Using ALOS PALSAR Coherence to Delineate Glacier Extent

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• GLIMS Project
• Difficulties of Glacier Delineation
• Loss of SAR Coherence as a Tool
• Refining the method
• Technical Limitations
• Final Example
• Conclusions and Future Plans
GLIMS Project

GLIMS (Global Land Ice Measurements from Space) Project

- Create and update a global database of digital glacier outlines
- Rely on contributions of institutions worldwide
- Current database presently contains outlines covering 261,000 km², or approximately 34% of Earth's land ice cover
- Manual extraction of outlines from satellite optical imagery such as Landsat and ASTER

Walsh and Logan Glaciers
Challenges of Optical Approach

Clouds and darkness

Debris-cover
Synthetic Aperture Radar

SAR addresses issue of visibility

- Independent of solar illumination and clouds

Amplitude and Phase
Extensive use of SAR Interferometry (InSAR) to measure glacier velocity

Velocity map overlaid on top of Radarsat mosaic. Speeds vary from 1 – 3000 m/yr.
Interferometric Coherence

correlation coefficient between the two complex SAR images $u_1$ and $u_2$:

$$\gamma = \frac{E\{u_1 u_2^*\}}{\sqrt{E\{|u_1|^2\} E\{|u_2|^2\}}}$$

coherence estimate:

$$|\hat{\gamma}[i,k]| = \frac{|\sum_{w} u_1[i,k] u_2^*[i,k]|}{\sqrt{\sum_{w} |u_1[i,k]|^2 \sum_{w} |u_2[i,k]|^2}}$$

$W$ : small window centered around pixel $[i,k]$
Contributions to Coherence

\[ \gamma = \gamma_{\text{thermal}} \cdot \gamma_{\text{spatial}} \cdot \gamma_{\text{temporal}} \]

\[ \gamma_{\text{thermal}} = \frac{1}{1 + \frac{1}{\text{SNR}}} \]

\[ \gamma_{\text{spatial}} = 1 - \frac{2|B|R_y \cos^2 \vartheta}{\lambda r} \]

\( \gamma_{\text{temporal}} \) follows from physical changes in the surface over time
Temporal Decorrelation

- Main limitation in repeat-pass interferometry

This poses problems for moving glaciers!
Glacier Delineation

• Let’s turn a liability into a strength
  – Produce glacier coherence plots from ALOS (46 day repeat cycle)
  – Identify glaciers by their low coherence
  – Signal is independent of debris cover

• Use SAR coherence as tool for delineating glaciers, particularly problematic ones with extensive debris cover
Glacier Delineation

L-band coherence from ALOS PALSAR image pair (46 day revisit)

HSV image (coherence/amplitude/coherence) image of Taku Glacier
Mask Generation

Coherence Thresholding

- Summer interferograms
- Phase filtering
- Use of DEM in coherence estimation
- Layover, imperfect DEMs and environmental variability lead to over-estimate
Mask Generation

After Slope Thresholding

• Using DEM, establish maximum slope for glaciers
• Eliminate low coherence caused by extreme topography
• Consistent delineation of nunataks
Mask Generation

After Morphological Operations

- Inflation/Dilation operations
- Fill small holes
- Remove small patches
Mask Generation

After Patch Size Filtering

- Segmentation into sub-regions
- Size evaluation
- Threshold set at 500 m²
Terrain Correction

- Imports SAR data in native format
- Can perform polarimetric decompositions
- Uses DEM to remove geometric distortions (terrain correction)
- Geocodes data to commonly-used projections/datums
- Generates “GIS-ready” geotiffs

MapReady Tool Kit at:
www.asf.alaska.edu/sardatacenter/
Terrain Correction

SAR Image
With Layover

Terrain Corrected Image
Without Layover
Mask Generation

Final mask

• After Terrain Correction
Mask Generation

Generation of glacier shapefile

- Raster to polygon
Example: Taku Glacier
Example: Taku Glacier
Example: Kennicott Glacier

Extensive debris-cover near terminus
Final Results
Final Results
Conclusions and Plans for Future

- Glacier mass loss forms largest contribution to sea level rise
- Monitoring programs such as GLIMS are critical to understanding this process
- SAR represents opportunity to overcome limitations of optical glacier delineation
- ALOS employs a Basic Observation Strategy for repeated global coverage
- L-band coherence is ideal tool for completing the GLIMS database and providing long-term monitoring

Future Plans
- Further optimization of method to address water bodies and ice falls
- Development of GLIMS database for Alaska
Questions?