Use of satellites: what do you see on Earth?

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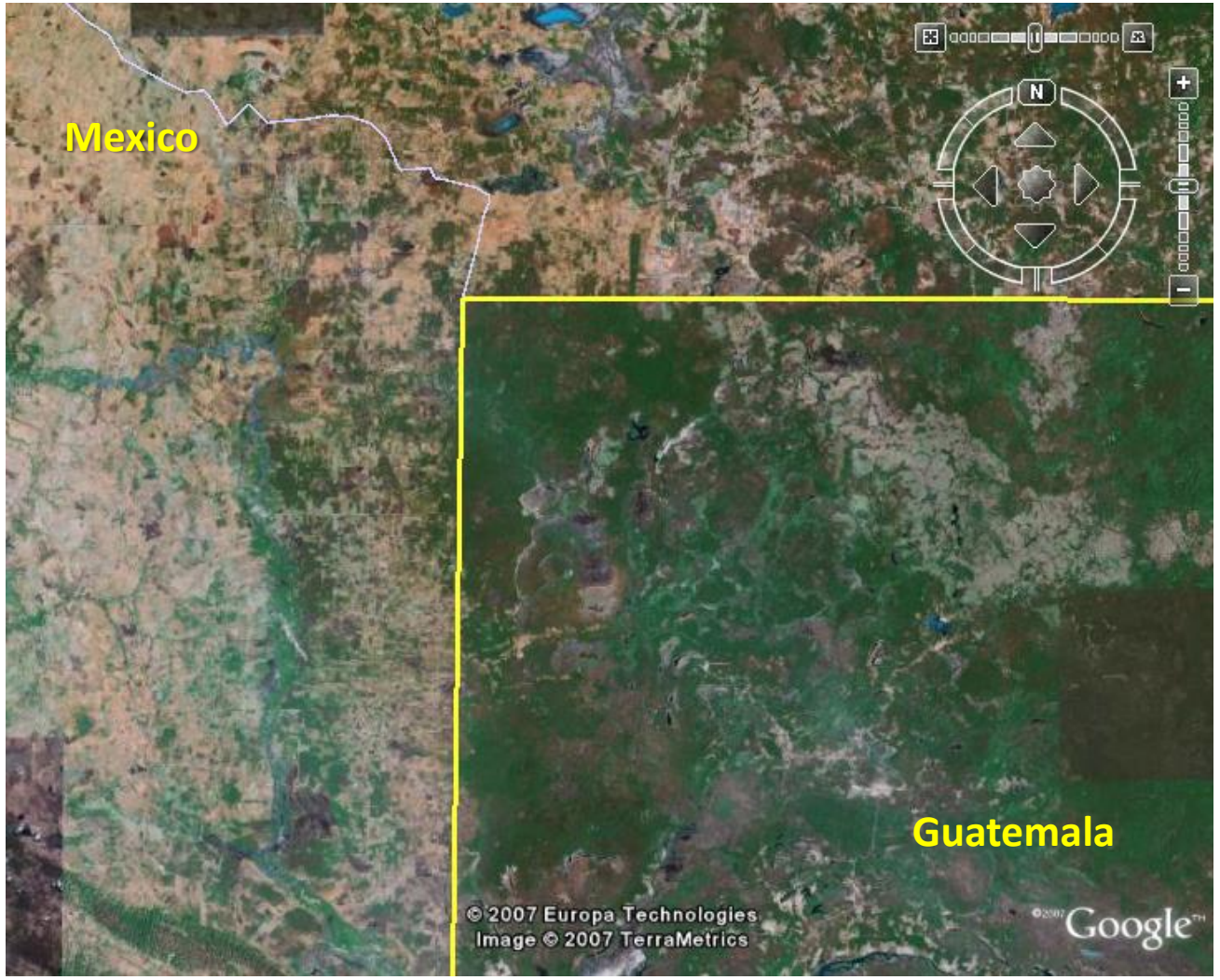


Use of satellites: what do you see on Earth?

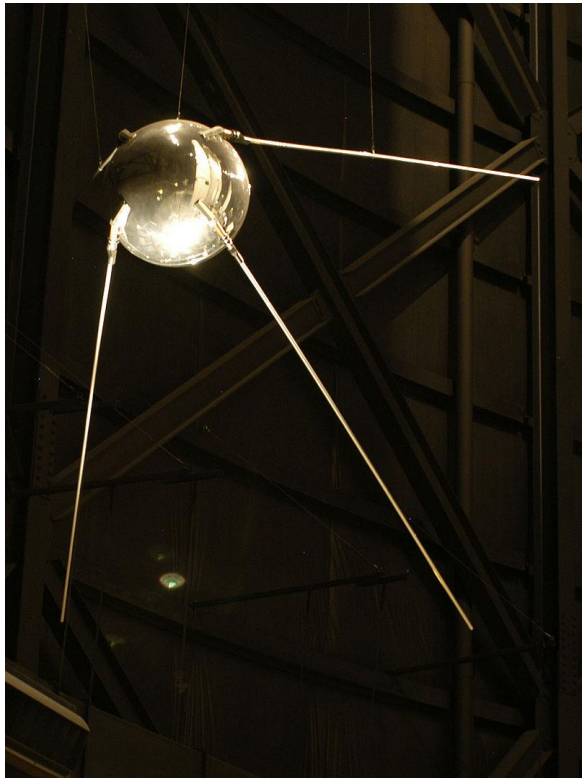
Image source and more applications:
https://www.nasa.gov/feature/goddard/2017/new-night-lights-maps-open-up-possible-real-time-applications

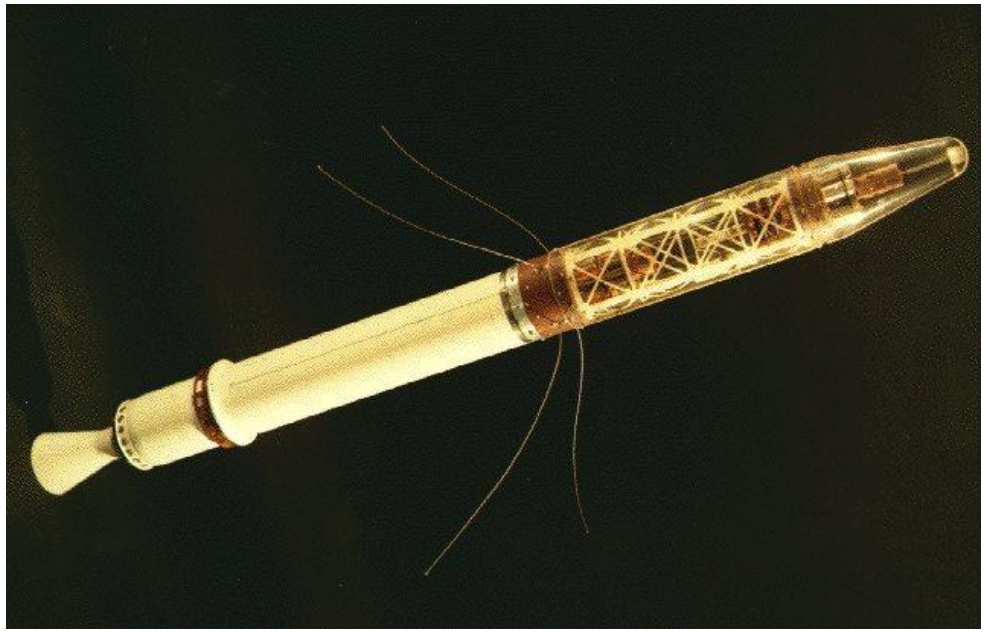
Credit: *NASA Earth Observatory images by Joshua Stevens, using Suomi NPP VIIRS data from Miguel Román, NASA's Goddard Space Flight Center*

Remote Sensing History: first steps

Soviet Union launched Sputnik on October 4, 1957. It was ~ 60 cm in diameter and weighed ~ 80 kg.

NASA (National Aeronautics and Space Agency) was established in 1958 as a part of “space” competition and first US satellite Explorer 1 was launched on January 31, 1958.





Explorer 1: https://www.youtube.com/watch?v=Pbs85I_AfEg

Image source: https://en.wikipedia.org/wiki/Explorer_1

Image source: https://en.wikipedia.org/wiki/Sputnik_1

Remote Sensing History: cold war

Corona – satellite that was in operation 1960 – 1972

Declassified in 1995

"President Eisenhower and Director of Central Intelligence Allen Dulles inspected the mission's photographs. In films "good to very good," the camera had photographed **1.5 million square miles of the Soviet Union and East European countries.** From this imagery **64 Soviet airfields and 26 new surface-to-air missile (SAM) sites were identified**. That the first satellite rnission could produce such results stunned knowledgeable observers from imagery analysts to the President." (From report series CIA Cold War Records, "CORONA: America's First Satellite Program", https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/books-and-monographs/corona.pdf)

CIA video on CORONA: https://www.youtube.com/watch?v=dEkMh54otJ8&feature=youtu.be

CORONA free access data archive: https://lta.cr.usgs.gov/declass_1

Electromagnetic Energy: reflected (emitted) and incident

“There are two types of remote sensing instruments—passive and active.

Passive instruments detect natural energy that is reflected or emitted from the observed scene. Passive instruments sense only radiation emitted by the object being viewed or reflected by the object from a source other than the instrument. Reflected sunlight is the most common external source of radiation sensed by passive instruments.”

Active instruments provide their own energy (electromagnetic radiation) to illuminate the object or scene they observe. They send a pulse of energy from the sensor to the object and then receive the radiation that is reflected or backscattered from that object. “

Source: NASA Earth Observatory,
https://earthobservatory.nasa.gov/Features/RemoteSensing/remote_08.php

Advantages/disadvantages:

https://www.slideshare.net/VivekSrivastava22/passive-and-active-sensors

Electromagnetic (EM) spectrum: the light energy wavelengths

https://earthobservatory.nasa.gov/Features/RemoteSensing/remote_03.php

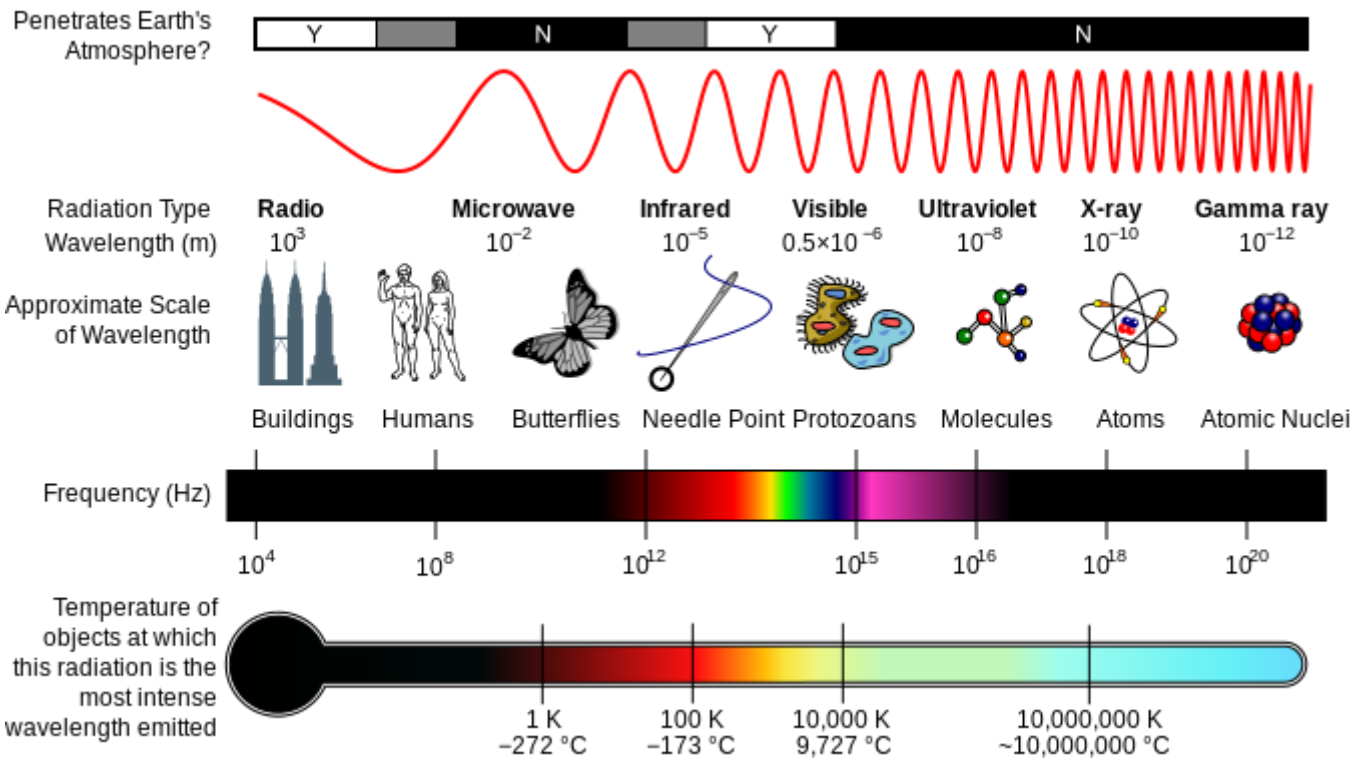


Image source: https://en.wikipedia.org/wiki/Electromagnetic_spectrum

NASA EM Video Explanation: https://www.youtube.com/watch?v=lwfJPc-rSXw

Specific ranges of common electromagnetic bands (µm):

UV:	0.01 – 0.4
Blue:	0.4 – 0.5
Green:	0.5 – 0.6
Red:	0.6 – 0.7
IR (infrared):	0.7 – 100

NIR (near IR):	0.7 – 1.3
MIR (middle IR):	1.3 – 3.0
TIR (thermal IR):	3.0 – 14.0

Role of the atmosphere: can absorb or pass wavelengths

Atmospheric window: passing selective wavelengths

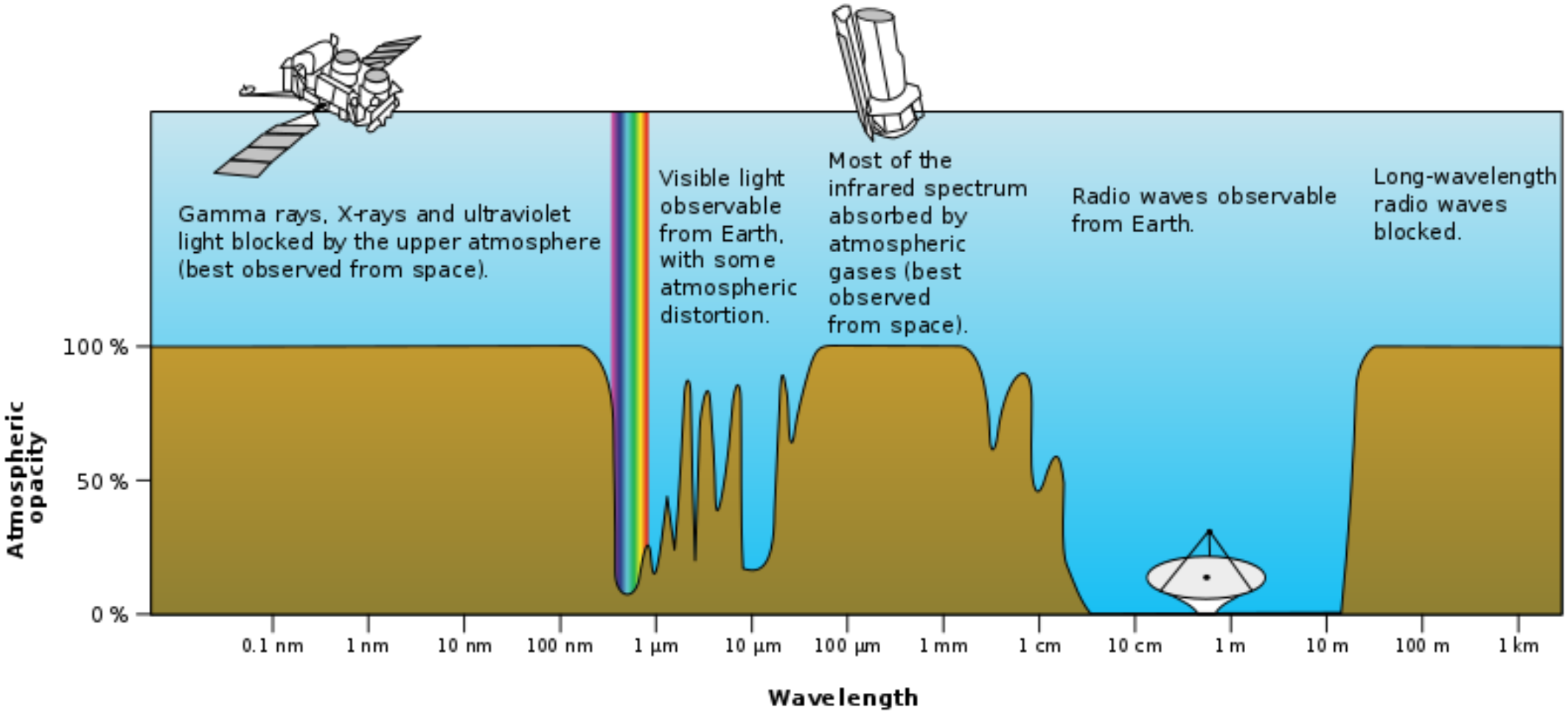


Image source: https://commons.wikimedia.org/wiki/File:Atmospheric_electromagnetic_opacity.svg

Role of the atmosphere: can absorb or pass wavelengths

Rayleigh scattering: scattering of light caused by atmospheric particles smaller than the wavelength being scattered (e.g. oxygen, nitrogen, carbon dioxide); causes sky to look blue because of high scattering rate of blue (short wave) light.

Mie scattering: scattering of light caused by atmospheric particles the same size as the wavelength being scattered (e.g. water vapor, smoke, dust); creates a white halo around the sun.

Nonselective scattering: scattering of light caused by atmospheric particles larger than the wavelength being scattered (e.g. aerosols, smoke, ice crystals, clouds, fog, etc.); clouds and fog appears white because of the proportional scattering of blue, green and red light.

Measuring spectral reflectance:

Transmittance (T): light passes through a target;

Reflection (R): light is reflected back to space

Absorption (A): light is trapped and held by target

Incident energy (I): total amount of energy that interacts with an object

$$I = R + A + T$$

$$\rho = (R / I) \times 100$$

ρ - spectral reflectance, i.e. the % of total energy per wavelength that was reflected off a target

Spectral signature:

a unique identifier for an object, generated by charting the % of reflected energy per wavelength against a value for that wavelength

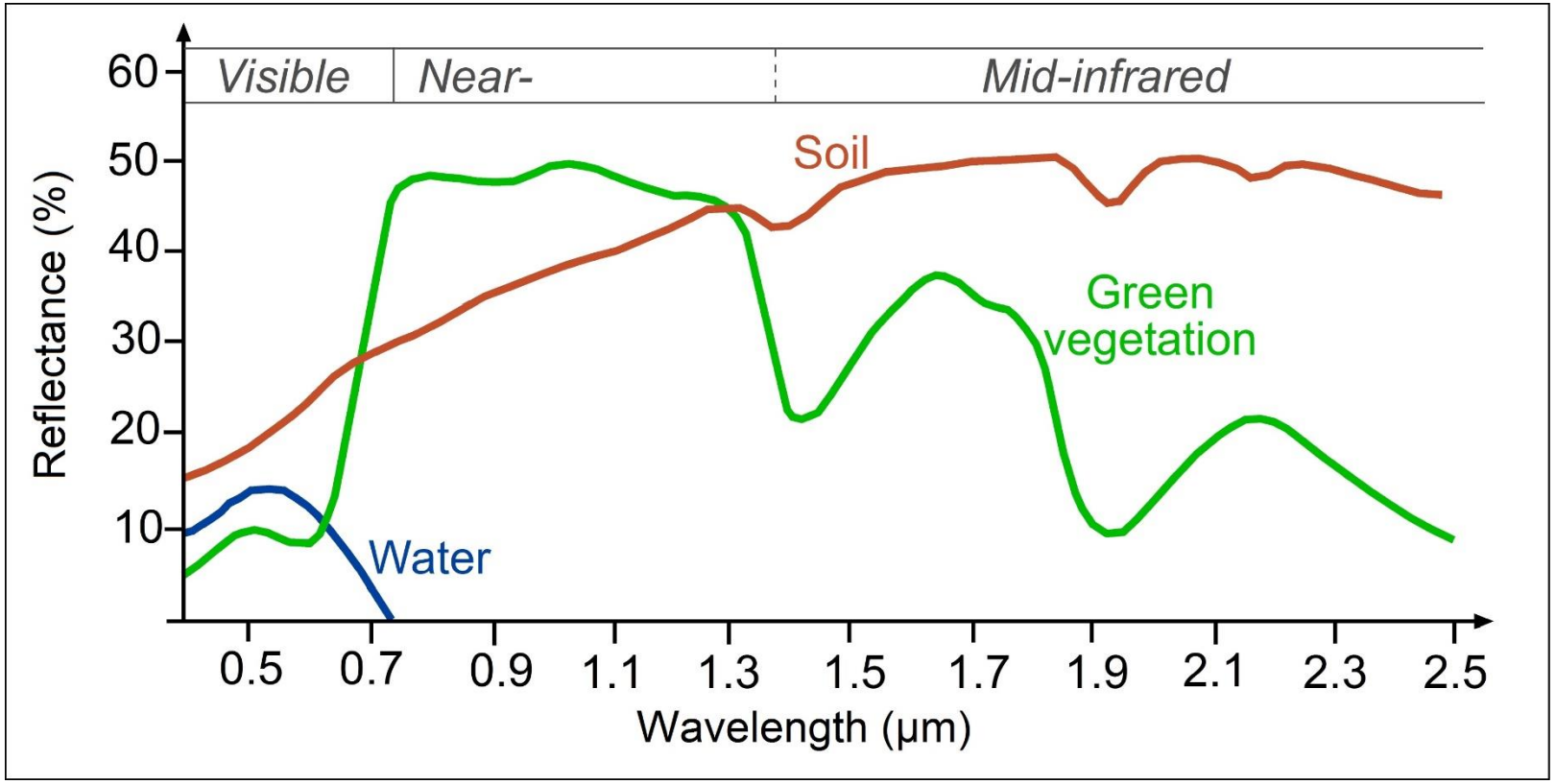


Image source: http://www.seos-project.eu/modules/classification/classification-c00-p05.html

Spectral signature

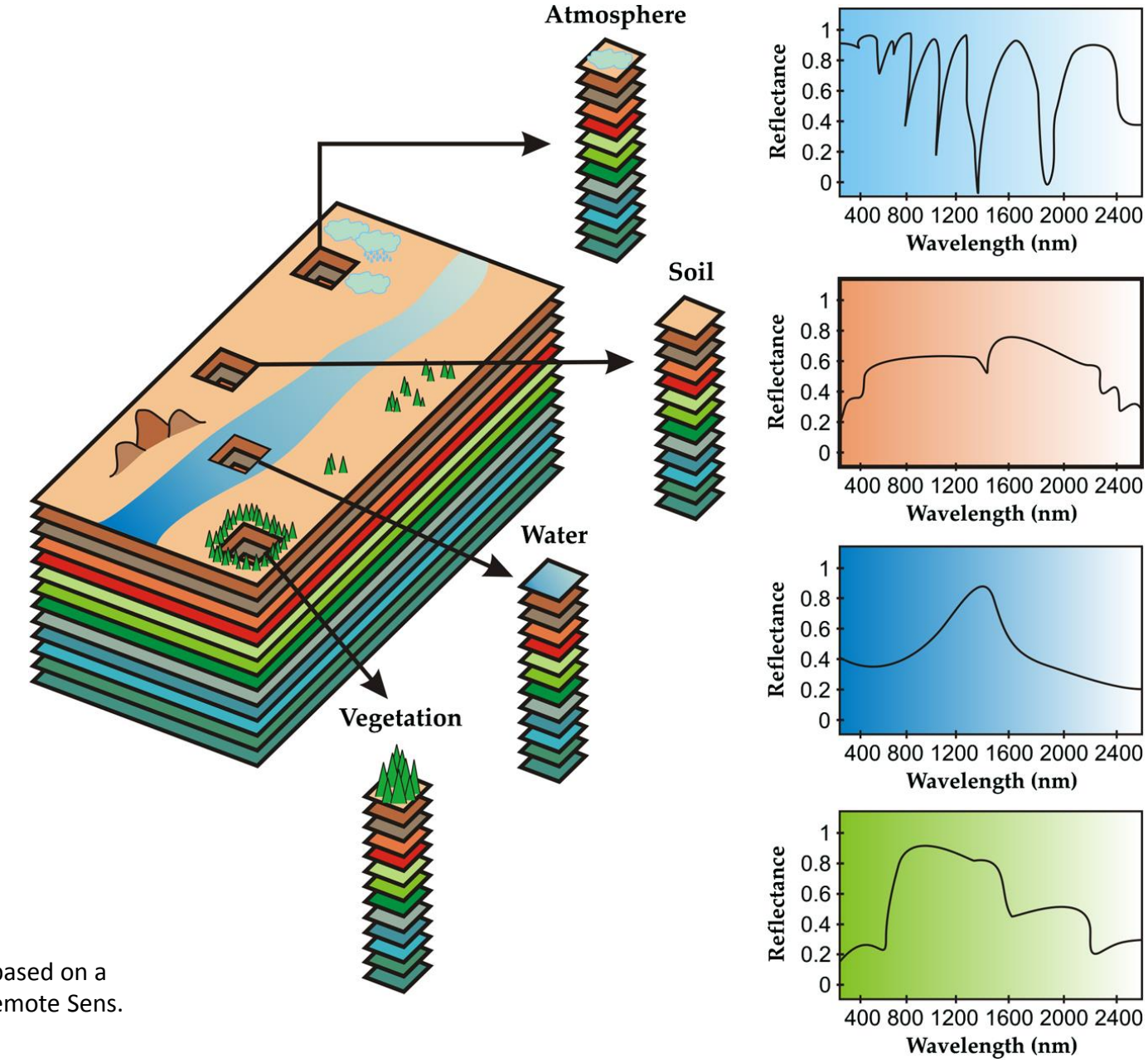


Image source:
Molero JM, Garzón EM, García I, Plaza A; Anomaly detection based on a parallel kernel rx algorithm for multicore platforms. J. Appl. Remote Sens. 0001;6(1):061503-1-061503-10. doi:10.1117/1.JRS.6.061503.

Data collection by satellites

Explanation of satellite orbits by Dr. Martin Wooster:

https://www.youtube.com/watch?v=EnF_ljgk3gk

Cyan represents low Earth orbit, 160 to 2,000 km (100–1,240 miles)

Red dotted line represents the orbit of the International Space Station (ISS);

Yellow represents medium Earth orbit, 2,000 - 35,786 km (1,240 – 22,236 miles)

Green dash-dot line represents the orbit of Global Positioning System (GPS) satellites.

Black dashed line represents geosynchronous orbit.

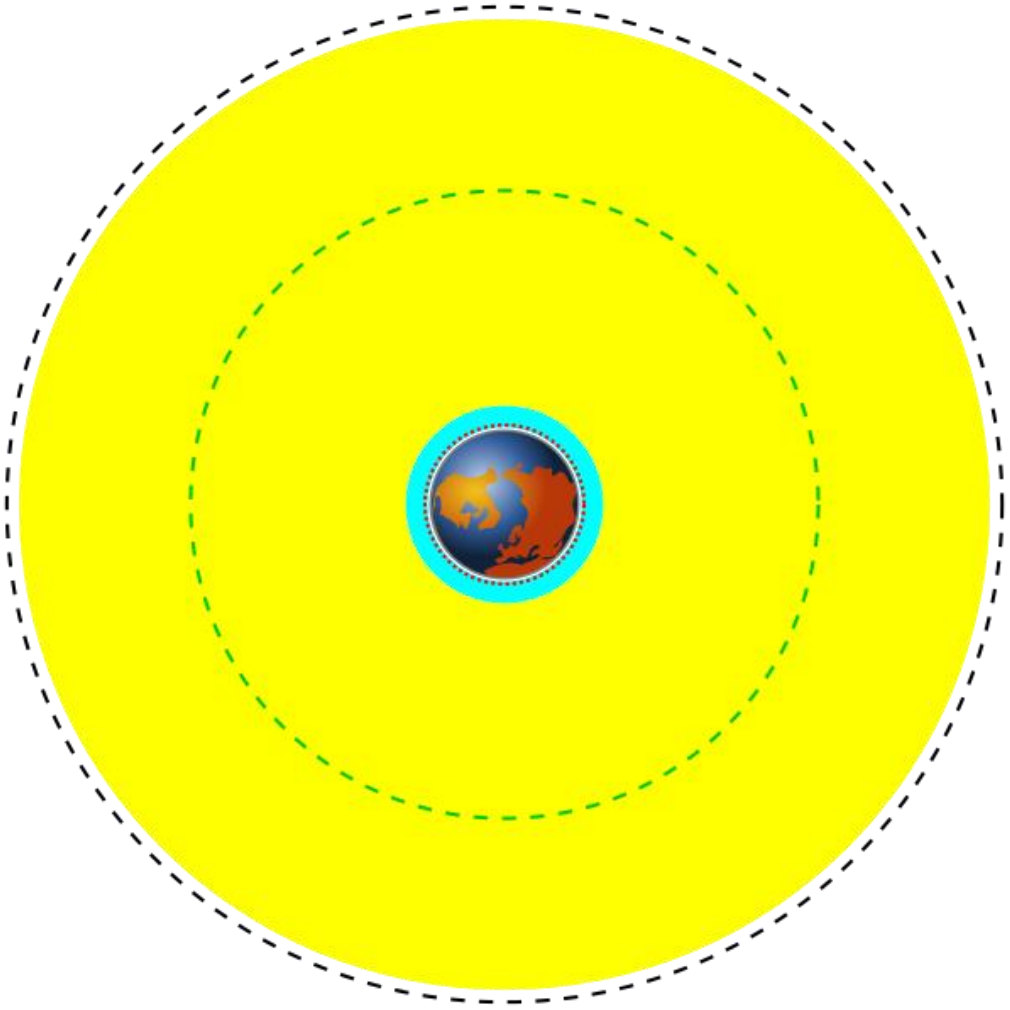


Image source:
https://commons.wikimedia.org/wiki/File:Orbits_around_earth_scale_diagram.svg

Landsat Mission: https://landsat.usgs.gov/

Landsat mission explanation: https://www.youtube.com/watch?v=JCzIageDf0k

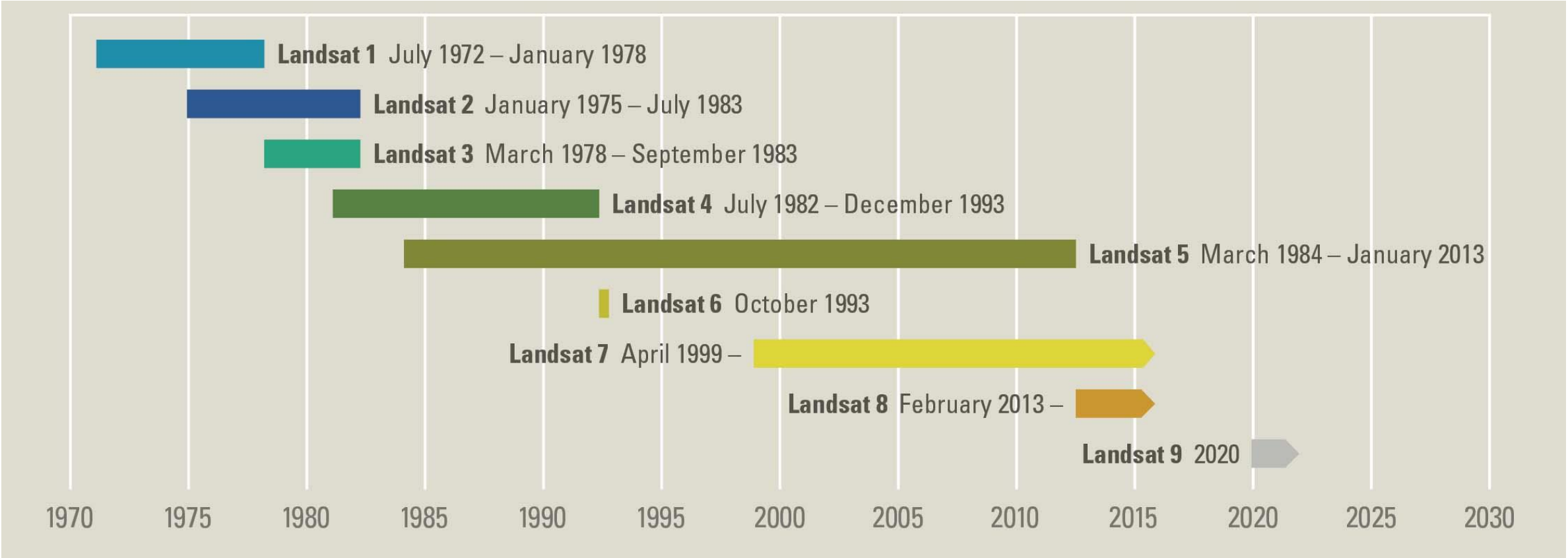


Image source: https://landsat.usgs.gov/landsat-missions-timeline

Landsat 8 satellite

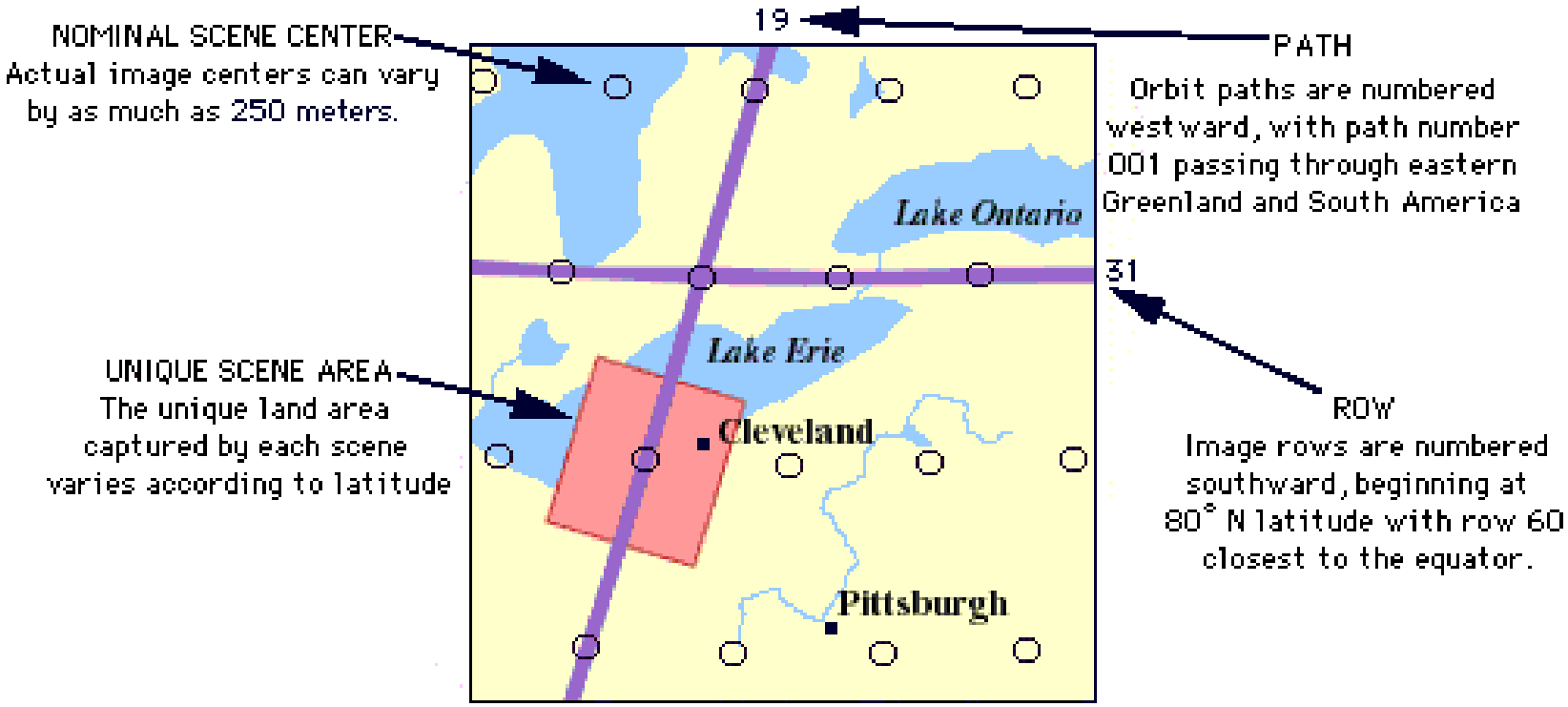


Image source:
http://www.migall.fastmail.fm/astronomy/earth_remote_sensing/landsat_intro/landsat_info_usgs/landsat_7_dataset.htm

The Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) are instruments onboard the Landsat 8 satellite, which was launched in February of 2013.

The satellite collects images of the Earth with a 16-day repeat cycle, 705 km altitude, polar, sun-synchronous orbit, scene size 170 x 185 km.

Two thermal bands (TIRS) capture data with a minimum of 100 meter resolution, but are registered to and delivered with the 30-meter OLI data product.

How do remote sensing satellites collect data?

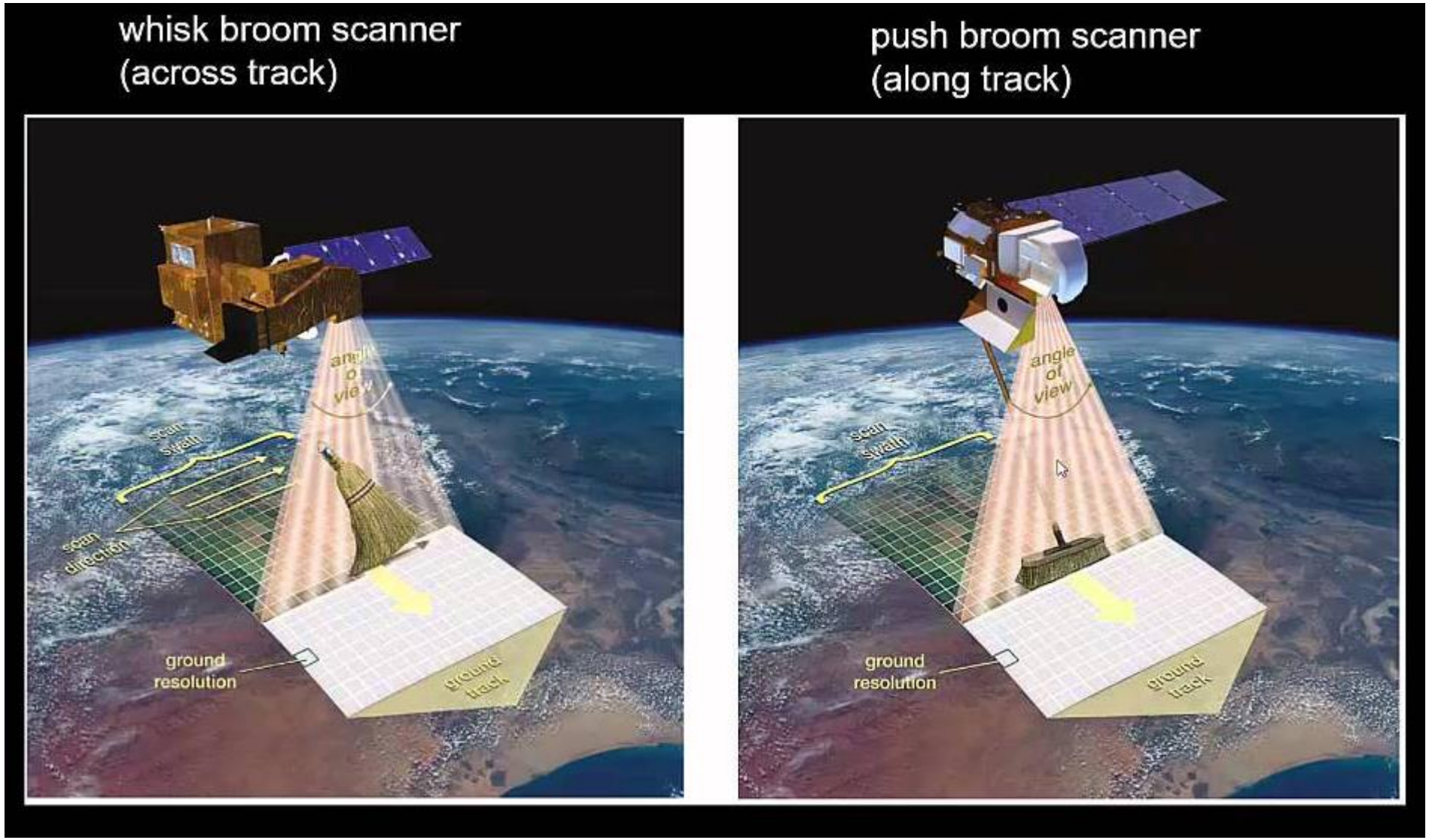


Image source: https://www.youtube.com/watch?v=eFJs_edUWKs

Properties of a satellite sensor:

Spatial resolution – ground size (usually meters or km) represented by one pixel of satellite imagery; panchromatic imagery has higher spatial resolution than multispectral;

Radiometric resolution – sensor's ability to determine fine differences in a band of energy measurements

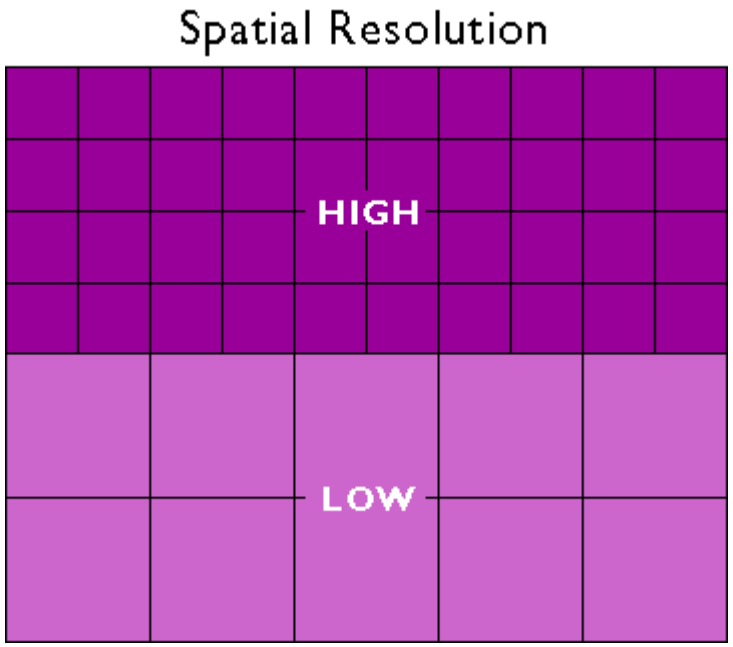
Temporal resolution –how often sensor views the same location on the ground

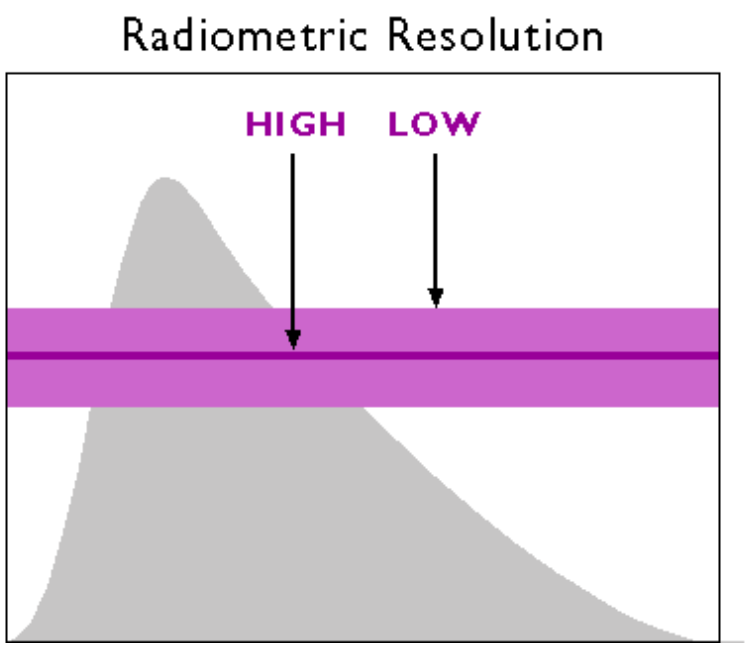
Spectral resolution – bands and wavelengths measured by a sensor.

Panchromatic sensor – measures only one range of wavelengths (e.g. black-and-white image)

Spatial, Radiometric, Spectral and Temporal Resolutions explained:

https://www.e-education.psu.edu/natureofgeoinfo/node/1904





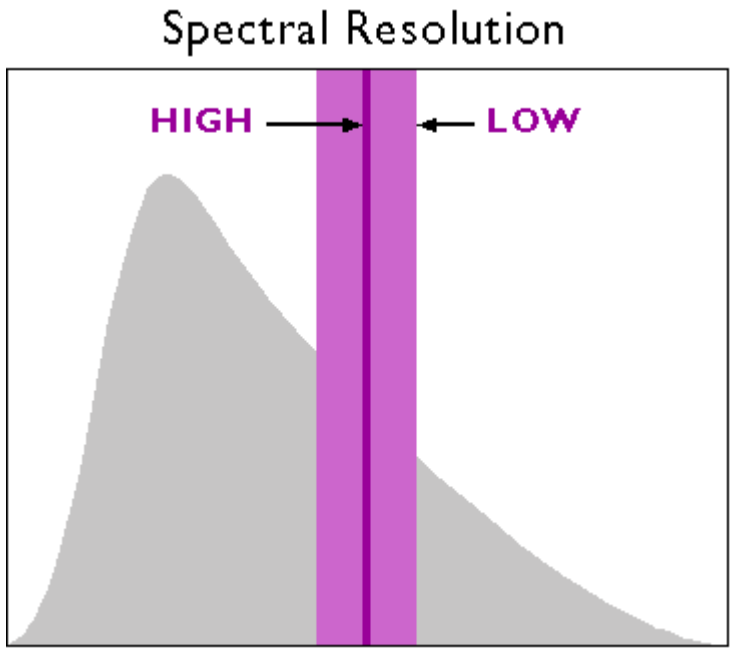
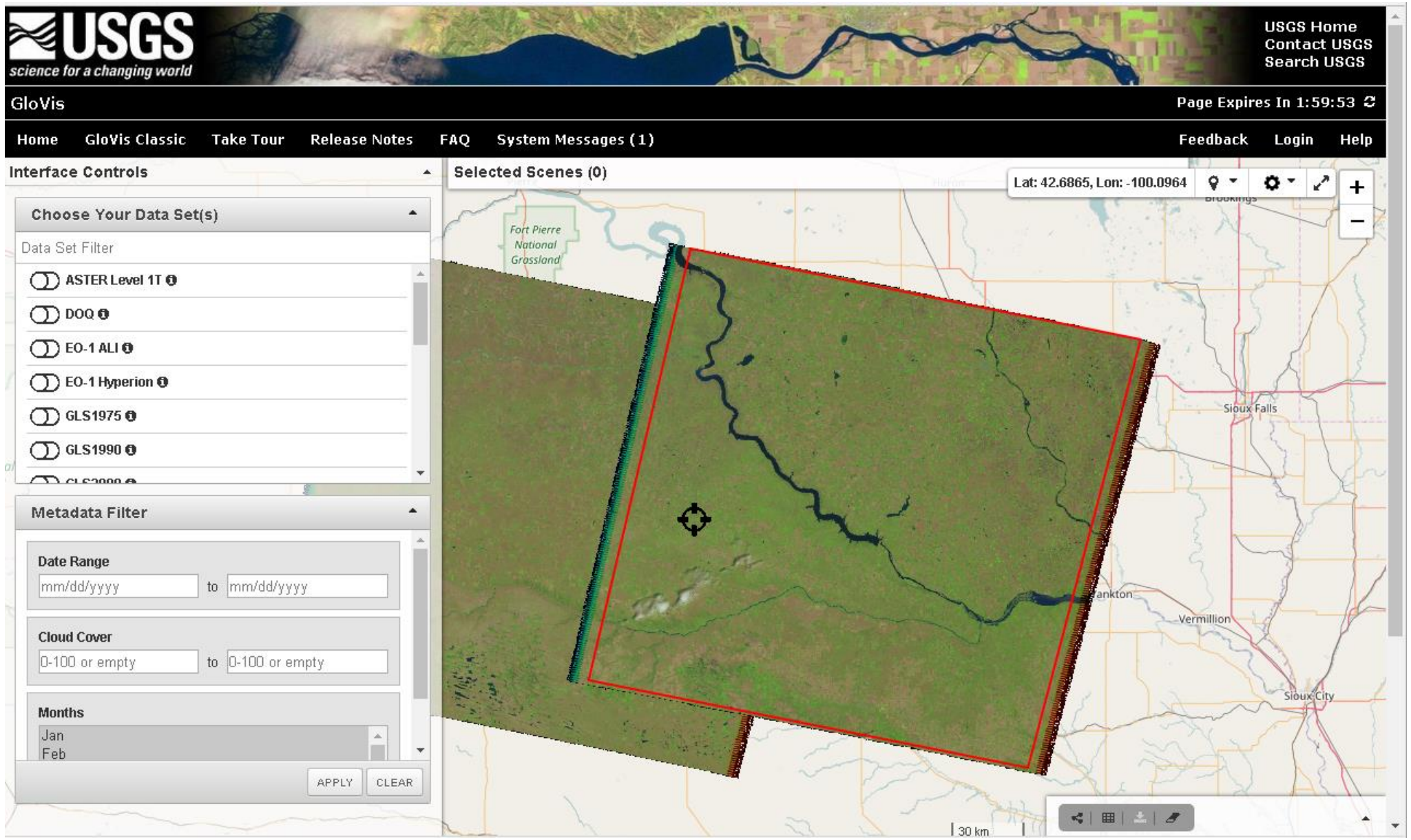


Image source: https://www.e-education.psu.edu/natureofgeoinfo/node/1904

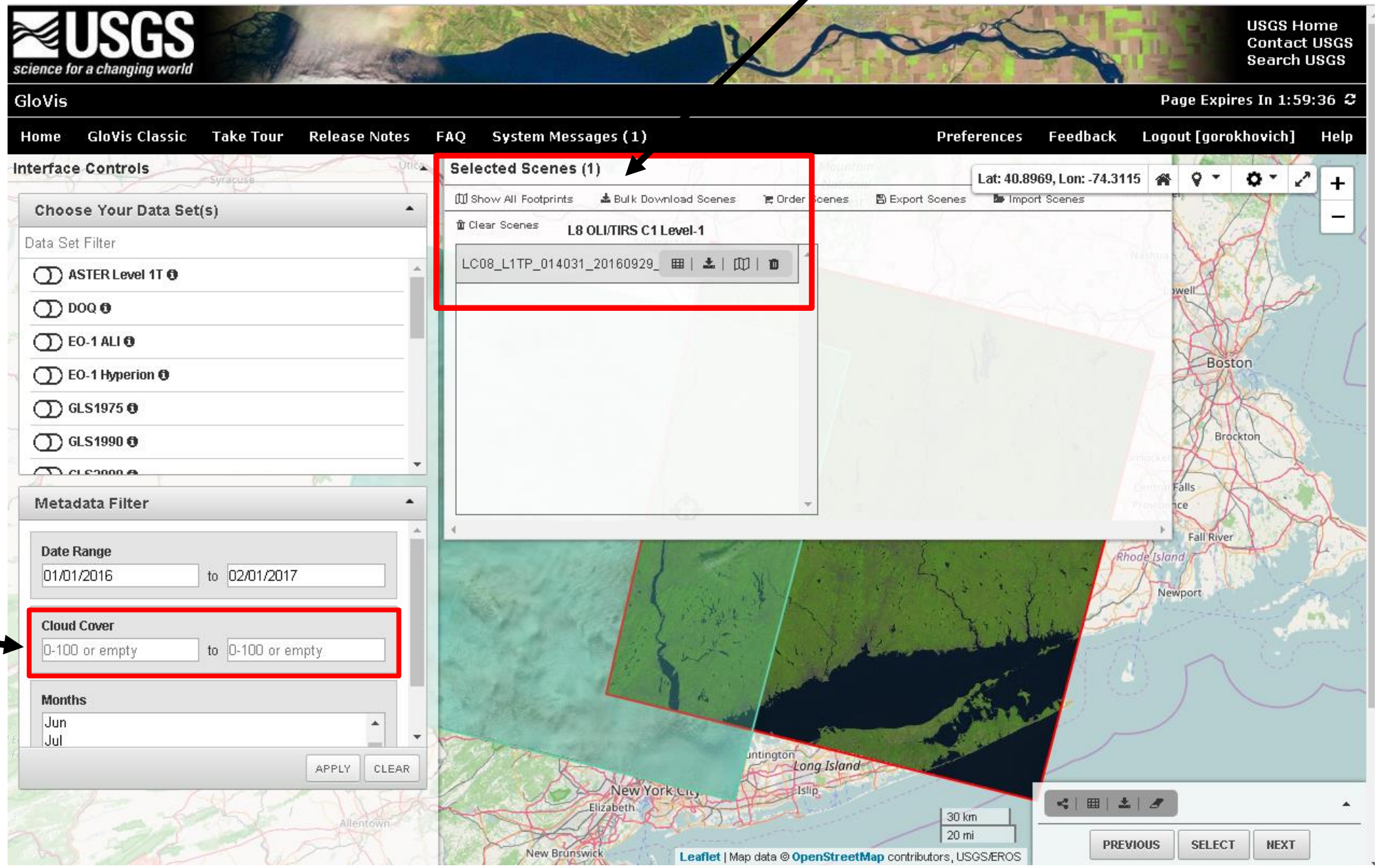
SATELLITE PRODUCTS DISTRIBUTION



GLOVIS site: https://glovis.usgs.gov/next/

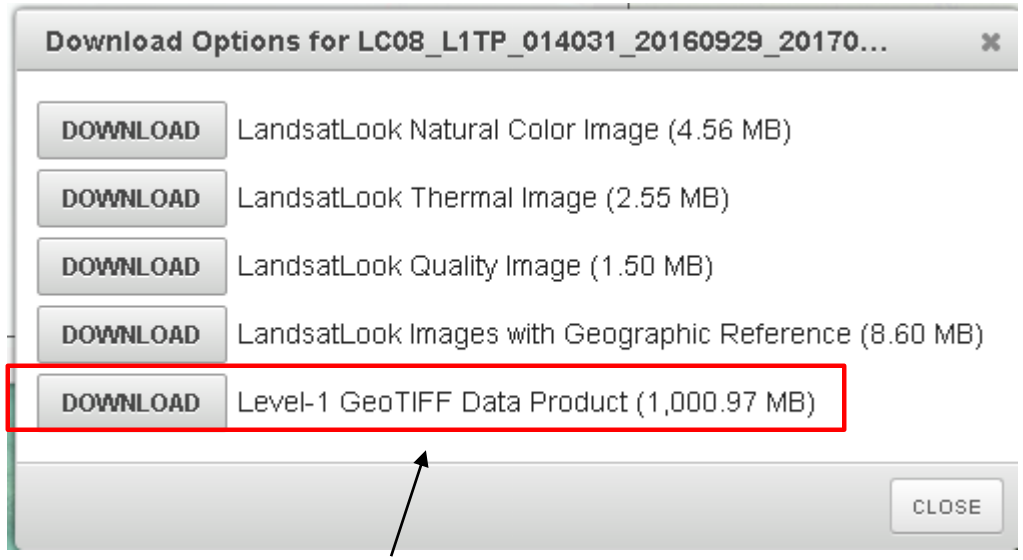
GLOVIS site: https://glovis.usgs.gov/next/

Getting data



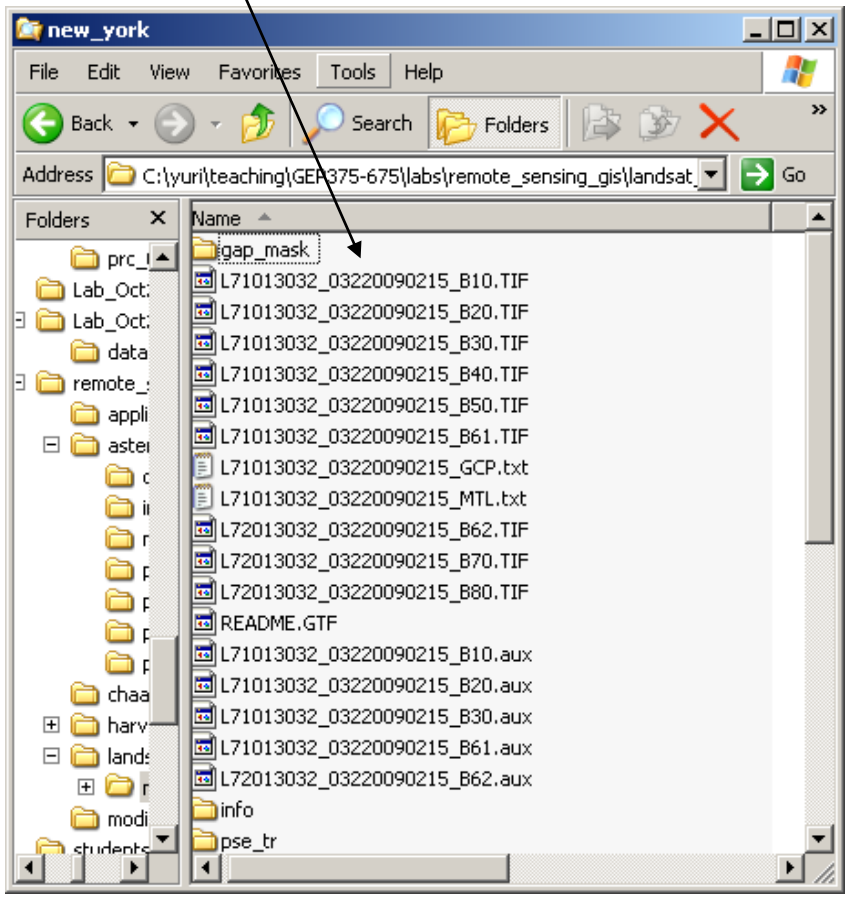
Quality

SATELLITE PRODUCTS DISTRIBUTION



Select product

Download



SATELLITE PRODUCTS DISTRIBUTION: NAMING CONVENTION

Landsat 8 file naming convention:

Includes both OLI and TIRS: LC8**039**0**22**2**013**0**76**EDC00

Includes only OLI: LO80390222013076EDC00

Includes only TIRS: LT80390222013076EDC00

DECODING LANDSAT DATAFILE NAME:

L: Landsat

C/O/T: Instrument; C=Combined, O=OLI, T=TIRS

8: Satellite

039: Path (WRS-2)

022: Row (WRS-2)

2013: Year

076: Julian Day (Day 76 of the calendar year = 17 March)

EDC: Ground Station where the data was received

00: Archive version number

Source: http://landsat.usgs.gov/about_LU_Vol_7_Issue_2.php#2a

LANDSAT bands:

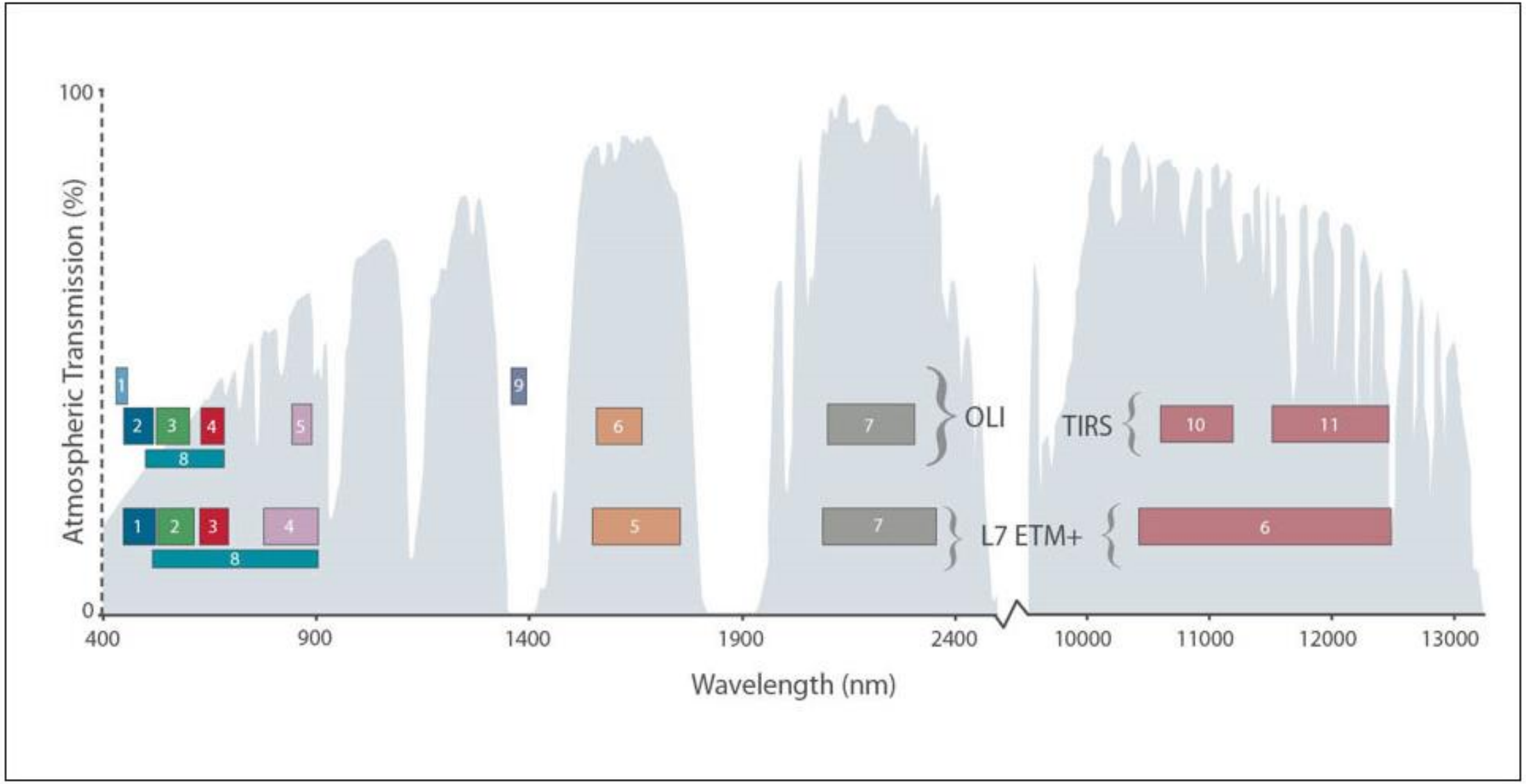


Image source: https://landsat.gsfc.nasa.gov/landsat-data-continuity-mission/

Landsat 8 Bands

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. The ultra blue Band 1 is useful for coastal and aerosol studies. Band 9 is useful for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 meters. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures and are collected at 100 meters. The approximate scene size is 170 km north-south by 183 km east-west (106 mi by 114 mi).

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 - Ultra Blue (coastal/aerosol)	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - Shortwave Infrared (SWIR) 1	1.57 - 1.65	30
	Band 7 - Shortwave Infrared (SWIR) 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product.

Source: https://landsat.usgs.gov/what-are-band-designations-landsat-satellites

SATELLITE PRODUCTS DISTRIBUTION: METADATA FILE (.TXT)

Metadata File: LC80140312013232LGN00_MTL.TXT

These are files that come with Landsat dataset, usually zipped.

LC80140312013232LGN00.jpg	8/20/2013 5:17 PM	IrfanView JPG File	5,756 KB
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LC80140312013232LGN00.wld	8/20/2013 5:17 PM	WLD File	1 KB
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Metadata File: LC80140312013232LGN00_MTL.TXT

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Metadata File: LC80140312013232LGN00_MTL.TXT

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  RADIANCE_MAXIMUM_BAND_11 = 22.00180
  RADIANCE_MINIMUM_BAND_11 = 0.10033
END_GROUP = MIN_MAX_RADIANCE
GROUP = MIN_MAX_REFLECTANCE
  REFLECTANCE_MAXIMUM_BAND_1 = 1.210700
  REFLECTANCE_MINIMUM_BAND_1 = -0.099980
  REFLECTANCE_MAXIMUM_BAND_2 = 1.210700
  REFLECTANCE_MINIMUM_BAND_2 = -0.099980
  REFLECTANCE_MAXIMUM_BAND_3 = 1.210700
  REFLECTANCE_MINIMUM_BAND_3 = -0.099980
  REFLECTANCE_MAXIMUM_BAND_4 = 1.210700
  REFLECTANCE_MINIMUM_BAND_4 = -0.099980
  REFLECTANCE_MAXIMUM_BAND_5 = 1.210700
  REFLECTANCE_MINIMUM_BAND_5 = -0.099980
  REFLECTANCE_MAXIMUM_BAND_6 = 1.210700
  REFLECTANCE_MINIMUM_BAND_6 = -0.099980
  REFLECTANCE_MAXIMUM_BAND_7 = 1.210700
  REFLECTANCE_MINIMUM_BAND_7 = -0.099980
  REFLECTANCE_MAXIMUM_BAND_8 = 1.210700
  REFLECTANCE_MINIMUM_BAND_8 = -0.099980
  REFLECTANCE_MAXIMUM_BAND_9 = 1.210700
  REFLECTANCE_MINIMUM_BAND_9 = -0.099980
END_GROUP = MIN_MAX_REFLECTANCE
GROUP = MIN_MAX_PIXEL_VALUE
  QUANTIZE_CAL_MAX_BAND_1 = 65535
  QUANTIZE_CAL_MIN_BAND_1 = 1
  QUANTIZE_CAL_MAX_BAND_2 = 65535
  QUANTIZE_CAL_MIN_BAND_2 = 1
  QUANTIZE_CAL_MAX_BAND_3 = 65535
  QUANTIZE_CAL_MIN_BAND_3 = 1
  QUANTIZE_CAL_MAX_BAND_4 = 65535
  QUANTIZE_CAL_MIN_BAND_4 = 1
  QUANTIZE_CAL_MAX_BAND_5 = 65535
  QUANTIZE_CAL_MIN_BAND_5 = 1
  QUANTIZE_CAL_MAX_BAND_6 = 65535
  QUANTIZE_CAL_MIN_BAND_6 = 1
  QUANTIZE_CAL_MAX_BAND_7 = 65535
  QUANTIZE_CAL_MIN_BAND_7 = 1
  QUANTIZE_CAL_MAX_BAND_8 = 65535
  QUANTIZE_CAL_MIN_BAND_8 = 1
  QUANTIZE_CAL_MAX_BAND_9 = 65535
  QUANTIZE_CAL_MIN_BAND_9 = 1
  QUANTIZE_CAL_MAX_BAND_10 = 65535
  QUANTIZE_CAL_MIN_BAND_10 = 1
  QUANTIZE_CAL_MAX_BAND_11 = 65535
  QUANTIZE_CAL_MIN_BAND_11 = 1
END_GROUP = MIN_MAX_PIXEL_VALUE
GROUP = RADIOMETRIC_RESCALING
  RADIANCE_MULT_BAND_1 = 1.2607E-02
  RADIANCE_MULT_BAND_2 = 1.2855E-02
  RADIANCE_MULT_BAND_3 = 1.1771E-02
  RADIANCE_MULT_BAND_4 = 9.9694E-03
  RADIANCE_MULT_BAND_5 = 6.0496E-03
  RADIANCE_MULT_BAND_6 = 1.5242E-03
```

Metadata File: LC80140312013232LGN00_MTL.TXT

```
  RADIANCE_MULT_BAND_7 = 4.9582E-04
  RADIANCE_MULT_BAND_8 = 1.1230E-02
  RADIANCE_MULT_BAND_9 = 2.4860E-03
  RADIANCE_MULT_BAND_10 = 3.3420E-04
  RADIANCE_MULT_BAND_11 = 3.3420E-04
  RADIANCE_ADD_BAND_1 = -63.03253
  RADIANCE_ADD_BAND_2 = -64.27659
  RADIANCE_ADD_BAND_3 = -58.85568
  RADIANCE_ADD_BAND_4 = -49.84716
  RADIANCE_ADD_BAND_5 = -30.24781
  RADIANCE_ADD_BAND_6 = -7.62094
  RADIANCE_ADD_BAND_7 = -2.47908
  RADIANCE_ADD_BAND_8 = -56.14967
  RADIANCE_ADD_BAND_9 = -12.43008
  RADIANCE_ADD_BAND_10 = 0.10000
  RADIANCE_ADD_BAND_11 = 0.10000
  REFLECTANCE_MULT_BAND_1 = 2.0000E-05
  REFLECTANCE_MULT_BAND_2 = 2.0000E-05
  REFLECTANCE_MULT_BAND_3 = 2.0000E-05
  REFLECTANCE_MULT_BAND_4 = 2.0000E-05
  REFLECTANCE_MULT_BAND_5 = 2.0000E-05
  REFLECTANCE_MULT_BAND_6 = 2.0000E-05
  REFLECTANCE_MULT_BAND_7 = 2.0000E-05
  REFLECTANCE_MULT_BAND_8 = 2.0000E-05
  REFLECTANCE_MULT_BAND_9 = 2.0000E-05
  REFLECTANCE_ADD_BAND_1 = -0.100000
  REFLECTANCE_ADD_BAND_2 = -0.100000
  REFLECTANCE_ADD_BAND_3 = -0.100000
  REFLECTANCE_ADD_BAND_4 = -0.100000
  REFLECTANCE_ADD_BAND_5 = -0.100000
  REFLECTANCE_ADD_BAND_6 = -0.100000
  REFLECTANCE_ADD_BAND_7 = -0.100000
  REFLECTANCE_ADD_BAND_8 = -0.100000
  REFLECTANCE_ADD_BAND_9 = -0.100000
END_GROUP = RADIOMETRIC_RESCALING
GROUP = TIRS_THERMAL_CONSTANTS
  K1_CONSTANT_BAND_10 = 774.89
  K1_CONSTANT_BAND_11 = 480.89
```

M_L

A_L

K_1

```
  K2_CONSTANT_BAND_10 = 1321.08
  K2_CONSTANT_BAND_11 = 1201.14
END_GROUP = TIRS_THERMAL_CONSTANTS
GROUP = PROJECTION_PARAMETERS
  MAP_PROJECTION = "UTM"
  DATUM = "WGS84"
  ELLIPSOID = "WGS84"
  UTM_ZONE = 18
  GRID_CELL_SIZE_PANCHROMATIC = 15.00
  GRID_CELL_SIZE_REFLECTIVE = 30.00
  GRID_CELL_SIZE_THERMAL = 30.00
  ORIENTATION = "NORTH_UP"
  RESAMPLING_OPTION = "CUBIC_CONVOLUTION"
END_GROUP = PROJECTION_PARAMETERS
END_GROUP = L1_METADATA_FILE
END
```

K_2

Radiance Mult/Add Band values (M_L and A_L) are used to calculate spectral radiance in Temperature calculation

K constants are used to calculate Temperature (K_1 and K_2)

(See slides on Temperature calculation)

Display of satellite images

Digital Number (DN) or brightness value: the energy measured at a single pixel according to a pre-determined scale;

NOTE: DN is used to calculate NDVI, Temperature and other environmental characteristics.

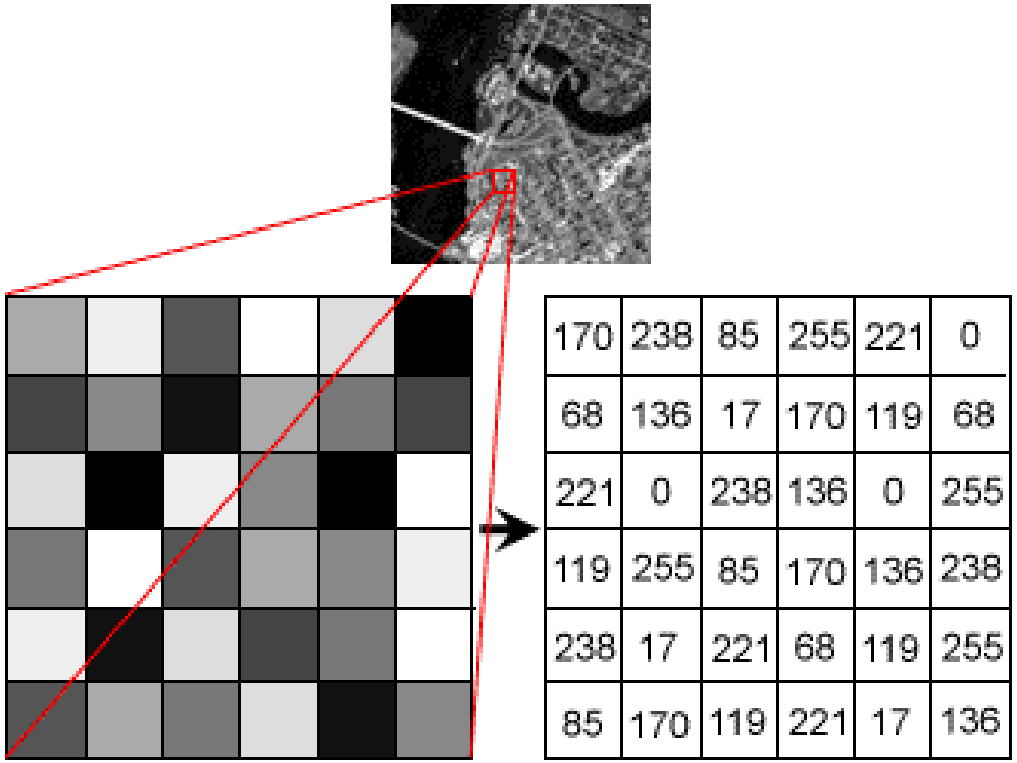


Image source: http://hosting.soonet.ca/eliris/remotesensing/bl130lec10.html

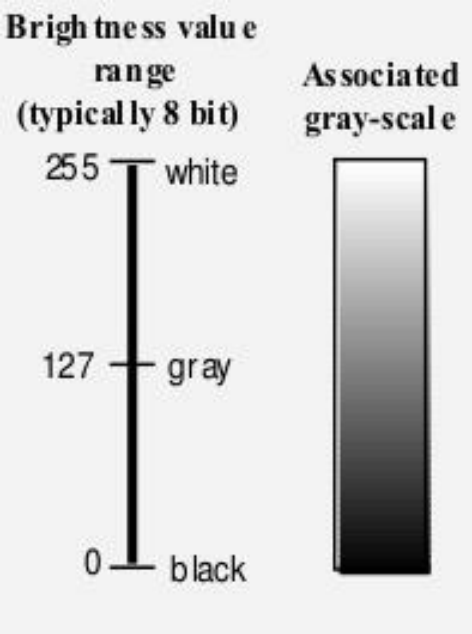


Image source: https://www.slideshare.net/civilenggverma/ece-402-unit2

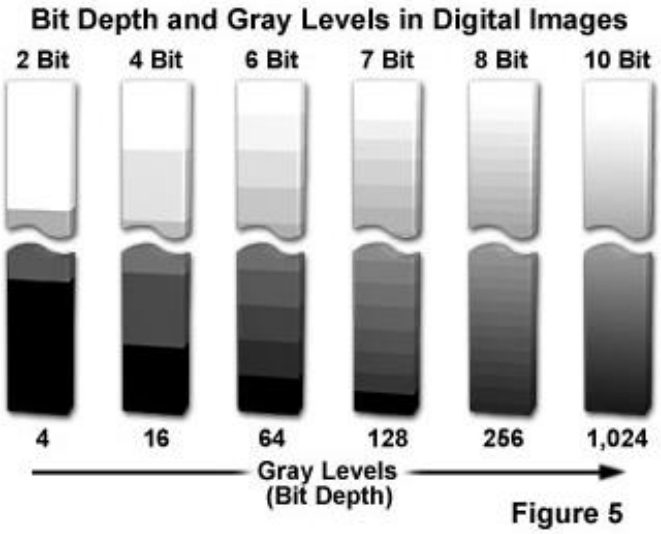


Image source: http://www.olympusmicro.com/primer/digitalimaging/digitalimagebasics.html

Display of Landsat images:

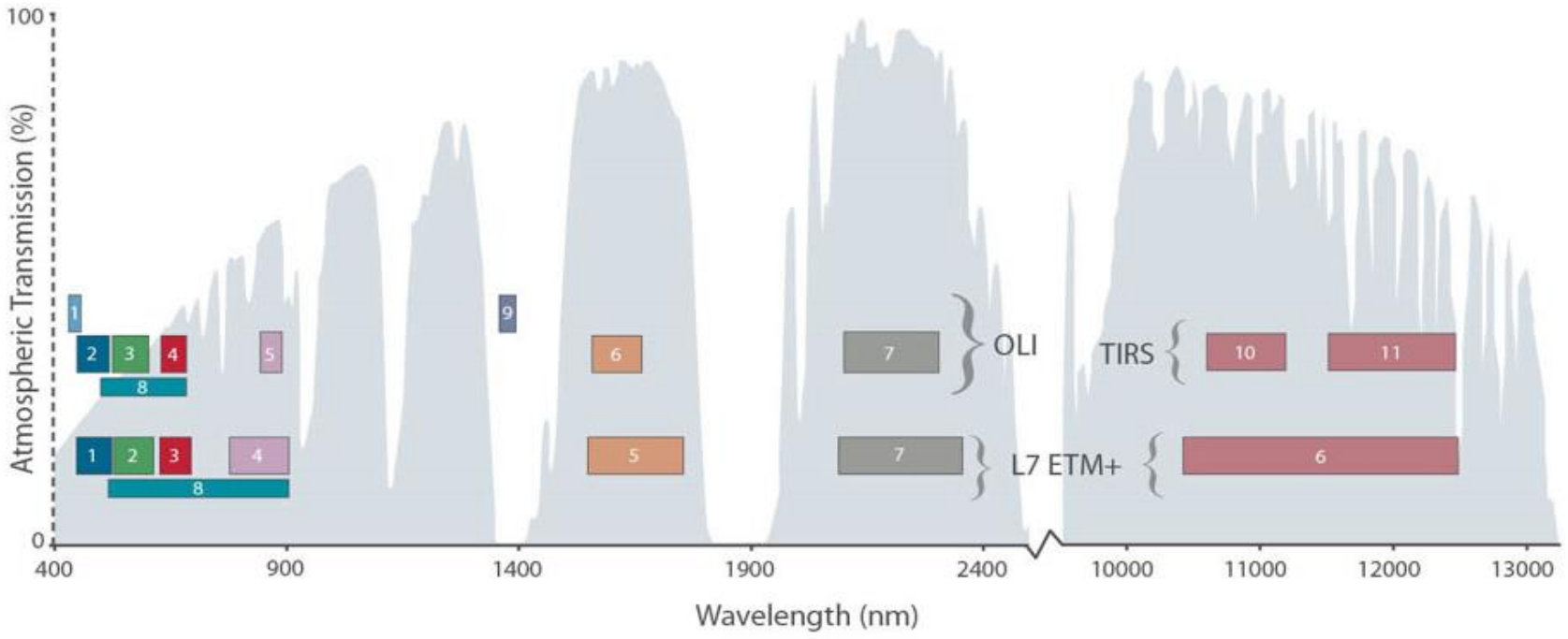


Image source: https://landsat.gsfc.nasa.gov/landsat-data-continuity-mission/

Viewing of satellite imagery involves a process of mixing measured bands, so-called composite imagery. In more general terms we create a filter that helps to see more distinctly various features of interest (e.g. water, plants, etc.)

http://gsp.humboldt.edu/olm_2015/Courses/GSP_216_Online/lessons/composites.html

Common Landsat 8 Band Combinations

Combination Name	Red Wavelength	Green Wavelength	Blue Wavelength	Landsat 8 Bands
Natural Color (actual RGB)	0.64-0.67µm	0.53-0.59µm	0.45-0.51µm	4 3 2
False Color (urban)	2.11-2.29µm	1.57-1.65µm	0.64-0.67µm	7 6 4
Color Infrared (vegetation)	0.85-0.88µm	0.64-0.67µm	0.53-0.59µm	5 4 3
Agriculture	0.85-0.88µm	0.64-0.67µm	0.53-0.59µm	5 4 3
Atmospheric Penetration	2.11-2.29µm	1.57-1.65µm	0.85-0.88µm	7 6 5
Healthy Vegetation	0.85-0.88µm	1.57-1.65µm	0.45-0.51µm	5 6 2
Land/Water	0.85-0.88µm	1.57-1.65µm	0.64-0.67µm	5 6 4
Natural With Atmospheric Removal	2.11-2.29µm	0.85-0.88µm	0.53–0.59µm	7 5 3
Shortwave Infrared	2.11-2.29µm	0.85-0.88µm	0.53–0.59µm	7 5 3
Vegetation Analysis	1.57-1.65µm	0.85-0.88µm	0.64-0.67µm	6 5 4

http://satsummit.github.io/landscape/#

Display of Landsat images:

Useful Links:

In-depth explanation about band combinations:

http://web.pdx.edu/~emch/ip1/bandcombinations.html

Landsat Spectral Band Information:

http://gif.berkeley.edu/documents/Landsat%20Band%20Information.pdf

ArcGIS tutorial on band combination:

https://www.youtube.com/watch?v=a-DbA1E678c

Using spectral characteristics:
NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI):

http://earthobservatory.nasa.gov/Features/MeasuringVegetation/

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

https://www.youtube.com/watch?v=rxOMhQwApMc

The NDVI process creates a single-band dataset that mainly represents greenery index. This index outputs values between -1.0 and 1.0.

The negative values of this index represent clouds, water, and snow.

Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow.

Moderate values represent shrub and grassland (0.2 to 0.3)

High values indicate temperate and tropical rainforests (0.6 to 0.8)

Global NDVI:

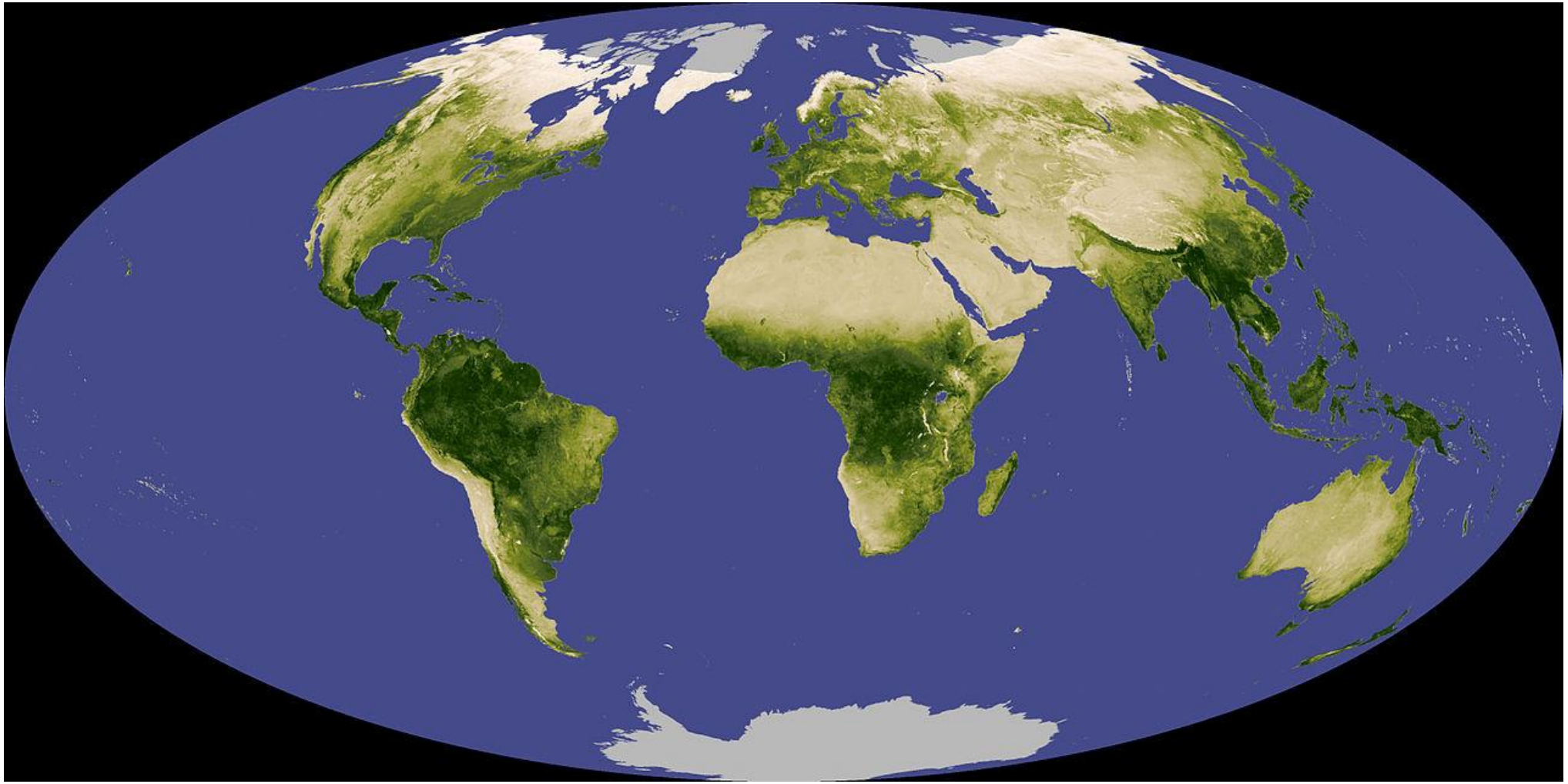


Image source: https://commons.wikimedia.org/wiki/File:Globalndvi_tmo_200711_lrg.jpg

NDVI in June over the British Isles (NOAA AVHRR)

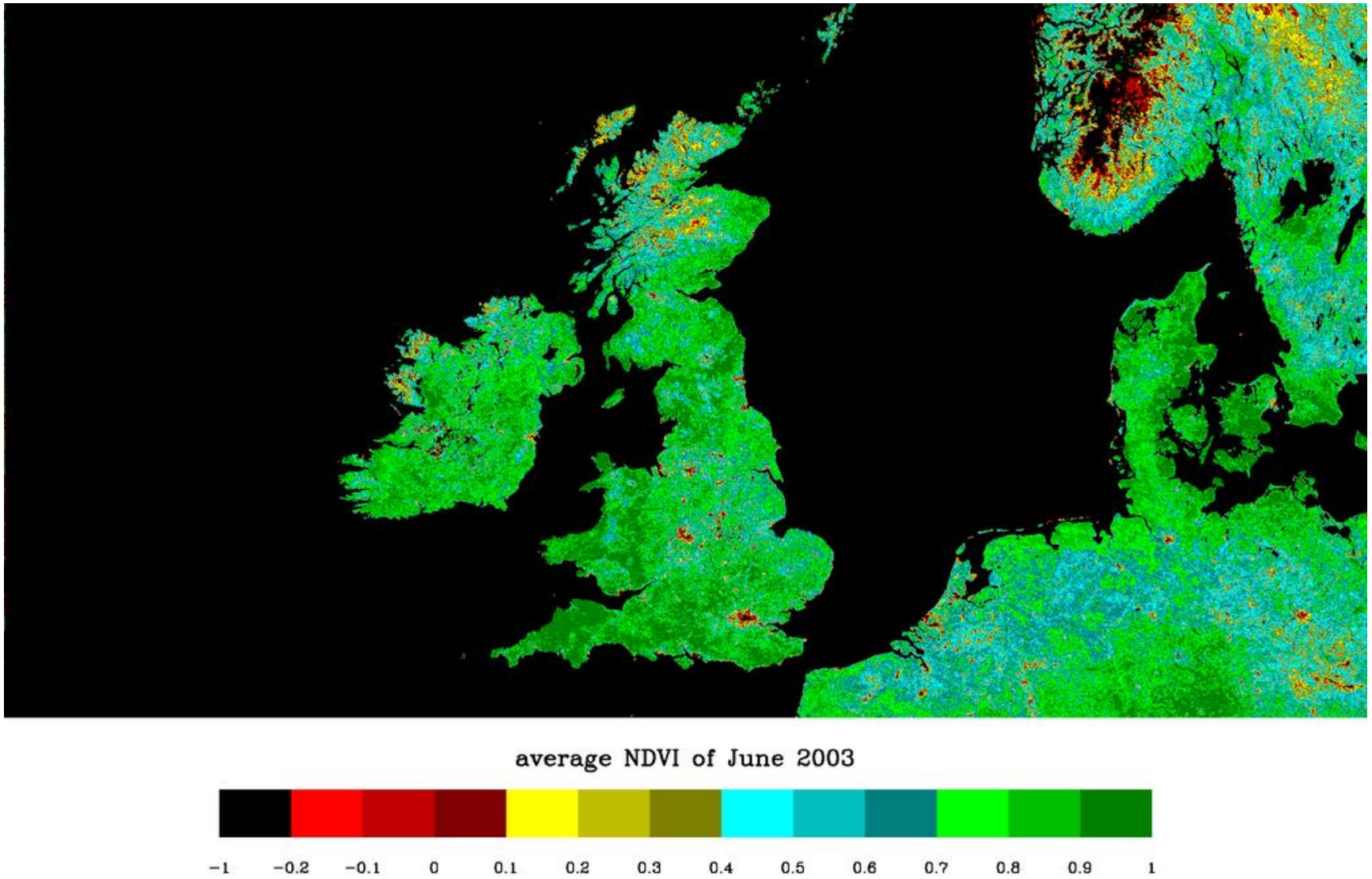
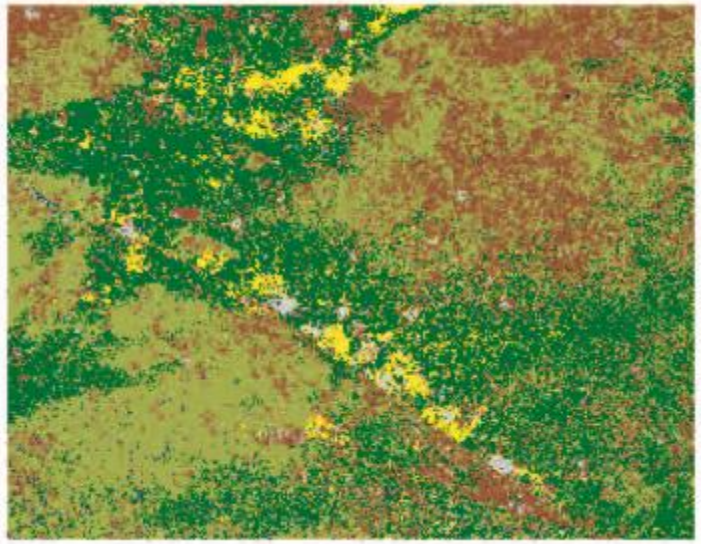


Image source: https://commons.wikimedia.org/wiki/File:NDVI_062003.png

SURFACE TEMPERATURE:

The temperature distribution in an area is important in relation with growth transpiration and precipitation.

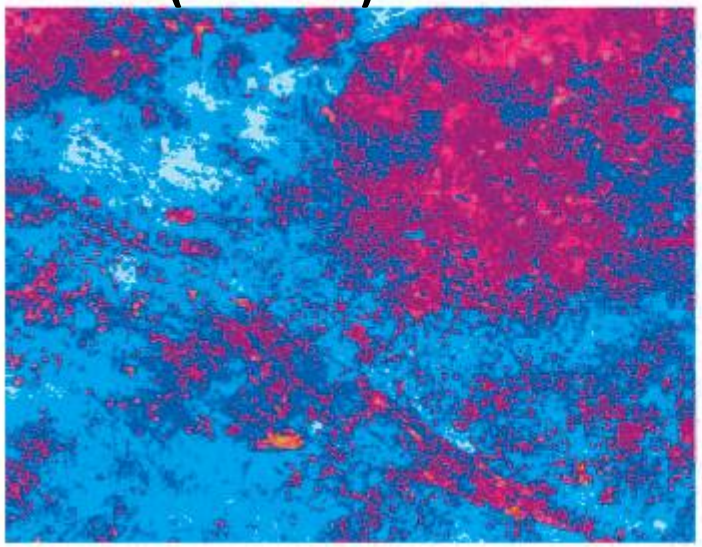
Bands 1 - 5



Land cover

- Unclassified
- Urban/roads
- Water/shadow
- Bare fields/soil
- Intensified agriculture
- Early-mid successional forest
- Mid-late successional forest

Band 6 (thermal)



Temperatures (°C)

- 25.0 - 25.9
- 26.0 - 26.9
- 27.0 - 27.9
- 28.0 - 28.9
- 29.0 - 29.9
- 30.0 - 30.9
- 31.0 - 31.9
- 32.0 - 32.9
- 33.0 - 33.9
- 34.0 - 34.9

Mature forest has the lowest temperatures.

Cleared, bare soil has the highest temperatures of the natural surfaces

Urban/roads having the highest temperatures overall.

Source:
Southworth J. 2004. An assessment of Landsat TM band 6 thermal data for analysing land cover in tropical dry forest regions. Int. J. Remote Sensing, 20 February, 2004, Vol. 25, No. 4, 689–706

SURFACE TEMPERATURE:

The surface temperature (Celsius) can be generated from thermal band 10 or 11 in Landsat 8

Step 1: Conversion to TOA (Top Of Atmosphere) Radiance.

OLI and TIRS band data can be converted to TOA spectral radiance using the radiance rescaling factors provided in the metadata file:

$$L_\lambda = M_L Q_{cal} + A_L$$

where:

L_λ = TOA spectral radiance (Watts/(m2 * srad * µm))
M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)
A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)
Q_{cal} = Quantized and calibrated standard product pixel values (DN)

Sources: https://landsat.usgs.gov/Landsat8_Using_Product.php

SURFACE TEMPERATURE:

Step 2: Conversion to At-Satellite Brightness Temperature.

TIRS band data can be converted from spectral radiance to brightness temperature using the thermal constants provided in the metadata file:

$$T = \frac{K_2}{Ln(\frac{K_1}{L_\lambda} + 1)}$$

where:

T = At-satellite brightness temperature (K)
L_λ = TOA spectral radiance (Watts/(m2 * srad * µm))
K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the band number, 10 or 11)
K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the band number, 10 or 11)

Sourcs: https://landsat.usgs.gov/Landsat8_Using_Product.php

SURFACE TEMPERATURE:

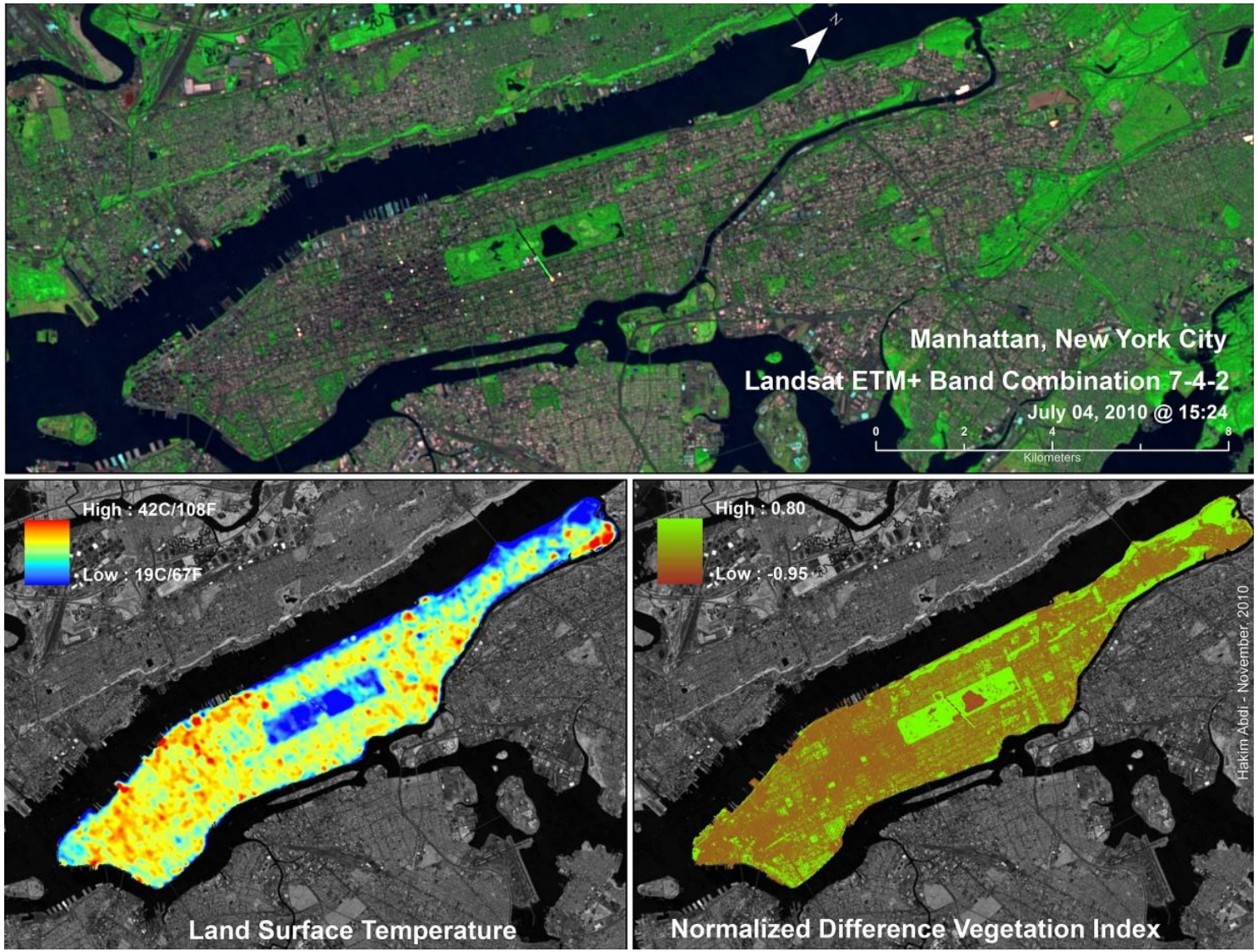


Image Source: http://www.hakimabdi.com/20111030/estimating-land-surface-temperature-from-landsat-thermal-imagery/