



How Live Modeling Can Support Public Safety in a Storm

SeSwA Seminar - April 21, 2023



WOOLPERT
ARCHITECTURE | ENGINEERING | GEOSPATIAL

What is Live Modeling?



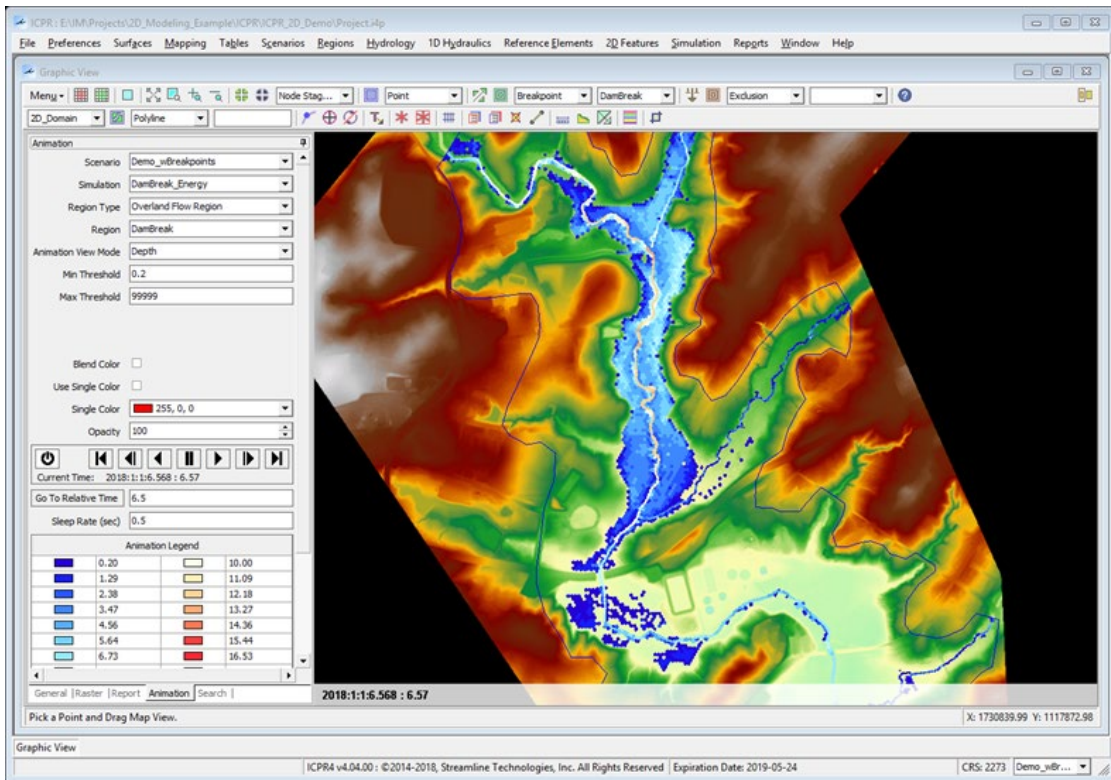
What is Live Modeling?

Traditional Modeling

- Historically statistically based
- Design Storms (e.g. 25-YR, 24-Hr, Type II)
- Physically based algorithms
- Predictions based on interpolation

Live Modeling

- Near Real Time
- Short term forecasting
- Adaptive
 - Measurements
 - Updated forecasting



H&H Modeling vs. ML Modeling

H&H modeling



Rules are defined in modeling software and by importing **Input**, the **Output** is computed

ML modeling



Input and **Output** are available (Observations) and through machine learning process **Rules** are explored

Examples

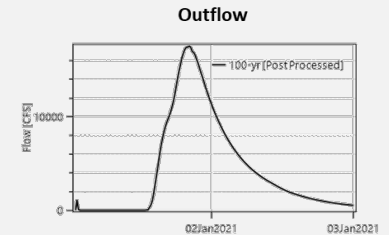
Input



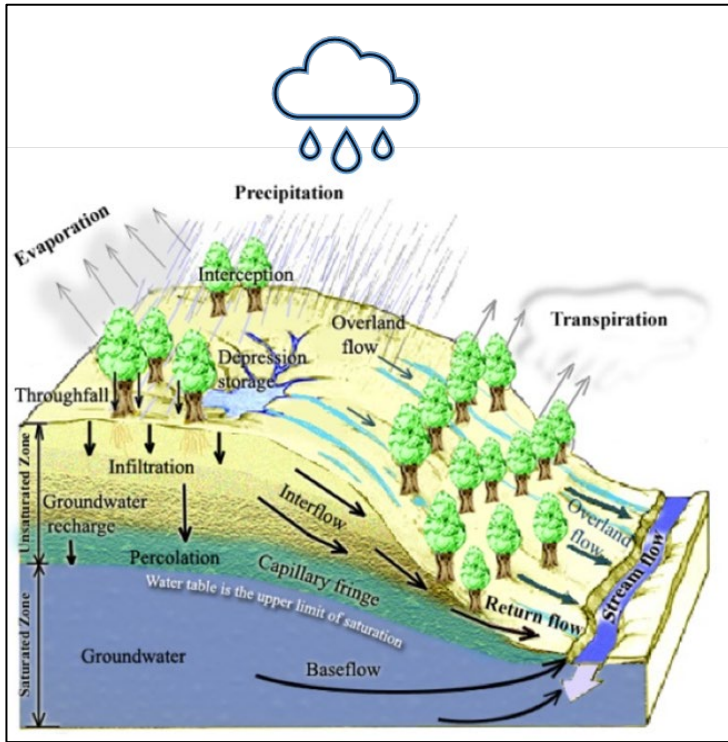
Rules

$$Q = VA = \left(\frac{1.49}{n} \right) AR^{\frac{2}{3}} \sqrt{S}$$
$$S = \frac{25400}{CN} - 254$$

Output



Traditional H&H Models for Forecasting



XPSWMM

EPA SWMM

InfoWorks
ICM



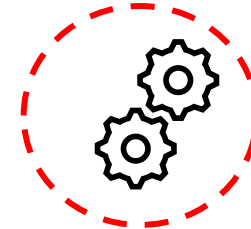
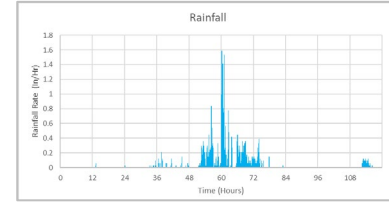
HEC-RAS



HEC-HMS



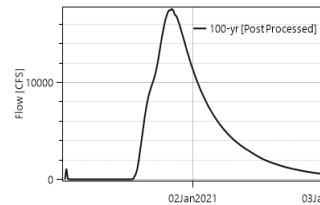
PCSWMM



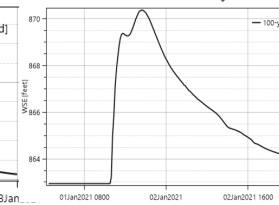
H&H
Modeling



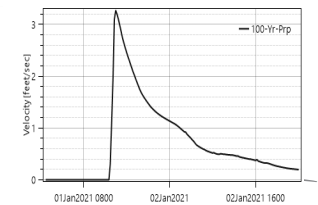
Outflow



WSE

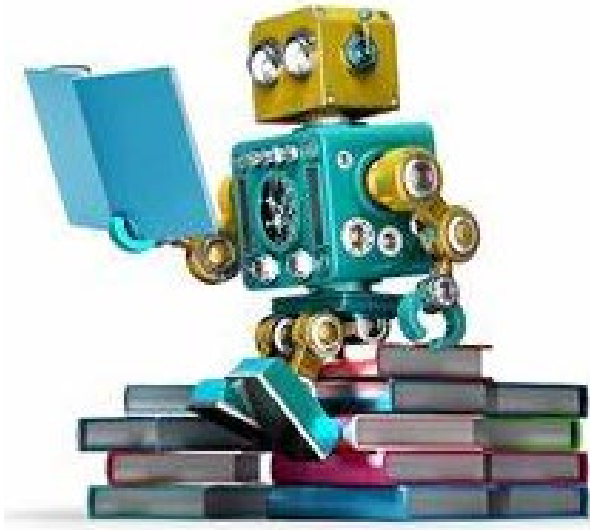


Velocity



Machine Learning Models

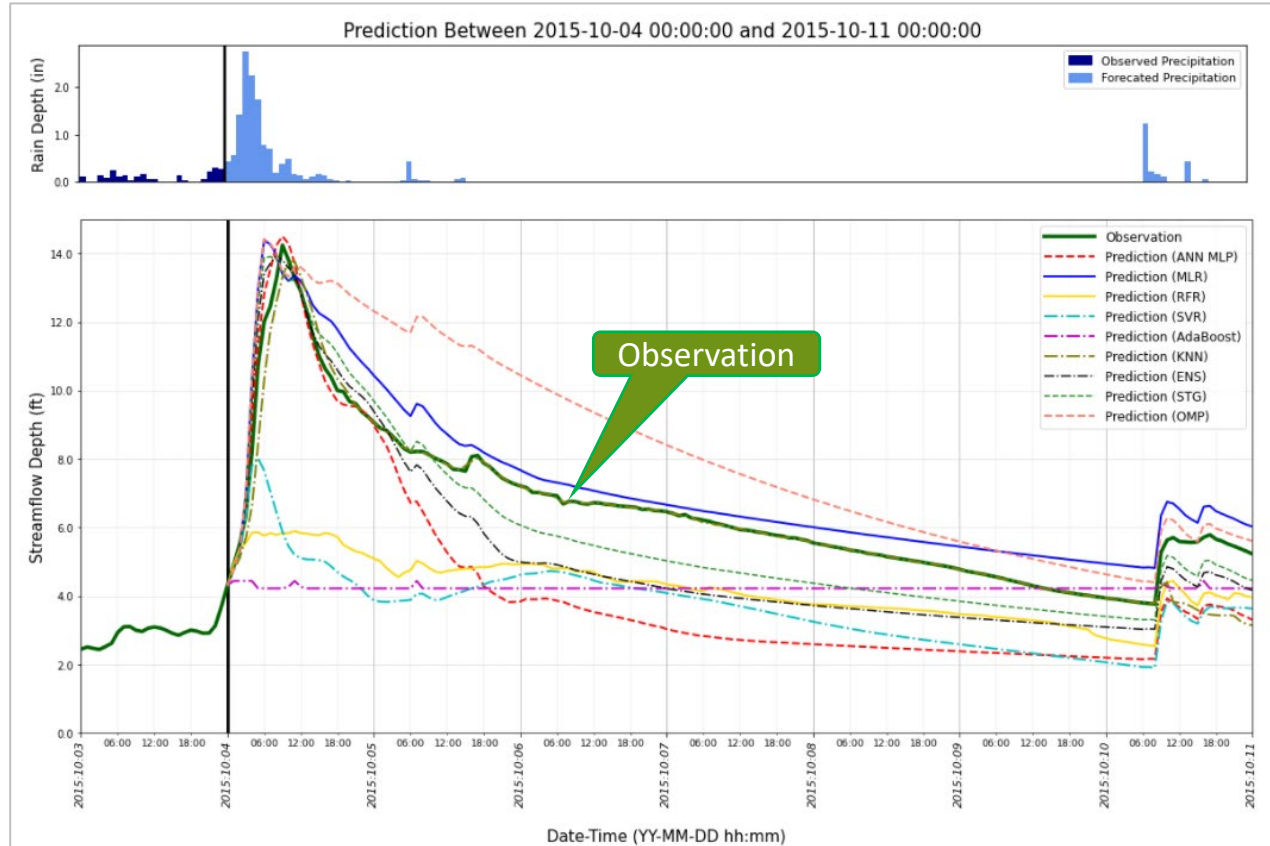
Arthur Samuel (1959) - “A field of study that gives the computers the ability to learn without being explicitly programmed”



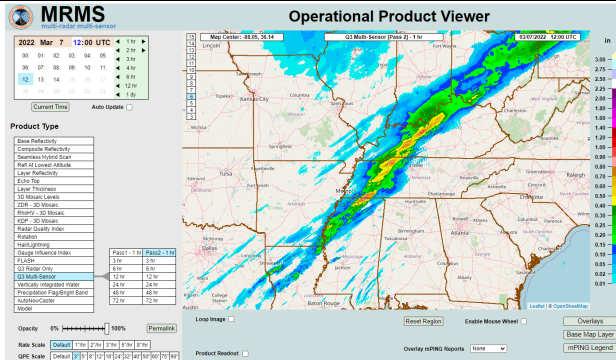
- Machine learning provides the capability of **identifying the patterns** in massive noisy datasets with an accuracy that usually exceeds that of human domain experts.
- Machine learning models are very good at **capturing correlations and finding relationships** between input and output.

Different Machine Learning Algorithms

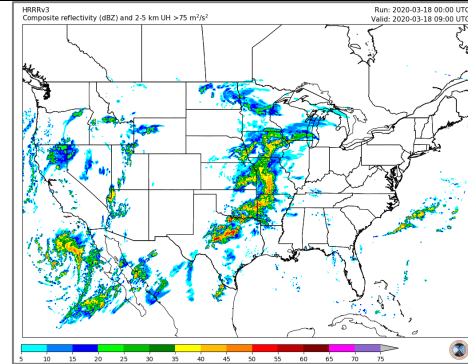
- Artificial Neural Network – Multi Layer Perceptron (ANN MLP)
- Multi Linear Regression (MLR)
- Random Forest Regression (RFR)
- Support Vector Regression (SVR)
- Adaptive Boosting (AdaBoost)
- K-nearest Neighborhood (KNN)
- Ensemble Learning (ENS)
- Stacked Generalization (STG)
- Orthogonal Matching Pursuit (OMP)



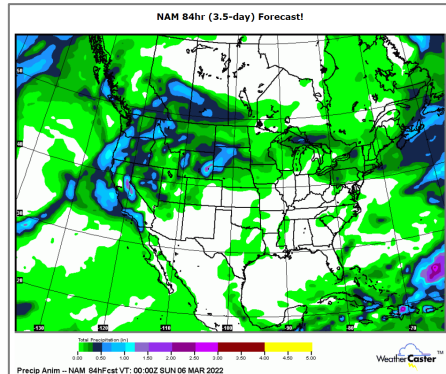
NOAA Datasets – GRIB Processing



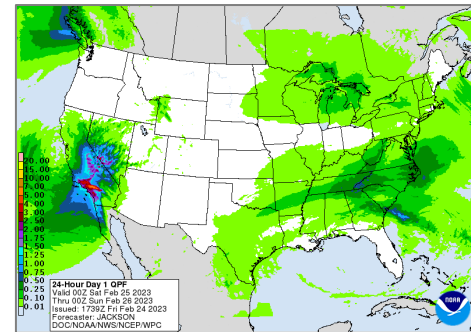
QPE - Multi-Radar / Multi-Sensor (2-mins)



QPF – HRRR (Hourly)



QPF – NAM HiRES (6 hrs)



QPF – WPC (6 or 12 hr)



NBM – New Process

National Blend of Models

A nationally consistent and skillful suite of calibrated forecast guidance based on a blend of both National Weather Service and external numerical weather prediction model data and post-processed model guidance.

A highly accurate, skillful and consistent starting point for the gridded forecast.

Probabilistic and bias-corrected weather elements across several service areas.

Providing forecasters with a suite of information to use for their forecasts.

An important part of the efforts to evolve NWS capabilities to achieve a Weather-Ready Nation.

NBM Inputs

WRF MEM2	GEFS
WRF ARW	GFS
RAP	NAM-Parent
RAPX	SREF
HRRR	NAM-Nest
HRRRX	NEMS NMME
GFS GMOS	WRF ARW
NAM GMOS	CMC GDPS
EKDMOS/BMOS	CMC RDPS
GLMP	CMC REPS
WW3D (0.5)	CMC GEPS
WW3E (0.5)	ECMWF D
WW3D-Regional	ECMWF E
GLW	NAV GEM D
HWRF	NAV GEM E
HMON	FN MOC
wTCM	ACCESS-G

▶ NOAA

▶ Canadian Meteorological Centre

▶ European Centre for Medium-Range Weather Forecasts

▶ U.S. Navy Fleet Numerical Meteorology and Oceanography Center

▶ Australia Bureau of Meteorology



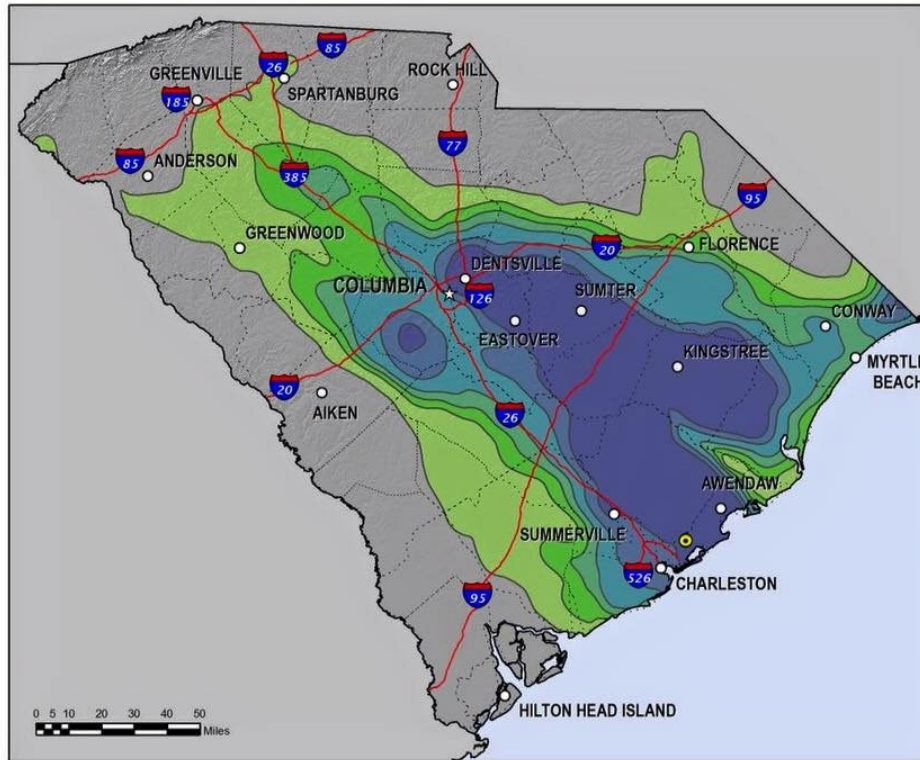
Why is Live Modeling Compelling?

- Short term predictions
- Short term resource allocations
- Higher confidence level
- Cross coordination across departments
 - EMD
 - Public Works
 - Resiliency
 - Transportation
 - Fire and Rescue
 - Law Enforcement
- Timely public notifications
- Worst case scenarios



October 2015





South Carolina Annual Exceedance Probabilities (AEPs) for 72-hour Rainfall 2 - 4 October 2015

Hydrometeorological Design Studies Center
National Water Center, National Weather Service
National Oceanic and Atmospheric Administration
<http://www.nws.noaa.gov/ohd/hdsc/>



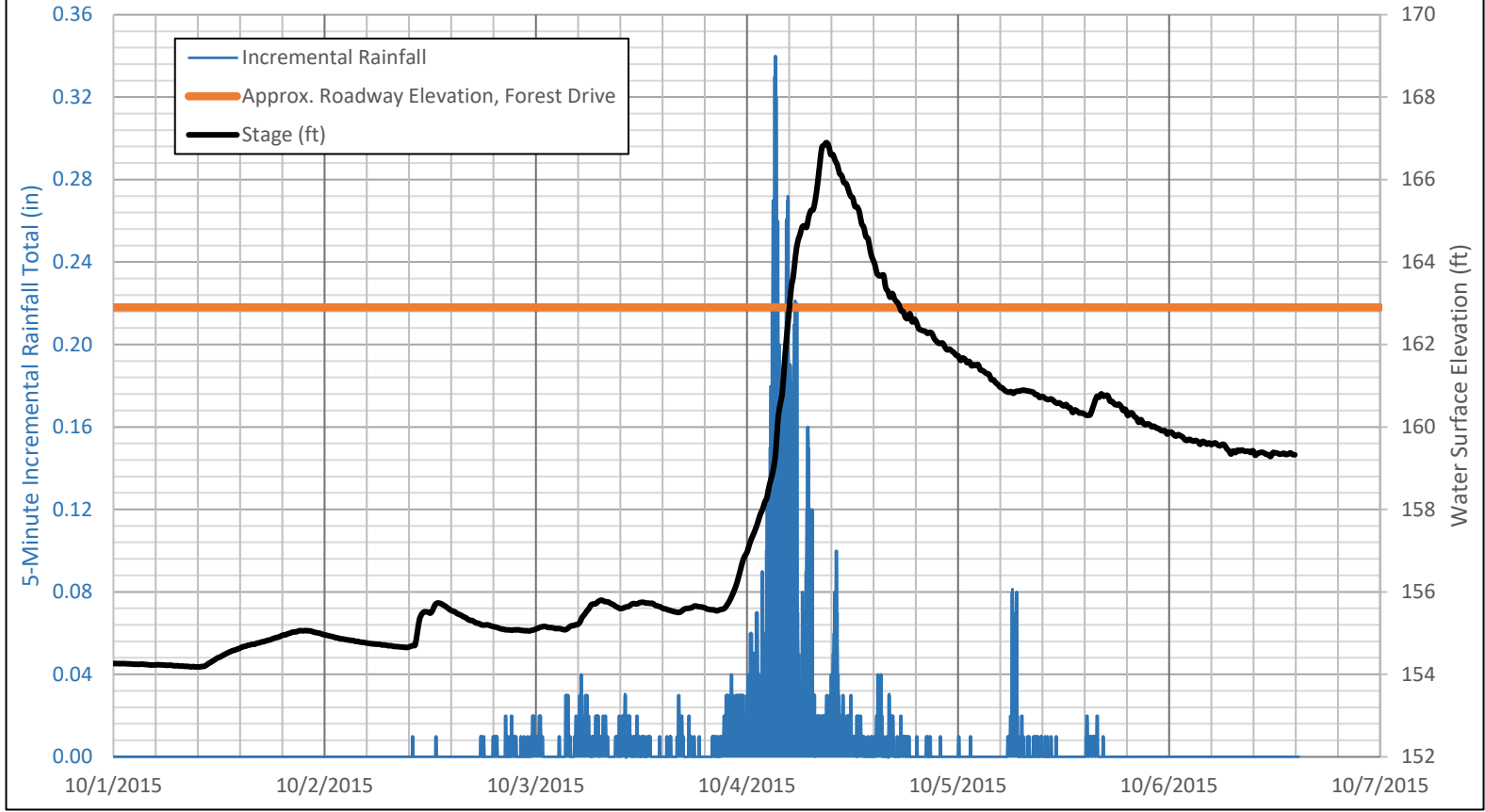
Created 6 September 2015

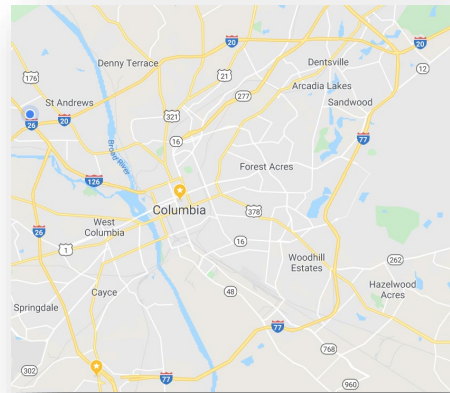
Precipitation frequency estimates are from NOAA Atlas 14, Volume 2, Version 3.
 Rainfall values come from 6-hour multi-sensor data.



Gauge Name	Rainfall (Inches)									
	Total	1 Hour	2 Hours	3 Hours	6 Hours	12 Hours	24 Hours	2 Days	3 Days	4 Days
KCAE	11.46	1.56	2.83	3.60	5.46	7.33	8.68	10.75	11.35	11.46
KCUB	12.45	1.67	3.16	4.49	6.43	8.48	9.71	11.79	12.40	12.45
KMMT	11.47	2.41	4.36	6.75	8.23	8.66	10.20	11.08	11.37	11.46
Trib to Rocky Branch	11.30	1.87	2.86	4.17	5.96	7.73	8.83	10.57	11.27	11.30
Columbia-GILA RG	16.20	2.88	5.05	7.15	9.82	12.04	13.47	15.28	16.18	16.20
Columbia-GILB RG	13.84	2.77	4.69	6.73	9.34	11.46	12.33	13.82	13.84	13.84
Columbia-GILC RG	10.88	2.14	3.20	4.60	6.58	8.37	9.17	10.83	10.88	10.88
Columbia-RocA RG	13.63	1.17	2.26	3.30	6.12	8.63	10.10	12.58	13.49	13.63
Columbia-RocB RG	12.39	2.59	3.62	4.95	6.60	8.54	9.74	11.66	12.26	12.39
Columbia-Kin RG	14.65	1.99	3.10	4.70	7.06	9.31	10.69	12.69	13.42	13.94
Columbia-SmiB-RG	14.58	2.39	3.72	5.41	7.92	10.18	11.69	13.72	14.50	14.58
PRG06	14.63	2.28	4.08	5.82	8.57	10.67	12.12	13.88	14.51	14.63
PRG05	13.32	1.80	2.84	4.29	6.46	8.64	9.91	11.86	12.38	12.82
PRG03	11.97	2.12	3.04	4.35	6.09	8.04	9.23	11.14	11.87	11.97
PRG04	12.95	2.08	3.27	4.80	6.92	8.94	10.30	12.18	12.81	12.92
PRG01	13.81	2.46	4.39	6.02	7.87	10.06	11.36	13.36	13.80	13.81
PRG07	14.11	2.39	3.97	4.88	7.36	10.13	11.77	13.64	14.05	14.10
PRG02	15.43	2.78	4.85	6.65	9.18	11.31	12.71	14.52	15.42	15.43

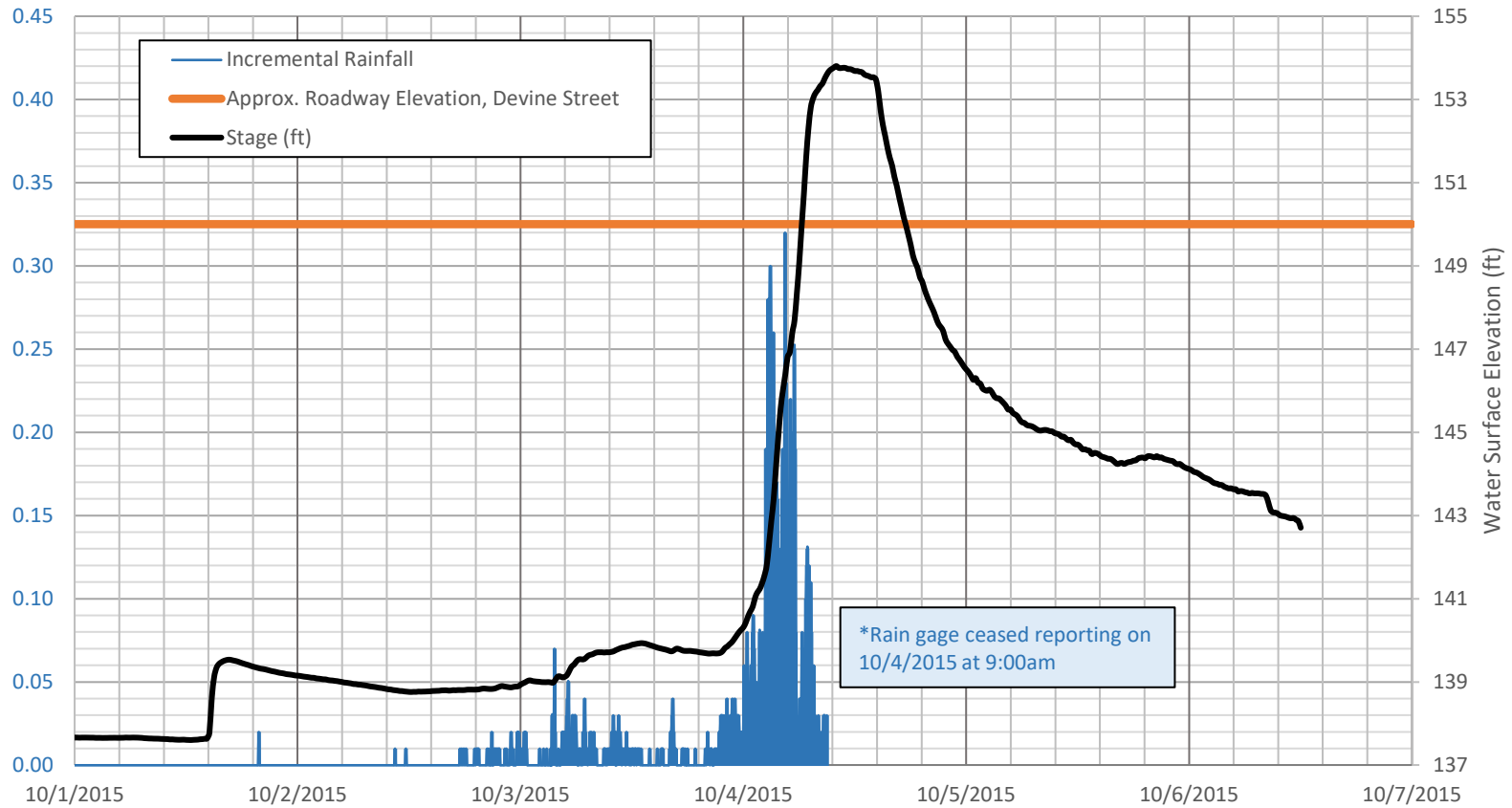
City of Columbia Gills Creek Monitoring Station at Forest Drive

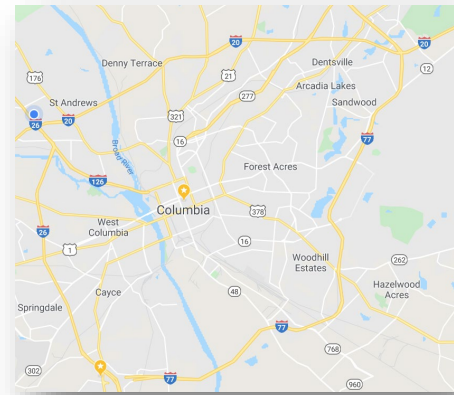


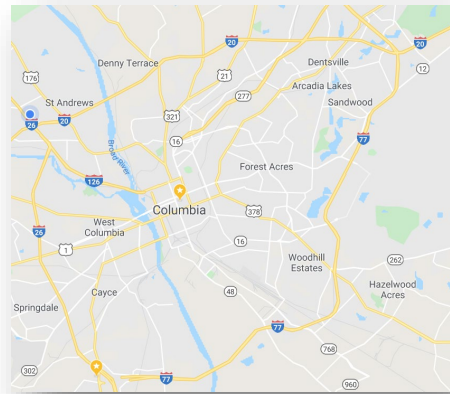


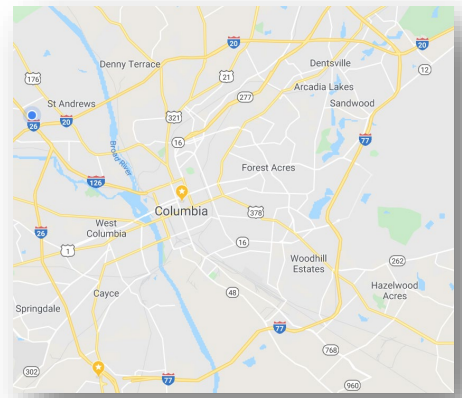
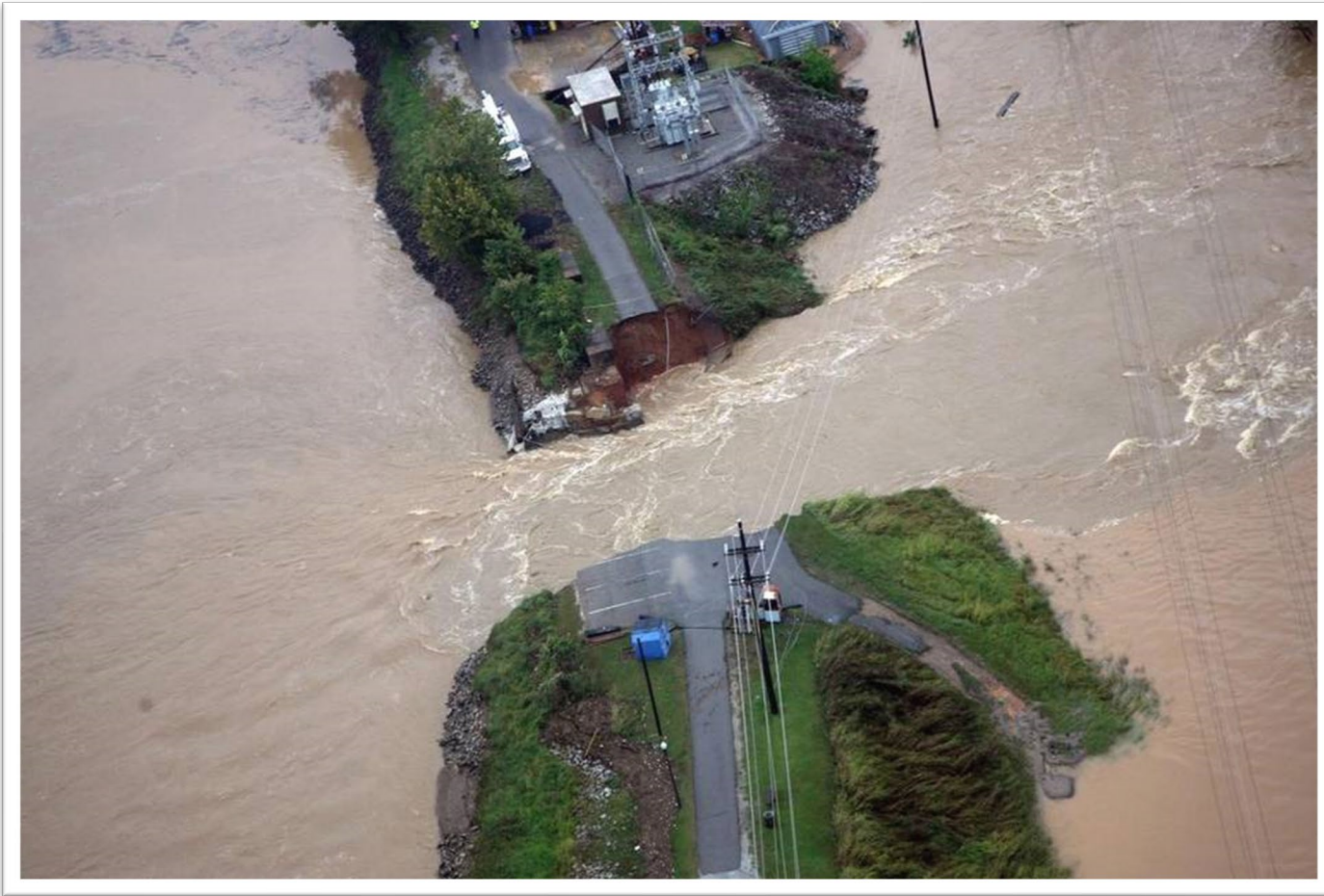


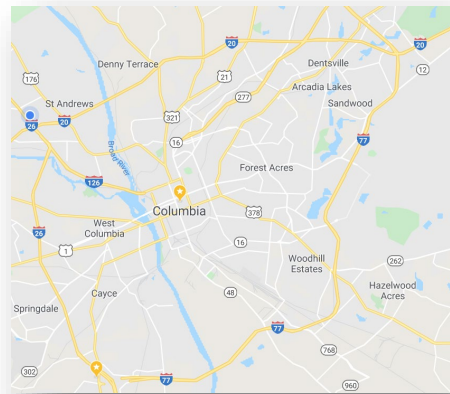
City of Columbia Gills Creek Monitoring Station at Devine Street

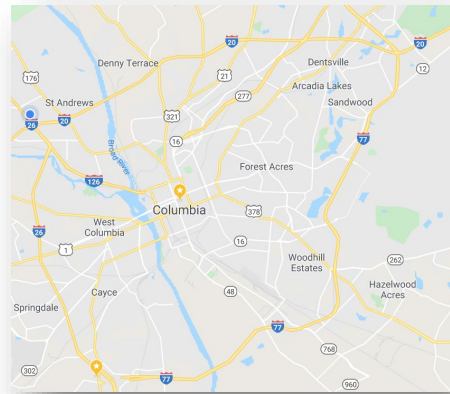


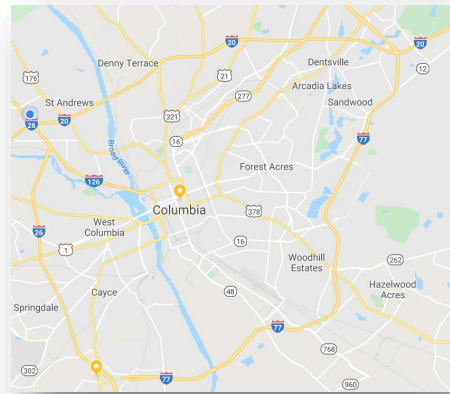


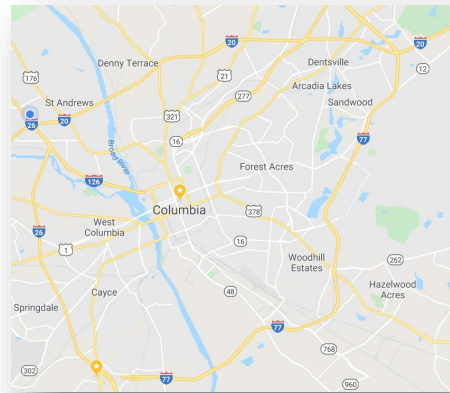












October 2015

20+ inches of rain on coast and central SC

20 USGS gauge stations exceeded record flood stage

19 Fatalities

- 9 in Richland County
- Primarily trapped in vehicles swept into high water

410 Roads and bridges closed

- 74 miles of I-95
- I-20 Broad River Bridge
- I-126 Broad River Bridge
- I-26 Saluda River Bridge

36 Regulated dam failures

100+ Non-regulated dam failures

1,500+ Water rescues



Service Assessment

The Historic South Carolina Floods of October 1–5, 2015



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
Silver Spring, Maryland



How Could We Have Known?

US Army Corps Report 1988

- Special Project Storm 15-in, 24-HR
- Predicted flood elevations within 6-in
- Predicted which dams would breach
- Suggested Projects
- Collecting dust

INTERIM REVIEW OF REPORT SANTEE RIVER-SOUTH CAROLINA

DRAFT

GILLS CREEK FLOOD CONTROL FEASIBILITY STUDY



US Army Corps
of Engineers
Charleston District

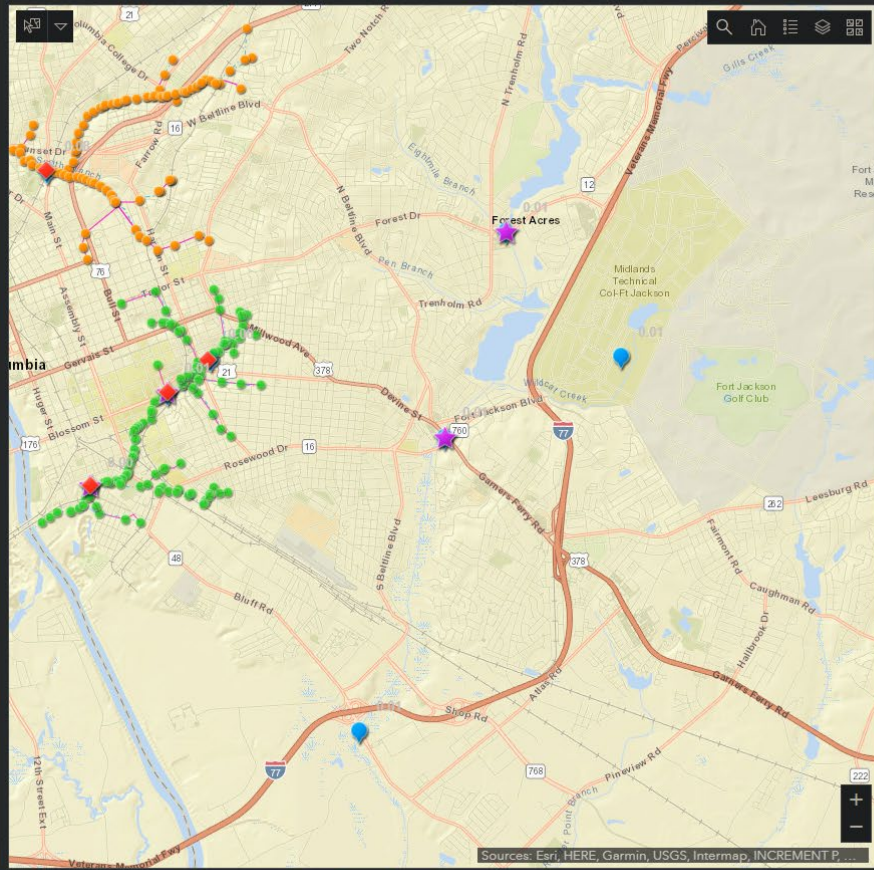
JULY 1988



With Live Modeling

- Hazard notifications
 - Reverse 911
 - TV alerts
 - Cell phone alerts
 - Door to door
 - Local and State government web sites
- Evacuations in Flood Zone
- Evacuations below at-risk dams
- Road closures
- Shelters set up
- Government personnel on call
- Equipment and personnel staging
- Sand bags
- Etc., etc....





SWMM Node Hydrographs

- ◆ SWMM Node: **MLK96**
MLK
- ◆ SWMM Node: **WG10**
ROC A
- ◆ SWMM Node: **MV11**
ROC B
- ◆ SWMM Node: **J_SB_12974**
SMI A

Last update: a few seconds ago

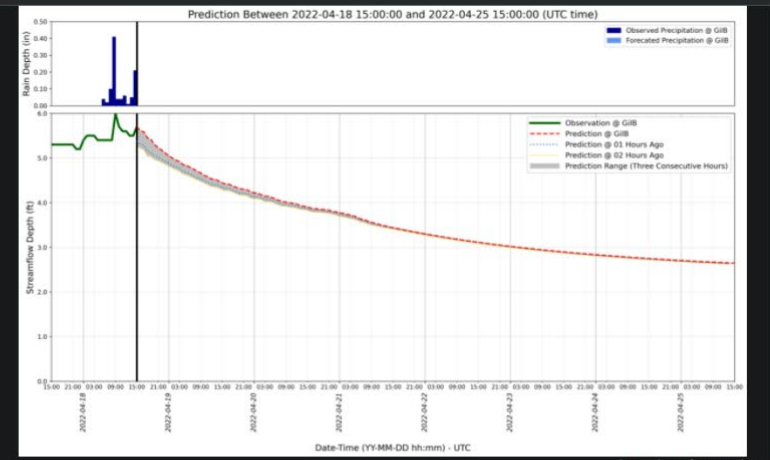
ML Forecast Stations

- ★ GILA
- ★ GILB
- ★ ROC A
- ★ ROC B

Last update: a few seconds ago

Node	Flood Stage	Max WS	Max Time (Local)	Ref Time (Local)	WS 002-yr	WS 010-yr	WS
COC_RockyBranch_USCNW20	0	196.36	4/18/2022, 11:04 AM	4/18/2022, 8:00 AM	201.78	202.9	
COC_RockyBranch_MLK92	0	222.94	4/18/2022, 11:01 AM	4/18/2022, 8:00 AM	227.8	228.67	
COC_RockyBranch_MLK91	0	222.07	4/18/2022, 11:02 AM	4/18/2022, 8:00 AM	225.94	226.85	
COC_RockyBranch_MLK90	0	216.26	4/18/2022, 11:06 AM	4/18/2022, 8:00 AM	222.32	223.25	
COC_RockyBranch_MLK96	0	217.27	4/18/2022, 11:05 AM	4/18/2022, 8:00 AM	222.56	223.47	
COC_RockyBranch_MLK95	0	217.57	4/18/2022, 11:04 AM	4/18/2022, 8:00 AM	222.67	223.62	
COC_RockyBranch_MLK101	0	209.99	4/18/2022, 11:06 AM	4/18/2022, 8:00 AM	219.14	220.24	
COC_RockyBranch_MLK99	0	210.34	4/18/2022, 11:06 AM	4/18/2022, 8:00 AM	220.49	221.35	
COC_RockyBranch_MLK98	0	217.89	4/18/2022, 11:03 AM	4/18/2022, 8:00 AM	222.93	223.86	Last update: a few seconds ago

SWMM Max Values RG Actual Measured RG Forecast

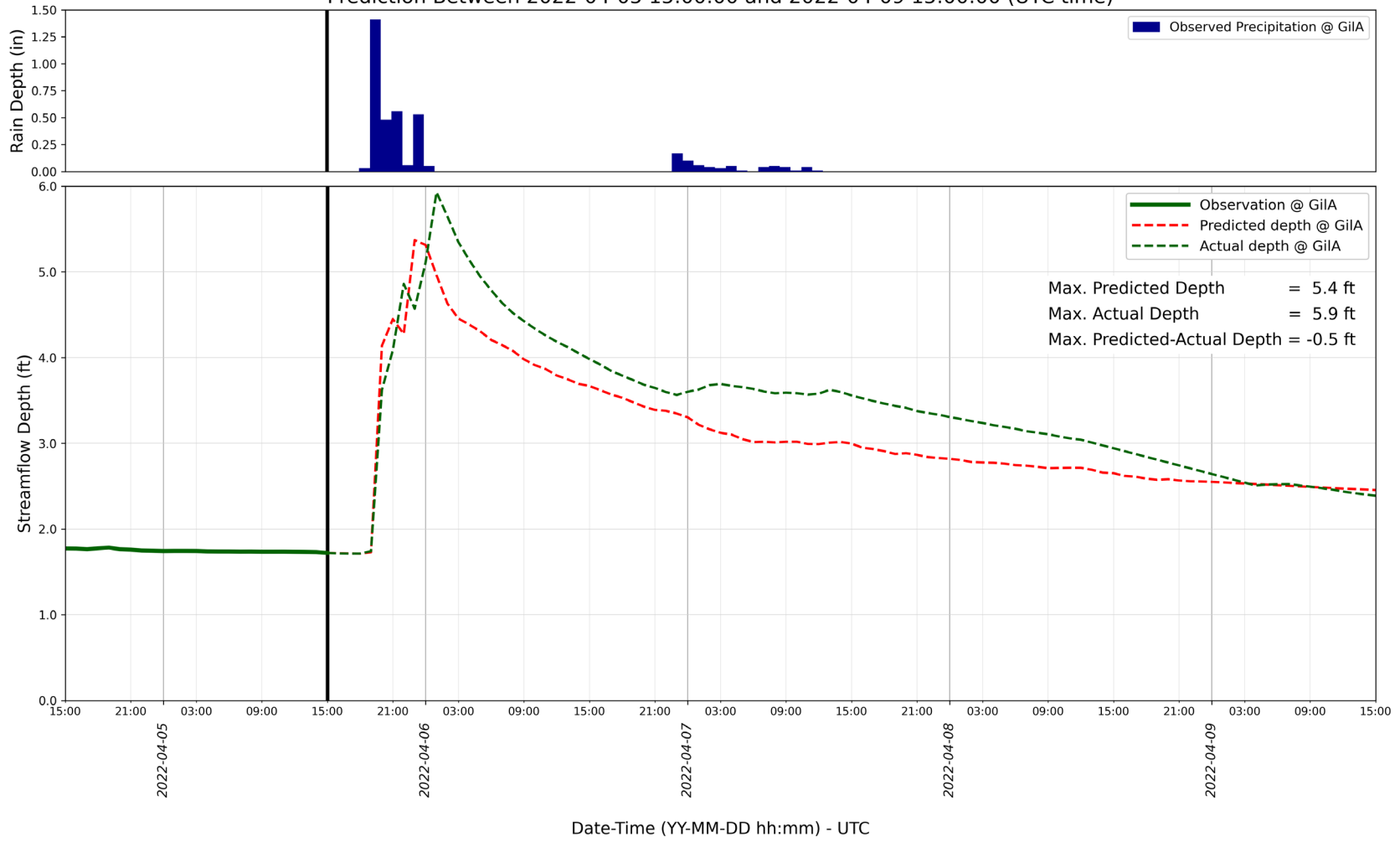


Last update: a few seconds ago

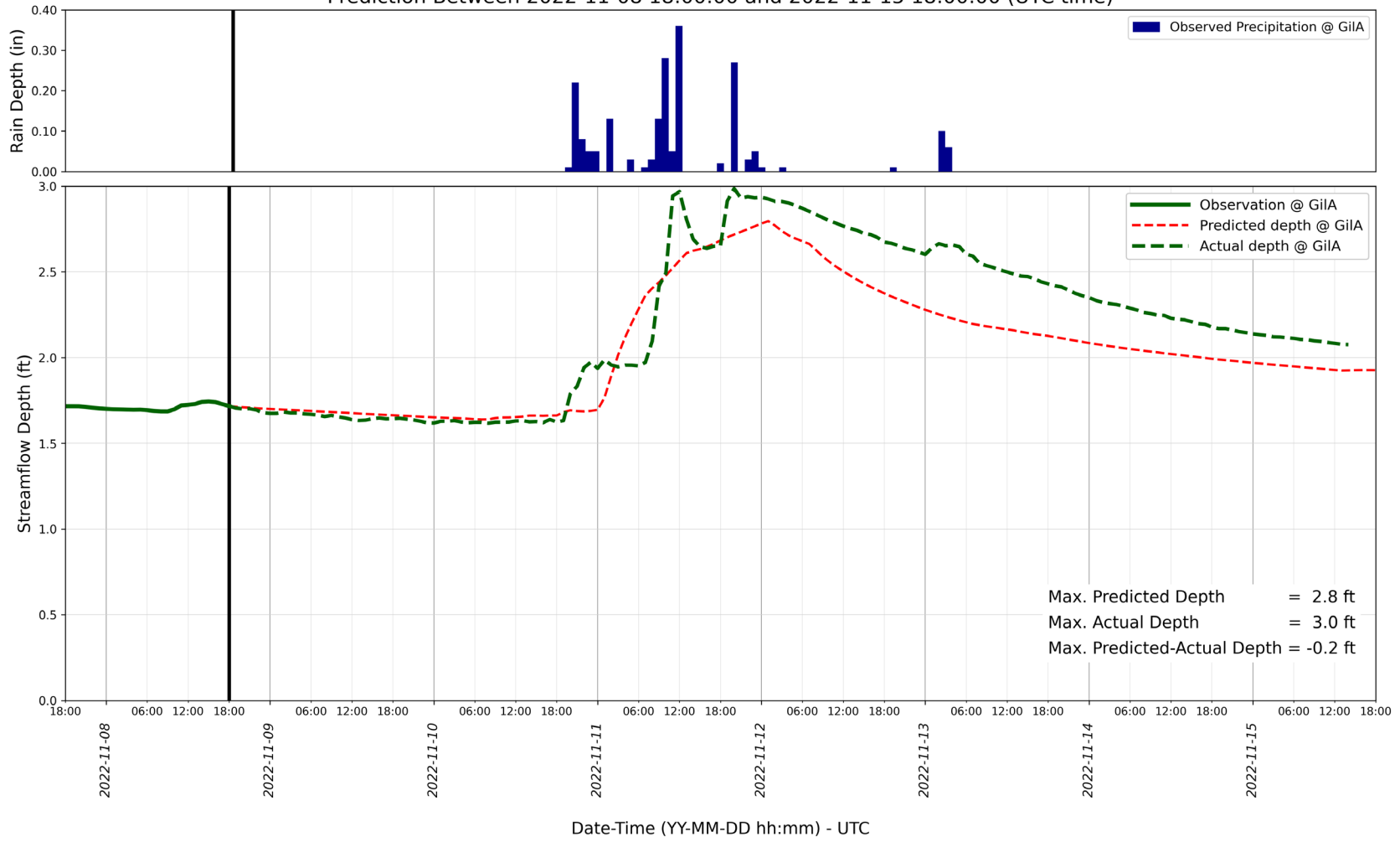
SWMM Forecast 1 SWMM Forecast 2 SWMM Forecast 3 ML Forecast ML w/Range ML with 3F



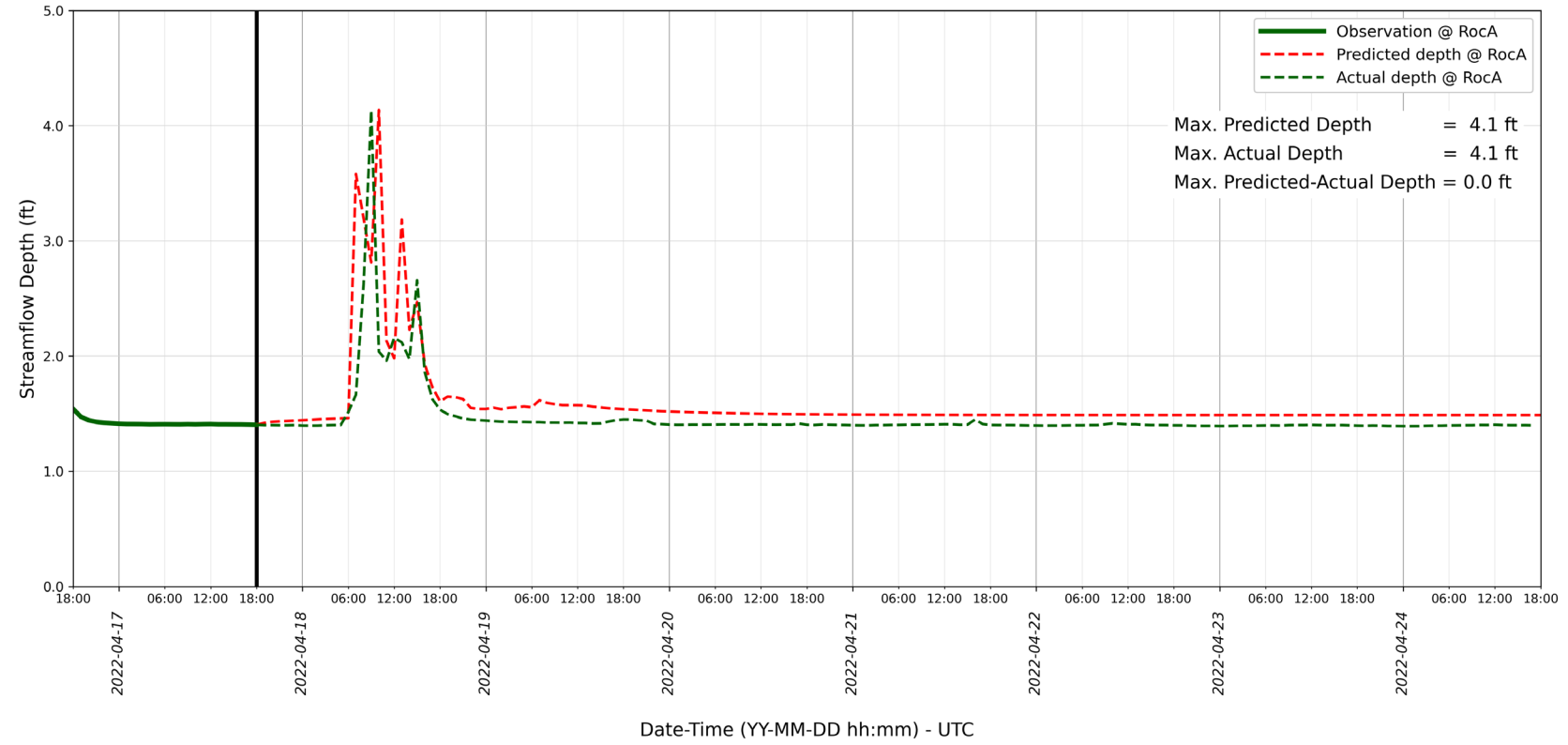
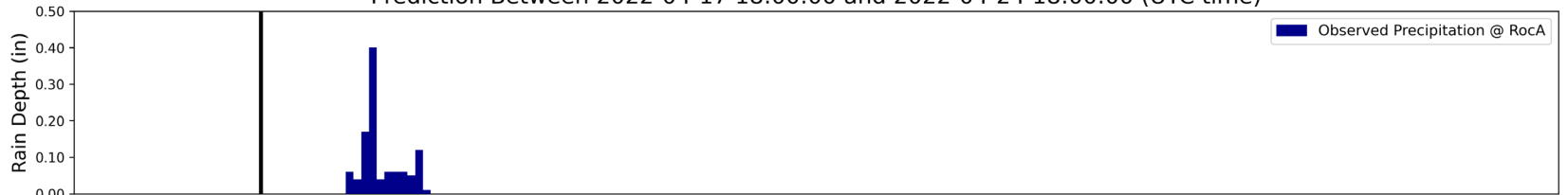
Prediction Between 2022-04-05 15:00:00 and 2022-04-09 15:00:00 (UTC time)



Prediction Between 2022-11-08 18:00:00 and 2022-11-15 18:00:00 (UTC time)



Prediction Between 2022-04-17 18:00:00 and 2022-04-24 18:00:00 (UTC time)

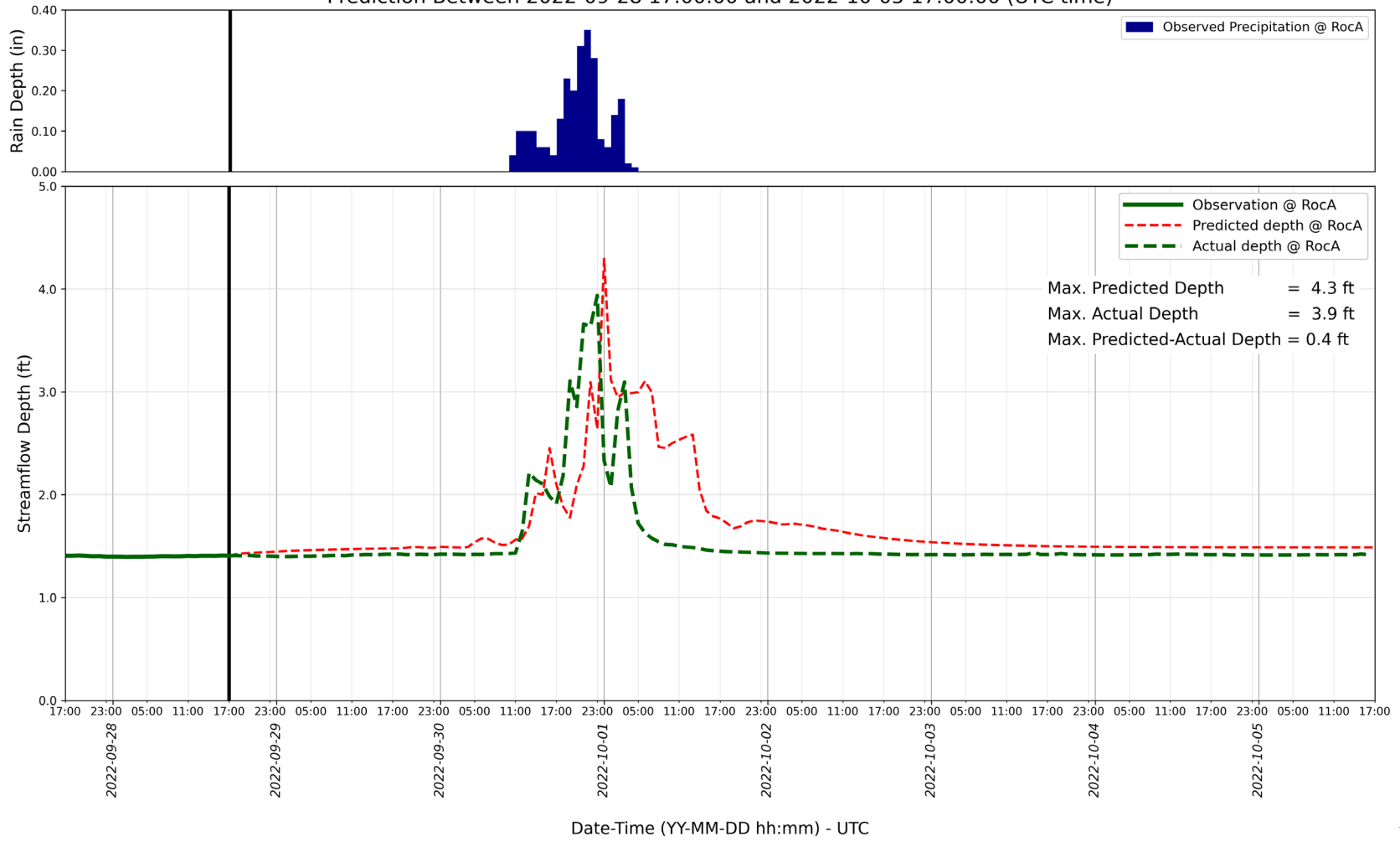


Hurricane IAN

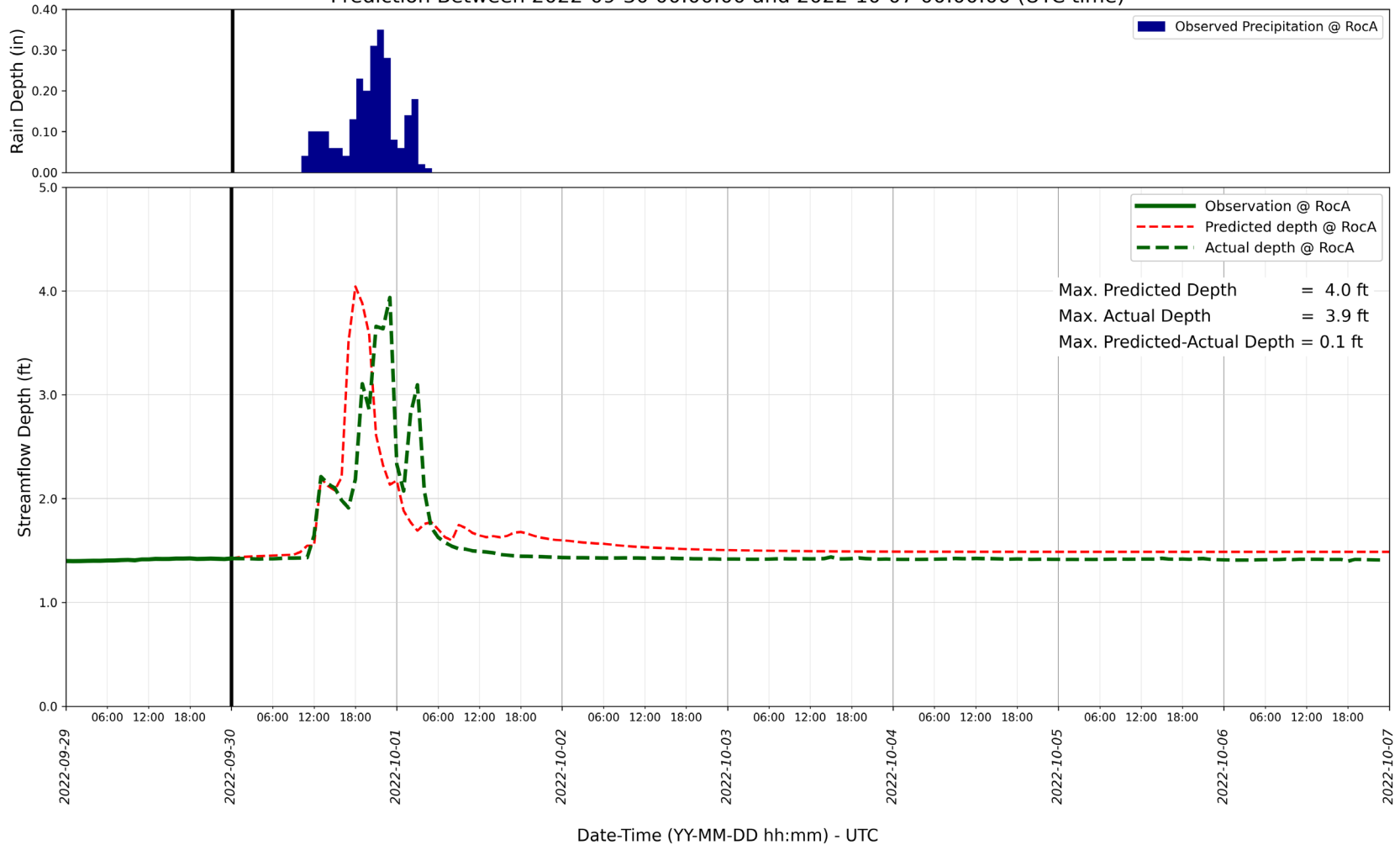
Prediction vs Observed



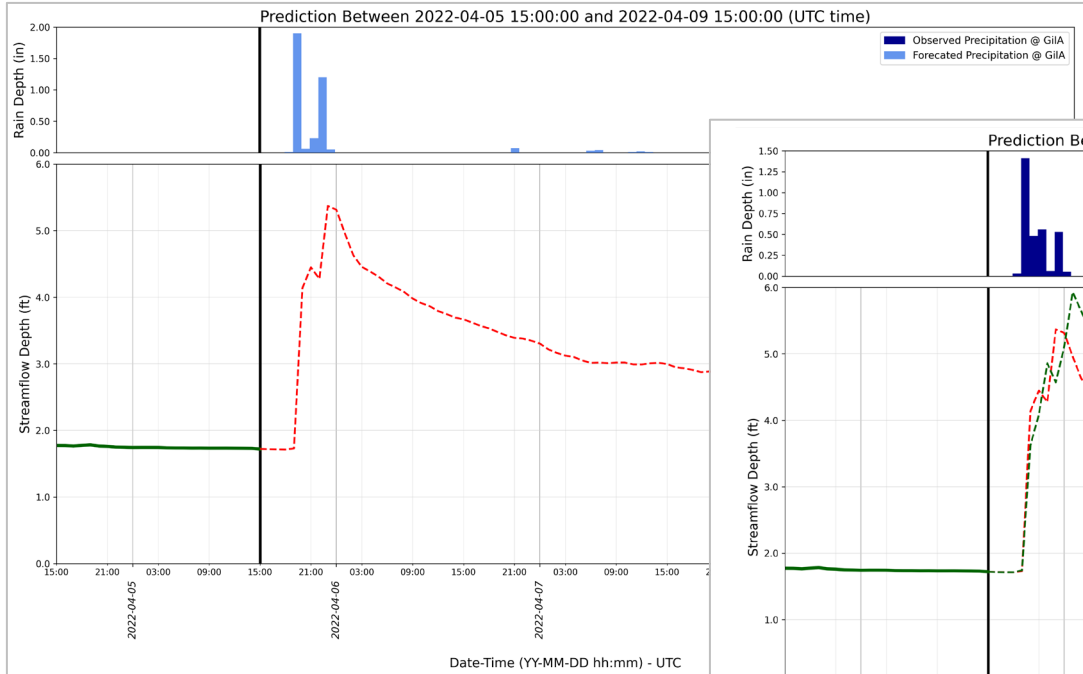
Prediction Between 2022-09-28 17:00:00 and 2022-10-05 17:00:00 (UTC time)



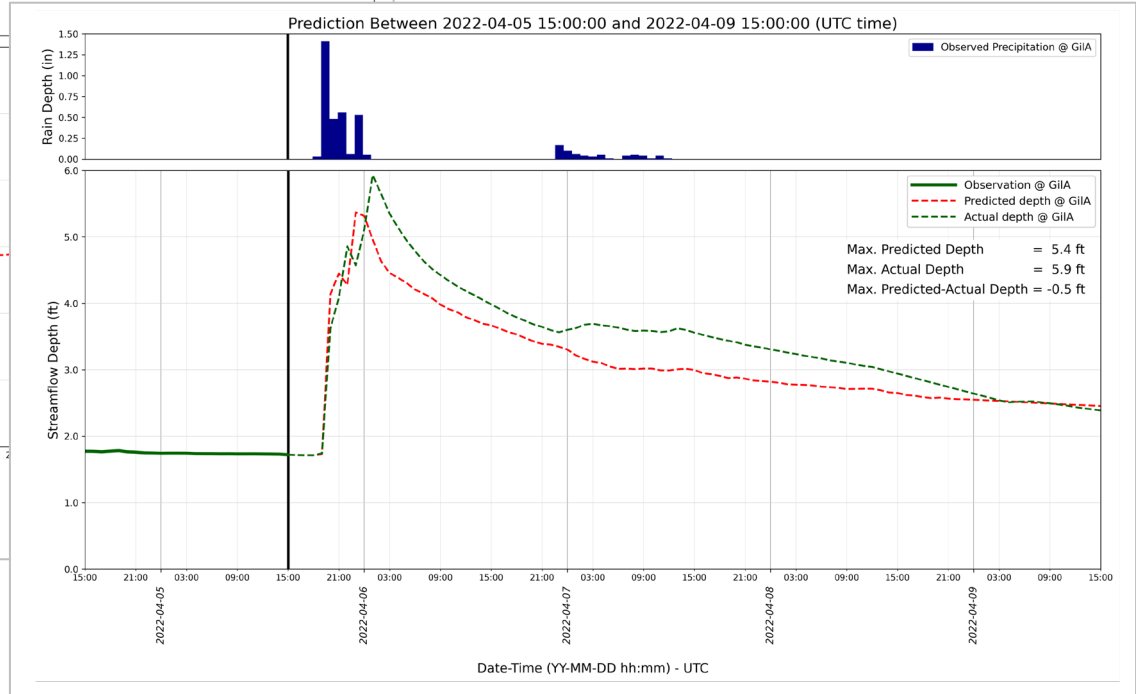
Prediction Between 2022-09-30 00:00:00 and 2022-10-07 00:00:00 (UTC time)



Prediction vs Measured Streamflow Depth Example

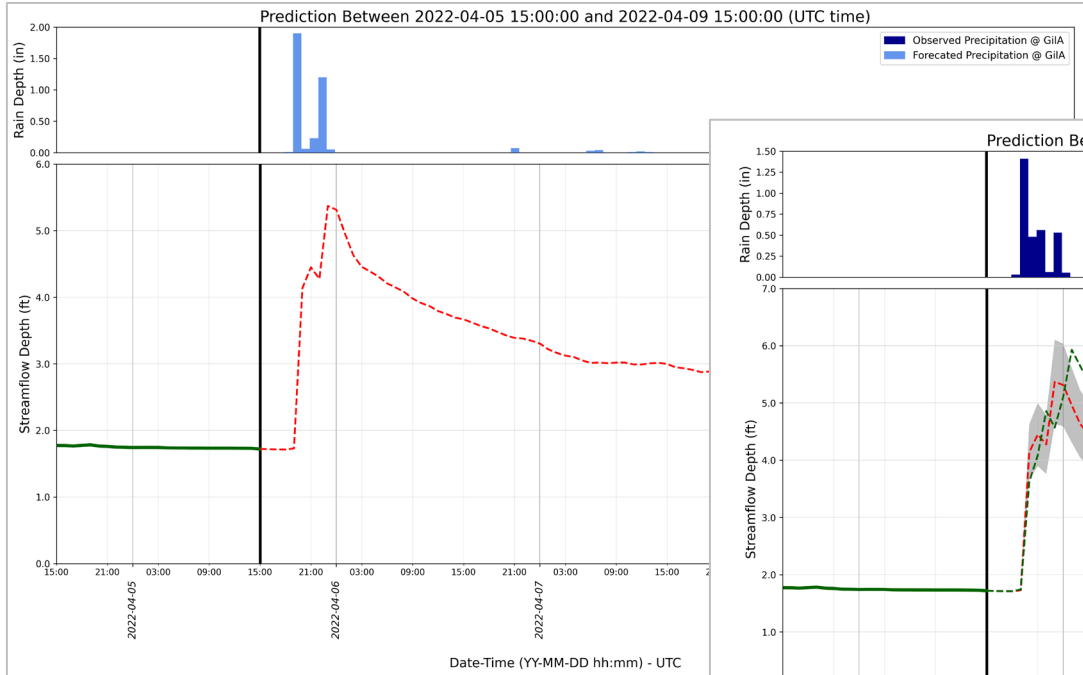


Prediction 4 Hours Before Rainfall
Begins and 8 Hours Before Peak Stage

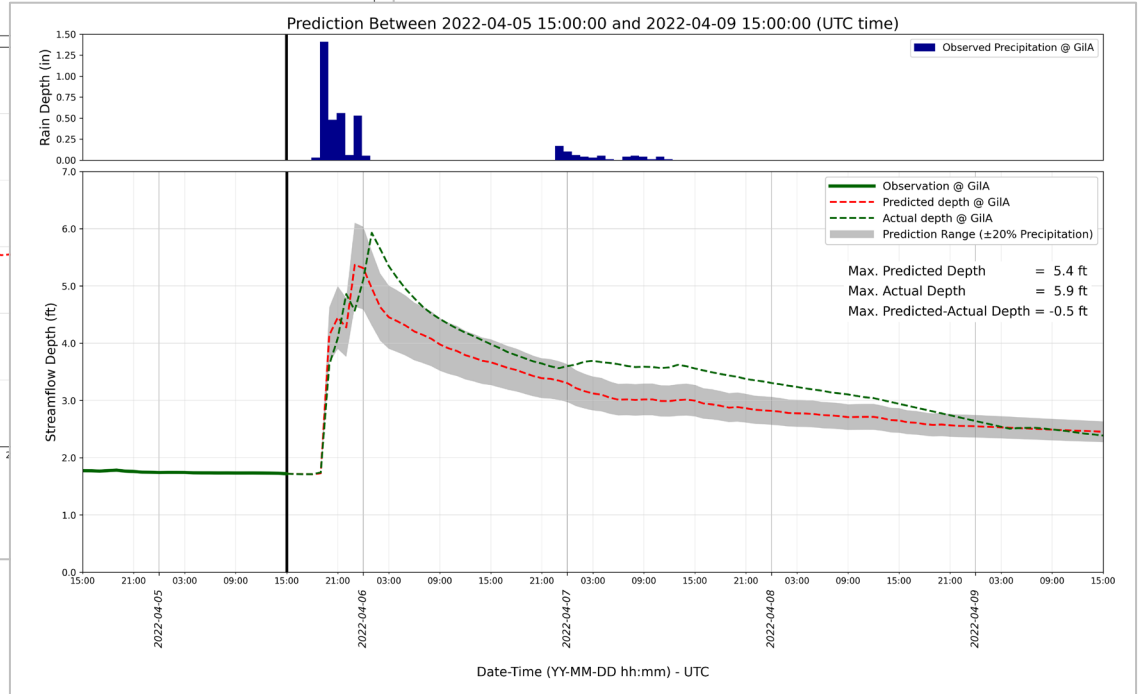


Predicted Stage vs Observed Stage with Actual Rainfall

Prediction vs Measured Streamflow Depth Example



Prediction 4 Hours Before Rainfall
Begins and 8 Hours Before Peak Stage



Predicted Stage vs Observed Stage with Actual Rainfall

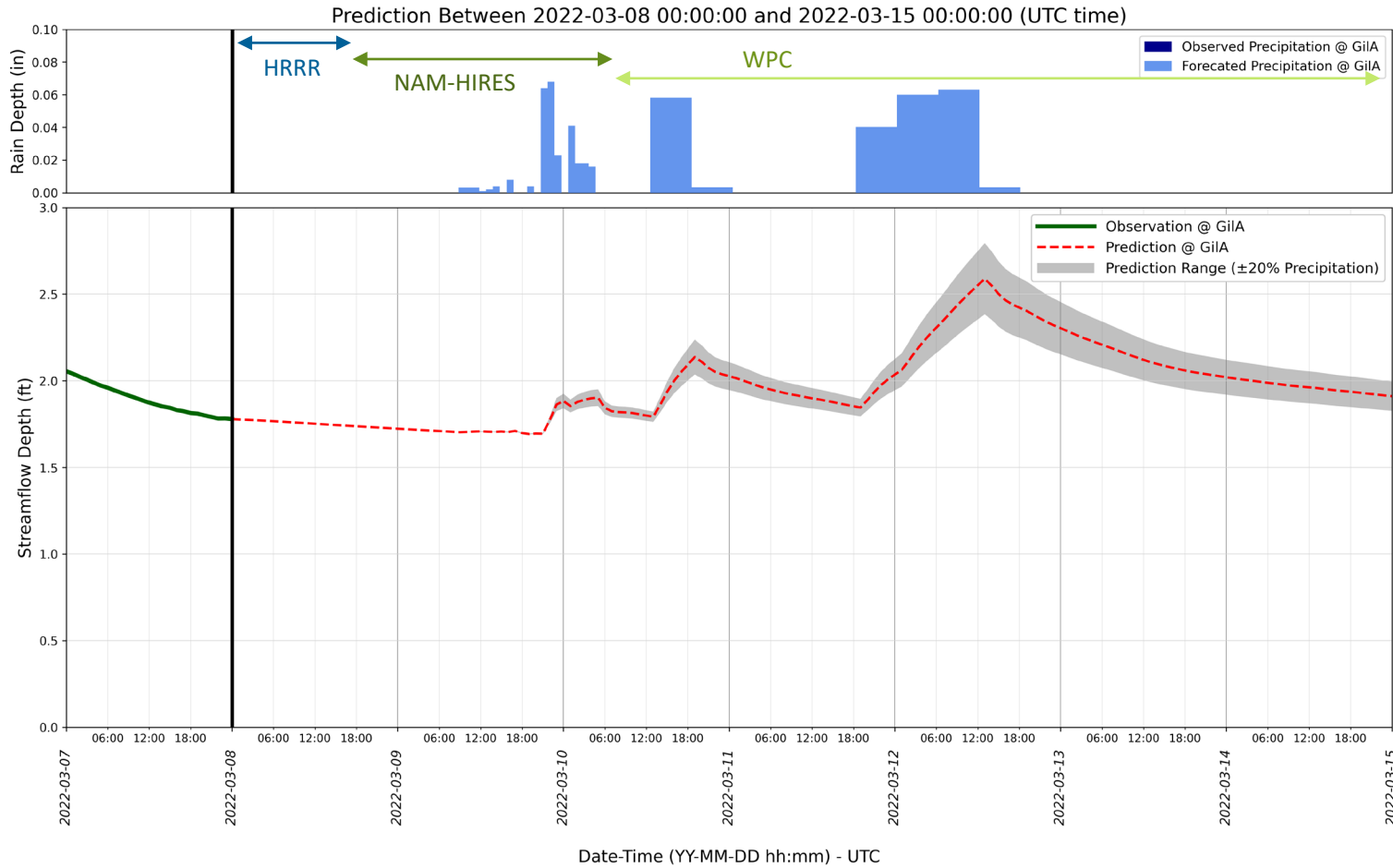
Adaptive (or Dynamic) Outlet Control

- Optimize discharges based on real-time data and near real-time rainfall forecasts.



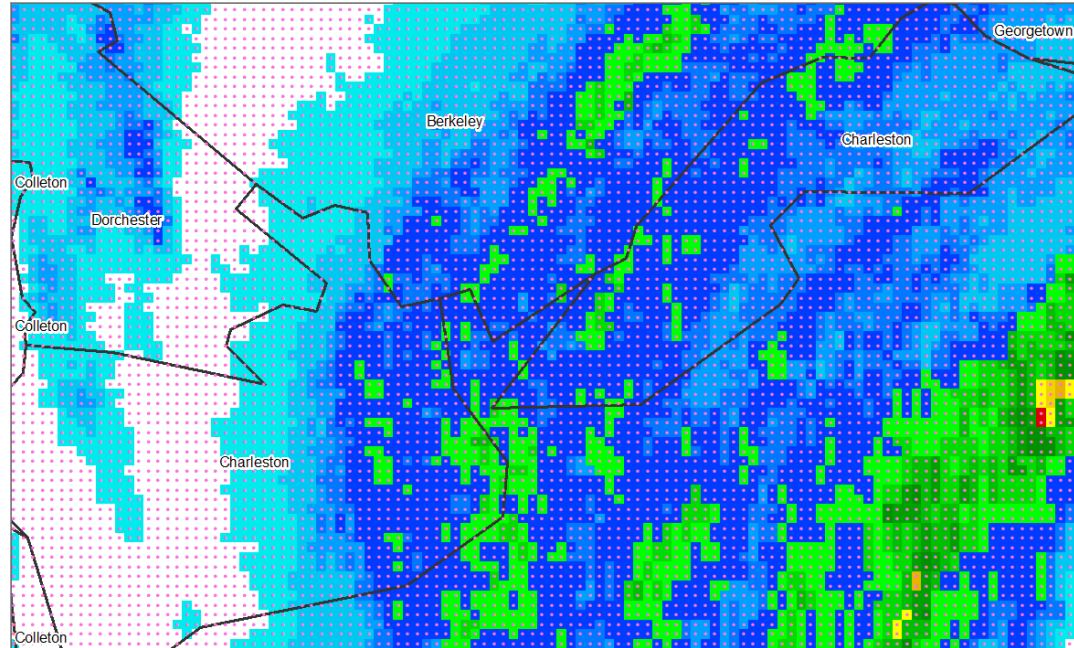


Questions?



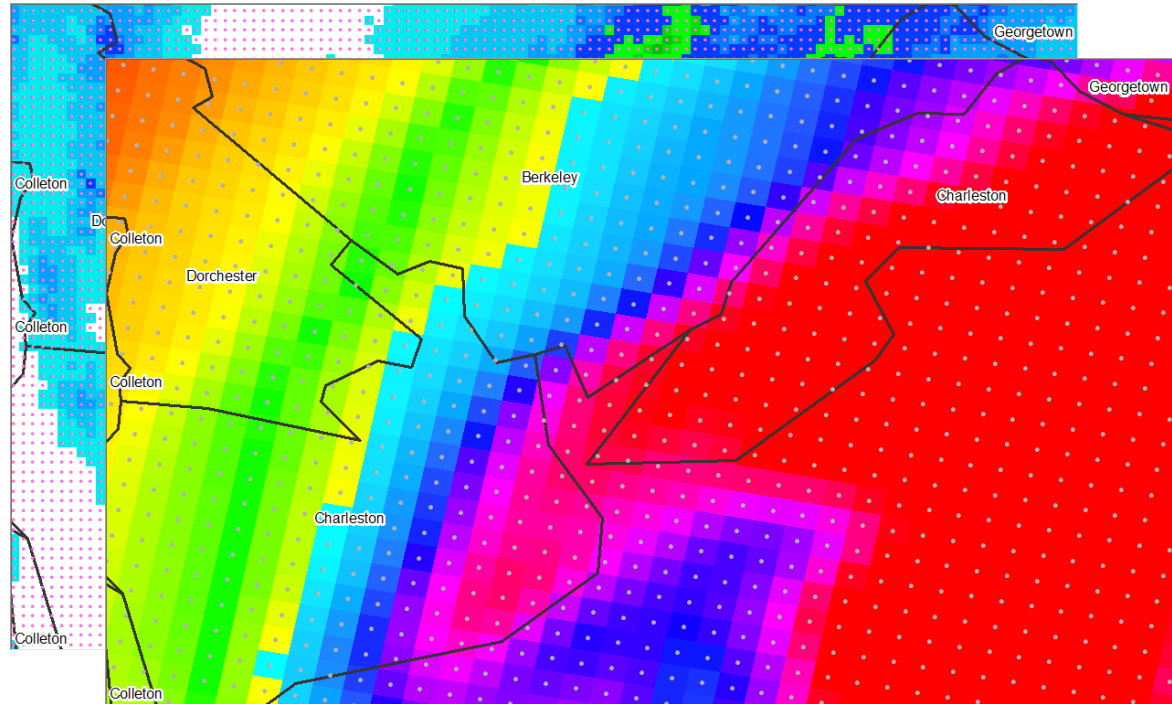
Composite Radar/Rainfall Data Summary

- MRMS (QPE)
 - 1 km Grid
 - 2 minute precip rate
 - 1 Hr Rainfall Totals
 - 1 Hr Gauge Corrected
- HRRR (QPF)
 - 3 km Grid
 - 1 Hr Rainfall Totals
 - 1 to 18 Hr Forecasts
- NAM-HIRES (QPF)
 - 3 km Grid
 - 1 Hr Rainfall Totals
 - Updated 4 Times Daily
 - 18 to 60 Hr Forecasts
- WPC (QPF)
 - 2.5 km Grid
 - 6 Hr Rainfall Forecast
 - Updated 4 Times Daily
 - 60 to 168 Hr Forecasts



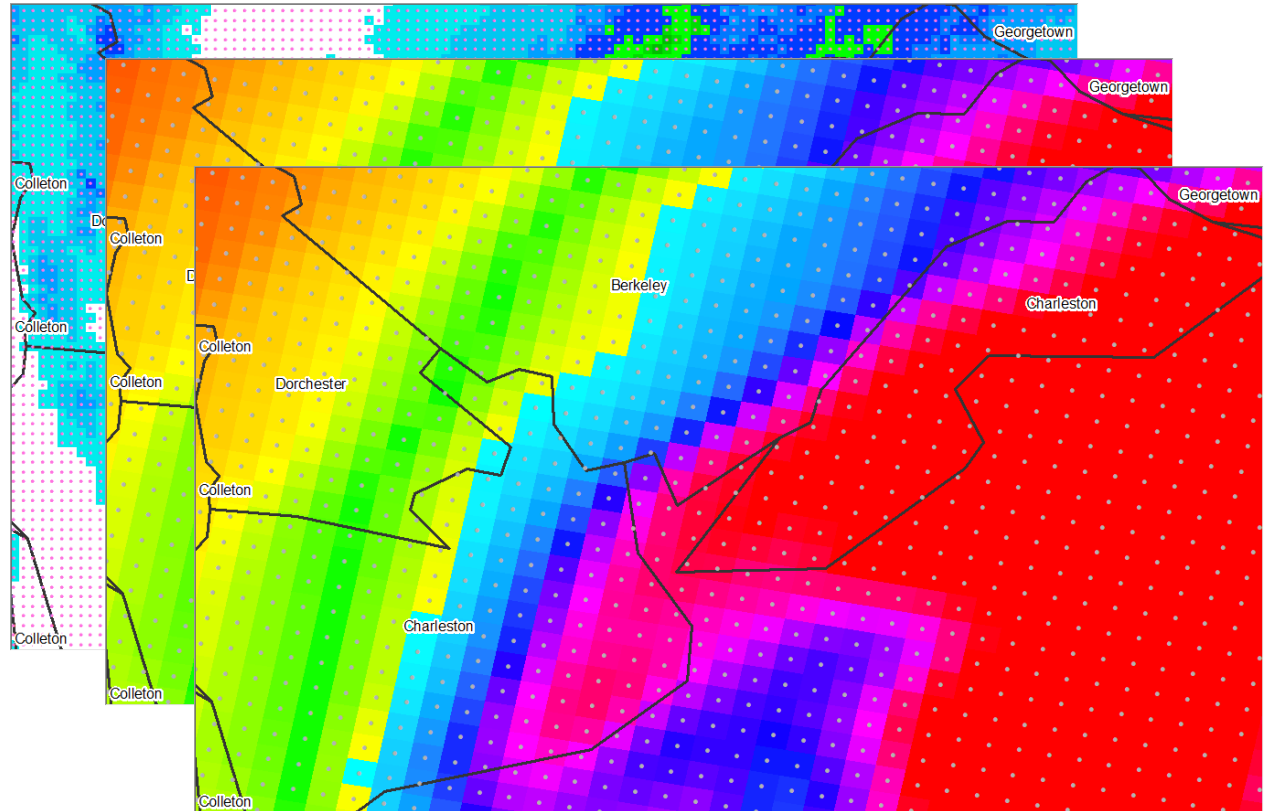
Composite Radar/Rainfall Data Summary

- MRMS (QPE)
 - 1 km Grid
 - 2 minute precip rate
 - 1 Hr Rainfall Totals
 - 1 Hr Gauge Corrected
- HRRR (QPF)
 - 3 km Grid
 - 1 Hr Rainfall Totals
 - 1 to 18 Hr Forecasts
- NAM-HIRES (QPF)
 - 3 km Grid
 - 1 Hr Rainfall Totals
 - Updated 4 Times Daily
 - 18 to 60 Hr Forecasts
- WPC (QPF)
 - 2.5 km Grid
 - 6 Hr Rainfall Forecast
 - Updated 4 Times Daily
 - 60 to 168 Hr Forecasts



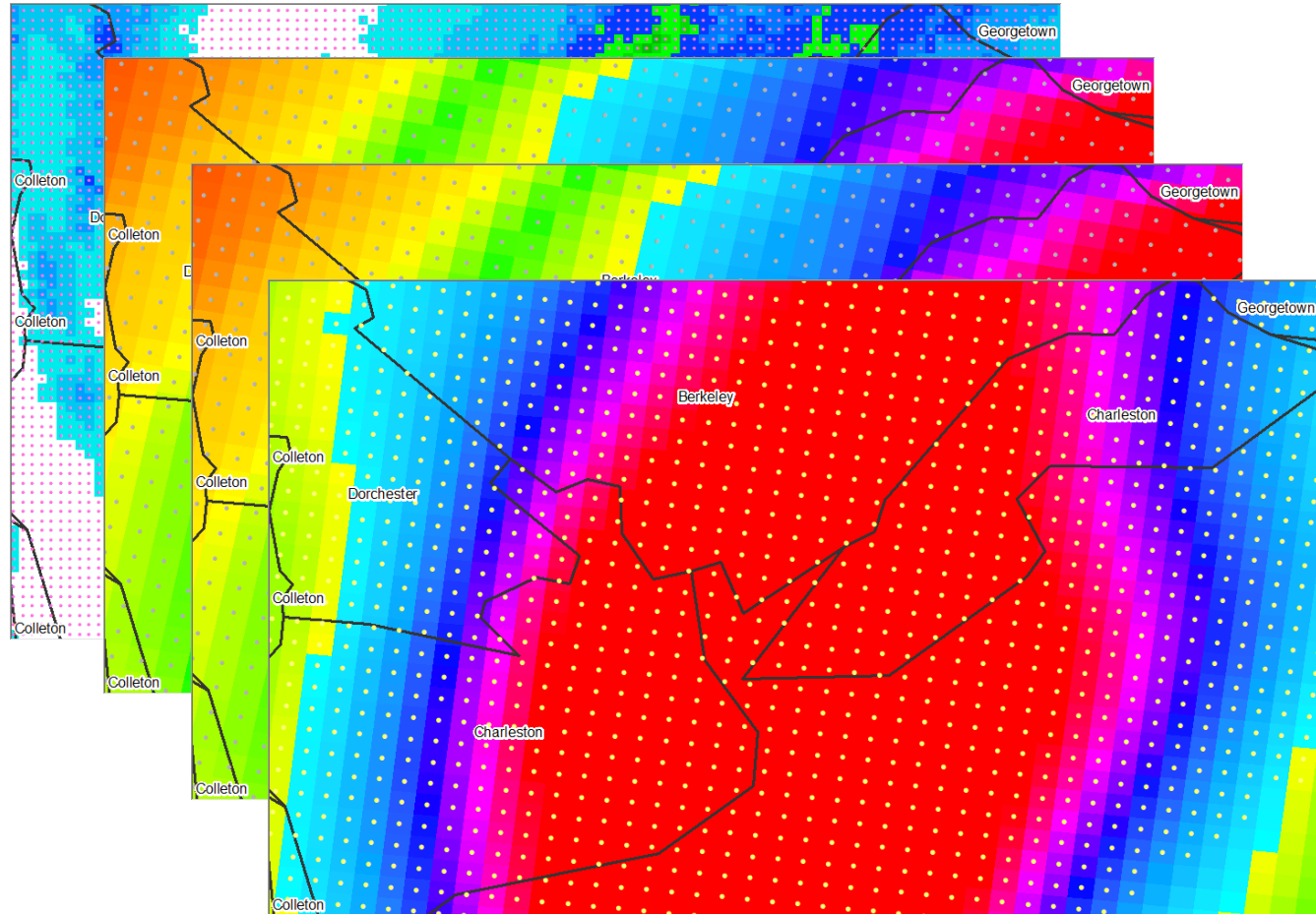
Composite Radar/Rainfall Data Summary

- MRMS (QPE)
 - 1 km Grid
 - 2 minute precip rate
 - 1 Hr Rainfall Totals
 - 1 Hr Gauge Corrected
- HRRR (QPF)
 - 3 km Grid
 - 1 Hr Rainfall Totals
 - 1 to 18 Hr Forecasts
- NAM-HIRES (QPF)
 - 3 km Grid
 - 1 Hr Rainfall Totals
 - Updated 4 Times Daily
 - 18 to 60 Hr Forecasts
- WPC (QPF)
 - 2.5 km Grid
 - 6 Hr Rainfall Forecast
 - Updated 4 Times Daily
 - 60 to 168 Hr Forecasts

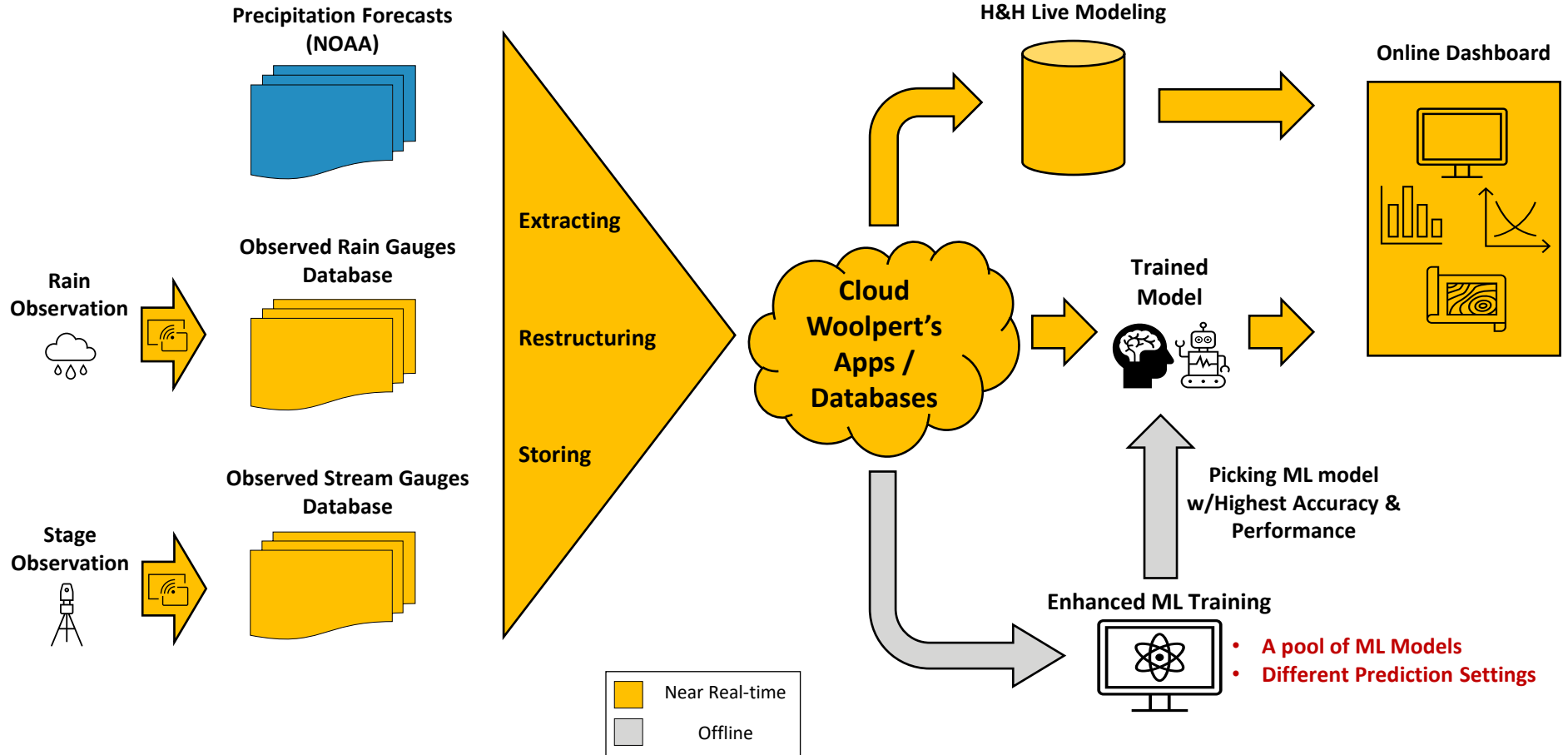


Composite Radar/Rainfall Data Summary

- MRMS (QPE)
 - 1 km Grid
 - 2 minute precip rate
 - 1 Hr Rainfall Totals
 - 1 Hr Gauge Corrected
- HRRR (QPF)
 - 3 km Grid
 - 1 Hr Rainfall Totals
 - 1 to 18 Hr Forecasts
- NAM-HIRES (QPF)
 - 3 km Grid
 - 1 Hr Rainfall Totals
 - Updated 4 Times Daily
 - 18 to 60 Hr Forecasts
- WPC (QPF)
 - 2.5 km Grid
 - 6 Hr Rainfall Forecast
 - Updated 4 Times Daily
 - 60 to 168 Hr Forecasts



Infrastructure for Real-Time Forecasts





W O O L P E R T

ARCHITECTURE | ENGINEERING | GEOSPATIAL