Deck 9 – Remote Sensing

Remote Sensing and Rasters

Intro to GIS – UMass Amherst – Michael F. Nelson

We'll try to have all midterms graded by Thursday's lecture.

Earn back:

- You may earn back missed points, up to a maximum of 100%
- I'll post earn back details after you've had a chance to review your midterm grade.

Questions:

- After you've reviewed your midterm, please feel free to submit any questions in class, or over email. We can work through points of confusion together.

Announcements: GIS Strategies

- Don’t rush through the lab walkthroughs!
- Don’t expect to finish the lab during lab period. They are designed to take longer.
- Ask your instructor and/or TA for feedback on your maps before you submit them.
- Pay careful attention to the lab questions and the map specs. Attention to detail is very important in this course.
- Step away from ARC and think through a problem-solving strategy.
- Remember that ARC PRO is not GIS. It’s just an ***implementation*** of many tools we use in GIS.

Announcements: GIS Strategies

- Remember that ARC PRO is not equivalent to GIS. It's an ***implementation*** of many tools we use in GIS.
- You could complete all of the lab tasks in many other platforms, for example:
  - GRASS
  - QGIS
  - R
  - Python
- I know the technical aspects of Arc are difficult but try to keep it in perspective. It's important to think of concepts in addition to their specific implementation.

Announcements

- Plan to utilize the remaining lab sessions to work on both labs and final projects!
- The last two labs are difficult and quite technical. Expect to spend quite a bit of time on them, if you want to do well. I have a few suggestions:
  - Do your risk analysis process twice, in two independent sessions. It's easy to miss a little step or checkbox. If you get the same answer twice, it's evidence that you did it right.
- I will post the midterm earn-back questions this week.

For Your Consideration

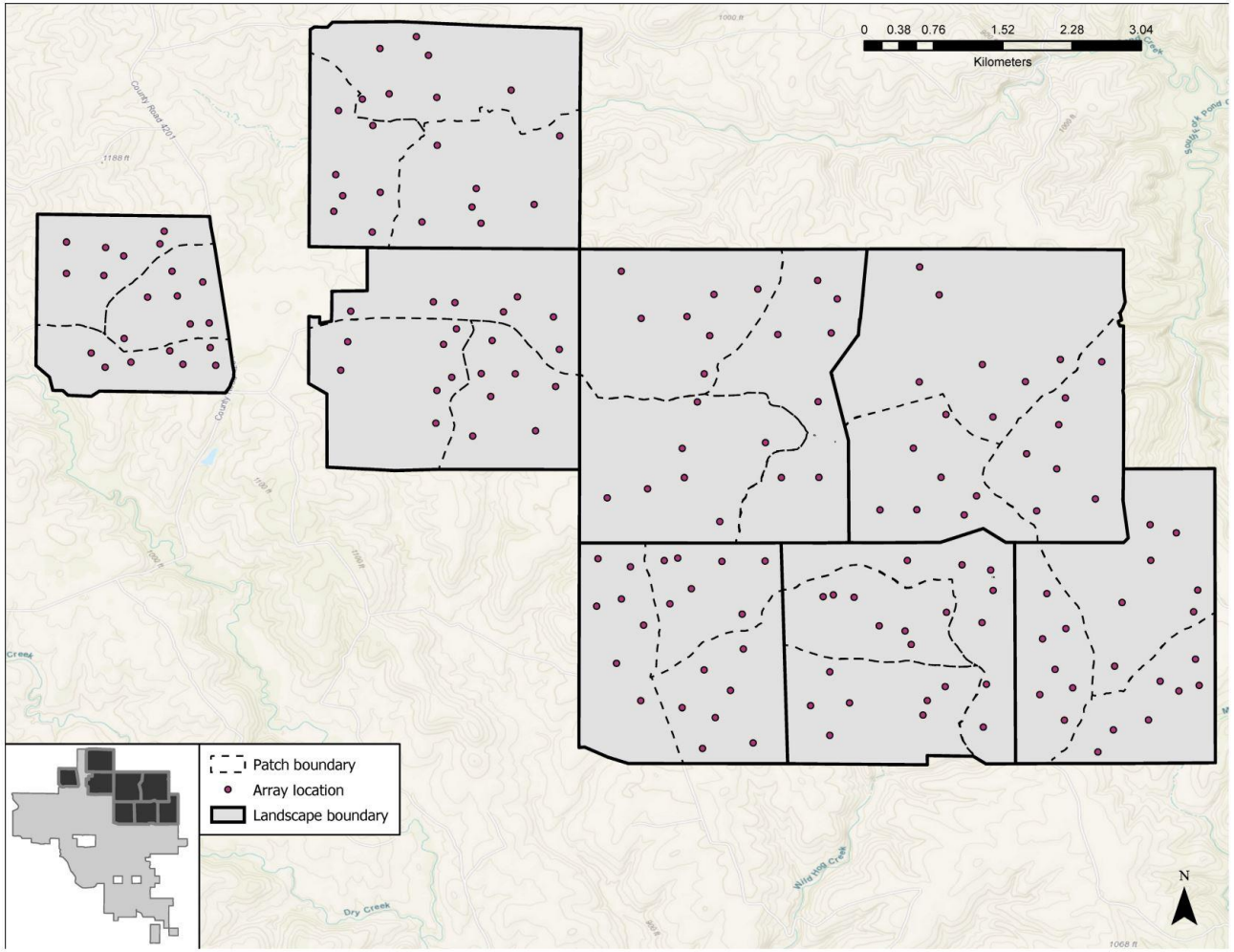


FIGURE 1 Map showing the layout of our landscapes (polygons), patches (dashed lines) and array locations (points) across our study area at the Nature Conservancy's Joseph H. Williams Tallgrass Prairie Preserve. The map also shows whether landscapes were burned during the dormant season (i.e. March–April; green polygons) or the growing season (i.e. August–September; red polygons), and whether they were also treated with herbicide (hatched lines).

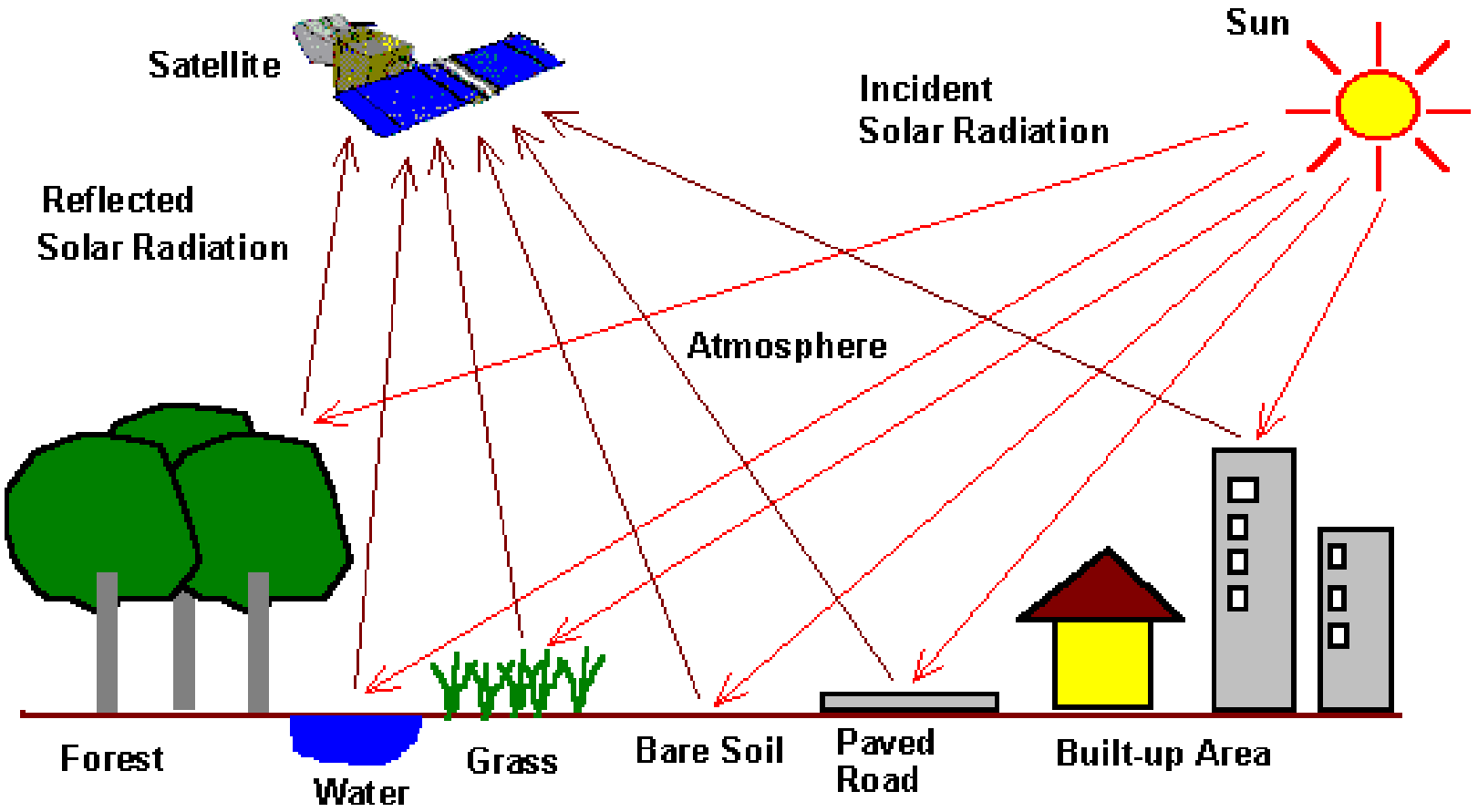
Remote Sensing: Components and Colors

Why remote sensing?

This is where your land cover (and land cover change) maps come from!

Maps based on remote sensing (of a vegetation type, disturbance regime, geologic feature etc.) can be analyzed in GIS

Remote Sensing Components



Remote Sensing

Interactions and obstacles

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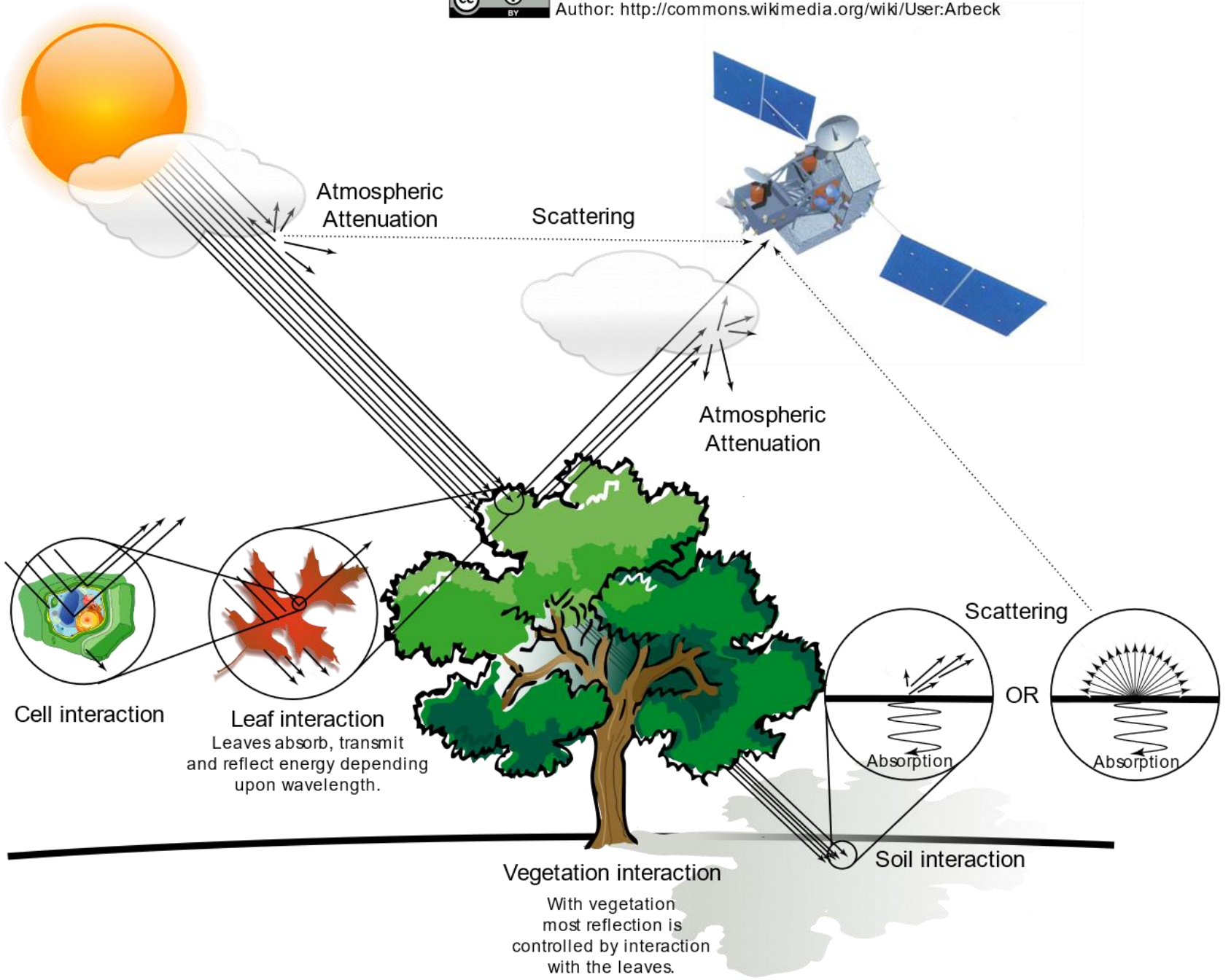
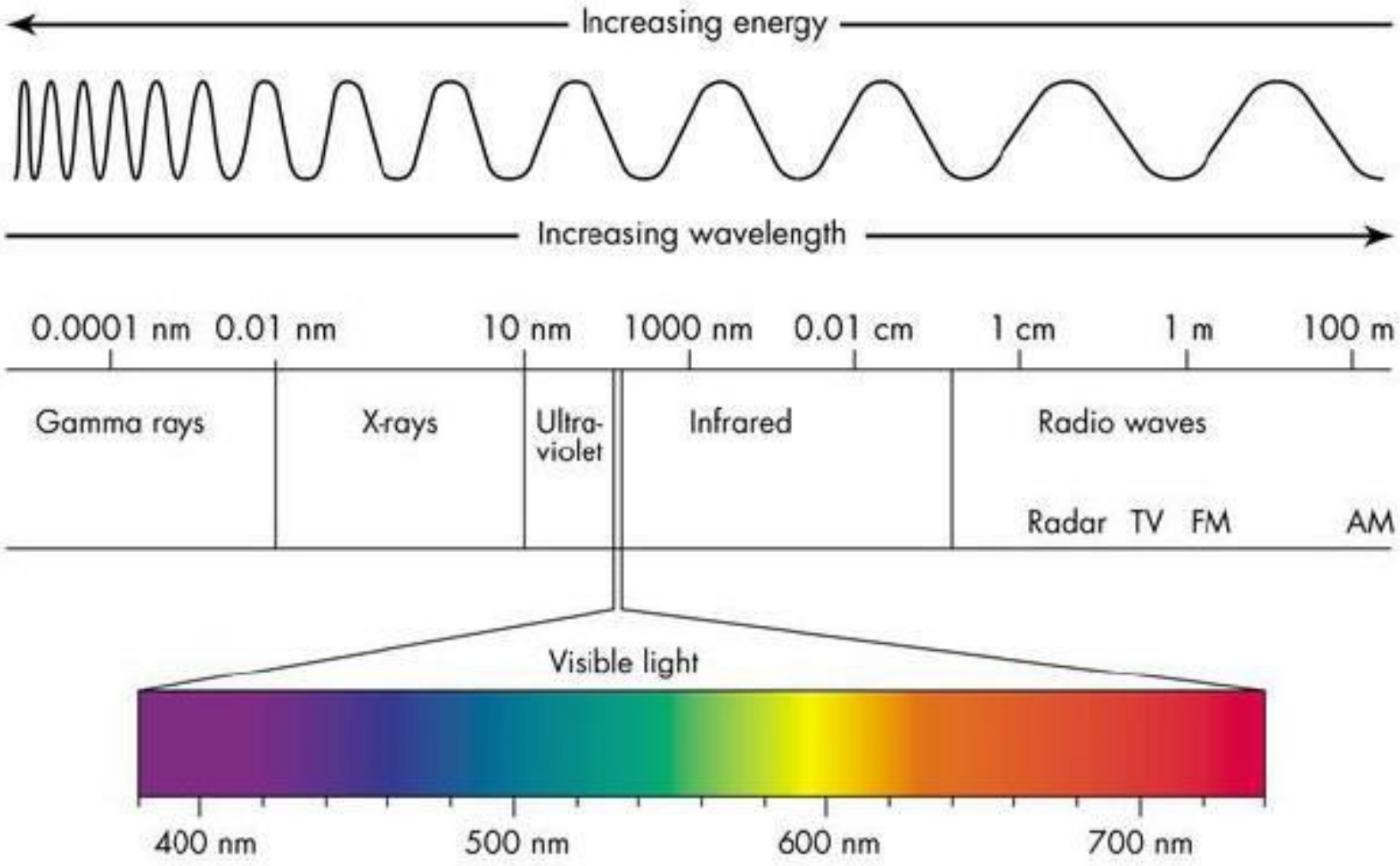
Author: http://commons.wikimedia.org/wiki/User:Arbeck



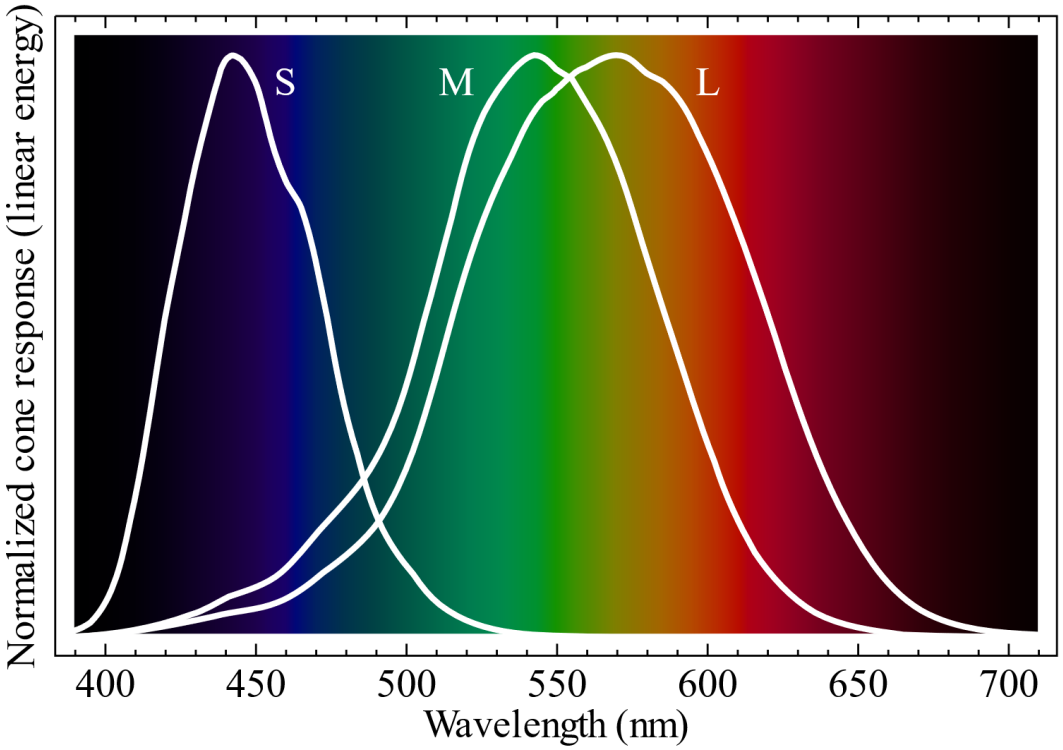
What is color?



Color is: All in our heads!

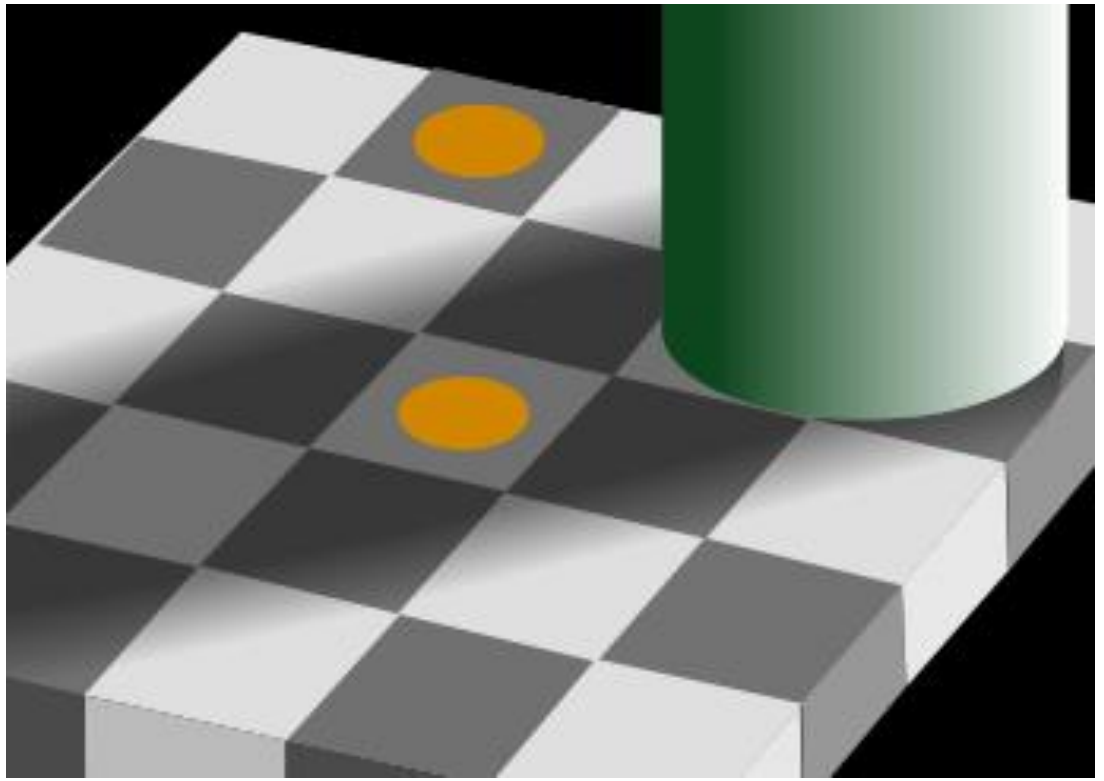
How we perceive visible light reflected from objects.

We can see roughly 10 million different colours.



Public domain image, created by WikiMedia user BenRG

Context matters



https://upload.wikimedia.org/wikipedia/commons/thumb/1/1e/Cones_SMJ2_E.svg/287px-Cones_SMJ2_E.svg.png

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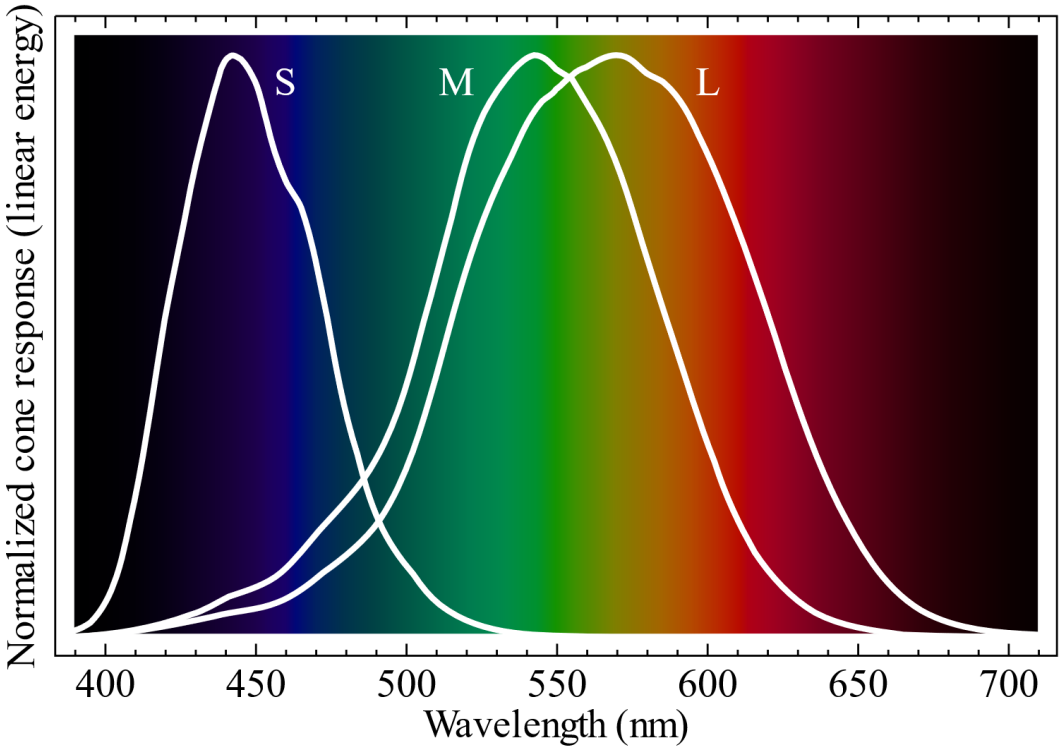

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Our eyes have two classes of photoreceptor cells: rods, for low-light vision, and cones which respond to different wavelengths.

There are 3 classes of cone cells

- Cone cells' pigments respond to different segments of the EM spectrum
- S: Short wavelengths, i.e. blue
- M: Medium wavelengths (greens)
- L: Long waveelgths (reds)

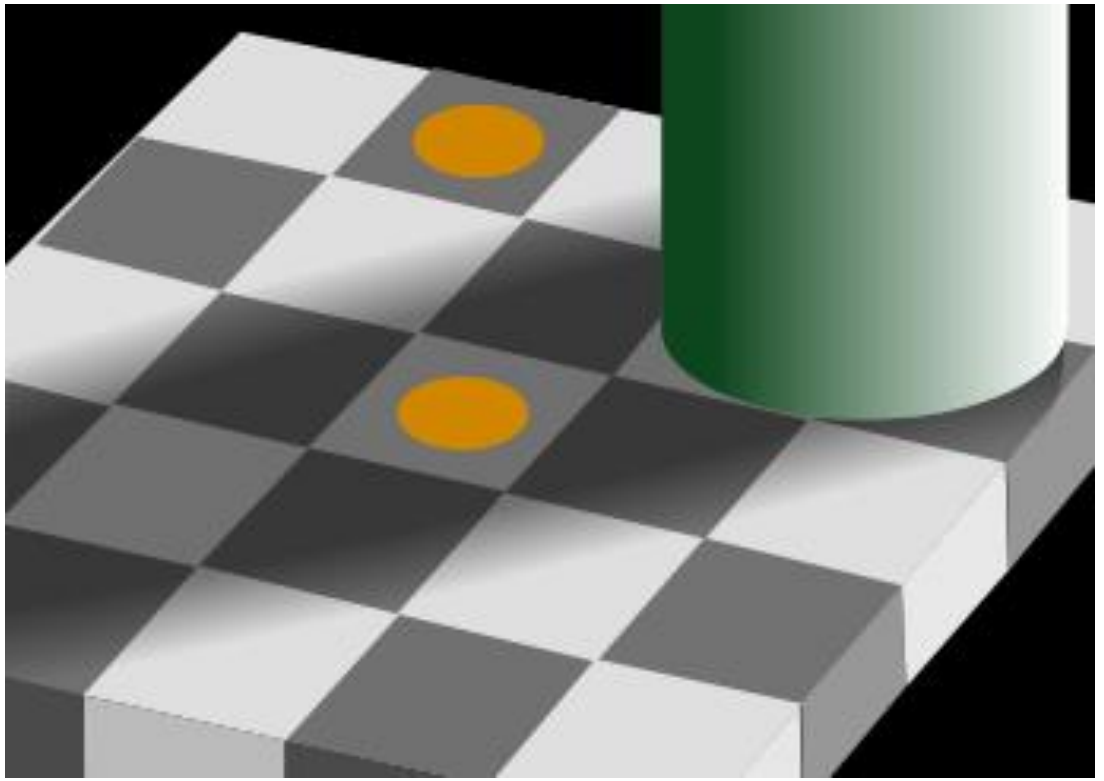
Color is: All in our heads!

Our brains pre-process the raw data

- We have mental models of how things should look and behave.
- Our mental models help us simplify the complicated world we perceive into something we can understand.
- This helps us, but can also trick us: Is the dress blue and black, or white and gold?

By Cecilia Bleasdale - https://web.archive.org/web/20150227014959/http://swiked.tumblr.com/post/112073818575/guys-please-help-me-is-this-dress-white-and, Fair use, https://en.wikipedia.org/w/index.php?curid=45522095

Context matters: The two orange dots are the same shade!

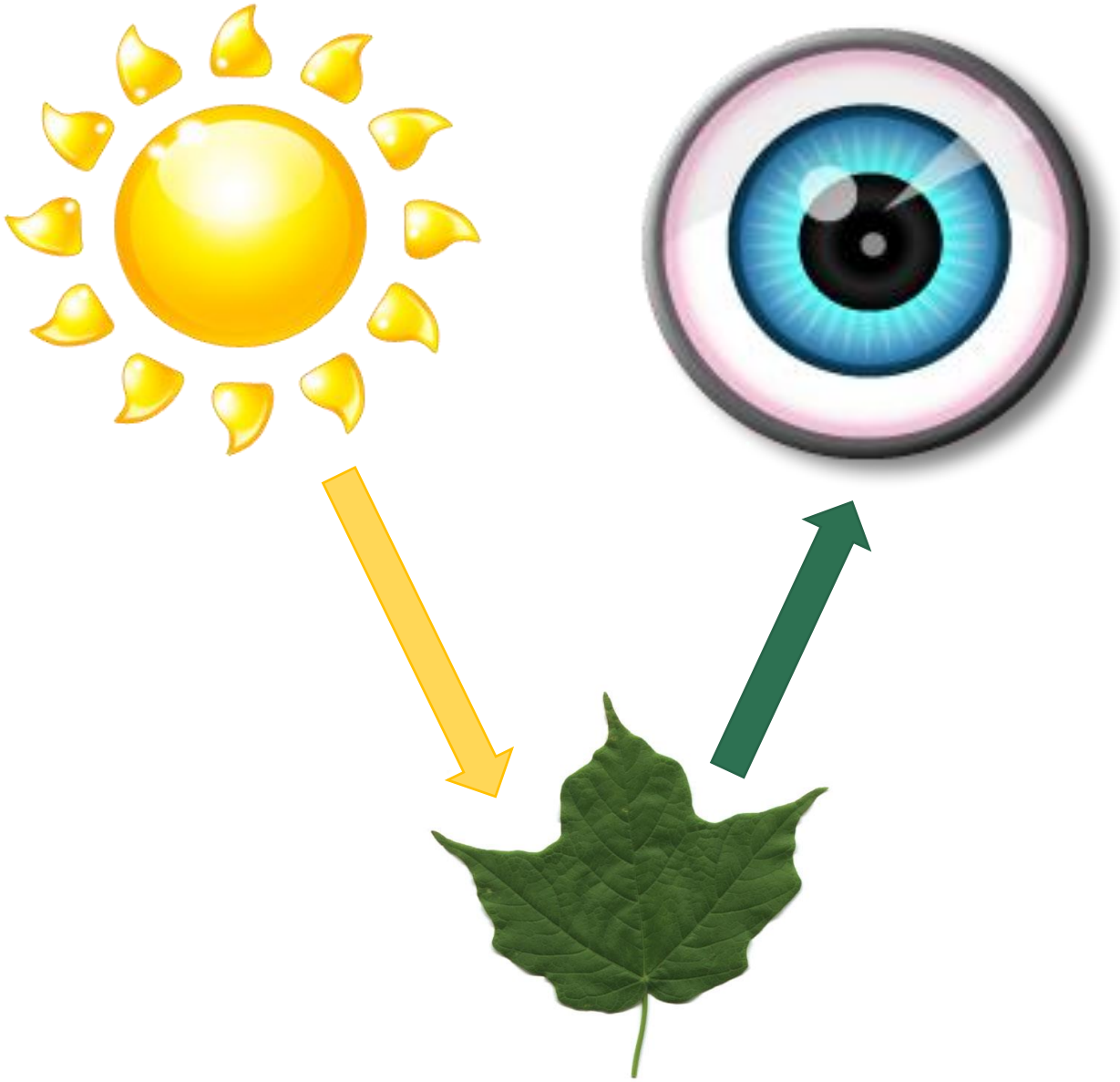


https://upload.wikimedia.org/wikipedia/commons/thumb/1/1e/Cones_SMJ2_E.svg/287px-Cones_SMJ2_E.svg.png

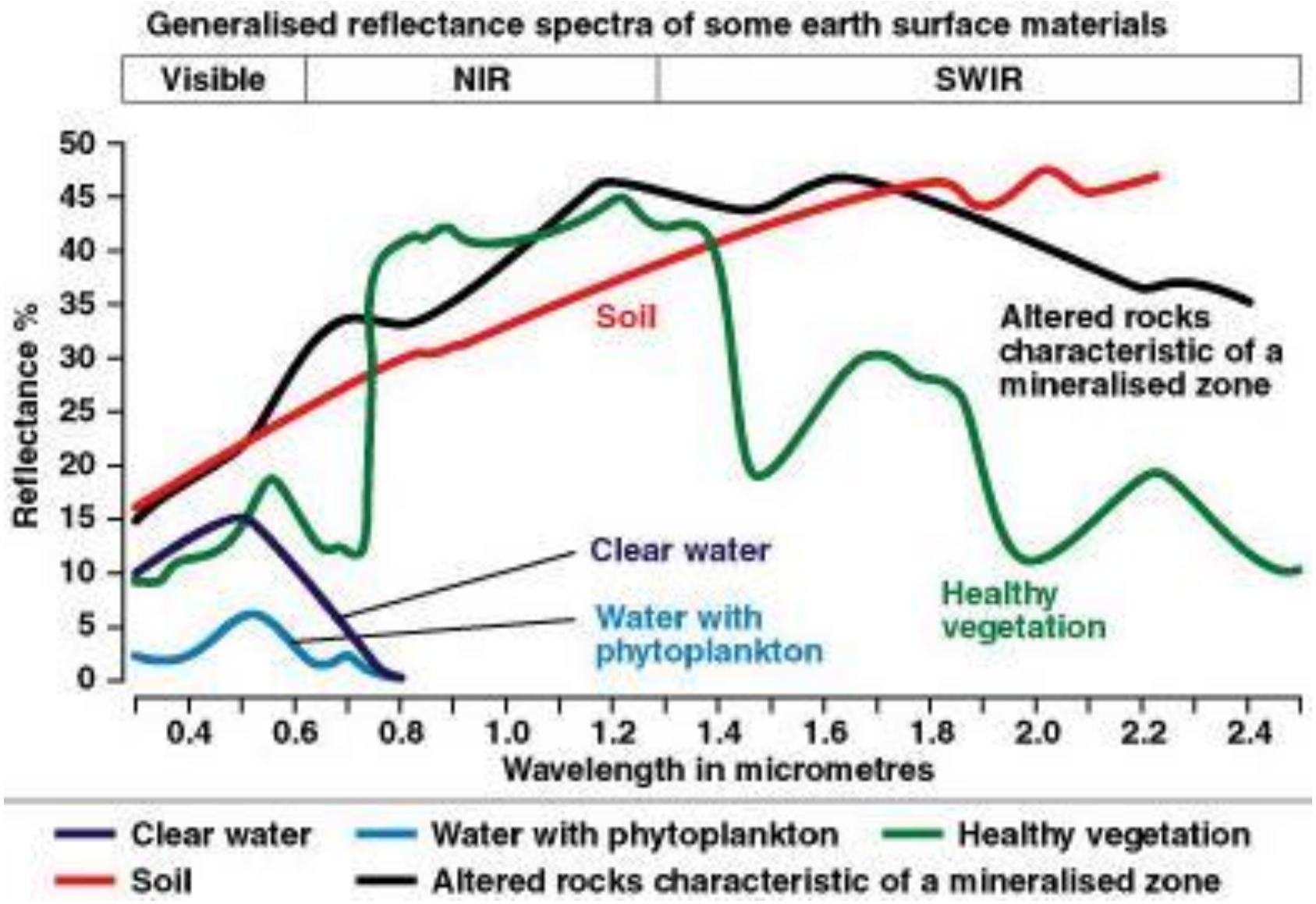
Contrast: Context Matters

Light hits an object. The object has two ‘choices’:

1. Absorb
2. Reflect



Reflectance Spectra - what are they?



Why are leaves green?

False Color

Seeing outside the visible range

RGB Color Model

RGB

- Three color channels
  - Additive effect
  - Red, Green, Blue
- (Approximately) simulates our eye physiology
  - Cone cells are stimulated by different wavelengths.
- Computer screen pixels have R, G, and B light emitters.

What else could we represent in the 3 channels?

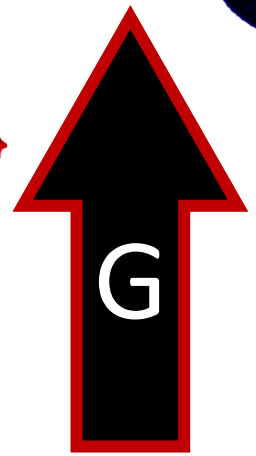
We simulate different colors in the visible range by varying the amount of light from the R, G, and B emitters. But we can also use the channels to represent frequencies that we can't see:

- UV
- Infrared
- Gamma

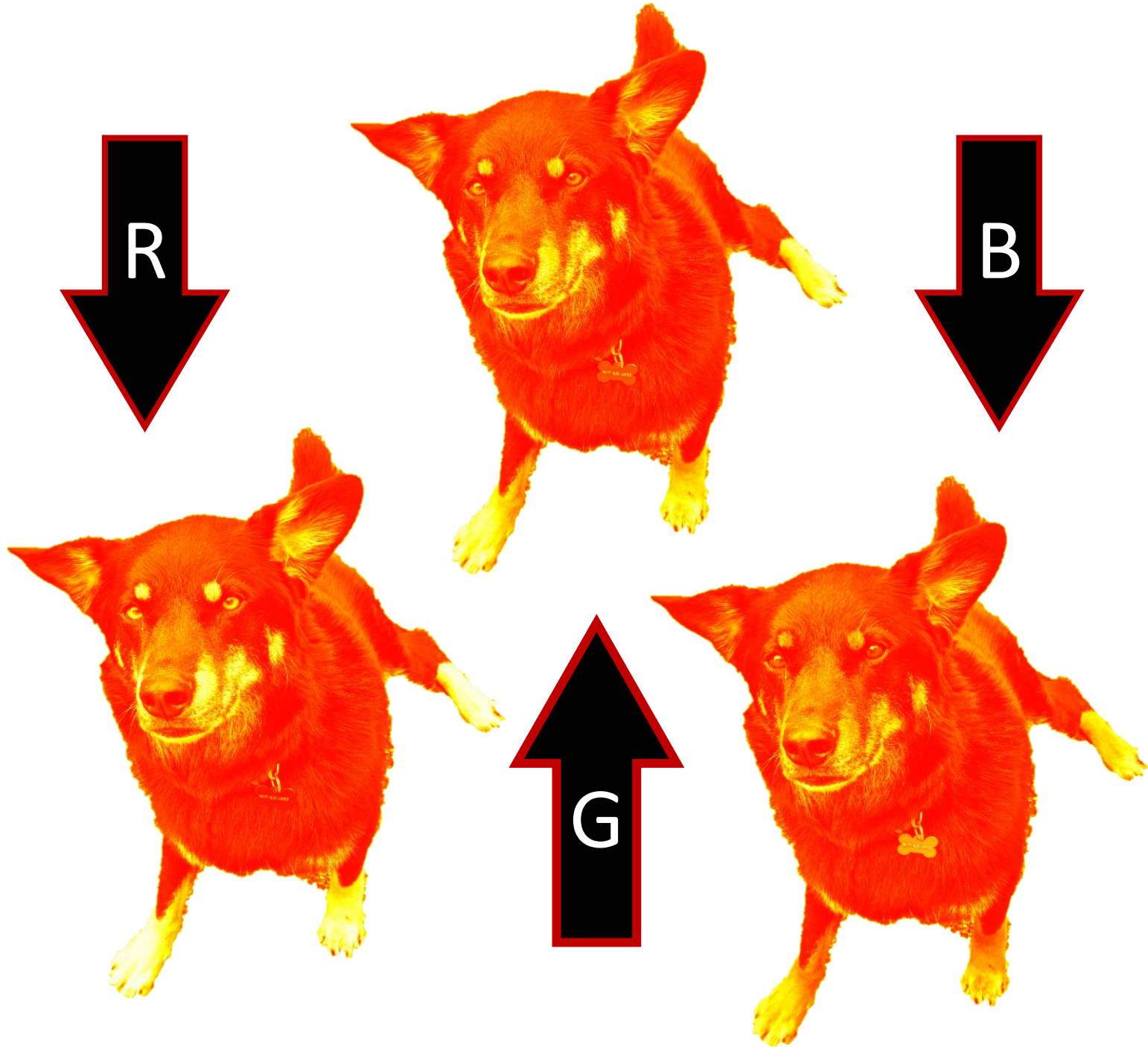
Copper is a good boy!

But how does he do with RGB?

Copper’s 3 color channels



Copper in 3 normalized gradients



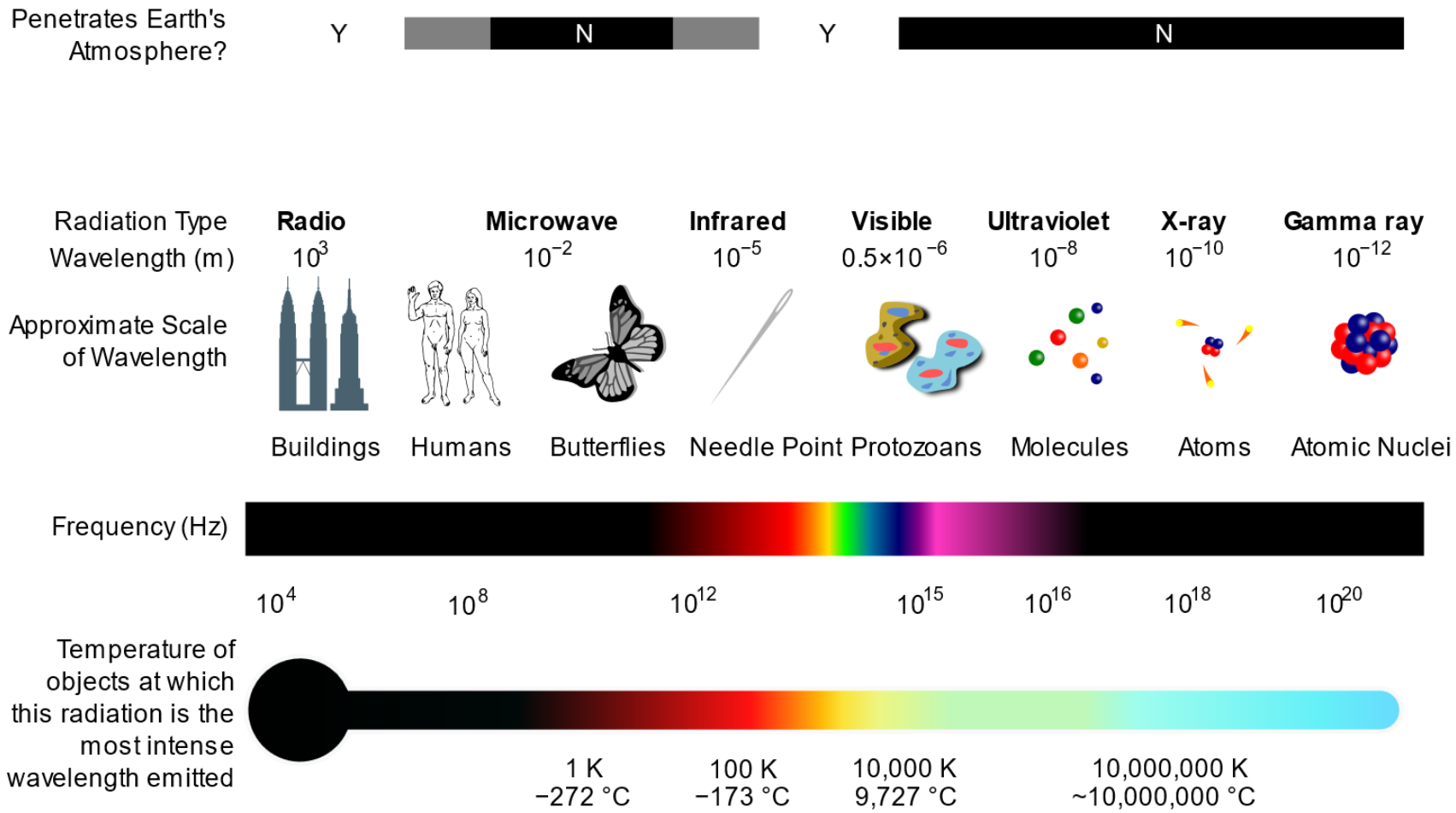
Choropleths for each color channel.

R

B

G

The Electromagnetic Spectrum: There's a lot going on that we can't see!



By Inductiveload, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2974242

Bees can see in UV

Bees use their UV vision to detect floral nectar guides, visible in the ultraviolet range.

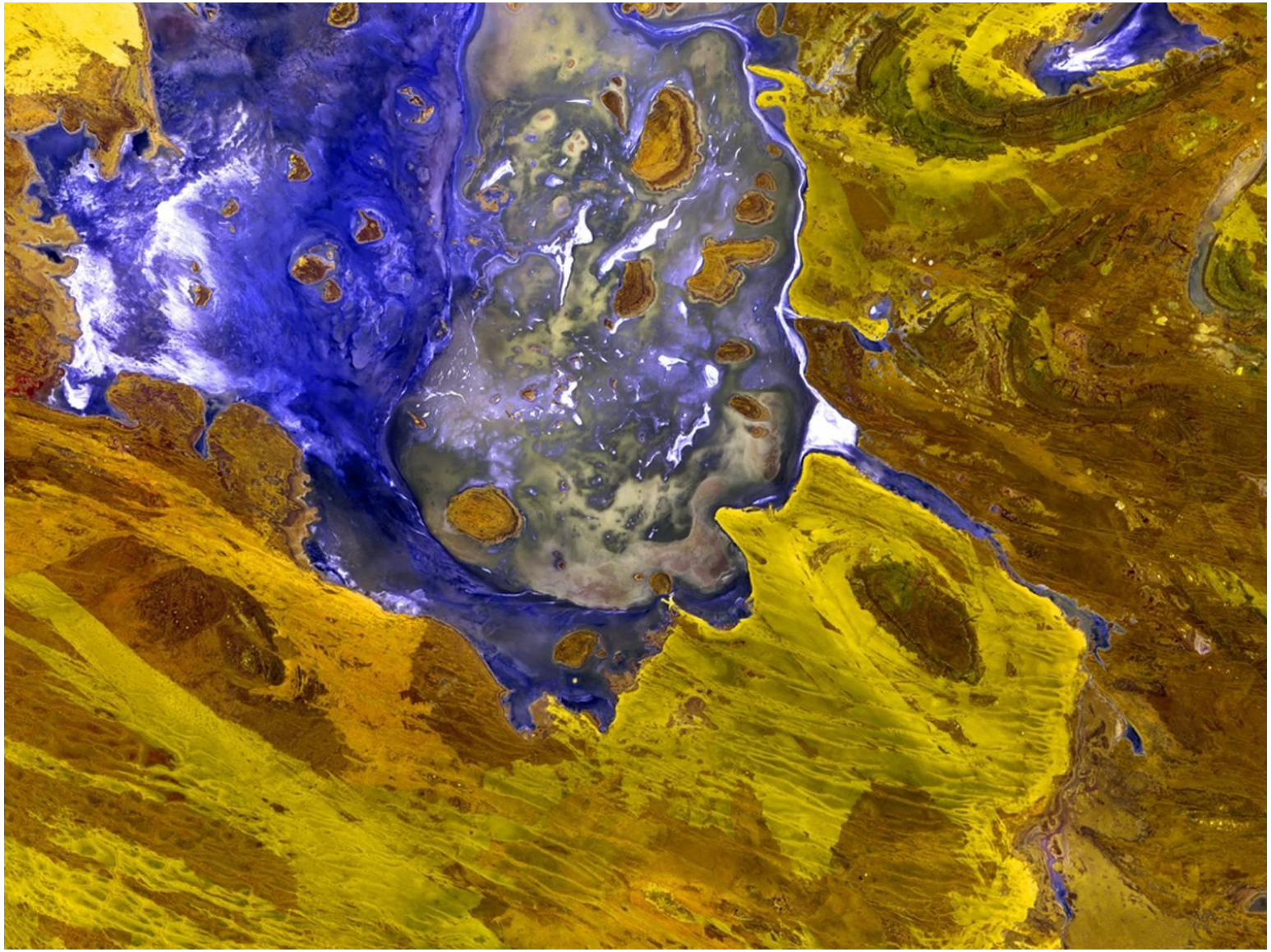
By Plantsurfer - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=3683900

Thermal Imaging

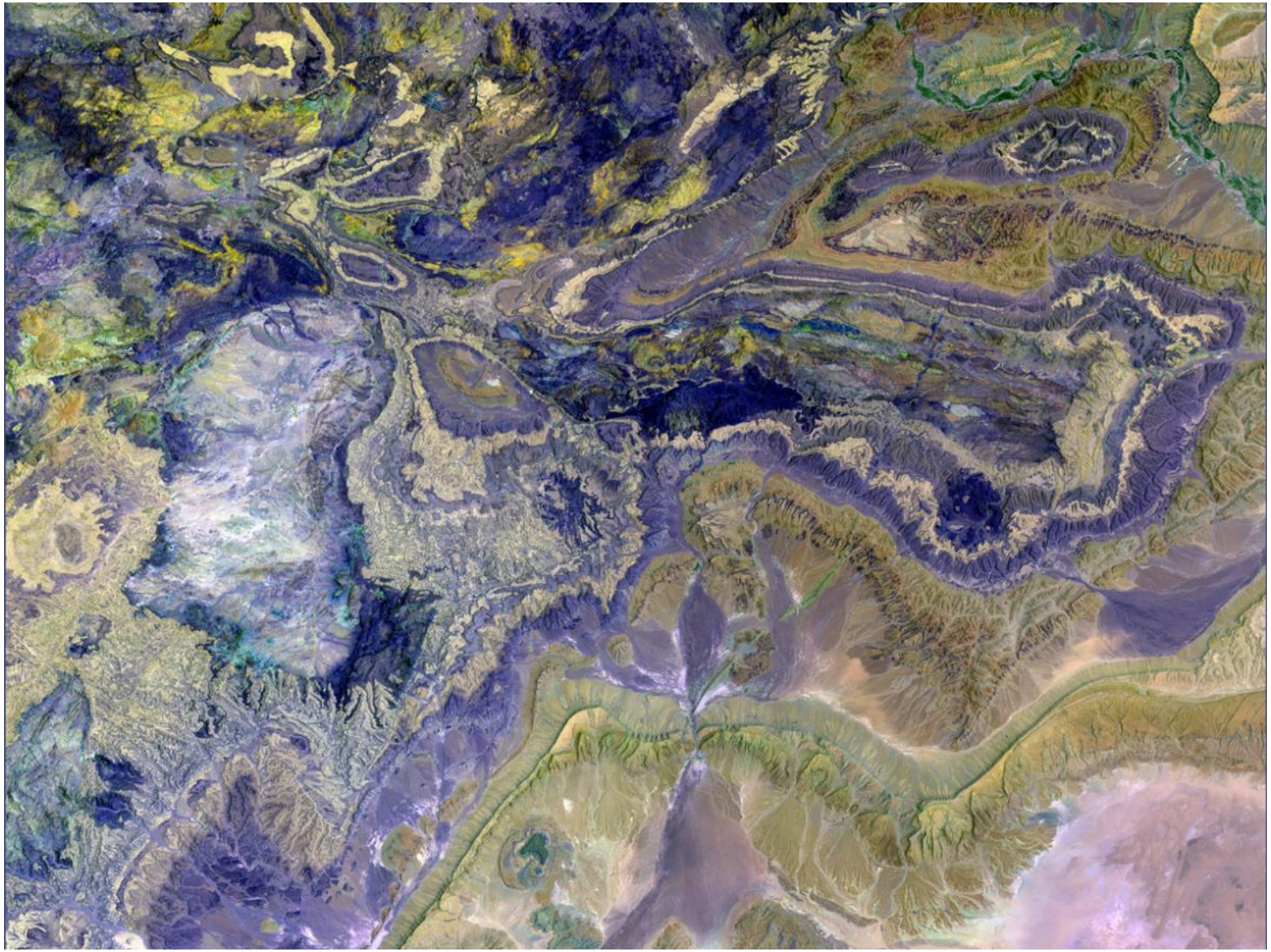
Thermal emissions at infrared wavelengths ~10,000 nm (10 µm)

https://www.best-quadcopter.com/news/2020/03/top-thermal-cameras-for-drones/

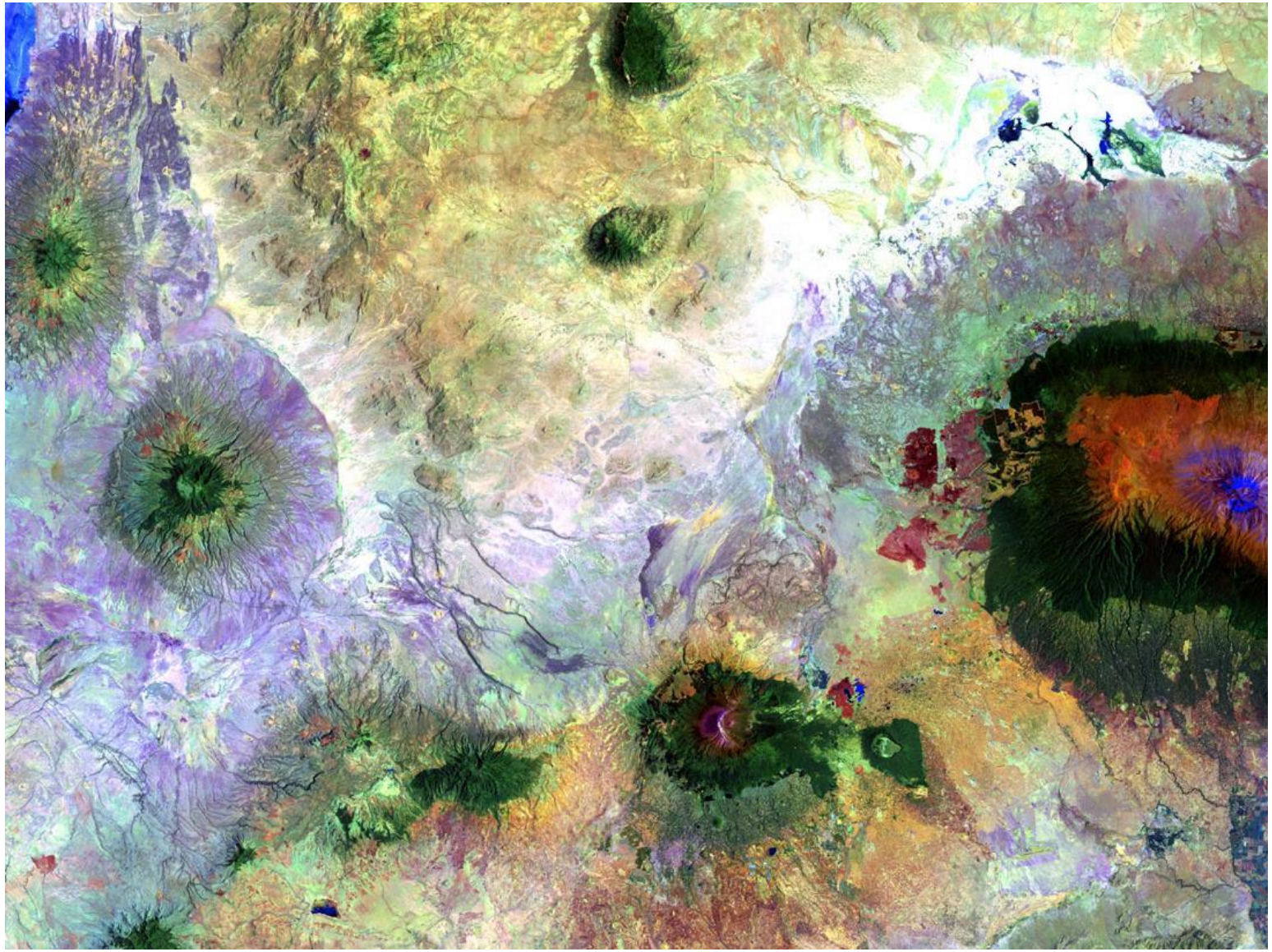
How can we use color to make a map?



Is this true (visible) color?

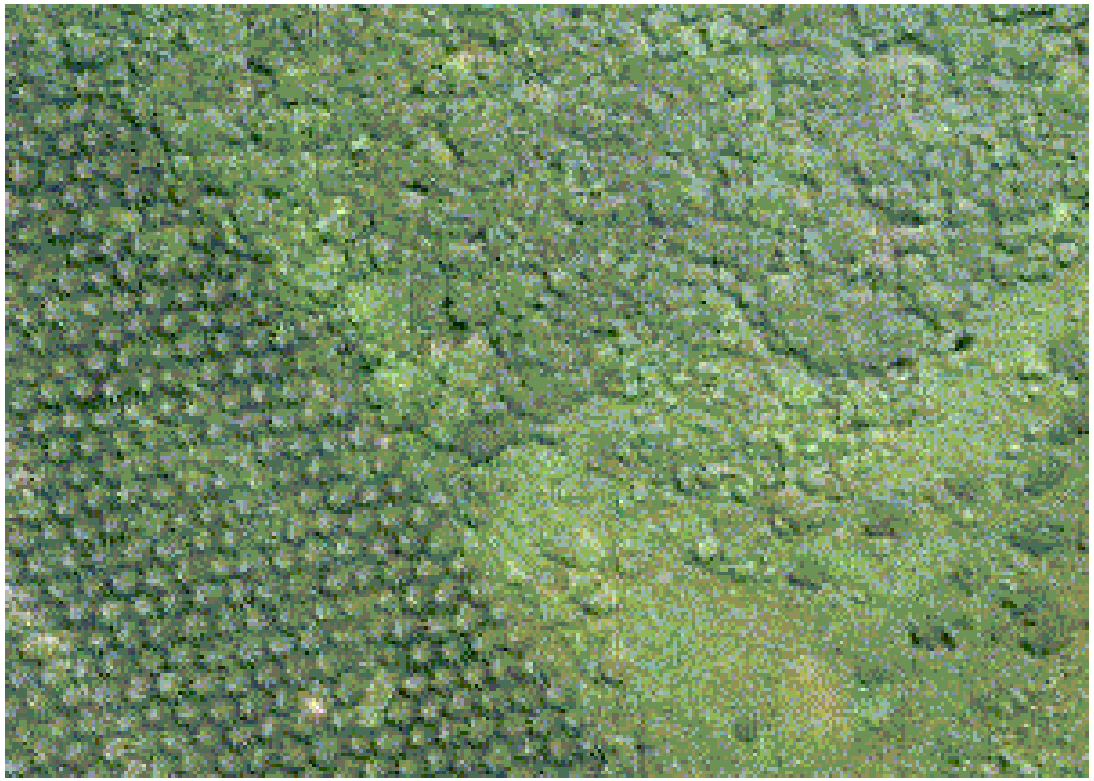


Is this true or false color?

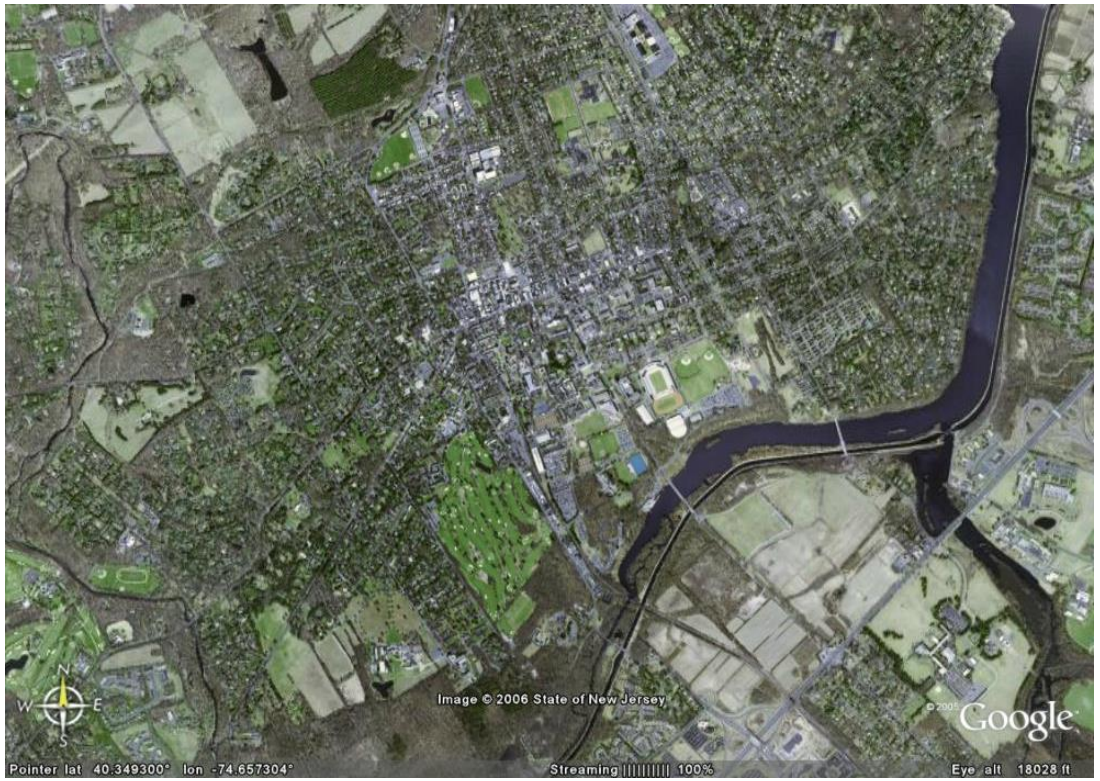


What else can we use to make a map? Texture

Oil palm plantation



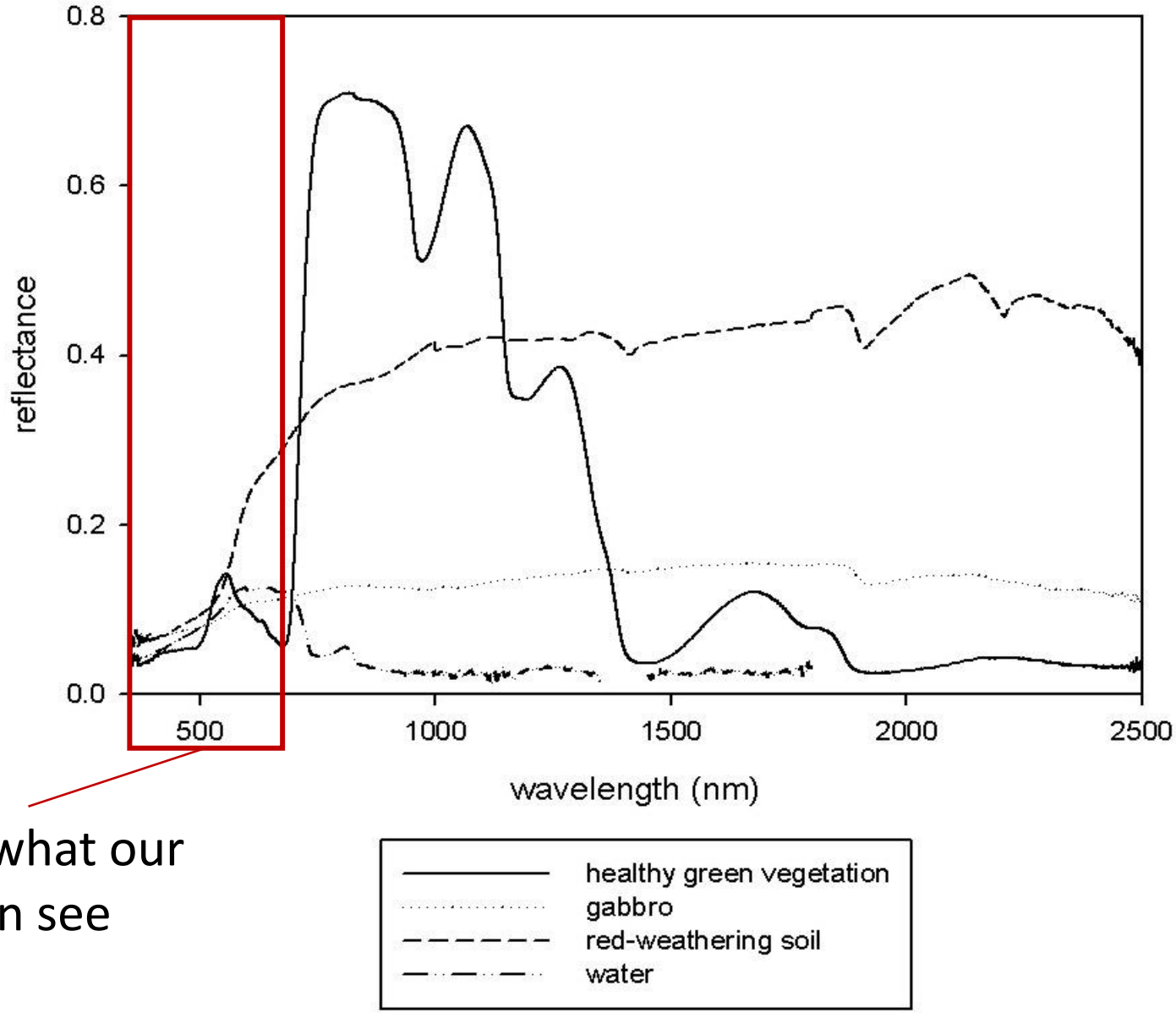
New Jersey suburbs



What patterns do you see?

What hypotheses could you test?

Why is false color visualization useful?



Here's what our eyes can see

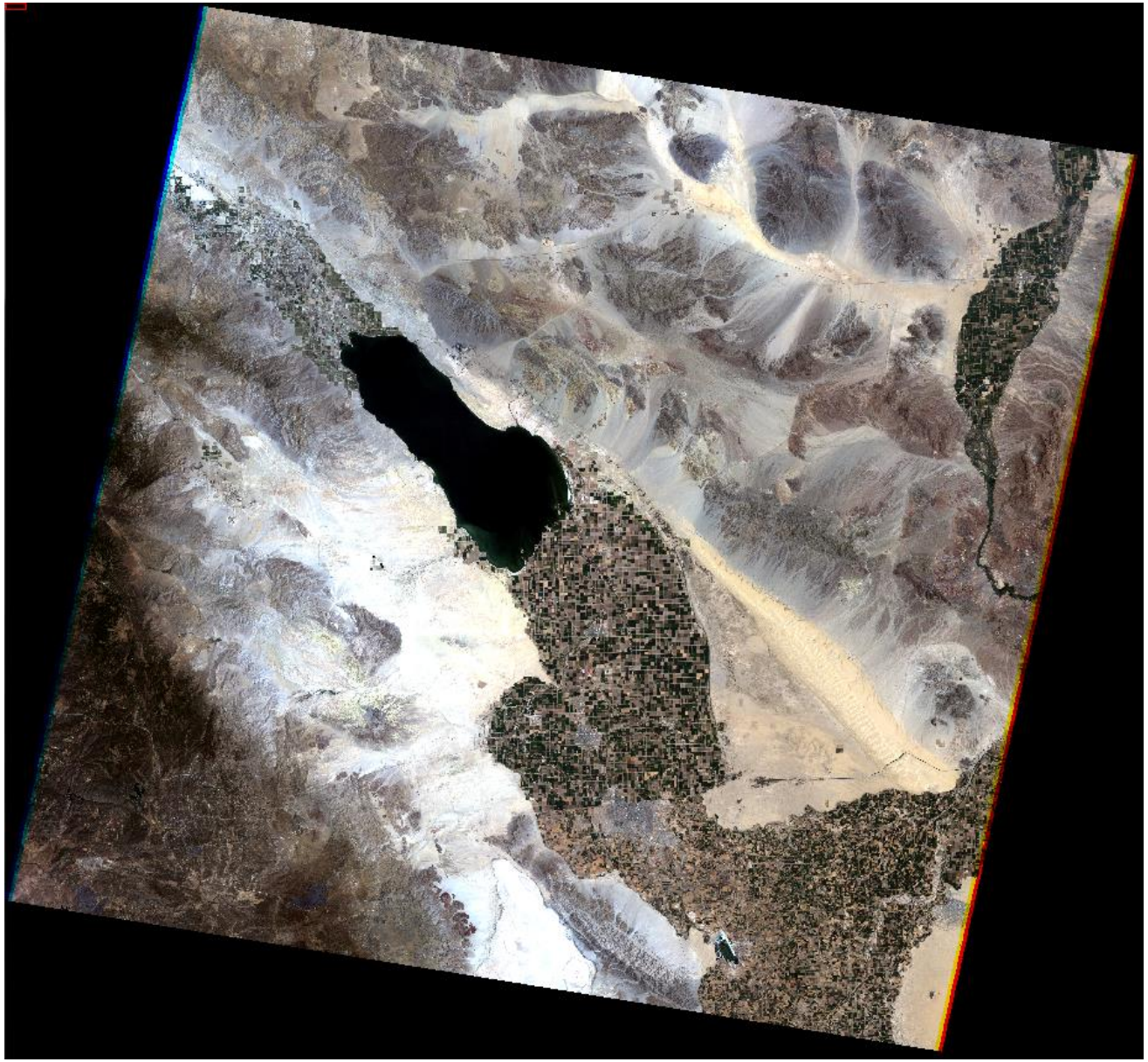
Salton Sea

321

(R) Red

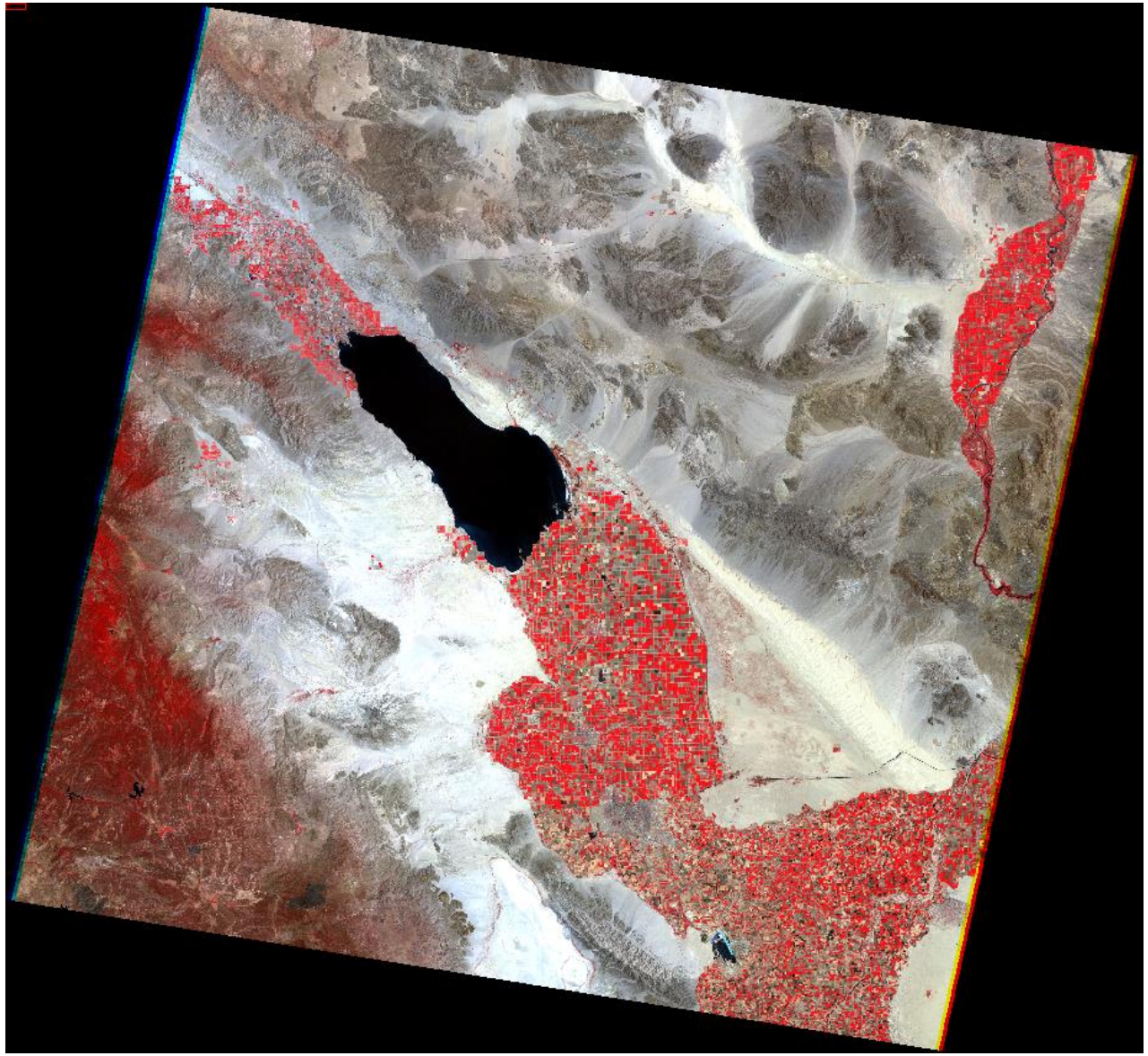
(G) Green

(B) Blue



Salton Sea
432

(R) NIR
(G) Red
(B) Green

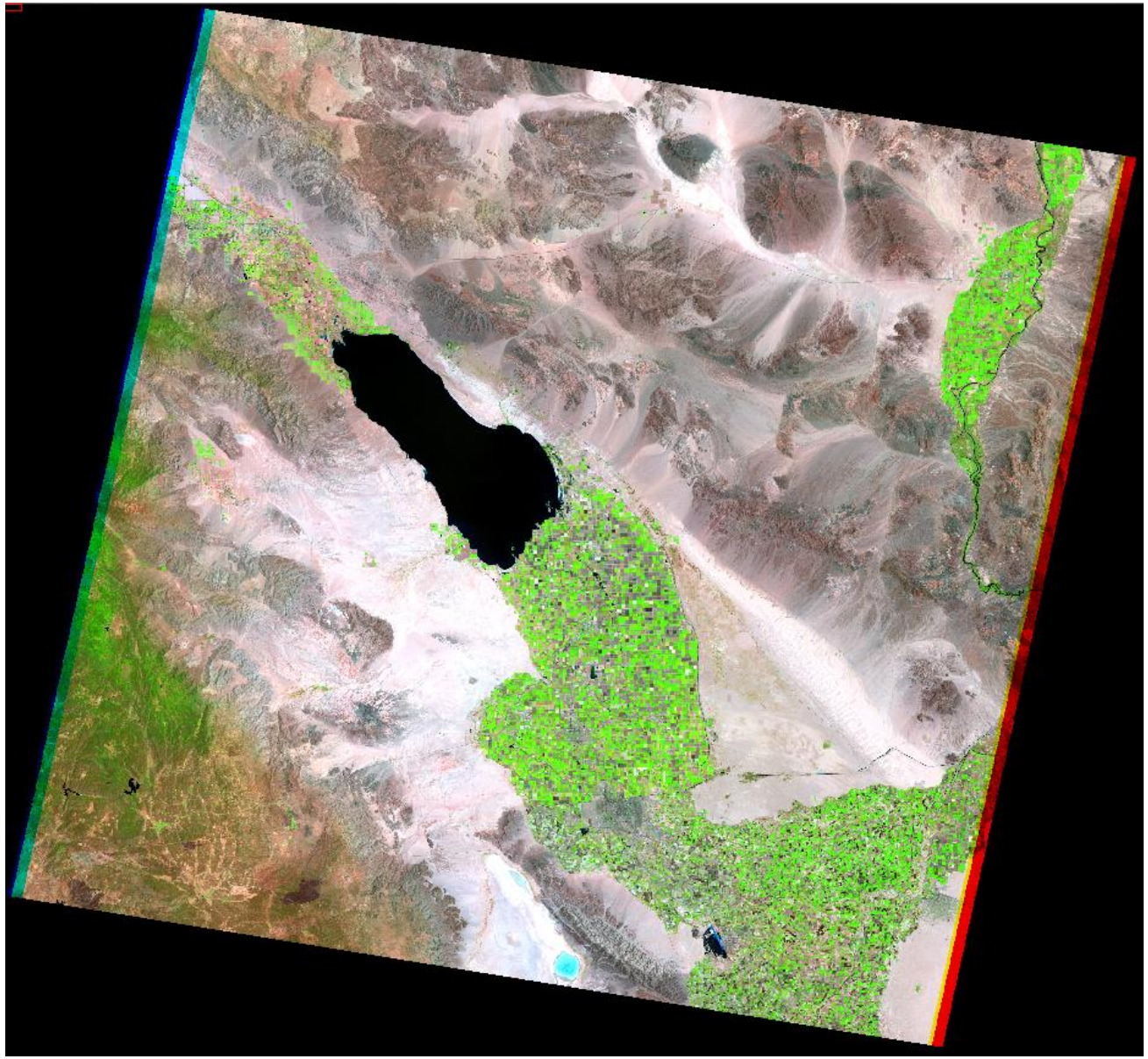


Salton Sea 543

R: Mid-IR

G: NIR

B: Red



NDVI

Normalized difference vegetation index

Plants Perceive Light Differently

Plants don’t use the entire visual spectrum for photosynthesis

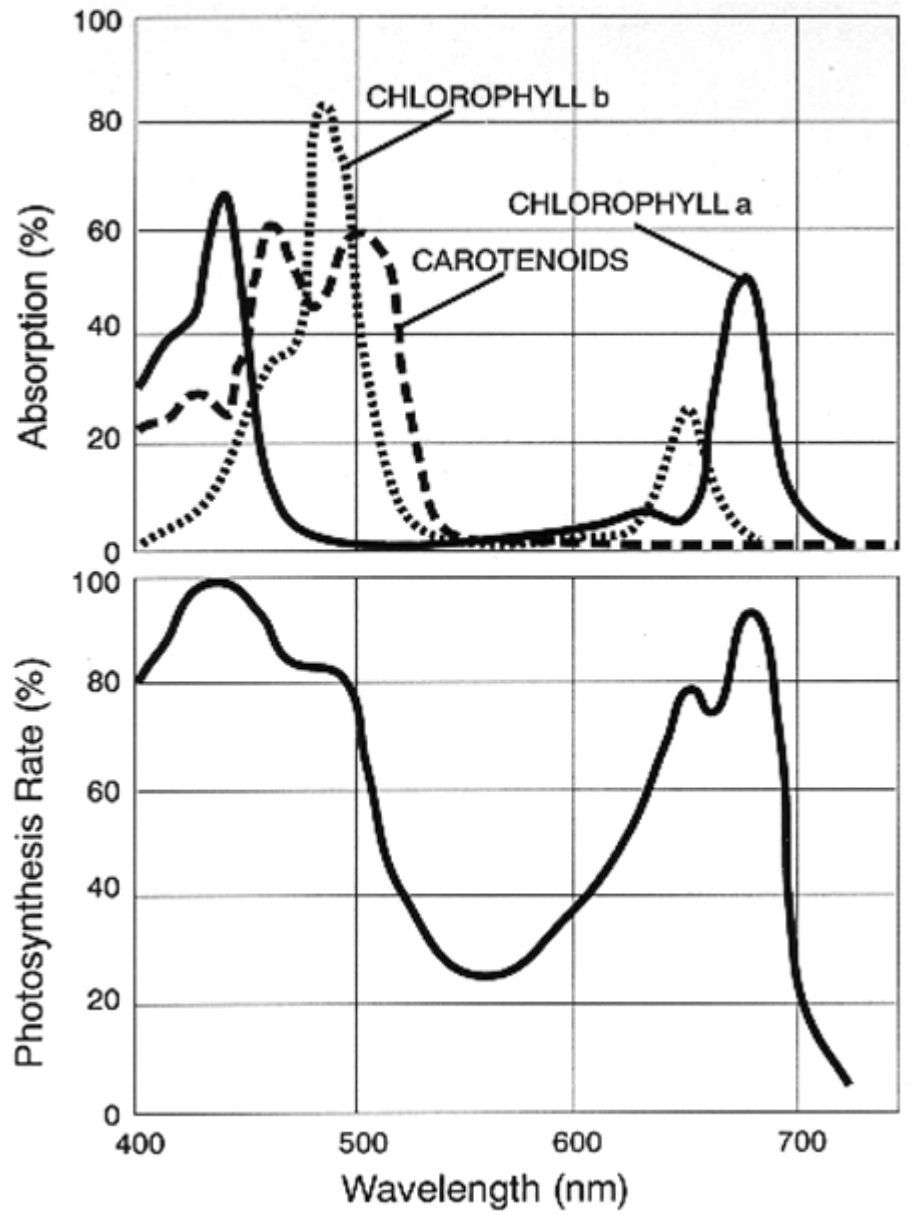
What color do leaves appear to us?

- Can this give us a clue about the wavelengths they use?
- Think bout absorbance and reflectance
- Infrared frequencies can nalso tell us important information about plant health

PAR

Photosynthetically Active Radiation…

It’s not just chlorophyll!



Absorbance of Red

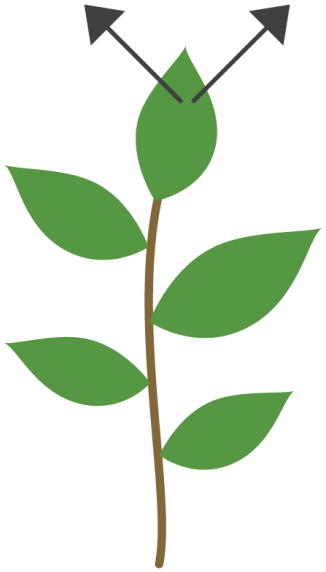
1. Useful for photosynthesis

Re-emission of NIR

- NIR causes overheating

HEALTHY
VEGETATION REFLECTANCE

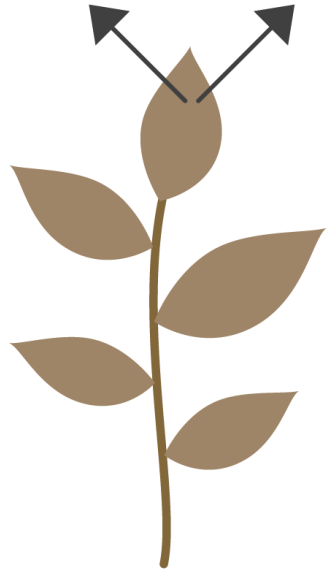
50% NIR 8% RED



NDVI = 0.72

STRESSED
VEGETATION REFLECTANCE

40% NIR 30% RED

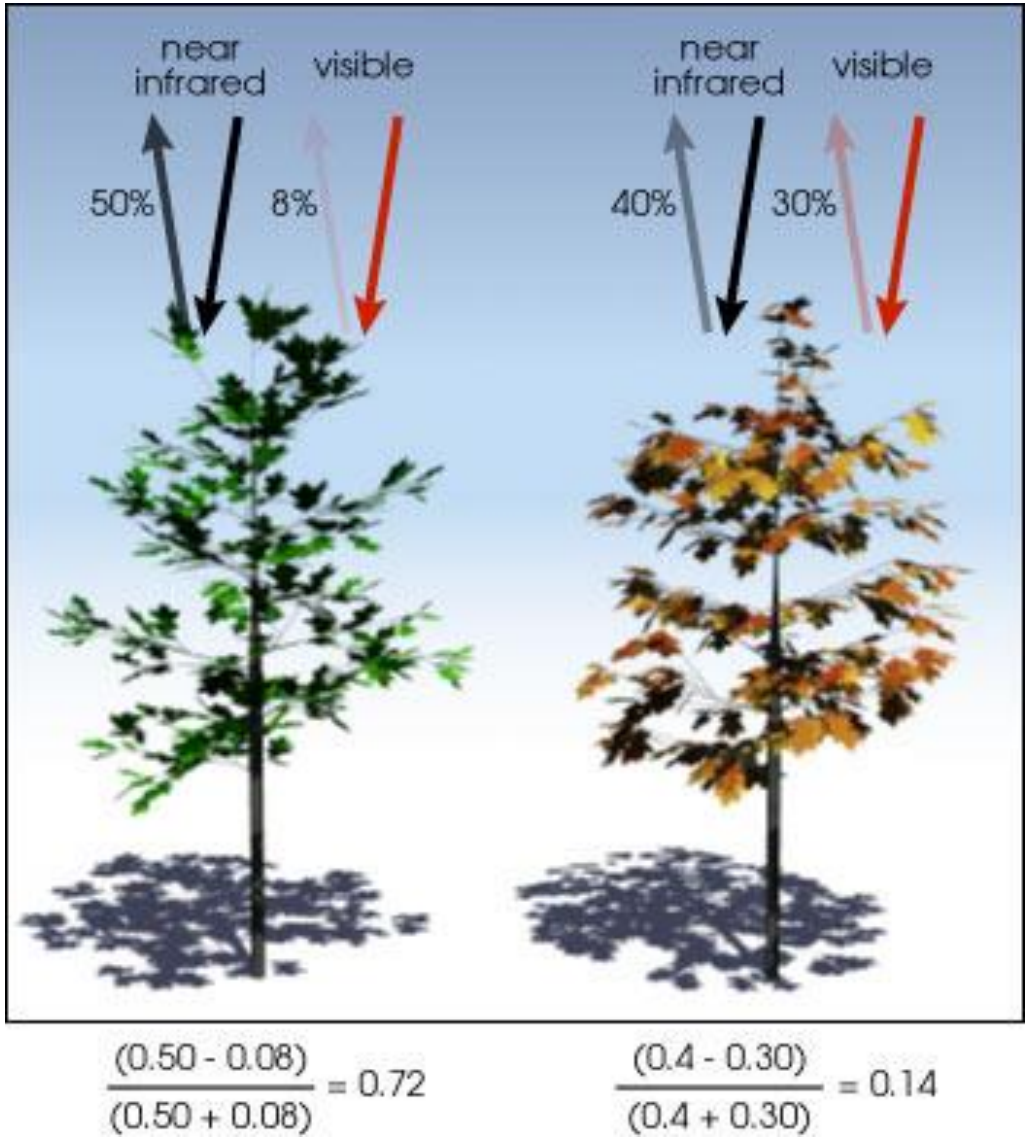


NDVI = 0.14

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

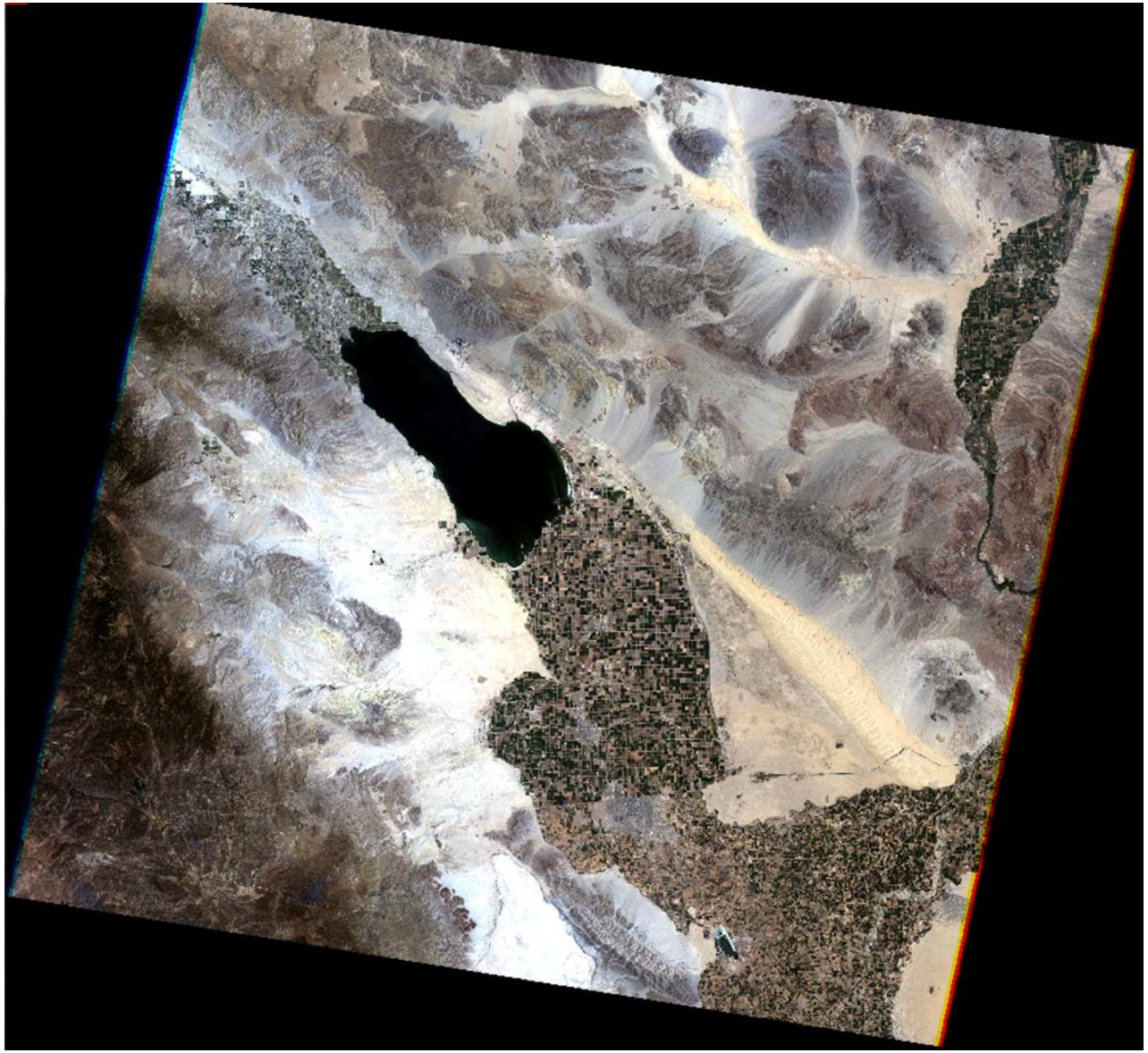
NDVI ranges from -1 to 1. That's why it's called *normalized*!

- -1 to 0: dead plants, or non-vegetation
- 0 – 1: live plants.
- Values near 1: healthy
- Values closer to 0: unhealthy



Salton Sea 321 (true color)

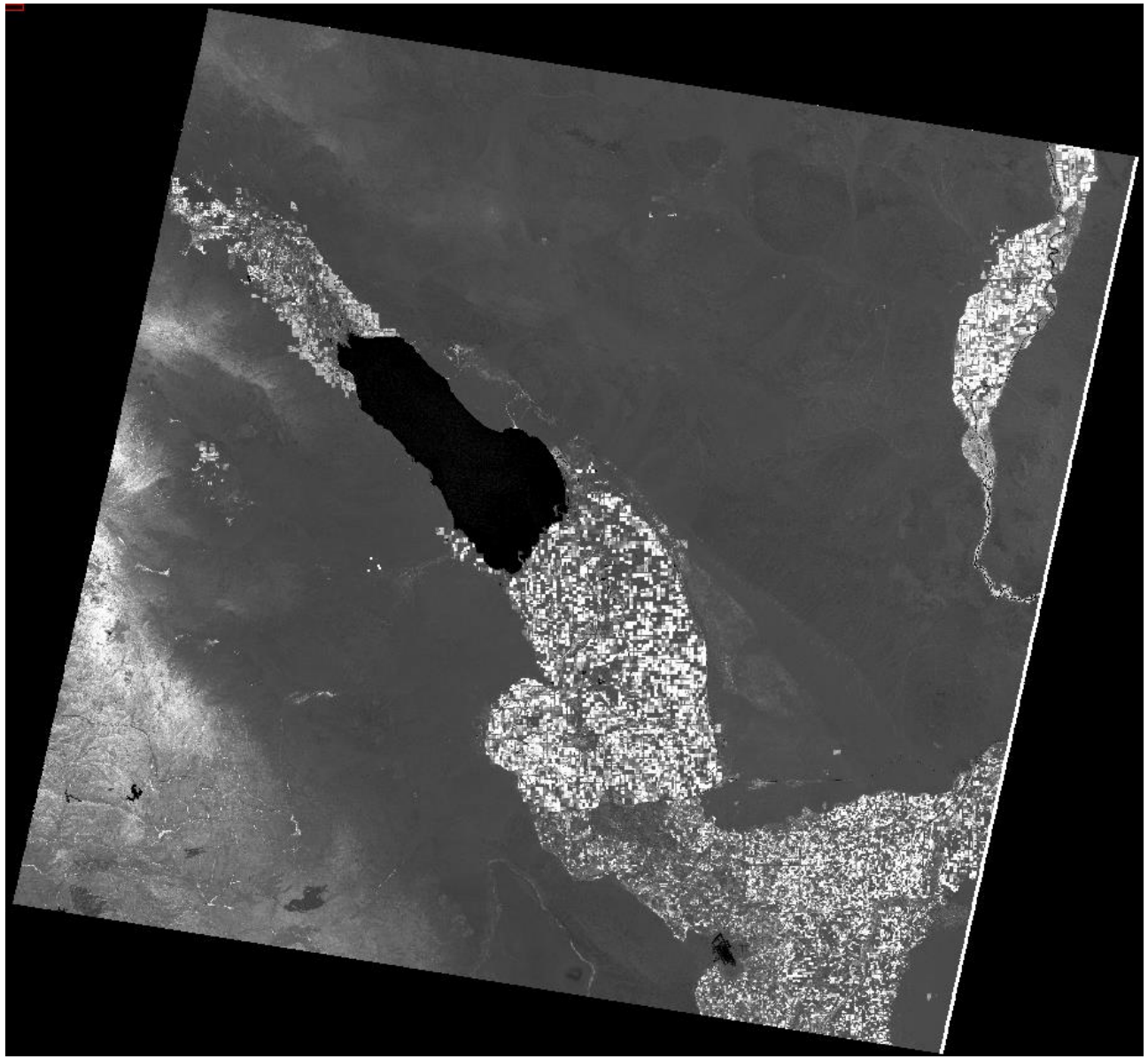
(R) Red
(G) Green
(B) Blue



Salton Sea NDVI

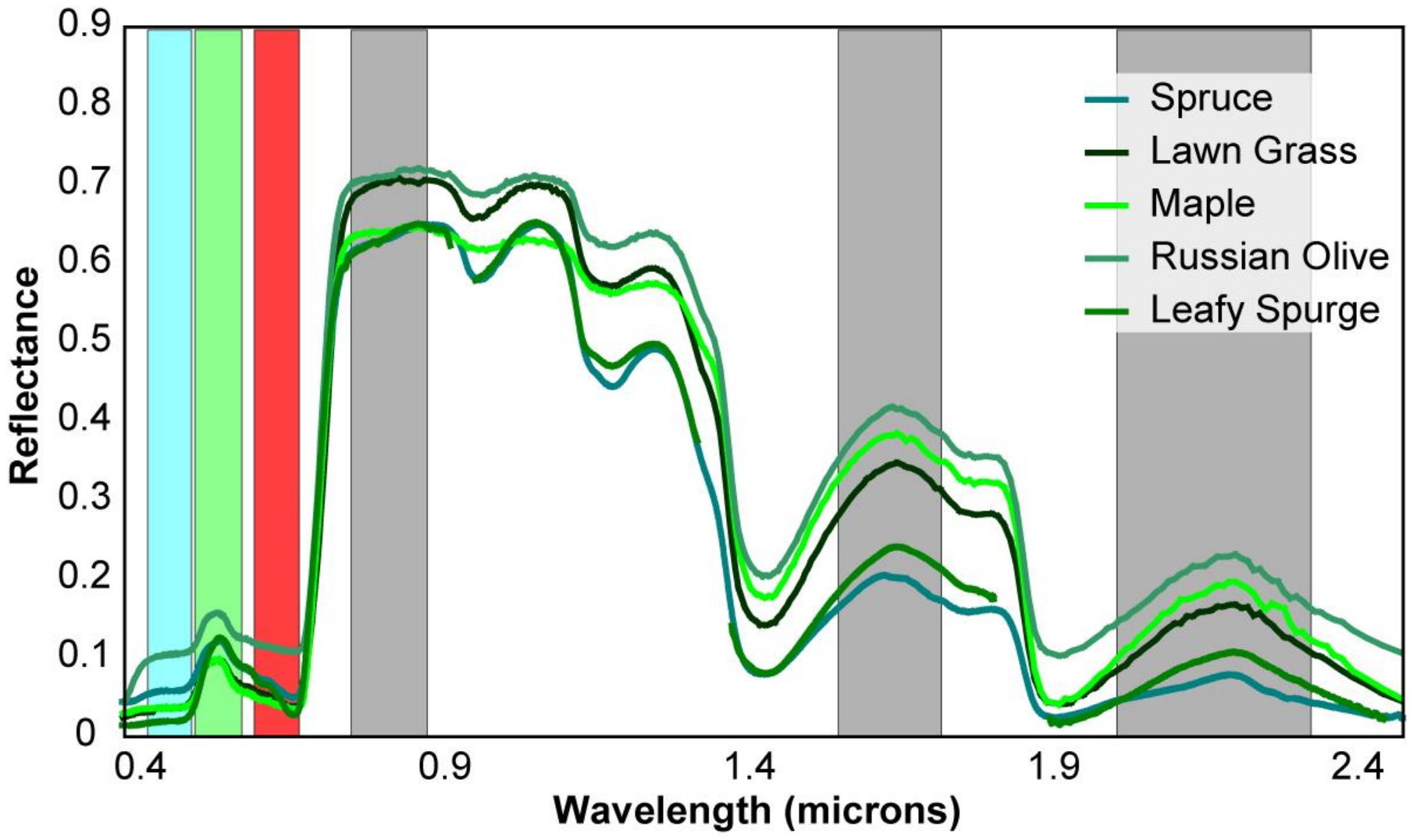
High values symbolized by light shade

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

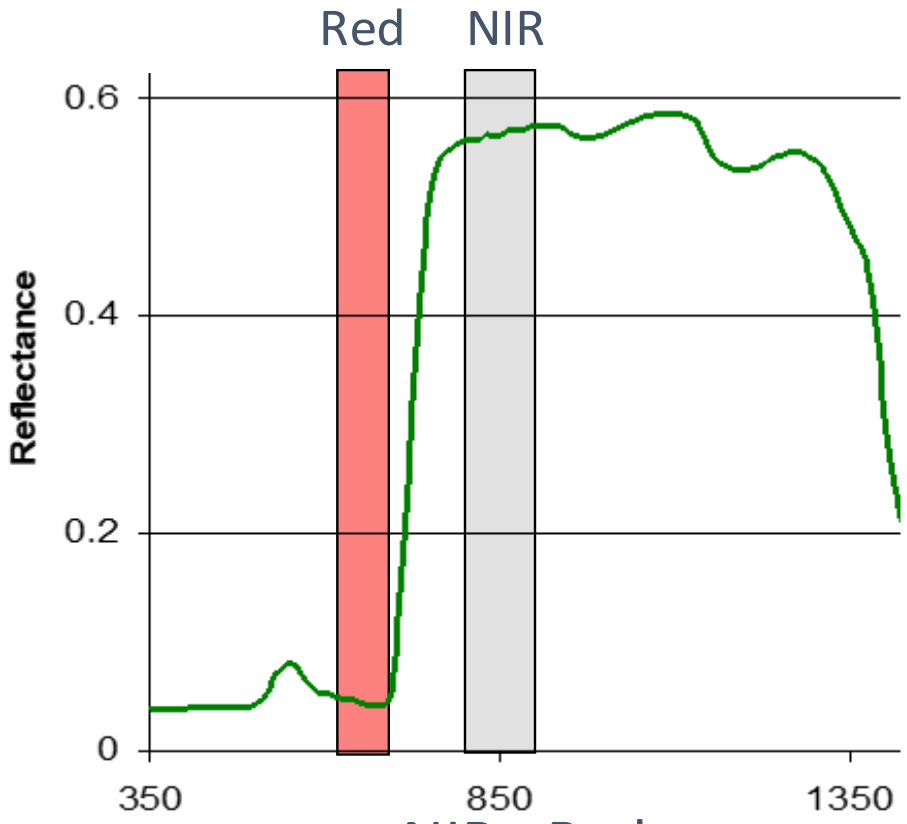


Green plants look similar, but not the same, to satellites…

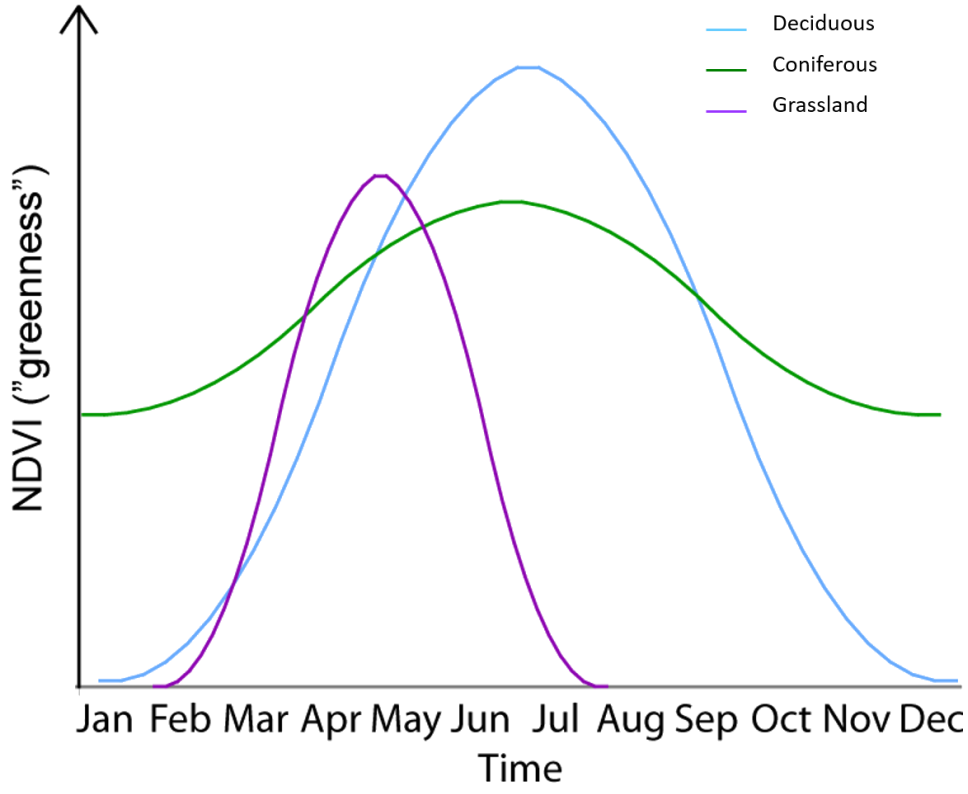
Spectral profiles can still be useful



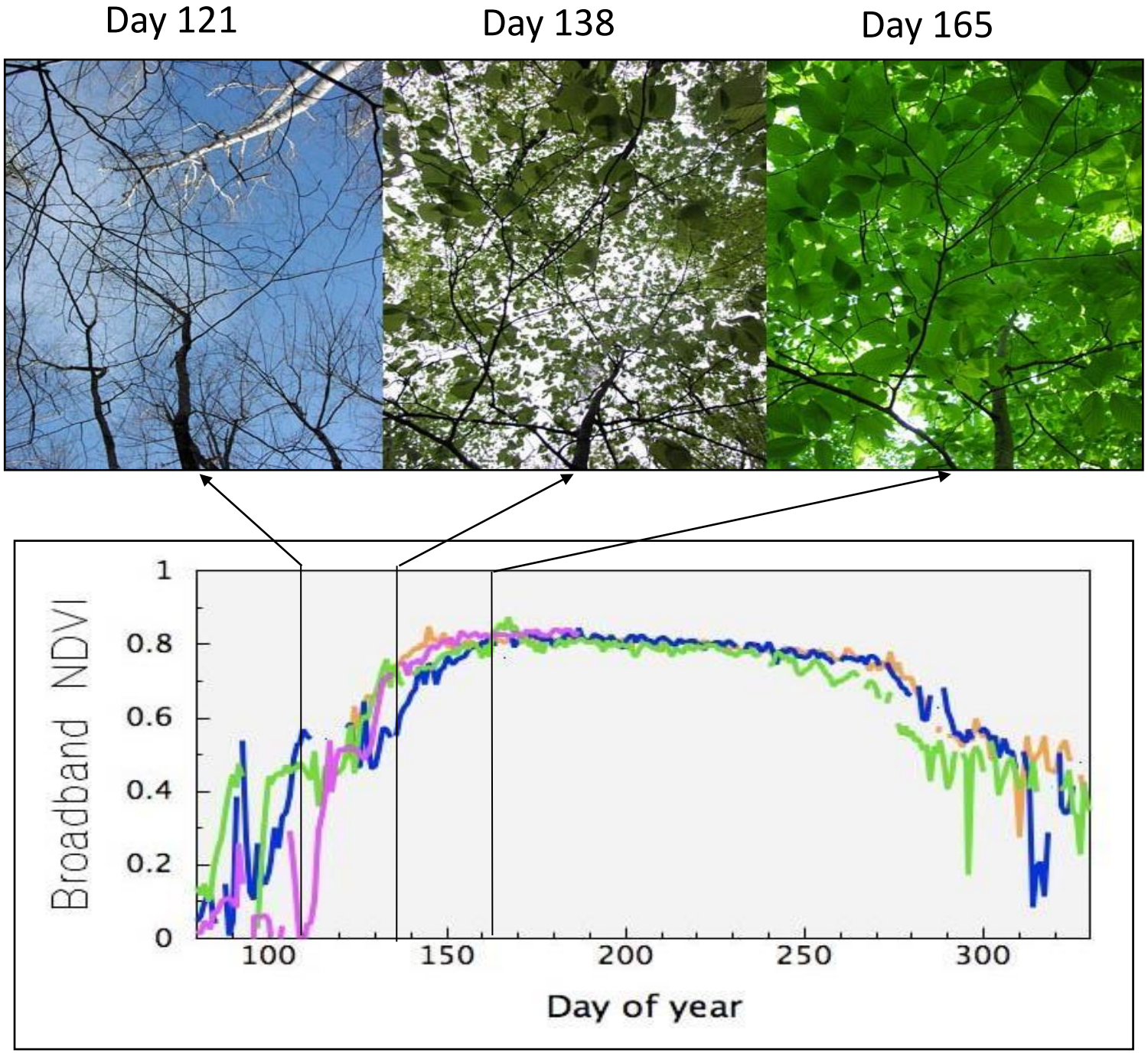
Identifying land cover based on phenology



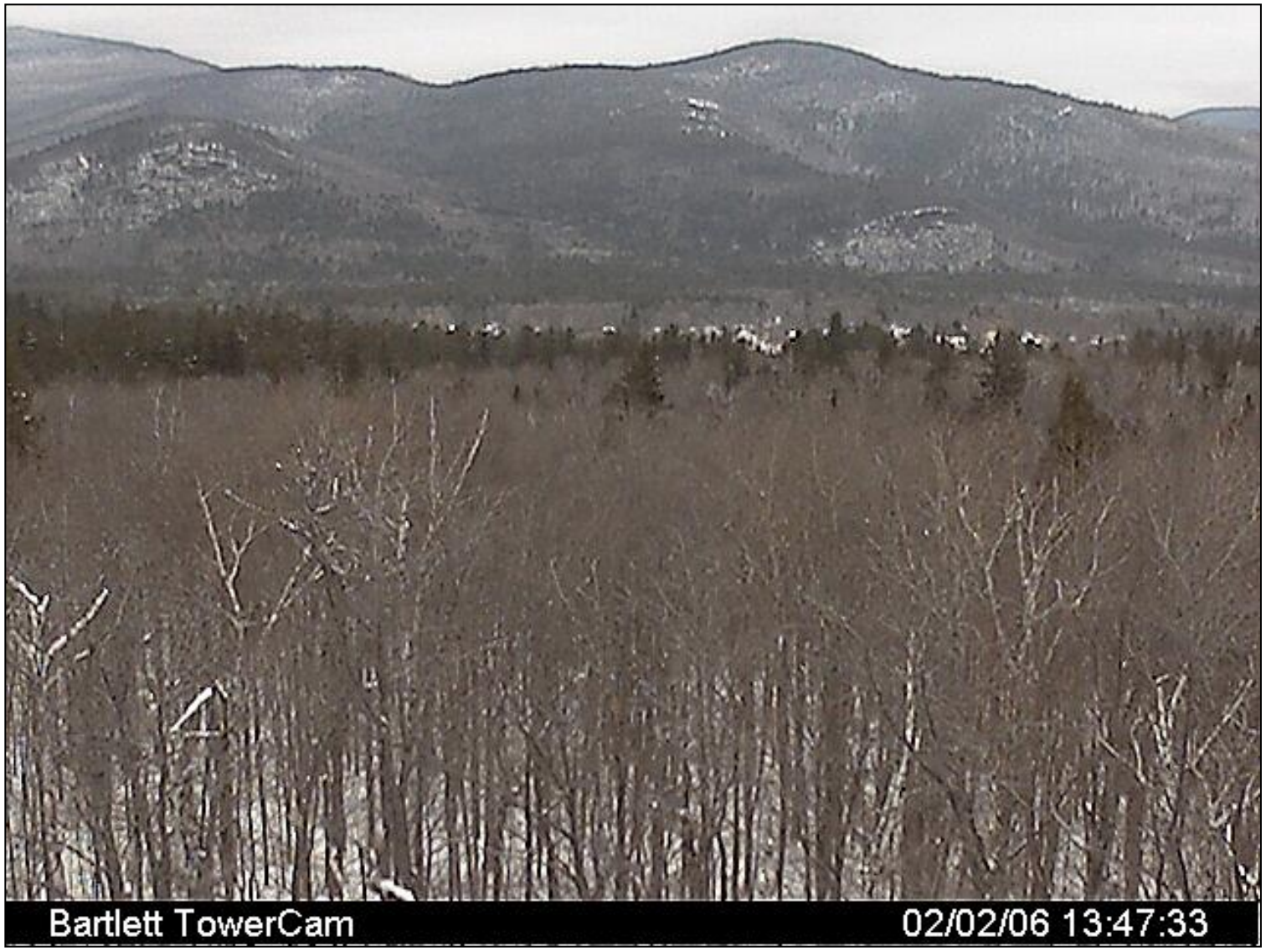
$$NDVI = \frac{NIR - Red}{NIR + Red}$$



2005 Spring green-up

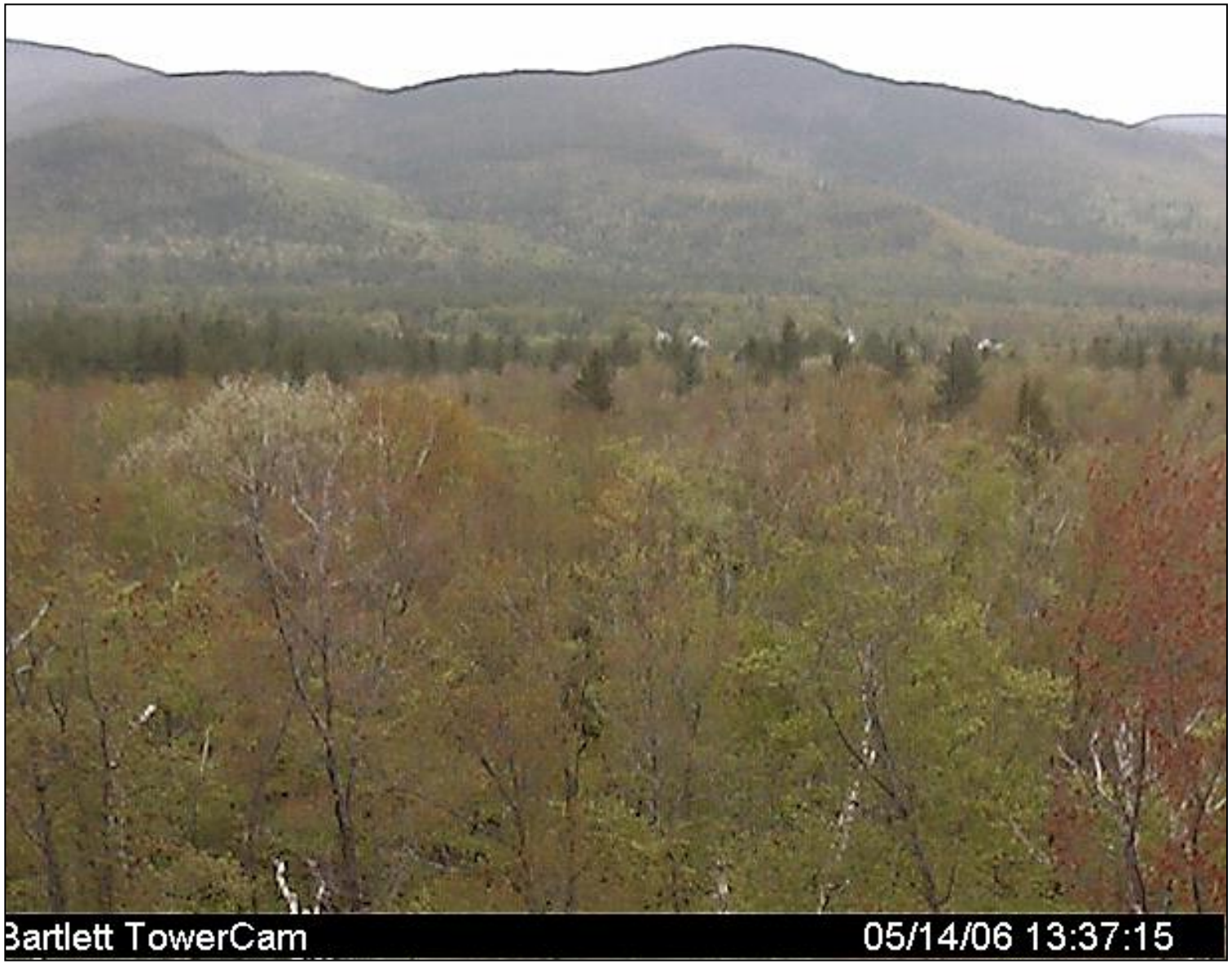


Seasonal Variations I: Feb 2006

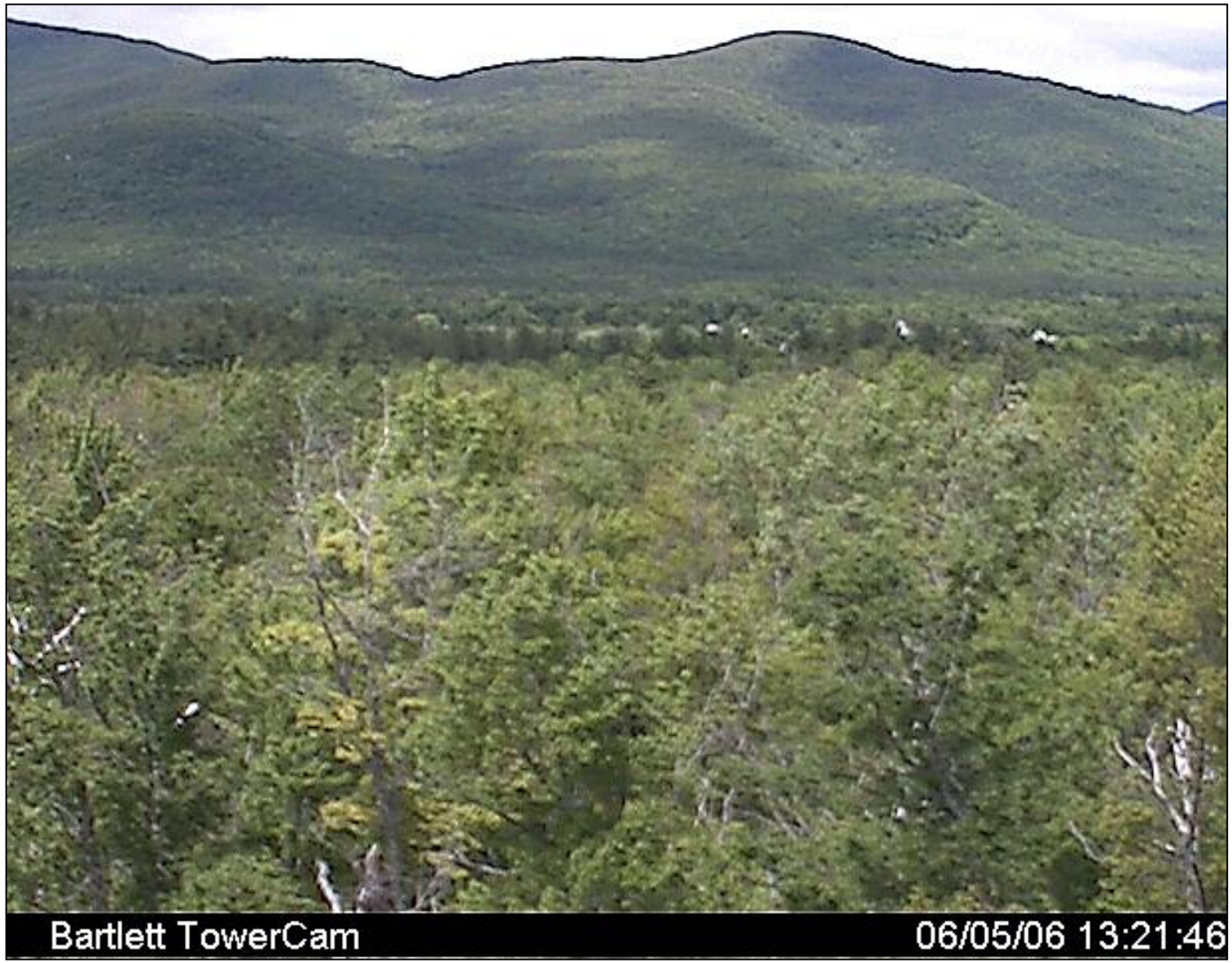


Seasonal Variations II: Apr 2006

Seasonal Variations III: May 2006



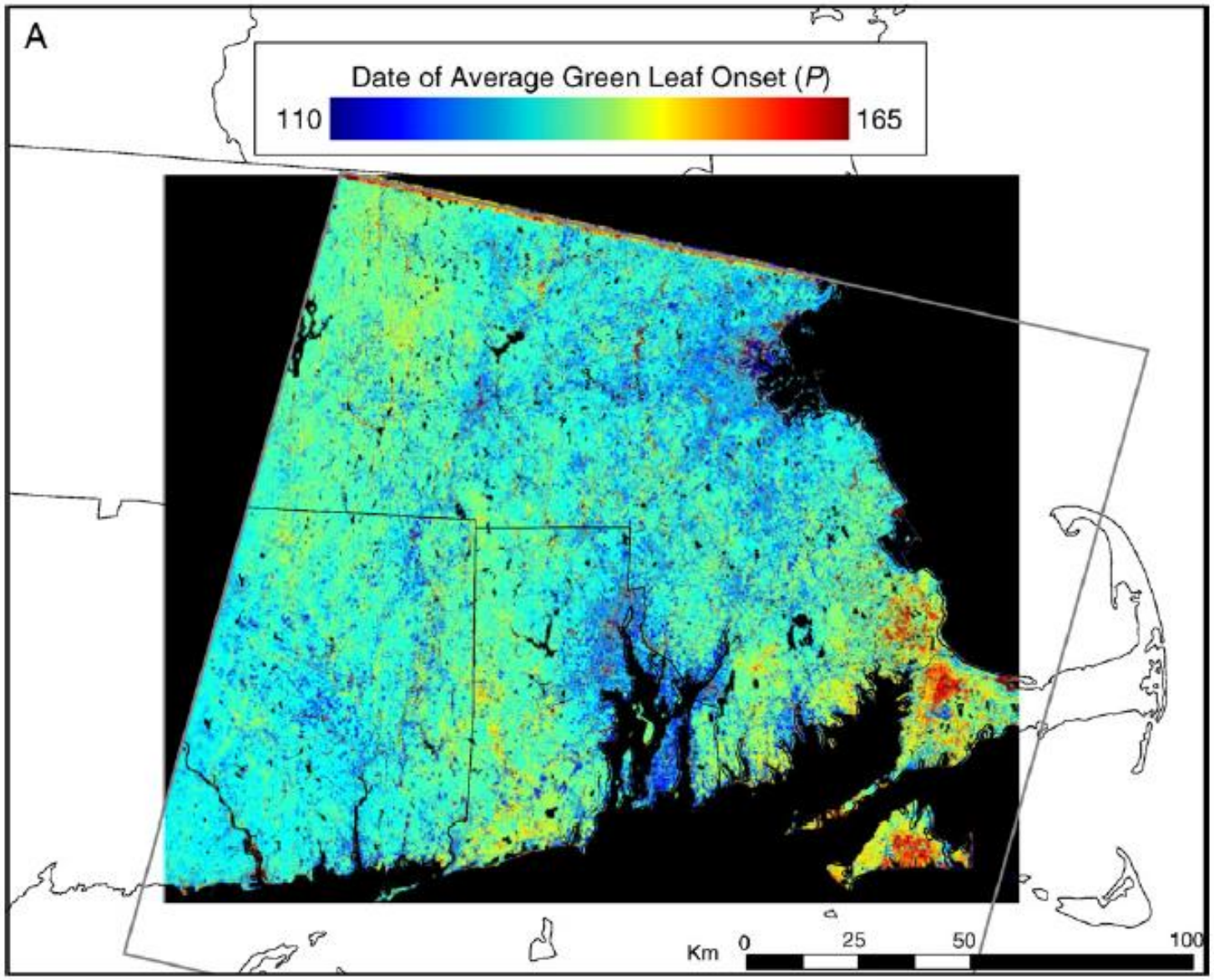
Seasonal Variations IV: June 2006



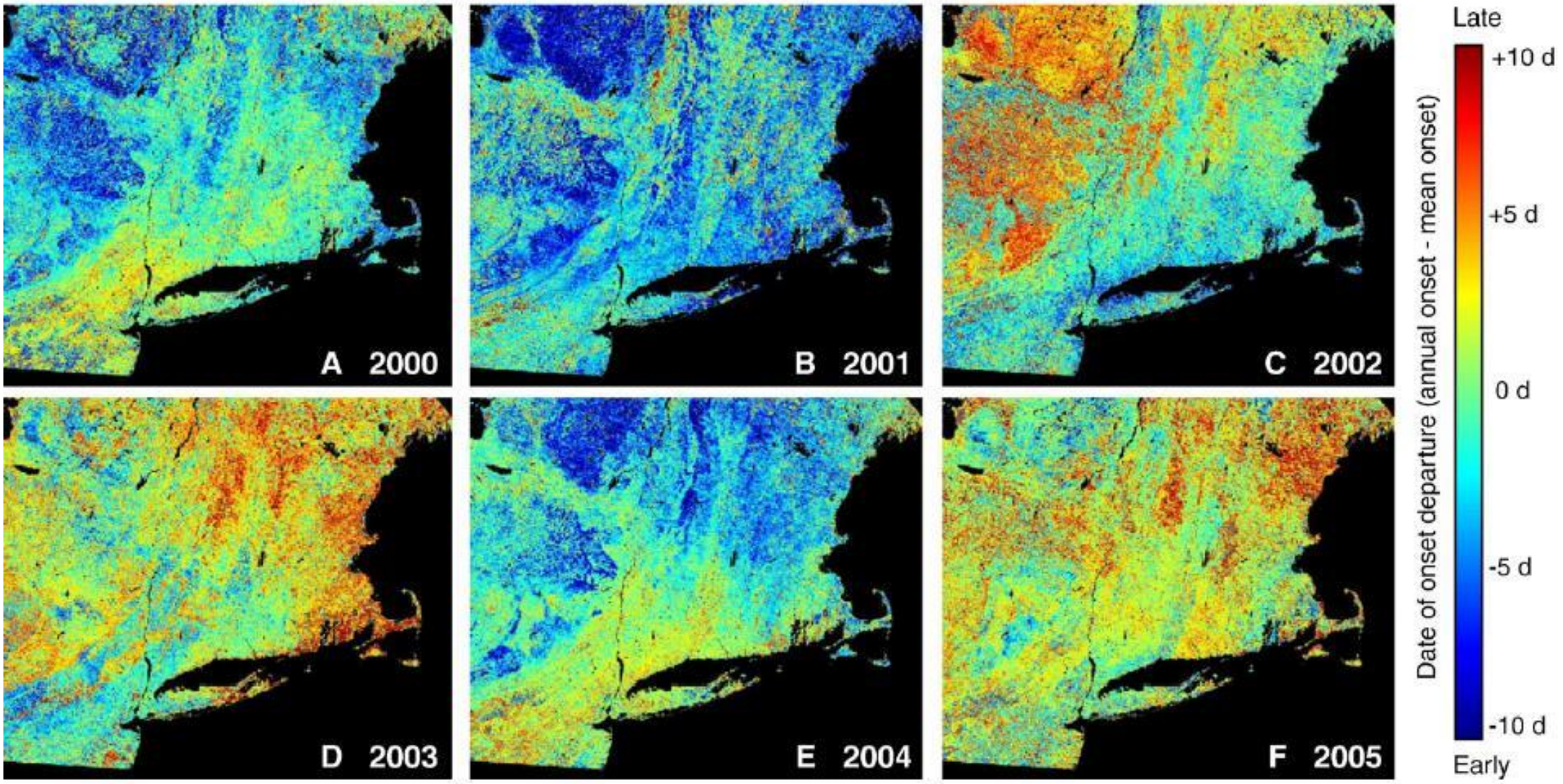
Seasonal Variations V: Oct 2006

April 2023

Timing of green-up in New England



Inter-annual variability of green-up

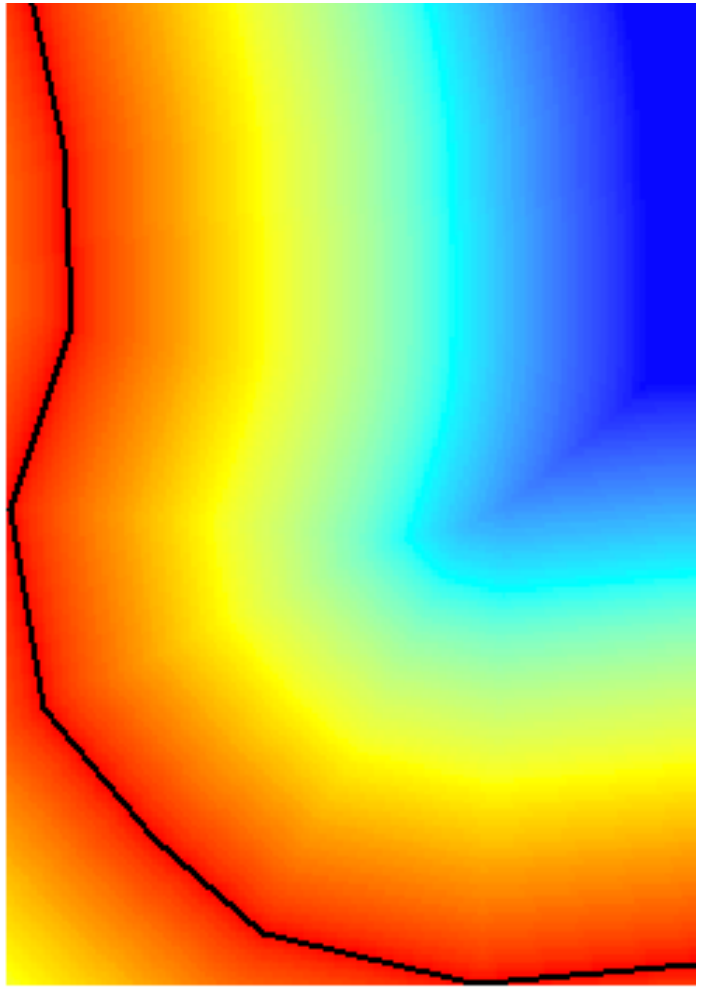


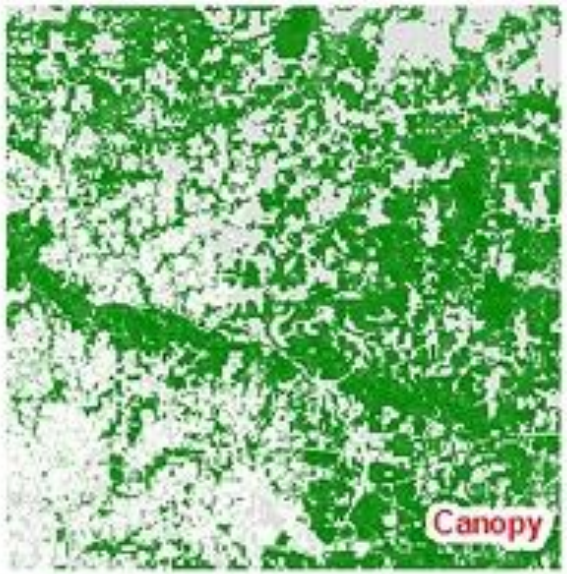
Did you notice anything about the format of all the remote sensed data?

Rasters Recap

Rasters are great for continuous coverage

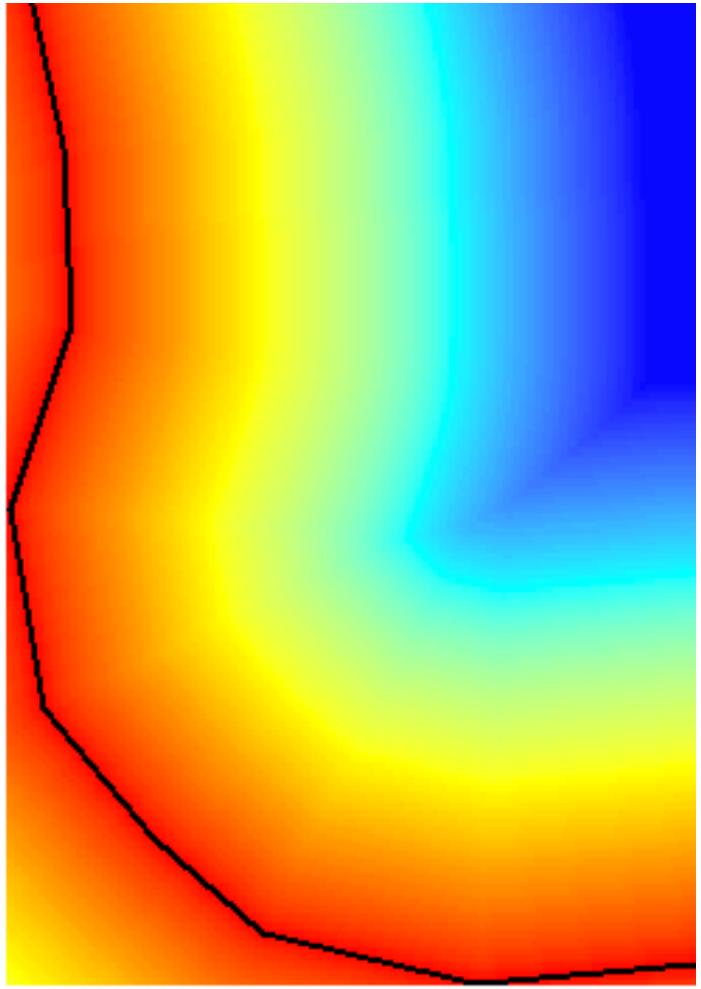
- Raster cells **tile** an entire area.
- Rasters allow us to record gradients or other quantities that vary continuously on the landscape.
- Rasters can show categories:
  - Landcover classes
  - Presence/absence





Rasters are great for continuous coverage

- Rasters are essential for geostatistics.
- Raster data is a fundamentally different data model paradigm than vector data.
  - It may seem like I'm overly focused on this, but it's important, and something that students, and even some GIS professionals don't adequately grasp!

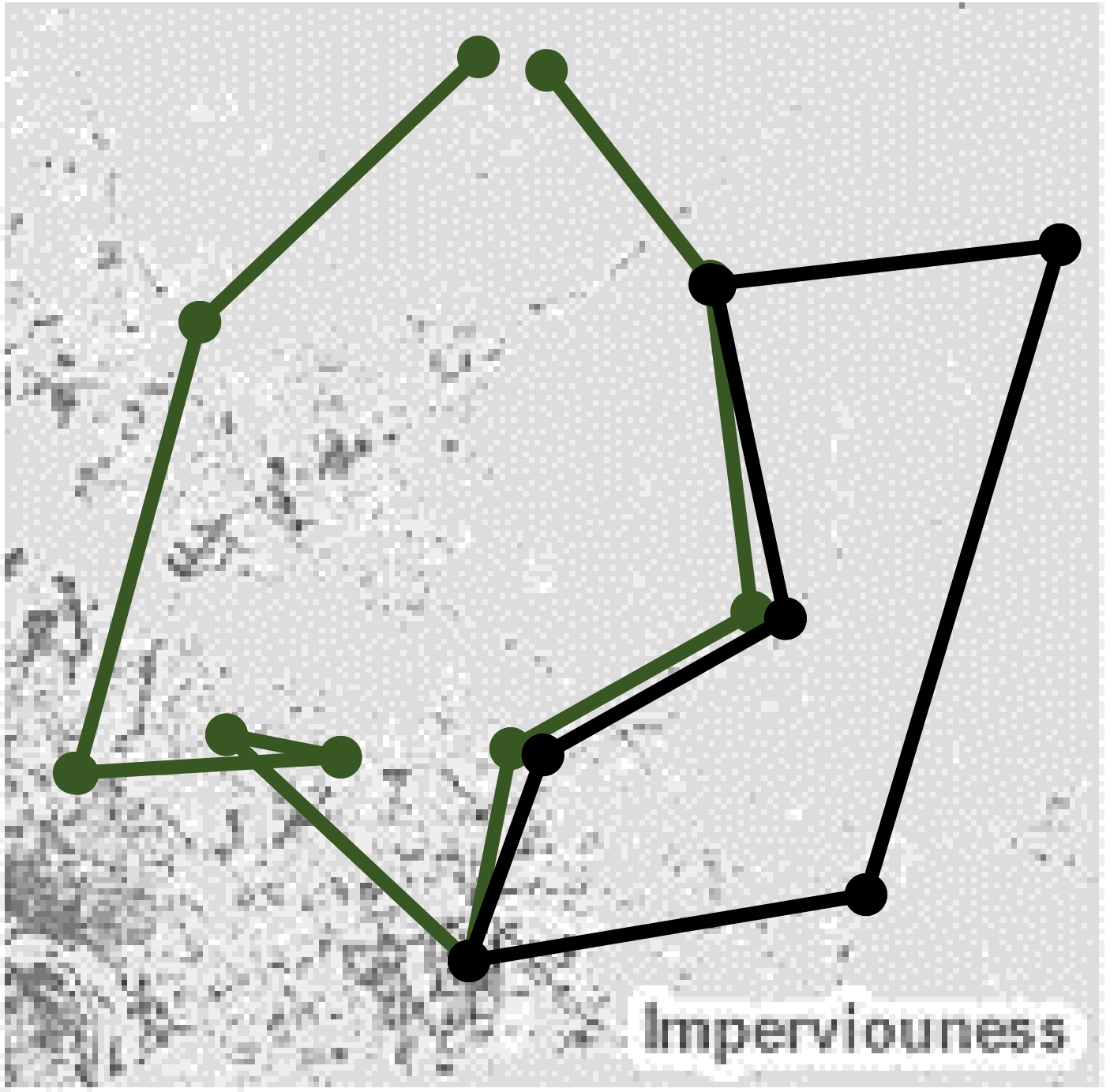


Raster data is a fundamentally different data paradigm than vector data.

- Why do I keep emphasizing this point?
- Rasters are essential for geostatistics.
- Continuous vs. patchy coverage.

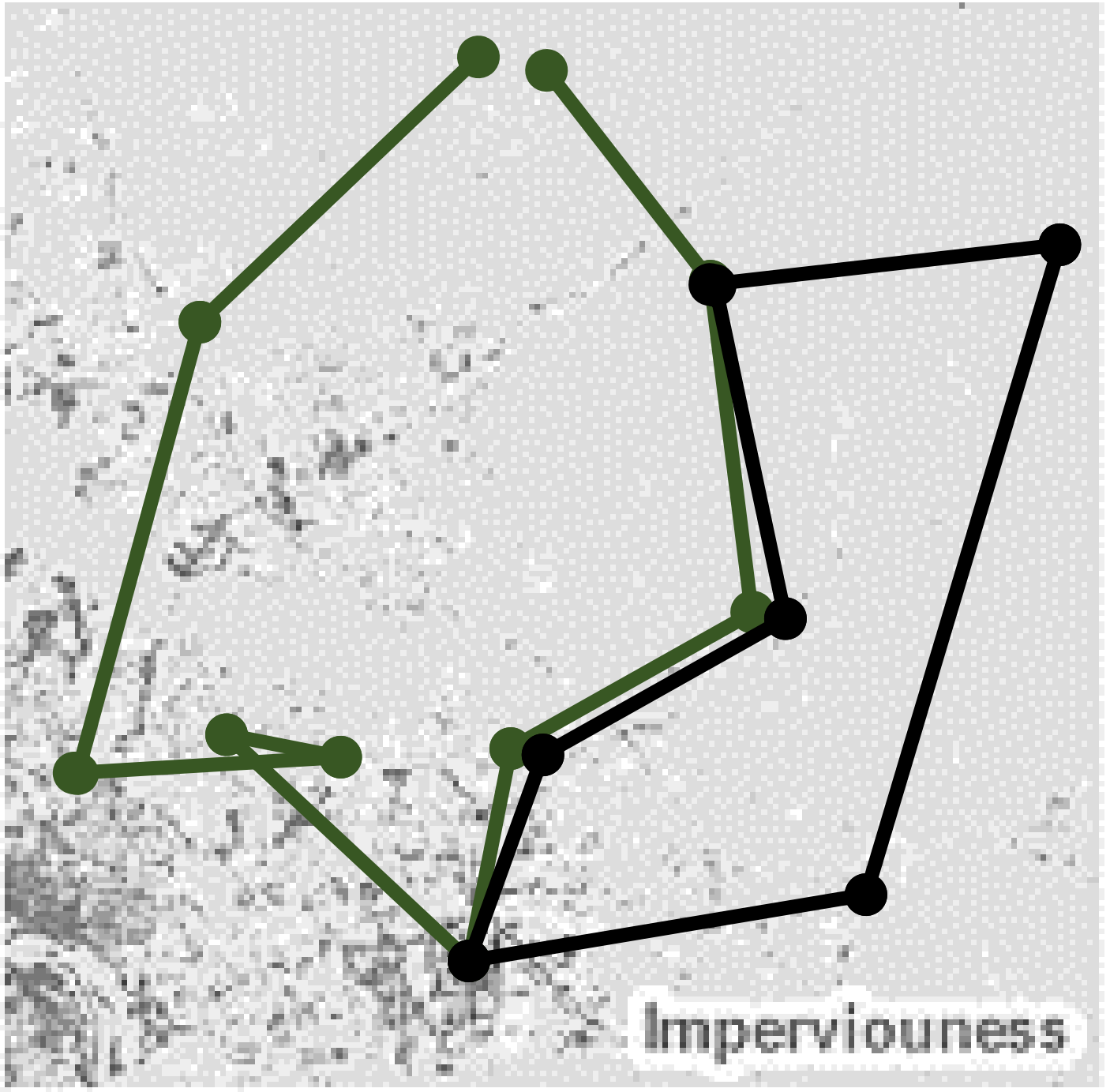
“Tradeoffs” between rasters and vectors

- Continuous vs. patchy coverage.
- Rasters cells don’t have the alignment issues that than plague vector data*:
  - Mis-aligned vertices of shared borders
  - Improper geometry: self-intersections
  - Improper geometry: polygons that don’t close

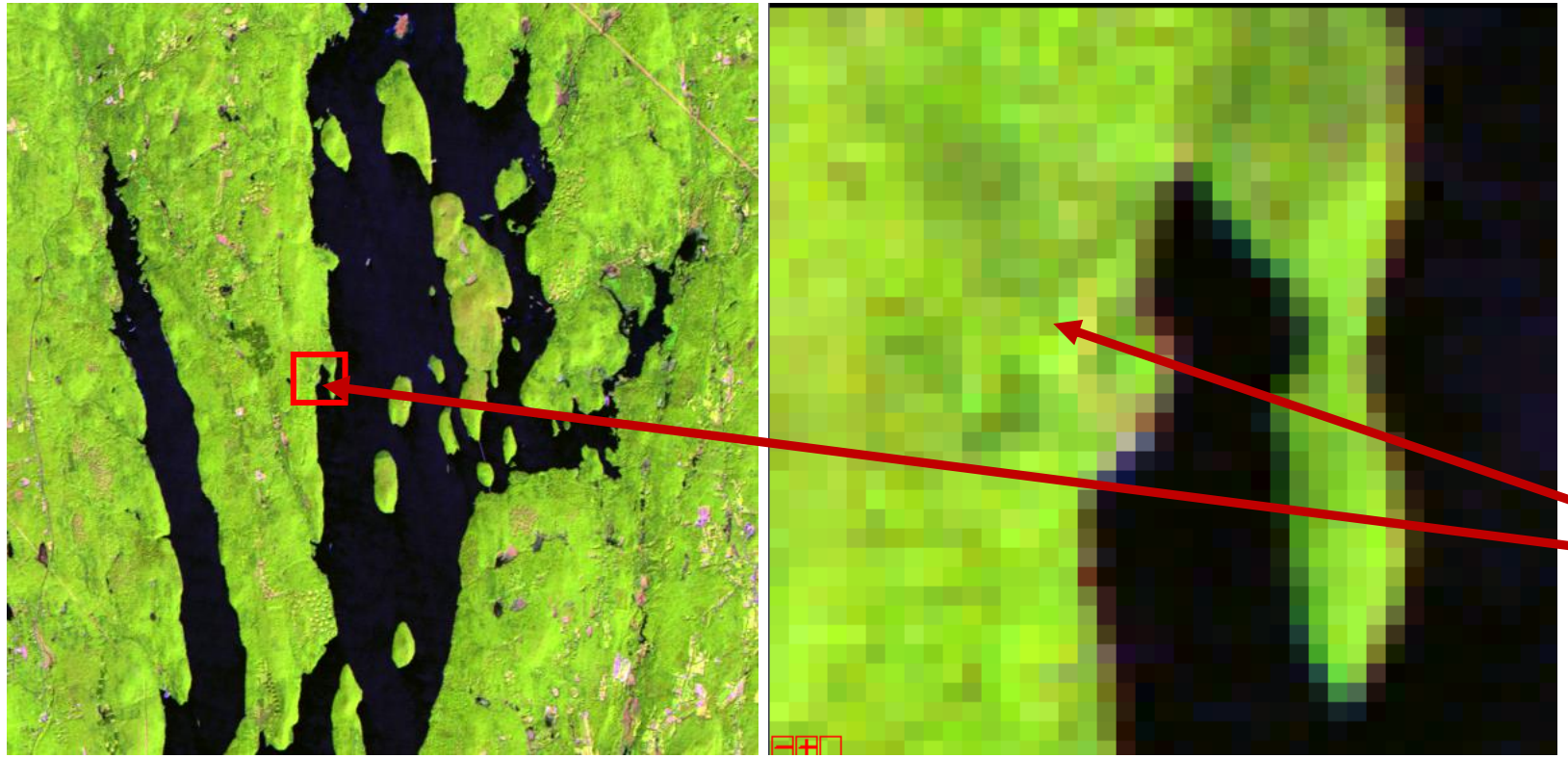


“Tradeoffs” between rasters and vectors

- Rasters cells don’t have the alignment issues that than plague vector data*:
  - Slight lie…
  - What happens when you need to work with raster data that have different cell sizes or are in different coordinate systems?



Raster Data



- We can think of rasters as digital images.
- They can store 1 or more layers:
  - Grayscale
  - RGB color

Red: 47
Green: 75
Blue: 14

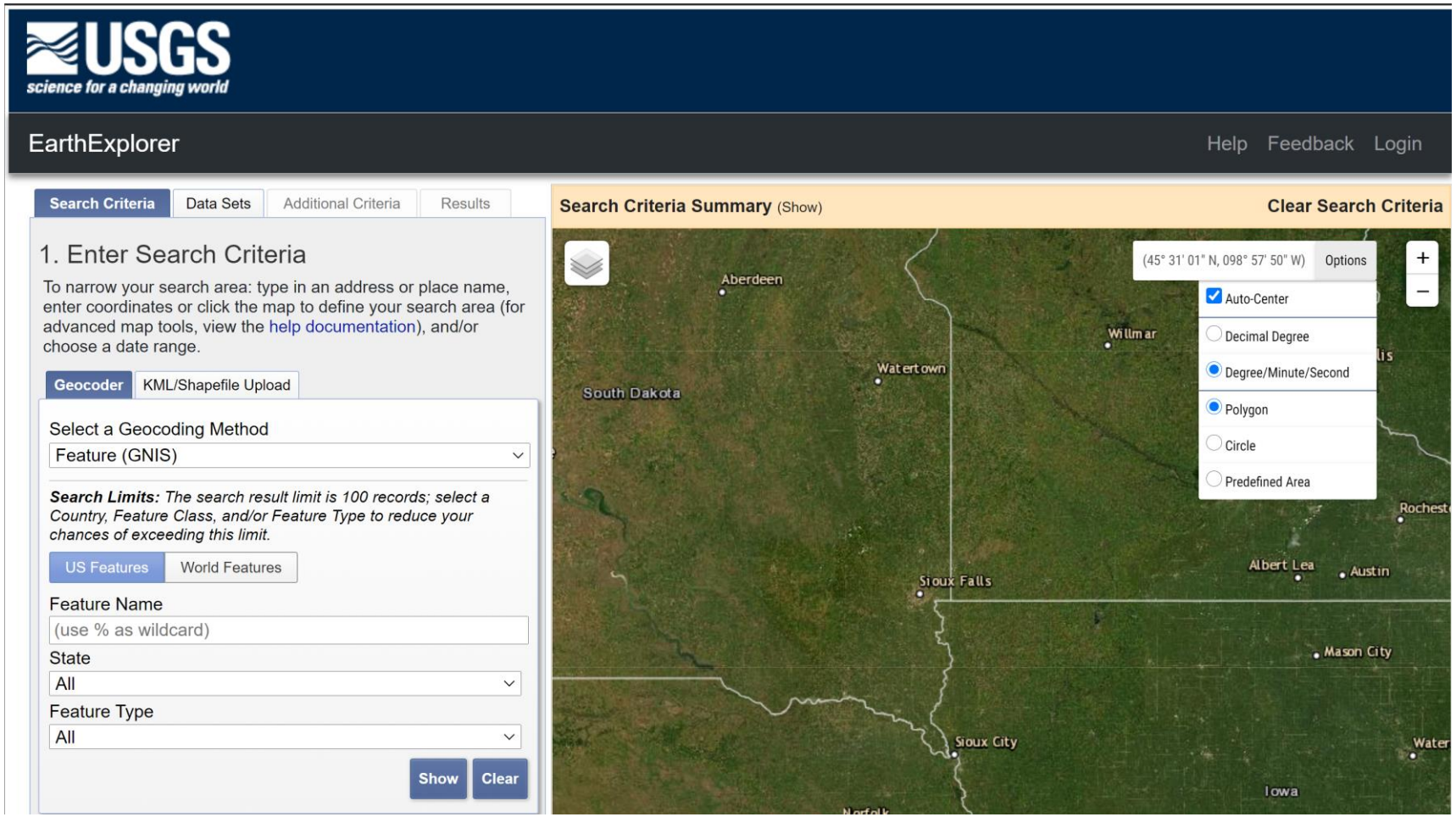
Satellite Imagery

Satellite records are getting longer

https://earthengine.google.com/timelapse/

- Monitoring change over time
- Multiple satellite projects, including:
  - Landsat
  - MODIS (Moderate Resolution Imaging Spectroradiometer): Terra and Aqua satellites
  - Spy satellites?

More and more data satellite data and data products are available

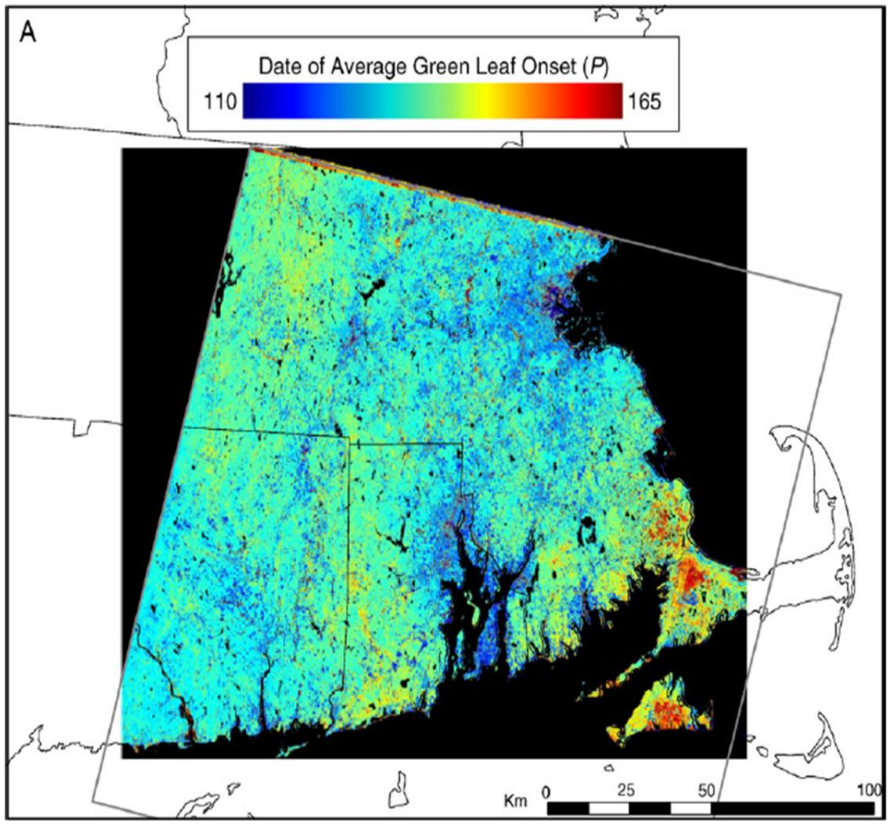


https://earthexplorer.usgs.gov/

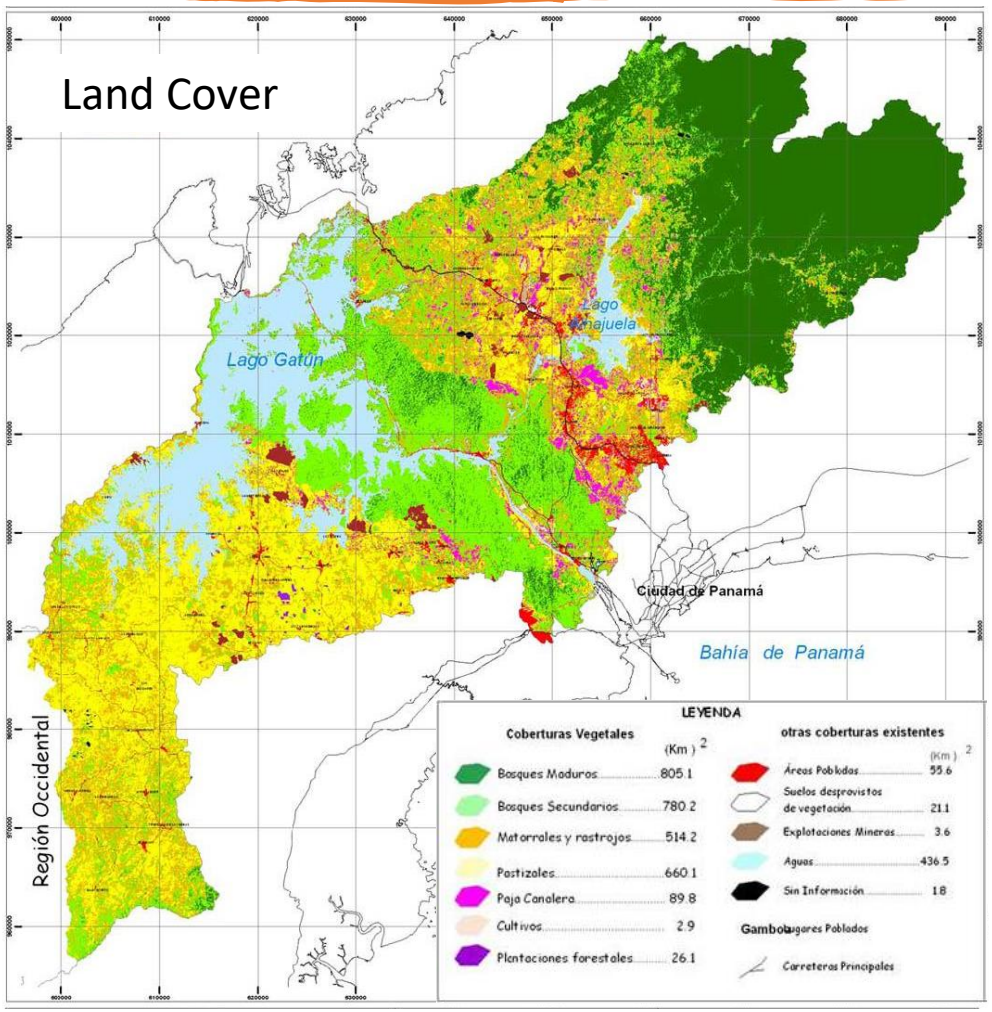
Take home points

- Create maps with Remote Sensing

Phenology



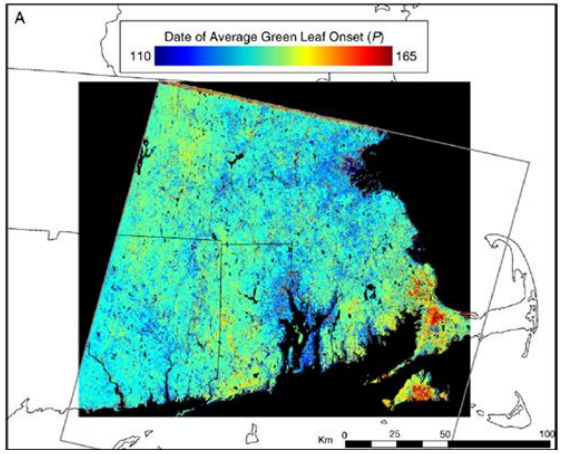
Land Cover



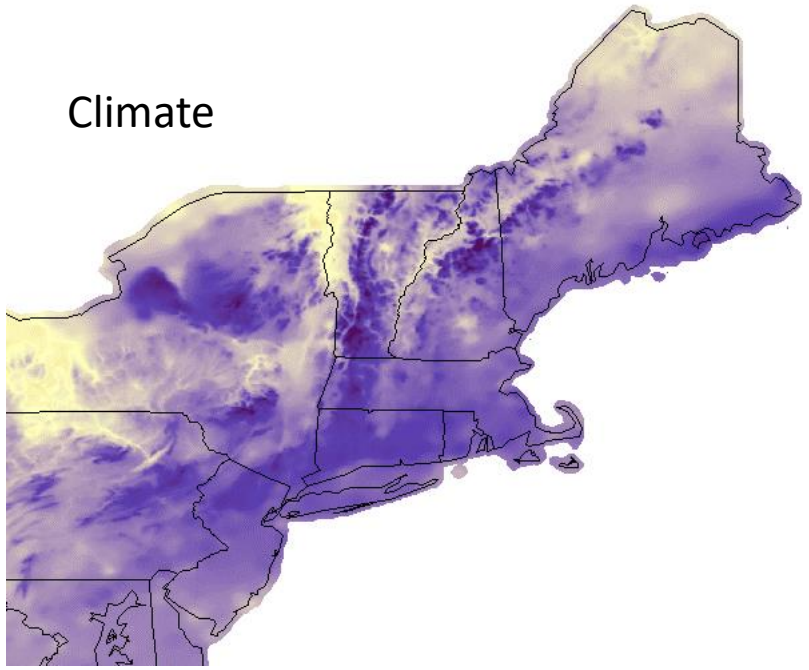
Take home points

- Create maps with Remote Sensing
- Analyze maps with GIS

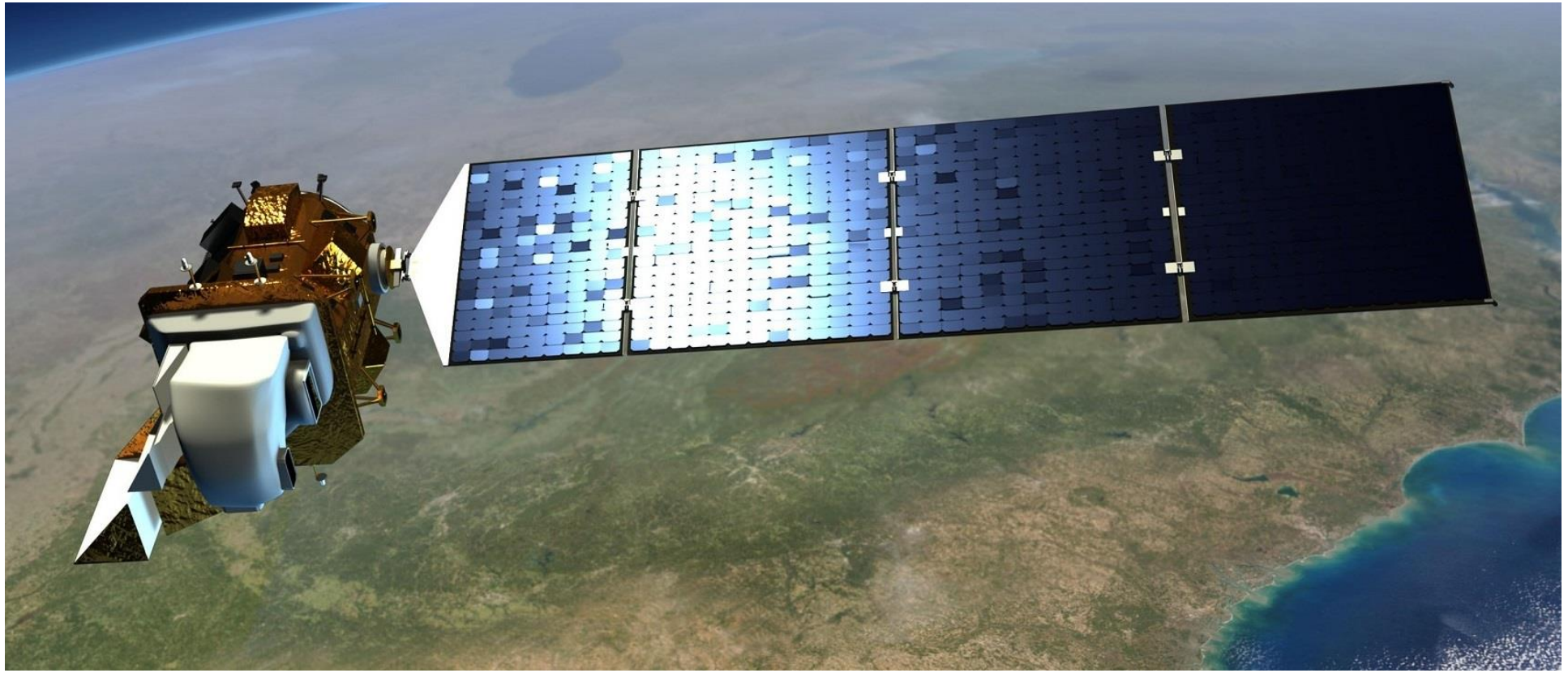
Phenology



Climate



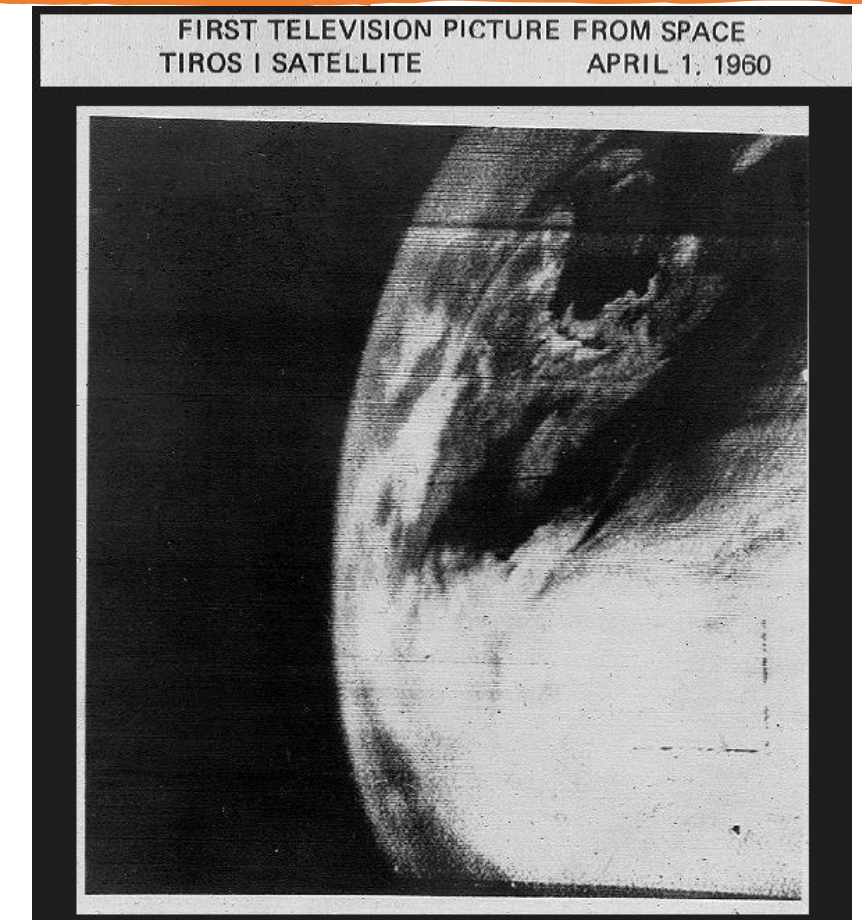
Talking About Landsat



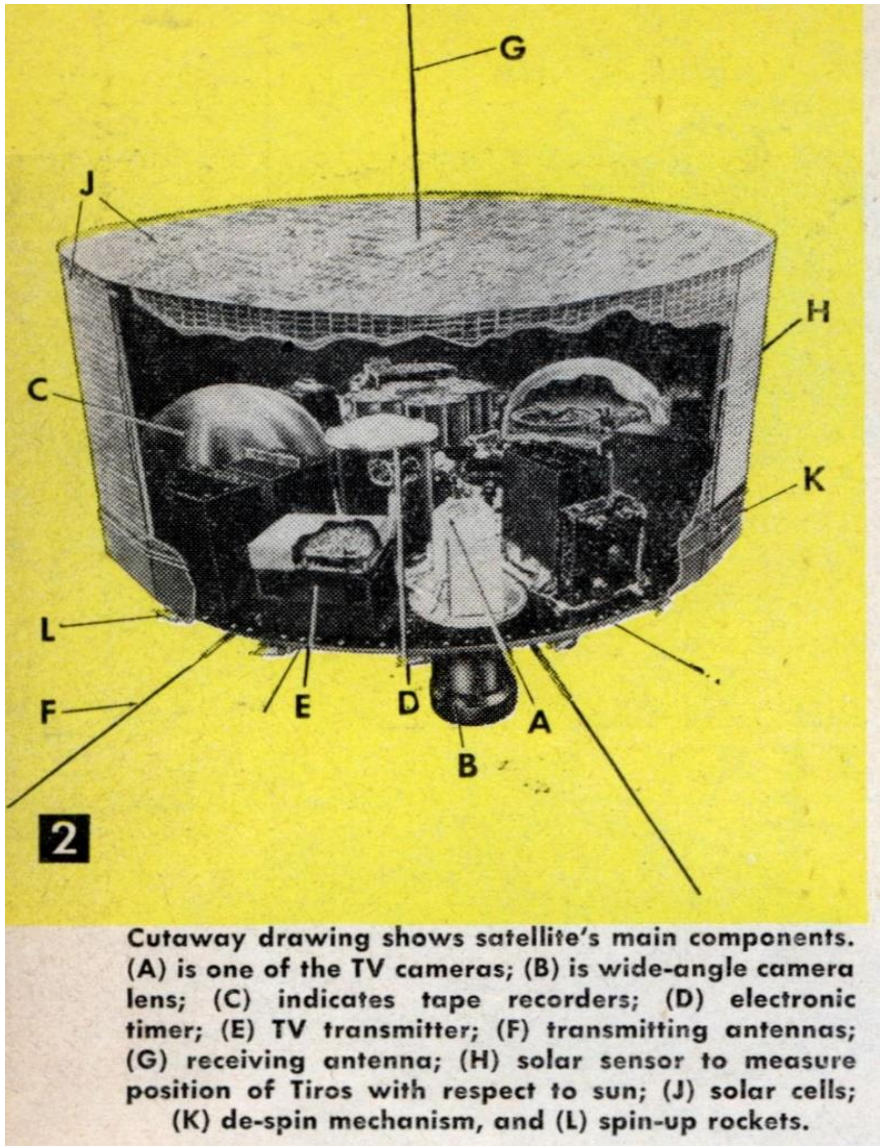
Beginning of Satellite RS

- TIROS sent first orbital images of Earth in 1960.

- Eventually, the DoD & NOAA launched their own weather satellites.



TIROS



Cutaway drawing shows satellite's main components. (A) is one of the TV cameras; (B) is wide-angle camera lens; (C) indicates tape recorders; (D) electronic timer; (E) TV transmitter; (F) transmitting antennas; (G) receiving antenna; (H) solar sensor to measure position of Tiros with respect to sun; (J) solar cells; (K) de-spin mechanism, and (L) spin-up rockets.

TIROS diagram from 1960s magazine 'Science and Mechanics';

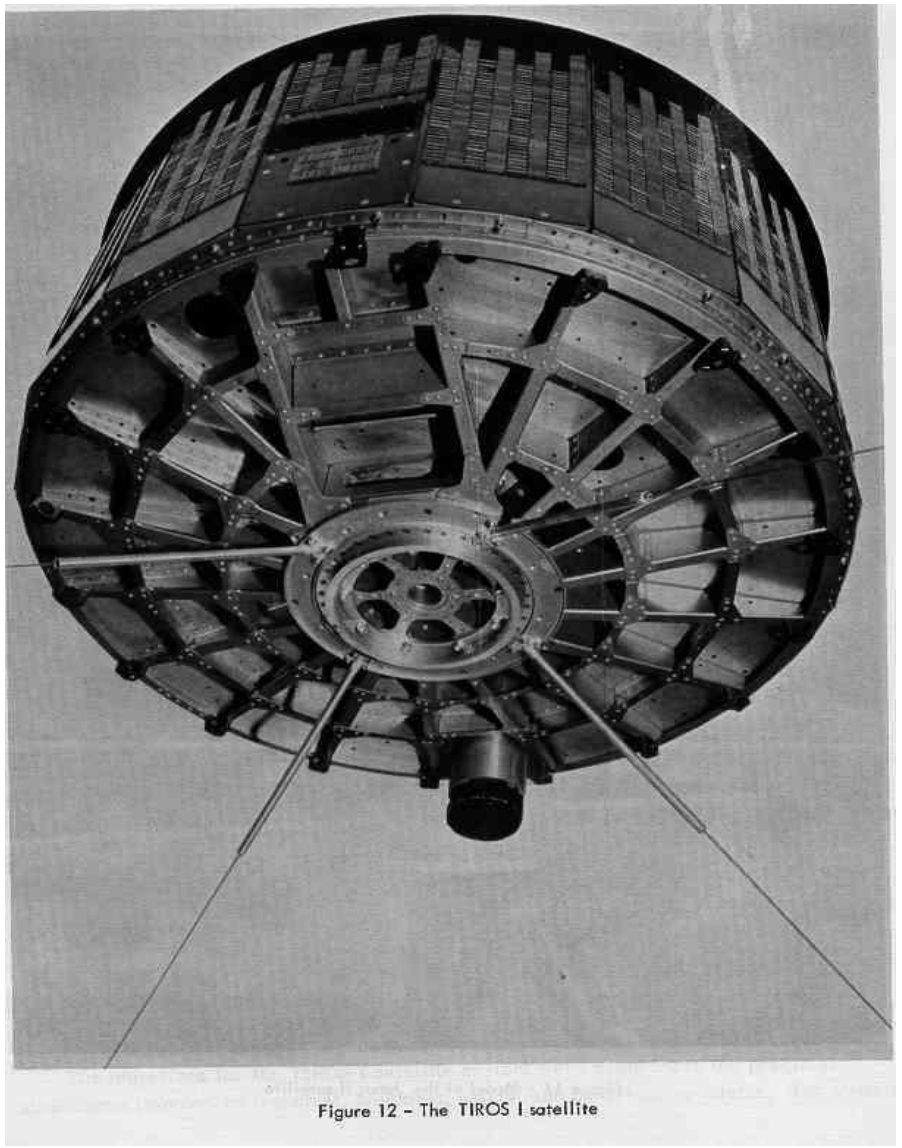


Figure 12 – The TIROS I satellite

TIROS satellite model from NASA.

Political Perceptions

“The benefits which a satellite system should make possible within a few years will stem largely from a vastly increased capacity to exchange information cheaply and reliably with all parts of the world by telephone, telegraph (😂), radio, and television.”

President John F. Kennedy, statement when signing the ‘Communications Satellite Act’ in **1964.**

Political Recognition

“The diversity of our activities in space shows that space technology has become an integral part of our lives—in communications, in **remote sensing** for defense and civilian purposes, and in studies of the earth and the universe. ” –

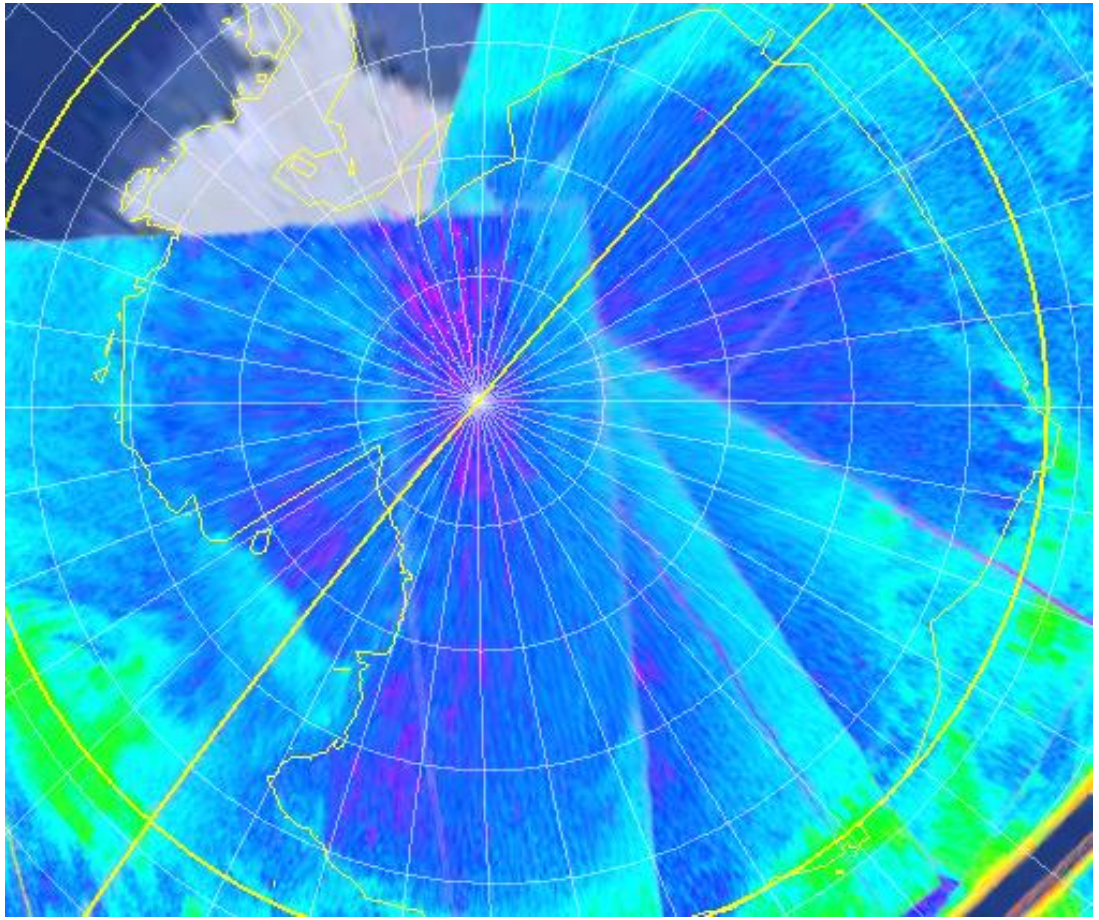
President Jimmy Carter, **1980** State of the Union Address.

Political Recognition

"The budget outline does keep funding for NOAA's current generation of polar satellites, a key part of what the National Weather Service uses for weather forecasting. But it also calls for "savings" in funding for the Polar Follow-On satellite program, which would launch two satellites in the coming decade. If the budget does affect those satellites, it could degrade monitoring capabilities for events like snowstorms and hurricanes" [Or climate change?]

https://www.scientificamerican.com/article/trump-wants-deep-cuts-in-environmental-monitoring/

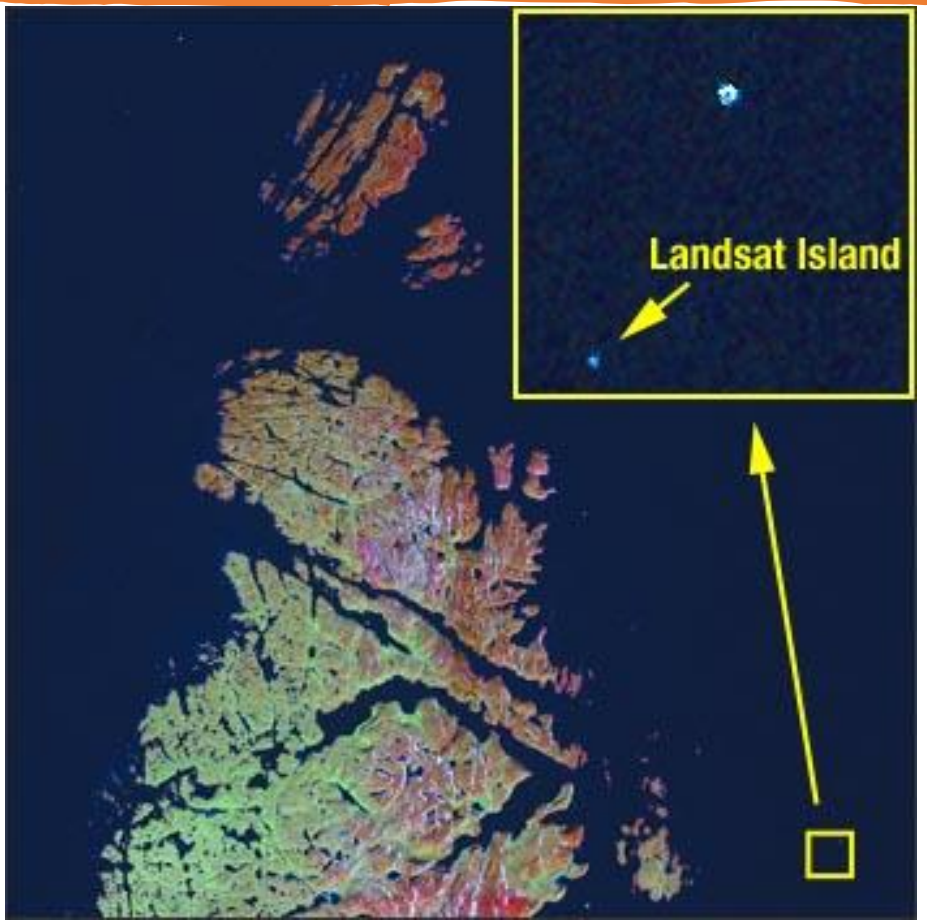
Nimbus



- Nimbus platforms expanded US technological capabilities in the 1960s and 1970s.
- Series of meteorological satellites
- Left, Nimbus temperature data of Antarctica, Sept. 23, 1966

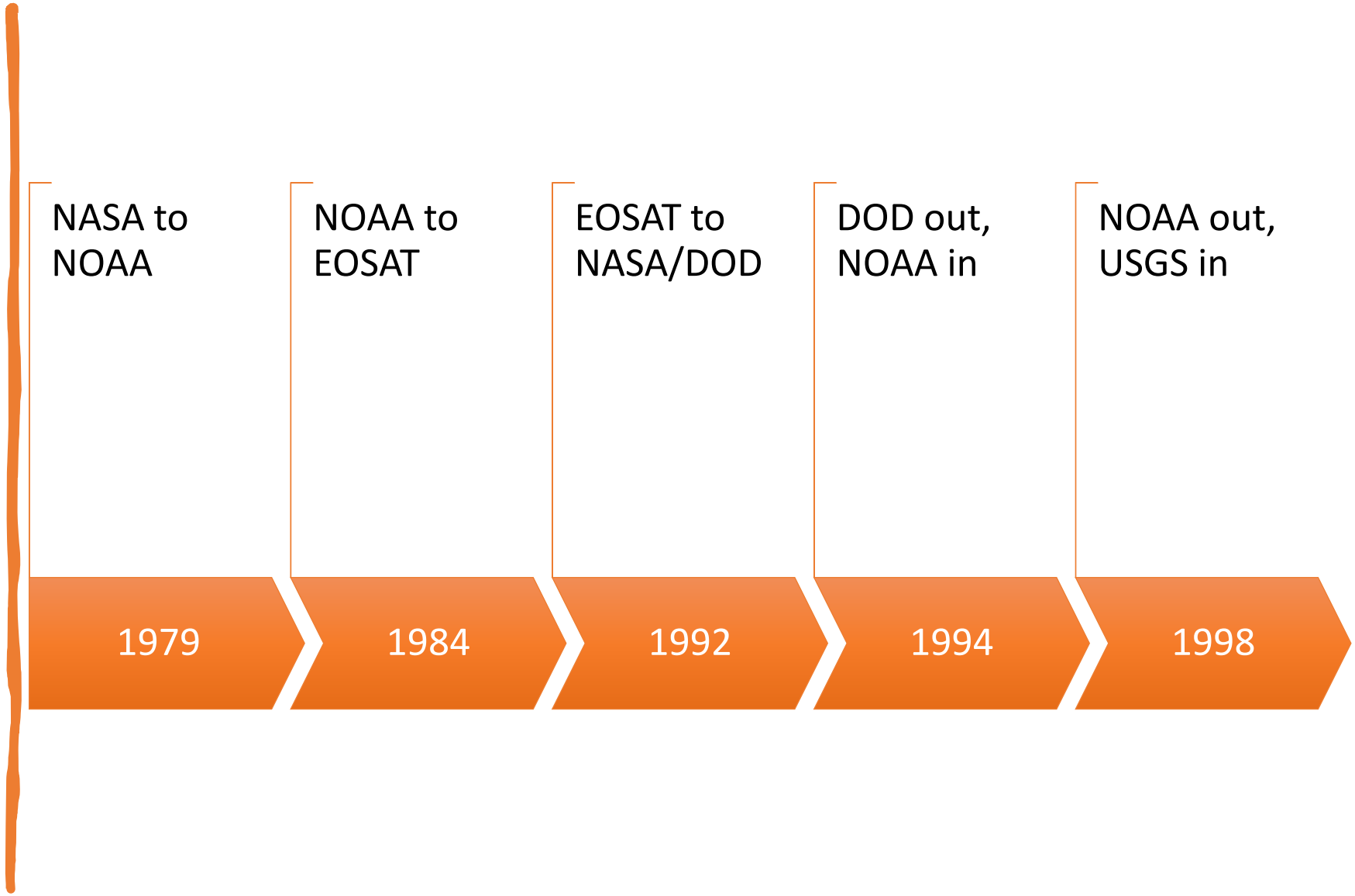
Landsat

- Beginning in the 1970s, Landsat, equipped with the Multi Spectral Sensor, changed the remote sensing paradigm in the United States.
- Multiple subsequent generations.
- Landsat 9 – September 2021

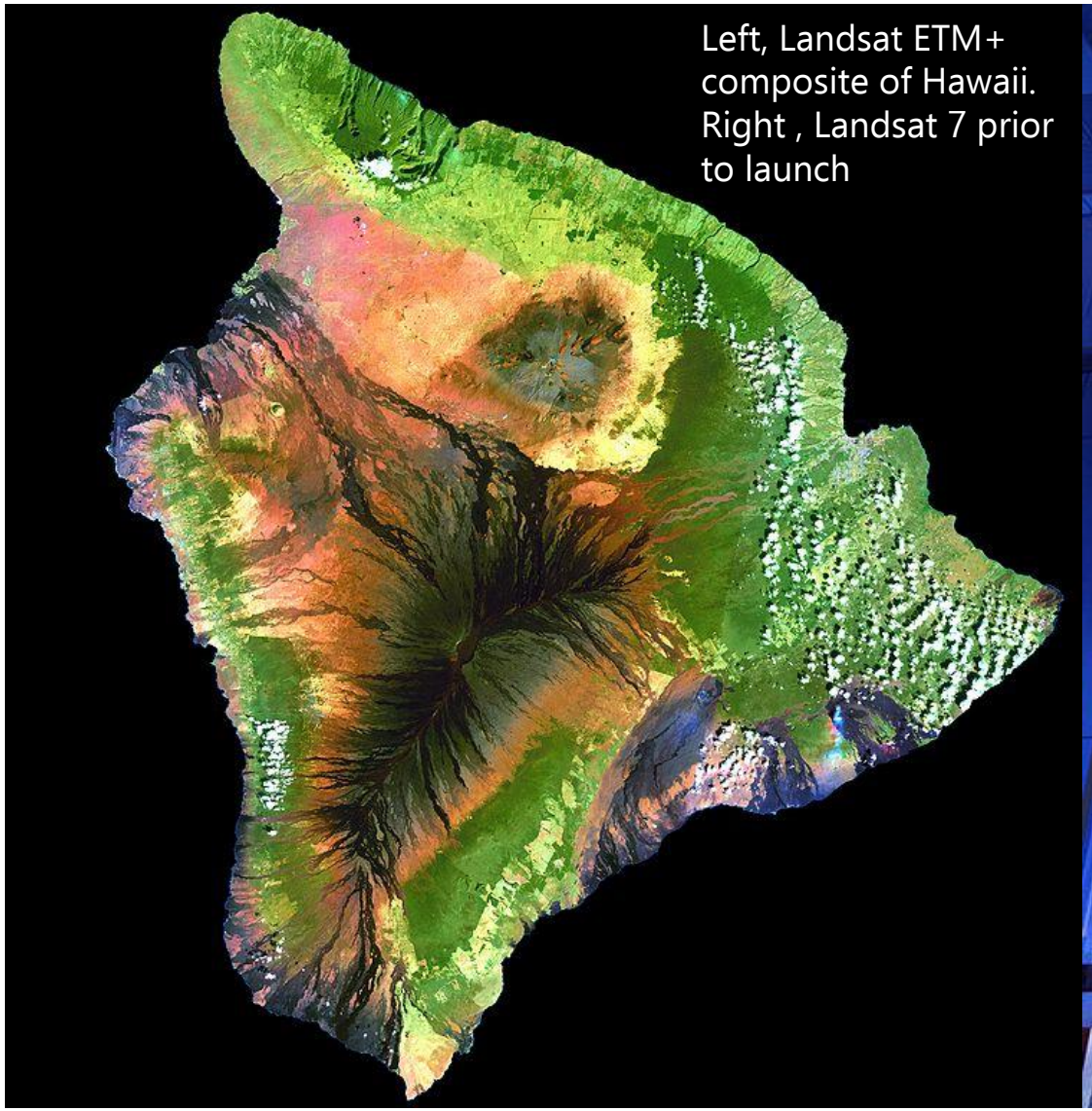


The Landsat ‘Football’

Despite the usability of Landsat, as a program it has been transferred among agencies five times.



Landsat

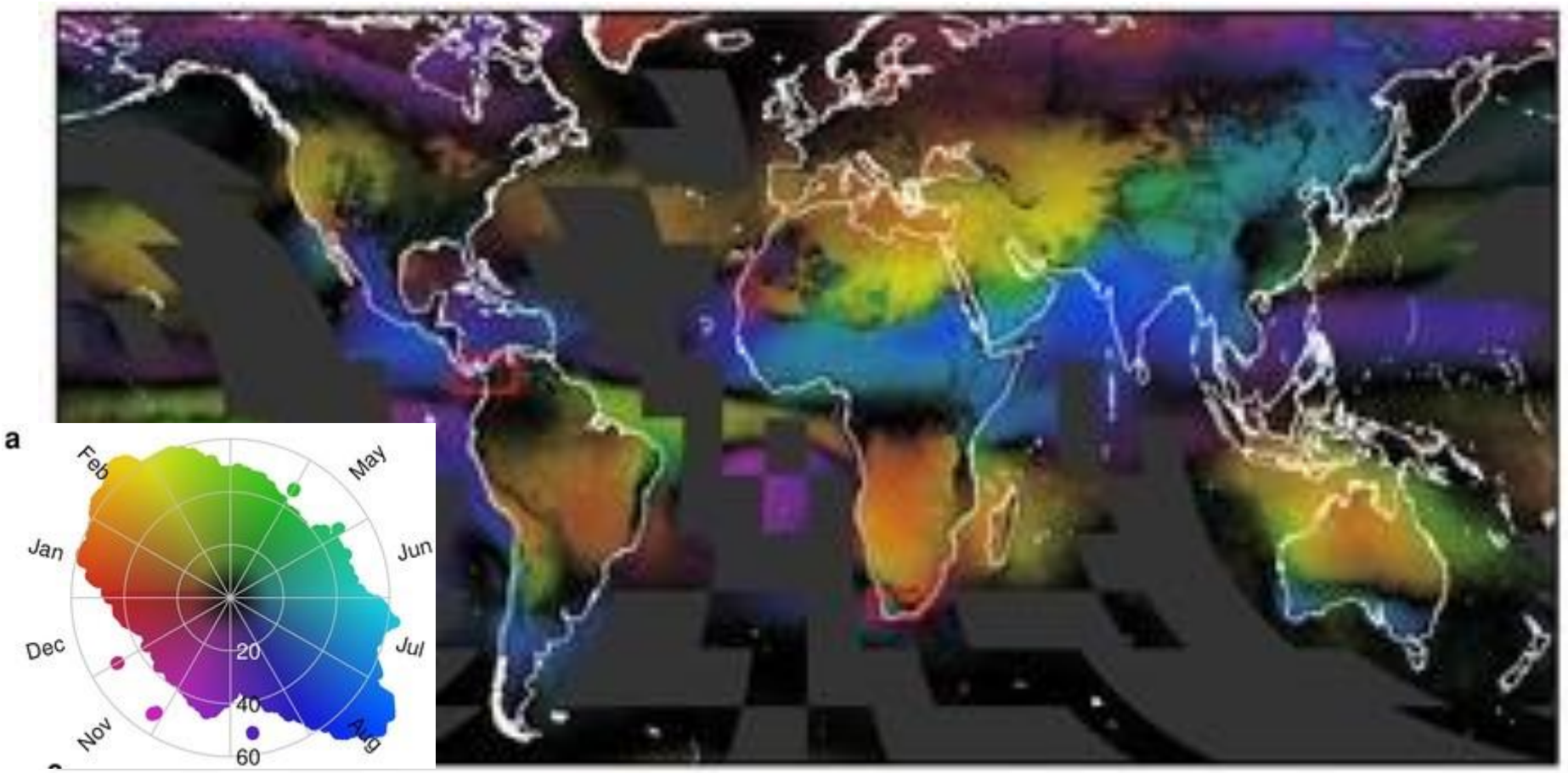


Left, Landsat ETM+ composite of Hawaii. Right , Landsat 7 prior to launch

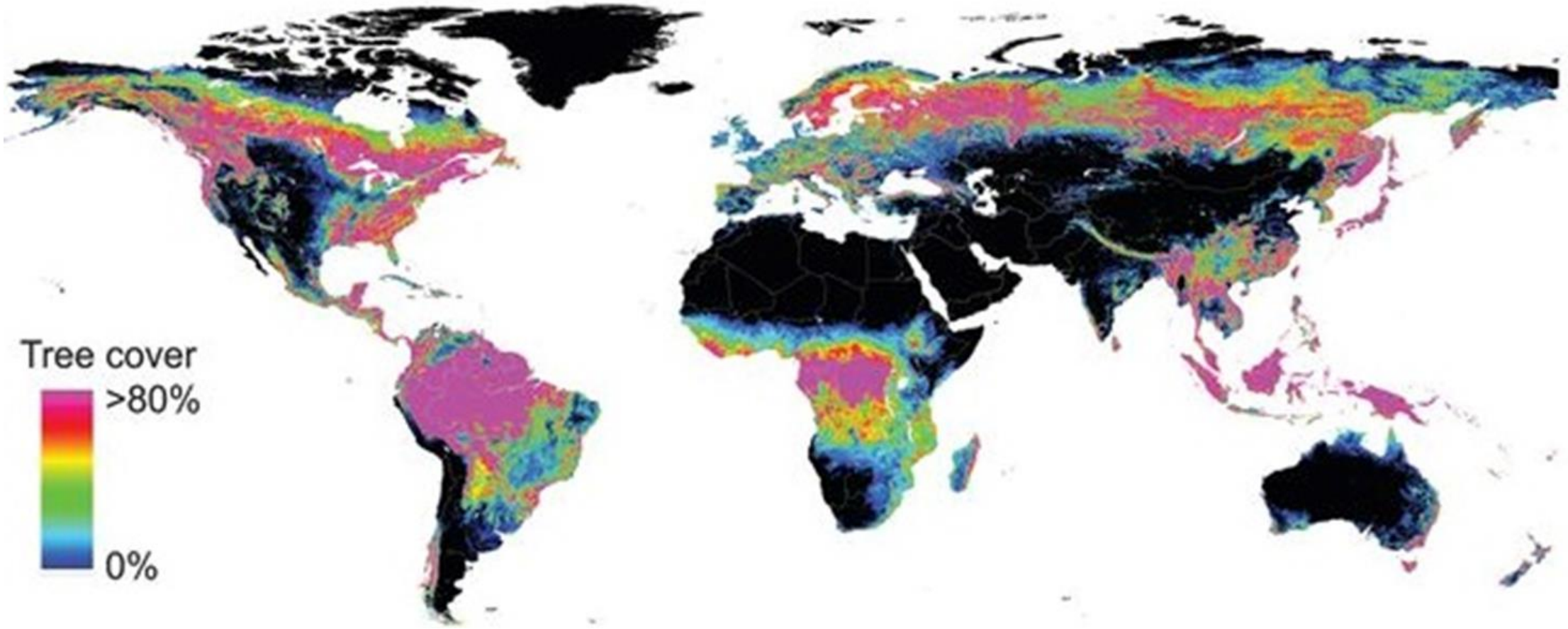
MODIS thermal bands (temperature) OR color differences due to fire scars are used to detect active fires or burned area

Moderate Resolution Imaging Spectroradiometer

Global cloud cover products based on MODIS identify seasonality of clouds



Global tree cover and tree cover change from Landsat



Global tree cover and tree cover change from Landsat