Introduction to Change Detection

Lecture 1: Overview and Image Selection

Instructor: Lila Leatherman (they/them)

November 17-18, 2021

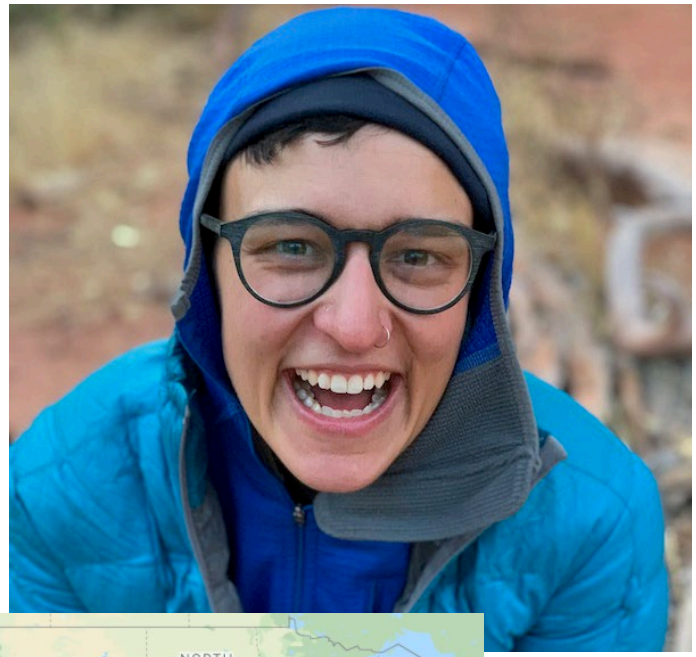
Housekeeping

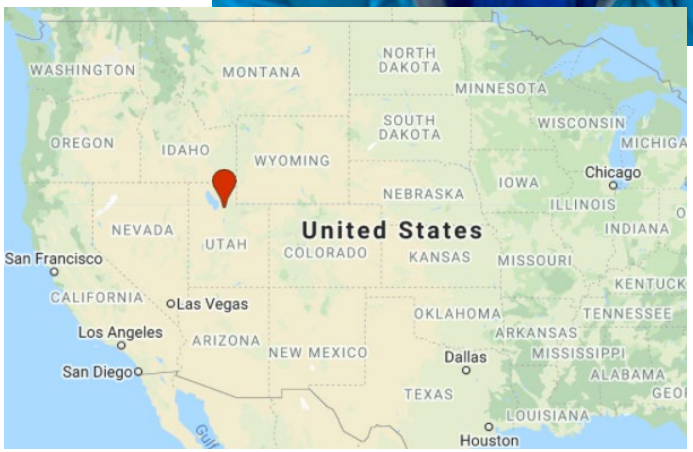
- Keep video off and stay on mute
- If you have questions:
  - Raise hand in Teams
  - Respond in chat box
  - Q + A at the end
- Closed captions are available
- Take care of your body!

* this webinar will be recorded*

Personal intro

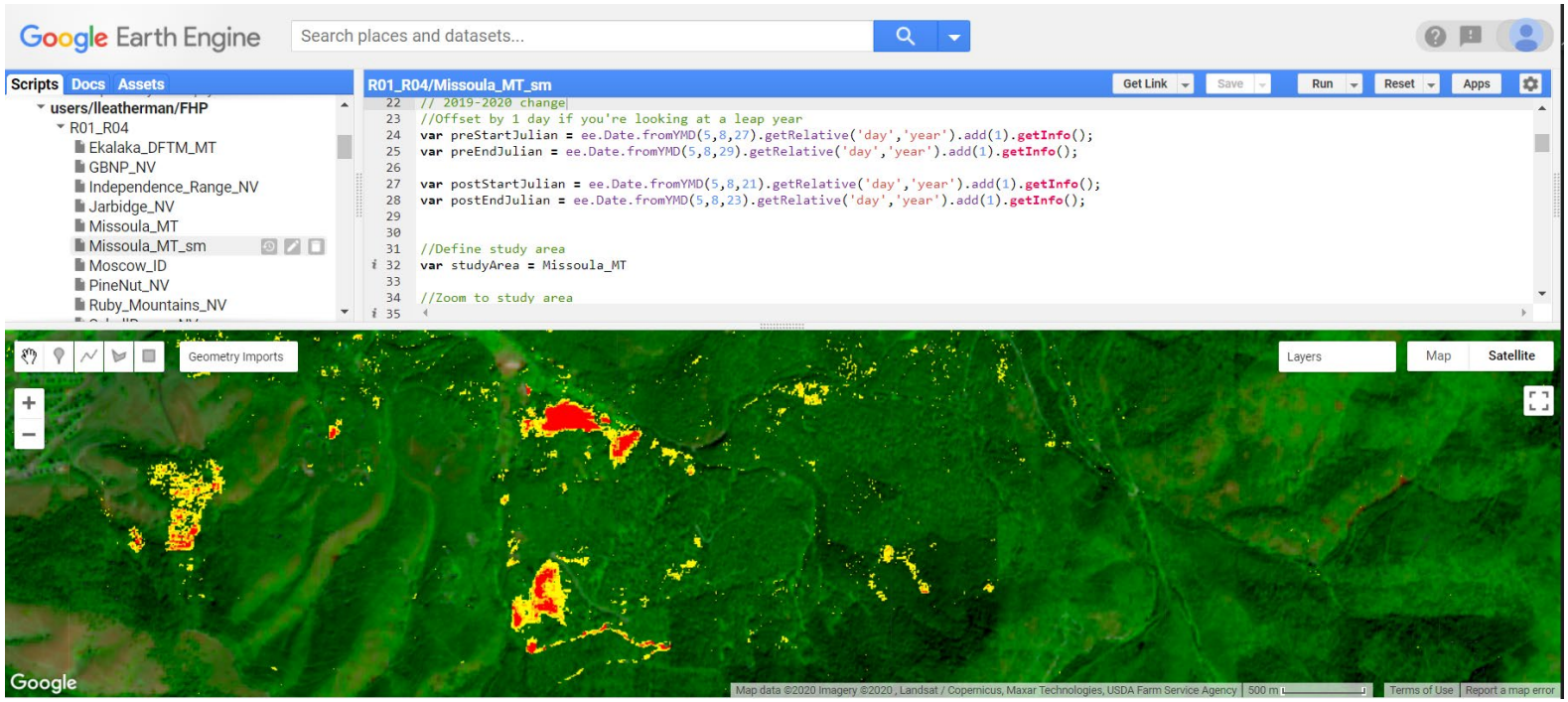
- Lila Leatherman (they/them)
- Remote Sensing Specialist
- Oberlin College, Oregon State University
- Spatiotemporal stats, ecophysiology, biogeography, Google Earth Engine
- Trail runner, rock climber, newbie mountain biker





DeltaViewer Overview

- Basic two-date change detection
- Implemented in Google Earth Engine (GEE)
- Used in FHP to supplement aerial surveys grounded by COVID
- Delta Viewer Hub Site on AGOL



Software and course data

- Required Software:
  - ArcGIS 10.x
- Suggested Software
  - Google Earth Engine account
- Course data
  - Available via the tutorial or agenda (unnecessary with GEE account)
    - Data.zip (542 MB)
  - Contents:
    - Landsat imagery

Introduction to Change Detection

- Course objectives
  - Establish a conceptual foundation for change detection
  - Increase awareness of applications and capabilities
  - Acquire a conceptual and technical toolset enabling you to conduct/evaluate change analyses

Outline and Course Agenda

- Day 1:
  - Concepts and overview
  - Scene selection and image pre-processing
  - Identifying change: Spectral characteristics of change
- Day 2:
  - Measuring and mapping spectral change
  - Classifying and validating change

Course Agenda

- Day 1 – Morning
  - 10:00-10:45 – Presentation: Course overview and image selection and preparation
  - 10:30-10:45 – Demonstration: Overview of GEE
  - 11:00-11:10 – Break
  - 11:10-11:30 – Presentation: Image correction
  - 11:30-12:00 – Demonstration: Creating cloud-free composites in EE

Tasks to complete before the next session: Exercise 1 + 2

- Day 1 – Afternoon
  - 2:00-2:30 – Presentation: Band ratios and image transformations
  - 2:30-3:00 – Demonstration: Identifying significant landscape change
  - 3:00-4:00 – Q&A and Exercise Help

Tasks to complete before next session: Exercise 3

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Lecture outline:

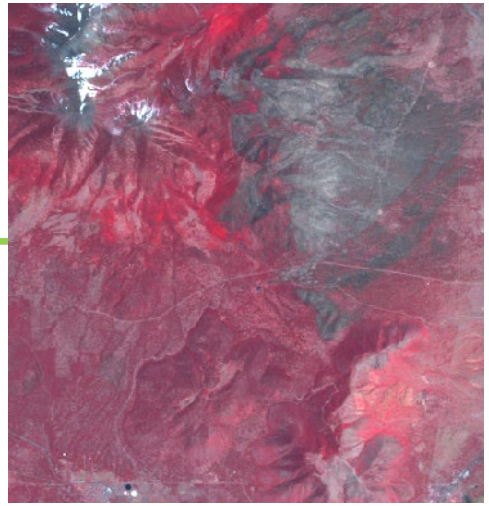
- What is change detection?
  - Review of remote sensing principles
  - Principles of change detection
  - Analysis considerations
  - Analysis methods
- Two-date change detection
  - Methods
    - Image selection
    - Image processing
    - Image enhancement
    - Analysis
    - Evaluation

What is Change Detection?

- Identifying landscape change from remotely sensed images
  - Analyze images from different times to map/quantify change
  - Assumption:

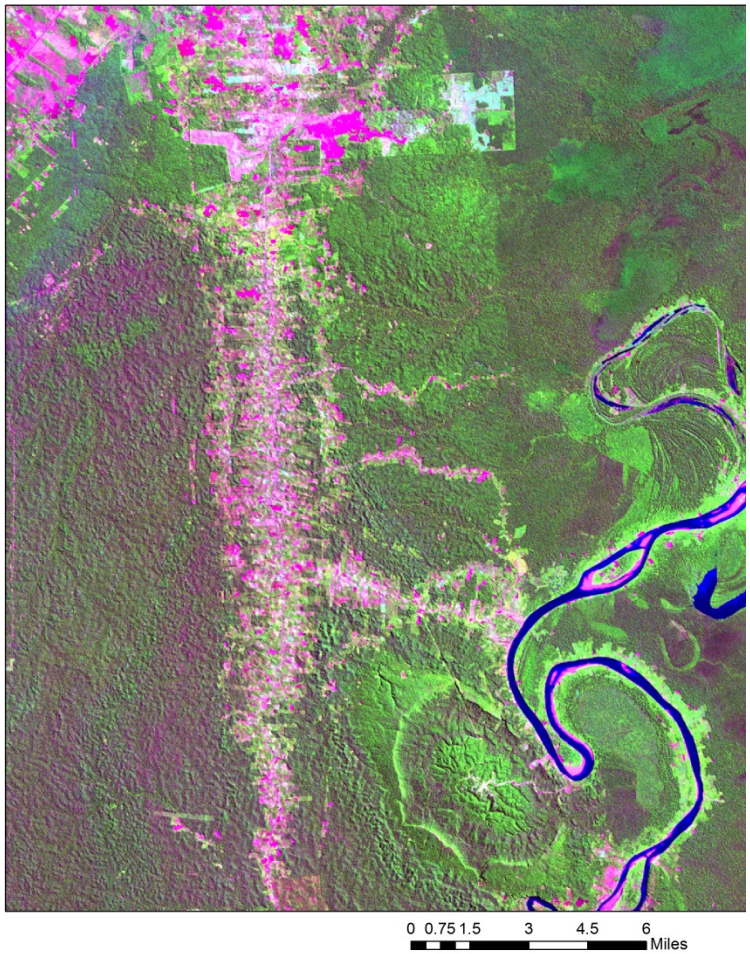
    Landscape change -> Spectral change

Coconino NF – Schultz fire effects

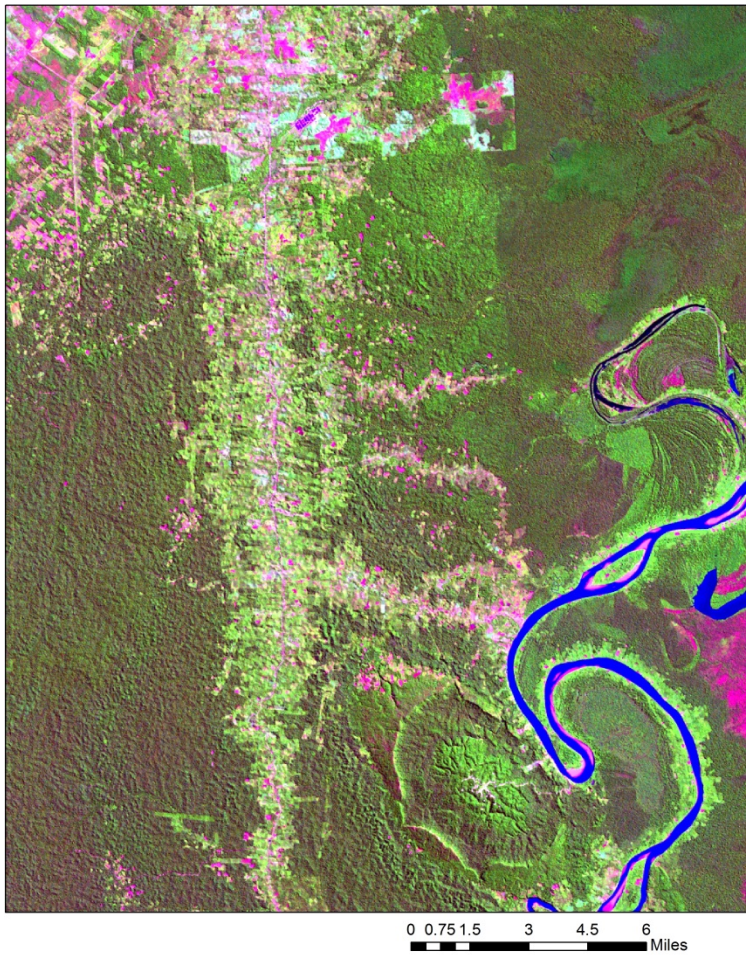


Landsat TM5 image – 1 year post fire

What is Change Detection?



What is Change Detection?



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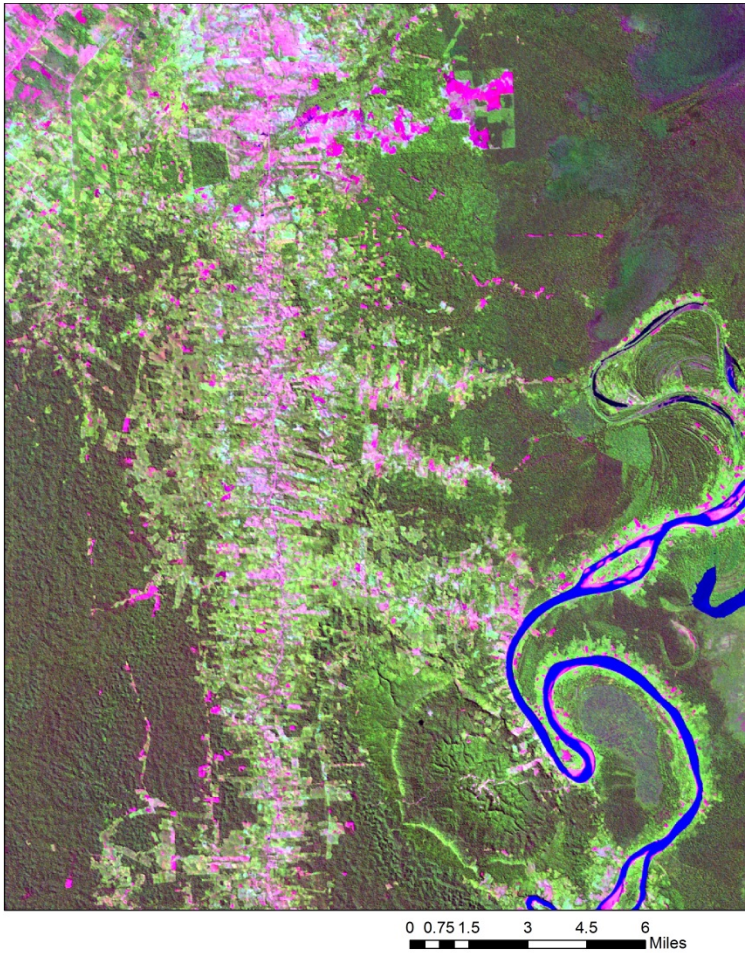

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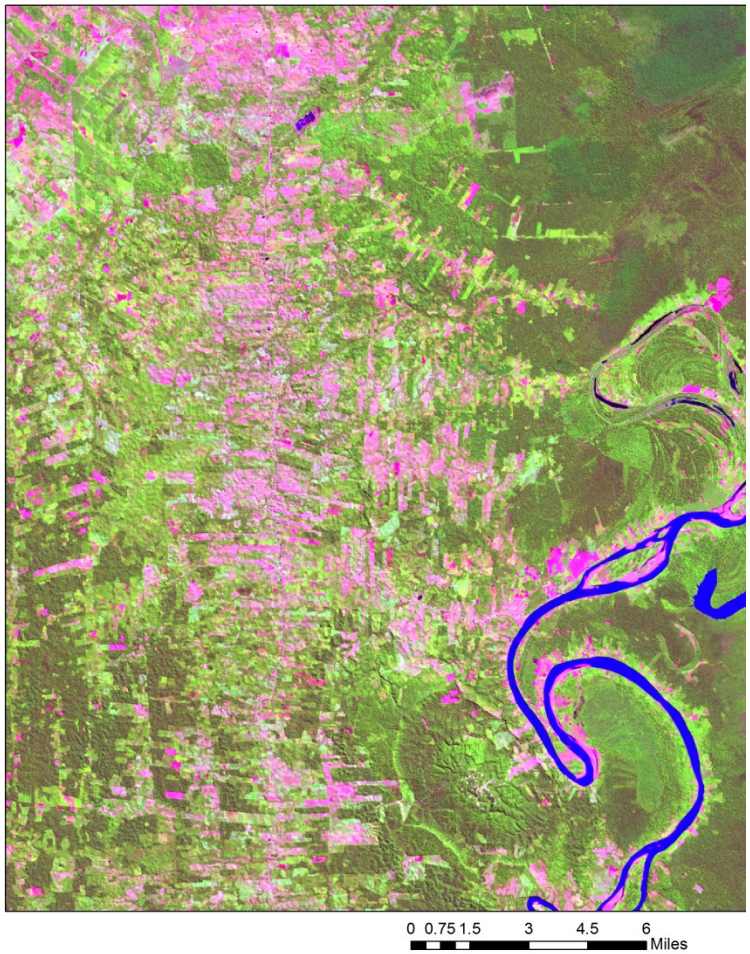

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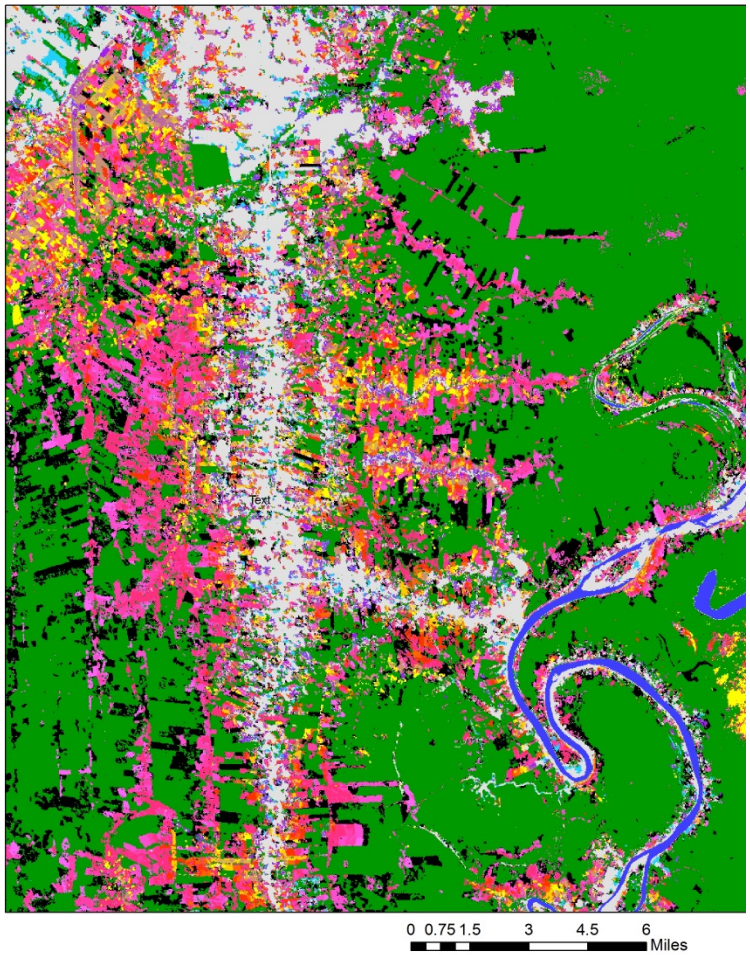
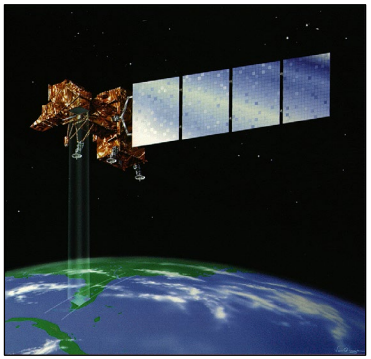


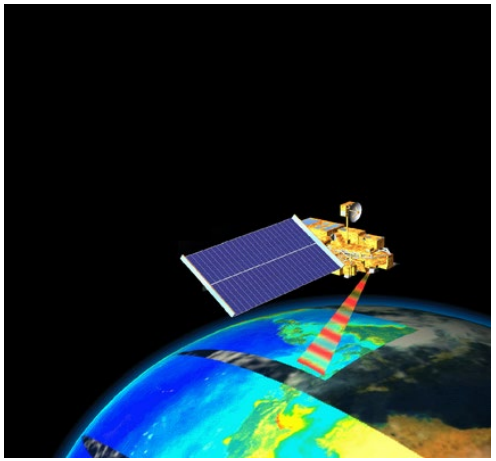
Monitoring Change with Remote Sensing

- Satellite and aerial sensors provide:
  - Consistent, repeatable measurements
  - An ever-growing archive of imagery

Several sensors/image programs available with different spatial scales, spectral resolutions and return intervals

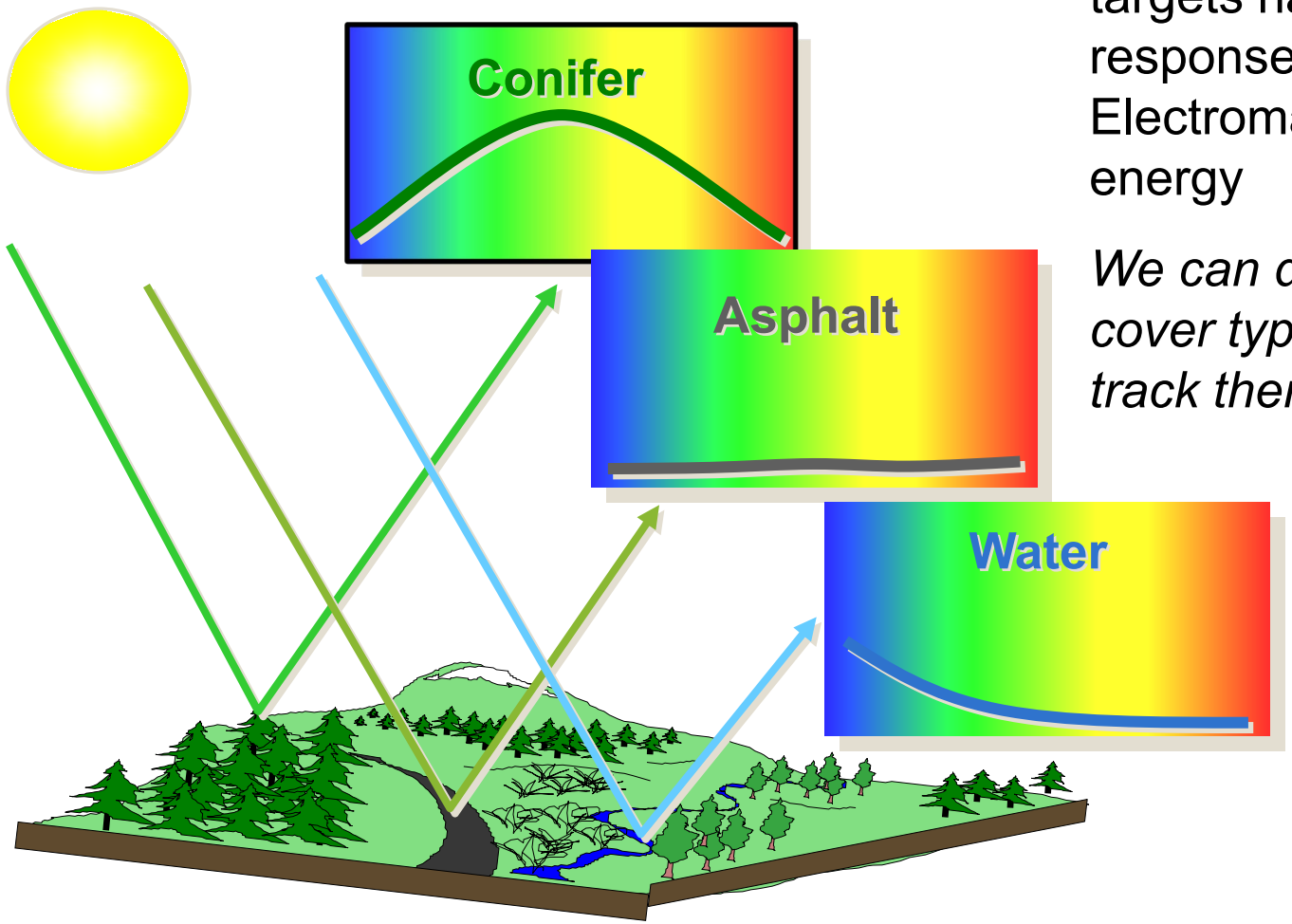
Landsat





SPOT

Review - Optical Remote Sensing Basics

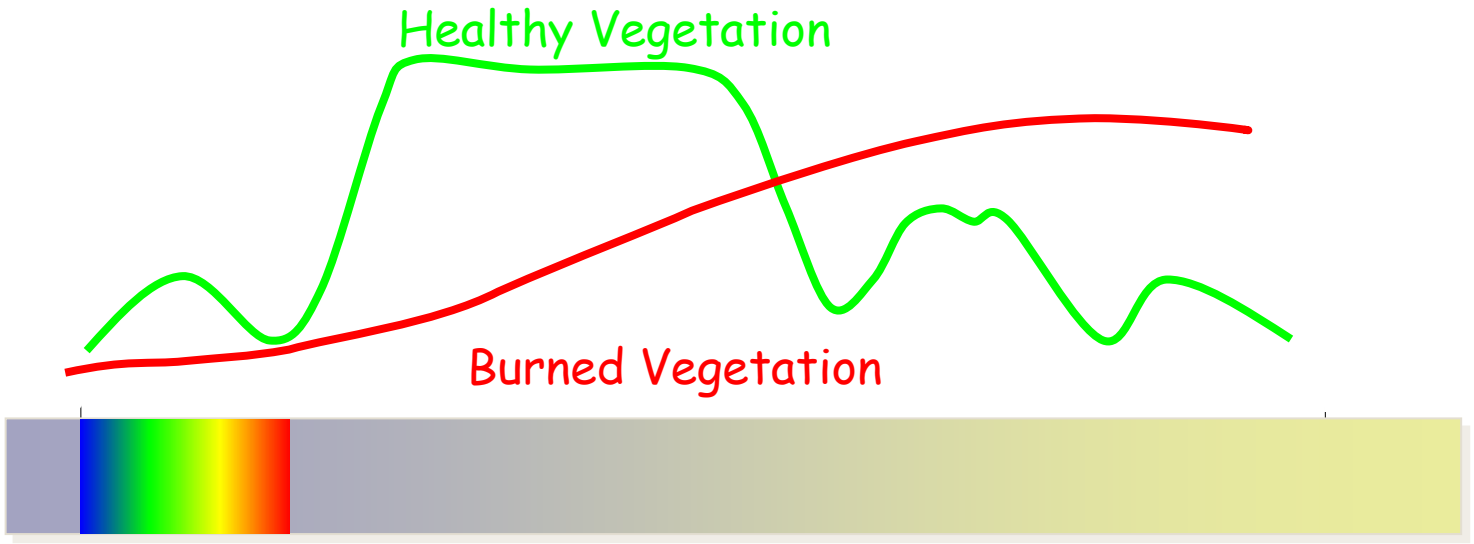


Remote sensing relies on the fact that different targets have unique responses to Electromagnetic (EM) energy

We can distinguish land-cover types spectrally and track them through time

How do we detect change from imagery?

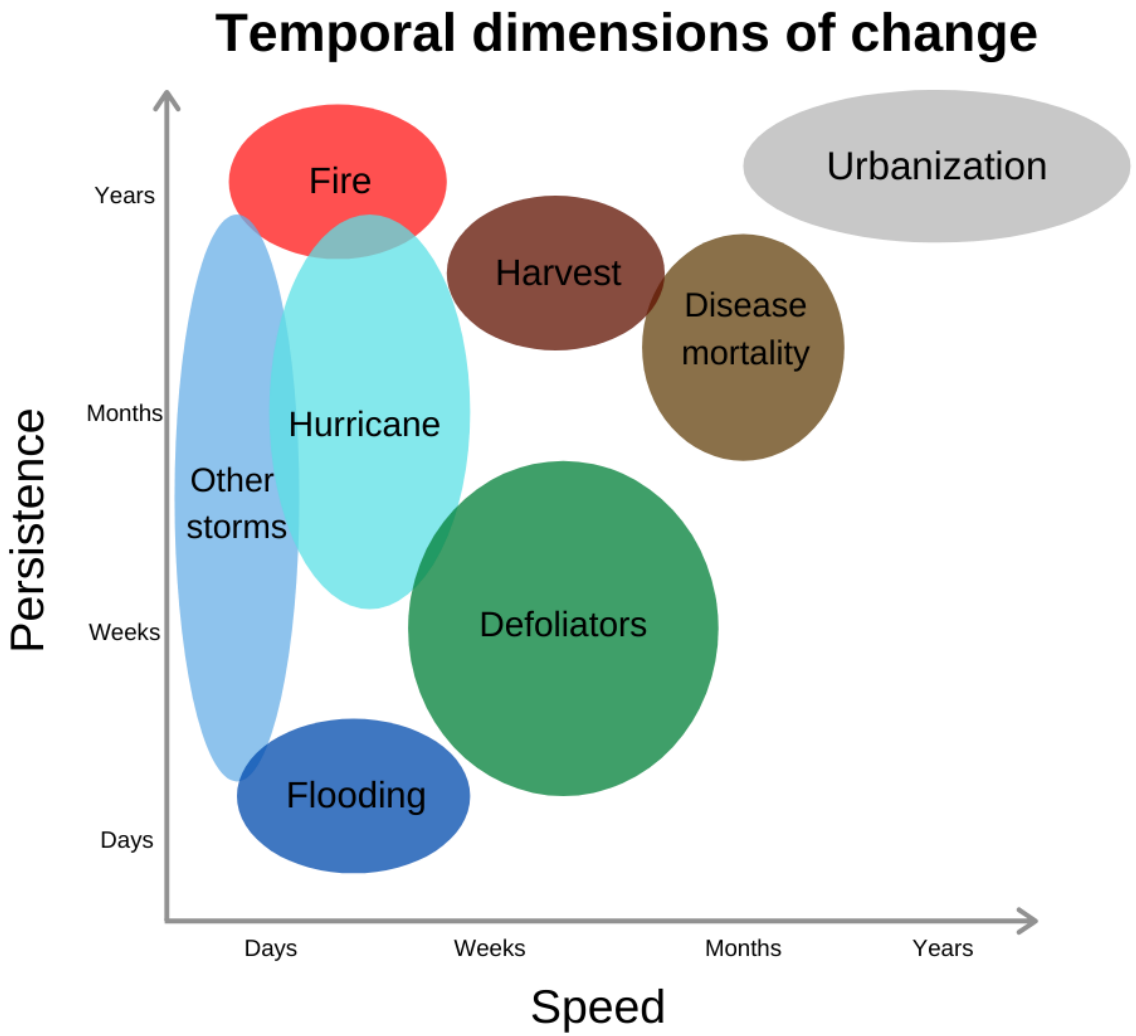
- Changes on the landscape can be detected as changes in the '*spectral space*' occupied by an image pixel



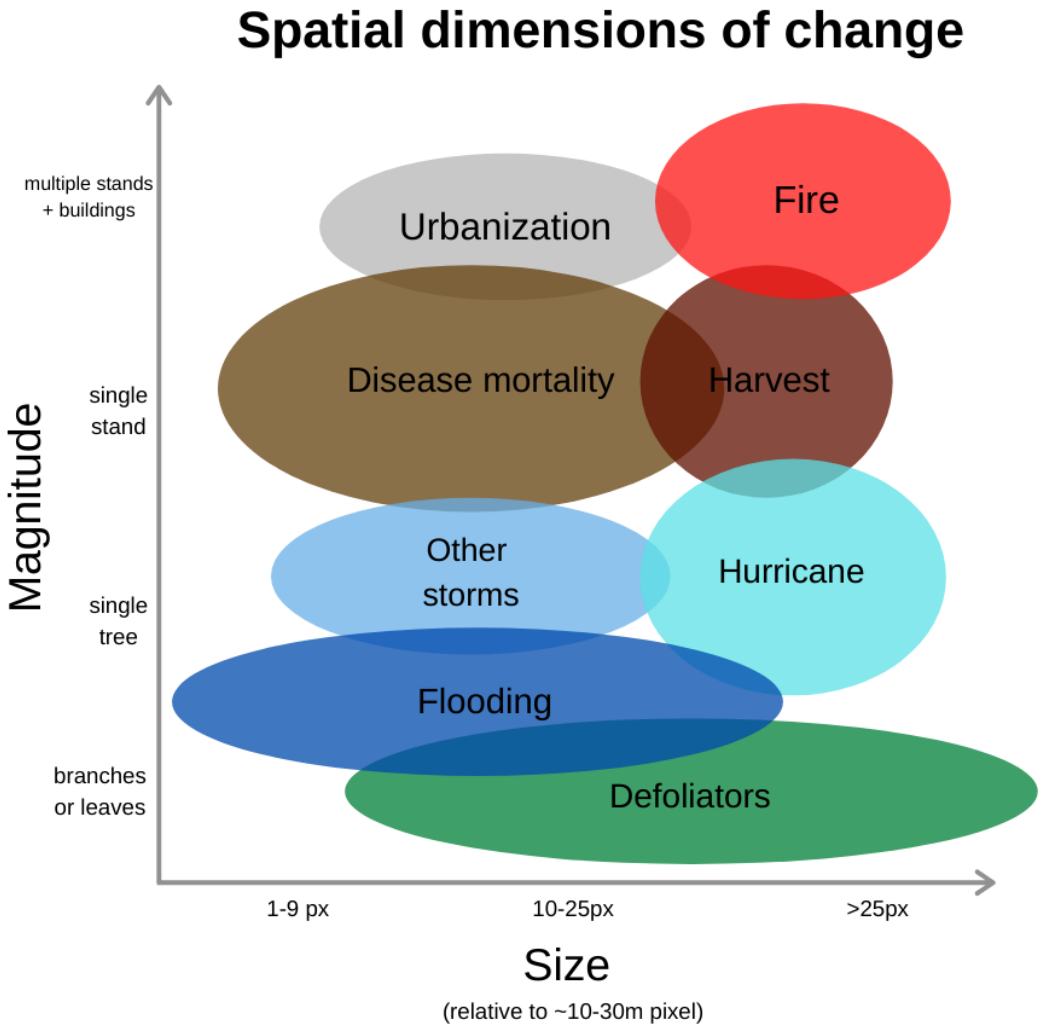
Change Agents

- Natural or anthropogenic
  - Change agents affecting forests:
    - Wildfire, insect outbreaks, succession, drought or climate change, regeneration, storms, etc.
    - Harvest, management, agriculture, development, invasive species, etc.

Dimensions of Change



Dimensions of Change



Sensor Characteristics

Sensor	Number of Bands	Spatial Resolution	Temporal Resolution	Radiometric Resolution	Swath width/Footprint
MODIS	36	250 m, 500 m, 1000 m	*1 day	4096	2330 km swath width
Sentinel-2	13/1	10 m, 20 m, 60 m	*5 days	4096	290 km swath width
Landsat 5 & 7/Pan	7/1	30 m/15 m	*8 days	256	34,225 km^2 footprint
Landsat 8/Pan	10/1	30 m/15 m	16 days	4096	34,225 km^2 footprint
SPOT 5/Pan	3/1	20 m/10 m	*2-3 days	256/256	3600 km^2 footprint
IKONOS/Pan	4/1	4 m/1 m	~3 days	2048/2048	11.3 km swath width
QuickBird/Pan	4/1	2.4 m/0.6 m	2-11 days	2048/2048	16.4 km swath width

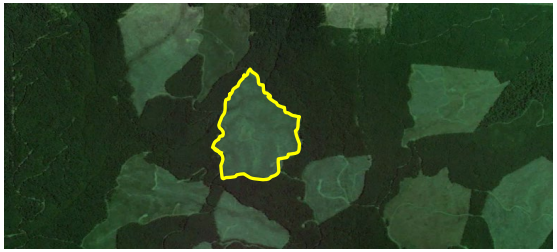
Analysis Prerequisites

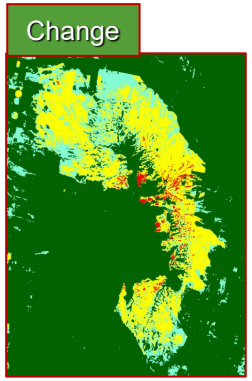
- Clearly define objectives
  - Identify the problem:
    - Change phenomena of interest *(e.g., fire effects, forest mortality, stream channel changes, etc.)*
    - Define study area
    - Determine frequency for change analysis *(e.g., seasonal, annual, biennial, etc.)*
    - Consider limitations

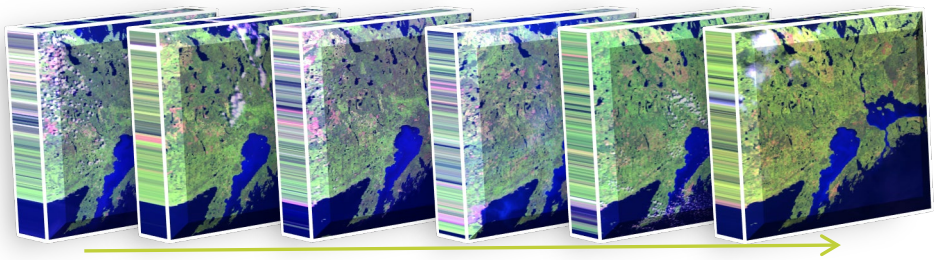
These considerations determine appropriate methods and whether change can even be detected

Approaches

- Manual
  - Image interpretation
- Automated
  - Two-date change detection
    - pre- and post-imagery
  - Trend analysis
    - Multi-temporal image stacks







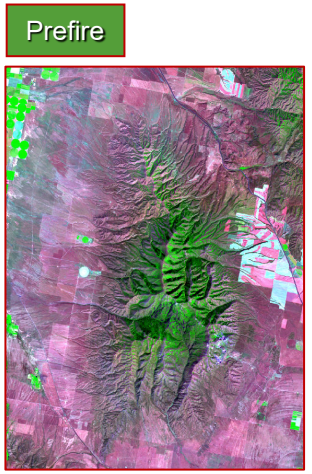
Two-date Change Detection

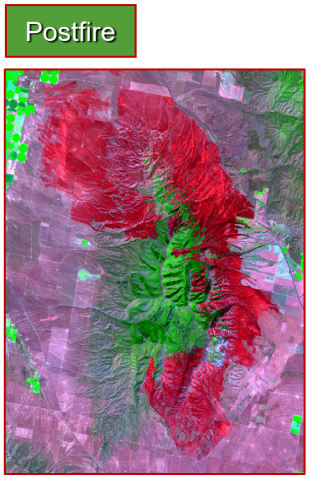
Multiple approaches with common core concepts:

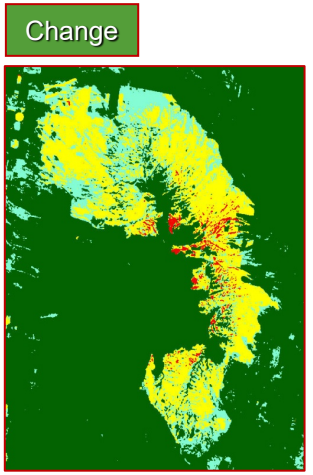
- Identify spectral characteristics of significant change and separate it from *noise*

Focus of this course:

- Two-date image differencing
- Moderate resolution satellite imagery
- Provides a foundation for other methods
- Can be accomplished using readily available tools







Challenge

- Separate ***real*** change from spectral change caused by:
  - Seasonal variation and phenology
  - Image misregistration
  - Clouds and shadows
  - Radiometric inconsistencies
    - Sensor
    - Variability in illumination (sun-angle, sensor position)
    - Atmospheric effects

Two-Date Methods Overview

1. Image selection and acquisition
   - Imagery and reference data
2. Image processing
   - Correction
3. Image enhancement
   - Normalization and transformation
4. Analysis
   - Quantify differences and create a change map
5. Evaluation
   - Accuracy assessment

Image Selection - Overview

- Four primary considerations
  - Type, timing, quality, cost/availability

Image Selection - Overview

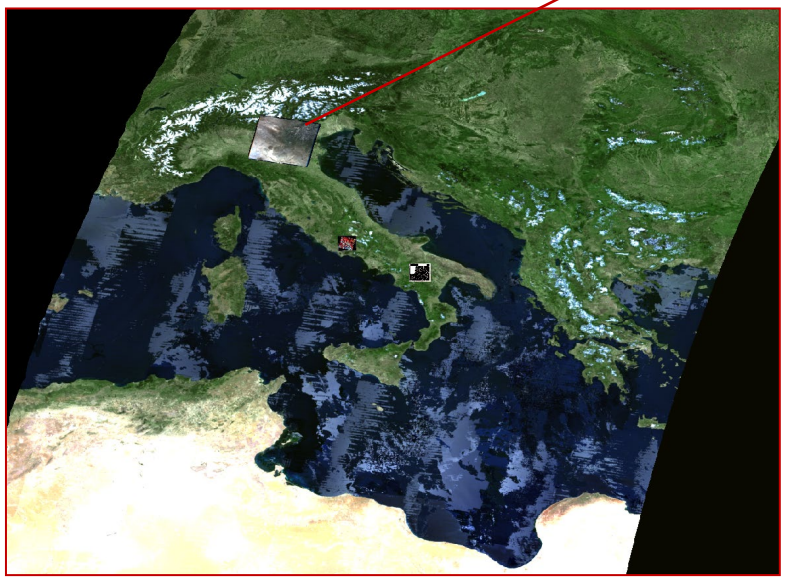
- Four primary considerations
  - Type, timing, quality, cost/availability

Goals:

- Capture the change of interest
  - Consider image and change phenomenon resolution (spatial, temporal and spectral)
- Minimize non-target change or ‘noise’
  - Select near anniversary dates to minimize illumination and seasonal differences

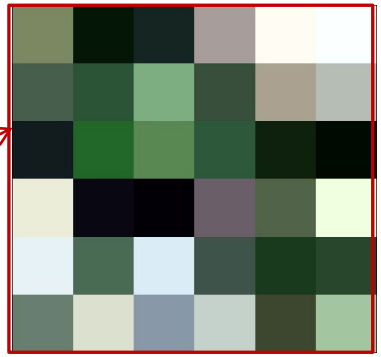
Image Selection - Spatial Considerations

- Spatial resolution
  - (pixel size)
- Extent
- *Trade-off between resolution and extent*

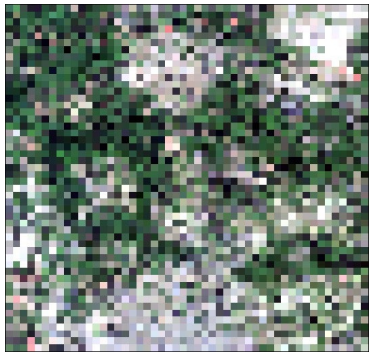


Simulated imagery data

MODIS (250m)



Landsat (30m)



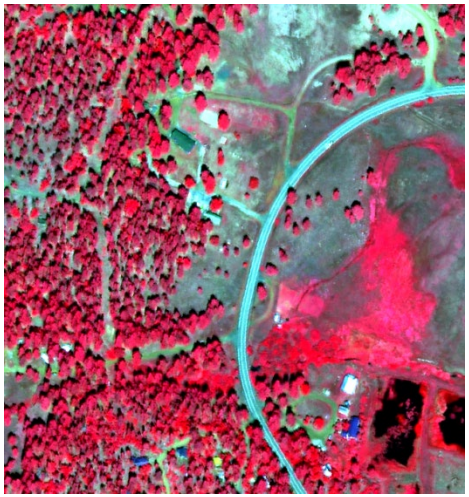
Sentinel-2 (10m)

WorldView (2m)

Image Selection - Temporal Considerations

Seasonal mismatch - World View2

March 2011



September 2011

- Seasonal and environmental effects (e.g., soil moisture, phenology)
- Persistence of change phenomena
  - (i.e., consider recovery and succession)

Figure adapted from Kennedy et al 2007

Image Processing - Overview

This is now automated in Google Earth Engine!

- **Geometric**
  - Co-registration
    - *Pixel-to-pixel alignment is especially important for image differencing*
- **Image Correction**
  - Correct or normalize the spectral values in the image pair

Image Processing - Registration Errors

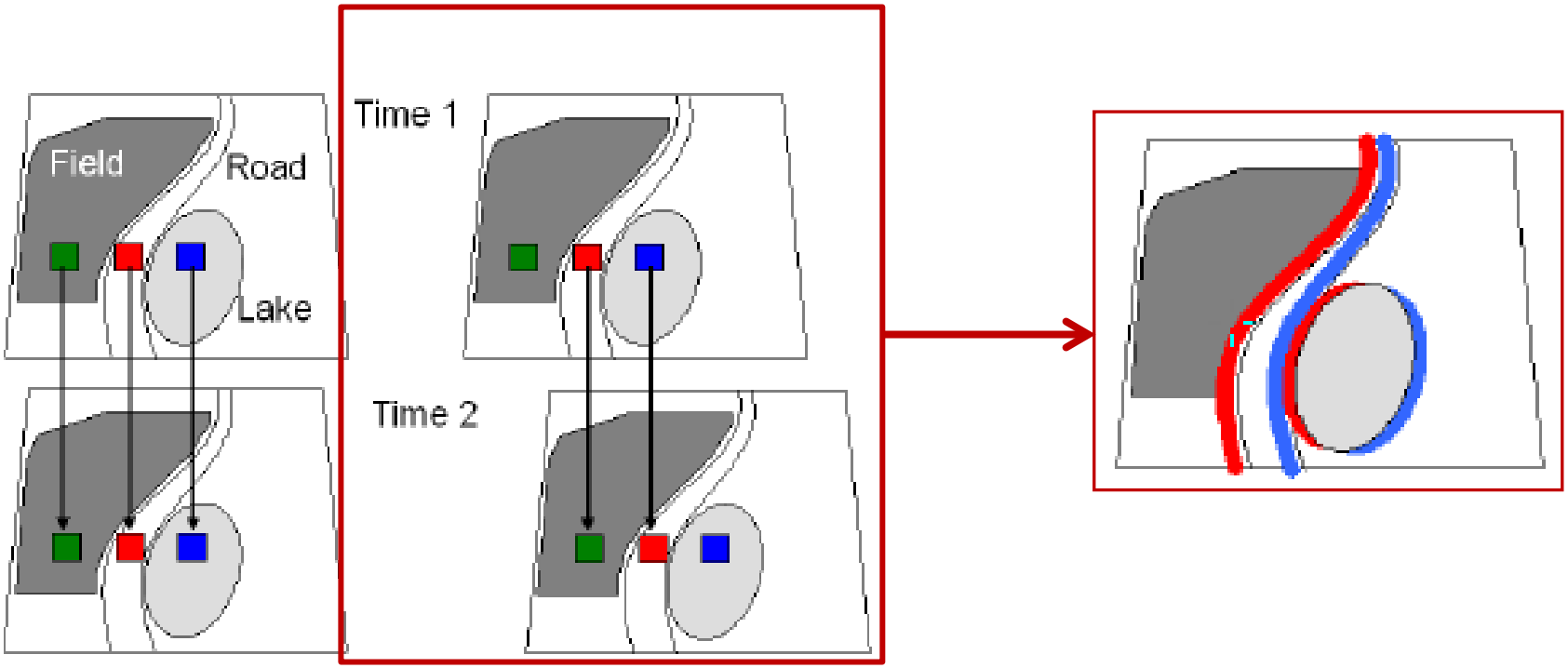
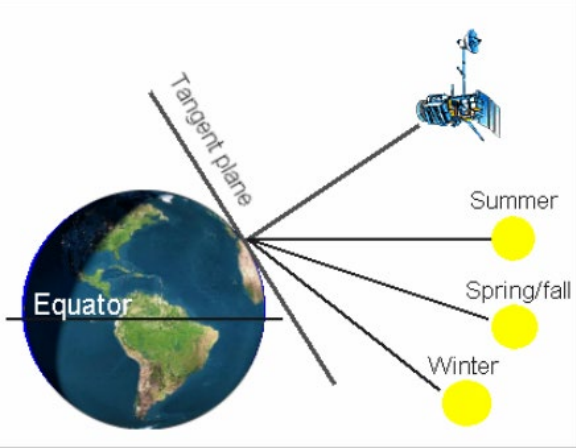


Image Processing - Image Correction

- Radiometric
  - Sensor calibration, illumination and view angle



- Atmospheric
  - Selective scattering and absorption of light alters reflectance

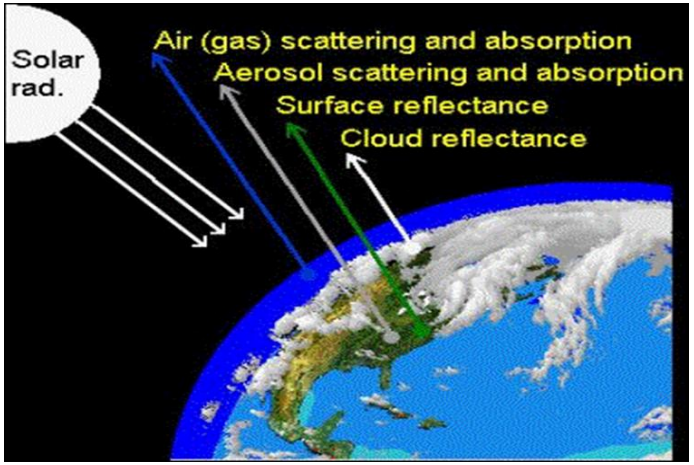


Image Enhancement or Transformation

- Derive and compare attributes highlighting scene features of interest
  - E.g., NDVI, NDMI, Tasseled Cap Greenness layers
- Advantages:
  - Reduce data and noise
  - Simplify comparisons

Image Enhancement or Transformation

4- band image
NAIP image

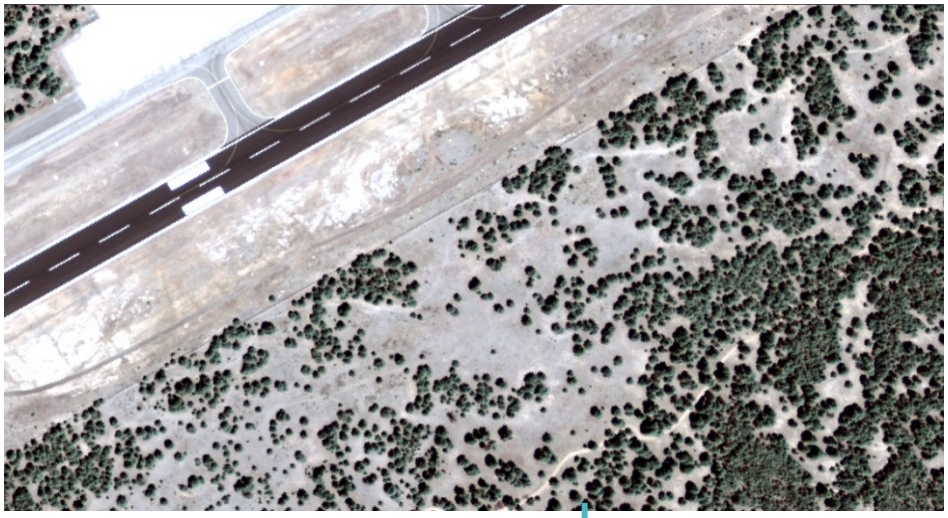
↓

Single band
NDVI image

NDVI = (NIR – Red) / (NIR + Red)

Normalized Difference Vegetation Index (NDVI)

1m NAIP imagery – 4band (blue, green, red, NIR)



1m NAIP NDVI – 1band (NDVI) ↓

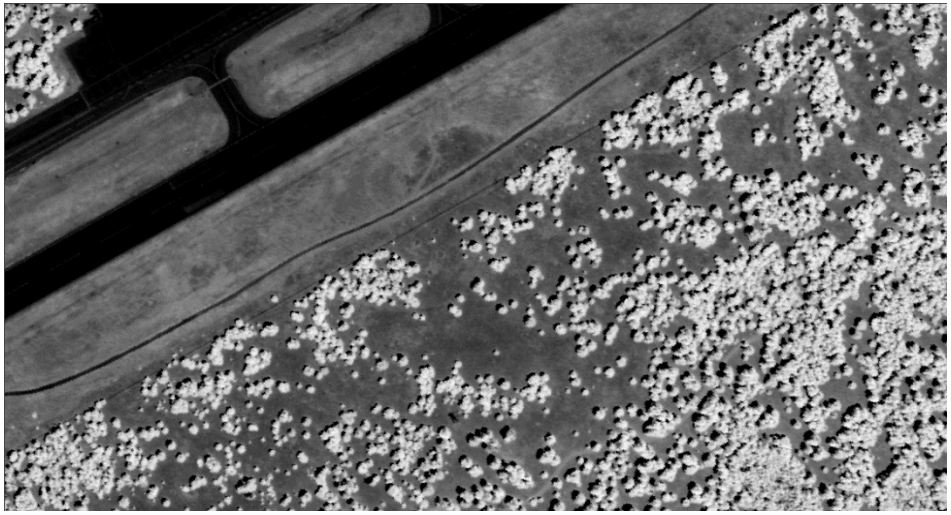


Image Enhancement or Transformation

4- band image
NAIP image

↓

Single band
NDVI image

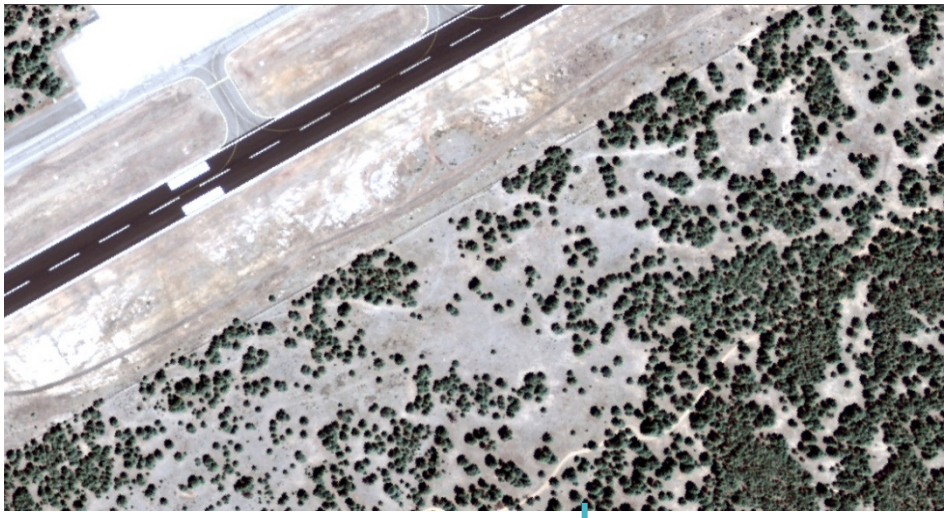
NDVI = (NIR – Red) / (NIR + Red)

Vegetation appears bright (high values)

Non-vegetation appears dark (low values)

Normalized Difference Vegetation Index (NDVI)

1m NAIP imagery – 4band (blue, green, red, NIR)



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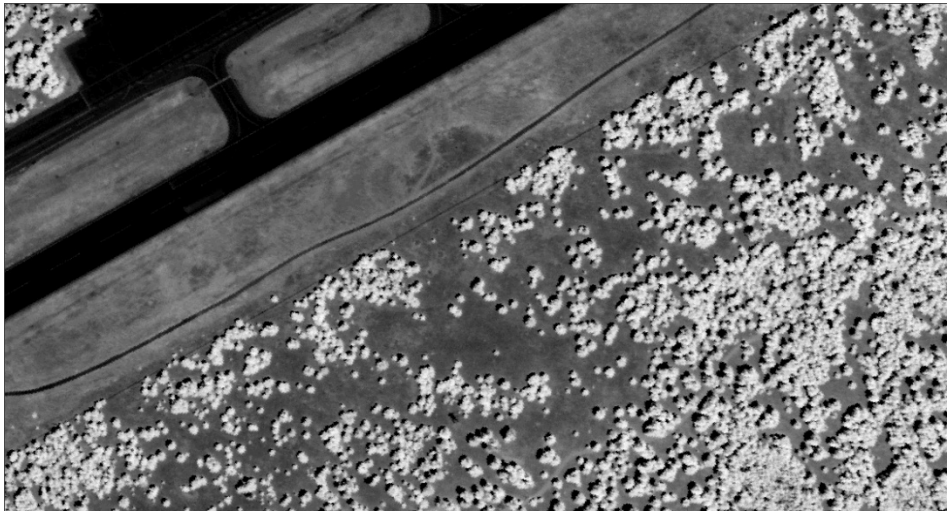

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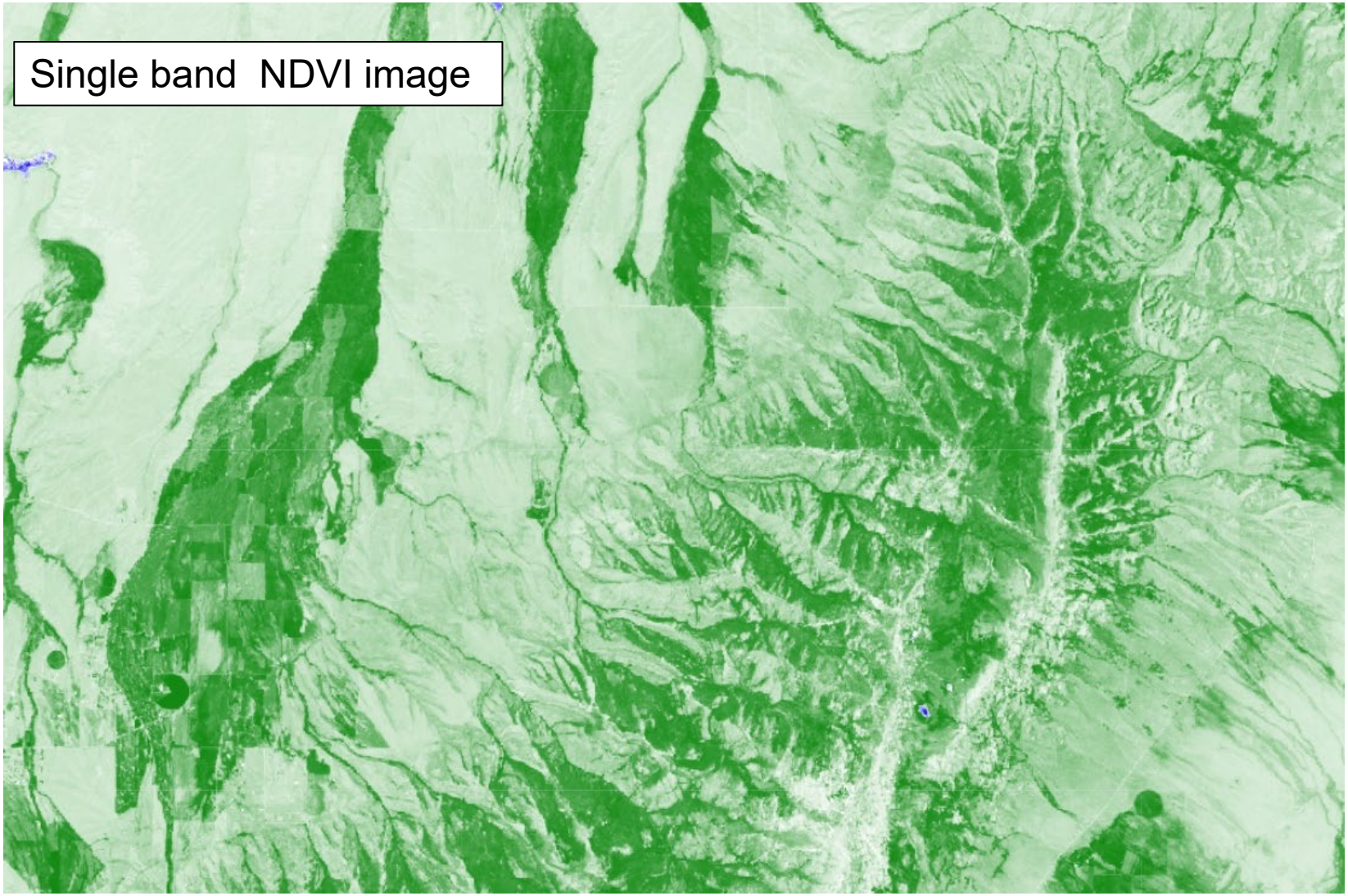
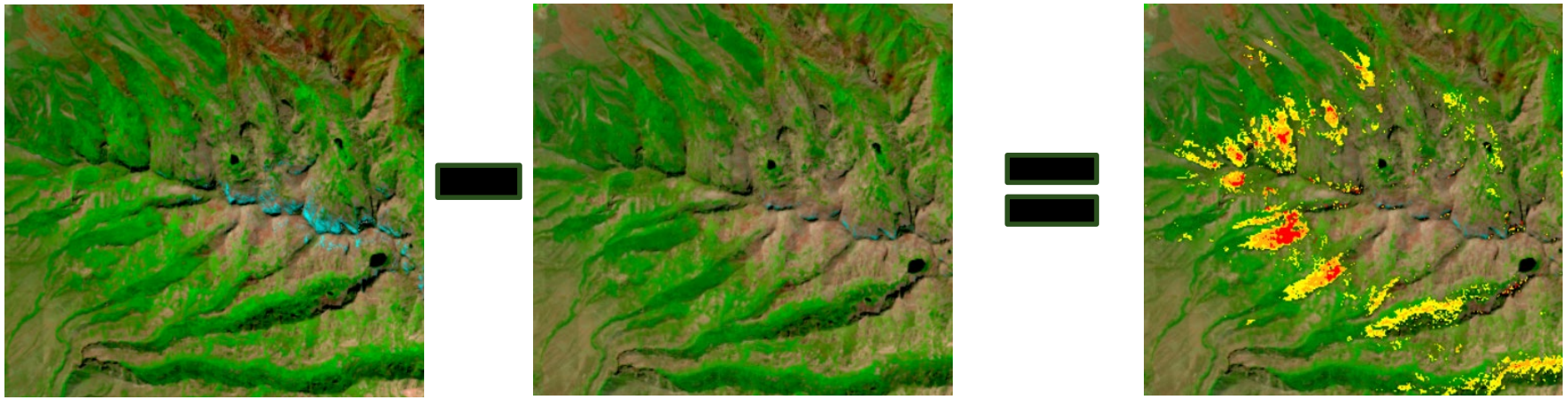


Analysis- Image Differencing

- Use raster math to calculate a difference image
  - Pixel values in change image represent spectral change (positive/negative)



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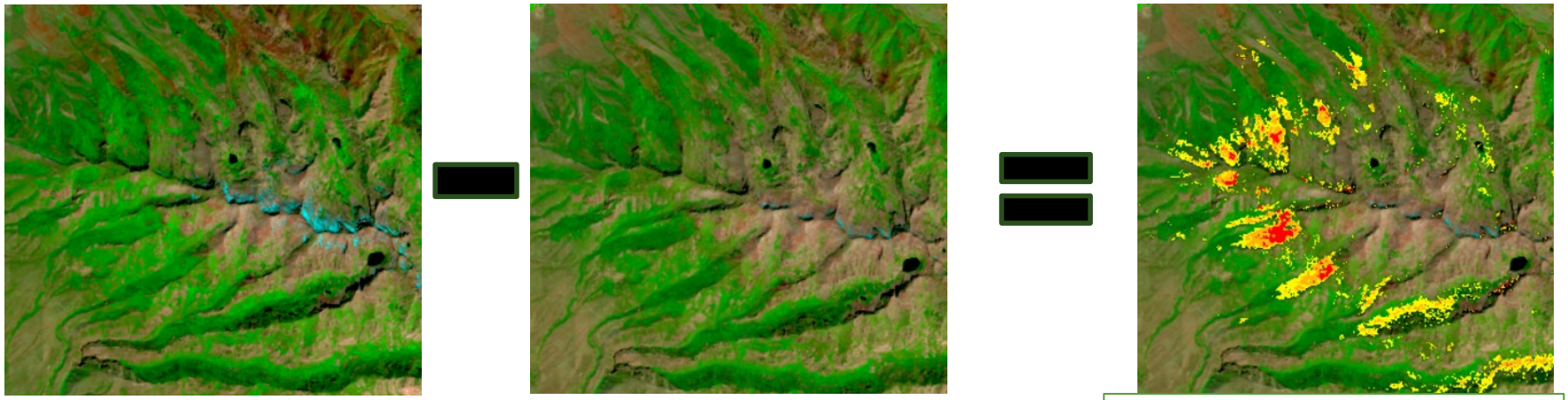

Pre-change image composite

Post-change image composite

Difference image, thresholded to represent change

Analysis- Image Differencing

- Use raster math to calculate a difference image
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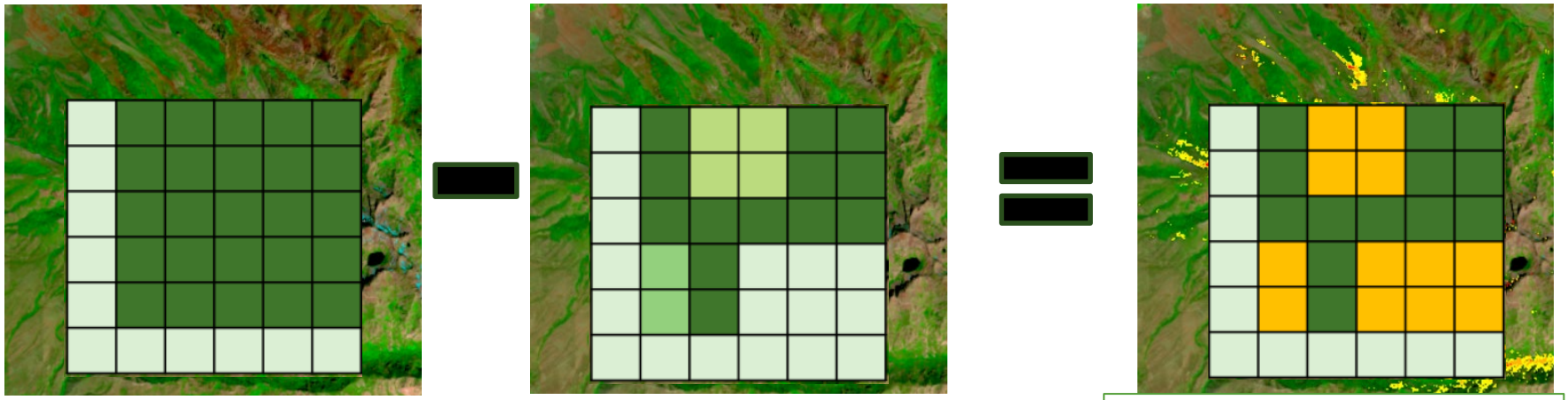


Pre-change image composite

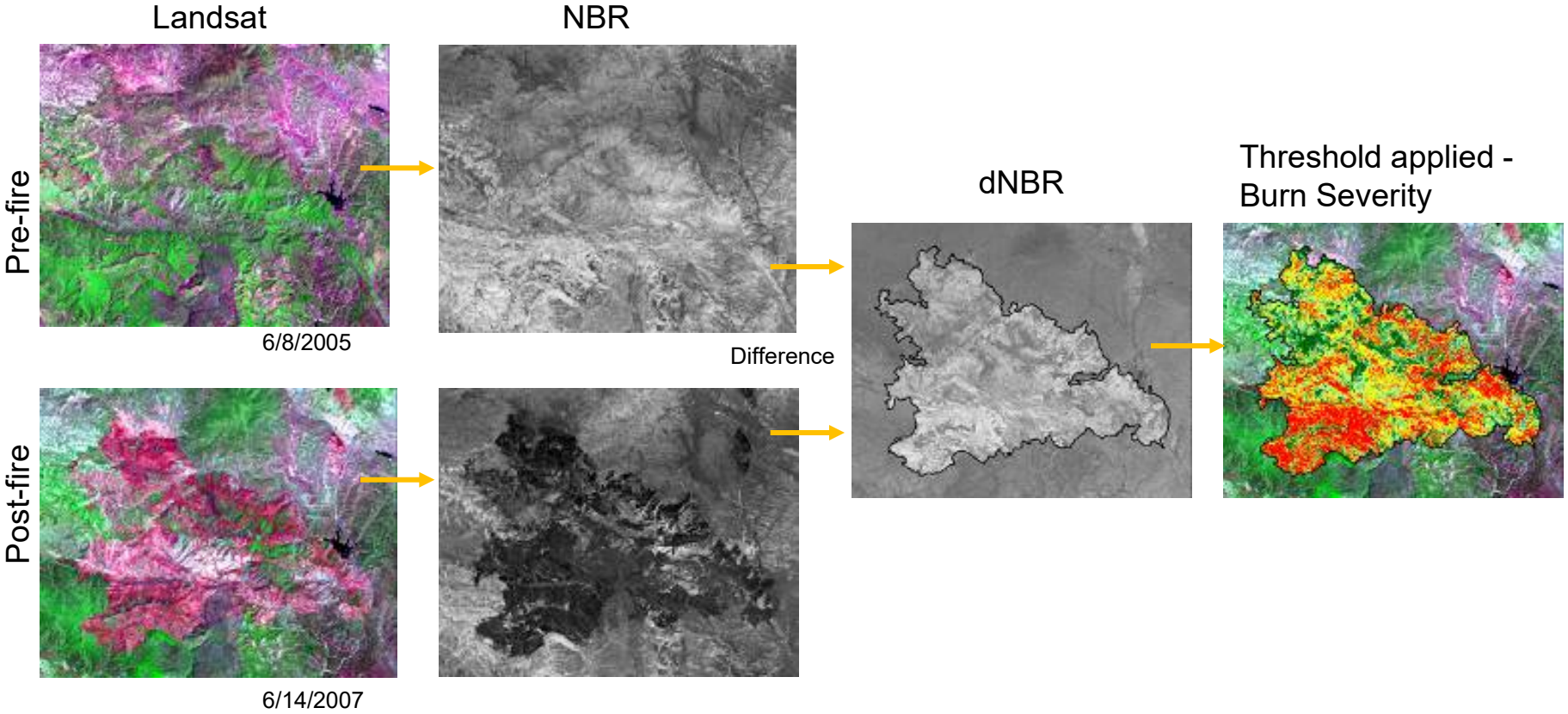
Post-change image composite

Difference image, thresholded to represent change

Analysis - Image Differencing

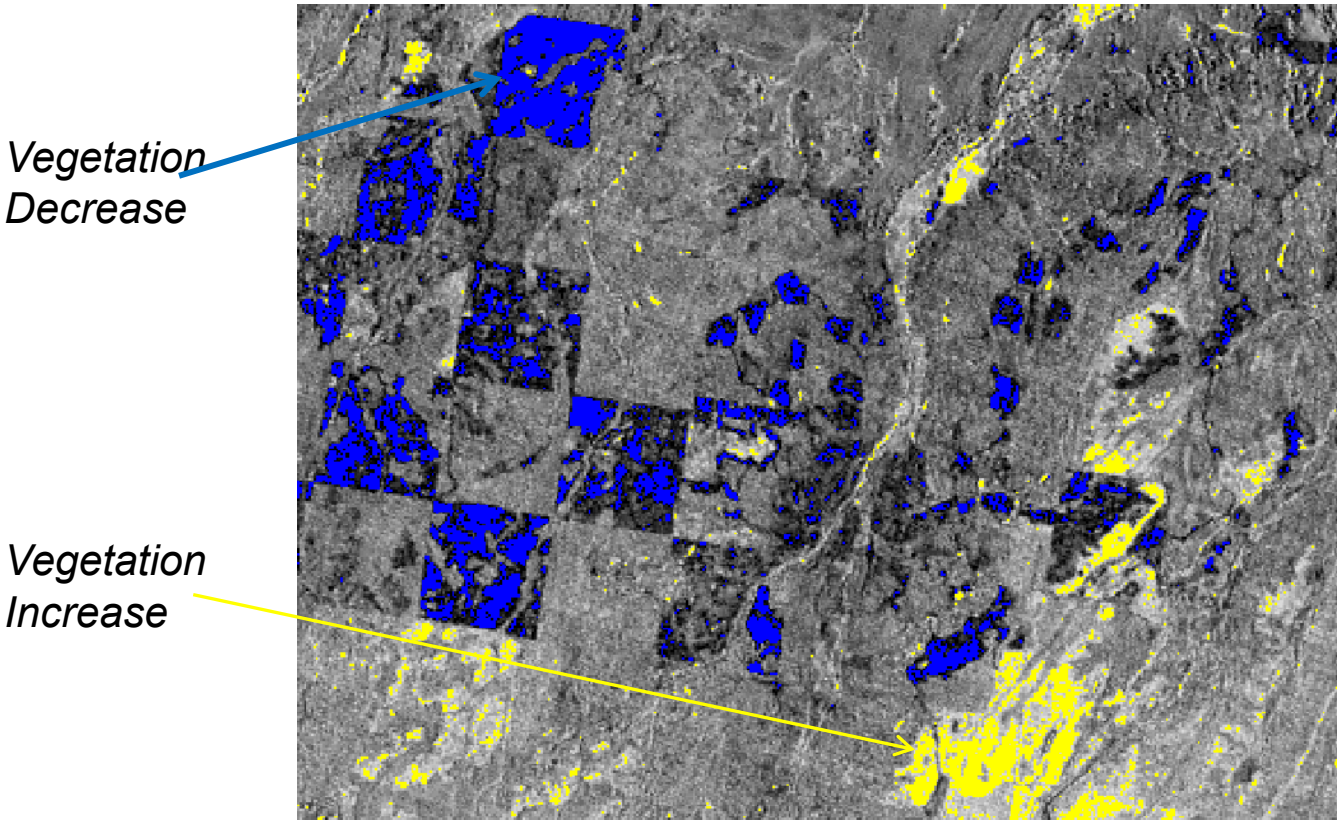
Example:

- Normalized Burn Ratio (NBR) = NBR = (NIR – SWIR) / (NIR + SWIR)
- Difference NBR = dNBR = Pre NBR – Post NBR
- Burn Severity = Thresholds applied to dNBR



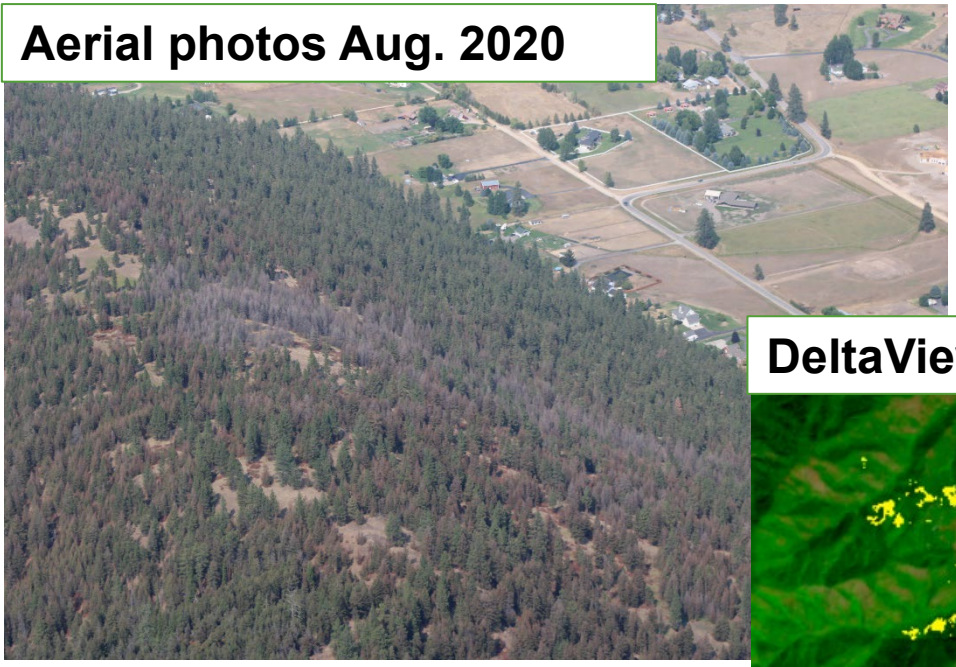
Analysis – Thresholding

- Partition change image (change/no change)
- Example – *Landsat NDVI difference image and a threshold of 2 standard deviations (+/-)*



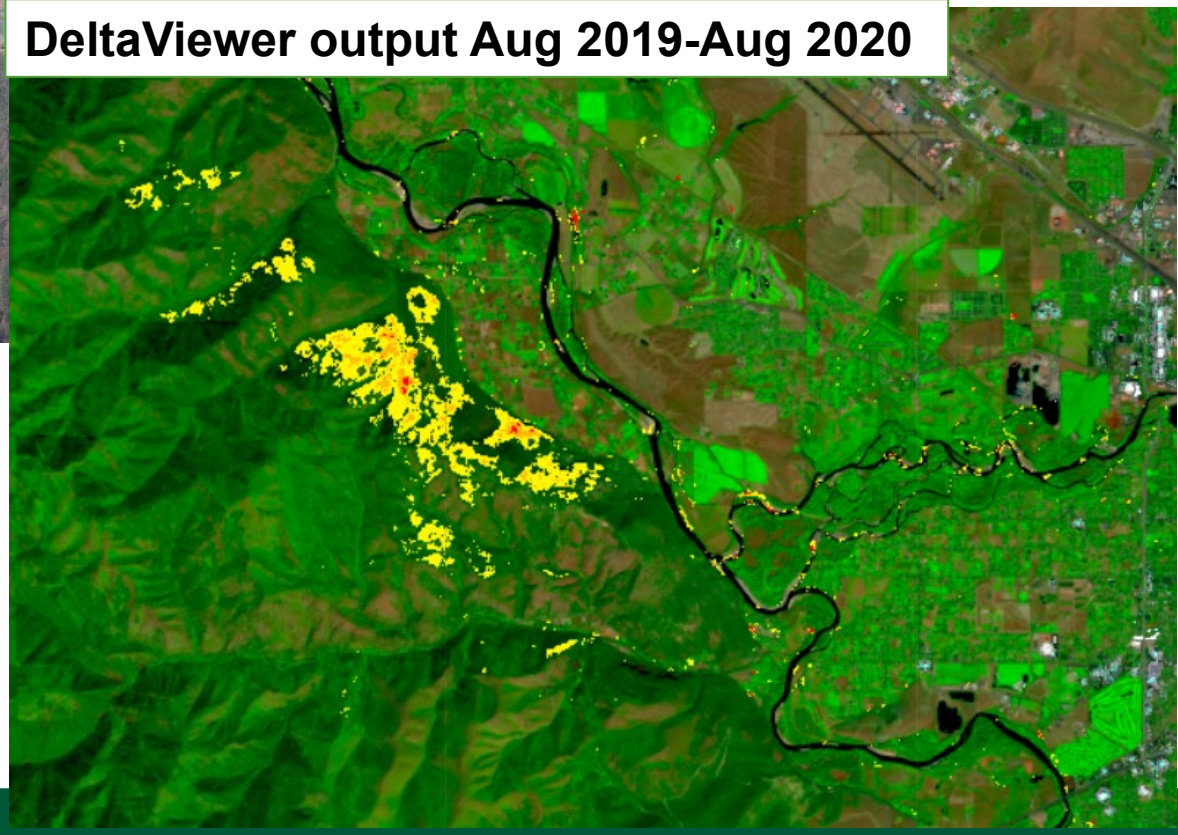
Analysis – Thresholding

Aerial photos Aug. 2020



Missoula, MT
Douglas Fir Tussock Moth

DeltaViewer output Aug 2019-Aug 2020

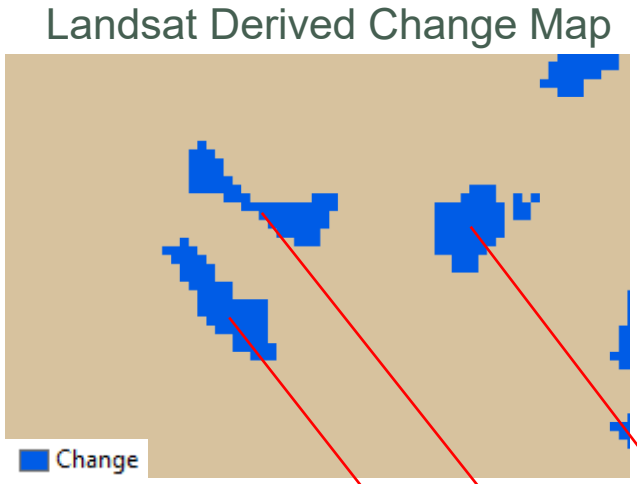


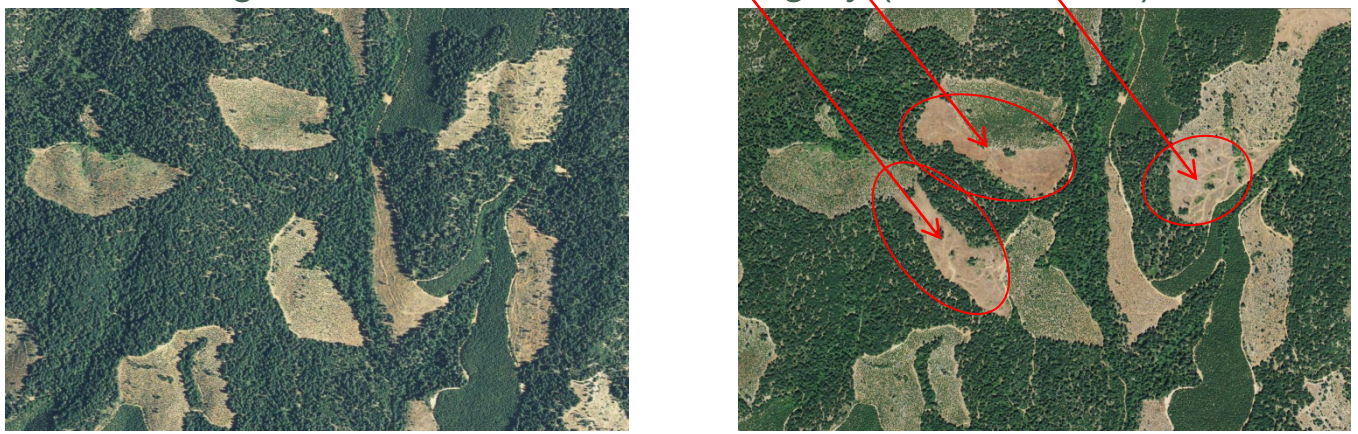
Sentinel-2 Imagery, false color visualization

Yellow-orange-red: thresholds representing severity of change

Evaluation– Accuracy Assessment

- Evaluate change maps using reference data





Change Detection - Summary

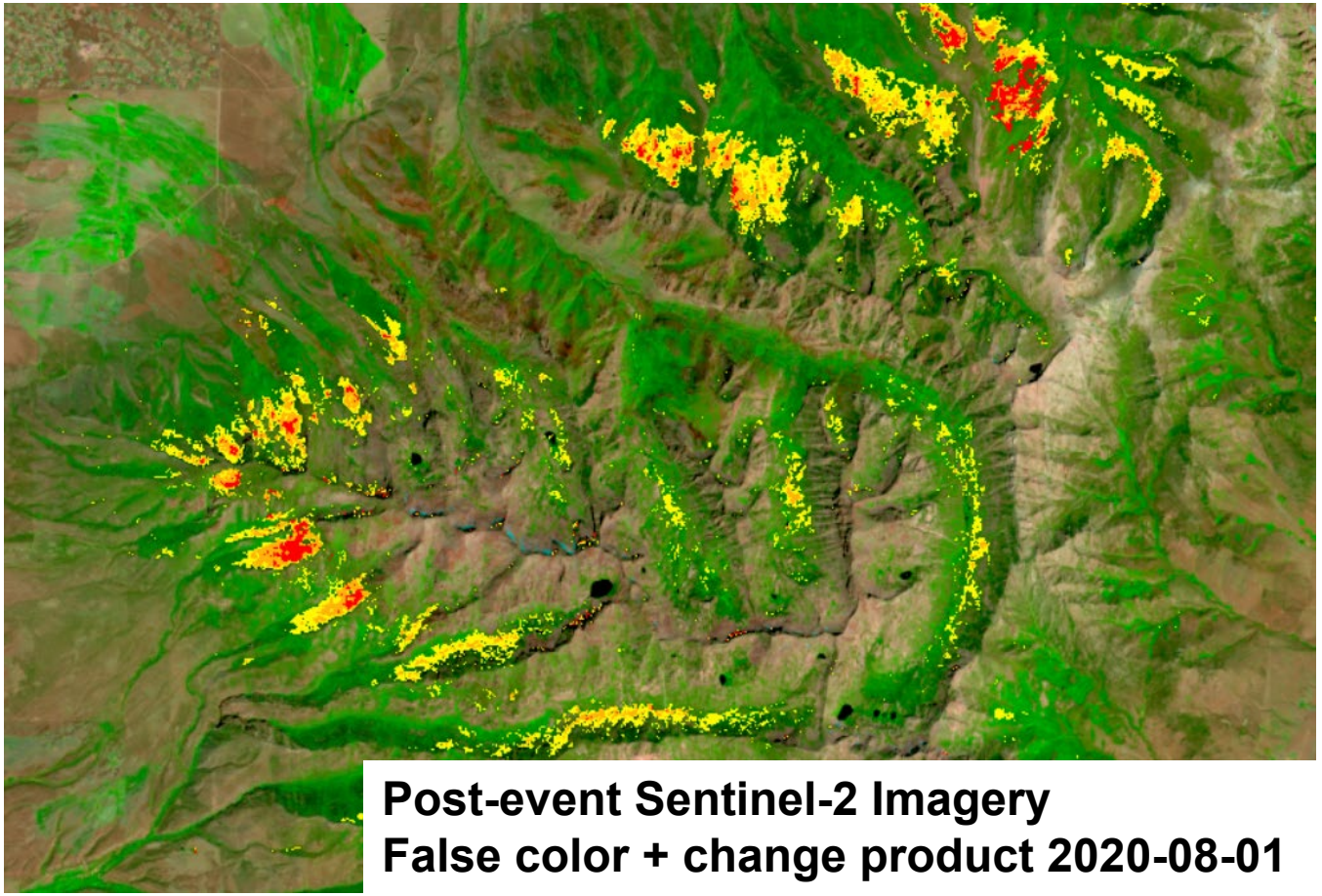
- Many considerations and approaches
  - Manual and automated methods
  - Two-date and trend analysis methods

- A multistep process
  - Image selection/acquisition
  - Preprocessing
  - Enhancement/transformation
  - Analysis - mapping change
  - Evaluation

Overall Goal

Minimize noise and map spectral change that represents significant landscape change

Ruby Mountains, NV
Mtn Pine Beetle, Fir Engraver, Aspen mortality



Post-event Sentinel-2 Imagery
False color + change product 2020-08-01

Demonstration

Exercise 1: Overview of GEE