Humid Tropical Forest Monitoring with Multi-Temporal L-, C- and X-Band SAR Data

Janik Deutscher, Karlheinz Gutjahr, Roland Perko, Hannes Raggam, Manuela Hirschmugl, Mathias Schardt
MultiTemp 2017, Bruges, 27.6.-29.6.2017
the project idea

- develop a **forest monitoring** processing line for multi-temporal and multi-sensor SAR data (L, C, X band)

- combine SAR forest change detection results from multiple sensors and/or different time frames on a result level
SAR image data and training/reference data

- data from 4 SAR sensors:

<table>
<thead>
<tr>
<th>sensor</th>
<th>band</th>
<th>mode</th>
<th>nr. of images</th>
<th>time span</th>
<th>orbits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentinel-1</td>
<td>C</td>
<td>IW GRD</td>
<td>36</td>
<td>11-4-2015 to 10-04-2016</td>
<td>7, 109, 161</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>X</td>
<td>MGD-SM</td>
<td>10</td>
<td>19-06-2008 to 08-12-2015</td>
<td>ASC</td>
</tr>
<tr>
<td>TerraSAR-X</td>
<td>X</td>
<td>MGD-SC</td>
<td>4</td>
<td>10-01-2016 to 18-04-2016</td>
<td>ASC</td>
</tr>
<tr>
<td>ALOS PALSAR-1</td>
<td>L</td>
<td>FBD</td>
<td>12</td>
<td>04-07-2007 to 12-07-2010</td>
<td>ASC&amp;DSC</td>
</tr>
<tr>
<td>ALOS PALSAR-1</td>
<td>L</td>
<td>FBS</td>
<td>13</td>
<td>09-01-2010 to 27-02-2011</td>
<td>ASC&amp;DSC</td>
</tr>
<tr>
<td>ALOS PALSAR-2</td>
<td>L</td>
<td>FBD</td>
<td>12</td>
<td>02-03-2015 to 6-10-2016</td>
<td>ASC&amp;DSC</td>
</tr>
</tbody>
</table>

- training/reference data for 2015/2016: Sentinel-2 data / Landsat-7/8 data
- training/reference data for 2007-2011: Spot-5, RapidEye, Landsat; GeoEye, IKONOS
Republic of the Congo test site

- humid tropical forest site near Ouesso in the Republic of the Congo
- a mix of open and dense evergreen and semi-deciduous forests, very open forests with agriculture and some swamp forests.
- forest fires in early 2016
- some logging activities
- previous forest studies

"Vegetation structure and greenness in Central Africa from MODIS multi-temporal data", Gond et al., 2013
A SAR pre-processing workflow was developed in JR RSG software * including:

- data ingestion
- multi-looking
- radiometric terrain correction
- speckle filtering & multi-temporal filtering
- image/stack co-registration
- multi-temporal stack statistics
- orthorectification

* www.remotesensing.at
SAR pre-processing - examples

- S-1 example of multi-temporal SAR filtering (cf. Quegan)

unfiltered GRD scene

MT filter with 11 images
The forest change detection workflow is based on the coefficient of variation of the image stack. A backscatter trend is derived for each pixel. The coefficient of variation and backscatter trend are combined. Assumption: high coeff. variation and negative backscatter trend = vegetation loss. Threshold values for forest change are derived from optical training data. Non-forest areas are removed (based on Global Forest Watch data). Final forest change map per sensor/orbit.
forest change detection workflow - examples

S-1: mean coefficient of variation (VV, VH)
S-1: VV backscatter trend
S-1: combined image
S-1: forest change classification (black: non-forest area GFW)
forest degradation examples

- different types of forest degradation

- selective logging
- deforestation >0.5 ha
- oil palm plantations
- logging roads
- forest fires
mapping examples

combined forest change map from S-1, TSX SM, PALSAR-2 sensors (02.03.2015 to 06.10.2016)

green: forest
white: non-forest (from GFW)
red: forest changes

deforestation & degradation examples:
[1]: areas affected by forest fires
[2]: logging in oil palm plantations
[3]: new logging roads & selective logging
[3b]: re-opening of old logging road
[4]: logging activities at settlements
the derived forest change maps were compared to University of Maryland - GLAD **Humid Tropical Forest Alert** data (Hansen et al., 2016)

yellow: GLAD Forest Alert data from 04/2015-06/2016

red: S-1 forest change map (one orbit/10 images from 11/2015-06/2016)

blue: TSX SM forest change map (from 04/2015-10/2015)

black: non-forest (GFW + Forest Alert data)
the derived forest change maps were compared to University of Maryland - GLAD Humid Tropical Forest Alert data (Hansen et al., 2016)

- yellow: GLAD Forest Alert data from 04/2015-06/2016
- red: S-1 forest change map (one orbit/10 images from 11/2015-06/2016)
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  white: non-forest (GFW + Forest Alert data)
validation of forest change maps

- forest change data by area for Sentinel-1 and GLAD Forest Alert data

<table>
<thead>
<tr>
<th>time frame: 11-4-2015 to 10-04-2016</th>
<th>Forest change area in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLAD Forest Alert data</td>
<td>124.51</td>
</tr>
<tr>
<td>Sentinel-1 change map</td>
<td>143.01</td>
</tr>
<tr>
<td>Identified by both</td>
<td>91.00</td>
</tr>
<tr>
<td>Identified by SAR only</td>
<td>52.01</td>
</tr>
<tr>
<td>Identified by GLAD FA only</td>
<td>34.50</td>
</tr>
<tr>
<td>Total forest area</td>
<td>7567.0</td>
</tr>
</tbody>
</table>

GLAD Forest Alert data signifies 1.65% of total forest area, while Sentinel-1 change map signifies 1.89% of total forest area. Identified by both shows a consistency of 67%.
validation of forest change maps

- A validation was carried out for all forest change maps based on 50 reference areas from optical imagery. Only forest change areas > 0.5ha were considered (=deforestation).

- A more detailed validation based on degradation types was carried out on pixel level (20m) based on multi-temporal optical reference data (S-2, L-7/8). Validation points were selected by an independent researcher.

98% for S-1
96% for TSX
96% for PALSAR-2
76% for PALSAR-1 (6 images covering 3 years)
validation of forest change maps

- Validation by disturbance type: example for Sentinel-1 vs. GLAD Forest Alert data

<table>
<thead>
<tr>
<th>disturbance type</th>
<th>nr. of reference points</th>
<th>% detected by S-1</th>
<th>% detected by Forest Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>burnt forest areas</td>
<td>223</td>
<td>88.3</td>
<td>91.9</td>
</tr>
<tr>
<td>deforestation in oil palm plantation</td>
<td>12</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>deforestation large &gt; 1 ha</td>
<td>19</td>
<td>58.0</td>
<td>100</td>
</tr>
<tr>
<td>deforestation small + degradation &lt; 1 ha</td>
<td>118</td>
<td>78.9</td>
<td>78.9</td>
</tr>
<tr>
<td>selective logging patches &lt; 0.2 ha</td>
<td>7</td>
<td>14.2</td>
<td>14.2</td>
</tr>
<tr>
<td>logging roads</td>
<td>66</td>
<td>75.6</td>
<td>75.6</td>
</tr>
<tr>
<td>∑</td>
<td>445</td>
<td>81.8</td>
<td>85.6</td>
</tr>
<tr>
<td>∑ non-fire disturbances</td>
<td>222</td>
<td>75.2</td>
<td>79.3</td>
</tr>
</tbody>
</table>
validation of forest change maps

- Validation by disturbance type: example for Sentinel-1 + GLAD Forest Alert data

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ongoing research and outlook

- further validation is needed, including commission errors
- test applicability to other forest types (e.g. dry tropical forests)
- develop joint processing lines with optical data (e.g. Sentinel-1 + Sentinel-2)
- develop workflows for near real-time tropical forest disturbance alerts

- MultiTemp2017, Thursday 29th; 10:30; Natural Hazard Session:

“Combined Use of SAR and Optical Time Series Data for Near Real-Time Forest Disturbance Mapping”
Thank you for your interest!

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