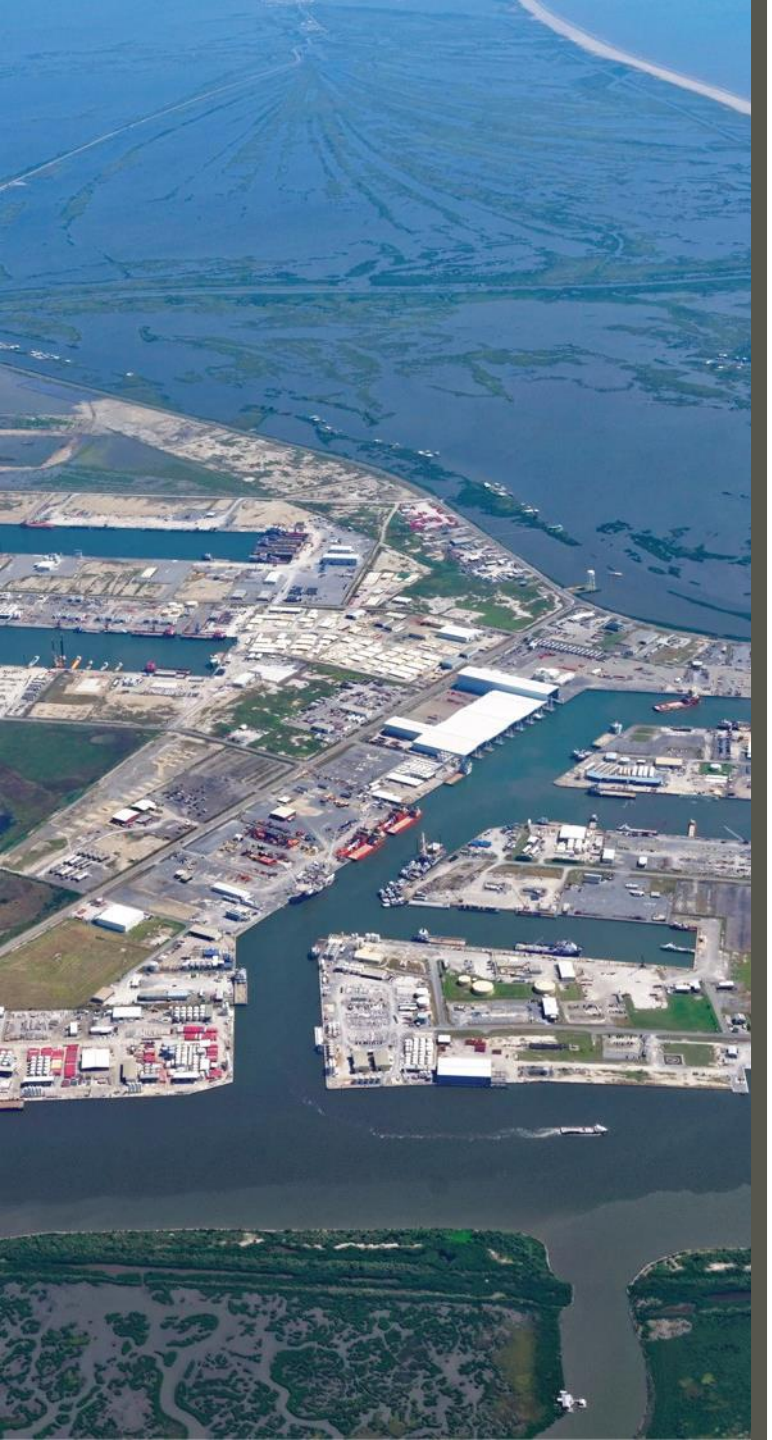

THE WATER INSTITUTE

# DEVELOPMENT OF A FLEXIBLE, MULTI-MODEL, REAL TIME, COMPOUND FLOOD FORECASTING SYSTEM FOR TROPICAL AND NON-TROPICAL EVENTS

3RD INTERNATIONAL WORKSHOP ON WAVES, STORM SURGES, AND COASTAL HAZARDS

OCTOBER 4, 2023

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# ACKNOWLEDGEMENT

COASTAL RESILIENCE CENTER

*A U.S. Department of Homeland Security Center of Excellence*



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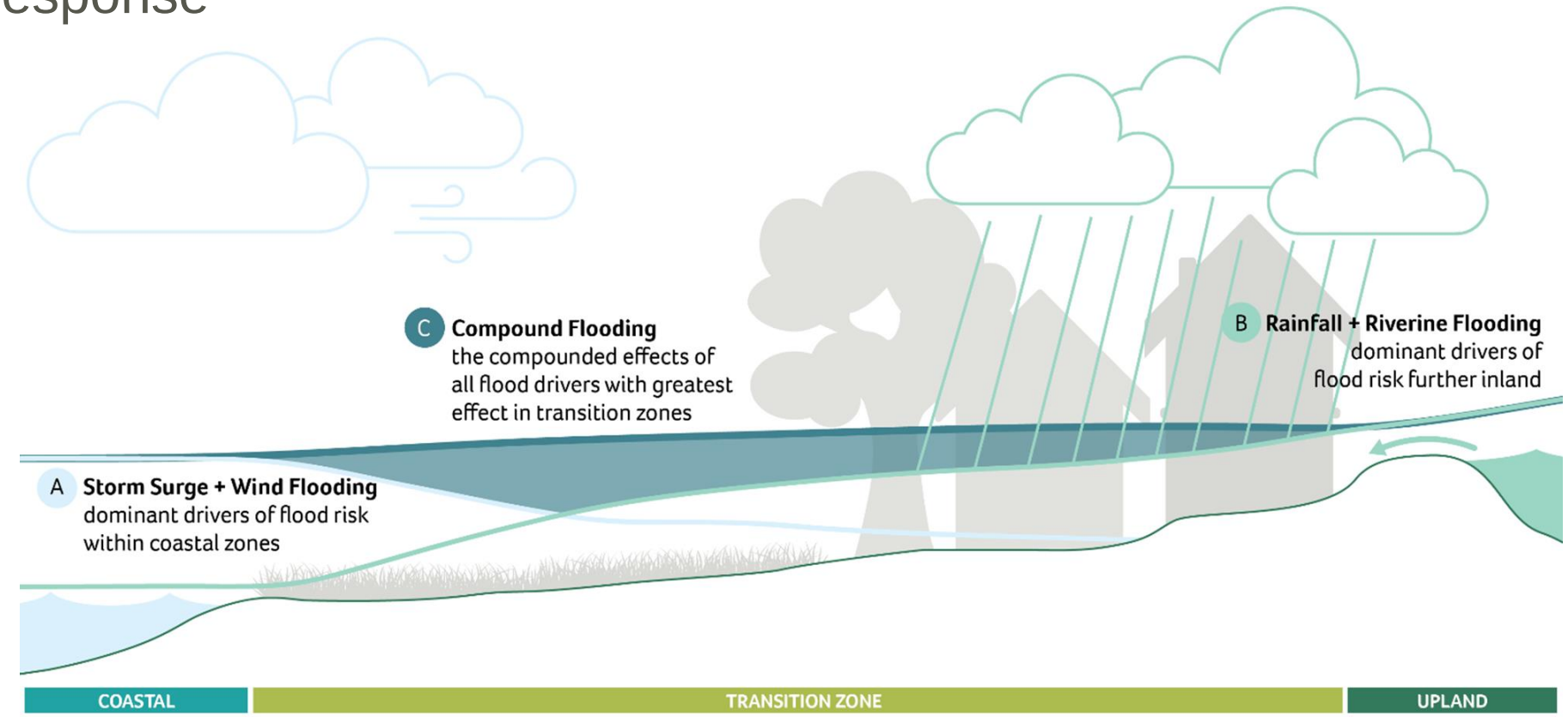
working together for sustainability and resilience

# GOAL #1

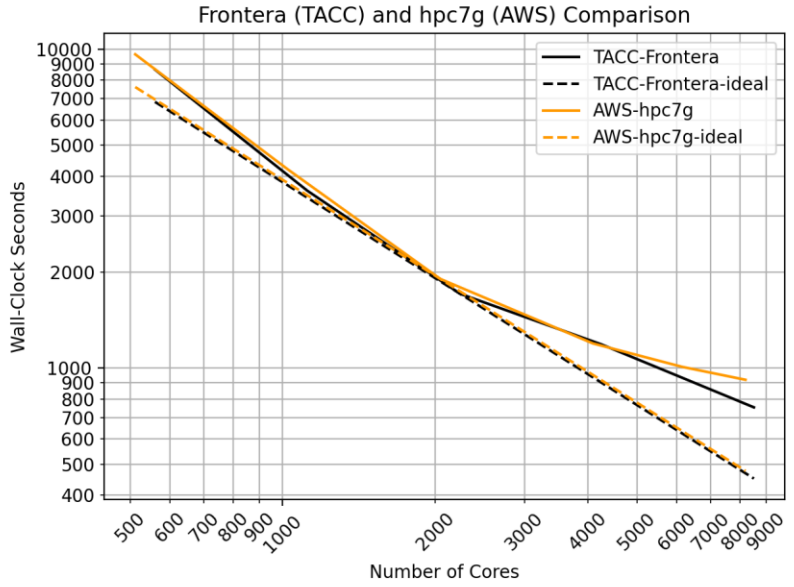
- Allow prediction of total water levels in Coastal Louisiana
  - Aid decisionmakers in having best available information and easily digestible
  - Very conservative estimates are not always useful for emergency response



# GOAL #2

- Flexibility and Ease of Use
  - Run on most Linux systems:
    - HPC Systems
    - Cloud Systems
    - Local Linux machine
    - Containerized Linux
  - Run on multiple architectures:
    - x86_64 – Most common
    - aarch64 – Growing in popularity with excellent performance
  - Minimally Intrusive Installation
    - User should not need to manually install or manage the environment
    - User should be able to have multiple instances running side by side
      - i.e., development, production


Amazon Web Services (AWS) re:Invent HPC Keynote (2022)



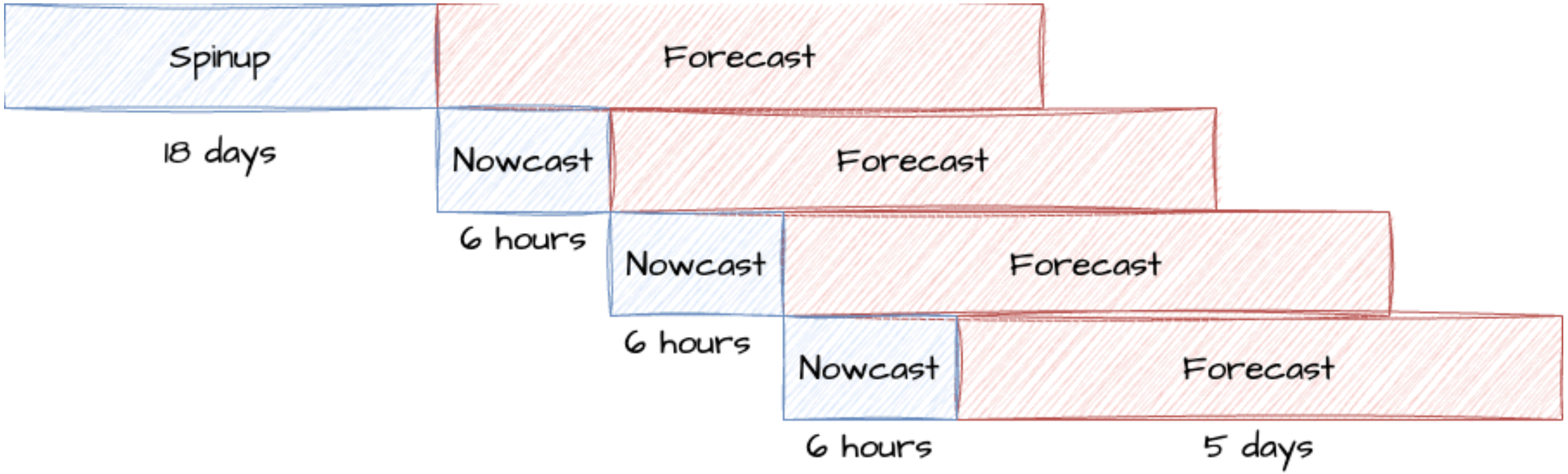
# GOAL #3

- Allow execution of different models and ease of extension
  - Types of models:
    - Native Compiled: We have the source and can build it on the machine where we will run
    - Native Pre-built: We have a precompiled binary which works with the machine
    - Non-Native Pre-built: We don’t have the source or a binary that works on our OS
    - Scripts: Models which are simple enough to be in Python or other scripting languages
  - Why is this necessary?
    - Model geometry reuse → Many models already developed nationwide
    - Source code not always available
      - Some models are provided as a Linux binary only, which may not work on all OS’s
  - Allow users to extend the models available
    - Minimal requirements to add new models to the system

# GOAL #4

- Allow best available external inputs transparent to user
- Types of Met forcing
  - GFS [NOAA]
  - GEFS [NOAA]
  - NAM [NOAA]
  - HRRR (CONUS, Alaska) [NOAA]
  - HWRF [NOAA]
  - HAFS-A, HAFS-B [NOAA]
  - COAMPS-TC [NRL]
  - NHC (GAHM) [NOAA]
  - WPC [NOAA]
- Types of Lateral Inflow Forcing
  - USGS WaterData API
  - River Forecast Center (RFC)

# ANATOMY OF A FORECAST SYSTEM



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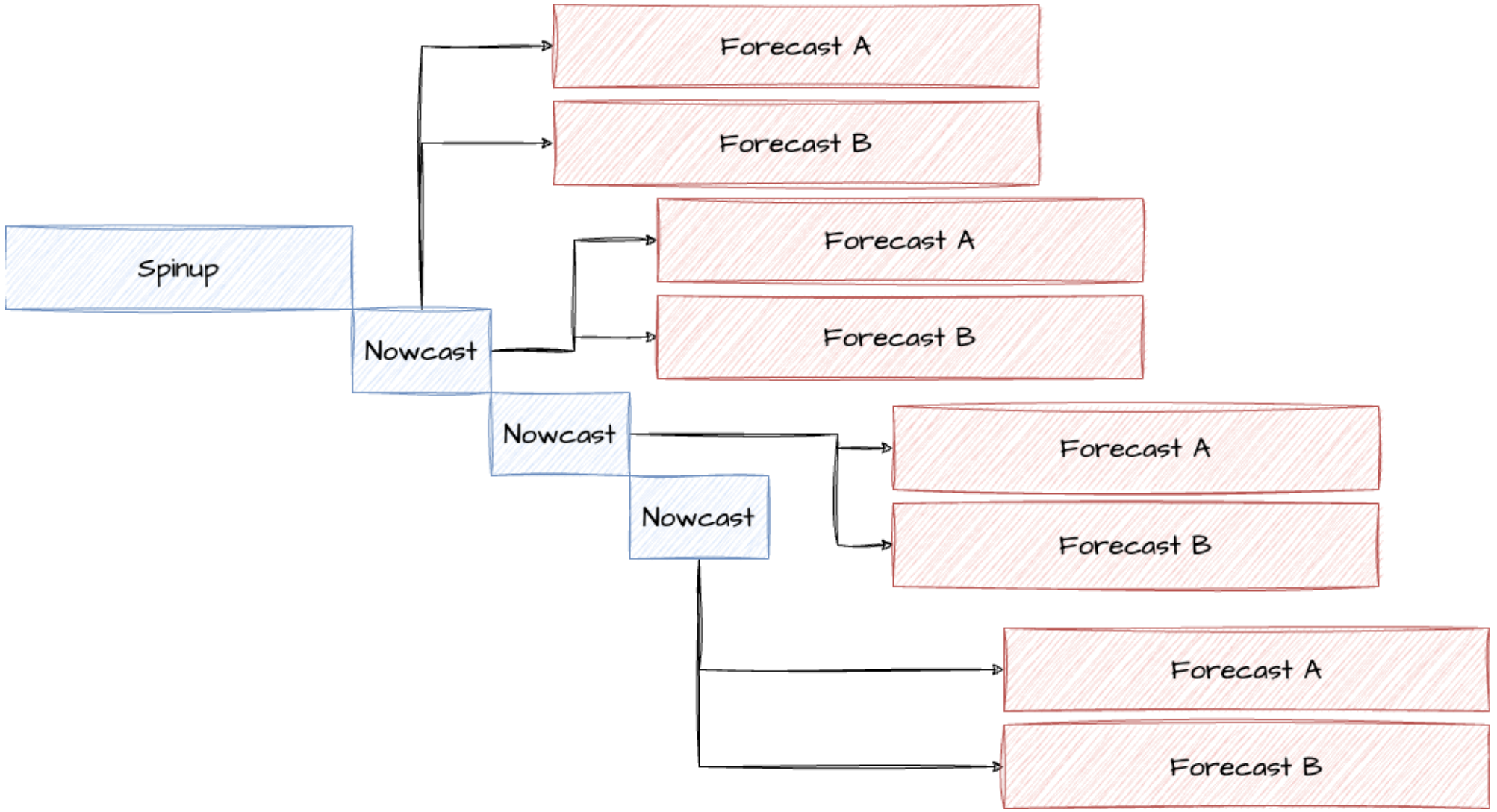

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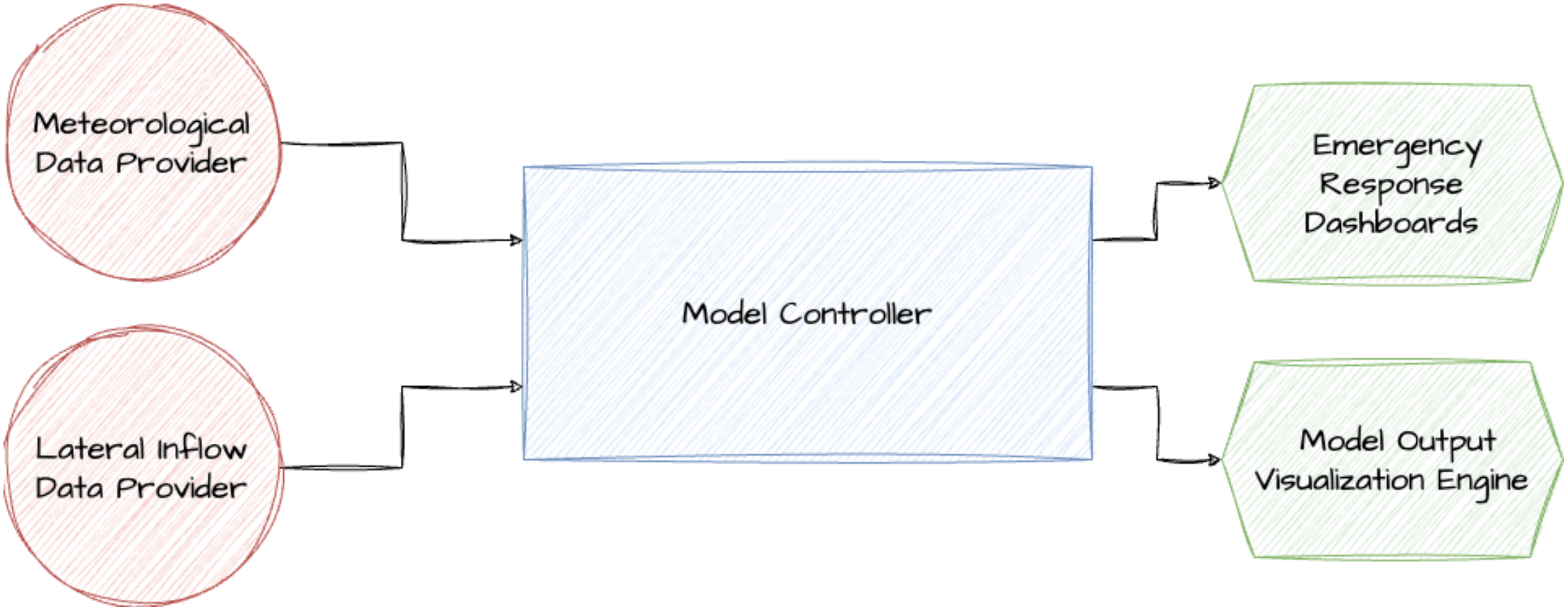
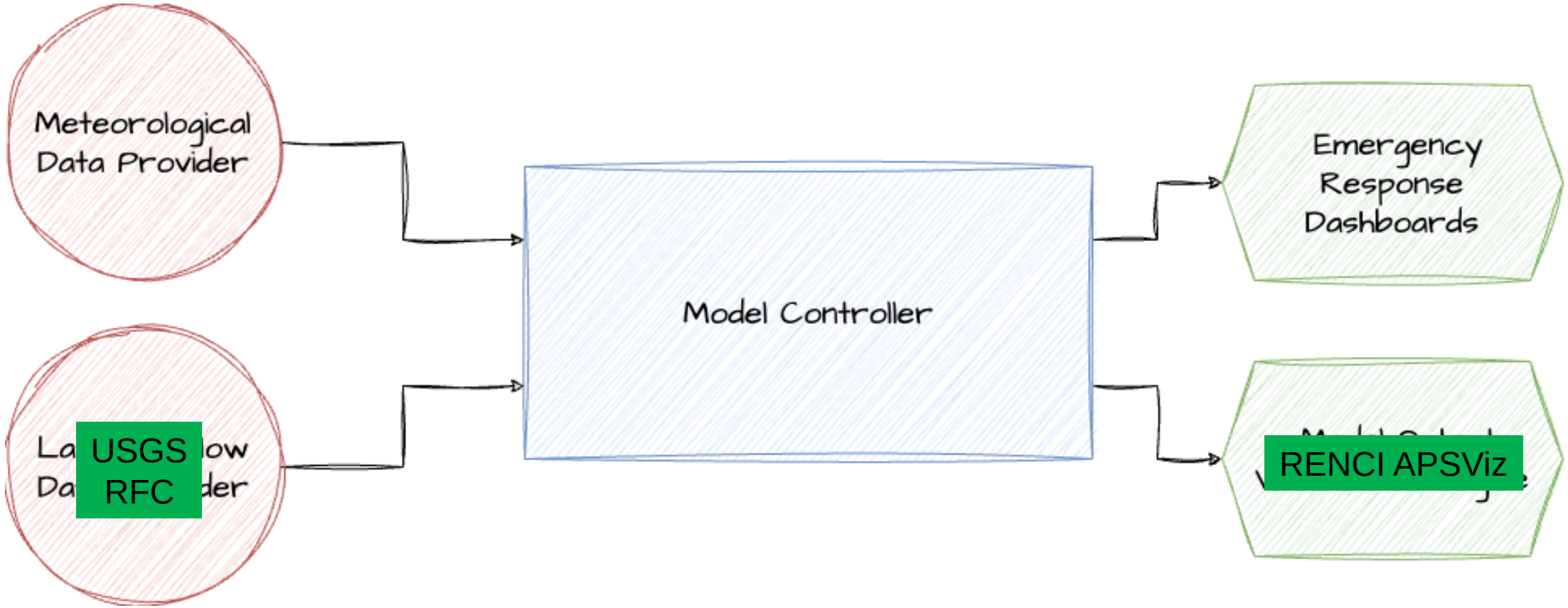


# FloodID: SYSTEM ARCHITECTURE



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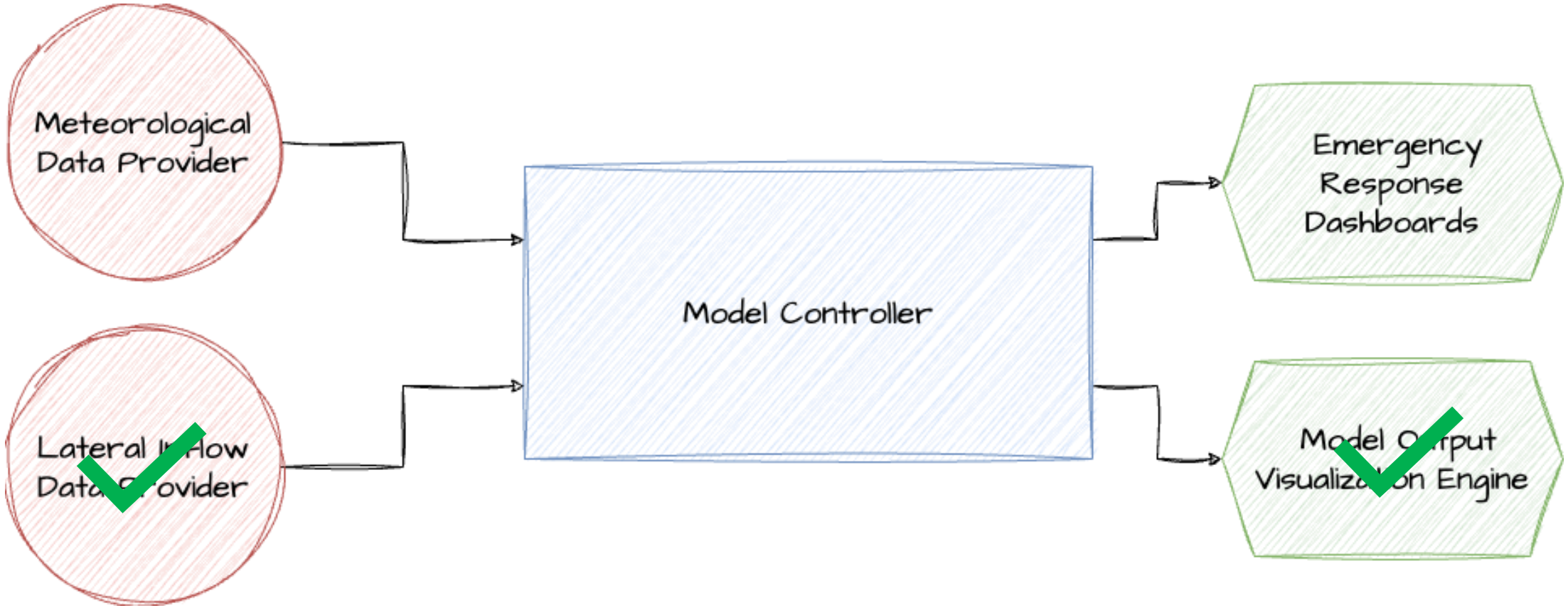
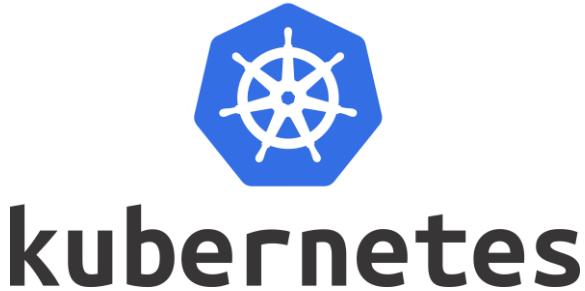
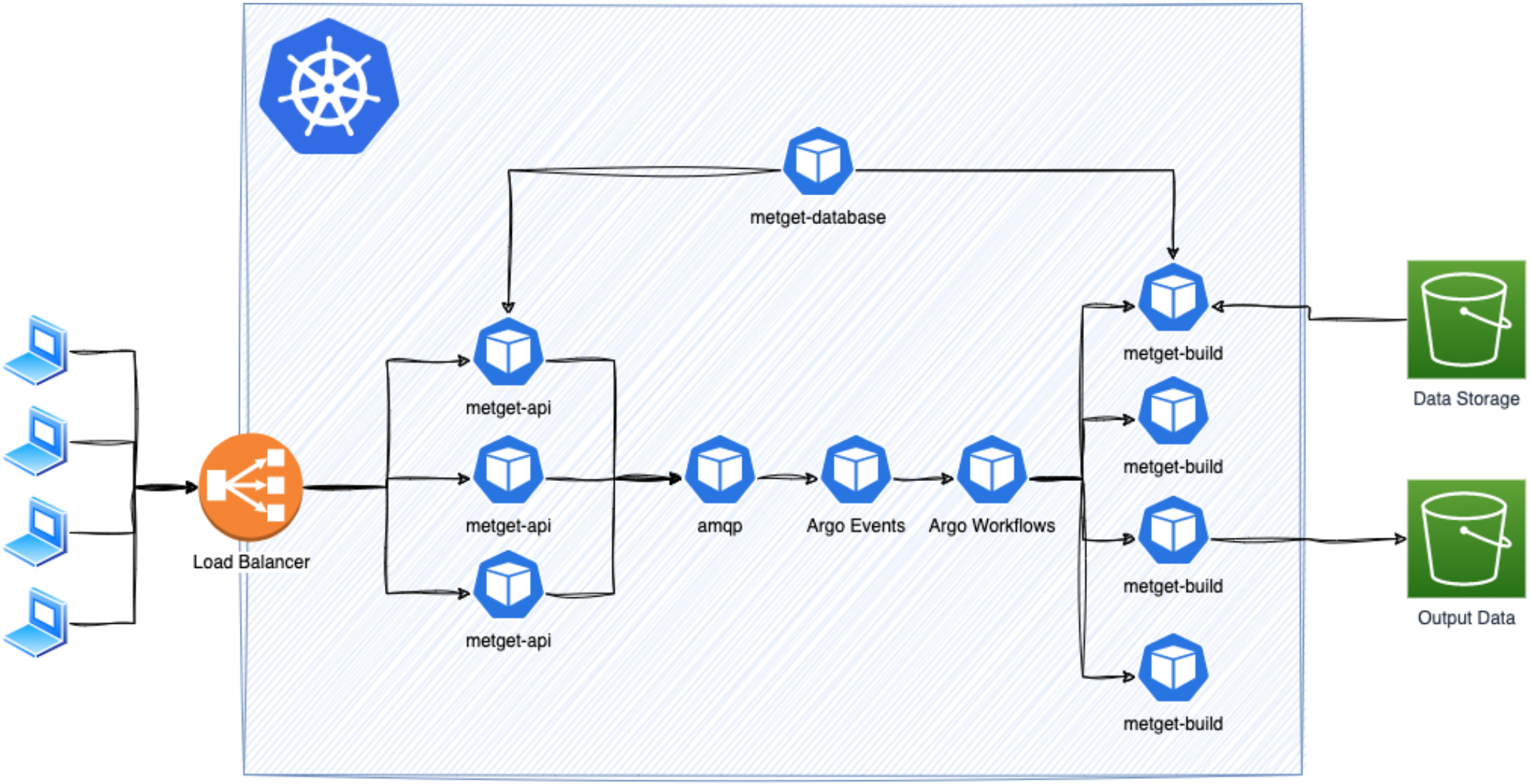


# METGET – OVERVIEW

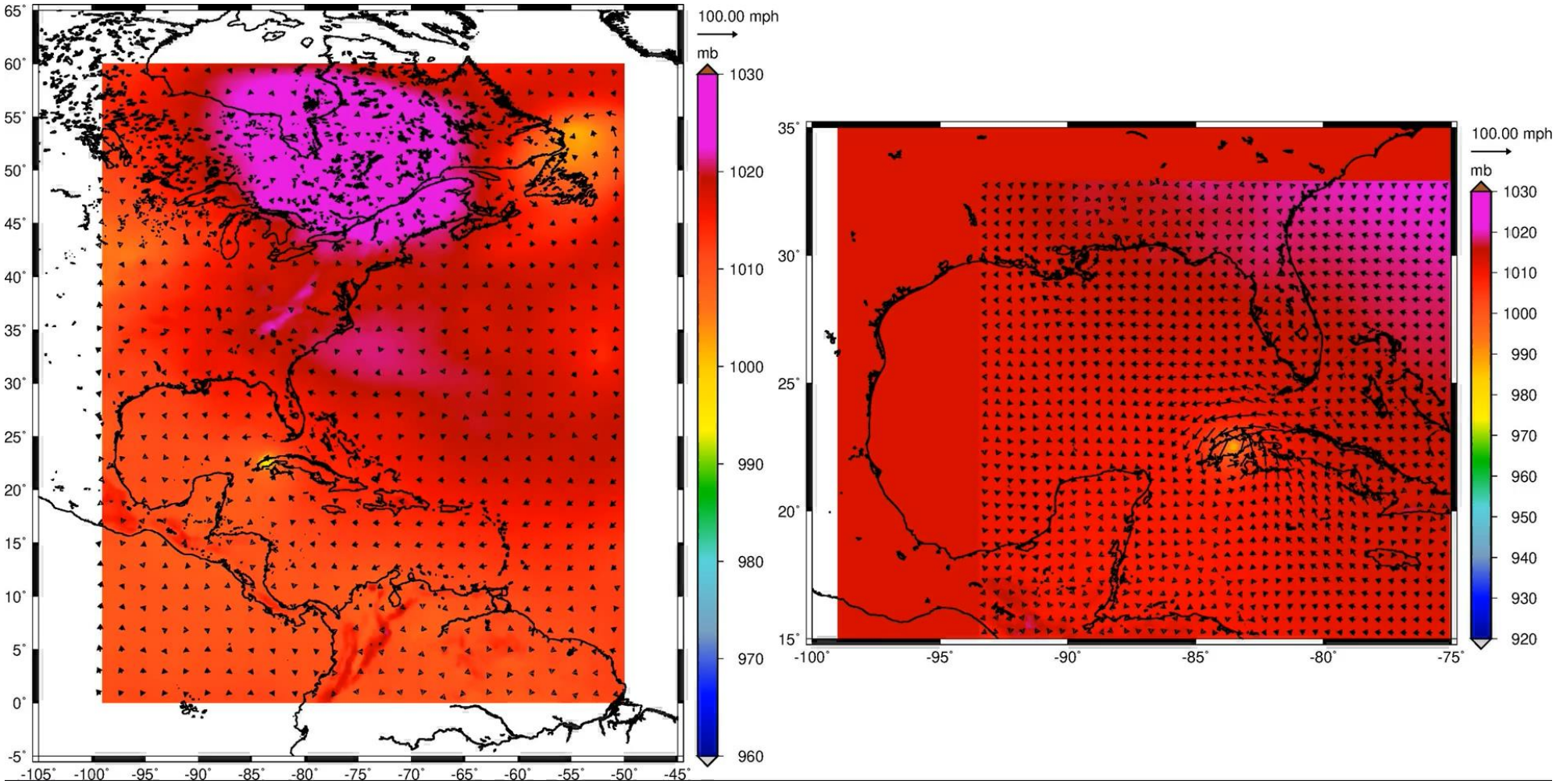
- MetGet initial deployment
  - Service deployed starting in 2021
  - Cloud service which allows modelers to request meteorological data in model native formats from various sources:
    - GFS, GEFS, NAM, NHC, HWRF, COAMPS-TC, HRRR, WPC-QPF
  - Model Formats
    - CF-Compliant netCDF, ADCIRC, Delft3D
  - Model Variables
    - Wind, Pressure, Precipitation, Temperature, Humidity
  - Open-source project
    - https://github.com/waterinstitute/metget
      - Languages: Python, C++
      - Libraries: netCDF, eccodes, sqlalchemy
      - Database: Postgres
      - Frameworks: Kubernetes, Argo, Flask
  - Operational on http://metget.org
    - Contact me for access

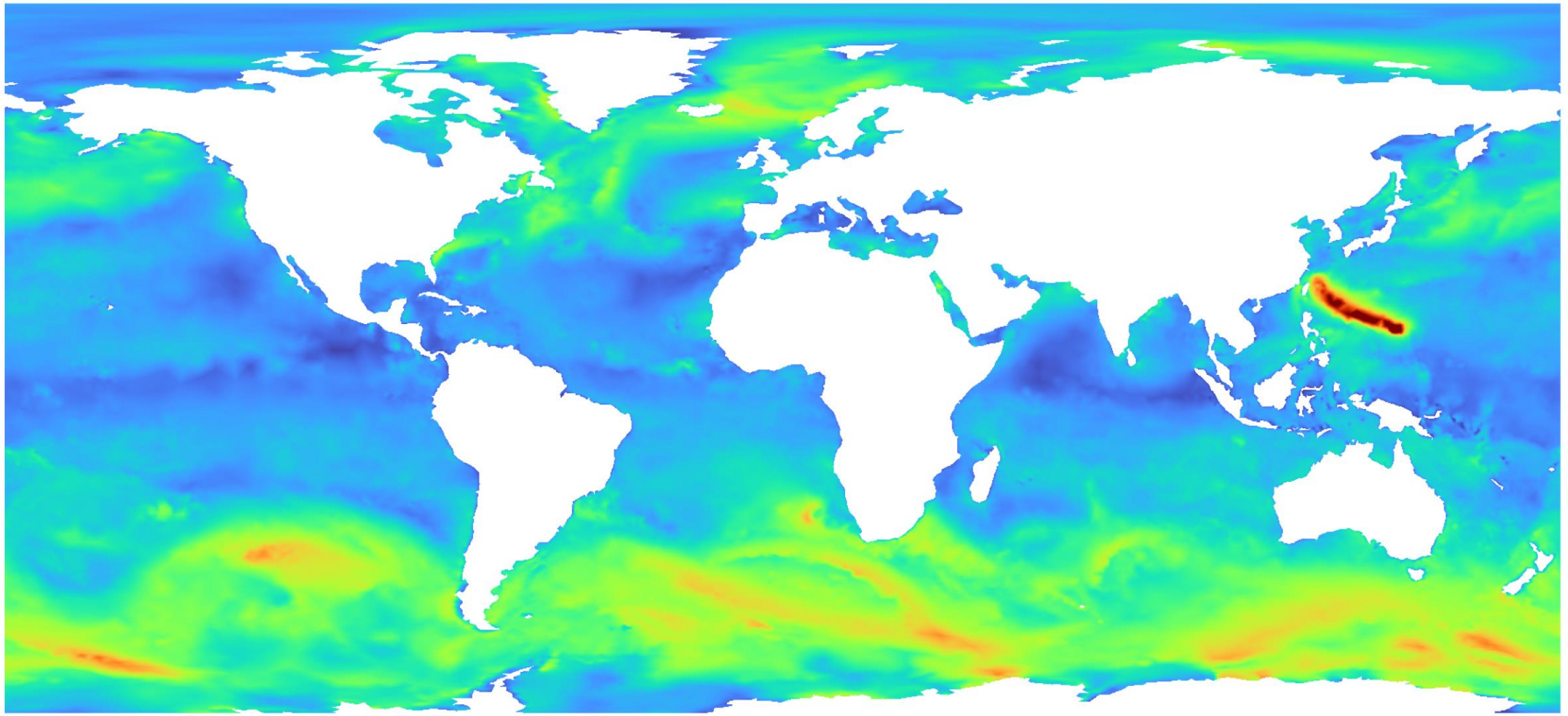

# WORKFLOW DIAGRAM



# MULTI-DOMAIN OUTPUT - HURRICANE IDA, GFS+HWRF



# TYPHOON MAWAR: GFS+HWRF



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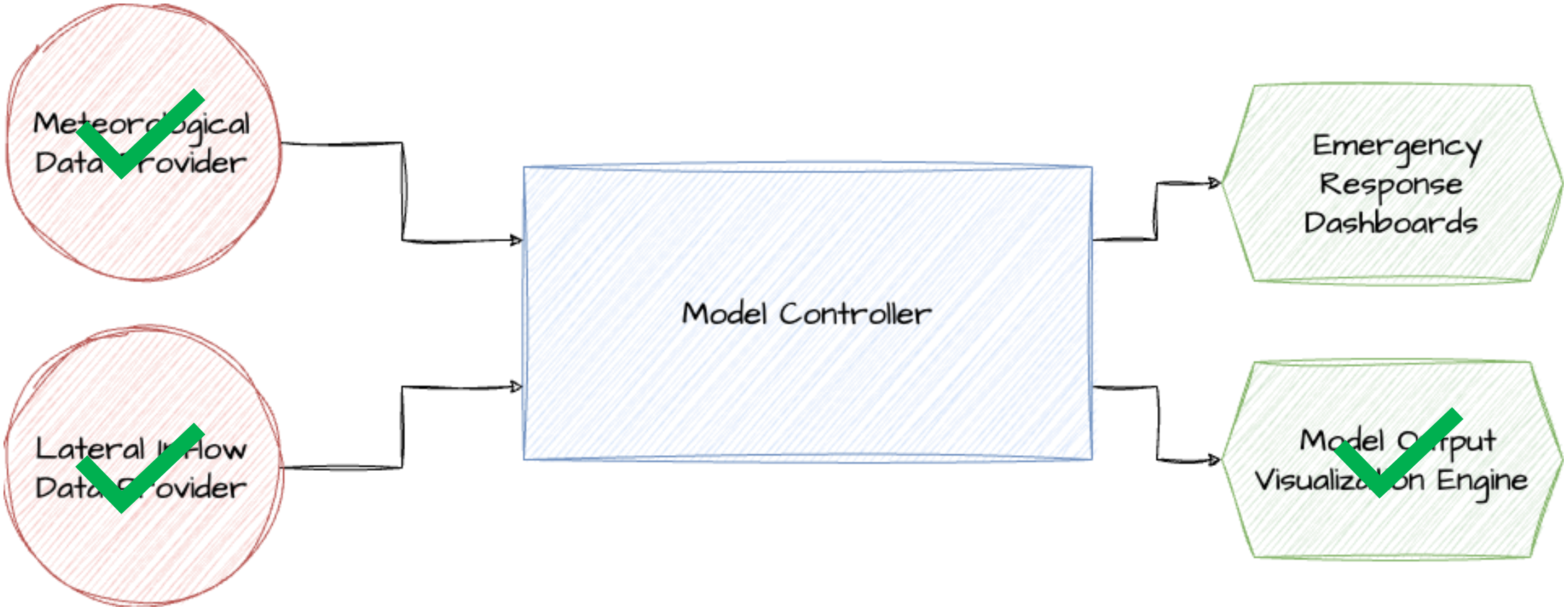

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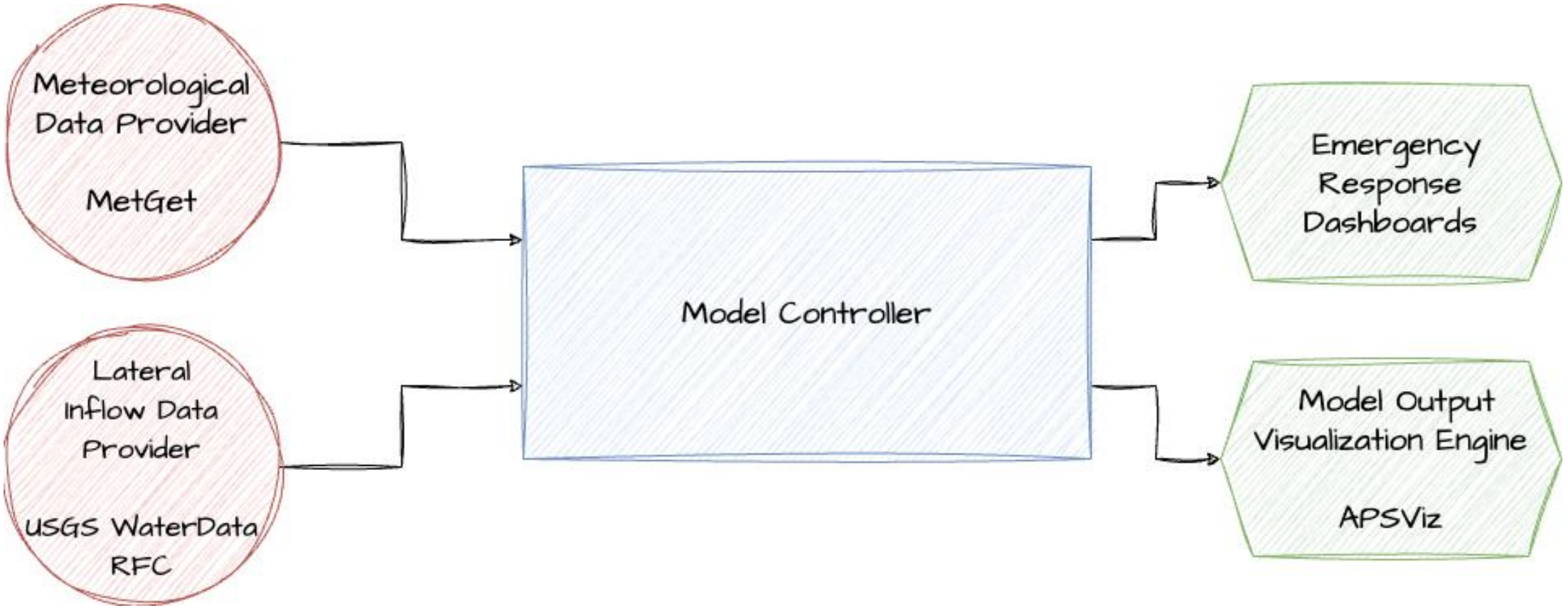

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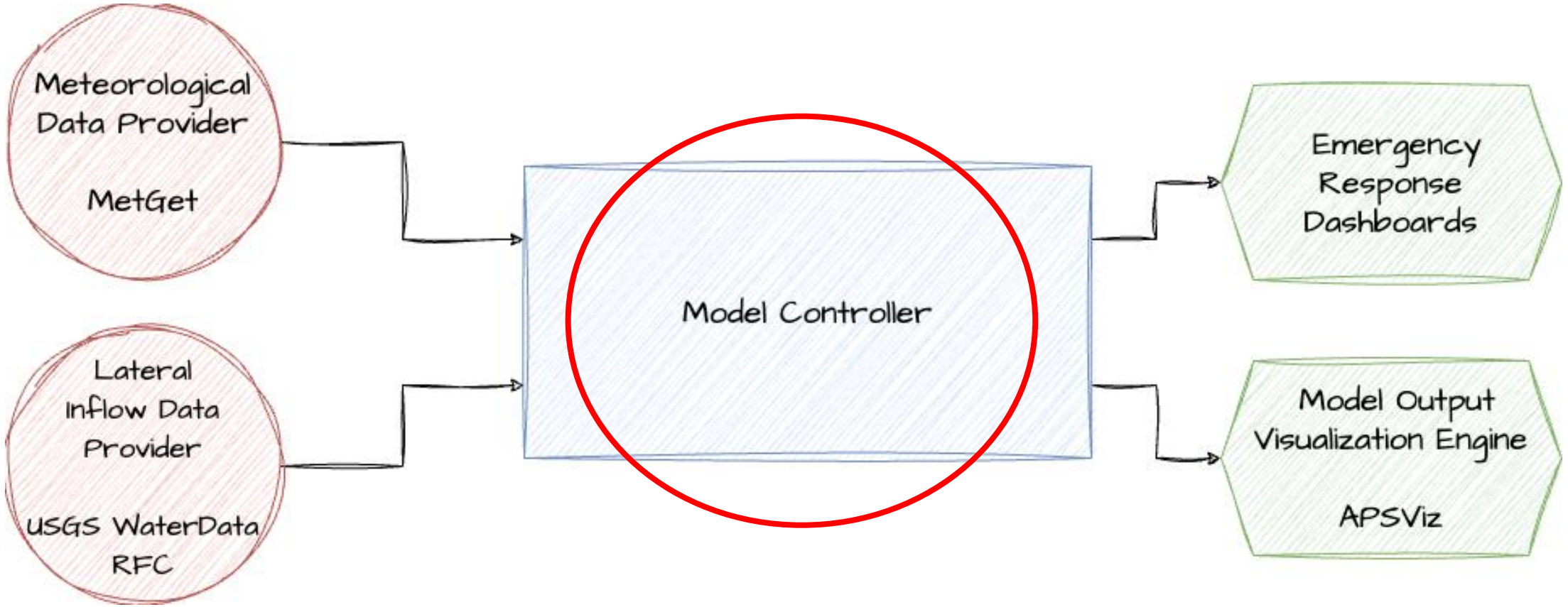
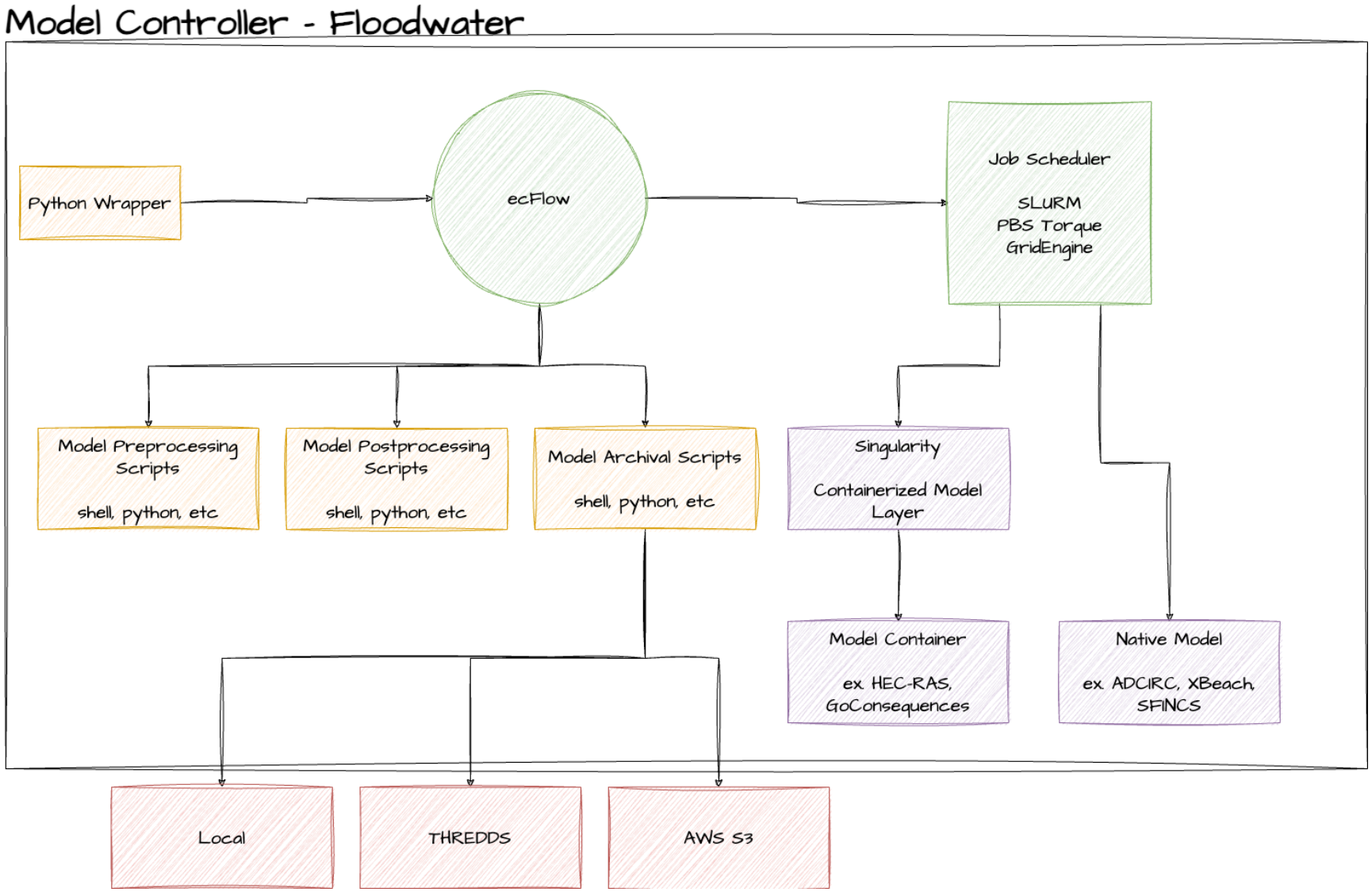


# MODEL CONTROLLER



# FLOODWATER

- Utilizes the ecFlow framework
  - Robust and well tested by other forecasting agencies
  - Allows developers to write python wrapper around system
  - Installable via Anaconda for most systems
    - Buildable from sources for specific architectures (i.e., AWS Graviton)
  - Interreacts well with job schedulers (i.e., SLURM, PBS)
  - Allows users to write and execute code snippets rather than monolithic code
  - The hard stuff is solved:
    - Job triggers, dependencies, tracking, server daemons, etc.
- Floodwater controlled using reusable YAML files
  - Suite, System, Credentials
  - Models are built from an abstract class (model.py)
    - Inheritance → Defined set of overloads user must implement

# EXAMPLE CONFIGURATION FILE

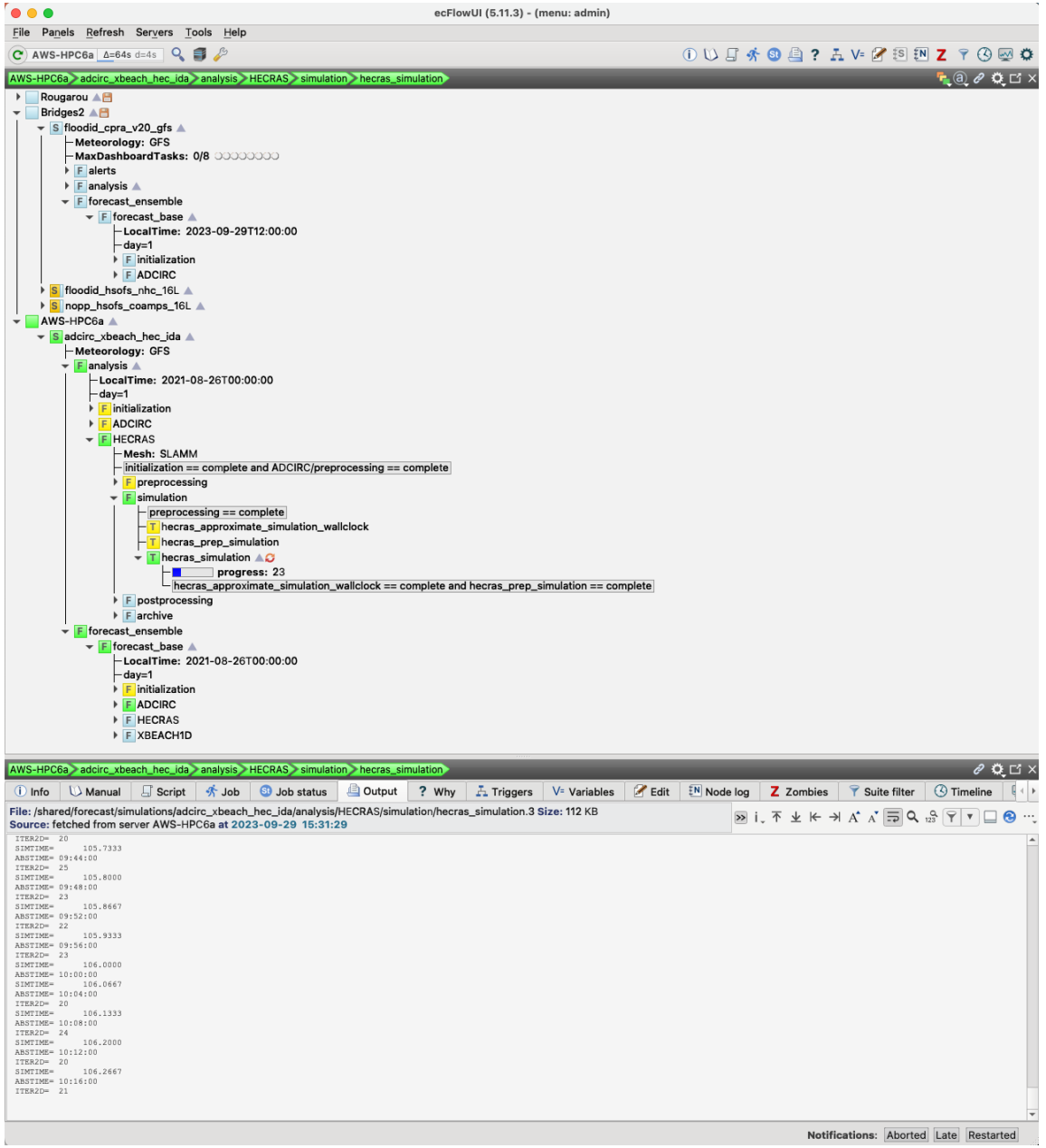
- Set up:
  - ADCIRC Louisiana model with waves
  - HEC-RAS model for coastal Louisiana for compound flooding
  - XBeach-1D model for barrier islands along Mississippi coast
  - Send push alerts to user if jobs fail or are slow
  - Note that the models may be individually enabled/disabled

```yaml
#...Basic configuration information
prefix: adcirc_xbeach_hec_ida
directory: /shared/forecast/simulations
system_config: /shared/forecast/suites/support/system.yaml
credential_file: /shared/forecast/suites/support/credentials.yaml
project_code: waves_2023
#...Start date for first forecast
start: 2021-08-26 00:00
#...Simulation parameters
simulation:
  #...Set the initial water level to 0.2m
  water_level: 0.2
  #...Set the forecast length (days)
  forecast_length: 5
  #...Conduct a simulation using gfs forcing
  meteo: gfs
  #...List of models to enable in the system
  models:
    #...ADCIRC module configuration
    adcirc:
      geometry: /shared/forecast/models/adcirc/cpra_2023_v20a
      waves: true
    #...HEC-RAS module configuration
    hecras:
      geometry: /shared/forecast/models/hecras/slamm
    #...XBeach Module Configuration
    xbeach-1d:
      geometry: /shared/forecast/models/xbeach1d
      transect_selection_method:
        proximity:
          wave_height: 0.5
          x: -88.13843
          y: 30.25047
          radius: 1.0
#...Send push alerts for failed or late jobs
alerts:
  push:
    enabled: true
    interval: 10
```

Note: This YAML is checked/validated at load time to detect critical errors as early as possible

# GUI INTERFACE

- ecFlow provides a GUI interface
  - May be linked to multiple HPC centers
  - Allows simultaneous management of many forecast configurations



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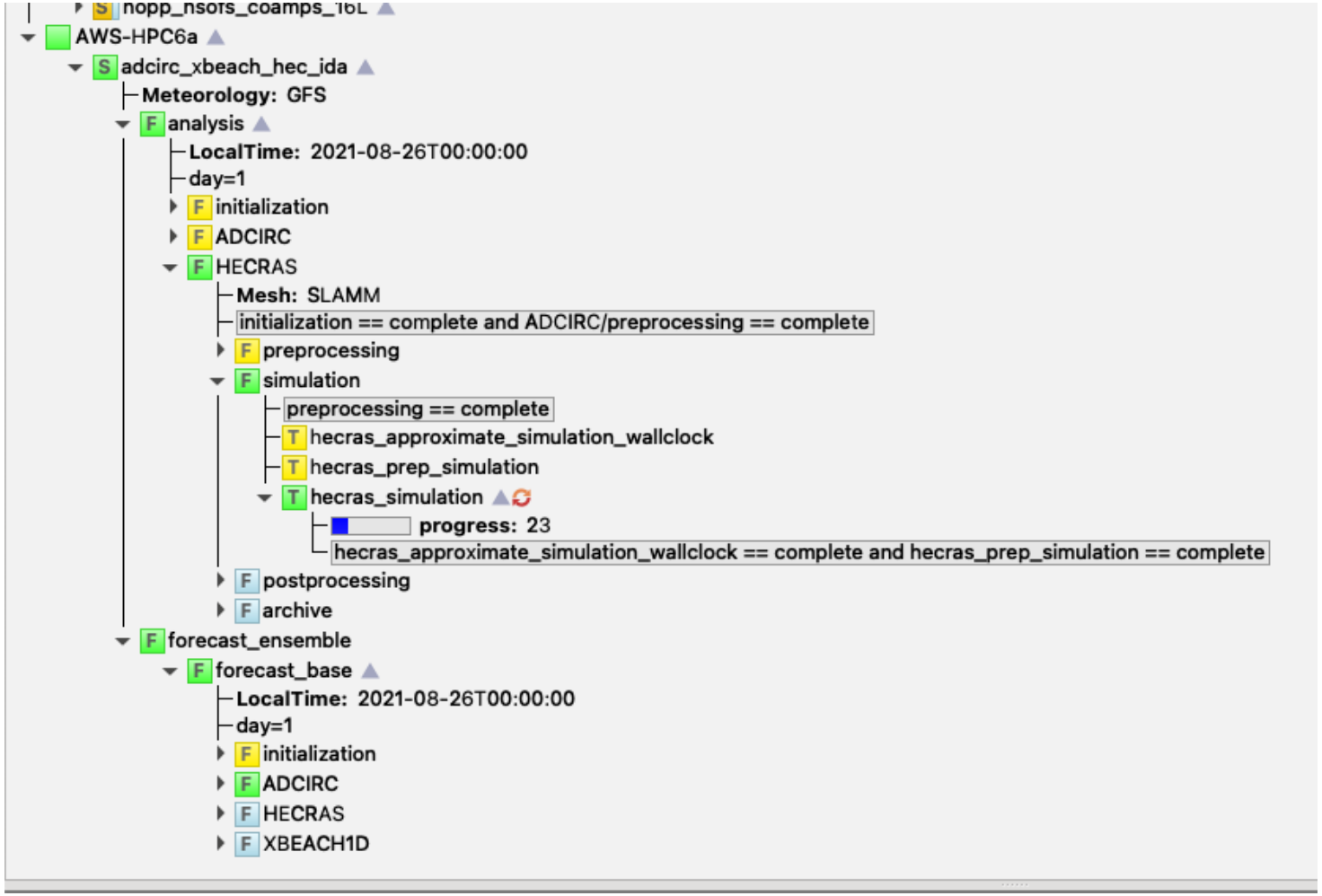
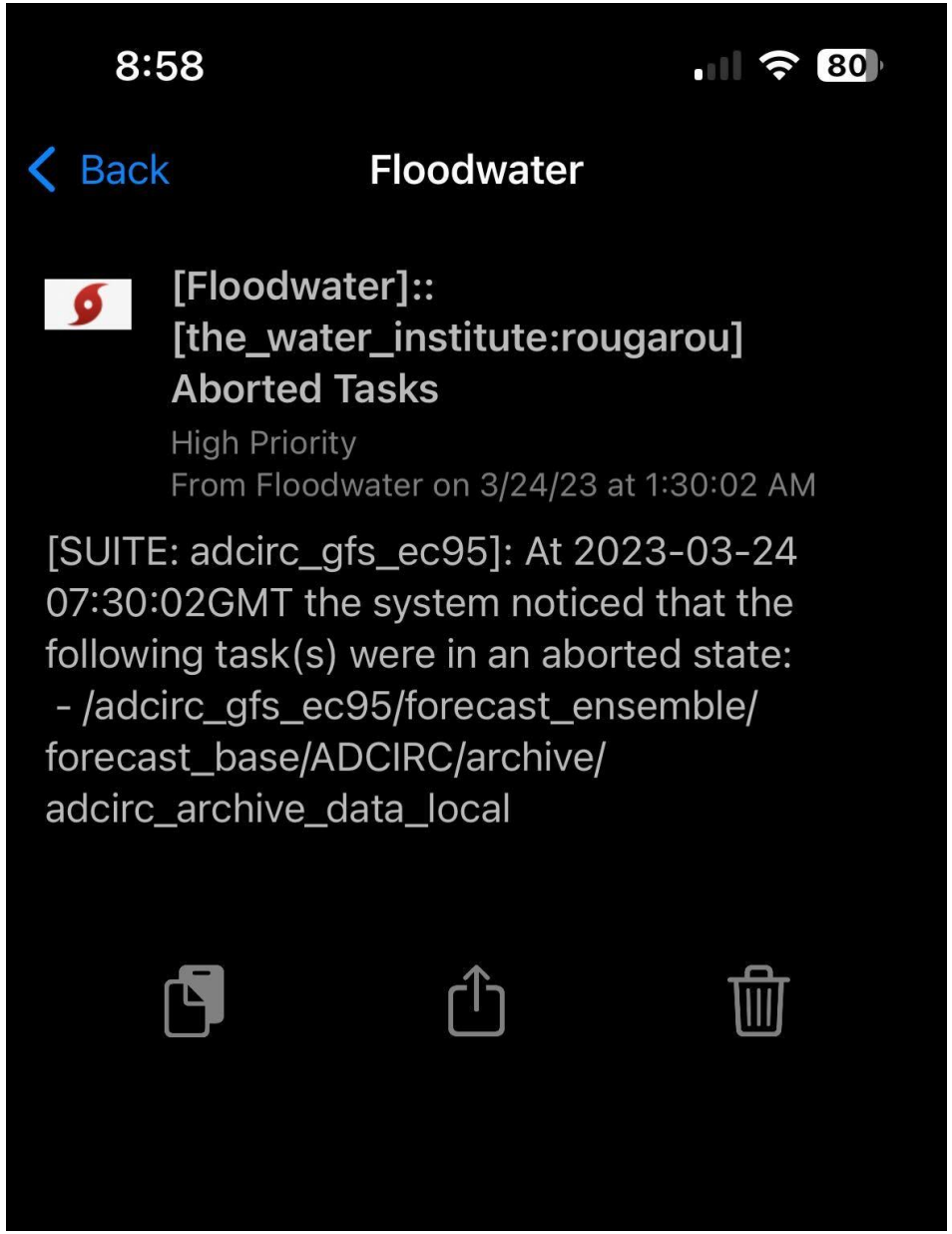


# PUSH ALERTS

- System can send pushes to alert operators of errors or slow-to-complete jobs
- More effective than email since alert is targeted



# FLOODWATER

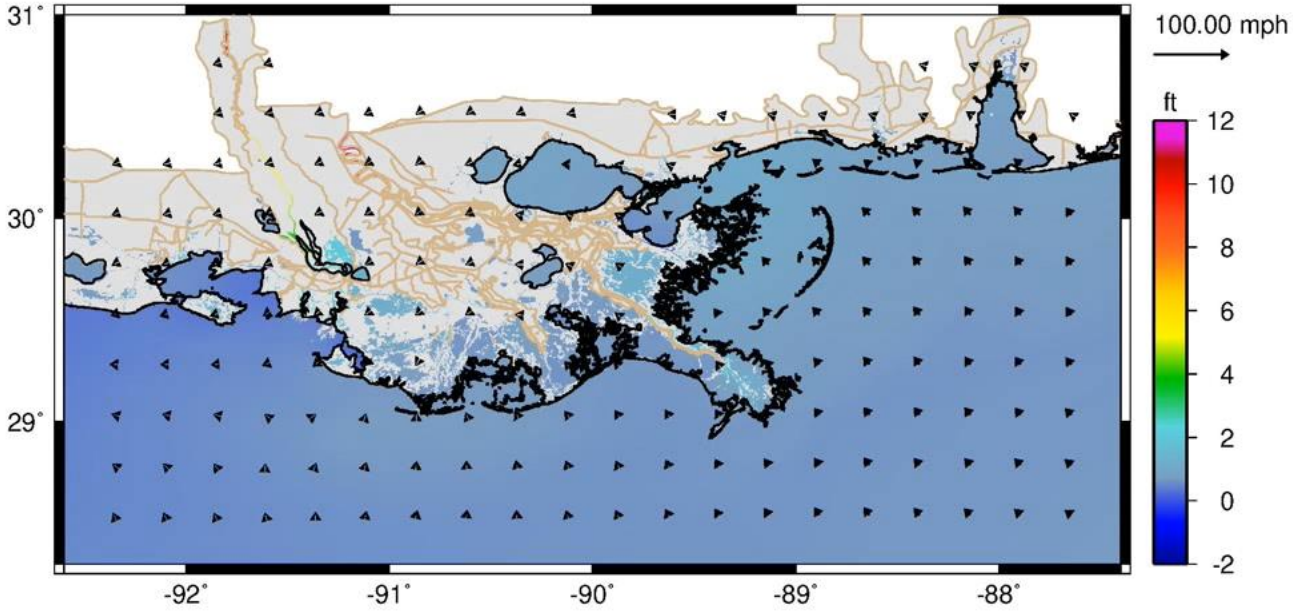
- Code will be open source this winter
  - Currently, documentation being written
  - http://github.com/waterinstitute/floodwater

# EXAMPLE FORECAST SCENARIO

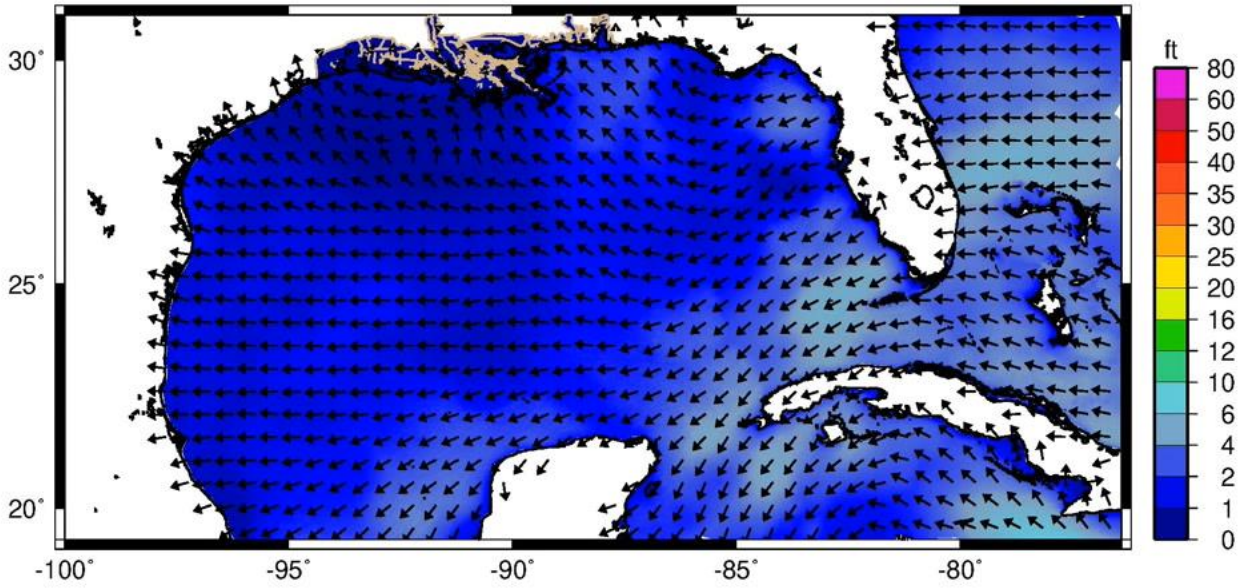
- Forecast simulation of Hurricane Ida
  - ADCIRC → Coastal Water Levels
  - HEC-RAS → Compound Flooding
    - Forced with ADCIRC water level at boundary
  - XBeach-1D → Barrier Island Morphology
    - Forced with ADCIRC water levels and SWAN waves
    - Barrier island transects near Mississippi/Alabama shoreline
  - Forced with NOAA GFS
    - Additional options for Met: HWRF, HRRR, or NHC-GAHM
    - GFS issued every 6 hours
- Forecast Runtimes (5-day forecast)
  - ADCIRC+SWAN: 45 minutes, 1024 cores @ AWS EC2
  - HEC-RAS: 10 minutes, 48 cores @ AWS EC2
  - XBeach1D: Max/Min: 0.5,1.5 hours, 1-core/transect

# ADCIRC

Water Level and Wind Vector

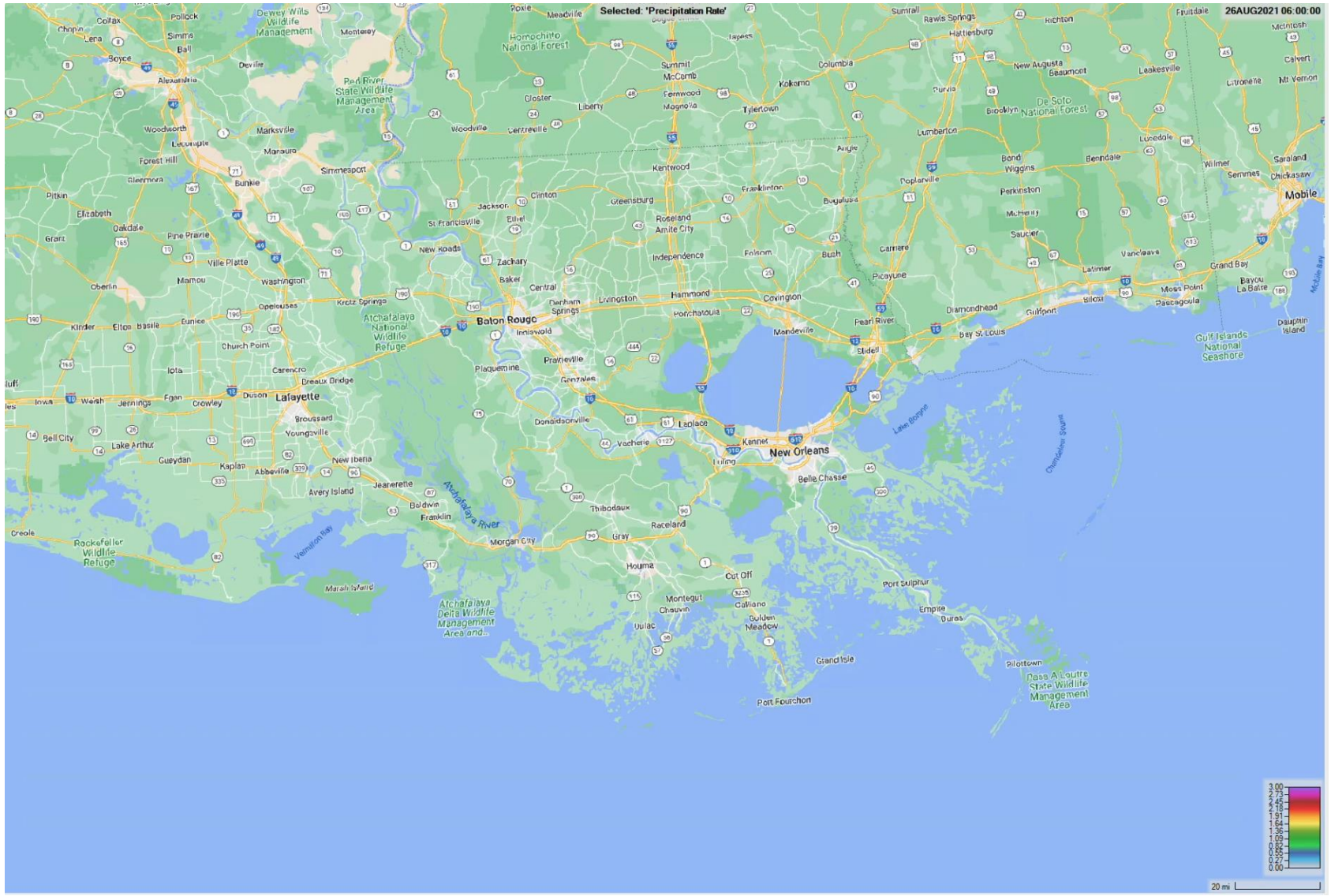



Significant Wave Height and Wave Direction



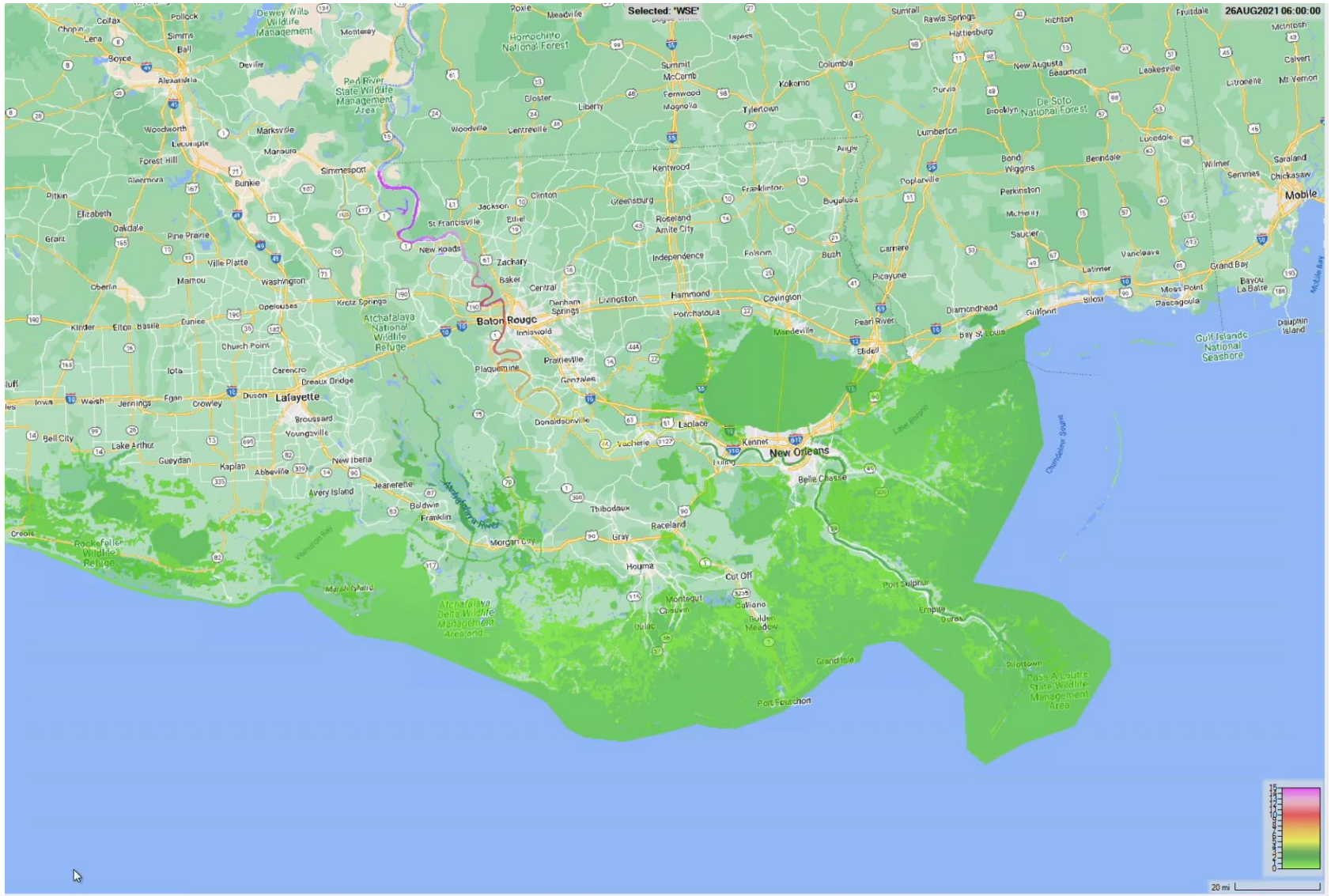

Forecast Initialized 2021-08-26 06:00

# HEC-RAS – PRECIPITATION RATE



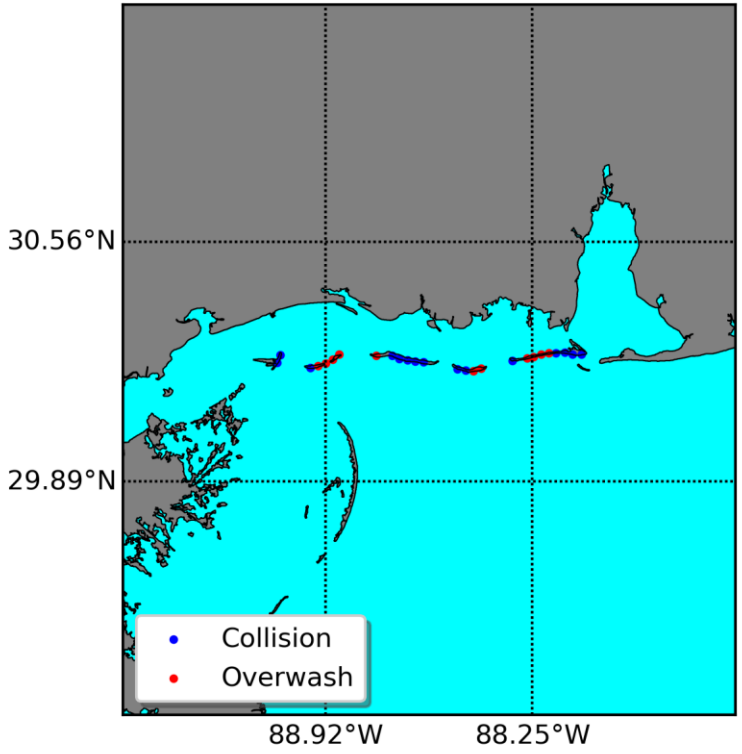

Forecast Initialized 2021-08-26 06:00

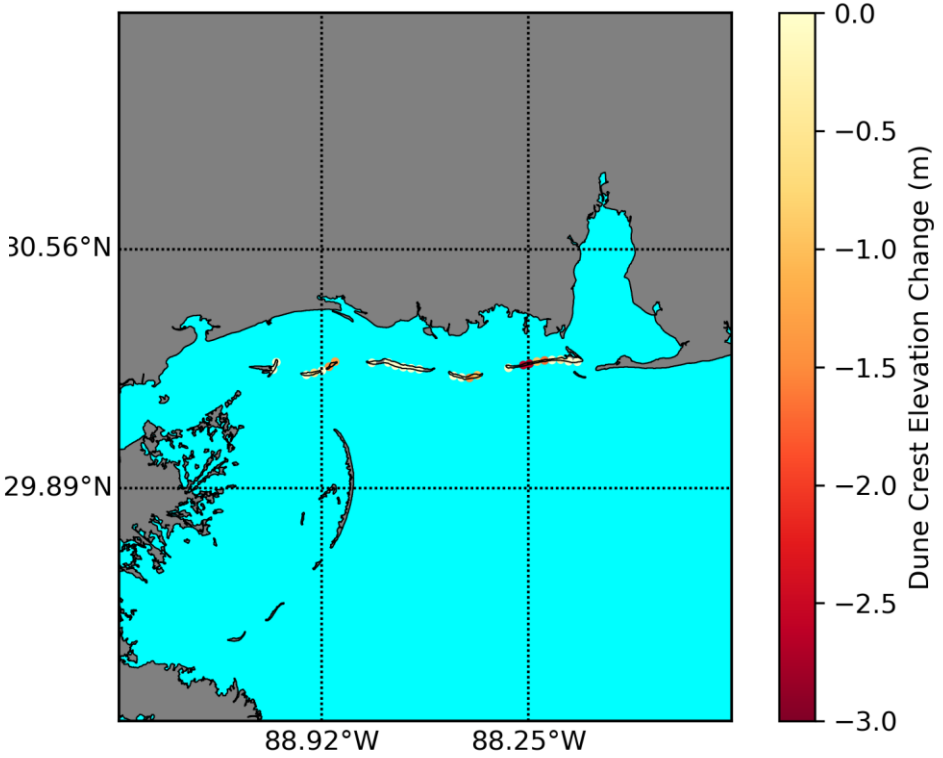
# HEC-RAS – WATER LEVEL

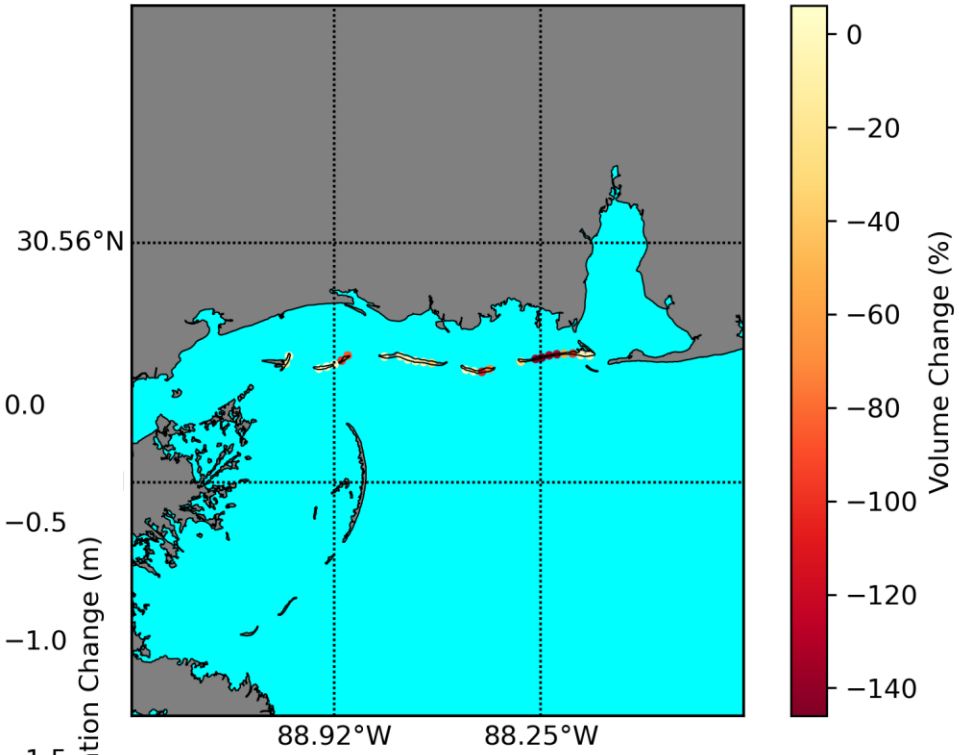



Forecast Initialized 2021-08-26 06:00

# XBEACH-1D SUMMARY MAPS

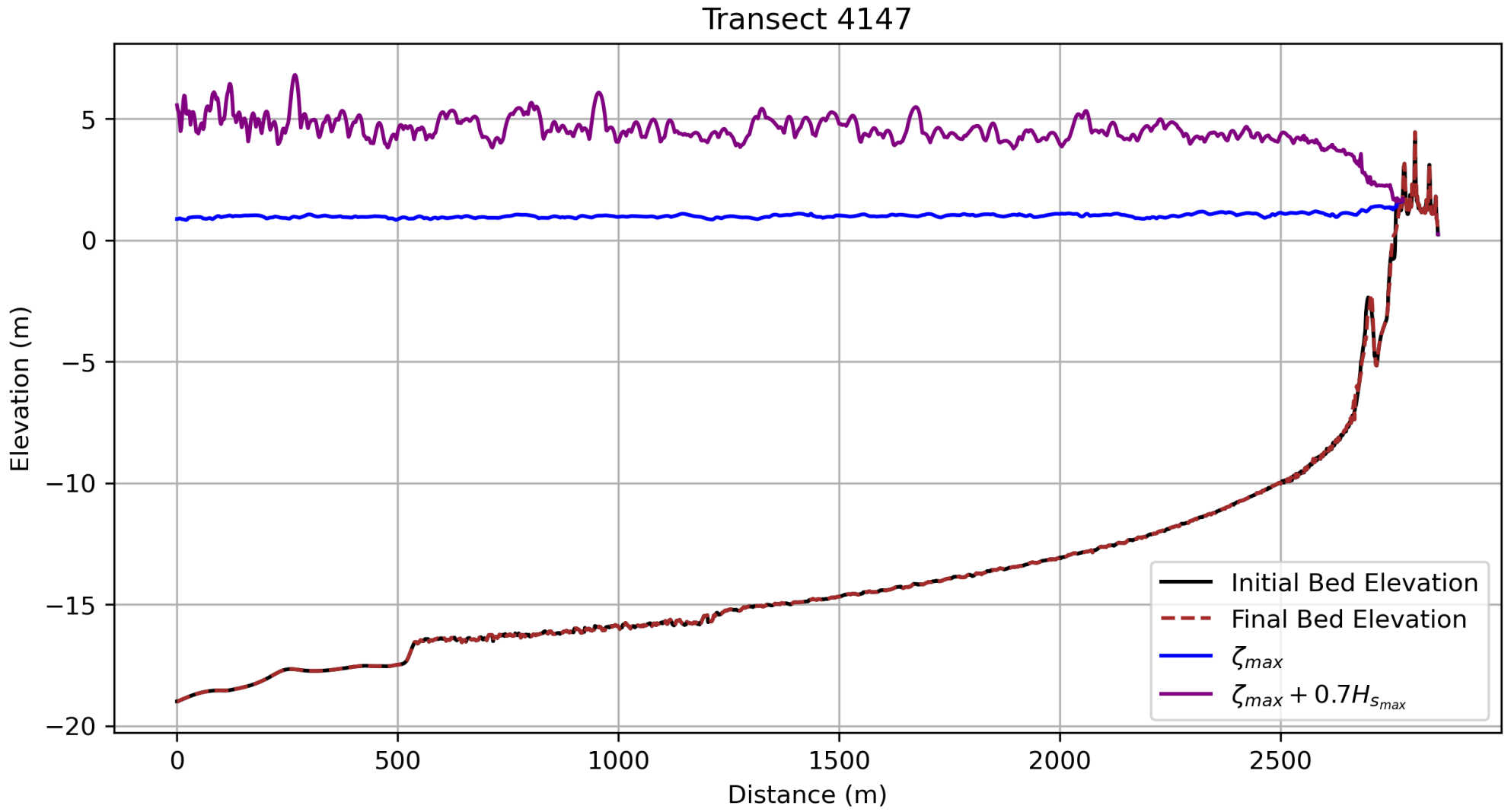



Forecast Initialized 2021-08-26 06

# XBEACH-1D PROFILES



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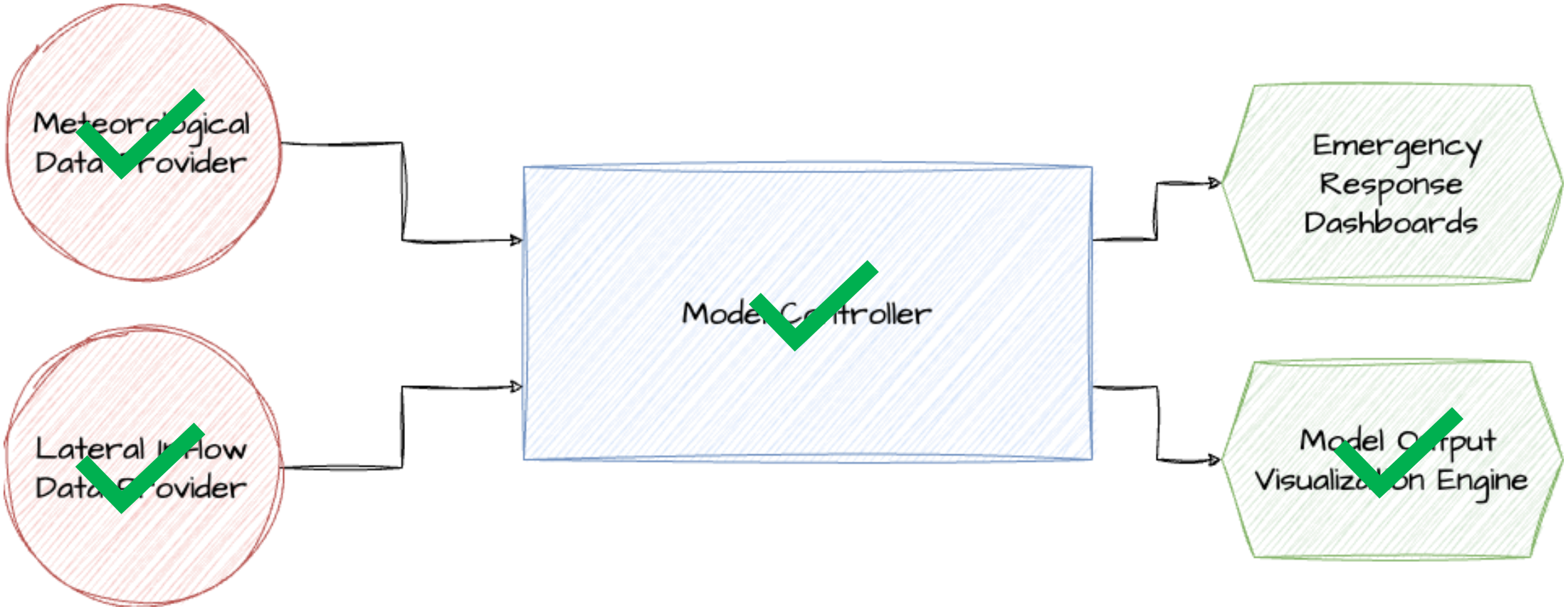
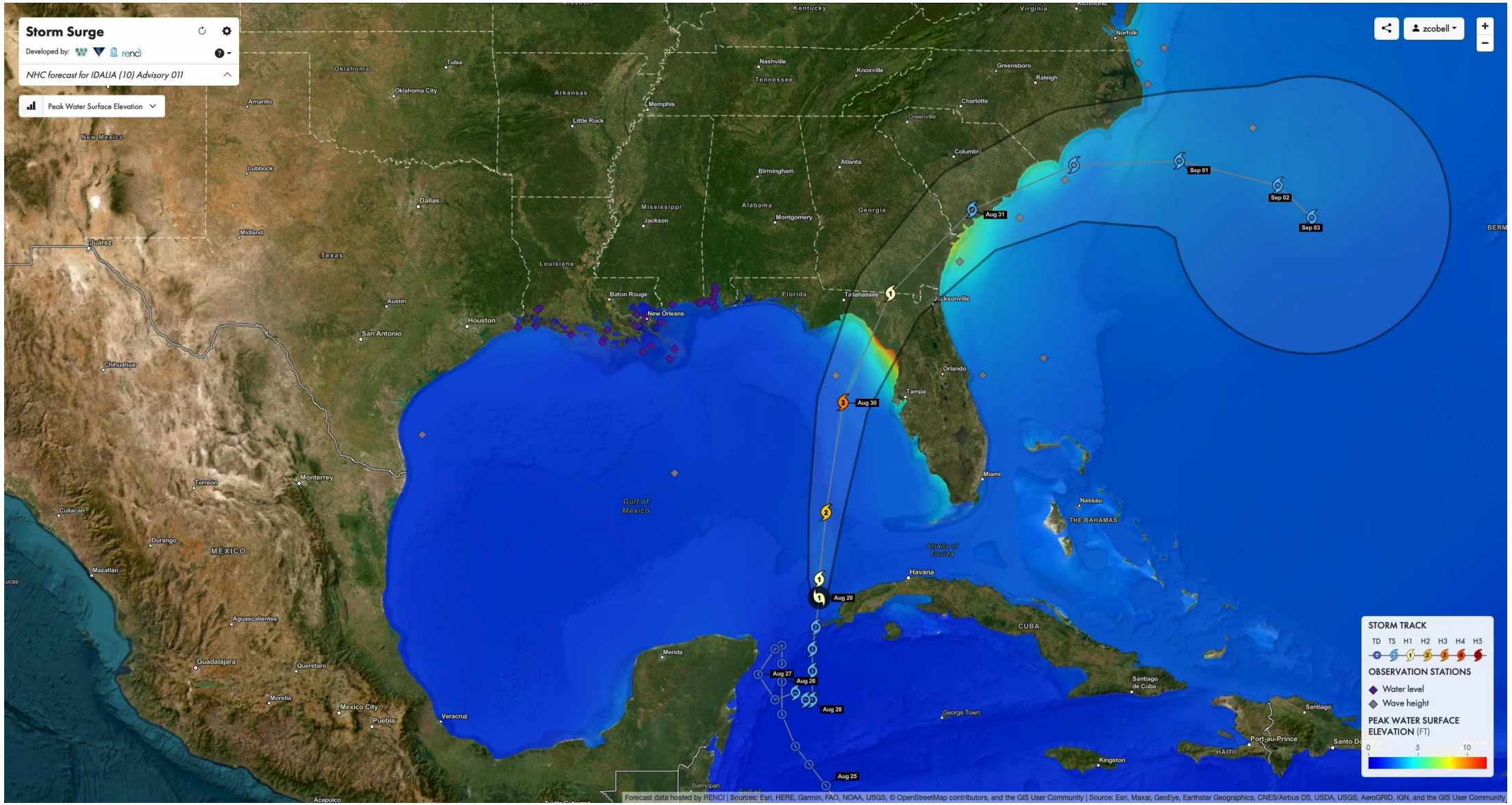


# EMERGENCY MANAGEMENT DASHBOARDS EXAMPLE

## HURRICANE IDALIA



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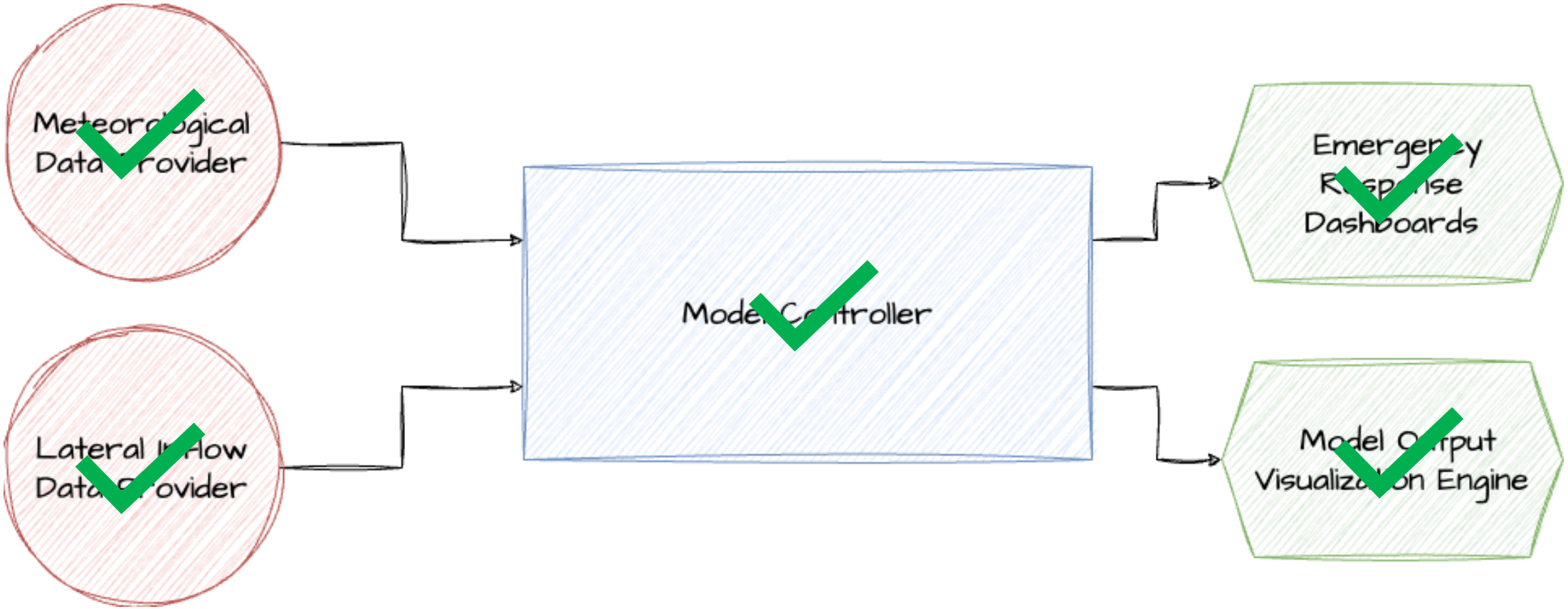
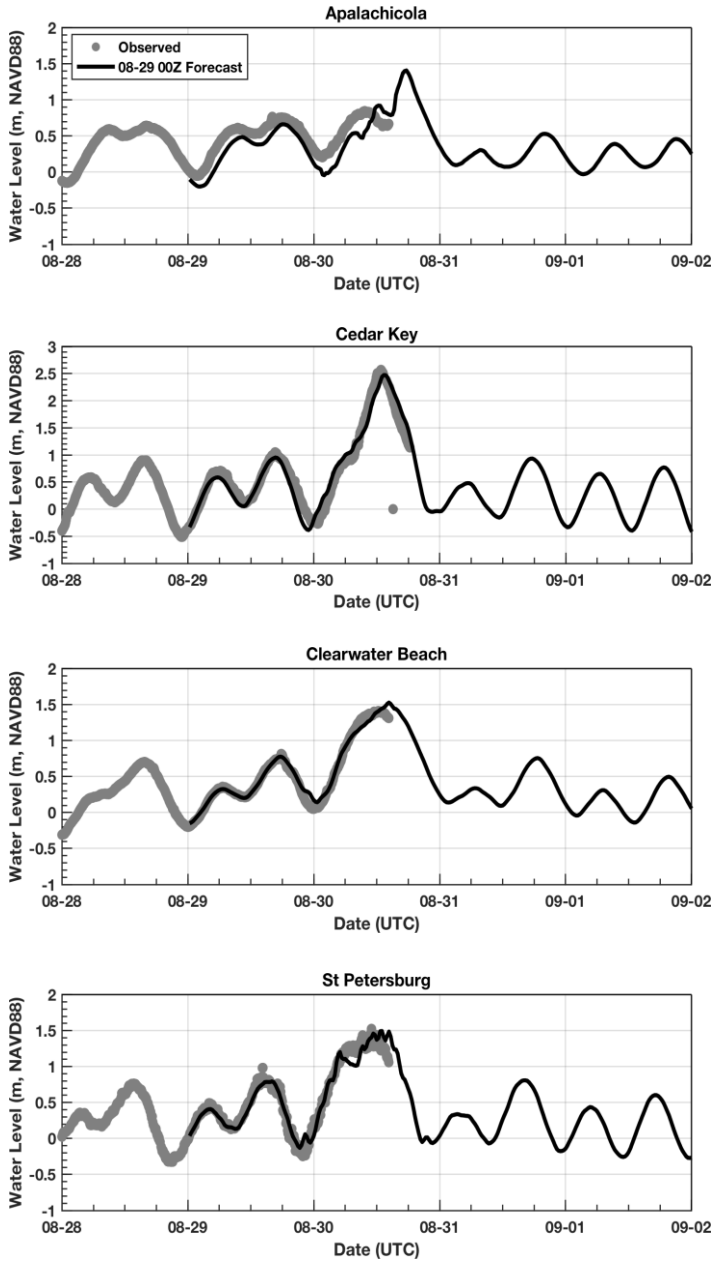


# WHAT'S NEXT?

- Modeling system operational for 2 years
- Continue refinement and learning from operational experience
- Integration of additional models
- Surrogate Modeling
  - i.e., CHIPS (USACE), in-house methods
- Probabilistic/Ensemble Modeling
  - Generate storm track ensembles
    - NCEP models
    - NHC track based methods
      - i.e., Smith 2017, Pringle 2023
  - Rainfall ensembles
    - NCEP models
    - Villarini et al, etc.




Hurricane Idalia, Initialized 2023-08-29 00Z


# QUESTIONS?

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