

# **Development of a Coastal Wave Energy Climatology**

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# **Coastal Wave Climate Research Questions**

- Can we assemble a long-term coastal observation record?
- What are the climatic trends of wave energy from
  - Tropical Storms
  - Extratropical Storms
  - South Atlantic Storms
  - Trade Winds
  - Regional Weather



• How are each of these controlled by known weather oscillations (El Nino, North Atlantic Oscillation, etc.)?

#### **Duck FRF Long-Term Wave Measurements**

#### **Stations**

18m 1D Waverider: 1980-1996 18m 2D Waverider: 1996-present 1990-2012 8m Pressure Array: 48m NDBC Buoy: 1997-present 26m 2D Waverider: 2008-present 2008-present 6-11m AWAC Array:





**Nearshore Acoustic** Array (1.5-11 m depth)



18-m Datawell Waverider



48-m NDBC 44014

### Hurricane Sandy: October 2012



18-m Depth Waverider Buoy (3 km Offshore)



# **Data Gaps**

18m 1D Waverider:	1980-1996
18m 2D Waverider:	1996-2014
8m Pressure Array:	1990-2012
26m 2D Waverider:	2008-2014
6-11m AWAC Array:	2008-2014

55%	Gaps
7%	Gaps
5%	Gaps
17%	Gaps
18-28%	Gaps





#### Developing a Long-Term Record Target: 18m Station

#### **FRF XShore Array**



- Transform wave spectra from all stations to 18m depth
- Fill 18m gaps with transformed data
- Artificial Neural Net (ANN) modeling
  - Shallow water non-linear behavior
  - Multi-parameter inputs
  - Fast efficient processing



# Spectral Validation

#### **Energy-Freq Spectra**





### **Hs Validation**



### Depth-Dependant Spectral Wave Power and Energy Calculations

**Frequency Spectrum (1D)** E(f) (m<sup>2</sup>/Hz)

**Wave Power** 
$$W_p = \rho g \int E(f) \cdot c_g(f) df$$
 (W/m)

Group Velocity (d is water depth, k is wave number)

$$c_g = \frac{1}{2} \sqrt{\frac{g}{k}} \tanh(kd) \left( 1 + \frac{2kd}{\sinh(2kd)} \right) \quad \text{(m/s)}$$

Total Wave Energy 
$$E_t = \int w_p dt$$
 (J/m)

### FRF 34-Year Gap-Filled Wave Record



#### FRF 34-Year Gap-Filled Wave Record



#### **Wave System Classification**



### **Wave System Classification**

#### Sample Records 15-13 May 2009

- Wave partitioning combined with swell system tracking
- Sort wavefield energy by source type/region



### **Wave System Classification**

#### Sample Records 15-13 May 2009



- Wave system classification scheme based on Hs/Tp/Dir attributes
- Applied to 23-year 2D wave record

### Wave System Energy Budget



## Wave System Energy Budget









# Summer / Fall Coastal Storms





ONI: R = 0.4 NAO: R = -0.1

# **By-Passing Storms**





# **Directional Classification**





# Summary



NC Wave energy dominated by coastal storms

- > Winter/North wave energy is trending down
- South wave energy is trending up
- Local wave energy is trending up
- NAO exhibits very weak influence on NC waves
- El Niño has a strong influence on NC waves
  - > El Niño events increase winter/spring wave energy
  - El Niño events decrease summer/southerly wave energy





#### Thank you...



#### Hurricane Sandy Waves hit the FRF Pier Photo Credit: Steven Vogt