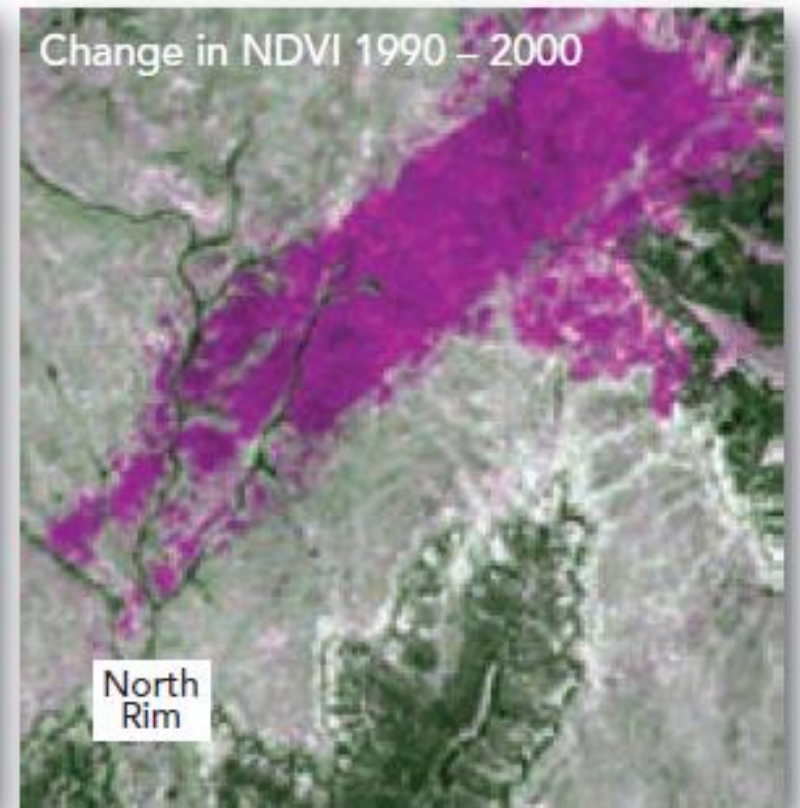
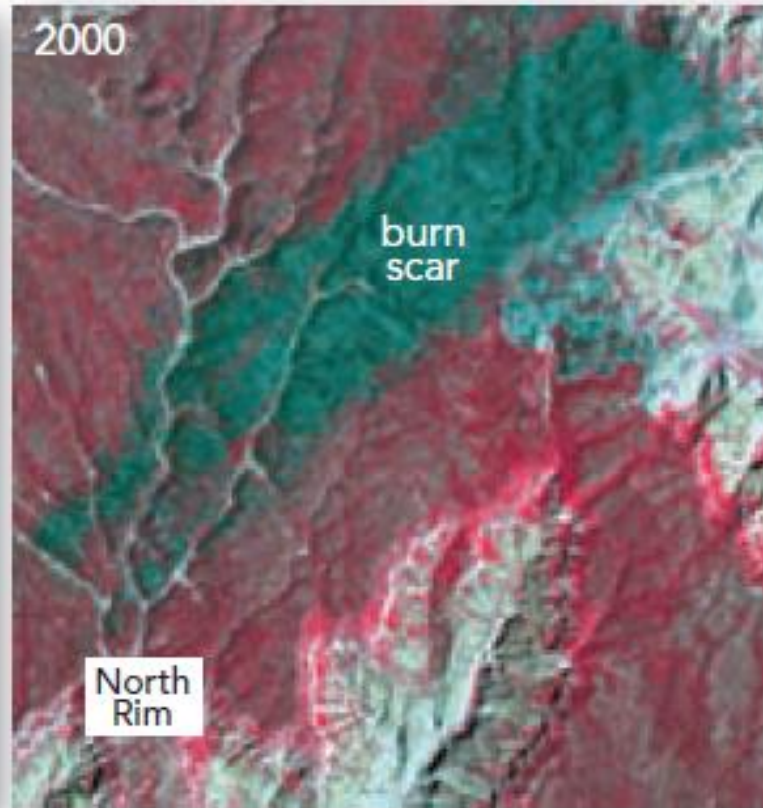
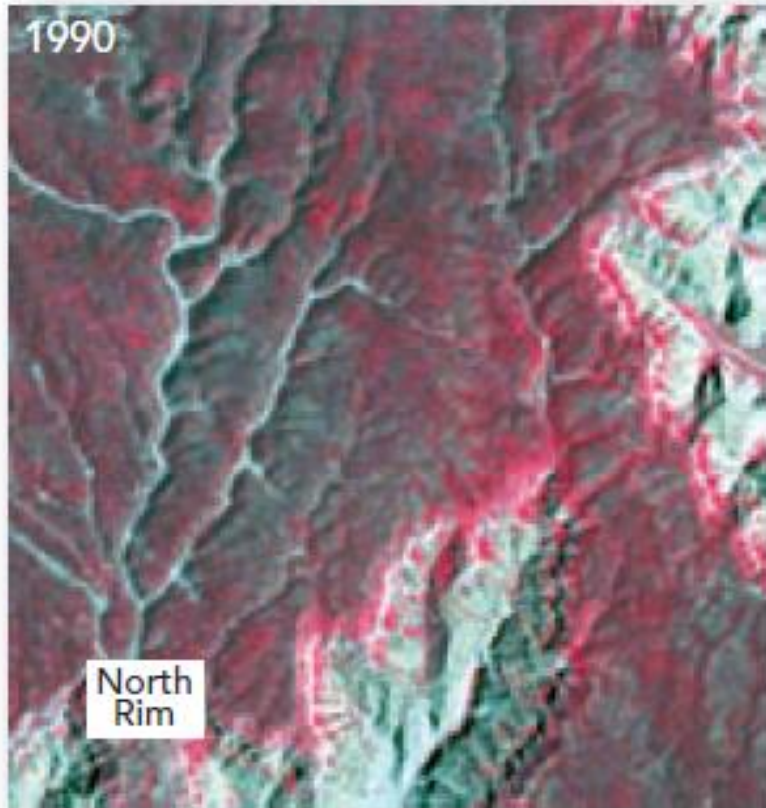


COURSE: SATELLITE IMAGE PROCESSING

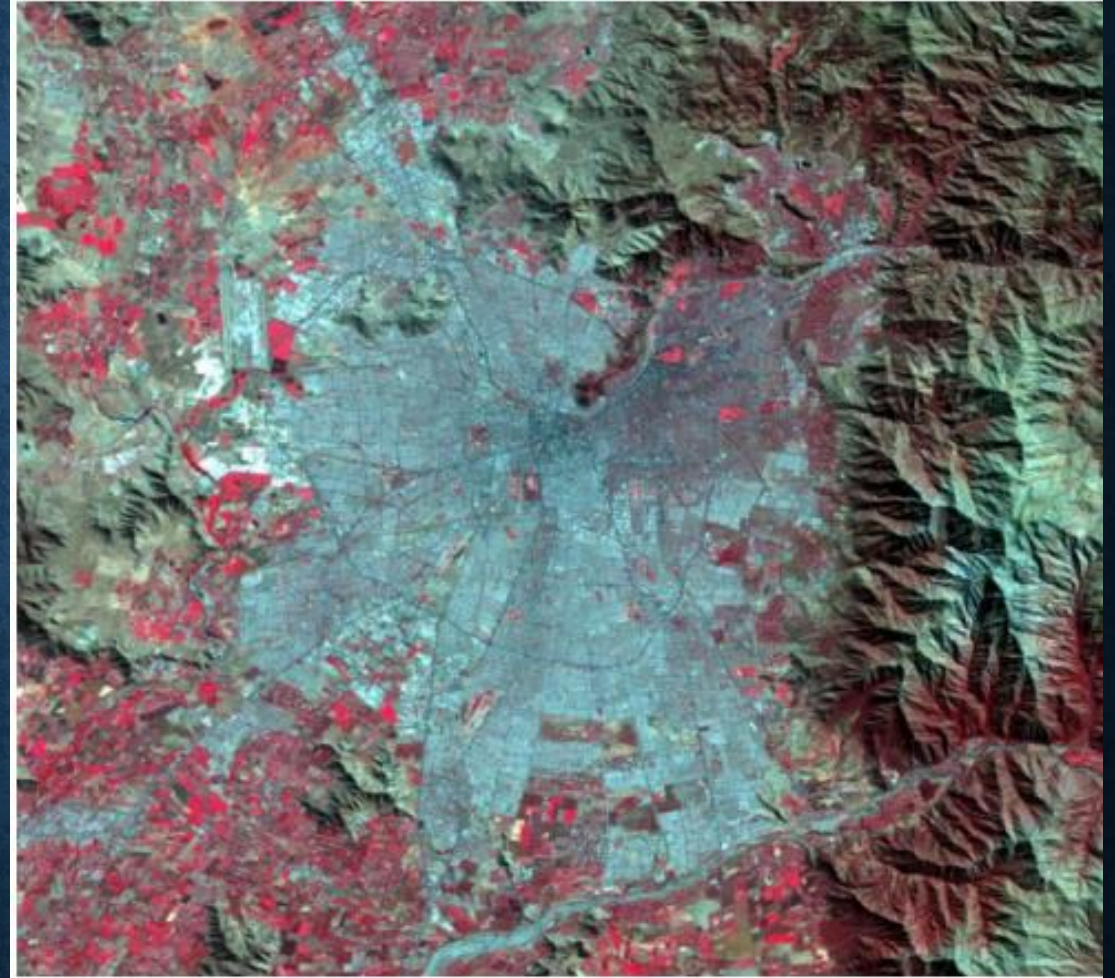
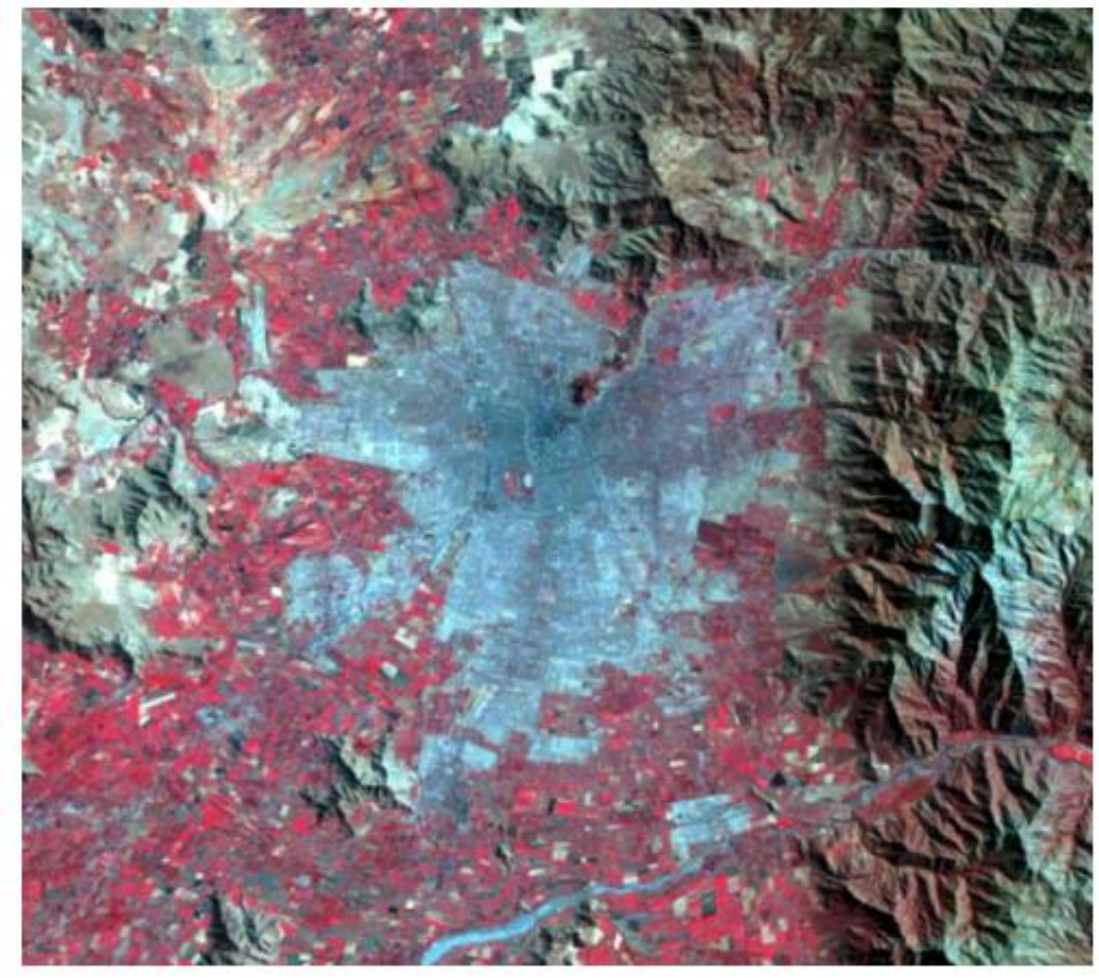
LECTURE 11 – Change Detection

Lecturer: Dr. Tingneyuc Sekac, Ph.D. PNG University of Technology

Detecting changes in Remote Sensing Digital Imagery



Detecting changes in Remote Sensing Digital Imagery



What is Change Detection?

- ❑ The conversion of the landscape from one dominant feature type to another.
- ❑ Examples:
 - Changes in tree cover due to wildfire or land clearing
 - Urbanization
 - Land degradation due to over grazing

What is Change Detection?

- Information that can be derived from satellites:
 - Where and when has change taken place?
 - How much and what kind of change has occurred?
 - What are the cycles and trends in the change?

Change Impact

- ❑ Land-use/land-cover change is a major variable impacting global climate change

(Foley et al., 2005).

- ❑ Significant effort has gone into the development of change detection methods using remotely sensed data.

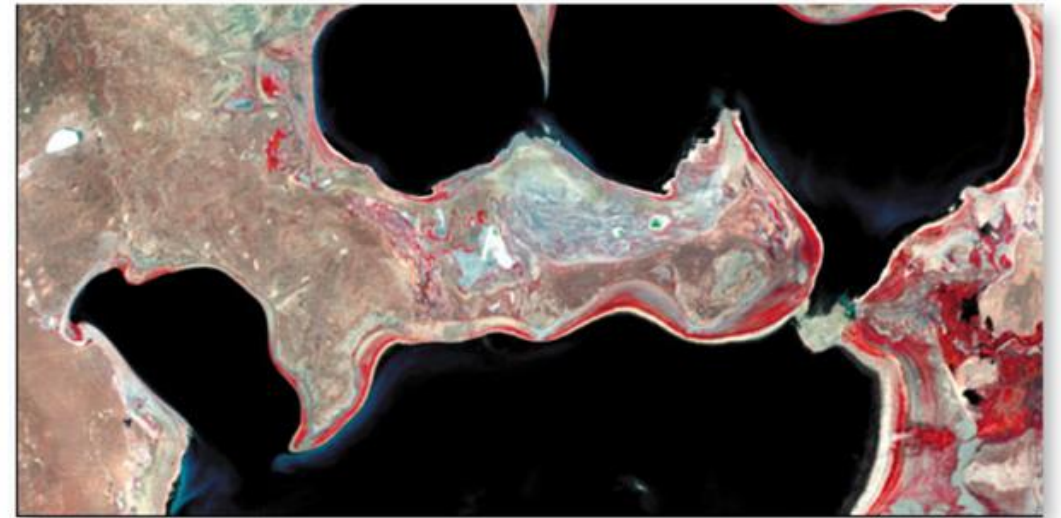
- ❑ Monitoring land cover change every five years

(Fry et al., 2011).

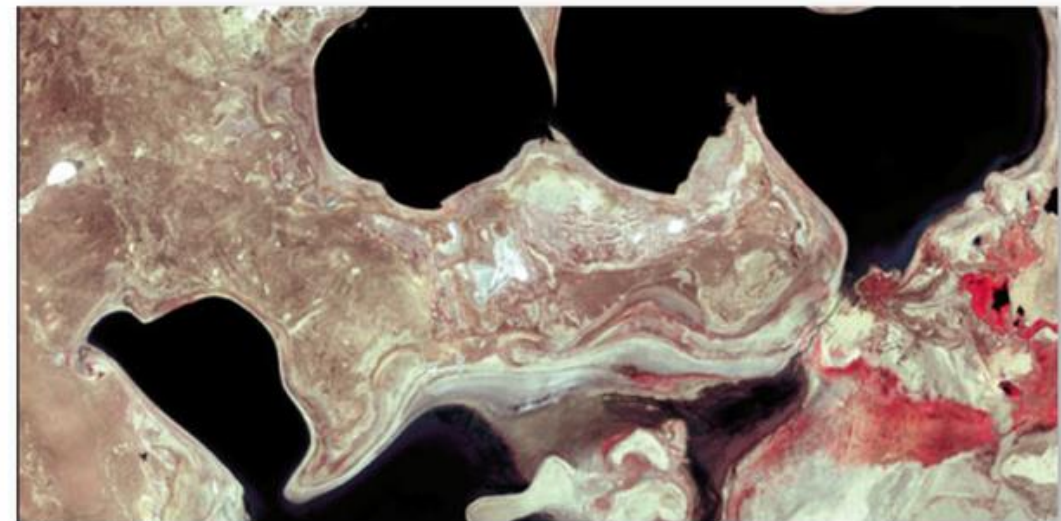
Change Impact – Drawdown of the sea water size; 1973 - 2000



a. Landsat MSS image obtained on May 29, 1973.



b. Landsat MSS image obtained on August 19, 1987.



c. Landsat 7 ETM+ image obtained on July 29, 2000.

Change Detection Time Period

- ❑ Time period selected over which change is to be monitored is too short or too long to capture the information of interest
- ❑ Time period selection is dictated by the nature of the problem.
- ❑ Traffic transportation studies might require a change detection period of just a few seconds or minutes.
- ❑ Images obtained monthly or seasonally might be sufficient to monitor the greening-up of a continent

Steps Used to Conduct Digital Change Detection Using Remote Sensor Data

- 1. State the nature of the change detection problem.**
- 2. Considerations of significance when performing change detection.**
- 3. Process remote sensor data to extract change information.**
- 4. Perform accuracy assessment.**
- 5. Accept or reject previously stated hypothesis.**
- 6. Distribute results if accuracy is acceptable.**

1. State the nature of the change detection problem

- ✓ Specify thematic attribute(s) or indicator(s) of interest.
- ✓ Specify change detection geographic region of interest (ROI).
- ✓ Specify change detection time period (e.g., daily, seasonal, yearly).
- ✓ Define the classes of interest in a classification system.
- ✓ Select hard and/or fuzzy change detection logic.
- ✓ Select per-pixel or object-based (OBIA) change detection.

2. Considerations of significance when performing change detection.

A. Remote sensing system considerations:

B. Environmental characteristic.

A. Remote sensing system considerations:

- Spatial,
- spectral,
- temporal, and
- radiometric resolution

Spatial Resolution Consideration

- The remotely sensed data are acquired by a sensor system that collects data with the same **IFOV** on each date.

- For example;

Landsat TM data collected at 30×30 m spatial resolution on two dates are relatively easy to register to one another.

Spatial Resolution Consideration

- If different spatial resolution;
- Example;

Landsat TM data (30×30 m) for Date 1 and SPOT data (20×20 m) for Date 2.

- Decide on a representative minimum mapping unit (e.g., 20×20 m) and then resample both datasets to this uniform pixel size.

Look Angle Consideration

- Remote sensing systems like SPOT and QuickBird can collect data at off-nadir *look angles* as much as $\pm 20^\circ$
- Two images with significantly different look angles can cause problems when used for change detection.

- Example;

SPOT at 0° nadir will look directly down on the top of the canopy.

SPOT image acquired at 20° off-nadir will record reflectance from the side of the canopy.

- Acquire data with approximately the same look angle.

Spectral Resolution Consideration

- Ideally, the same sensor system is used to acquire imagery on multiple dates.
- For multiple sensors, Analyst should select bands that approximate one another.
- For example,
SPOT bands 1 (green), 2 (red), and 3 (near-infrared), can be used successfully with Landsat ETM+ bands 2 (green), 3 (red), and 4 (near-infrared).

When spectral characteristics of bands from one sensor system do not match those of another sensor system, the change detection algorithm does not work properly

Temporal Resolution Consideration

Temporal resolutions should be held constant during change detection using multiple dates of remotely sensed data, if possible.

- Use a sensor system that acquires data at approximately the same time of day.

This eliminates diurnal Sun angle effects that can cause anomalous differences in the reflectance properties of the remotely sensed data.

- Acquire remote sensor data on anniversary dates; for example, June 1, 2012, and June 1, 2013.

It minimizes the influence of seasonal Sun-angle and plant phenological differences.

Radiometric Resolution Consideration

- Ideally, the sensor systems collect the data at the same radiometric precision on both dates.
- If one of the dates of imagery has a radiometric resolution that is lower than the other:
 - Example:
one consists of 8-bit data and one consists of 10-bit data), then it is general practice to transform the lower resolution data (e.g., 8-bit with values from 0 to 255) to the same radiometric level as the superior radiometric resolution (e.g., 10-bit with values from 0 to 1,023).

• Environmental Characteristics:

(a) Atmospheric conditions

- Cloud cover and cloud shadow
- Relative humidity

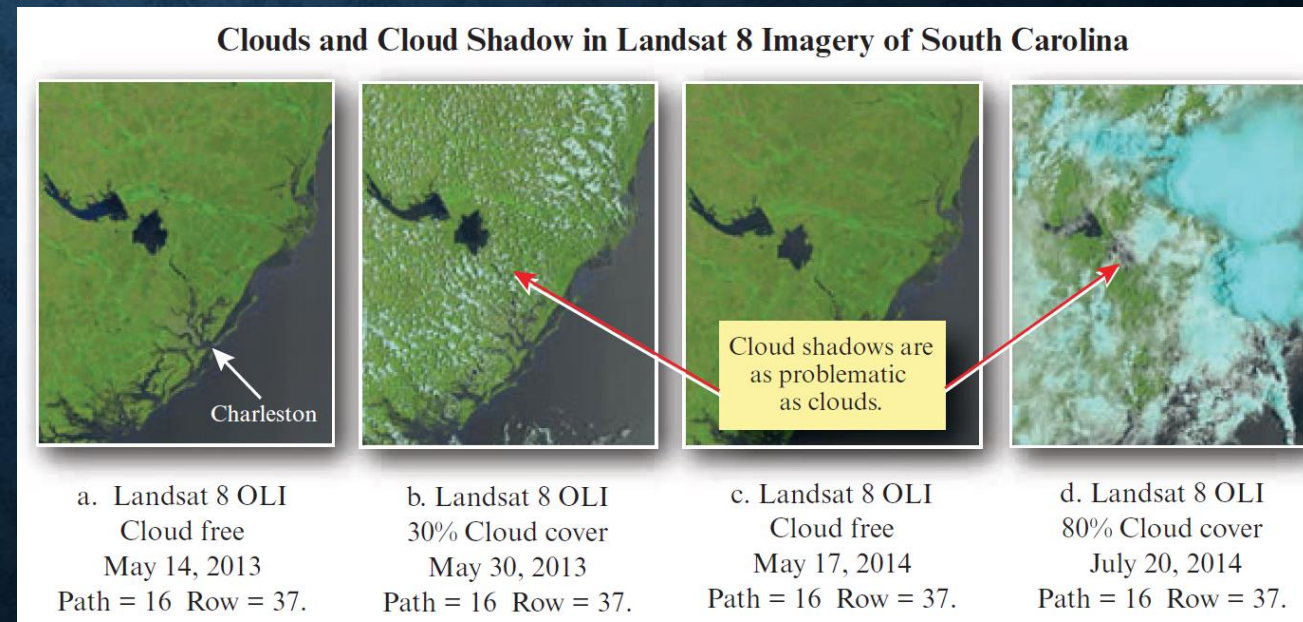
(b) Soil moisture conditions

(c) Phenological cycle characteristics

- natural (e.g., vegetation, soil, water, snow and ice)
- man-made phenomena

(d) Obscuration considerations

- natural (e.g., trees, shadows)
- man-made (e.g., structures, shadows)

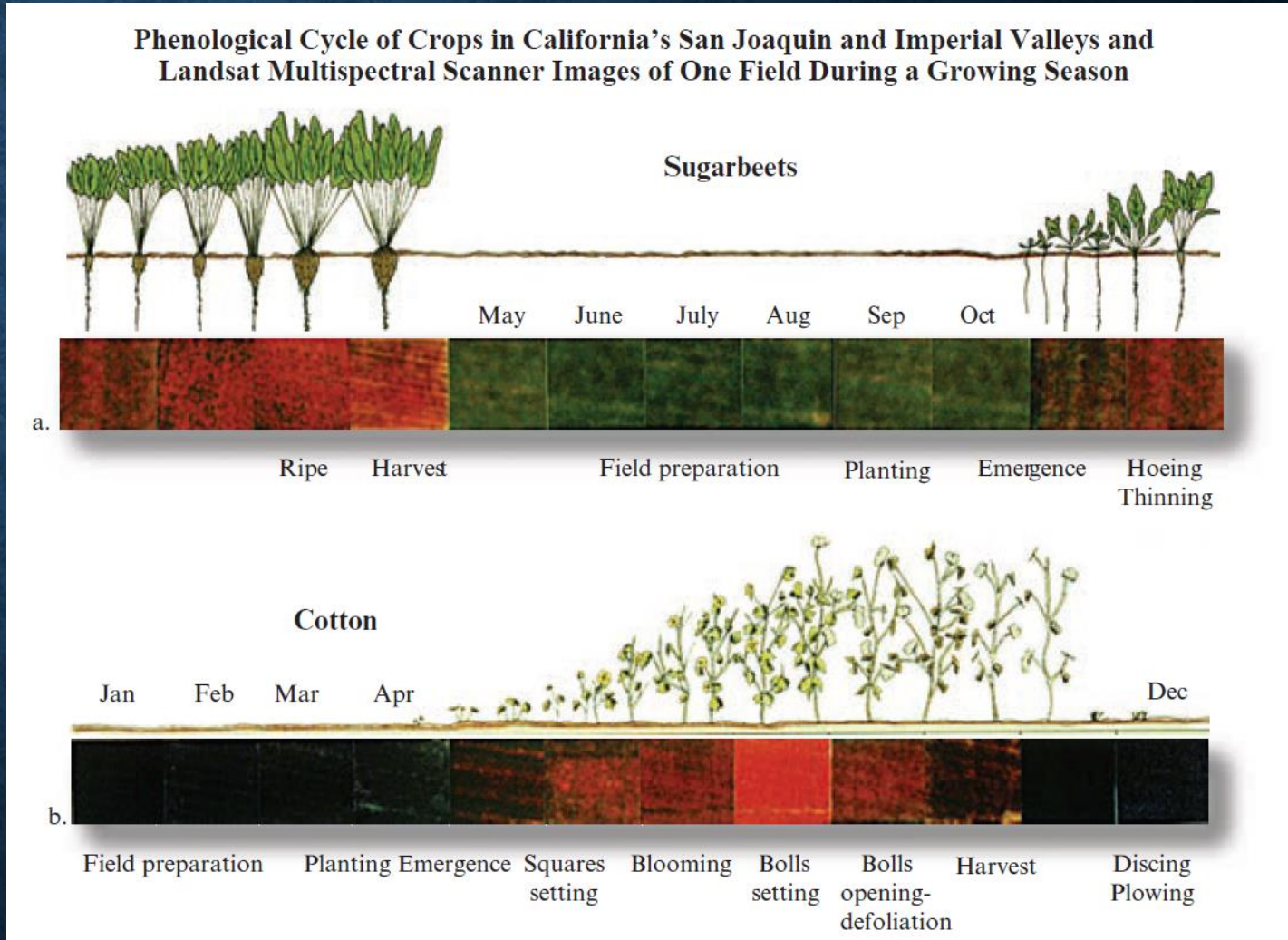


Environmental Consideration When Performing Change Detection: Soil Moisture

- Soil moisture conditions should be identical for all dates of imagery used in a change detection project.
- Extremely wet or dry conditions on one of the dates can cause change detection problems.
- Apply radiometric normalization to one of the images to make it have approximately the same spectral reflectance characteristics as the other image
- If only a portion exhibits higher/lower, then Stratify (cut out) those affected areas and perform a separate change detection analysis, which can be added back in the final stages of the project.

Environmental Consideration When Performing Change Detection: Vegetation Phenology

- Vegetation grows according to relatively predictable diurnal, seasonal, and annual *phenological cycles*.
- Obtaining near-anniversary images greatly minimizes the effects of seasonal phenological differences that may cause spurious change to be detected in the imagery.



Source: John R. Jesen, 4th Ed; Jensen et al., 2012

Selection of the Change Detection Algorithm

Change detection algorithms commonly used include:

1. Binary Change Detection Algorithms - Provide Change/no change information:

- I. *analog 'on-screen' visualization change detection*
- II. *binary change detecting using image algebra (e.g., band differencing and ratioing) or PCA*

2. post-classification comparison

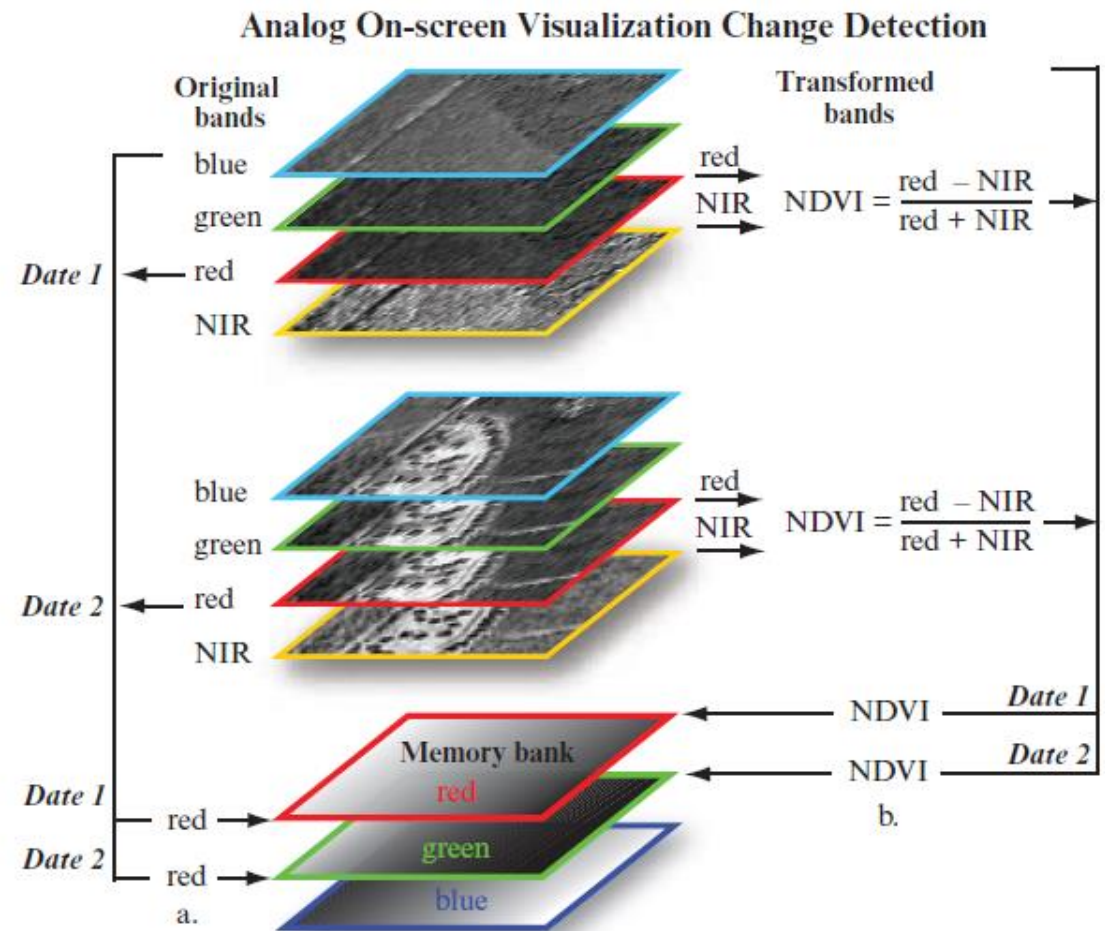
3. ancillary data source used as Date 1

4. spectral change vector analysis

Selection of the Change Detection Algorithm

I. Analog 'on-screen' visualization change detection

Individual bands or derivative products such as NDVI from multiple dates of imagery are systematically inserted into each of the three memory banks (RGB) to highlight any changes in the imagery.



Advantages

- * Visual examination of 2 or 3 years of nonspecific change
- * Requires date-to-date histogram matching, not atmospheric correction

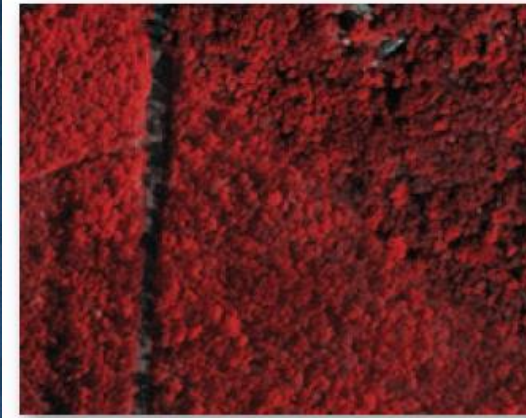
Disadvantages

- * Nonquantitative
- * No "from-to" change class information

imagery courtesy of Richland County GIS Department.

Analog 'on-screen' visualization change detection

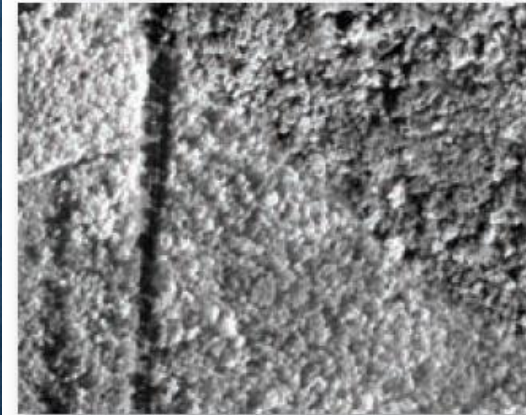
The use of analog visualization to detect changes in high spatial resolution imagery collected in 2004 and 2007 of an area near Ballentine



a. 2004 color-infrared 1 × 1 ft. color composite.



b. 2007 color-infrared 1 × 1 ft. color composite.



c. 2004 near-infrared band.



d. 2007 near-infrared band.

e. Analog visualization of change created by placing the 2004 NIR band in the red memory bank and the 2007 NIR band in the green and blue memory banks.

Binary Change Detection Using Image Algebra

Binary change between two rectified images is typically performed using raster image algebra such as;

- band differencing/band ratioing logic
- multiple date composite image dataset and
- Principal Components Analysis

Binary Change Detection Using Image Algebra

The logic of image algebra change detection using image differencing or band rationing

Image Differencing Change Detection:

Subtracting band k of the Date 2 image from band k of the Date 1 image. The subtraction ideally results in positive and negative values in areas where radiance has changed and zero values in areas of no change in a new change image.

$$\Delta BV_{i,j,k} = BV_{i,j,k}(1) - BV_{i,j,k}(2) + c \quad (12.1)$$

where

$\Delta BV_{i,j,k}$ = change pixel value

$BV_{i,j,k}(1)$ = brightness value on date 1

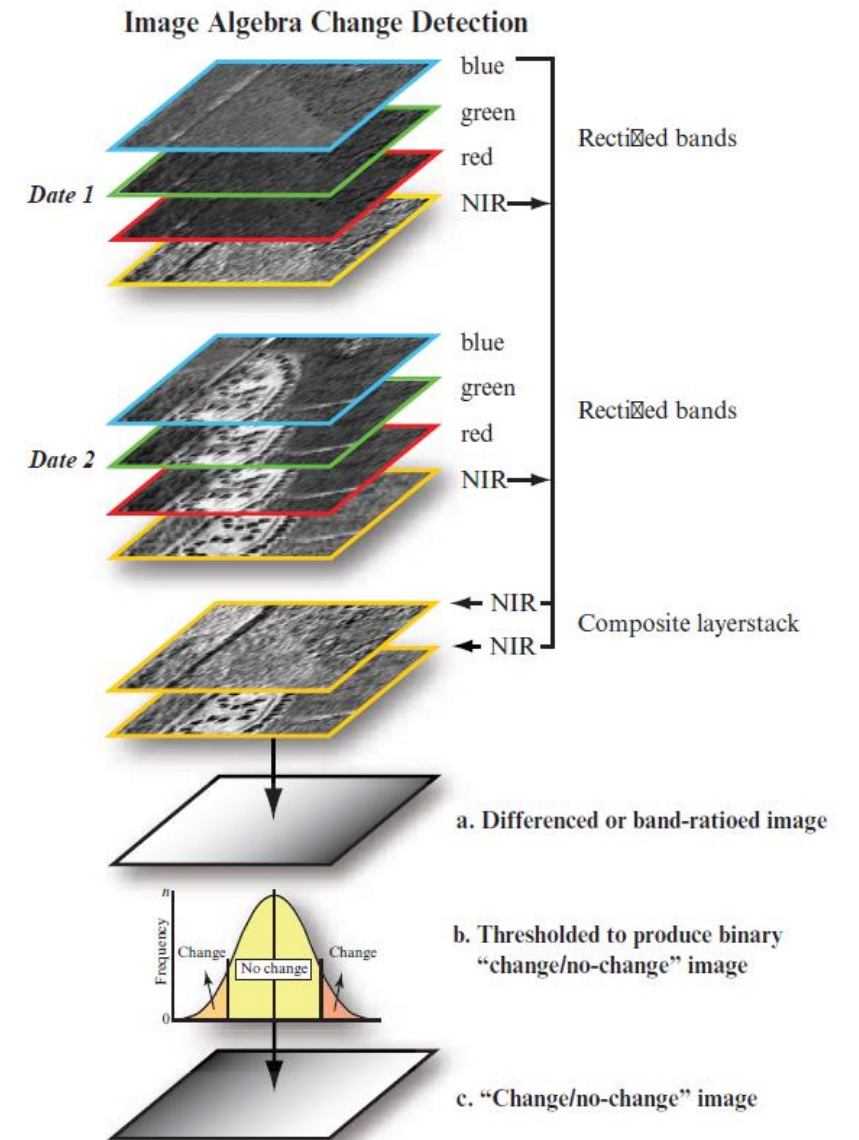
$BV_{i,j,k}(2)$ = brightness value on date 2

c = a constant (e.g., 127)

i = line number

j = column number

k = a single band (e.g., IKONOS band 3).



Advantages

- * Does not require atmospheric correction, only histogram matching
- * Useful for identifying pixels that have changed in brightness value between dates

Disadvantages

- * No "from-to" change information available
- * Requires careful selection of the "change/no change" threshold

Binary Change Detection Using Image Algebra

The logic of image algebra change detection using image differencing or band rationing

Image Algebra Band Rationing Change Detection:

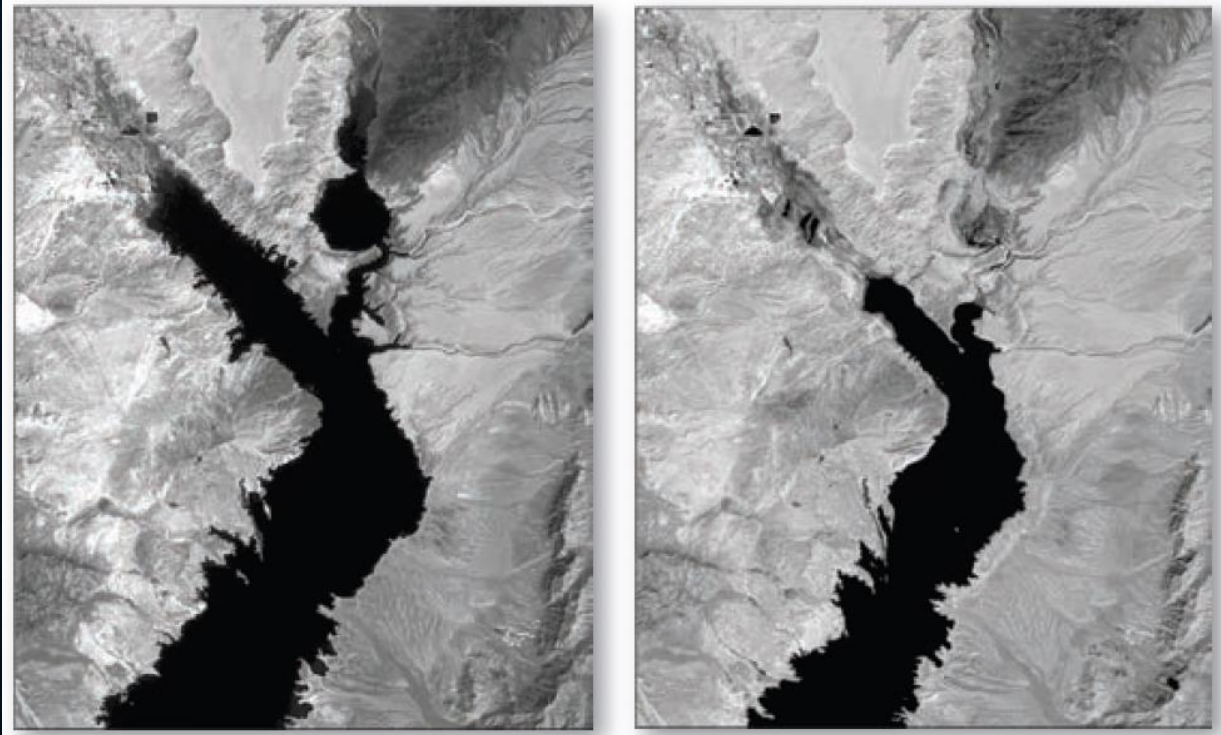
Binary change detection using band ratioing involves dividing band k of the Date 1 image by band k of the Date 2 imagery.

$$\Delta BV_{i,j,k} = \frac{BV_{i,j,k}(1)}{BV_{i,j,k}(2)}$$

The resultant change image contains values that have a range from 1/255 to +255 (8 bit).

With the histogram of change image, a result close to 1.0 (mean center) indicates that there has been little to no change in the spectral characteristics, however, there's significant changes towards tail.

Binary Change Detection Using Image Algebra – Image Differencing Change Detection



a. Landsat ETM+ obtained on May 3rd, 2000 (RGB=bands 4, 3, 2).

ASTER data obtained on April 19th, 2003 (RGB=bands 3, 2, 1).

Histogram of the Floating Point image created by Subtracting 2000 ETM+ Data from 2003 ASTER data

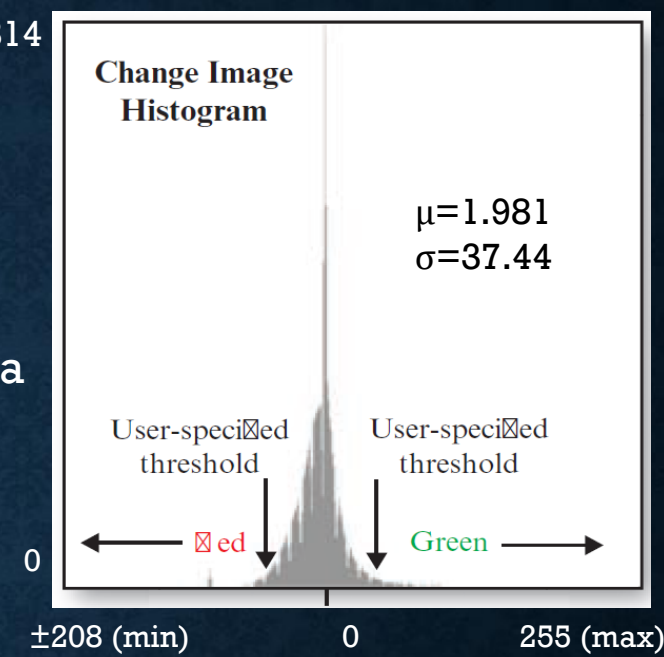
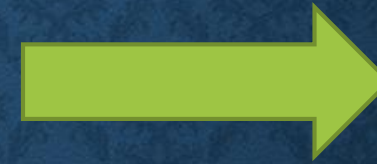
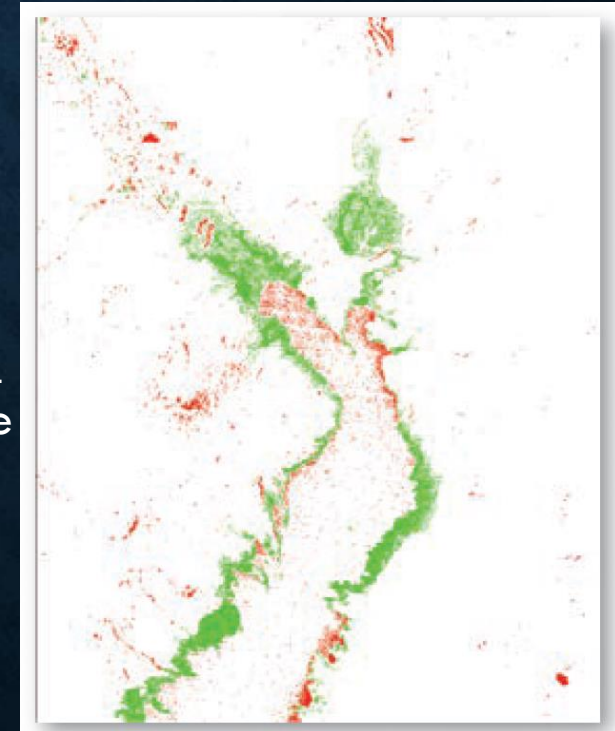


Image differencing change detection. Red and green change pixels are associated with thresholds located in the tails of the histogram.



Binary Change Detection Using Image Algebra

The logic of image algebra change detection using image differencing or band rationing

- Band ratioing or image differencing change detection does not have to be based on just the individual bands of remote sensor data.
- It may also be extended to comparing vegetation or other type of index information derived from multiple dates of imagery.
- For example, scientists often compute an NDVI on two dates and then subtract one from another to determine change:

$$\Delta \text{NDVI}_{i,j} = \text{NDVI}_{i,j} (1) - \text{NDVI}_{i,j} (2) + c$$

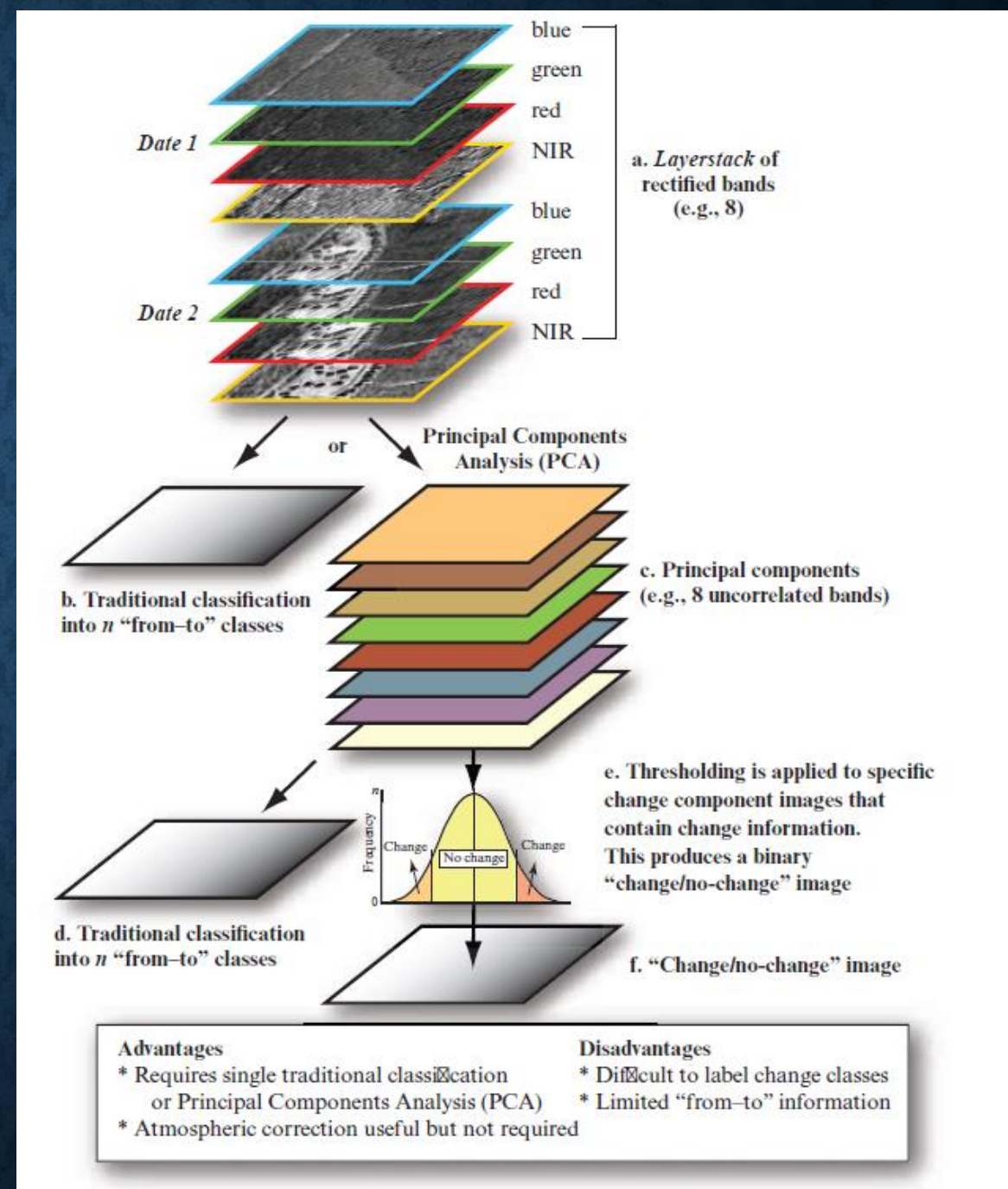
Multiple date composite image Change Detection

The logic of performing change detection using multiple dates of imagery placed in a layer stack.

The layer-stack can then be analyzed using:

b) traditional unsupervised or supervised classification techniques, or

c) by using PCA.



Multiple date composite image Change Detection

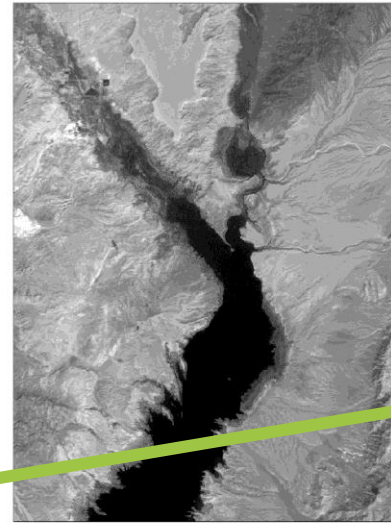
In this example, Principal Component 2 is a good indicator of change in the image

Multiple-Date Composite Image Change Detection Based on Principal Components Analysis

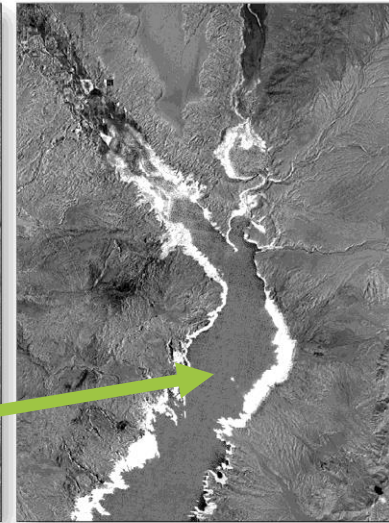
Lake Mead, NV, dataset consists of

* Landsat ETM+ data obtained on May 3, 2000 (bands 2, 3, 4)

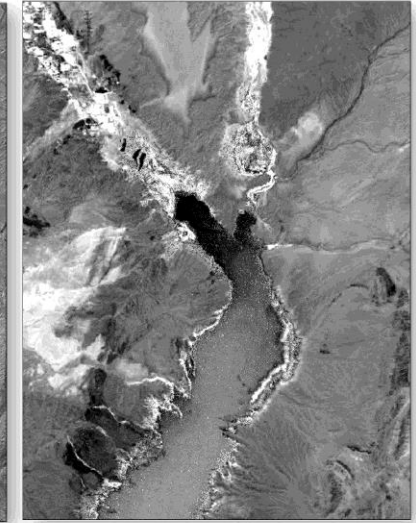
* ASTER data obtained on April 19, 2003 (bands 1, 2, 3)



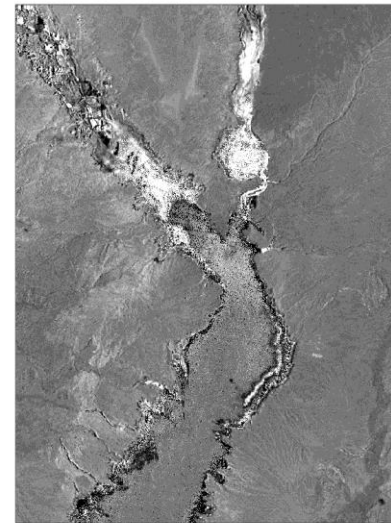
a. Principal component 1.



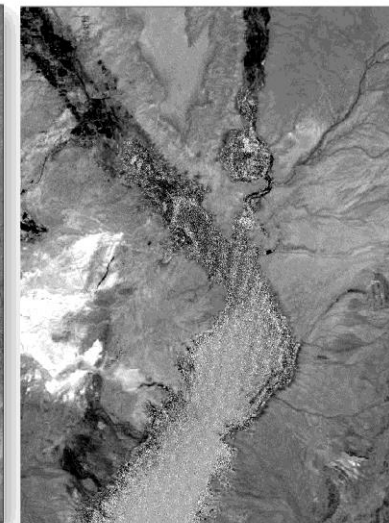
b. Principal component 2.



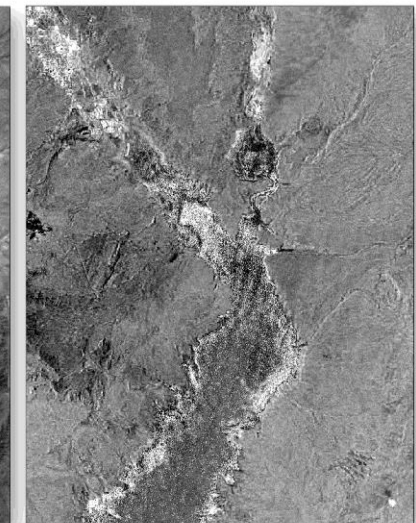
c. Principal component 3.



d. Principal component 4.



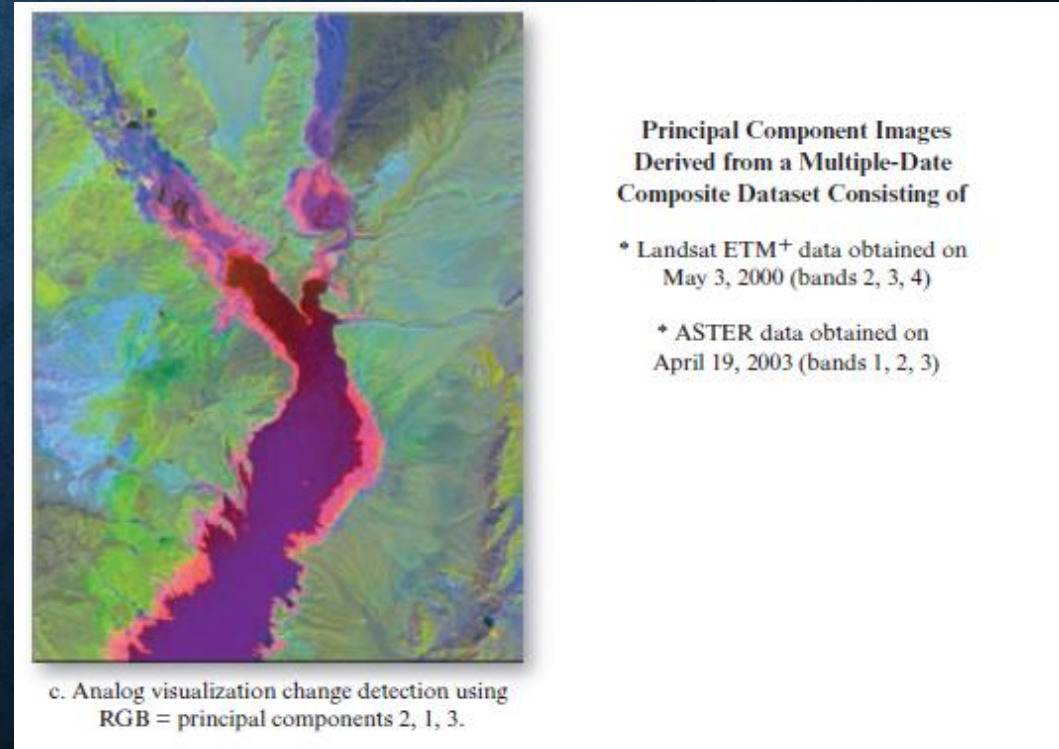
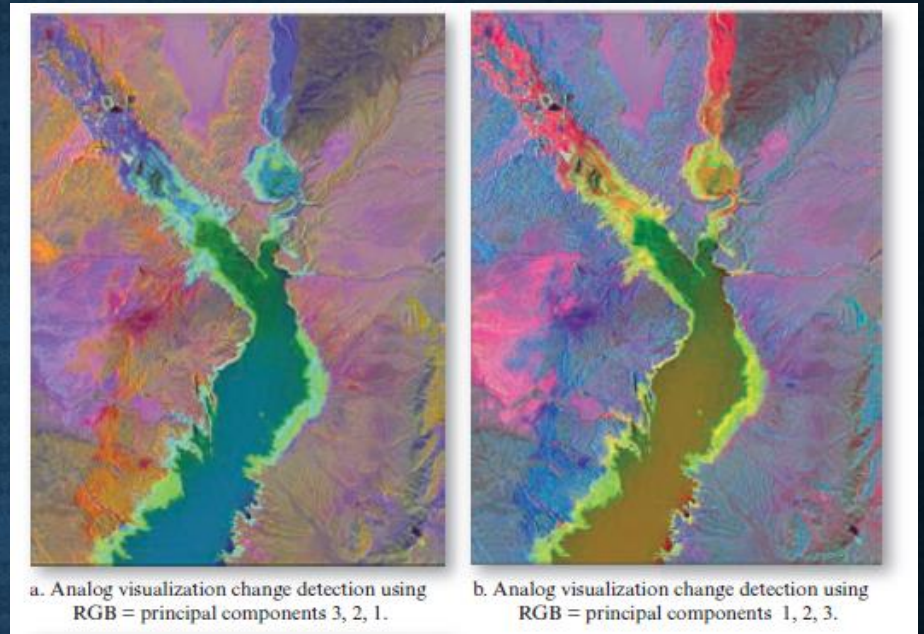
e. Principal component 5.



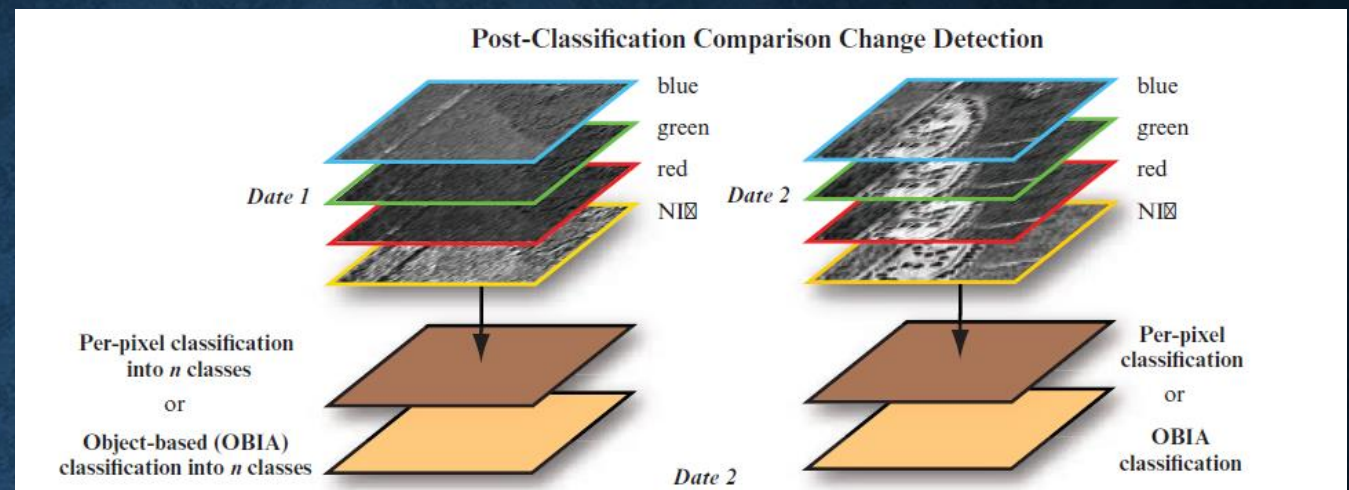
f. Principal component 6.

Multiple-Date Composite Image Change Detection Based on PC Viewed Using Analog Visualization

- ❑ Multiple-date composite image change detection using PCA images that were created from a multiple-date composite dataset consisting of Landsat ETM+ and ASTER data.
- ❑ Analog visualization was used to highlight the information content of the various PC images.
- ❑ PC 2 and 3 contain much of the change information



Post-Classification Comparison Change Detection



Change Detection Matrix



No change (1,6,11,16)

Vegetation to building (9)

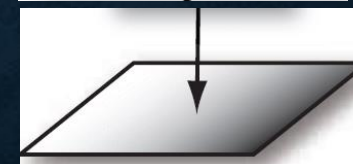
Vegetation to road (10)

To:

Class 1 - Building
Class 2 - Road
Class 3 - Vegetation
Class 4 - Water

From:

Class 1 - Building	☒	☒	☒	☒
Class 2 - Road	☒	6	7	8
Class 3 - Vegetation	☒	☒☒	☒☒	☒☒
Class 4 - Water	☒☒	☒☒	☒☒	☒6



Change map produced using change detection matrix logic applied to Date 1 and Date 2 classification maps

Post-Classification Comparison Change Detection

- ❑ ab) Rectified Landsat Thematic Mapper data (RGB = bands 4, 3, 2).
- ❑ cd) Classification maps of the Fort Moultrie, SC, study area produced from the November 9, 1982, and December 19, 1988, Landsat TM data.
- ❑ Compare Classification from each date to look for change



a. Fort Moultrie, SC , on November 9, 1982 .



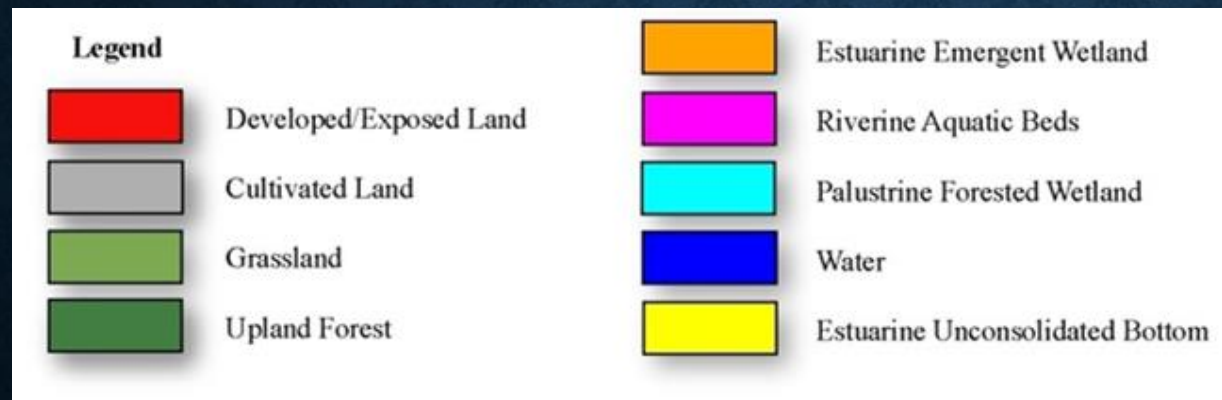
b. Fort Moultrie, SC , on December 19, 1988 .



c. Fort Moultrie, SC , on November 9, 1982 .



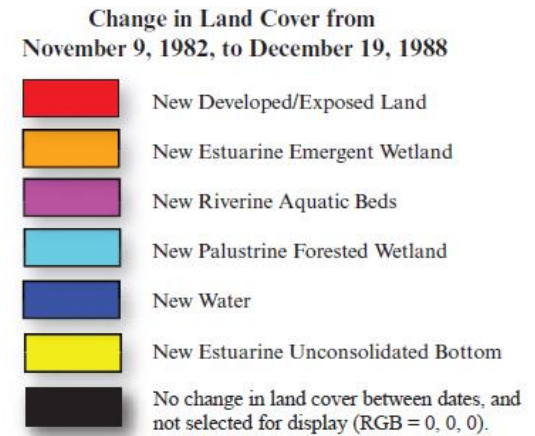
d. Fort Moultrie, SC , on December 19, 1988 .



Post-Classification Comparison Change Detection

For example,;

all pixels that changed from any land cover in 1982 to Developed Land in 1988 were color coded red (RGB = 255, 0, 0) by selecting the appropriate 'from - to' cells in the change detection matrix (10, 19, 28, 37, 46, 55, 64, and 73).



a. Fort Moultrie, SC.

b.

From - To
Change Detection Matrix

		To								
		Developed/Exposed Land	Cultivated Land	Grassland	Upland Forest	Estuarine Emergent Wetland	Riverine Aquatic Beds	Palustrine Forested Wetland	Water	Estuarine Unconsolidated Bottom
From 1982	Developed/Exposed Land	1	2	3	4	5	6	7	8	9
	Cultivated Land	10	11	12	13	14	15	16	17	18
	Grassland	19	20	21	22	23	24	25	26	27
	Upland Forest	28	29	30	31	32	33	34	35	36
	Estuarine Emergent Wetland	37	38	39	40	41	42	43	44	45
	Riverine Aquatic Beds	46	47	48	49	50	51	52	53	54
	Palustrine Forested Wetland	55	56	57	58	59	60	61	62	63
	Water	64	65	66	67	68	69	70	71	72
	Estuarine Unconsolidated Bottom	73	74	75	76	77	78	79	80	81

Color look-up table values in change detection map

Red	255	255	255	255	255	255	0	0	255
Green	0	255	255	255	163	0	255	0	255
Blue	0	255	255	255	0	255	255	255	0

Post-Classification Comparison Change Detection

Advantages:

- * Does not require atmospheric correction.
- * Provides detailed 'from – to' change class information.
- Next base year map is already complete.

Disadvantages:

- * Dependent on the accuracy of the Date 1 and Date 2 classification maps.
- * Requires two separate classifications holding all class names constant.

References:

Jensen, John R., 2015- Introductory digital image processing : a remote sensing perspective / John R. Jensen, University of South Carolina.
pages cm. -- (Pearson series in geographic information science) 4th ed.