

NASA Applied Remote Sensing Training Program (ARSET)

Using Satellites for Improved Flood Monitoring and Prediction

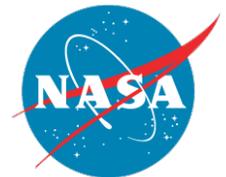
The World Bank
Washington DC

March 7, 2013

ARSET

Apply**R**emote **S**ensing **T**rain**I**ng

A project of NASA Applied Sciences



Objective:

Provide Overview of NASA Remote Sensing Observations-based Flood-related Tools



Outline

- Types of flood monitoring tools -- what are they?
 - *Use of remote sensing and hydrologic models*

- Introduction to global and regional, operational and experimental, near-real time flood monitoring tools
 - *Based on TRMM-TMPA, MERRA, MODIS, AMSR*

Remote Sensing and Flood Monitoring

Basic Concepts

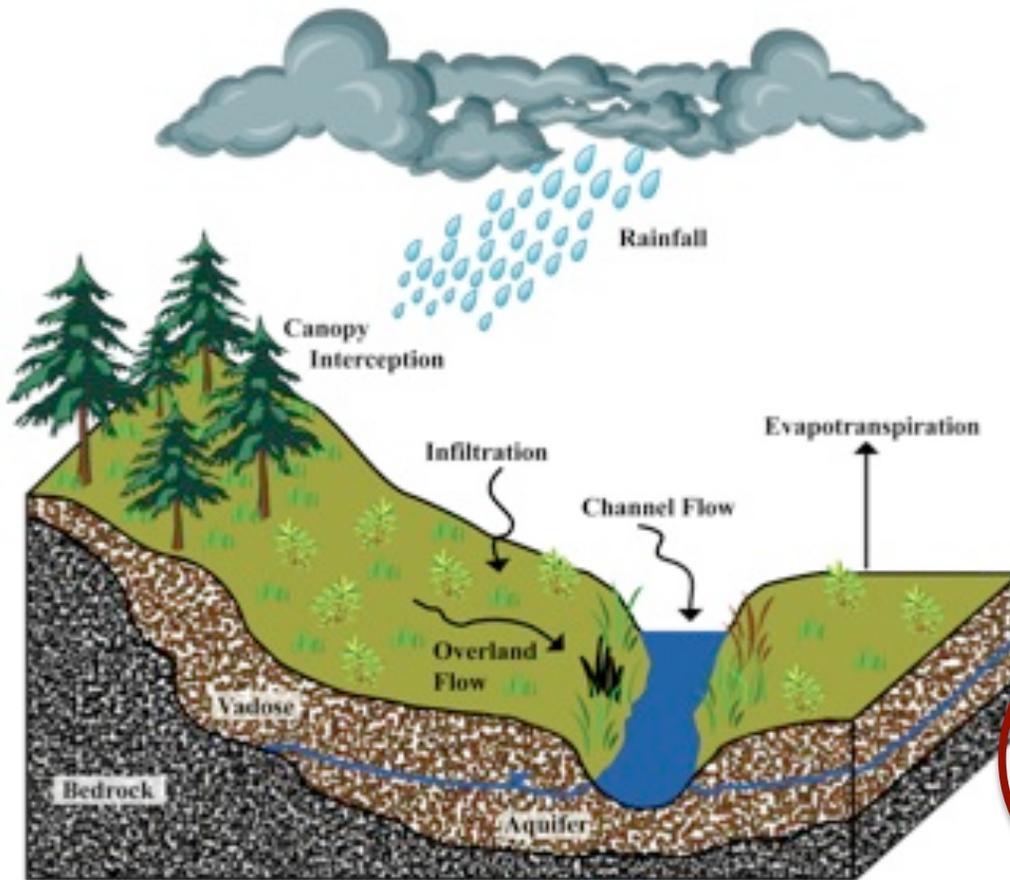
- **Satellite Observations**

- Direct use in detection of surface water/inundation
- In observing flood-related weather quantities : Rainfall, Temperature, Humidity, Winds

- **Hydrologic Models**

- Forced with satellite-based land and atmospheric measurements [rain, air temperature and humidity, wind speed, radiation, vegetation, soil type, terrain]
- Hydrological Models route water within a channel/river basin/watershed region according to the atmospheric and surface conditions, calculation of Streamflow – indicative of flooding conditions

Hydrological Models



Mathematical representation of water cycling processes in the atmosphere-land system

Calculates run-off and streamflow of water -- used in detecting flooding conditions

From Remote Sensing Measurements

for given atmospheric and surface conditions --rain, air temperature and humidity, wind speed, solar radiation, vegetation, soil type, terrain

Streamflow--the water discharge that occurs in a natural channel. Measured in cubic meters per second -- volume of water flowing per unit time (m^3/s)

Web Tools for Flooding Applications

Provide any or all of the following on global and/or regional basis:

- Near-real time flood monitoring: Flood probability/potential, extreme rain, streamflow, inundation extent)
- Flood forecasting: Flood probability/potential, extreme rain, streamflow, inundation extent)
- Information about past flooding events
- Additional information (for example about – weather, land-cover, roads, dams, population density etc.)

Interactive Flood Tools

- NASA-TRMM Current Heavy Rain, Flood, and Landslide Estimates
- **Global Flood Monitoring System (GFMS)**
- **SERVIR Regional Visualization and Monitoring System**
- **Global MODIS Inundation Mapping**
- **Dartmouth Flood Observatory (DFO)**
- Global Disaster Alert and Coordination System (GDACS)/
Global Flood Detection System (GFDS)

All the tools include Interactive Maps and Regional Sub-setting and zooming capability of flooding events

Types of Flood Tools

- Tools based on Remote Sensing observations and Hydrologic Models
- Inundation Mapping Tools based on MODIS
- Experimental Flood Mapping based on Passive Microwave Brightness Temperatures
- Disaster Mapping

Flood Tools Using Remote Sensing and Hydrologic Models



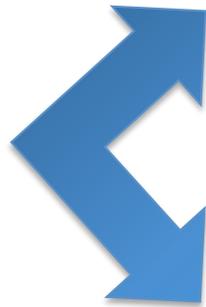
Flood Tool	Satellite/ Instrument Or Model	Quantity Used	Hydrological Model
NASA-TRMM	TRMM/ TMPA-RT	Rain Rate	NRC-CN ¹
GFMS	TRMM/ TMPA- RT MERRA	Rain Rate Surface Temperature Winds	VIC- UMD DRTR ²
DFO	TRMM/ TMI and Aqua/ AMSR-E	37 Ghz Brightness Temperature	Global Runoff Model
SERVIR	TRMM/ TMPA- RT	Rain Rate	CREST ³

¹Natural Resources Conservation Service (NRCS) runoff curve number (CN) method

²The University of Washington Variable Infiltration Capacity (VIC) land surface model coupled with the University of Maryland Dominant River Tracing Routing (DRTR) model

³ The Couples Routing and Excess Storage (CREST) distributed hydrology model

Remote Sensing based Flood Tools



Flood Tool	Satellite/ Instrument	Quantity Used
MODIS NRT	Terra and Aqua/MODIS	Reflectance Bands 1, 2, 7
DFO	Terra and Aqua / MODIS	Reflectance Bands 1, 2, 7
GFDS	TRMM/TMI and Aqua/ AMSR-E	37 Ghz Brightness Temperature
GDACS	TRMM/TMPA	Rain rate
	TerraSAR-X	9.65 Ghz Synthetic Aperture Radar Reflectivity
	SPOT-5 Worldview-1/ 2	Visible/near-IR Images

Information Provided by the Flood Tools

Flood Tool	Rainfall	Flood potential/ Intensity	River Discharge/ Streamflow	Inundation Map
NASA-TRMM	X	X		
GFMS	X	X	X	
SERVIR	X		X	
MODIS/NRT				X
DFO			X	X
GDACS/ GFDS	X	X		X

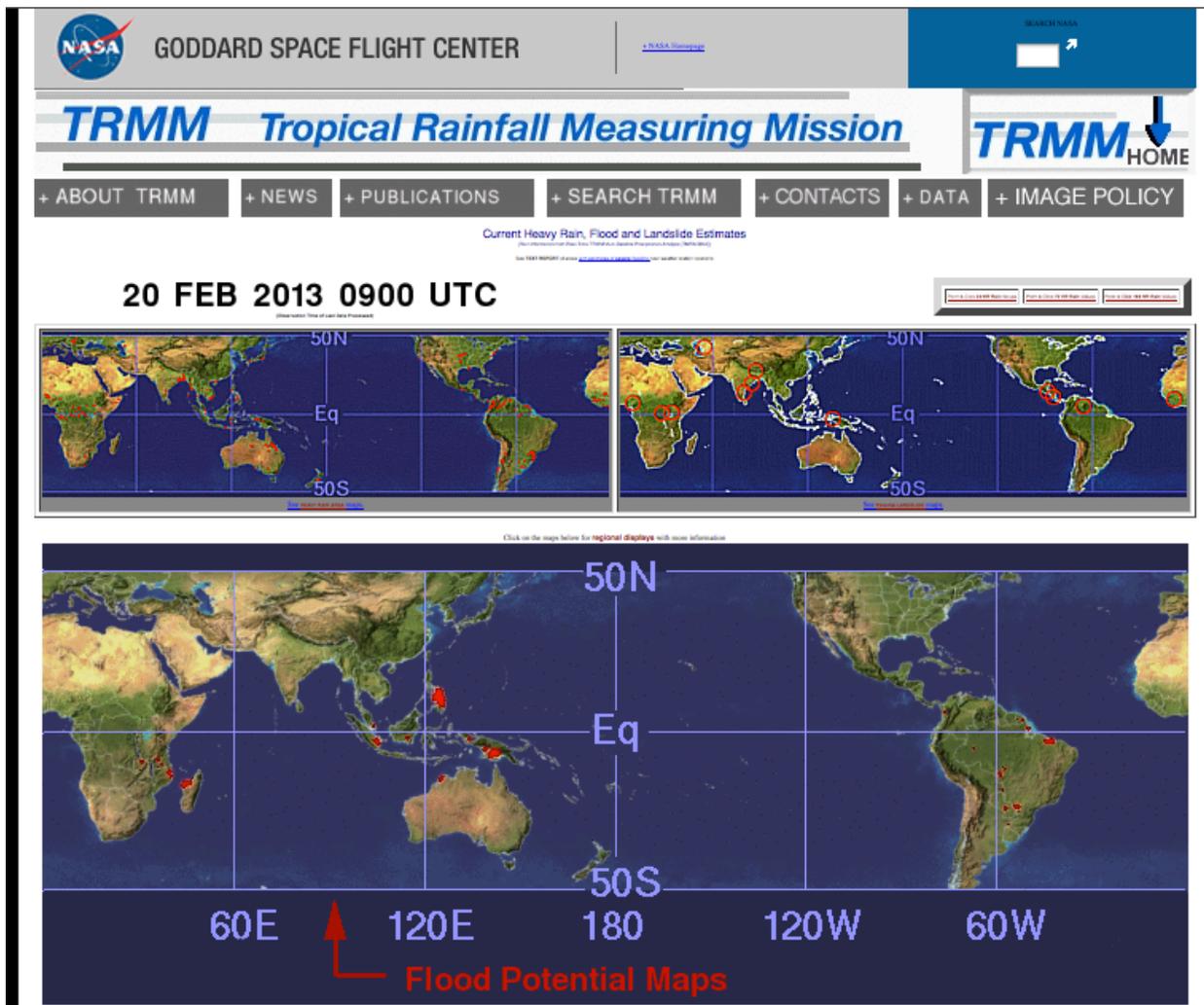
More About the Flood Tools

Flood Monitoring Tool	Spatial Coverage and Resolution	Comment
NASA-TRMM NRT	50°S-50°N 12 Km	Includes GFMS, Landslide Potential
GFMS	50°S-50°N 12 Km	Will be available at 1Km resolution. Predictive capability will be added soon
MODIS NRT	Global 250 M	May not be effective in presence of clouds
DFO	Global 250 m and 10 km	Same as MODIS NRT. River discharge data derived from TMI and AMSR
SERVIR	East Africa 1 km	Regional, Disaster monitoring tool with multiple information layers
GDACS	Global – a few meters to Kms	Disaster Alert tool. Uses US and European satellite images, including commercial satellites. Post-flood images available for selected cases
GFDS	Global 10 km	Flood Potential

Flood Tools based on Remote Sensing-based Quantities and Hydrologic Models

TRMM Near-real Time Flood and Landslide Information Tool

(http://trmm.gsfc.nasa.gov/publications_dir/potential_flood_hydro.html)



TRMM Near-real Time Flood and Landslide Information Tool

(http://trmm.gsfc.nasa.gov/publications_dir/potential_flood_hydro.html)

20 FEB 2013 0900 UTC

(Observation Time of Last Data Processed)

[Point & Click 24 HR
Rain Values](#)

[Point & Click 72 HR
Rain Values](#)

[Point & Click 168 HR
Rain Values](#)



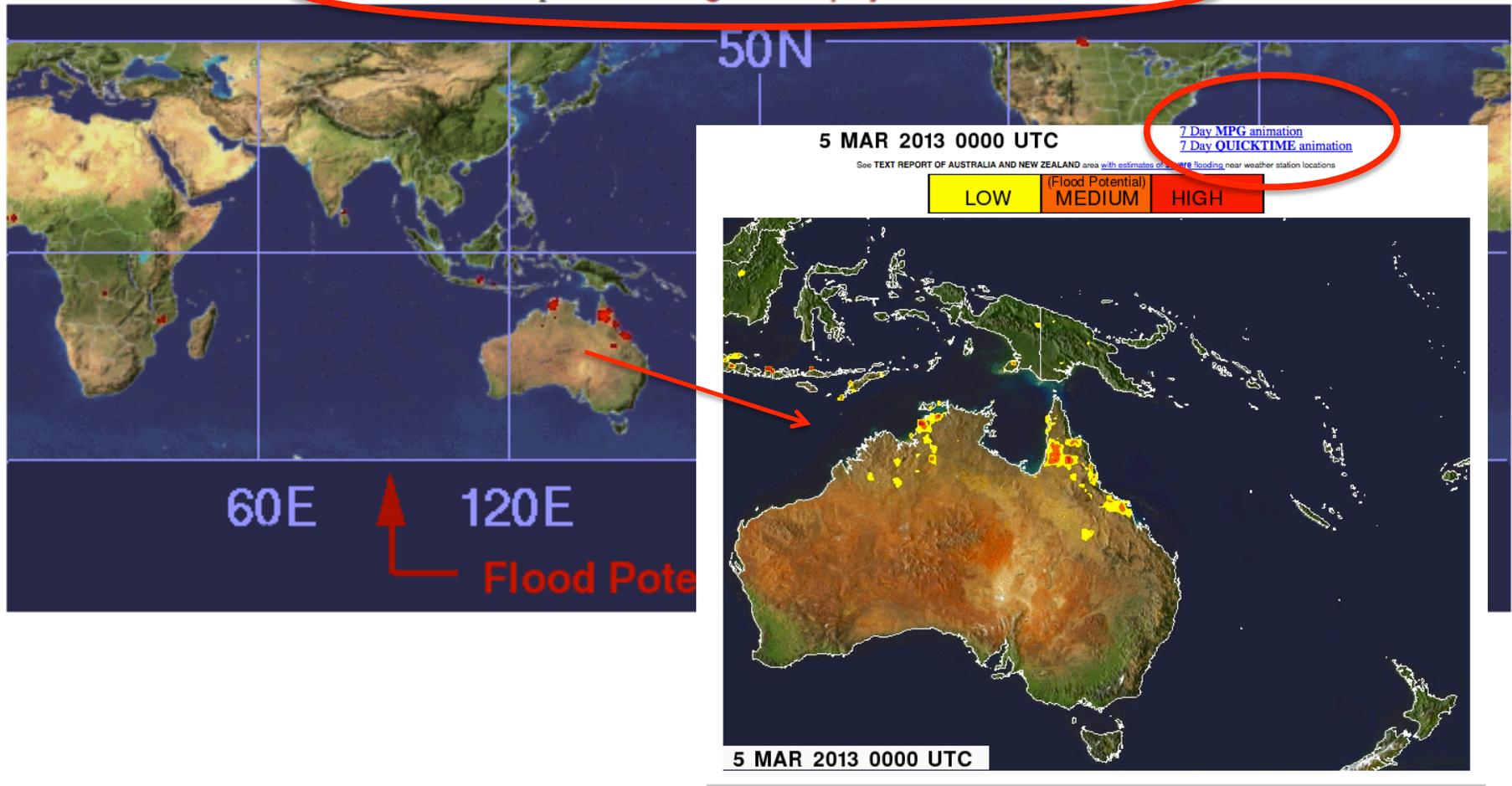
Provides global maps (50°S-50°N) of:

- Heavy rain
- Accumulated rain over 24, 72 and 168 hours
- Potential Landslide

TRMM Near-real Time Flood and Landslide Information Tool

(http://trmm.gsfc.nasa.gov/publications_dir_potential_flood_hydro.html)

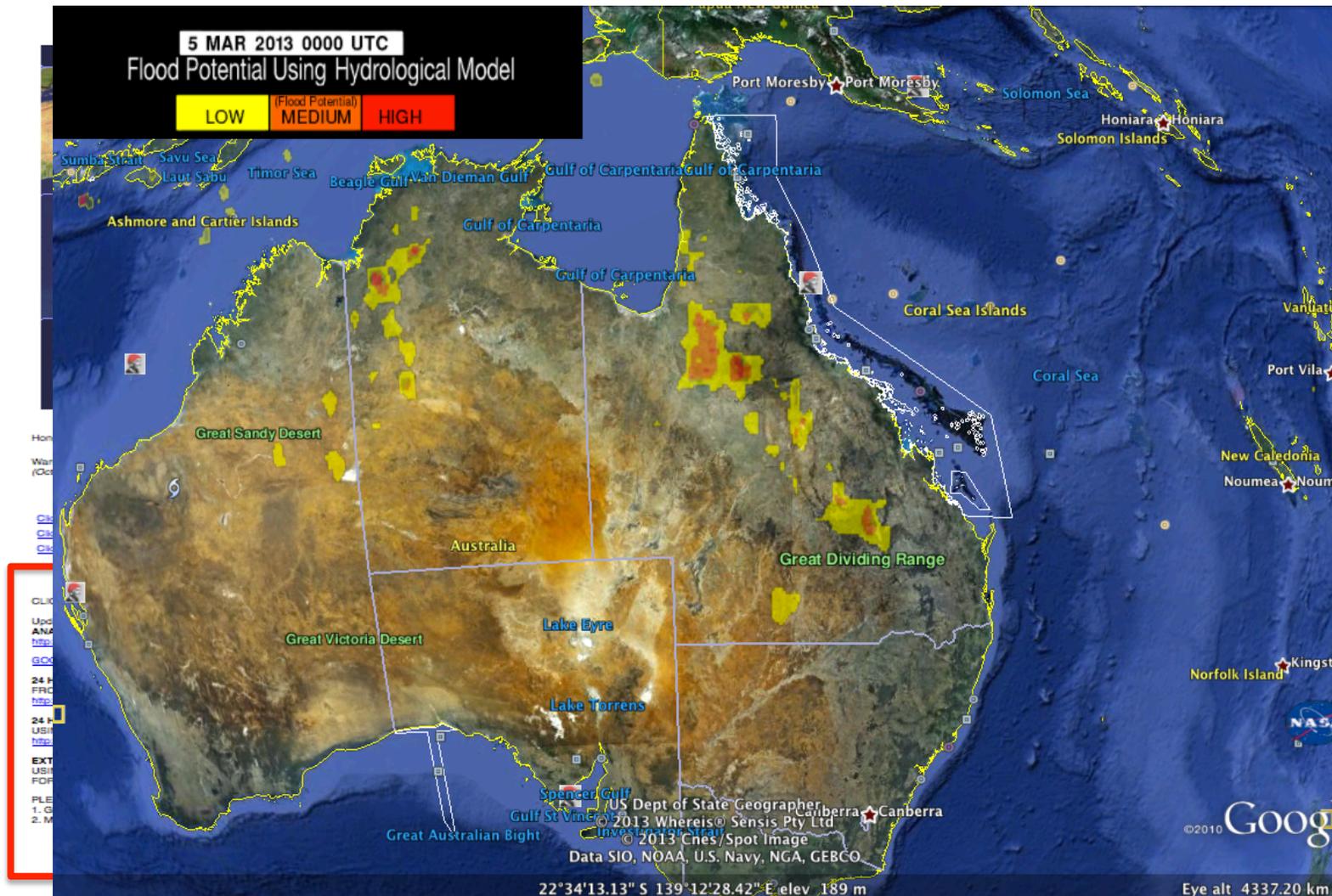
Click on the maps below for **regional displays** with more information



Global and Regional Flood Potential (Low, Middle, and High)

TRMM Near-real Time Flood and Landslide Information Tool

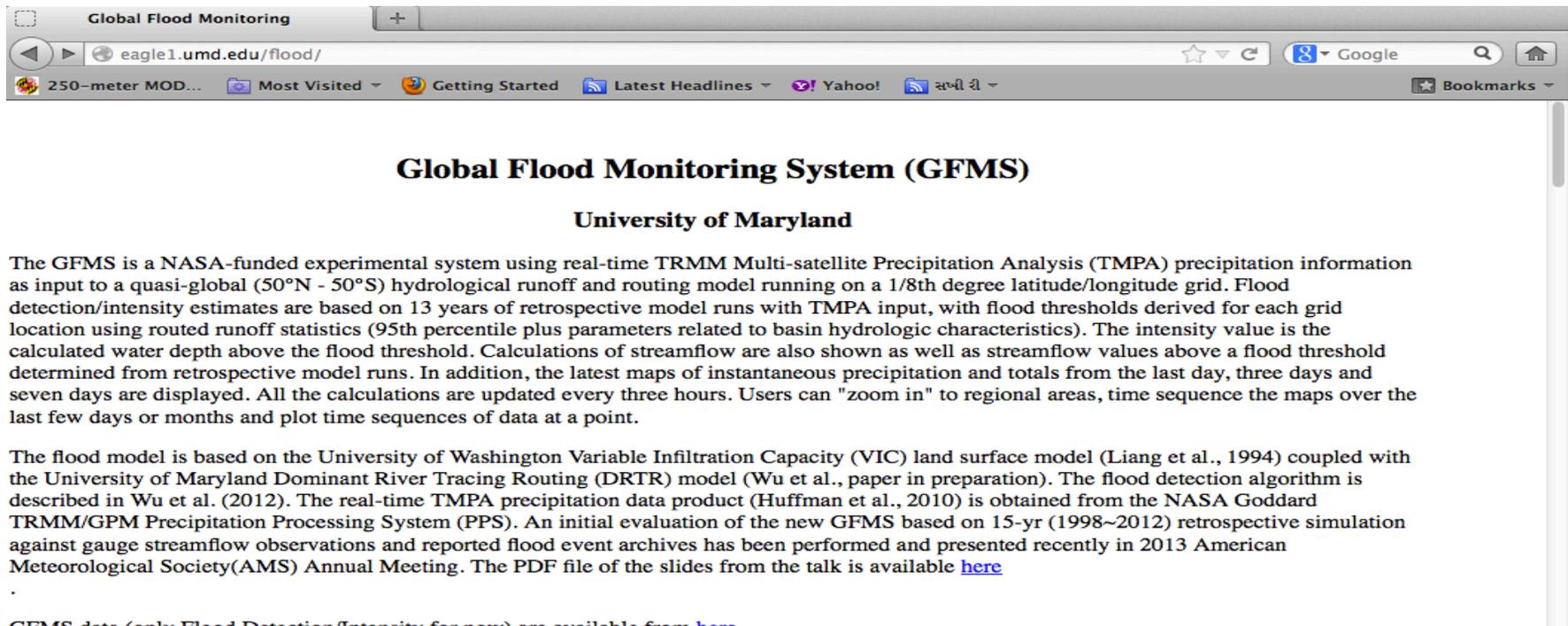
(http://trmm.gsfc.nasa.gov/publications_dir_potential_flood_hydro.html)



Maps available on Google Earth

Global Flood Monitoring System (GFMS)

<http://flood.umd.edu>

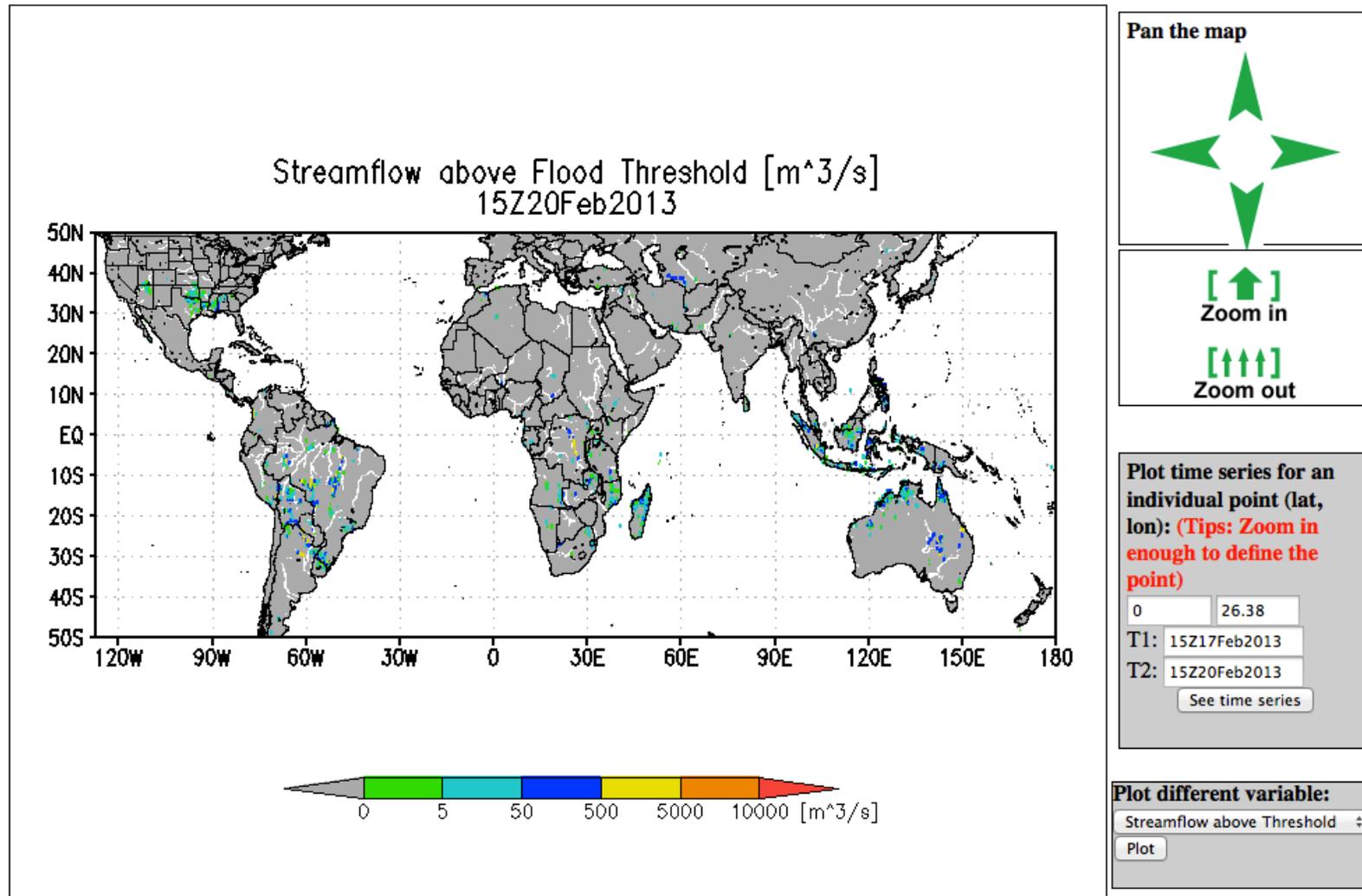


Provides global maps, time series, animation (50°S-50°N) of:

- **Instantaneous Rain**
- **Accumulated rain over 24, 72, and 168 hours**
- **Stream flow rates and flood detection at 1/8th degree (~12 km) grid resolution**

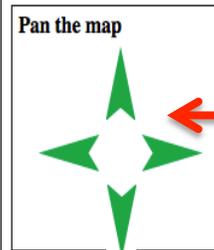
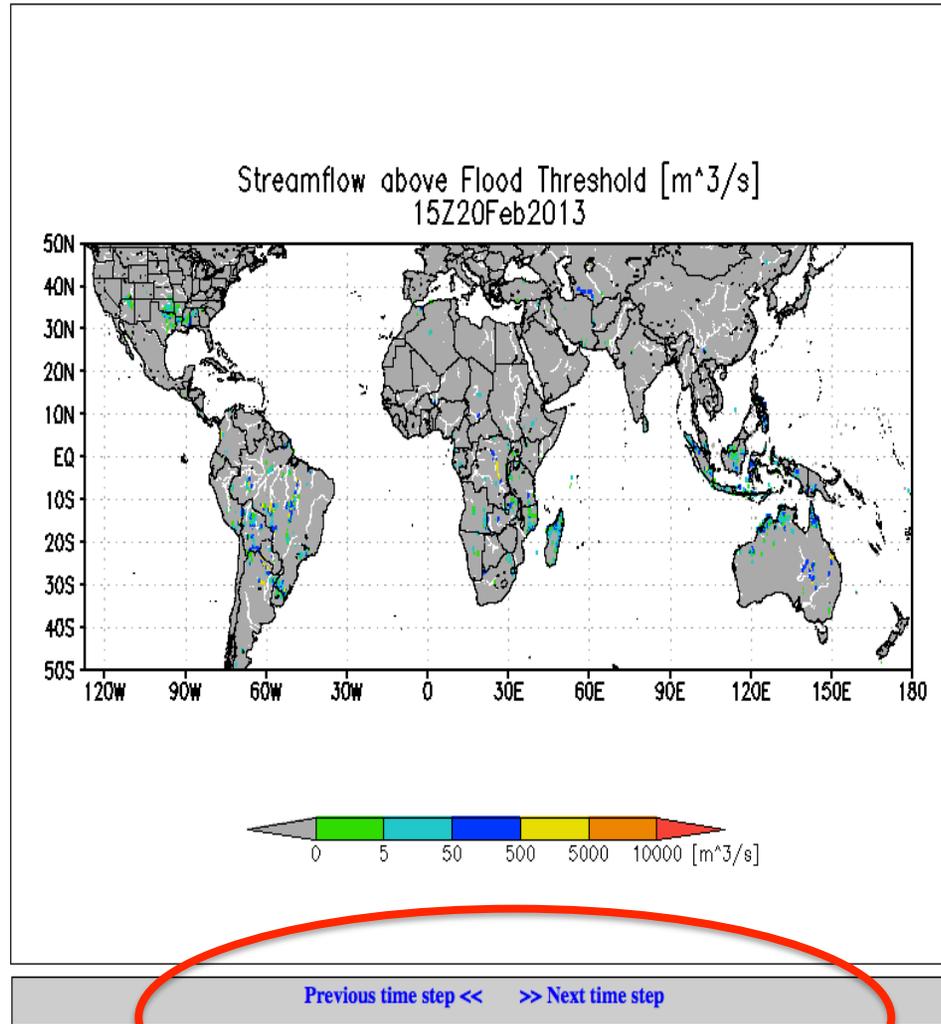
Global Flood Monitoring System (GFMS)

<http://flood.umd.edu>

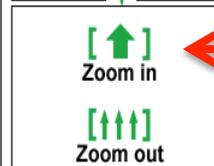


Global Flood Monitoring System (GFMS)

<http://flood.umd.edu>



- Map navigation



- Zoom in/out

Plot time series for an individual point (lat, lon): (Tips: Zoom in enough to define the point)

0 26.38

T1: 15Z17Feb2013

T2: 15Z20Feb2013

See time series

- Select individual grid point for data for time sequence

Plot different variable:

Streamflow above Threshold

Plot

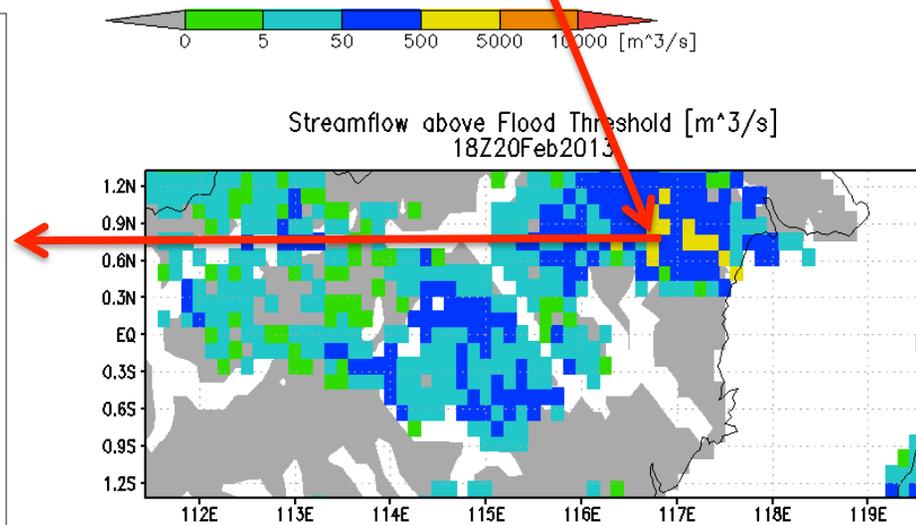
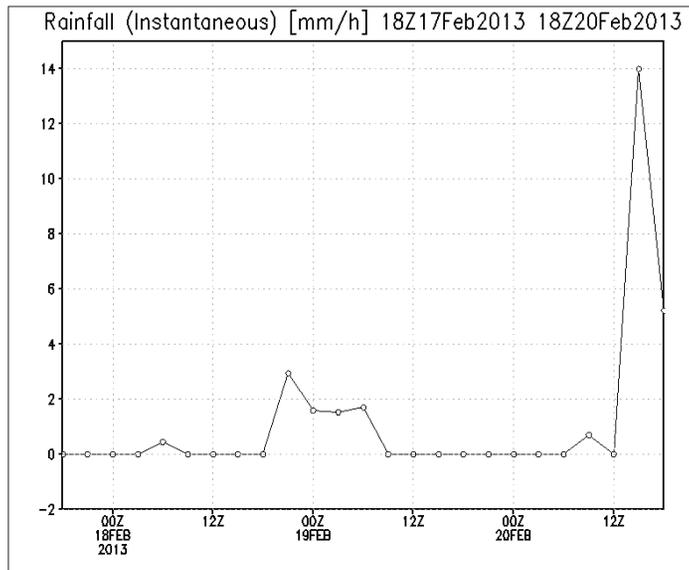
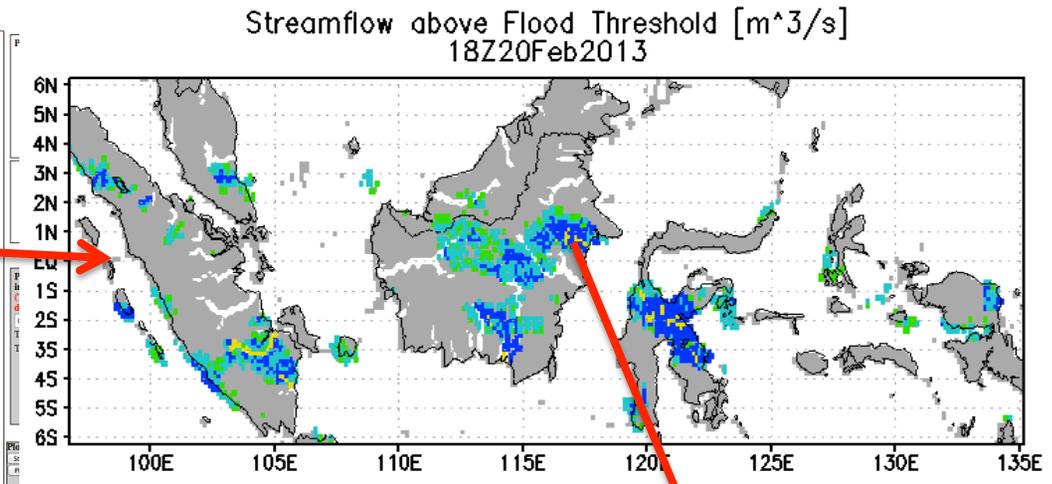
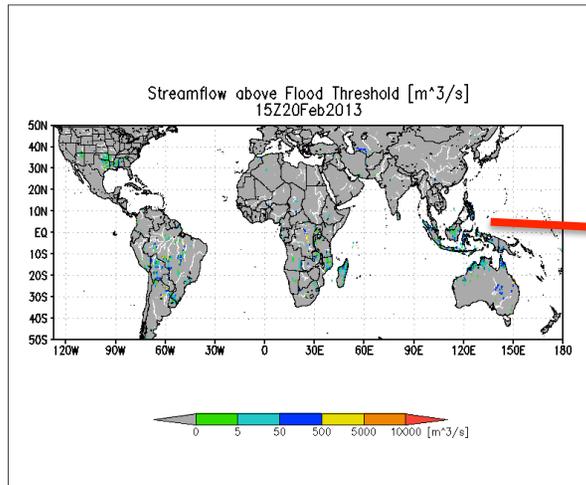
- Plot different variables

Reset

- 3-hourly output

Global Flood Monitoring System (GFMS)

Regional Flood Intensity over Indonesia



SERVIR

(<https://www.servirglobal.net/Global.aspx>)

The image shows a screenshot of the SERVIR GLOBAL website homepage. The browser address bar displays <https://www.servirglobal.net/Global.aspx>. The page features a dark blue header with the SERVIR GLOBAL logo and the tagline "The Regional Visualization and Monitoring System". Logos for USAID and NASA are visible in the top right. A search bar is located below the logos. The main navigation menu includes "GLOBAL", "MESOAMERICA", "AFRICA", "HIMALAYA", and "MyCOE Opportunities". A secondary menu lists "Home", "Our Work", "Maps & Data", "About", "News", and "GEOSS Themes". The central content area features a 3D globe with four colored circles (red, yellow, green, and white) highlighting specific regions. Below the globe are two columns of content: "Success Stories" and "Latest News", each with a "View All" link. The "Success Stories" section includes a photo of a group of people and a headline about a summit in Huntsville, Alabama. The "Latest News" section includes a photo of a satellite launch and a headline about the newest Landsat satellite. A vertical sidebar on the right side of the page is labeled "DISASTER SUPPORT ACTIVITIES" and features a circular logo at the bottom.

SERVIR GLOBAL
The Regional Visualization and Monitoring System

USAID FROM THE AMERICAN PEOPLE NASA

Search This Site... SEARCH

GLOBAL MESOAMERICA AFRICA HIMALAYA MyCOE Opportunities

Home Our Work Maps & Data About News GEOSS Themes

Success Stories View All

Latest News View All

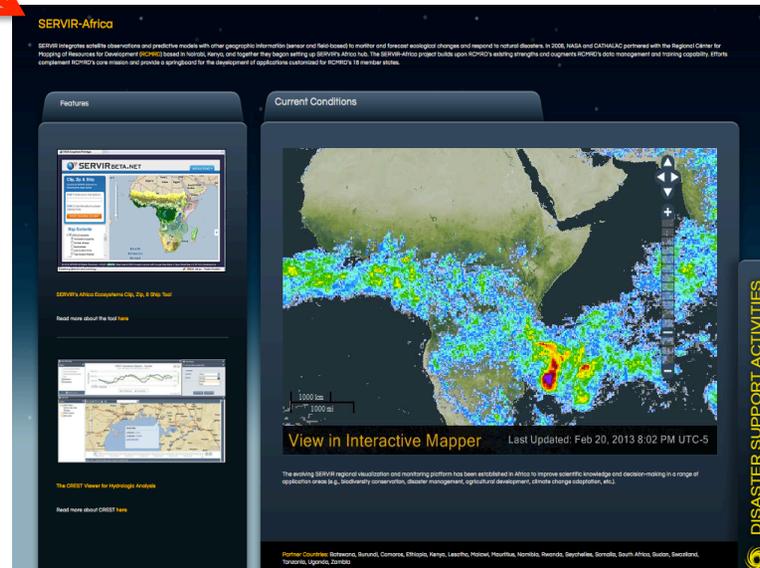
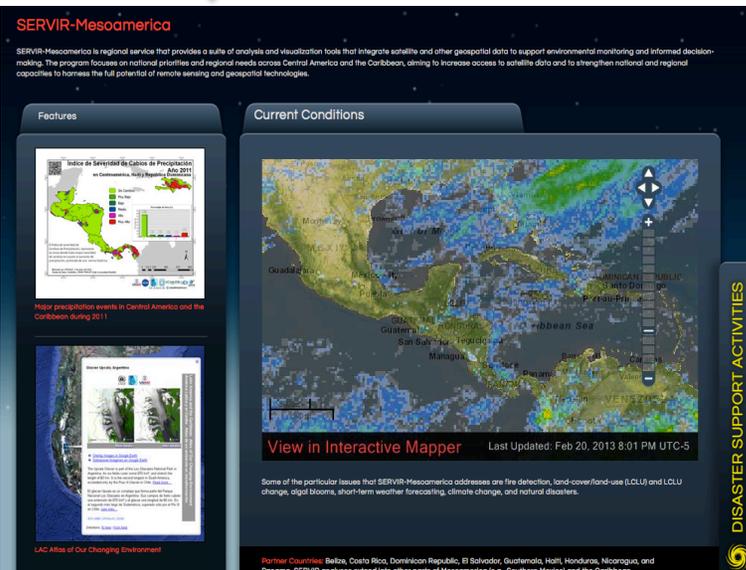
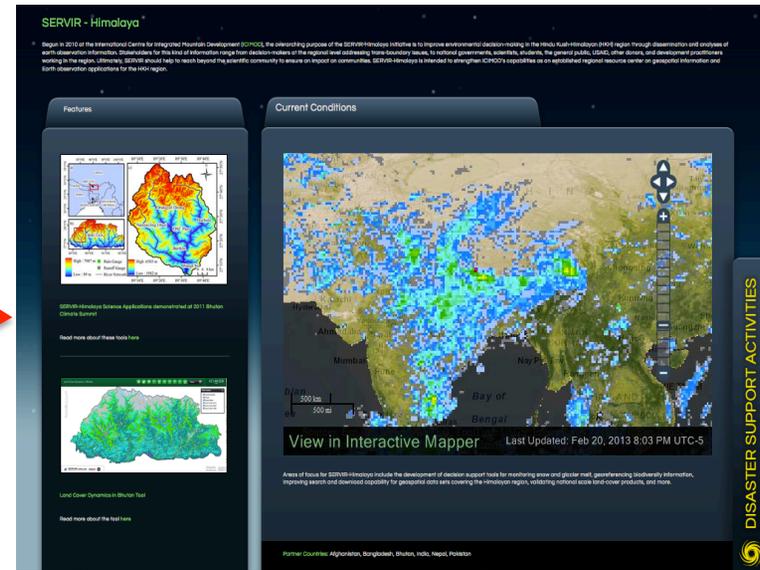
SERVIR's first official summit a success
In a first-of-its-kind five-day summit in Huntsville, Alabama, 15-19 October 2012, SERVIR—the Regional Visualization and Monitoring...

SERVIR team members watch newest Landsat satellite take off
With a picture-perfect launch into the dazzling blue sky on February 11, the newest member of the Landsat family of satellites joined the...

DISASTER SUPPORT ACTIVITIES

SERVIR – Regional

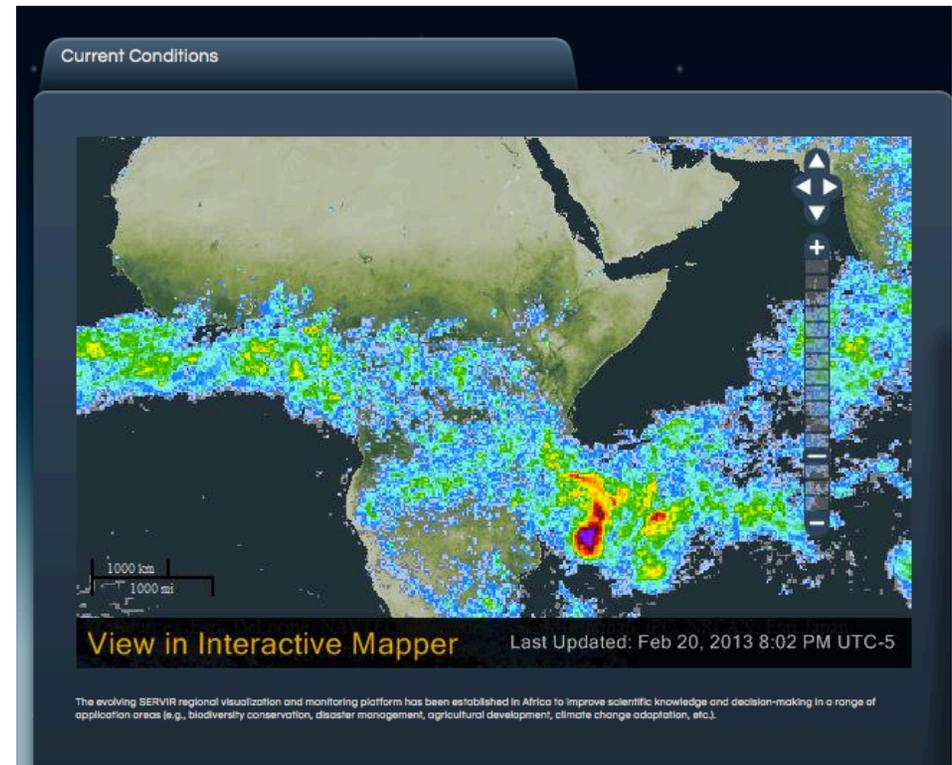
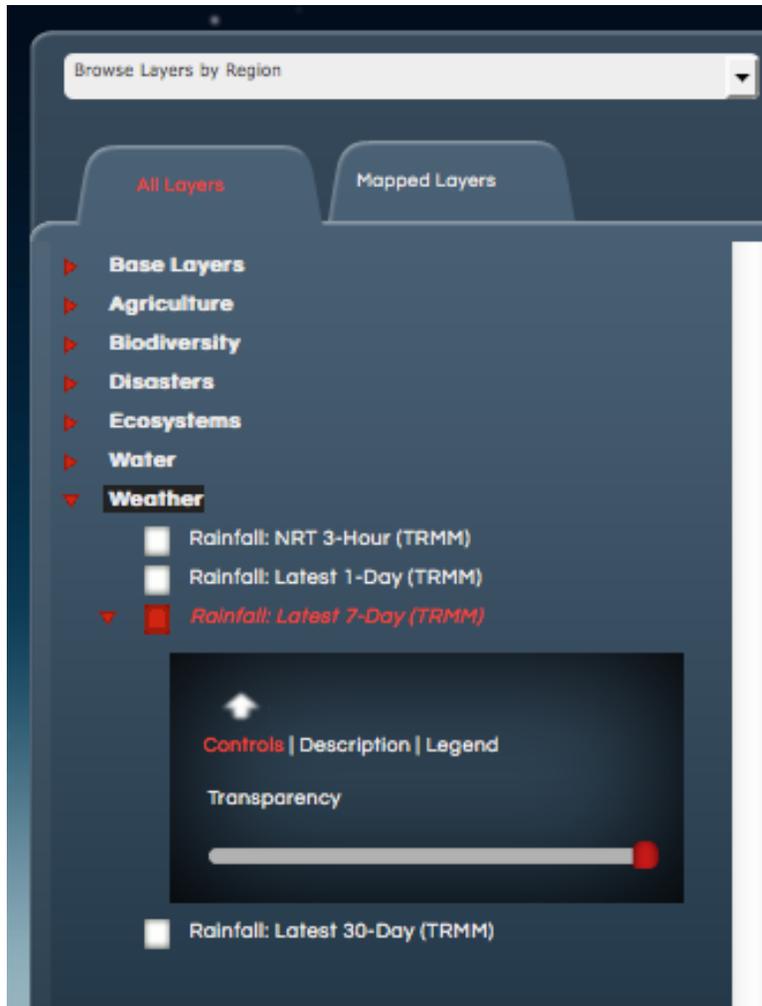
(<https://www.servirglobal.net/Global.aspx>)



SERVIR Regional: More Than Flood Mapping

(<https://www.servirglobal.net/Global.aspx>)

Multiple GIS-based Layers



Interactive Mapping

Inundation Mapping Tools based on MODIS

MODIS Inundation Mapping

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

The screenshot shows the NASA MODIS Inundation Mapping website. At the top left is the NASA logo and the text "National Aeronautics and Space Administration". Below this is a banner image showing a satellite view of a river system with the text "NRT Global MODIS Flood Mapping" overlaid. To the left of the banner are two small inset images: one of a flooded road with a yellow sign and another of a flooded urban area. Below the banner is a navigation menu with links for Home, Algorithm, Product Description, Data Download, Multimedia, Future Upgrades & Enhancements, and News/Status. A "Mailing list" section is also present, with a link to subscribe. The main content area is titled "Global Map" and features a world map with a grid overlay. A legend indicates that blue squares represent "10° Flood Map Tile Production" and orange squares represent "Erroneous flood detected due to low solar zenith angle: interpret with caution!". A red arrow points to a specific tile in the grid, and the text "10°x10°" is displayed below it. At the bottom of the main content area, there is a link for more information: "For more information, please contact floodmap at lists.nasa.gov".

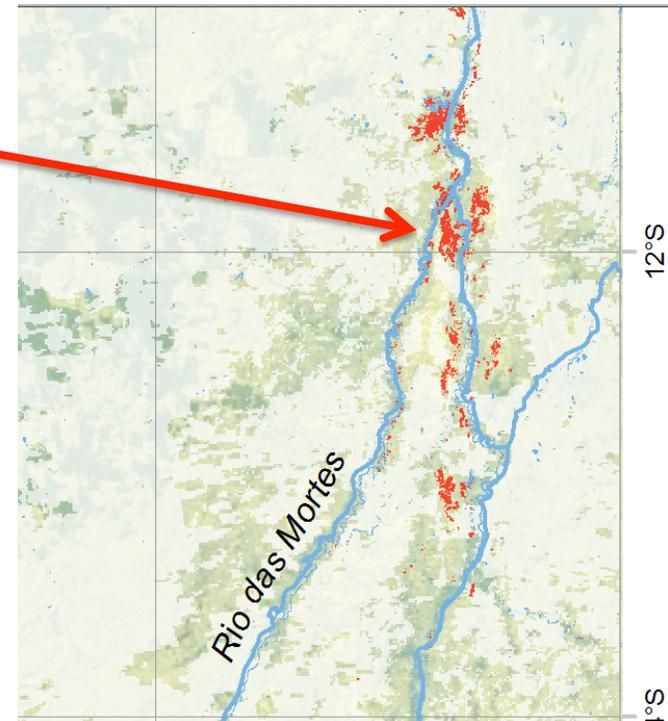
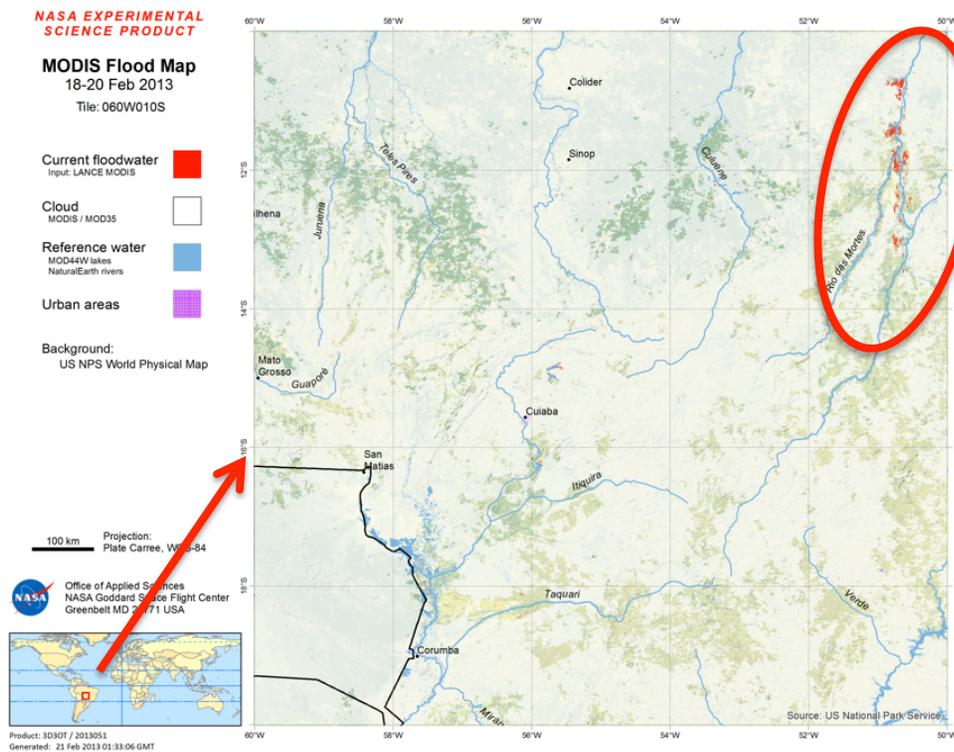
10°x10°

MODIS Inundation Mapping: Zoom on a region

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

Regional Mapping

Pixel size 250 m



MODIS Inundation Mapping

NRT Global MODIS Flood Mapping

Home
Algorithm
Product Description
Data Download
Multimedia
Future Upgrades & Enhancements
News/Status
Mailing list

2 Days Composite | 1 Day Composite

-- June 2012 --
S M T W T F S
3 4 5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23
24 25 26 27 28 29 30

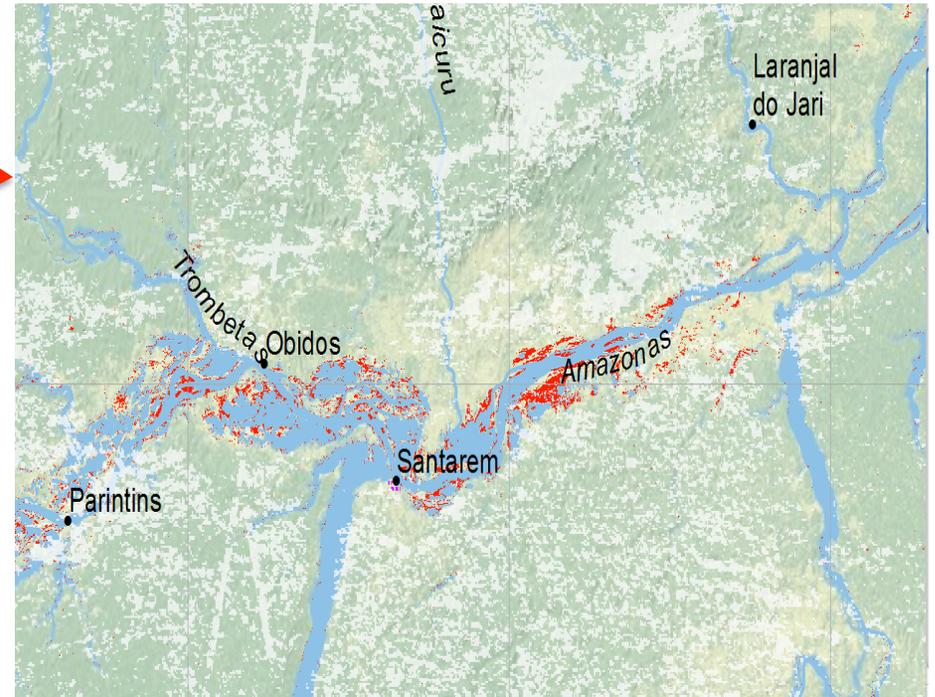
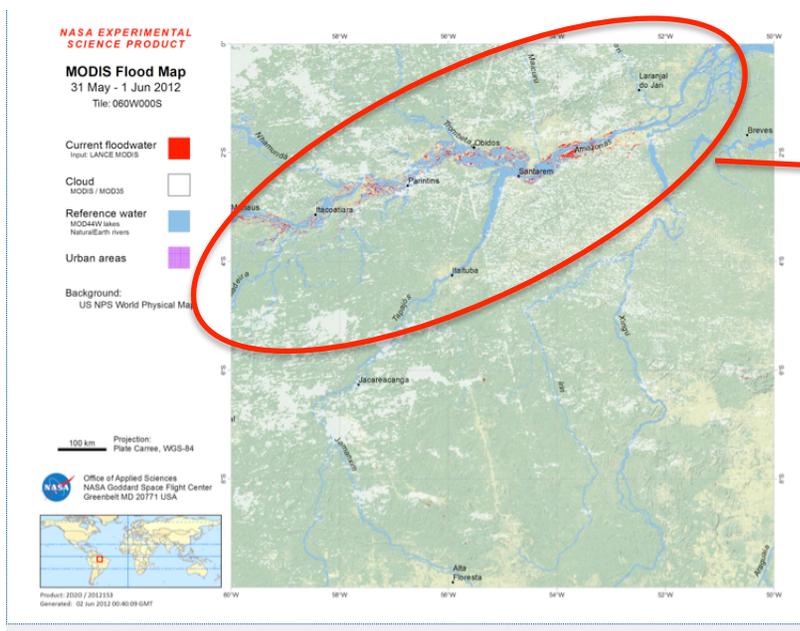
Products	Available Downloads
MODIS Flood Map MFM	png
MODIS Flood Water MFW	shapefile (.zip) KMZ
MODIS Surface Water MSW	shapefile (.zip) KMZ
MODIS Water Product MWP	geotiff
README (for all products)	pdf txt

Check slide show for the last 10 days.

Compass: N, S, E, W

Archive Available

png, kmz, geotiff images available



Dartmouth Flood Observatory

<http://floodobservatory.colorado.edu/>

[Home](#)

[Active
Archive of
Large
Floods,
1985-Present](#)

- [Global
and
Regional
Analyses](#)

[Master Index
of
Inundation
Maps](#)

[The Surface
Water
Record](#)

[River Watch](#)

[Other Flood
Detection
Tools](#)

[Sample
Images and
Maps](#)

**Dartmouth
Flood Observatory**

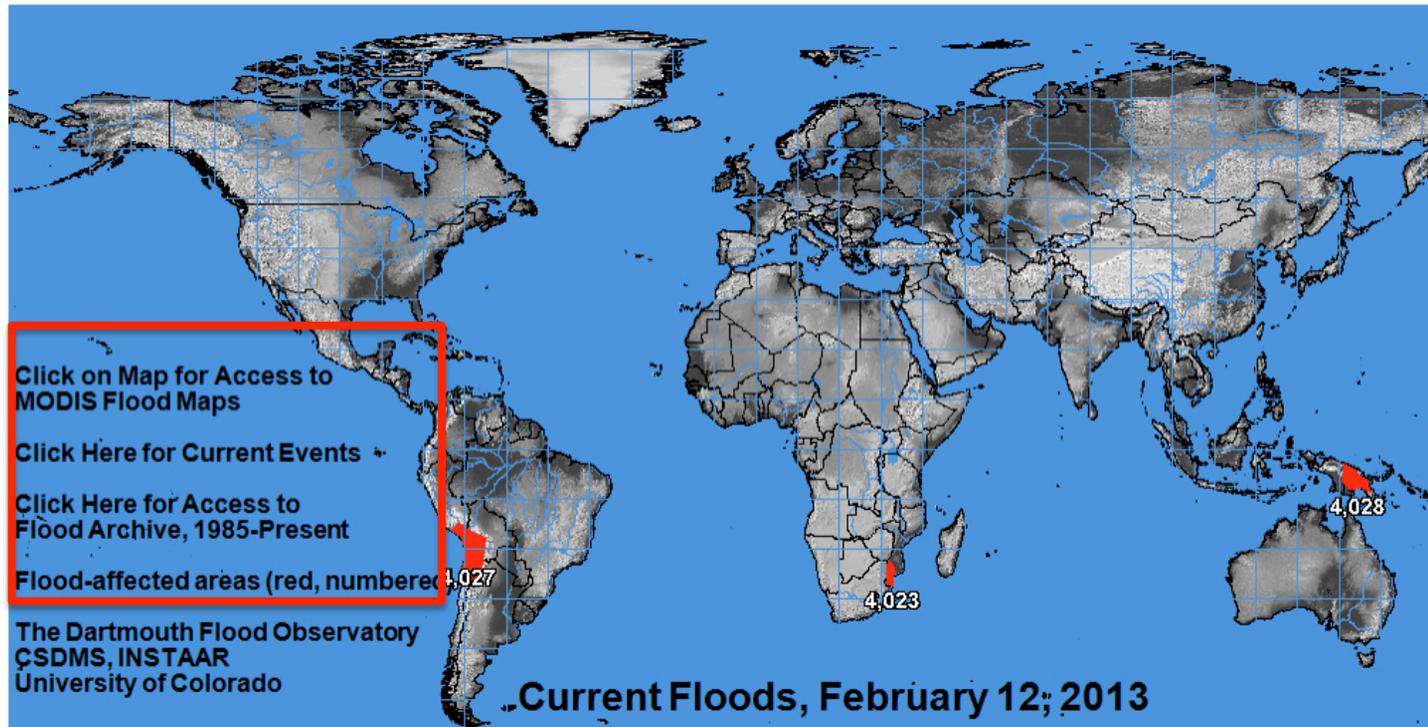
Space-based Measurement and Modeling of Surface Water
For Research, Humanitarian, and Water Management Applications

Flood Observatory Director: [Prof. C. Robert Schwab](#)

[Mission Statement](#)

[Community Surface Dynamics Modeling System](#)
University of Colorado, Campus Box 406, Boulder, CO 80509 USA

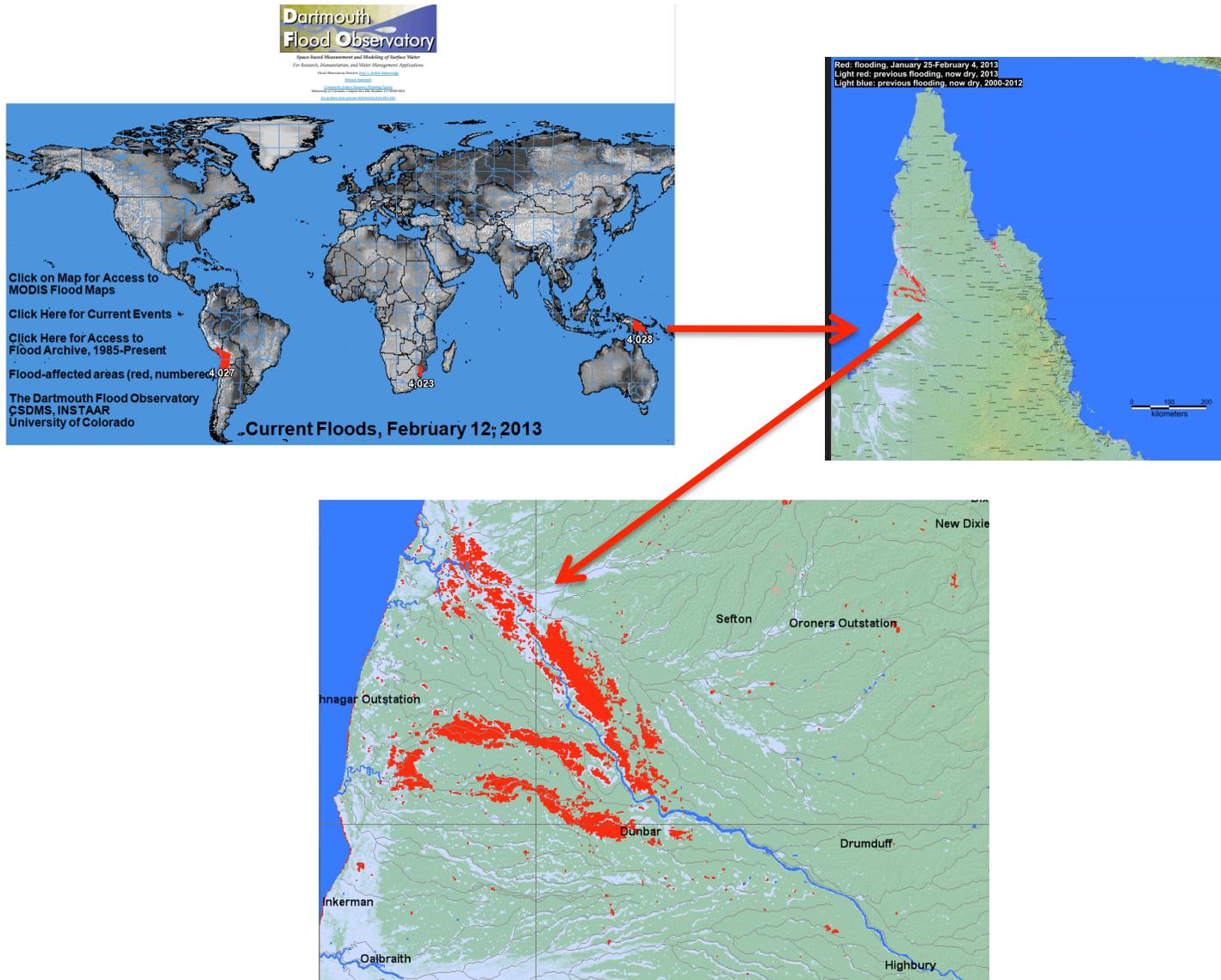
[Get an Access Key and use Information from Web Sites](#)



[Access to Experimental Satellite-based River Discharge Measurements](#)

Dartmouth Flood Observatory: MODIS Flood Mapping

<http://floodobservatory.colorado.edu/>



Experimental Flood Mapping based on Passive Microwave Brightness Temperatures

Dartmouth Flood Observatory: MODIS Flood Mapping

<http://floodobservatory.colorado.edu/>

River Watch Project provides river discharge based on passive microwave remote sensing – TRMM/TMI and AMSR 37 Ghz Brightness temperatures used together with global run off model



140E010S Surface Water Record

This display shows areas of expanded surface water during recent flooding. It also provides the observed history of flooding, commencing in the year 2000. See the [Drought Display](#) for areas of reduced surface water.

Red is most recent flooding mapped. Water areas are accumulated over 10 days to remove obscuration by cloud cover. See also [NRT Global MODIS Flood Mapping](#) for today's two-day composite, including areas of cloud cover. Very recent flooding (past several days) may not appear on this map if cloud cover is heavy.

Light red is previous flooding in the current year.

Light blue is previous flooding since January, 2000.

Dark blue is the reference water (February, 2000, from the [Shuttle Radar Topography Mission Water Body data](#)).

During flood events, and as the extent of lakes, reservoirs, and rivers expand, red areas appear and increase in size. As flooding wanes and floodplains dry, red transitions to light red and then (in the new year) to light blue.

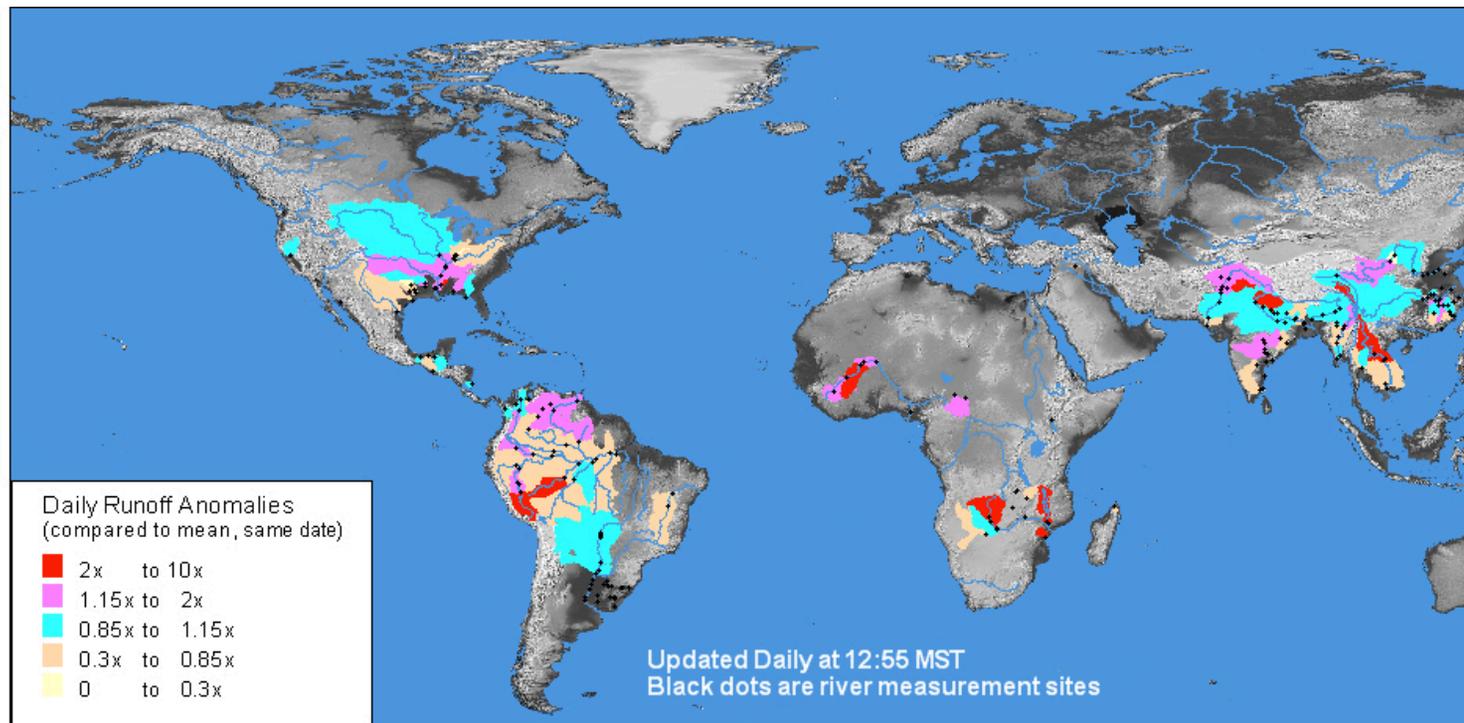
Error notes: 1) In mountainous regions, terrain shadows mimic surface water and are mis-classified as water in our current algorithm. We are working to reduce such noise. 2) Reservoirs and impoundments constructed since yr 2000 appear permanently in red. 3) The observational record illustrated may not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

Other information: See also the [FAQ](#). Any clickable black dots on these displays link to the [River Watch](#) satellite discharge measurement sites. The shaded relief background is from topography provided by NASA SRTM data. Recent GIS data (daily surface water information, as .shp file water boundaries) from the automated MODIS-LANCE NRT Flood processor are located (find appropriate 10 degree folder) at http://cscdm.colorado.edu/pub/flood_observatory/MODISlance/. GIS data (MapInfo format) of the long term record of flooding are also available: [at this location](#). Finally, see the [technical description](#), and the time series of annual flooding via a [powerpoint slide file](#).

Dartmouth Flood Observatory: River Discharge Data

<http://floodobservatory.colorado.edu/>

From Water Balance Model and TRMM/TMI and AMSR-E
Brightness Temperatures



Anomaly : difference from mean value

River Run-off anomalies show where flooding may be occurring

Global Flood Detection System (GFDS)

<http://old.gdacs.org/flooddetection>



Global Flood Detection System - Version 2



An experimental system to detect and map in near-real-time major river floods based on daily passive microwave satellite observations. The purpose is to identify and measure floods with potential humanitarian consequences after they occur.

[Home](#)

[Current floods](#)

[Global map](#)

[Search areas](#)

[Custom areas](#)

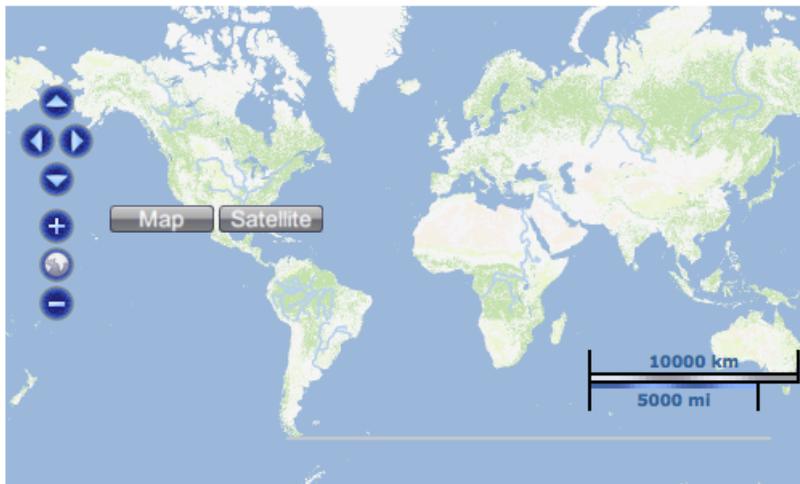
[Regions](#)

[Animations](#)

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[About](#)

maps and animations.



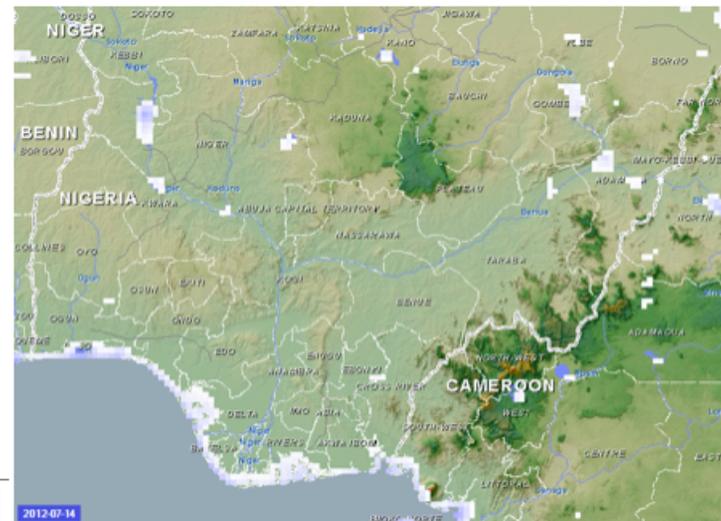
Full map view

[Dfo](#) [Emm](#) [Floods](#)

[Site 2306 in Australia \(on river De Grey\)](#) (10.329374357056: Magnitude detected): [Site 2315 \(Australia\)](#)

[Site 10905 in Democratic Republic of the Congo \(on river Lualaba\)](#) (8.04468607637613: Magnitude detected): [Site 10440 \(River Lualaba\)](#)

GFDS currently monitors around 10000 areas, defined in collaboration with [partners](#). For these areas, the flood signal is further processed to generate time series, flood maps and flood animations. See a full list of [current floods](#) or [search for areas](#) by river, country or name.



All data are available as global raster maps. The brightness temperature measured by AMSR-E and TRMM sensors is normalized into a water signal (showing the amount of surface water in each pixel). For each pixel, anomalies in surface water are calculated by comparing the values to the normal surface water (see methodology). The flood magnitude is defined as the number of standard deviations above the mean.

Global Flood Detection System (GFDS)

<http://old.gdacs.org/flooddetection>



Global Flood Detection System - Version 2



An experimental system to detect and map in near-real-time major river floods based on daily passive microwave satellite observations. The purpose is to identify and measure floods with potential humanitarian consequences after they occur.

Home

Current floods

Global map

Search areas

Custom areas

Regions

Animations

Download

About

10,000 pixel areas covering river basins

End-users can choose areas

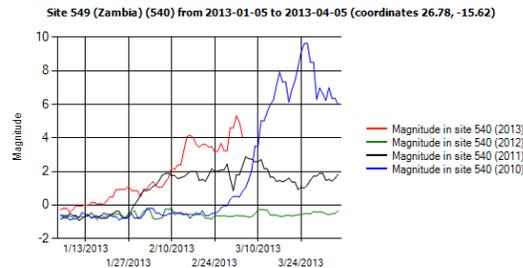
Specific regions

List of floods on the 2013-03-05

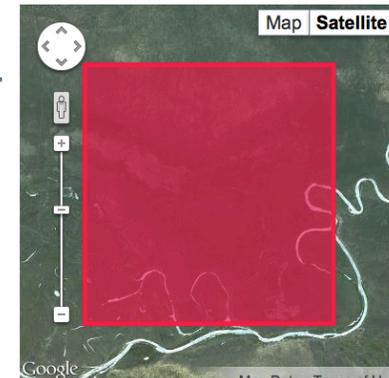
Change date:

- Afghanistan
- Australia
- Bolivia
- Brazil
- China
- Democratic Republic of the Congo
- Global
- Iraq
- Mexico
- Pakistan
- Sudan
- Tajikistan
- USA
- Vietnam
- Zaire
- Zambia

The flood magnitude is a measure of the size of the flood. Since lower signals generally accounts for increased water coverage, extreme events, or major floods, should represent anomalies in the time series of a given site. The reference value for normal flow is calculated as the average signal for the site since June 2002. Flood magnitude is defined as the number of standard deviations (sd) from the mean (avg). [Read more...](#)



[Customize this graph](#) | [Download data:](#)



Site coordinates: Latitude:-14.57, Longitude:27.82. See on [Google Maps](#).

Global Flood Detection System (GFDS)

<http://old.gdacs.org/flooddetection>

Flood status report for Bangladesh



Status: **Green**. Current satellite observations show 4 out of 125 areas (3%) having critically high flood magnitude.

The Bangladesh monitoring region consists of 125 areas that are analyzed daily, including the following rivers: **Meghna, Ganges, Brahmaputra, Bramaputra, Bramaputra Trib.**

Flood status report for Bangladesh automatically created on 3/5/2013 8:25 AM.

Select another monitored region:

Bangladesh

This report does not provide early warning or forecasting information, but describes the current flood status of rivers based on the past 24h of satellite observations.

The status is determined by the number of areas with high flood magnitude (see below), as determined by the Global Flood Detection System based on passive microwave satellite observations of surface water. The status is set to "Red" if more than 10 areas or more than 30% of areas have high flood magnitude. The status is set to "Orange" if more than 5 or more than 10% of areas have high flood magnitude. Otherwise, the status is set to "Green".

Current Status of monitoring areas

Legend: green = no flood, orange = magnitude > 2 (small potential flood), red = magnitude > 4 (potential flood with high return period)



Large Flood Potential

Disaster Mapping Tool

Global Disaster Alert and Coordination System (GDACS)

(<http://www.gdacs.org/>)

The screenshot displays the GDACS website interface. On the left, there is a 'Latest disaster alerts' section with a yellow header and RSS icon. It lists earthquakes and tropical cyclones. The 'TROPICAL CYCLONES' section includes:

- EIGHTEEN-13** Off shore (130.4km/h) 24 Feb 12:00UTC
- RUSTY-13** Australia (175.4km/h) 24 Feb 12:00UTC
- HARUNA-13** Madagascar (185.1km/h) 24 Feb 12:00UTC
- TWO-13** Off shore (46.7km/h) 21 Feb 06:00UTC

Below this is a section for 'Disasters in past 4 days' with links to 'See smaller and archived alerts...', 'Search alerts...', 'About thresholds and models', and 'About earthquake selection'.

In the center, there is a 'map of latest disaster alerts' showing a world map with green boxes indicating earthquake locations.

On the right, there is an 'OPEN EMERGENCIES' section featuring 'Tropical Cyclone Haruna 21-Feb' updated on 24-Feb-2013.

At the bottom right, a 'More...' menu is circled in red, listing several services:

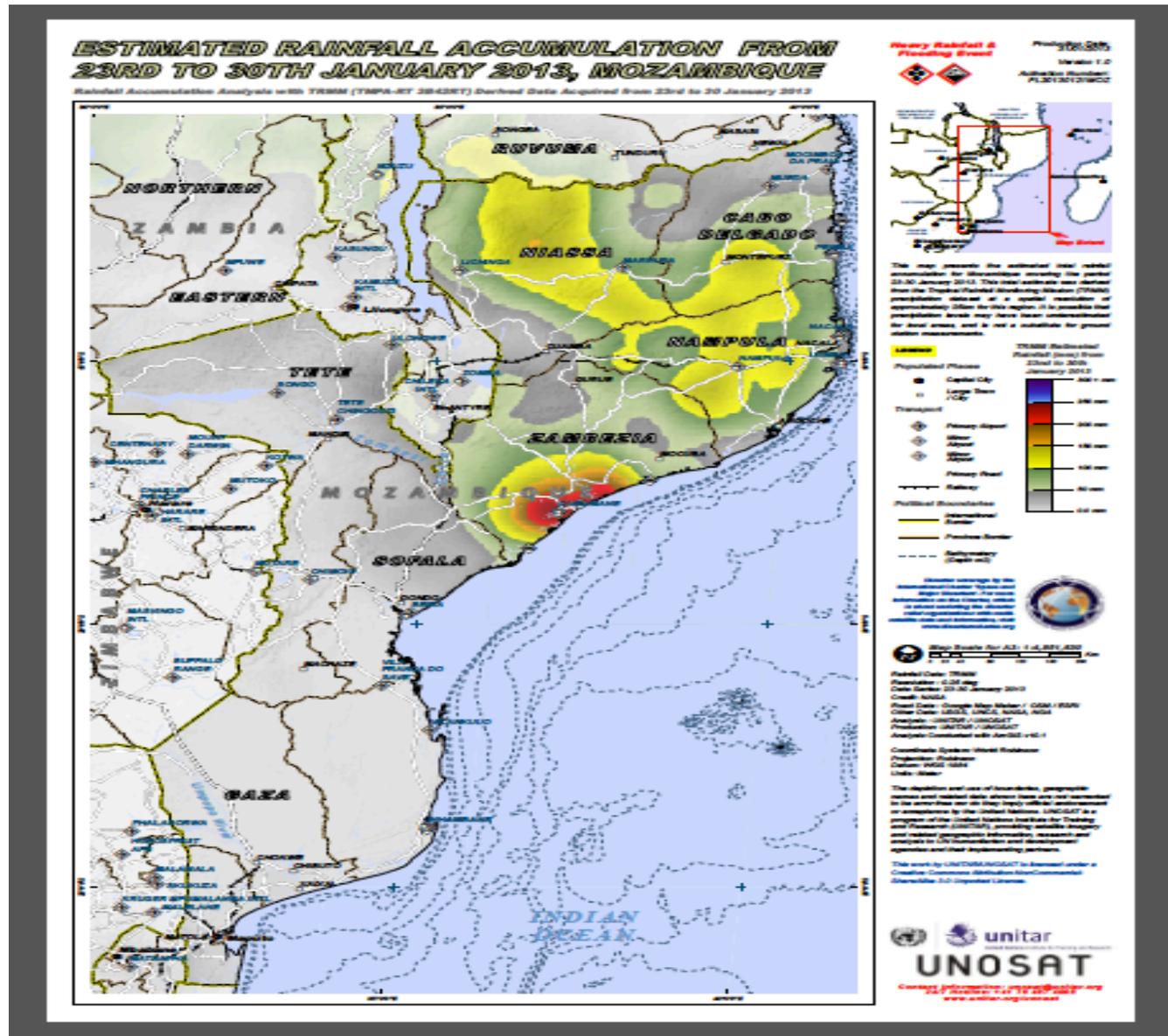
- [Satellite maps](#). Rapid post-disaster maps from various sources.
- [Global Flood Initiative](#)
- [Beta products](#). Social media, flood monitoring
- [GDACS platform](#). Resources for developers
- [GDACS monitor](#). View for operation rooms

At the bottom of the map area, a note states: 'Disaster alerts in the past 4 days. Last 24 hours events are highlighted in yellow. Small earthquakes are shown as green boxes.'

Cooperative effort between the United Nations, the European Commission and disaster managers worldwide

Global Disaster Alert and Coordination System (GDACS)

TRMM/TMPA Accumulated Rainfall over Mozambique 23-30 January 2013



Global Disaster Alert and Coordination System (GDACS)

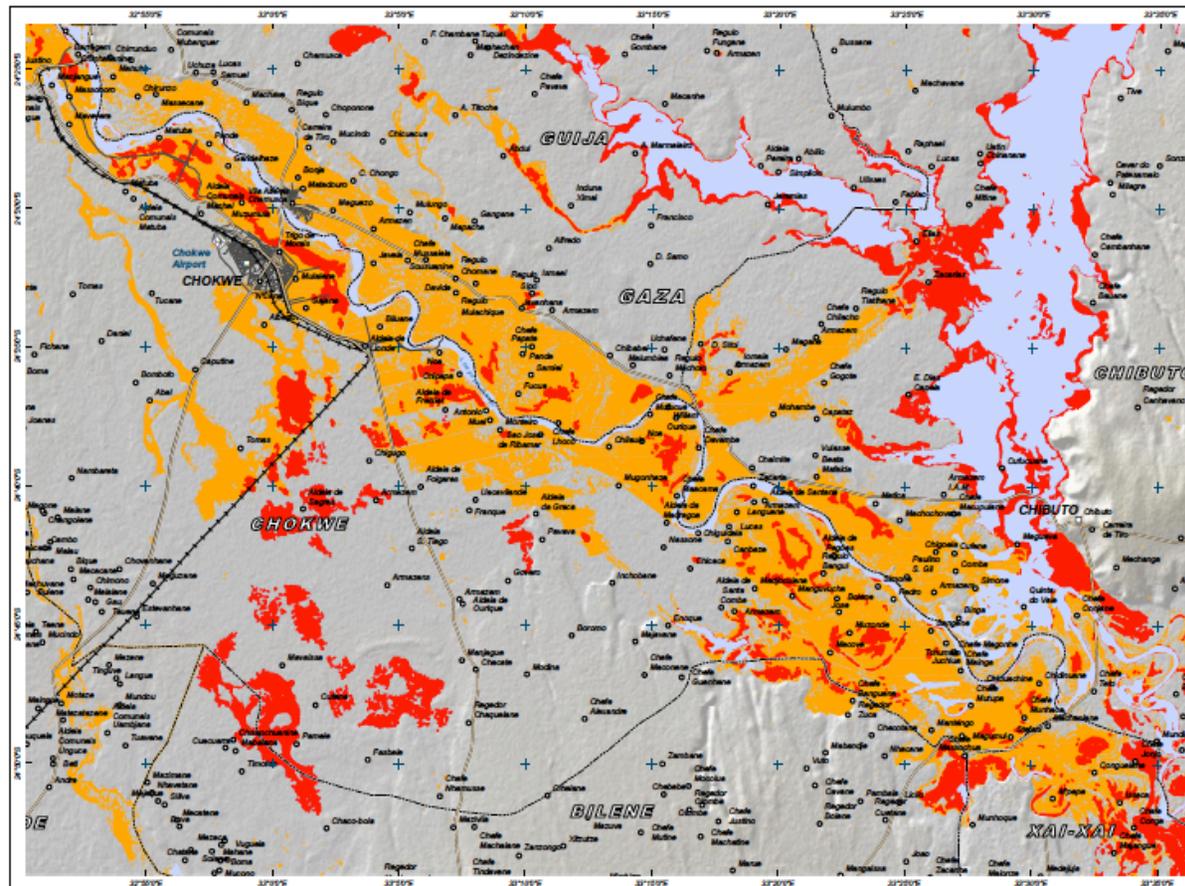
Flood Water Extent over Mozambique 24 January and 2nd February From Radasat-2 and TerraSAR-x

UPDATE 1: FLOOD WATERS OVER CHOKWE, GUIKA, BILENE, AND XAI-XAI DISTRICTS, GAZA PROVINCE, MOZAMBIQUE

Analysis with Radarsat-2 Data Acquired 2 February 2013 and TerraSAR-X Data Acquired 24 January 2013

This map illustrates satellite-detected flood waters along the Limpopo River in the Gaike and Chokwe division of Gaza Province, Mozambique, as detected by Radarsat-2 imagery acquired 2 February 2013 and compared to SPOT-5 imagery acquired 24 January 2013. This analysis indicates floodwaters have receded considerably as of 2 February 2013. While several villages are still partially inundated by flood waters, these have decreased considerably in recent days. Sections of road remain potentially affected or flooded, though are likely to become accessible as the water levels continue to recede. This analysis has not yet been validated in the field. Please send ground feedback to UNSTAR/UNOSAT.

Disaster coverage by the International Charter 'Space and Major Disasters'. For more information on the Charter, which is about seeking the disaster relief organizations with satellite data and information, visit www.spaceanddisasters.org



- LEGEND**
- City
 - Town
 - Airport
 - District
 - International Border
 - Primary Road
 - Local Road
 - Railroad

FLOOD WATER EXTENT ANALYSIS
(Satellite-Based Classification)

- Probable Standing Flood Waters: Radarsat-2 2 Feb 2013
- Probable Standing Flood Waters: TerraSAR-X 24 Jan 2013
- Pre-Cross Water Extent

Map Scale for A3: 1:235,370

Scale: 0 1 2 3 4 5 6 7 8 9 10 Km

Satellite Data (1): Radarsat-2
Imagery Date: 2 February 2013
Resolution: 28 m
Copyright: CSA
Source: Canadian Space Agency

Satellite Data (2): TerraSAR-X
Imagery Date: 24 January 2013
Resolution: 3.25 m
Copyright: DLR
Source: DLR
Road Data: Google Map Maker / OSM / ESR
Other Data: USGS, UNCS, NASA, NGA
Analysis: UNSTAR / UNOSAT
Production: UNSTAR / UNOSAT
Analysis conducted with ArcGIS v10.1
Coordinate System: WGS 1984 UTM Zone 36S
Projection: Transverse Mercator
Datum: WGS 1984
Units: Meter

The depiction and use of boundaries, geographic names and related data shown here are not warranted to be accurate nor do they imply official endorsement or acceptance by the United Nations. UNOSAT is a program of the United Nations Institute for Training and Research (UNITAR), providing satellite imagery and related geographic information, research and analysis to UN humanitarian and development agencies and their implementing partners.

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Summary

- Several global and regional flood monitoring tools available based on NASA remote sensing observations
- Most tools have interactive, near-real time flood mapping – flood potential, streamflow/run-off, or inundation
- Tools vary in spatial/temporal extent and resolution
- Regional usage and evaluation by end-users very important

Thank You!

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