

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

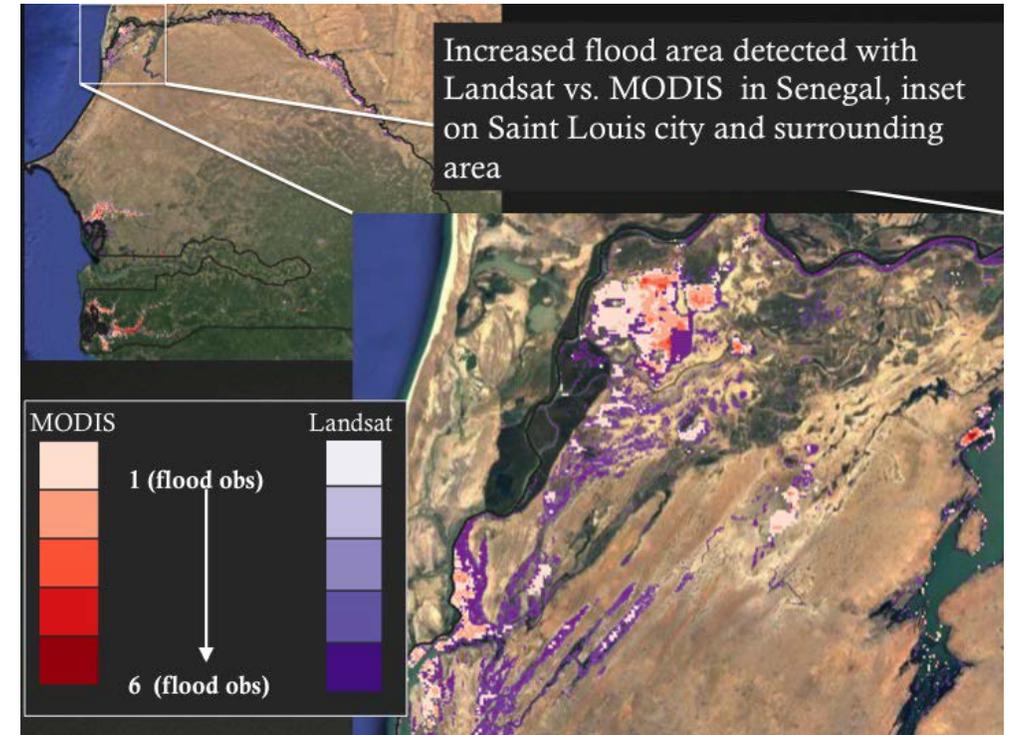
Overview of Remote Sensing Data for Urban Flooding



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

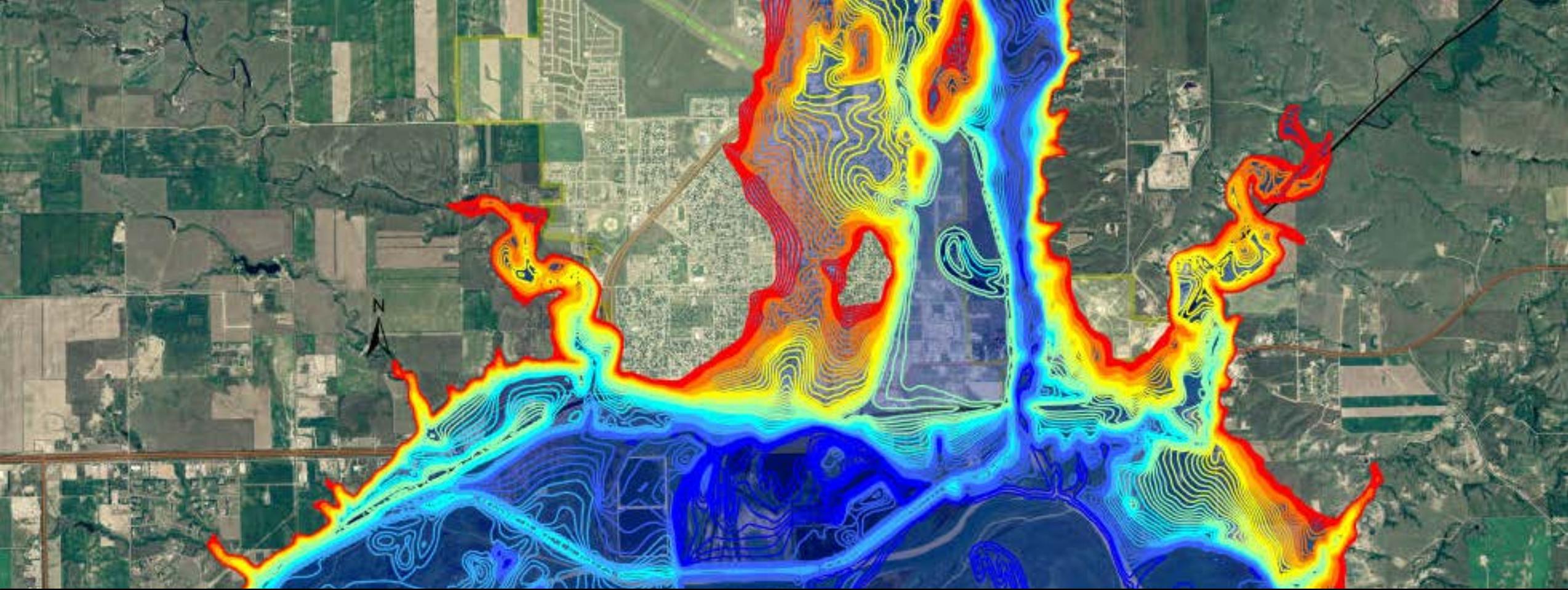
- Homework will be available after Session-1 and Session-2 from <https://arset.gsfc.nasa.gov/water/webinars/>
- **Answers must be submitted via Google Form**
- Certificate of Completion:
 - Attend both webinars
 - Complete homework assignment by the deadline (15 August 2018)
 - You will receive certificates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



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:





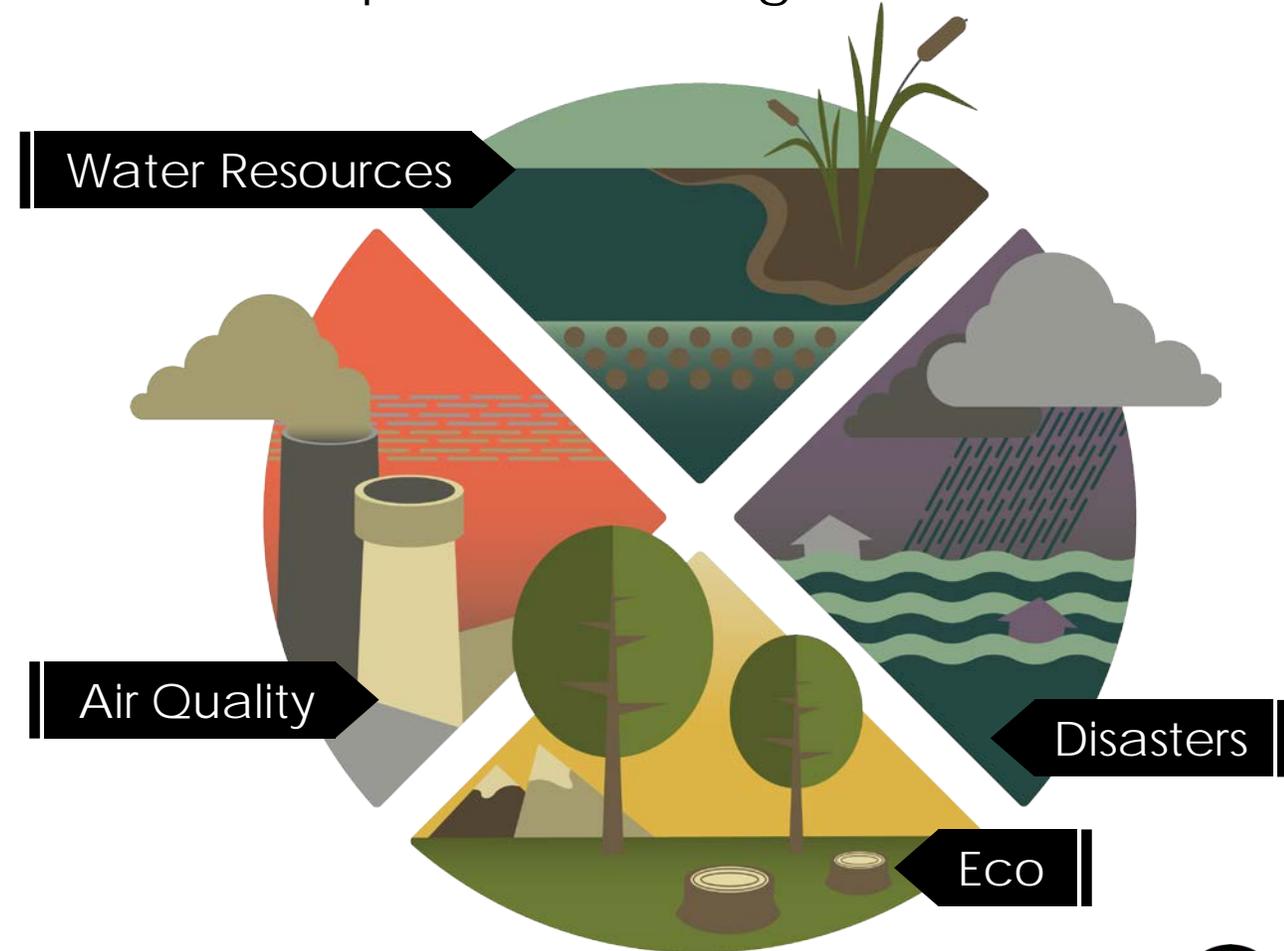
About ARSET

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

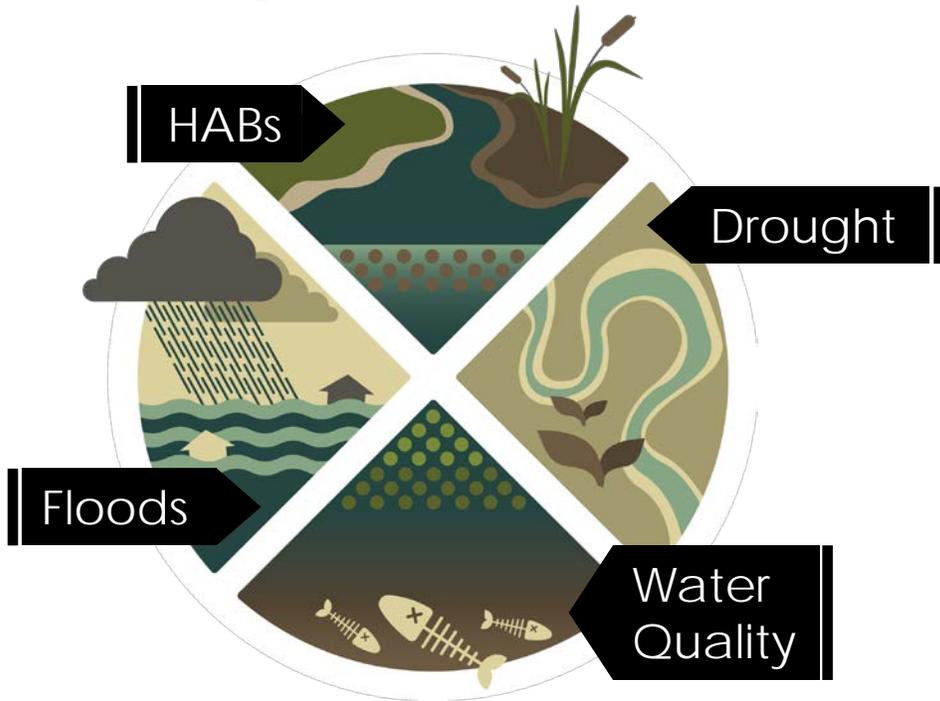


110+ countries

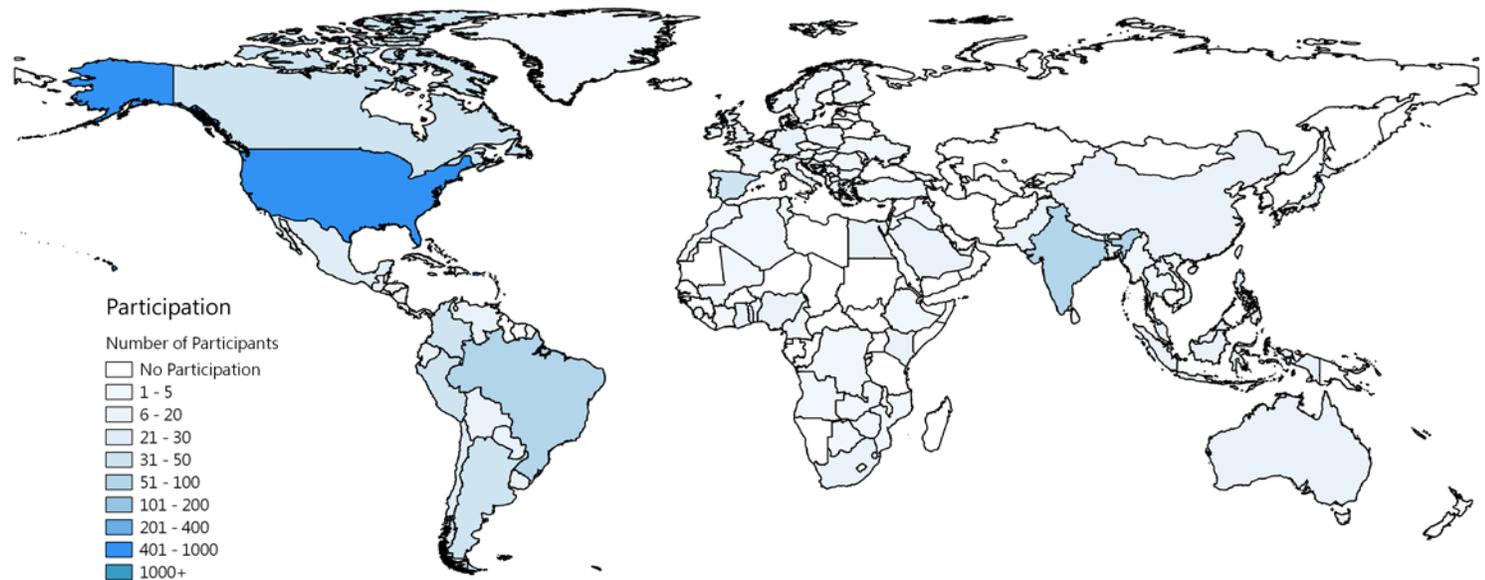


880+ organizations

Training Topics Include...



Global Water Resources Training Attendees (2017)



ARSET Training Impacts: Disasters Management (2013 – 2018)



10 trainings



3,000+ participants

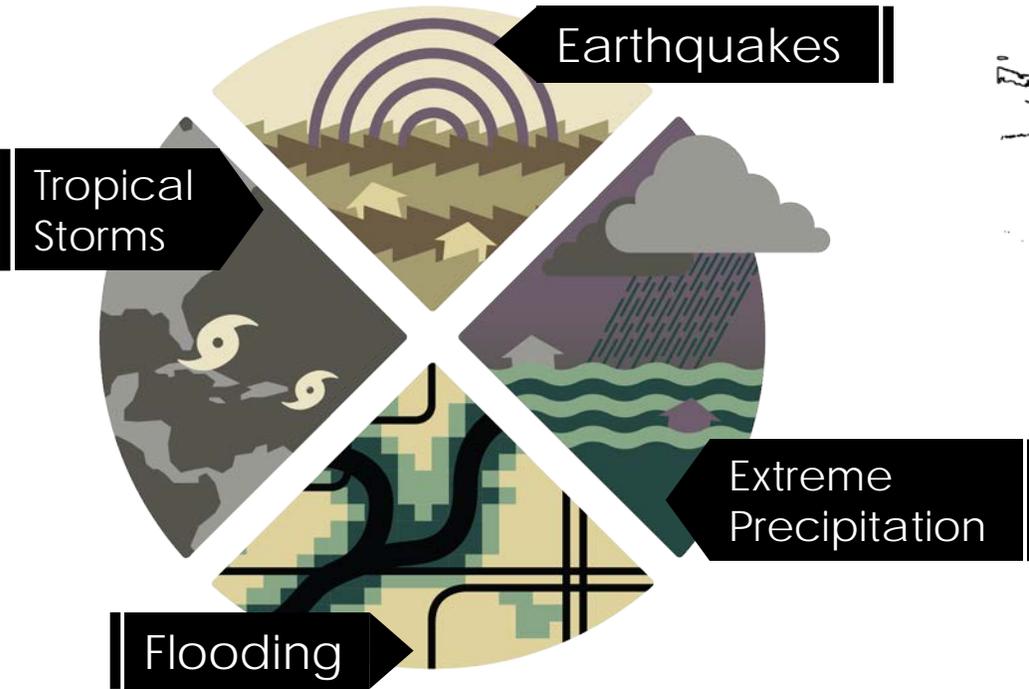


119+ countries

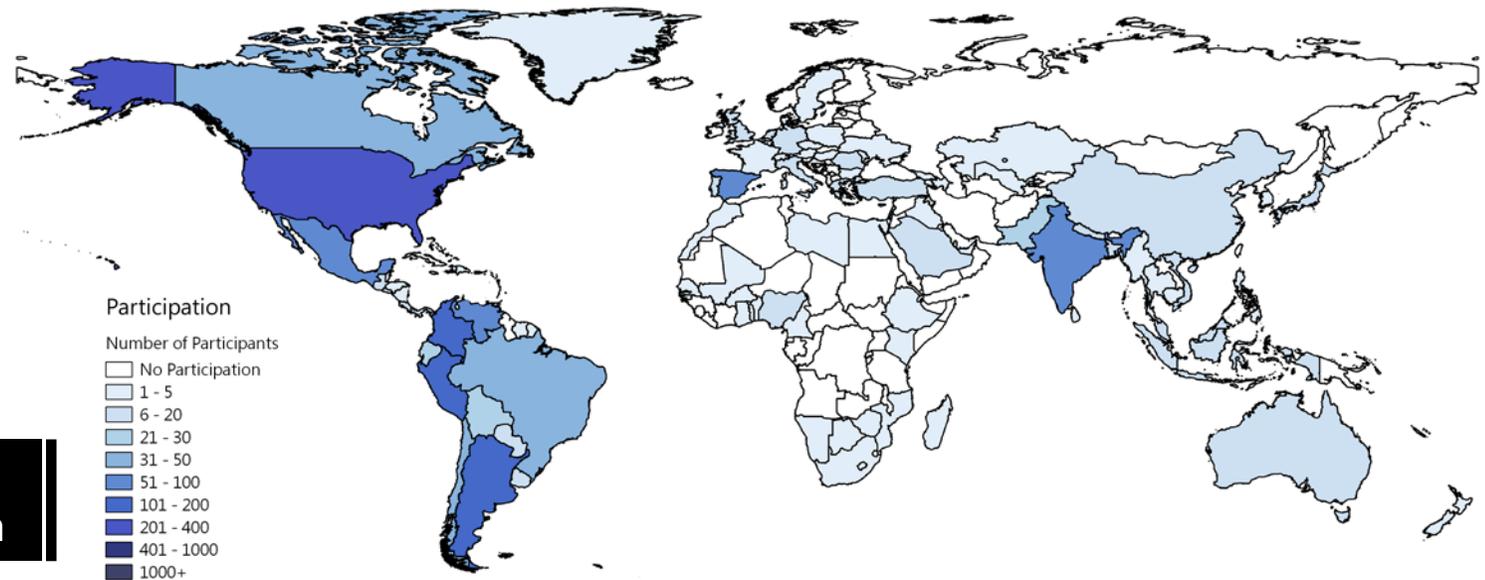


770+ organizations

Training Topics Include...



Global Disaster Training Attendees (2017)

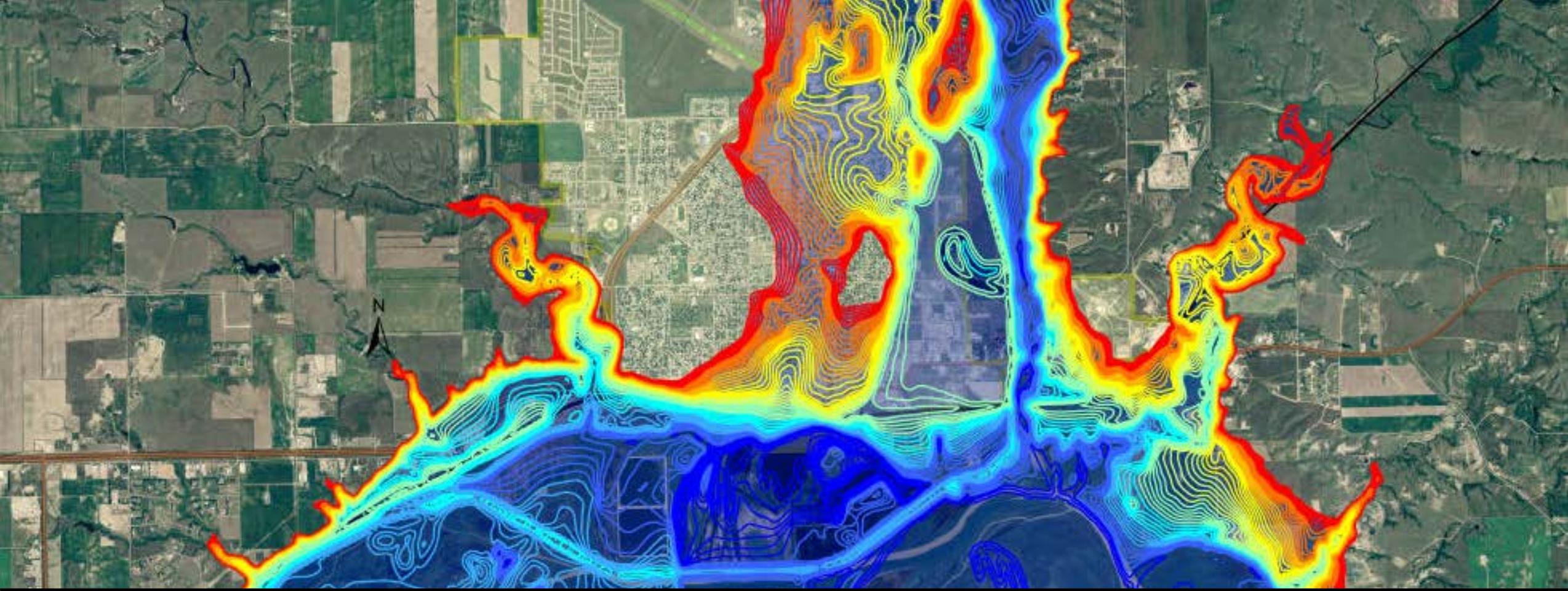


ARSET Website & Listserv

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

The screenshot displays the ARSET website interface. At the top, the NASA logo and 'ARSET Applied Remote Sensing Training' are visible. Navigation links include 'Home', 'About', and 'Trainings'. A search bar is located in the top right. The 'Trainings' menu is open, showing categories: Fundamentals, Disasters, Health & Air Quality, Land, and Water Resources. A featured training announcement for 'Introduction to Remote Sensing of Harmful Algal Blooms' is highlighted, with a 'Register Now' button. A sidebar on the right contains a list of links: ARSET, Online Trainings, In-Person Trainings, Sign up for the Listserv (highlighted with a mouse cursor), Tools Covered, Suggest a Training, Personnel, and Resources. Below this is a section for 'Upcoming Training' with a sub-section for 'Water' and a link for '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

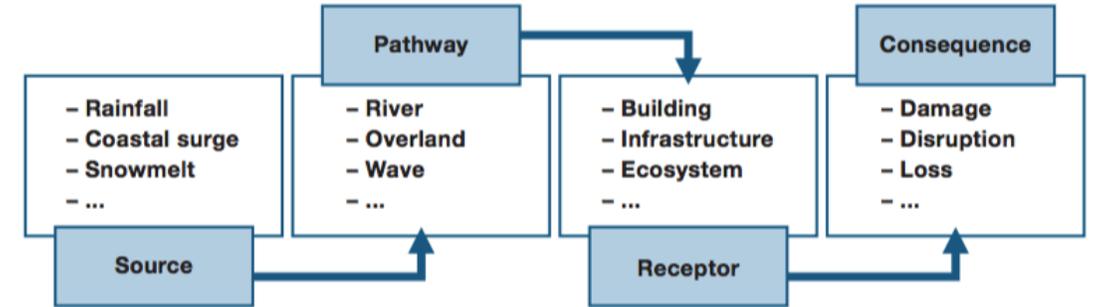


Figure 1.1: The Source, Pathway, Receptor Model

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: Ajju Bora

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

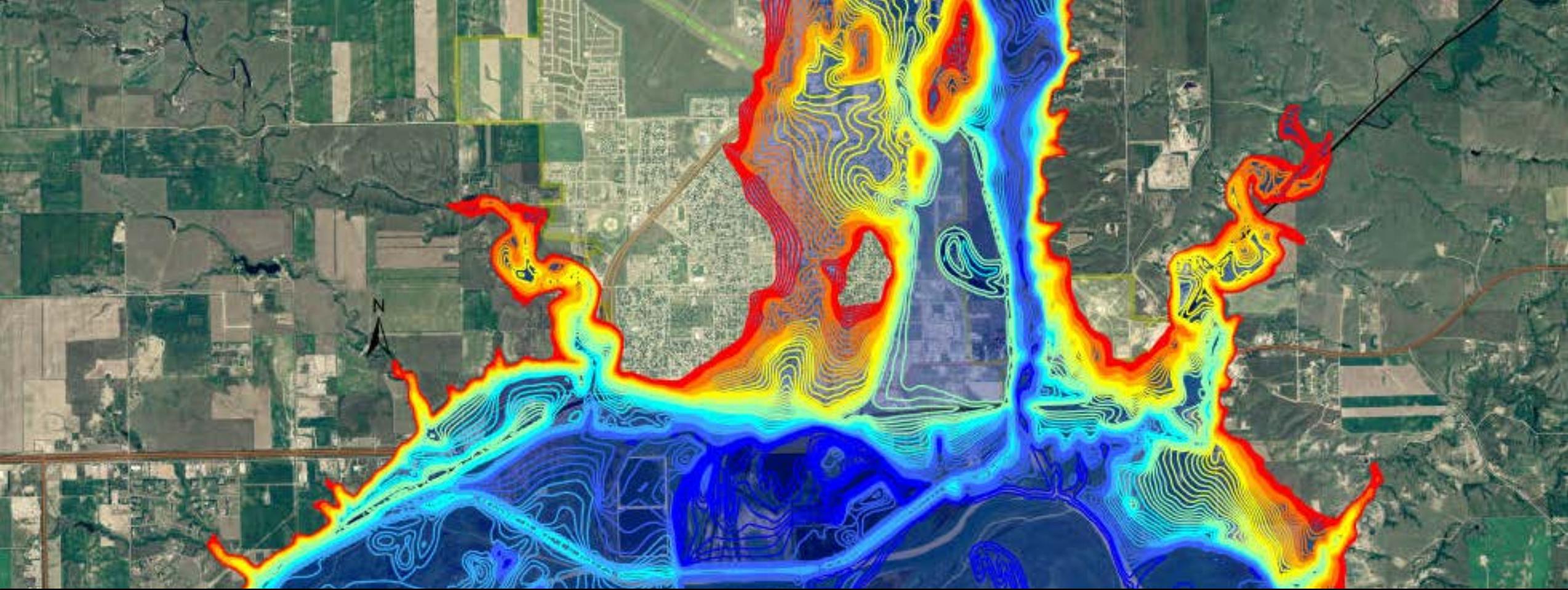
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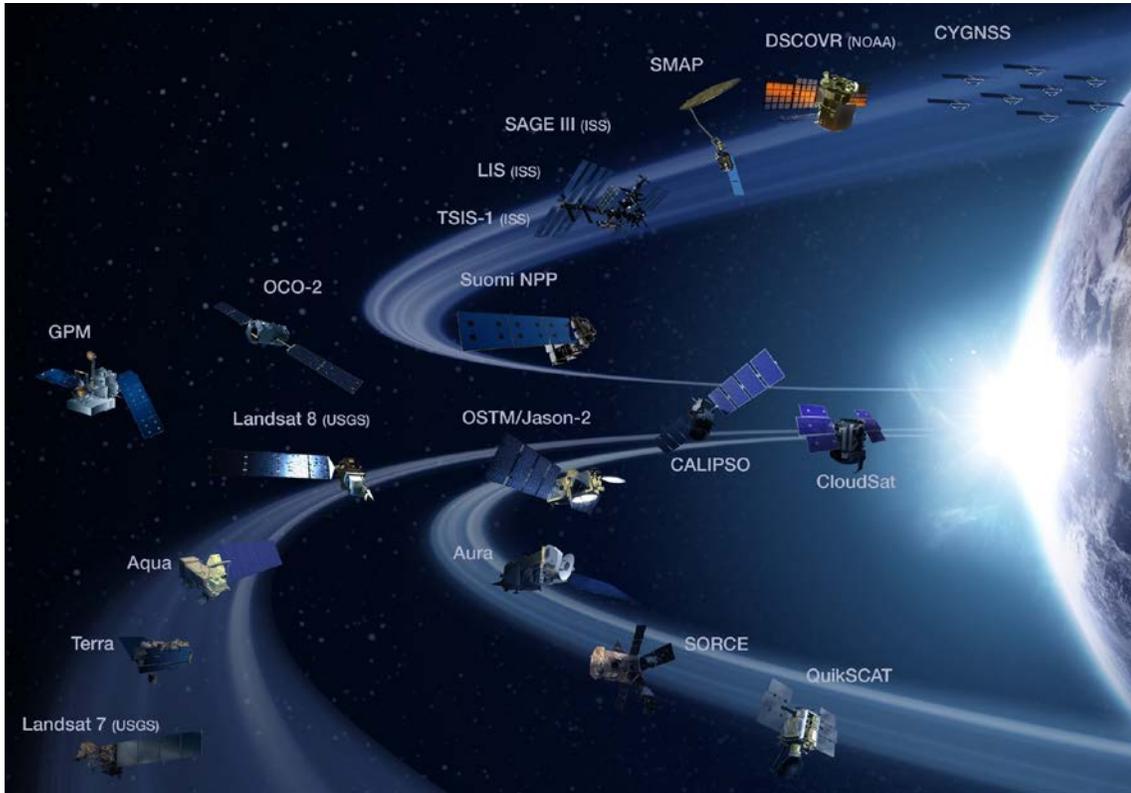
- Storm Water System Design and Capacity
- Design and Capacity of Dams and Levees
- Land Use Change: Exposed Soil Versus Build Areas
- Human Population
- Infrastructure (e.g., buildings, roads)





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	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



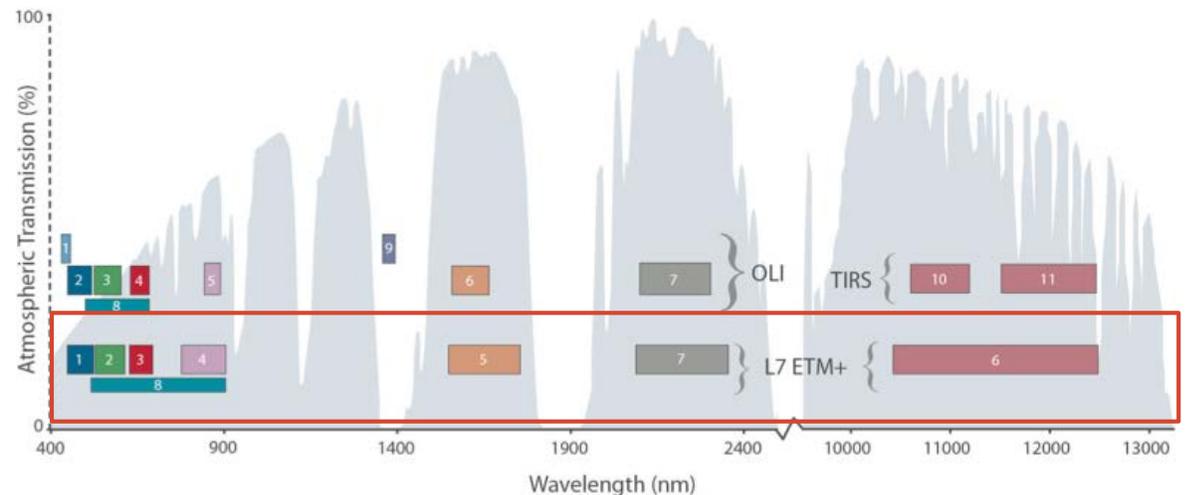
Enhanced Thematic Mapper (ETM+)

- 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

<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

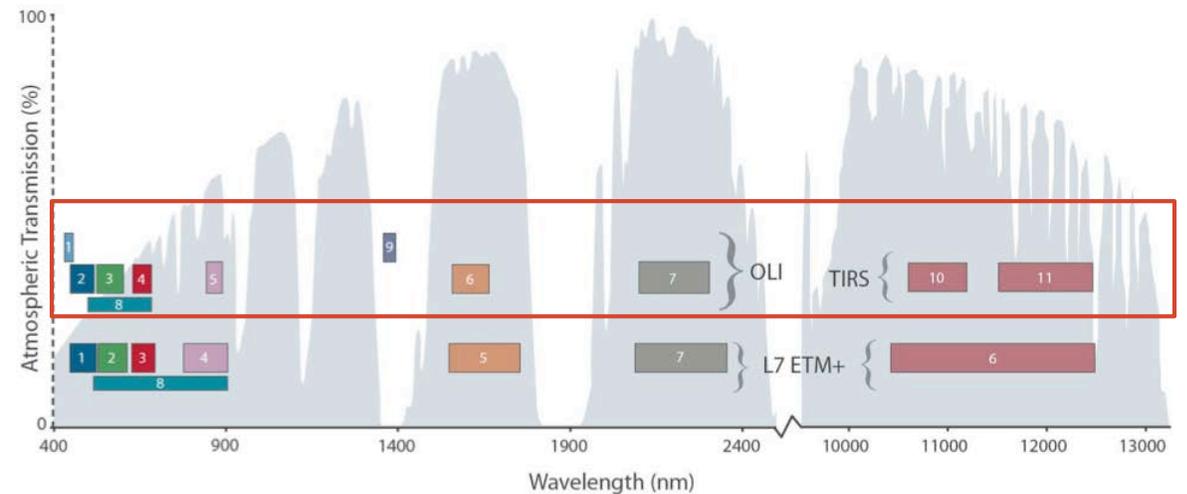


Operational Land Imager (OLI)

- 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

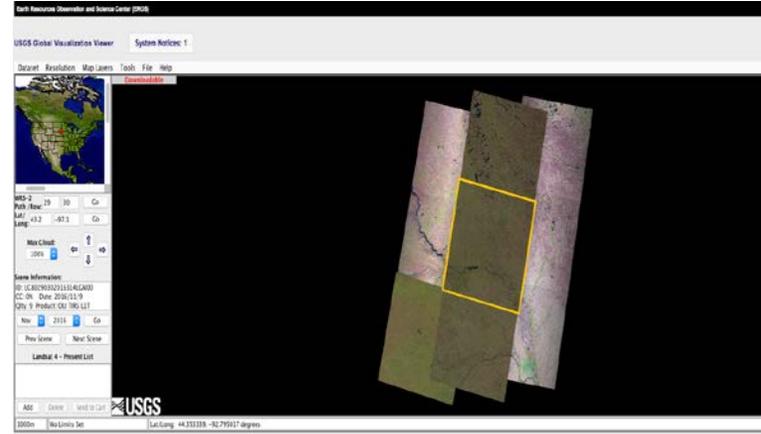
- 9 bands (blue-green, green, red, near IR, shortwave and thermal IR)
 - Bands 1-7, 9: 30m
 - Band 8:15m



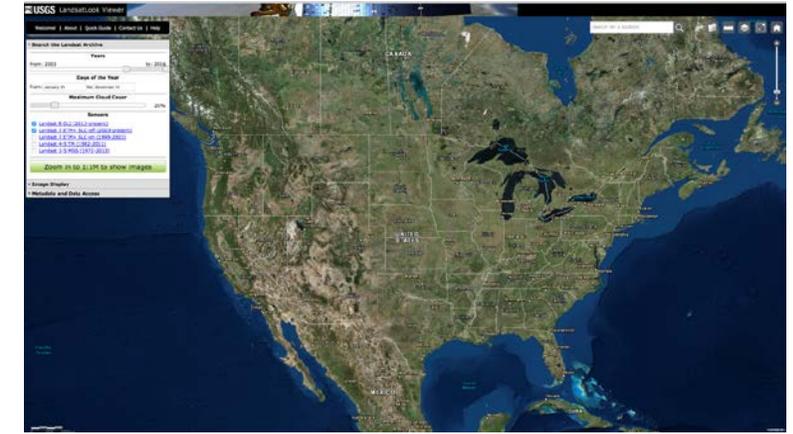
Where can you get Landsat images & spectral reflectance data?



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



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



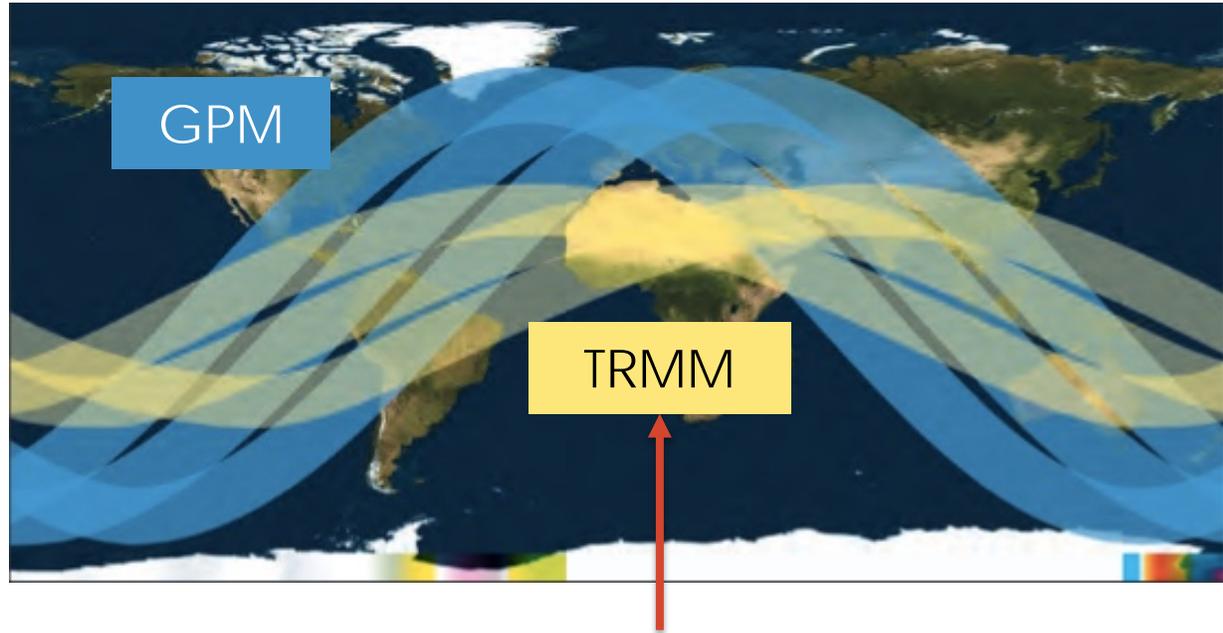
USGS Landlook Viewer
<https://landlook.usgs.gov/viewer.html>



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>

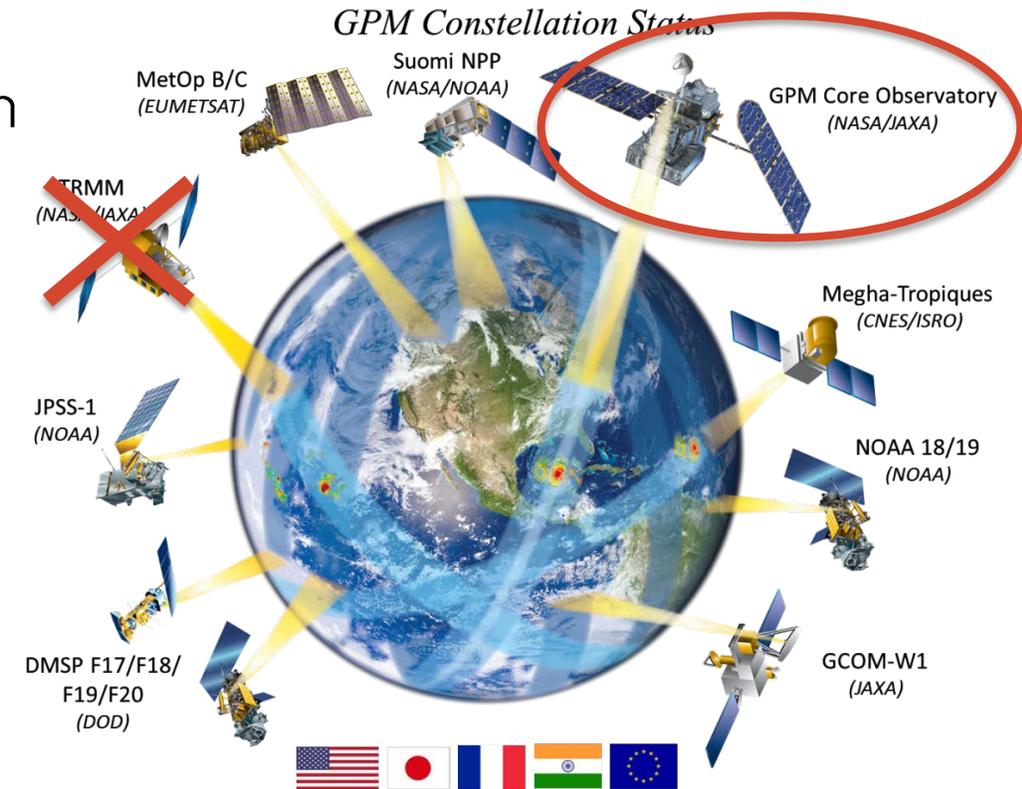
- TRMM & GPM Core satellites are used to calibrate microwave observations from a constellation of national and international satellites
- Allow improved spatial and temporal coverage of precipitation data
- TRMM Multi-satellite Precipitation Analysis (**TMPA**)
- Widely used for applications
- TMPA will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

- 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>

Data Access

- Extreme Weather News
- Data Downloads & Documentation
 - TRMM
 - GPM
 - Ground Validation
- Data Sources
- Data Recipes
- Data News
- Google Earth
- NASA Worldview
- Using the PPS FTP
- Training
- Data FAQ

Connect With Us

- Twitter
- Facebook
- Youtube

Need Help?

- View Frequently Asked Questions
- View the PMM Glossary

How to Access TRMM & GPM Precipitation Data

Precipitation data from the GPM and TRMM missions is made available free to the public in a variety of formats from several sources at [NASA](#) Goddard Space Flight Center. This section outlines the different types of data available, the levels of processing, the sources to download the data, and some helpful tips for utilizing precipitation data in your research.

- GPM Data Downloads & Documentation**
- TRMM Data Downloads & Documentation
- Explanation of GPM & TRMM Data Sources
- Data Processing "Recipes"
- Precipitation Data in Google Earth
- Frequency Asked Questions (FAQ)

GET DATA
GLOBAL PRECIPITATION MEASUREMENT

New Users Start Here

Use of the **PPS FTP** and **STORM** requires you to first register your email address. [Click here to register.](#)

- 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 with several red callout boxes highlighting key features:

- Analysis and Plot Options:** A box pointing to the "Select Plot" section, which includes radio buttons for "Maps: Time Averaged Map", "Comparisons: Select...", "Vertical: Select...", "Time Series: Select...", and "Miscellaneous: Select...".
- Temporal and Spatial Search Map & shapefile selection for various countries or the U.S.:** A box pointing to the "Select Date Range (UTC)" and "Select Region (Bounding Box or Shape)" sections. The date range section includes input fields for "YYYY-MM-DD" and "HH:mm" with a "Valid Range: 1948-01-01 to 2018-04-16" note. The region section includes a text input field and a "Format: West, South, East, North" note.
- Search data by keyword:** A box pointing to the "Number of matching Variables: 0 of 1901" and "Total Variable(s) included in Plot: 0" section, which includes a "Keyword:" input field and "Search" and "Clear" buttons.
- Plot Data:** A box pointing to the "Plot Data" button at the bottom right of the interface.

The interface also features a top navigation bar with "EARTHDATA", "Data Discovery", "DAACs", "Community", and "Science Disciplines". A sidebar on the left lists "Select Variables" under "Disciplines" and "Measurements". The bottom navigation bar includes "Help", "Reset", "Feedback", and "Plot Data" buttons.



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



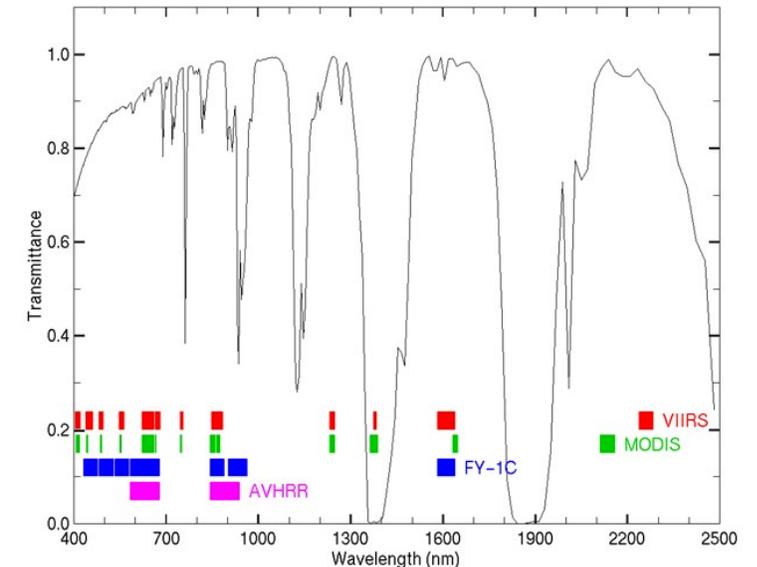
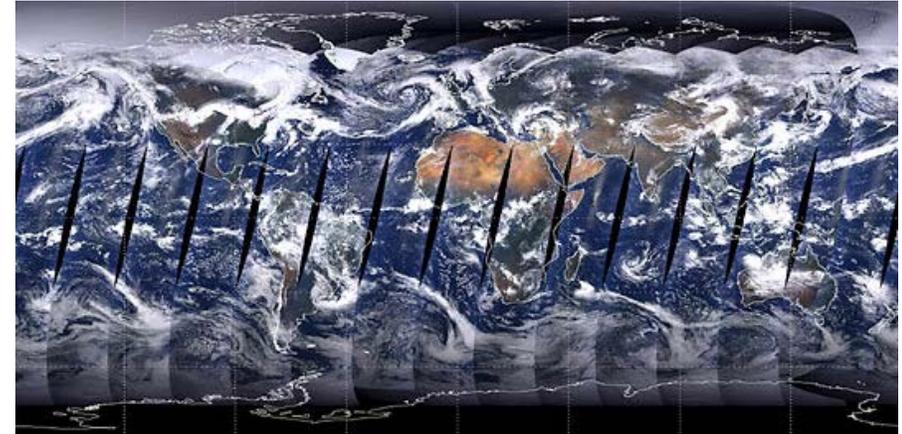
MODerate Resolution Imaging Spectroradiometer (MODIS)

<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:

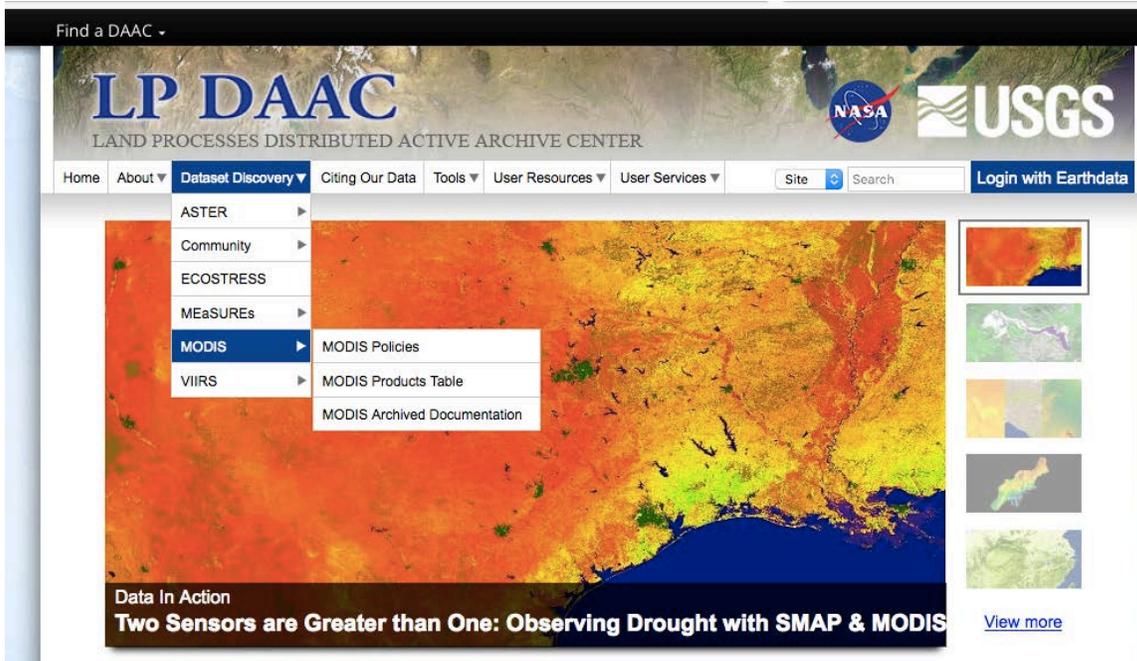
Land Processing Distributed Active Archive Center

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



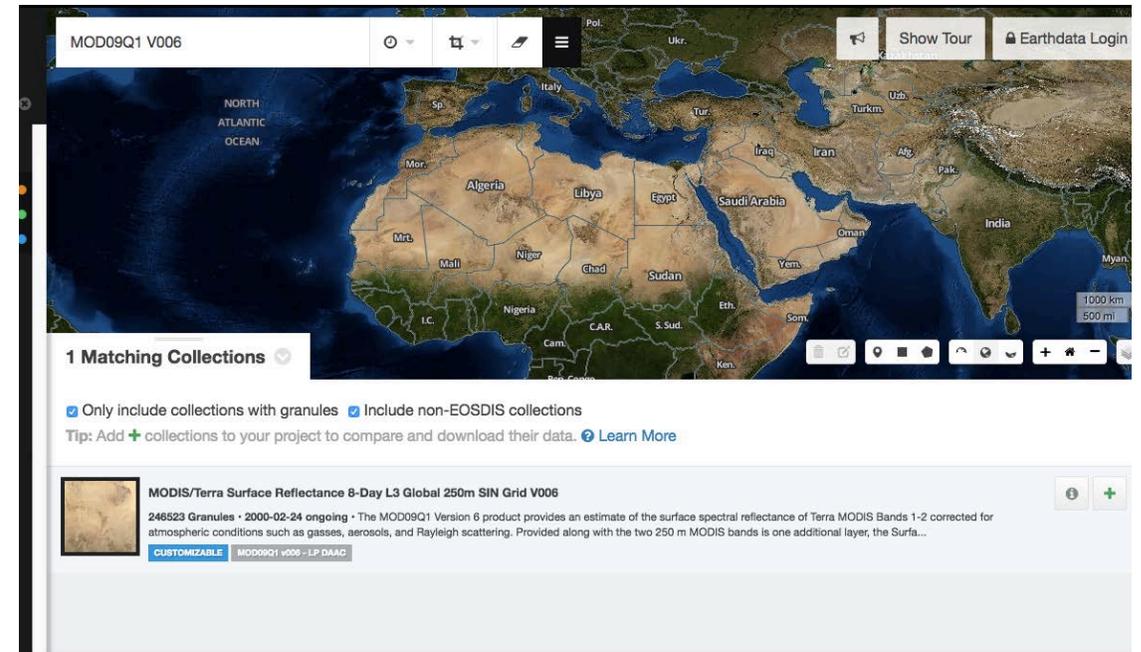
Where to Get MODIS Reflectance Data?

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



The screenshot shows the LP DAAC (Land Processes Distributed Active Archive Center) website. The header includes the LP DAAC logo, NASA and USGS logos, and navigation links for Home, About, Dataset Discovery, Citing Our Data, Tools, User Resources, and User Services. A search bar and a 'Login with Earthdata' button are also present. The 'Dataset Discovery' menu is open, showing options for ASTER, Community, ECOSTRESS, MEaSUREs, MODIS, and VIIRS. The MODIS option is selected, and a sub-menu is displayed with links to MODIS Policies, MODIS Products Table, and MODIS Archived Documentation. A large satellite image of a landscape is visible in the background, and a 'Data In Action' banner at the bottom reads 'Two Sensors are Greater than One: Observing Drought with SMAP & MODIS'.

Data Information



The screenshot shows the Earthdata Search interface. At the top, there is a search bar with the text 'MOD09Q1 V006'. Below the search bar, a map of the Middle East and surrounding regions is displayed. The search results section shows '1 Matching Collections' and includes filters for 'Only include collections with granules' and 'Include non-EOSDIS collections'. A tip suggests adding collections to a project for comparison and download. A collection entry is shown with a thumbnail image and the following text: 'MODIS/Terra Surface Reflectance 8-Day L3 Global 250m SIN Grid V006', '246523 Granules · 2000-02-24 ongoing · The MOD09Q1 Version 6 product provides an estimate of the surface spectral reflectance of Terra MODIS Bands 1-2 corrected for atmospheric conditions such as gasses, aerosols, and Rayleigh scattering. Provided along with the two 250 m MODIS bands is one additional layer, the Surfa...'. There are buttons for 'CUSTOMIZABLE' and 'MOD09Q1 v006 - LP DAAC'.

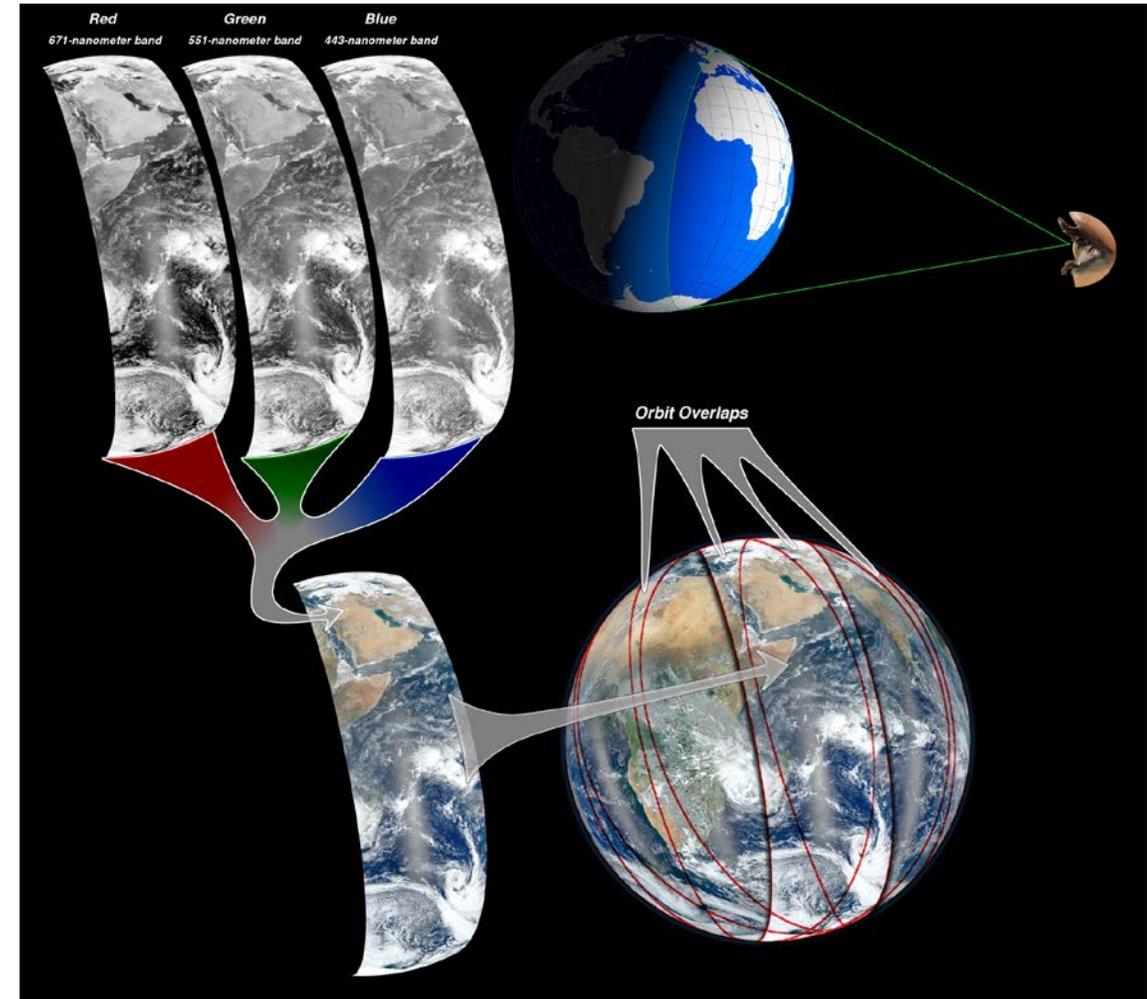
Data Search, Subset, and Download



Suomi National Polar Partnership (SNPP)

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

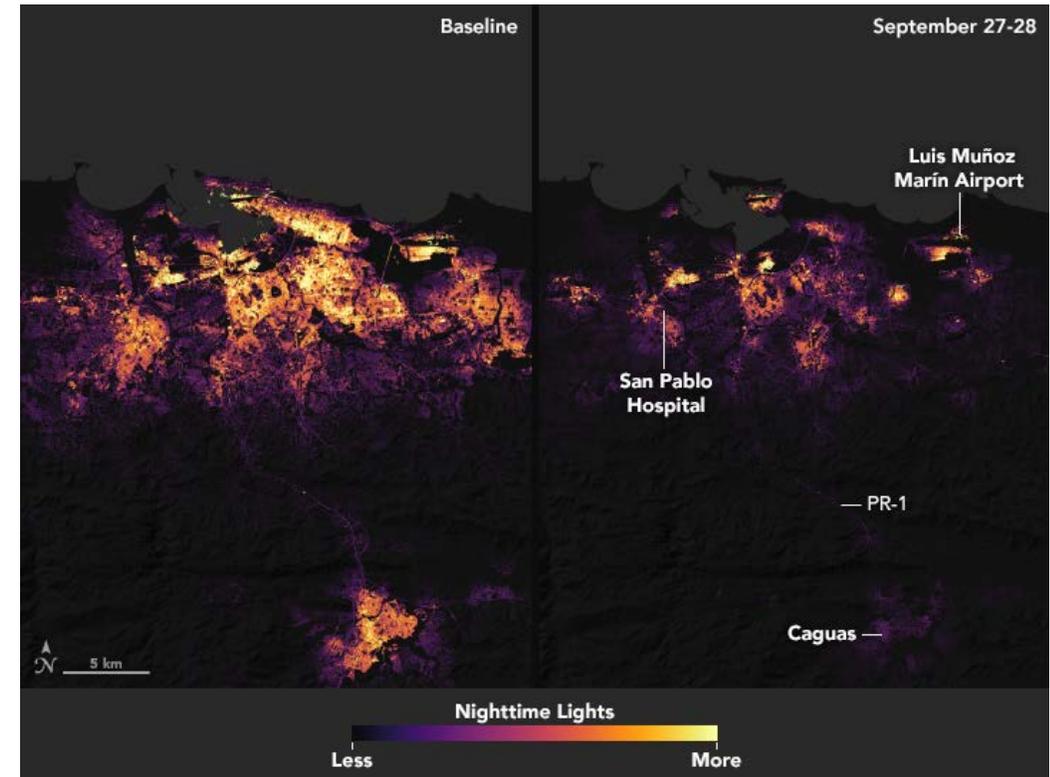
- Polar orbit, 1:30 p.m. equator crossing time
- Global coverage
- November 21, 2011 – present
- Sensors:
 - VIIRS, ATMS, CrIS, OMPS, CERES



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/

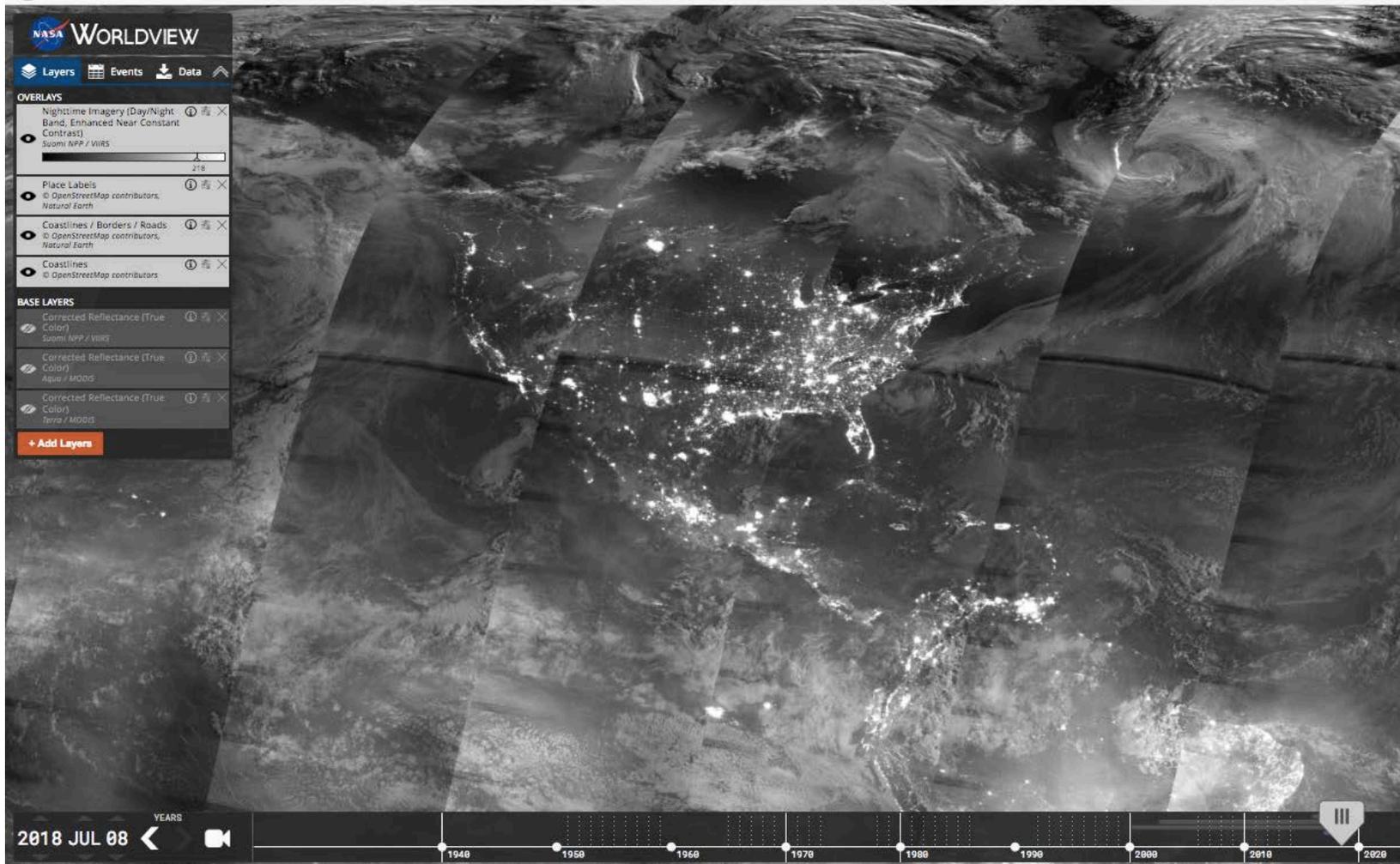


Power Outages in Puerto Rico as a Result of Hurricane Maria



Where to Get VIIRS Night Light Imagery?

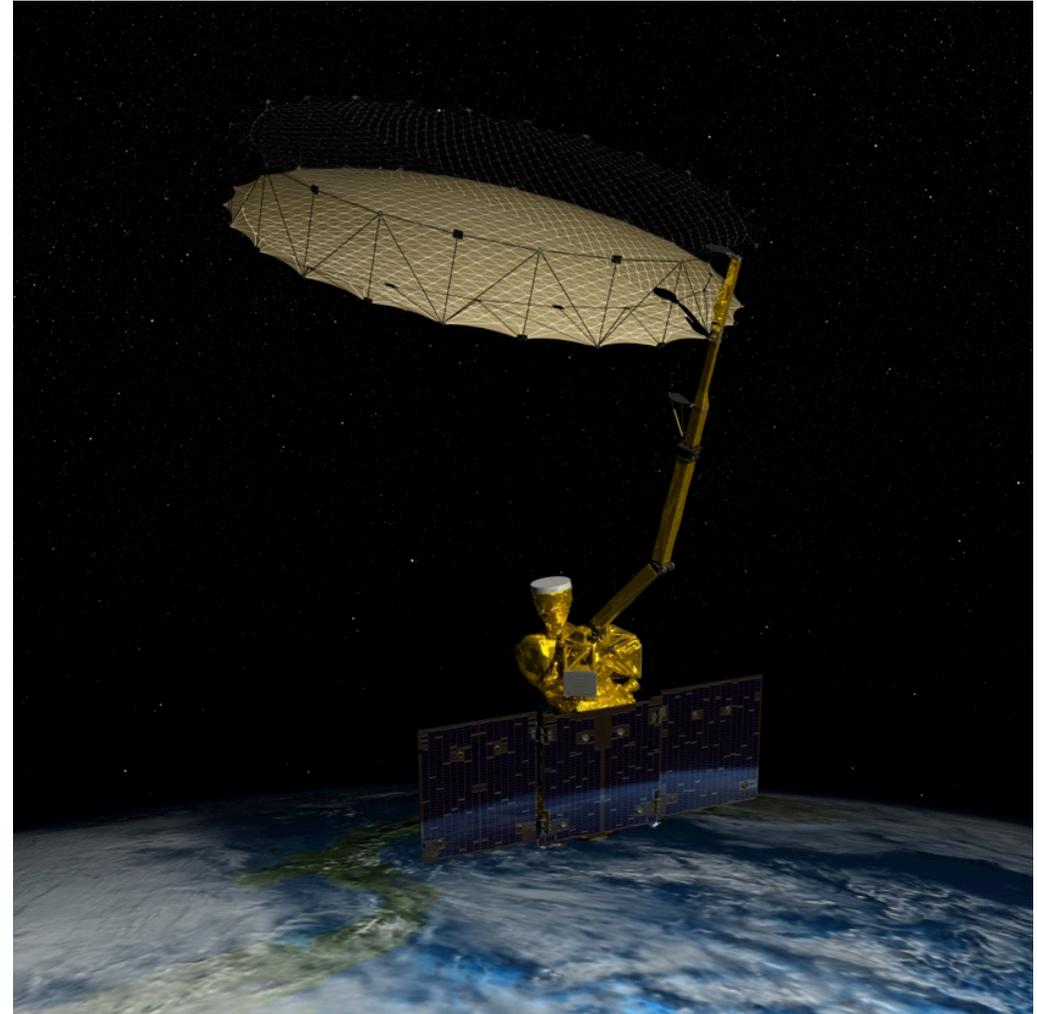
<https://worldview.earthdata.nasa.gov>



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)

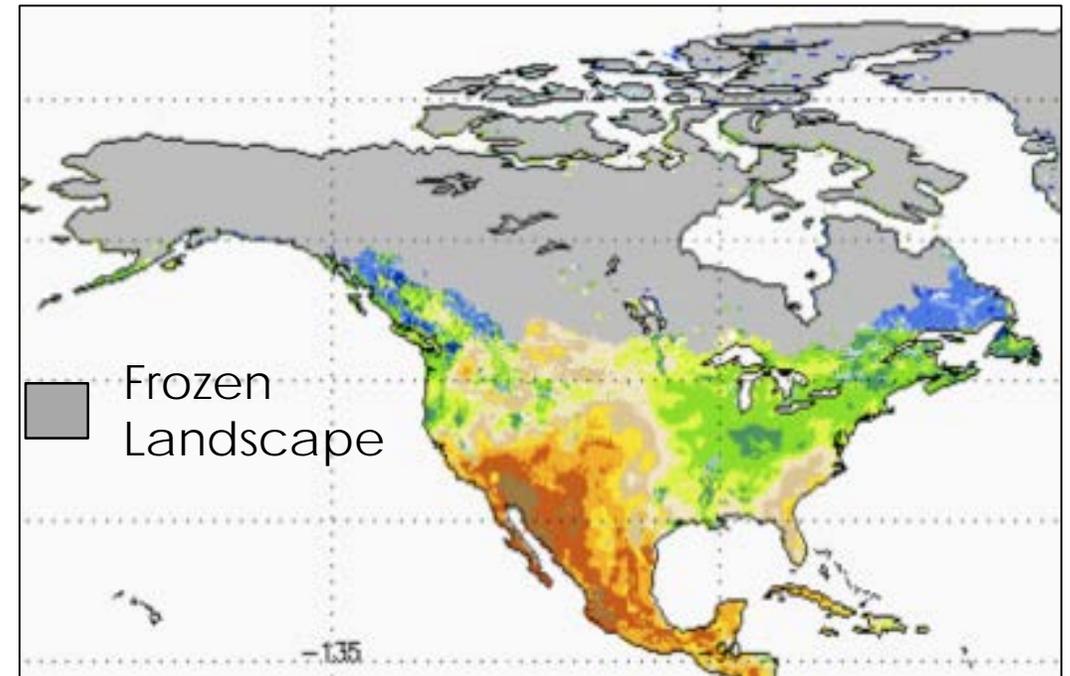


SMAP Microwave Radiometer & Radar

<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/>

NSIDC National Snow & Ice Data Center

DATA RESEARCH NEWS ABOUT

SEARCH Web pages

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

Showing 1-25 of 236 Data Sets

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

Parameter

Filter Parameters

- Active Layer (20)
- Aerosols (2)
- Air Temperature (40)
- Albedo (4)
- Altitude (2)
- Antenna Temper... (1)
- Atmospheric Ch... (4)
- Atmospheric Pre... (18)
- Atmospheric Pro... (28)

Spatial Coverage

- Show Global Only (25)

Temporal Duration

- < 1 year (164)
- 1+ years (68)
- 5+ years (32)
- 10+ years (22)
- Not specified (4)

Format

- ASCII Text (128)
- Binary (25)
- Documents (13)
- ESRI Shapefile (3)
- GRIB (1)

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 as ...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 ...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 radiome ...More Detail

SMAP L4 9 km EASE-Grid Surface and Root Zone Soil Moisture Geophysical Data

Level 2 to Level 4 data



Synthetic Aperture Radar (SAR) Imagery For Flood Detection

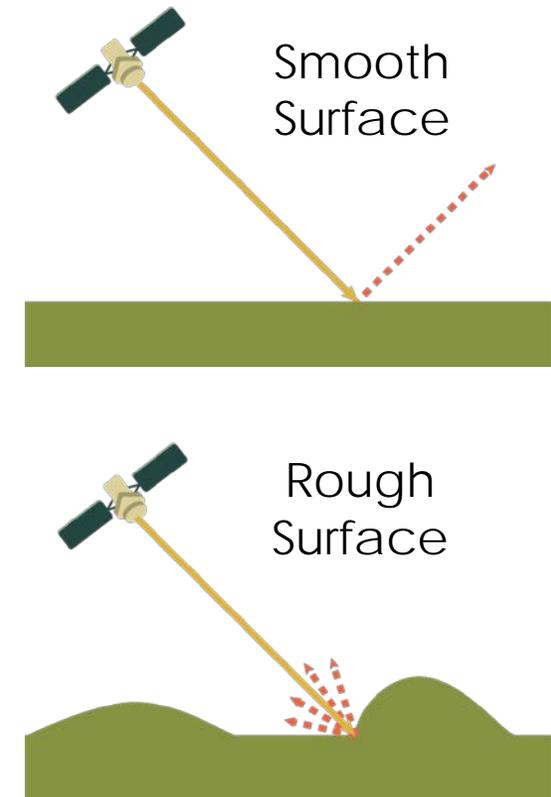
<https://arset.gsfc.nasa.gov/disasters/webinars/intro-SAR>

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

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



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/>

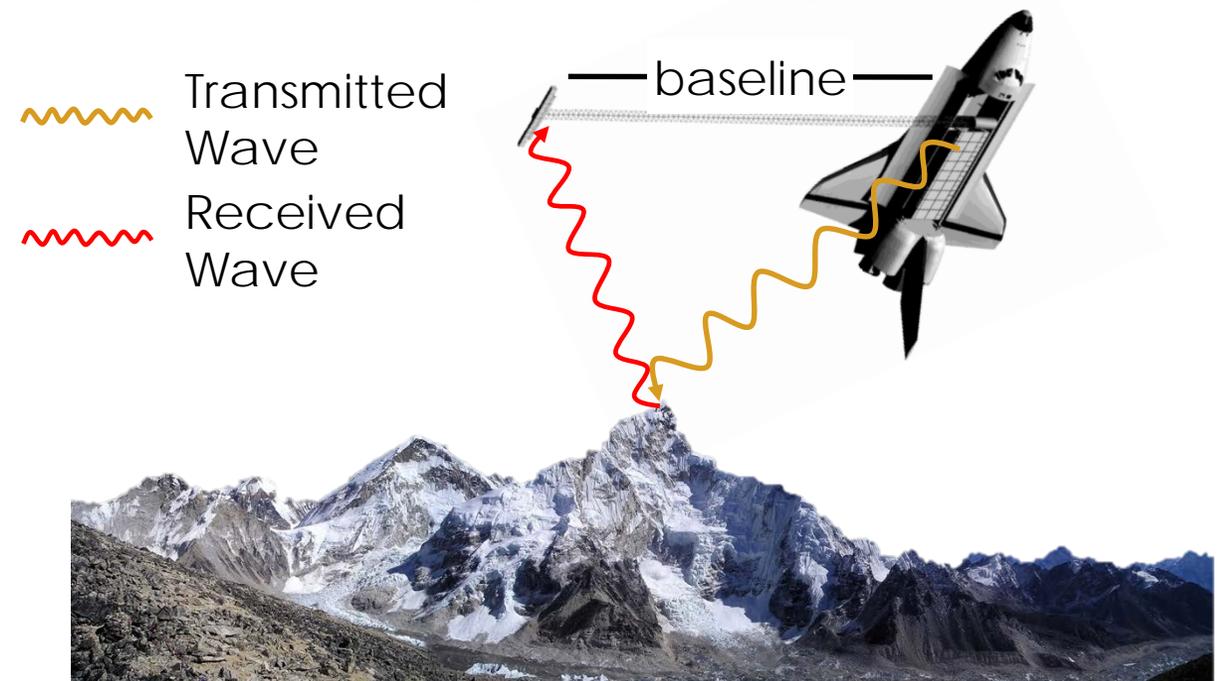


Terrain Data From Shuttle Radar Topography Mission (SRTM)

<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/>

The screenshot displays the Global Data Explorer (GDEx) interface. At the top, there are navigation menus for 'EARTHDATA', 'Data Discovery', 'DAACs', 'Community', and 'Science Disciplines'. The main header features the USGS logo with the tagline 'science for a changing world' and the NASA LP DAAC logo. On the right, there are links for 'USGS Home', 'Contact USGS', and 'Search USGS'. The central map area shows a topographic view of the United States and Mexico. A toolbar above the map contains various icons for map navigation and data selection. Three callout boxes with arrows point to specific icons: 'Zoom' points to the magnifying glass icon, 'Define region of interest by bounding box, state, country, or lat/long' points to a box containing icons for a globe, the US flag, a bounding box, and a state outline, and 'Download' points to a folder icon with a plus sign. On the right side, the 'Map Layers' panel is visible, showing a list of data layers including 'ASTER Global DEM', 'NASA Blue Marble', 'Data Coverage', 'ASTER Global DEM V2', 'NGA SRTM 1 arcsec', 'NGA SRTM 3 arcsec', 'NASA SRTM 1 arcsec', and 'NASA SRTM 3 arcsec'. The 'Legend' panel at the bottom right shows a map outline with a red dashed box indicating the current view area.

[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
Page Last Modified: 01/27/2017



[User Guide](#) | [GMU](#) | [CSISS](#) | [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	

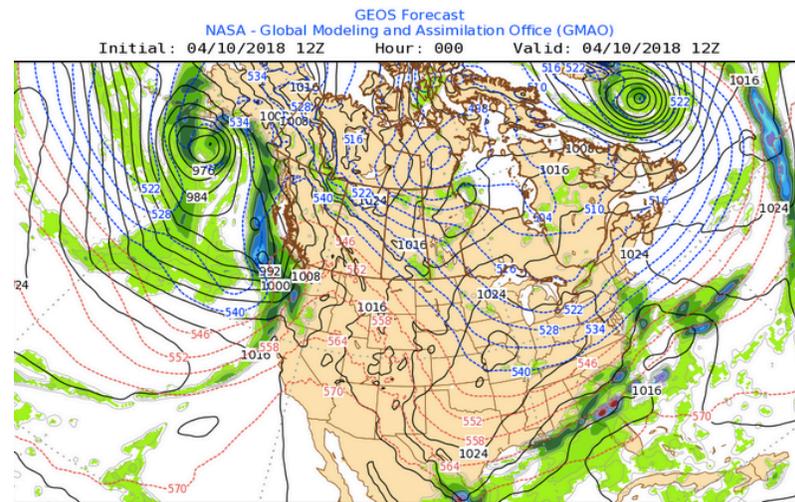
FORECAST INITIAL TIME

10Apr2018 12z

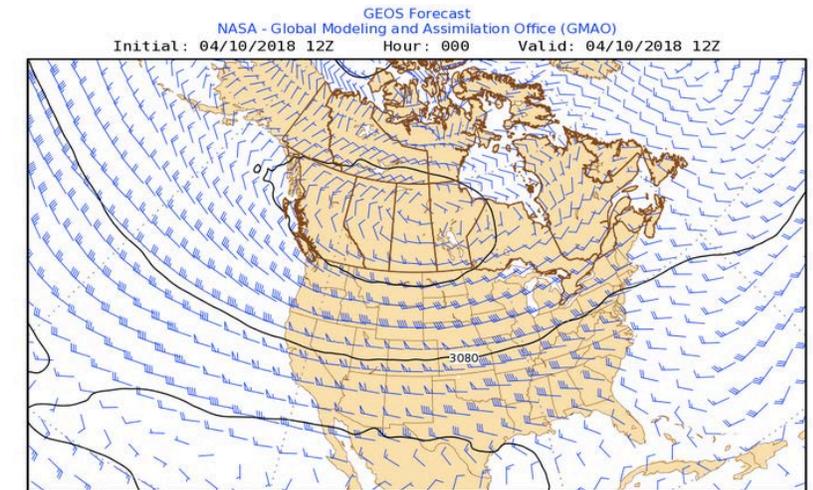
FORECAST LEAD HOUR

000 10Apr2018 12z

Precipitation Sea Level Pressure



Wind Speed & Direction



GEOS-5 Weather Data Access

https://portal.nccs.nasa.gov/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
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	
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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	

HTTP Files

Year & Month

Day

Hourly Files

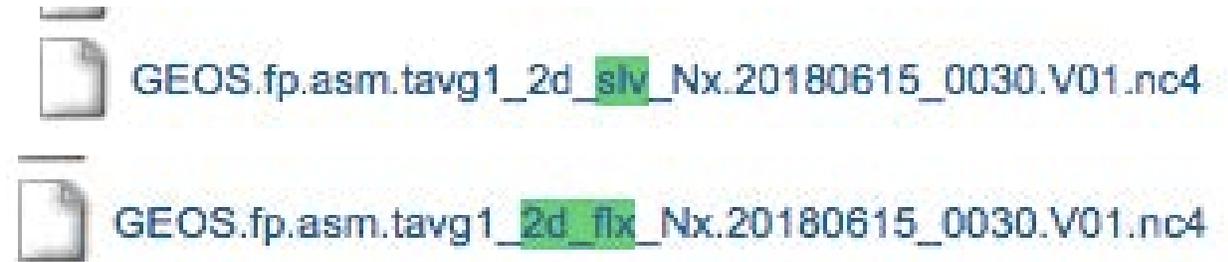


GEOS-5 Weather Data Access

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/>

SOCIOECONOMIC DATA AND APPLICATIONS CENTER (SEDAC)
A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS) — Hosted by CIESIN at Columbia University

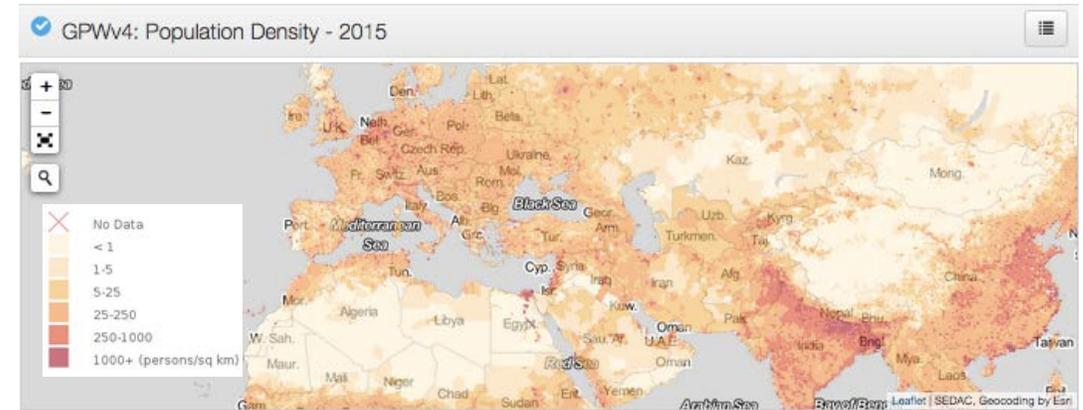
DATA | MAPS | THEMES | RESOURCES | SOCIAL MEDIA | ABOUT | HELP

Data Collections (41)

1 of 2
Prev | Next

- 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



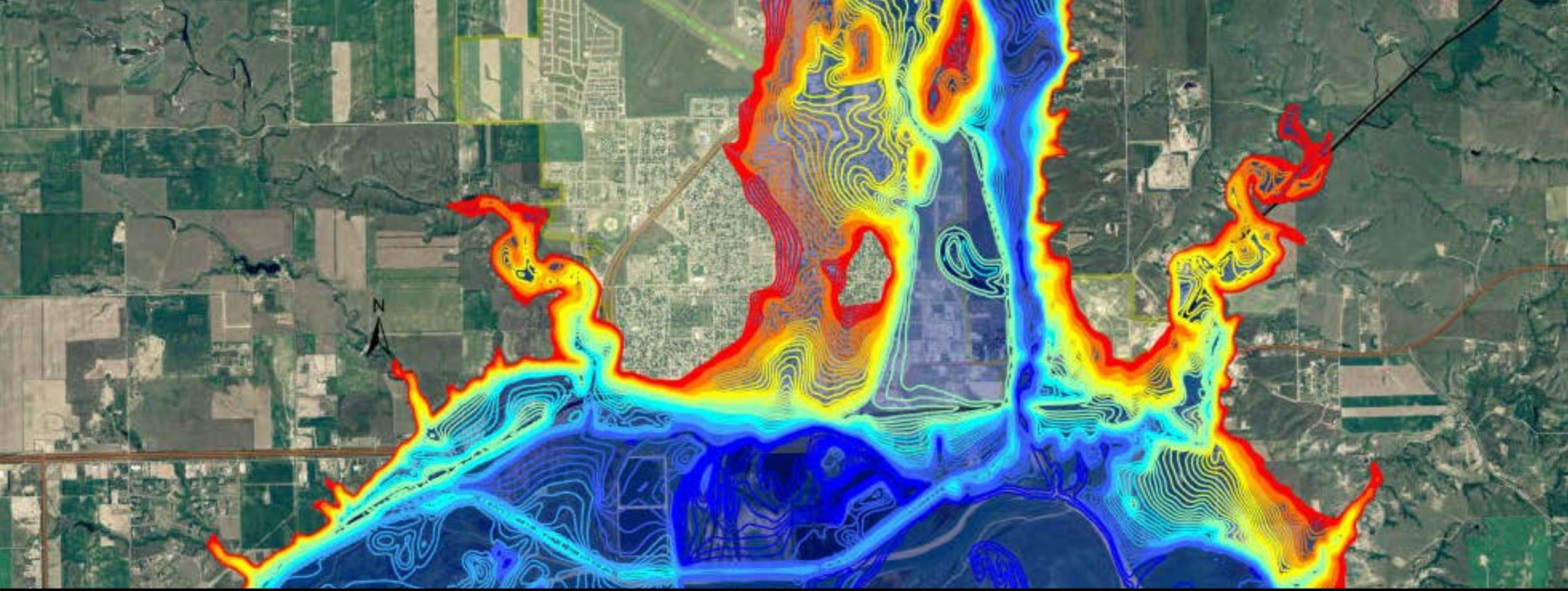
- Other Useful Datasets:
 - Global urban data from the Landsat satellite
 - Global reservoir and dam
 - Low elevation coastal zones
 - Global roads
 - Energy infrastructure



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

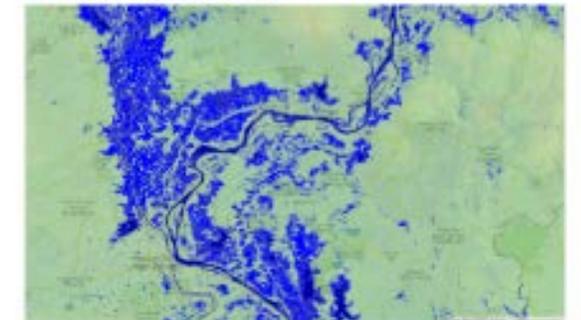


Focus Area

• 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](#)

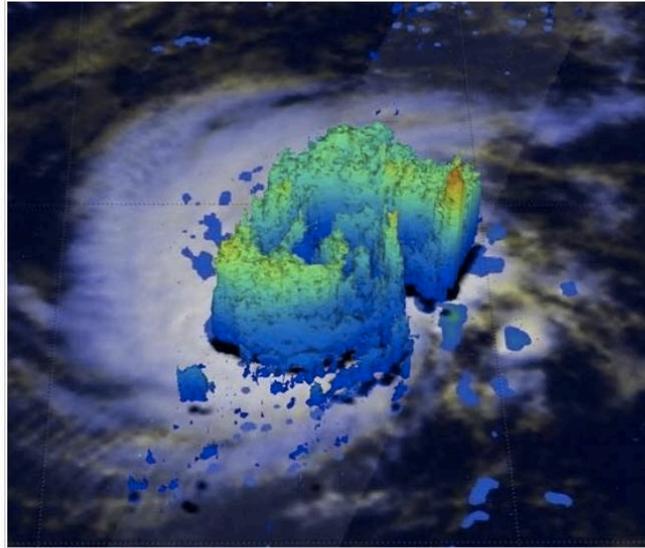
Project End-Users

- 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.”

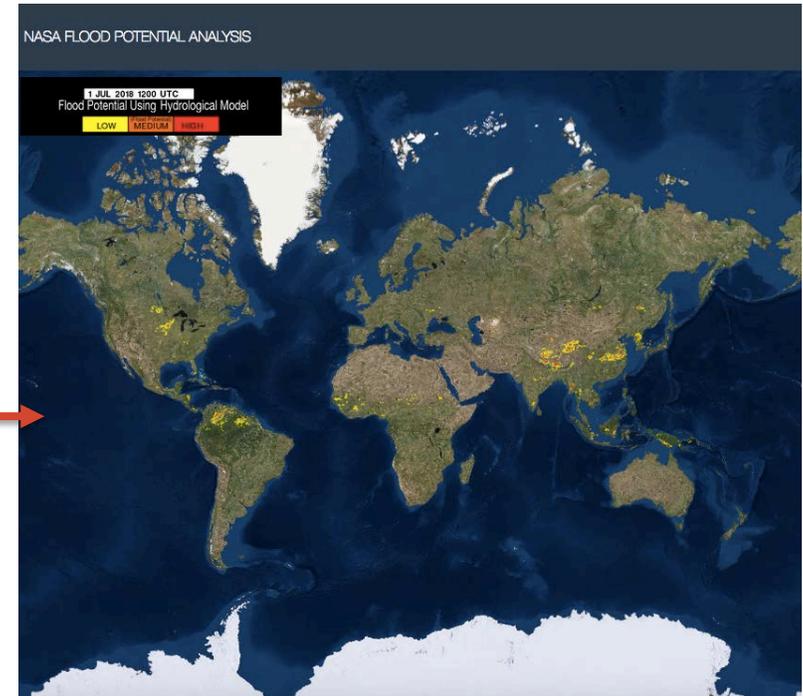
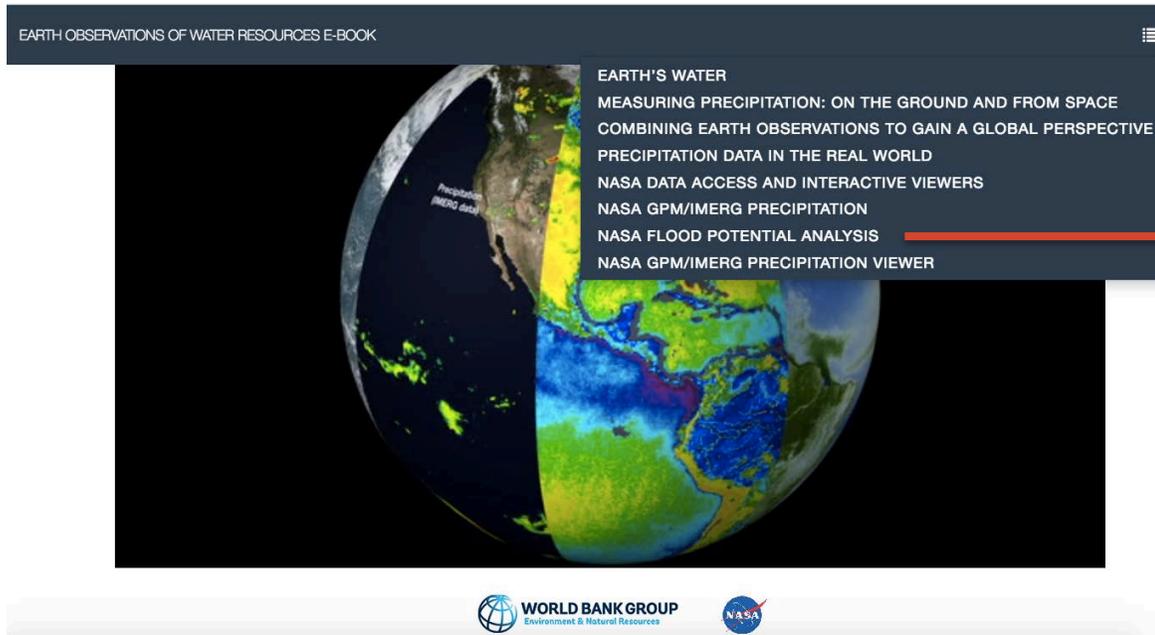
– Antoine Bavandi, a DRFIP financial sector specialist



The World Bank & NASA E-Book

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

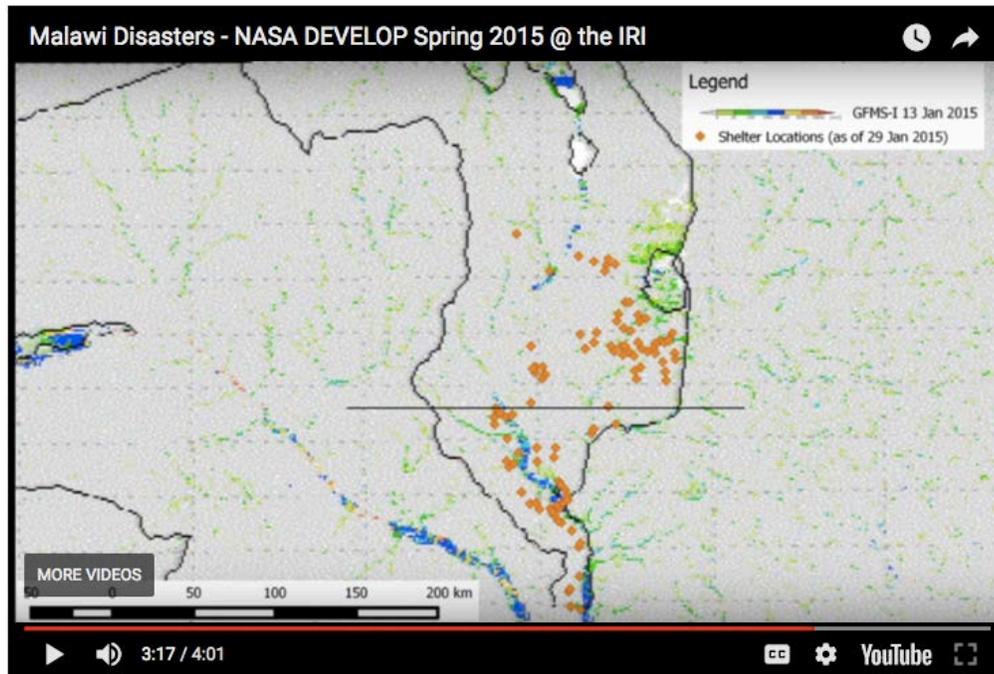
- TRMM/GPM – Based Flood Potential
- Disseminated via the World Bank Open Learning Campus



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/>

Jump to:		
Hurricanes	Earthquakes	Volcanoes
Floods	Landslides	Tsunami
Tornadoes & Severe Weather	Winter Weather	Avalanche
Wildfires	Excessive Heat	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

- 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
- Japan Meteorological Agency - West 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>

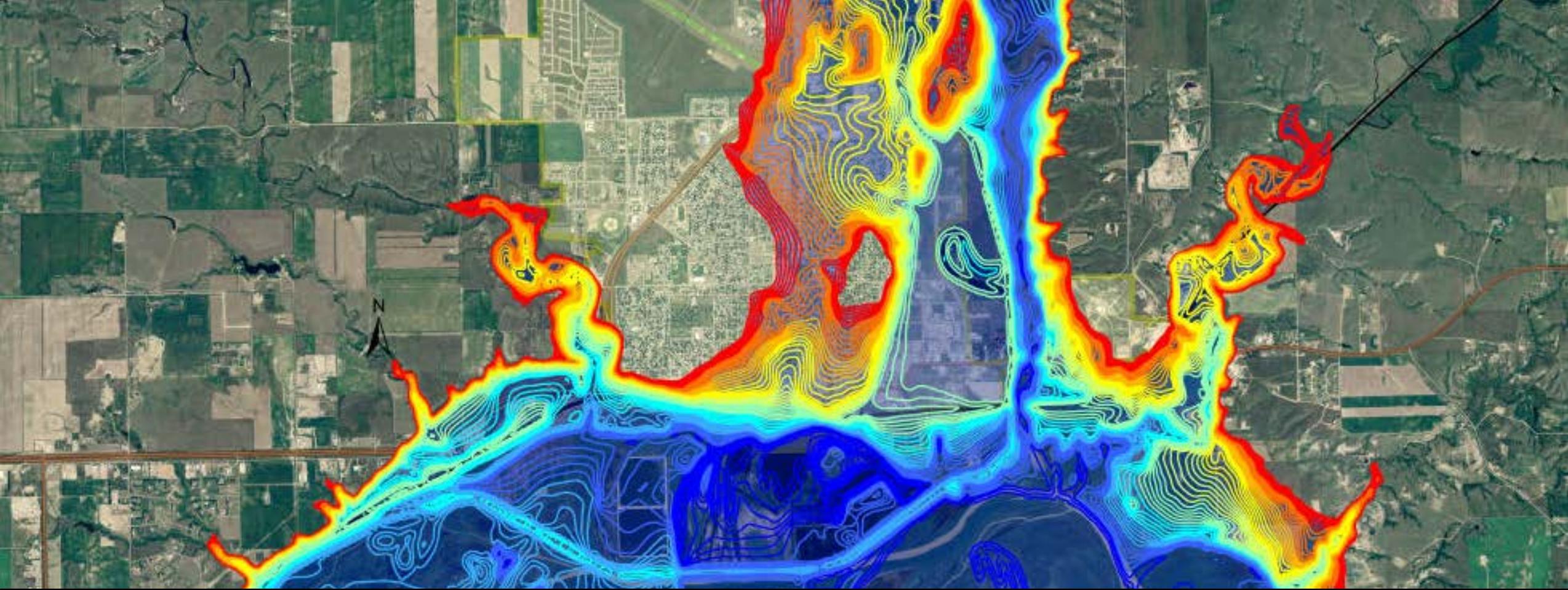
- Uses resources from several federal, state, and professional associations, including information from the NASA Disasters Portal
- <http://www.dcr.virginia.gov/dam-safety-and-floodplains/fppubs>

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

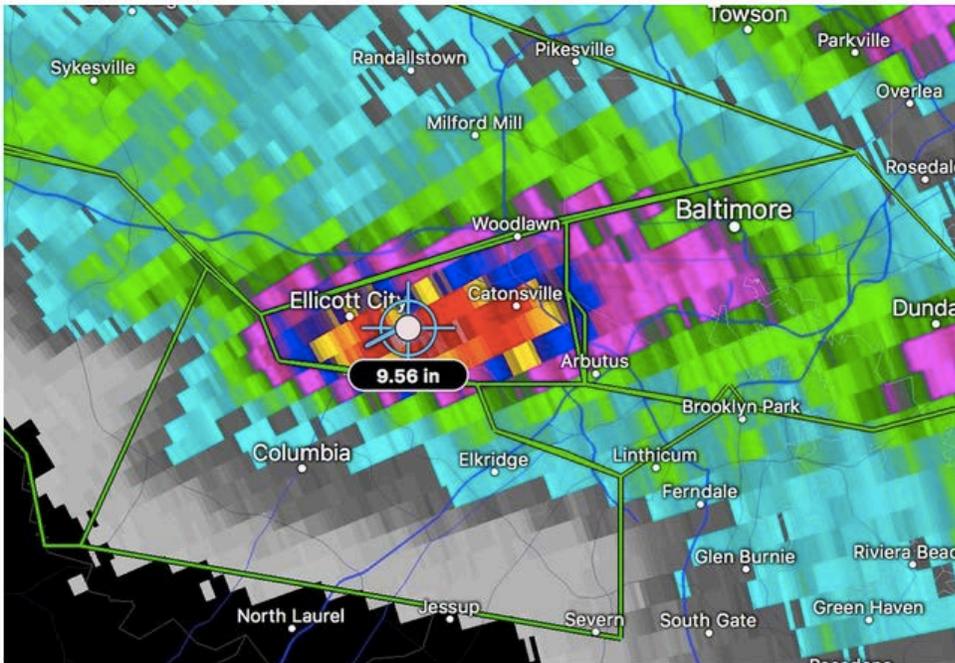
- Ellicott City, Maryland
Flash Flood occurred on 27 May 2018
- Houston, Texas
Heavy rain cause flooding on 4 July 2018



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.



(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.

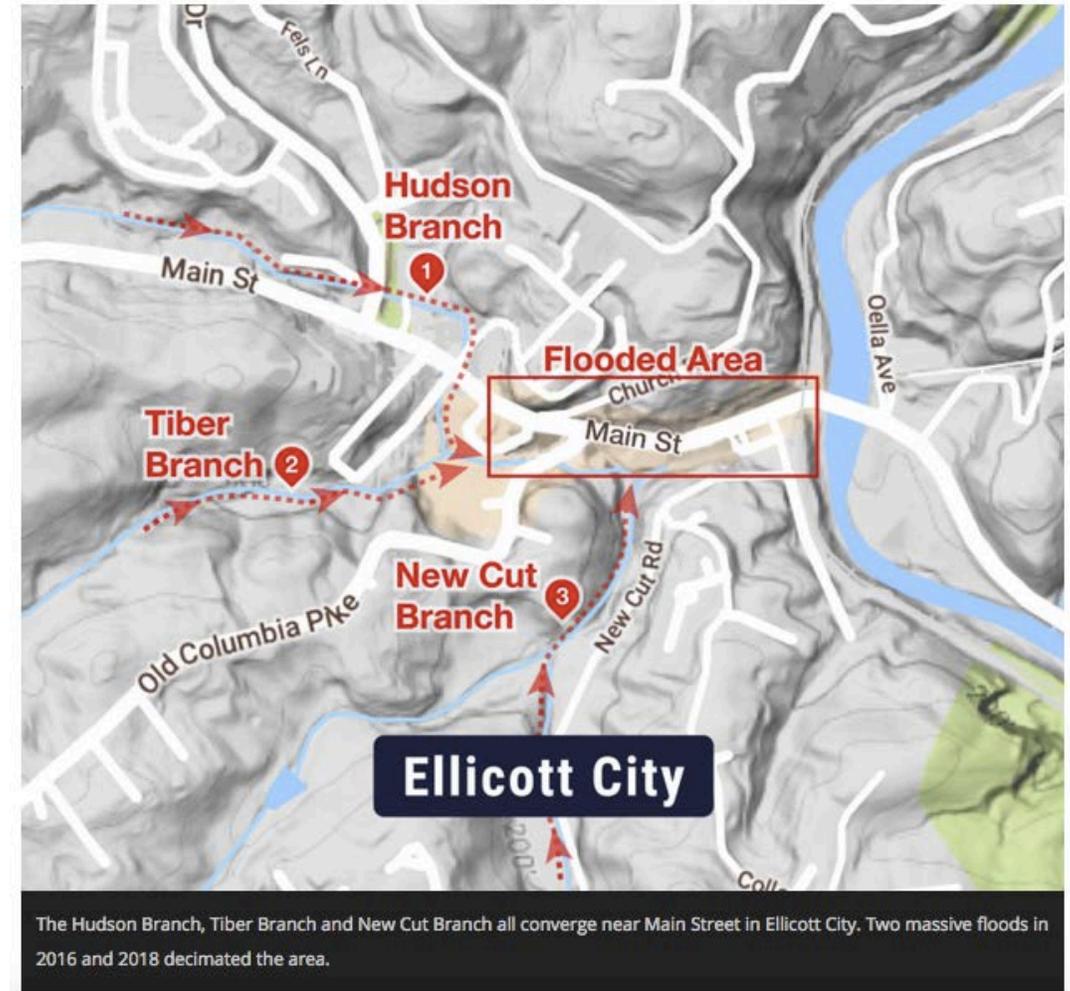


Image Credits: (left) [Washington Post](https://www.washingtonpost.com), (right) [WTOP](https://www.wtop.com)



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.

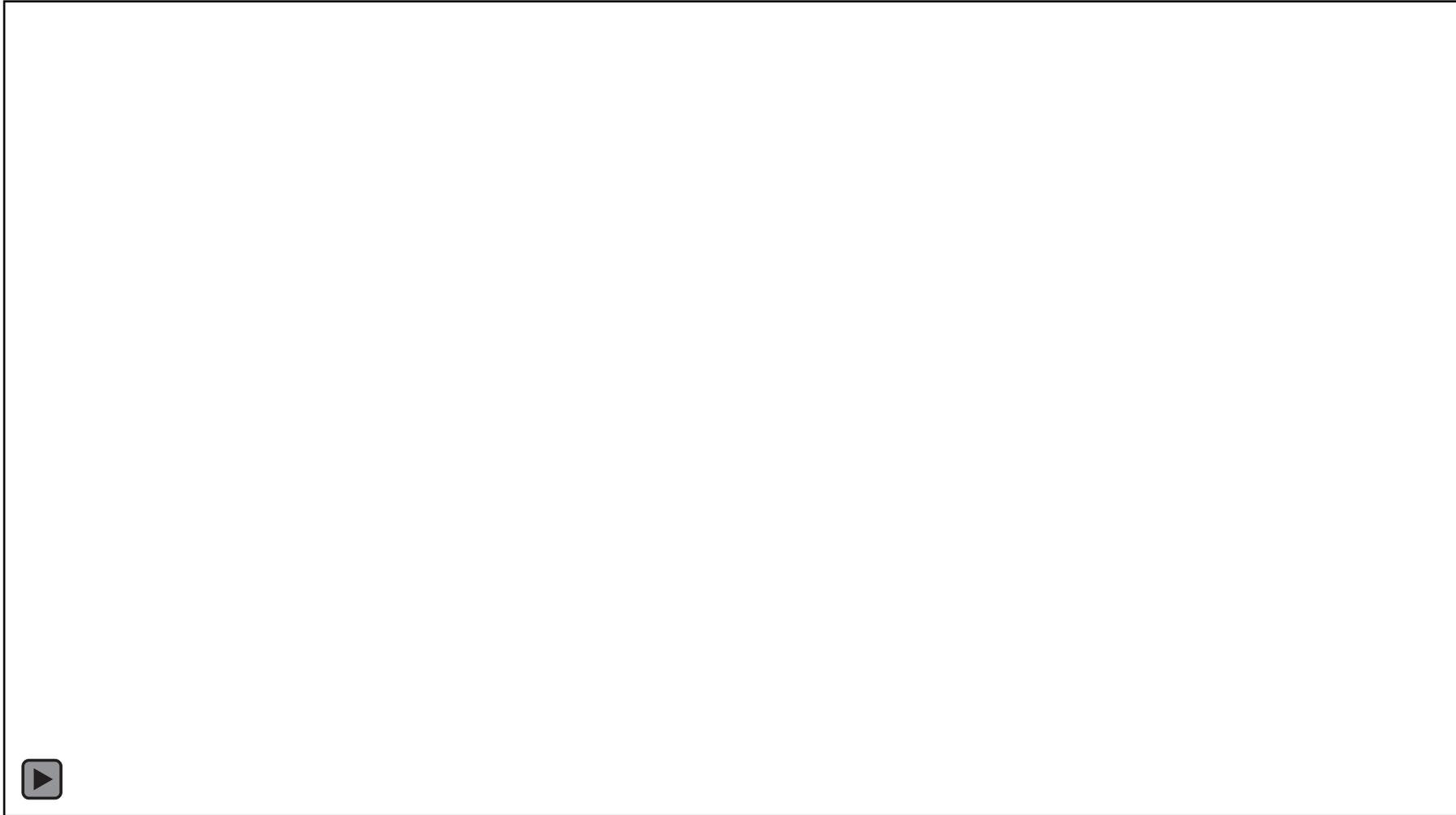


Urban Flood Case Analysis

- 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!