Earth Observations for Informing Disaster Risk and Response to Drought, Wildfire, and Flooding in Mexico

Remote Sensing of Precipitation

May 8, 2023

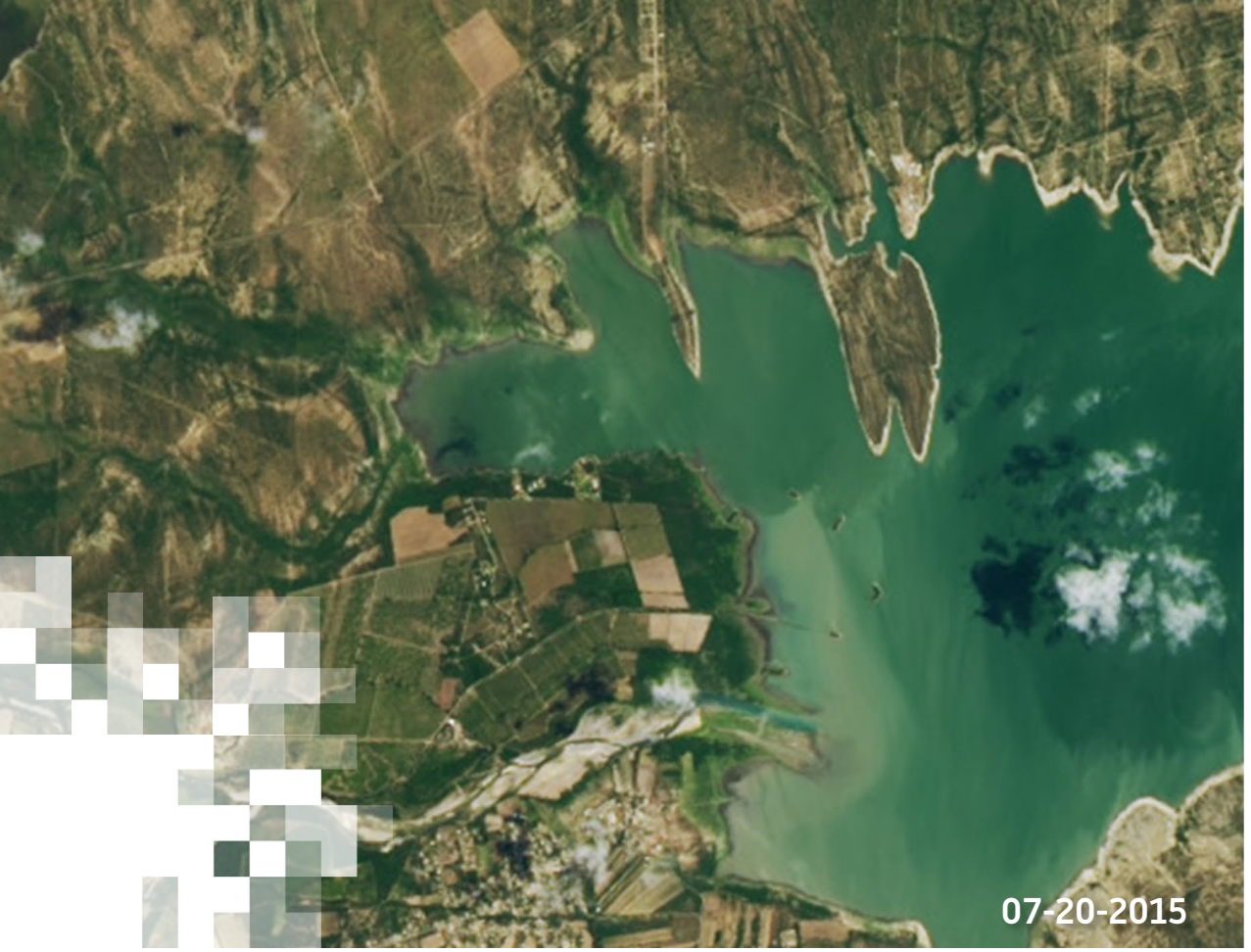
Objectives:

- By the end of this presentation, you will learn concepts related to how precipitation data are derived from satellite observations, and learn about two state-of-the art precipitation data sets:
  - Integrated Multi-satellitE Retrievals for GPM (IMERG)
  - Climate Hazards group Infrared Precipitation with Stations (CHIRPS)

Outline

- Precipitation remote sensing
- NASA Precipitation Missions and Data
- IMERG Data Access and Visualization
- Overview of CHIRPS Data

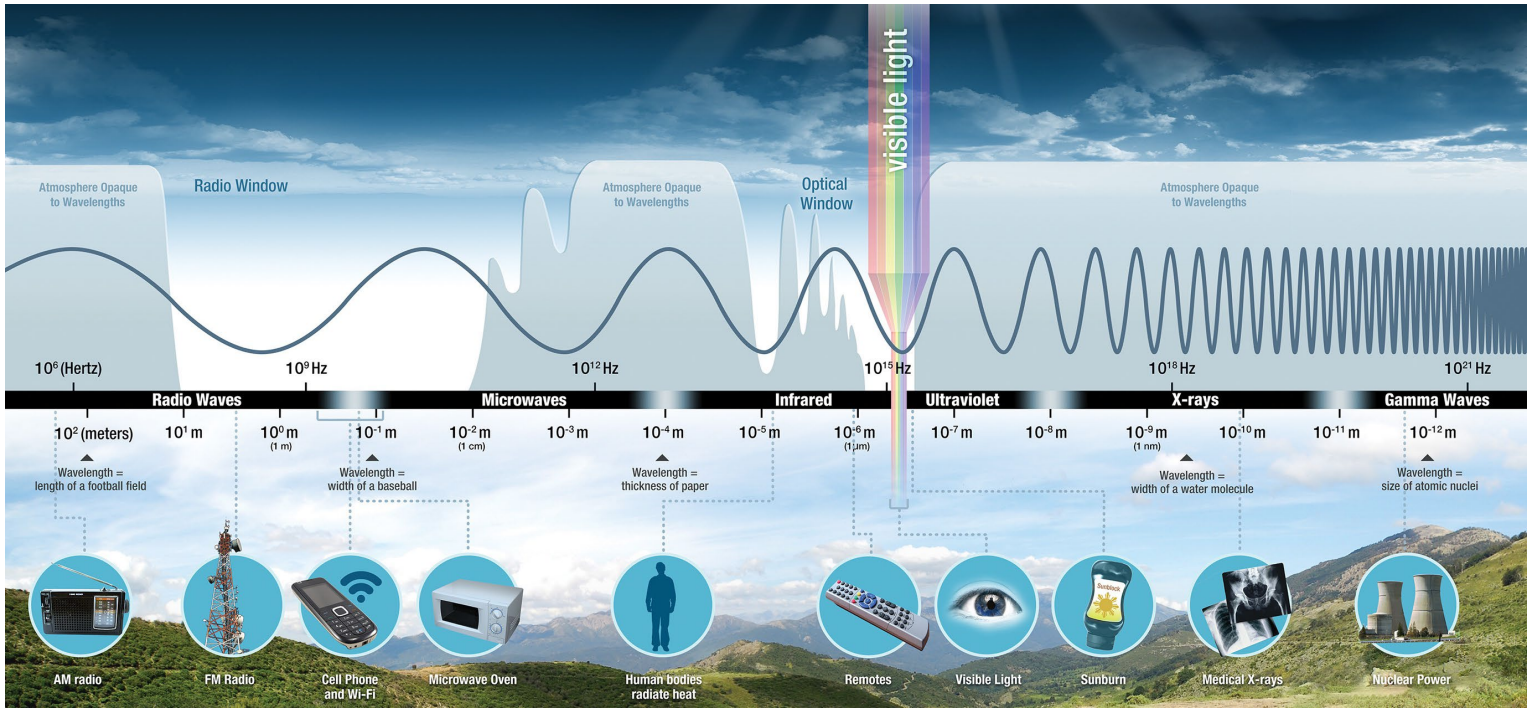
[1]ASTER: Advanced Spaceborne Thermal and Reflection Radiometer



Precipitation Remote Sensing

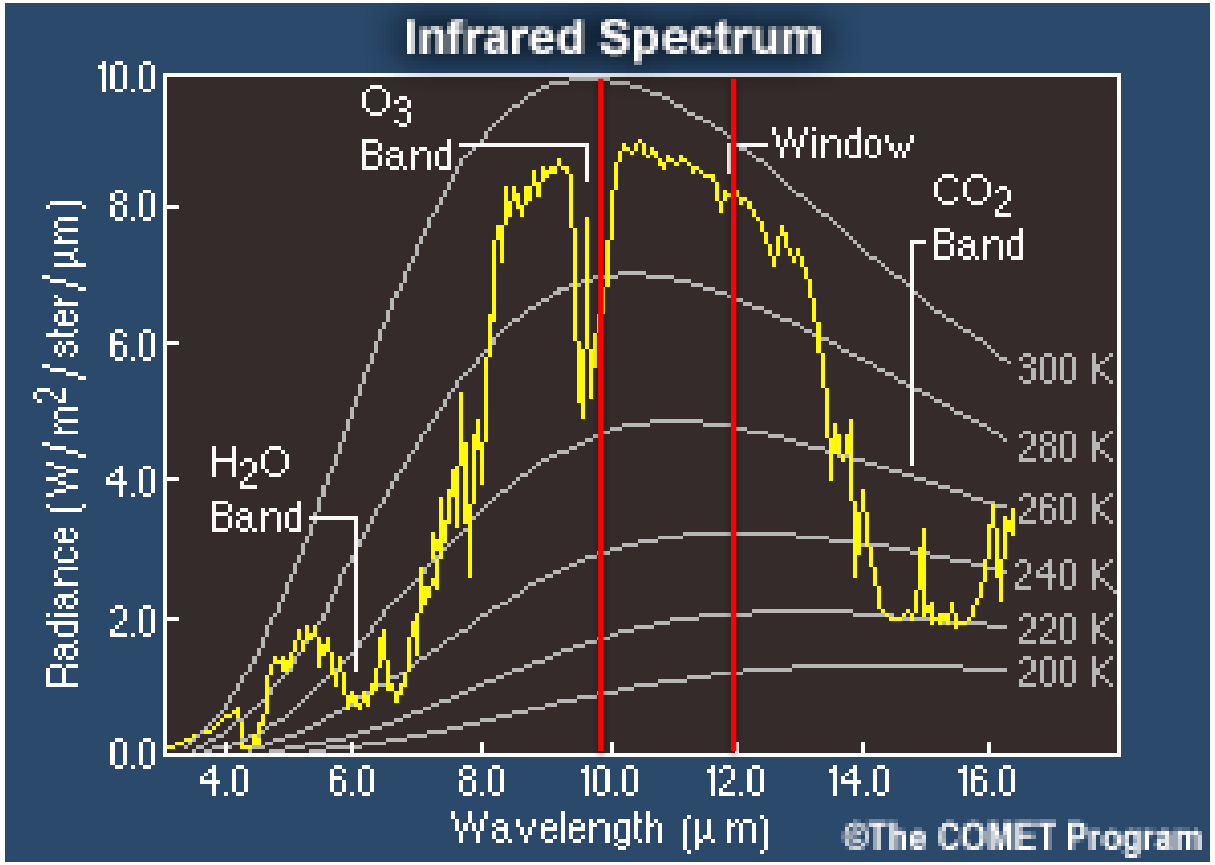
Spectral Bands Used for Precipitation Remote Sensing

- Derived from:
  - reflected visible radiation (0.5 to 0.6 micrometer wavelength)
  - emitted infrared radiation (10 to 12 micrometer wavelength)
  - emitted and scattered microwave radiation (10 to 183 Ghz frequency or mm to cm wavelength)



Precipitation Remote Sensing

Passive Remote Sensing: Inferred indirectly from emitted infrared (IR) radiation by clouds



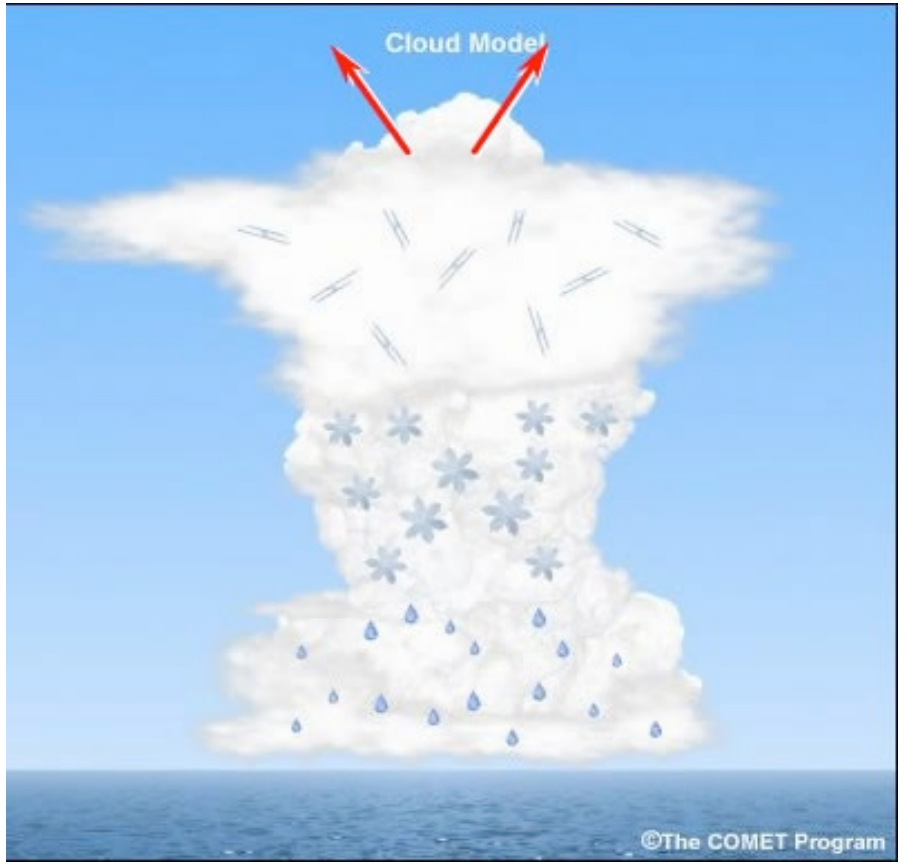
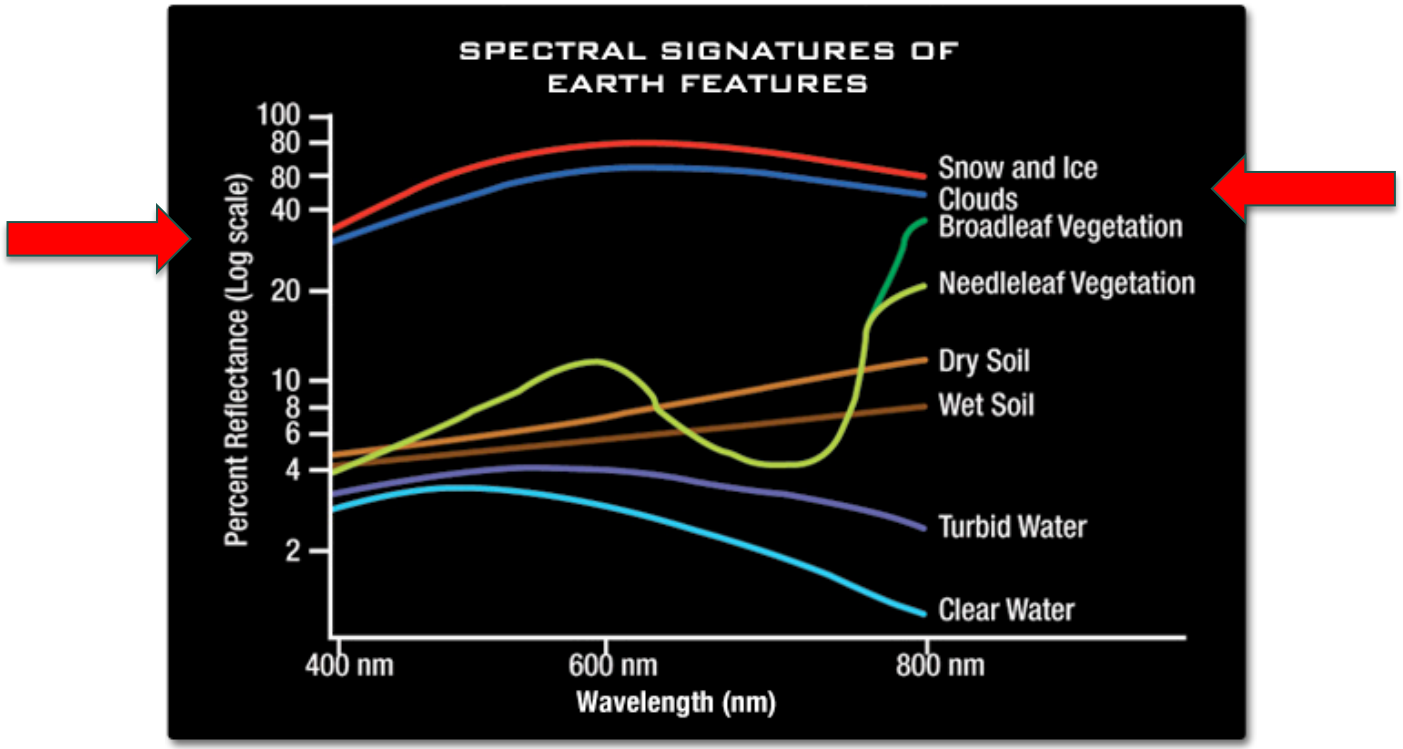


Image credit: UCAR COMET, comet.ucar.edu

Precipitation Remote Sensing

Passive Remote Sensing: Inferred indirectly from reflected solar visible (VIS) radiation by clouds



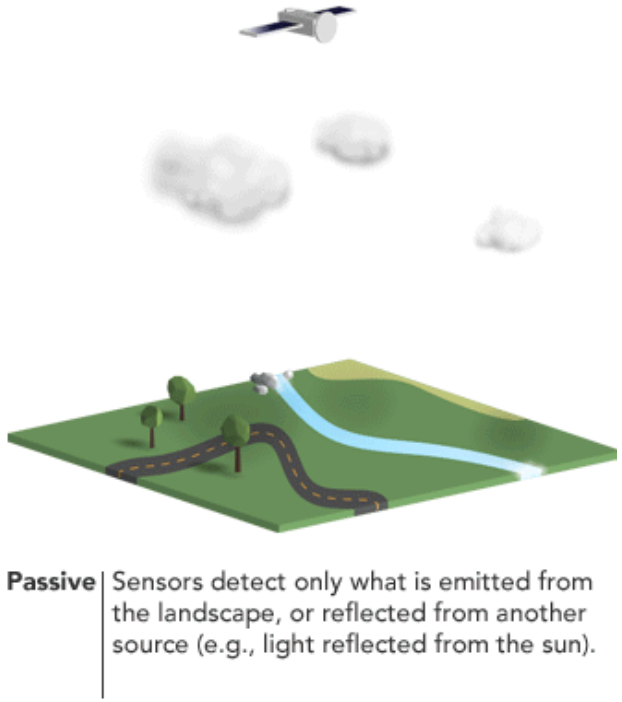


Image credit: UCAR COMET, comet.ucar.edu

Precipitation Remote Sensing

Passive Remote Sensing: Estimated from microwave radiation emitted or scattered by precipitation particles

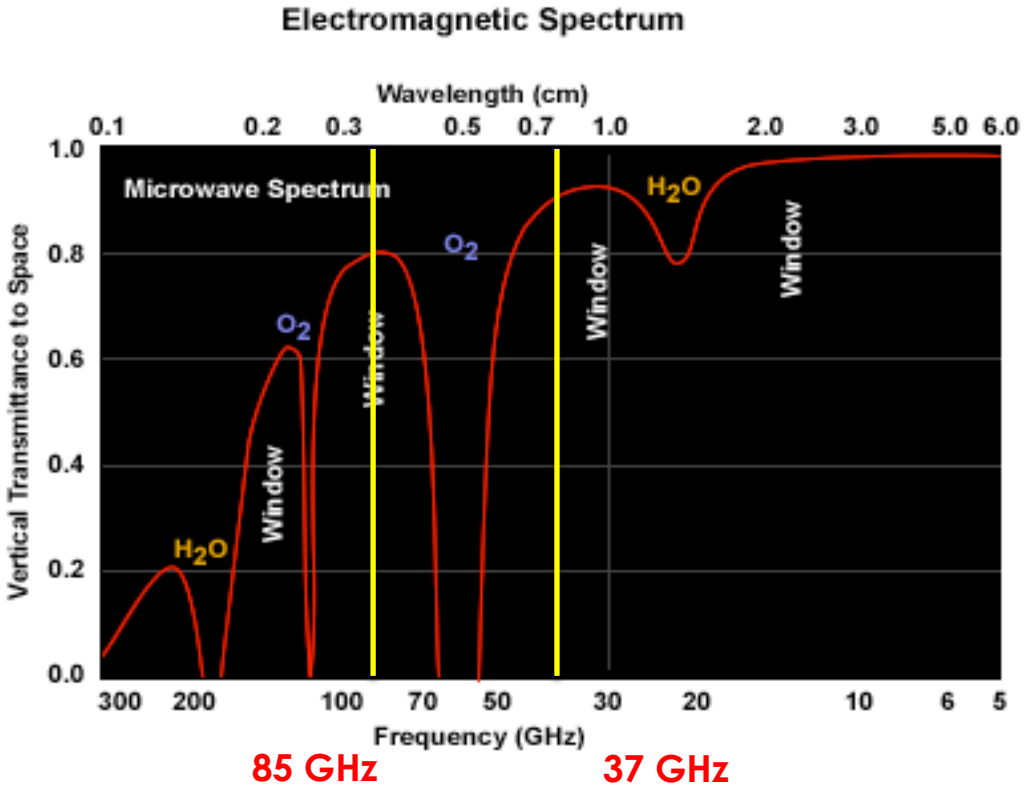
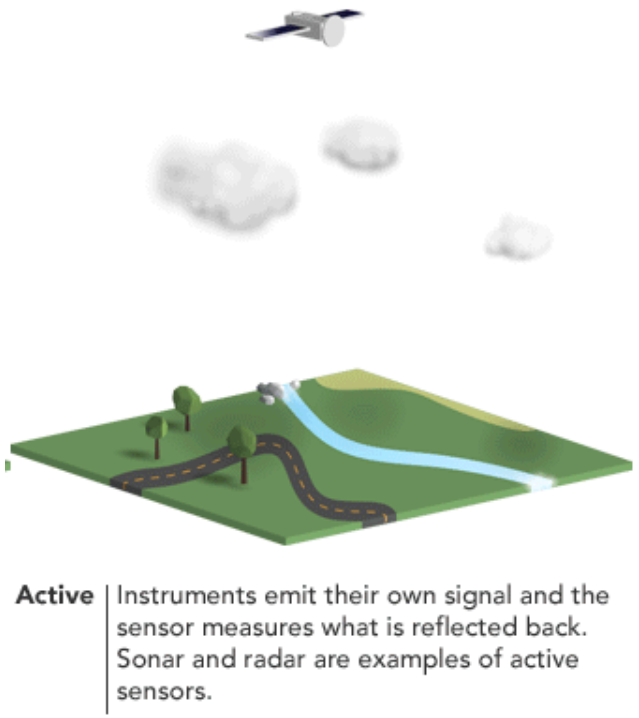


Image credit: UCAR COMET, comet.ucar.edu

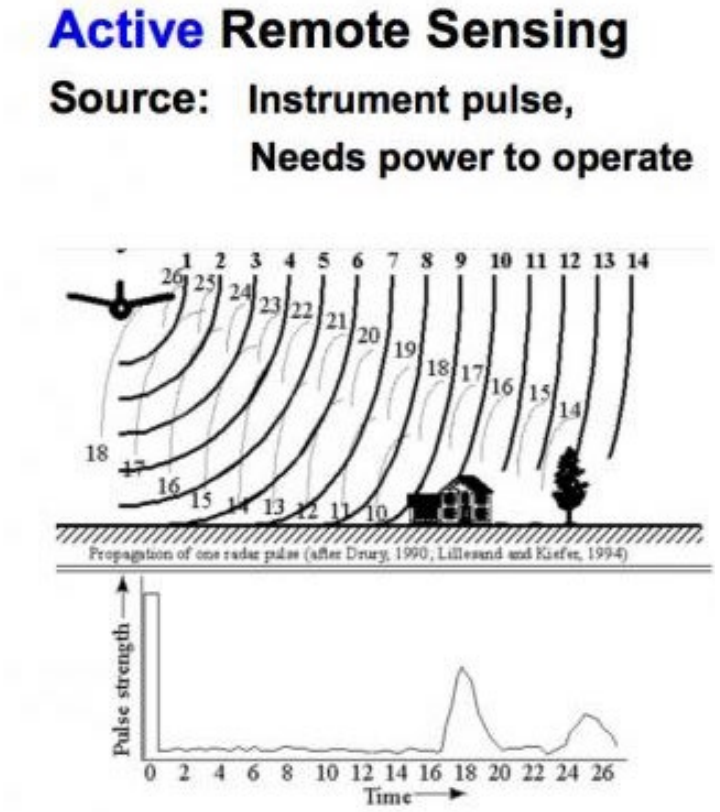
- The lower frequencies, referred to as "emissions channels," measure precipitation mainly from energy emitted by raindrops (37 GHz).
- The higher frequencies, or "scattering channels," gather energy scattered by ice particles above the freezing level (85 GHz).

Precipitation Remote Sensing

Active Remote Sensing: Estimated from back-scattered microwave radiation transmitted by radars

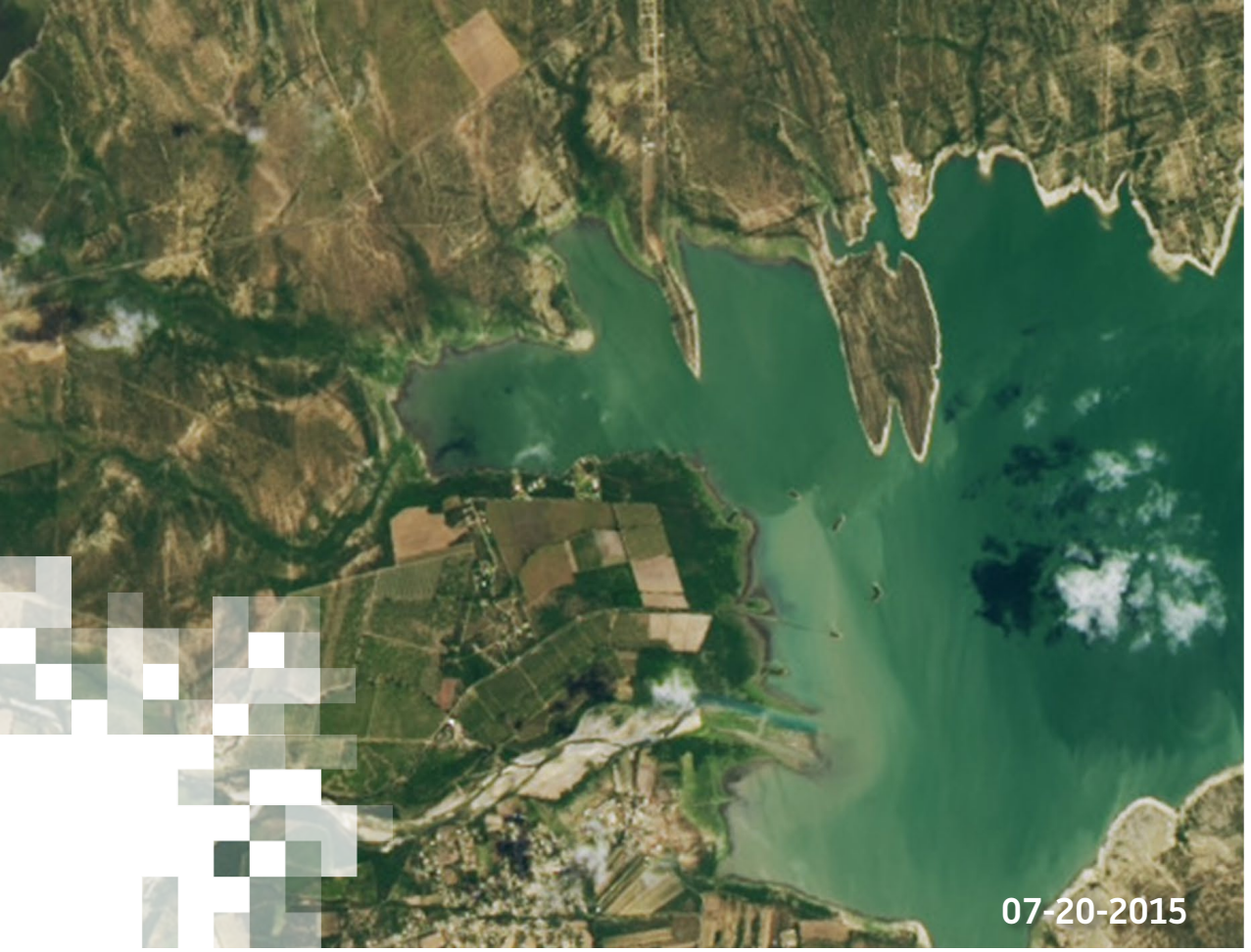


Active | Instruments emit their own signal and the sensor measures what is reflected back. Sonar and radar are examples of active sensors.



- NASA Satellites TRMM and GPM use K-band radar.
- K-band generally has a frequency range within Ku (12–18 GHz) and Ka (27–40 GHz).

Image credit: Paul Messina, Hunter College

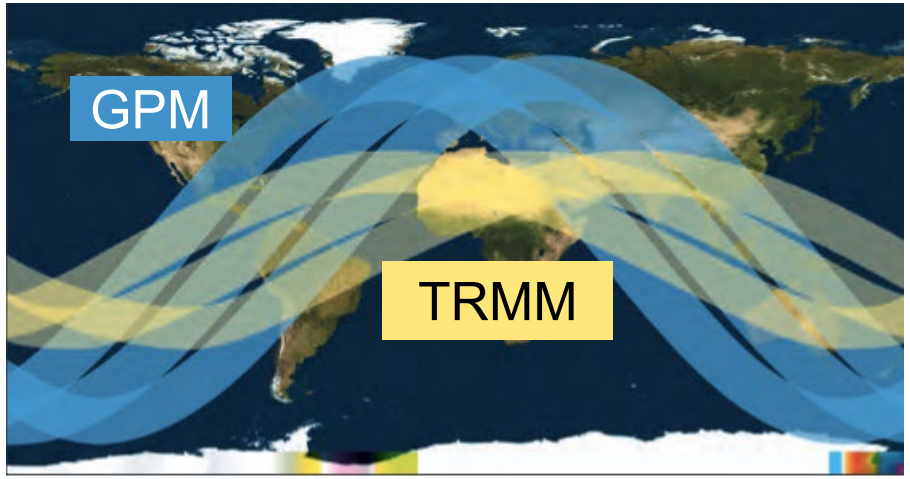


NASA Precipitation Missions and Data

GPM (Current) and TRMM (Past)

http://pmm.nasa.gov/

- Dedicated missions to measure rainfall 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 and GPM Sensors

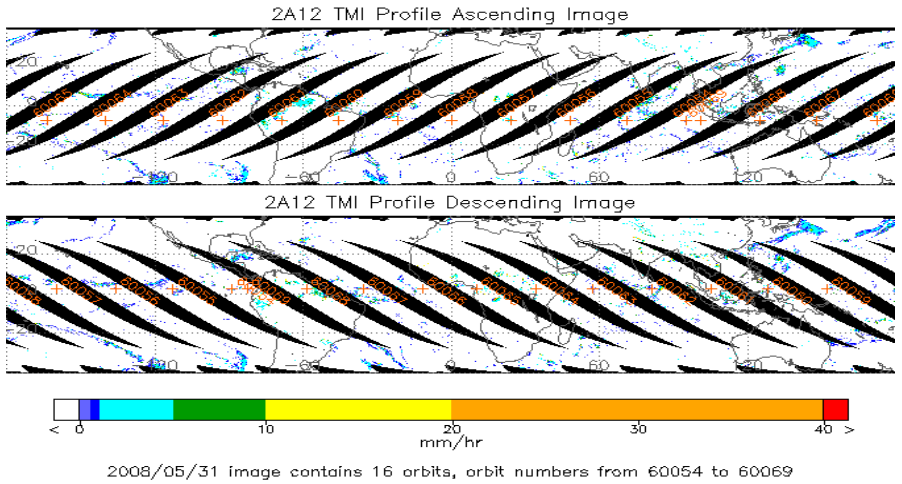
https://gpm.nasa.gov/category/mission-affiliation/pmm

- **TRMM Sensors:**
  - TRMM Microwave Imager (TMI)
  - Precipitation Radar (PR)
  - Visible and Infrared Scanner (VIRS)
  - Lightening Imaging Sensor (LIS)
  - Clouds and the Earth's Radiant Energy System (CERES)
- **GPM Sensors**:
  - GPM Microwave Imager (GMI)
  - Dual-frequency Precipitation Radar (DPR)

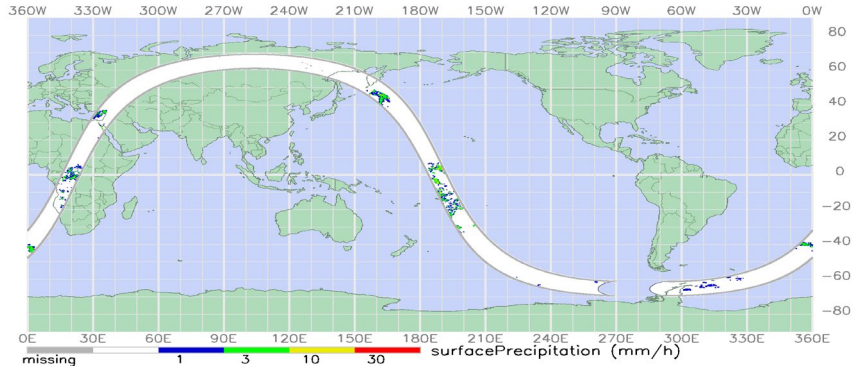
gpm.nasa.gov/category/mission-affiliation/pmm

TRMM and GPM Precipitation Sensor Summary

TMI Swath



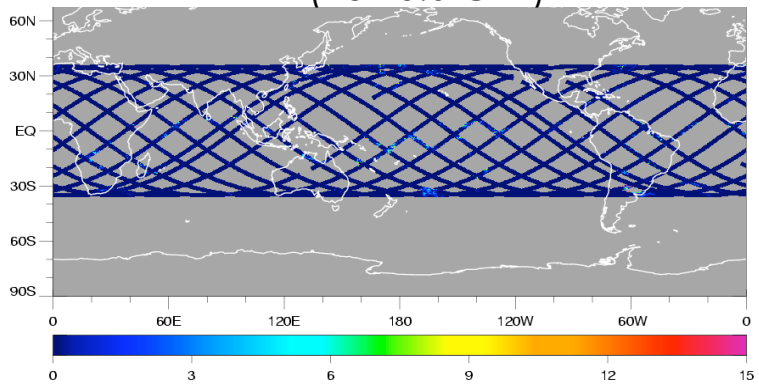
GMI Swath



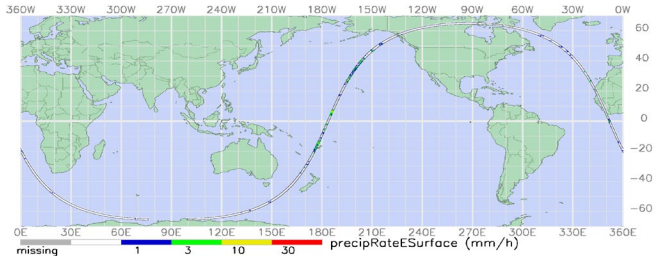
- Channel Frequencies (GHz):
  TMI: 10.7, 19.4, 21.3, 37, 85.5
  GMI: 10.6, 18.7, 23.8, 36.5, 89,166,183
- Swaths:
  TMI: 760 km (878 km after 8/2001)
  GMI: 885 km
- Spatial resolution: frequency-dependent, varies from 4.3 to 32 km
- About 16 orbits per day, non-continuous spatial coverage

TRMM and GPM Precipitation Sensor Summary

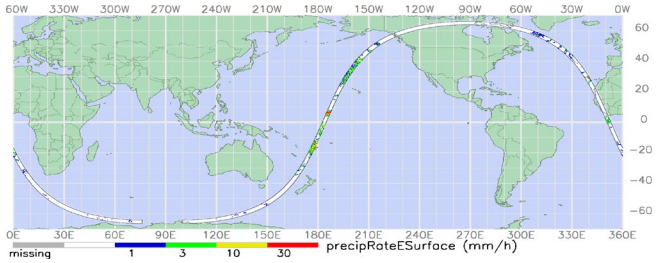
PR Swath
(Ku 13.6 GHz)



DPR Swaths
Ka 35.5 GHz



Ku 13.6 GHz



- Radar frequencies (GHz):
  PR: 13.6 (Ku band)
  DPR: 13.6 and 35.5 (Ku and Ka bands)
- Swaths (km):
  PR: 215 (247 after 8/2001)
  DPR: 245 (Ku band) & 120 (Ka band)
- Spatial resolution (km):
  PR: 4.5 (5 after 8/2001)
  DPR: 5.3
- Narrower swaths compared to TMI & GMI

Precipitation Algorithms for TRMM and GPM

http://pmm.nasa.gov/science/precipitation-algorithms

There are four major algorithms used to obtain precipitation estimates from GPM/TRMM observations:

1. Radar Algorithms
2. Radiometer Algorithms
3. Combined Radar + Radiometer Algorithms
4. **Multi-Satellite Algorithms**
    - **TRMM and GPM Core Observatory are used to calibrate multiple national and international satellites constellation.**

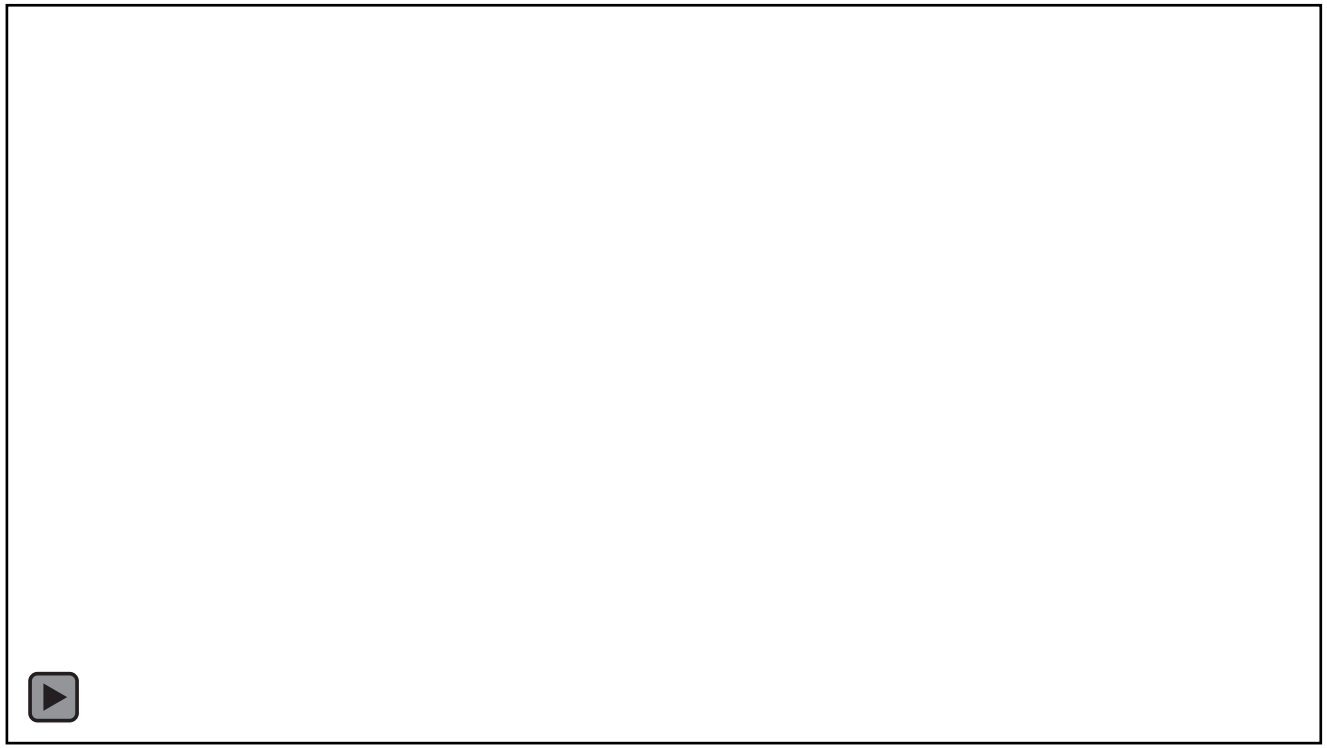
pmm.nasa.gov/science/precipitation-algorithms

Multi-Satellite Algorithms for TRMM and GPM

http://pmm.nasa.gov/science/precipitation-algorithms

- 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.

GPM Satellite Constellation



- Allows improved spatial and temporal coverage of precipitation data

IMERG

	IMERG
Spatial Resolution	0.1° x 0.1°
Spatial Coverage	Global, 60°S – 60°N (will be extended from pole to pole)
Temporal Resolution	30 minutes
Temporal Coverage	June 2000 – present

Huffman et al: https://gpm.nasa.gov/sites/default/files/document_files/IMERG_doc_190909.pdf

Integrated Multi-satellitE Retrievals for GPM (IMERG)

http://pmm.nasa.gov/sites/default/files/document_files/IMERG_ATBD_V4.5.pdf

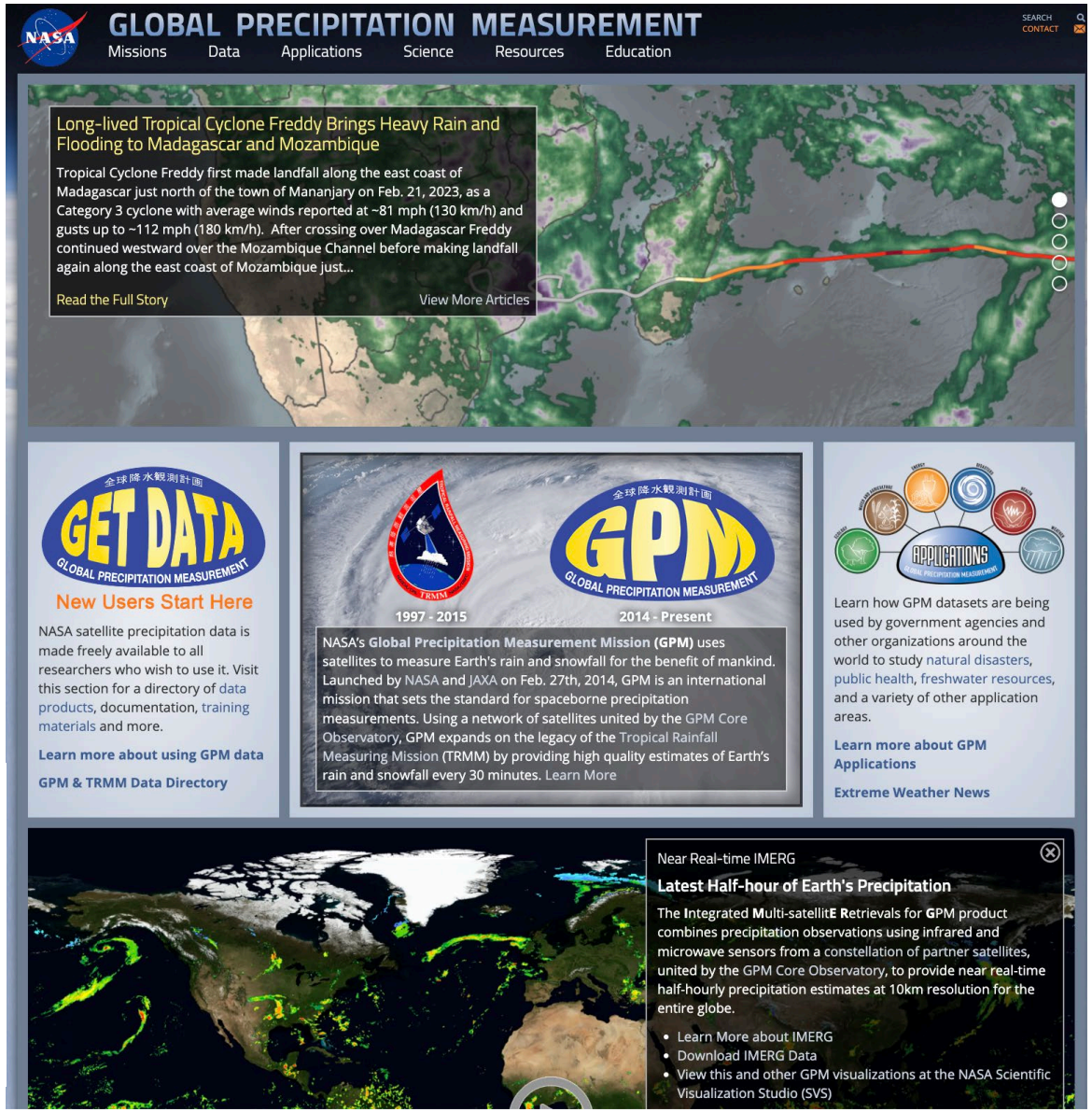
- **Multiple runs accommodate different user requirements for latency and accuracy.**
  - "Early" – now 5 hours (flash flooding) – will be 4 hours.
  - "Late" – now 15 hours (crop forecasting) – will be 12 hours.
  - "Final" – 3 months (research data)
  - Value-added products at 3 hrs., 1, 3, and 7 days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

http://pmm.nasa.gov/sites/default/files/document_files/IMERG_ATBD_V4.5.pdf

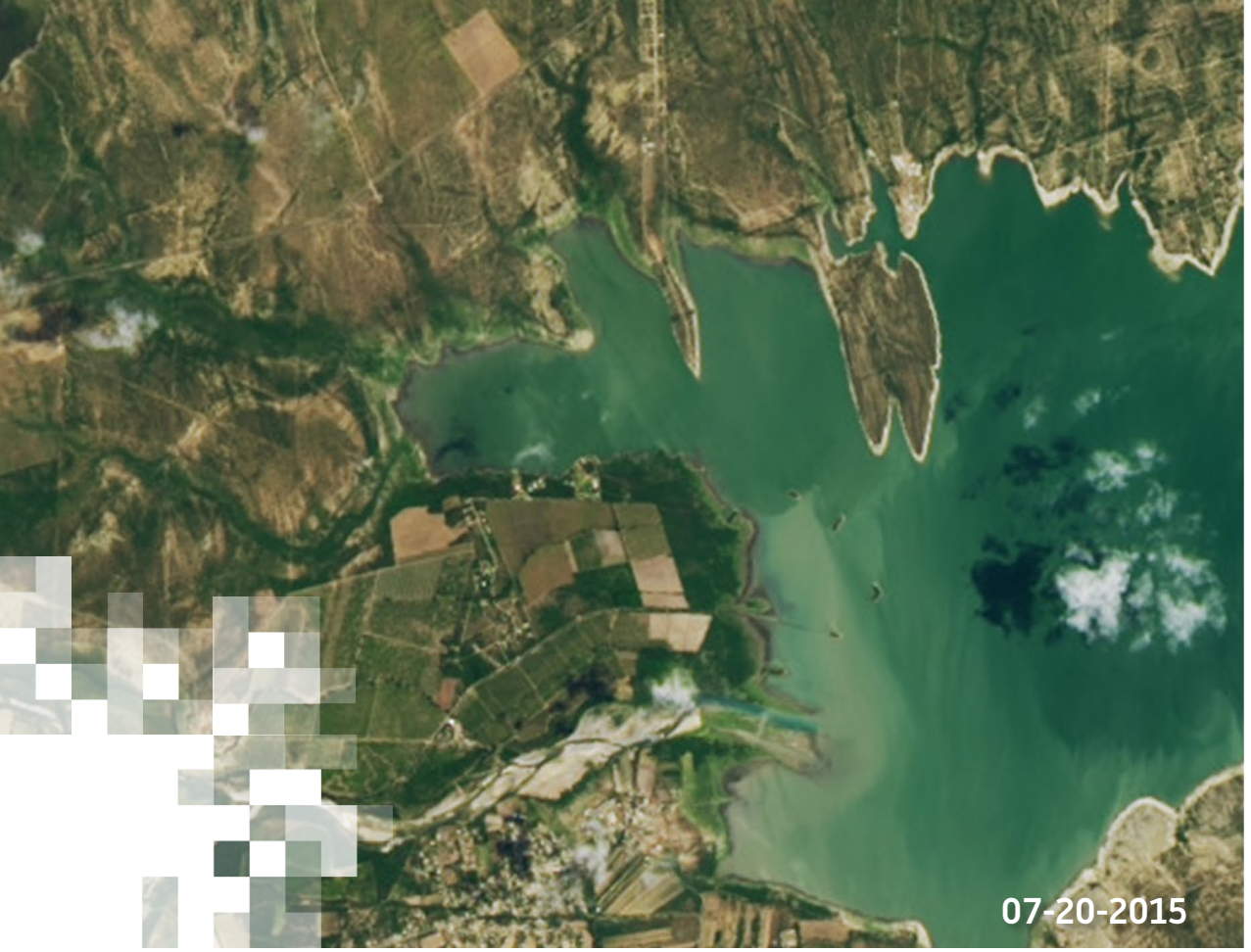
Information about Precipitation Measurement Mission

https://pmm.nasa.gov/

- Home of all information related to the precipitation missions
- Links to data documentation and access



http://pmm.nasa.gov/



IMERG Data Access and Visualization

Precipitation Data Access Tools

Tool	Data & Format	Features
PPS/STORM http://storm.pps.eosdis.nasa.gov/	• 3-hr Rain Rate (TRMM, GPM, IMERG) • HDF, PNG	• Orbital and Gridded Data Search • Spatial/Temporal Subsetting • Individual Data and FTP Batch Download • Images and Interactive Data Viewer

Giovanni
http://giovanni.gsfc.nasa.gov/
	• 3-hr Rain Rate, Daily, Monthly Rain (TRMM, GPM, IMERG)
	• NetCDF, GeoTIFF, PNG, KMZ, CSV (time series only)
		• 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 GES DISC https://disc.gsfc.nasa.gov/	• 3-hr Rain Rate, Daily, Monthly Rain (TRMM, GPM, IMERG) • NetCDF, GeoTIFF	• Spatial/Temporal Subsetting • Bulk download using wget or curl
Google Earth Engine	• 3-hr Rain Rate, Daily,	• Spatial/Temporal Subsetting • Analysis: • Time-averaged maps, animation, time

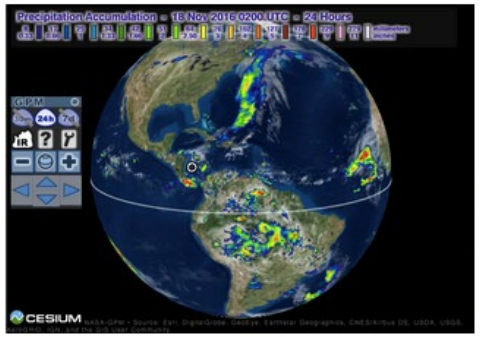
Data Visualization

https://pmm.nasa.gov/data-access/visualization

Data Visualization

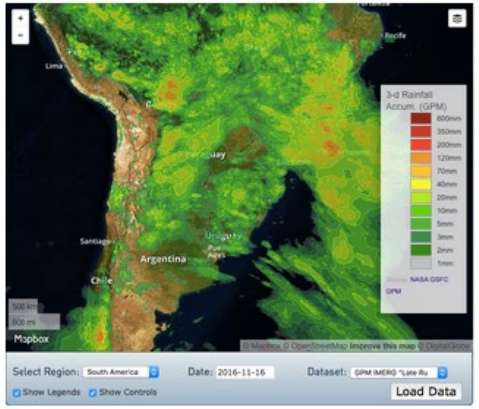
Global Viewer

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.



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.



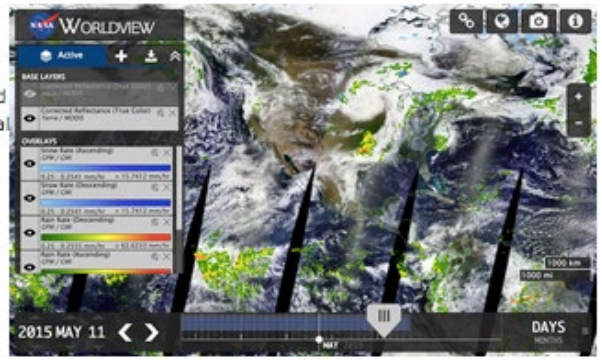
STORM Event Viewer

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)

NASA Worldview

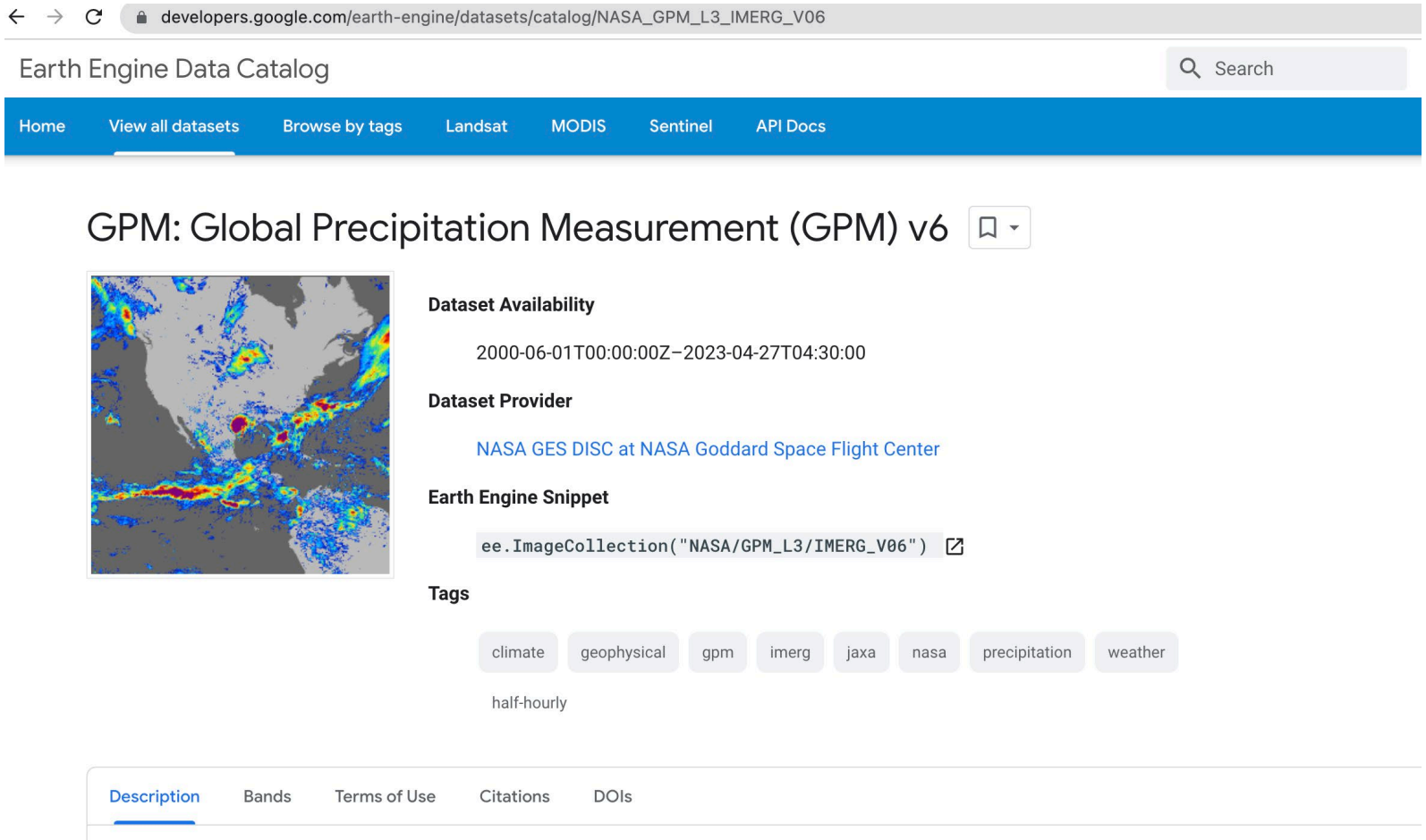
This tool from NASA's Earth Observing System Data and Information System (EOSDIS) provides the capability to interactively browse global, full-resolution satellite imagery and then download the underlying data, including data from the Global Precipitation Measurement Missions.



https://pmm.nasa.gov/data-access/visualization

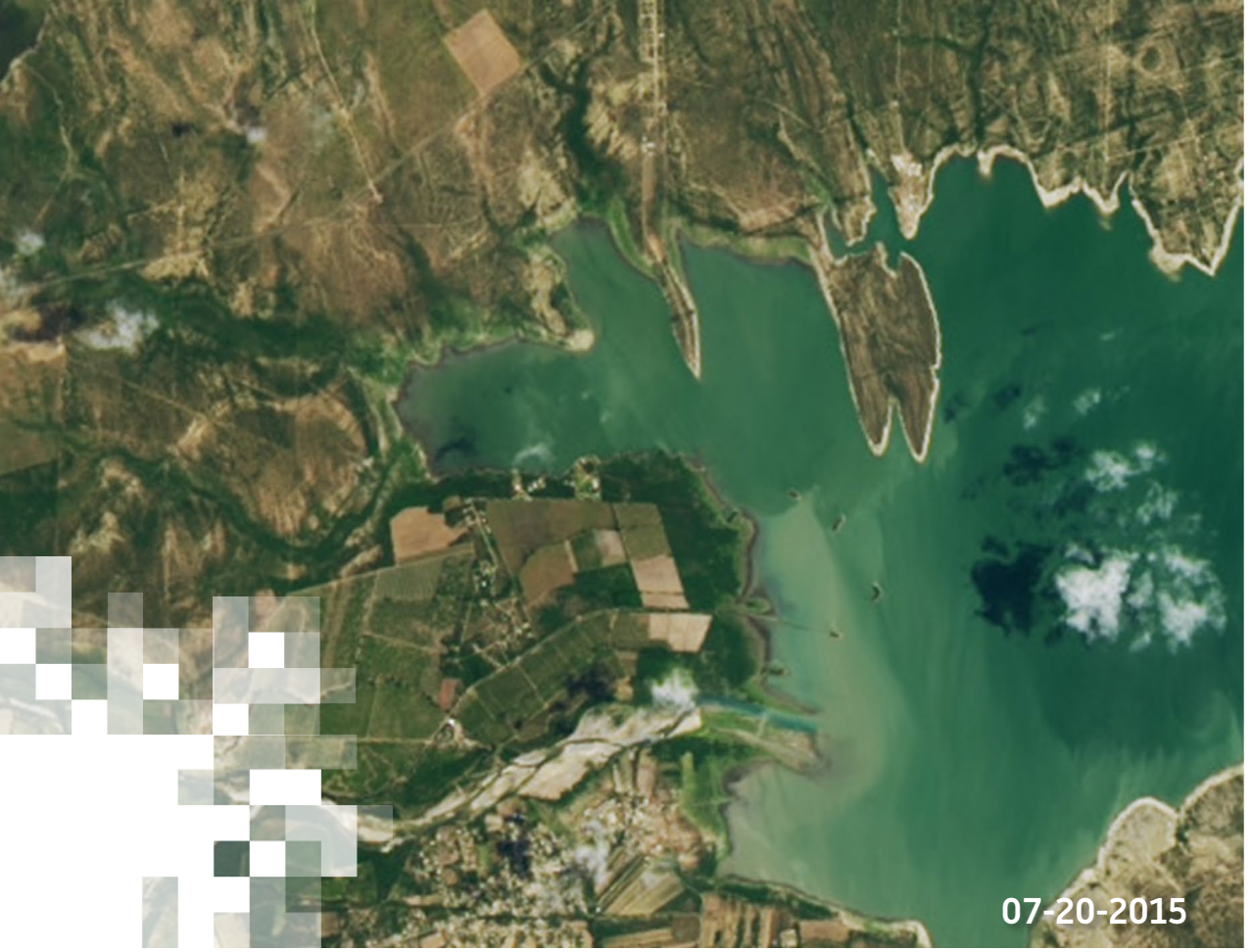
Data Access and Visualization: Google Earth Engine (GEE)

https://earthengine.google.com/



We will be using GEE for precipitation data analysis and visualization.

earthengine.google.com/



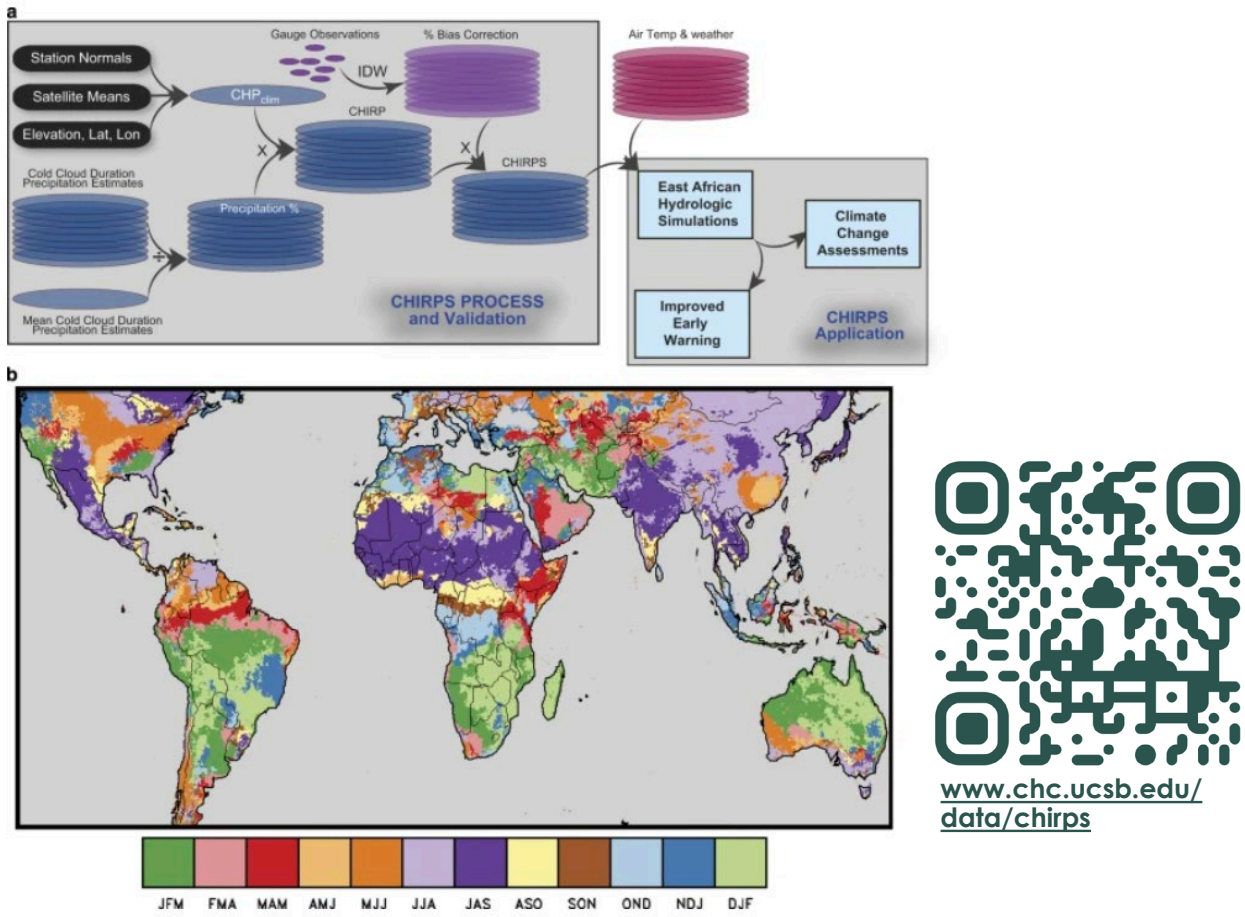
Overview of CHIRPS Data

Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)

https://www.chc.ucsb.edu/data/chirps

- Developed to support the United States Agency for International Development (USAID) Famine Early Warning Systems Network (FEWS NET).
- Based on thermal IR – derived, cold-cloud based rainfall, calibrated with TRMM/GPM multi-satellite rainfall data.
- The satellite-derived rainfall is combined with interpolated rain gauge data and regional, station-based climatological time series of rainfall to get final rainfall product.

Overview of CHIRPS process and validation
Funk et al. (2015)



www.chc.ucsb.edu/data/chirps

(**a**) CHIRPS production and application schema.

(**b**) Map showing the wettest three-month seasons based on climatology.

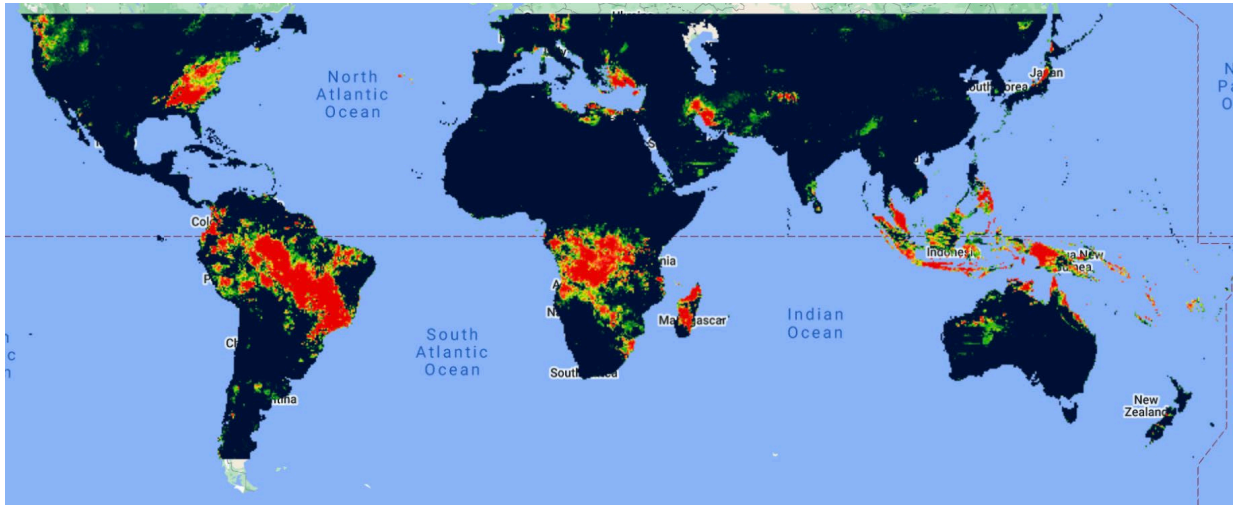
Funk et al., 2015: The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Sci Data 2, 150066 (2015). https://doi.org/10.1038/sdata.2015.66

Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)

https://www.chc.ucsb.edu/data/chirps

- Temporal coverage: 1981 to present
- Temporal resolution: six-hourly, daily, 5-day mean, monthly, seasonal aggregates
- Spatial coverage: global, 50°S – 50°N
- Spatial resolution: 0.05° (~5 km)

Annual Mean Rainfall (2021)



CHIRPS Data Access

https://data.chc.ucsb.edu/products/CHIRPS-2.0/

Links to Access CHIRPS Data

https://data.chc.ucsb.edu/products/CHIRPS-2.0/

https://clim-engine-development.appspot.com/fewsNet

https://climateserv.servirglobal.net/

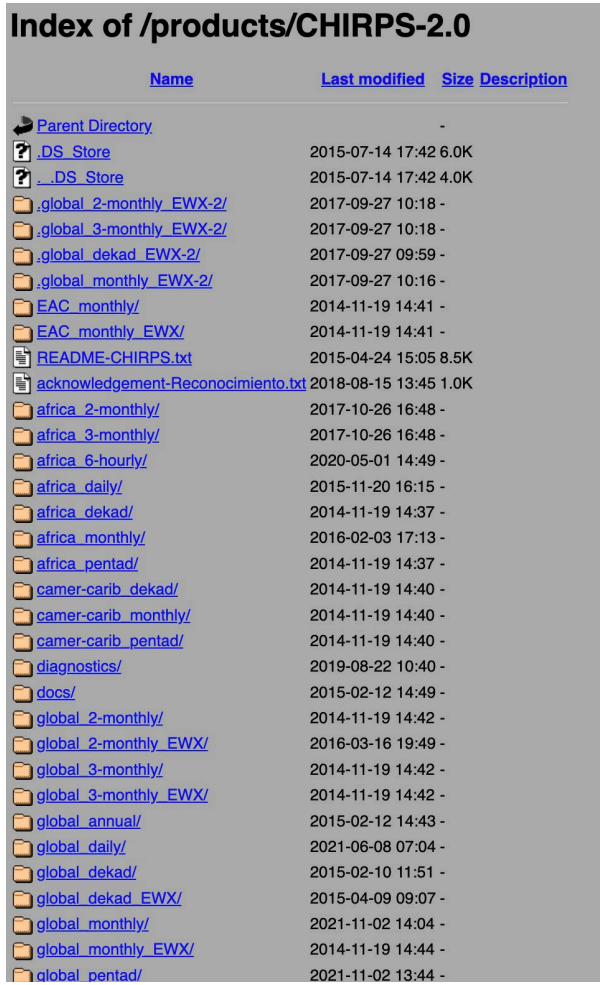
https://developers.google.com/earth-engine/datasets/catalog/UCSB-CHG_CHIRPS_DAILY

https://developers.google.com/earth-engine/datasets/catalog/UCSB-CHG_CHIRPS_PENTAD

https://earlywarning.usgs.gov/fews/ewx/index.html

data.chc.ucsb.edu/products/CHIRPS-2.0/

Direct Download



Index of /products/CHIRPS-2.0

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._.DS_Store	2015-07-14 17:42	4.0K	
.global_2-monthly_EWX-2/	2017-09-27 10:18	-	
.global_3-monthly_EWX-2/	2017-09-27 10:18	-	
.global_dekad_EWX-2/	2017-09-27 09:59	-	
.global_monthly_EWX-2/	2017-09-27 10:16	-	
EAC_monthly/	2014-11-19 14:41	-	
EAC_monthly_EWX/	2014-11-19 14:41	-	
README-CHIRPS.txt	2015-04-24 15:05	8.5K	
acknowledgement-Reconocimiento.txt	2018-08-15 13:45	1.0K	
africa_2-monthly/	2017-10-26 16:48	-	
africa_3-monthly/	2017-10-26 16:48	-	
africa_6-hourly/	2020-05-01 14:49	-	
africa_daily/	2015-11-20 16:15	-	
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africa_pentad/	2014-11-19 14:37	-	
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camer-carib_pentad/	2014-11-19 14:40	-	
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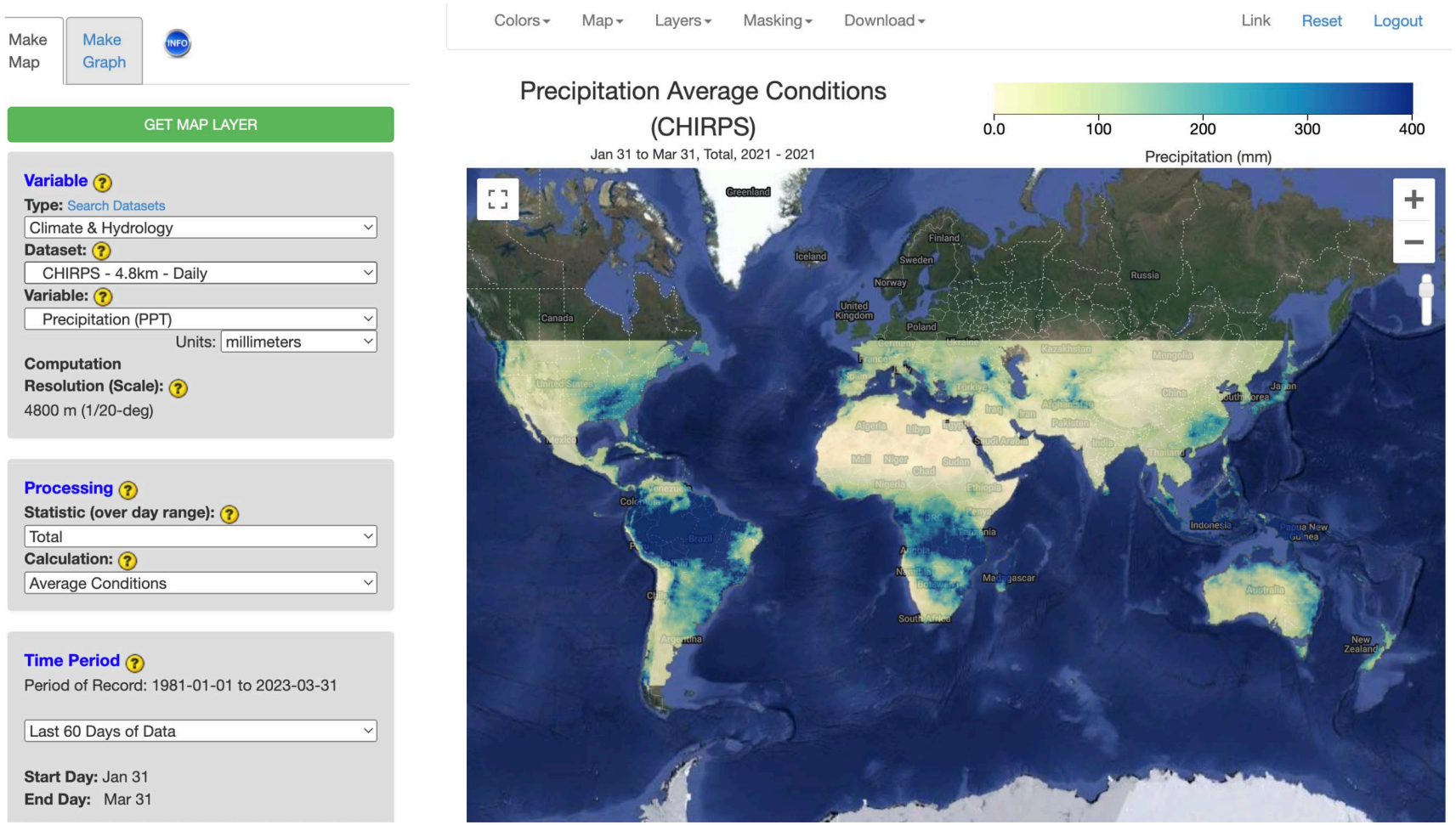
global_3-monthly/	2014-11-19 14:42	-	
global_3-monthly_EWX/	2014-11-19 14:42	-	
global_annual/	2015-02-12 14:43	-	
global_daily/	2021-06-08 07:04	-	
global_dekad/	2015-02-10 11:51	-	
global_dekad_EWX/	2015-04-09 09:07	-	
global_monthly/	2021-11-02 14:04	-	
global_monthly_EWX/	2014-11-19 14:44	-	
global_pentad/	2021-11-02 13:44	-	

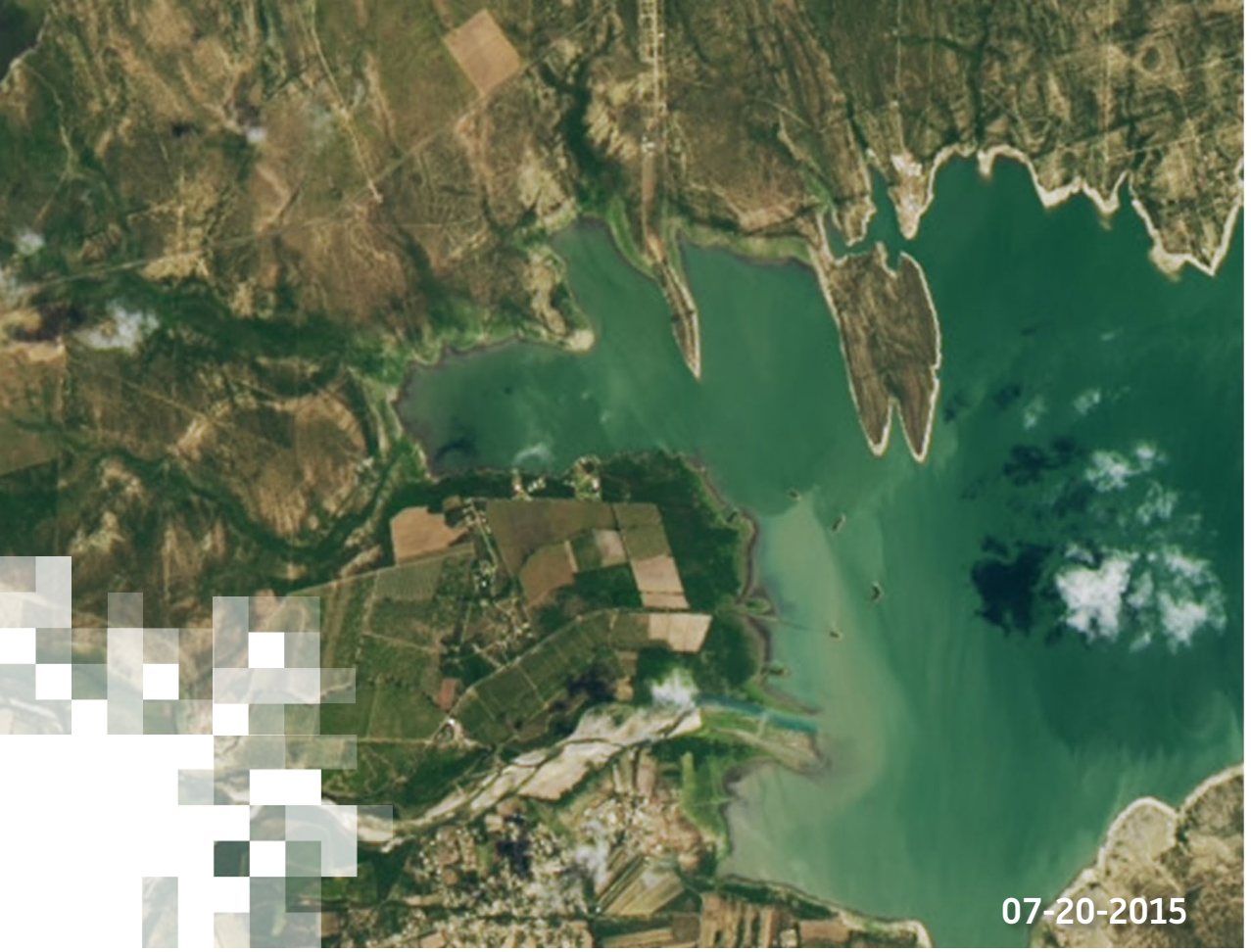
CHIRPS Data Access, Analysis, and Visualization: Climate Engine

https://app.climateengine.org/climateEngine



We will be using **Earth Engine** and **Climate Engine** for CHIRPS data access and analysis.

app.climateengine.org/climateEngine



Next: Demonstration of Precipitation Data Access, Analysis, and Visualization


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!