Wave Breaking Energy in Coastal Region

Ray-Qing Lin (DTMB) &
Lihwa Lin (USACE)

Motivation
Wave Model
Observation
Conclusions

Motivation

Scientific Objective:

To understand why Huang (2006) suggested that wave breaking in the coastal region is a major energy source for the ocean circulation based on the observational data. Because coastal region area generally represents 5% or less of the ocean, the energy loss from wave breaking in the coastal region must be significantly greater than in the open ocean.

Motivation

Where the Breaking Energy Come from in the coastal region?

Theories:

- **Four nonlinear wave-wave interaction;**
  (1) three local wind waves interact with one long wave dominated;
  (2) wave-wave interaction increases with water depth decreases.

- **Mass conservation Law.**

Numerical Model

1) Action Conservation:

$$\frac{\partial A}{\partial t}+\frac{\partial[(c_{gx}+u)A]}{\partial x}+\frac{\partial[(c_{gy}+v)A]}{\partial y}+\frac{\partial[c_{g\theta}A]}{\partial \theta}+\frac{\partial[c_{g\sigma}A]}{\partial \sigma}=S_{in}+S_{dp}+S_{nl}$$

2) Nonlinear Source Function

$$\frac{\partial A_{(\mathbf{k}_1)}}{\partial \tau}=4\pi\int_{\mathbf{k}_i-\Delta\mathbf{k}}^{\mathbf{k}_i+\Delta\mathbf{k}} d\mathbf{k}_2 \int_{\theta_i^{'}-\Delta\theta}^{\theta_i^{'}+\Delta\theta} d\theta[2\oint ds\left|\frac{\partial OB(\mathbf{s},\mathbf{n})}{\partial \mathbf{n}}\right|^{-1}]\cdot T_{i,1,2,3}^{2}$$
$$\{\mathrm{A}_{(\mathbf{k}_3)}\mathrm{A}_{(\mathbf{k}_2)}[\mathrm{A}_{(\mathbf{k}_1)}+\mathrm{A}_{(\mathbf{k}_i)}]-\mathrm{A}_{(\mathbf{k}_1)}\mathrm{A}_{(\mathbf{k}_i)}[\mathrm{A}_{(\mathbf{k}_3)}+\mathrm{A}_{(\mathbf{k}_2)}]\}d\mathbf{k}_1 d\mathbf{k}_2 d\mathbf{k}_3$$

Simulation Results and Observational Data

1. Nonlinear Transfer Rate from the model

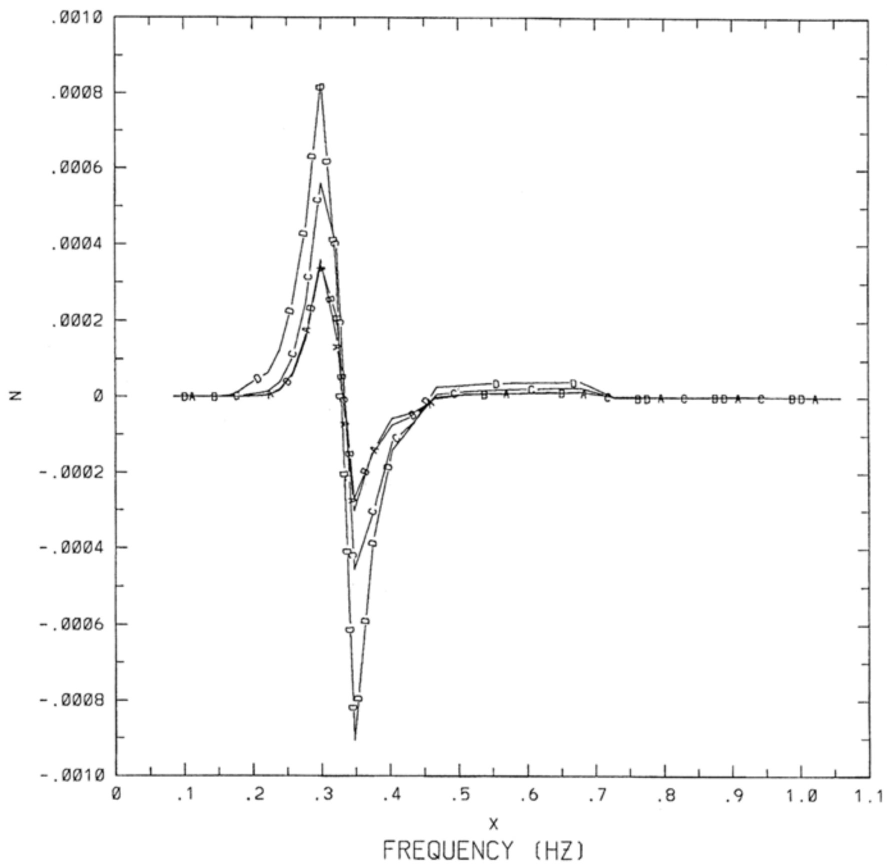

Figure 1. One-dimensional nonlinear transfer rate for JONSWAP spectra: lines A, B, C, and D represent *kh* = 36.3, 1.58, 1.0 and 0.8 (Lin and Perrie, 1999)

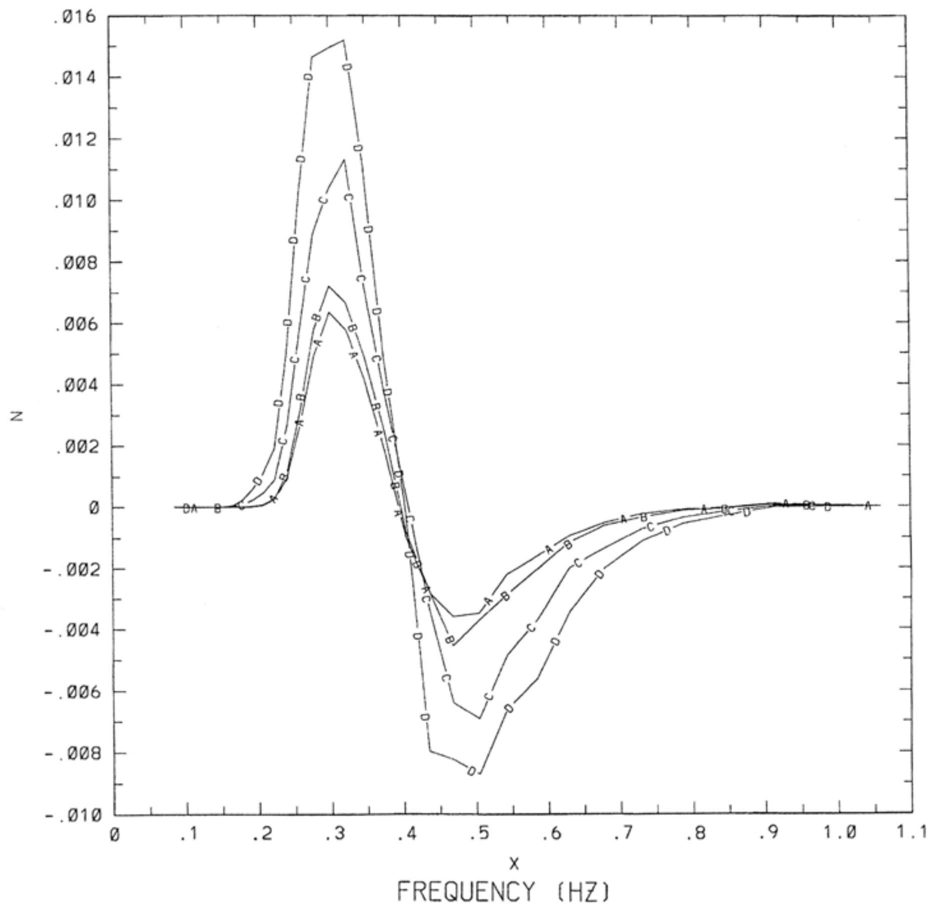

Figure 2. One-dimensional nonlinear transfer rate for P-M spectra: lines A, B, C, and D represent *kh* = 36.3, 1.58, 1.0 and 0.8 (Lin and Perrie, 1999)

2. Observational results

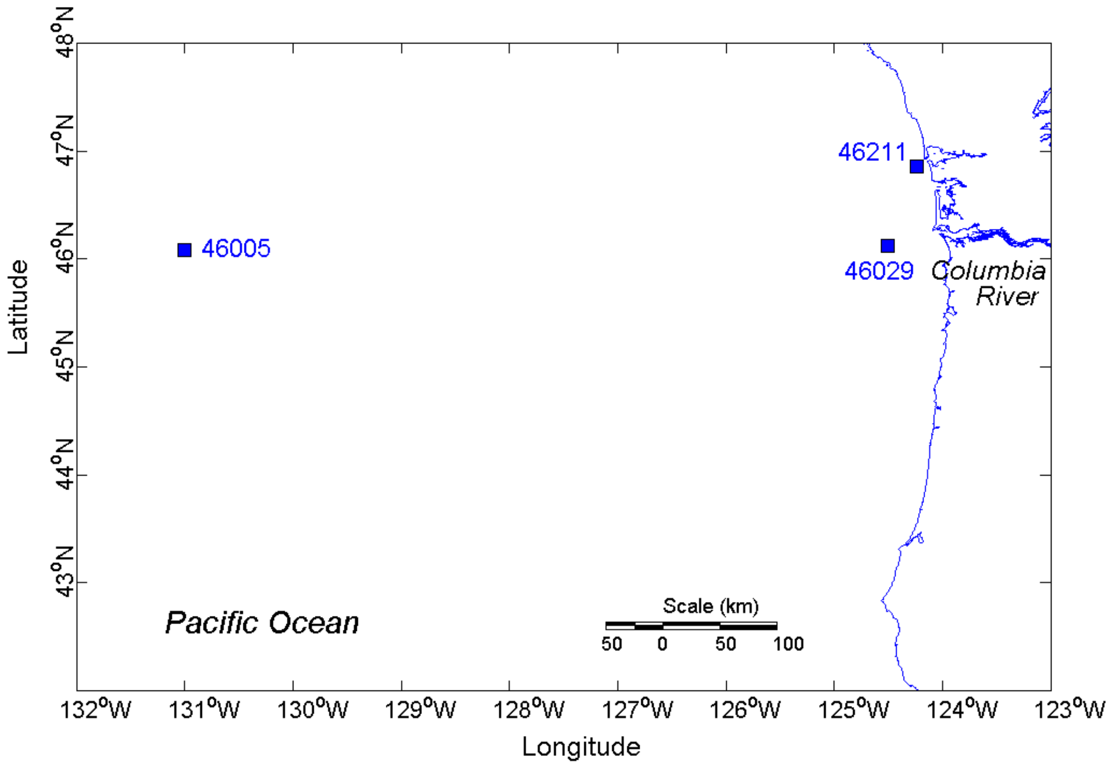

Figure 3. Location Map of Pacific Coast buoys

Table 1
Buoy Station Information

Station	Coordinates	Depth (m)	Data collection period
NDBC 46005	46° 03’ 00” N, 131° 01’ 12” W	2853	September 1976 to December 2004
NDBC 46029	46° 07’ 00” N, 124° 30’ 36” W	128	March 1984 to September 2006
CDIP 46211	46° 51’ 24” N, 124° 14’ 40” W	39	November 1981 to September 2006

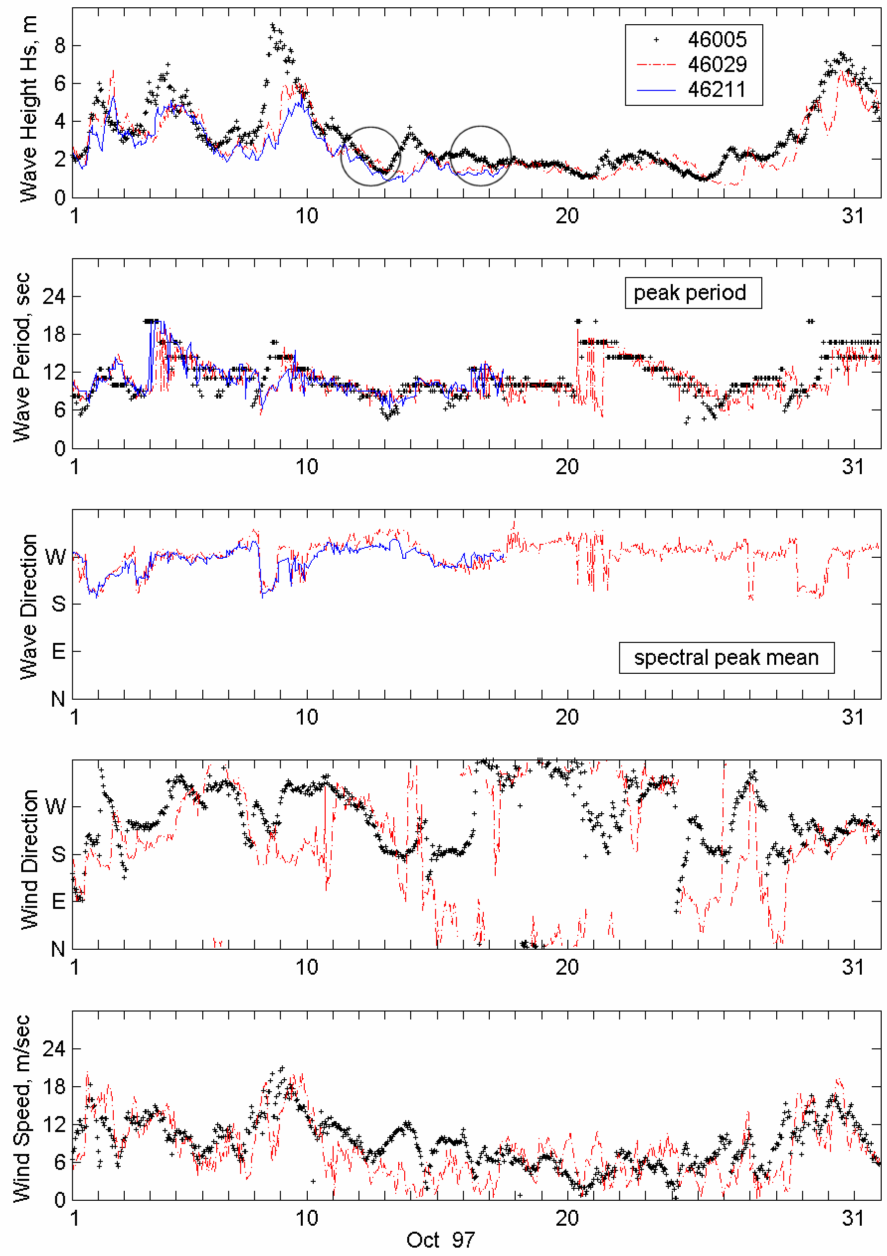

Figure 4. Wind and wave time series of interest (in circles)

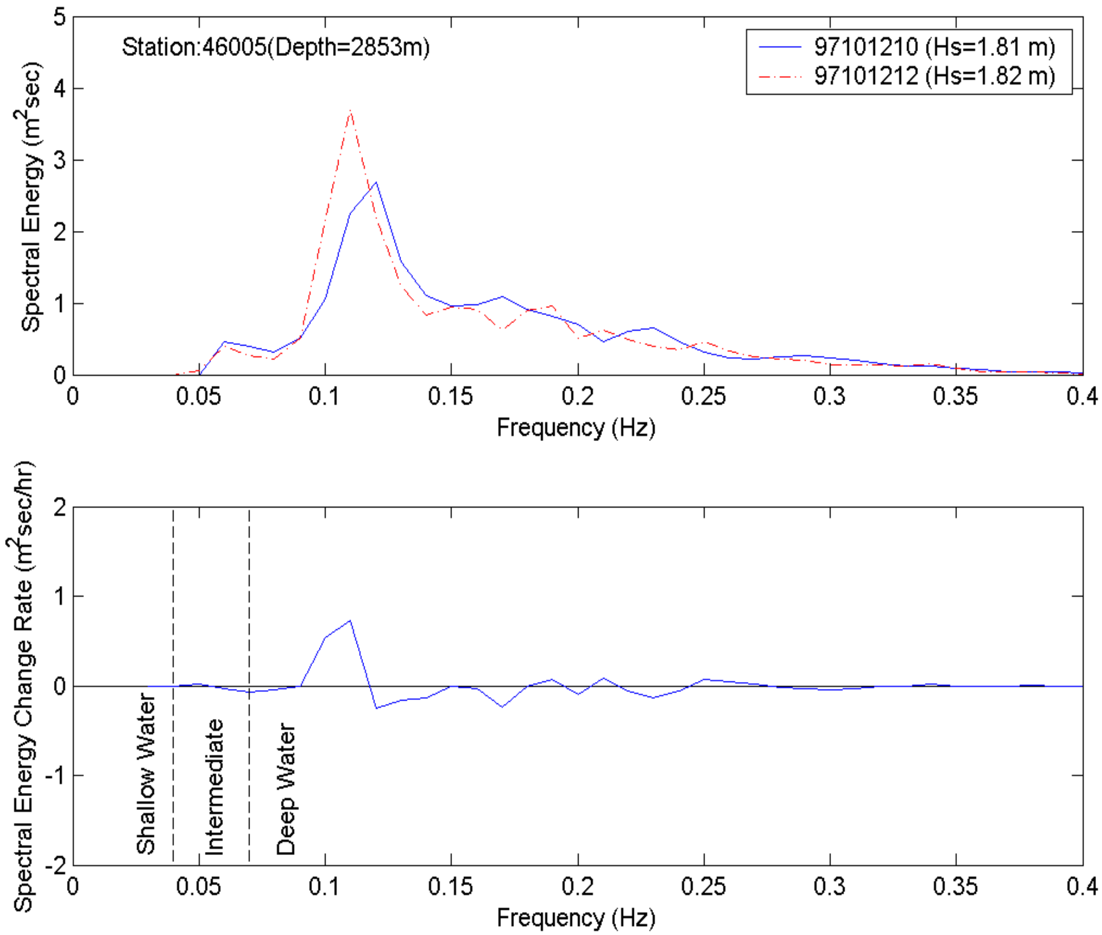

Figure 5. Measured one-dimensional frequency spectra at 10:00 and 12:00 GMT, 12 October 1997, and spectral energy change rate estimation at Buoy 46005

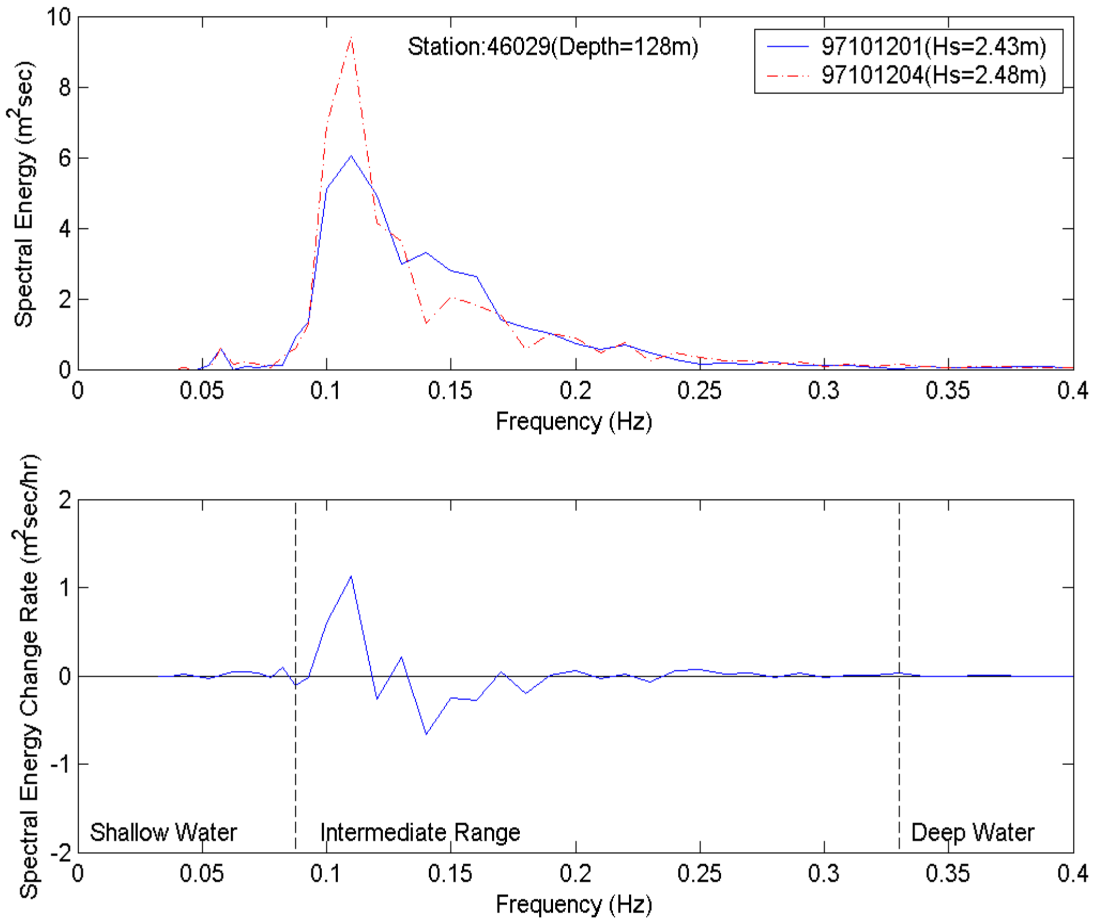

Figure 6. Measured one-dimensional frequency spectra at 01:00 and 04:00 GMT, 12 October 1997, and spectral energy change rate estimation at Buoy 46029

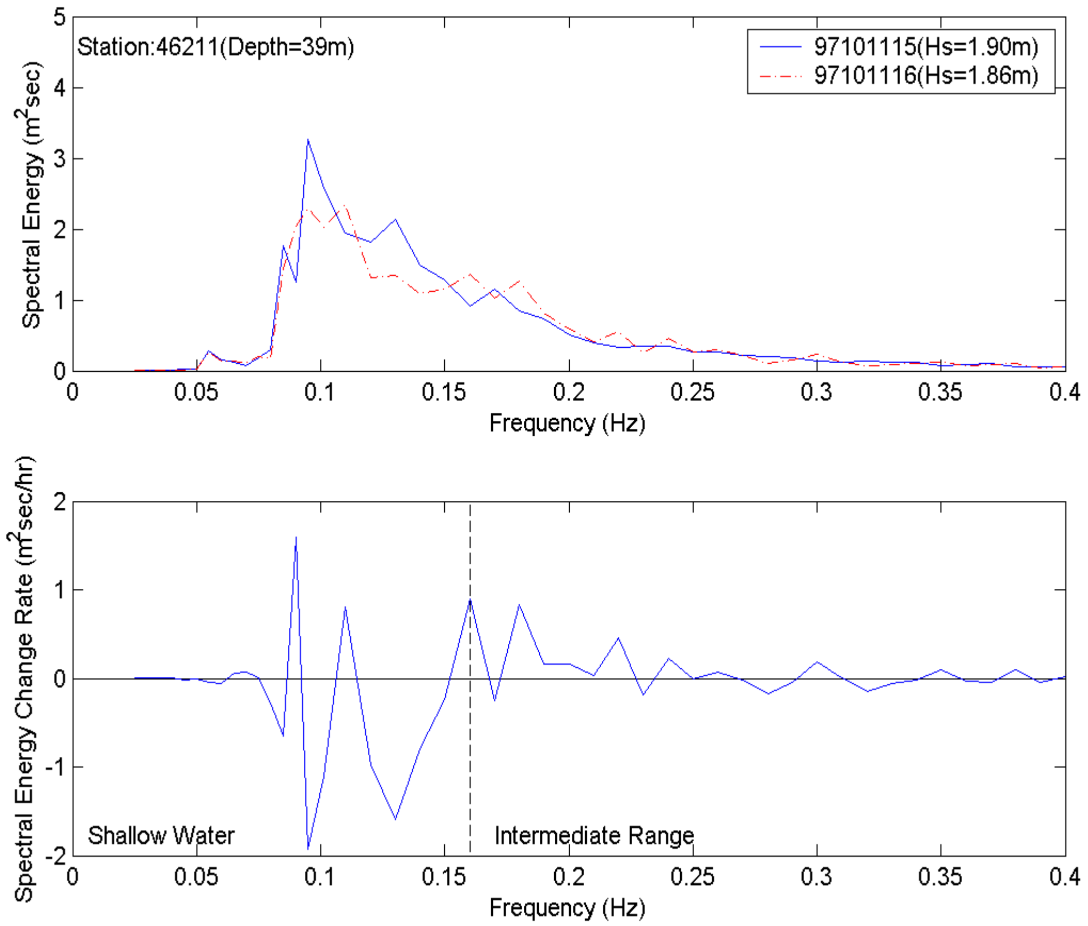

Figure 7. Measured one-dimensional frequency spectra at 15:00 and 16:00 GMT, 11 October 1997, and spectral energy change rate estimation at Buoy 46211

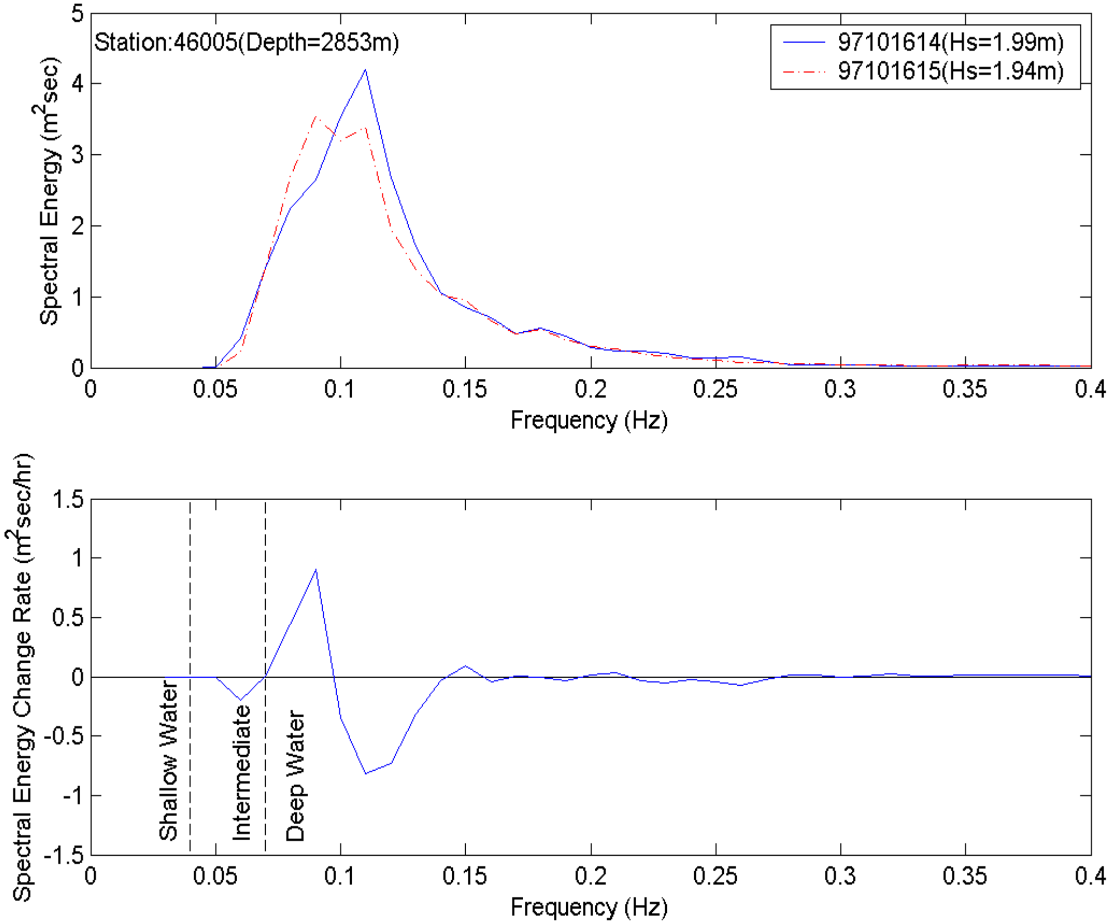

Figure 8. Measured one-dimensional frequency spectra at 14:00 and 15:00 GMT, 16 October 1997, and spectral energy change rate estimation at Buoy 46005

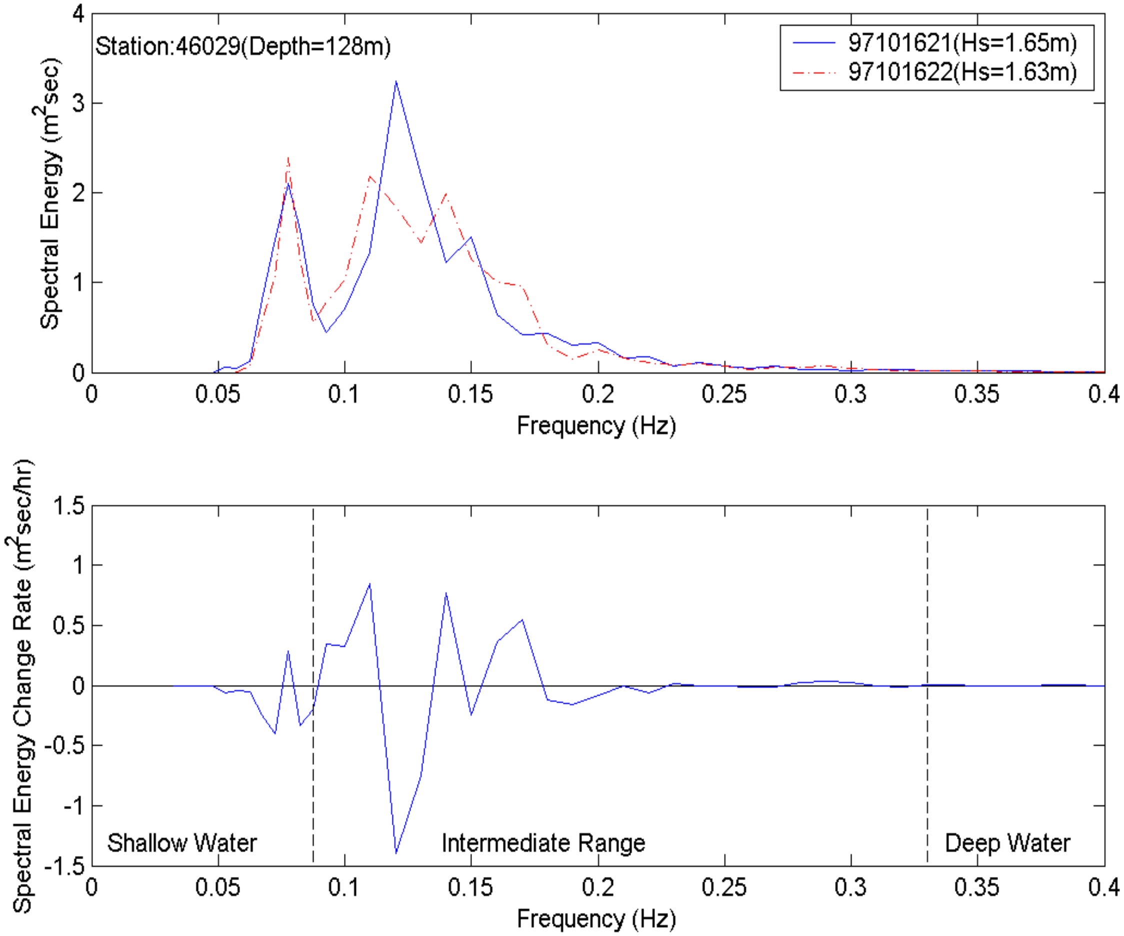

Figure 9. Measured one-dimensional frequency spectra at 21:00 and 22:00 GMT, 16 October 1997, and spectral energy change rate estimation at Buoy 46029

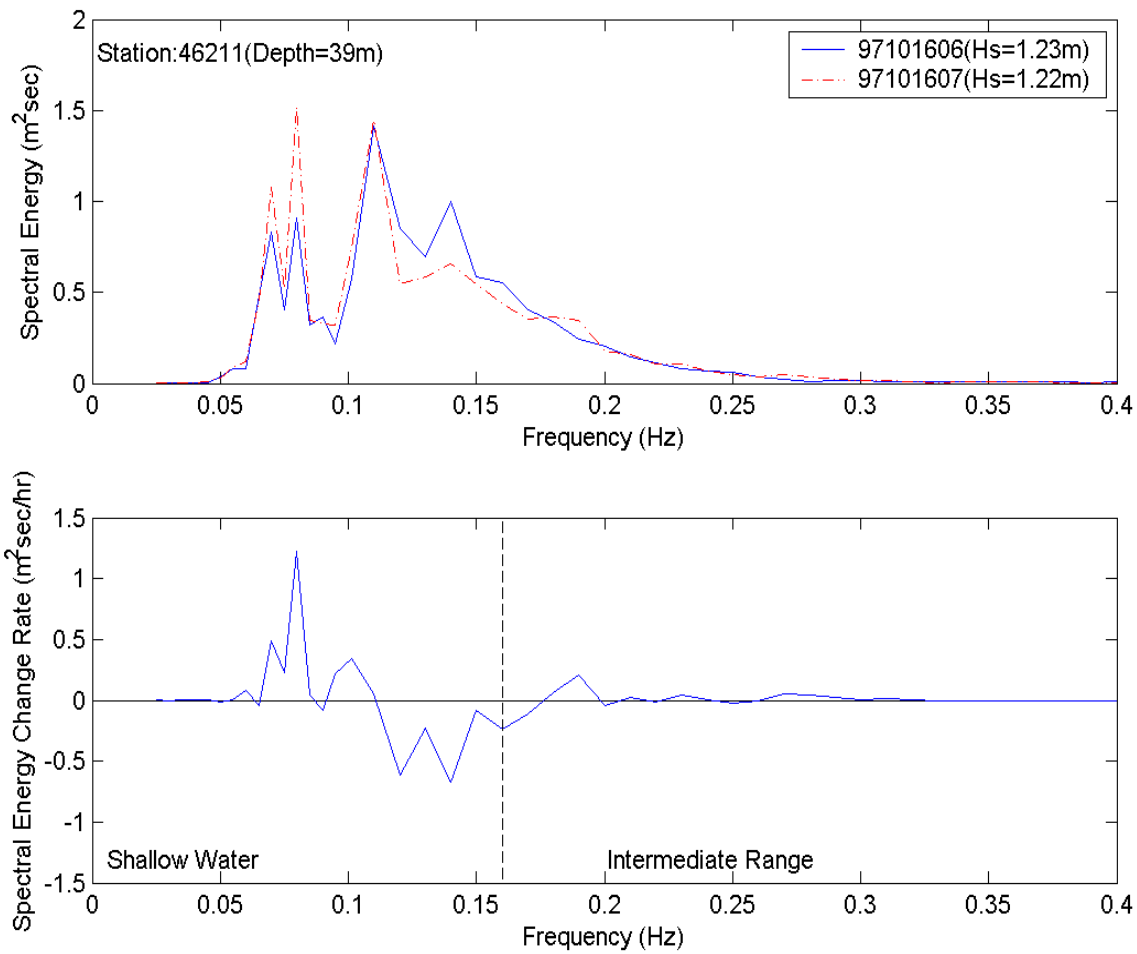

Figure 10. Measured one-dimensional frequency spectra at 06:00 and 07:00 GMT, 16 October 1997, and spectral energy change rate estimation at Buoy 46211

Summary

1. The effect of stronger nonlinear interaction in the shallow water region is the transfer of more energy from shorter waves into longer waves in the coastal region

2. These large, longer waves break in the shallow water, and a small fraction of the energy can be reflected back to the ocean, resulting in stronger currents along the coast.