National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

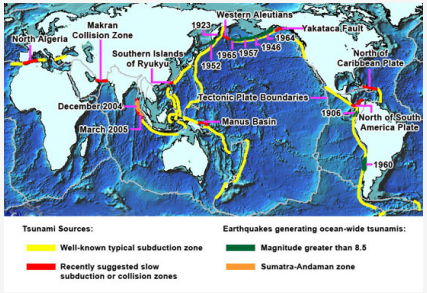
@NASAARSET

Introduction to Remote Sensing for Disaster Management

Week 4
Monitoring Landslides, Storms, and Floods Using Remote Sensing Observations

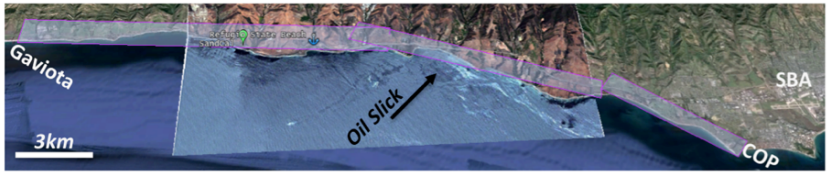
Course Outline

Week 1: Monitoring Earthquakes, and Tsunamis Using NASA Remote Sensing and Models

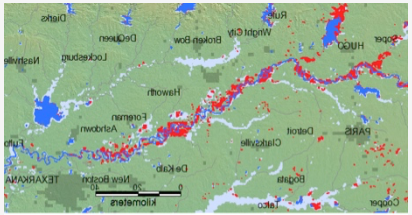


Week 2: Overview of Remote Sensing for Wildfire Applications

Week 3: Observation of Oil Spills Using Remote Sensing Measurements



Week 4: Monitoring Landslides, Storms, & Flooding Using Remote Sensing Observations



Course Structure

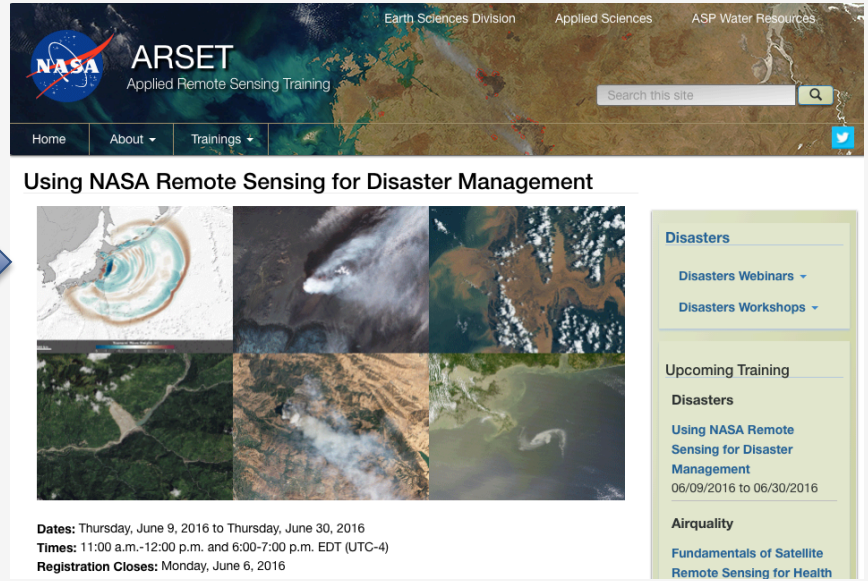
- **One session per week on June 9, 16, 23, and 30, 2016**
  - 11 a.m. – 12 p.m. EDT (UTC-4)
  - 6 p.m. – 7 p.m. EDT (UTC-4)
- **Each session may include**
  - Presentation
  - A homework assignment
- **Q&A following each session or by email to Tim Stough** (stough@jpl.nasa.gov) **or Amita Mehta** (amita.v.mehta@nasa.gov)

Course Material

http://arset.gsfc.nasa.gov/disasters/webinars/disaster-overview-2016

Webinar presentations, exercises, homework assignments, and recordings

Links will be available on the ARSET course page



Week-4: Agenda

- Finding the Slippery Slope: Detecting Landslide from Space

  Guest Speaker: Dalia Kirschbaum
  NASA-GSFC

- Monitoring Storms and Floods Using Remote Sensing Observations

  Speaker: Amita Mehta (ARSET)
  NASA-GSFC

Finding the Slippery Slope: Detecting Landslides from Space

Dr. Dalia Kirschbaum
Research Scientist
NASA Goddard Space Flight Center

National Aeronautics and Space Administration

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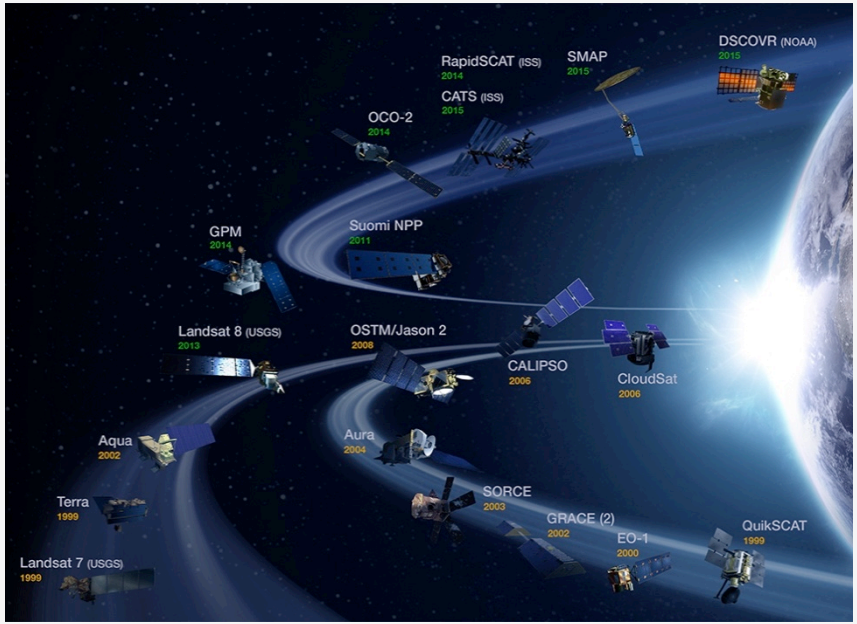
Monitoring Storms and Floods Using Remote Sensing Observations

Outline

- Remote Sensing Measurements Used for Storm and Flood Monitoring
- Overview of NASA Hurricane and Tropical Storm Portal
- Overview of Flood Monitoring Tools Based on Remote Sensing Observations

Remote Sensing Measurements Used for Storm and Flood Monitoring

NASA Satellites and Sensors Used For Storm and Flood Monitoring



- Tropical Rainfall Measuring Mission (TRMM): 11/1997-15/2015
- Global Precipitation Measurements (GPM): 2/2014-present
- Terra: 12/1999-present
- Aqua: 5/2002-present

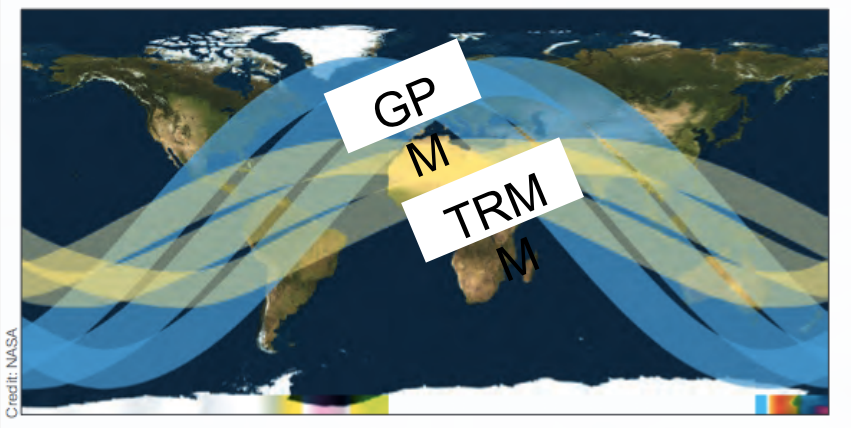
TRMM and GPM

http://pmm.nasa.gov/

- Both in non-polar, low-inclination orbits

- TRMM Precipitation Sensors:
  - TMI (TRMM Microwave Imager)
  - PR (Precipitation Radar)
  - VIRS (Visible and Infrared Scanner)

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



- TRMM measurements are limited to the tropics
- GPM measurements span middle & high latitudes

Multi-Satellite Precipitation From 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**)

TMPA and IMERG

Used for Storms and Flood Monitoring

	TMPA	IMERG
Spatial Resolution	0.25° x 0.25°	0.1°x0.1°
Spatial Coverage	Global, 50°S-50°N	Global, 60°S-60°N (will be extended from pole-pole)
Temporal Resolution	3 hours	30 minutes
Temporal Coverage	12/1997 – Present*	2/27/2014-Present+

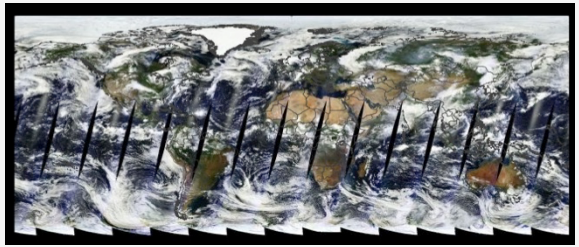
+ TMPA and IMERG combined data will be available in late 2017 at IMERG data resolution

* After 15 April 2015 TRMM climatological calibration is being used to generate TMPA

Terra and Aqua

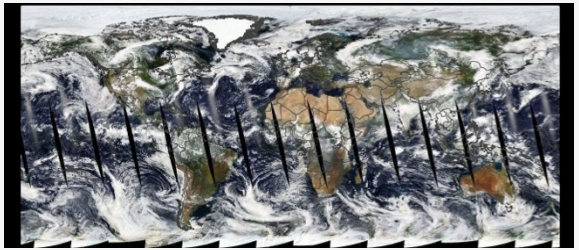
Terra

- Polar orbit, 10:30 a.m. equator crossing time
- Global coverage
- Dec 18, 1999 – present
- 1-2 observations per day
- Sensors:
  - ASTER, CERES, MISR, MODIS, MOPITT



Aqua

- Polar orbit, 1:30 p.m. equator crossing time
- Global coverage
- May 4, 2002 – present
- 1-2 observations per day
- Sensors:
  - AIRS, AMSU, CERES, MODIS, AMSR-E



MODerate Resolution Imaging Spectroradiometer (MODIS)

http://modis.gsfc.nasa.gov

- On-board Terra and Aqua
- Designed for land, atmosphere, ocean, and cryosphere observations
- Spatial Coverage and Resolution:
  - Global, Swath: 2,330km
  - Spatial Resolution Varies: 250m, 500m, 1km
- Temporal Coverage and Resolution:
  - 2000-present, 2 times per day

Spectral Bands

- 36 bands (red, blue, IR, NIR, MIR)
  - Bands 1-2: 250m
  - Bands 3-7: 500m
  - Bands 8-16: 1000m

Hurricane Katrina (8/29/2005)
Observed by Aqua/MODIS

http://phys.org/news/2015-08-nasa-hurricanes.html

Overview of NASA Hurricane and Tropical Storm Portal

Monitoring Hurricanes and Storms

- Satellite Images and Precipitation Products are used to monitor storms

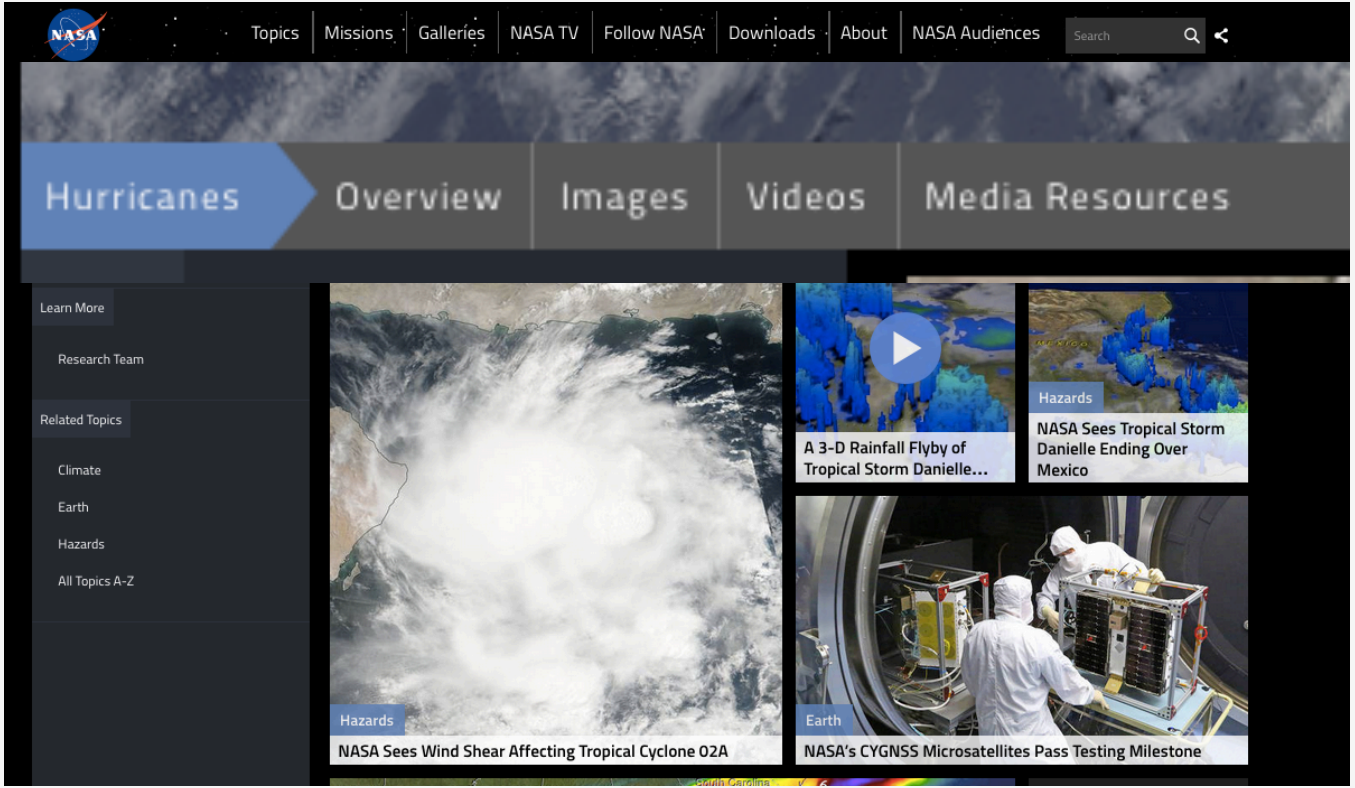
- Web-tools are available for past and near real-time storm information:

  Hurricanes and Tropical Storms
  http://www.nasa.gov/mission_pages/hurricanes/main/index.html

  Precipitation Measurement Mission (PMM) Tropical Cyclones
  https://pmm.nasa.gov/applications/tropical-cyclones

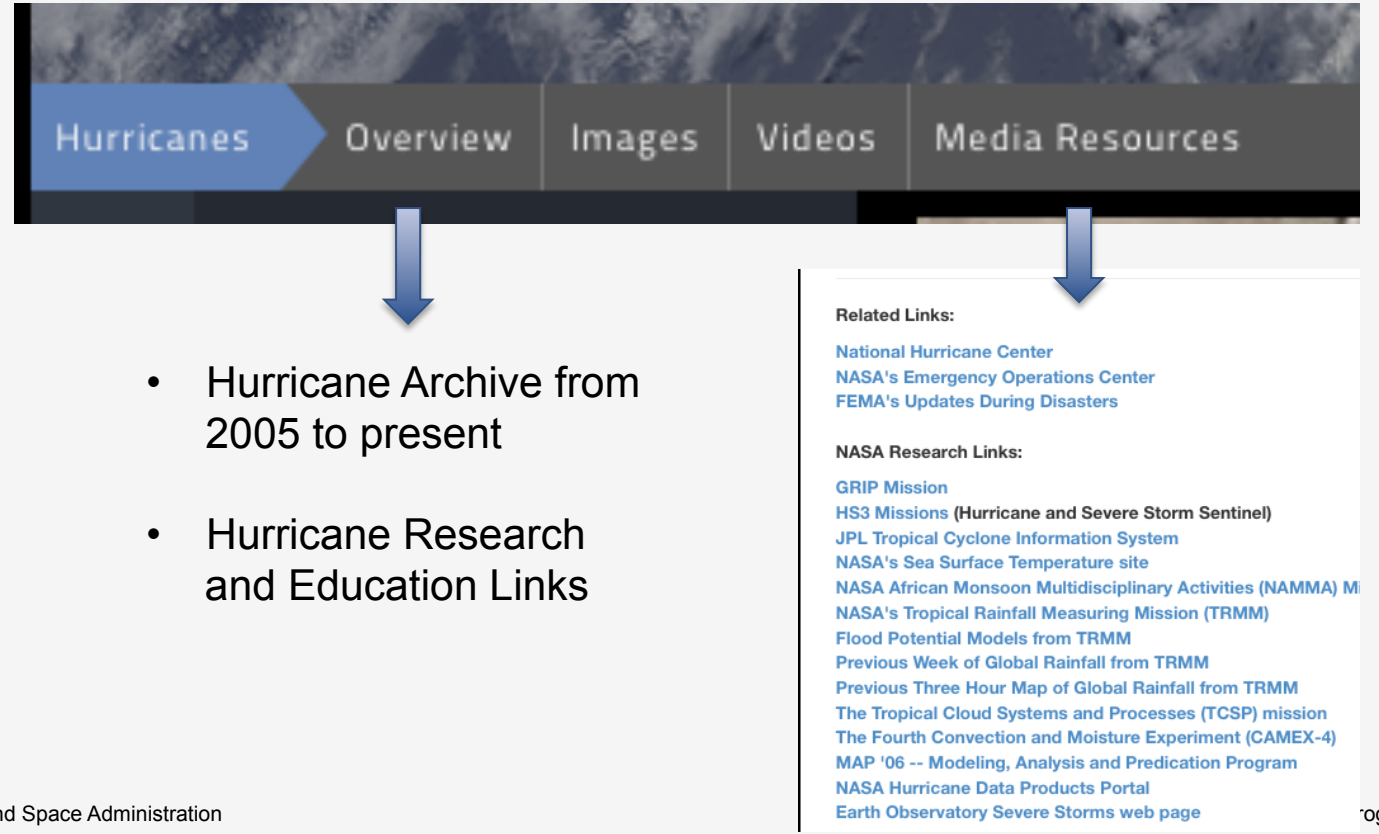
Hurricanes and Tropical Storms

http://www.nasa.gov/mission_pages/hurricanes/main/index.html



Hurricanes and Tropical Storms

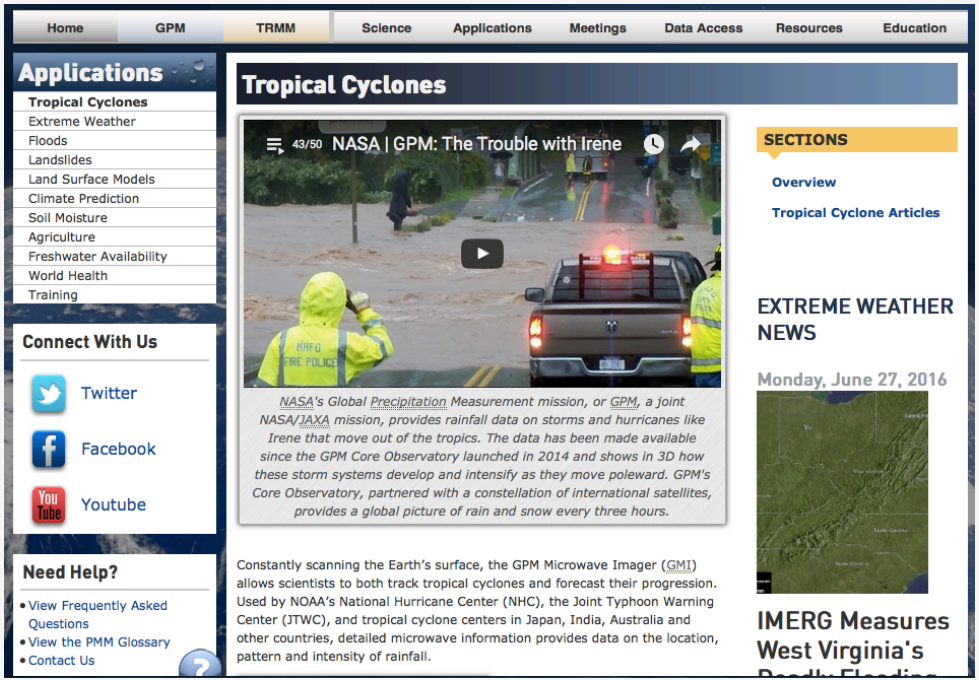
http://www.nasa.gov/mission_pages/hurricanes/main/index.html



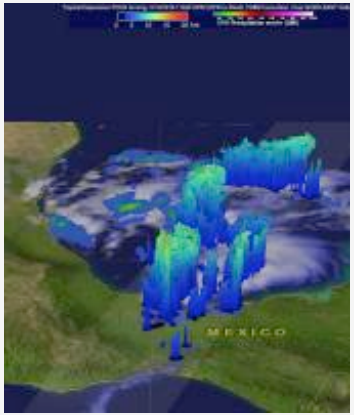
- Hurricane Archive from 2005 to present
- Hurricane Research and Education Links

PMM Tropical Cyclones

http://pmm.nasa.gov/applications/tropical-cyclones



- Near Real-time Monitoring using GPM
- Archives from TRMM & GPM



GPM sees Tropical Storm Danielle Forming : June 20, 2016

Overview of Flood Monitoring Tools Based on Remote Sensing Observations

NASA Remote Sensing Observations for Flood Monitoring

https://arset.gsfc.nasa.gov/disasters/webinars/advfloodwebinar

There are primarily **3 types** of flood monitoring tools that use remote sensing observations:

1. Derive streamflow & runoff to monitor flooding conditions by using rainfall and weather data in a hydrology model
2. Infer flooding conditions by using satellite-derived precipitation
3. Detect flood water on previously dry land surfaces by using satellite-derived land-cover observations

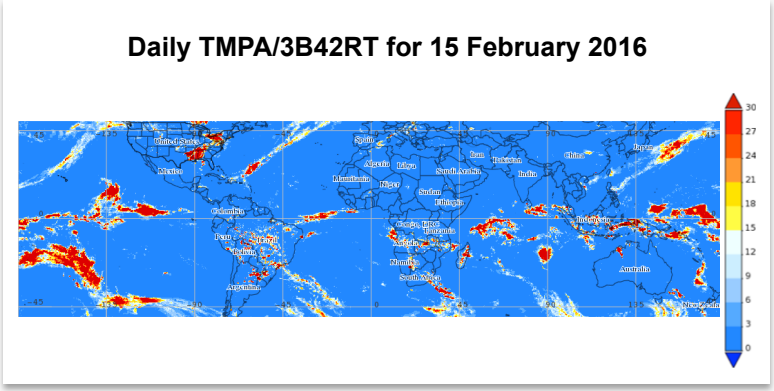
Flood Monitoring Using NASA Rainfall Observations

1. Derive streamflow & runoff to monitor flooding conditions by using rainfall and weather data in a hydrology model
   - Global Flood Monitoring System (GFMS): http://flood.umd.edu
2. Infer flooding conditions by using satellite-derived precipitation
   - Extreme Rainfall Detection System (ERDS): http://erds.ithacaweb.org
3. Detect flood water on previously dry land surfaces by using satellite-derived land-cover observations

NASA Rainfall Observations Used in GFMS & ERDS2

TRMM Multi-satellite Precipitation Analysis (TMPA)

- Combines precipitation from TRMM and several national/international satellites to obtain 3-hourly, 0.25°x0.25° resolution data with **global coverage between 50°S to 50°N**



- TMPA will be replaced with Integrated Multi-SatellitE Retrievals (IMERG) for Global Precipitation Measurement (GPM) data with half-hourly, 0.1°x0.1° resolution and **global coverage between 65°S to 65°N**

Note: TRMM is no longer flying, but TRMM-based calibration is used to provide near real-time rainfall from a constellation of national & international satellites for flooding applications. Near real-time IMERG data is also available from: ftp://jsimpson.pps.eosdis.nasa.gov

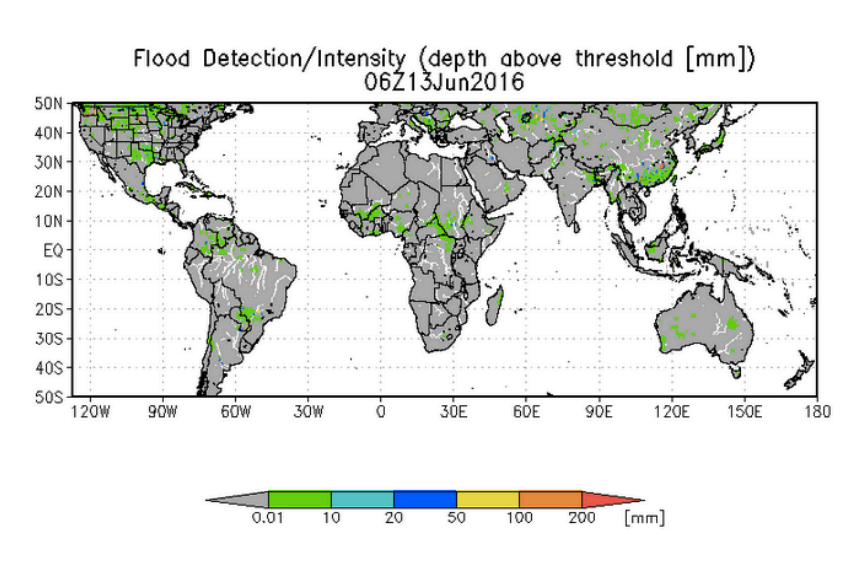
Global Flood Monitoring System (GFMS)

GFMS

http://flood.umd.edu

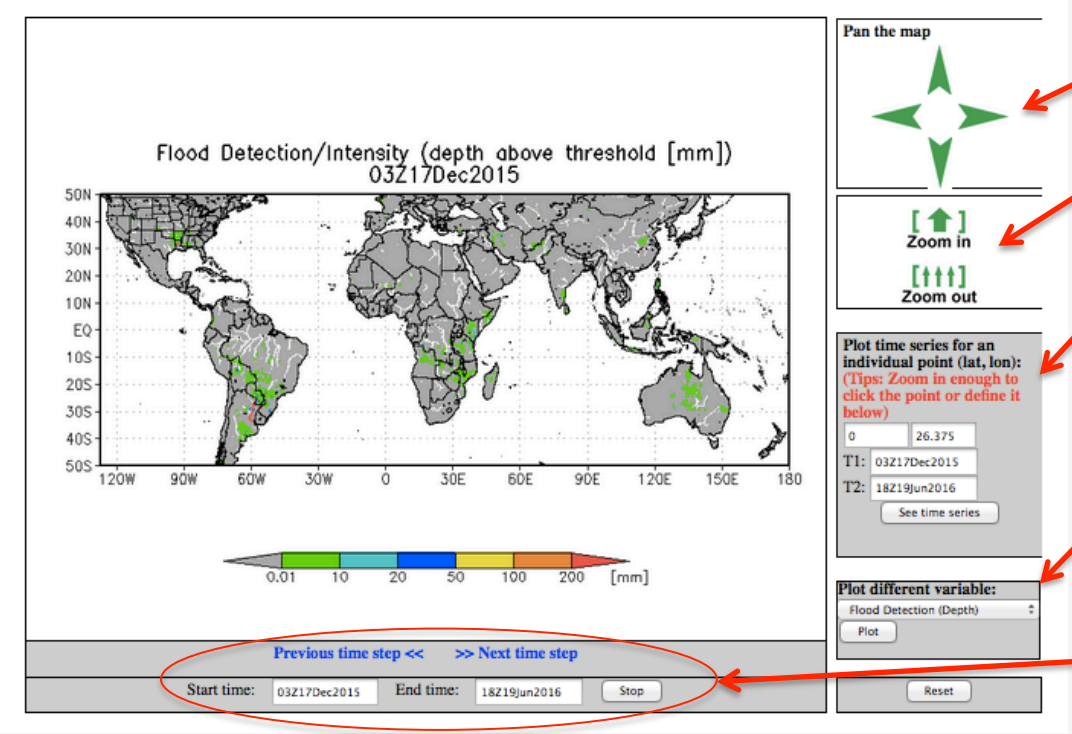
Provides global maps, time series, and animations (50°S-50°N) of:

- Instantaneous Rain
- Accumulated rain over 24, 72, and 168 hours
- Streamflow rates and flood detection at 1/8th degree (~12 km) and also at 1 km



GFMS Features

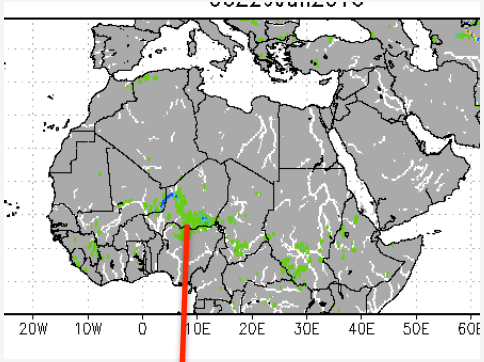
http://flood.umd.edu

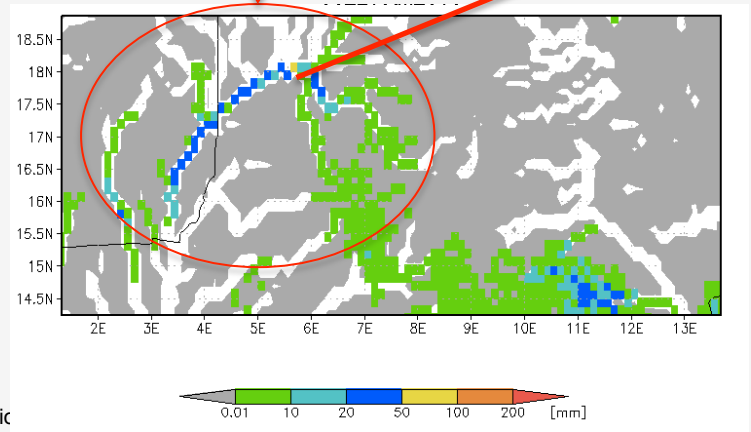


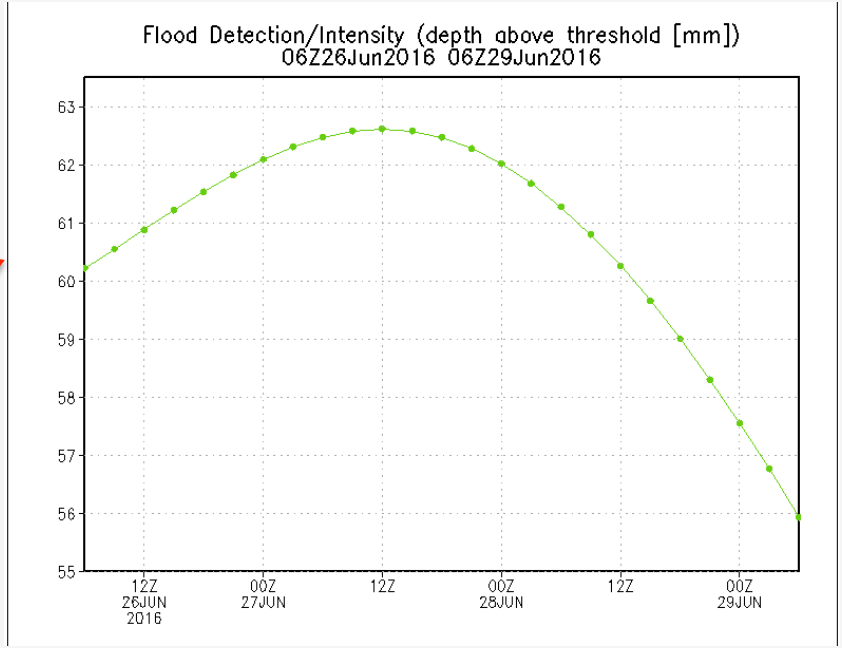
- Map navigation
- Zoom in/out
- Select individual grid point for data for time sequence
- Plot different variables
- 3-hourly output

Flooding in Niger River Basin – June 29, 2016

http://flood.umd.edu





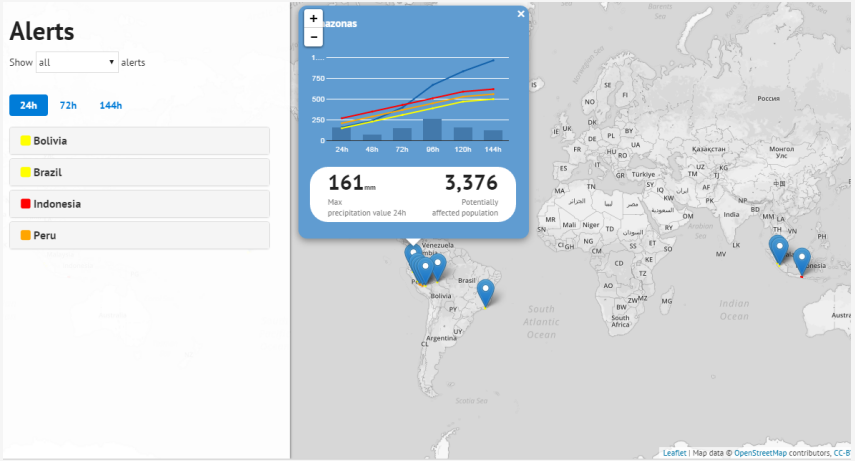


Extreme Rainfall Detection System (ERDS)

ERDS

http://erds.ithacaweb.org/

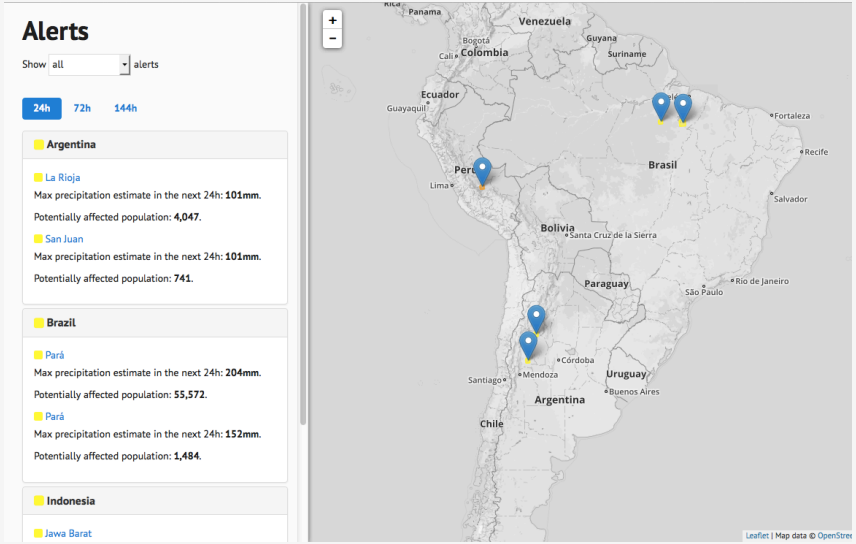
- Near real-time TRMM and NOAA-Global Forecasting System (GFS) data for monitoring & forecasting accumulated rainfall
- TRMM historical archive is used for calculation of extreme rainfall thresholds
- TRMM near real-time rainfall amount, GFS forecasted rainfall information, & reference data combine to generate flooding event-specific information



ERDS

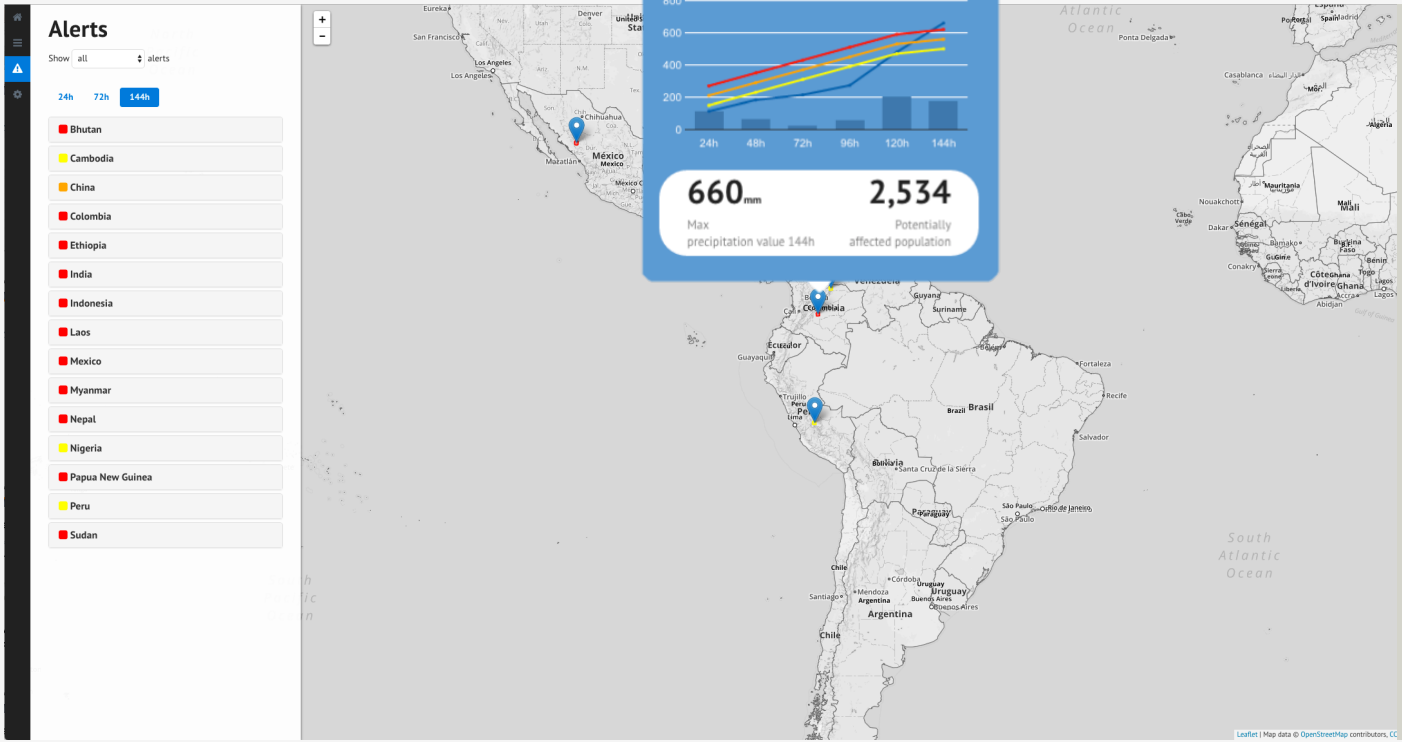
http://erds.ithacaweb.org/

- Global maps and time series of near real-time (50°S-50°N) and forecasted accumulated rainfall over 24, 48, 72, 96, 120 & 144 hours
- Extreme rainfall alerts at 0.25°x0.25° level and at administrative districts level
- Event-specific information, including:
  - the list of the affected countries
  - an estimation of the affected population
- Currently the ERDS system is one of the tools used by OMEP, UN World Food Programme (WFP) Emergency Preparedness Unit



ERDS Alerts

http://erds.ithacaweb.org



72-hour alert in Meta River, Colombia, provided on 27th June 2016

Maximum Rain forecast and potentially affected population

NASA Remote Sensing Observations for Flood Monitoring

http://arset.gsfc.nasa.gov/disasters/webinars/advfloodwebinar

There are primarily **3 types** of flood monitoring tools that use remote sensing observations:

1. Derive streamflow & runoff to monitor flooding conditions by using rainfall and weather data in a hydrology model
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3. Detect flood water on previously dry land surfaces by using satellite-derived land-cover observations

Inundation Mapping

Using Satellite-Derived Land-Cover Observations

3. Detect flood water on previously dry land surfaces by using satellite-derived land-cover observations
   - MODIS NRT Global Flood Mapping: http://oas.gsfc.nasa.gov/floodmap
   - Dartmouth Flood Observatory: http://floodobservatory.colorado.edu

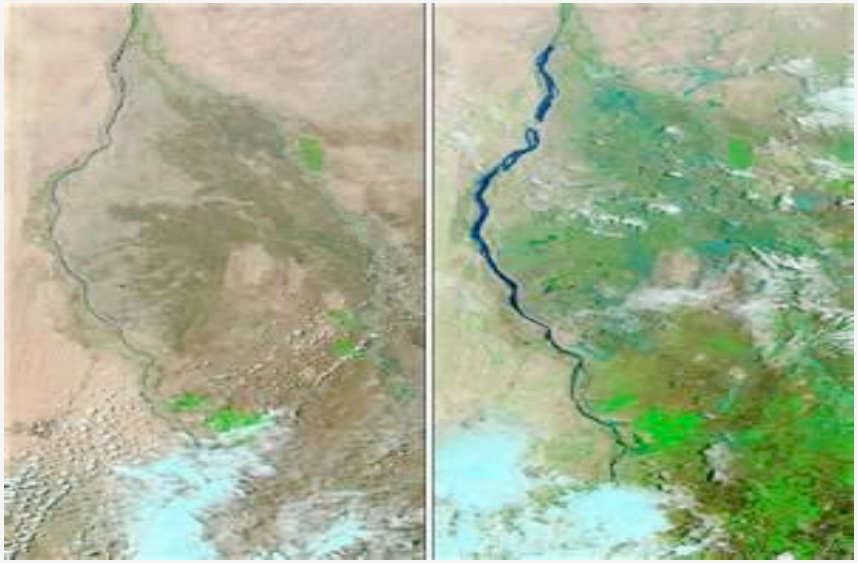
Inundation Mapping

Using Terra/Aqua MODerate Resolution Imaging Spectroradiometer (MODIS)

- MODIS provides observations of land surface
- Reflectance from bands indicate presence of water on previously dry land
  - 1 (620-670nm)
  - 2 (841-876 nm)
  - 7 (2105-2155nm)
- Global reference database of water bodies formed at 250m resolution
- MODIS cannot see the surface through clouds

Flooding along the White Nile, Sudan

earthobservatory.nasa.gov



MODIS-Aqua
6/19/2003

MODIS- Terra
8/11/2003

MODIS Near Real-Time Global Flood Mapping

MODIS NRT Global Flood Mapping

- Flood mapping based on MODIS reflectance at 250m resolution
- Composited on 2, 3, and 14 days
- Flood maps available in 10°x10° tile
- Permanent water and surface flood water data available
- Cloud shadows or terrain shadows can be misinterpreted as surface water

Provides near real-time and past flood mapping from April 2011.
http://oas.gsfc.nasa.gov/floodmap

MODIS NRT Global Flood Mapping: Available Quantities

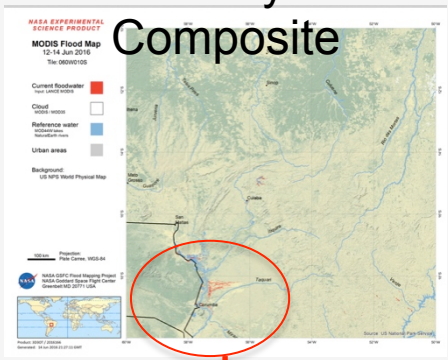
http://oas.gsfc.nasa.gov/floodmap

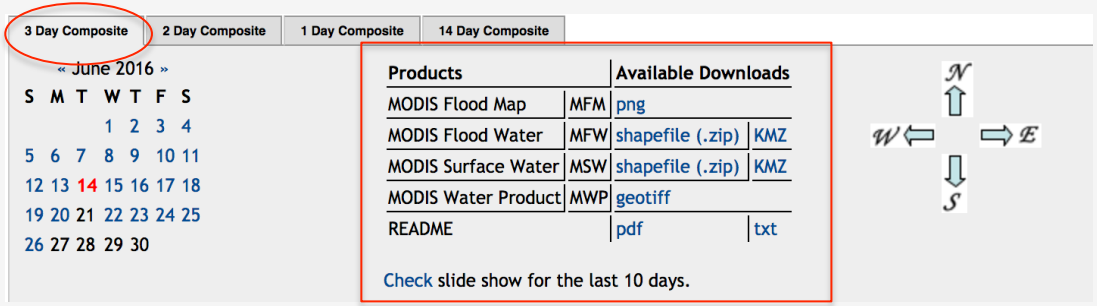
Products		Available Downloads	
MODIS Flood Map	MFM	png	
MODIS Flood Water	MFW	shapefile (.zip)	KMZ
MODIS Surface Water	MSW	shapefile (.zip)	KMZ
MODIS Water Product	MWP	geotiff	
README		pdf	txt

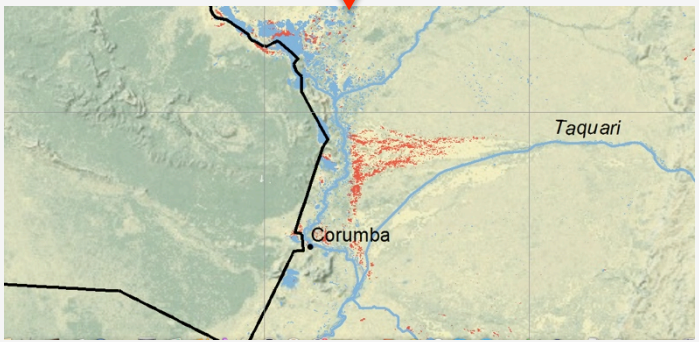
Check slide show for the last 10 days. 10-day Slides

MODIS Flood Mapping: Flooding in Southern Brazil June 12-14, 2016

3-day Composite







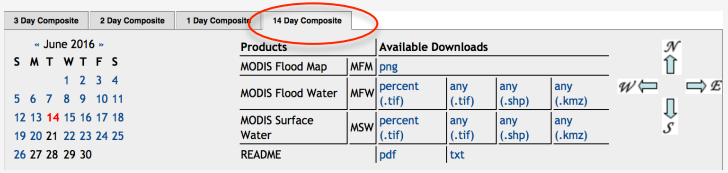
Filename Convention:

PRODUCT_DATE_TILE_COMPOSITE_XTRA.EXT

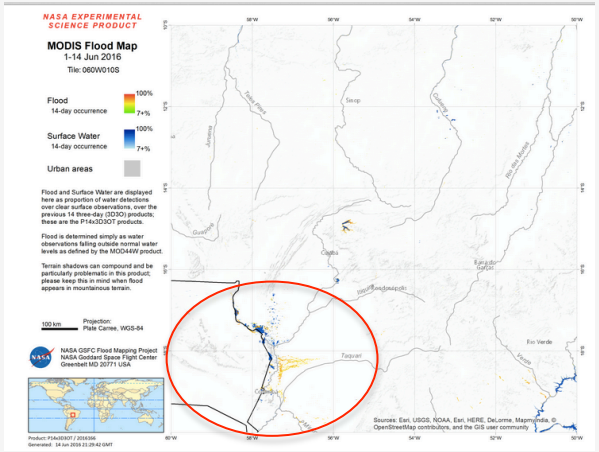
MSW_2012009_020E000S_3D3**O**_V.shp
MFM_2012009_020E000S_2D2**O**.png

(yyyydoy lon-lat 2 or 3 day **O**bservations
(Year and day of year)

MODIS Flood Mapping: Flooding in Southern Brazil 12-14, 2016



Composites of the previous 14 days' 3-day product



Similar filename convention with additional processing for composite field:

N: No shadow masking

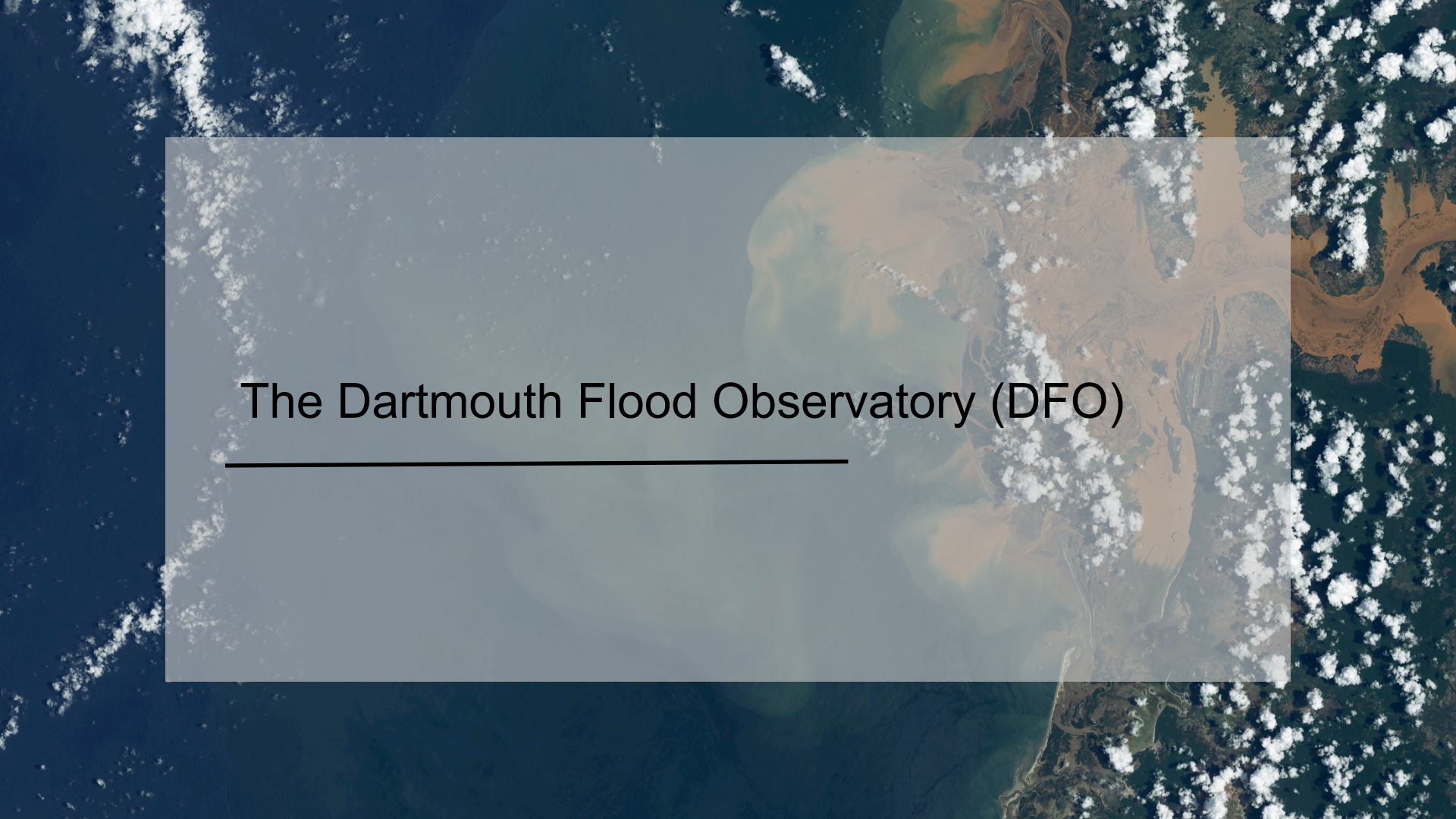
T: Terrain shadow masking

C: Cloud shadow masking

S: Both terrain & shadow masking

e.g. 2D2OT:
2 days imagery, 2 observations required, terrain shadow masking applied

- Provides occurrence of water as % clear observations over the last 14 days' products
  - GeoTIFF are 0-1 images (1 if % water is >0)

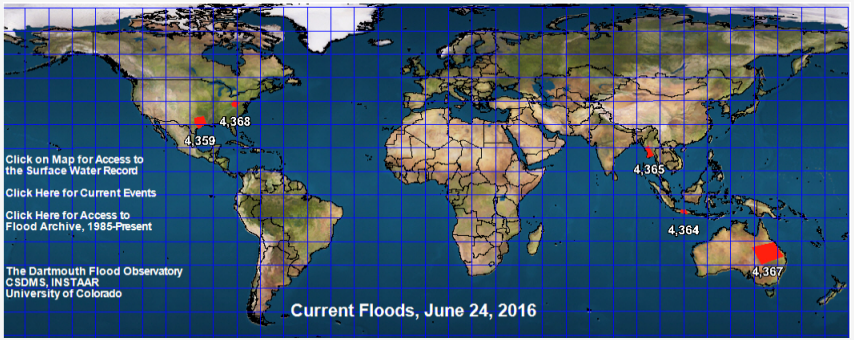


The Dartmouth Flood Observatory (DFO)

DFO

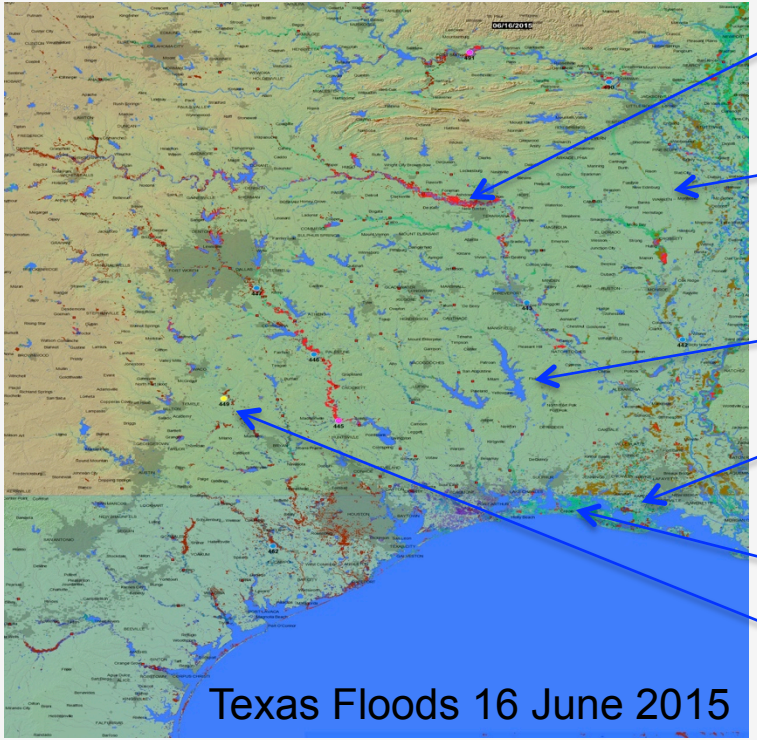
http://floodobservatory.colorado.edu

- Uses flood mapping based on MODIS reflectance
- Also uses Landsat-8 and EO-1 images and COSMO-SkyMed and Sentinel-1 synthetic aperture radar (SAR) images when available
- Experimental river discharge obtained by using Microwave data (AMSR, AMSR-2, TMI, GMI0 and a run-off model



Provides near-real time flood mapping and current/past flood event mapping

DFO Flood Event Mapping



Red: Flooding within past 14 days (MODIS animated product)

Light Red: Flooding during this event (earlier MODIS coverage of non-automated MODIS mapping)

Dark Blue: Permanent water, Feb 2000 (Shuttle Water Boundary Data)

Darker Red: Flooded areas (High resolution SAR or Landsat 8 data)

Bright Green: Past Floods

Colored dots show *access River Watch Site*

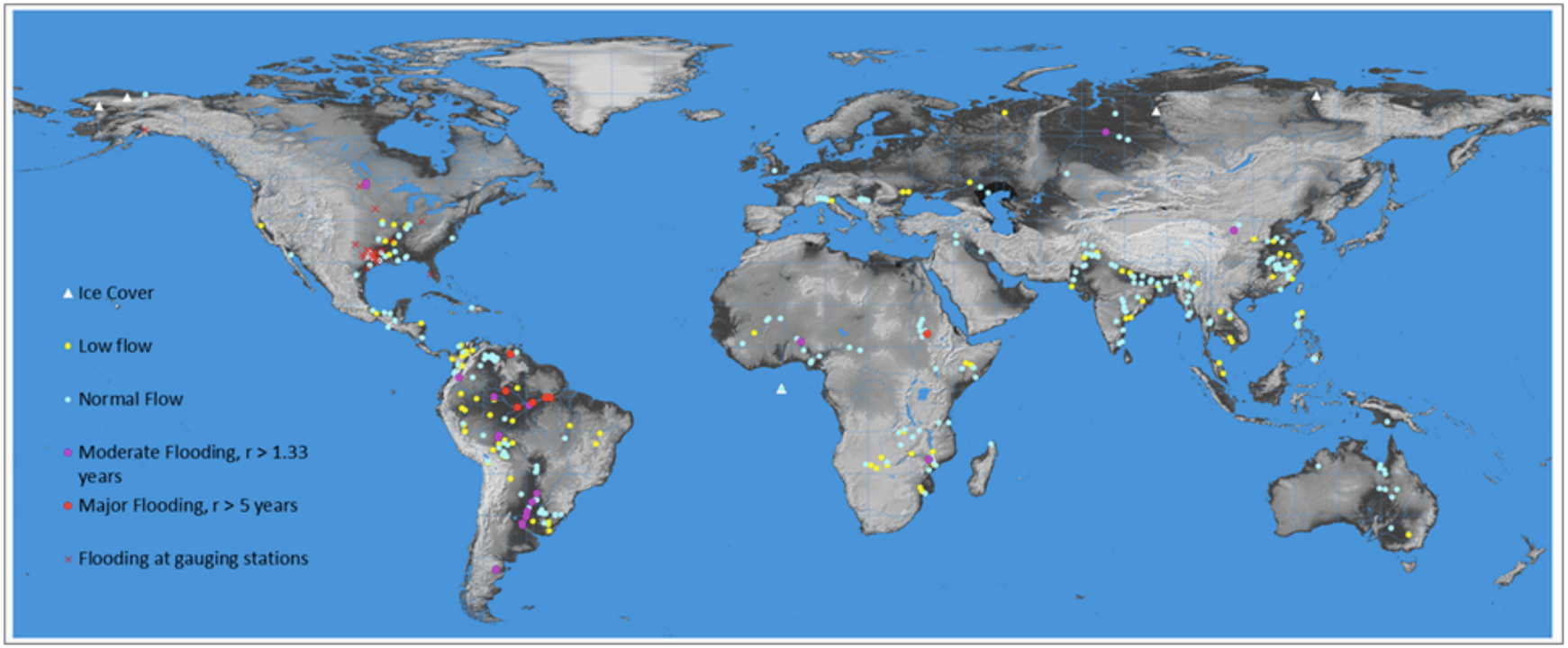
DFO Experimental River Watch

http://floodobservatory.colorado.edu

- Sensitive to portions of water and dry land:
  - Advanced Microwave Scanning Radiometer-2 from GCOM-W (Japanese Space Agency Mission)
  - TRMM Microwave Imager (ended 8 April 2015)
  - GPM Microwave Imager
- **These microwave observations are converted to actual river discharge** by combining them with surface discharge measurements and then to runoff by using a Water Balance Model (WBM)
- Runoff calculations are available starting in 2003, seven-day runoff deviation started in 2003-2007
- Mean runoff is mapped to indicate low, normal, moderate, and major flooding

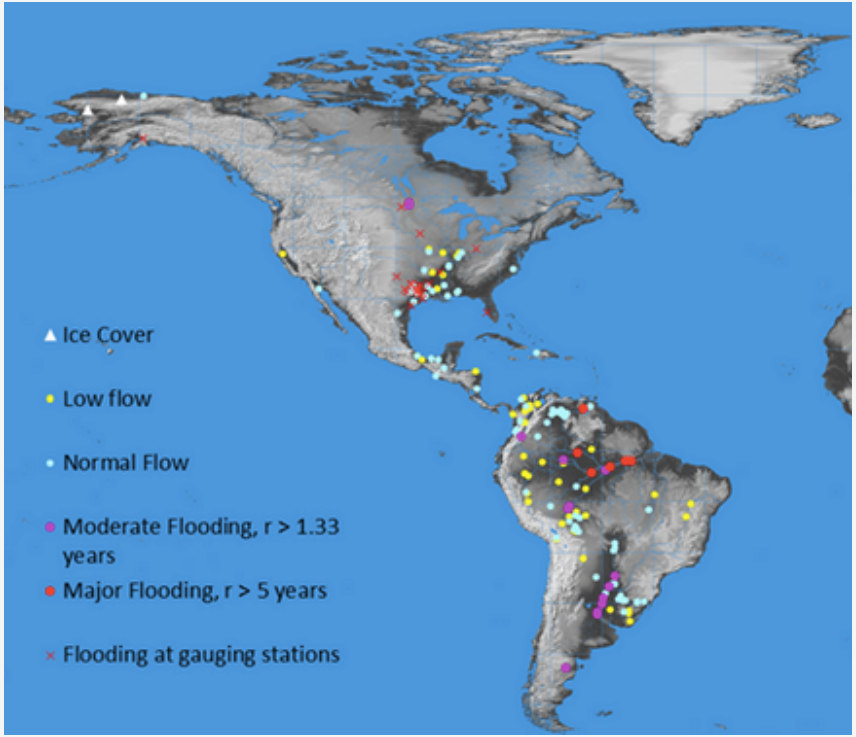
DFO River Watch Locations

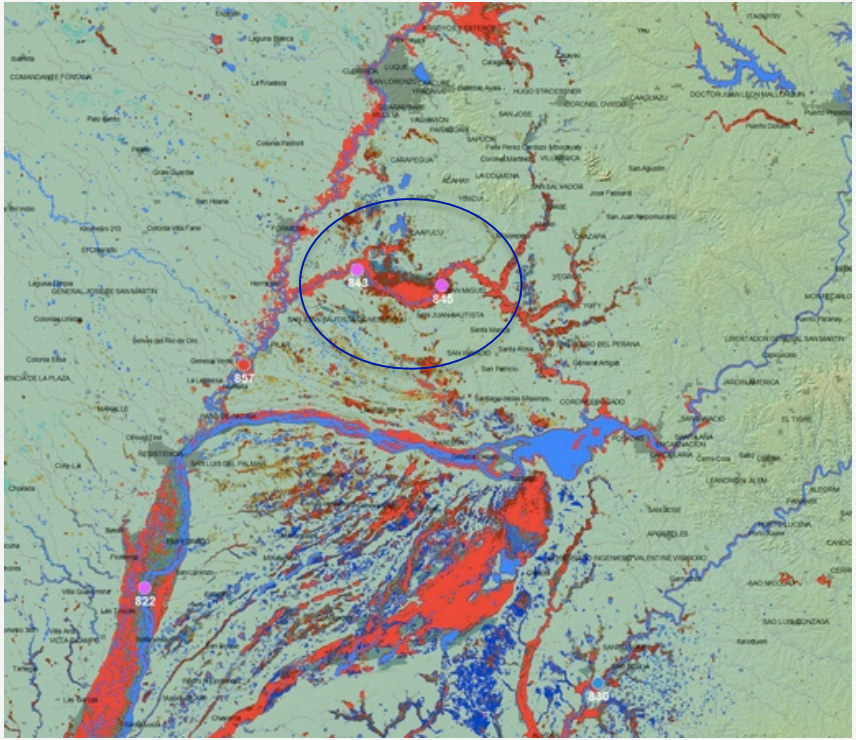
http://floodobservatory.colorado.edu



DFO River Watch Paraguay

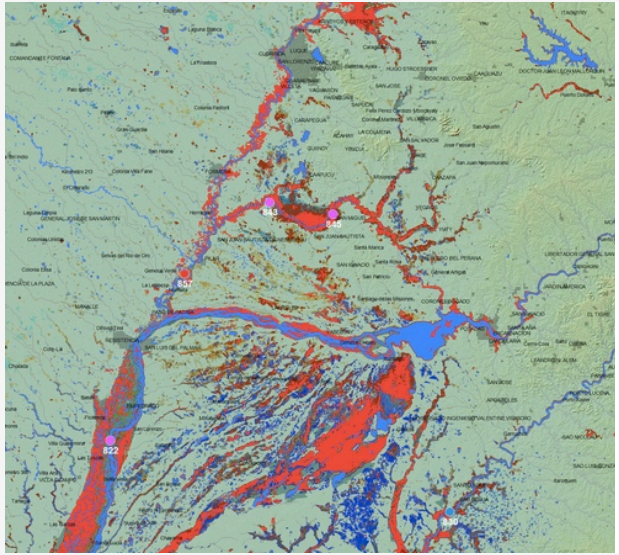
http://floodobservatory.colorado.edu





DFO River Watch Paraguay

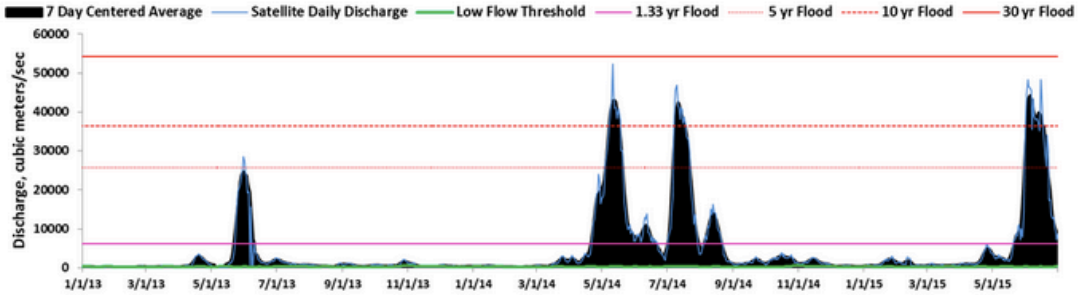
http://floodobservatory.colorado.edu



River Watch Version 2

Experimental Satellite-Based River Discharge Measurements using passive microwave radiometry

DFO Site Number	Site 854 (Paraguay)		Tebicuary	Center:	-57.194	Long.
GFDS Site Number	845		River	Center:	-26.505	Lat.
DRAFT			Paraguay		67905	sq km WBM contributing area
Last measured:	19-Jun-16				Obtain Data	
Average Discharge:	**562**	m3/sec	Status:	**2**	(1, low flow; 2, normal flow; 3, moderate flood; 4, major flood, r >5 yr)	
7-day Runoff	**#N/A**	mm		**#N/A**	(7-day runoff compared to 10 yr average for this date, 2003-2012)	
Recent Record					Technical Summary	



Summary of Storm and Flood Web-Tools

Storms:

- http://www.nasa.gov/mission_pages/hurricanes/main/index.html
- http://pmm.nasa.gov/applications/tropical-cyclones

Floods

- http://flood.umd.edu
- http://erds.ithacaweb.org
- http://oas.gsfc.nasa.gov/floodmap
- http://floodobservatory.colorado.edu

Homework and Certificate

Certificate of Completion

- Attend all 4 webinar sessions
- Complete all homework assignments
- Certificates will be emailed approximately 2 months after the course finishes, by Marines Martins (marines.martins@ssaihq.com)

Homework

- Answers to homework questions via Google form
- Available at: http://arset.gsfc.nasa.gov/disasters/webinars/disaster-overview-2016
- Assignments ***(available now)***
  - Prerequisite on Fundamentals (Due June 13) – deadline extended to June 30
  - Assignment #1: Earthquakes, Tsunamis, Volcanoes, and Wildfire Disasters (Due July 14)
  - Assignment #2: Oil Spills, Storms, Floods, and Landslide Disasters (Due July 14)

National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Thank You!