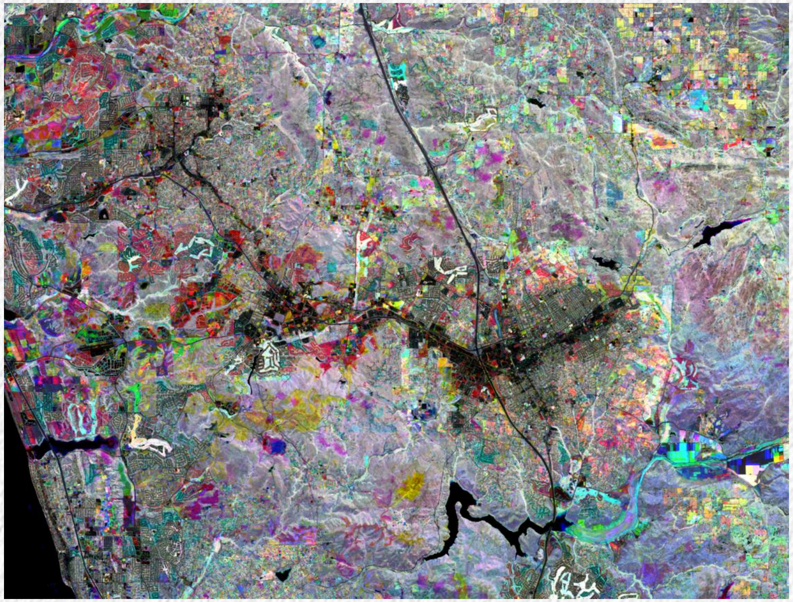
Wavelengths for ecologists

Remote sensing of the environment



Dr. Bill Kristan, Chair of Dept. Biological Sciences, CSU San Marcos

Women in Science at CSUSM Biology

- In honor of International Women’s Day
  - Current faculty
    - Tracey Brown, Vicki Fabry, Julie Jameson
    - Jane Kim, Debbie Kristan, Bianca Mothe
    - Casey Mueller, Betsy Read
  - New faculty for Fall 2018
    - Elinne Beckett, Darcy Taniguchi

Dr. Tracey Brown

Herpetology, physiological ecology

Dr. Vicki Fabry

Effects of ocean acidification on calcifying marine animals

Dr. Denise Garcia

Genetics of viral resistance in shrimp, science education

Dr. Julie Jameson

Molecular mechanisms of wound healing

Dr. Jane Kim

Mechanisms of DNA repair in yeast

Dr. Debbie Kristan

Cost of parasitism to hosts, caloric restriction and aging

Dr. Bianca Mothe

Virology, vaccine development for rapidly mutating viruses (HIV, SIV)

Dr. Casey Mueller

Developmental physiology in fish

Dr. Betsy Read

Molecular mechanisms of calcification in *E. huxleyi*

Coming soon...

Dr. Darcy Taniguchi

Predator/prey effects on plankton communities

Dr. Elinne Beckett

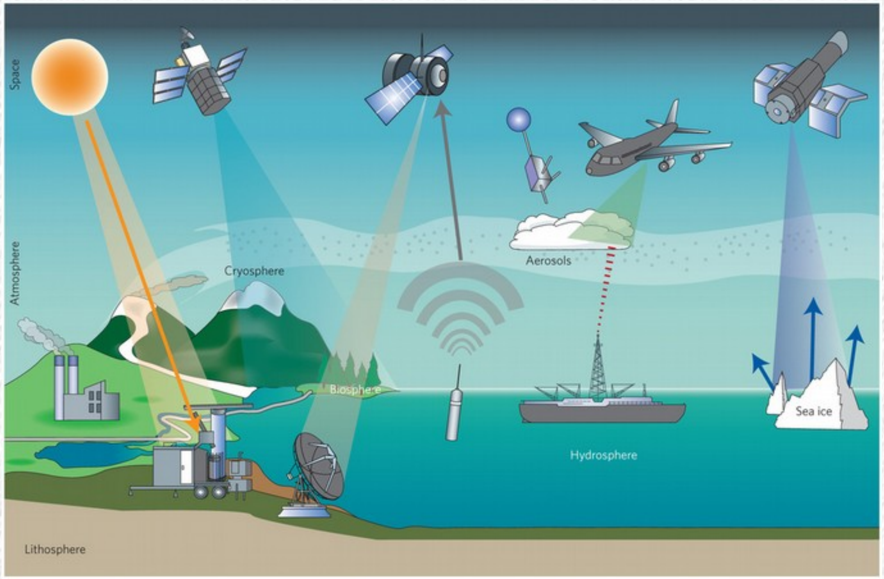
Bacteriology, genetics of antibiotic resistance

My work

- Habitat ecology
  - Bald eagles
  - Songbirds
  - Mammals
- Subsidized predators
  - Common Ravens
- Urban drool
- One thing in common – all of my projects have used remote sensing and geographic information systems

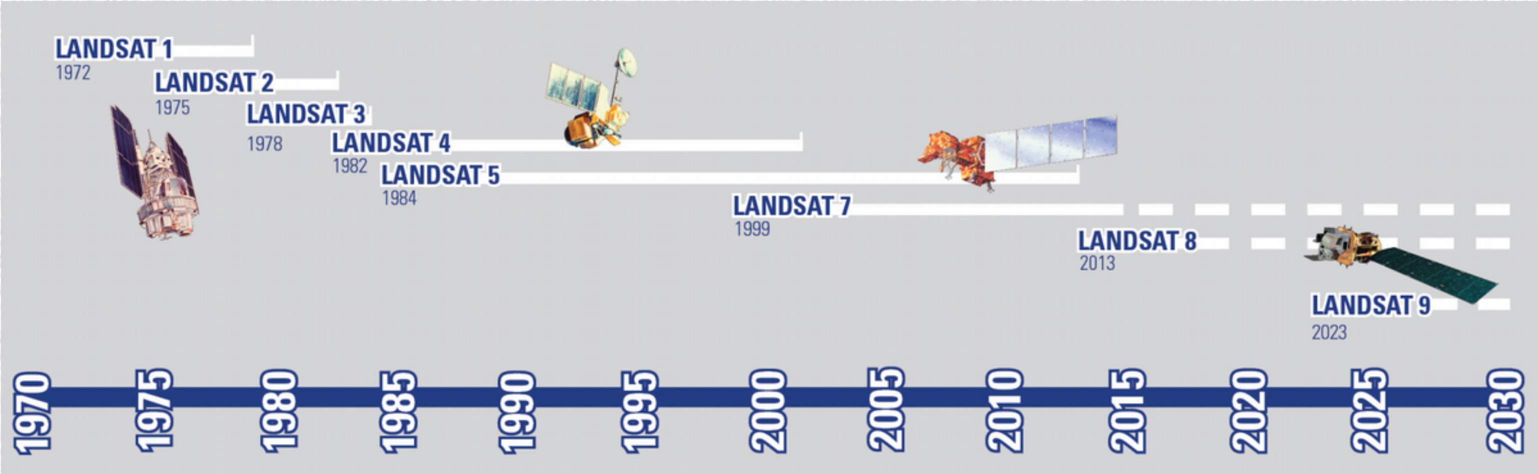
Remote sensing

- Observing or recording something from a distance
- Images – cameras mounted on aerial platforms
  - Julius Neubronner's pigeons (1908)
  - Satellites (today)



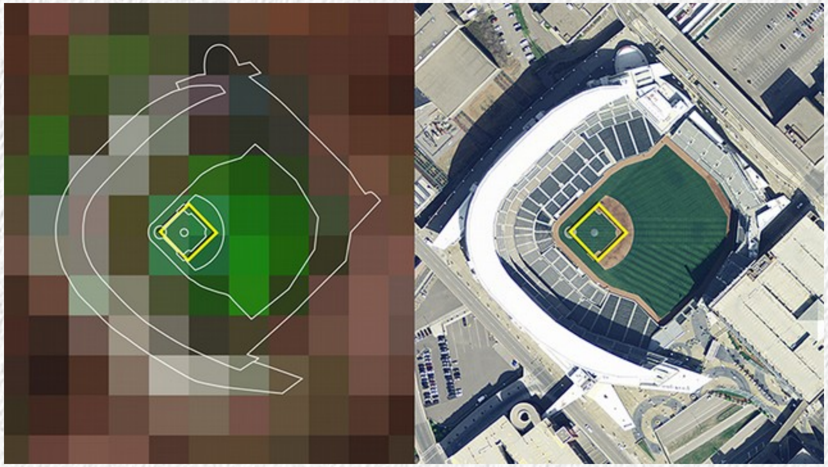
LandSat

- LandSat is a remote sensing mission run by NASA and the US Geological Survey
- There have been 8 LandSat satellites launched so far, first one launched in 1972
- Longest continuously running program in the world
- Useful to ecologists for identifying cover types, monitoring change over time over large areas



LandSat images

- Like digital pictures
  - Made up of pixels = squares
  - Intensity of EM radiation in a particular wavelength range (called a **band**) is recorded for each pixel
  - Multiple bands are recorded, both in the visible and infrared part of the spectrum

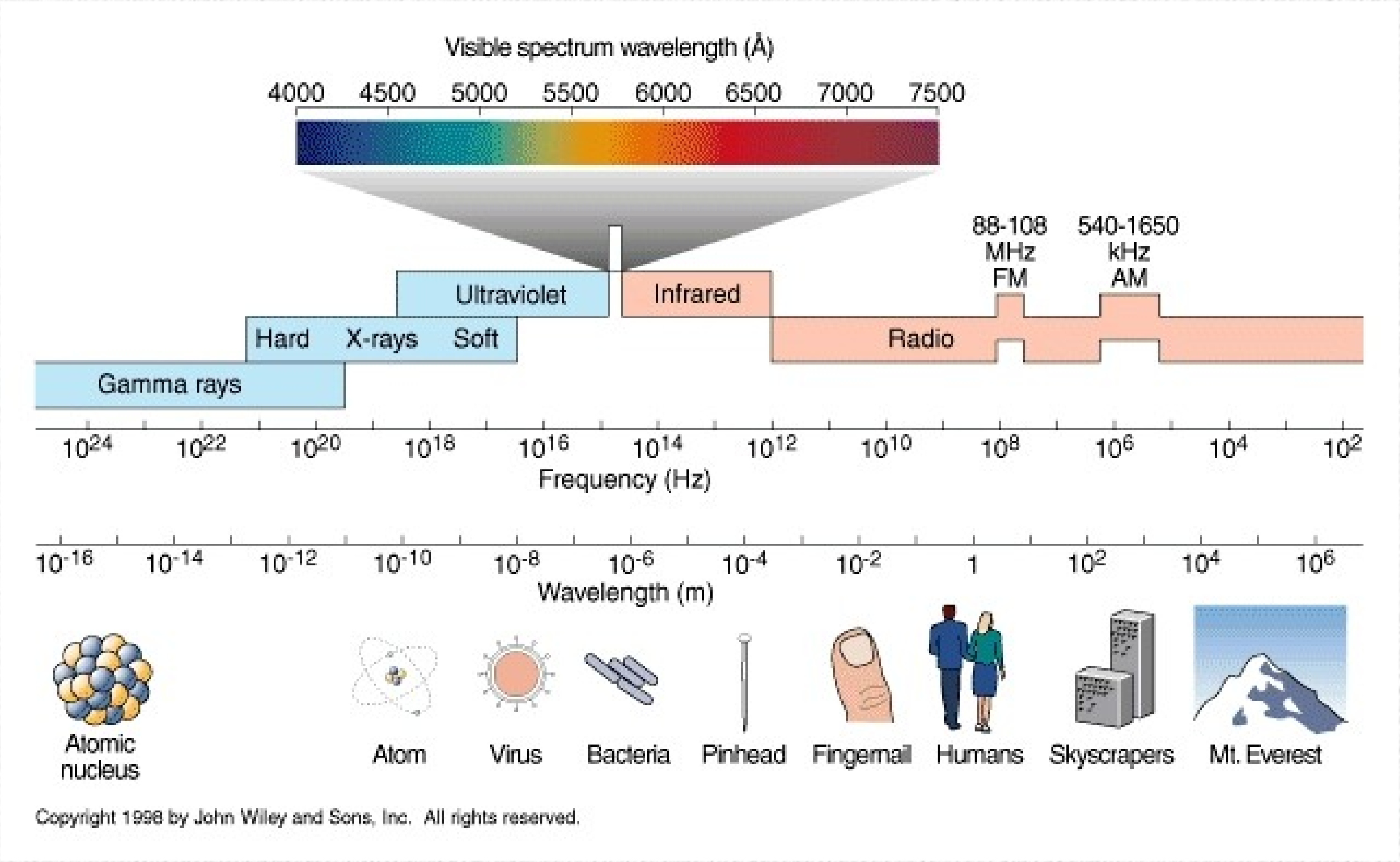


- LandSat's pixels are too big to see fine detail on the ground, but large features are visible
- Visualizing, mapping → image interpretation

Tornado track, Mass.

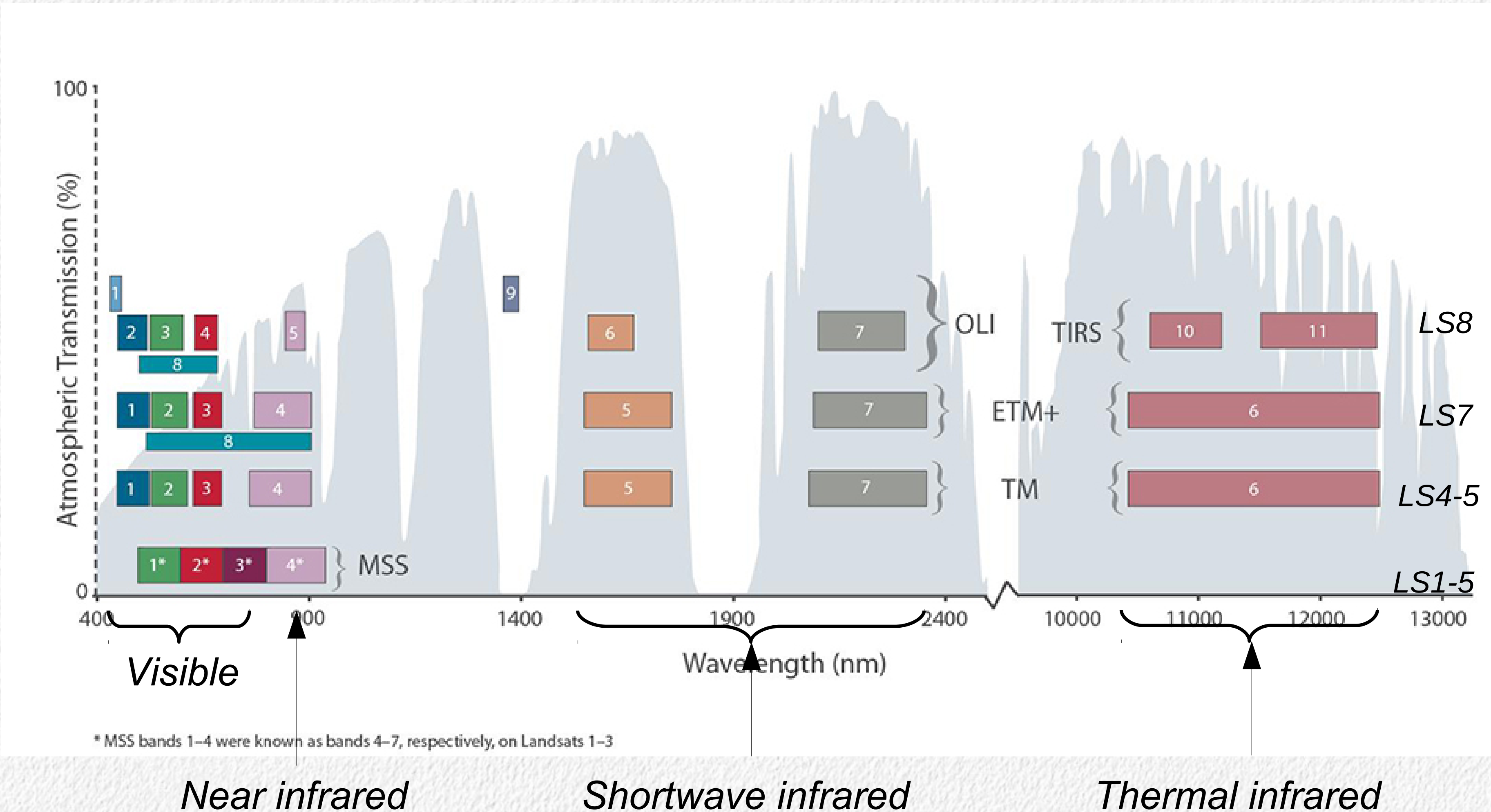
Sediment discharge from the Connecticut River

The EM spectrum



EM wavelengths we can see are called "light"
Different wavelengths of visible light are different colors

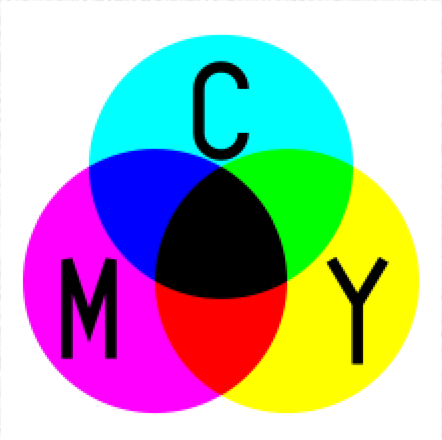
Bands recorded by LS 1 through LS 8



Making pictures with satellite imagery

- Visualizing LandSat data is done by assigning image **layers** that record wavelength **bands** to color **channels** on a monitor
- The way that the bands mix together determines what color you see
- How this works with visible light...

Subtractive color mixing – pigments

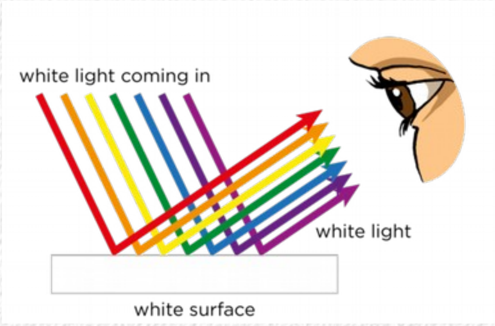


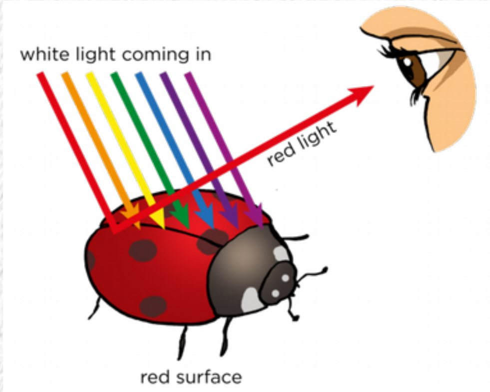
Pigments selectively absorb wavelengths from white light – what you see is what is reflected

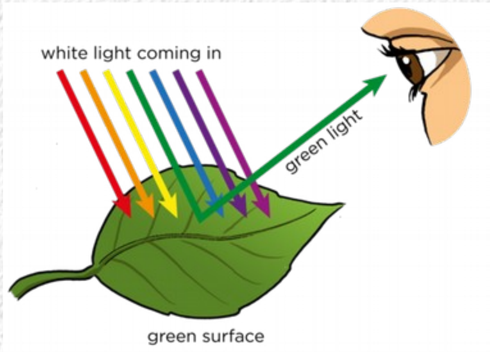
Primary pigment colors are red, blue, yellow (old) or cyan, magenta, yellow (modern)

Mixes of primary colors determine what is left to reflect to your eye

Lack of pigment = white
Pigments of all colors = black

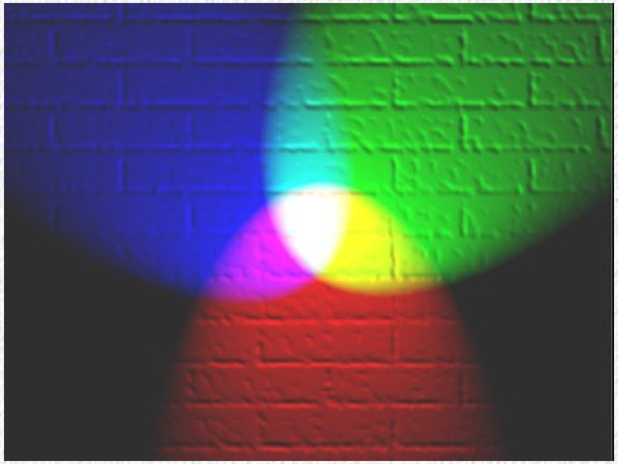






Additive color mixing – emitted light

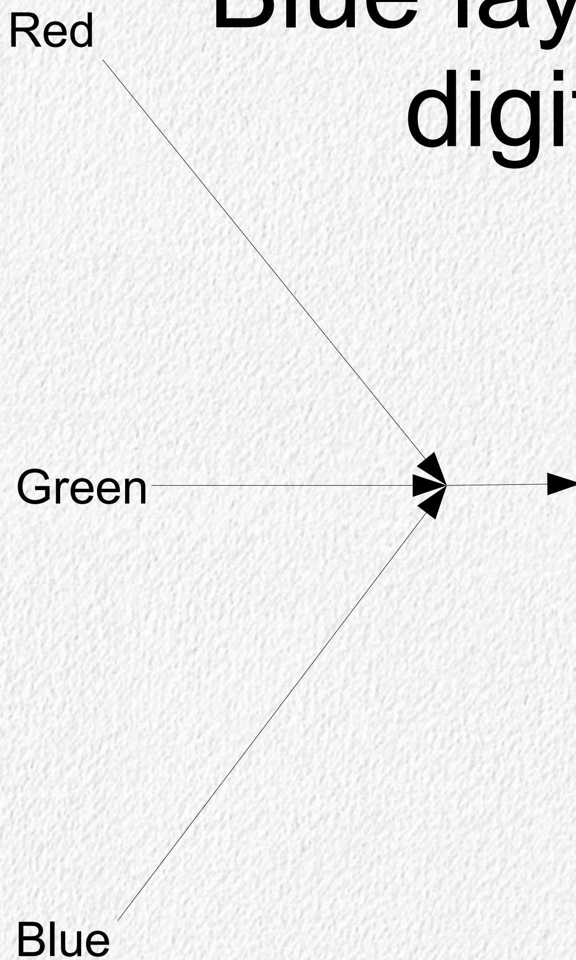
- Red, green, blue are the primary colors of light
  - Lack of all three → black
  - Mixes of equal amounts of R,G,B give shades of gray
  - Equal, high levels → white
  - Mixes of R, G, B in different amounts → all other colors
- G + R = ?

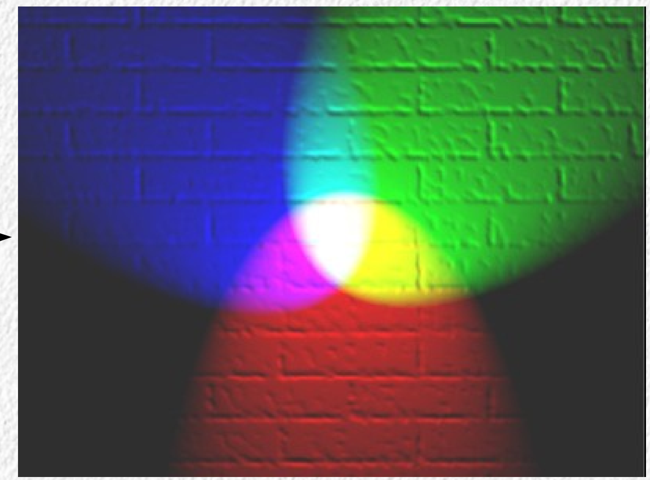


Digital color

- Computer monitors emit light → additive color mixing
- Digital images record intensity of red, green, and blue wavelengths in separate layers
  - 0 = no light emitted in a band
  - 255 = maximum amount of light emitted in a band
- This gives 256^3 = 16,277,216 different colors that can be represented by a level of red, green, and blue light
- More colors than human vision can discern, so this is considered “true color”

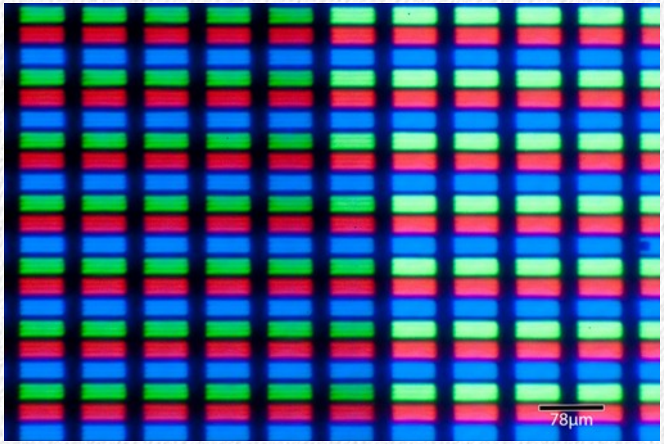
Red, Green, and Blue layers in a color digital image



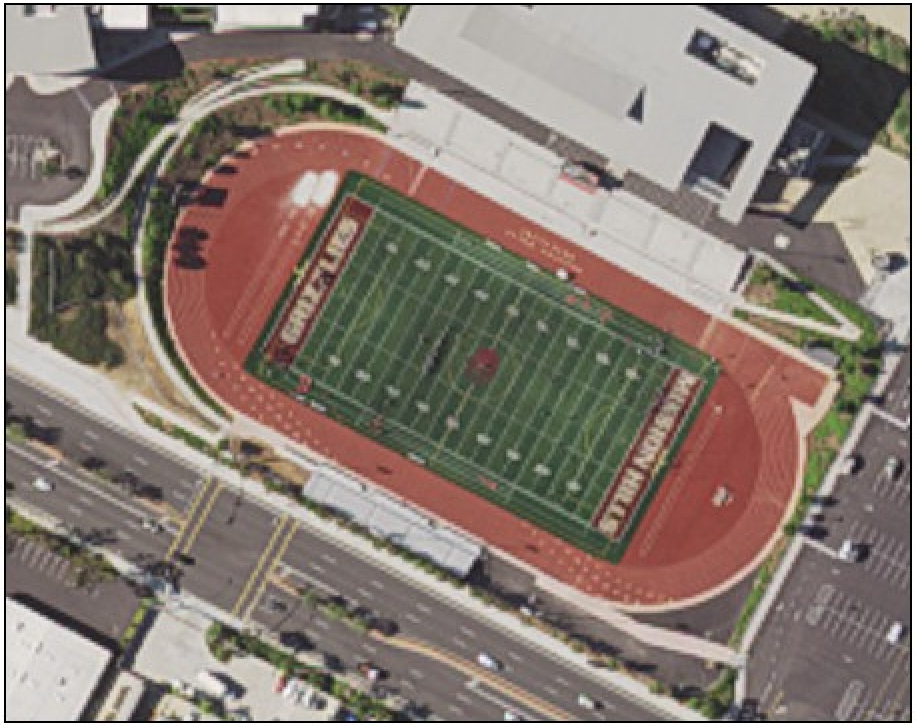


Color on a computer monitor

- LCD monitors are made up of arrays of light-emitting diodes
  - Pixels are groups of 3 diodes: one R, one G, one B
  - Each color is a channel – displays data from a single layer in an image
- For digital pictures, layers are mapped to channels in the expected way:
  - Red layer → Red channel
  - Green layer → Green channel
  - Blue layer → Blue channel
- Assigning LandSat bands in this way assignment gives us a “natural color” image



Natural color assignment



We aren't required to be natural

- LandSat 5 bands are:

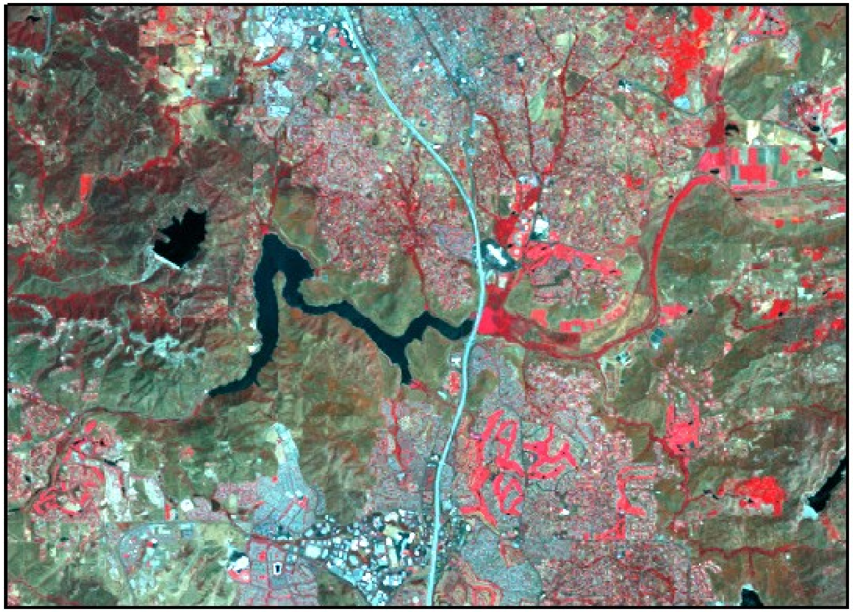
Visible light:
- Band 1 = Visible blue
- Band 2 = Visible green
- Band 3 = Visible red

Infrared (not visible):
- Band 4 = Near infrared
- Band 5 = Mid infrared 1
- Band 6 = Thermal infrared
- Band 7 = Mid infrared 2

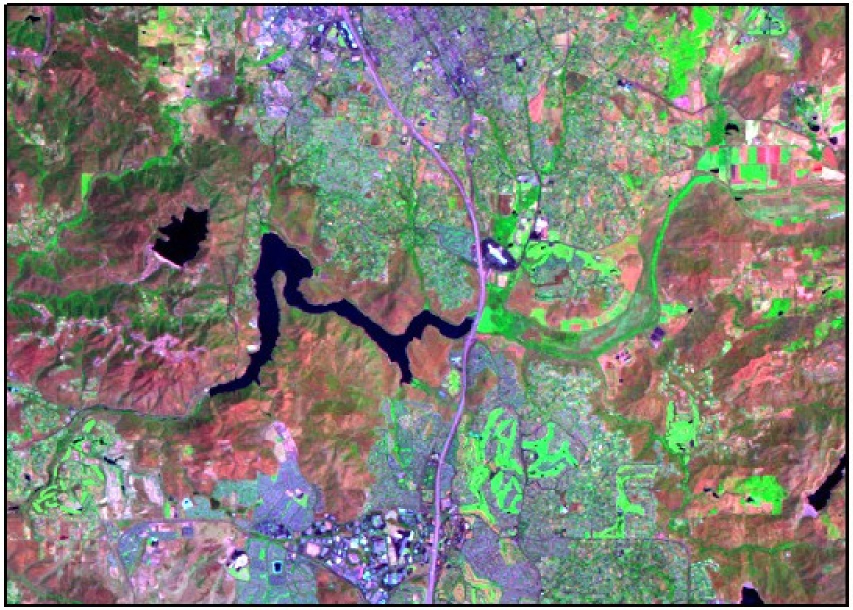
- Assigning an infrared **layer** to a color **channel** on our computer monitor translates it into a wavelength we can see
- The assignment of an invisible wavelength to a visible light channel makes a **false-color image**
- Different assignments are useful for seeing different features

Natural color (3,2,1)

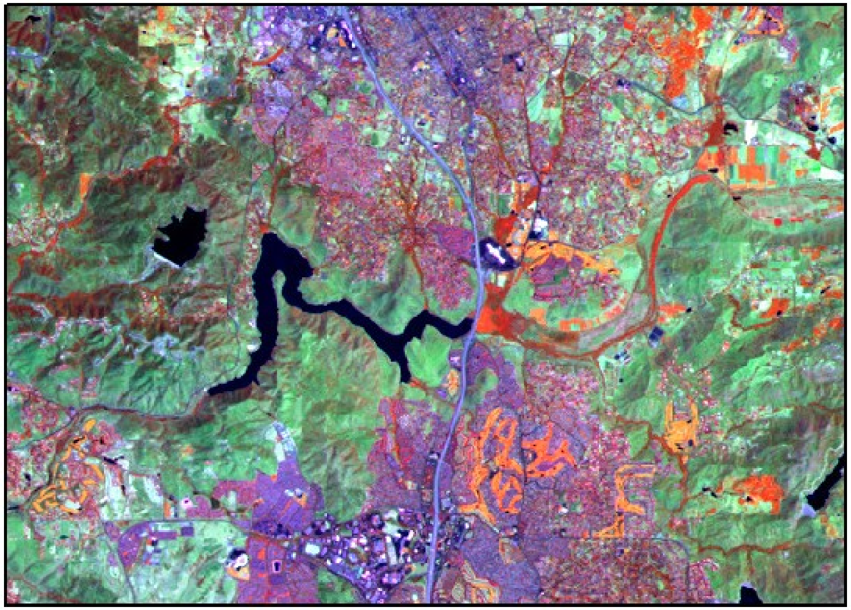
Color infrared (4,3,2)



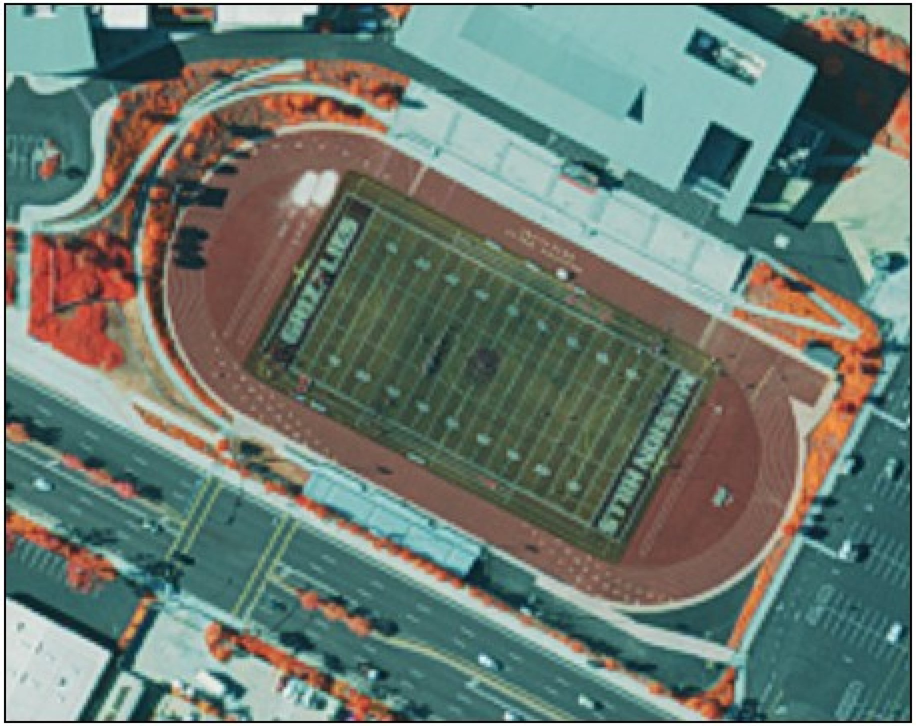
Atmosphere penetrating (7,4,2)

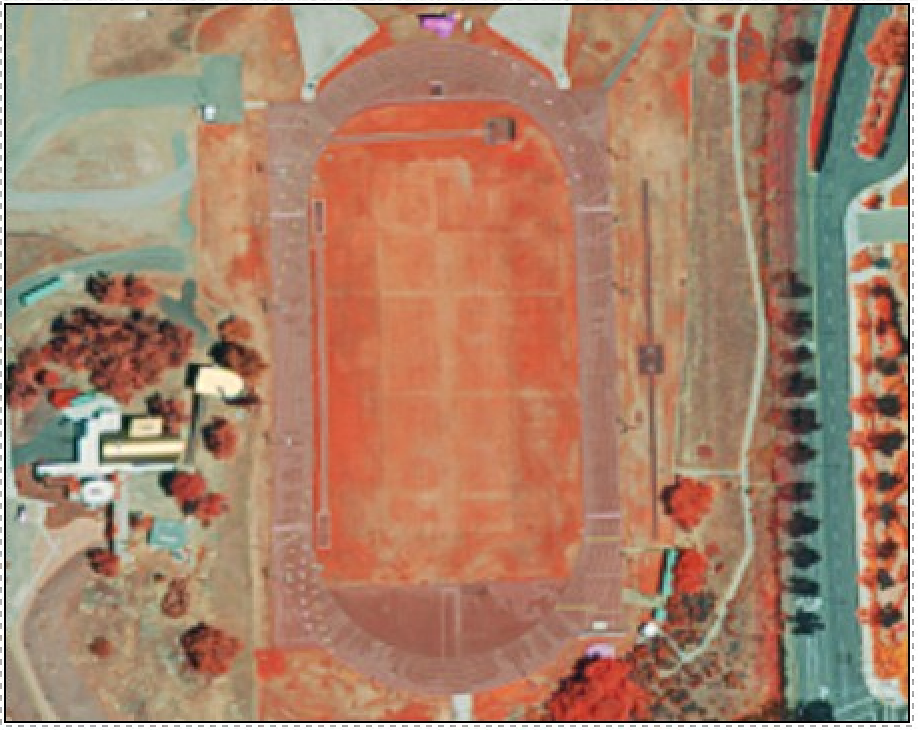


Land/water boundaries (4,5,3)



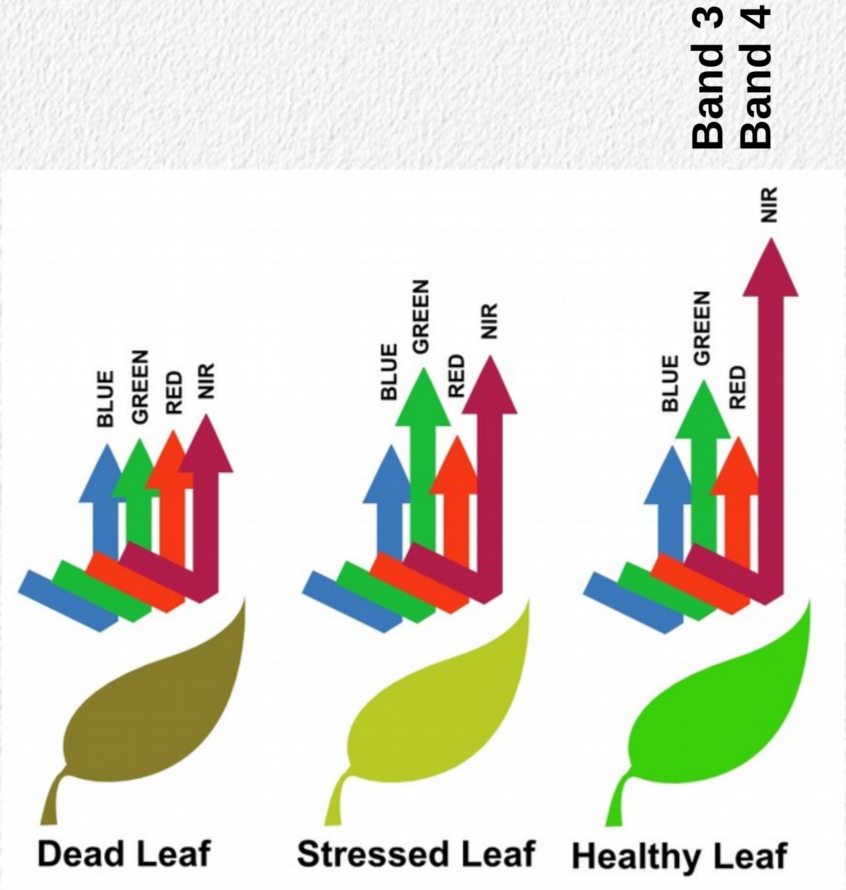
Color infrared – turf vs. grass





Deriving ecological data from LandSat

- Can derive ecologically useful data directly from LandSat imagery
- Example: vegetation indices, such as the Normalized Difference Vegetation Index (NDVI)
- Based on differences in amount of visible red and near infrared radiation that reflects off of leaves

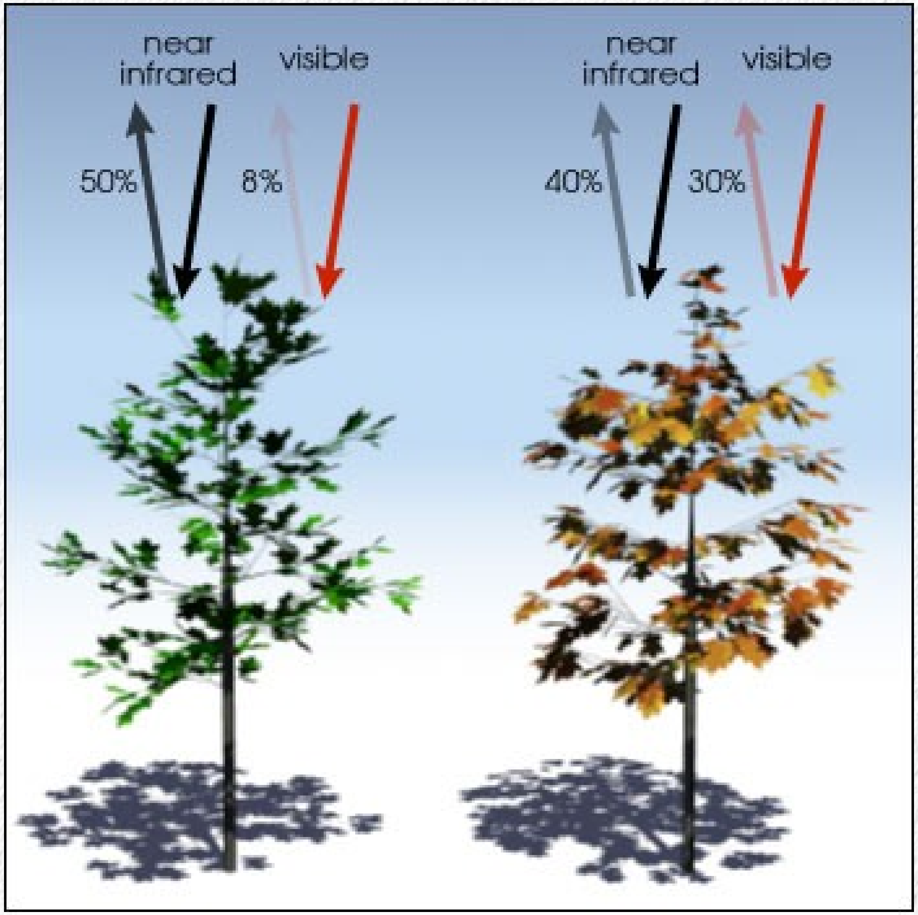


NDVI

- The formula is:

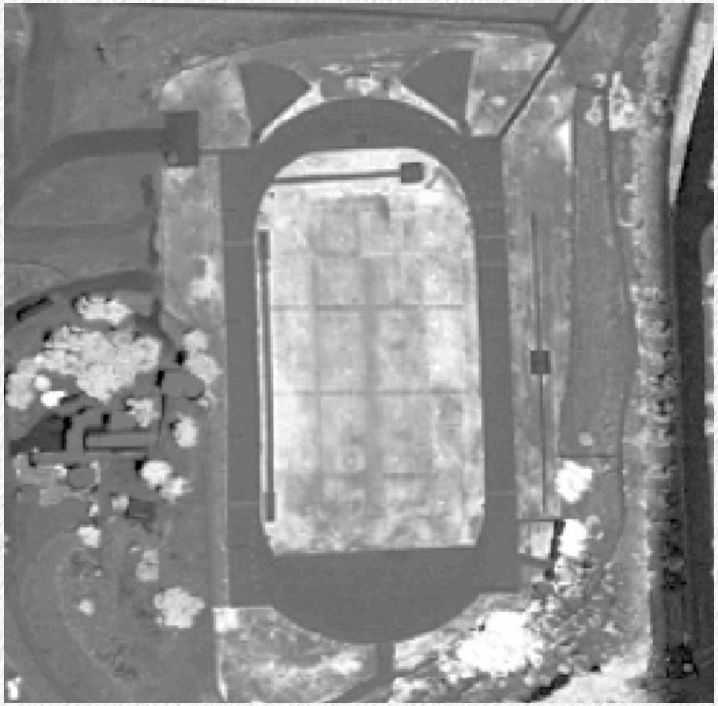
$$NDVI = \frac{\text{Band } 4 - \text{Band } 3}{\text{Band } 4 + \text{Band } 3}$$

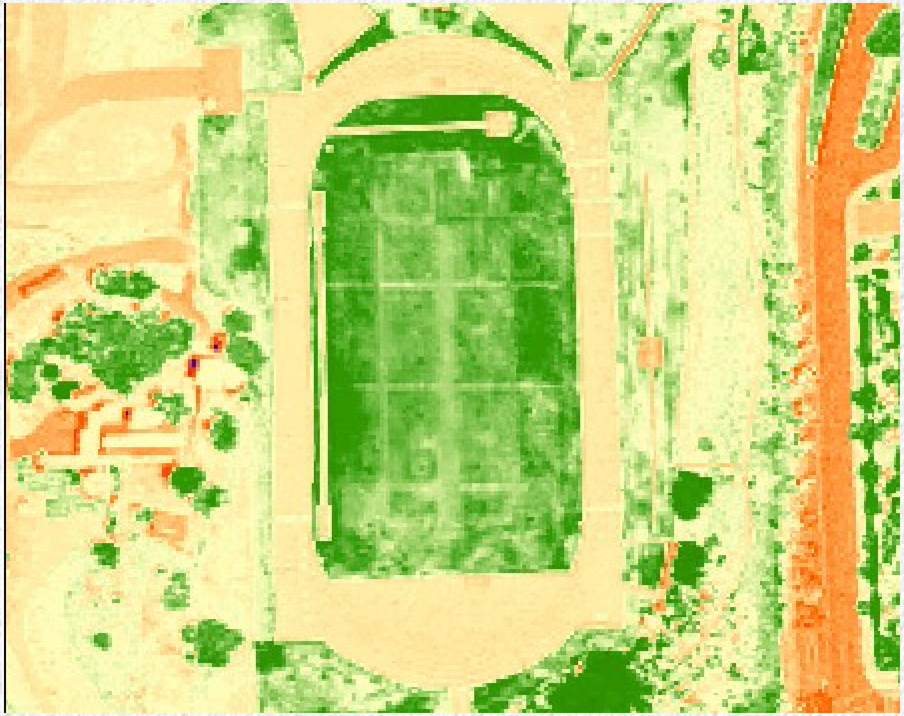
- High values indicate photosynthetically active vegetation



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

NDVI

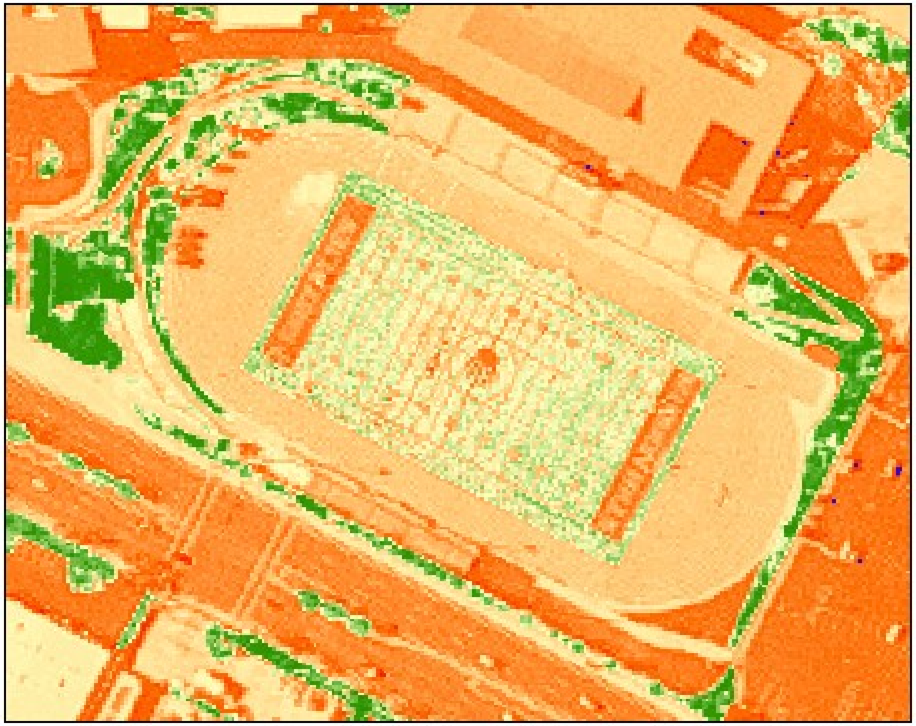


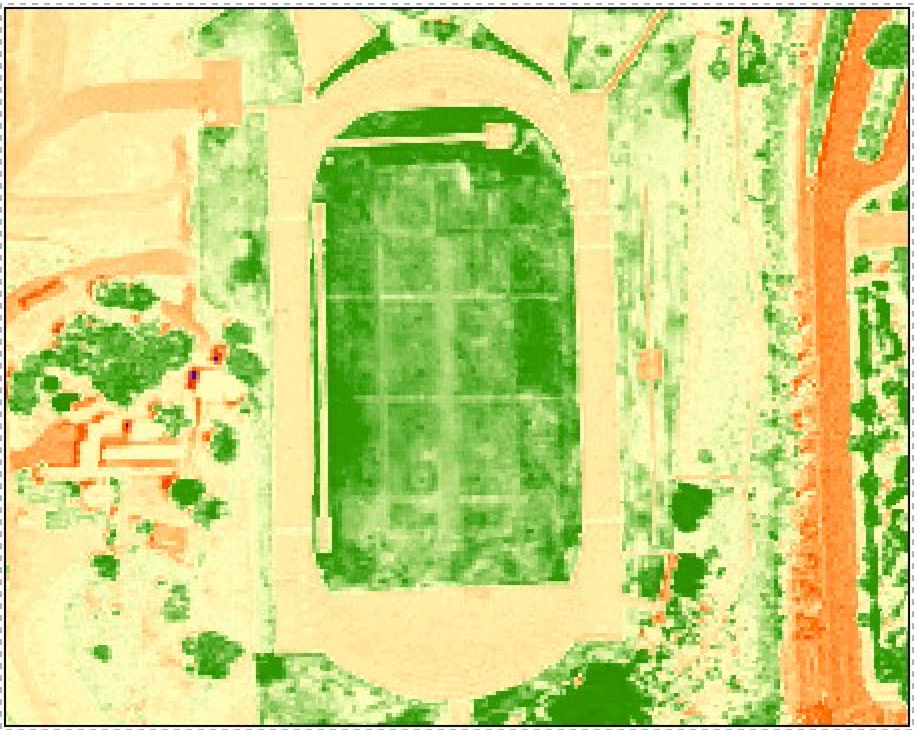


NDVI is a single number

Color on the right is a color ramp assigned to low levels (blue/orange) through moderate (yellow) to high (green) levels of NDVI

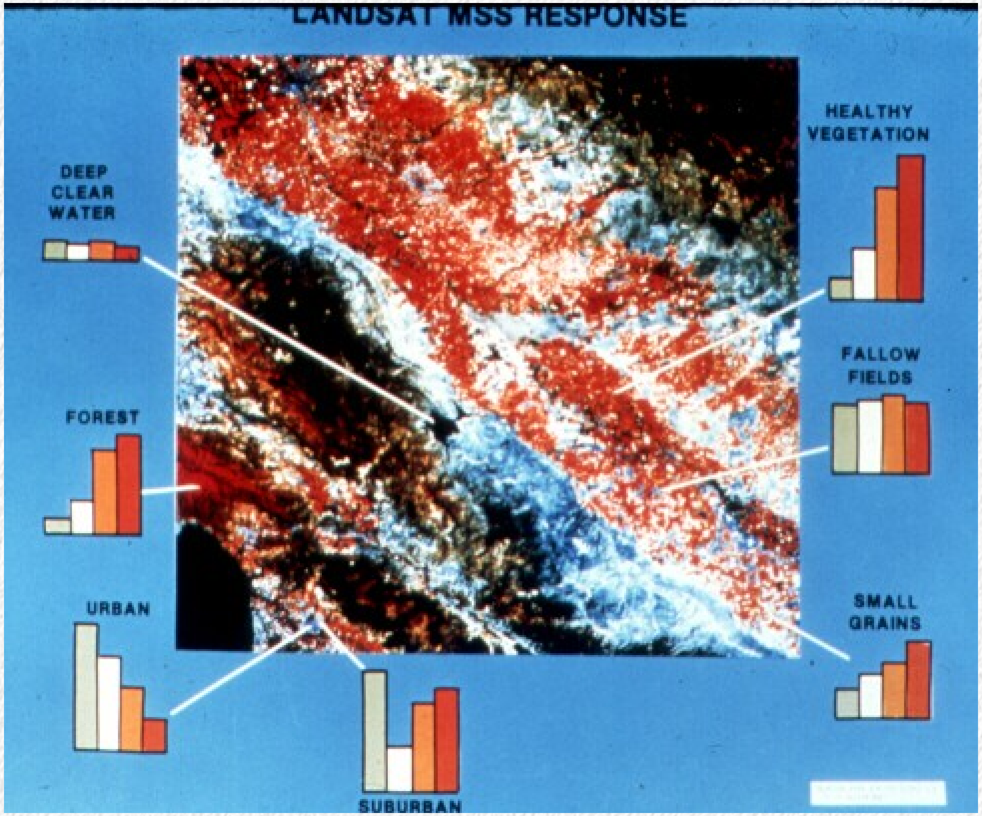
Low NDVI for artificial turf



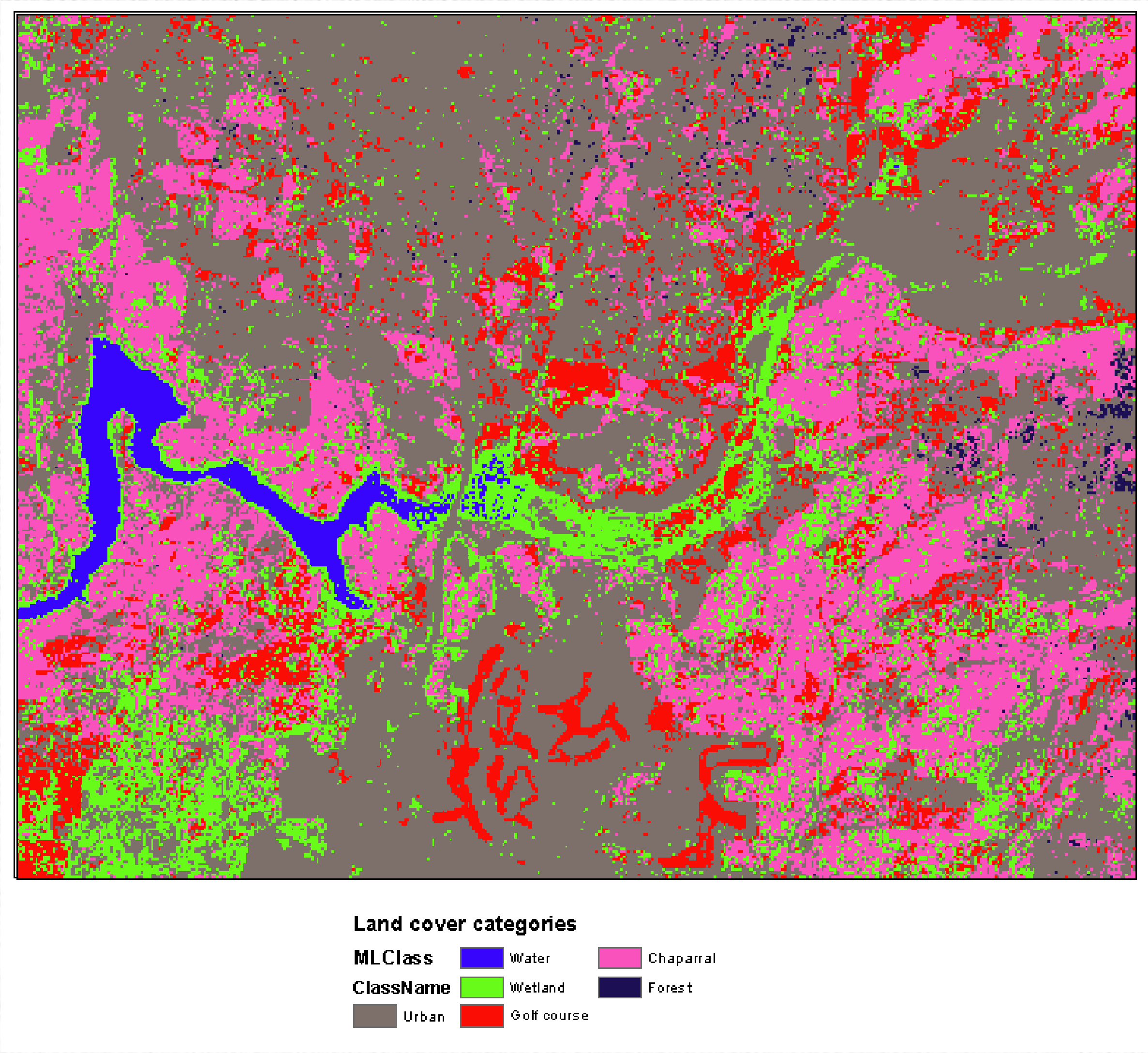


Cover types from images

- Wavelengths reflect differently from different types of land cover
- Can use the patterns of reflectance across the LandSat bands to classify land cover
- Possible to map cover types over large areas repeatedly to monitor for change

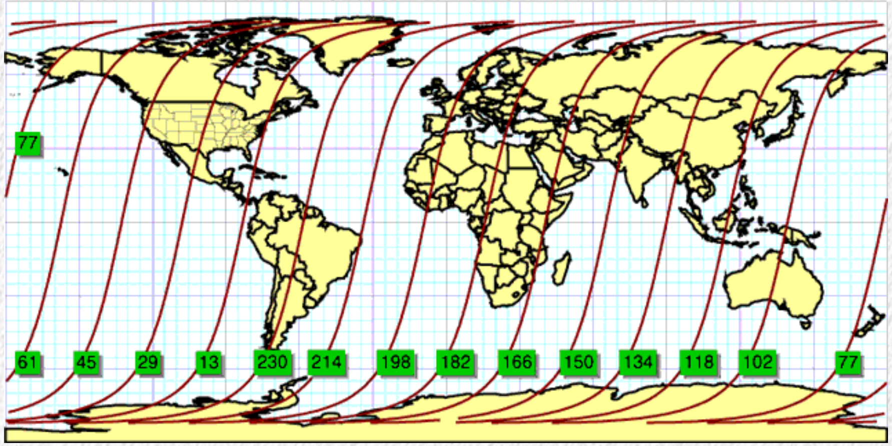


Classified cover types



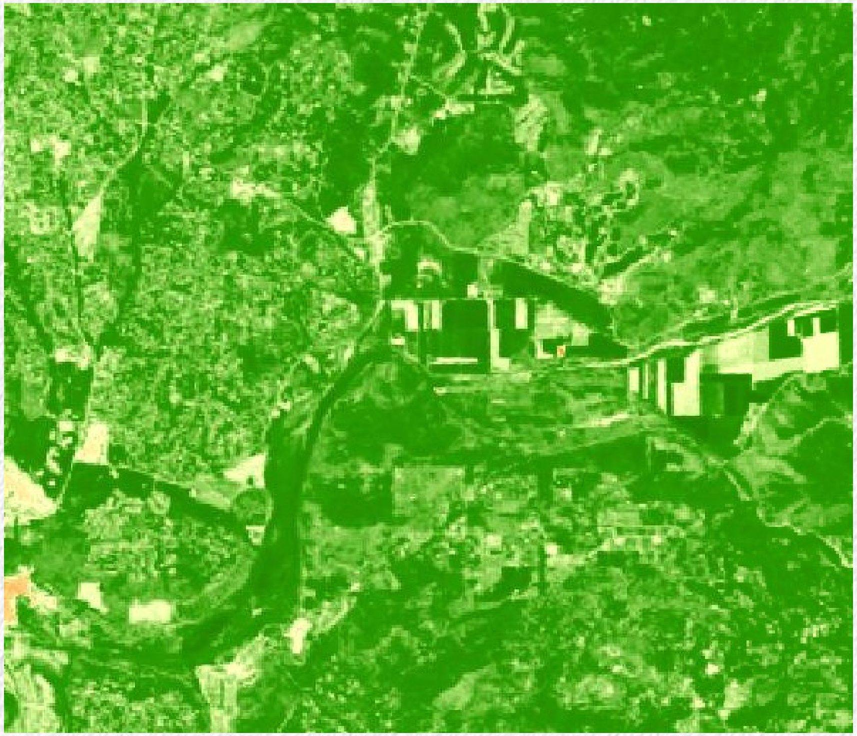
Change detection

- If we compare images over time we can see how the landscape is changing
- Can compare:
  - Different seasons of the same year
  - Same seasons over time



We are Path 40, row 37

Spring vs Fall NDVI



April 2011

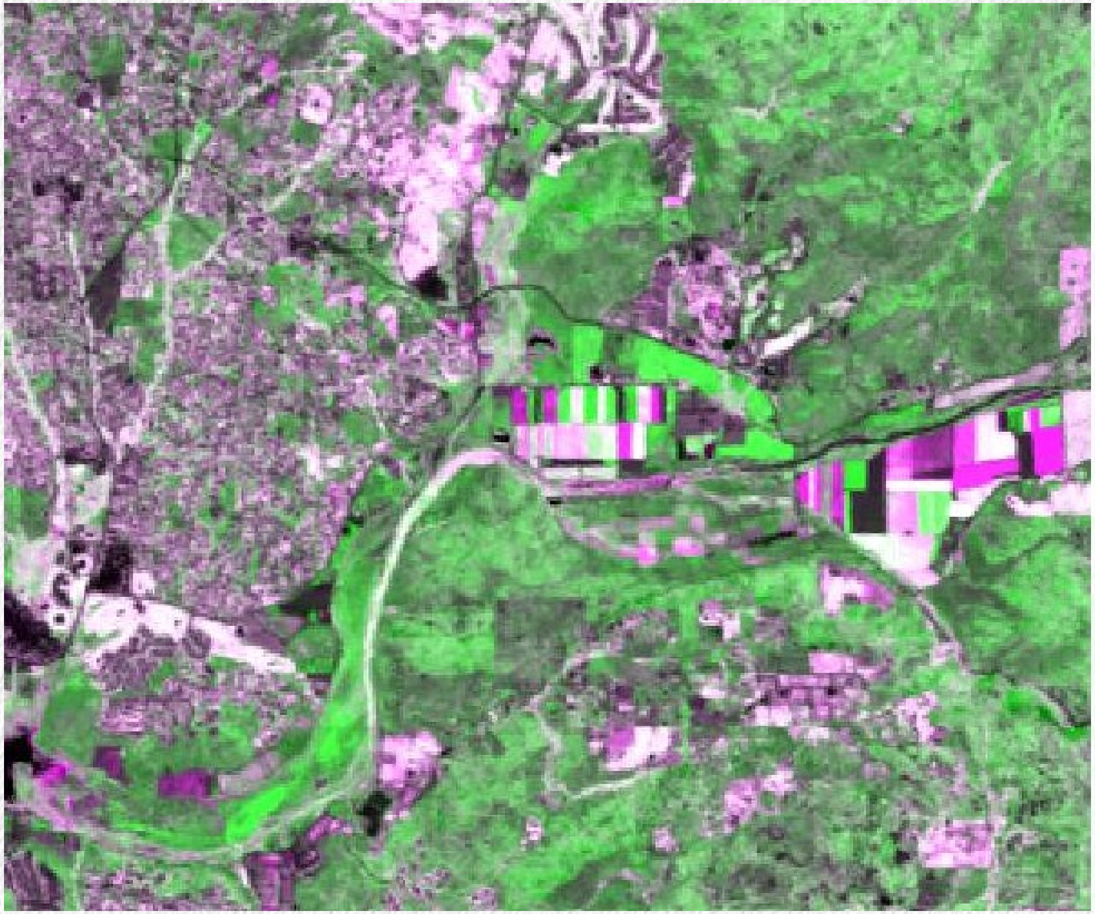
November 2011

Which month is greener in general? Exceptions?

Visualizing seasonal difference

- We can make a **composite** image of the two NDVI layers
  - Assign April NDVI to green channel
  - Assign November NDVI to red and blue
- Color then becomes an indication of differences in NDVI between the seasons

April NDVI assigned to green, November NDVI to red and blue



What makes an area green? What makes it white? What makes it black? What makes it purple?

Visualizing change from 1984 to 2011

- NDVI calculated for spring images for three years (1984, 1992, 2011)
- Assign:
  - 1984 NDVI to red
  - 1992 NDVI to green
  - 2011 NDVI to blue
- Color will indicate when vegetation was removed or added

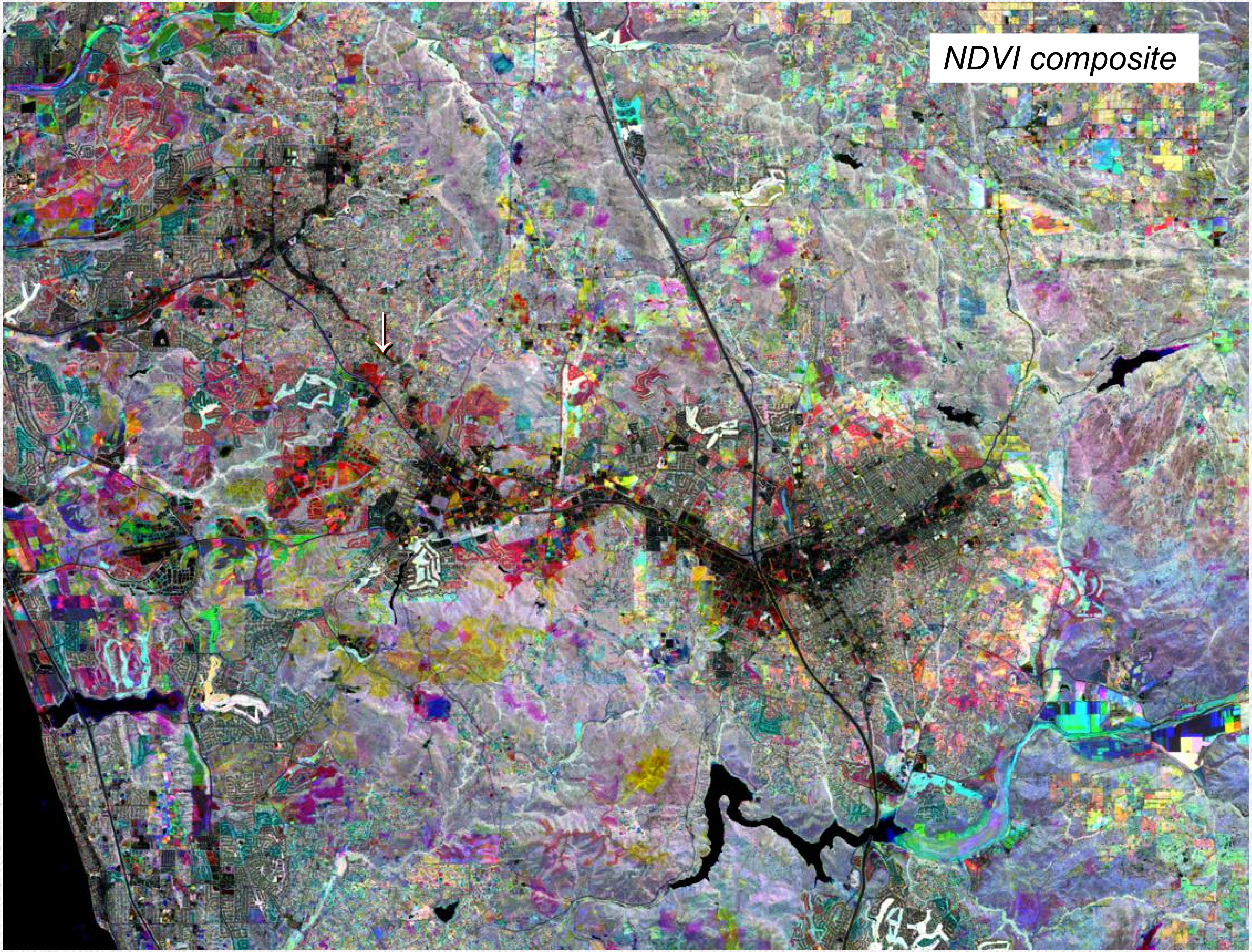
RGB color – a few examples

1984
1992
2011

Shades of gray when R,G,B are the same

0,0,0 = black

255,255,255 = white


NDVI composite

Wrap-up

- LandSat imagery gives ecologists a way of:
  - Mapping cover types
  - Assessing vegetation health/productivity
  - Tracking change over time
- Questions can be addressed over spatial scales and time scales that are hard for people to comprehend otherwise
- You can download your own - https://earthexplorer.usgs.gov/
- Wavelength!
- Thank you for your attention