Google Earth Engine Implementation of the Floodwater Depth Estimation Tool (FwDET-GEE) for Rapid and Large Scale Flood Analysis

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WaterServ

A Cyberinfrastructure for Analysis, Visualization, and Sharing of Hydrological Data

https://waterserv.ua.edu/

Funding & Acknowledgements

Background & Motivation

- Floods are **recurring natural disasters** that impact the socioeconomic well-being of humans across the globe

- According to the recent International Disaster Database report, approximately **85 million people globally** were affected by floods each year between 2007 and 2016 [1],[2]

- Flood depth maps are critical tools for urban planning and **emergency response** and the floodwater depth estimation tool (FwDET) is a fast geographic solution that relies on minimal inputs [3]

- **So, we can make flood depth maps relatively quickly, but how can we scale the process?**

How FwDET Works
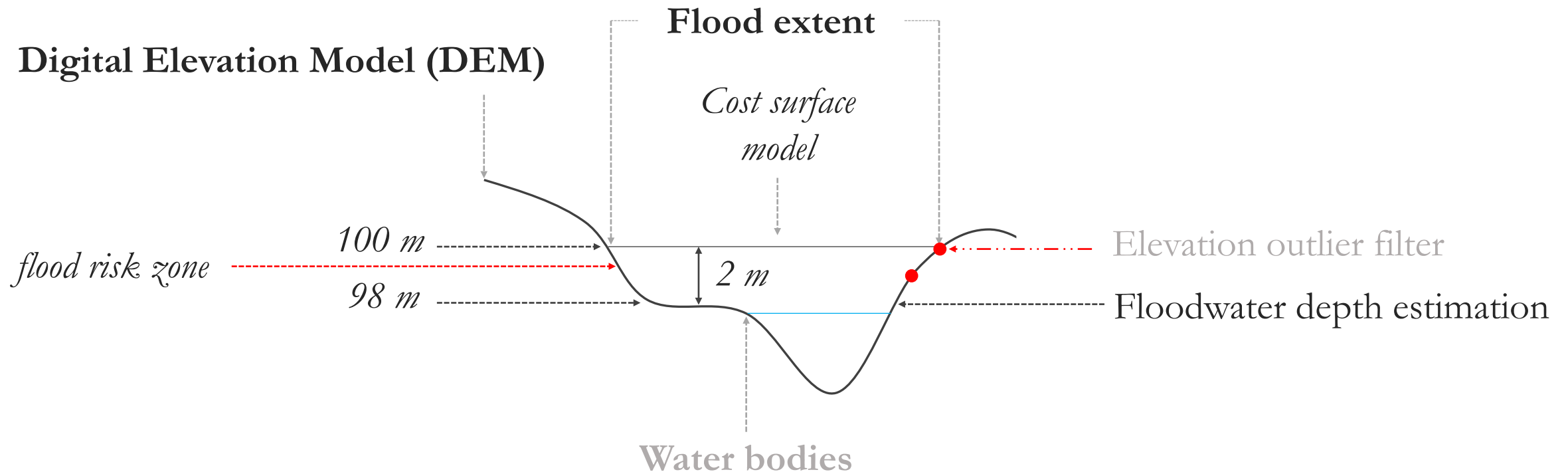
Digital Elevation Model (DEM)

Flood extent

Cost surface model

flood risk zone

100 m

2 m

98 m

Elevation outlier filter

Floodwater depth estimation

Water bodies

S. Cohen et al., "Estimating floodwater depths from flood inundation maps and topography," *JAWRA J. Amer. Water Resour. Assoc.*, vol. 54, no. 4, pp. 847–858, Aug. 2018. [3]

Why FwDET-GEE?

- Streamlines FwDET by utilizing the **cloud-sourced** geospatial data and analysis functionalities of Google Earth Engine (GEE) [4]

- **Open access** and easy-to-use for **rapid** inundation mapping

- **Geographically scalable** solution for mapping flood depths across large areas

- Ability to access and use DEMs stored in the GEE repository greatly reduces FwDET's most time-consuming preprocessing step

- Shareable GEE application capabilities enhance and **simplify the production and delivery of outputs**

A Google Earth Engine implementation of the Floodwater Depth Estimation Tool (FwDET-GEE)

Version 3.0

Peter, Brad; Cohen, Sagy; Lucey, Ronan; Munasinghe, Dinuke; Raney, Austin, 2020, "A Google Earth Engine implementation of the Floodwater Depth Estimation Tool (FwDET-GEE)", https://doi.org/10.7910/DVN/JQ4BCN, Harvard Dataverse, V3

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Google Earth Engine Implementation of the Floodwater Depth Estimation Tool (FwDET-GEE) for Rapid and Large Scale Flood Analysis
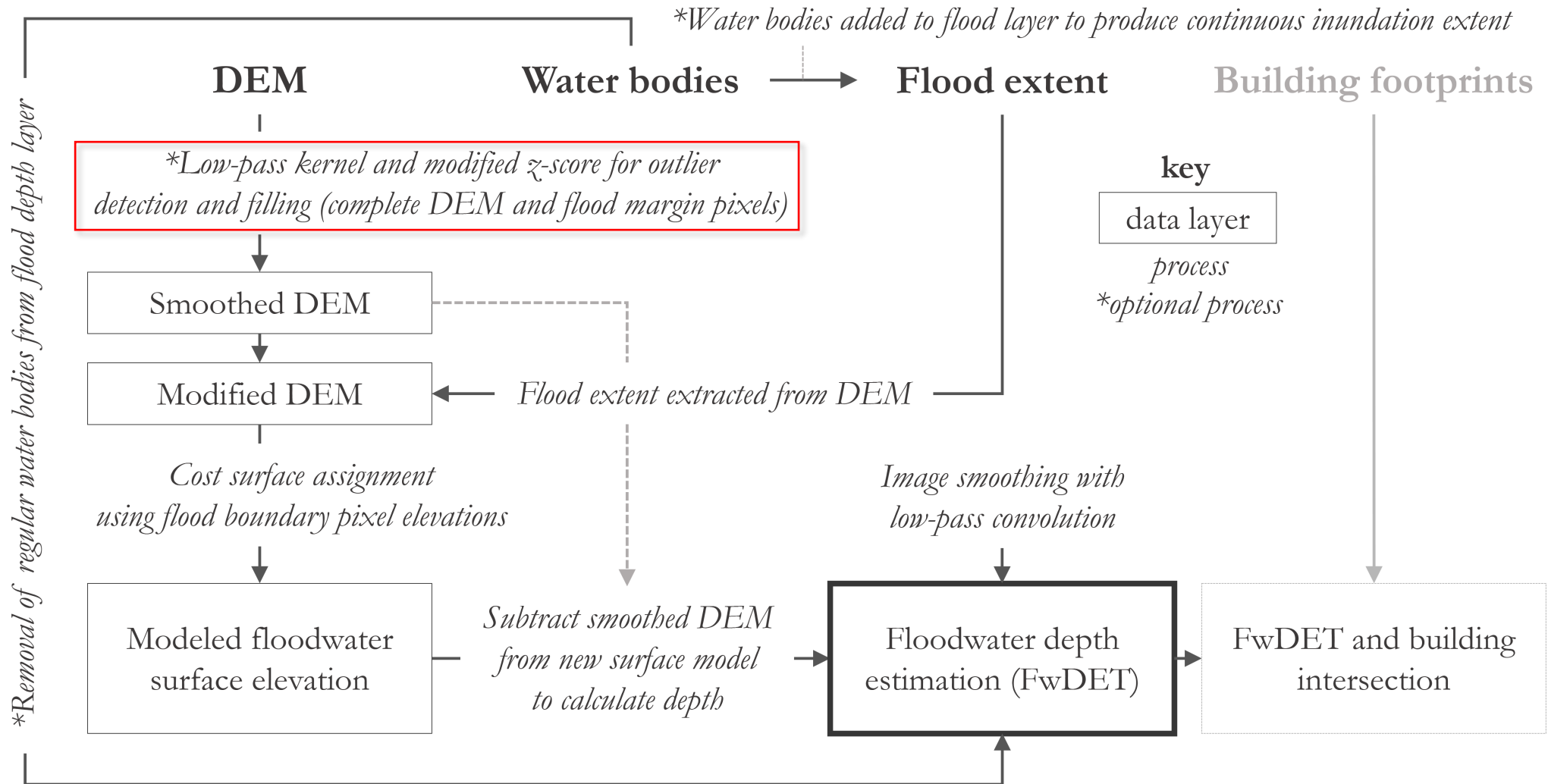
Publisher: IEEE   Cite This   📄 PDF

Brad G. Peter ⓘD ; Sagy Cohen; Ronan Lucey; Dinuke Munasinghe ⓘD ; Austin Raney; G. Robert Brakenridge ⓘD   All Authors

DEM   **Water bodies** → **Flood extent**   **Building footprints**

Water bodies added to flood layer to produce continuous inundation extent

Low-pass kernel and modified z-score for outlier detection and filling (complete DEM and flood margin pixels)

key
| data layer |

process
**optional process*

Smoothed DEM

Modified DEM ← *Flood extent extracted from DEM*

Removal of regular water bodies from flood depth layer

Cost surface assignment using flood boundary pixel elevations

Image smoothing with low-pass convolution

Modeled floodwater surface elevation

Subtract smoothed DEM from new surface model to calculate depth

Floodwater depth estimation (FwDET)

FwDET and building intersection

Peter, B. G., Cohen, S., Lucey, R., Munasinghe, D., Raney, A., and Brakenridge, G. R. 2020. **Google Earth Engine Implementation of the Floodwater Depth Estimation Tool (FwDET-GEE) for Rapid and Large Scale Flood Analysis**. *IEEE Geoscience and Remote Sensing Letters* 1–5. doi: 10.1109/LGRS.2020.3031190 [5]
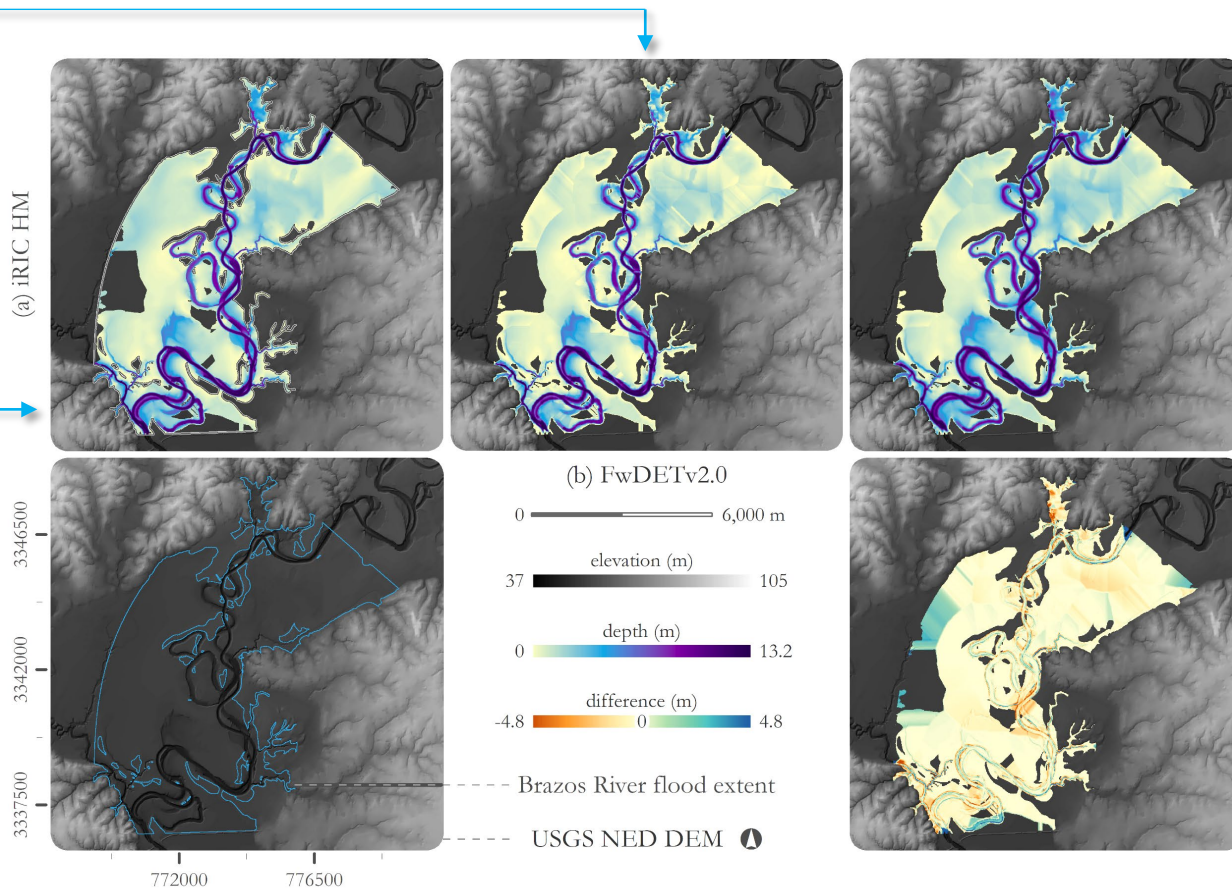
Step-by-Step Procedure

- Conceptual/technical replication of FwDETv2.0 [6]

- DEM acquisition

- **Local outlier filtering** of flood margin elevation pixels using the modified Z-score

- Extraction of the flood extent boundary pixel elevations from the DEM

- Construction of a new estimated water surface elevation using a **cost accumulation algorithm**

- Subtraction of the smoothed DEM from the modeled flood surface elevation to calculate depth

- A **low-pass convolution** to smooth the produced flood depth estimation layer
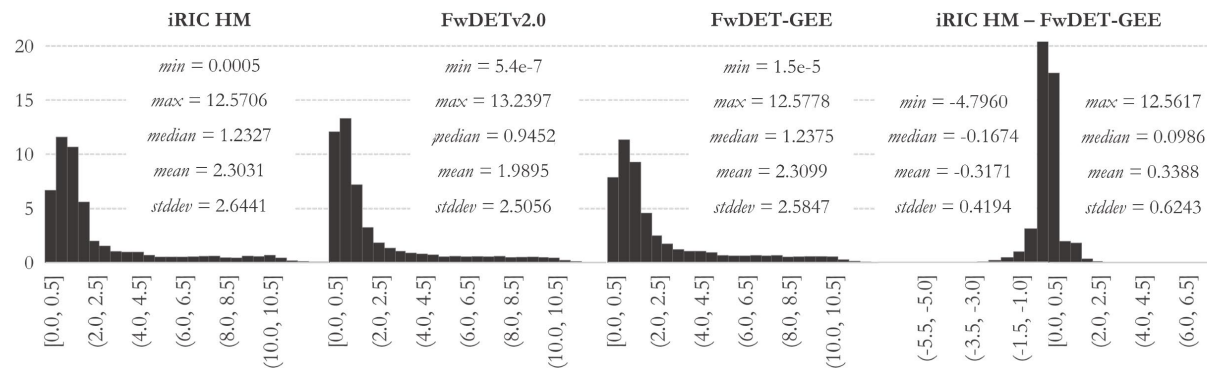
FwDETv2.0
RMSE 0.68

iRIC
validation layer

FwDET-GEE
RMSE 0.62

Area: 54 km²
Export time: **4 minutes**

(a) iRIC HM

(c) FwDET-GEE

(b) FwDETv2.0

(d) iRIC HM − FwDET-GEE

0   6,000 m

elevation (m)
37   105

depth (m)
0   13.2

difference (m)
-4.8   0   4.8

Brazos River flood extent

USGS NED DEM

iRIC HM	FwDETv2.0	FwDET-GEE	iRIC HM − FwDET-GEE
min = 0.0005	min = 5.4e-7	min = 1.5e-5	
max = 12.5706	max = 13.2397	max = 12.5778	min = -4.7960 max = 12.5617
median = 1.2327	median = 0.9452	median = 1.2375	median = -0.1674 median = 0.0986
mean = 2.3031	mean = 1.9895	mean = 2.3099	mean = -0.3171 mean = 0.3388
stddev = 2.6441	stddev = 2.5056	stddev = 2.5847	stddev = 0.4194 stddev = 0.6243

How to Use FwDET-GEE

- Sign up for Google Earth Engine at https://earthengine.google.com/

- Copy the script from the Harvard Dataverse repository (https://doi.org/10.7910/DVN/JQ4BCN) and paste it into your code editor in GEE at https://code.earthengine.google.com/ [7]

- Upload a flood extent Shapefile or GeoTIFF to GEE to use in the application

- Add the uploaded asset path name, follow parameterization directions, and click run
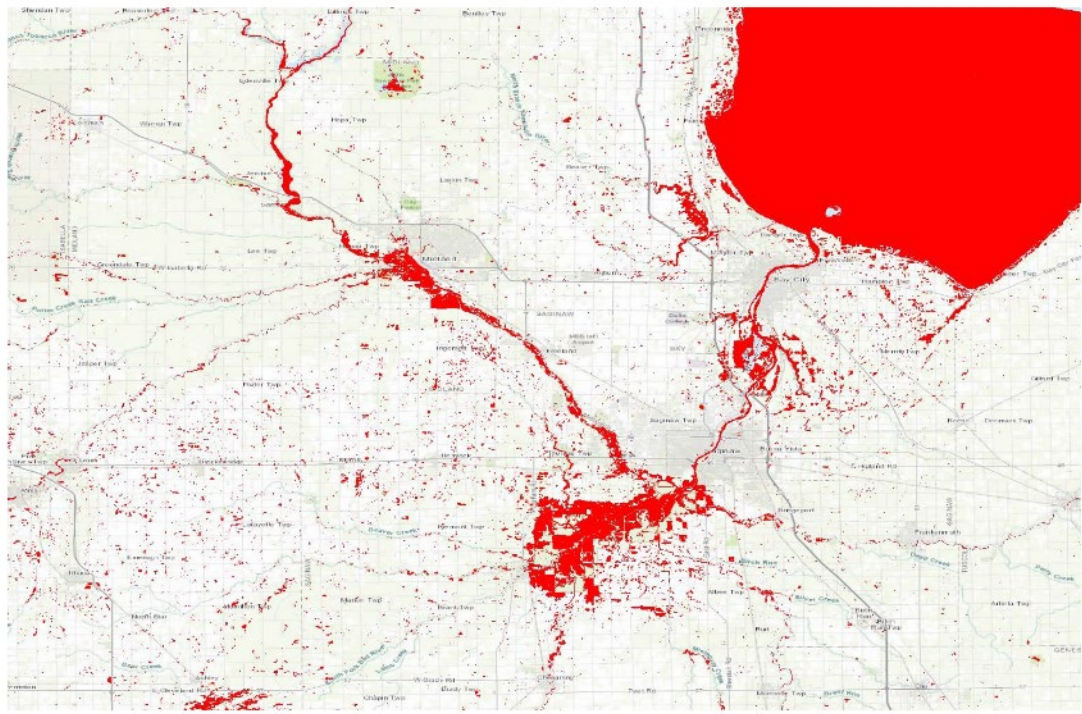 - **var** flood = **ee.Image**('users/username/folder/flood_extent')
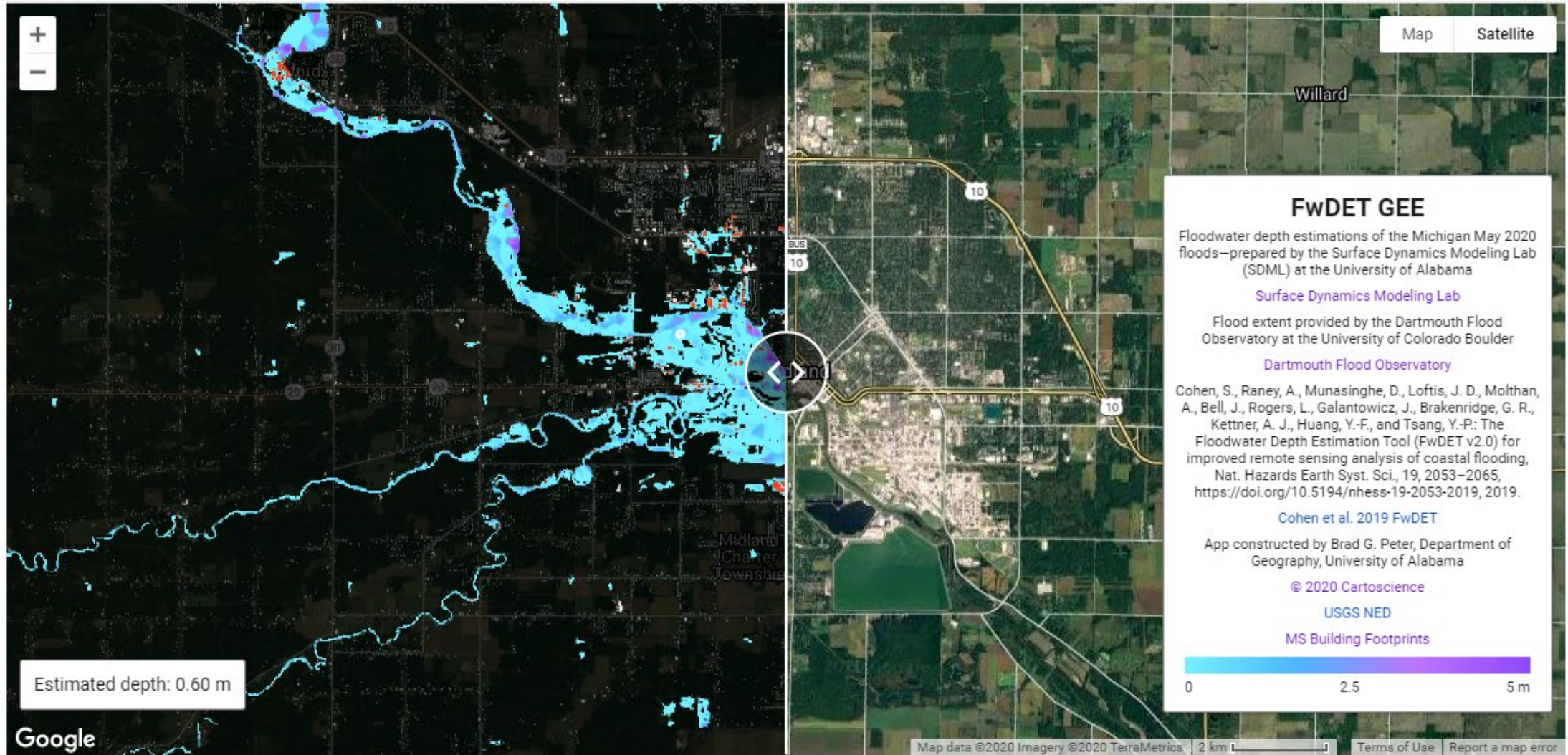
FwDET-GEE Parameterization

- Available **DEM options** (1) are USGS/NED (U.S.) and USGS/SRTMGL1_003 (global).

- Other options include: (2) running the elevation outlier filtering algorithm,

- (3) adding water body data to the **inundation extent**,

- (4) add a water body data layer uploaded by the user rather than using the JRC global surface water data,

- (5) **masking** out regular water body data,

- (6) masking out 0 m depths,

- (7) choosing whether or not to export,

- (8) **exporting additional data layers**, and

- (9) setting an export file name.

- The **simpleVis option** (10) bypasses the time-consuming processes and is meant for visualization only; set this option to false to complete the entire process and enable exporting.

GFP Activation—Michigan

Midland County flooding after 2 dams failed in May 2020 [8]

https://floodobservatory.colorado.edu/Events/4915/2020USA4915.html

https://waterserv.ua.edu/data-services/fwdet-gee/
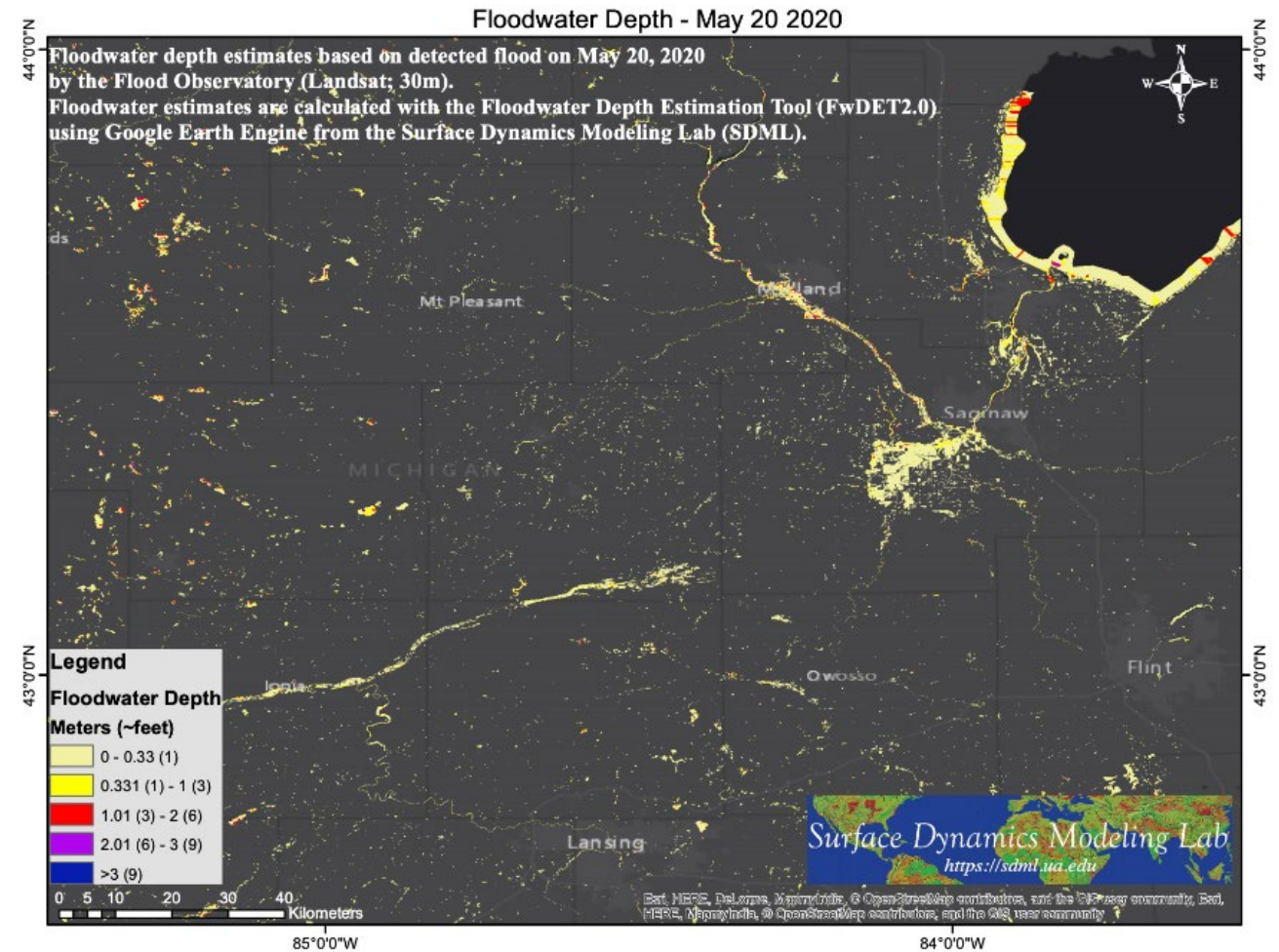
Building Impact - May 20 2020 - Midland

Floodwater depth estimates based on detected flood on May 20, 2020
by the Flood Observatory (Landsat; 30m).
Floodwater estimates are calculated with the Floodwater Depth Estimation Tool (FwDET2.0)
using Google Earth Engine from the Surface Dynamics Modeling Lab (SDML).

Midland

Water Depth Range [meters]	Number of Buildings	Cumulative %
0 - 0.33	156	72.22%
0.33 - 1	40	90.74%
1 - 2	15	97.69%
2 - 3	3	99.07%
> 3	2	100.00%
Total	216	

Michigan

Water Depth Range [meters]	Number of Buildings	Cumulative %
0 - 0.33	2048	54.07%
0.33 - 1	928	78.56%
1 - 2	399	89.10%
2 - 3	174	93.69%
> 3	239	100.00%
Total	3788	

Legend

Water Depth

	0.00 - 0.33
	0.34 - 1.00
	1.01 - 2.00
	2.01 - 3.00
	3.01 - 20.44
	Flood Extent

Surface Dynamics Modeling Lab
https://sdml.ua.edu
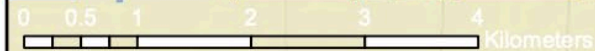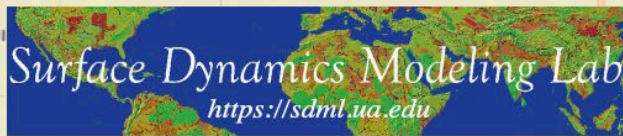
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Area: 1,182 km²
Export time: **41 minutes**

- Flood indunation maps uploaded to DFO website within 2 days of the flood event
- With FwDET-GEE complete, such products can be produced and shared in a matter of hours, depending on availability of flood extent data

Next Steps & Future Research

Next steps

- Develop a standalone application in *WaterServ* (https://waterserv.ua.edu/) to eliminate the user's need to interact with the code

- Integrate FwDET-GEE with remote sensing-based observations of flood extent

Future Research

- Intersect floodwater depth estimations with urban infrastructure to characterize damage risk

- Evaluate FwDET-GEE with DEMs of multiple spatial resolutions (e.g., NED, SRTM, ALOS, MERIT, and LiDAR)

- Validate against field data on floodwater depth as availability arises

- Map more floods in partnership with GFP and the NASA Earth Science Disasters Program
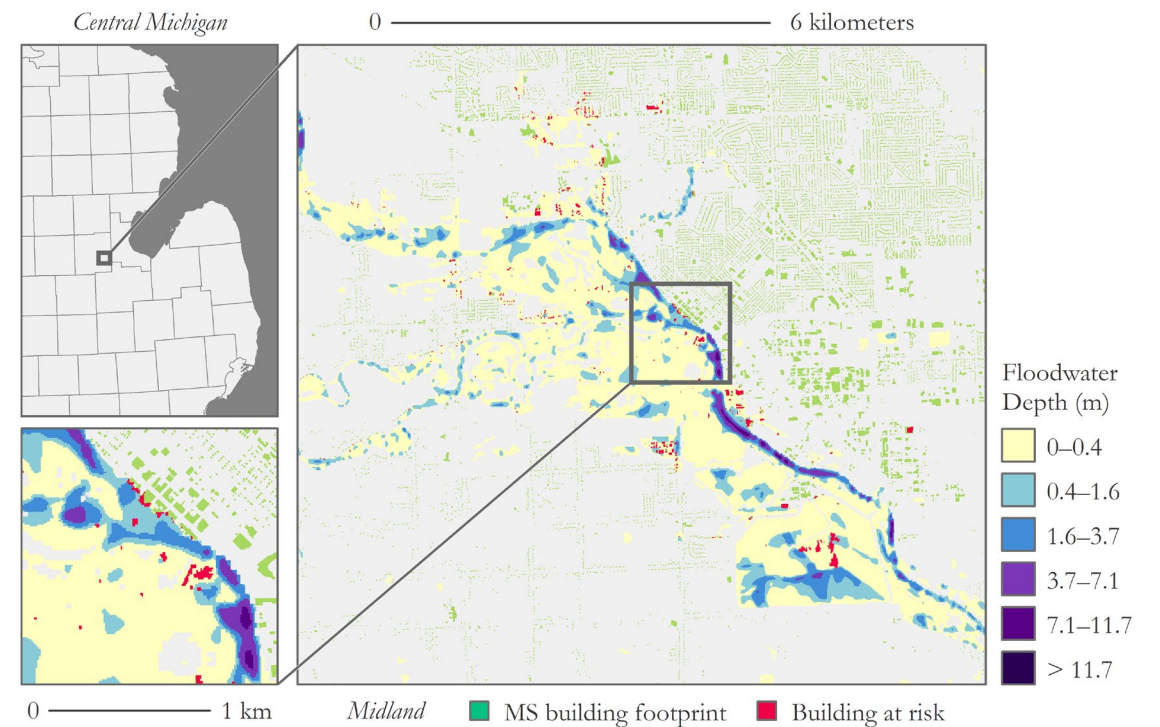
Estimating Flood Damage Risk

Area: 20,271 km²

Export time: **73 minutes**
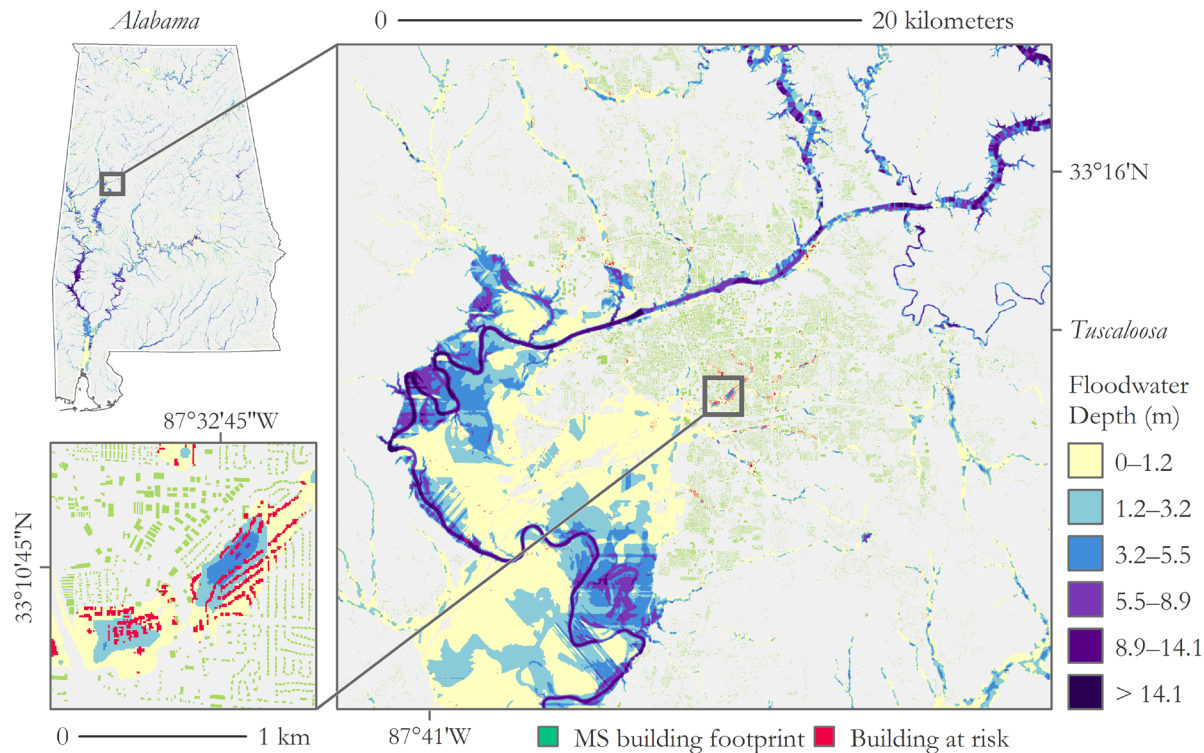
Intersecting floodwater depth with urban infrastructure

Modeled using the Microsoft building footprint data and EnviroAtlas 100-year flood layer [9], [10]

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Thank you!   # Contact and Collaboration

Thank you to the Global Flood Partnership (GFP) for organizing this event.

https://gfp.jrc.ec.europa.eu/

Questions?

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