Making UAVSAR Data More Accessible
Lessons from PolSAR Classification in Arctic Alaska

Don Atwood
Geophysical Institute
University of Alaska Fairbanks

Bruce Chapman and Scott Hensley
NASA Jet Propulsion Lab
• Introduce UAVSAR and Current Data Products

• UAVSAR processing issues associated with PolSAR Classification
  • Need for “Entry-level” visualization
  • Handling Data Volume – Need for Multilooking
  • Role of Radiometric Normalization
  • Dealing with Ellipsoidal and Local Incidence Angles

• Summary of Value-added Products and Final Remarks
## Current SAR Status

<table>
<thead>
<tr>
<th></th>
<th>ERS-2</th>
<th>RADARSAT-1</th>
<th>ENVISAT</th>
<th>ALOS PALSAR</th>
<th>RADARSAT-2</th>
<th>TanDEM-X</th>
<th>COSMO-SkyMed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Band</strong></td>
<td>C-band</td>
<td>C-band</td>
<td>C-band</td>
<td>L-band</td>
<td>C-band</td>
<td>X-band</td>
<td>X-band</td>
</tr>
<tr>
<td><strong>Polarization</strong></td>
<td>VV</td>
<td>HH</td>
<td>HH/VV, HH/HV, VV/VH</td>
<td>Quad/Dual/Single</td>
<td>Quad/Dual/Single</td>
<td>Quad/Dual/Single</td>
<td>Selectable</td>
</tr>
<tr>
<td><strong>Swath</strong></td>
<td>100 km</td>
<td>50-460 km</td>
<td>100-400 km</td>
<td>70-350 km</td>
<td>20-500 km</td>
<td>5-100 km</td>
<td>10-200 km</td>
</tr>
<tr>
<td><strong>Resolution</strong></td>
<td>30m</td>
<td>10-30m</td>
<td>30-150m</td>
<td>10-100m</td>
<td>3-100m</td>
<td>1-16m</td>
<td>1-100m</td>
</tr>
<tr>
<td><strong>Repeat Cycle</strong></td>
<td>35 days</td>
<td>24 days</td>
<td>35 days</td>
<td>46 days</td>
<td>24 days</td>
<td>11 days</td>
<td>Constellation</td>
</tr>
</tbody>
</table>
The UAVSAR L-band radar is housed in a pod flown on the NASA G-3 platform, shown here in flight over Edwards Air Force Base, California.
NASA Jet Propulsion Lab’s UAVSAR Instrument

- Reconfigurable L-band, quad-polarimetric SAR
- Developed specifically for repeat track differential interferometry
- Designed to be flown aboard a UAV (Unmanned Aerial Vehicle)
- Currently being flown aboard a Gulfstream III
- Mission-based data acquisition
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- Lacks coverage of spaceborne SAR, but offers higher resolution (than many) and better noise floor
- Rich diversity of datasets exist in the archive
## Operational Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>L-Band 1217.5 to 1297.5 MHz (80 MHz bandwidth)</td>
</tr>
<tr>
<td>Resolution</td>
<td>1.7 m Slant Range, 1.0 m Azimuth</td>
</tr>
<tr>
<td>Polarization</td>
<td>Quad-Polarization (HH, HV, VH, VV)</td>
</tr>
<tr>
<td>Swath Width</td>
<td>&gt;16km</td>
</tr>
<tr>
<td>Repeat Track Accuracy</td>
<td>± 5 meters</td>
</tr>
<tr>
<td>Transmit Power</td>
<td>&gt; 3.1 kW</td>
</tr>
<tr>
<td>Radiometric Calibration</td>
<td>1.2 dB absolute, 0.5 dB relative</td>
</tr>
<tr>
<td>Noise Floor</td>
<td>-47 dB average</td>
</tr>
</tbody>
</table>

![Graph](image-url)
UAVSAR Data

• More than 100 missions in the Western Hemisphere
• Disciplines span:
  • Glaciology
  • Forestry
  • Hydrology
  • Volcanology
  • Oceanography
  • Land Cover
  • Earthquakes
  • Oil Spills
  • Lost Aircraft
Current Data Holdings
Current Data Holdings
Current Data Holdings
Alaska Satellite Facility

UAVSAR as Unrestricted Dataset – Instant Download
http://www.asf.alaska.edu/
First earthquake deformation captured by the UAVSAR system, using data acquired on October 21, 2009 and April 13, 2010
JPL Polarimetric SAR Products:

- Covariance matrix elements (GRD binary files)
  - Fully terrain corrected
  - Three real, three complex
- Covariance matrix elements (MLC binary files)
  - Three real, three complex
- Annotation file for metadata
- Digital Elevation Model (DEM)
- GIF image (HH, HV, VV)
- KMZ file
- Stokes Matrix
Classification Procedure

Generate Multilooked C3
Radiometric Correction
POA Compensation

Perform Wishart
Unsupervised
Classification

Convert to GeoTIFF
Export to GIS
Assign Classes
Classification of Florida Everglades

Yamaguchi Decomposition  Wishart Segmentation  Land Cover Classification
Classification Results

USGS NLCD 2006

PolSAR Classification

NLCD 2001 Land Cover Classification Legend

- 11 Open Water
- 12 Perennial Ice/Snow
- 21 Developed, Open Space
- 22 Developed, Low Intensity
- 23 Developed, Medium Intensity
- 24 Developed, High Intensity
- 31 Barren Land
- 41 Deciduous Forest
- 42 Evergreen Forest
- 43 Mixed Forest
- 51 Dwarf Scrub*
- 52 Shrub/Scrub
- 71 Grassland/Herbaceous
- 72 Sedge/Herbaceous*
- 74 Moss*
- 81 Pasture Hay
- 82 Cultivated Crops
- 90 Woody Wetlands
- 95 Emergent Herbaceous Wetlands

* Alaska Only
Visualization Products

500 x 800 GIF Image in KMZ:
HH HV VV

Pauli Decomposition GeoTIFF:
HH-VV HV HH+VV

CEOS Meeting - Nov 7-9, 2011
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Value-Added Products
Requirements

• Simple GIS-ready decompositions as “point of entry” for UAVSAR
Land Cover Classification of Yellowstone

ylwstn_26903_10067
Aug 10, 2010
Resolution Effects

Optical image

Wishart 5m Resolution
~ 2 GB per C3 element

Wishart 3x3 MultiLook
15m resolution

Wishart 5x5 MultiLook
25m resolution
Value-Added Products
Requirements

- Simple GIS-ready decompositions as “point of entry” for UAVSAR
- Large data volumes can prove burdensome for PC applications
  - Need for multilooked data sets
Topographic Effects

Optical Image

Wishart Segmentation

Need for Radiometric Normalization
Ulander Approach:
• angle-based radiometric normalization
• operates on Ellipsoidal Sigma nought
• corrects for local topography

\[ \sigma_{RTC}^0 = \sigma_0 \left( \frac{\cos \varphi}{\sin \theta_i} \right) \]

Radiometric Normalization

No Correction

with Radiometric Correction

Improving PolSAR Land Cover Classification with Radiometric Correction of Coherency Matrix
D.K. Atwood, D. Small, and R. Gens
Submission to IEEE JSTARS
Classification Results

ALOS AVNIR-2

PolSAR Classification
Value-Added Products

Requirements

• Simple GIS-ready decompositions as “point of entry” for UAVSAR

• Large data volumes can prove burdensome for PC applications
  Need for multilooked data sets

• Classifications require accurate radiometric normalization
Implications of an Airborne Platform

- Unlike Spaceborne SAR, Airborne SAR exhibits much greater range of look angles
- UAVSAR look angles range from 15 to 65 degrees
- Impact is more significant when local topography is considered

Question: What is the impact upon the scattering mechanisms for specific land cover classes?
Incidence Angle Variability

Hillshade DEM
Incidence Angle Variability

Local Incidence Angle
Segmentation of Local Incidence Angle
Investigating Scattering Mechanisms

- 3x3 Multilooked C3
- POA compensation
- VanZyl Decomposition
- Export to GIS
  Find scattering mechanisms for each land cover class
Extracting Scattering Strengths from Land Cover

GIS Procedure:
- Normalize VanZyl decomposition components (Surface, Double, Volume) for each resolution cell
- Determine Probability Distribution Function of Scattering Strengths for each Land Cover Class
Extracting Scattering Strengths from Land Cover

Double Bounce
Volume Scattering
Surface Bounce
Incidence Angle Analysis

Evergreen
Incidence Angle: 0-15 Degrees

Graph showing the probability distribution function of scattering strength for Evergreen with an incidence angle of 0-15 degrees.
Incidence Angle Analysis

Evergreen
Incidence Angle: 15-30 Degrees

Probability Distribution Function vs. Scattering Strength
Incidence Angle Analysis

Evergreen
Incidence Angle: 30-45 Degrees
Incidence Angle Analysis

Evergreen
Incidence Angle: 45-60 Degrees
Incidence Angle Analysis

Evergreen
Incidence Angle: 75-90 Degrees

Scattering Strength

Probability Distribution Function
Evergreen Trend Analysis

Scattering Strength vs. Incidence Angle

- Evergreen
- Surface
- Double Bounce
- Volume

Incidence Angle

Scattering Strength

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• Scattering mechanisms vary as a function of local incidence angle for all classes

• Trend is diminishing surface scattering and increasing volume and double bounce scattering as incidence angle increases

• Effect is most pronounced for smooth surfaces (e.g. barren ground)

At current time, no effective means exists for addressing incidence angle effects (Except Polarization Orientation Angle Compensation)
Value-Added Products
Requirements

• Simple GIS-ready decompositions as “point of entry” for UAVSAR

• Large data volumes can prove burdensome for PC applications
  Need for multilooked data sets

• Classifications require accurate radiometric normalization

• Broad range of ellipsoidal and local incidence angles require attention
  (Incidence angle maps useful as overlays)
Value-Added Products
Requirements

• Simple GIS-ready decompositions as “point of entry” for UAVSAR

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  (Incidence angle maps useful as overlays)

• Potential exists for performing rigorous calculation of POA, instead of estimation
New Value-Added Products

- UAVSAR Flight Lines
- Pauli Decomposition (Byte) in GeoTIFF
- DEM in GeoTIFF
- Zipped binary GRD files in three formats:
  - 1x1
  - 3x3
  - 5x5 Multilooked
New Value-Added Products

- Ellipsoidal Incidence Angle (degrees)
- Local Incidence Angle (degrees)
- Local DEM slope in East and North directions
  - possible computation of POA
- Ulander Radiometric Normalization factor
Final Remarks

- UAVSAR offers many advantages over SAR satellite data
  - higher resolution, better incidence angles, lower noise floor

- UAVSAR well-suited for fundamental PolSAR projects, but currently under-utilized

- Trivial to download data from ASF Archive

- Mission support available for both:
  - “NASA-funded” and “Non-NASA investigations with NASA concurrence”
Questions?

Don Atwood
dkatwood@alaska.edu
(907) 474-7380

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