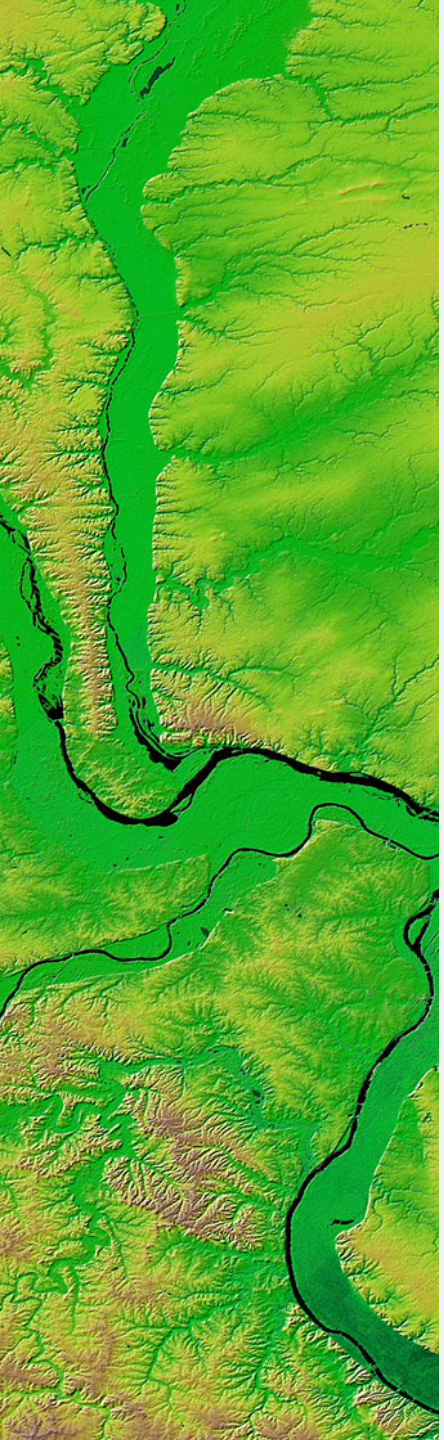


National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Overview of Flood Monitoring and Mapping Tools

Amita Mehta

Learning Objectives

By the end of this presentation, you will be able to:

- Understand flood monitoring schemes
  - based on remote sensing of precipitation observations
  - based on remote sensing of land surface observations
- Use precipitation-based flood tools to monitor
  - flood potential based on accumulated precipitation
  - streamflow, runoff, flood intensity, and flood extent
- Use land surface-based flood tools to monitor
  - Inundation maps
  - media reports
  - a flood-related disaster alert system

Remote Sensing-Based Flood Detection

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

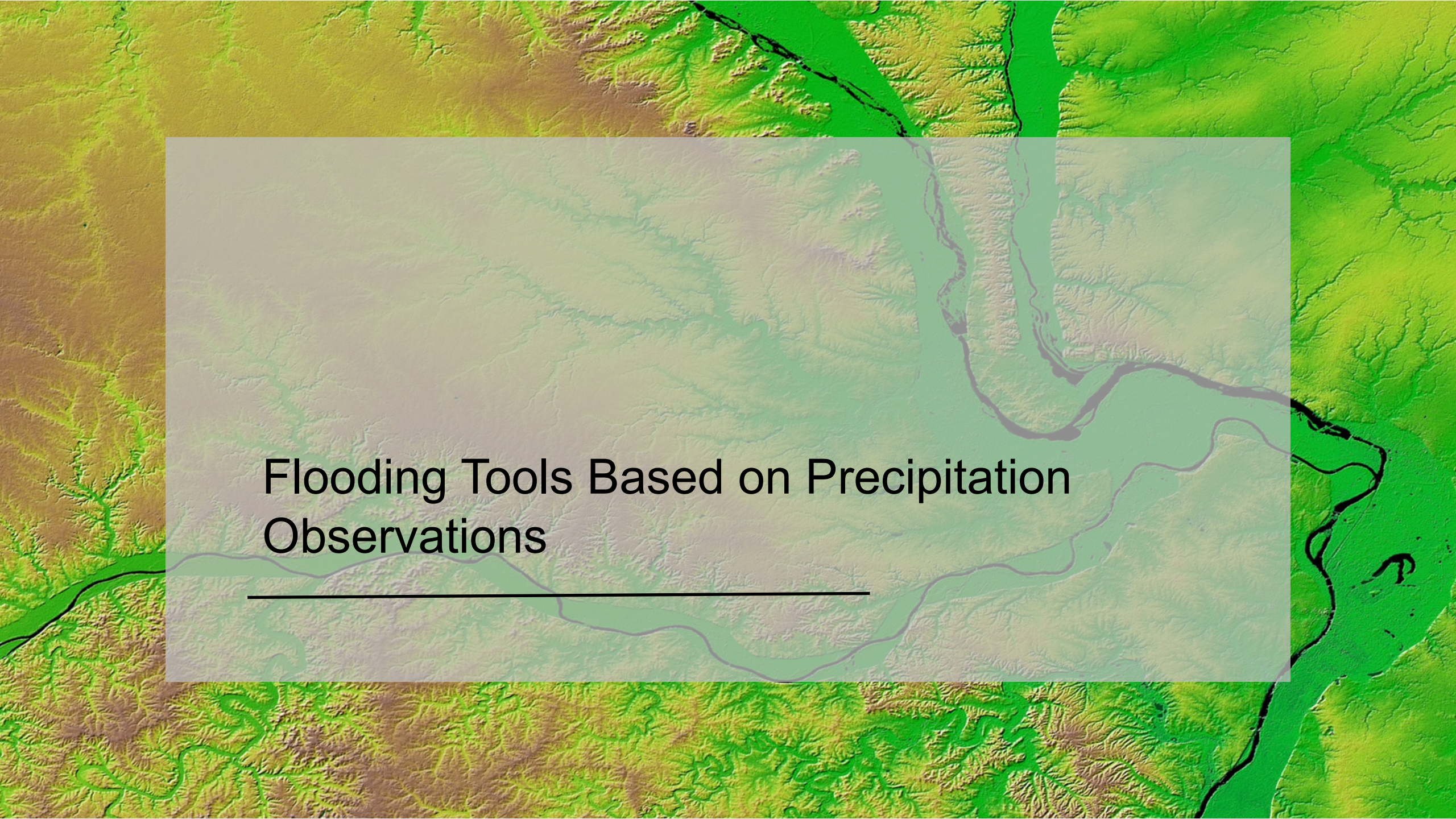
There are three approaches to using remote sensing observations for flood monitoring:

1. Hydrology models that derive streamflow and runoff, using precipitation and weather data from satellites and models
2. Infer flooding conditions using satellite-derived precipitation
3. Detect flood water on previously dry land surfaces using satellite-derived land cover observations

Note: Each flooding tool also uses model and/or surface-based data in addition to satellite data

Outline

- Flooding Tools Based on Precipitation Observations
  - Global Food Monitoring System (GFMS)
  - Extreme Rainfall Detection System-2 (ERDS2)
- Flooding Tools Based on Land Cover Observations
  - MODIS Near Real-Time (NRT) Flood Mapping
  - Dartmouth Flood Observatory (DFO, DFO River Watch)
  - Global Flood Detection System 2 (GFDS2)
- Global Disasters Alert and Coordination System (GDACS)
- Demonstration of GFMS, ERDS2 (before and during flooding events)
- Demonstration of MODIS-NRT, DFO, GDACS (during and after flooding events)



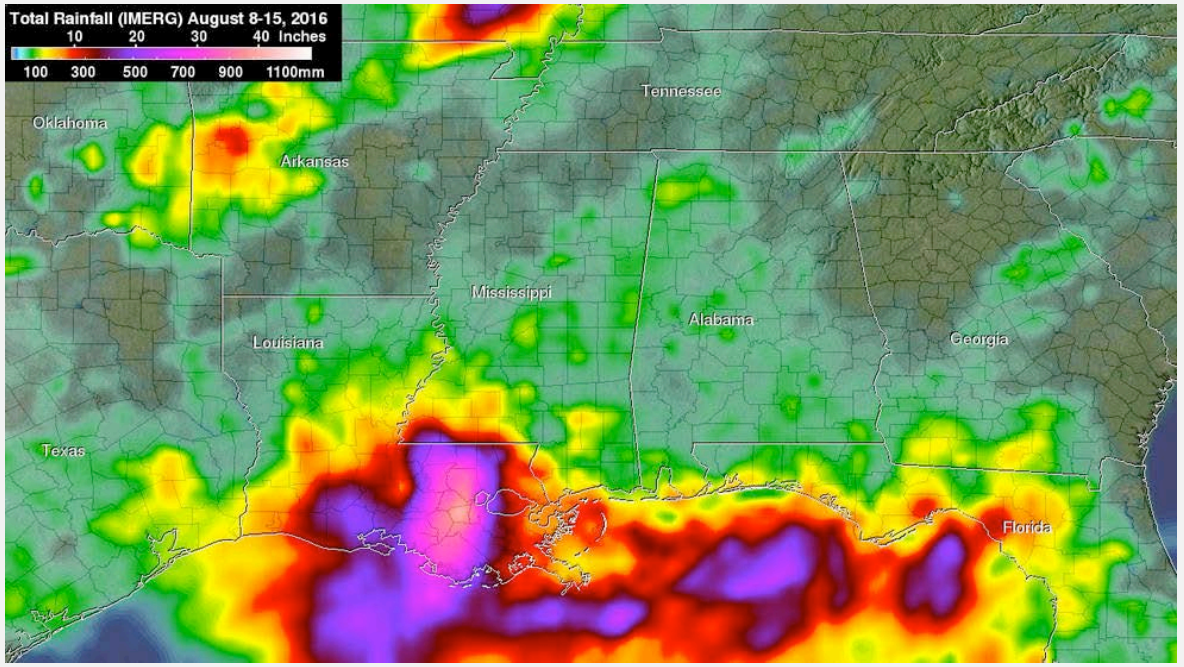
Flooding Tools Based on Precipitation Observations

Precipitation-Based Flood Tools

- GFMS and ERDS2 use TRMM Multi-satellite Precipitation Analysis (TMPA) data

- GFMS is currently transitioning to using GPM-IMERG data

Record-Setting Rain Cause Deadly Louisiana Flooding
August 8-15, 2016

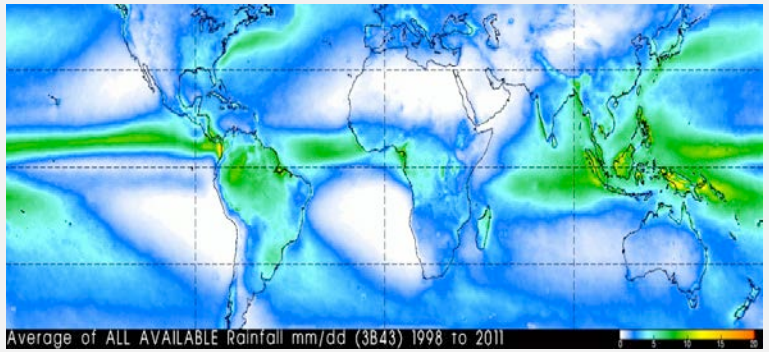


TRMM Multi-satellite Precipitation Analysis (TMPA)

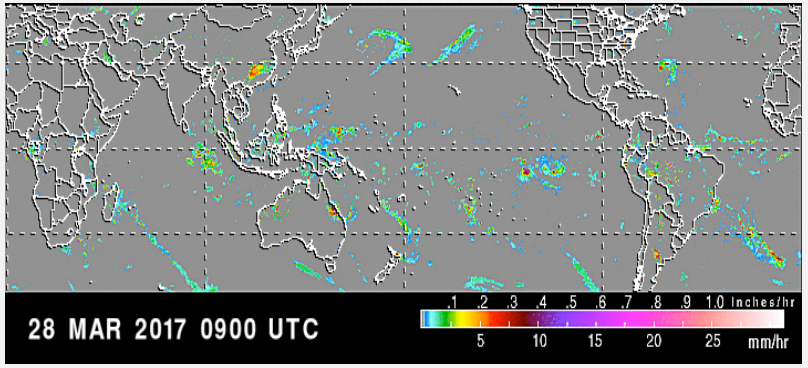
http://trmm.gsfc.nasa.gov/

- 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**
- Data are available since December 1997
- TMPA will be replaced with Integrated Multi-SatellitE Retrievals for Global Precipitation Measurement (GPM) [IMERG] data with half-hourly 0.1°x0.1° resolution data with **global coverage between 65°S to 65°N**

TRMM Climatology



TRMM 3-Hourly Precipitation



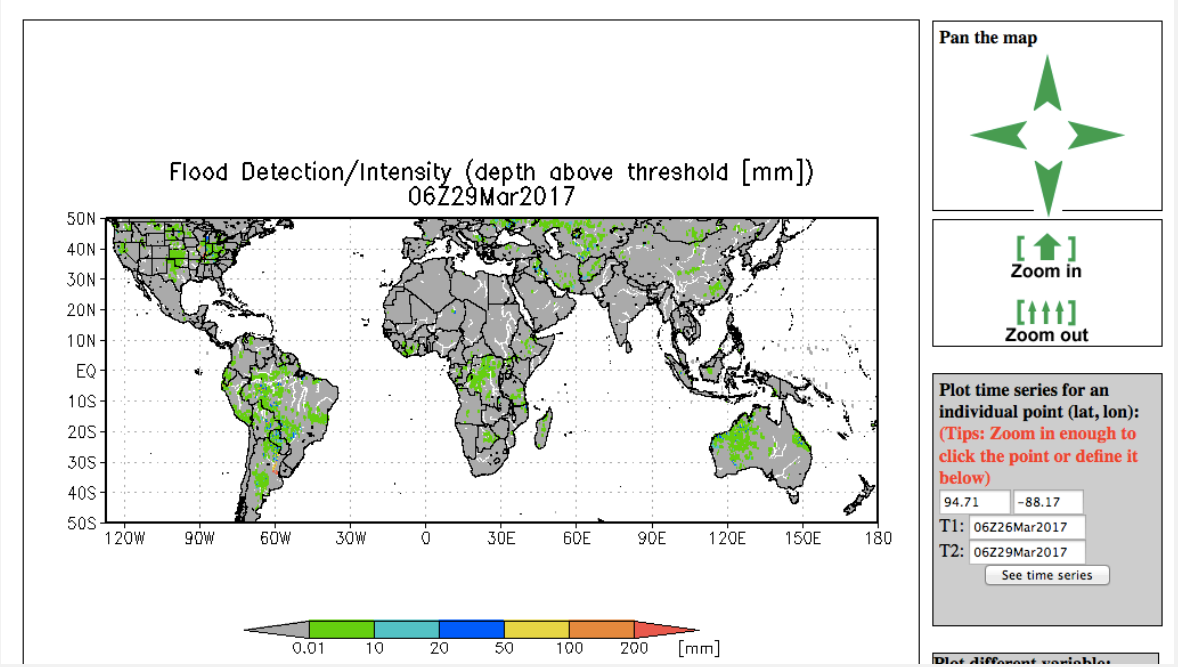
Note: TRMM is no longer flying, but TRMM-based calibration is used to provide near real-time rainfall from a constellation of national & international satellites for flooding applications. Near real-time IMERG data are available from: ftp://jsimpson.pps.eosdis.nasa.gov

Global Flood Monitoring System (GFMS)

http://flood.umd.edu/

- Provides global maps, time series, and animations (50°S-50°N) of:
  - instantaneous rain rate every 3 hrs
  - accumulated rain over 24, 72, and 168 hrs
  - streamflow rates and flood intensity at 1/8th degree (~12 km) and 1 km
  - Near real-time and archives since 2013

Interactive Features



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 are available from: ftp://jsimpson.pps.eosdis.nasa.gov

GFMS

http://flood.umd.edu/

- USES a hydrological model together with:
  - TMPA
  - surface temperature and winds from NASA reanalysis model, Modern Era Retrospective Analysis for Research and Applications (MERRA)
  - runoff generation from UW Variable Infiltration Capacity (VIC) model
  - Runoff routing model from UMD

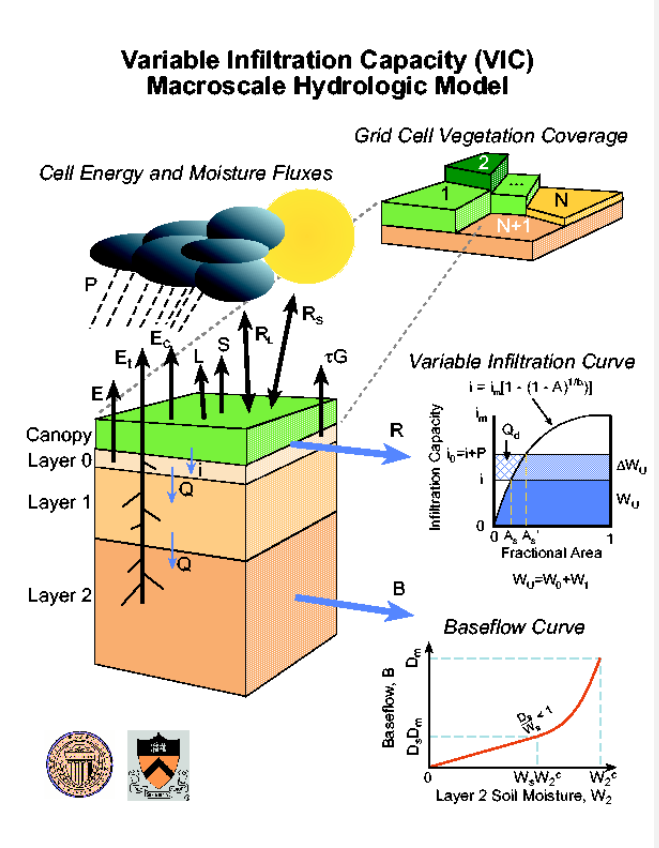


Image Credit: University of Washington VIC Macroscale Hydrologic Model
http://www.hydro.washington.edu/Lettenmaier/Models/VIC/Overview/ModelOverview.shtml

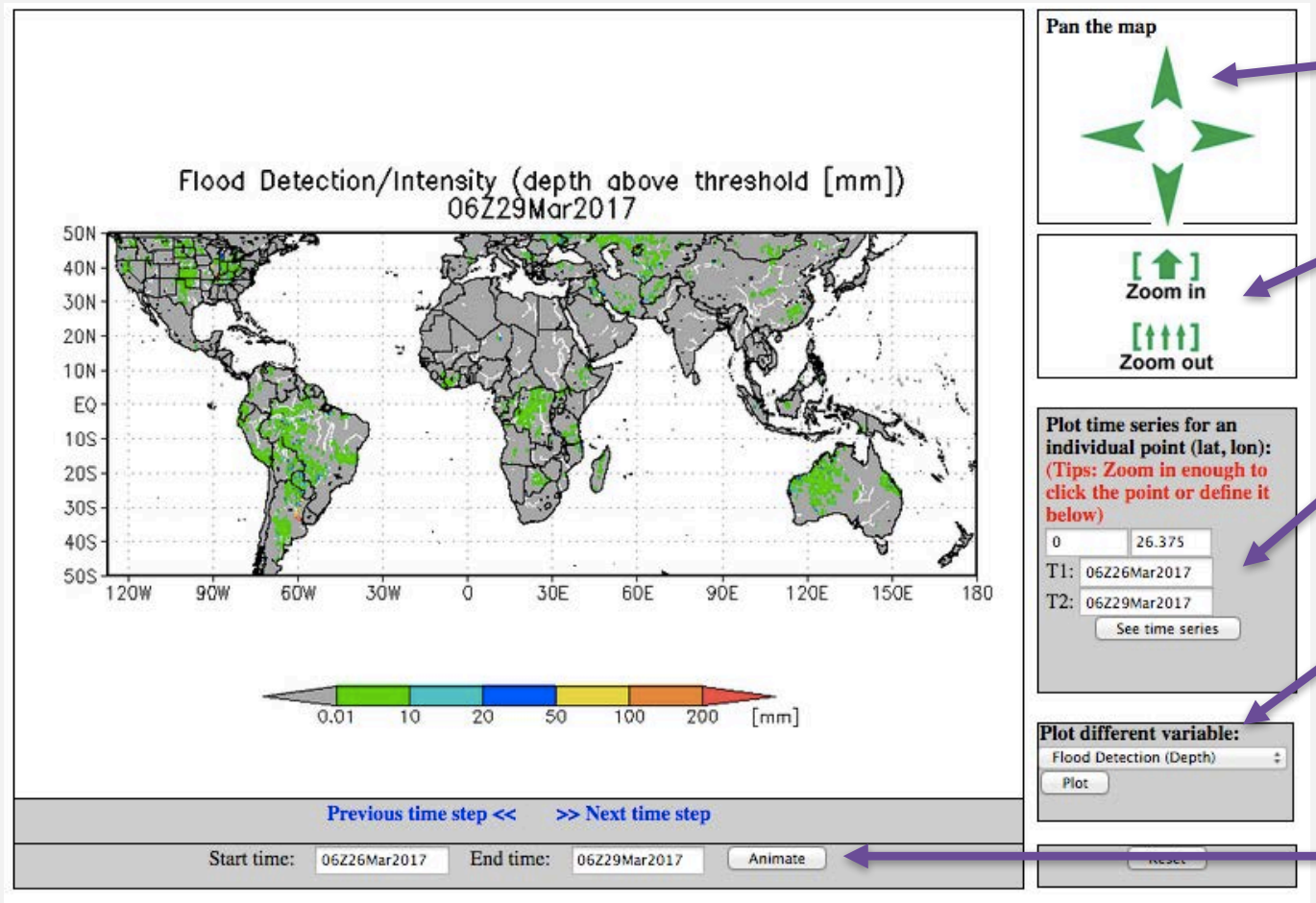
References:

Wu, H., R. F. Adler, Y. Tian, G. J. Huffman, H. Li, and J. Wang (2014), Real-time global flood estimation using satellite-based precipitation and a coupled land surface and routing model, Water Resour. Res., 50, 2693.2717, doi:10.1002/2013WR014710.

Wu H., R. F. Adler, Y. Hong, Y. Tian, and F. Policelli (2012), Evaluation of Global Flood Detection Using Satellite-Based Rainfall and a Hydrologic Model. J. Hydrometeor, 13, 1268.1284

GFMS

http://flood.umd.edu/



Map Navigation

Zoom in/out

Select individual grid point for time series data

Plot different variables

3-hourly output

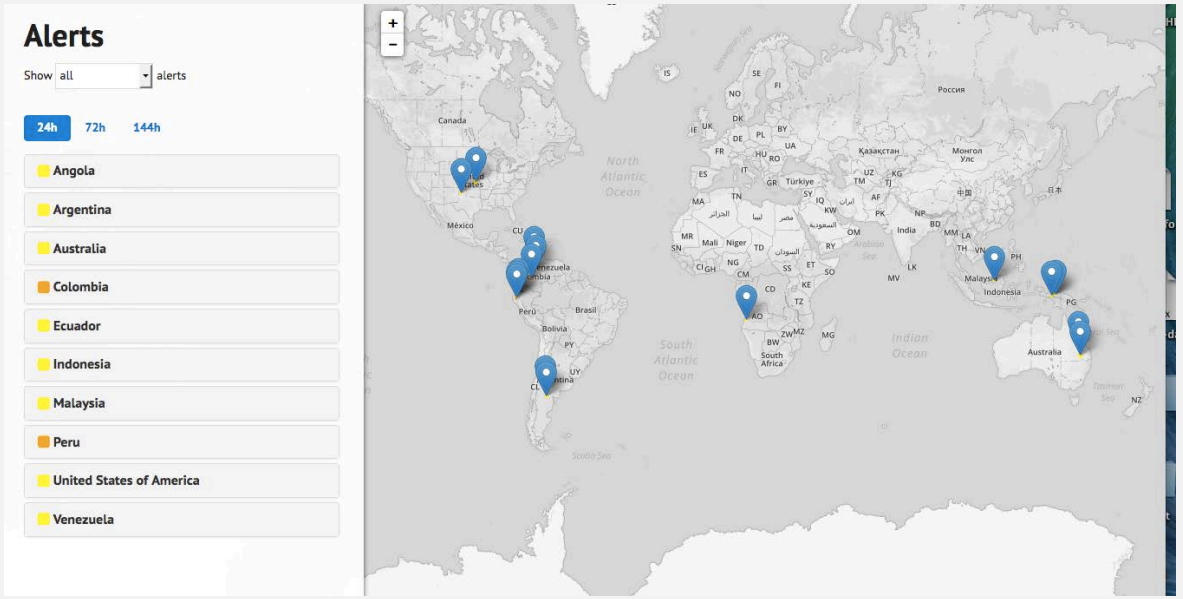
Animation

Extreme Rainfall Detection System-2 (ERDS2)

http://erds.ithacaweb.org/

- Uses near real-time TRMM-TMPA and NOAA-Global Forecasting System (GFS) rainfall for monitoring and forecasting accumulated rainfall
- The TMPA historical archive is used as reference data to calculate extreme rainfall thresholds
- The combination of TMPA rainfall amount, GFS forecasted rainfall information, and the reference data, generates flooding information

- ERDS is one of the tools used by the UN World Food Programme (WFP) Emergency Preparedness Unit

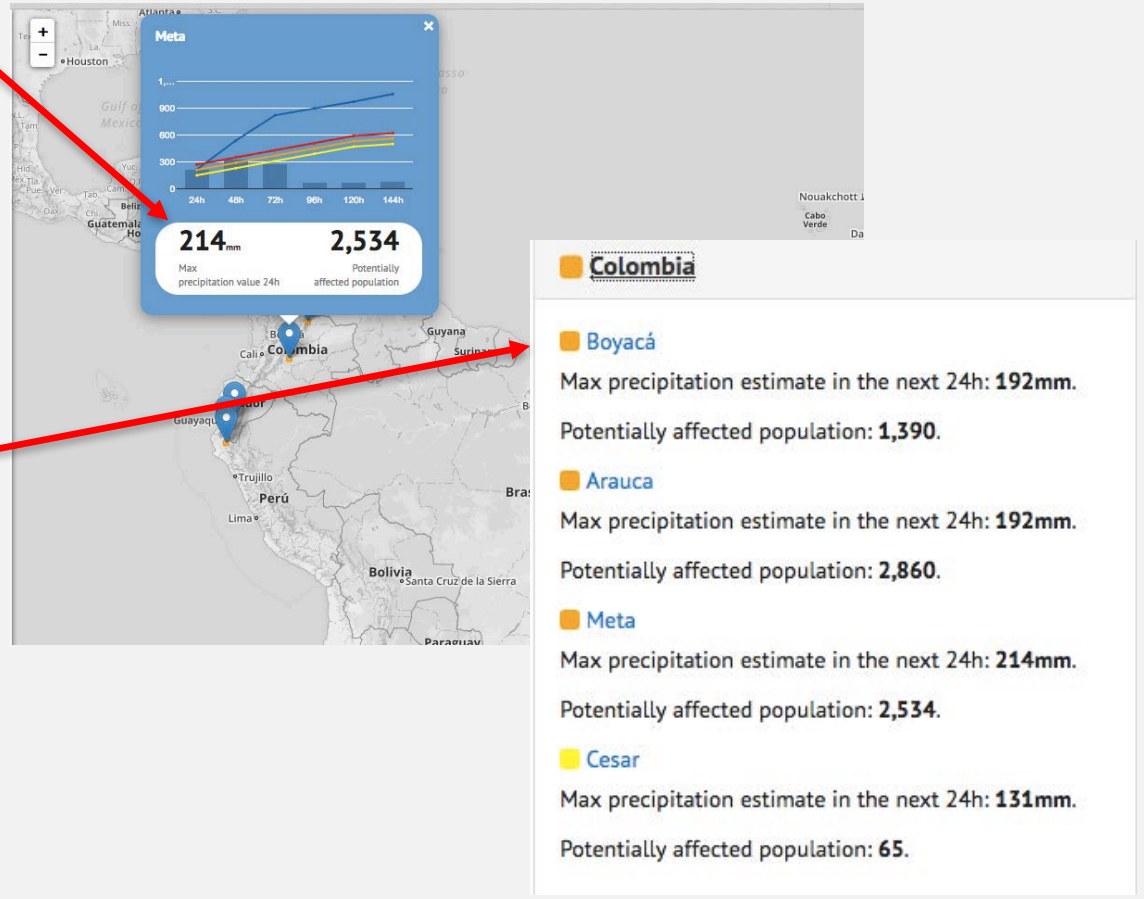


Extreme Rainfall Detection System-2 (ERDS2)

http://erds.ithacaweb.org/

- Global maps and time series of near real-time (50°S-50°N) and forecasted accumulated rainfall
  – 24, 48, 72, 96, 120, and 144 hours
- Extreme rainfall alerts at 0.25°x0.25° levels and administrative district levels
- Event-specific information
  – list of affected countries
  – an estimation of affected population

Value-Added Flood Information

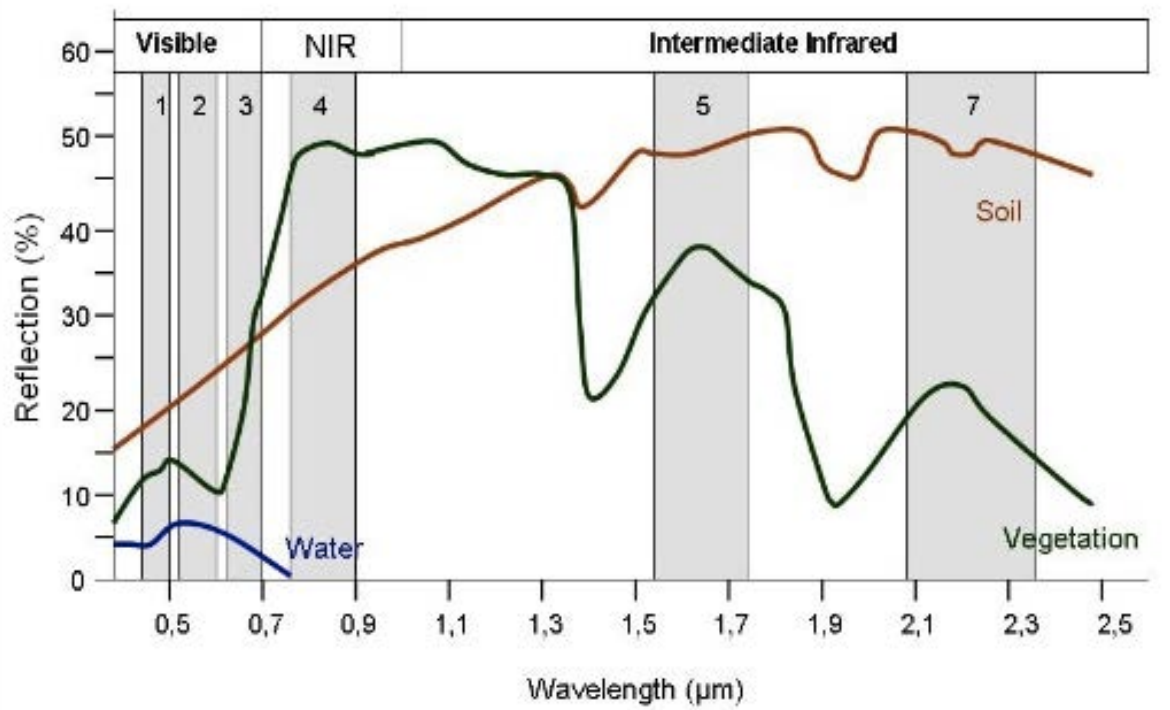


Flooding Tools Based on Land Cover

Land Cover Based Flooding Tools

Visible Radiation

- Reflected by the surface and depends on the surface type



Used for Flood Mapping

- Source:
  - Terra/Aqua MODerate Resolution Imaging Spectroradiometer (MODIS) reflectance changes
- Tools:
  - MODIS NRT Flood Mapping
  - Dartmouth Flood Observatory

Land Cover Based Flooding Tools

Microwave Radiation

- Emitted by the surface and is influenced by the presence of water on the surface
- Sources:
  - Microwave (37 GHz) brightness temperatures from TRMM Microwave Imager (TMI)
  - GPM Microwave Imager (GMI)
  - GCOM-W based Advanced Microwave Scanning Radiometer 2 (AMSR2)
- Tools:
  - GFDS2 (GDACS)
  - DFO River Watch

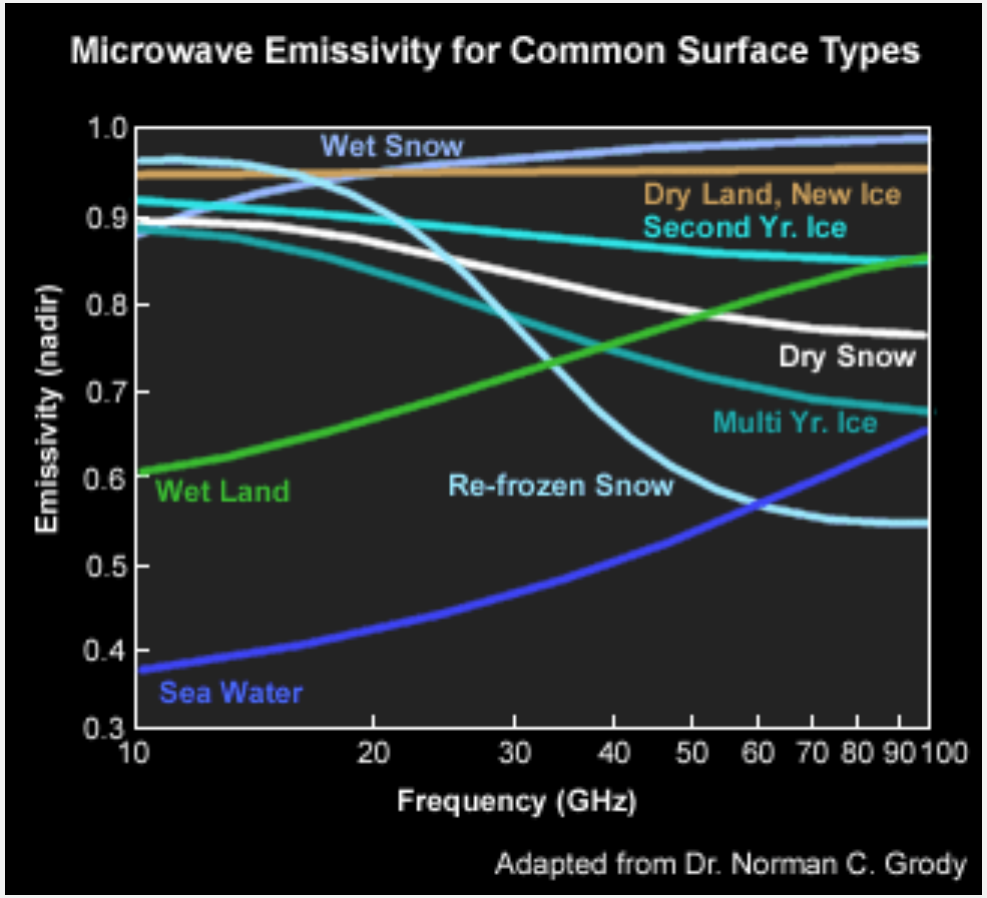
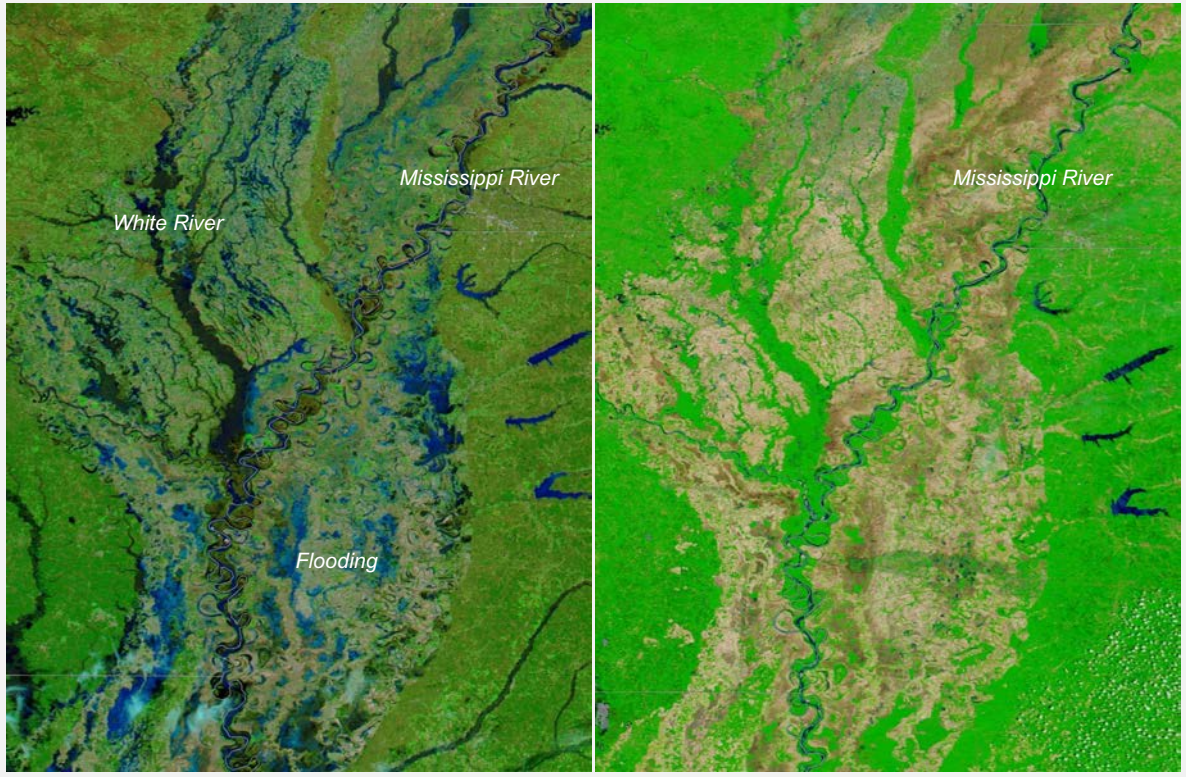


Image Source: COMET MetEd

MODIS-Based Inundation Mapping

- MODIS provides observations 1-2 times per day
- Certain bands indicate water on previously dry surfaces:
  - Band 1: 620-670 nm
  - Band 2: 841-876 nm
  - Band 7: 2105-2155 nm
- Mapped with respect to a global reference database of water bodies
- MODIS cannot see the surface in the presence of clouds

Mississippi River Flooding 2016



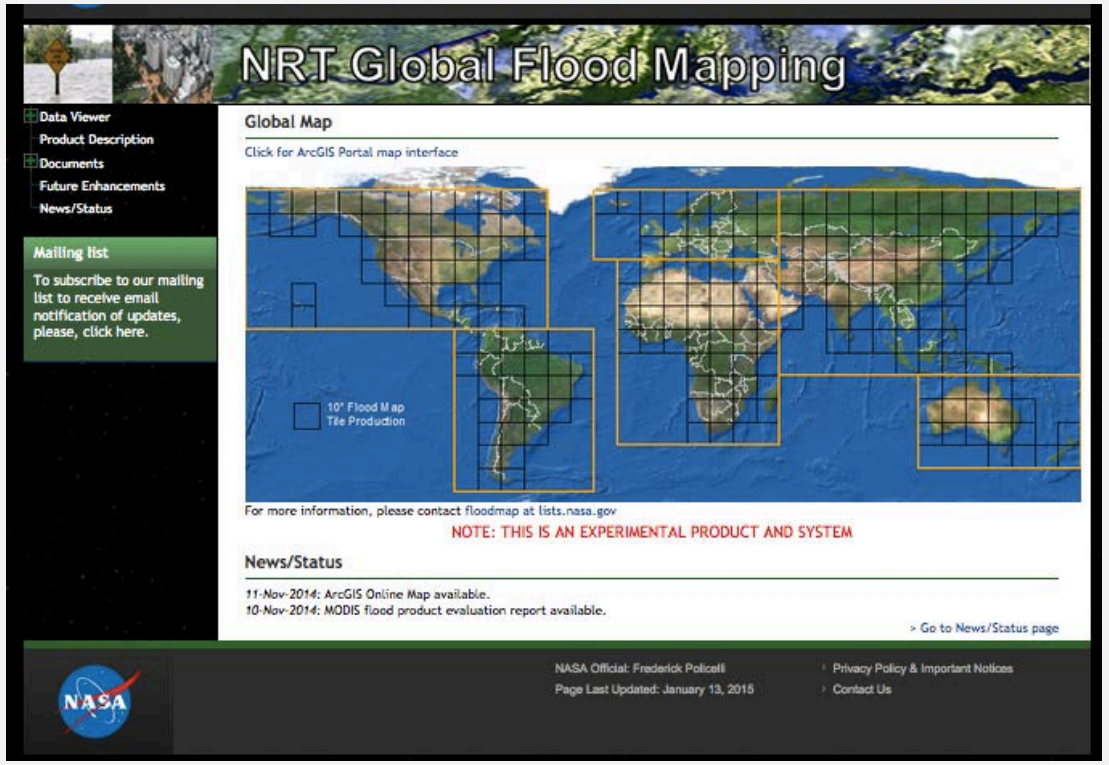
MODIS (Aqua)
Mar 15, 2016

MODIS (Terra)
May 13, 2016

MODIS NRT Global Flood Mapping

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

- Based on MODIS reflectance at 250 m resolution composited on 2, 3, and 14 days
- Flood maps available on 10°x10° tile
- Permanent and surface flood water data available
- Cloud or terrain shadows can be misinterpreted as surface water
- Provides near real-time flood mapping since Jan 2013



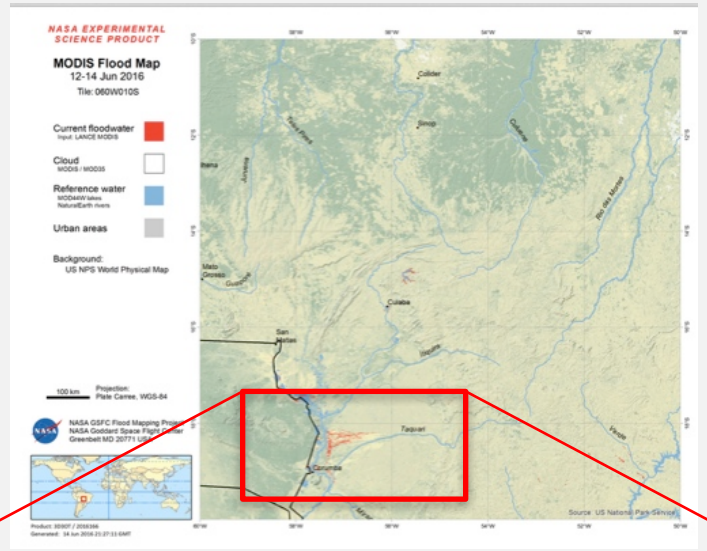
MODIS NRT Global Flood Mapping: Available Quantities

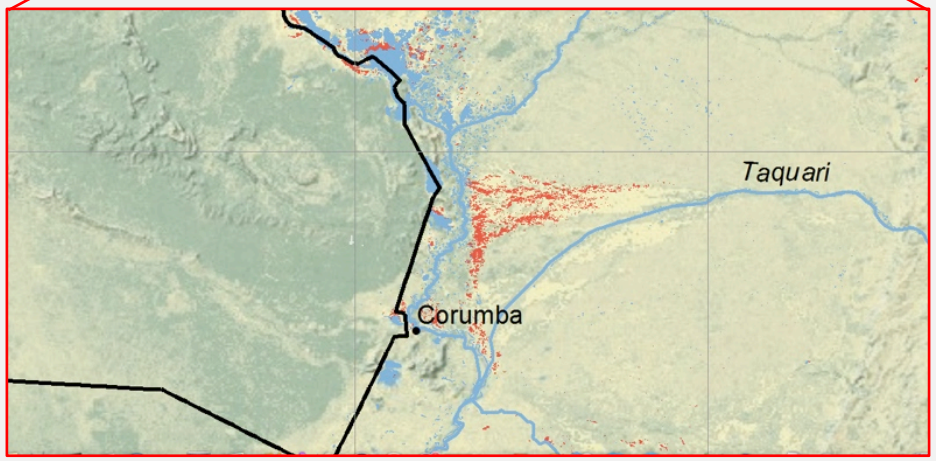
http://oas.gsfc.nasa.gov/

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

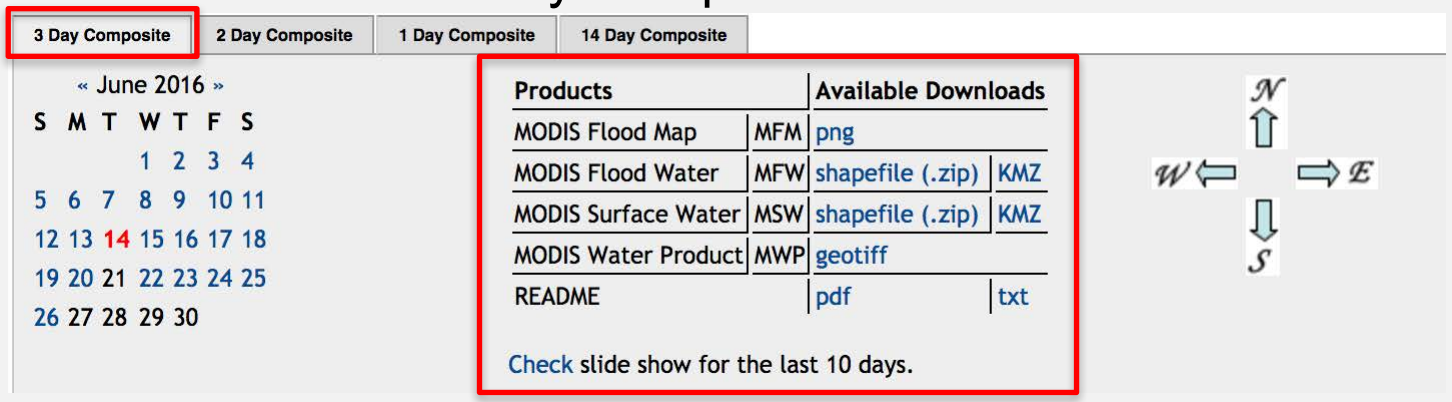
MODIS Flood Mapping: Southern Brazil, June 12-14, 2016

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





3-Day Composites



Filename Convention

product_date_tile_composite_xtra.ext

MSW_2012009_020E000S_3D3O_V.shp

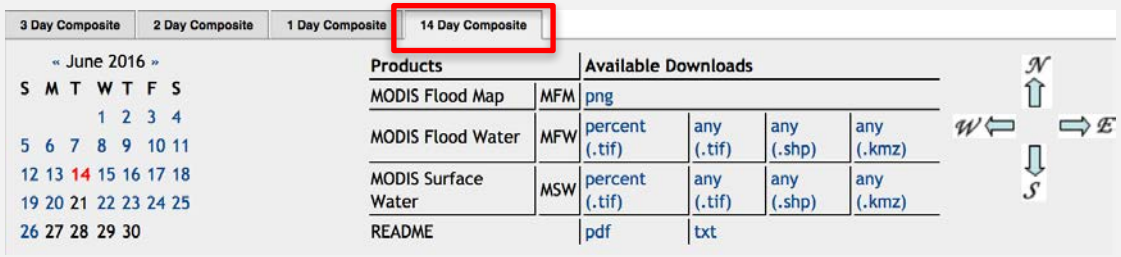
MFM_2012009_020E000S_2D2O.png

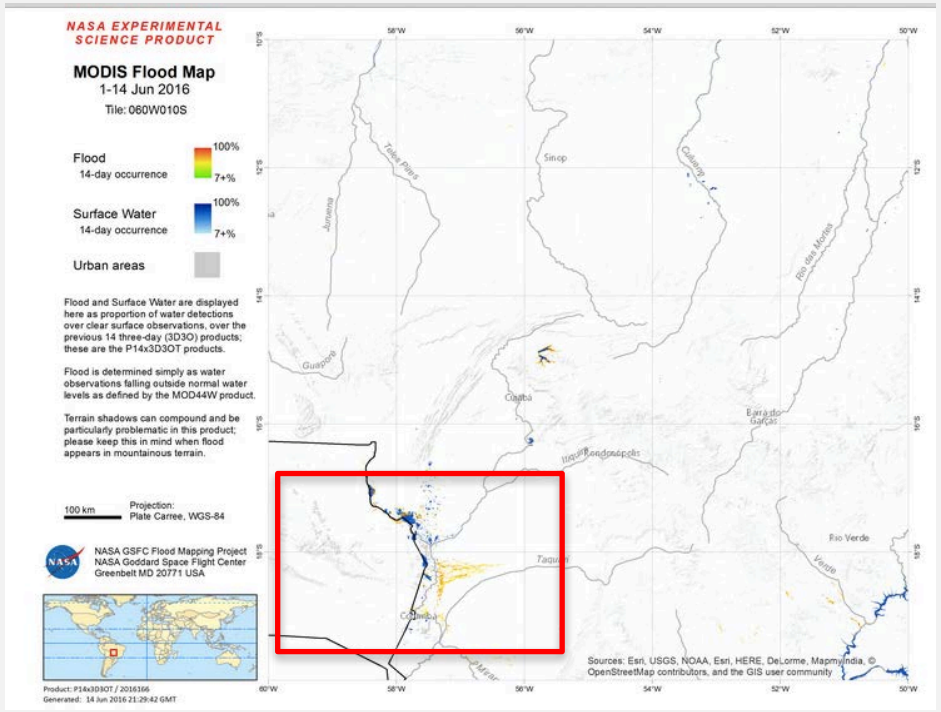
yyyydoy (year, day of year)

lon-lat

2 or 3 day observations

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





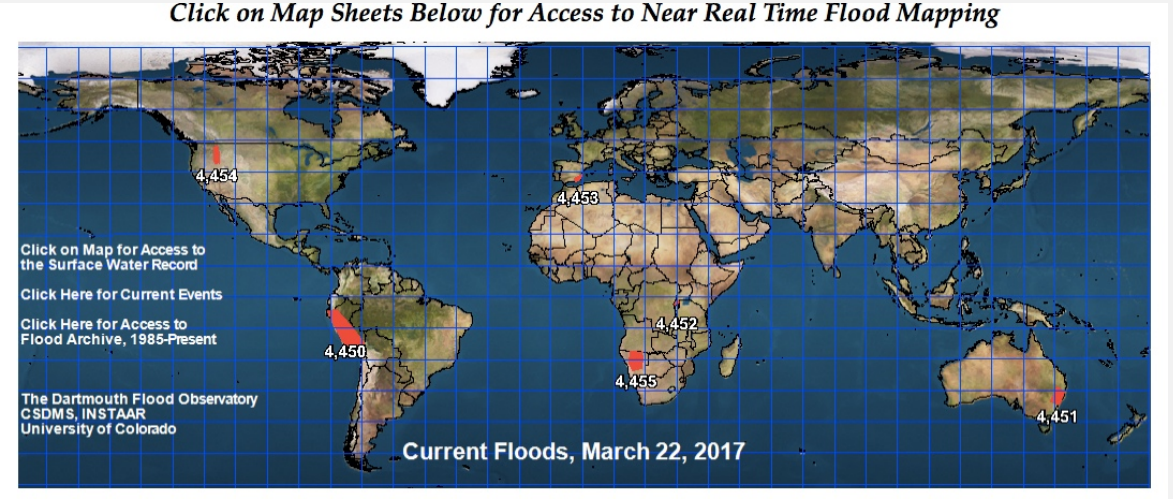
14-Day Composites

- Similar filename convention with additional processing for composite field
  - N: no shadow masking
  - T: terrain 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 percent clear observation over the last 14 days' products
- GeoTIFF are 0-1 images (1 if % water > 0)

Dartmouth Flood Observatory (DFO)

http://floodobservatory.colorado.edu/

- Uses flood mapping based on MODIS reflectance
  – same as MODIS NRT
- Also uses Landsat 8, EO-1, and ASTER images
  – uses COSMO-SkyMed and Sentinel-1 synthetic aperture radar (SAR) when available)
- Current flood events are analyzed with multiple data sources (next two slides), including media report



- Provides near real-time, current, and past flood event mapping
- Red areas (above) indicate inundated surface

DFO Current Flood Event: Peru

http://floodobservatory.colorado.edu/

Coastal flooding during local El Nino conditions (middle, Mar 27, 2017), compared to previous year (left image, Mar 27, 2016). Source: MODIS

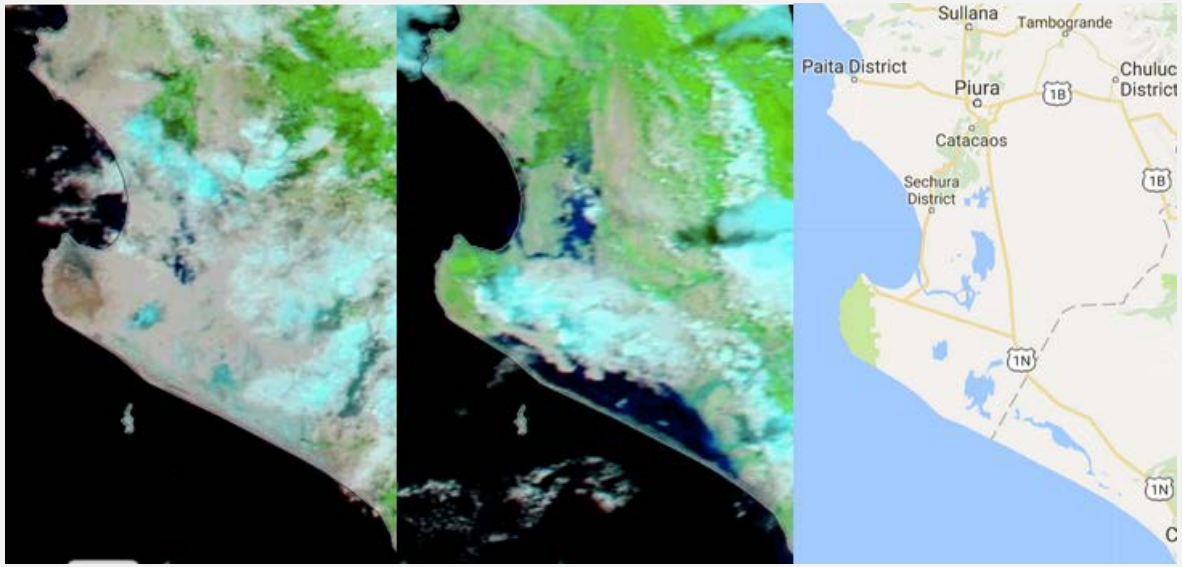


Image Sources: DFO

Flooding (red) from comparing Mar 20, 2017 and Jan 19, 2017.

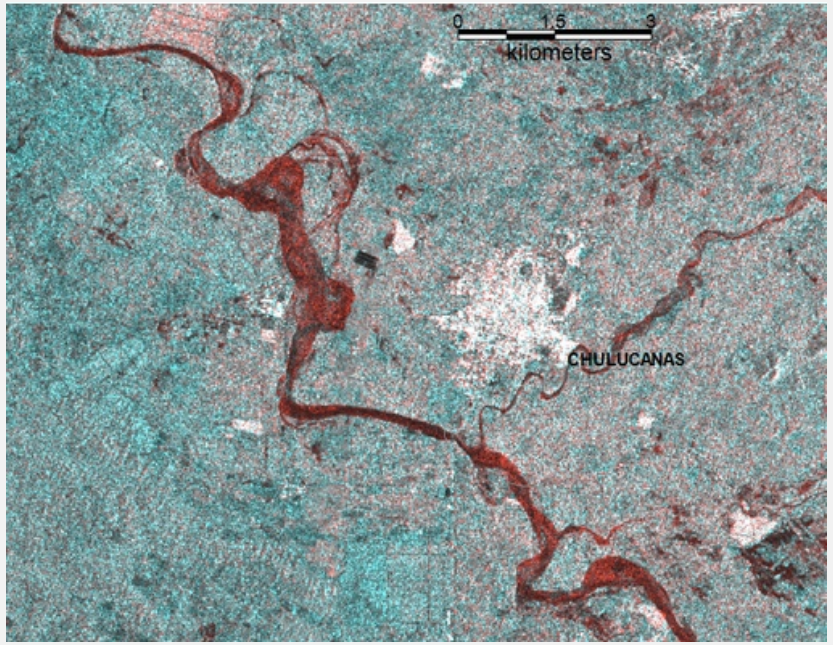
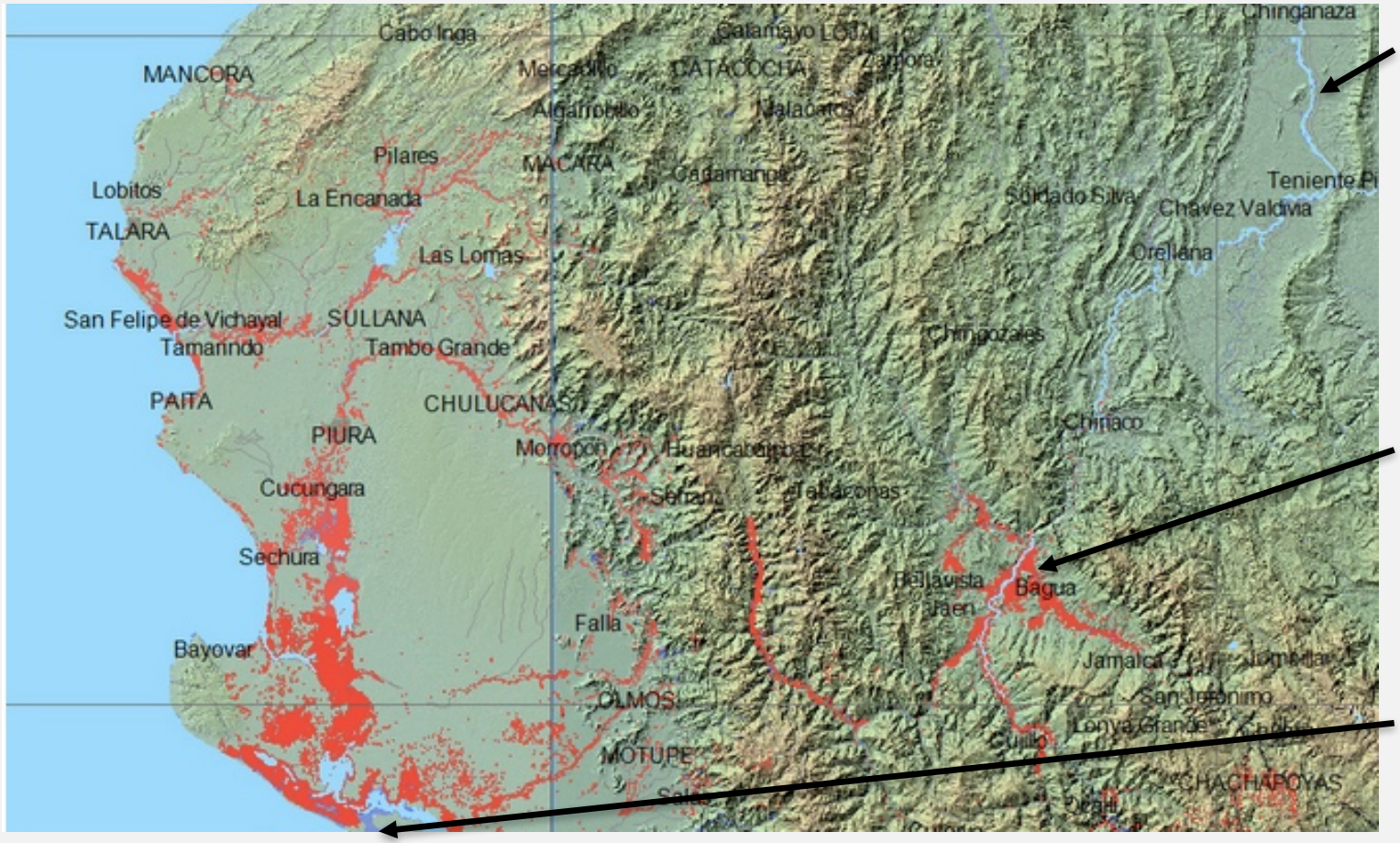


Image contains modified Copernicus Sentinel 1 data (2017), from Dartmouth Flood Observatory

DFO Current Flood Event: Peru

http://floodobservatory.colorado.edu/



Light Blue: normal annual water extent from Feb 2000 (shuttle water boundary data)

Red: flood water mapped from ESA Sentinel-1 SAR

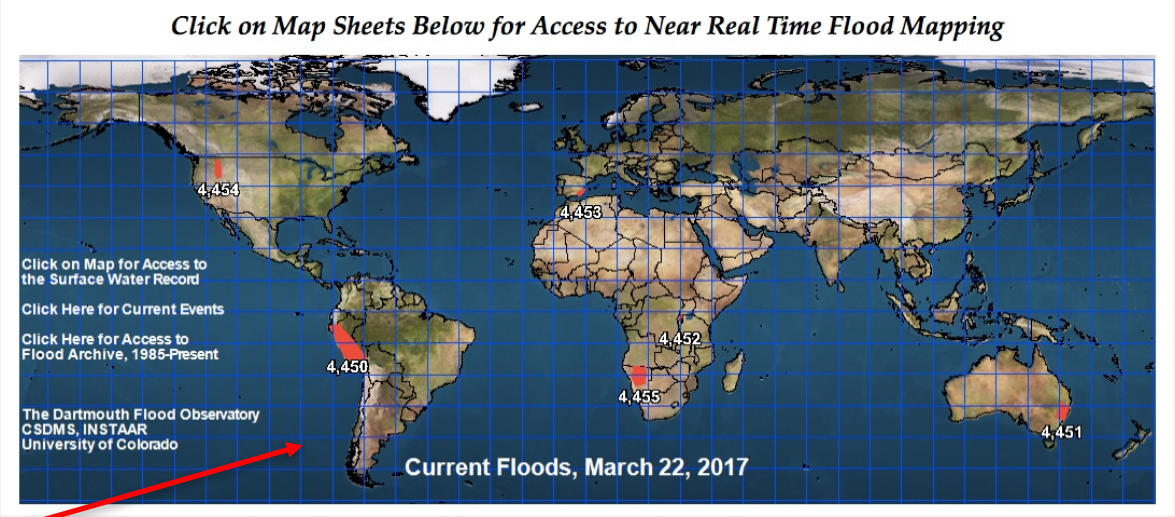
Dark Blue: previous flood extent

DFO Surface Water Record

http://floodobservatory.colorado.edu/Version3/120W050Nv3.html

- Surface water (SW) is based on twice-daily images
  - from Terra and Aqua MODIS
  - 250 m resolution
  - composited over 14 days
- Change in SW from SWDB (shuttle water boundary data) since 2000 also provided
- Available in 10°x 10° grids

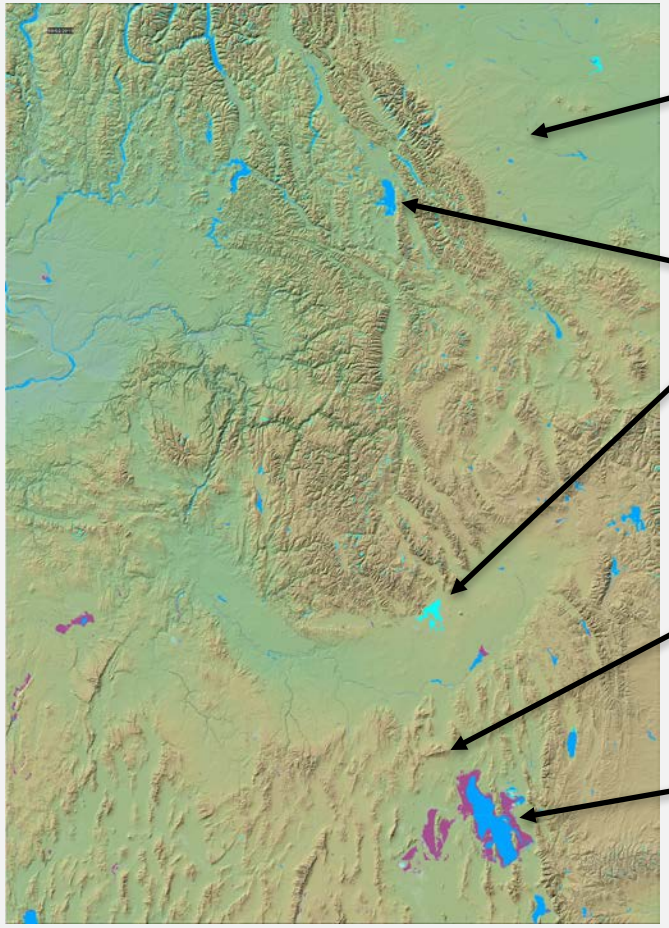
SW Access Through the Map



DFO Current Surface Water Extent

http://floodobservatory.colorado.edu/Version3/120W050Nv3.html

Map 120W050N



Map Legend (at time of map date)

small areas of purple: water mapped by SWBD, but not resolved by MODIS

dark blue: current water imaged by MODIS

bright blue: flooding or expanded water areas mapped by MODIS compared to SWDB (any post-2000 reservoir or new water body is also depicted as bright blue)

light blue-gray: all previous flooding imagined and mapped by the Flood Observatory (now dry land)

large areas of purple: dry land (compared to SWBD)

Error Notes from DFO

1. In mountainous regions, terrain shadows mimic surface water and are mis-classified as water in our current algorithm. We are working to reduce such noise.
2. Reservoirs and impoundments constructed since yr 2000 appear permanently in red.
3. The observational record illustrated may not include all floods: prior to 2011 the records were obtained manually and focus was on major flood events

Land Cover Based Flooding Tools

Visible Radiation

- Used for flood mapping:
  - Terra/Aqua MODerate Resolution Imaging Spectroradiometer (MODIS) reflectance changes
- Used by:
  - MODIS NRT Flood Mapping
  - Dartmouth Flood Observatory
- Used to observe land cover changes:
  - Reflectance from Landsat
- Used by: NOAA Coastal Flood Watch

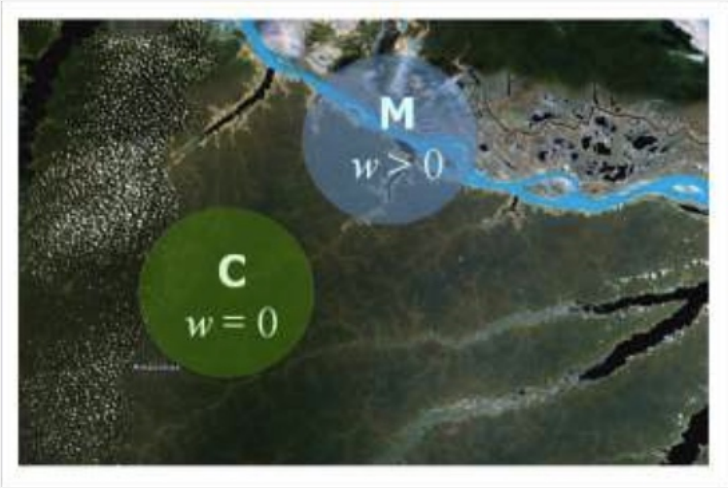
Microwave Radiation

- Used to detect inundated surface:
  - Microwave (37 GHz) brightness temperatures from TRMM Microwave Imager (TMI)
  - GPM Microwave Imager (GMI)
  - GCOM-W based Advanced Microwave Scanning Radiometer 2 (AMSR2)
- Used by:
  - GFDS2 (GDACS)
  - DFO River Watch

About GFDS2 and DFO River Watch

http://floodobservatory.colorado.edu/technical.html

- GFDS2 and DFO River Watch are collaborative programs
- Use microwave brightness temperatures (T_b) from TRMM, GPM, and GCOM-W satellites to detect surface inundation

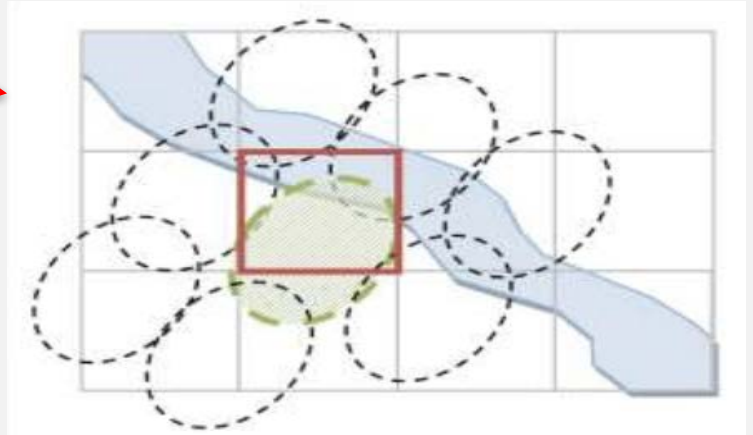


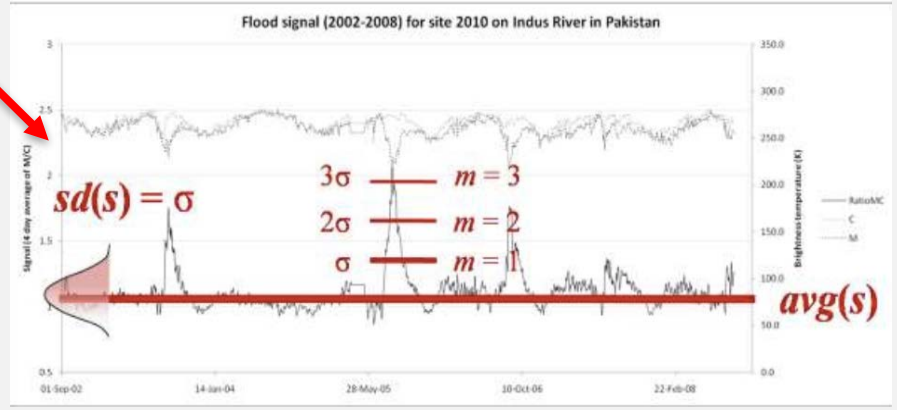
- S: satellite-based flood signal
- M: T_b from a measurement pixel centered over the river and its floodplain
- C: daily calibrating value that represents the 95th percentile of the day's driest (brightest) T_b within a 9x9 pixel array surrounding the M pixel
- Departures from the mean value (anomalies) of the ratio is used to detect flooding conditions

GFDS2 Flood Magnitude

http://bit.ly/GFDS_specs_15

- Joint Research Center (JRC) from the European Commission produces daily, 10 km grids of satellite signal (S) to be used by GFDS2 and DFO River Watch
- GFDS2 derives flood magnitude based on the anomalies of the ratio (S) compared to its value averaged over 7 years (records start in Jun 2002)
- GFDS2 flood magnitudes are used by GDACS to provide near real-time alerts

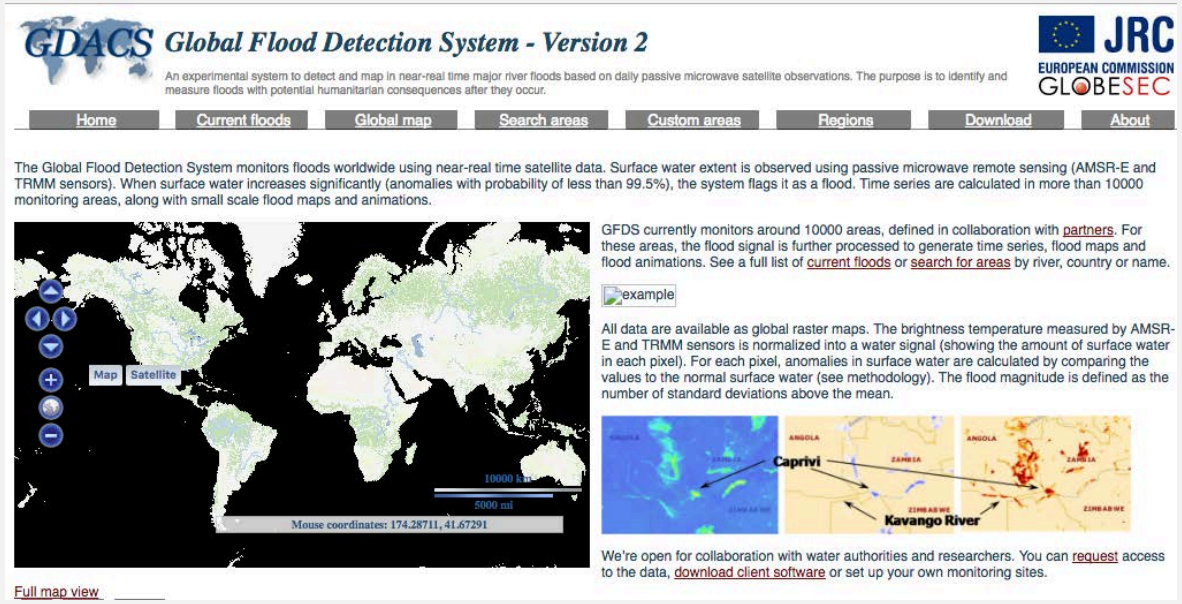




Global Flood Detection System 2 (GFDS2)

http://www.gdacs.org/flooddetection/

GFDS2 flooding information is used by GDACS



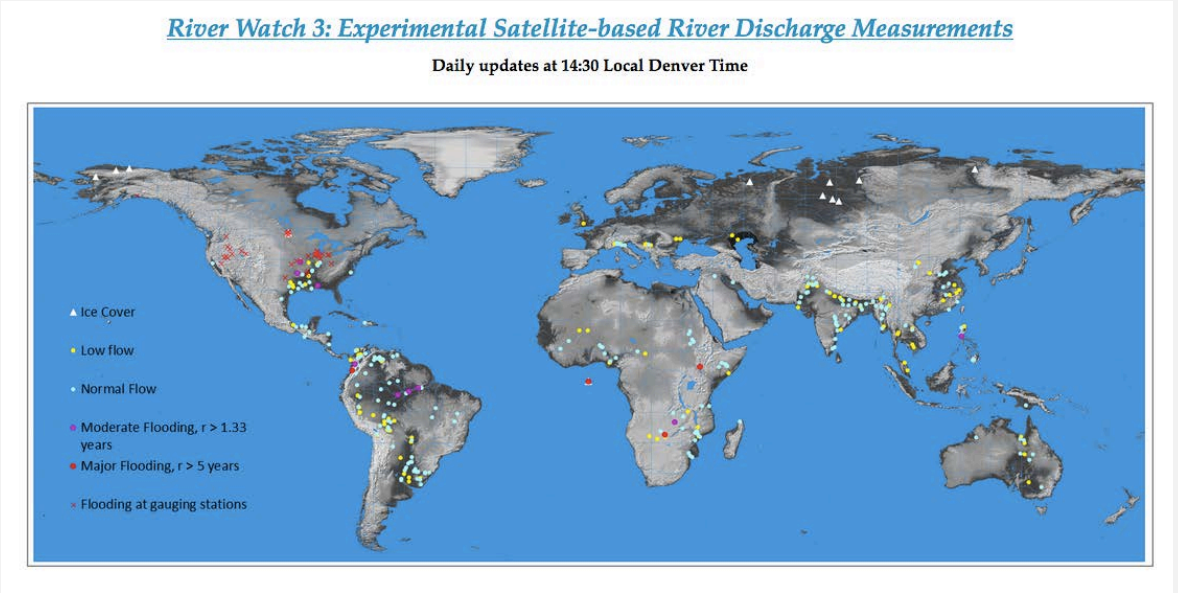
Developed for GDACS in collaboration with DFO

Interactive current flood map and flood list

DFO River Watch

http://floodobservatory.colorado.edu/GlobalRunoff.html

- DFO River Watch system uses the JRC-powered satellite signal (S – microwave brightness T_b ratio) at specific surface river gauging locations
- S values are converted to river discharge by combining them with surface discharge measurements and then converted to runoff by using a Water Balance Model (WBM)



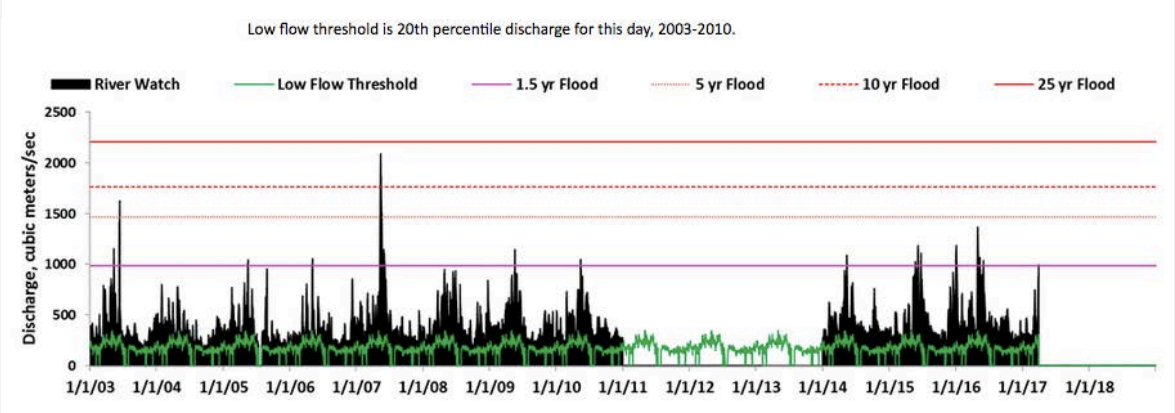
DFO River Watch

http://floodobservatory.colorado.edu/GlobalRunoff.html

- Runoff calculations are available starting in 2003
- Satellite-derived runoff is compared to the 7 year (2003-2010) mean runoff record to decide low, normal, moderate, and major flooding
- Daily and monthly runoff time series are available at the river gauge sites

- Flood magnitude is assigned when runoff volume exceeds a threshold decided based on the recurrence period from the runoff record

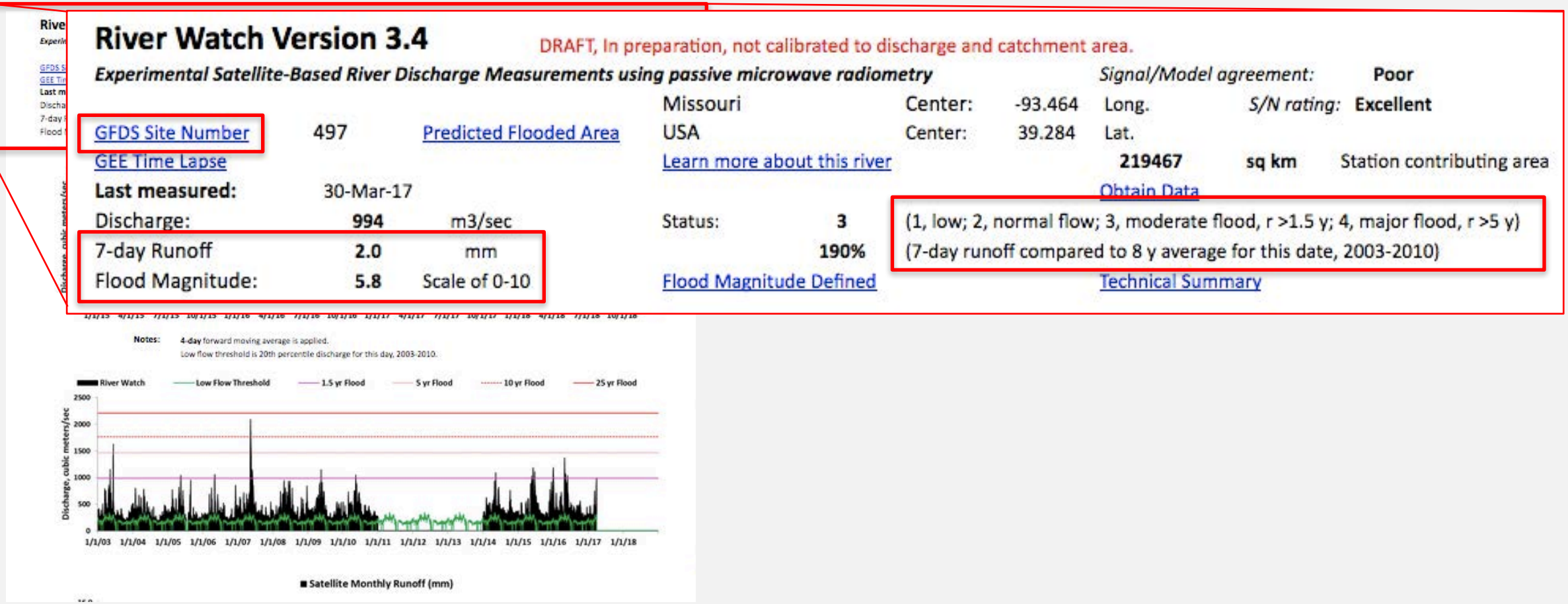
Missouri River Discharge



Reference: Merged AMSR-2 and GPM Passive Microwave Radiometry for Measuring River Discharge and Runoff. G. Robert Brakenridge, Son. V. Nghiem (http://floodobservatory.colorado.edu/Publications/2016IEEEPaper.pdf)

DFO River Watch

http://floodobservatory.colorado.edu/GlobalRunoff.html

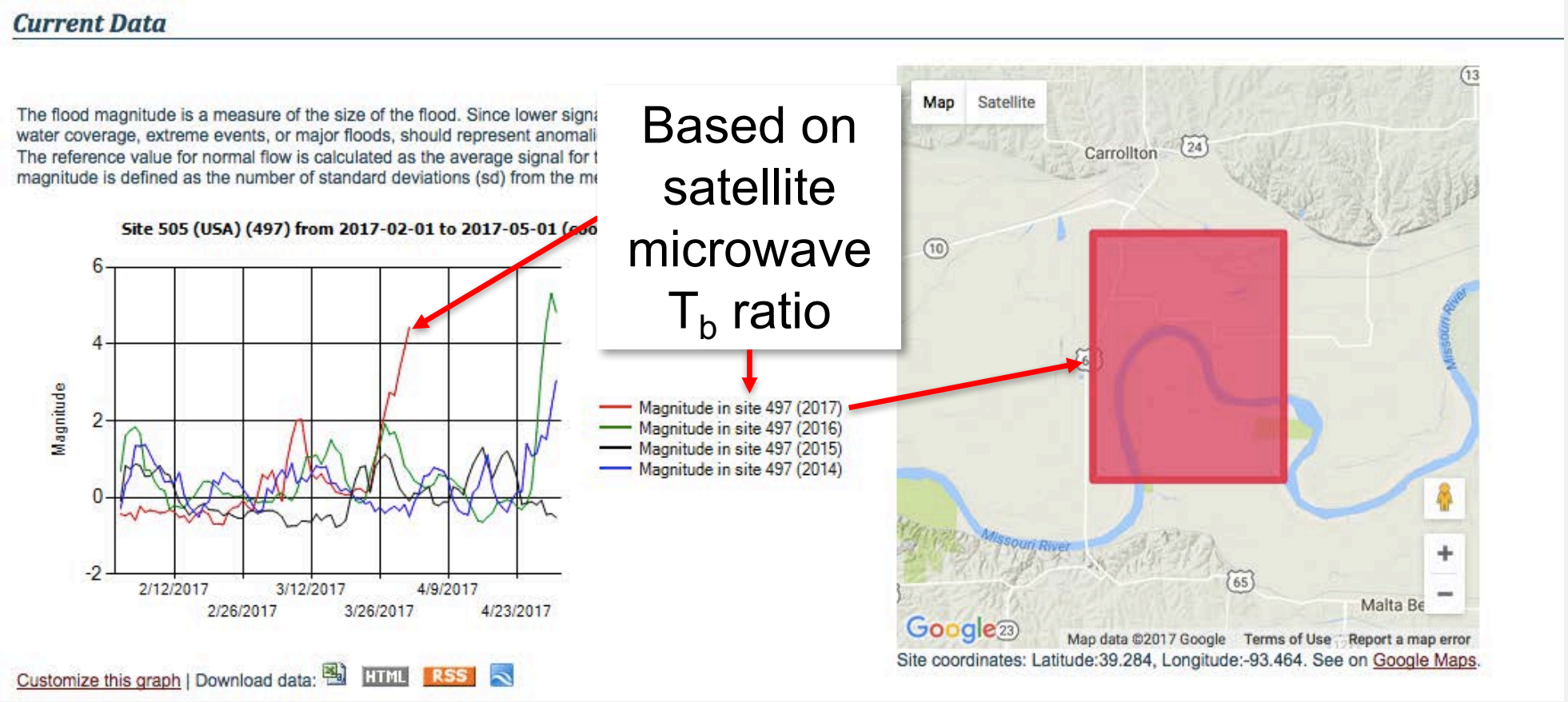


Reference: Merged AMSR-2 and GPM Passive Microwave Radiometry for Measuring River Discharge and Runoff. G. Robert Brakenridge, Son. V. Nghiem (http://floodobservatory.colorado.edu/Publications/2016IEEEPaper.pdf)

GFDS2 Flood Magnitude for the Missouri River

http://floodobservatory.colorado.edu/GlobalRunoff.html

- GFDS2 flooding information is used by GDACS



Global Disasters Alert and Coordination System (GDACS)

http://arset.gsfc.nasa.gov/disasters/webinars/GDACS17

What is GDACS?

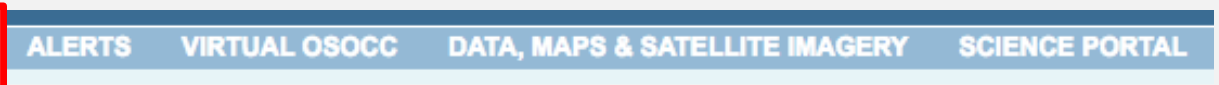
http://www.gdacs.org/

- A cooperation framework between the UN, the European Commission and disaster managers worldwide to improve alerts, information exchange and coordination in the first phase after major sudden-onset disasters
- Develops data tools and services that complement existing materials:
  - International Search and Rescue Advisory Group (INSARAG) Guidelines
  - UN Disaster Assessment and Coordination (UNDAC) Field Handbook
  - International Federation of Red Cross and Red Crescent Societies (IFRC) Publications
  - Standard Operating Procedures from the European Community Mechanism for Civil Protection
  - International Humanitarian Partnership (IHP)
  - Euro Atlantic Disaster Response Coordination Centre (EADRCC)

* *Global Disaster Alert and Coordination System Guidelines* [PDF]. (2014). GDACS.org

GDACS Tools and Services

http://www.gdacs.org/



- Interactive map with near real-time disasters alerts
- Color coded alerts
  - white: minor events
  - green: moderate events
  - orange: potential local disasters
  - red: potentially severe disasters

GDACS Disaster Alerts

http://www.gdacs.org/

- **Floods**
  - inundation
  - deaths
  - displacement
- **Tropical Cyclones**
  - winds
  - heavy rains
  - storm surge
- **Earthquakes and Tsunamis**
  - intensity and magnitude
  - hypocenter depth
  - population within 100 km of epicenter
  - vulnerability of affected countries

Various models and data are used to obtain this information: http://portal.gdacs.org/Models

GDACS Disaster Alerts

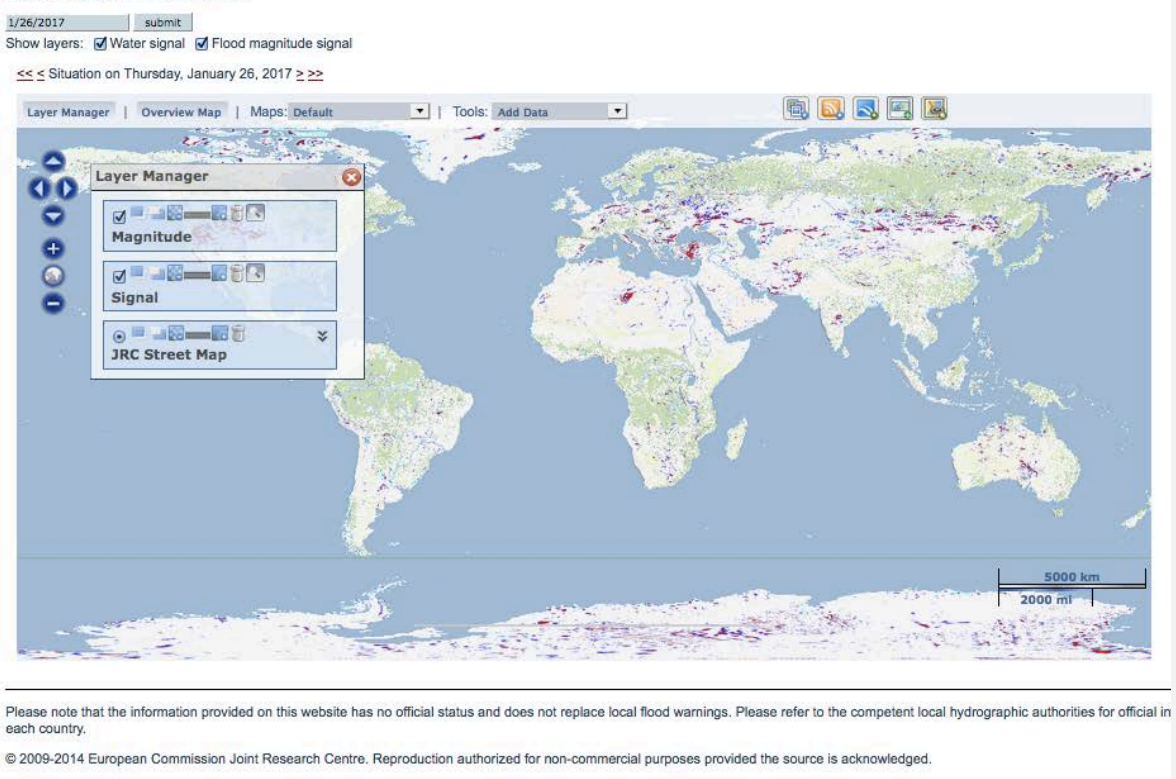
http://www.gdacs.org/

- **Floods**
  - inundation
  - deaths
  - displacement
- **Tropical Cyclones**
  - winds
  - heavy rains
  - storm surge
- **Earthquakes and Tsunamis**
  - intensity and magnitude
  - hypocenter depth
  - population within 100 km of epicenter
  - vulnerability of affected countries

GDACS Approach for Disaster Alerts: Floods

http://portal.gdacs.org/Models/

Issues flood alerts and maps using satellite-based information from the GFDS2 and population data



- Red Alert
  - more than 1,000 dead or 800,000 displaced
- Orange Alert
  - more than 100 dead or 80,000 displaced
- Green Alert
  - All other floods

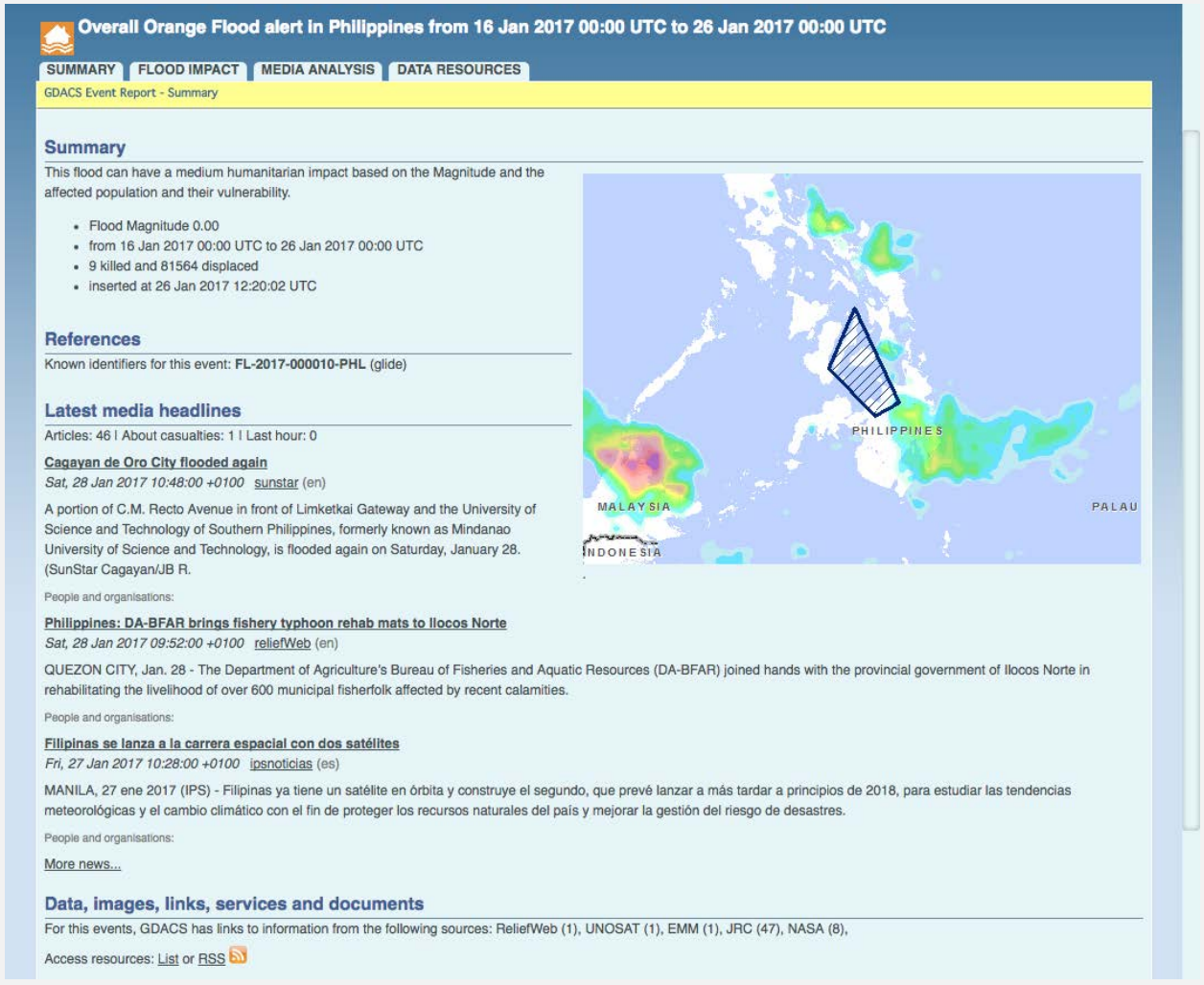
Image Credit: GFDS Version 2 http://www.gdacs.org/flooddetection/global_map.aspx

GDACS Virtual On-Site Operations Coordination Center (OSOCC)

http://vosocc.unocha.org/

Recent Flood in the Philippines

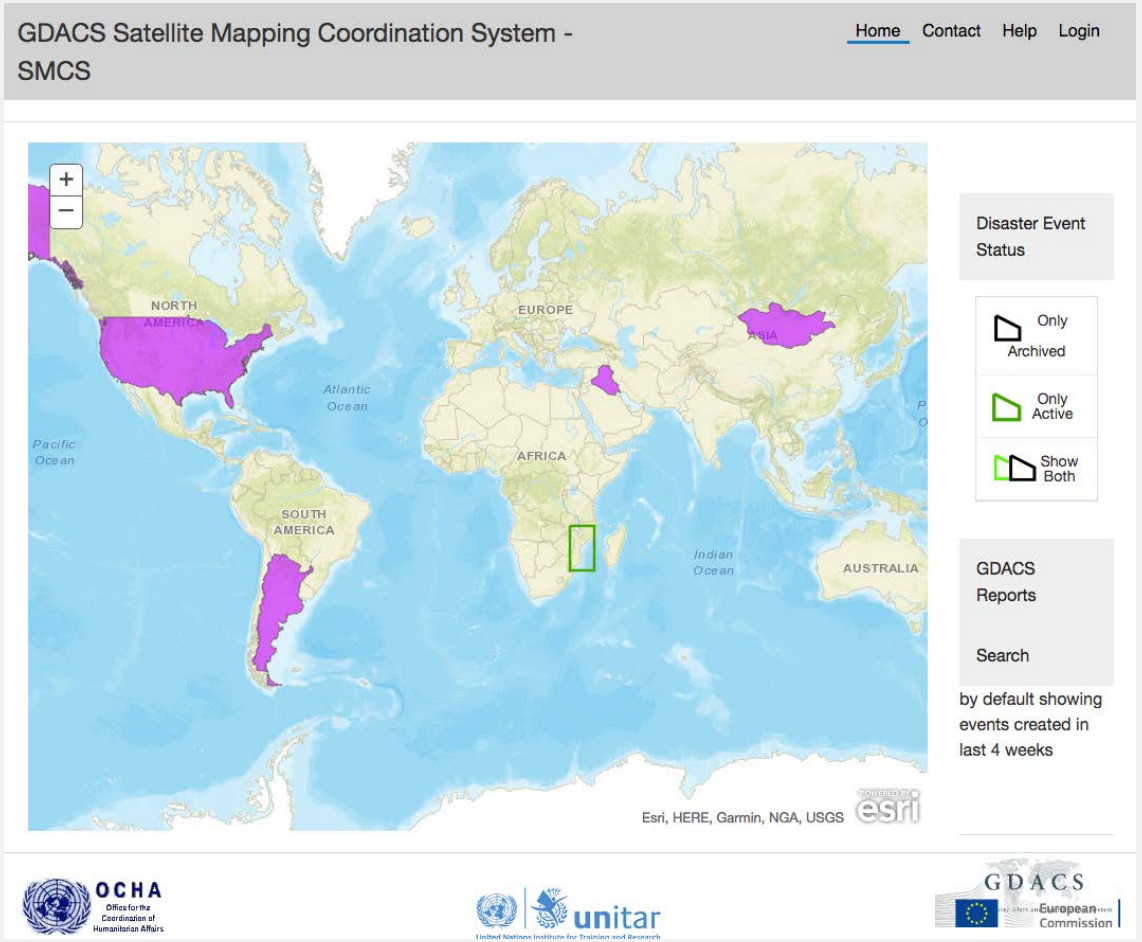
- Summary Report:
  - deaths
  - displacement
- Latest news
- Data, Images, and Documents



GDACS Satellite Mapping Coordinate System (SMCS)

http://gdacs-smcs.unosat.org/

- Led by UNITAR-UNOSAT
- Includes NASA and ESA satellite data
- A GIS-based tool of satellite imagery for specific disaster events
  – requires user registration
- Provides past and real-time imagery for an event
- Also offers:
  – baseline maps
  – situation specific maps
  – damage assessment maps
  – weather forecast maps

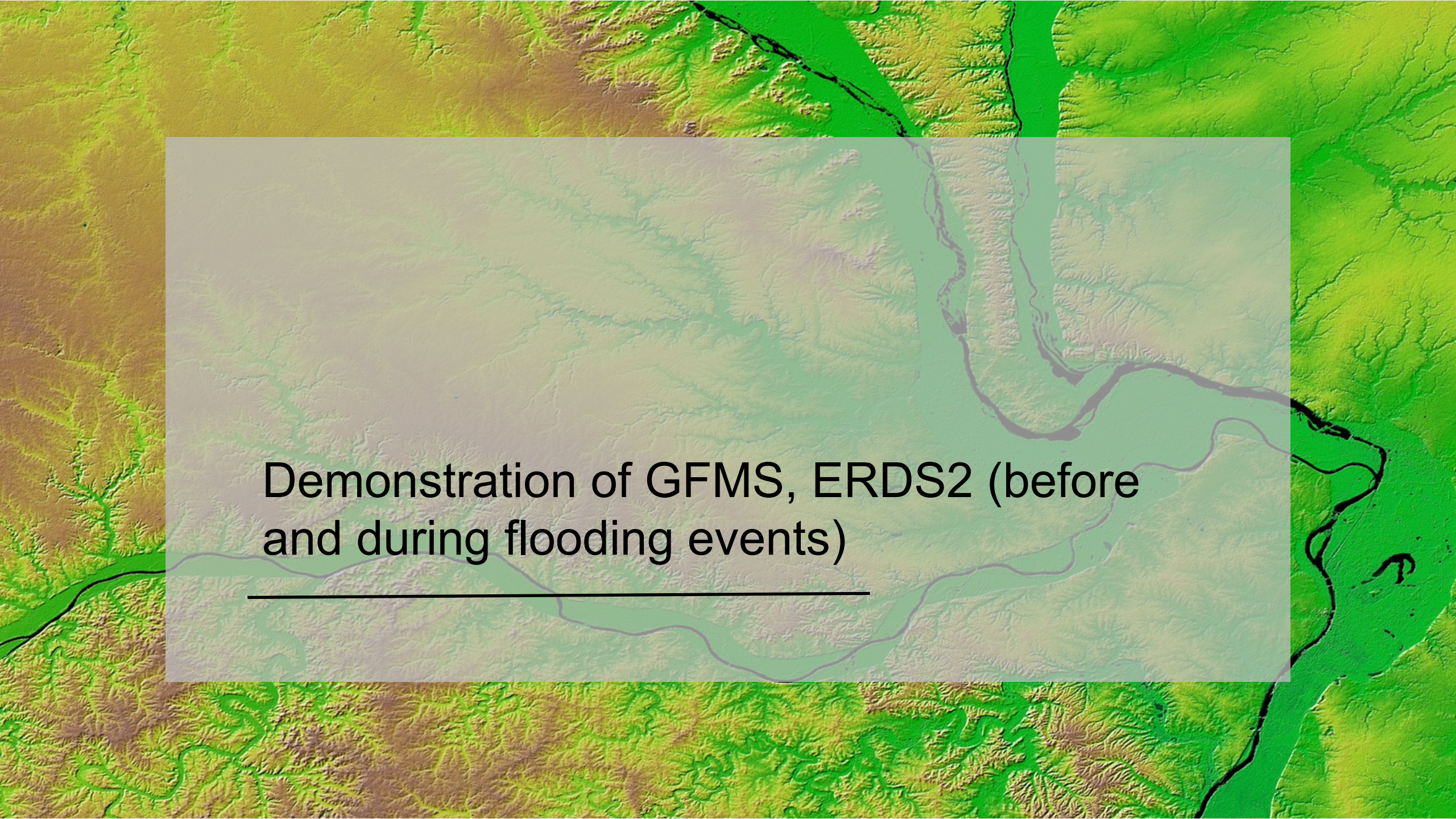


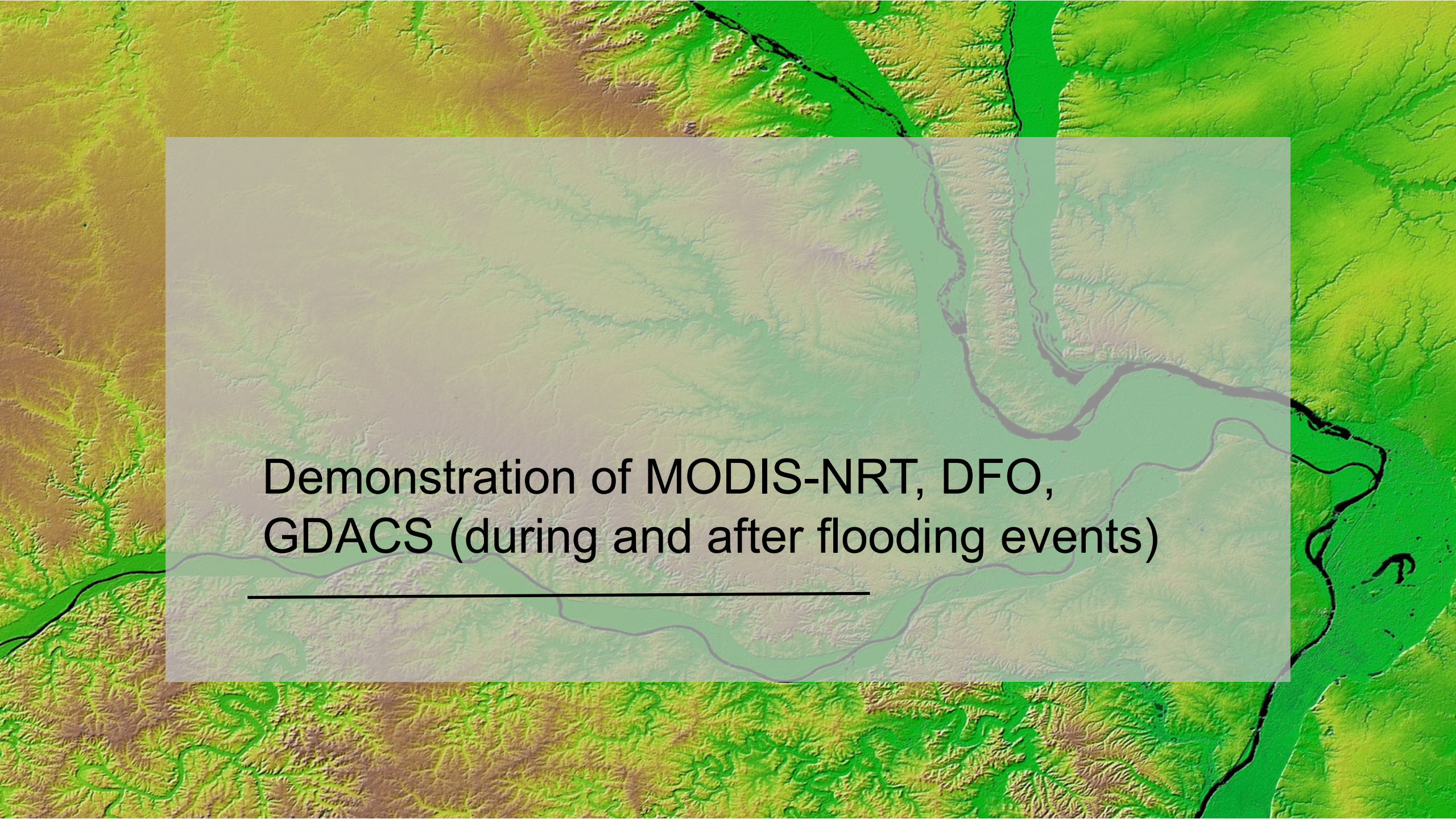
Summary of Flooding Web Tools Based on Precipitation

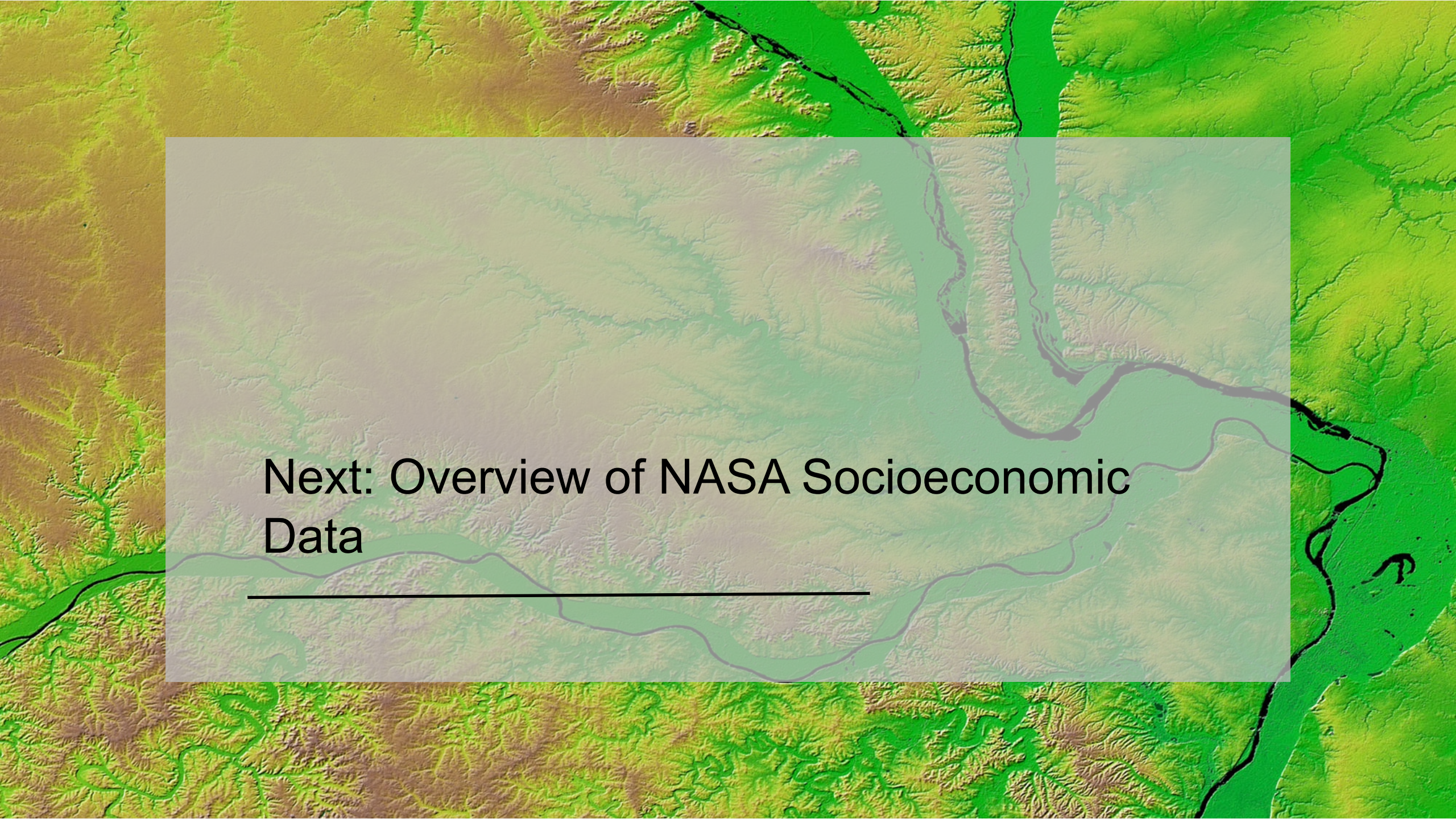
Flood Tool, Satellite, Instrument, or Model	Quantities Used as Inputs	Hydrological Model	Output	Spatial Coverage and Temporal Resolution
GFMS • TRMM/ TMPA-RT • MERRA	• Rain rate • Surface temperature • Winds	• VIC-UMD DRTR	• Flood intensity • Streamflow • Accumulated rainfall	• 50°S-50°N • 12 km and 1 km • Jan 2001 – NRT 3 hr updates
ERDS • TRMM/ TMPA-RT • GFS	• Rain rate		• NRT & Forecast flood alerts • Accumulated rainfall • Population affected	• 50°S-50°N • 0.25°x0.25° • NRT and up to 72 hr forecast, 3 hr updates

Summary of Flooding Web Tools Based on Land Surface Observations

Flood Tool, Satellite, Instrument, or Model	Quantities Used as Inputs	Output	Spatial Coverage and Temporal Resolution
MODIS-NRT • Terra/Aqua MODIS	• Reflectance Bands 1, 2, 7	• Inundation map • Flood water • Surface water	• Global 250 m • NRT 2, 3, and 14 day composites • 2013-present
DFO • Terra/Aqua MODIS	• Reflectance Bands 1, 2, 7	• MODIS Inundation map • Images when available: SAR EO-1 Landsat	• Global 250 m • 14 day composite • Flood catalog (since 1985)
GFDS2 & DFO River Watch • Aqua/AMSR-E,TRMM/TMI, GCOM-W/AMSR2, GPM/GMI	• Microwave Brightness Temperature (37 GHz) • Water Balance Model • River Gauge Discharge	• Flood Magnitude • River discharge time series at selected locations	• Global, NRT • Past flood since 2003


Demonstration of GFMS, ERDS2 (before and during flooding events)


Demonstration of MODIS-NRT, DFO,
GDACS (during and after flooding events)


Next: Overview of NASA Socioeconomic Data