

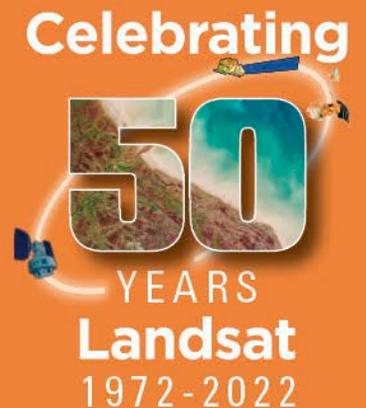
PECORA22

Opening the Aperture to Innovation: Expanding Our Collective Understanding of a Changing Earth

Near Real-time Agricultural Flood Monitoring and Crop Impact Assessment under Google Earth Engine

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Outline

- Background and Objectives
- Methodology
- Flood Extent Detection Algorithms
- Flood Extent Detection Applications
 - Hurricanes Harvey and Fiona
- Flood Depth Algorithm and Applications
 - Hurricane Fiona
- Crop Impact Assessment
- Summary and Future Research



Disclaimer: The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.

Background and Objectives

- Near real-time agricultural flood monitoring is critical to government agencies, farmers, ag business decision makers, and other stakeholders for rapid crop impact assessment.
- Google Earth Engine (GEE) is an ideal platform to develop web-based applications for rapid processing and visualization of flood inundation.
- In this study, a GEE app was implemented and different algorithms for flood detection were evaluated.
- Current existing remote sensing-based algorithms for flood detection are limited to the estimation of flood extent only, without depth.
- To fill this gap, a new algorithm was developed in the GEE application to estimate flood depth throughout the flood extent.

Methodology

- Open water bodies typically exhibit lower backscattering than other ground features. The flood can thus be detected by comparing SAR's images captured before and after a flood event.
- A common method for flood identification is to detect changes in backscattering from SAR's polarization bands acquired before and after a flood event.

Methodology - Flood extent detection algorithms

Absolute Threshold Differencing (ATD)

- Water bodies on both pre and post event images are identified using a threshold of $\beta_{vh} < -20$ or $\beta_{vw} < -14$
- Flood pixels identified by image differencing between pre and post event water

z-score

$$\mathbf{z\text{-score} = (x_i - \mu) / \sigma}$$

Pixels on the post-event image with a z-score < -1.96 are considered as “floods”, as they are statistically significantly different from the mean values of the specified time period at a 95% confidence level.

Relative Threshold Differencing (RTD)

Pixels on the post-event image with a β_{vh} value 30% lower than normal are considered as “floods”

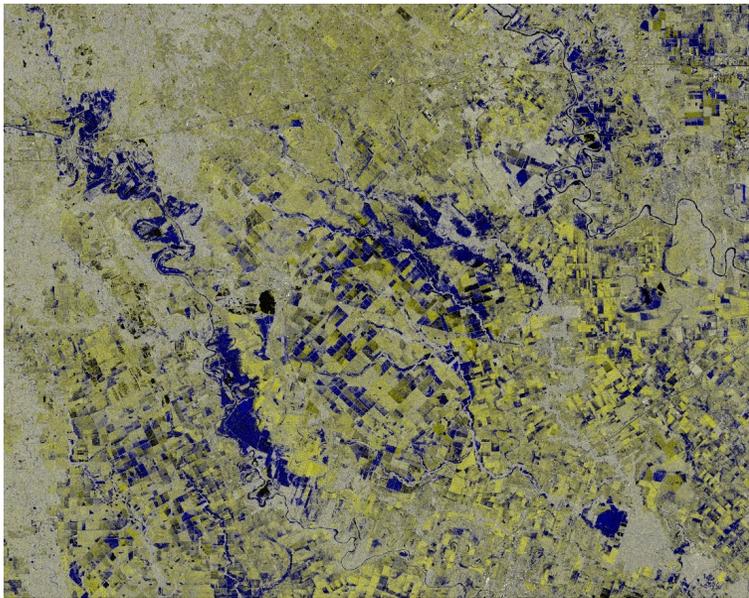
Modified z-score (Robust z-score)

$$\text{Modified z-score} = (X_i - \text{median}) / (1.4826 * \text{MAD})$$

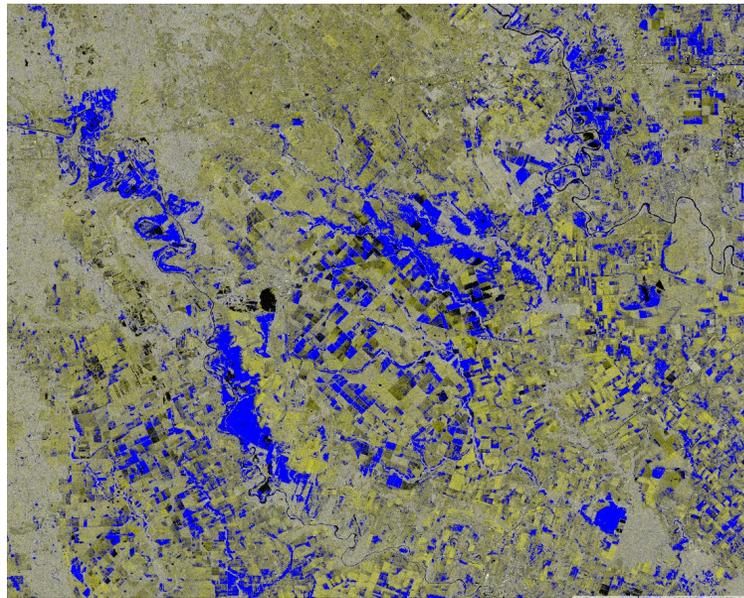
- MAD is defined as the median of the absolute deviations from the data's median

$$\text{MAD} = \text{median}(|X_i - \tilde{X}|)$$

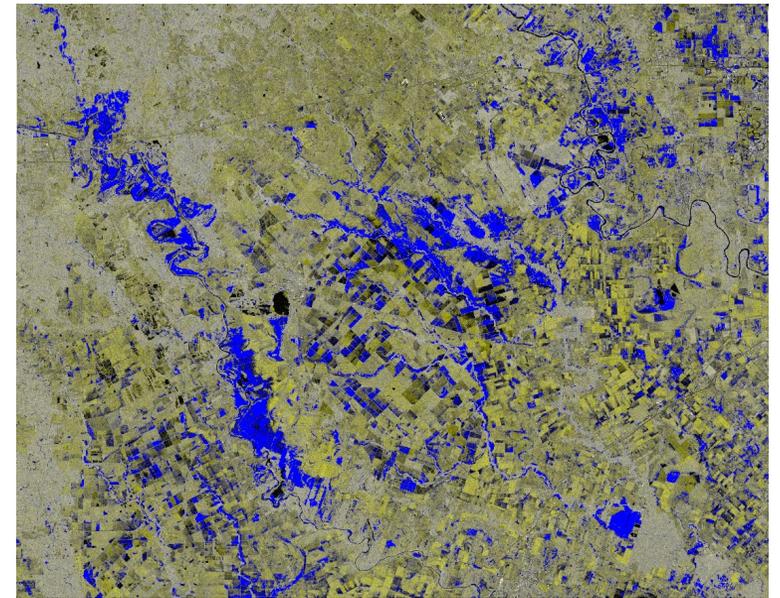
- 1.4826 is a scalar constant linked to the assumption of normality of the data.
- $1.4826 * \text{MAD}$ is conceptually equivalent to standard deviation.
- In this case, pixels on the post-event image with a modified z-score < -1.96 are considered as “floods”.



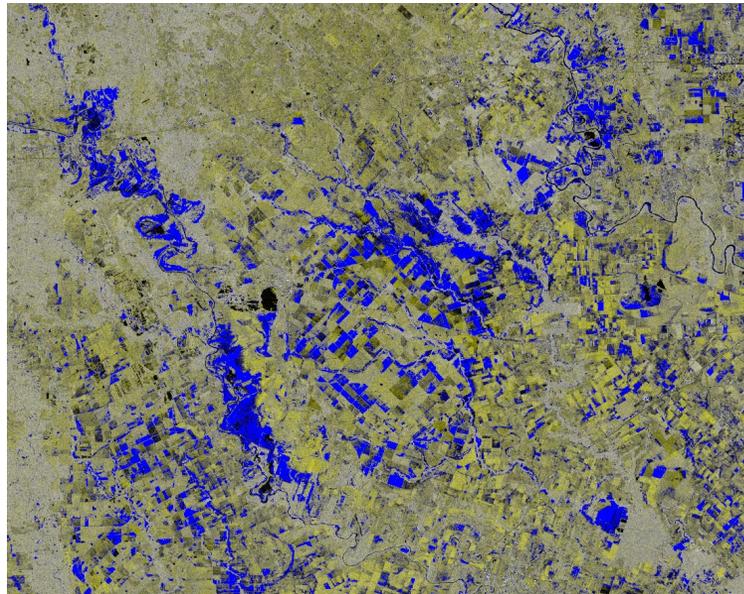
Sentinel-1 SAR false color composite (R: post-event VH, G: post-event VH, B: post-event VH) showing anomaly



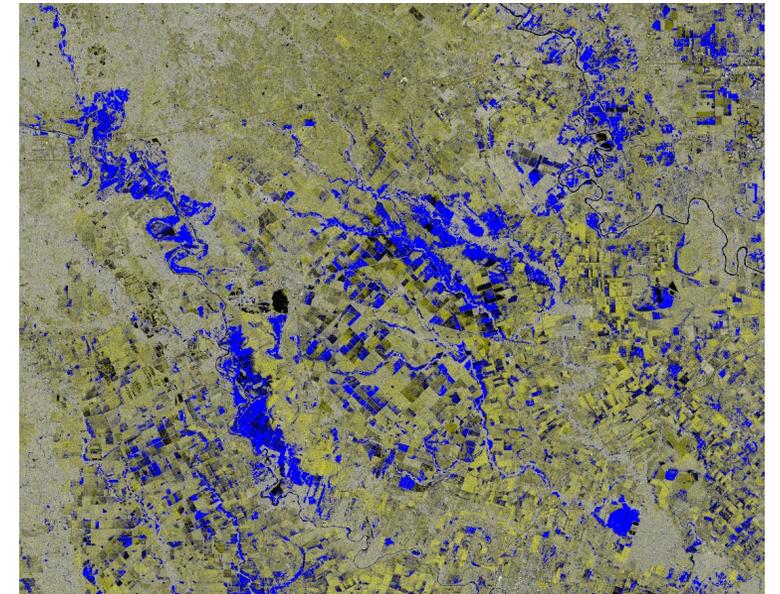
Absolute Threshold Differencing ($\beta_{vh} < -20$)



z-score ($z < -1.96$)



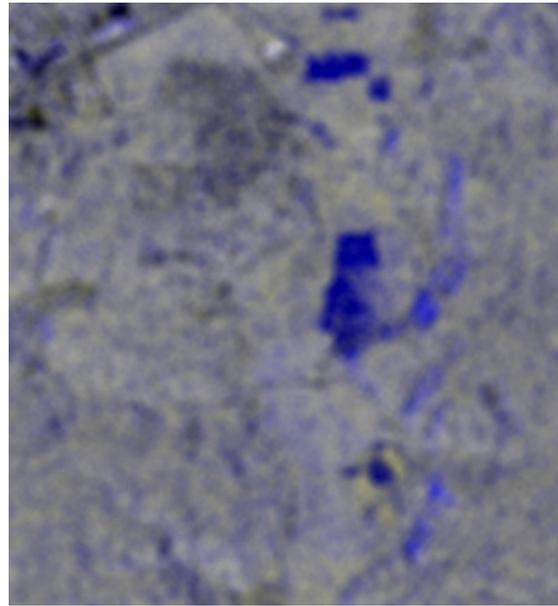
Relative Threshold Differencing (post-event β_{vh} 30% lower than normal)



Modified z-score ($z < -1.96$)

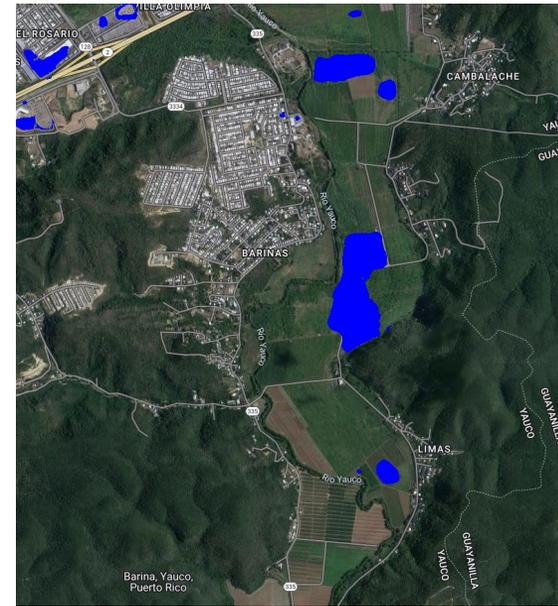
Flood detection using different methods for Hurricane Harvey (Aug 27- Sep 05, 2017)

Flood detection using different methods for Hurricane Fiona Puerto Rico (Sep 18 - 28, 2022)



Sentinel-1 SAR false color composite (R: post-event VH, G: post-event VH, B: post-event VH) showing anomaly

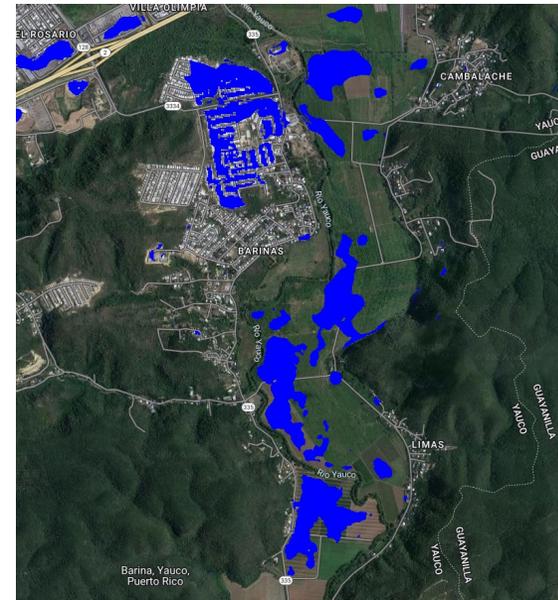
The maps show inundated plantain fields in a tropical farm, Yauco, Puerto Rico



Absolute Threshold Differencing ($\beta_{vh} < -20$)



z-score ($z < -1.96$)



RTD (post-event β_{vh} 30% lower than normal)



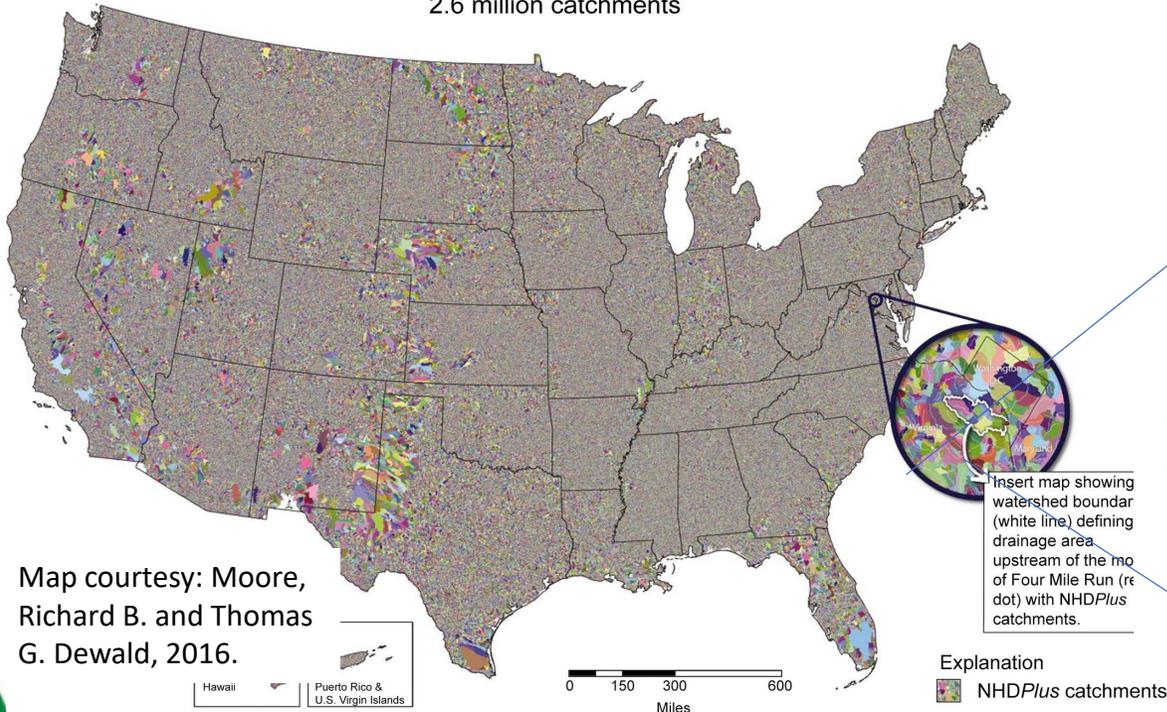
Modified z-score ($z < -1.96$)

Methodology - Flood depth estimation algorithms

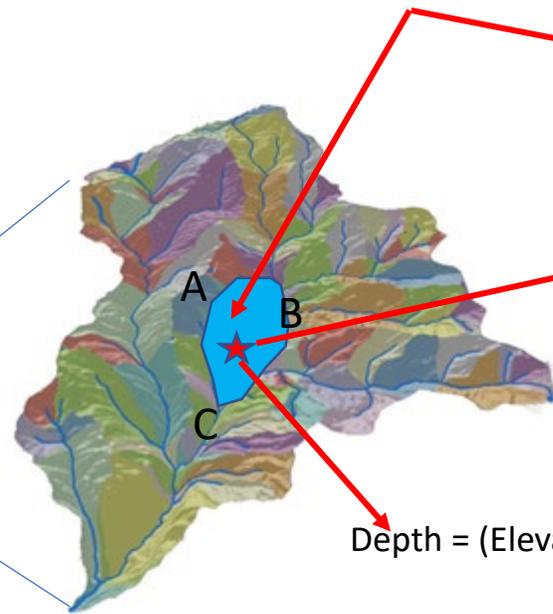
- A **flood depth** estimation algorithm was developed and implemented by integrating USGS 3DEP National Map Seamless 1/3 Arc-Second (10m) DEM, and NHDPlusV2 catchment geospatial products.

Elevation-Derived Catchments
From the National Hydrography Dataset Plus (NHDPlus)

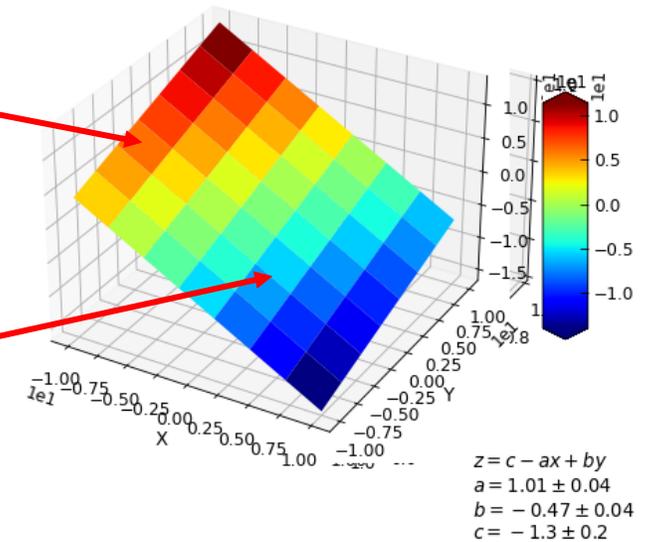
2.6 million catchments



Flood water surface



$$ax + by + cz + d = 0,$$



$$\text{Depth} = (\text{Elevation_water_surface} - \text{Elevation_terrain})$$

Flood Detection and Monitoring System v1.0 – A Google Earth Engine Web App for rapid visualization and assessment

code.earthengine.google.com

Google Earth Engine Search places and datasets...

Region of Interest: Puerto Rico

Date filter: Event start date (format: yyyy-MM-dd): 2022-09-19, Event end date (format: yyyy-MM-dd): 2022-09-30

Add more layers: PlanetScope, Sentinel-2, Landsat 8/9

PlanetScope imagery of before and after the event used for validation

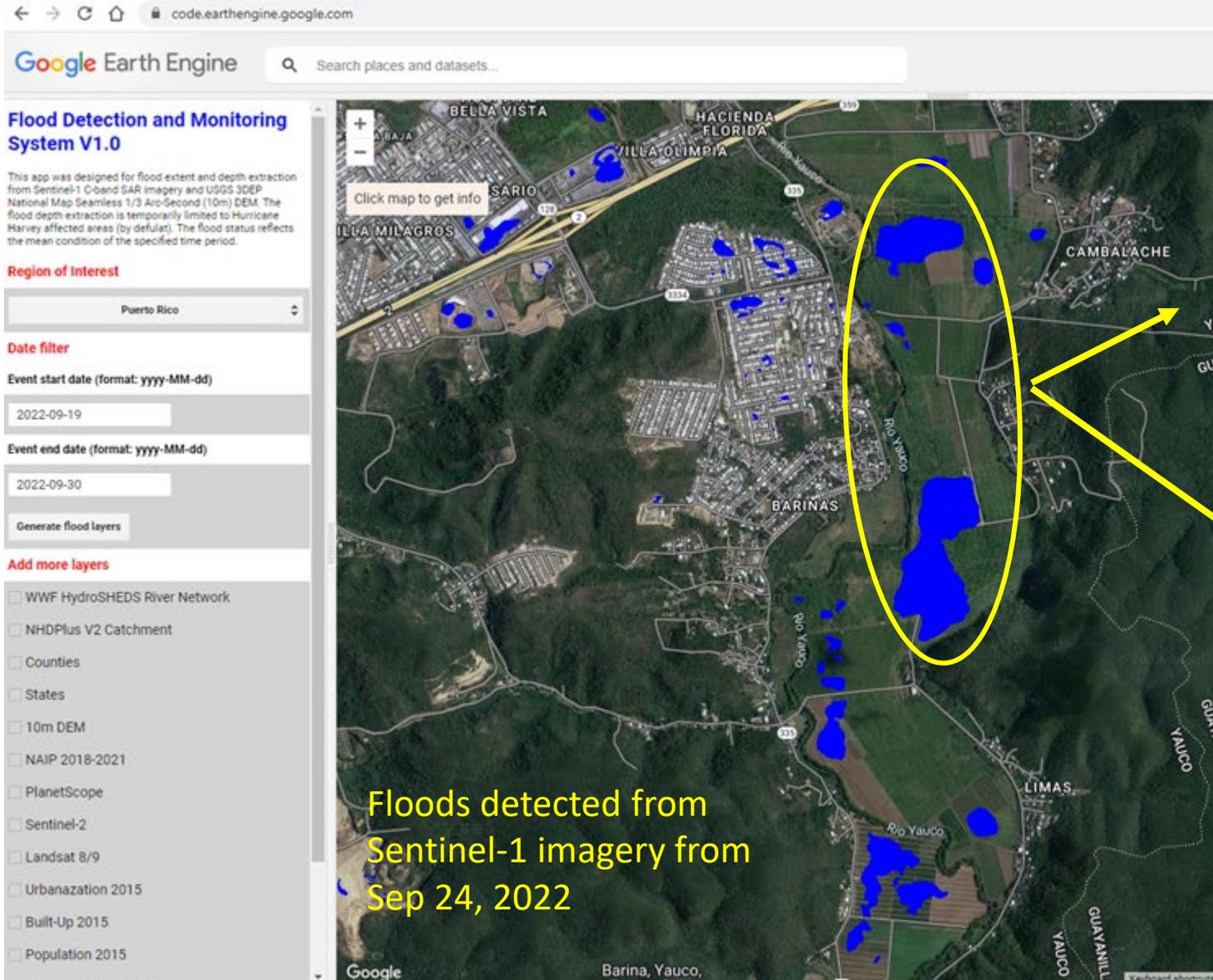
Sep 26, 2022

Sep 25, 2022

Keyboard shortcuts | Map data ©2022 Google | 10 km | Terms of Use

Hurricane Fiona Puerto Rico, Sep 18 - 28, 2022

Plantain fields in Tropical Farm, Yauco, Puerto Rico, Sep 19, 2022



Plantain fields in Tropical Farm, Yauco, Puerto Rico, Sep 26, 2022



Using USGS 10m DEM and NHDPlusV2 catchment geospatial products for flood depth estimation

Inundated plantain in Tropical Farm, Yauco, Puerto Rico, Sep 19, 2022



code.earthengine.google.com

Google Earth Engine

USGS 3DEP National Map Seamless 1/3 Arc-Second (10m) DEM. The flood depth extraction is temporarily limited to Hurricane Harvey affected areas (by default). The flood status reflects the mean condition of the specified time period.

Region of Interest

Puerto Rico

Date filter

Event start date (format: yyyy-MM-dd)
2022-09-19

Event end date (format: yyyy-MM-dd)
2022-09-30

Generate flood layers

Add more layers

- WWF HydroSHEDS River Network
- NHDPlus V2 Catchment
- Counties
- States
- 10m DEM
- NAIP 2018-2021
- PlanetScope
- Sentinel-2
- Landsat 8/9
- Urbanization 2015
- Built-Up 2015
- Population 2015
- ESA WorldCover 2020
- USDA NASS CDL 2021

Dashboard 1
 Location: Lat 18.02, Lon -66.84
 Elevation: 23.36 m
 Flood depth: 0.26 m
 CDL for accessment (2022): N/A
 CDL 2021: N/A
 ESA WorldCover 2020: Trees

Dashboard 2
 Location: Lat 18.01, Lon -66.84
 Elevation: 19.23 m
 Flood depth: 2.33 m
 CDL for accessment (2022): N/A
 CDL 2021: N/A
 ESA WorldCover 2020: Trees

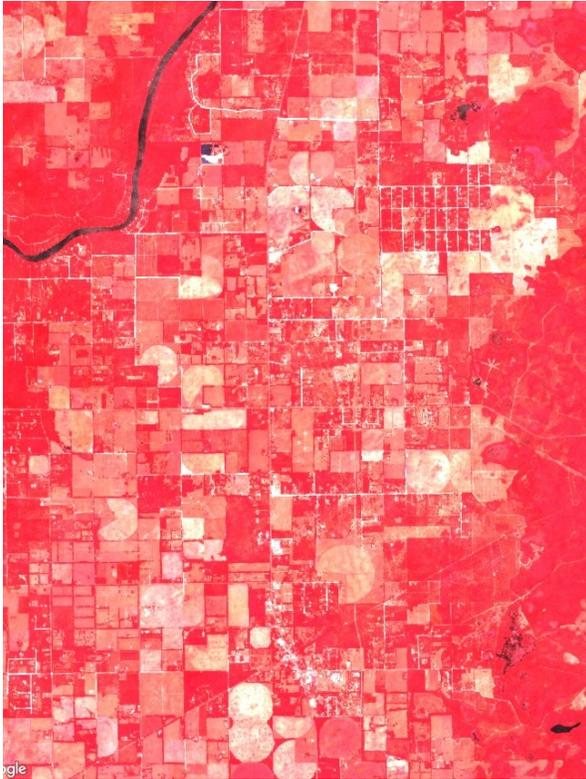
Floods detected from Sentinel-1 imagery from Sep 24, 2022

The Puerto Rican plantain trees grow to be less than 10 feet (~3 m) tall.

Plantain fields in Tropical Farm, Yauco, Puerto Rico, Sep 26, 2022

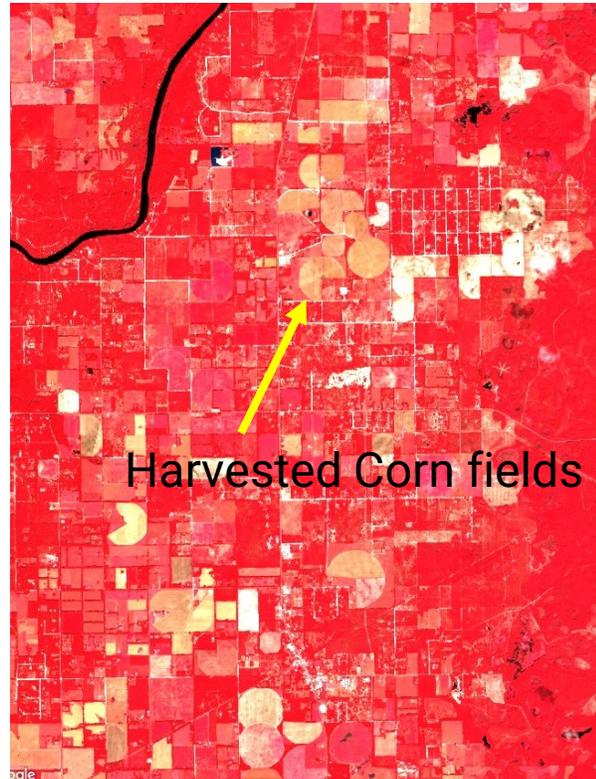


Removal of false alarm flooding detected from Sentinel-1 SAR imagery



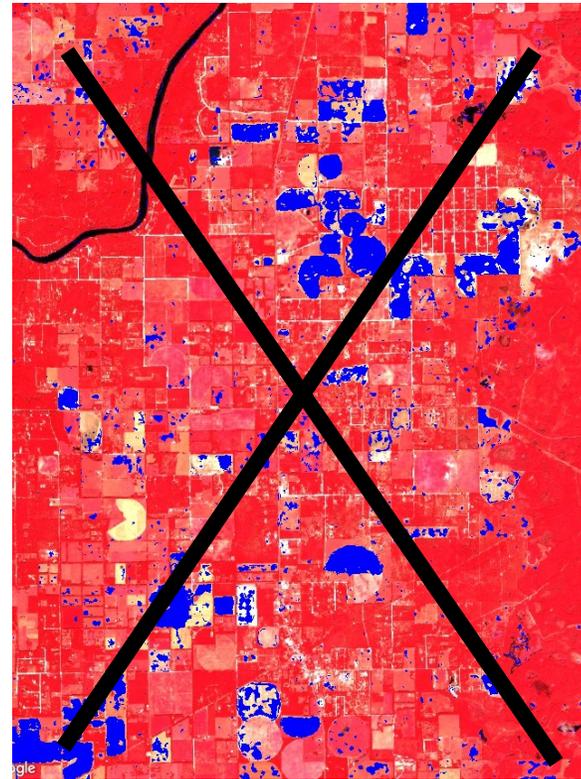
Sentinel-2 image before event

▼ Sentinel-2 pre-event NDVI: Image (1 band)
NDVI: 0.707317054271698
▼ Sentinel-2 post-event NDVI: Image (1 band)
NDVI: 0.16485686600208282

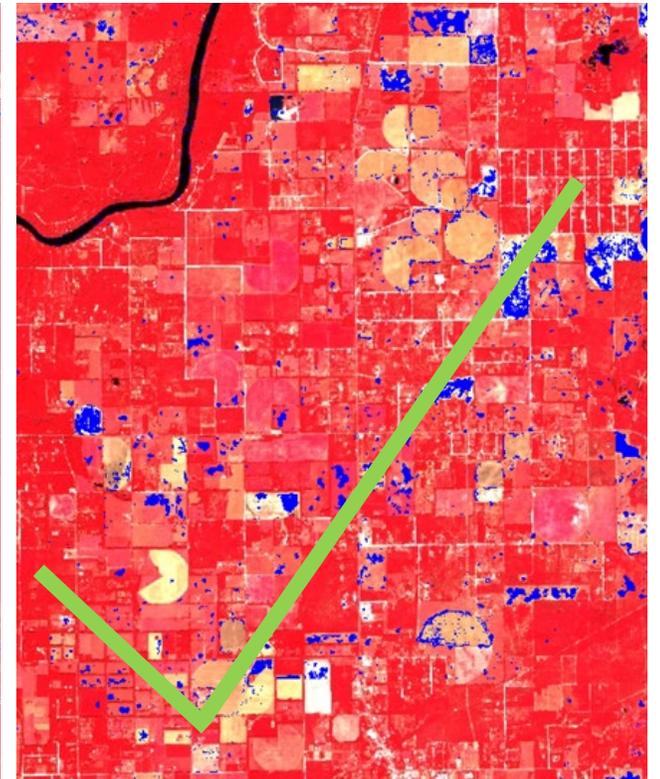


Sentinel-2 image after event

▼ Sentinel-2 pre-event MNDWI true: Image (1 band)
MNDWI: -0.2868894636631012
▼ Sentinel-2 post-event MNDWI true: Image (1 band)
MNDWI: -0.49059560894966125

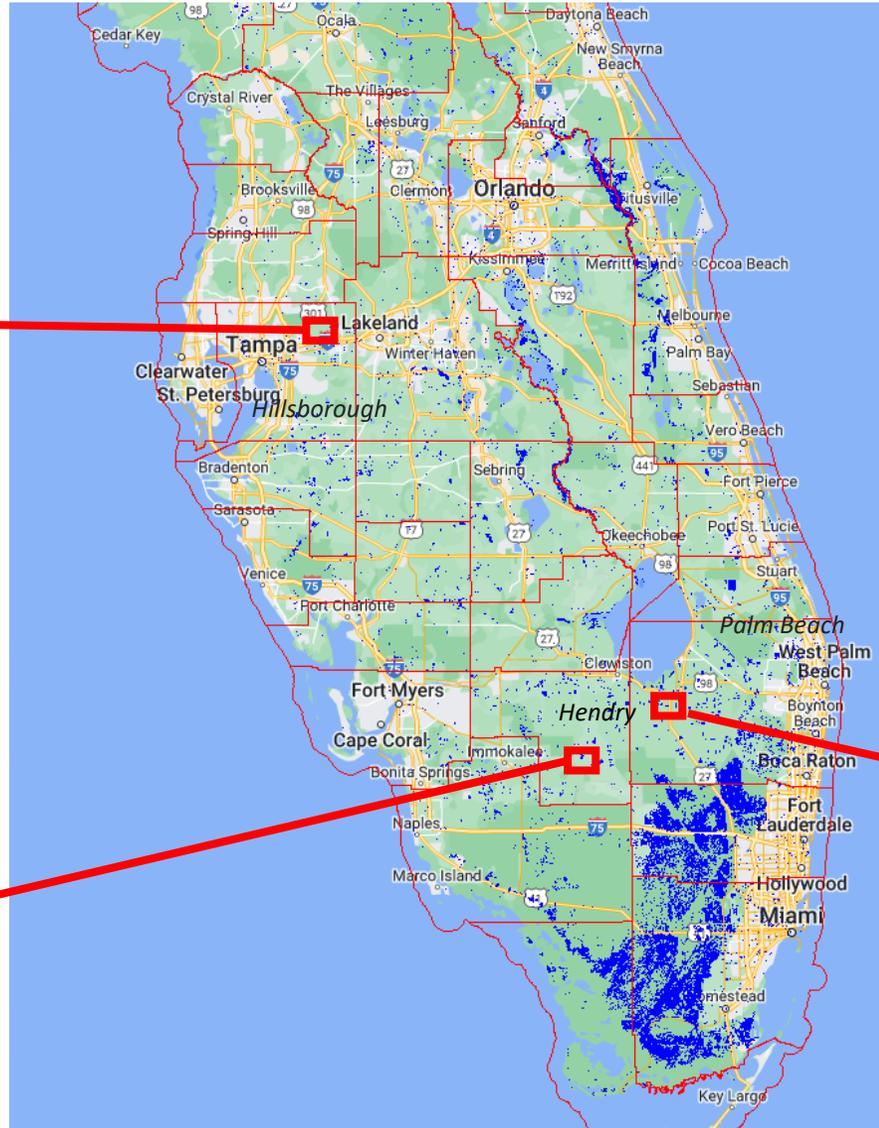
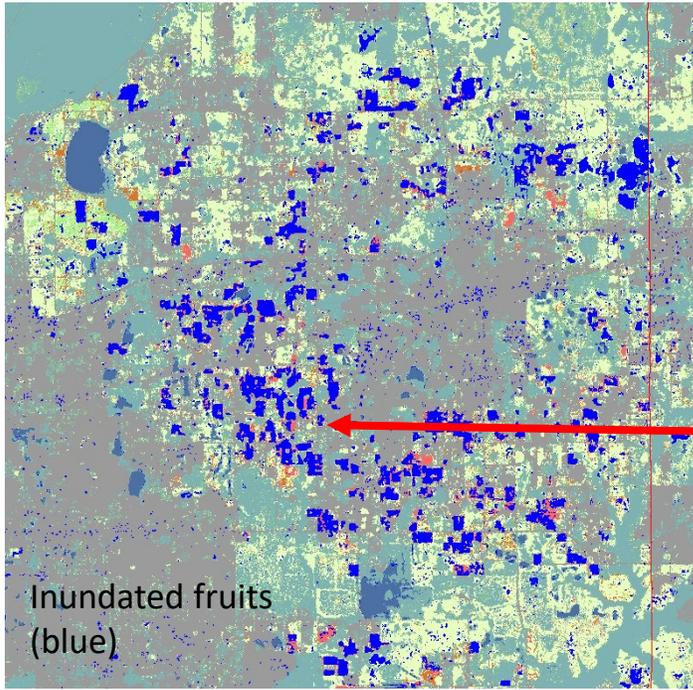


False floods detected from Sentinel-1 SAR imagery

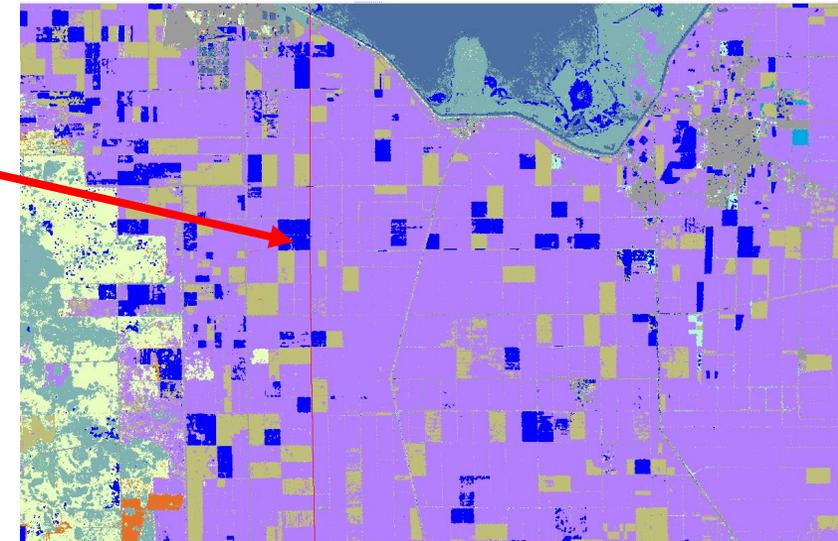
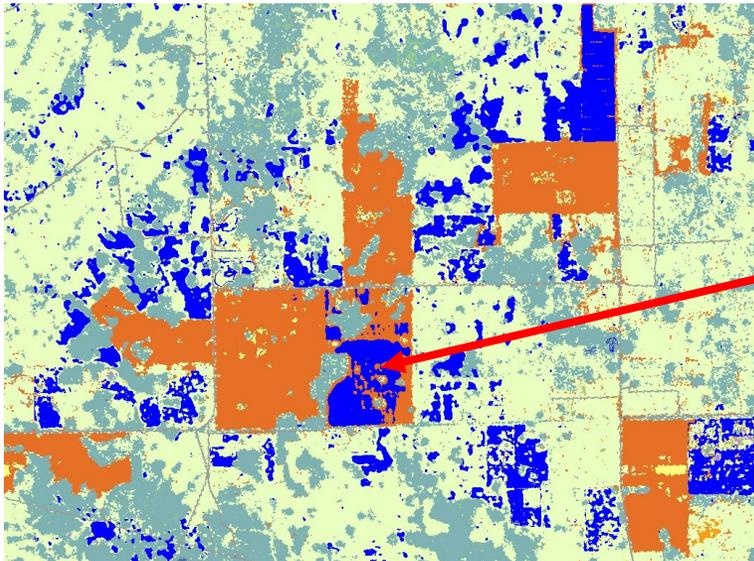


False floods eliminated by applying MNDWI

Flood detection with “harvested land filter” applied



Inundated croplands (blue) during Hurricane Ian Florida (Sep 2022) based on 2021 NASS CDL



Inundated oranges (blue)

Inundated land in Florida after Hurricane Ian (blue)

Inundated sugarcane (blue)

Crop Impact Assessment

code.earthengine.google.com

Google Earth Engine Search places and datasets...

Event start date (format: yyyy-MM-dd)
2022-09-29

Event end date (format: yyyy-MM-dd)
2022-10-05

Generate flood layers

Add more layers

- WWF HydroSHEDS River Network
- NHDPlus V2 Catchment
- Counties
- States
- 10m DEM
- NAIP 2018-2021
- PlanetScope
- Sentinel-2
- Landsat 8/9
- Urbanization 2015
- Built-Up 2015
- Population 2015
- ESA WorldCover 2020
- USDA NASS CDI 2021

Crop impact assessment

Run crop impact assessment

Remove assessment

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Click map to get info

Total acres of impacted land: 307151.52

Crop Type	Acre	Percent
,Sugarcane:	127753.29	41.59%
,Woody Wetlands:	60046.52	19.55%
,Grassland/Pasture:	38511.23	12.47%
,Fallow/Idle Cropland:	11411.23	3.70%
,Evergreen Forest:	11411.23	3.70%
,Corn:	9631.23	3.14%
,Developed/Low Intensity:	7413.23	2.41%
,Herbaceous Wetlands:	4942.11	1.61%
,Aquaculture:	4200.79	1.37%
,Rice:	3953.68	1.29%
,Developed/Open Space:	1729.74	0.56%
,Other Hay/Non Alfalfa:	988.42	0.32%
,Developed/Med Intensity:	988.42	0.32%
,Developed/High Intensity:	988.42	0.32%
,Sorghum:	247.11	0.08%
,Shrubland2:	247.11	0.08%
,Dbl Crop WinWht/Soybeans:	247.11	0.08%
,Winter Wheat:	0.00	0.00%
,Wetlands:	0.00	0.00%
,Watermelons:	0.00	0.00%

Under Construction



Summary and Future Work

- A GEE app was developed using four algorithms for flood extent detection and applied to major flood events for near real-time monitoring and assessment.
- Initial results indicate that all four algorithms can effectively capture major floods. However, ATD is most reliable and the default in this app.
- The Modified z-score method outperformed standard z-score for the Hurricane Fiona test. Further, the RTD method captured more “floods” than other algorithms and will be evaluated further.
- The Z-score, modified z-score and RTD methods can serve as ancillary anomaly detection tools to complement floods omitted by ATD. Further validation will be conducted when more ground reference data are available.

Summary and Future Work cont.

- When integrating MNDWI, this app can minimize the effects caused by false inundation alarms such as harvested croplands.
- By integrating DEM and NHD catchments, this app can provide reasonable flood depth estimates.
- To better characterize flood extents and depths, the L-band SAR data from the upcoming NISAR mission, and the observables (i.e., water level, water extent, etc.) from the upcoming satellite altimeter - the Surface Water and Ocean Topography mission (SWOT) will be integrated into the GEE flood monitoring app.



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Thank you and Questions

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