EDS 223: Geospatial Analysis & Remote Sensing
Week 7

USGS via Unsplash


FACULTY FLASH TALKS
VOTE FOR YOUR FAVS!
GRADE YOUR PROFESSORS
Chris Costello | Arturo Keller
Ruth Oliver | Naomi Tague
Hunter Lenihan | Eric Masanet
Joan Dudney | Andy MacDonald
Ranjit Deshmukh | Kelly Caylor
Ashley Larsen | Mark Buntaine
FRIDAY NOVEMBER 17 2 - 4PM
HOSTED BY ANDREW PLANTINGA IN BREN 1414
RECEPTION TO FOLLOW

Welcome!

- **Course logistics**
  - This week
    - Office hours moved to Thursday @ 3:30
  - Next week
    - Tuesday hybrid option and recording
    - Office hours and discussion section cancelled
    - Enjoy the holiday!

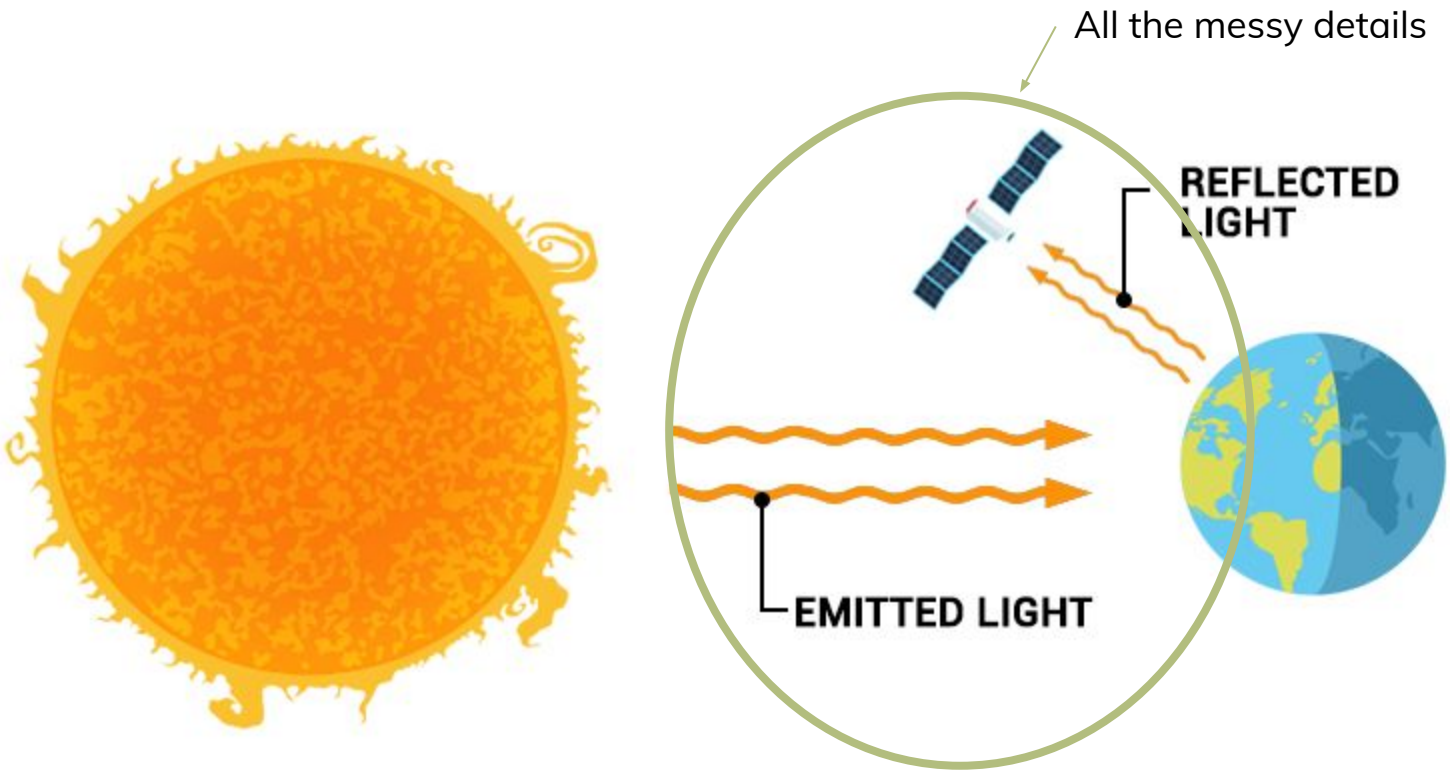
Welcome!

- **Course logistics**
  - This week
    - Office hours moved to Thursday @ 3:30
  - Next week
    - Tuesday hybrid option and recording
    - Office hours and discussion section cancelled
    - Enjoy the holiday!

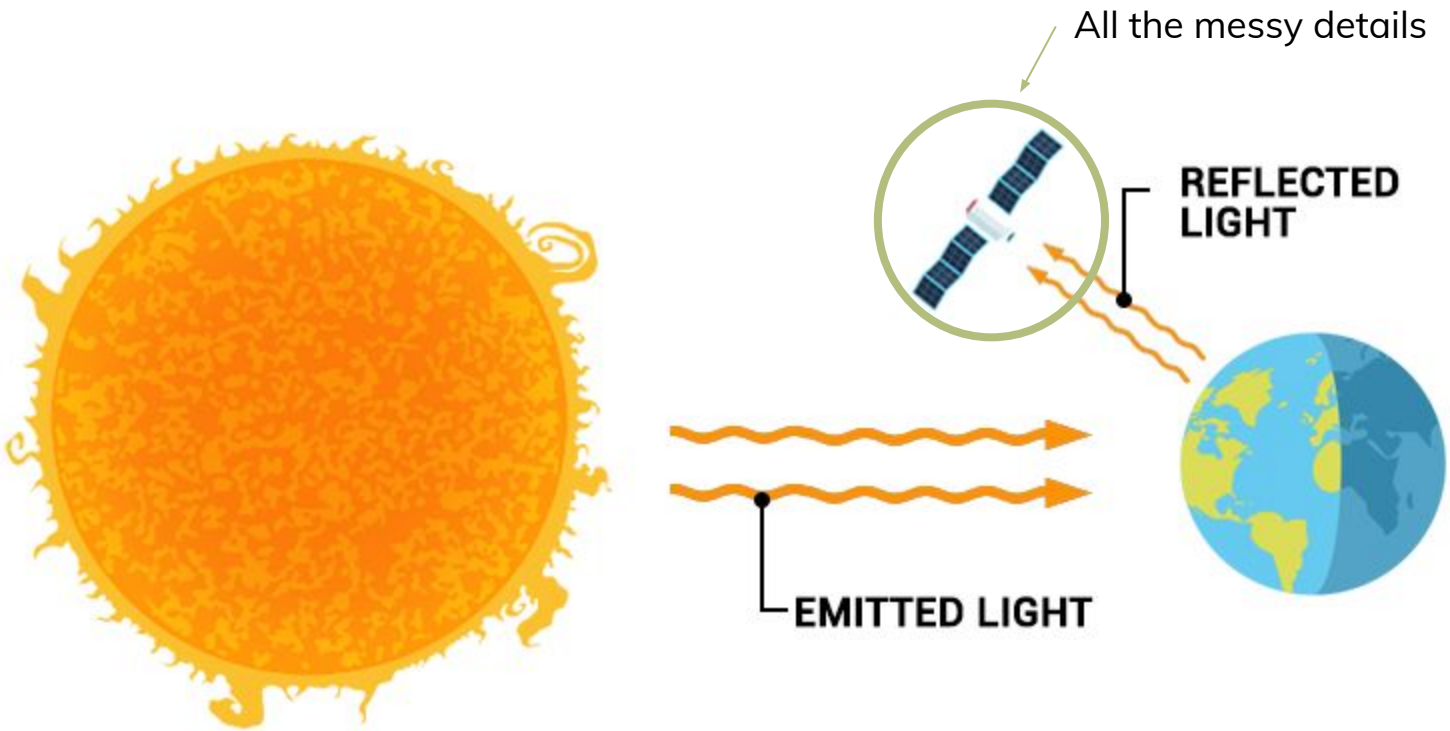
Jane Oliver
Guest instructor

Welcome!

- Recap of last week
- Image resolutions
- Digital images
- True/False color imagery
- Final project guidance
- Raster operations
- Check-in quiz



Source: GIS Geography



Source: GIS Geography

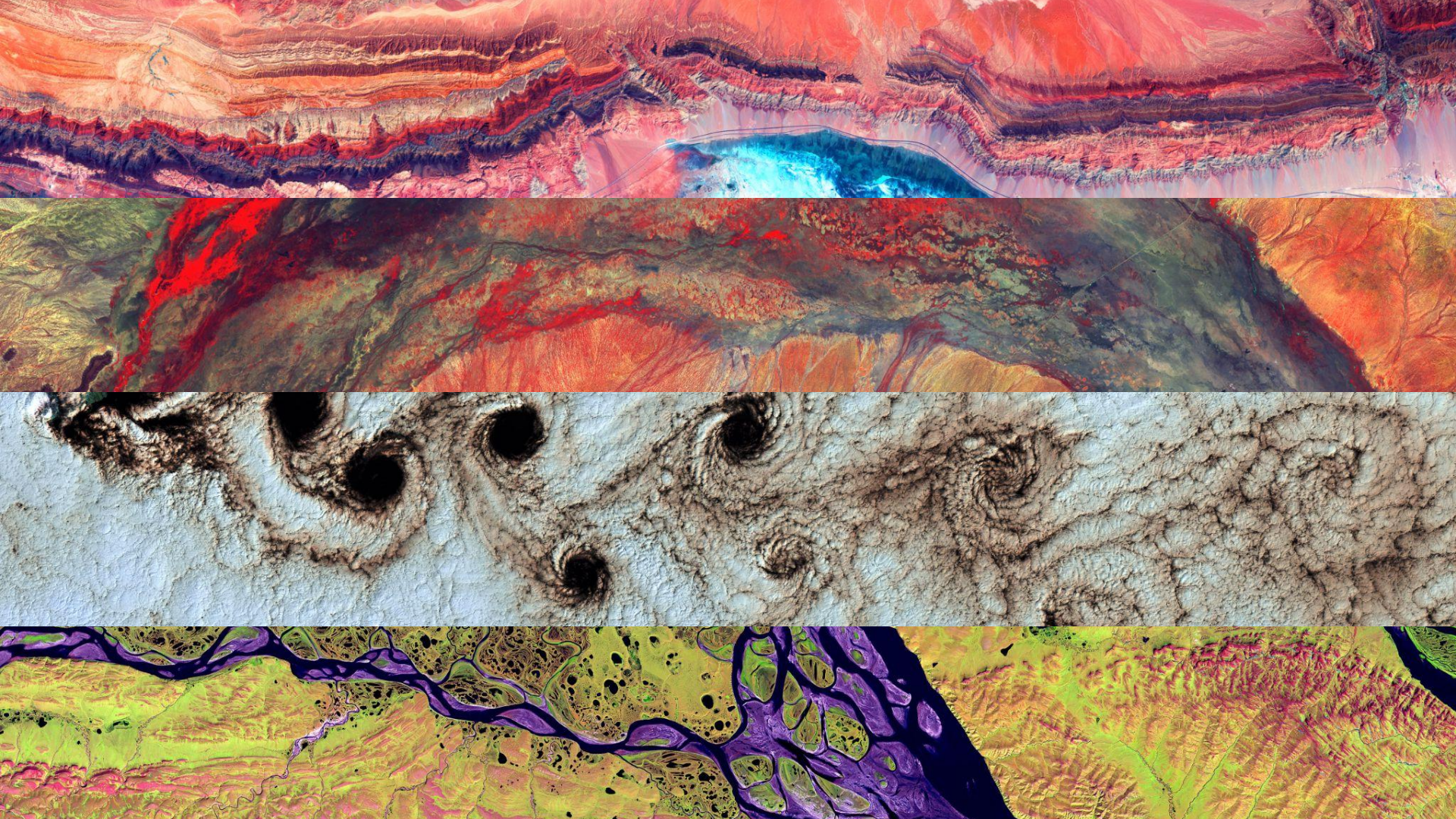
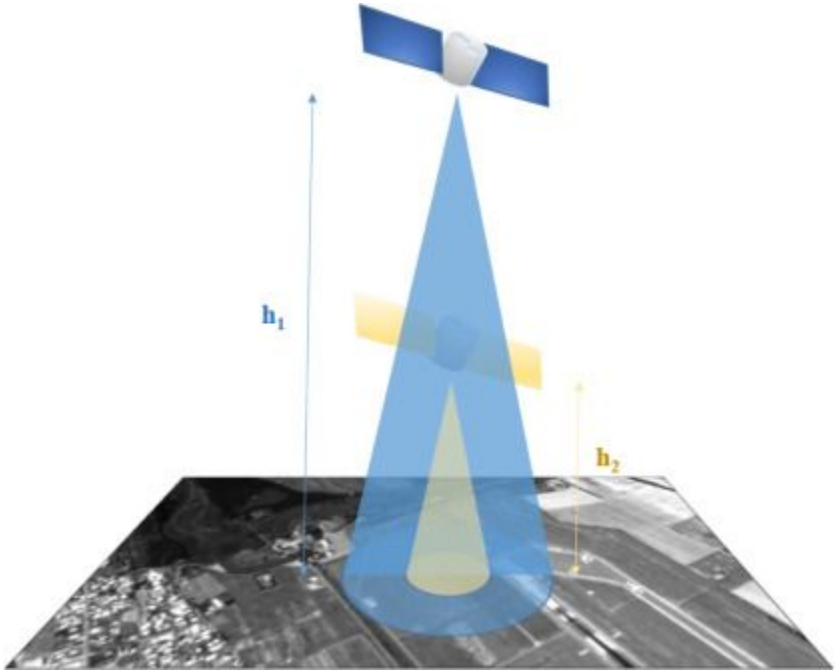


Image resolutions

- Spatial
- Temporal
- Spectral
- Radiometric

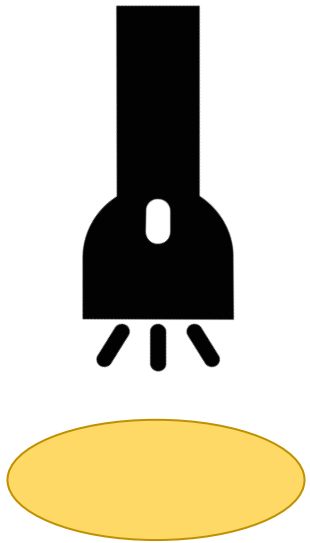
What makes an image?

Spatial resolution

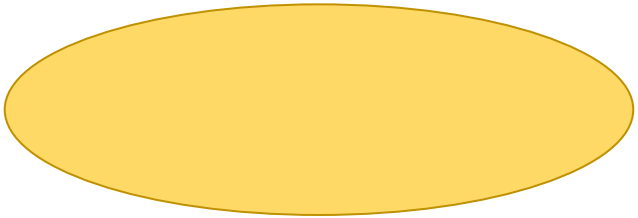


Source: Ose et al. 2016

Spatial resolution

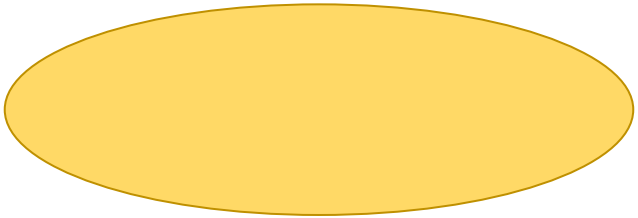


Spatial resolution



Spatial resolution

↑ Lit area ↑ Distance from source



Spatial resolution

↑ Lit area ↑ Distance from source

Spatial resolution

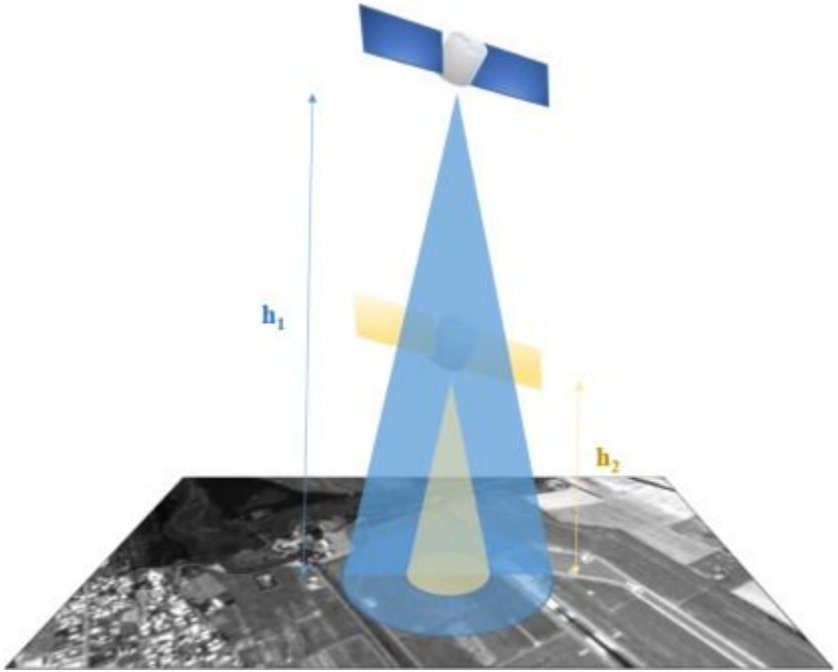
↑ Lit area ↑ Distance from source

Spatial resolution

↑ Lit area ↑ Distance from source

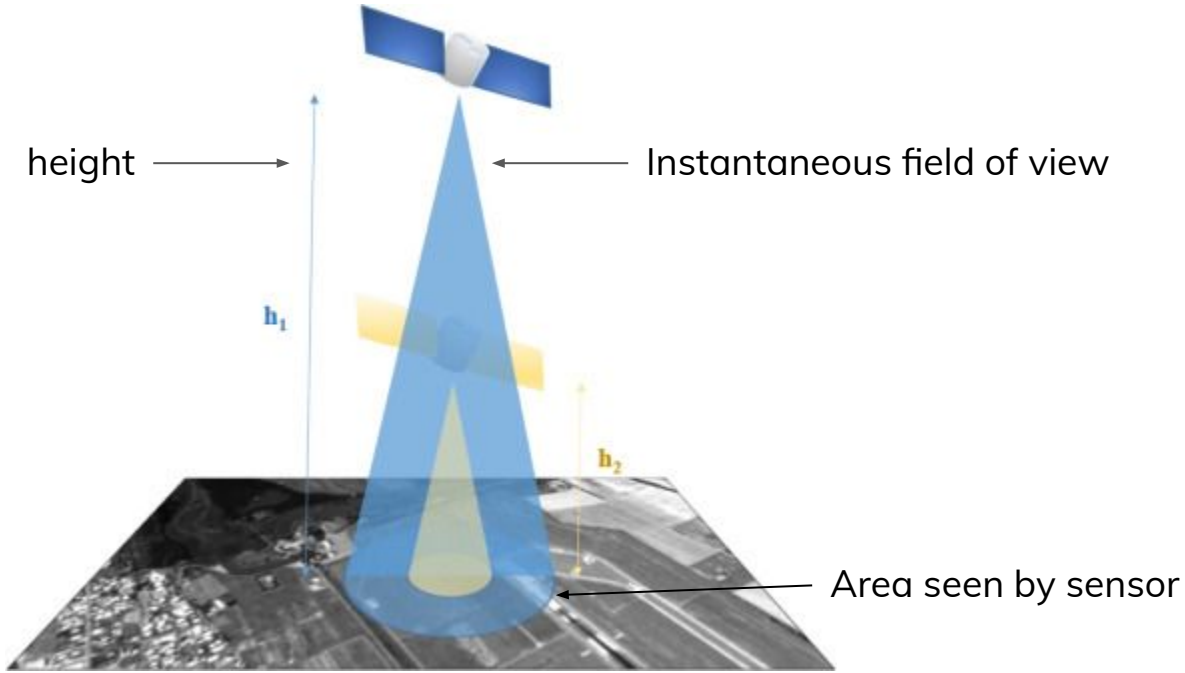
↑ Lit area ↑ size of source

Spatial resolution



Source: Ose et al. 2016

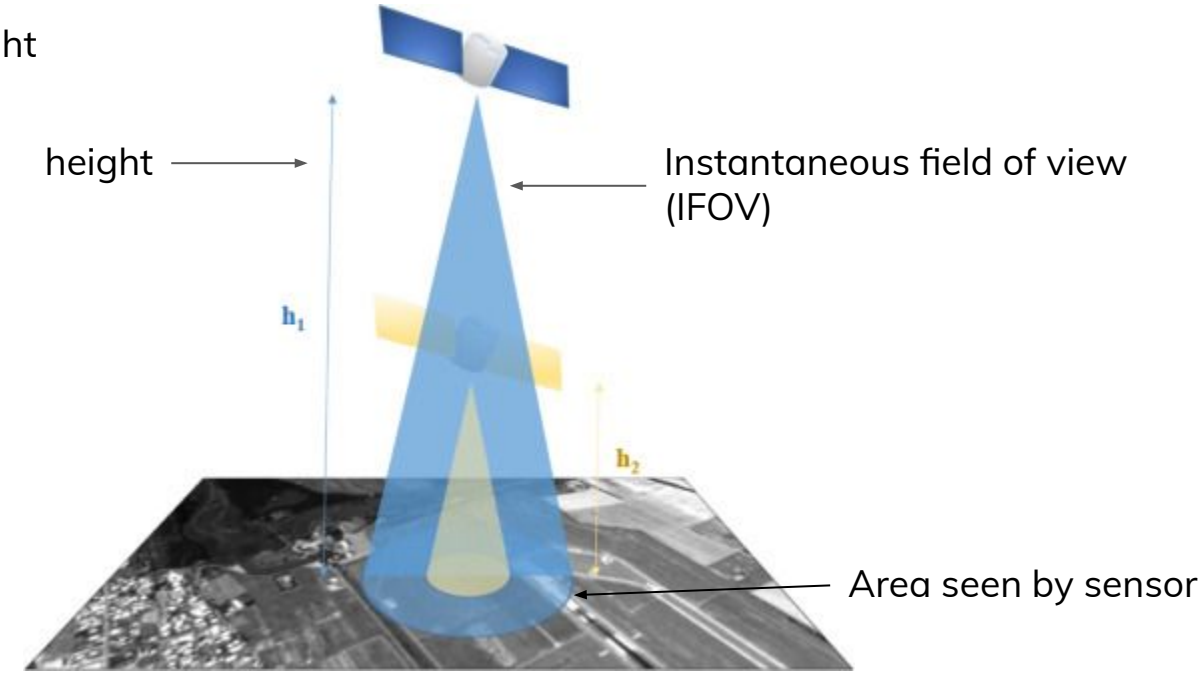
Spatial resolution



Source: Ose et al. 2016

Spatial resolution

Pixel length = IFOV x height

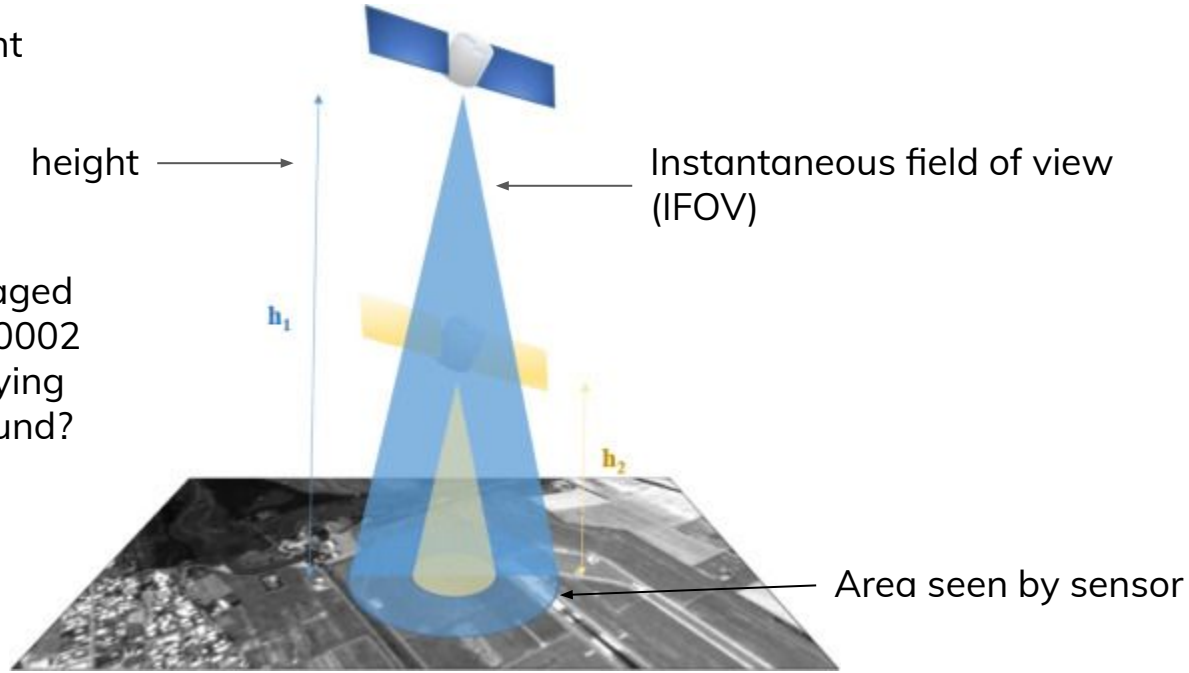


Source: Ose et al. 2016

Spatial resolution

Pixel length = IFOV x height

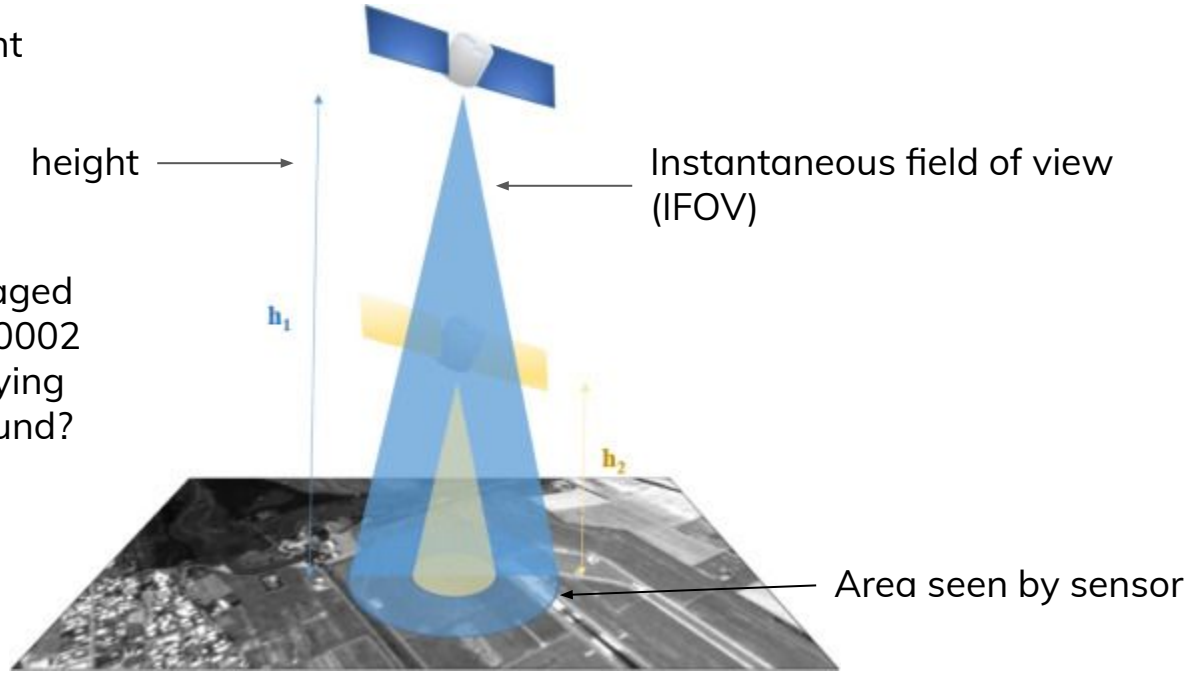
What is the pixel length imaged by a sensor if the IFOV is 0.0002 radians and the aircraft if flying 5000 meters above the ground?



Source: Ose et al. 2016

Spatial resolution

Pixel length = IFOV x height

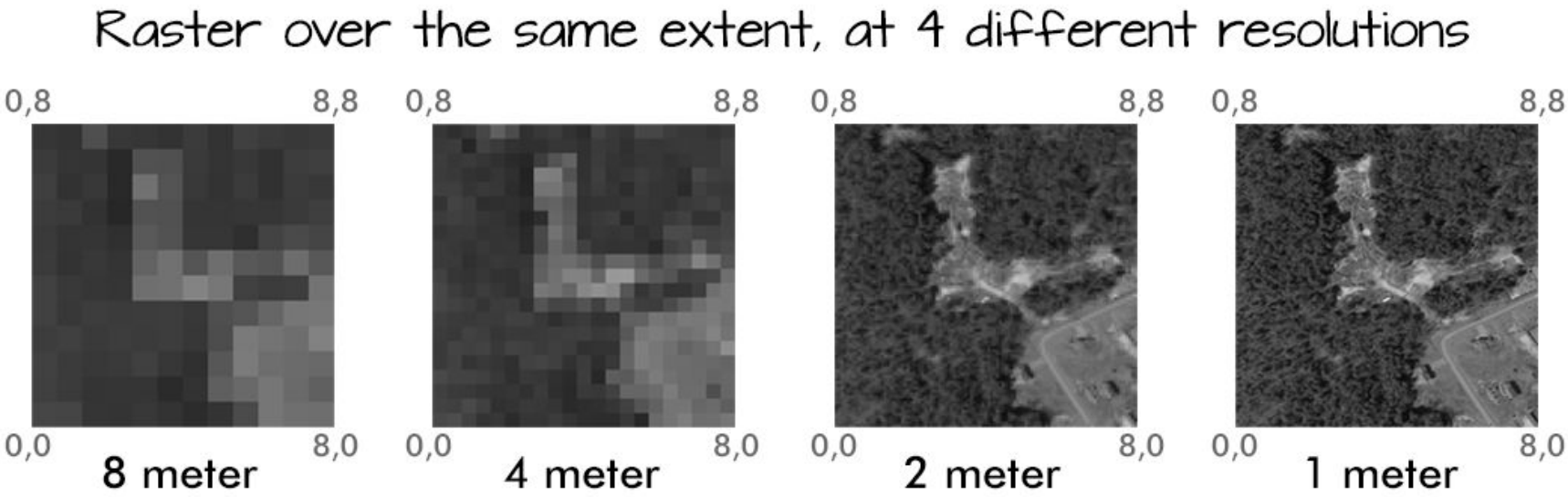


What is the pixel length imaged by a sensor if the IFOV is 0.0002 radians and the aircraft if flying 5000 meters above the ground?

Pixel length
= 0.0002 radians * 5000 m
= 1 m

Source: Ose et al. 2016

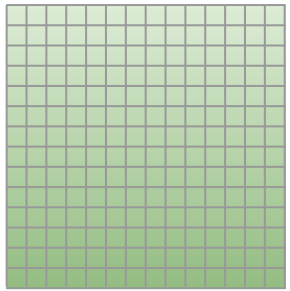
Spatial resolution



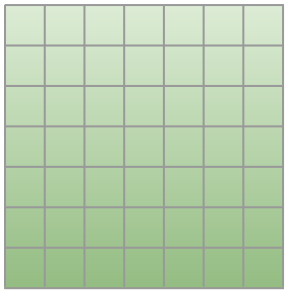
Source: Colin Williams, NEON

Spatial resolution

- **Measure of the smallest angular or linear separation between two object**
  - The smallest feature that can be detected
  - Usually refers to the size of one pixel



high, fine, better



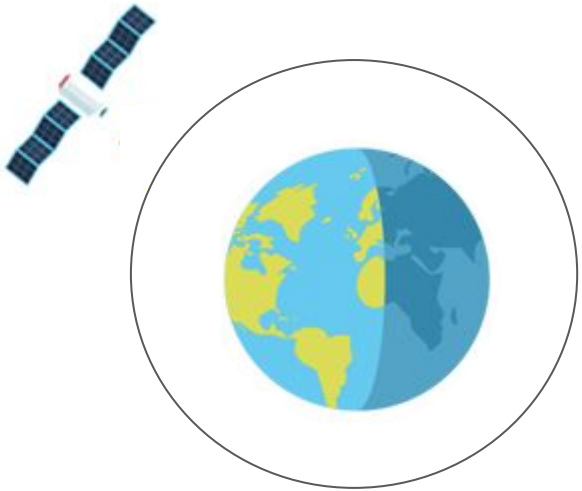
low, coarse, worse

Better resolution	Worse resolution
0.5 m	20 m

Image resolutions

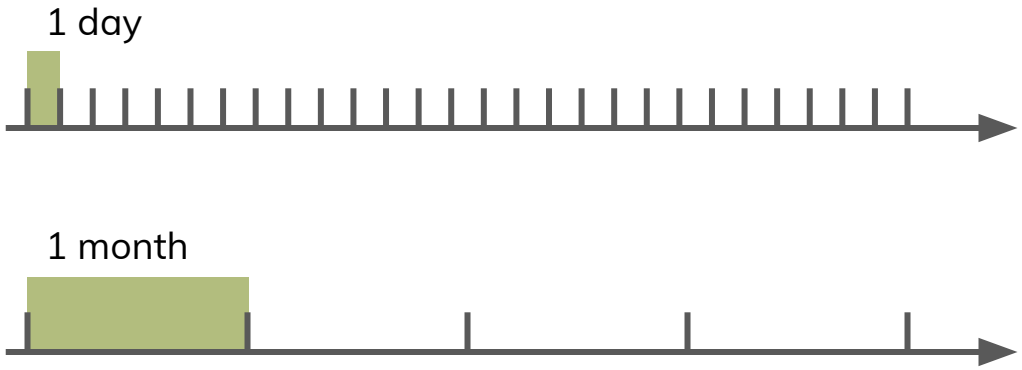
- **Spatial**
  - Raster resolution
- **Temporal**
- **Spectral**
- **Radiometric**

Temporal resolution



Temporal resolution

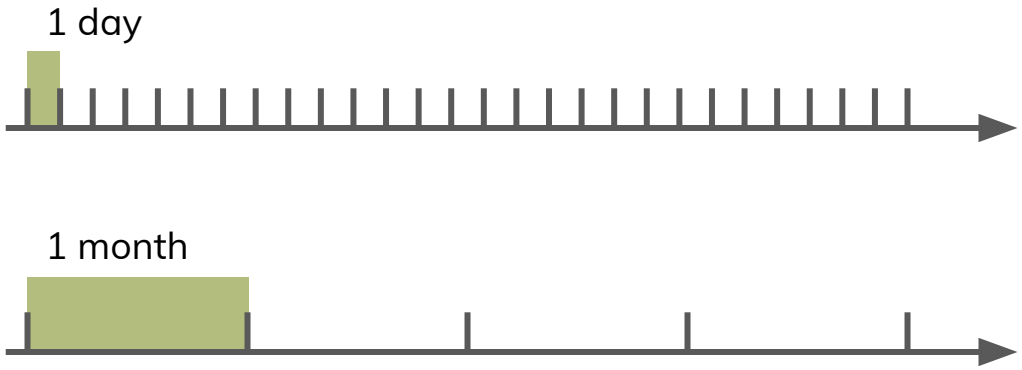
- Time interval between acquisitions of a particular area



Better resolution	Worse resolution
1 day	1 month

Temporal resolution

- Time interval between acquisitions of a particular area

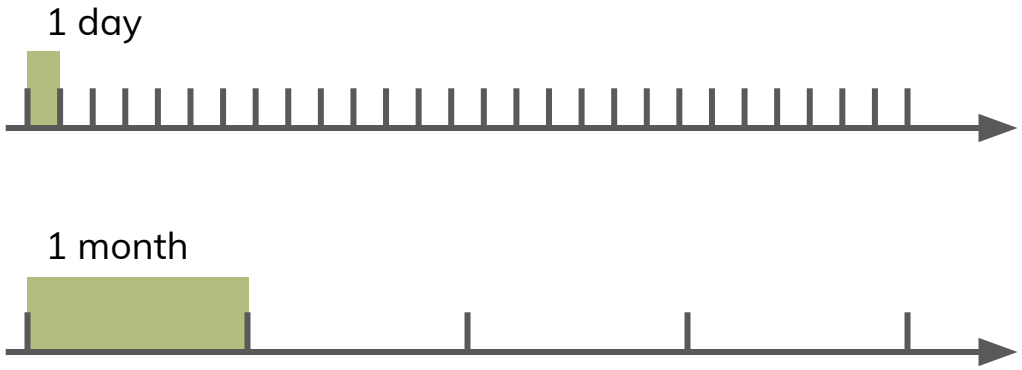


Better resolution	Worse resolution
1 day	1 month

- **Factors determining temporal resolution:**
  - satellite/sensor capabilities, orbit

Temporal resolution

- Time interval between acquisitions of a particular area



Better resolution	Worse resolution
1 day	1 month

- **Factors determining temporal resolution:**
  - satellite/sensor capabilities, orbit
- **Factors affecting ACTUAL resolution:**
  - Clouds, sunlight

Spatial and temporal resolution of major satellites

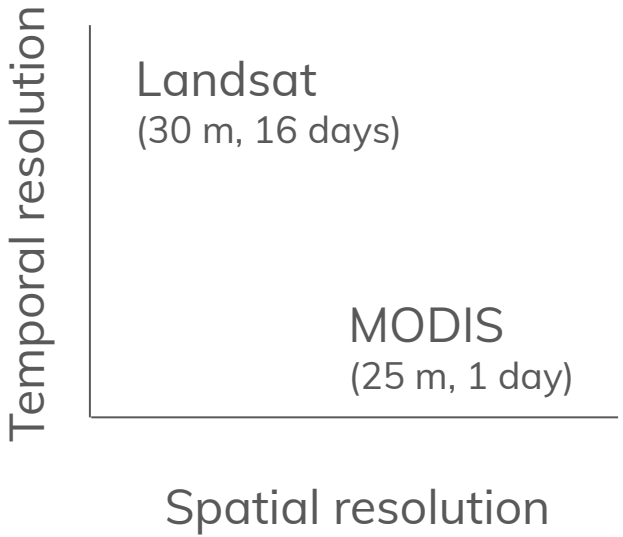
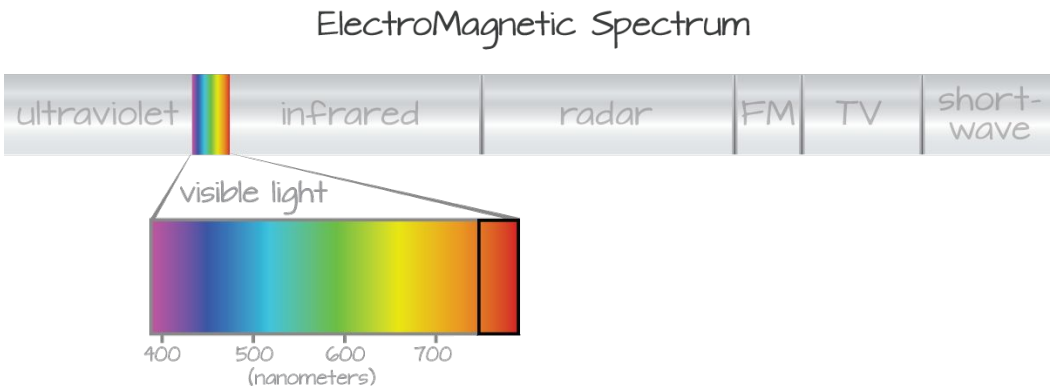


Image resolutions

- **Spatial**
  - Raster resolution
- **Temporal**
  - Number of rasters for same location
- **Spectral**
- **Radiometric**

Spectral resolution

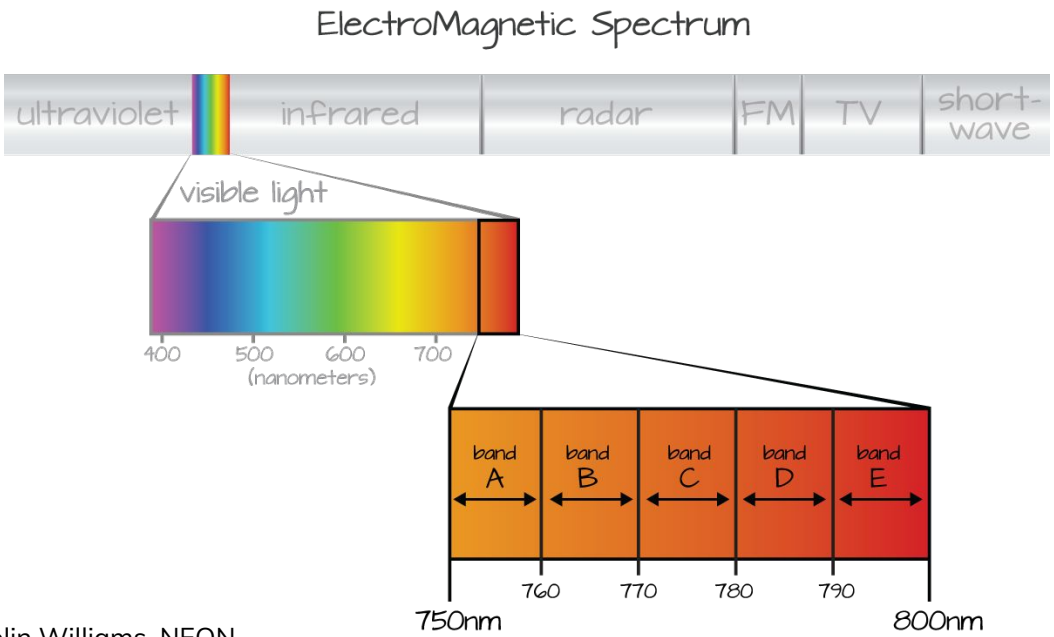
- Number of dimensions (or bands) of a specific wavelength to which a remote sensing instrument is sensitive and the range of those channels



Source: Colin Williams, NEON

Spectral resolution

- Number of dimensions (or bands) of a specific wavelength to which a remote sensing instrument is sensitive and the range of those channels

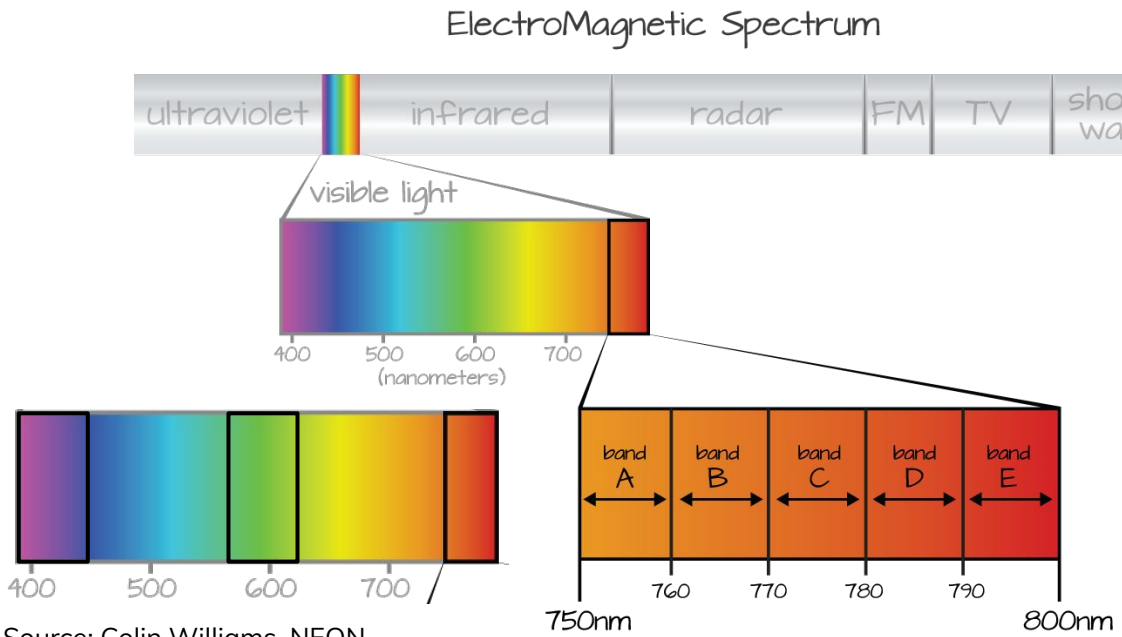


Better resolution	Worse resolution
36 bands 10 nm bandwidth	4 bands 100 nm bandwidth

Source: Colin Williams, NEON

Spectral resolution

- Number of dimensions (or bands) of a specific wavelength to which a remote sensing instrument is sensitive and the range of those channels

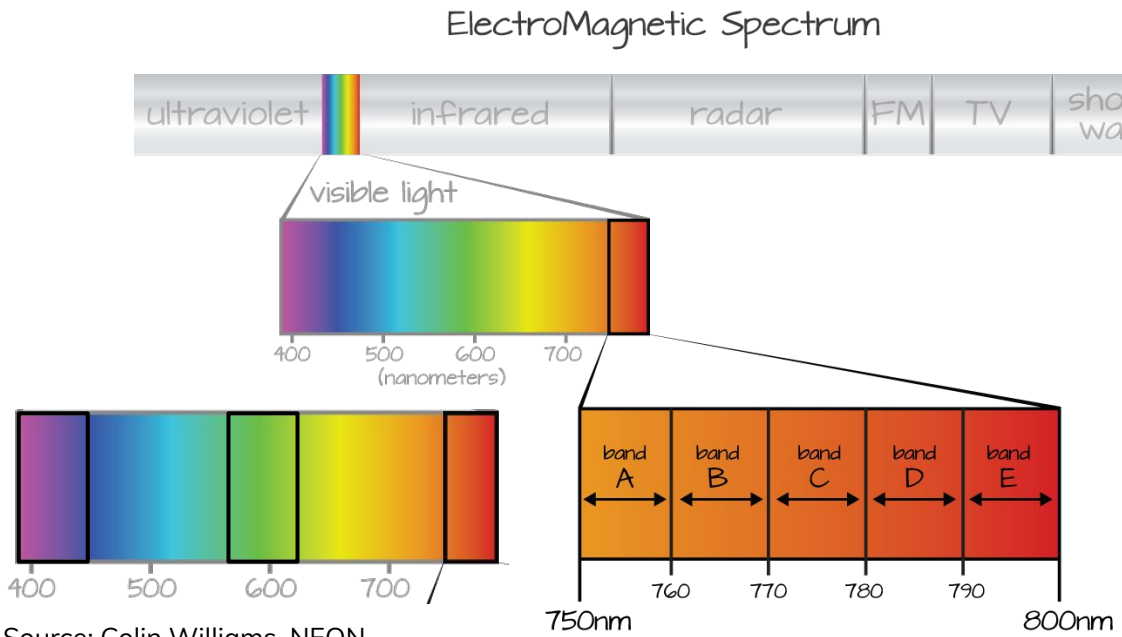


Better resolution	Worse resolution
36 bands 10 nm bandwidth	4 bands 100 nm bandwidth

Source: Colin Williams, NEON

Spectral resolution

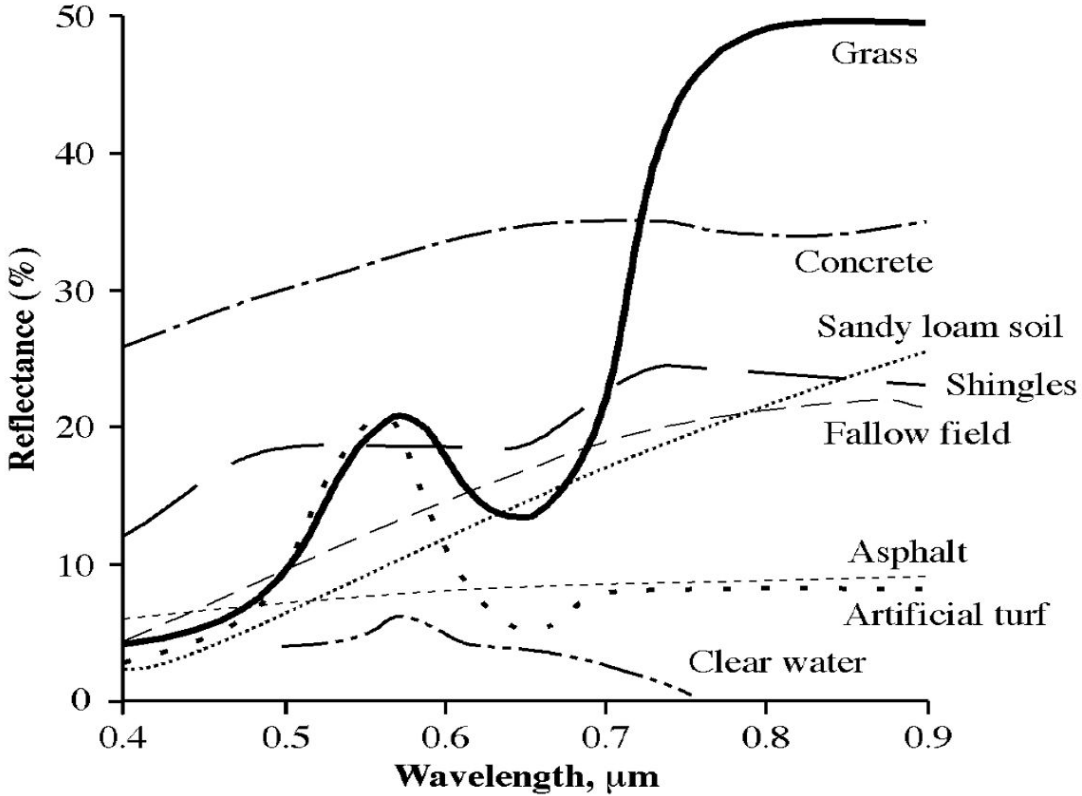
- Number of dimensions (or bands) of a specific wavelength to which a remote sensing instrument is sensitive and the range of those channels



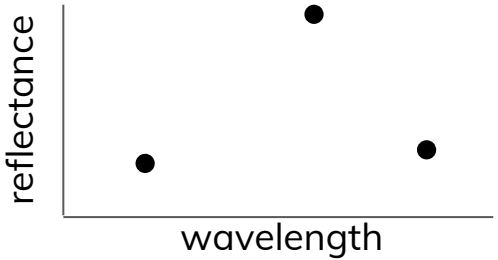
Better resolution	Worse resolution
36 bands 10 nm bandwidth	4 bands 100 nm bandwidth

Source: Colin Williams, NEON

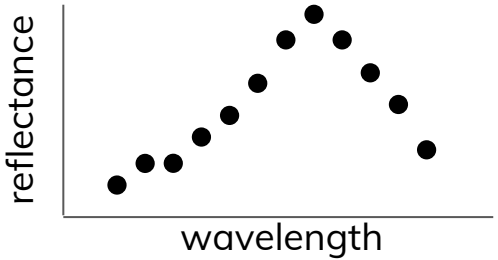
Spectral resolution



worse



better



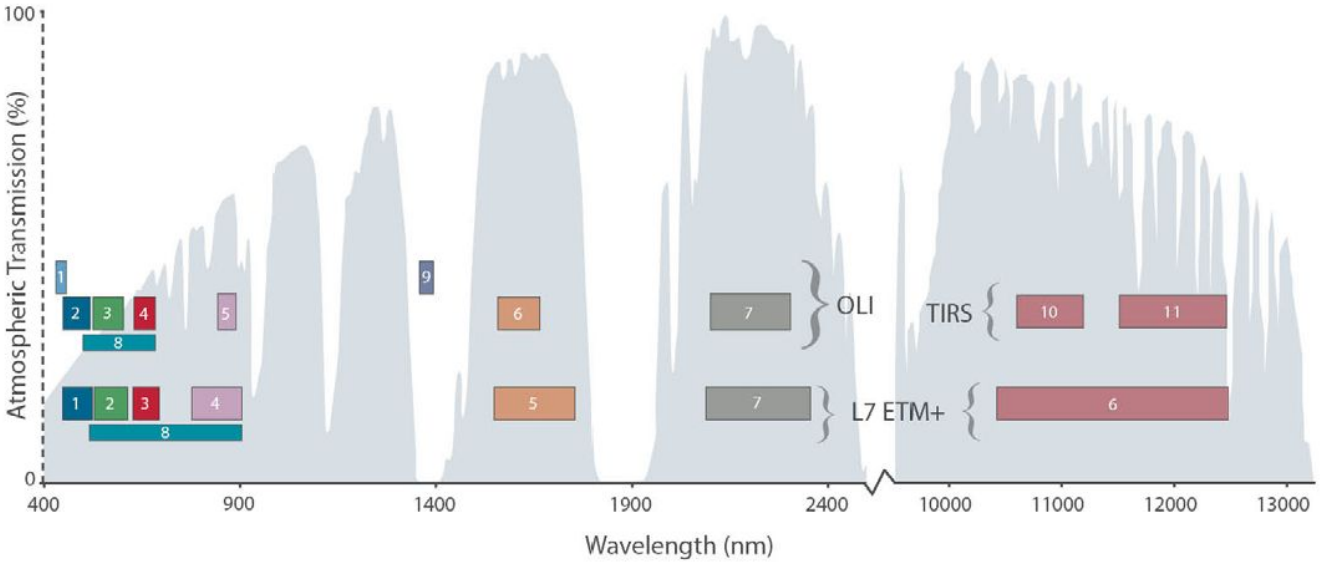
Spectral resolution

Landsat 8 Bands

Band	Wavelength range (nm)	Spatial Resolution (m)	Spectral Width (nm)
Band 1 - Coastal aerosol	430 - 450	30	2.0
Band 2 - Blue	450 - 510	30	6.0
Band 3 - Green	530 - 590	30	6.0
Band 4 - Red	640 - 670	30	0.03
Band 5 - Near Infrared (NIR)	850 - 880	30	3.0
Band 6 - SWIR 1	1570 - 1650	30	8.0
Band 7 - SWIR 2	2110 - 2290	30	18
Band 8 - Panchromatic	500 - 680	15	18
Band 9 - Cirrus	1360 - 1380	30	2.0

Landsat 8

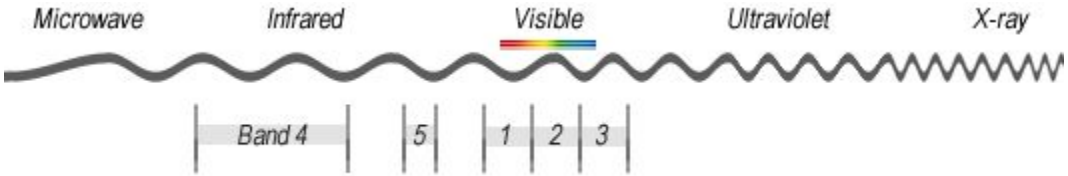
Landsat 7



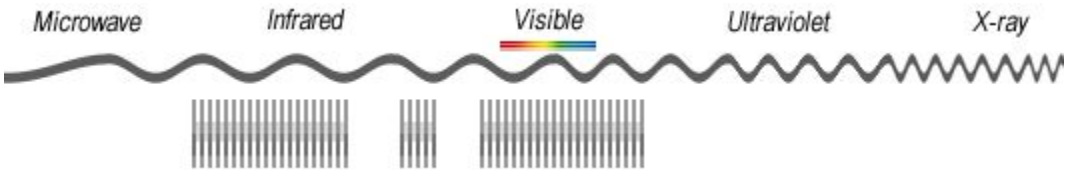
Source: USGS

Spectral resolution

Multispectral

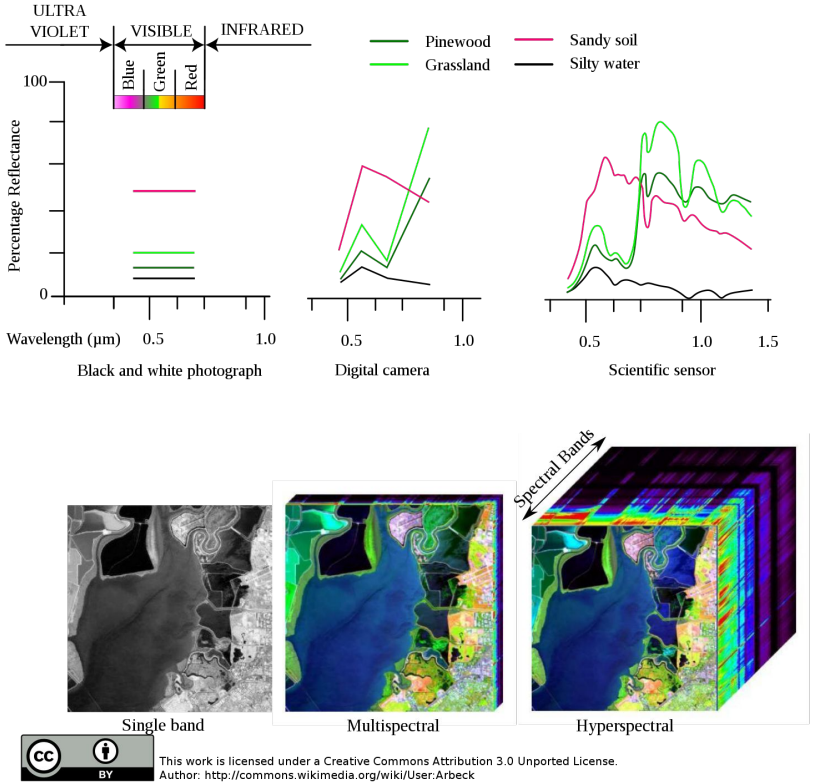


Hyperspectral



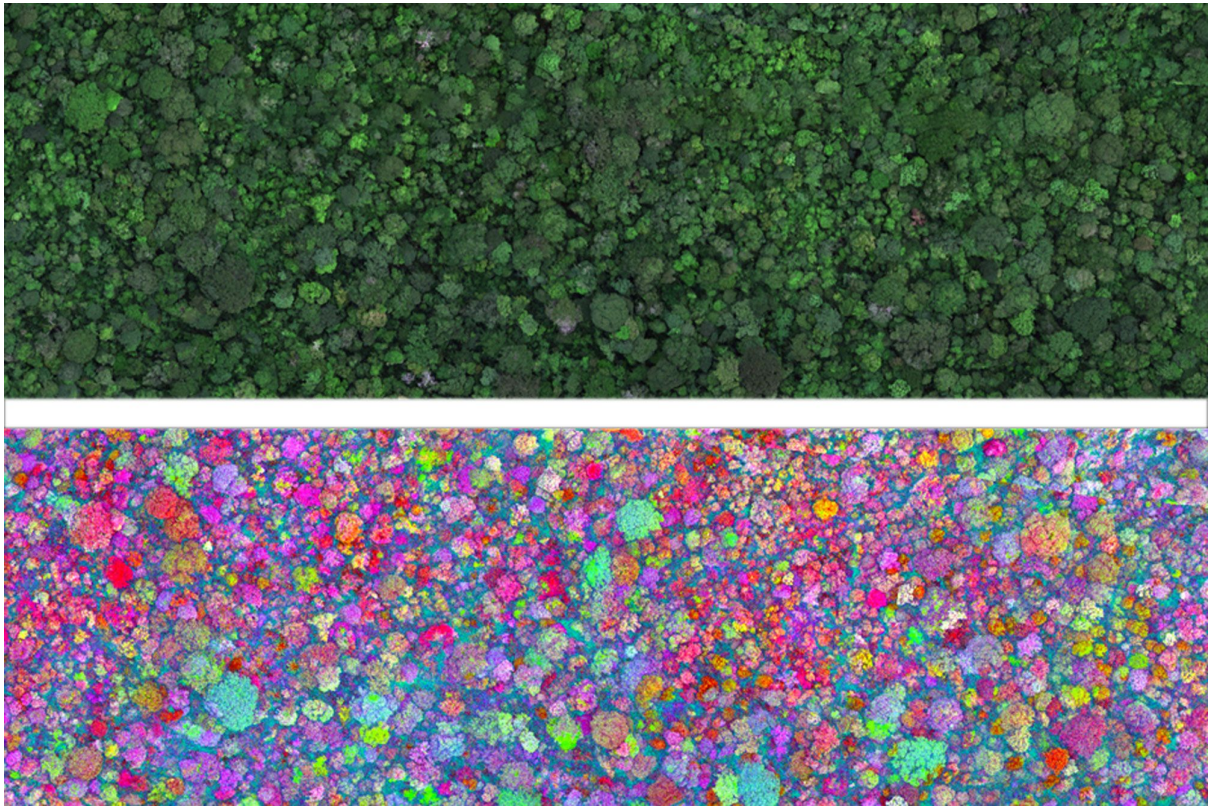
Source: GIS Geography

Spectral resolution



Source: Wikimedia Commons

Spectral resolution



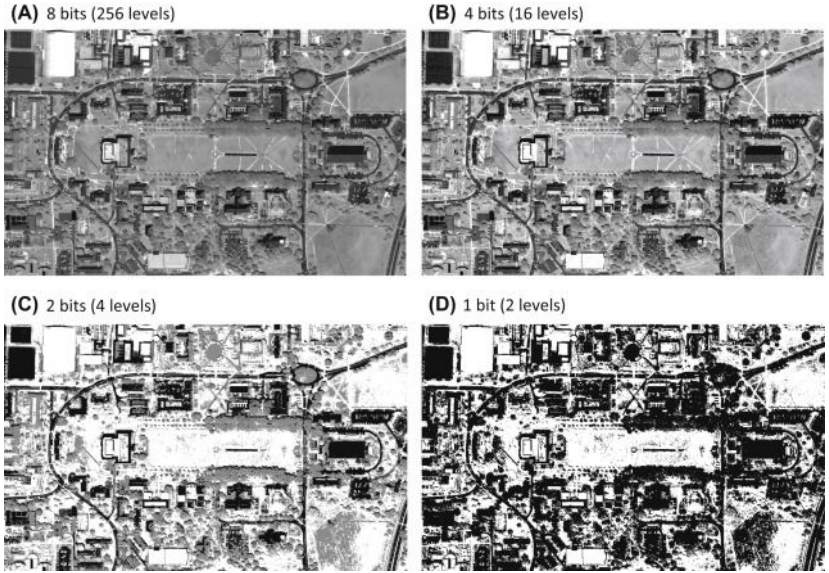
Source: Asner Lab

Image resolutions

- **Spatial**
  - Raster resolution
- **Temporal**
  - Number of rasters for same location
- **Spectral**
  - Number of layers for each raster
- **Radiometric**

Radiometric resolution

- Number of different output numbers in each band of data
  - Determined by the number of bits into which the recorded radiation is divided
  - “Dynamic range”

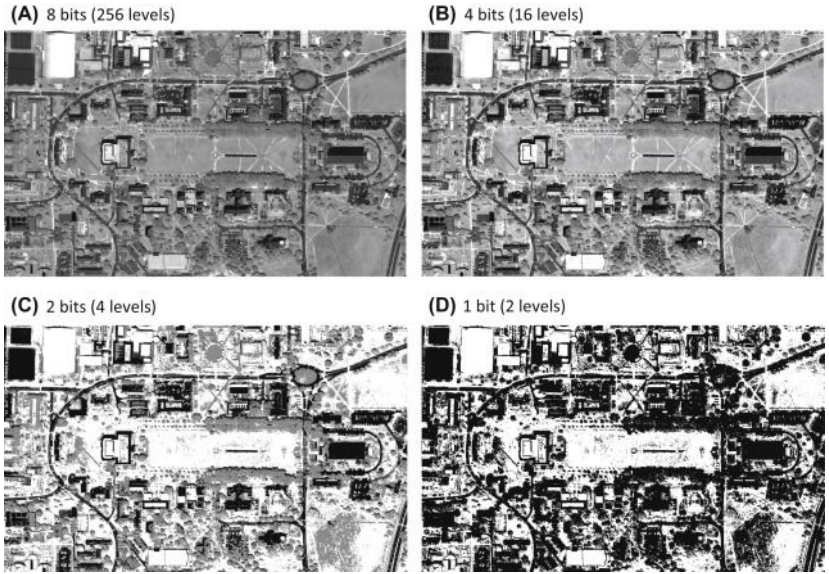


Better resolution	Worse resolution
8 bit	2 bit

Source: Advanced Remote Sensing 2020

Radiometric resolution

- Number of different output numbers in each band of data
  - Determined by the number of bits into which the recorded radiation is divided
  - “Dynamic range”

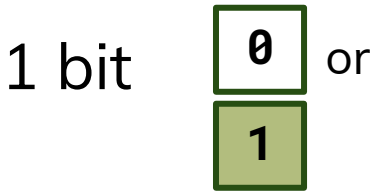


Better resolution	Worse resolution
8 bit	2 bit

Source: Advanced Remote Sensing 2020

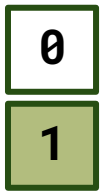
What is a bit?

- A single placeholder which be a 0 (off) or 1 (on)



What is a bit?

- **A single placeholder which be a 0 (off) or 1 (on)**

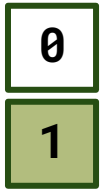
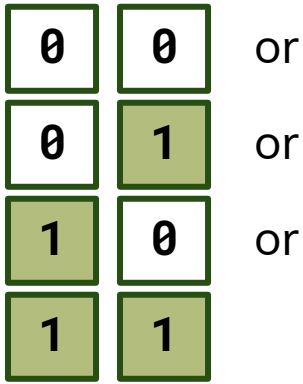
1 bit 

or

Number of possible values	Possible values
2	0-1

What is a bit?

- A single placeholder which be a 0 (off) or 1 (on)

		Number of possible values	Possible values
1 bit		2	0-1
2 bit		4	0-3

What is a bit?

- A single placeholder which be a 0 (off) or 1 (on)

		Number of possible values	Possible values
1 bit	0 or 1	2	0-1
2 bit	0 0 or 0 1 or 1 0 or 1 1	4	0-3

What is a bit?

- **A single placeholder which be a 0 (off) or 1 (on)**

	Number of possible values	Possible values
1 bit	2	0-1
2 bit	4	0-3
n bit	2^n	0 - (2^n-1)

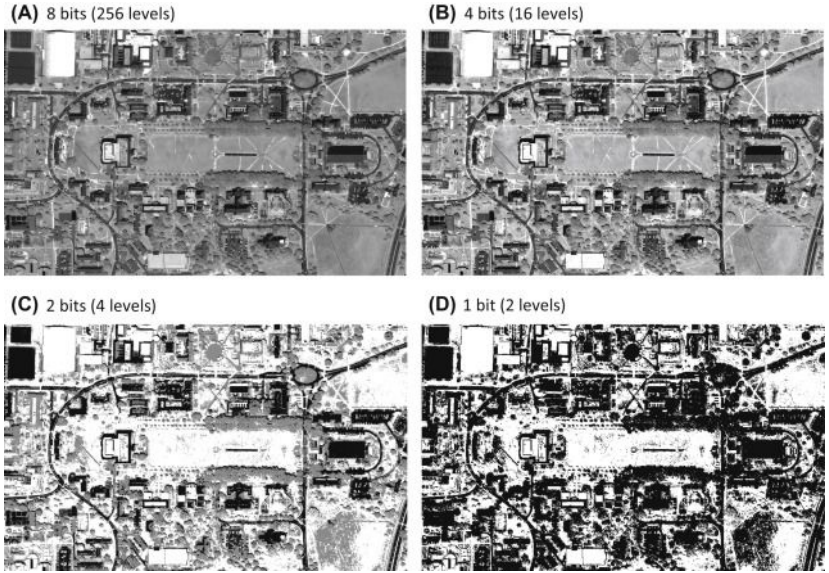
What is a bit?

- **A single placeholder which be a 0 (off) or 1 (on)**

	Number of possible values	Possible values
1 bit	2	0-1
2 bit	4	0-3
8 bit	256	0-255
n bit	2^n	0 - (2^n-1)

Radiometric resolution

- Number of different output numbers in each band of data
  - Determined by the number of bits into which the recorded radiation is divided
  - “Dynamic range”



Better resolution	Worse resolution
8 bit	2 bit

Source: Advanced Remote Sensing 2020

Image resolutions

- **Spatial**
  - Raster resolution
- **Temporal**
  - Number of rasters for same location
- **Spectral**
  - Number of layers for each raster
- **Radiometric**
  - Number of possible values for each raster cell

Image resolutions

- **Spatial**
  - Measure of the smallest angular or linear separation between two object
    - Pixel size
- **Temporal**
  - Time interval between acquisitions of a particular area
    - Revisit time
- **Spectral**
  - Number of dimensions (or bands) of a specific wavelength to which a remote sensing instrument is sensitive and the range of those channels
    - Number and range of bands
- **Radiometric**
  - Number of different output numbers in each band of data
    - Number of shades of grey

Image resolutions

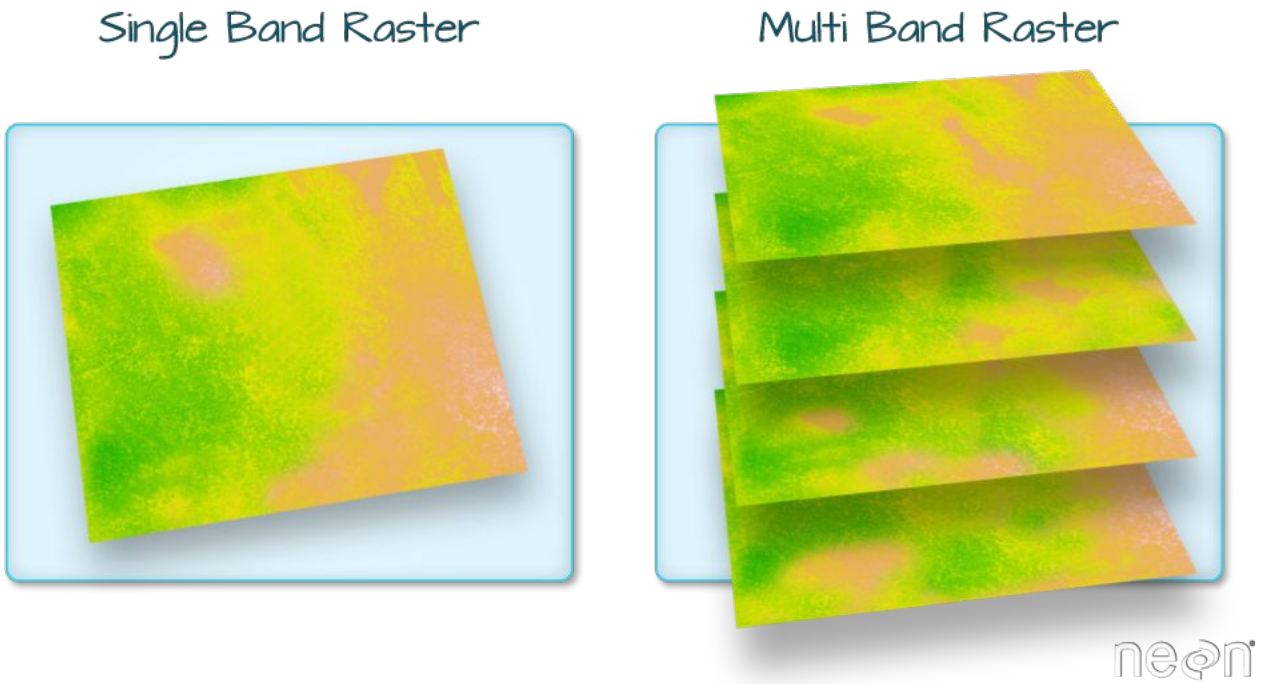
↑ **Spatial resolution** ↓ **Less light collected** ↓ **Radiometric resolution**

↑ **Temporal resolution** ↓ **Less light collected** ↓ **Spatial resolution**

↑ **Spectral or spatial resolution** ↑ **File size**

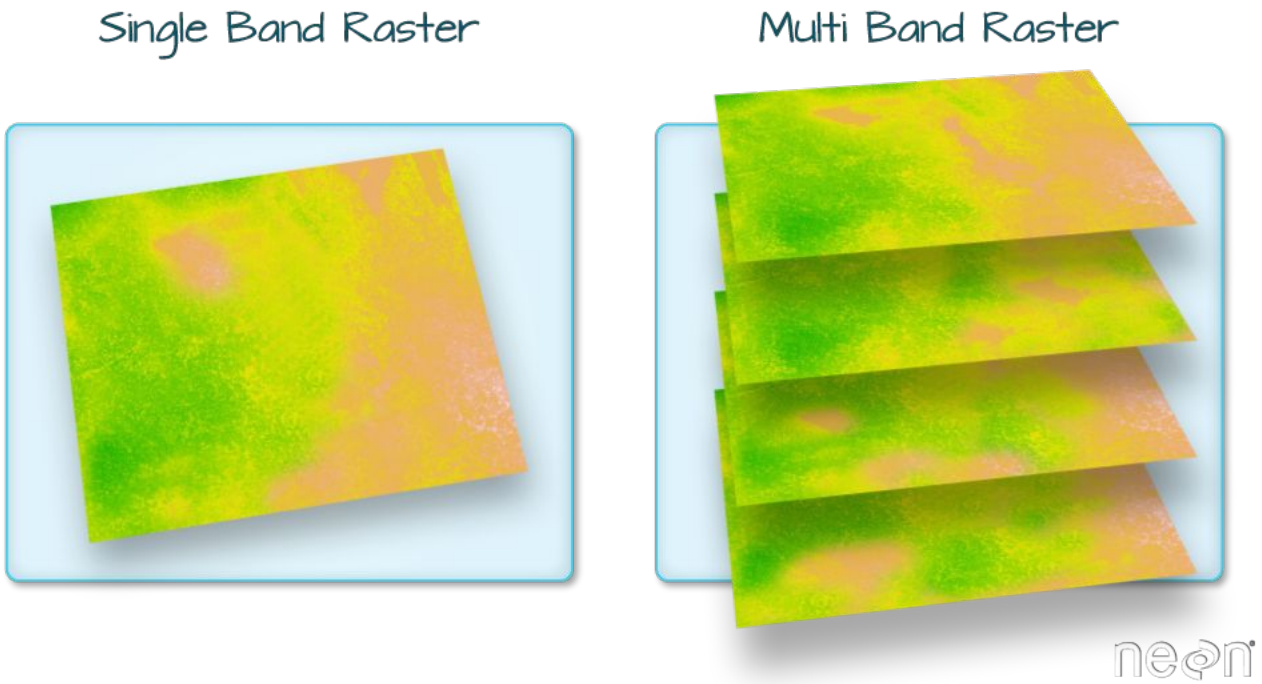
Size of image = number of pixels * bits per pixel

Working with remote sensing data

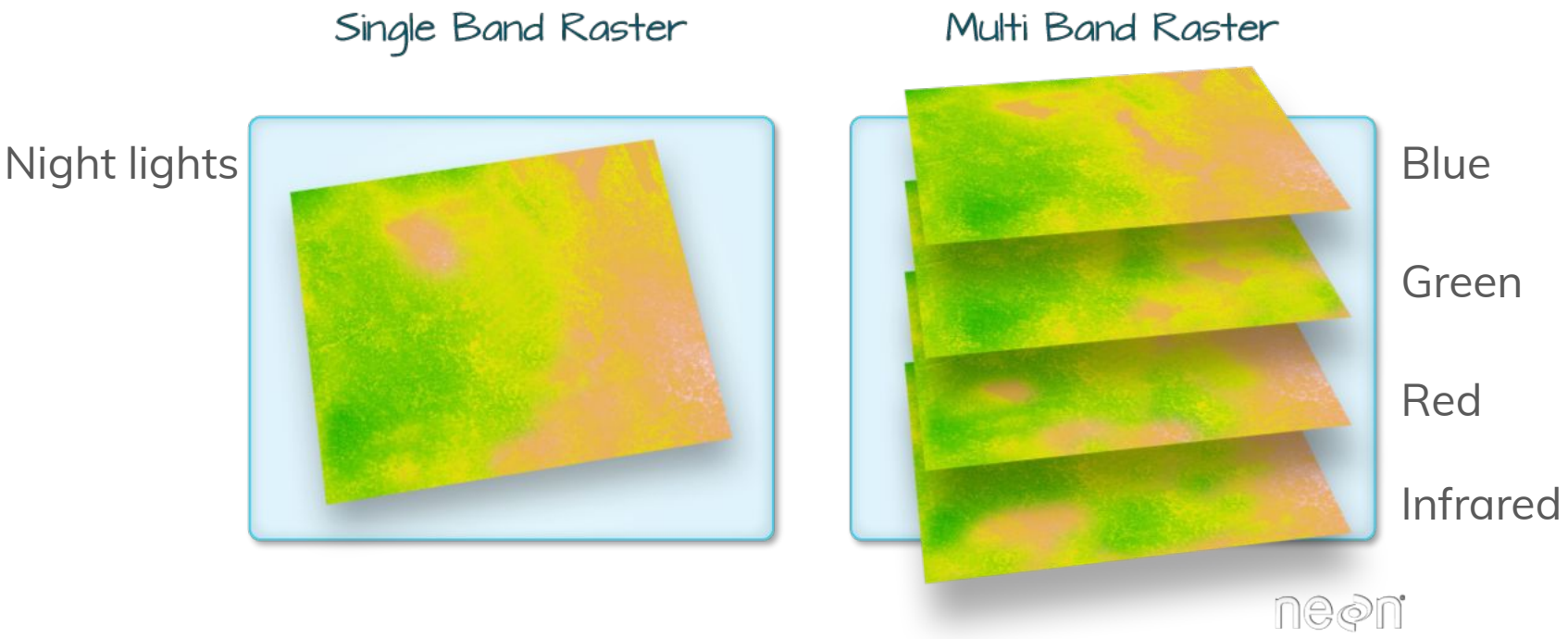


Working with remote sensing data

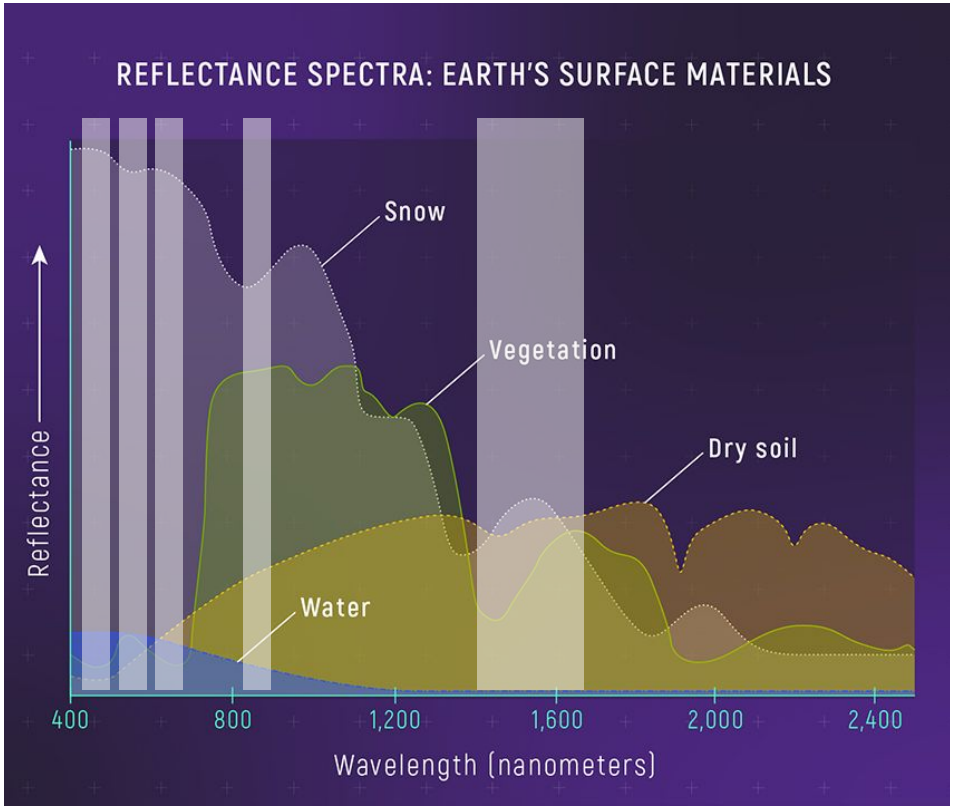
Plot it!



Working with remote sensing data



Visualizing remote sensing data

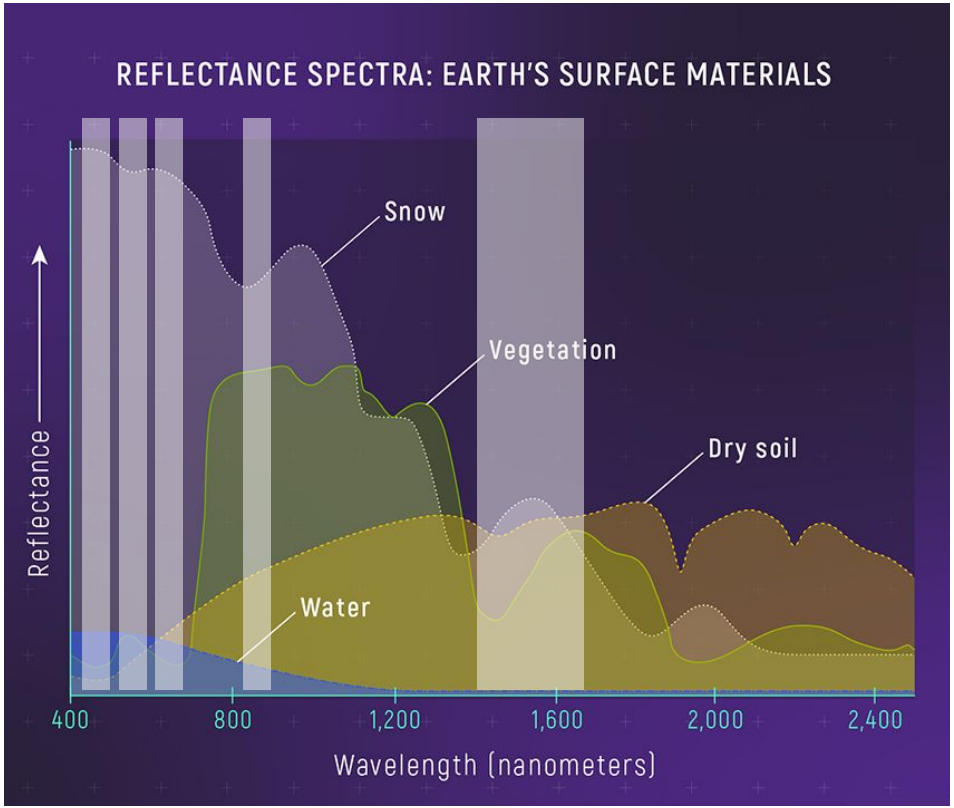


Source: NASA, Leah Hustak

Visualizing remote sensing data

vegetation

wavelength	reflectance
blue	low
green	high
red	low
infrared	really high

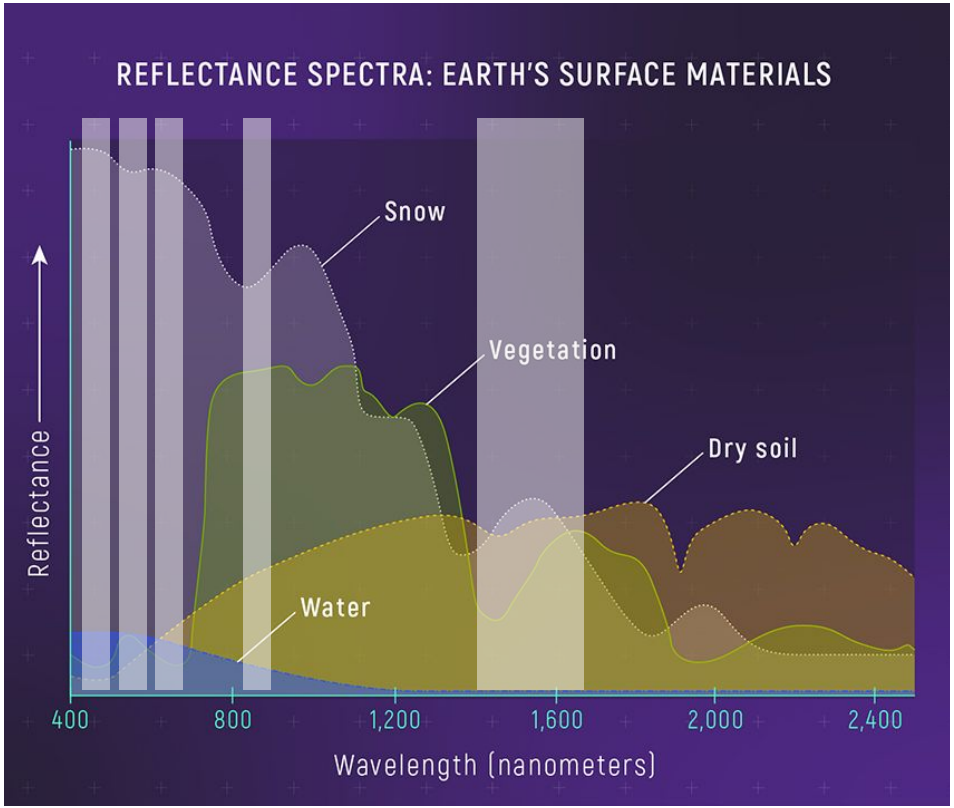


Source: NASA, Leah Hustak

Visualizing remote sensing data

vegetation

wavelength	reflectance
blue	low
green	high
red	low
infrared	really high

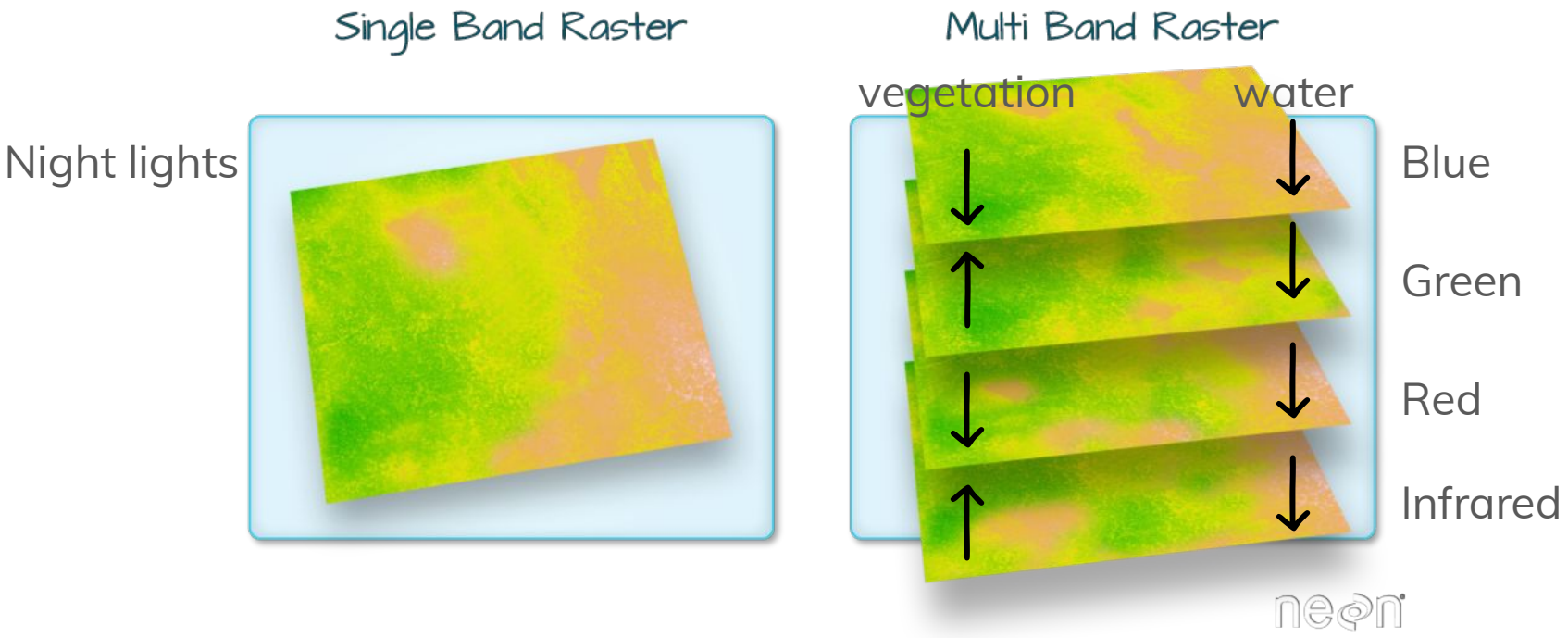


water

wavelength	reflectance
blue	low
green	low
red	low
infrared	low

Source: NASA, Leah Hustak

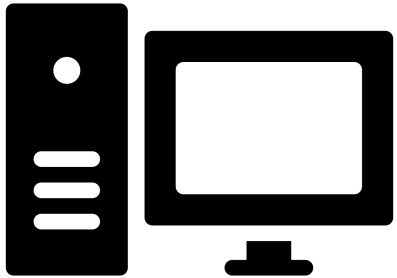
Working with remote sensing data



What is remote sensing?

"the **art**, **science, and technology** of obtaining reliable information about physical objects and the environment, through the process of recording, measuring, and interpreting imagery and digital representations of **energy** patterns derived from **non-contact sensor systems**."
(Colwell, 1997)

Visualizing remote sensing data

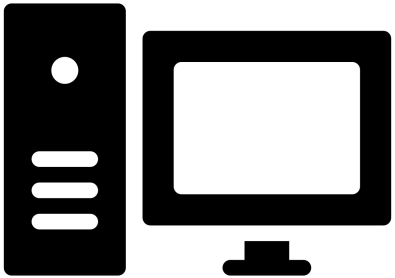


Visualizing remote sensing data

What you see..

Your computer sees..

1	11	155
4	20	174
6	55	202
23	72	33
37	90	41

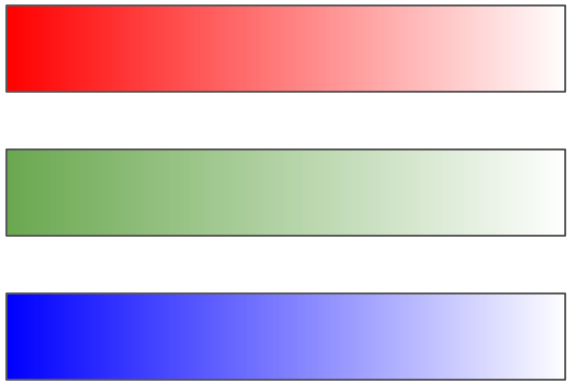


Low values

High values

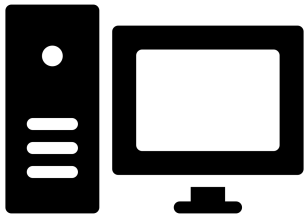
Visualizing remote sensing data

Low values High values

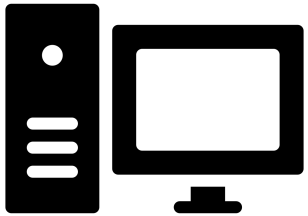


8 bit image: 2^8 = 256 values per band

RGB display: 256 * 256 * 256 = more than 16 million color combinations



Visualizing remote sensing data



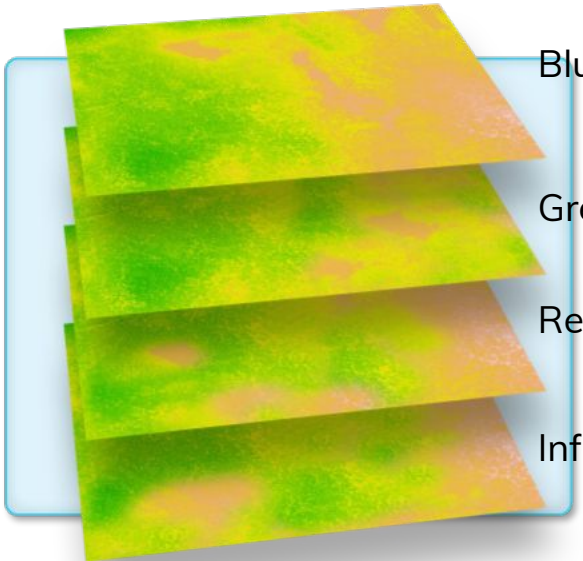
Low values High values

Red channel

Green channel

Blue channel

Multi Band Raster



Blue band

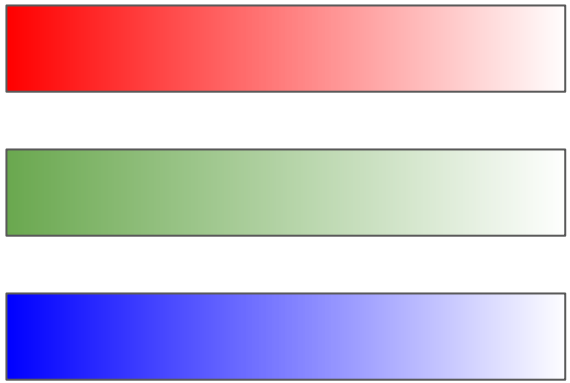
Green band

Red band

Infrared band

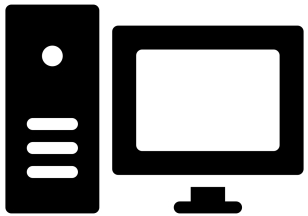
Visualizing remote sensing data

Low values High values



8 bit image: 2^8 = 256 values per band

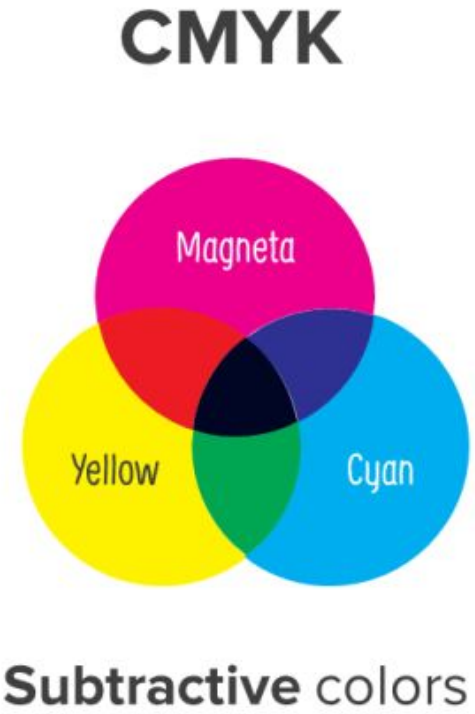
RGB display: 256 * 256 * 256 = **more than 16 million color combinations**



Color mixing: RGB

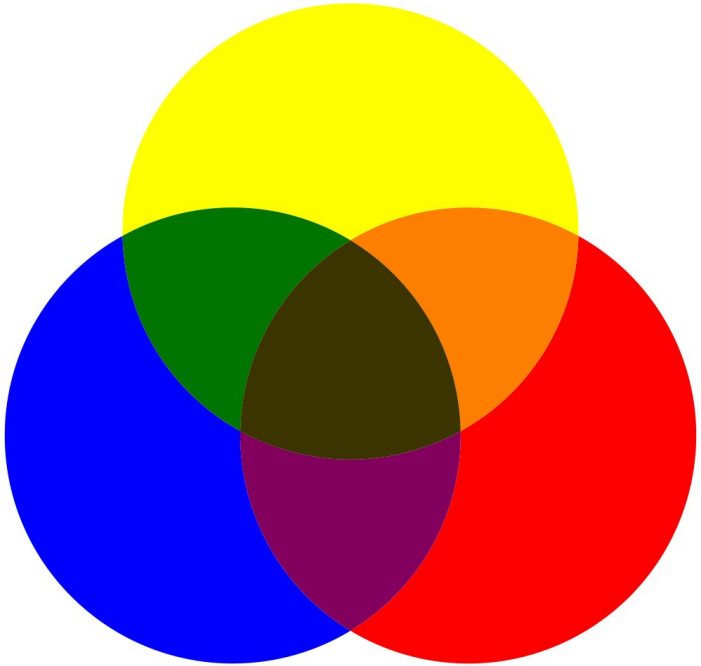
- Red, Green, Blue color model
- Additive color model
- Start with black and “add” colors to make white
- Primary colors
  - Red
  - Green
  - Blue
- Secondary colors
  - Magenta
  - Yellow
  - Cyan
- Purpose: digital display
- How light actually works!

Color mixing: CMYK



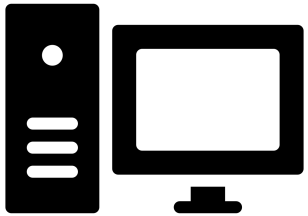
- Cyan, Magenta, Yellow, Key (black) color model
- Subtractive color model
- Start with white and “subtract” colors to make black
- Primary colors
  - Magenta
  - Yellow
  - Cyan
- Secondary colors
  - Red
  - Green
  - Blue
- Purpose: paints

Wait…. What about RYB?



- Red, Yellow, Blue color model
- Subtractive color model
- Predates modern color theory

True and False color imagery



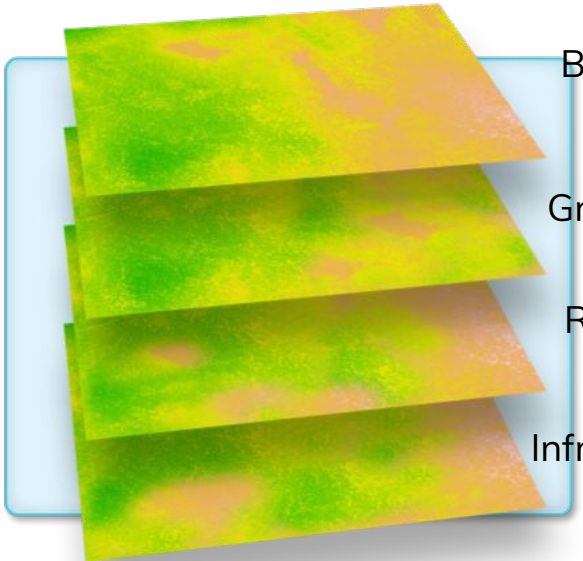
Low values High values

Red channel

Green channel

Blue channel

Multi Band Raster



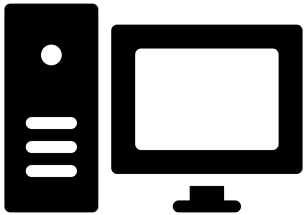
Blue band

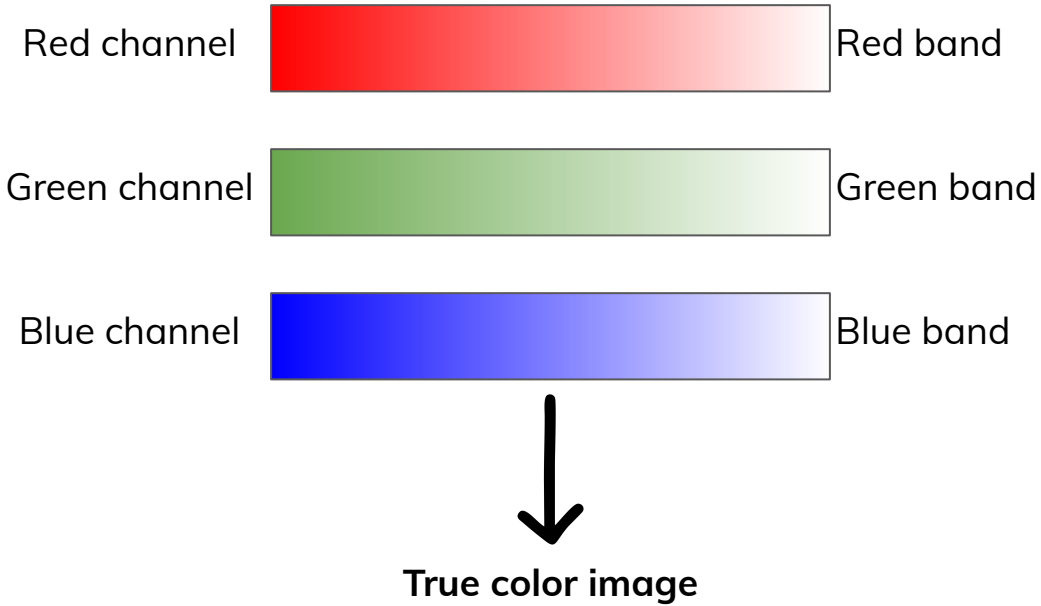
Green band

Red band

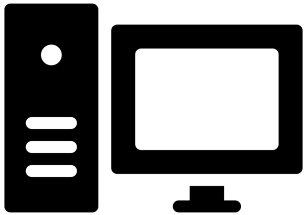
Infrared band

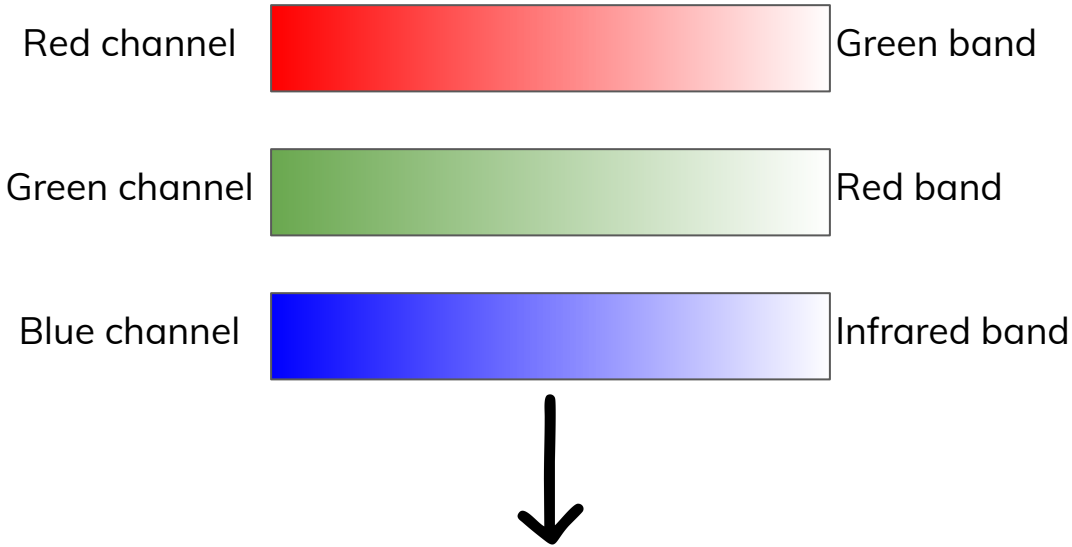
True and False color imagery



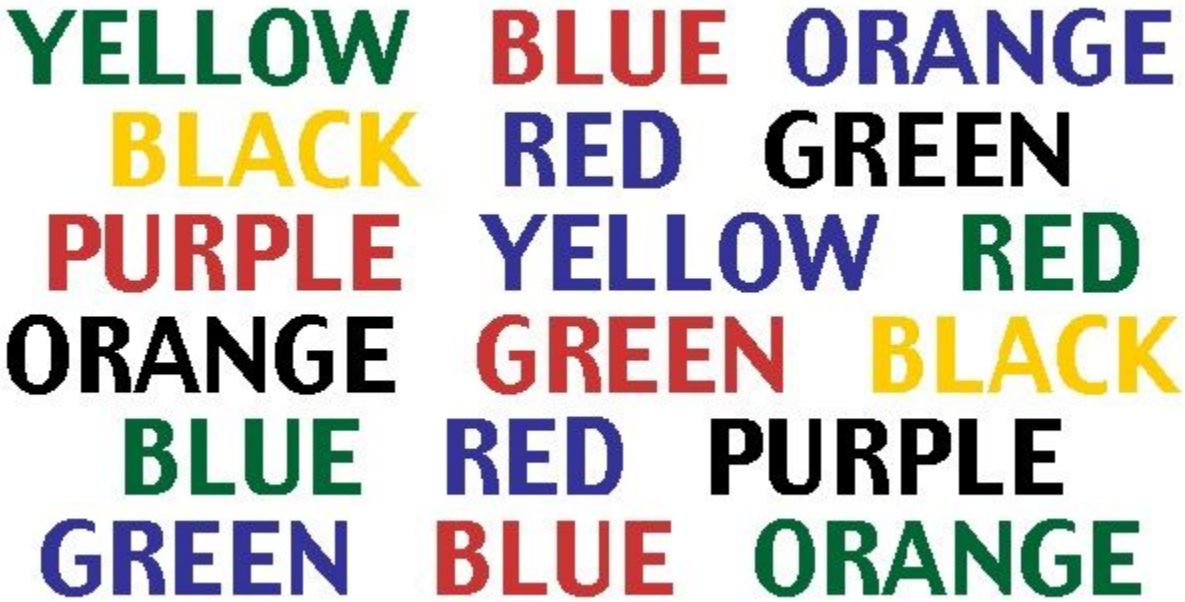


True and False color imagery





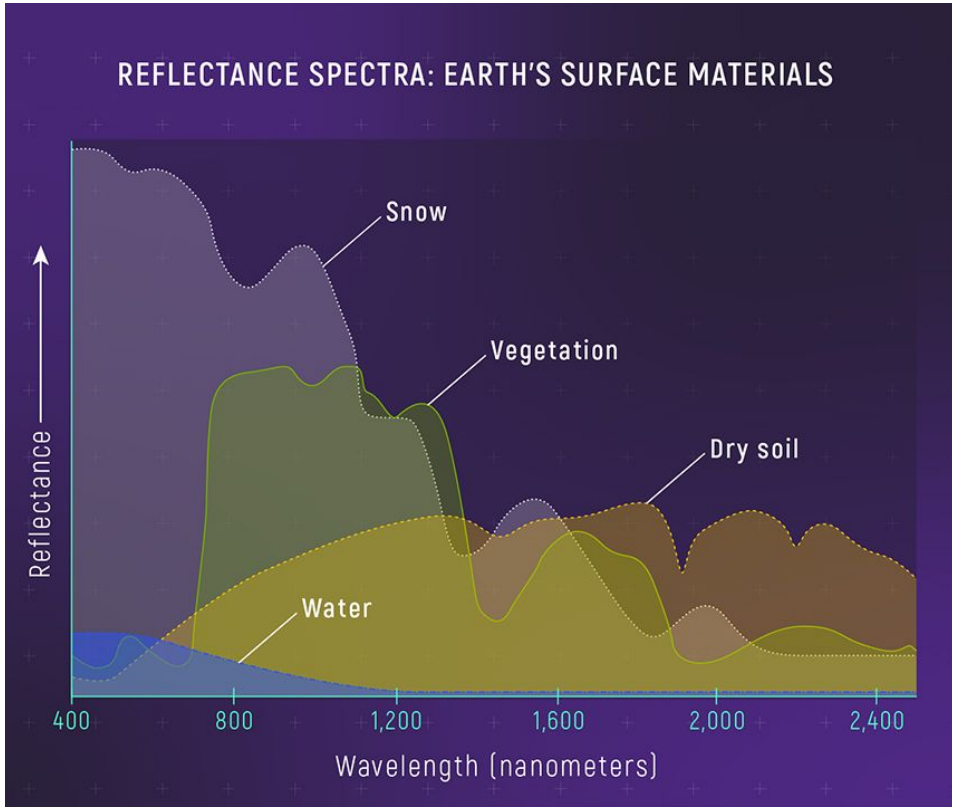
True and False color imagery



Break down

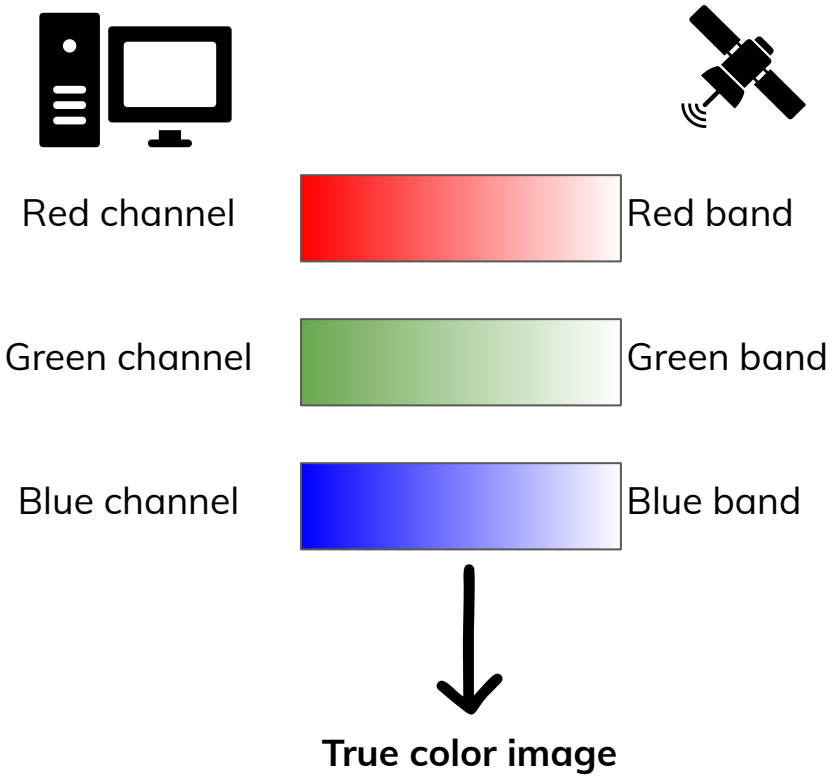
Add labels to wavelengths

True and False color imagery



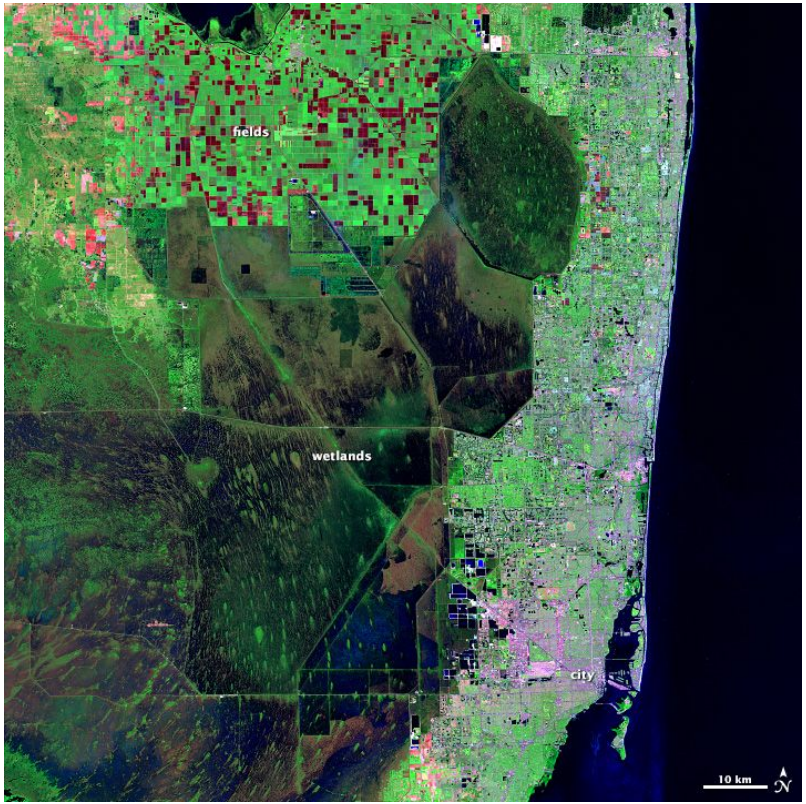
- **Blue light** (450-490 nm)
  - Reflects:
    - Water
    - Manmade features
- **Green light** (490-580 nm)
  - Reflects:
    - Chlorophyll
    - Sediment in water
- **Red light** (620-780 nm)
  - Reflects:
    - Iron and iron oxides
  - Absorbs:
    - Healthy vegetation
- **Near infrared** (700-1100 nm)
  - Absorbs:
    - Water
- **Shortwave infrared** (1100-3000 nm)
  - Reflects:
    - Fire, newly burned area
  - Absorbs:
    - Water

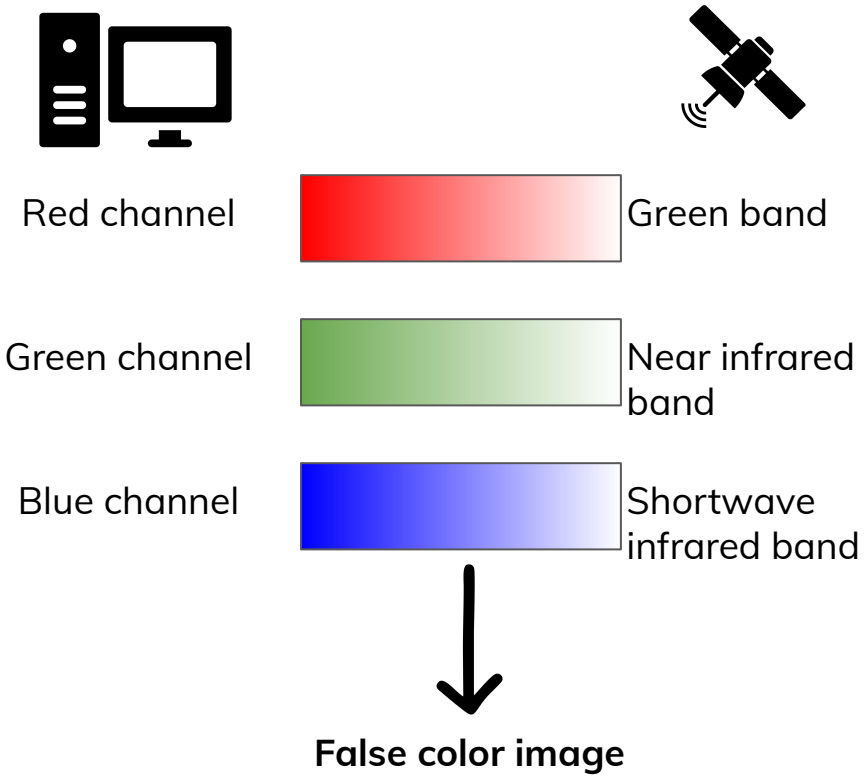
True and False color imagery



Source: NASA Earth Observatory

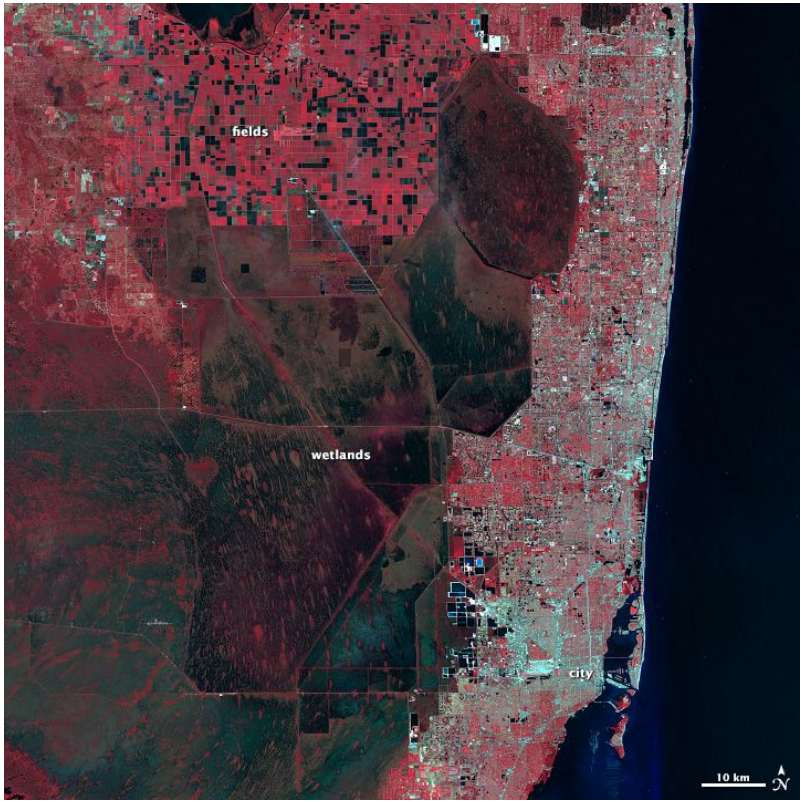
True and False color imagery

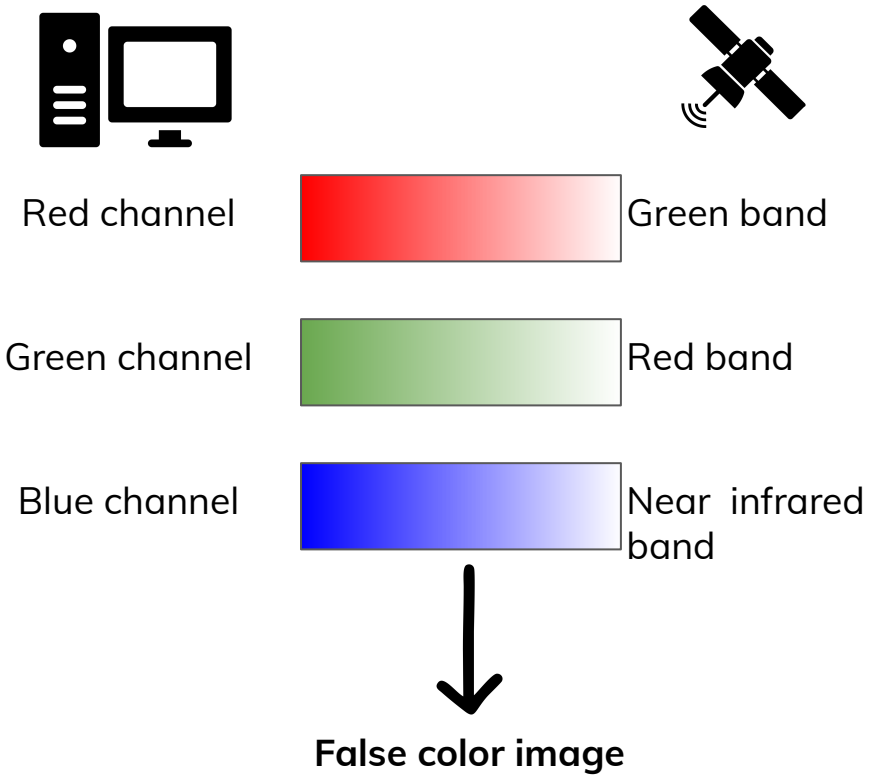




Source: NASA Earth Observatory

True and False color imagery



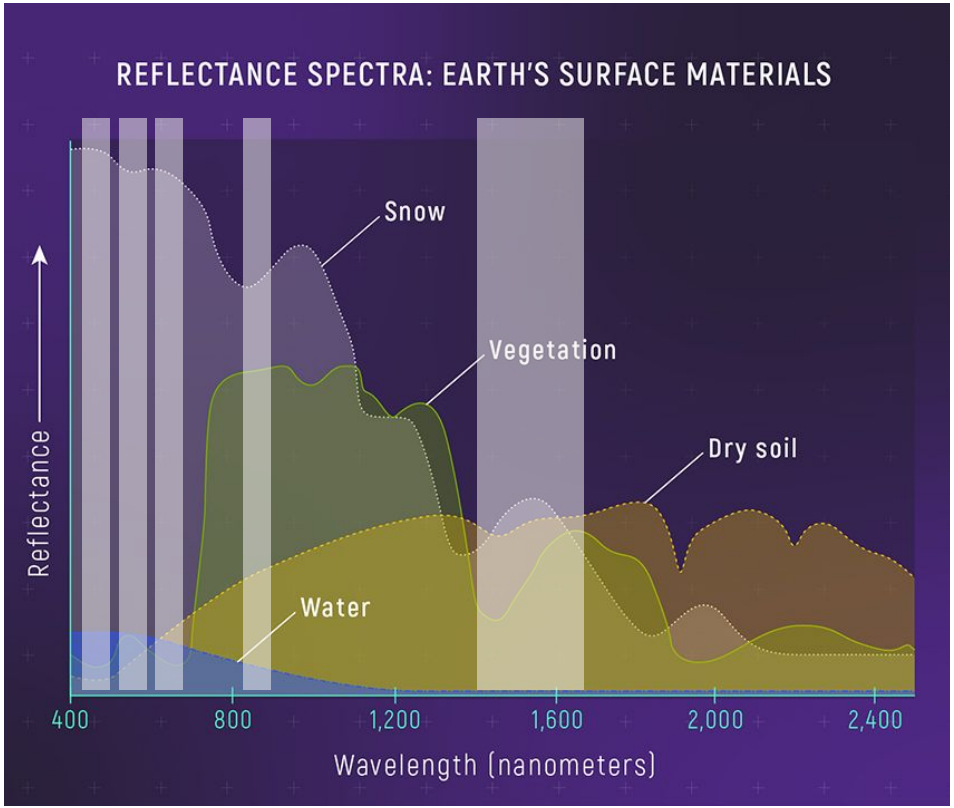


Source: NASA Earth Observatory

Visualizing remote sensing data

vegetation

wavelength	reflectance
blue	low
green	high
red	low
infrared	really high

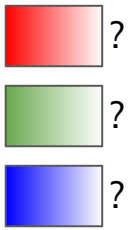


water

wavelength	reflectance
blue	low
green	low
red	low
infrared	low

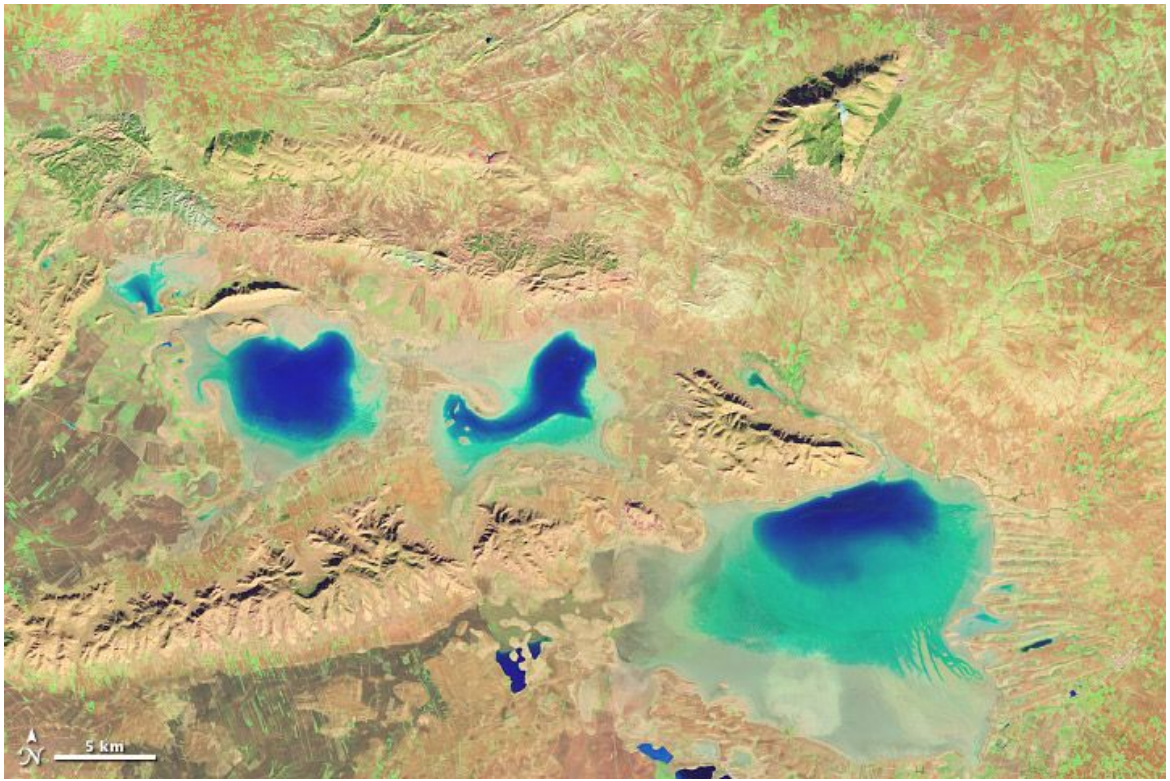
Source: NASA, Leah Hustak

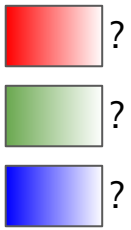
False color imagery



Source: NASA Earth Observatory

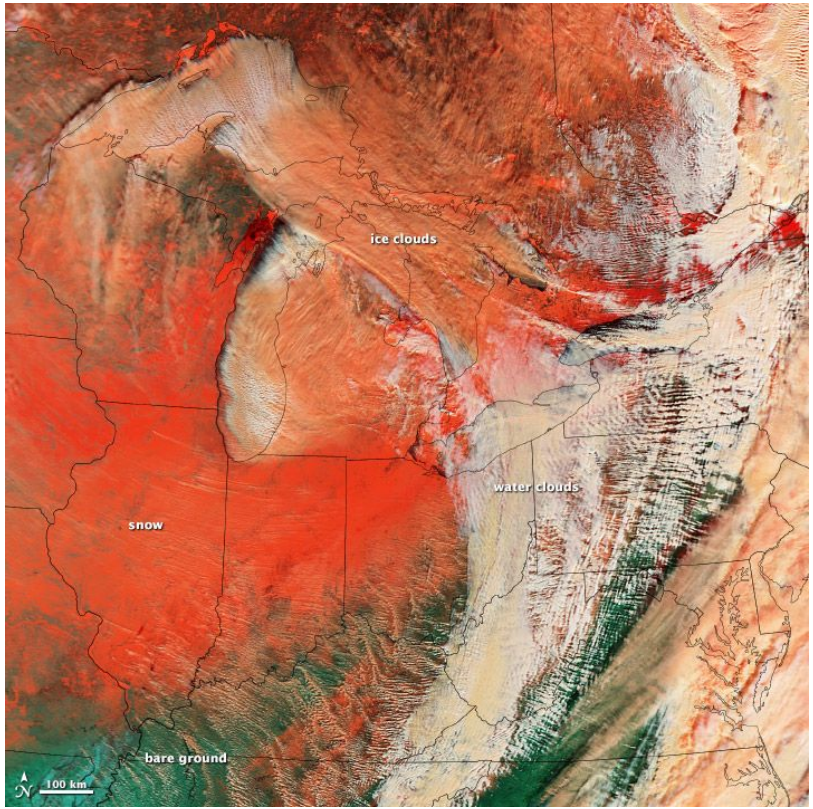
False color imagery

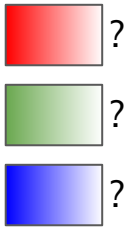




Source: NASA Earth Observatory

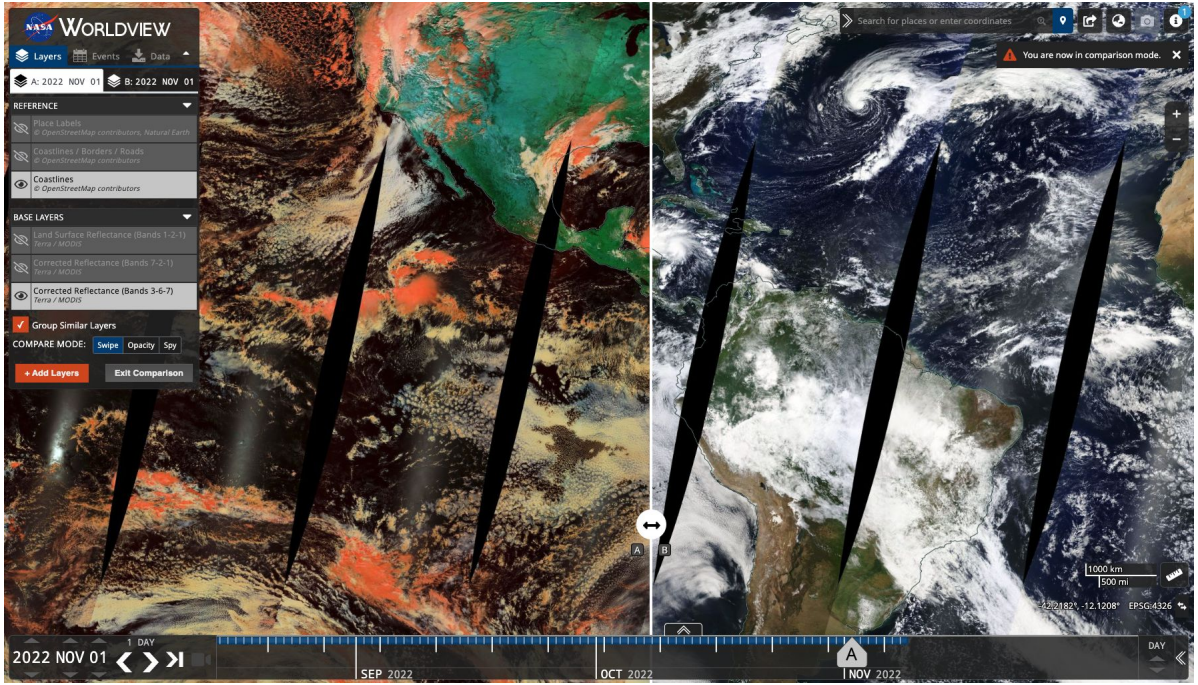
False color imagery





Source: NASA Earth Observatory

False color imagery



- Select an image
- Determine which bands are being displayed in which channels
    - What wavelengths correspond to RGB display?
- Discuss what patterns this band combination reveals

EDS 223: Geospatial Analysis & Remote Sensing
Week 7

USGS via Unsplash

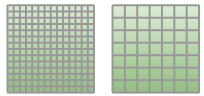
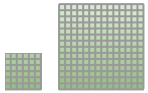
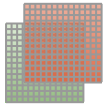
Final project guidance

terra vs. stars

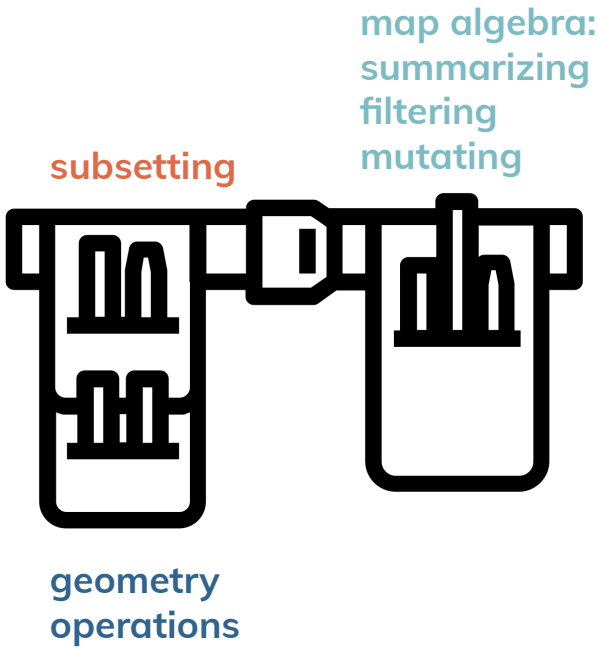
terra	stars
• Formal replacement of `raster` • Handles “regular” grids • Not explicitly set up to handle data with a temporal dimension • Simpler data structure • Good documentation	• Not a replacement of `raster` • Can handle irregular grids • Can handle data with a temporal dimension • More complicated data structure • Sparse documentation

Share a lot of functionality!

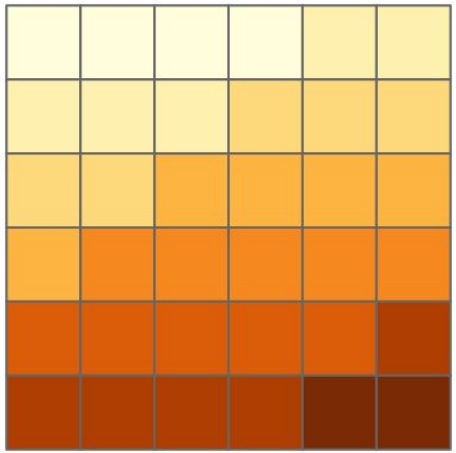
Raster data model

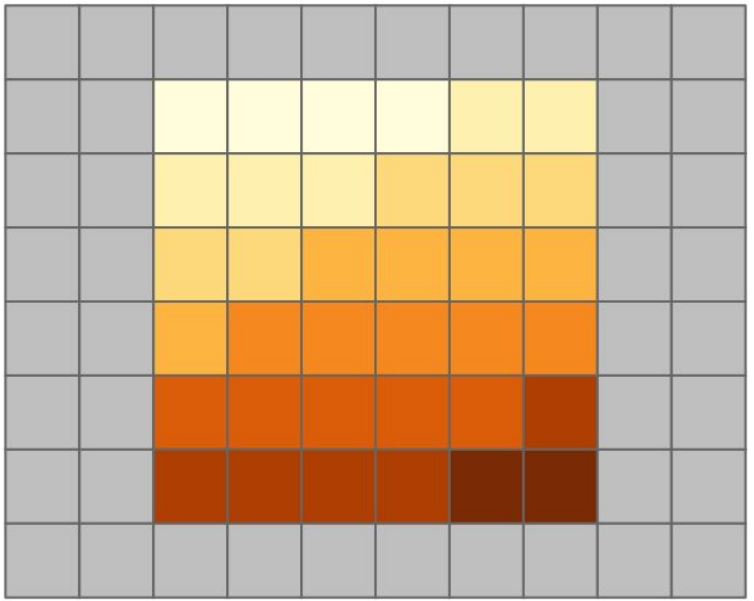
- Resolution 
- Extent 
- Position 

Toolbelt for solving spatial problems



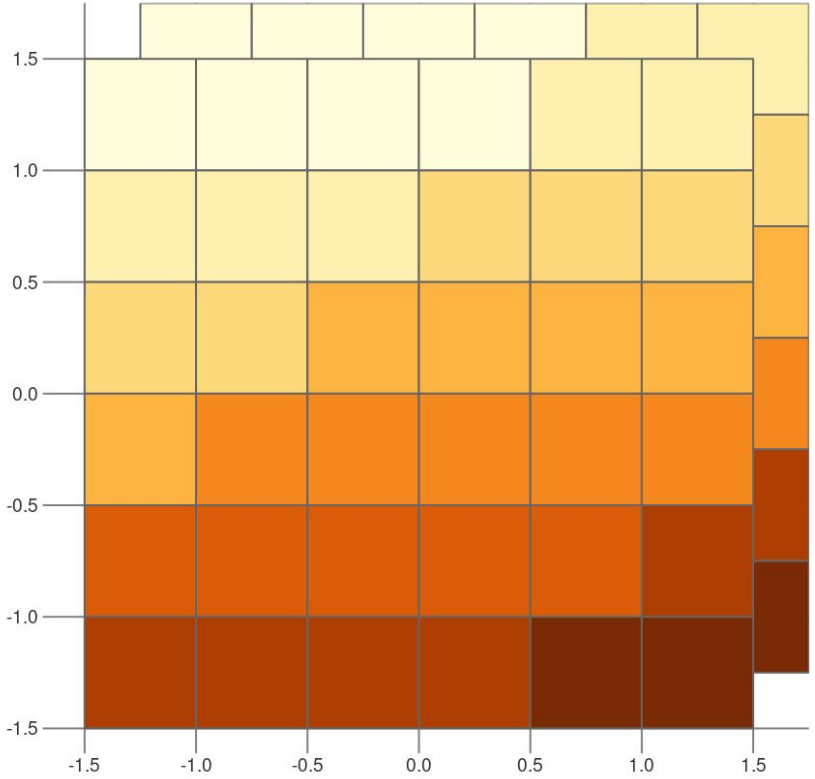
Changing extent and origin





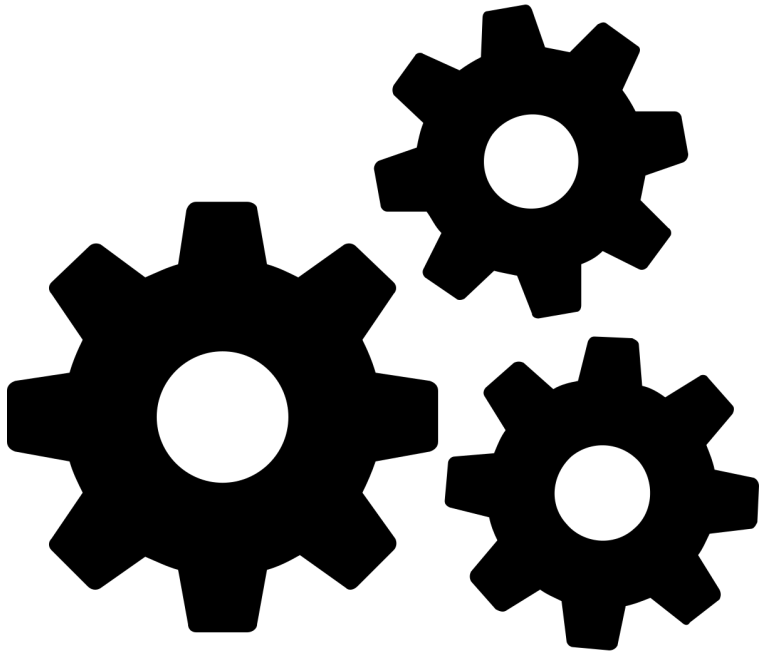
Source: Geocomputation with R, chapter 4

Changing extent and origin

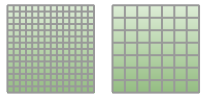
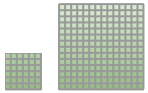
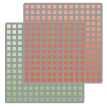


Source: Geocomputation with R, chapter 4

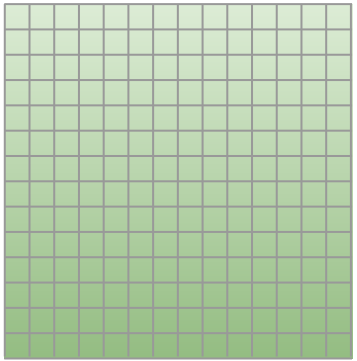
Switching gears...

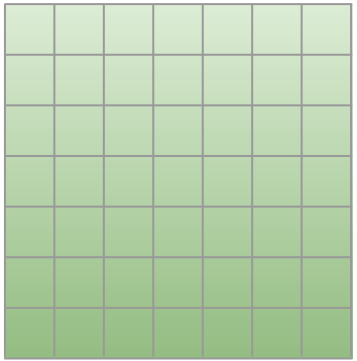


Raster data model

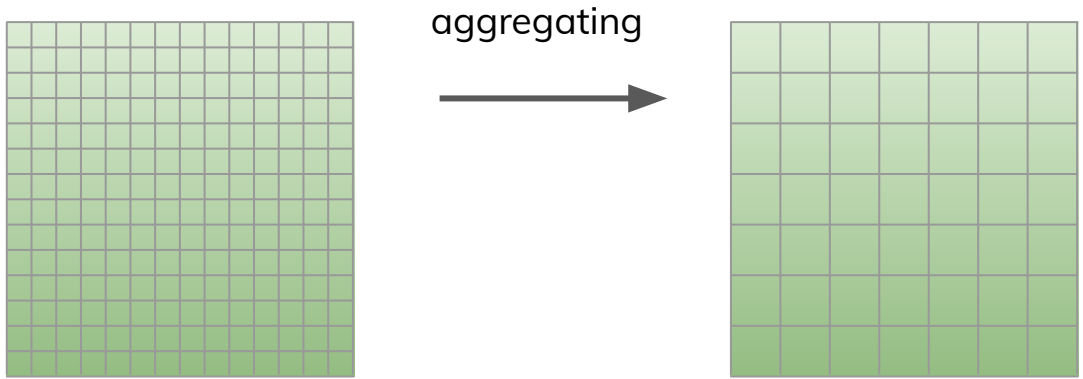
- Resolution 
- Extent 
- Position 

Changing resolution

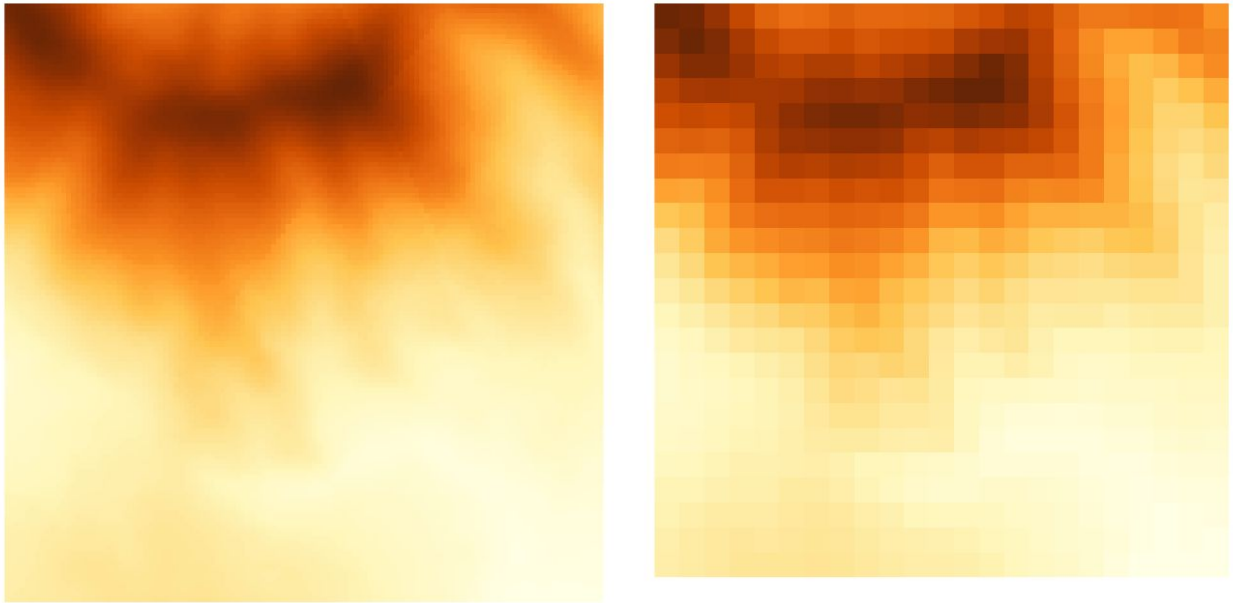




Changing resolution

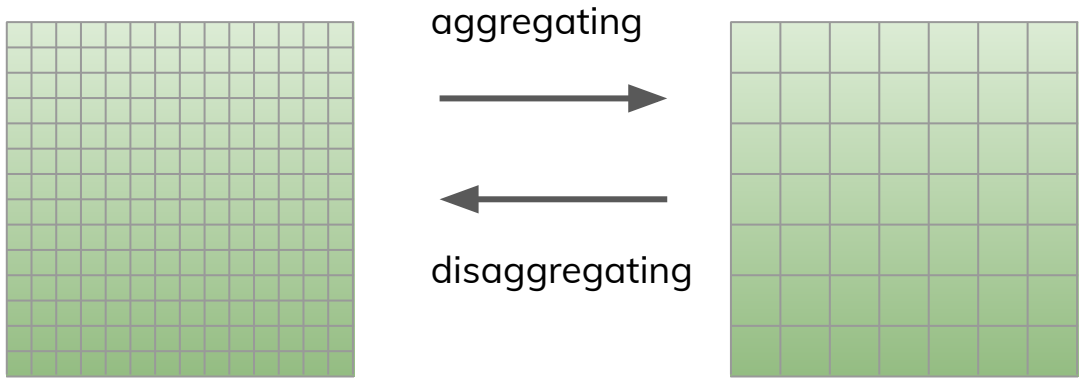


Changing resolution



Source: Geocomputation with R, chapter 5

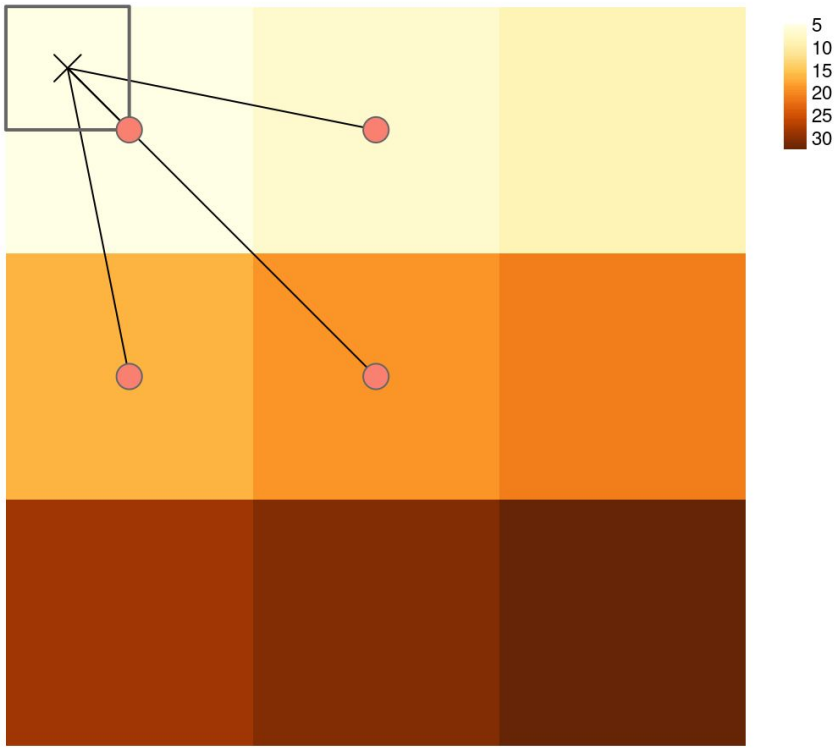
Changing resolution



Changing resolution

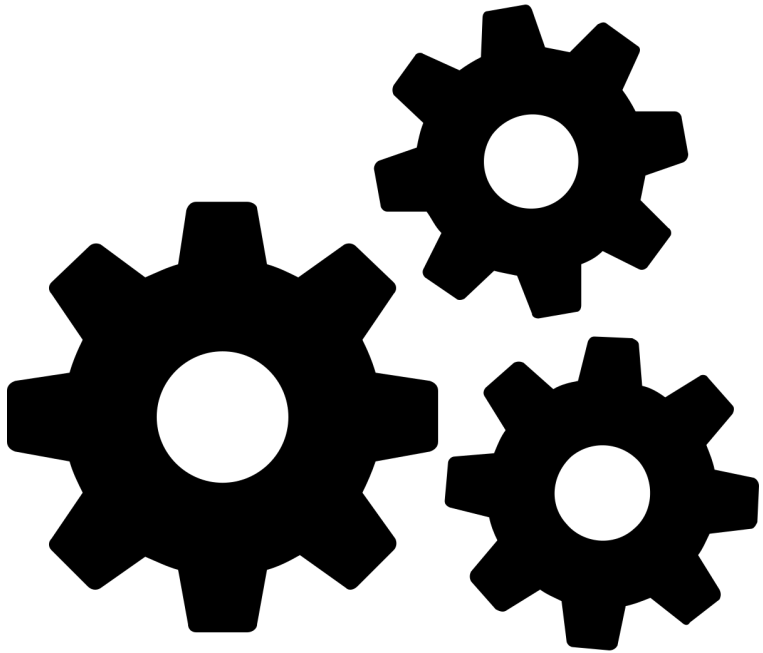
Nearest neighbor

Bilinear interpolation



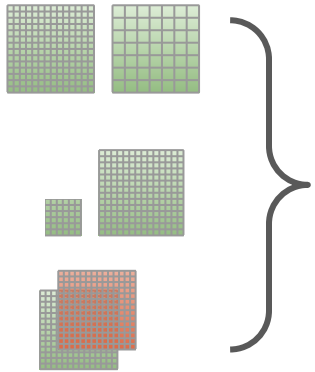
Source: Geocomputation with R, chapter 5

Switching gears...



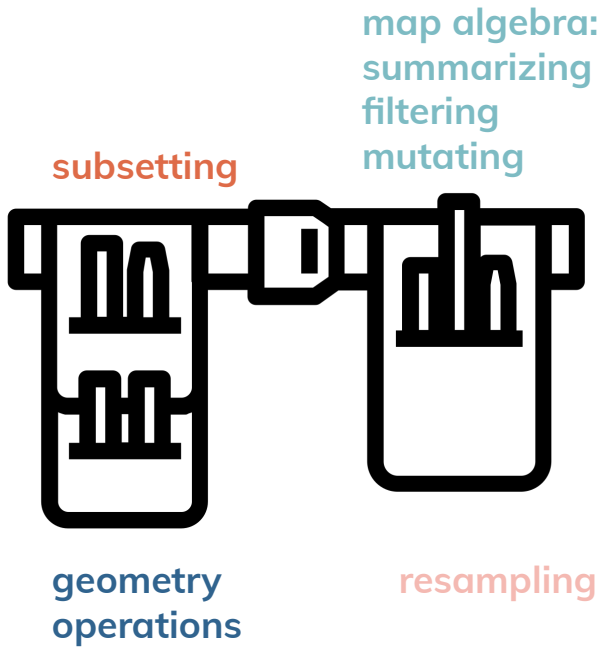
Raster data model

- Resolution
- Extent
- Position

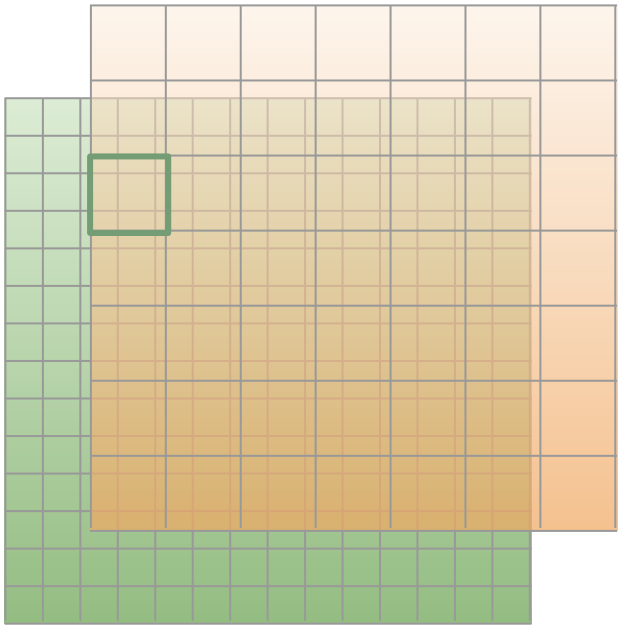


mismatch!

Toolbelt for solving spatial problems



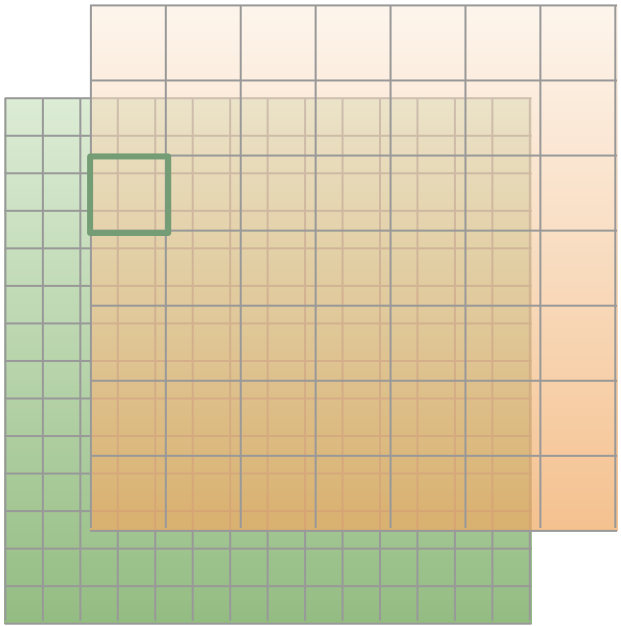
Resampling



Resampling

Nearest neighbor

Bilinear interpolation



Switching gears...