Near real-time monitoring of forest disturbance using MODIS data: algorithms and assessment framework

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Objectives

1. Develop algorithms for near real-time monitoring of forest disturbance:
   - Apply prediction model to daily time series of MODIS data
   - Fuse Landsat and MODIS data to overcome inherent variability of sequential MODIS observations

2. Develop framework for assessment of performance of near real-time monitoring systems

3. Develop prototype for operational near real-time monitoring
Base Algorithm: CCDC

- Two term harmonic model to capture the seasonality and trends in surface reflectance
- Detects change by comparing new observation to predicted value

(Zhu and Woodcock, 2014)
Algorithm 1: NRT-CCDC

- CCDC modified for MODIS data
- Daily surface reflectance products screened by view angle threshold (VZA lower than 35°)
- Change detection based on 250 m NDVI
- 500 m Green and SWIR bands used for multi-temporal cloud screening
Algorithm 1: NRT-CCDC

Before change

After change

2013199

2014162

Change

NDVI


0.8  0.6  0.4
Algorithm 2: Fusion approach

- Use swath surface reflectance (MOD09) to identify the footprint of each MODIS observation
- Use Landsat-based time series model to predict the surface reflectance of each MODIS observation
- Change detected by comparing predicted and observed surface reflectance
Algorithm 2: Fusion approach

Residual Time Series

Date

Red (Residual)

Change
Three different time series analyses of a recent deforestation event in Pará, Brazil.
Three different time series analyses of a recent deforestation event in Rondônia, Brazil
MODIS-BASED NEAR REAL-TIME MONITORING

Landsat-based (CCDC): most spatial details

MODIS-based: easiest to implement

Fusion: detects change faster

Three different time series analyses of a recent deforestation event in Rondônia, Brazil

Date of change
Date of detection
Three different time series analyses of a recent deforestation event in Rondônia, Brazil
Deforestation, Para, Brazil (P227R065)

Recent Landsat 8 image

Change map from Fusion

- Blue: Deforestation before 2013
- Red: Deforestation after 2013
Need for assessment framework

- Last 5 years, guidance on statistical inference matured but guidance focused on area estimation of REDD activities as stipulated by IPCC

- Assessment protocols of near real-time studies diverge: non-existent to comparison to non-probability samples, other maps, field plots, etc.

- Augment guidance for NRT: focus on disturbance events, average lag [days] of alerts and minimum disturbance patch [ha]
Application of assessment framework

- Three products: Terra-i + aforementioned algorithms
- Population: three Landsat footprints in Brazil and Colombia
- Stratification: maps combined to identify level of agreement
- Landsat-based information added to capture omission errors
MODIS-BASED NEAR REAL-TIME MONITORING

Forest
1 map flags disturbance
2 maps flag disturbance
3 maps flag disturbance
Non-forest
Landsat-based change
Sample Design

- Stratified Random Sampling
- Total sample size: 765
- Spatial assessment unit: MODIS pixels (250 m)

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Forest</th>
<th>1 Flags</th>
<th>2 Flag</th>
<th>3 Flag</th>
<th>Non-forest</th>
<th>Landsat</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area [ha]</td>
<td>7,091,271</td>
<td>146,859</td>
<td>39,503</td>
<td>14,672</td>
<td>2,346,622</td>
<td>65,847</td>
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<td>Area [Pct]</td>
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<td>1.51%</td>
<td>0.41%</td>
<td>0.15%</td>
<td>24%</td>
<td>0.68%</td>
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<tr>
<td>Samples</td>
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<td>75</td>
<td>75</td>
<td>75</td>
<td>116</td>
<td>75</td>
<td>765</td>
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</table>
Three levels of operational readiness

■ Terra-i:
  ▪ 16-day MODIS NDVI product
  ▪ Operational, updates every three months

■ NRT-CCDC:
  ▪ Daily MODIS gridded surface reflectance (view angle filtering)
  ▪ Easy to implement, operational-ready

■ Fusion:
  ▪ Daily MODIS swath surface reflectance (no filtering)
  ▪ Requires Landsat model in place
  ▪ Have the potential to detect change faster
Operational-ready product

- Result from NRT-CCDC is currently being tested
- Open source; updated daily; [view on internet](https://bullocke.github.io/NRT/)
Summary

■ Work completed:
  ▪ Developed 2 algorithms of near real-time monitoring
  ▪ Developed framework for assessment
  ▪ Collected reference observation for assessment

■ Currently working on:
  ▪ Analysing the results (*What size and magnitude of change can we detect? How soon can we detect it?*)

■ Future work:
  ▪ Publish both algorithms and the framework of assessment (including comparison of the three products)
  ▪ Develop operational-ready products