GOPHER: Global Observatory of Planetary Health and Ecosystem Resources

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Outline

- Motivation for Land Cover Change Detection
- Limitation of Current Techniques
- Brief Overview of New Algorithms
- Illustrative Examples & Global Results
- Validation
- Concluding Remarks

Monitoring Global Vegetation Cover: Motivation

Forestry

- Identify degradation in forest cover due to logging, conversions to cropland or plantations and natural disasters like fires.
- Applications: UN REDD+ , national monitoring, reporting and verification systems, etc.

Agriculture

- Identify changes related to farmland, e.g. conversion to biofuels, changes in cropping patterns and changes in productivity.
- Applications: estimating regional food risks and ecological impact of agricultural practices.

Urbanization

- Identify scale, extent, timing and location of urbanization.
- Applications: policy planning, understanding impact on microclimate, water consumption, etc.

Traditional Approach for Land Cover Change Detection

- Two or more high quality satellite images acquired on different dates are compared for change identification.
- Images differ if a change has occurred between the two dates.

2005

2009

Images for a location in California before and after change in vegetation

Traditional Approach for Land Cover Change Detection

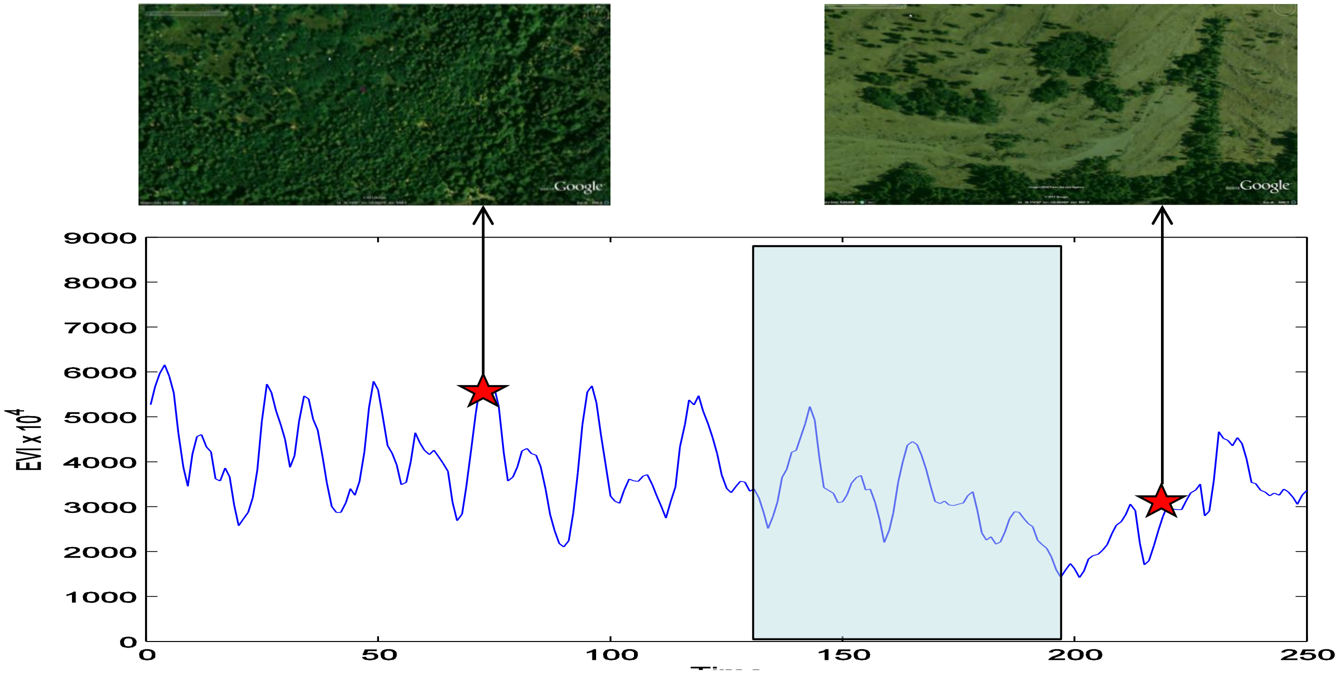
- ➢ Two or more high quality satellite images acquired on different dates are compared for change identification.
- ➢ Images differ if a change has occurred between the two dates.

Limitations:

- ➢ High quality observations are infrequent in many parts of the world such as the tropics.
- ➢ Unable to detect changes outside the image acquisition window.
- ➢ Difficult to identify when the change has occurred.
- ➢ Parameters such as rate of change, extent, speed, and pattern of growth cannot be derived.
- ➢ **Requires training data for each specific change of interest making it inherently unsuitable for global analysis.**

Alternate Approach: Analyzing Vegetation Time Series

- Time series analysis can be used for
  - Identifying changes in land cover
  - Identifying when the change occurred i.e. the exact date of change



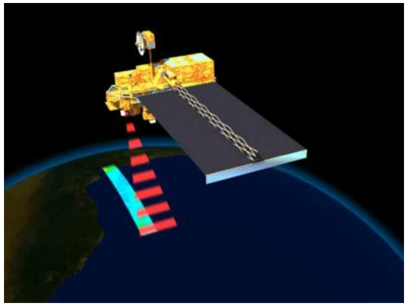
Images

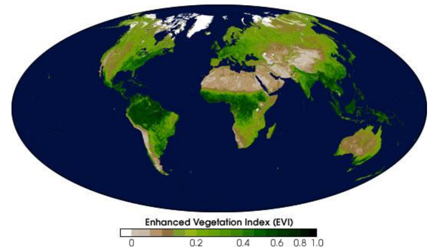
Vegetation Time Series

Existing Time Series-based Change Detection Methods in Remote Sensing

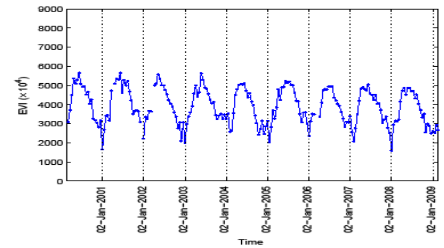
Paper Title	Year	Author
Burned area mapping using multi-temporal moderate spatial resolution data—a bi-directional reflectance model-based expectation approach	RSE 2002	Roy et. al.
Major Disturbance Events in Terrestrial Ecosystems Detected Using Global Satellite Data Sets	GCB 2003	Potter et. al.
Land-Cover Change Detection Using Multi-Temporal MODIS NDVI Data	RSE 2006	Lunetta et. al.
Cumulative Sum Charts - A Novel Technique for Processing Daily Time Series of MODIS Data for Burnt Area Mapping in Portugal	MultiTemp 2007	Kucera et. al.
Land Cover Change Detection: A Case Study **(Recursive Merging)**	KDD 2008	Boriah et. al.
PARASID: Near Real Time Monitoring Of Habitat Change Using A Neural Network And M O D I S Data	2009	Jarvis et. al.
Detecting trends in forest disturbance and recovery using yearly Landsat time series (**LandTrendr**).	RSE 2010	Kennedy et. al.
FORMA: Forest Monitoring for Action— Rapid Identification of Pan-tropical Deforestation Using Moderate-Resolution Remotely Sensed Data	CGD Working paper 2010	Hammer et. al.
Detecting trend and seasonal changes in satellite image time series. **(BFAST)**	RSE 2010	Verbesselt et. al.
A Comparative Study of Algorithms for Land Cover Change	CIDU 2010	Boriah et. al.
Optimal use of land surface temperature data to detect changes in tropical forest cover	JGR 2011	Van Leeuwen et. al.
Monitoring Global Forest Cover Using Data Mining	TIST 2011	Mithal et. al.

Data Used in Our Study: Enhanced Vegetation Index





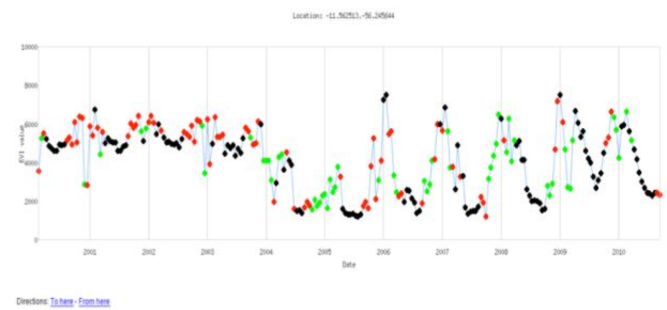
EVI shows density of plant growth on the globe.



EVI time series for a location

- Bi-weekly EVI at spatial resolution of 250m and 1km from MODIS.

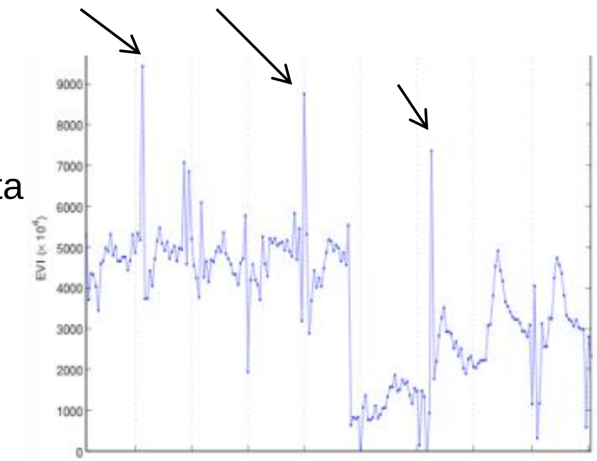
- Our proposed algorithms can be used with any data set, regularly sampled in time and indicating amount of vegetation.



Pixel reliability color coded EVI

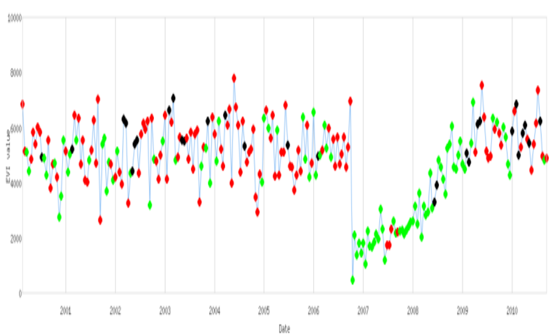
Challenges for Change Detection Methods using Remote Sensing Time Series

- **Poor data quality and high variability**
  - Atmospheric noise in observations
  - Inter-annual variability
  - Algorithms should be robust and work with noisy and variable data



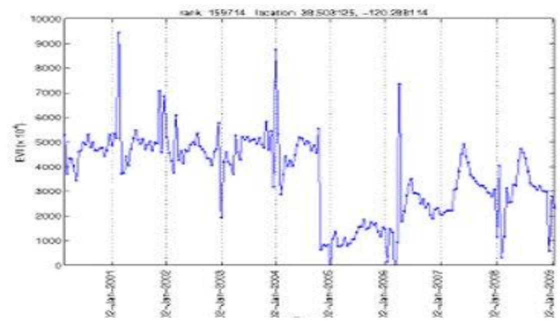
- **Massive data sets: 10 billion locations at 250 m for the globe**
  - Algorithms need to be highly scalable for global applicability

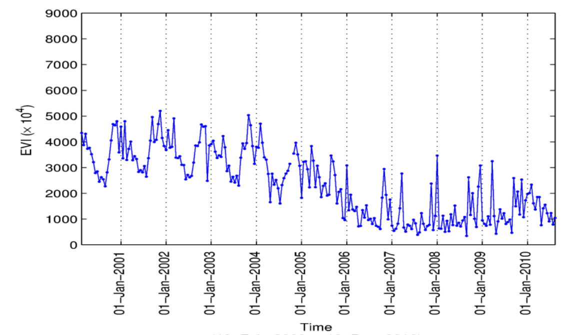
- **Existing methods are unable to address one or more of these challenges thus limiting their global applicability**

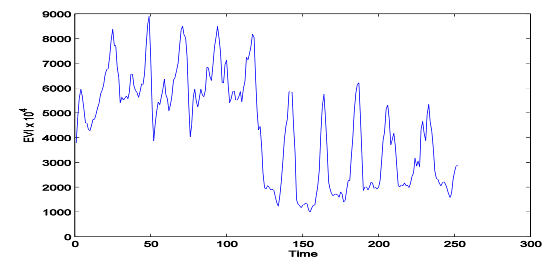


Changes of Interest

- **Abrupt Changes**
  - Large and unexpected reduction in vegetation.
  - Examples: forest fires, mechanized clearings.
- **Gradual Changes**
  - Gradual decrease in EVI, spanning several years.
  - Examples: beetle infestations, gradual logging.
- **Changes in Land Cover Type**
  - Examples: clearing of forests for agriculture, cropping patterns, urban expansion.

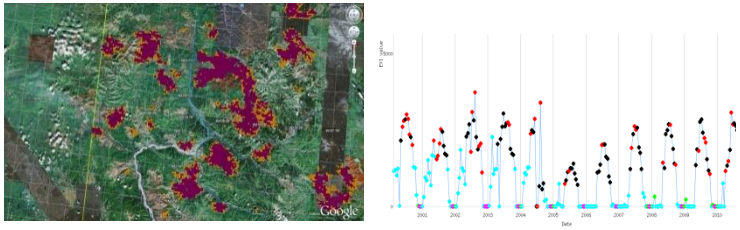






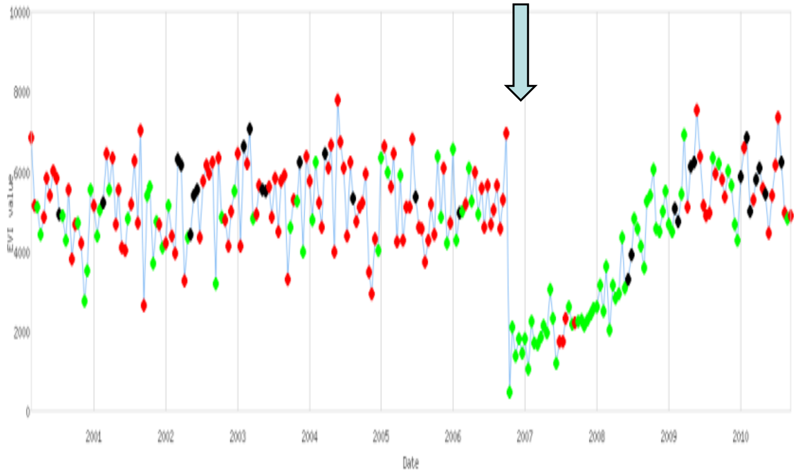
Prediction-based Approaches for Abrupt Change Detection

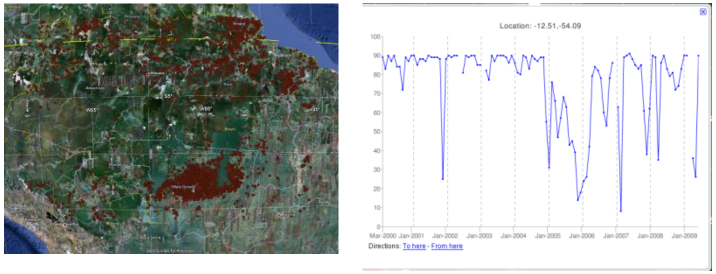
- Build a model for predicting EVI values using previous observations.
- The difference between observed and predicted values is used to identify changes/disturbances.
  - Model needs to account for seasonality, inter-annual variations and noise.



Forest Fires in Yukon, Canada

Change

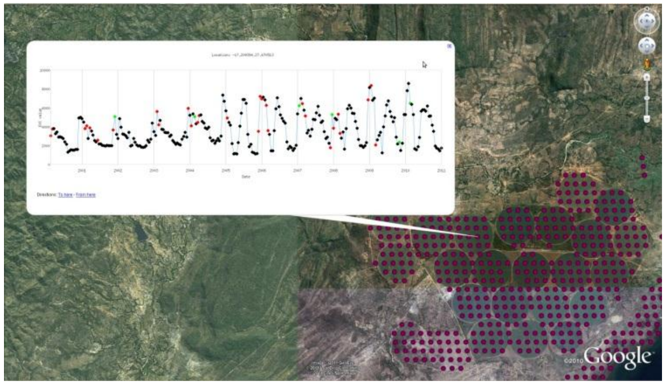




Deforestation in Mato Grosso, Brazil.

Segmentation-based Approaches for Detecting Land Cover Changes

- Divide time series into homogenous segments such that intra-segment similarity is high, inter-segment similarity is low.
- Boundary of segments is considered time of conversion.

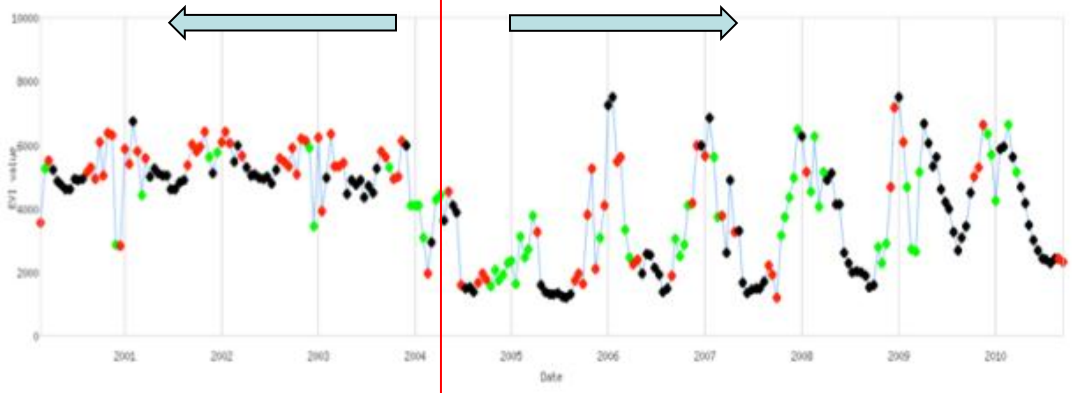


Agriculture intensification in Zambia.

Conversion time

before

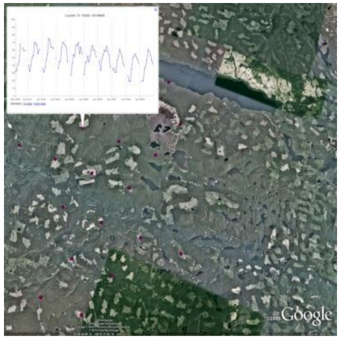
after



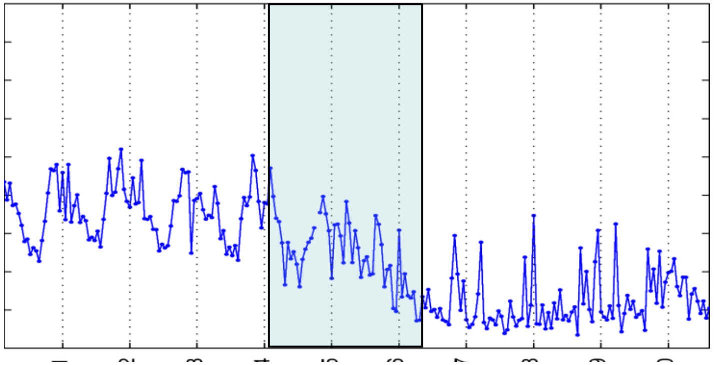
EVI time series for a 250 m by 250 m of land in Iowa, USA that changed from fallow land to agriculture land.

Gradual Change Detection

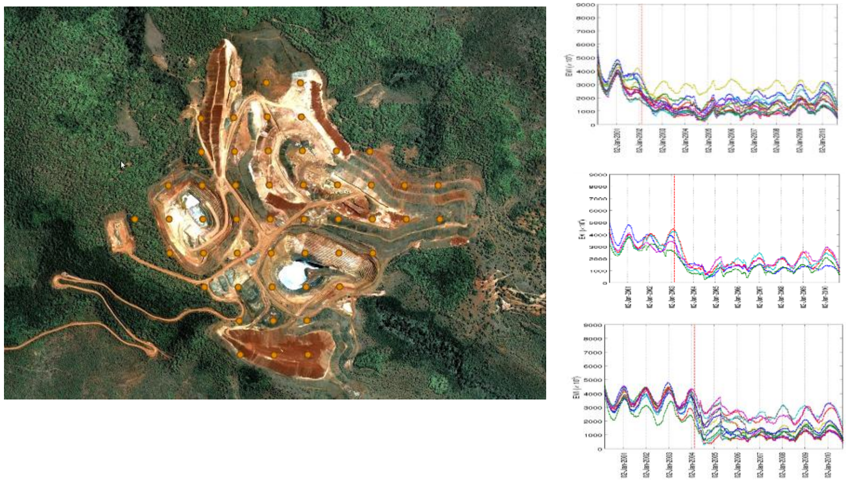
- Detect subsequences of large enough length that indicate a decreasing trend.
  - Challenge is to distinguish an actual decrease from one due to seasonality, noise or natural inter-annual variations.



Clear cut areas in British Columbia indicating logging. Source: NASA

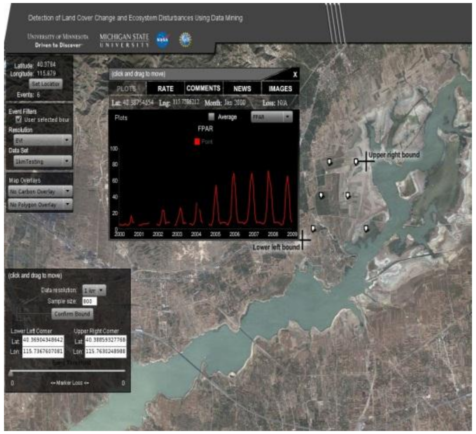


EVI time series for a location in California that appears to have been logged.

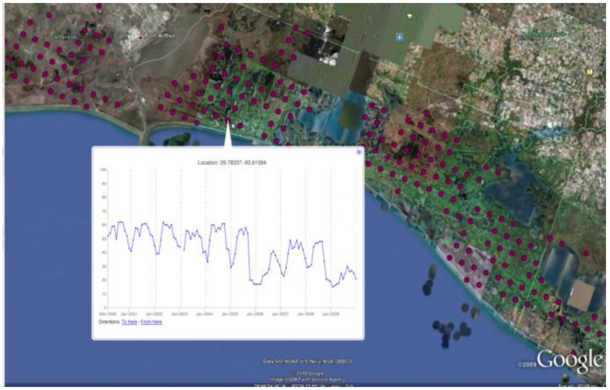


Progress of development of a gold mine in UNEP protected area in Tanzania.

Other Land Cover Changes Detected

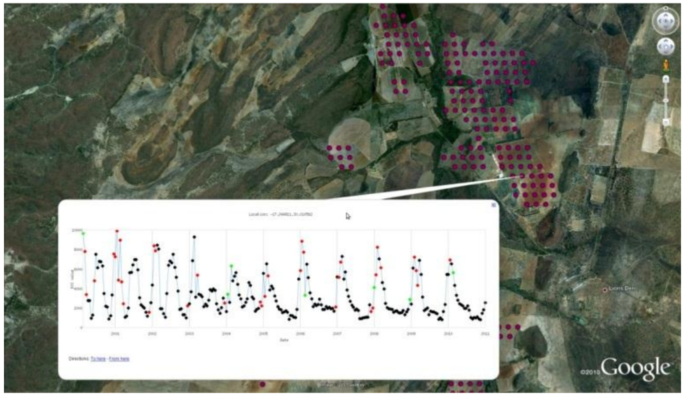


Reforestation in China



Hurricane Katrina

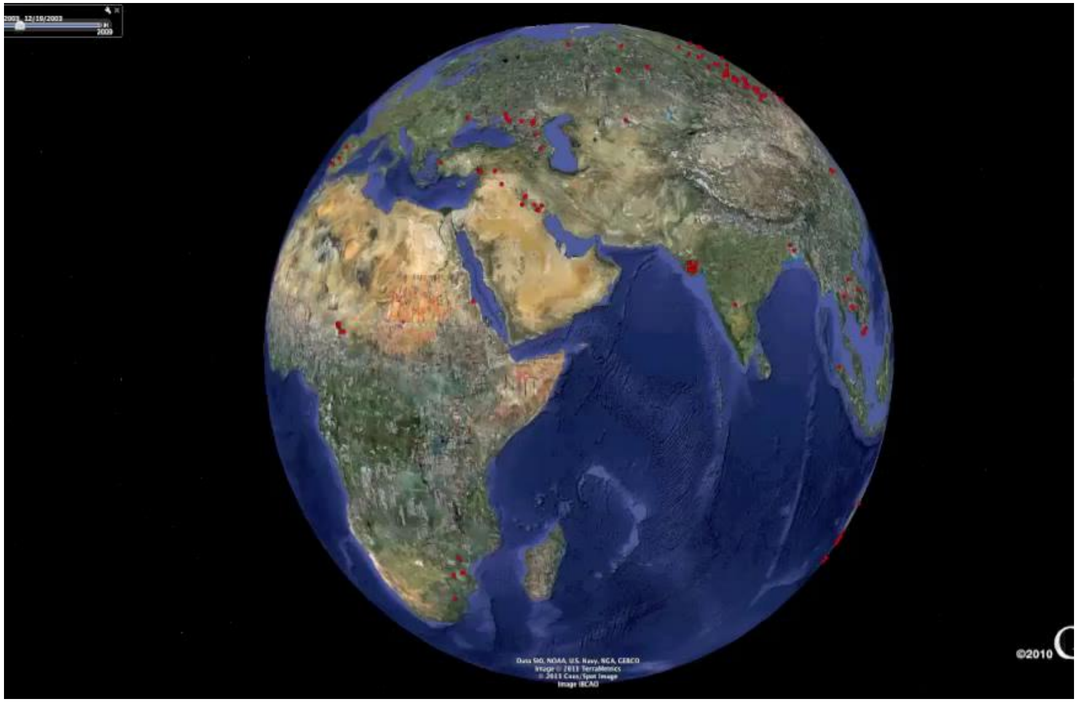
Flooding along Ob River, Russia



Farm abandonment in Zimbabwe during political conflict between 2004 and 2008.

Change Detection by GOPHER

- Detected over a million high confidence change events at 1km globally from last 10 years data.
- Computationally Efficient
  - Less than a day for entire globe at 1 km
- Unsupervised
  - Do not require training samples
- Are global in application



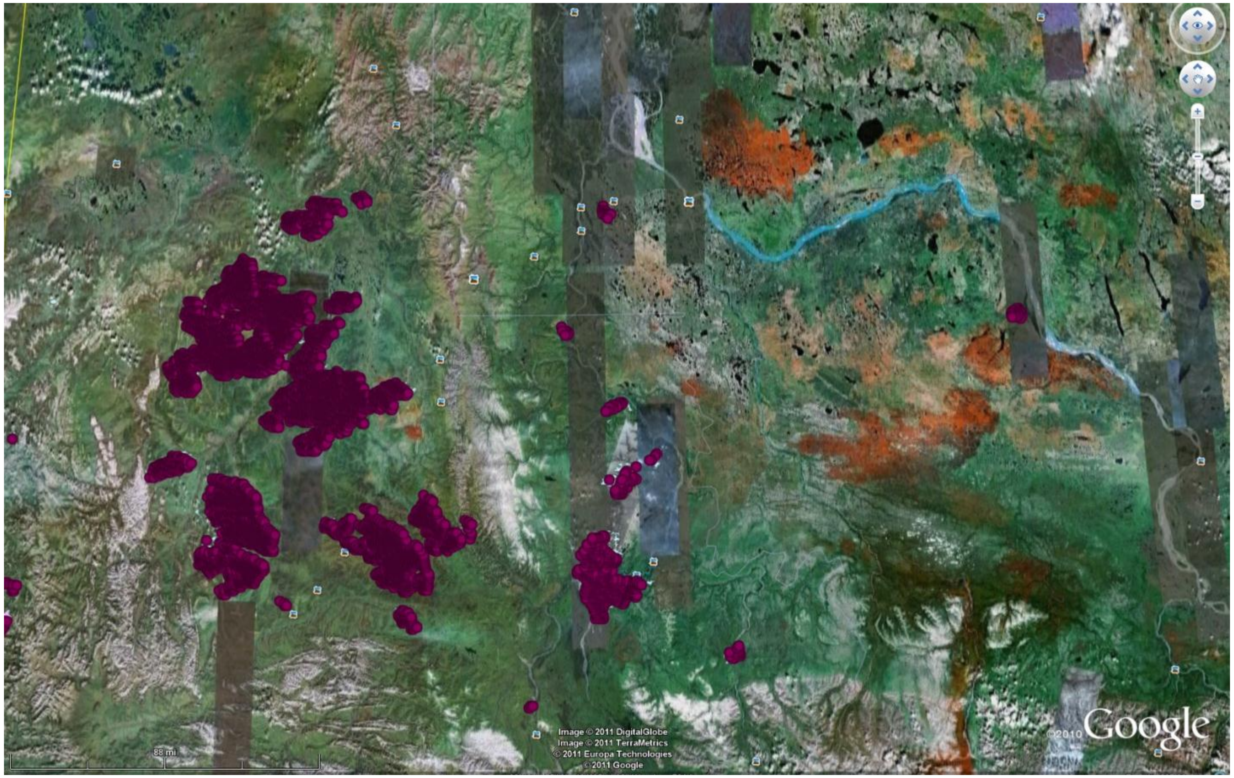
The red dots on the globe above is a sample of locations that were identified by our three algorithms.

Validation for forest fires in Canada

Blue regions represent the fire boundaries identified by Canadian Forest Service

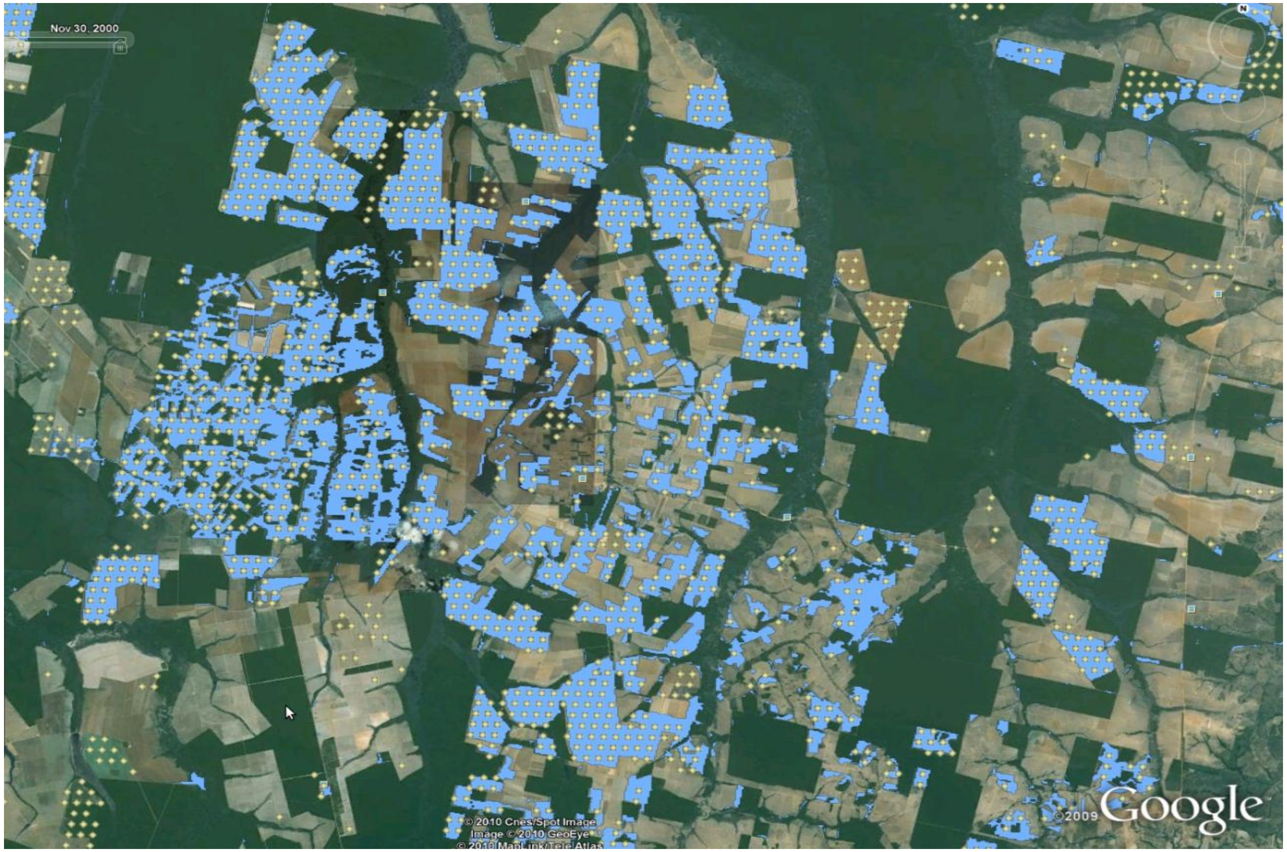
Validation for forest fires in Canada

Excellent match with fire polygons



Natural Resource Canada – Canadian Forest Service

Deforestation in the Amazon Rainforest: Comparison with PRODES



PRODES is a system for monitoring deforestation in Brazilian Amazon.

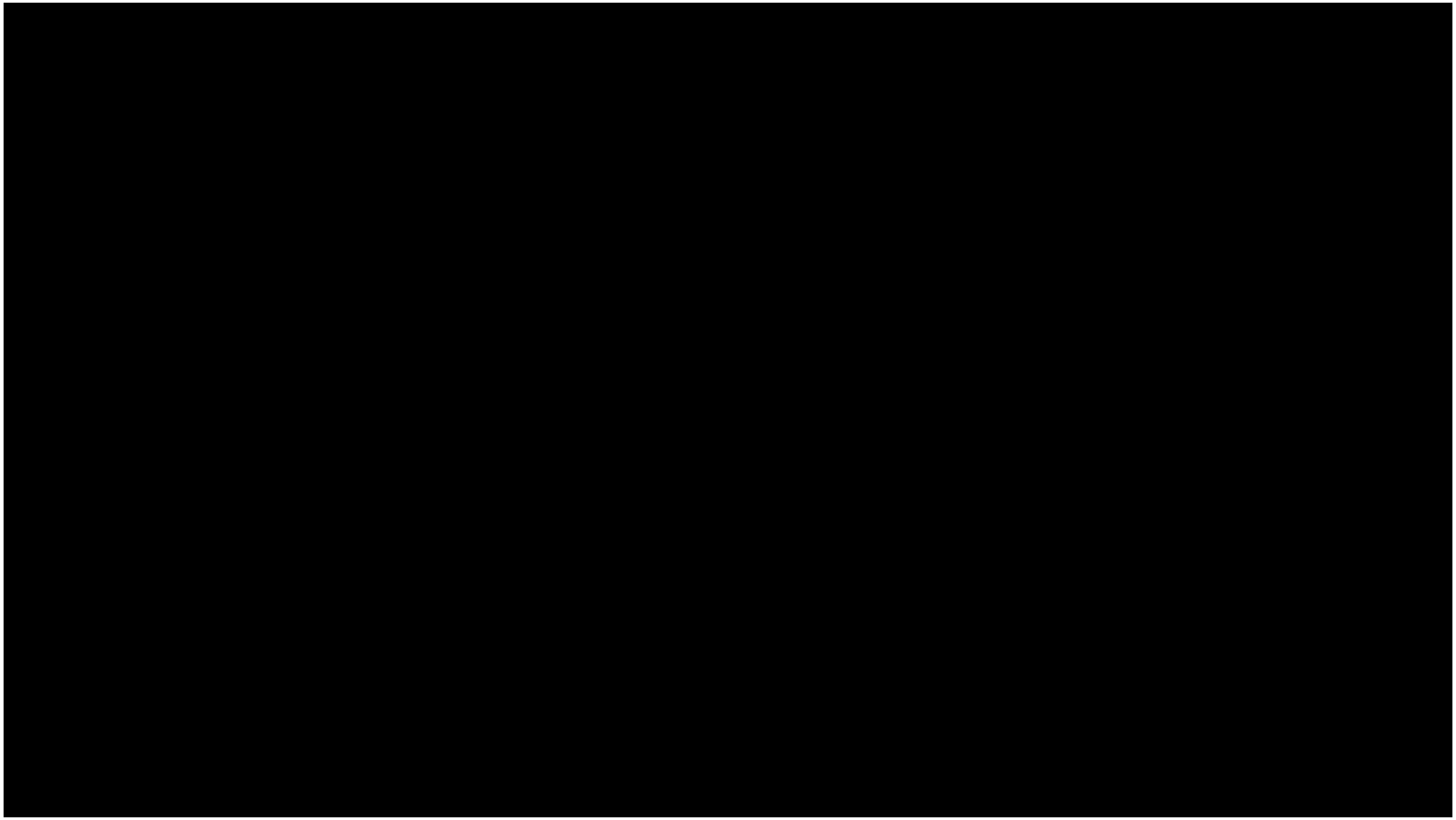
The blue polygons are deforestation changes marked by PRODES.
Yellow dots are events detected by our algorithm.

Deforestation in the Amazon Rainforest: Comparison with PRODES

Events detected outside PRODES polygons

The blue polygons are deforestation changes marked by PRODES.
Yellow dots are events detected by our algorithm.

Automated Land-change Evaluation, Reporting and Tracking System (ALERTS)



Jointly developed with Planetary Institute (PSI)

Impact on REDD+

The Economist

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Monitoring forests

Seeing the world for the trees

An international deal on deforestation makes it ever more important to measure the Earth's woodlands

Dec 16th 2010 | CANCÚN | from PRINT EDITION

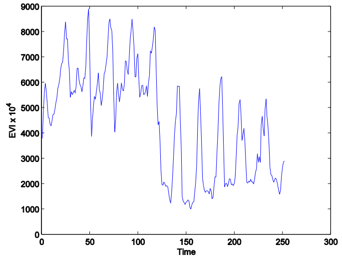
"The [Peru] government needs to spend more than $100m a year on high-resolution satellite pictures of its billions of trees. But … a computing facility developed by the Planetary Skin Institute (PSI) … might help cut that budget."

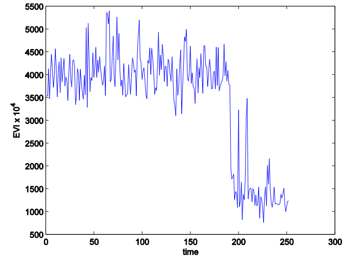
"ALERTS, which was launched at Cancún, uses … data-mining algorithms developed at the University of Minnesota and a lot of computing power … to spot places where land use has changed."

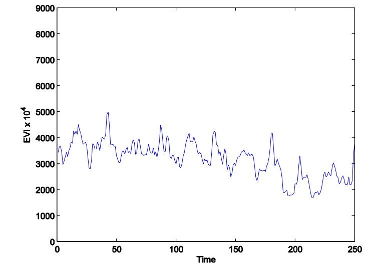
- The Economist 12/16/2010

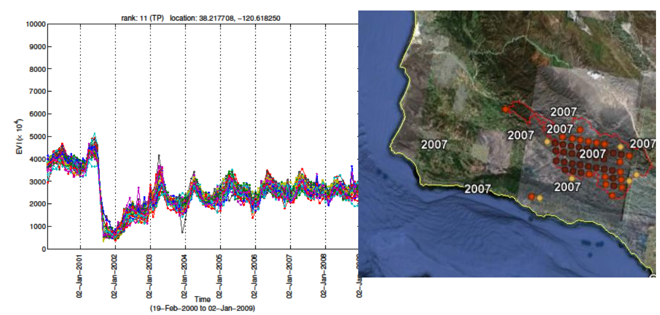
Monitoring Forest Cover Change: Challenges Ahead

- Designing robust change detection algorithms
- Automated characterization of land cover changes
- Multivariate analysis
  - Detecting some types of changes (e.g. crop rotations) will require additional variables.
- Data quality improvement
  - Preprocessing of data using spatial-temporal noise removal and smoothing techniques can increase performance of change detection.
- Incremental update and early detection
- Spatial event identification









Future Directions

Techniques for change detection, characterization, and risk scoring developed in the context of land cover can be extended to these other areas:

- Urbanization
- Natural Disasters
- Energy
- Food
- Water