Numerical Simulation of Wind Wave Field

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Outline

1. **Numerical Model**
2. **Wind Input Function**
3. **Wave Dissipation**
4. **Case Studies**
5. **Summary and Conclusions**

1. Numerical Model

Governing Equation (Steady State, two-dimensional spectral model) – Wave-Action Balance Equation with Diffraction (WABED), Mase et al. 2001

diffraction coefficient ~ 1

$$\frac{\partial[(c_{gx}+u)A]}{\partial x}+\frac{\partial[(c_{gy}+v)A]}{\partial y}+\frac{\partial[c_{g\theta}A]}{\partial \theta}=\frac{\kappa}{2\sigma}\{(cc_g\cos^2\theta A_y)_y-\frac{1}{2}cc_g\cos^2\theta A_{yy}\}+S_{in}+S_{dp}$$

where $A=E/\sigma$ is the wave-action spectrum and

$E=E(\sigma,\theta)$ is the directional wave spectrum.

Here *x* is normal to seaward boundary, *y* is parallel to seaward boundary

2. Wind Input Function

$$S_{in} = \frac{a_1\sigma}{g} F_1(\vec{w} - \vec{c}_g) F_2(\frac{c_g}{w}) E^*_{PM}(\sigma)\Phi(\theta) + \frac{a_2\sigma}{g} F_1(\vec{w} - \vec{c}_g) F_2(\frac{c_g}{w}) F_3(\frac{c_g}{w}) E$$

$$F_1(\vec{w} - \vec{c}_g) = \begin{cases} w\cos(\theta_{wind} - \theta) - c_g(\sigma,\theta), & c_g < w \\ 0, & c_g \geq w \end{cases}$$

$$F_2(\frac{c_g}{w}) = \begin{cases} (\frac{c_g}{w})^{0.8}, \\ 1, \end{cases} \qquad F_3(\frac{c_g}{w}) = \begin{cases} \log_{10}[(\frac{c_g}{w})^{-1}], & c_g < w \\ 0, & c_g \geq w \end{cases}$$

$E^*_{PM}(\sigma) = \dfrac{g^2}{\sigma^5}\exp(-0.74\dfrac{\sigma_0^4}{\sigma^4})$, $\sigma_0 = g / w$, and $\Phi(\theta) = \dfrac{8}{3\pi}\cos^4(\theta - \theta_{wind})$

3. Wave Energy Dissipation

- White capping

where $$S_{dp} = -C_{ds}(ak)^{1.5}\frac{\sigma}{g}c_g(\sigma,\theta)F_4(\vec{w},\vec{u}_{current},\vec{c}_g)F_5(kh)E$$

and $$F_4(\vec{w},\vec{u}_{current},\vec{c}_g) = \left|\frac{\upsilon + w}{\vec{w}+\vec{u}_{current}+\vec{c}_g}\right|, \quad F_5(kh) = \frac{1}{\tanh kh}$$

$a = \sqrt{E(\sigma,\theta)\mathrm{d}\sigma\mathrm{d}\theta}$, wavelet calculated for each grid cell

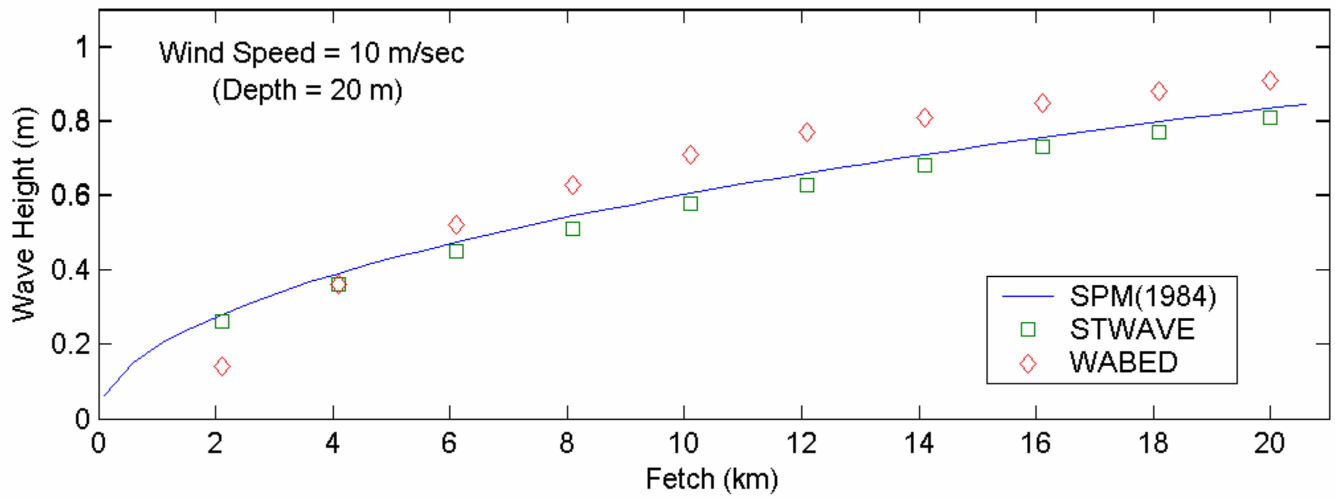
- Breaking

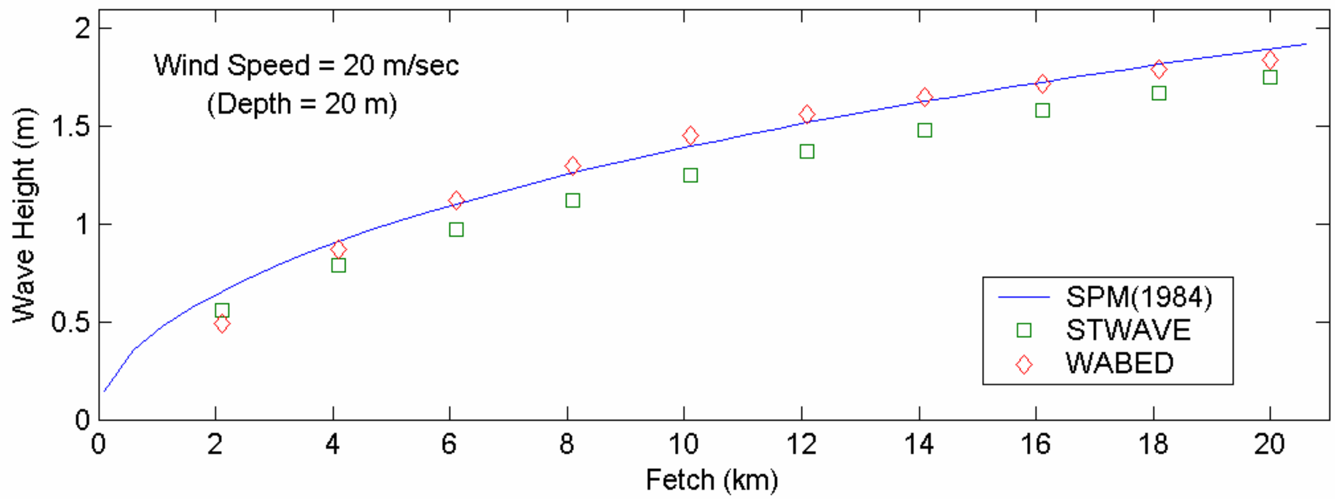
Miche's and Goda's breaking limitations: $S_{dp} = -\varepsilon_b A$

- Bottom friction

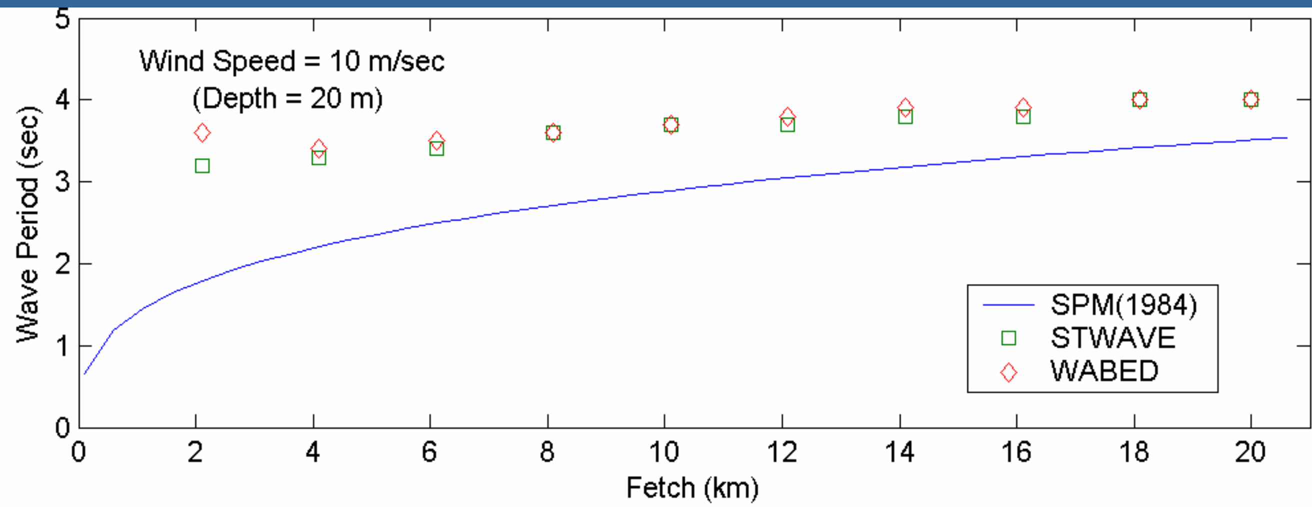
$$S_{dp,fric} = -C_f\frac{\sigma}{g}\frac{< u_b >}{\sinh^2 kh}E, \text{ where } < u_b > = \frac{1}{2}\sqrt{\frac{g}{h}E_{total}}$$

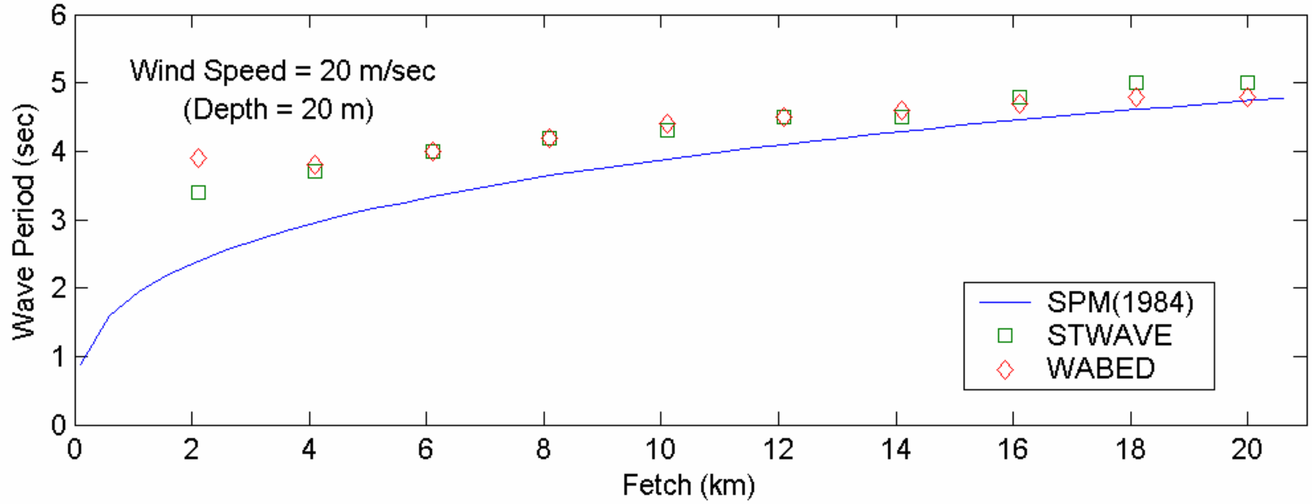
Idealized Wind Wave Growth
Wave Height Comparison



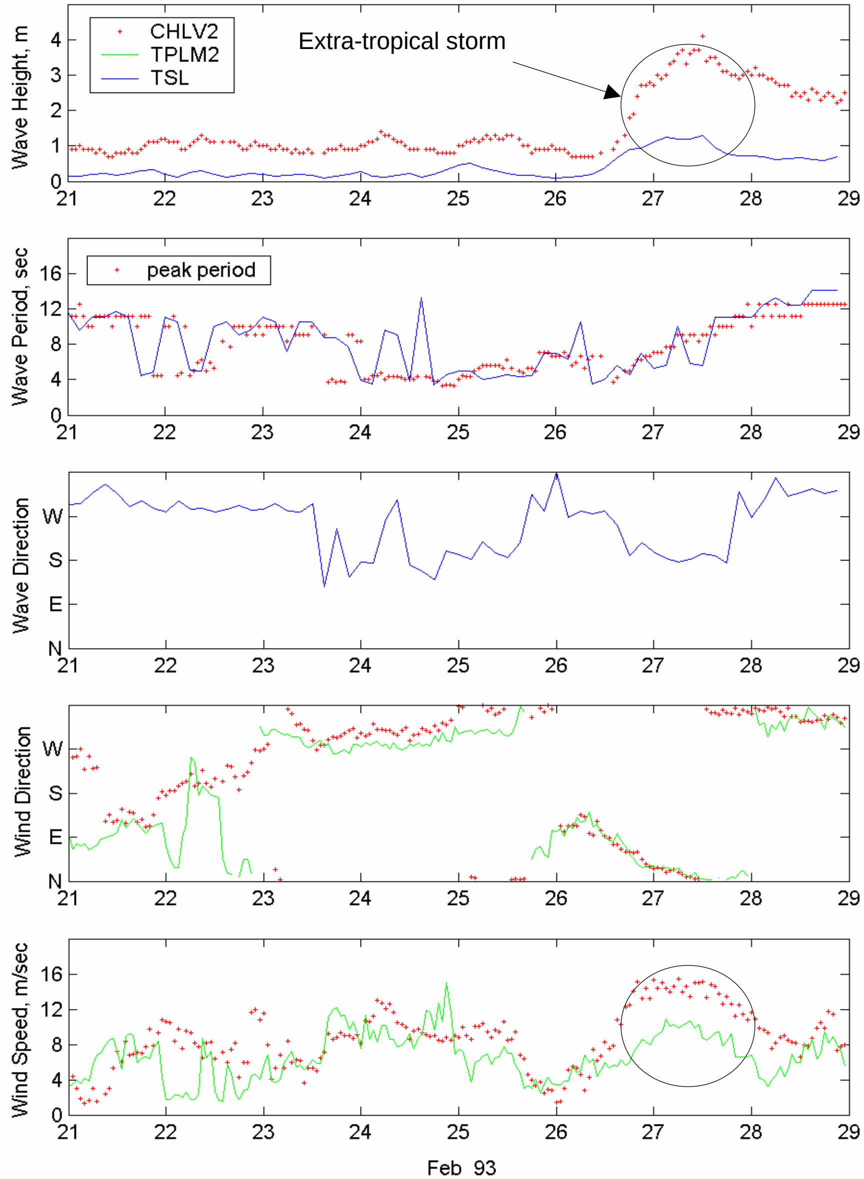


Idealized Wind Wave Growth
Wave Period Comparison

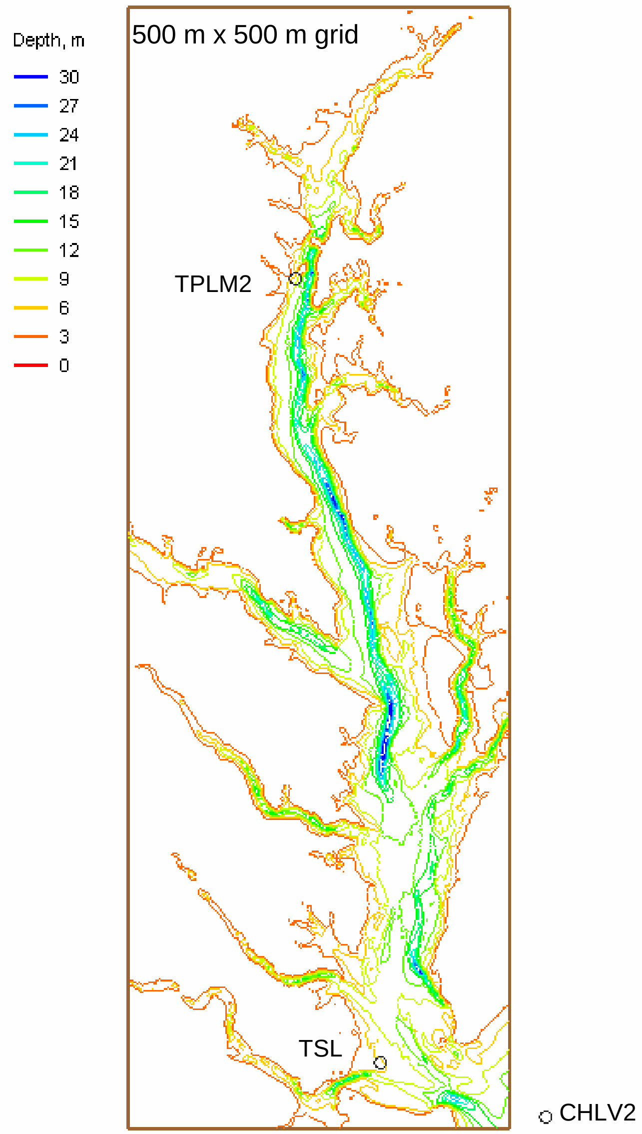




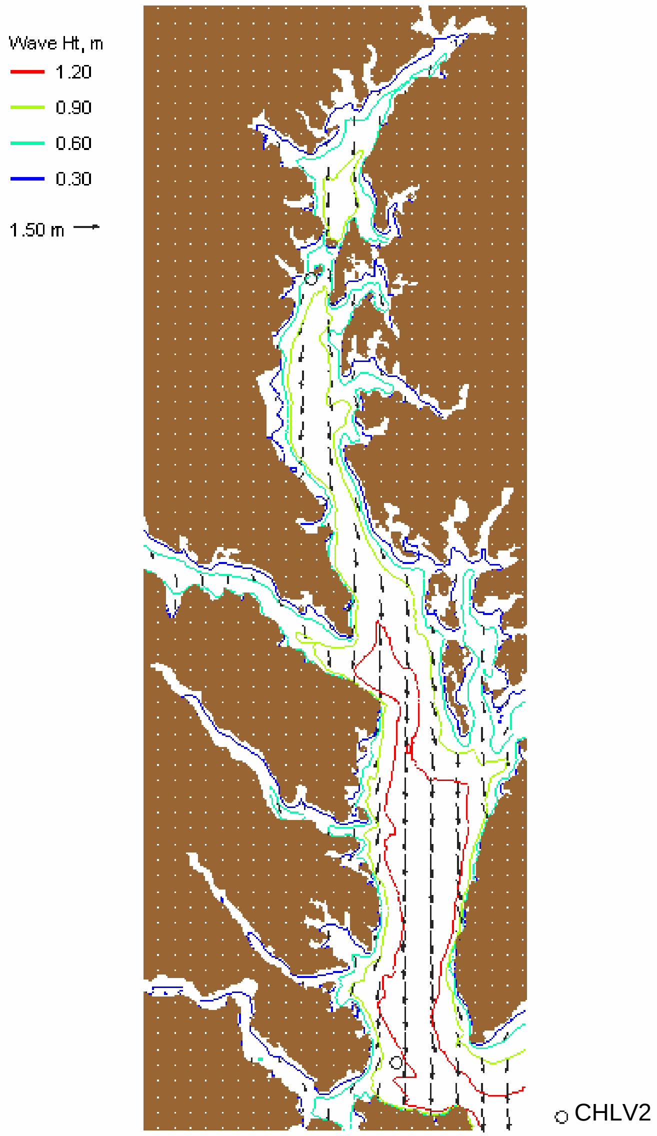
4.1 Chesapeake Bay Wind and Wave Data Stations CHLV2, TPLM2, TSL



Model Domain and Calculated Wave Field under a Steady Northerly Wind at 15 m/sec

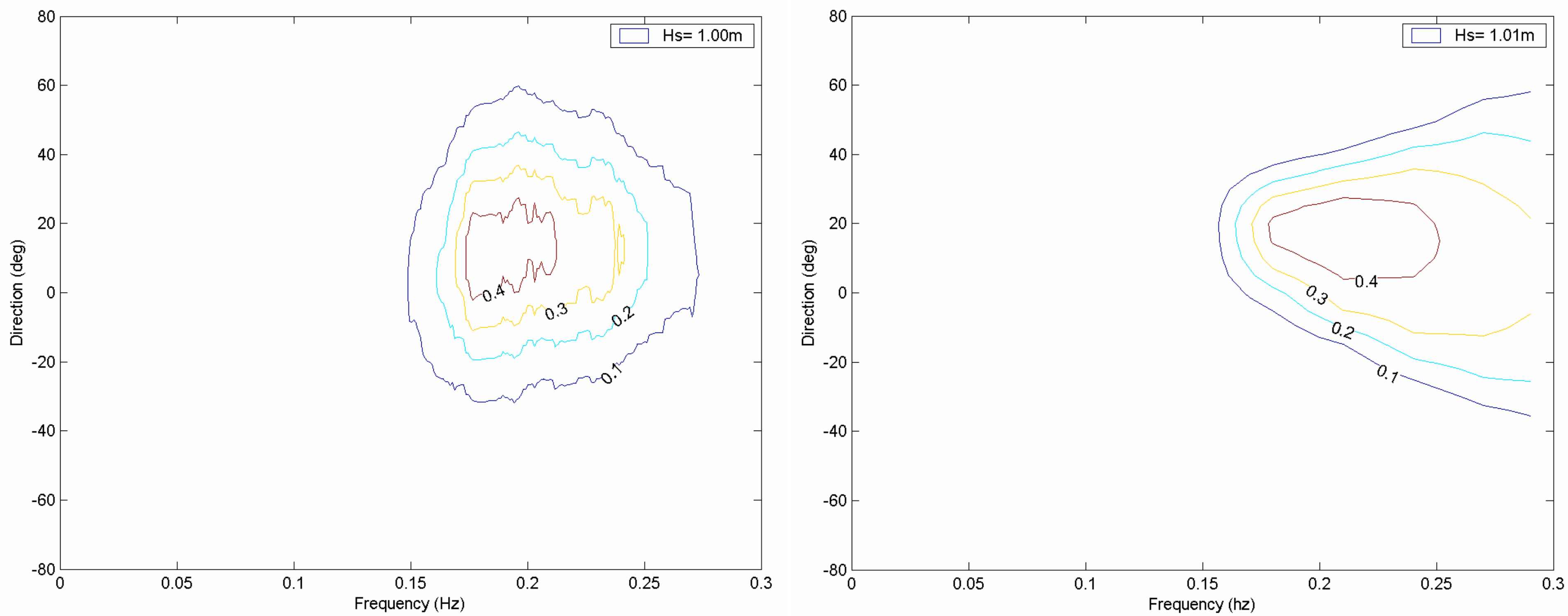


(a) Model bathymetry domain



(b) Calculated wave field

Measured and Model Directional Spectra
Chesapeake Bay TSL Station
12:00 GMT, 27 February 1993

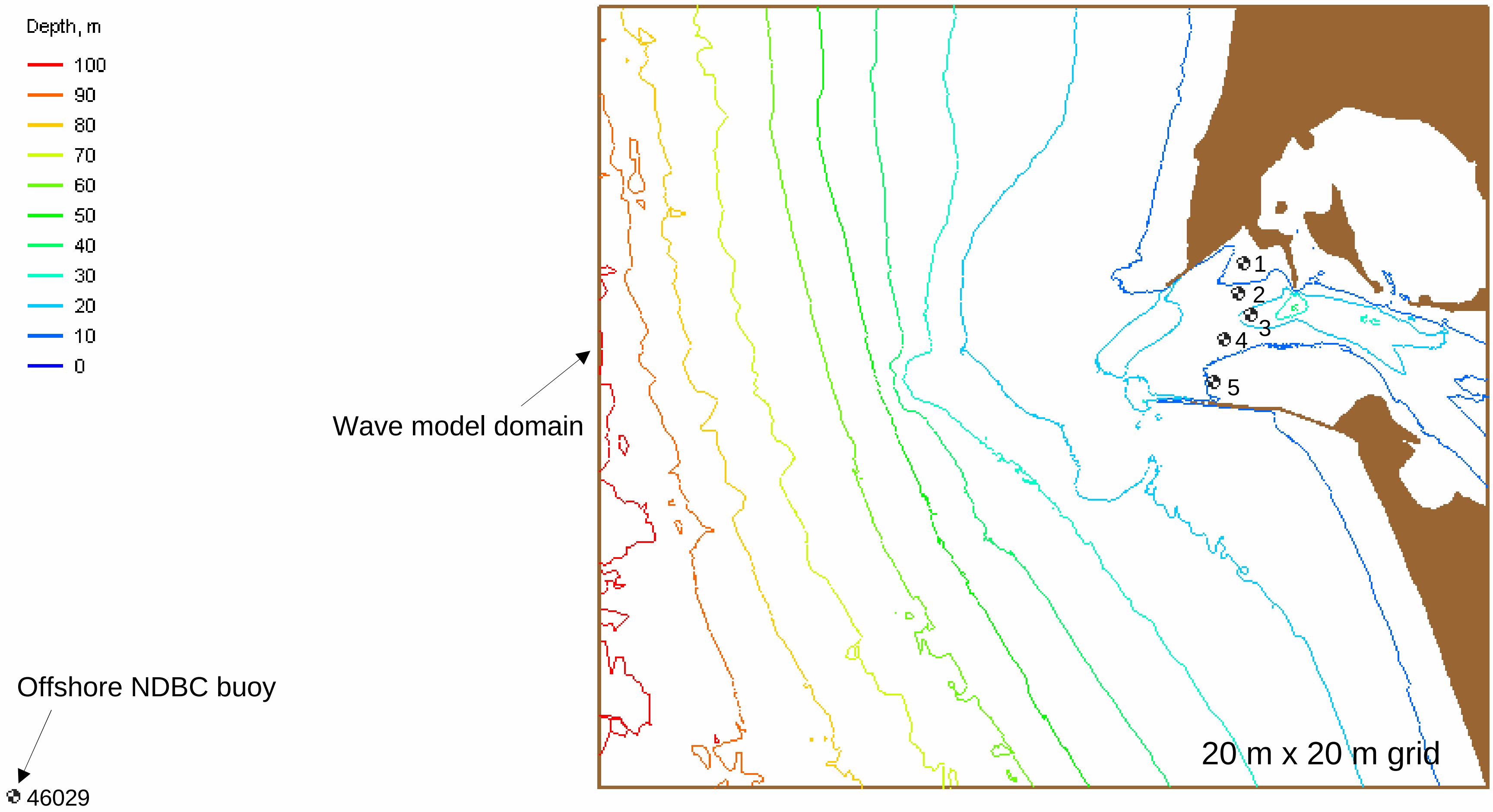


(a) Measured

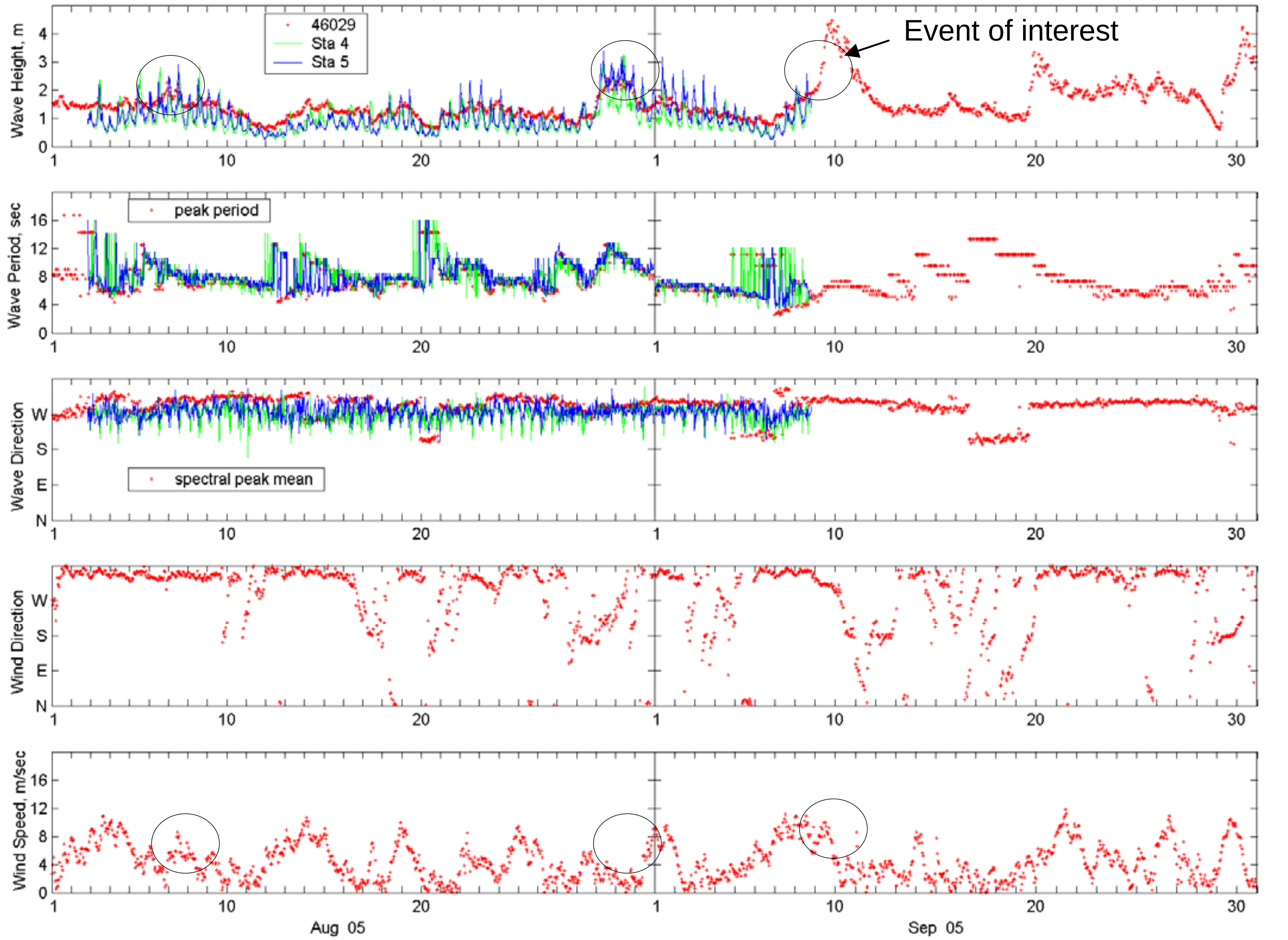
(b) Calculated

Steady wind Speed = 15 m/sec, wind direction = 0 deg (from north)

4.2 Wave Model Grid and Data Collection Stations Mouth of Columbia River (MCR), OR/WA



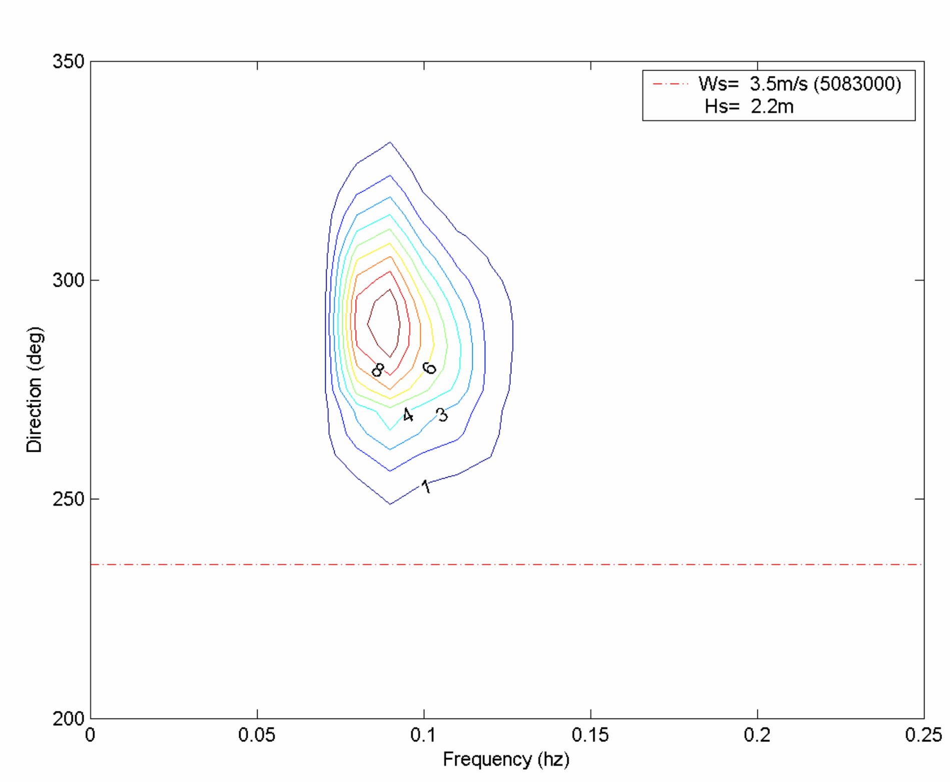
Wave and Wind Data Collected at Buoy 46029, Sta 4 and Sta 5 – Aug-Sep 05



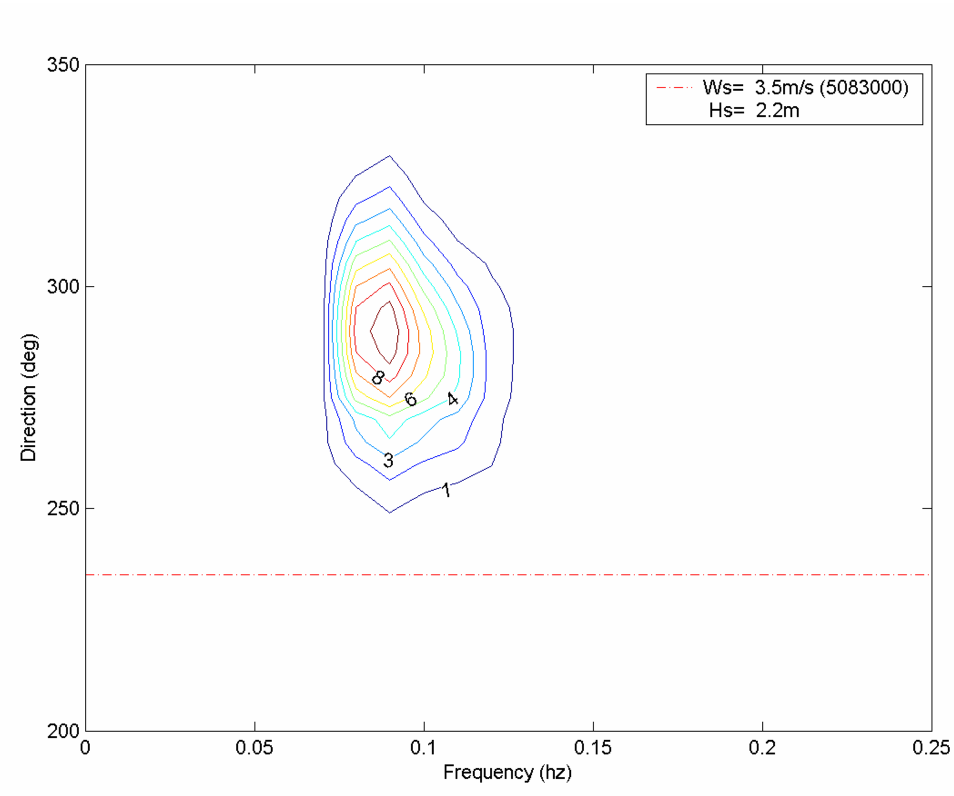
MCR Wind/Wave Station Information

Station	Coordinates	Water depth (m)
1	46°16’16”N, 124°03’23”W	9.7
2	46°15’47”N, 124°03’29”W	12.9
3	46°15’27”N, 124°03’13”W	21.7
4	46°15’04”N, 124°03’46”W	14.2
5	46°14’24”N, 124°03’58”W	10.4
Buoy 46029	46°07’00”N, 124°30’36”W	128

Buoy and Model Seaward Boundary Spectra 00:00 GMT, 30 August, 2005

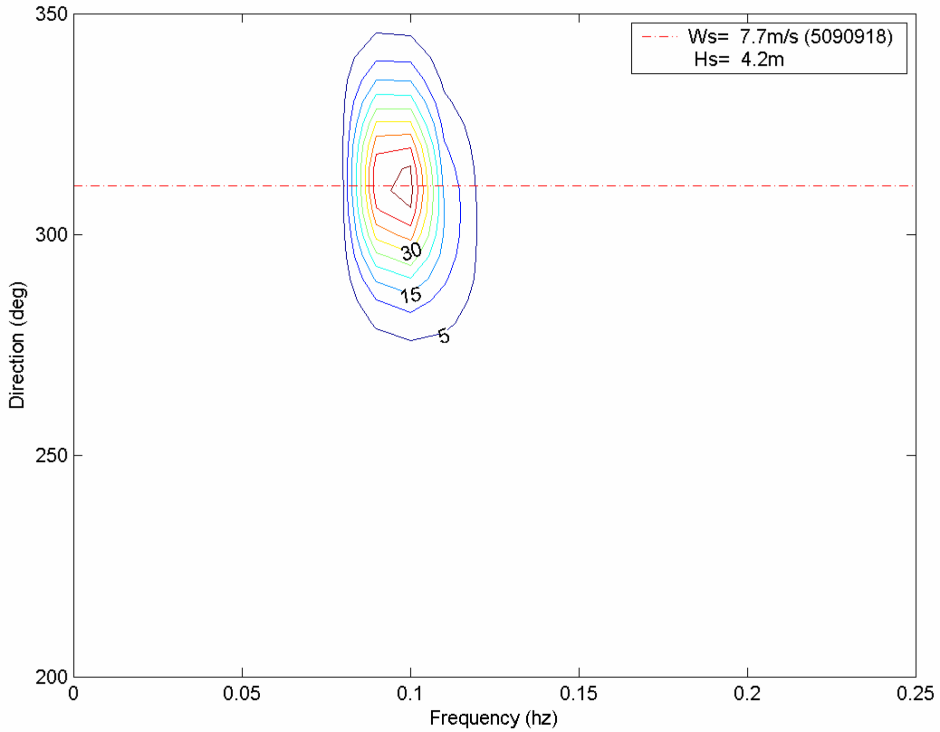


(a) Buoy spectrum

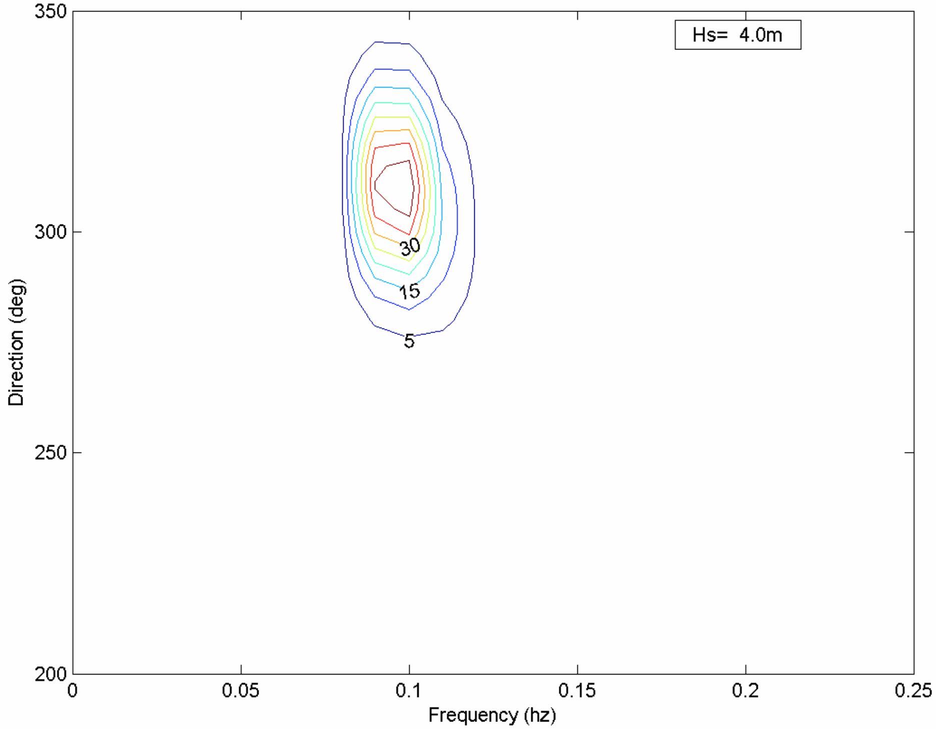


(b) Model seaward boundary spectrum

Buoy and Model Seaward Boundary Spectra
18:00 GMT, 9 September 2005

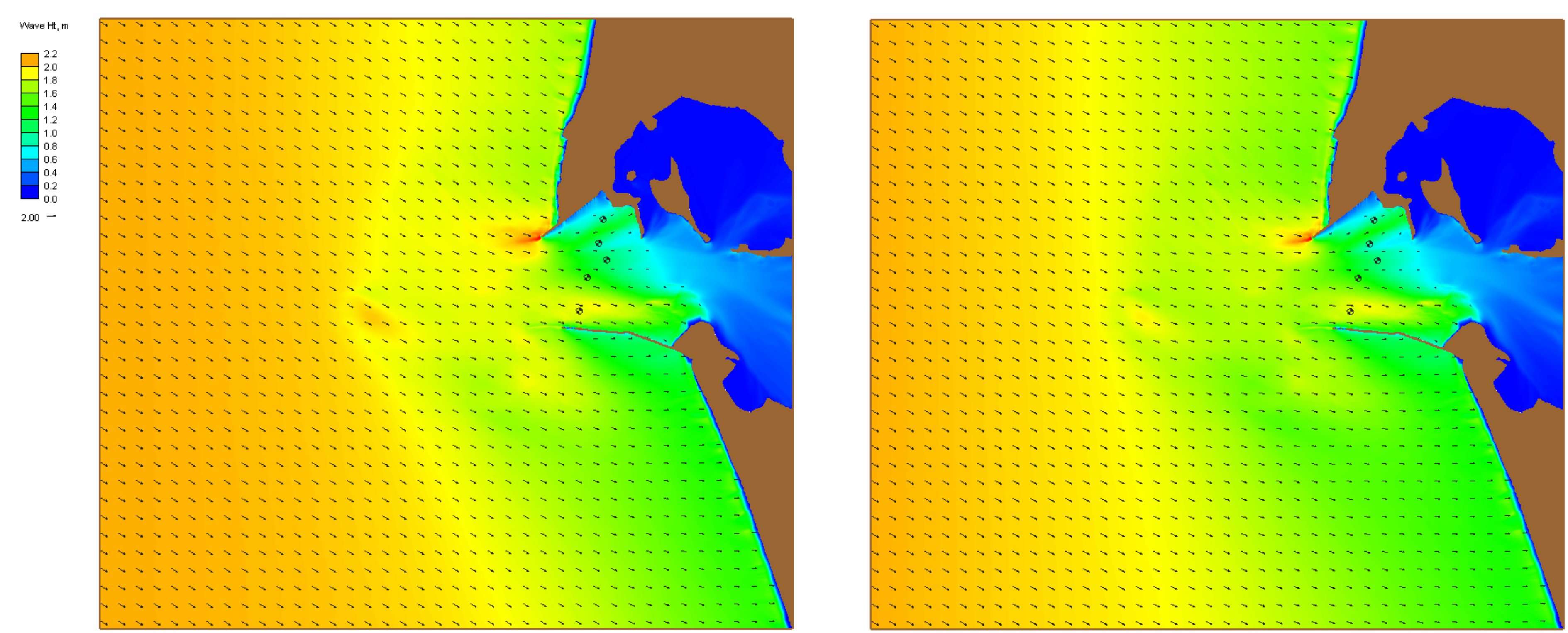


(a) Buoy spectrum



(b) Model seaward boundary spectrum

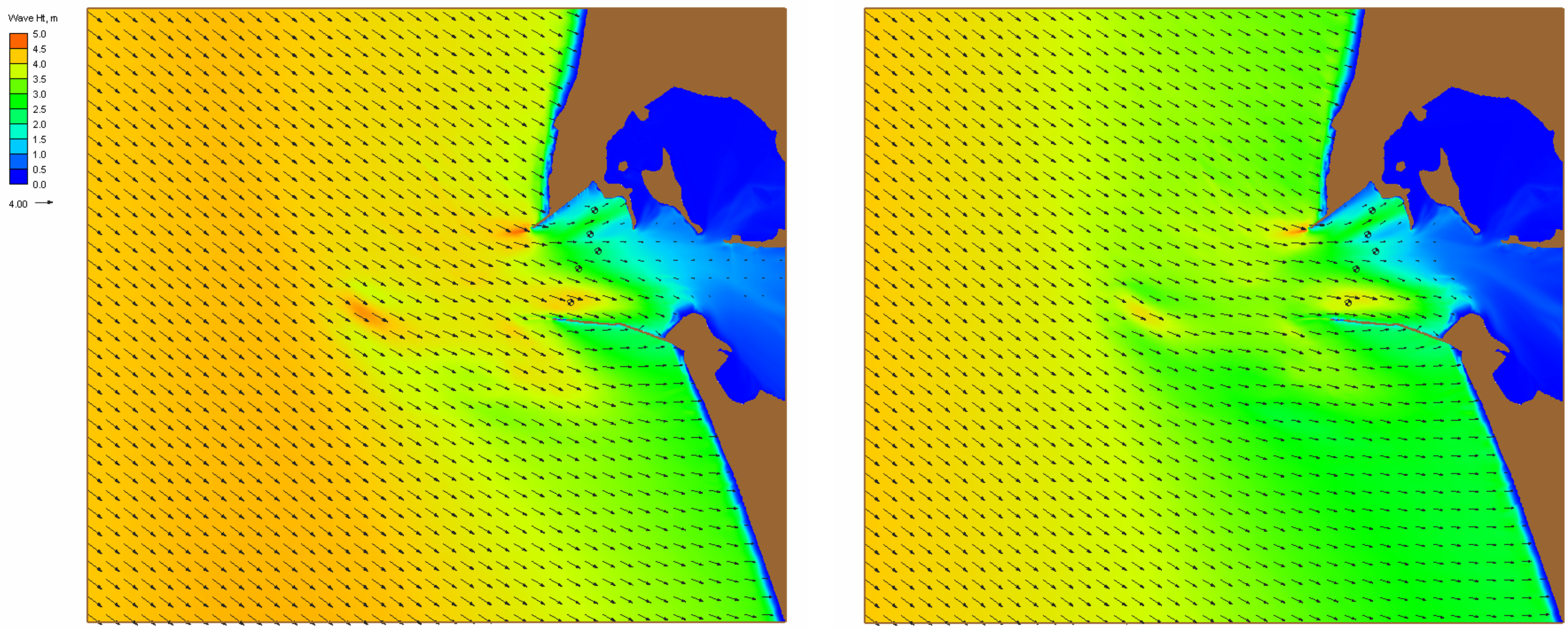
Wave Field Simulation – 10:00 GMT, 7 August
Wave Input: 2 m, 8.3 sec, 300 deg



(a) With wind input: 7.7 m/sec and 344 deg

(b) Without wind input

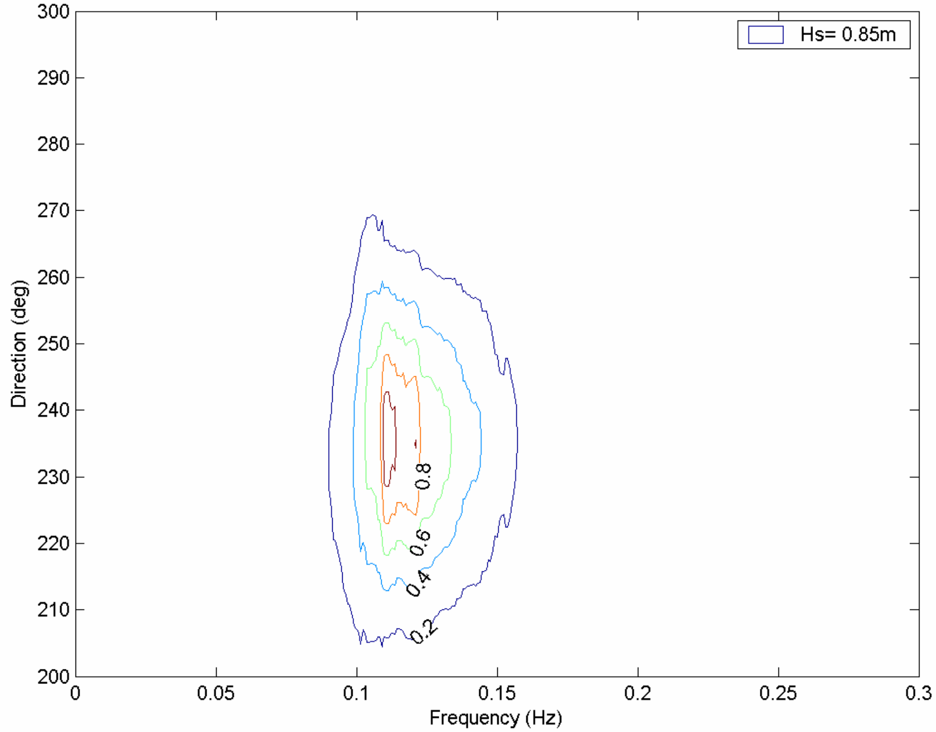
Wave Field Simulation - 18:00 GMT, 9 September
Wave Input: 4 m, 10 sec, 307 deg



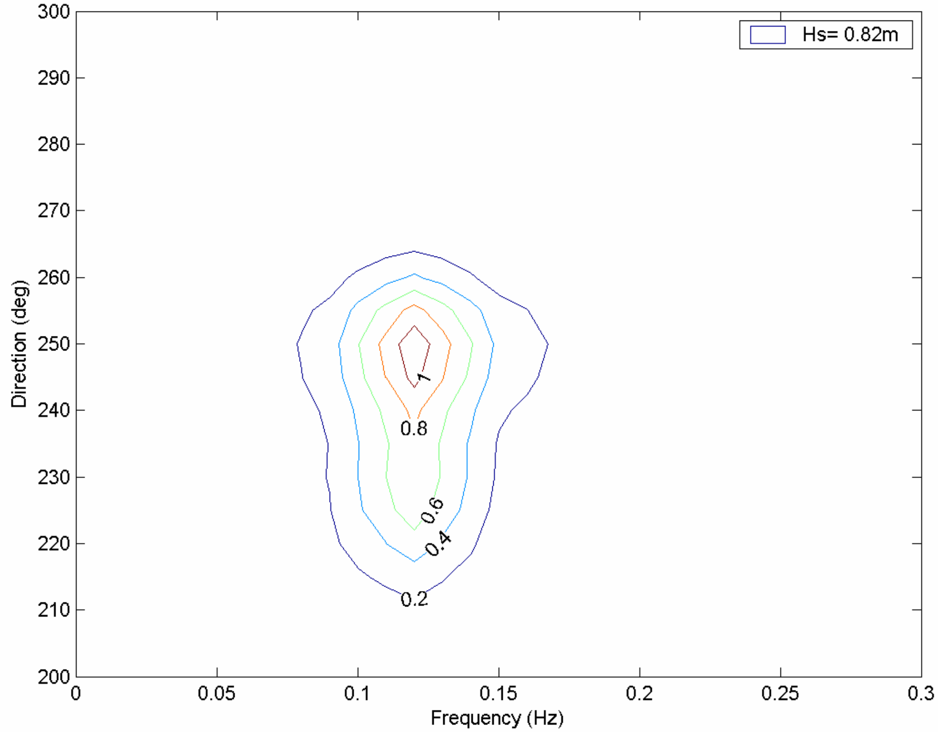
(a) With wind input: 7.6 m/sec and 311 deg

(b) Without wind input

Measured and Calculated Directional Spectra MCR Sta 1 - 10:00 GMT, 7 August 2005

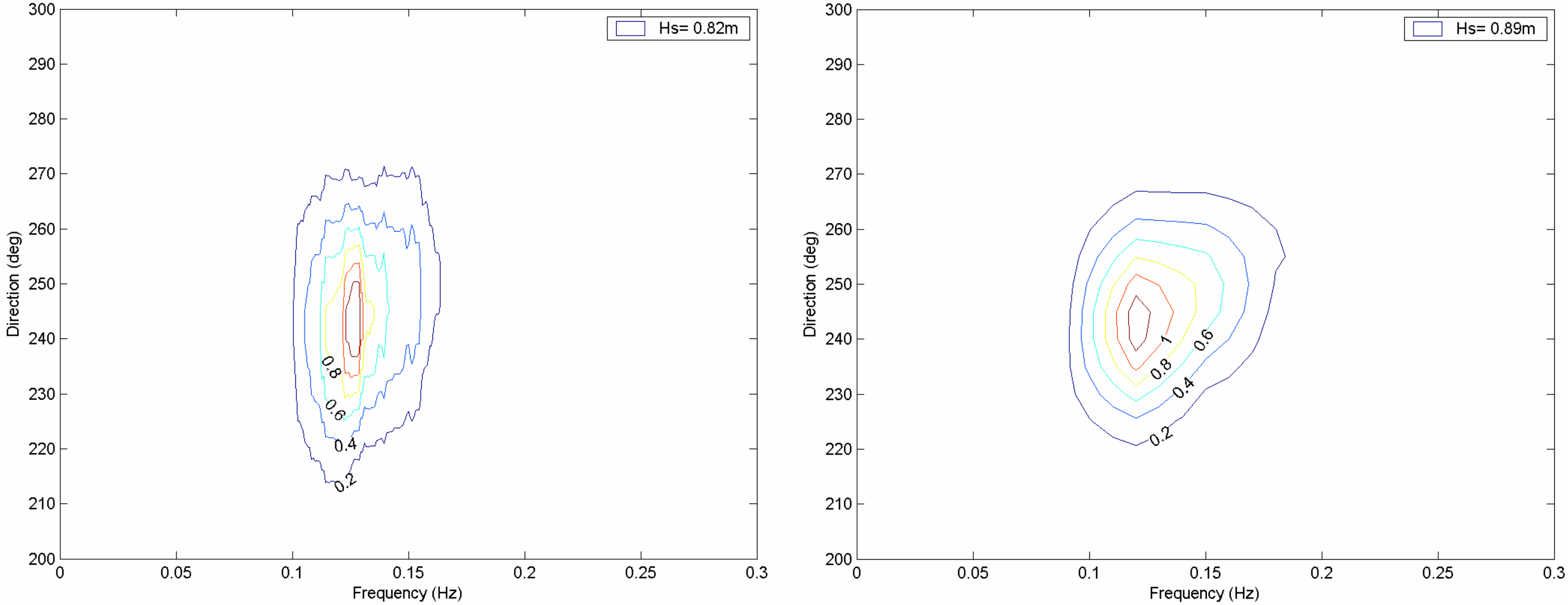


(a) Measured



(b) Calculated

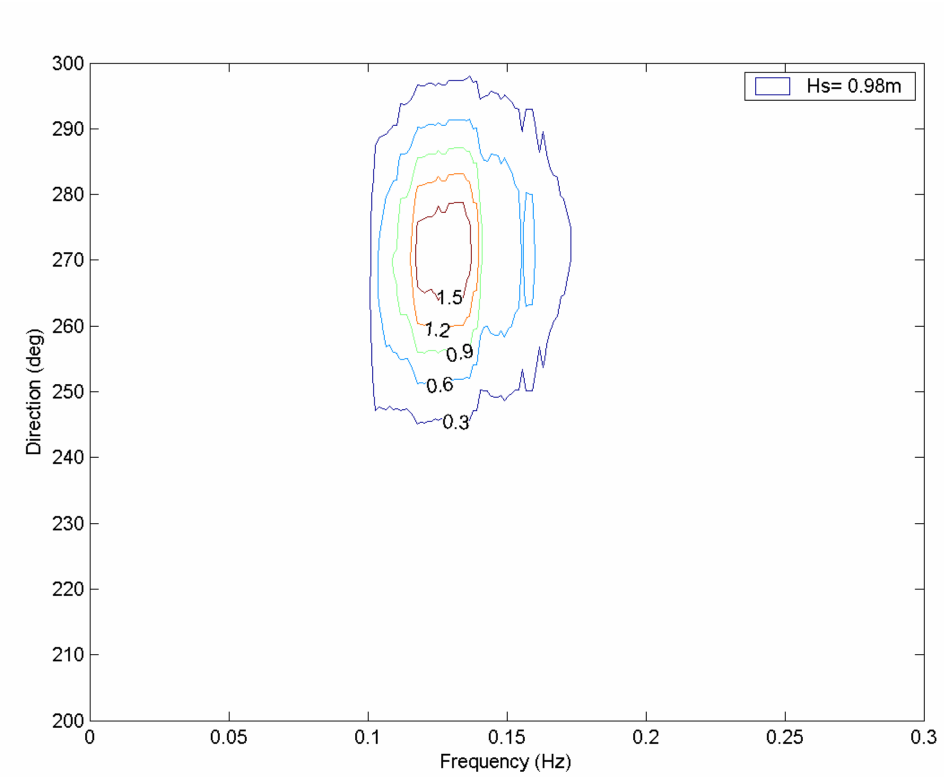
Measured and Calculated Directional Spectra MCR Sta 2 - 10:00 GMT, 7 August 2005



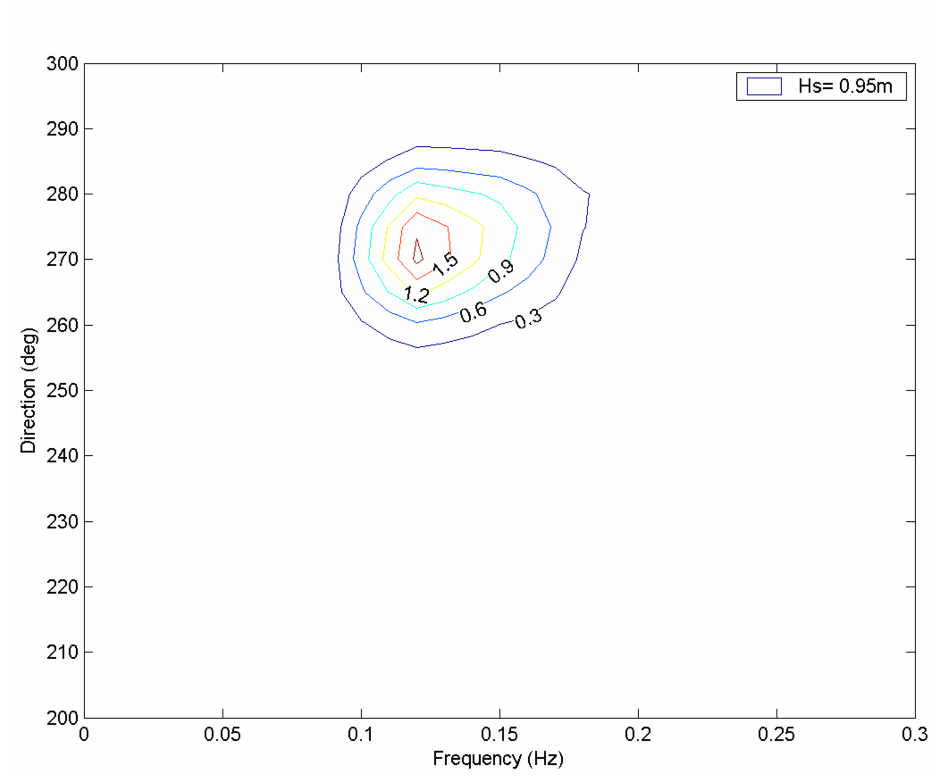
(a) Measured

(b) Calculated

Measured and Calculated Directional Spectra
MCR Sta 3 - 10:00 GMT, 7 August 2005

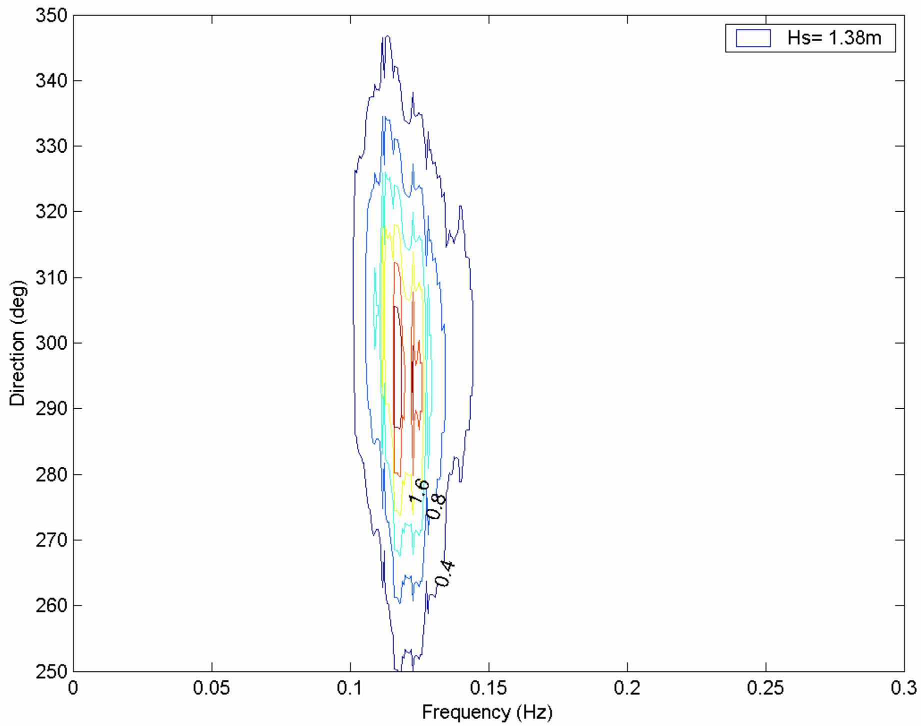


(a) Measured

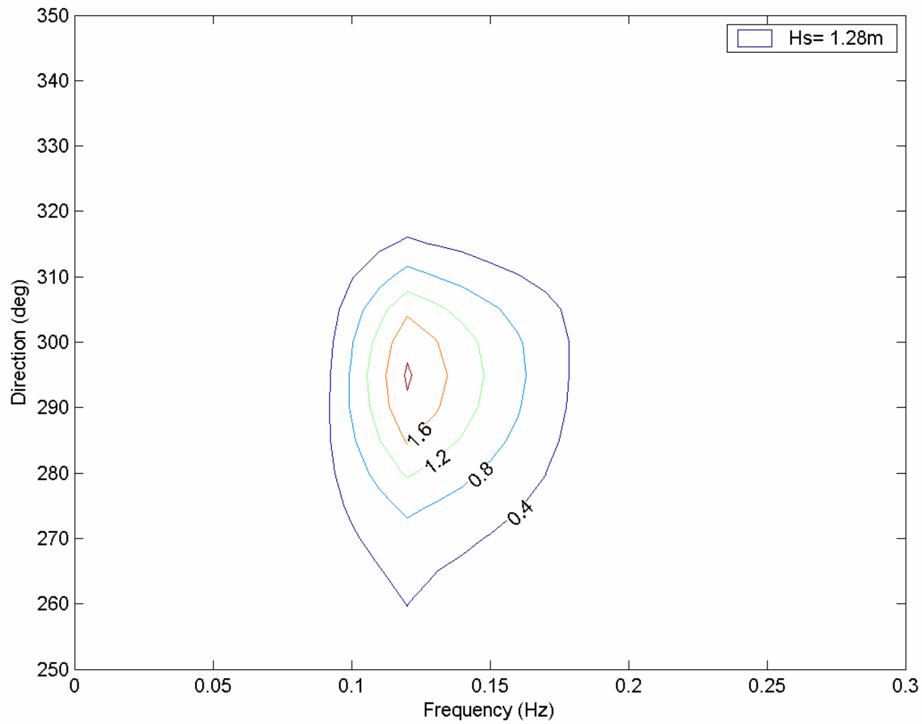


(b) Calculated

Measured and Calculated Directional Spectra MCR Sta 4 - 10:00 GMT, 7 August 2005

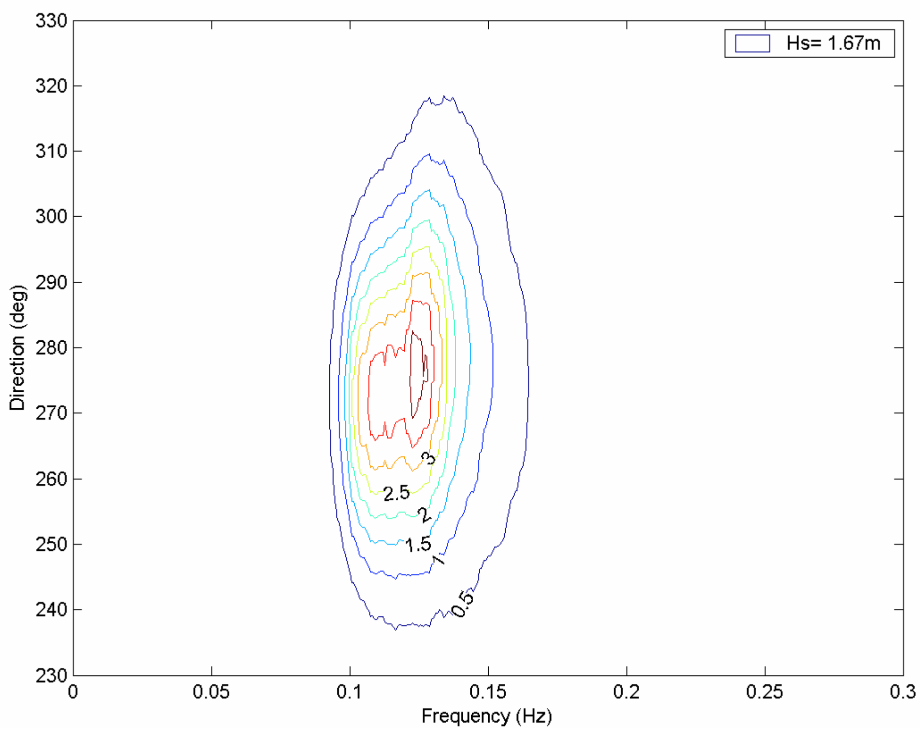


(a) Measured

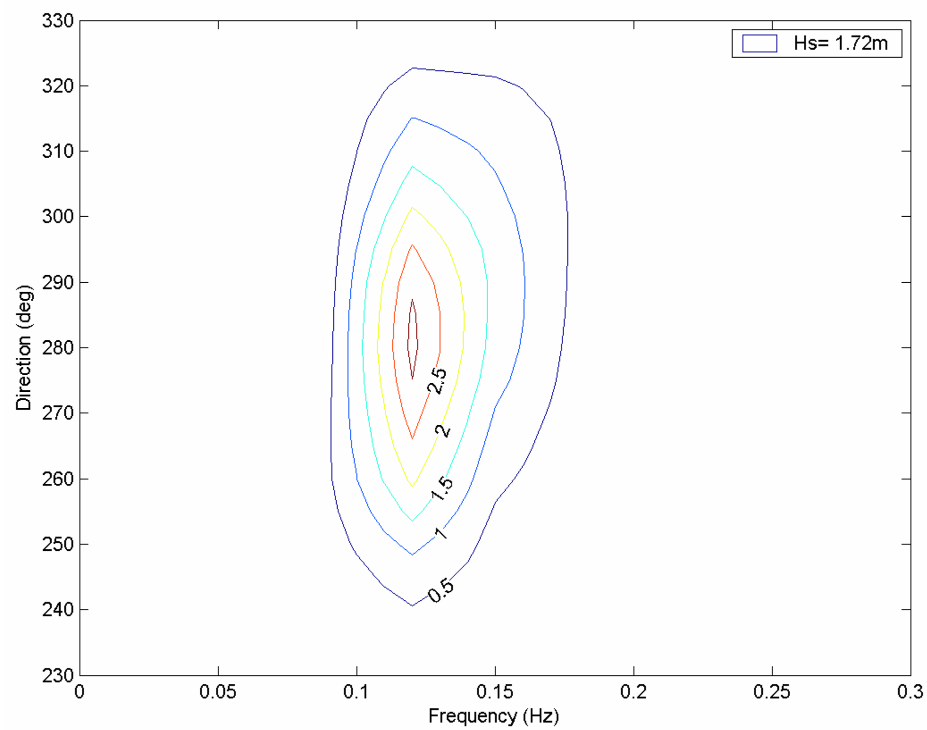


(b) Calculated

Measured and Calculated Directional Spectra MCR Sta 5 - 10:00 GMT, 7 August 2005

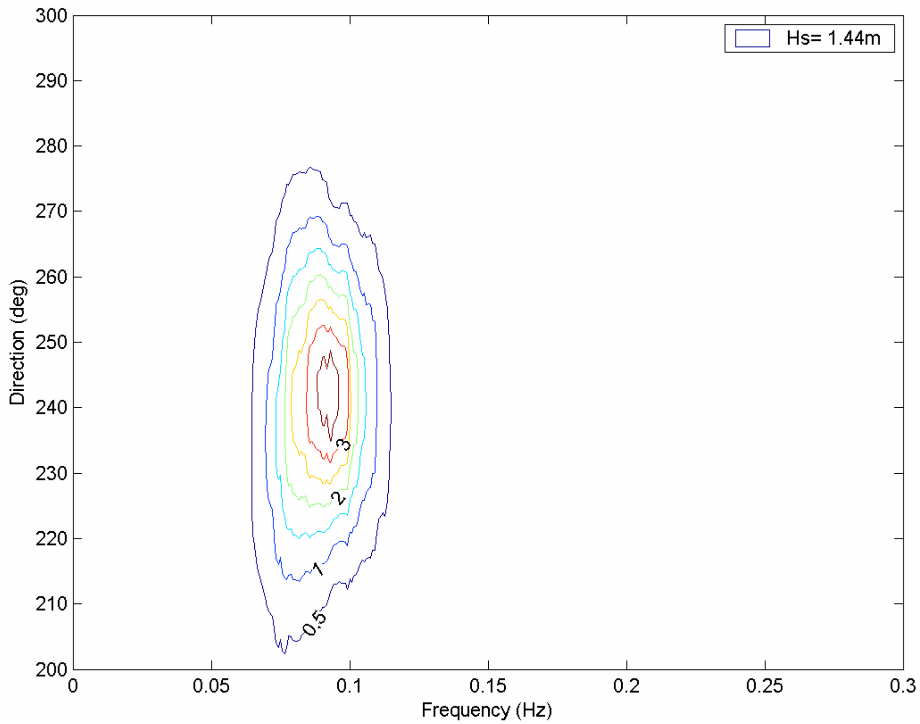


(a) Measured

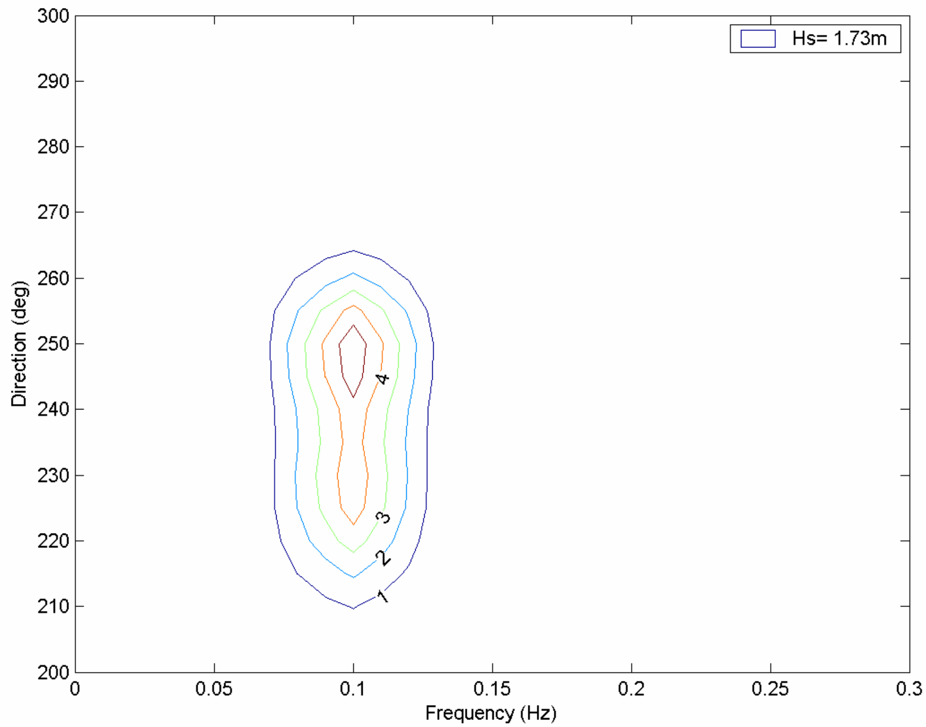


(b) Calculated

Measured and Calculated Directional Spectra MCR Sta 1 - 00:00 GMT, 30 August 2005

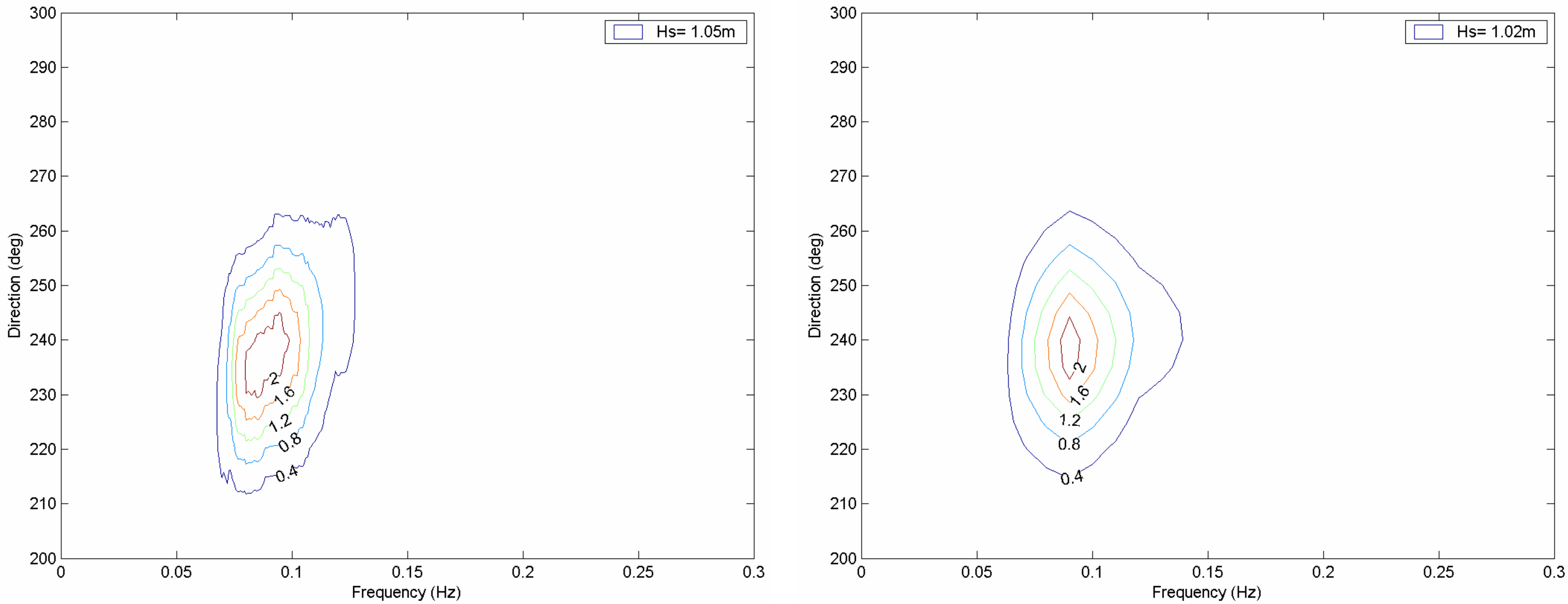


(a) Measured



(b) Calculated

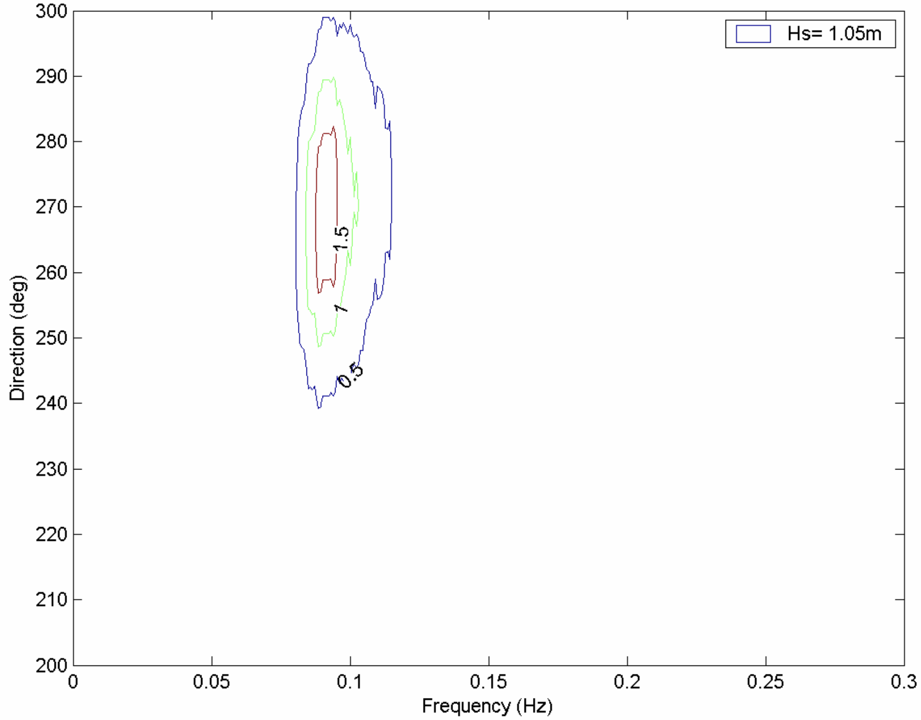
Measured and Calculated Directional Spectra MCR Sta 2 - 00:00 GMT, 30 August 2005



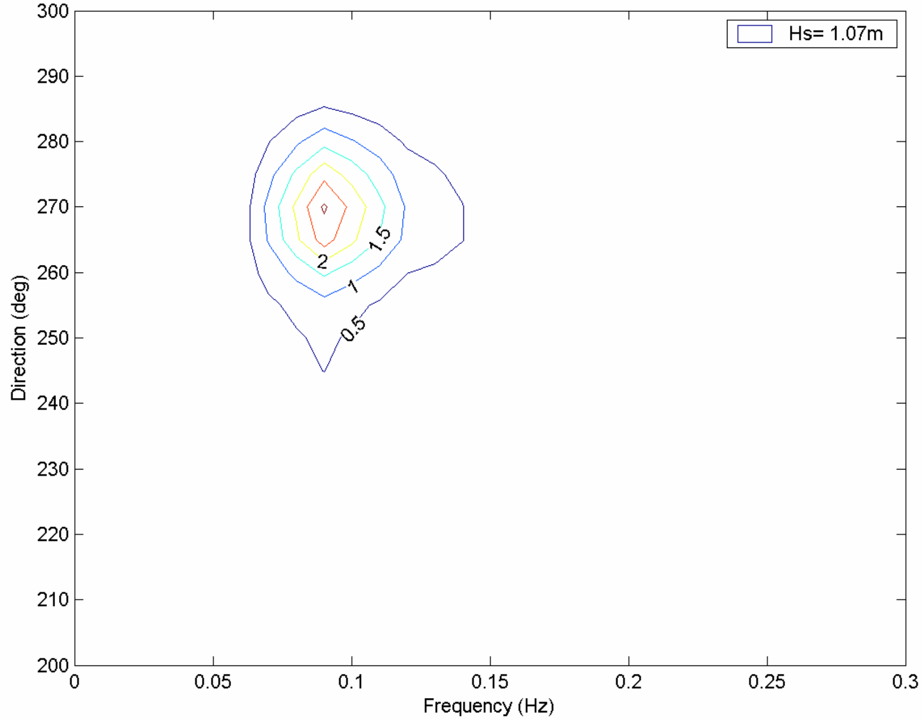
(a) Measured

(b) Calculated

Measured and Calculated Directional Spectra MCR Sta 3 - 00:00 GMT, 30 August 2005

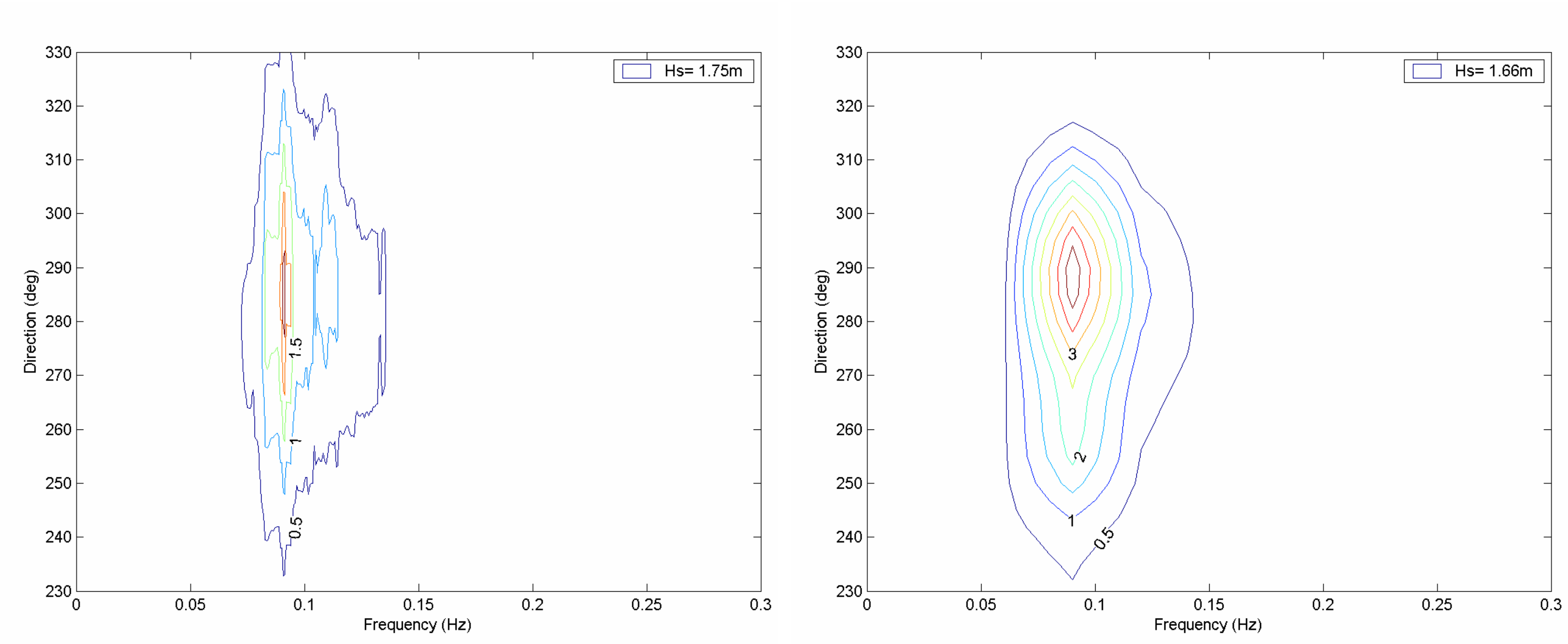


(a) Measured



(b) Calculated

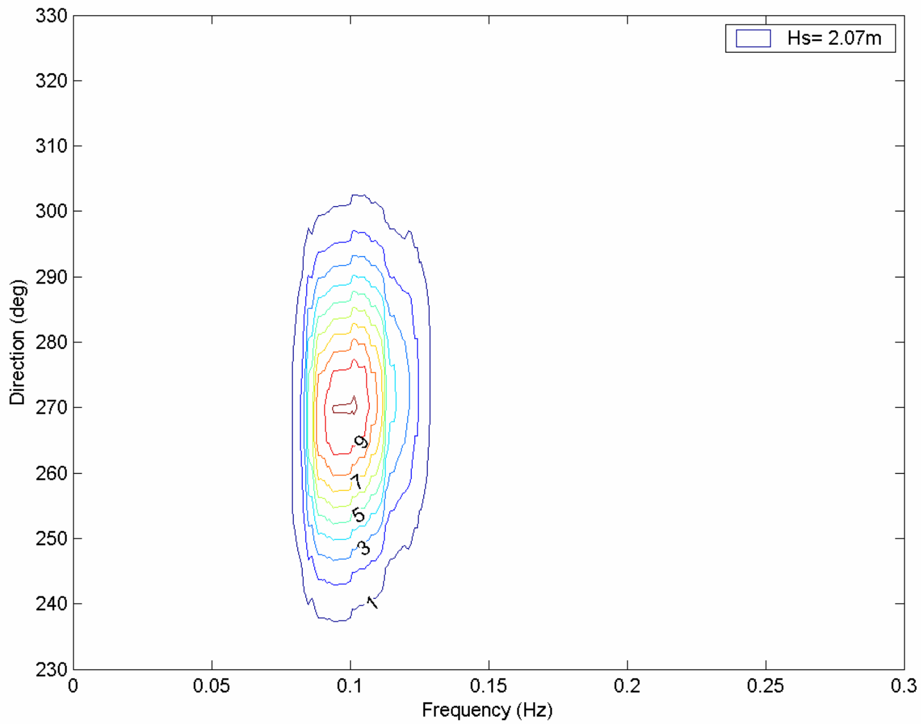
Measured and Calculated Directional Spectra MCR Sta 4 - 00:00 GMT, 30 August 2005



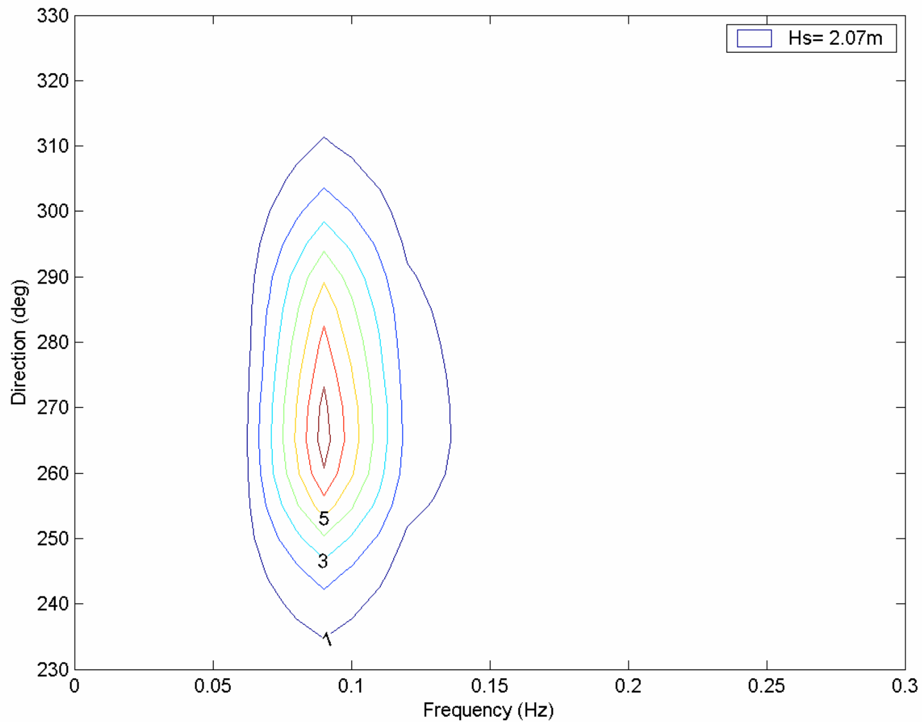
(a) Measured

(b) Calculated

Measured and Calculated Directional Spectra MCR Sta 5 - 00:00 GMT, 30 August 2005

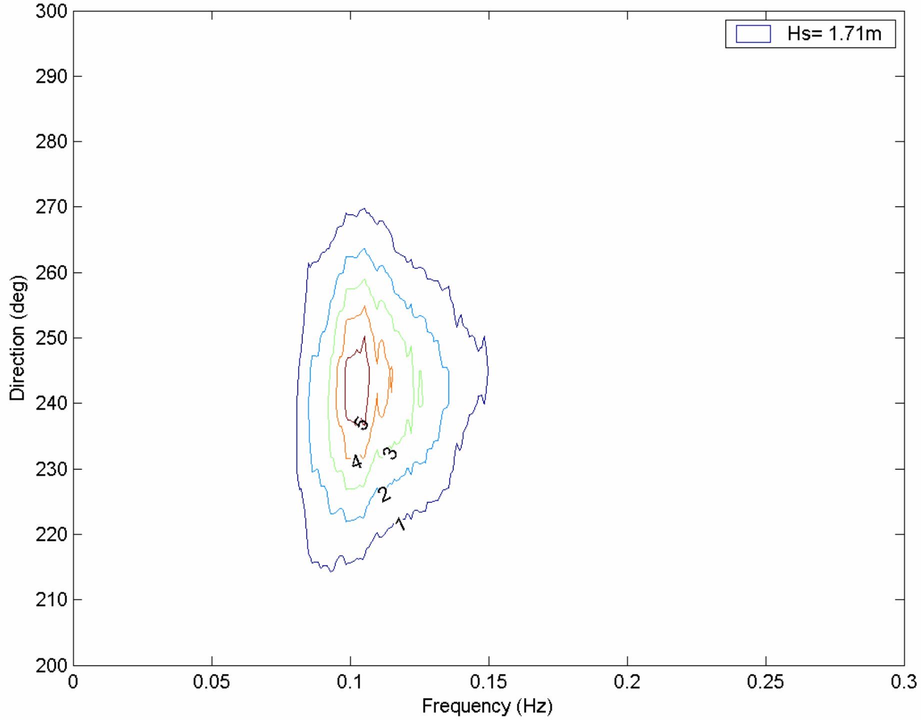


(a) Measured

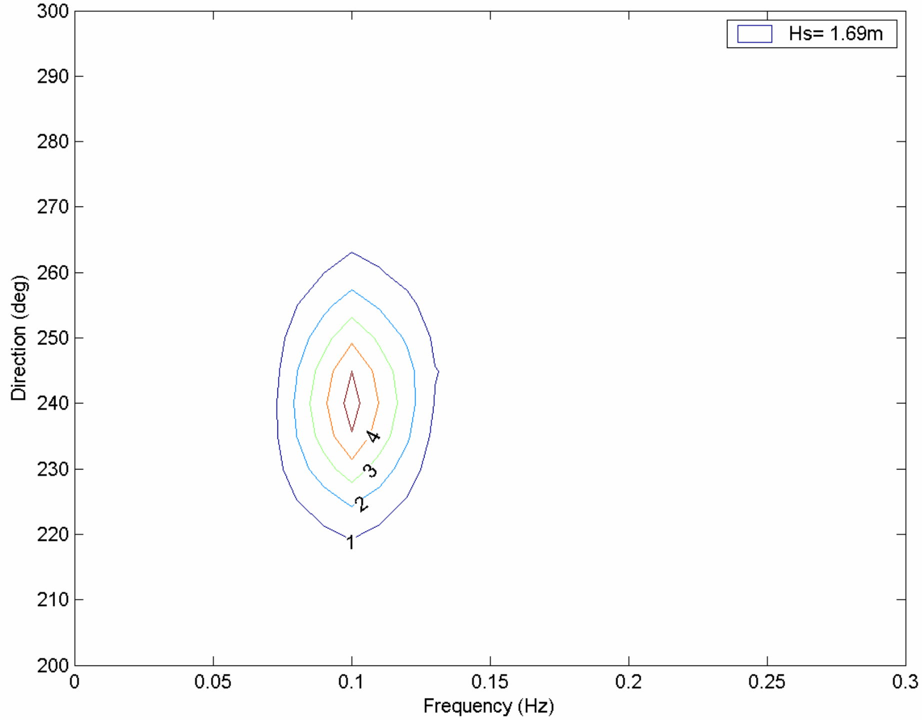


(b) Calculated

Measured and Calculated Directional Spectra MCR Sta 2 - 18:00 GMT, 9 September 2005

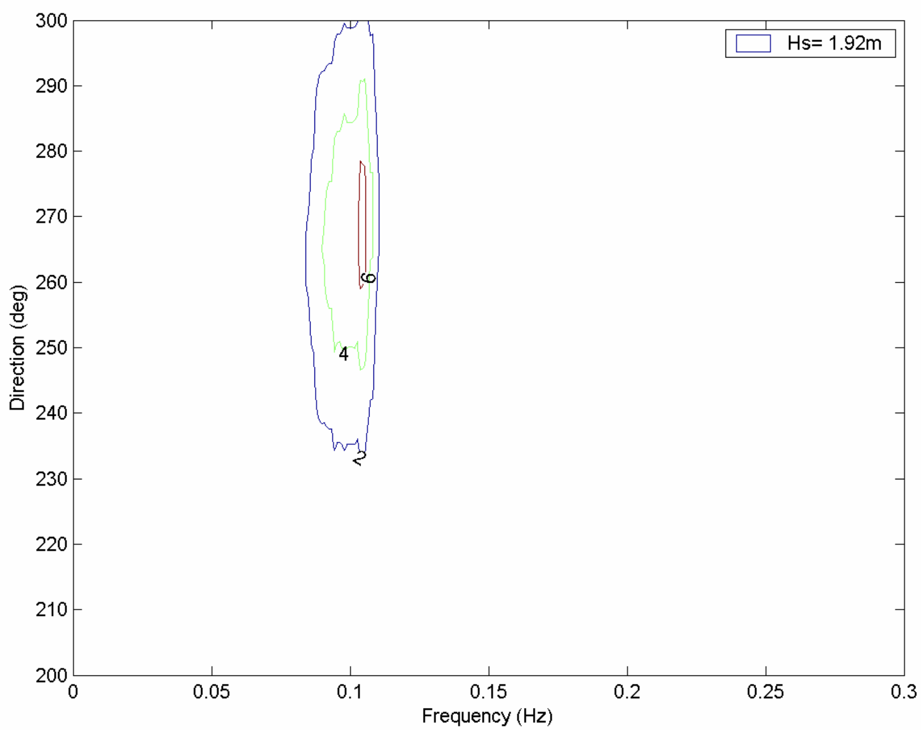


(a) Measured

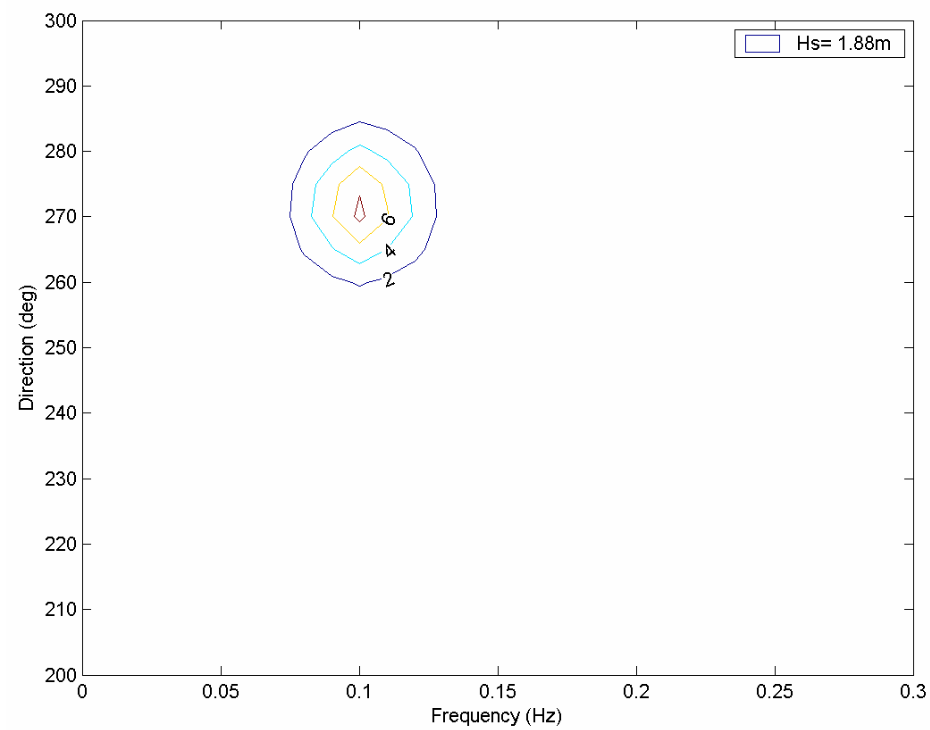


(b) Calculated

Measured and Calculated Directional Spectra MCR Sta 3 - 18:00 GMT, 9 September 2005



(a) Measured

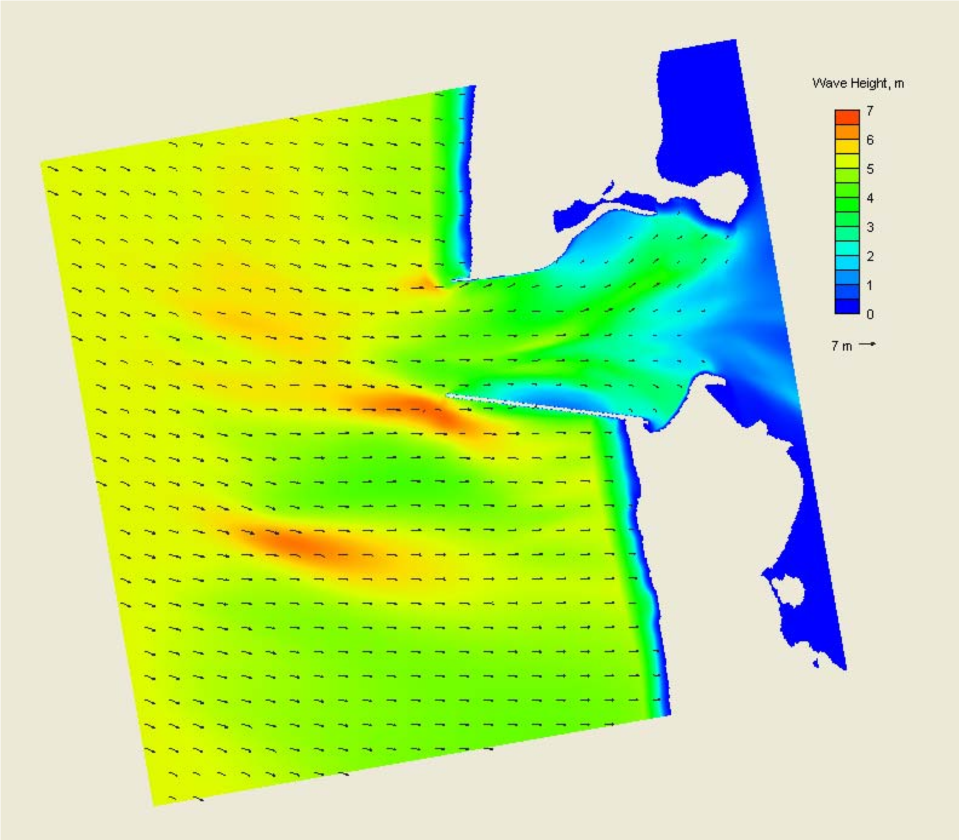


(b) Calculated

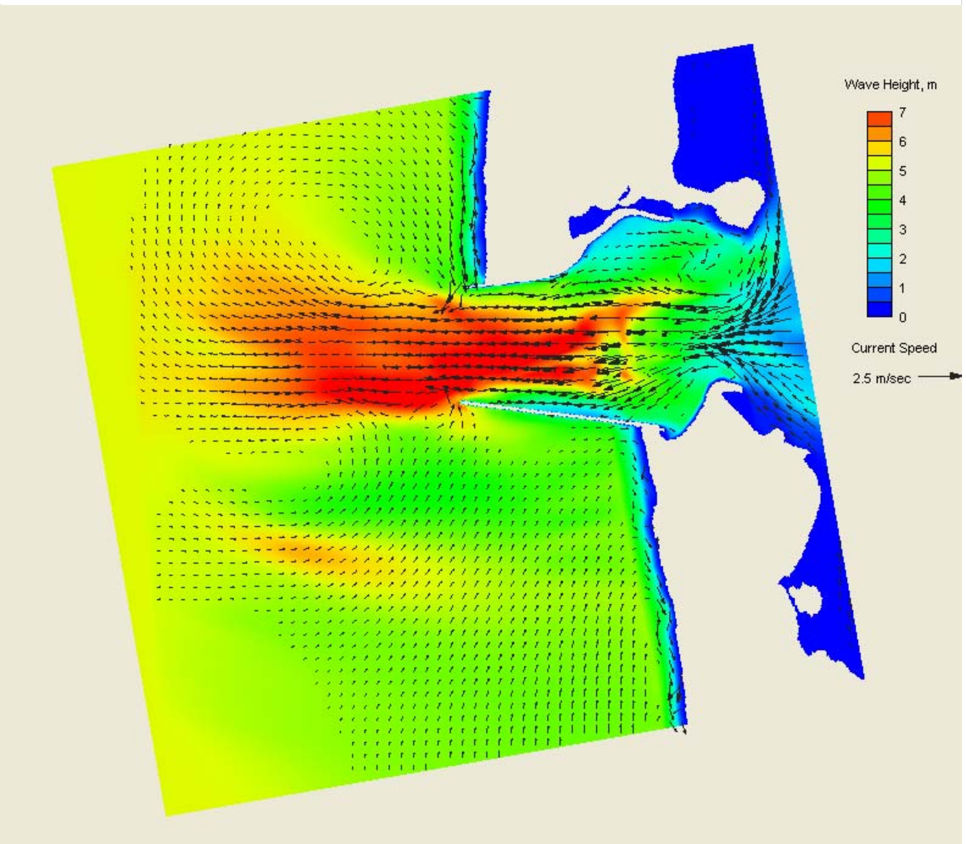
5. Summary and Conclusions

1. Wind input and wave energy dissipation functions developed from previous studies (Lin & Lin, 2004) were implemented in a directional spectral model to simulate wind wave fields at two sites.
2. The comparison of model results with data shows that the effect of non-linear wave-wave interactions is significant in shallow water.
3. The calculated wave growth is significant along the coast under a moderate wind as compared to model result without wind input.
4. The present model does not calculate the nonlinear wave-wave interaction. As a result, the model spectrum tends to skew toward higher frequencies and has a narrower directional distribution as compared to data. Future studies will describe the nonlinear wave energy transfer and comparison with additional data.

Grays Harbor, WA
Incident Waves: 5 m, 18 sec, from NWW
M2D/WABED Models



(a) Without Current



(b) With Strong Ebb Current