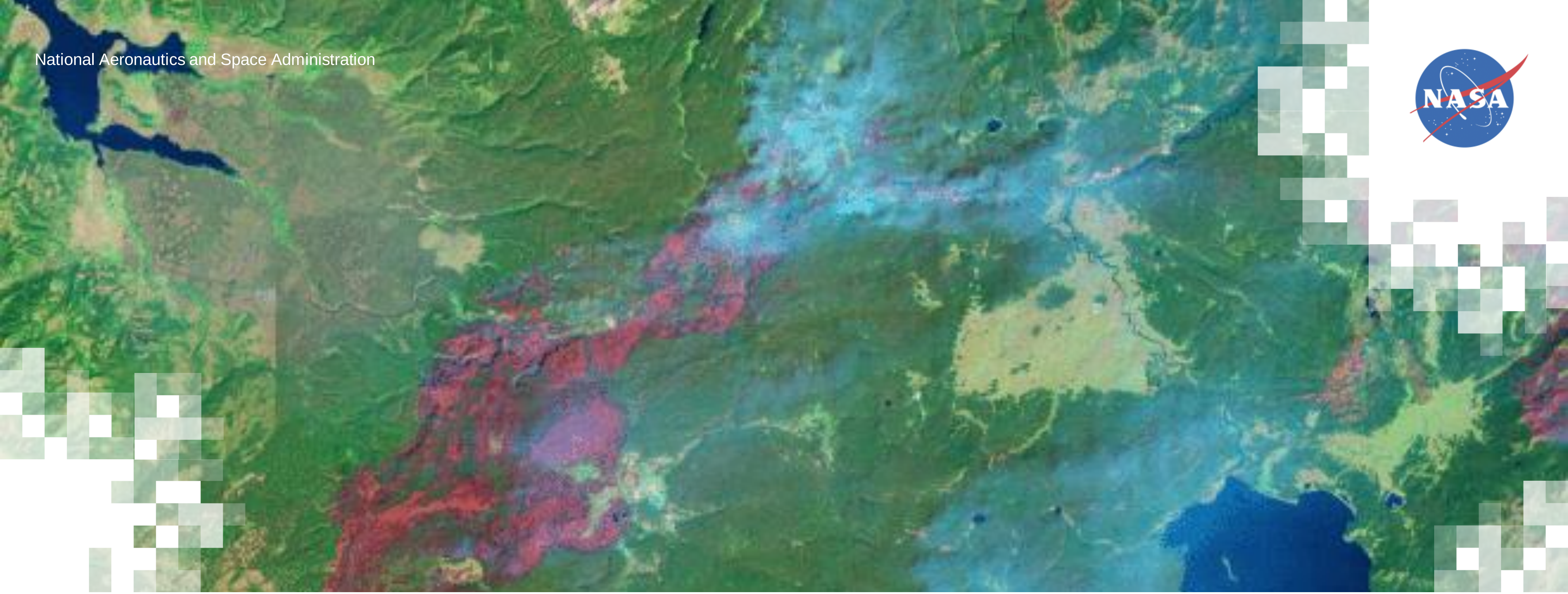
National Aeronautics and Space Administration



# Investigating Time Series of Satellite Imagery

Cindy Schmidt, Amber McCullum

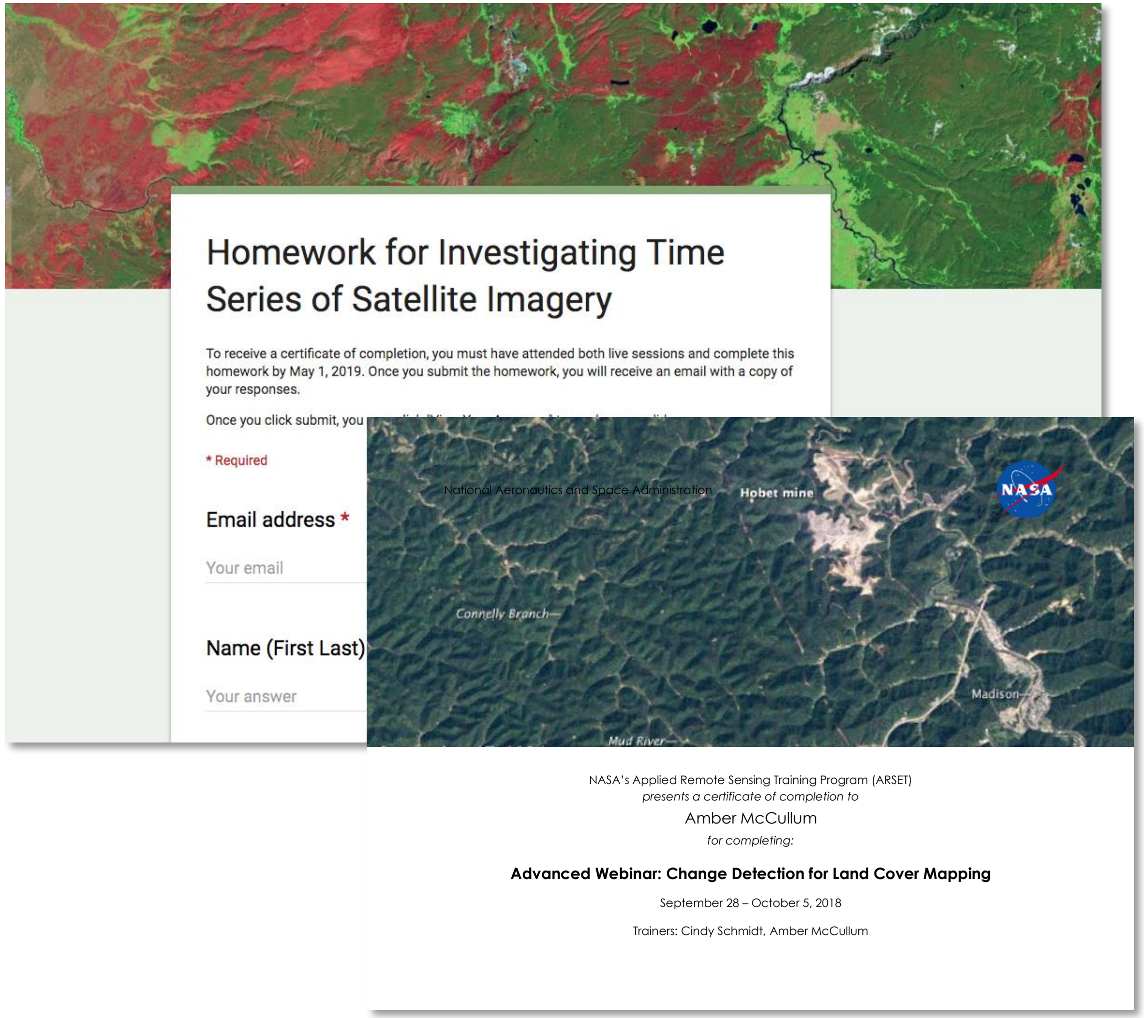
April 17, 2019

# Course Structure

- Two, two-hour sessions on April 15 and April 17, 2019
- The same content will be presented at two different times each day:
  - Session A: 10:00-12:00 EST (UTC-4)
  - Session B: 18:00-20:00 EST (UTC-4)
  - **Please only sign up for and attend one session per day**
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - https://arset.gsfc.nasa.gov/land/webinars/time-series-19
- Q&A: Following each lecture and/or by email
    - cynthia.l.schmidt@nasa.gov, or
    - amberjean.mccullum@nasa.gov

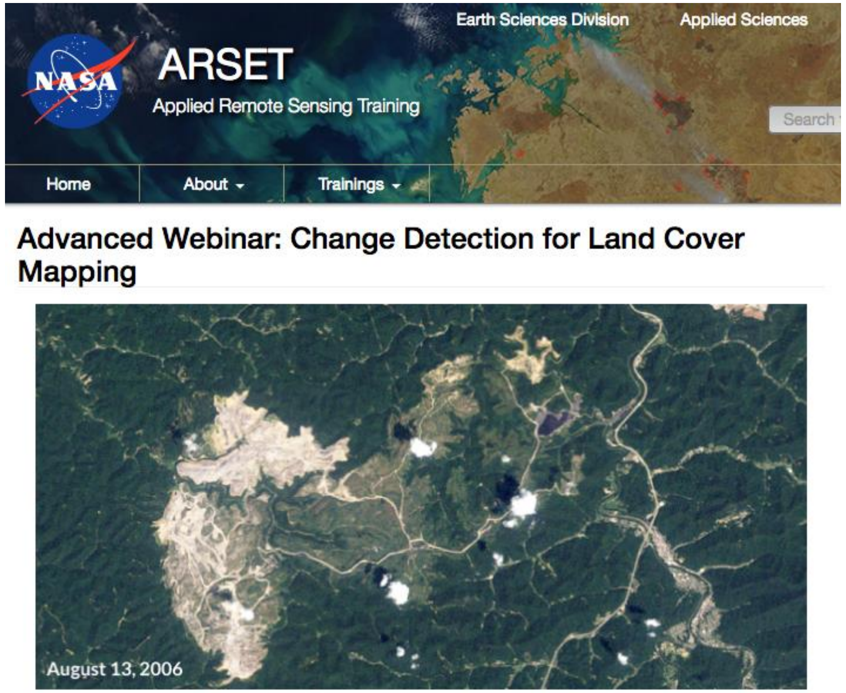
# Homework and Certificates

- Homework
  – One homework assignment
  – Answers must be submitted via Google Forms
- Certificate of Completion:
  – Attend both live webinars
  – Complete the homework assignment by the deadline (access from ARSET website)
    - HW Deadline: Wednesday May 1st
  – You will receive certificates approximately two months after the completion of the course from: [marines.martins@ssaihq.com](mailto:marines.martins@ssaihq.com)



# Prerequisites

- ARSET Webinar *Introduction to Remote Sensing* or equivalent knowledge
- Complete the [Advanced Webinar: Change Detection for Land Cover Mapping]
- Install Google Chrome: https://www.google.com/chrome/
  - For the Google Earth Engine exercise, Chrome should be used to make sure all features work
- Sign up for the Google Earth Engine Code Editor: https://signup.earthengine.google.com/



# Accessing Course Materials

## https://arset.gsfc.nasa.gov/land/webinars/time-series-19

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### Advanced Webinar: Investigating Time Series of Satellite Imagery

**Time Series**

**Date Range:** Mondays, April 15, 2019. April 17, 2019.
**Times:** 10:00-12:00 and 18:00-20:00 EDT (UTC-4)

Evaluation of satellite imagery for an area over time can be used to identify trends and changes. This type of time series analysis can be used to assess forest disturbance, land cover changes, vegetation health, and agriculture monitoring and expansion. NASA Earth observations can provide long-term records from Landsat, and frequent imagery from sensors including MODIS. This training will focus on two tools, AppEEARS from the LPDAAC and LandTrendr via Google Earth Engine (GEE). AppEEARS enables users to integrate point or polygon ground-based data with satellite imagery. The GEE implementation of LandTrendr enables users to analyze land cover dynamics, including short-term disturbances and long-term trends. Both sessions will feature a lecture, followed by time for hands-on exercises and questions.

**Learning Objectives:**

By the end of this training, attendees will:

- Become familiar with time series analysis techniques
- Understand how to evaluate time series of MODIS & Landsat data
- Learn how to integrate point data with satellite imagery using the AppEEARS web-based interface
- Learn the basics of the GEE implementation of LandTrendr including:
  - Generating annual land surface reflectance images
  - Plotting a time series of land surface reflectance
  - Creating a map of change detection, magnitude of change, duration of change event, and

**Land Management**

Online Trainings
In-Person Trainings

**Upcoming Training**

Water
Introductory Webinar: Using Earth Observations to Monitor Water Budgets for River Basin Management
Mar 13, 2019, Mar 20, 2019, Mar 27, 2019, Apr 03, 2019

Land
Advanced Webinar: Investigating Time Series of Satellite Imagery
Apr 15, 2019, Apr 17, 2019

Disasters
Intermediate Webinar: Remote Sensing for Disasters Scenarios; Capacitación Nivel Intermedio: Teledetección para Escenarios de Desastres
Apr 16, 2019, Apr 23, 2019, Apr 30, 2019

View All Events

**Prerequisites:**

Attendees that do not complete prerequisites may not be adequately prepared for the pace of the course.

- Complete Sessions 1 & 2A of Fundamentals of Remote Sensing, or equivalent experience
- Complete the Advanced Webinar: Change Detection for Land Cover Mapping
- Install Google Chrome: https://www.google.com/chrome/
  - For the Google Earth Engine exercise, Chrome should be used to make sure all features work
- Sign up for the Google Earth Engine Code Editor: https://signup.earthengine.google.com/

**Audience:**

Advanced users of remote sensing data within local, regional, state, federal, and non-governmental organizations involved in land management and conservation efforts. Professional organizations in the public and private sectors engaged in environmental management and monitoring will be given preference over organizations focused primarily on research.

**Registration Information:**

There is no cost for the webinar, but you must register to attend the sessions. Because we anticipate a high demand for this training, please only sign up for one session. Sessions will only be broadcast in English - Session A will cover the same content as Session B. Professional organizations in the public and private sectors engaged in water resources management and monitoring will be given preference over organizations focused primarily on research.

- Register for Session A, 10:00-12:00 EDT (UTC-4) »
- Register for Session B, 18:00-20:00 EDT (UTC-4) »

**Course Agenda:**

Agenda_41.pdf

April 15, 2019

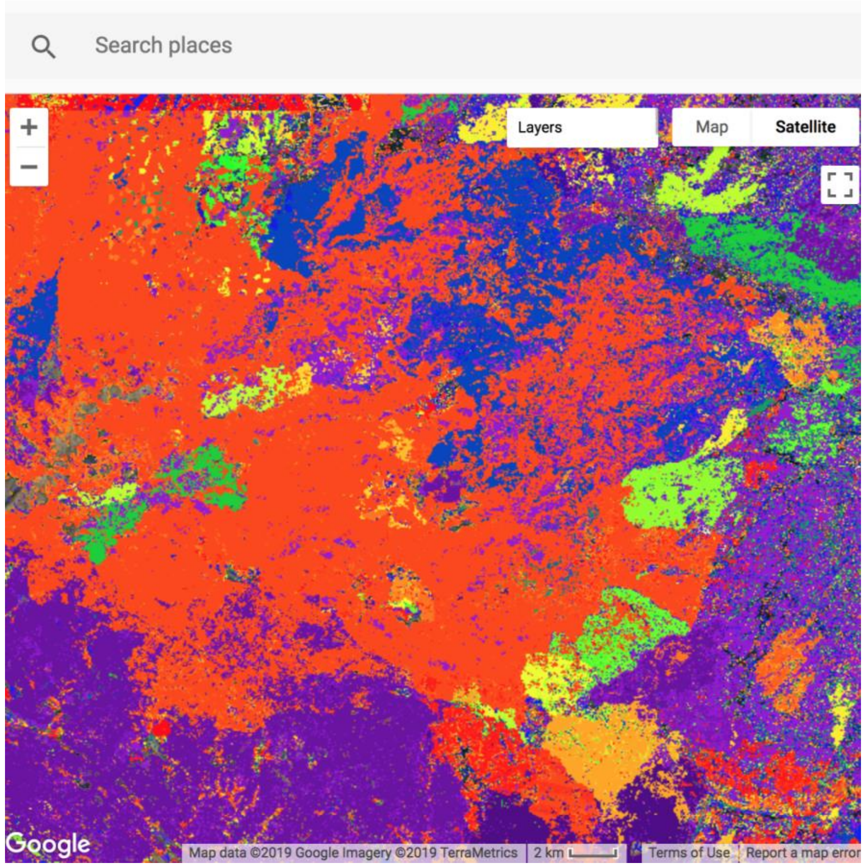
This session will include a review of MODIS and Landsat, a review of change detection, an overview of time series analysis methods, and an AppEEARS hands-on exercise.

**Application Area:** Land
**Available Languages:** English
**Instruments/Missions:** Terra, Landsat, MODIS, Aqua
**Keywords:** Ecosystems, Land-Cover and Land-Use Change (LCLUC), Satellite Imagery, Tools

# Course Outline

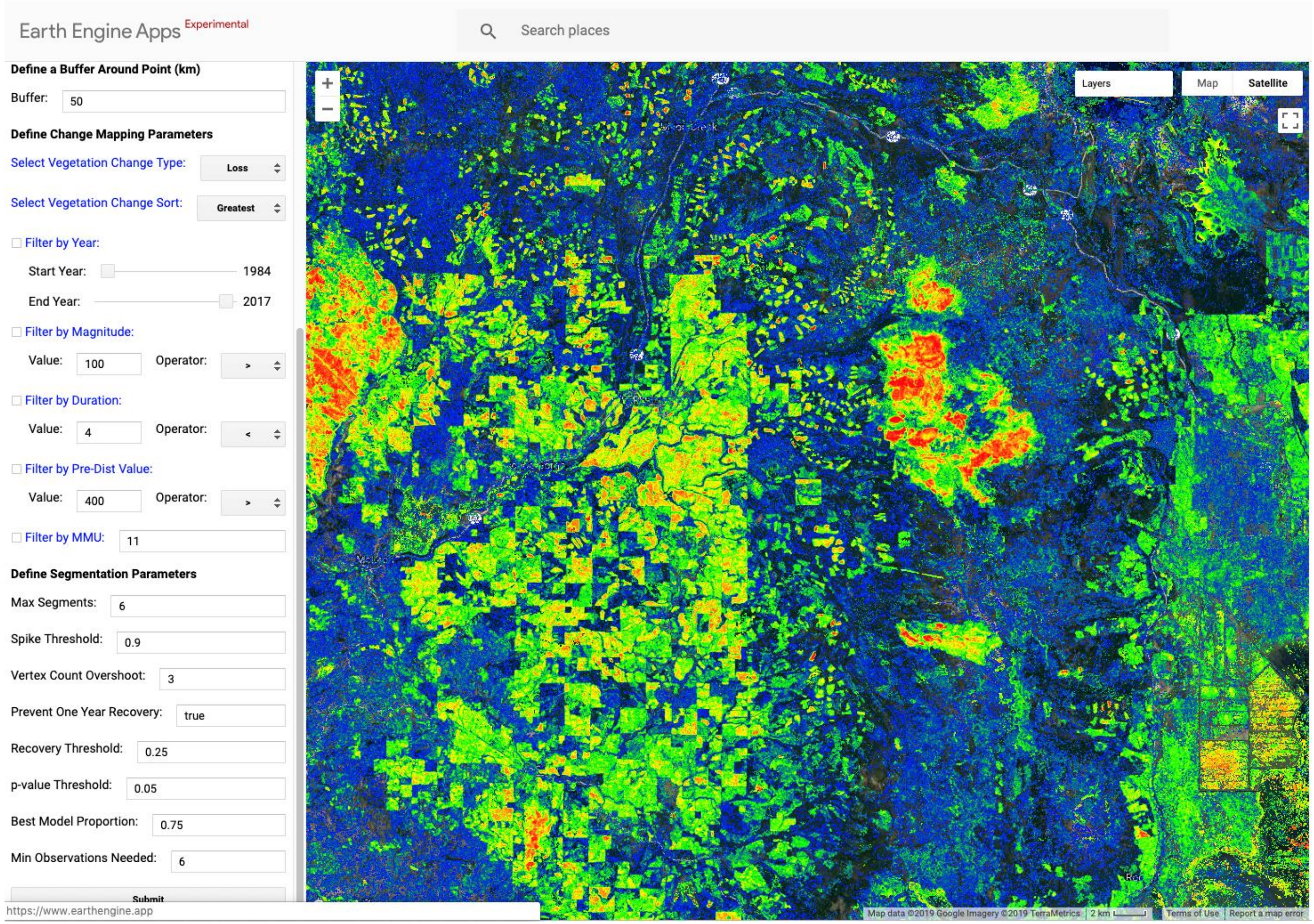
Session 1: Intro to Time Series and AppEEARS

Session 2: LandTrendr Overview and Applications

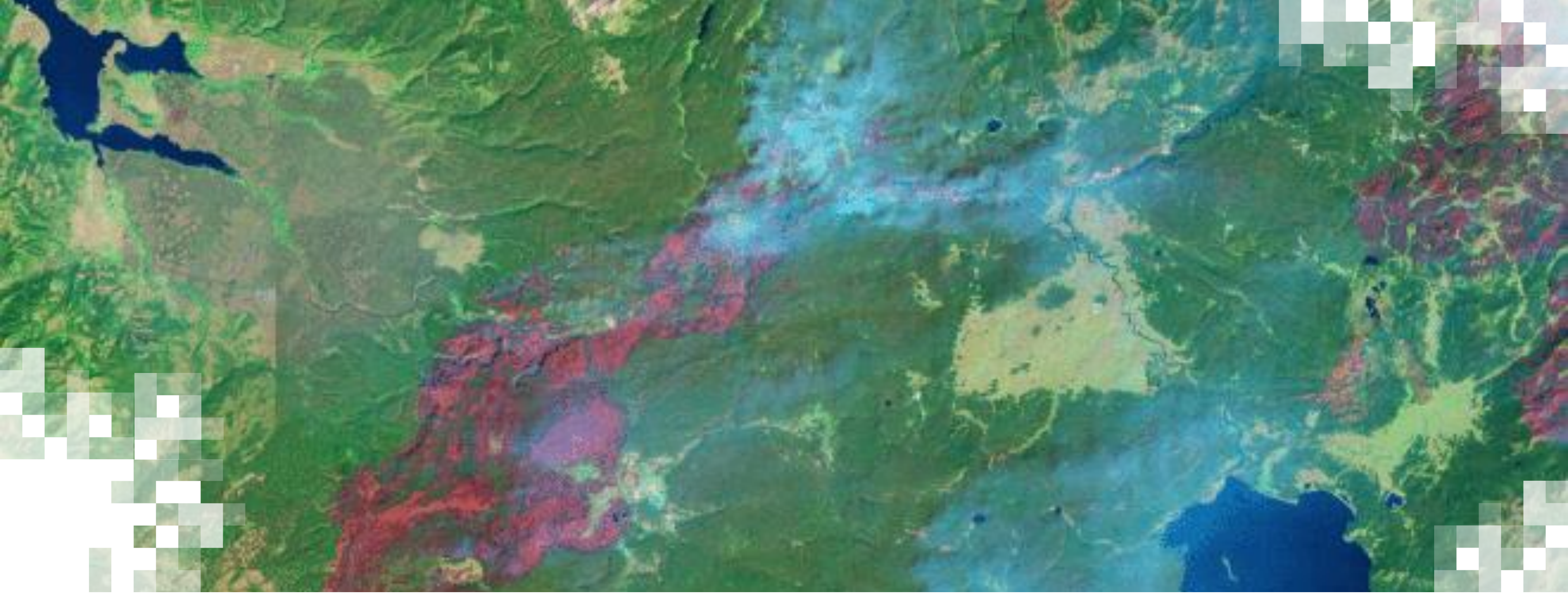


# Session 2 Agenda

- Forest Disturbance Algorithms Overview
- LandTrendr Overview
- LandTrendr in GEE
- Other Vegetation Disturbance Algorithms
  - Review paper: Cohen et al., 2017
- LandTrendr Exercise




LandTrendr Change Mapper: Magnitude of Disturbance



# Forest Disturbance Algorithms Overview

# Time Series of Forest Disturbance

**Used for:**

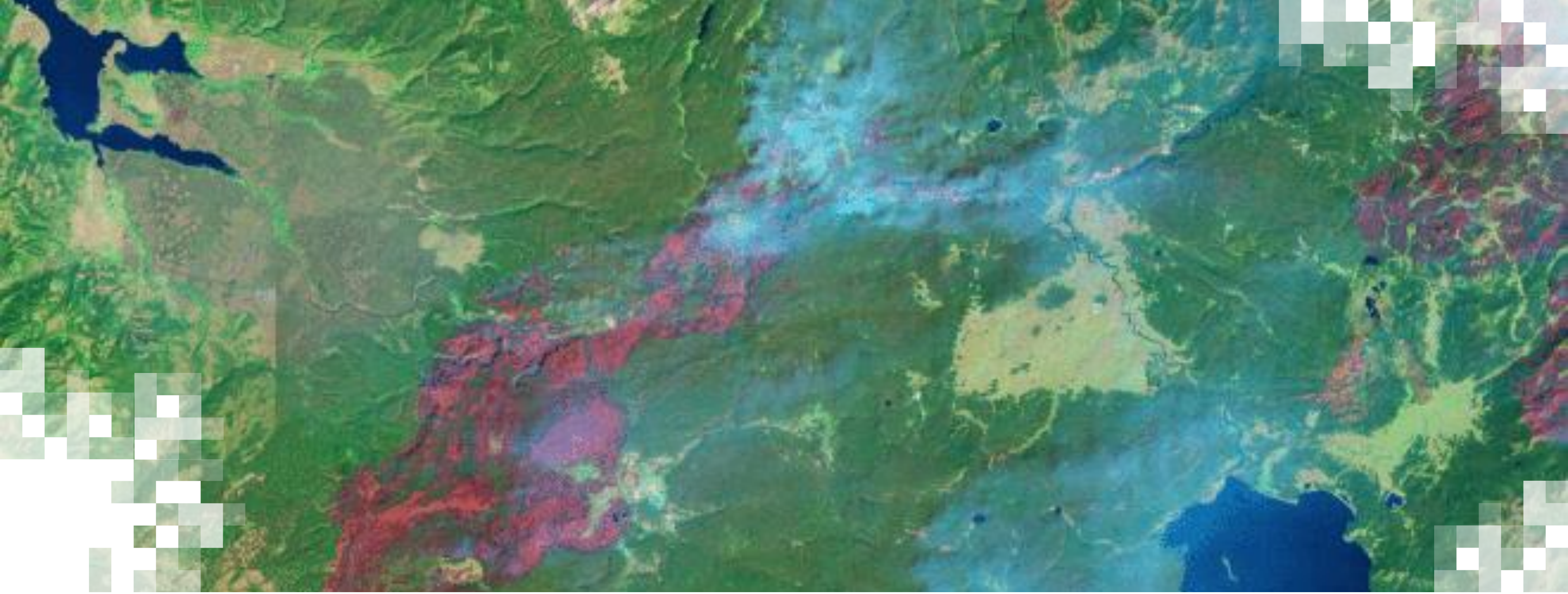
- Mapping disturbance patterns
- Establishment of historic relationships between human and natural disturbance drivers
  – Urban development vs. insects
- Evolution of post-disturbance recovery

**Two Primary Approaches:**

- Deviations (short events)
- Trends (long-term events)

# Forest Disturbance Algorithms

- Multiple algorithms used for Landsat, depending on factors of interest
- Additional algorithm differences include:
  - Use of different bands or indices (e.g., NBR, NDVI, relative change vectors, etc.)
  - Vegetation type (e.g., forests only, all woody vegetation, all land cover types)
  - Disturbance magnitude (e.g., high magnitude events vs. broad range of magnitude)
- Focus in this training: Landsat-Based Detection of Trends in Disturbance and Recovery (LandTrendr)



# LandTrendr Overview

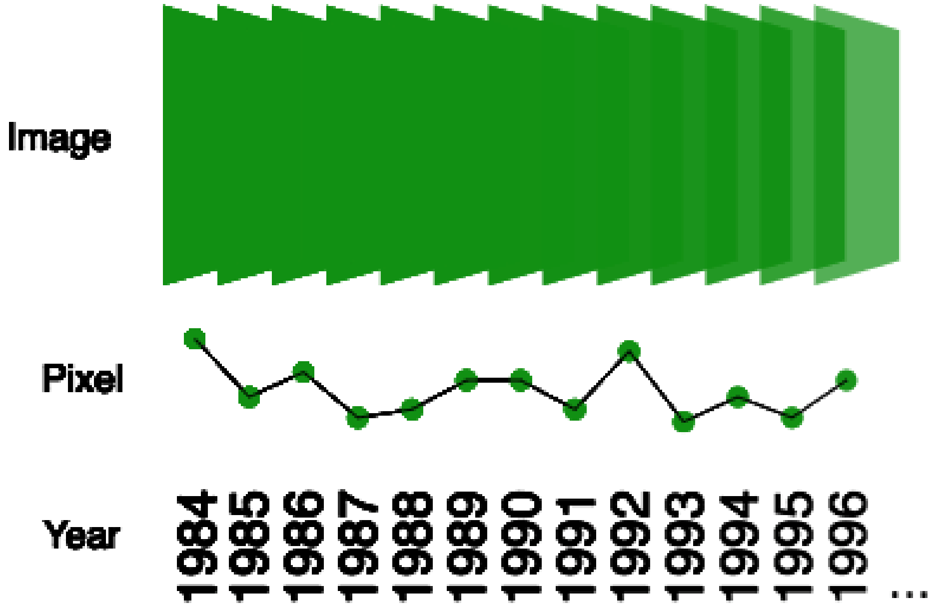
# Landsat-Based Detection of Trends in Disturbance and Recovery (LandTrendr)

- Recognizes that change is not generally a contrast between two dates, but a continual process operating on multiple timescales
  - Short duration (e.g. wildfires) and long-term trends
- Extracts spectral trajectories of land surface change from yearly Landsat time-series stacks (LTS)
- 3 Components:
  - Track yearly changes (not intra-yearly)
  - Pixel-based
  - Allow for single events and spectral smoothing (arbitrary temporal segmentation)

Kennedy, et al., 2010

# Yearly Mosaics

- Multiple images per year used to eliminate data gaps, clouds, snow, smoke, and shadows
- Geometric and radiometric correction applied
- Pixel-based on-the-fly mosaic generated
- Landsat image stack for each year analysis created



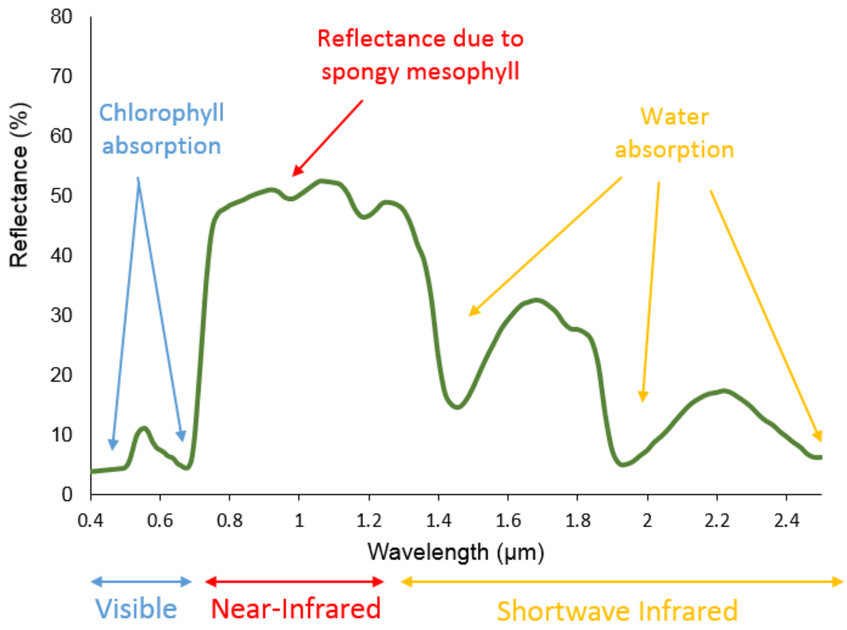

Landsat stack will contain one mosaicked image per year

Image Credit: [LandTrendr website]

# Pixel-Based

- The spectral signature of each pixel is used
- Tasseled Cap Transformation
- In a yearly mosaic, pixel is chosen from the image closest to the median Julian day of the images in the whole stack
  - Iteratively the next closest day if the pixel contains a cloud

Example of pixels in a field




Example of vegetation spectral signature

Image Credits: (Left) GIS Ag Maps; (Right) Humbolt State GSP 216

# Trajectory Segmentation

- Captures abrupt and slow changes
- Models each pixel's spectral signature each year as a sequence of straight line segments
  - Captures trends
  - Eliminates noise while retaining detail
- Steps:
  - Create complex fitted model
  - Iteratively simplify the model
  - Choose the best model based on statistics
  - Remove change that is considered noise

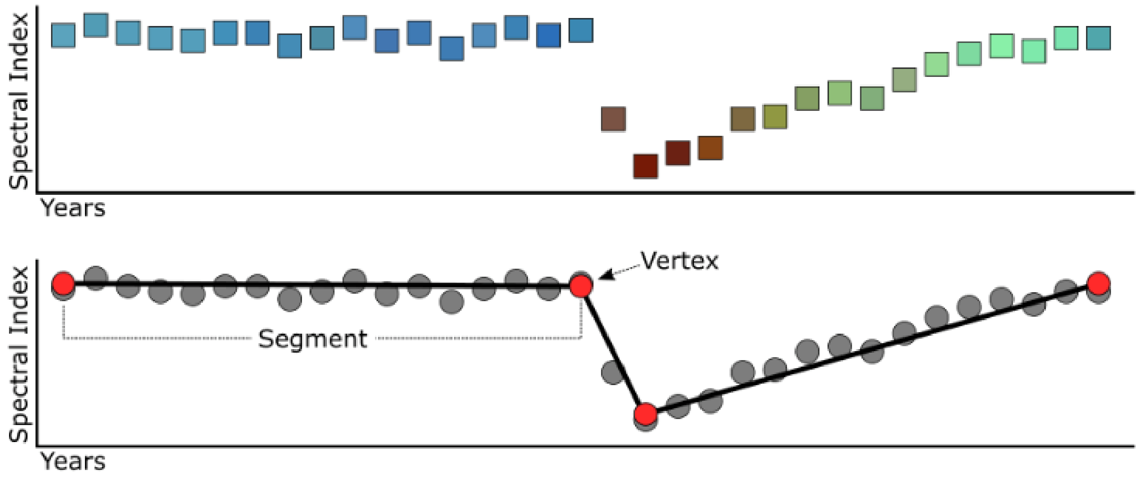
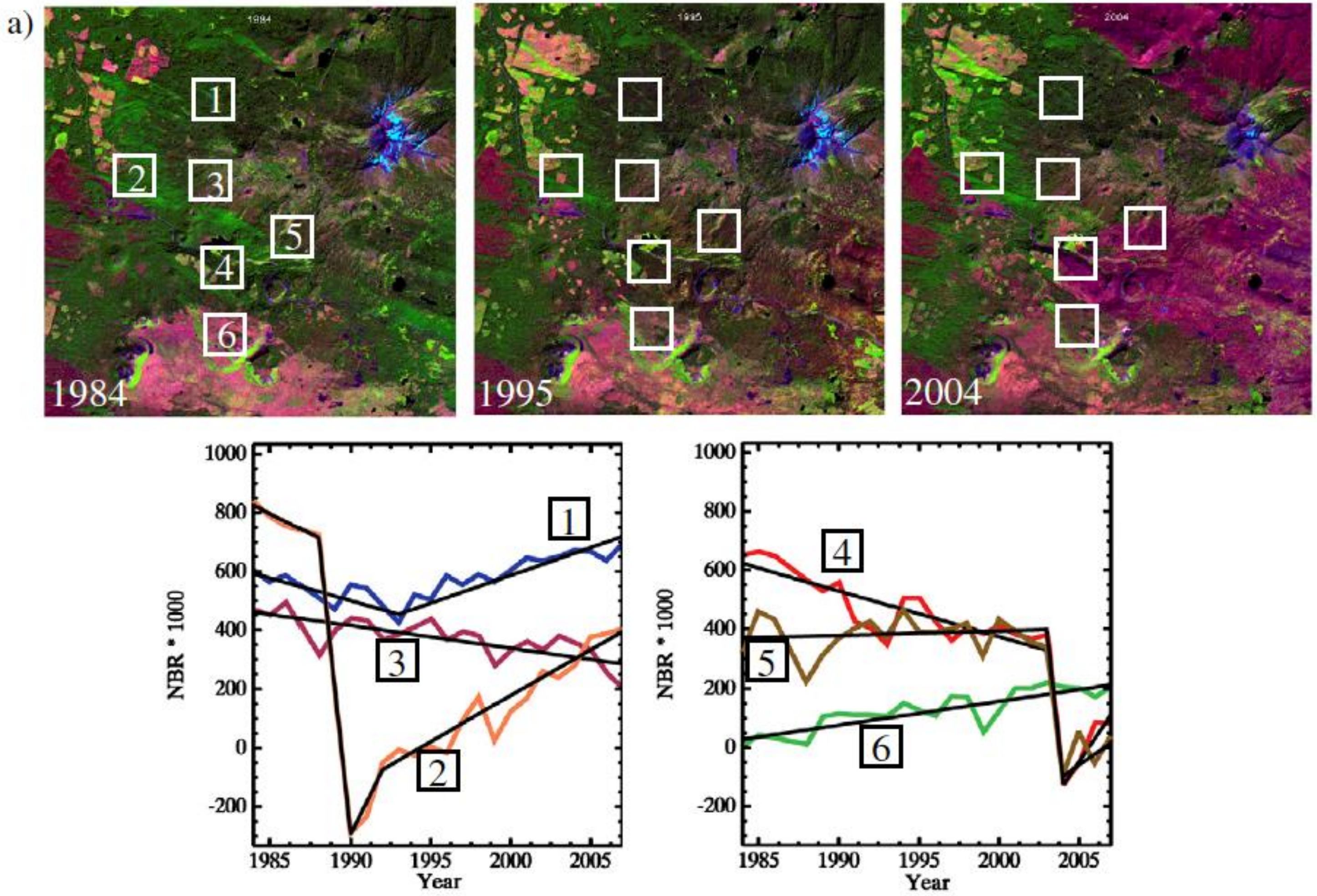



Image data is reduced to a single band or spectral index and then divided into a series of straight line segments by breakpoint (vertex) identification

Image Credit: [LandTrendr GEE website]

# Analyze the Results




1. Insects
2. Clear-cutting
3. Insects
4. Insects followed by fire
5. Stability followed by fire
6. Recovery from fire

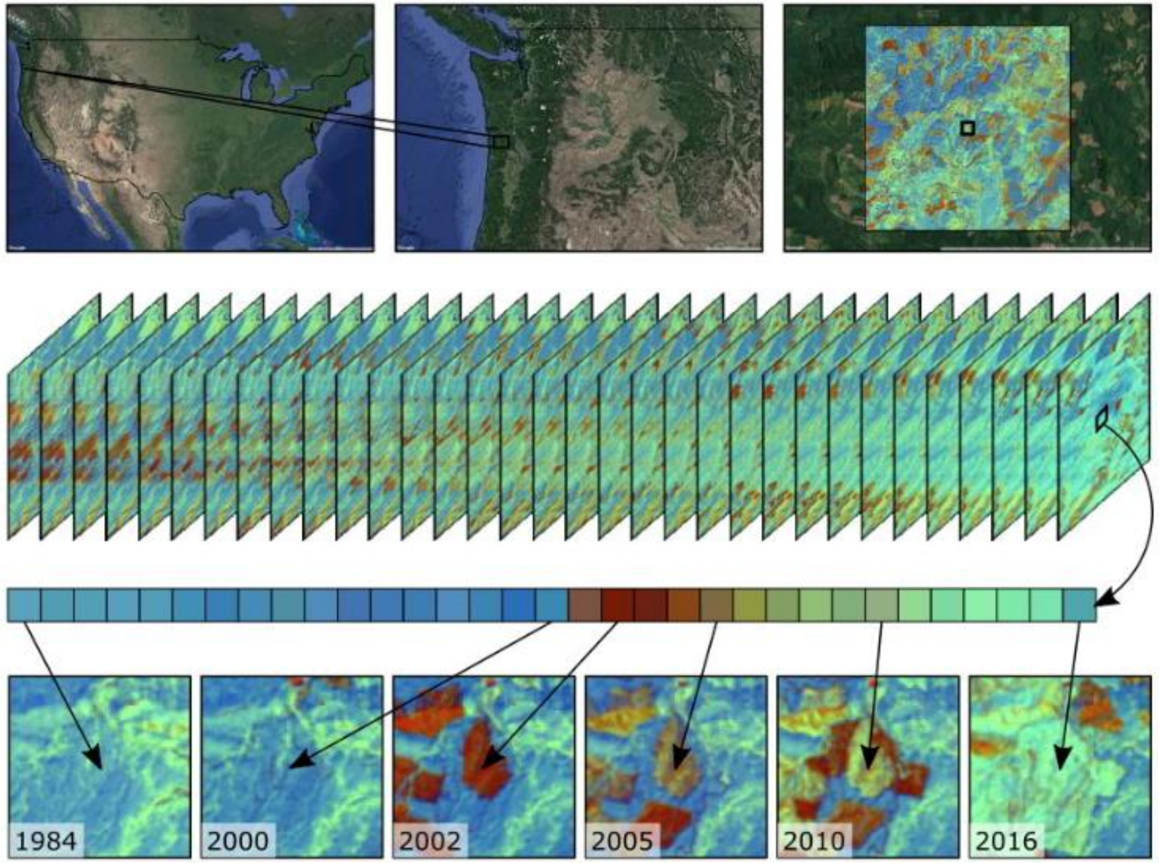
Image Credit: [Kennedy, et al., 2010]

# Analyze the Results: Example 2

- Conifer-dominated industrial forest in Pacific Northwest

**Analysis:**

- 1984 - 2000: Little change
- 2000 - 2001: Service road built
- 2002 - 2010: Harvest (clear-cut)
- 2016: Regrowth



# LandTrendr in Google Earth Engine

- The algorithm was initially implemented in Interactive Data Language (IDL)
- Now in GEE
  - Script-based processing (JavaScript)
  - User Interface (UI)
- Corrections and Cloud mask applied within GEE
- Can use different types of vegetation indices
  - Vegetation loss is represented by positive data (e.g. Normalized Burn Index (NBR) multiplied by -1)

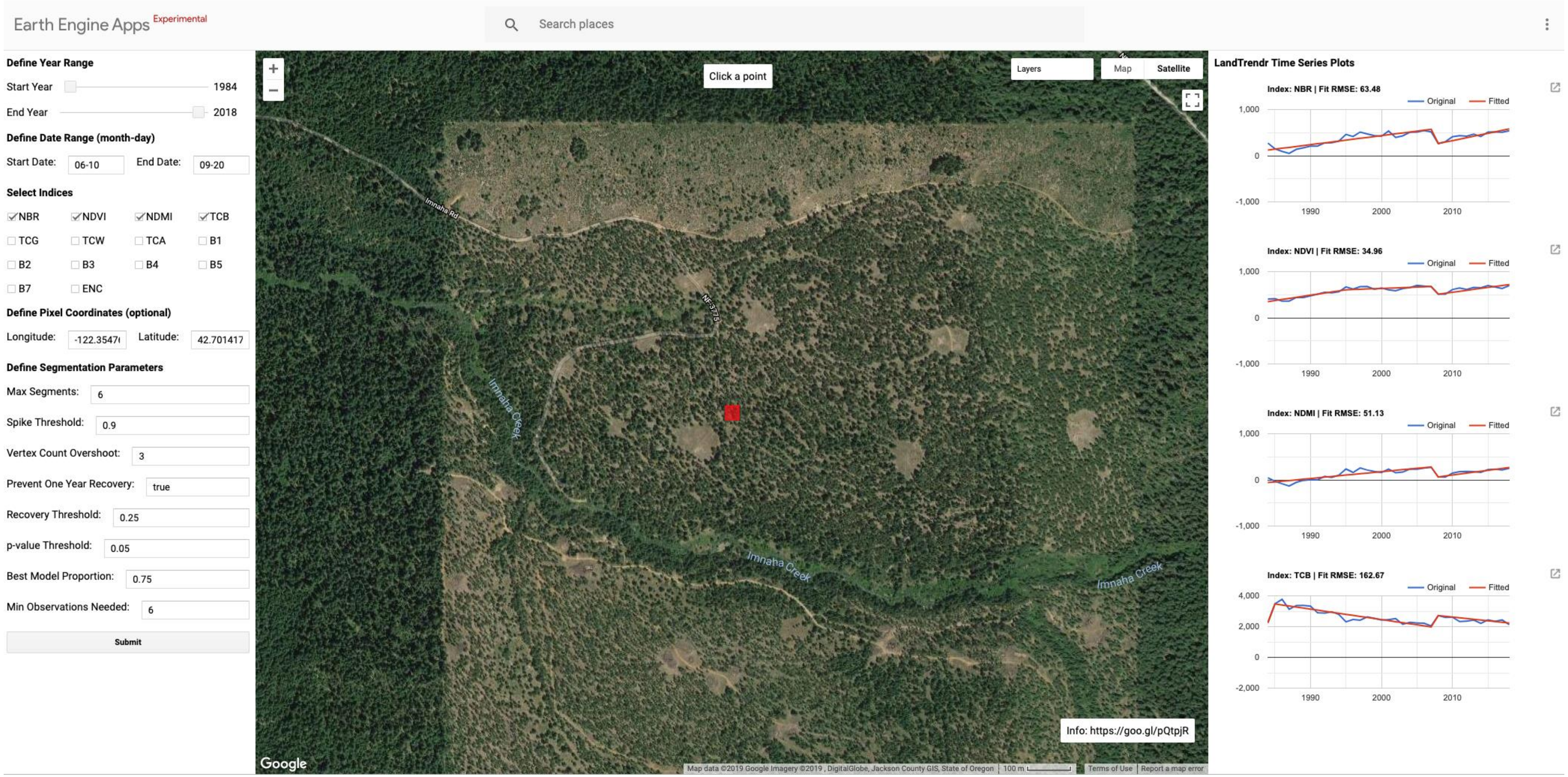
Image Credit: LandTrendr for GEE website

# LandTrendr's User Interface in GEE

**Three Applications**

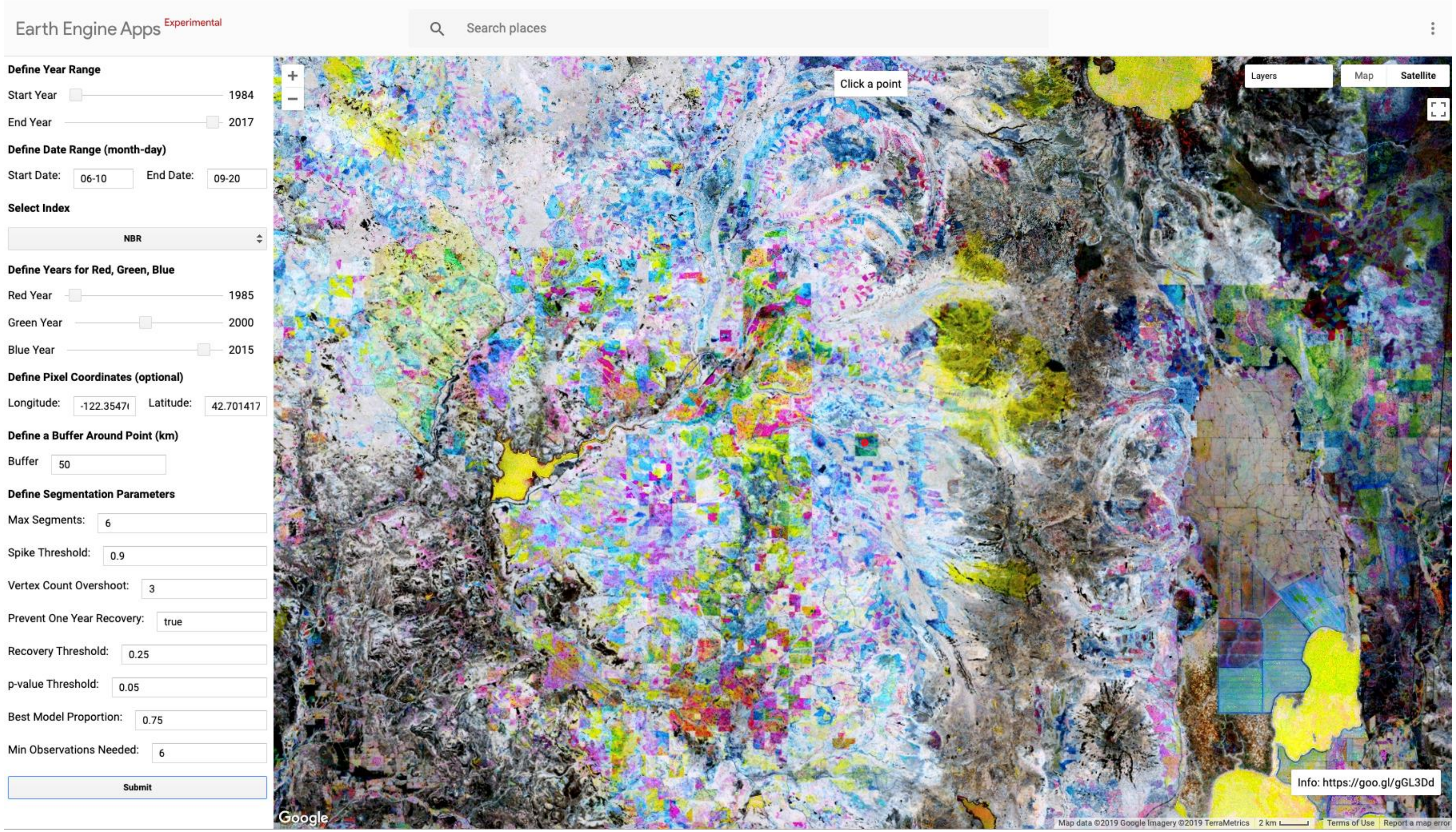
- Pixel Time Series Plotter
  - Creates figures of the index values over time for a specific pixel
- Change Mapper
  - Maps disturbance with multiple layers
- Fitted Index Delta RGB Mapper
  - Displays an Red, Green, Blue (RGB) map of spectral or index values at three time periods

# Pixel Time Series Plotter

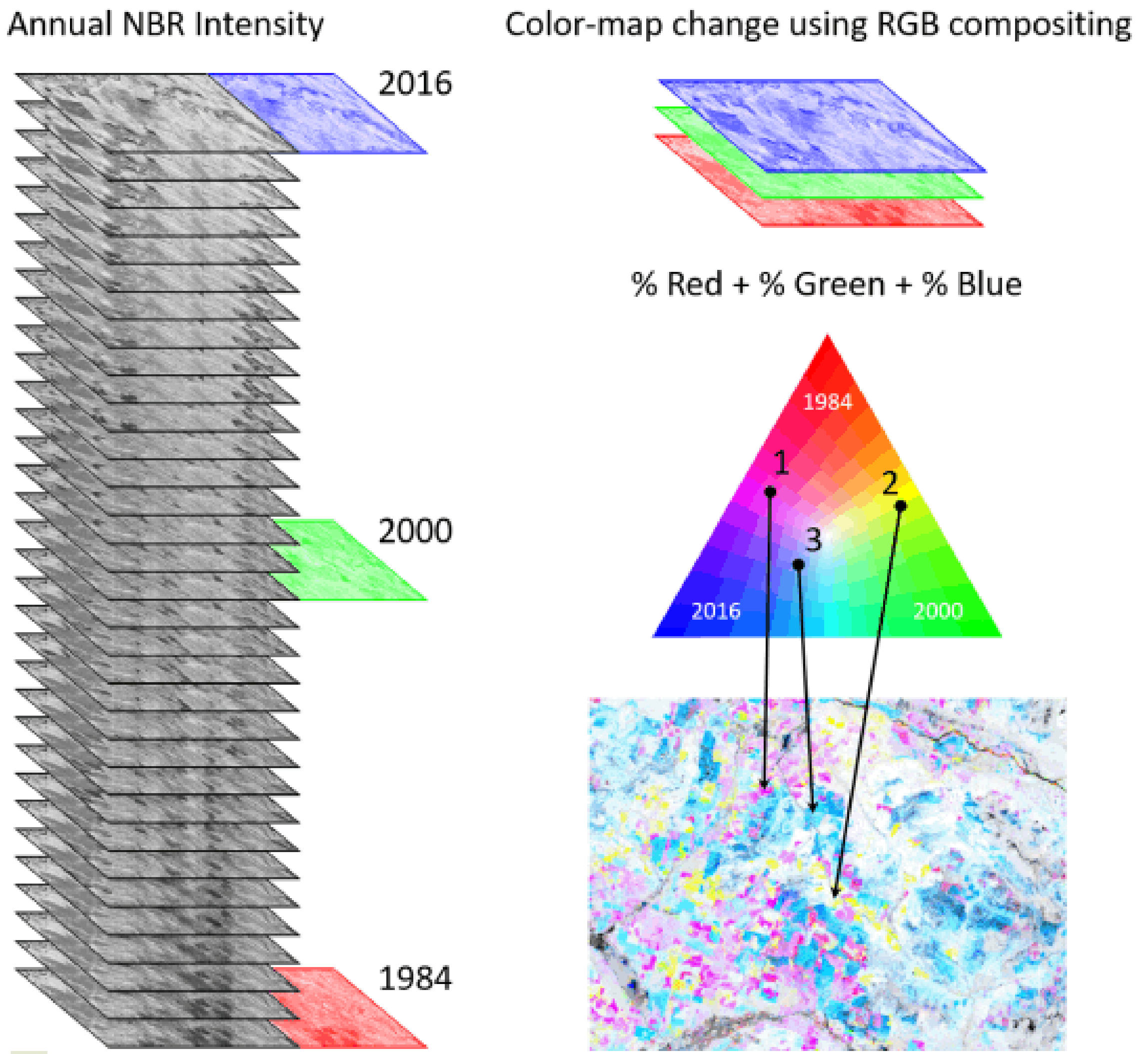


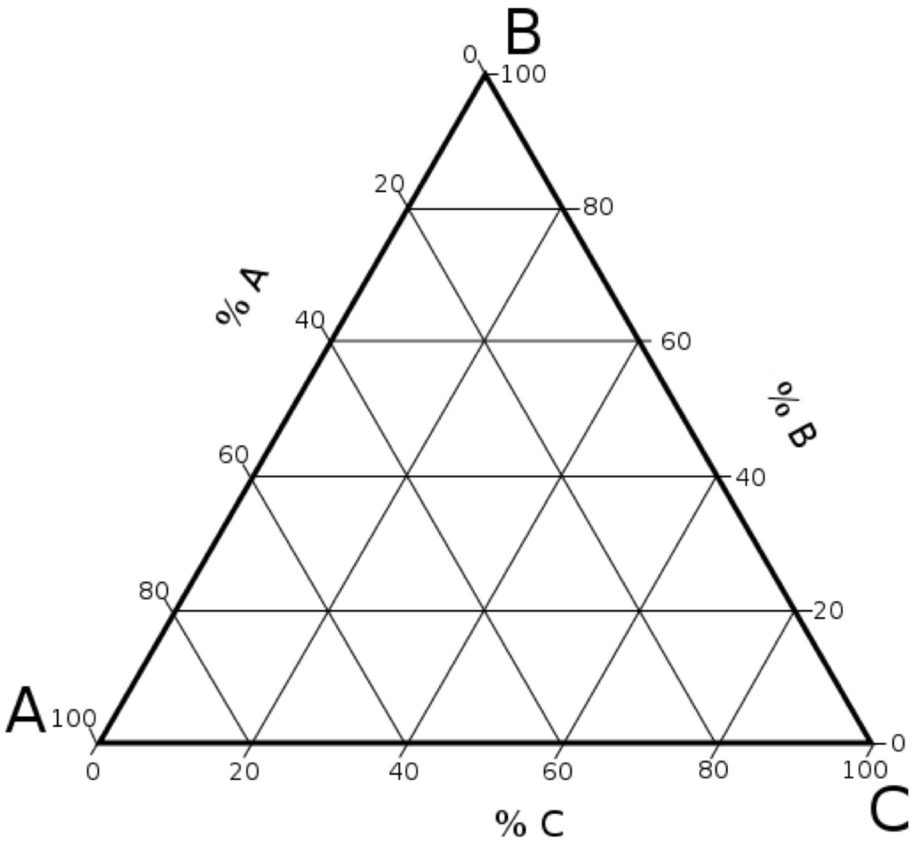
# Change Mapper

# Fitted Index Delta RGB Mapper



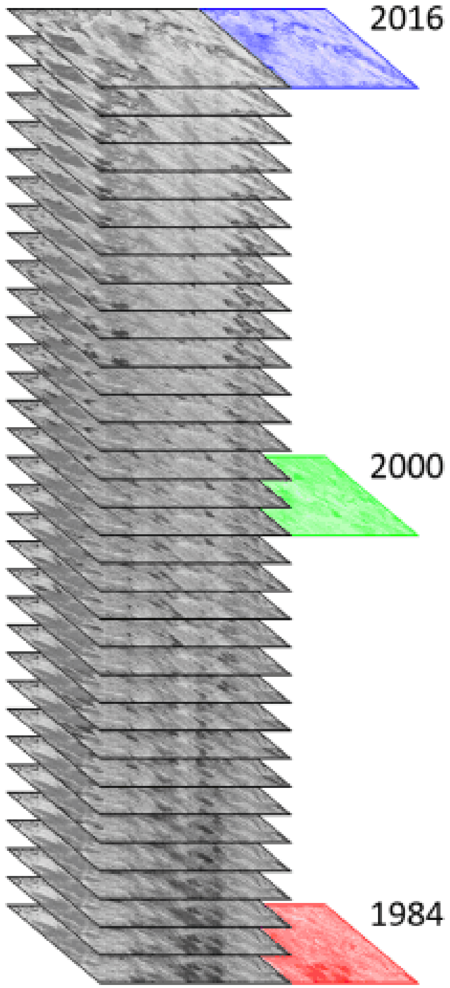
# Fitted Index Delta RGB Mapper



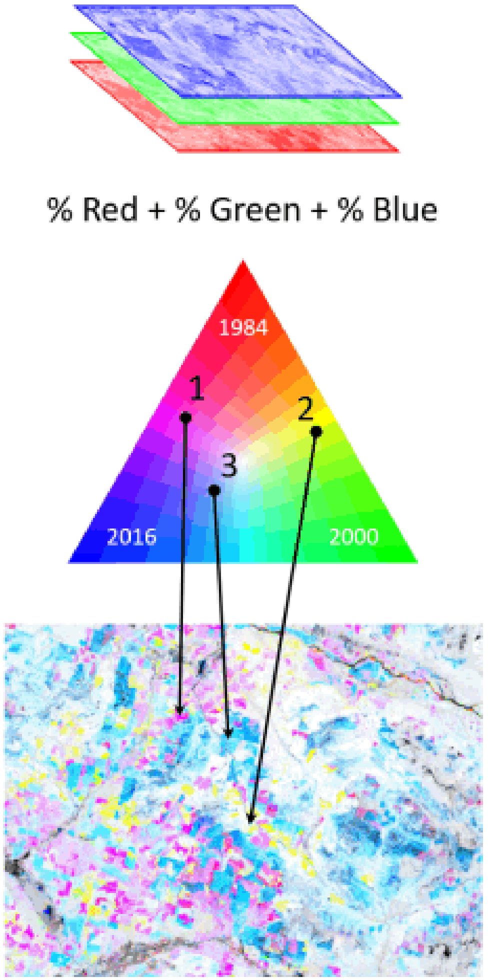



# Fitted Index Delta RGB Mapper

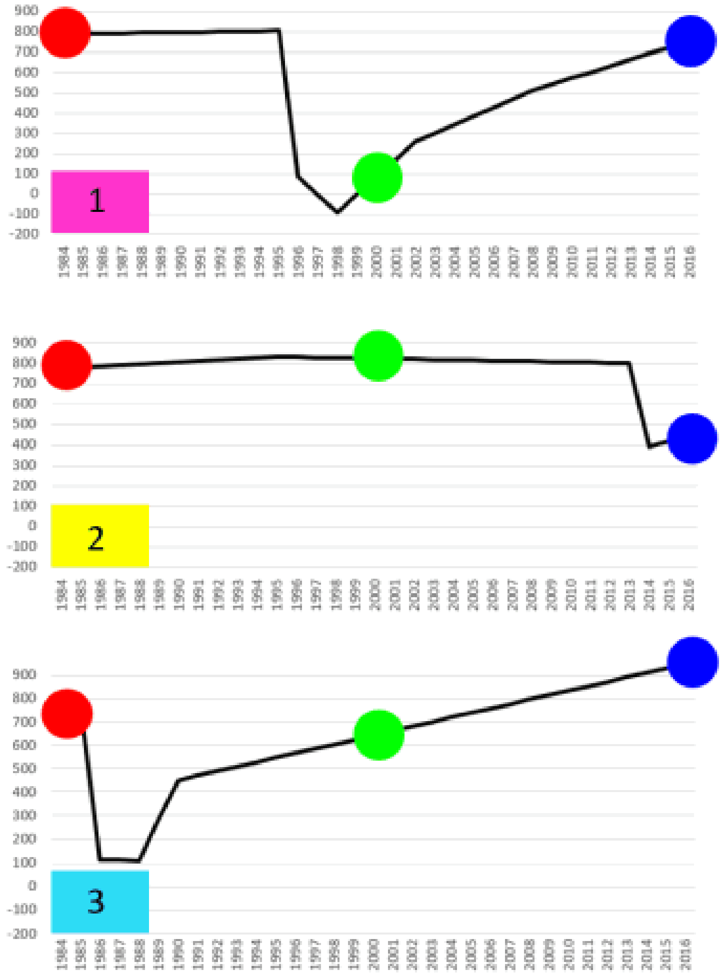
Annual NBR Intensity

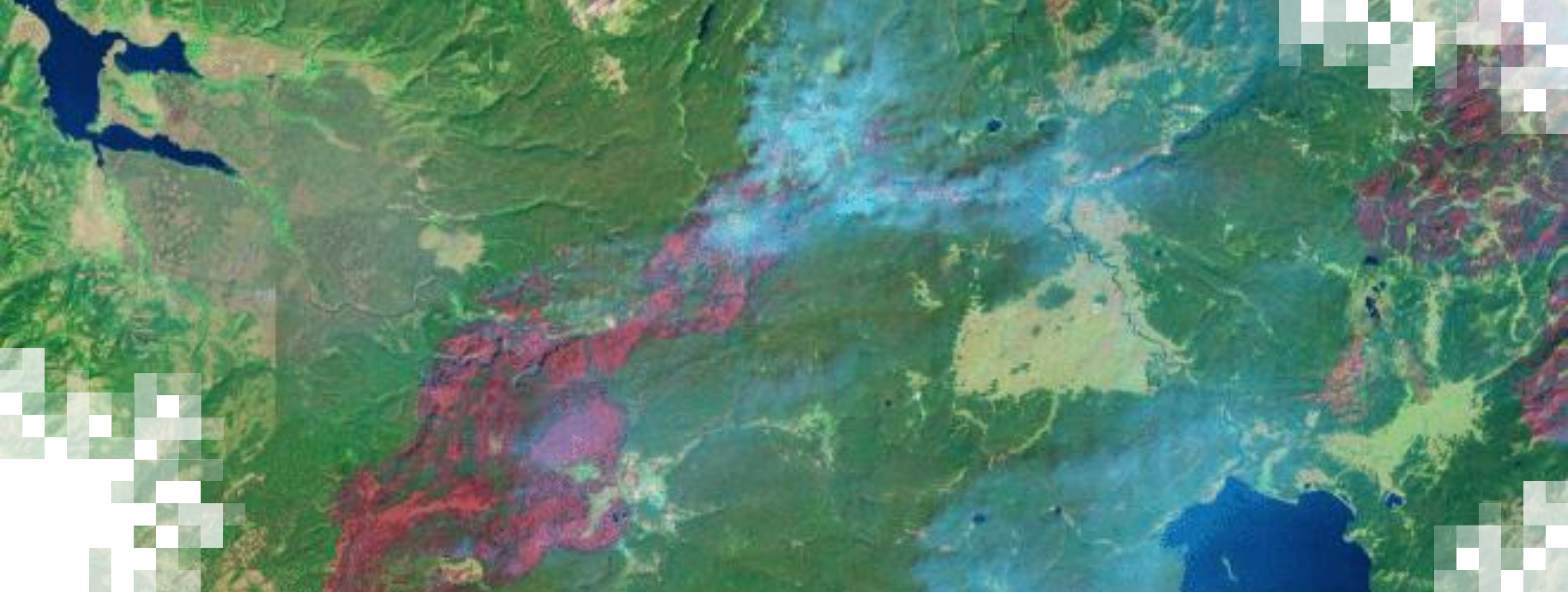



Color-map change using RGB compositing




Spectral-temporal time series examples





# Other Vegetation Disturbance Algorithms

# Vegetation Change Tracker (VCT)

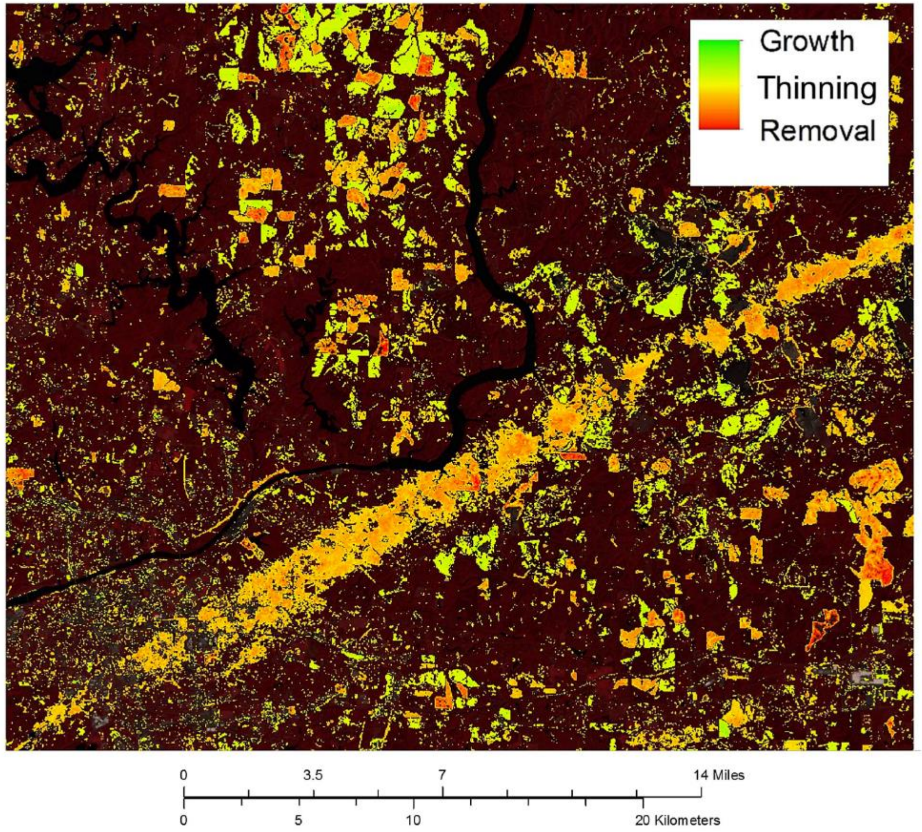
- Similar to LandTrendr, but uses different mechanisms
- Used for forests only
- Best for short-term high-magnitude events
- 2 step-approach
  - Create mask and calculate spectral indices for each image in the stack
    - This measures forest likelihood
  - Time series analysis of Forest Score and Normalized Burn Ratio (NBR)

Examples of VCT use-cases such as wildfire (left) and clear cutting (right)

Image Credit: Huang et al., 2010

# Exponentially Weighted Moving Average Change Detection (EWMACD)

- Uses residuals from time series regression to detect subtle changes in vegetation across multiple years
- Best for discrete events
- Broad range of disturbance magnitudes (low to high)
- Used for forests only
- Best for short-term high-magnitude events

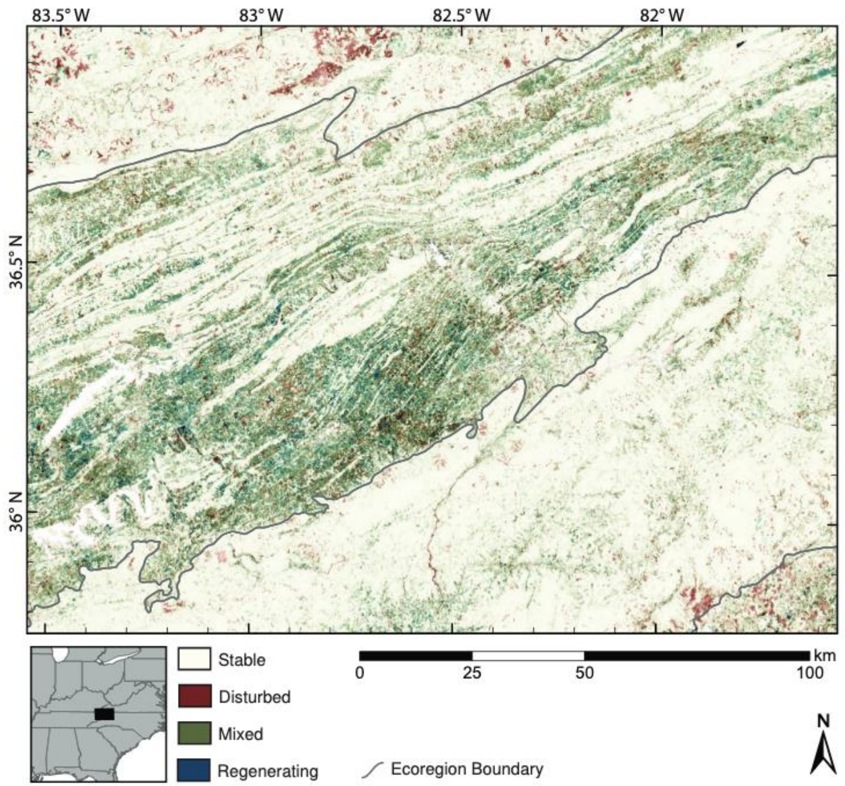



Results from the EWMACD showing a spectrum of change from growth to removal. The line across the image is a tornado path near Tuscaloosa AL

Image Credit: [Brooks et al., 2014]

# Vegetation Regeneration and Disturbance Estimates Through Time (VeRDET)

- Uses neural network classifications to explore the spectral information of each pixel
- Different from LandTrendr in that is constructs segments of pixels and assigns a common value prior to detecting change
- Discrete events and gradual change (variable length disturbance)
- Broad range of disturbance magnitudes (low and high)
- Only forests

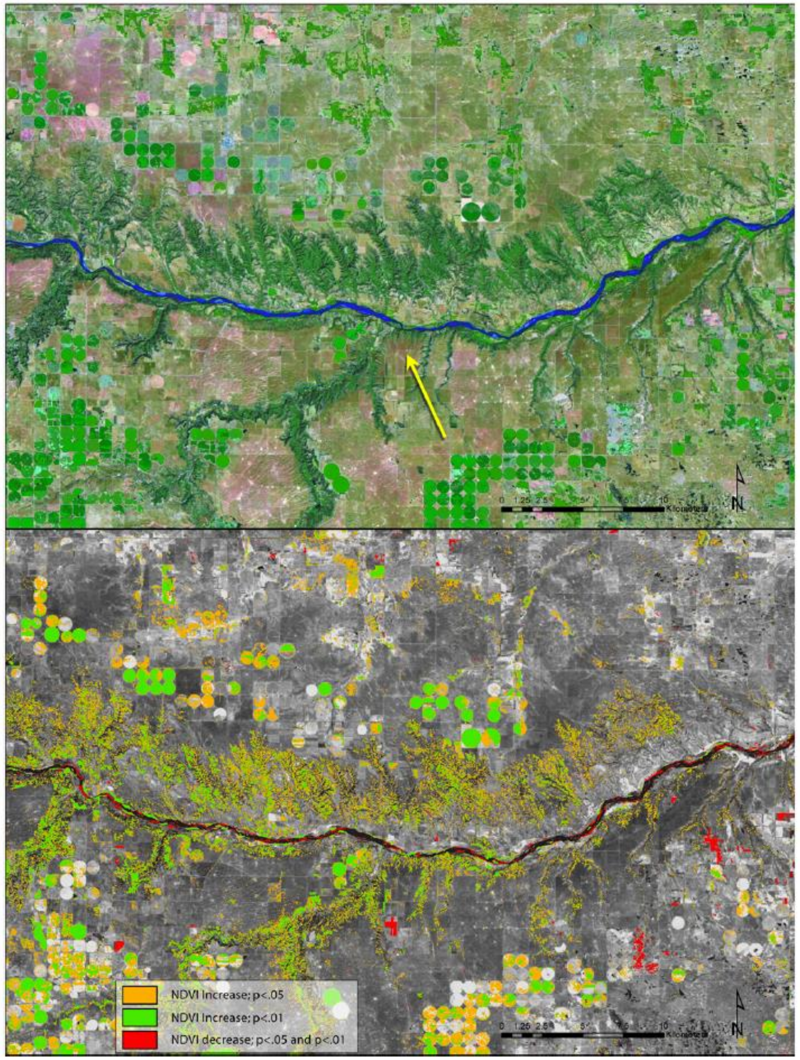



Example of results from VeRDET where darker areas have higher change than lighter areas. Disturbed regions are red, Regenerating regions are blue, and Grey regions have both

Image Credit: [Hughes, 2014]

# Image Trends from Regression Analysis (ITRA)

- Uses slope of annual series over multiple years for each pixel
  - Simple design
  - Highlights gradual trends
  - Broad range of disturbance magnitudes
  - Used for all vegetation (not just forests)
  - NDVI most commonly used



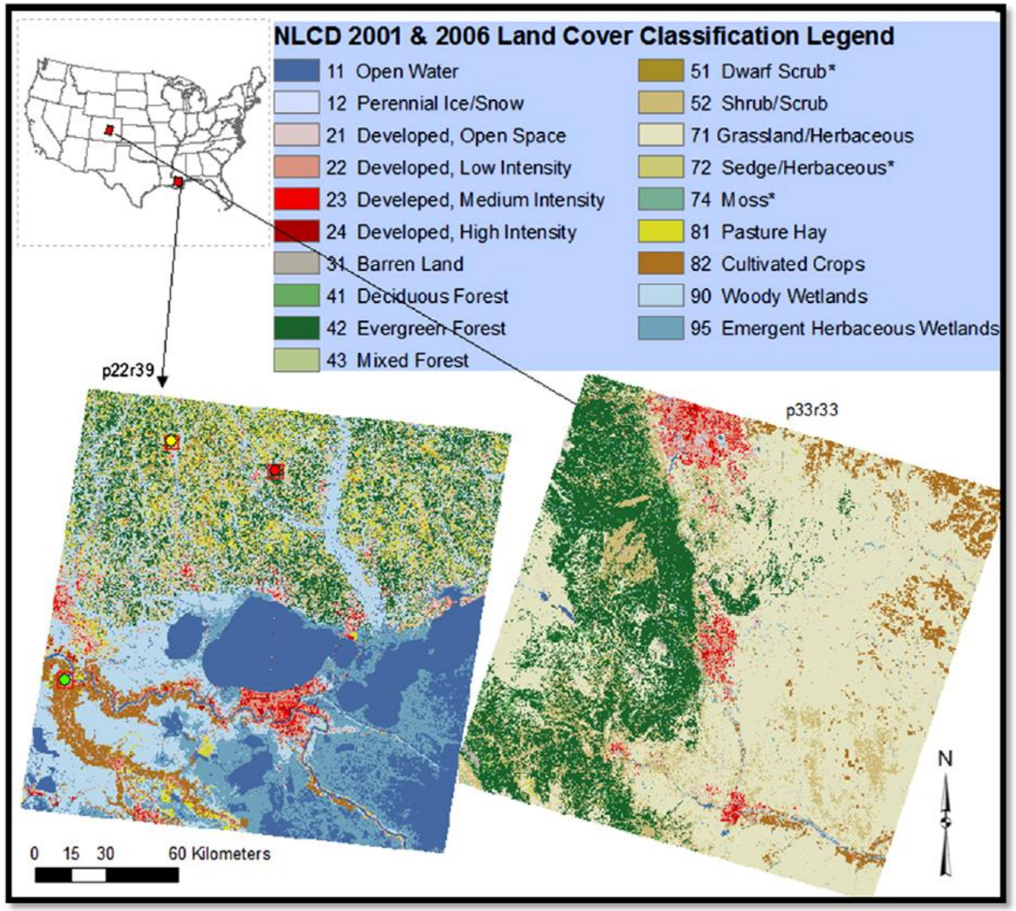

All woody vegetation

NDVI trends highlighting increased forested area from 1988 to 2010 using the ITRA approach

Image Credit: [Vogelmann et al., 2012]

# Multi-index Integrated Change Analysis (MIICA)

- Algorithm used in the development of the U.S. National Land Cover Database (NLCD)
- Uses four spectral indices
- Best for discrete events
- Limited range of disturbance magnitudes
- All land cover types
- Best for high-magnitude events

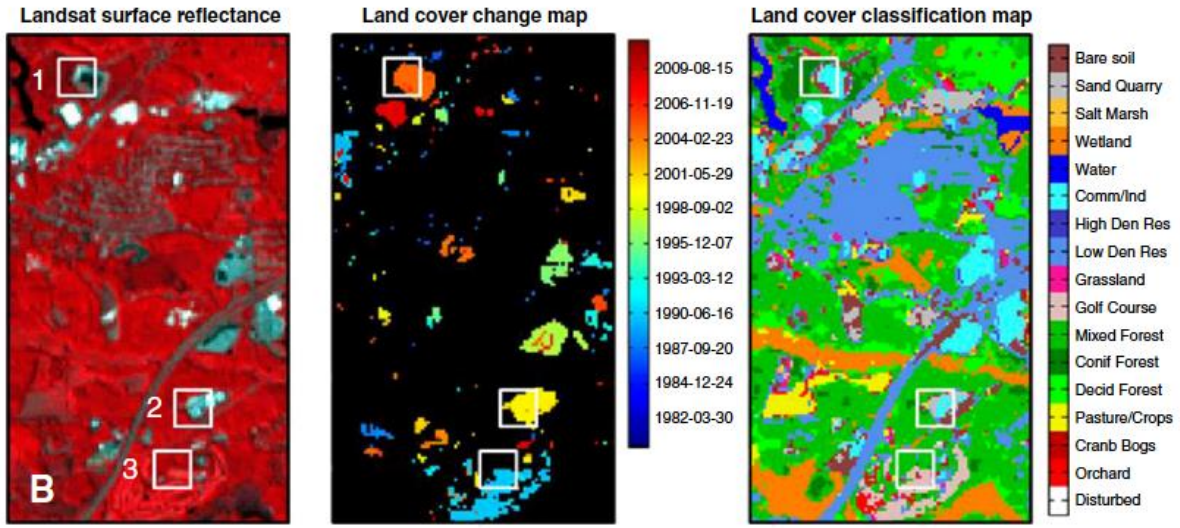



Examples from the National Land Cover Database 2006 map

Image Credit: Jin et al., 2013

# Continuous Change Detection and Classification (CCDC)

- Uses seasonality, trend, and break estimates to detect change
- Two-step approach (similar to many others)
  - Cloud/snow mask
  - Time series analysis of surface reflectance and brightness temperature
- Best for discrete events
- Limited range of disturbance magnitudes
- All land cover types
- Best for high-magnitude events

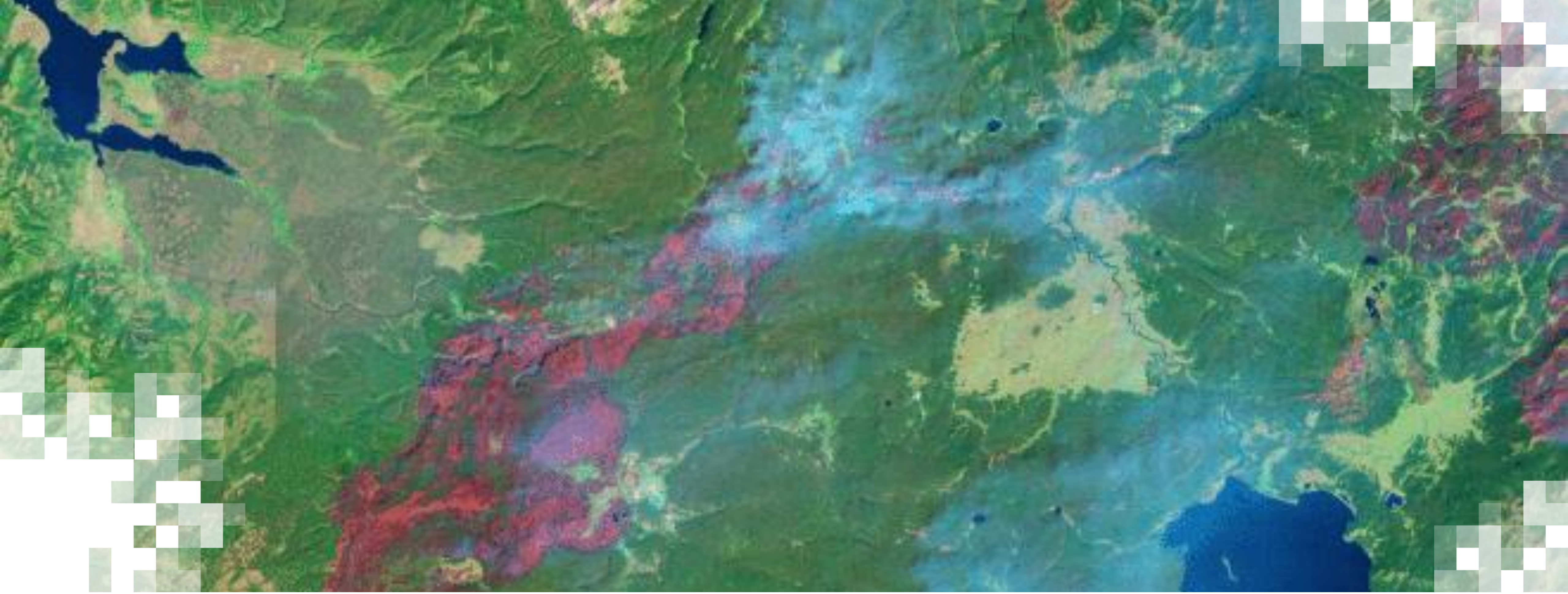



Example of results from CCDC from July 2011 from a forested region in Massachusetts. The image displays the surface reflectance as false color (left), the change map (center), and the classification map (right)

Image Credit: [Zhu and Woodcock, 2014]

# Summary

- Time series analysis of Landsat images can be used for mapping disturbance patterns across a landscape
  - Can establish relationships between human activities and drivers of natural disturbances.
- LandTrendr is used to identify patterns of change in forests at that differ in length and magnitude
  - LandTrendr in GEE is quick and effective
- There are many algorithms for mapping disturbance and user should choose based on interest in vegetation type, length of disturbance, and magnitude of disturbance

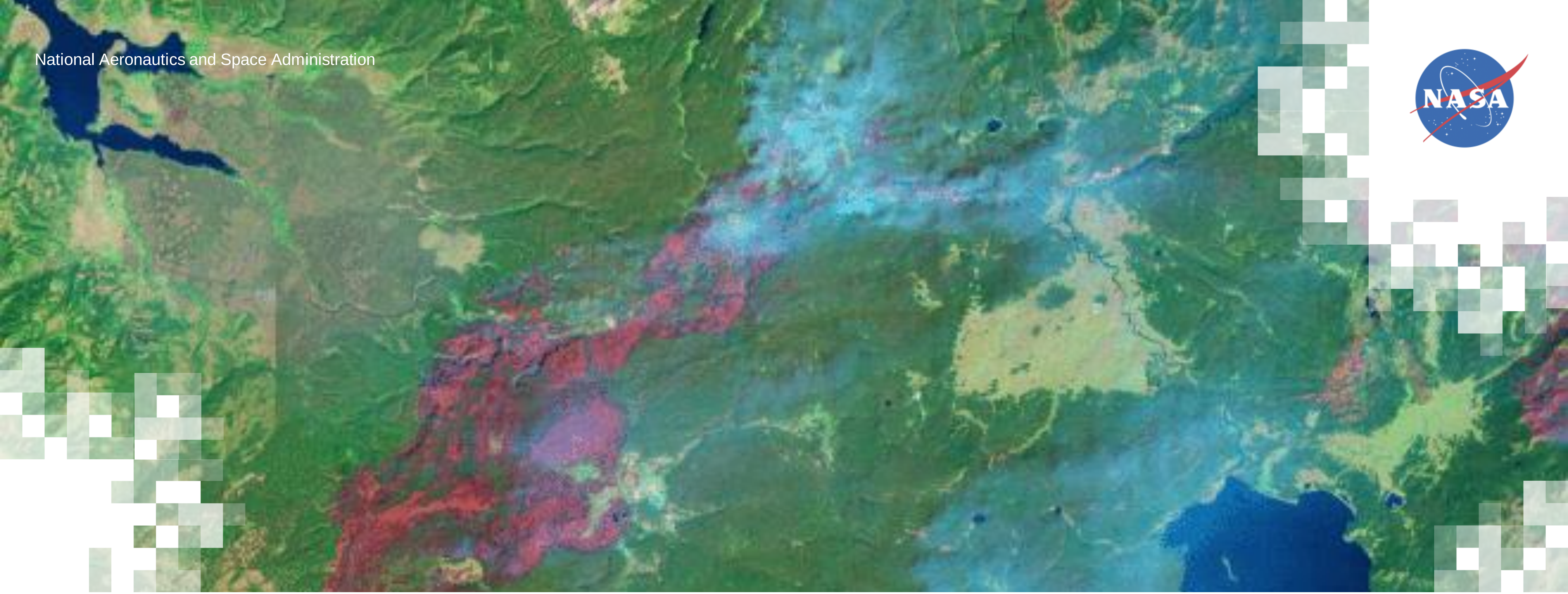


# LandTrendr Exercise

# Contacts

- ARSET Land Management & Wildfire Contacts
  - Cynthia Schmidt: Cynthia.L.Schmidt@nasa.gov
  - Amber McCullum: AmberJean.Mccullum@nasa.gov
- General ARSET Inquiries
  - Ana Prados: aprados@umbc.edu
- ARSET Website:
  - http://arset.gsfc.nasa.gov

National Aeronautics and Space Administration



# Thank You

Complete your homework by May 1, 2019

04/17/2019