GeoSAR IFSAR Processing

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Outline

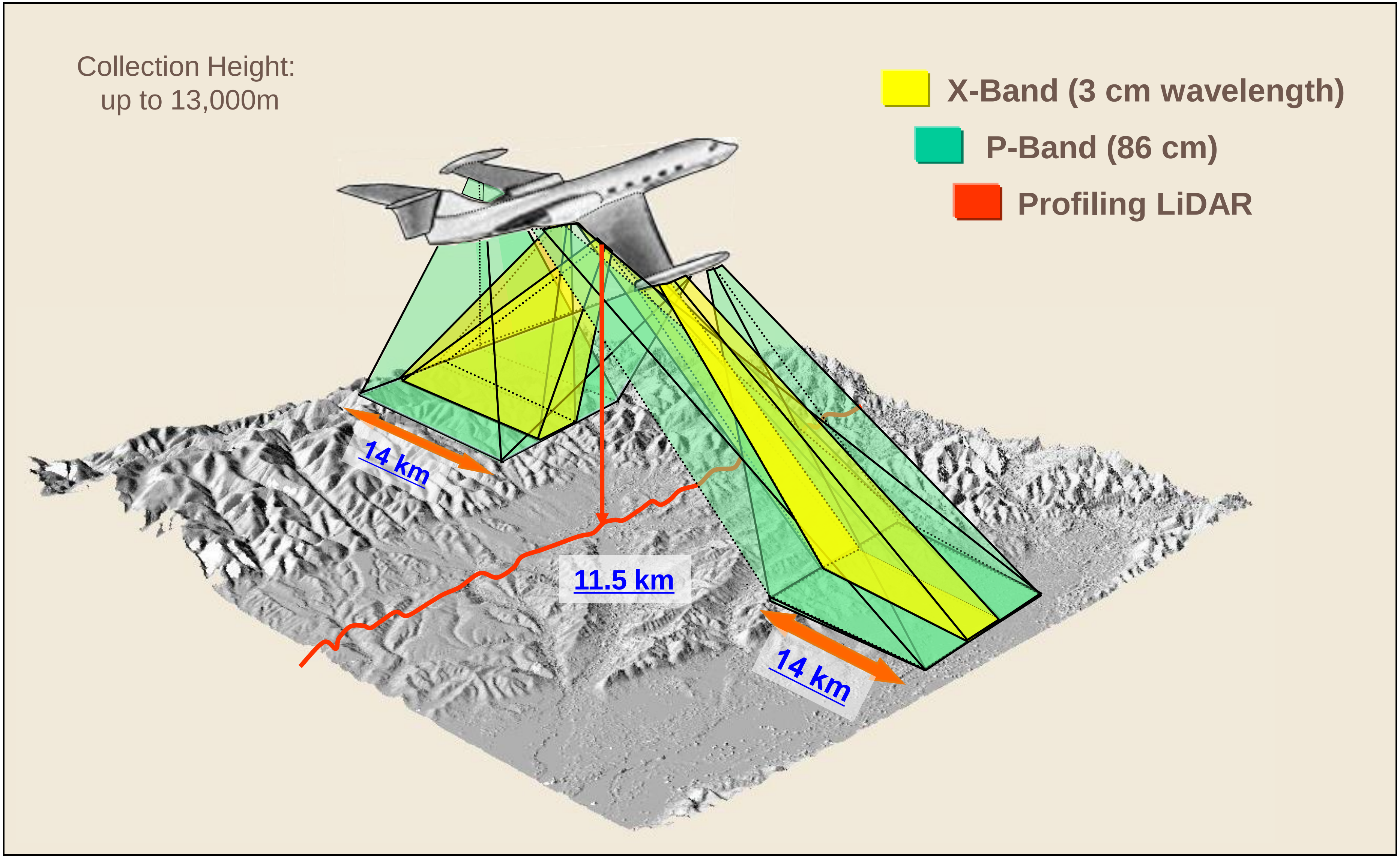
- GeoSAR Airborne Mapping Radar
- Alaska Statewide Mapping Project
- Positional Accuracy Assessment with LiDAR
- Search and Rescue Application
- P-Band folpen and icepen
- Conclusions

GeoSAR System Overview

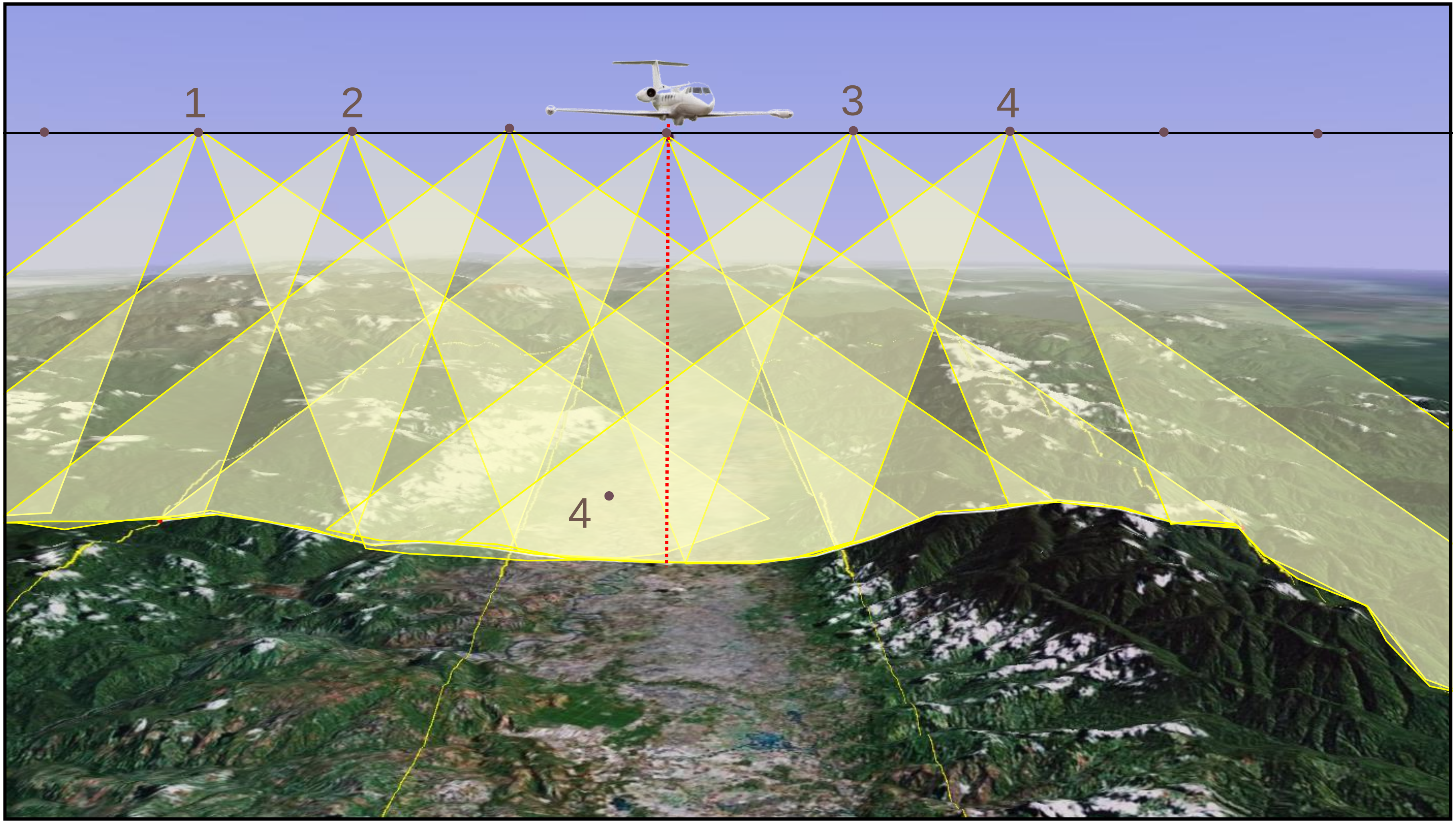
- Airborne Radar Gulfstream-II @40kft (~12 km)
- Single-Pass Interferometry
- Dual-Band (P + X)
- Dual-Sided (L + R)
- Dual-Baseline (SAT + PP)
- Quad-Pol (P)
- Profiling LiDAR

Fairbanks Airport, July 2010

GeoSAR Measurements Systems



Acquisition Redundancy Improves Data Quality



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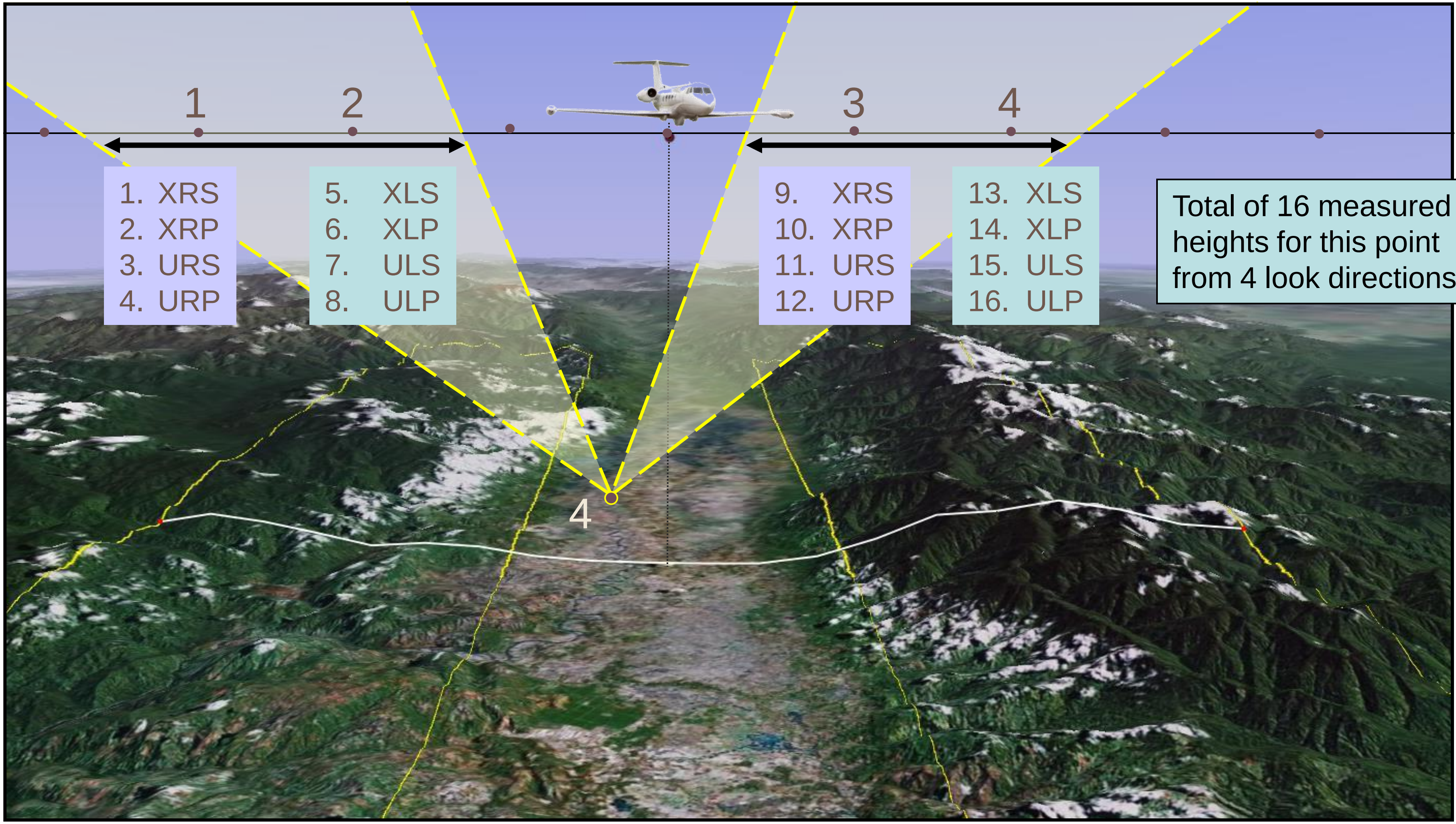
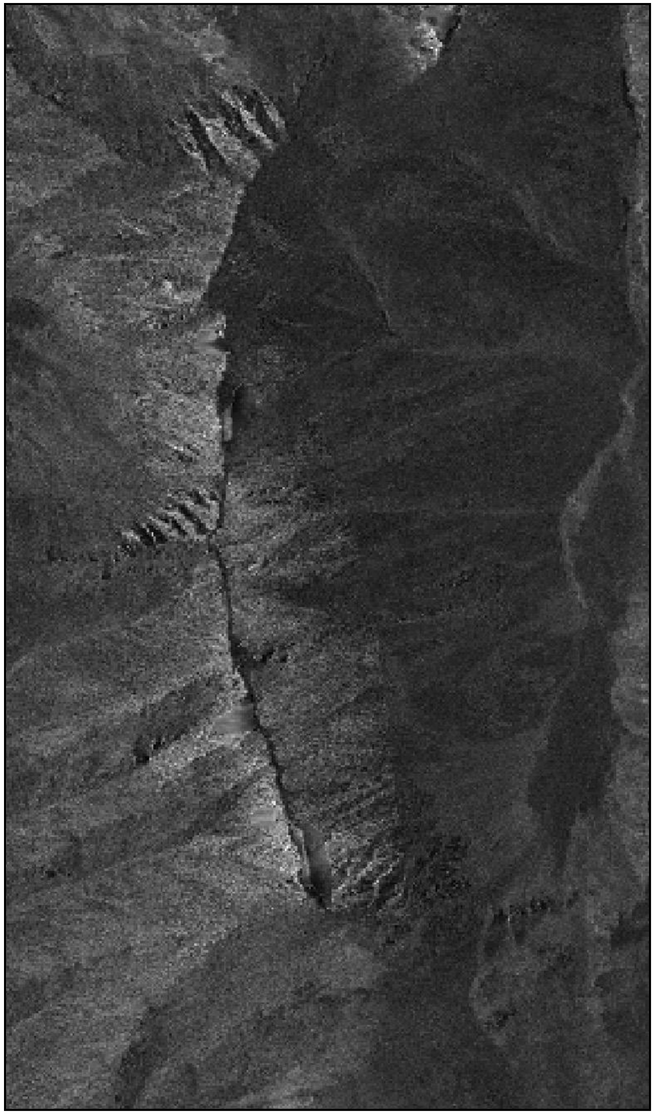
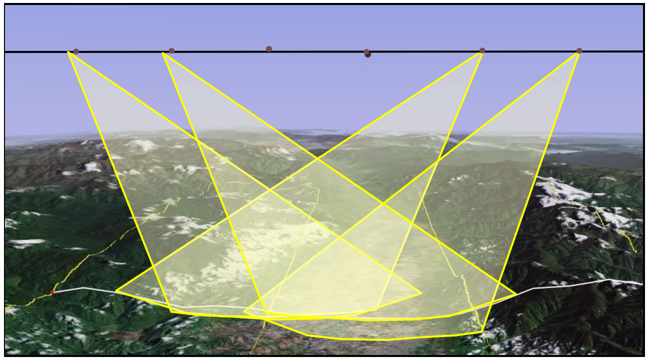


Orthorectified Radar Imagery





- East+West Views Average

Optimal Imagery Question

- Lively debate on what is best
  - 5m, 2.5m, 1.25m?
  - Single look direction/ All look average?
  - Zoomed out 3D “optical” perspective? Maximum intelligence value?
  - 8bit histogram scaling parameters?
- End-user feedback panel organized with the help of Tom Heinrichs (UAF/GINA) and Anne Johnson (DNR) to optimize value for the users.
  - Urban areas/ rural/ mountainous

GeoSAR Accuracy, Precision and Reliability

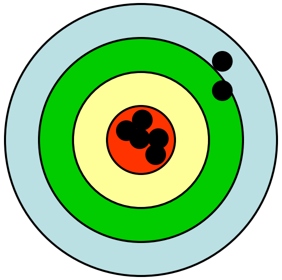
- **Accuracy (absolute location)**
  - Calibration
  - P-Band Measurements through Vegetation
  - LiDAR Ground Control

High accuracy, low precision

- **Precision (relative error)**
  - Airborne Interferometry
  - Multiple-Look Average

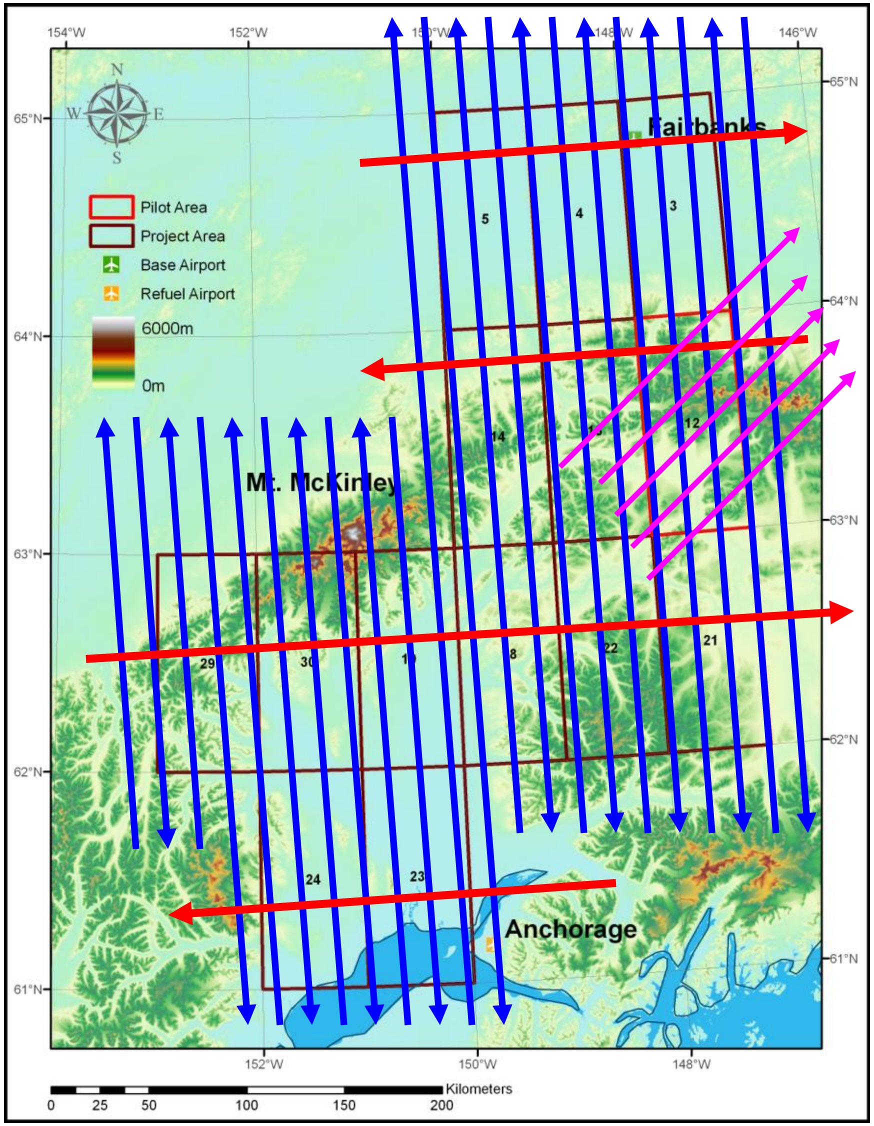
High accuracy, high precision

- **Reliability (the ability to correct errors)**
  - Redundantly Recorded Radar Data allows 16 Height Estimations for each Pixel
  - Dual-Sided Coverage



Ability to Detect Outliers

Project Overview



- Alaska Statewide Digital Mapping Initiative (SDMI)
- Main funding USGS/ NGA through Dewberry as prime contractor
- Fugro GeoSAR Project Area consists of 14 $1^o x 1^o$ cells between Fairbanks, Mt. McKinley (Denali; 6149m) and Anchorage
- Data collected in late July 2010

- North-South Mapping Lines
- East-West Cross-Ties (Mosaick)
- Filler Lines to deal with Shadow and Layover based on ray-tracing

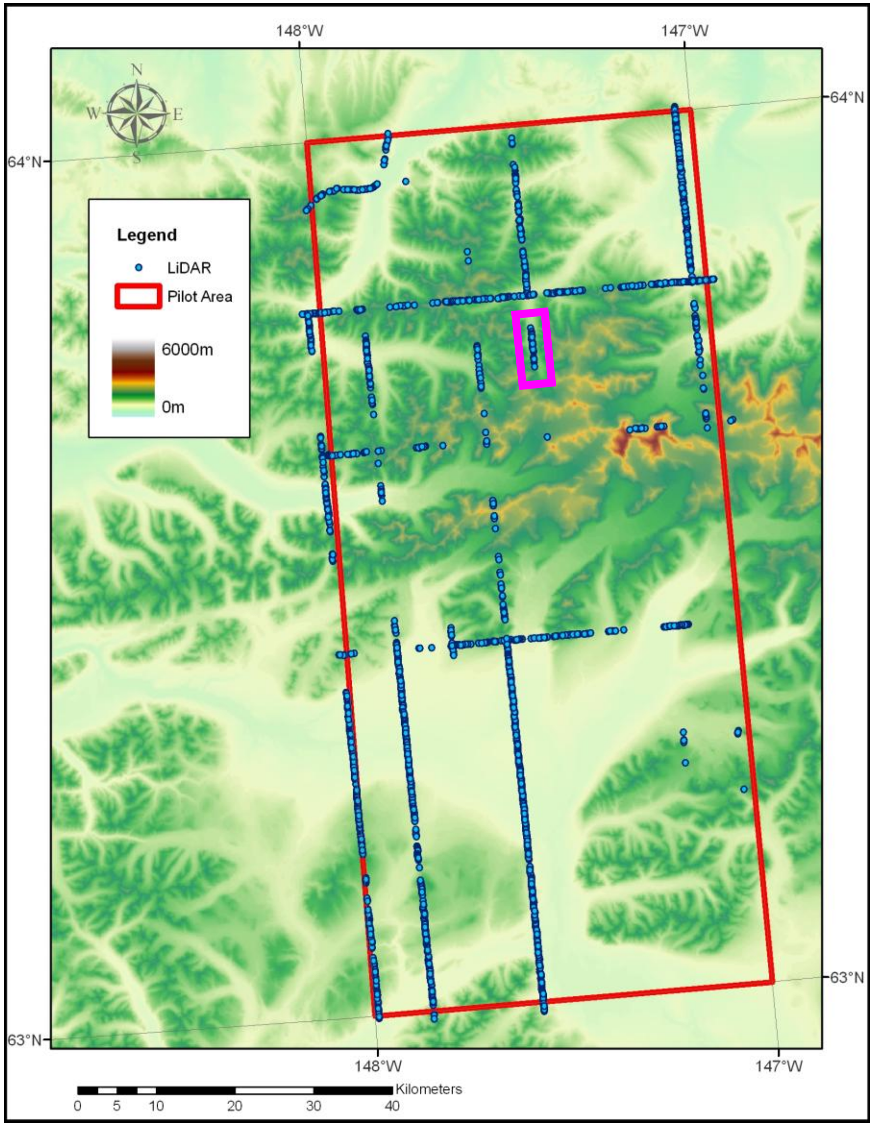
Extremely Varying Terrain Type

Project Deliverables

Product	Description	GeoSAR Observations
DTM	▪ Digital Terrain Model ▪ Vegetation and Buildings Removed ▪ Hydrologically Enforced	▪ P-band & X-band Interferometry ▪ Multiple Looks
DSM	▪ Digital Surface Model ▪ Hydrologically Enforced	▪ X-band Interferometry ▪ Multiple Looks
ORI	▪ Orthorectified Radar Magnitude ▪ Multiple view directions average	▪ X-band* ▪ Multiple Looks
Masks	▪ Quality Masks ▪ Hydrology, Voids, Fills, Slopes	▪ P-band & X-band
Metadata	▪ Meta Information	▪ FDGC compliant

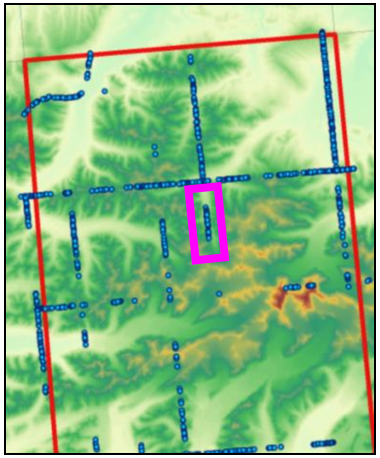
**Hi-Res MAG, hydro; P-band MAG, and cross-pol MAG are not a deliverable.*

Fugro Internal Quality Assessment

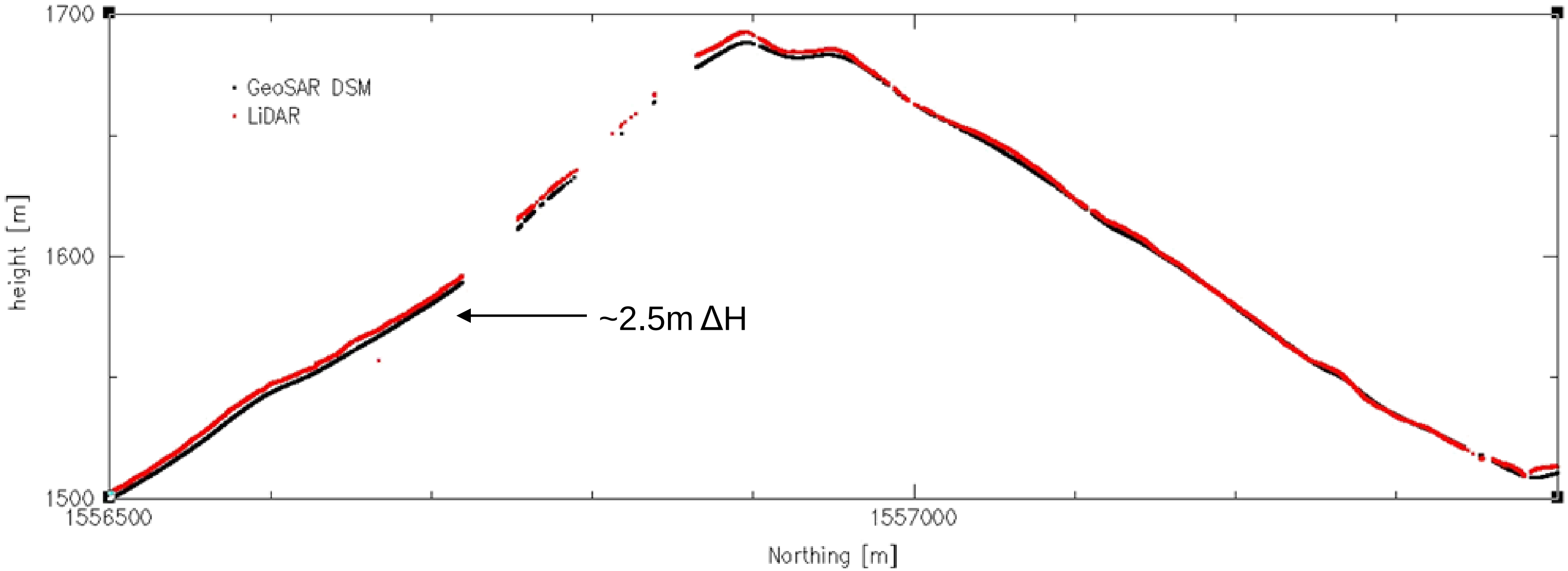


- GeoSAR is equipped with a profiling LiDAR, providing vertical ground control
- 12,628,042 usable LiDAR observations in the Pilot Area, after removing points with heights above the maximum elevation in the Pilot Area (cloud returns)
- LiDAR points were sub-sampled by a factor 200 to have ~5m spacing between points and filtered for water body returns

LiDAR Profile Comparison



- Terrain slope ~25°
- Terrain slopes located correctly in GeoSAR DEM
- Differences ~0-4m at the peak



DTM vs. LiDAR Statistics (not culled)

Slope	$0^o – 10^o$	$10^o – 20^o$	$20^o – 30^o$	30^o+	Overall
Number of Points	32,184	10,358	3,856	2,035	**48,433**
Average (m)	0.08	0.88	1.23	1.20	**0.40**
Standard Deviation (m)	1.11	1.55	1.79	3.12	**1.49**
Minimum difference (m)	-8.01	-17.13	-7.27	-52.60	**-52.88**
Maximum difference (m)	16.87	11.65	16.18	25.05	**25.05**
RMSE (m)	1.11	1.78	2.17	3.44	**1.54**
LE90 (m)	**1.80**	**2.89**	**3.52**	**5.58**	**2.50**
Spec (LE90)	**3.00**	**6.00**	**9.00**	**12.00**	**n/a**

***Note**: For product generation LiDAR points are automatically selected that are believed to be in flat and open, bare-earth, areas (using the terrain slope and 3 LiDAR returns). ~350 points that fulfilled these thresholds were used to determine a single z-bump of the DEM to best fit the average LiDAR elevation at these points.

Search and Rescue

- Following 11 slides copied with permission from:
  - Dave Maune, Dewberry, as presented during the Alaska Surveying and Mapping Conference, Anchorage, AK, Feb. 24, 2011.

- http://www.alaskamapped.org/asmc/2011/Dewberry-Maune-Alaska_Conference_2_24_2011.pptx

What if an F-22 crashes in Alaska?

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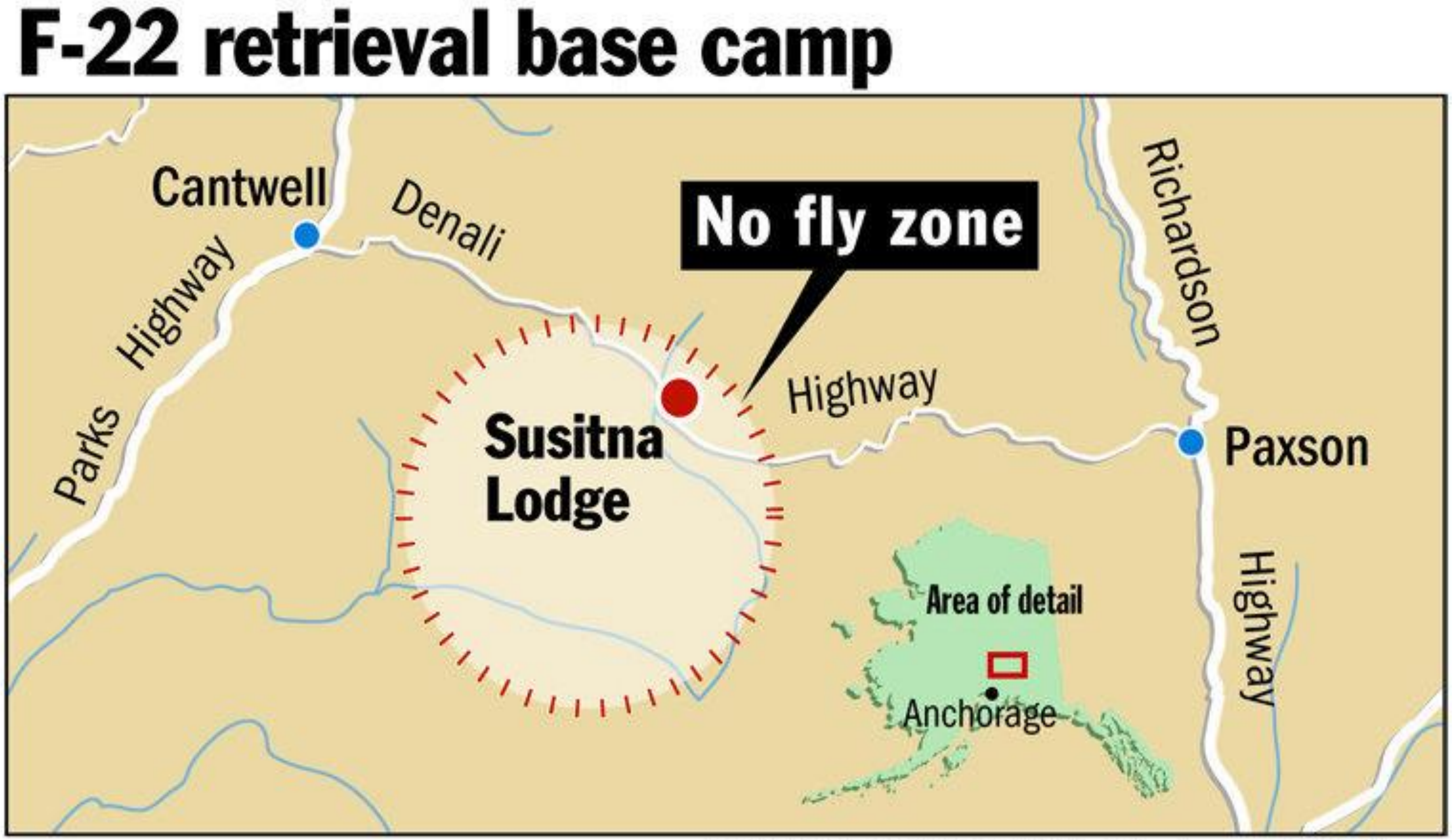
F-22 Crash, Nov 16, 2010

- $150M F-22 from Elmendorf AFB crashed; pilot killed
- Rugged terrain, 15 miles southwest of Denali Highway
- Rescue teams established base at closed-down wilderness lodge, 60 miles east of Cantwell, the nearest town
- Crash site on State selected federal land managed by BLM
- Crash site is underwater and located adjacent to a creek
- Environmentally sensitive due to composite material of the F-22 (considered HAZMAT upon breakup)
- Winter snow and runoff could expose other hazardous parts that contain highly pressurized gasses or dangerous flammable components

F-22 Recovery



PAMELA DUNLAP-SHOHL / Anchorage Daily News

Weather/Terrain Challenges for Recovery

- Search and rescue operations until Saturday Nov 20th at which point it became a recovery operation
- USAF: 3rd Wing, 673d Air Base Wing
- USA: Alaska's 3rd Maneuver Enhancement Brigade
- Joint Army-Air Force Tactical Operations Center
- 6th Engineer Battalion provided logistical and mobility support for recovery operations; LTC Hoffmeister said: "Weather and terrain were particularly challenging, and presented extreme mobility challenges for our vehicles and soldiers."
- Heavy snow and snow storms in steep mountain terrain raised avalanche concerns, especially with Blackhawk and Chinook helicopters with increased rotor wash and sound.

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Elevation Data Needed -- Quickly Provided

- Existing USGS NED was insufficient to aid in identification of ground safety hazards, establishment of landing zones and slope analysis for potential avalanche zones
- Errors >90 meters were identified in the NED
- Current imagery was not available; sun elevations at this latitude limited commercial imagery collection until late February
- On 11/30/10, USGS asked Dewberry if we could help
- Determined crash site on Fugro's cell #21 which delivered "as is" IFSAR data to Dewberry
- Dewberry FedEx'd "as is" IFSAR DTM, DSM and ORI to Mike Davis at Elmendorf AFB on 12/02/10.

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Uses of IFSAR Data

- Accurate base elevations for 3D modeling and visualization of the surrounding crash site
- Analysts added and eliminated LZ's previously identified
- Detailed terrain analysis with increased reliability over NED
- Creation of secondary products:
  - Establishment of avalanche safety zones
  - Ingress/egress route planning
- Line of communications analysis, radio repeater deployment
- Will support springtime fieldwork and remediation efforts, orthorectification, hazards mitigation, development of field survey strategy; tundra will be damp, wet or muddy
- IFSAR data will play a vital role if need arises to build a road into the site or a base camp for further cleanup

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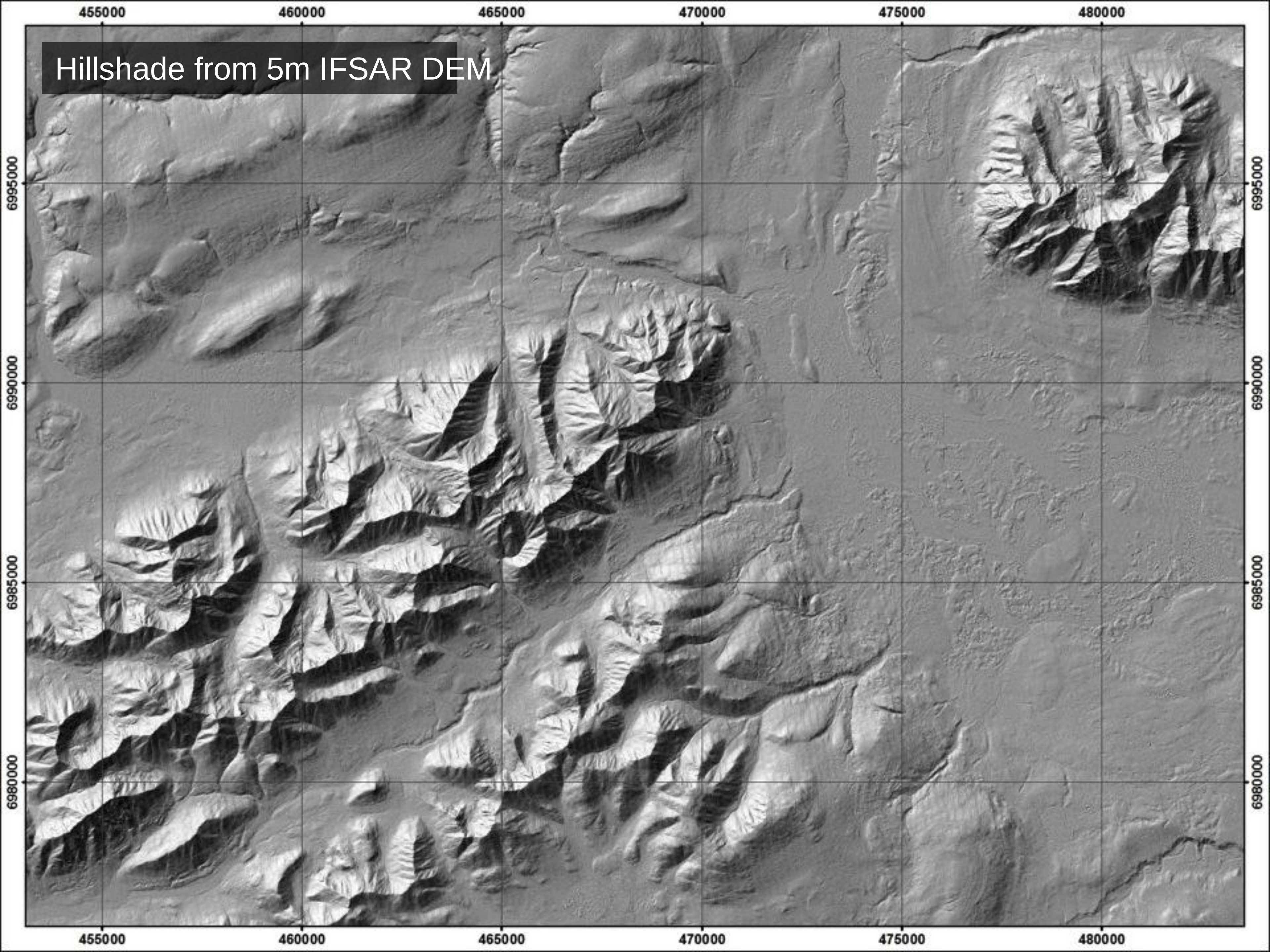
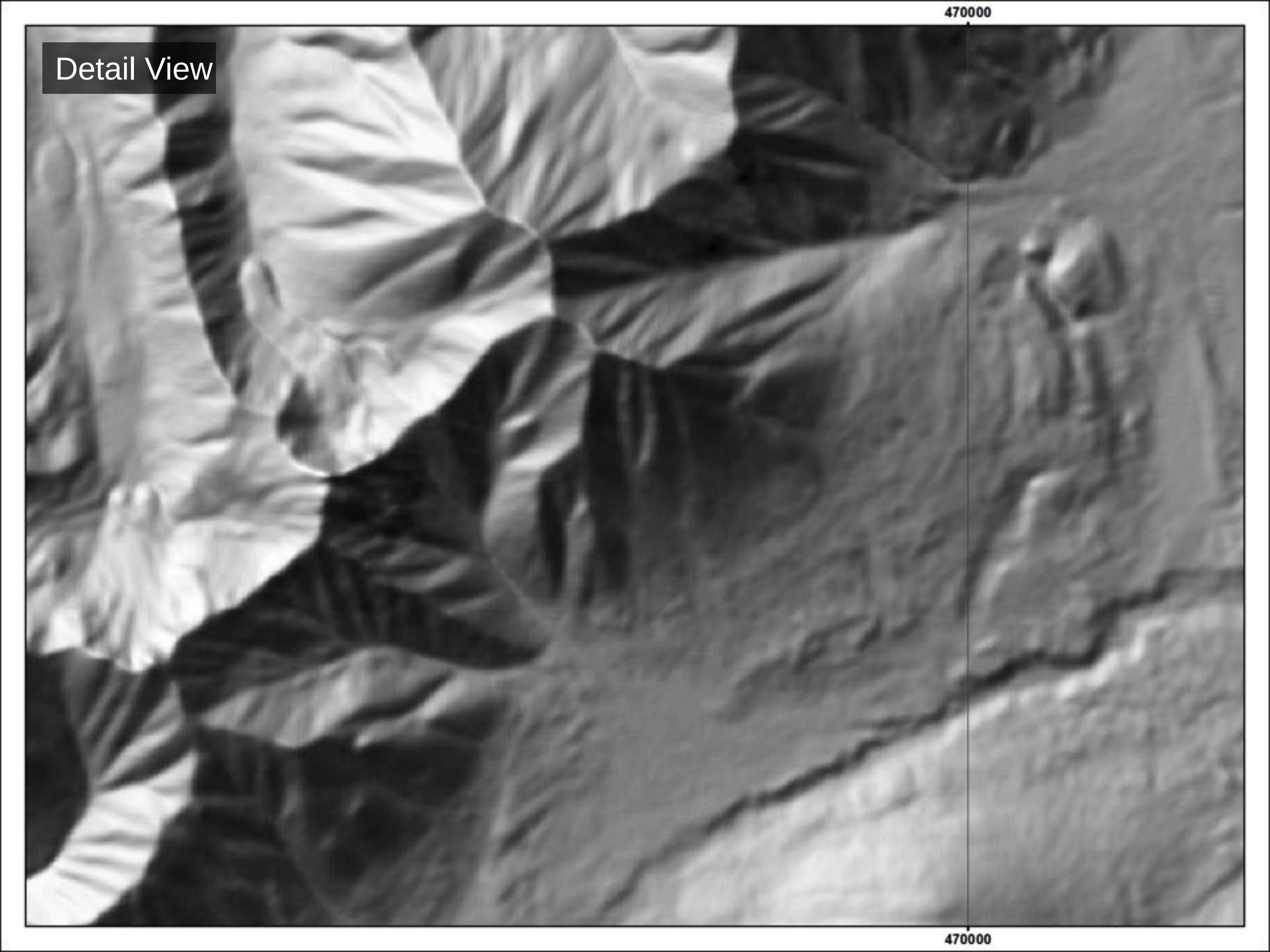
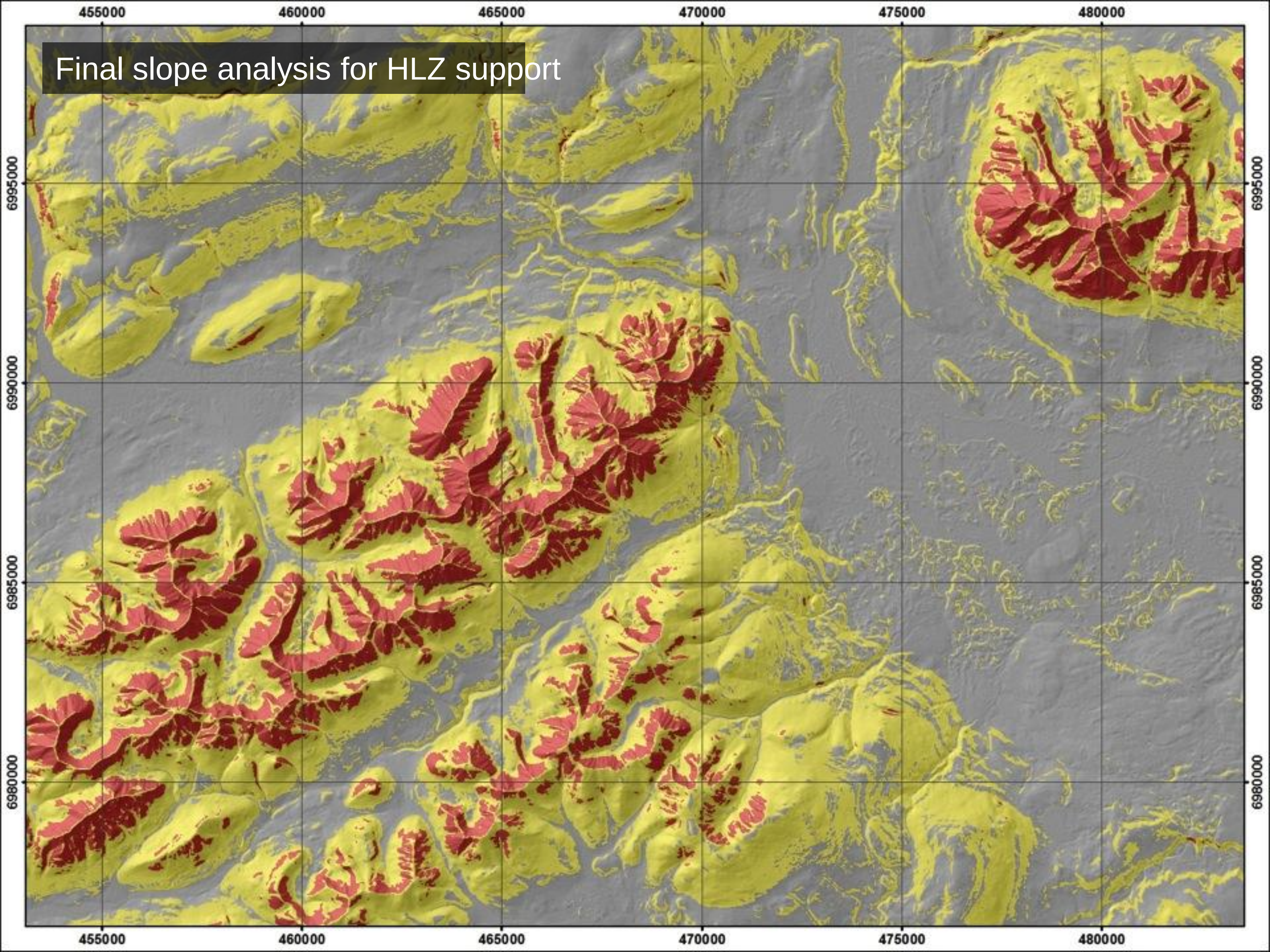

Hillshade from 5m IFSAR DEM
455000
460000
465000
470000
475000
480000
6995000
6990000
6985000
6980000


470000
Detail View
470000


Final slope analysis for HLZ support
455000
460000
465000
470000
475000
480000
6995000
6990000
6985000
6980000

Images of News Story

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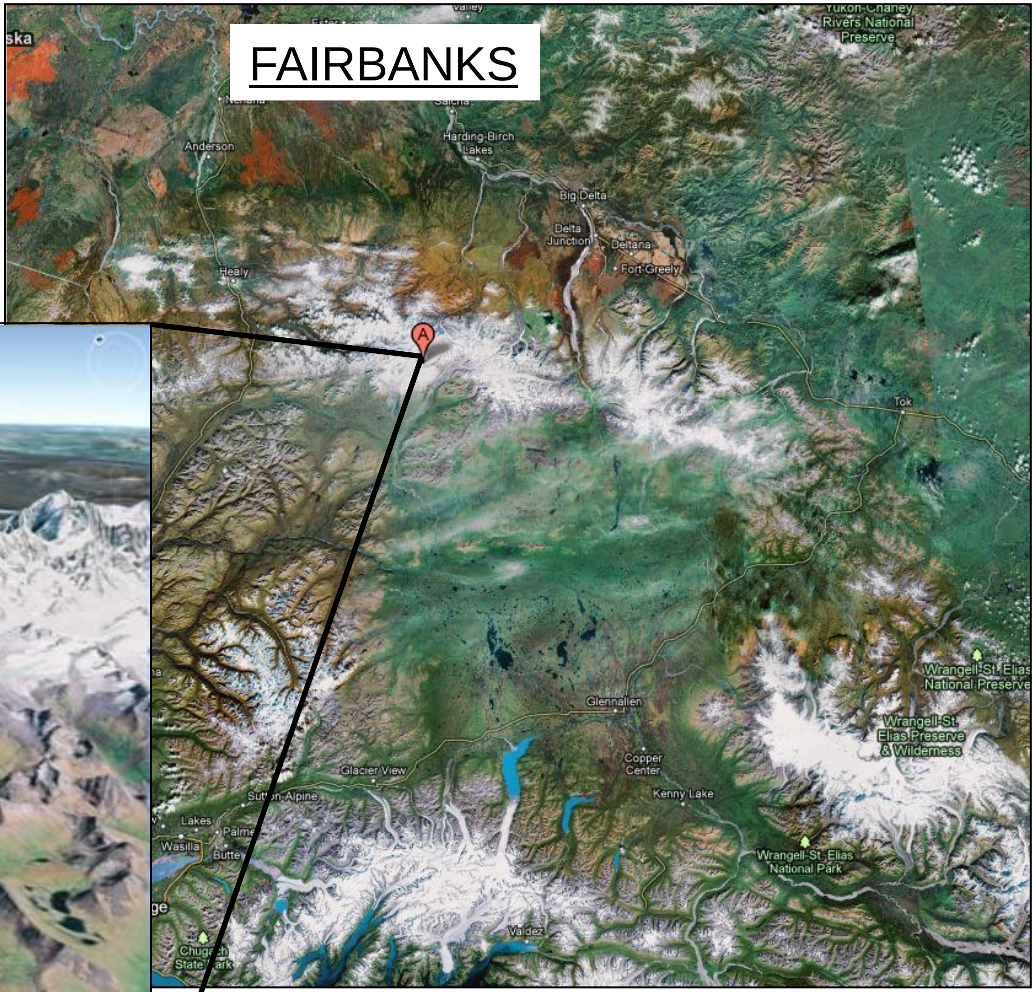
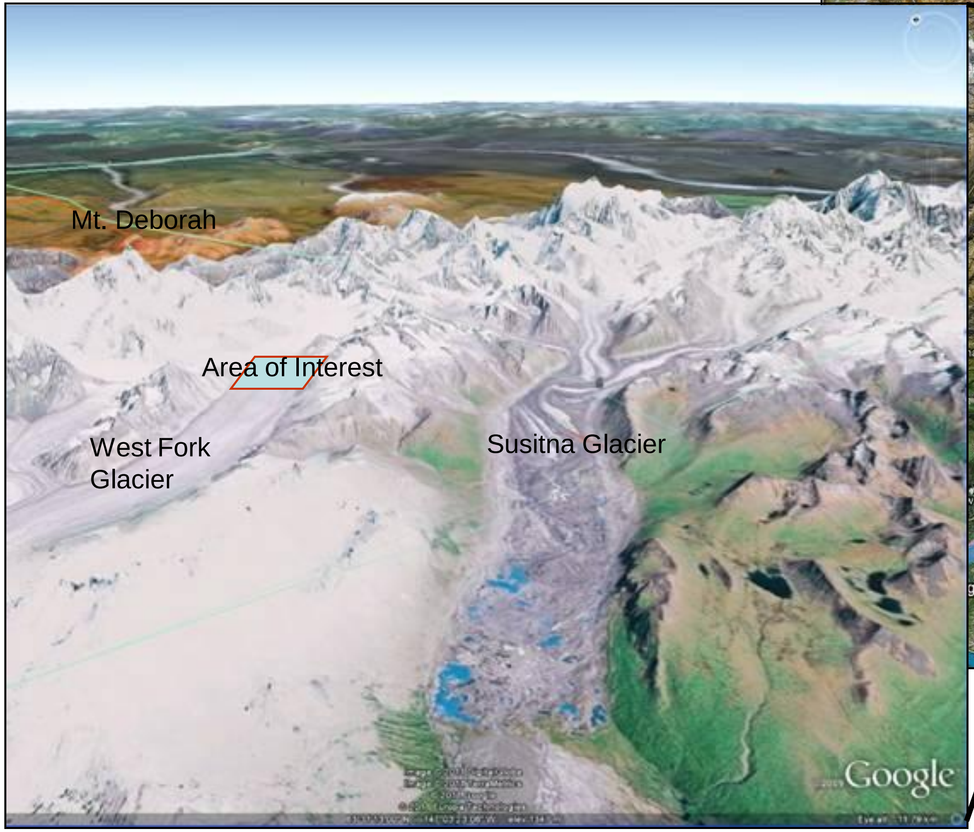
F22 SAR Summary

- One man and one $150M plane crashed in a remote location.
- >100 people involved; could have potentially put more people into harms way had the IFSAR DEM not been available.
- Human lives are valued at >$1M each; if we put XX people into a valley with unsafe condition without the proper DEM analysis we could potentially have lost lives valued at much more than the cost of IFSAR statewide.
- What is the real value of IFSAR data in Alaska?
- The F-22 incident occurred within the 10% of the state in which DEM data was collected in 2010. Like Katmai, what do we do the next time where accurate DEM data not available?
- DEMs are needed for much more than just traditional applications, DEMs could save lives

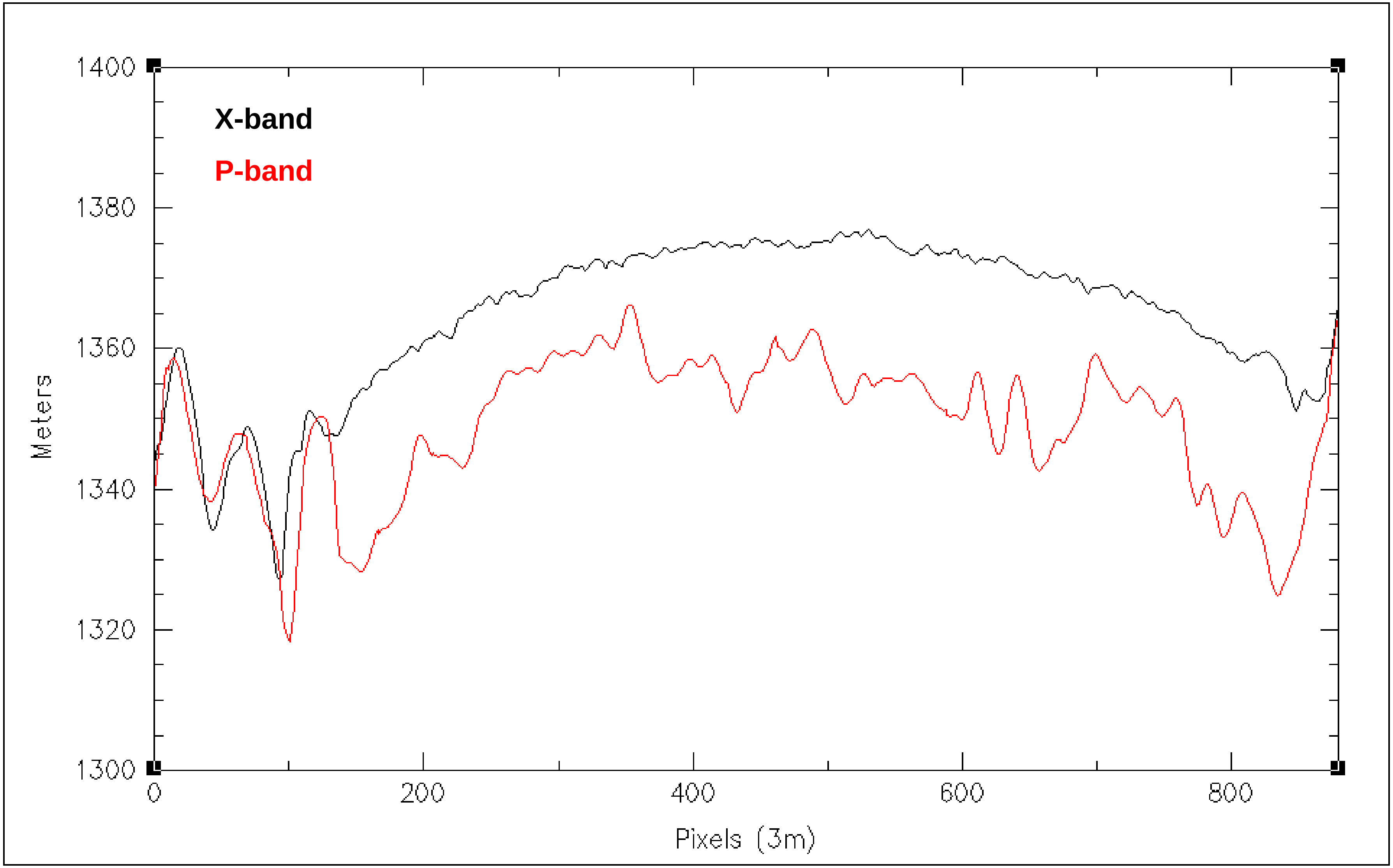
P-band Surface Penetration: Ice and Snow

Susitna Glacier, West Fork, Alaska

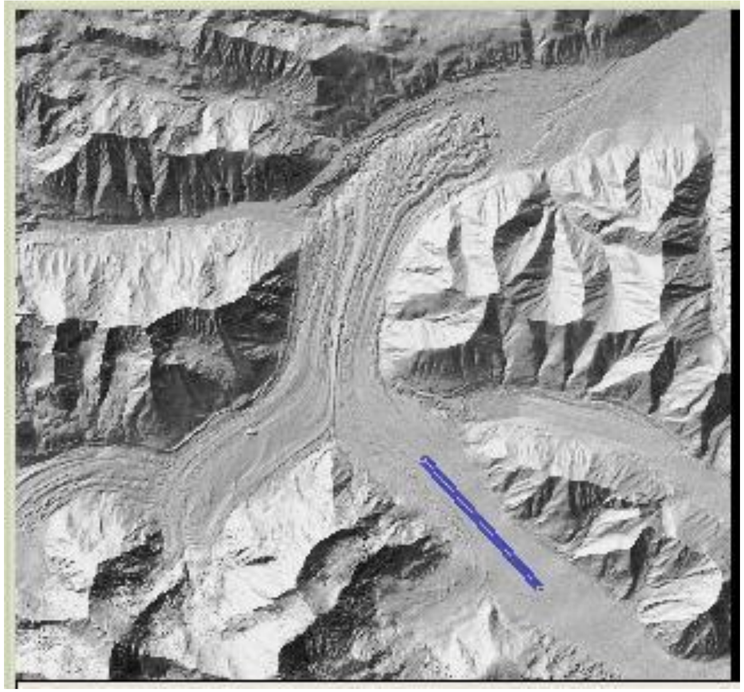




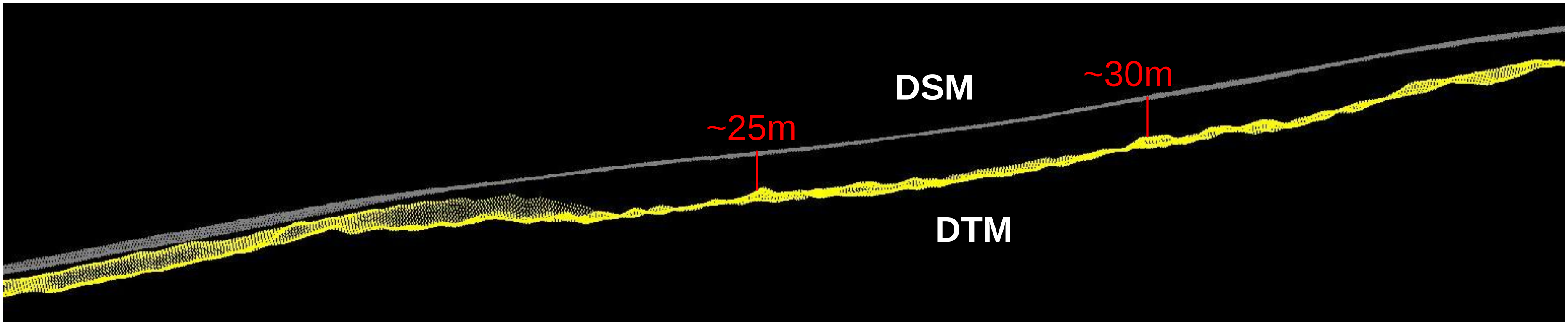
Glacial Profile in X-band an P-band



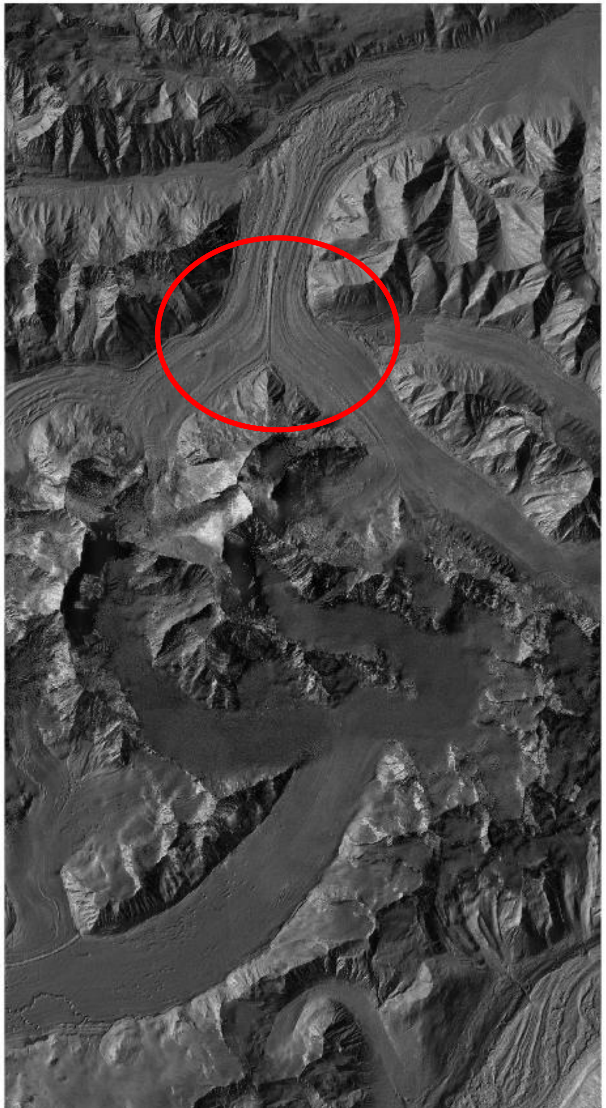
Glacier Ice Penetration with P-Band

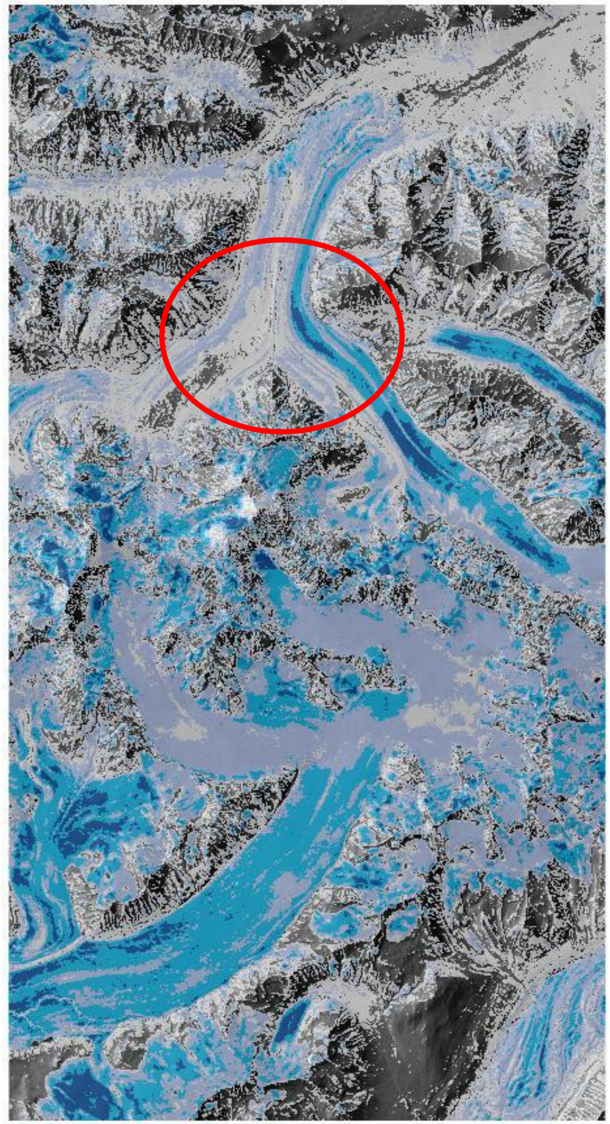


- Up to ~30m penetration of P-Band in this profile



Snow and Ice P-Band Penetration



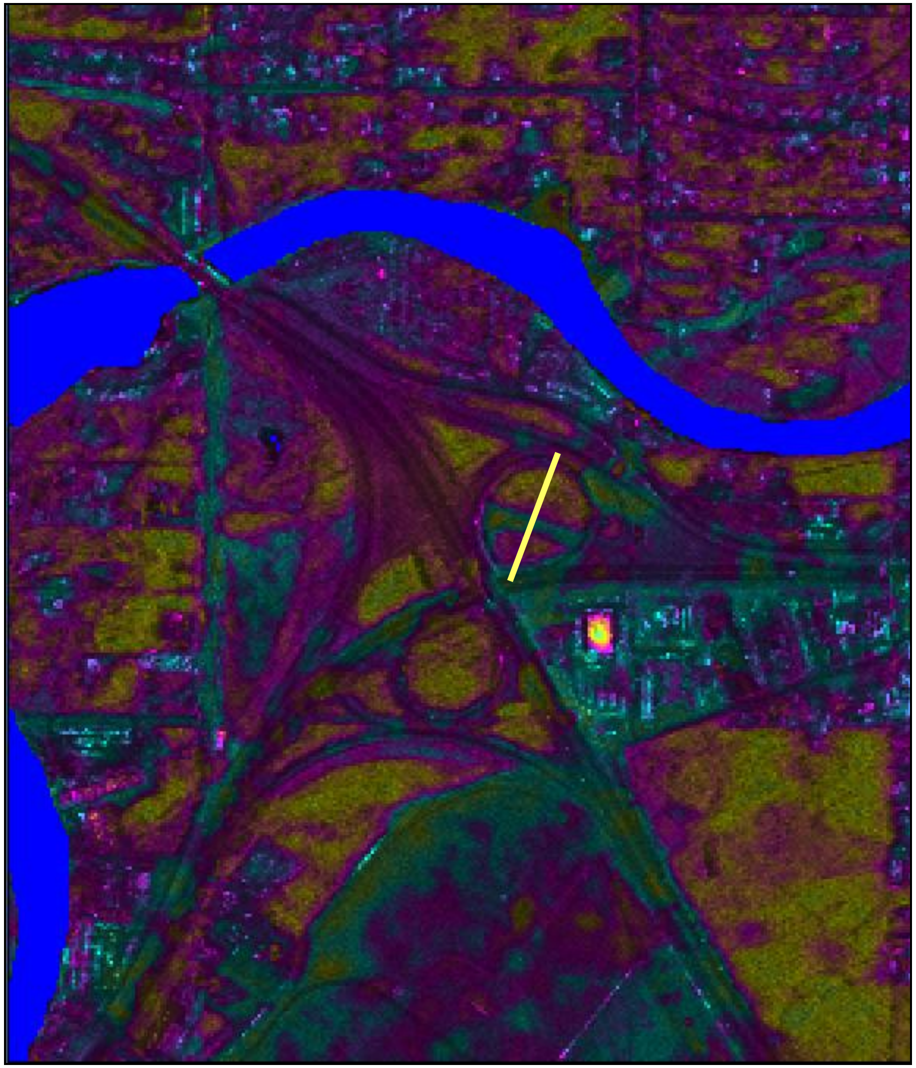


- X-Band is the basis for the DTM product in glacier areas.

Fairbanks GeoSAR Data Example

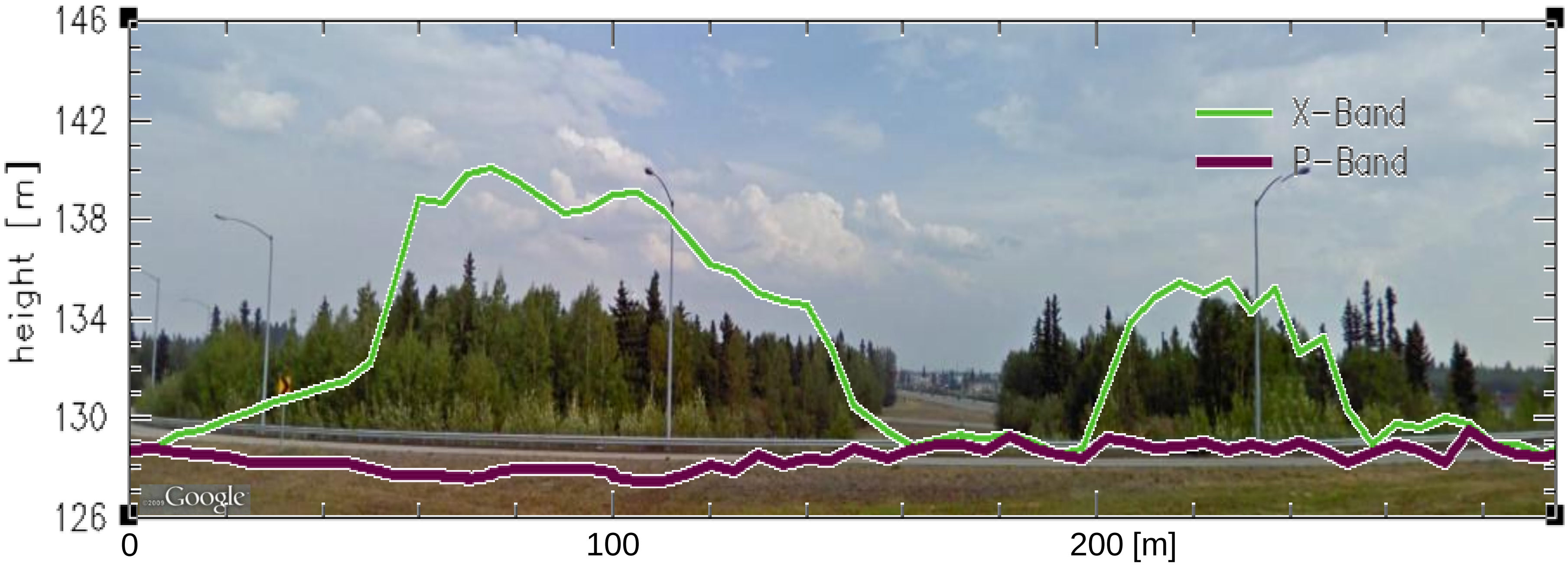
- Map
- Optical
- X SLC
- P SLC

Fairbanks Vegetation X-P ~ Tree Height

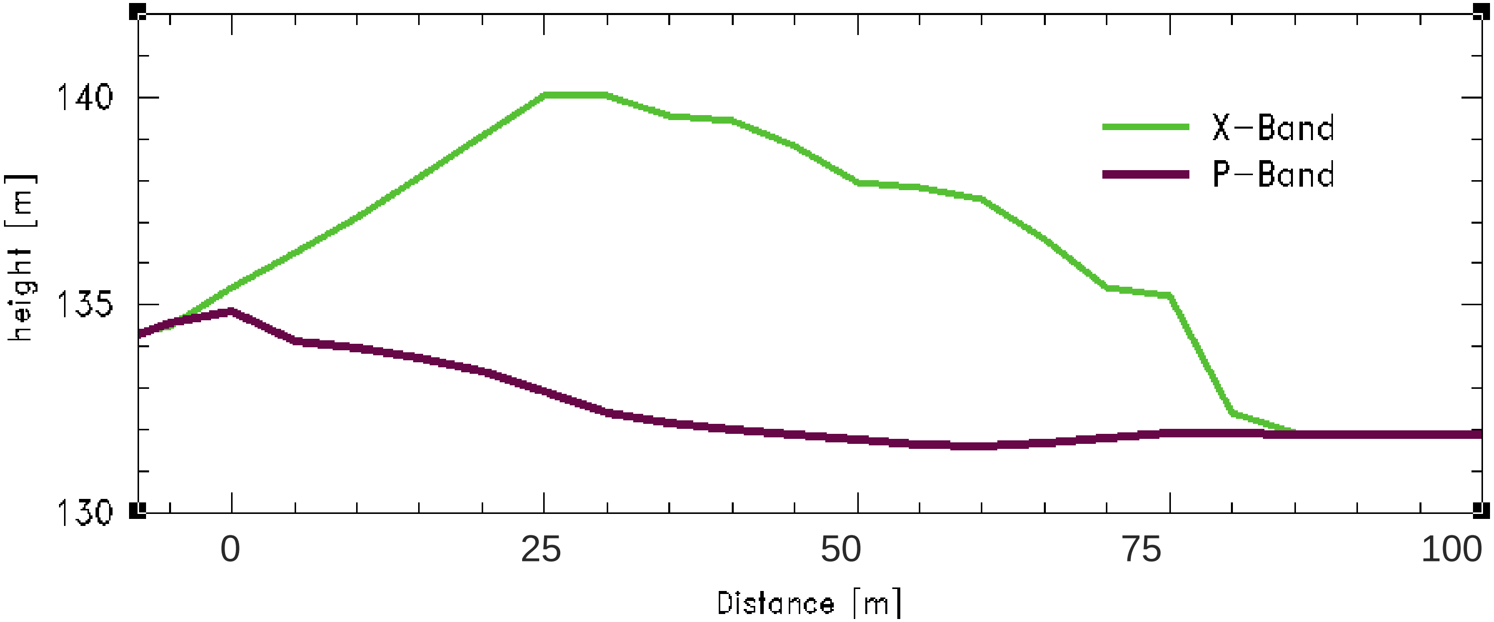


X-band – P-band Height

Fairbanks GeoSAR Data Example



Fairbanks Street View Example 2



Conclusions

- **GeoSAR Airborne IFSAR**
  - Dual-Band: X-Band and P-Band *at the same time*
  - Dual-Sided: Left and Right looking *at the same time*
  - Single-Pass: Interferometric data *at the same time*
  - LiDAR: Collect Ground Control *at the same time*

- **P-Band Data**
  - Provide measurements through vegetation
  - P-band penetrates snow and ice
  - Topography, hydrology, geology, and more

- **Alaska Pilot Area**
  - $RMSE_Z$ = 1.1 m (terrain slopes 0^o-10^o; 32184 LiDAR points)
  - $RMSE_Z$ = 3.4 m (terrain slopes >30^o; 2035 LiDAR points)

  - The Alaska data show many interesting things that should be applied and explored further!

Thank You