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
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 truthing 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 regular basis.

For information, requests, or data contribution contact the Project PI: Dr. Sagy Cohen (sagy.cohen@ua.edu) or Lead Developers: Dilanike Munsinghe (dilinmunsinghe@crimson.ua.edu) and James Misiak (jamesmisiak@crimson.ua.edu) (formerly Bradford Bates).

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

Flood events are listed once a layer is selected from the side panel or the map.

Download links will not work when using Safari 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 on the Google Maps display is at a considerably lower spatial resolution than the actual (shapefile) layers.

### Table of Flood Events

<table>
<thead>
<tr>
<th>River Name</th>
<th>State</th>
<th>Year</th>
<th>Date</th>
<th>Platform</th>
<th>Mapped Inundation Area (ha)</th>
<th>Source</th>
<th>Shapefile</th>
<th>Download</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Joaquin</td>
<td>Texas</td>
<td>2016</td>
<td>May 30</td>
<td>10m Sentinel 1</td>
<td>94.7</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Brazos (near Matagorda)</td>
<td>Texas</td>
<td>2016</td>
<td>May 28</td>
<td>30m Landsat 8 OLI</td>
<td>48.7</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Brazos (near Richmond)</td>
<td>Texas</td>
<td>2016</td>
<td>May 30</td>
<td>10m Sentinel 1</td>
<td>214.9</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Mesquakes</td>
<td>Iowa</td>
<td>2016</td>
<td>Sep 26</td>
<td>30m Landsat 8 OLI</td>
<td>59.5</td>
<td>DFO</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Cedar</td>
<td>Iowa</td>
<td>2016</td>
<td>Sep 26</td>
<td>30m Landsat 8 OLI</td>
<td>233.1</td>
<td>DFO</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Wapsipinnicon</td>
<td>Iowa</td>
<td>2016</td>
<td>Sep 26</td>
<td>30m Landsat 8 OLI</td>
<td>154.8</td>
<td>DFO</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Wapsipinicon</td>
<td>Iowa</td>
<td>2016</td>
<td>Sep 26</td>
<td>30m Landsat 8 OLI</td>
<td>533.33</td>
<td>DFO</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Washita</td>
<td>Oklahoma</td>
<td>2015</td>
<td>May 29</td>
<td>10m Sentinel 1</td>
<td>43.9</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Iowa</td>
<td>Iowa</td>
<td>2016</td>
<td>Sep 26</td>
<td>30m Landsat 8 OLI</td>
<td>136.4</td>
<td>DFO</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Lumber &amp; Little Pee Dee</td>
<td>N/C</td>
<td>2016</td>
<td>Oct 13</td>
<td>30m Landsat 8 OLI</td>
<td>581.1</td>
<td>DFO</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Black (SC)</td>
<td>South Carolina</td>
<td>2016</td>
<td>Oct 13</td>
<td>30m Landsat 8 OLI</td>
<td>253.9</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Willow Creek</td>
<td>Texas</td>
<td>2016</td>
<td>May 28</td>
<td>30m Landsat 8 OLI</td>
<td>15.7</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Spring Creek</td>
<td>Texas</td>
<td>2016</td>
<td>May 28</td>
<td>30m Landsat 8 OLI</td>
<td>57.1</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Chickasawhatchee River</td>
<td>Alabama/Florida</td>
<td>2016</td>
<td>Jan 4</td>
<td>30m Landsat 8 OLI</td>
<td>562.9</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Pea River</td>
<td>Alabama</td>
<td>2016</td>
<td>Jan 4</td>
<td>30m Landsat 8 OLI</td>
<td>61</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Holmes Creek</td>
<td>Florida</td>
<td>2016</td>
<td>Jan 4</td>
<td>30m Landsat 8 OLI</td>
<td>27.1</td>
<td>SDML</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Mississippi River</td>
<td>Missouri</td>
<td>2017</td>
<td>May 4</td>
<td>10m Sentinel 1</td>
<td>68.6</td>
<td>DFO</td>
<td>Download</td>
<td></td>
</tr>
<tr>
<td>Castor River</td>
<td>Missouri</td>
<td>2017</td>
<td>May 4</td>
<td>10m Sentinel 1</td>
<td>44.9</td>
<td>DFO</td>
<td>Download</td>
<td></td>
</tr>
</tbody>
</table>
U.S. Flood Inundation Map Repository (USFIMR)

http://sdml.ua.edu/usfimr
U.S. Flood Inundation Map Repository (USFIMR)

May 30, 2016: San Jacinto River above Lake Houston near Porter, TX

description

Download Shapefile:
http://tinyurl.com/zsyqr3k

Download 1/3 ArcSecond DEMs:
http://tinyurl.com/j4s4oa2

Most upstream USGS Gage: 08068090
USGS Gage website:
http://tinyurl.com/zy98tus

Generated using 10m Sentinel-1 Synthetic Aperture Radar (SAR) imagery. Polygon simplified for viewing speed.

Image Analyst: Bradford Bates, Surface Dynamics Modeling Lab, University of Alabama Department of Geography.

http://sdml.ua.edu/usfimr
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. Sagi Cohen (sagi.cohen@ua.edu) or Lead Developer Dinukul Munasinghe (dnanayakkaramunasinghe@crimson.ua.edu) and James Misfeldt (jamisfeldt@crimson.ua.edu).

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 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.

http://sdml.ua.edu/glofimr
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:

![Diagram of floodwater depth estimation](image)

  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
import arcpy
from arcpy.sa import *

def main():
    arcpy.CheckOutExtension("Spatial")
    arcpy.env.overwriteOutput = True
    WS = arcpy.env.workspace = r"C:\\WindowsShared\NASA_Coastal\FloodwaterDepth_fullExtent.gdb"
    arcpy.env.scratchWorkspace = r"C:\\WindowsShared\NASA_Coastal\Scratch.gdb"
    WMname = "InundationWM"
    InundPolygon = "WaterExtent_smooth"
    ClipDEM = "dem_clipDEM"
    arcpy.env.extent = WMname
    dem = arcpy.Raster(WMname)
    cellSize = dem.meanCellWidth
    boundary = CalculateBoundary(dem, InundPolygon, cellSize, WS)
    extent = str(dem.extent.XMin) + " " + str(dem.extent.XMax) + " " + str(dem.extent.YMin) + " " + str(dem.extent.YMax)
    print extent
    print 'Starting the iteration' -- input name, extent, ClipDEM, InundPolygon, cellSize, 'ClippingGeometry', 'NO_MAINTAIN_EXTENT'
    print 'First focal'
    OutRas = FocalStatistics(boundary, 'Circle 3 CELL', "MAXIMUM", "DATA")
    print '1'
    for i in range(3, 200):
        print i
        neighbor = 'Circle 3 + str(i) + ' CELL'
        OutRasTemp = FocalStatistics(boundary, neighbor, "MAXIMUM", "DATA")
        OutRas = Con(OutRas, OutRasTemp, OutRas)
        print 'Focal loop done'
        OutRas.save('FocalInWM')
        waterDepth = Minus(OutRas, ClipDEM)
        print 'waterDepth = Minus(OutRas, ClipDEM)'
        arcpy.GetMessages()
        waterDepth = Con(waterDepth < 0, 0, waterDepth)
        waterDepth.save('WaterDepthInWM')
        waterDepthFilter = Filter(waterDepth, "LOW", "DATA")
        print 'waterDepthFilter.save('WaterDepthInWM')'
        print 'Done'

def CalculateBoundary(dem, InundPolygon, cellSize, WS):
    arcpy.PolygonToLine_management(InundPolygon, "\polyline"
    arcpy.PolygonToLine_conversion(\polyline", "\polyline", "INVERTED", WS="\\linerast15", "MAXIMUM_LENGTH", "NONE", cellSize)
    print 'after polygon to raster'
    InMaster = MasterReferences("\\linerast15")
    InTrueRaster = dem
    InFalseConstant = "#"
    whereClause = "VALUE >= 0"
    print 'Con'
    boundary = Con(InMaster, InTrueRaster, InFalseConstant, whereClause)
    boundary.save(boundary)
main()
```
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
10m DEM
(NED)

Average: 1.95m

Average: 1.49m

RMSD: 0.37m
St Vrain Creek, Lyons CO
1m LiDAR

Average: 0.72m
Average: 1.28m
RMSD: 0.38m
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