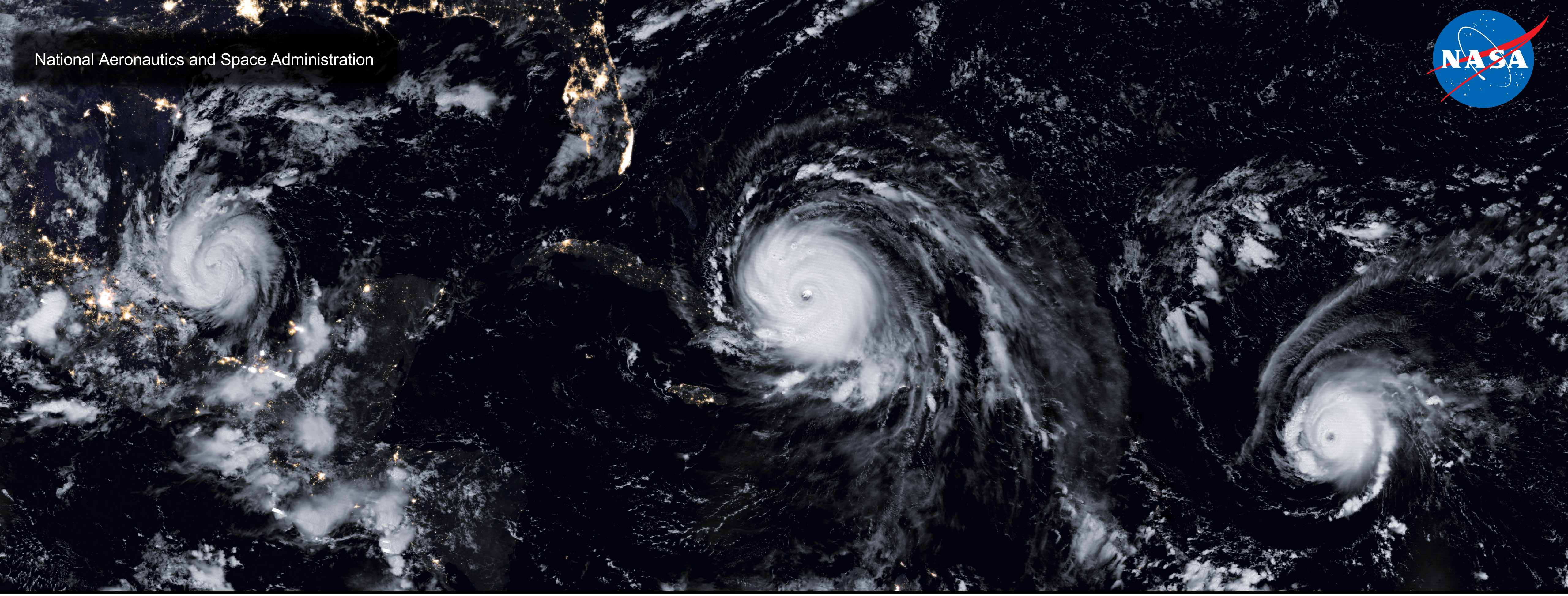


Monitoring Tropical Storms for Emergency Preparedness

Amita Mehta

May 10, 2018

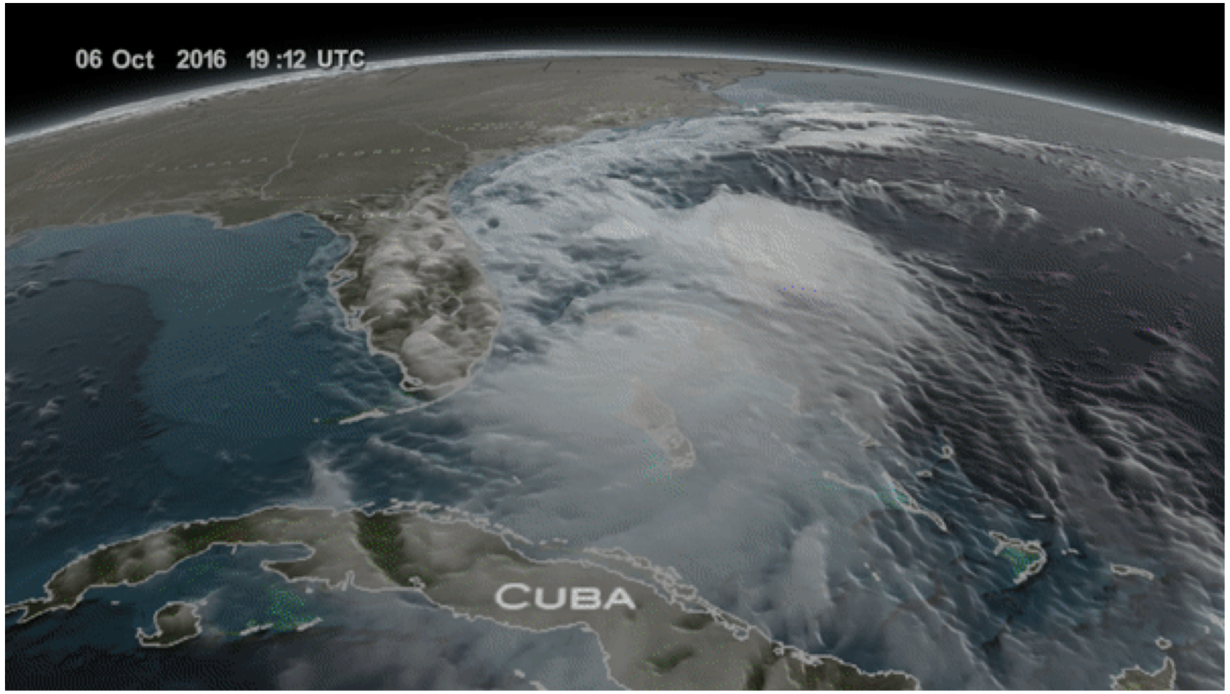
Course Outline

May 3

Overview of Tropical Storms and Their Impacts

May 10

Monitoring Tropical Storm Conditions During and After Storms



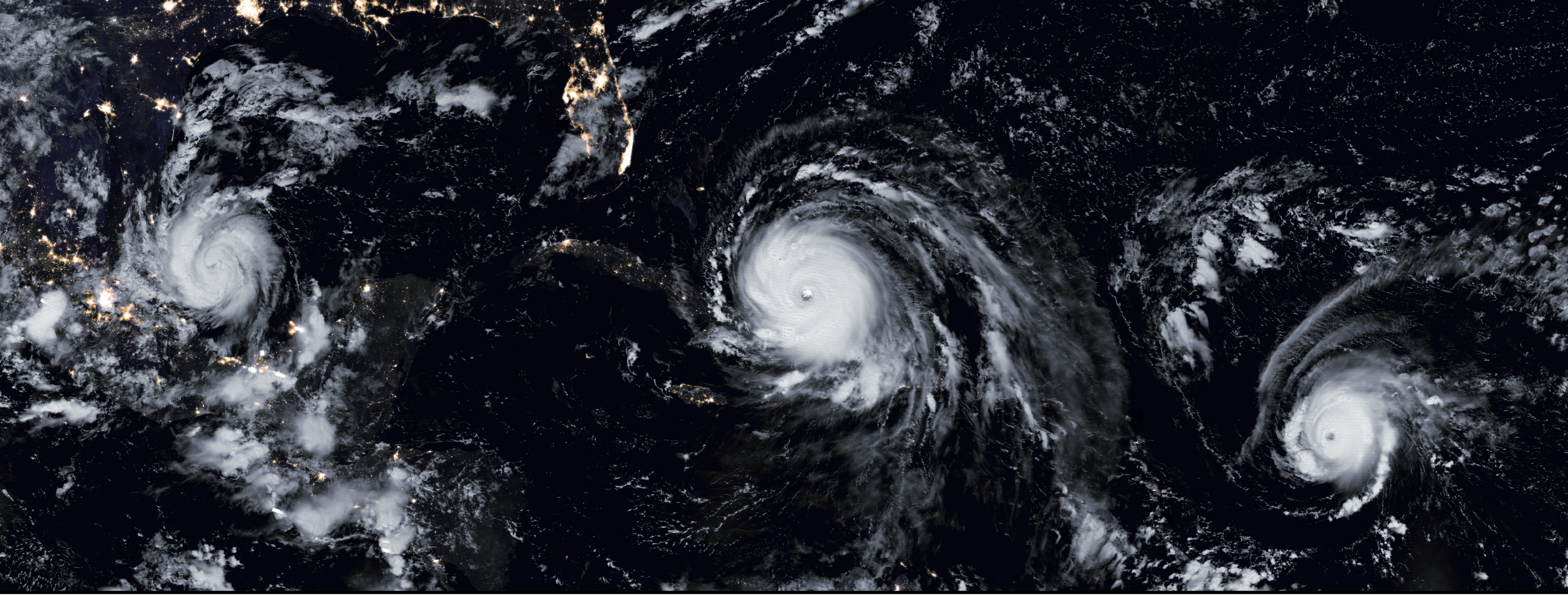
In this animation Hurricane Matthew travels up the east coast from Florida to the Carolinas. On October 8, 2016 Matthew (still a category 2 hurricane) dumps massive amounts of rain throughout the southeast dousing North and South Carolina.

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 (31 May 2018)
  - You will receive certificates approx. two months after the completion of the course from: marines.martins@ssaihq.com

Outline For Session 2

- Review from Session 1
- Monitoring Winds, Precipitation, Storm Surge
- Monitoring Flooding During and After Storms for Emergency Response and Relief Planning
  - Extreme Rainfall Detection System (ERDS)
  - Global Flood Monitoring System (GFMS)
  - The Flood Observatory
  - MODIS NRT Flood Mapping
  - Synthetic Aperture Radar Imagery
- Examples of NASA Remote Sensing Data Applications
- Demonstration of Case Studies: Hurricane Harvey



Review From Session 1

Tropical Cyclone Intensity

https://www.nhc.noaa.gov/climo/

- **Tropical Depression**
  - tropical cyclone with maximum sustained winds of 38 mph (61 km/h, 33 kt) or less
- **Tropical Storm**
  - tropical cyclone with maximum sustained winds of 39 to 73 mph (62-117 km/h, 34-63 kt)
- **Hurricane or Typhoon**
  - tropical cyclone with maximum sustained winds of 74 mph (119 km/h, 64 kt) or higher
  - in the western North Pacific, hurricanes are called typhoons – similar storms in the Indian Ocean and South Pacific Ocean are called cyclones
- **Major Hurricane**
  - tropical cyclone with maximum sustained winds of 111 mph (178 km/h, 96 kt) or higher

Hurricane Category

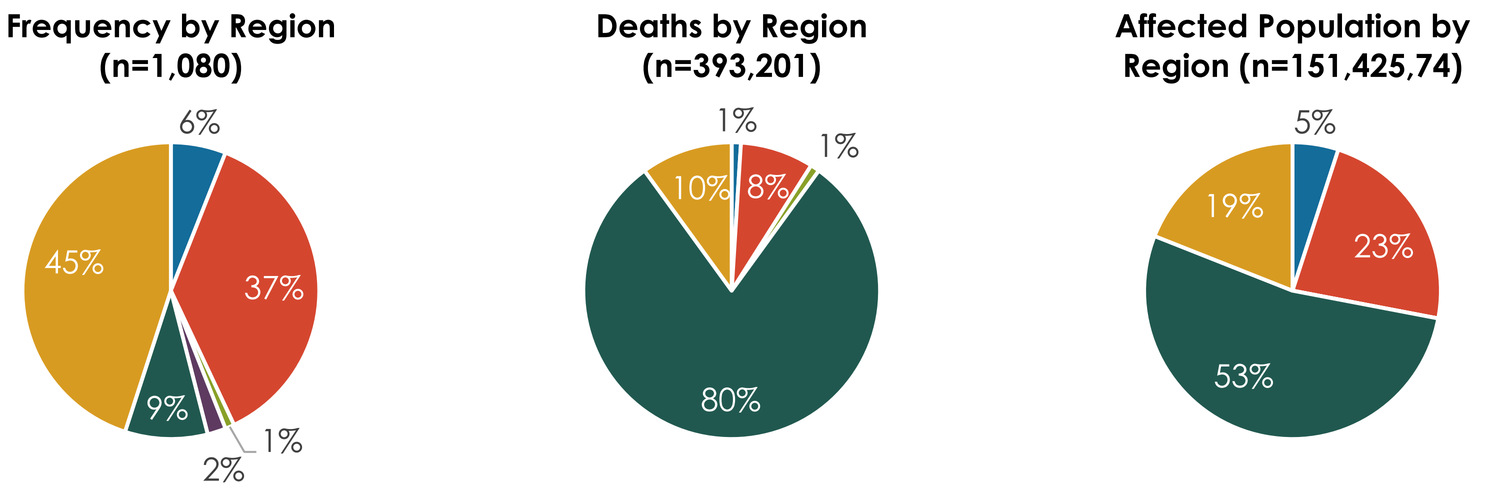
https://www.nhc.noaa.gov/pdf/sshws_2012rev.pdf

Hurricane Category	Saffir-Simpson Wind Scale
1	74-95 mph (119-153 km/h, 64-82 kt)
2	96-110 mph (154-177 km/h, 83-95 kt)
3	111-129 mph (178-278 km/h, 96-112 kt)
4	130-156 mph (209-251 km/h, 113-136 kt)
5	≥ 157 mph (≥ 252 km/h, ≥ 137 kt)

In the western North Pacific, a super typhoon is ≥ 150 mph (≥ 241km/h, ≥ 130 kt)

Cyclone Impacts

Impacts of Tropical Storms (1980-2009)



WHO Regions

- AFRO = African Region
- AMRO = Region of the Americas
- EURO = European Region
- EMRO = Eastern Mediterranean Region
- SEARO = Southeast Asia Region
- WRPRO = Western Pacific Region

- Southeast Asia, the Western Pacific, and regions of America are impacted substantially
- The Western Pacific and American regions have high storm frequency but the Southeast Asian region has the highest number of storm-related deaths

Image Credit: Doocy S, et al. The Human Impact of Tropical Cyclones: a Historical Review of Events 1980-2009 and Systematic Literature Review. PLOS Currents Disasters. 2013 Apr 16 . Edition 1. doi: 10.1371/currents.dis.2664354a5571512063ed29d25ffbce74.

Cyclone Impacts

https://www.nhc.noaa.gov/prepare/hazards.php

Major Causes For Damage, Destruction, Loss of Lives:

- Storm Surge and Coastal Flooding
- Heavy Rainfall and Inland Flooding
- High Sustained Winds and Gusts
- Tornadoes
- Rip Currents

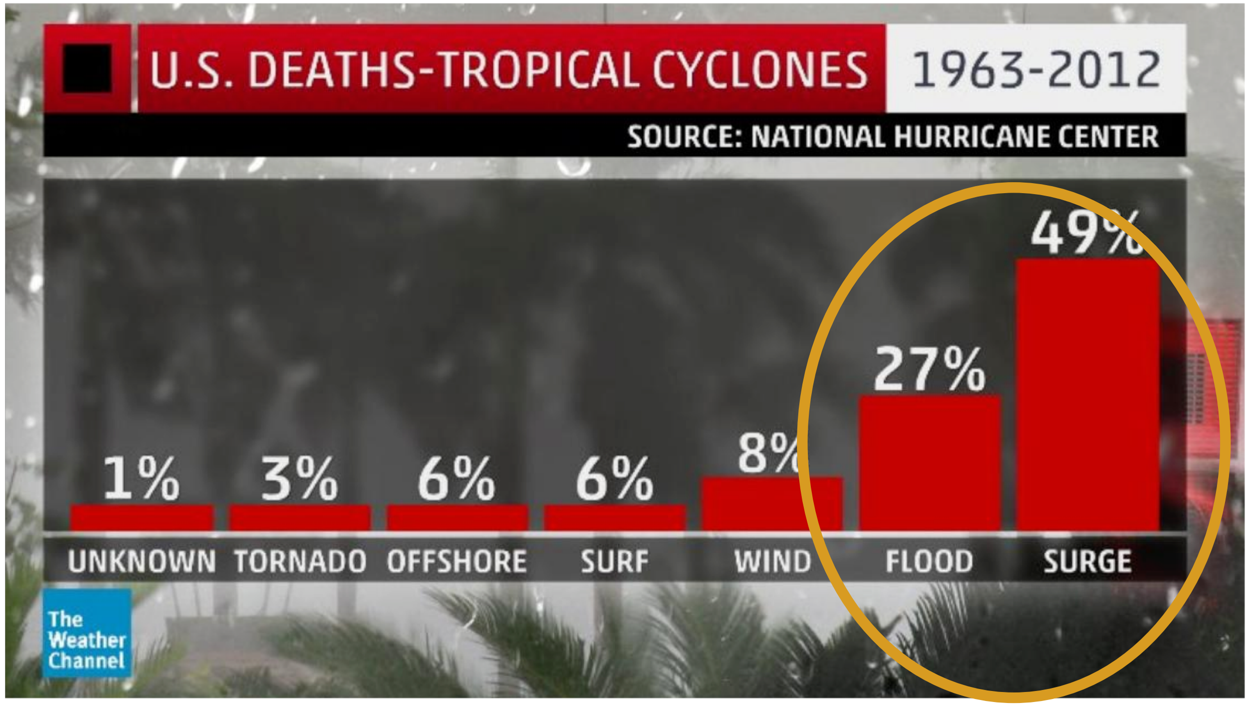
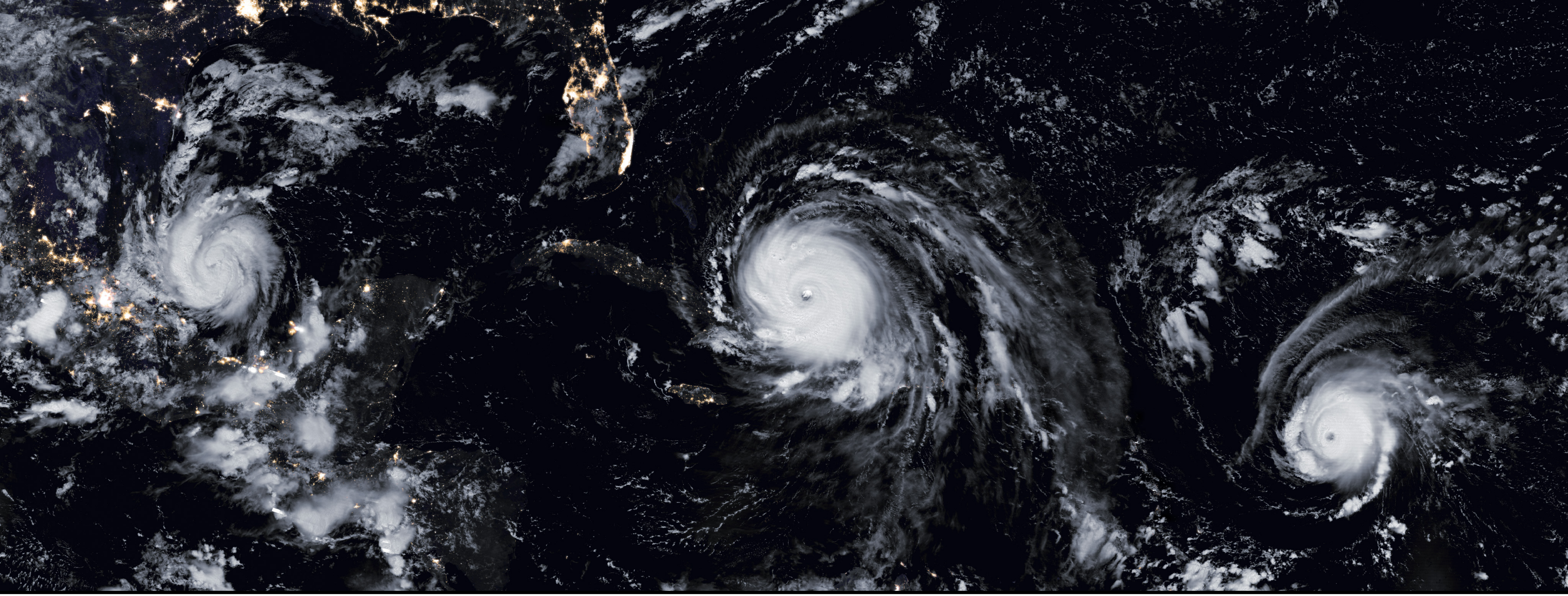


Image Credit: The Weather Channel

Monitor an Approaching Storm

Data	Source	Tool
Precipitation	GPM IMERG	Giovanni, http://giovanni.gsfc.nasa.gov/giovanni
Winds and Sea Level Pressure	GEOS-5 Model	https://fluid.nccs.nasa.gov/weather/wxmaps/
Clouds, True Color Images, Night Light Imagery	Terra and Aqua MODIS, SNPP-VIIRS	Worldview: https://worldview.earthdata.nasa.gov/
Alerts, Rain, Storm Surge, Damage, and Destruction Reports	Satellites, Models, Media Reports	GDACS: http://www.gdacs.org/

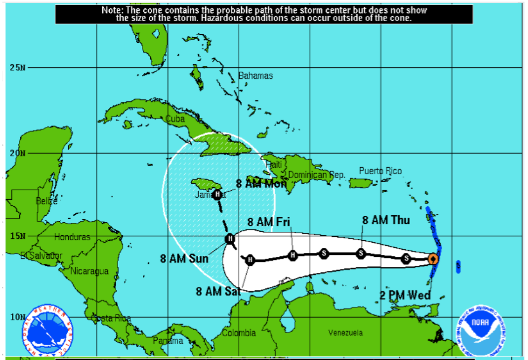


Monitoring Winds, Precipitation, Storm Surge
Hurricane Matthew
September 28 – October 9, 2016

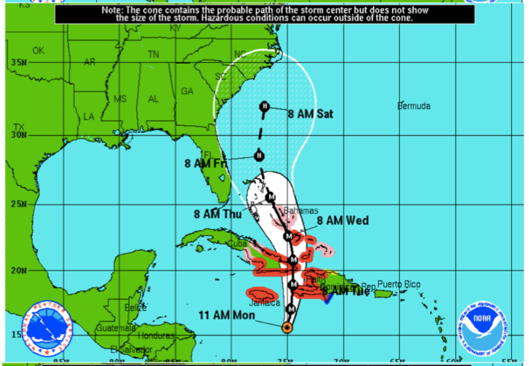
Monitoring Precipitation and Winds

- Operational centers (NHC, CPHC, JTWC) provide early warnings for hurricanes, cyclones, and typhoons
  - Tracks
  - Forecast maps
  - Wind probability
- GPM IMERG and GEOS-5 data can be used to monitor precipitation and winds

Sept 28



Oct 3



Oct 6

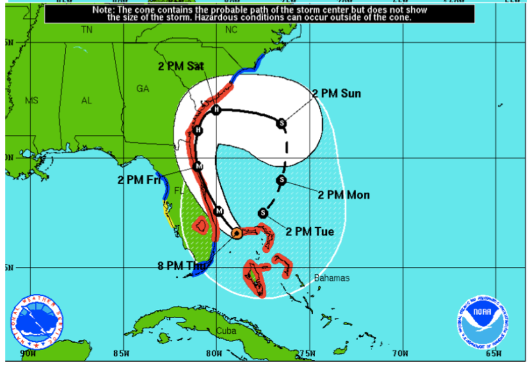


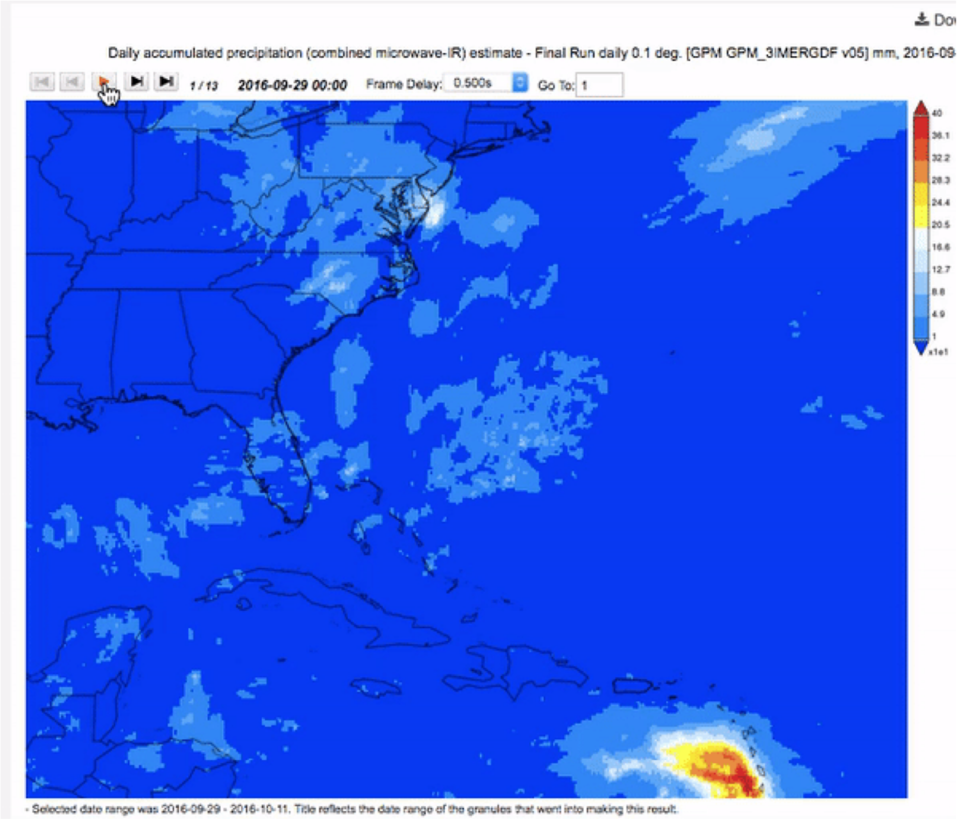
Image Credit: https://www.nhc.noaa.gov/archive/2016/graphics/al14/loop_5W.shtml

GPM IMERG Precipitation During Hurricane Matthew

Giovanni: https://giovanni.gsfc.nasa.gov/giovanni/

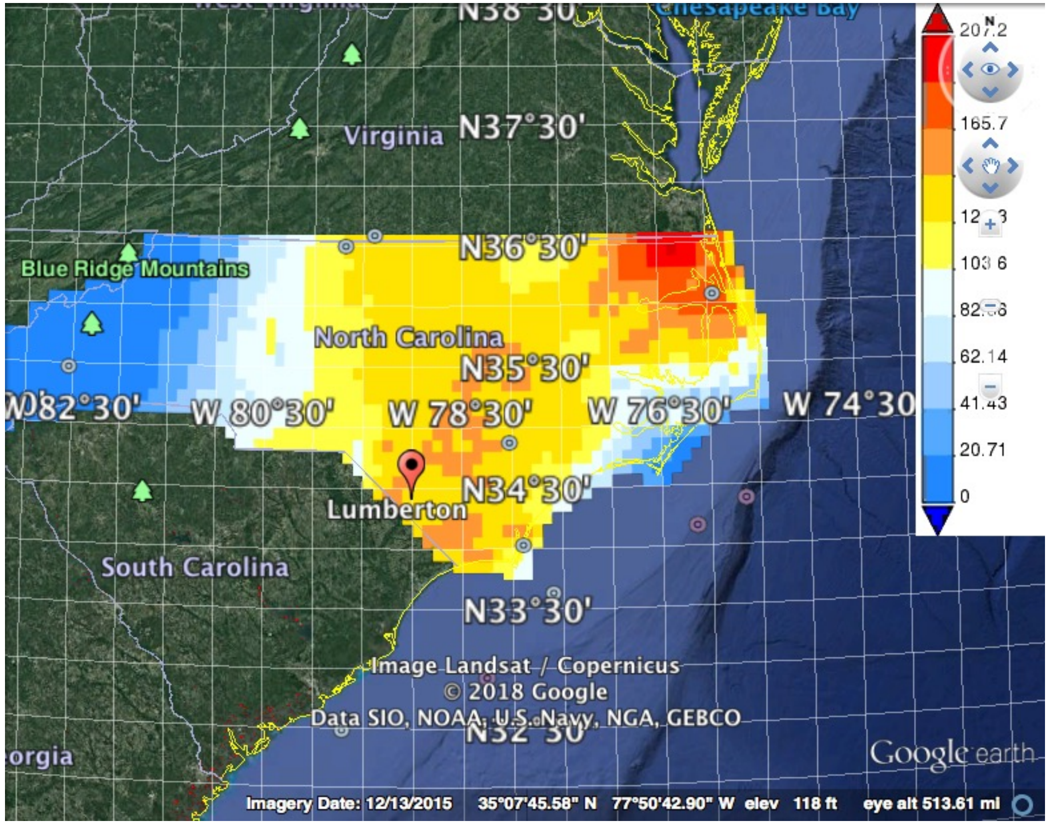
Daily Precipitation

September 29 - October 11, 2016



Accumulated Precipitation

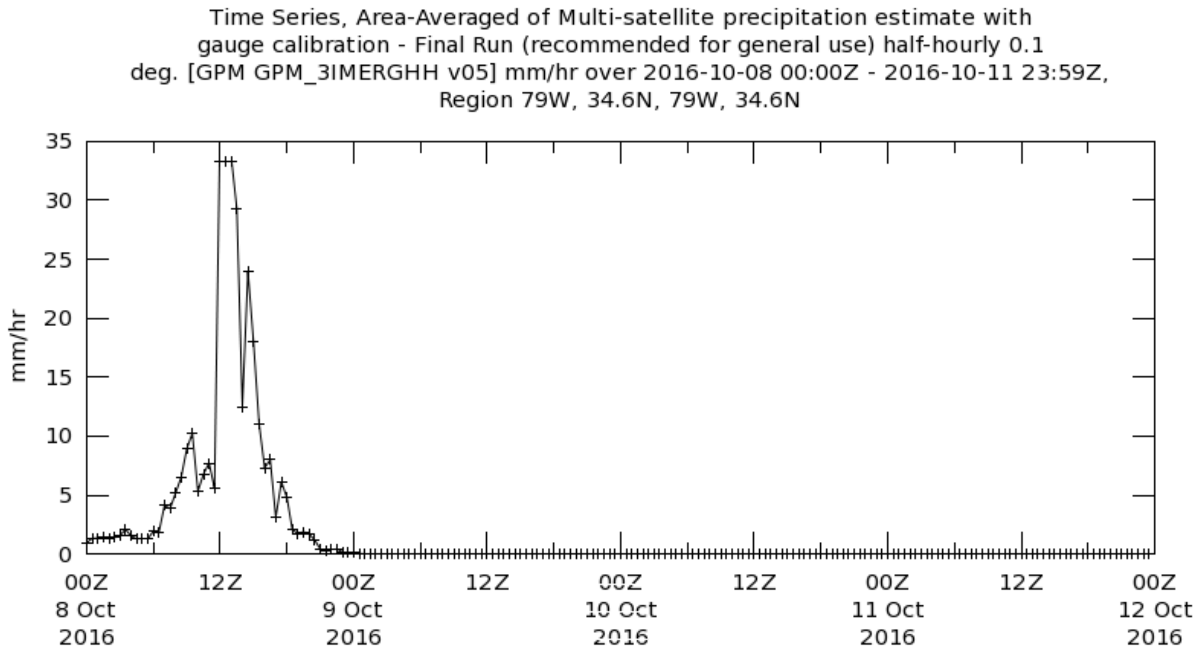
October 6-10, 2016



GPM IMERG Precipitation During Hurricane Matthew

Giovanni: https://giovanni.gsfc.nasa.gov/giovanni/

Half-Hour Rain Rate in and around Lumberton, NC



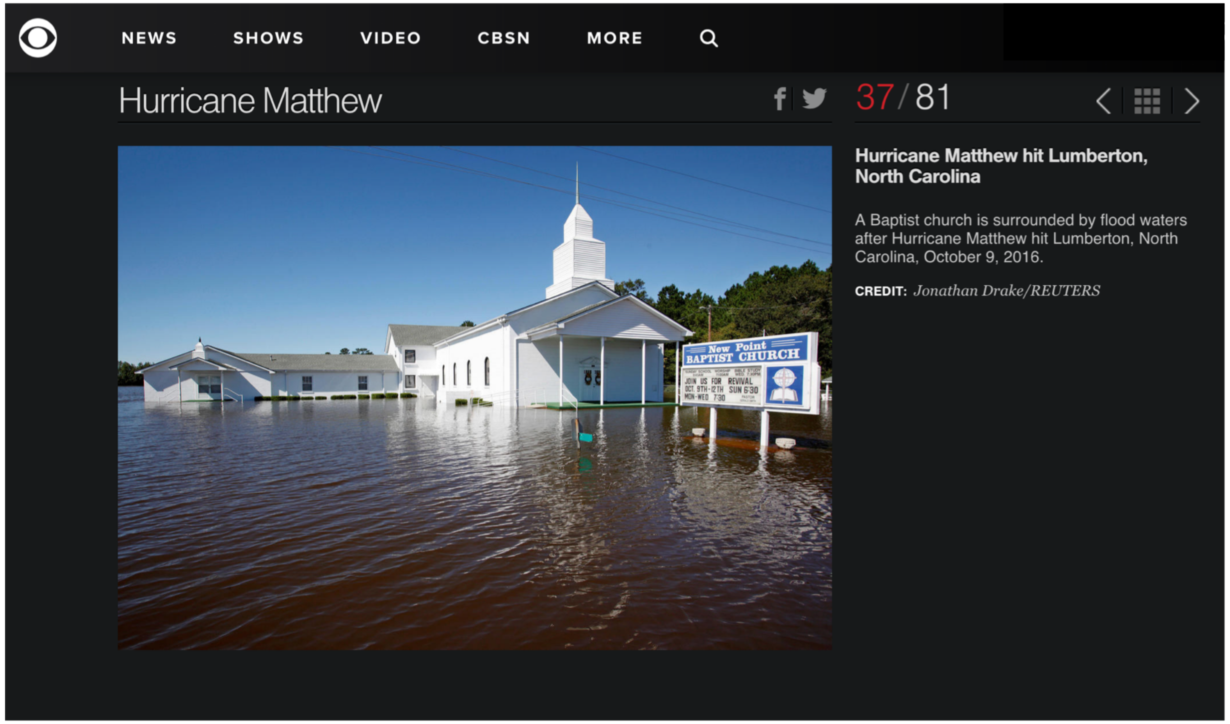
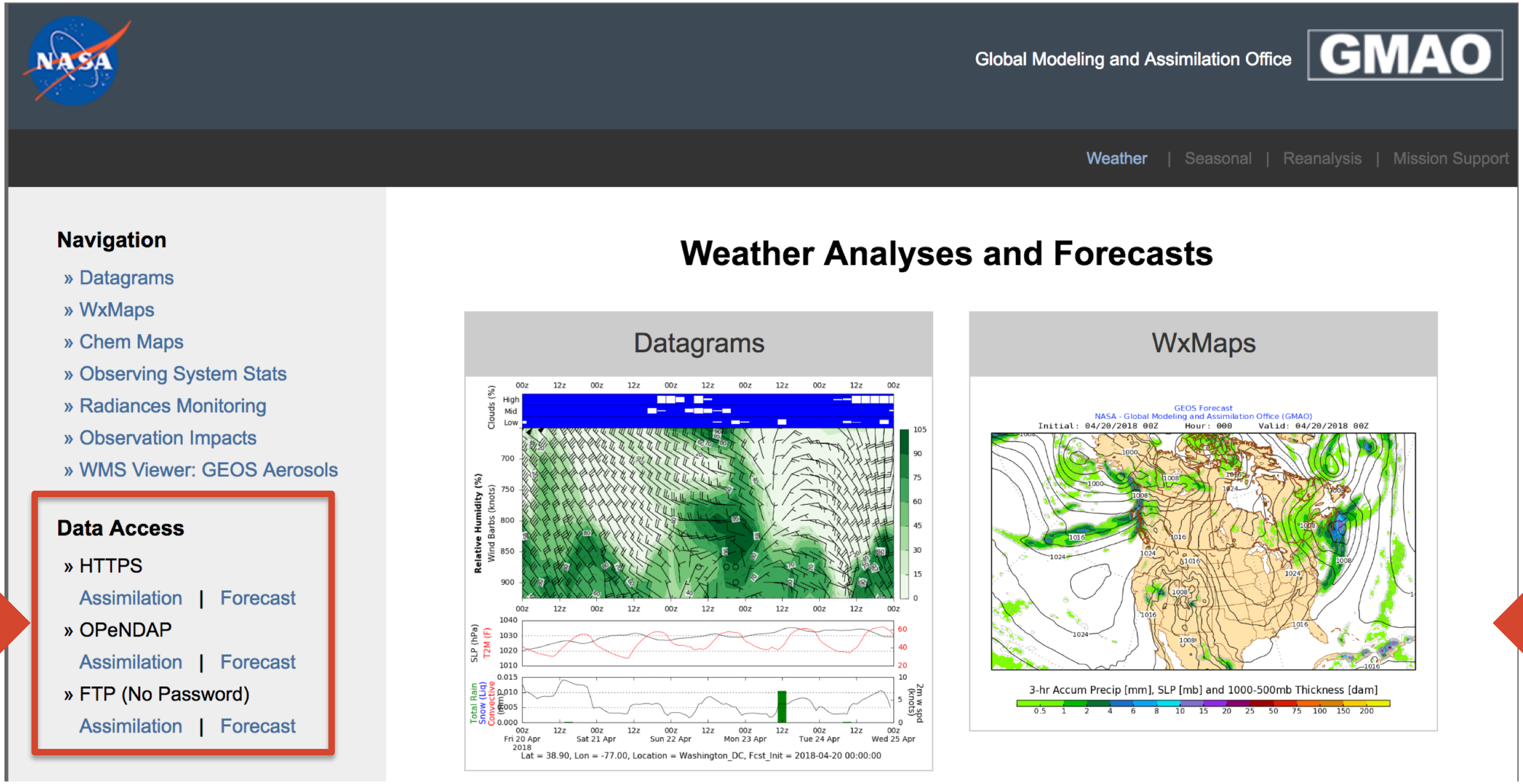


Image Credit: CBS News

GEOS-5 Winds

https://fluid.nccs.nasa.gov/weather/

Data



Maps

GEOS-5 Winds

https://portal.nccs.nasa.gov/datashare/gmao_ops/pub/fp/das/

Data Access

» HTTPS

Assimilation | Forecast

» OPeNDAP

Assimilation | Forecast

» FTP (No Password)

Assimilation | Forecast

HTTP Files

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	-	

Year & Month

Name	Last modified	Size	Description
Parent Directory		-	
D01/	02-Oct-2016 09:42	-	
D02/	03-Oct-2016 09:42	-	
D03/	04-Oct-2016 09:41	-	
D04/	05-Oct-2016 09:56	-	
D05/	06-Oct-2016 09:37	-	
D06/	07-Oct-2016 09:42	-	
D07/	08-Oct-2016 13:29	-	
D08/	09-Oct-2016 09:45	-	
D09/	10-Oct-2016 09:49	-	
D10/	11-Oct-2016 09:45	-	
D11/	12-Oct-2016 09:44	-	
D12/	13-Oct-2016 10:00	-	
D13/	14-Oct-2016 09:49	-	
D14/	15-Oct-2016 09:55	-	
D15/	16-Oct-2016 10:12	-	
D16/	17-Oct-2016 11:17	-	
D17/	18-Oct-2016 09:47	-	
D18/	19-Oct-2016 09:41	-	
D19/	20-Oct-2016 09:43	-	
D20/	21-Oct-2016 10:19	-	
D21/	22-Oct-2016 09:55	-	
D22/	23-Oct-2016 09:49	-	

Day

GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0030.V01.nc4	09-Oct-2016 09:38	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0130.V01.nc4	09-Oct-2016 09:38	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0230.V01.nc4	09-Oct-2016 09:38	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0330.V01.nc4	09-Oct-2016 13:56	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0430.V01.nc4	09-Oct-2016 13:56	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0530.V01.nc4	09-Oct-2016 13:56	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0630.V01.nc4	09-Oct-2016 13:56	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0730.V01.nc4	09-Oct-2016 13:56	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0830.V01.nc4	09-Oct-2016 13:56	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_0930.V01.nc4	09-Oct-2016 20:53	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1030.V01.nc4	09-Oct-2016 20:53	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1130.V01.nc4	09-Oct-2016 20:53	47M
GEOS.fp.asm.tavg1_2d_slv_Nx.20161009_1230.V01.nc4	09-Oct-2016 20:53	47M
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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

Hourly File Name

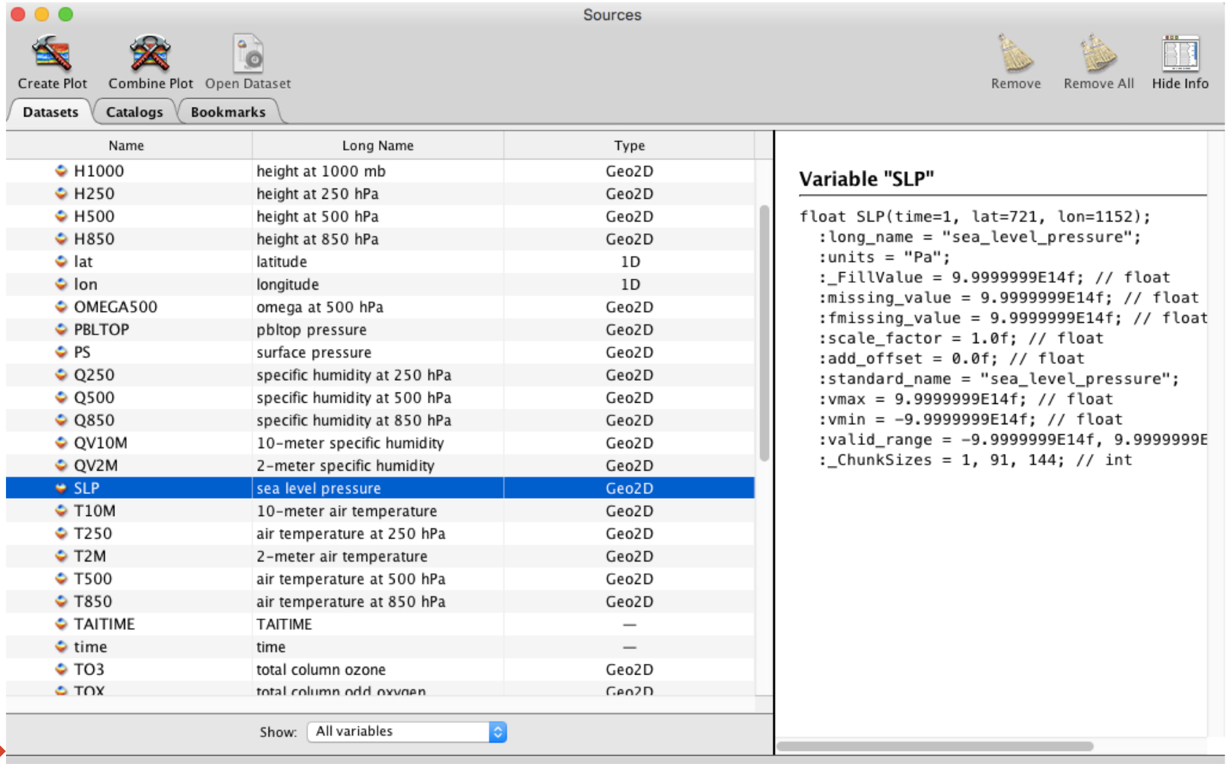
GEOS-5 Winds During a Cyclone

https://portal.nccs.nasa.gov/datashare/gmao_ops/pub/fp/das/

- Download Single Level (SLV) files (hourly_ during a cyclone
  - See this document for filename convention: https://gmao.gsfc.nasa.gov/products/documents/GEOS_5_FP_File_Specification_ON4v1_1.pdf
- Download and install Panoply (analysis and visualization tool)
  - Instructions: https://www.giss.nasa.gov/tools/panoply/download
- Open the SLV file using Panoply

SLV File for 13:30Z, October 9, 2016

Opened in Panoply

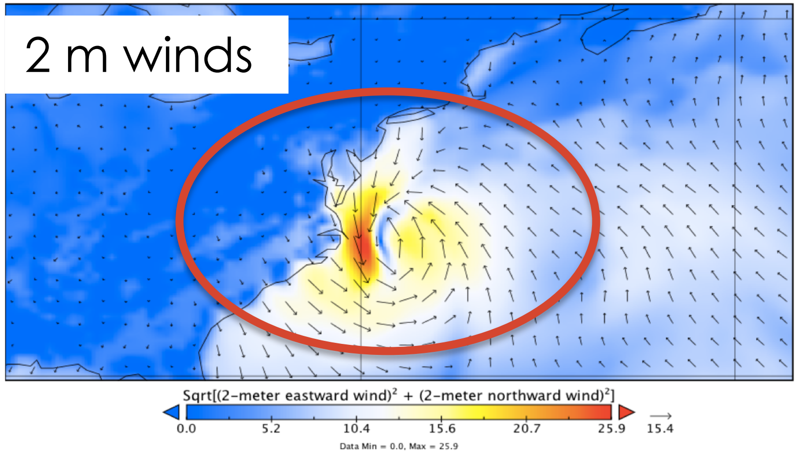


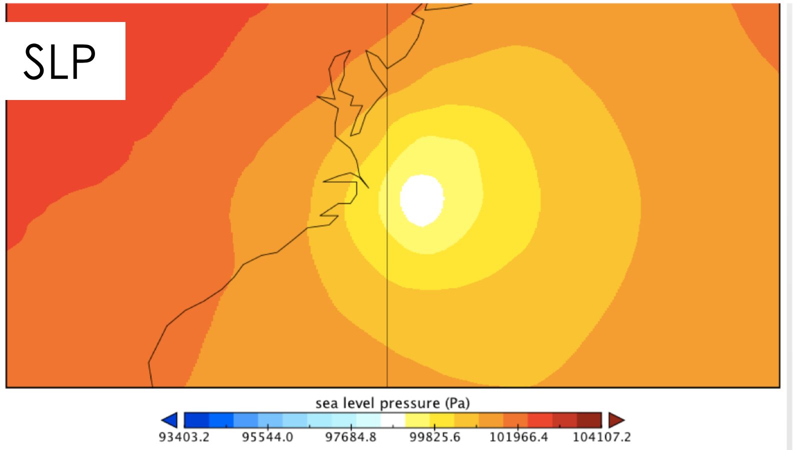
GEOS-5 Winds During Hurricane Matthew

https://portal.nccs.nasa.gov/datashare/gmao_ops/pub/fp/das/

- Plot wind speed and wind vectors using Panoply
- GEOS-5 winds and sea level pressure (SLP) for near real-time and forecasts can be examined using Panoply

13:30Z, October 9, 2016

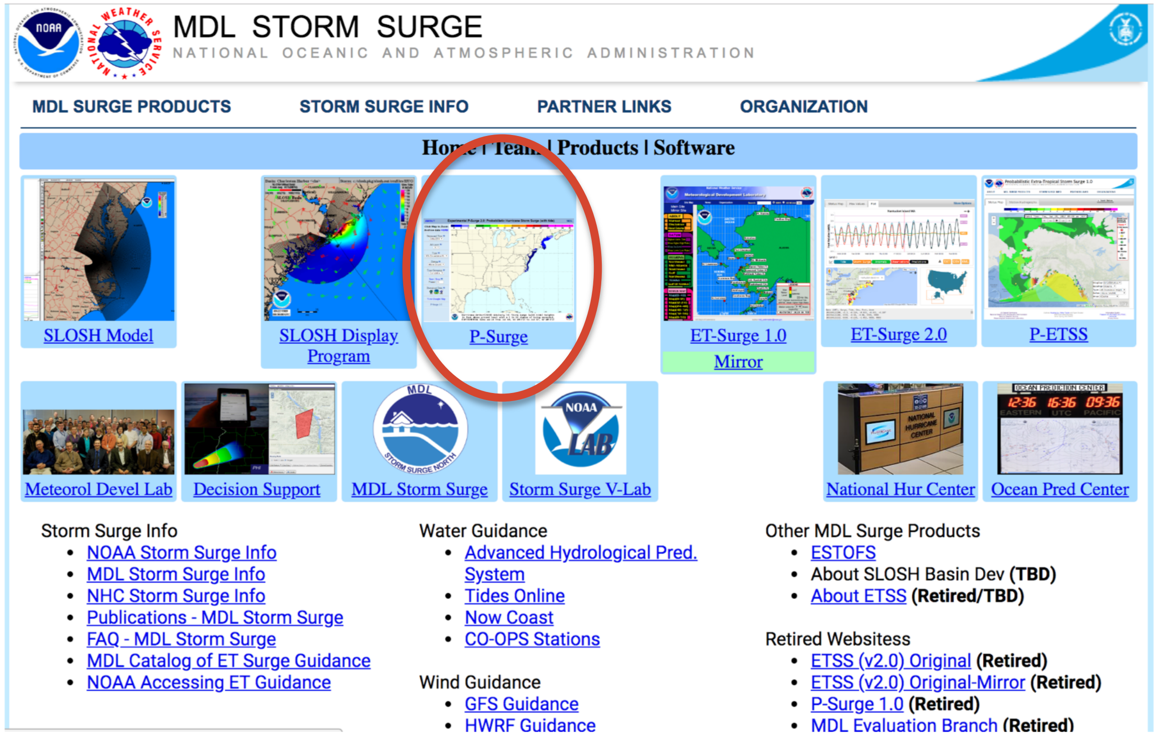




Monitoring Storm Surge: U.S.

http://slosh.nws.noaa.gov/

- Based on Sea Lake and Overland Surge from Hurricanes (SLOSH)
- The SLOSH model computes storm surge heights from tropical cyclones to create a model of the wind field using
  - Pressure
  - Size
  - forward speed
  - track data
- Applies to:
  - The entire U.S. East coast, Gulf of Mexico, Hawaii, Guam, Puerto Rico, and the U. S. Virgin Islands coastal regions

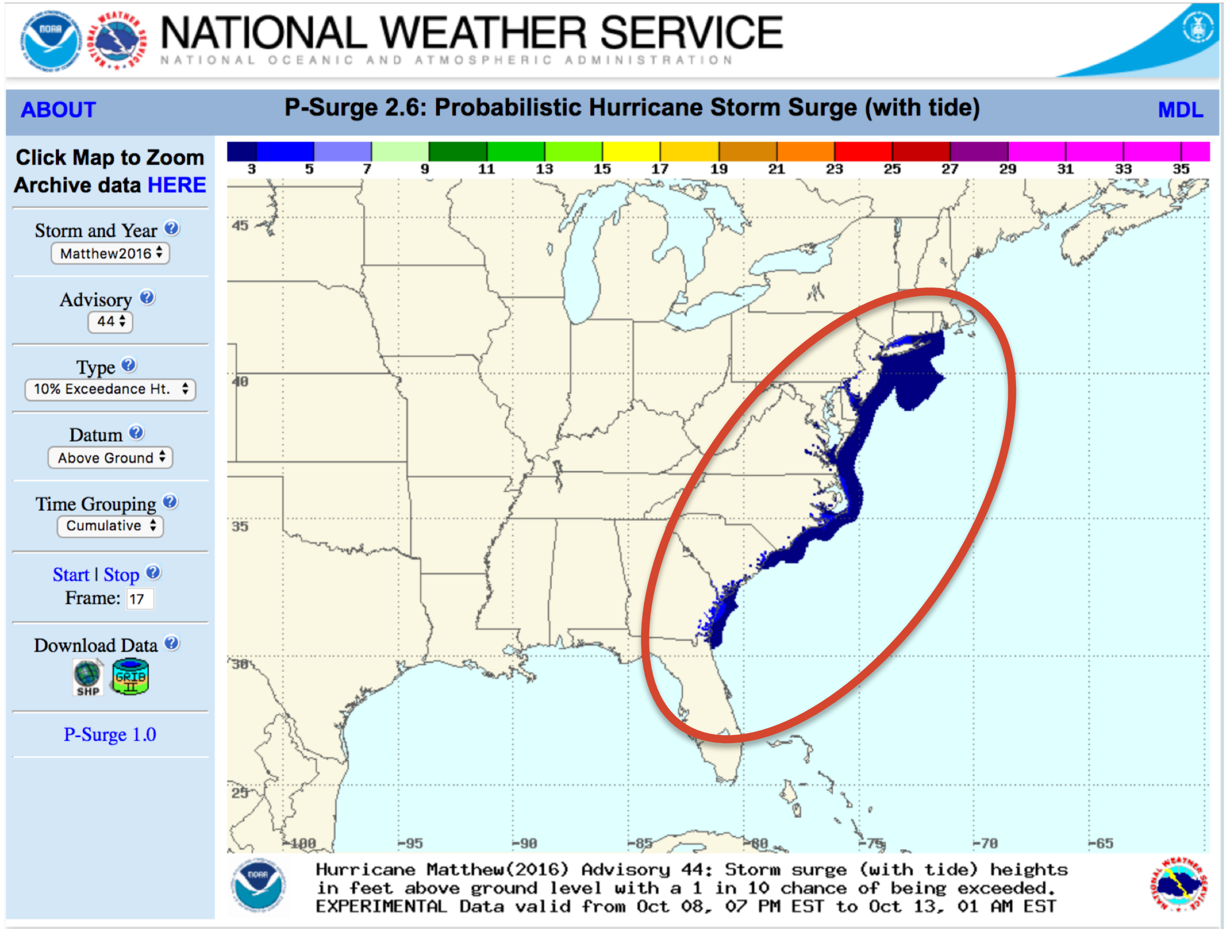


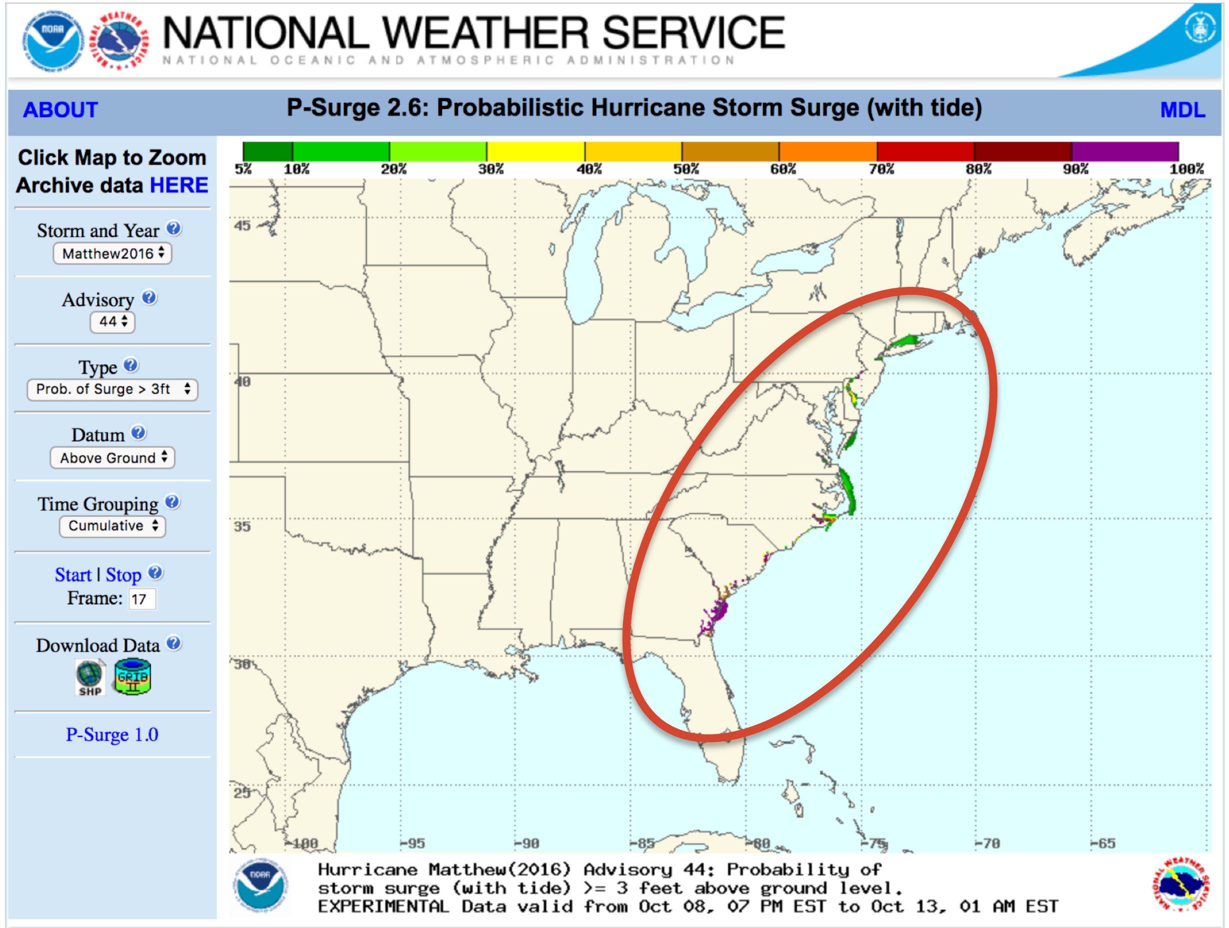
Probabilistic Hurricane Storm Surge

Monitoring Storm Surge: Hurricane Matthew

http://slosh.nws.noaa.gov/psurge/

Areas with probability of surge > 3 ft

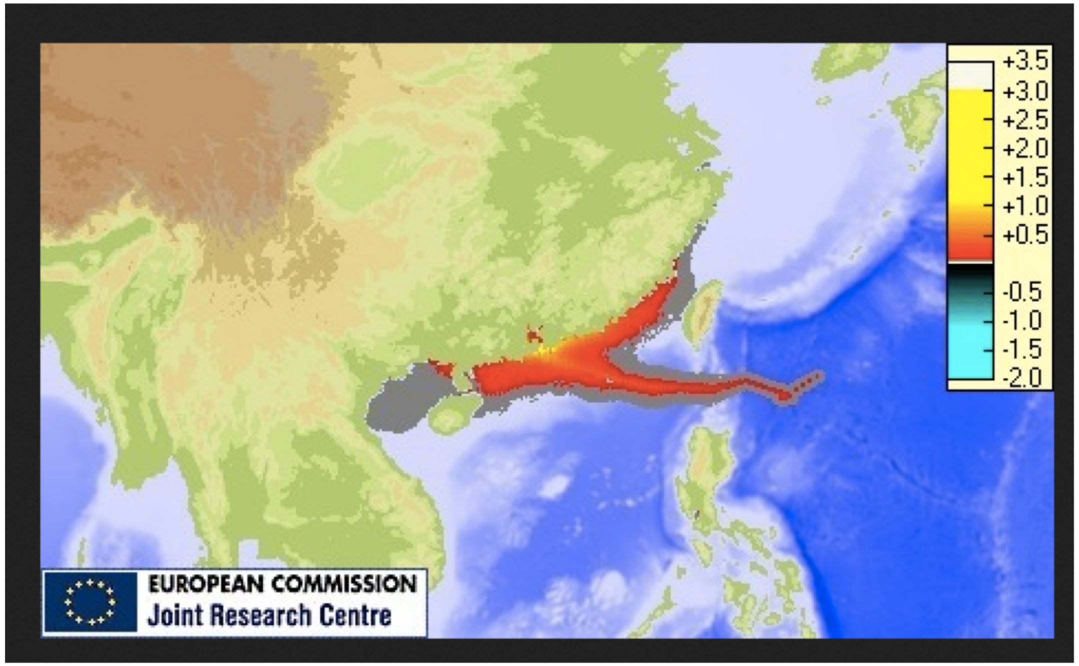




Monitoring Storm Surge: Global

Hurricane Matthew
Maximum Surge

Cyclone Hato (Aug 2017)
Maximum Surge



Based on Joint Research Center Storm Surge Calculation Model (Delf3D)

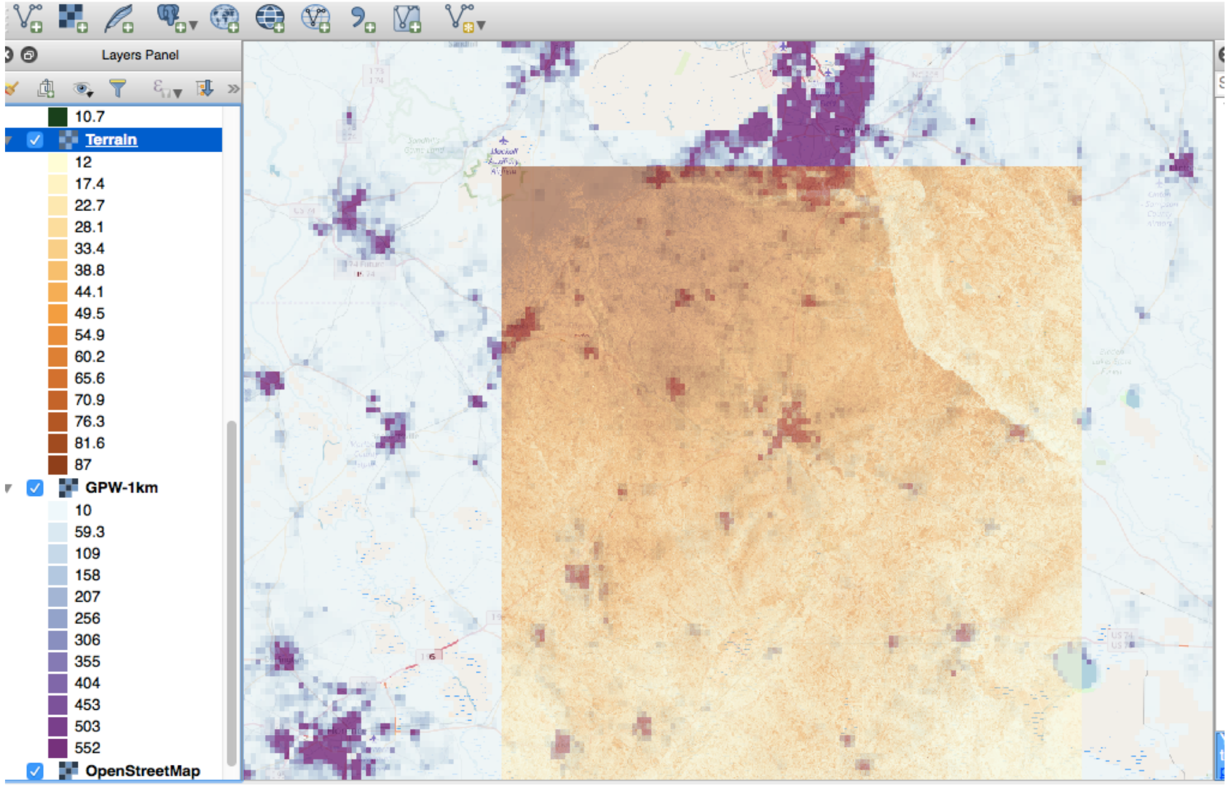
http://bit.ly/2J9kP7d

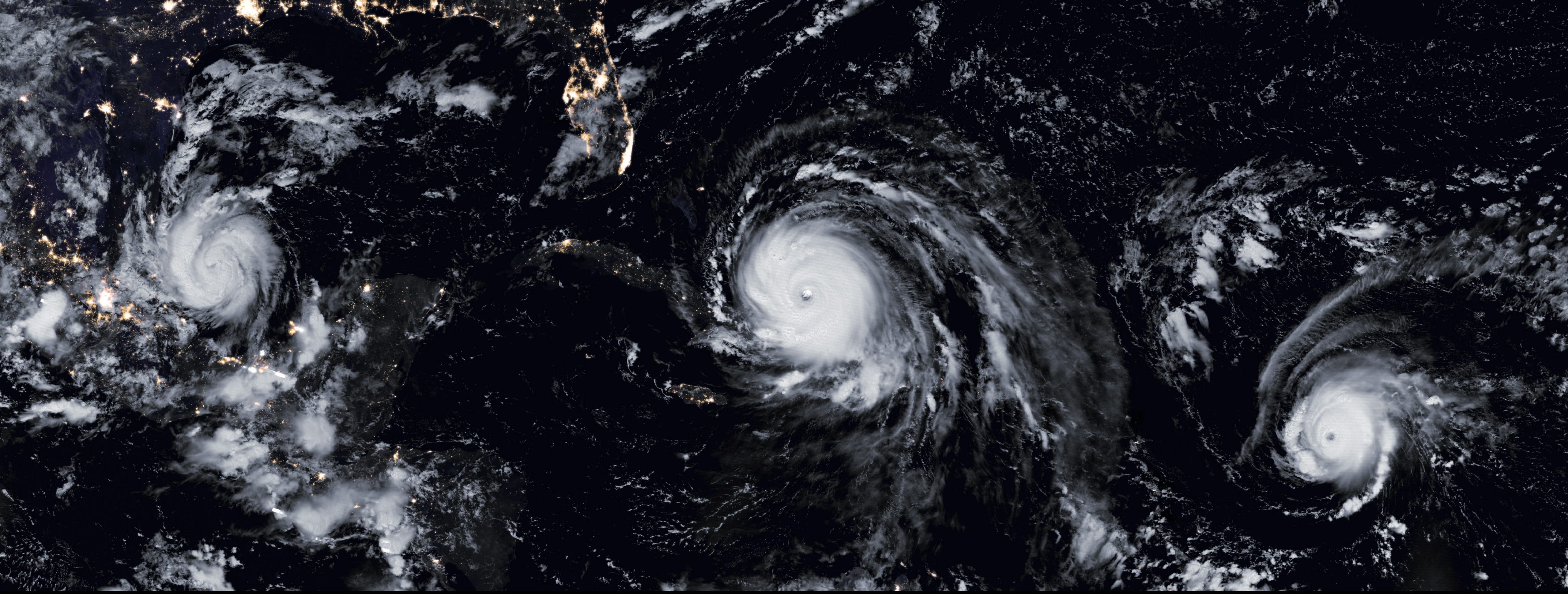
Image Credits: [WEBCRITECH - JRC]()

Terrain, Roads, and Population Data for Emergency Planning

- SRTM terrain, obtained from GDEX:
  - https://gdex.cr.usgs.gov/gdex/
- Population density per km obtained from SEDAC
  - http://sedac.ciesin.columbia.edu/
- Import data into geospatial software (e.g. QGIS)

North Carolina





Monitoring Flooding During and After Storms for Emergency Response Planning

Remote Sensing-Based Flood Detection

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

Learn more in ARSET's Advanced Webinar: Using NASA Remote Sensing for Flood Monitoring and Management

Precipitation-Based Flood Tools

- ERDS uses GPM-IMERG
- GFMS uses TRMM Multi-satellite Precipitation Analysis (TMPA) data
- GFMS will be transitioning to using GPM-IMERG data

Extreme Rainfall Detection System (ERDS)

http://erds.ithacaweb.org/

- Uses near real-time GPM IMERG precipitation data and NOAA Global Forecasting System (GFS) rainfall for monitoring and forecasting accumulated rainfall
- The Global Precipitation Climatology Center land-based rain gauge mean data are used as reference to calculate extreme rainfall thresholds
- ERDS is one of the tools used by the UN World Food Programme (WFP) Emergency Preparedness Unit

Extreme Rainfall Detection System (ERDS)

http://erds.ithacaweb.org/

- Provides cumulative precipitation based on near real-time IMERG data and 6-day GFS Forecast
- Provides alerts for extreme rainfall and potential flooding
- Experimental product – needs verification at local scale

Demonstration of ERDS

24 Hour Accumulated Rain

Last analyzed GPM date: 15 Apr 2018 - 18:59 UTC
Last analyzed GFS date: 17 Apr 2018 - 00:00 UTC

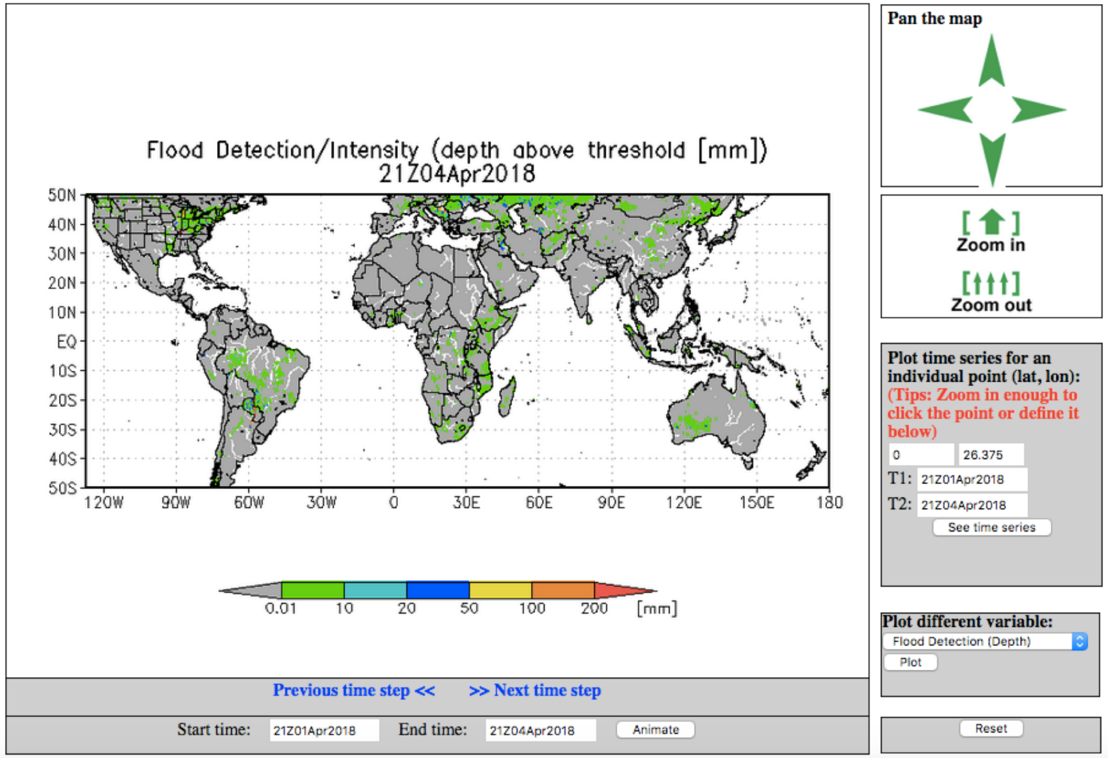
Global Flood Monitoring System (GFMS)

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

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

Interactive Features



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 the UW Variable Infiltration Capacity (VIC) model
  - Runoff routing model from UMD

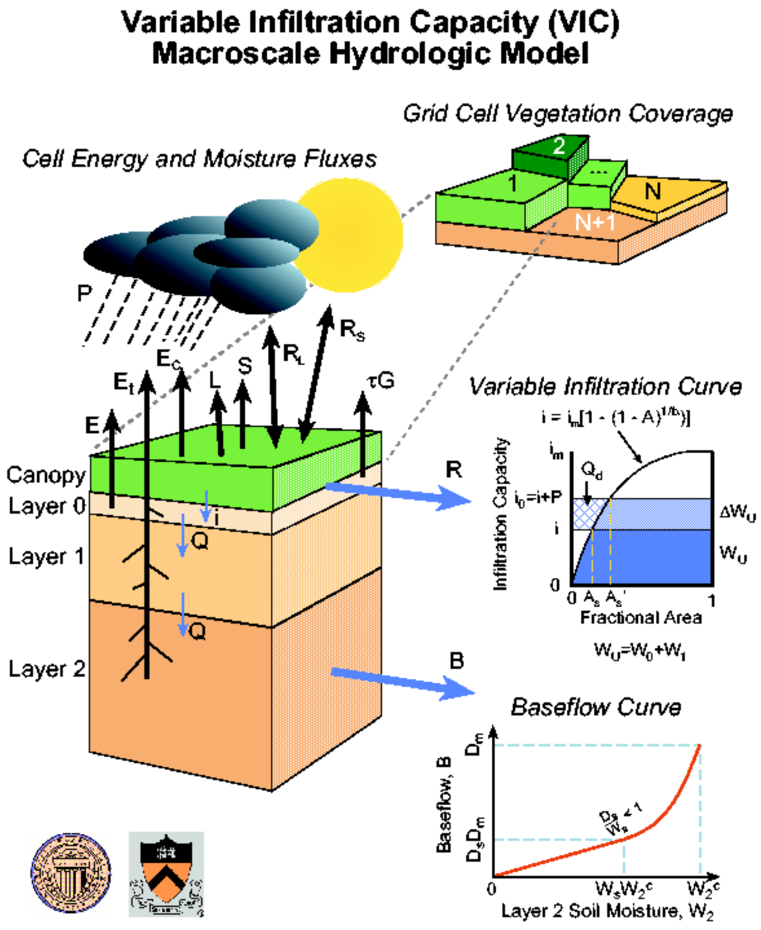
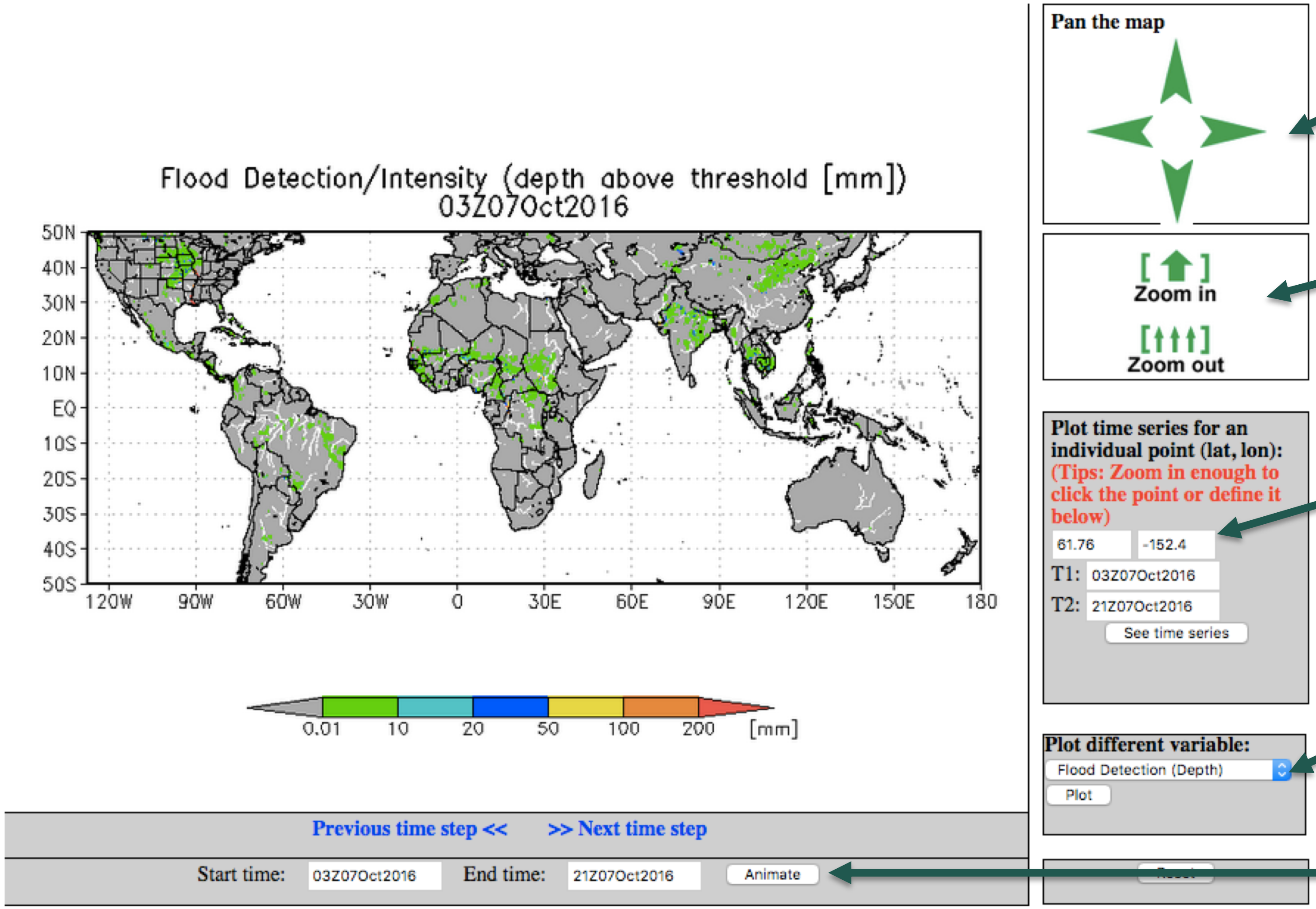


Image Credit: [UW VIC Macroscale Hydrologic Model](); References: Wu, H., R. F. Adler, Y. Tian, G. J. Huffman, H. Li, and J. Wang (2014), Real-time global flood estimation using satellite-based precipitation and a coupled land surface and routing model, Water Resour. Res., 50, 2693.2717, doi:10.1002/2013WR014710.;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

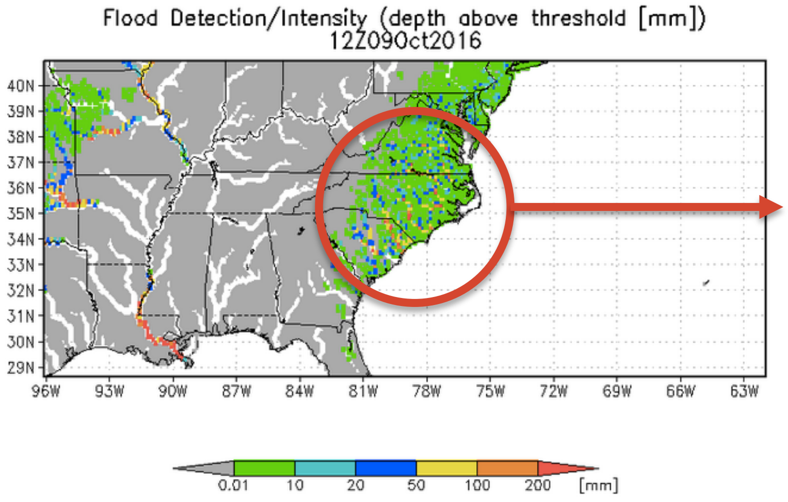
Zoom in/out

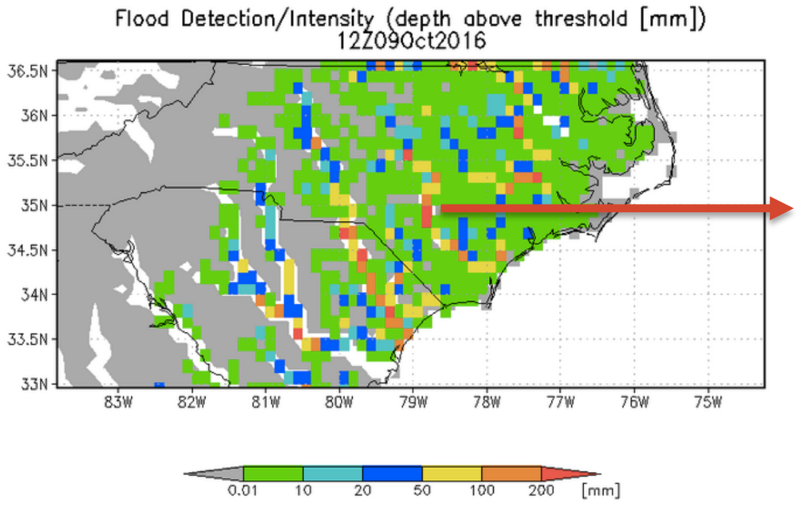
Select individual grid point for time series data

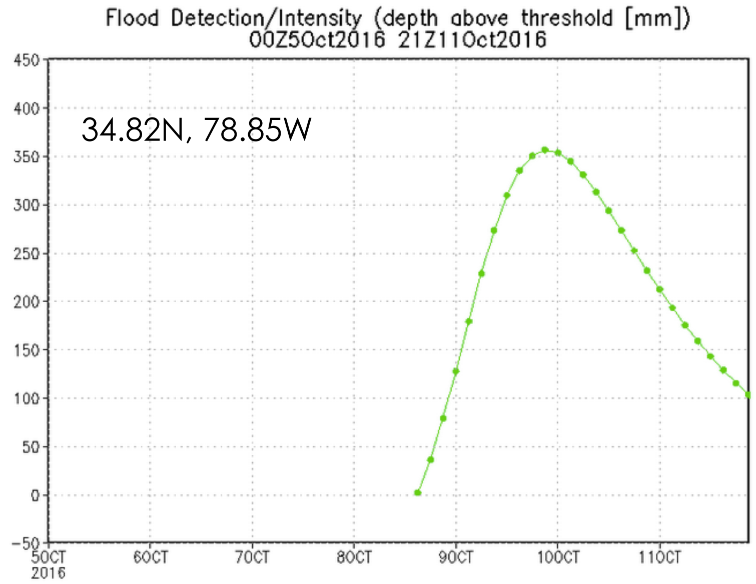
Plot different variables

Animation

GFMS: Flooding from Hurricane Matthew



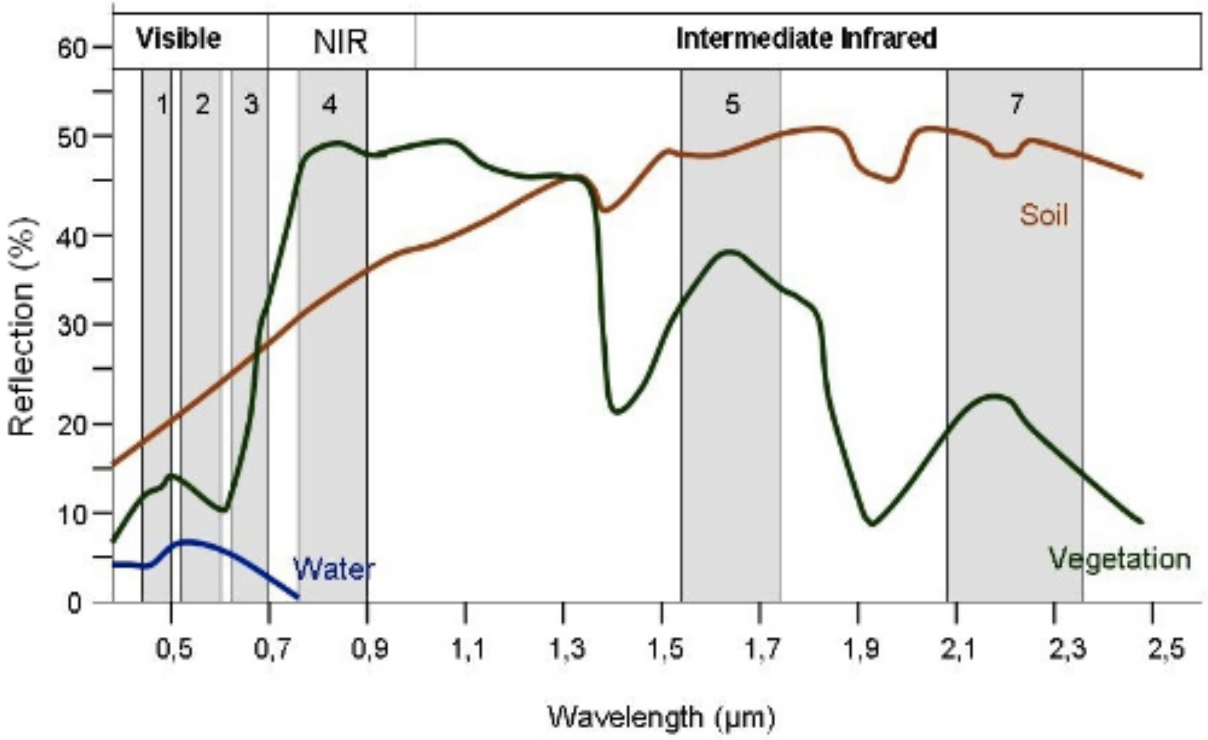




Land Cover Based Flooding Tools

Visible Radiation

- Reflected by the surface and depends on surface type



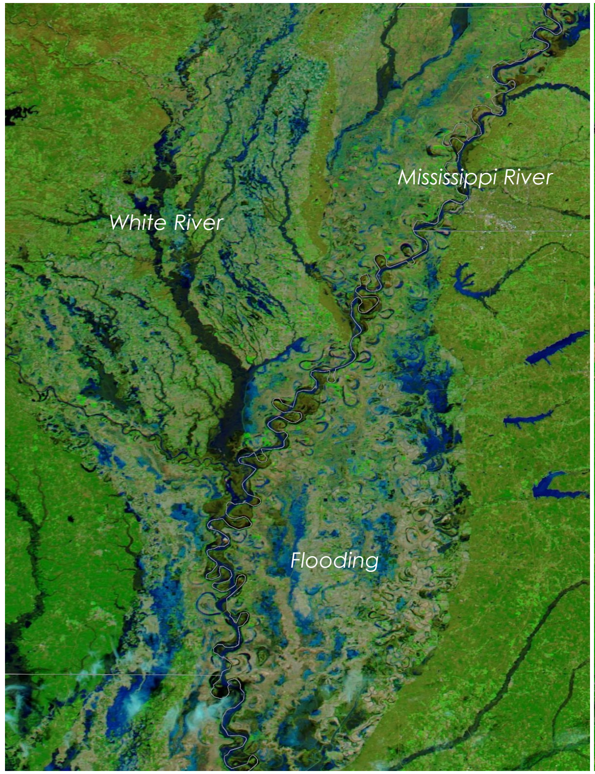
Used for Flood Mapping

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

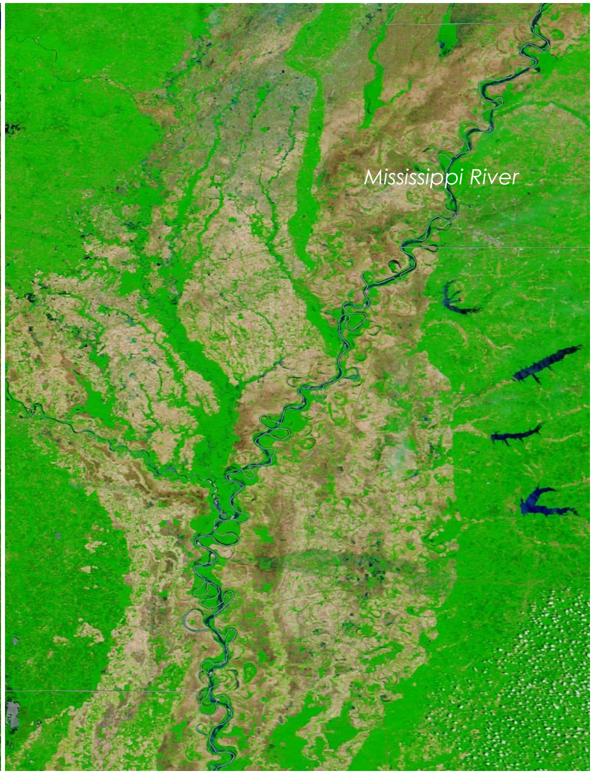
MODIS-Based Inundation Mapping

- 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

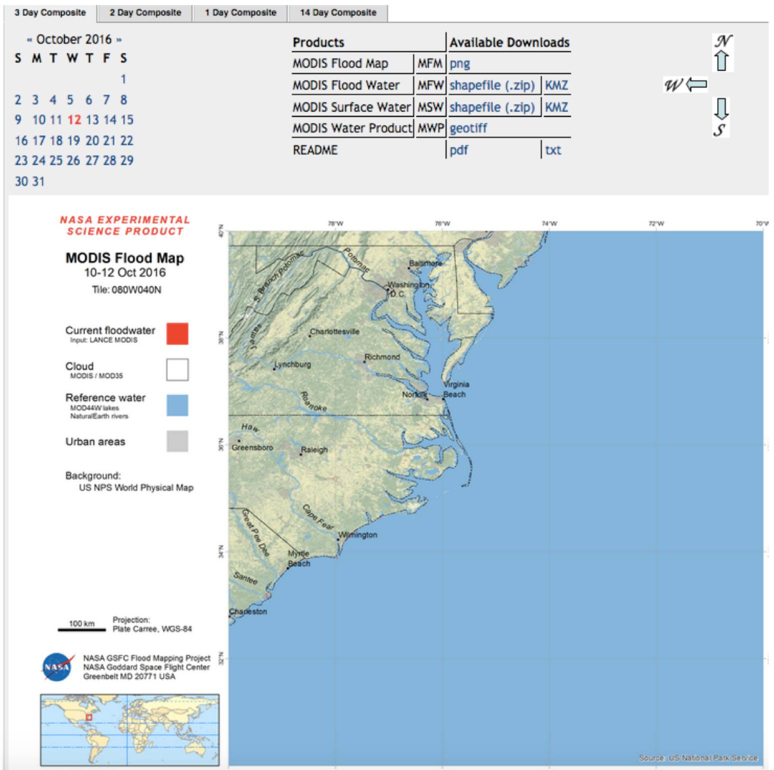
http://oas.gsfc.nasa.gov/

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

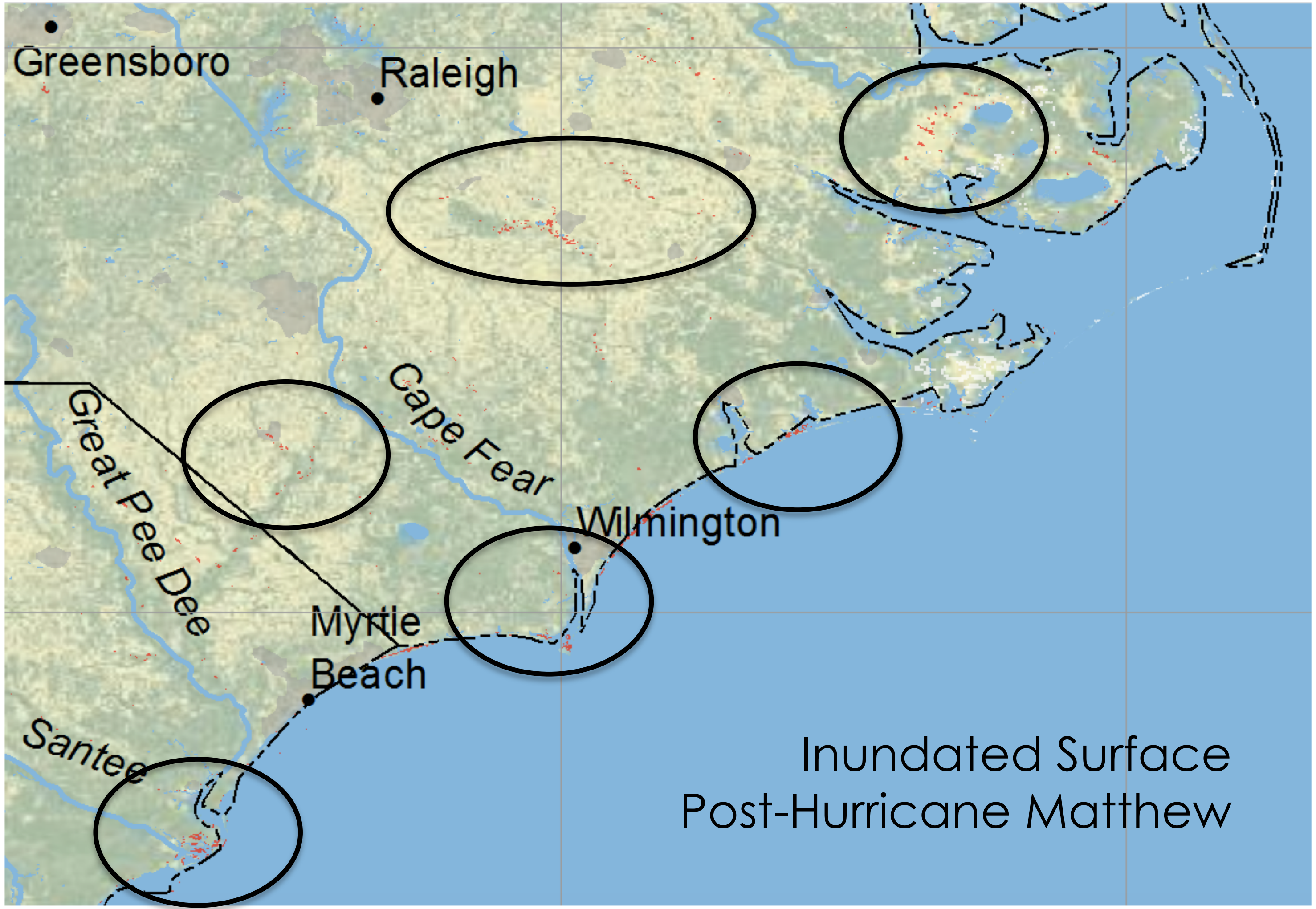
MODIS NRT Global Flood Mapping: North Carolina Oct 10-12, 2016

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

Tile 80W40N



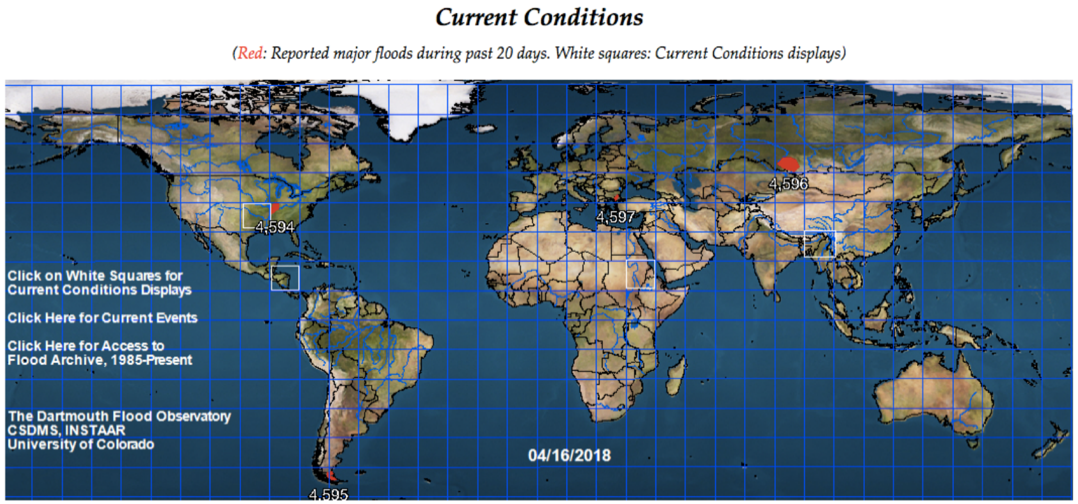
Note: MODIS cannot see the surface when clouds are present



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, including media report

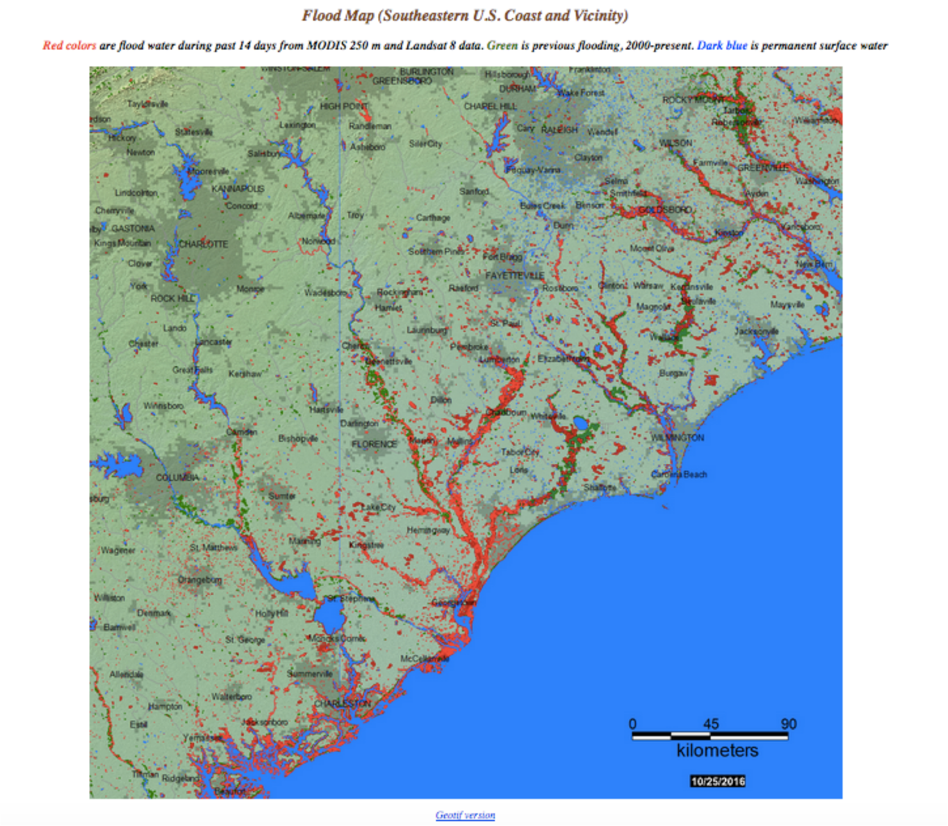


- Provides near real-time, current, and past flood event mapping
- Red areas (above) indicate inundated surfaces

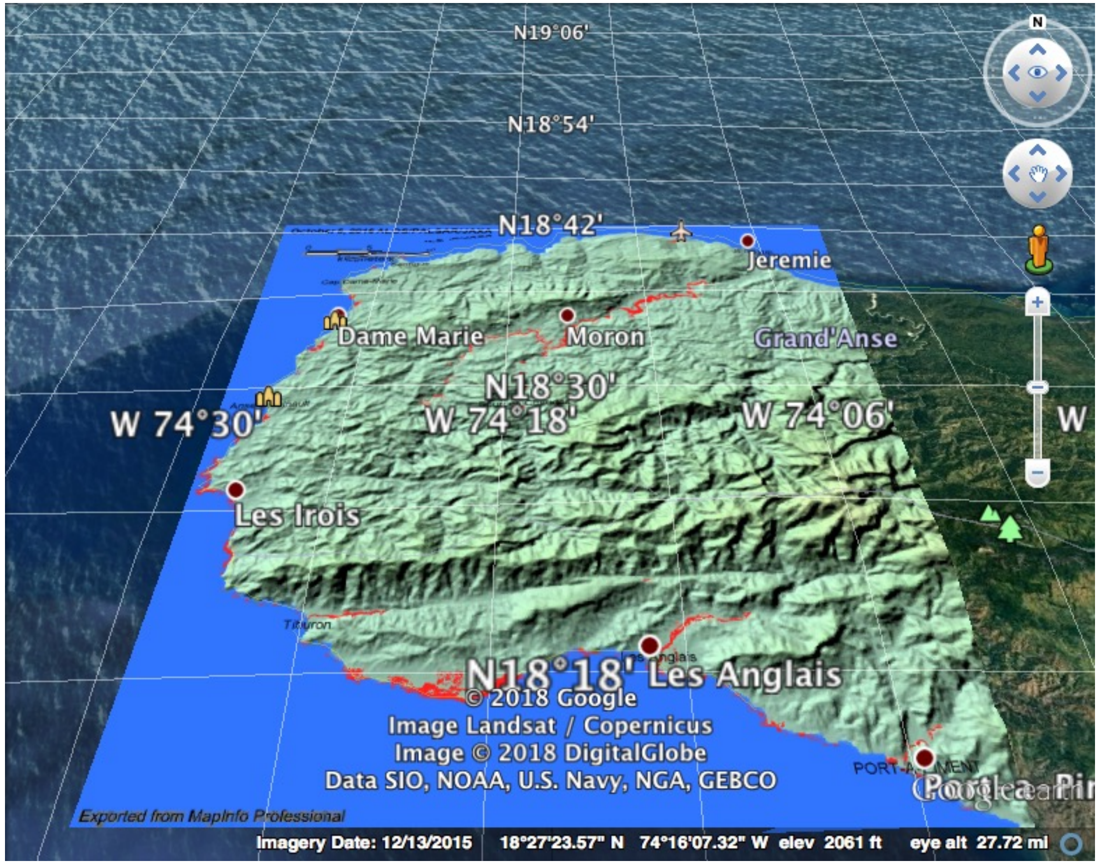
DFO: Flooding Due to Hurricane Matthew

https://floodobservatory.colorado.edu/Events/2016USA4402/2016USA4402.html

Flooded Areas for Previous 14 Days (MODIS)



Flood Map (Grand'Anse SUD, Haiti)
JAXA ALOS/PALSAR: October 5, 2016



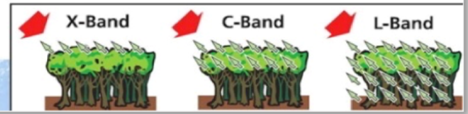
Synthetic Aperture Radar (SAR) Imagery For Flood Detection

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

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

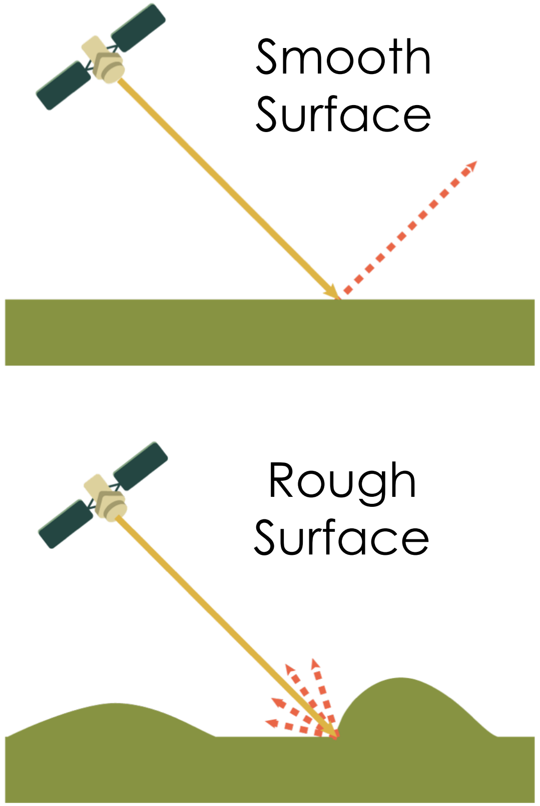
Commonly Used Frequency Bands

Frequency band	*Frequency range*	*Application Example*
• VHF	300 KHz - 300 MHz	Foliage/Ground penetration, biomass
• P-Band	300 MHz - 1 GHz	biomass, soil moisture, penetration
• L-Band	1 GHz - 2 GHz	agriculture, forestry, soil moisture
• C-Band	4 GHz - 8 GHz	ocean, agriculture
• X-Band	8 GHz - 12 GHz	agriculture, ocean, high resolution radar
• Ku-Band	14 GHz - 18 GHz	glaciology (snow cover mapping)
• Ka-Band	27 GHz - 47 GHz	high resolution radars



- The backscatter signal is primarily sensitive to surface structure
- The scale of the objects on the surface relative to the wavelength determine how rough or smooth they appear to the radar signal and how bright or dark they will appear on the image

Backscattering Mechanisms

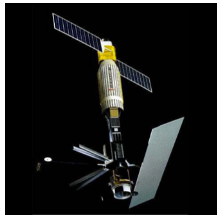


Radar Data from Different Satellites

freely accessible

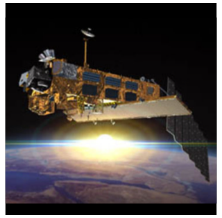
freely accessible & reliably repeated acquisition plan

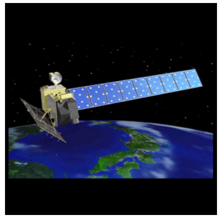
The Legacy:

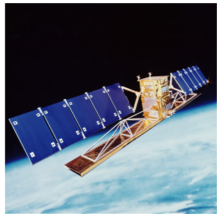
1978

SeaSAT

1991-2011

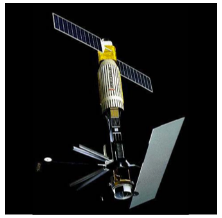
ERS 1/2

2002-2012

ENVISAT

2002-2012

ALOS-1

1995-2013

Radarsat-1

The New:

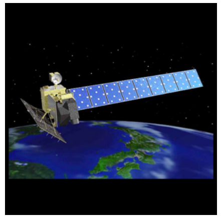
2007

TanDEM-X

2007

Radarsat-2

2007

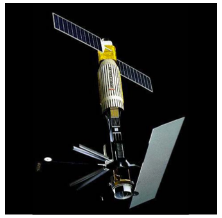
COSMO-SkyMed

2014

ALOS-2

2014

Sentinel-1

The Future:

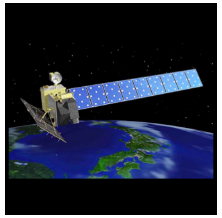
2018

SAOCOM

2018

PAZ SAR

2018

RCM

2021

NISAR

2021

Biomass

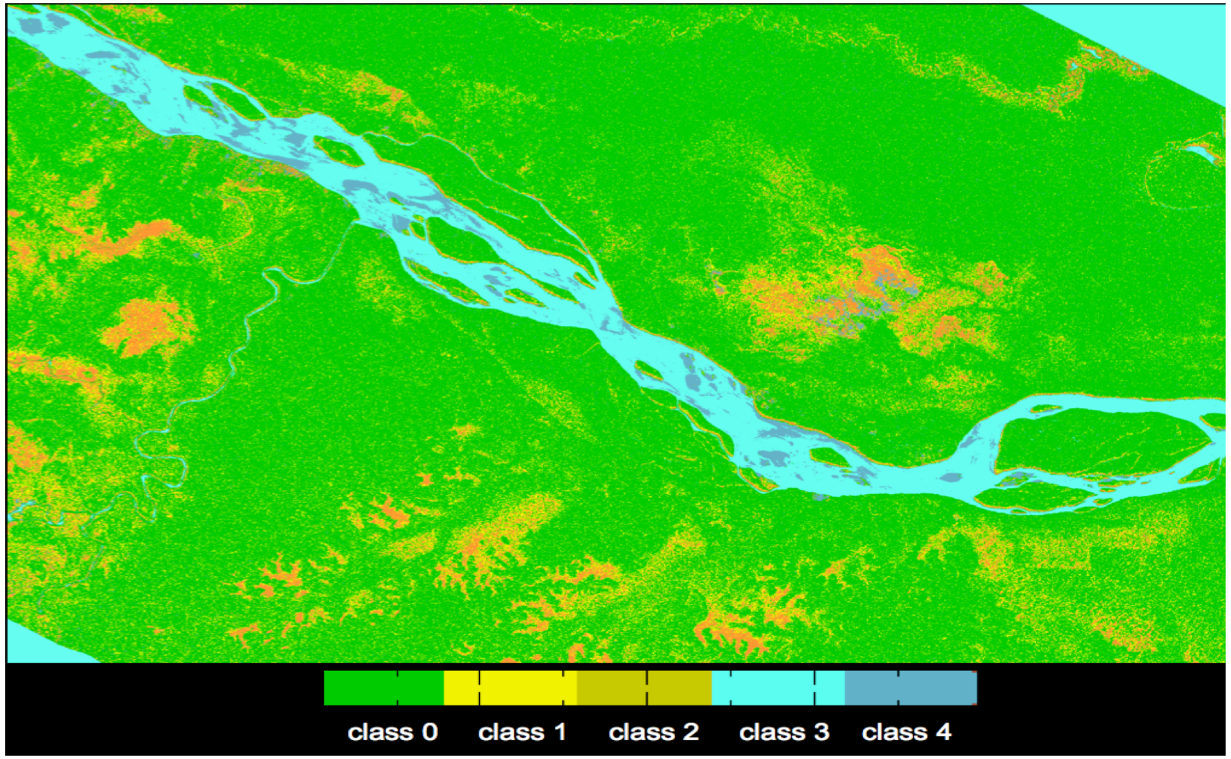
Credit: Franz Meyer, University of Alaska, Fairbanks

SAR Applications

1. Wetland Ecosystems
2. Vegetation Studies
3. **Disaster Monitoring**
4. Ground Subsidence
5. Cryosphere
6. Oceans
7. Urban Area/Infrastructure Change

Unlike optical sensors, such as MODIS and VIIRS, microwave SAR can see through clouds!

Classification Based on SAR Observables



Green: not inundated
Yellow & **Orange**: inundated vegetation
Blue (light & dark): open water

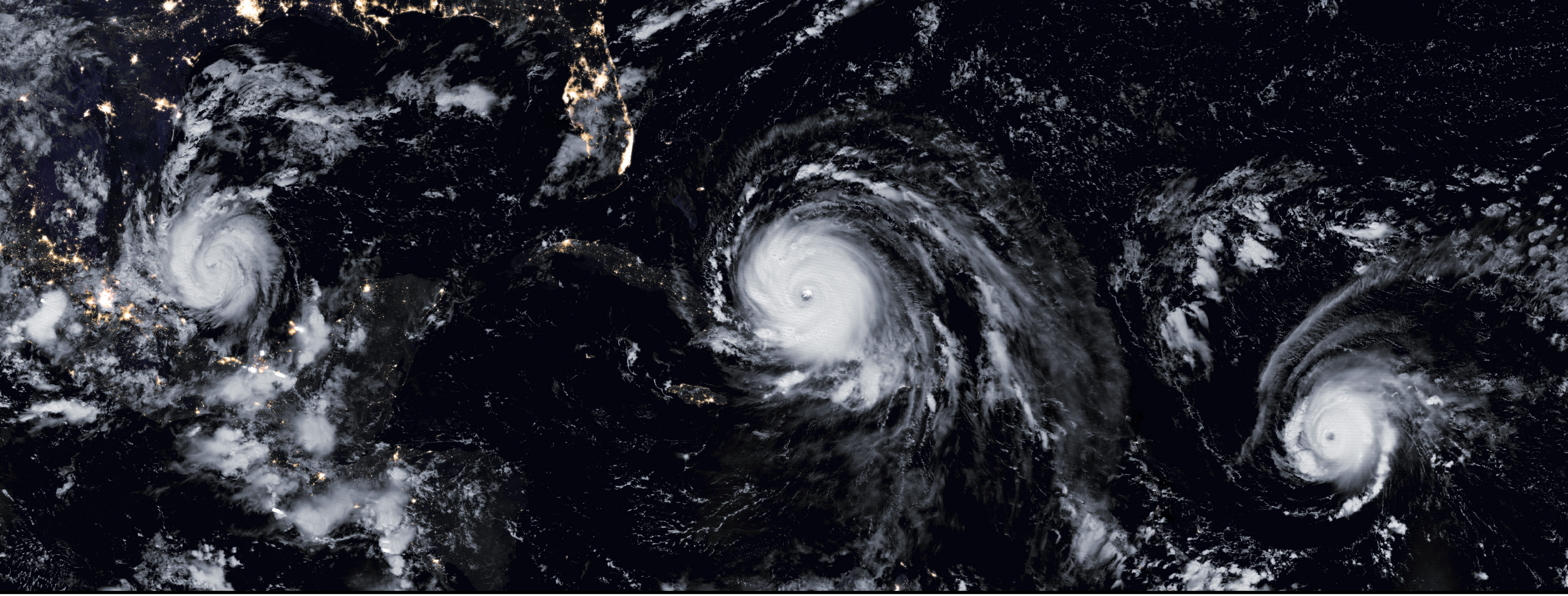
Sentinel 1 SAR Image Processing

- 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 require 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 July 2018

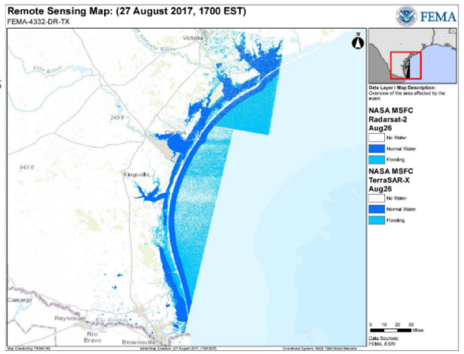
Sentinel 1 SAR Images: Before and After Hurricane Matthew

Inundation in Coastal North Carolina



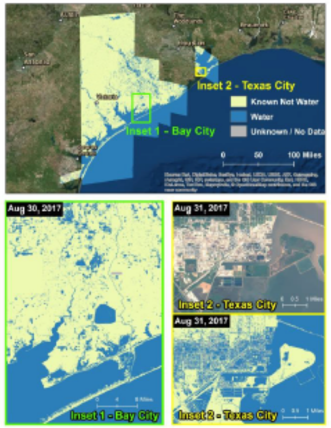
Examples of NASA Remote Sensing Data Applications

NASA Data for FEMA After Hurricane Harvey



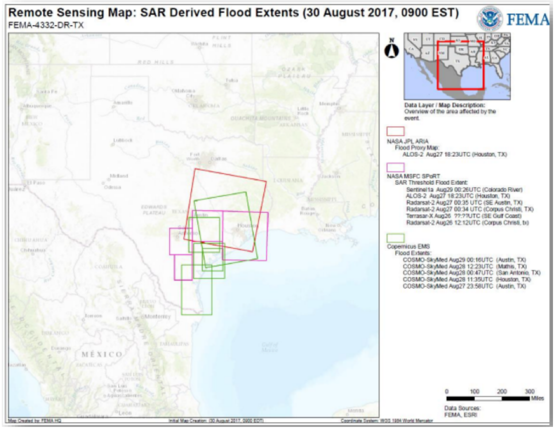
SAR Threshold Flood Extent Map provided from NASA MSFC showing normal/daily water areas (dark blue) vs. likely flooded areas (light blue): Image created using RadarSat-2 and TerraSAR-X collections from 8/26; threshold may be affected by signal from wind or other constraints (e.g., moist agricultural fields, sensor resolution, etc.)

Aug 27:
FEMA Situation Briefing includes SAR Threshold Flood Extent Map and request for UAV SAR



Sep 4:
New flood extents available derived from COSMO-SkyMed (Copernicus) and SPOT6 (NASA MSFC)

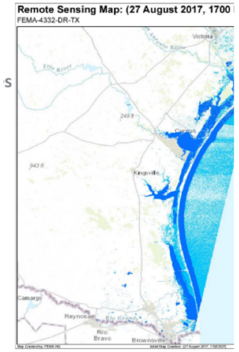
Aug 25:
Hurricane Harvey makes landfall



Aug 31:
Remote sensing products from NASA available on FEMA FTP server

NASA MSFC & JPL generate flood extents based on ALOS-1 & Sentinel data

NASA Data for FEMA After Hurricane Harvey



SAR Threshold Flood Extent Map provid
water areas (dark blue) vs. likely floode
RadarSat-2 and TerraSAR-X collections fro
from wind or other constraints (e.g., mois

Index of /NationalDisasters/HurricaneHarvey/Data/RemoteSensing/NASA

Name	Last modified	Size	Description
Parent Directory		-	
20170826_000000_TsX_thresh025sd_WGS84.zip	27-Aug-2017 18:28	15M	
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SP06N28_572766W096_1985882017083000000000MS00_water_20170830.zip	04-Sep-2017 12:07	1.0M	
SP06N28_918559W095_6180512017083000000000MS00_GG003002001_water_20170830.zip	04-Sep-2017 12:07	885K	
SP06N29_273468W096_1994622017083000000000MS00_GG003002001_water_20170830.zip	04-Sep-2017 12:08	2.3M	

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O-
s) and
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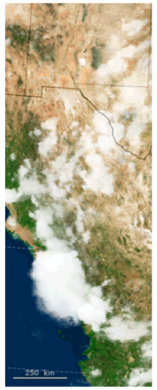
Aug 25:
Hurricane



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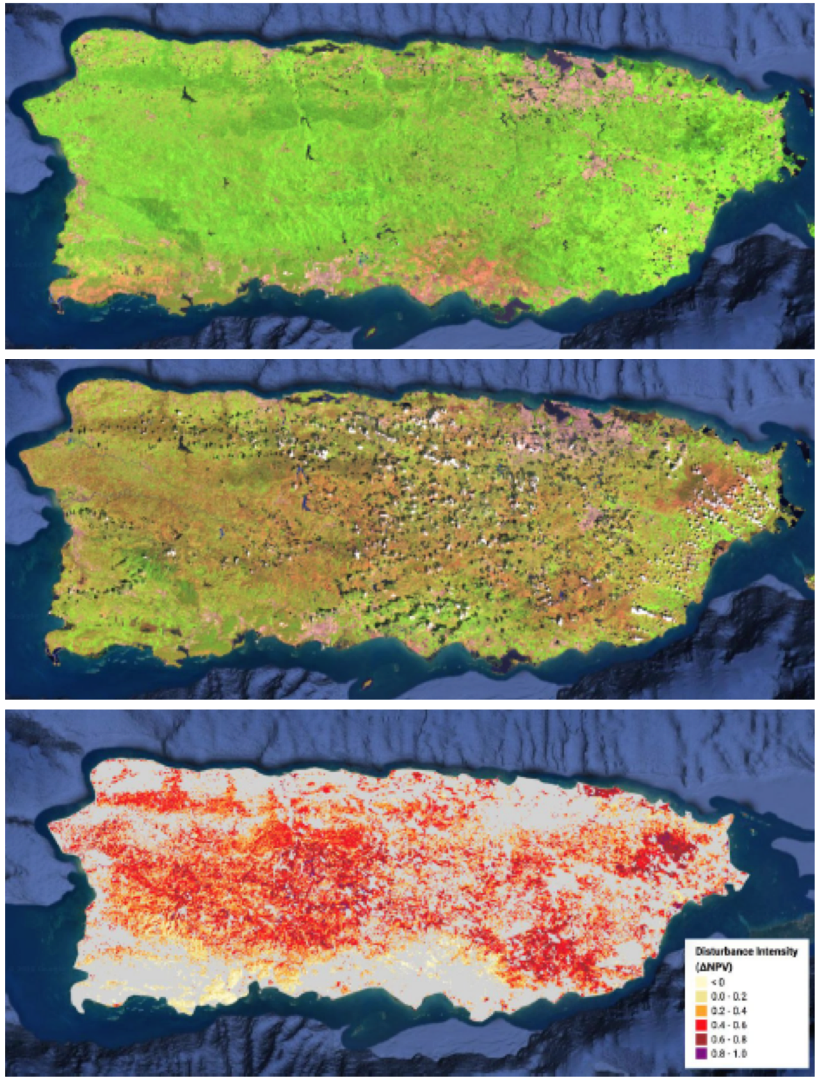
Tracking Vegetation Changes in Puerto Rico After Hurricane Maria

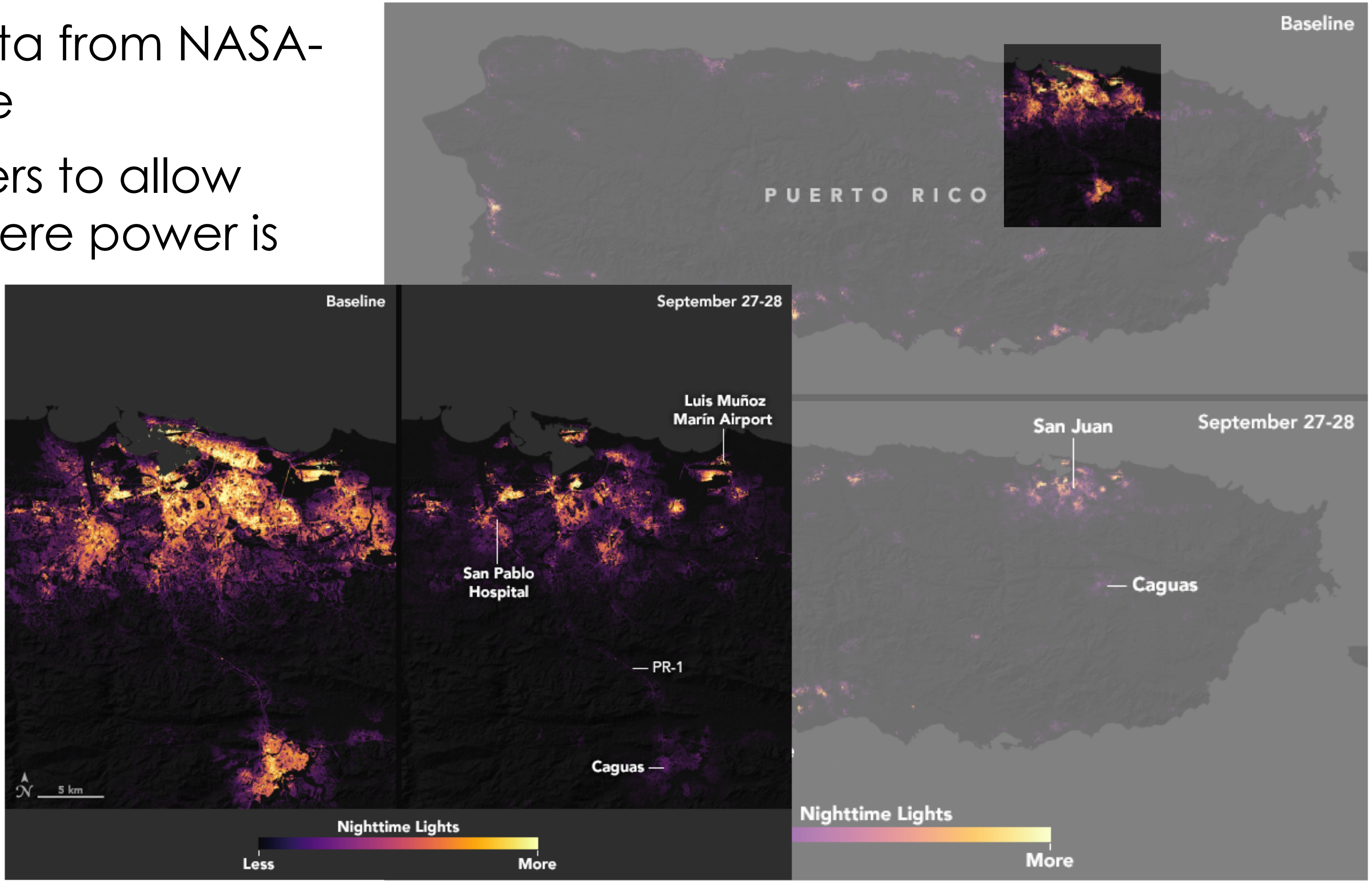
- Quantify forest disturbance on Puerto Rico as a result of Hurricane Maria (Sep 2017)
- Used Landsat 8 scenes
- Top figure: Pre-Maria false color Landsat 8 image
- Middle figure: Post-Maria false color Landsat 8 image
  – heavily impacted areas show up as large increases in SWIR (red)
- Bottom figure: map of change in non-photosynthetic vegetation (NPV) – exposed wood and surface litter



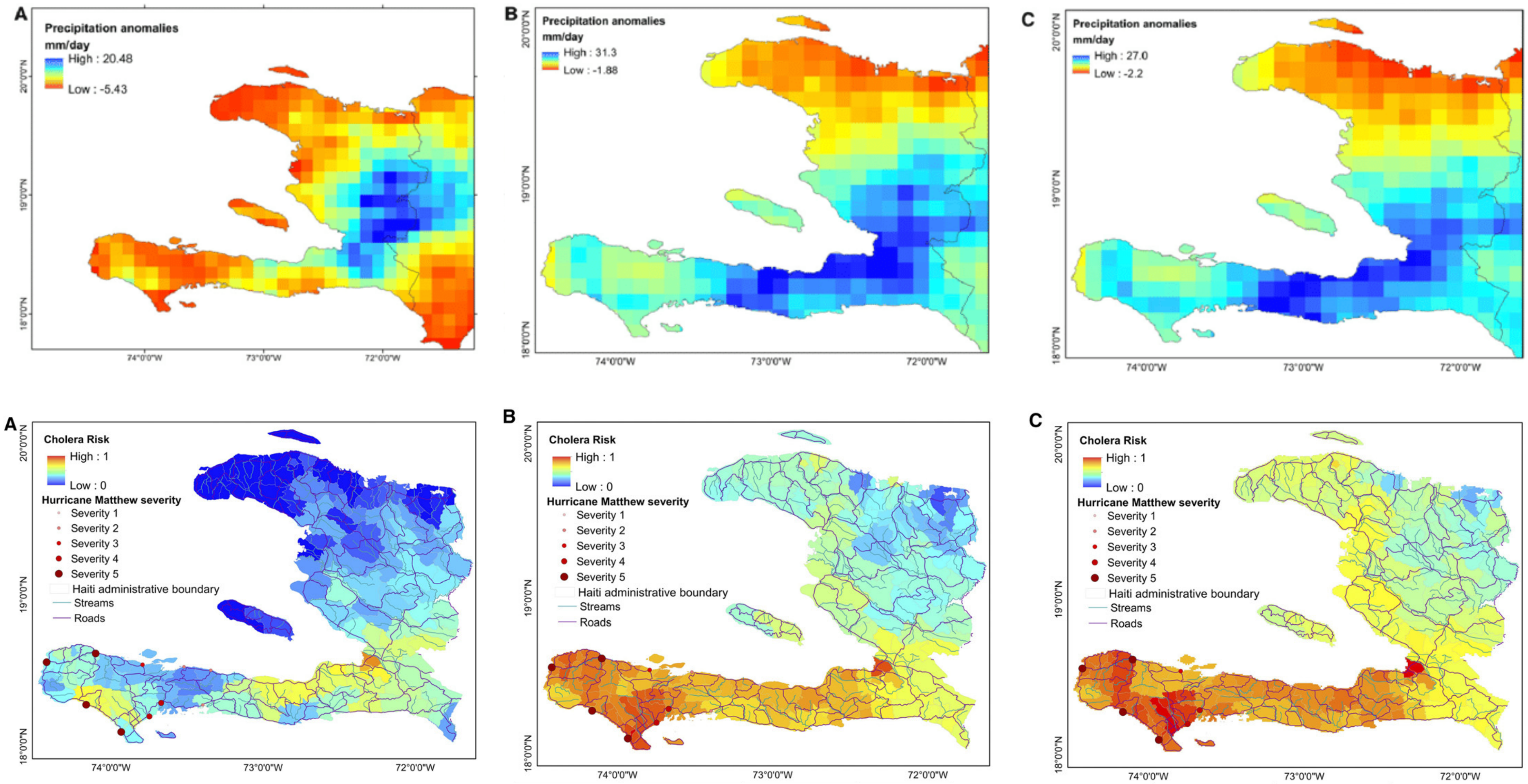
Feng, Y., Negron-Juarez, R., Patricola, C. M., Collins, W. D., Uriarte, M., Hall, Hall, J.S., Clinton, N., Chambers, J. (2018). Rapid remote sensing assessment of impacts from hurricane maria on forests of puerto rico. PeerJ PrePrints, http://dx.doi.org/10.7287/peerj.preprints.26597v1

Monitoring Power Outages as a Result of Hurricane Maria

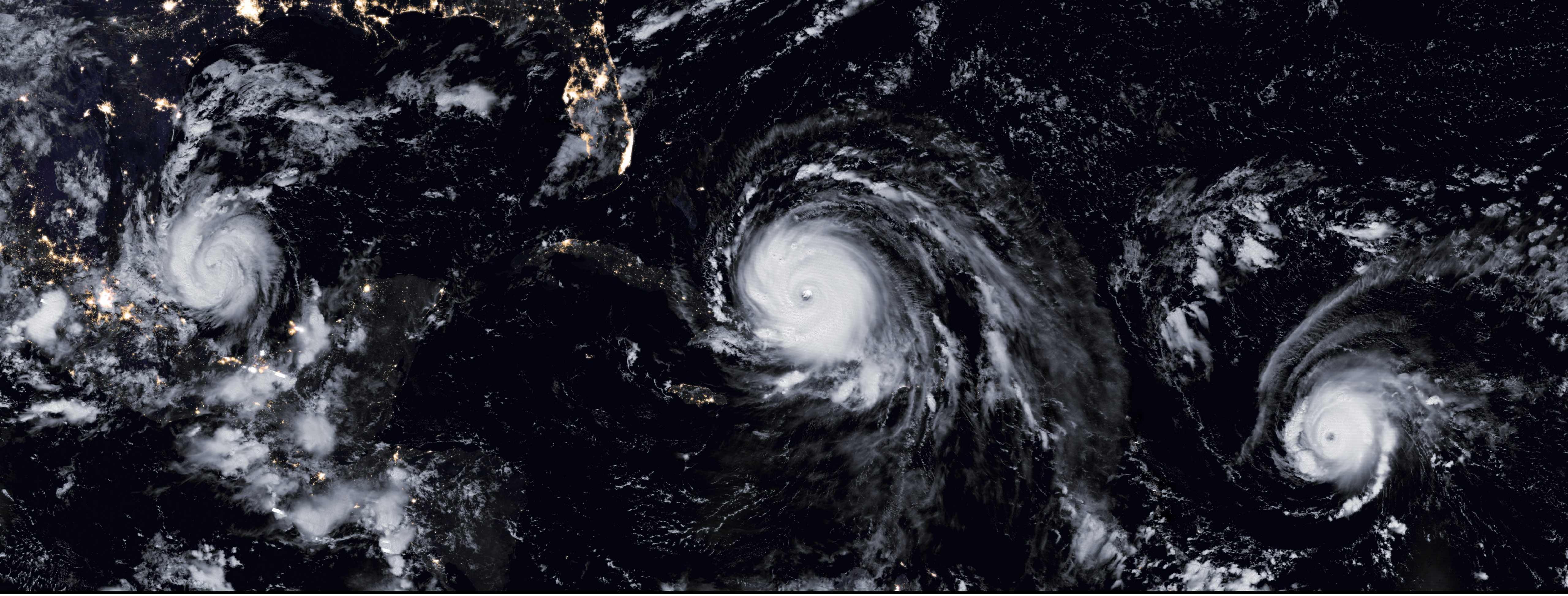
- Generated based on data from NASA-NOAA Suomi NPP satellite
- Provided to first responders to allow them to quickly know where power is out



GPM Used to Estimate Cholera Risk After Hurricane Matthew



Khan, R., Anwar, R., Akanda, S., McDonald, M., Huq, A., Jutla, A., Colwell, R. (2017) Assessment of Risk of Cholera in Haiti Following Hurricane Matthew. American Journal of Tropical Medicine and Hygiene, http://www.ajtmh.org/content/journals/10.4269/ajtmh.17-0048



Demonstration of Case Studies

Summary

- NASA remote sensing and Earth system model data **augment operational tropical storm data** from centers such as NHC, CPHC, JTWC, and compliment storm monitoring capability at different stages: initiation, propagation, and dissipation
- At a given location, NASA data can be used in decision-making to prepare for emergencies by enabling access before, during, and after storm conditions, specifically:
  - Wind and Sea Level Pressure (GEOS-5)
  - Precipitation (GPM IMERG)
  - True Color Imagery (MODIS, VIIRS)
  - River Flooding & Surface Inundation (ERDS, GFMS, MODIS Inundation Mapping, and the Flood Observatory)
  - Night Light Imagery (VIIRS)
- NOAA and JRC provide storm surge monitoring capability

Summary

- Storm related emergency preparedness, response, and relief operations can benefit from the combined use of
  - Weather data
  - Flooding data
  - Terrain data
  - Socioeconomic data

Remote Sensing Data Applications for Preparedness and Planning

- Satellite data provides a comprehensive history of storm tracks, intensity, precipitation and flooding
  - GOES-5, TMPA/IMERG, and MODIS have a combined historical record of ~20 years
- Combining with in situ data about storm damages, destruction, and economic impacts can help with the decision-making process

  - Monitor winds, rain, and flooding
  - Low-lying areas
  - Flooded streets and roads

Now/Prepare

Sign up for local alerts and warnings. Monitor local news and weather reports.

Prepare to evacuate by testing your emergency communication plan(s), learning evacuation routes, having a place to stay, and packing a "go bag."

Stock emergency supplies.

Protect your property by installing sewer backflow valves, anchoring fuel tanks, reviewing insurance policies, and cataloging belongings.

Collect and safeguard critical financial, medical, educational, and legal documents and records.

During/Survive

Follow guidance from local authorities.

If advised to evacuate, grab your "go bag" and leave immediately.

For protection from high winds, stay away from windows and seek shelter on the lowest level in an interior room.

Move to higher ground if there is flooding or a flood warning.

Turn Around Don't Drown.® Never walk or drive on flooded roads or through water.

Call 9-1-1 if you are in life-threatening danger.

After/Be Safe

Return to the area only after authorities say it is safe to do so. Do not enter damaged buildings until they are inspected by qualifie professionals.

Never walk or drive on flooded roads or through floodwaters.

Look out for downed or unstable trees, poles, and power lines.

Do not remove heavy debris by yourself. Wear gloves and sturdy, thick-soled shoes to protect your hands and feet.

Do not drink tap water unless authorities say it is safe.

For more resources about hurricane risk, visit ready.gov/prepare

- Monitor flooding
- Monitor power outages with night light imagery

Image Credit: FEMA

Remote Sensing Data Advantages and Limitations

- Remote sensing and modeling data provide global coverage
- Data are open source and are available not only for near-real time monitoring but also for past storms which together with in situ and impacts data can be used to develop emergency planning strategies
- NASA data tools help easy access, analysis, and visualization capabilities, convenient for monitoring emergency situations
- NASA data covered here result from research and local/regional validation is recommended
- Remote sensing and model data from various sources have different spatial and temporal resolutions – often require further analysis for quantitative applications (e.g. integrated in GIS or hydrological model)

Thank You!