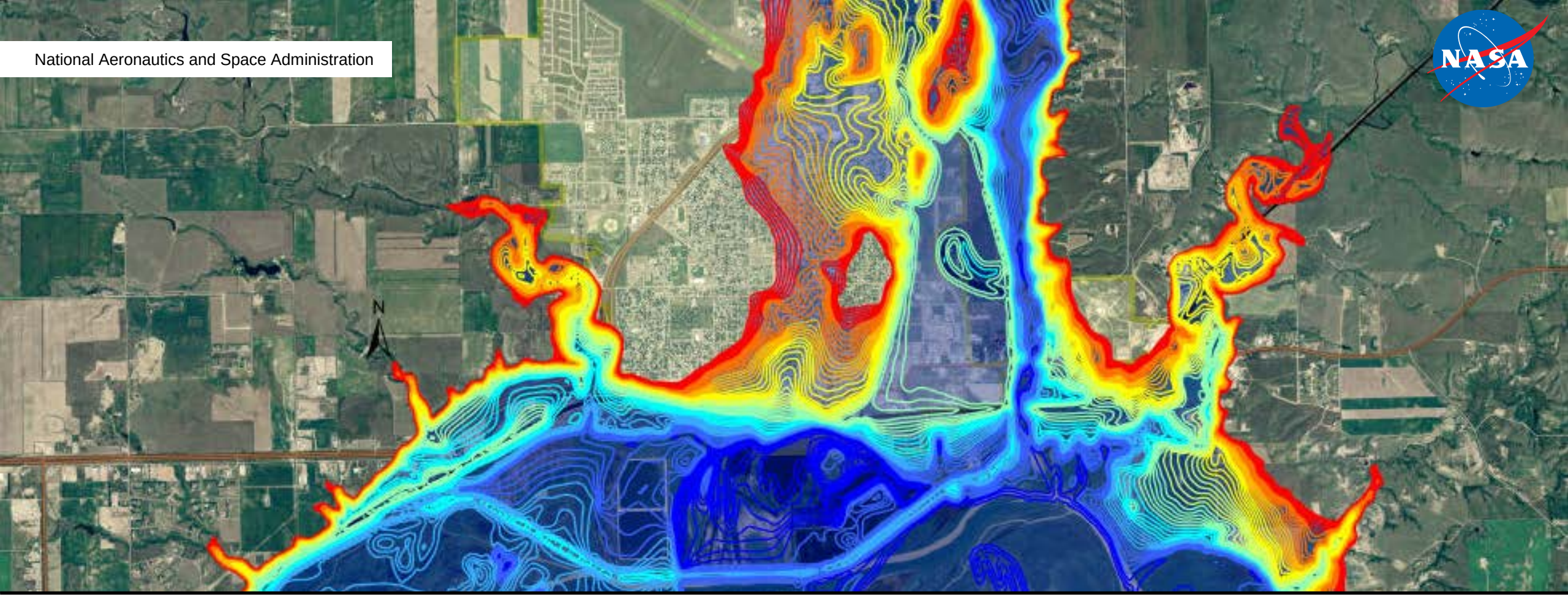
National Aeronautics and Space Administration



Urban Flood Monitoring Using Remote Sensing Observations

Amita Mehta

25 July 2018

Training Objectives

- Identify remote sensing and earth system model data and tools relevant for urban flood monitoring for planning warning, response, and recovery
- Identify main challenges in monitoring urban flooding

Course Outline

July 25

Overview of Remote Sensing Data for Urban Flooding

August 1

Access and Analysis of Remote Sensing Observations for Urban Flood Monitoring

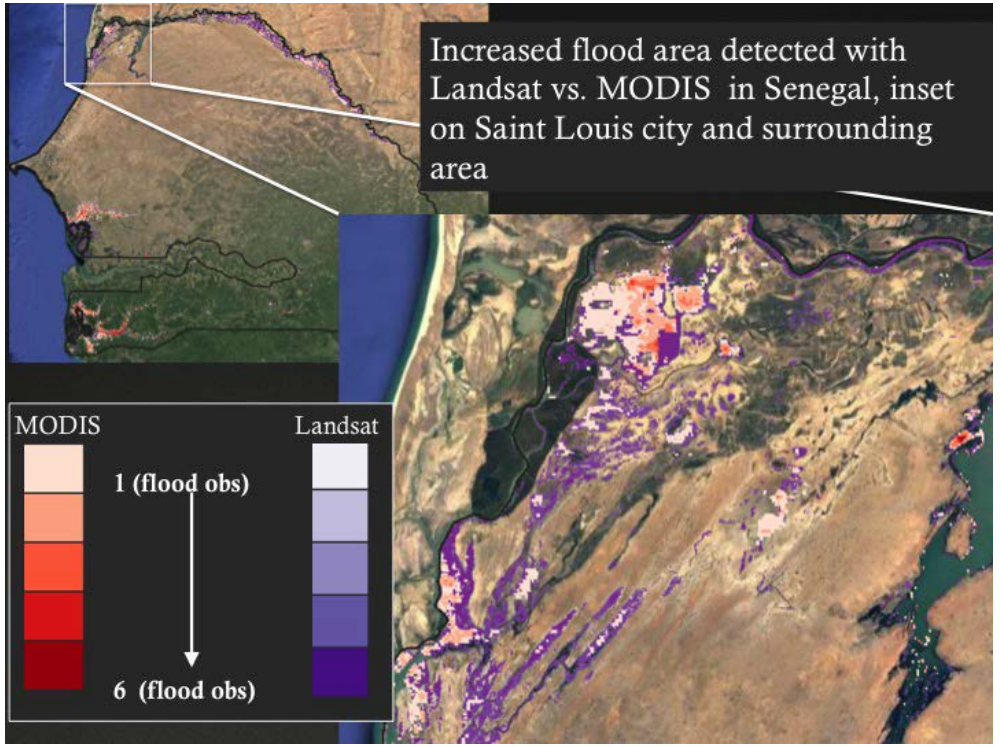


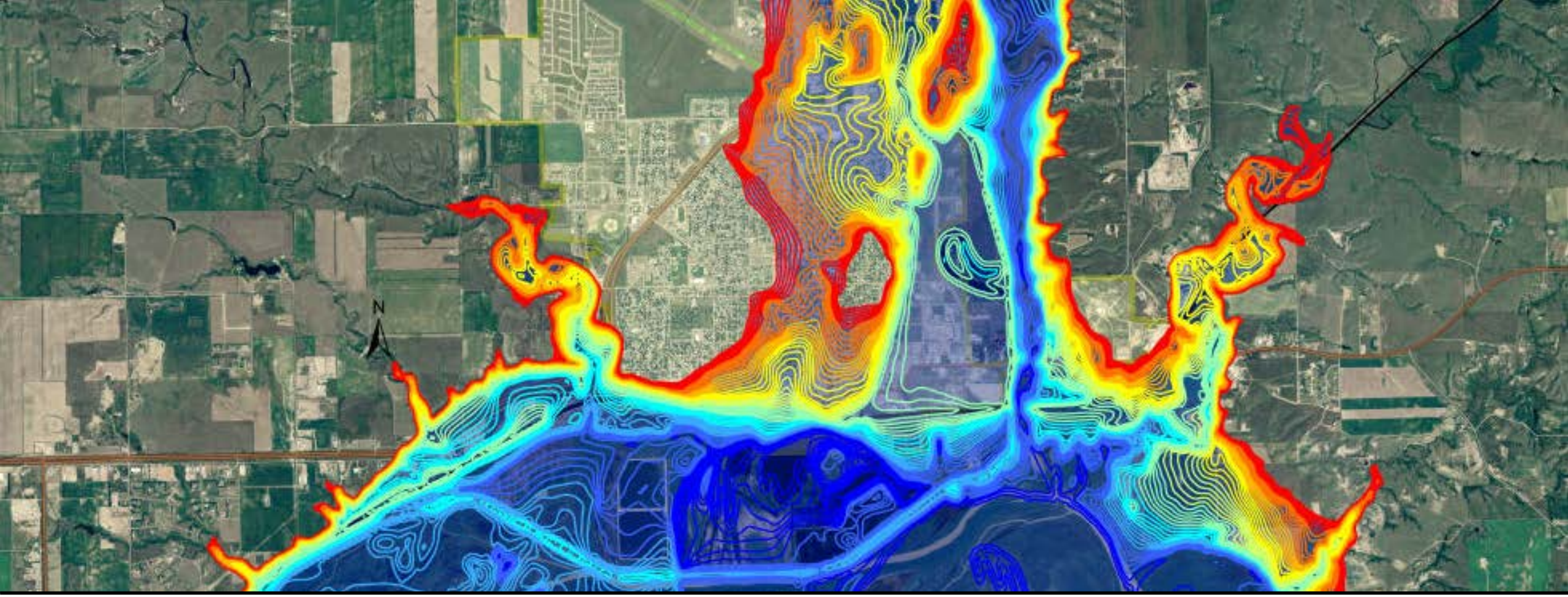
Image Credits: (left) https://blogs.worldbank.org/taxonomy/term/14333; (right)

Homework and Certificates

- Homework will be available after Session-1 and Session-2 from https://arset.gsfc.nasa.gov/water/webinars/
- **Answers must be submitted via Google Form**
- Certificate of Completion:
  - Attend both webinars
  - Complete homework assignment by the deadline (15 August 2018)
  - You will receive certificates approx. two months after the completion of the course from: marines.martins@ssaihq.com

Outline for Session 1

- About ARSET
- About Urban Flooding
- Monitor Urban Flooding Using NASA Remote Sensing and Earth System Model Data and Tools
  - Analyze terrain and Flood-prone Areas
  - Monitor approaching Weather Systems
- Examples of Urban Flood Management Using Remote Sensing
- Urban Flood Case study:



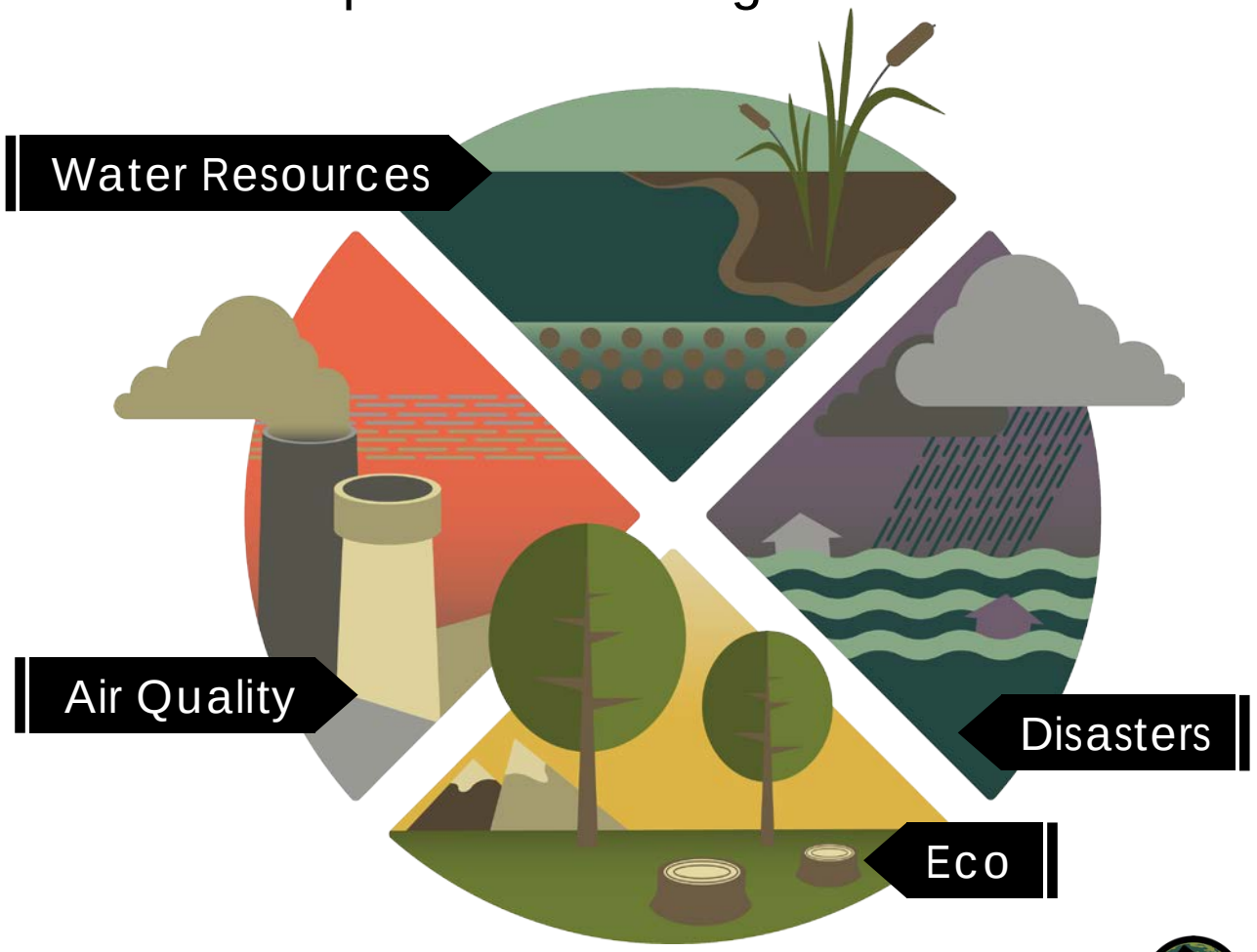
About ARSET

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
- Goal to increase the use of Earth science in decision-making through training for:
  - policy makers
  - environmental managers
  - other professionals in the public and private sector

Topics for Trainings Include:



ARSET Team Members

Program Support

- Ana Prados, Program Manager (GSFC)
- Brock Blevins, Training Coordinator (GSFC)
- David Barbado, 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 (GSFC)
- Erika Podest (JPL)

Land & Wildfires

- Cynthia Schmidt (ARC)
- Amber Jean McCullum (ARC)

Health & Air Quality

- Pawan Gupta (GSFC)
- Melanie Cook (GSFC)

Acknowledgement:

- We wish to thank Nancy Searby for her continued support

ARSET Training Formats

Online

- Offered through the internet
- Available live and recorded
- Typically 4-6 hours long
- Available at all training levels:
  - Fundamentals of Remote Sensing
  - Introductory
  - Advanced

In-Person

- 2-7 days in length
- Held in a computer lab
- Mixture of lectures and exercises
- Locally relevant case studies
- Available levels:
  - Introductory
  - Advanced

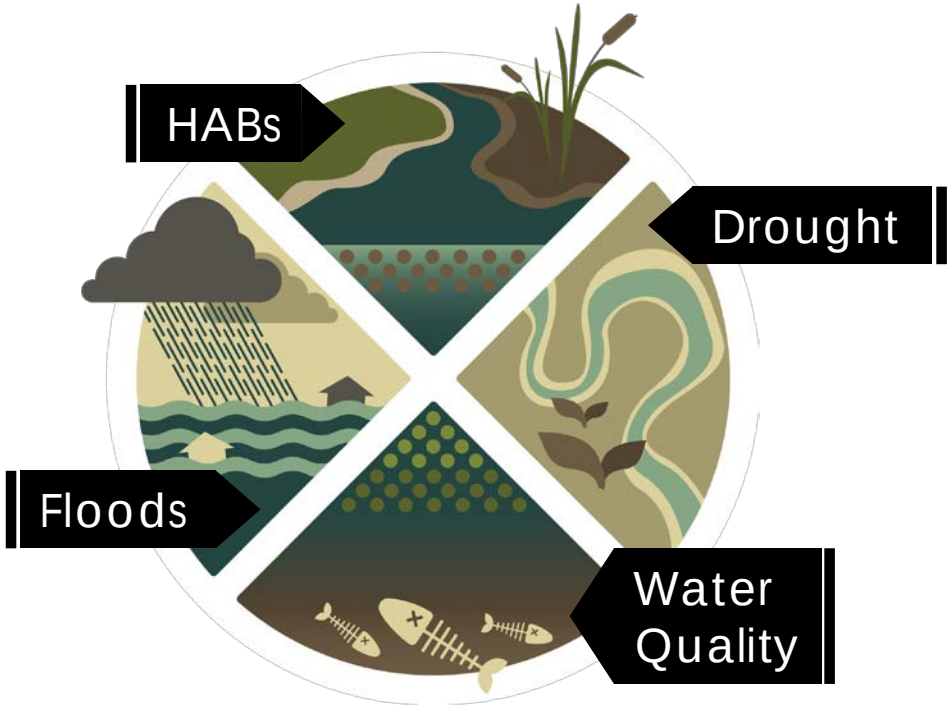
Train the Trainers

- Trainings and materials
- Offered online & in-person
- For organizers seeking to develop their own applied remote sensing training programs

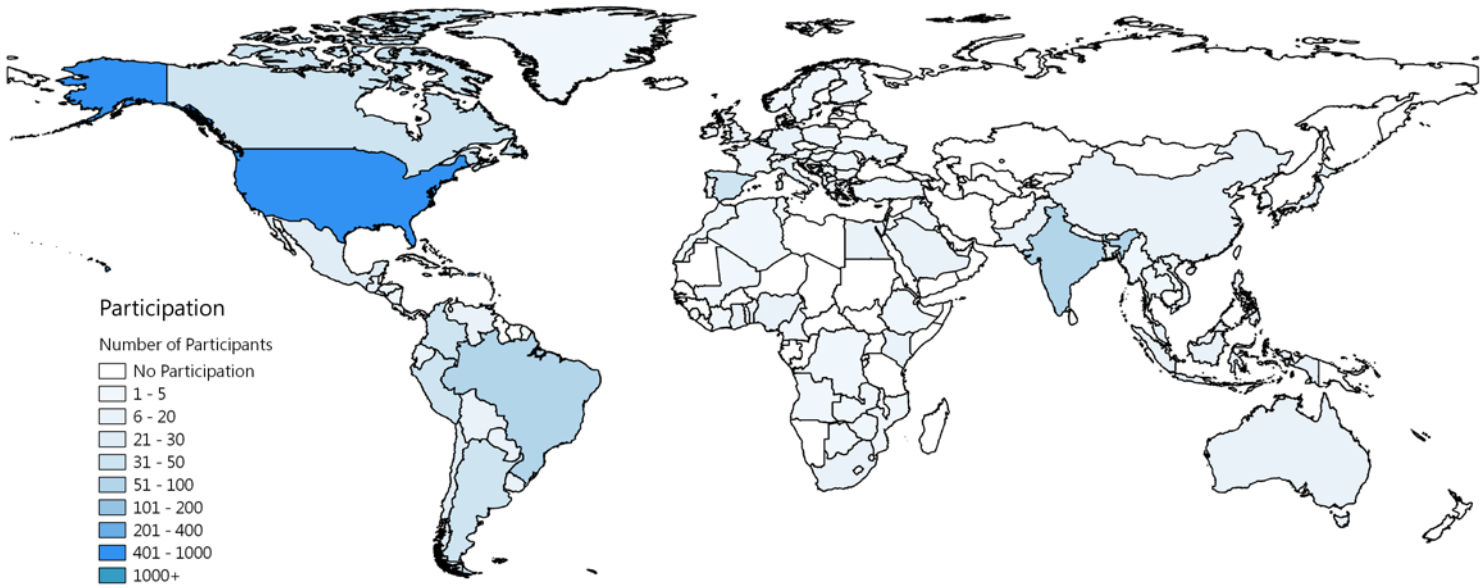
ARSET Training Impacts: Water Resources (2014 – 2018)

15 trainings | 3,000+ participants | 110+ countries | 880+ organizations

Training Topics Include…



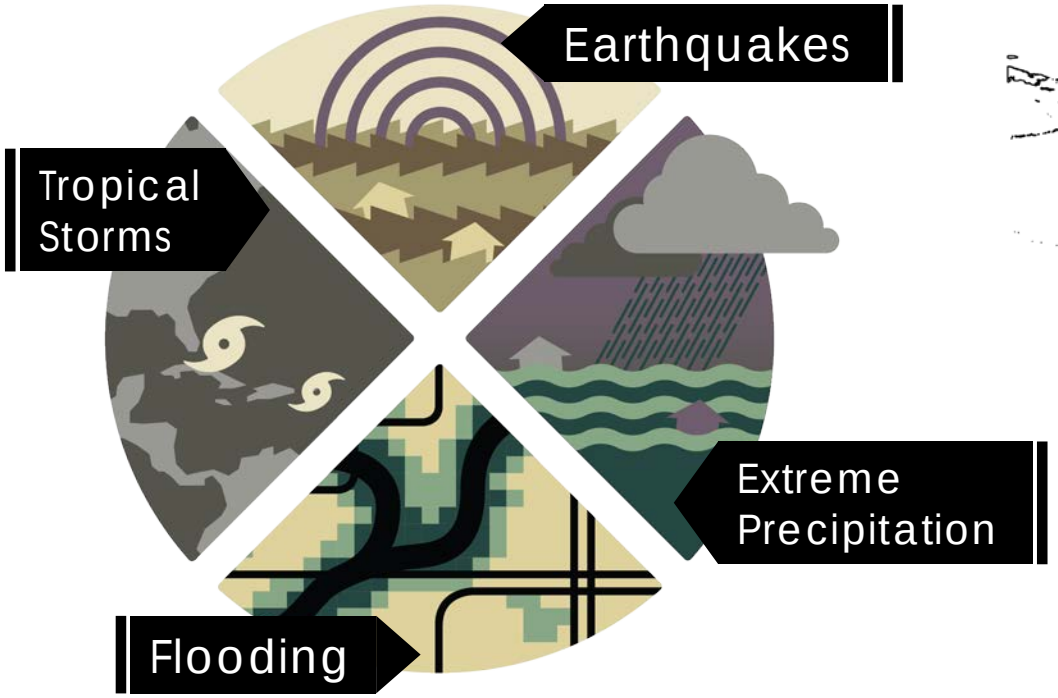
Global Water Resources Training Attendees (2017)



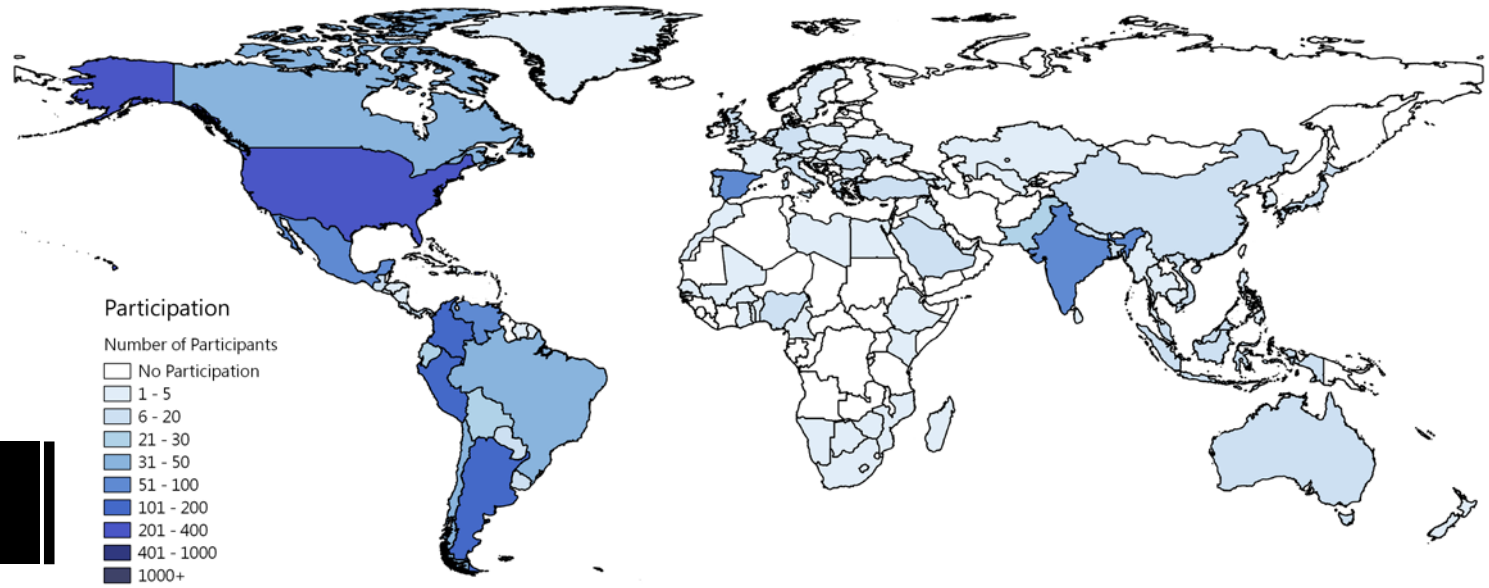
ARSET Training Impacts: Disasters Management (2013 – 2018)

10 trainings | 3,000+ participants | 119+ countries | 770+ organizations

Training Topics Include…

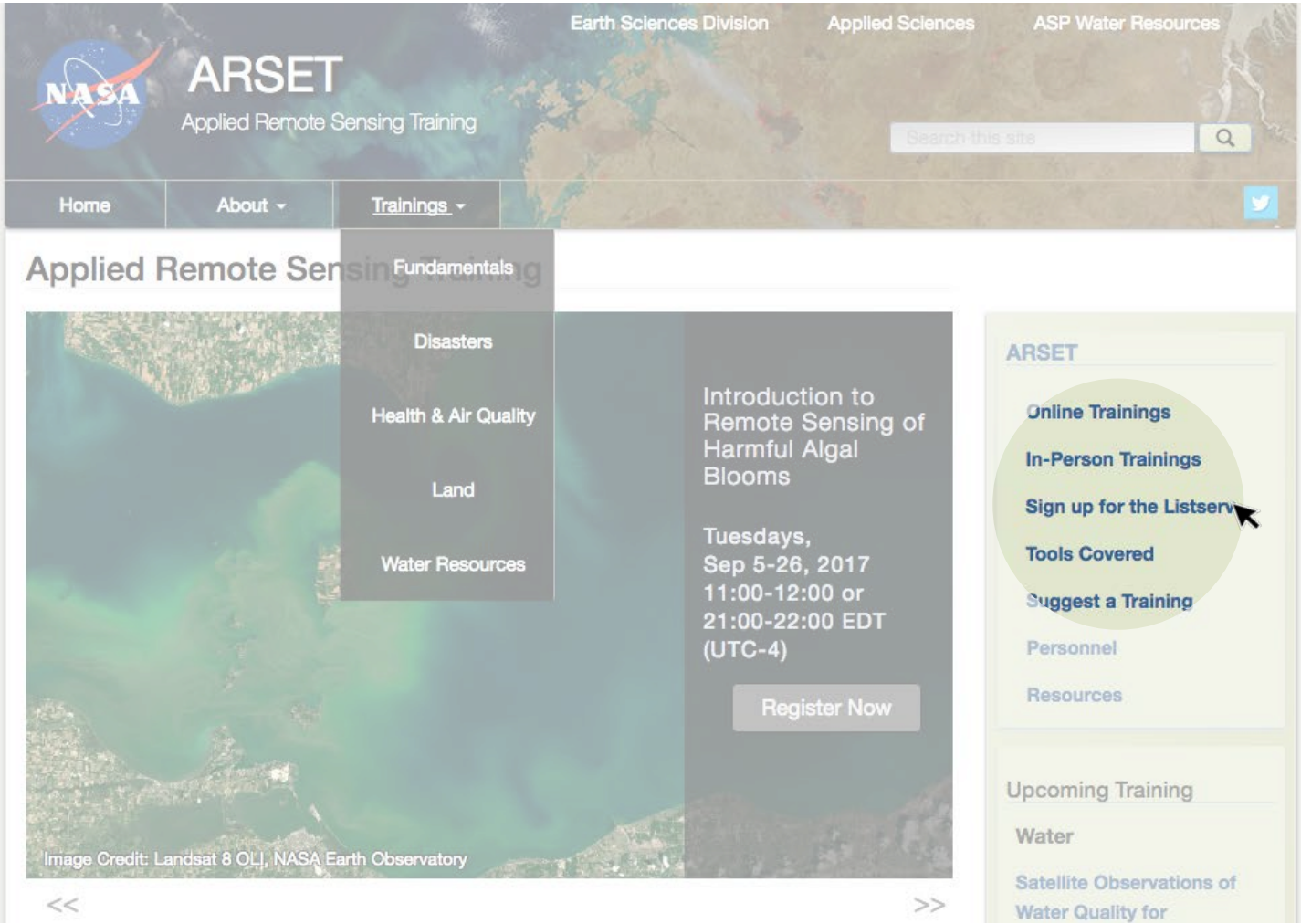


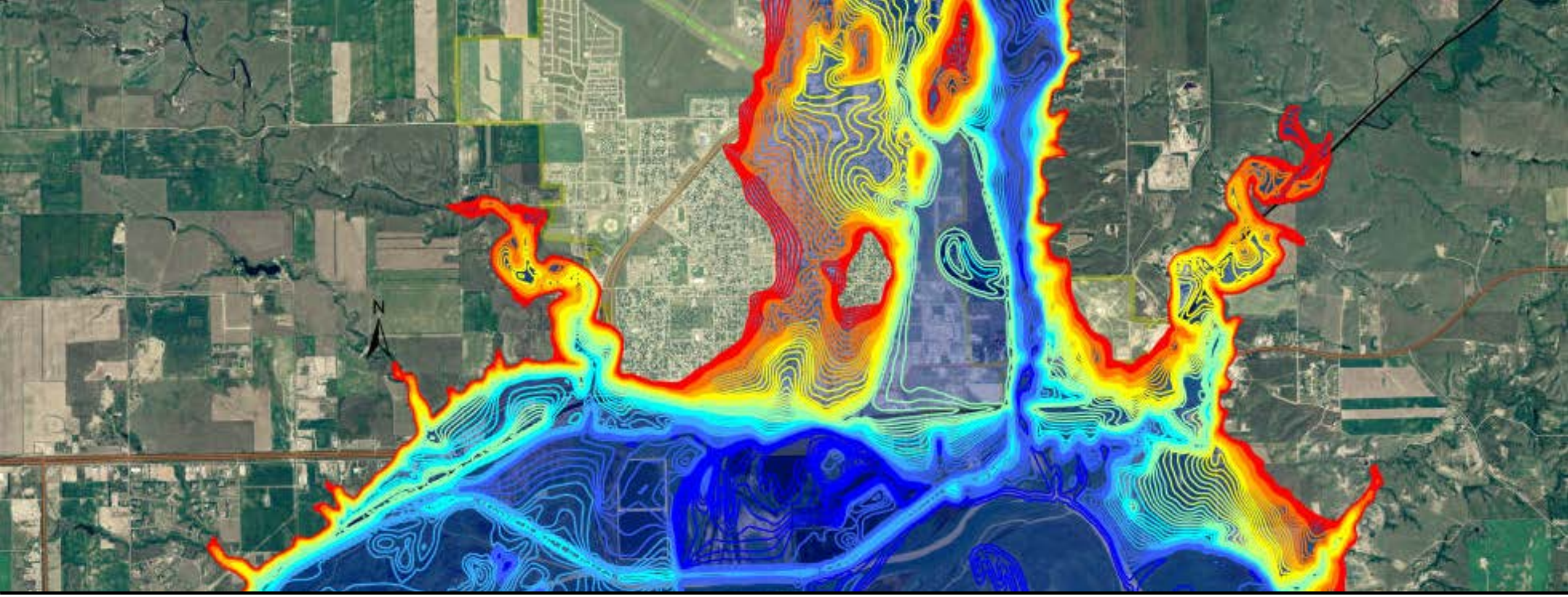
Global Disaster Training Attendees (2017)



ARSET Website & Listserv

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





About Urban Flooding

Urban Flooding

Causes: Natural and Human-Induced

- Heavy Precipitation and Flash Floods
- Snowmelt
- River Floods and Over-Bank Flow
- Coastal Floods: Storms, Changing Sea Level
- Lack of Proper Drainage Systems
- No Water Infiltration in the Ground Due to Build and Impermeable Surfaces
- Unplanned Development
- Infrastructure Failure: Levees or Dam Failure, Burst Water or Drainage Pipes

Flash Flooding, Ellicott City, MD, 2018

Flooding in Bulacan, north of Manilla, Philippines

References: http://www.floodsite.net; Cities and Flooding : A Guide to Integrated Urban Flood Risk Management for the 21st Century. Image Credits: (top) Baltimore Sun; (bottom) Time Magazine, AFP/Getty Images

Urban Flood: Risks

- Danger to Human Lives
- Damage to Buildings, Housing, Roads, Utility Works, Drainage Systems
- Direct Economic Impacts
  - Income Losses in Industry and Trade
  - Loss of Household Assets
  - Loss of Employment for Daily Workers

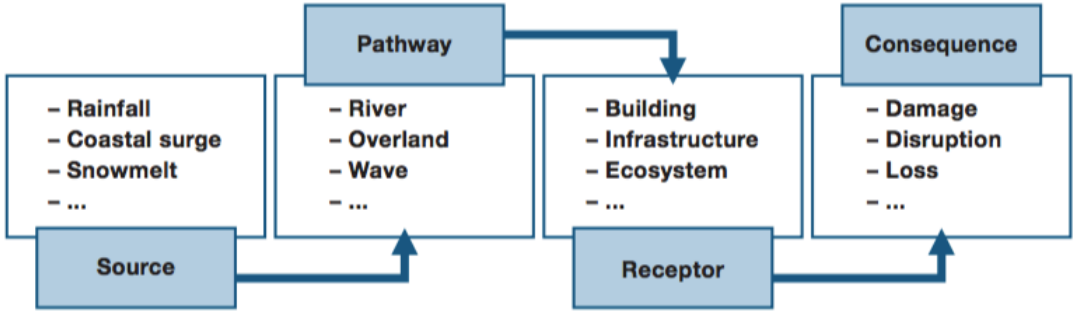


Figure 1.1: The Source, Pathway, Receptor Model

Image Credit: Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century

The Importance of Understanding Urban Flooding Issues

- Projections indicate that by 2050, two thirds of the world's population will be living in urban areas
- Rapid, unplanned increases in urbanization, growing numbers of slum dwellers, and inadequate infrastructure make cities more vulnerable to urban floods

Image Credit: UNDP

The Importance of Understanding Urban Flood Issues

- For sustainable cities and communities, as outlined by the UN Sustainable Development Goals, it is necessary to:
  - 11.b.2: have strategies for urban disaster reduction
  - 11.5.1: reduce the number of deaths related to disasters
  - 11.5.2: mitigate disaster damage to infrastructure for basic services
- Natural and human development factors are influencing cities
- Coping with flooding in expanding urban areas, and increasing population is a major challenge for decision-makers on all levels, from local to national

Urban Flood Risk Reduction: Data Needs

Natural:

- Floodplain Map: Terrain, Digital Elevation Model, Drainage Channels
- River Stage and Inundation
- Coastal Surges and Inundation
- Weather Data: Precipitation Intensity, Frequency, Forecast
- Flood Hazard Map and Return Period

Anthropogenic

- Storm Water System Design and Capacity
- Design and Capacity of Dams and Levees
- Land Use Change: Exposed Soil versus Build Areas
- Human Population
- Infrastructure (e.g., buildings, roads)

Urban Flood Risk Reduction: Data Needs

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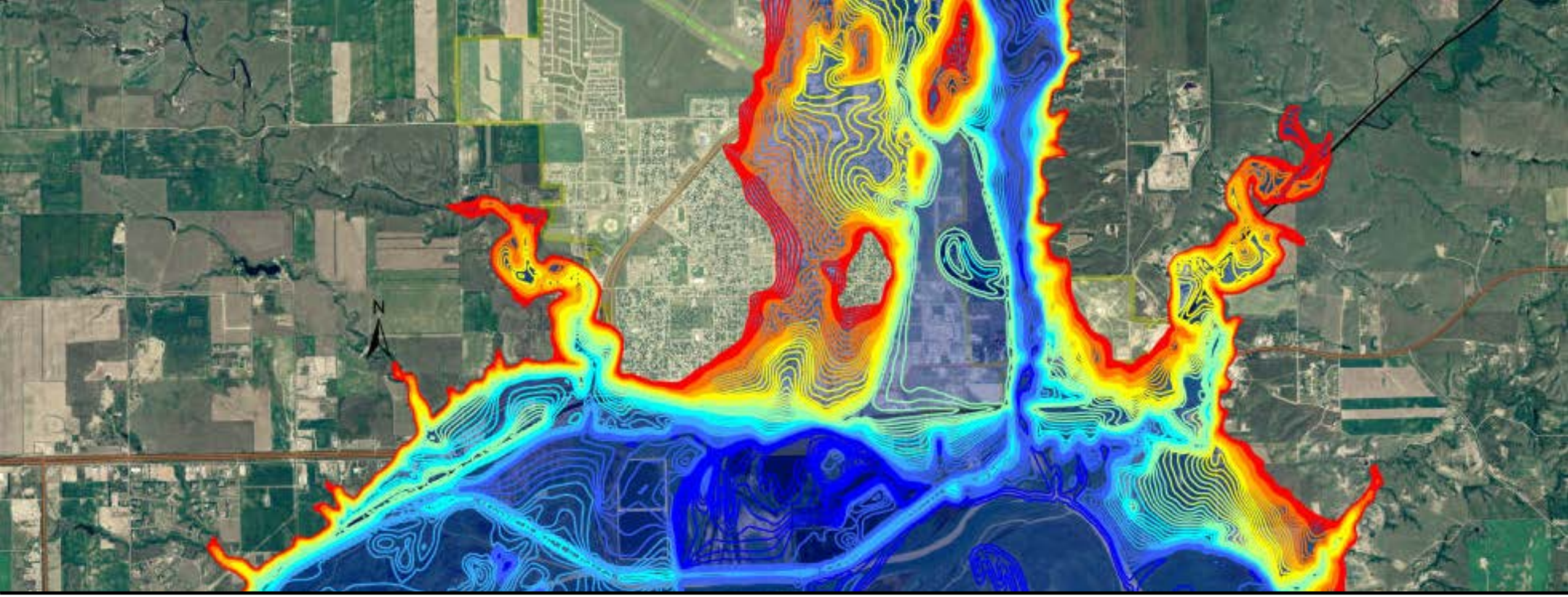
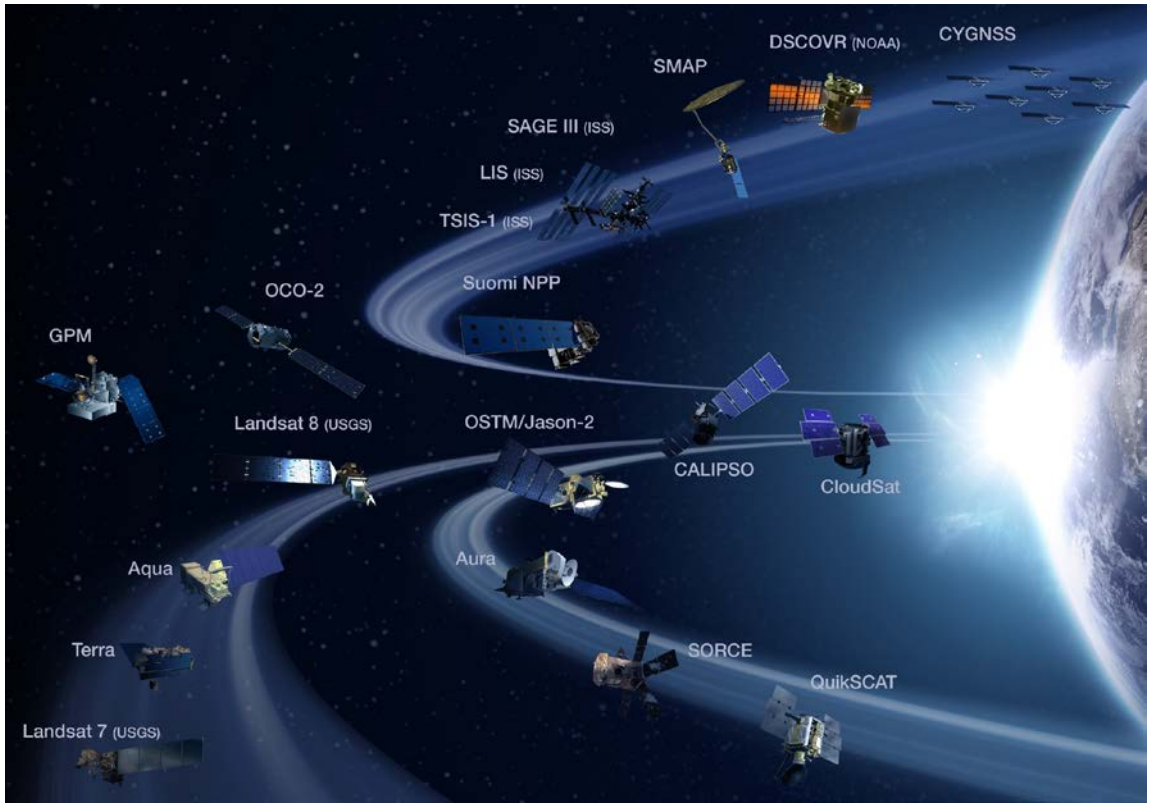


Monitor Urban Flooding Using NASA Remote Sensing and Earth System Model Data and Tools

Satellites Relevant for Monitoring Urban Flooding



- 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 Urban Flooding

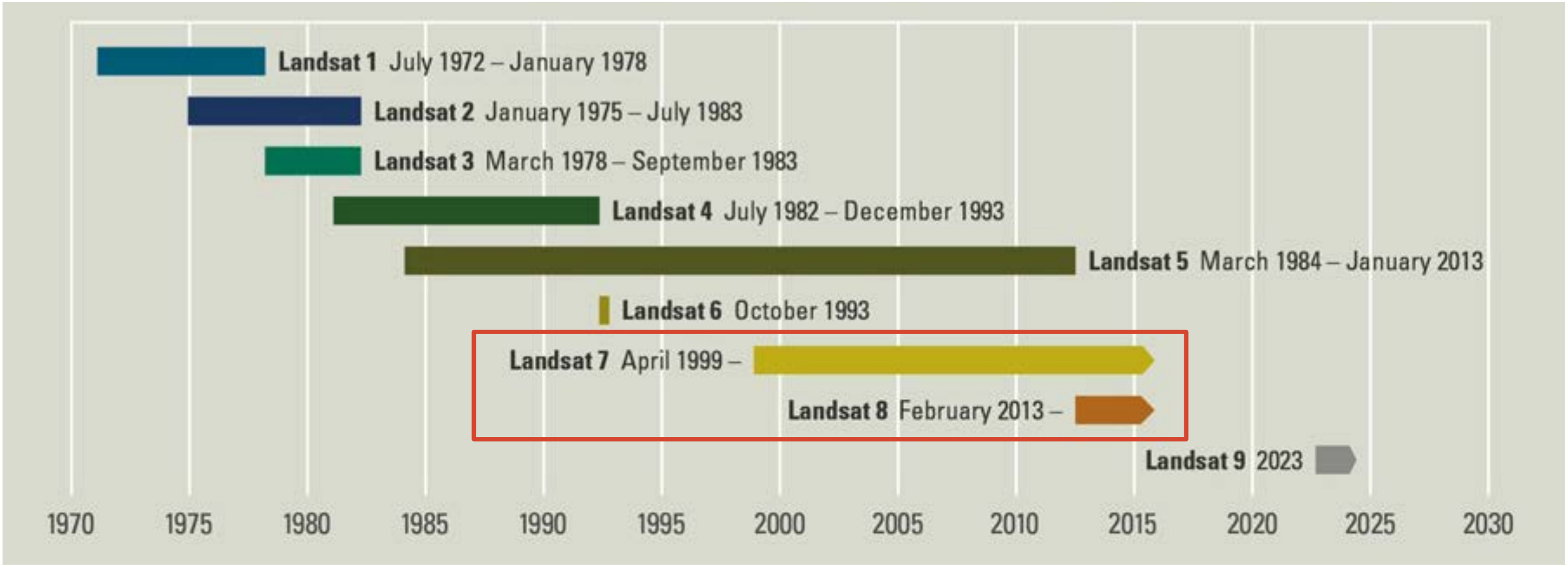
Satellites	Sensors	Spectral Measurements	Parameter
Landsat 5, 7,8	ETM+, OLI	Visible, Near IR, Middle IR, Thermal IR	Reflectance/True Color Image, Land Cover, Surface Inundation
TRMM & GPM	Microwave Radiometer and RADAR TMI, PR GMI, DPR	TMI: 10-85 Ghz GMI: 10-183 GHZ PR and DPR (Ku and Ka)	Precipitation
Terra & Aqua	MODIS	Visible, Near IR, Middle IR	Reflectance/True Color Image, Surface Inundation, Land Cover
SNPP	VIIRS		Day/Night Imagery
SMAP	Microwave Radiometer	1.41 GHz	Soil Moisture
Sentinel 1A and 1B	Synthetic Aperture RADAR (SAR)	C-Band	Backscatter/Surface Inundation
Space Shuttle Endeavour	SRTM	C-Band	Terrain

Earth System Model and Ancillary Data for Monitoring Urban Flooding

Source	Parameter
Earth System Model GEOS-5	Precipitation, Winds, Soil Moisture
LIDAR	High Resolution Topography
SEDAC	Socioeconomic data

Landsat Satellites and Sensors

http://landsat.usgs.gov/about_mission_history.php

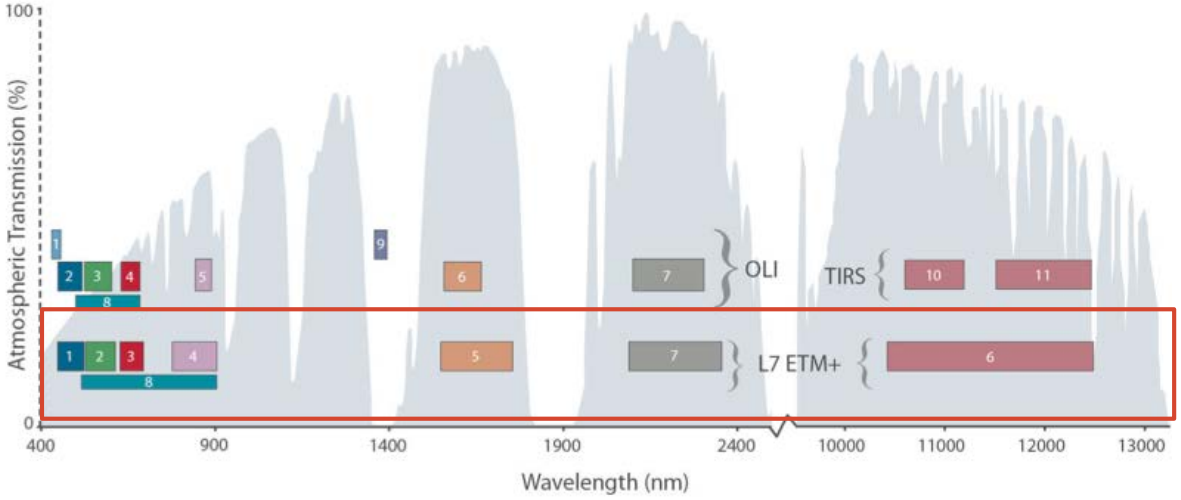


Enhanced Thematic Mapper (ETM+)

- Onboard Landsat-7
- Polar orbiting satellite
- Spatial Coverage and Resolution:
  - Global, Swath: 185km
  - Spatial Resolution: 15m, 30m, 60m
- Temporal Coverage and Resolution:
  - April 15, 1999-present
  - 16-day revisit time

Spectral Bands

- 8 bands (blue-green, green, red, reflected & thermal IR, panchromatic)
  - Bands 1-5, 7: 30 m
  - Band 6: 60 m
  - Band 8:15 m



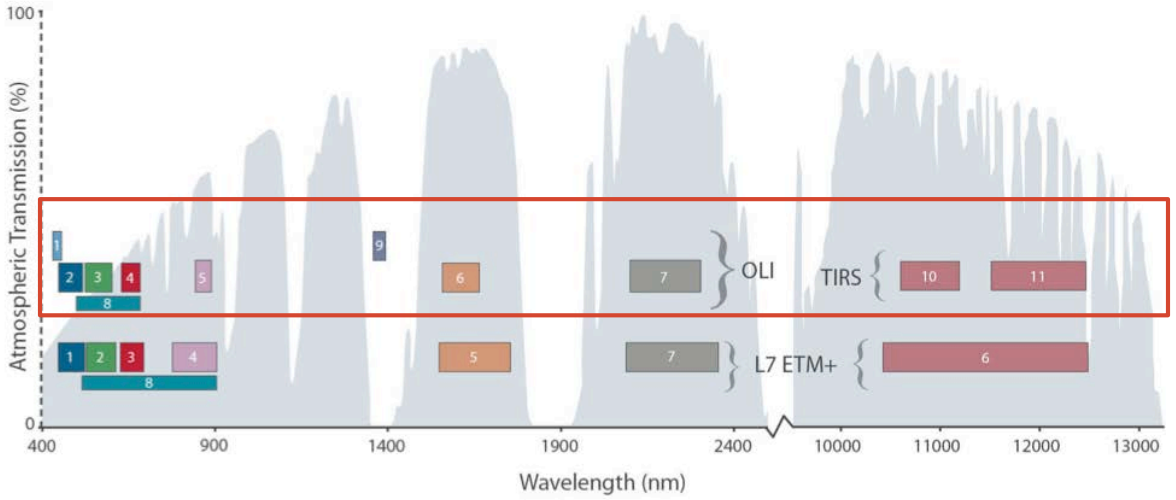
http://geo.arc.nasa.gov/sge/landsat/l7.html

Operational Land Imager (OLI)

- Onboard Landsat-8
- Polar orbiting satellite
- Spatial Coverage and Resolution:
  - Global, Swath: 185km
  - Spatial resolution: 15m, 30m
- Temporal Coverage and Resolution:
  - Feb 11, 2013 – present
  - 16-day revisit time

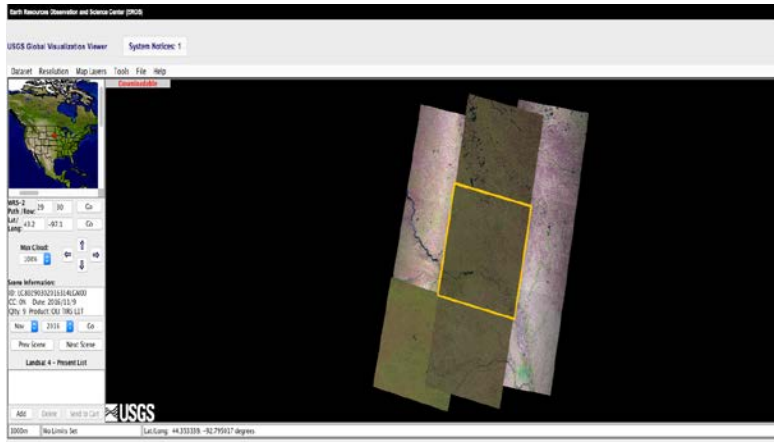
Spectral Bands

- 9 bands (blue-green, green, red, near IR, shortwave and thermal IR)
  - Bands 1-7, 9: 30m
  - Band 8:15m

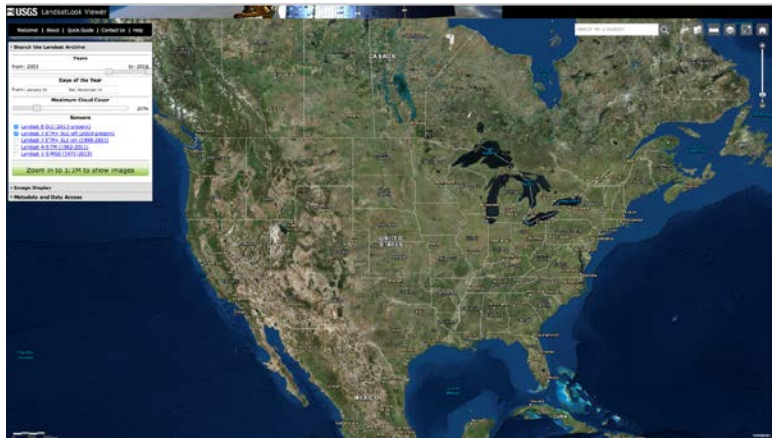


Where can you get Landsat images & spectral reflectance data?

USGS Earth Explorer
http://earthexplorer.usgs.gov/



USGS Global Visualization Viewer
http://glovis.usgs.gov/

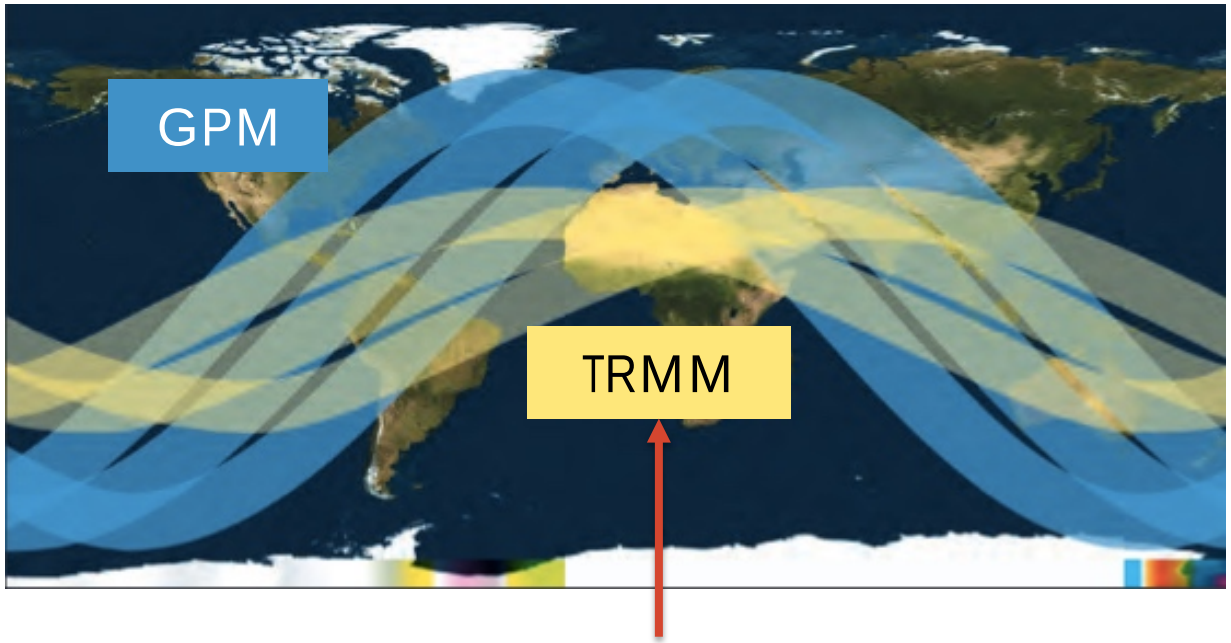


USGS Landlook Viewer
https://landlook.usgs.gov/viewer.html

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

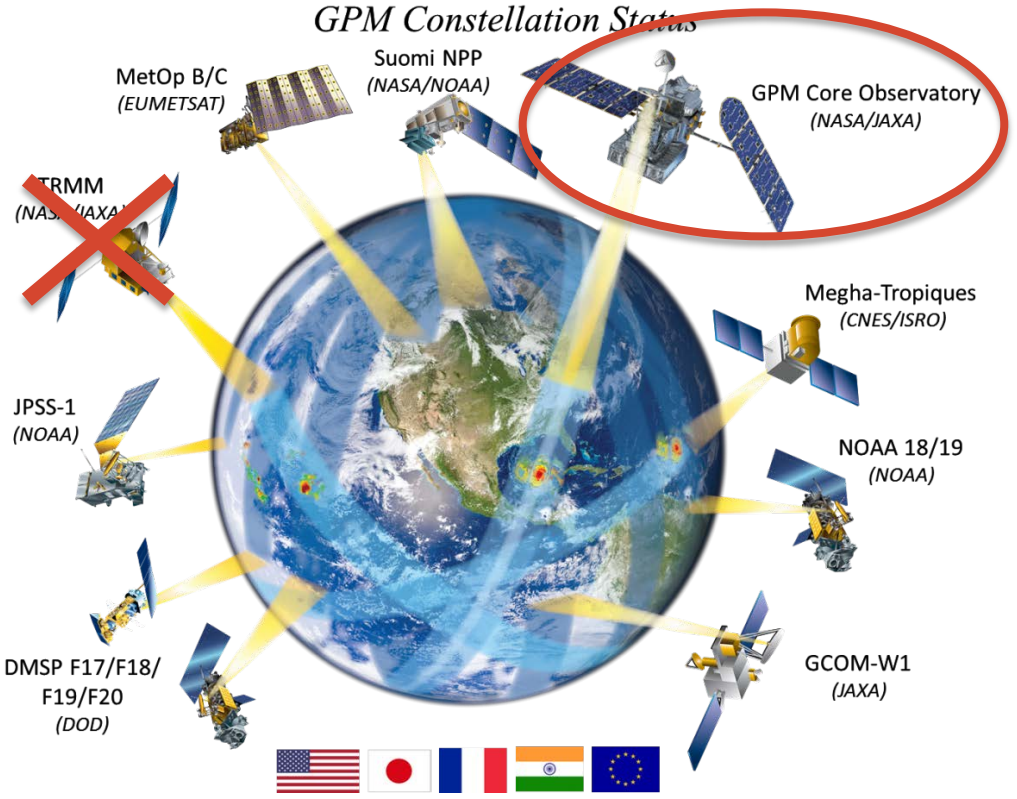
http://pmm.nasa.gov/science/precipitation-algorithms

- 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

- 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



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 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+

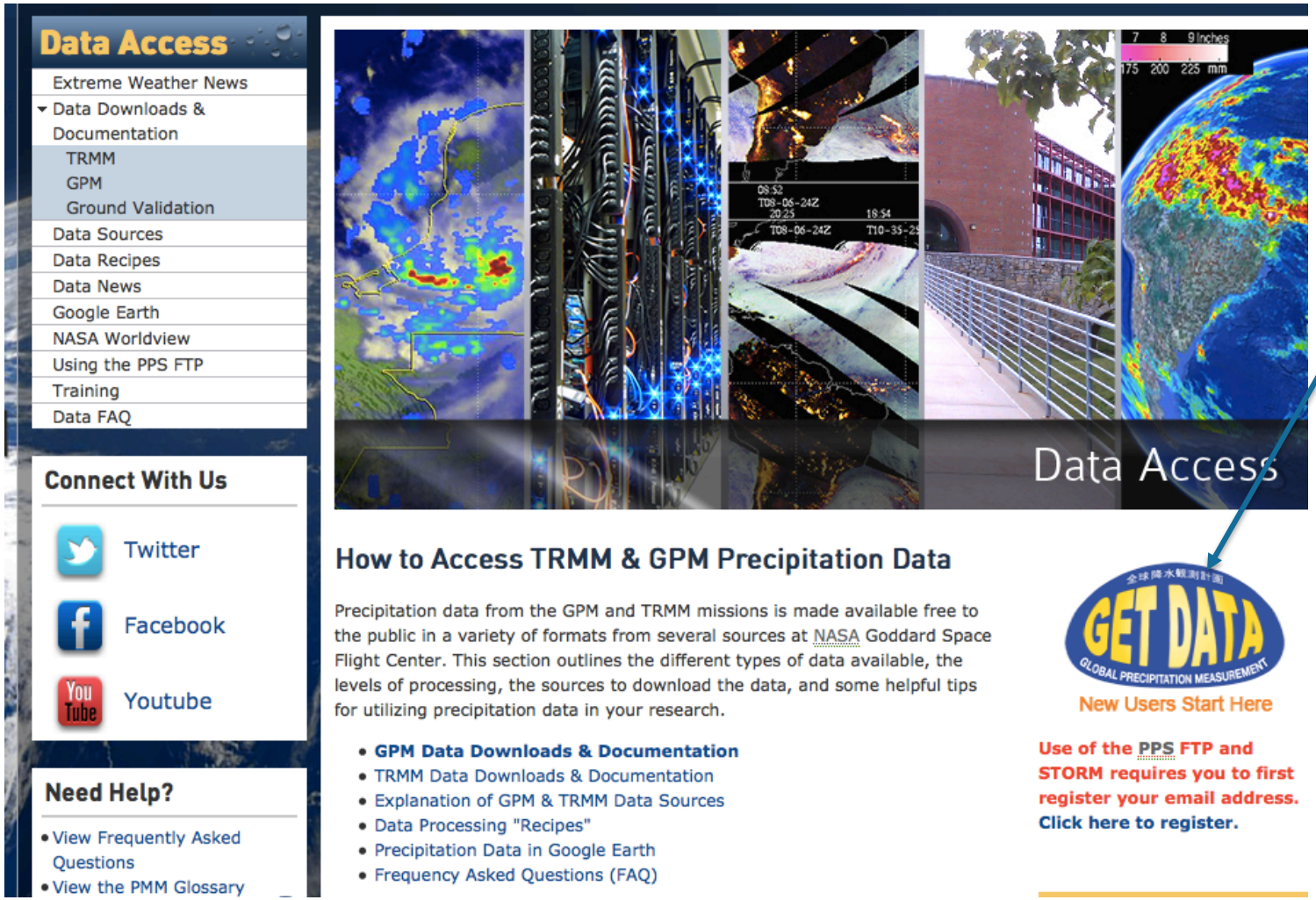
* After April 8, 2015, TRMM climatological calibration is being used to generate TMPA

+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 near future

GPM IMERG Data Access

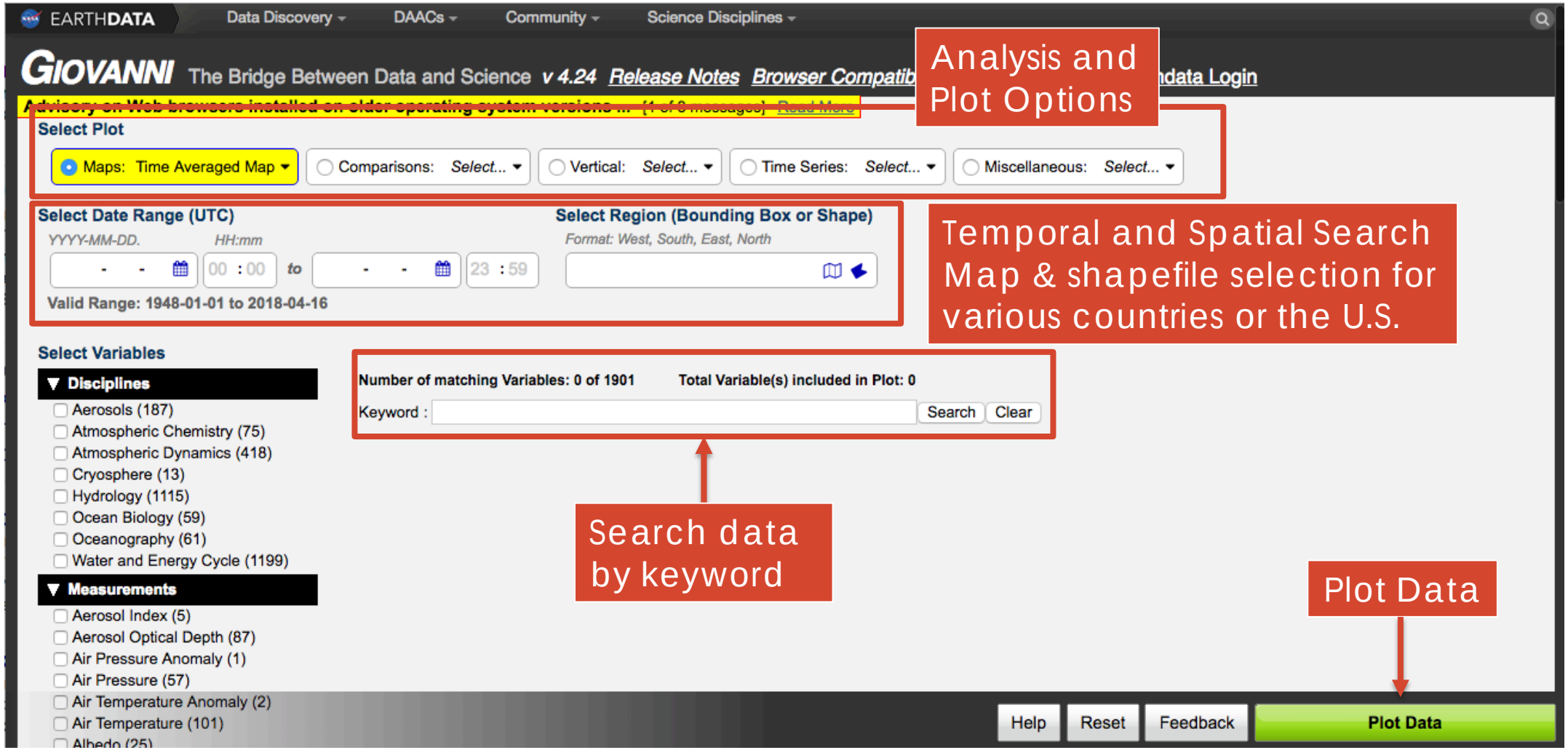
https://pmm.nasa.gov/data-access



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

Precipitation Data Access and Analysis

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



Terra and Aqua Satellites and MODIS Sensor

Terra

http://terra.nasa.gov

- Polar orbit, 10:30 a.m. equator crossing time
- Global Coverage
- December 18, 1999 – Present
- 1-2 observations per day

Aqua

http://aqua.nasa.gov/

- Polar orbit, 1:30 p.m. equator crossing time
- Global Coverage
- May 4, 2002 – Present
- 1-2 observations per day

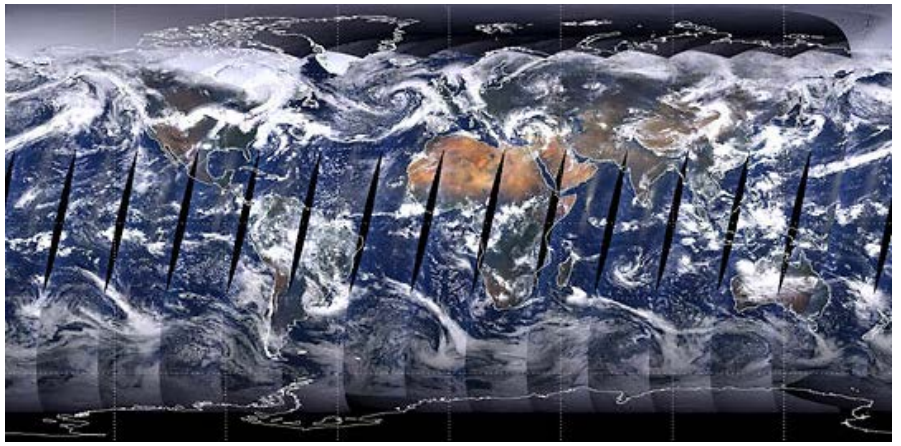
MODerate Resolution Imaging Spectroradiometer (MODIS)

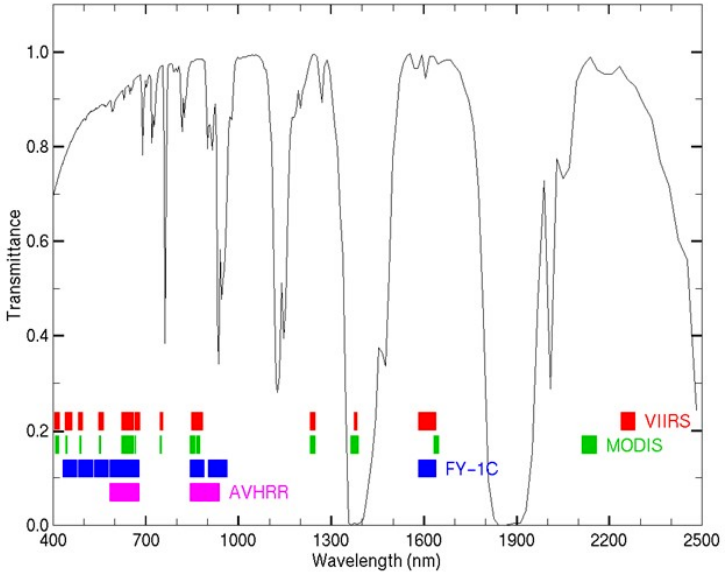
http://modis.gsfc.nasa.gov/

- Spectral Bands
  - 36 bands (red, blue, IR, NIR, Middle-IR)
- Spatial Resolution
  - Global, swath: 2,330 km
  - 250 m, 500 m, 1 km
- Temporal Resolution
  - Daily, 8 day, 16 day, monthly, quarterly, yearly
  - 2000 – present
- Data Access:

  Land Processing Distributed Active Archive Center

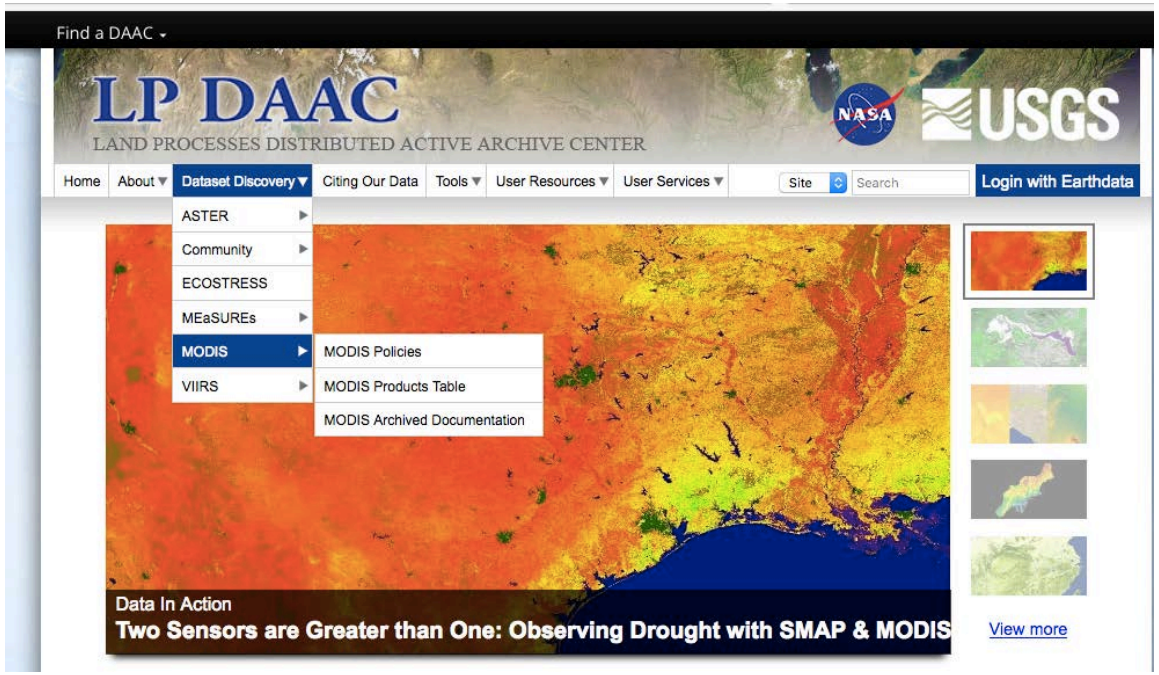
  http://lpdaac.usgs.gov/dataset_discovery/modis/



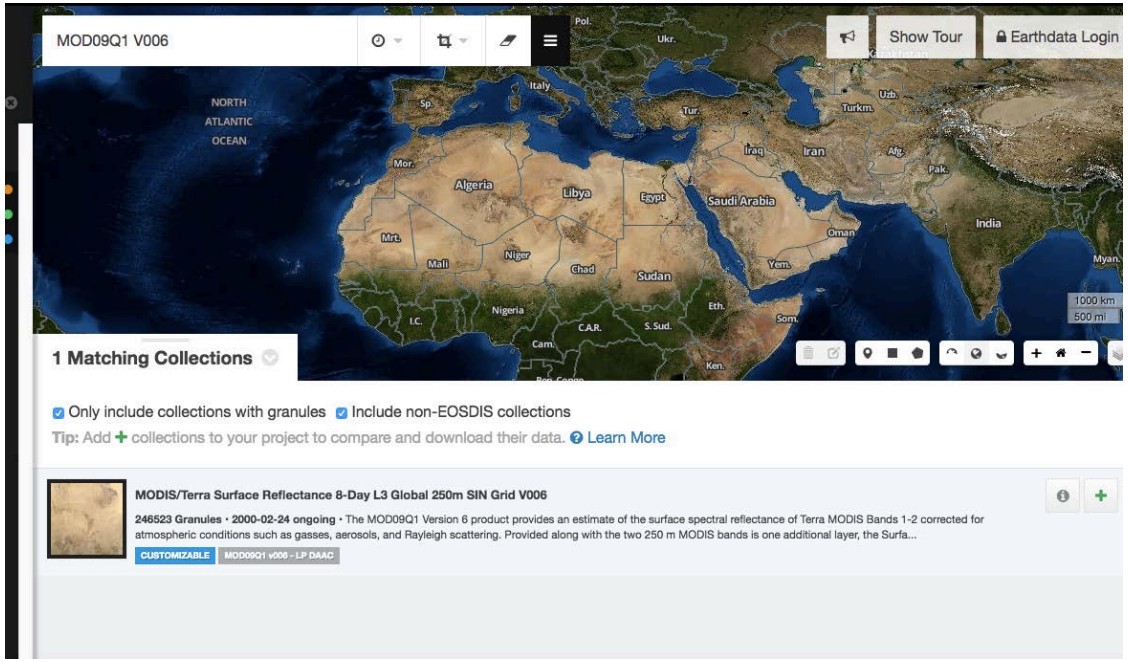


Where to Get MODIS Reflectance Data?

https://lpdaac.usgs.gov/ and https://search.earthdata.nasa.gov/



Data Information

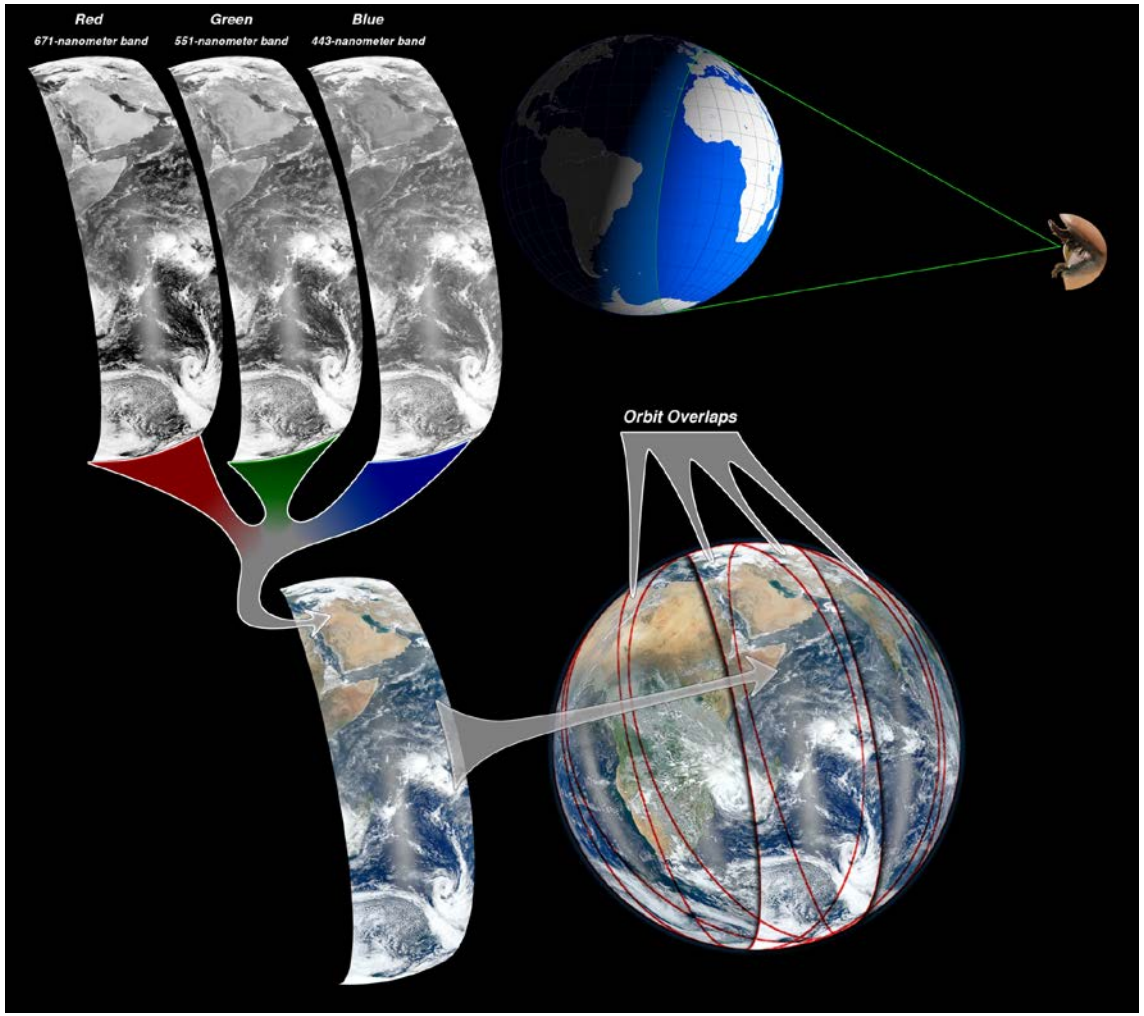


Data Search, Subset, and Download

Suomi National Polar Partnership (SNPP)

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

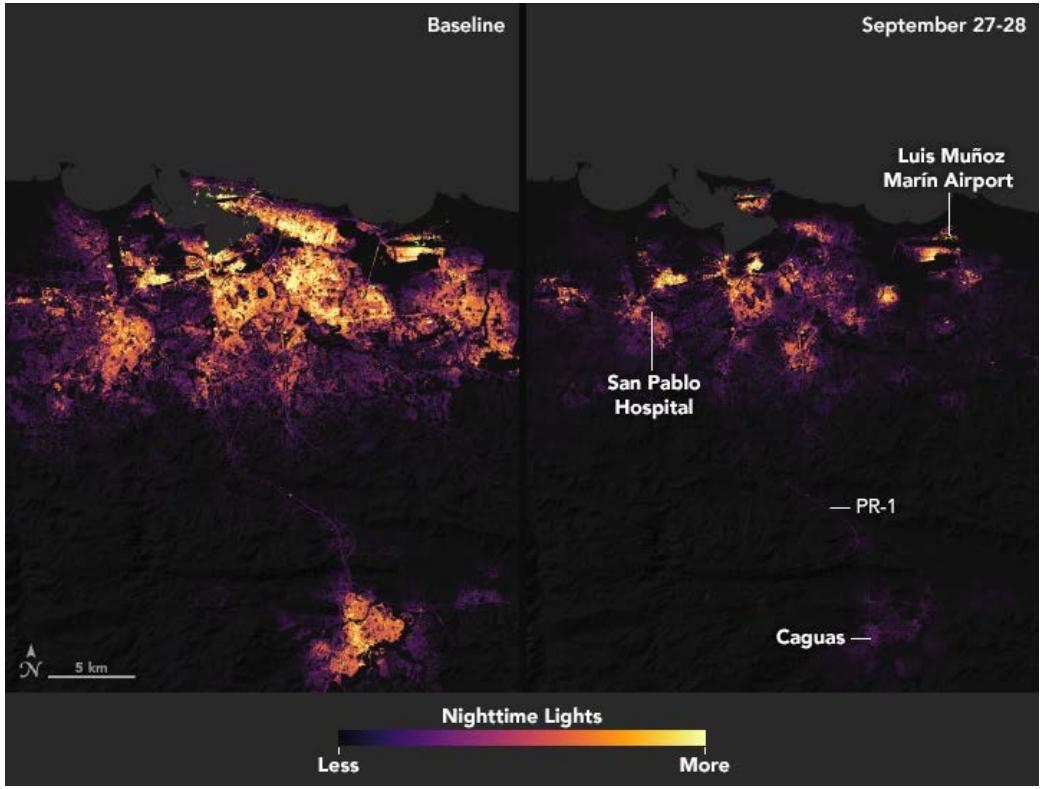
- Polar orbit, 1:30 p.m. equator crossing time
- Global coverage
- November 21, 2011 – present
- Sensors:
  - VIIRS, ATMS, CrIS, OMPS, CERCES



Visible Infrared Imaging Radiometer Suite (VIIRS)

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

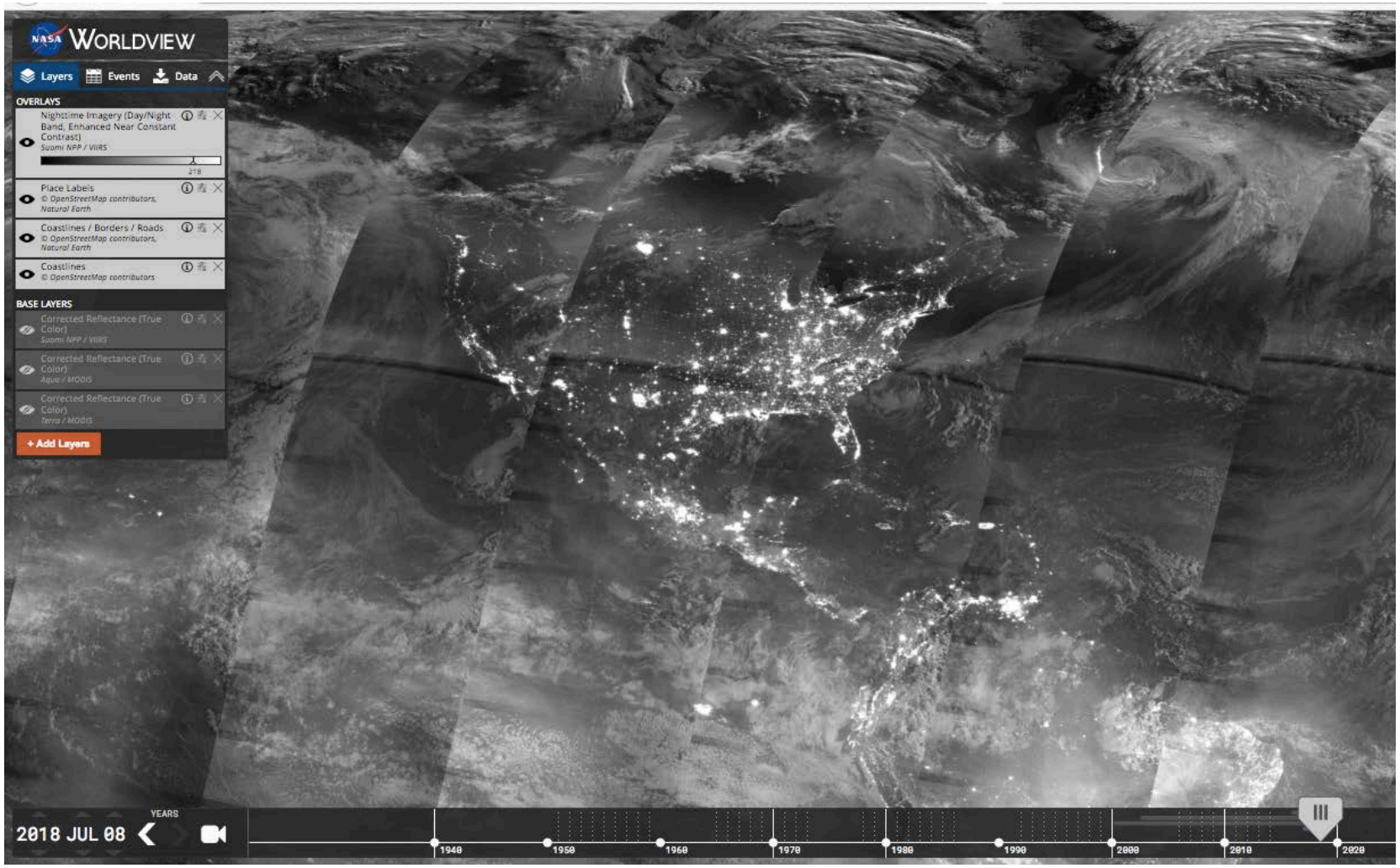
- Functionality similar to MODIS
- Spectral Bands
  - 22 bands (visible, IR, NIR, Mid-IR, day/night)
- Spatial Coverage and Resolution
  - Global; swath width: 3,040 km
  - Spatial Resolution: 375 – 750 m
- Temporal Coverage and Resolution
  - Oct 2011 – present
  - 1-2 times per day
- Data Access
  - 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?

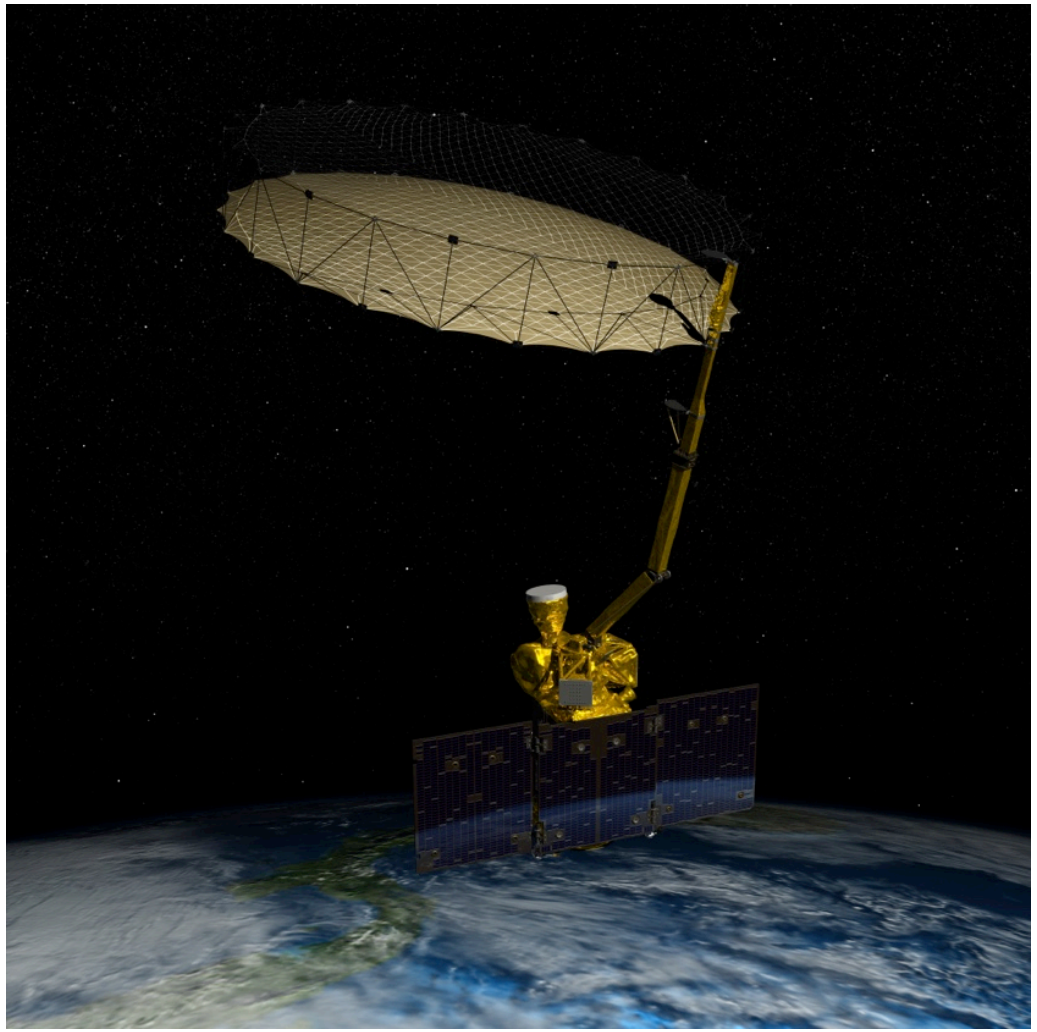
https://worldview.earthdata.nasa.gov



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)

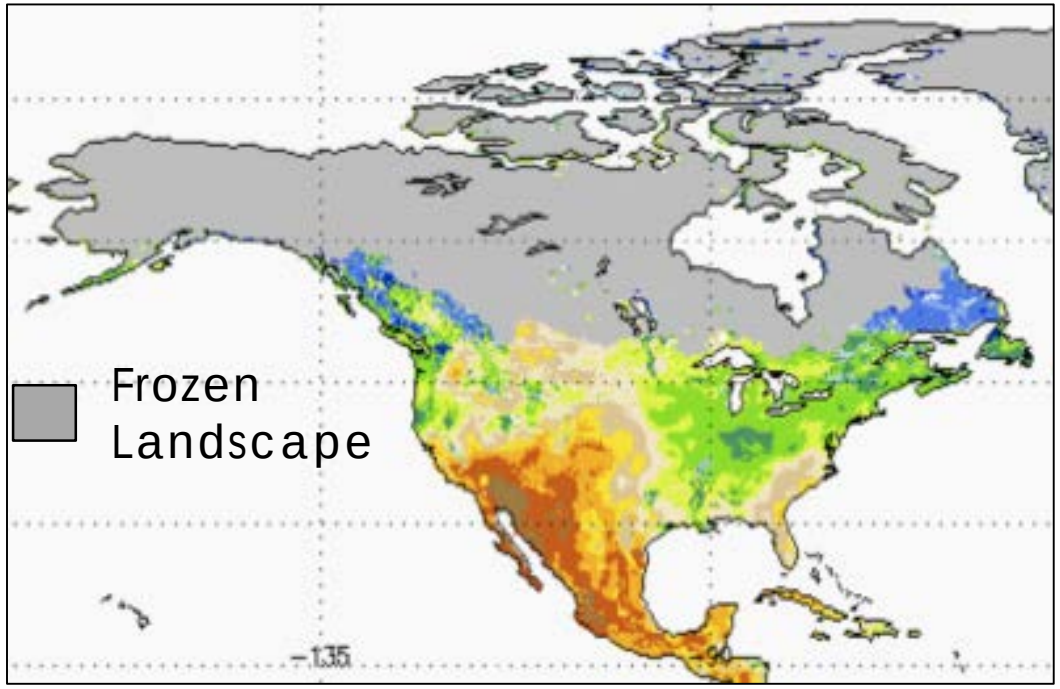


SMAP Microwave Radiometer & Radar

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

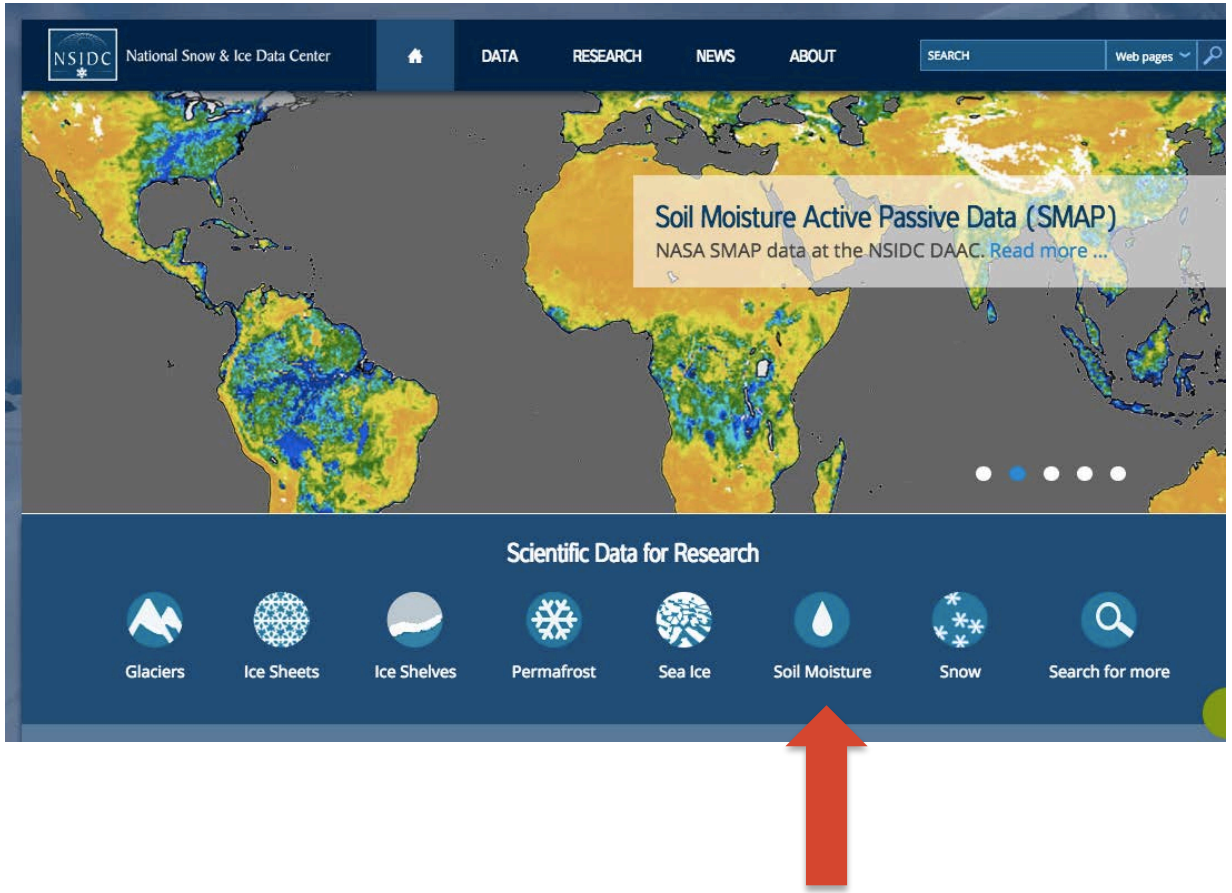
Measures moisture in the top 5 cm of the soil

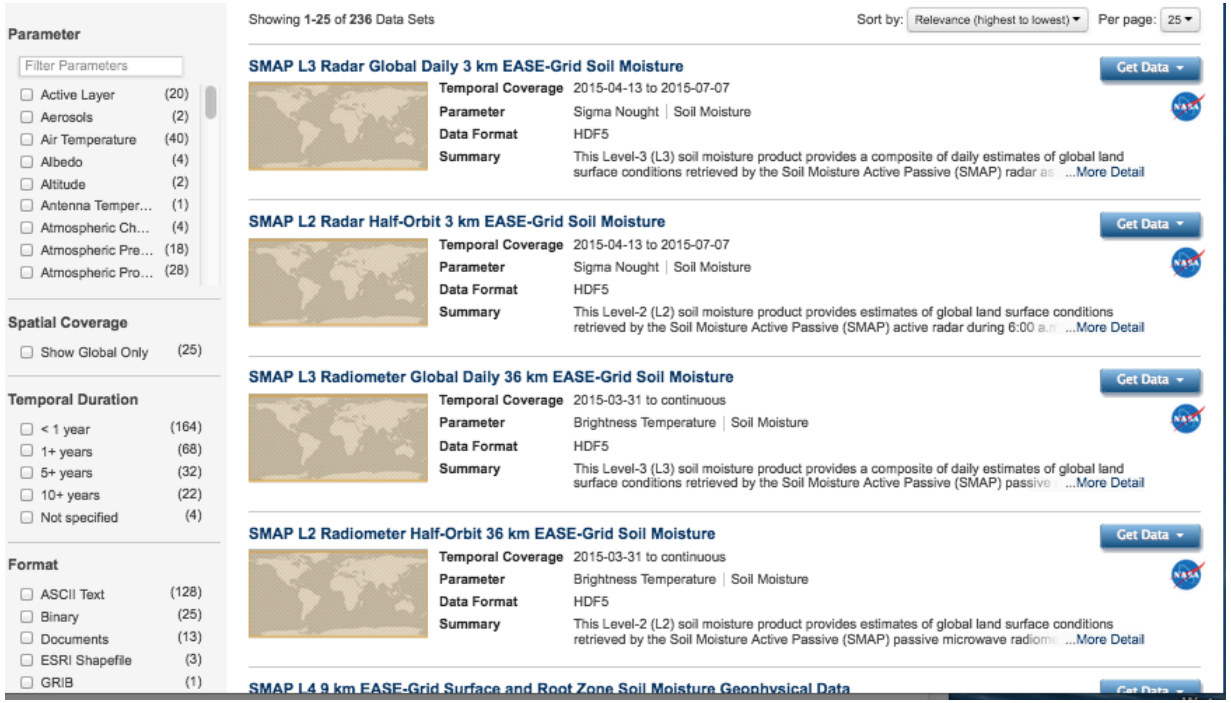


useful for flood monitoring

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

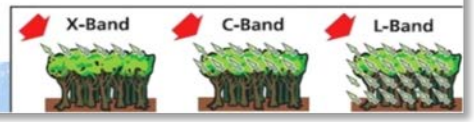
Synthetic Aperture Radar (SAR) Imagery For Flood Detection

https://arset.gsfc.nasa.gov/disasters/webinars/intro-SAR

- SAR is an active sensor operating in microwave frequencies – collect backscattered signal

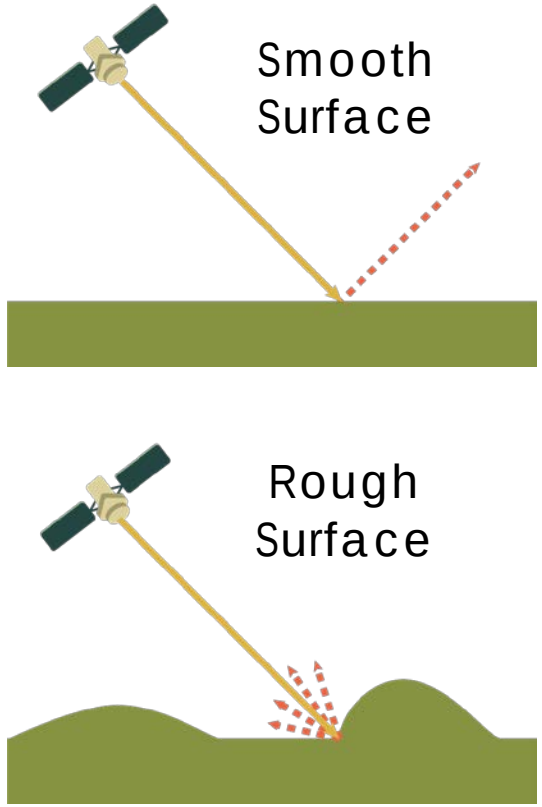
Commonly Used Frequency Bands

Frequency band	*Frequency range*	*Application Example*
• VHF	300 KHz - 300 MHz	Foliage/Ground penetration, biomass
• P-Band	300 MHz - 1 GHz	biomass, soil moisture, penetration
• L-Band	1 GHz - 2 GHz	agriculture, forestry, soil moisture
• C-Band	4 GHz - 8 GHz	ocean, agriculture
• X-Band	8 GHz - 12 GHz	agriculture, ocean, high resolution radar
• Ku-Band	14 GHz - 18 GHz	glaciology (snow cover mapping)
• Ka-Band	27 GHz - 47 GHz	high resolution radars



- The backscatter signal is primarily sensitive to surface structure
- The scale of the objects on the surface relative to the wavelength determine how rough or smooth they appear to the radar signal and how bright or dark they will appear on the image

Backscattering Mechanisms



Sentinel 1 SAR Image Access and Processing

- Sentinel-1 SAR data are available from:
  - https://vertex.daac.asf.alaska.edu/
- Sentinel-1 SAR data can be processed by using Sentinel-1 Application Toolbox (SNAP)
- SNAP is an open source toolbox and can be downloaded from:
  - http://step.esa.int/main/download/
- Processing SAR images is complex and requires advance training
- For more information see
  - https://arset.gsfc.nasa.gov/disasters/webinars/intro-SAR

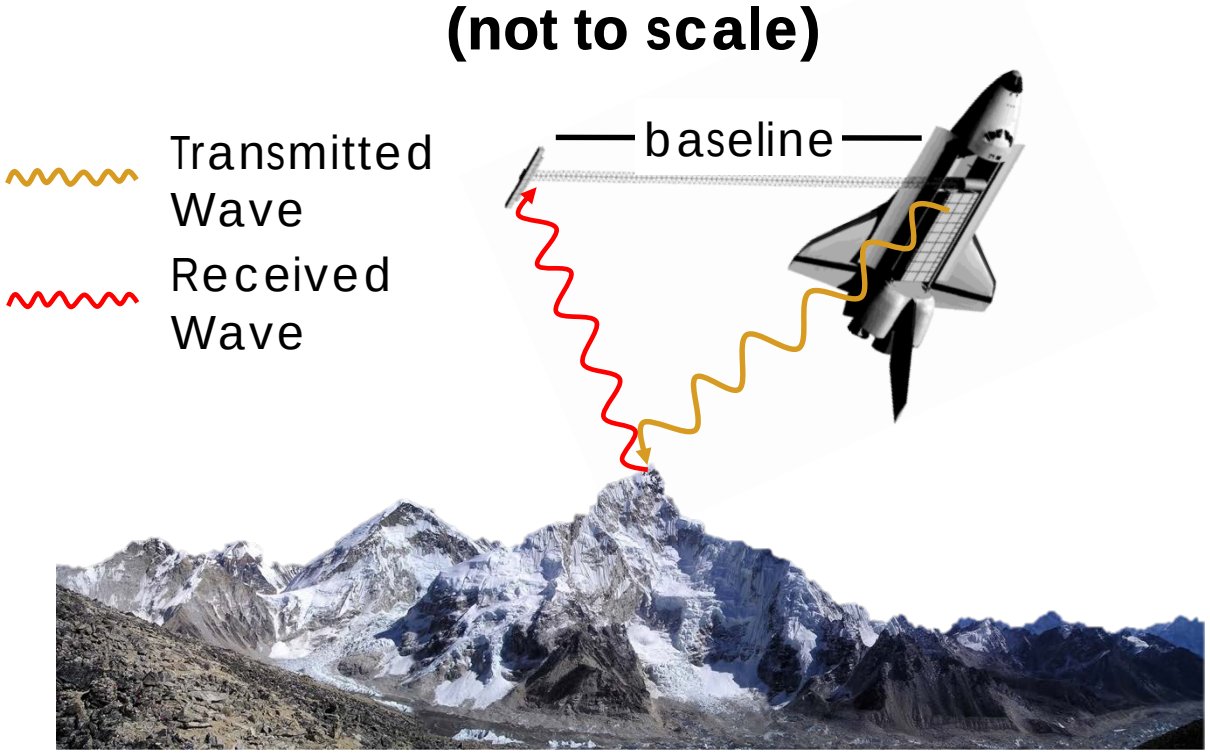
ARSET will host an advanced webinar on SAR data and applications in August 2018
https://arset.gsfc.nasa.gov/disasters/webinars/advanced-SAR-18/

Terrain Data From Shuttle Radar Topography Mission (SRTM)

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

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

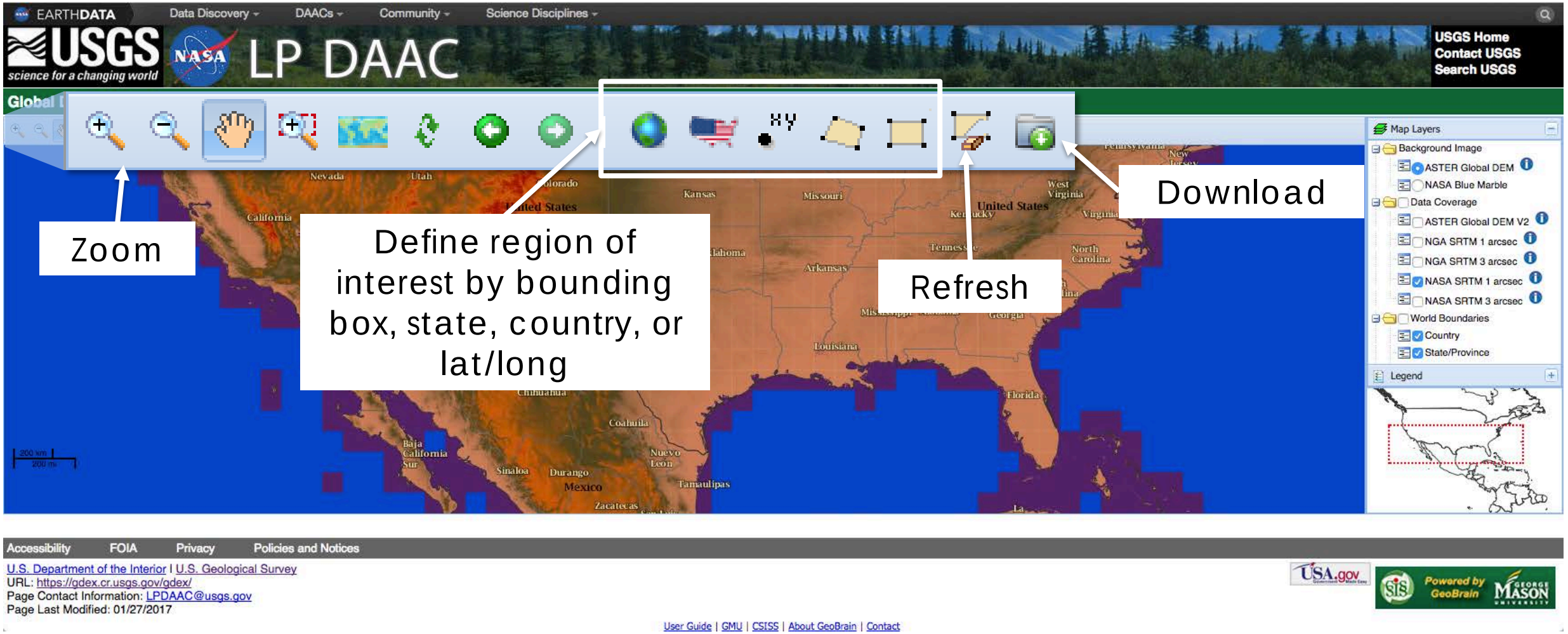
Radar signals being transmitted and received on the SRTM mission (not to scale)



Spatial Resolution: 30 m

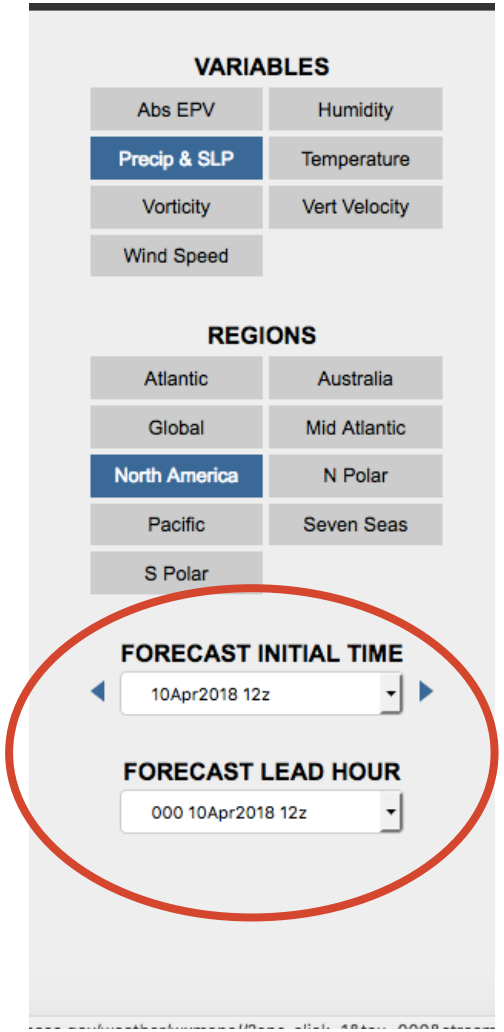
SRTM Elevation Data Access From Global Data Explorer (GDEx)

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

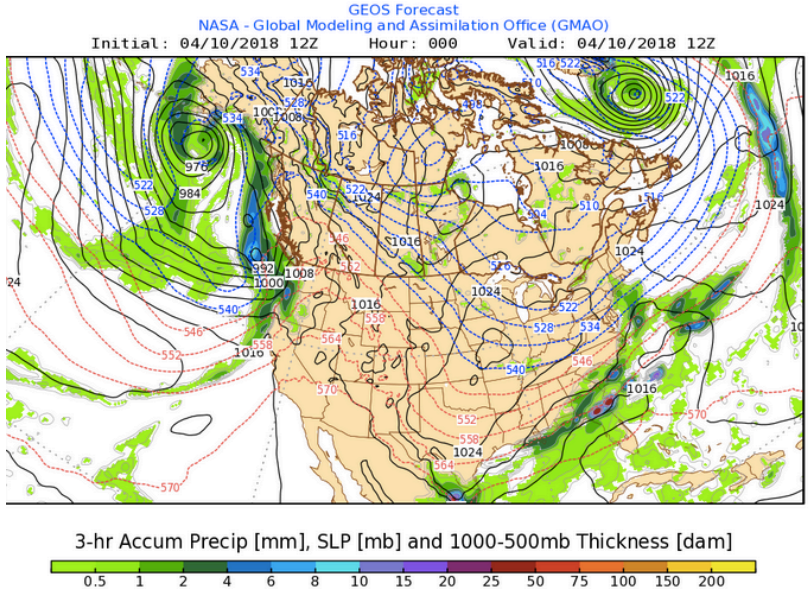


GEOS-5 Weather Data Maps – NRT and Forecast

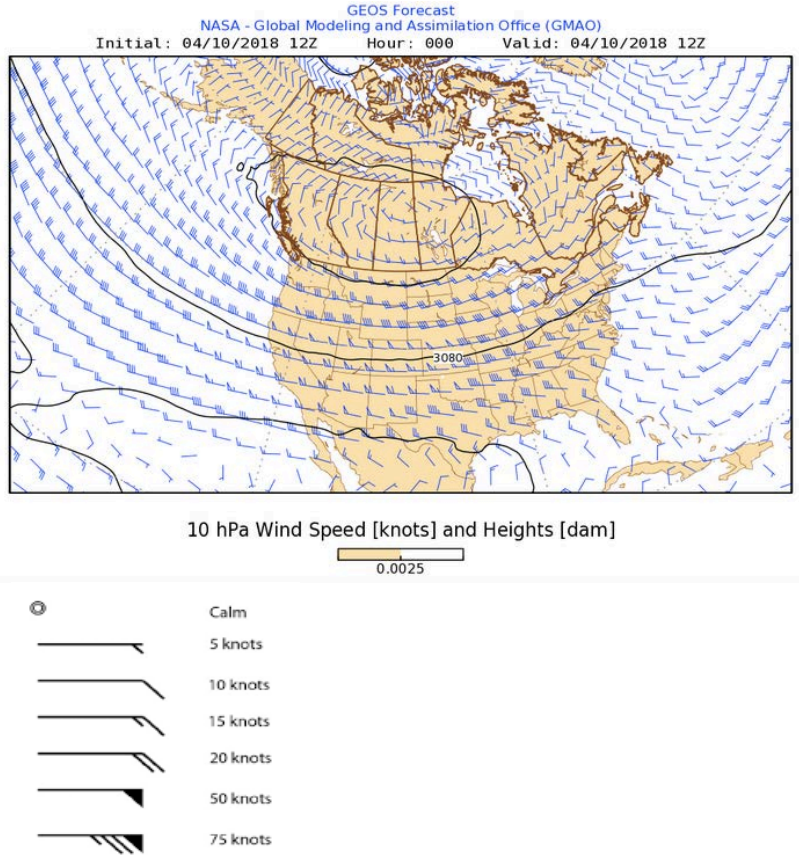
https://fluid.nccs.nasa.gov/weather/wxmaps/



Precipitation Sea Level Pressure



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

NCCS Dataportal - Datashare

Name	Last modified	Size	Description
Parent Directory		-	
GEOS.fp.asm.const_2d_asm_Nx.00000000_0000.V01.nc4	17-Apr-2018 05:50	26M	
Y2014/	03-Jun-2015 13:42	-	
Y2015/	01-Dec-2015 11:19	-	
Y2016/	01-Dec-2016 09:35	-	
Y2017/	01-Dec-2017 11:03	-	
Y2018/	01-Apr-2018 13:33	-	

NCCS Dataportal - Datashare

Name	Last modified	Size	Description
Parent Directory		-	
M01/	31-Jan-2016 09:52	-	
M02/	29-Feb-2016 10:14	-	
M03/	31-Mar-2016 10:09	-	
M04/	30-Apr-2016 10:09	-	
M05/	31-May-2016 10:44	-	
M06/	30-Jun-2016 10:11	-	
M07/	31-Jul-2016 09:56	-	
M08/	31-Aug-2016 10:06	-	
M09/	30-Sep-2016 09:35	-	
M10/	31-Oct-2016 09:36	-	
M11/	30-Nov-2016 10:05	-	
M12/	31-Dec-2016 09:33	-	

Name	Last modified	Size	Description
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D02/	03-Oct-2016 09:42	-	
D03/	04-Oct-2016 09:41	-	
D04/	05-Oct-2016 09:56	-	
D05/	06-Oct-2016 09:37	-	
D06/	07-Oct-2016 09:42	-	
D07/	08-Oct-2016 13:29	-	
D08/	09-Oct-2016 09:45	-	
D09/	10-Oct-2016 09:49	-	
D10/	11-Oct-2016 09:45	-	
D11/	12-Oct-2016 09:44	-	
D12/	13-Oct-2016 10:00	-	
D13/	14-Oct-2016 09:49	-	
D14/	15-Oct-2016 09:55	-	
D15/	16-Oct-2016 10:12	-	
D16/	17-Oct-2016 11:17	-	
D17/	18-Oct-2016 09:47	-	
D18/	19-Oct-2016 09:41	-	
D19/	20-Oct-2016 09:43	-	
D20/	21-Oct-2016 10:19	-	
D21/	22-Oct-2016 09:55	-	
D22/	23-Oct-2016 09:49	-	

GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0030.V01.nc4	09-Oct-2016 09:38	47M	
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GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0330.V01.nc4	09-Oct-2016 13:56	47M	
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0430.V01.nc4	09-Oct-2016 13:56	47M	
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0530.V01.nc4	09-Oct-2016 13:56	47M	
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0630.V01.nc4	09-Oct-2016 13:56	47M	
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GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1430.V01.nc4	09-Oct-2016 20:53	47M	
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1530.V01.nc4	10-Oct-2016 01:54	47M	
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1630.V01.nc4	10-Oct-2016 01:54	47M	

HTTP Files

Year & Month

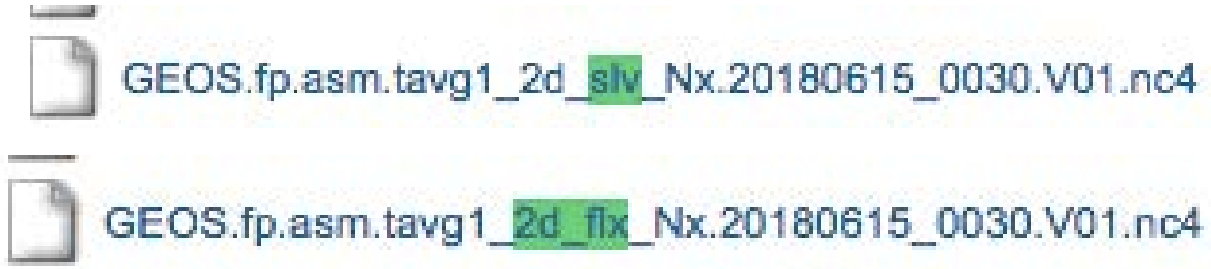
Day

Hourly Files

GEOS-5 Weather Data Access

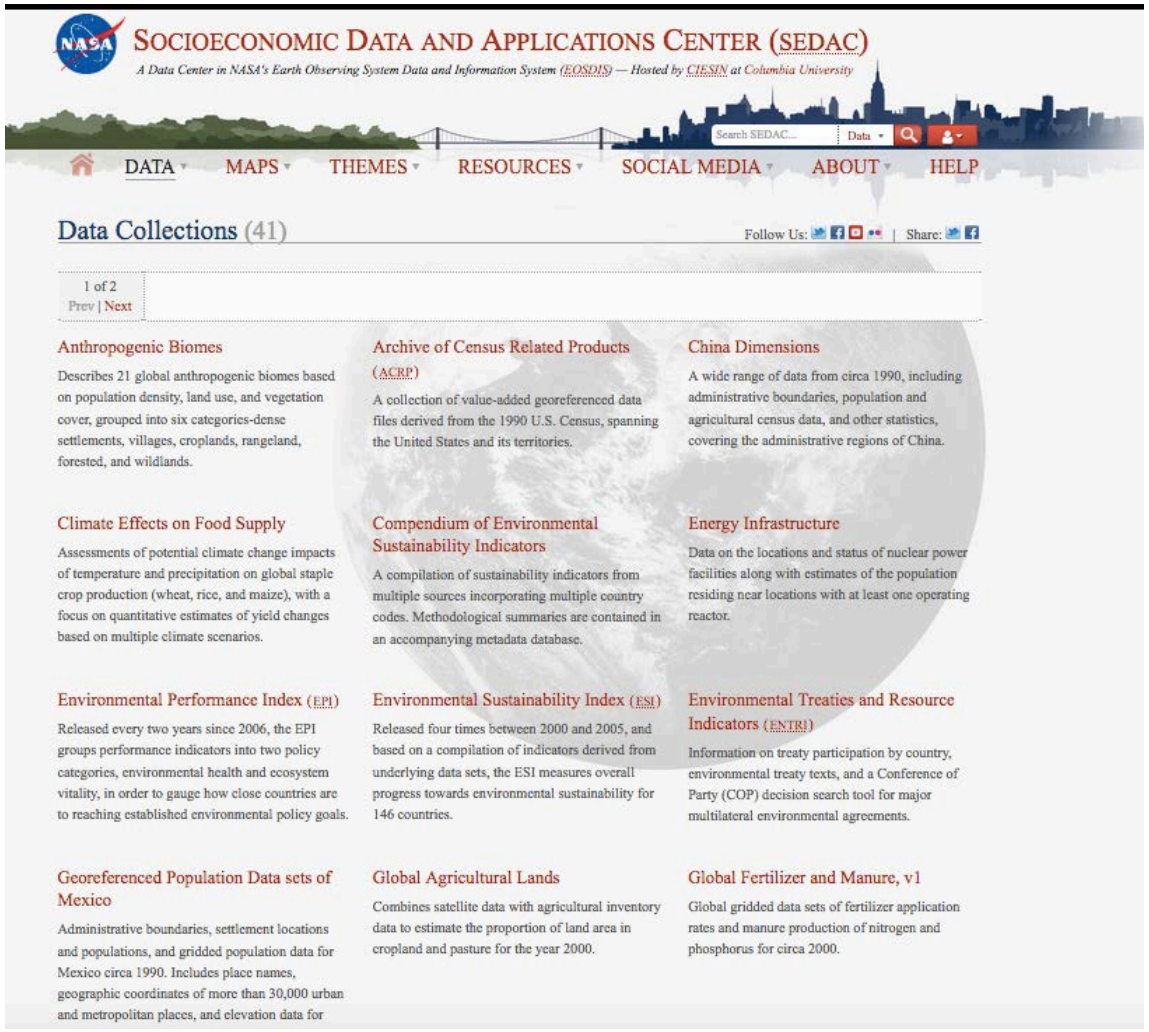
https://portal.nccs.nasa.gov/datashare/gmao_ops/pub/fp/das/

- 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

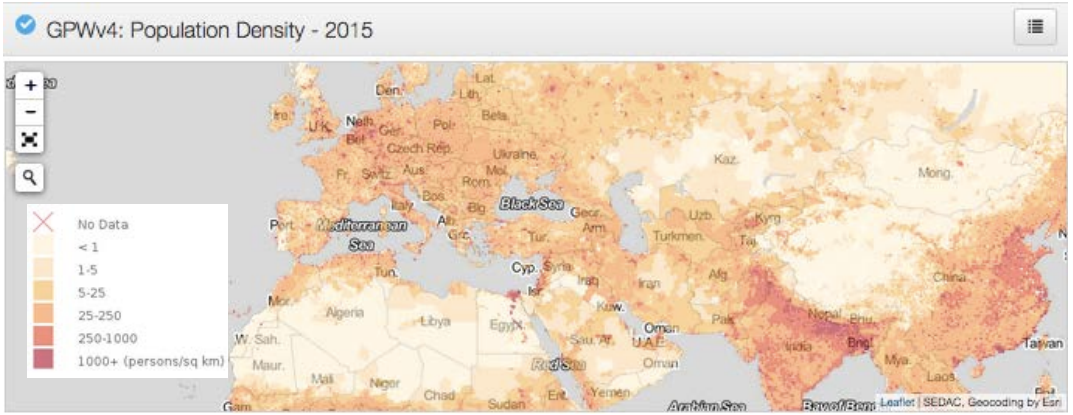


Socioeconomic Data

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



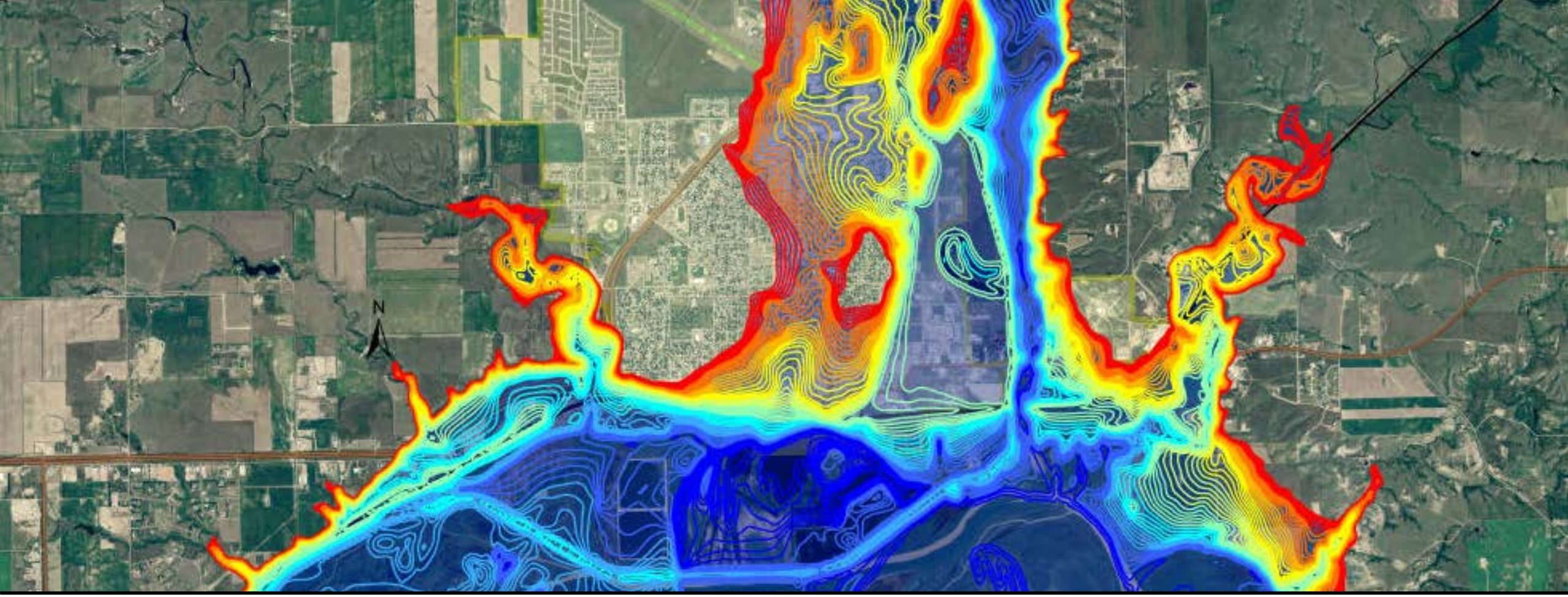
Global Population Density



- Other Useful Datasets:
  - Global urban data from the Landsat satellite
  - Global reservoir and dam
  - Low elevation coastal zones
  - Global roads
  - Energy infrastructure

Urban Flood Related Data Availability From Remote Sensing

- Floodplain Map: Terrain, Digital Elevation Model, Drainage Channels **(SRTM, LIDAR)**
- River Stage/Streamflow and Surface Inundation (**TRMM/GPM-based Global Flood Monitoring System, Terra/Aqua, Landsat**)
- Coastal Surges and Surface Inundation (**Terra/Aqua, Landsat**)
- Weather Data: Historical, Current and Forecast of Precipitation Intensity, Frequency **(TRMM/GPM, GEOS-5)**
- Flood Hazard Map and Return Period **(TRMM/GPM, GEOS-5**)
- Land Use Change: Exposed Soil versus Built Areas (**Landsat**, **MODIS**)
- Human Population (**SEDAC**)
- Infrastructure (e.g. Roads, Powerplants) (**SEADC**)

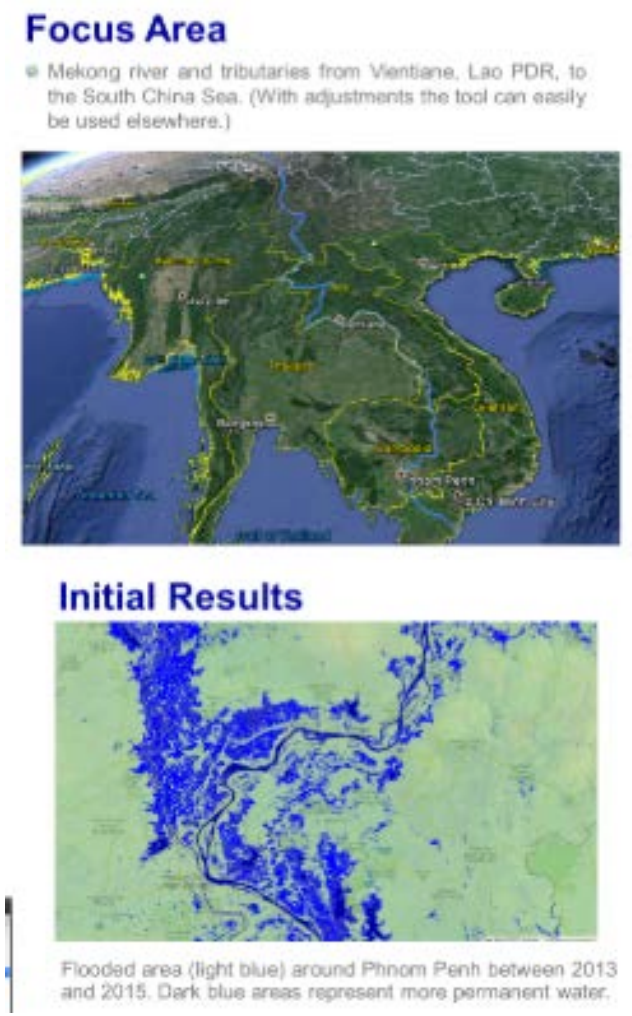


Examples of Urban Flood Management Using Remote Sensing

Asian Disaster Preparedness Center (ADPC)

https://servir.adpc.net/publications/flood-extent-mapping

- NASA-USAID SERVIR-Mekong responds to Lower Mekong Countries' Disasters Needs

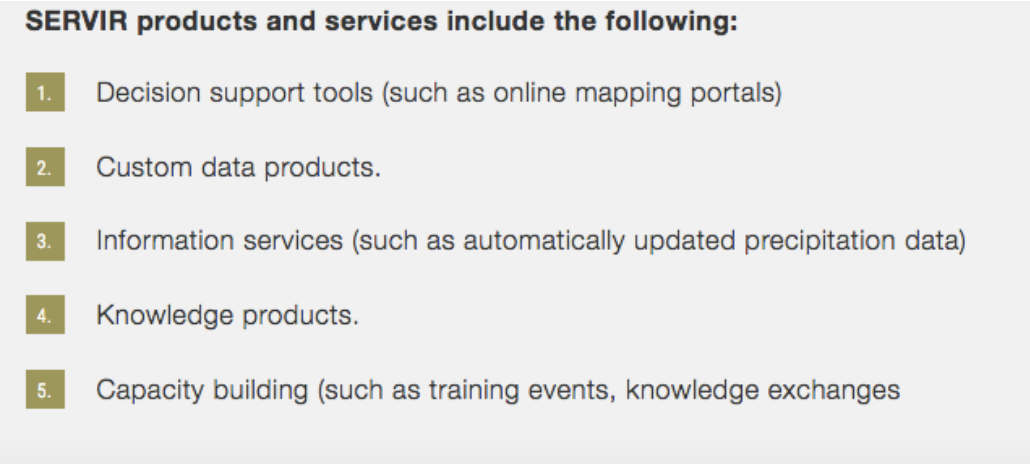


Asian Disaster Preparedness Center (ADPC)

https://servir.adpc.net/publications/flood-extent-mapping

NASA Earth Observations Used

- Landsat-7 and -8
- SRTM 30 m Digital Elevation
- MODIS



SERVIR products and services include the following:

1. Decision support tools (such as online mapping portals)
2. Custom data products.
3. Information services (such as automatically updated precipitation data)
4. Knowledge products.
5. Capacity building (such as training events, knowledge exchanges

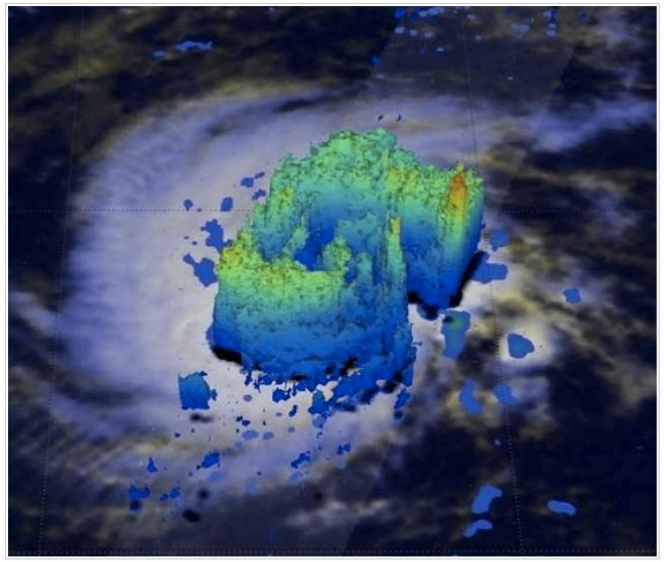
SERVIR Mekong Products & Services Summary

Project End-Users

- Natural Heritage Institute
- Vietnam: Institute of Meteorology, Hydrology, and Environment
- Cambodia: Ministry of Water Resources and Meteorology
- LAoPDR: Ministry of Natural Resources and Environment
- Ministry of Energy and Mines
- Thailand: Department of Water Resources
- Mekong River Commission (MRC)
- WWF Greater Mekong Freshwater Program

The World Bank Uses Remote Sensing to Assess Rapid Response for Floods

http://blogs.worldbank.org/psd/new-project-uses-satellites-rapid-assessment-flood-response-costs



Satellite-based flood forecasting capabilities: Hurricane Pali precipitation levels as captured by NASA/JAXA GPM Core Observatory satellite, showing the forming of an eye on January 11, 2016.

A view of the eastern part of the Sundarbans in Bangladesh showing seasonally flooded river basins (European Space Agency, March 2016).

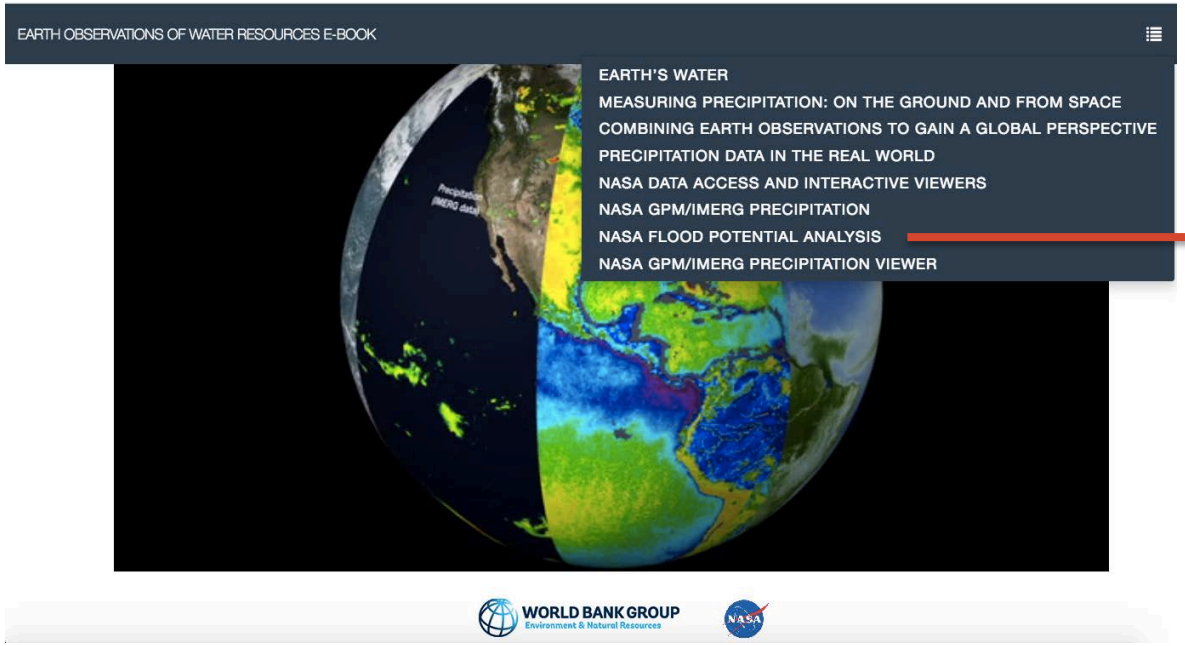
"These preliminary results we've seen are promising and options to combine satellite-based measurements with traditional hydrologic model-based approaches are also being explored. The longer-term objective is to help developing countries make risk-informed decisions on their disaster relief financing."

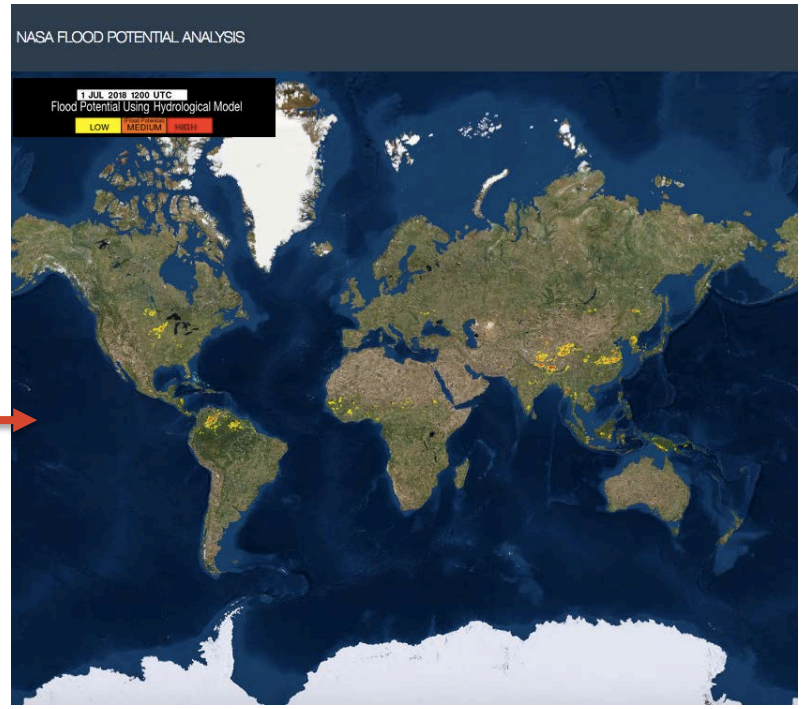
– Antoine Bavandi, a DRFIP financial sector specialist

The World Bank & NASA E-Book

http://www.appsolutelydigital.com/Nasa/index.html#page-top

- TRMM/GPM – Based Flood Potential
- Disseminated via the World Bank Open Learning Campus

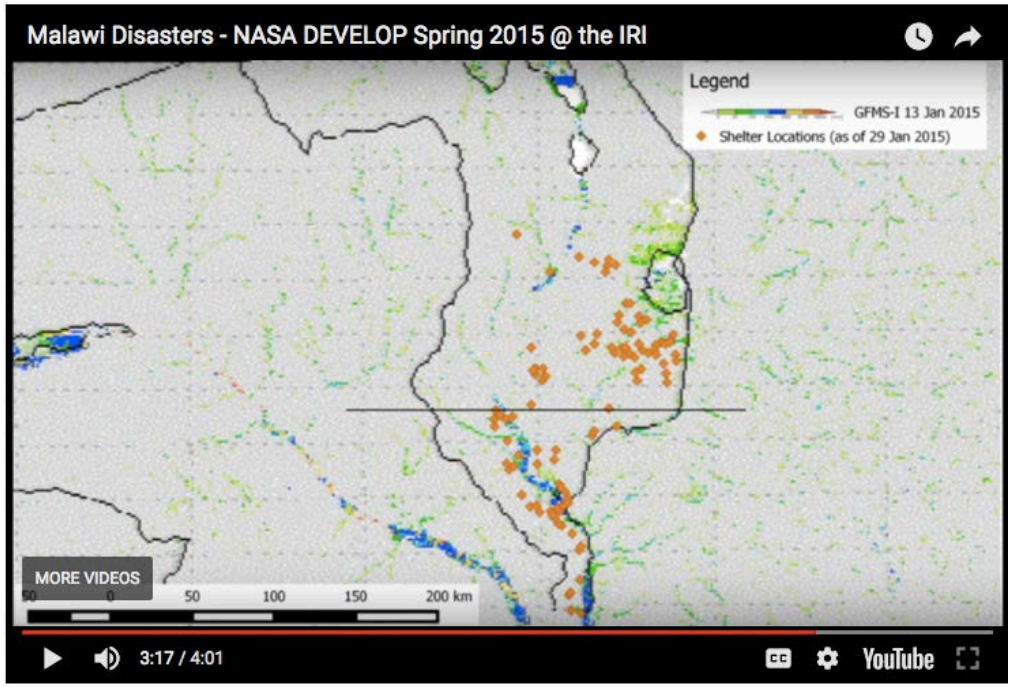




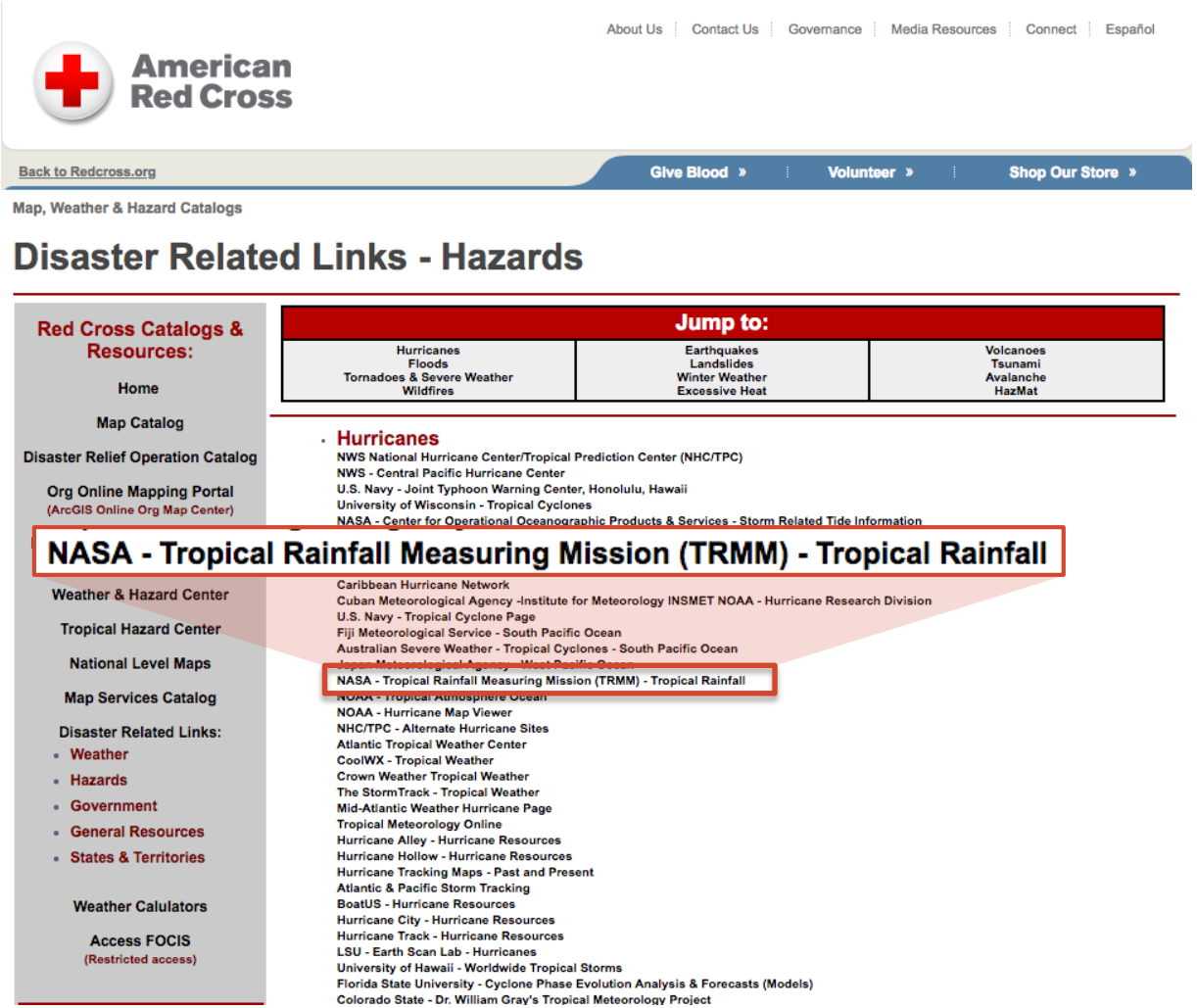
Red Cross Disaster Mapping

http://maps.redcross.org/website/Links/ARC_Disaster_Links_Hazards.html

- The American Red Cross uses precipitation data and flood monitoring tools for hazard mapping



https://earthzine.org/2015/04/04/iri-malawi-disasters/

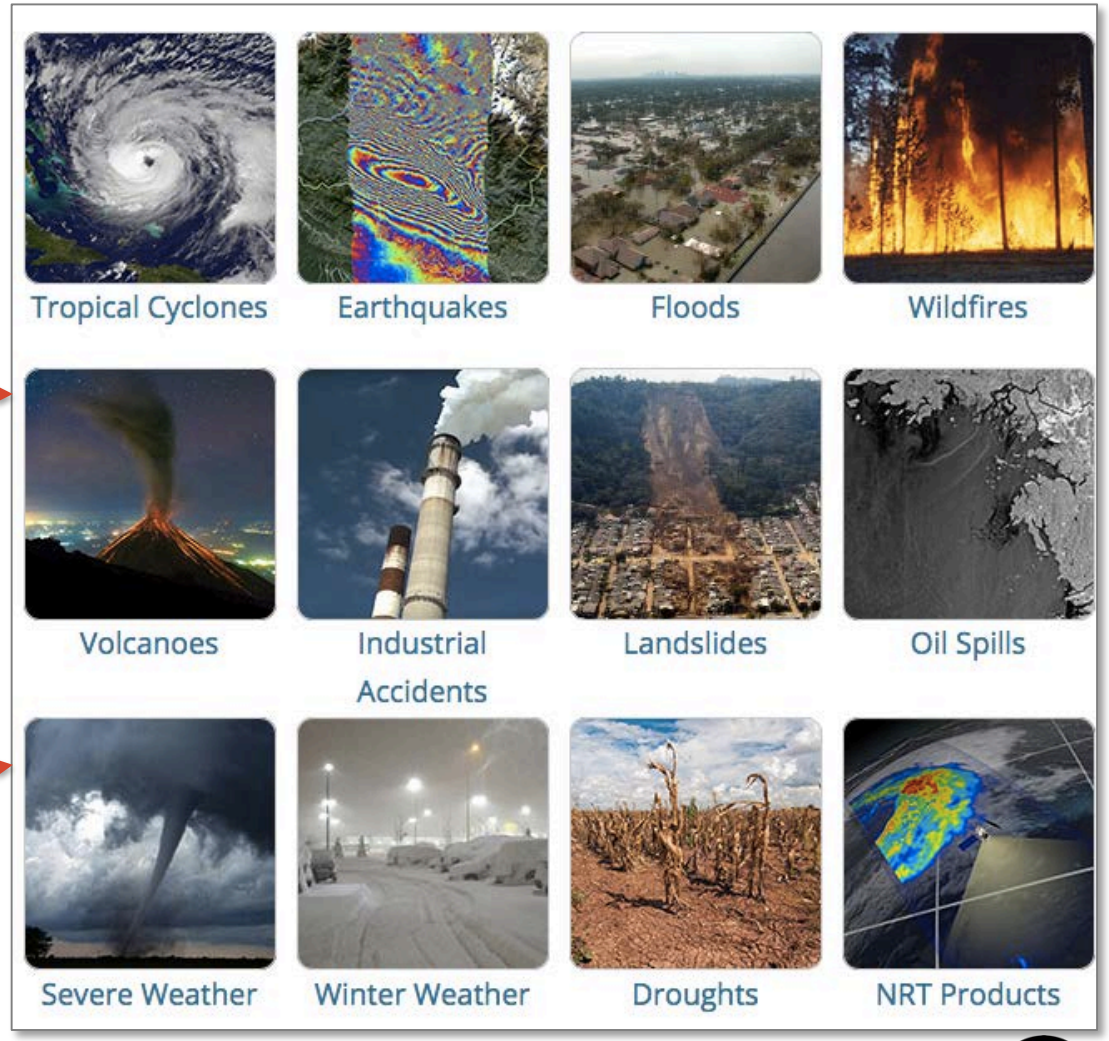


VA Dept of Conservation & Recreation: Floodplain Management

http://www.dcr.virginia.gov/dam-safety-and-floodplains/fppubs

Mapping Resources

- Virginia Flood Risk Information System (VFRIS)
- FEMA's Map Service Center
- Preliminary FEMA Map Products
- FEMA's Flood Risk Study Engineering Library
- FEMA's National Flood Hazard Layer (NFHL) and FIRMette Builder
  - NFHL for Google Earth
- NASA's Disasters Program Mapping Portal
- The Nature Conservancy's Coastal Resilience Mapping Tool for Virginia's Eastern Shore



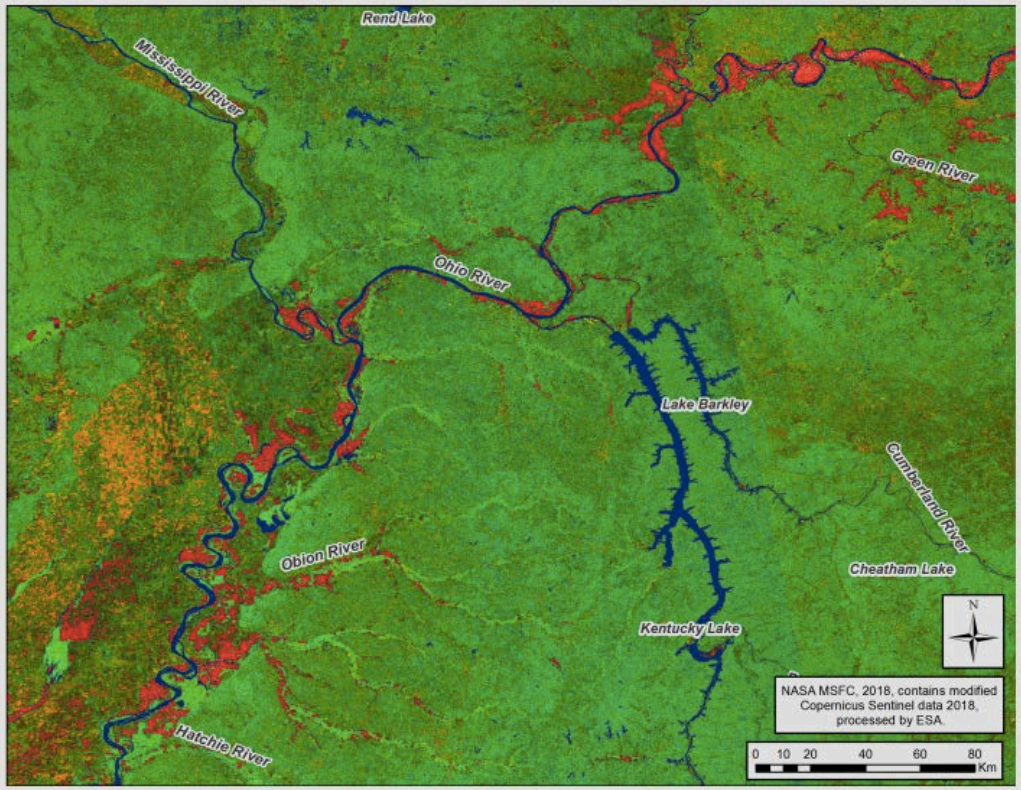
- Uses the NASA disaster portal for floodplain mapping, which provides a number of satellite-based data products
- https://maps.disasters.nasa.gov/

FEMA Floodplain Management

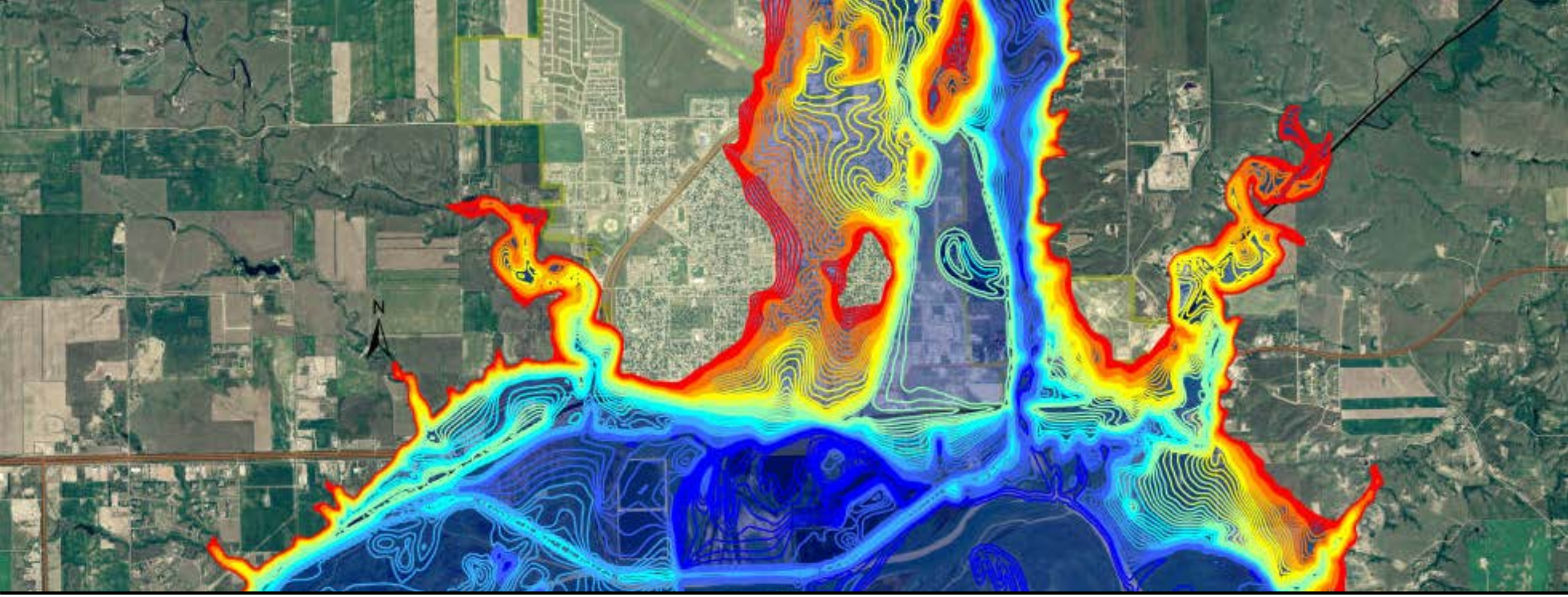
http://www.dcr.virginia.gov/dam-safety-and-floodplains/fppubs

- Uses resources from several federal, state, and professional associations, including information from the NASA Disasters Portal
- http://www.dcr.virginia.gov/dam-safety-and-floodplains/fppubs

Overview



RGB composite image of two Sentinel 1 passes from the 23 and 28th of February 2018 over the Ohio and Mississippi Rivers with the derived flood water extents (shown in red) overlaid.



Urban Flood Cases: Data Access Demonstration

Urban Flood Cases

- Ellicott City, Maryland

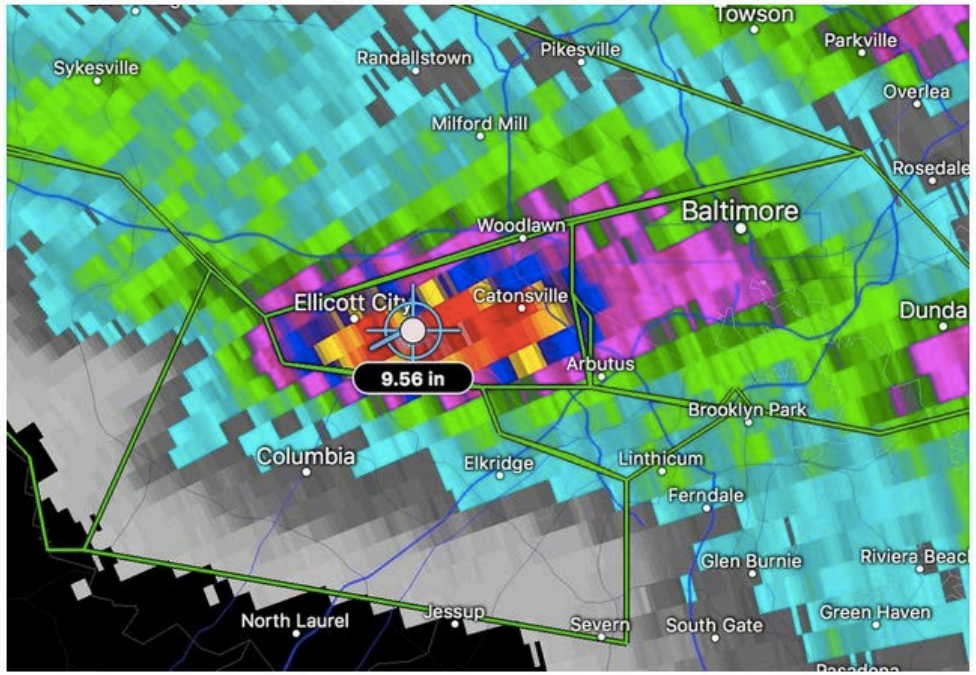
  Flash Flood occurred on 27 May 2018
- Houston, Texas

  Heavy rain cause flooding on 4 July 2018

Flood Case: Ellicott City, Maryland, USA

A torrent of rain

The image below shows the devastating pocket of extreme rain that befell a small region of central Maryland, bracketing Ellicott City, Catonsville and the campus of the University of Maryland Baltimore County over a nearly three-hour period.



(Radarscope)

The radar estimates 9.6 inches of rain fell midway between Ellicott City and Catonsville, with somewhat lesser surrounding amounts. It indicates about 6 inches fell in Ellicott City proper.

The Hudson Branch, Tiber Branch and New Cut Branch all converge near Main Street in Ellicott City. Two massive floods in 2016 and 2018 decimated the area.

Image Credits; (left) Washington Post, (right) WTOP

Flood Case: Houston, Texas, USA

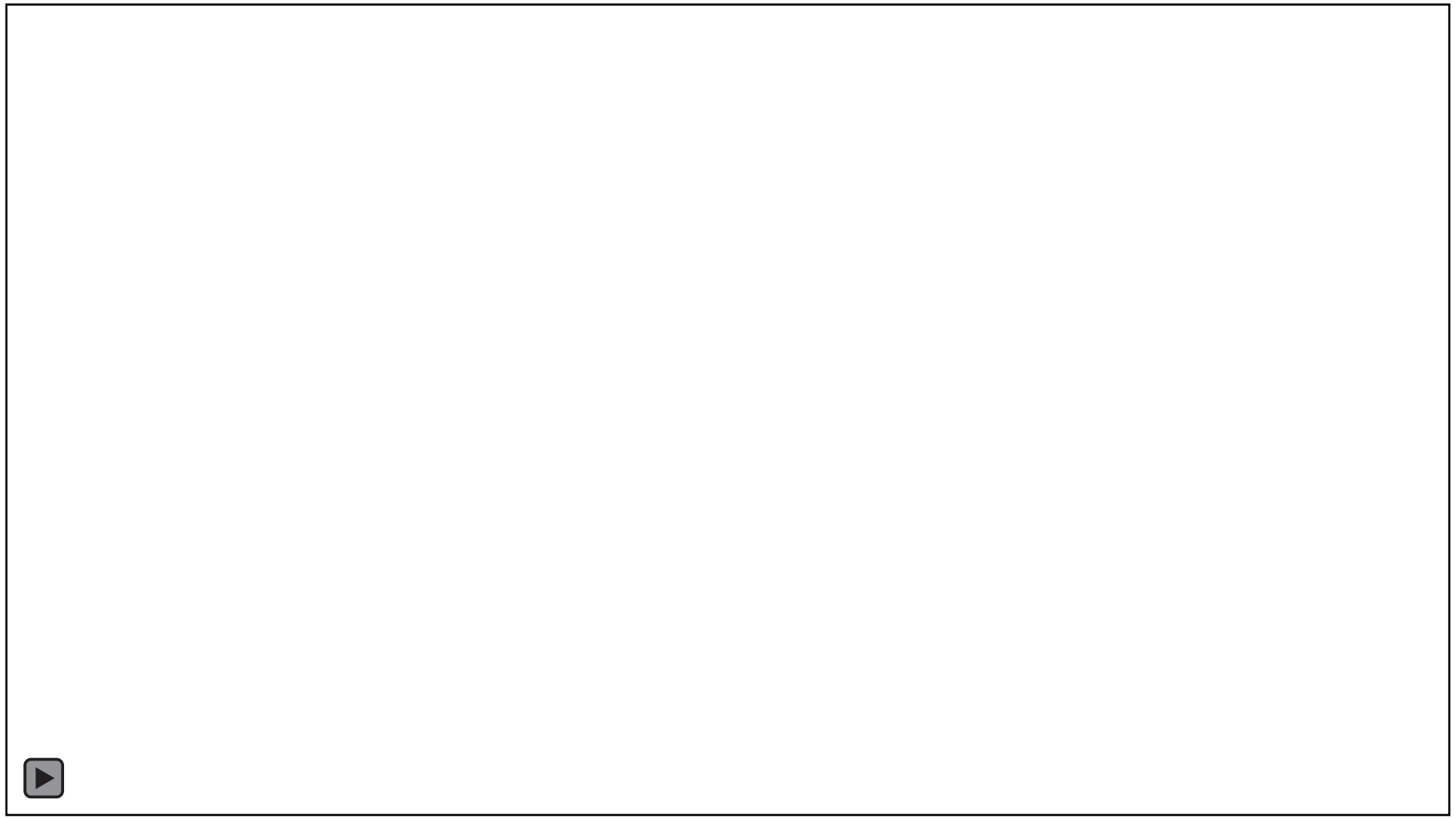
Close to 200 mm of rain caused street flooding

Image Credits: (left) CNN, (right) CW39 Houston

Urban Flood Case Analysis

- Access and Geospatial Analysis of
  - SRTM Terrain
  - GPM IMERG Precipitation

Monitoring Urban Changes for Flood Hazard Mitigation



Source: http://svs.gsfc.nasa.gov/11506

Next Week

- Examples of SAR-based Urban Flood Monitoring
- Examples of LIDAR Data for Urban Floodplain Detection
- Landsat-based Urban Data
- Flood Mapping Tools: MODIS, DFO, GFMS
- Socioeconomic Data


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!