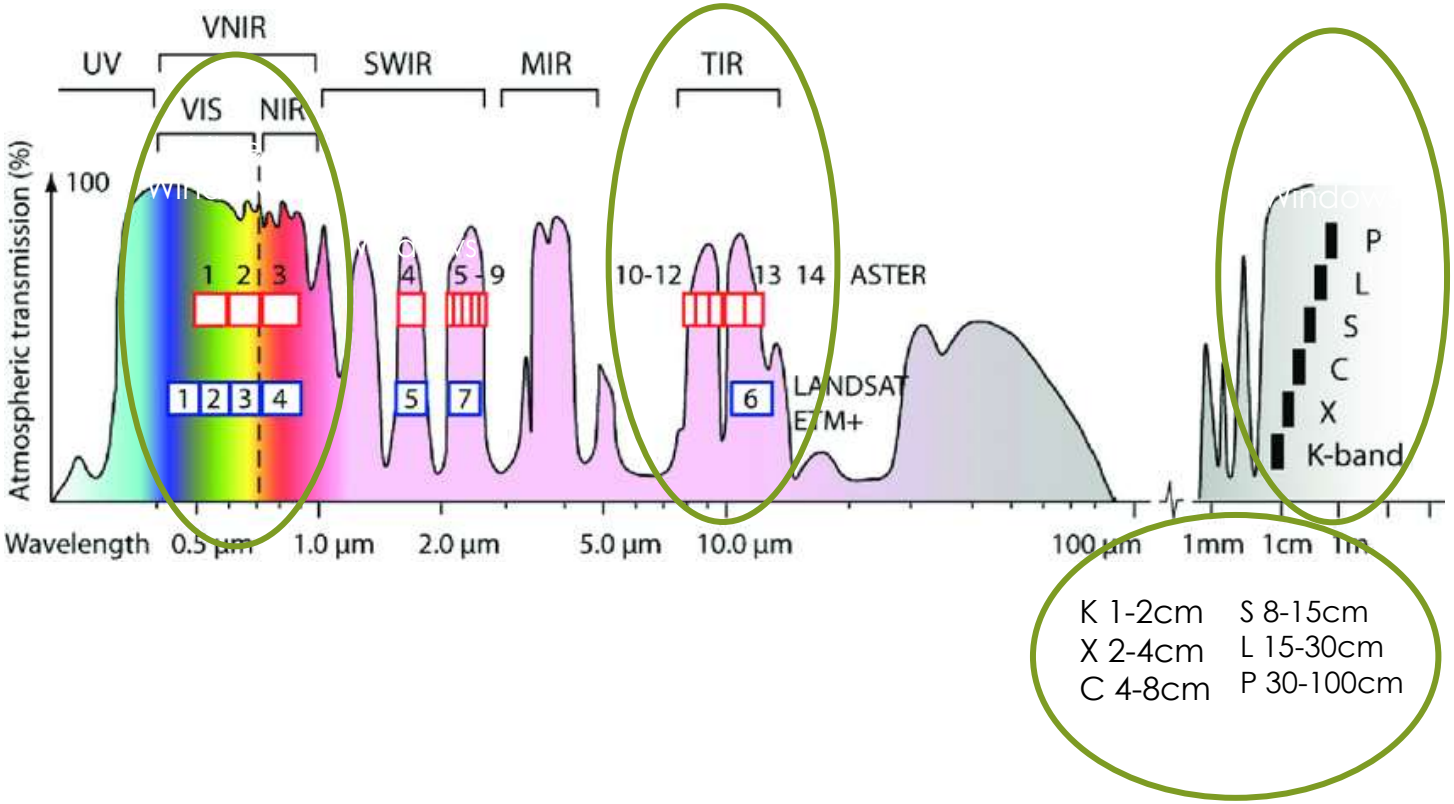
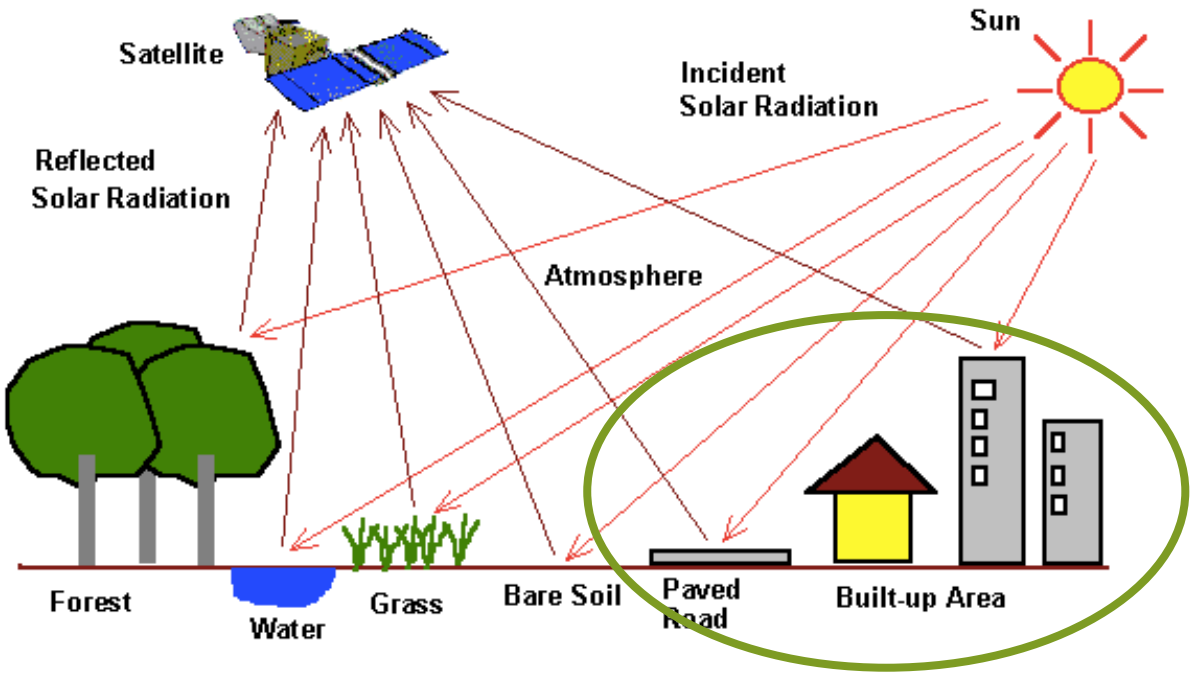
Land Remote Sensing: Introduction

GARIK GUTMAN,
LAND-COVER/LAND-USE CHANGE PROGRAM MANAGER,
NASA HEADQUARTERS
WASHINGTON, DC

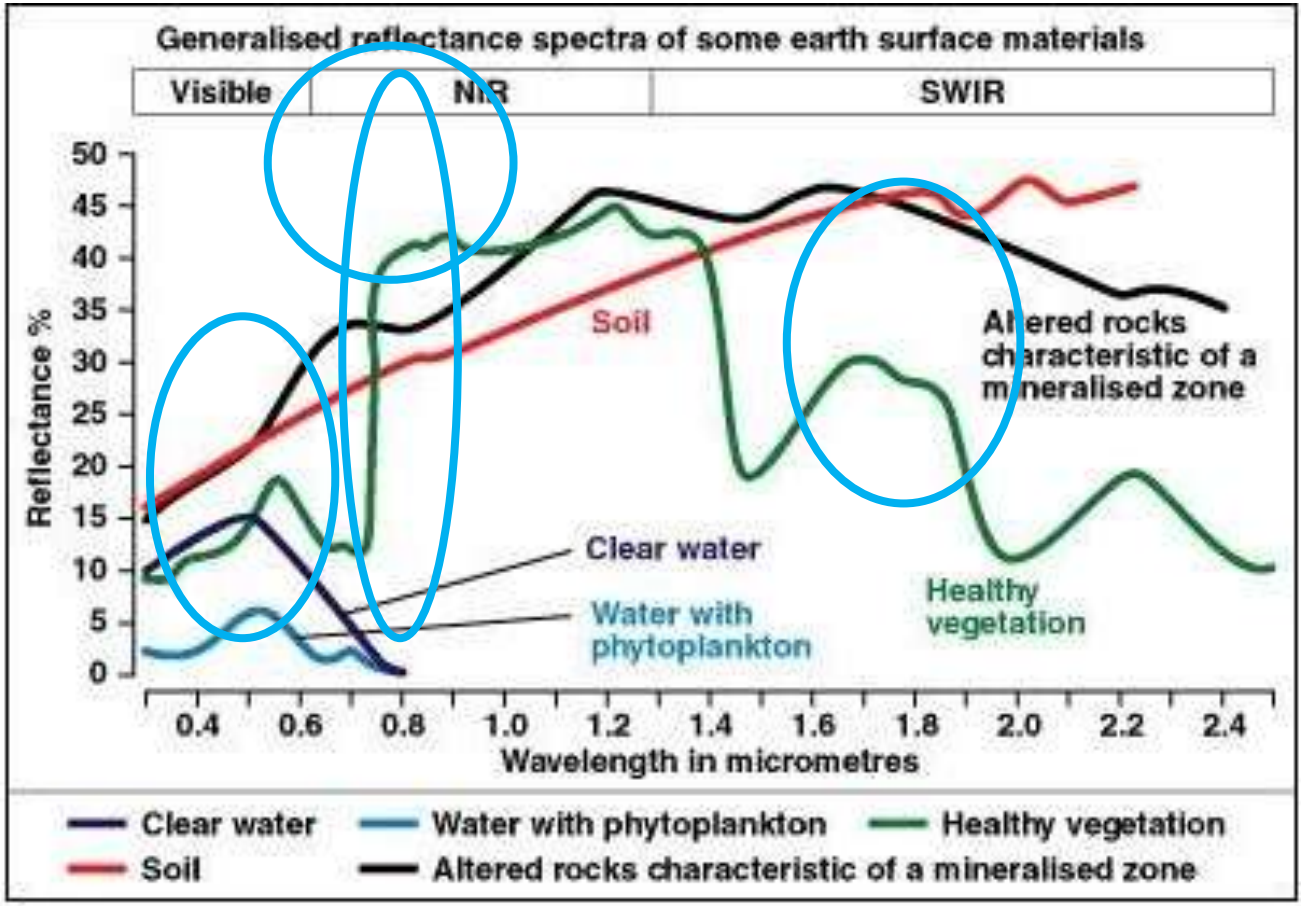
Atmospheric windows for surface remote sensing



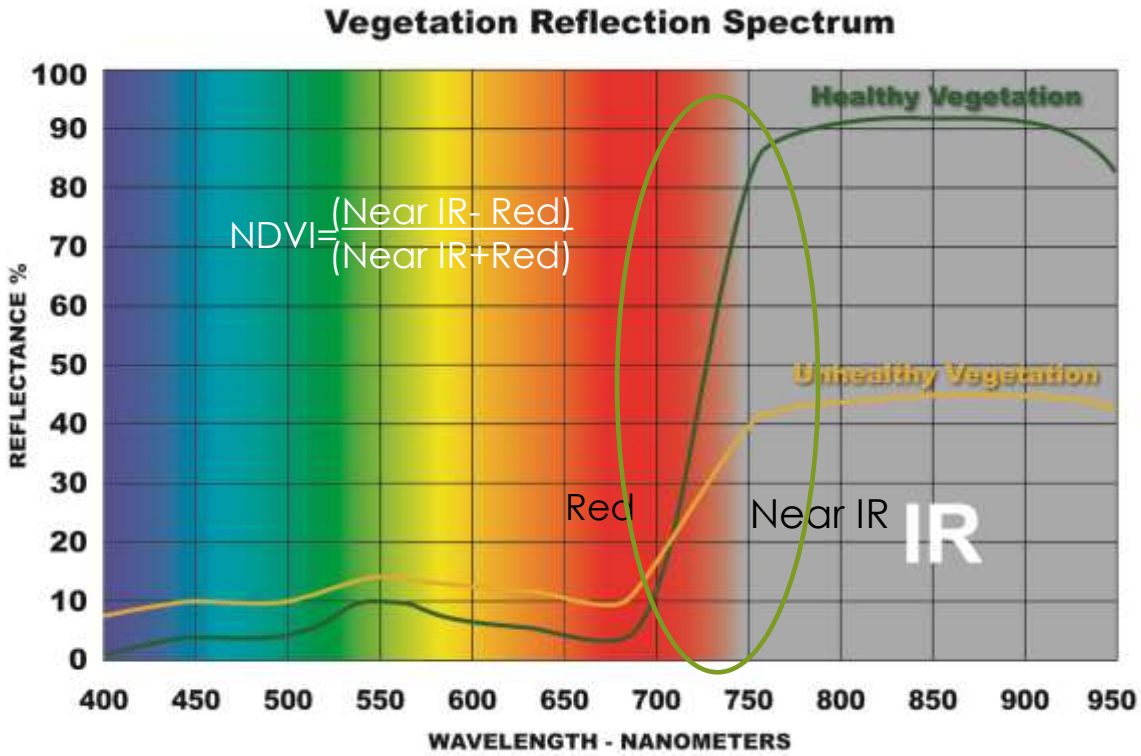
Remote Sensing of Reflected Sun Radiation



Reflectance Spectra of Earth Surfaces

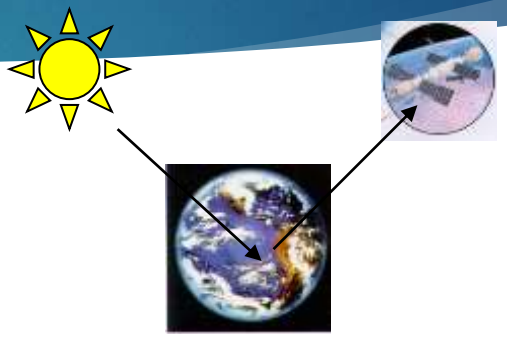


Green vegetation vs non-green veg. or soil

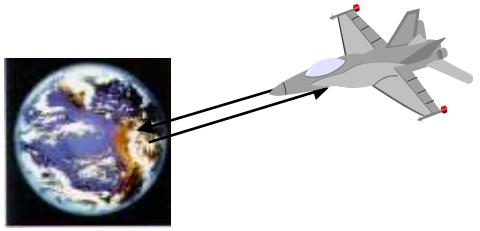


Remote Sensing: Passive - Active

- Passive Systems
  - Use natural energy sources: Sun
  - Reflected or emitted energy
- Active Systems
  - Have their own energy source
  - Radar, Lidar
  - Work in the dark
  - Radar – all-weather sensor
  - Lidar – optical, clear conditions

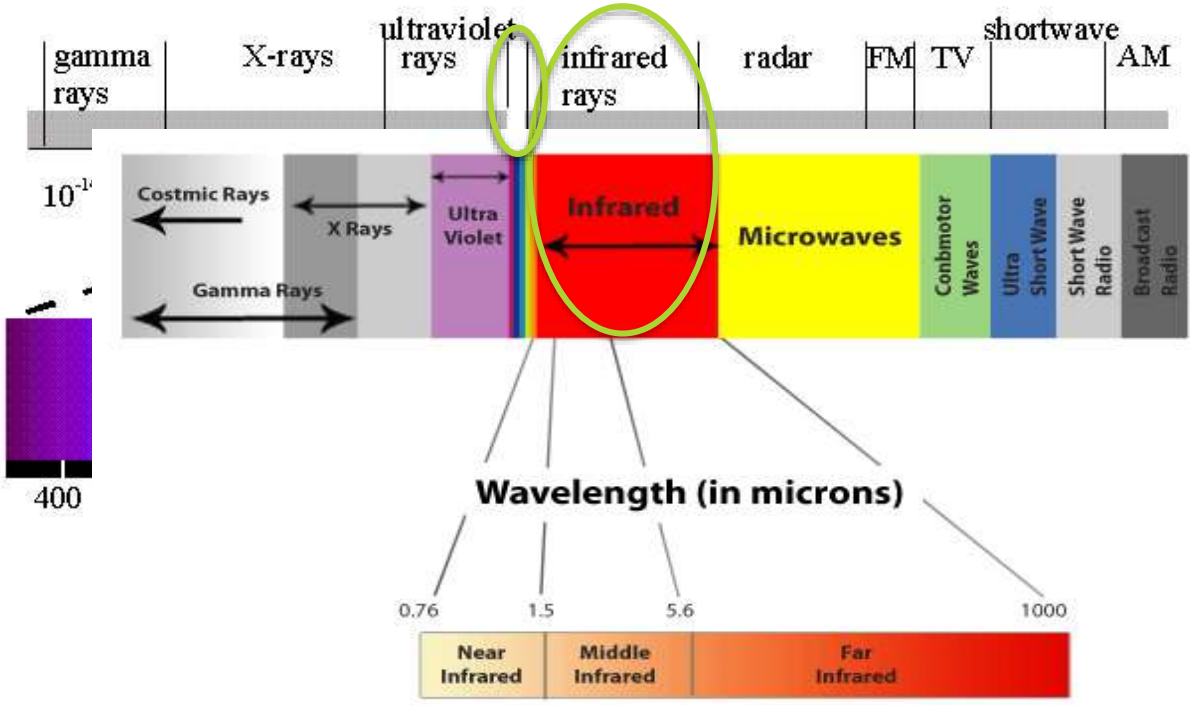


Passive, Reflected



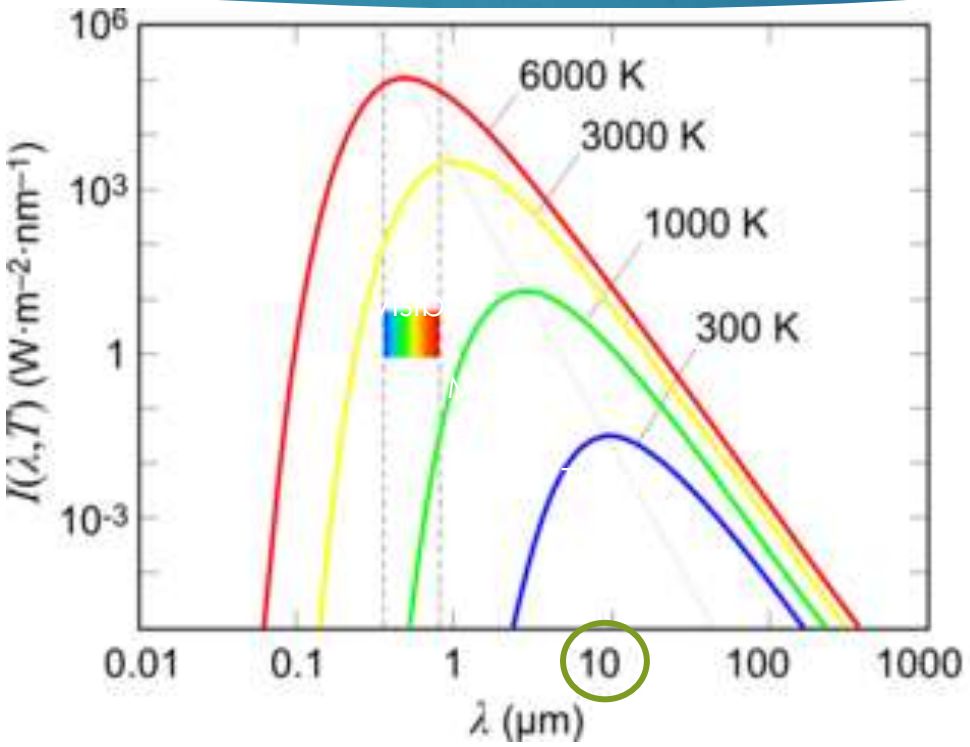
Active

Electromagnetic Spectrum



Principle of Thermal Remote Sensing

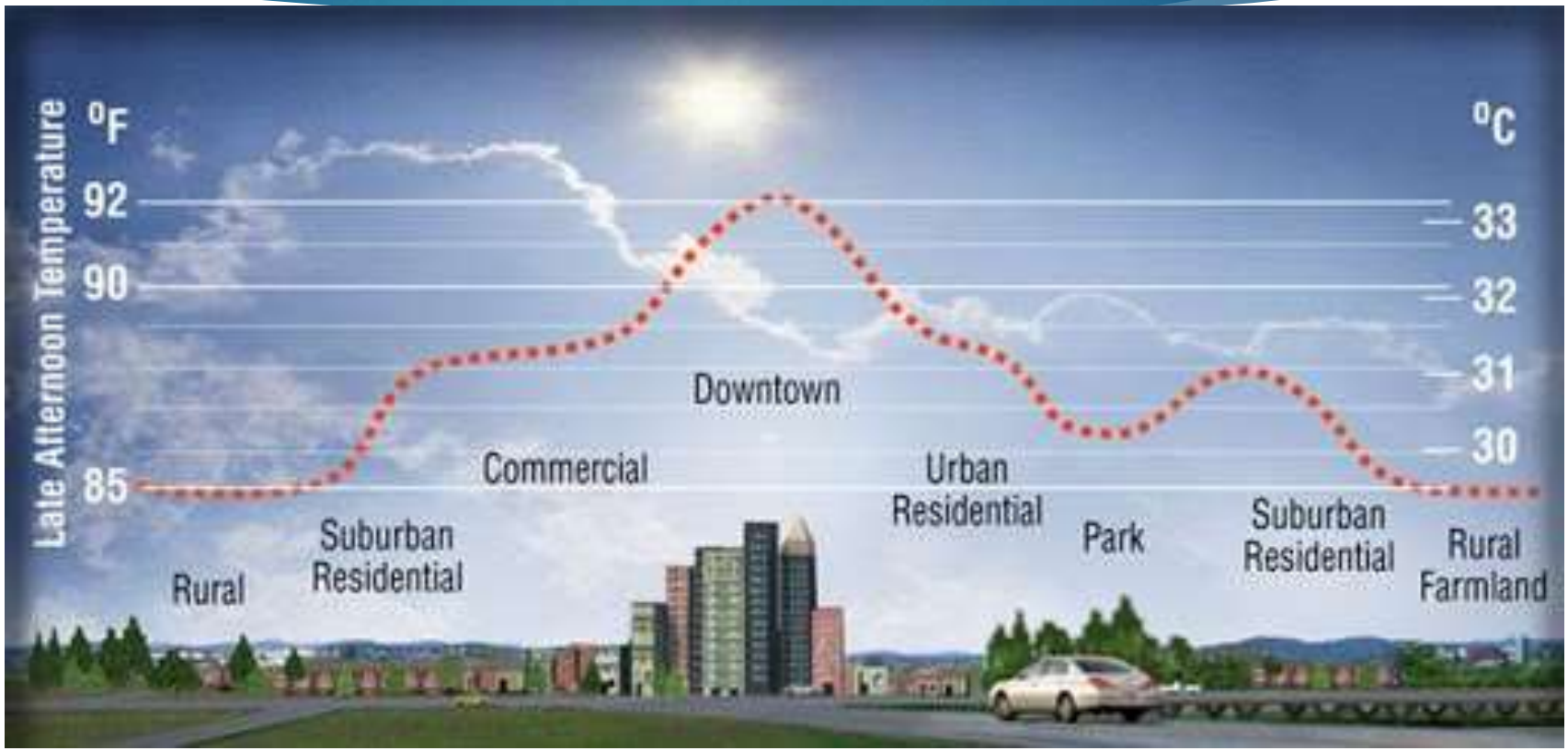
Spectral radiant emittance in W/(m^2/micron)



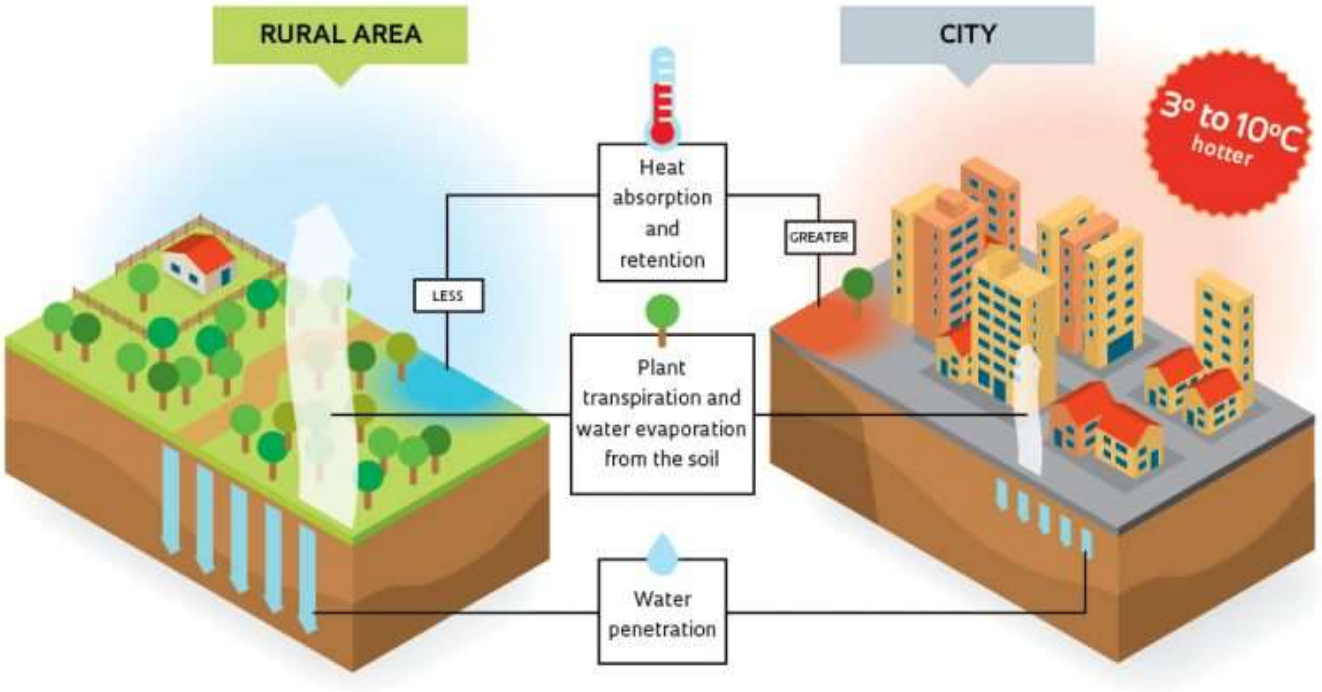
Planck law (log log scale)

The amount of electromagnetic energy radiated by a black body for different wavelengths in thermal equilibrium

Heat Island Effect

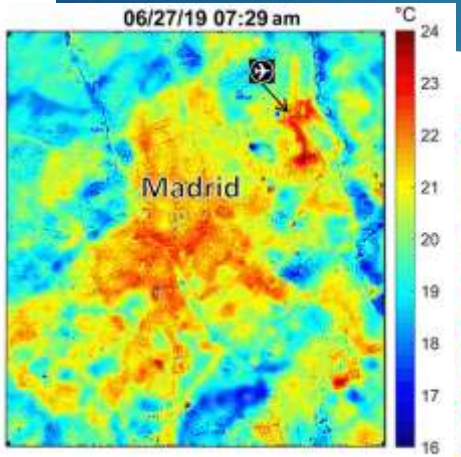


Why the urban heat island effect occurs

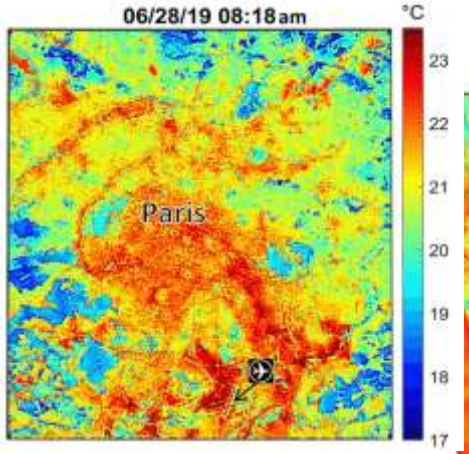


- **Surface permeability**
- **Vegetation cover**

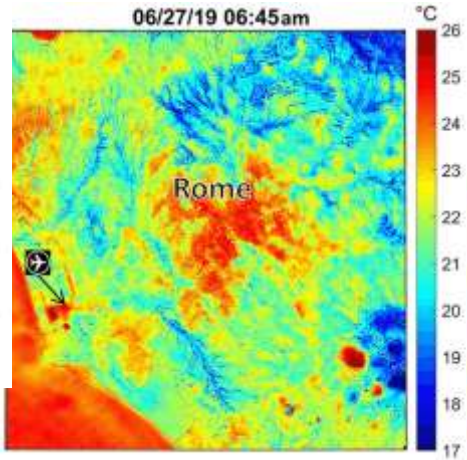
Heat island effect in European cities as observed from space (ECOSTRESS on ISS): June 2019



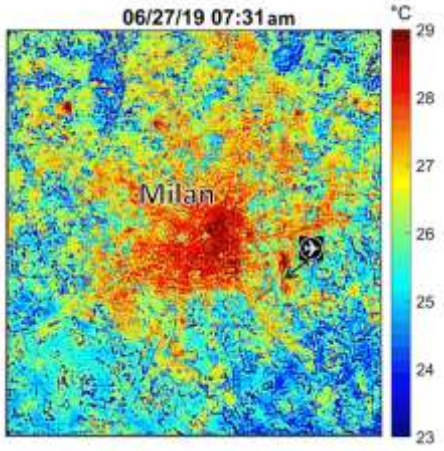
Madrid



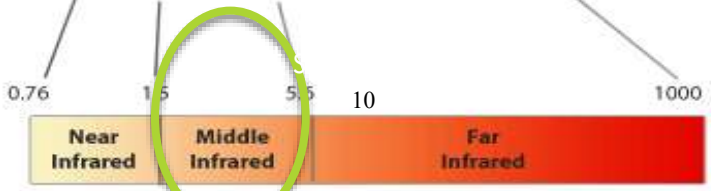
Paris



Rome



Milan



TV remote control
0.94 micron

Fire 4 microns

Humans, at normal body temperature, radiate most strongly at about **10 microns**.

William Herschel

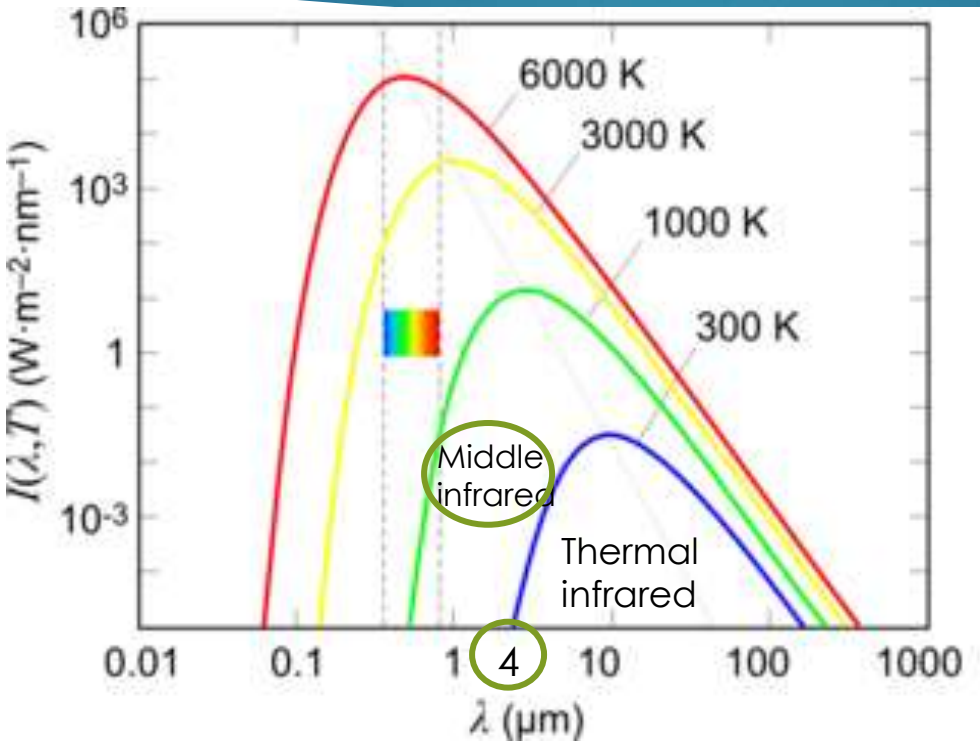
- Discovered IR in 1800
- Discovered Uranus
- Court Astronomer for George III

https://en.wikipedia.org/wiki/Infrared#History_of_infrared_science

Principle of Monitoring Fires

Spectral radiant emittance in W/(m^2/micron)

An inverse relationship between the wavelength of the peak of the emission of a black body and its temperature



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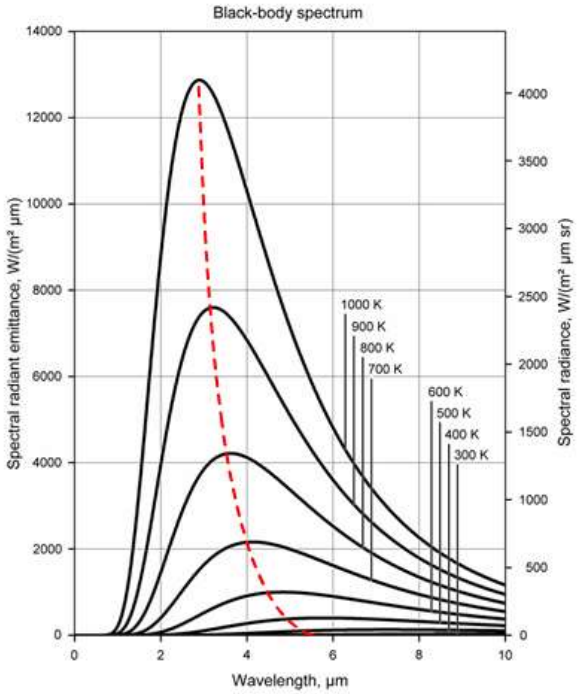


Wiens' displacement law

The hotter an object is, the shorter the wavelength, at which it will emit most of its radiation

Detecting fire hot spots with middle infrared

2019 hot spots

Image credit: NASA Earth Observatory/J. Stevens

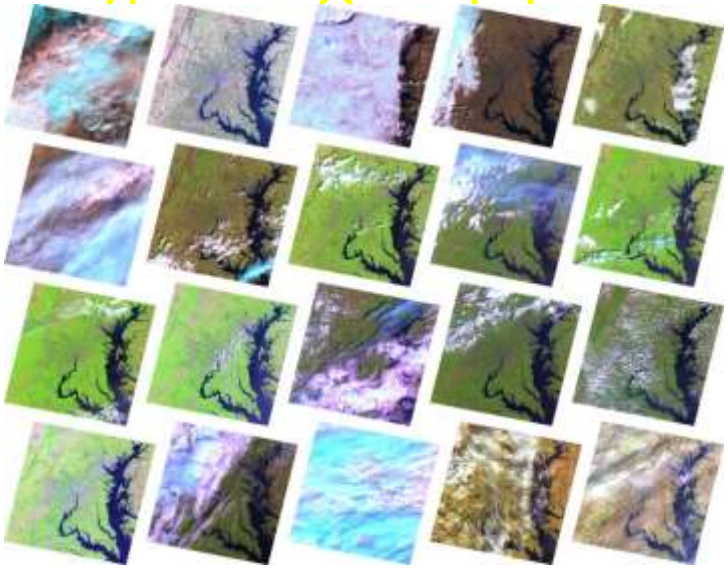
Hot spots map based on MODIS 4 μm data

Air photo

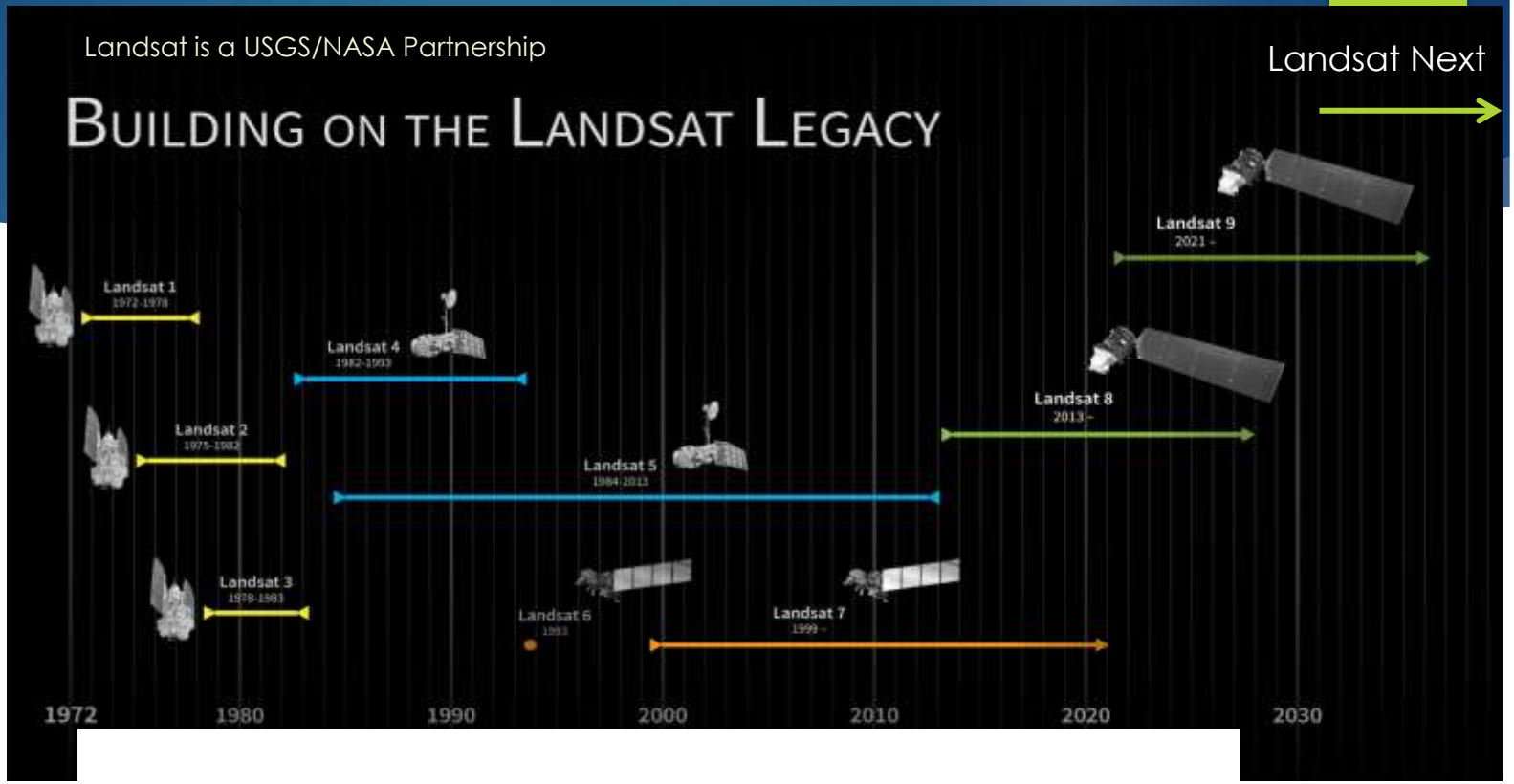
Monitoring land with Landsat system

50 years of an eye in the sky

30-METER OBSERVATION EVERY 8 DAYS

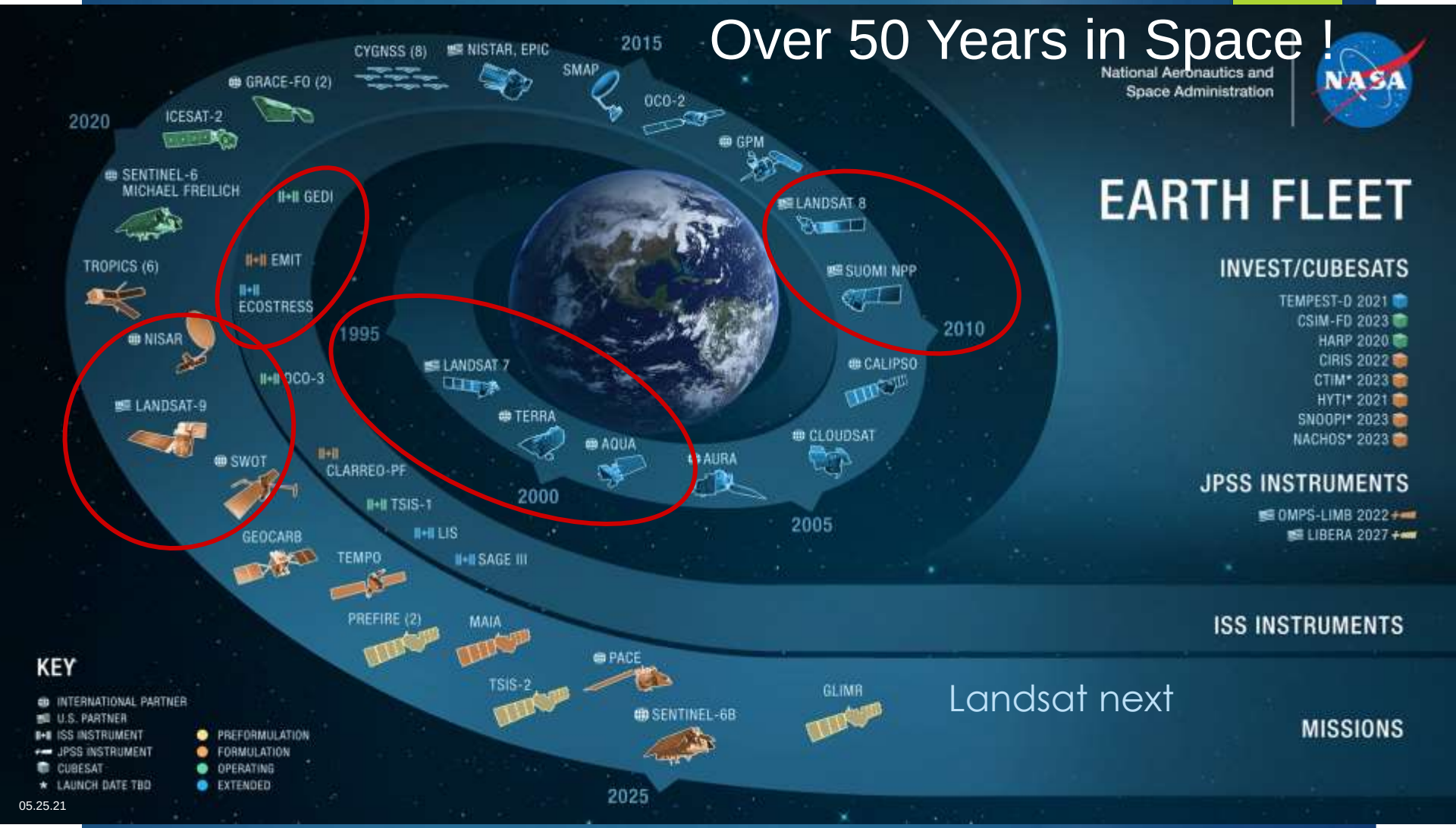


Washington, D.C., between January-November 2002



- The Landsat program: Earth Resources Technology Satellites Program 1966, Landsat 1 (ERTS) launched in July 1972
- Thermal band added for Landsat 3 and beyond
- After launch, Landsat operations are transferred from NASA to USGS to collect, archive, process, and distribute the image data
- Until 2010 expensive, FREE NOW!
- Two-Landsat system frequency revisit time: 8 days -- in some areas may not provide enough observations for monitoring rapid changes (e.g., Ag) but sufficient for slow changes (e.g., Urban)

NASA Operating Missions



NASA Land Surface-Relevant Missions

Systematic Missions - Observation of Key Earth System Interactions

coarse resolution

moderate-→ high resolution

Landsat 5 & 7
3/1/84 & 4/15/99

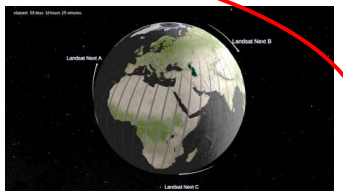
Terra
12/18/99
ASTER

Aqua
5/3/02
MODIS

Suomi-NPP
10/28/11
VIIRS

Landsat 8
2/11/13

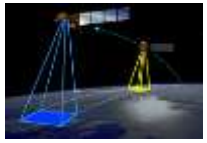
Landsat 9
9/27/21



Landsat Next
Nov 2030

Exploratory Missions –
Exploration of Specific Earth System Processes and Demonstration of Technologies

ShuttleRadar Topography Mission SRTM
2/11/02-2/22/02
Space Shuttle Endeavour



Earth Observing EO-1
ALI (predecessor of Landsat-8)
Hyperion – first hyperspectral in space
11/21/00-3/30/2017

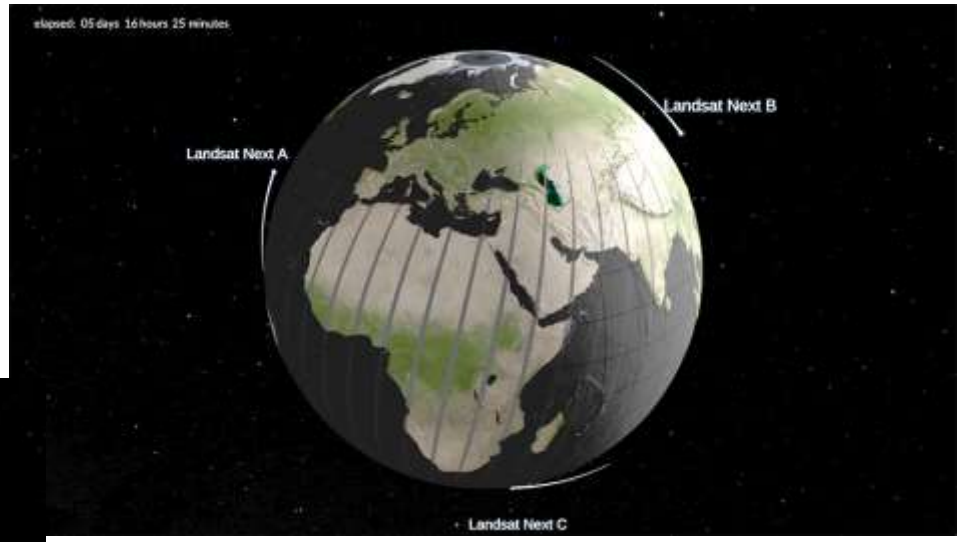
International Space Station (ISS)

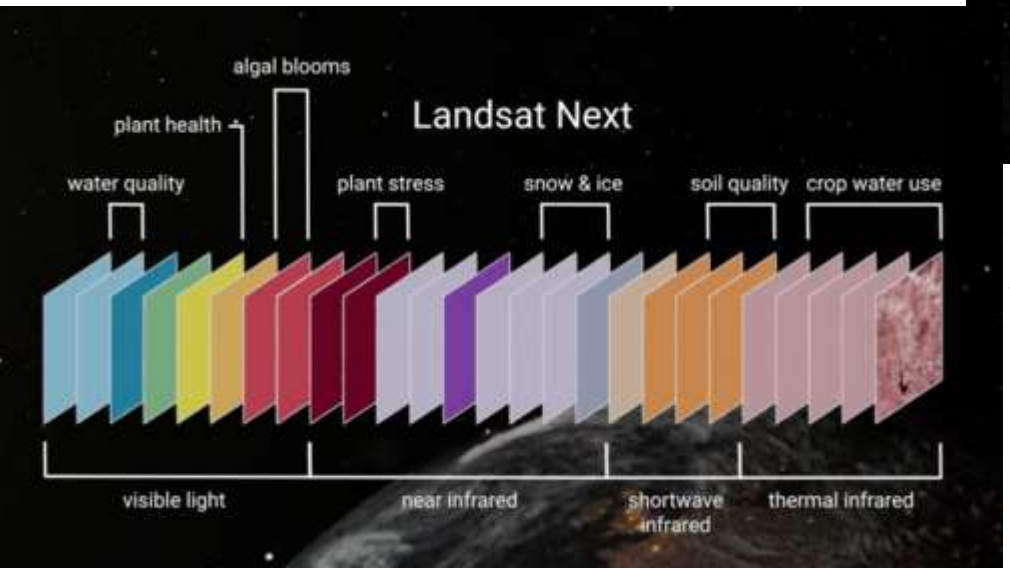
ECOSTRESS (thermal IR)
GEDI (Lidar)
DESIS (Hyperspectral)
Deployed in 2018

EMIIT (Hyperspectral)
Deployed in 2022

Landsat Next

- Constellation of 3 small satellites
- 26 wavelengths bands
- More frequent and finer resolution
- Launch: late 2030





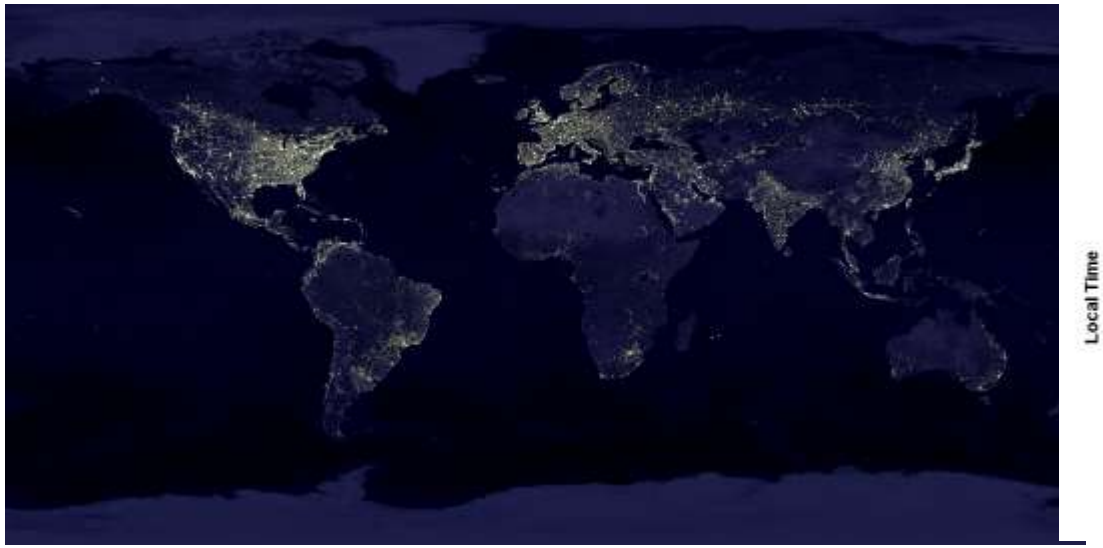
Landsat Next constellation of three spacecraft will provide finer spatial resolution (10-20m) and expanded spectral (26 band) imaging capabilities every six days (at the equator)

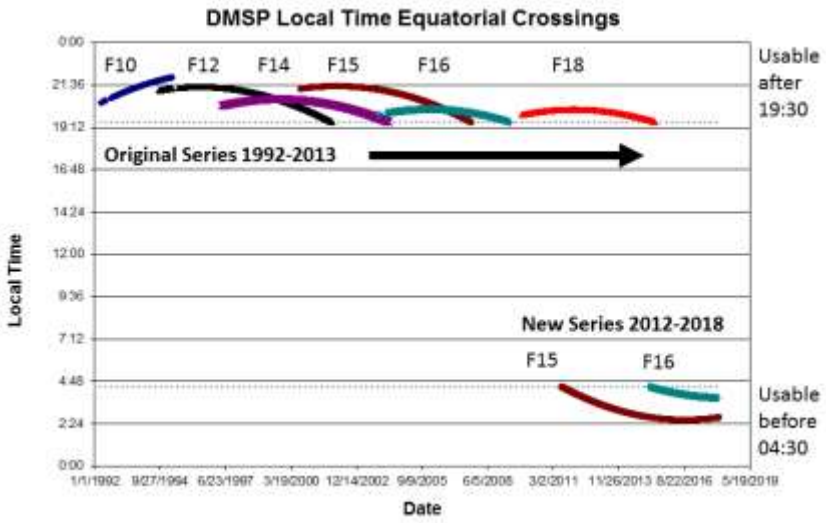
Defense Meteorological Space Program

Operational Linescan System: Night Lights

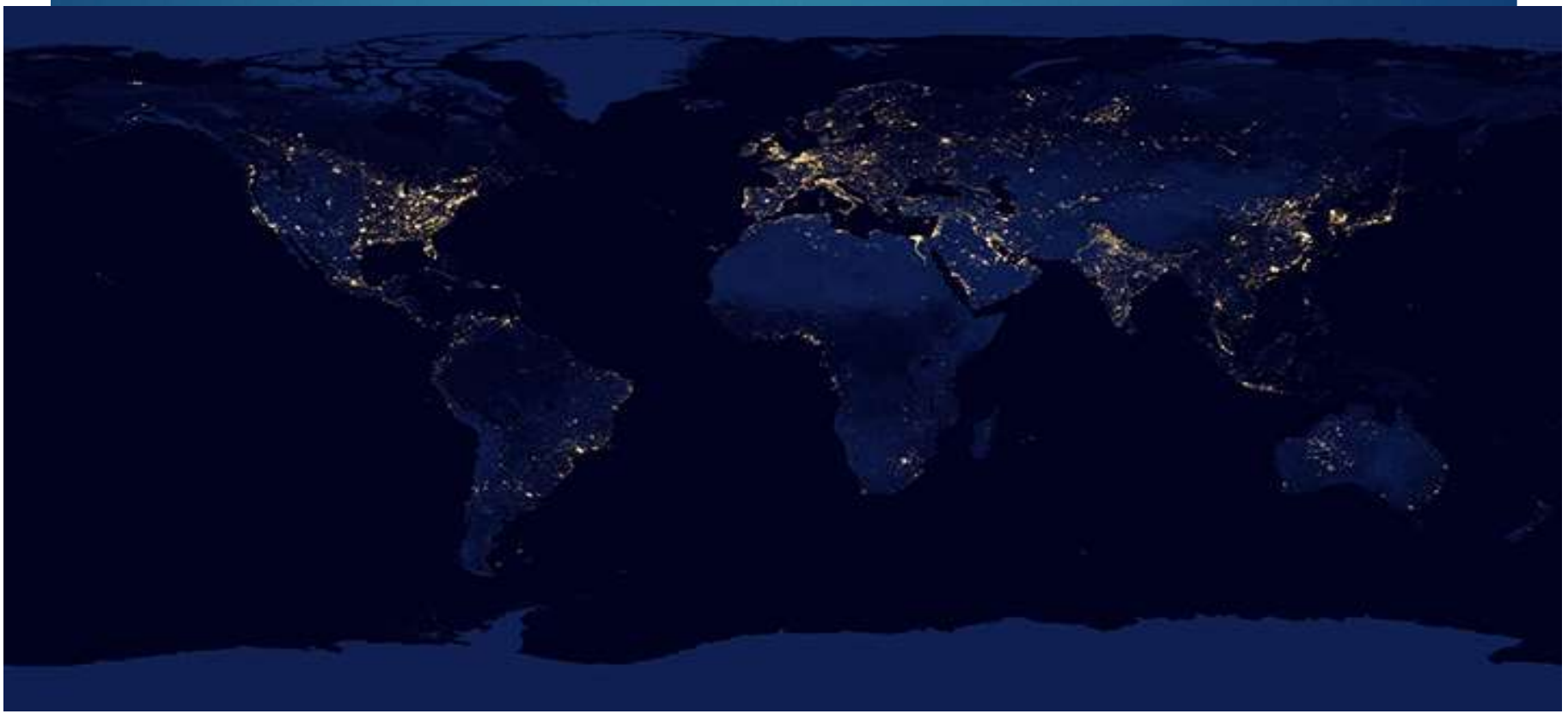
Non-NASA Mission: Dept. of Defense and NOAA

Original Time series: from1992 to 2013
New time series: 2012-2018





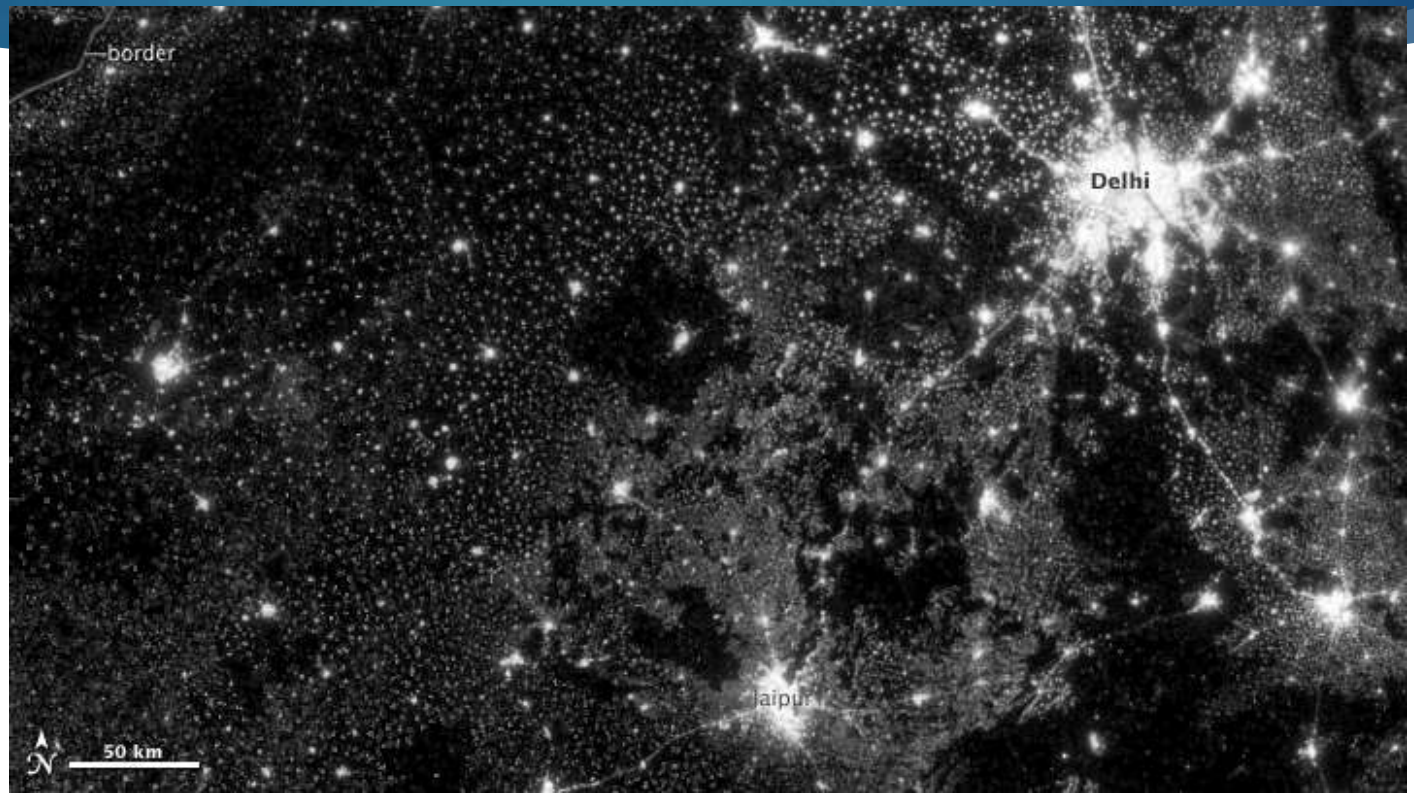
Global Night Lights: DMSP/OLS→ VIIRS/S-NPP



From OLS (5km^2/ 6 bits) to VIIRS(742 m^2 /14 bit)

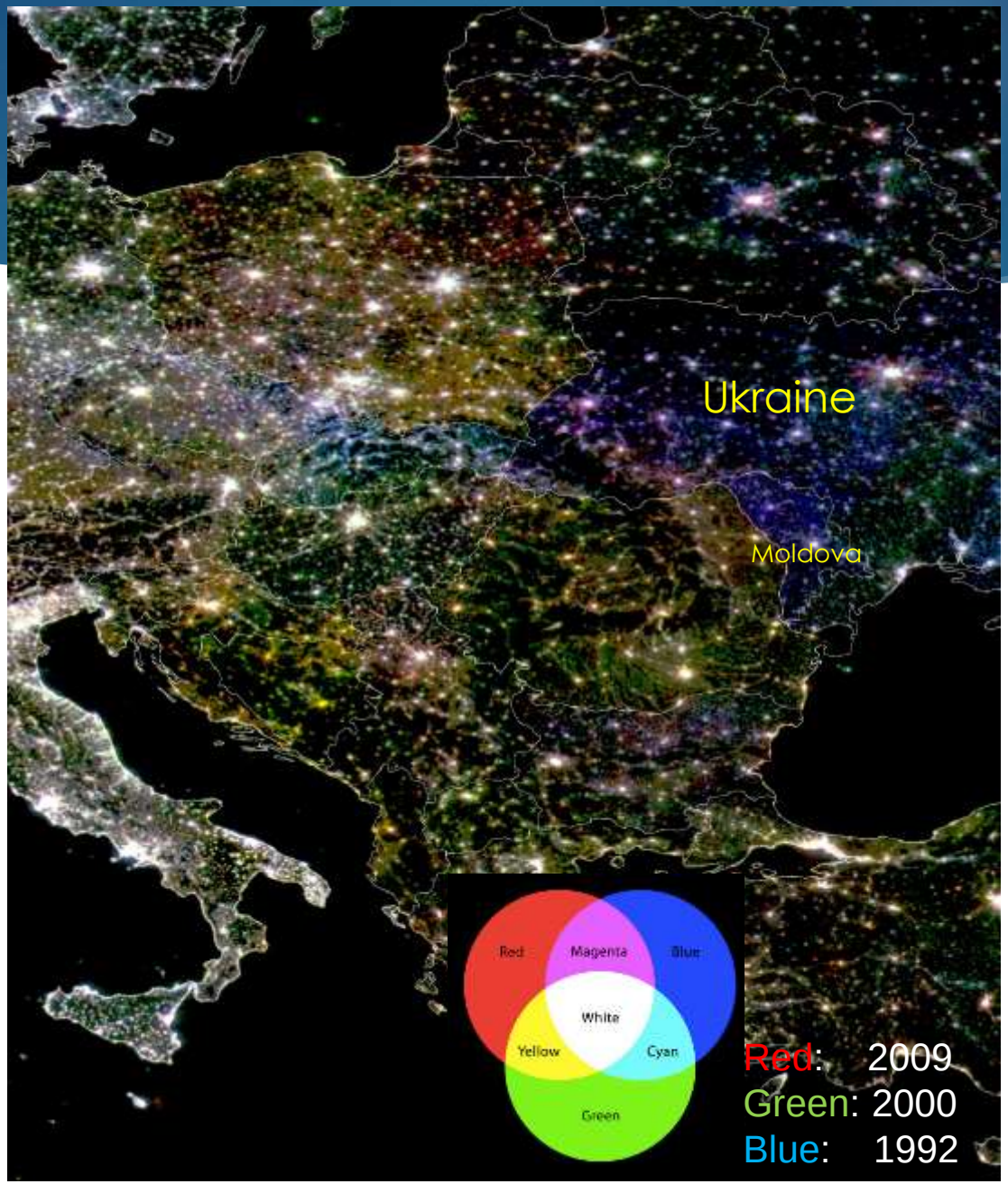
The Night Lights composite assembled from data acquired by the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite over nine days in April 2012 and thirteen days in October 2012.

DMSP/OLS → NPP/VIIRS: Delhi, India



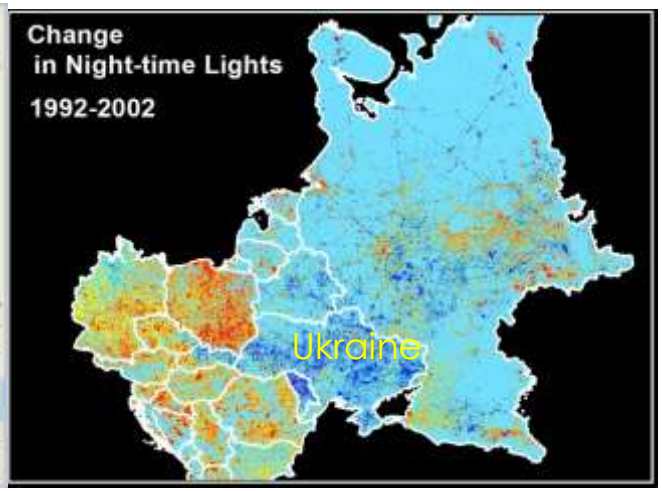
From OLS (5km^2/ 6 bits) to VIIRS(742 m^2 /14 bit)

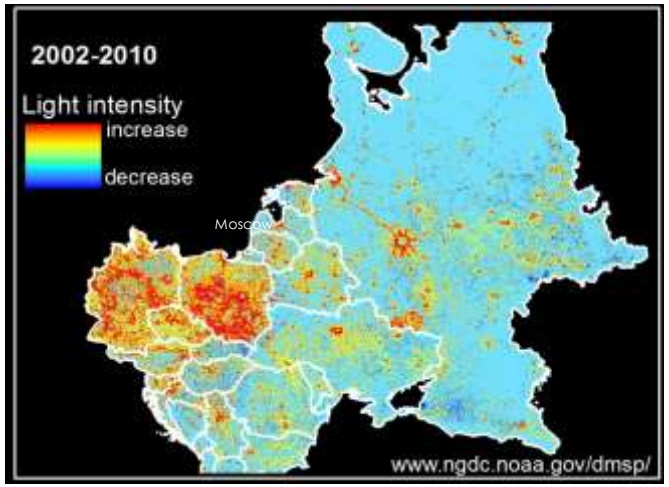
DMSP/OLS Night Lights Over Europe: 1992-2009



DMSP Night Lights Reflecting Changes in Economy

The Decade of Collapse **The Decade of Recovery**





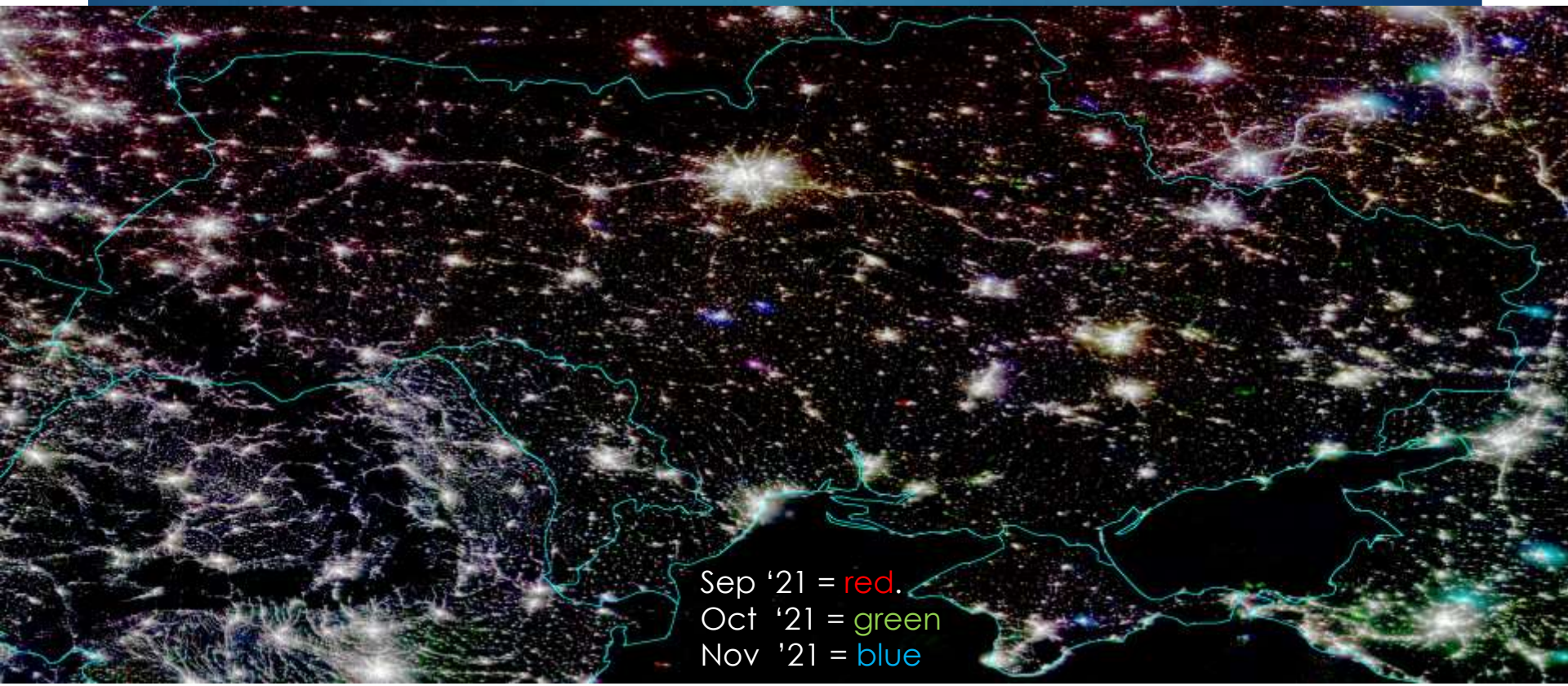
Deep Blue: Depressed Economies
(e.g. Ukraine & Moldova)
Red: Positive Economy Development

Light Blue: neutral (not much change)

Red: Economy and urban expansion (e.g. Moscow)

Courtesy: Chris Elvidge (formerly at NOAA)
Volker Radeloff (U. Wisconsin)

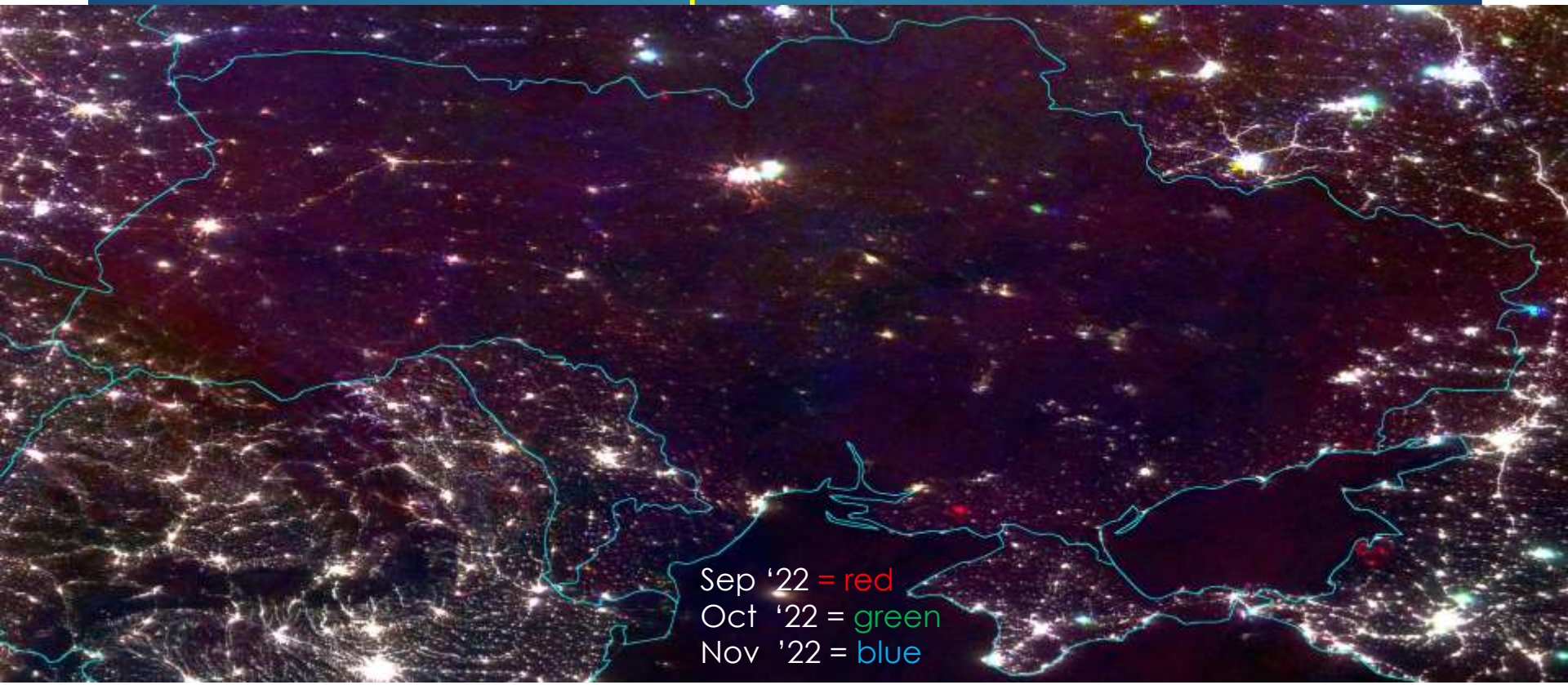
2021 Pre-war Condition



The image shows three months of 2021 VIIRS nighttime lights as red, green, and blue. September 2021 = red. October 2021 = green. November 2021 = blue. The white tones indicate the brightness of lighting is near equal in all three months.

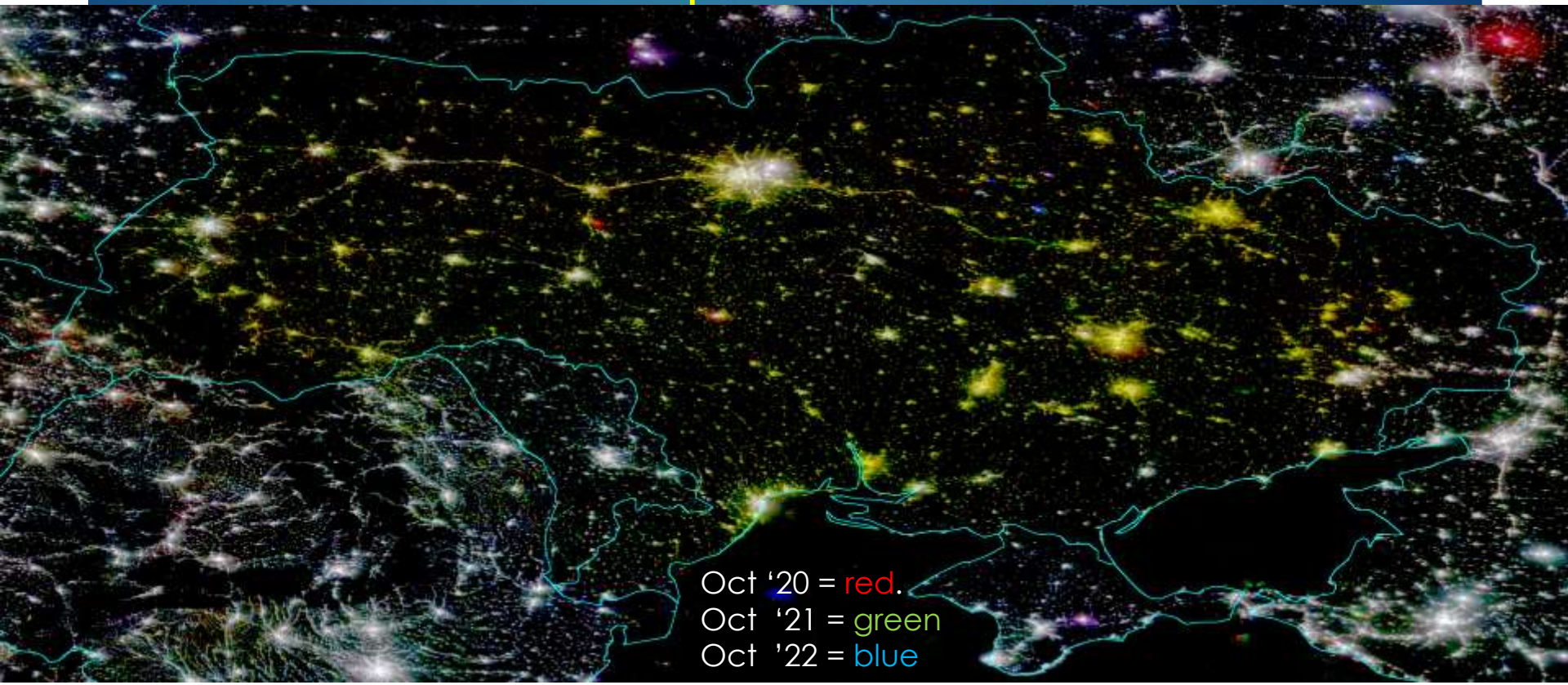
Courtesy: Chris Elvidge (School of Mining)

2022 War Impacted Condition



The image shows VIIRS nighttime lights as red, green, and blue. September 2022 = red. October 2022 = green. November 2022 = blue. The white tones indicate the brightness of lighting is near equal in all three months. Most of the 2021 lighting features have been lost in the Ukraine in 2022. Note that lighting is still present in the center of Kyiv and Lviv. Lights are on in portions of Russian controlled Donbas and Crimea.

2022 War Impacted Condition



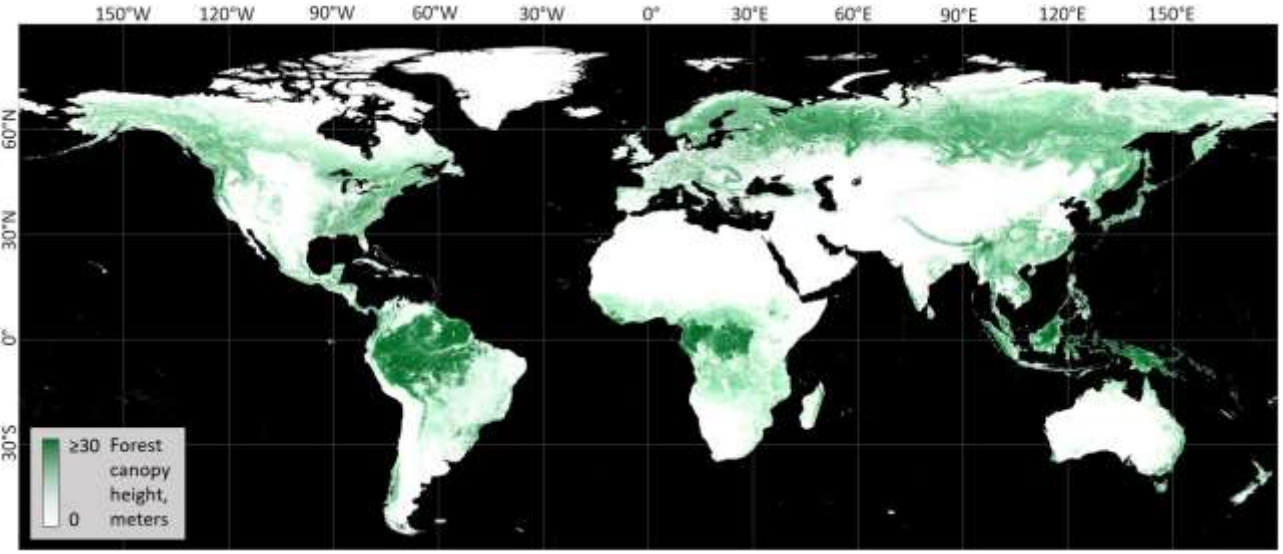
The image shows VIIRS nighttime lights from three Octobers as red, green, and blue. October 2020 = red. October 2021 = green. October 2022 = blue. The white tones indicate the brightness of lighting is near equal in all three months. Most of the lighting features in Ukraine are a golden-yellow, indicating that lighting was not detected in 2022. Note that lighting is still present in the center of Kyiv and Lviv. Lights are on in portions of Russian controlled Donbas and Crimea.

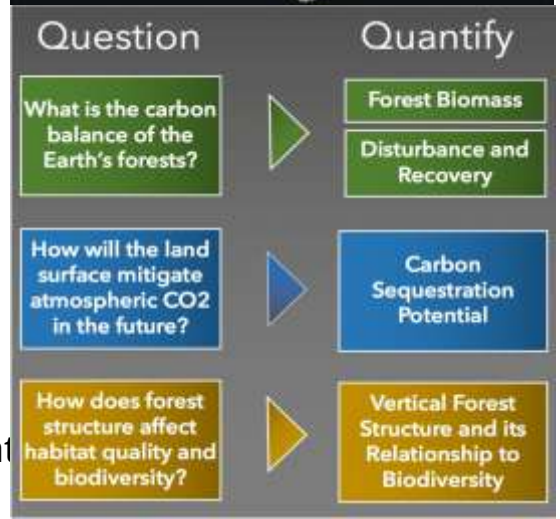
Global Ecosystem Dynamics Investigation
NASA GEDI instrument on ISS

- High resolution laser ranging observations
  - Launched June 29, 2018
  - three lasers produce eight parallel tracks of observations
  - each laser fires 242 times per second and illuminates a 25 m spot (a footprint) on the surface

GLAD Global Land Analysis & Discovery

Global Forest Canopy Height: 2019



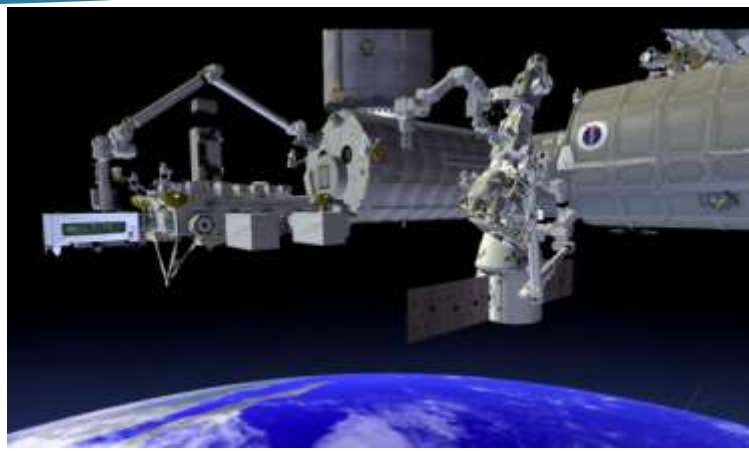


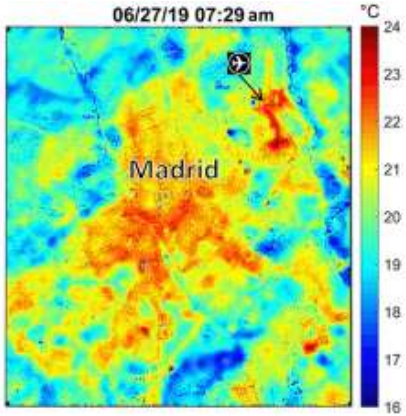
Integration of the GEDI lidar forest structure measurements and Landsat analysis-ready data time-series

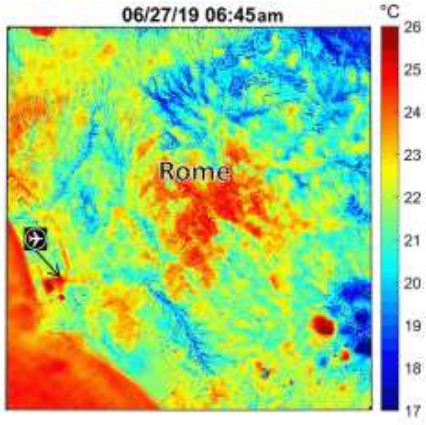
ECOSTRESS: NASA Instrument on ISS

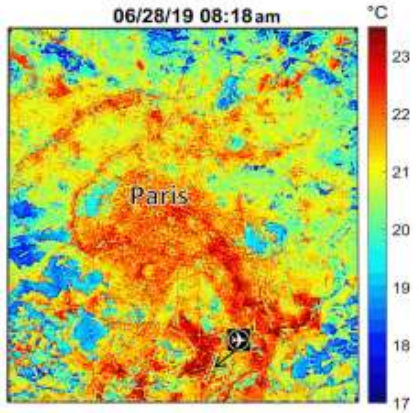
ECOsystem Spaceborne Thermal Radiometer Experiment on the International Space Station (ISS)

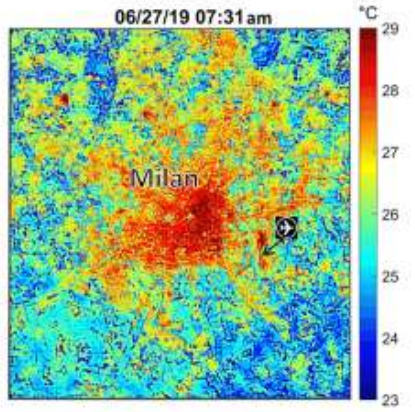
- Prototype HyspIRI **Thermal Infrared** Radiometer
  - Launched June 29, 2018
  - 5 spectral bands in the 8-12.5 µm range +1.6 µm
  - Spatial resolution ~70 m
  - **Advantage** over ASTER (on TERRA) – more frequent revisit
- Science objectives
  - Identify critical thresholds of water use and water stress in key biomes (e.g., tropical/dry transition forests, boreal forests)
  - Detect the timing, location, and predictive factors leading to plant water uptake decline and cessation over the diurnal cycle
  - Measure agricultural water consumptive use over CONUS at spatiotemporal scales applicable to improving drought estimation accuracy







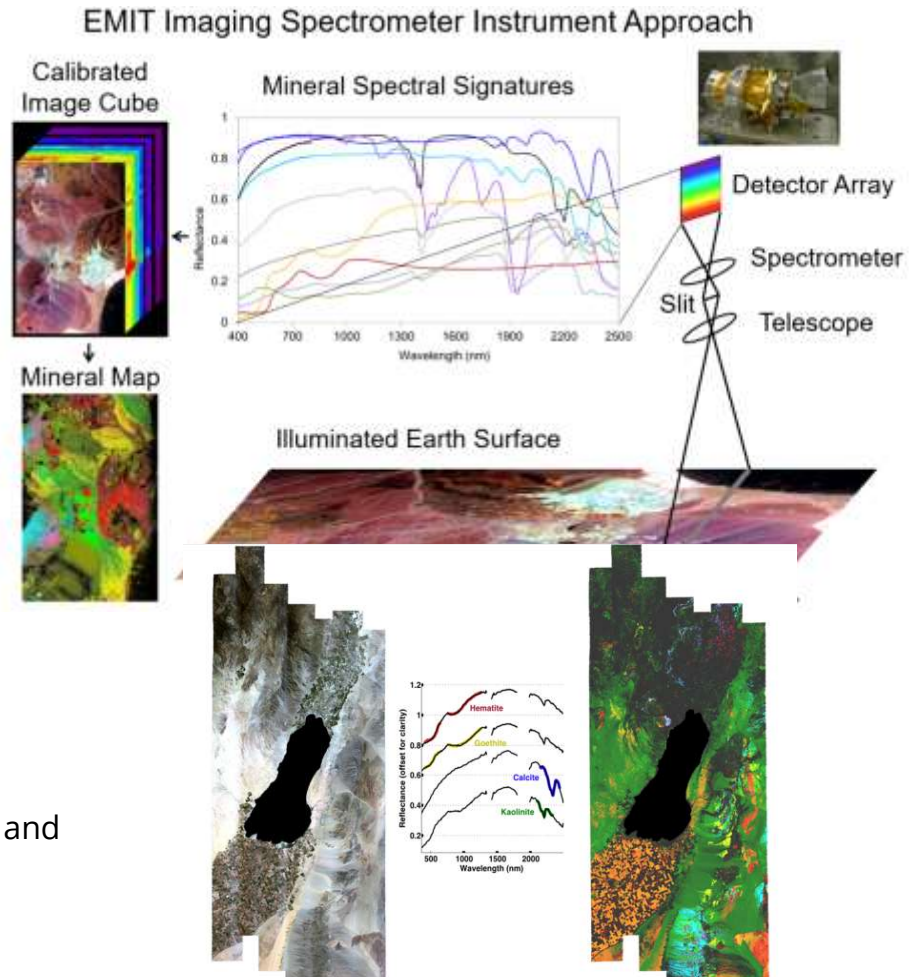




EMIT on ISS

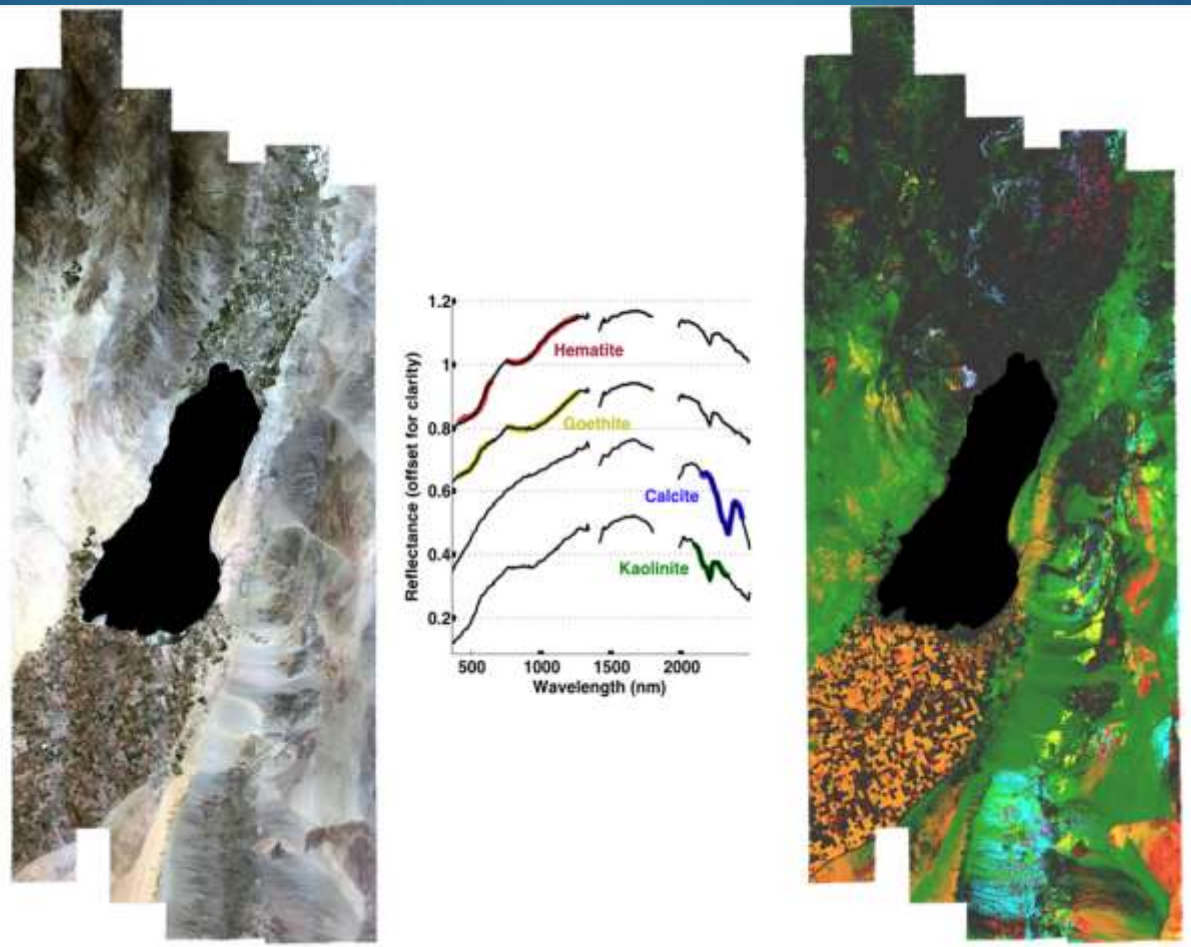
Earth Surface Mineral Dust Source Investigation

- Advanced imaging spectrometer with spectra range: 380-2500 nm
- Launched July 14, 2022
- **Primary applications: mineral dust, its heating and cooling effects in the atmosphere**
- **Potential applications: natural hazards (** flood extent, ecosystem impacts, and surface water sediment load); **environmental pollution (**oil spills, ocean plastics, acid mine drainage, etc.); **coastal waters and harmful algal blooms (**ocean phytoplankton, harmful algal bloom biomass and composition, coral presence and bleaching events, and the health of coastal ecosystems)



Airborne AVIRIS mapping of hematite, goethite, calcite, and kaolinite over the Salton Sea region of California

Mapping Mineral Composition



AVIRIS mapping of hematite, goethite, calcite, and kaolinite over the Salton Sea region of California

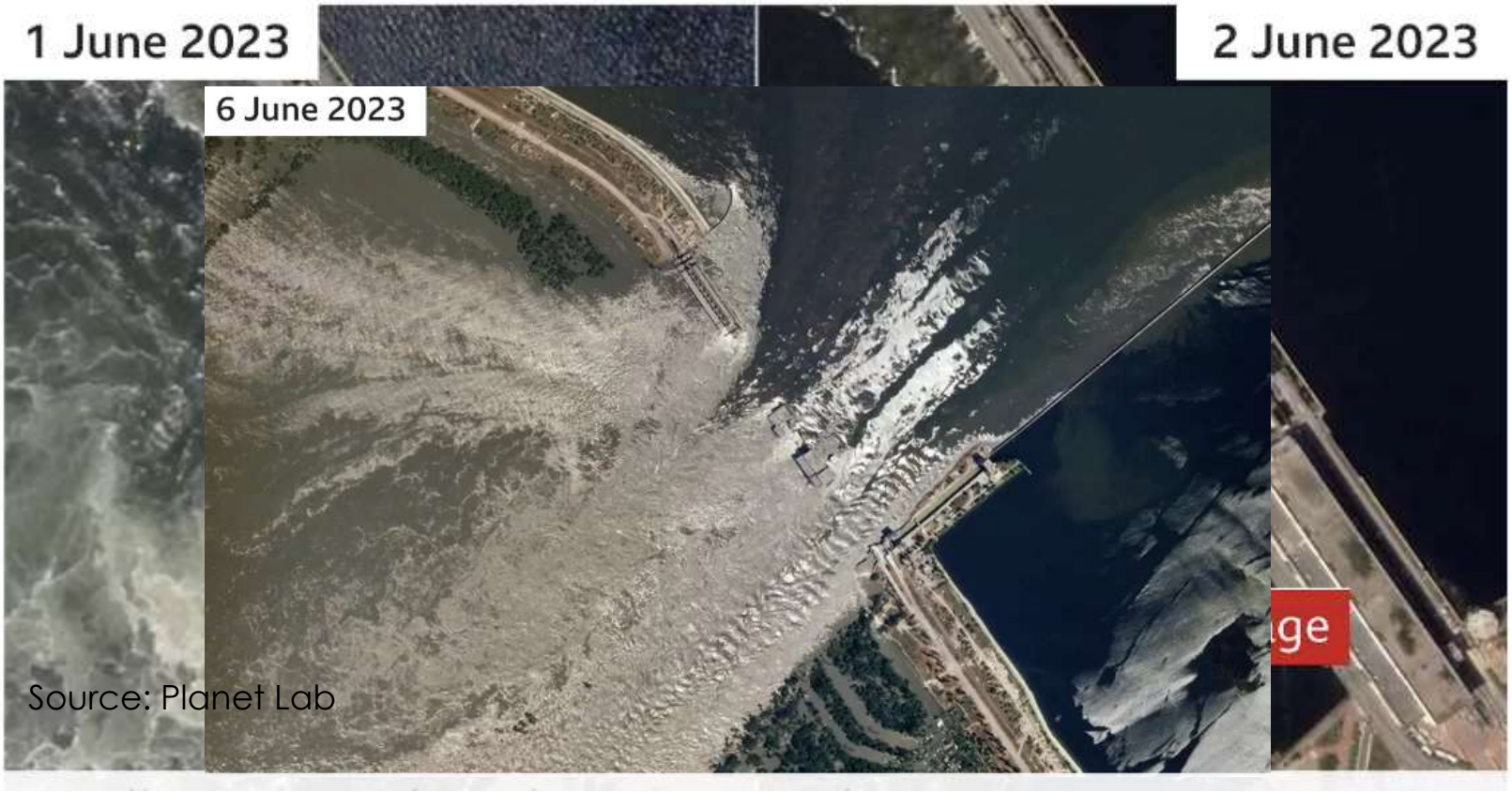
Using Very High- Resolution Observations

Commercial satellites offer images at fine spatial scale and high temporal resolution

- The first NASA Data Buy 2003 – Ikonos
- Planet Labs constellation (>200 sats) acquire daily images of the Earth with 3-m resolution
- Maxar (Digital Globe, WorldView) with 1m resolution

- NASA Commercial Smallsat Data Acquisition (CSDA)
- Limited Planet datasets are available for free at Universities
- Wall-to-wall VHR data over tropics purchased by the government of Norway (to tackle tropical deforestation)
- **Special Issue in Remote Sensing (2020) on applications of VHR data in LCLUC studies**

Damage to Ukraine's Nova Khakovka dam



Flooded streets in Kherson

South Kherson severely affected by flooding

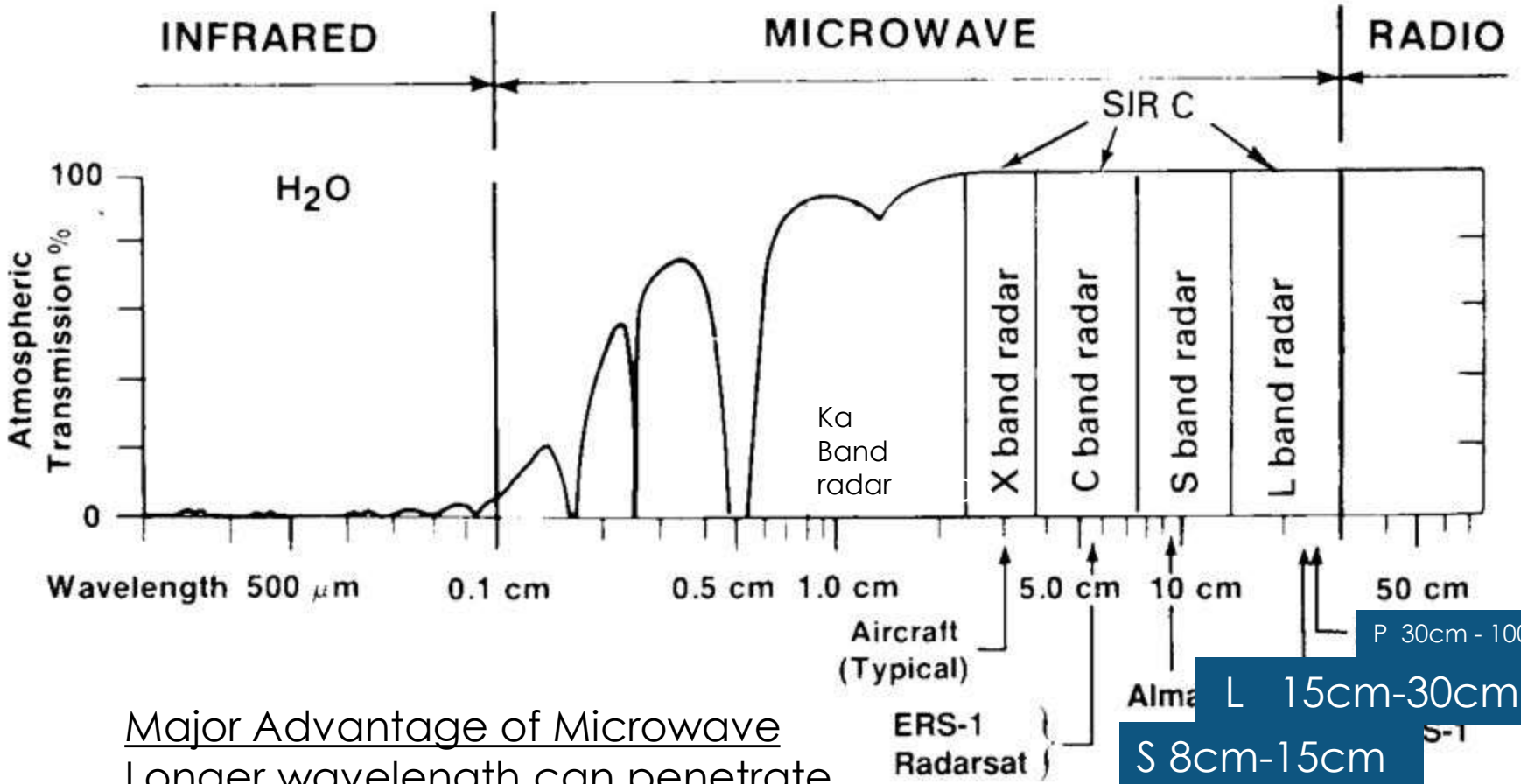
Kherson district, Ukraine: Flood, June 2023

Source: Maxar

Infrared Image from Sentinel-3

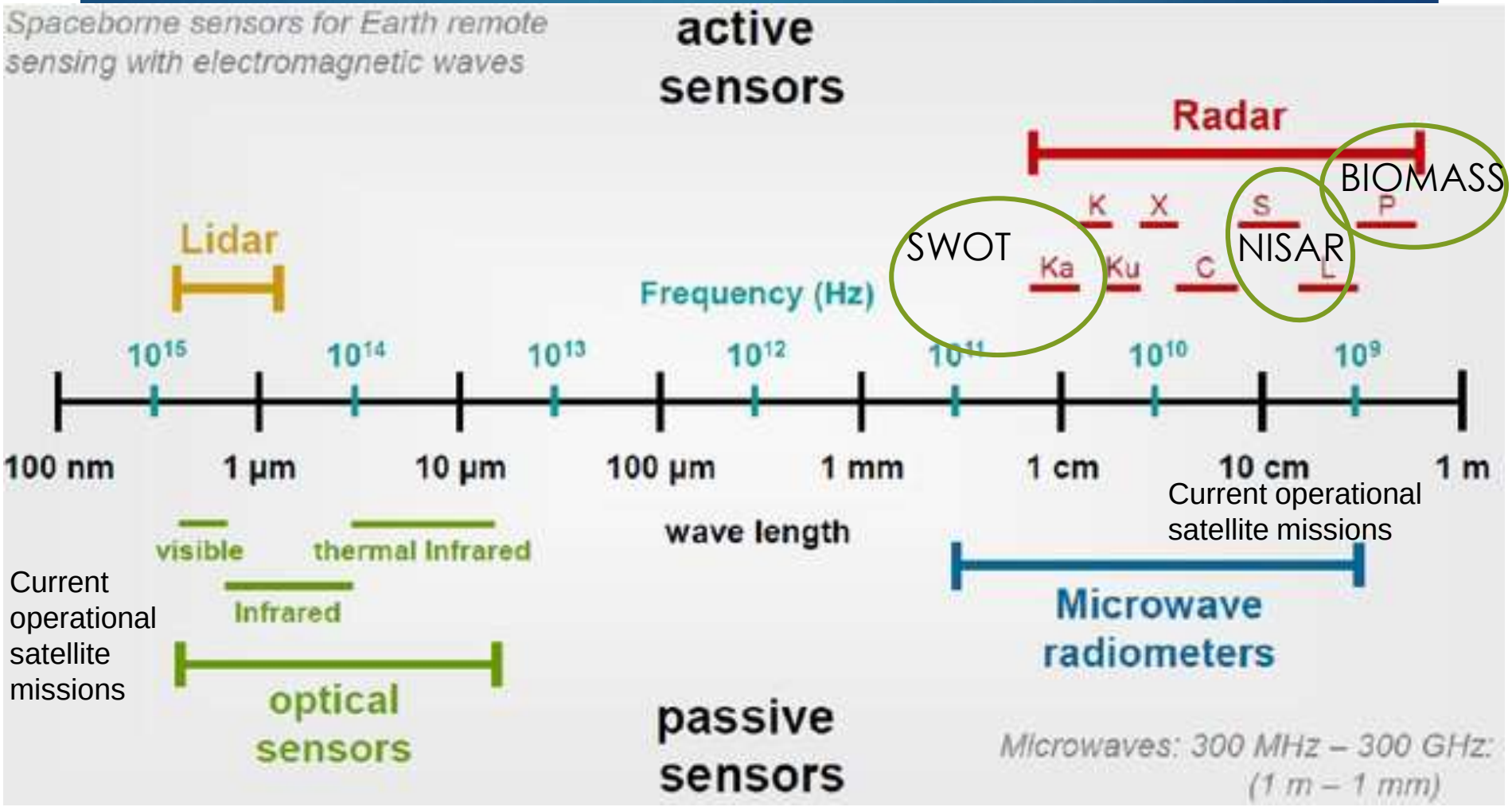
Microwave Atmospheric Window

https://www.youtube.com/watch?v=UZeBzTI5Omk&list=PL09E558656CA5DF76&index=4



<u>Major Advantage of Microwave</u>
Longer wavelength can penetrate through clouds, haze and rain

Passive and Active remote sensing



Passive: M**icrowave** radiometer records the natural **microwave** emission from the Earth
the **spatial resolution** of **passive microwave** observations is generally low **(SMOS 35-50km)**

NASA-CNES Surface Water and Ocean Topography (SWOT)

- SWOT's 120-km-wide swath with overlaps over most of the globe with an average revisit time of 11 days
- Launched Dec 16, 2022
- On land, it will collect data on lakes and reservoirs larger than 62,500 m^2 and rivers wider 100 m with 50-m spatial and 10-cm height resolutions
- All weather - penetrate cloud cover and the dark of night

SWOT will survey nearly all water on Earth's surface for the first time with Ka-band Radar Interferometer (KaRIn, frequency between 26.5 and 40 GHz)

NASA-ISRO SAR (NISAR)

- Will observe Earth's land and ice-covered surfaces globally with 12-day repeat cycle
- Swath of 242 km
- Resolution 3–48 m for L-band
- Resolution of 3-24 m for S-band
- Planned Launch Date: 2024
- Will observe the distribution of vegetation and biomass to better understand ecosystems' responses to disturbance and recovery
- Will map above-ground woody biomass density for estimating carbon emissions from land-use change with much more accuracy

L-band (24 cm) and S-band (12 cm) polarimetric SAR

ESA SAR P-band BIOMASS Mission

- BIOMASS satellite is part of ESA's Living Planet Programme
- Will provide global maps of the amount of carbon stored in the world's forests
- SAR instruments:
  - **P-band** (~70 cm) – first in space!
- Planned launch: 2024

The SAR antenna is based on a large deployable reflector (12 m circular projected aperture)

https://earth.esa.int/web/guest/missions/esa-future-missions/biomass
https://www.sciencedirect.com/science/article/pii/S0034425717301943

Source: ESA

Christian Doppler

Austria-born, Doppler got a professorship of math and geometry at the **Prague Polytechnic Institute** (now Czech Technical University in Prague).

In 1842, gave a lecture to the **Royal Bohemian Society of Sciences** with a postulated principle: Doppler effect (*the observed frequency of a wave depends on the relative speed of the source and the observer*). In 1847 he **left Prague** for the professorship of mathematics, physics, and mechanics at the **Academy of Mines and Forests in Hungary (now Slovakia)**, from where he **left for Vienna** in 1849.

While at U. Vienna, Doppler influenced the development of **Gregor Mendel** - a student at the U, Vienna from 1851 to 1853.

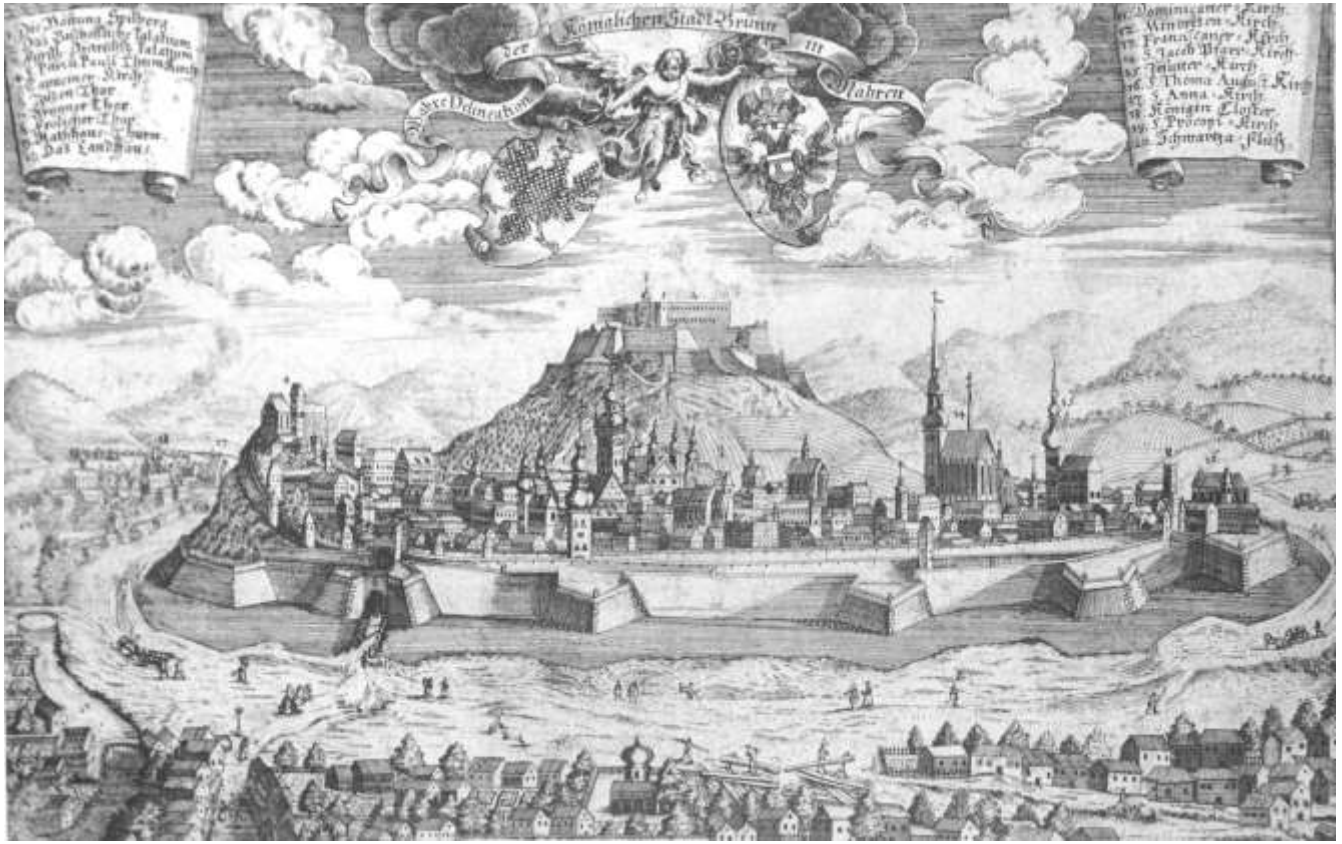
"The most rewarding research projects are those that delight the thinker and are of benefit to humankind" – Doppler's motto

1803 – 1853

Brno

- 780 years ago (in 1243): Brno was recognized as a town by Wenceslaus I, King of Bohemia
- One of the industrial centers of Moravia and the Austro-Hungarian Empire – sometimes referred to as the "Moravian Manchester"
- The city of Gregor Mendel

Děkuji!



View of Brno in the year 1700