Fast Forecasting of Hurricane Waves and Inundation in Hawaii

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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)
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)
• 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

(a) Nawiliwili Harbor

(b) 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

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: 21.30 degrees
- Landfall Longitude: -158.20 degrees
- Track Angle: 200.00 degrees
- Central Pressure: 950.00 mbar
- Forward Speed: 12.00 knots
- Radius of Maximum Winds: 60.00 km
- Time to Landfall: 40.00 hours

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
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.
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