Cost Effective Flash Flood and Flood Warning using Existing Floodplain Models?

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Introduction: Thinking Out loud

It’s the **next thing.**

We are **not satisfied** leaving models on the shelf.

Dewberry Engineers **want** to do it.

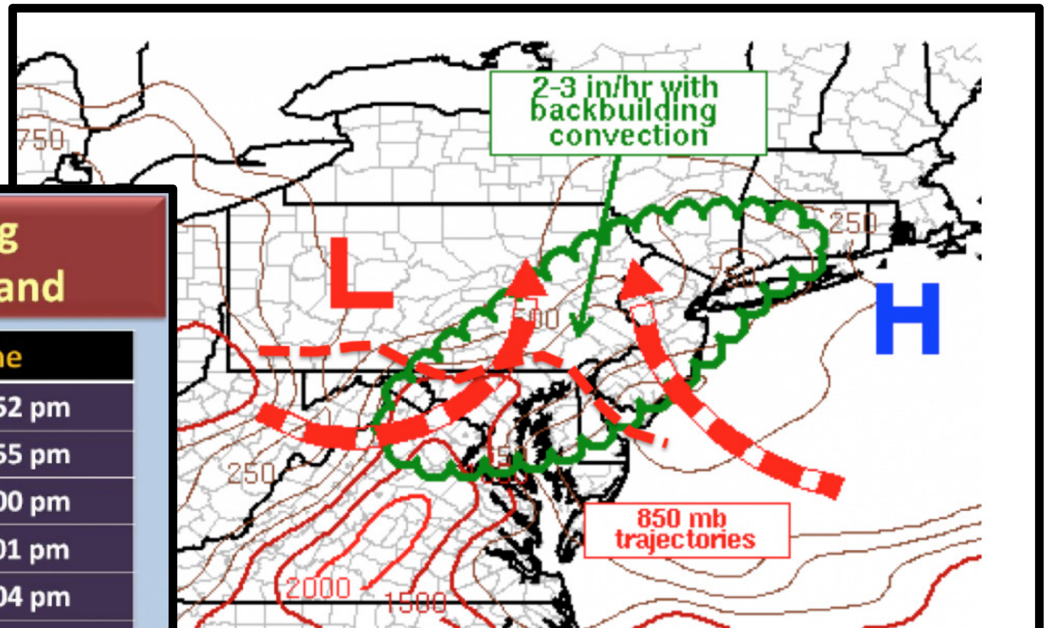
University Partners **are asking.**

Emergency Managers **are waiting.**

Opportunity to develop **open source solutions.**

Challenges for Forecasting: When?

Analysis at 5 p.m. that shows how air streams (heavy red, dashed arrows) at the 5,000-foot level were converging over Maryland.



ash flood event July 30. (National Weather Service, adapted by Jeff Halverson)

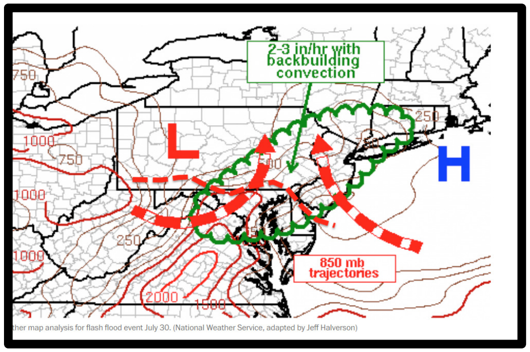
Historic Rainfall and Flash Flooding Saturday Night in Ellicott City, Maryland

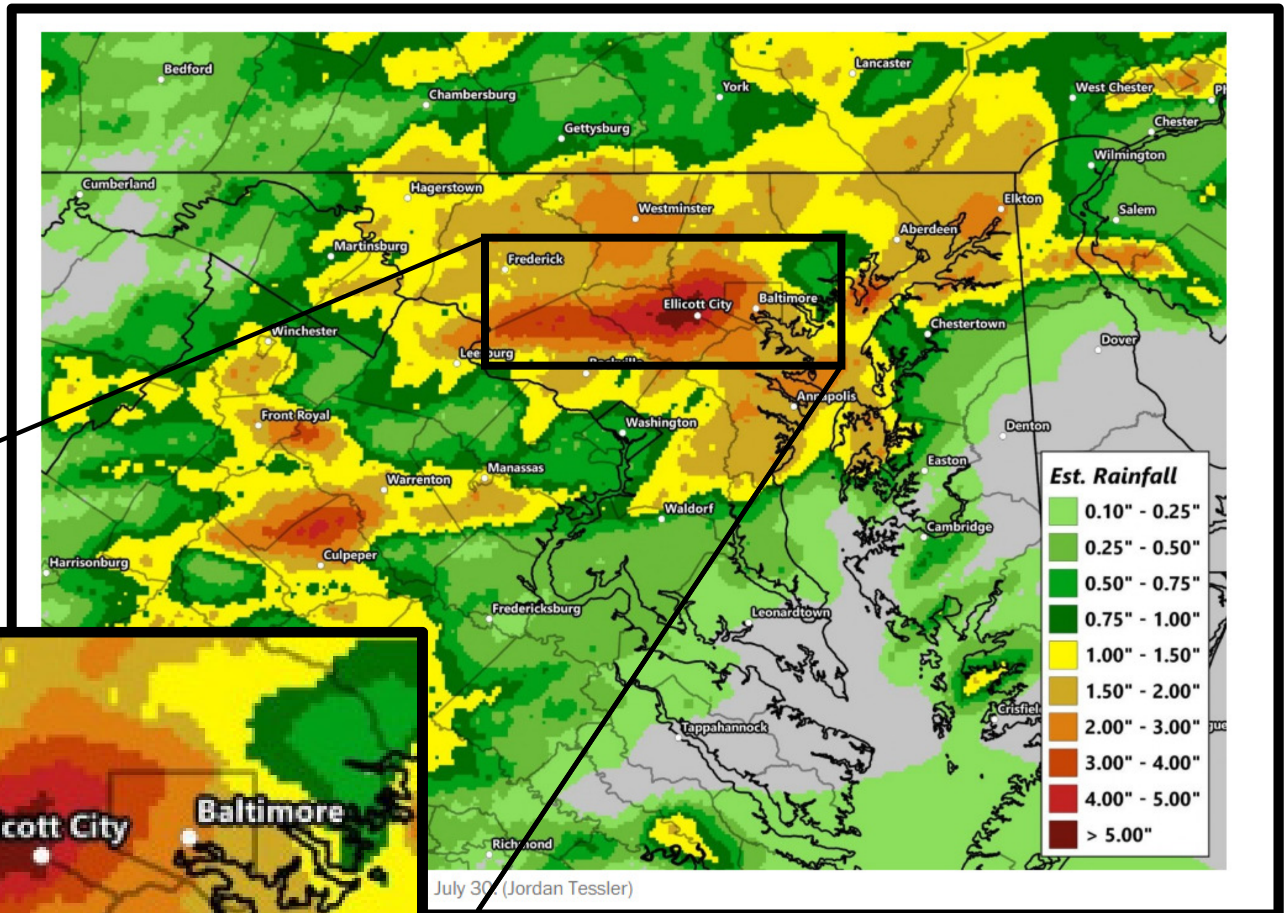
Duration	Rainfall Total	Time
1 minute	0.20"	7:51-7:52 pm
5 minutes	0.80"	7:50-7:55 pm
10 minutes	1.44"	7:50-8:00 pm
15 minutes	2.04"	7:46:8:01 pm
20 minutes	2.48"	7:44-8:04 pm
30 minutes	3.16"	7:36-8:06 pm
60 minutes	4.56"	7:30-8:30 pm
90 minutes	5.52"	7:00-8:30 pm
2 hours	5.92"	6:45-8:45pm

The storm total rainfall at Ellicott City was 6.50 inches. Based on the preliminary precipitation frequency estimates in NOAA Atlas 14 from the nearest location, the rainfall amounts with duration 10 minutes to 2 hours statistically have a less 0.1% chance of occurring in any given year, or a 1 in 1000 year event.

https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/08/01/this-is-how-an-off-the-charts-flood-ravaged-ellicott-city/

Challenges for Forecasting: Where?





https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/08/01/this-is-how-an-off-the-charts-flood-ravaged-ellicott-city/

Forecasting Framework

1. Transform Hydrologic Models
2. Develop Data Acquisition & Processing Schema
3. Automate Forcing & Input/Output
4. Bias Correction & Modeling Tasks
5. Evaluate/Configure Hydraulic connection
6. Post Processing/Forecast Product
7. Latency & Utility

Background: GMU Flood Hazard Lab

Hydro-Meteorological Monitoring Network

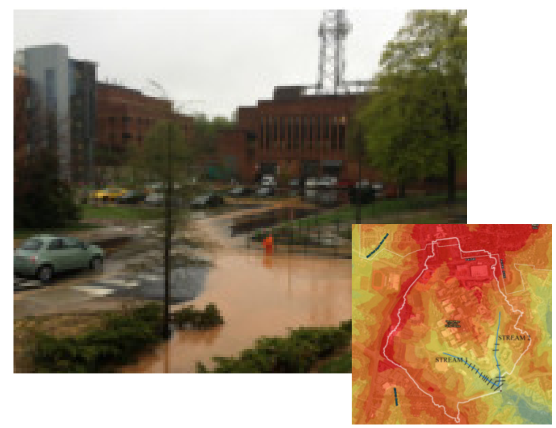
- ✓ Precipitation, wind, temperature…
- ✓ Water Levels, velocity, flow

Campus

- ✓ History of Flooding
- ✓ HEC-HMS
- ✓ HEC-RAS (1D2D), surveyed XS's

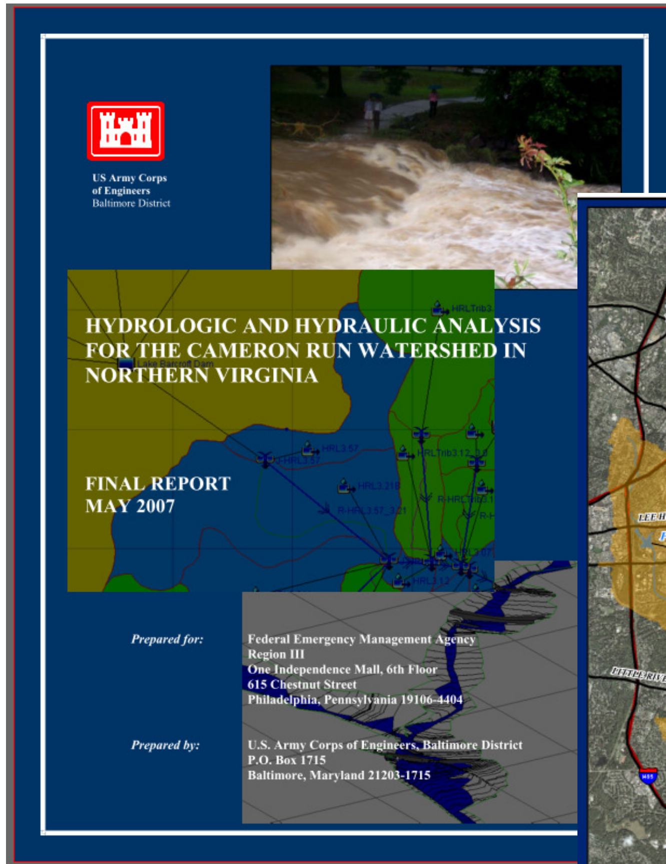
Poseidon Server for Real-time Flood Modeling

- ✓ Coastal Model : Running
- Riverine Model: In Progress



Background: Cameron Run Watershed

- High Resolution, Calibrated Models
- Nuisance/Flash Flooding
- Well Gaged
- Reservoir


US Army Corps of Engineers Baltimore District

HYDROLOGIC AND HYDRAULIC ANALYSIS FOR THE CAMERON RUN WATERSHED IN NORTHERN VIRGINIA

FINAL REPORT
MAY 2007

Prepared for: Federal Emergency Management Agency
Region III
One Independence Mall, 6th Floor
615 Chestnut Street
Philadelphia, Pennsylvania 19106-4404

Prepared by: U.S. Army Corps of Engineers, Baltimore District
P.O. Box 1715
Baltimore, Maryland 21203-1715

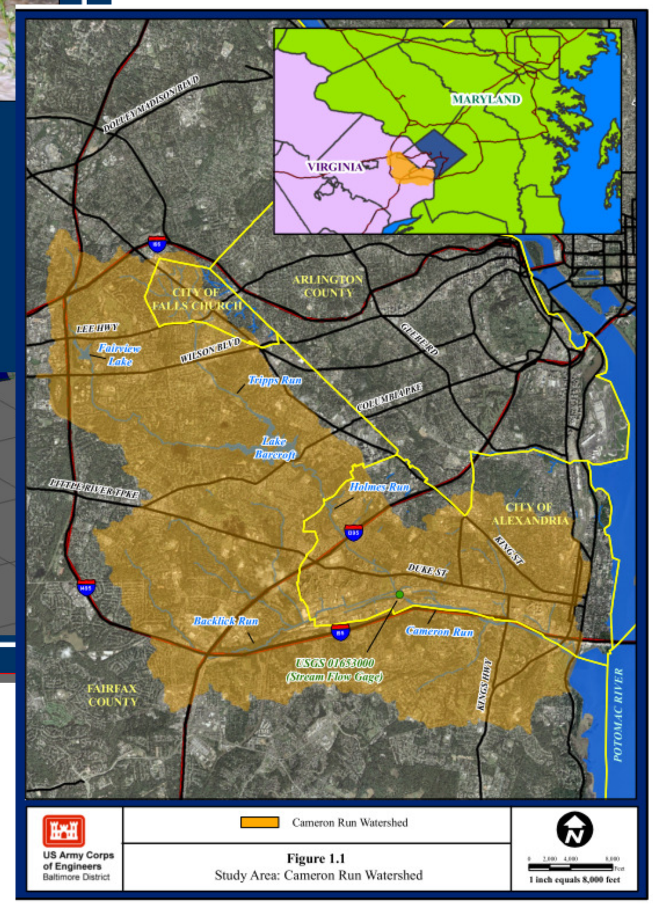
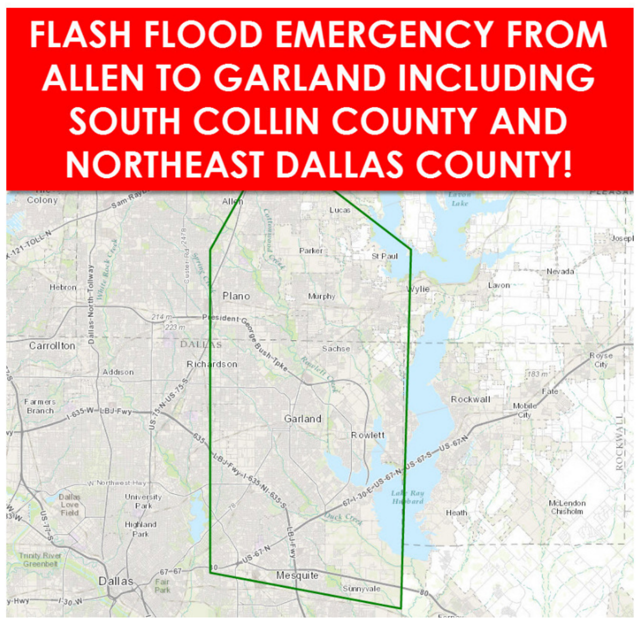


Figure 1.1
Study Area: Cameron Run Watershed

http://www.fairfaxcounty.gov/dpwes/publications/stormwater/huntingtonfinal_ch2.pdf

Background: Duck Creek Watershed

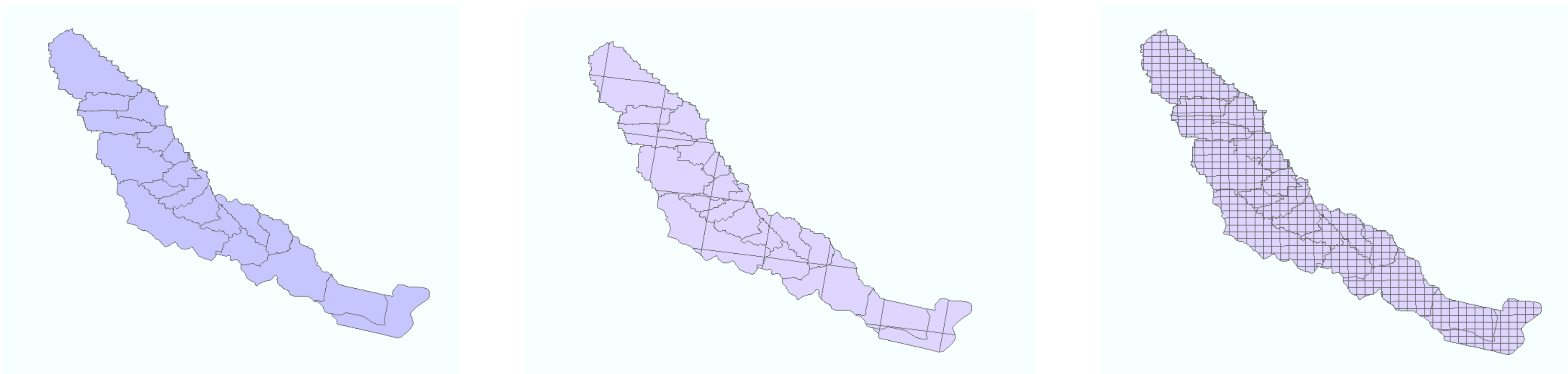
- Flash Flooding
- Structural Data
- Existing Models
- Extensive Ground Radar Network



http://www.fairfaxcounty.gov/dpwes/publications/stormwater/huntingtonfinal_ch2.pdf

HMS Model Set-Up: HRAP or SHG Grid

1. Transform Hydrologic Models



Result: A coarse meteorological grid forcing a highly resolved hydrologic model

Map HRAP Grid Cell to Intersecting HMS Subbasin:

HMS .mod file

HRAP.mod

```
Parameter Order: Xcoord Ycoord TravelLength Area
End:

Sub
 
End

Sub
 
 
End
```

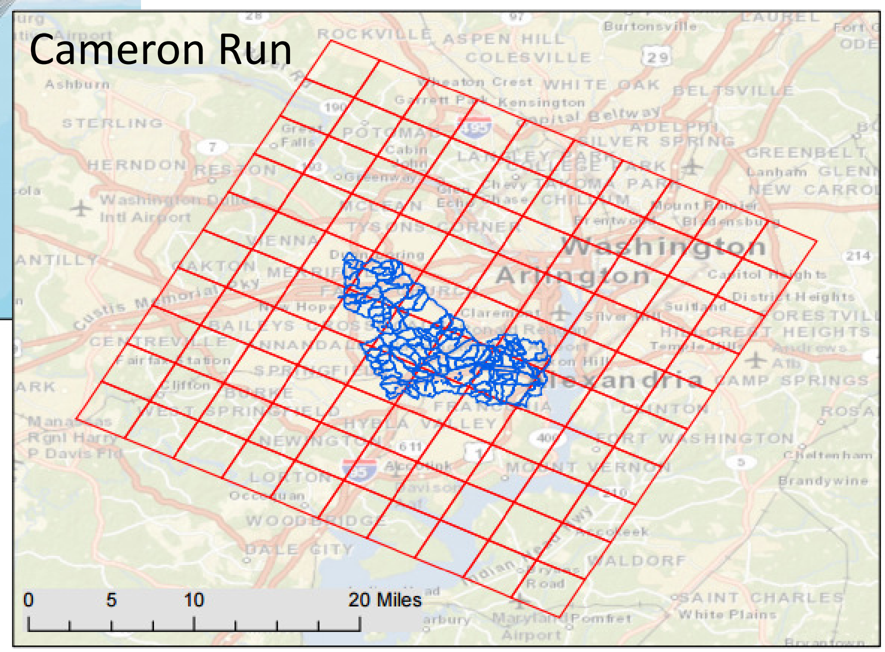
SHG.mod

```
Parameter Order: Xcoord Ycoord TravelLength Area
End:

Subbasin: PB2.10
     GridCell: 961 543 0.10000000000000000 0.61935
End:

Subbasin: CRTrib.11_1.13
     GridCell: 961 544 0.10000000000000000 0.065952
     GridCell: 962 544 0.10000000000000000 0.485423
End:
```

HMS Model Set-Up: QPF & HRAP

1. Transform Hydrologic Models

Mid-Atlantic River Forecast Center: Quantitative Precipitation Forecast (QPF) Coverage Area on the HRAP Grid



Extracted Area of Interest: HMS Sub-basins for the Cameron Run Watershed

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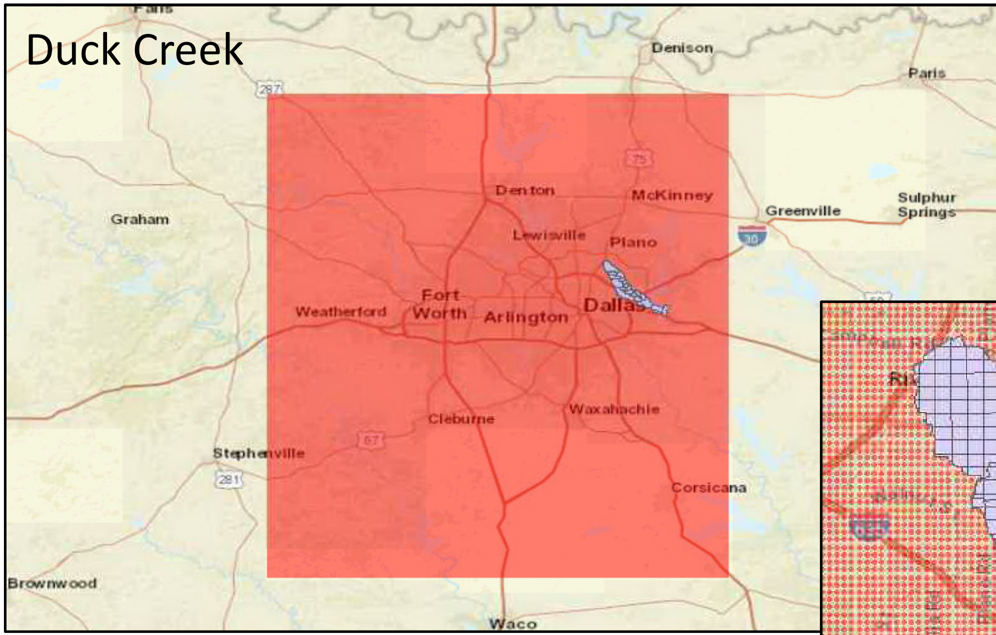
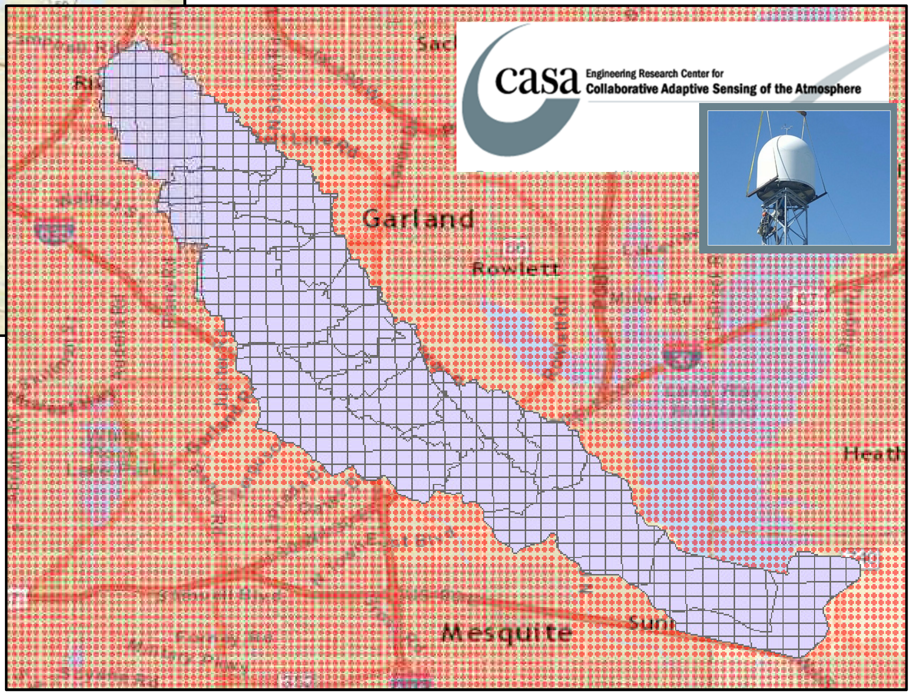
HMS Model Set-Up : Now-cast & SHG

1. Transform Hydrologic Models



Ground Radar Observations at 10 min Past the hour: 250 meters



Now-casts available for 30 min-3 hour leading to and during events

http://www.casa.umass.edu/main/research/urbantestbed/?_ga=1.111027269.1922312974.1476753705

HMS Model: Meteorological Forcing

2. Develop Data Acquisition & Processing Schema

Python Library Development

- Read Met File Data:
  - Grib/Grib2
  - XMRG
  - NETCDF
- Extract Area of Interest
- Resample Data
- Write DSS files
- Run HMS

```
class Grid(object):

    def __init__(self, grid, coords, cellsize):
        self.grid = grid
        self.coords = coords
        self.cellsize = cellsize

    def lats(self):
        f = Dataset(self.grid,'r')
        lats    = f.variables['Latitude'][:]
        return lats

    def lons(self):
        f = Dataset(self.grid,'r')
        lons    = f.variables['Longitude'][:]
        return lons

    def precip(self):
        f = Dataset(self.g
        precip  = f.variab
        return precip
```

```
class dssWriter:

    def __init__(self, name):
        self.name = name

    def date(self):
        f = self.name.split('_')
        date = datetime.strptime(f[0]+f[1],'%d%b%Y%H%M%S')
        return date

    def dss_start(self):
        dss_start = self.date().strftime('%d%b%Y:%H%M')
        return dss_start

    def delta_t(self):
        f = self.name.split('_')
        interval = findall('\d+|\D+', str(f[2][:-3]))
        scalar, unit = interval[0], interval[1]

        if unit == 'min.':
            unit = 'minutes'
        elif unit == 'hour':
            unit = 'hours'
```

Getting a Hydrograph: Automation

3. Automate Forcing & Input/Output

How Dispensable is the Modeler?

https://s-media-cache-ak0.pinimg.com/564x/00/67/46/0067467e56db97e5ff2f6e2d3d8d161d.jpg

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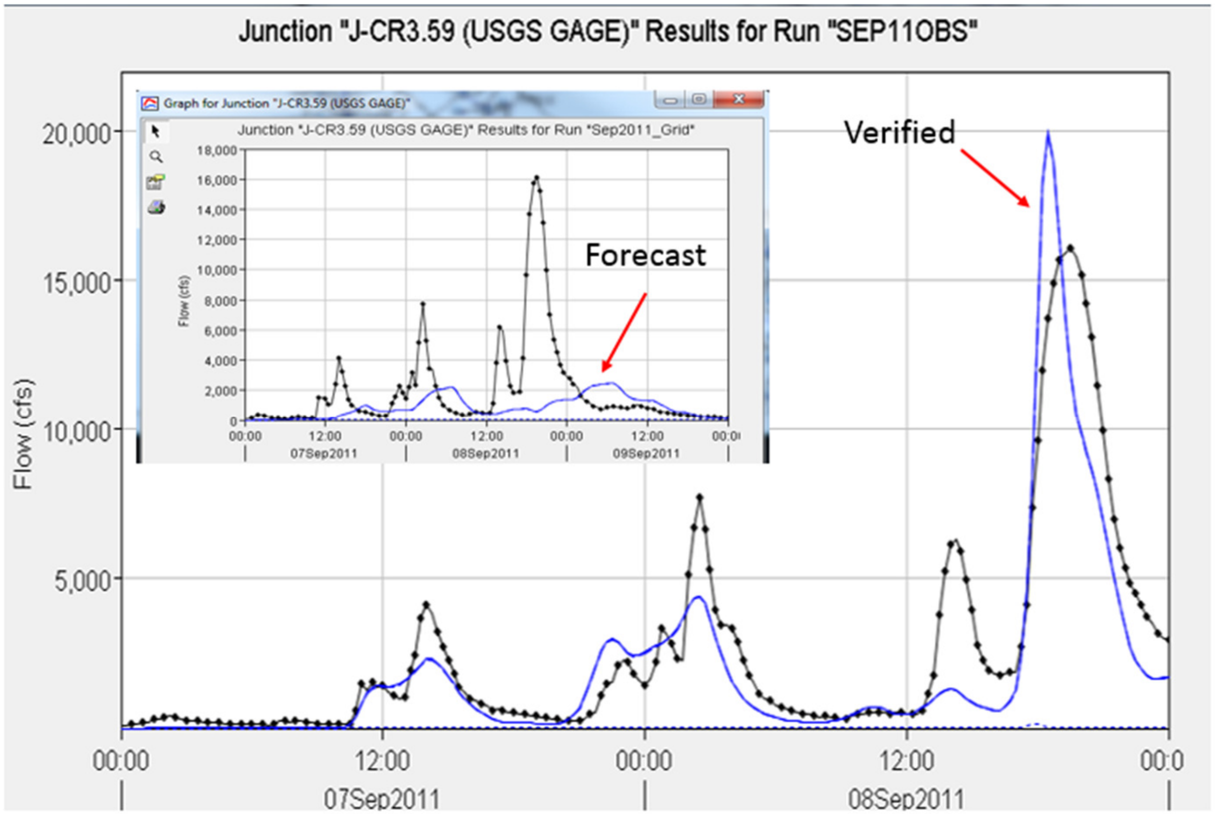
Living with the hydrograph(s)

4. Bias Correction & Modeling Tasks



Where is the correction made....precipitation forecast, hydrograph?

When is bias correction Applied?

How?

HMS Model: Meteorological Forcing

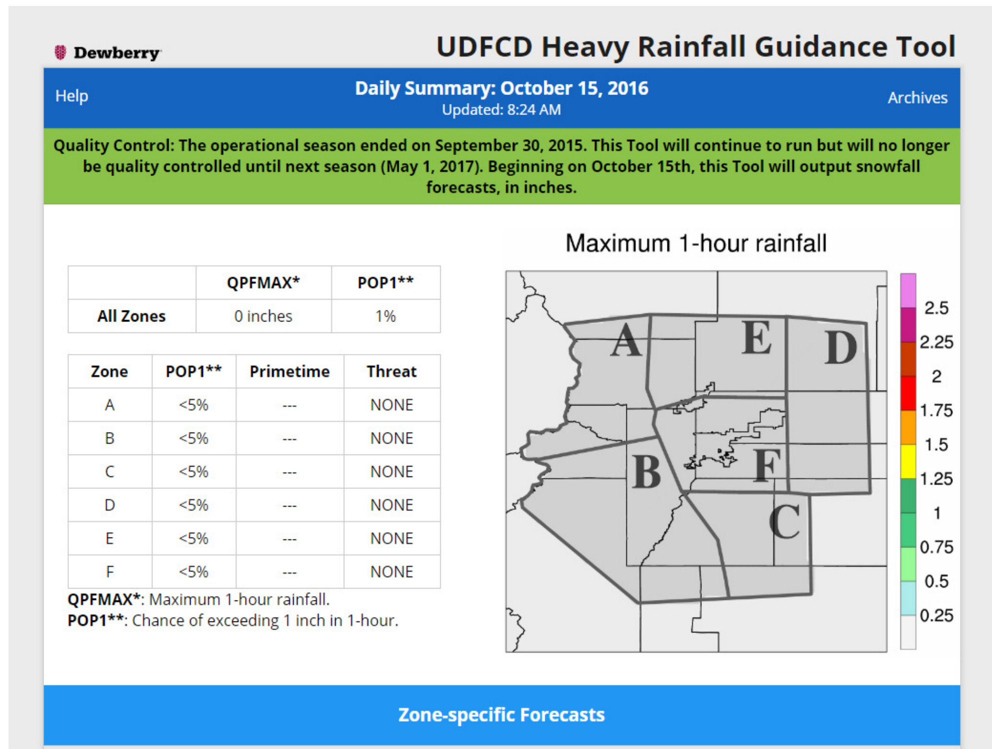
4. Bias Correction & Modeling Tasks

Table 4: *Sources of QPF data.*

Modeling center	Ensembles (Model/Family)	Total ensembles
National Severe Storms Laboratory (NSSL)[a]	1. arw / A 2. arw-ctl / A 3. arw-p1 / A 4. arw-n1 / A 5. arw-p2 / A 6. nmb-ctl / B 7. nmb-n1 / B 8. nmb-p1 / B 9. nmb-p2 / B	9
National Centers for Environmental Prediction (NCEP)[+]	10. hires-arw / C 11. hires-nmm / D 12. namnest-00Z / E 13. namnest-06Z / E	4
National Center for Atmospheric Research (NCAR)[a]	10 members (#14-23) Family: F	10*
[a]Research / operational center *[+]Operational center* **Not used in 2015 operations, only for testing*	**Total Ensembles**	**13 (ops)** **23 (ops + testing)**

Developed by Dewberry Meteorologist & Hydro-meteorologists

Creation of QPF's for Daily Colorado Flood Threat Guidance Tool



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Using all the tools

4. Bias Correction & Modeling Tasks

Statistical Methods

Ensemble Forecasts

Synthetic Storms

Table 4: *Sources of QPF data.*

Modeling center	Ensembles (Model/Family)	Total ensembles
National Severe Storms Laboratory (NSSL)ᵃ	1. arw / A 2. arw-ctl / A 3. arw-p1 / A 4. arw-n1 / A 5. arw-p2 / A 6. nmb-ctl / B 7. nmb-n1 / B 8. nmb-p1 / B 9. nmb-p2 / B	9
National Centers for Environmental Prediction (NCEP)⁺	10. hires-arw / C 11. hires-nmm / D 12. namnest-00Z / E 13. namnest-06Z / E	4
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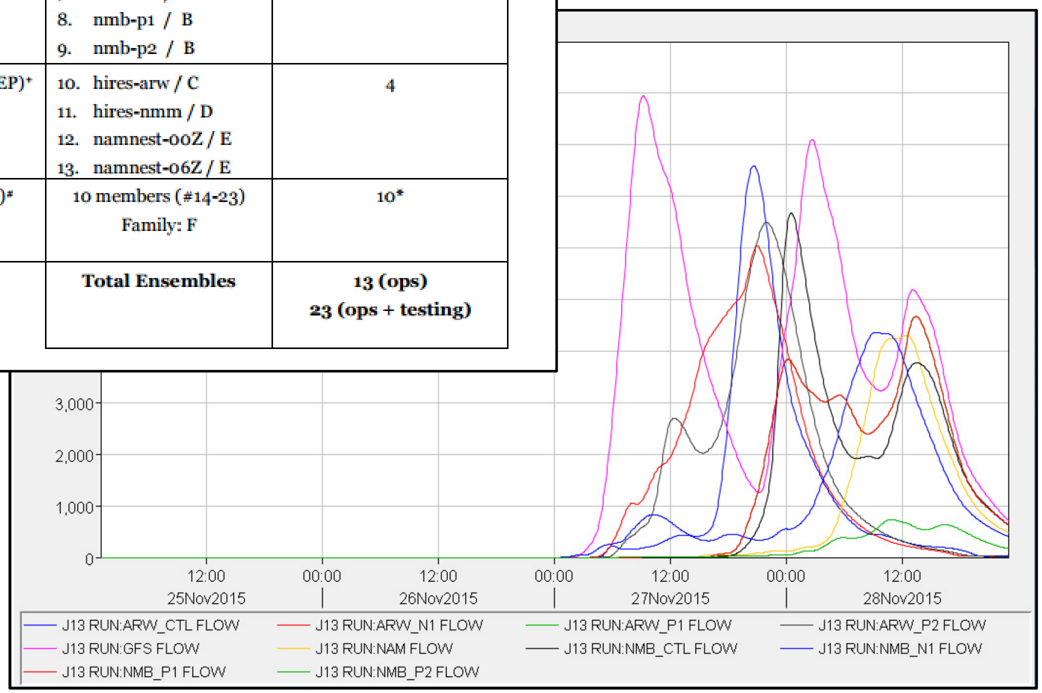


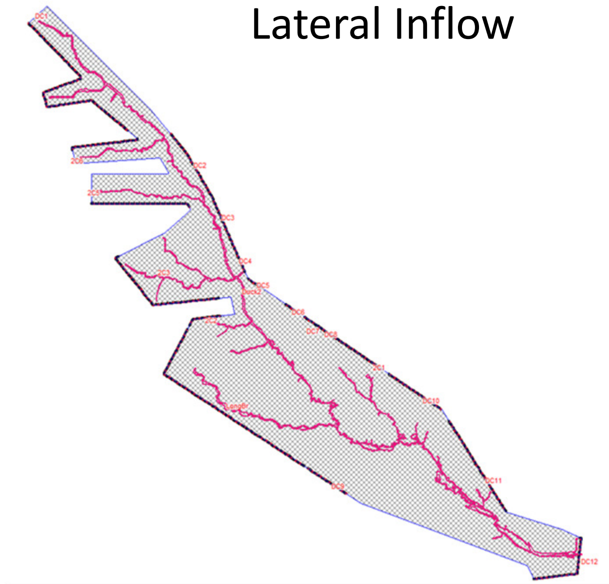
Data Assimilation

Rating Curves

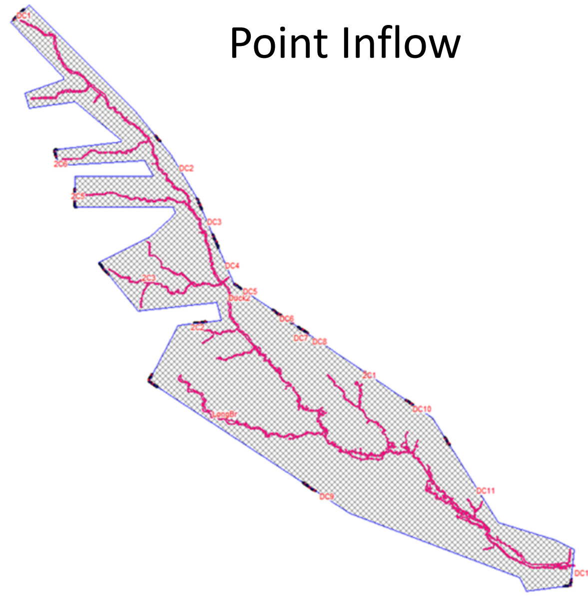
RAS Model: Forcing

5. Configure Hydraulic connection: 2D

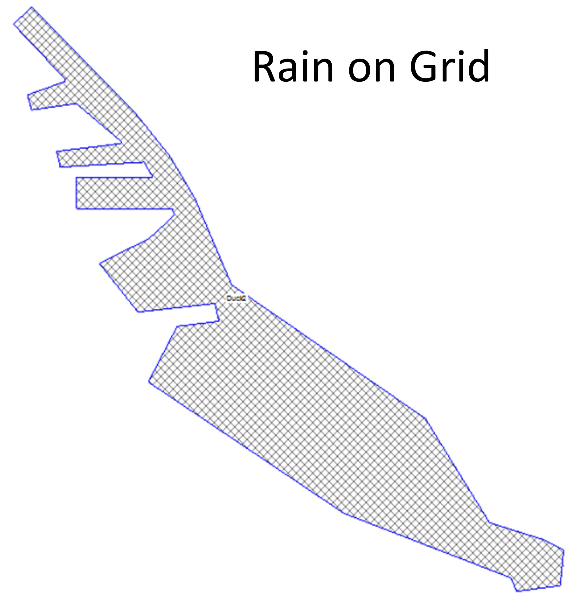
Lateral Inflow



Point Inflow



Rain on Grid



Cells	Cell Size (ft)	Computational Time-step (min)	Run Time (hh:mm:ss)
60,000	200		0:03:30
120,000	100	5	0:14:30
360,000	50		0:58:00

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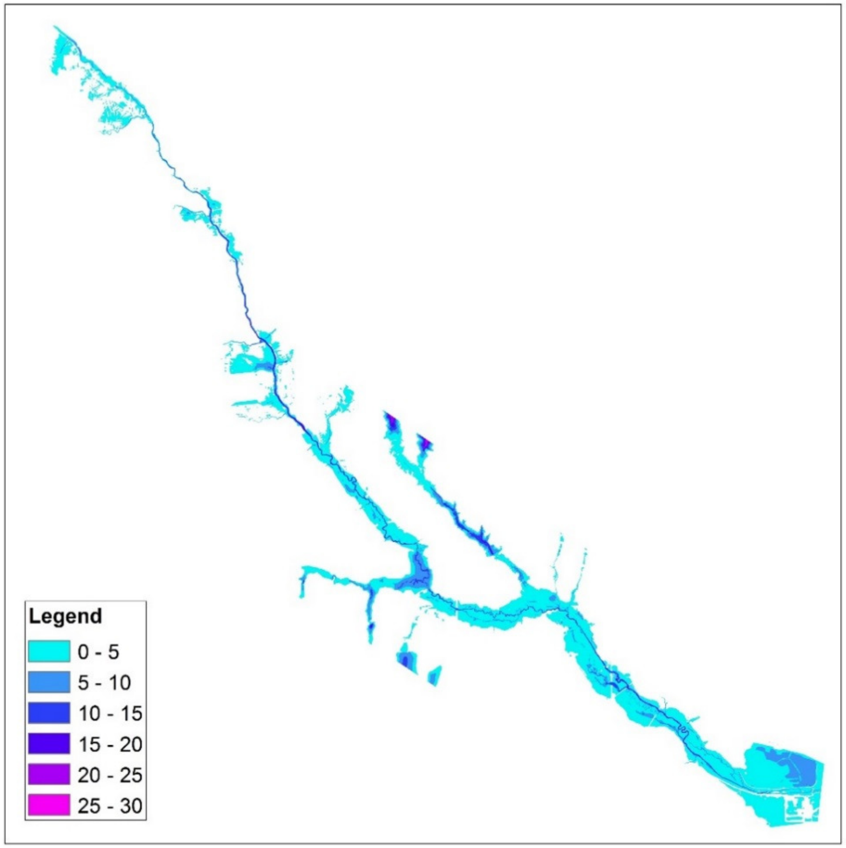
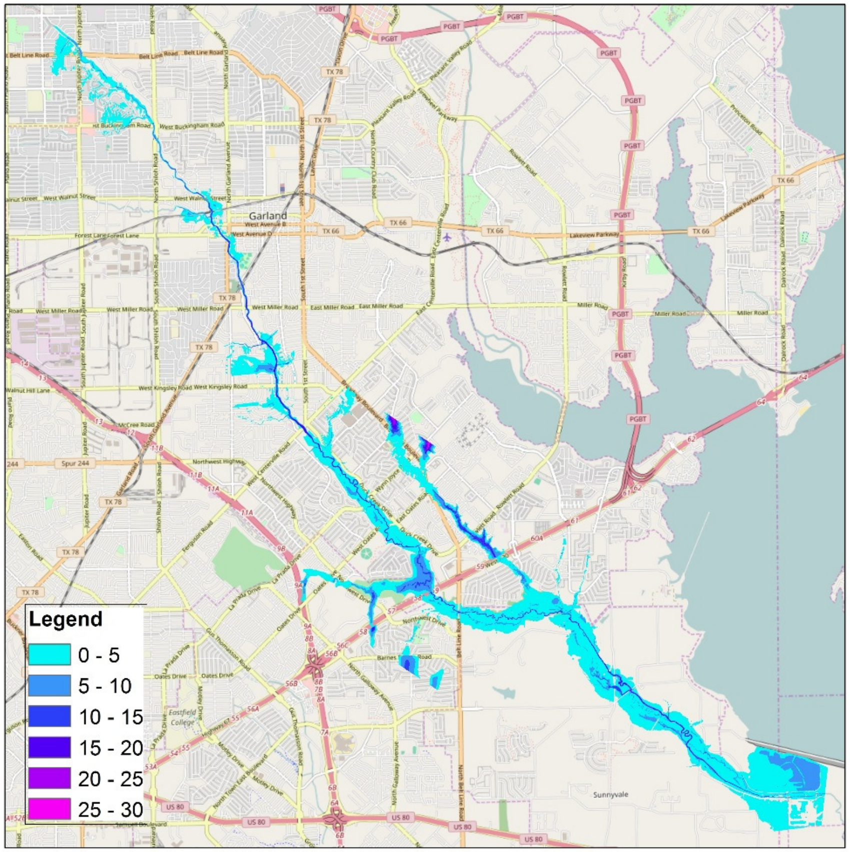
RAS Model: Post Processing

6. Post Processing/Forecast Product





HEC-RAS 5.0 Post Processing

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Precip ==> Flow ==> Floodplain Extent

7. Latency & Utility

t0 = Precipitation Forecast Available

t1 = Precipitation Data processed

t2 = Hydrologic Simulation

t3 = Hydraulic Simulation

t4 = Floodplain/Flow Forecast Available

Latency = t0+ t1+ t2+ t3+t4

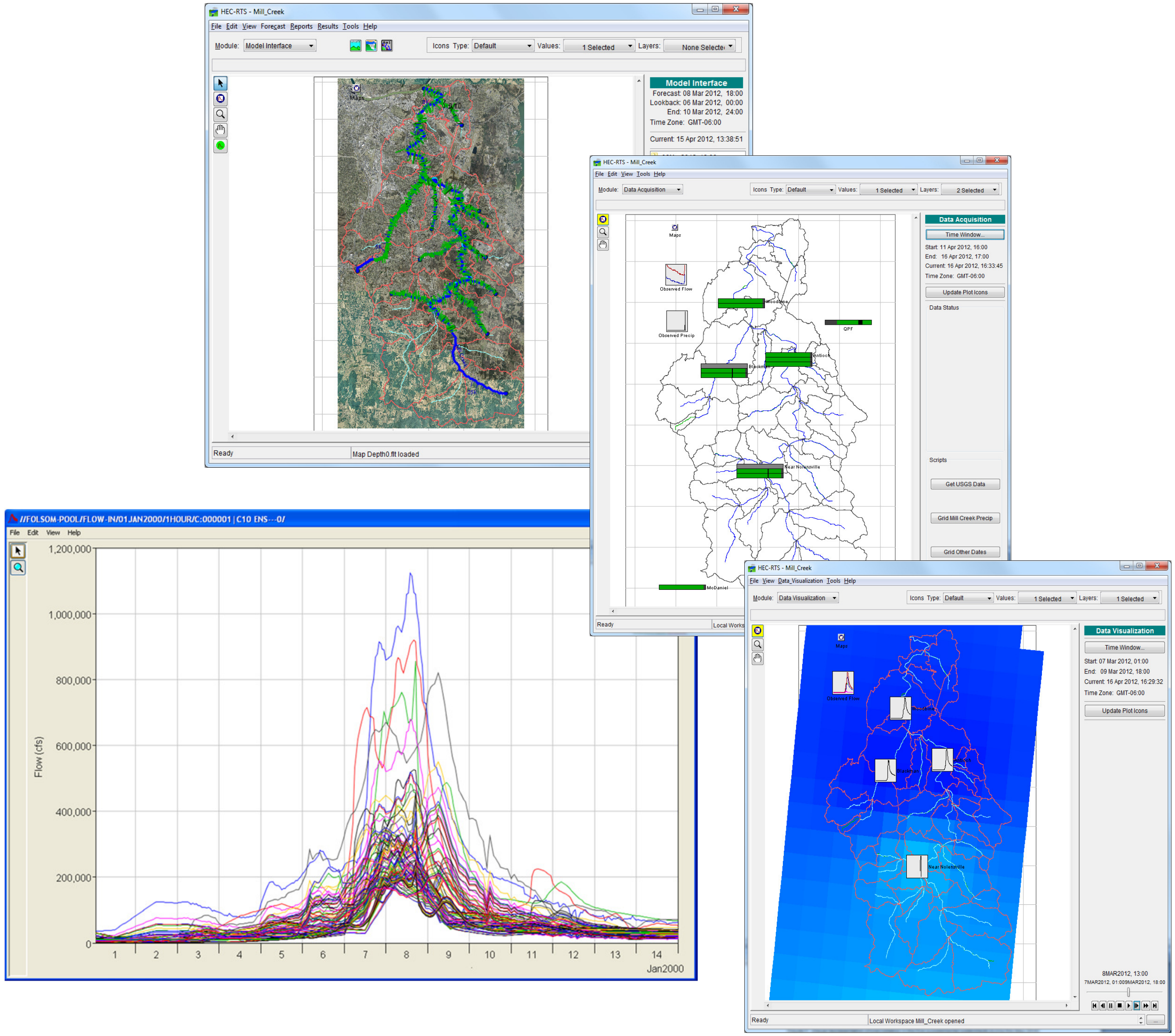
At hour 00, Latency (minutes) = 5 + 10 + 5 + 25: **45minutes**

Utility = Success – (False Alarms + Latency + Non-Detection)

USACE

- Corps Water Management System (CWMS)
  - HEC Products
  - Oracle Database
  - Unix Operating System
  - Data Retrieval Client Based

- Real Time Simulation (RTS)
  - HEC Products
  - HEC-DSS
  - Windows PC
  - Scripting Capability



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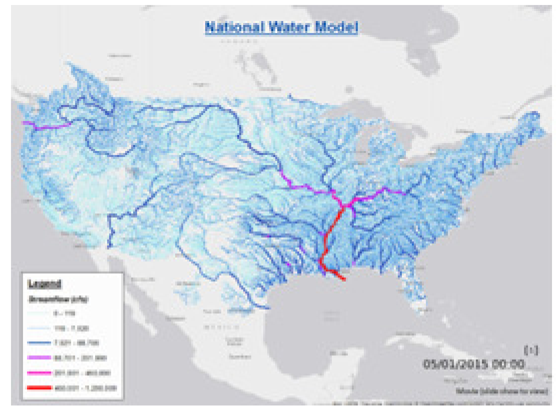
NWS: National Water Model

Current River Forecast Points (~3,600)

NWM Streamflow Output Points (~2.7 mil)

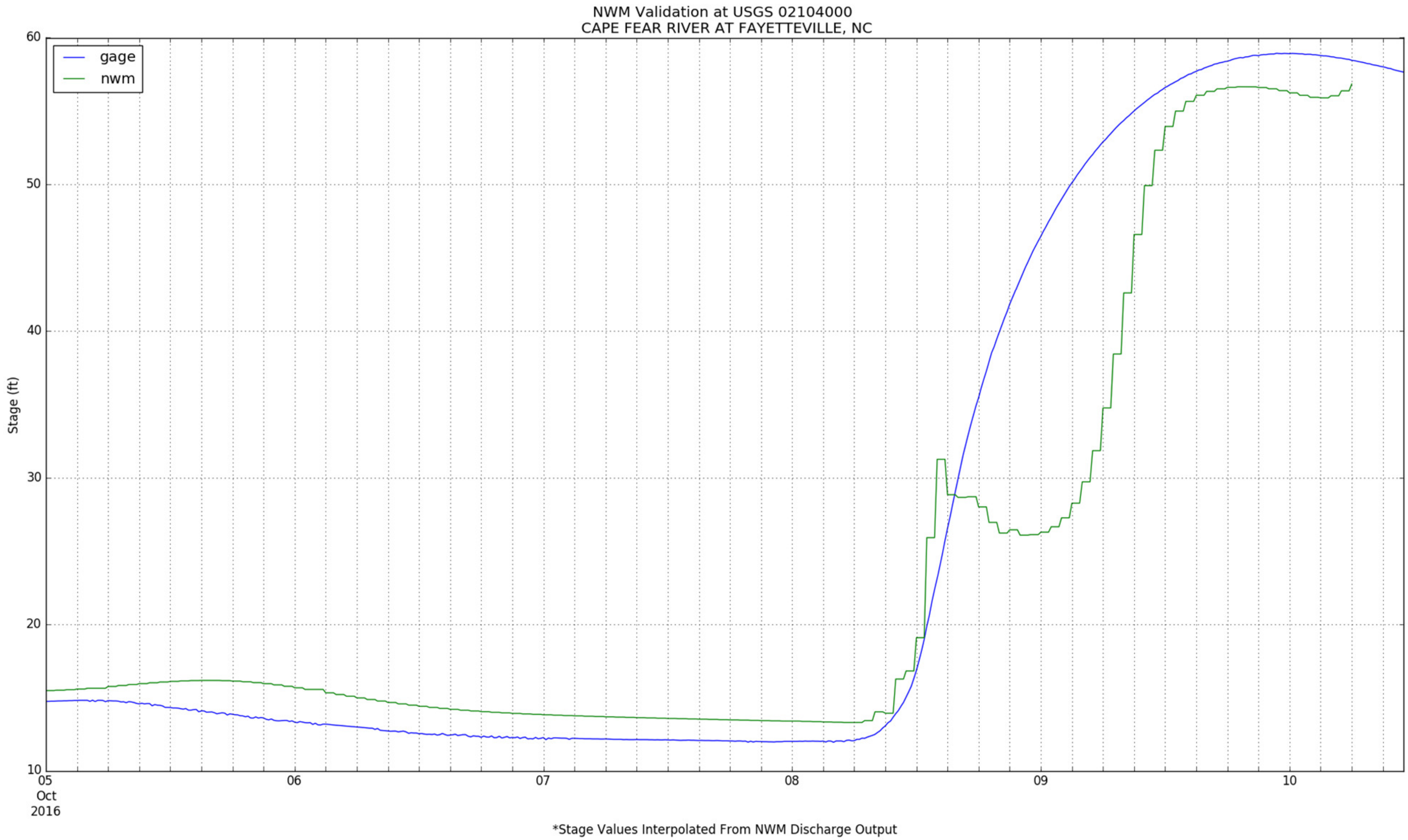


Model Details

	Analysis & Assimilation	Short-Range	Medium-Range	Long-Range
Cycling Frequency	Hourly	Hourly	Daily at 06Z	Daily Ens (16 mem)
Forecast Duration	- 3 hrs	0-15 hours	0-10 days	0-30 days
Forecast Latency (latency of external forcing data accounts for most of delay)	1 hour	1 hour 45 mins	6 hours	19 hours
Meteorological Forcing	MRMS blend/ HRRR/ RAP bkgnd.	Downscaled HRRR/RAP blend	Downscaled GFS	Downscaled & bias-corrected CFS
Spatial Discretization & Routing	1km/250m/NHDPlus Reach	1km/250m/NHDPlus Reach	1km/250m/NHDPlus Reach	1 km/NHDPlus Reach
	Assimilation of USGS Obs			
	Reservoirs (1260 water bodies parameterized with level pool scheme)			

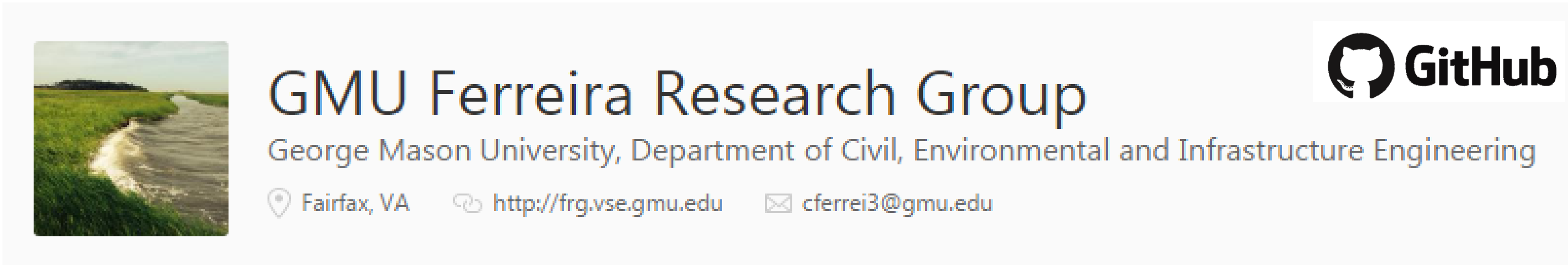
http://water.noaa.gov/about/nwm

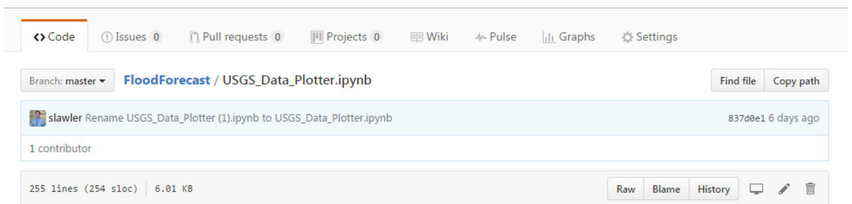
NWS: National Water Model



http://water.noaa.gov/about/nwm

Open Source Tools





Step-by-step guide to retrieving data from USGS API

Example:

Get streamflow data from selected gage for time period of interest & plot timeseries results

```
In [ ]: # Import libraries

        %matplotlib inline
        import pandas as pd
        import requests
        import json
        from datetime import datetime
        from collections import OrderedDict

In [ ]: # Enter Desired Data
        gage       = "01646500"                          # USGS Gage

        y0, m0 ,d0 = 2013, 4, 30                         # Start date (year, month, day)
        y1, m1 ,d1 = 2014, 5, 10                         # End date

        parameter  = "00060"                             # Parameter
        obser      = "StreamFlow"                        # Observed data Requested
        dformat    = "json"                              # Data Format
        url        = 'http://waterservices.usgs.gov/nwis/iv' # USGS API

In [ ]: # Create Datetime Objects
        start     = datetime(y0, m0, d0,0)
        stop      = datetime(y1, m1 ,d1,0)

        # Format Datetime Objects for USGS API
        first    =  datetime.date(start).strftime('%Y-%m-%d')
        last     =  datetime.date(stop).strftime('%Y-%m-%d')
```

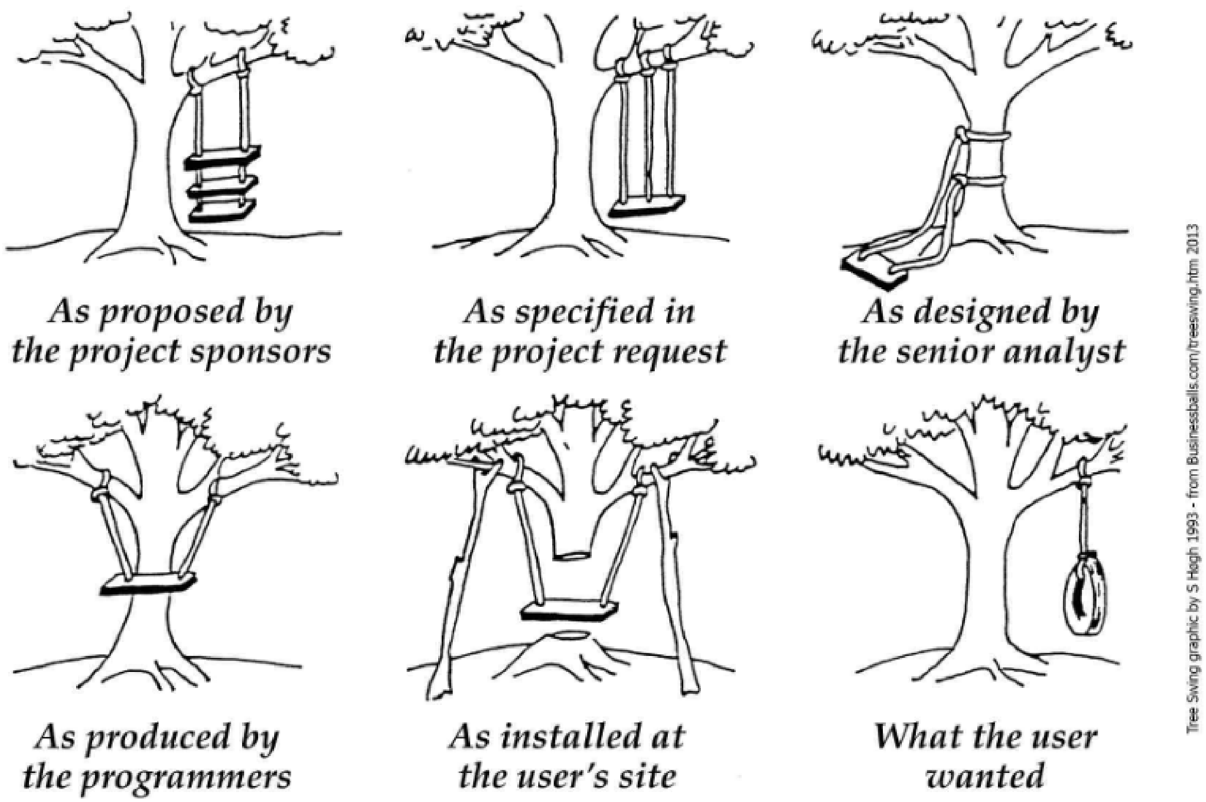
Open source, interactive data science and scientific computing across over 40 programming languages.

https://github.com/GMU-FerreiraResearchGroup
http://jupyter.org/

Summary & Conclusions

- In many cases, existing models can be refitted for forecasting
- Tools are readily available for transforming to an operational forecast capacity
- Forecast can be done at regional and local levels to augment national operations
- Water Resources Engineers need to become more familiar with the data types and data tools in use by meteorologist
- Flood Alerts: Operational forecast maps
- Competing Products are our friends

Questions?



http://www.businessballs.com/treeswing.htm

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