



# Fast Forecasting of Hurricane Waves and Inundation in Hawaii

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**Interdepartmental Hurricane Conference 6 March 2012**



# Fast ~~Tracking~~ **Guidance** of Hurricane Waves and Inundation in Hawaii

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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

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- **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

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- **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)

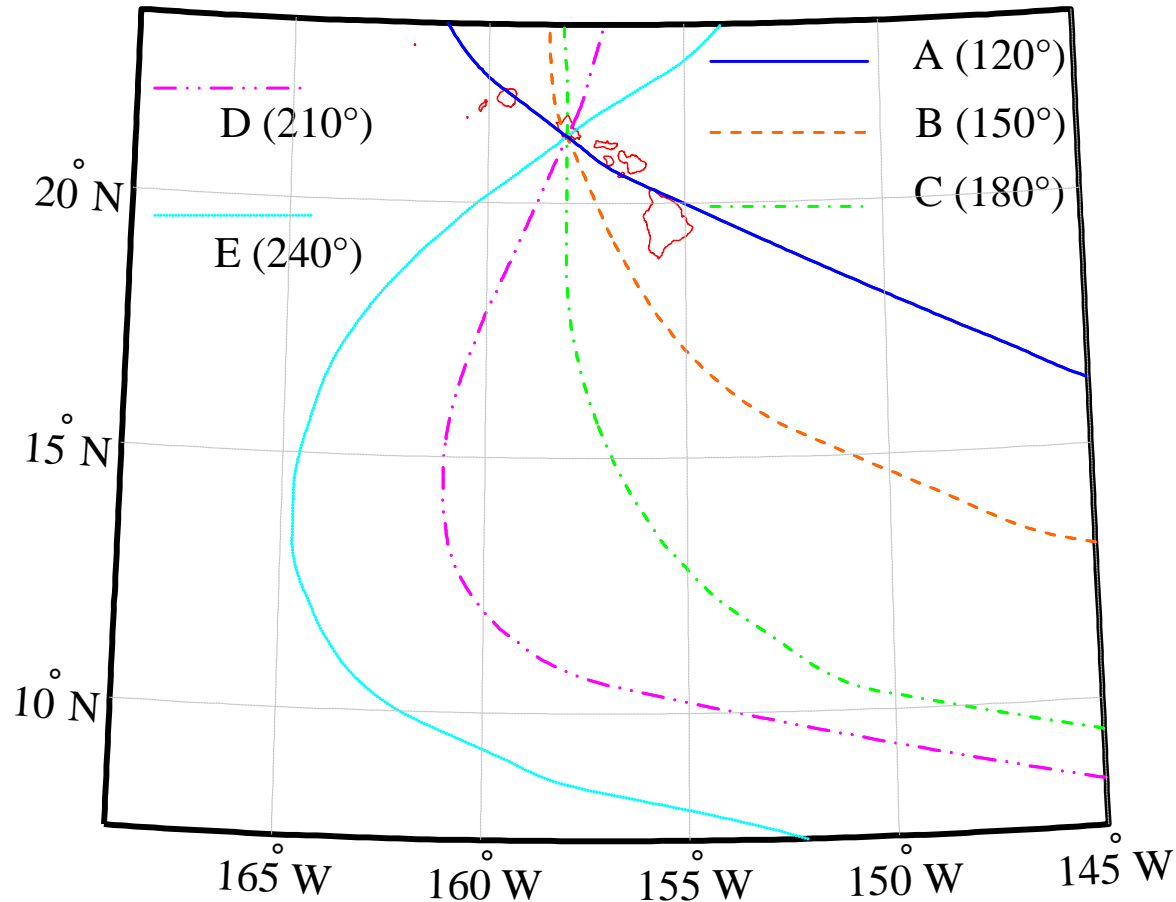


*Hurricane Iniki*



# Storm Selection: Tracks

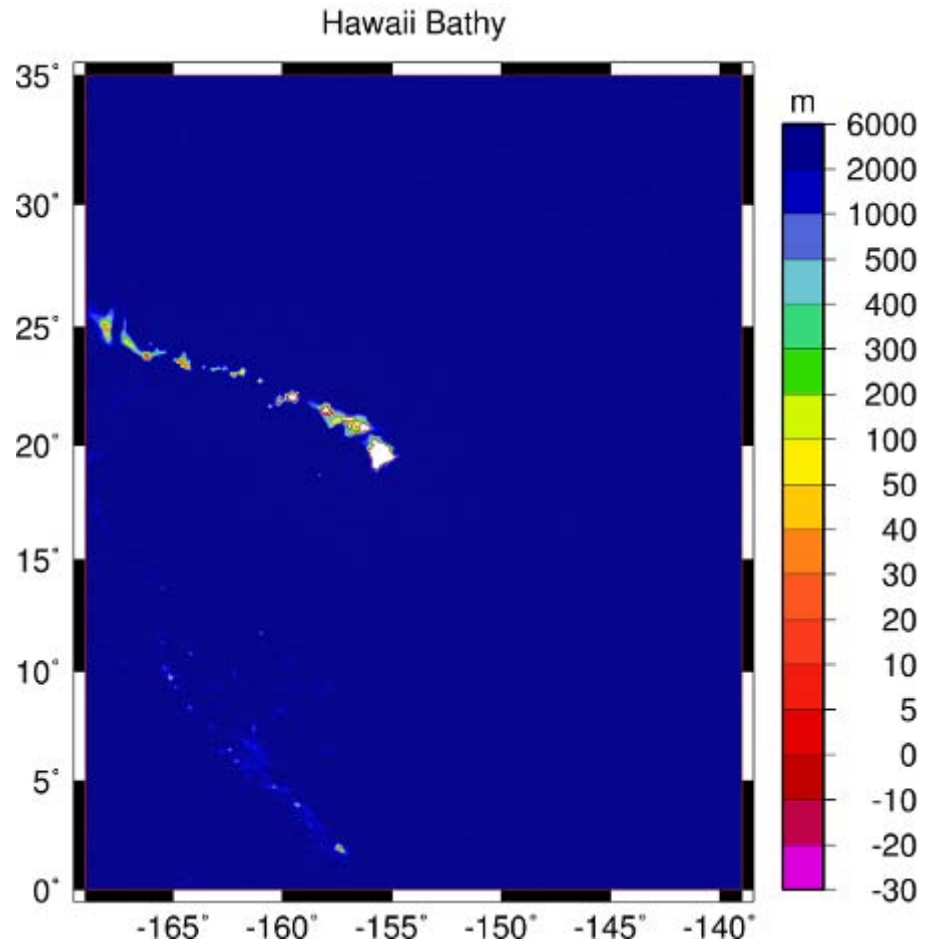
- Five base storm tracks from hurricane climatology (NWS)
- Tracks shifted to give 28 landfall locations
- Tracks and parameters varied to give a matrix of potential storms (bound most possible landfall scenarios)





# 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

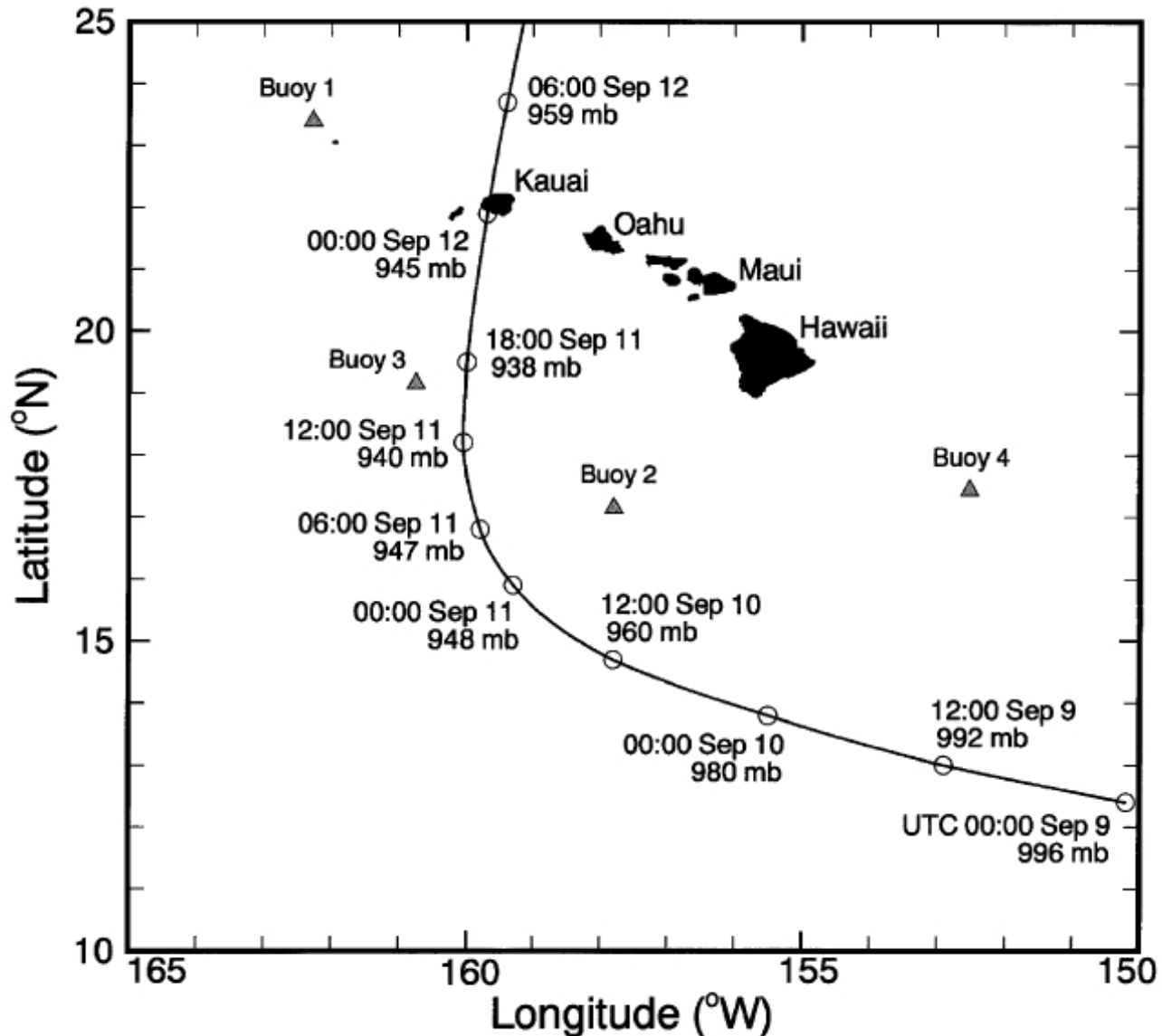
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- **ADCIRC** solves for water surface elevations and currents in two dimensions
- **SWAN** solves the wave action density and is a phase-averaged wave model with wave energy represented by a spectrum
- **ADCIRC** passes water elevation and currents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





# Hurricane Iniki (1992)







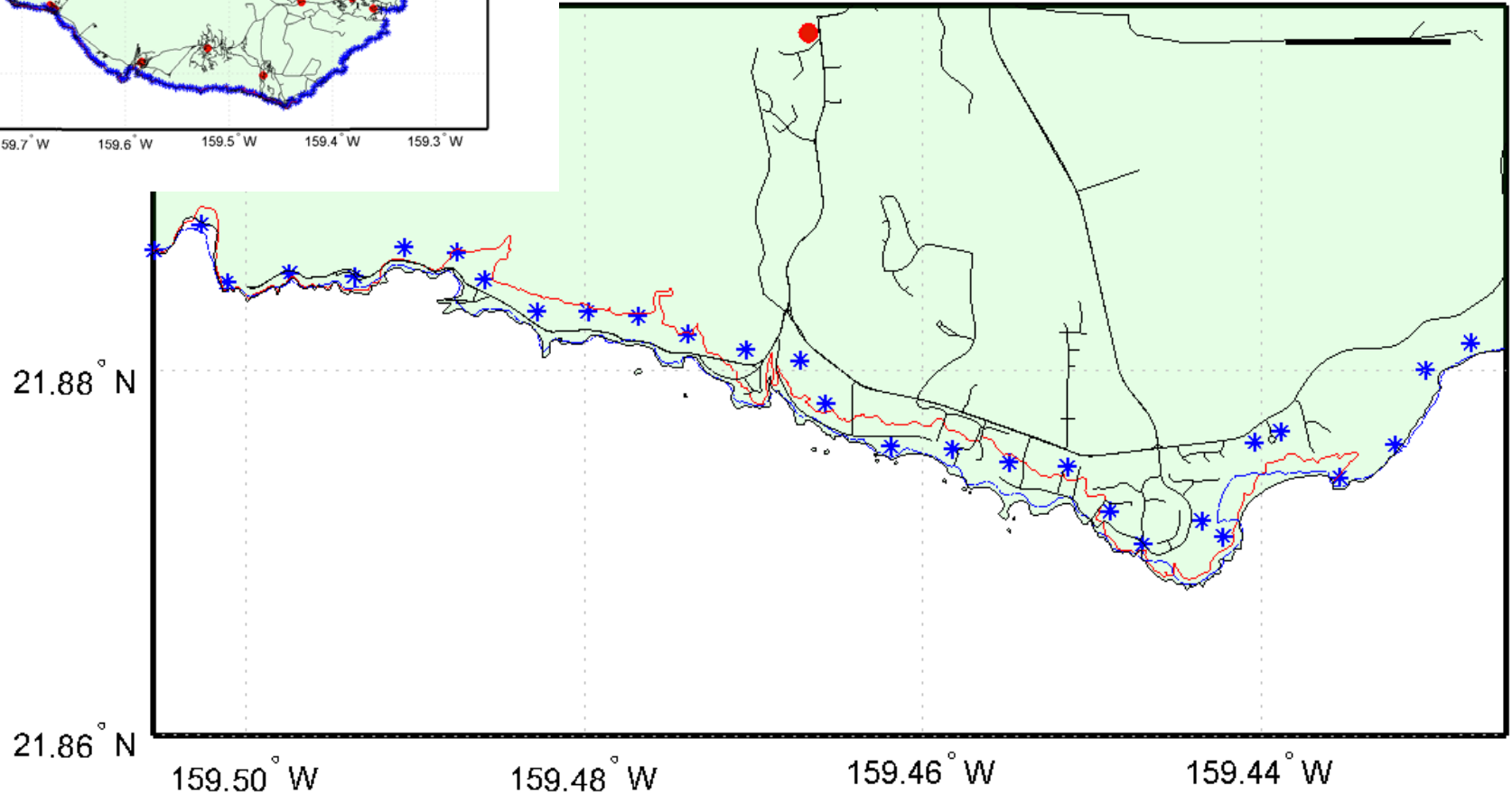
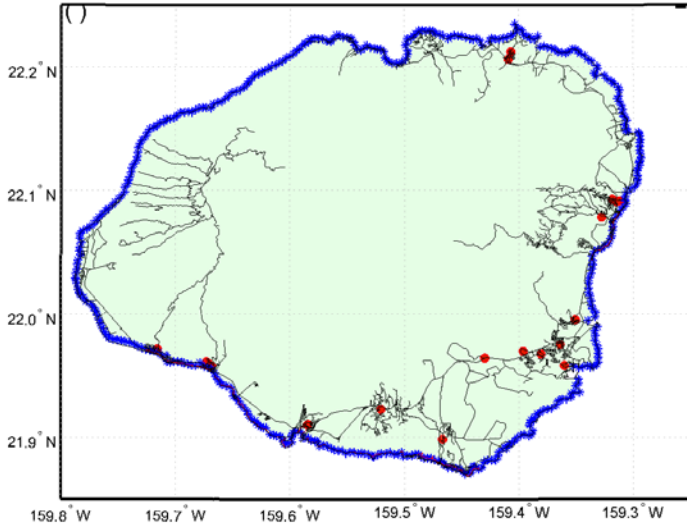
# Wave Runup Analyses

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- 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



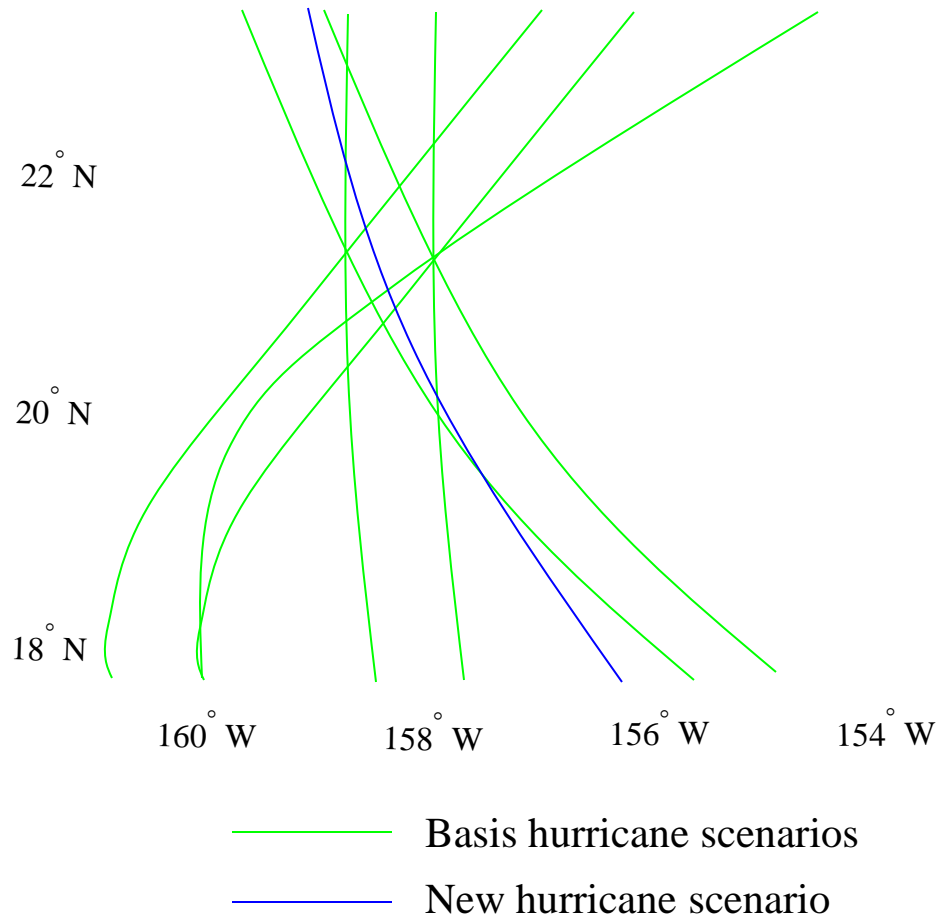
# Hurricane Iniki Inundation





# Surrogate Model

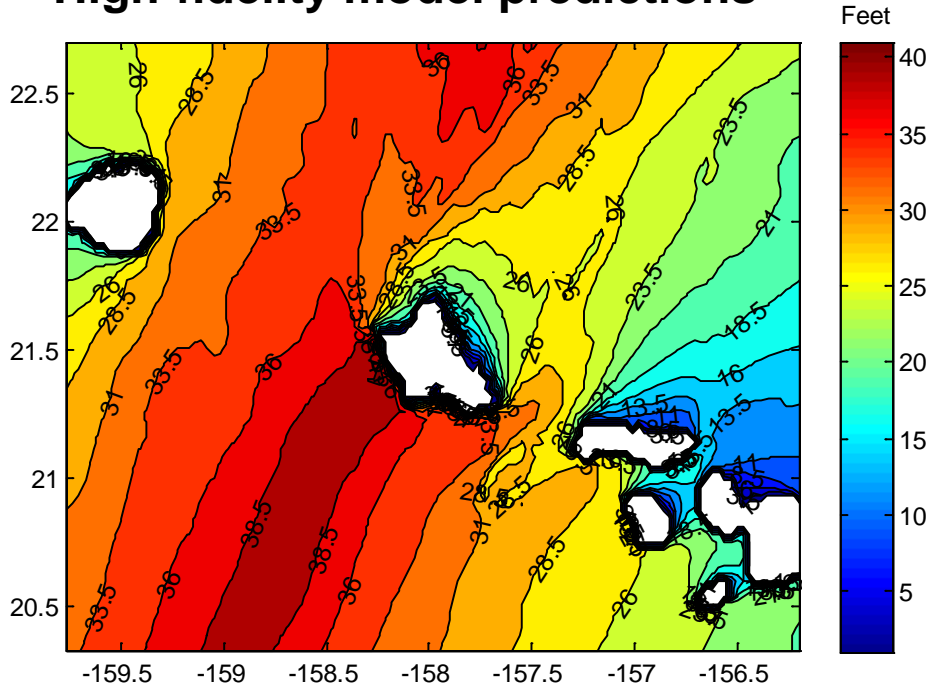
- Pre-run suite of basis hurricane scenarios
- ↓
- Moving least-squares response surface surrogate model
- ↓
- Predict the output for any new hurricane scenario



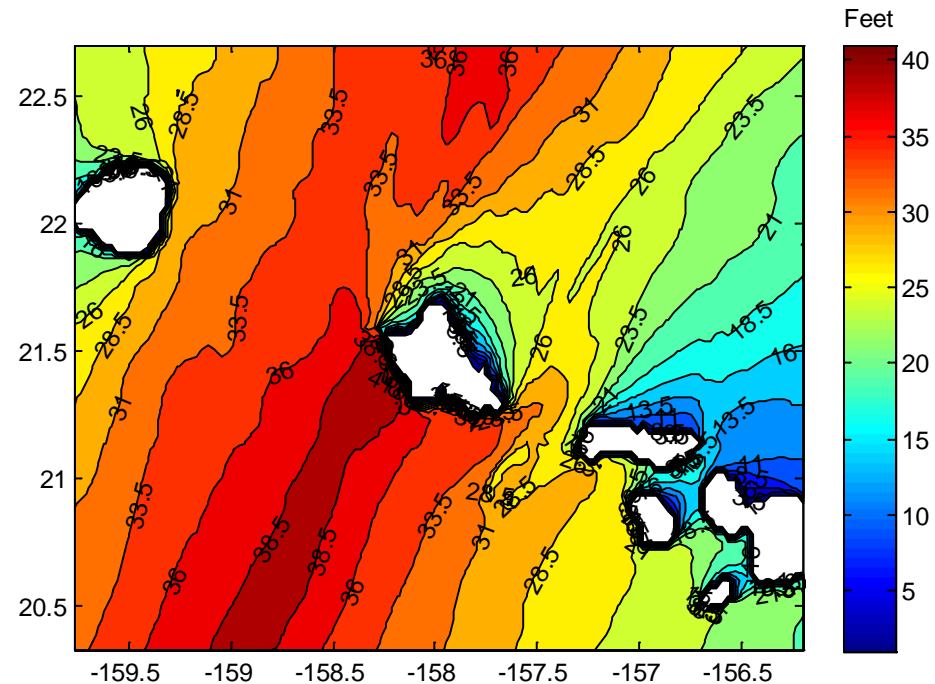


# Comparison of Hurricane Output Predictions

## High-fidelity model predictions



## Surrogate model predictions





# Graphical User Interface

**Instructions**

Output for hurricane has been created. Figures may be now generated.  
Need to select each time one type of output and for which type of analysis to generate the figures

**Figures created in separate window(s); may now select different output or analysis to generate figures for or change input**

**Input (Characteristics of hurricane track)**

Landfall Latitude  degrees

Landfall Longitude  degrees

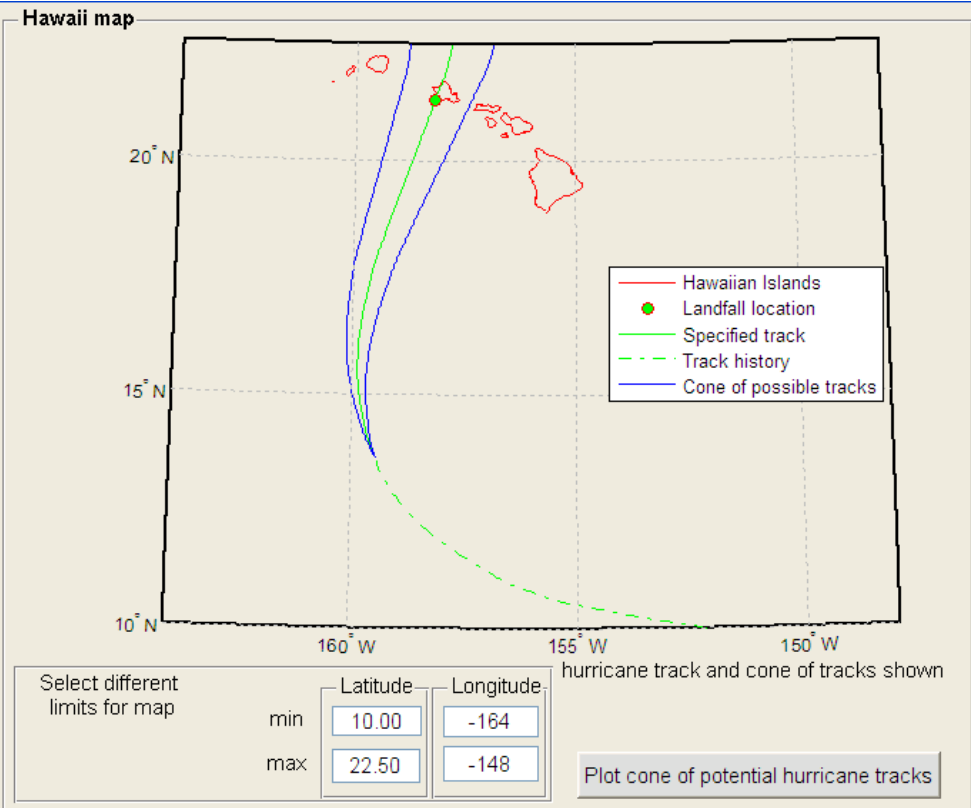
Track Angle  degrees

Central Pressure  mbar

Forward Speed  knots

Radius of Maximum Winds  km

Time to Landfall  hours



**US Army Corps of Engineers®**



**Calculate output**

Type of output to calculate

- Runup
- Still water level
- Significant wave height

Type of analysis to perform

- Exact track
- Cone of possible tracks

**Generate figures for calculated output**

Type of output to create figure for

- Runup
- Still water level
- Significant wave height

Type of analysis to create figure for

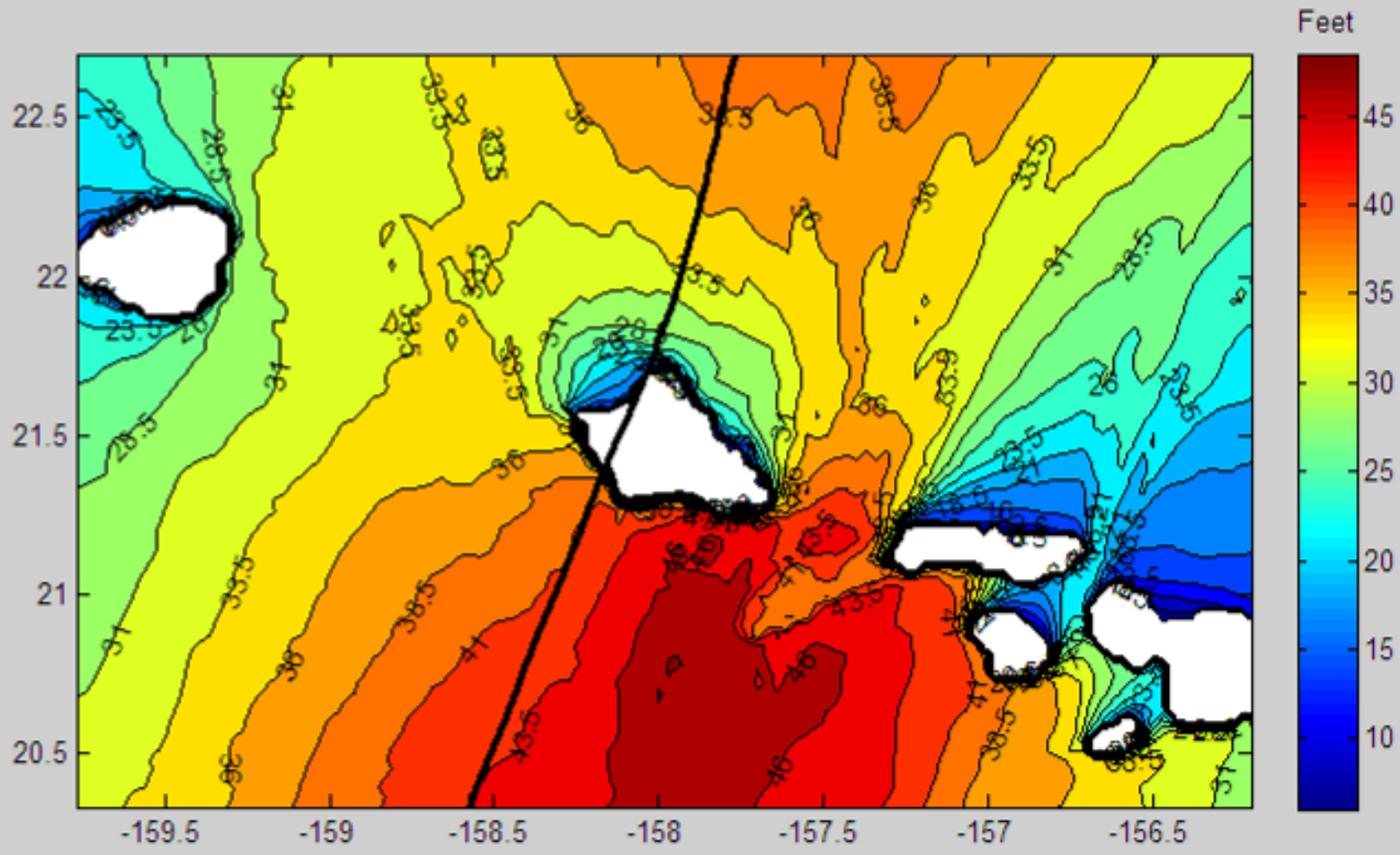
- Exact track (deterministic)
- Average output over all potential tracks
- Output with probability of exceedance (%)
- Probability that output exceeds (feet)

**Shapefiles**

If for wave runup or still water shapefiles should be also generated press button and also select file name

# Wave height with probability of exceedance 20 % for cone of possible tracks

File







# Runup (yellow) and Still Water (red)





# SWIMS Summary

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- 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