The role of polarimetry on the estimation of forest structure from SAR tomography

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Context and motivation

Importance of Forests …
- 30% of the total earth surface.
- The most biodiverse habitat.
- Primary resources: wood and food.
- Carbon cycle: CO₂ sink through the Biomass.

Common ways to study of forest …
- Ground data: Individual tree parameters.
- Optical images: Very easy to interpret.
- Lidar: Accurate 3D information from ground or aircraft.

Synthetic aperture radar …
- Global coverage, low revisit time, Weather & Day/night cycle.
- Already some applications: Forest height, forest/non forest maps.
- SAR missions with tomographic capabilities: 3D imaging.
Forest structure does not have a clear definition
From SAR Tomography to 3D forest structure

From tomography
- Not individual tree measurements.
- 3D radar reflectivity profiles.
- Assumption: A group of trees produce a local maxima.

“Processing chain” to get forest structure

1st - Definition of 3D forest structure
2nd - Tomographic vertical profiles
3rd - Local maxima from each profile

4th - Forest structure

**Horizontal Structure**
Density of local maxima

\[ HS_{radar} = \frac{N_{\text{upper}}}{\text{Area}} \]

**Vertical Structure**
Variance of the heights of the local maxima

\[ VS_{radar} = M \ var(H) \]

\[ N_{\text{upper}} = \text{Number of local maxima in the upper part} \]
\[ M = \text{Number of maxima with different height} \]
\[ H = \text{Different heights in the area} \]

Tomographic profiles depend on the polarization!
Test site

Traunstein, Germany

**Tomographic SAR data set**

- **Gradient of structure from W → E**
- **East: Mono-layered homogenous stands.**
- **Gap with scattered trees.**
- **West: Multi-layered heterogeneous stands.**

<table>
<thead>
<tr>
<th>Sys.</th>
<th>Date</th>
<th>Trac.</th>
<th>Freq.</th>
<th>k_z</th>
<th>HoA</th>
<th>Resolution</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>F-SAR</td>
<td>15</td>
<td>L</td>
<td>0 to 1.05</td>
<td>84 m</td>
<td>6 m, 1.2 m, 0.6 m</td>
</tr>
</tbody>
</table>

Area of interest: ~1 Km

~350 m

Area of interest
Capon tomograms at different polarizations: HH, HV, VV

Lidar point clouds

~1.25 Km

Capon HH

Capon HV

Capon VV
Local maxima at different polarizations: HH, HV, VV

Capon HH
Without ground HH has 40% less maxima than HV

Capon HV

Capon VV
Without ground VV has 30% less maxima than HV
RGB composition: HH, HV, VV

Lidar point clouds

“tomogram” of trees (height based on the diameter)

Capon HH, HV, VV

Local maxima HH, HV, VV
Vertical profiles different areas

- HV has lower contribution of the ground than HH and VV.
- HV has a wider canopy profiles.
- Different shape profiles for each area.

Definition of homogenous areas based on optical, Lidar and ground info.
Tomograms at different polarizations

Lidar height

Optical image

lidar

HH

HV

VV
Local maxima at different polarizations

Lidar height

Optical image

lidar

HH

HV

VV
Maps of forest structure: All channels

Reflectivity profiles → Local Maxima → Forest structure

From SAR tomography **using all channels**

*Structure obtained at scale of 50 by 50 m.*
Maps of forest structure: All channels

Reflectivity profiles $\rightarrow$ Local Maxima $\rightarrow$ Forest structure

*Structure obtained at scale of 50 by 50 m.*

From SAR tomography **using all channels**

**Horizontal**

**Vertical**

From Individual **tree measurements**

**Horizontal**

Stand Density Index (Reineke 1933)

**Vertical**

Standard deviation of dbh (McElhinny 2005)
“1 line” forest structure: All channels

Horizontal

Vertical

- Similar trend for both systems.
- Left part high structure
- Gradient of structure.
- Gap in the middle.

More details in:

Maps of forest structure: HH, HV, VV

HH

HV

VV

Horizontal

Vertical

Horizontal

Vertical

Horizontal

Vertical
“1 line” forest structure: HH, HV, VV

**Horizontal**

- HV is the most similar to the *all channels* case.
- Horizontal *saturates* for HH and VV.
  - High dependency on the number of local maxima

**Vertical**

- Vertical has similar results.
  - Less dependency on the number of local maxima
Forest structure by areas: All channels

- Same areas as before
- Horizontal structure using all channels
- Vertical structure using all channels
Forest structure by areas: All channels

› Same areas as before

› 2D distribution of points inside the area
Forest structure by areas: All channels

- Same areas as before

- 2D distribution of forest structure values for each area.

- Each area is located in a different position of the plane.
Forest structure by areas: HH, HV and VV

HH and VV have problems to differentiate some areas.

HV is similar to the all channels case.
Summary & Conclusions

› Definition of a forest structure concept.

› Algorithm to get forest structure from SAR tomography.

› HV retrieves more scatters in the canopy.

› Across the site, vertical profiles and local maxima are different.

› For the estimation of forest structure …

› HH & VV pols are suboptimum as different areas are mixed.

› HV performs better in differentiating the different structures.
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Thanks for your attention!

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