Wave Breaking Function

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Topics

1. Existing Models
2. Field Wind Wave Data
3. Case Investigations
4. New Wave Breaking Formula
5. Summary and Conclusions

1. Existing Models of Wave Spectral Dissipation

(a) Whitecapping (Michell, 1893; Hasslemann, 1974; Komen et al. 1994)

$$S_{wc}(\sigma,\theta) = C_{ds}\bar{S}^{n}\frac{\bar{\sigma}}{\bar{k}}kE(\sigma,\theta)$$

where $\bar{\sigma}$ = mean frequency

$\bar{S}$ = mean wave steepness

$\bar{k}$ = mean wave number

C_{ds} = 0.000024 (empirical coef)

n = 4 (empirical power)

Existing Model (continued)

(b) Bottom Friction (Collins, 1972; Hasselmann et al. 1973)

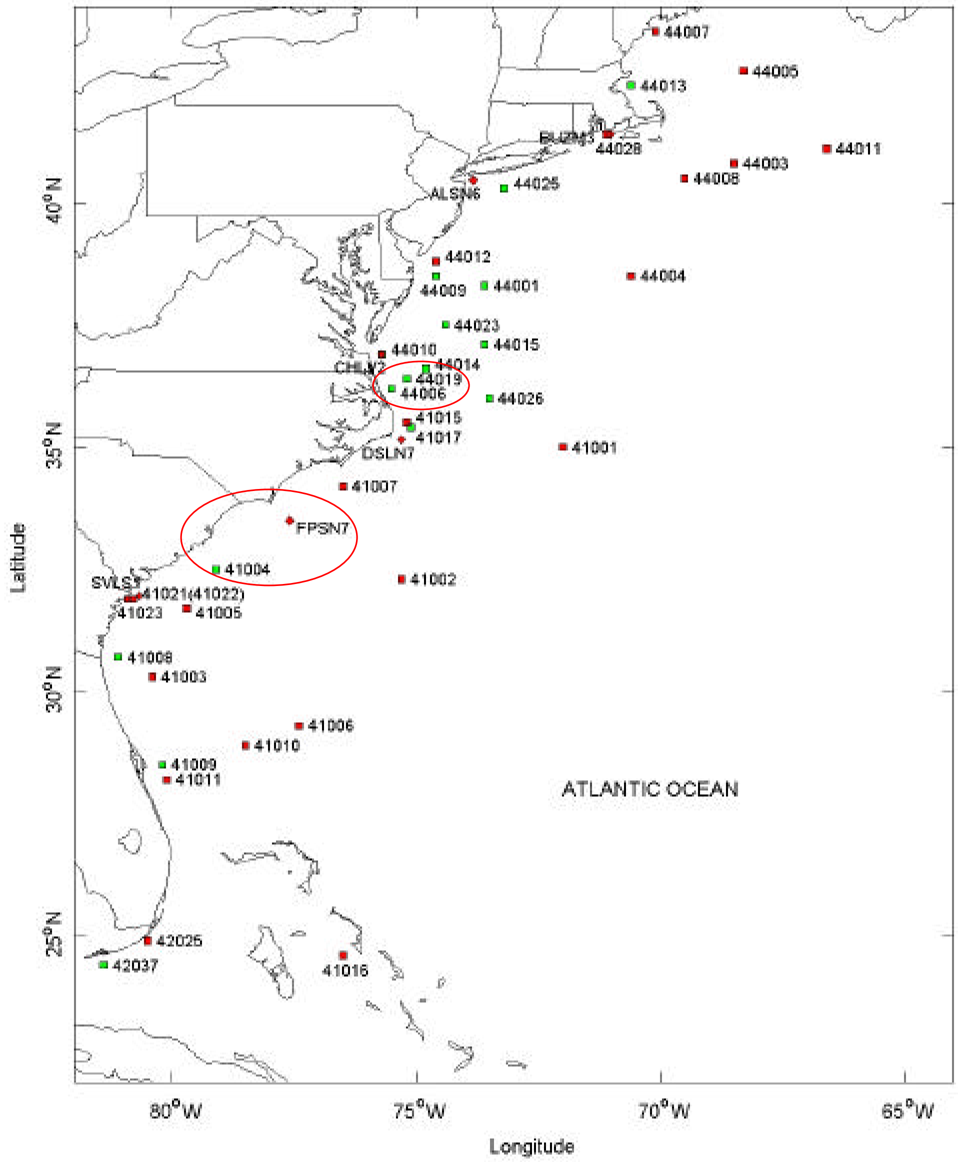
$$S_b(\sigma,\theta) = -C_f \frac{\sigma^2 < u_b >}{g \sinh^2(kh)} E(\sigma,\theta)$$

where $< u_b >$ = root-mean-square horizontal bottom velocity (water depth is h)

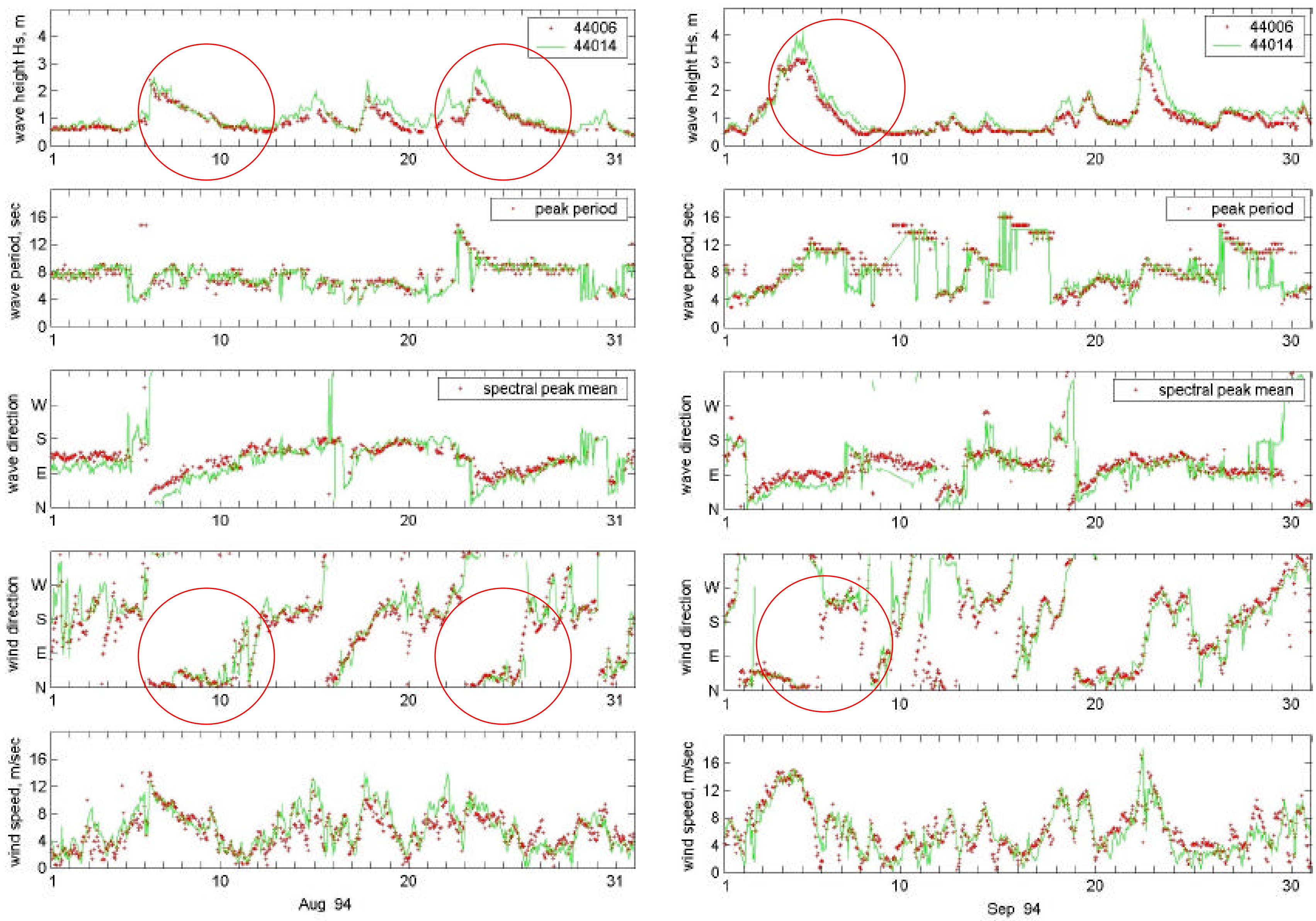
(c) Depth-limited Breaking (Miche, 1944; Battjies and Janssen, 1978; Eldeberky and Battjies, 1995)

$$\frac{< H >}{h} < \kappa \quad \text{(a constant)}$$

2. Field Wind Wave Data Network
National Data Buoy Center (NDBC)



NDBC Buoy 44006 and 44019 Data
Wave Energy Dissipation Events



Ideal Cases for Wave Dissipation Investigation

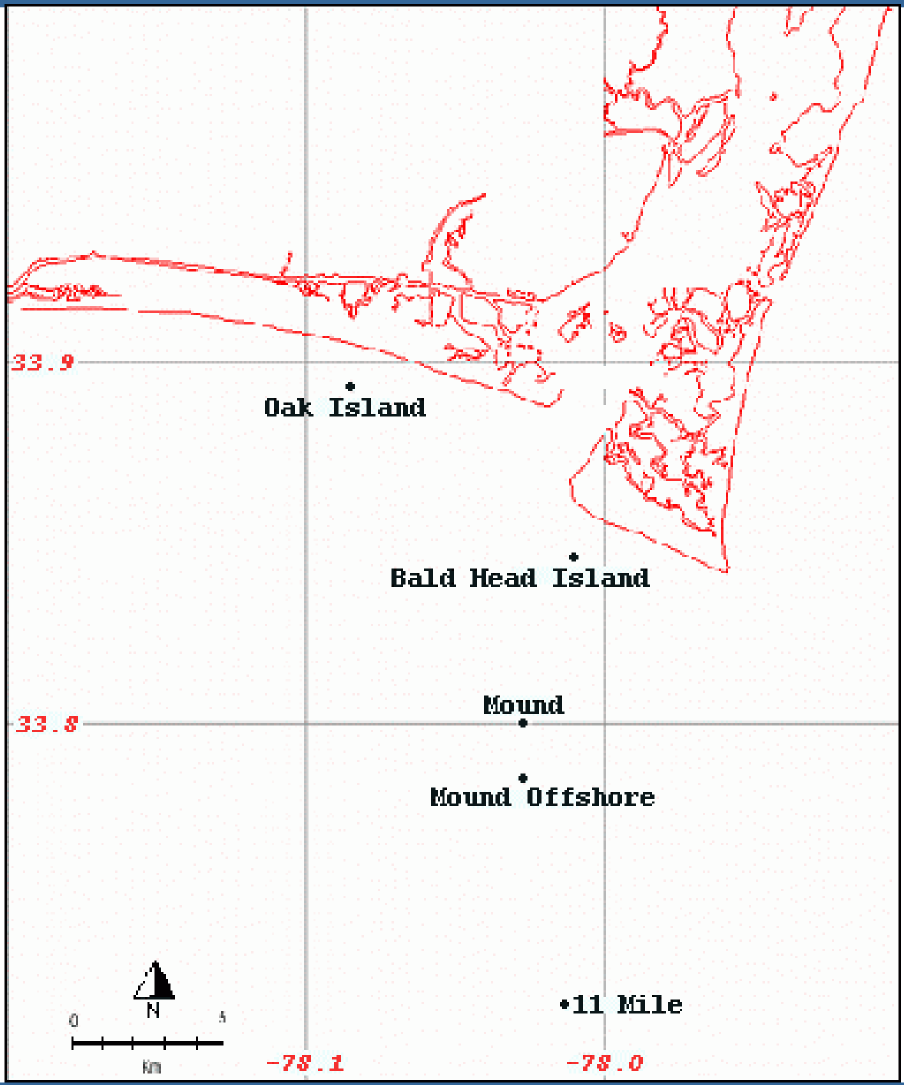
1. Small or mild wind condition – wind speed in the range of 0 to 10 knots (so, wind input effect is minimal)

2. A sudden change in wind direction – from one direction to a new one (so, wave dissipation is under a new wind condition) and new wind direction is either following or against the wave direction

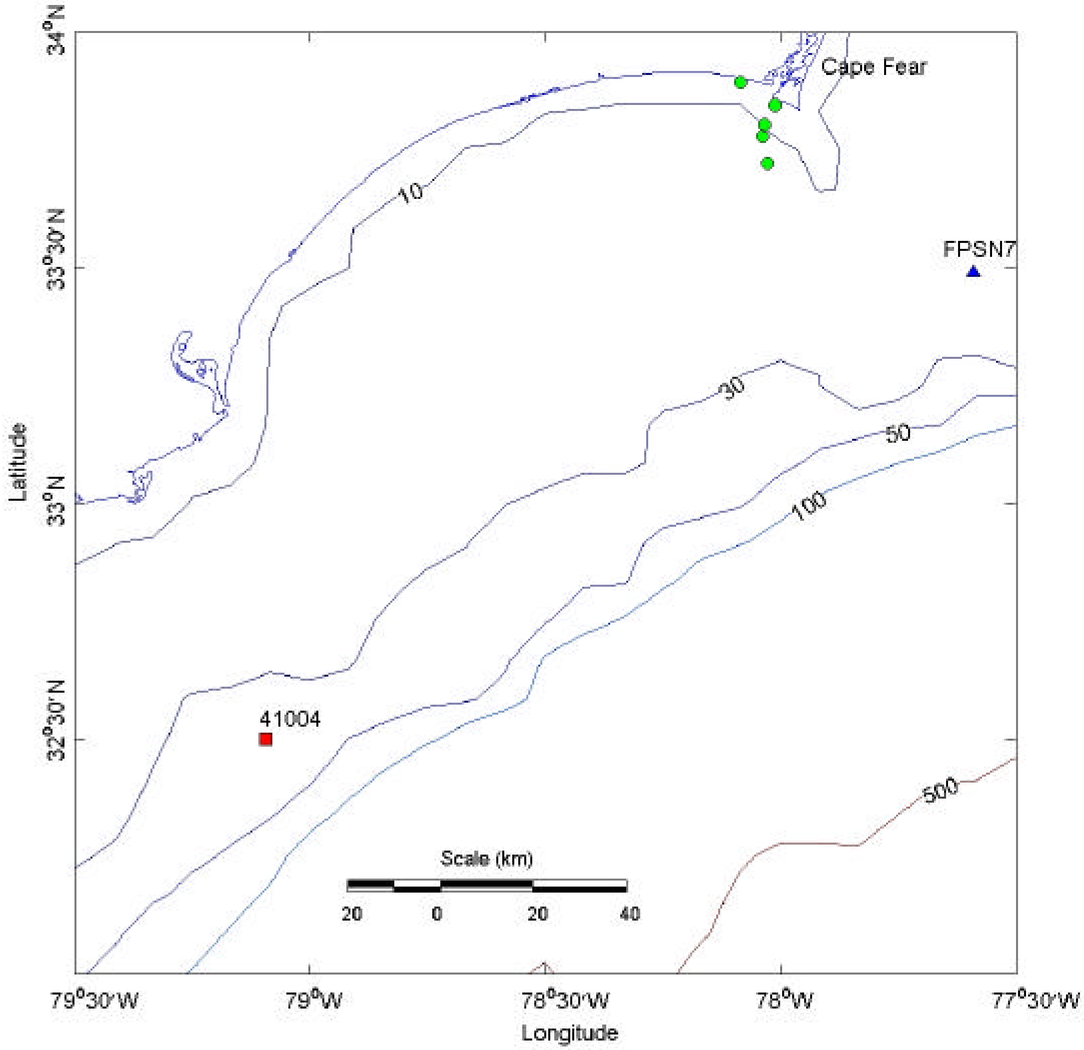
3. Constant wind speed and direction after the wind direction changes (so, no further variation of wind speed and direction)

4. Wave measurements from a network of stations that are close to each others in the intermediate water depth (so spatial variation is included in the investigation)

Cape Fear Directional Wave Data Network (2000-2003)



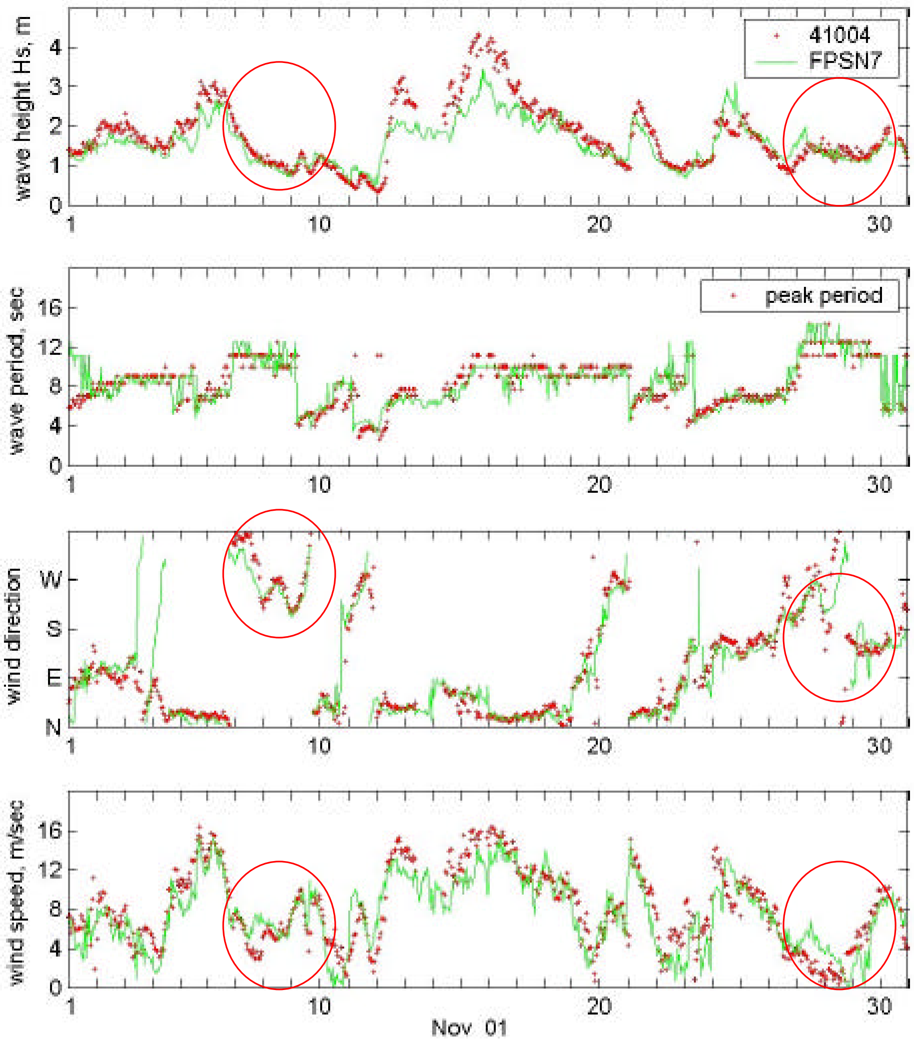
Wind Stations 41004 and FPSN7 (1978-2004)

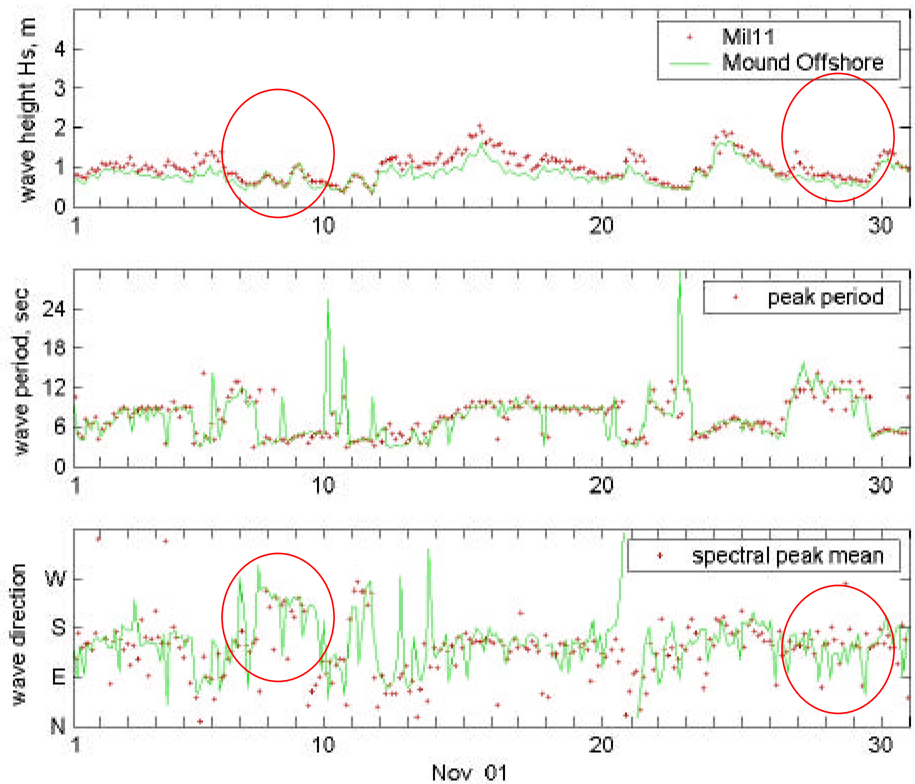


Wind/Wave Station Information

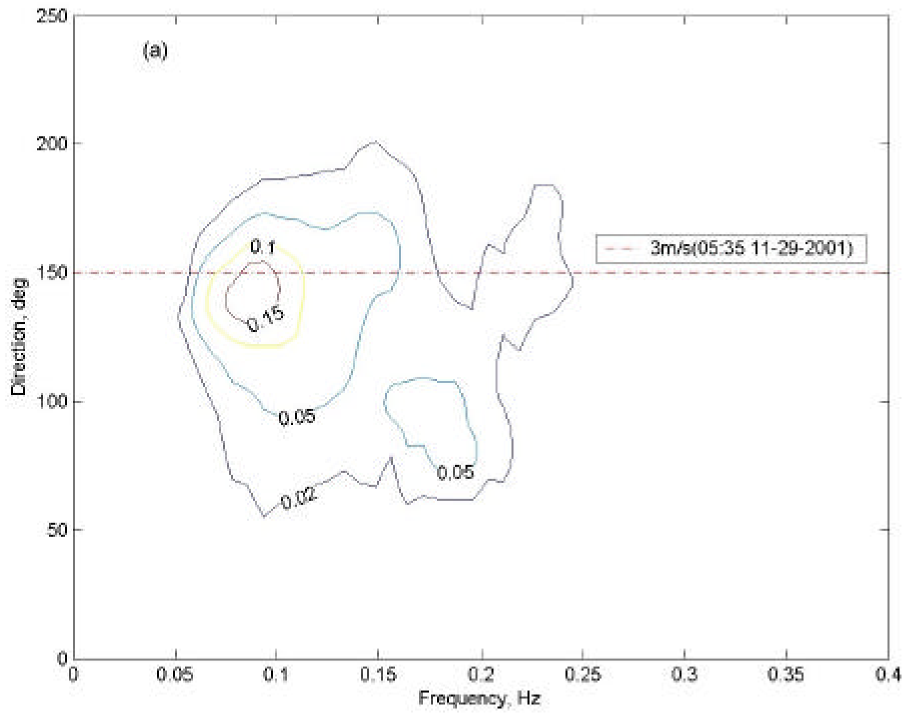
Station	Water depth (m)	Data length
Oak Island	7	Sep 00 – May 03
Bald Head Island	5.8	Sep 00 – June 03
Mound Crest	7	July 01 – June 02
Mound Offshore	12.8	Aug 01 – July 02
Mile 11	12.8	Sep 00 – June 03
FPSN7	14	Nov 84 – present
Buoy 41004	38	June 78 – present

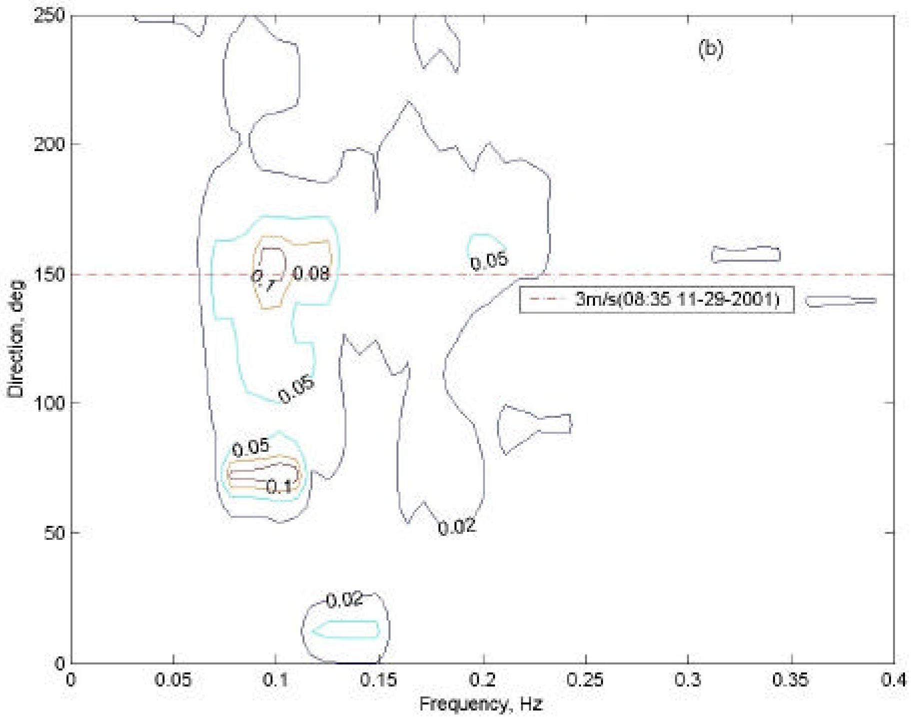
3. Case Investigations



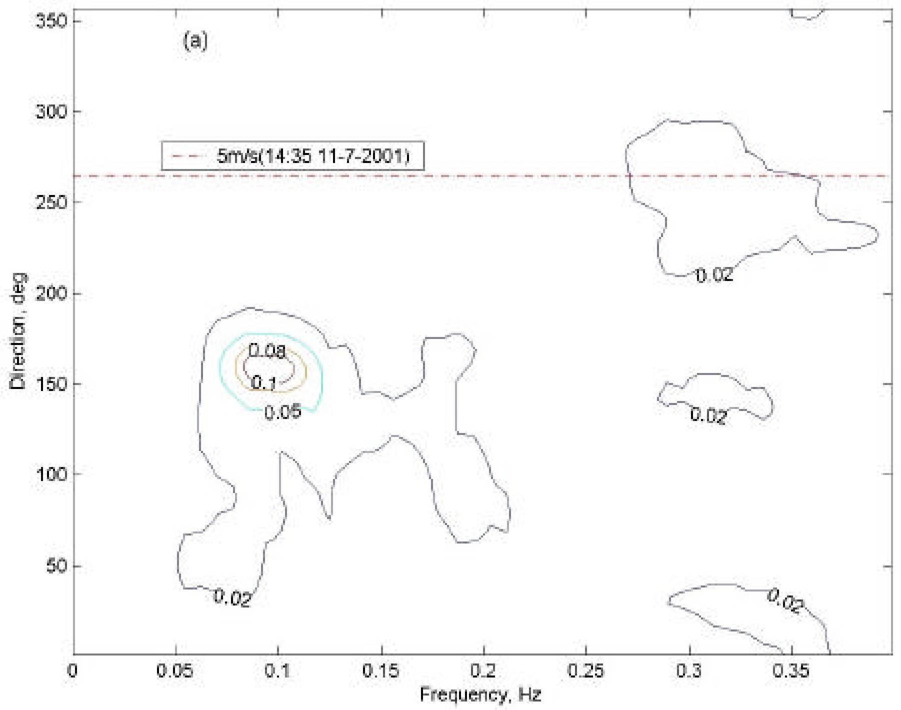


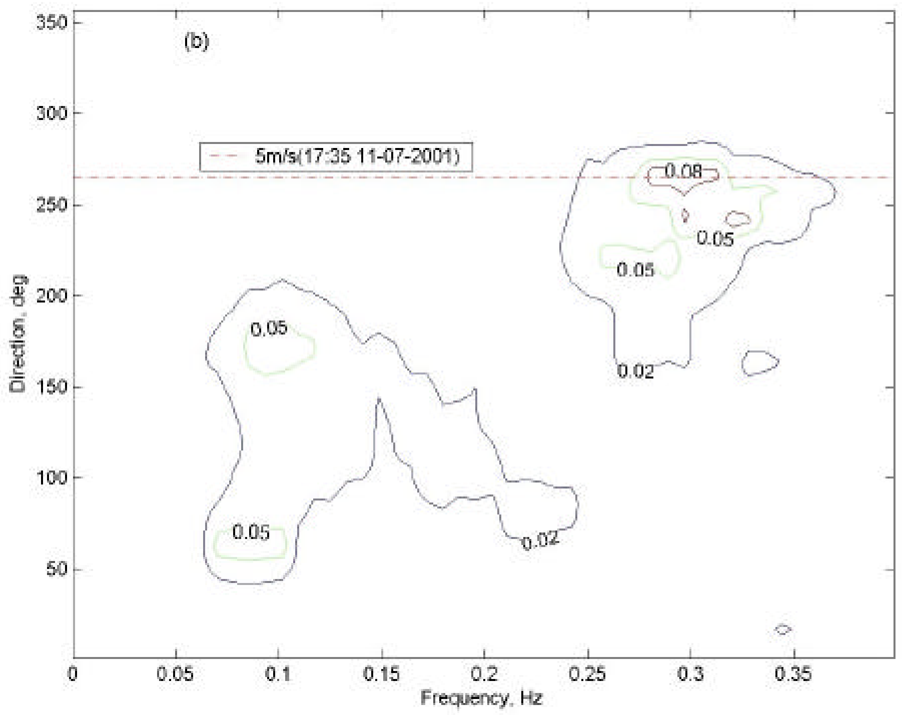
Example 1: Light wind condition with wind direction similar to wave direction – Wave spectra from Mile 11 at (a) 05:35 and (b) 08:35, Nov 29, 01



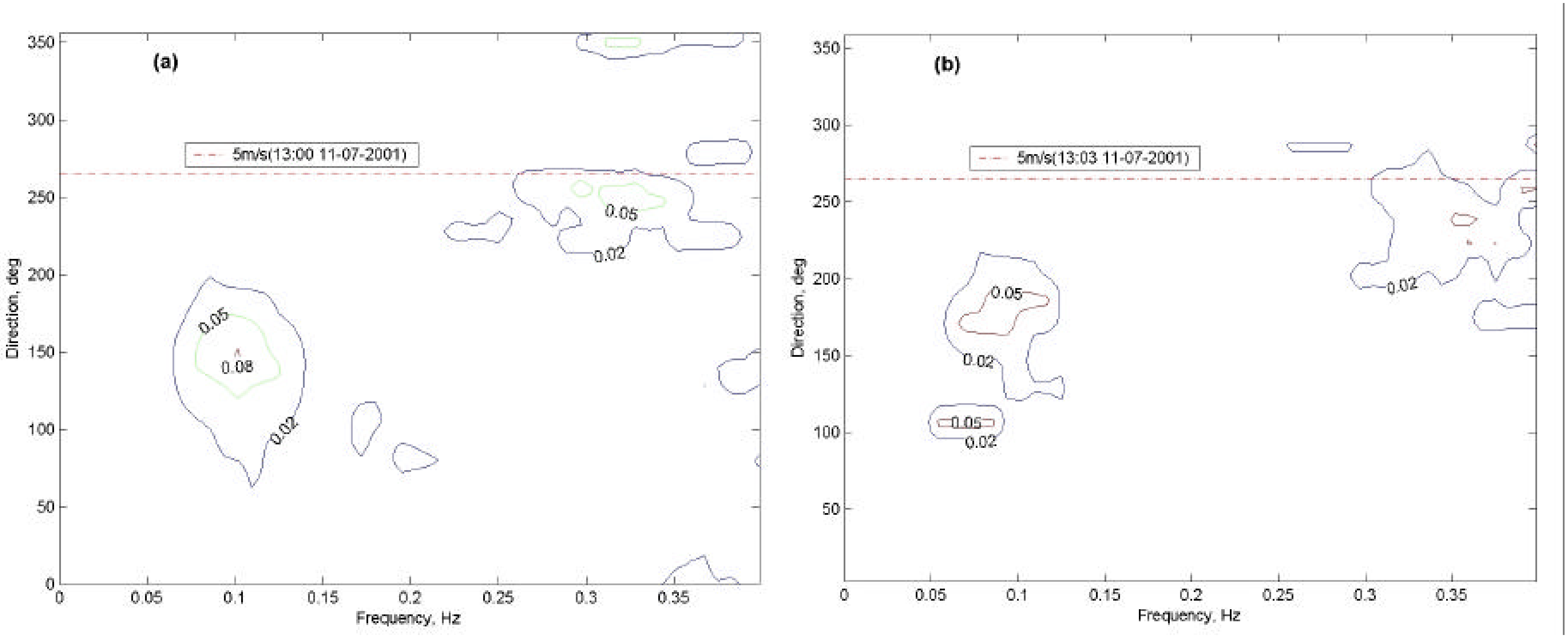


Example 2: Mild wind condition with wind direction opposite to wave direction – Wave spectra from Mile 11 at (a) 14:35 and (b) 17:35, Nov 7, 01

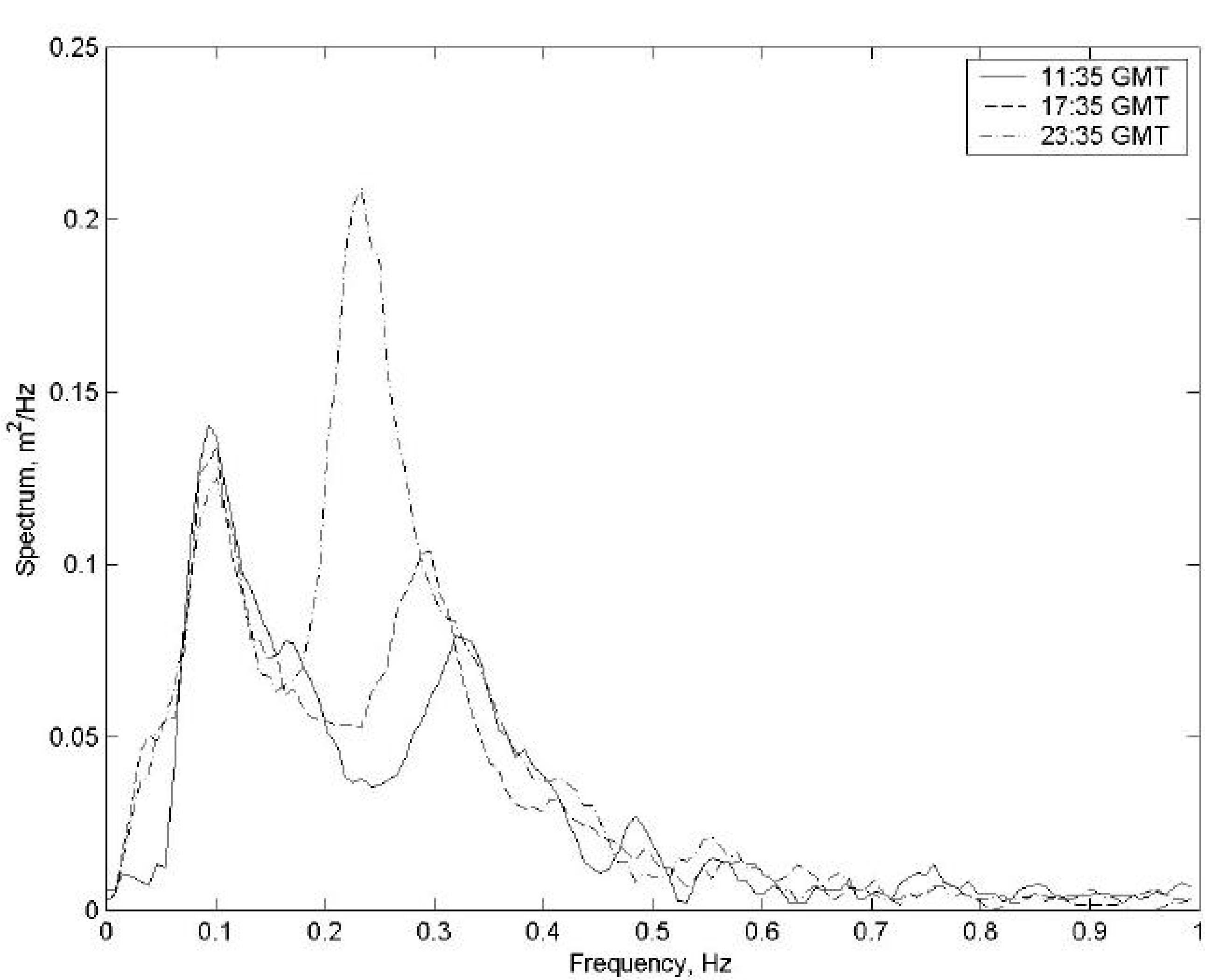




Example 3: Same as Example 2 – Wave spectra from (a) Mound Offshore at 13:00 and (b) Oak Island at 13:03, Nov 7, 01



Example 4: Same as Example 2 – Bi-modal wave spectra at Mile 11 from 11:35 to 23:35, Nov 7, 01



Strong winds (20 to 30 knots) against waves Photo taken at Turtle Bay Resort, Oahu, HI Nov 15, 04

Whitecapping under strong winds (20 knots)
Photo taken at Turtle Bay Resort, Oahu, HI
Nov 15, 04

4. New Wave Breaking Formula

$$S_{wc}^{*}(s,q) = -C_{ds}(ak)^{n}\frac{s}{g}c(s,q)F_1(\vec{u}_{wind},\vec{u}_{current},\vec{c})F_2(h)E(s,q)$$

where

$$F_1(\vec{u}_{wind},\vec{u}_{current},\vec{c}_{wave}) = \left|\frac{\vec{c}_{wave}}{\vec{u}_{wind}+\vec{u}_{current}+\vec{c}_{wave}}\right|$$

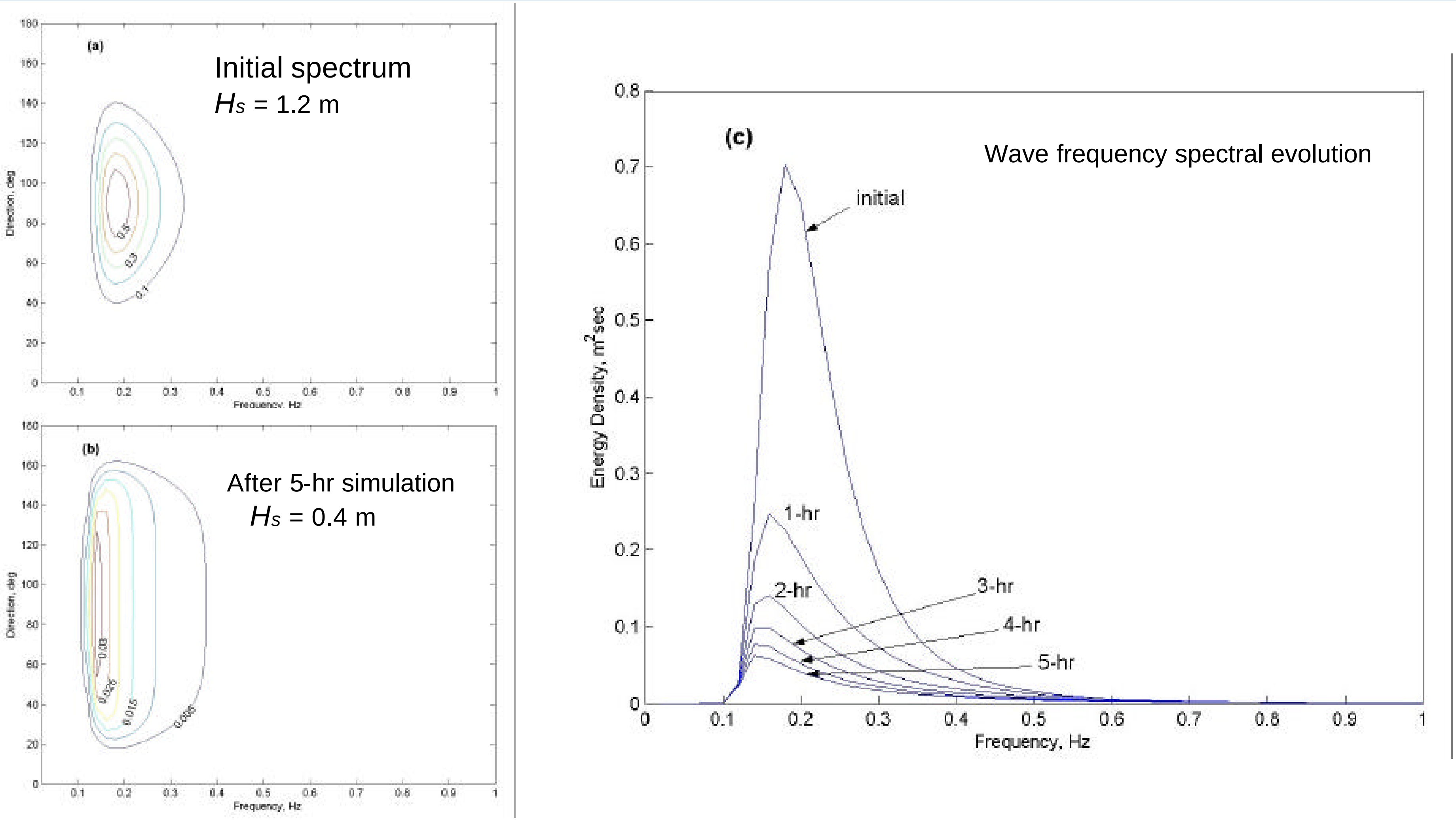
and

$$F_2(h) = \begin{cases} \dfrac{1}{kh}, & \text{if} \quad kh < 1; \\ 1, & \text{if} \quad kh \geq 1. \end{cases}$$

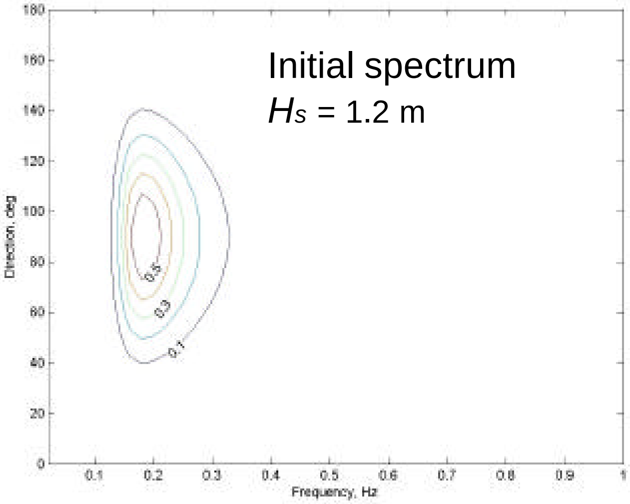
Estimation of C_{ds} and *n*

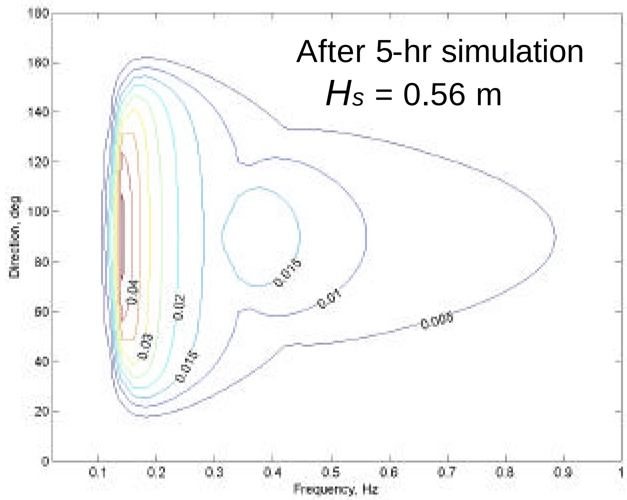
- Using wave spectra collected at Mound Offshore and Mile 11 (depth is 12.8 m at both locations)
- Excluding wind input energy
- Surface current speed is assumed to be 5% of the wind speed and the current direction is the same as the wind direction
- Best fit solutions: C_{ds}= 0.03 and *n*=1.5

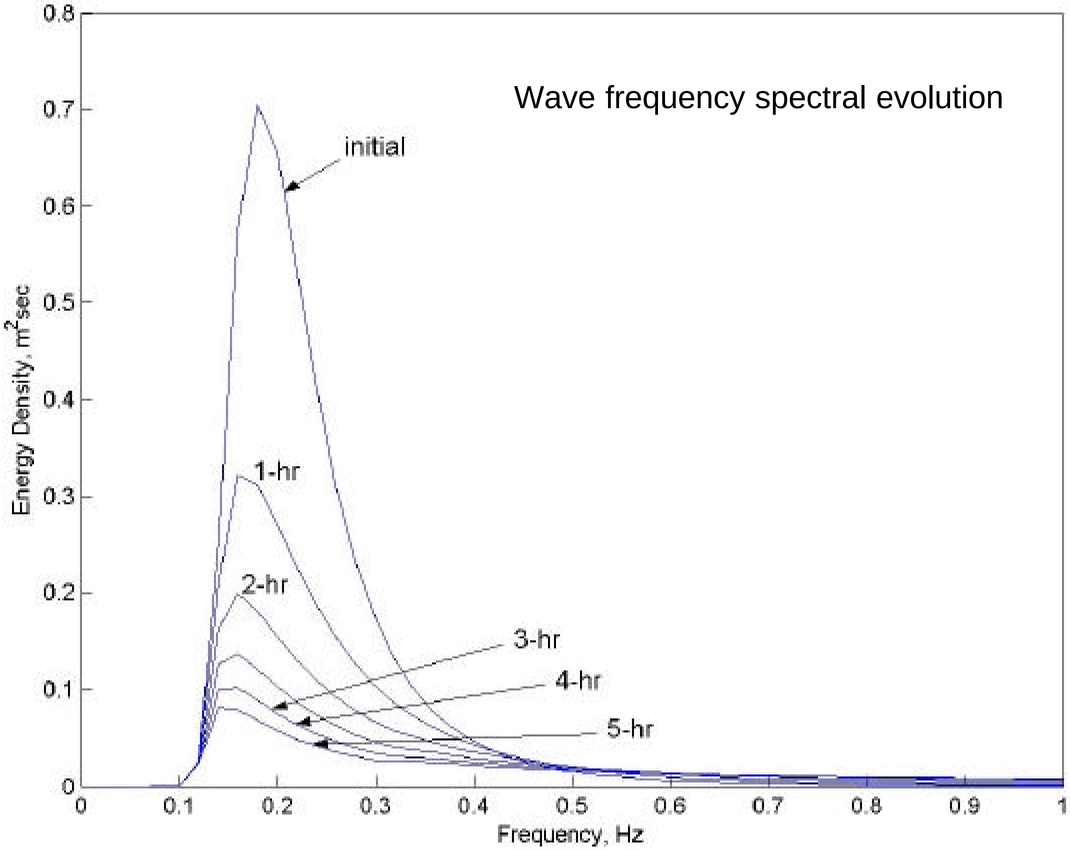
Example 1: Deformation of a P-M spectrum (initial significant height = 1.2 m) in 18-m water depth for 5-hr simulation under the calm wind condition



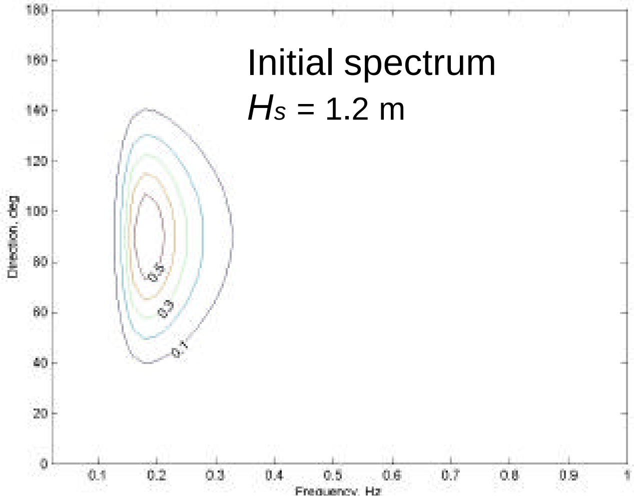
Example 2: Spectral deformation under a mild wind condition (wind vector at 5 m/sec and in the mean wave travel direction)

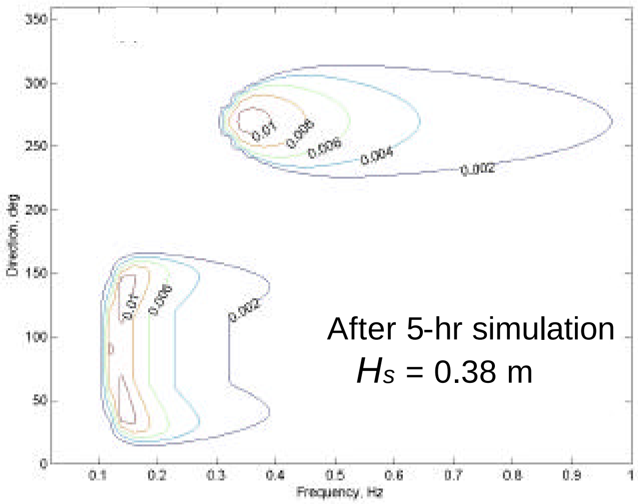


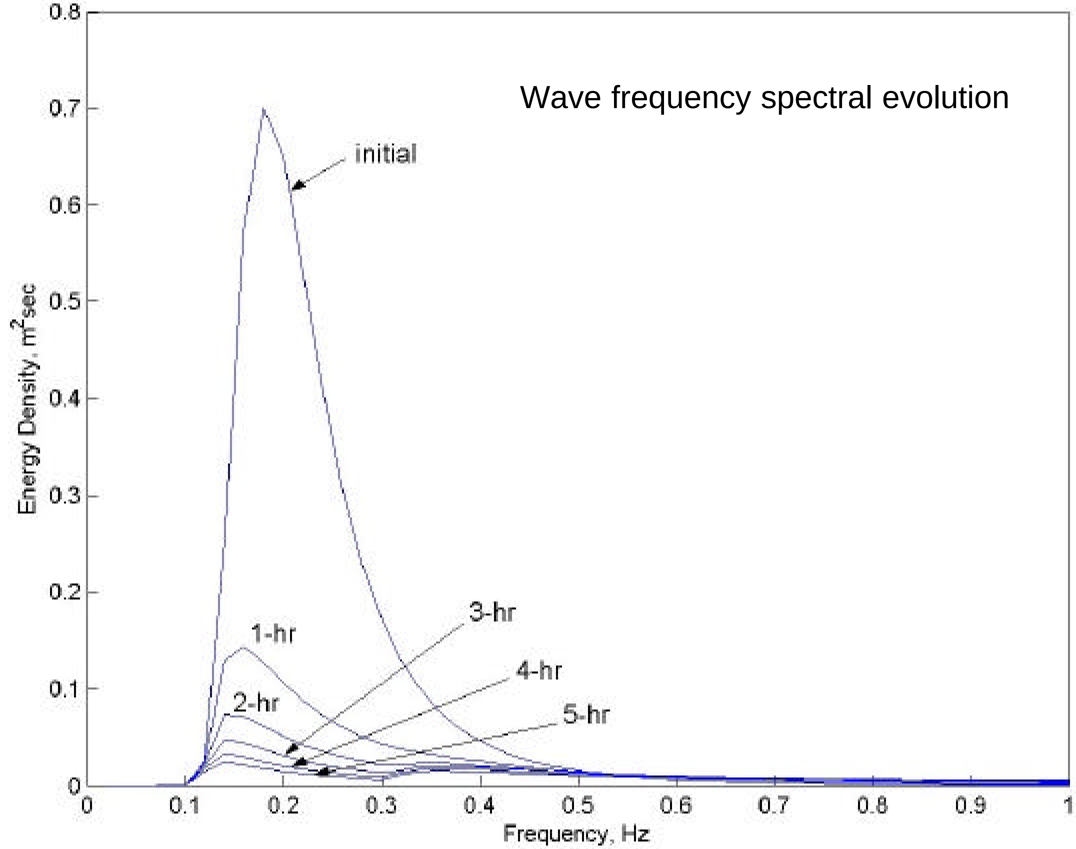




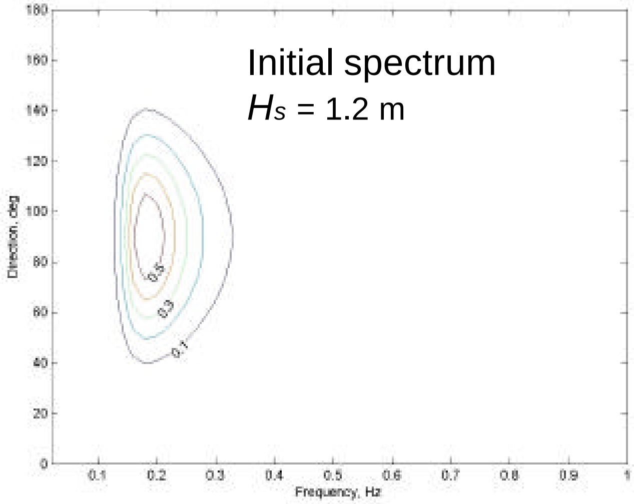
Example 3: Spectral deformation under a mild wind condition (wind vector at 5 m/sec and opposite to the mean wave travel direction)

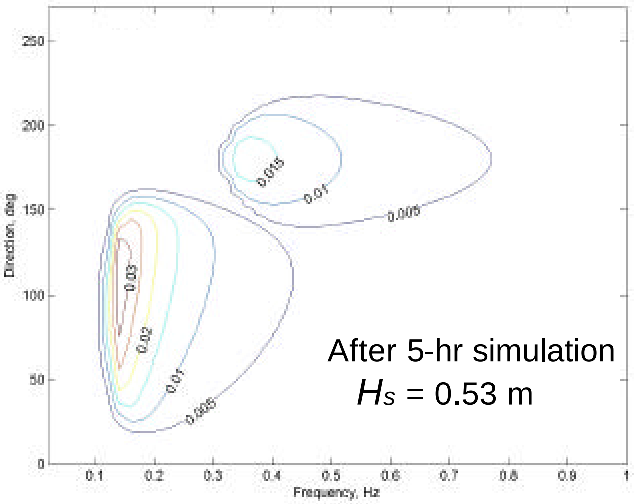


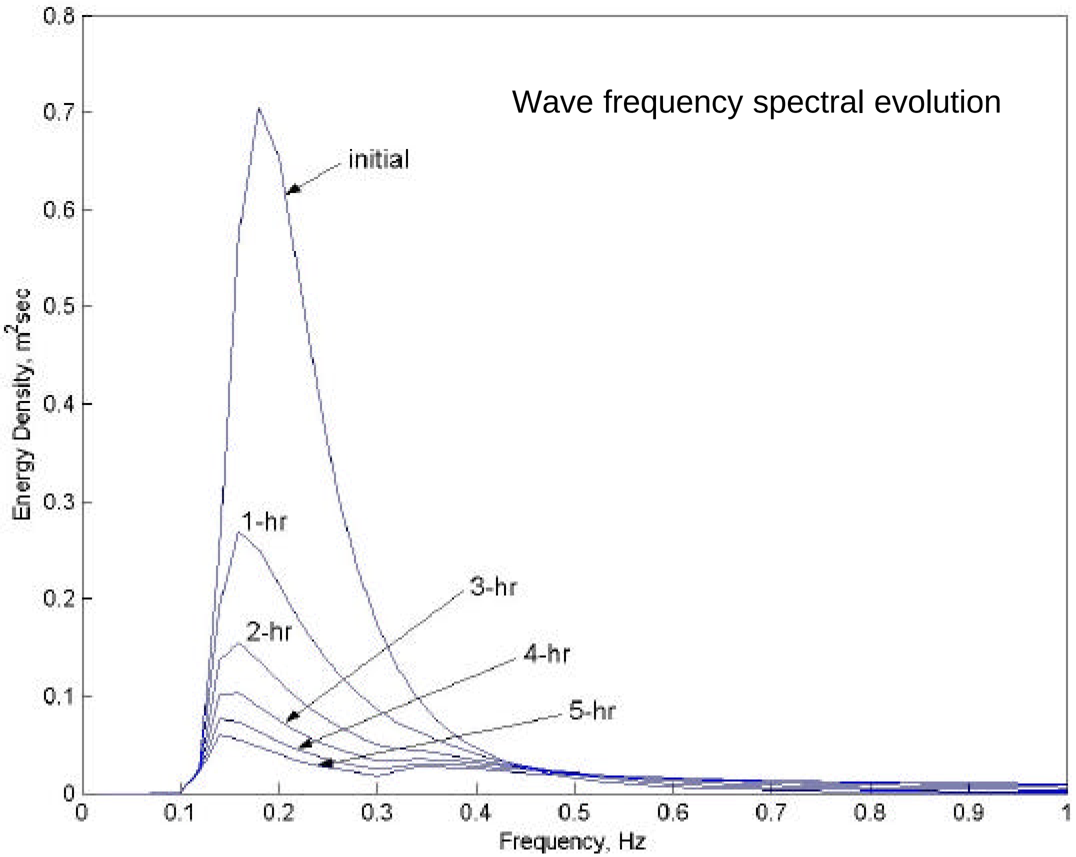




Example 4: Spectral deformation under a mild wind condition (wind vector at 5 m/sec and perpendicular to the mean wave propagation)







5. Summary and Conclusions

1. A new wave spectral dissipation function is proposed for whitecapping
2. The new wave breaking formula considers the effect of individual wave steepness rather than the mean wave steepness.
3. The new formula includes wind and current effects on wave dissipation
4. The formula was calibrated based on very limited field data for the idealized wind and wave conditions. It does not count for wave energy dissipation in the surf zone. More studies are necessary for the reliability of the proposed new wave breaking function.