

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)

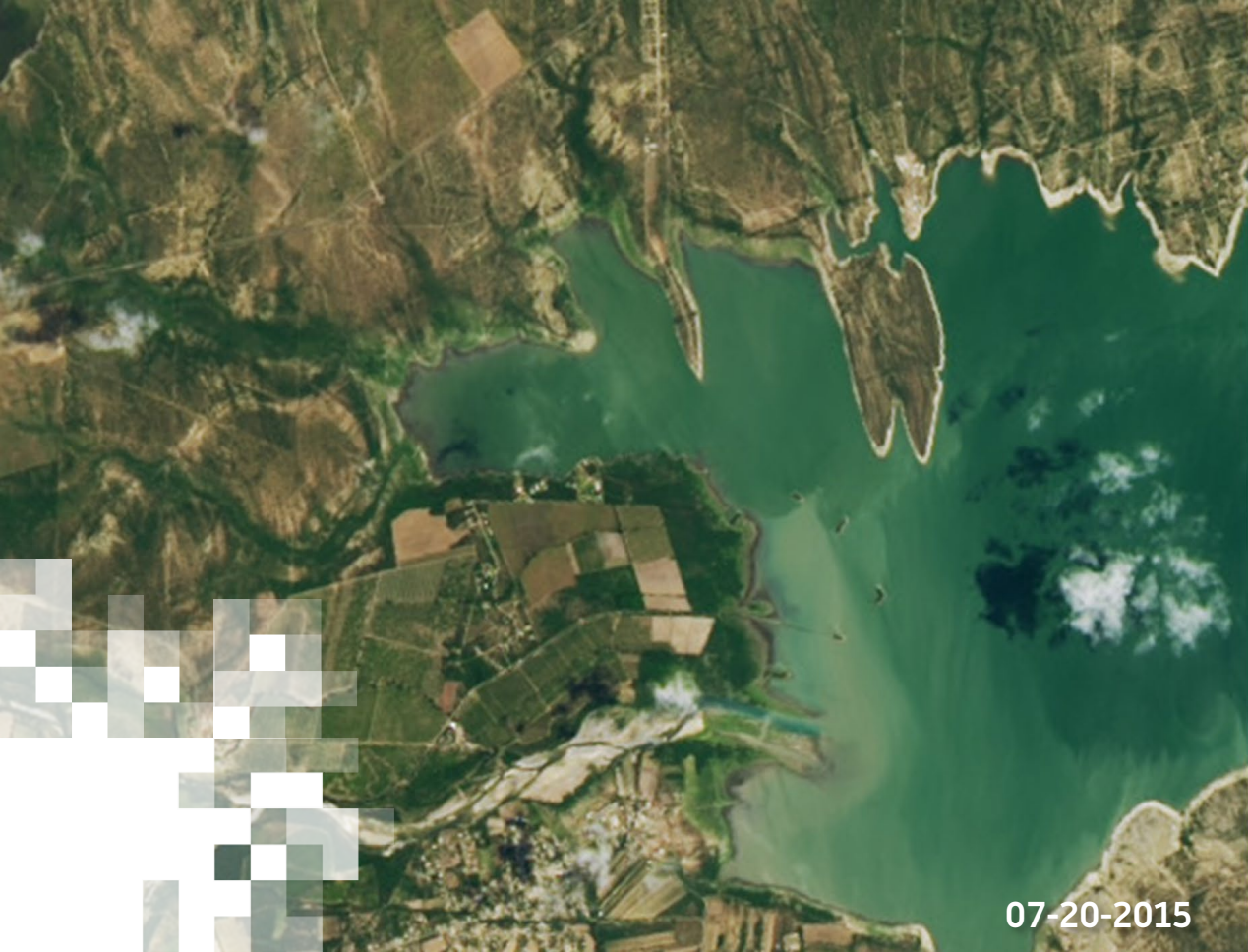


Outline

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



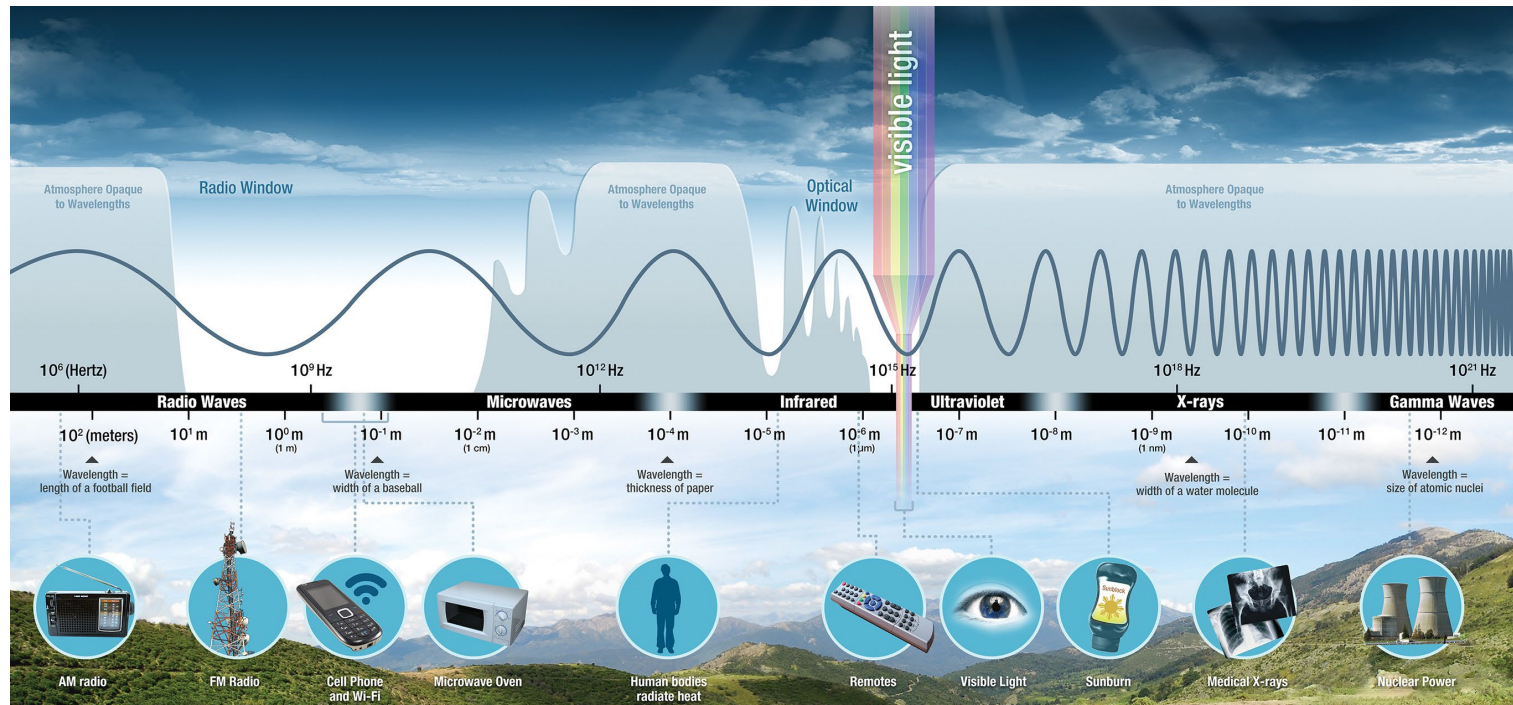
¹ASTER: Advanced Spaceborne Thermal and Reflection Radiometer



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

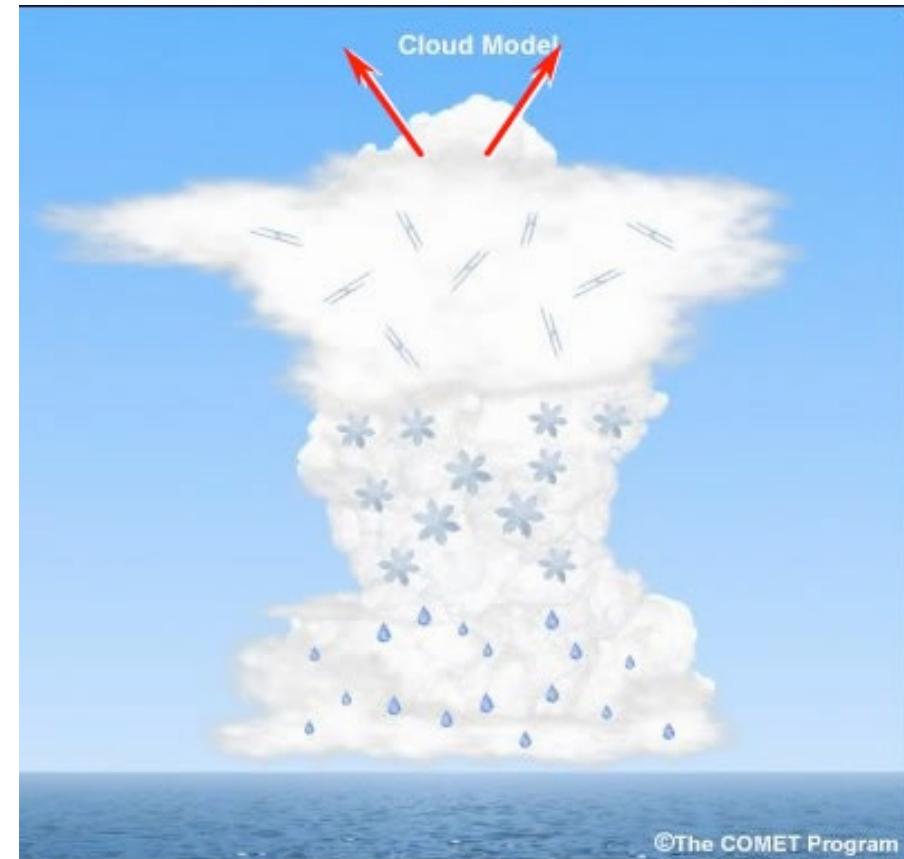
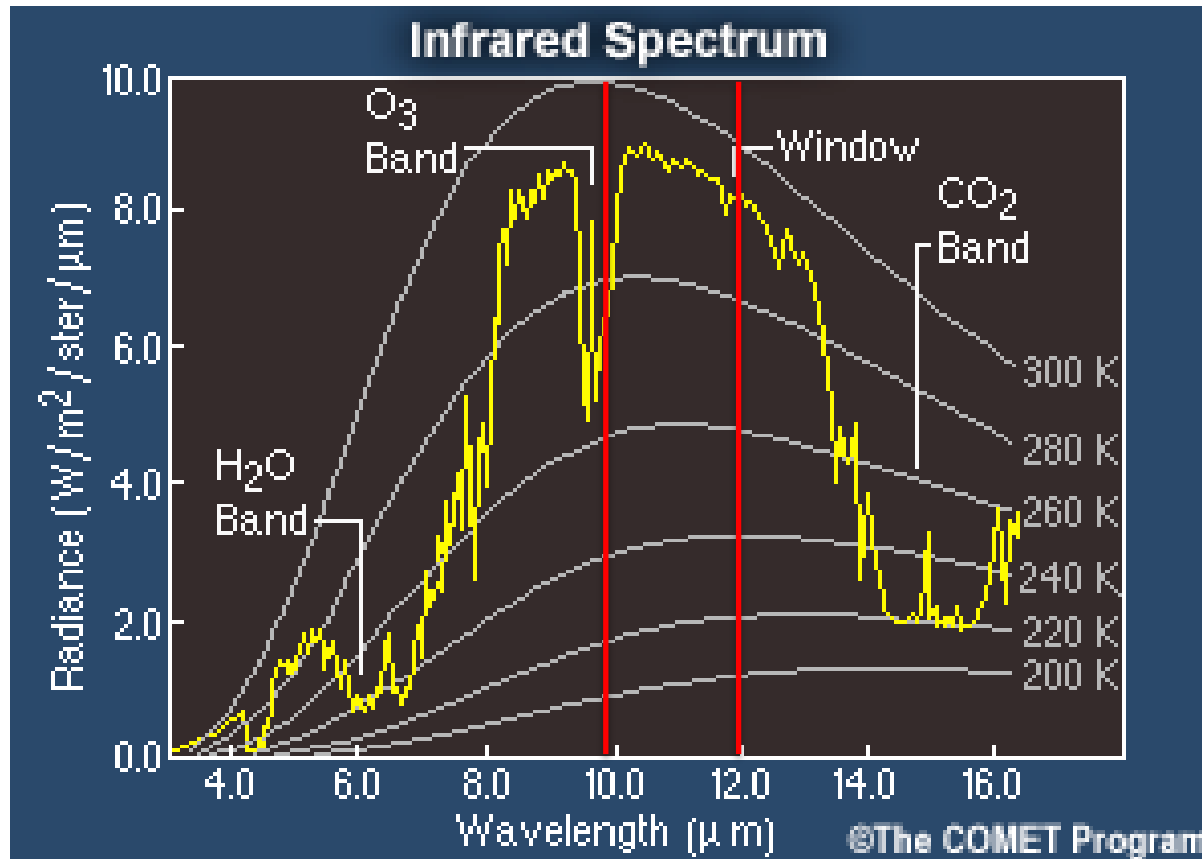
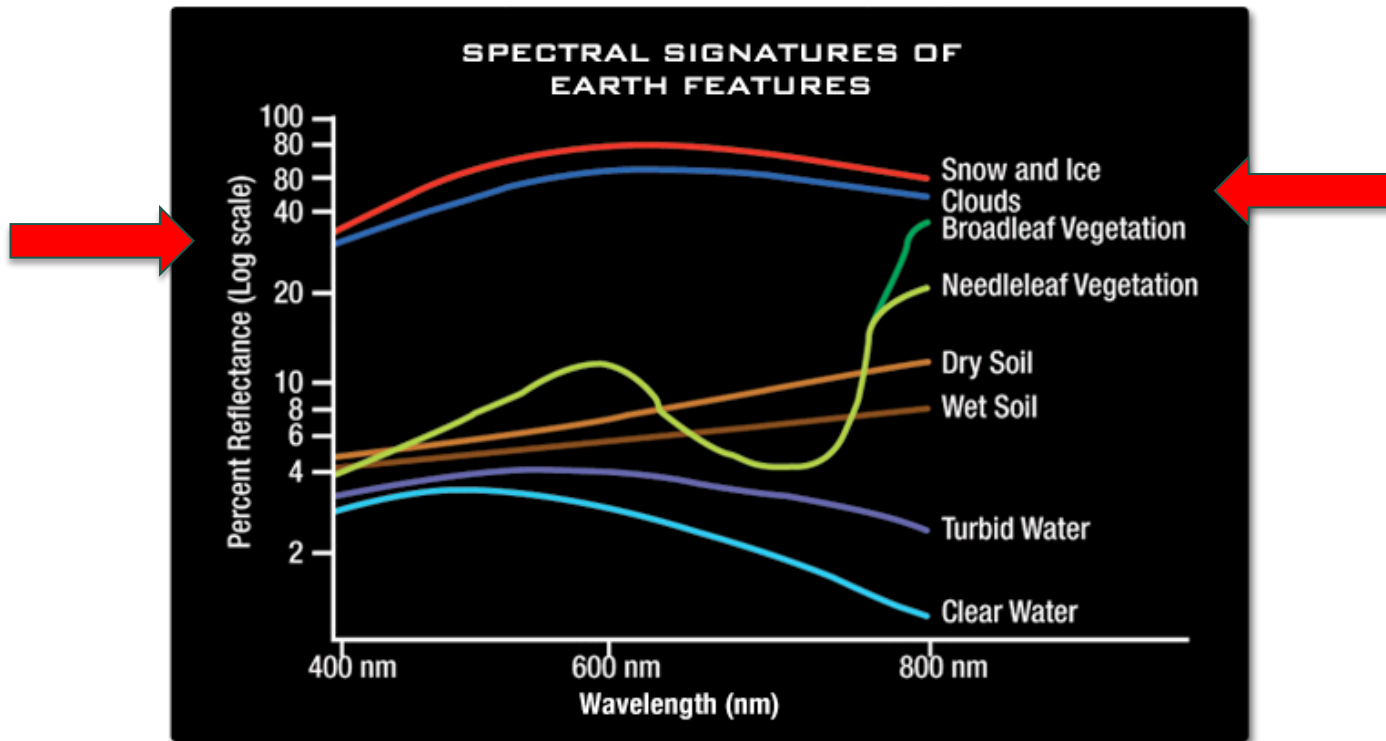


Image credit: UCAR COMET, comet.ucar.edu



Precipitation Remote Sensing

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



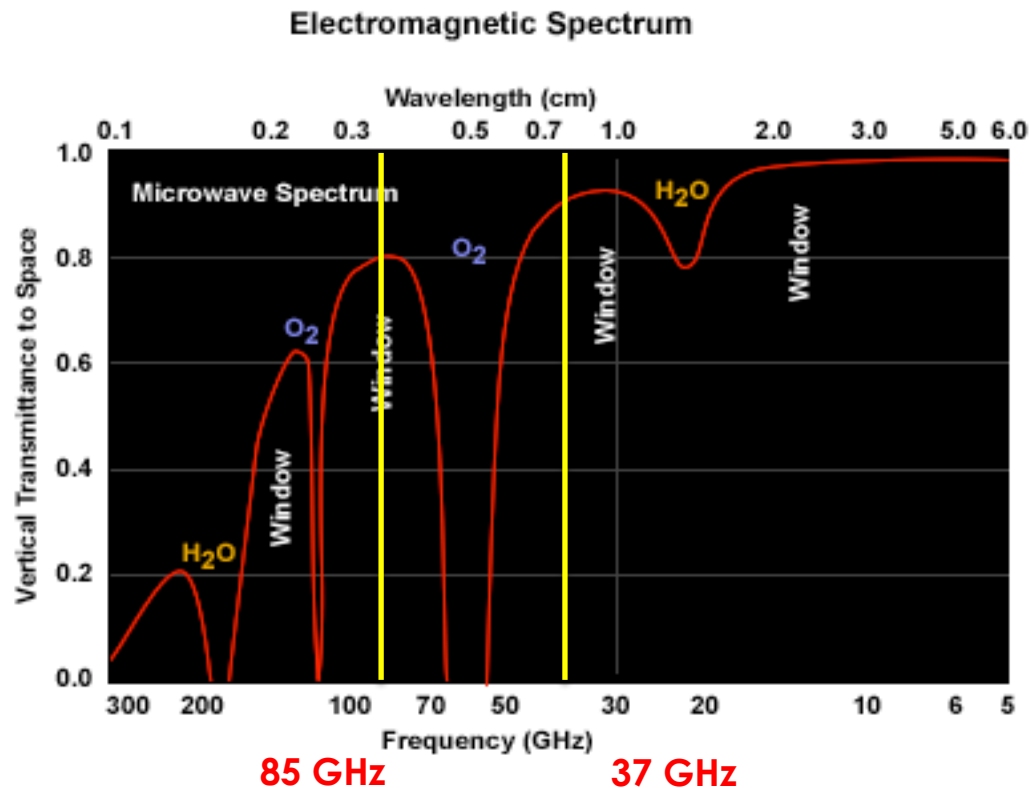
Passive | Sensors detect only what is emitted from the landscape, or reflected from another source (e.g., light reflected from the sun).

Image credit: UCAR COMET, comet.ucar.edu



Precipitation Remote Sensing

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



- 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).

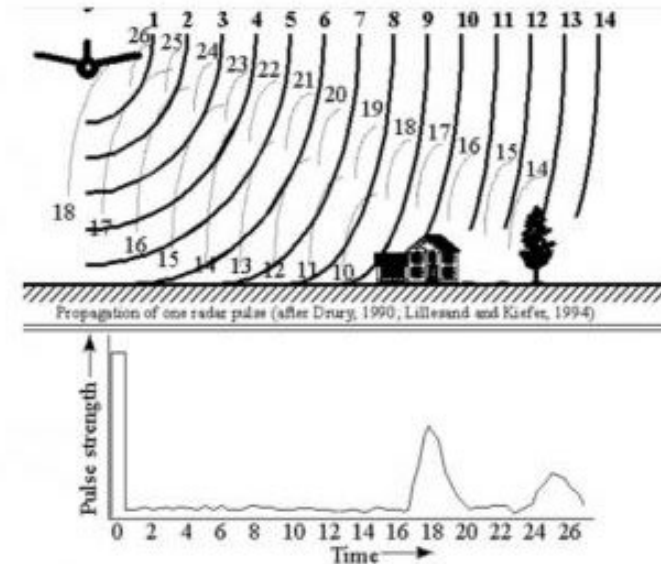
Image credit: UCAR COMET, comet.ucar.edu

Precipitation Remote Sensing

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

Active Remote Sensing

Source: Instrument pulse,
Needs power to operate

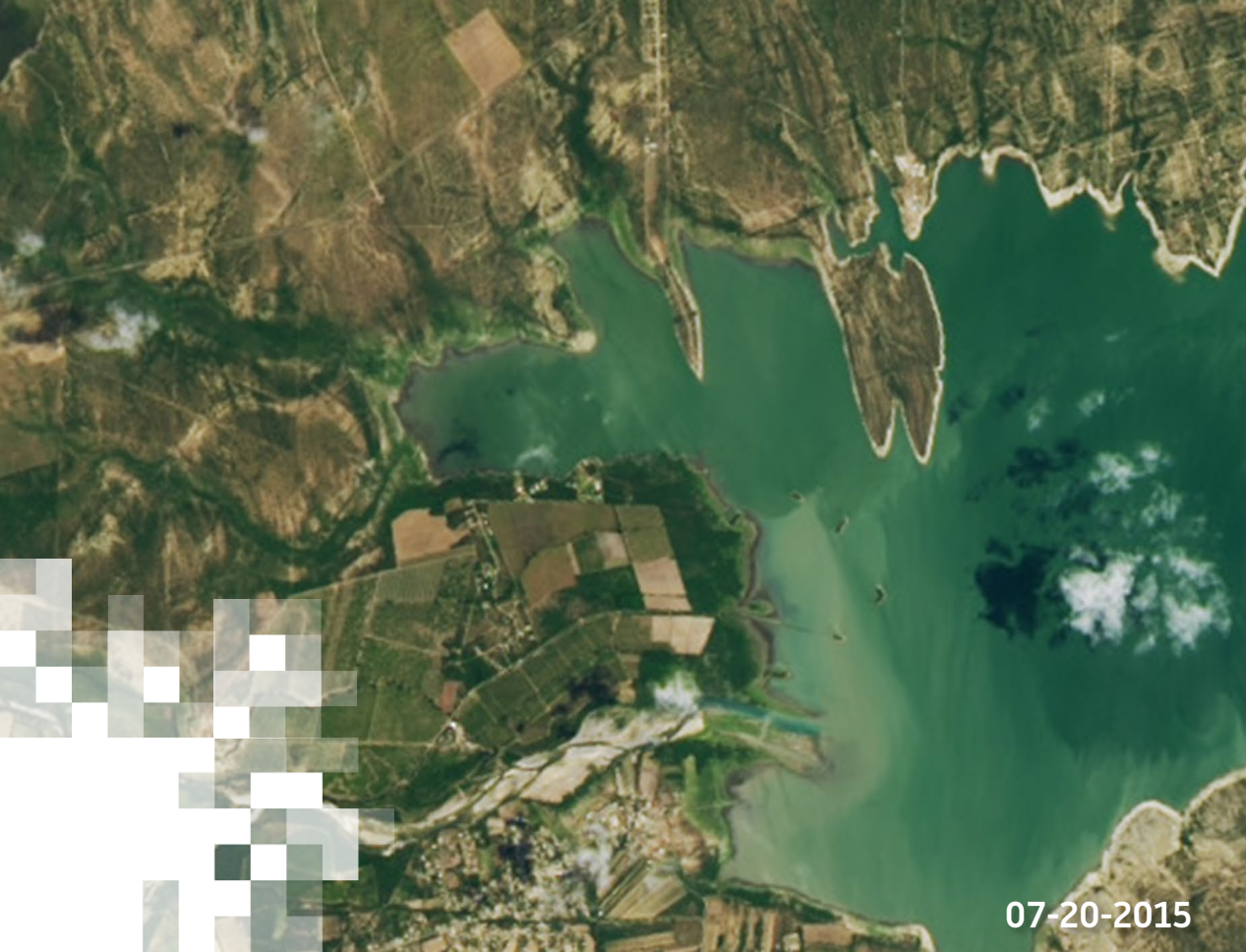


Active | Instruments emit their own signal and the sensor measures what is reflected back. Sonar and radar are examples of active sensors.

Image credit: Paul Messina, Hunter College

- 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).



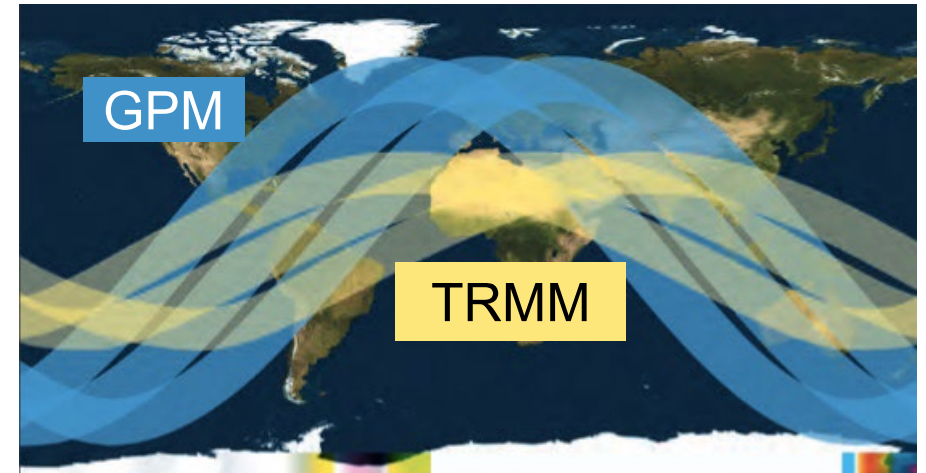


NASA Precipitation Missions and Data

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).



TRMM and GPM Sensors

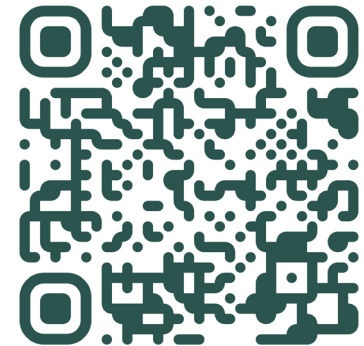
<https://gpm.nasa.gov/category/mission-affiliation/pmm>

- **TRMM Sensors:**

- TRMM Microwave Imager (TMI)
- Precipitation Radar (PR)
- Visible and Infrared Scanner (VIRS)
- Lightning Imaging Sensor (LIS)
- Clouds and the Earth's Radiant Energy System (CERES)

- **GPM Sensors:**

- GPM Microwave Imager (GMI)
- Dual-frequency Precipitation Radar (DPR)

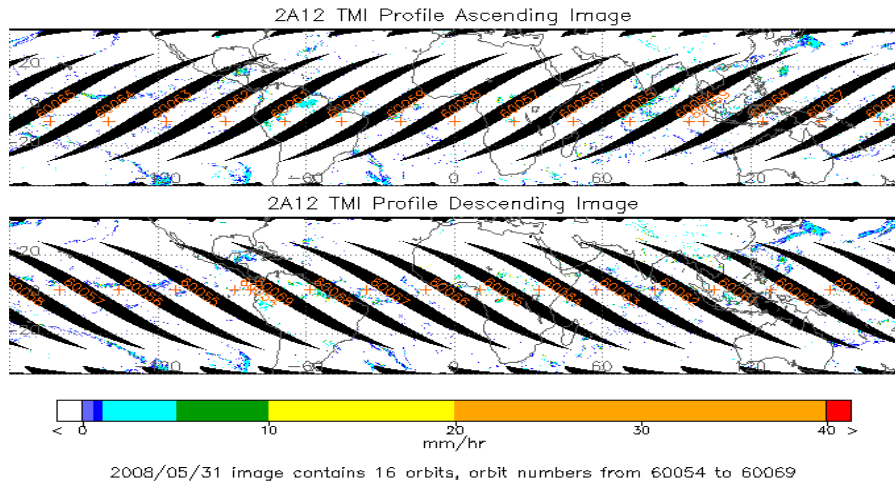


[gpm.nasa.gov/category/
mission-affiliation/pmm](https://gpm.nasa.gov/category/mission-affiliation/pmm)

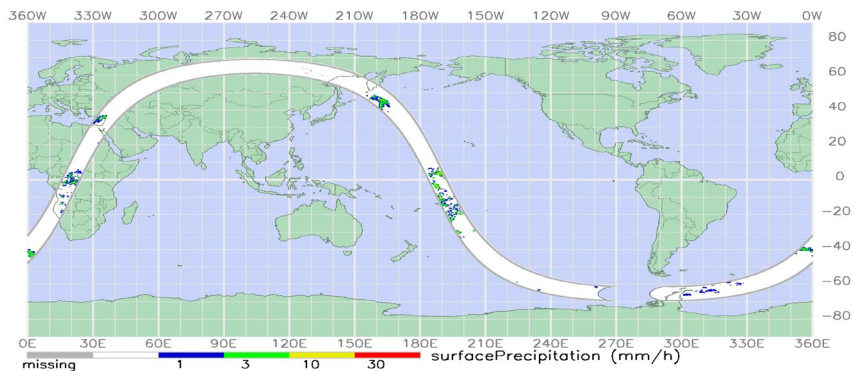


TRMM and GPM Precipitation Sensor Summary

TMI Swath



GMI Swath

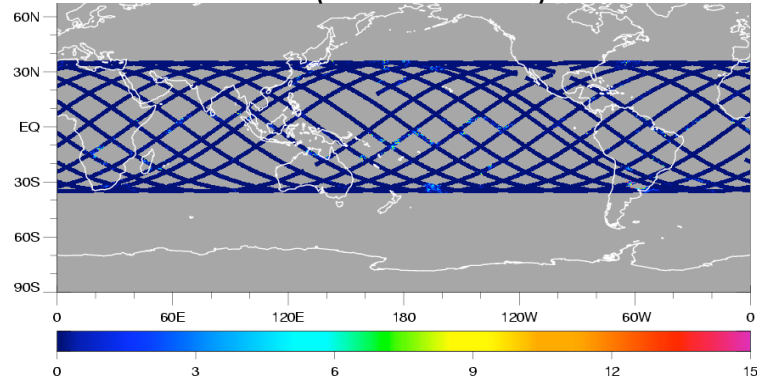


- Channel Frequencies (GHz):
TMI: 10.7, 19.4, 21.3, 37, 85.5
GMI: 10.6, 18.7, 23.8, 36.5, 89, 166, 183
- Swaths:
TMI: 760 km (878 km after 8/2001)
GMI: 885 km
- Spatial resolution: frequency-dependent, varies from 4.3 to 32 km
- About 16 orbits per day, non-continuous spatial coverage

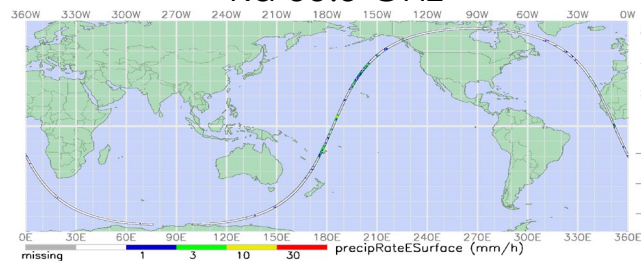


TRMM and GPM Precipitation Sensor Summary

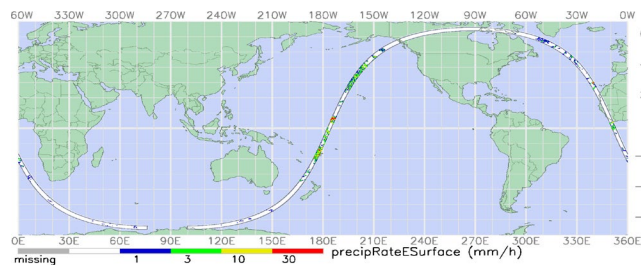
PR Swath
(Ku 13.6 GHz)



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

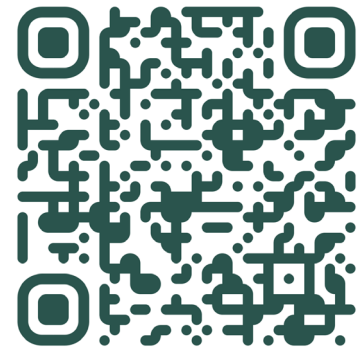


Precipitation Algorithms for TRMM and GPM

<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

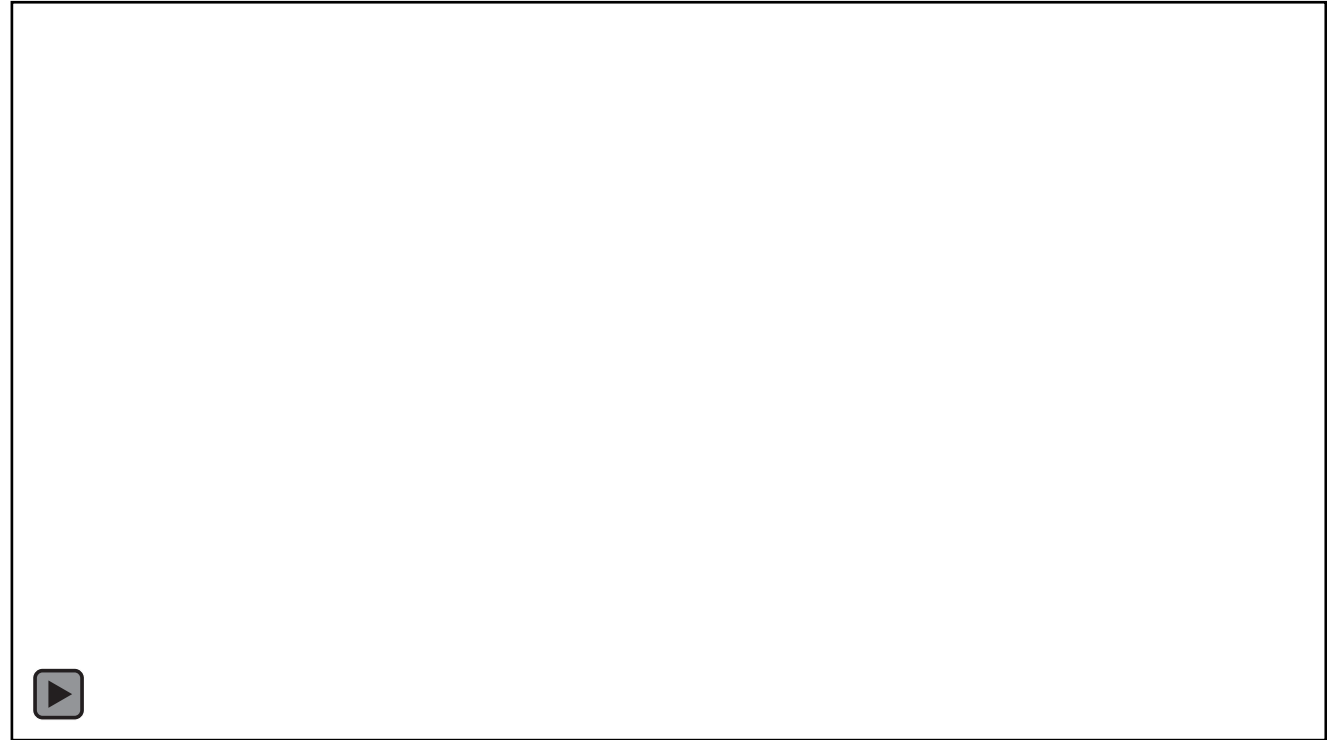


Multi-Satellite Algorithms for TRMM and GPM

<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

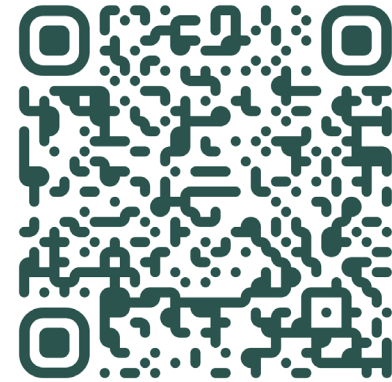
Huffman et al: https://gpm.nasa.gov/sites/default/files/document_files/IMERG_doc_190909.pdf



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/>

GLOBAL PRECIPITATION MEASUREMENT
Missions Data Applications Science Resources Education

Long-lived Tropical Cyclone Freddy Brings Heavy Rain and Flooding to Madagascar and Mozambique
Tropical Cyclone Freddy first made landfall along the east coast of Madagascar just north of the town of Mananjary on Feb. 21, 2023, as a Category 3 cyclone with average winds reported at ~81 mph (130 km/h) and gusts up to ~112 mph (180 km/h). After crossing over Madagascar Freddy continued westward over the Mozambique Channel before making landfall again along the east coast of Mozambique just...

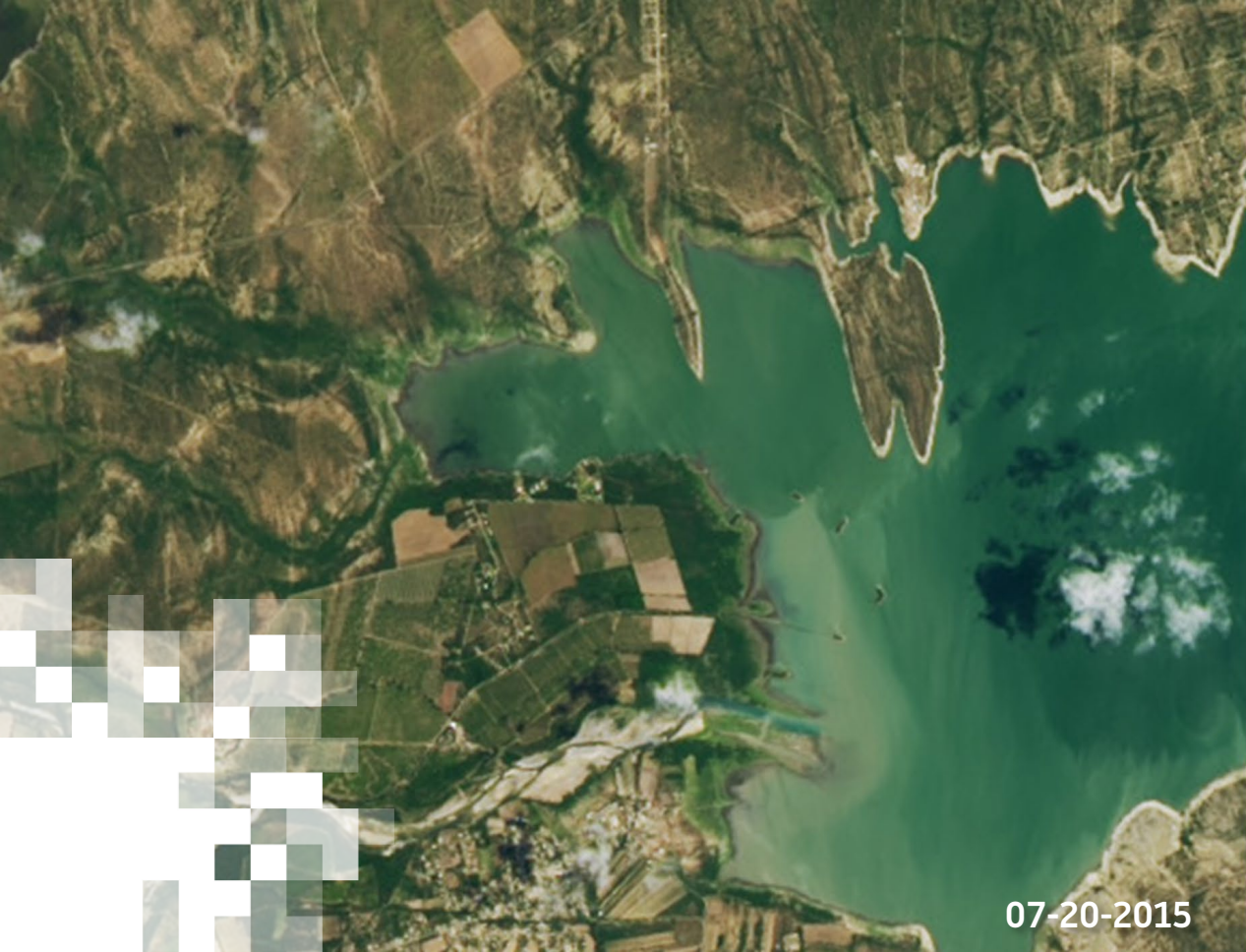
GET DATA
GLOBAL PRECIPITATION MEASUREMENT
New Users Start Here
NASA satellite precipitation data is made freely available to all researchers who wish to use it. Visit this section for a directory of data products, documentation, training materials and more.
Learn more about using GPM data
GPM & TRMM Data Directory

GPM
GLOBAL PRECIPITATION MEASUREMENT
1997 - 2015
2014 - Present
NASA's Global Precipitation Measurement Mission (GPM) uses satellites to measure Earth's rain and snowfall for the benefit of mankind. Launched by NASA and JAXA on Feb. 27th, 2014, GPM is an international mission that sets the standard for spaceborne precipitation measurements. Using a network of satellites united by the GPM Core Observatory, GPM expands on the legacy of the Tropical Rainfall Measuring Mission (TRMM) by providing high quality estimates of Earth's rain and snowfall every 30 minutes. Learn More

APPLICATIONS
GLOBAL PRECIPITATION MEASUREMENT
Learn how GPM datasets are being used by government agencies and other organizations around the world to study natural disasters, public health, freshwater resources, and a variety of other application areas.
Learn more about GPM Applications
Extreme Weather News

Near Real-time IMERG
Latest Half-hour of Earth's Precipitation
The Integrated Multi-satellite Retrievals for GPM product combines precipitation observations using infrared and microwave sensors from a constellation of partner satellites, united by the GPM Core Observatory, to provide near real-time half-hourly precipitation estimates at 10km resolution for the entire globe.
• Learn More about IMERG
• Download IMERG Data
• View this and other GPM visualizations at the NASA Scientific Visualization Studio (SVS)





IMERG Data Access and Visualization

Precipitation Data Access Tools

Tool	Data & Format	Features
<p>PPS/STORM http://storm.pps.eosdis.nasa.gov/</p>	<ul style="list-style-type: none"> • 3-hr Rain Rate (TRMM, GPM, IMERG) • HDF, PNG 	<ul style="list-style-type: none"> • Orbital and Gridded Data Search • Spatial/Temporal Subsetting • Individual Data and FTP Batch Download • Images and Interactive Data Viewer
<p>Giovanni http://giovanni.gsfc.nasa.gov/</p>	<ul style="list-style-type: none"> • 3-hr Rain Rate, Daily, Monthly Rain (TRMM, GPM, IMERG) • NetCDF, GeoTIFF, PNG, KMZ, CSV (time series only) 	<ul style="list-style-type: none"> • Spatial/Temporal Subsetting • Analysis: <ul style="list-style-type: none"> • Time-averaged maps, animation, time series, scatter plots, map correlations, vertical profiles, time-averaged differences • Visualization: <ul style="list-style-type: none"> • Maps, time series, scatter plots, histograms • Near Real-Time Rain Rate Access
<p>NASA GES DISC https://disc.gsfc.nasa.gov/</p>	<ul style="list-style-type: none"> • 3-hr Rain Rate, Daily, Monthly Rain (TRMM, GPM, IMERG) • NetCDF, GeoTIFF 	<ul style="list-style-type: none"> • Spatial/Temporal Subsetting • Bulk download using wget or curl
<p>Google Earth Engine</p>	<ul style="list-style-type: none"> • 3-hr Rain Rate, Daily, 	<ul style="list-style-type: none"> • Spatial/Temporal Subsetting • Analysis: <ul style="list-style-type: none"> • Time-averaged maps, animation, time

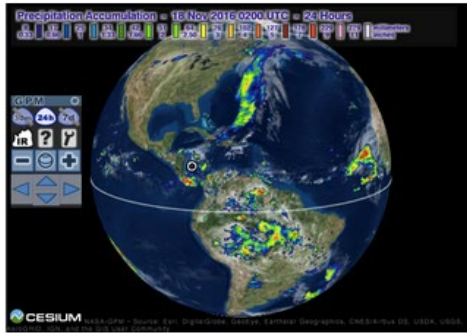
Data Visualization

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

Data Visualization

Global Viewer

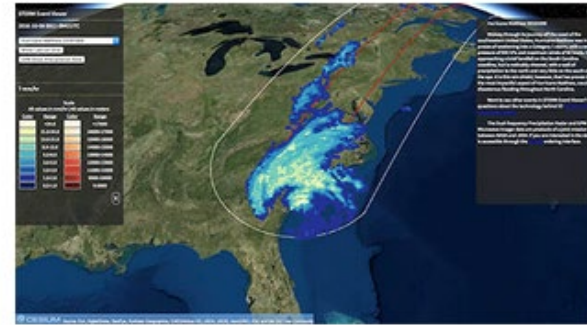
View the latest near-realtime **GPM IMERG** global precipitation datasets (30 minute, 1 day, 7 day) on an interactive 3D globe in your web browser.



STORM Event Viewer

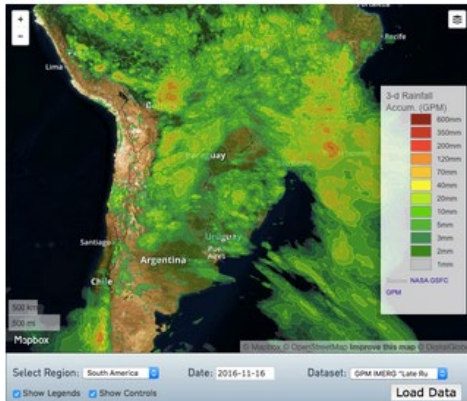
View 2D **GMI** and 3D **DPR** data from the latest extreme weather events on an interactive 3D globe in your web browser.

(click here for mobile version)



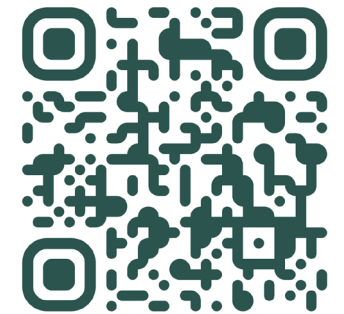
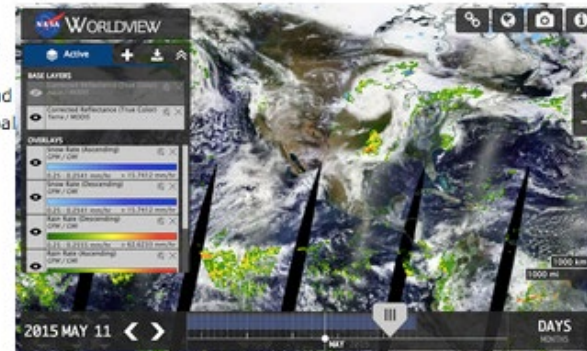
Precipitation and Applications Viewer

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.

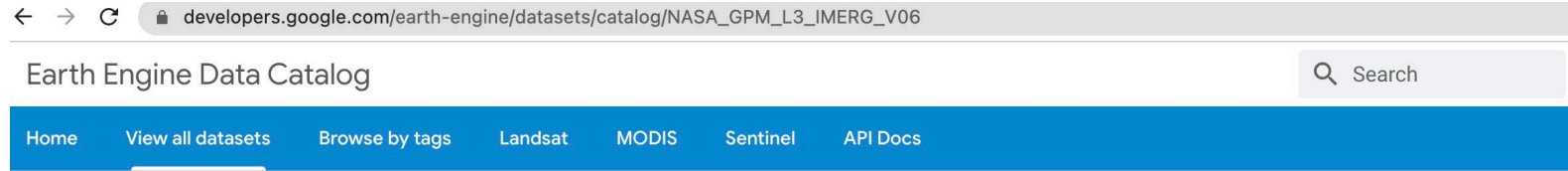


<https://pmm.nasa.gov/data-access/visualization>

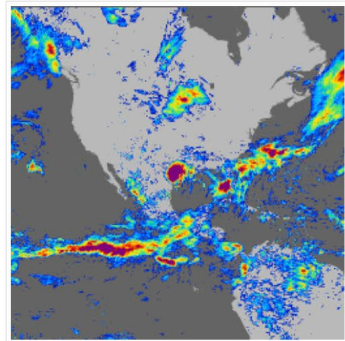


Data Access and Visualization: Google Earth Engine (GEE)

<https://earthengine.google.com/>



GPM: Global Precipitation Measurement (GPM) v6 🔖



Dataset Availability

2000-06-01T00:00:00Z–2023-04-27T04:30:00

Dataset Provider

[NASA GES DISC at NASA Goddard Space Flight Center](#)

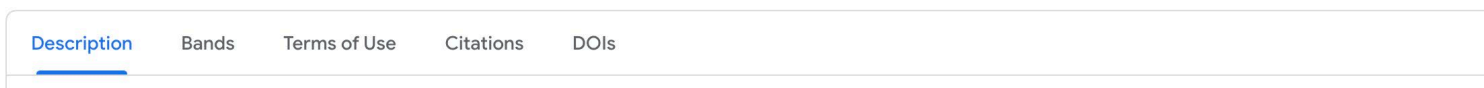
Earth Engine Snippet

```
ee.ImageCollection("NASA/GPM_L3/IMERG_V06")
```

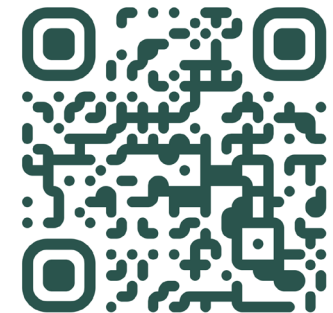
Tags

climate geophysical gpm imerg jaxa nasa precipitation weather

half-hourly

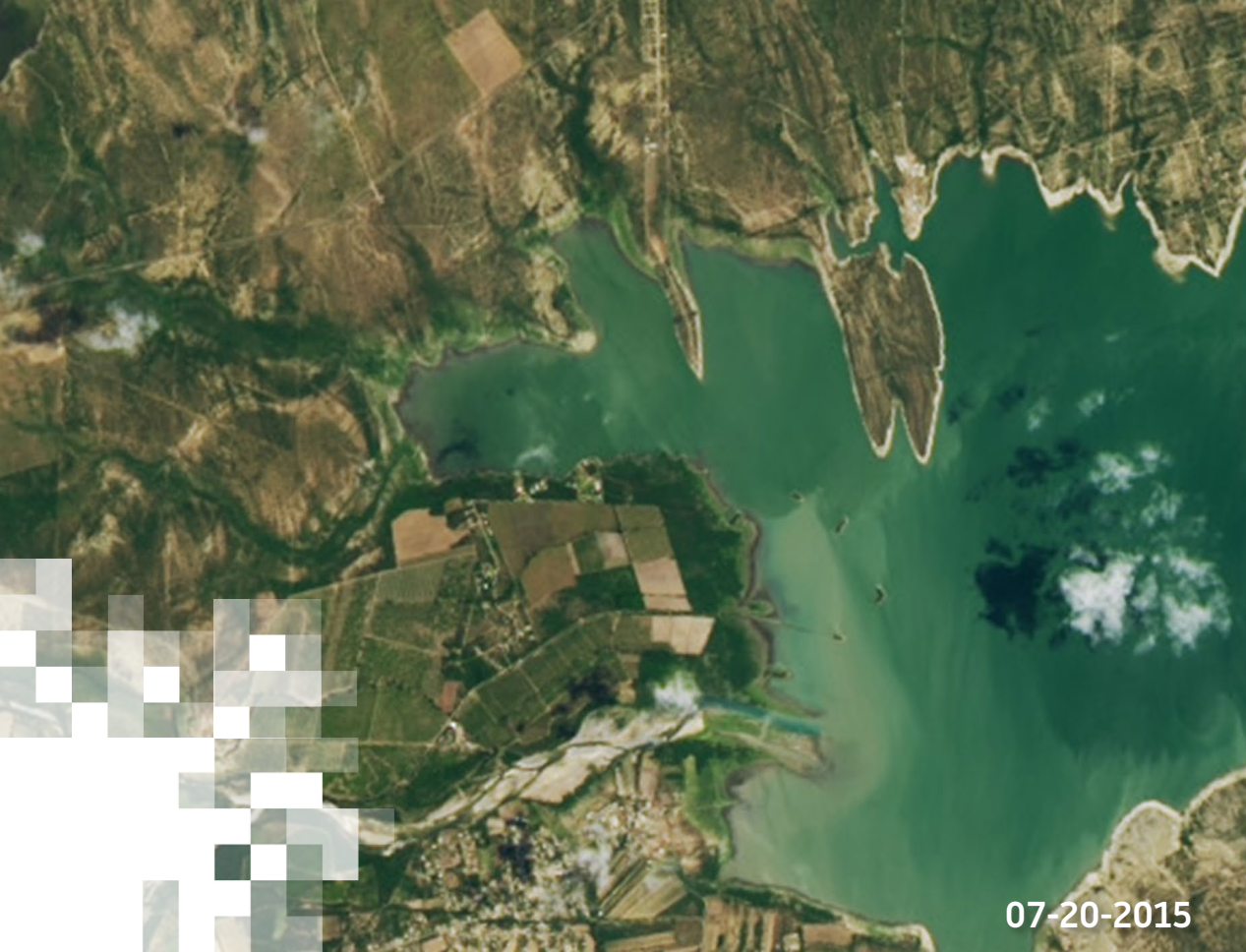


We will be using GEE for precipitation data analysis and visualization.



earthengine.google.com/





Overview of CHIRPS Data

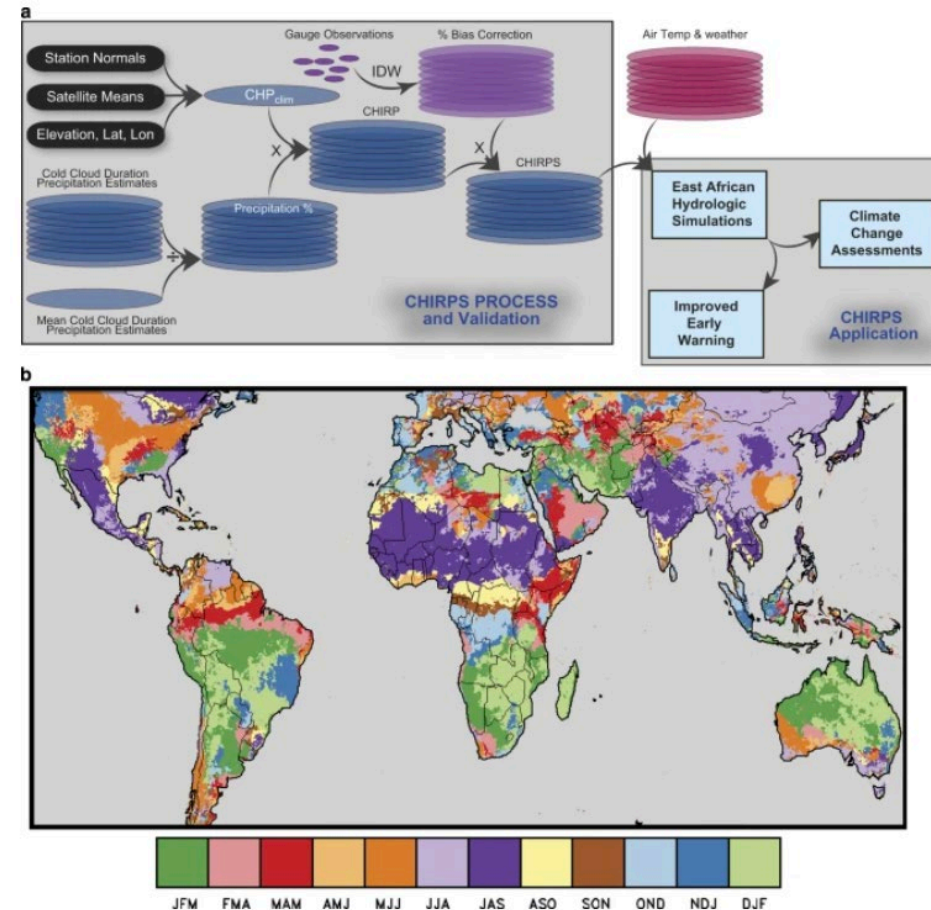
Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)

<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.

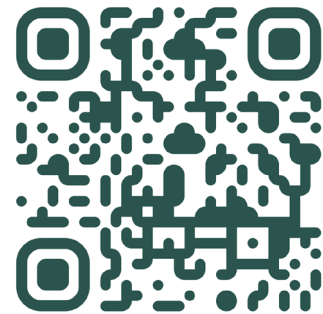
Funk et al., 2015: The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Sci Data* 2, 150066 (2015). <https://doi.org/10.1038/sdata.2015.66>

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



(a) CHIRPS production and application schema.

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



www.chc.ucsb.edu/data/chirps

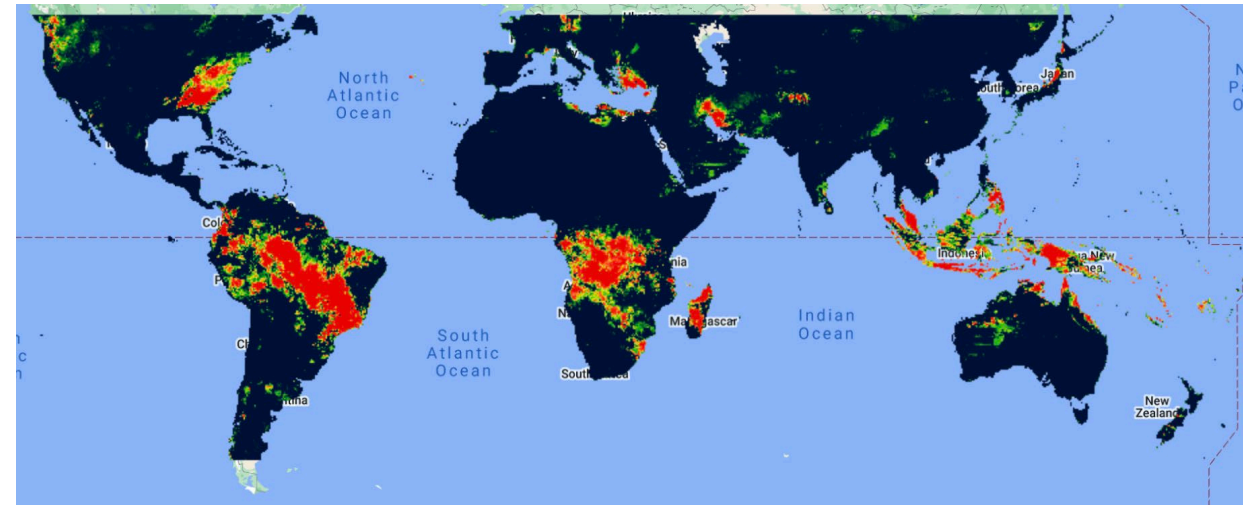


Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)

<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/> 

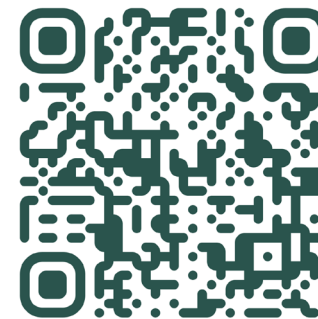
<https://clim-engine-development.appspot.com/fewsNet>

<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

Name	Last modified	Size	Description
Parent Directory	-	-	-
?_DS_Store	2015-07-14 17:42	6.0K	
?.._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	-	
africa_dekad/	2014-11-19 14:37	-	
africa_monthly/	2016-02-03 17:13	-	
africa_pentad/	2014-11-19 14:37	-	
camer-carib_dekad/	2014-11-19 14:40	-	
camer-carib_monthly/	2014-11-19 14:40	-	
camer-carib_pentad/	2014-11-19 14:40	-	
diagnostics/	2019-08-22 10:40	-	
docs/	2015-02-12 14:49	-	
global_2-monthly/	2014-11-19 14:42	-	
global_2-monthly_EWX/	2016-03-16 19:49	-	
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>

Make Map

Variable

Type: Search Datasets
Climate & Hydrology

Dataset:
CHIRPS - 4.8km - Daily

Variable:
Precipitation (PPT)
Units: millimeters

Computation
Resolution (Scale):
4800 m (1/20-deg)

Processing

Statistic (over day range):
Total

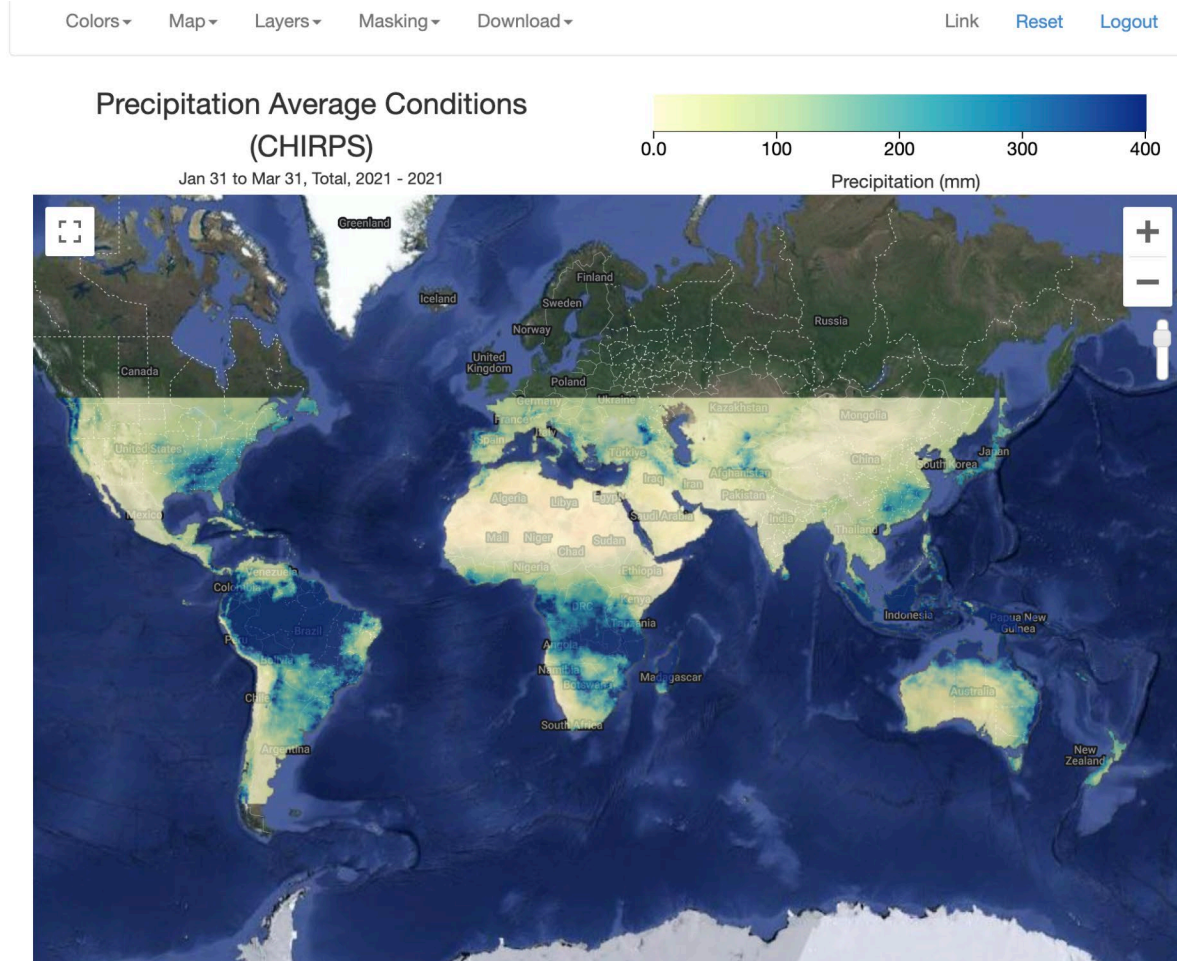
Calculation:
Average Conditions

Time Period

Period of Record: 1981-01-01 to 2023-03-31

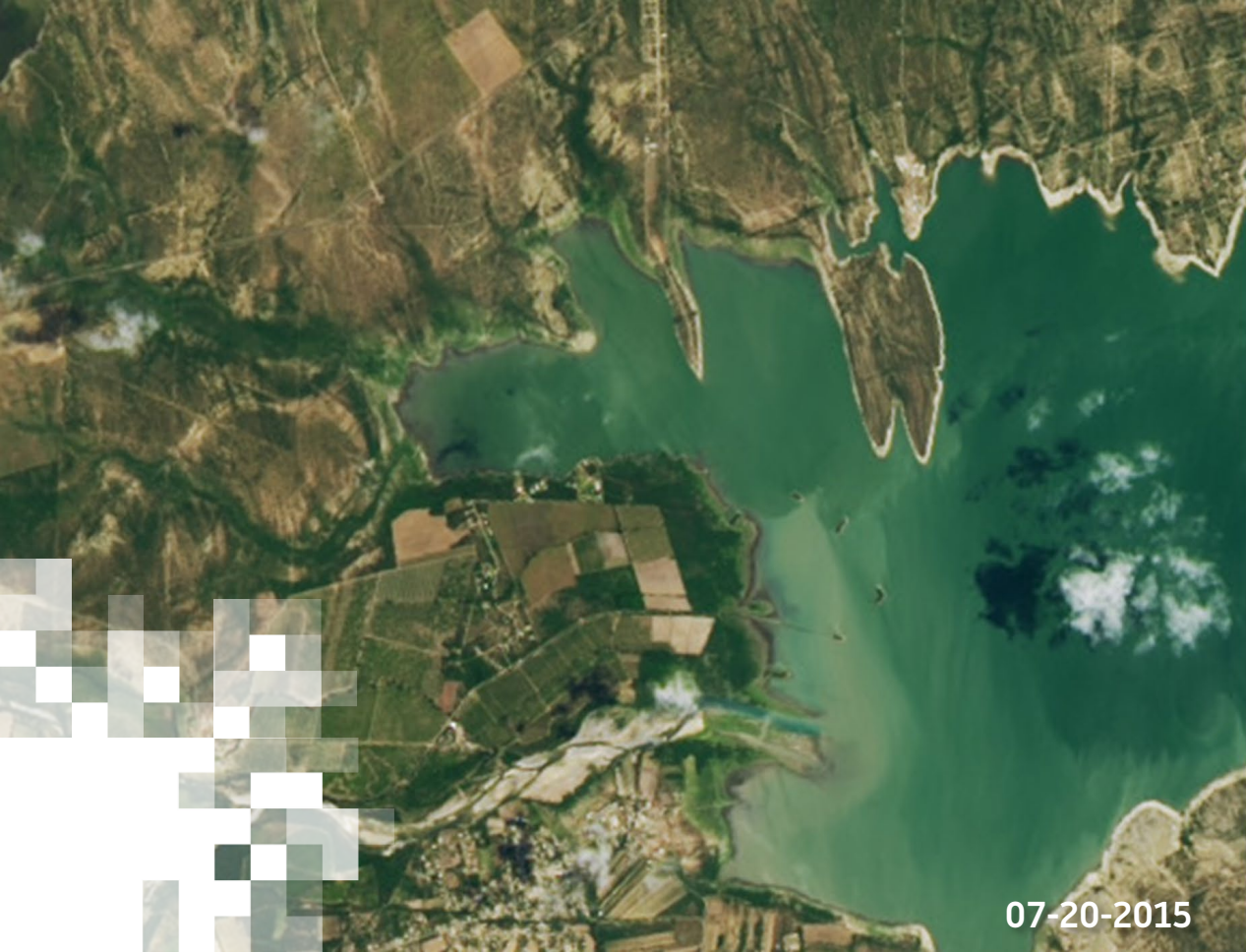
Last 60 Days of Data

Start Day: Jan 31
End Day: Mar 31



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





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



Thank You!

