Analysis of Shallow Water Wave Measurements Recorded at the Field Research Facility

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Friday 4th November 2011

Motivation of Study

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- Wave height with given return period is required for designing coastal structures
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- Hindcast data is typically available in deep water but not shallow depths.
  - Evolution of frequency spectrum
- Low-frequency waves cause erosion, excite harbour seiches, break ice shelves & cause resonance of moored vessels
  - Infragravity wave prediction

Methodology

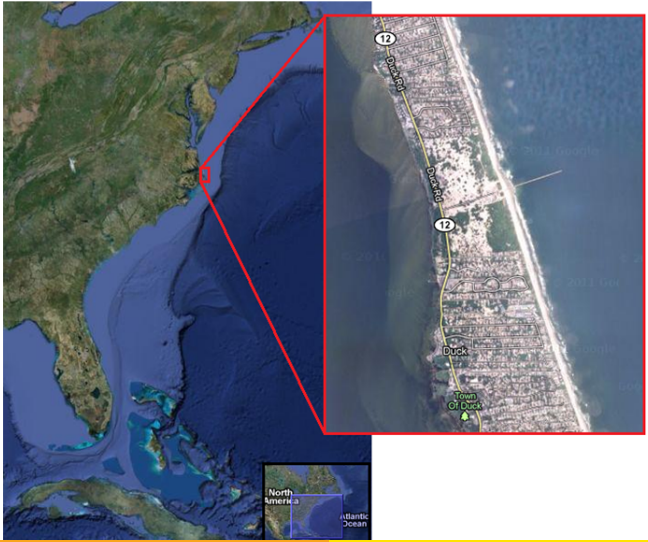
- Field measurements with 34 mins sample duration
- Wave height probability disribution
  - Zero-crossings and ranking wave heights
- Evolution of frequency spectrum
  - Welch method for ensemble averaging of spectrum
- Infragravity wave prediction
  - Run Ideal Surf Beat (IDSB) model

Summary of Conclusions

- Wave height distribution
  - Performed a Kolmogorov-Smirnov test on 1442 individual sea states
  - Glukovskiy distribution (as formulated by van Vledder, 1991) provided best fit to data
- Evolution of frequency spectrum
  - TMA spectrum was not comparable with the field measurements, especially for low frequencies
  - Greater attenuation with larger spectral density for all ranges of kd
- Infragravity wave prediction
  - Ideal Surf Beat (IDSB) model has an average skill of 78%

Field Measurements: Location

- Duck, North Carolina, USA



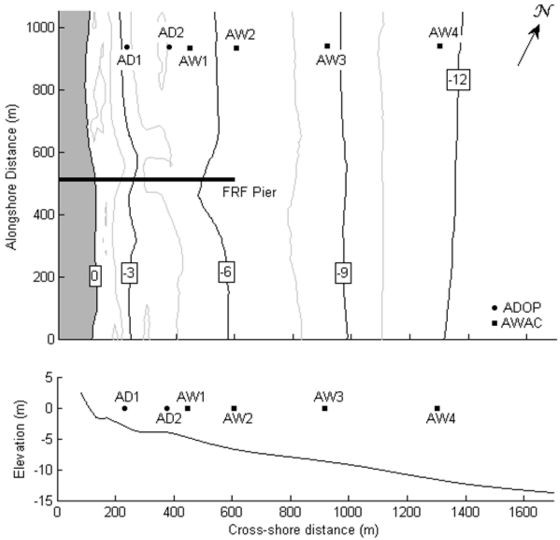
Field Measurements: Cases Examined

- Instruments
  - Nortek Aquadopp (ADOP)
  - Nortek Acoustic Wave And Current (AWAC) meters
  - Sample at 2 Hz for 34 mins every hour
- Data available for 1442 sea states in 5 storm events

Case	Date	Max. H_s $[\mathrm{m}]$	Mean T_p [s]
E1	01–05 September 2010	3.2	12.3
E2	21–23 August 2009	3.3	15.1
E3	11–16 November 2009	3.0	12.0
E6	26–28 March 2009	2.9	13.6
E8	29–30 August 2010	1.7	12.7

- Case E2 corresponds to Hurricane Bill

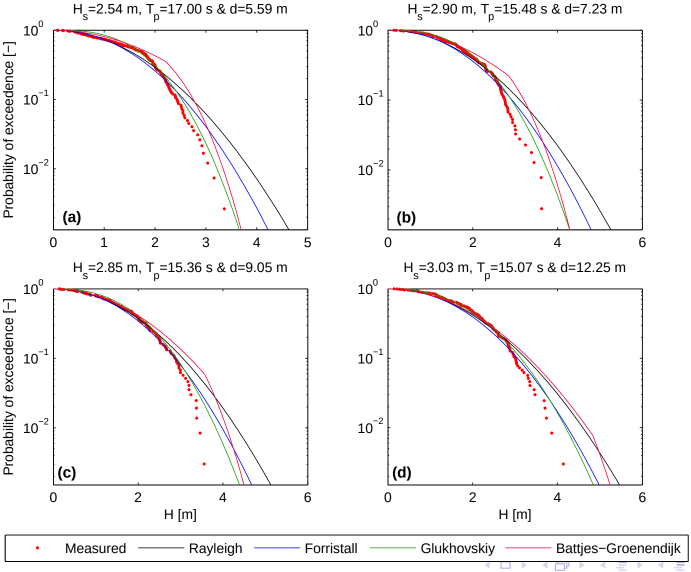
Field Measurements: Bathymetry



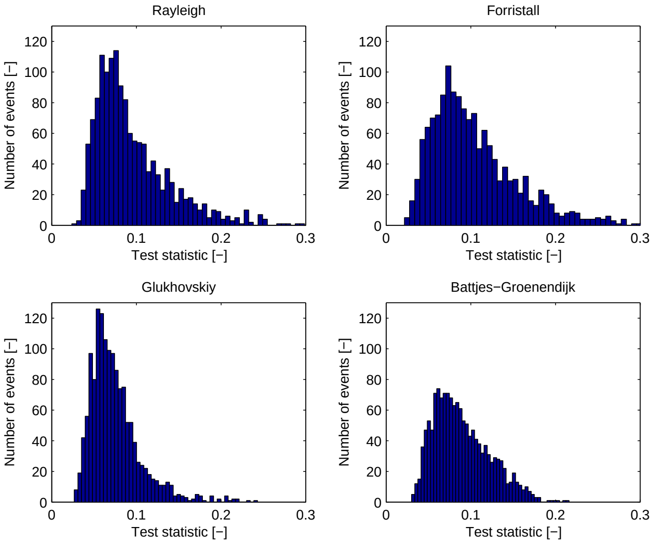
Wave Height Distribution

- Theoretical distributions
  1. Rayleigh: $f(H_s)$
  2. Forristall (1978): $f(H_s)$
  3. Glukhovskiy (formulation of van Vledder, 1991): $f(H_s, d)$
  4. Battjes and Groenendijk (2000):$f(H_s, d, \alpha)$
- Distributions 1 and 2 are for deep water
- Distributions 3 and 4 were developed specifically for shallow water
- Battjes-Groenendijk distribution is a composite Weibull in 2 parts
- None of the distributions has an upper limit
- Analysis
  - Visual inspection for individual sea states
  - Kolmogorov-Smirnov test for goodness of fit

Example Probability Distributions for Individual Sea States



Test Statistic from K-S Test: Histograms



Test Statistic from K-S Test: Summary

- Summary of test statistic, k^*

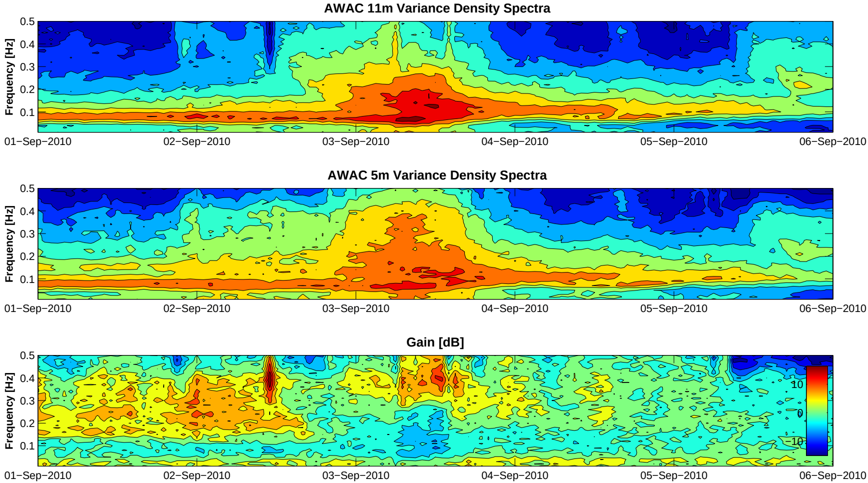
Distribution	**Mean** k^*	**Mode** k^*	**Median** k^*	**Std** k^*	**Pass [%]**
Rayleigh	0.094	0.059	0.082	0.044	87
Forristall	0.104	0.091	0.092	0.051	80
Glukovskiy	0.075	0.063	0.069	0.030	96
Battjes-Gronendijk	0.089	0.059	0.084	0.033	91

- Glukhovskiy has the best agreement with the field measurements

Evolution of Frequency Spectrum

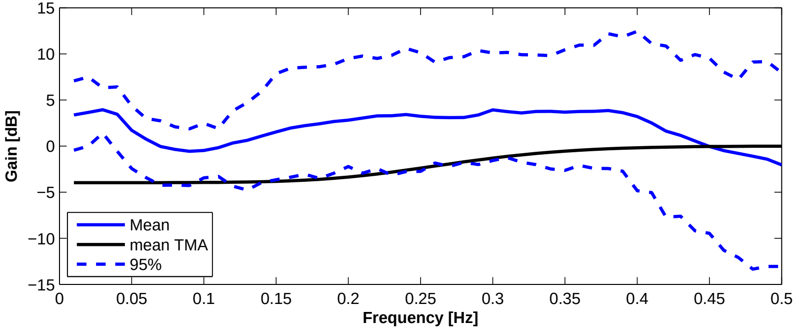
- Frequency resolution of 0.01 Hz
- Analyse spectral evolution of the frequency variance density spectra in time and space
- Focus on difference between spectra at 11 m & 5 m AWACs
- Calculate the gain between the two spectra
- Compare gain to TMA transfer function

Evolution of Spectrum & Gain

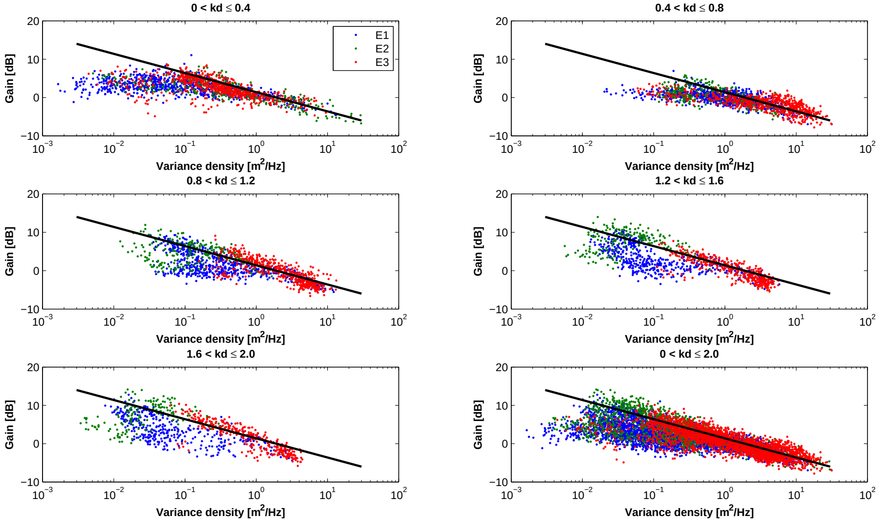


Mean Gain

- Calculate difference between frequency spectrum at 11 m and 5 m
- Take the mean of this difference
- Compare to TMA transfer function between 11 m and 5 m



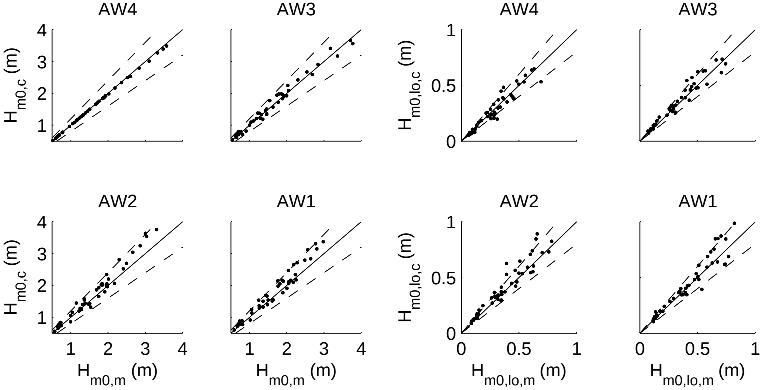
Attenuation



Ideal Surf Beat (IDSB) Model

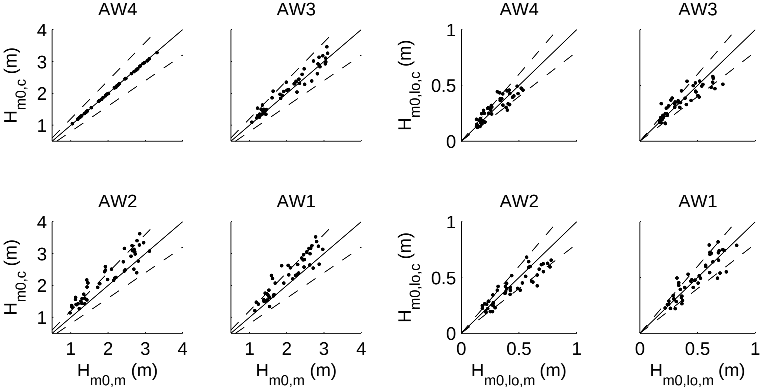
- Infragravity waves have period between 20 s & 200 s
- IDSB can simulate generation of bound and free infragravity waves
  - Reniers *et al.* (2002) JGR
- Assumptions
  - Linear shallow-water wave model
  - Constant along shore bathymetry
  - Full reflection of IG waves at shoreline
  - Narrow spectrum in both frequency and direction
- Incoming and outgoing waves
  - Incoming directionally-spread short waves
  - Incoming *bound* IG waves
  - Outgoing trapped and leaky *free* IG waves

Calculated vs Measured: Case E2



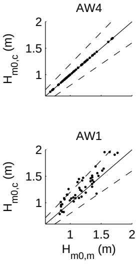
(a) Short waves (b) Infragravity waves

Calculated vs Measured: Case E6

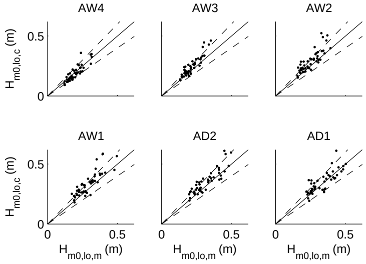


(c) Short waves (d) Infragravity waves

Calculated vs Measured: Case E8



(e) Short waves



(f) Infragravity waves

Calculated vs Measured: Table

- Determine the skill, s, at each instrument and overall

$$s = 1 - \frac{\sqrt{\langle (H_{rms,m} - H_{rms,c})^2 \rangle}}{\langle H_{rms,m}^2 \rangle}$$

Case	AW4	AW3	AW2	AW1	AD2	AD1	Overall
E2	0.78	0.83	0.78	0.73	-	-	0.78
E6	0.78	0.75	0.74	0.81	-	-	0.77
E8	0.83	0.78	0.74	0.75	0.8	0.81	0.79

- Average skill of 78%

Conclusions

- Analysed new shallow water measurements at FRF
  - Data available for 1442 sea states in 5 storm events
- Wave height distribution
  - Performed a Kolmogorov-Smirnov test on every sea state
  - Glukovskiy distribution (as formulated by van Vledder, 1991) provided best fit to data
- Evolution of frequency spectrum
  - TMA spectrum was not comparable with the field measurements, especially for low frequencies
  - Greater attenuation with larger spectral density for all ranges of kd
- Simulating infragravity waves with Ideal Surf Beat (IDSB) model
  - Average skill of 78%

Acknowledgements

- ONR for providing funding for NOPP project
- US Army Corps. of Engineers for data from FRF: J. Hanson & K. Hathaway
- T. U. Delft staff members: L. Holthuijsen, G. Stelling, M. Zijlema, J. Pietrzak, M. de Schipper & A. Reniers