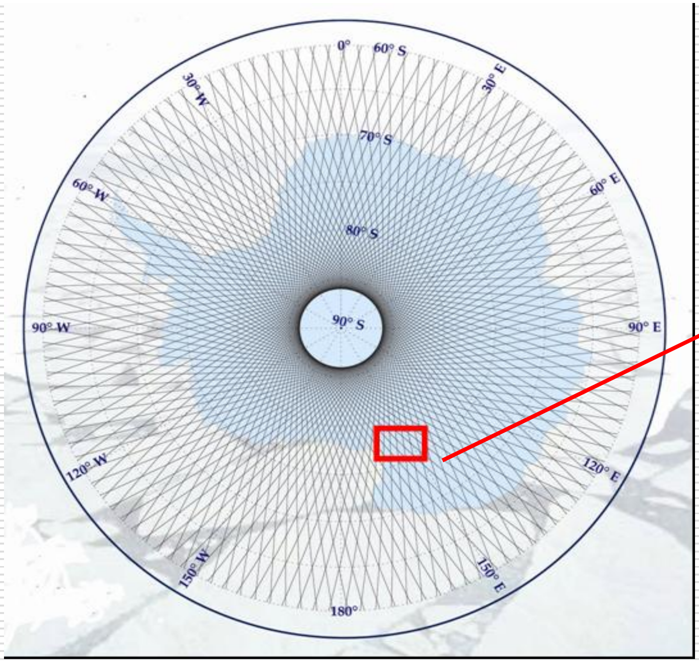
•Maximum orbital altitude

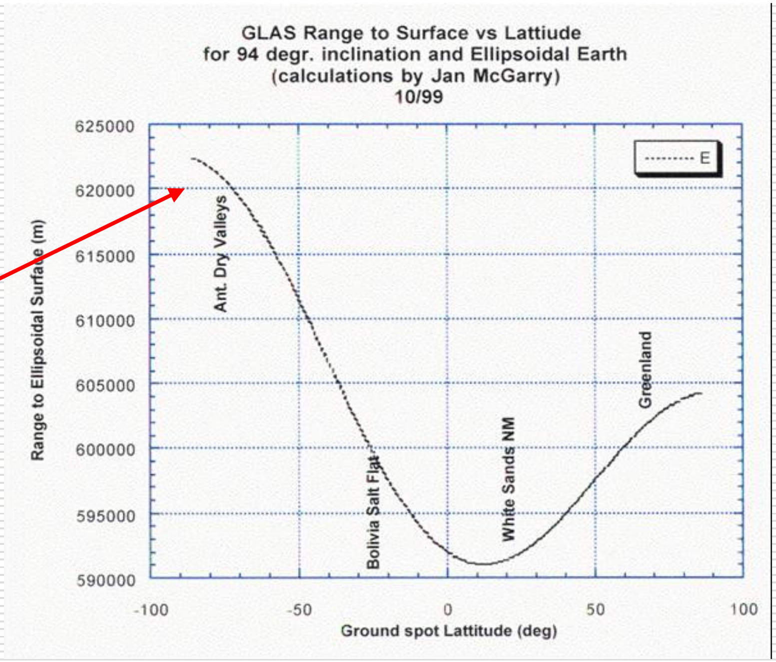
•Close to major science targets



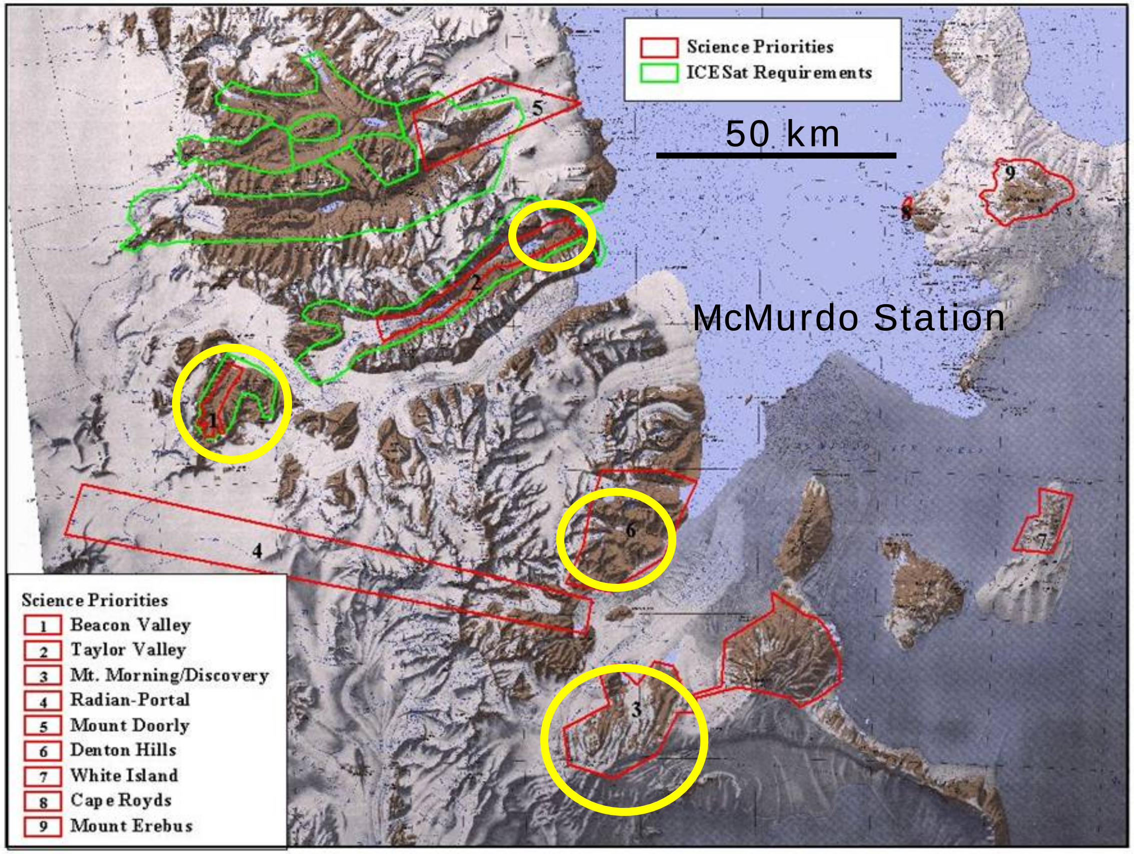
Why did we select Dry Valleys as ICESat calibration site? (cont.)

- High track density (left)
- Maximum range part of ICESat orbit (right)

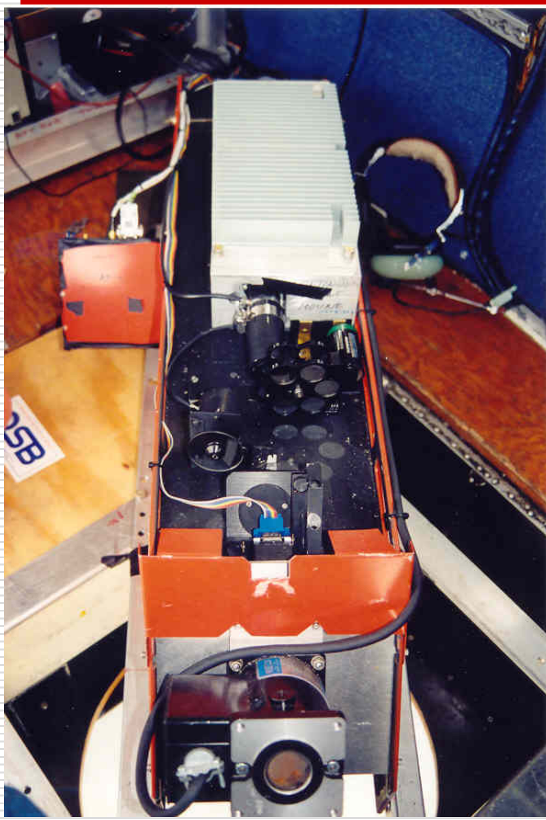




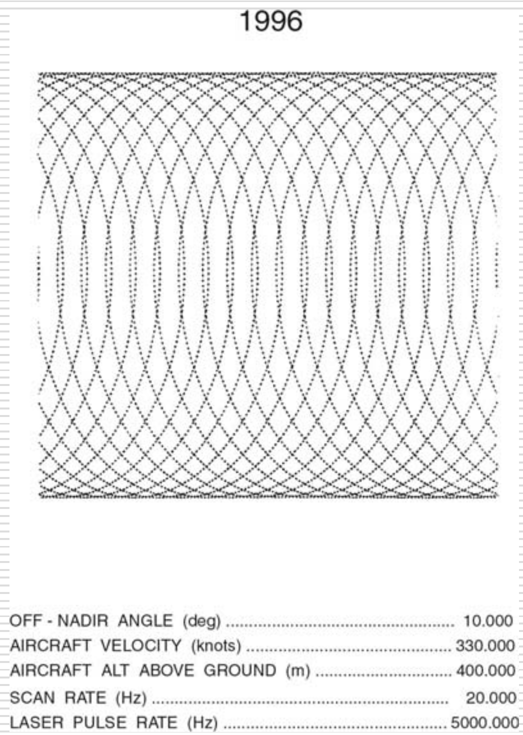
Target areas for testing geological and glaciological applications



Data acquisition system: Airborne Toporaphic Mapper, NASA/WFF



Conical scan pattern



Installed in P-3 (Orion) or Twin Otter aircrafts

Specifications:

- Spectra Physics TFR laser
- Green wavelength
- Scan with nutating mirror
- 10-20 degree off nadir angle
- 10-15 Hz scan rate
- 5,000-20,000 pulse rate
- Installed in P3-B Orion
- Intensity + passive channel
- 1 meter footprint size

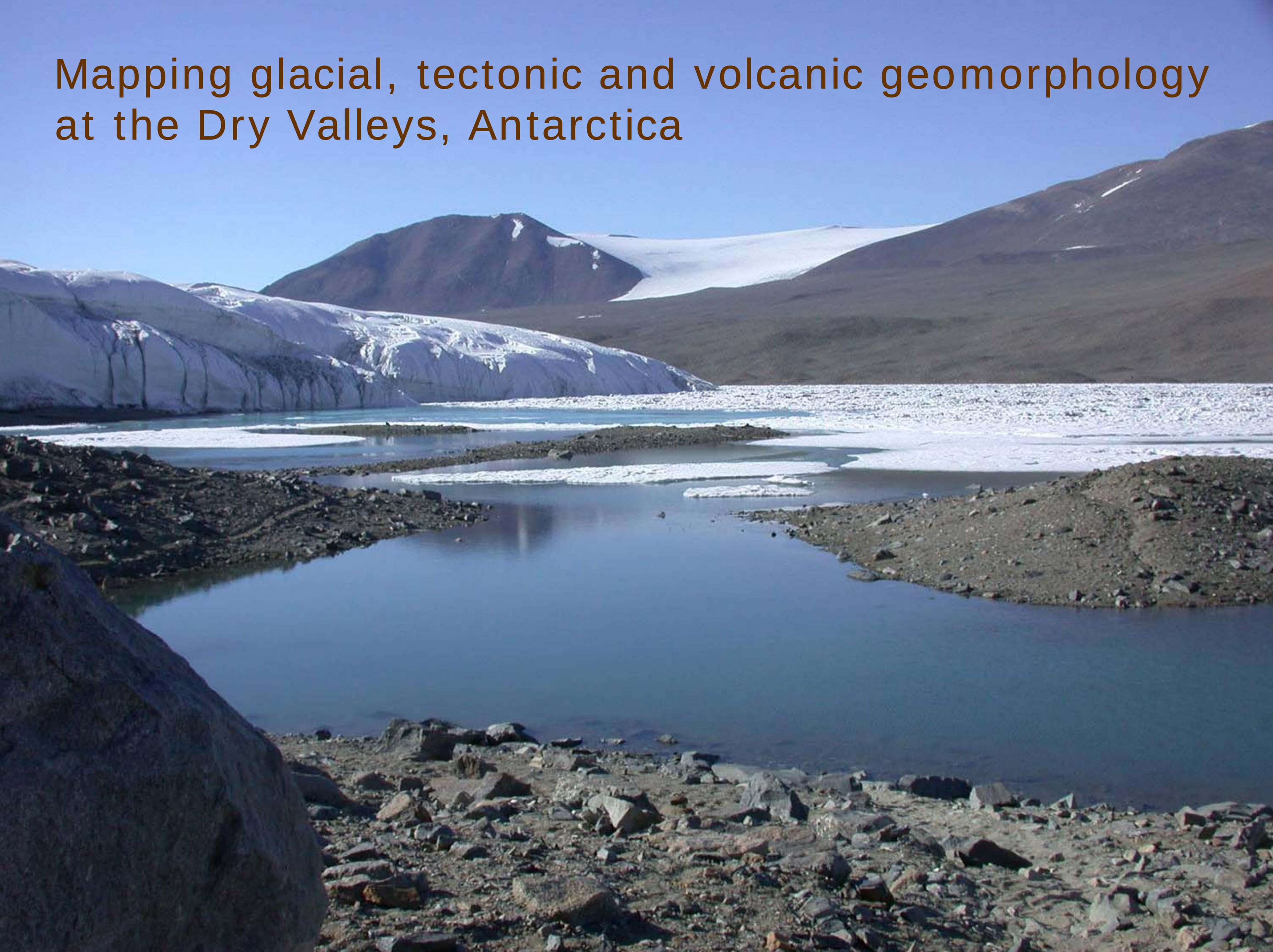
Data Processing Steps

NASA WFF	Data acquisition	GPS/INS/range/intensity/....
	Data processing	t/long/lat/elevation/....
OSU	Database generation	flat file to relational DB
	DEM generation	2m x 2m, 4m x 4m regular grid
	DEM quality control	relative/absolute accuracy
USGS	Data dissemination	DEM/'clean' laser points/....

Accuracy of DEMs
Data Distribution

- Accuracy
  - RMS error of 0.05+-0.5 m is estimated by comparison with 80+ ground GPS points.
  - Note: For most stations the exact height of the antanna phase center above the topographic surface is not known. Therefore the RMS error of the DEM might be overestimated → accuracy studies are ongoing
- Data distribution:
  - USGS, contact person is Cheryl Hallam, USGS, challam@usgs.gov

Mapping glacial, tectonic and volcanic geomorphology at the Dry Valleys, Antarctica



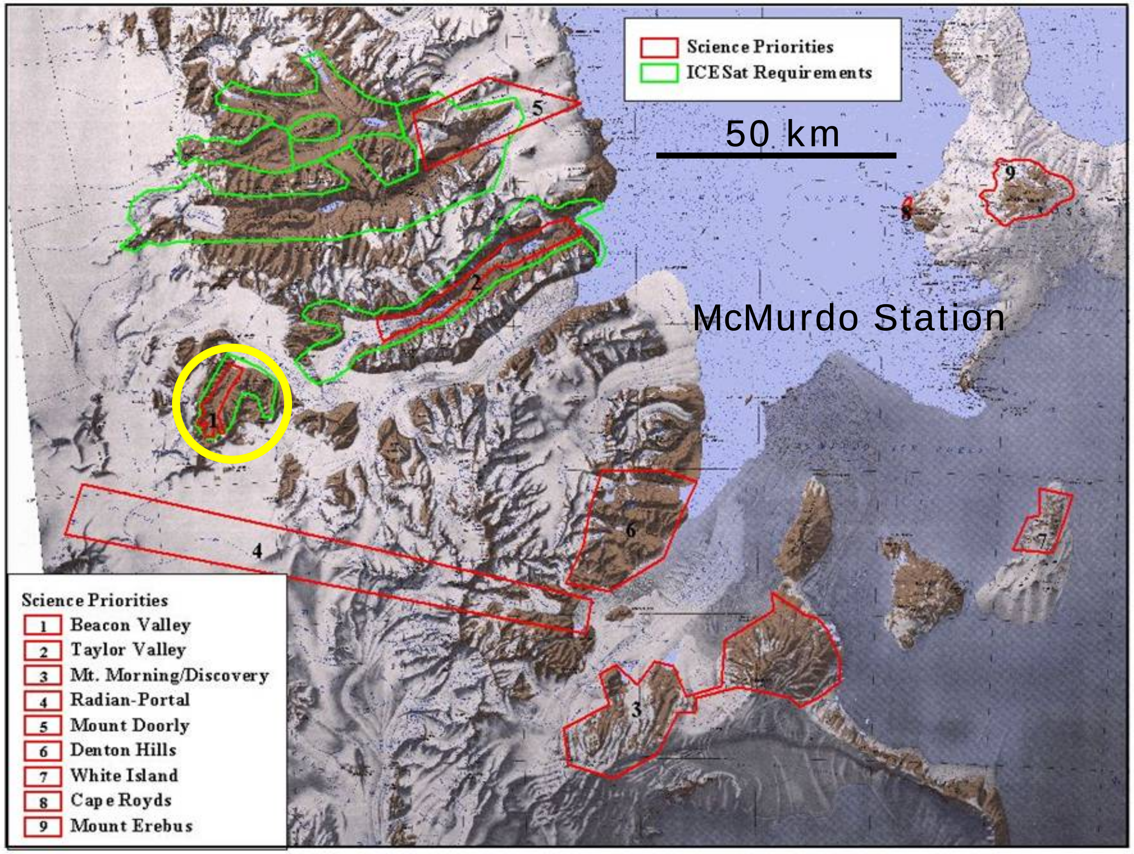
Research interest

- Glaciology, glacial and periglacial geomorphology
  Areas: Taylor, Wright, Victoria, McKelvey, Balham, Beacon and Arena valleys, Bull Pass
  - Glacier surface models
  - Drainage patterns
  - Patterned ground
  - Rock Glaciers
- Mapping volcanic cones
  Areas: White Island, Mt. Morning, Mt. Erebus, Mt. Discovery
- Radian Glacier to The Portal
  - Relationship between bedrock structure and ice flow

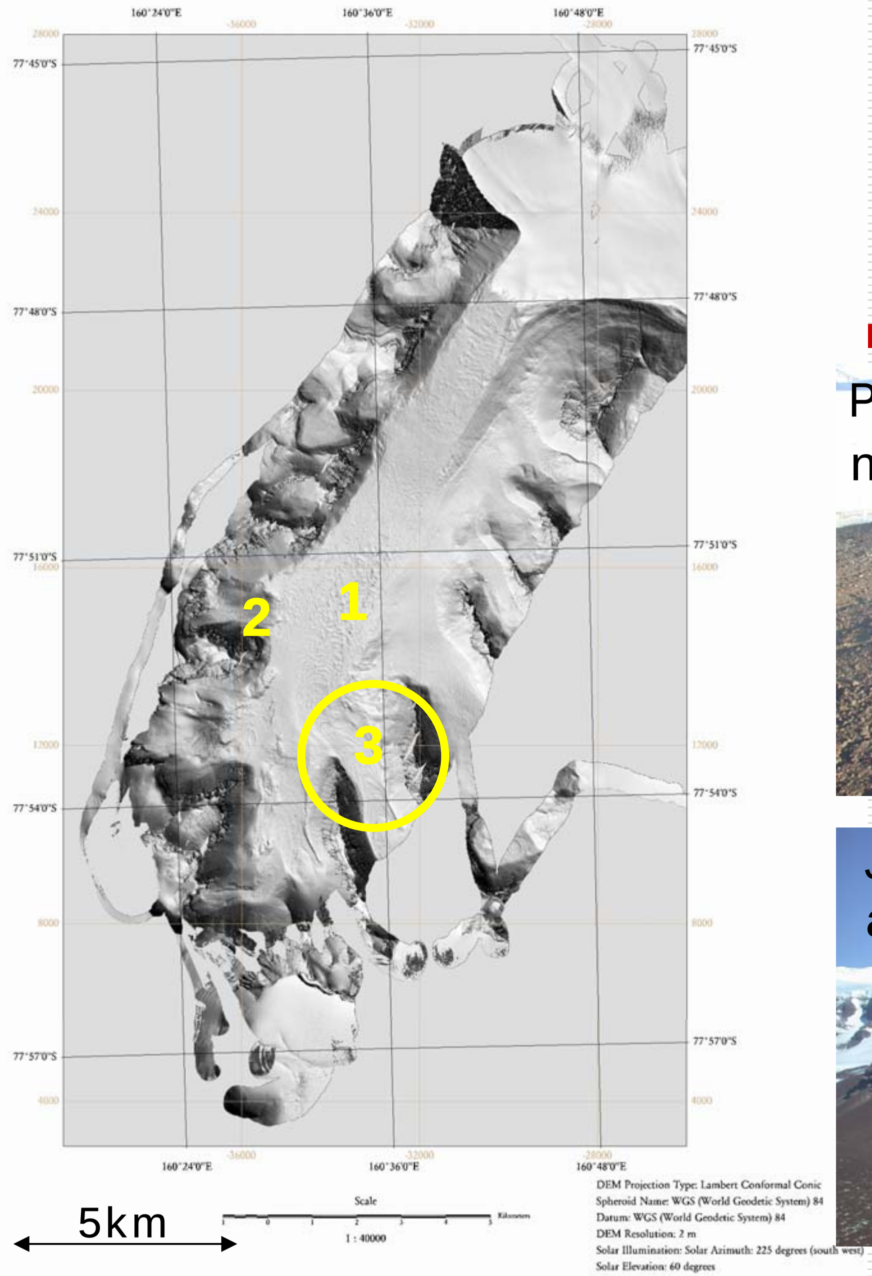
Research Interest (cont.)

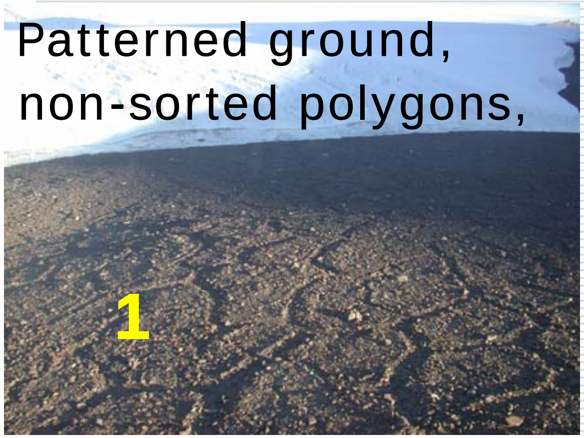
- Denton Hills
  - Fault Structure
  - Landscape Analysis
- Wilson piedmont glaciers
  - lineaments and bedrock structure
- Cape Royds
  - Pinguin rockery landscape

Target areas for testing geological and glaciological applications



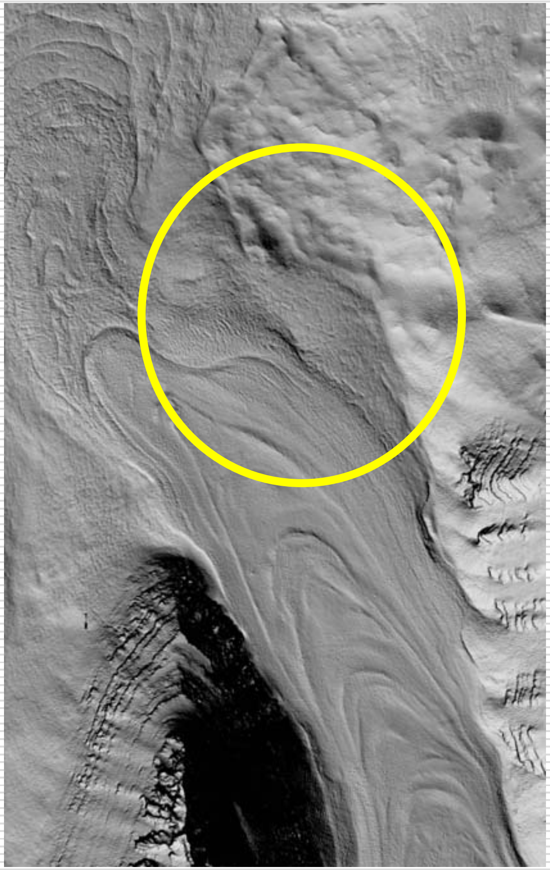
Beacon Valley





Rock glacier
surface

Closer look at the DEM



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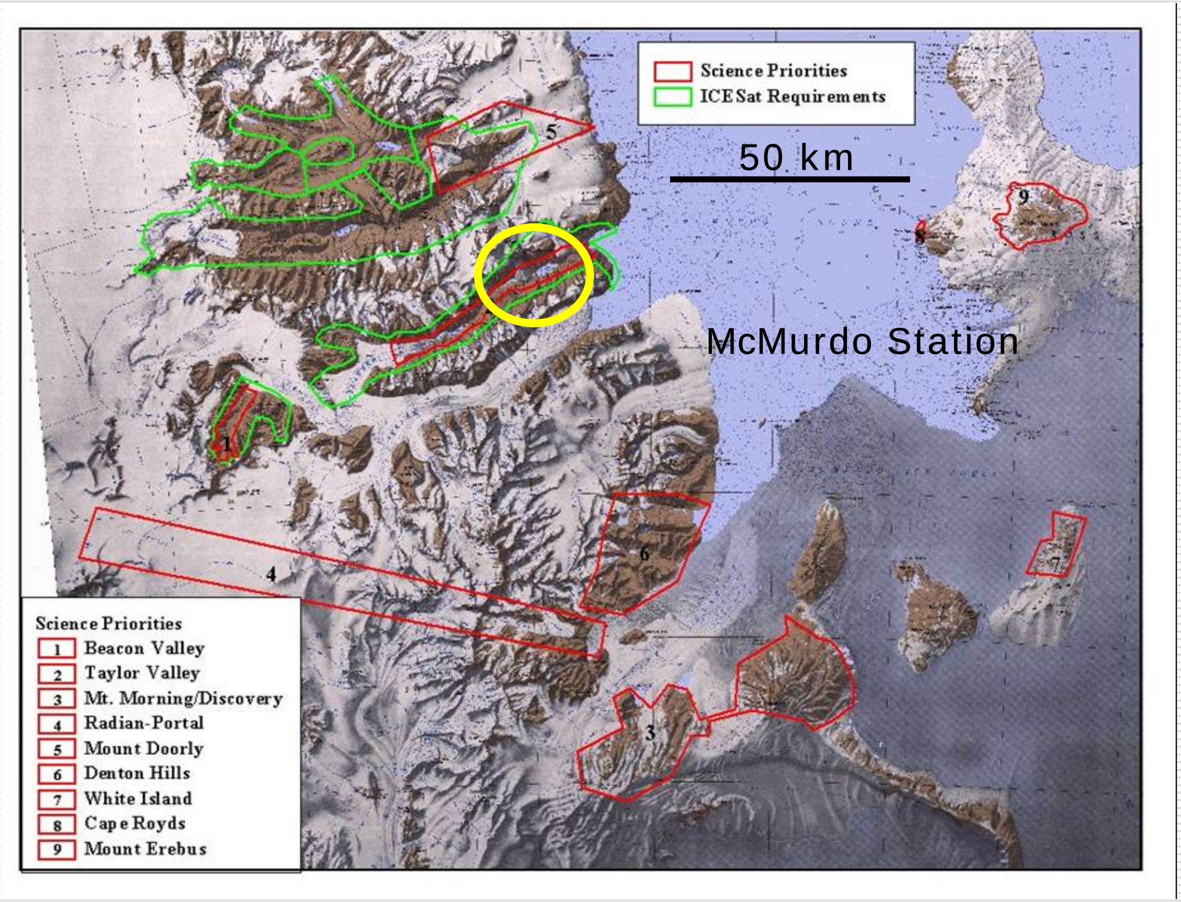
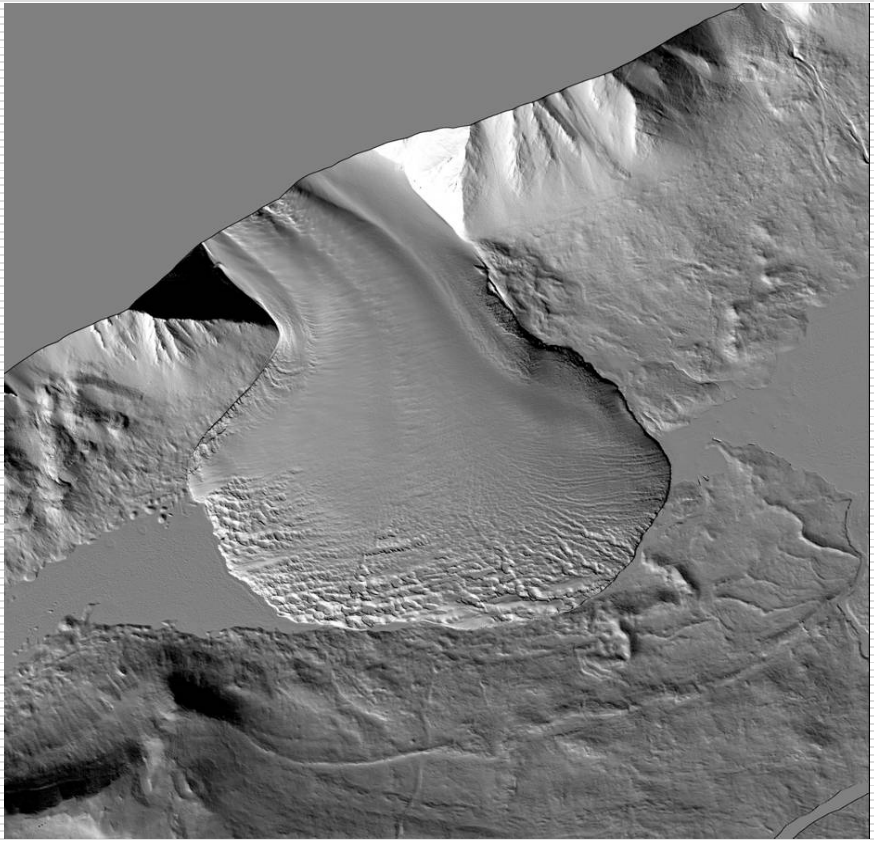
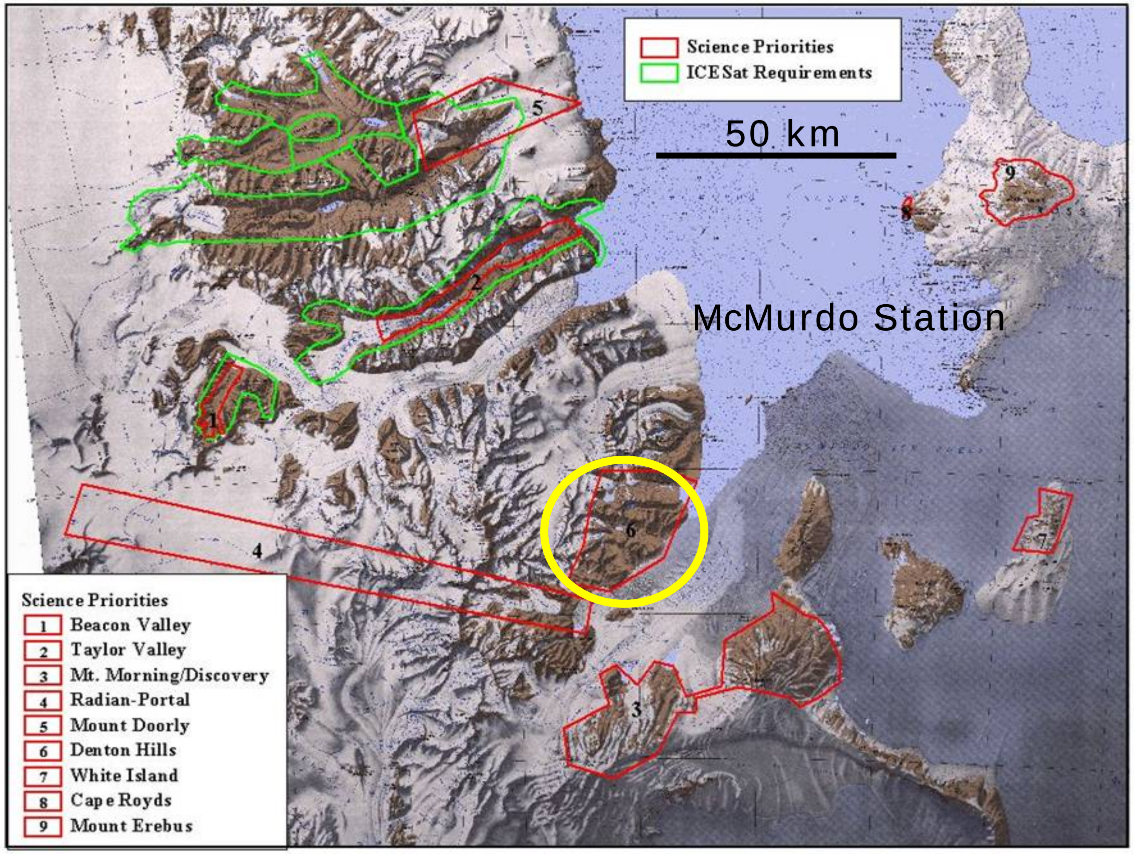


Canada glacier (Taylor Valley)



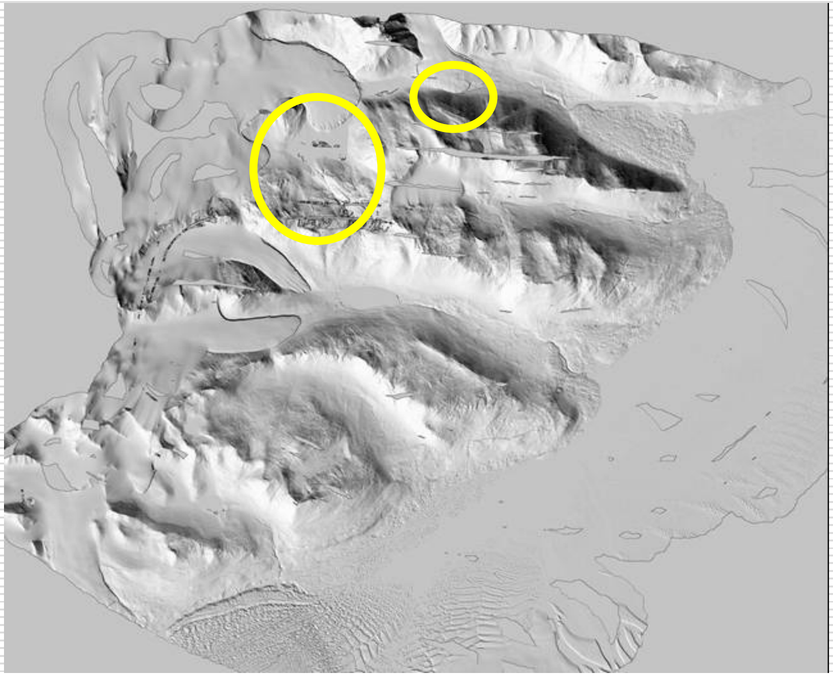
10 km

Target areas for testing geological and glaciological applications

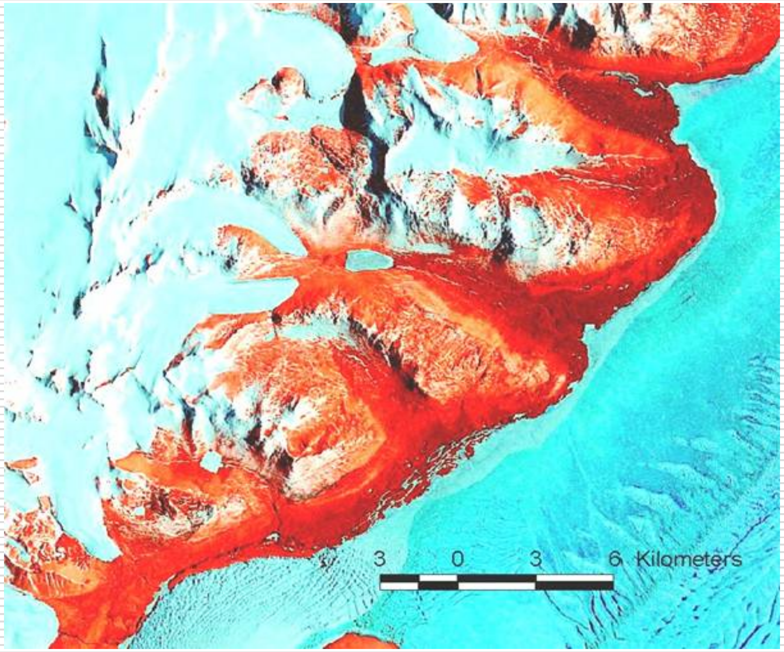


Denton Hills

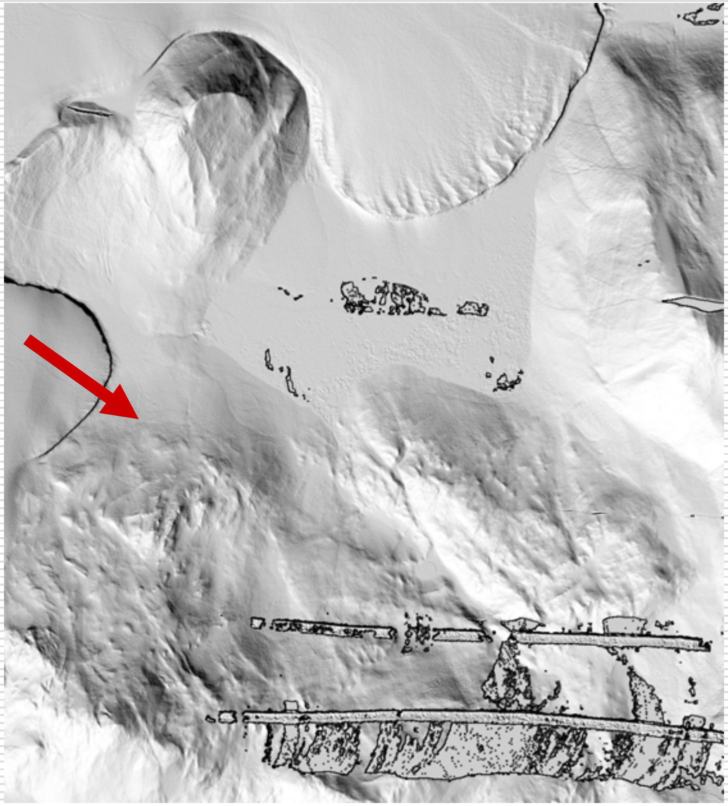
Shaded refief DEM from laser

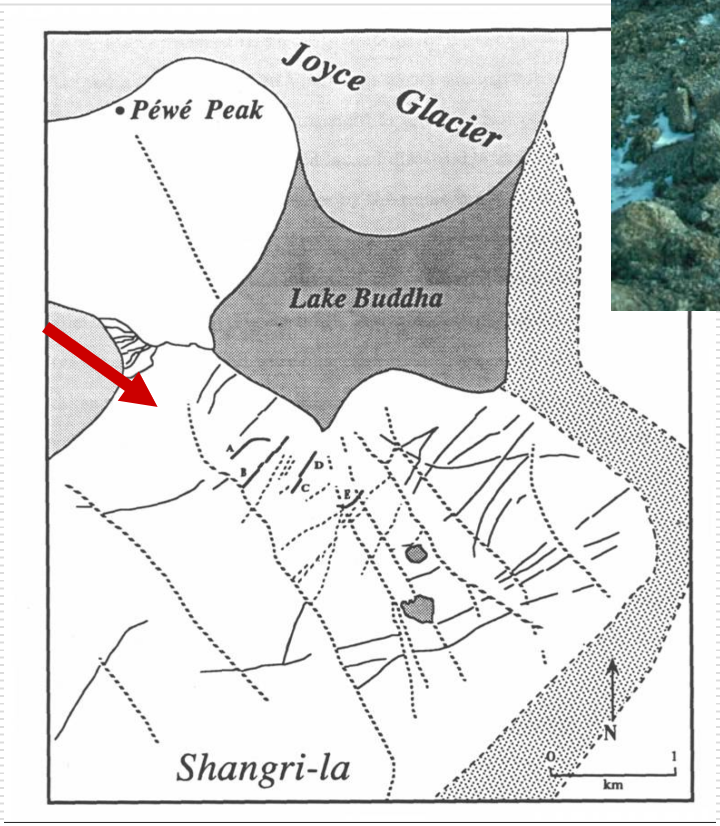


Landsat TM mosaic (USGS)

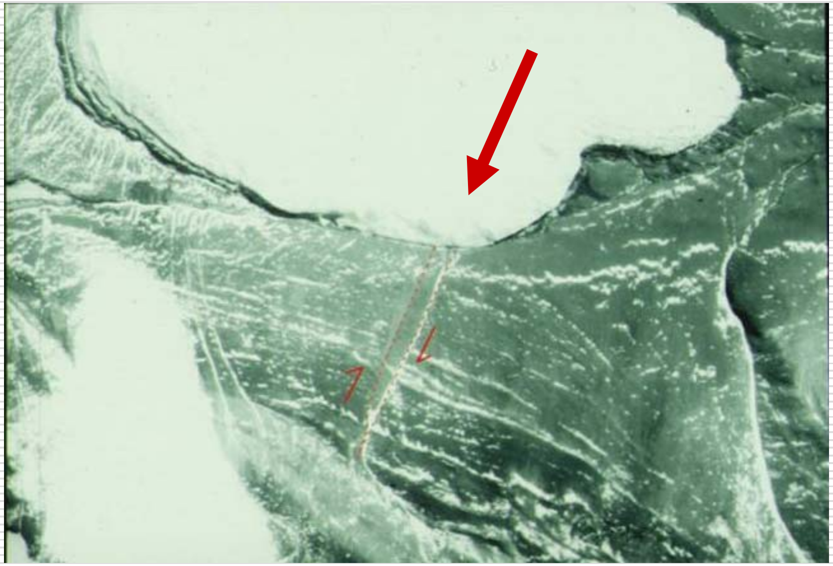


Cross-cutting fault array S of Joyce glacier

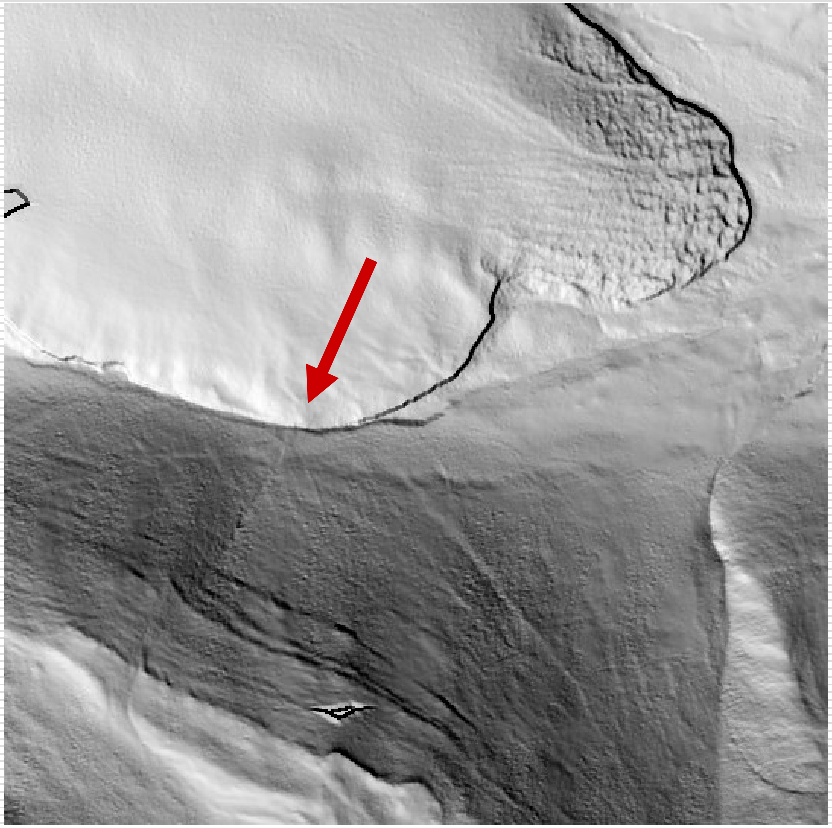




Quaternary fault, Garwood valley



from Jones, 1996



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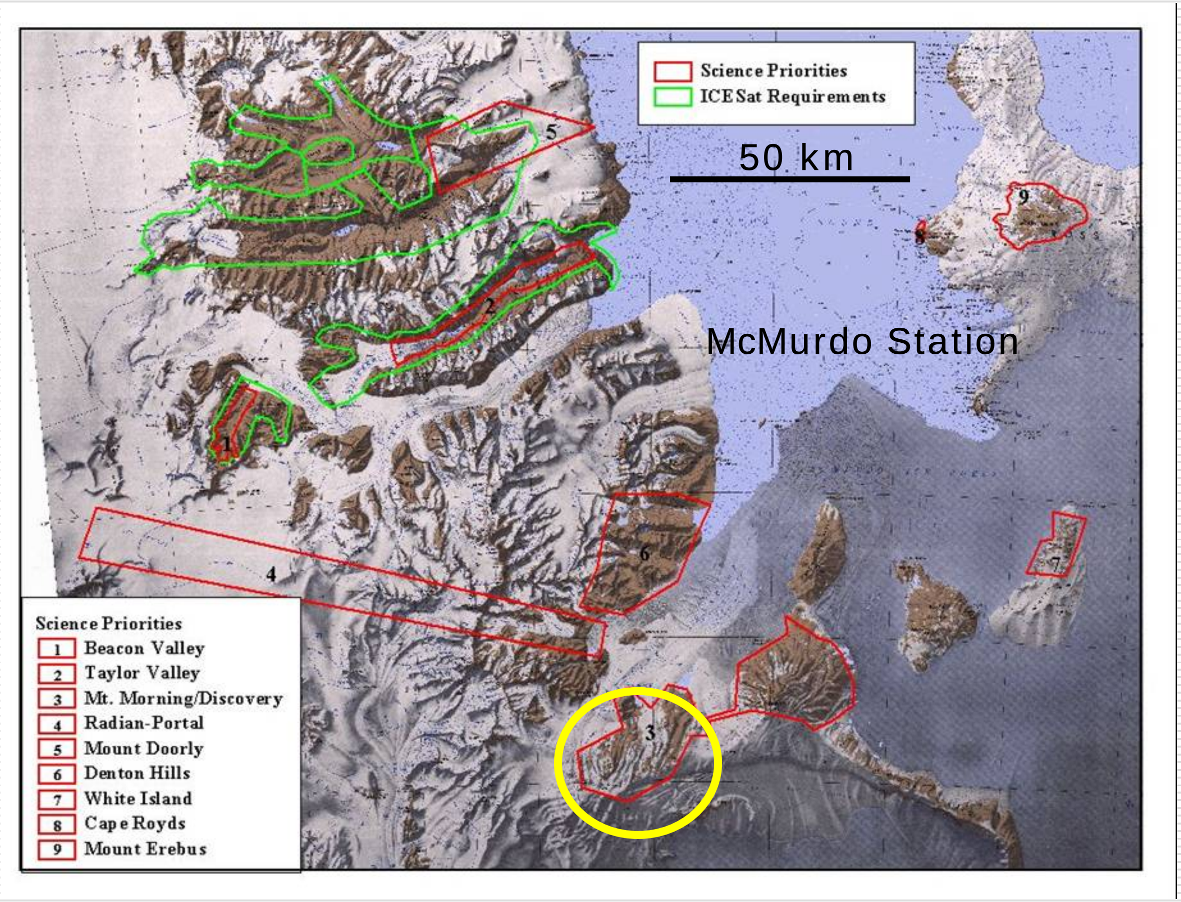
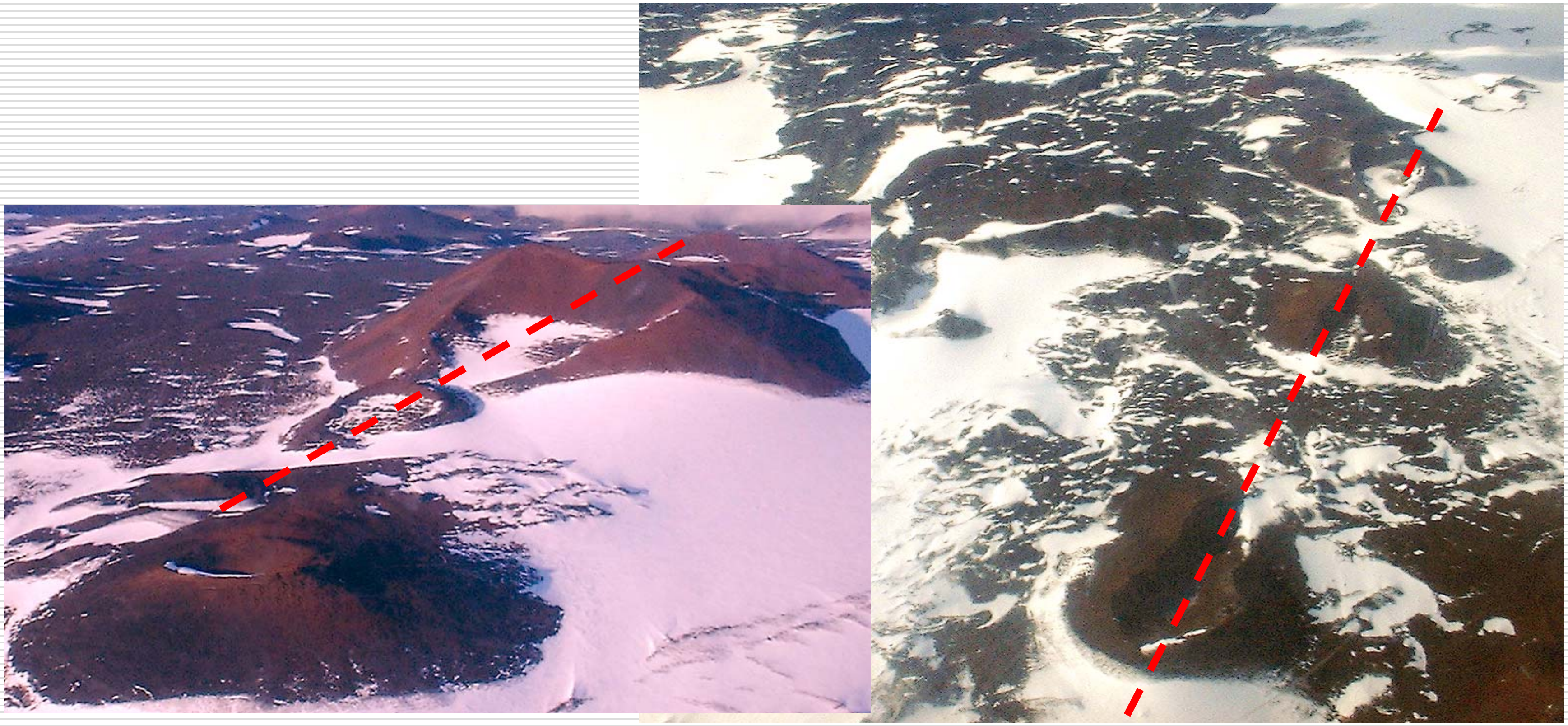


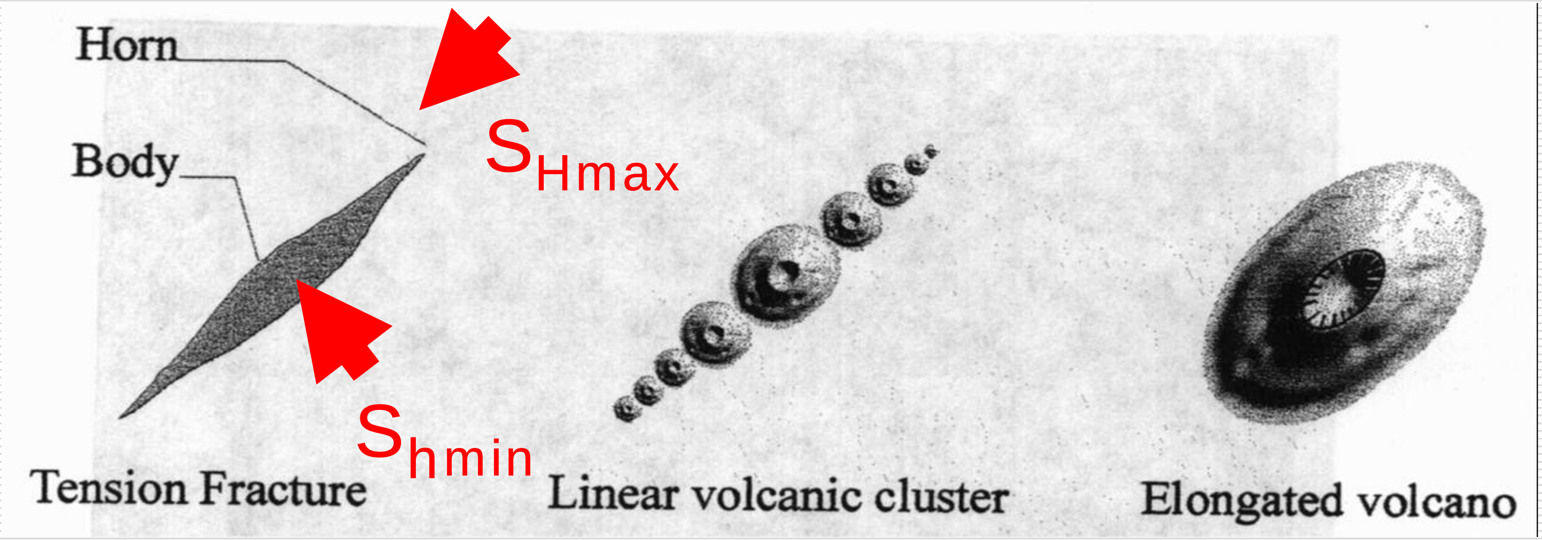
Erebus Volcanic Province

NE cone elongation and alignments



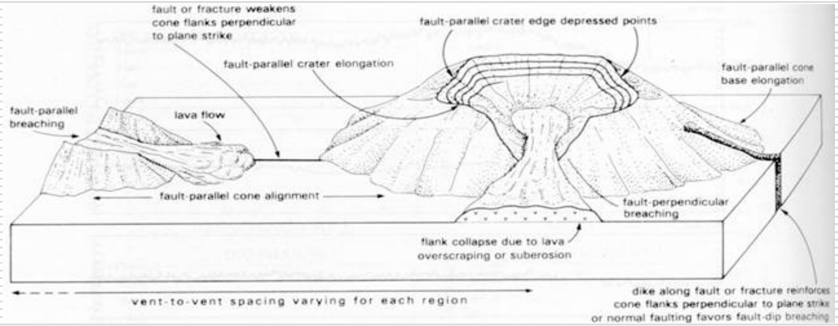
Surface signatures of volcanic fissures

Horizontal stress direction



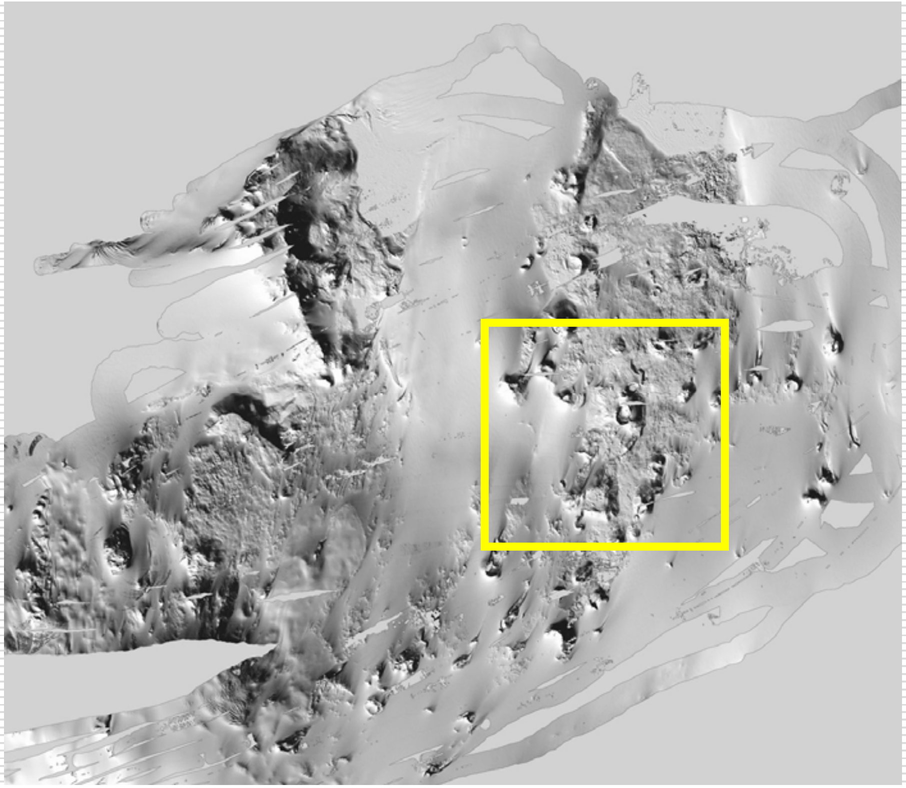
Cone morphology –
indicator of fault control

(Tibaldi, 1995)

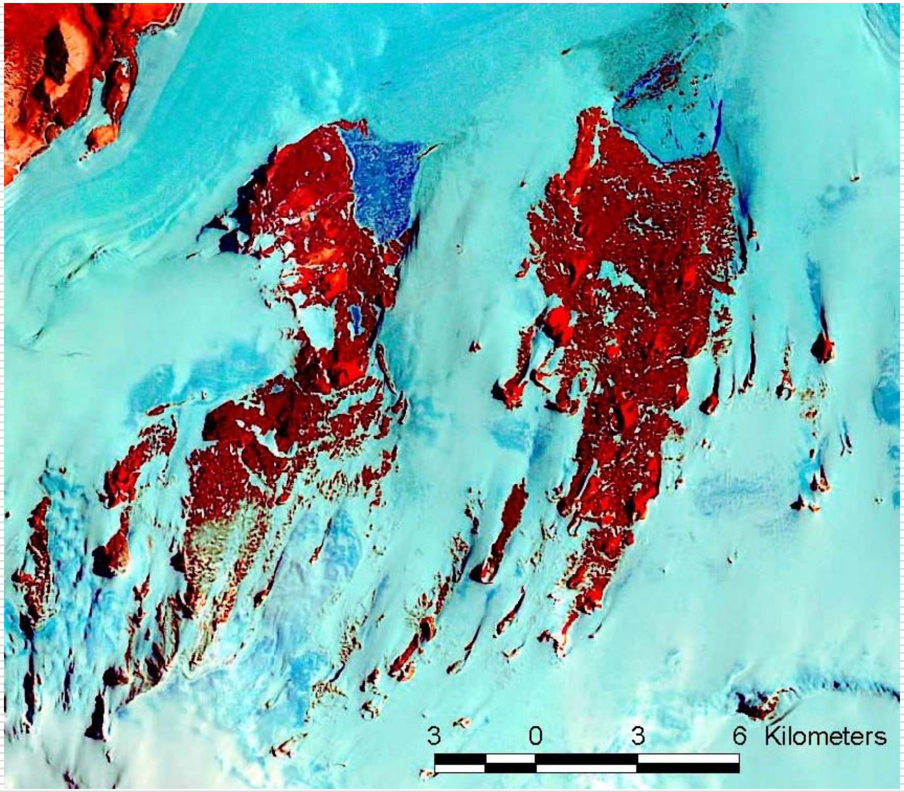


N slope of Mt. Morning

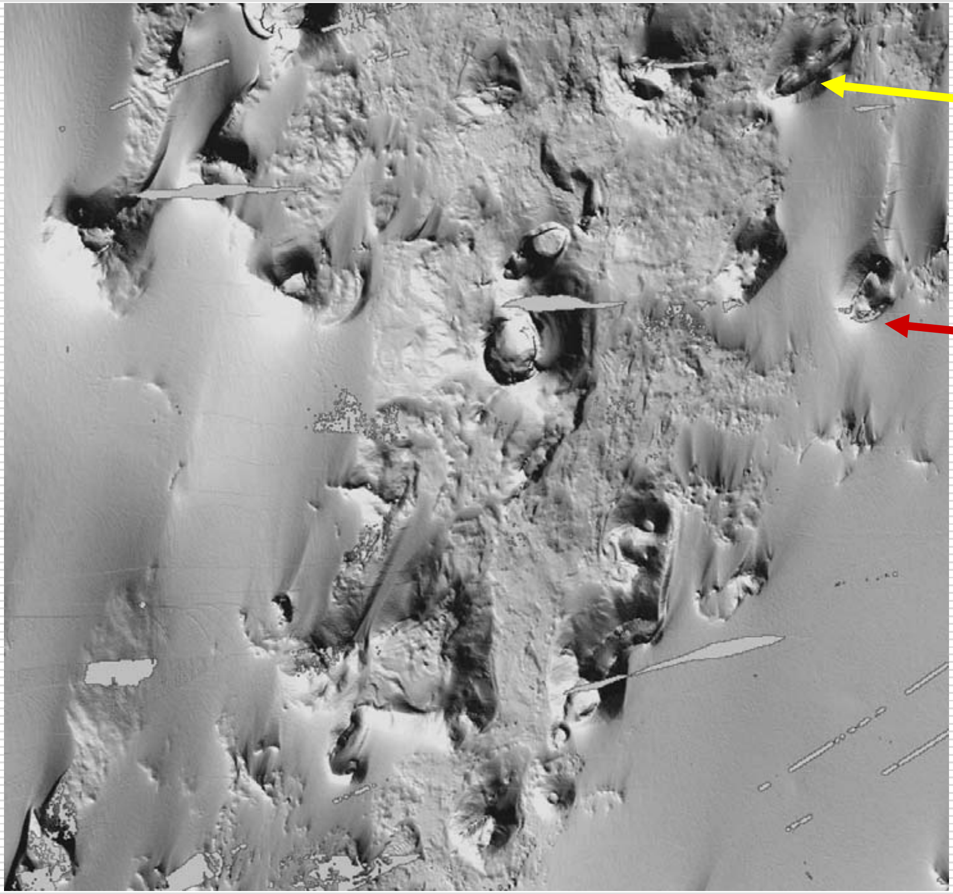
Shaded relief DEM from laser alt.



Landsat color composite



Details of cones on shaded relief DEM

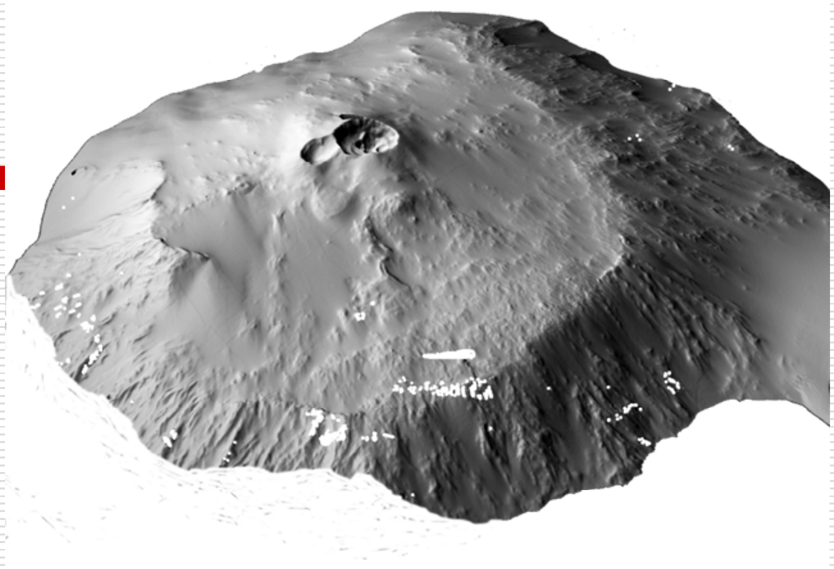


Fault parallel elongation

Linear alignment and fault parallel breaching

3 km

Mount Erebus



Conclusions

- Laser mapping provides precise and detailed surface elevations and DEMs
- It is an exciting new tool for mapping glacial, tectonic and volcanic geomorphology
- Further research is needed for further validation of the results and for developing tools for feature mapping and measurements