Fast Forecasting of Hurricane Waves and Inundation in Hawaii

Jane McKee Smith ERDC
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Interdepartmental Hurricane Conference 6 March 2012

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Motivation

- **Island communities are vulnerable to storms**
  - Nowhere to evacuate
  - Infrastructure within hazard zone
- **Islands Task Force Report (2001)**
  - Mainland modeling technology largely unsuitable for islands
- **Unique/Important Island Features & Physics**
  - Steep slopes
  - Reef flat dynamics (breaking, ponding, wave reformation)
  - Reef roughness
  - Importance of waves
  - Growth of infragravity waves

SWIMS Fast Forecasting System

- **Pre-run storms with high-fidelity models**
  - ADCIRC (water levels)
  - unSWAN (waves)
  - BOUSS-1D (runup)
- **Create database of response**
- **Develop surrogate model to forecast inundation**
  - Deterministic
  - Probabilistic
- **Hurricane Evacuation Studies Mass Management System (MMS)**
  - Interface for Emergency Managers

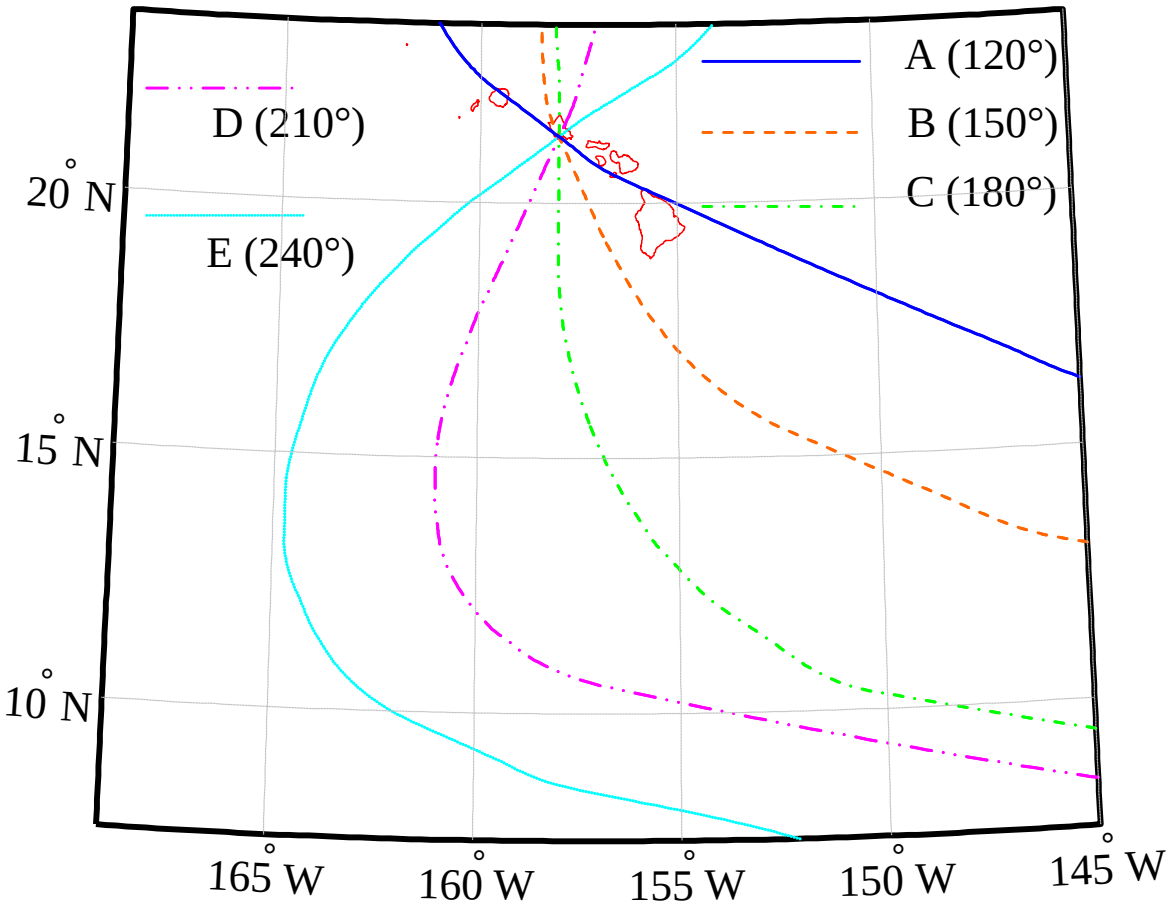
Storm Selection

- **Cat 4 storm on Oahu**
  - Severe damage to air & sea ports
  - Island-wide power and communications outages (1 month or longer)
  - 80% of homes destroyed
  - 650,000 people seeking shelter
- **Since 1950:**
  - Nina (1957)
  - Dot (1959)
  - Iwa (1982)
  - Estelle (1986)
  - Iniki (1992)

Hurricane Iniki

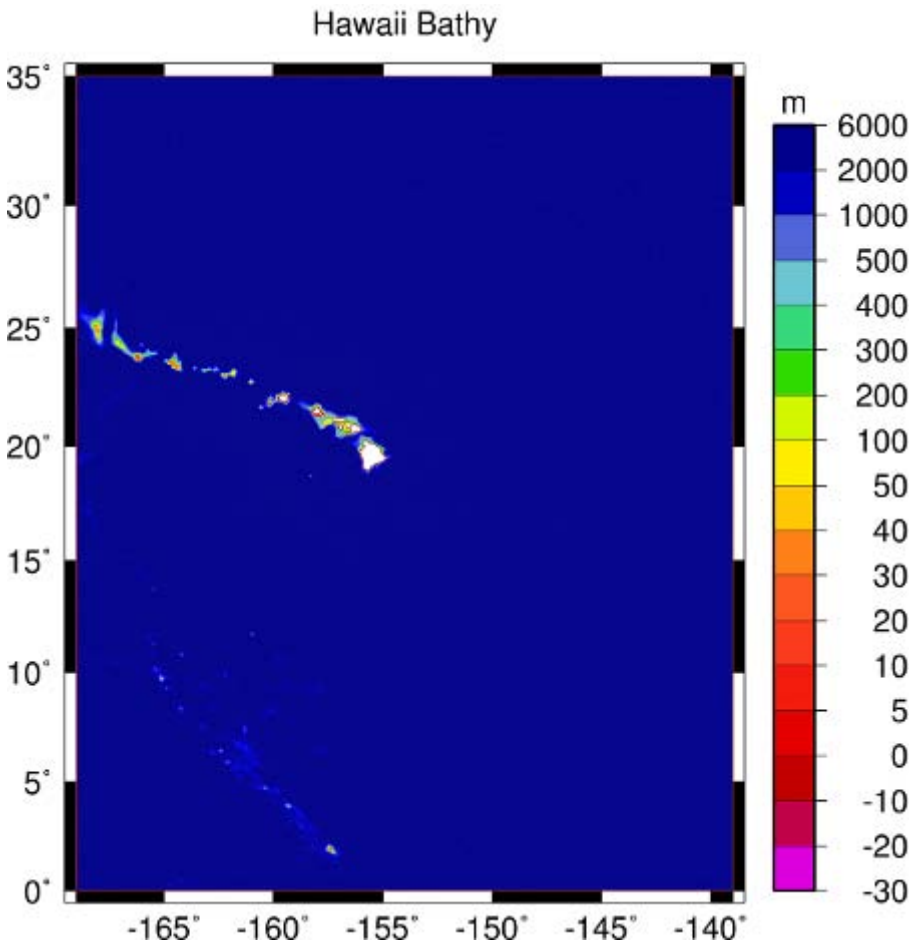
Storm Selection: Tracks

- Five base storm tracks from hurricane climatology (NWS)
- Tracks shifted to give 28 landfall locations
- Tracks and parameters varied to give a matrix of potential storms (bound most possible landfall scenarios)



Grid Domain

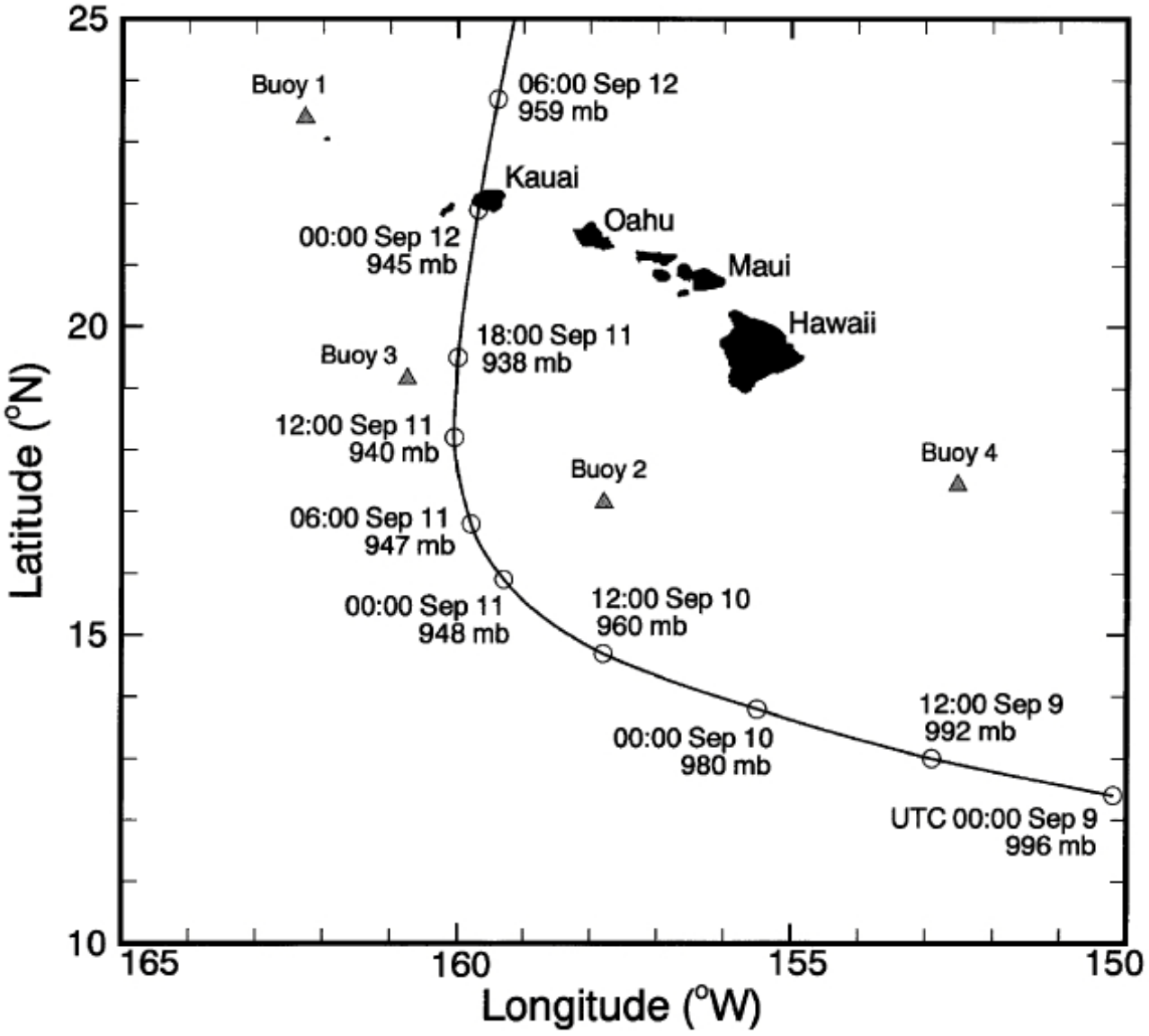
- Hawaiian Islands and north central Pacific Ocean
- Grid resolution
  - 30 m on land and in the nearshore
  - 5000 m in deep water
- Incorporates high resolution features, channels, coral reefs and wave breaking zones
- 1,590,637 nodes
- 3,527,785 elements



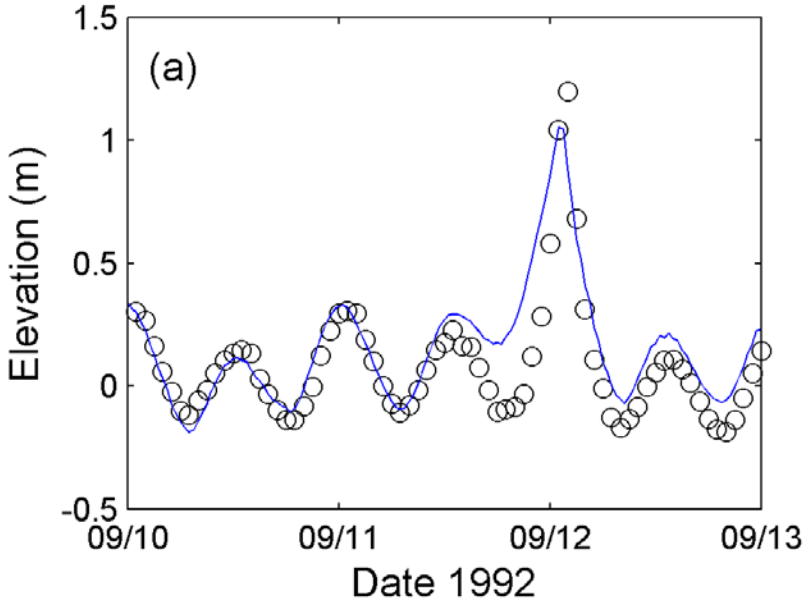
SWAN+ADCIRC Model – Coupled Waves and Currents on Unstructured Grids

- ADCIRC solves for water surface elevations and currents in two dimensions
- SWAN solves the wave action density and is a phase-averaged wave model with wave energy represented by a spectrum
- ADCIRC passes water elevation and currents to SWAN
- SWAN passes wave radiation stresses to ADCIRC
- Models run in parallel on the same grid

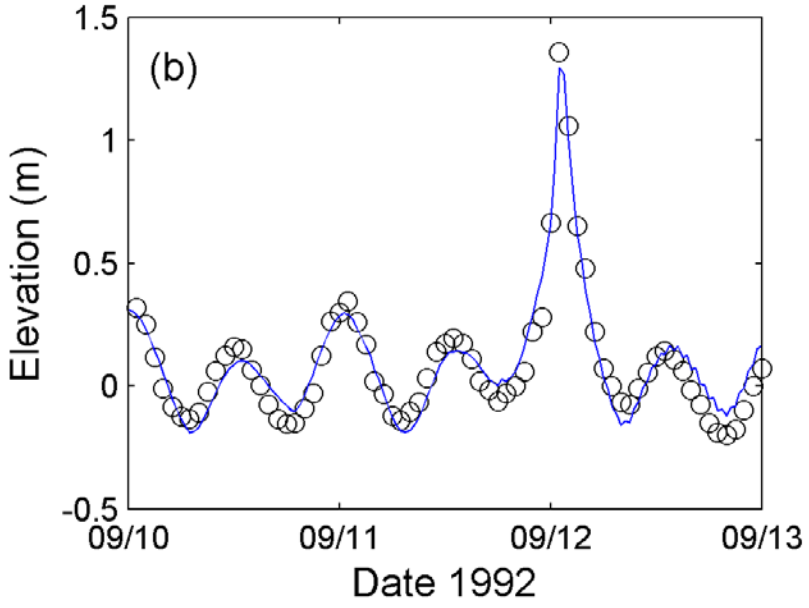
Hurricane Iniki (1992)



Hurricane Iniki Water Levels



Nawiliwili Harbor

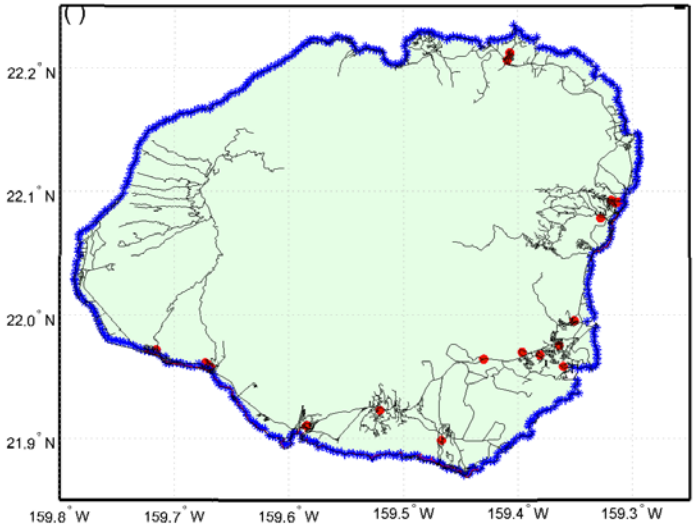


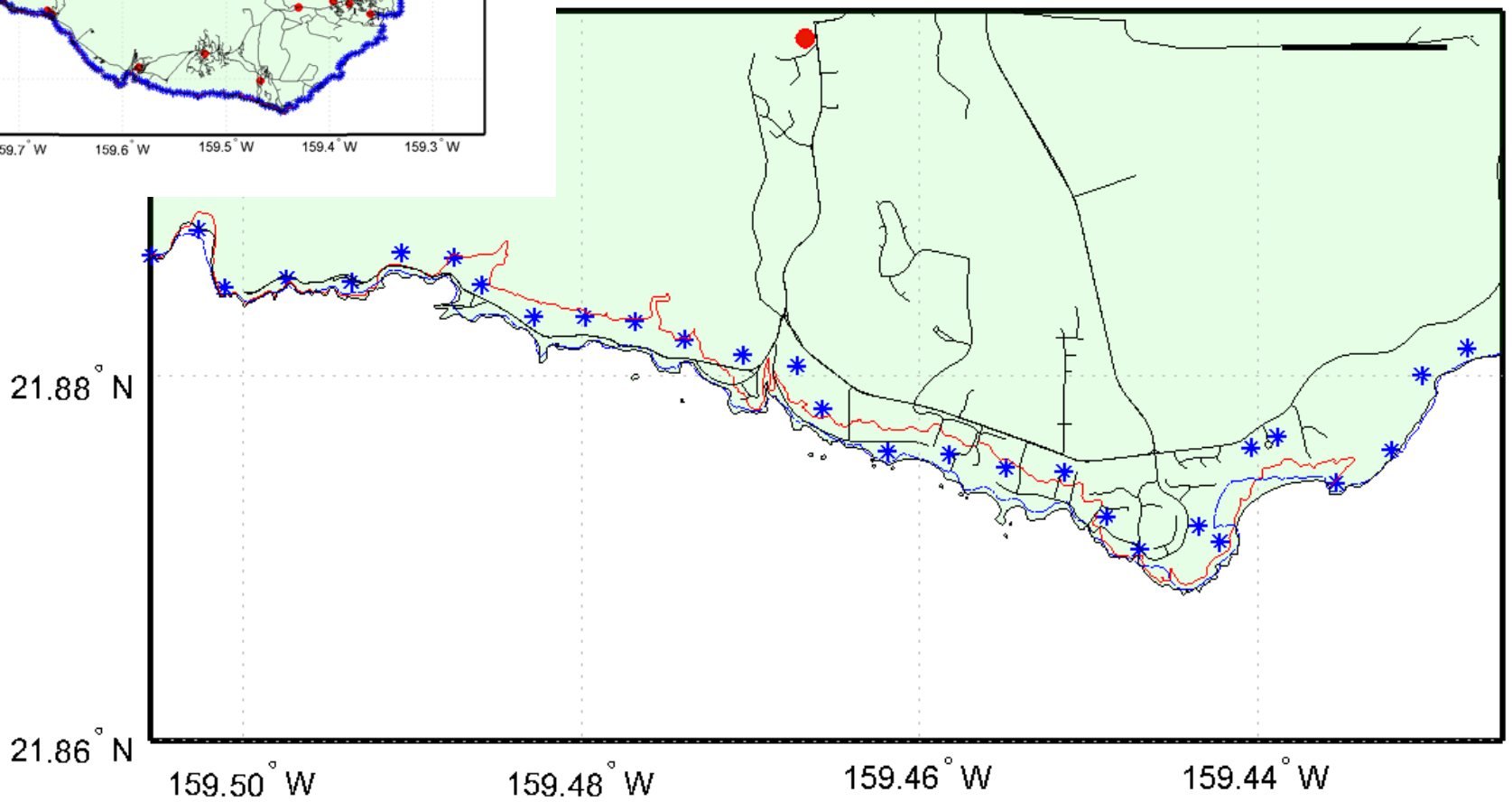
Port Allen

Wave Runup Analyses

- SWAN+ADCIRC gives wave heights and still water levels near shore
- Wave runup (intermittent wave inundation at the shore) can be dominant in some storms
  - Hundreds of meters inland, several meters more elevation than still water level
  - Large during Hurricane Iniki (6-8m)
- Two approaches to wave runup
  - Parameterized relations predict runup given the significant wave height, wave period, and basic nearshore bathymetry
  - Boussinesq modeling along one-dimensional transects
- Hawaiian topography too complex to use parameterized results

Hurricane Iniki Inundation





Surrogate Model

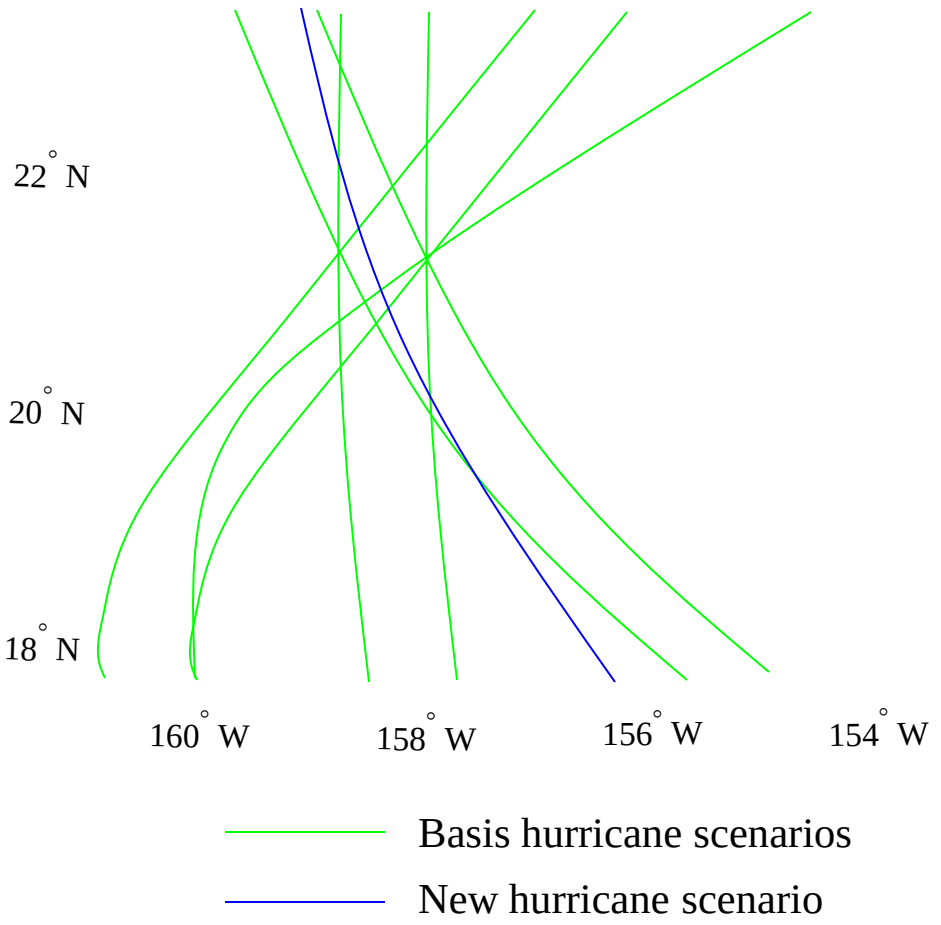
- Pre-run suite of basis hurricane scenarios

⬇

- Moving least-squares response surface surrogate model

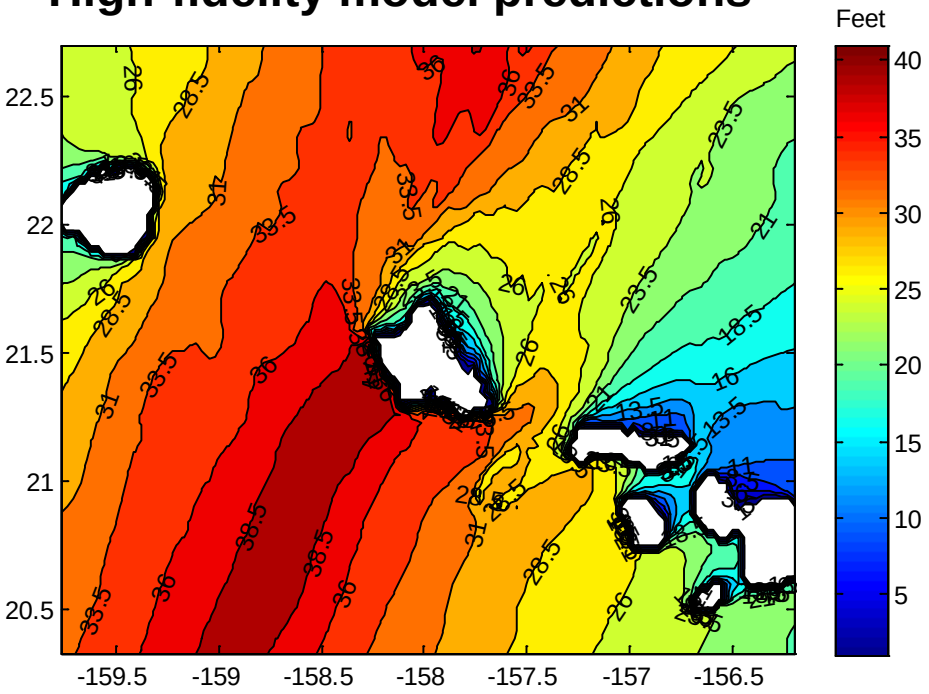
⬇

- Predict the output for any new hurricane scenario

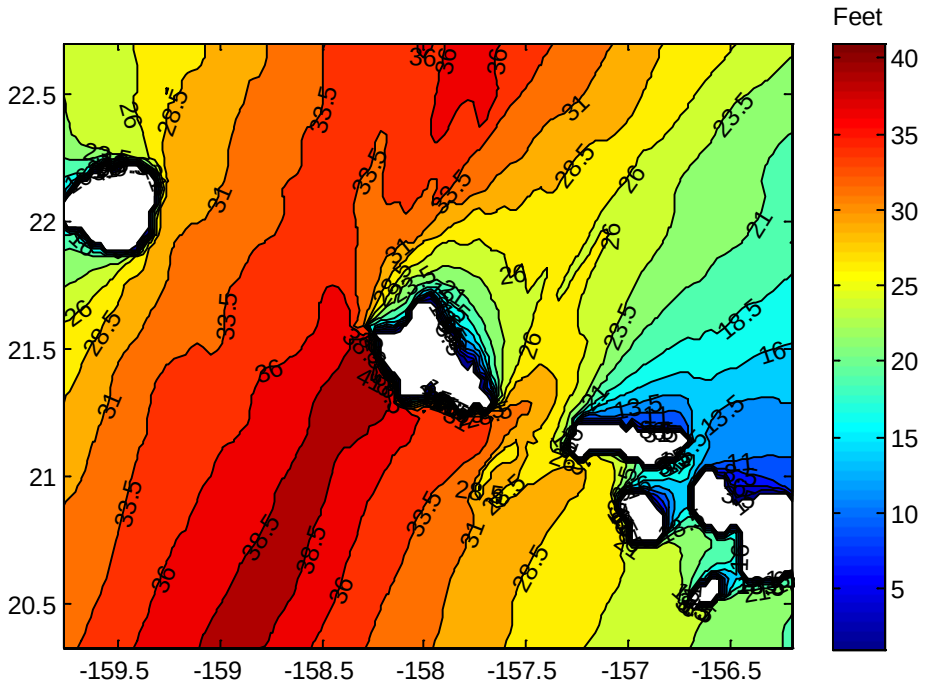


Comparison of Hurricane Output Predictions

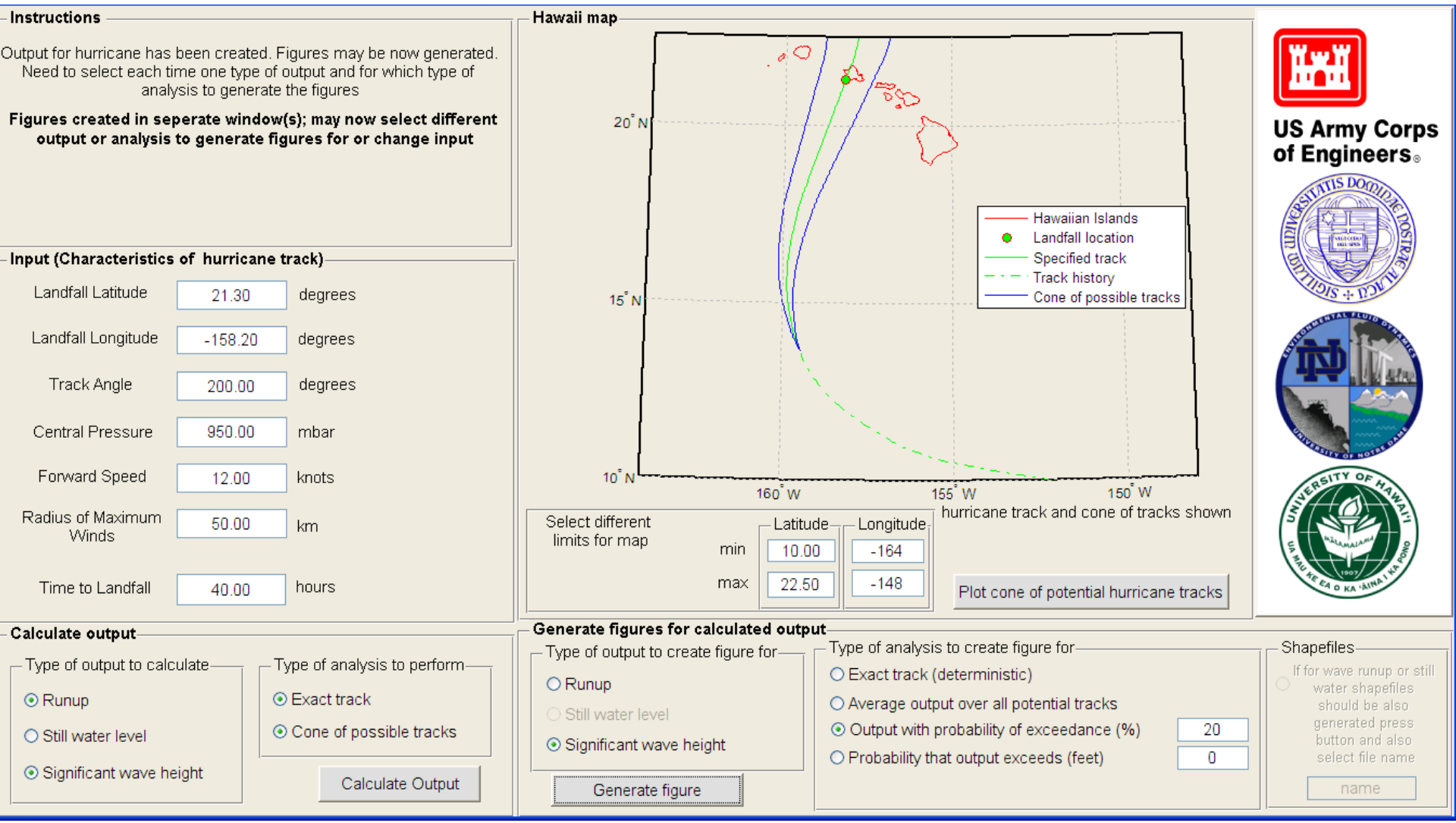
High-fidelity model predictions

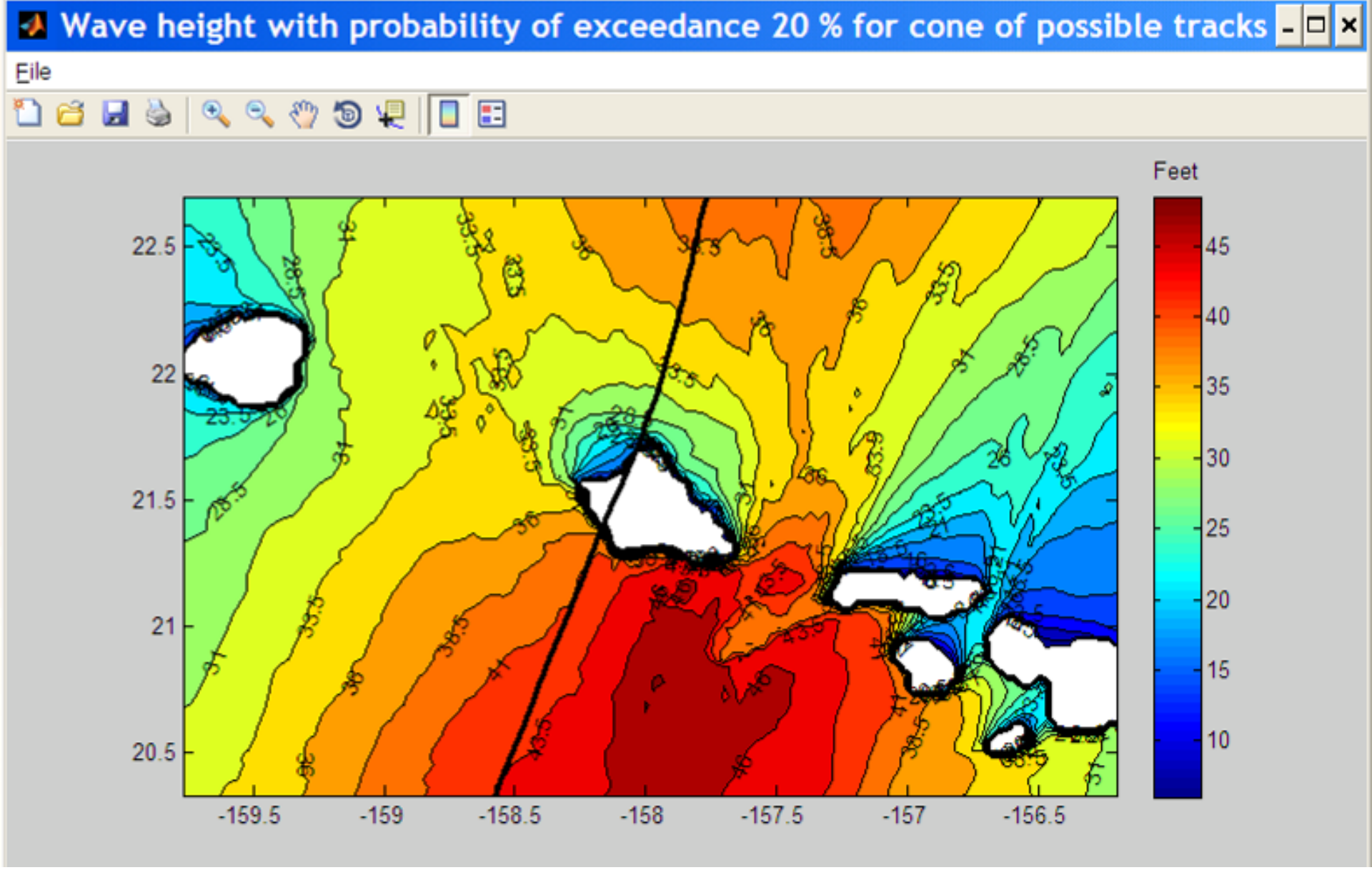


Surrogate model predictions



Graphical User Interface




Wave height with probability of exceedance 20 % for cone of possible tracks
File
Feet
45
40
35
30
25
20
15
10
22.5
22
21.5
21
20.5
-159.5
-159
-158.5
-158
-157.5
-157
-156.5

Runup (yellow) and Still Water (red)

SWIMS Summary

- Fast Forecasting System provides framework for dynamic and fast evaluation of waves, surge and inundation
- **High-fidelity, high-resolution** models to simulation hundreds of hurricanes
- Query the database for deterministic or probabilistic estimates
- Robust results in **seconds to minutes**
- Status
  - Oahu and Kauai complete
  - Big Island and Maui County complete in March
- Expand to territories