GFOI Expert Workshop 1: Sensor interoperability (and sensor complementarity)

SAR – optical complementarity and interoperability within Australia’s operational forest monitoring framework

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10-11 June, 2014
Brief Presentation Outline

• Overview of Australia’s carbon accounting framework
  – Methods
  – Other products

• Study area and datasets

• SAR – optical complementarity

• SAR – optical interoperability

• Conclusions
Australia’s Land Cover Change Program

• Part of Australia’s National Inventory system
  – reports on Australia’s greenhouse gas emissions
  – compiled under the reporting rules applicable to the UNFCCC and the Kyoto Protocol

• Land Cover Change Program:
  – identify where and when human-induced land cover change occurs – e.g. land clearing and forestry, key drivers of the pattern of greenhouse gas emissions
  – operational system (continuous monitoring): Landsat coverage (MSS, TM, ETM+, OLI) for 22 time epochs between 1972 and 2013, annual updates
  – operates at large scale (national/continental): ~769 million hectares, 25 m pixel resolution

Australia’s Land Cover Change Program

- Follows consistent QC protocols and specifications for land cover change
- Focus on interpretability, simplicity, computing efficiency, accuracy, verifiable methods, etc.
- Methods:
  - discriminant analysis
  - thresholding
  - spatial-temporal processing (missing data & uncertainty)
- F/NF estimates
  → Integration of SAR data
  - flexible framework
  - "minimum cost" approach
Australia’s Land Cover Change Program

Related operational product: sparse forest monitoring (5 – 20% canopy cover)

Australia’s Land Cover Change Program

Related operational product: vegetation density trends (forest degradation)

Australia’s Land Cover Change Program

Related operational product: mapping plantation type (pre/post-1990, hardwood/softwood)

Australia’s Land Cover Change Program

Indonesia’s National Carbon Accounting System (INCAS)
Study Area and Datasets

• Tasmania
  – 6.8 million ha
  – elevation to 1,500 m
  – varied land cover / land use
  – 9 bioregions, 3 calibration sites
  – GEO-FCT demonstrator

• Landsat data
  – 19 epochs, 1972 – 2010
  – 25 m pixel size

• ALOS PALSAR data
  – 4 epochs, 2007 – 2010
  – HH / HV dual polarisation
  – 12.5 m pixel size

IBRA bioregions
1. King Island (4,256 km²)
2. Northern Slopes (6,231 km²)
3. Flinders (5,375 km²)
4. West (15,651 km²)
5. Central Highlands (7,678 km²)
6. Northern Midlands (4,154 km²)
7. Ben Lomond (6,575 km²)
8. Southern Ranges (7,572 km²)
9. South East (11,318 km²)
SAR – Optical Complementarity

Discriminant analysis: using Canonical Variate Analysis

- quantify the level of forest discrimination achieved by various band combinations
  → significant complementarity between PALSAR and Landsat

- similar analysis carried out with PALSAR texture

<table>
<thead>
<tr>
<th>image bands</th>
<th>Mathinna</th>
<th>Takone</th>
<th>Warra</th>
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</thead>
<tbody>
<tr>
<td><strong>PALSAR</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>HH</td>
<td>22.2 %</td>
<td>19.7 %</td>
<td>21.1 %</td>
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<tr>
<td>HV</td>
<td>66.0 %</td>
<td>49.9 %</td>
<td>60.4 %</td>
</tr>
<tr>
<td>HH + HV</td>
<td>66.6 %</td>
<td>50.3 %</td>
<td>60.9 %</td>
</tr>
<tr>
<td><strong>RADARSAT</strong></td>
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<tr>
<td>VV</td>
<td>4.8 %</td>
<td>2.0 %</td>
<td>5.0 %</td>
</tr>
<tr>
<td>VH</td>
<td>14.0 %</td>
<td>5.7 %</td>
<td>12.5 %</td>
</tr>
<tr>
<td>VV + VH</td>
<td>14.8 %</td>
<td>5.8 %</td>
<td>12.9 %</td>
</tr>
<tr>
<td><strong>PALSAR + RADARSAT</strong></td>
<td>68.4 %</td>
<td>50.9 %</td>
<td>62.2 %</td>
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<tr>
<td><strong>Landsat TM</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>best band</td>
<td>54.0 % (B5)</td>
<td>71.2 % (B5)</td>
<td>42.4 % (B5)</td>
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<tr>
<td>best 2 bands</td>
<td>59.5 % (B4, B5)</td>
<td>74.1 % (B5, B6)</td>
<td>47.3 % (B1, B5)</td>
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<tr>
<td>best 4 bands</td>
<td>60.3 % (B2, B4, B5, B6)</td>
<td>76.8 % (B3, B4, B5, B6)</td>
<td>56.1 % (B1, B4, B5, B6)</td>
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<tr>
<td>all bands</td>
<td>61.0 %</td>
<td>76.8 %</td>
<td>58.2 %</td>
</tr>
<tr>
<td><strong>Landsat TM + RADARSAT</strong></td>
<td>72.9 %</td>
<td>80.7 %</td>
<td>69.5 %</td>
</tr>
<tr>
<td><strong>Landsat TM + PALSAR</strong></td>
<td>97.4 %</td>
<td>99.9 %</td>
<td>98.3 %</td>
</tr>
<tr>
<td><strong>TM + PALSAR + RADARSAT</strong></td>
<td>100.0 %</td>
<td>100.0 %</td>
<td>100.0 %</td>
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</table>
## SAR – Optical Interoperability

**Processing of PALSAR data:** single-date F/NF classifications

– classification indices and thresholds → variable both **spatially** and **over time**

<table>
<thead>
<tr>
<th>zone</th>
<th>index 1</th>
<th>index 2</th>
<th>index 1 thresholds</th>
<th>index 2 thresholds</th>
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<td>(4, -9)</td>
<td>(6, 4)</td>
<td>(105.0, 124.0)</td>
<td>(103.0, 118.0)</td>
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<td>(96.0, 117.0)</td>
<td>(95.0, 118.0)</td>
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<td>(4, -8)</td>
<td>(1, 6)</td>
<td>(92.0, 100.0)</td>
<td>(87.0, 99.0)</td>
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<td>(85.0, 96.0)</td>
<td>(85.0, 96.0)</td>
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<tr>
<td>3</td>
<td>(4, -8)</td>
<td>(7, 1)</td>
<td>(109.0, 125.0)</td>
<td>(103.1, 119.2)</td>
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<td>(104.0, 114.0)</td>
<td>(98.0, 115.0)</td>
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<tr>
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<td>(6, -5)</td>
<td>(2, 6)</td>
<td>(26.0, 40.0)</td>
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<td>(26.0, 35.0)</td>
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<td>(5, -5)</td>
<td>(7, 2)</td>
<td>(47.0, 55.0)</td>
<td>(43.0, 75.0)</td>
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<td>(42.0, 54.0)</td>
<td>(43.0, 70.0)</td>
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<tr>
<td>6</td>
<td>(2, -8)</td>
<td>(6, 3)</td>
<td>(117.0, 135.0)</td>
<td>(117.0, 130.0)</td>
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<td>(120.3, 141.2)</td>
<td>(112.0, 125.0)</td>
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<td>7</td>
<td>(3, -10)</td>
<td>(5, 4)</td>
<td>(140.0, 148.0)</td>
<td>(138.0, 153.0)</td>
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<td>(130.0, 140.0)</td>
<td>(130.0, 145.0)</td>
</tr>
<tr>
<td>8</td>
<td>(5, -7)</td>
<td>(6, 3)</td>
<td>(60.0, 90.0)</td>
<td>(57.0, 85.0)</td>
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<td></td>
<td>(63.0, 80.0)</td>
<td>(60.0, 80.0)</td>
</tr>
<tr>
<td>9</td>
<td>(3, -7)</td>
<td>(6, 3)</td>
<td>(95.0, 110.0)</td>
<td>(94.0, 110.0)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(88.0, 105.0)</td>
<td>(90.0, 107.0)</td>
</tr>
</tbody>
</table>
SAR – Optical Interoperability

Processing of PALSAR data: SAR vs. Landsat 2007 classifications
SAR – Optical Interoperability

Landsat 1972
Landsat 2005
Landsat 2006
Landsat 2009
Landsat 2010

PALSAR 2007
PALSAR 2009
PALSAR 2010

spatial-temporal forest classification

1972 SAR-optical F/NF
2005 SAR-optical F/NF
2006 SAR-optical F/NF
2007 SAR-optical F/NF
2009 SAR-optical F/NF
2010 SAR-optical F/NF

2005 – 2009 SAR-optical forest change

SAR – optical interoperability assessment

Landsat 1972
Landsat 2005
Landsat 2009
Landsat 2010

PALSAR 2007
PALSAR 2009
PALSAR 2010

spatial-temporal forest classification

1972 optical F/NF
2005 optical F/NF
2009 optical F/NF
2010 optical F/NF

2005 – 2009 optical forest change

GEO Group on Earth Observations
GFOI Global Forest Observations Initiative

www.gfoi.org/RD
SAR – Optical Interoperability

Tasmania-wide F/NF extents (spatial-temporal model outputs)

- - - - : mixed Landsat – PALSAR time series
--- : Landsat-only time series

→ ~Small differences in “global” F/NF extents (~3% max of total area)
SAR – Optical Interoperability

Tasmania-wide forest change (spatial-temporal model outputs)

--- : mixed Landsat – PALSAR time series
- - - - : Landsat-only time series

→ Significant differences with afforestation & deforestation counts!
SAR – Optical Interoperability

Forest mapping discrepancies...

<table>
<thead>
<tr>
<th></th>
<th>Landsat TM</th>
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<th>ALOS – PALSAR</th>
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<tr>
<td>2008</td>
<td></td>
<td>2009</td>
<td>2010</td>
<td>2008</td>
<td>2009</td>
<td>2010</td>
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</table>

[Images of satellite imagery for each year and sensor pair]
Conclusions

• Limited / partial SAR – optical interoperability within Australia’s current carbon accounting framework
  – existing system and legacy methods
  – large-scale & operational
  – “minimum cost” approach used here

• Improvements in interoperability thus likely to come with increased operational costs (additional resources and/or processing)
  – joint SAR – optical monitoring system developed from the ground up
  – SAR – optical fusion at data level (need to ensure temporal coincidence)
  – investigations of different classifiers, use of segmentation, SAR entropy and/or coherence, ancillary data, etc.

• Will have to account for F/NF discrepancies resulting from different sensing principles (sensor bias)


K. Lowell *et al.* (2012). *Areal sample units for accuracy evaluation of single-date and multi-temporal image classifications*, International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences (Accuracy 2012), pp. 7-12, Florianópolis, SC, Brazil.


Thank you

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