Earth Observations in Support of Insurance & Finance Sector Decision-Making

Observations and Modeled Weather Data for Precipitation and Floods

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Learning Objectives

- By the end of this presentation attendees will be able to:
  - Identify observational and model-based datasets applicable to flood monitoring
    - Precipitation measurements: IMERG
    - Weather parameters (wind speed, surface pressure, humidity, temperature: MERRA-2
    - Nighttime lights imagery: VIIRS
  - Explore case studies showcasing data applications

IMERG: Integrated Multi-satellitE Retrievals for GPM

MERRA-2: The Modern-Era Retrospective Analysis for Research and Applications, Version 2

VIIRS: Visible Infrared Imaging Radiometer Suite

Outline

- Overview of:
  - IMERG precipitation data
  - MERRA-2 weather data
  - VIIRS nighttime lights data
- Examples of Data Applications

IMERG: Integrated Multi-satellitE Retrievals for GPM

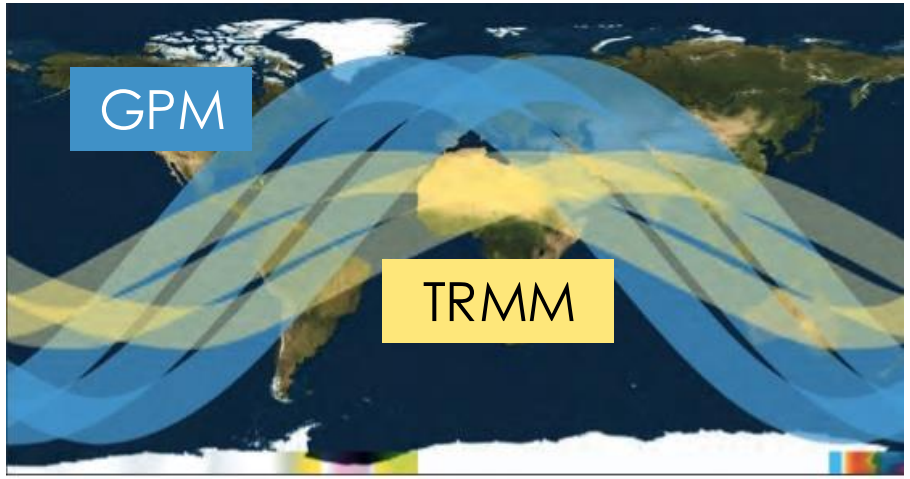
MERRA-2: The Modern-Era Retrospective Analysis for Research and Applications, Version 2

VIIRS: Visible Infrared Imaging Radiometer Suite

Overview of IMERG Precipitation Data

GPM (Operational) and TRMM (Legacy)

- Dedicated precipitation measurement missions (PMM) to measure precipitation from active and passive microwave observations.
- Collaborative missions between NASA and Japanese Space Agency (JAXA).
- TRMM was and GPM is in low-inclination, non-polar orbit.
- **TRMM: November 1997 to April 2015**
- **GPM: February 2014 to present**
- **Combined, TRMM and GPM provide 20+ years of precipitation data.**



- TRMM measurements were limited to the tropics (35° north/south latitude).
- GPM measurements span middle and high latitudes (65° north/south latitude).

http://pmm.nasa.gov/

TRMM: Tropical Rainfall Measuring Mission

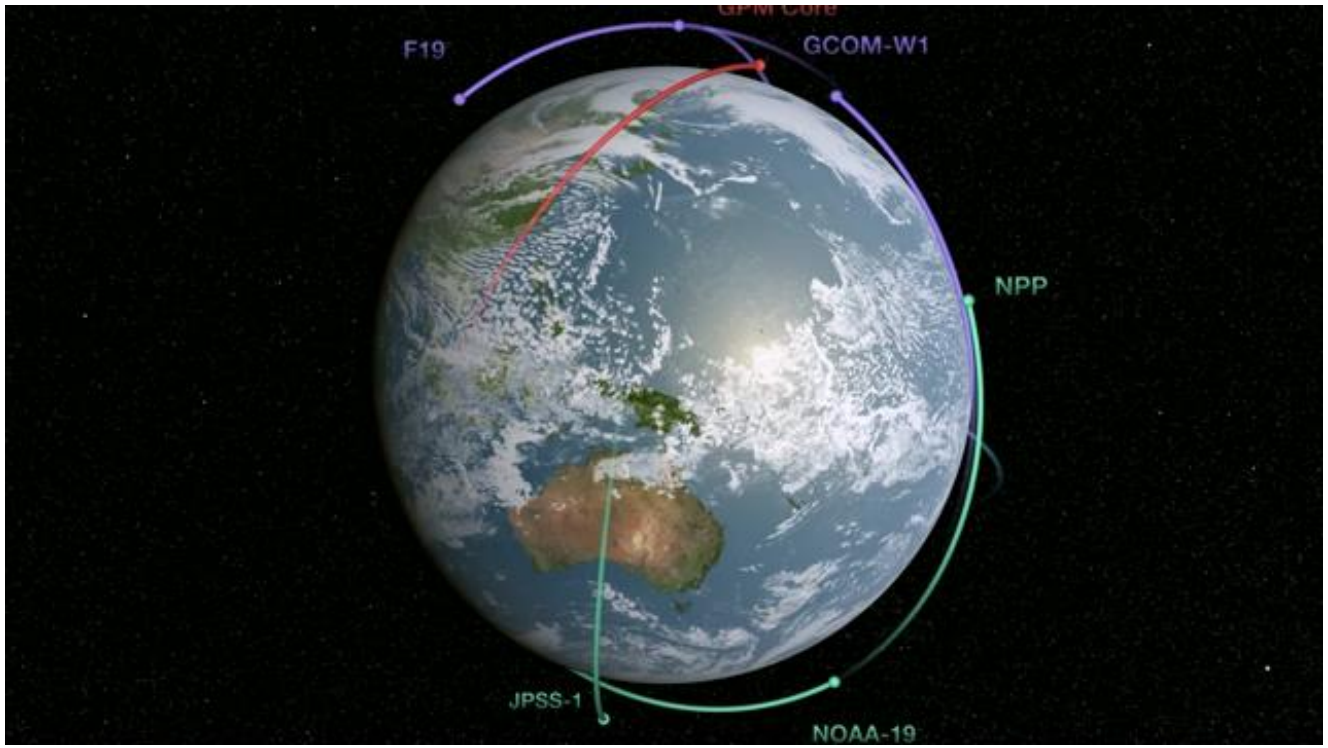
GPM: Global Precipitation Measurement

Multi-Satellite Algorithms for TRMM and GPM

- TRMM & GPM core satellites are used to calibrate microwave observations from a constellation of national and international satellites.
- TRMM Multi-satellite Precipitation Analysis (**TMPA**)
- Integrated Multi-satellitE Retrievals for GPM (**IMERG**)
- IMERG is calibrated with TMPA to provide long-term precipitation record.
- Lean more about the precipitation algorithms.

GPM Satellite Constellation

Allows improved spatial and temporal coverage of precipitation data



Credit: NASA Science Visualization Studio

Integrated Multi-satellitE Retrievals for GPM (IMERG)

- **Multiple runs accommodate different user requirements for latency and accuracy.**
- GPM IMERG Algorithm Theoretical Basis Document (ATBD)
- Latency:
  - "Early" – now 5 hours (flash flooding) – will be 4 hours.
  - "Late" – now 15 hours (crop forecasting) – will be 12 hours.
  - "Final" – 3 months (research data)
- Value-added products at 3 hrs., 1, 3, and 7 days – .tiff will be available
- Initial release covers 60°N–60°S – will be 90°N–90°S.

IMERG Technical Specifications

Parameters	IMERG
Spatial Resolution	0.1° x 0.1°
Spatial Coverage	Global
Temporal Resolution	30 minutes
Temporal Coverage	1998 – present

Integrated Multi-satellitE Retrievals for GPM (IMERG) Technical Documentation. Huffman et al. (2019)

Data Visualization

https://gpm.nasa.gov/data/visualization

Data Visualization

Global Viewer

View the latest near-realtime GPM IMERG global precipitation datasets (30 minute, 1 day, 7 day) on an interactive 3D globe in your web browser.

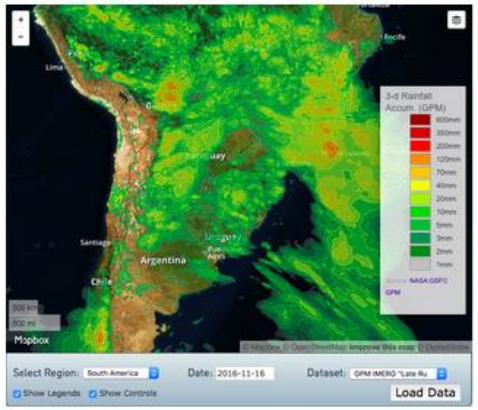
STORM Event Viewer

View 2D GMI and 3D DPR data from the latest extreme weather events on an interactive 3D globe in your web browser.

(click here for mobile version)

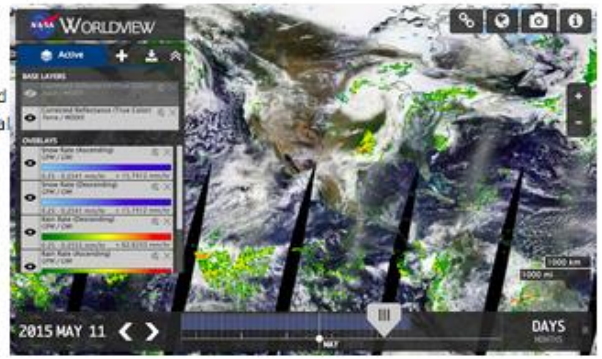
Precipitation and Applications Viewer

View and download various precipitation and applications datasets from the past 60 days (30 minute, 1 day, 3 day, 7 day precipitation, floods nowcast, landslides nowcast). Download datasets in various popular formats (TIF, SHP, arcJSON, geoJSON, topoJSON) and learn how to directly access the data via the PMM Publisher API.



NASA Worldview

This tool from NASA's Earth Observing System Data and Information System (EOSDIS) provides the capability to interactively browse global, full-resolution satellite imagery and then download the underlying data, including data from the Global Precipitation Measurement Missions.



Overview of Weather Parameters from MERRA-2

MERRA-2 Weather Data Products

MERRA-2 provides core meteorological information in two-dimensional (single-level or vertically integrated) and three-dimensional (pressure or model levels) formats.

- Air Temperature: 2-meter, 10-meter, and multiple atmospheric levels.
- Winds: Eastward and northward wind components at 10-meters and various pressure/model levels.
- Humidity: Specific humidity at 2-meters and various levels.
- Pressure: Sea-level pressure and surface pressure.
- Precipitation: Total precipitation, convective precipitation, and snowfall.
- Clouds: Cloud fraction and in-cloud optical thickness for different cloud layers.

MERRA-2

Technical information about MERRA-2 model reanalysis and data products

GMAO

NASA

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Reanalysis | Weather Analysis & Prediction | Seasonal-Decadal Analysis & Prediction | Global Mesoscale Modeling | Observing System Science | Explore

Home > GMAO Products > GMAO Reanalysis Products

GMAO Reanalysis Products

Product ID	Description	Information	Periods Covered	Data Access	Documentation
MERRA-2	Atmospheric reanalysis for the satellite era, including coupled aerosols	MERRA-2 Project Page	1/1/1980 - ongoing	• Data available at MDISC, managed by GES DISC • MERRA-2 Visualizations • MERRA-2 User Metrics	• MERRA-2 File Specifications • MERRA-2 Technical Memorandum

Webtools for IMERG and MERRA-2 Data Access and Analysis

Tool	Features

Giovanni	• Spatial/Temporal subsetting
	• Analysis:
	  • Time-averaged maps, animation, time series, scatter plots, map correlations, vertical profiles, time-averaged differences
	• Visualization:
	  • Maps, time series, scatter plots, histograms
	• Near real-time rain rate access

NASA Earthdata Search	• Spatial/Temporal subsetting • Bulk download

Google Earth Engine	• Spatial/Temporal subsetting
	• Analysis:
	  • Time-averaged maps, animation, time series, scatter plots, map correlations, vertical profiles, time-averaged differences
	• Visualization:
	  • Maps, time series, scatter plots, histograms

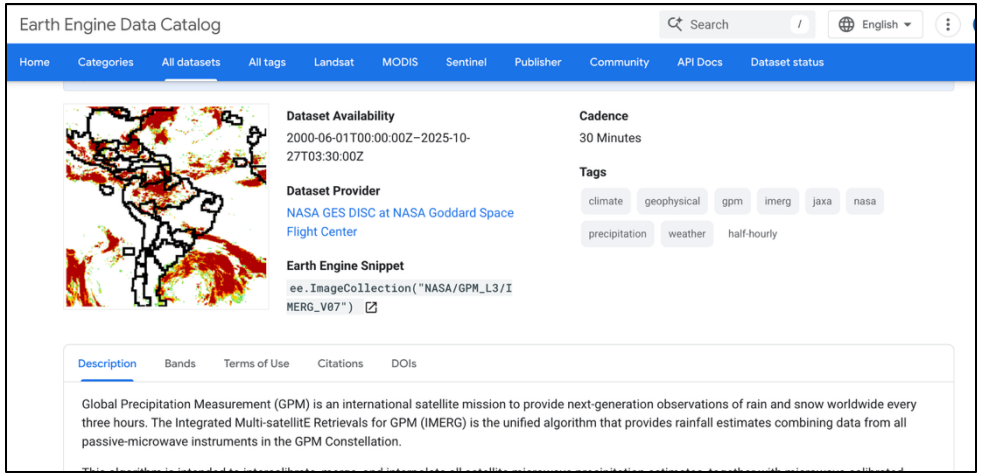
IMERG and MERRA-2 Data Access, Analysis, Visualization

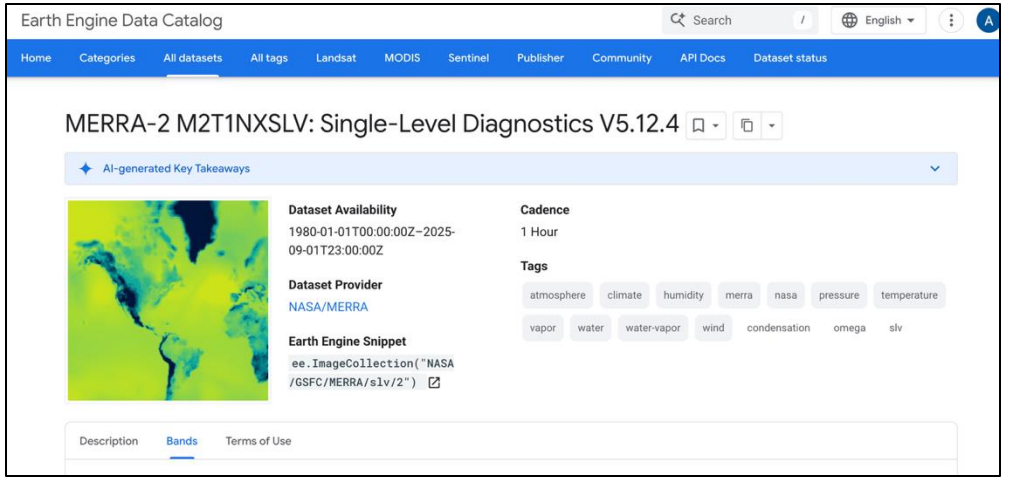
[NASA Earthdata Search]

[Giovanni]

[NASA Worldview]

[Google Earth Engine]





Overview of Nighttime Lights from VIIRS

Black Marble Nighttime Lights Product

- Uses Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night band (DNB)
- DNB is a panchromatic channel covering the wavelengths from 500 nm to 900 nm
- It is sensitive to visible and near-infrared radiation from daylight to the low-level radiation observed at night
- A daily calibrated, corrected, and validated product suite to observe nightlights
- Black Marble Webpage

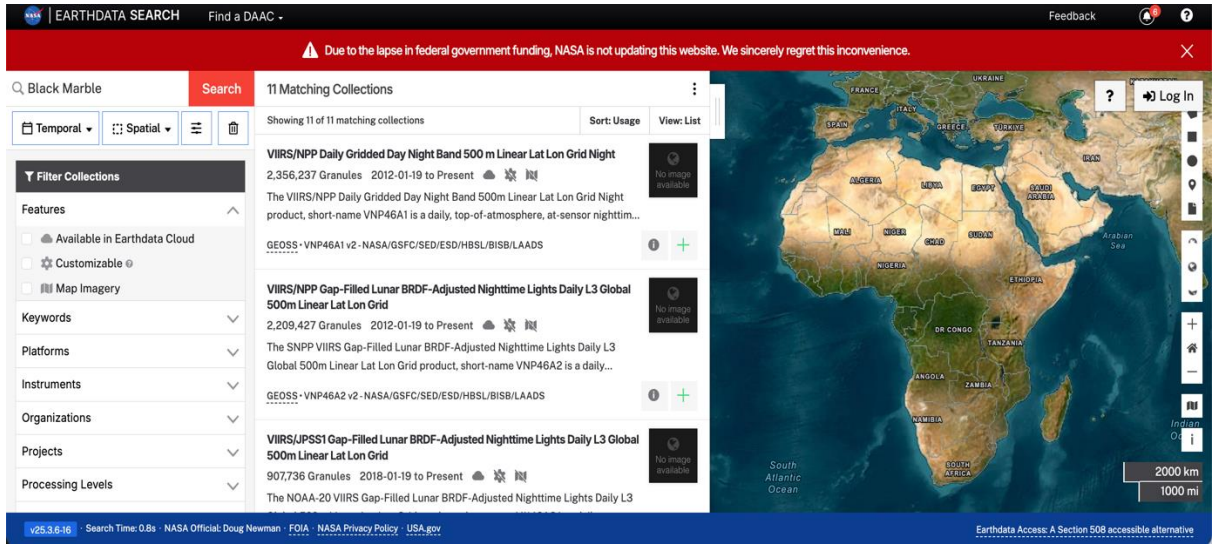
Credit: NASA Black Marble Team

ARSET Training (2020): Introduction to NASA "Black Marble" Night Lights Data

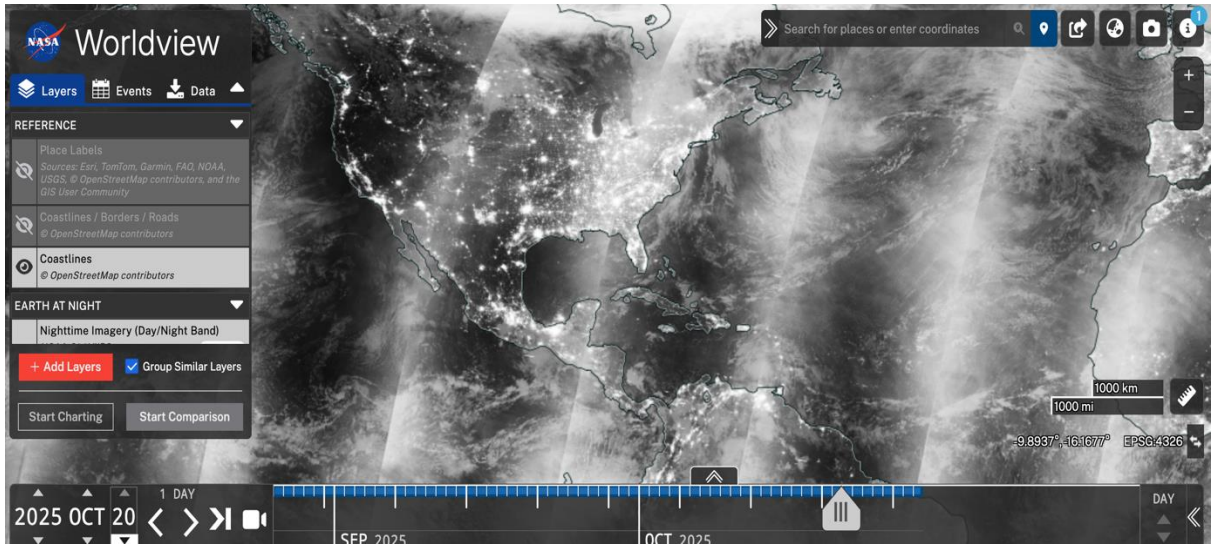
Black Marble Data Access and Visualization

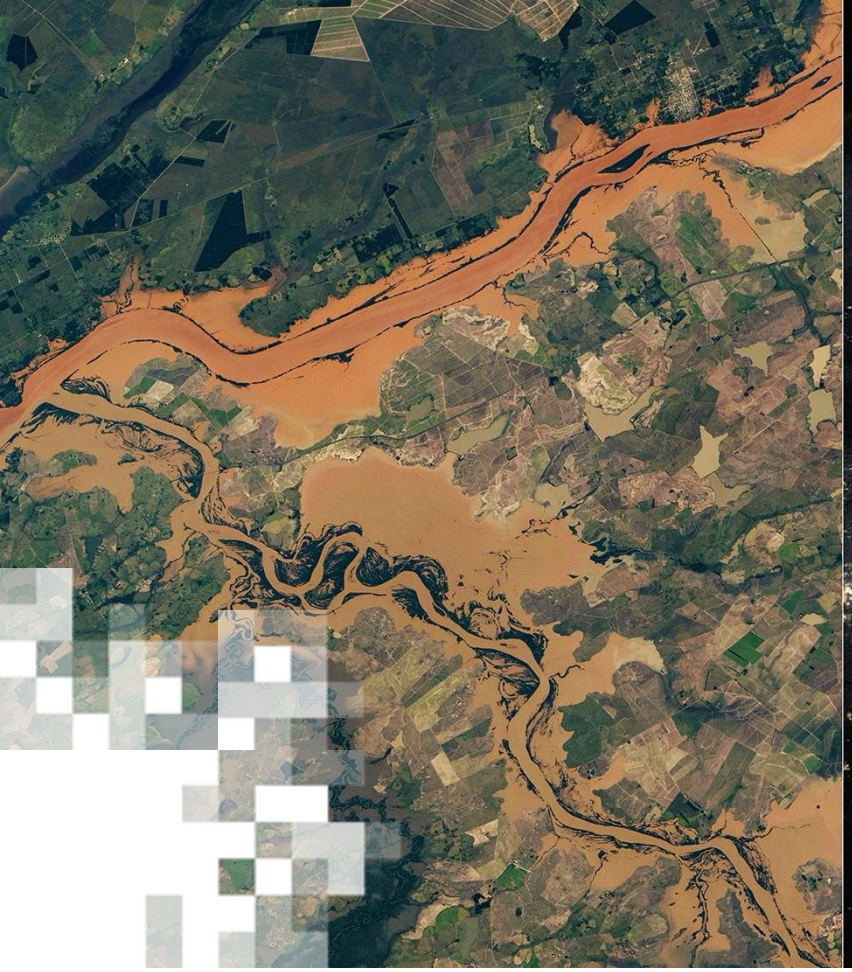
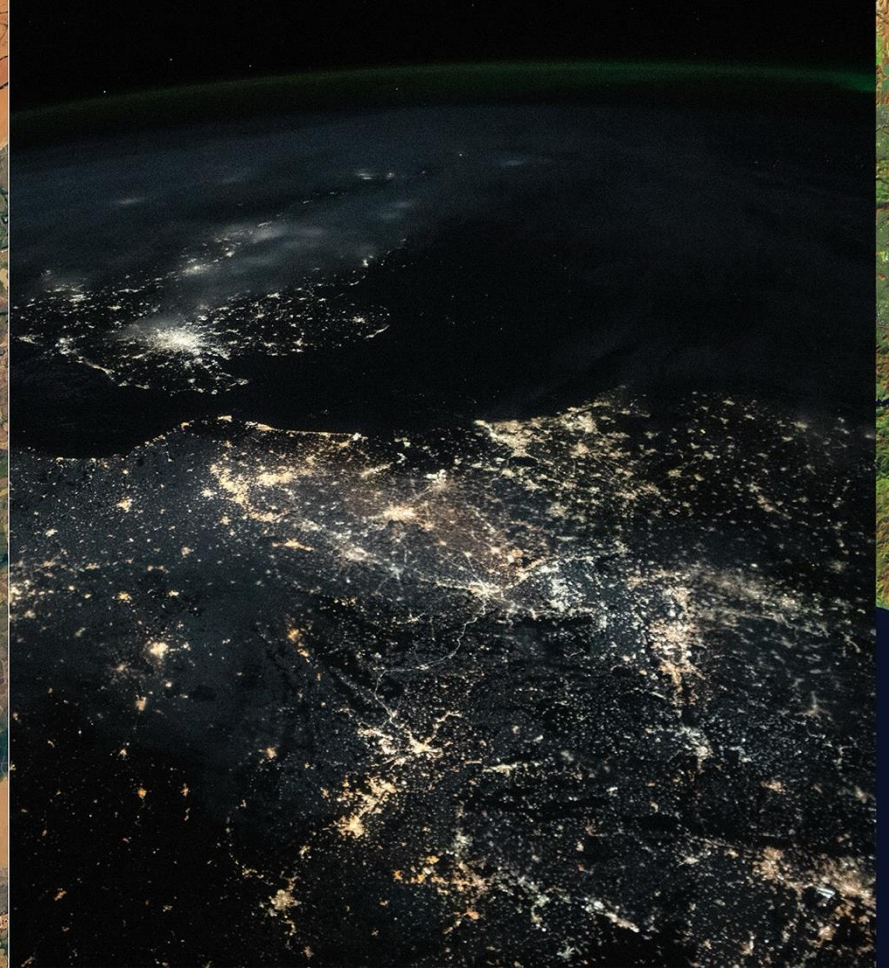
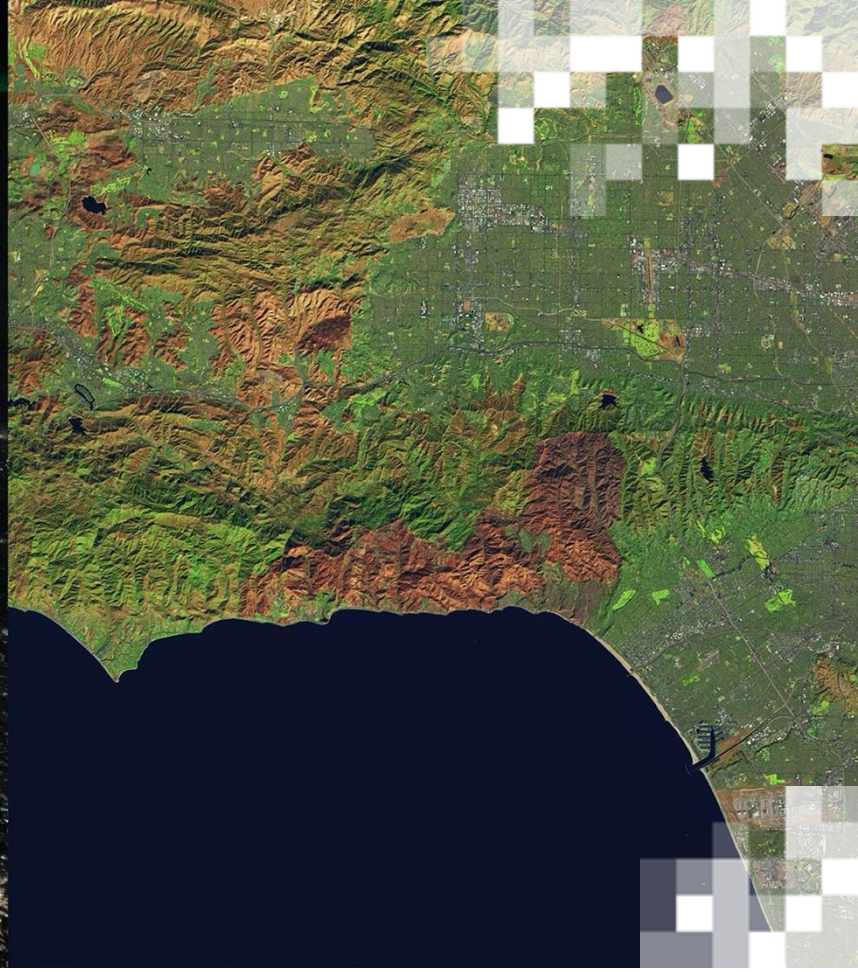
Product Name	SNPP	JPSS-1
Daily Gridded Day Night Band 500m Linear Lat Lon Grid Night	VNP46A1	VJ146A1
Gap-Filled Lunar BRDF-Adjusted Nighttime Lights Daily L3 Global 500m Linear Lat Lon Grid	VNP46A2	VJ146A2
Lunar BRDF-Adjusted Nighttime Lights Monthly L3 Global 15 arc second Linear Lat Lon Grid	VNP46A3	VJ146A3
Lunar BRDF-Adjusted Nighttime Lights Yearly L3 Global 15 arc second Linear Lat Lon Grid	VNP46A4	VJ146A4

NASA Earthdata Search



NASA Worldview



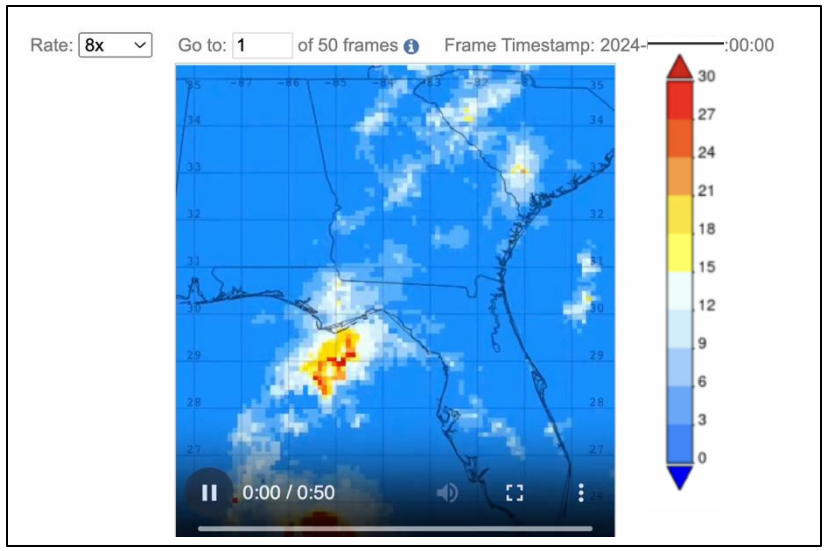




Example of Data Applications

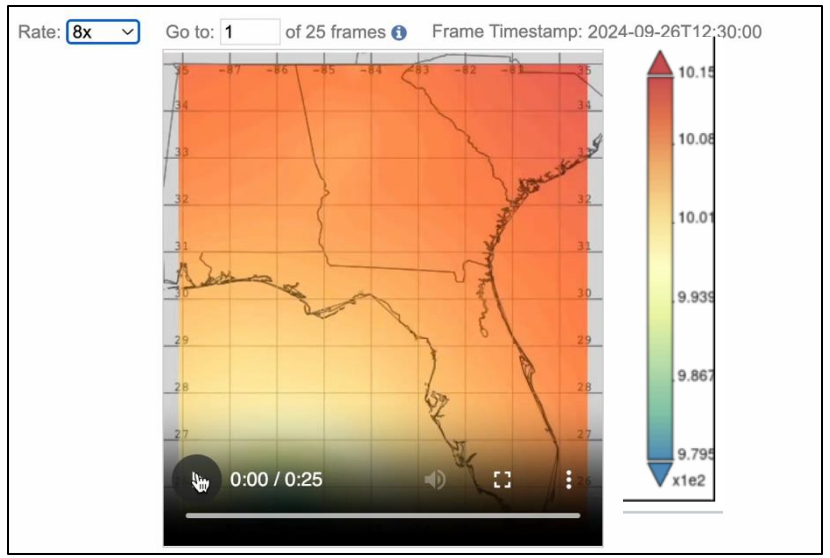
Monitoring Hurricane Helene (26–27 September 2024)

Monitor Hurricane Helene using Giovanni Data Analysis and Visualization Capability

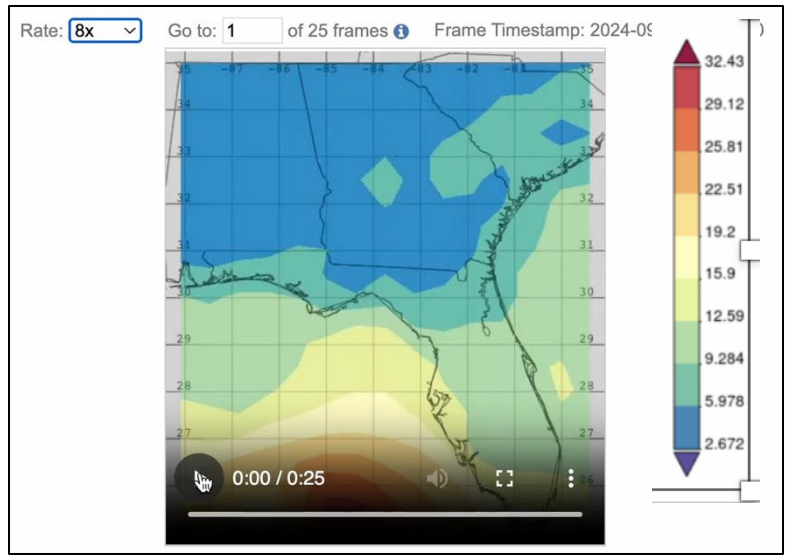
IMERG Rainfall $mm.hr^{-1}$



MERRA-2 Sea Level Pressure hPa



MERRA-2 Surface Wind Speed. $m.s^{-1}$

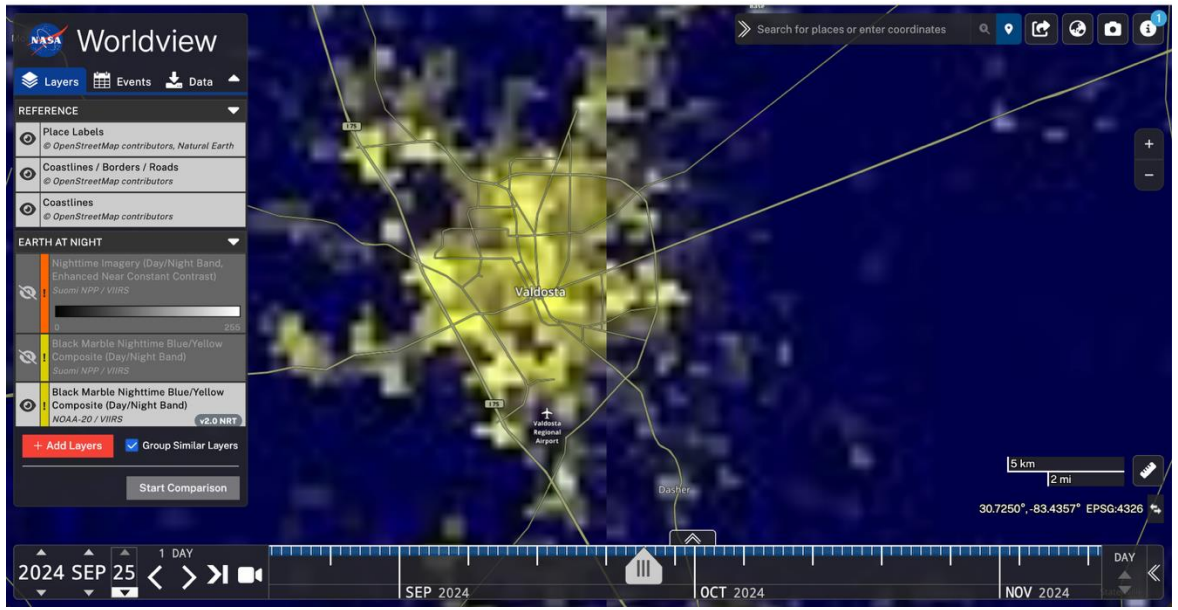


Monitoring Hurricane Helene (26–27 September 2024)

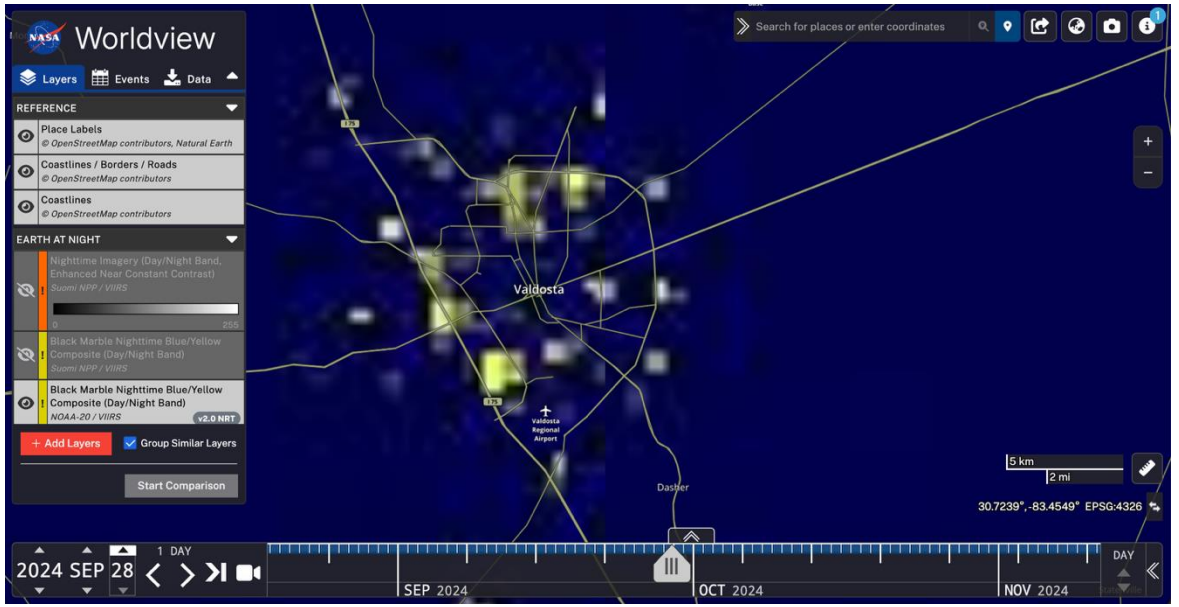
Monitor Post-Hurricane Power Outages using NASA Worldview

Night Light Imagery from NOAA-20 VIIRS

25 September 2024



28 September 2024

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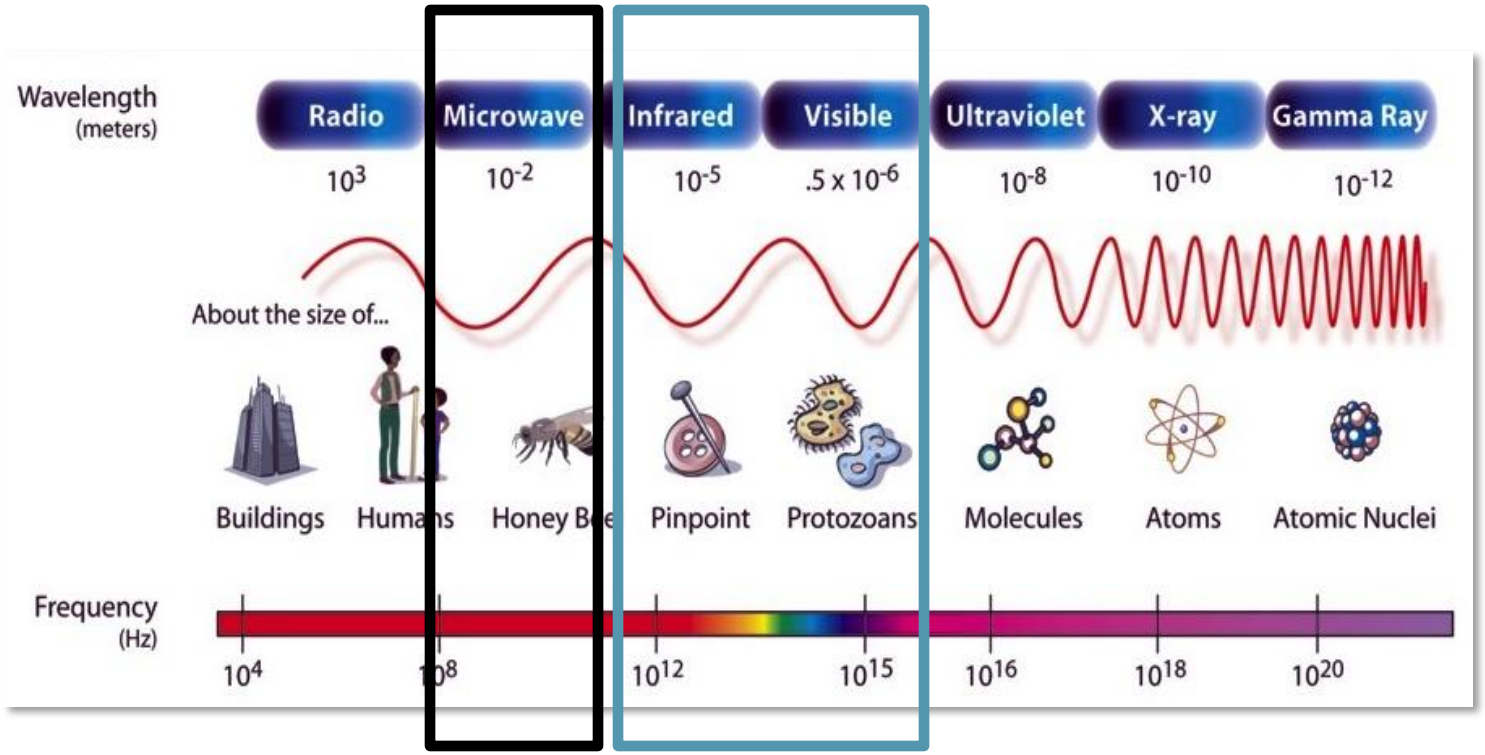
Thank You!

Radar Data

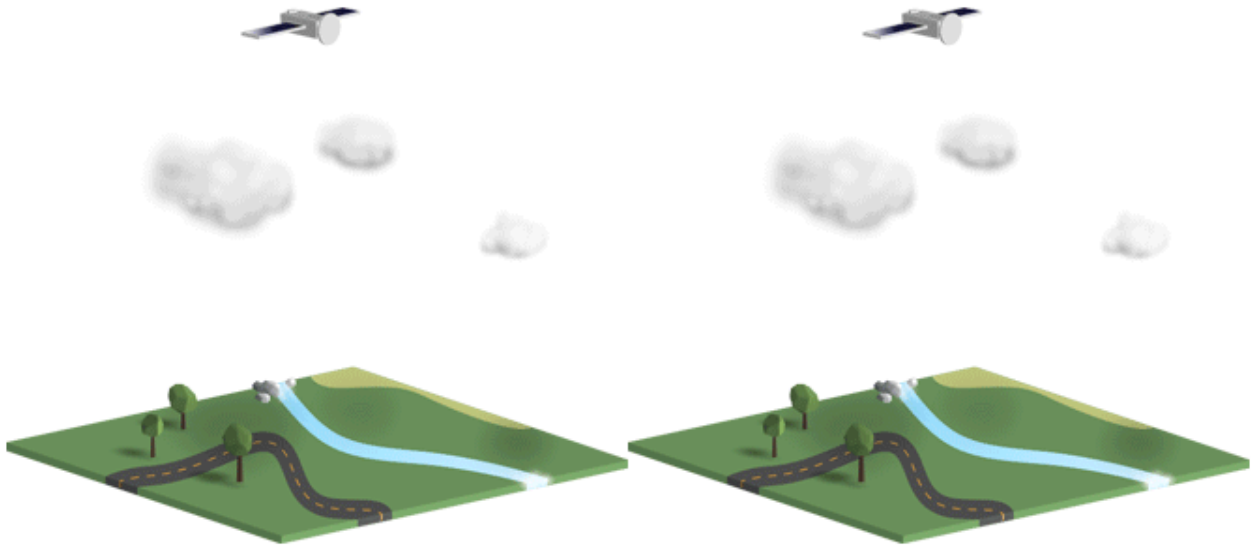
Electromagnetic Radiation for Remote Sensing



Optical Sensors use infrared–visible regions.

- Optical sensors measure reflected solar light and only function in the daytime.
- The surface of the Earth cannot be imaged with visible or infrared sensors when there are clouds.
- Microwaves can penetrate through clouds and vegetation and can operate in day or night conditions.

Active and Passive Remote Sensing



Passive: Sensors detect only what is emitted from the landscape or is reflected from another source (e.g., light reflected from the sun).

Active: Instruments emit their own signal and the sensor measures what is reflected back. Sonar and radar are examples of active sensors.

Passive Sensors:

- The source of radiant energy arises from natural sources
- e.g., the Sun, Earth, other "hot" bodies

Active Sensors

- Provide their own artificial radiant energy source for illumination
- e.g., **Radar, Synthetic Aperture Radar (SAR)**, LiDAR

Advantages and Disadvantages of Radar Over Optical Remote Sensing

Advantages

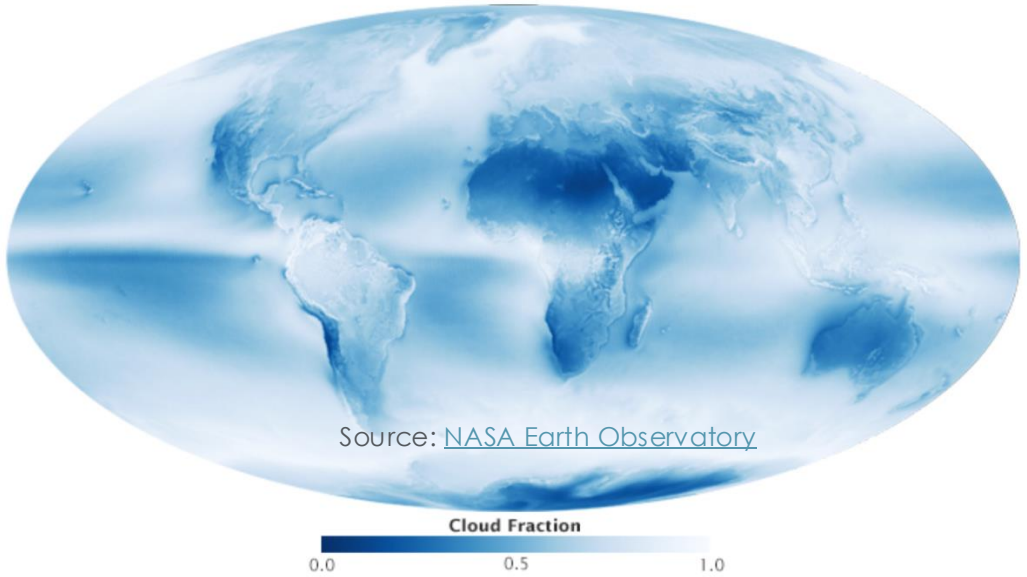
- Nearly all-weather capability
- Day or night capability
- Penetration through the vegetation canopy
- Penetration through the soil
- Minimal atmospheric effects
- Sensitivity to dielectric properties (liquid vs. frozen water)
- Sensitivity to structure

Disadvantages

- Information content is different than optical and sometimes difficult to interpret
- Speckle effects (graininess in the image)
- Effects of topography

Optical vs. Radar

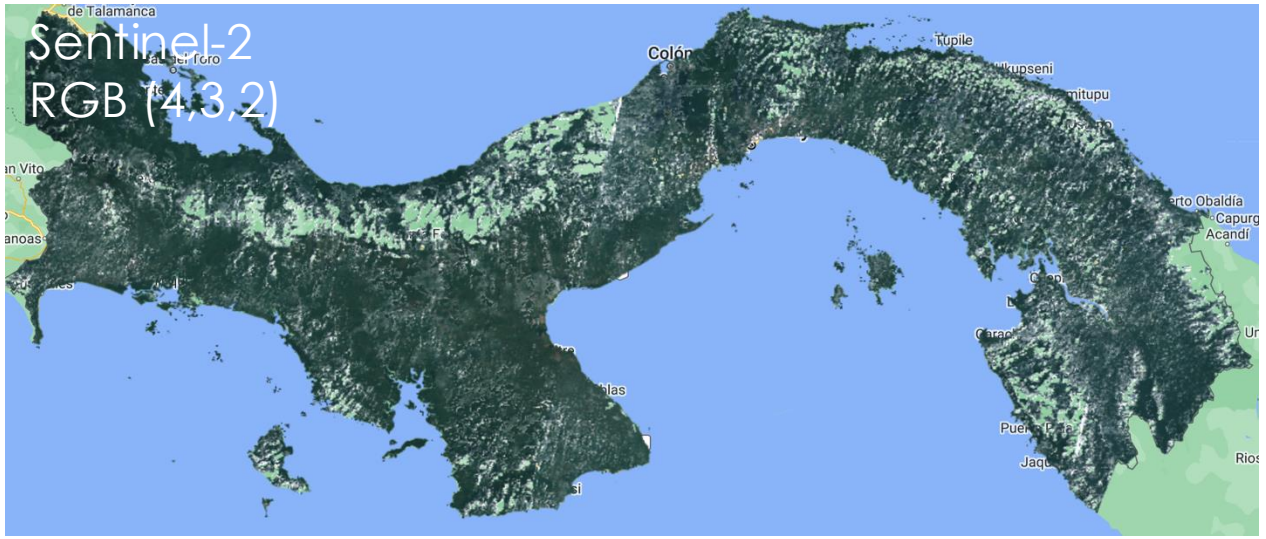
Global Cloud Coverage

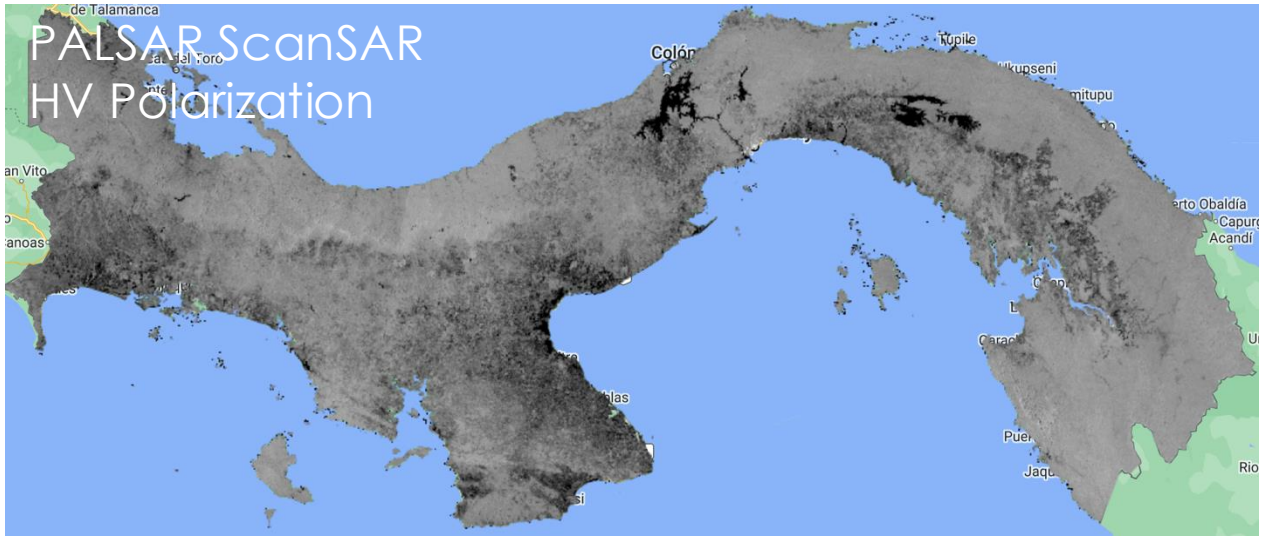


Source: NASA Earth Observatory

Cloud fraction averaged from 200–-2015, compiled using data from MODIS on Aqua.

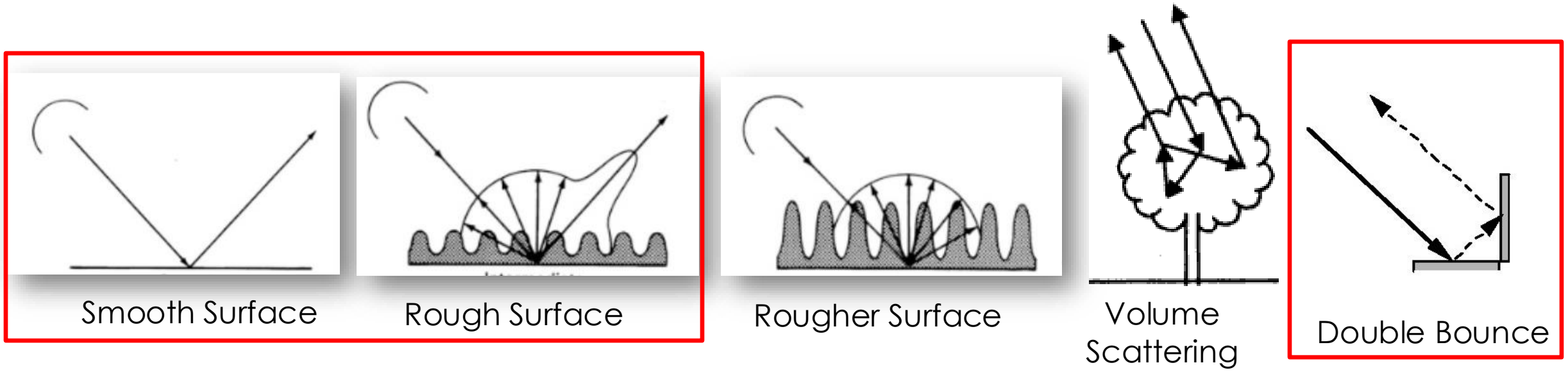
Panama: Nov. 1–30, 2019



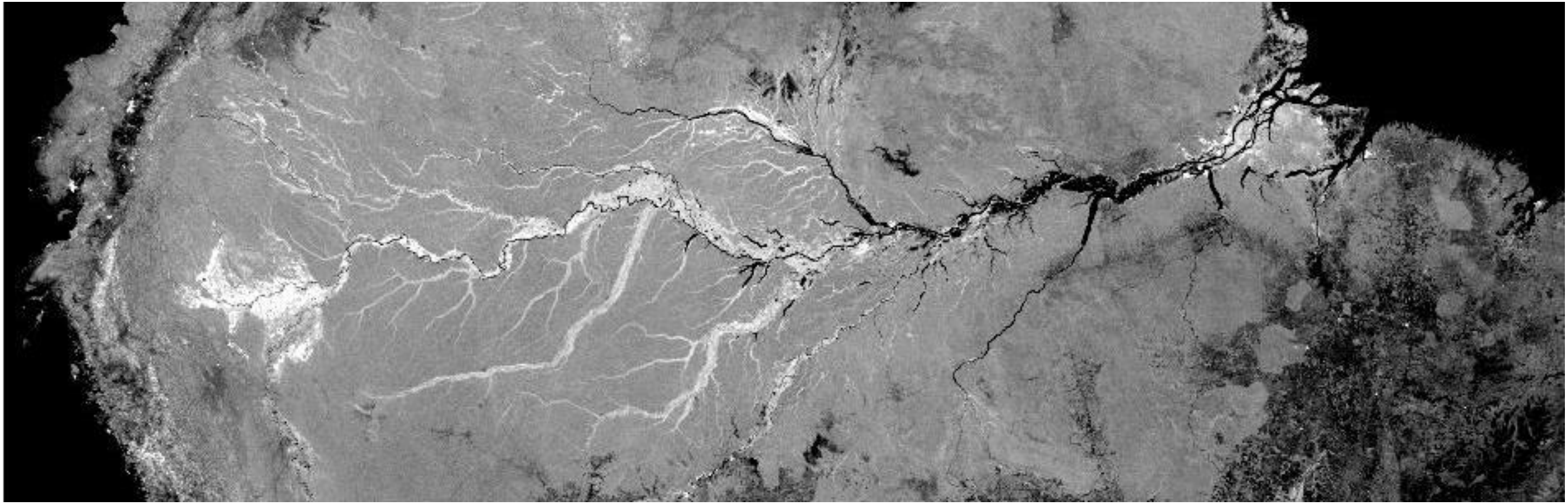


Source: Sentinel-2 and PALSAR ScanSAR from GEE

SAR Signal Scattering Over Inundated Regions



Radar Image



Applications of Radar (SAR) Data for Flood Detection

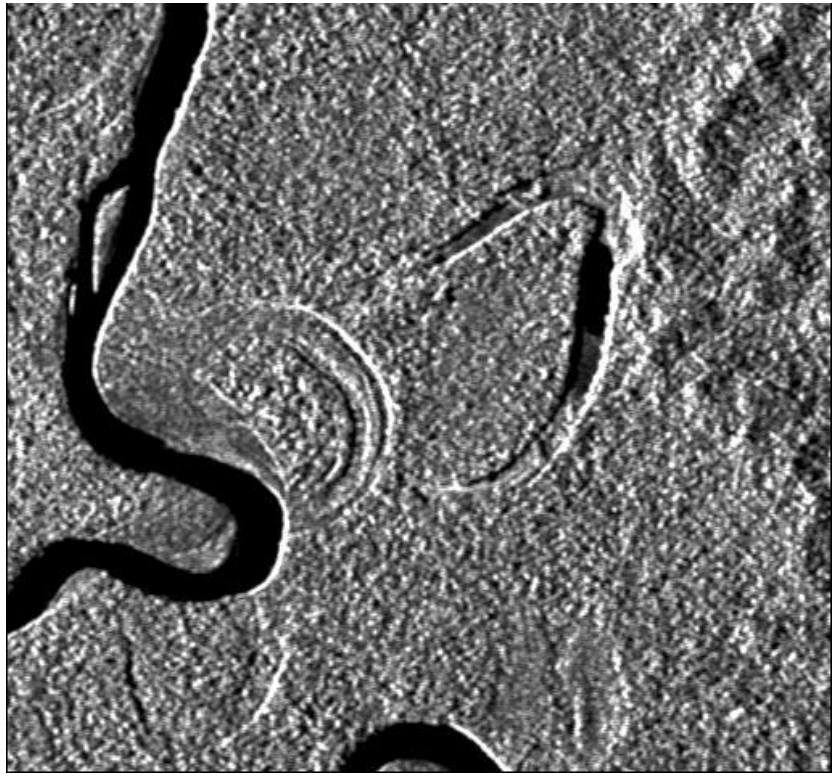
Flood Detection with Radar

- **Inundated vegetation**: the temporary or permanent occurrence of a water surface beneath a vegetation canopy
- **Open water**: water without any standing vegetation

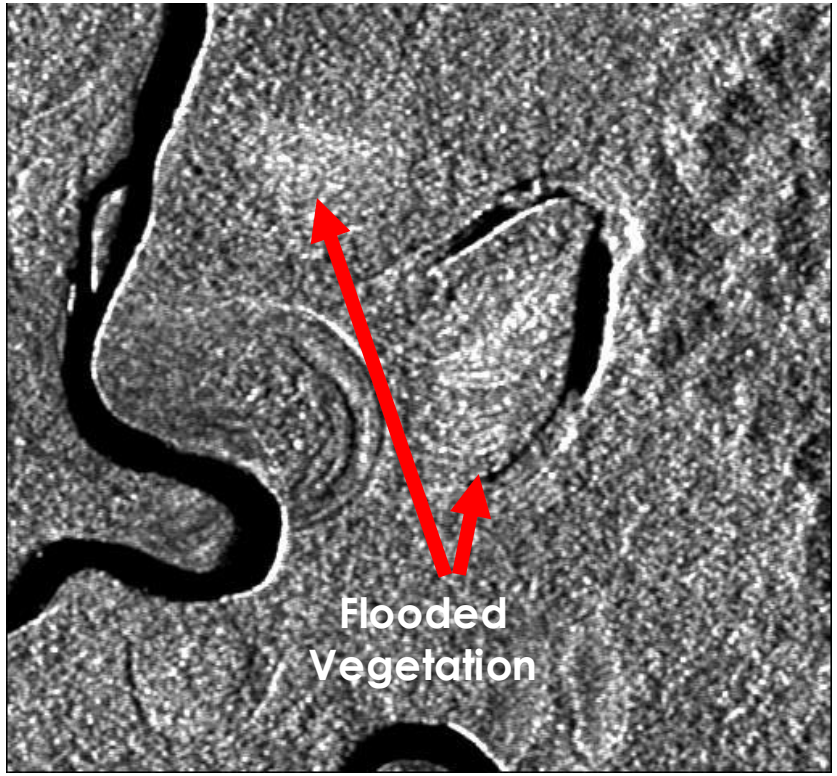
Signal Penetration Over Flooded Vegetation

Multifrequency AIRSAR data in Manu National Park, Peru

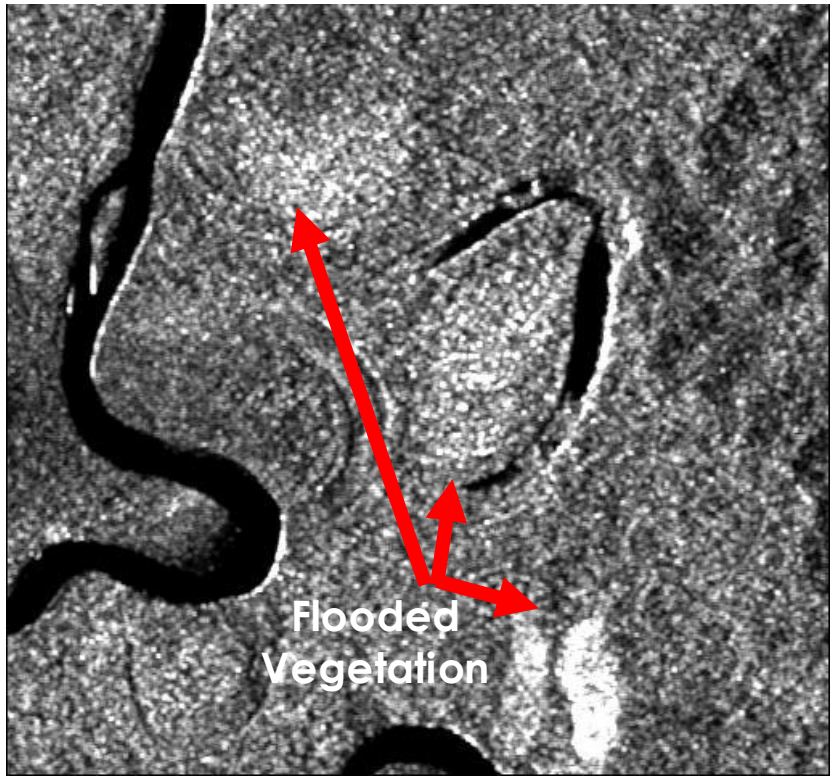
C-Band



L-Band



P-Band



Wetland Inundation

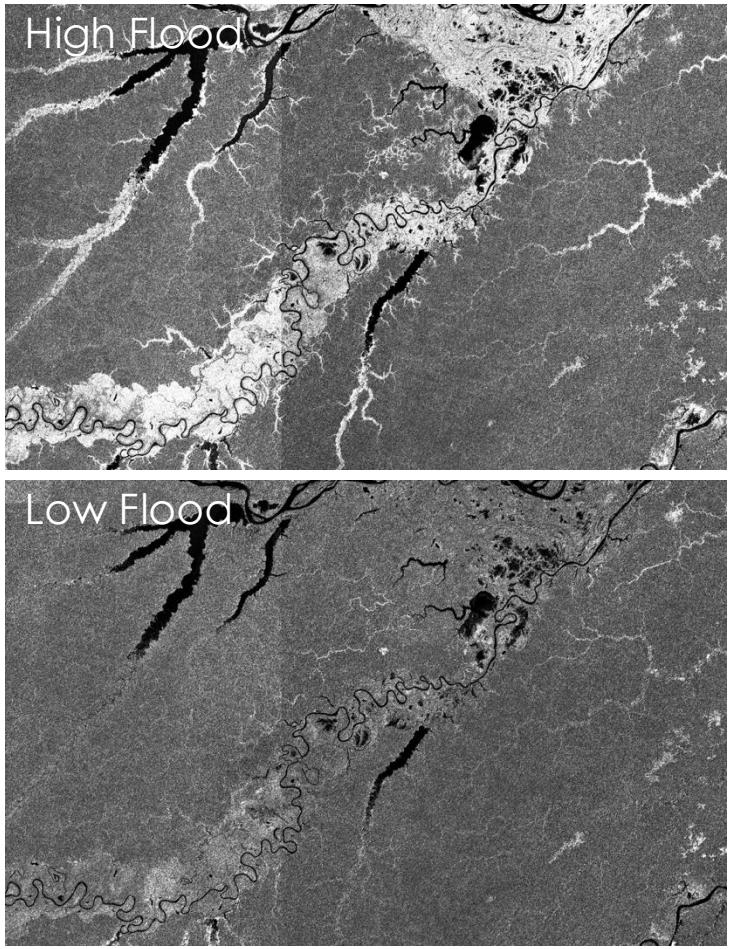
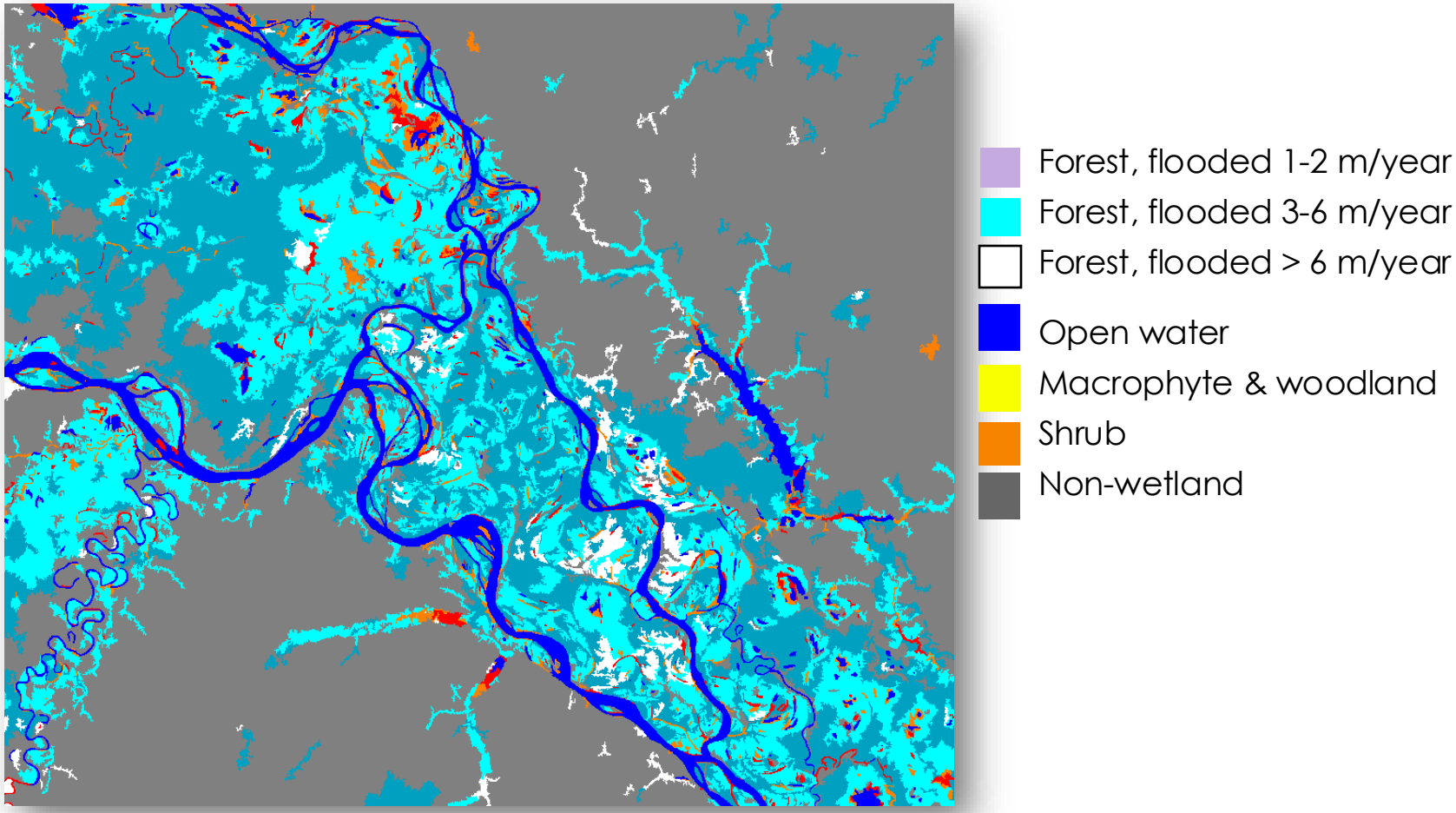


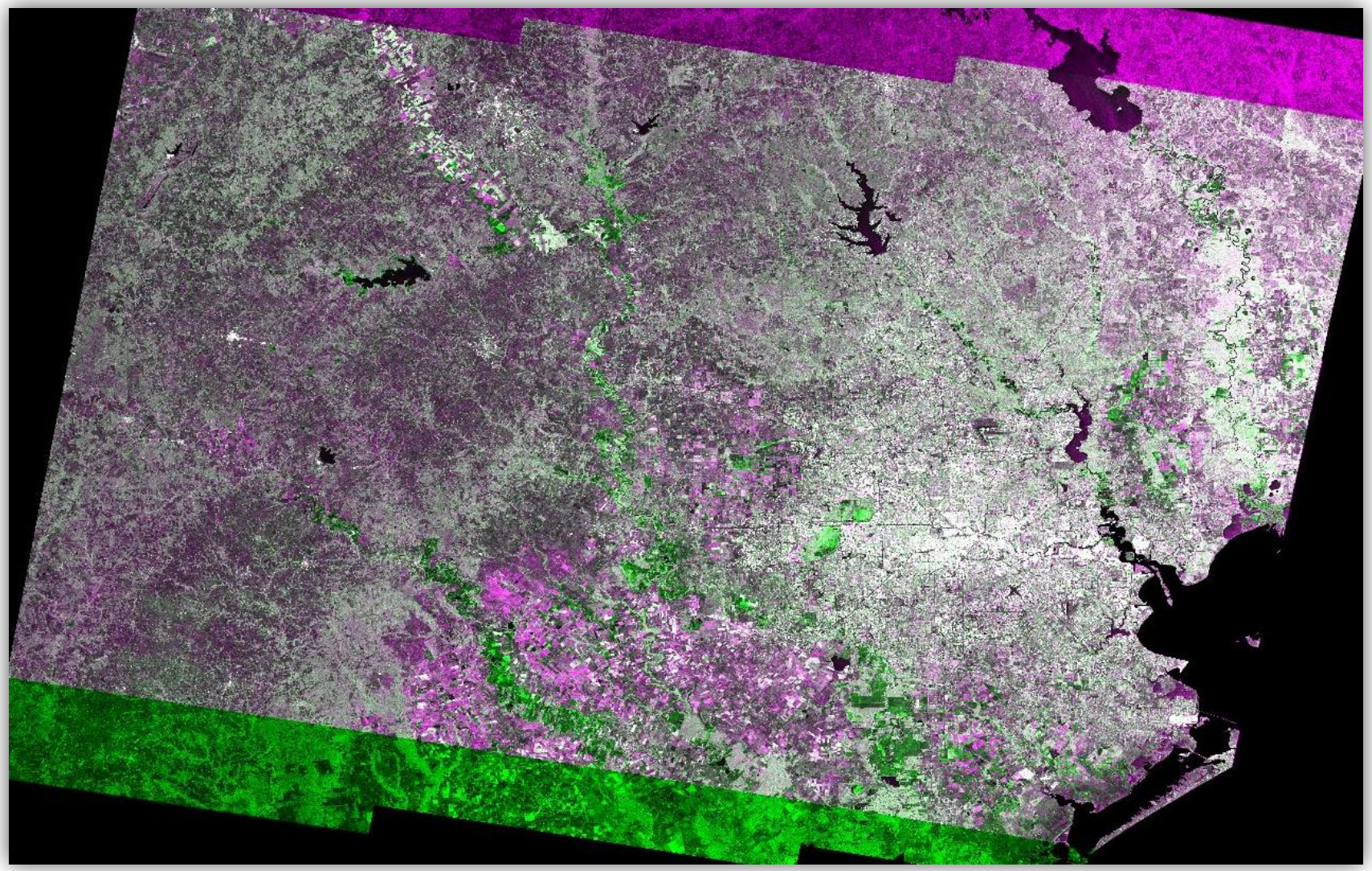
Image Credit: L. Hess, B. Chapman, and K. McDonald



Wetland vegetation and inundation period product derived from changes in flooding state using multi-date PALSAR ScanSAR

Hurricane Harvey in Houston Texas - Before and During the Event

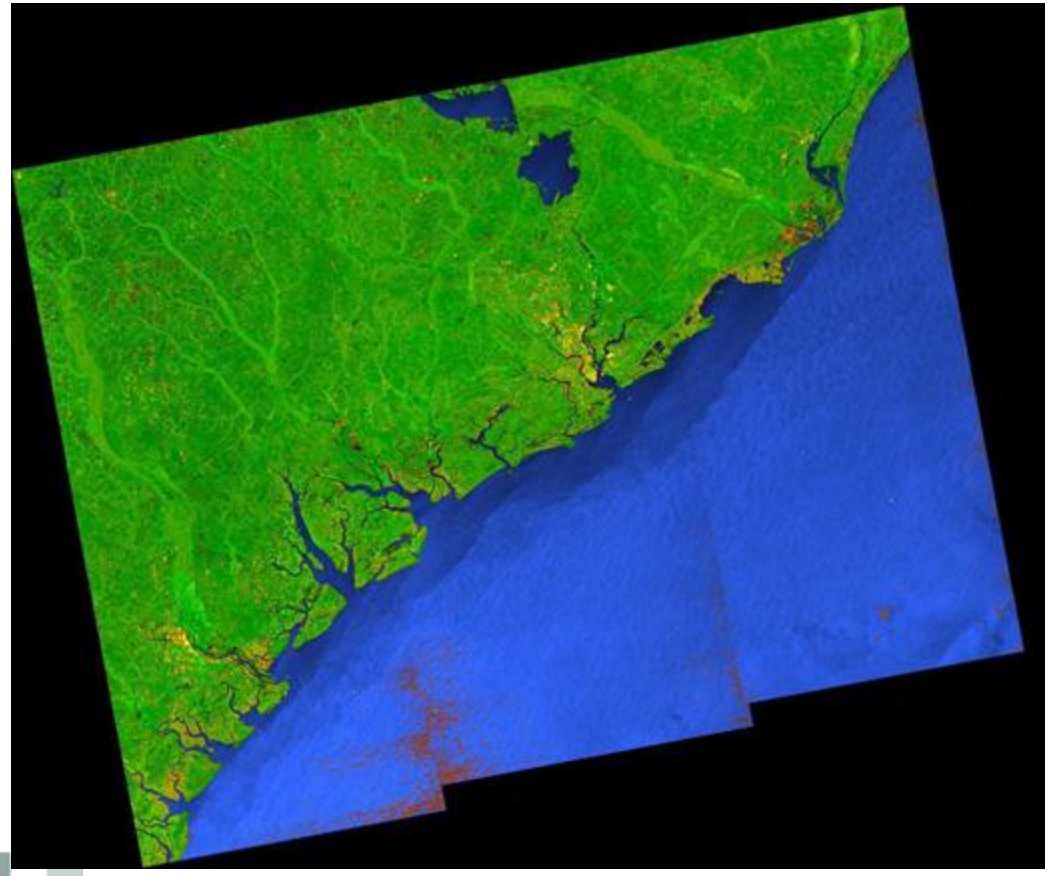
Sentinel-1 Radar Images, RGB: Aug 30 (R), Aug 18 (G), Aug 30 (B)



Hurricane Matthew on the East Coast of the U.S. – Coastal Flooding

Sentinel-1 Radar Images (R-VV; G-VH; B-VV/VH)

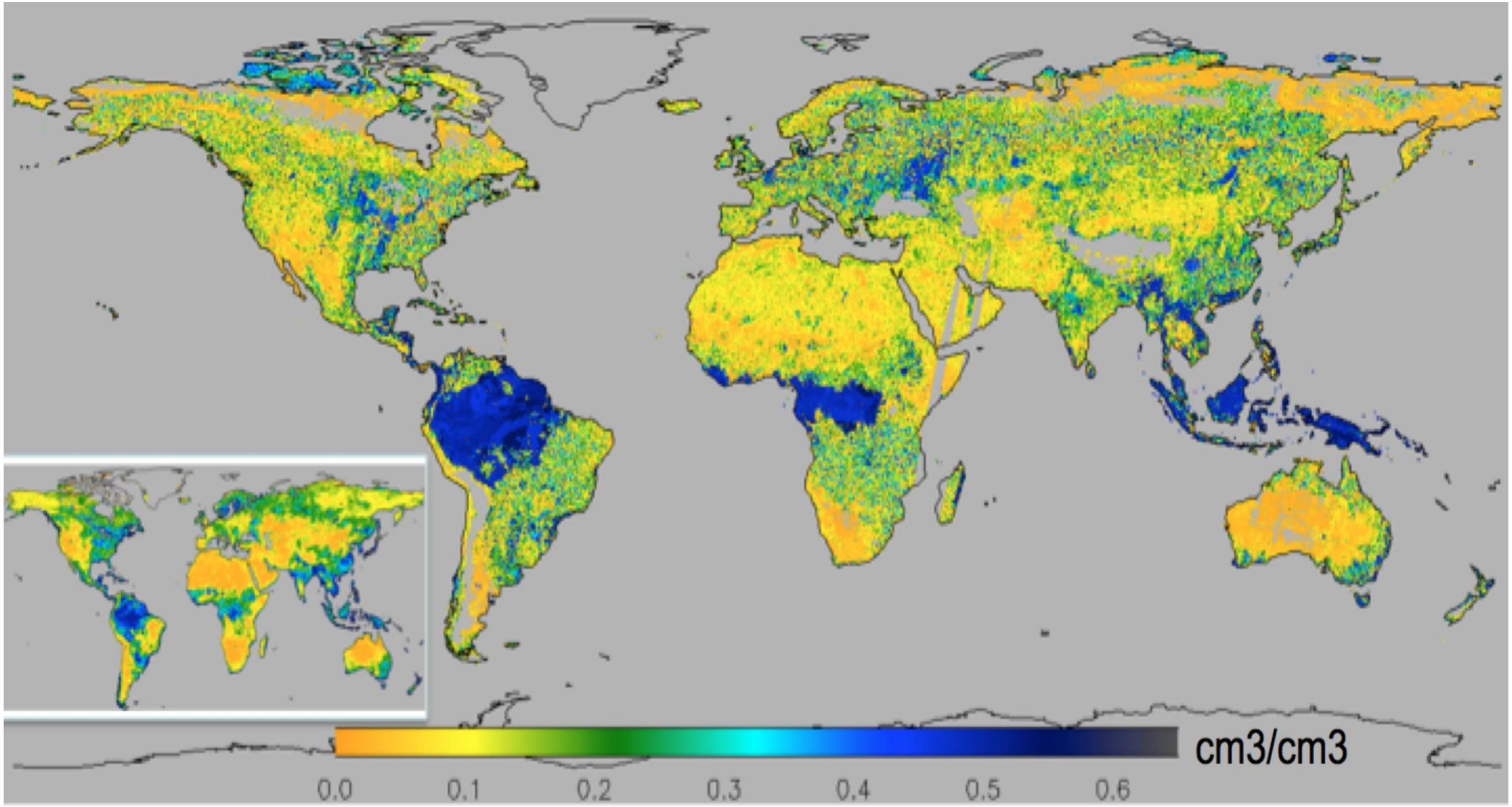
Oct 4, 2016
(Before the Event)



Oct 16, 2016
(After the Event)

Soil Moisture Monitoring

Soil Moisture from the SMAP Radar (HH, HV) - June 19–26, 2015



Data Access – Radar Data and Products

Webtools & Data Portals

Webtool	Data
Google Earth Engine	• Sentinel-1 (2014–Present) • PALSAR ScanSAR (2014–Present) • Global PALSAR Yearly Global Mosaics (2007–2024) • Global PALSAR Forest/Non-forest Maps (2007–2021) • SMAP Soil Moisture
Alaska Satellite Facility	• PALSAR (2006–2011) • PALSAR-2 ScanSAR (2014–Present) • Sentinel-1 (2014-Present) • NISAR (coming soon)
Copernicus Hub	• Sentinel-1 • Sentinel-1 Monthly Mosaics • BIOMASS (in the future)
JAXA	• JERS-1 • PALSAR • PALSAR-2 • PALSAR Yearly Global Mosaics • PALSAR Yearly Global Forest/Non-forest Maps
NSIDC DAAC (SMAP Soil Moisture)	• SMAP Soil Moisture Data (9 and 36 km)
NASA AppEEARS	• SMAP Soil Moisture (subsetting tool available)

NISAR

NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath >240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3-10 meters mode-dependent SAR resolution	Small-scale observations
3 years since operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
>30% observation duty cycle	Complete land/ice coverage
Left/Right pointing capability	Polar coverage, North and South
Noise Equivalent Sigma Zero ≤ -23 db	Surface characterization of smooth surfaces

- Major partnership between US National Aeronautics and Space Administration (NASA) and Indian Space Research Organization (ISRO)
- Launch date: July 30, 2025
- Dual frequency L- and S-band Synthetic Aperture Radar (SAR)
  - L-band SAR from NASA and S-band SAR from ISRO
- 3 years science operations (5+ years consumables)
- All science data (L- and S-band) will be made available free and open

Resources

ARSET Trainings

- An Introduction to Synthetic Aperture Radar (SAR) and its Applications
- SAR for Detecting and Monitoring Floods, Sea Ice, and Subsidence from Groundwater Extraction
- Disaster Assessment Using Synthetic Aperture Radar
- SAR for Disasters and Hydrological Applications

Other Resources

- Synthetic Aperture Radar (SAR) – NASA Earthdata
- The SAR Handbook – NASA Earthdata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Observations and Modeled Data for Landcover and Elevation Products

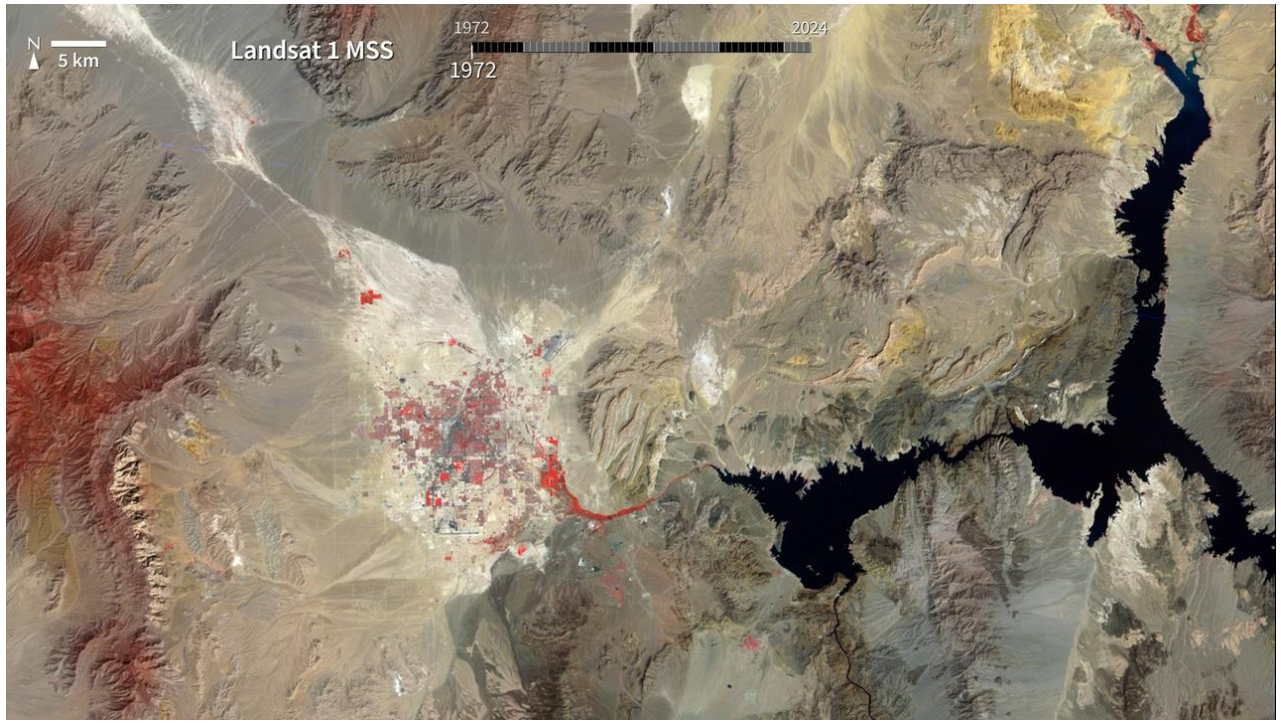
Learning Objectives

- By the end of this presentation attendees will be able to:
  - Discover relevant land cover/land use products for regional and global applications
  - Access publicly available land cover data products
  - Identify characteristics of aerial versus satellite-based Digital Elevation Models (DEMs)
  - Access DEMs for hydrological and flood analysis

Land Cover and Land Use Products

Applications – Land Cover and Land Use

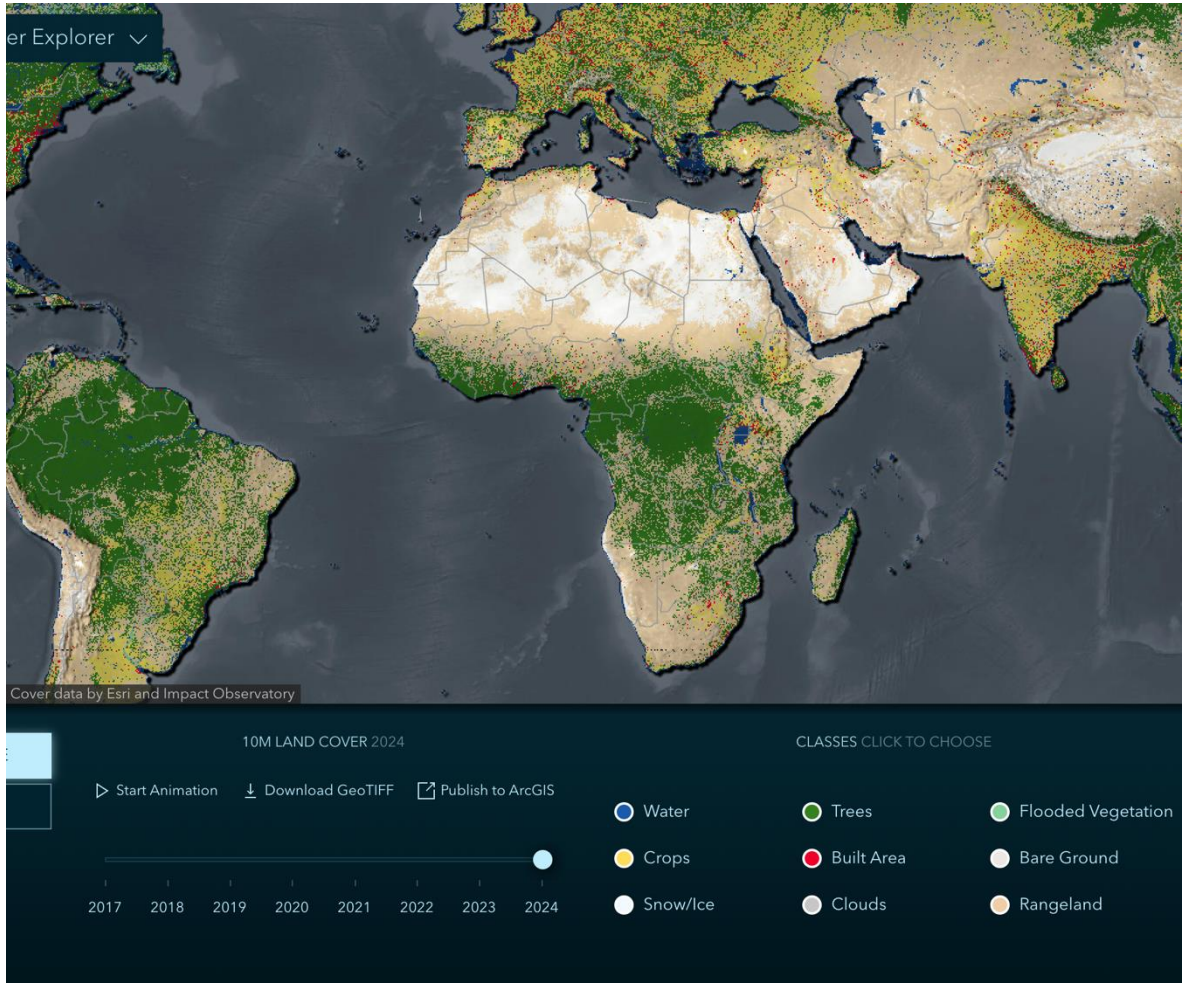
- Economic Applications: 1) Agricultural economics, 2) Real estate and property valuation, 3) Natural resources, 4) Infrastructure, 5) Risk management and finance
- Environmental Monitoring – Track deforestation, urbanization, and habitat changes over time
- Climate and Weather Applications – Support climate modeling and carbon cycle studies
- Natural Resource Management – Inform water resource and land management decisions
- Disaster Risk Assessment – Model flood risk and wildfire susceptibility
- Urban and Regional Planning – Track urban sprawl and growth
- Scientific Research – Change detection analysis
- Policy and Governance – Inform environmental policy decisions



False-color imagery – rapid urbanization of Las Vegas between 1972 and 2023. Credit: NASA Scientific Visualization Studio

Global Land Cover and Land Use (LCLU) Products

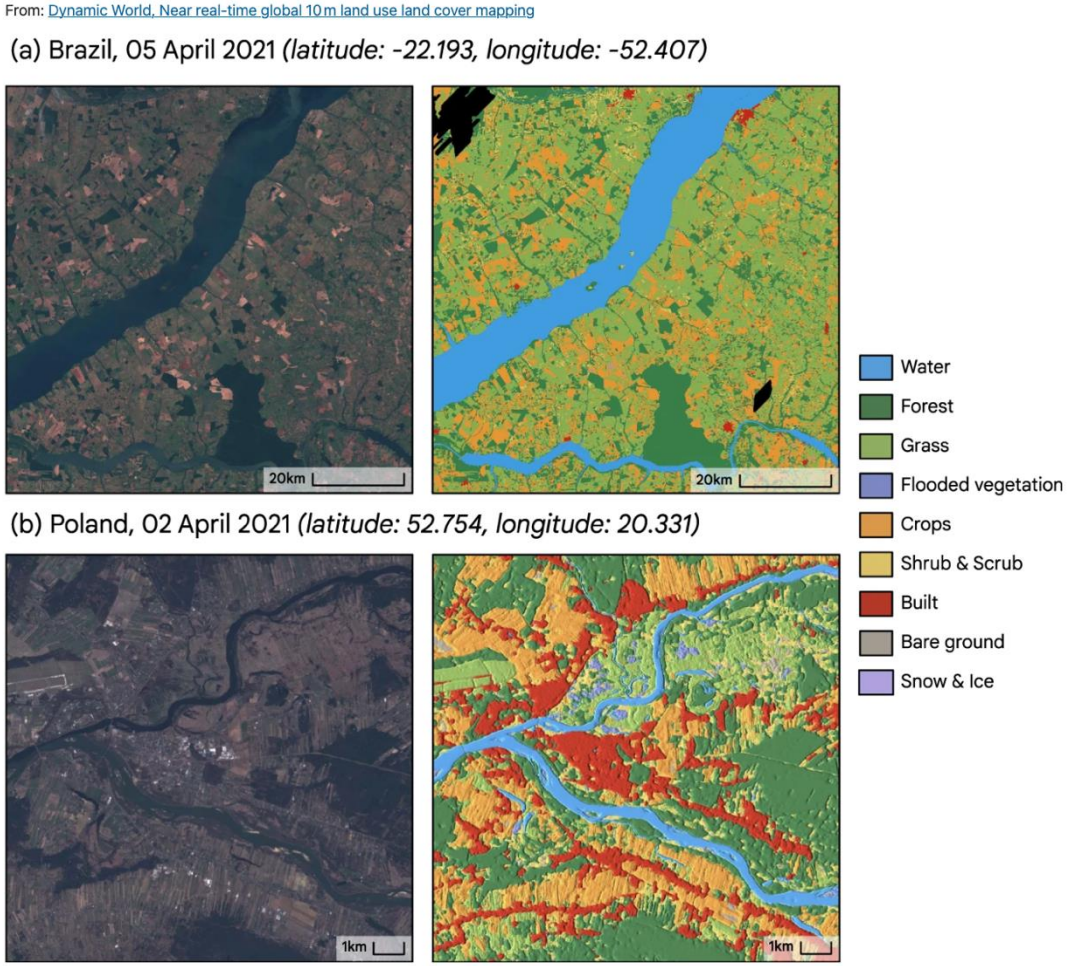
- ESRI Global Land Cover Map
  - Temporal coverage: 2017–2024
  - Spatial resolution: **10 meters**
  - Temporal resolution: Annual
  - Geographic extent: Global
  - Distributed using a Creative Commons by Attribution (CC BY 4.0) license
  - ESRI | Sentinel-2 Land Cover Explorer



Credit: Esri & Impact Observatory

Global Land Cover and Land Use (LCLU) Products

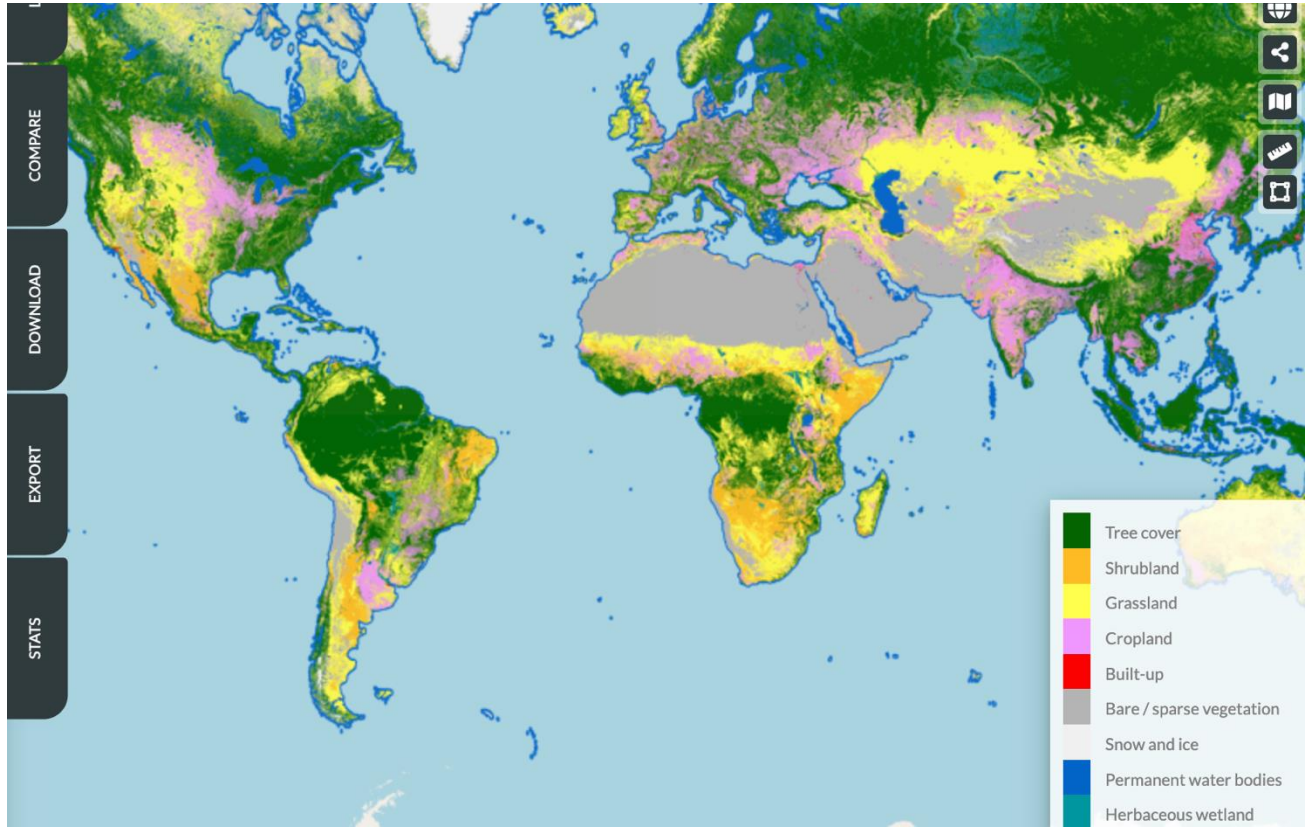
- Dynamic World (Google/World Resources Institute)
  - Temporal coverage: June 2015–Present
  - Spatial resolution: **10 meters**
  - Temporal resolution: **3–5 days**
  - Geographic extent: Global
  - Near real-time (NRT) predictions of LCLU **estimated class probabilities** (0–1)
  - Dynamic World, **near real-time** global 10 m land use land cover mapping Brown et al. (2022)



Credit: Brown et al. Scientific Data 9, Article 251 (2022)

Global Land Cover and Land Use (LCLU) Products

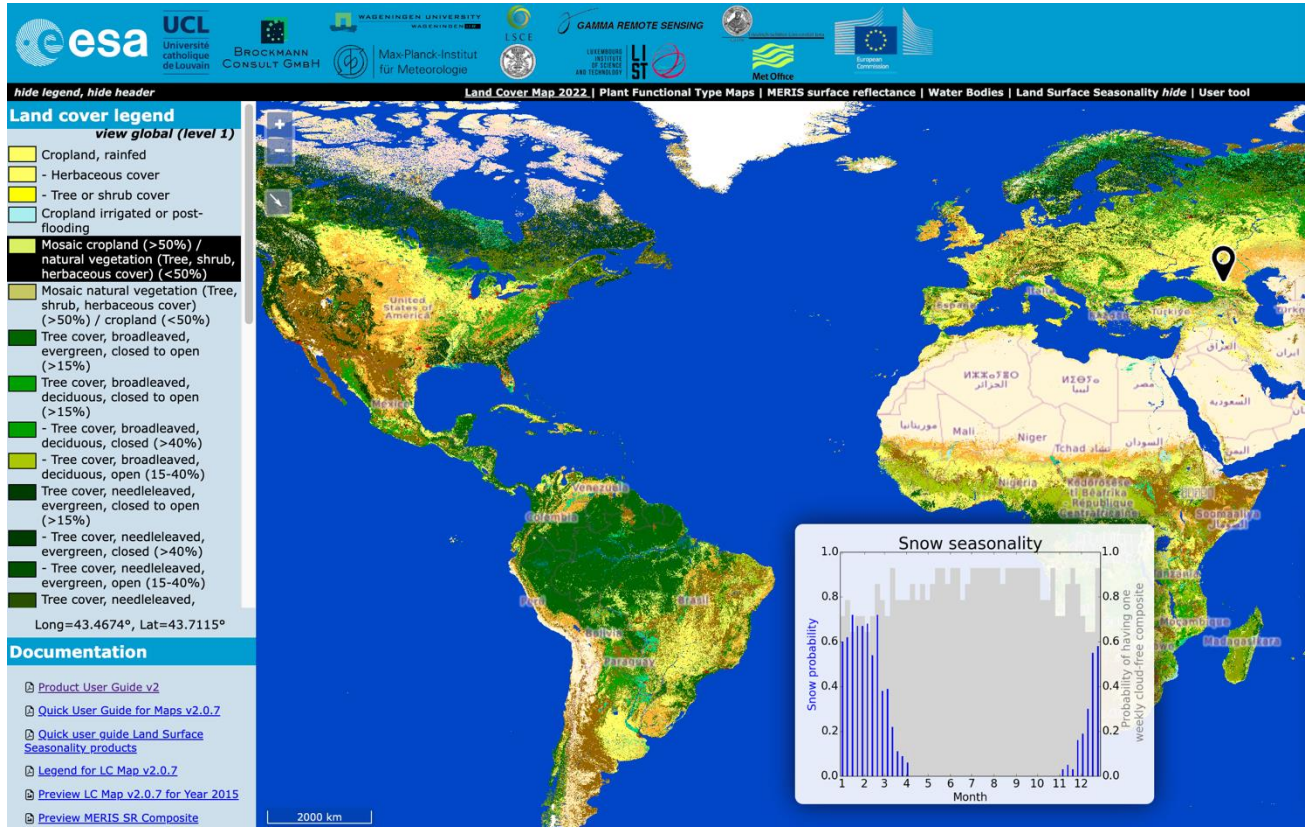
- ESA WorldCover
  - Temporal coverage: 2020 & 2021
  - Spatial resolution: 10 meters
  - Temporal resolution: Annual
  - Geographic extent: Global
  - Based on both Sentinel-1 and Sentinel-2 data
  - User Manual



Credit: European Space Agency (ESA)

Global Land Cover and Land Use (LCLU) Products

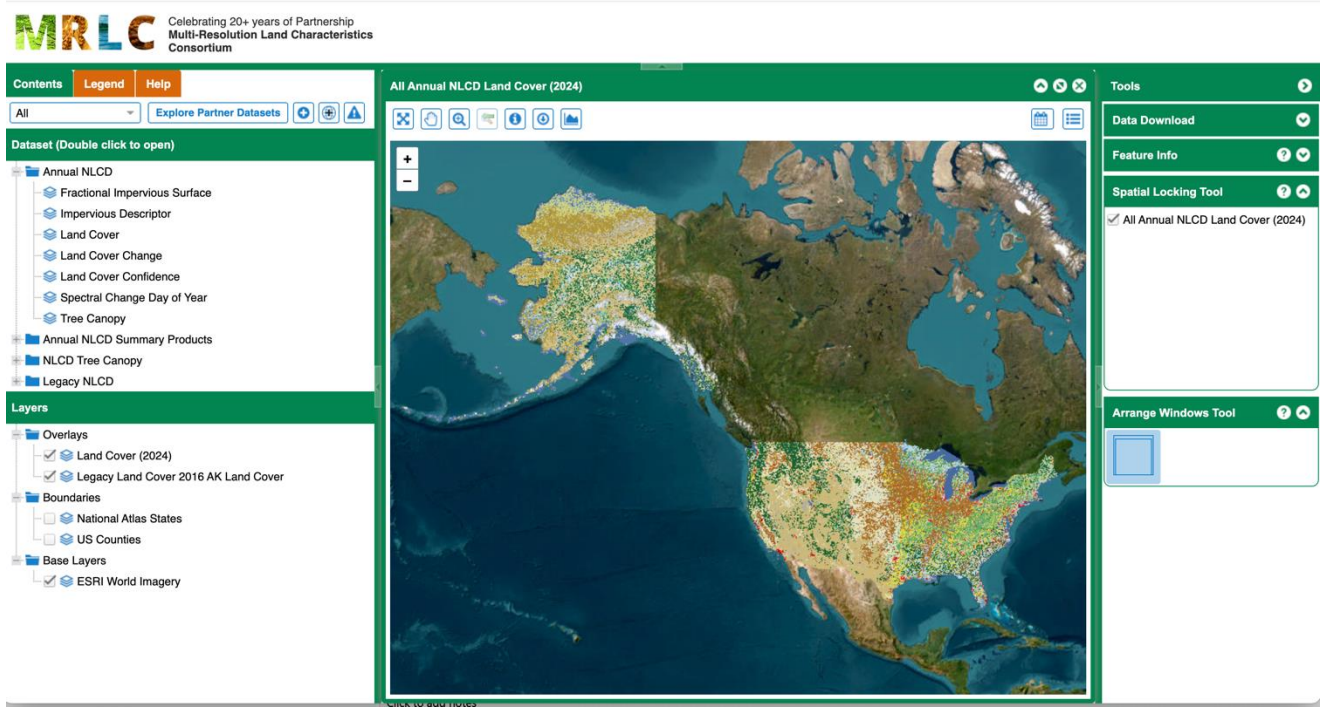
- ESA Climate Change Initiative Land Cover (CCI-LC)
  - Temporal coverage: **1992–2022 (31 years)**
  - Spatial resolution: 300 meters
  - Temporal resolution: Annual
  - Geographic extent: Global
  - User Guide
  - Viewer



Credit: European Space Agency (ESA)

Regional Land Cover and Land Use (LCLU) Products

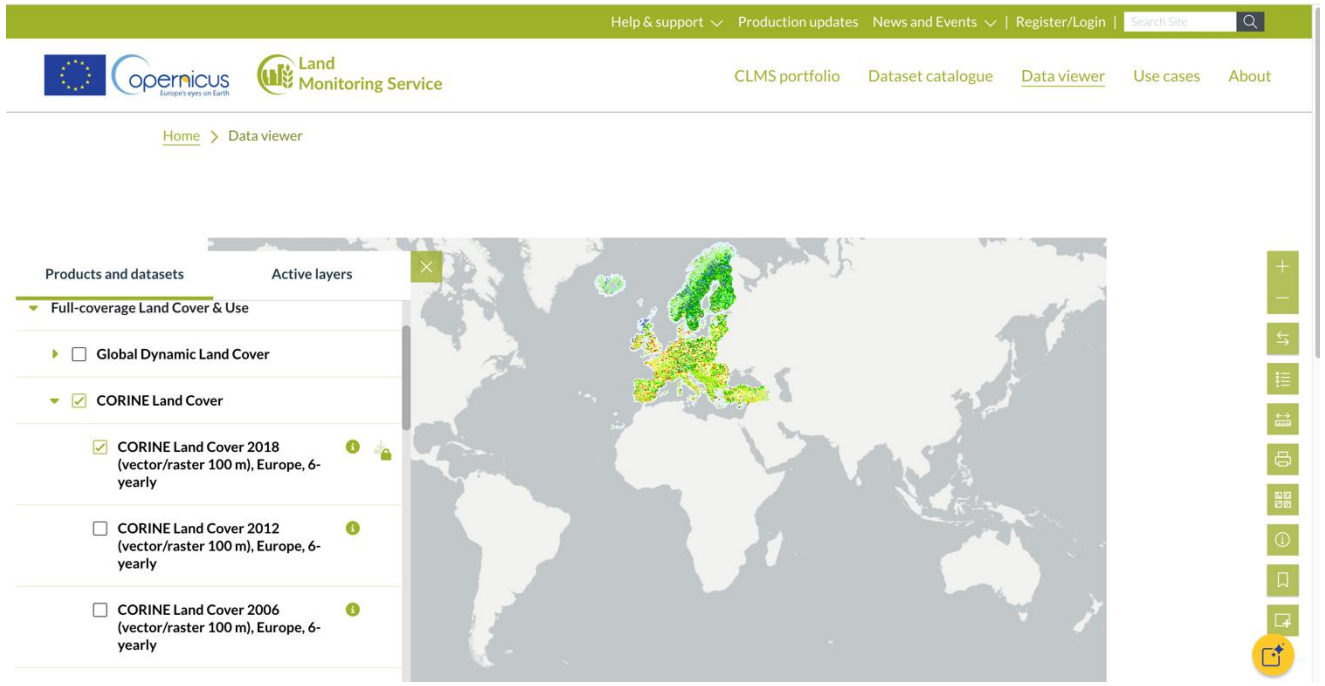
- Annual National Land Cover Database (NLCD)
  - Temporal coverage: **1985 – 2024 (39 years)**
  - Spatial resolution: 30 meters
  - Temporal resolution: Annual
  - Geographic extent: **United States**
  - Collective effort between USGS and the Multi-Resolution Land Characteristics (MRLC) Consortium
  - User Guide
  - Viewer



Credit: MRLC

Regional Land Cover and Land Use (LCLU) Products

- CORINE Land Cover
  - Coordination of Information on the Environment (CORINE) Land Cover (CLC)
  - Temporal coverage: **1990 – 2018**
  - Spatial resolution: 100 m
  - Temporal resolution: Every 6 years
  - Geographic extent: **Europe**
  - Documentation
  - Viewer



Credit: Copernicus Land Monitoring Service

Data Access – Land Cover and Land Use Products

Webtools & Data Portals

Webtool	Data
Google Earth Engine	• Dynamic World V1 (Tutorial) • WorldCover v100 (2020) • WorldCover v200 (2021) • NLCD 2019 • NLCD 2021 • CORINE Land Cover
ArcGIS Living Atlas of the World Esri | Sentinel-2 Land Cover Explorer	• ESRI Global Land Cover Map
WorldCover Viewer Amazon Web Services (AWS) Terrascope WMS	• WorldCover
CCI-LC viewer	• ESA Climate Change Initiative Land Cover (CCI-LC)
MRLC data download MRLC Viewer	• Annual National Land Cover Database (NLCD)
CORINE data download CORINE Data Viewer	• CORINE Land Cover

Overview of Digital Elevation & Surface Models

Definitions – Digital Elevation & Surface Models

- A Digital Elevation Model (DEM) represents the ground surface in three dimensions, excluding trees, buildings, and other above-ground features.
- A Digital Surface Model (DSM) is a 3D representation of the Earth's surface that includes all features visible from above, such as buildings, trees, and terrain
- Generated from traditional topographic maps, modern LiDAR data, and other aerial and satellite-based platforms.
- Satellite platforms employ radar interferometry, laser altimetry, stereo optical imagery – moderate spatial resolution (10–90 m) but regional to global coverage

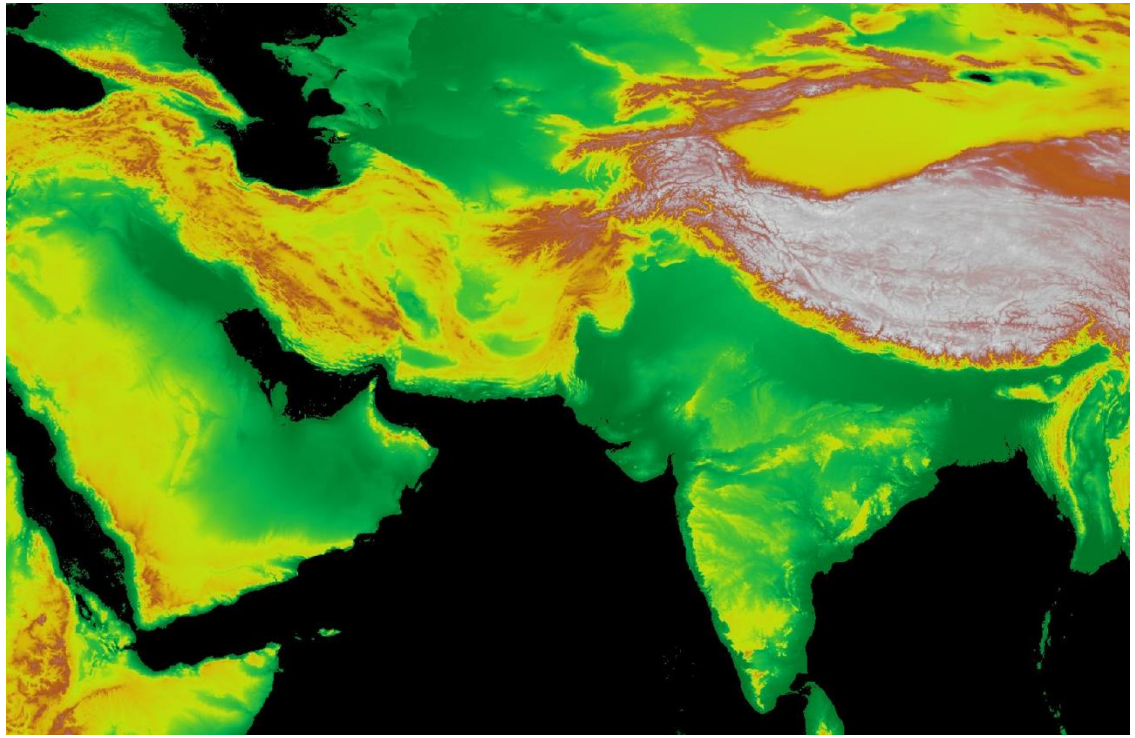


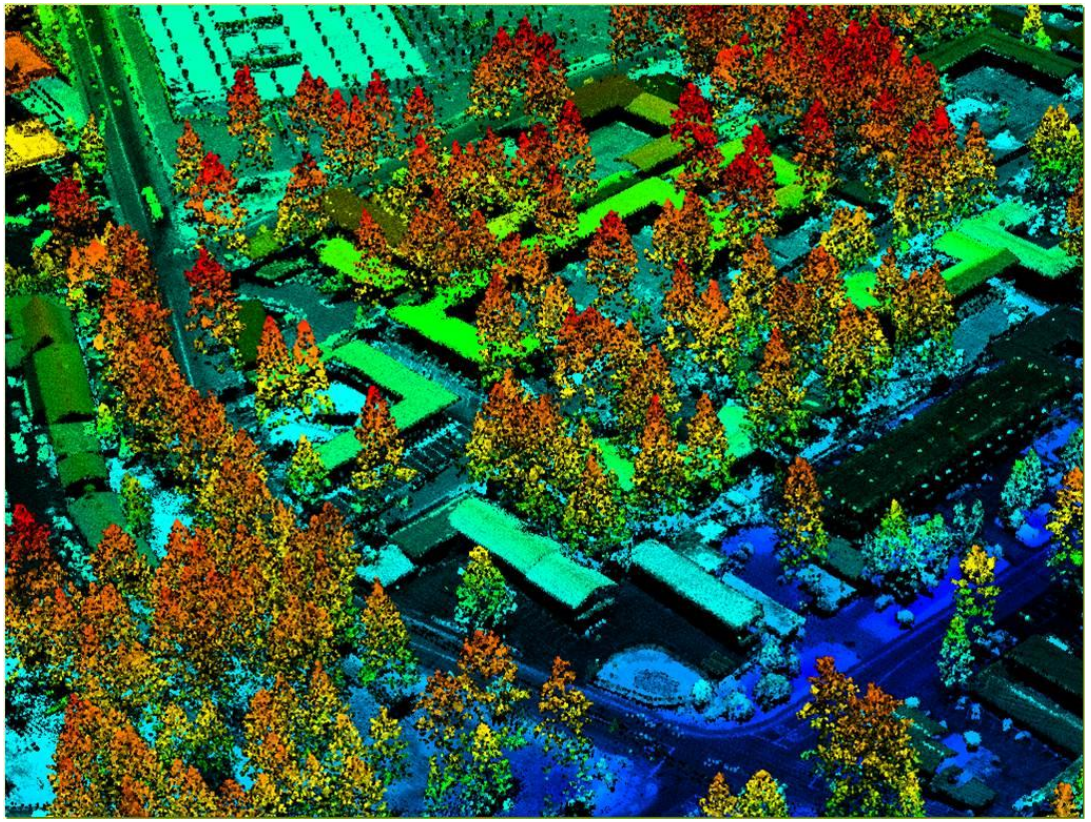
Image Credit: NASA

Trade-offs – Digital Elevation & Surface Models

Aspect	Aerial	Satellite
Spatial resolution	Very High	Moderate
Accuracy	Higher	Lower
Coverage	Limited globally	Extensive
Update frequency	On-demand	Periodic
Applications	Detailed engineering, urban planning, small watersheds	Regional studies, global analysis, large-area mapping

Applications – Digital Elevation & Surface Models

- Hydrology and Water Management
  - Watershed delineation and drainage network mapping
  - Flood modeling and inundation mapping
- Disaster Risk Assessment
  - Landslide susceptibility mapping
  - Tsunami and storm surge modeling
- Urban and Infrastructure Planning
  - Site suitability analysis for development
  - Transportation corridor planning
- Engineering
  - Dam and reservoir design
  - Solar panel installation optimization
- Military and Defense
  - Terrain analysis for operations
  - Optimize placement of surveillance systems



North shore Lake Tahoe LiDAR point cloud data
Credit: USGS

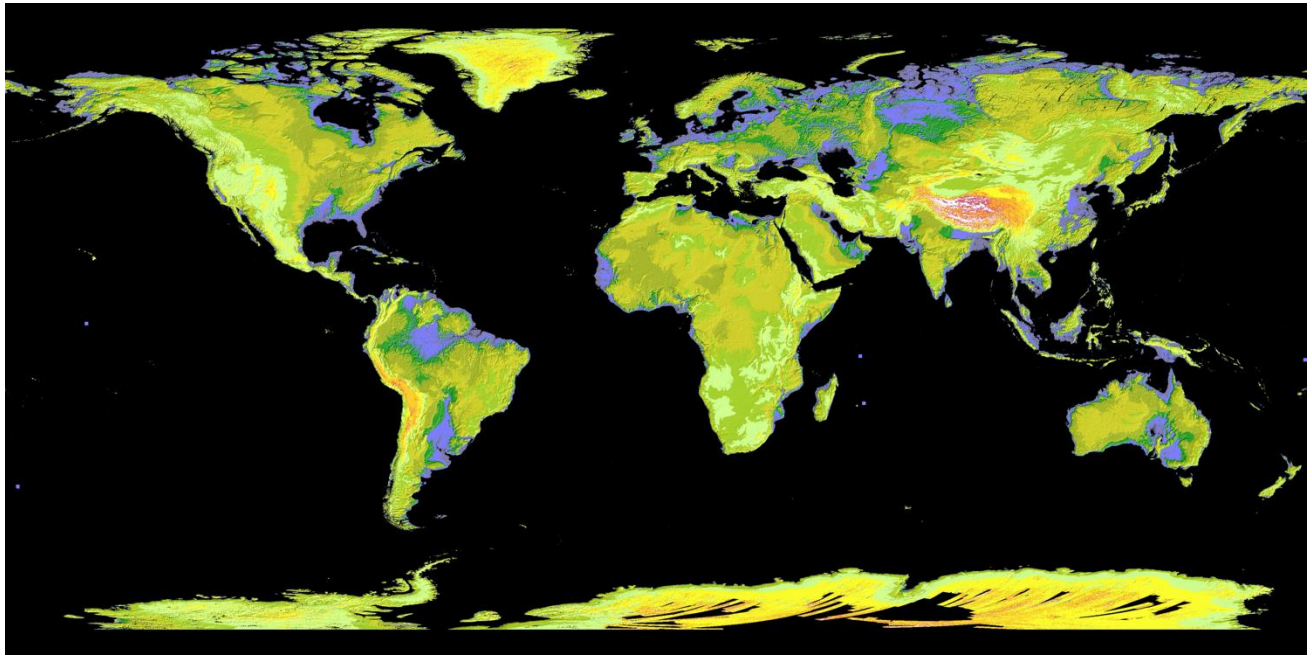
Global DEM & DSM Products

- Shuttle Radar Topography Mission (SRTM)
- C-band & X-band radar
- Payload onboard Space Shuttle Endeavour
- Completed mission in February 2000
- 1 arc second (30m), 3 arc second (90m), 30 arc second (1000m)
- Acquired digital terrain elevation data of all land between 60°N – 56°S latitude (~80% of Earth's total land mass)
- User Guide

Credit: NASA

Global DEM & DSM Products

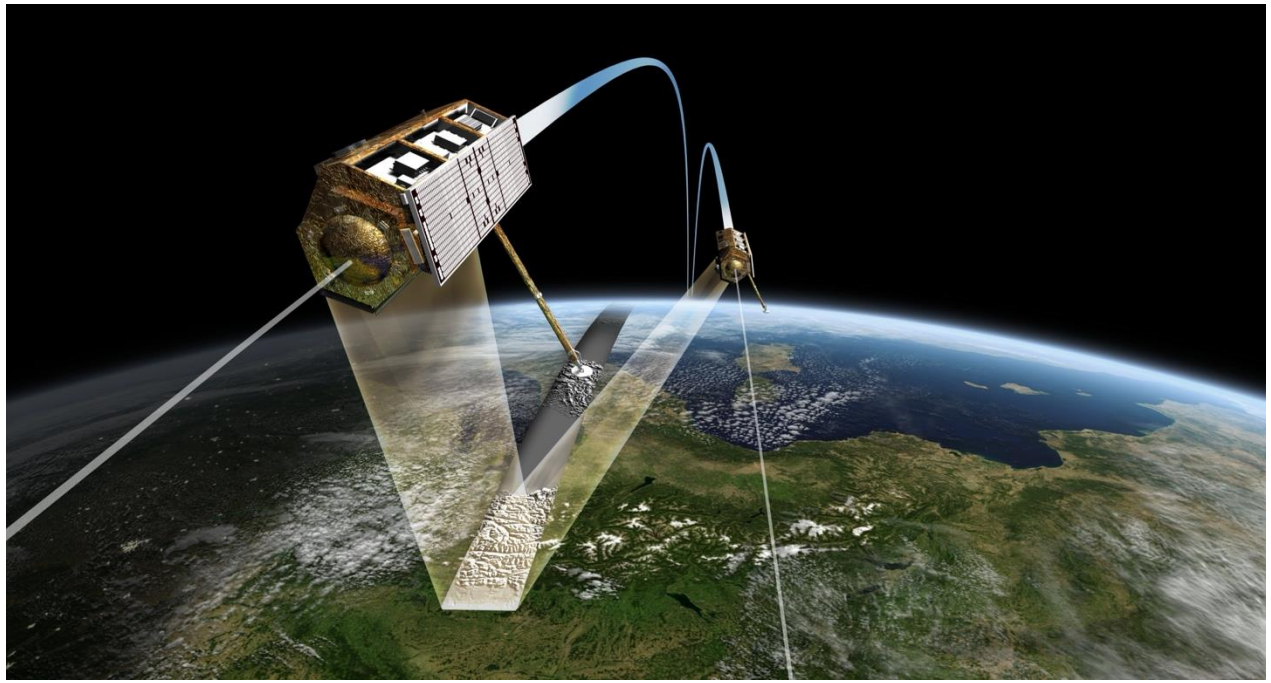
- Advanced Spaceborne Thermal and Reflection Radiometer (ASTER)
- Instrument onboard Terra satellite – polar orbiting satellite launched Dec 1999
- Spatial Resolution: 30 m (global)
- Spectral Resolution (14 bands)
  - Bands 1–3: 15 m (VNIR)
  - Bands 4–9: 30 m (SWIR)
  - Bands 10–14: 90 m (TIR)
- User Guide



Credit: NASA

Global DEM & DSM Products

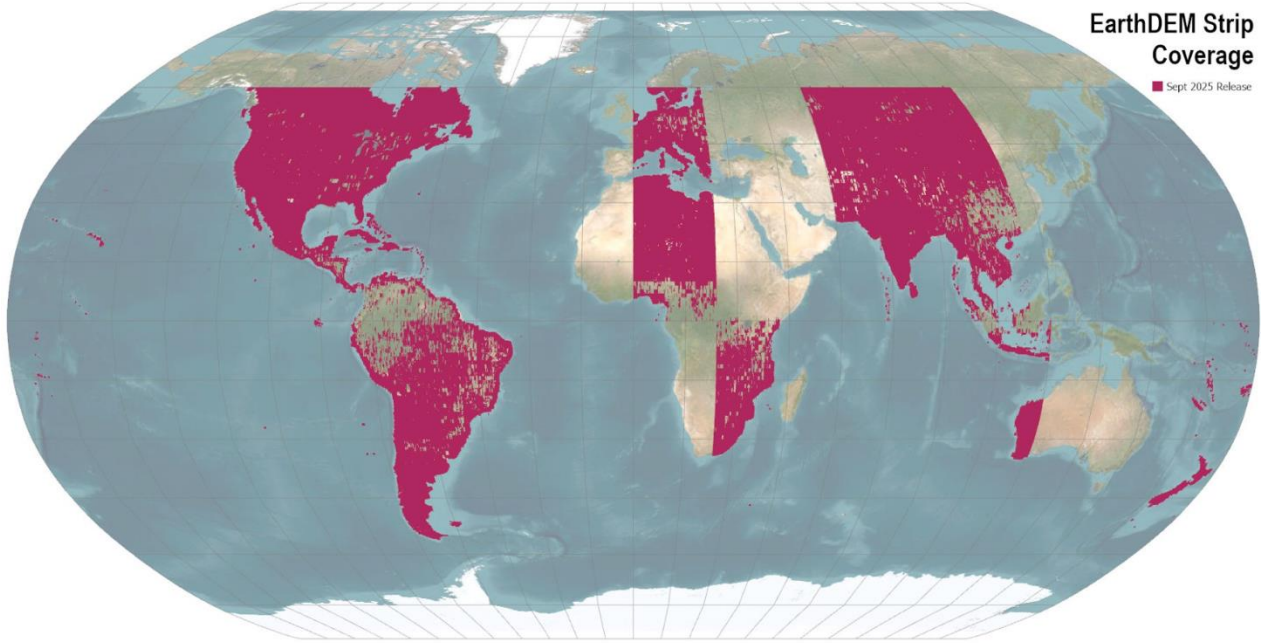
- Copernicus DEM
- Data were acquired by the TanDEM-X mission between 2011 and 2015
- Spatial Resolution: GLO-30 (30m), GLO-90 (90m)
- Registered users can freely access the 30m & 90m data – access to the 10m instances over Europe is limited to a specific subset of users.
- Copernicus Browser



Credit: DLR

Global DEM & DSM Products

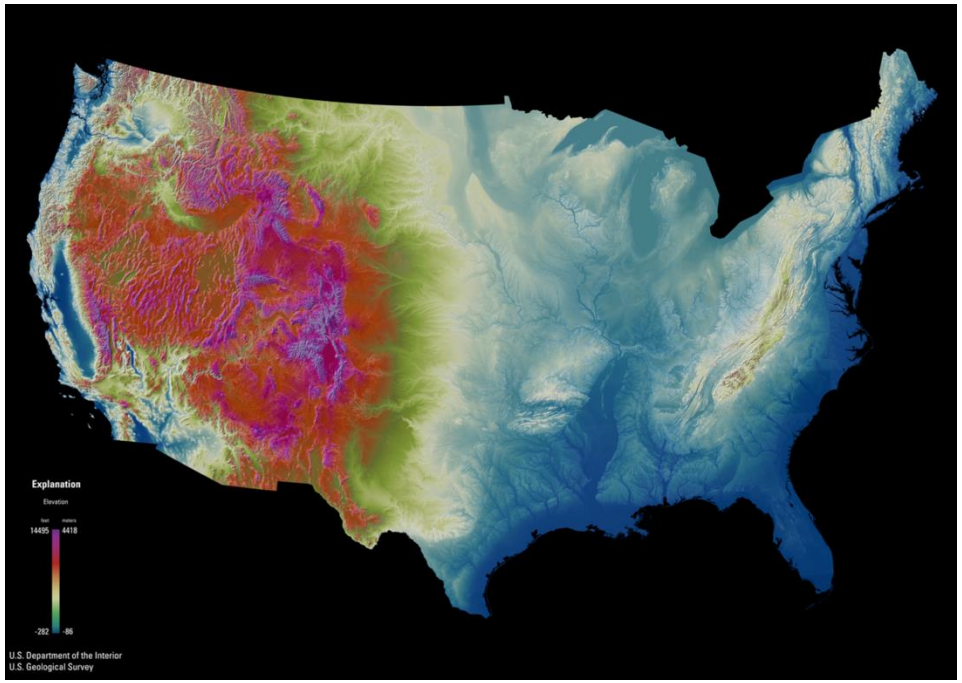
- EarthDEM
- High-resolution Digital Surface Models (DSM) in non-polar regions at 2-meter spatial resolution.
- Spatial Resolution: 2 m
- Constructed using hundreds of thousands of individual stereoscopic DEMs extracted from pairs of submeter (0.32 to 0.5 m) resolution Maxar satellite imagery
- Covers land surface between 60 degrees N and 60 degrees South excluding Alaska, Greenland, and the Kamchatka Peninsula
- Open Data on AWS



Credit: Polar Geospatial Center (PGC) at the University of Minnesota

Regional DEM & DSM Products

- USGS 3D Elevation Program (3DEP)
- 3DEP launched in 2016 and reached 98.3% U.S. coverage by 2024.
- Collected by LiDAR instruments mounted to aerial platforms
- 1/3 arc-second (10m) seamless DEM for the U.S. and 1 arc-second (30m) seamless DEM for conterminous U.S. and Alaska (most of Canada and Mexico).
- 1-meter and 1/9 arc-second (3m) are project-based
- Acquired as DEM products and lidar point clouds
- National Map Downloader
- topoBuilder



Credit: USGS

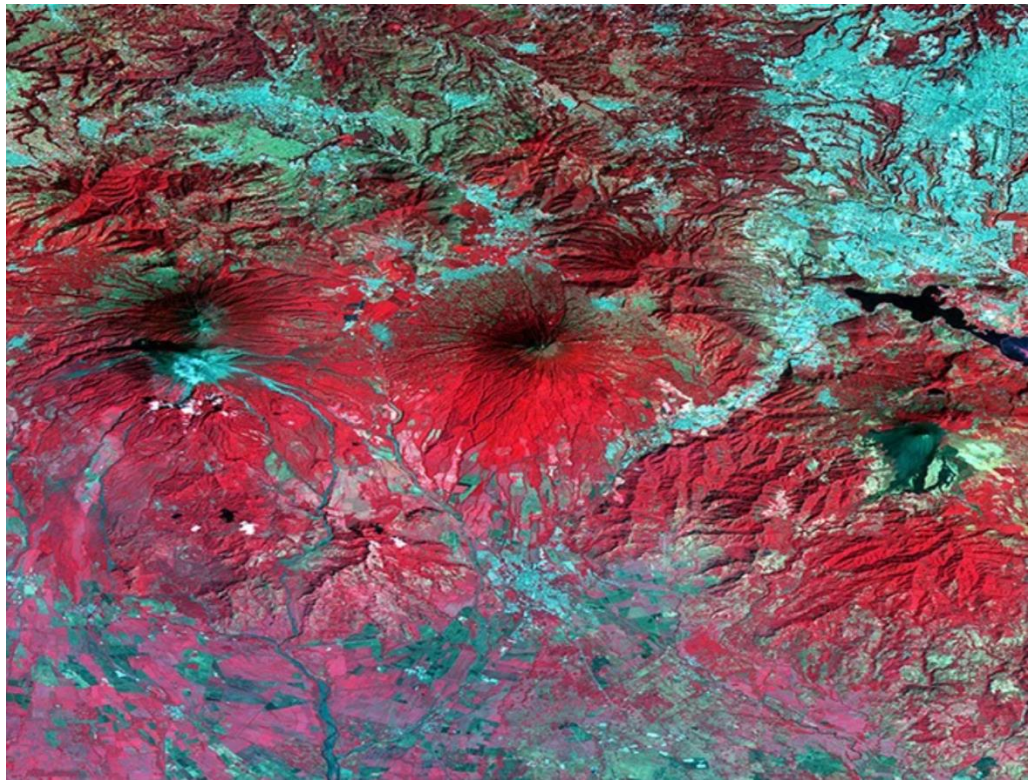
Data Access – Digital Elevation Models

Webtools & Data Portals

Webtool	Data
Google Earth Engine	• SRTM DEM • ASTER GDEM V002 • Copernicus DEM
Application for Extracting and Exploring Analysis Ready Samples (AppEEARS)	• SRTM DEM
Earthdata Search	• SRTM DEM • ASTER DEM
AWS	• Copernicus DEM • USGS 3DEP LiDAR Point Clouds • EarthDEM
Copernicus Browser	• Copernicus DEM
Open Topography	• NASADEM • Copernicus DEM • ALOS World 3D • Continental Europe Digital Terrain Model • 3DEP
National Map Downloader	• 3DEP

Summary

- Number of publicly available land cover & land use datasets available on regional to global scales.
- Many use recent satellite data (10 m) from the last decade, while others incorporate 30 m sensors spanning 40 years.
- DEM & DSM are generated from traditional topographic maps, modern LiDAR data, and other aerial and satellite-based platforms.
- Available publicly at regional to global scales ranging from 1 m to 30 m.



Credit: NASA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