Science motivations for LiDAR (high resolution topography)

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Outline

• Introduction and motivation
• Technology overview
• Tectonic geomorphology application
• Ecological applications
• Volcano deformation application
• Terrestrial Laser scanning (TLS)
Introduction:

• Landscape development a combination of many processes:
  – Tectonic
  – Hillslope
  – Fluvial
  – Biologic
  – Anthropogenic

• High-resolution representation of landscape is central to qualitative and quantitative study of process.

• Aerial photography traditional tool for geomorphic studies

• 2D representation

• Qualitative tool

*Crosby, MS 2006*
Introduction:

- Digital topography provides 2.5D representation of landscape

- Widely avail. digital topography (digital elevation models - DEMs) are too coarse to provide representation of small geomorphic features / process.

- USGS 30 m DEM = best available national coverage
Introduction:

- Digital topography provides 2.5D representation of landscape

- Widely avail. digital topography (digital elevation models - DEMs) are too coarse to provide representation of small geomorphic features / process.

- USGS 10 m DEM
Introduction:

- LiDAR / ALSM data
- DEMs at resolutions not previously possible.
  - sub-meter resolution
- Applicable to:
  - Geomorphology
  - Landslide & flood hazards
  - Forestry/Ecology
  - Civil Engineering
  - Urban planning
  - Volcanology
- One of the hottest tools in the Geosciences

Crosby, MS 2006
Surface processes act to change elevation through erosion and deposition while tectonic processes depress or elevate the surface directly.
**Major themes**

- Identifying and extracting topographic features
- Coupling tectonic and climatic processes with landform evolution
- Testing landscape evolution models
- Detecting landscape change
- Feedbacks between life and topography
- Routing water and sediment through watersheds
- Linking structural geology to geomorphology

**Opportunities**

- Understanding effects of human-induced changes in landscape characteristics
- Discovering new ways of extracting landscape features from the topographic data, identifying new methods to quantify topographic trends
- Developing new physical and mathematical descriptions of the landscape
- Bringing these data into the classroom and informal science education opportunities
ALSM workflow:
Survey->Process->Classify->Interpolate/Grid->Analyze

Geodesy and signal processing

Detection Methods: Digitized Waveform, Pulse-Width, Discrete Return

Point Cloud $x_n, y_n, z_n, i_n$

Answer science question

Interpolated products
## Comparisons of Techniques for measuring surfaces and detecting changes in surfaces*

<table>
<thead>
<tr>
<th></th>
<th>GPS</th>
<th>InSAR</th>
<th>ALSM</th>
<th>TLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Density</td>
<td>1 site/10 km²</td>
<td>10,000 pixels/ km²</td>
<td>1-10 hits/ m²</td>
<td>1000 hits/ m²</td>
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<tr>
<td>Position Precision</td>
<td>1-20 mm</td>
<td>2-3 m</td>
<td>5-15 cm</td>
<td>0.6-5 cm</td>
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<tr>
<td>Change Detection</td>
<td>1 mm</td>
<td>1-2 cm</td>
<td>10 cm</td>
<td>1 cm</td>
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<tr>
<td>Scale</td>
<td>Global</td>
<td>100 km</td>
<td>10-100 Km</td>
<td>1 km</td>
</tr>
</tbody>
</table>

* Ball park numbers for typical applications

- Phillips, Meertens, and Jackson, UNAVCO
New Looks at Active Faults: Tectonic Geomorphology using Airborne Laser Swath Mapping (ALSM)

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USGS 30 m DEM & Matthes 1906 5' topographic map

2 m DEM from ALSM
Increase understanding of fault slip history over centennial to millennial time scales

Garlock fault zone high resolution topography
Fault zone mapping from ALSM—a major application

Arrowsmith and Zielke, 2009
Cholame case study

A) Explanation for fault strip mapping

**Vedder and Wallace, 1970**
- Local features with annotation
- Regional features
- Recently active breaks, certain
- Recently active breaks, less obvious
- Ponds and lakes

**Stone and Arrowsmith**
- Fault trace
- Fault trace, concealed
- Fault trace, inferred
- Lineament
- Landslide deposit
- Landslide scarp
- Sag

**Zielke, this study**
- Fault traces: red for main trace, blue for secondary traces
- Fault trace, certain
- Fault trace, inferred
- Fault trace, queried
- Fault trace, uncertain
- Landslide deposit and scarp

Location of mapped panels
A new view of fault zone tectonic landforms

Arrowsmith and Zielke, 2009
Carrizo Plain area 1 m DEM representation of B4 data along San Andreas Fault

Wallace Creek area
Carrizo Plain, 1857 Offsets

Zielke, 2009
Carrizo Plain, 1857 Offsets

Zielke, 2009
Carrizo Plain, 1857 Offsets

Zielke, 2009
Carrizo Plain, 1857 Offsets

Zielke, 2009
Post earthquake laser scanning and repetition (B4, Hector Mine, Denali)
Ecology Applications:

- 3D vegetation information & interactions between vegetation and topography
- 3D vegetation structure:
  - estimation of stand height
  - total aboveground biomass
  - foliage biomass
  - basal area
  - tree density,
  - canopy base height
  - canopy bulk density

Stoker et al., 2006
Note the greater resolution provided by the lidar DEM image and profile (Figure 2b), and the correspondence of higher slope (Figure 2b) with spawning habitat (Figure 2c).
Elevation change at Mt St Helens, September 2003 to October 4-5, 2004

Ralph Haugerud (USGS), David Harding (NASA), Vivian Queija (USGS), Linda Mark (USGS)