A Detailed Analysis of Repeat-pass Interferometry and Polarimetric ALOS/PALSAR data over the Harvard Forest

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Introduction

1200 ha in Western Massachusetts, New England Upland Region (200 - 400 m elevation), mean precipitation of 110 cm/year. Transition Hardwoods, White Pine and Hemlocks.

Dominant Species
- Red Oak, Red Maple, White Pine, Eastern Hemlock

Secondary Species
- White and Black Oak, Sugar Maple

- Region was heavily forested in early 20th century.
- Donated in 1907 to Harvard University to study sustainable forestry.
- In the 21st century, it has been heavily imaged by ALOS/PALSAR
Above are shown ALOS perpendicular baselines (in meters) for all possible interferometric pairs for a variety of observing modes.
Processing and Data Inputs

- Backscatter
- Interferometric phase
- SRTM DEM
- Differential phase
- Correlation Magnitude
- NLCD
A landcover classification (NLCD 2001) is used to perform post-analysis, and to understand the impact of landcover type.
Correlation (uncorrected)

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 Temporal Decorrelation Study

- Temporal and volumetric effects on interferometric correlation are hard to separate.

\[ \gamma_{\text{temporal}} \gamma_{\text{vol}} = \frac{\gamma_{\text{obs}}}{\gamma_{\text{SNR}} \gamma_{\text{geom}}} \]

- Need a data set that has inherently minimal volumetric decorrelation to isolate and analyze temporal effects.

\[ \gamma_{\text{vol}} \leq 1 - \frac{h_v^2 k_z^2}{24} \leq \text{sinc}(k_z h_v / 2) \]

\[ k_z = \frac{4\pi B_\perp}{\lambda r \sin \theta} \]
SIR-C dataset

- Repeat pass duration of 24 hours, from October of 1994, over the eastern US.
- Maximum perpendicular baseline of 40m.

Volumetric effects from the largest trees in the northeast (55m) would at most account for only 5% of the total observed decorrelation.

- Spans more than 1 million hectares.
Statistics of forests and crops along track

- Active precipitation during pass 2
- Peak fall colors occur in early November
- Peak fall colors occur in mid October
- High winds
Precipitation signatures
Wind effects
Wind data from the National Climate Data Center
Seasonal dependence
Statistics of forests and crops along track
Statistics of temporal decorrelation (one day)

**Probability Density Functions**

- **Water**
- **Cultivated Land**
- **Evergreen forests**
- **Deciduous forests**

**Cumulative Distribution Functions**

- **Water**
- **Cultivated Land**
- **Evergreen forest**
- **Deciduous forest**

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* A draft paper is available for those interested.

**Example**

"72% of the time, the temporal decorrelation was more than 0.10 (10%) over pixels classified as evergreen forests"
Look who’s coming to dinner!
Back To The Harvard Forest

- Local region of the Harvard Forest (fully covered by ALOS observations).

- LVIS full waveform LiDAR data collected in July of 2004.

- Harvard University has 44 biomass sites (700 m²), 34 of which are covered by the LVIS observations.
Working With LiDAR Data

Google Earth

Lidar counts

Height from ground return (m)

30m
Biomass to LiDAR Relationships

\[
\text{Biomass} = a_0 + a_1 \cdot \text{rh50} + a_2 \cdot \sigma^2_{\text{rh50}} + a_3 \cdot (\text{rh50})^2
\]

\[
\text{Biomass} = a_0 + a_1 \cdot \text{rh50} \quad (\text{rmse 33 Mg/ha})
\]

Other Variables
- rh100
- rh75
- rh50
- rh25
- (rh50)^2
- (rh100)^2
- \sigma^2_{\text{rh50}}
- \sigma^2_{\text{rh100}}
A Biomass Map of the Harvard Forest
Biomass Estimation using Radar RCS

\[ \sigma_{hv}^o = -12 + 0.5 \ln \text{AGB} \]

\[ \sigma_{hv}^o = -22.5 + 3.0 \ln \text{AGB} \]
Other Backscatter Relationships

\[ \sigma_{\text{HH}} \]

\[ \sigma_{\text{HV}} \]

Lidar measured tree height
Little phase difference seen between the principle polarizations

Poincare sphere is sampled with same-polarization synthesis between passes (i.e. $w_1 = w_2$)

Standard deviation not an indicator in this data set for vegetation height
An alternate approach is necessary. Perhaps one that 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.
Conclusions

- Temporal Decorrelation is prevalent in all interferometric data, even one-day repeat pass interferometry

- Significant ALOS, dual-pol and quad-pol observations exist over the Harvard Forest

- Because of temporal decorrelation, we have been looking so far only at the radar cross-section

- Full waveform data from LVIS was used to generate a biomass map.

- Fully polarimetric data shows a loose relationship to biomass for the cross-pol. Nothing for the co-pol. Likely due to the steep incidence angle.

- Next will look at polarimetric decompositions and at the FBS/FBD data.
Precipitation data from the NCDC

Pass 1

9th: 200 hours

9th: 300 hours

9th: 400 hours

Pass 2

10th: 200 hours

10th: 300 hours

10th: 400 hours

time