Product Delivery Report for K&C Phase 2

SAR Backscatter, InSAR and Lidar Studies for Measuring Vegetation Structure Over the Harvard Forest Region

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K&C deliverables

Papers and Reports

1. Published
   - K&C Phase-1 and Phase-2 reports
   - One “contribution” to the K&C Booklet (SAR, InSAR and Lidar Studies for Measuring Vegetation Structure Over the Harvard Forest Region)

2. Submitted/in preparation
   - Expect to submit at least one paper, based on the K&C phase-2 report, to the RSE special issue.
K&C deliverables

Data sets and Thematic products
(mosaics, classification maps etc.)

This project has been about process development and error analysis. Deliverables have been in the form of methodology and technique comparison.

Ground Validation data over the Harvard Forest and Northeast can be made available to the K&C project.

We would like to work with JAXA on the validation and refinement of the global forest and biomass map.
The Harvard Forest as a Test Site

- The Harvard Forest in Western Massachusetts is being used to develop scalable algorithms that can be applied world-wide. The target variety, terrain flatness and history of observation makes it an appealing remote sensing target for calibration/validation and vegetation studies.
In all, over 10,000 trees were catalogued over 15 one hectare regions, 225 25x25m subplots, for species, dbh, and live-or-dead
Within the 15 one hectare validation sites, DBH, species and number density were recorded. These are converted into Biomass and carbon content via allometric equations. The range of biomasses are from 120 to 310 tons per hectare.
ALOS/PALSAR DATA

ALOS/PALSAR
48 FBS Scenes
20 FBD Scenes
30 PLR Scenes
46 day repeat

Data has been processed interferometrically, but suffers from temporal decorrelation

<table>
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<th>Value</th>
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<td>Center Frequency</td>
<td>1270MHz</td>
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<tr>
<td>Modes</td>
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<td>Bandwidth</td>
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<tr>
<td>Polarization</td>
<td>HH</td>
</tr>
<tr>
<td>Resolutions</td>
<td>4.6x3.5m</td>
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</table>
As reported by many, a 46-day repeat period causes problems in terms of using the interferometric coherence for InSAR and PolInSAR for quantitative estimation of vegetation characteristics.

Use of coherence may still be suitable for forest/non-forest classification.
A C-band DEM and PALSAR interferometric pairs could, in principal, be used to measure differential penetration.

Initial results show that the signature is dominated by atmospheric effects.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Frequency</td>
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<td>Bandwidth</td>
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<td>Polarization</td>
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<td>Look Angles</td>
<td>25 - 65 degrees</td>
</tr>
<tr>
<td>Resolution</td>
<td>1.6 x 0.66 m</td>
</tr>
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</table>
UAVSAR observation strategy

All passes occur at same altitude (12.5 km), with a 40 degree look angle to center swath.
UAVSAR and ALOS Backscatter Comparison

Local incidence angles are equivalent
Data selected for comparison and analysis

ALOS/PALSAR

- 8 FBD scenes (9.5 x 3.5m resolution)
- The acquisition dates range from 2006 to 2009
- All scenes acquired between the months of July and October
- Backscatter data has been compensated for area projection and local incidence angle variations using 30m SRTM DEM

UAVSAR

- 10 scenes (1.6 x 0.66m) from 5° heading
- Data acquired on three days; August, 6th, 8th and 16th of 2009.
- Projection area and incidence angle variations compensated for using 30m SRTM DEM

Ground Validation

- Biomass estimates from 240 survey locations (subplots)
Backscatter (HV) and biomass

25mx25m subplots

100mx100m plots

UAVSAR: 220 looks, ALOS: 7 looks

UAVSAR: 3520 looks, ALOS: 112 looks
Relative error as a function of area

\[ \sigma = A\left(1 - e^{-Bb}\right) + Cb^{\alpha} e^{-Bb} \]

\[ \frac{\Delta \sigma}{\sigma} = \frac{1}{\sqrt{N}} \left(1 + \frac{1}{SNR}\right) \]
Hectare scale estimates

Over one-hectare sized plots, the variance is significantly reduced, thus improving the ability for making biomass estimates from backscatter observations.

This is a strong argument for increased bandwidth. A difficult quantity to come by.
The observed relationship is not a strong function of polarization, but a “bias” between co-pol and cross-pol is evident in the data as expected.

Saturation does appear to occur at lower biomass levels for co-pol compared to cross-pol.
Segmentation Approach

- Due to difficulties in measuring structure from backscatter and repeat-pass interferometry, an alternate approach to structure estimation is being investigated.

- Relies on the fundamental sensitivity of SAR backscatter power, texture and polarimetry to varying ground cover.

- Aggregate regions of a like response via an image segmentation

- Utilize coincident LiDAR observations on a scene by scene basis to assign values of interest to the segmented RaDAR image.
LVIS - Full Waveform Lidar

Collected full waveform data during a campaign over the Harvard Forest Region in 2003, and again in 2009. Data are being analyzed.
Backscatter (HV)

Orthophoto (1m)

Rh100

Land use map

PH1: Red pine, 936 trees

PH3: Maple, oak and birch, 476 trees

PH6: Oak, 817 trees
Backscatter (HV)
Orthophoto (1m)
Rh100
Land use map
Backscatter (HV)
Orthophoto (1m)
Rh100
Land use map

Lidar signature complicated by water beneath the canopy
Backscatter (HV)
Orthophoto (1m)
Rh100
Land use map
Conclusions

- Biomass data from 15 hectares in the Harvard Forest was collected during a field campaign in summer of 2009.
- The biomass data was analyzed with Spaceborne (ALOS/PALSAR) and Airborne (UAVSAR) HH, and HV radar backscatter data.
- Cross-polarized (HV) backscatter data appears to have a relationship with ground measured biomass even at the high biomass levels prevalent in the Harvard Forest. More polarimetric analysis is ongoing.
- A large number of independent looks are required for estimating biomass from radar backscatter. Work is underway to determine the minimum number of necessary looks. THIS MEANS LARGE BANDWIDTH IS CRITICAL FOR BACKSCATTER TO BIOMASS ALGORITHMS.
- Full waveform lidar data from 2003 and 2009 are being analyzed. Work is underway to establish height to biomass relationships using LVIS and ground measured heights.
- Segmentation approach is just now being explored
- Interferometric analysis indicates that temporal decorrelation dominates any signature that may be related to the forest structure.
Backscatter (HV)
Orthophoto (1m)
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