Rapid Modeling of In-Season Catastrophic Flood Events

Prepared by Hojjat Seyyedi of Impact Forecasting
Agenda

Section 1  Fluvial Component
Section 2  Pluvial Component
Section 3  Real-time Flood Modeling
Section 4  Validation
Section 5  Vulnerability Modeling
Section 6  Summary
Section 1: Fluvial Component

- Real-time USGS stream gauge measurements
- River routing model
Real-time stream gauge measurements

- USGS has historically maintained approximately 22,500 stream gauges
  - Provide direct measurement of river flow and height
  - Capture all types of flood events
  - Errors related to instrumentation and methods are within 5-10%
Discharge Data Recorded

Data for the following 1 site(s) are contained in this file

USGS 06730200 BOULDER CREEK AT NORTH 75TH ST. NEAR BOULDER, CO

Data provided for site 06730200

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A Approved for publication -- Processing and review completed.

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Section 2: Pluvial Component

- Intensity Duration Frequency (IDF) curve development
- Pre-calculated scenarios
Intensity Duration Frequency (IDF) curve development

- Over 50,000 IDF curves are developed in order to cover the entirety of the U.S.
Rainfall Runoff Modelling

- A two-dimensional hydrodynamic model is used to simulate flood depth
- The model is a physically based distributed model and Solving 2D St. Venant equations:

\[
\frac{\partial h}{\partial t} + \frac{\partial hU}{\partial x} + \frac{\partial hV}{\partial y} = e
\]

\[
\frac{\partial hU}{\partial t} + \frac{\partial hUU}{\partial x} + \frac{\partial hVU}{\partial y} = \frac{\partial hT_{xx}}{\partial x} + \frac{\partial hT_{xy}}{\partial y} - gh \frac{\partial z}{\partial x} - \frac{\tau_{bx}}{\rho}
\]

\[
\frac{\partial hV}{\partial t} + \frac{\partial hUV}{\partial x} + \frac{\partial hVV}{\partial y} = \frac{\partial hT_{xy}}{\partial x} + \frac{\partial hT_{yy}}{\partial y} - gh \frac{\partial z}{\partial y} - \frac{\tau_{by}}{\rho}
\]
Pre-calculated flood scenarios

- Pluvial flood cases are pre-calculated for each selected modeled domain
Section 3: Real-time flood modeling

- Smaller event: Setting up a new model
- Large event: Using pre-calculated scenarios
- Validation
August 2-4, 2015: Tampa, FL Flash Flood Event

Small event
Overview

- August 2-4, 2015 Flood Reanalysis
  - Nearly two weeks of continuous rainfall beginning ~July 20 fell across West Central Florida, particularly in Pinellas, Pasco, and Hillsborough counties in the Tampa Bay metro region
  - Excessive soil saturation was already an issue prior to a high intensity rainfall event that occurred from overnight on August 2 into August 3
  - Flash floods were reported in several areas of the Tampa Bay metro region
    - Flood heights of 1-4 feet
    - Multiple rivers overflowed their banks, including the Anclote and Hillsborough rivers
    - Numerous neighborhoods evacuated due to flood inundation
  - The following flash flood regions were modeled for this event:
    - Pasco County, FL
    - Hillsborough County, FL (including Tampa)
    - Pinellas County, FL
NASA TRMM Rainfall Data (July 20 – August 5)
Flash Flood Extent

- The image below shows the overall coverage of the flood footprint, which was modeled using full 2D hydrodynamic Rainfall – runoff model.
October 2015: South Carolina Flood Event

Large event
Meteorological Recap

- A highly complex atmospheric pattern with multiple surface and mid-level weather features working congruently to bring several days of excessive rainfall

- A plume of tropical moisture, which was partially aided by Hurricane Joaquin, tracked over the Carolinas for nearly 72 consecutive hours
  - Previous event during the last week of September brought 10+ inches of rain to region which left soils saturated and river levels elevated

Some areas recorded in excess of a 1-in-1,000 year rainfall total

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<th>Storm Total Rainfall</th>
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<td>Boone Hall Plantation, SC</td>
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<td>18.79 inches</td>
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<td>Shadowmoss, SC</td>
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<td>17.40 inches</td>
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<td>Charleston, SC</td>
<td>23.61 inches</td>
<td>Wilmington Airport, NC</td>
<td>8.79 inches</td>
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Source: NOAA
Rainfall Map

7-day rainfall map ending October 5 (Source: NOAA)
Overall Flood Extent
Map Showing Areas of Maximum Loss Potential

Columbia

Myrtle Beach

Charleston
More recent flood events
May 2015: TX/OK flood events
Flood Extent

Austin, TX

Dallas, TX

Oklahoma City, Ok

Houston, TX
April 2016: Houston Flash Flood Event
Flood Extent Map(s)
July 2016: Maryland Flash Flood Event

July 31, 2016 1-Day Observed Precipitation
Created on: August 02, 2016 - 19:40 UTC
Valid on: July 31, 2016 12:00 UTC
Flood Extent
The modelled results depict the inundation

The simulation accurately depicted water flow through residential communities downstream of the failures

Source: South Carolina Flooding Imgur
Impact Forecasting validated its flood heights

The modelled discharge captured the true extent of the damages in multiple locations

High water mark

1.89m
The extents matched many of the areas inspected

For example the hardest hit building, Title Max Loan, was modelled within a few feet of the observed height
The confluence discharge is modelled accurately

Although the discharge was 185,000 cubic feet per second (cfs), the maximum recorded in history was 364,000 cfs in 1908

Source: South Carolina Flooding Imgur
Section 5: Vulnerability Modeling
Comparison of depth damage functions

Typical USACE Vulnerability Functions

Typical IF Building Vulnerability Function
Summary

- Utilizing real-time satellite based precipitation data for pluvial flood modeling
- Utilizing real-time stream gauge measurements for fluvial flood modeling
- Flood extents and inundation depth validated based on on-site visits, reports and loss estimation
- Impact Forecasting is releasing flood extents 1-2 days after the event
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