National Aeronautics and Space Administration

Satellite Remote Sensing for Flood Monitoring and Management

Amita Mehta and Erika Podest

18-19 November 2018

Training Objectives

- Learn about NASA and ISRO remote sensing data and web-tools relevant for flood monitoring and management
- Learn to utilize remote sensing data and web-tools to facilitate flood early warning and to assess and monitor flood extent in support of response, relief, and mitigation activities.

Training Outline: 18 November 2018

Time	Topic	Type	Presenter
	Session 1		
10:30-11:30 AM	Overview of NASA Satellite Remote Sensing and Earth System Modeling Relevant For Flood Monitoring	Presentation	Amita Mehta
11:30 AM-1:00 PM	Data Access and Analysis: Precipitation, Soil Moisture, Weather Data, Terrain, Socioeconomic Data	**Demonstration GDeX, SEDAC, Hands-on Exercise:** QGIS, Giovanni AppEEARS	Amita Mehta Erika Podest
1:00-2:00 PM	**Lunch**		
	Session 2		
2:00-2:30 PM	Data Access and Analysis: Continue	**Hands-on Exercise (continue)**	Amita Mehta Erika Podest
2:30-3:30 PM	Overview of ISRO Satellite Remote Sensing for Flood Monitoring and Mapping	Presentation	C. M. Bhatt
3:30-3:45 PM	**Break**		
	Session 3		
3:45-5:100PM	Data Access and Analysis: Hydrological variables, optical, SAR, scatterometer & altimeter	**Hands-on Exercise:** Bhuvan, NDC	Praveen K. Thakur C M Bhatt
5:00-5:45 PM	Presentation by Participants	QGIS Analysis from Session-1&2	
5:45-6:00 PM	Summary & Q/A		

Training Outline: 19 November 2018

Time	Topic	Type	Presenter
	Session 4		
9:30-10:00 AM	Overview of Flood Monitoring and Mapping Based on Remote Sensing of Land Cover	Presentation	Amita Mehta
10:00-11:00 AM	Overview and Applications of Synthetic Aperture Radar (SAR)	Presentation	Erika Podest
11:00-11:15 AM	Break		
11:15 AM-12:30 PM	SAR Application for Flood Mapping (SNAP)	**Hands-on Exercise**	Erika Podest , Praveen K. Thakur, Amita Mehta
12:30-1:00 PM	Overview of Flood Monitoring and Mapping Based on Precipitation Data	Presentation	Amita Mehta
1:00-2:00 PM	**Lunch**		
	Session 5		
2:00-2:30	NRT Flood Monitoring (ERDS, GDACS, DFO)	**Demonstration**	Amita Mehta
2:30-3:30 PM	ISRO Flood Monitoring and Modeling Tools (Altimeter & Hydro models)	Presentation	Praveen K. Thakur
3:30-3:45 PM	**Break**		
	Session 6		
3:45-5:00 PM	Flood Monitoring Case Study GFMS, MODIS NRT Flood Mapping, IIRS/NRSC flood cases from ISRO	**Hands-on Exercise**	Amita, Erika, Praveen
5:00-5:45 PM	**Presentation by Participants**		
5:45-6:30 PM	Summary, Q/A, & Survey		

Overview of NASA Satellite Remote Sensing and Earth System Modeling Relevant For Flood Monitoring

Presentation Outline

- About ARSET
- Flood Monitoring and Management Data Needs
- NASA Earth Science Data For Flood Monitoring and Management
- Data Description: Precipitation, Soil Moisture, Weather Data [Winds, Temperature, Moisture], Terrain, Socioeconomic Data, Nightlight Imagery
- Data Access Demonstration: Weather, Terrain, Socioeconomic Data
  - Case Study: Kerala Floods, 2018

For details see: https://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing

Sessions 1 and 2B

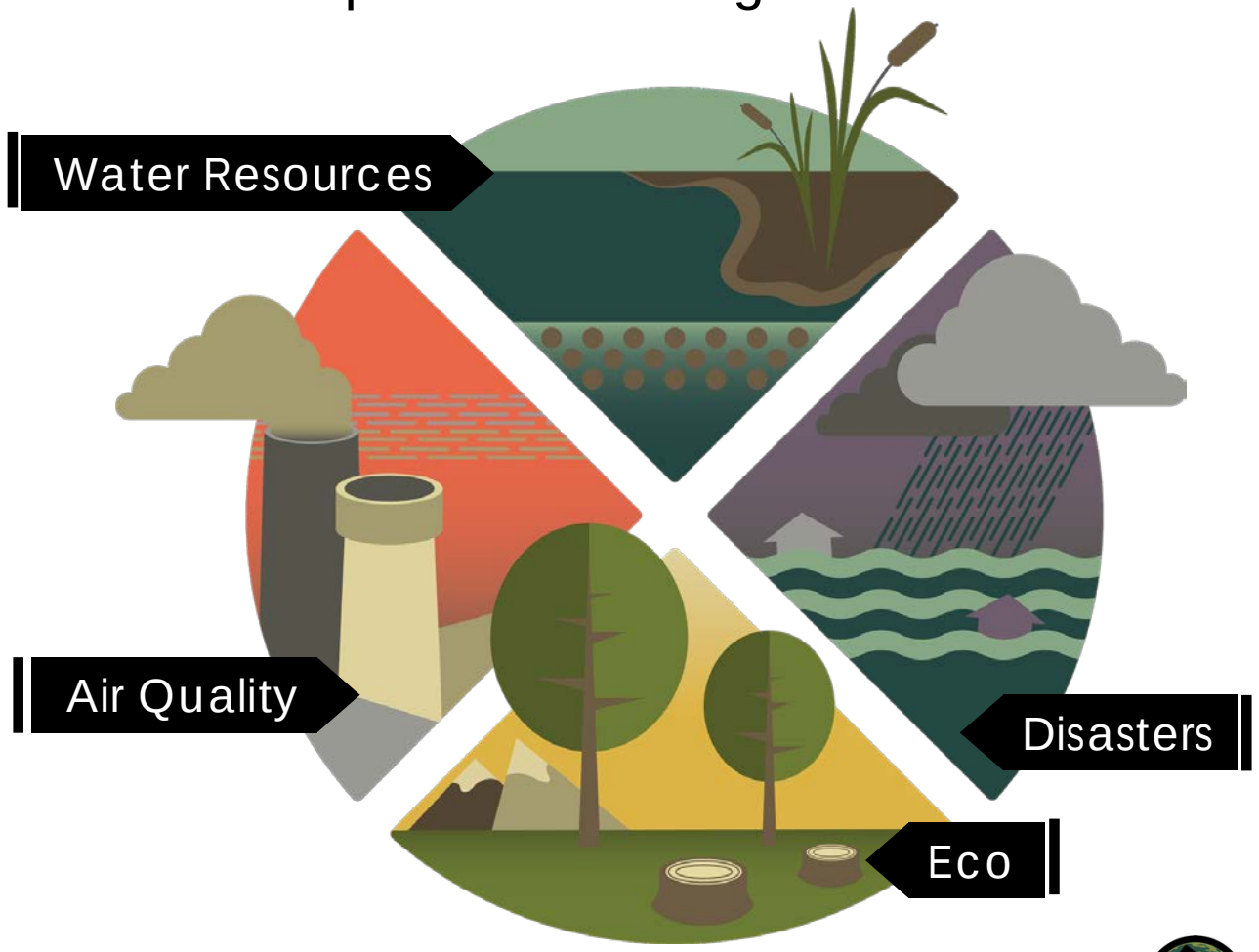
About ARSET

NASA's Applied Remote Sensing Training Program (ARSET)

http://arset.gsfc.nasa.gov/

- Empowering the global community through remote sensing training
- Part of NASA's Applied Sciences Capacity Building Program
- Seeks to increase the use of Earth science in decision-making through training for:
  - policymakers
  - environmental managers
  - other professionals in the public and private sectors

Topics for Trainings Include:



ARSET Training Formats

Online

Typically offered via the internet

2-5 weeks long

1-2 hours a week

Available at all levels

Live & recorded

Free

Materials available in English & Spanish

In-Person

Hosted with a partner

Typically in a computer lab

2-7 days long

Focus on locally-relevant case studies

Certain topics can be presented in Spanish

Train the Trainer

Online or in-person

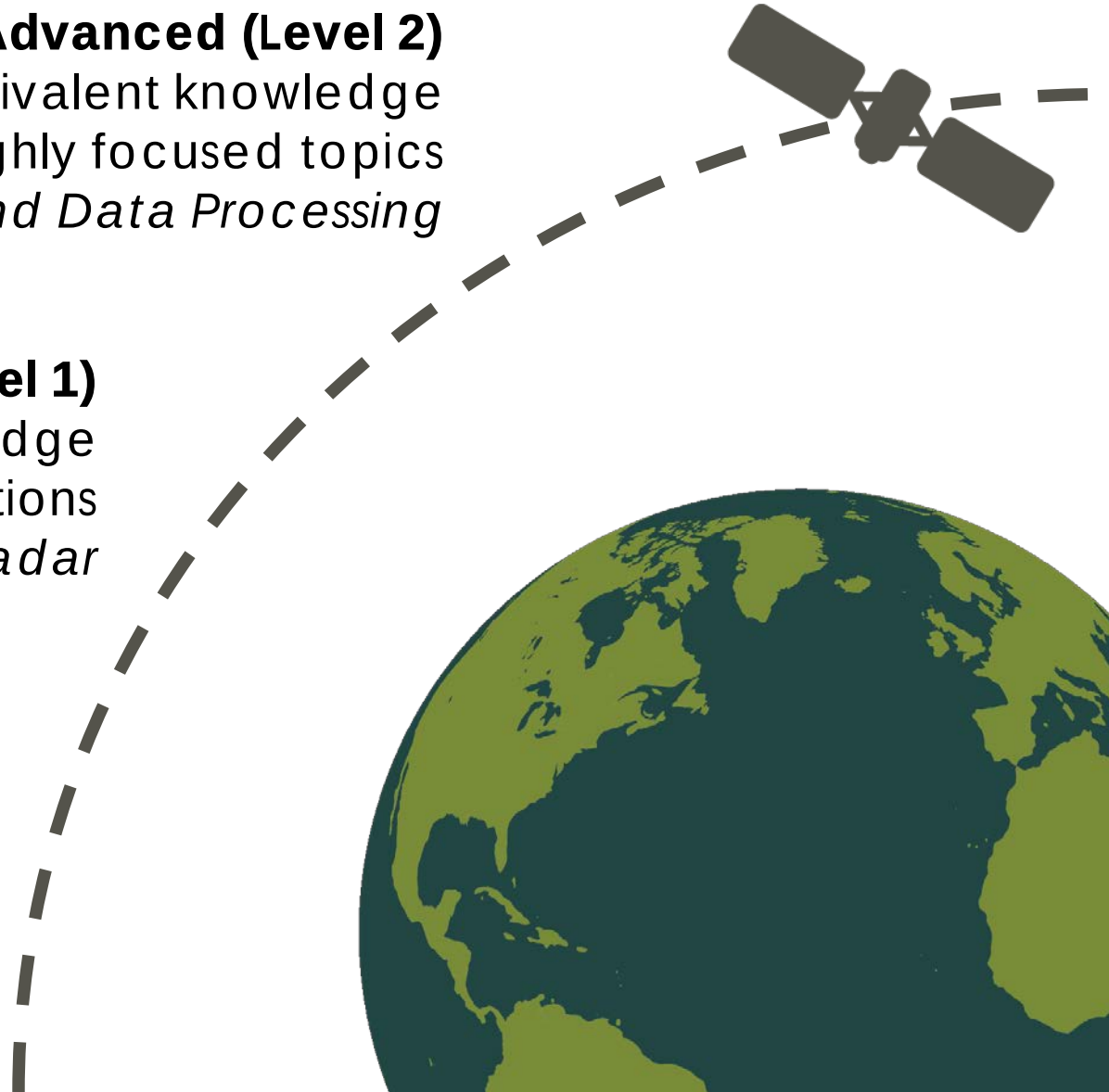
Designed for individuals and organizations looking to develop their own applied remote sensing trainings

ARSET Training Levels

Advanced (Level 2)
Requires level 1 training or equivalent knowledge
In-depth and highly focused topics
Advanced Webinar: SAR Image and Data Processing

Basic (Level 1)
Requires level 0 training or equivalent knowledge
Covers specific applications
Introduction to Synthetic Aperture Radar

Fundamentals (Level 0)
Assumes no prior knowledge of remote sensing
Fundamentals of Remote Sensing



ARSET Team Members

Program Support

- Ana Prados, Program Manager (GSFC)
- Brock Blevins, Training Coordinator (GSFC)
- David Barbato, Spanish Translator (GSFC)
- Annelise Carleton-Hug, Program Evaluator (Consultant)
- Elizabeth Hook, Technical Writer/Editor (GSFC)
- Selwyn Hudson-Odoi, Training Coordinator (GSFC)
- Marines Martins, Project Support (GSFC)
- Stephanie Uz, Program Support (GSFC)

Disasters & Water Resources

- Amita Mehta, Instructor (GSFC)
- Erika Podest, Instructor (JPL)
- Sean Mccartne, GIS Specialist (GSFC)

Land & Wildfires

- Cynthia Schmidt, Lead (ARC)
- Amber Jean McCullum, Instructor (ARC)

Health & Air Quality

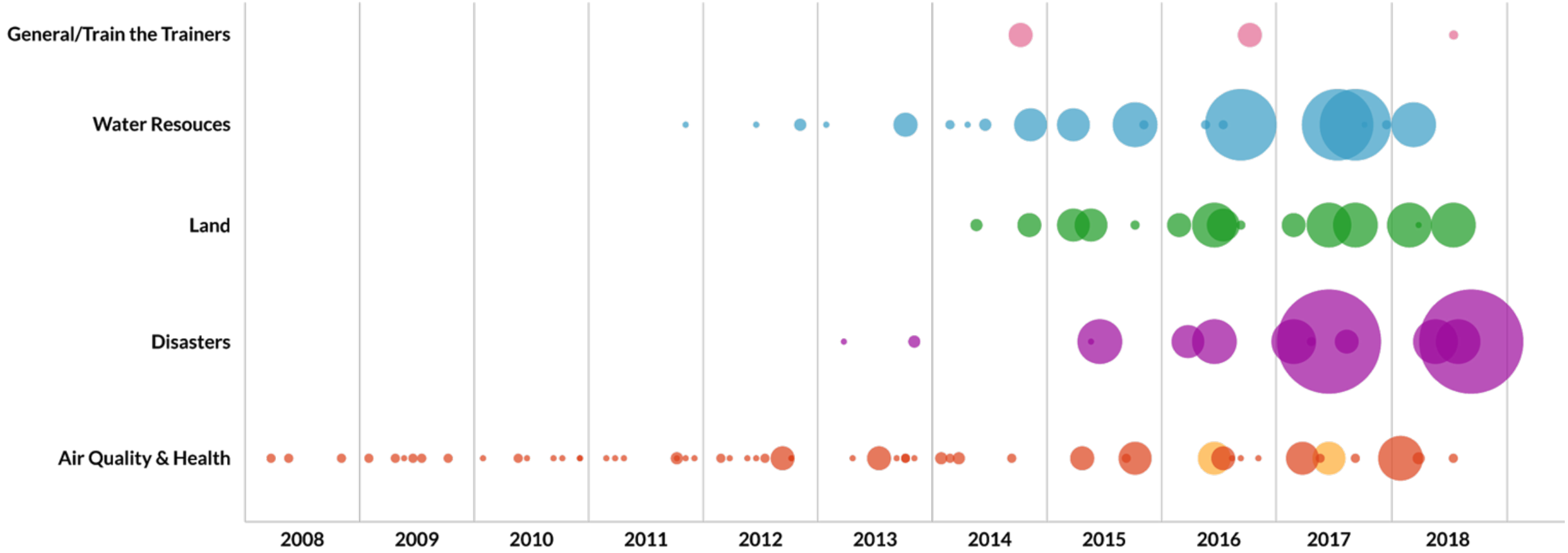
- Pawan Gupta, Lead (GSFC)
- Melanie Cook, Instructor (GSFC)

Acknowledgement:

- We wish to thank Nancy Searby for her continued support

ARSET Trainings

100 trainings | 13,000+ participants | 160+ countries | 3,700+ organizations

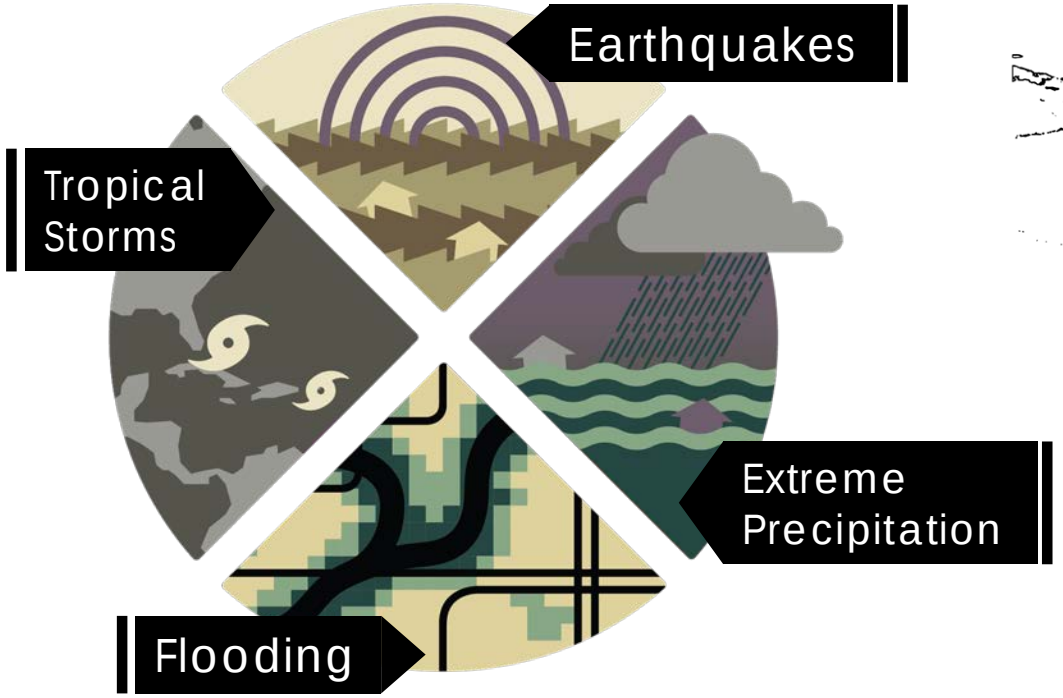


* size of bubble corresponds to number of attendees

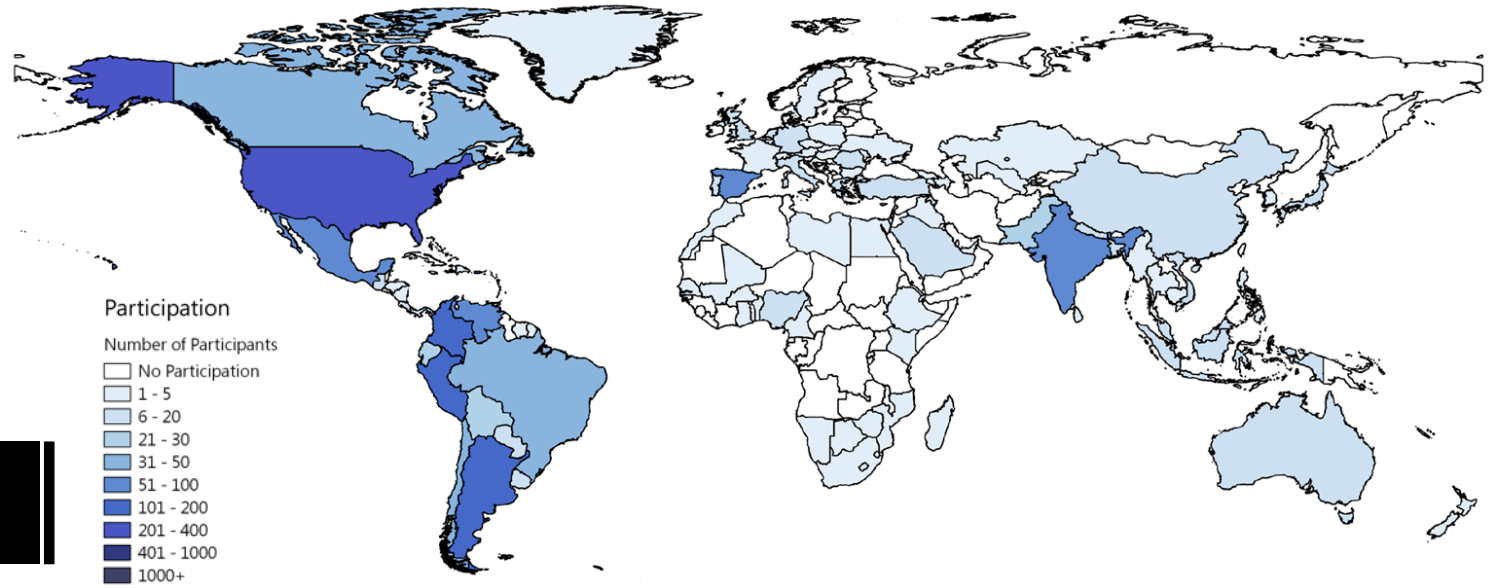
ARSET Training Impacts: Disaster Management (2013 – 2018)

13 trainings | 4,990+ participants | 130+ countries | 1,435+ organizations

Training Topics Include…



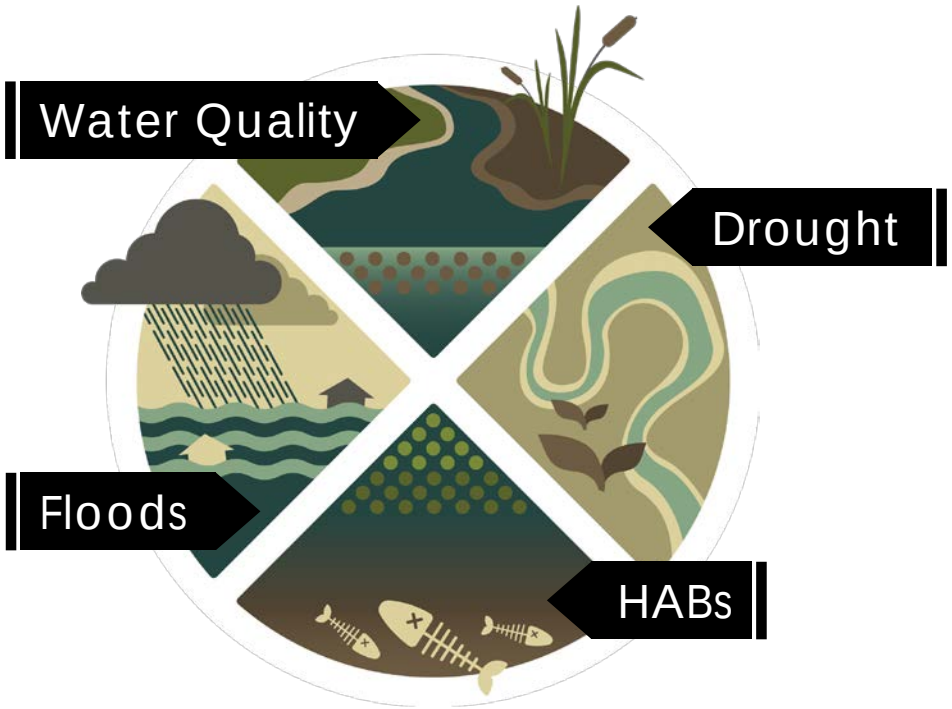
Global Disaster Training Attendees (2017)



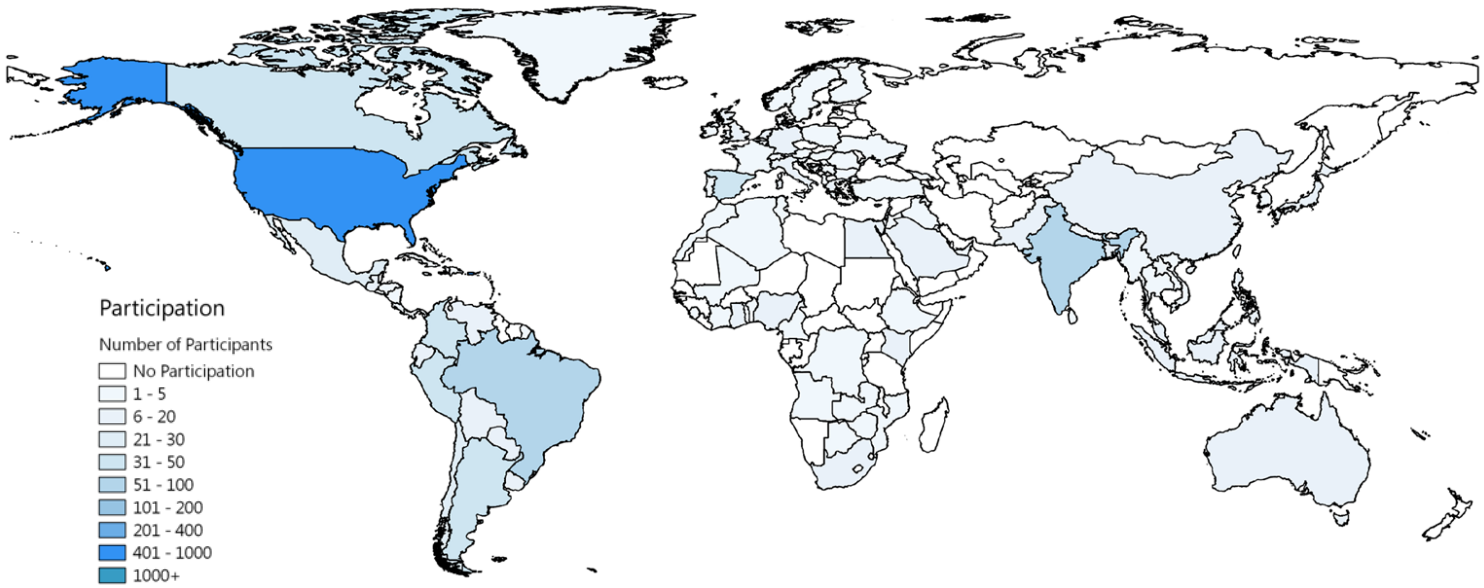
ARSET Training Impacts: Water Resources (2014 – 2018)

23 trainings | 4,300+ participants | 135+ countries | 1,770+ organizations

Training Topics Include…

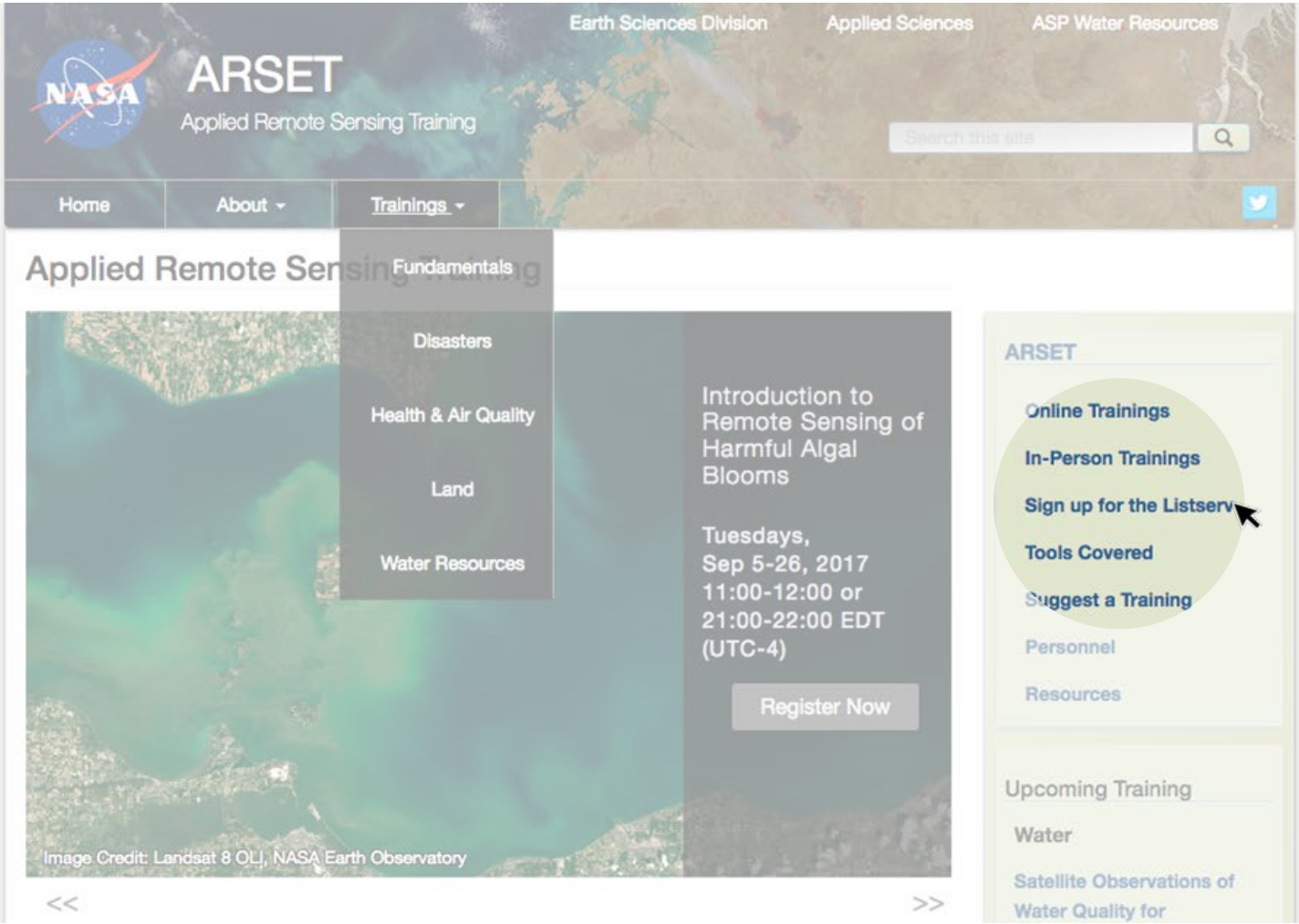


Global Water Resources Training Attendees (2017)



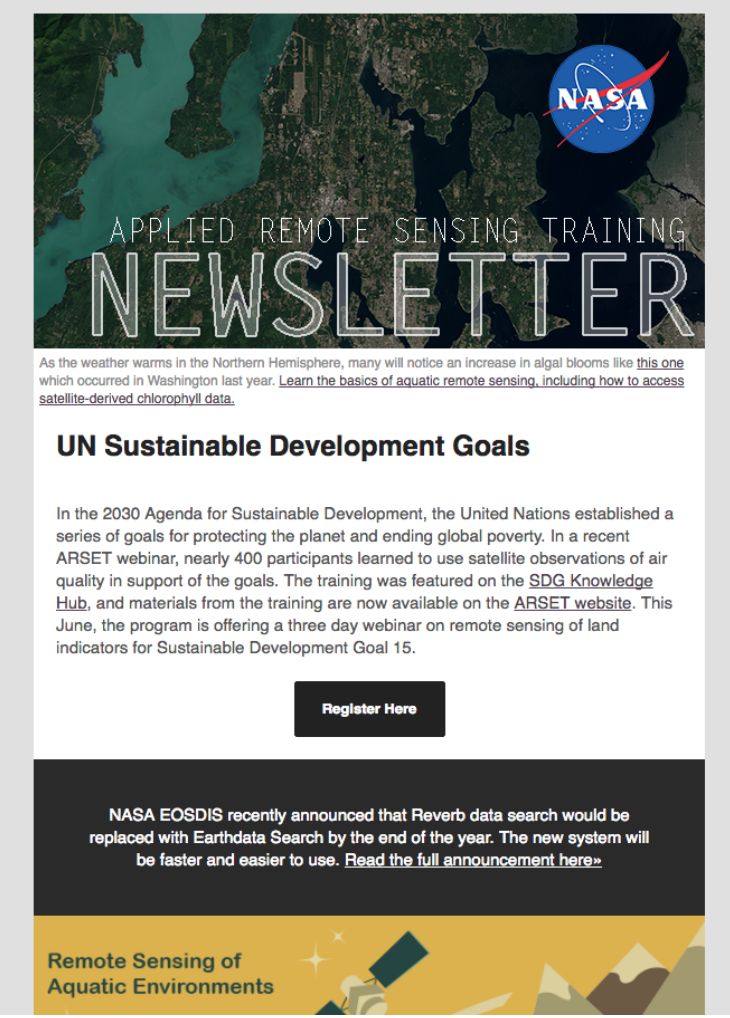
Learn More About ARSET

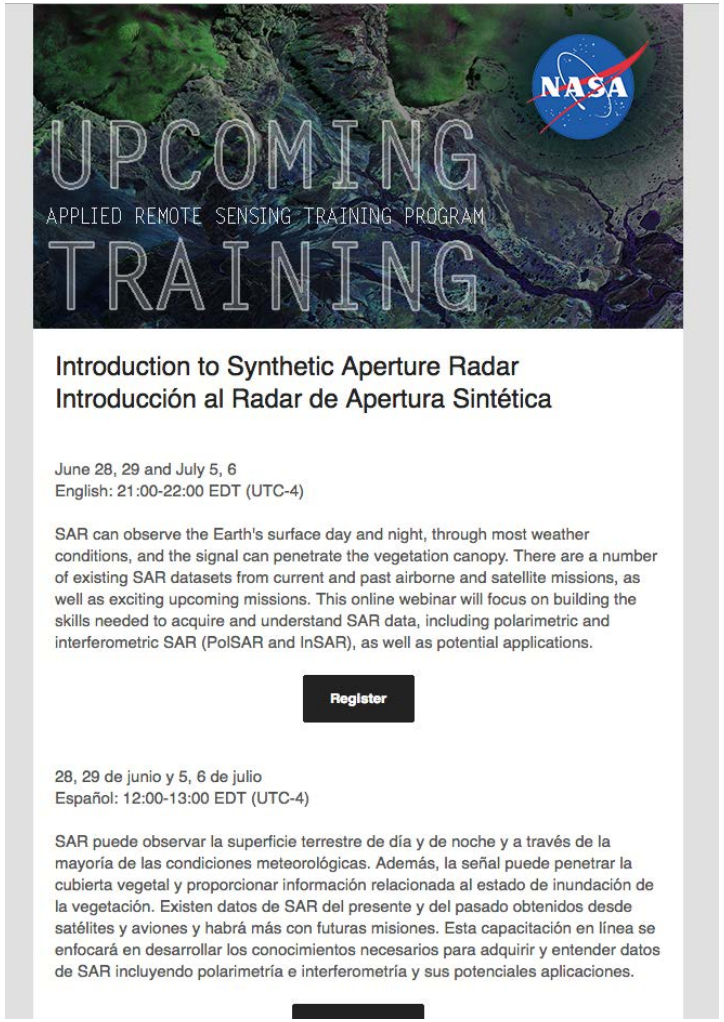
http://arset.gsfc.nasa.gov/

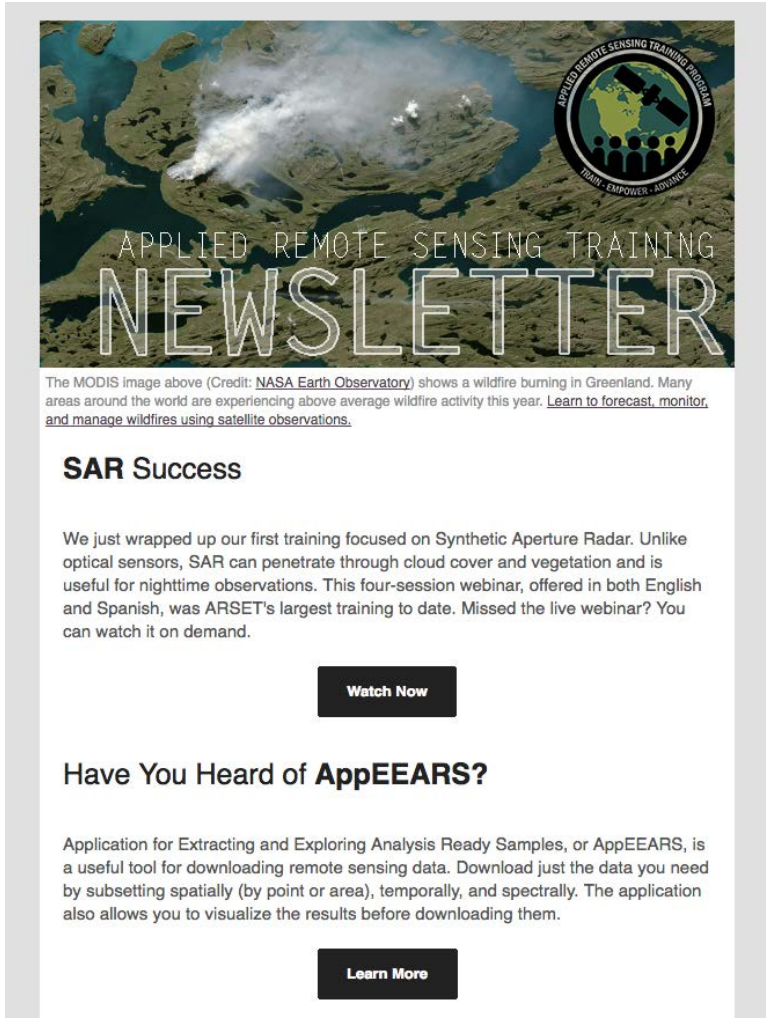


Sign up for the ARSET Listserv

https://lists.nasa.gov/mailman/listinfo/arset







Flood Monitoring and Management Data Needs

About Floods

https://www.ready.gov/floods

- Flooding is a temporary overflow of water onto land that is normally dry
- The most common disaster affecting human lives
- Can cause infrastructure damage, power outages
- Disrupt transportation
- Create landslides
- About six inches (15 cm) of moving water can knock one down, and one foot (30 cm) of moving water can sweep a vehicle away!

About 12% of the Indian subcontinent is flood prone and about 76% of the coastline is prone to cyclone-related flooding

http://iopscience.iop.org/article/10.1088/1755-1315/80/1/012054/pdf

Types of Floods

- Pluvial Floods: Result of intense rainfall or snowmelt
- Fluvial Floods: Result of riverine flooding and over-bank flow
- Storm Surge Floods: Occur in coastal regions due to winds and wave activities
- Overflow of dams or water reservoirs

Flash Floods, Riverine Floods, Urban Floods, Coastal Floods, and Ponding all occur in India due to monsoon rains and tropical cyclones

https://www.mapsofindia.com/top-ten/geography/india-flood.html

Flood Monitoring and Management

Require geophysical and socioeconomic data:

- Floodplain Map: Terrain, Digital Elevation Model, Low-lying areas
- Precipitation Intensity, Frequency
- River Stage, Streamflow, Inundation
- Coastal Surges and Inundation
- Land Use Change: Exposed Soil versus Built-up Areas, Soil Moisture
- Population, Infrastructure
- Drainage and Storm Water System Capacity (Urban Floods)
- Flood Return Period
- Hydrology and Routing Model

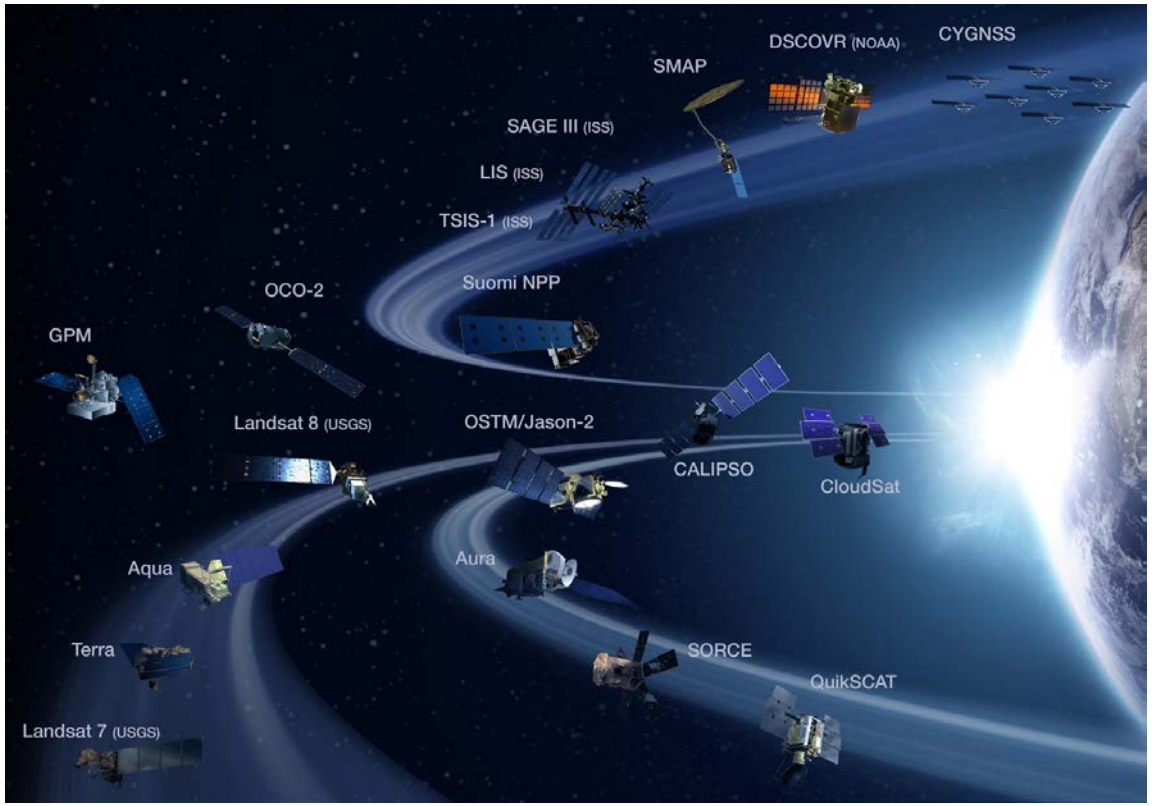
Flood Monitoring and Management Data Needs

Flood Stage	Data
Watch (Conditions Favorable for Flooding)	Weather Forecast (Precipitation Systems, Storms), Probability of Flooding based on past cases, Hydrologic Model Forecast of Streamflow
Warning (Flooding Imminent or Occurring)	Near Real-time Precipitation, Streamflow, Surface Inundation
Response (During Flooding)	Near Real-time Precipitation, Streamflow, Surface Inundation, Power Outages, Rescue Plans, Equipment, Routes, Shelter
Relief and Recovery (Post-flood)	Near Real-time Precipitation, Streamflow, Surface Inundation, Ponding, Power Outages, Damage Assessment, Infrastructure Safety, Relief Activity planning
Mitigation (Long-term Preparedness and Planning)	Historical Information: Flood Cases, Precipitation, Streamflow, Inundation, Damage data

Population, Infrastructure (buildings, roads), Elevation and Slope, Location (Urban/Rural, Coastal, Land Cover Type)

NASA Earth Science Data For Flood Monitoring and Management

Satellites Relevant for Flood Monitoring and Management



- European Space Agency
  - Sentinel-1A: 4/2014 – present
  - Sentinel-1B: 4/2016 – present

- Landsat: 07/1972 – present
- Tropical Rainfall Measuring Mission (TRMM): 11/1997 – 04/2015
- Global Precipitation Measurement mission (GPM): 02/2014 – present
- Terra: 12/1999 – present
- Aqua: 05/2002 – present
- Suomi National Polar-Orbiting Partnership (SNPP): 11/2011-Present
- Soil Moisture Active Passive (SMAP): 01/2015 – present
- Shuttle Radar Topography Mission (SRTM) 2001

Satellites and Sensors for Monitoring Flooding

Satellites	Session
Landsat 7, 8	Session 1 & 2
TRMM & GPM	Session 1 & 2
Terra & Aqua	Session 4
SNPP	Session 1
SMAP	Session 1 & 2
Sentinel 1A and 1B/SAR	Sessions 3 & 4
Space Shuttle Endeavour/SRTM	Session 1 & 2

NASA Earth System Model and Ancillary Data for Monitoring and Management

Source	Session
Earth System Model Goddard Earth Observing System (GEOS-5)	Session 1& 2
SEDAC	Session 1 & 2

Remote Sensing-Based Flood Monitoring Tools

Tool	Session
NRT Global Flood Mapping https://floodmap.modaps.eosdis.nasa.gov// Dartmouth Flood Observatory http://floodobservatory.colorado.edu/	Sessions 4, 5, 6
Global flood Monitoring System (GFMS) http://flood.umd.edu/ Extreme Rainfall Detection System (ERDS) http://erds.ithacaweb.org/	Sessions 4, 5, 6
GDACS: http://www.gdacs.org/	Sessions 5

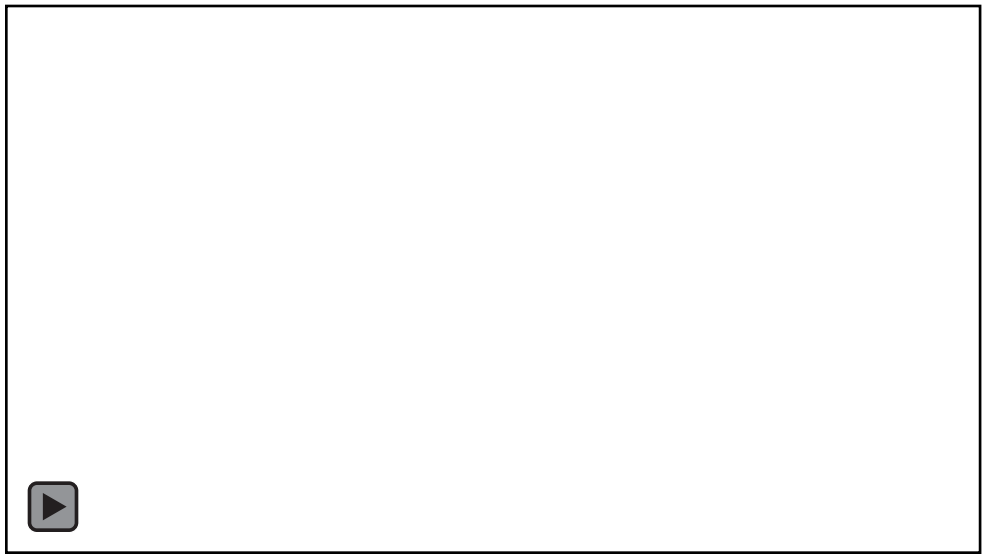
Data Description: Precipitation, Soil Moisture, Weather Data [Winds, Temperature, Moisture], Terrain, Socioeconomic Data, Night Light Imagery

Integrated Multi-satellitE Retrievals for GPM (IMERG)

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

- GPM Core satellite data (GMI & DPR) are used to calibrate and combine microwave data from GPM constellation satellites
- GPM constellation satellites include:
  - GCOM-W
  - DMSP
  - Megha-Tropiques
  - MetOp-B
  - NOAA-N'
  - NPP
  - NPOESS
- Final rain product is calibrated with rain gauge analyses on monthly time scale

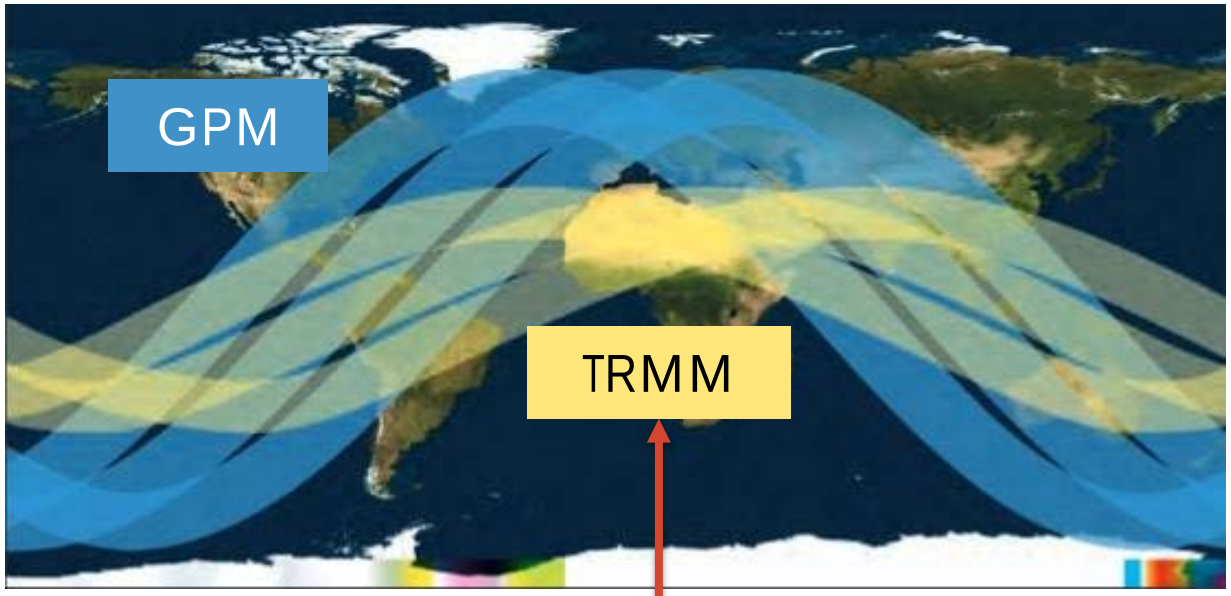
GPM Core and Constellation Satellites



Global Precipitation Measurement (GPM) Mission

http://pmm.nasa.gov/GPM/

- Core satellite launched Feb 27, 2014
  - non-polar, low-inclination orbit
    - Altitude: 407 km
- Spatial Coverage
  - 16 day orbits a day, covering global area between 65°S – 65°N
- Along with constellation of satellites, GPM has a revisit time of 2-4 hrs over land
- Sensors:
  - GMI (GPM Microwave Imager)
  - DPR (Dual Precipitation Radar



Tropical Rainfall Measurement Mission

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
- Allow improved spatial and temporal coverage of precipitation data
- TRMM Multi-satellite Precipitation Analysis (**TMPA**)
- Widely used for applications
- TMPA will be extended to match Integrated Multi-satellitE Retrievals for GPM (**IMERG**)

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)
- Native time intervals are half-hourly and monthly (final only)
  - Value-added products at 3 hrs,1, 3, and 7 days are available
  - Initial release covers 60°N-60°S – will be extended to 90°N-90°S

TMPA and IMERG

	TMPA	IMERG
Spatial Resolution	0.25° x 0.25°	0.1° x 0.1°
Spatial Coverage	Global, 50° S-50°N	Global, 60°S-60°N (will be extended from pole to pole)
Temporal Resolution	3 hours	30 minutes
Temporal Coverage	12/1997 – Present*	2/27/2014 – Present+

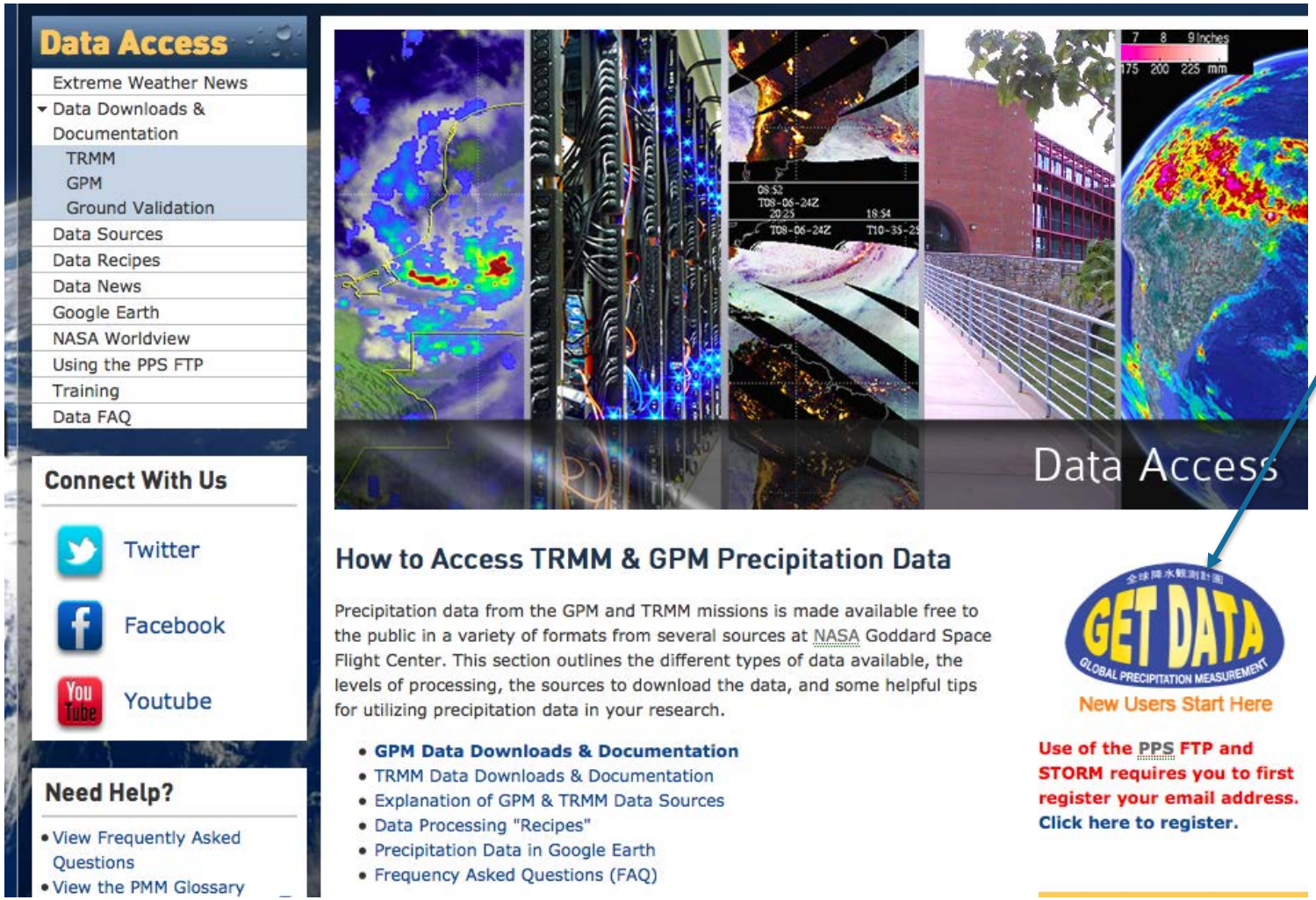
* After April 8, 2015, TRMM climatological calibration is being used to generate TMPA

+TMPA and IMERG combined data will be available in early 2018 at IMERG data resolution

TMPA is widely used for flood modeling and IMERG will replace it in the near future

GPM IMERG Data Access

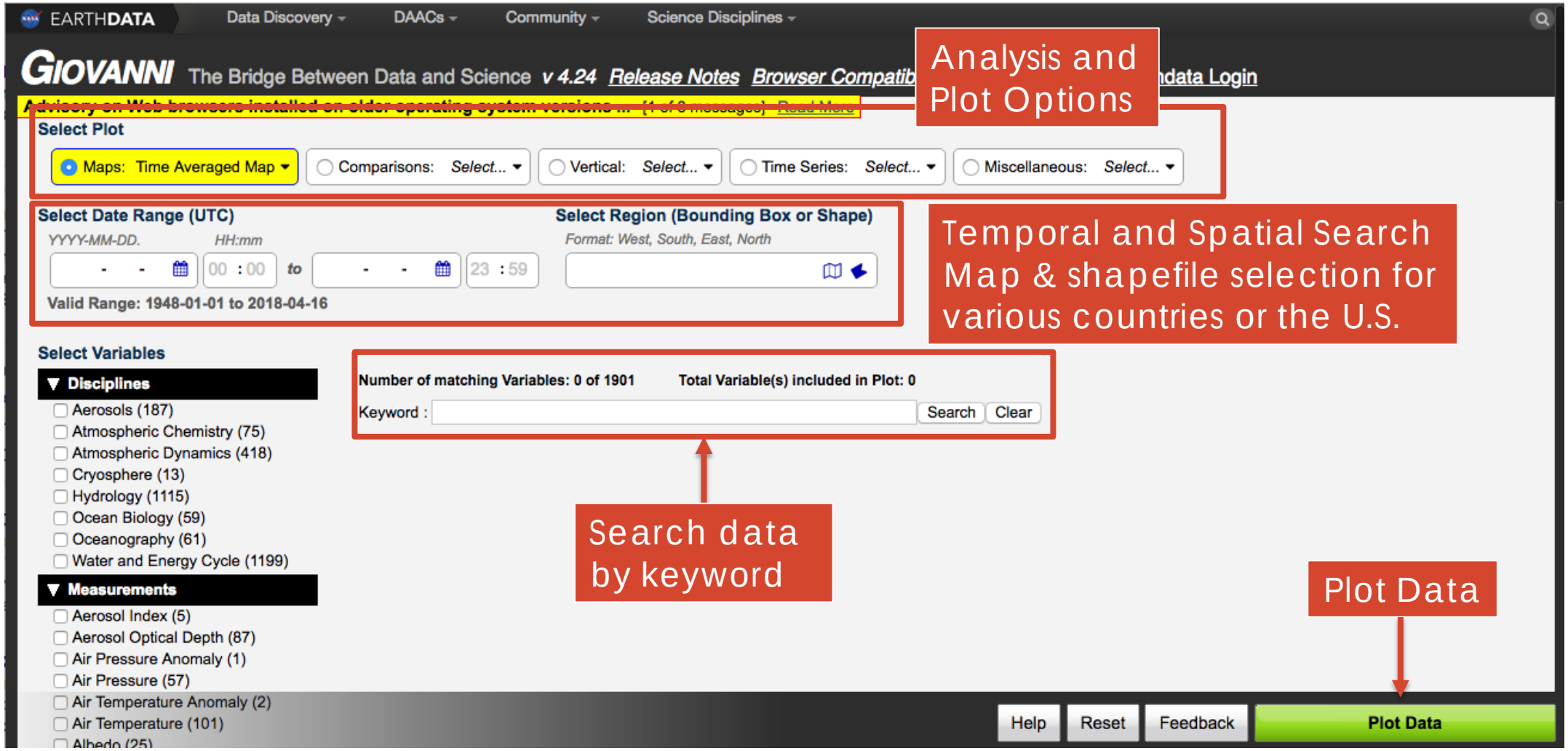
https://pmm.nasa.gov/data-access



- All about GPM data
  - Including updates, news, and FAQ
- Quick data access links and user registration
- For more information about GPM and data access visit: https://pmm.nasa.gov/training

Precipitation Data Access and Analysis

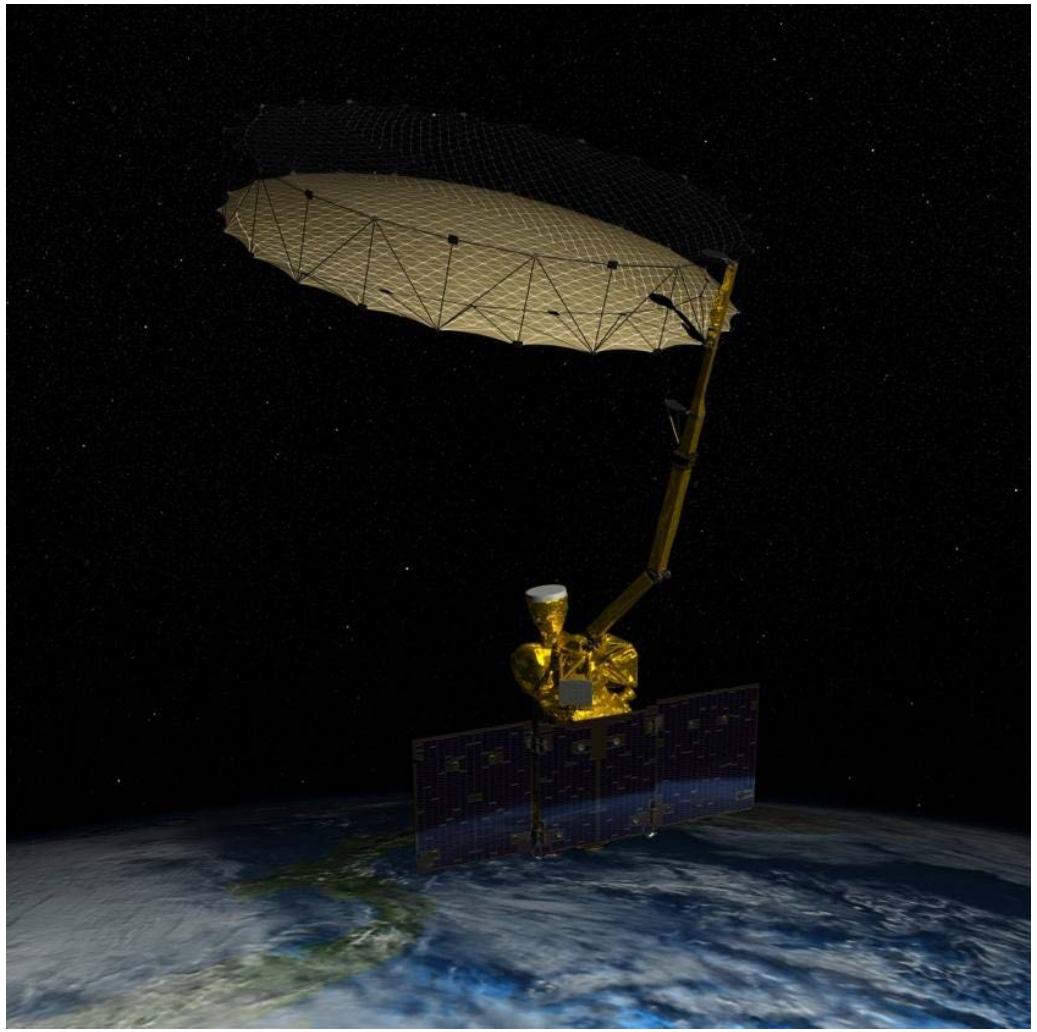
https://giovanni.gsfc.nasa.gov/giovanni/



Soil Moisture Active Passive (SMAP)

http://smap.jpl.nasa.gov

- Polar Orbit
  - Altitude: 685 km
- Spatial Coverage:
  - Global
- Launched Jan 31, 2015
- Temporal Coverage:
  - April 2015 – present
- Sensors:
  - Microwave Radiometer
  - Microwave Radar (not currently available)

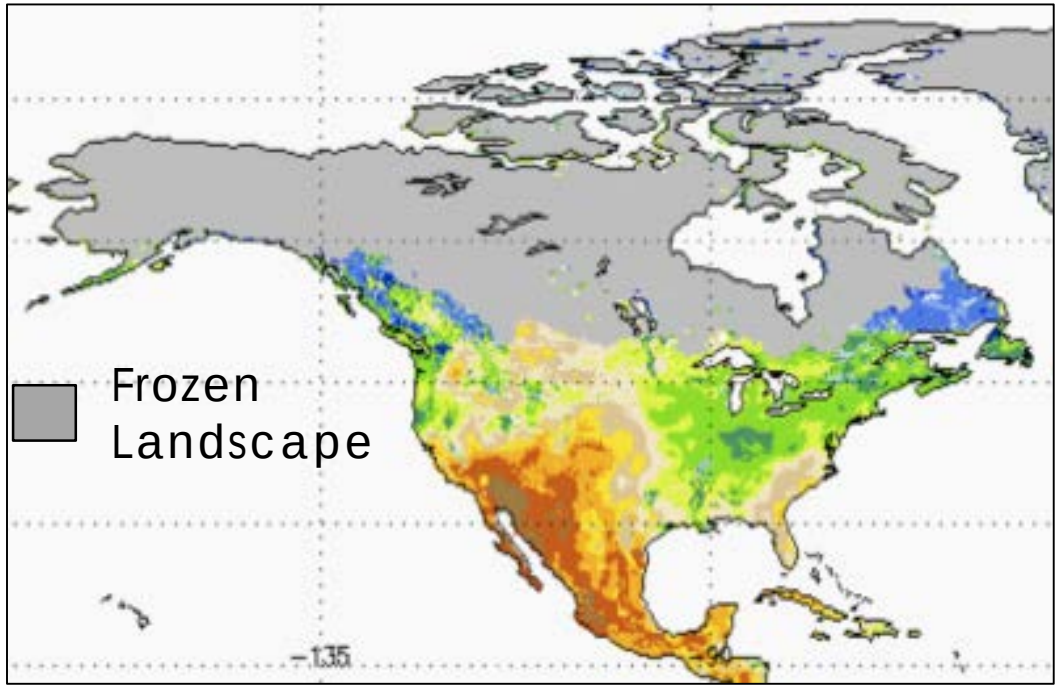


SMAP Microwave Radiometer & Radar

http://smap.jpl.nasa.gov/observatory/instrument/

- Radiometer:
  - Swath: 1,000 km
  - Frequency: 1.41 GHz
  - Polarization: H, V, 3rd & 4th Stokes
  - Resolution: 40 km
- Radar: designed to work as Synthetic Aperture Radar (SAR)
  - Frequency: 1.26 GHz
  - Polarization: VV, HH, HV
  - Resolution: 3 km
  - **Stopped operating after Jul 7, 2015**
- Temporal Resolution:
  - Every 3 days

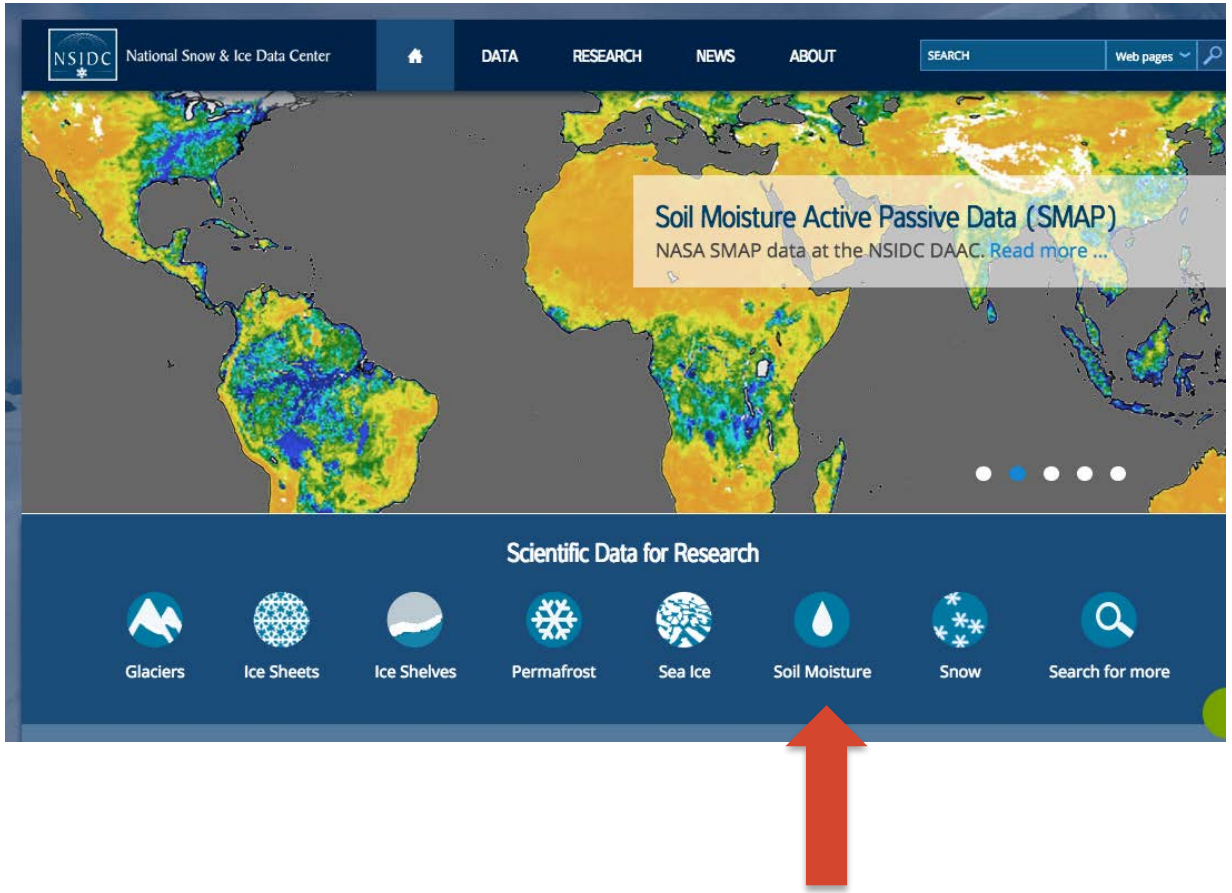
Measures moisture in the top 5 cm of soil

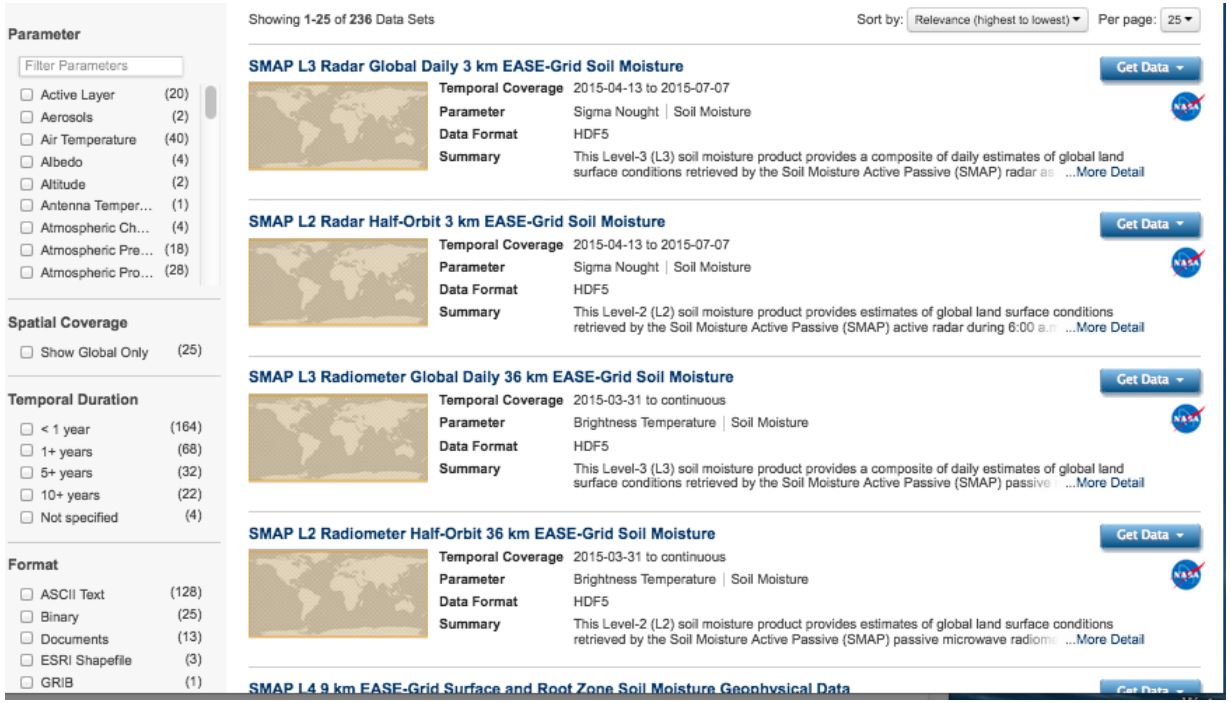


useful for flood monitoring

Where do you get SMAP data?

Available from the National Snow & Ice Data Center:
http://nsidc.org/data/search/#keywords=soil+moisture/



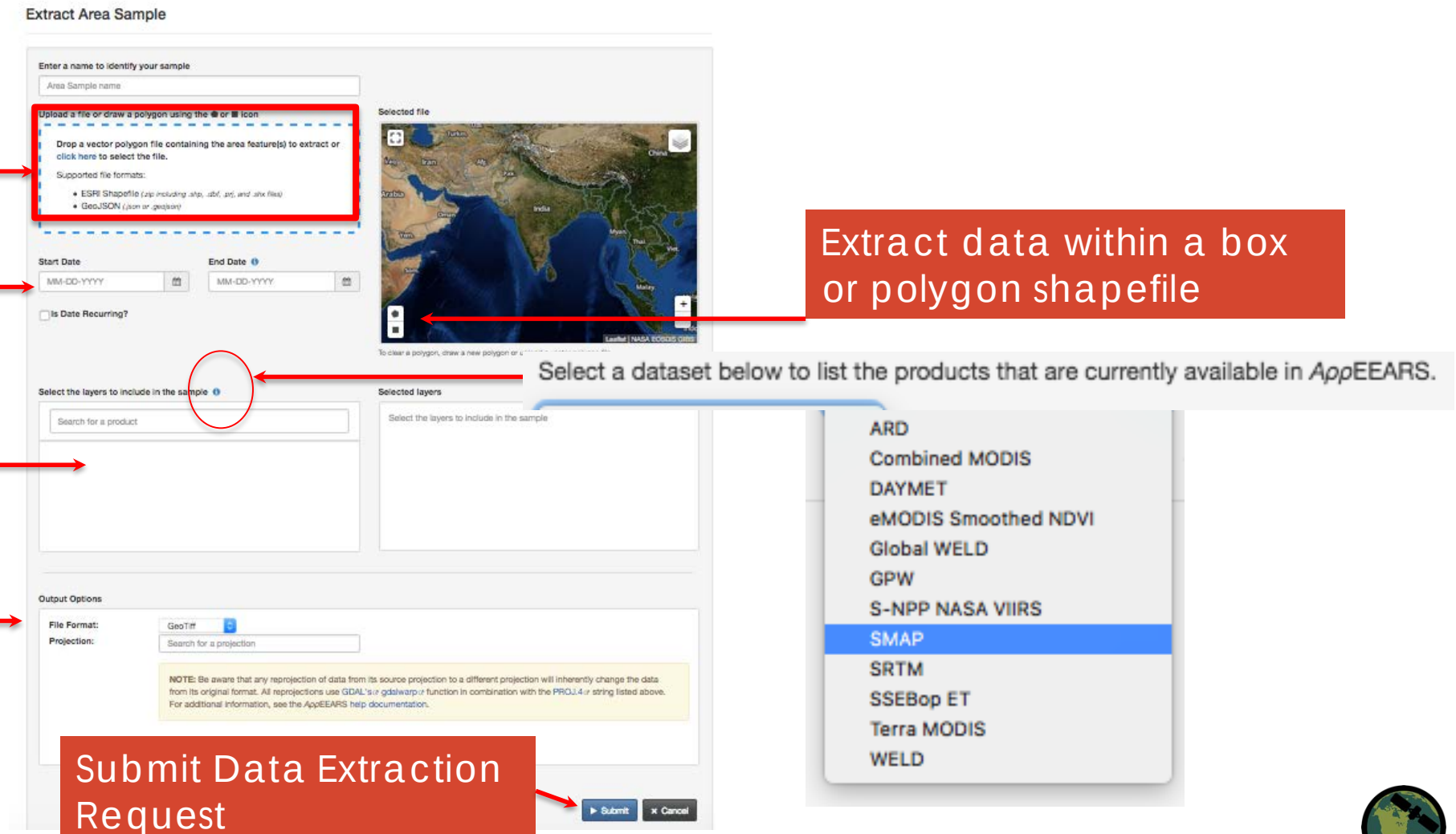


Level 2 to Level 4 data

Where do you get SMAP data?

Application for **E**xtracting and **E**xploring **A**nalysis **R**eady **S**amples (***A**pp***EEARS**)

https://lpdaacsvc.cr.usgs.gov/appeears/



Extract data by custom shapefile

Temporal Selection

Data & Layer Selection

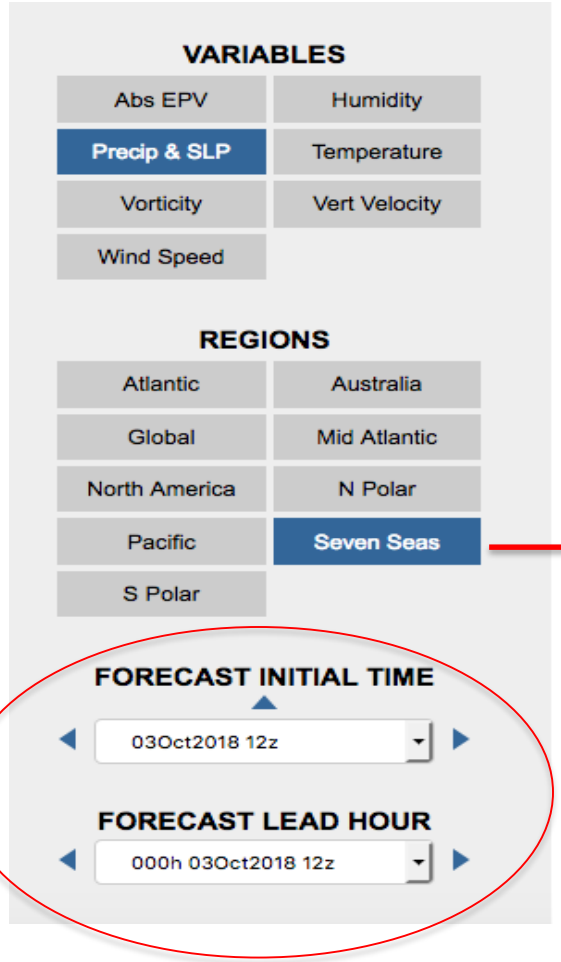
Data Format

Extract data within a box or polygon shapefile

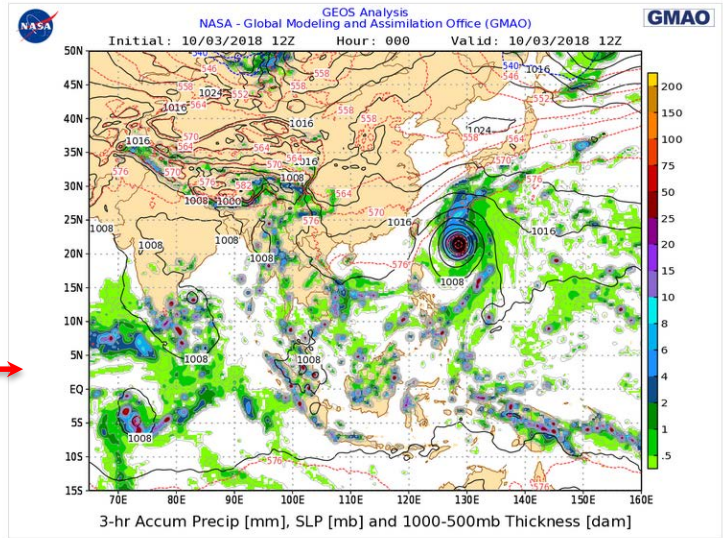
Submit Data Extraction Request

GEOS-5 Weather Data Maps – NRT and Forecast

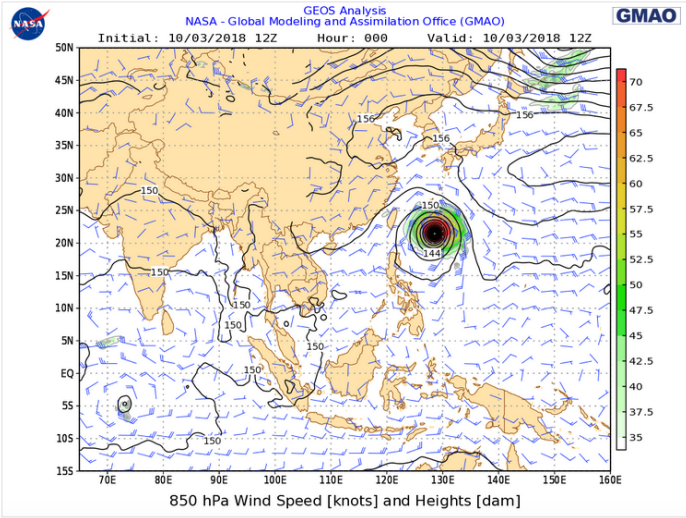
https://fluid.nccs.nasa.gov/weather/wxmaps/

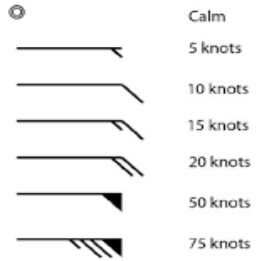


Precipitation and SLP



Wind Speed & Direction





GEOS-5 Weather Data Access

https://portal.nccs.nasa.gov/datashare/gmao_ops/pub/fp/das/

Data Access

» HTTPS

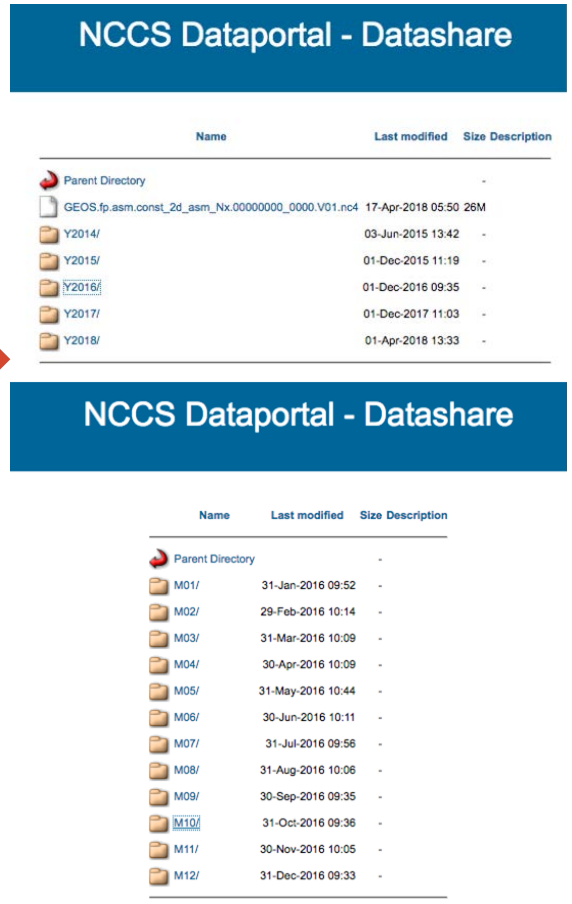
Assimilation | Forecast

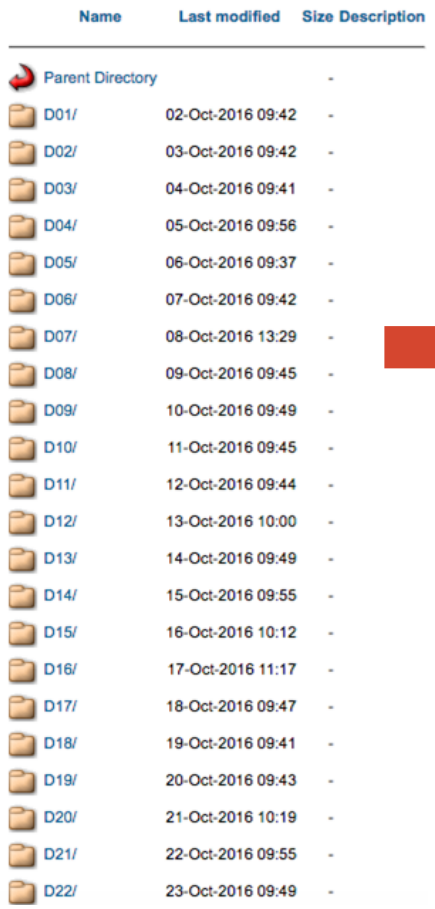
» OPeNDAP

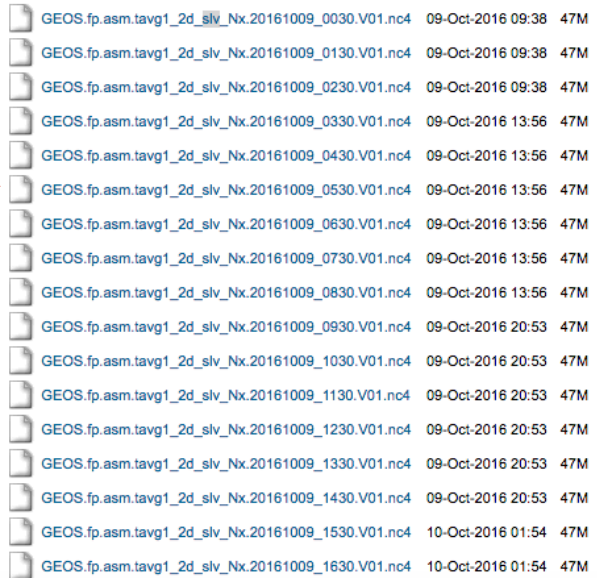
Assimilation | Forecast

» FTP (No Password)

Assimilation | Forecast





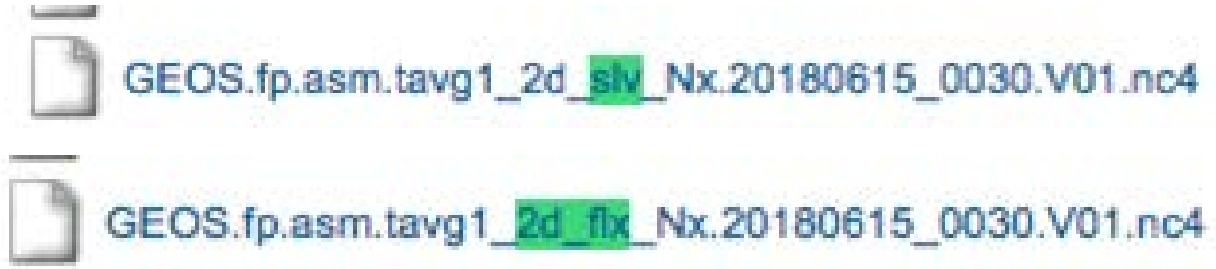


HTTP Files | Year & Month | Day | Hourly Files

GEOS-5 Weather Data Access

https://portal.nccs.nasa.gov/datashare/gmao_ops/pub/fp/das/

- Download Single Level (SLV) files (hourly_ For Winds and Humidity
- Download 2-d Time Averaged Surface Flux Diagnostics for Precipitation
- See this document for filename convention: https://gmao.gsfc.nasa.gov/products/documents/GEOS_5_FP_File_Specification_ON4v1_1.pdf

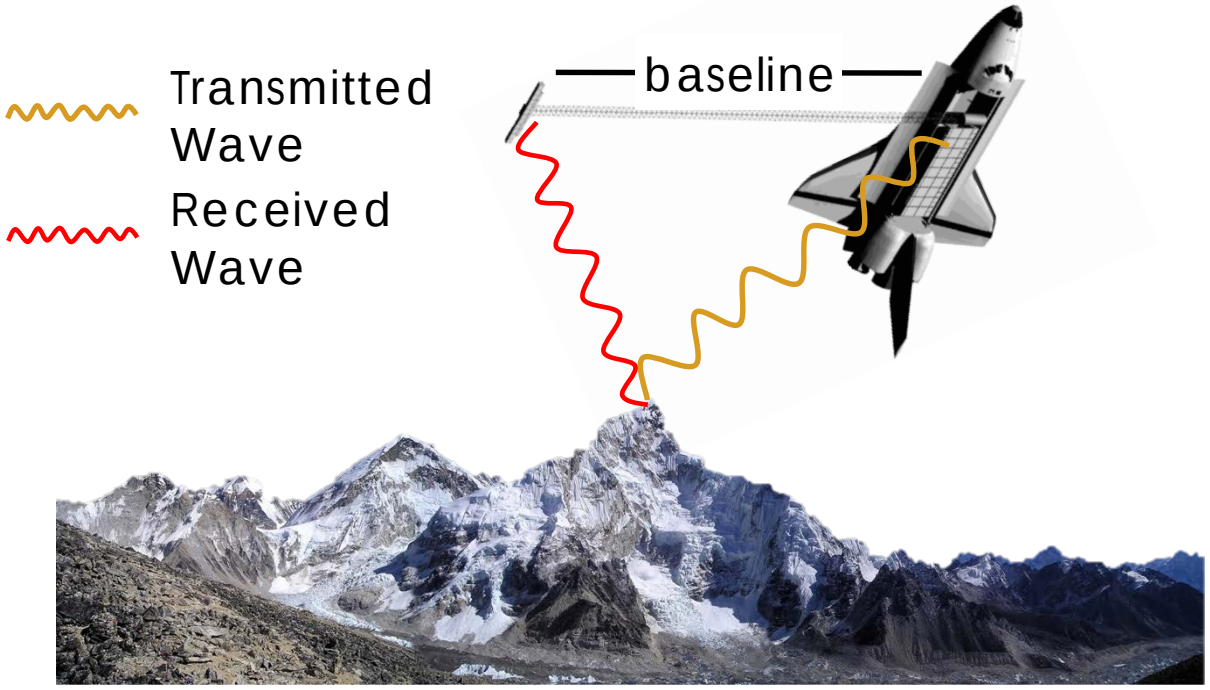


Terrain Data From Shuttle Radar Topography Mission (SRTM)

https://www2.jpl.nasa.gov/srtm/mission.htm

- A C-band (5.6 cm) SAR mission
- On NASA Space Shuttle Endeavour
- Completed February 2000
- 176 orbits around Earth in 11 days
- Generated digital elevation maps of all land between 60°N- 56°S latitude
- ~80% of Earth's total land mass
- SRTM used interferometry to generate topographic (elevation) maps
- For detailed information see: https://arset.gsfc.nasa.gov/sites/default/files/water/Brazil_2017/Day3/S6P2.pdf

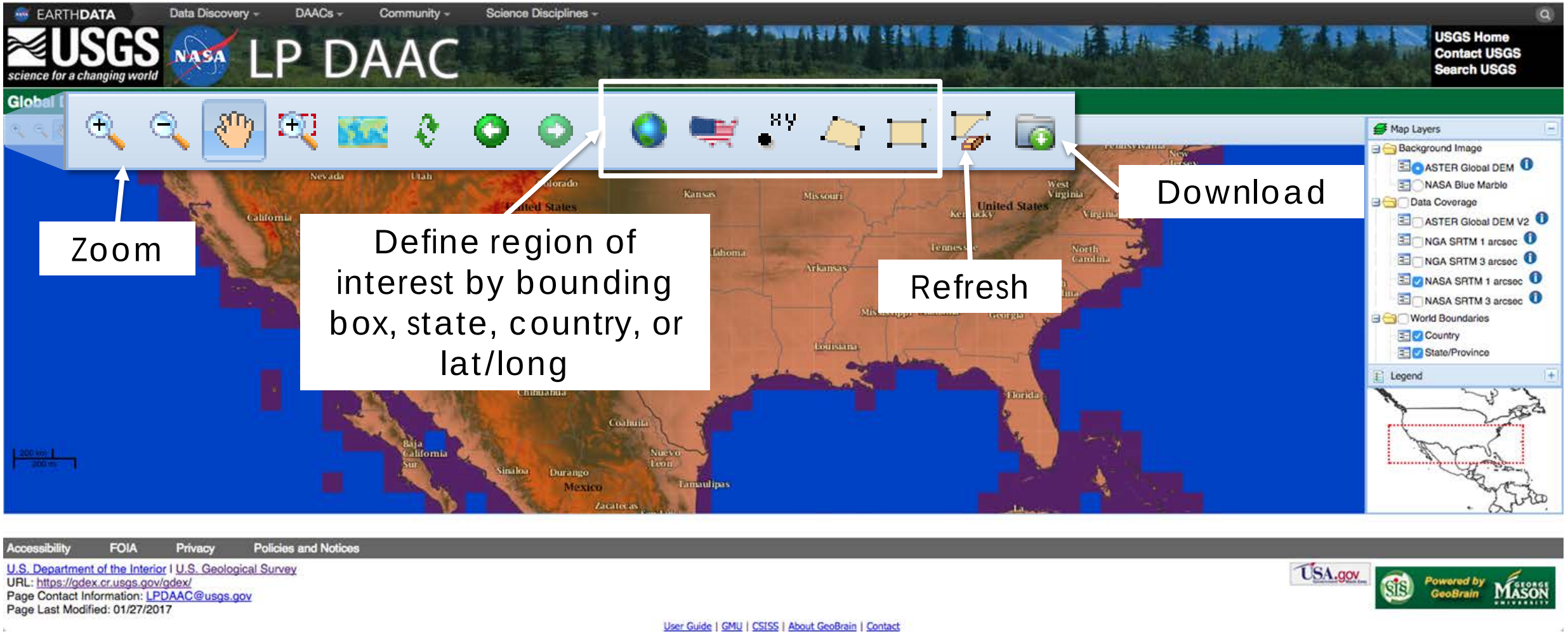
Radar signals being transmitted and received on the SRTM mission (not to scale)



Spatial Resolution: 30 m

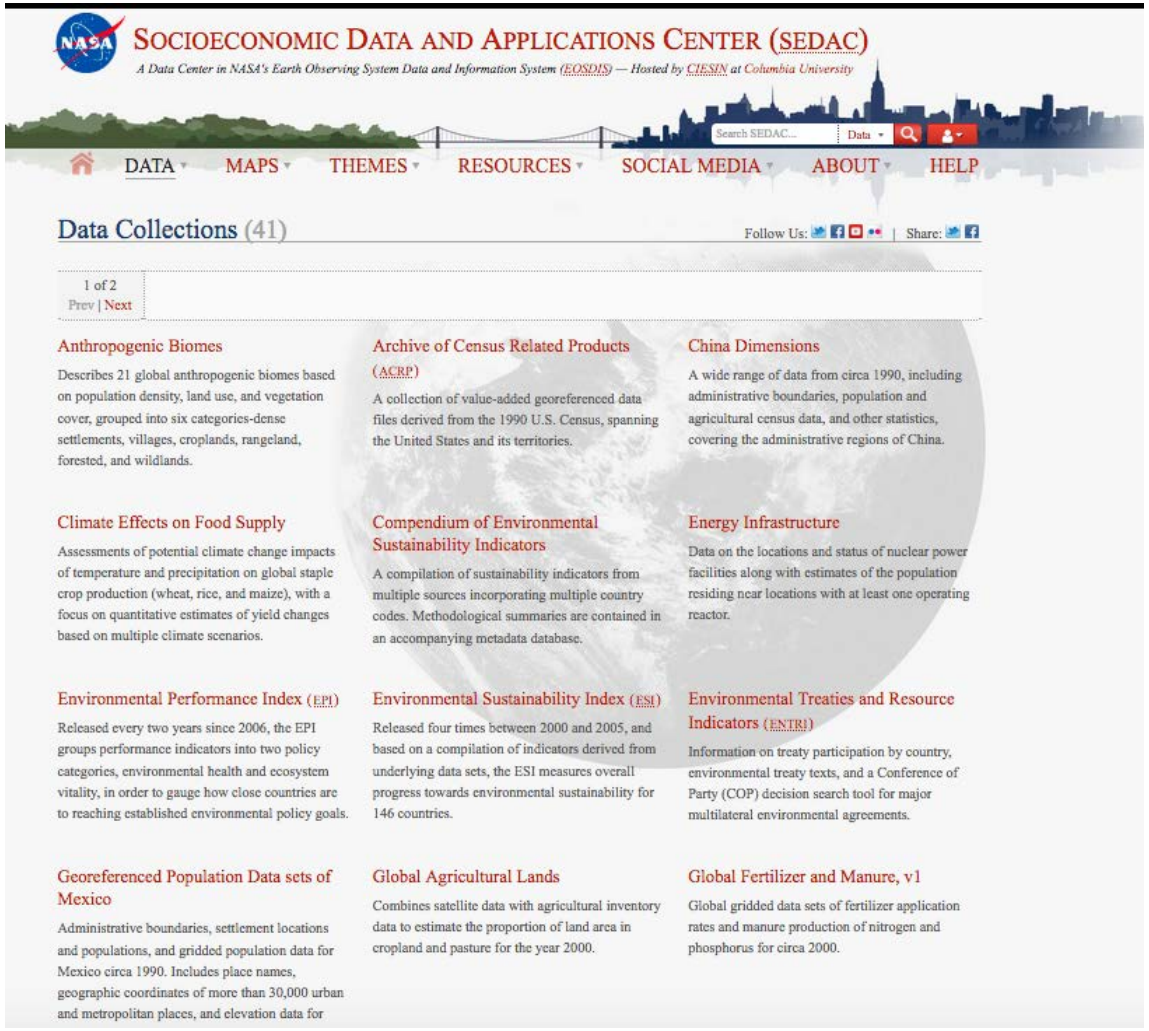
SRTM Elevation Data Access From Global Data Explorer (GDEx)

http://gdex.cr.usgs.gov/

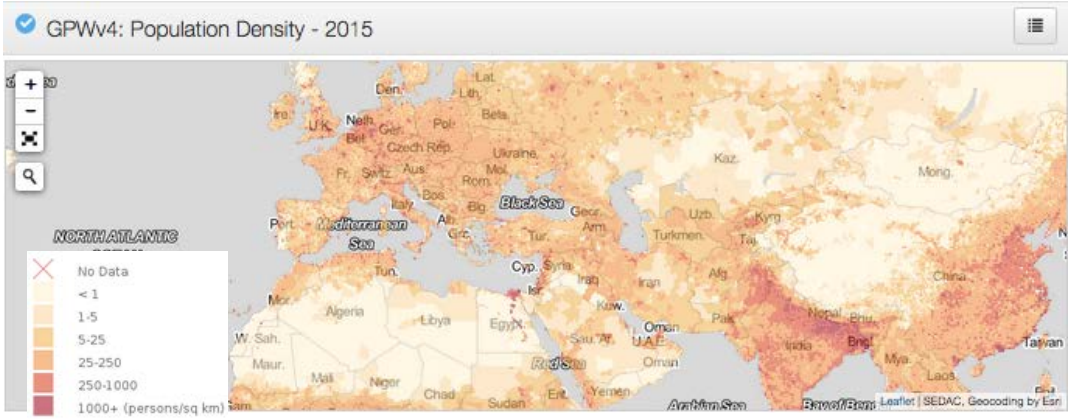


Socioeconomic Data

http://sedac.ciesin.columbia.edu/



Global Population Density

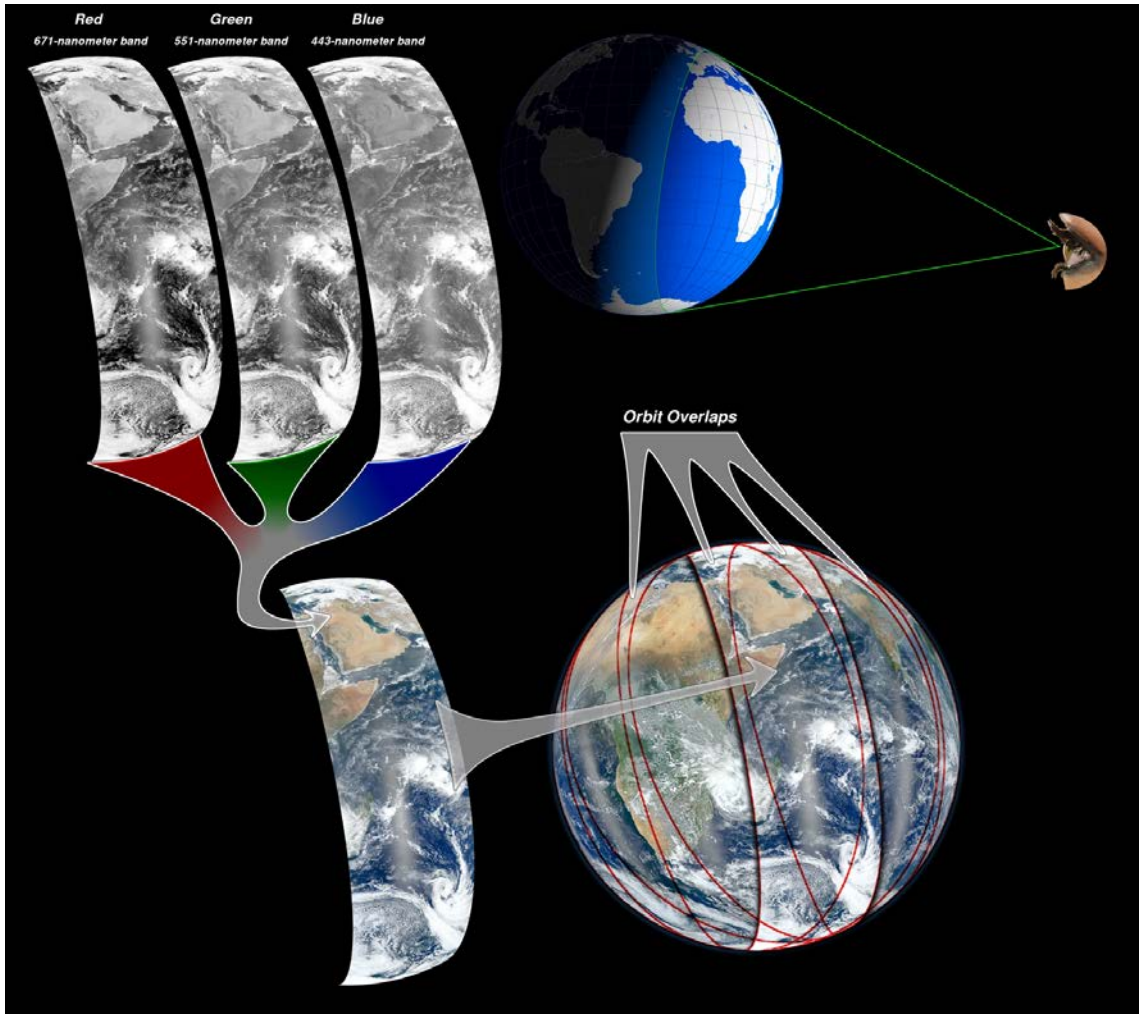


- Other Useful Datasets:
  - Global impermeable surface data from Landsat satellites
  - Global reservoir and dam
  - Low elevation coastal zones
  - Global roads
  - Energy infrastructure

Suomi National Polar Partnership (SNPP)

http://nasa.gov/mission_pages/NPP/

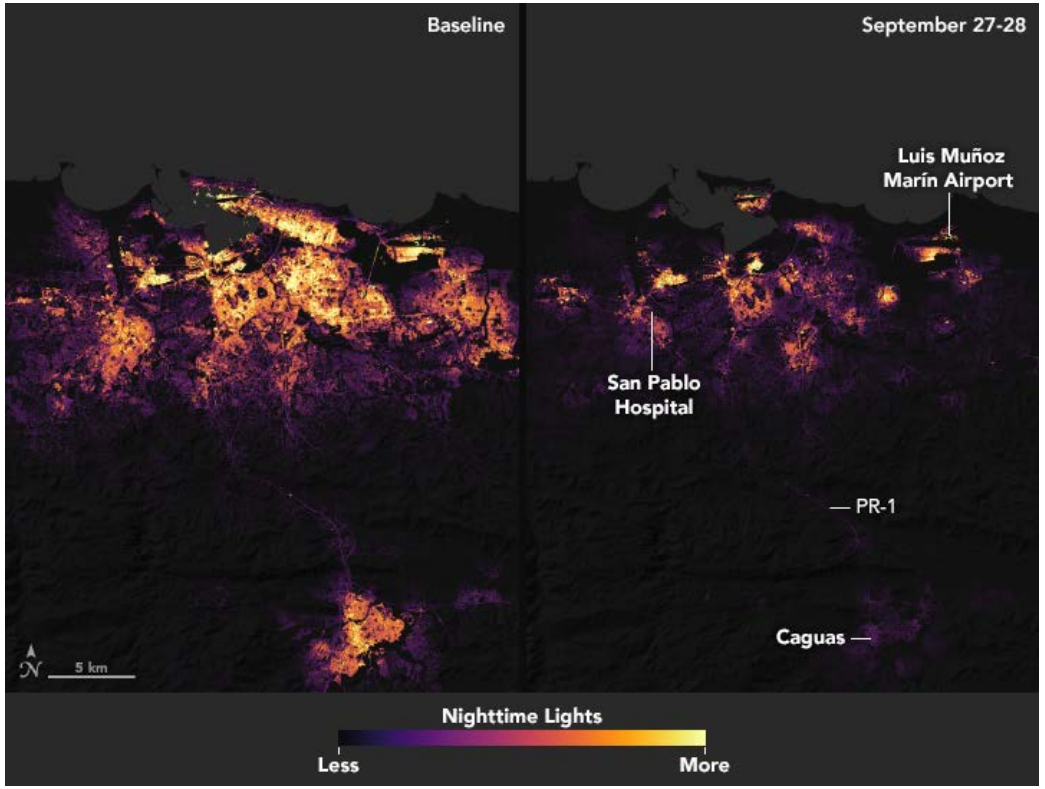
- Polar orbit, 1:30 p.m. equator crossing time
- Global coverage
- November 21, 2011 – present
- Sensors:
  - VIIRS, ATMS, CrIS, OMPS, CERCES



Visible Infrared Imaging Radiometer Suite (VIIRS)

http://jointmission.gsfc.nasa.gov/viirs.html

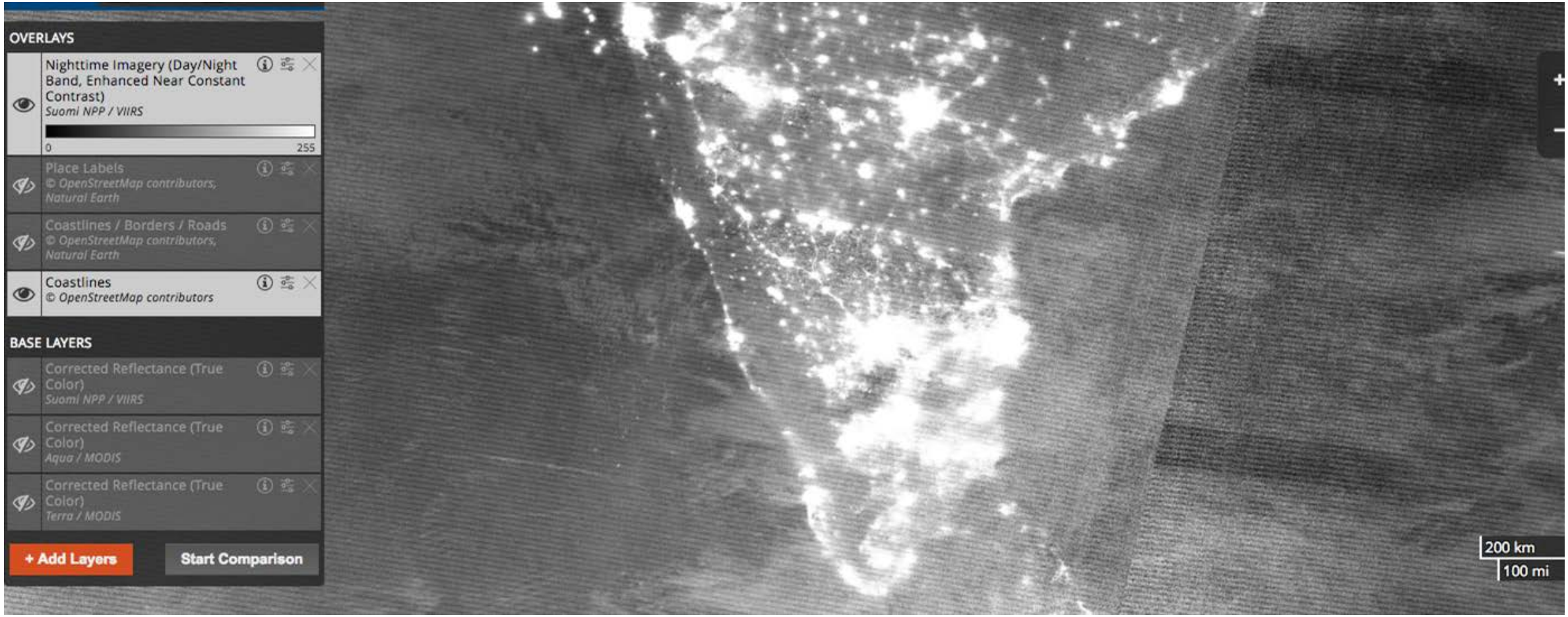
- Functionality similar to MODIS
- Spectral Bands
  - 22 bands (visible, IR, NIR, Mid-IR**, day/night**)
- Spatial Coverage and Resolution
  - Global; swath width: 3,040 km
  - Spatial Resolution: 375 – 750 m
- Temporal Coverage and Resolution
  - Oct 2011 – present
  - 1-2 times per day
- Data Access
  - Land Processing Distributed Active Archive Center: https://lpdaac.usgs.gov/dataset_discovery/viirs/



Power Outages in Puerto Rico as a Result of Hurricane Maria

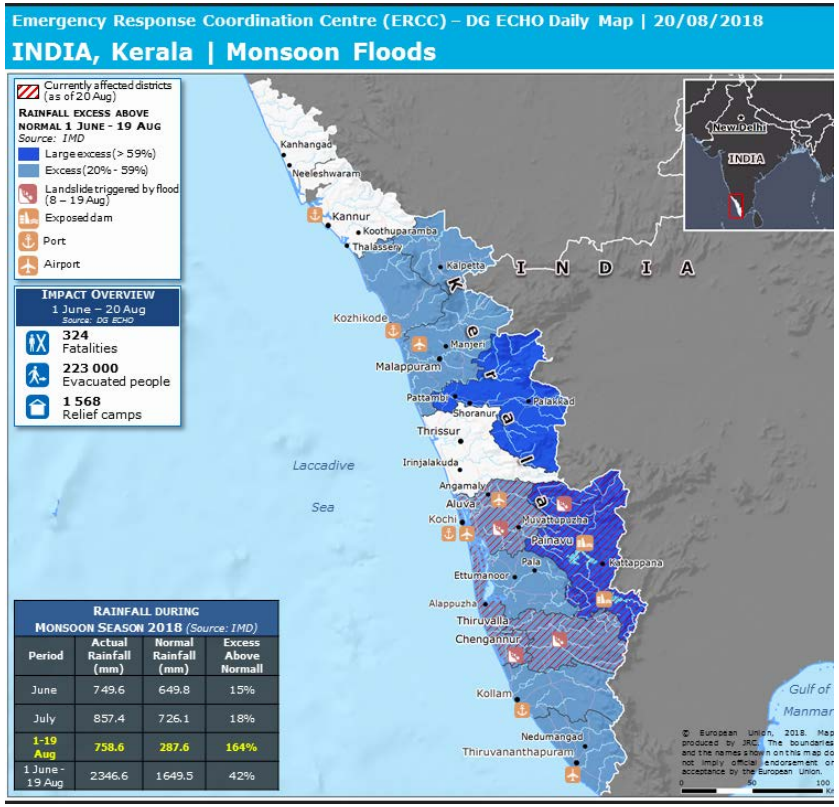
Where to Get VIIRS Night Light Imagery?

https://worldview.earthdata.nasa.gov



Data Access

Flood Case: Kerala Floods, 1-19 August 2018



http://www.gdacs.org/contentdata/maps/daily/FL/1000212/ECDM_20180820_Kerala_Floods.png

https://www.theguardian.com/world/2018/aug/17/kerala-floods-death-toll-rescue-effort-india

Demonstration

Data Access and Download for Kerala

- GEOS-5 Weather Data: https://gmao.gsfc.nasa.gov/GMAO_products/
- Terrain Data: http://gdex.cr.usgs.gov/
- Population, Impermeable Surface Data: http://sedac.ciesin.columbia.edu/

Next
Exercise: Download and Analyze Precipitation, Soil Moisture Analyze Terrain, Population Data

Case Study: Kerala Floods, 1-19 August 2018