

# 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

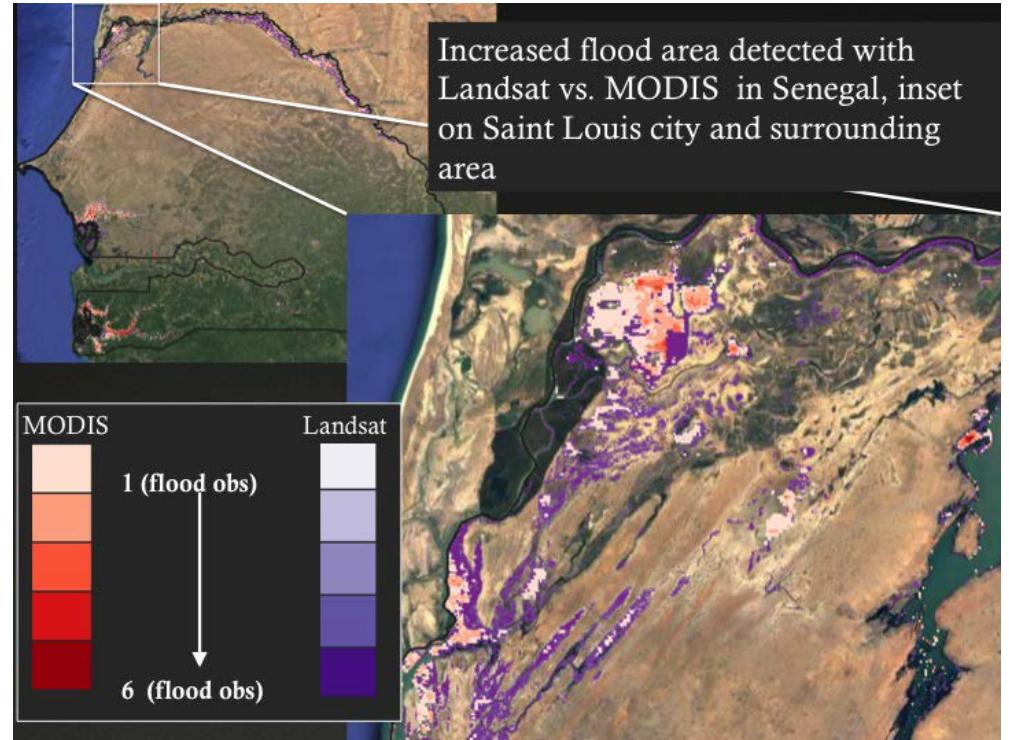
Overview of Remote Sensing Data for  
Urban Flooding



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

August 1

Access and Analysis of Remote Sensing  
Observations for Urban Flood Monitoring



# Homework and Certificates

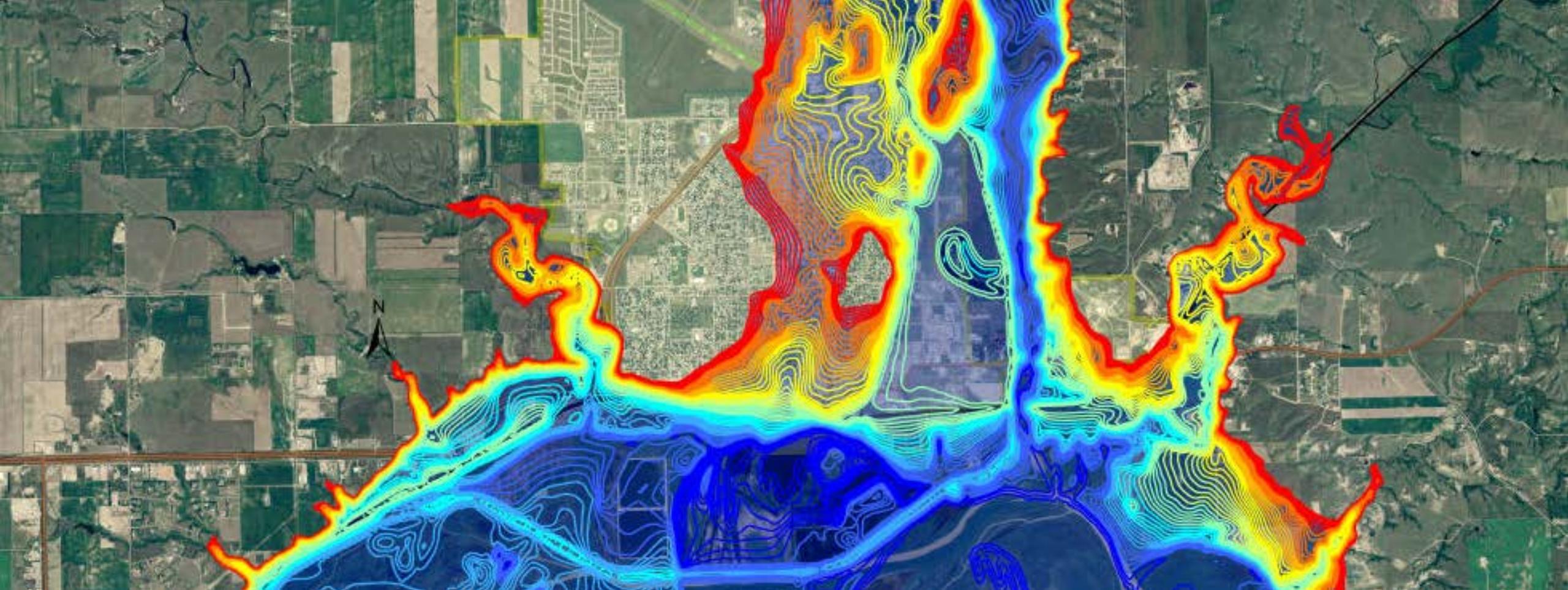
- Homework will be available after Session-1 and Session-2 from <https://arset.gsfc.nasa.gov/water/webinars/>
- **Answers must be submitted via Google Form**
- Certificate of Completion:
  - Attend both webinars
  - Complete homework assignment by the deadline (15 August 2018)
  - You will receive certificates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





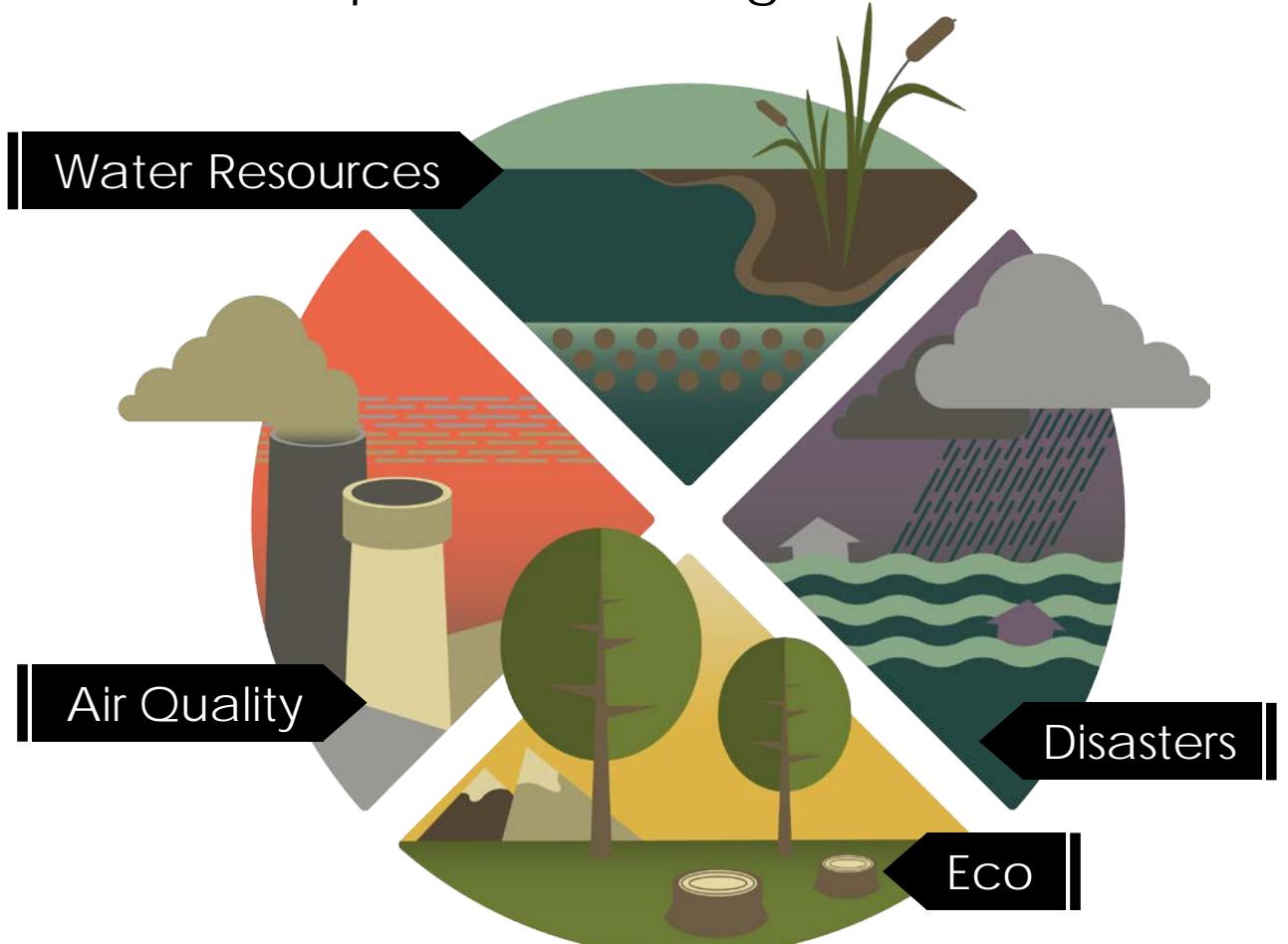
About ARSET

# 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

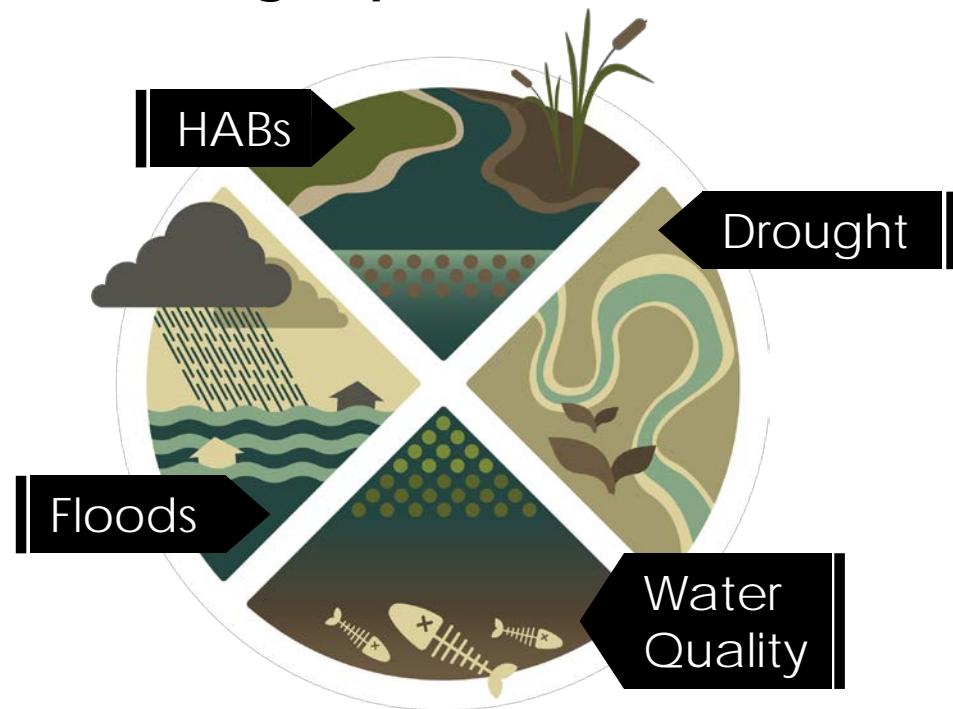


110+ countries

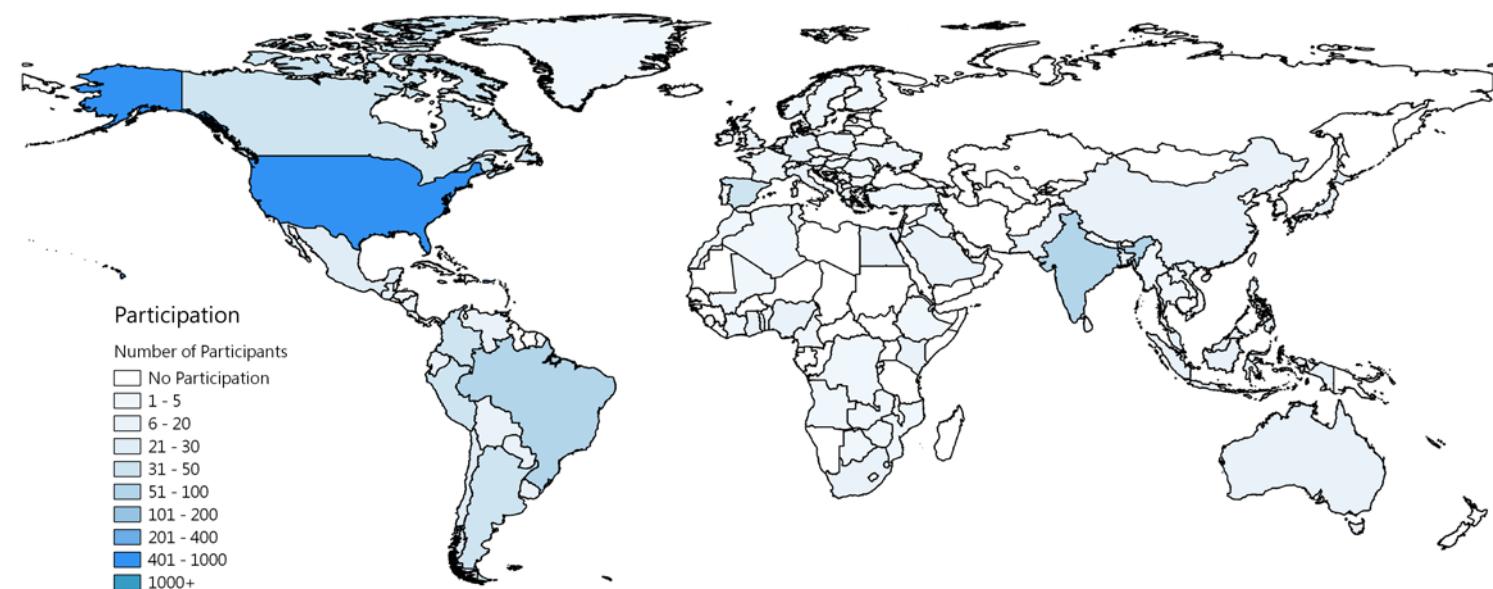


880+ organizations

## Training Topics Include...



## Global Water Resources Training Attendees (2017)



# ARSET Training Impacts: Disasters Management (2013 – 2018)



10 trainings



3,000+ participants

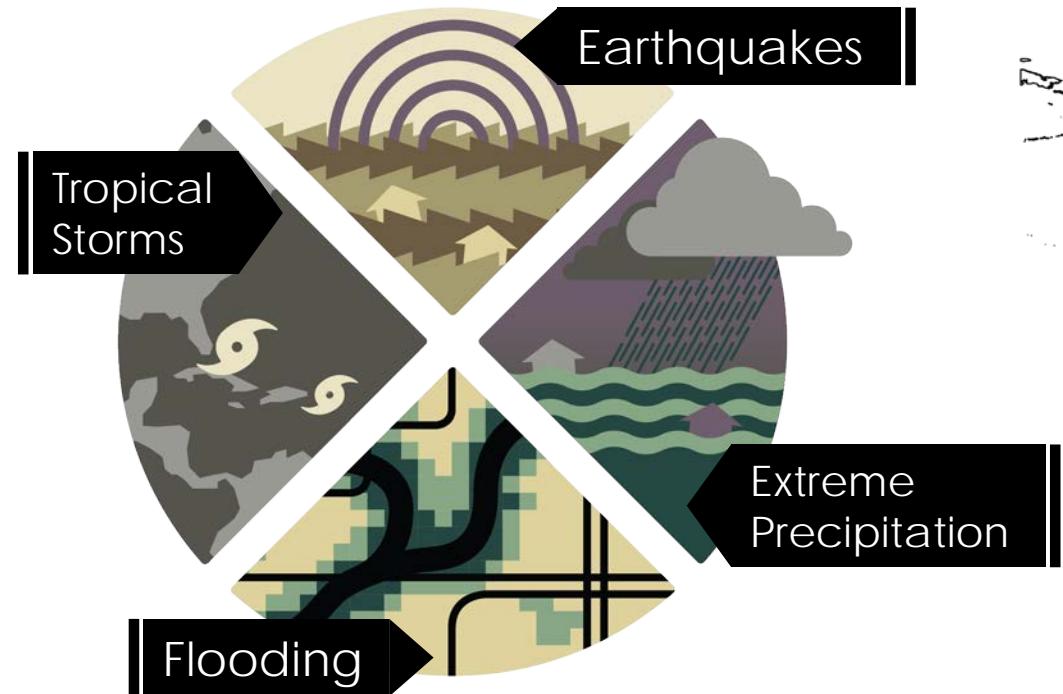


119+ countries

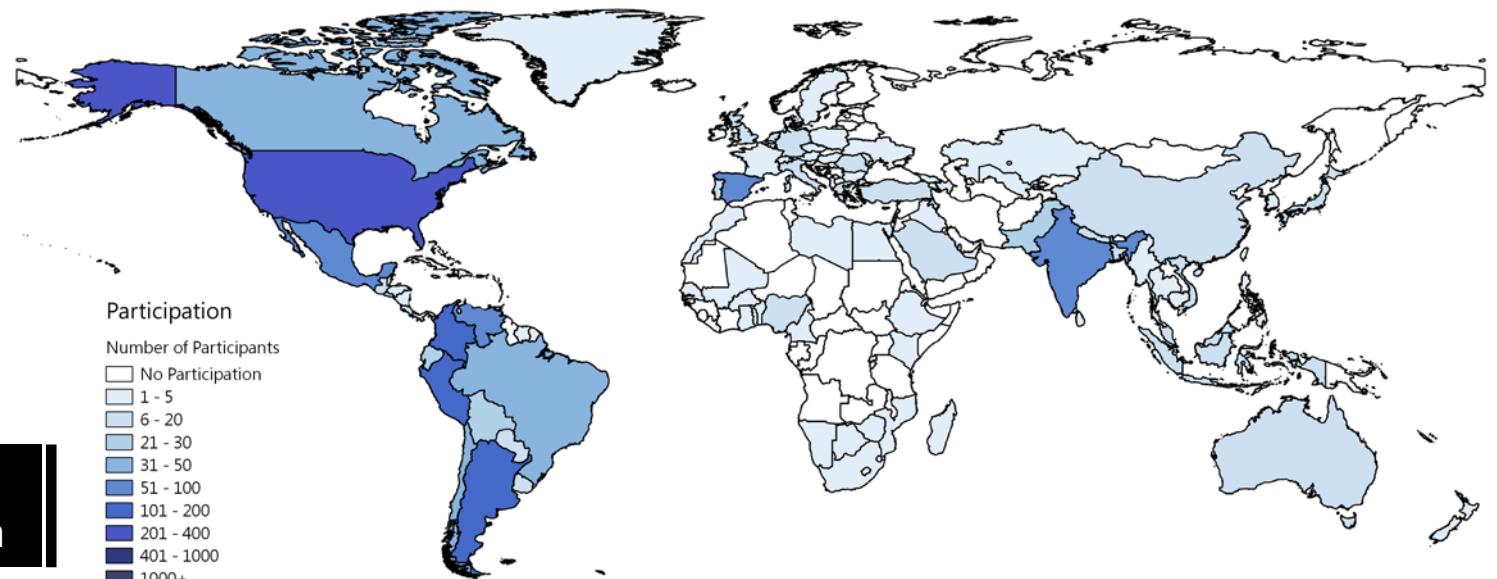


770+ organizations

## Training Topics Include...



## Global Disaster Training Attendees (2017)

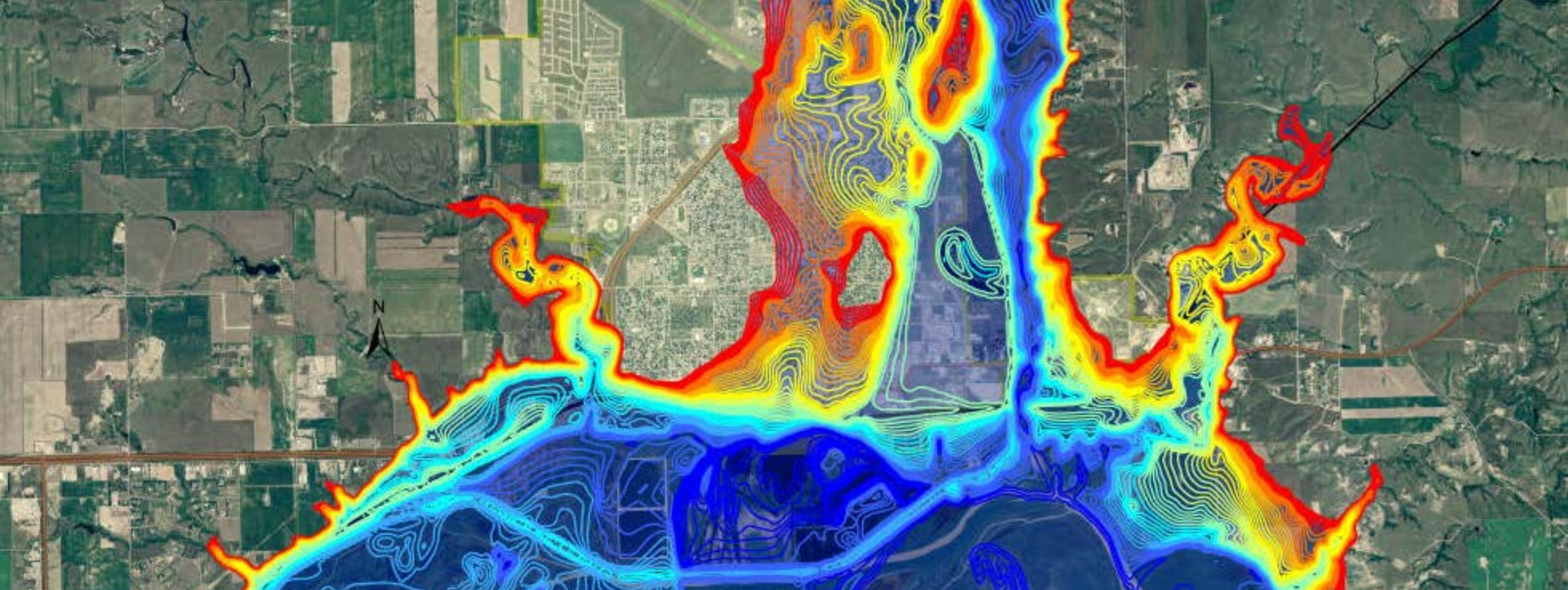


# ARSET Website & Listserv

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

The screenshot shows the ARSET website homepage. At the top, there's a banner featuring a satellite image of a coastal area with green land and blue water. Overlaid on the banner are the NASA logo, the ARSET logo, and the text "Applied Remote Sensing Training". The top navigation bar includes links for "Earth Sciences Division", "Applied Sciences", and "ASP Water Resources". A search bar and a Twitter icon are also present. Below the banner, the main menu has options for "Home", "About", "Trainings", and "Resources". The "Trainings" menu is expanded, showing categories like "Fundamentals", "Disasters", "Health & Air Quality", "Land", and "Water Resources". A specific training event is highlighted: "Introduction to Remote Sensing of Harmful Algal Blooms" occurring on Tuesdays, Sep 5-26, 2017, from 11:00-12:00 or 21:00-22:00 EDT (UTC-4). A "Register Now" button is provided. To the right, a sidebar titled "ARSET" contains links for "Online Trainings", "In-Person Trainings", "Sign up for the Listserv" (which is circled with a red arrow), "Tools Covered", "Suggest a Training", "Personnel", and "Resources". Another section titled "Upcoming Training" lists "Water" and "Satellite Observations of Water Quality for".





# 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



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

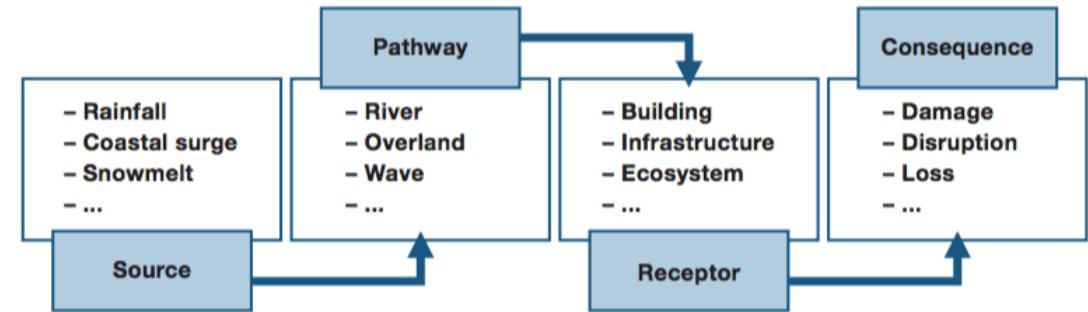


Figure 1.1: The Source, Pathway, Receptor Model

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

**Our cities are on the frontline of changing climate**



India has four of the 20 cities most vulnerable to flooding, with growth and development its exposure to disaster risk could increase to more than US\$150 billion by 2030. Photo: Abju BORO

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

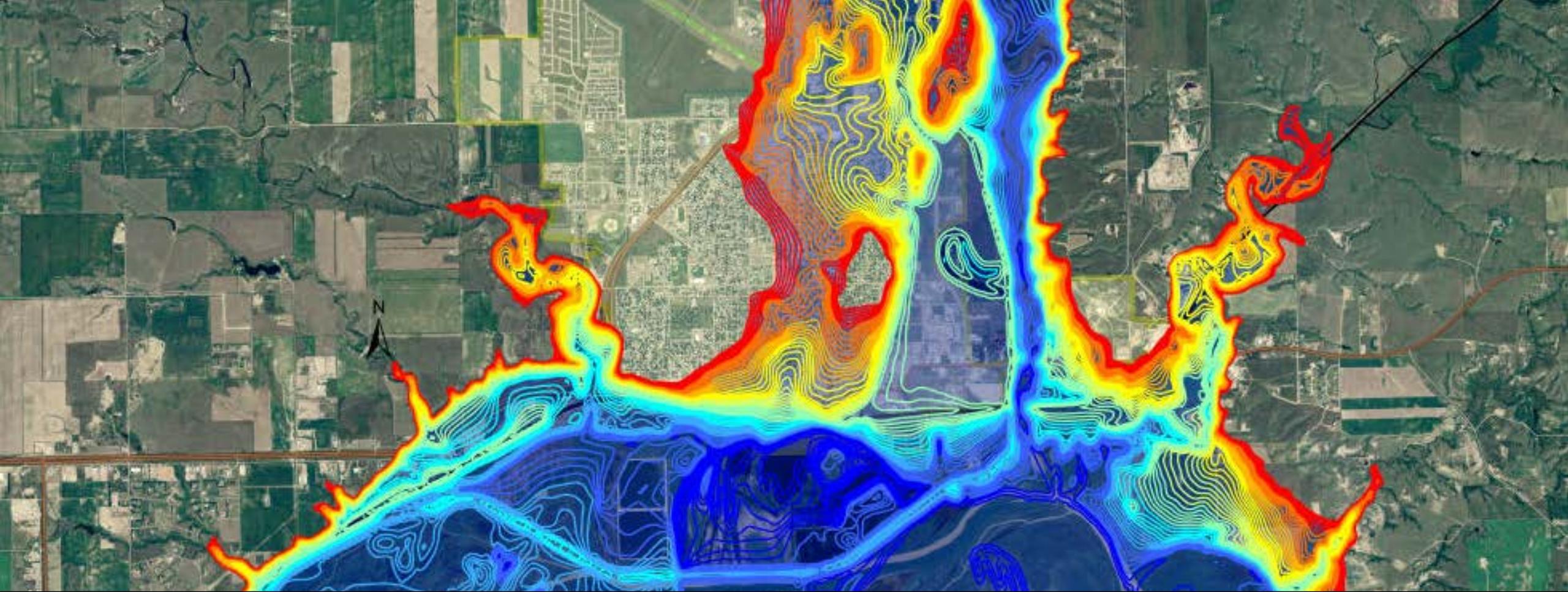
## Natural:

- 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

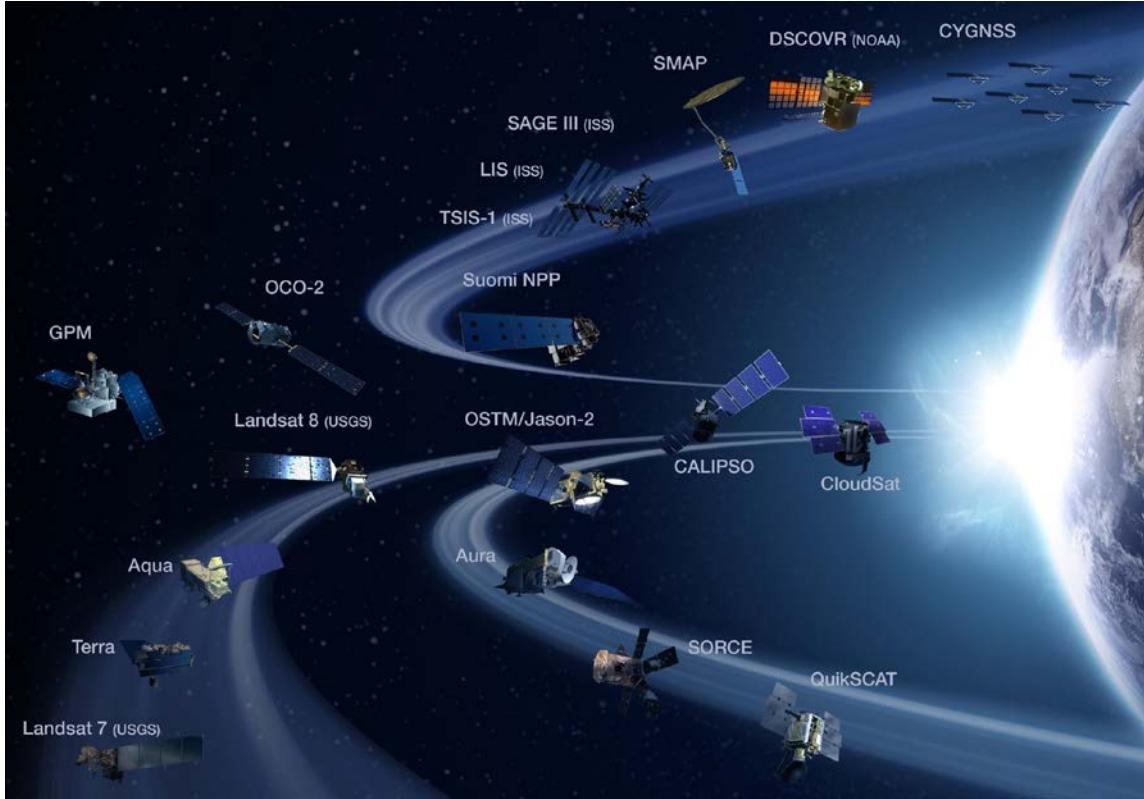
- Storm Water System Design and Capacity
- Design and Capacity of Dams and Levees
- Land Use Change: Exposed Soil Versus Build Areas
- Human Population
- Infrastructure (e.g., buildings, roads)





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	VIIIRS		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](http://landsat.usgs.gov/about_mission_history.php)



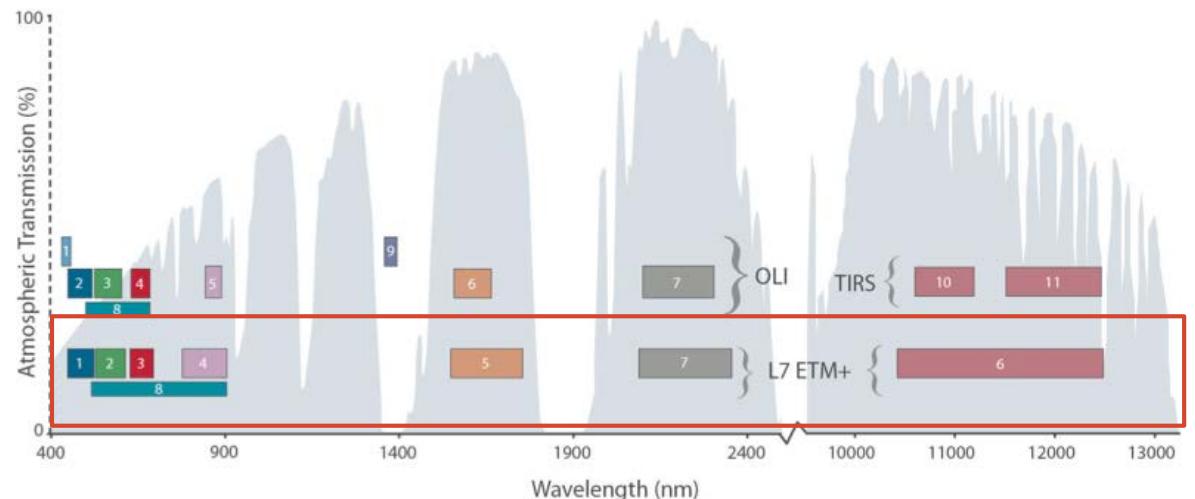
# Enhanced Thematic Mapper (ETM+)

- 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

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

## 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

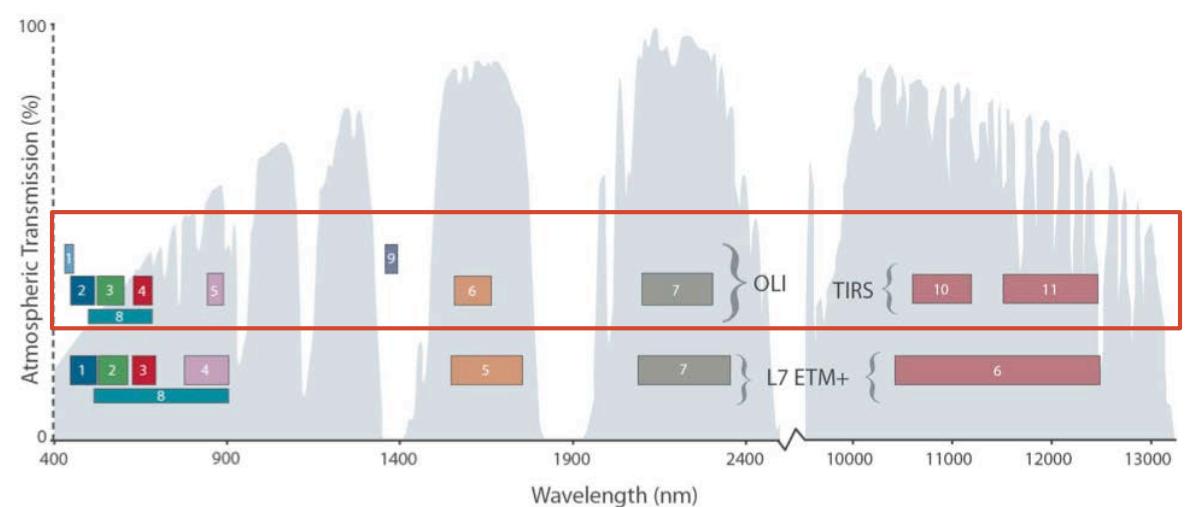


# Operational Land Imager (OLI)

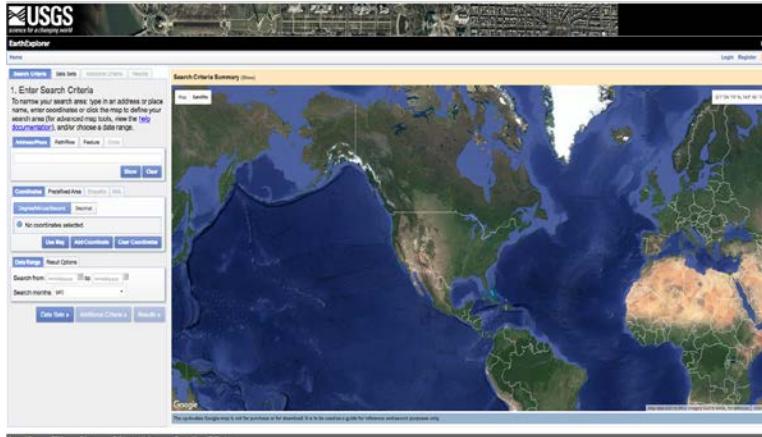
- Onboard Landsat-8
- Polar orbiting satellite
- Spatial Coverage and Resolution:
  - Global, Swath: 185km
  - Spatial resolution: 15m, 30m
- Temporal Coverage and Resolution:
  - Feb 11, 2013 – present
  - 16-day revisit time

## Spectral Bands

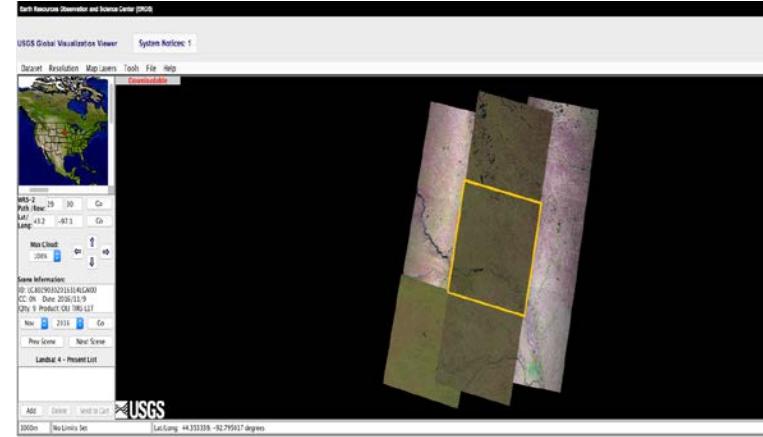
- 9 bands (blue-green, green, red, near IR, shortwave and thermal IR)
  - Bands 1-7, 9: 30m
  - Band 8: 15m



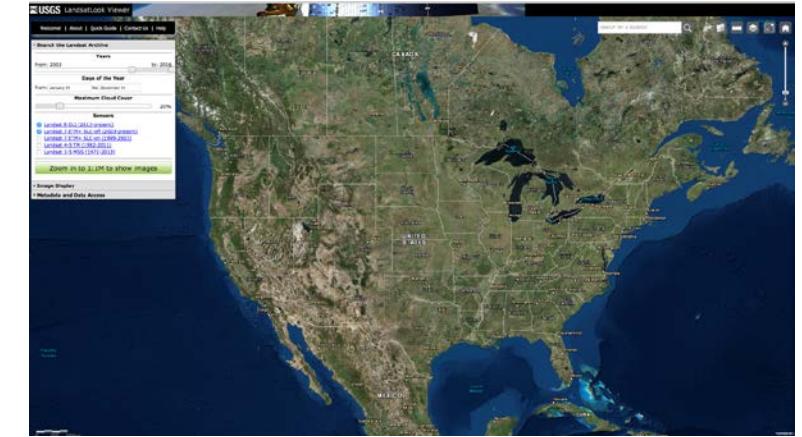
# Where can you get Landsat images & spectral reflectance data?



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



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



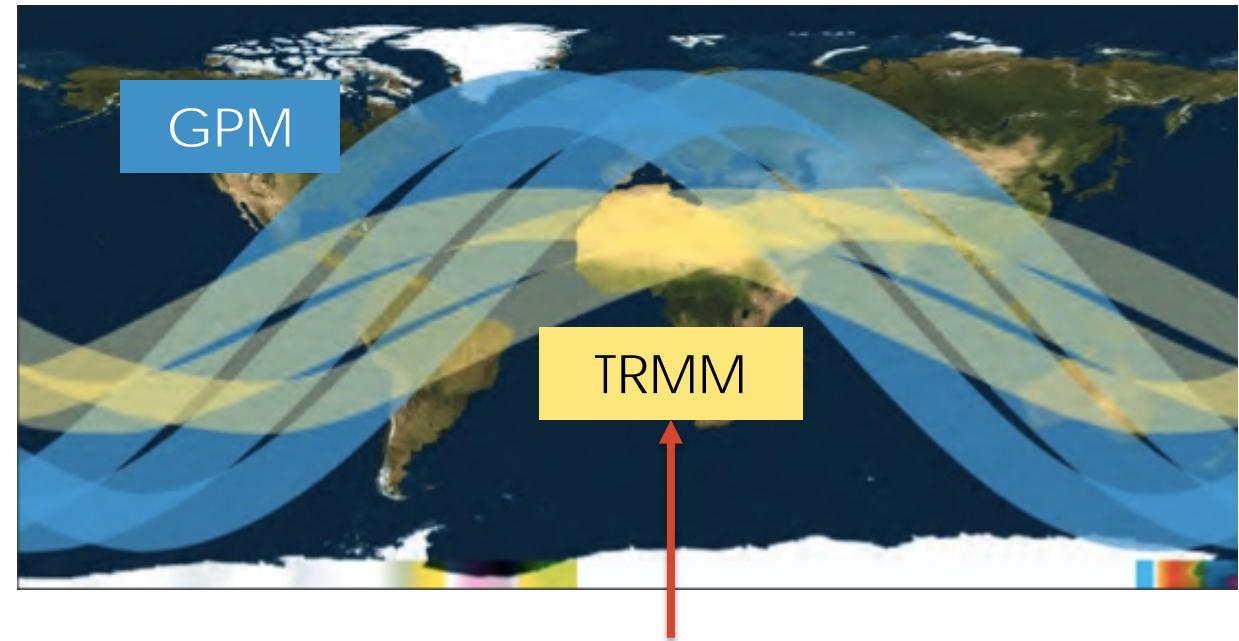
USGS Landlook Viewer  
<https://landlook.usgs.gov/viewer.html>



# 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>

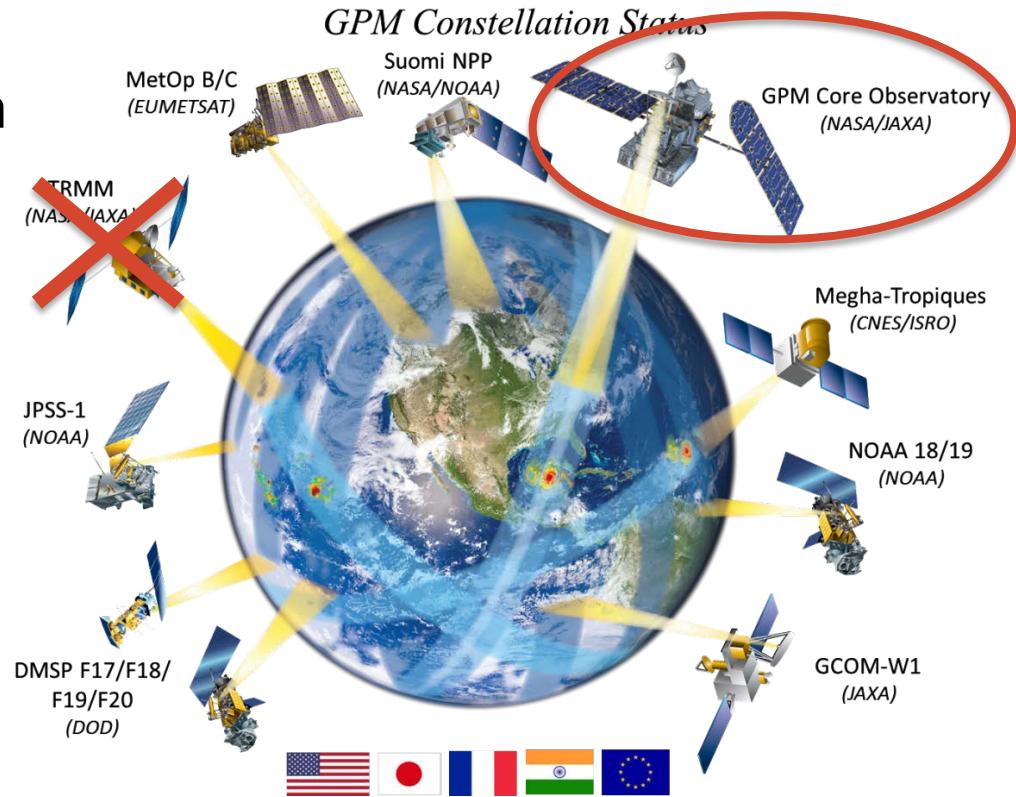
- TRMM & GPM Core satellites are used to calibrate microwave observations from a constellation of national and international satellites
- Allow improved spatial and temporal coverage of precipitation data
- TRMM Multi-satellite Precipitation Analysis (**TMPA**)
- Widely used for applications
- TMPA will 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](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](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

	<b>TMPA</b>	<b>IMERG</b>
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 <sup>+</sup>

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

<sup>+</sup>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>

The screenshot shows the homepage of the GPM IMERG Data Access website. The left sidebar contains a navigation menu with sections like 'Data Access', 'Extreme Weather News', 'Data Downloads & Documentation' (which includes TRMM, GPM, and Ground Validation), 'Data Sources', 'Data Recipes', 'Data News', 'Google Earth', 'NASA Worldview', 'Using the PPS FTP', 'Training', and 'Data FAQ'. Below this is a 'Connect With Us' section with links to Twitter, Facebook, and YouTube. A 'Need Help?' section lists 'View Frequently Asked Questions' and 'View the PMM Glossary'. The main content area features a collage of images related to space science and data processing, with the text 'Data Access' overlaid. Below this is a section titled 'How to Access TRMM & GPM Precipitation Data'. It explains that precipitation data from the GPM and TRMM missions is available free to the public in various formats. It includes a 'GET DATA' button with the text 'New Users Start Here' and a note about using the PPS FTP and STORM requiring email registration. A list of links under 'GPM Data Downloads & Documentation' includes TRMM Data Downloads & Documentation, Explanation of GPM & TRMM Data Sources, Data Processing "Recipes", Precipitation Data in Google Earth, and Frequency Asked Questions (FAQ).

- 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/>

The screenshot shows the GIOVANNI web interface. At the top, there's a navigation bar with links for EARTHDATA, Data Discovery, DAACs, Community, Science Disciplines, and a search icon. Below the navigation is the GIOVANNI logo and a banner stating "The Bridge Between Data and Science v 4.24 Release Notes Browser Compatibility". A yellow advisory message about browser compatibility is also present. To the right, there are "Analysis and Plot Options" and a "User Login" link.

**Select Plot:** A group of radio buttons for "Maps: Time Averaged Map" (selected), "Comparisons", "Vertical", "Time Series", and "Miscellaneous".

**Select Date Range (UTC):** Date and time input fields for start and end dates, with a range from 1948-01-01 to 2018-04-16.

**Select Region (Bounding Box or Shape):** Input fields for West, South, East, and North coordinates, along with a map and shapefile selection area.

**Temporal and Spatial Search:** A red callout box explaining the search functionality.

**Select Variables:** A section with two expandable dropdown menus: "Disciplines" and "Measurements".

- Disciplines:** Includes checkboxes for Aerosols (187), Atmospheric Chemistry (75), Atmospheric Dynamics (418), Cryosphere (13), Hydrology (1115), Ocean Biology (59), Oceanography (61), and Water and Energy Cycle (1199).
- Measurements:** Includes checkboxes for Aerosol Index (5), Aerosol Optical Depth (87), Air Pressure Anomaly (1), Air Pressure (57), Air Temperature Anomaly (2), Air Temperature (101), and Albedo (25).

**Number of matching Variables:** 0 of 1901. **Total Variable(s) included in Plot:** 0. **Keyword:** [Input field] **Search** **Clear**.

**Search data by keyword:** A red callout box pointing to the Keyword search field.

**Plot Data:** A red callout box pointing to the "Plot Data" button at the bottom right.

At the bottom, there are buttons for Help, Reset, Feedback, and Plot Data (highlighted in green). A large green arrow points from the "Search data by keyword" box down to the "Plot Data" button.



# 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/>

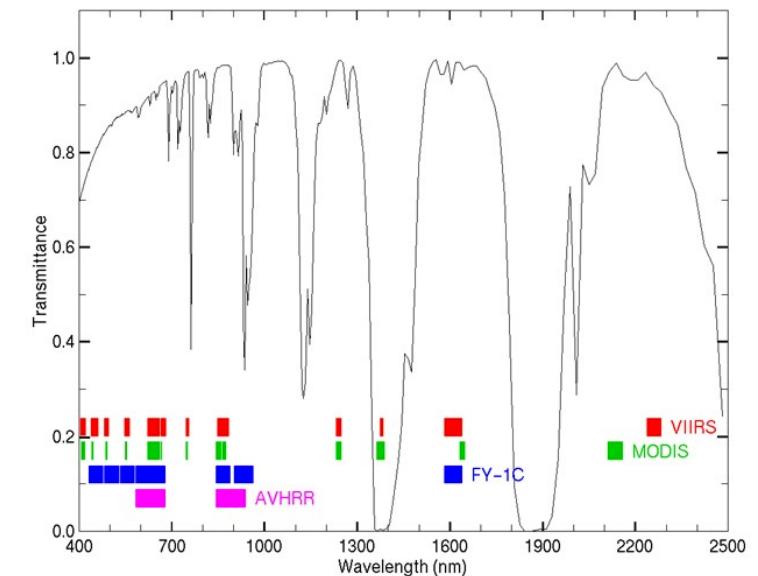
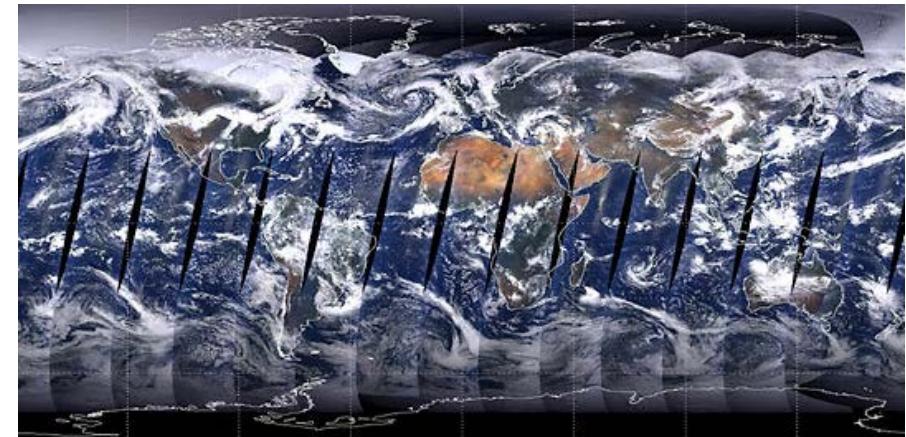
- Polar orbit, 1:30 p.m. equator crossing time
- Global Coverage
- May 4, 2002 – Present
- 1-2 observations per day



# MODerate Resolution Imaging Spectroradiometer (MODIS)

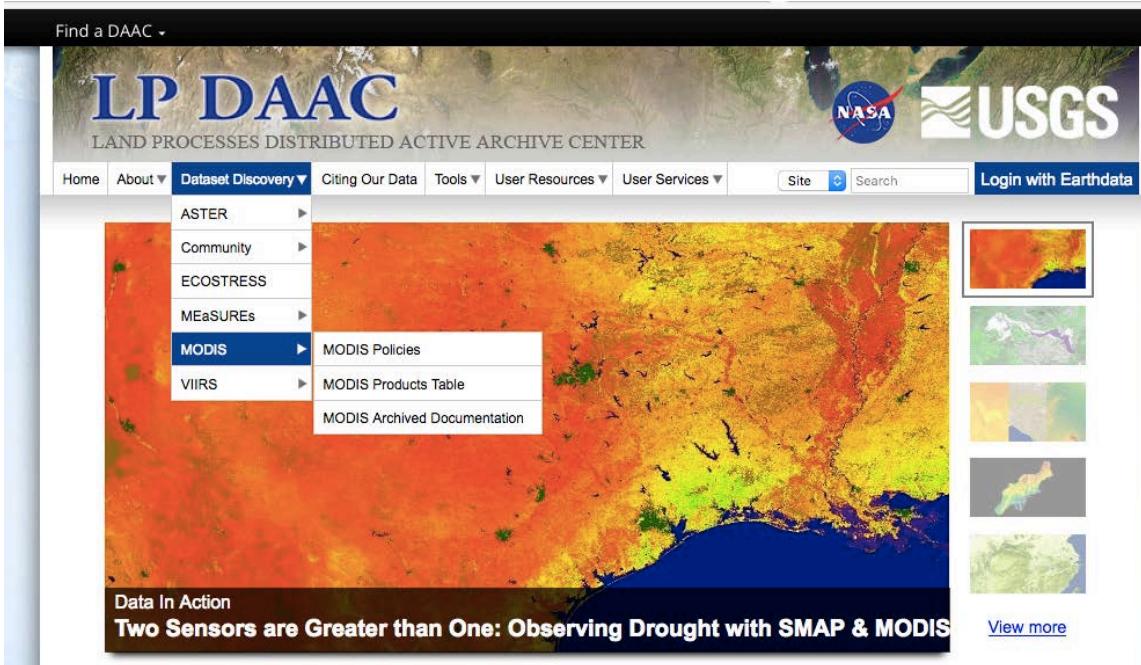
<http://modis.gsfc.nasa.gov/>

- 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/](http://lpdaac.usgs.gov/dataset_discovery/modis/)

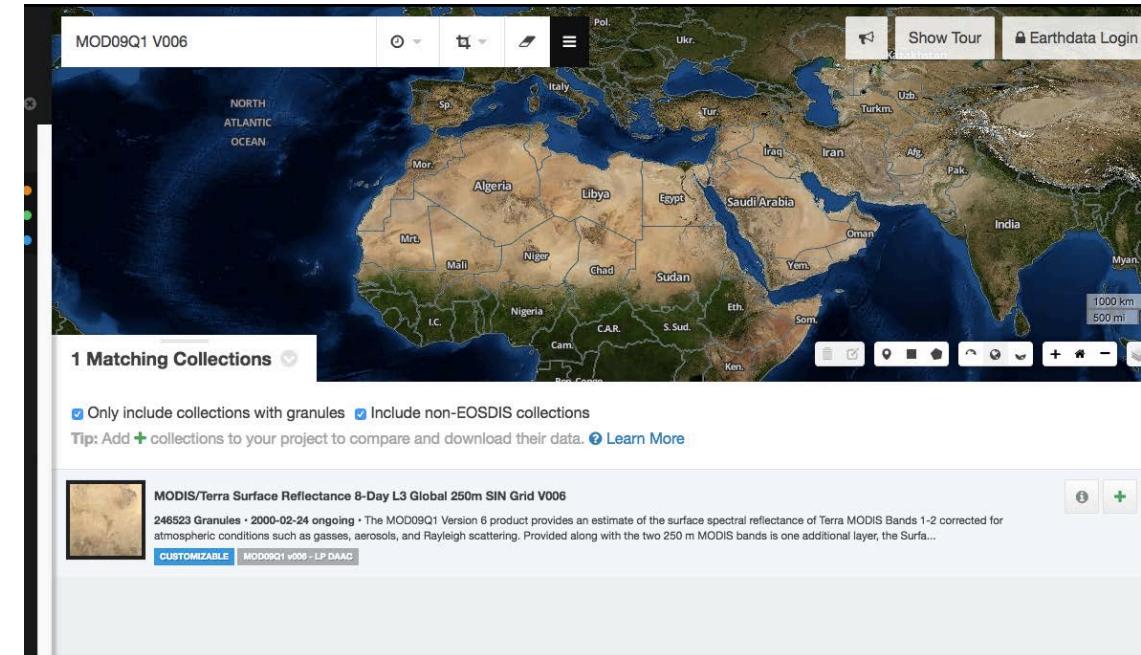


# Where to Get MODIS Reflectance Data?

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



Data Information



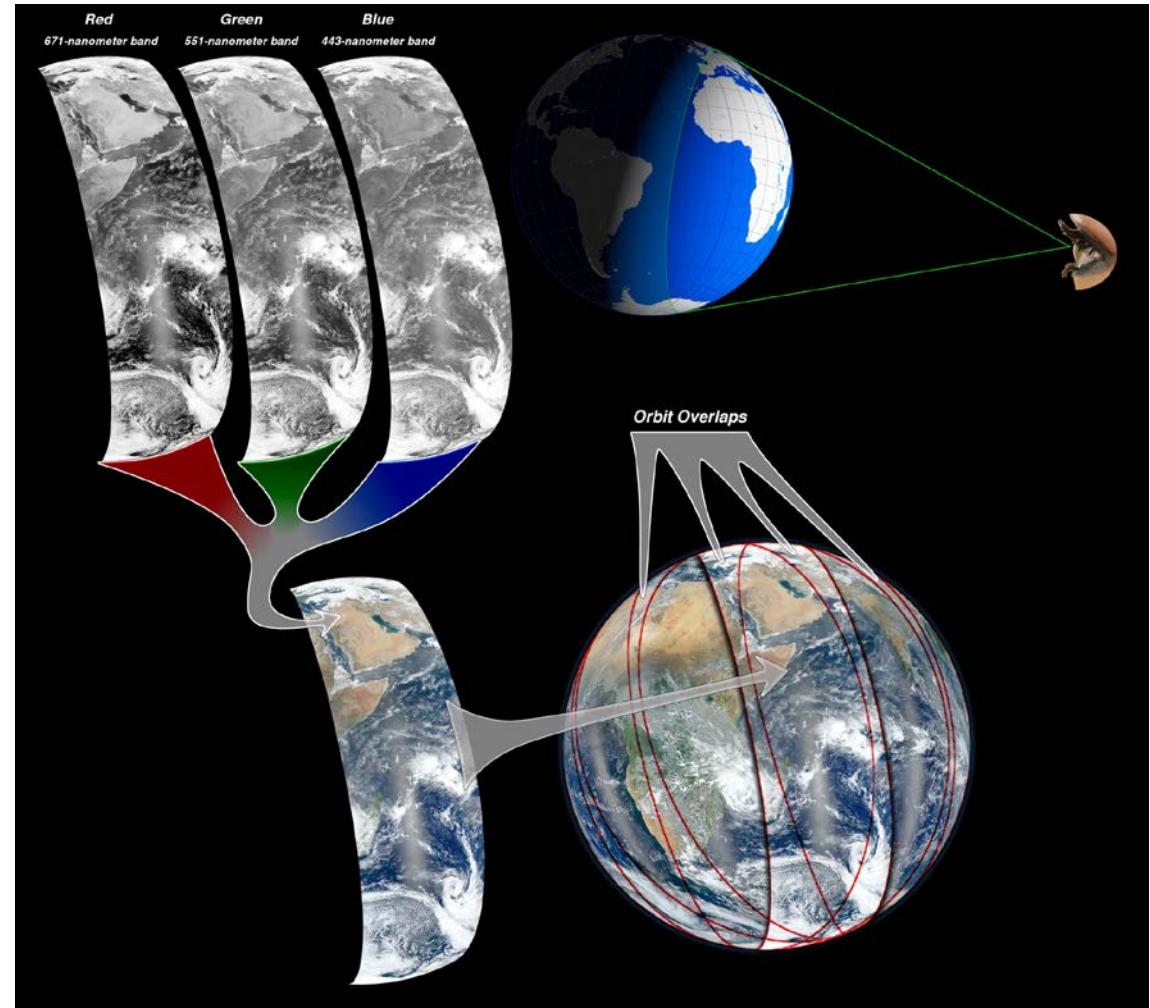
Data Search, Subset, and Download



# Suomi National Polar Partnership (SNPP)

[http://nasa.gov/mission\\_pages/NPP/](http://nasa.gov/mission_pages/NPP/)

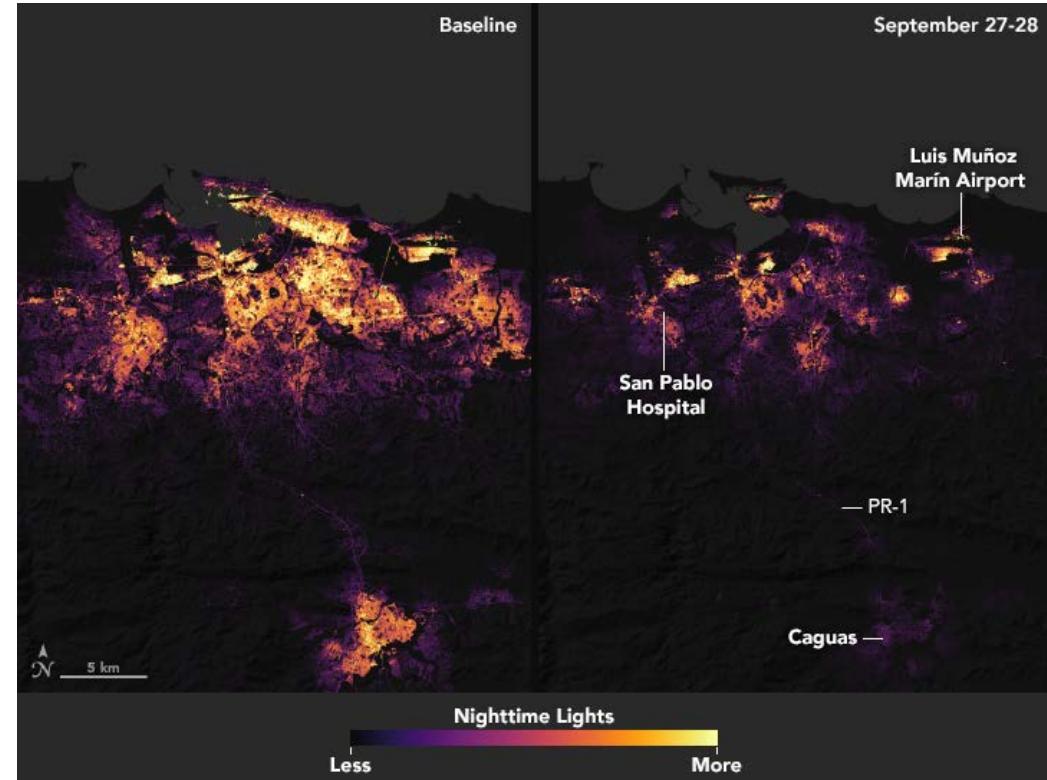
- Polar orbit, 1:30 p.m. equator crossing time
- Global coverage
- November 21, 2011 – present
- Sensors:
  - VIIRS, ATMS, CrIS, OMPS, CERES



# 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/](https://lpdaac.usgs.gov/dataset_discovery/viirs/)

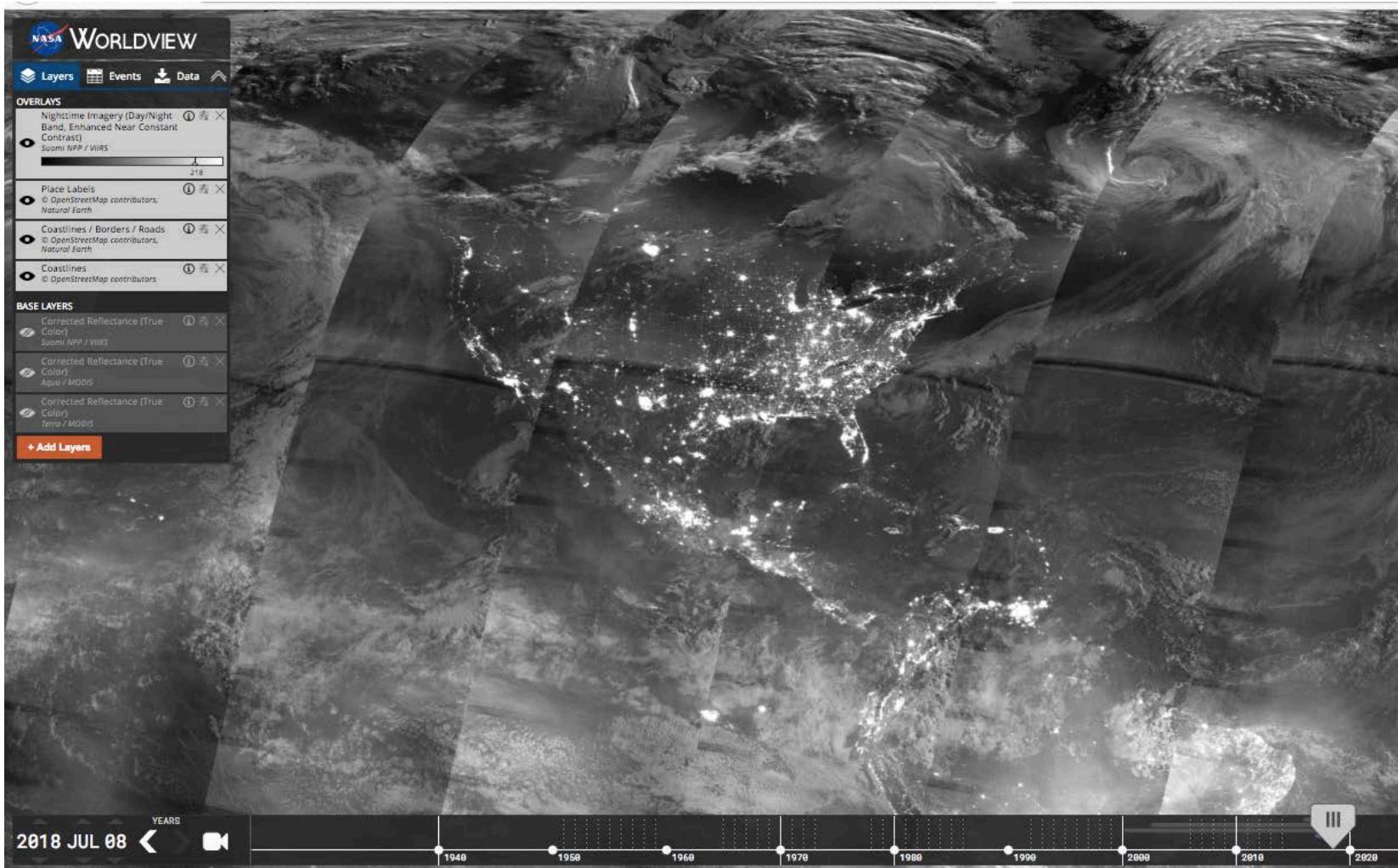


Power Outages in Puerto Rico as a Result of Hurricane Maria



# Where to Get VIIRS Night Light Imagery?

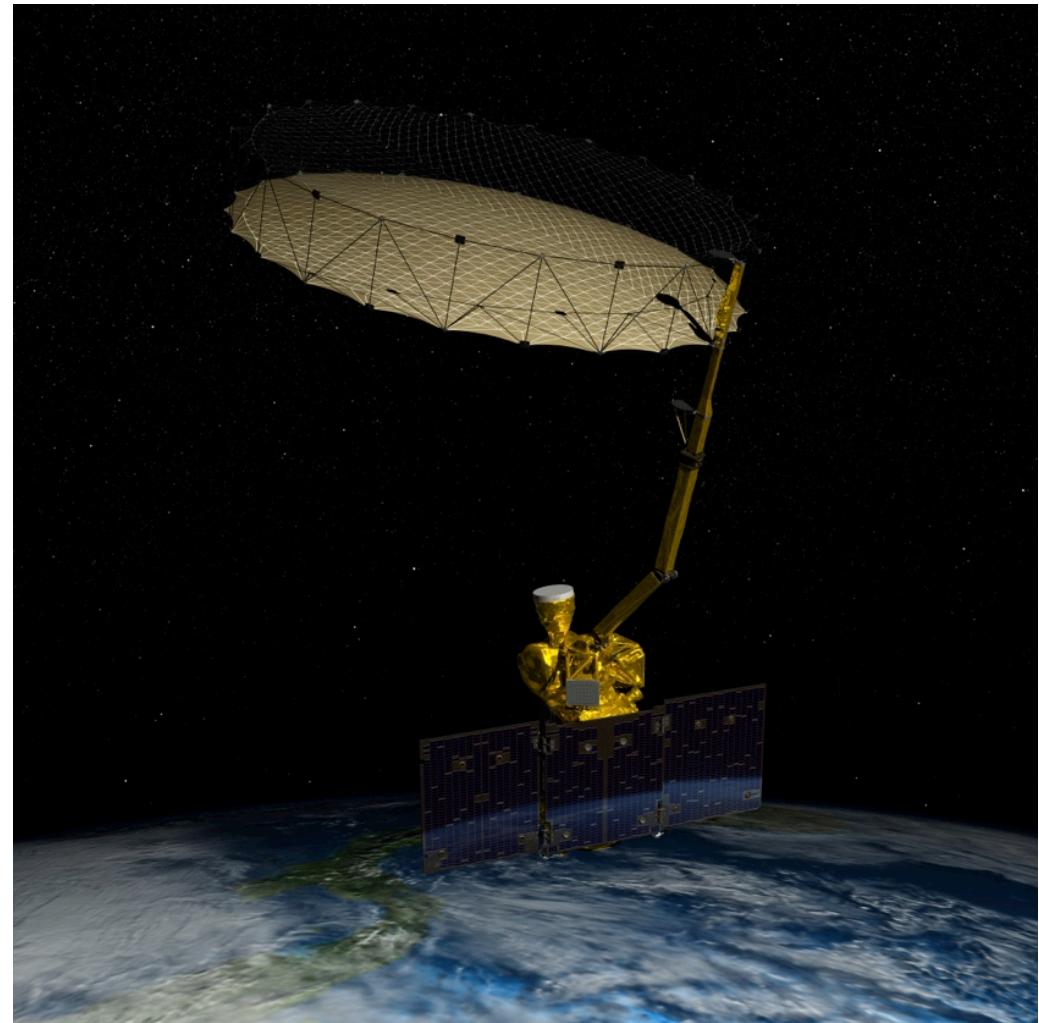
<https://worldview.earthdata.nasa.gov>



# 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)

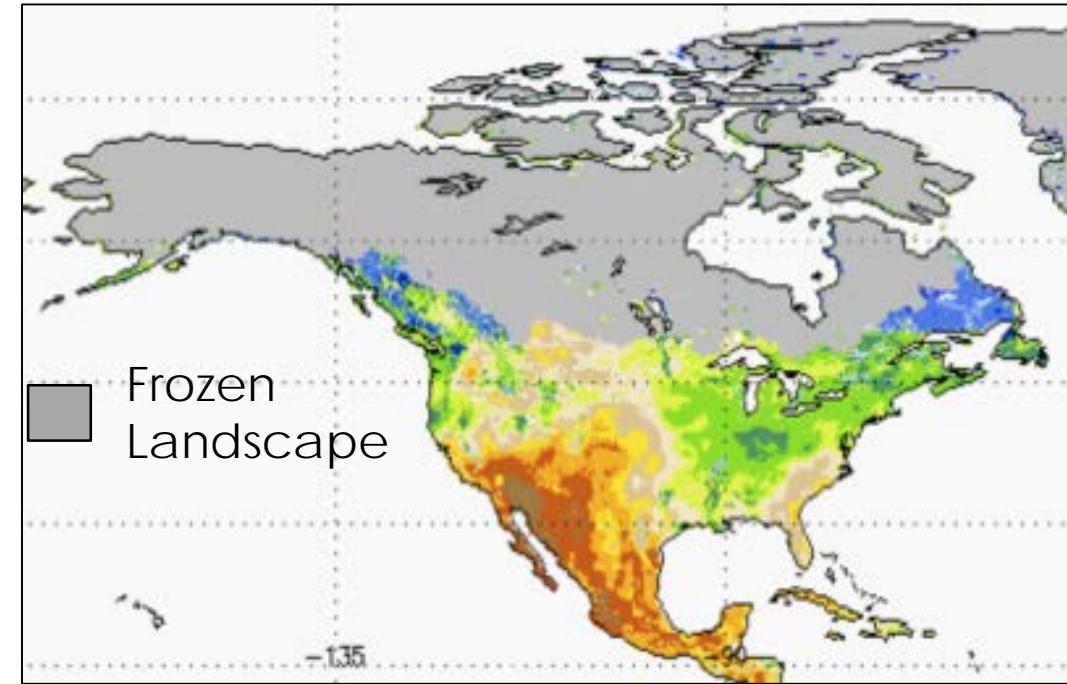


# SMAP Microwave Radiometer & Radar

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

- Radiometer:
  - Swath: 1,000 km
  - Frequency: 1.41 GHz
  - Polarization: H, V, 3<sup>rd</sup> & 4<sup>th</sup> 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

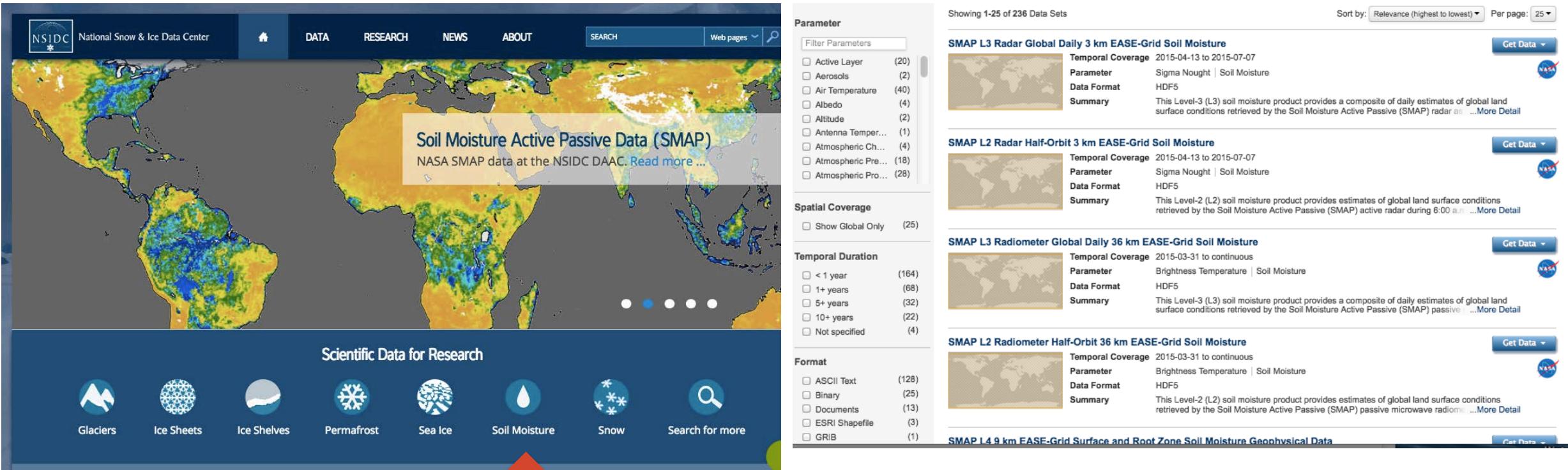


useful for flood monitoring



# Where do you get SMAP data?

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



The screenshot shows the NSIDC homepage with a world map displaying soil moisture data. A red arrow points from the 'Soil Moisture' icon in the 'Scientific Data for Research' section to the search results page on the right.

**NSIDC National Snow & Ice Data Center**

**DATA** **RESEARCH** **NEWS** **ABOUT** **SEARCH** **Web pages** **Get Data**

**Soil Moisture Active Passive Data (SMAP)**  
NASA SMAP data at the NSIDC DAAC. [Read more ...](#)

**Scientific Data for Research**

Glaciers Ice Sheets Ice Shelves Permafrost Sea Ice Soil Moisture Snow Search for more

**Parameter**

Showing 1-25 of 236 Data Sets

Sort by: Relevance (highest to lowest) Per page: 25

**SMAP L3 Radar Global Daily 3 km EASE-Grid Soil Moisture**  
Temporal Coverage: 2015-04-13 to 2015-07-07  
Parameter: Sigma Nought | Soil Moisture  
Data Format: HDF5  
Summary: This Level-3 (L3) soil moisture product provides a composite of daily estimates of global land surface conditions retrieved by the Soil Moisture Active Passive (SMAP) radar. [...More Detail](#)

**SMAP L2 Radar Half-Orbit 3 km EASE-Grid Soil Moisture**  
Temporal Coverage: 2015-04-13 to 2015-07-07  
Parameter: Sigma Nought | Soil Moisture  
Data Format: HDF5  
Summary: This Level-2 (L2) soil moisture product provides estimates of global land surface conditions retrieved by the Soil Moisture Active Passive (SMAP) active radar during 6:00 a.m. [...More Detail](#)

**SMAP L3 Radiometer Global Daily 36 km EASE-Grid Soil Moisture**  
Temporal Coverage: 2015-03-31 to continuous  
Parameter: Brightness Temperature | Soil Moisture  
Data Format: HDF5  
Summary: This Level-3 (L3) soil moisture product provides a composite of daily estimates of global land surface conditions retrieved by the Soil Moisture Active Passive (SMAP) passive microwave radiometer. [...More Detail](#)

**SMAP L2 Radiometer Half-Orbit 36 km EASE-Grid Soil Moisture**  
Temporal Coverage: 2015-03-31 to continuous  
Parameter: Brightness Temperature | Soil Moisture  
Data Format: HDF5  
Summary: This Level-2 (L2) soil moisture product provides estimates of global land surface conditions retrieved by the Soil Moisture Active Passive (SMAP) passive microwave radiometer. [...More Detail](#)

**SMAP L4 9 km EASE-Grid Surface and Root Zone Soil Moisture Geophysical Data**  
Temporal Coverage: 2015-03-31 to continuous  
Parameter: Brightness Temperature | Soil Moisture  
Data Format: HDF5  
Summary: This Level-4 (L4) soil moisture product provides geophysical parameters derived from the SMAP passive microwave radiometer. [...More Detail](#)

Level 2 to Level 4 data

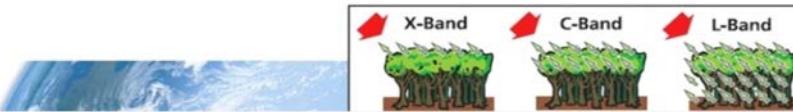


# Synthetic Aperture Radar (SAR) Imagery For Flood Detection

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

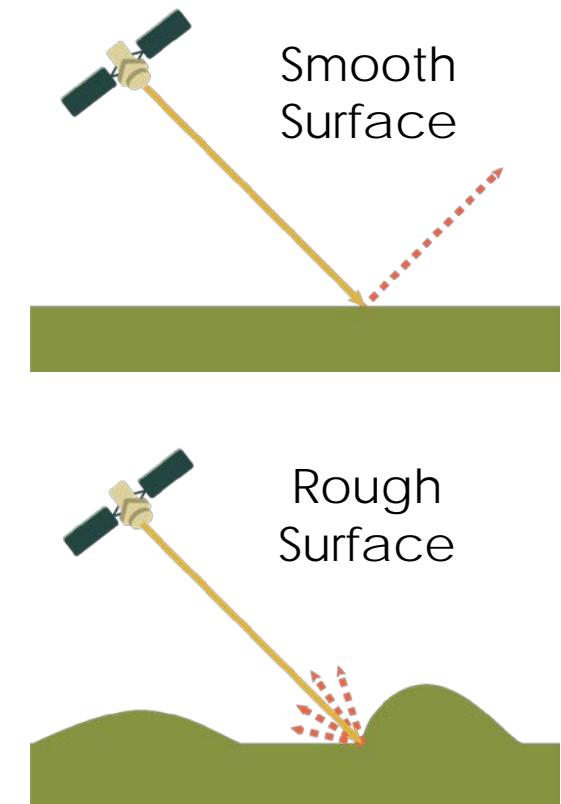
- SAR is an active sensor operating in microwave frequencies – collect backscattered signal

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/>

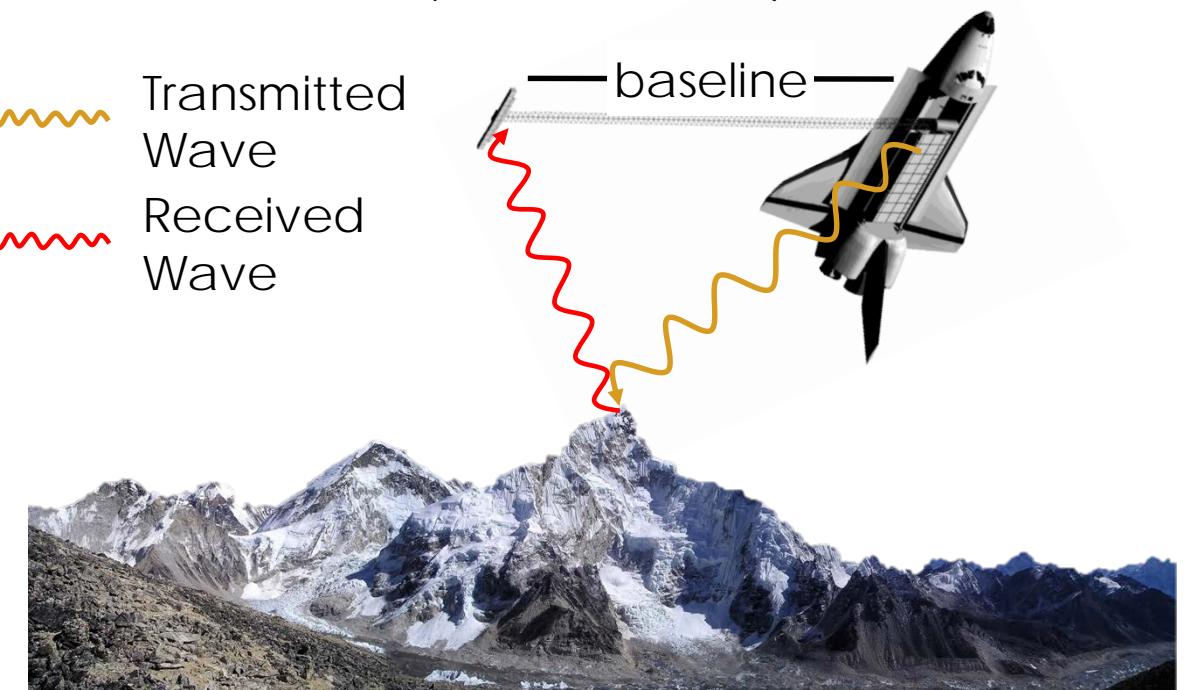


# Terrain Data From Shuttle Radar Topography Mission (SRTM)

<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](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)

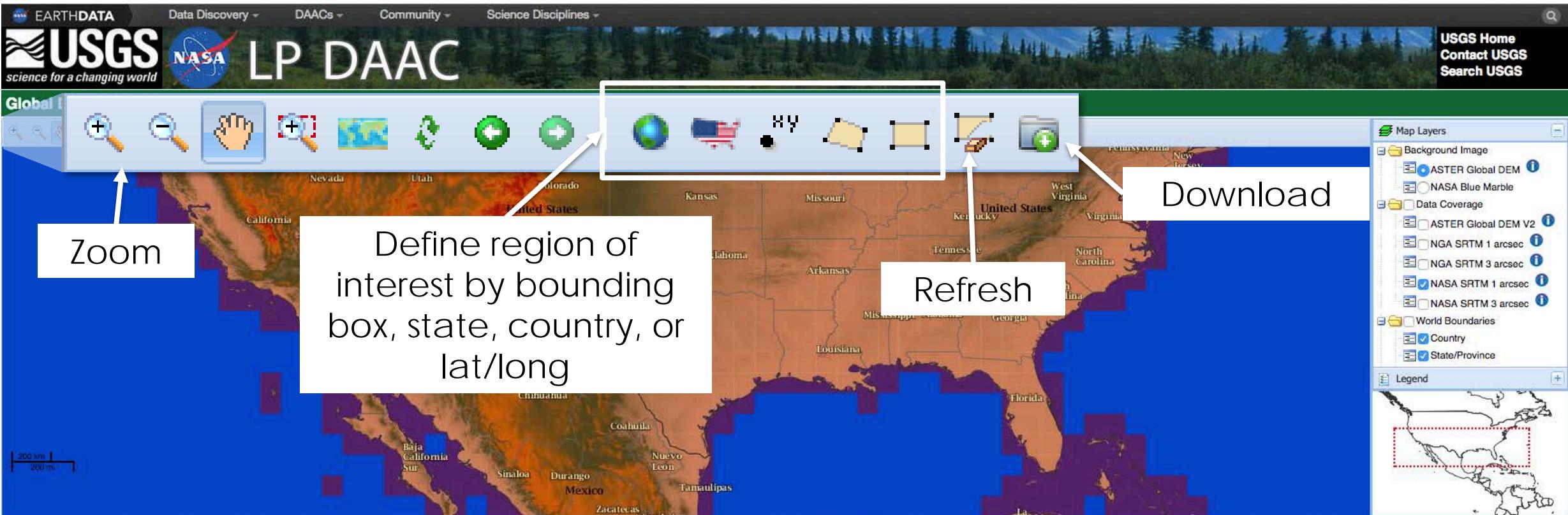


Spatial Resolution: 30 m



# SRTM Elevation Data Access From Global Data Explorer (GDEx)

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



Accessibility   FOIA   Privacy   Policies and Notices

[U.S. Department of the Interior](#) | [U.S. Geological Survey](#)

URL: <https://gdex.cr.usgs.gov/gdex/>

Page Contact Information: [LPDAAC@usgs.gov](mailto:LPDAAC@usgs.gov)

Page Last Modified: 01/27/2017

[User Guide](#) | [GMU](#) | [CISS](#) | [About GeoBrain](#) | [Contact](#)



# GEOS-5 Weather Data Maps – NRT and Forecast

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

VARIABLES

Abs EPV	Humidity
Precip & SLP	Temperature
Vorticity	Vert Velocity
Wind Speed	

REGIONS

Atlantic	Australia
Global	Mid Atlantic
North America	N Polar
Pacific	Seven Seas
S Polar	

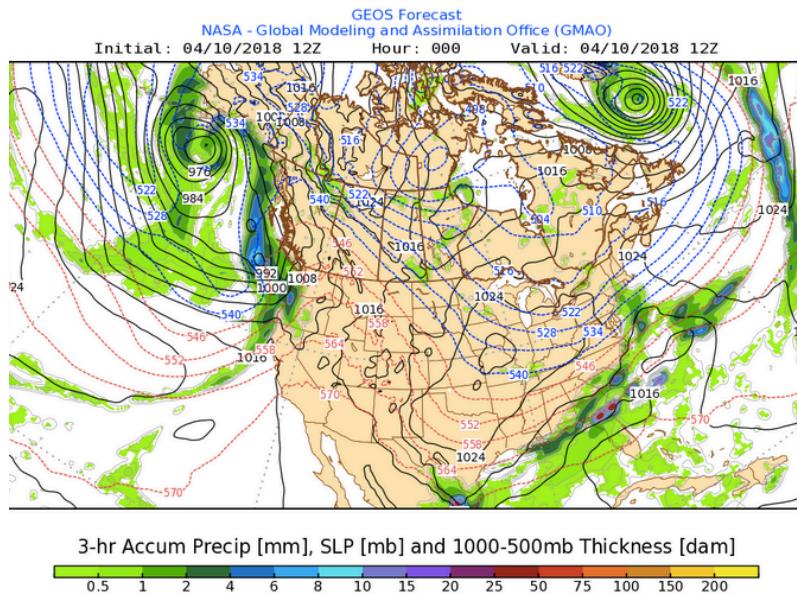
FORECAST INITIAL TIME

10Apr2018 12z

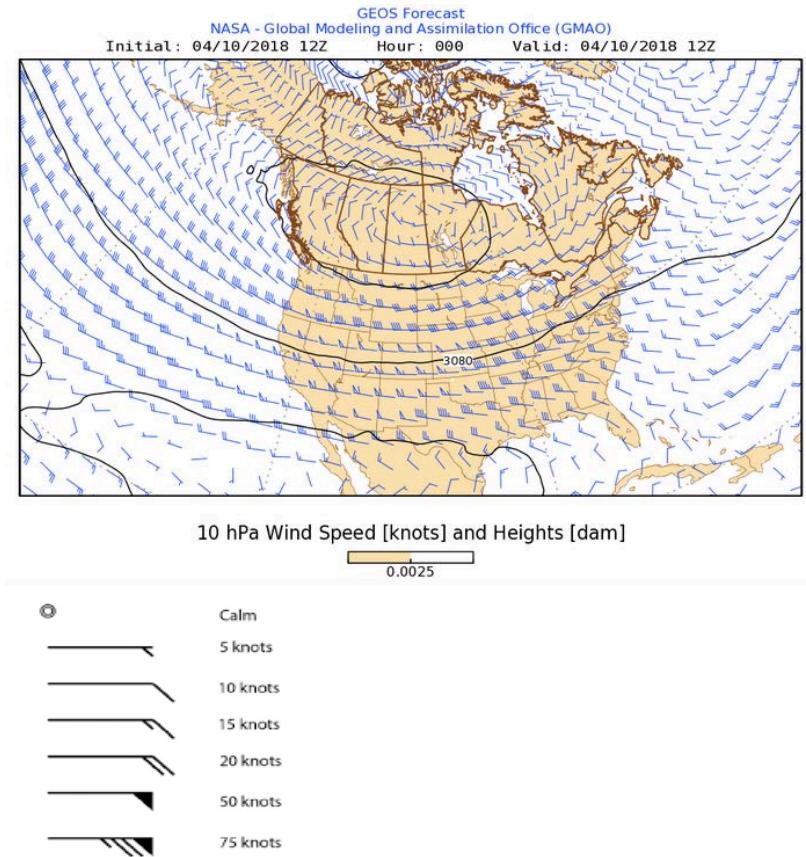
FORECAST LEAD HOUR

000 10Apr2018 12z

## Precipitation Sea Level Pressure

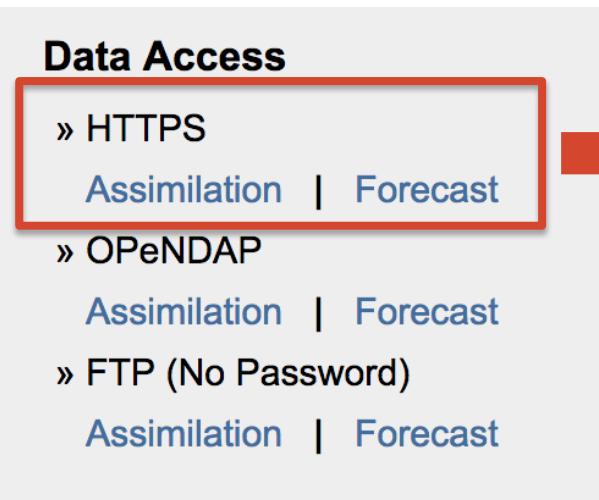


## Wind Speed & Direction



# GEOS-5 Weather Data Access

[https://portal.nccs.nasa.gov/dashshare/gmao\\_ops/pub/fp/das/](https://portal.nccs.nasa.gov/dashshare/gmao_ops/pub/fp/das/)



## NCCS Dataportal - Datashare

Name	Last modified	Size Description
Parent Directory	-	-
GEO5.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	-

HTTP Files

Year & Month

Name      Last modified      Size Description

Parent Directory	-	-
D01/	02-Oct-2016 09:42	-
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
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0130.V01.nc4	09-Oct-2016 09:38	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0230.V01.nc4	09-Oct-2016 09:38	47M
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
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0730.V01.nc4	09-Oct-2016 13:56	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0830.V01.nc4	09-Oct-2016 13:56	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0930.V01.nc4	09-Oct-2016 20:53	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1030.V01.nc4	09-Oct-2016 20:53	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1130.V01.nc4	09-Oct-2016 20:53	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1230.V01.nc4	09-Oct-2016 20:53	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1330.V01.nc4	09-Oct-2016 20:53	47M
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



Day

Hourly Files

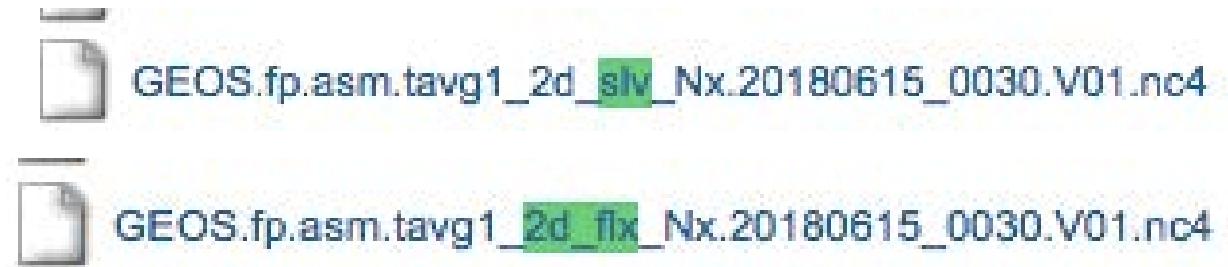


# GEOS-5 Weather Data Access

[https://portal.nccs.nasa.gov/dashshare/gmao\\_ops/pub/fp/das/](https://portal.nccs.nasa.gov/dashshare/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](https://gmao.gsfc.nasa.gov/products/documents/GEOS_5_FP_File_Specification_ON4v1_1.pdf)



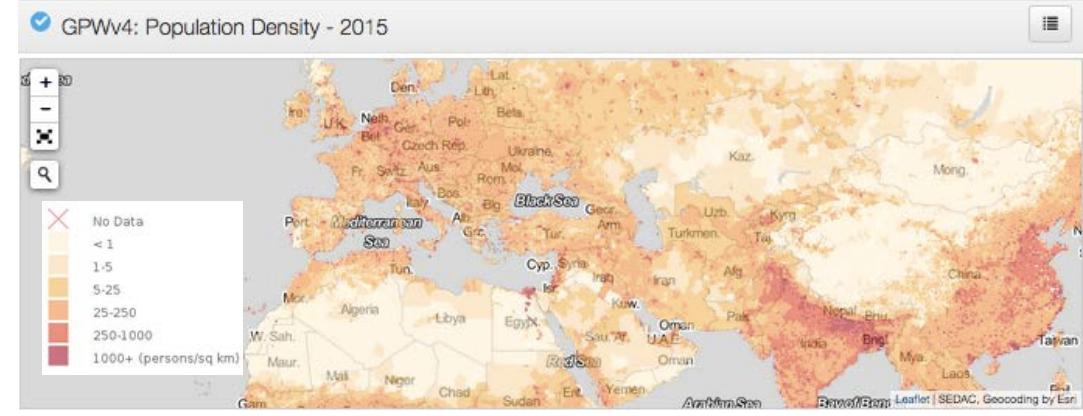
# Socioeconomic Data

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

The screenshot shows the homepage of the Socioeconomic Data and Applications Center (SEDAC). At the top, there is a navigation bar with links for DATA, MAPS, THEMES, RESOURCES, SOCIAL MEDIA, ABOUT, and HELP. Below the navigation bar, there is a section titled "Data Collections (41)" which lists various datasets. The datasets include:

- Anthropogenic Biomes**: Describes 21 global anthropogenic biomes based on population density, land use, and vegetation cover, grouped into six categories: dense settlements, villages, croplands, rangeland, forested, and wildlands.
- Archive of Census Related Products (ACRP)**: A collection of value-added georeferenced data files derived from the 1990 U.S. Census, spanning the United States and its territories.
- China Dimensions**: A wide range of data from circa 1990, including administrative boundaries, population and agricultural census data, and other statistics, covering the administrative regions of China.
- Climate Effects on Food Supply**: Assessments of potential climate change impacts of temperature and precipitation on global staple crop production (wheat, rice, and maize), with a focus on quantitative estimates of yield changes based on multiple climate scenarios.
- Compendium of Environmental Sustainability Indicators**: A compilation of sustainability indicators from multiple sources incorporating multiple country codes. Methodological summaries are contained in an accompanying metadata database.
- Energy Infrastructure**: Data on the locations and status of nuclear power facilities along with estimates of the population residing near locations with at least one operating reactor.
- Environmental Performance Index (EPI)**: Released every two years since 2006, the EPI groups performance indicators into two policy categories, environmental health and ecosystem vitality, in order to gauge how close countries are to reaching established environmental policy goals.
- Environmental Sustainability Index (ESI)**: Released four times between 2000 and 2005, and based on a compilation of indicators derived from underlying data sets, the ESI measures overall progress towards environmental sustainability for 146 countries.
- Environmental Treaties and Resource Indicators (ENTRI)**: Information on treaty participation by country, environmental treaty texts, and a Conference of Party (COP) decision search tool for major multilateral environmental agreements.
- Georeferenced Population Data sets of Mexico**: Administrative boundaries, settlement locations and populations, and gridded population data for Mexico circa 1990. Includes place names, geographic coordinates of more than 30,000 urban and metropolitan places, and elevation data for
- Global Agricultural Lands**: Combines satellite data with agricultural inventory data to estimate the proportion of land area in cropland and pasture for the year 2000.
- Global Fertilizer and Manure, v1**: Global gridded data sets of fertilizer application rates and manure production of nitrogen and phosphorus for circa 2000.

## Global Population Density



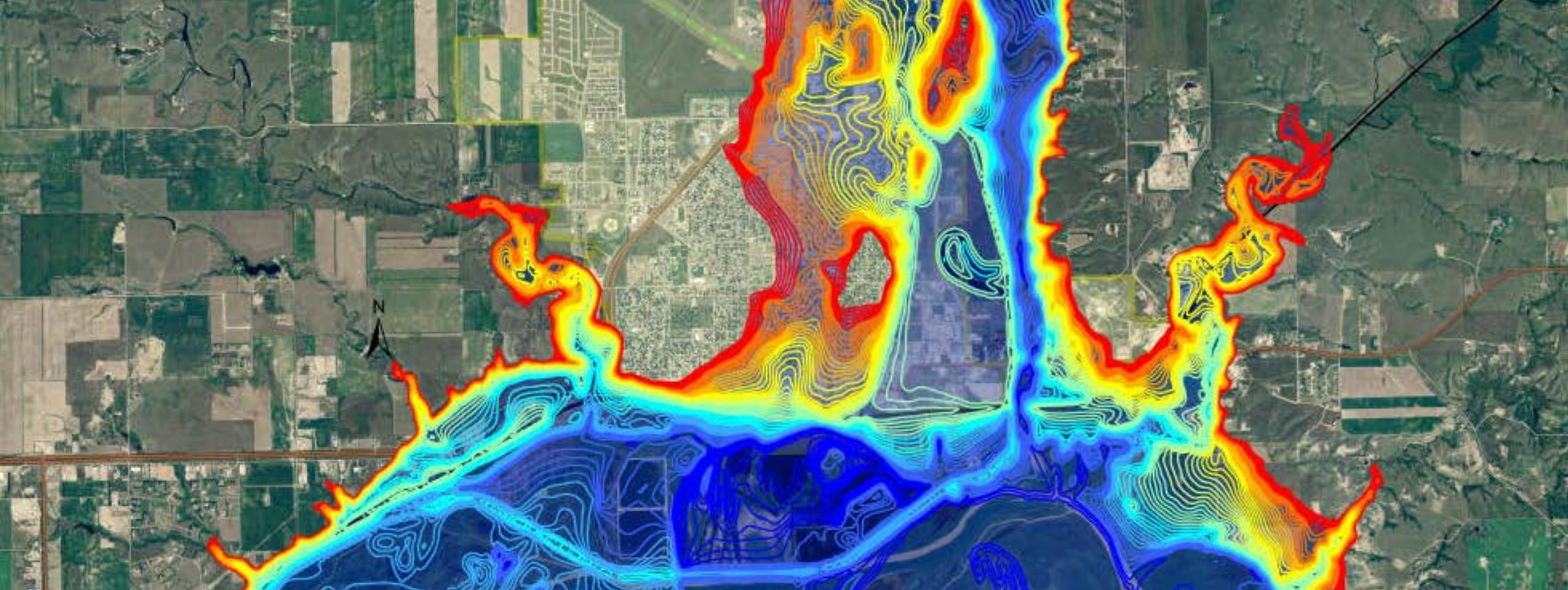
- Other Useful Datasets:
  - Global urban data from the Landsat satellite
  - Global reservoir and dam
  - Low elevation coastal zones
  - Global roads
  - Energy infrastructure



# 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>



**USAID**  
FROM THE AMERICAN PEOPLE

**SERVIR MEKONG**

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

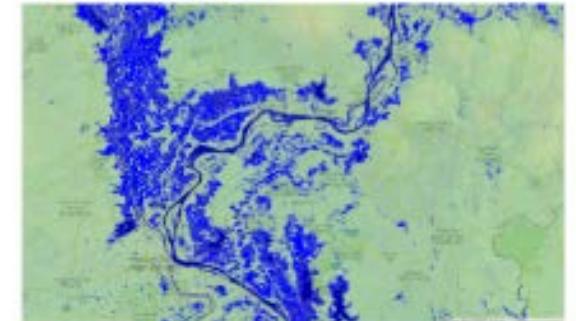


## Focus Area

- Mekong river and tributaries from Vientiane, Lao PDR, to the South China Sea. (With adjustments the tool can easily be used elsewhere.)



## Initial Results



Flooded area (light blue) around Phnom Penh between 2013 and 2015. Dark blue areas represent more permanent water.



# 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

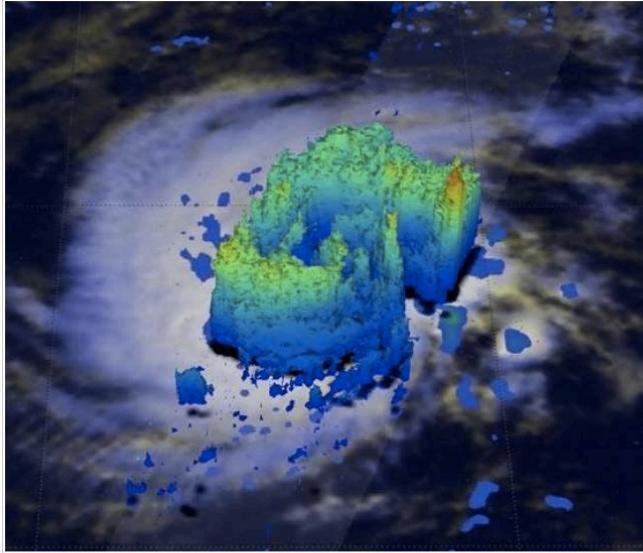
## Project End-Users

- 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

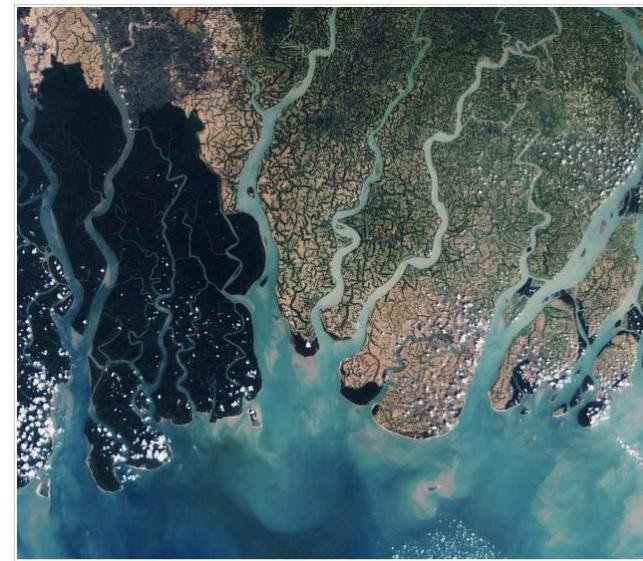


# The World Bank Uses Remote Sensing to Assess Rapid Response for Floods

<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.”

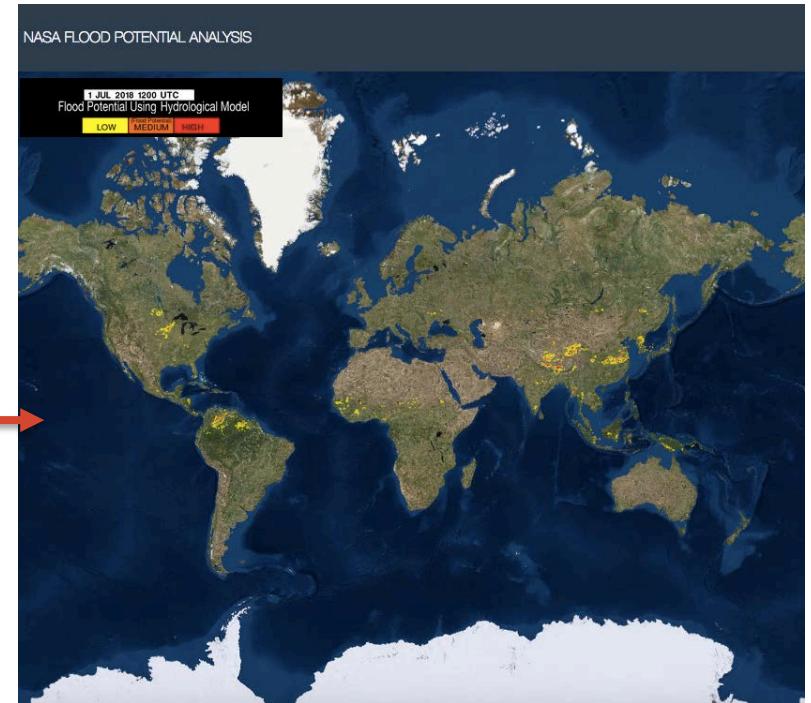
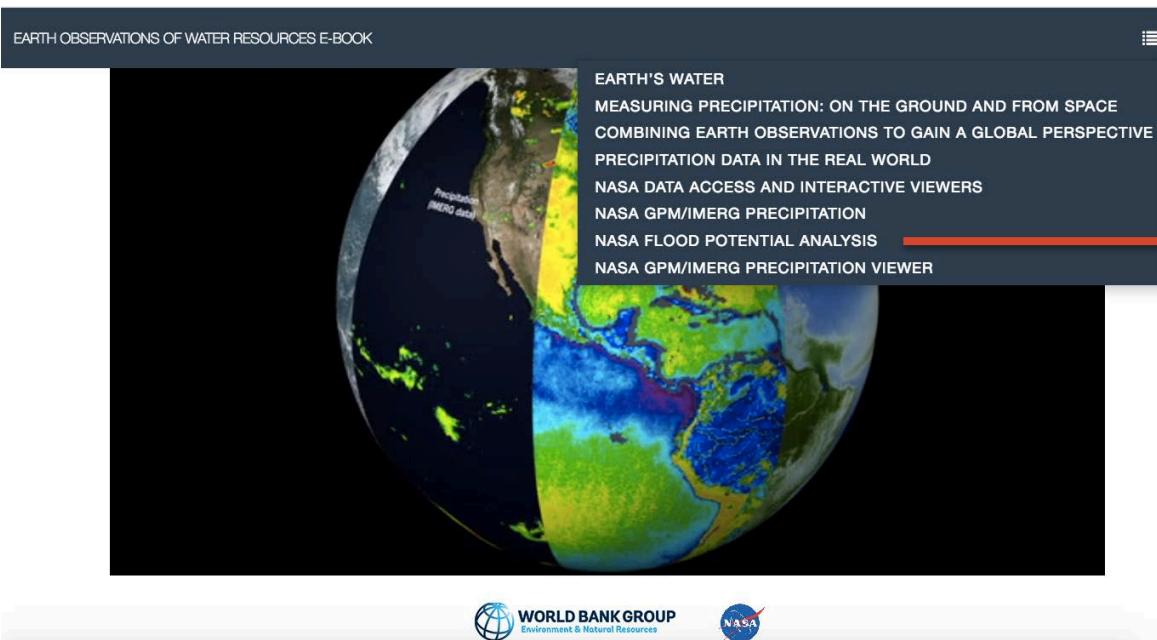
– Antoine Bavandi, a DRFIP financial sector specialist



# The World Bank & NASA E-Book

<http://www.appslutelydigital.com/Nasa/index.html#page-top>

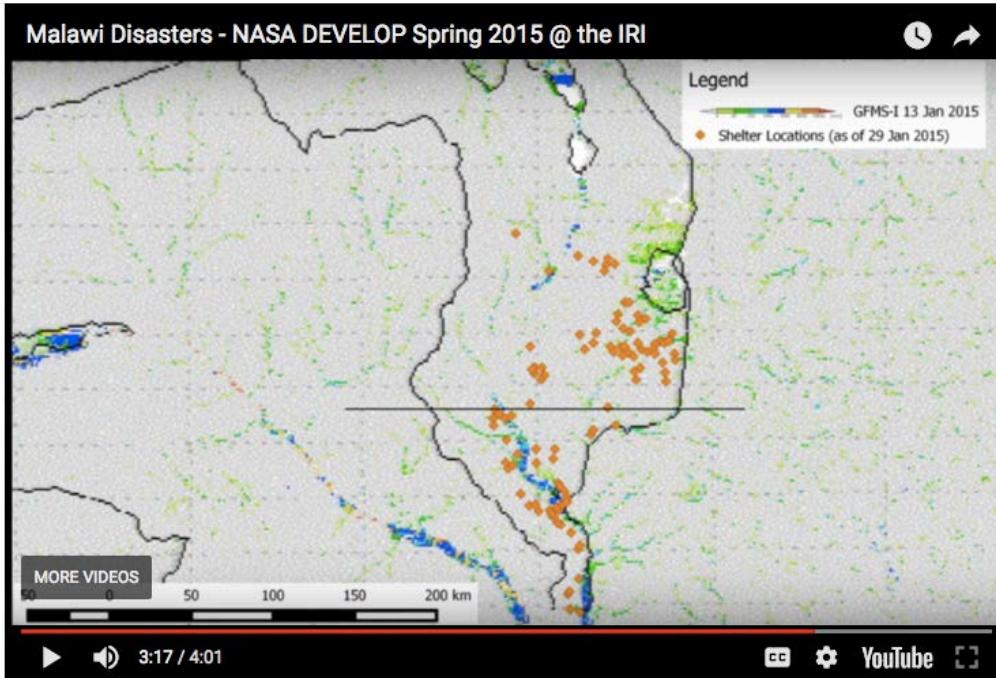
- TRMM/GPM – Based Flood Potential
- Disseminated via the World Bank Open Learning Campus



# Red Cross Disaster Mapping

[http://maps.redcross.org/website/Links/ARC\\_Disaster\\_Links\\_Hazards.html](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/>

American Red Cross

About Us | Contact Us | Governance | Media Resources | Connect | Español

Back to Redcross.org | Give Blood | Volunteer | Shop Our Store

Map, Weather & Hazard Catalogs

## Disaster Related Links - Hazards

**Red Cross Catalogs & Resources:**

- Home
- Map Catalog
- Disaster Relief Operation Catalog
- Org Online Mapping Portal (ArcGIS Online Org Map Center)

**Jump to:**

Hurricanes Floods Tornadoes & Severe Weather Wildfires	Earthquakes Landslides Winter Weather Excessive Heat	Volcanoes Tsunami Avalanche HazMat
---	---	---

**Hurricanes**

- NWS National Hurricane Center/Tropical Prediction Center (NHC/TPC)  
NWS - Central Pacific Hurricane Center  
U.S. Navy - Joint Typhoon Warning Center, Honolulu, Hawaii  
University of Wisconsin - Tropical Cyclones  
NASA - Center for Operational Oceanographic Products & Services - Storm Related Tide Information

**NASA - Tropical Rainfall Measuring Mission (TRMM) - Tropical Rainfall**

Weather & Hazard Center  
Tropical Hazard Center  
National Level Maps  
Map Services Catalog  
Disaster Related Links:

- Weather
- Hazards
- Government
- General Resources
- States & Territories

Weather Calculators  
Access FOCIS (Restricted access)

Caribbean Hurricane Network  
Cuban Meteorological Agency -Institute for Meteorology INSMET NOAA - Hurricane Research Division  
U.S. Navy - Tropical Cyclone Page  
Fiji Meteorological Service - South Pacific Ocean  
Australian Severe Weather - Tropical Cyclones - South Pacific Ocean  
NASA - Tropical Rainfall Measuring Mission (TRMM) - Tropical Rainfall  
NOAA - Tropical Atmosphere Ocean  
NOAA - Hurricane Map Viewer  
NHC/TPC - Alternate Hurricane Sites  
Atlantic Tropical Weather Center  
CoolWX - Tropical Weather  
Crown Weather Tropical Weather  
The StormTrack - Tropical Weather  
Mid-Atlantic Weather Hurricane Page  
Tropical Meteorology Online  
Hurricane Alley - Hurricane Resources  
Hurricane Hollow - Hurricane Resources  
Hurricane Tracking Maps - Past and Present  
Atlantic & Pacific Storm Tracking  
BoatUS - Hurricane Resources  
Hurricane City - Hurricane Resources  
Hurricane Track - Hurricane Resources  
LSU - Earth Scan Lab - Hurricanes  
University of Hawaii - Worldwide Tropical Storms  
Florida State University - Cyclone Phase Evolution Analysis & Forecasts (Models)  
Colorado State - Dr. William Gray's Tropical Meteorology Project



# 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>

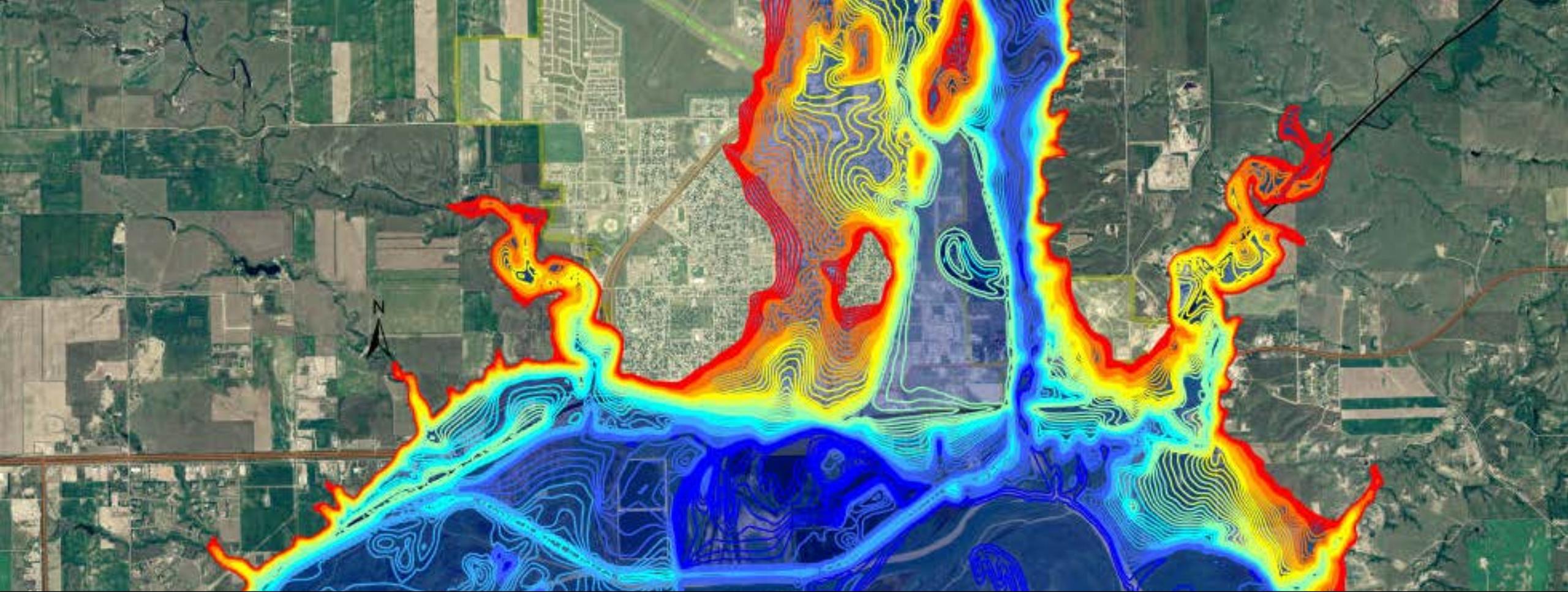
- Uses resources from several federal, state, and professional associations, including information from the NASA Disasters Portal
- <http://www.dcr.virginia.gov/dam-safety-and-floodplains/fppubs>

## 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

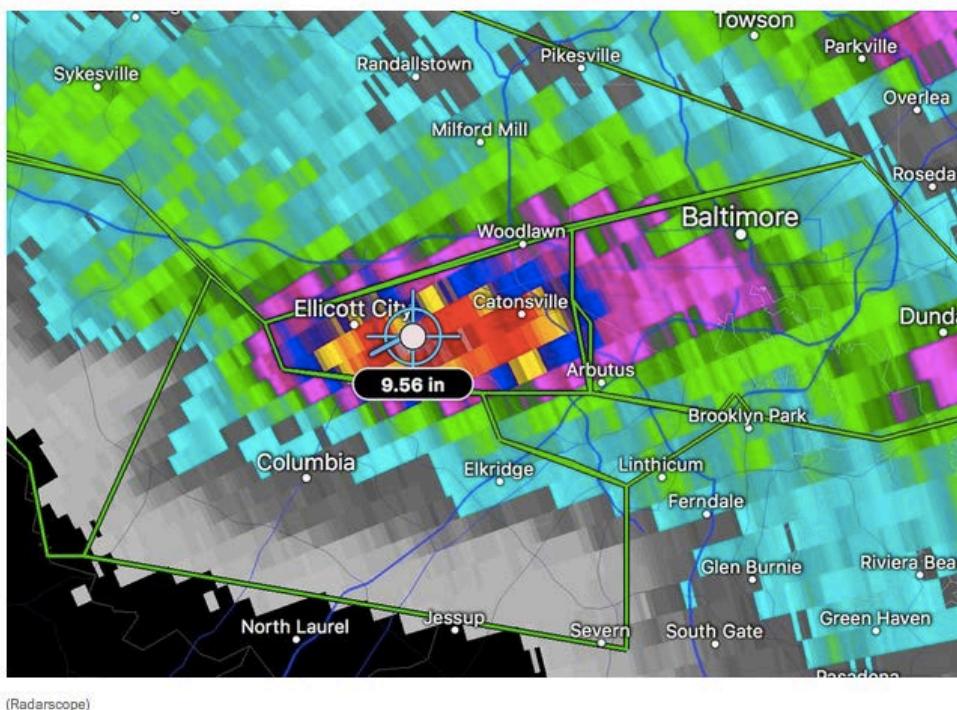
- Ellicott City, Maryland  
Flash Flood occurred on 27 May 2018
- Houston, Texas  
Heavy rain cause flooding on 4 July 2018



# 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.



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.



Image Credits: (left) [Washington Post](#), (right) [WTOP](#)



# Flood Case: Houston, Texas, USA

## Houston streets flood after heavy rains, sparking memories of Harvey



By [Eric Levenson](#) and [Keith Allen](#), CNN

Updated 5:36 AM ET, Thu July 5, 2018



Flash floods strike Texas again 00:57

## Close to 200 mm of rain caused street flooding

Image Credits: (left) [CNN](#), (right) [CW39 Houston](#)

## Flooding in Houston area as heavy rain pounds city, canceling multiple 4th of July events

POSTED 7:03 AM, JULY 4, 2018, BY [ALEX GREEN](#), UPDATED AT 05:02PM, JULY 4, 2018



HARRIS COUNTY, Texas— The [National Weather Service](#) extended a Flash flood warning for Harris County until 9 p.m. Wednesday as heavy rain pounded the area.

The warning comes as showers and storms associated with an upper disturbance continue to move from east to west towards southeast Texas.

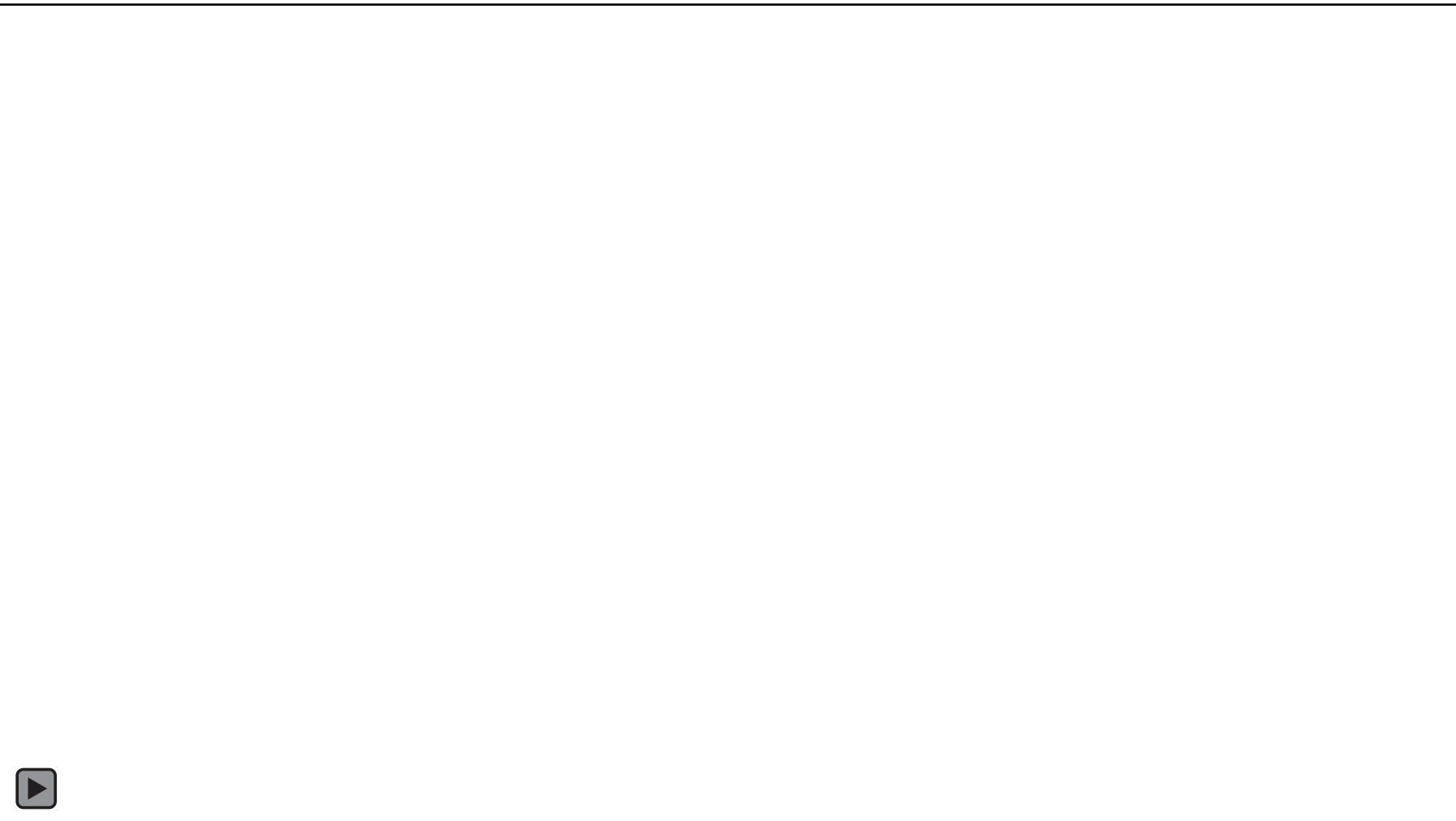


# Urban Flood Case Analysis

- 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





Thank You!