Accuracy Assessment of Polarimetric SAR Land Cover Classification Using Topographic Compensation

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Alaska Satellite Facility
Project Overview

- Investigate potential of polarimetry for land cover classification
  - Focus on species differentiation
- Address the impact of topography on classification results
- Terrain-correct all polarimetric products to facilitate comparison with ground truth
  - Demonstrate synergy of PolSARpro and MapReady Tools
- Compare results with “ground truth” and evaluate classification accuracy
- Quantify the optimal classification approach for Interior Alaska
Species Differentiation

Spruce and Birch

Summer

Winter
Study Area

Boreal environment of Interior Alaska

- Characterized by:
  - rivers
  - wetlands
  - herbaceous tundra
  - black spruce forests (north facing)
  - birch forests (south facing)
  - low intensity urban areas
Study Area Classes

NLCD 2001 Land Cover Classification Legend

- 11 Open Water
- 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
- 90 Woody Wetlands
Study Area
Classes
Study Area Classes

NLCD 2001 Land Cover Classification Legend

- 11  Open Water
- 22  Developed, Low Intensity
- 41  Deciduous Forest
- 42  Evergreen Forest
- 90  Woody Wetlands
Classification Process
Traditional H/A/alpha

ALOS Quad-Pol data

PolSARpro
- Extract Coherency Matrix
- Lee Sigma Filter
- Compute H / A / alpha
- Wishart Segmentation

MapReady
- Terrain Correct
- Project to UTM
- Generate GeoTIFF

Wishart H/A/alpha Terrain-Corrected GeoTIFF

SLC
Classification Result
Traditional H/A/alpha

PolSARpro Classification

USGS Classes
### Accuracy Assessment without corrections

<table>
<thead>
<tr>
<th>PolSARpro</th>
<th>USGS</th>
<th>Open Water</th>
<th>Urban</th>
<th>Deciduous</th>
<th>Evergreen</th>
<th>Woody Wetlands</th>
<th>TOTALS</th>
<th>USER'S ACCURACY</th>
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<td>67%</td>
<td>76%</td>
<td>82%</td>
<td>51%</td>
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</table>
Topographic Impact on Classification

PolSARpro Classification

Simulated SAR
Coherency Matrix

\[ S = \begin{pmatrix} S_{XX} & S_{XY} \\ S_{YY} & S_{YY} \end{pmatrix} \]

Scattering Matrix

\[ T_{11} : \text{“Single Bounce”} \quad T_{22} : \text{“Double Bounce”} \quad T_{33} : \text{“Volume Scattering”} \]
Topographic Correction Methods

- Radiometric Terrain Correction:

\[
T_3 = \begin{bmatrix}
T_{11} & T_{12} & T_{13} \\
T_{21} & T_{22} & T_{23} \\
T_{31} & T_{32} & T_{33}
\end{bmatrix}
\]

\[
\text{correction factor from a DEM}
\]

\[
T_3 = \begin{bmatrix}
T_{11} & T_{12} & T_{13} \\
T_{21} & T_{22} & T_{23} \\
T_{31} & T_{32} & T_{33}
\end{bmatrix}
\]

- Span Normalization:

\[
T_3 = \begin{bmatrix}
T_{11} & T_{12} & T_{13} \\
T_{21} & T_{22} & T_{23} \\
T_{31} & T_{32} & T_{33}
\end{bmatrix}
\]

\[
\text{Span-normalized Coherency Matrix}
\]

\[
T_3 = \begin{bmatrix}
T_{11} & T_{12} & T_{13} \\
T_{21} & T_{22} & T_{23} \\
T_{31} & T_{32} & T_{33}
\end{bmatrix}
\]

\[
\text{Span}(T_3) = T_{11} + T_{22} + T_{33}
\]
Impact of Topography

$T_{11}$  $T_{22}$  $T_{33}$

No Corrections
# Impact of Topography

<table>
<thead>
<tr>
<th>No Corrections</th>
<th>Radiometric Terrain Correction</th>
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</thead>
<tbody>
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<tr>
<td>$T_{22}$</td>
<td><img src="image2.png" alt="Image" /></td>
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<td>$T_{33}$</td>
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Impact of Topography

$T_{11}$  $T_{22}$  $T_{33}$

<table>
<thead>
<tr>
<th>No Corrections</th>
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<tr>
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</tbody>
</table>

3rd ALOS Joint PI Symposium, 9-13 Nov. 2009  Don Atwood
Classification Process
Radiometric Terrain Correction

ALOS Quad-Pol data → PolSARpro
- Extract Coherency Matrix

MapReady
- Radiometry Correction
- Terrain Correct
- Project to UTM

Terrain-Corrected, Projected T3

PolSARpro
- Lee Filter
- Compute H / A/ alpha
- Wishart Segmentation
  - H /A/ alpha

Wishart H/A/alpha Terrain-Corrected GeoTIFF

MapReady
- Generate GeoTIFF

Pol Classes
Classification Result
Radiometric Terrain Correction

PolSARpro Classification

USGS Classes
### Accuracy Assessment for Rad-TC H/A/alpha

<table>
<thead>
<tr>
<th>PolSARpro</th>
<th>USGS</th>
<th>Open Water</th>
<th>Urban</th>
<th>Deciduous</th>
<th>Evergreen</th>
<th>Woody Wetlands</th>
<th>TOTALS</th>
<th>USER’S ACCURACY</th>
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<tbody>
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<td>Open Water</td>
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<td>61%</td>
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</tbody>
</table>
Classification Process
Span-Normalized

ALOS Quad-Pol data

PolSARpro
• Extract Coherency Matrix
• Lee Sigma Filter
• Span Normalization (manual)
• Compute H / A / alpha
• Wishart Segmentation
  • H / A / alpha

MapReady
• Terrain Correct
• Project to UTM
• Generate GeoTIFF

SLC
Pol Classes

Wishart H/A/alpha Terrain-Corrected GeoTIFF
Classification Result
Span Normalized

PolSARpro Classification

USGS Classes
Accuracy Assessment for Span-Normalized H/A/alpha

<table>
<thead>
<tr>
<th></th>
<th>Open Water</th>
<th>Urban</th>
<th>Deciduous</th>
<th>Evergreen</th>
<th>Woody Wetlands</th>
<th>TOTALS</th>
<th>USER'S ACCURACY</th>
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**PRODUCER'S ACCURACY**: 79% 45% 79% 85% 76% 73%
## Summary of Accuracy Assessments

### User and Overall Accuracies

<table>
<thead>
<tr>
<th>Land Cover Class</th>
<th>Lee-Filtered Only</th>
<th>Radiometric Terrain-Corrected</th>
<th>Span Normalized</th>
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</thead>
<tbody>
<tr>
<td>Open Water</td>
<td>0%</td>
<td>0%</td>
<td>93%</td>
</tr>
<tr>
<td>Urban</td>
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</tr>
<tr>
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<td>67%</td>
</tr>
<tr>
<td>Woody Wetlands</td>
<td>42%</td>
<td>42%</td>
<td>76%</td>
</tr>
<tr>
<td>Overall Accuracy</td>
<td>51%</td>
<td>61%</td>
<td>73%</td>
</tr>
</tbody>
</table>
Conclusions

• Polarimetric SAR Classification is difficult!
  • Data fusion provides greatest hope for success

• Radiometric variability caused by topography dominates classification

• Topographic compensation improves classification accuracy:
  • Radiometric Terrain Correction yielded 10% improvement in Overall Accuracy
  • Span Normalization yielded 22% improvement in Overall Accuracy

• Span Normalization approach is simple and effective, however not complete
  • Different scattering mechanisms (SB, DB, Volume) have different sensitivities to topography. Span normalization does not completely normalize.
• Polarimetric Orientation Angles should be investigated to see if accuracy can be further improved

• Data Fusion with optical will be explored

• Any attempt to quantify classification accuracy requires projection to ground range
  • PolSARpro and MapReady offer complementary capabilities

• Polarimetric operation in the GIS domain is now possible
Questions?