Improving Remote Sensing-based Flood Mapping using GIS (terrain-based) Analysis

Sagy Cohen

Surface Dynamics Modeling Lab

University of Alabama

U.S. Flood Inundation Map Repository (USFIMR)

- Started in 2016 in collaboration with Dartmouth Flood Observatory
- Developed and maintained at the Surface Dynamics Modeling Lab
- Support NWC Flood Prediction System – model calibrations and validations
- Currently over 30 flood maps (more added weekly) based on Landsat and Sentinel-1 (SAR) imagery
- Open web-interface (one-stop-shop for modelers)
- **Accept requests for flood mapping (if imagery is available)**

http://sdml.ua.edu/usfimr

UCAR COMMUNITY PROGRAMS | COMET | NWC NATIONAL WATER CENTER | NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE http://sdml.ua.edu/usfimr

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U.S. Flood Inundation Map Repository (USFIMR)

Home › U.S. Flood Inundation Map Repository (USFIMR)

The USFIMR project commenced in August 2016 with funding from NOAA. The project's main goal is to provide high-resolution inundation extent maps of past U.S. flood events to be used by scientists and practitioners for model calibration and flood susceptibility evaluation. The maps are based on analysis of Remote Sensing imagery from a number of Satellite sensors (e.g. Landsat, Sentinel-1) with some ground proofing based on secondary sources (e.g. news reports, social media). The maps are accessible via the online map repository below. The repository is currently under development and new maps are added on a weekly basis.

For information, requests and data contribution contact the project PI: Dr. Sagy Cohen (sagy.cohen@ua.edu) or Lead Developers: Dinuke Munasinghe (dsnanayakkaramunasinghe@crimson.ua.edu) and James Misfeldt (jamisfeldt@crimson.ua.edu). (formerly Bradford Bates).

Flood inundation maps are listed on the map side panel and at the table below.

Flood layer properties and download links* will be listed once a layer is selected from the side panel or the map.

** Download links will not work when using '**Safari**' web browser*

The dataset can also be accessed directly via Google Maps or through the SDML Datasets Portal.

Download the entire USFIMR in Shapefile format.

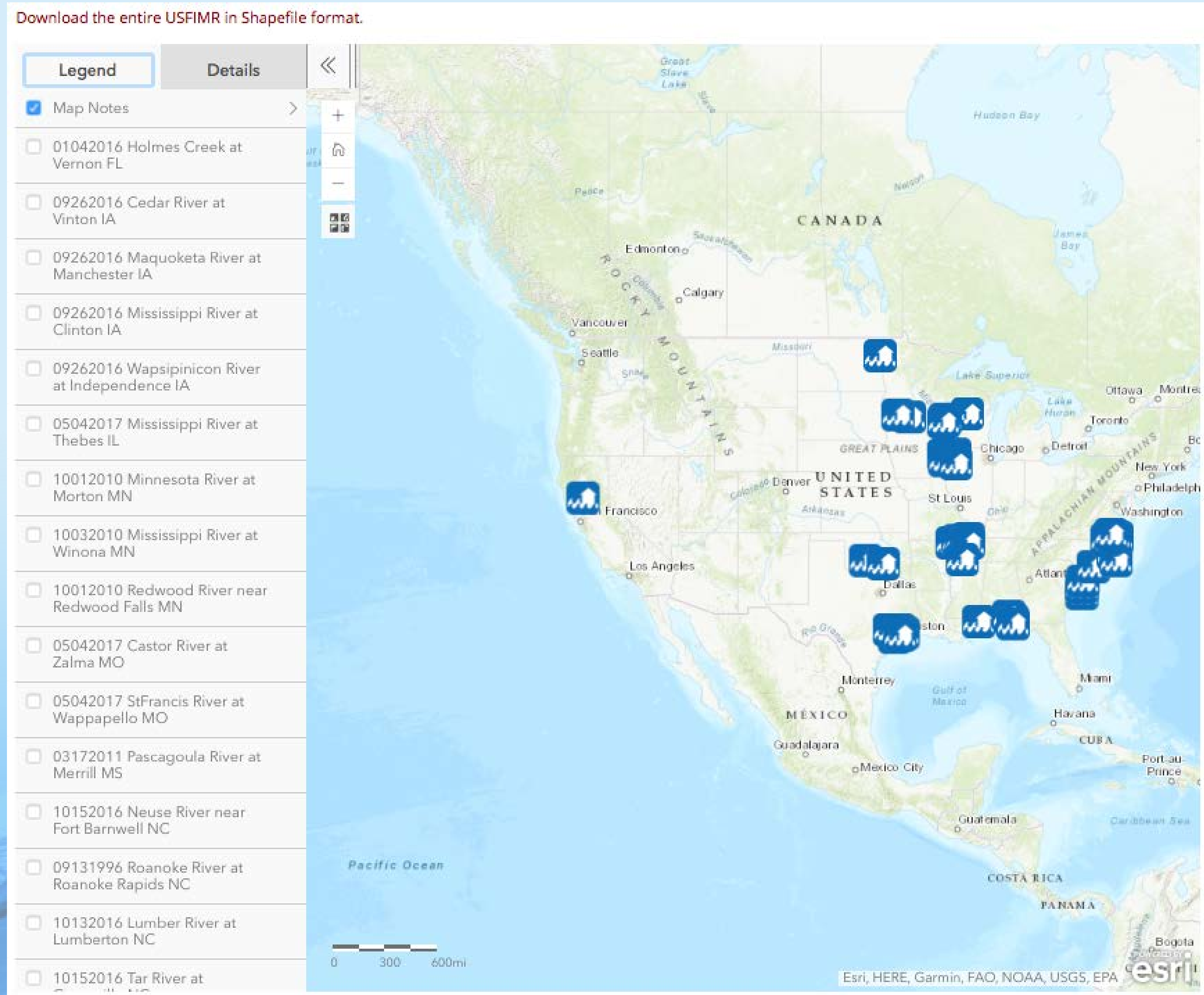
NOTE: Rendering of the flood inundation layers at the Google Maps display is at a considerably lower spatial resolution than the actual (shapefile) layers.

U.S. Flood Inundation Map Repository

Sortable list of flood events available at the repository

River Name	State	Year	Date	Platform	Mapped Inundation Area (sq km)	Source*	Shapefile Download
San Jacinto	Texas	2016	May 30	10m Sentinel-1 Synthetic Aperture Radar (SAR)	94.7	SDML	Download
Brazos (near Hempstead)	Texas	2016	May 28	30m Landsat 8 OLI	48.7	SDML	Download
Brazos (near Richmond)	Texas	2016	May 30	10m Sentinel-1 Synthetic Aperture Radar (SAR)	214.9	SDML	Download
Maquoketa	Iowa	2016	Sep 26	30m Landsat 8 OLI	59.5	DFO	Download
Cedar	Iowa	2016	Sep 26	30m Landsat 8 OLI	233.1	DFO	Download
Wapsipinicon	Iowa	2016	Sep 26	30m Landsat 8 OLI	154.8	DFO	Download
Mississippi	Iowa	2016	Sep 26	30m Landsat 8 OLI	533.33	DFO	Download
Washita	Oklahoma	2015	May 29	10m Sentinel-1 Synthetic Aperture Radar (SAR)	43.9	SDML	Download
Iowa	Iowa	2016	Sep 26	30m Landsat 8 OLI	136.4	DFO	Download
Lumber & Little Pee Dee	N/S Carolina	2016	Oct 13	30m Landsat 8 OLI	587.1	SDML	Download
Black (SC)	S Carolina	2016	Oct 13	30m Landsat 8 OLI	253.9	SDML	Download
Willow Creek	Texas	2016	May 28	30m Landsat 8 OLI	15.7	SDML	Download
Spring Creek	Texas	2016	May 28	30m Landsat 8 OLI	57.1	SDML	Download
Choctawhatchee River	Alabama/Florida	2016	Jan 4	30m Landsat 8 OLI	562.9	SDML	Download
Pea River	Alabama	2016	Jan 4	30m Landsat 8 OLI	61	SDML	Download
Holmes Creek	Florida	2016	Jan 4	30m Landsat 8 OLI	27.1	SDML	Download
Mississippi River	Missouri	2017	May 4	10m Sentinel-1 Synthetic Aperture Radar (SAR)	68.6	DFO	Download
Castor River	Missouri	2017	May 4	10m Sentinel-1 Synthetic Aperture Radar (SAR)	44.9	DFO	Download

U.S. Flood Inundation Map Repository (USFIMR)



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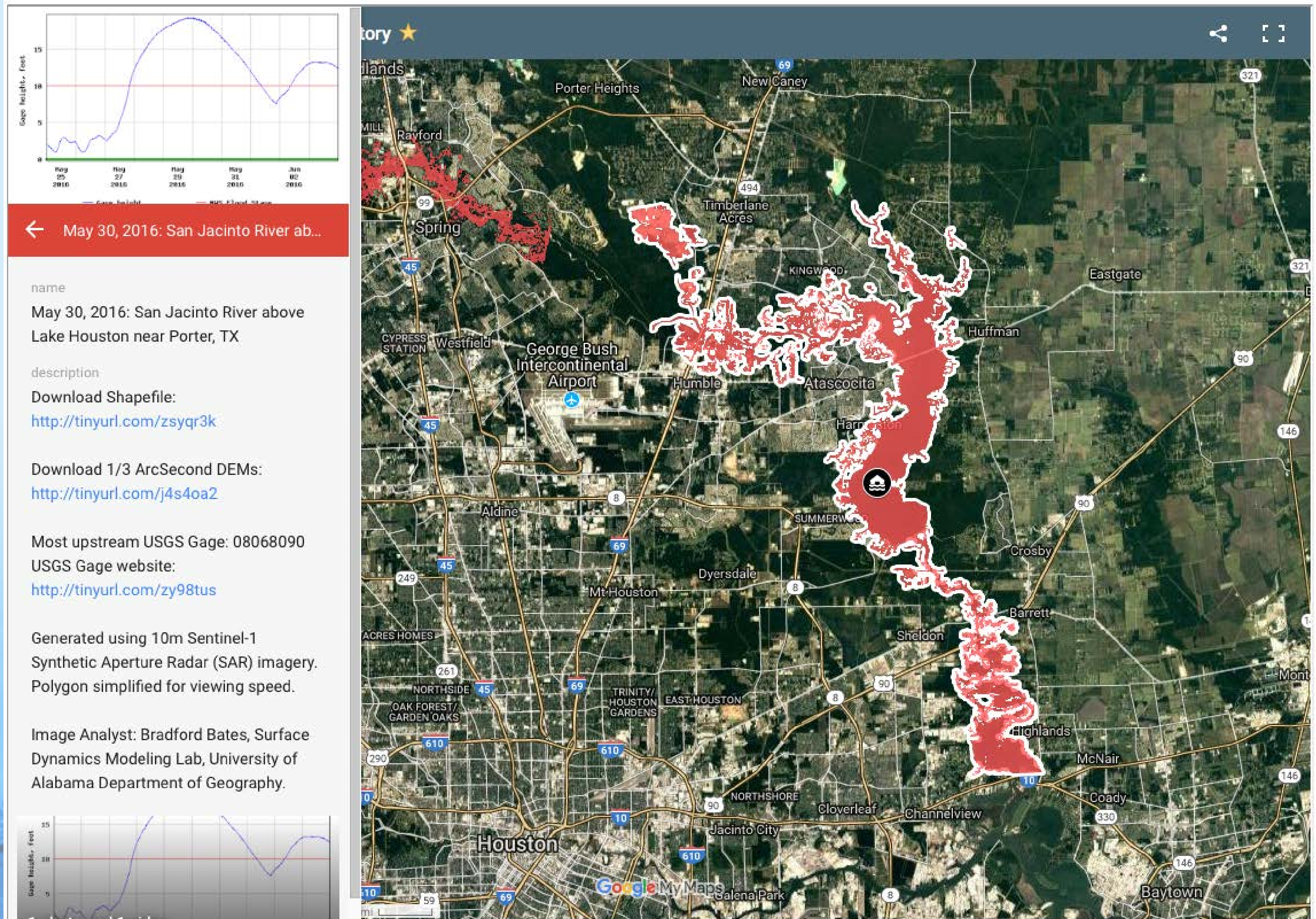
U.S. Flood Inundation Map Repository (USFIMR)



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Global Flood Inundation Map Repository (GloFIMR)

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Global Flood Inundation Map Repository (GloFIMR)

Home › Global Flood Inundation Map Repository (GloFIMR)

GloFIMR is an extension of the USFIMR project that commenced in August 2016 with funding from NOAA. The project's main goal is to provide high-resolution inundation extent maps of flood events to be used by scientists and practitioners for model calibration and flood susceptibility evaluation. The maps are based on analysis of Remote Sensing imagery from a number of Satellite sensors (e.g. Landsat, Sentinel-1, Sentinel-2). The maps are accessible via the online map repository below. The repository is under development and new maps are added upon request.

For information, requests and data contribution contact the project PI: Dr. Sagy Cohen (sagy.cohen@ua.edu) or Lead Developer: Dinuke Munasinghe dsnanayakkaramunasinghe@crimson.ua.edu and James Misfeldt (jamisfeldt@crimson.ua.edu).

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Download the entire dataset in Shapefile format.

NOTE: Rendering of the flood inundation layers at the Google Maps display is at a considerably lower spatial resolution than the actual (shapefile) layers.

Global Flood Inundation Map Repository

http://sdml.ua.edu/glofimr

GFP
global flood partnership

Surface Dynamics Modeling Lab

Floodwater Depth Algorithm

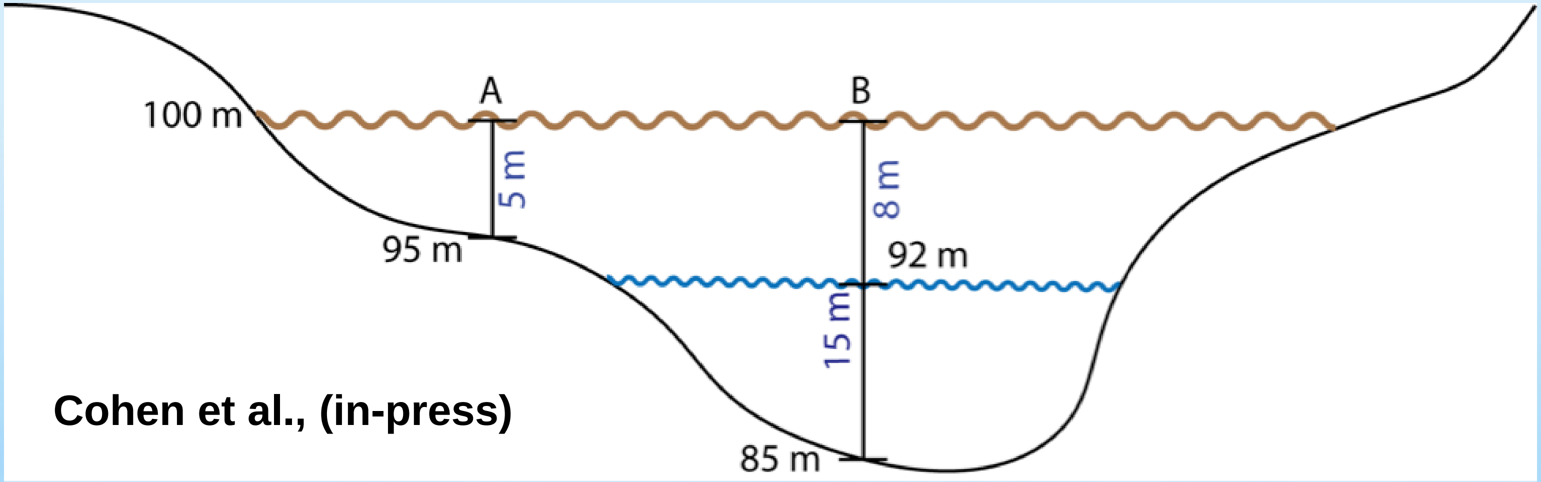
- **Why?**
  - Information on floodwater depth is critical for first responders, recovery efforts and resiliency planning.
  - Spatially-explicit estimation of floodwater depth for medium and large flood events is challenging.
  - Hydraulic models can be used but these require detailed flow and morphology information.

https://www.prlekija-on.net

http://cdn.msf.org

Floodwater Depth Algorithm

- **How?**
  Start with a simple concept:
    - Floodwater depth is easy to estimate at a cross-section scale based on local max flow elevation:



Cohen et al., (in-press)

- Expend spatially:
    - Use nearest flood boundary location (from aerial flood extent map) to compile a spatially-explicit estimate.

Floodwater Depth Algorithm - Methodology

- We developed the Floodwater Depth Estimation Tool (***FwDET***)
- Simple Python script that utilize ArcGIS tools (arcpy)
- Calculation steps:

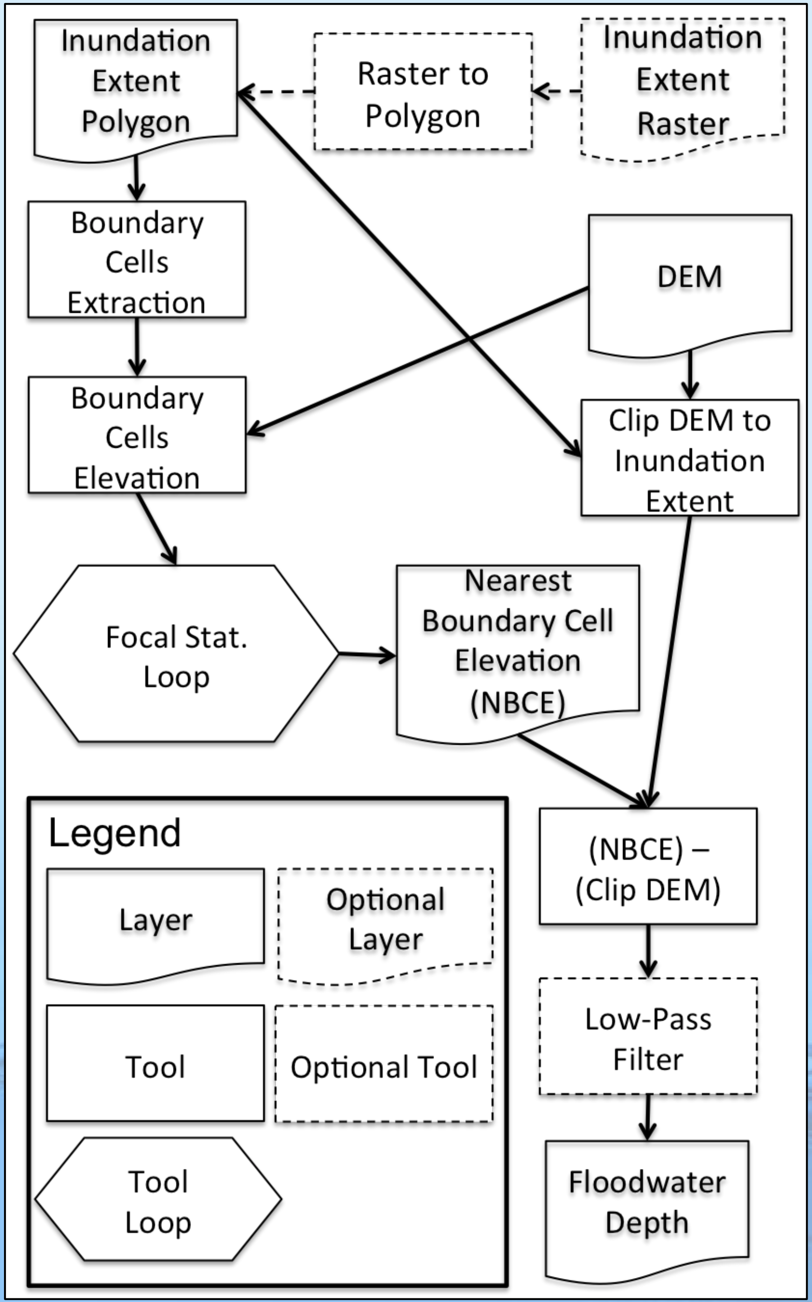
Step 1 – Identifying Boundary Cells

Step 2 – Extracting Elevation of Boundary Cells

Step 3 – Assigning Boundary Cells Elevation to Domain Cells

Step 4 – Floodwater Depth Calculation

Step 5 – Smoothing



Cohen et al., (in-press)

Floodwater Depth Algorithm - Methodology

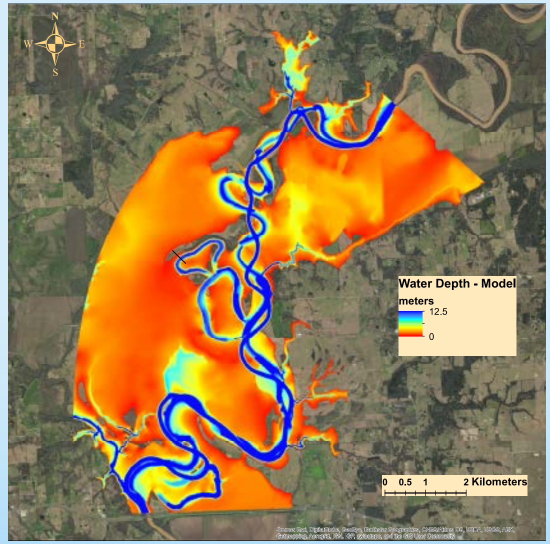
```python
'''
InundationDepth.py

Calculate water depth from a flood extent polygon (e.g. from remote sensing analysis) based on an underlying DEM.
Program procedure:
1. Flood extent polygon to polyline
2. Polyline to Raster - DEM extent and resolution (Env)
3. Con - DEM values to Raster
4. Focal Statistics to Con - loop 3x3 to 100x100
5. Iterative Con - if isNull than focal else last iteration (lower focal)

Created by Sagy Cohen, Surface Dynamics Modeling Lab, University of Alabama
email: sagy.cohen@ua.edu
web: http://sdml.ua.edu
June 30, 2016
'''

import arcpy
from arcpy.sa import *

def main():
    arcpy.CheckOutExtension("Spatial")
    arcpy.env.overwriteOutput = True
    WS = arcpy.env.workspace = r'T:\WindowsShared\NASA_Coastal\FloodwaterDepth_fullExtent.gdb'
    arcpy.env.scratchWorkspace = r'T:\WindowsShared\NASA_Coastal\Scratch.gdb'
    DEMname = 'Elevation10m'
    InundPolygon = 'WaterExtent_smooth'
    ClipDEM = 'dem_clip10m'
    #arcpy.env.mask = ClipDEM

    dem = arcpy.Raster(DEMname)
    cellSize = dem.meanCellHeight
    boundary = CalculateBoundary(dem, InundPolygon, cellSize, WS)
    #boundary = Raster('con_linerast1') # a raster layer with only the boundary cells having value (elevation)
    extent = str(dem.extent.XMin) + " " + str(dem.extent.YMin) + " " + str(dem.extent.XMax) + " " + str(dem.extent.YMax)
    print extent
    #arcpy.Clip_management(DEMname, extent, ClipDEM, InundPolygon, cellSize, 'ClippingGeometry', 'NO_MAINTAIN_EXTENT')
    print arcpy.GetMessages()
    arcpy.env.extent = arcpy.Extent(dem.extent.XMin,dem.extent.YMin,dem.extent.XMax,dem.extent.YMax)

    print 'First focal '
    OutRas = FocalStatistics(boundary, 'Circle 3 CELL', "MAXIMUM", "DATA")
    print '1'
    for i in range(3, 200):
        print i
        negihbor = 'Circle ' + str(i) + ' CELL'
        # negihbor = 'Rectangle ' + str(i) + ' ' + str(i) + ' CELL'
        OutRasTemp = FocalStatistics(boundary, negihbor, "MAXIMUM", "DATA")
        OutRas = Con(IsNull(OutRas), OutRasTemp, OutRas)
    print 'Focal loop done!'
    OutRas.save('Focafin10m')
    waterDepth = Minus(OutRas, ClipDEM)
    print arcpy.GetMessages()
    waterDepth = Con(waterDepth < 0, 0, waterDepth)
    waterDepth.save('WaterDepth10m')
    waterDepthFilter = Filter(waterDepth, "LOW", "DATA")
    print arcpy.GetMessages()
    waterDepthFilter.save('WaterDep10mf')

    print 'Done'

def CalculateBoundary(dem, InundPolygon,cellSize,WS):
    arcpy.PolygonToLine_management(InundPolygon, WS+'\polyline')
    arcpy.PolylineToRaster_conversion(WS+'\\polyline', 'OBJECTID', WS+'\linerast15', 'MAXIMUM_LENGTH', 'NONE', cellSize)
    print 'after polyline to raster'
    inRaster = Raster(WS+'\linerast15')
    inTrueRaster = dem
    inFalseConstant = '#'
    whereClause = "VALUE >= 0"
    print 'Con'
    boundary = Con(inRaster, inTrueRaster, inFalseConstant, whereClause)
    boundary.save('boundary1')
    return boundary
main()
```

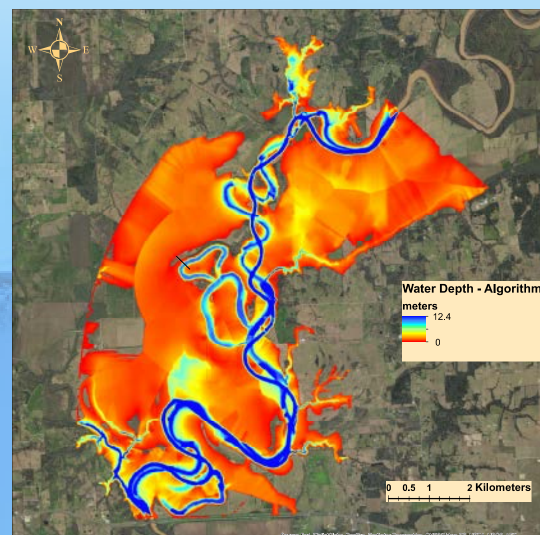
Floodwater Depth Algorithm - Evaluation

Water depth estimations by FwDET were compared to simulated depth with a hydraulic model (iRIC; USGS) for two flood events:

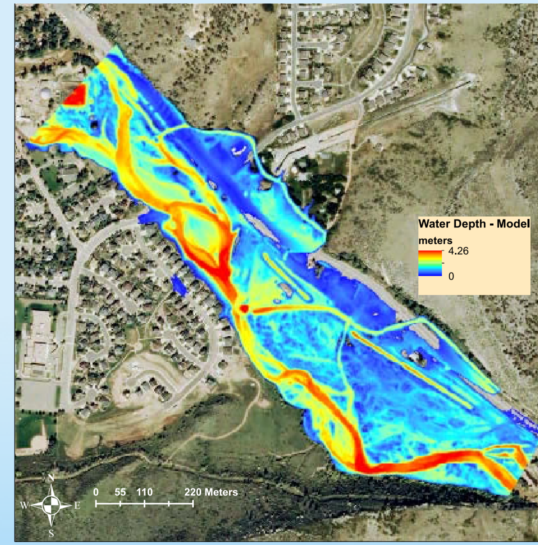
1. May 2016 at Brazos River (Texas, USA)
2. Sep 2013 at St. Vrain Creek near Lyons (Colorado, USA)

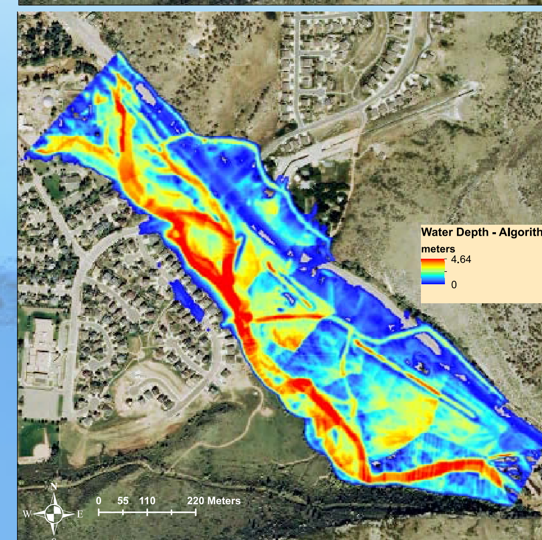
Brazos River, TX
10m DEM (NED)



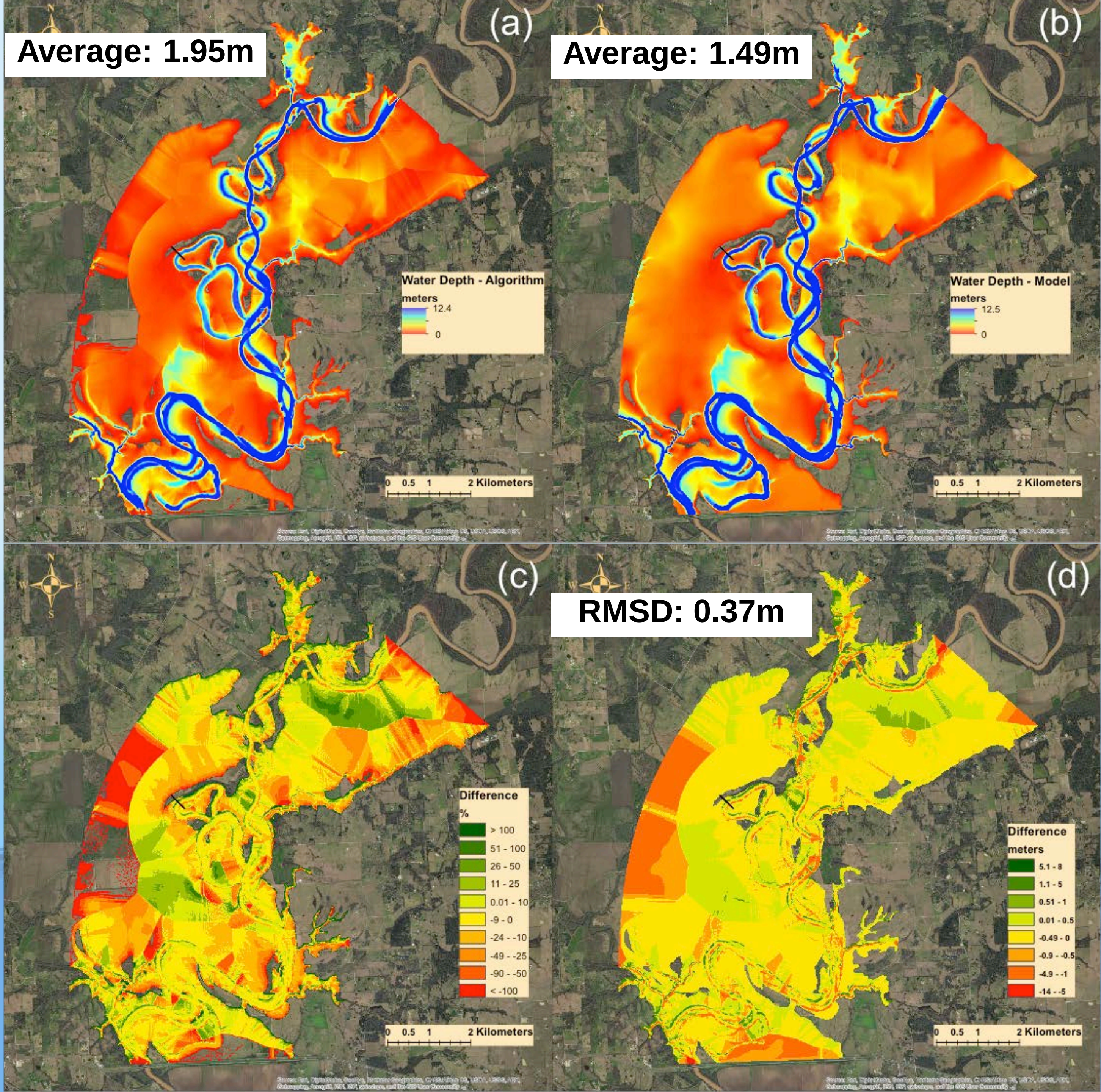


St Vrain Creek, Lyons CO
1m LiDAR





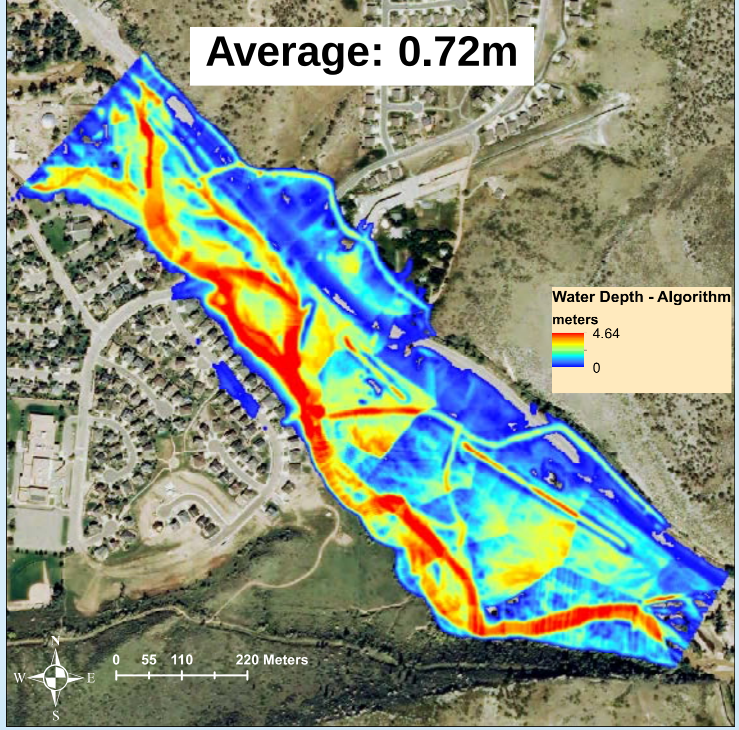
Brazos River
10m DEM (NED)



St Vrain Creek, Lyons CO

1m LiDAR

Average: 0.72m

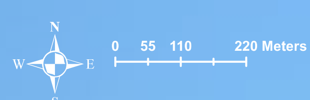


Average: 1.28m

(c)

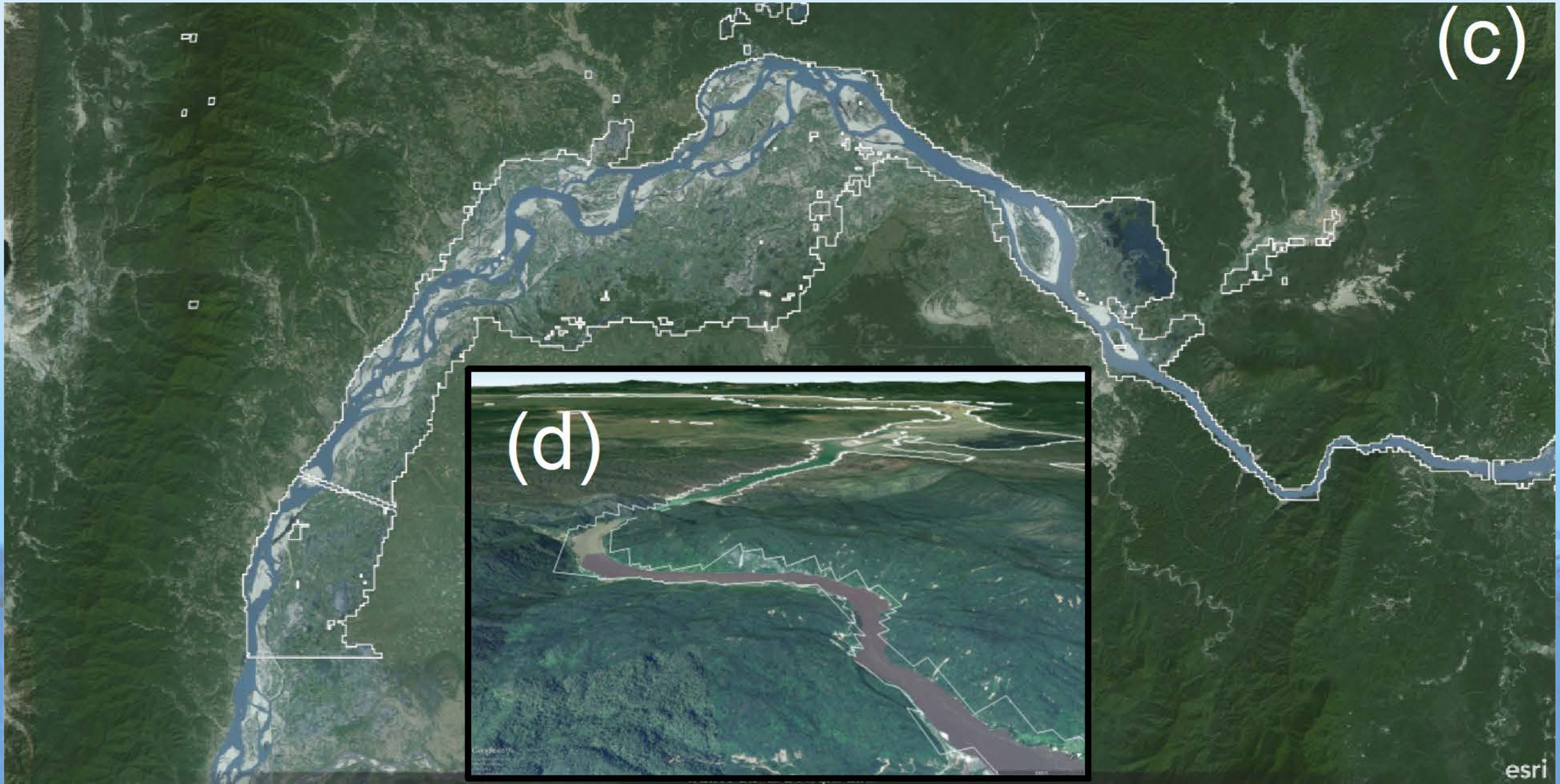
RMSD: 0.38m

4 - -10
-49 - -25
-99 - -50
<-100

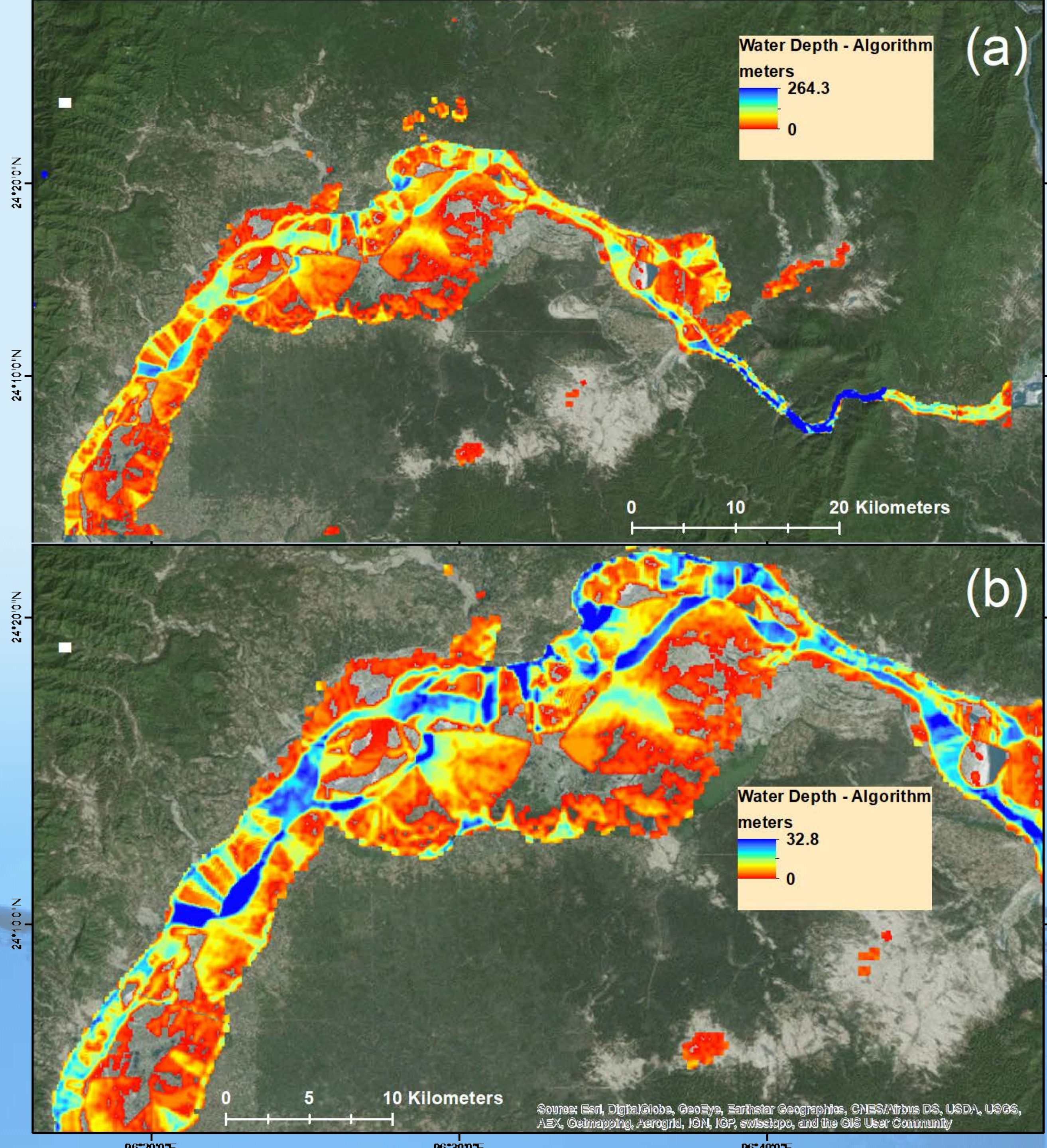


Floodwater Depth Algorithm - Demonstration

- August 2016 flood event at Irrawaddy River (Myanmar)
- MODIS-based water classification by DFO
- 15 arc-sec (~500 m) resolution DEM (HydroSHEDS)



August 2016 flood event at Irrawaddy River (Myanmar)

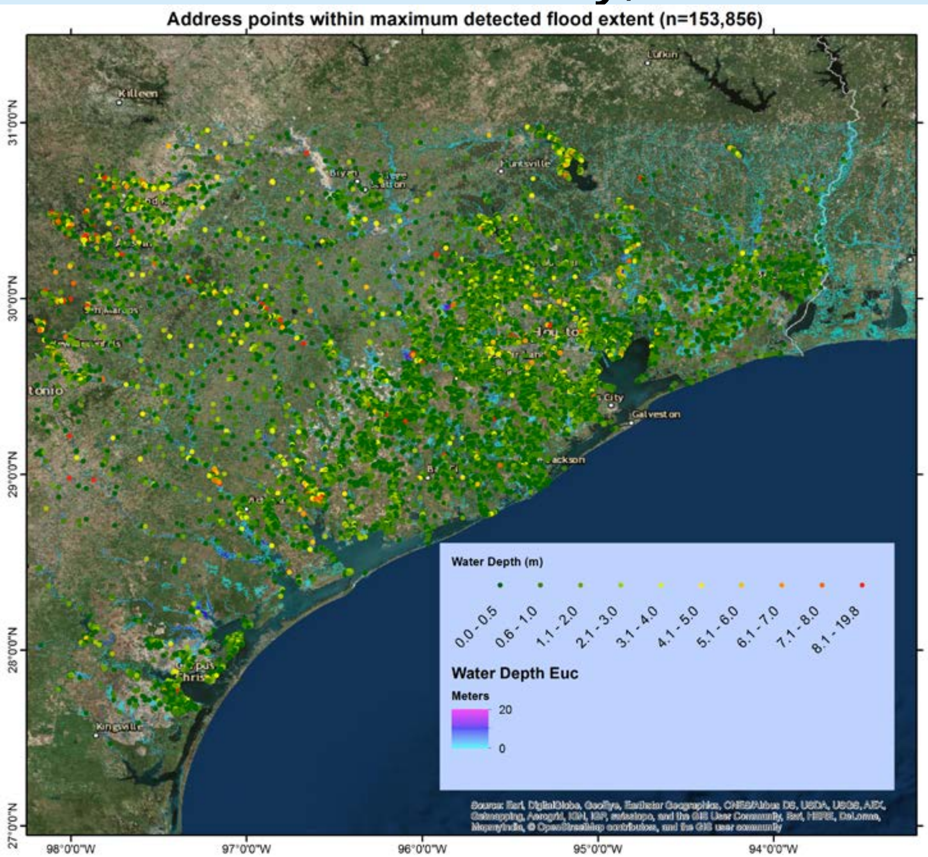


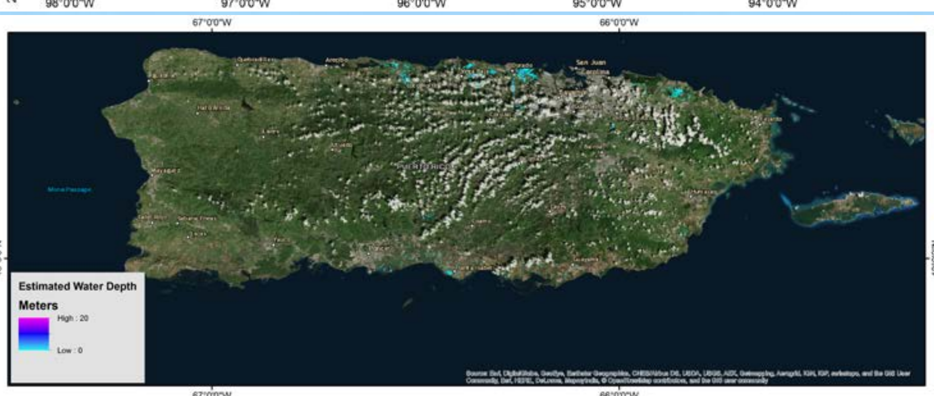
Floodwater Depth Algorithm – Conclusions

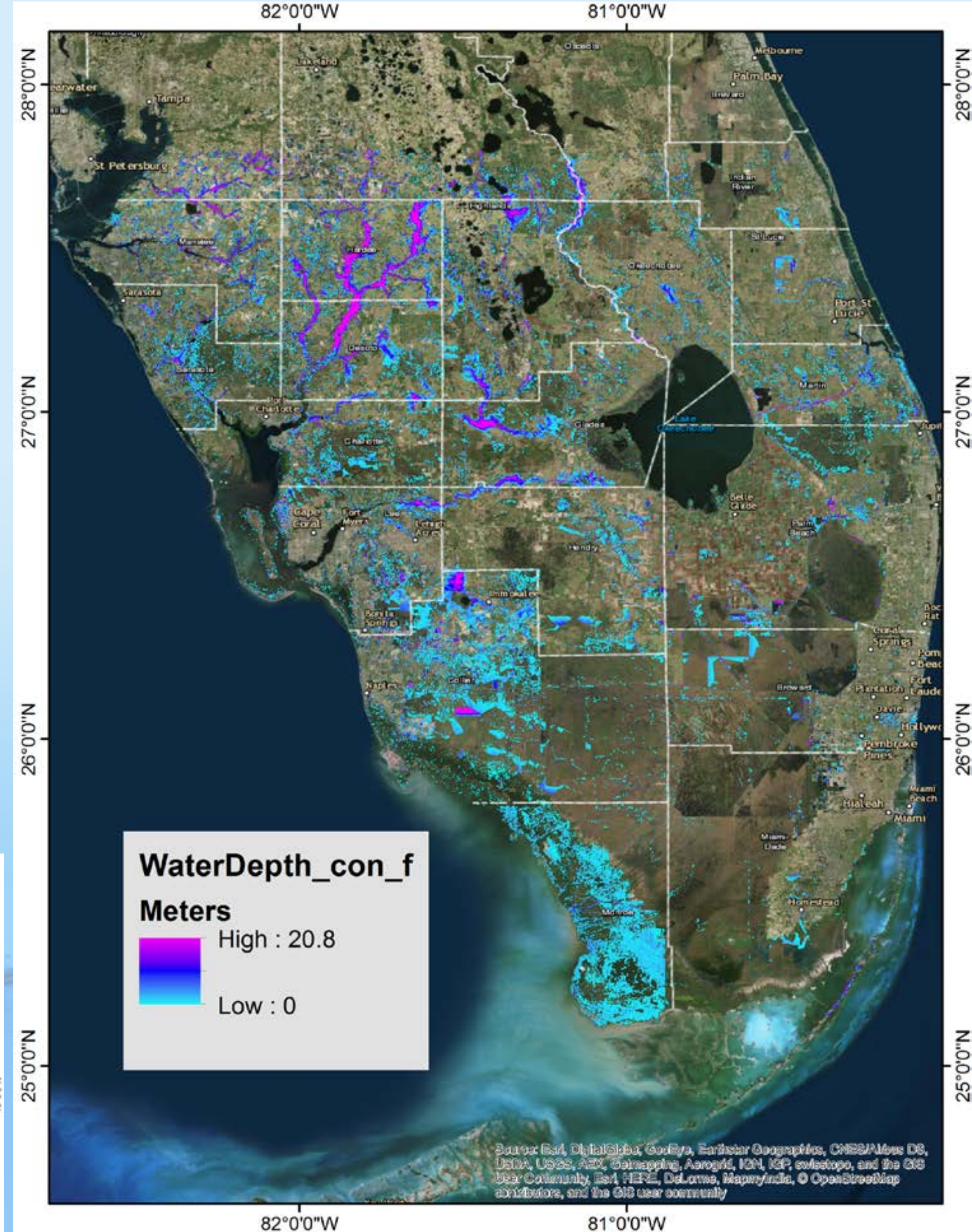
- Good agreement with hydraulic model-based water depth simulations.
- Steep terrain (e.g. narrow valley) may lead to considerable overestimations - highly sensitive to the resolution of the flood inundation map and DEM.
- Large water bodies are prone to underestimation due to because DEMs typically record surface elevation (large river channels will show similar biases).
- Complex inundation patterns and urban flooding are prone to localized hotspots of overestimation. Higher quality imaging and DEM inputs are found to limit the spatial extent of these hotspots.

Implementations

- Hurricane Harvey, Irma and Maria

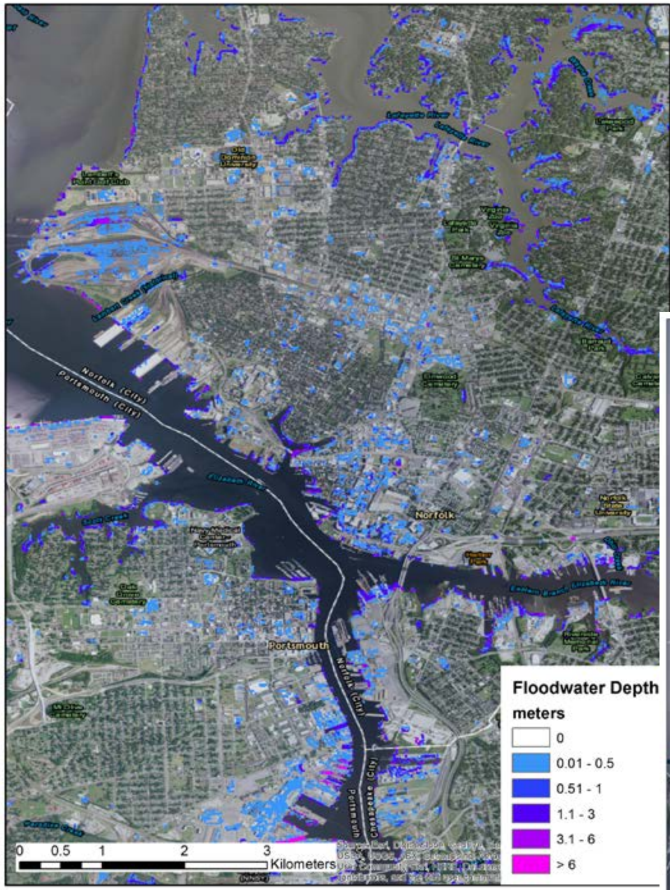


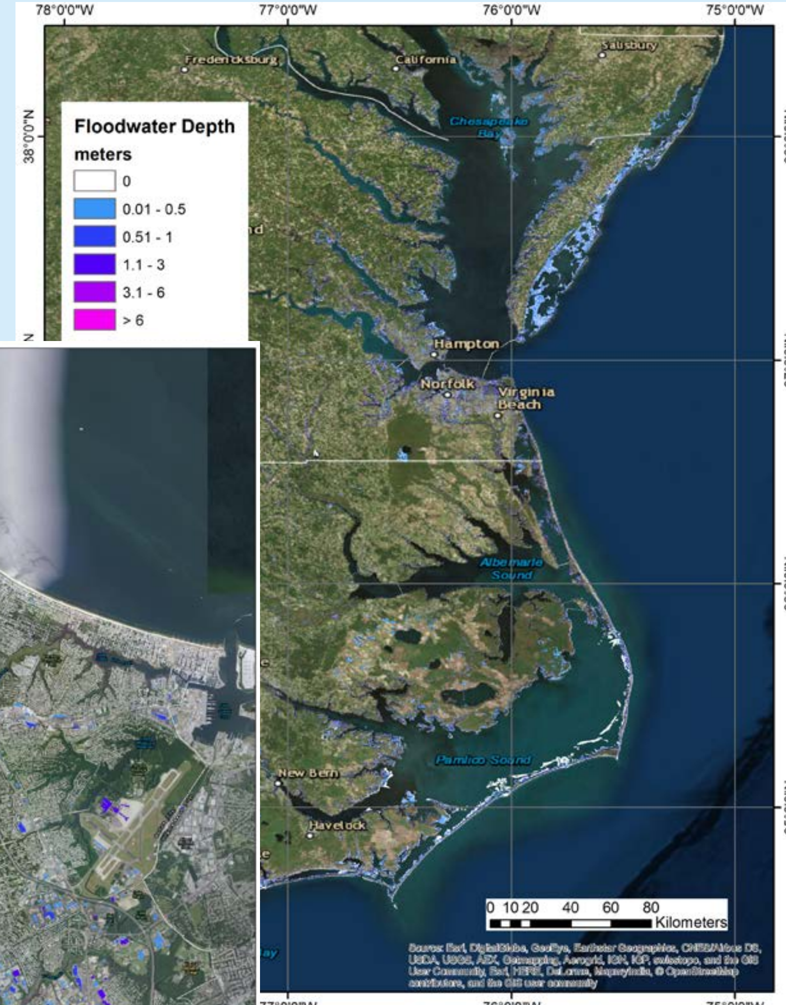




Implementations

- NASA Coastal Hazards Demo – Hurricane Irine





Research Funding by: