WAVE STATISTICS AND ENERGY CAPTURE

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NEED FOR THE STUDY

- Complexity!
- Calculated wave power has variability from month to month and year to year (changes of 20-50% from one year to the next are common).
- Year-to-year and longer-term climatic variability are especially important for estimating the lifetime extremes that a device will experience.
- Basic information such as approximate overall mean power level, distribution of power over time and by frequency is a prerequisite for matching any kind of device to its wave climate.
- Hydrodynamic response of wave energy devices is significantly affected by wave period; the power take-off equipment is more sensitive to the variation in the wave power level.

MAIN OBJECTIVES

- Establishment of means to improve the prediction of the magnitude, character and nature of individual waves, wave groups and extremes at sites

- Development of statistical and probabilistic models for the description of extremes of wave to assess survivability requirements of devices

- Development and test of numerical models to predict the wave-power characteristics

PROGRESS MADE

- Assembly of Metocean data from various sources
- Analysis of wave data for the calculation of summary wave statistics and other wave parameters
- Synthetic wave simulation and comparison with real ocean measurements
- Calculation of generic device power conversion
- Wave periods filtering and its effects on wave power
- Wave modelling for wave parameters statistics
- Wave modelling for individual waves and groups
- Device Array modification to the environment

Assembly of Metocean data from various sources

- North Sea data from North Alwyn platform
- Location 100 miles east of Shetland
- Water depth = 130m
- Three wave altimeters measuring waves

- European Marine Energy Centre's data
- Measured by two waverider buoys
- Water depth = 50m

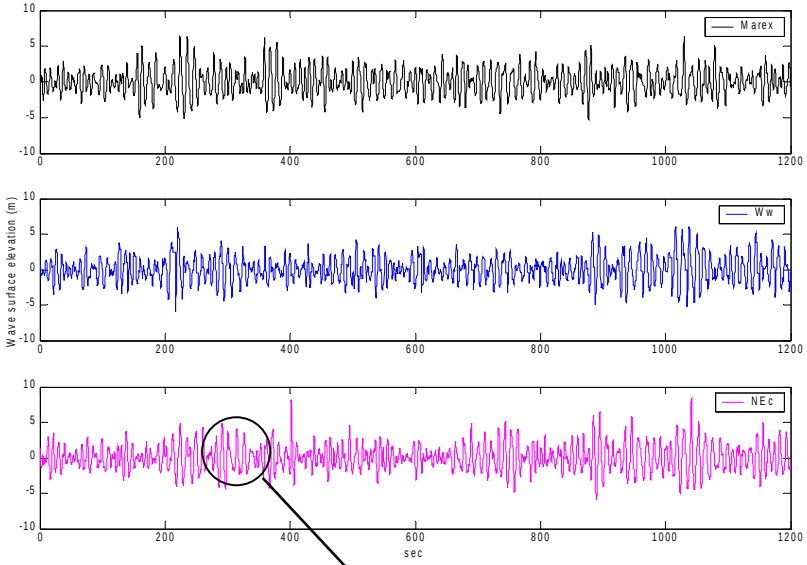
- WACSIS data from Dutch coast
- Water depth = 18m
- Baylor wave staff measuring waves

Assembly of Metocean data from various sources

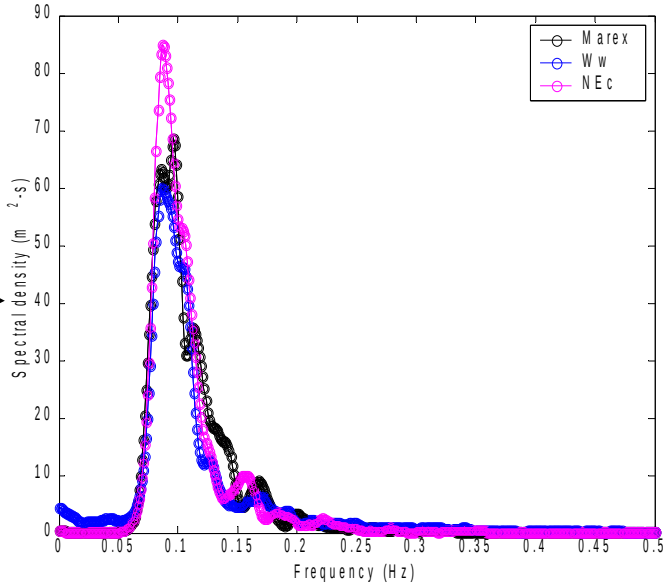
Outcome

- A wave database is compiled
  - ✓North Alwyn – 12 years information
  - ✓EMEC – about 2 years information (more data is expected from this source)
  - ✓WACSIS – about 1 year information

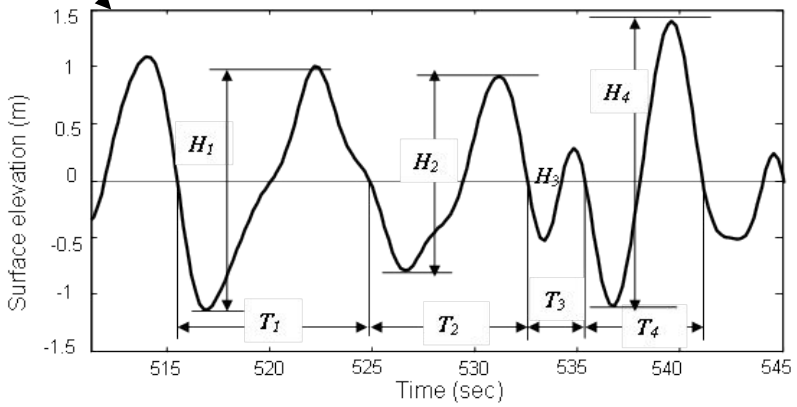
Analysis of wave data to calculate summary statistics and other wave parameters



North Alwyn data - a 20 minutes measurements



Corresponding wave spectra



Definition sketch for wave by wave analysis

Analysis of wave data to calculate summary statistics and other wave parameters

Resulting Parameters

- Significant wave height
- Peak wave period
- Individual wave heights and periods
- Energy wave period
- Zero crossing wave period
- Spectral moments
- Spectral bandwidth
- Groupiness index

Synthetic wave simulation

SUPERGEN MARINE

Correlation coefficients for time series from field measurements

	North Alwyn		EMEC		WACSIS	
	Mean(μ)	Std (σ)	Mean(μ)	Std (σ)	Mean(μ)	Std (σ)
successive wave heights	0.344	0.096	0.230	0.106	0.313	0.105
successive wave periods	0.251	0.089	0.193	0.082	0.245	0.091
H, T	0.636	0.056	0.689	0.095	0.673	0.049

Correlation coefficients for time series from Jonswap simulations

	d = 130m		d = 50m		d = 18m	
	Mean(μ)	Std (σ)	Mean(μ)	Std (σ)	Mean(μ)	Std (σ)
successive wave height	0.428	0.076	0.419	0.080	0.426	0.073
successive wave periods	0.283	0.075	0.284	0.085	0.278	0.078
H,T	0.604	0.058	0.614	0.062	0.588	0.051

$$\rho_{HH} = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}(H_i - \bar{H})(H_{i+1} - \bar{H})}{\frac{1}{N}\sum_{i=1}^{N}(H_i - \bar{H})^2}$$

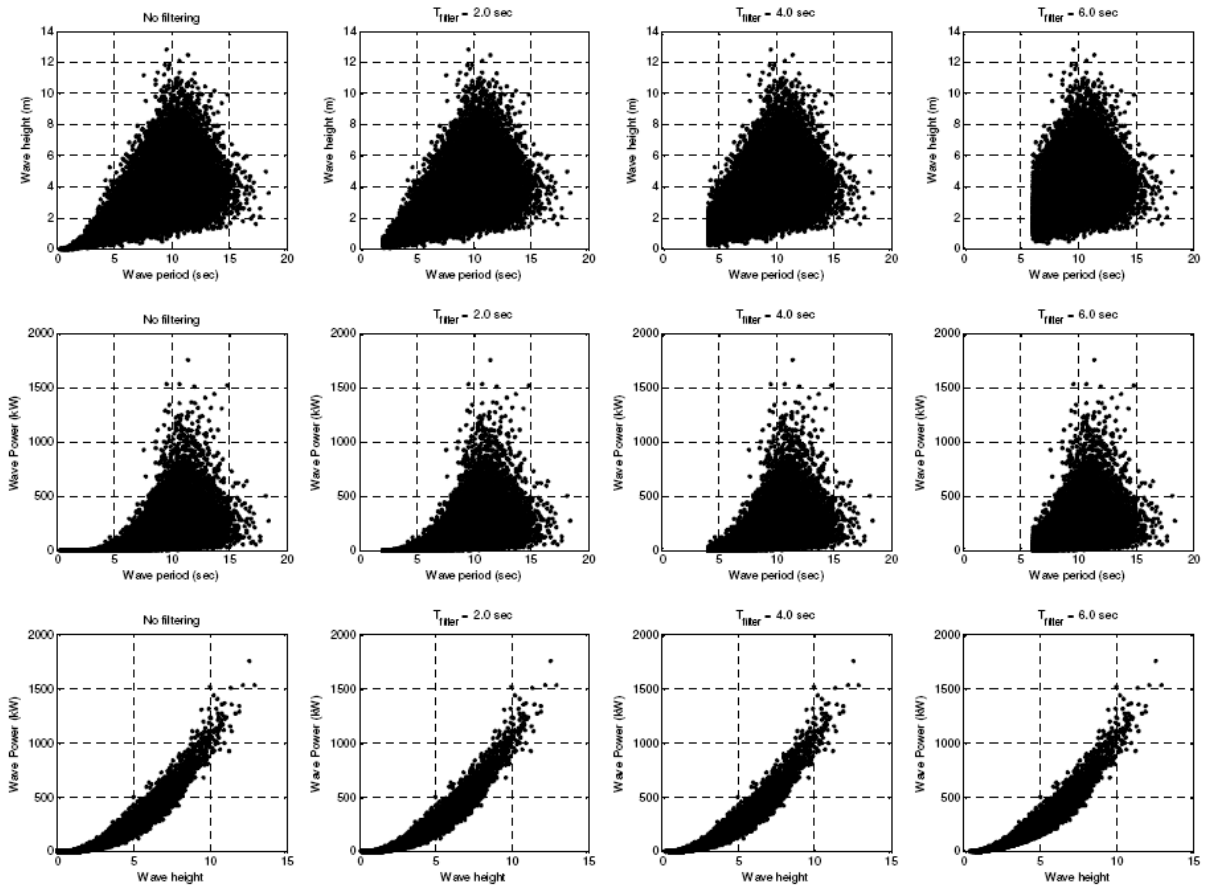
$$\rho_{TT} = \frac{\frac{1}{N-1}\sum_{i=1}^{N-1}(T_i - \bar{T})(T_{i+1} - \bar{T})}{\frac{1}{N}\sum_{i=1}^{N}(T_i - \bar{T})^2}$$

$$\rho_{H,T} = \frac{\sum (H_i - \bar{H})(T_i - \bar{T})}{\sum \sqrt{(H_i - \bar{H})^2 (T_i - \bar{T})^2}}$$

Synthetic wave simulation

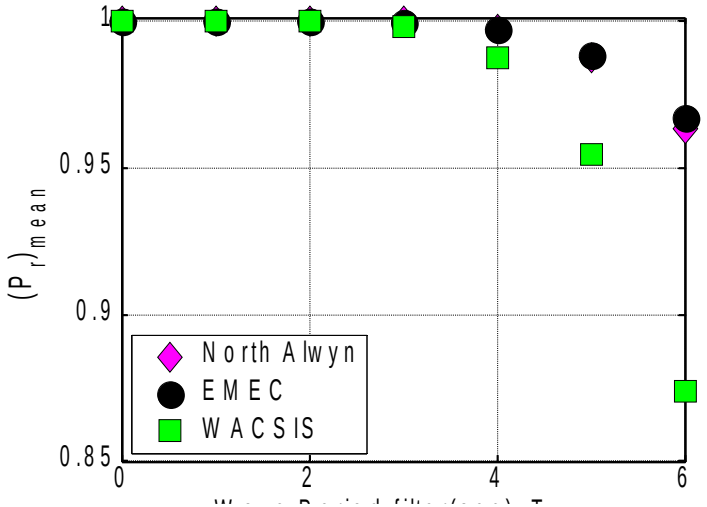
- Correlation coefficients and other summary statistics shows goods comparison between field measurements and numerical simulated wave data
- Simulated wave time series can be confidently used in scaled wave tank/wave basins study

Effect of wave period filtering on wave power



North sea data: Scatter diagram for H,T and P
about 27,000 individual waves

Effect of wave period filtering on wave power

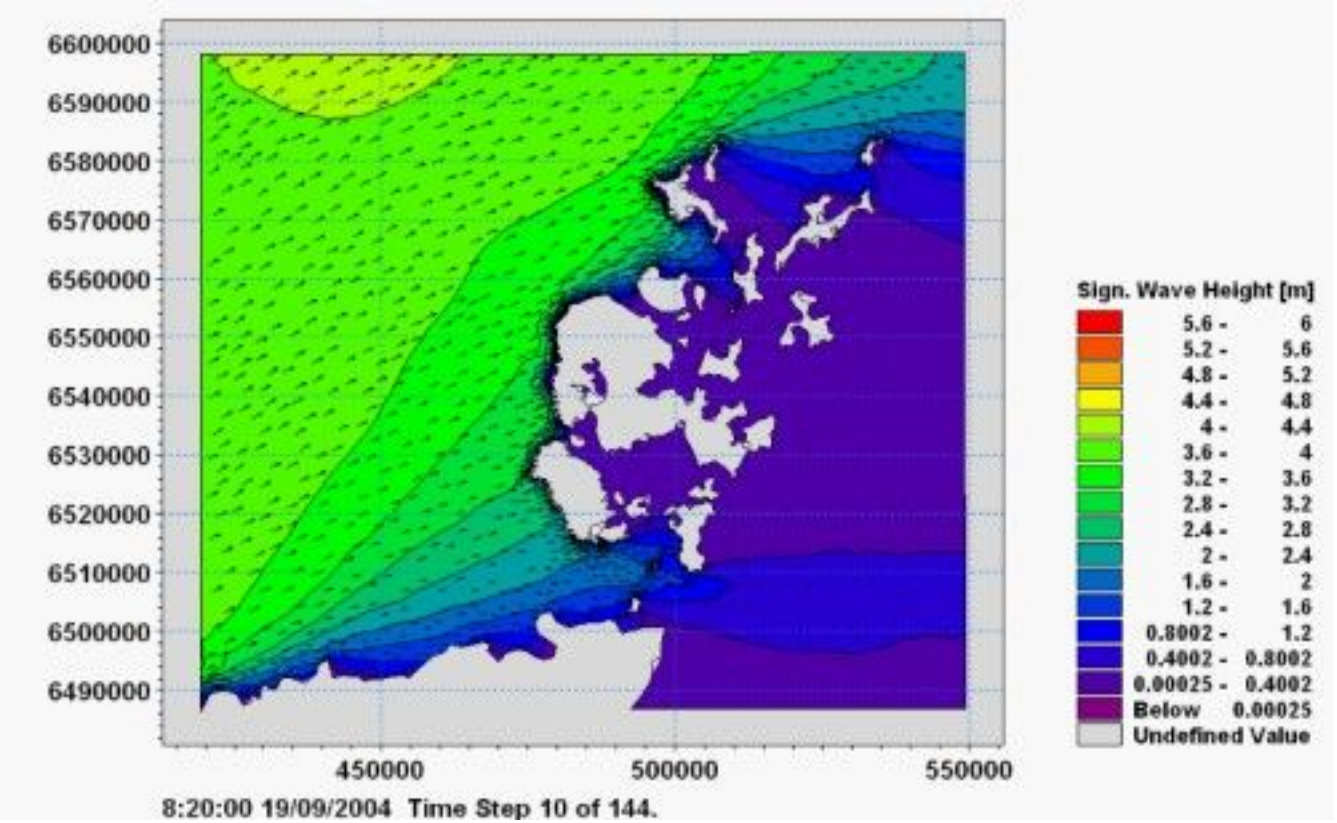


mean of the 'mean power ratio', $(P_r)_{mean}$

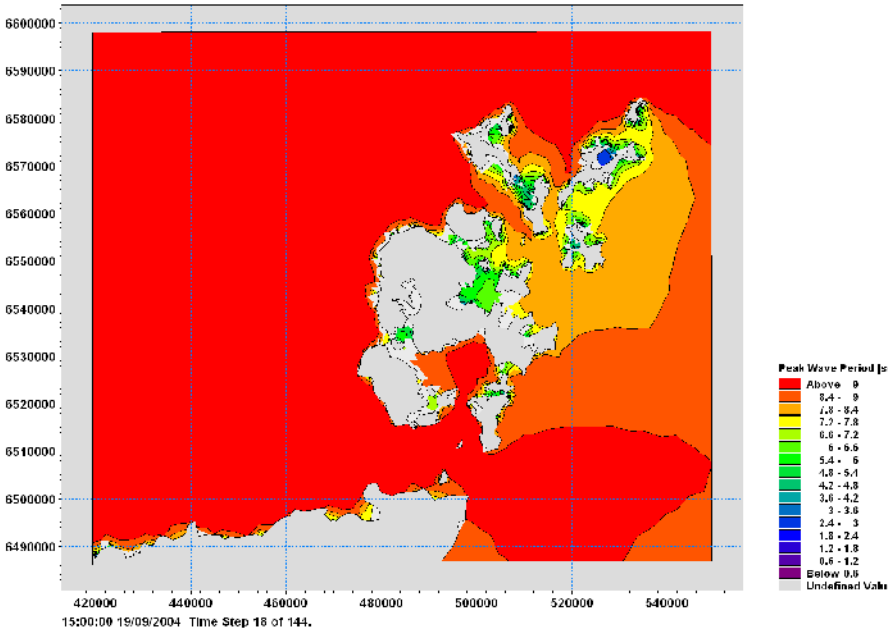
Outcome

- For shallow water (18m), the maximum reduction in wave power is within 5% for T_{filter} up to 5 sec. The T_{filter} = 6 sec results in wave power loss up to 12.5%.
- For deeper/intermediate water range (50-130m), filtering out waves up to 5 sec removes less than 2.5% of the wave power, and even using T_{filter} = 6 sec, limits the power reduction within 5%.

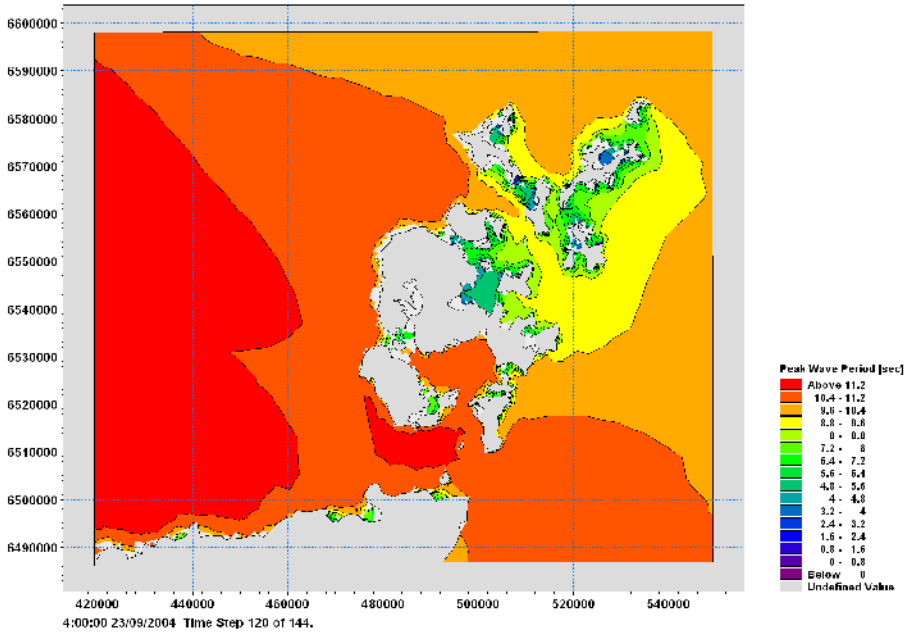
Wave modeling for Orkney – Variation of significant wave height
(animation not available)



Wave modeling for Orkney – variation of peak wave period

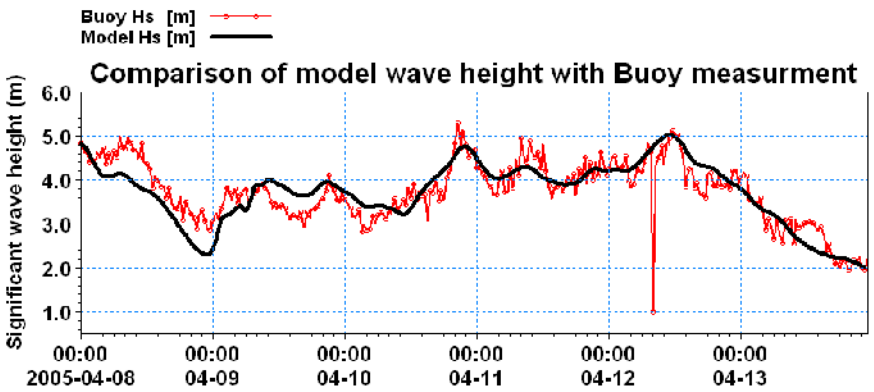


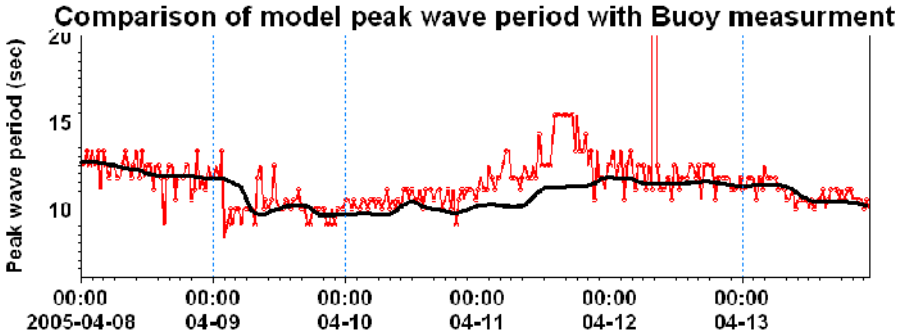
On 19/09/2004, at 15:00 hrs

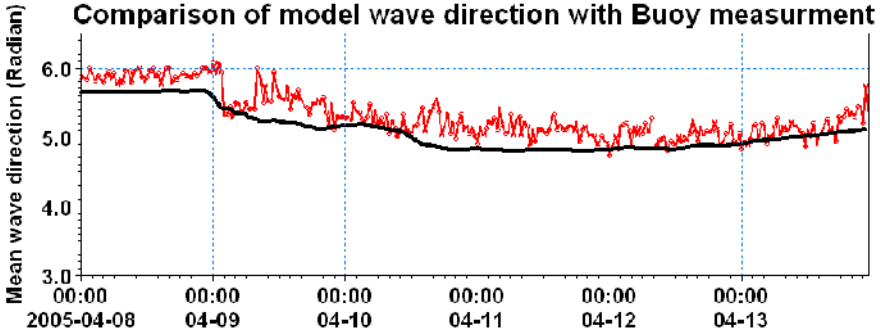


On 23/09/2004, at 4:00 hrs

Wave modeling for Orkney – model validation with buoy measurements

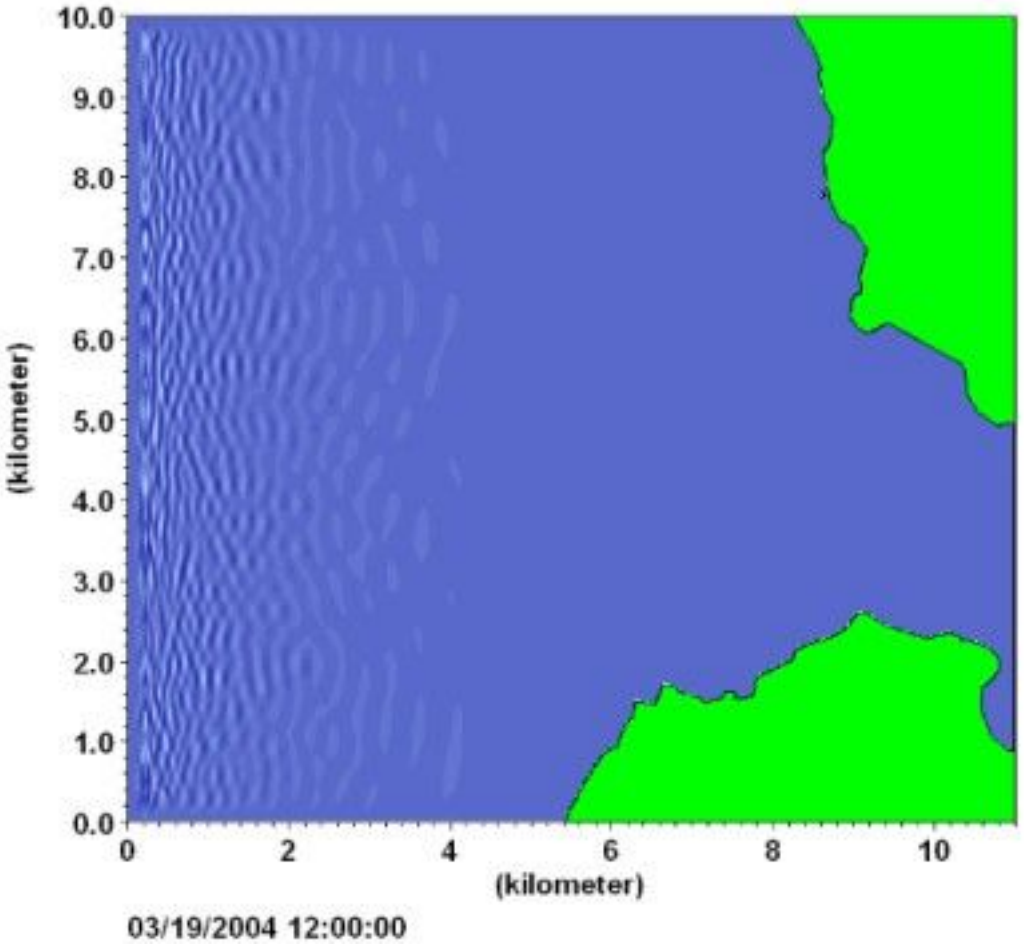




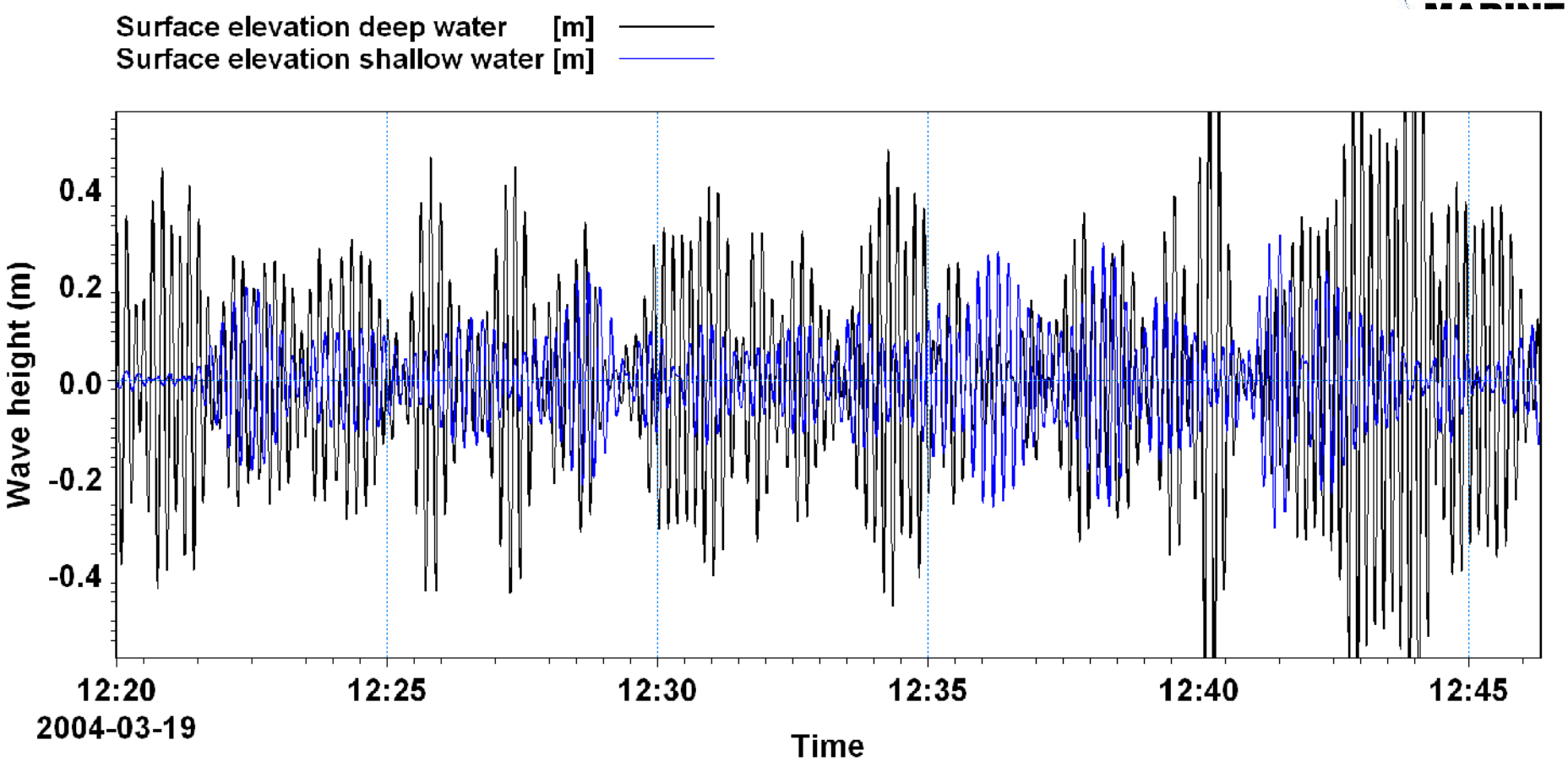


Wave modeling for the calculation wave time series

For Hs = 1m, Tp = 10sec
(animation not available)



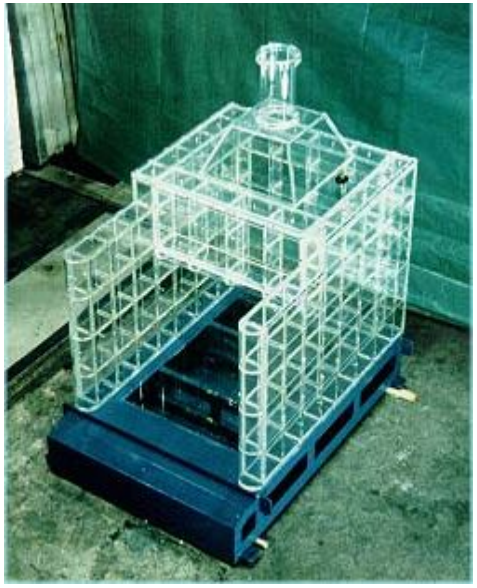
Individual wave/group evolution



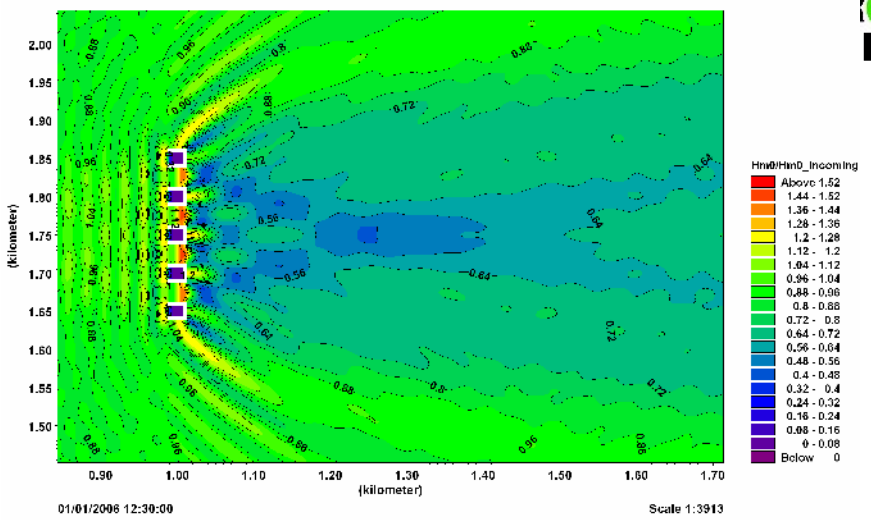
- Wave by wave time series is needed to establish corresponding wave energy time series
- Individual extreme waves and wave groups can be identified for device design and survival

Wave interaction with Oscillating water column device

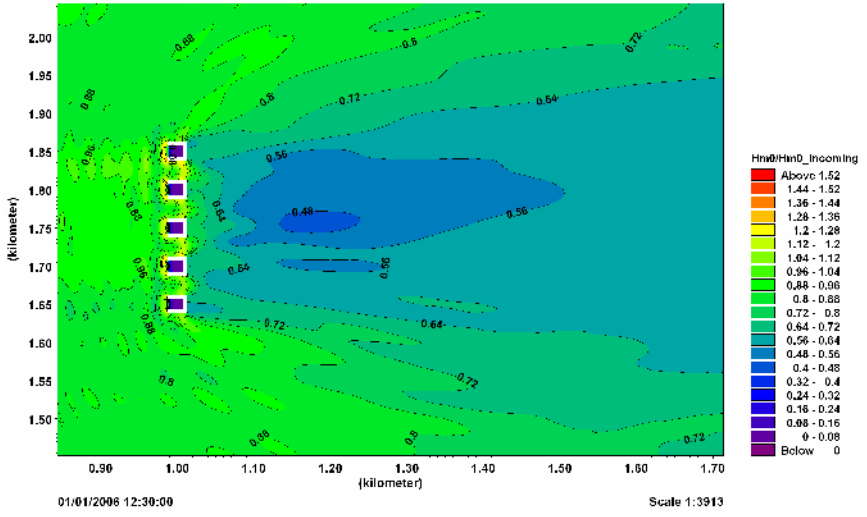
- H_S = 1m, T_p = 6 sec spacing = 25m
- Wave disturbance coefficient = H/H_input



OWC model at IIT, India



Unidirectional waves



Multi-directional waves

Achievements

- Compilation and analysis of a broad range of environmental wave measurements
  - Comparison of instruments and physical sea characteristics
- Comparison of statistics from real and synthetic data
- Generic method of determining power output from a device/ sea state combination
- Investigated possibility of tuning from “wave-by-wave” up to wave-group time periods
- Development of “site-specific” wave model of Orkney test berths
- Consideration of our ability to model “array effects”

Thank You