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

NIR Surface Reflectance
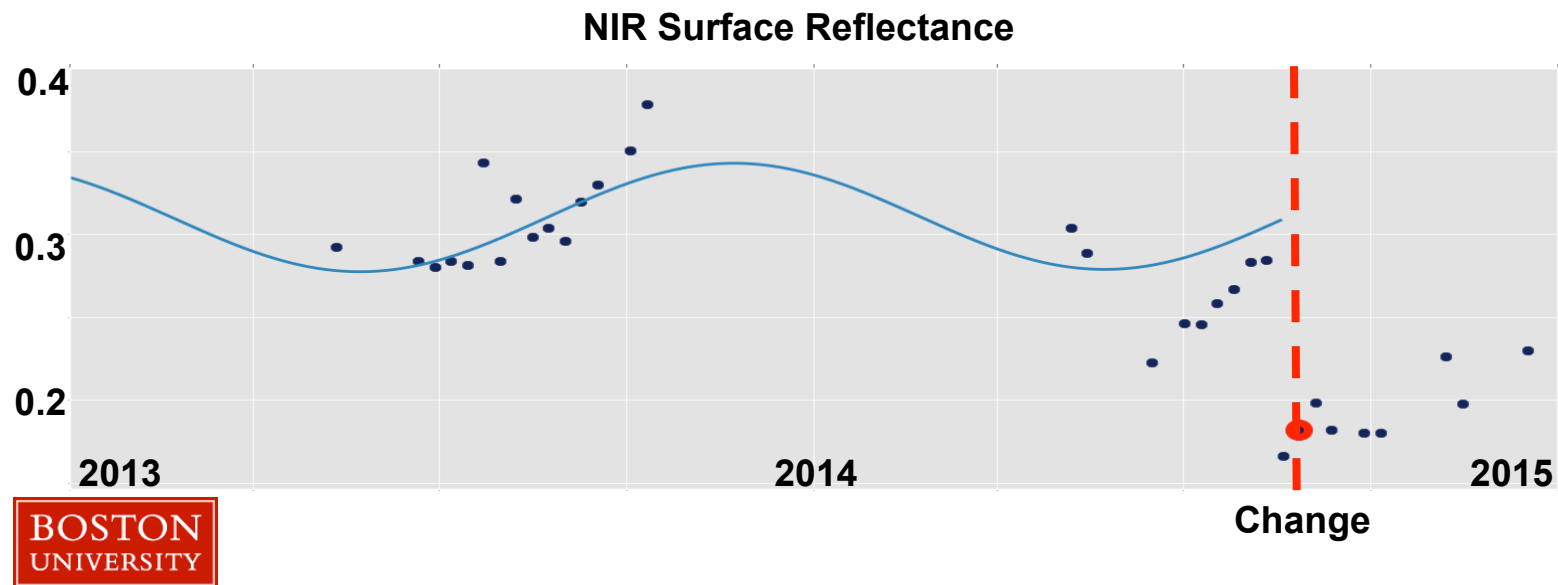
(Zhu and Woodcock, 2014)

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

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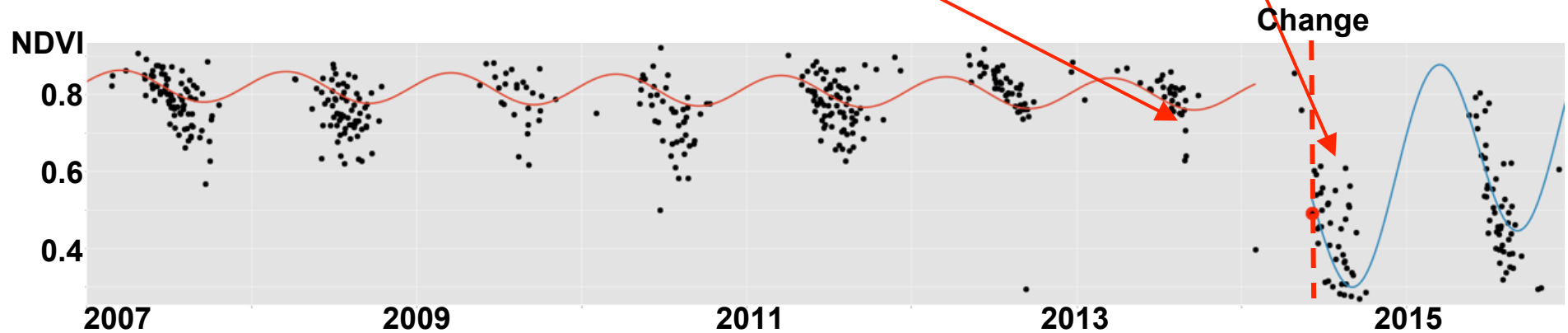# Algorithm 1: NRT-CCDC

Before change

2013199
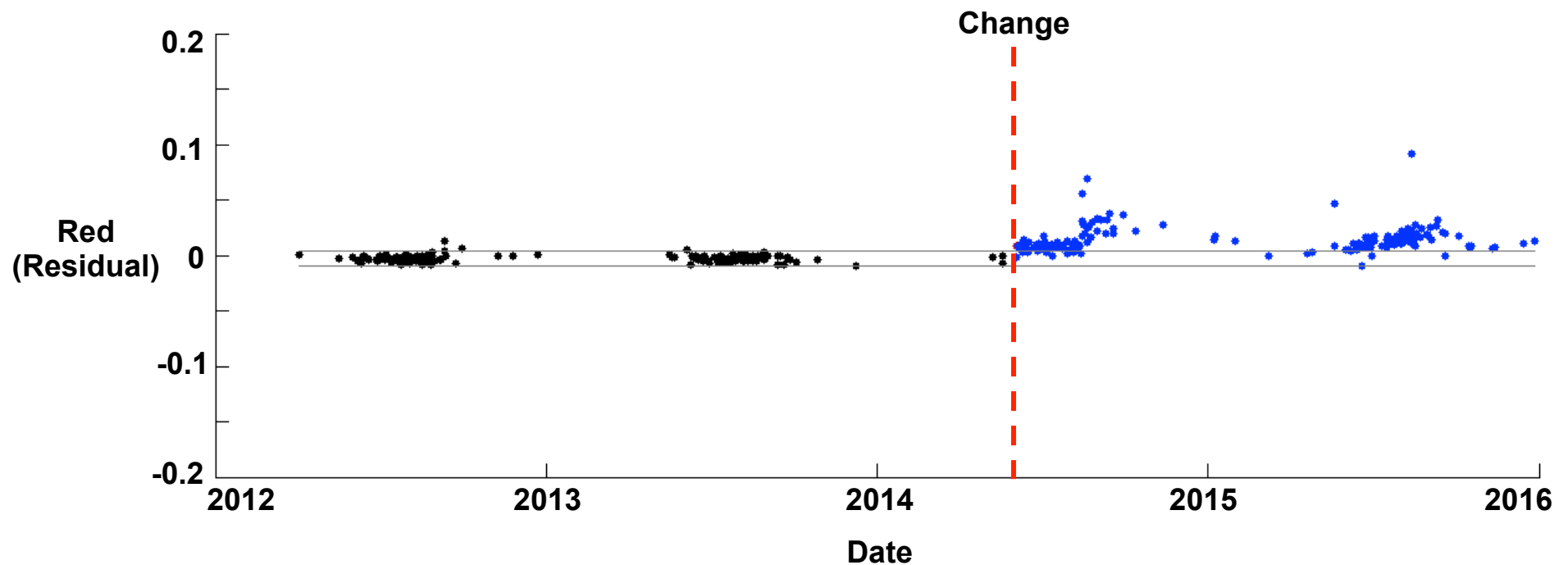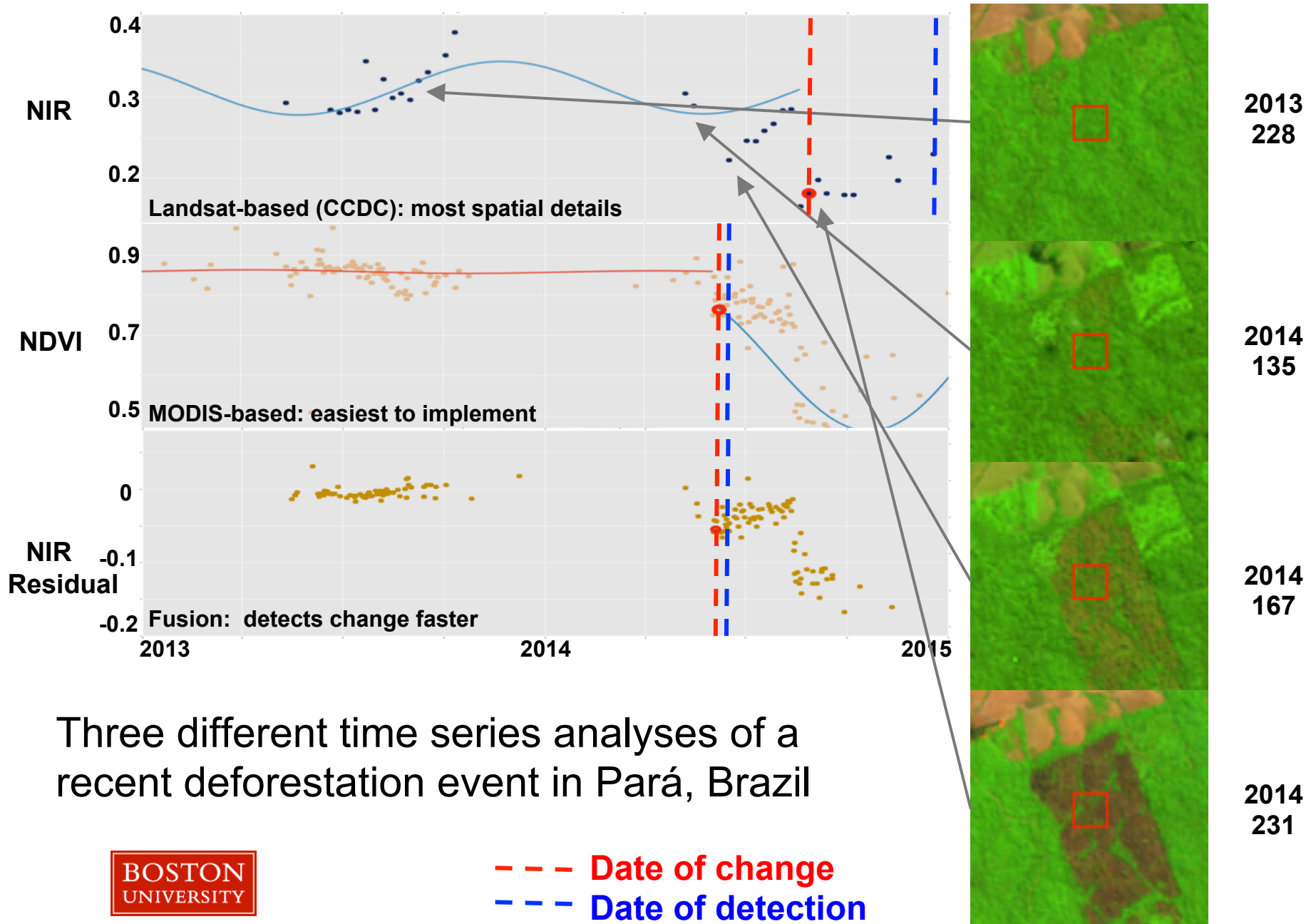
After change

2014162

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

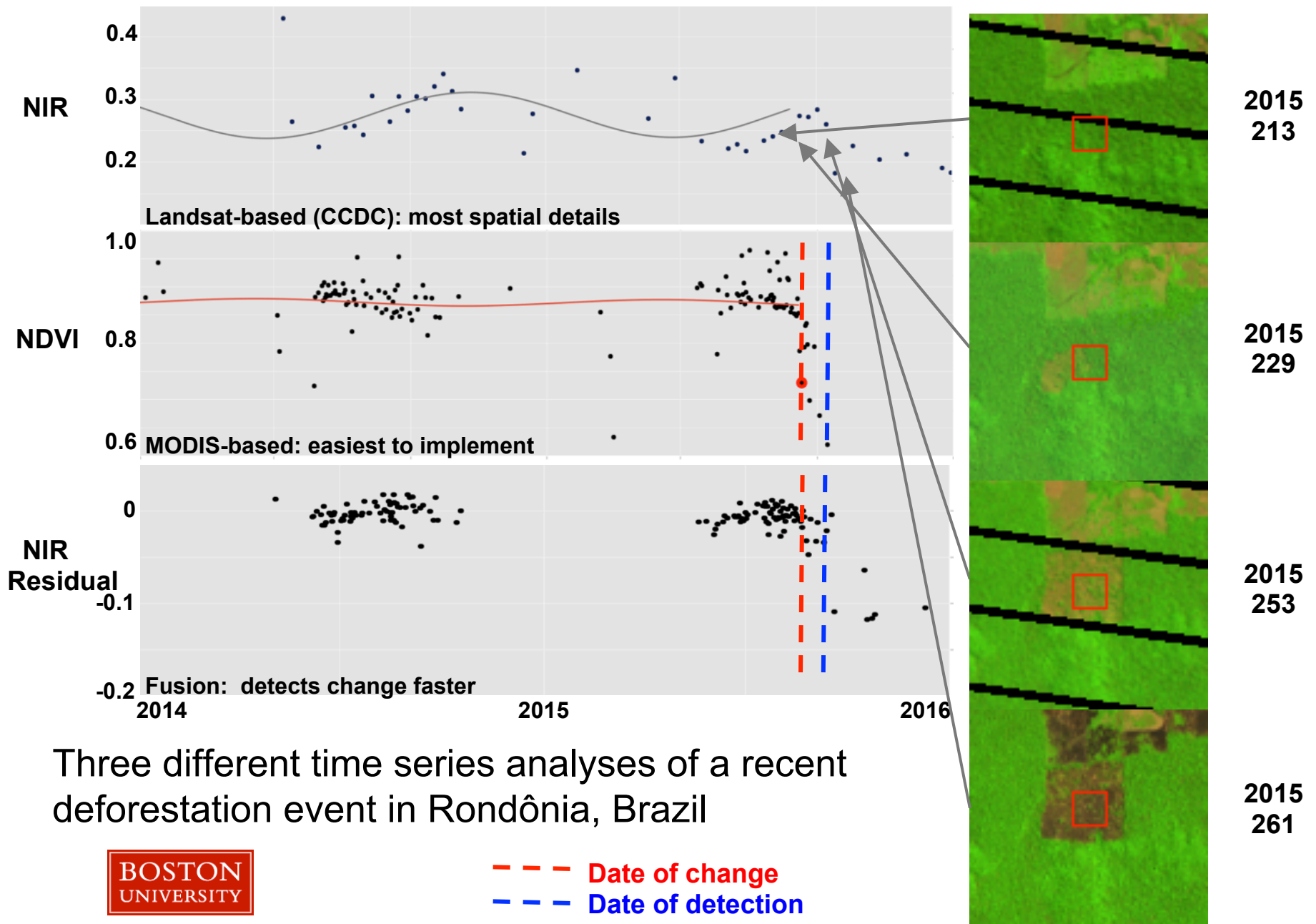- Change detected by comparing predicted and observed surface reflectance

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Algorithm 2: Fusion approach

Residual Time Series

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

Landsat-based (CCDC): most spatial details

MODIS-based: easiest to implement

Fusion: detects change faster

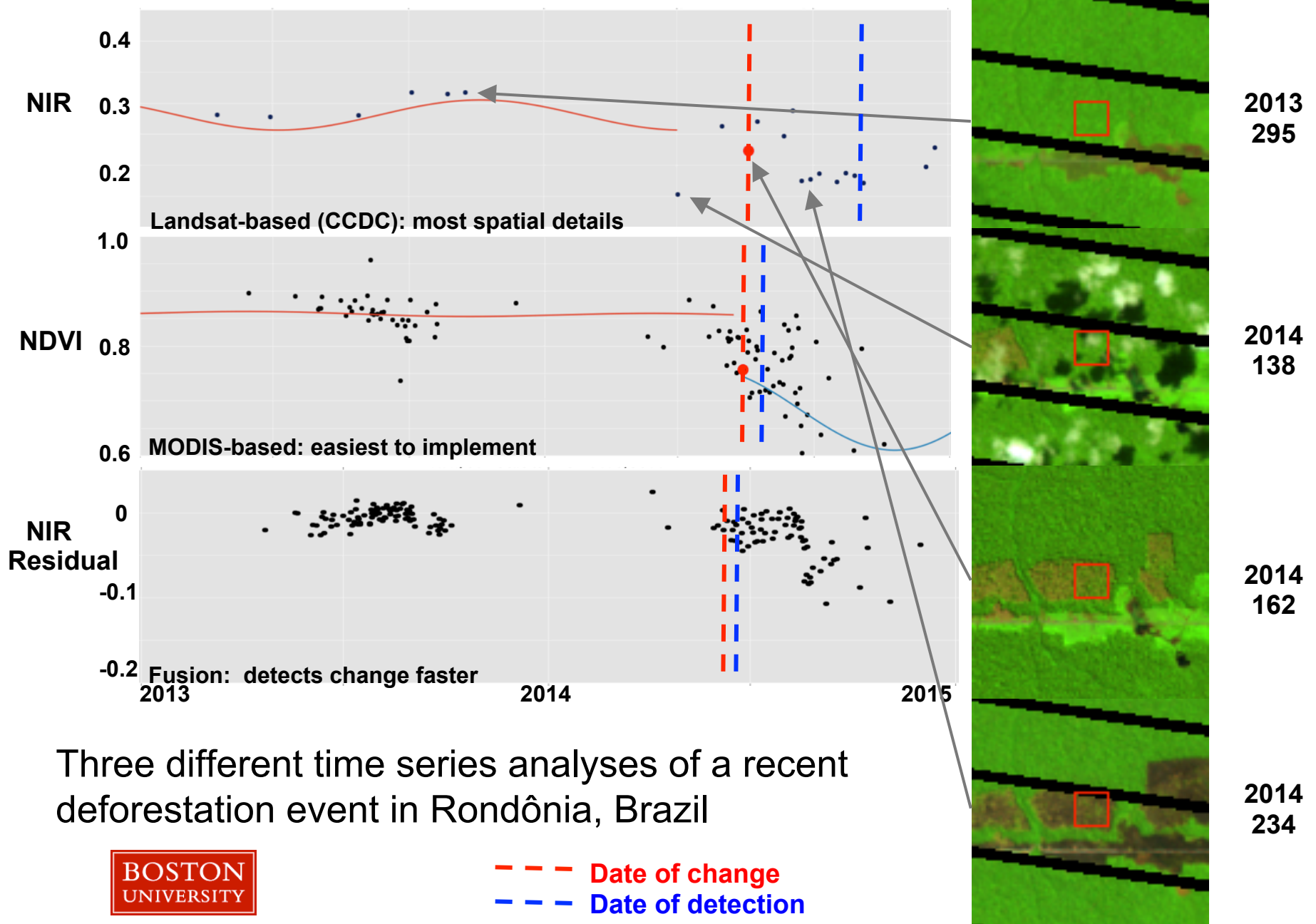- - - Date of change
- - - Date of detection

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

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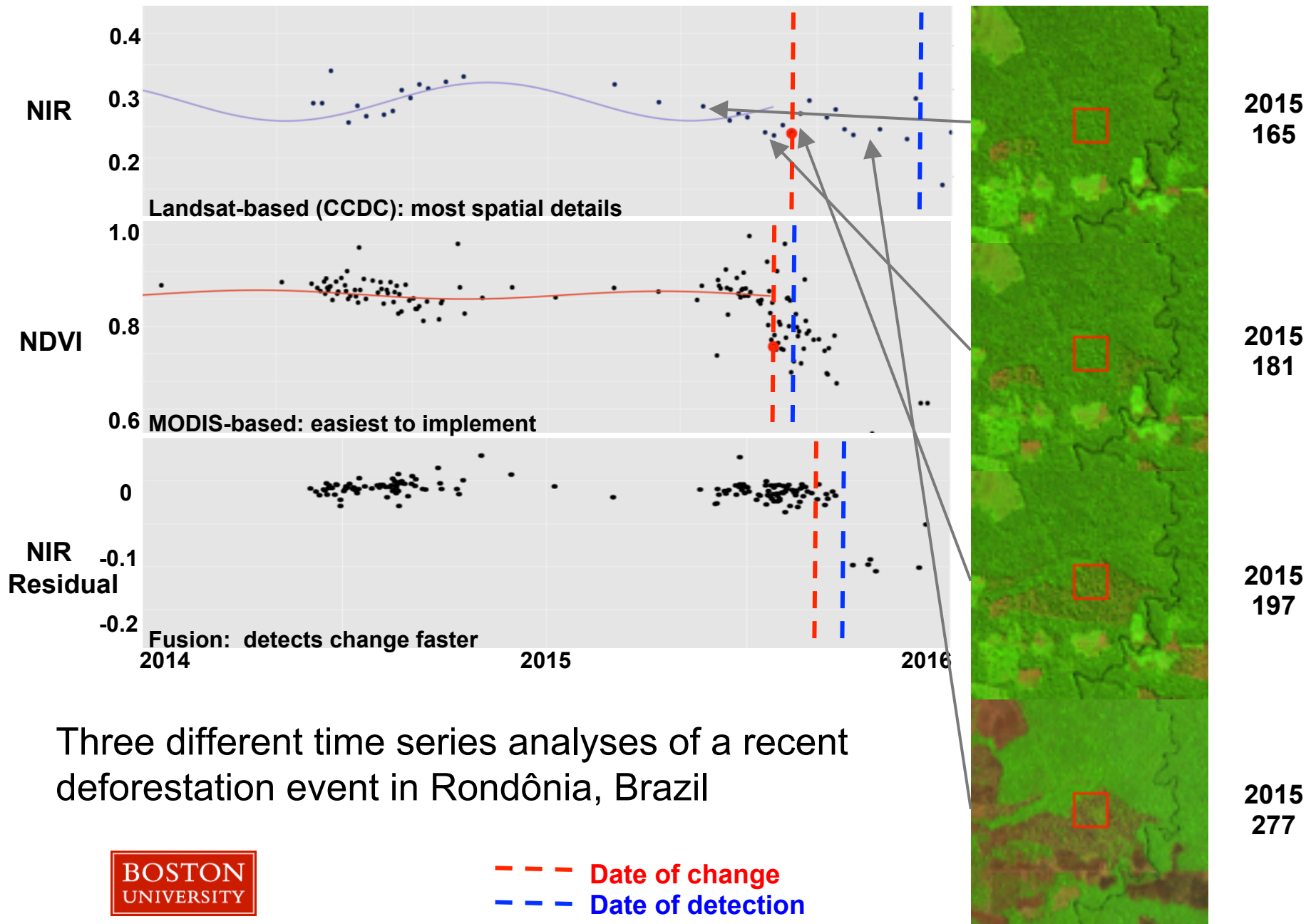
NIR

NDVI

NIR Residual

Landsat-based (CCDC): most spatial details

MODIS-based: easiest to implement

Fusion: detects change faster

2014   2015   2016

2015 165

2015 181

2015 197

2015 277

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

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– – – **Date of change**
– – – **Date of detection**

Deforestation, Para, Brazil (P227R065)

Recent Landsat 8 image
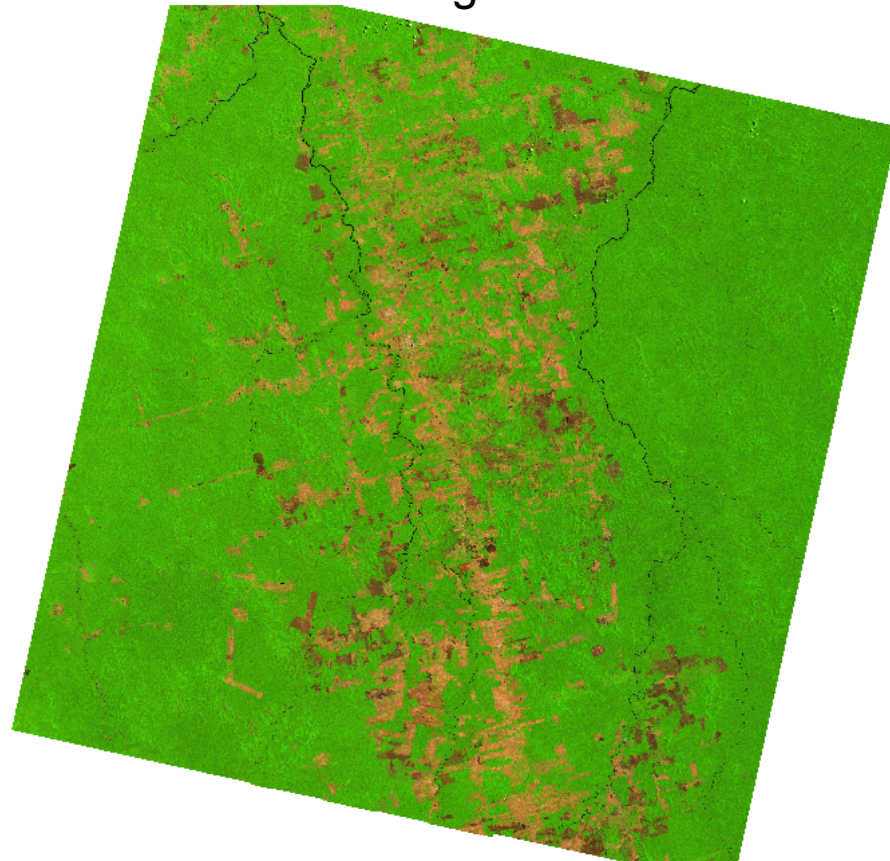
Change map from Fusion
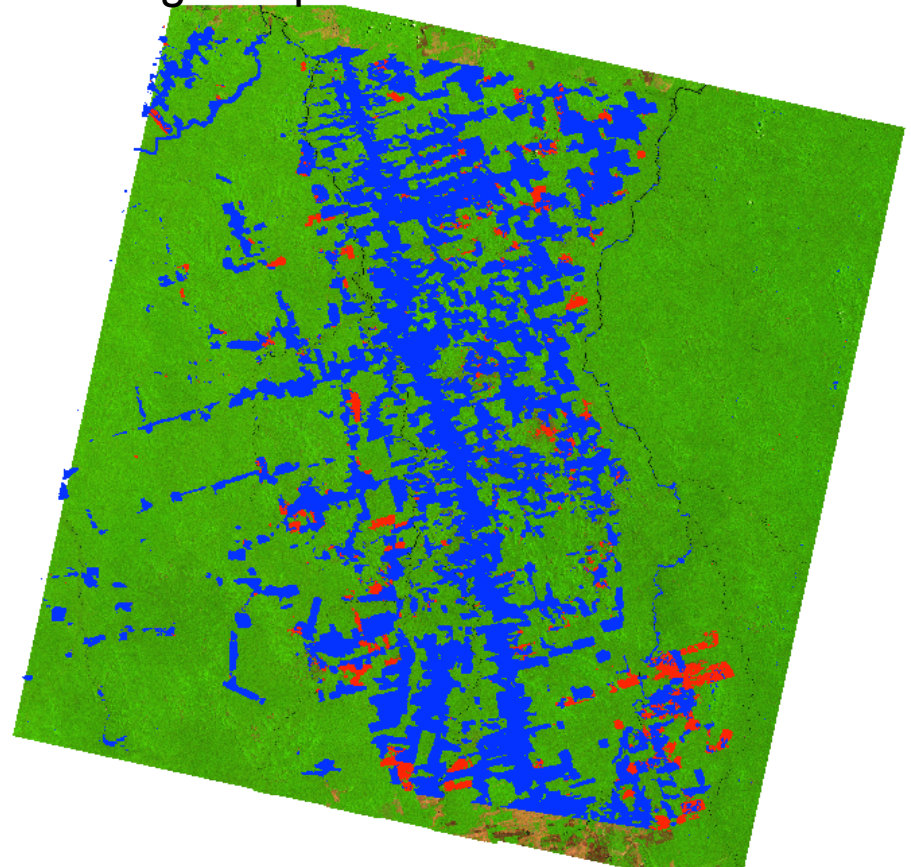
Deforestation before 2013

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]

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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

Colombia

Peru

Bolivia

Legend:
- Forest
- 1 map flag for disturbance
- 2 maps agree on disturbance
- 3 maps agree on disturbance
- Non-forest
- Landsat-based change

0   250   500 km

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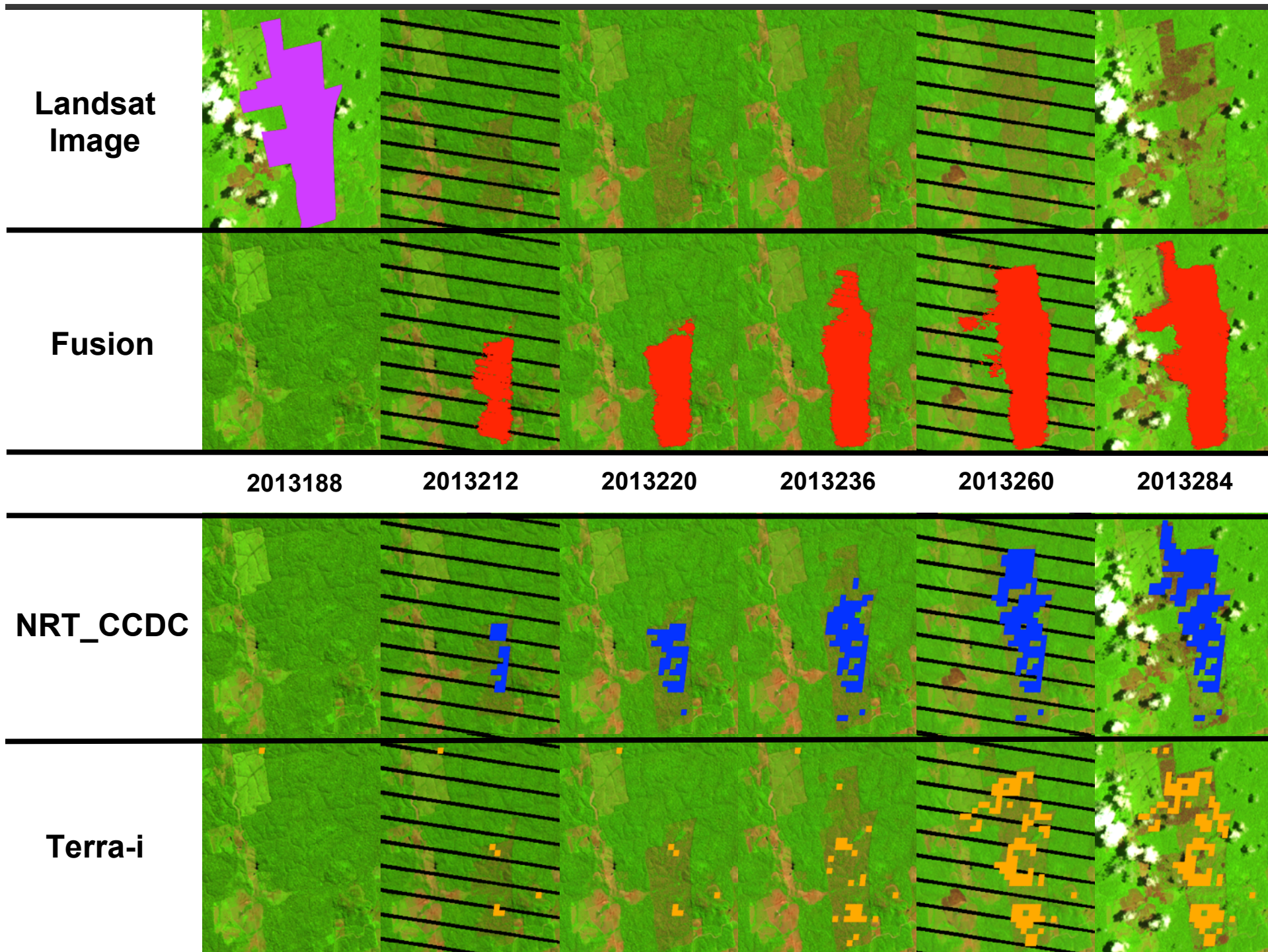Landsat-based change

0   5   10 km
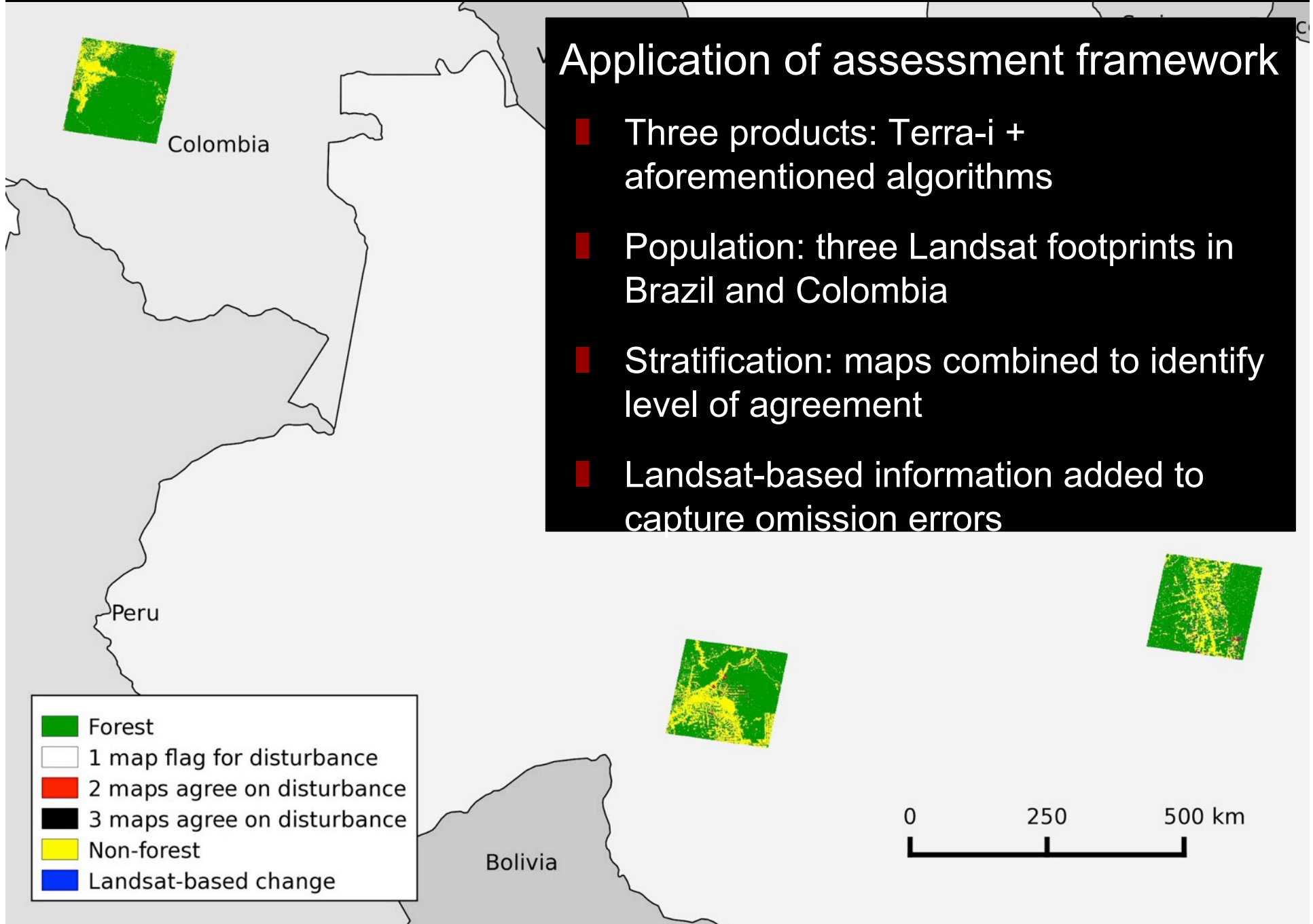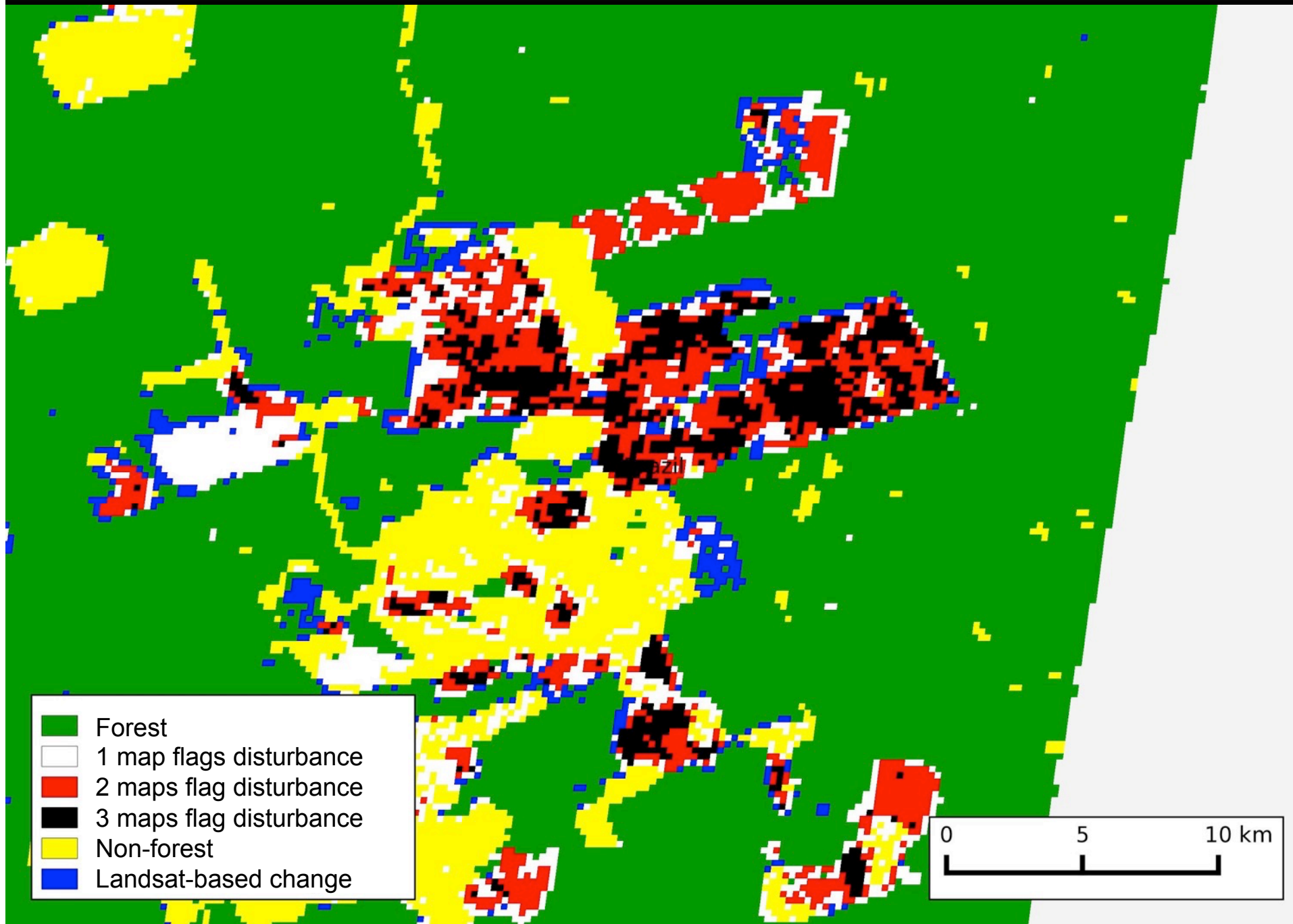
Sample Design

- Stratified Random Sampling

- Total sample size: 765

- Spatial assessment unit: MODIS pixels (250 m)

Stratum	Forest	1 Flags	2 Flag	3 Flag	Non-forest	Landsat	Total
Area [ha]	7,091,271	146,859	39,503	14,672	2,346,622	65,847	9,704,772
Area [Pct]	73%	1.51%	0.41%	0.15%	24%	0.68%	100%
Samples	349	75	75	75	116	75	765

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| Landsat Image | Fusion | NRT_CCDC | Terra-i |

| 2013188 | 2013212 | 2013220 | 2013236 | 2013260 | 2013284 |

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

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Operational-ready product

- Result from NRT-CCDC is currently being tested
- Open source; updated daily; view on internet
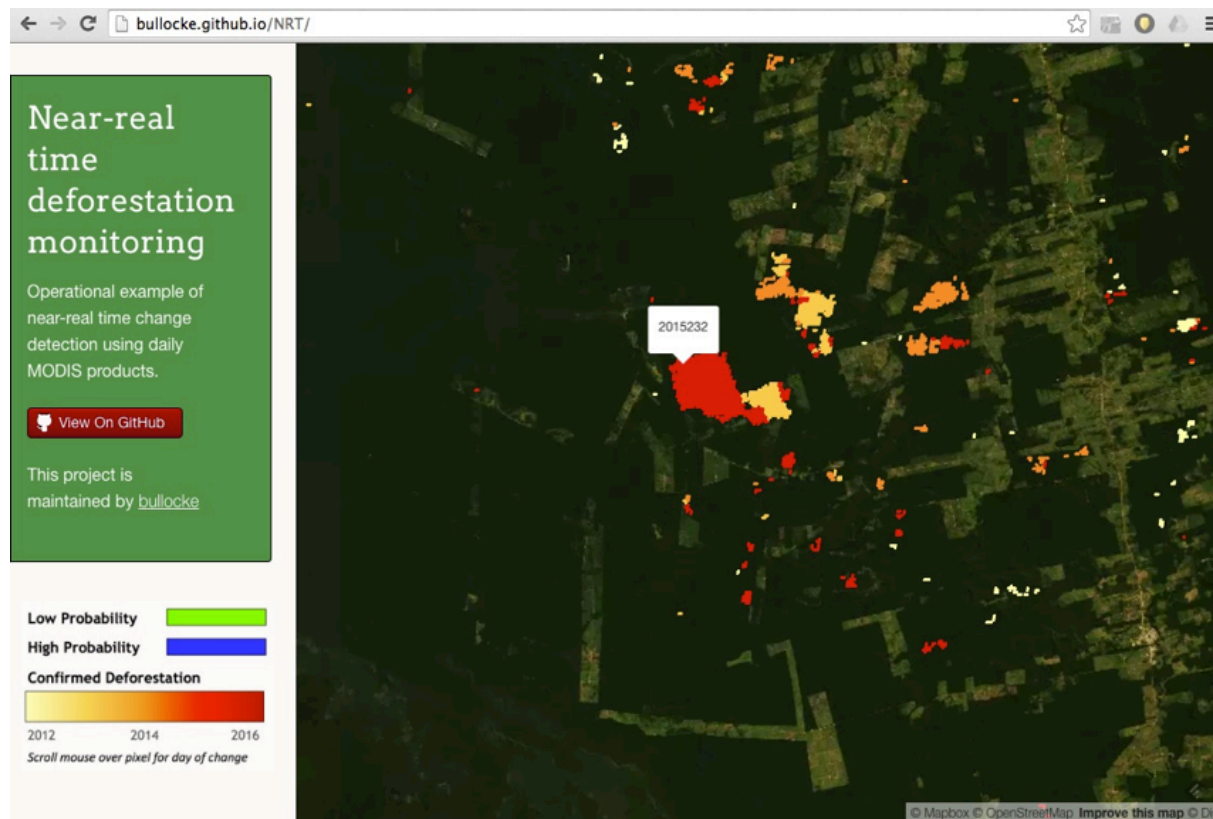
Summary

- **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

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