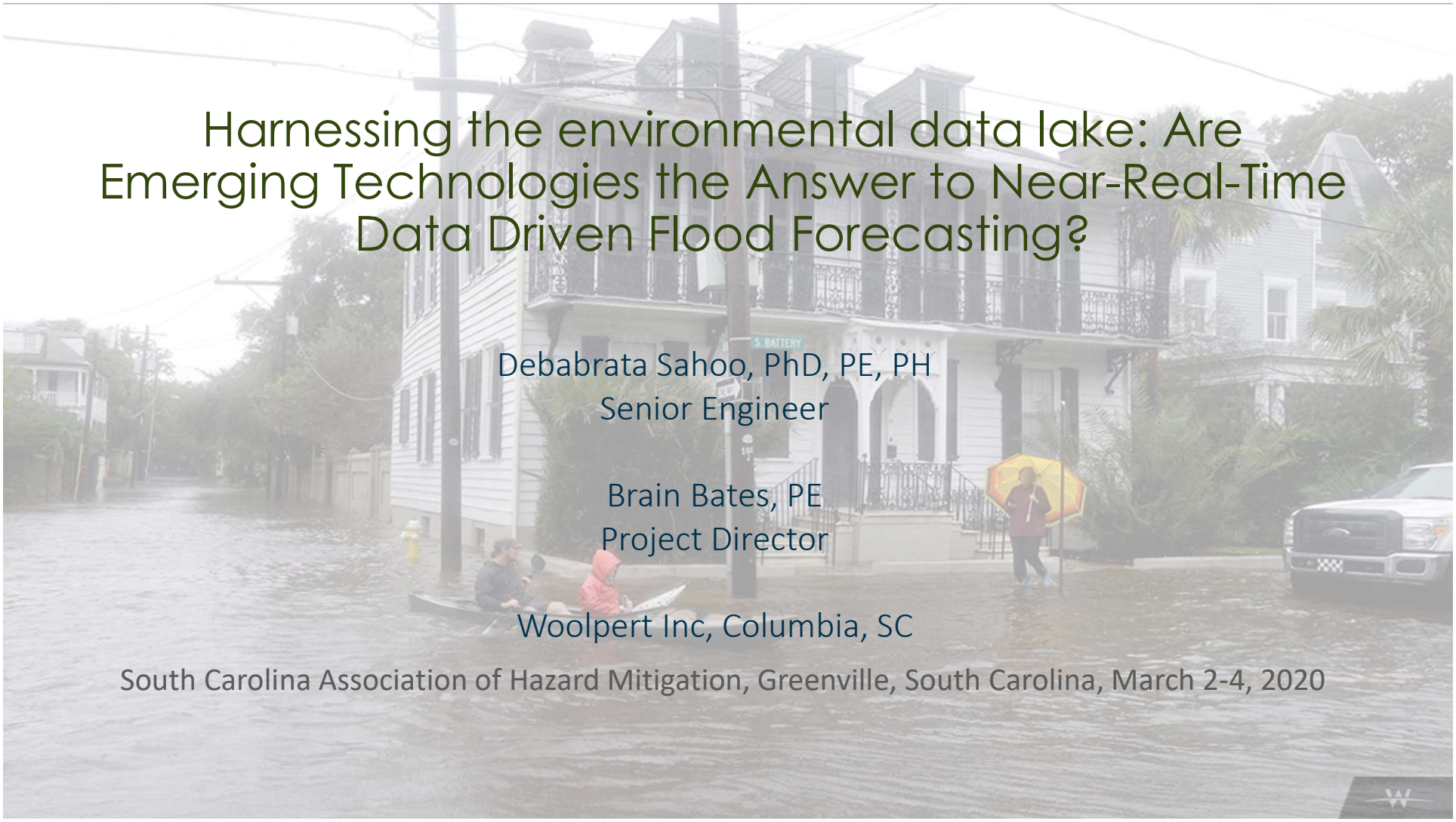
Harnessing the environmental data lake: Are Emerging Technologies the Answer to Near-Real-Time Data Driven Flood Forecasting?

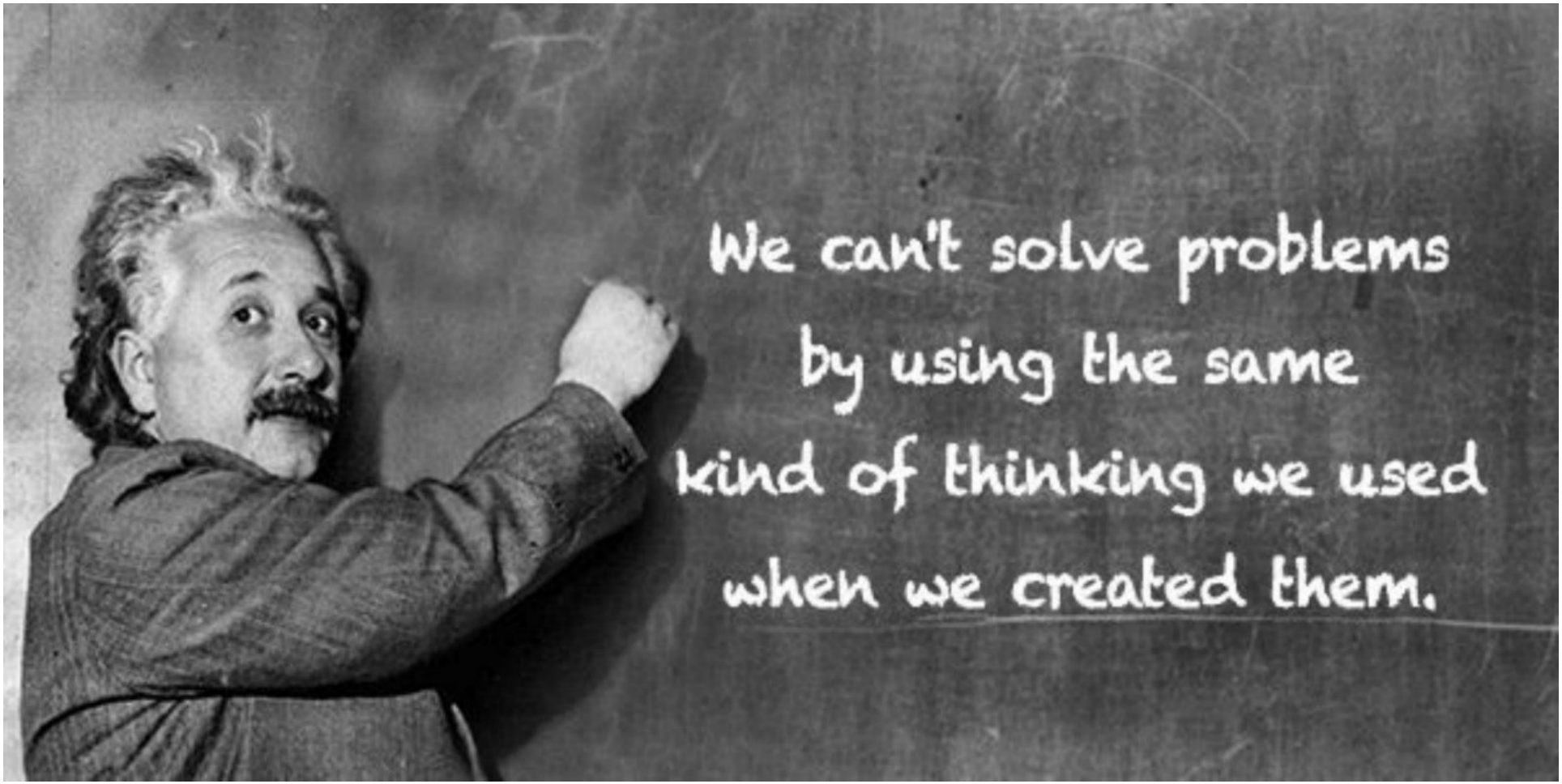


Debabrata Sahoo, PhD, PE, PH
Senior Engineer

Brain Bates, PE
Project Director

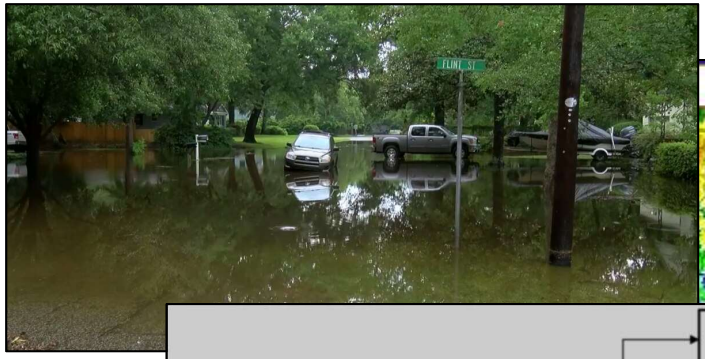
Woolpert Inc, Columbia, SC

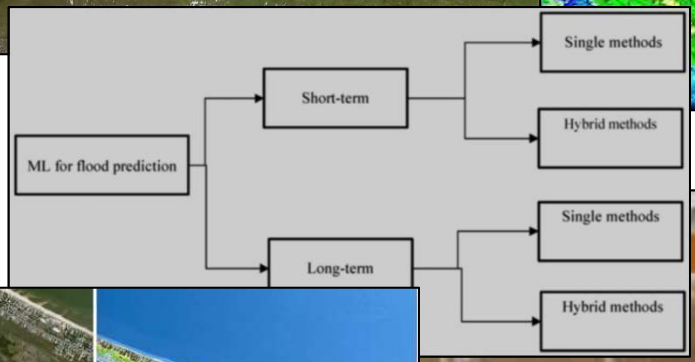
South Carolina Association of Hazard Mitigation, Greenville, South Carolina, March 2-4, 2020

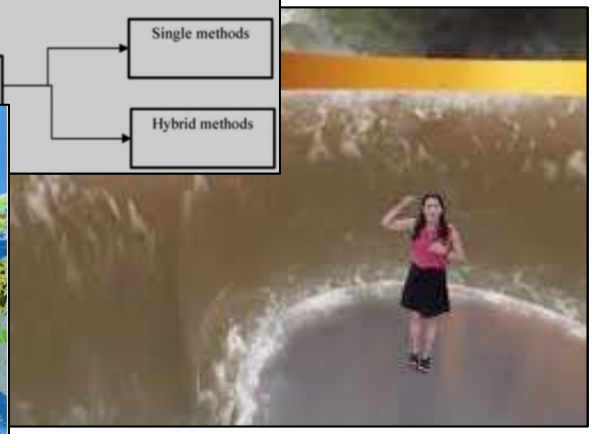

We can't solve problems
by using the same
kind of thinking we used
when we created them.

Agenda

- Introduction
  - Current practices
  - 5Ws of Live Modeling
- Live Modeling
  - Data driven models
  - AI, ML
- Data Needs
  - Inputs, Outputs
  - Watershed Characteristics
- Outcome
  - Dashboard
  - Analytics
  - Visualization
- Example
  - Charleston, SC

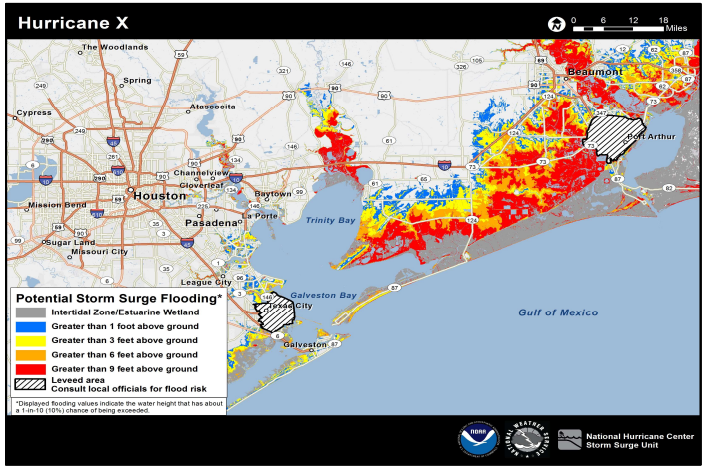






Flooding

- Runoff levels are exceeded
  - Riverine: River topping their banks
  - Flash flooding: Exceeds the stormwater drainage capacity
  - Coastal: Caused by the storm

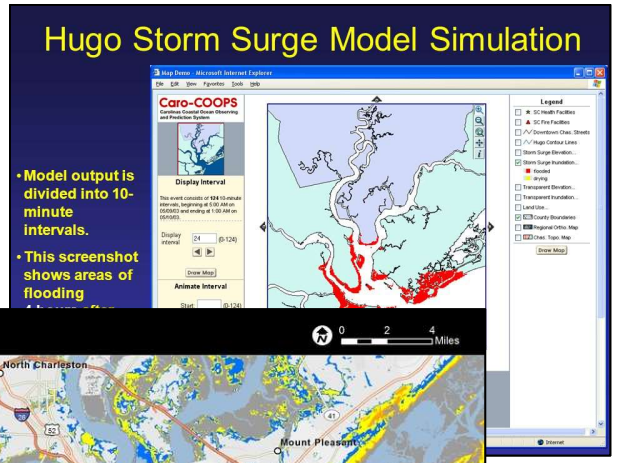


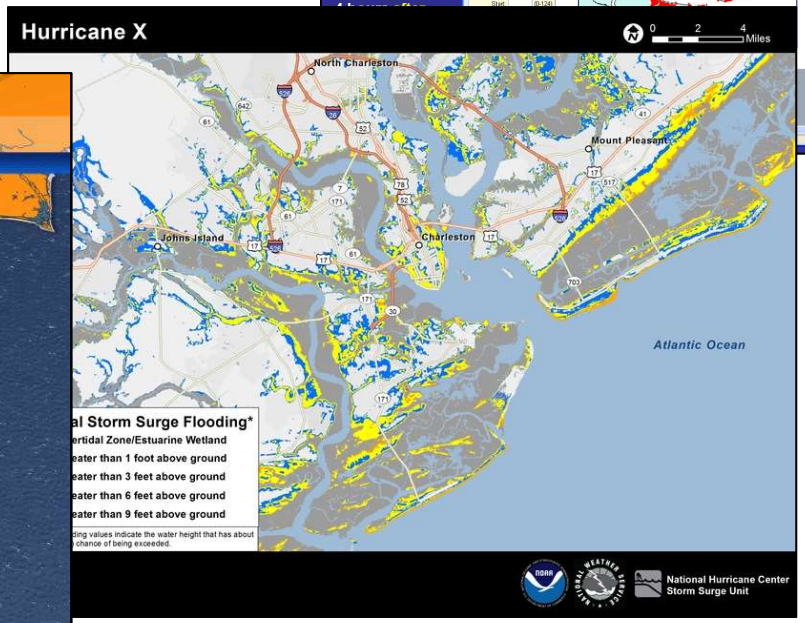
Consequences of flooding

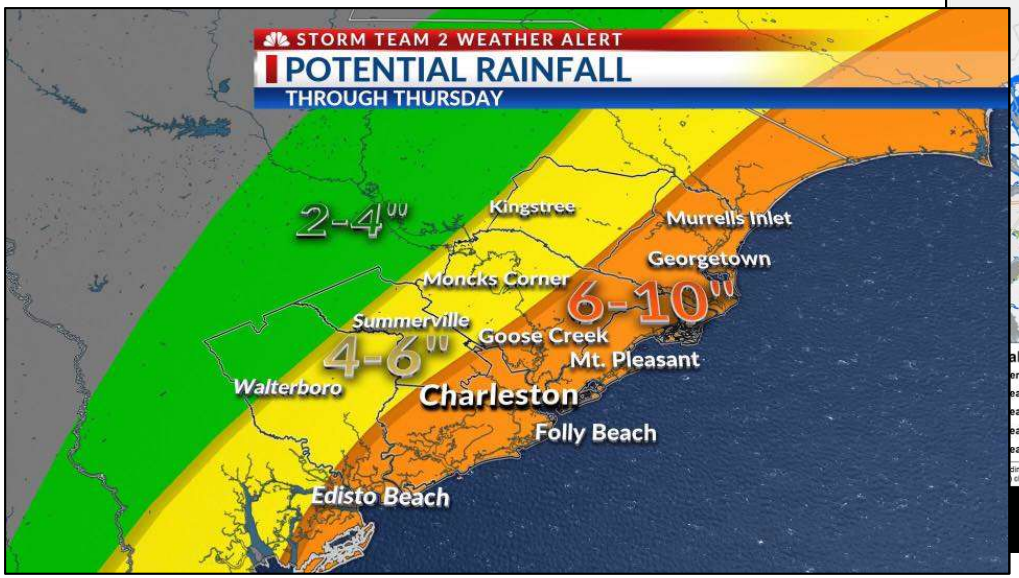
- Hurts the economy
- Damages infrastructure
- Impacts the environment
- Loss of lives

Protecting from flooding

- Traditional modeling
  - HEC RAS, and HMS, SWMM, ICPR
- Alerting about the potential flooding
  - NWS, local government

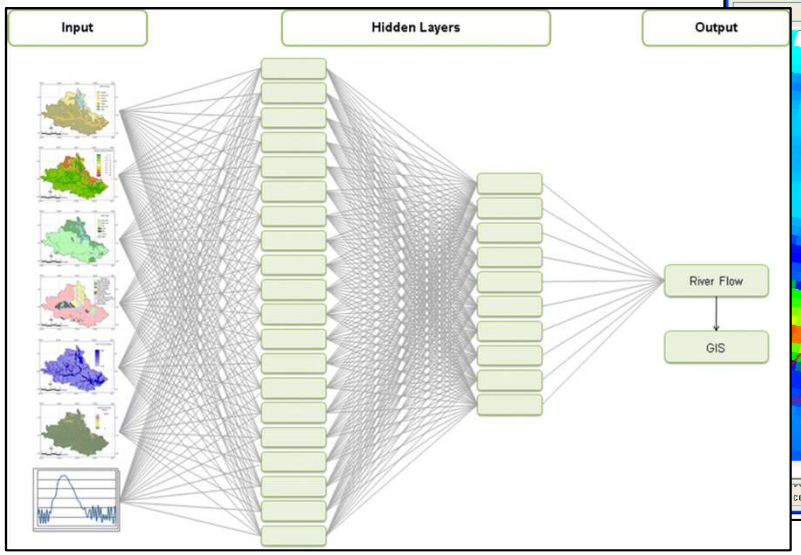


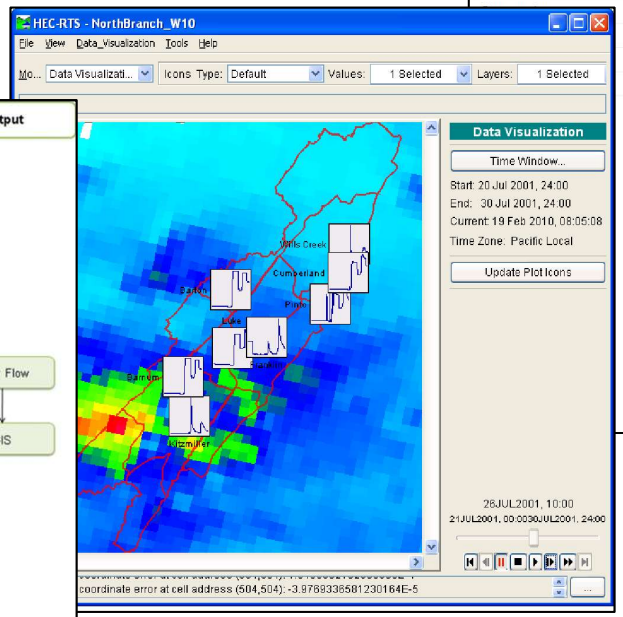


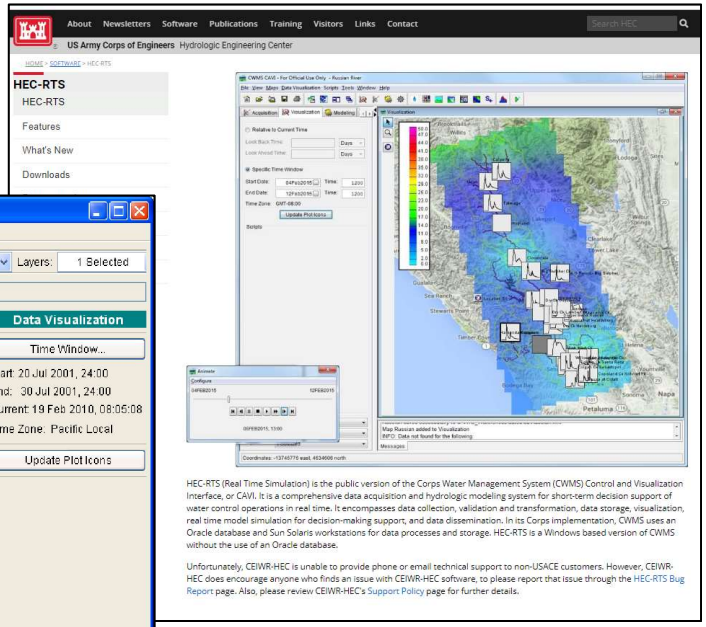


Live Modeling/Real-time Modeling (RTM)

- RTM models
  - HEC-RAS, HEC-HMS, SWMM, ICPR
- Data driven models
  - AI, ML, Deep Learning

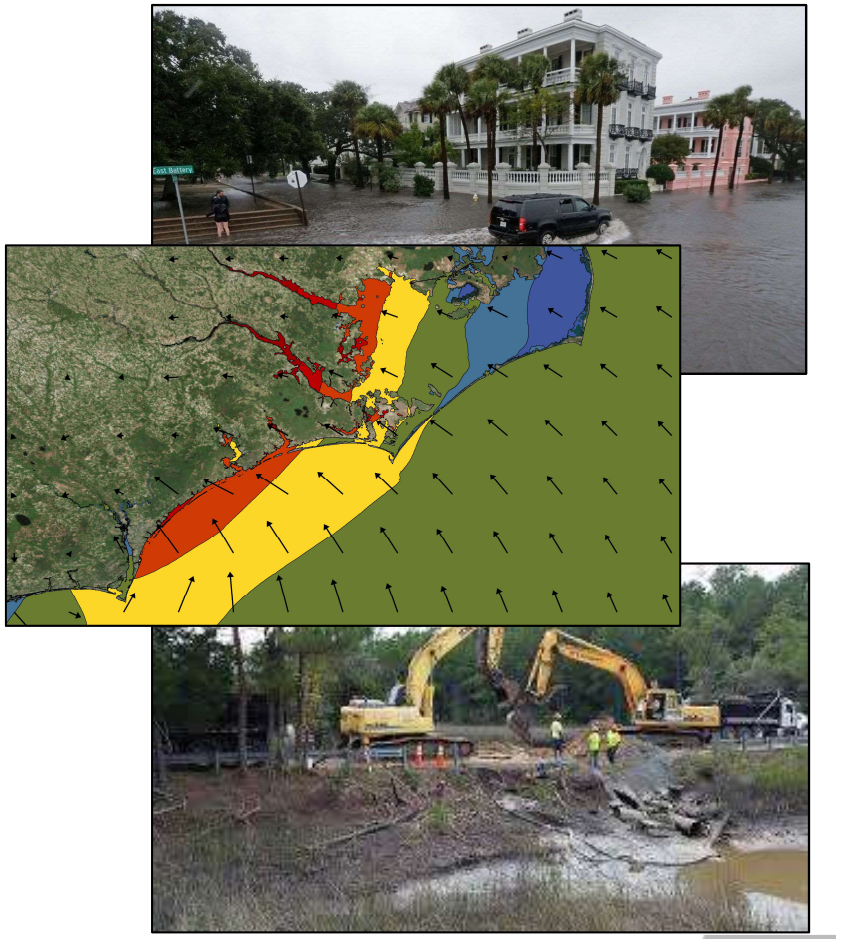




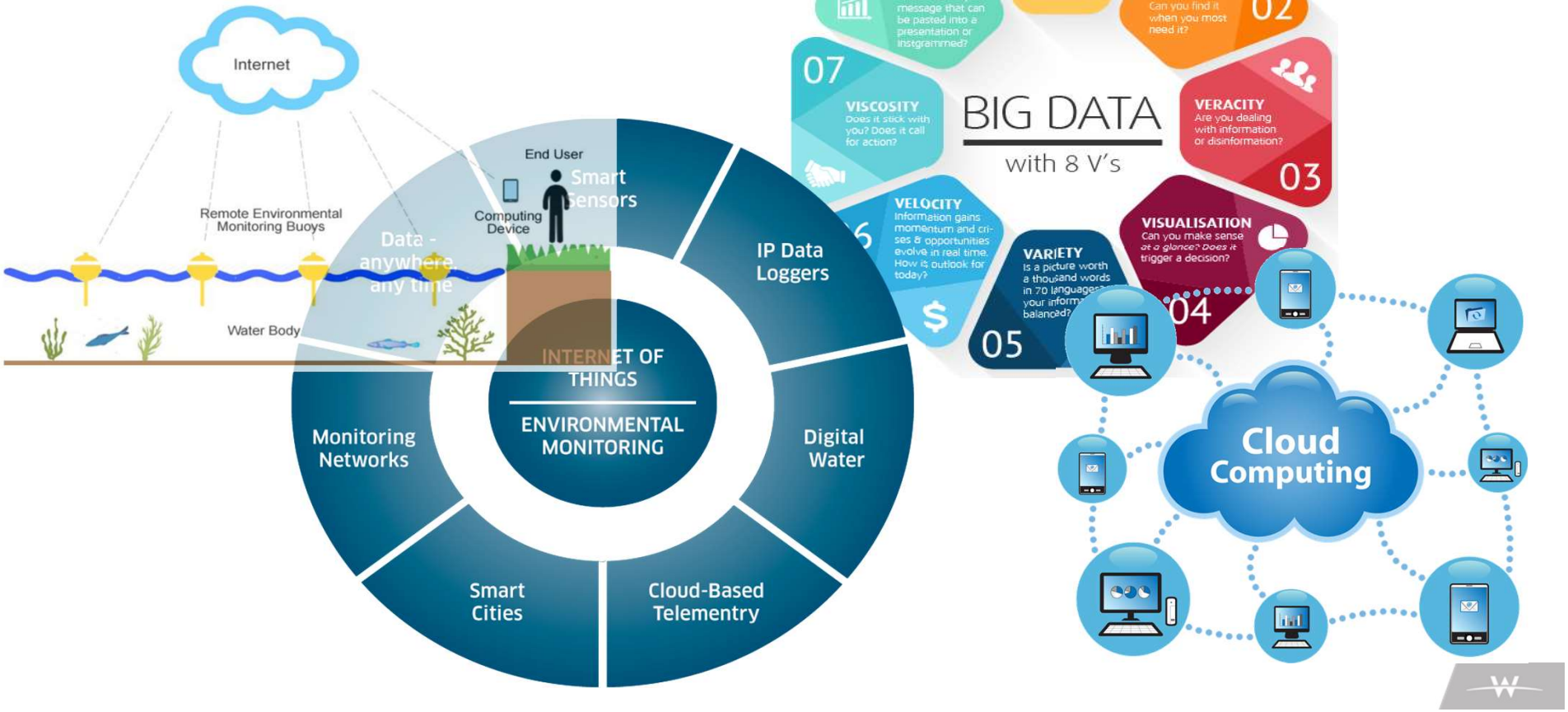


Why Data Driven Models?

- Traditional modeling
  - Data intensive
  - Cost
    - Computationally (time)
    - Economically
  - Helps in developing long-term strategies
- Data driven models
  - Data intensive
    - Volume but may not be variety
  - Cost
    - Computationally efficient
    - Economically acceptable
  - Helps in action oriented outcomes, immediate results



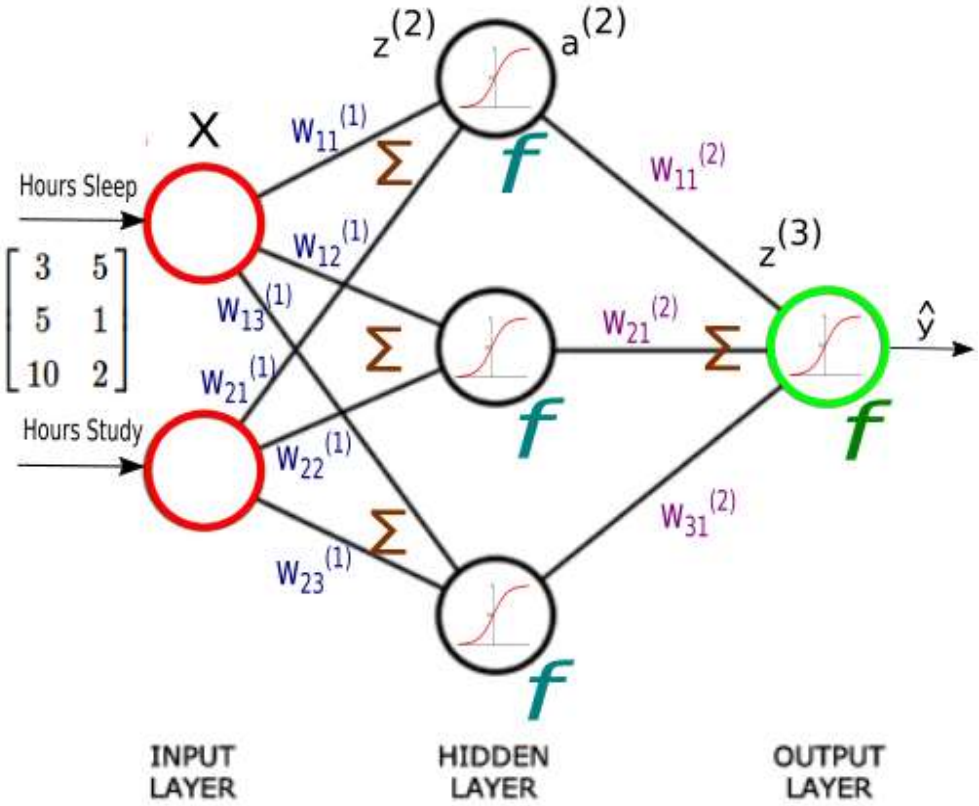
Data Driven Models: Why now?

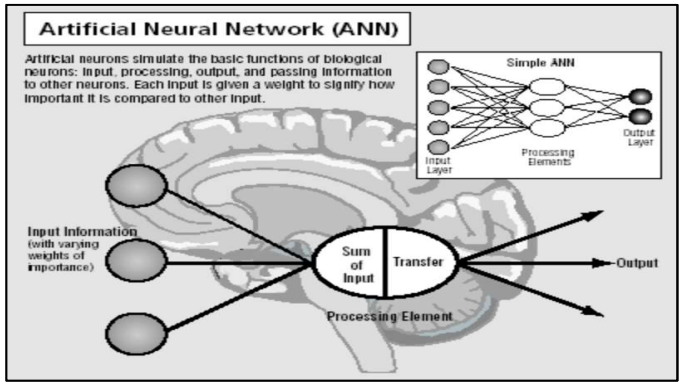


Tools for Data Driven models: AI, ML, Deep Learning

- Artificial Intelligence-
  - A technique which enables machines to mimic human behavior.
- Machine Learning-
  - Subset of AI technique which use statistical methods to enable machines to improve with experiences.
- Deep Learning-
  - Subset of ML which make the computation multi-layer neural network feasible.

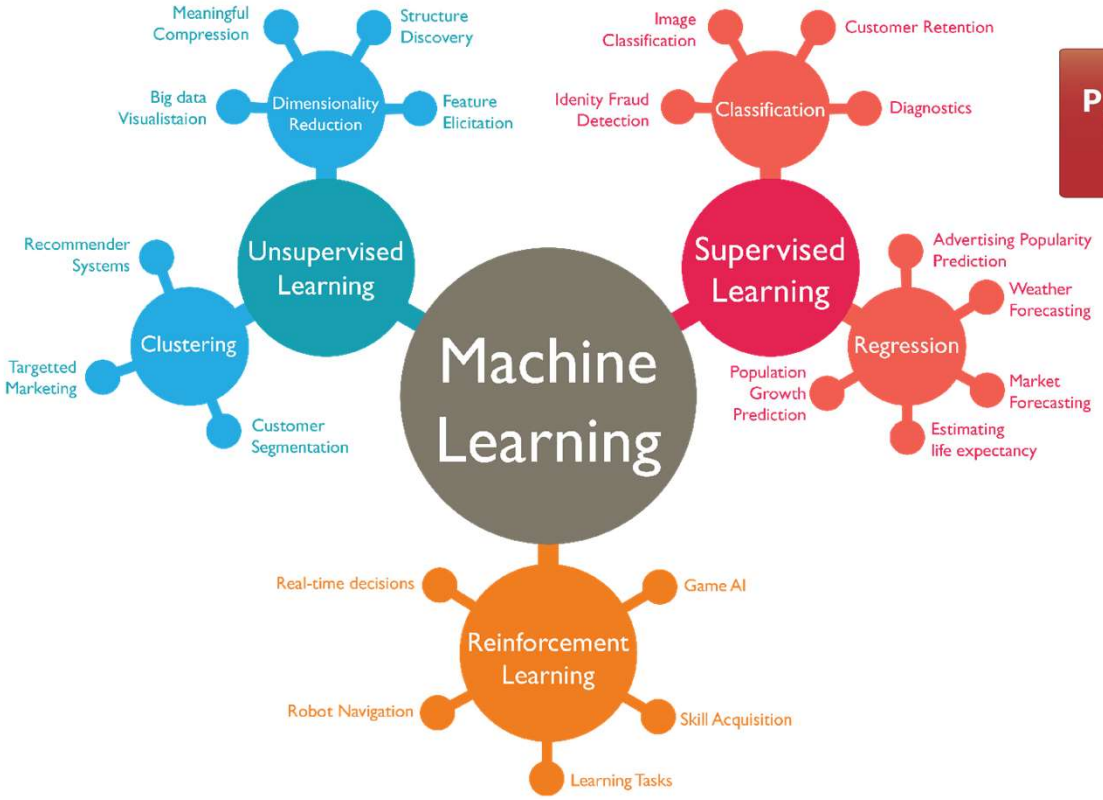
AI, ML, Deep Learning: How is it useful?

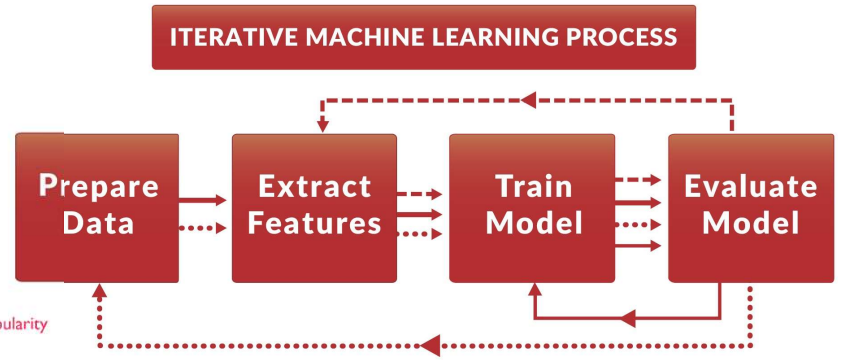


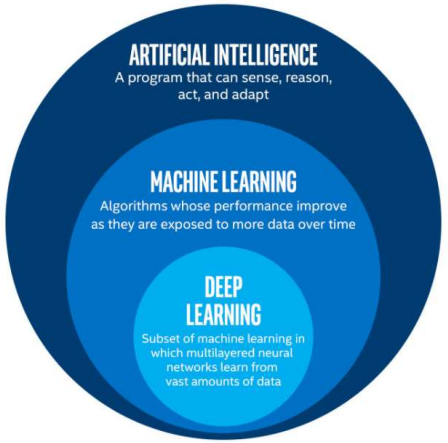


- Explores the relationship between the important variables w.r.t the outcome
- Works on complex data
- Promising for non-linear systems
- Not physically based, yet captures the physical processes
- Algorithms could self learn

Faces of Machine Learning





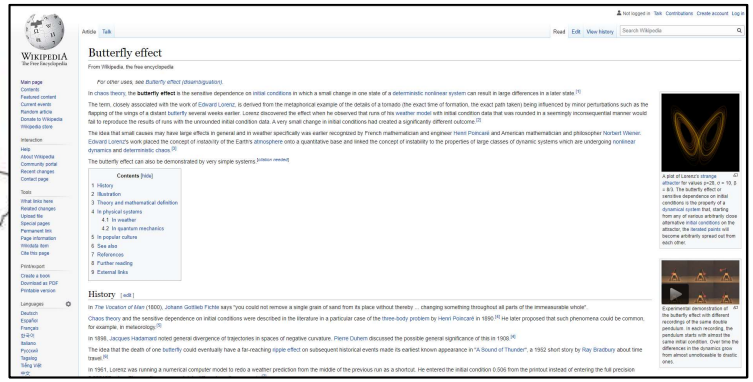


Do we live in a connected system?

BUTTERFLY EFFECT

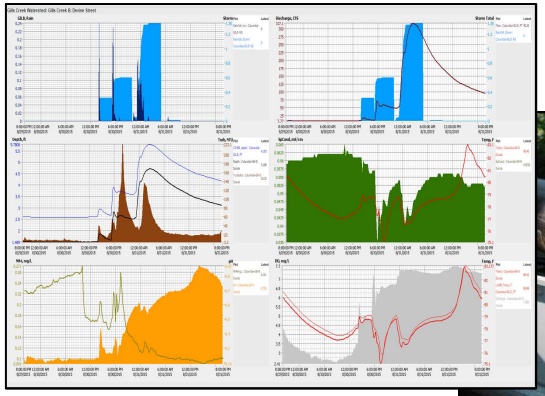
A very small difference in the initial state of a physical system can make a significant difference to the state at some later time.

Derived from the theoretical example of a hurricane's formation being contingent on whether or not a distant butterfly had flapped its wings several weeks earlier.



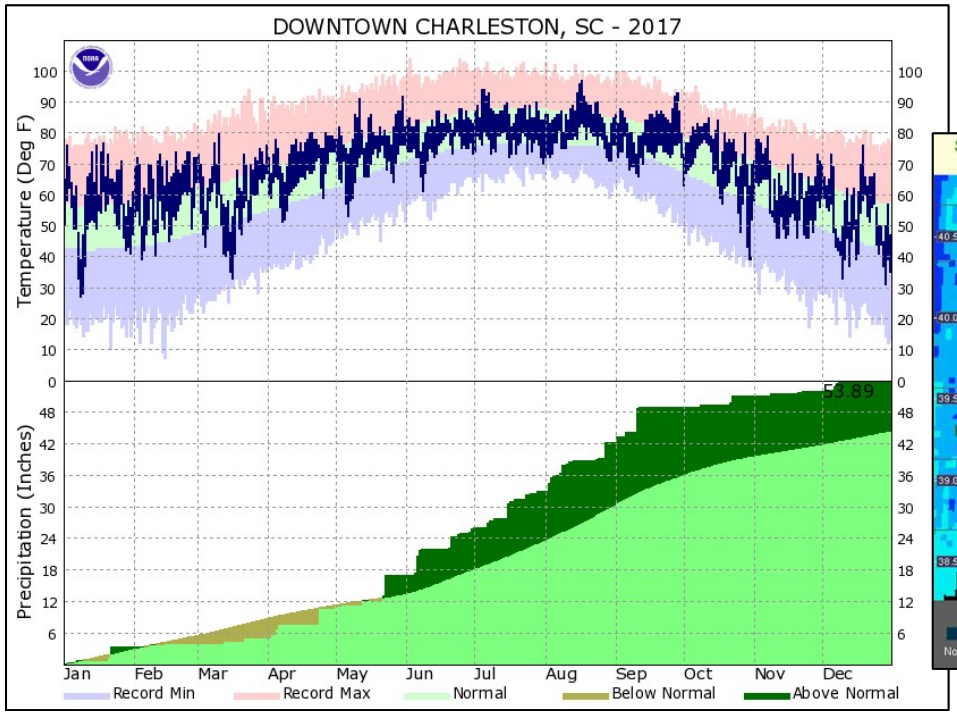
Data Acquisition

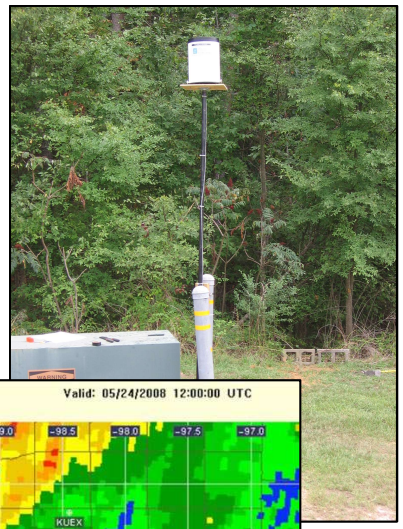
- Rainfall
- Forecasted rainfall
- Flow
- Wind speed
- Catchment features

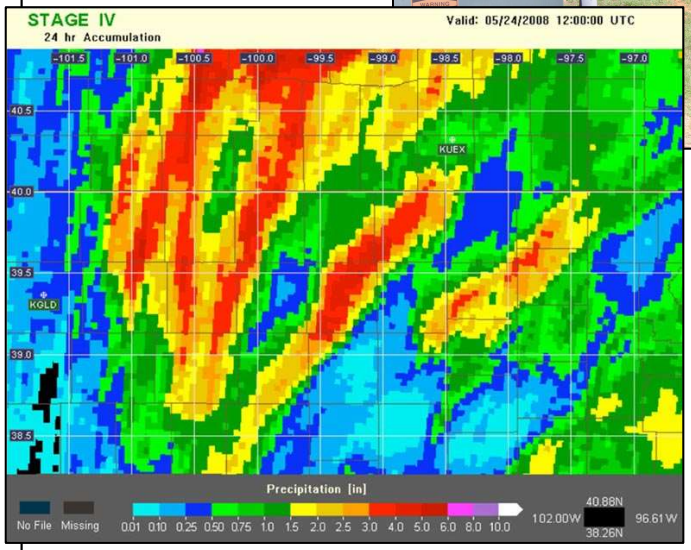


Historic and forecasted information: Model Building

- Meteorological Inputs
  - Rainfall, wind, storm surge, temperature, soil moisture, humidity, day/night
- Flow

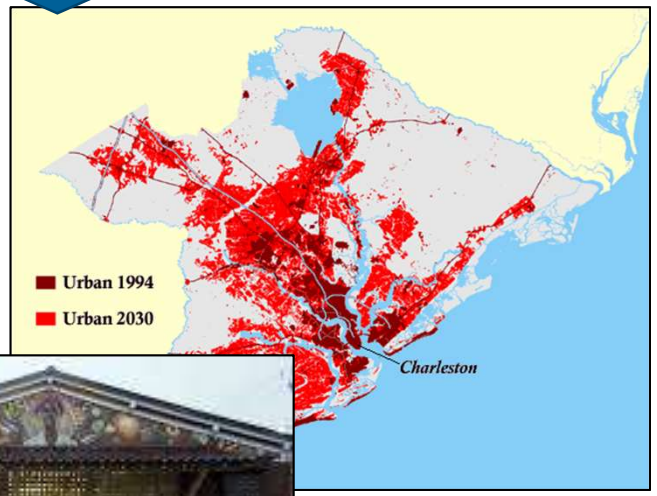






Catchment Features

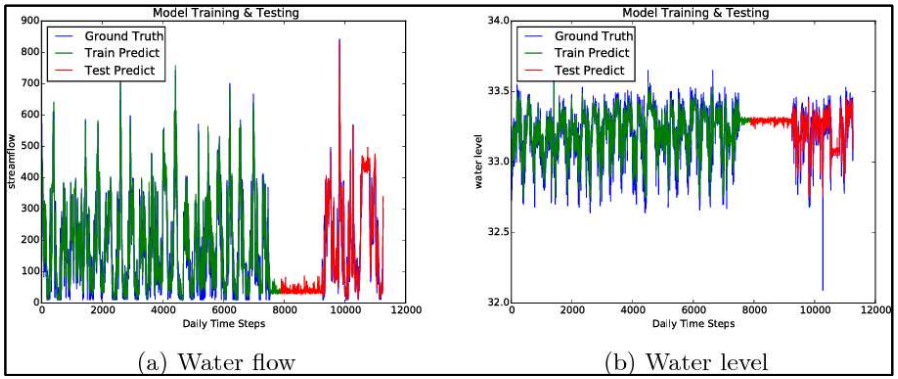
- Current watercourses
  - Path water will take
- Vegetation, soil and impervious surfaces
  - Affects total runoff and runoff velocity
- Obstructions
  - Alteration to watercourses
- Storages
  - Features that retain water



Historic and forecasted information: Validation and Verification

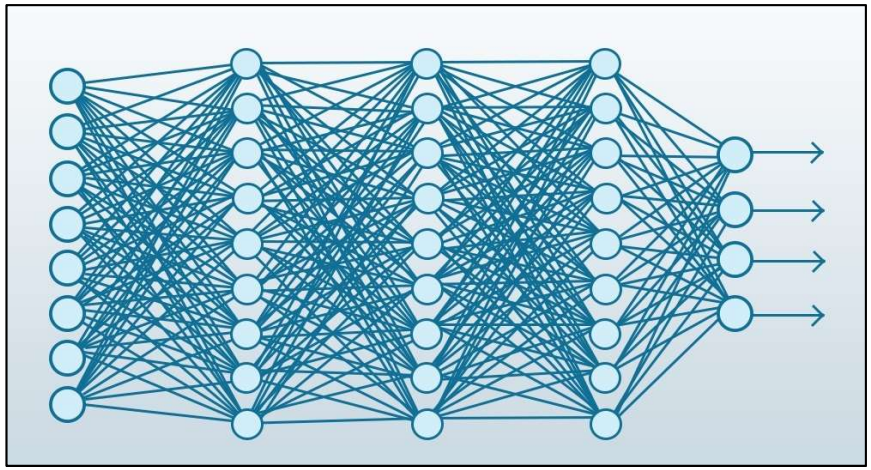
- Flow and Depth
  - Validation using observations

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (X_{obs,i} - X_{model,i})^2}{n}}$$



(a) Water flow (b) Water level

- Learn and re-learn
  - Machine Learning
  - Automation

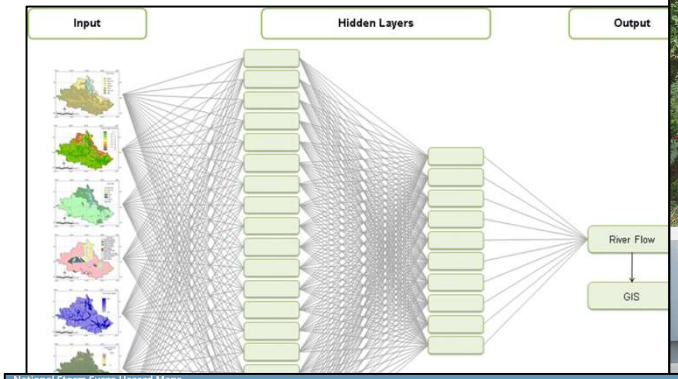


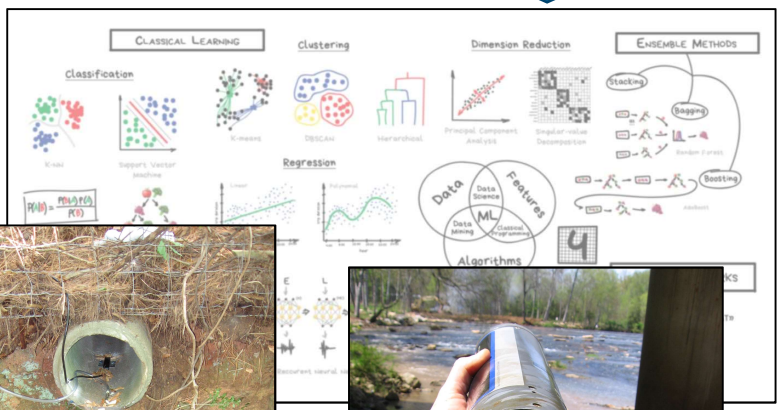
Introduction

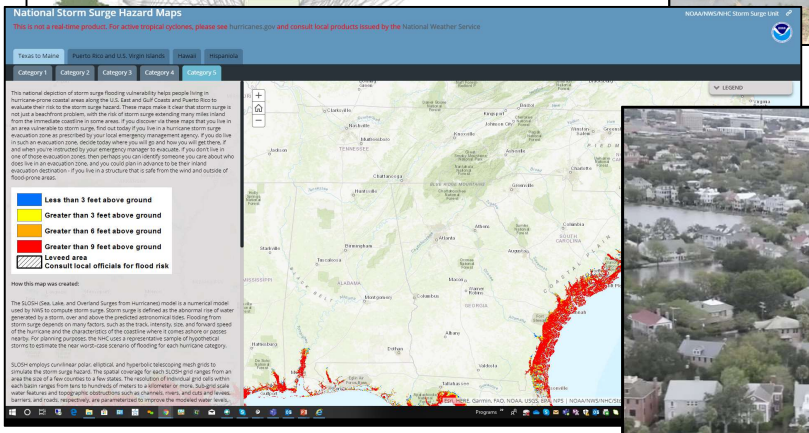
Live Modeling

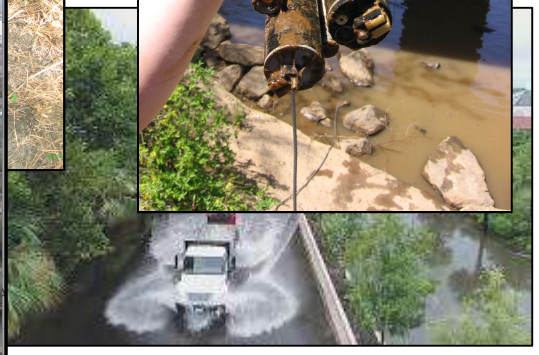
Data Needs

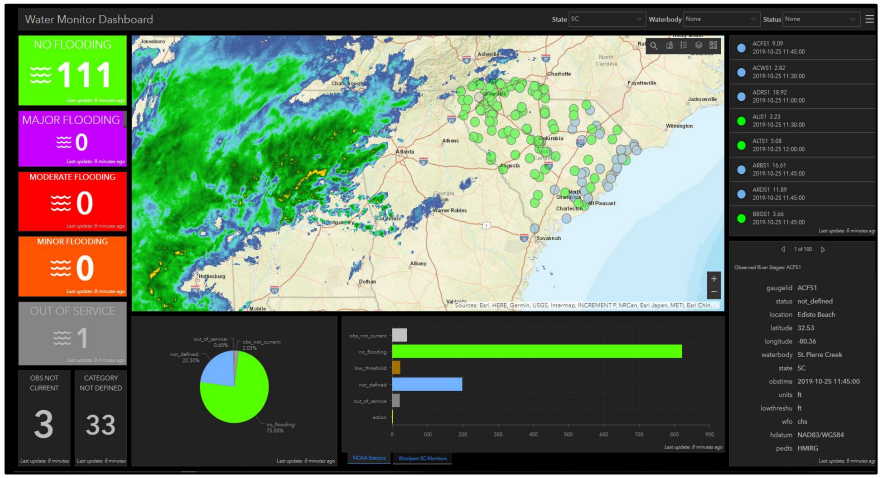
Outcome

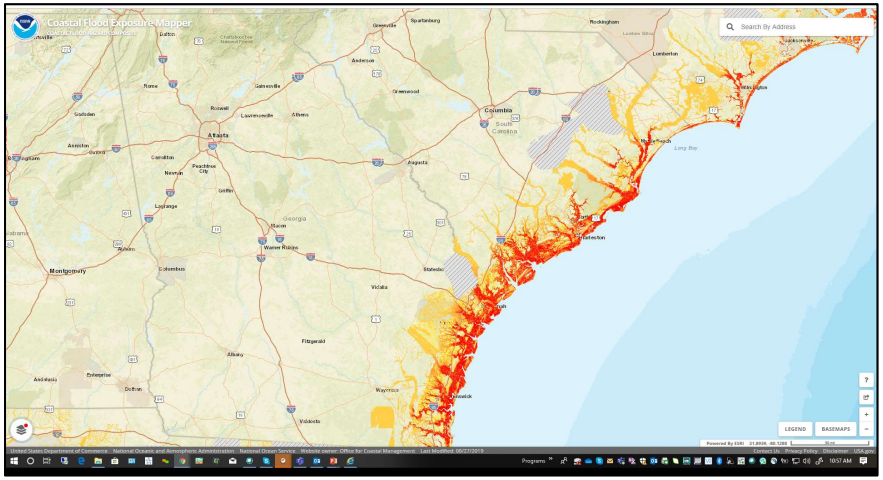








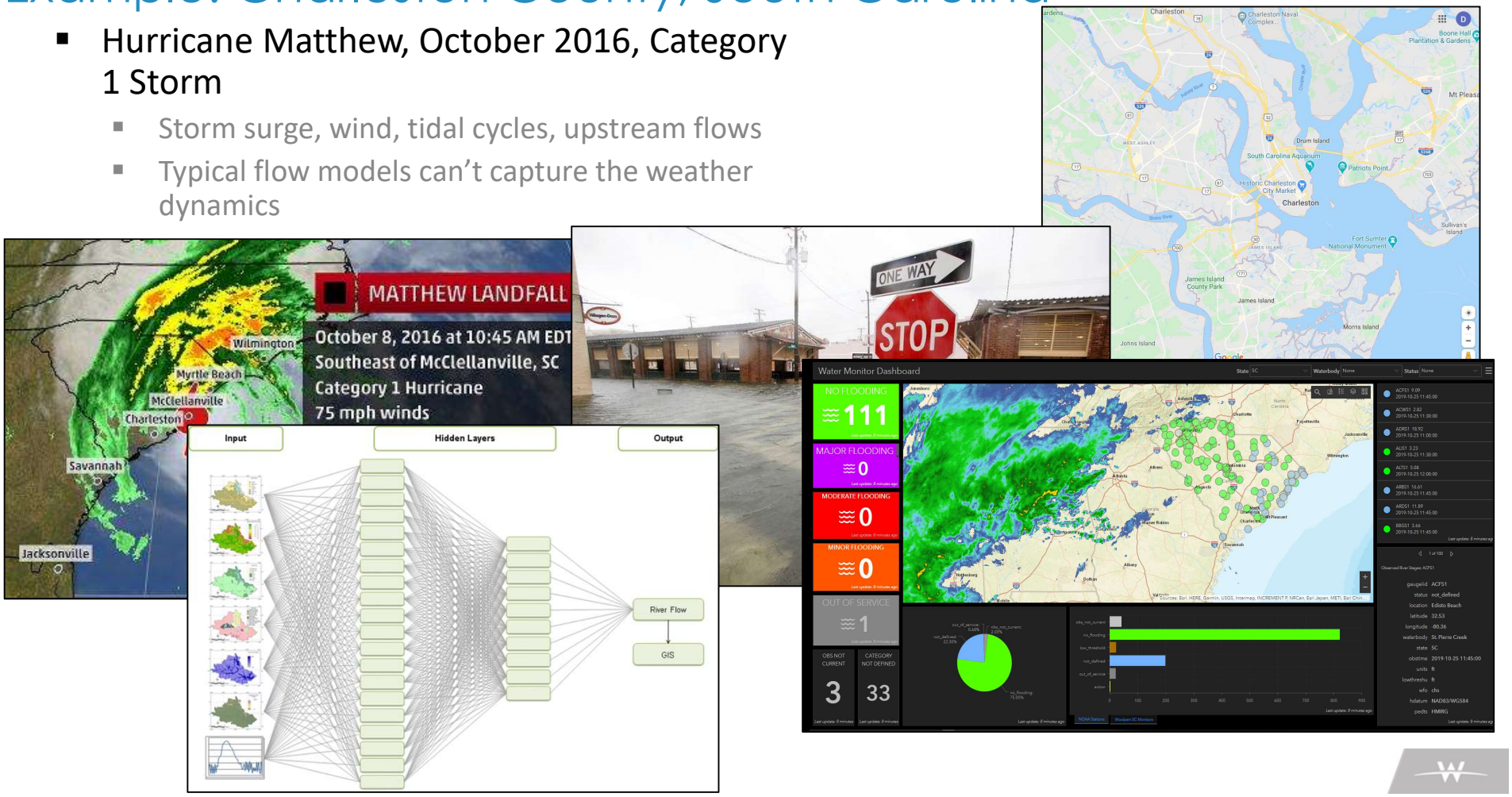




- Dashboard/Communication/Analytics tools
  - Visualize the short term near real-time predicted depth of the approaching storm over different temporal scales.
  - Visualize the spatial inundation, and spatially varying depths at different temporal resolutions.
  - Providing early information to the emergency officials, citizens and critical infrastructures.
  - Help businesses prioritize logistics.
  - Compare, contrast and visualize the actual and predicted rainfall and flow.
  - Compare, contrast, and visualize historic rainfall and flow information.

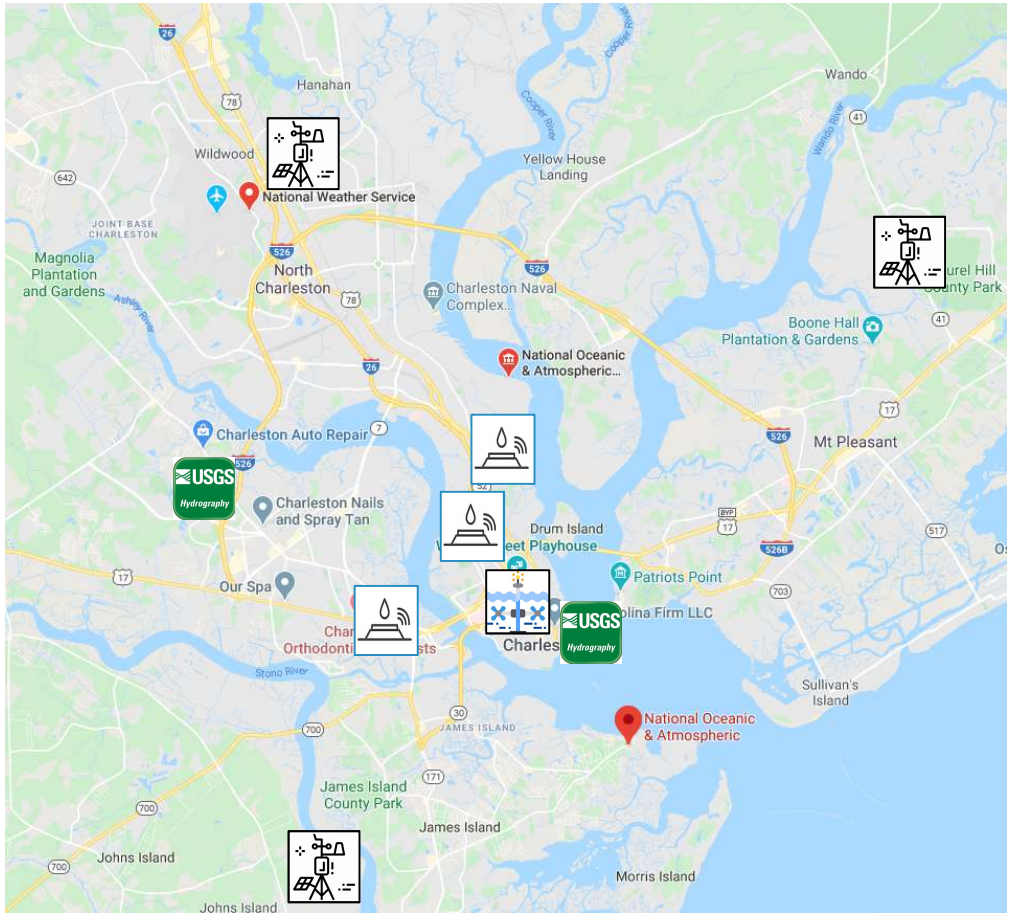
Example: Charleston County, South Carolina

- Hurricane Matthew, October 2016, Category 1 Storm
  - Storm surge, wind, tidal cycles, upstream flows
  - Typical flow models can't capture the weather dynamics



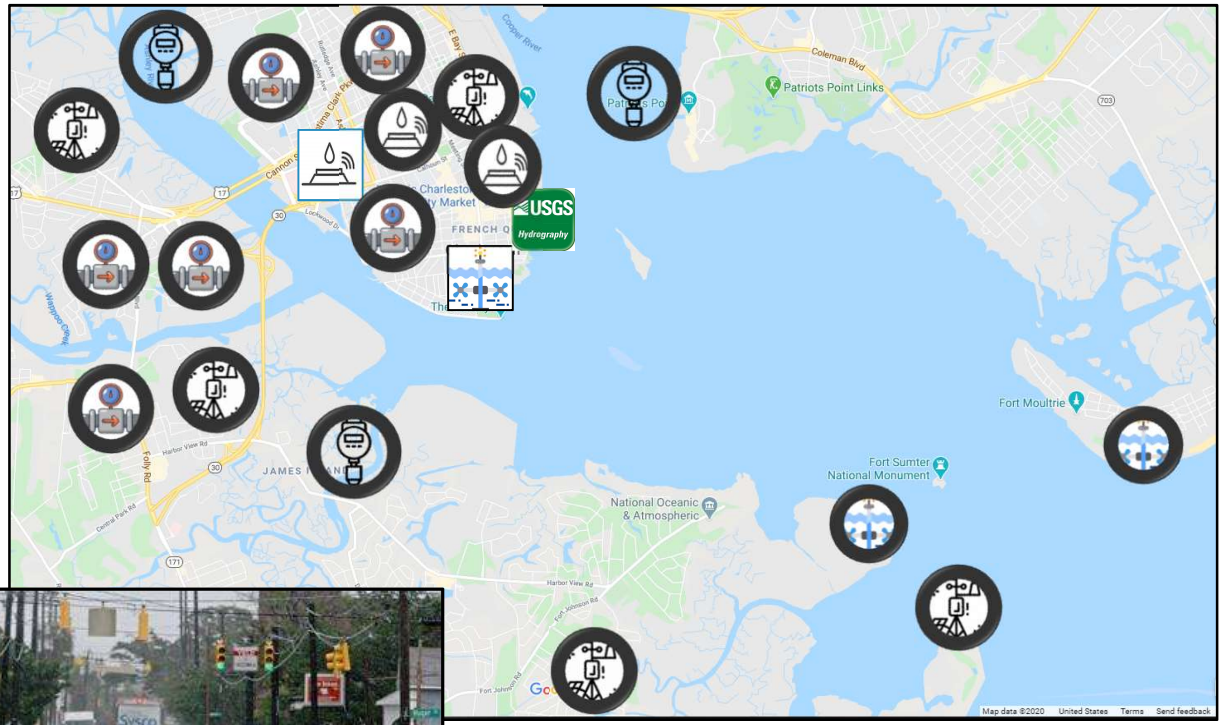
Example: Charleston, South Carolina

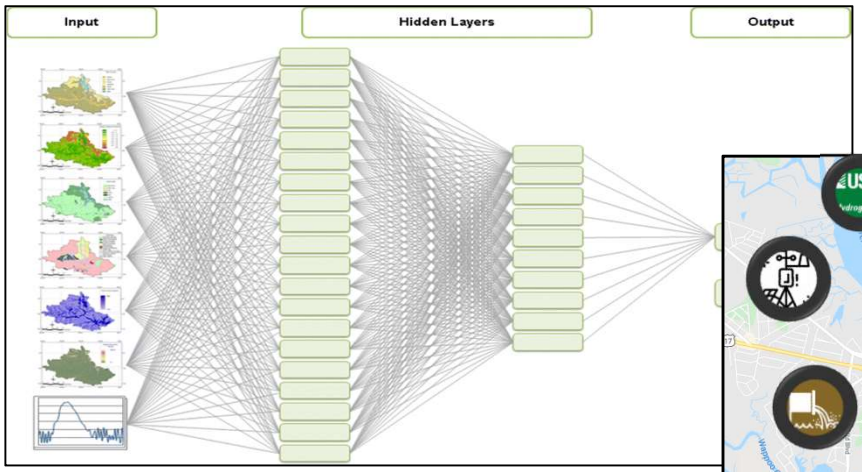
- Currently Available Data/Sources
  - NWS, NOAA
    - Temp, Rain, Cloud, Wind Speed
  - NWS and RAWS (MesoWest)
    - Temp, RH, Wind Speed, Pressure, 1 Hr, 3 Hr, 6 Hr, 24 Hr
  - NOAA
    - Tidal info
  - USGS Station
    - Flow
  - City of Charleston
    - Flood sensors, MS4 monitoring

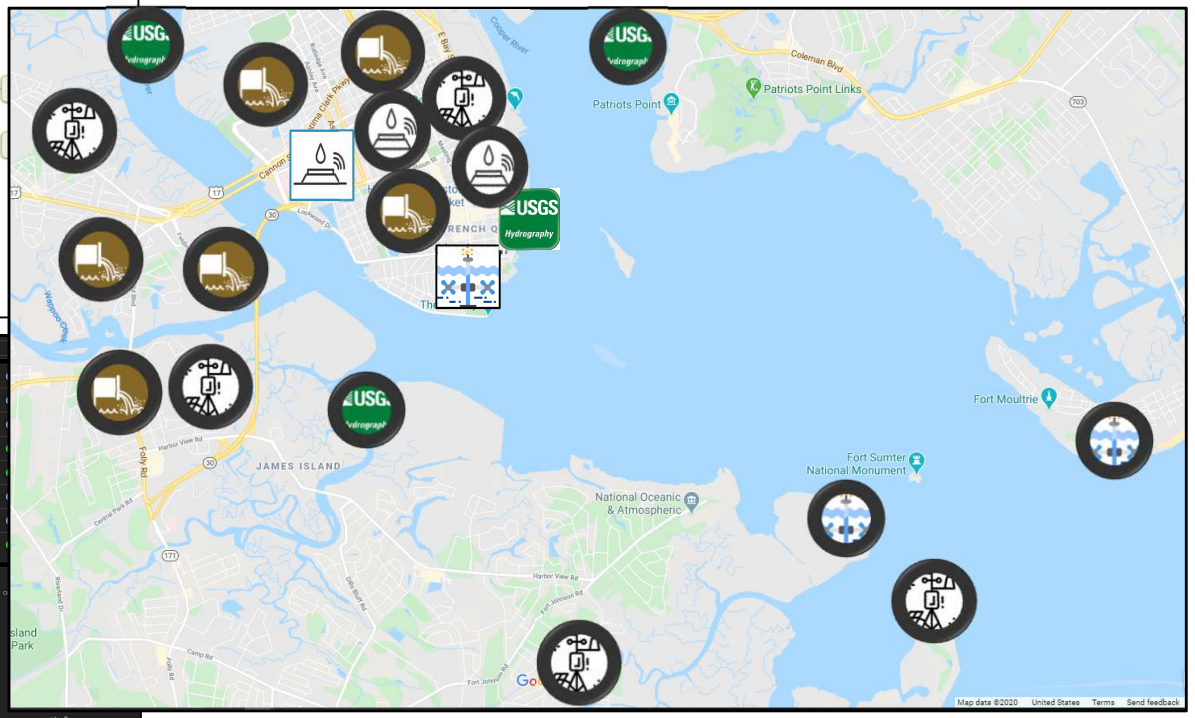


Example: Charleston, South Carolina

- Additional Data
  - Dense rain gauge network
  - Depth gauges for the piped system
  - Riverine gauges
  - Tidal gauges
  - Wind gauges
  - Soil moisture sensor network
  - Depth sensors on the roads




Input
Hidden Layers
Output


USGS
Hydrography
Patriots Point
Patriots Point Links
Coleman Blvd
JAMES ISLAND
Fort Moultrie
Fort Sumter
National Monument
National Oceanic
& Atmospheric
Map data ©2020
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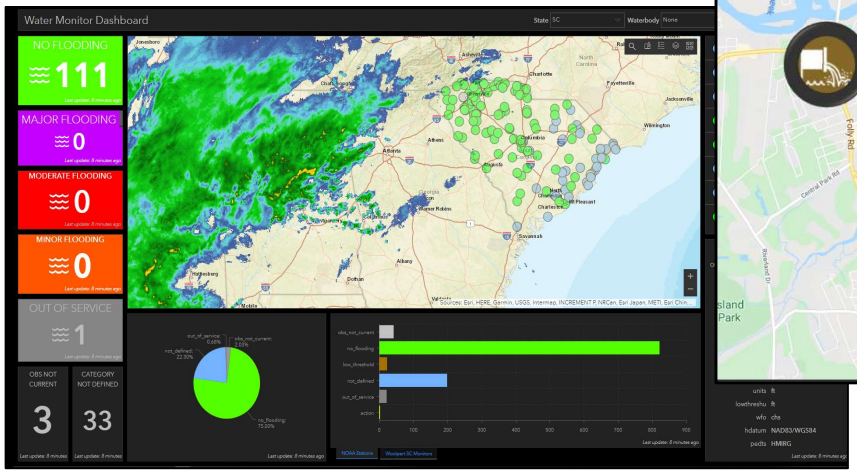
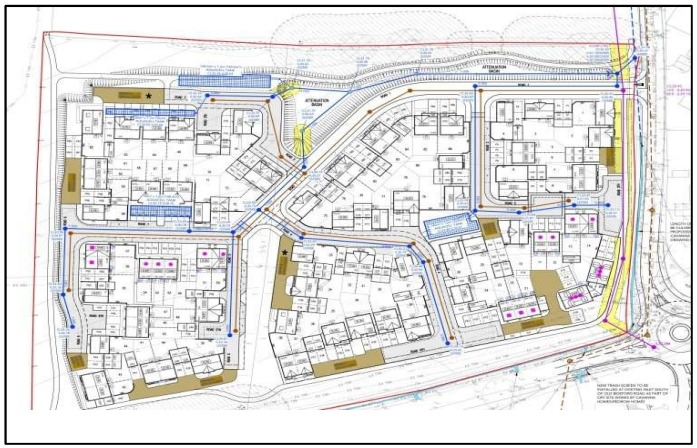
Send feedback


Water Monitor Dashboard
NO FLOODING
111
MAJOR FLOODING
0
MODERATE FLOODING
0
MINOR FLOODING
0
OUT OF SERVICE
1
OBS NOT CURRENT
3
CATEGORY NOT DEFINED
33

Challenges and Opportunities

- Designs and Regulations
- Funding Opportunities
- Training and Education
- Computing and Networking



Questions

The authors acknowledge google search for some of the images used in this presentation