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Coastal Wave Energy Dissipation: Observations and Modeling

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Motivation

1. A significant challenge to numerical wave modeling is capturing the dynamics of wave transformation in coastal waters

2. Dissipation processes are the least well-represented in numerical spectral wave models

3. Careful measurements of coastal wave transformation are required to support the advancement of improved model physics

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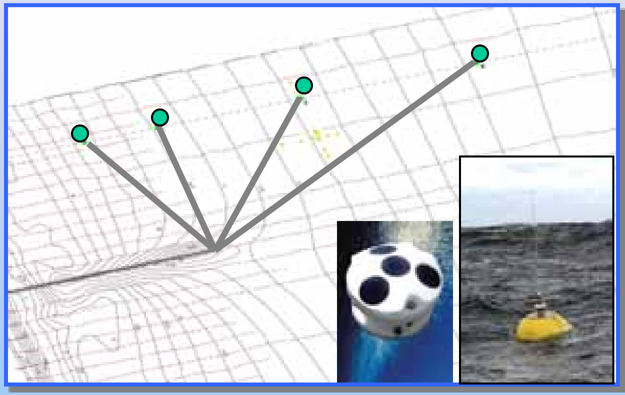
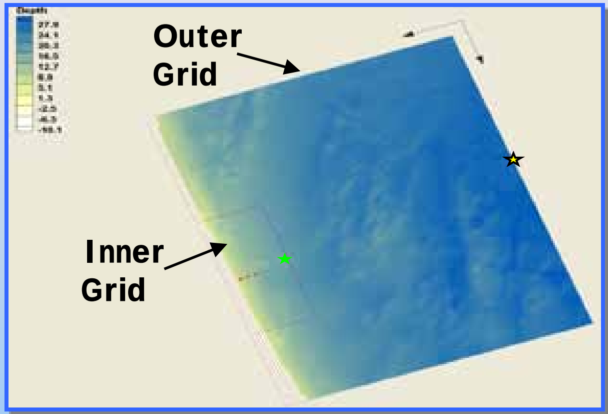
Approach



1. **Data obtained from a new cross-shore wave and current array in the energetic environment off Duck, NC**

Approach



1. Data obtained from a new cross-shore wave and current array in the energetic environment off Duck, NC

2. **Set up a high-resolution wave modeling test bed for the STeady-state spectral WAVE model – Full Plane version (STWAVE-FP)**

Approach

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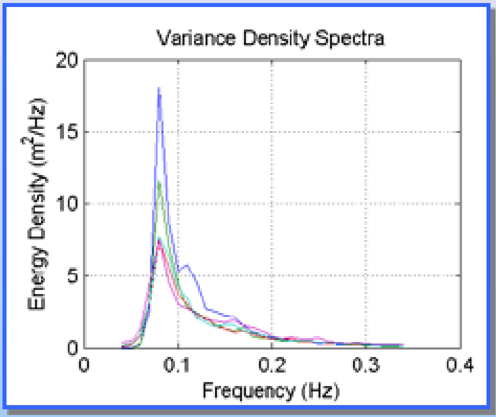

1. Data obtained from a new cross-shore wave and current array in the energetic environment off Duck, NC

2. Set up a high-resolution wave modeling test bed for the STeady-state spectral WAVE model – Full Plane version (STWAVE-FP)

3. **Quantify performance of the bottom friction source term in an energetic sandy coast environment.**

FRF Cross-Shelf Wave and Current Array

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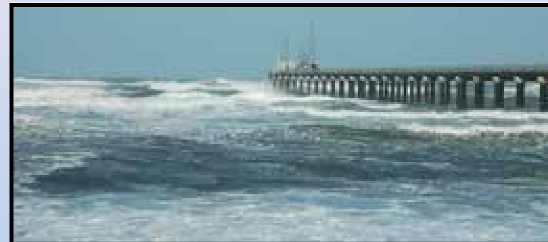
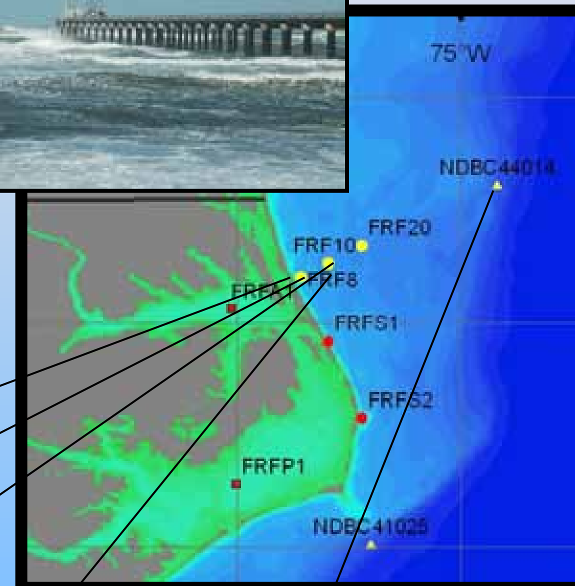
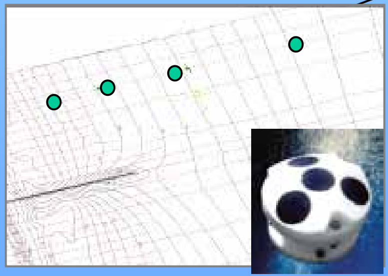
Data Collections

- 4 Nortek AWAC sensors
- 2 Datawell Waverider buoys
- NDBC Station 44014
- Pier-based meteorological station
- ARGUS Video system
- 24/7 Real-time data processing
- Monthly bathymetric surveys







8-m Array;
Nearshore AWAC
Array (5-11 m depth)

17-m Datawell Waverider

26-m Datawell Waverider

26-m Weather Station

48-m NDBC 44014

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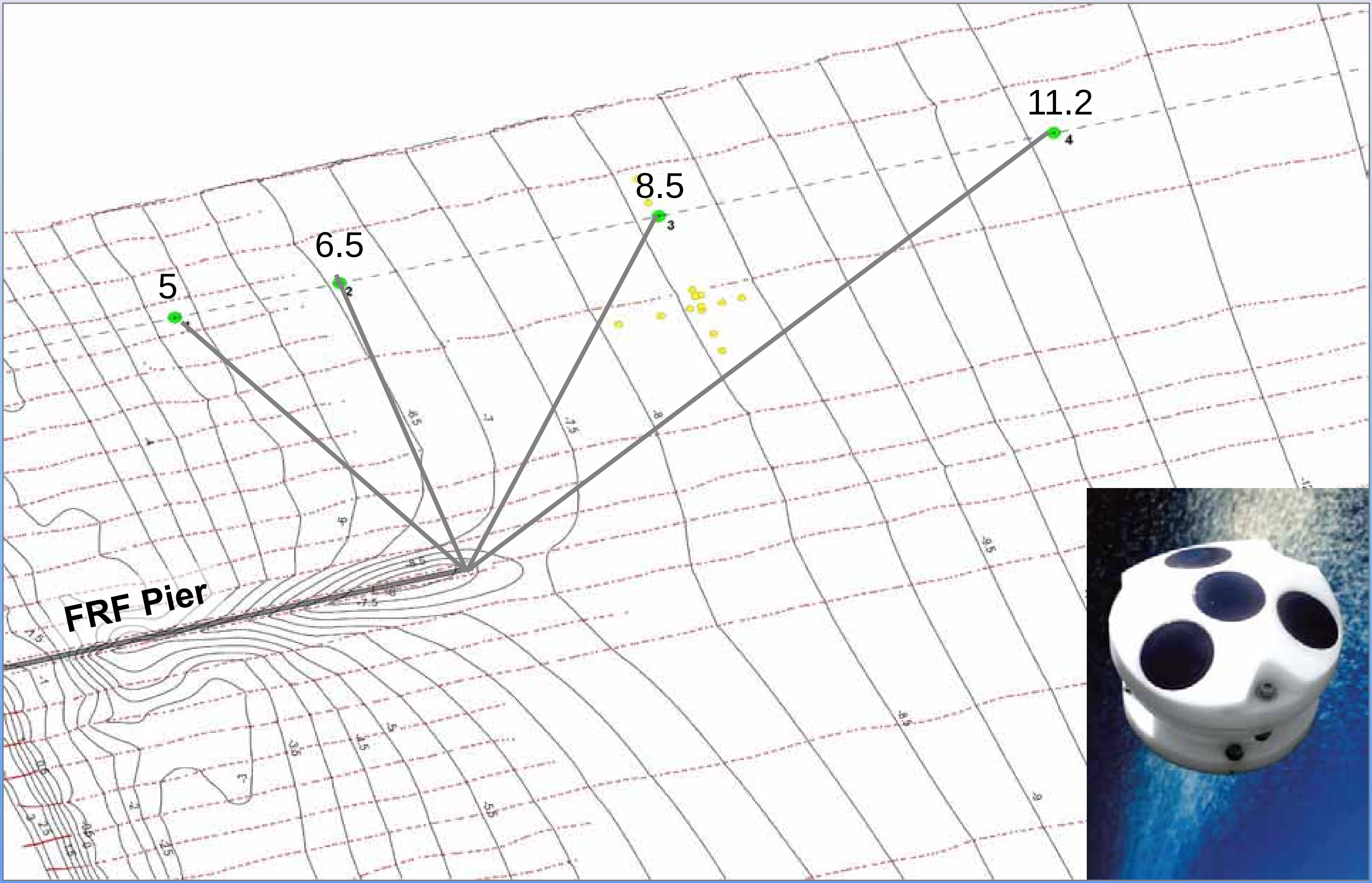
Acoustic Wave and Currents (AWAC) Station Depths (m)



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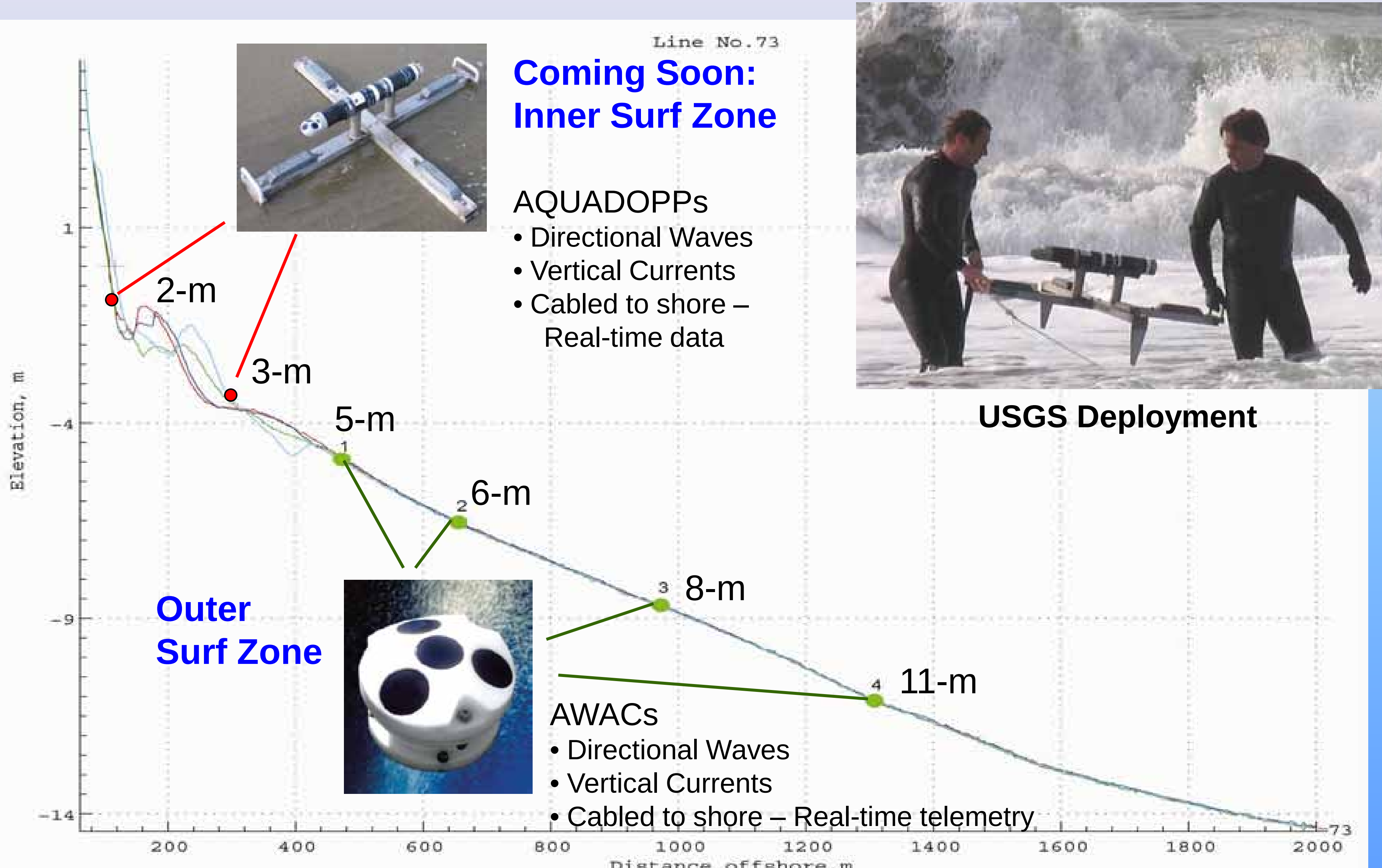
Cross-Shore Transect



USGS Deployment

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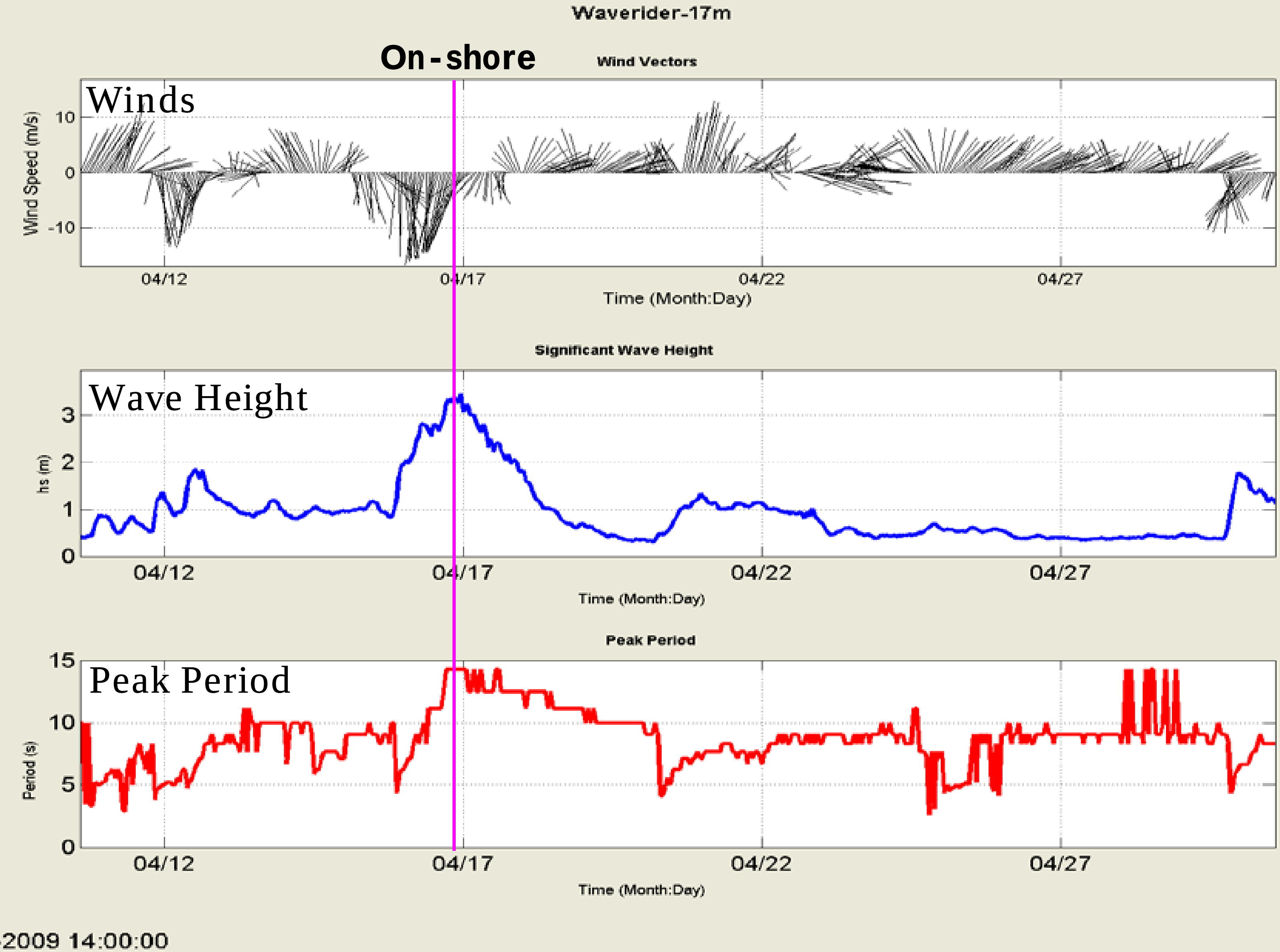
April 2009 Nor'easter



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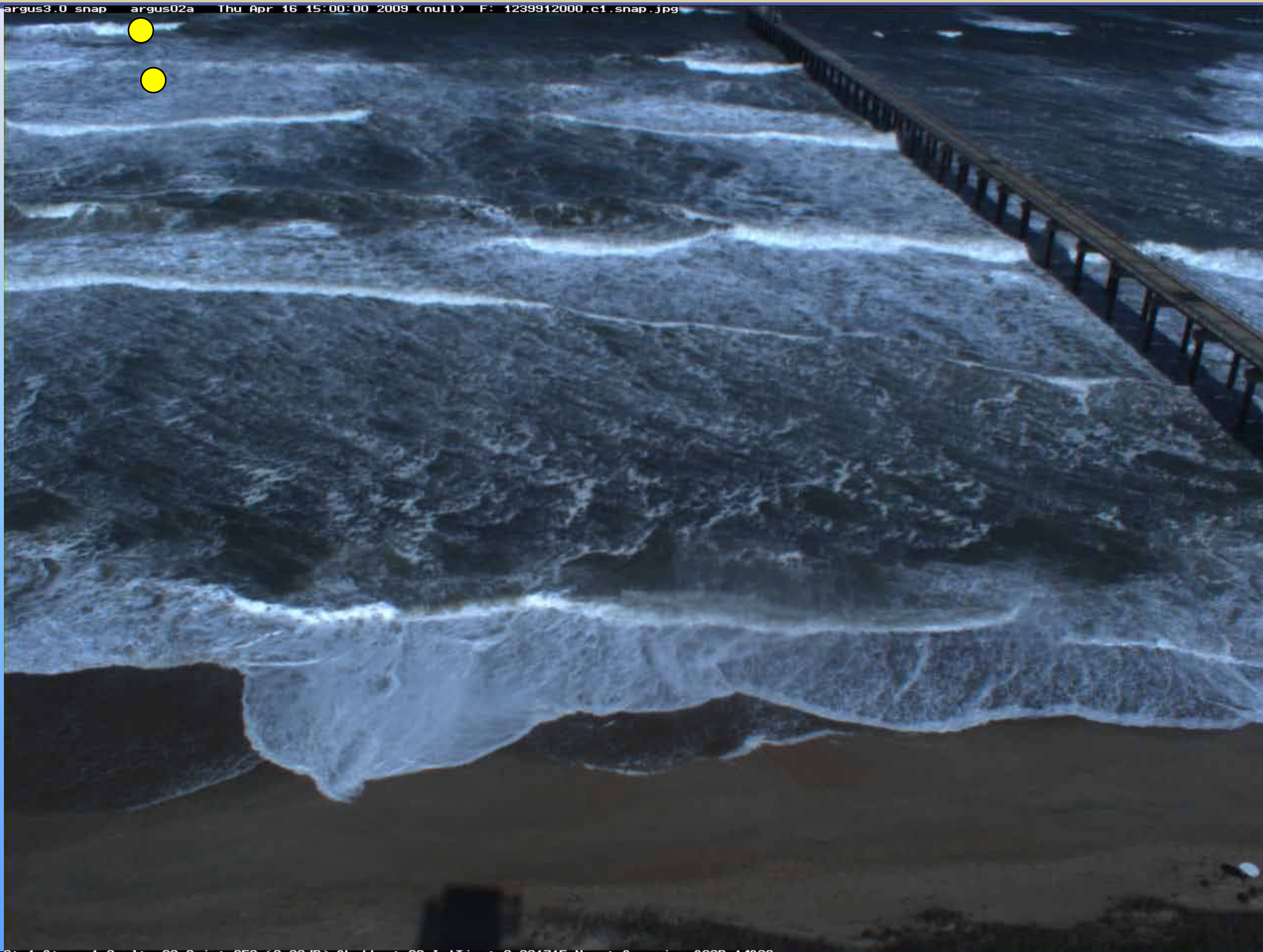
Nor’easter Wind Sea



Nor'easter Wind Sea Wave Transformation

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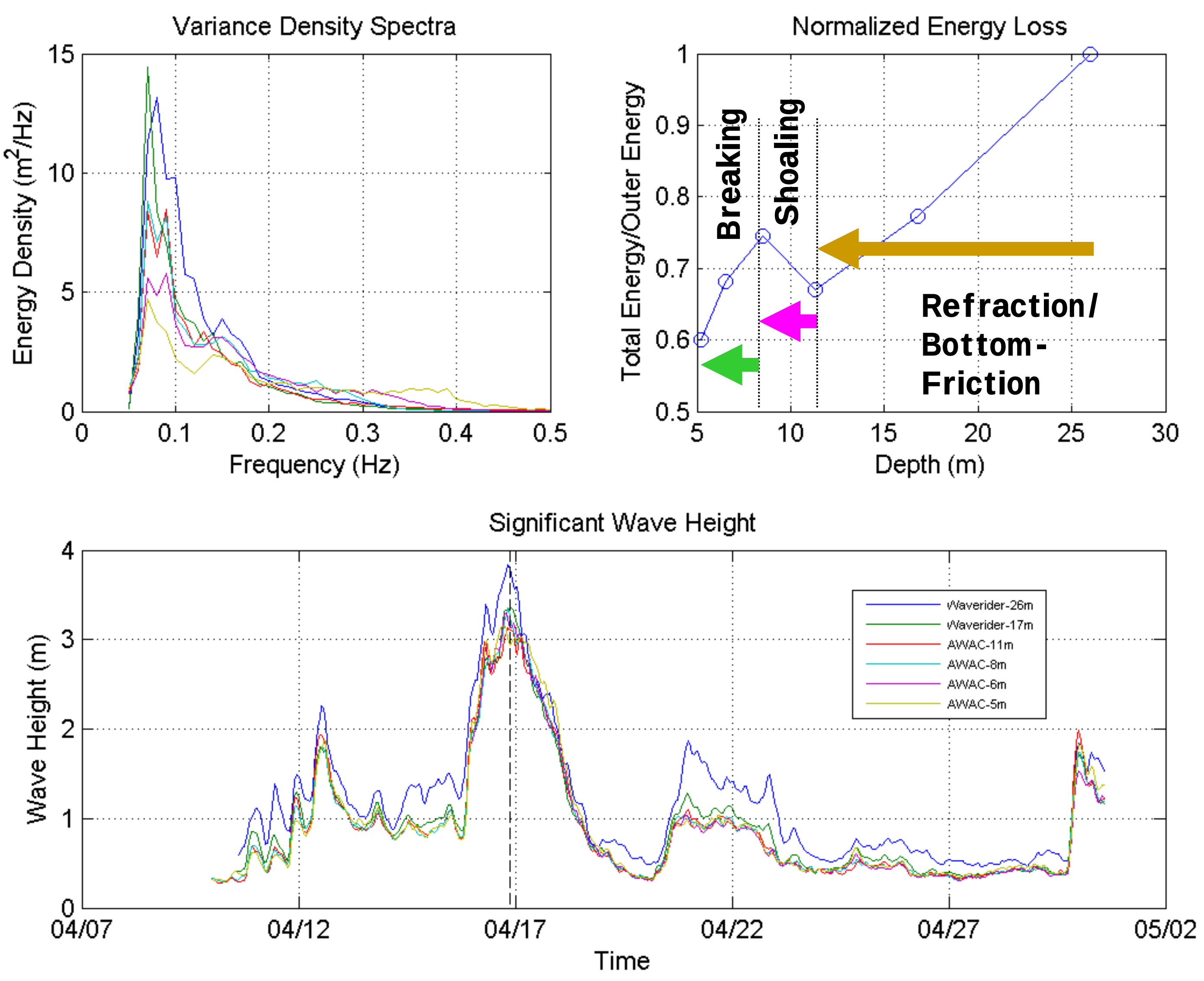

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Nor’easter Swell

Nor’easter Swell Transformation

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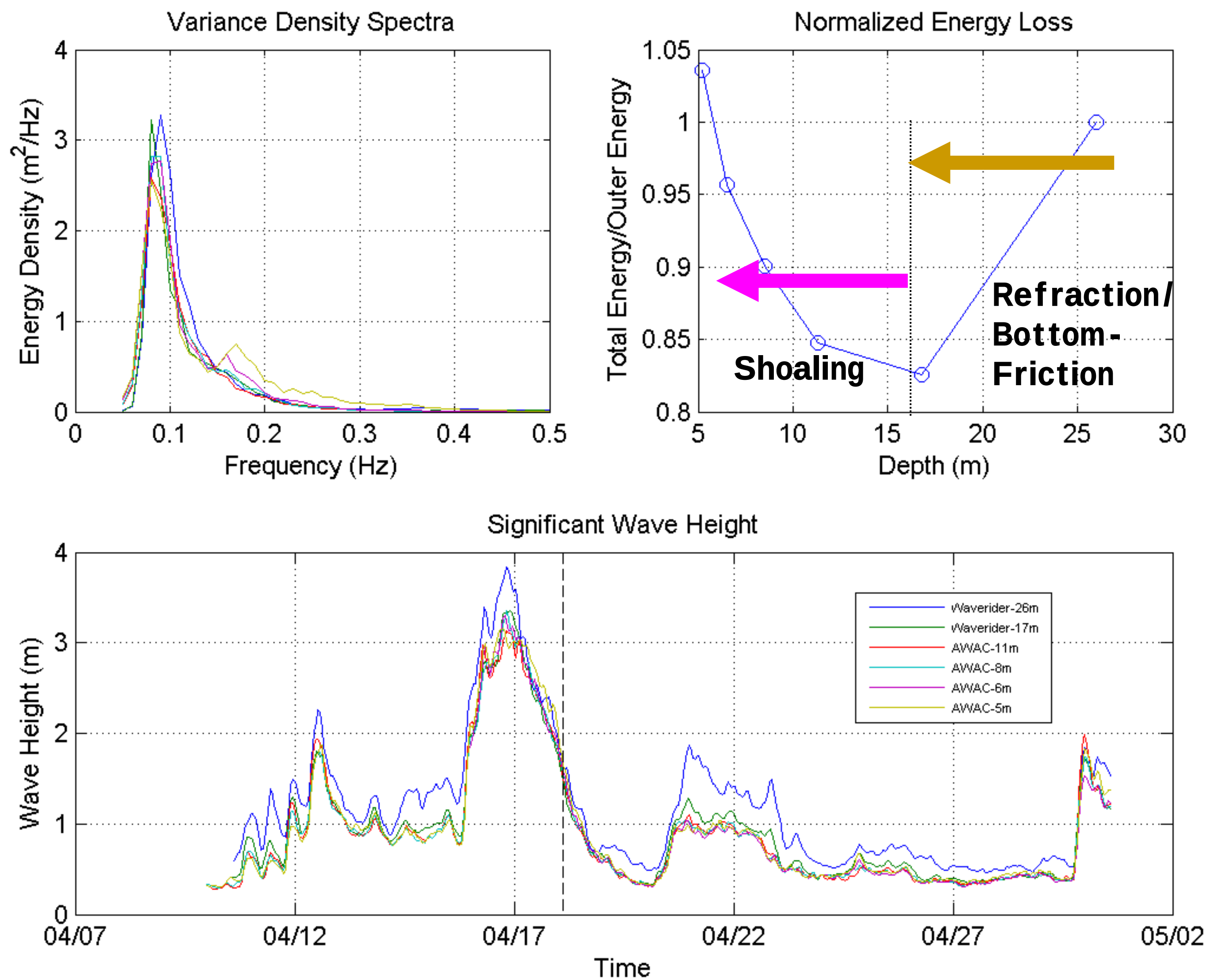

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STWAVE-FP Test Bed

Steady State Waves - Full Plane

- Capture refraction, shoaling, wave-wave interactions and bottom friction
- Forced by observations at boundaries

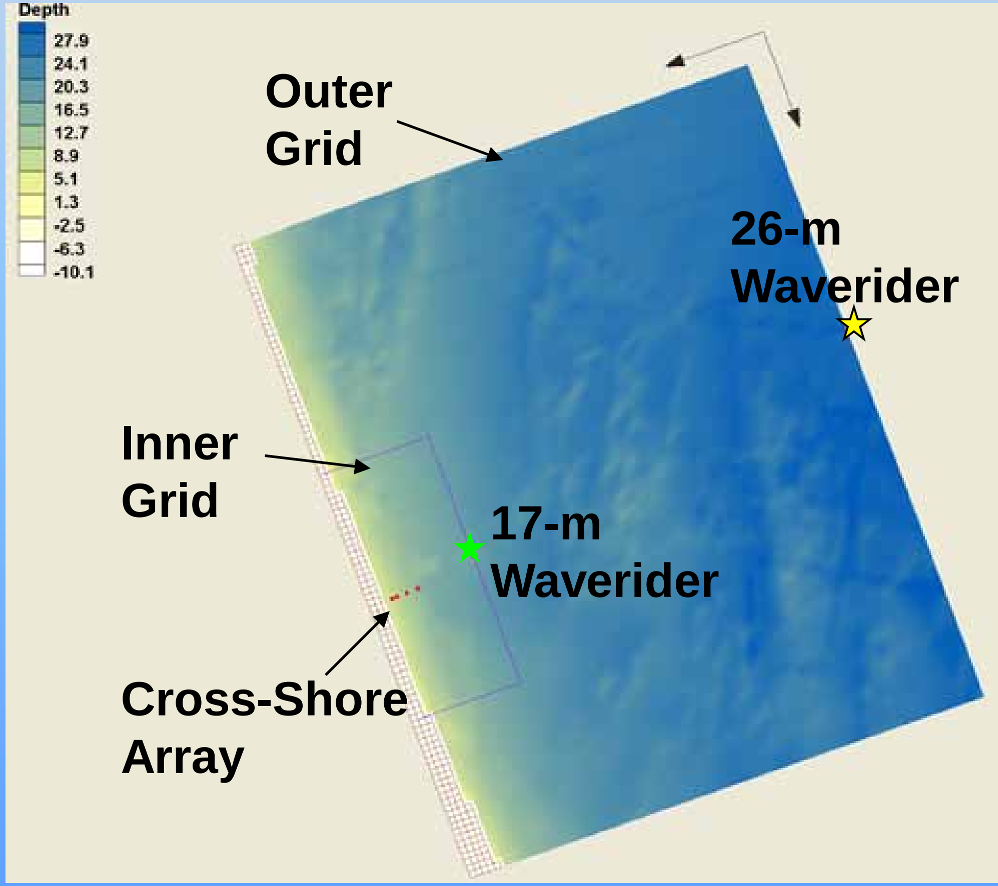
Model Set Up:

Outer Grid = 50x50 m
Inner Grid = 25x25 m
Time Step = 0.5-1 hour

Saved Spectra Locations:

- ☆ CDIP Waverider 26 m
- ★ Waverider 17 m
- ■ AWAC 11 m
- ■ AWAC 08 m
- ■ AWAC 06 m
- ■ AWAC 05 m

Model Domains



Bottom Friction Study

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Objective

Evaluate performance of bottom friction source term (Manning's Formulation)

- How important is bottom friction across array?
- What bottom friction coefficient is optimal?

Manning's n: $0.02 \leq n \geq 0.2$

Approach

Isolate pure swell events

- no wind input
- no whitecapping
- no depth breaking

à Bottom friction as the primary dissipation mechanism

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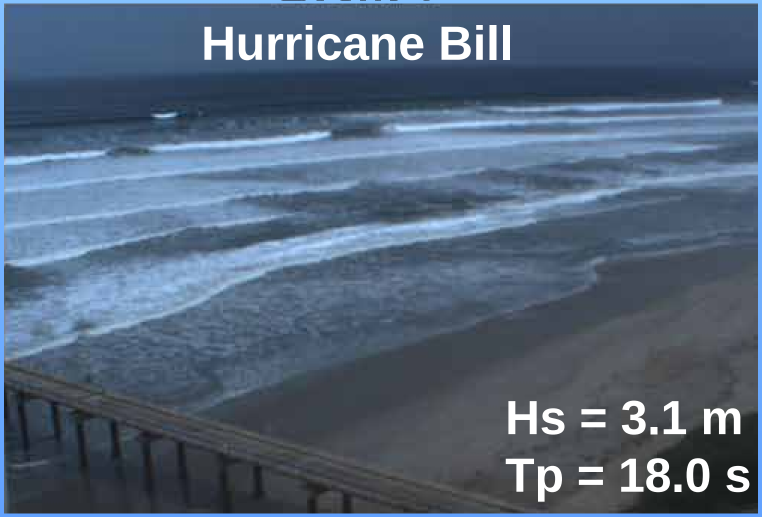
Selected Swell Events

Event 1

Event 2

Event 3

Event 4



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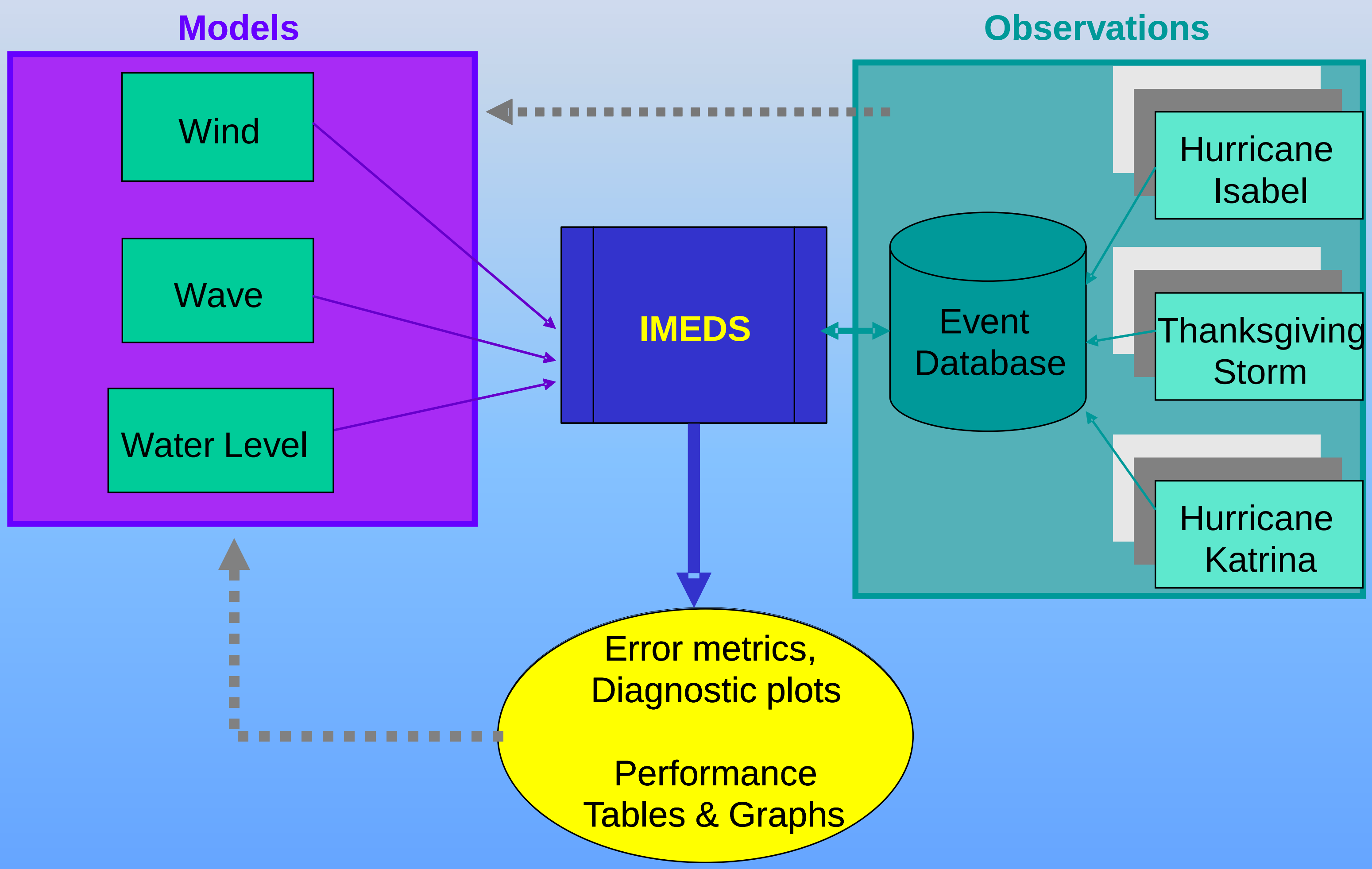
IMEDS

Interactive Model Evaluation and Diagnostics System



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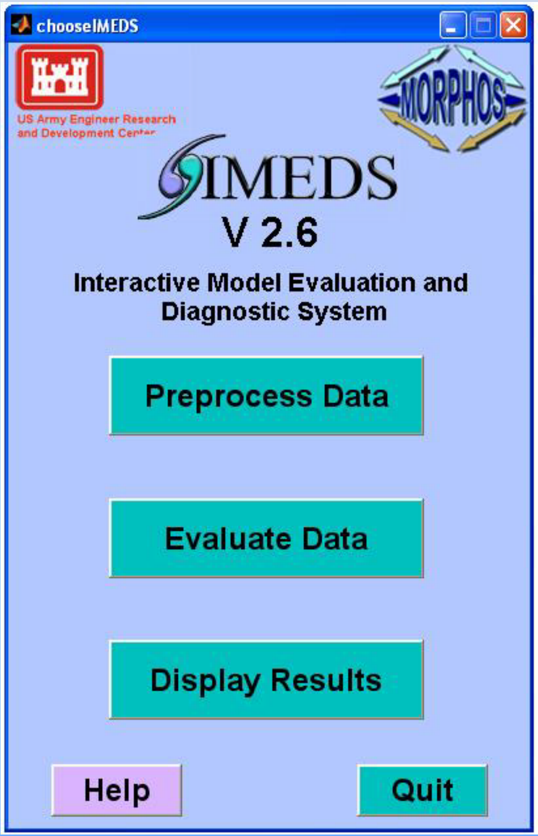
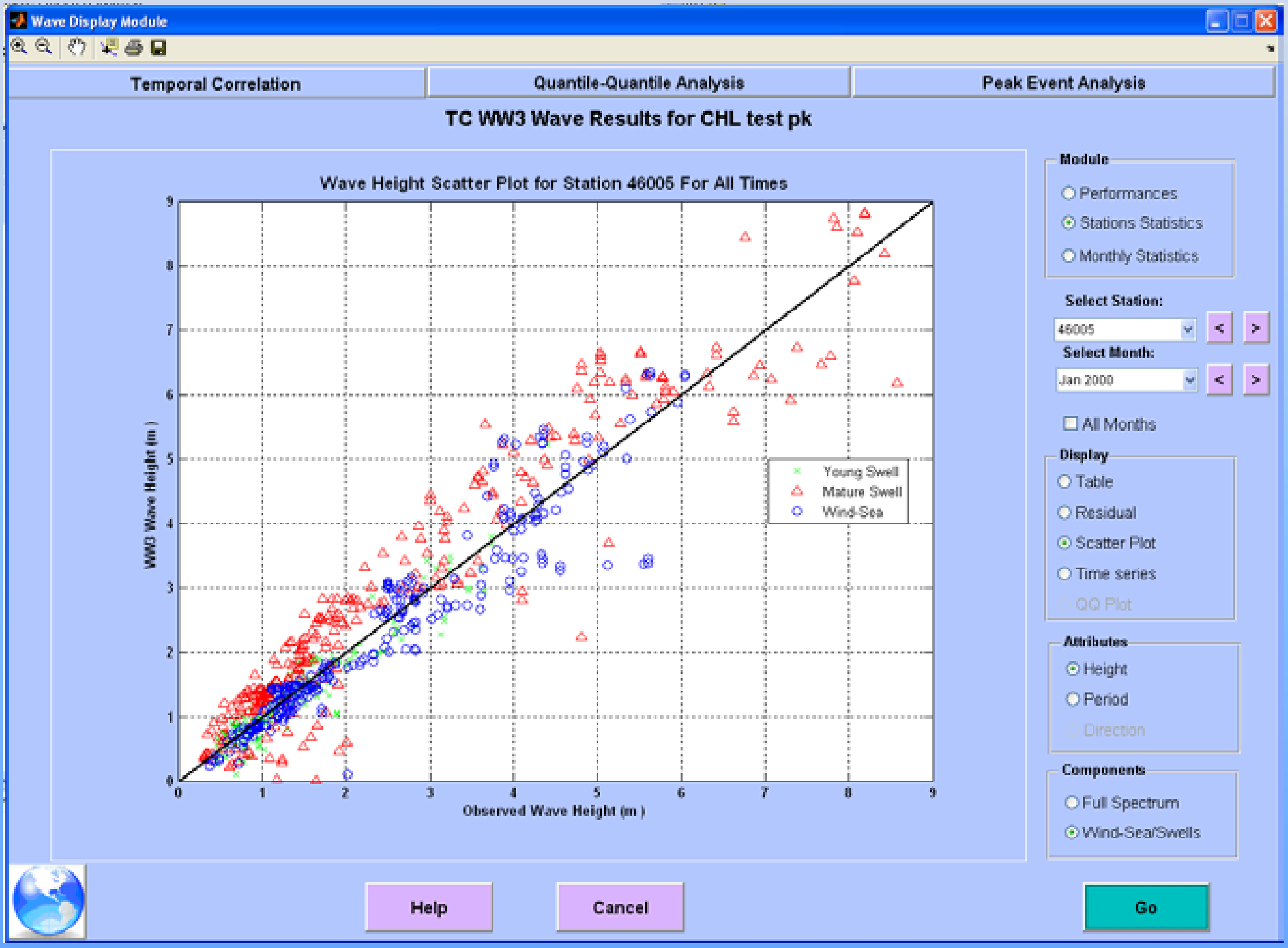
Robust Statistical Analysis of Model Performance





STWAVE Study: Wave height bias used to quantify model performance

Findings

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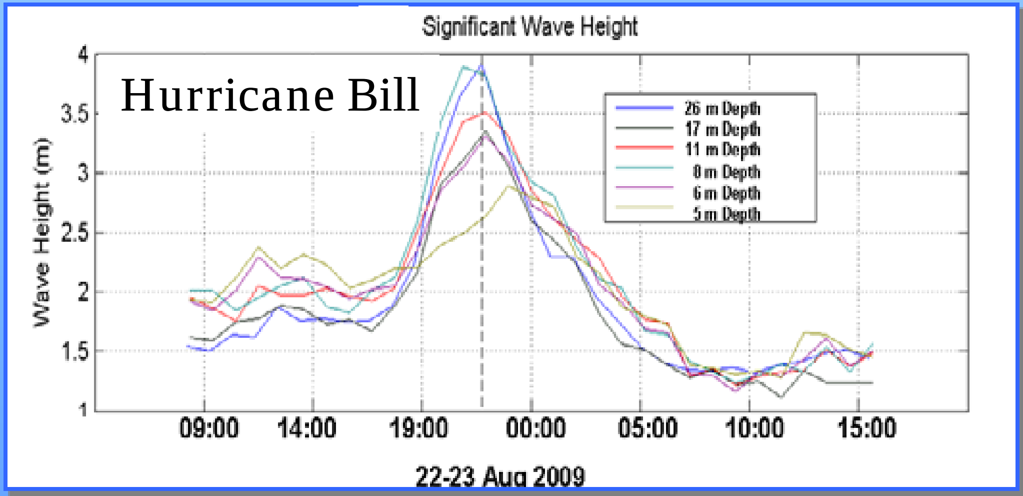
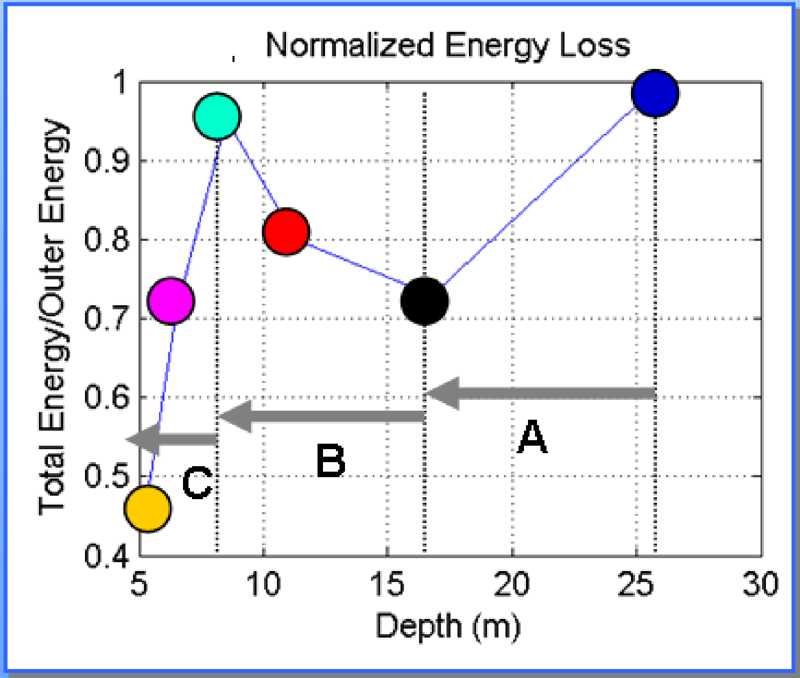
1. The FRF Cross-Shore wave array captures all phases of wave transformation across the shelf. Three transformation regimes were observed:

   A. Bottom friction dominated
   B. Shoaling dominated
   C. Depth breaking dominated





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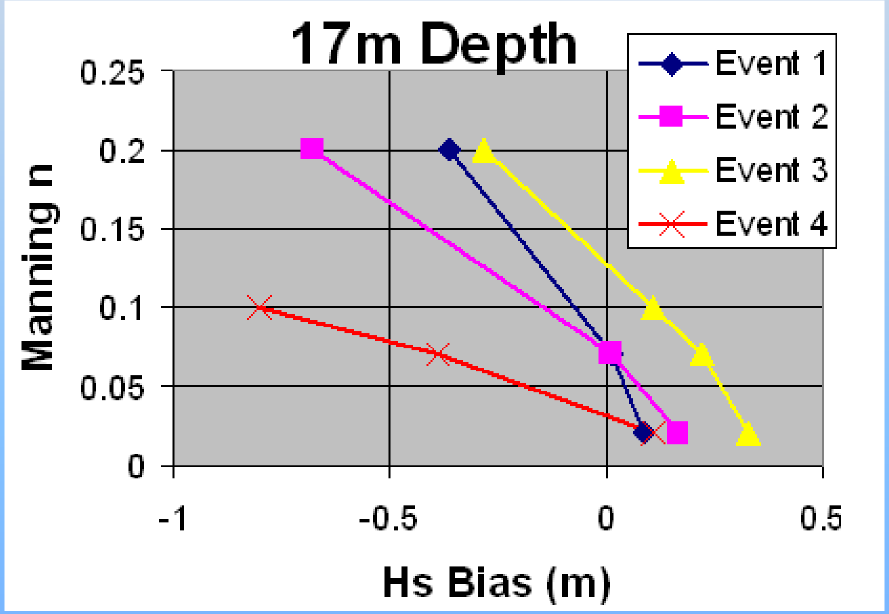
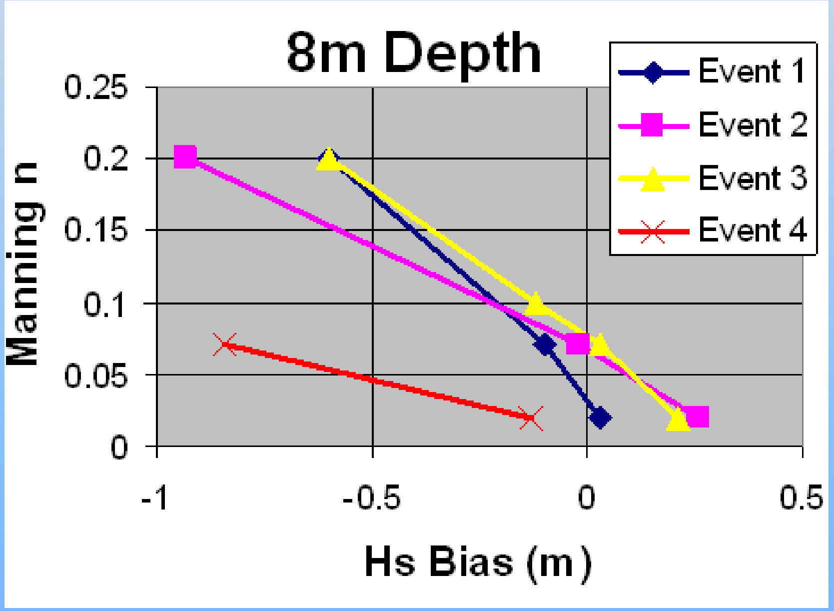
Findings

Dependence of STWAVE-FP Wave-Height Bias on Friction Coefficient (n)





2. Highly nonlinear Event 4 (Hurricane Bill) wave heights significantly under-predicted by STWAVE-FP at these shallow depths (using bottom friction source term)

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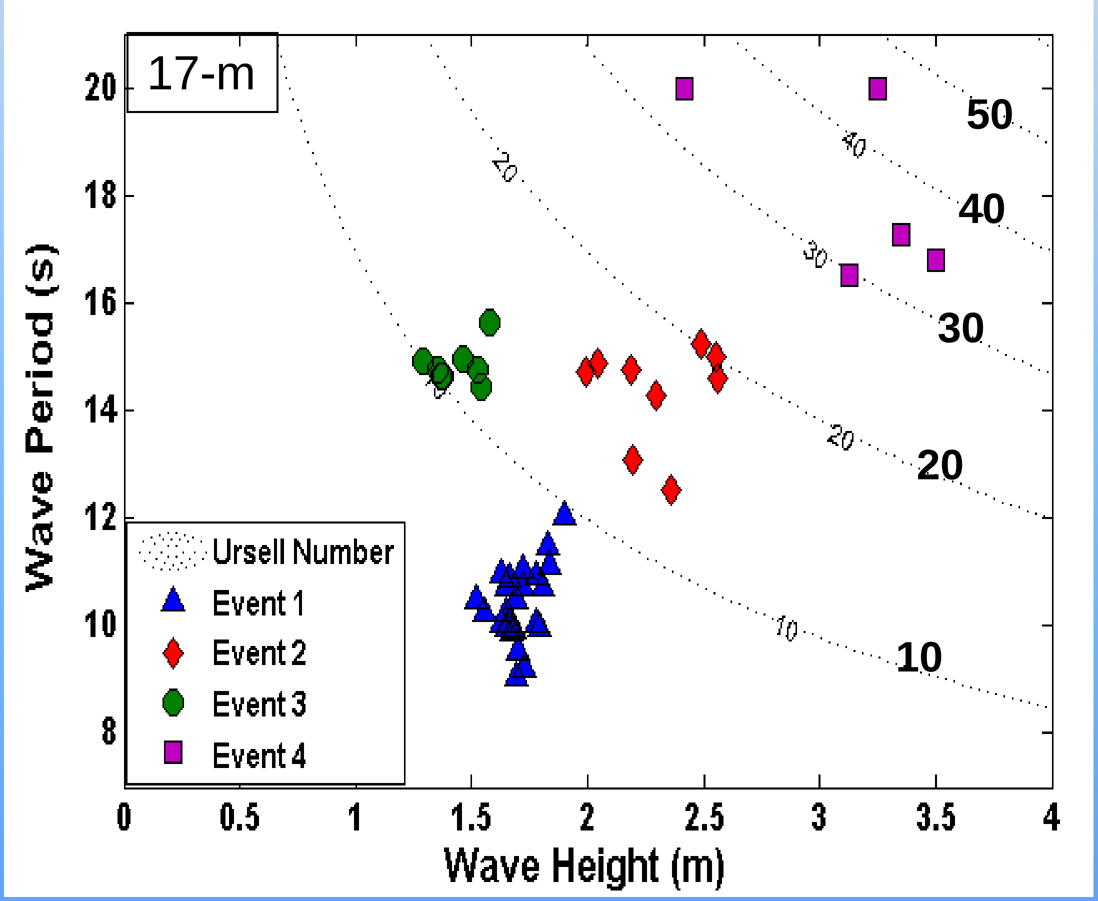
Findings

3. **Wave nonlinearity is a critical factor influencing STWAVE-FP results in shallow water. The Ursell Number was used as a guide in eliminating Event 4 (Hurricane Bill).**

The Ursell number compares Wave steepness to the water depth:

$$N_{Ursell} = \frac{g\, H_s\, T_p^2}{d^2}$$



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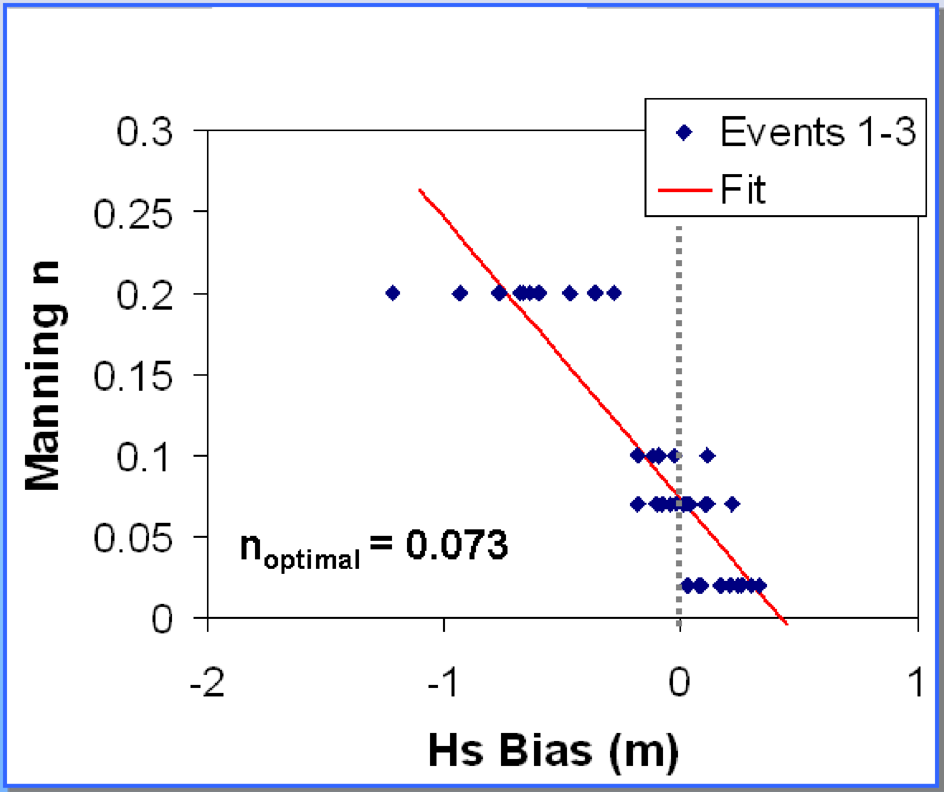
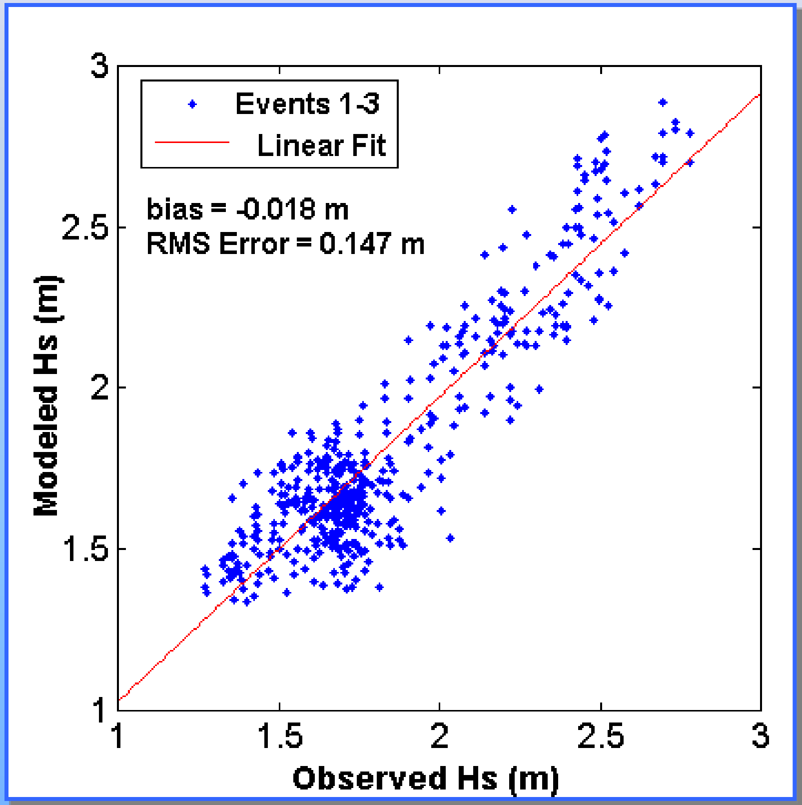
Findings

Model Hs Bias and Friction Coefficient



Model Performance with n = 0.07



4. Combined data from 3 wave events at all stations yields an optimum Mannings bottom friction coefficient of n ≈ 0.07, resulting in a wave height bias of -0.02 m and RMS error of 0.15 m.

Findings

1. The FRF Cross-Shore wave array captures all phases of wave transformation across the shelf. Three transformation regimes were noted: Bottom friction, Shoaling and breaking.

2. Highly nonlinear Event 4 (Hurricane Bill) wave heights significantly under-predicted by STWAVE-FP at these shallow depths (using bottom friction source term)

3. Wave nonlinearity is a critical factor influencing STWAVE-FP results in shallow water. The Ursell Number was used as a guide in selecting valid runs.

4. Combined data from 3 wave events at all stations yields an optimum Mannings bottom friction coefficient of $n \approx 0.07$, resulting in a wave height bias of -0.02 m and RMS error of 0.15 m.

Thank You…