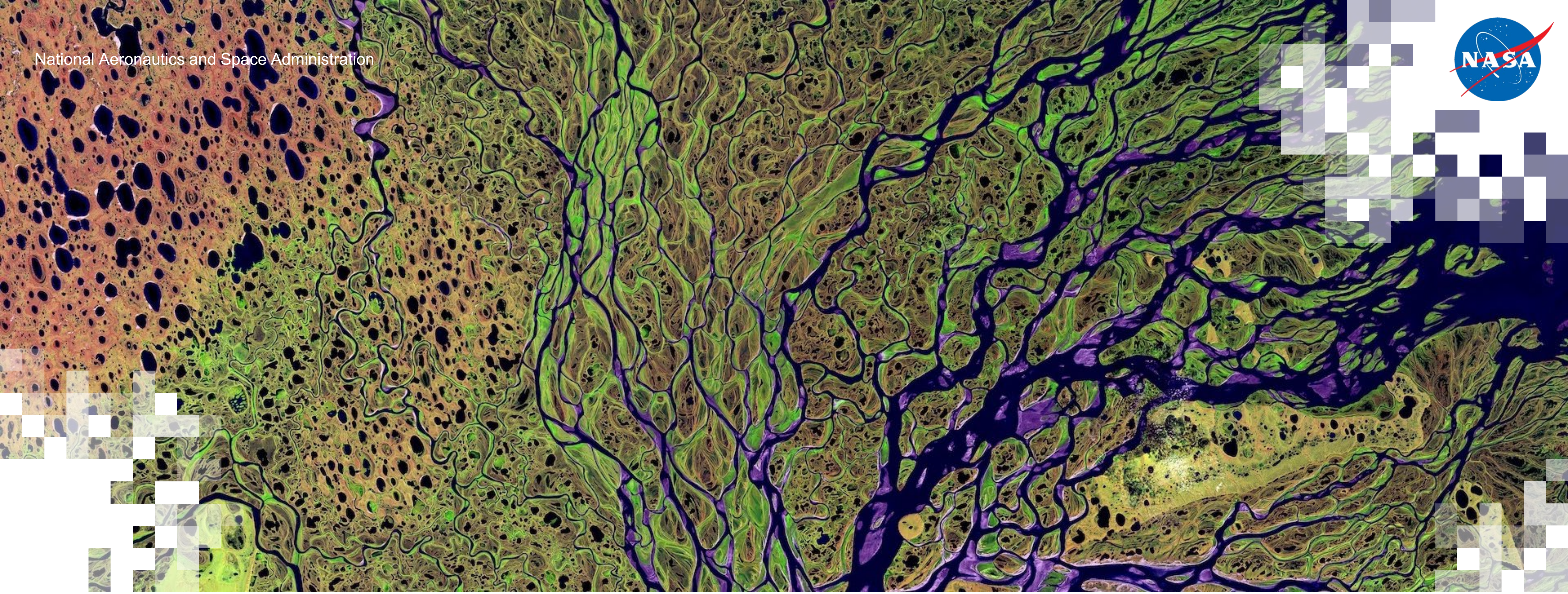
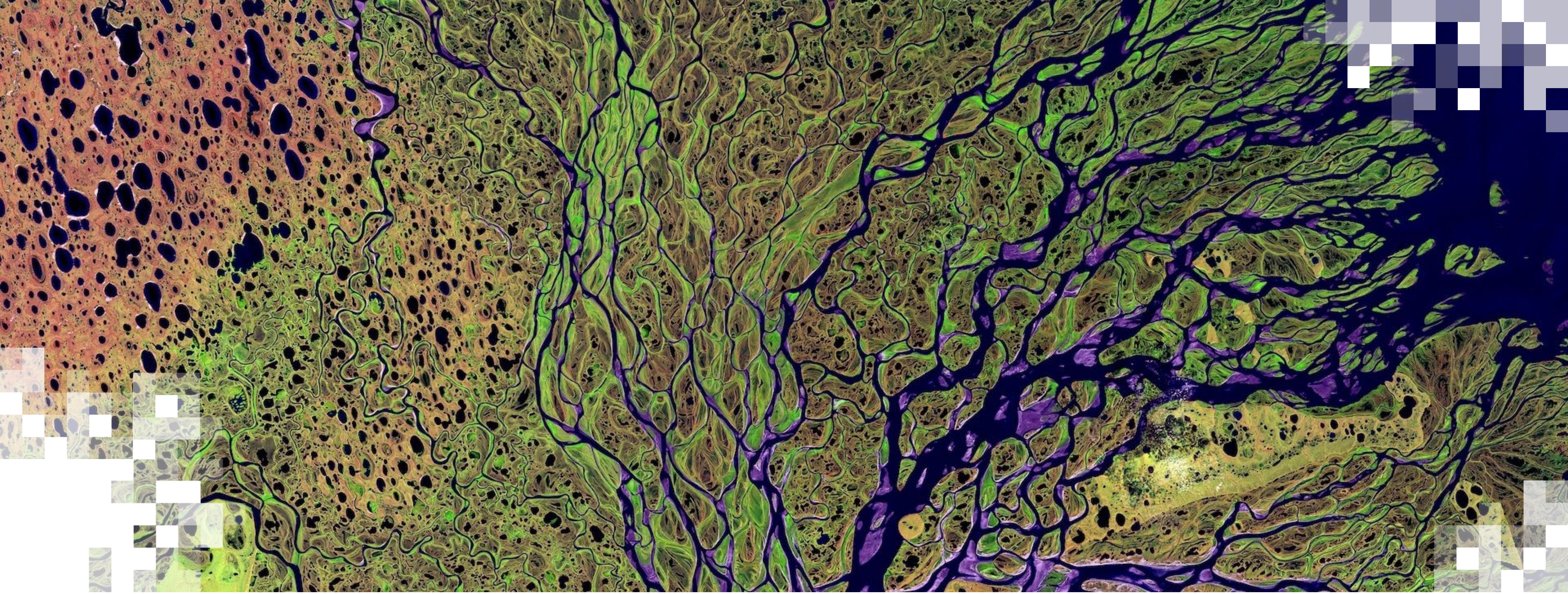
National Aeronautics and Space Administration



Overview of Earth Observations for Societal Benefit

Sean McCartney (NASA ARSET), Amita Mehta (NASA ARSET), Erika Podest (NASA ARSET),
Katie Baynes (NASA ESDS), Hannah Townley (NASA ESDS)

October 28, 2024



Training Overview

NASA Trainers

Katie Baynes	Sean McCartney	Amita Mehta	Erika Podest	Hannah Townley
ESDS	ARSET	ARSET	ARSET	ESDS
				

ESDS – Earth Science Data Systems

ARSET – Applied Remote Sensing Training Program

Objectives

By the end of this training, participants will be able to:

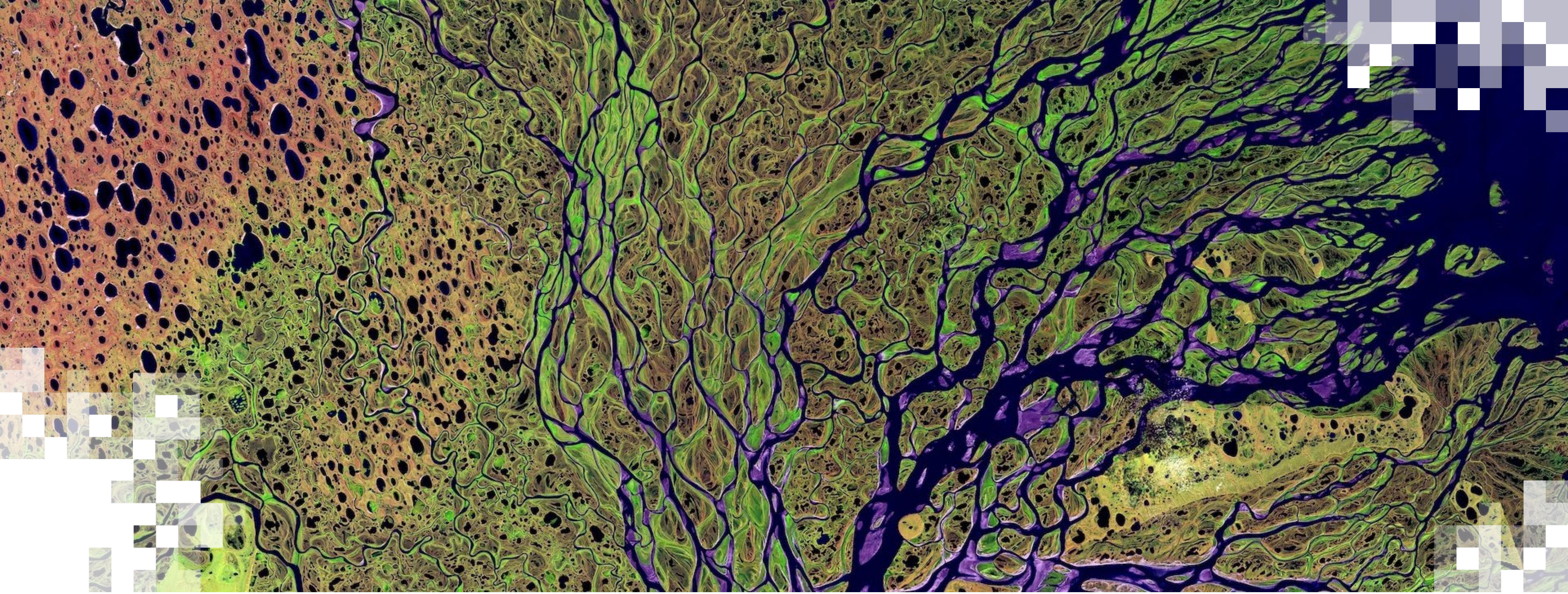
- Recognize how remote sensing observations can inform decision making
- Identify how to locate applicable NASA datasets and tools that support their decision making and policy work
- Apply workflows to access and visualize NASA datasets for societal benefit

Time	Topic
10:00 – 10:30	Welcome, Introductions, Training agenda • Aarti Holla-Maini, UNOOSA Director • Katie Baynes, NASA's Earth Data Officer • Learning Objectives • Training Outline
10:30 – 11:30	Remote sensing observations for atmosphere, water, and land applications • What is remote sensing • How NASA observes the planet • Advantages/limitations of remote sensing • Data and tools used in training • Energizer

11:30 – 12:15	Monitoring Disasters – Population, Fires, Floods, Heat – applicable NASA datasets
	• Data search
	  • Earthdata portal
	  • Earthdata pathfinders
	  • SEDAC

12:15 – 13:30	**Lunch**

Time	Topic
13:30 – 14:45	Fires – applicable tools • Energizer • Worldview demonstration (visualization tool, data available in near real time) • FIRMS demonstration (near real time and historic access to fire data) • Climate Engine (analysis tool, anomalies, climatology) • Q&A
14:45 – 15:45	Floods & Heat – applicable tools • Google Earth Engine demo • Climate Engine (analysis tool, anomalies, climatology) • Black Marble • Disaster Alert (maps available in near real time) • Q&A
15:45 – 16:05	**Break**
16:05 – 17:00	Earth Observations Toolkit for Sustainable Cities & Human Settlement • Energizer • Land use/land cover • Population • Humanitarian applications
17:00 – 17:30	**Wrap up + Q&A**



About ARSET

About – Applied Remote Sensing Training (ARSET) Program

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

AGRICULTURE

CLIMATE & RESILIENCE

DISASTERS

ECOLOGICAL CONSERVATION

HEALTH & AIR QUALITY

WATER RESOURCES

EARTH SCIENCE APPLIED SCIENCES

CAPACITY BUILDING

About ARSET Trainings

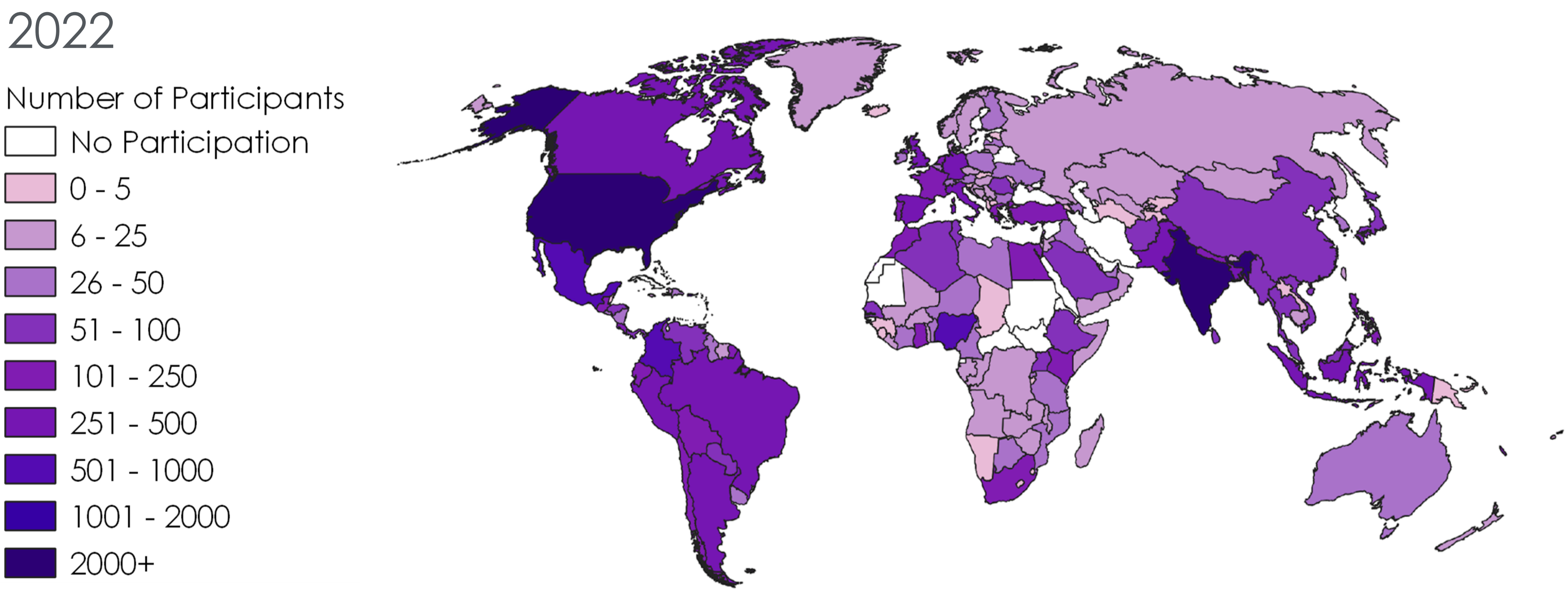
- Cost-free
- Online or in-person
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise
- Live and instructor-led or asynchronous and self-paced

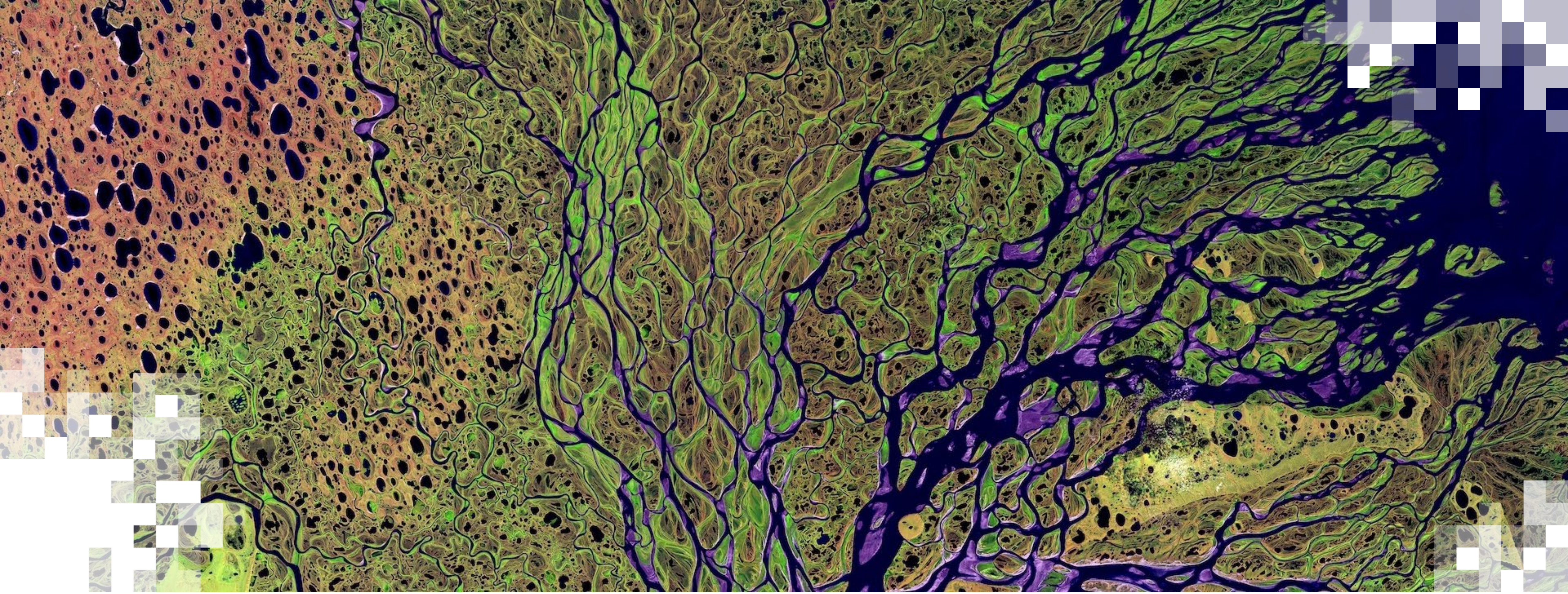
- Visit the ARSET website to learn more.

ARSET Trains an International Audience

2009 – 2024

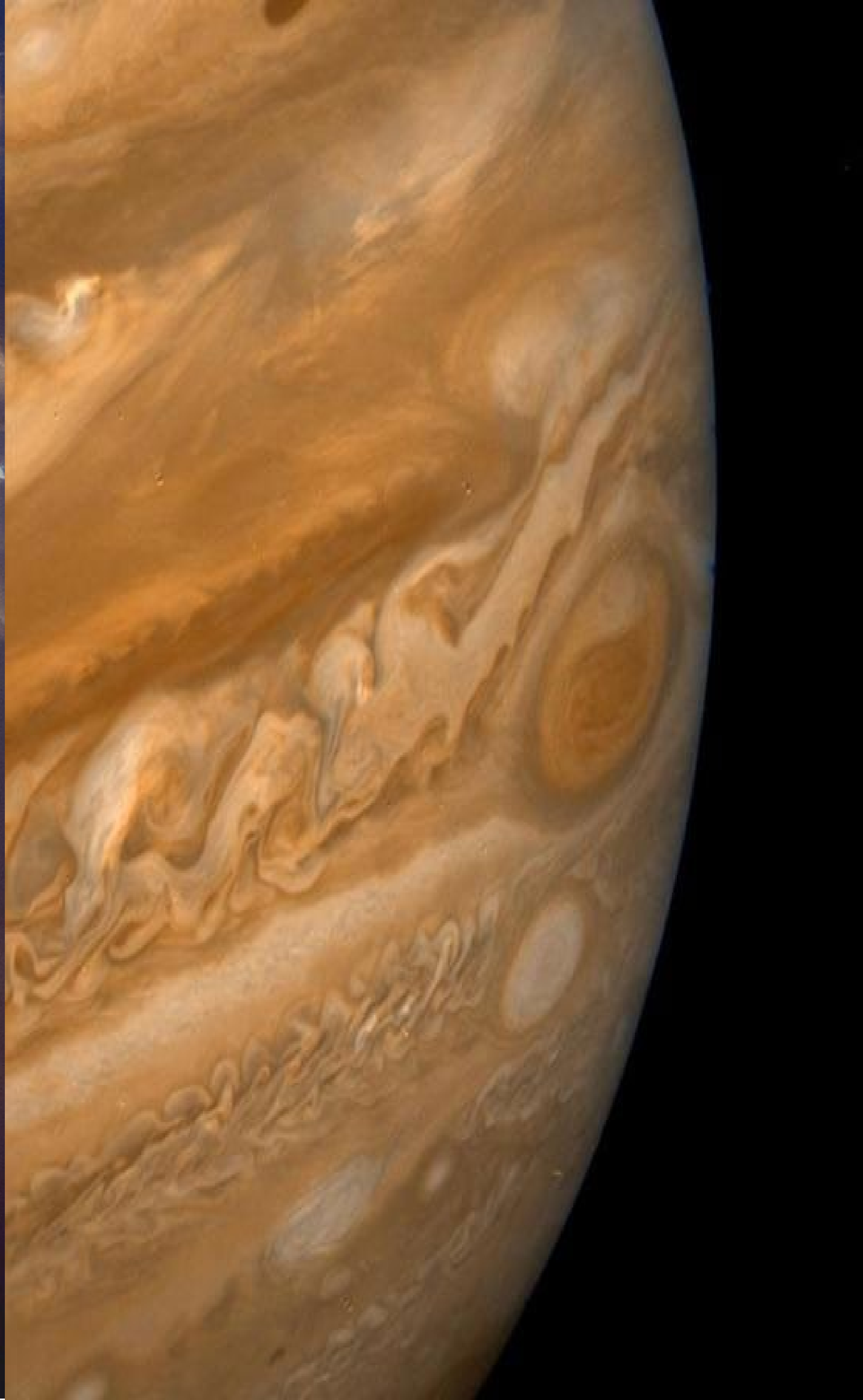
200+ trainings | 110,000+ participants | 188 countries | 17,000+ organizations

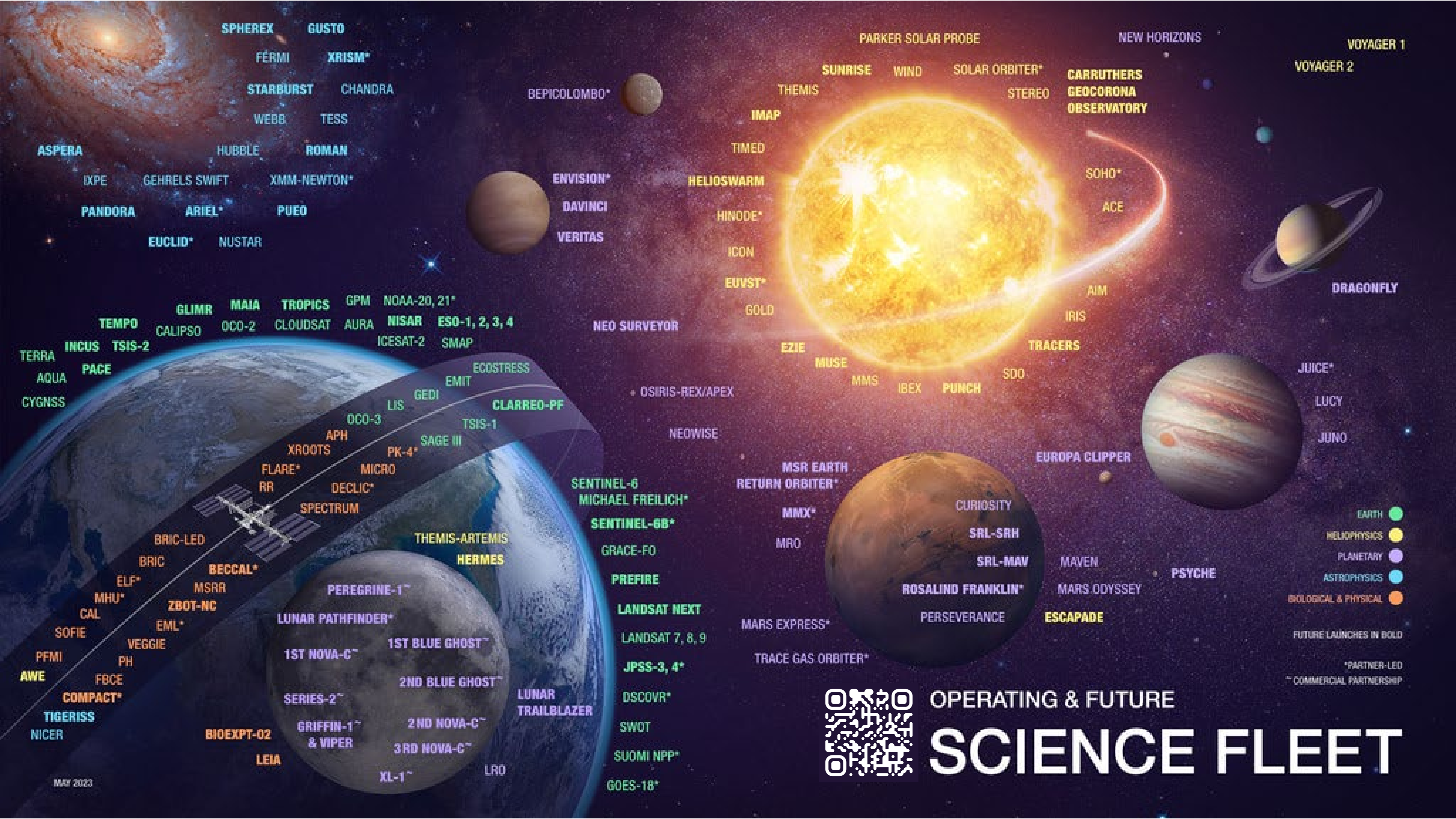




How NASA Observes Earth







OPERATING & FUTURE
SCIENCE FLEET
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GUSTO
FERMI
XRISM*
STARBURST
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HUBBLE
ROMAN
IXPE
GEHRELS SWIFT
XMM-NEWTON*
PANDORA
ARIEL*
PUEO
EUCLID*
NUSTAR
BEPICOLOMBO*
ENVISION*
DAVINCI
VERITAS
PARKER SOLAR PROBE
NEW HORIZONS
VOYAGER 1
VOYAGER 2
SUNRISE
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SOLAR ORBITER*
CARRUTHERS
GEOCORONA
OBSERVATORY
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JUICE*
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JUNO
EUROPA CLIPPER
MSR EARTH
RETURN ORBITER*
MMX*
MRO
CURIOSITY
SRL-SRH
SRL-MAV
ROSALIND FRANKLIN*
PERSEVERANCE
MAVEN
MARS ODYSSEY
PSYCHE
ESCAPADE
MARS EXPRESS*
TRACE GAS ORBITER*
GLIMR
MAIA
TROPICS
GPM
NOAA-20, 21*
TEMPO
CALIPSO
OCO-2
CLOUDSAT
AURA
NISAR
ESO-1, 2, 3, 4
TERRA
INCUS
TSIS-2
ICESAT-2
SMAP
AQUA
PACE
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ECOSTRESS
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CLARREO-PF
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SAGE III
XROOTS
PK-4*
FLARE*
MICRO
RR
DECLIC*
SPECTRUM
SENTINEL-6
MICHAEL FREILICH*
SENTINEL-6B*
GRACE-FO
PREFIRE
LANDSAT NEXT
LANDSAT 7, 8, 9
JPSS-3, 4*
DSCOVR*
SWOT
SUOMI NPP*
GOES-18*
THEMIS-ARTEMIS
HERMES
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EML*
SOFIE
VEGGIE
PFMI
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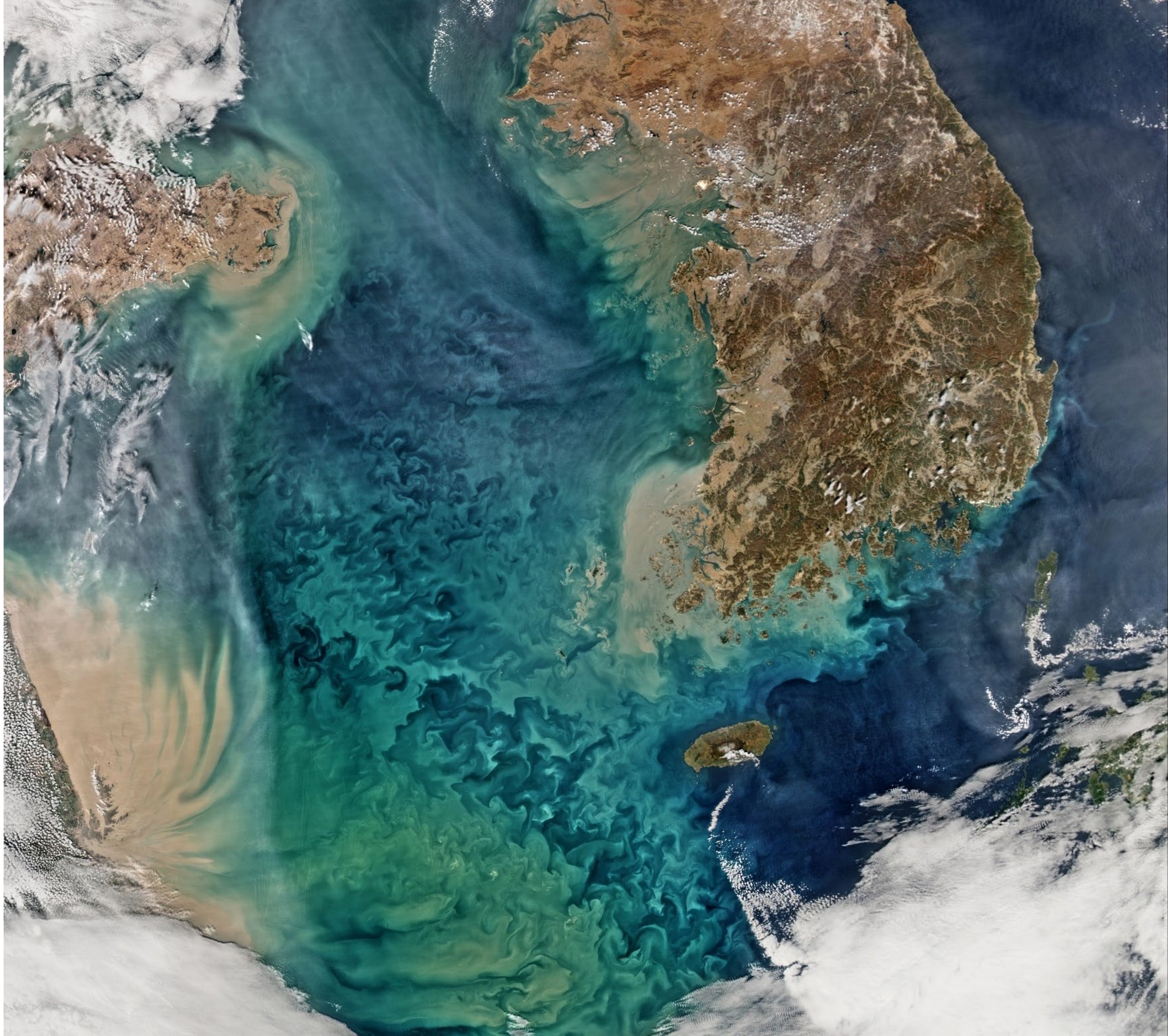
AWE
FBCE
COMPACT*
TIGERISS
NICER
BIOEXPT-02
LEIA
PEREGRINE-1~
LUNAR PATHFINDER*
1ST BLUE GHOST~
1ST NOVA-C~
2ND BLUE GHOST~
SERIES-2~
GRIFFIN-1~
& VIPER
2ND NOVA-C~
3RD NOVA-C~
XL-1~
LRO
LUNAR
TRAILBLAZER
EARTH
HELIOPHYSICS
PLANETARY
ASTROPHYSICS
BIOLOGICAL & PHYSICAL
FUTURE LAUNCHES IN BOLD
*PARTNER-LED
~ COMMERCIAL PARTNERSHIP
MAY 2023

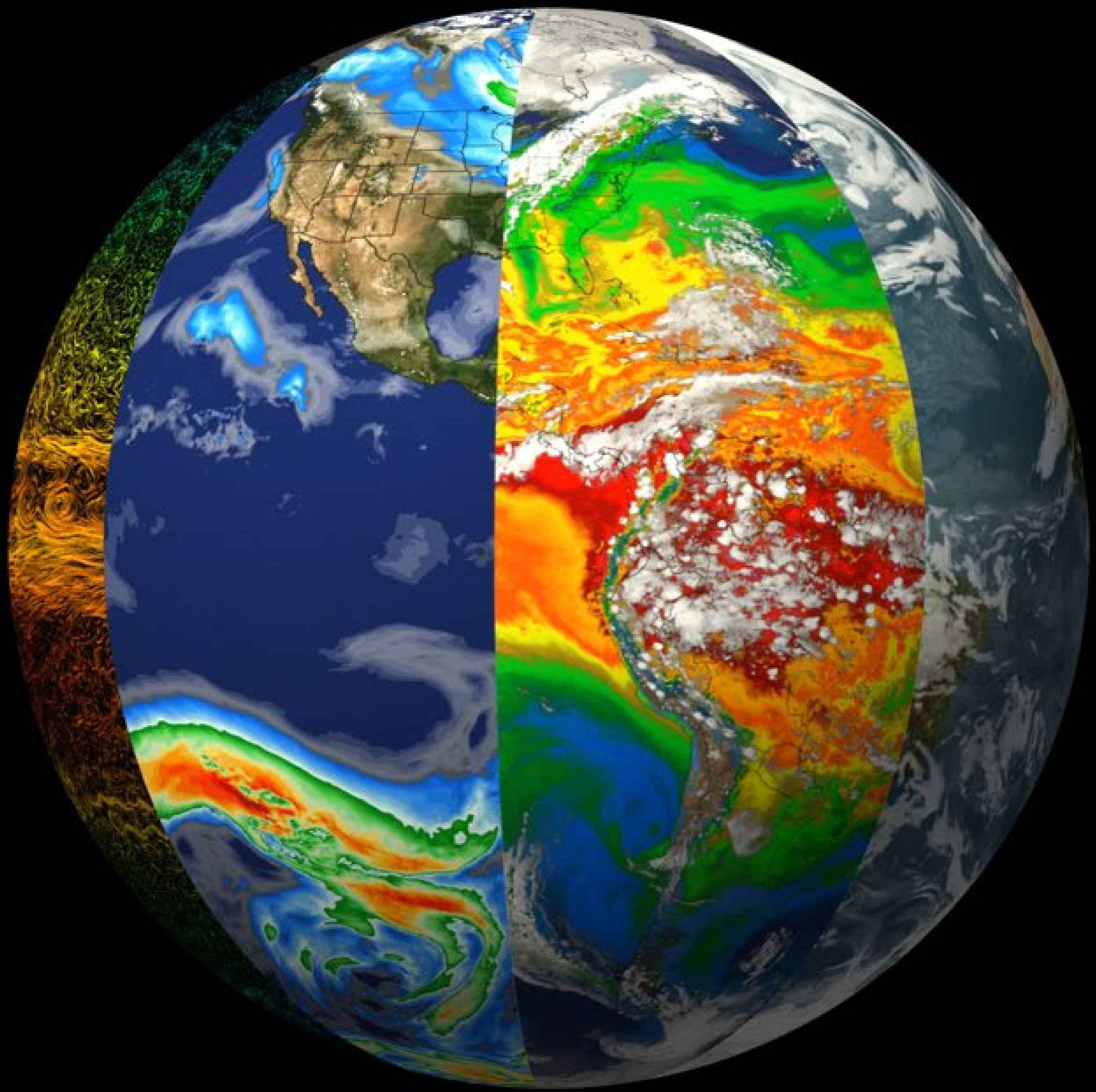
BIG QUESTIONS…

How is our climate changing?

How can science be used to benefit society?



Earth is a System of Systems.....



Animation by NASA Science Visualization Studio (SVS)

Earth: A System of Systems

Earth Observing Fleet

NASA SVS

Earth Observing Fleet

Global Precipitation every 30 minutes

NASA SVS

7/25/2014 00:55

Painting the World with Water

Liquid Precipitation Rate

0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50

mm/hour

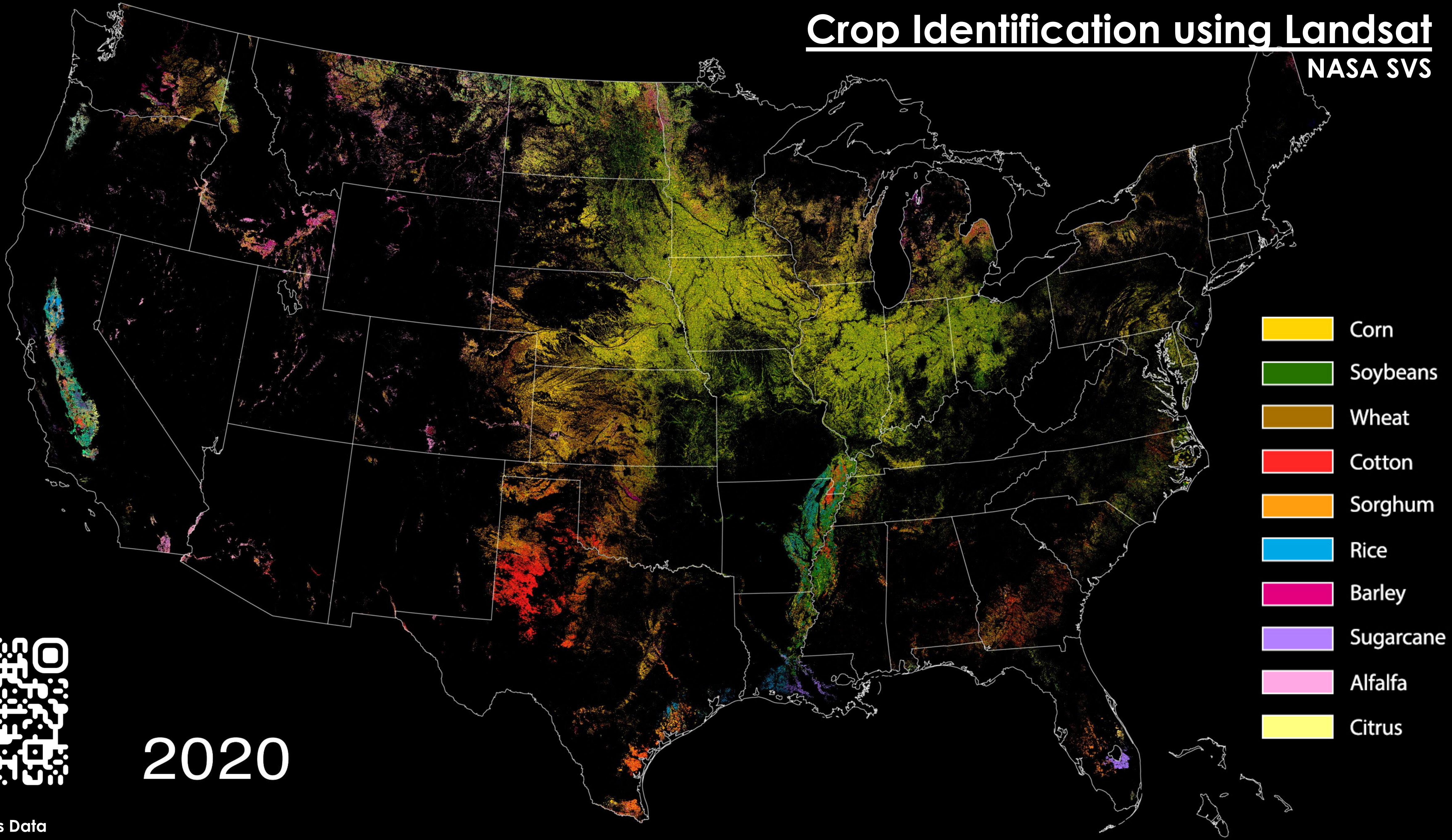
Frozen Precipitation Rate

0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50

mm/hour

Crop Identification using Landsat

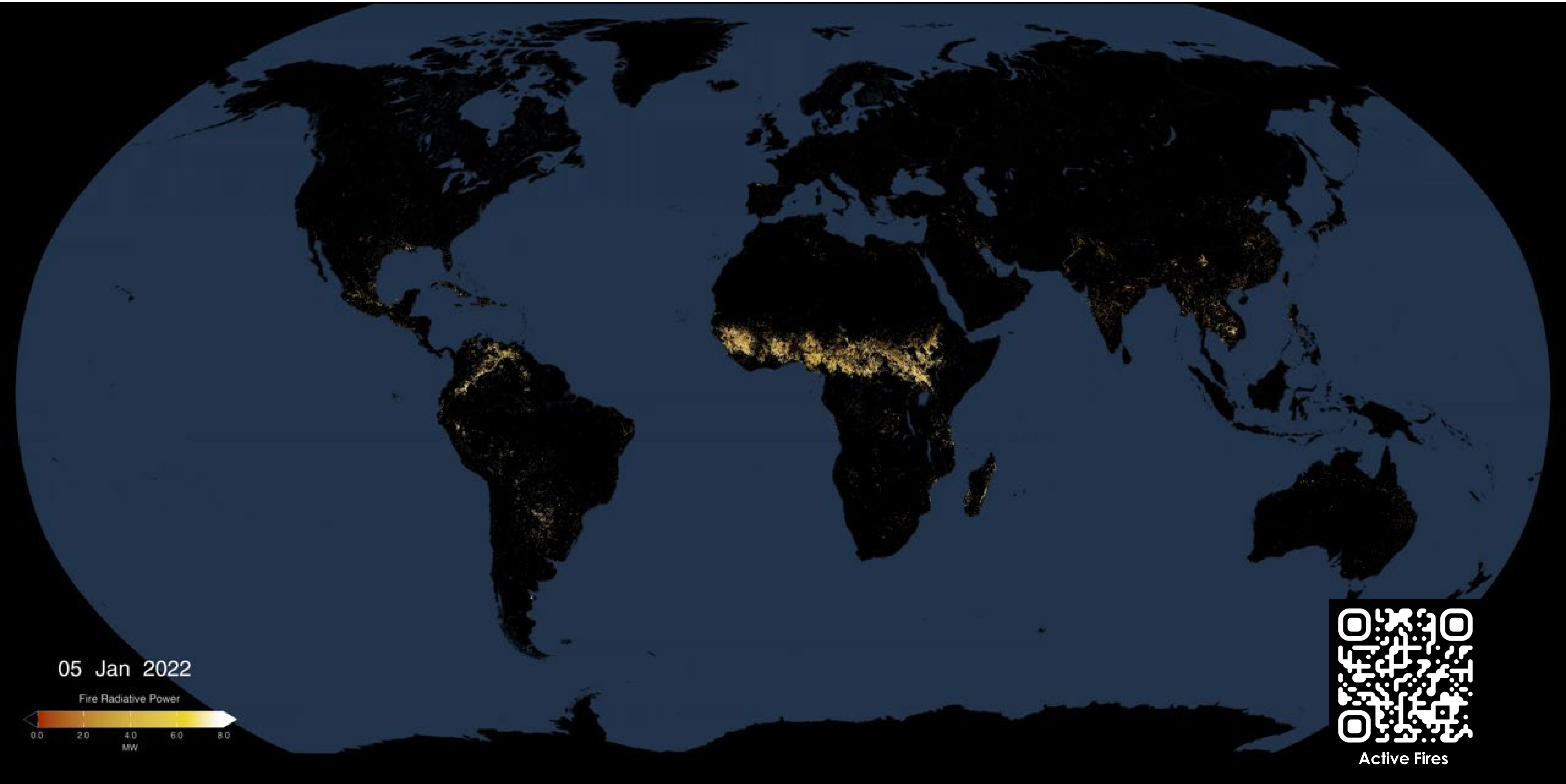
NASA SVS



2020

Landsat Croplands Data Overview

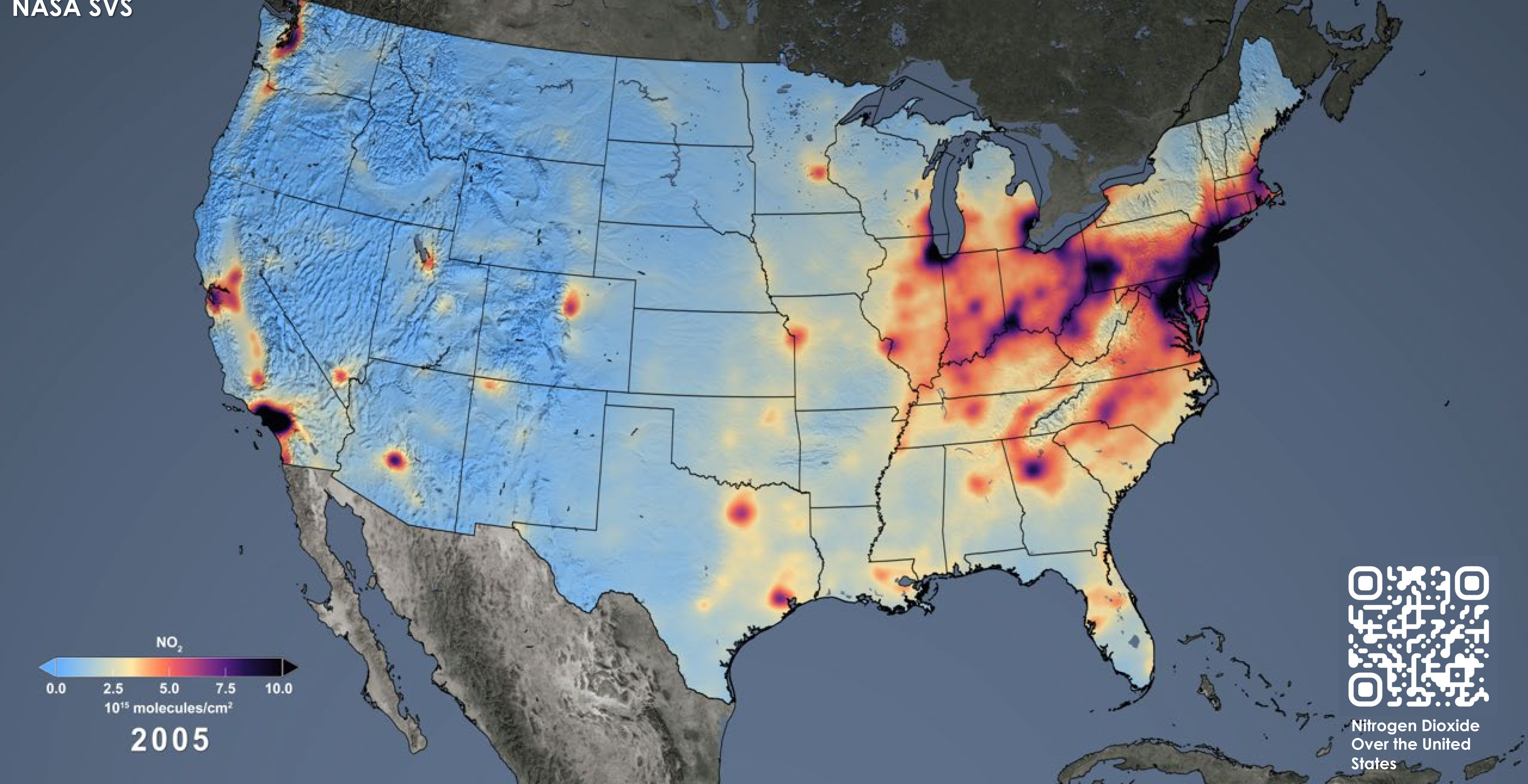
Fire Detections and Intensity
NASA SVS



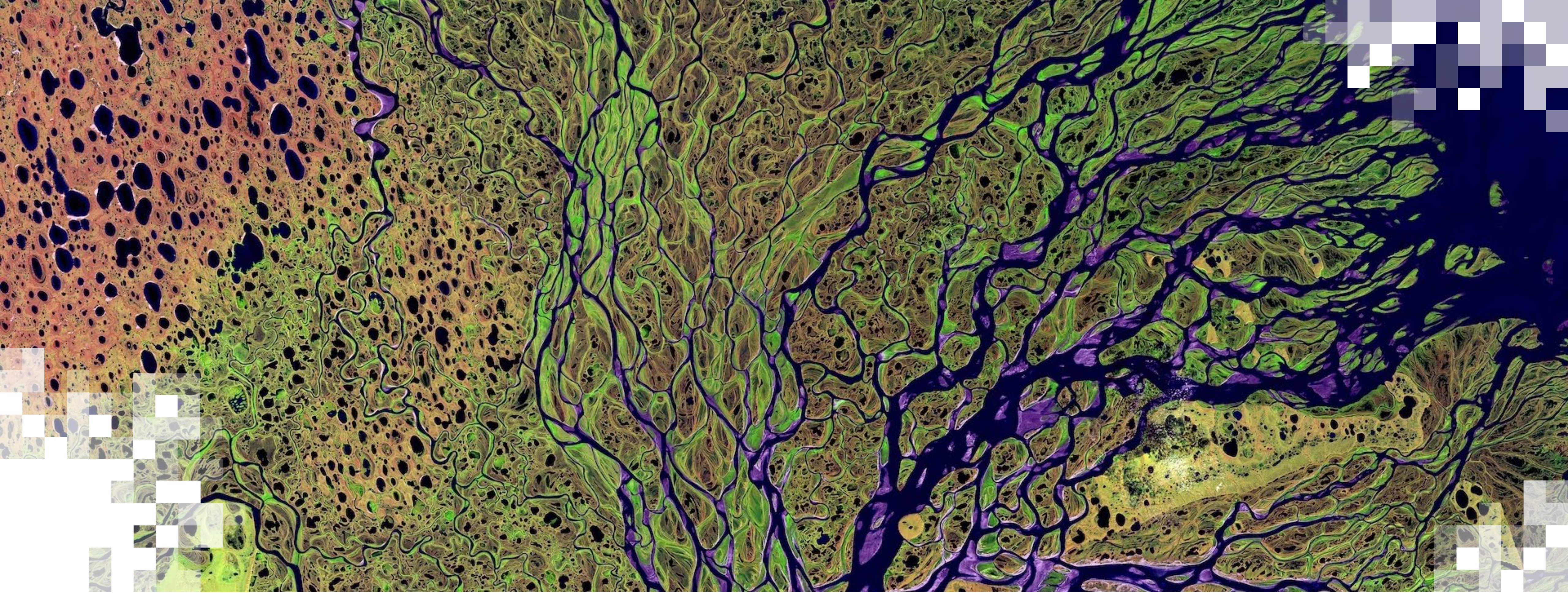
Active Fires

Changes in Nitrogen Dioxide (NO_2) from 2005–2022

NASA SVS

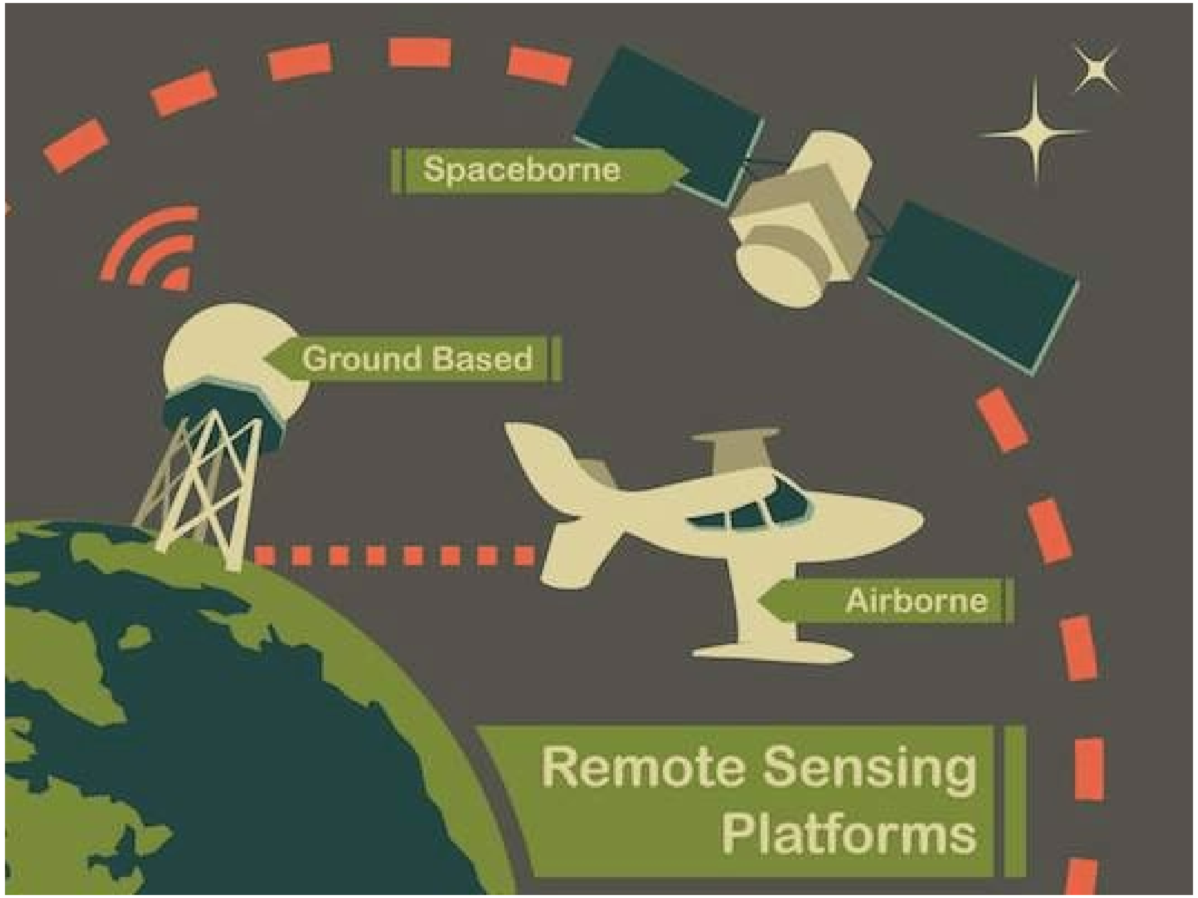


Nitrogen Dioxide Over the United States



What Is Remote Sensing?

What is Remote Sensing?



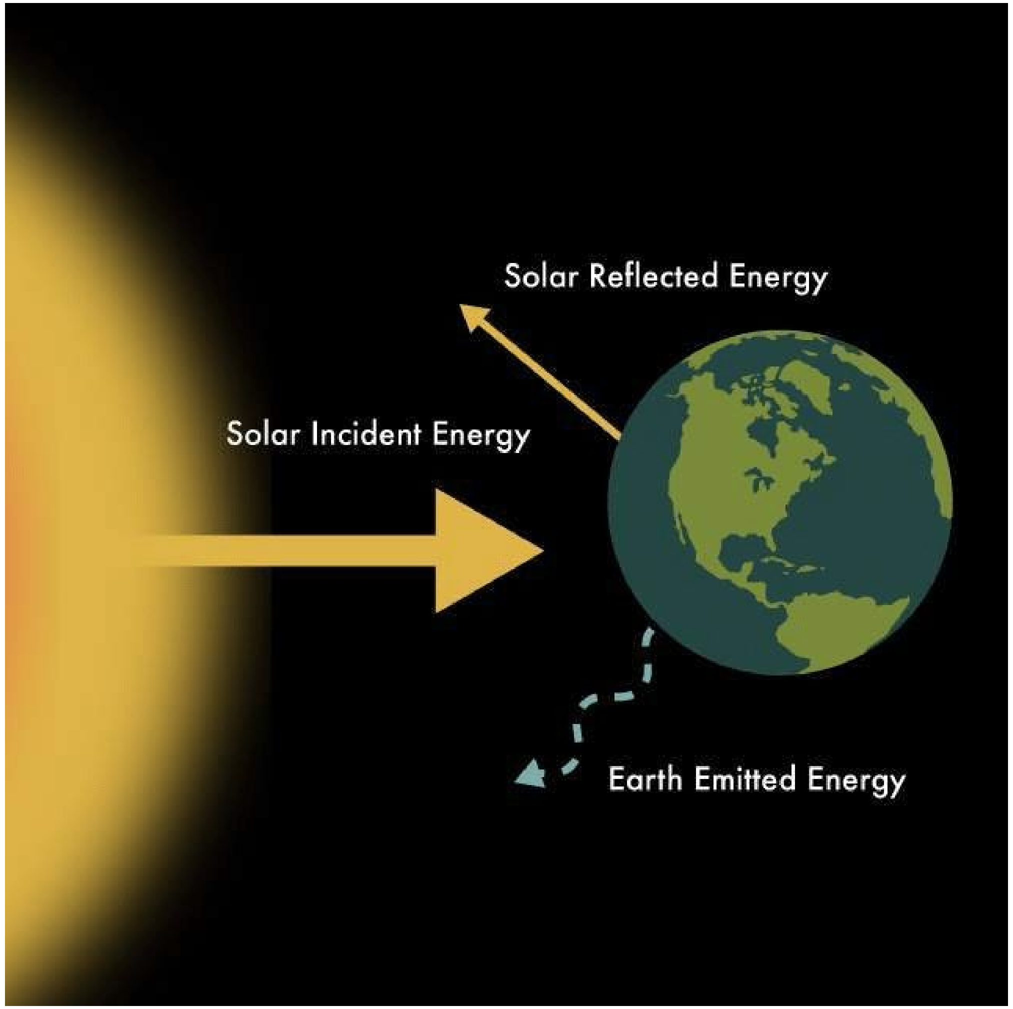
Remote sensing is obtaining information about an object from a distance.

There are different ways to collect data, and different sensors are used depending on the application.

Some methods collect ground-based data, others airborne or spaceborne.

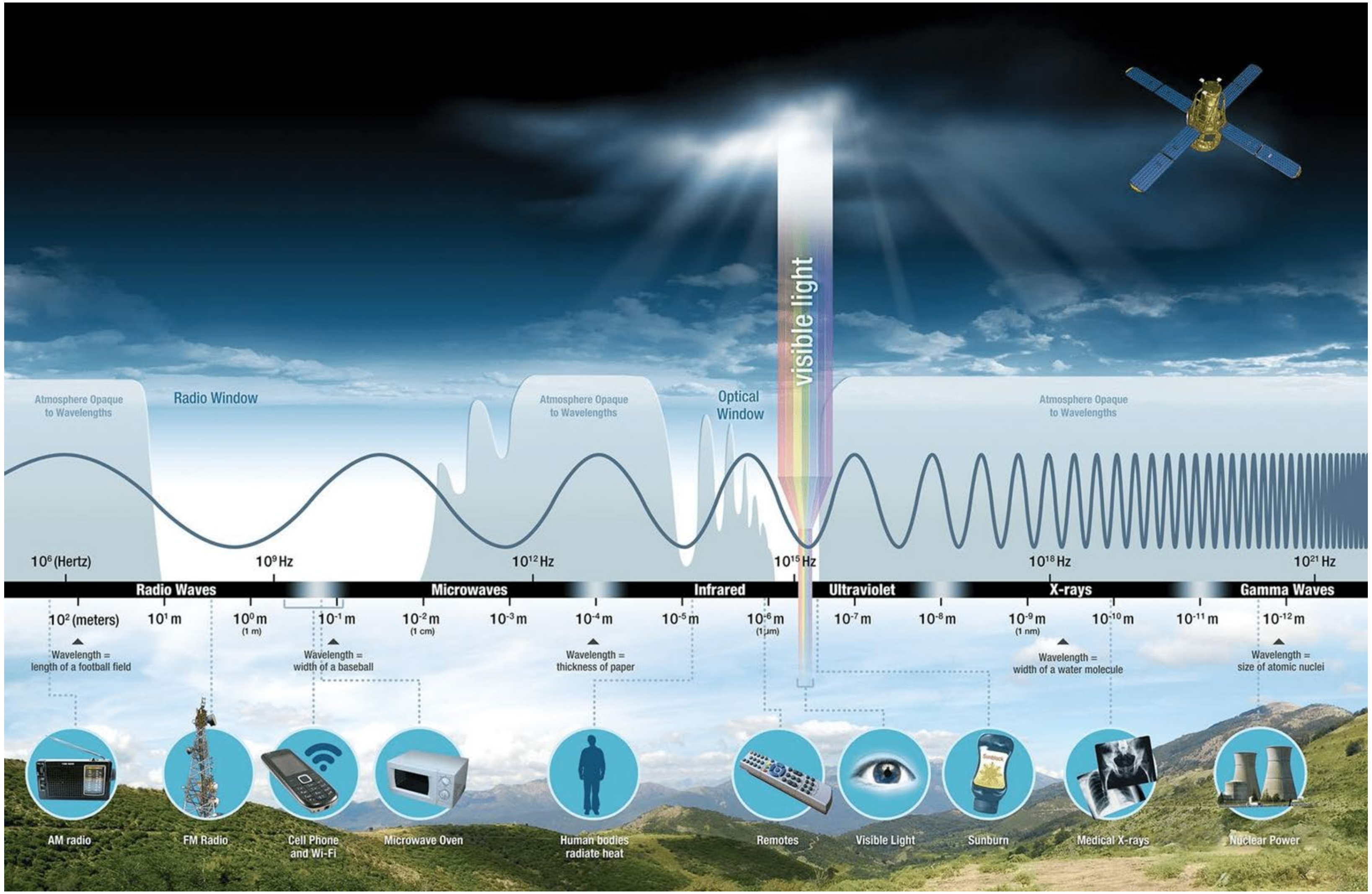
- What information do you need?
- How much detail?
- How frequently do you need the data?

Electromagnetic Radiation



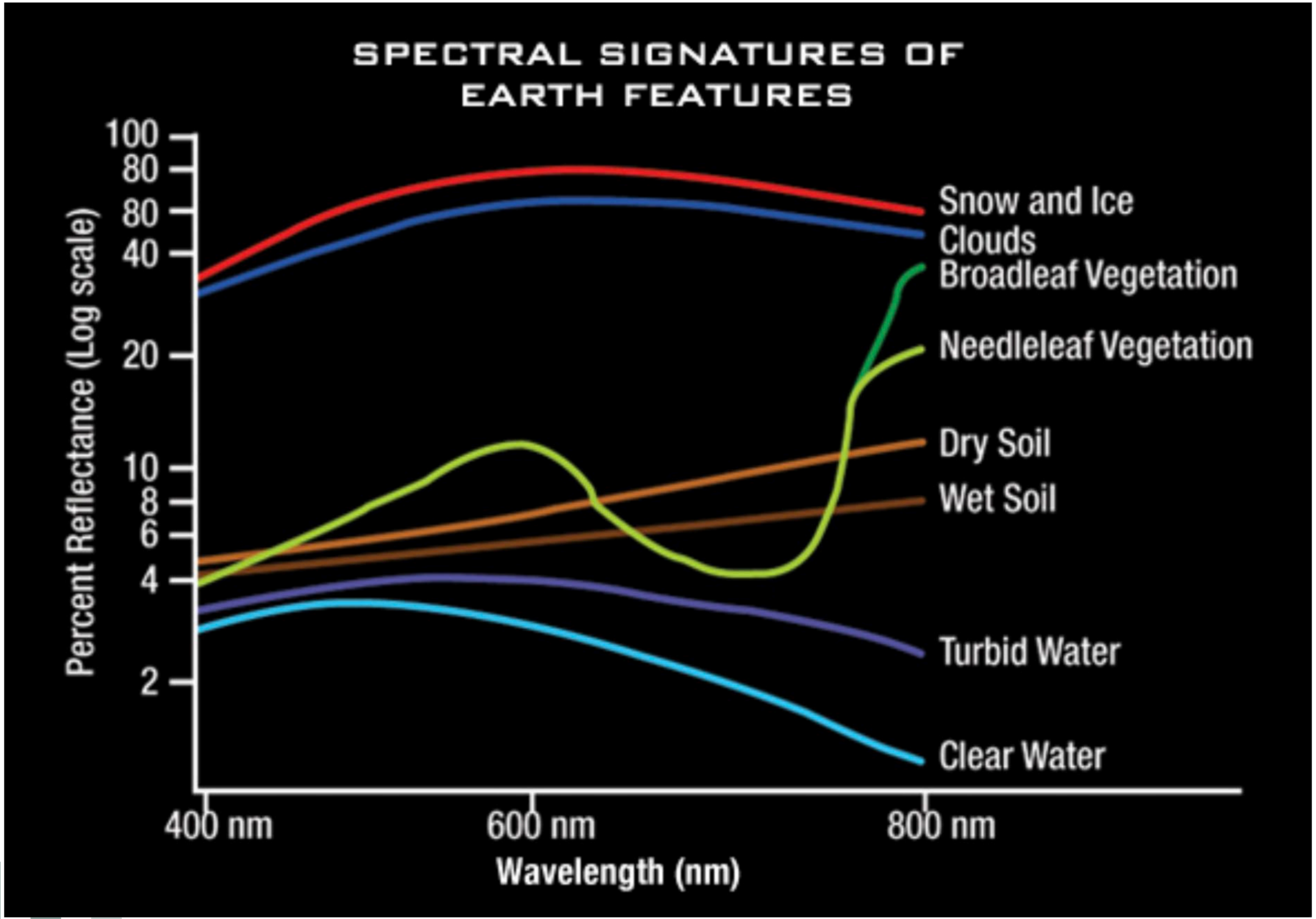
- The energy Earth receives from the sun is called **electromagnetic radiation**.
- Radiation is reflected, absorbed, and emitted by the Earth's atmosphere or surface, as shown by the figure on the left.
- Satellites carry instruments or sensors that measure electromagnetic radiation reflected or emitted from both terrestrial and atmospheric sources.

Electromagnetic Spectrum



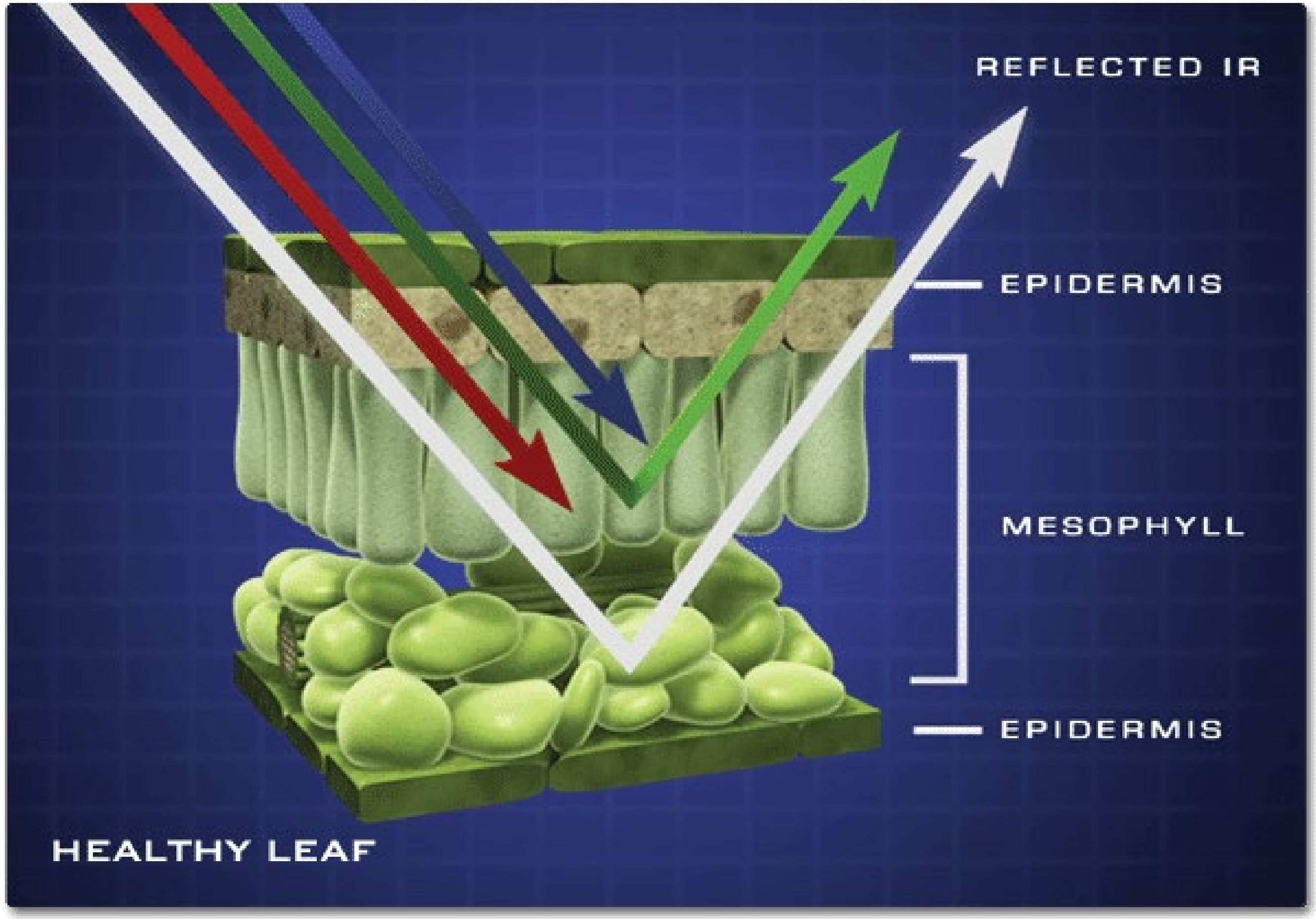
- The electromagnetic spectrum is simply the full range of **wave frequencies** that characterizes solar radiation.
- Although we are talking about light, most of the electromagnetic spectrum cannot be detected by the human eye. Even satellite detectors only capture a small portion of the entire electromagnetic spectrum.

Spectral Signatures



- Different materials reflect and absorb different wavelengths of electromagnetic radiation.
- You can look at the reflected wavelengths detected by a sensor and determine the type of material it reflected from. This is known as a **spectral signature**.
- In the graph on the left, compare the relationship between percent reflectance and the reflective wavelengths of different components of the Earth's surface.

Spectral Signature – Vegetation



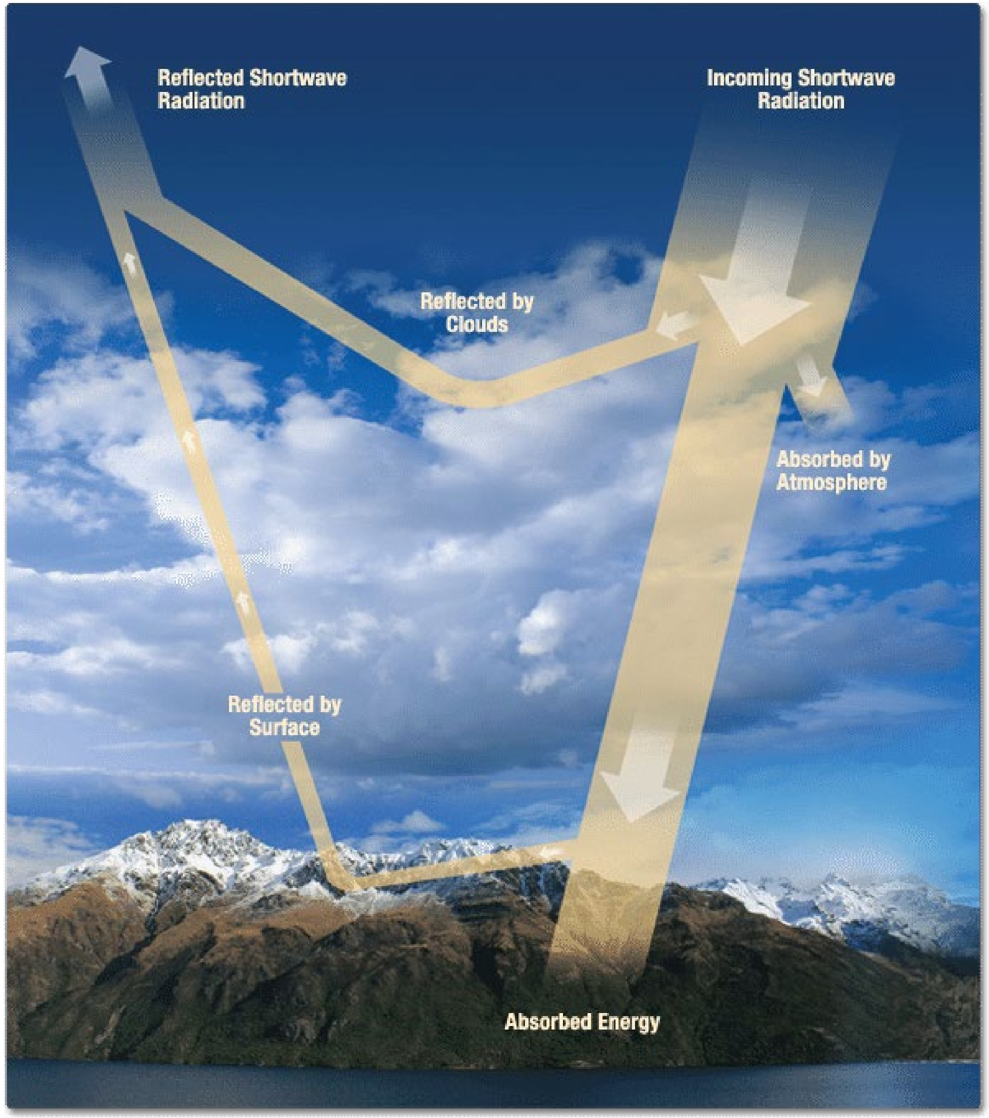
- Certain pigments in plant leaves strongly absorb wavelengths of visible (red) light.
- The leaves themselves strongly reflect wavelengths of near-infrared light, which is invisible to human eyes.
- Since we can't see infrared radiation, we see healthy vegetation as green.
- As a plant canopy changes from early spring growth to late-season maturity and senescence, these reflectance properties also change.

Spectral Signature – Water

Image Credit: NASA Earth Observatory, using Landsat data courtesy of USGS.

- Longer visible wavelengths (green and red) and near-infrared radiation are absorbed more by water than shorter visible wavelengths (blue) – so water usually looks blue or blue-green.
- Satellites provide the capability to map optically active components of upper water column in inland and near-shore waters.

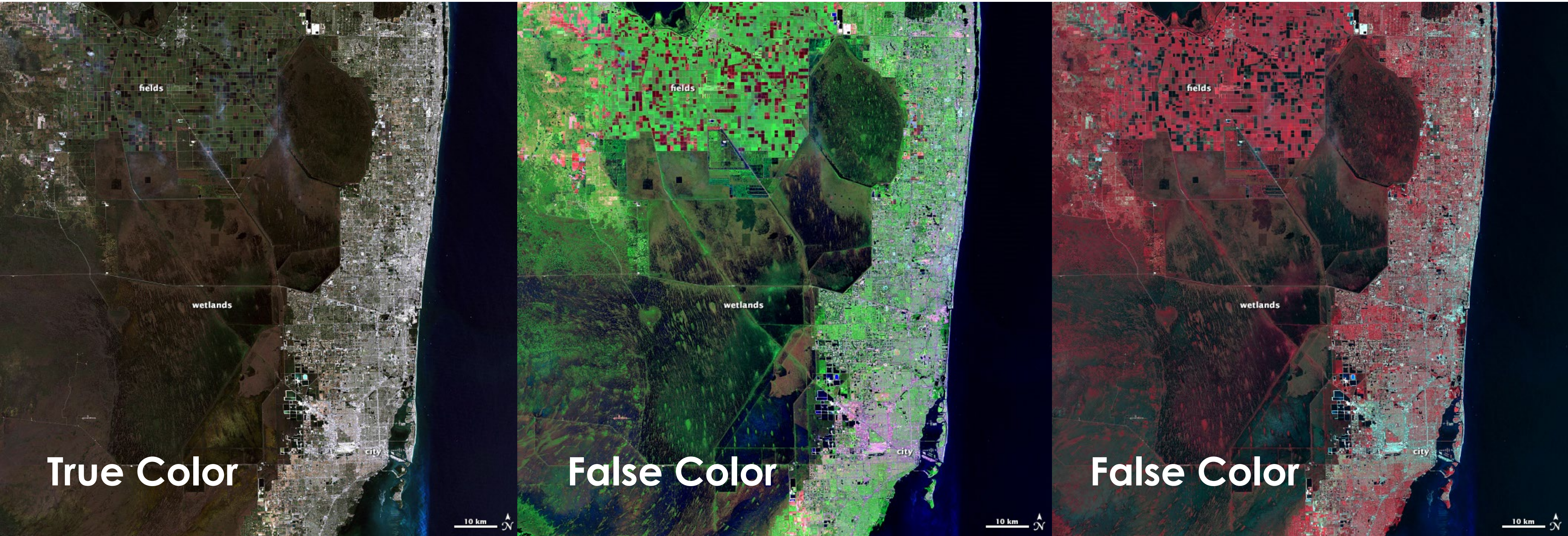
Spectral Signature – Atmosphere



- From the sun to the Earth and back to the sensor, electromagnetic energy passes through the atmosphere twice.
- Much of the incident energy is absorbed and scattered by gases and aerosols in the atmosphere before reaching the Earth’s surface.
- Atmospheric correction removes the scattering and absorption effects from the atmosphere to obtain the surface reflectance characterizing surface properties.

False-Color Satellite Image

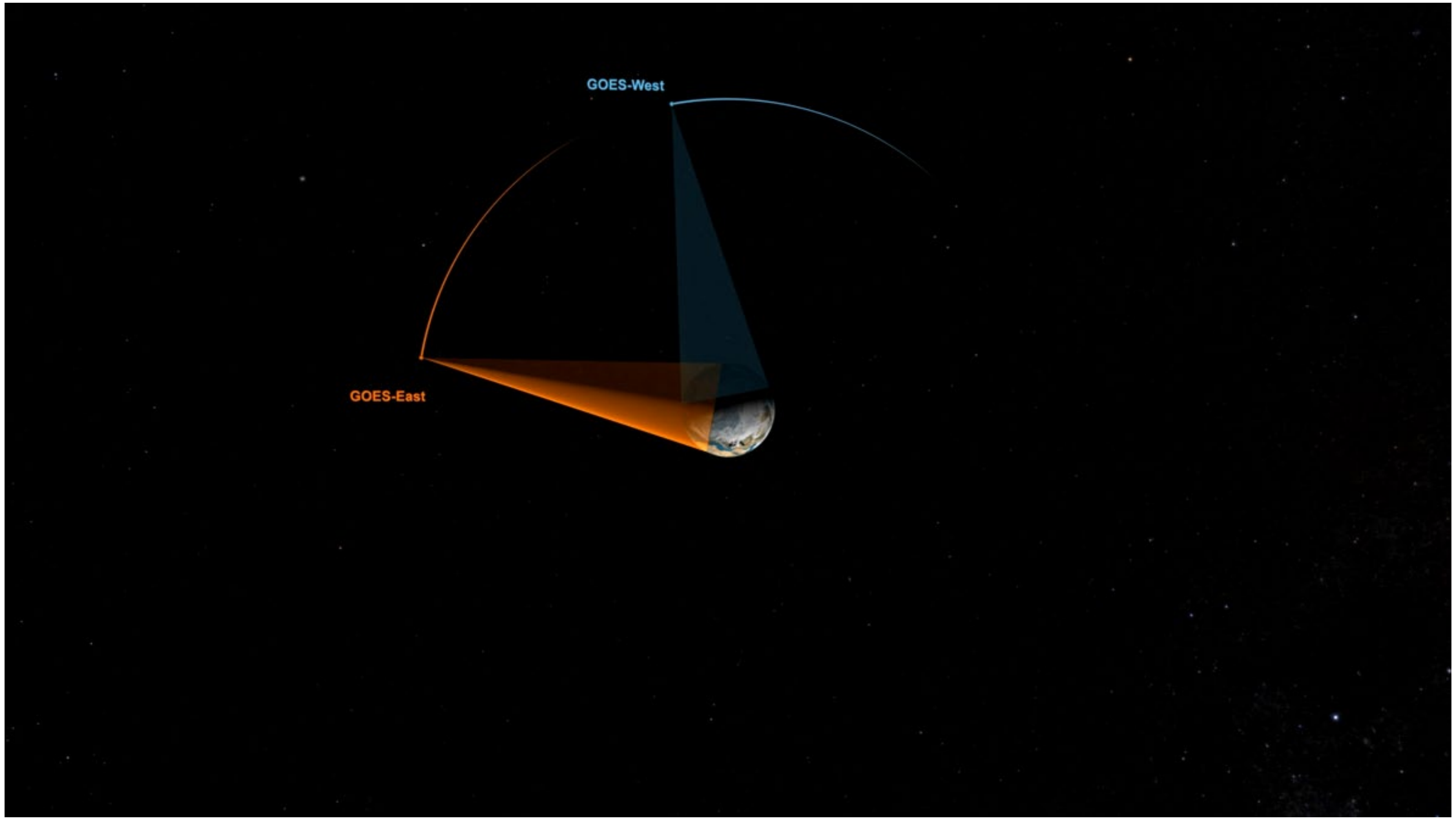
- A natural or "true-color" image combines actual measurements of red, green, and blue light.
- A false-color image uses at least one non-visible wavelength, though that band is still represented in red, green, or blue.



Satellite Characteristics

- **Orbits:** Polar/Non-Polar Orbit vs. Geostationary
- **Energy Source:** Passive vs. Active
- **Solar and Terrestrial Spectra:** Visible, UV, IR, Microwave...
- **Measurement Technique:** Scanning; Non-Scanning; Imager; Sounders
- **Resolution Type and Quality:** Spatial, Temporal, Spectral, Radiometric
- **Application:** Weather, Ocean Color, Land Mapping, Air Quality, Radiation Budget, etc.

Geostationary Orbit (GEO)



Video Credit: NASA

- Geostationary satellites typically orbit ~36,000 km over the equator with the same rotation period as Earth.
- Multiple observations/day
- Limited spatial coverage—observations are always of the same area
- Examples: Weather or communications satellites

Low Earth Orbit (LEO)

Video Credit: NASA

Low Earth Orbit (LEO)

- Orbit moving relative to Earth – can be polar or nonpolar
- Less frequent measurements
- Global (or near-global) spatial coverage
- Examples:
  - **Polar**: Landsat or Terra
  - **Nonpolar**: ISS or GPM

Satellite Sensors: Passive

- Passive remote sensors measure radiant energy **reflected** or **emitted** by the Earth-atmosphere system or changes in gravity from the Earth.
- Radiant energy is converted to bio-geophysical quantities such as temperature, precipitation, and soil moisture.
- Examples: Landsat OLI/TIRS, Terra MODIS, GPM GMI, GRACE, etc.
- https://earthdata.nasa.gov/learn/remote-sensors/passive-sensors

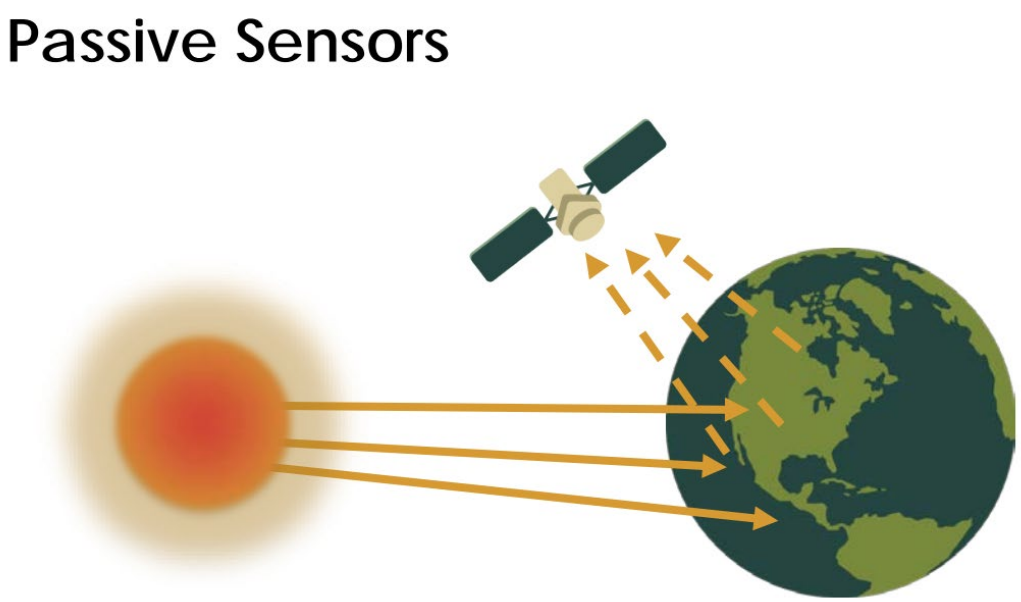


Image Credit: ARSET

Satellite Sensors: Active

- Active sensors provide their own energy source for illumination
- Most active sensors operate in the microwave portion of the electromagnetic spectrum, which makes them able to penetrate the atmosphere under most conditions and can be used day or night.
- Have a variety of applications related to meteorology and observation of the Earth's surface and atmosphere.
- Examples: Laser Altimeter, LiDAR, RADAR, Scatterometer, Sounder
- Missions: Sentinel-1 (C-SAR), ICESat-2 (ATLAS), GPM (DPR)
- https://earthdata.nasa.gov/learn/remote-sensors/active-sensors

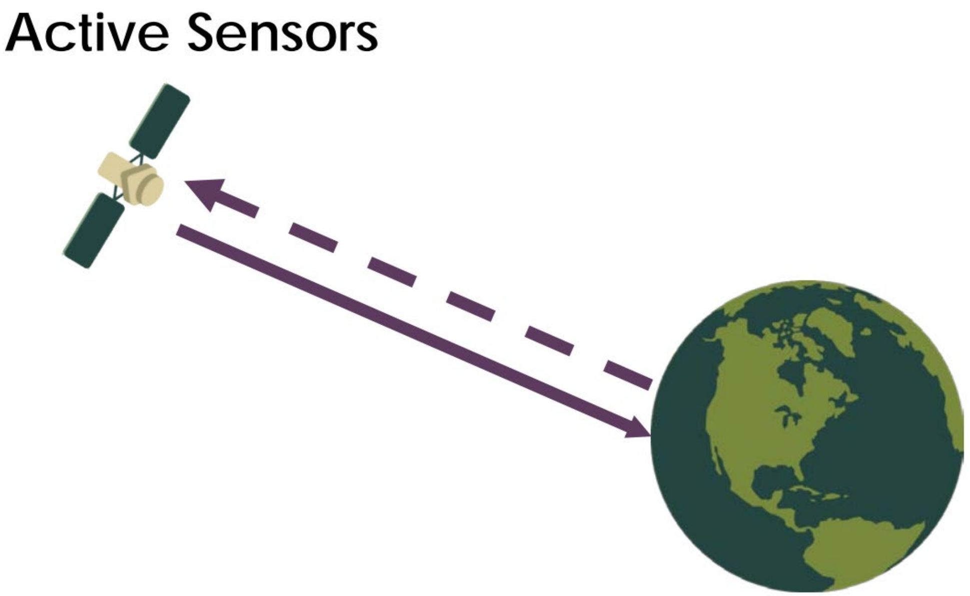
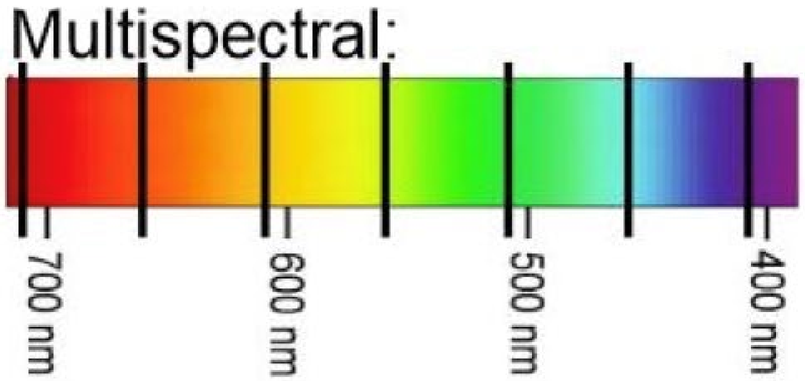
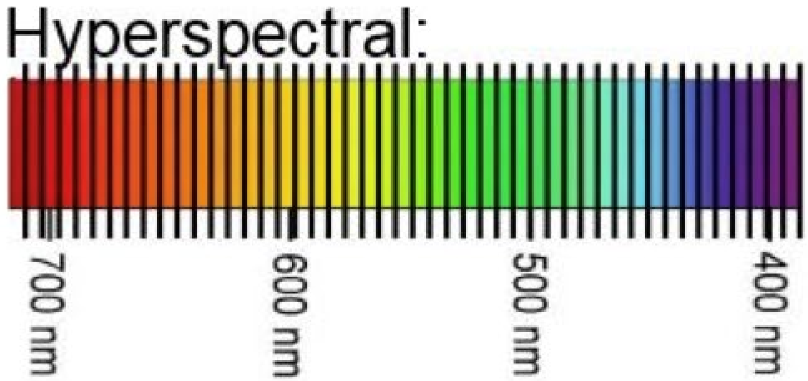


Image Credit: ARSET

Spectral Resolution

- Resolution depends upon satellite orbit configuration and sensor design. Different sensors have different resolutions.
- Signifies the number and width of spectral bands of the sensor. The higher the spectral resolution, the narrower the wavelength range for a given channel or band.
- More and finer spectral channels enable remote sensing of different parts of the Earth's surface.
- Typically, multispectral imagery refers to 3 to 10 bands, while hyperspectral imagery consists of hundreds or thousands of (narrower) bands (i.e., higher spectral resolution). Panchromatic is a single broad band that collects a wide range of wavelengths.





Spatial Resolution

- Different sensors have different resolutions.
- Signifies the ground surface area that forms one pixel in the image.
- The higher the spatial resolution, the less area is covered by a single pixel.
- On the right shows the same image at different spatial resolutions: (from left to right) 1 m, 10 m, and 30 m.

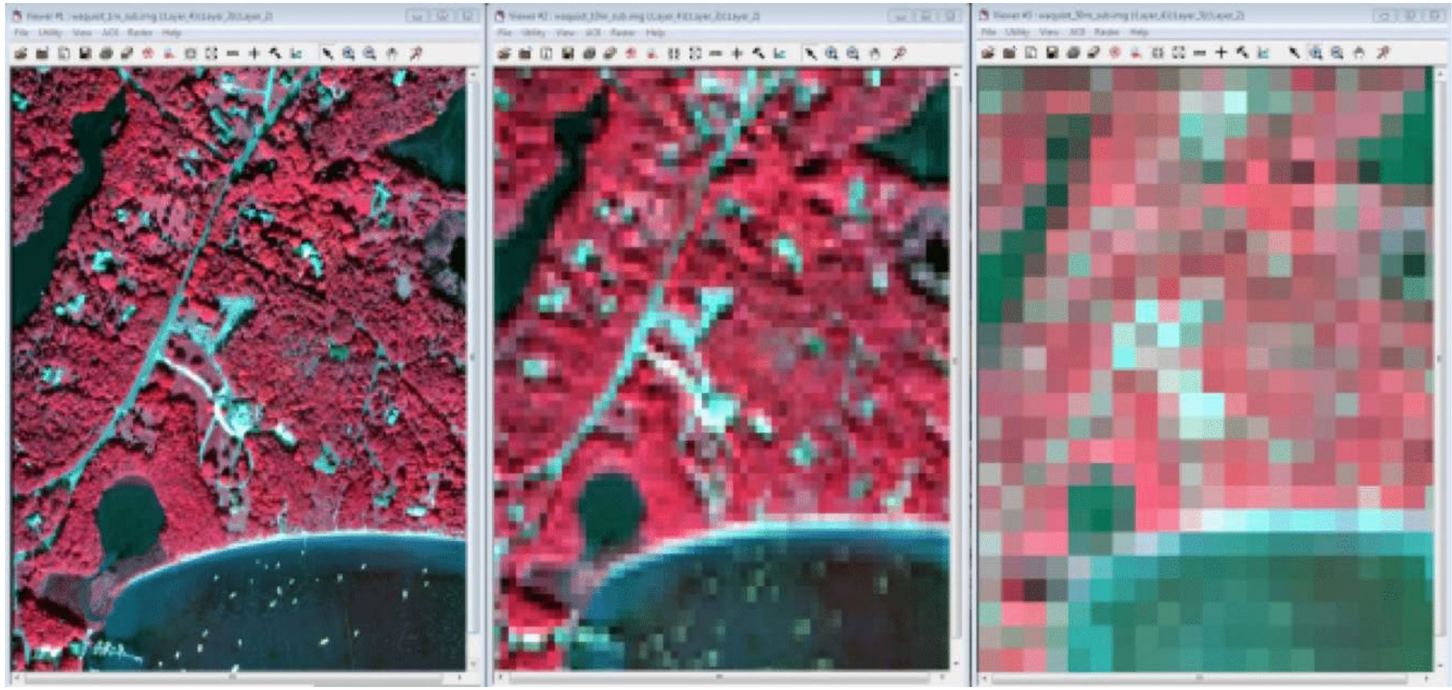
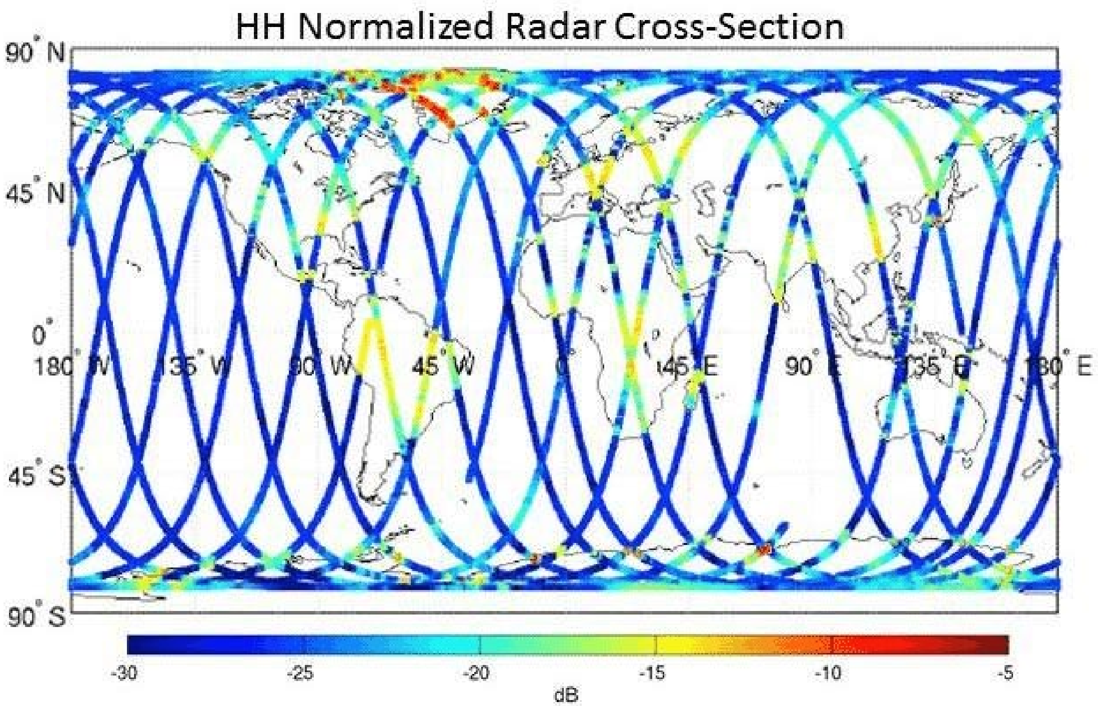


Image Credit: csc.noaa.gov

Temporal Resolution

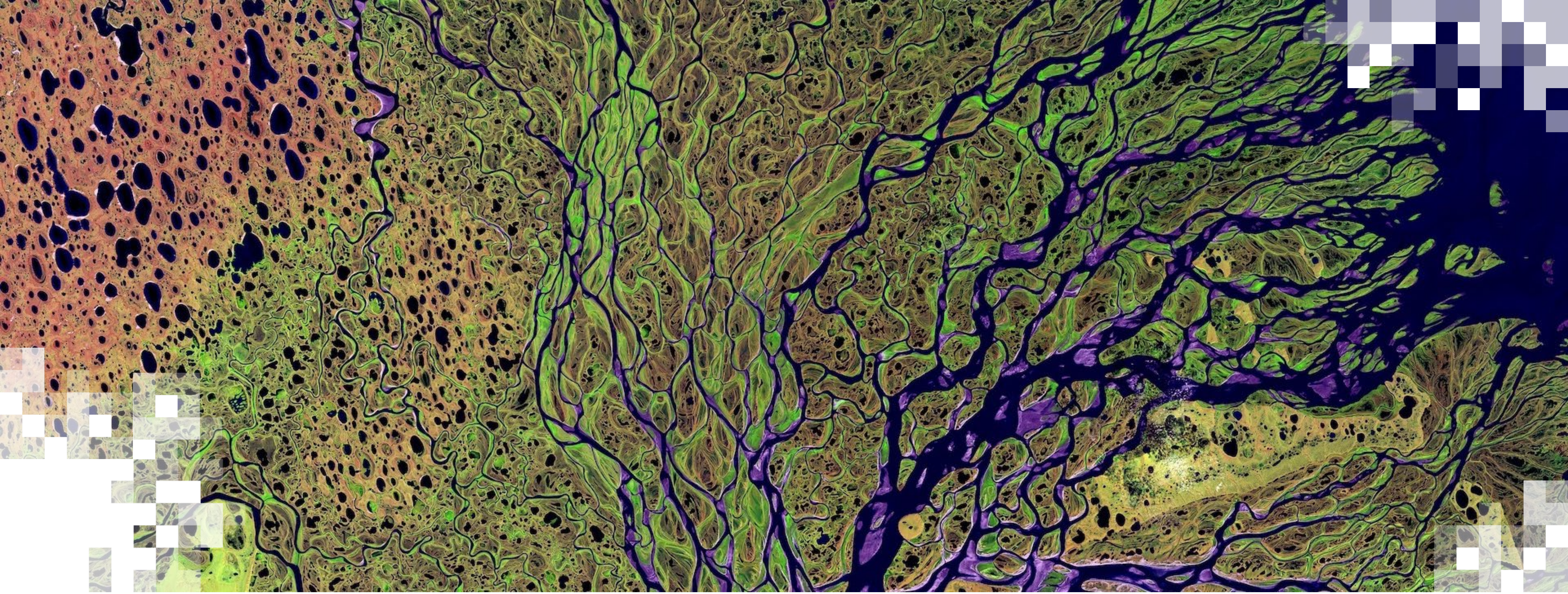
- The time it takes for a satellite to complete one orbit cycle—also called "revisit time"
- Depends on satellite/sensor capabilities, swath overlap, and latitude
- Some satellites have greater temporal resolution because:
  - They can maneuver their sensors
  - They have increasing overlap at higher latitudes

Sensor	Revisit time
Landsat	16-days
MODIS	2-days
Commercial (OrbView)	1-2 days



Satellite Data Processing Levels

- Satellite data is available at different stages (or levels) of processing, going from raw data collected from the satellite to polished products that visualize information.
- NASA takes the data from satellites and processes it to make it more usable for a broad array of applications. There is a set of terminology that NASA uses to refer to the levels of processing it conducts:
  - **Level 0 & 1** is the raw instrument data that may be time-referenced. It is the most difficult to use.
  - **Level 2** is Level 1 data that has been converted into a geophysical quantity through a computer algorithm (known as retrieval). This data is geo-referenced and calibrated.
  - **Level 3** is Level 2 data that has been mapped on a uniform space-time grid and quality controlled.
  - **Level 4** is Level 3 data that has been combined with models or other instrument data.
    - Level 3 & 4 data is the easiest to use.



Advantages and Limitations of Remote Sensing

Advantages of Remote Sensing

- **Wide Coverage**: Can cover large areas, making it suitable for monitoring extensive and hard to reach areas such as oceans, forests, floods.
- **Frequent Data Collection**: Can collect data at regular intervals, allowing for time-series analysis and monitoring of changes over time.
- **Cost-Effective**: Economical compared to extensive ground surveys, especially over large areas.
- **Multi-Spectral Data**: Data across different parts of the electromagnetic spectrum, enabling diverse applications in agriculture, forestry, urban planning, and climate studies.
- **Globally Consistent Observations**
- **Data Access:** Data are freely available and there are web-based tools for data analysis.

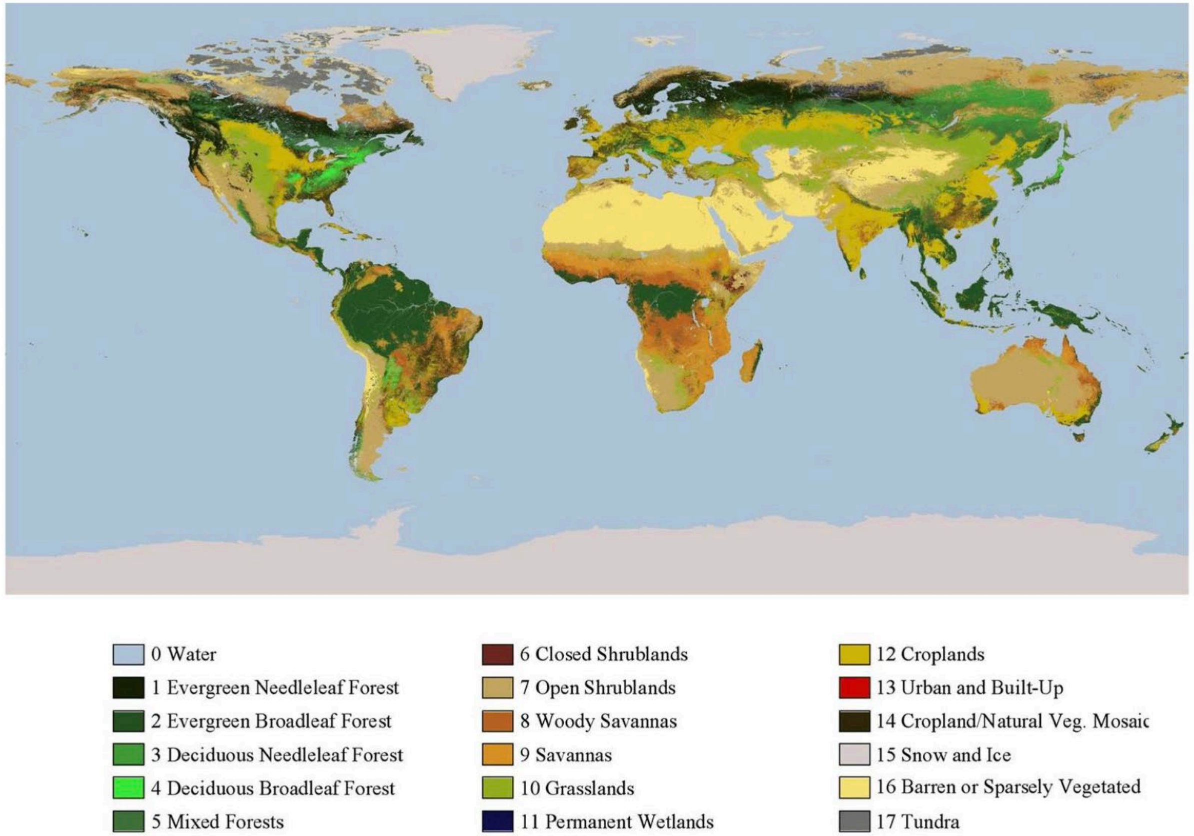
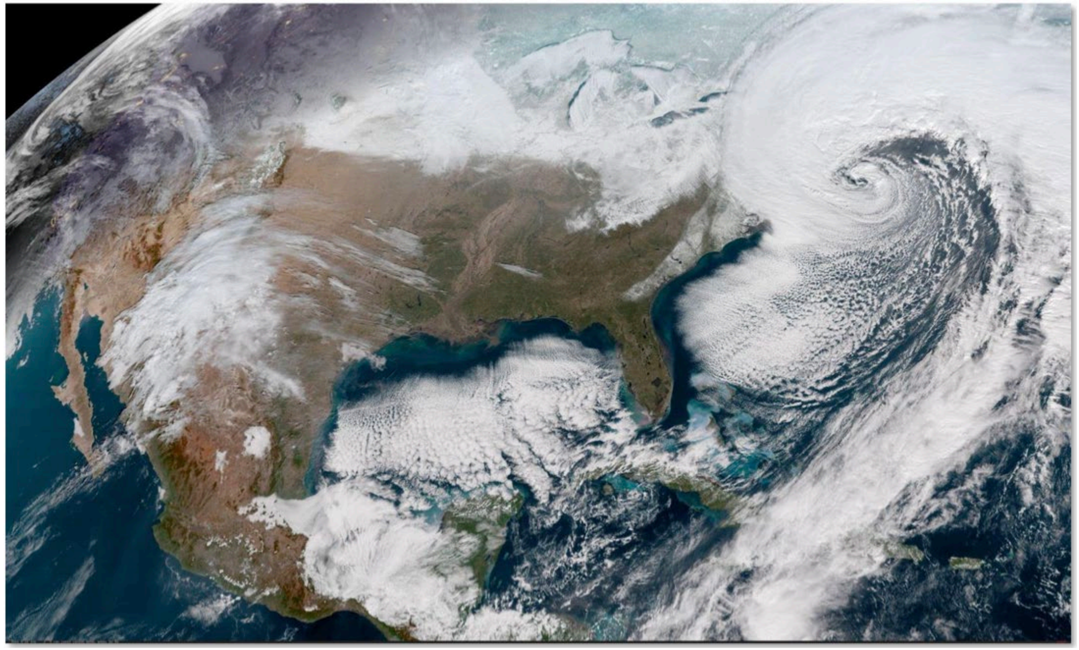


Image Credit: NASA GSFC

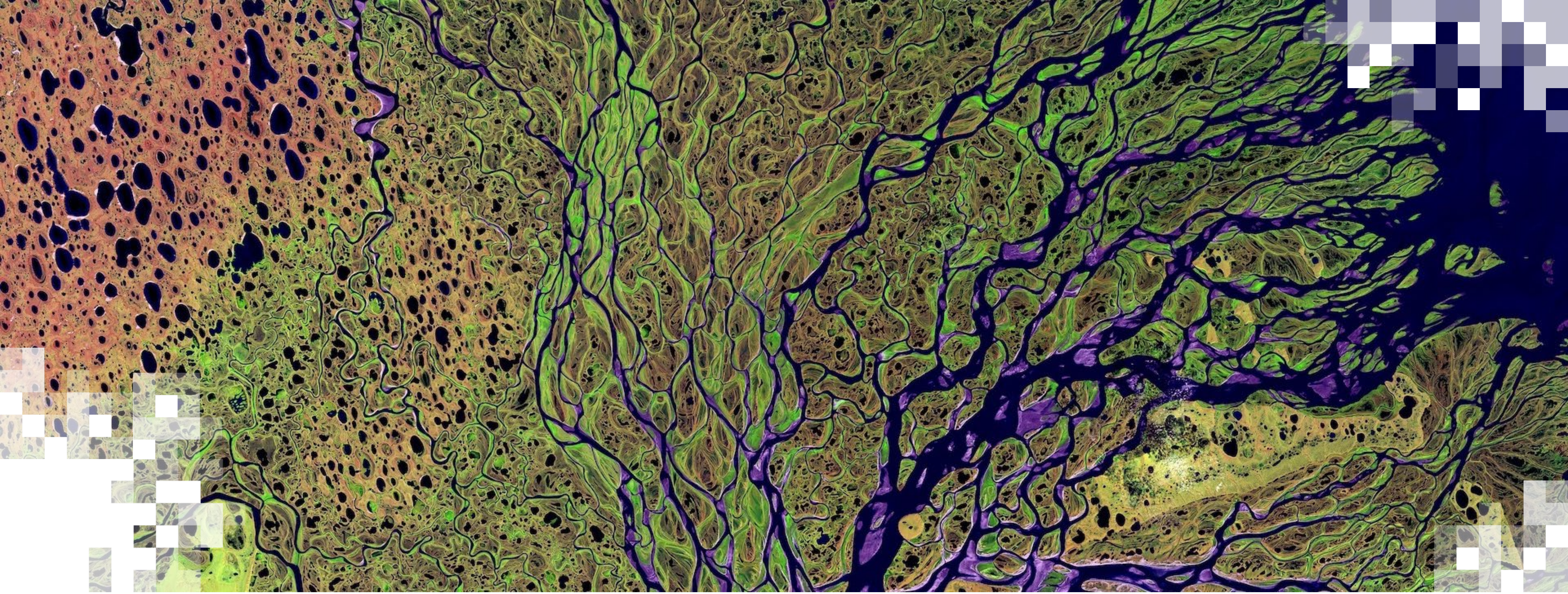
Limitations of Remote Sensing

- **Resolution Constraints**: The spatial, spectral, and temporal resolution may not always meet the specific requirements of certain applications.
- **Atmospheric Interference**: Atmospheric conditions (e.g., clouds, haze, and humidity) can affect the quality of the data and hinder the interpretation of optical and thermal sensors.
- **Data Interpretation Complexity**: Analyzing and interpreting remote sensing data often requires specialized knowledge and skills, making it challenging for non-experts.
- **Sensor Limitations**: Different sensors have inherent limitations, such as sensitivity to surface conditions, which can affect the accuracy of measurements.
- **Temporal Gaps**: Satellite overpasses may not align with the specific times of interest for data collection, leading to gaps in time-series data.



- **Ground Truth Validation**: Remote sensing data often requires ground truth validation to ensure accuracy, necessitating additional fieldwork.
- **Big Data**: Large amounts of data and a variety of data formats can lead to more processing and time

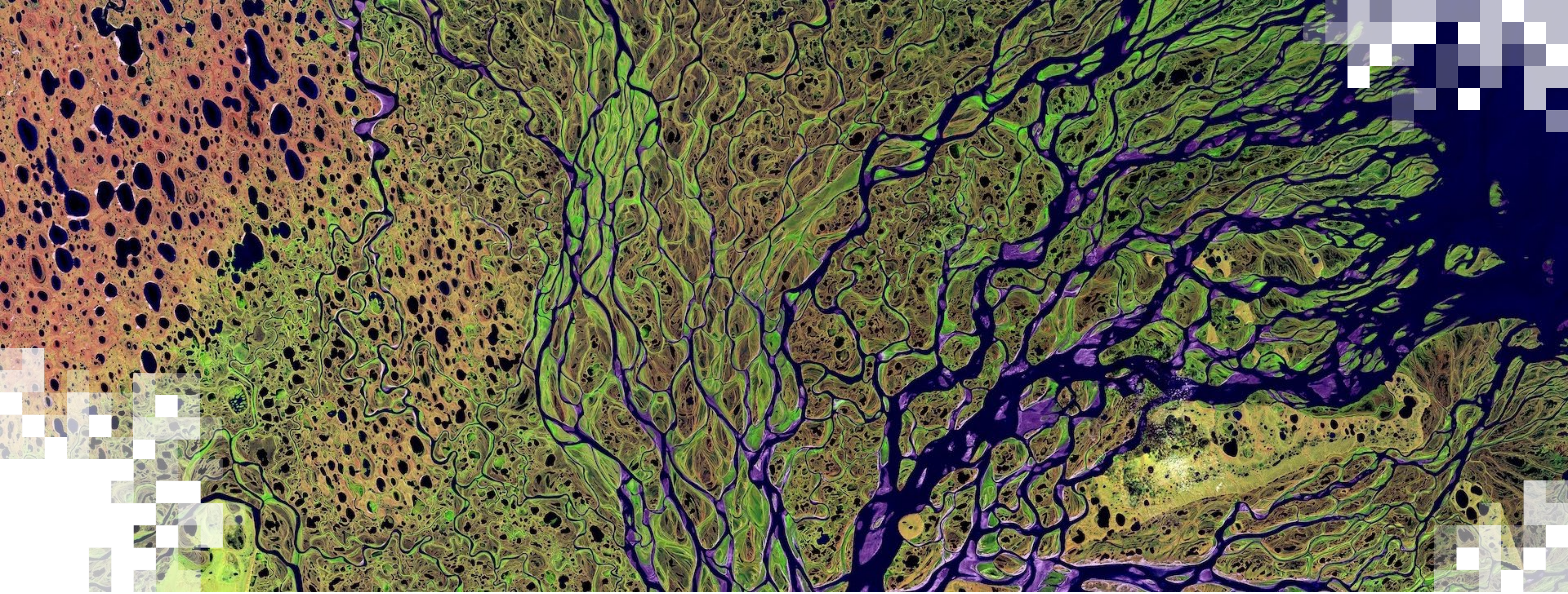
Image Credit: NOAA



Data & Tools Used in Training

Data & Tools

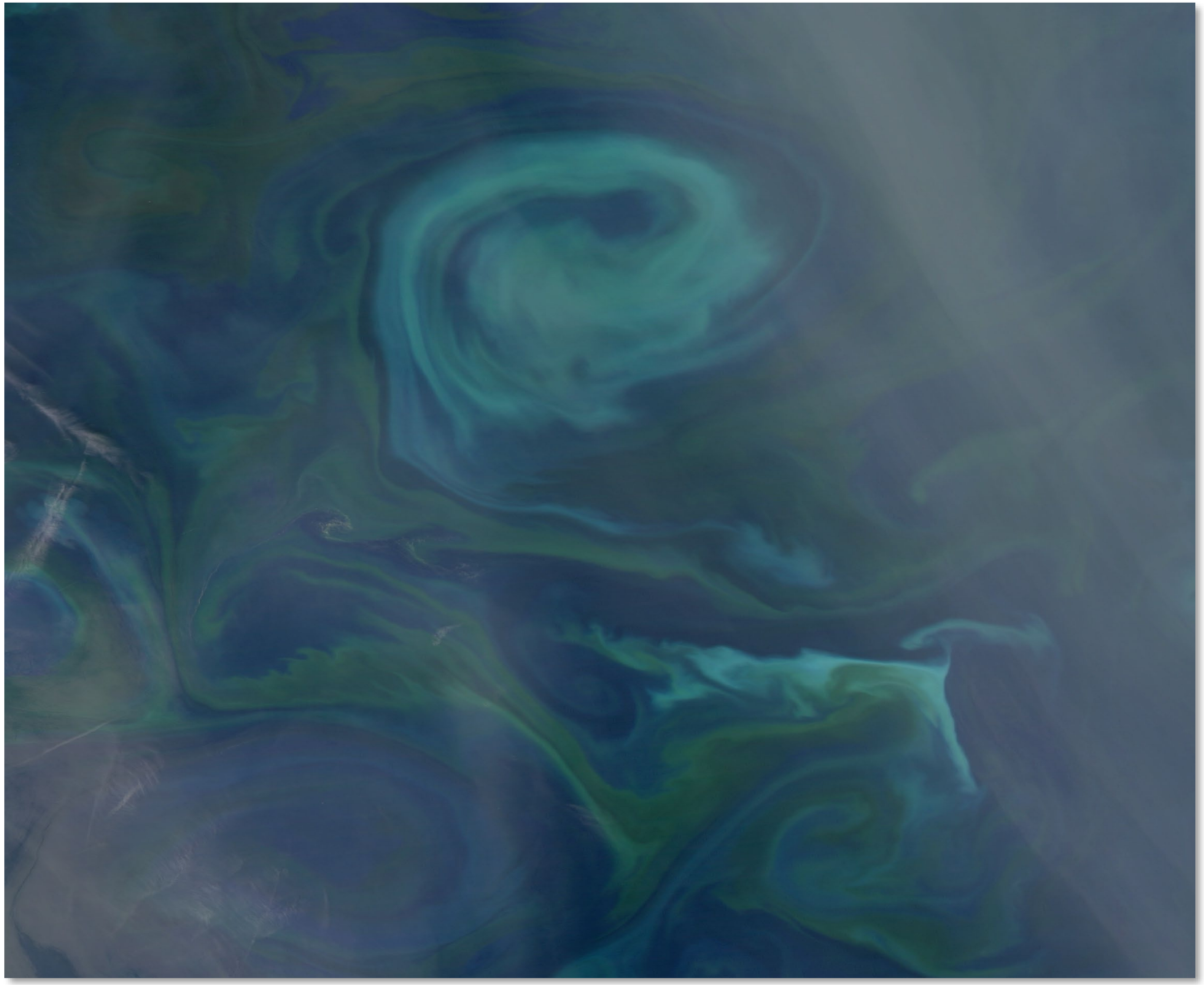
- NASA Earthdata
- NASA Worldview
- ESA WorldCover
- Global Forest Watch
- Earthdata Pathfinders
- Earthdata Data Catalog
- GEOGLAM Crop Monitor
- Global Land Analysis and Discovery (GLAD)
- NASA’s Environmental Justice Data Search Interface
- NASA's Socioeconomic Data and Applications Center (SEDAC)
- NASA’s Fire Information for Resource Management System (FIRMS)
- NASA's Land, Atmosphere Near real-time Capability for Earth observation (LANCE)



Energizer – Remote Sensing Game

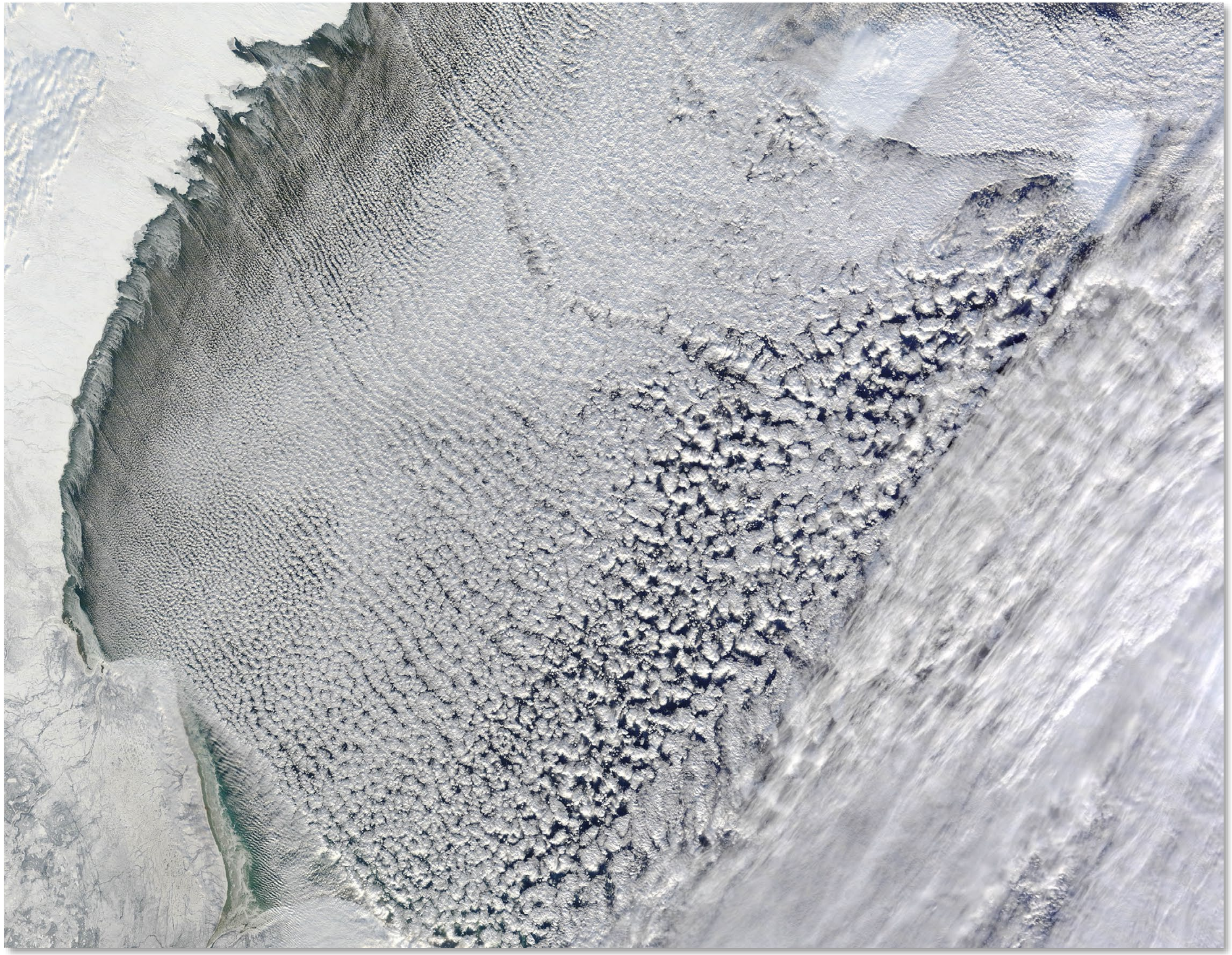
What color(s) do you think are reflected?

- RED
- BLUE
- GREEN



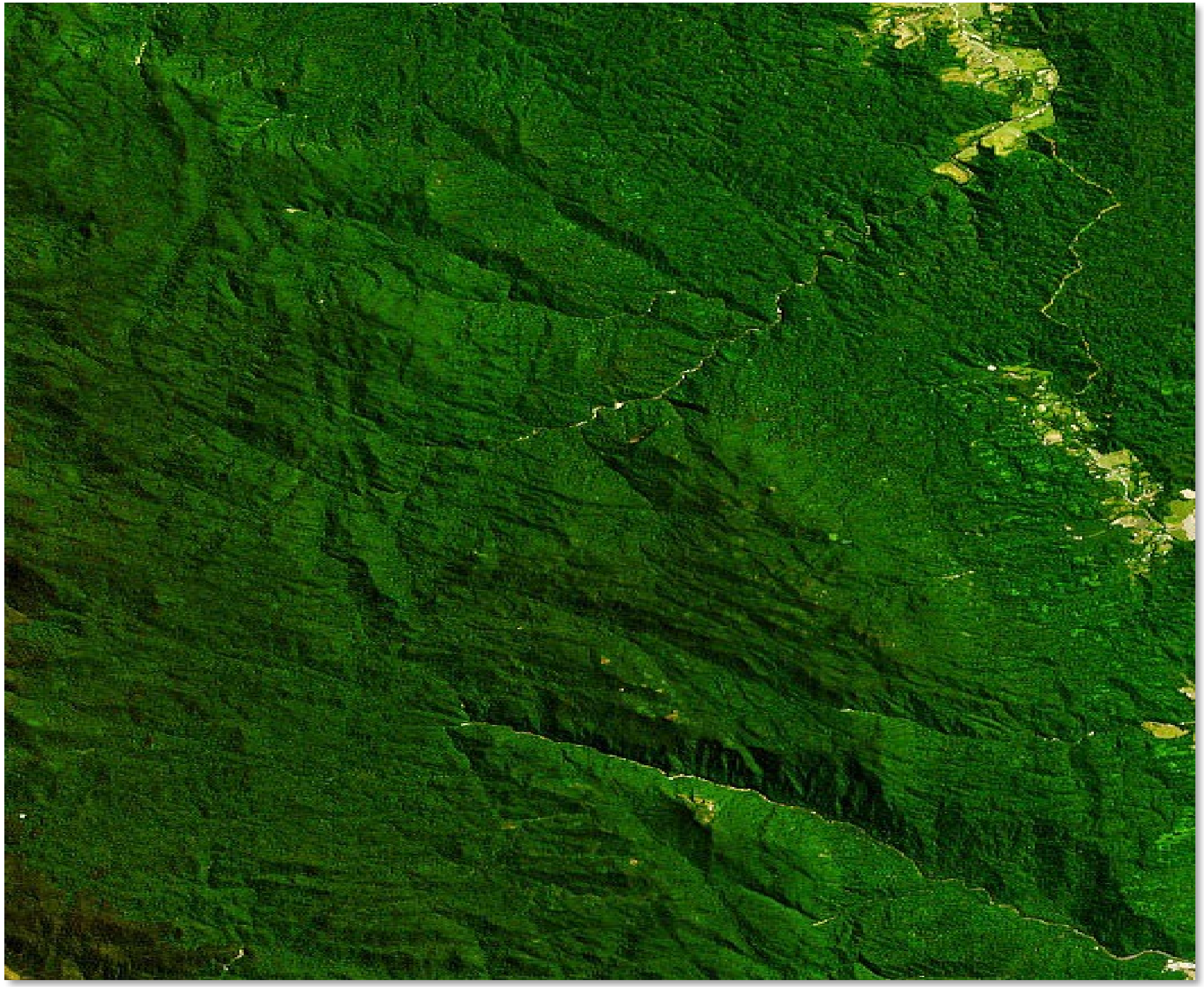
What color(s) do you think are reflected?

- RED
- BLUE
- GREEN



What color(s) do you think are reflected?

- RED
- BLUE
- GREEN



Thank You!