GeoSAR IFSAR Processing

Dr. Bert Kampes
Kevin Morgan
Mark Sanford
Snow and Ice Penetration @2:20PM

- See Kevin Morgan’s presentation, today @2:20PM

<table>
<thead>
<tr>
<th>Time</th>
<th>Presentation</th>
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</thead>
<tbody>
<tr>
<td>12:00 - 1:30</td>
<td>LUNCH</td>
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<tr>
<td>1:30 - 2:00</td>
<td>Evaluation of ALOS PRISM DEM Accuracy Using a LiDAR Reference</td>
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<tr>
<td></td>
<td>Rick Guritz, ASF/UAF</td>
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<tr>
<td>2:00 - 2:20</td>
<td>An Elevation Model for Alaska Using ALOS PRISM</td>
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<tr>
<td></td>
<td>Scott Arko, ASF/UAF</td>
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<td></td>
<td>Grant Cain, Kerri Crowder, Dan Bates, Rick Guritz, Don Atwood, Keith</td>
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<tr>
<td></td>
<td>Cunningham</td>
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<tr>
<td>2:20 - 2:40</td>
<td>Fugro GeoSAR Mapping Technology for Snow and Ice Penetration</td>
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<td></td>
<td>Kevin Morgan, Fugro EarthData</td>
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<td></td>
<td>Bert Kampbøs, Megan Blaskovich, Mark Sanford - Fugro EarthData</td>
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<tr>
<td>2:40 - 3:00</td>
<td>Alaska Glacier Change Observed with ALOS PRISM and AHAP Imagery</td>
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<td>Grant Cain, ASF/UAF</td>
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<td>3:00 - 3:30</td>
<td>BREAK</td>
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Outline

- Project Overview
- LiDAR Comparison
- Deployment Snapshots
- GeoSAR System
- Fairbanks Processed Data
- Conclusions
Project Overview

- Alaska Statewide Digital Mapping Initiative (SDMI)
- Fugro GeoSAR Project Area consists of 14 $1^\circ \times 1^\circ$ cells between Fairbanks, Mt. McKinley (Denali) 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

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>GeoSAR Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTM</td>
<td>- Digital Terrain Model&lt;br&gt;- Vegetation and Buildings Removed&lt;br&gt;- Hydrologically Enforced</td>
<td>- P-band &amp; X-band Interferometry&lt;br&gt;- Multiple Looks</td>
</tr>
<tr>
<td>DSM</td>
<td>- Digital Surface Model&lt;br&gt;- Hydrologically Enforced</td>
<td>- X-band Interferometry&lt;br&gt;- Multiple Looks</td>
</tr>
<tr>
<td>ORI</td>
<td>- Orthorectified Radar Magnitude&lt;br&gt;- Multiple view directions average</td>
<td>- X-band*&lt;br&gt;- Multiple Looks</td>
</tr>
<tr>
<td>Masks</td>
<td>- Quality Masks&lt;br&gt;- Hydrology, Voids, Fills, Slopes</td>
<td>- P-band &amp; X-band</td>
</tr>
<tr>
<td>Metadata</td>
<td>- Meta Information</td>
<td>- FDGC compliant</td>
</tr>
</tbody>
</table>

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

48,433 LiDAR points remaining with RMSEz = 1.46m (not culled).
East-West LiDAR Profile Comparison

- Terrain slope ~10°-25°
- Terrain slopes located correctly in GeoSAR DEM
- Differences ~0-2m between LiDAR and DSM

~2.0m ΔH
North-South LiDAR Profile Comparison

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

~2.5m ΔH
### DSM vs. LiDAR Statistics (not culled)

<table>
<thead>
<tr>
<th>Slope</th>
<th>0° – 10°</th>
<th>10° – 20°</th>
<th>20° – 30°</th>
<th>30°+</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Points</td>
<td>32,184</td>
<td>10,358</td>
<td>3,856</td>
<td>2,035</td>
<td>48,433</td>
</tr>
<tr>
<td>Average (m)</td>
<td>-0.12</td>
<td>0.63</td>
<td>0.98</td>
<td>1.16</td>
<td>0.18</td>
</tr>
<tr>
<td>Standard Deviation (m)</td>
<td>1.10</td>
<td>1.55</td>
<td>1.71</td>
<td>3.04</td>
<td>1.45</td>
</tr>
<tr>
<td>Minimum difference (m)</td>
<td>-8.04</td>
<td>-17.90</td>
<td>-7.50</td>
<td>-52.88</td>
<td>-52.88</td>
</tr>
<tr>
<td>Maximum difference (m)</td>
<td>16.35</td>
<td>11.48</td>
<td>15.96</td>
<td>25.07</td>
<td>25.07</td>
</tr>
<tr>
<td>RMSE (m)</td>
<td>1.13</td>
<td>1.64</td>
<td>1.97</td>
<td>3.25</td>
<td>1.46</td>
</tr>
</tbody>
</table>

*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.*
GeoSAR System Overview

- Airborne Radar Gulfstream-II @40kft (~13 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
Movie Clip: Acquisition Take Off

- Left Racks
  X-band
- Right Racks
  P-band
- Two radar operators
- Redundant data recording
Movie Clip: Moving Map Display

- Moving Map display
- Radar Channel Monitoring
- Wing pod P-band antenna
GeoSAR Measurements Systems

Collection Height: up to 13,000m

- X-Band (3 cm wavelength)
- P-Band (86 cm)
- Profiling LiDAR

14 km
14 km
11.5 km
Acquisition Redundancy Improves Data Quality
Acquisition Redundancy Improves Data Quality

Total of 16 measured heights for this point from 4 look directions
Orthorectified Radar Imagery

- East+West Views Average
GeoSAR Accuracy, Precision and Reliability

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

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

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

Image ©2011 Digital Globe
Fairbanks Street View Example 2
Conclusions

- GeoSAR 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: X-band for DTM
  - P-band contains information related to topographic features, hydrology, geology, and more

- Project Area Processing Well Underway
  - \( \text{RMSE}_Z = 1.1\text{m} \) (terrain slopes \( 0^\circ-10^\circ \); 32184 LiDAR points)
  - \( \text{RMSE}_Z = 3.3\text{m} \) (terrain slopes \( >30^\circ \); 2035 LiDAR points)

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