DRAGON POLinSAR (ID 5344)

DRAGON2 summary report:
Applying PolSAR and PollInSAR to Forest Structure
Information Extraction

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Contents

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DRAGON 2 – Project ID5344
Techniques for Deriving Land Cover and Earth Surface Deformation Information from Polarimetric SAR Interferometry

WP 1
Land Cover Analysis

WP 2
Earth Surface Deformation Monitoring and DEM Extraction

WP 3
Forest Vertical Structure Parameters Extraction

WP 4
PolSARpro Software Continued Development
Project research achievements & final results

Outlines

**WP 1: Land Cover Analysis**

--- Land cover mapping using C- and L-band polarimetric SAR data

--- Forest types classification method using POLinSAR data

**WP 2: Earth Surface Deformation Monitoring and DEM Extraction**

--- Applying coherence optimization methods to DEM extraction from ALOS POLinSAR data

**WP 3: Forest Vertical Structure Parameters Extraction**

--- Forest above Ground Biomass Estimation based on Polarization Coherence Tomography
Land Cover Mapping Using C- and L-band Polarmetric SAR Data
Test site center: 52° 26'N, 125° 32'E
In Tahe County, Heilongjiang Province, China
Climate Zone: Cold temperate zone.
Relatively flat with an average elevation ~330 m, slope less than 15°.
Key dominate tree species: Larch and White Birch.
One forest fire occurred in May 17, 2003

SPOT5 multi-spectral image (R: NIR; G: Red; B: Green)

Imaging date: July 27, 2006
Soybean Manual stimulated regeneration

Sparse forest / shrub vegetation

Soybean
SPOT 5 10m multi-spectral (R: NIR; G: R; B:G)

Imaging date: July 27, 2006

Land cover map from SPOT5 images

- Forest
- Grass
- Agriculture field
- Shrub
- River
- Urban, road, bare
- Others
## SAR data

<table>
<thead>
<tr>
<th>Data Types</th>
<th>Polarization</th>
<th>Imaging Date (y m d)</th>
<th>Incidence Angle (deg)</th>
<th>Orbit direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>PALSAR</td>
<td>HH,HV</td>
<td>20090702</td>
<td>38.7</td>
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<td>PALSAR</td>
<td>Quad-pol</td>
<td>20080907</td>
<td>23.9</td>
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<td>Radarsat-2</td>
<td>Quad-pol</td>
<td>20090714</td>
<td>38.4</td>
<td>Descending</td>
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<tr>
<td>Radarsat-2</td>
<td>Quad-pol</td>
<td>20091018</td>
<td>38.4</td>
<td>Descending</td>
</tr>
</tbody>
</table>
Qualitatively analysis:

➢ The Effect of Imaging Season to Forest Scar Mapping

Land cover map

Radarsat-2 data: Freeman decomposition results

Imaging date: 20060727
Wet, Summer Season

Imaging date: 20090714
Wet, Summer Season

Imaging date: 20091018
Dry, Fall Season
The Effect of Wavelength to Forest Scar Mapping

Pauli-decomposition

H-Alpha-A decomposition

Radarsat-2
imaged in 20091018

Inc: 38 deg

ALOS PALSAR
imaged in 20080907

Inc: 24 deg
Eigen values and relevant parameters from Radarsat-2 data (20091018)

(a) \(\lambda_1\)  
(b) \(\lambda_2\)  
(c) \(\lambda_3\)  
(d) RVI  
(e) SEP  
(f) H

DEM

Land cover map
Eigen values and relevant parameters from ALOS PALSAR data (20080907)

(a) $\lambda_1$

(b) $\lambda_2$

(c) $\lambda_3$

(d) RVI

(e) SEP

(f) $H$

DEM

Land cover map
Quantitatively analysis

- SVM based Multi-temporal POLSAR data land cover classification method study
  - Developed one semi-automatic feature selection method for SVM classifier
  - Quantitatively compared the LC classification ability of single and multi-temporal POLSAR data
    More detail to see the poster of Qi Feng.
  - Implemented one POLSAR data unsupervised classification method based on finite mixture Wishart model using EM and k-mean algorithm.
    More detail to see the poster of Lan Li.
Applying coherence optimization methods to DEM extraction from ALOS POLInSAR data
Test site and data

It is one warm temperate forest region;

Two major forest species:
- Black locust, and
- Chinese Pine

Test site location:

Taishan & Culai, Shandong Province
- Ground true collection for Culai test site

Plot size: 20m × 20m

Each tree:
- DBH;
- Height;
- Crown size.
Plot total number is 171, including *Black Locust* dominated 75, Pine dominated 69, and others 27.
The DEM of the test site

Taishan and Culai, the whole test site
Map scale of this DEM is 1:50,000

Culai test site
Digitized from 1:10,000 topo. map
In this report we only focus on the analysis of the two quad-pol images.
ALOS PALSAR data processing

**INPUT:**
Slant image space
Pixel size:
- Range: 9.37m
- Azimuth: 3.17m

**OUTPUT:**
DEM map space
Pixel size: 25m × 25m

- Multi-look Az7*Rng1
- Multi-looked Intensity

SAR simulation based **GTC & TRC**

- GTC and RTC image
- Local incidence angle image
- Layover & shadow mask image

**GTC:** Geocoded Terrain Correction

**TRC:** Terrain Radiometric correction
Quad-pol PALSAR image after TRC
Quad-polarization PALSAR data for forest volume estimation

- We have investigated the correlation between SAR parameters and mean forest stand volume \((m^3/m^2)\) in plot/pixel level, and observed that:
  - HH, HV, VH has low and negative correlation with forest volume
  - HV/HH, Alpha and Entropy have better correlation with forest volume
  - TRC can not improve the correlation, even worse
  - The correlation for Black Locust is better than Chinese Pine
POLinSAR data after coregistration and baseline parameters

2009.04.02 (master) 2009.05.18 (slave)

Pauli RBG image:
[s2] → 7looksAz*1looksRg

Baseline (226.9m):
• Cross track: 206.1m
• Normal: 94.9m

• Parallel comp.: 163.5m
• Perpendicular: 157.3m
POLinSAR data processing routes

**Master SLC**
(20090402)

**Slave SLC**
(20090518)

**Coregistration model**

**Resample Slave**
Considering common bandwidth filtering

**Slave resampled**
(20090518)

**Baseline Model**

**Flat earth phase removal**

**Coherence images generation**

**Forest height inversion (RVoG)?**

**Improve DEM accuracy?**
Coherence coefficient of three linear polarizations and three optimization methods

HH-HH  HV-HV  VV-VV  PDHigh  PDLow

Phase diversity coherence optimization method
-coherence of high phase center: PDHigh
-coherence of low phase center: PDLow
SVD coherence optimization method:
- OPT1: optimal coherence 1
- OPT2: optimal coherence 2
- OPT3: optimal coherence 3

Numerical radius coherence optimization method:
- NR1: Numerical radius coherence 1
- NR2: Numerical radius coherence 2
- NR3: Numerical radius coherence 3
DEM from three linear polarization and the reference DEM in slant range.
DEM produced from different coherence optimization methods

OPT1                  NR1                    PDHigh               PDLow
Quantitative validation results

RMSE (m):
- NR1: 24.4242
- PDLow: 24.7515
- OPT1: 25.674
- HH-HH: 31.985
- VV-VV: 35.651
- PDHigh: 46.8842
- HV-HV: 64.9409
Forest above Ground Biomass Estimation based on Polarization Coherence Tomography
• TREESR Campaign Site: TRAUNSTEIN
  – Topography 600~650m;
  – Spruce, beech and fir.

• E-SAR POLInSAR data:
  – L-band repeat pass InSAR;
  – 3000m above ground;
  – Incidence angle: 25~60deg;
  – SLC resolution: 1.5m*3m;
  – 5m nominal spatial baseline;
  – 20 minutes temporal baseline.
POLinSAR data

- POLinSAR data-SLC

Master

Slave

© DLR

1414 width × 4642 lines

20031011, 9:00

20031011, 8:40
Ground true data

Mean forest height (h100)

36.1m

13.0m

AGB (ton/ha)

445.2 ton/ha

38.7 ton/ha
**METHODS**

**POLInSAR preprocessing**

Cloude developed a PolInSAR height/topography estimation algorithm free of the exponential assumption.

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**Baseline information kz**

Stage 1: Height and Phase Estimation

\[ h_s = \frac{\text{arg}(\tilde{\gamma}_{zz}) - \phi}{k_z} + 0.8 \sin^{-1}(\frac{|\tilde{\gamma}_{zz}|}{h_s}) \]

where

\[ \phi = \text{arg}(\tilde{\gamma}_{zz} - \tilde{\gamma}_{xz}(1 - L_{zz})) \quad 0 \leq L_{zz} \leq 1 \]

\[ A = \frac{\nu^2 - 1}{2} B = 2 \text{Re}(\tilde{\gamma}_{xz} - \tilde{\gamma}_{yy}) \]

\[ C = \frac{1}{2} \tilde{\gamma}_{zz} - \tilde{\gamma}_{xx} \]

Stage 2: Coherence Normalisation

\[ k_z = \frac{k_\nu h_s}{2} \]

\[ \tilde{\gamma}_y(t) = \tilde{\gamma}(t)e^{-i \phi} \]

Stage 3: Legendre Estimate

\[
\begin{bmatrix}
a_{00} \\
a_{01} \\
a_{02}
\end{bmatrix} = \begin{bmatrix}
1 & 0 & 0 \\
0 & f_1 & 0 \\
0 & 0 & f_2
\end{bmatrix} \begin{bmatrix}
1 \\
\text{Im}(\tilde{\gamma}_y) \\
\text{Re}(\tilde{\gamma}_y) - f_0
\end{bmatrix}
\]

\[ f_0 = \frac{\sin k_v}{k_v} \]

\[ f_1 = \frac{(\sin k_v - \cos k_v)}{k_v} \]

\[ f_2 = \frac{1}{k_v^2} (3 \cos k_v - (3 - k_v^2) \sin k_v) \]

Stage 4: Profile estimate

\[ 0 \leq z_s \leq h_s \Rightarrow -1 \leq z = \frac{2z_s}{h_s} - 1 \leq 1 \]

\[ \hat{f}(z) = a_{00} + a_{01}z + \frac{a_{02}}{2} (3z^2 - 1) \]

---

**Polarization Coherence Tomography**
From pixel level reflectivity to stand level

RGB composite image of the polarimetric SAR data of the Traunstein scene in the Pauli basis

Vertical profile of the relative reflectivity function from PCT in the SAR azimuth direction (along the red line)

(a) stand #14
(b) stand #9
(c) stand #20
• The mean $f(z)$ of three typical forest stands of different AGB levels

(a) low(135.7 ton/hm$^2$)  (b) middle(303.3 ton/hm$^2$)  (c) high(402.6 ton/hm$^2$)
**Definition of some feature parameters to describe the $f(z)$**

**P1**: The 1st peak curve length/peak value

$$P_1 = (h_4 - h_2) / \hat{f}_{12}(w, h_3)$$

**P2**: For the 1st peak, curve value times height, then gets the sum

$$P_2 = \sum_{z=h_2}^{z=h_1} z \cdot \hat{f}_{12}(w, z)$$

**P3, 4, 5**: Fit the 1st peak with Gauss function, peak value reciprocal, mean and variance: P3, P4, P5;

**P6**: Reciprocal of the sum of curve value of the 1st peak

$$P_6 = 1 / \sum_{z=h_2}^{z=h_1} \hat{f}_{12}(w, z)$$

**P7**: Reciprocal of the sum of curve value of the 2nd peak

$$P_7 = 1 / \sum_{z=0}^{z=h_1} f(w, z)$$

**P8**: $P_8 = P_6 / P_7$

**P9**: For the 1st peak curve, cutting it into two parts along $h_3$, sum of curve value down half/top half,

$$P_9 = \sum_{z=h_2}^{z=h_3} \hat{f}_{12}(w, z) / \sum_{z=h_2}^{z=h_4} \hat{f}_{12}(w, z)$$
• Stepwise regression

\[ \ln(B) = \ln(b_0') + b_1 \ln(P_1) + b_2 \ln(P_2) + \cdots + b_n \ln(P_n) \]

• Model accuracy validation
  – m-fold cross validation method
  – Set \( m=10 \), total sample number \( N=20 \)
  – \( R^2 \) and RMSE
• AGB estimation model fitted

$$\ln B = -2.9966 + 1.7806 \ln (P_4) + 0.5765 \ln (P_8) - 0.2927 \ln (P_9)$$

• Estimation performance compared with that only using forest height

$$\ln B = -0.5270 + 1.8457 \ln (h_v)$$

(a) Using PCT
(b) Using forest height only

Scatter diagram between estimated and ground measured AGB
• Forest AGB map from PCT and from ground measurement

Ground measurement  Estimated from PCT

\( \text{ton/ha}^2 \)  \( \text{ton/ha} \)
➢ To extend the model to the whole image coverage area
  • need the forest stand polygons, so
  • developed one AGB mapping method by combining the method above with PolInSAR segmentation

➢ Exploring SKP decomposition and algebraic synthesis based method

**More details to see the poster of Weimei Li.**
Developed one unsupervised method for forest type classification

More details to see the poster of Xinshuang Wang.
Conclusions

• Two China test sites established
  – one for classification, one for forest parameter inversion;
  – PolSAR and PolInSAR and ground true data acquired and analyzed.

• Classification test site (China test site)
  – Multi-temporal PolSAR data are vital for forest scar mapping;
  – SVM classifier with semi-automatic feature selection method can improve performance;
  – PolSAR statistic model based method is still under developing.

• Forest parameters inversion test site (China test site)
  – ALOS PolInSAR data can not be used for forest height inversion..., but we find it is useful for under canopy topography extraction.

• Forest above ground biomass estimation (Germany test site)
  – Single baseline PCT information can be used for AGB estimation, but in forest stand (polygon) level
Papers published


## Young scientists training

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<td>Li Xiao</td>
<td>PollnSAR for forest information inversion</td>
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<td>Zhou Wei</td>
<td>DEM extraction using ALOS PolSAR data</td>
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## Academic exchange programmes

Armando Marino visit Chinese Academy of Forestry
From April 24 to May 30, 2010
Thanks for your attentions.