POL-INSAR TECHNIQUES FOREST CHARACTERISATION WITH TANDEM-X
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DLR, HR Institute
PolinSAR 2013, Frascati, 29-January-2013
Pursuit Monostatic

Both satellites transmit and receive independently
- Susceptible to temporal decorrelation & atmospheric disturbances
- No PRF and phase synchronisation required (backup solution)

Bistatic

- One satellite transmits and both satellites receive simultaneously
- Small along-track displacement required for Doppler spectra overlap
- Requires PRF and phase synchronisation

Alternating Bistatic

- Transmitter alternates between PRF pulses
- Provides three interferograms with two baselines in a single pass
- Enables precise phase synchronisation, calibration & verification

TanDEM-X Data Acquisition Modes

Standard DEM Mode

Allows Dual-Pol (HH/VV, HH/HV, VV/VH, HV/VH, HH/VH, VV/HV) acquisitions in an experimental mode
TanDEM-X Data Acquisition Modes

**Pursuit Monostatic**
- Both satellites transmit and receive independently.
- Susceptible to temporal decorrelation and atmospheric disturbances.
- No PRF and phase synchronisation required (backup solution).

**Bistatic**
- One satellite transmits and both satellites receive simultaneously.
- Requires PRF and phase synchronisation.
- Provides three interferograms with two baselines in a single pass.
- Enables precise phase synchronisation, calibration, and verification.

**Alternating Bistatic**
- Transmitter alternates between PRF pulses.
- Provides three interferograms with two baselines in a single pass.

**Experimental mode**
- Provides in one pass two different baselines (1 monostatic and 1 bistatic) in a single polarisation.

\[ Kz2 = 2\times Kz1 \]
X-band Inversion

\[ f(z) = \sigma v_0 \exp \left( \frac{2 \sigma z}{\cos \theta_0} \right) \]

\[ \gamma(\tilde{w}) = \exp(i\phi_0) \gamma_V \]

\[ \tilde{\gamma}_V(f(z)) = \frac{\int_0^h f(z) e^{ikz} dz}{\int_0^h f(z) dz} \]

Volume Height \( h_V \)

Form Factor \( \sigma \)

\[ m(\tilde{w}) = \frac{m_G(\tilde{w})}{m_V(\tilde{w})_0} \]

Vertical Wavenumber \( k_z = \frac{\kappa \Delta \theta}{\sin(\theta_0)} \)

Ground Phase \( \phi_0 \)

Exponential Backscattering profile

Single Pol Single Baseline

Dual Pol Single Baseline

A priori information (LIDAR)

Estimated from data

Volume Coherence

Single Pol Single Baseline

Exponential Backscattering profile
X-band Inversion

Vertical Wavenumber \[ k_z = \frac{\kappa \Delta \theta}{\sin(\theta_0)} \]

Volume Coherence

\[ \tilde{v}_V(f(z)) = \frac{\int_{0}^{h_y} f(z) e^{i k_z z} \, dz}{\int_{0}^{h_y} f(z) \, dz} \]

Exponential Backscattering profile

\[ f(z) = \sigma v_0 \exp\left(\frac{2 \sigma}{\cos \theta_0} z\right) \]

Ground Phase \( \varphi_0 \)

A priori information (LIDAR)

\[ \tilde{v}(\tilde{w}) = \exp(i \varphi_0) \tilde{v}_V \]

No ground phase needed

Observables

\[ Y_V(k_z) = \begin{vmatrix} \int_{0}^{h_y} f(z) e^{i k_z z} \, dz & h_y \\ \int_{0}^{h_y} f(z) \, dz & \sigma \end{vmatrix} \]

Unknowns

\[ Y_V(k_{z1}1) \]

\[ Y_V(k_{z2}2) \]

\[ k_{z1} \neq k_{z2} \]
Mawas Test Site

- Peat swamp forest
- Forest Height: 15m – 25m
- Biomass around 100-350t/ha
- Uniform structure
- Open canopy
- Flat Topography

Dry Season ~ April to November
Wet Season ~ November to April

Lidar Measurements August 2011

<table>
<thead>
<tr>
<th>Date</th>
<th>Baseline [m]</th>
<th>Incidence angle</th>
<th>Kz</th>
<th>Height of ambiguity</th>
<th>Polarisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. September 2011</td>
<td>113</td>
<td>36.7°</td>
<td>0.12/0.25</td>
<td>51m/25m</td>
<td>VV</td>
</tr>
</tbody>
</table>
Mawas Baseline sensitivity

Second Baseline not sensitive to heights larger than 25m
> Underestimation expected

Height of Ambiguity

Kz 1st = red
Kz 2nd = blue
## Data Overview

### Dual Baseline data sets

<table>
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<tr>
<th>Date</th>
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### Dual Pol data sets:

**Time Serie of 5 acquisitions in VV**

<table>
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<tr>
<th>Date</th>
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<th>Height of ambiguity</th>
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</tr>
</thead>
<tbody>
<tr>
<td>25. August 2011</td>
<td>92</td>
<td>30.5°</td>
<td>0.12</td>
<td>52m</td>
<td>HH/VV</td>
</tr>
<tr>
<td>13. December 2011</td>
<td>54</td>
<td>30.5°</td>
<td>0.07</td>
<td>89m</td>
<td>HH/VV</td>
</tr>
<tr>
<td>24. December 2011</td>
<td>55</td>
<td>30.5°</td>
<td>0.07</td>
<td>89m</td>
<td>HH/VV</td>
</tr>
<tr>
<td>4. January 2012</td>
<td>58</td>
<td>30.5°</td>
<td>0.08</td>
<td>79m</td>
<td>HH/VV</td>
</tr>
</tbody>
</table>
Mawas Alternating Bistatic Coherence

Amplitude

Coherence Bsl.1

Coherence Bsl.2
Mawas Alternating Bistatic Phase

Amplitude

Phase Bsl.1

Phase Bsl.2
Mawas Zoom Area of Interest

Amplitude with Lidar H100

Coherence Bsl.1

Coherence Bsl.2
Scattering Centre Height I

Amplitude with Lidar H100

Scattering Centre height over Coherence Bsl. 1

10.5m

$r = 0.92$
$RMSE = 10.5$
Sacattering Centre Height Temporal Evolution

25. August 2011
9.7m

4. September 2011
10.5m

13. December 2011
9.5m

Rain Season

24. December 2011
9.1m

4. January 2012
8.8m
Mawas Single Baseline 1

Amplitude with Lidar H100

Single Baseline Height First Baseline over Coherence

Offset due to dry forest condition (seasonal effect)
Mawas Single Baseline 2

Amplitude with Lidar H100

Single Baseline Height Second Baseline over Coherence

2nd

4.7m

1st

3.6m

Offset increases due to limited baseline sensitivity
Mawas Single Baseline Temporal Evolution

25. August 2011

3.7m

4. September 2011

3.6m

4. January 2012

1.9m

Rain Season

13. December 2011

2.3m

24. December 2011

2.1m

4. September 2011

4.7m

2nd
Mawas Dual Baseline I

Amplitude with Lidar H100

Dual Baseline Height over Coherence Bsl. 1

5.1m

2nd 4.7m

1st 3.6m
Mawas Comparison Dual Baseline vs. Dual Pol

25. August 2011

6.4m

4. September 2011

5.1m

13. December 2011

6.0m

Rain Season

13. December 2011

5.7m

4. January 2012

5.6m
Concluding Remarks

• Baseline limitations:
  Degraded performance of Dual Baseline Inversion due to insensitivity of the large baseline to high forest heights

• Seasonal effects in Heights Estimation could be observed (dry leafless treetops become invisible to the radar)

• Dual baseline inversion seems to perform better than dual pol inversion

• Probably insufficient polarisation dependent ground contribution for this forest type in X-band. Dual baseline inversion helps to solve this problem