Regional to global radar based observations of tropical forests and detection of change:
Towards and operational forest monitoring system for GEO

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Overview

• Forest monitoring requirements
  – Information requirements: Forest Carbon Tracking (FCT) task
  – National demonstrators (2009)

• The importance of radar
  – Radar systems
  – Integration with optical data

• Scaling and supportive datasets
  – Land cover information
    • Time series classifications
  – Forest inventory
    • Biomass
    • Structural attributes
  – Airborne data and derived products
    • LiDAR (height, cover, biomass)
    • Optical/hyperspectral (species, cover)

• Approaches to product generation
  – Forest/non-forest maps
  – Biomass, degradation and regrowth maps
Information requirements

• Forest/non-forest maps
  – Wall-to-wall, annual, 25 m mosaics
• Forest/non-forest
  – Annual trends
  – Accuracy metrics
• Forest degradation
  – Types and trends
• Context information
  – Land use
  – Forest classes
  – Plantation type
• Sparse woody perennial cover
• Biomass (carbon) stocks and changes
Forest Monitoring: National Demonstrators

- Established in 2009 to demonstrate capabilities for deriving forest cover information
- Key test sites
  - South America, Africa, Asia and Oceania
- Optical and radar data
  - 25 m spatial resolution
  - Annual wall-to-wall mosaics
- Near simultaneous remote sensing and ground observations
- Intensive validation sites
  - Forest inventory
  - High resolution remote sensing data
Current radar systems

- Complement optical data
- Key criteria for use:
  - Global, systematic, ongoing continuity, capacity to contribute to GEO objectives (e.g., forest/non-forest discrimination)

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Operational dates</th>
<th>Imaging mode</th>
<th>Target revisit time</th>
<th>Swath width (km)</th>
<th>Spatial resolution (m)</th>
<th>Incidence angle (°)</th>
<th>Cost (/km²)</th>
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<tbody>
<tr>
<td>Archive</td>
<td></td>
<td>C-, L-, P- Full pol</td>
<td>Target dependent</td>
<td>10 – 15</td>
<td>10</td>
<td>0 – 70</td>
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<td>AIRSAR POLSAR</td>
<td>1993 – 2000</td>
<td>C- interferometer</td>
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<td>JERS-1</td>
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<td>L-HH</td>
<td>44 days</td>
<td>75</td>
<td>18</td>
<td>32 – 38</td>
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<td>SRTM</td>
<td>Feb 2000</td>
<td>C-HH+VV and X-HH+VV</td>
<td>11 day mission only</td>
<td>50 – 225</td>
<td>30 – 90</td>
<td>17 – 65</td>
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<td>Dual Freq X-HH+HV and P-HH+HV LiDAR profiler</td>
<td>Target dependent</td>
<td>20</td>
<td>1.25 – 3 (X-), 1.25 – 5 (P-) 5 m (DEM)</td>
<td>34.3 – 41.5</td>
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<td>9.7 – 50.8</td>
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<td>1991-, 1995-</td>
<td>C-VV</td>
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<td>80 – 100</td>
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<td>C-HH</td>
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<td>10 – 100</td>
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<td>0.02 – 1.98</td>
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<td>C- Quad pol</td>
<td>24 days</td>
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<td>0.3 – 3.41</td>
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Radar: all weather, day and night observations, cloud and haze penetrating
Information content: optical *versus* radar

- **Optical data**
  - Retrieve information on 2D structure
  - 3D structure inferred

- **Radar data**
  - Lower frequency
    L-band microwaves penetrate canopy
  - 3D structure observed
Different frequencies of radar

AIRSAR 5 m - Fly River, PNG
Different polarisations of radar

• Different scattering mechanisms
  – Volume scattering
  – Double bounce
  – Single bounce
• Provision of retrieval of component biomass
Historical links: Decadal time-series data

Irian Jaya Indonesia / Papua New Guinea

JERS-1 1996 (1992-98) HH

PALSAR 2007 (2007-) HH, HV, Ratio
Time-series datasets: Annual

- Derive trend information about land use and forest cover changes
- Conversion of mangroves for aquaculture, Perak, Malaysia
Time-series datasets: Intra-annual
Provision of dry and wet season data

JERS-1 mosaic, SE Asia
Shimada et al., 2002

Dry season Jan/Feb 1997
Wet season Aug 1998
Integrating SAR data of different frequencies

- X-band VV magnitude
- P-band HH magnitude
- GeoSAR Height retrieval
- $H_{\text{int}}$ surrogate veg height (X- minus P-band height)
- GeoSAR magnitude
- PNG terrain classification
- Segmented span image (DEM difference & magnitude)
Scaling and supportive datasets

- Interpretation and validation of radar classifications
- Terrestrial laser scanner – complement ground measurements and derive vegetation parameters to interpret full waveform LiDAR – scale up to, and interpret radar
Species/community mapping

- Individual tree crown delineation and species differentiation
- Automated clustering to map community composition
Tree to Stand Level Products

Tree height (LiDAR)

Species (Hyperspectral)

Location and density of stems (LiDAR)

Stand-level biomass

Biomass: Leaf

Branch

Trunk

Total

(Integration with data from optical sensors)
Approaches to product generation

- Forest/non-forest
  - Landsat FPC which gives clear cut between forest and non-forest
  - QLD threshold 12% FPC (~20% canopy cover)
  - FPC is a measurable biophysical parameter
  - Radar equivalent using thresholds applied to L-band data and biomass
Approaches to product generation

- **Classification**
  - Pixel-based
  - Object orientated
Woody Regrowth Mapping

Landsat-derived Foliage Projected Cover
Woody Regrowth Mapping

Advanced Land Observing Satellite (ALOS)
L-band SAR (HH)
Approaches to product generation

- Biomass – indirect measurement using allometry
  - Intensity relationships
  - Polarimetric interferometry
- Increase knowledge of carbon stocks & biodiversity
• Time-series airborne LiDAR to detect environmental change
• Detection of change based on time-series comparison of SAR data requires robust field data to support interpretation and development of algorithms
Quantifying land/forest use

• Logging monitoring: TerraSAR-X Spotlight mode 1 m
Land/forest use

- Selective tree death – dead standing timber
- High L-band backscatter but low FPC
Land/forest use

- Treatment of pastures – detection of chaining or strip ploughing
Deforestation: importance of time-series

- Landsat time-series 1973-2003, Manuas, Brazil
  - Information on forest age but also history of land use prior to abandonment to regenerating forest
Regrowth mapping using multi-frequency radar

Reduced return from Acacia-dominated regrowth with decreasing frequency

Areas of *Acacia* regrowth particularly prominent (red) in total power image (C-band in red)
Concluding remarks

- Forest monitoring requirements
  - Required products for National Demonstrators
- The importance of radar
  - Time-series from 1990s-
  - Cloud-penetrating
  - Different frequencies and polarisations
  - Integration with optical data
- Supportive datasets
  - Land cover information
  - Forest inventory: biomass and structure measurements
  - Airborne data and derived products:
    - LiDAR (height, cover, biomass)
    - Optical/hyperspectral (species, cover)
- Approaches to product generation
  - Forest/non-forest maps: integration with optical, e.g., Landsat FPC
  - Approaches to classification
  - Integration of radar and optical data for mapping regrowth
  - Biomass maps: intensity and polarimetric interferometry
  - Land/forest use, degradation and regrowth maps