Signal processing applied to ocean waves: dissipation and nonlinear interactions

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Show the application of Fourier Transforms in the study of ocean waves

“The smart, brute force”

1

Justification of studying the transformation of ocean waves

US | Fri Dec 5, 2014 4:49pm EST

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ORLANDO, FLA. | BY BARBARA LISTON

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AMY GREEN

Beach sediment relocalization
is linked to **wave transformation**
at inner-shelf shoals

C. INICIO SECCIONES MULTIMEDIA

El mar está a 27 metros del volcán de Arboletes

La erosión sigue. El volcán está junto a los árboles. FOTO CORTESÍA

MEDIO AMBIENTE URABÁ

PUBLICADO EL 24 DE ENERO DE 2015

EL TIEMPO Viernes 7 de agosto de 2015 BUSCAR INGRESA CREA UNA CUENTA

OPINIÓN COLOMBIA BOGOTÁ MUNDO POLÍTICA ECONOMÍA DEPORTES ENTRETENIMIENTO TECNÓSFERA VIDA CLASIFICADOS

COLOMBIA BOGOTÁ MEDELLÍN CALI BARRANQUILLA OTRAS CIUDADES

TEMAS DEL DÍA | Intolerancia El Tino Asprilla Animales en Colombia Catherine Ibargüen ÚLTIMAS NOTICIAS

El mar se come el litoral del golfo de Urabá

El volcán de lodo y Arboletes están en alto riesgo. Hacen estudios para determinar solución.

Por: Yeison Gualdrón |
1:49 a.m. | 26 de enero de 2015

Foto: EL TIEMPO
El turismo es la principal fuente de ingresos de Arboletes.

Teleantioquia noticias

EN VIVO Teleantioquia N YouTube

INICIO TITULARES VALLE DE ABURRÁ ANTIOQUIA COLOMBIA DEPORTES INTERNACIONAL ESPECIALES

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Preocupación por la erosión costera en el Urabá antioqueño

CARACOL.COM.CO LA LUCIÉRNAGA PULSO DEL FÚTBOL PROGRAMAS EMISORAS BOG

ES NOTICIA EN ESTE MOMENTO:

Desaparecen los manglares del golfo de Urabá

1 COMPARTIDO

RELACIONADO CON: Catástrofes Naturales Antioquia

El golfo de Urabá, el más extenso del Caribe colombiano, se halla amenazado ambientalmente según reveló el proyecto Expedición Estuarina golfo de Urabá.

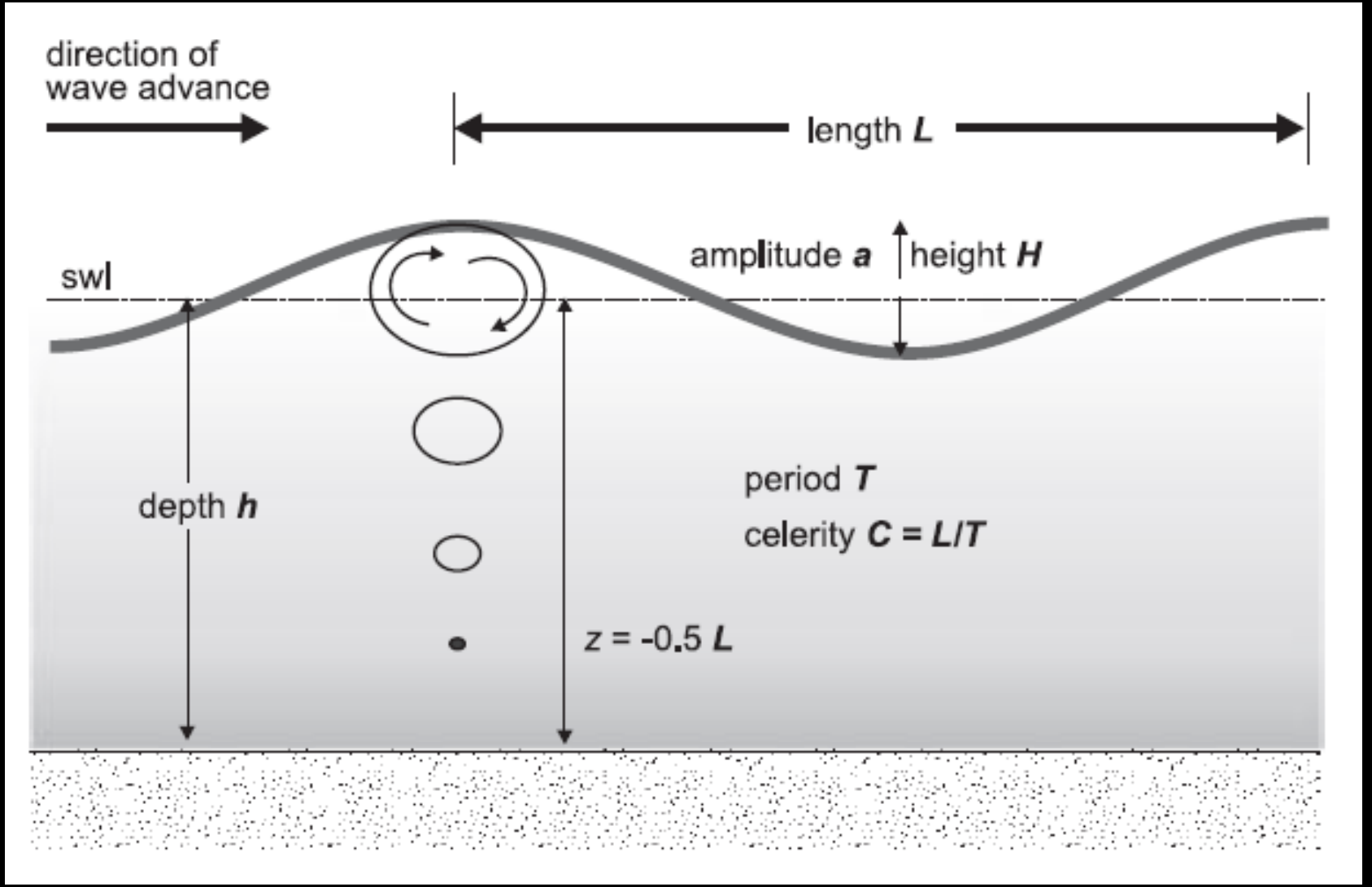
Caracol Radio | 6 de Febrero de 2013

http://data.whicdn.com/images/58661336/large.jpg

2

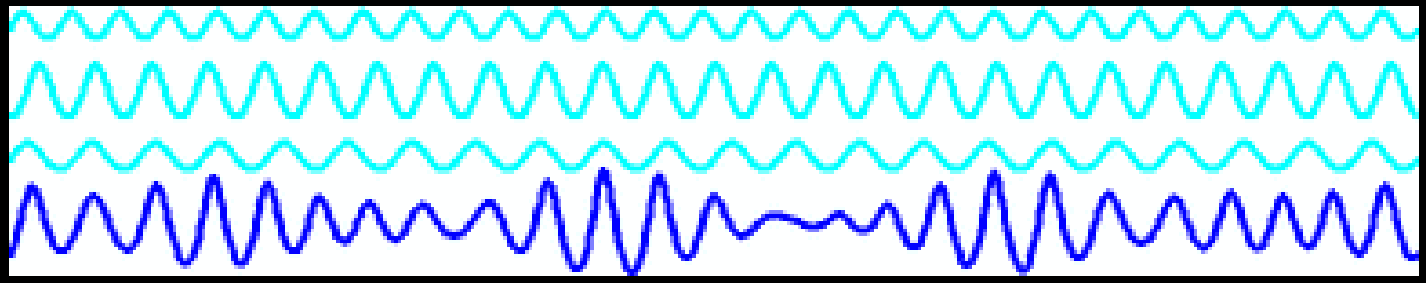
Frequency-dispersive waves

SEA-SWELL -- 3 to 20 s



[1]

SIMILAR PERIODS



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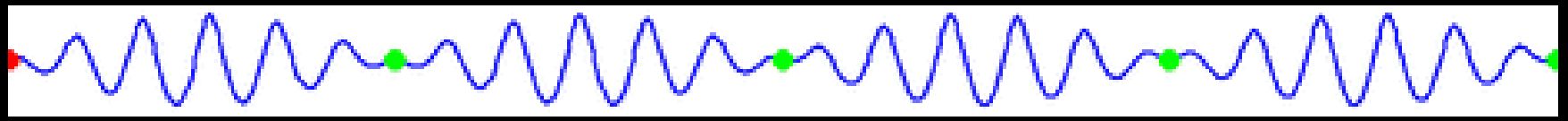

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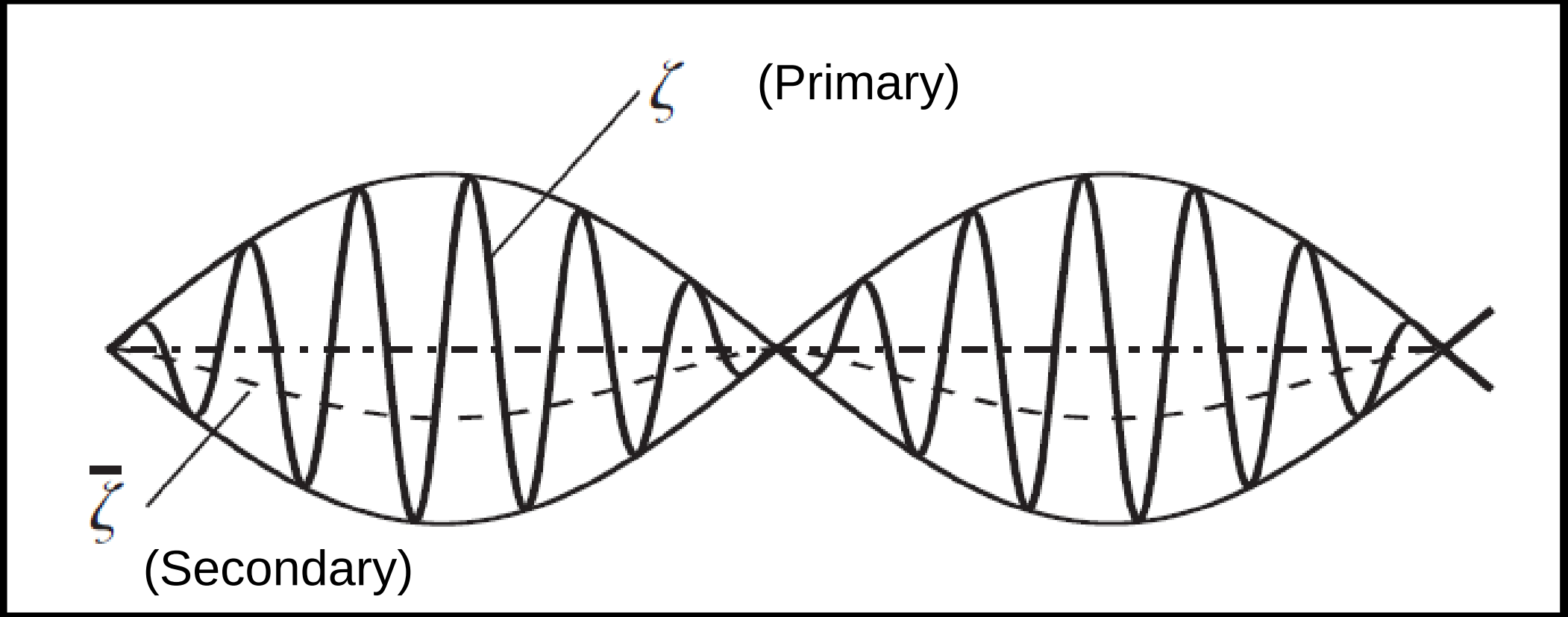
SURF BEAT – FORCED INFRAGRAVITY MOTIONS



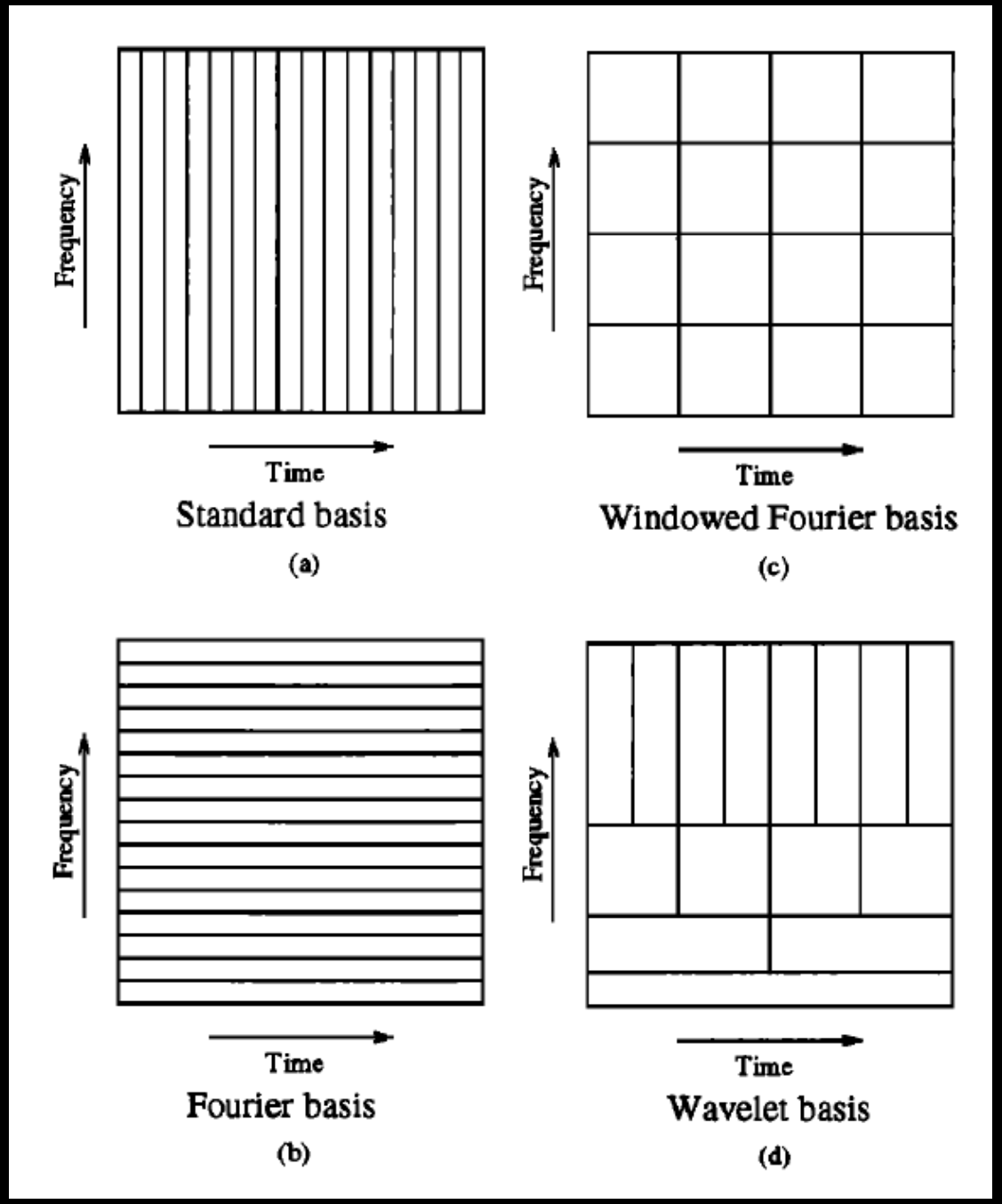
20 to 500 s

[2]

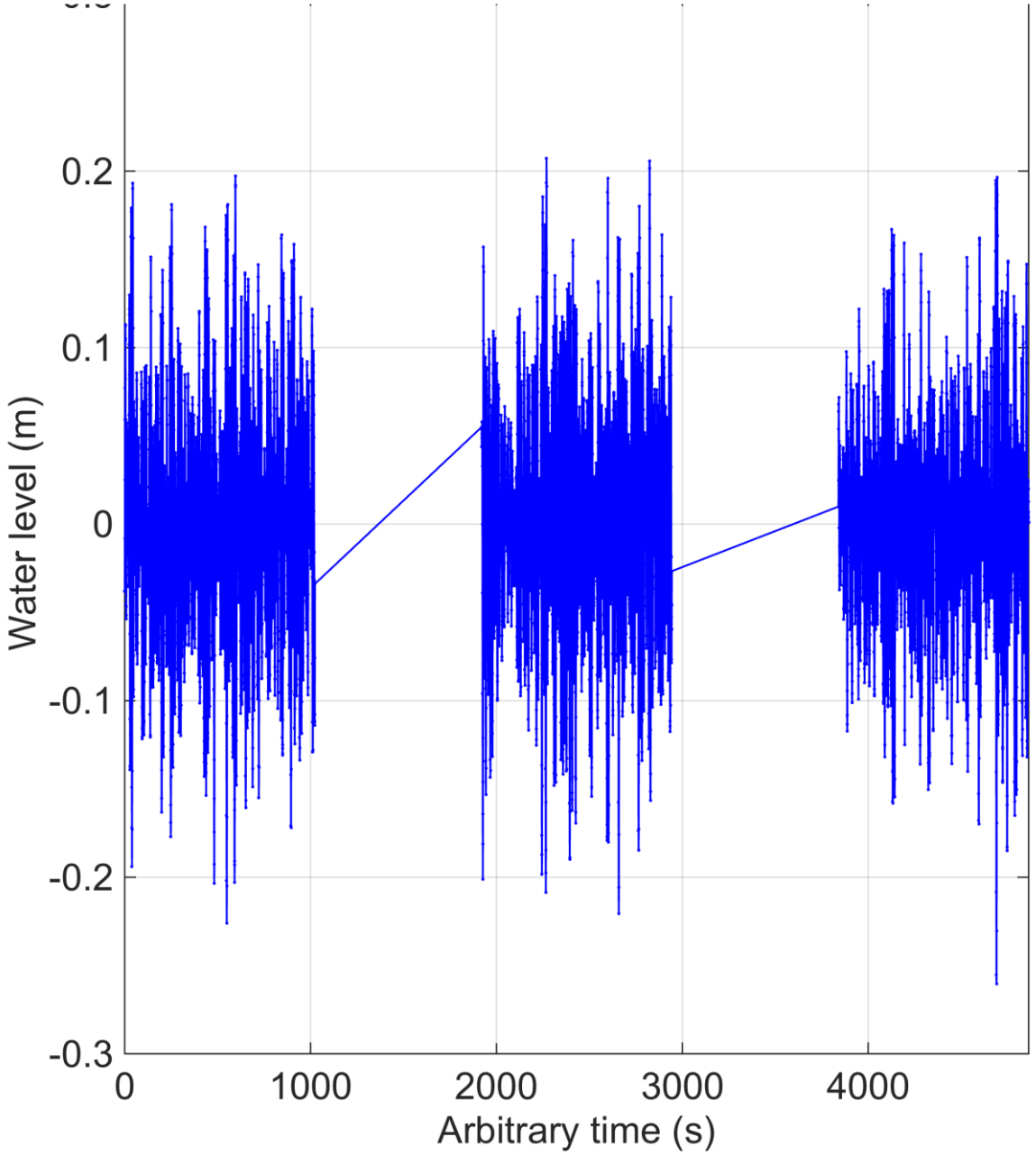
3

Fourier series representation of ocean waves

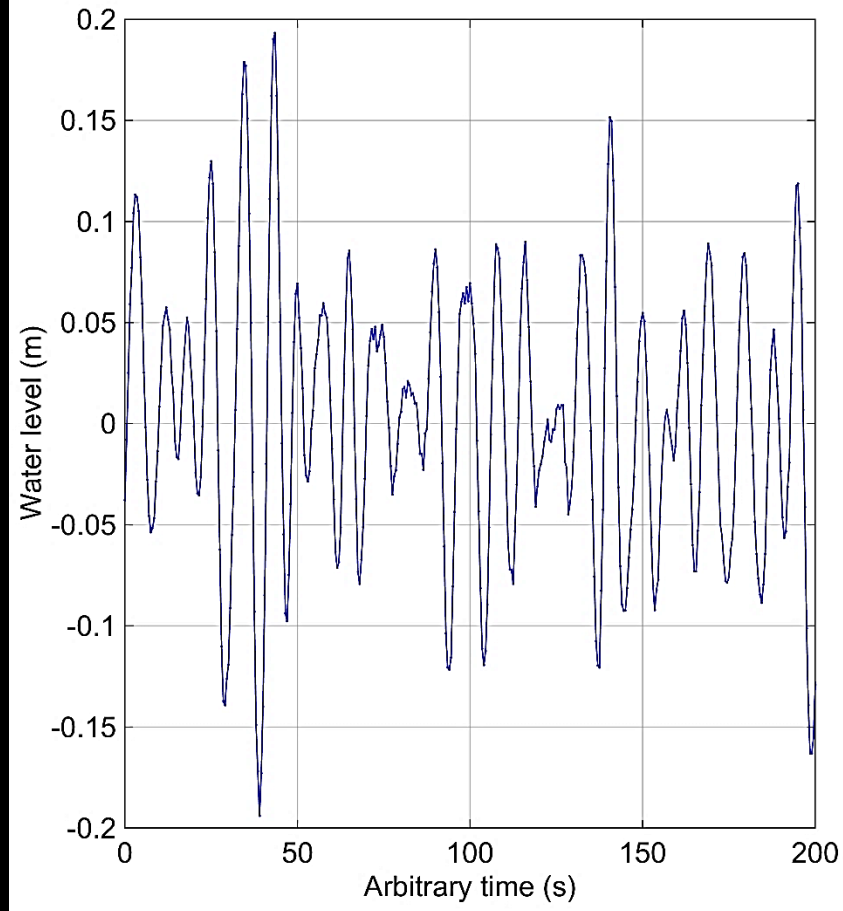
[3]


Frequency
Time
Standard basis
(a)
Frequency
Time
Windowed Fourier basis
(c)
Frequency
Time
Fourier basis
(b)
Frequency
Time
Wavelet basis
(d)

WATER LEVEL



WATER LEVEL



$$\eta\left(x,t\right)=\sum_{k=1}^{N-1}\left[\hat{x}_k e^{i\left(\kappa_k x-\omega_k t\right)}+\hat{x}_k^* e^{-i\left(\kappa_k x-\omega_k t\right)}\right]$$

$$\omega_k^2=g\kappa_k\tanh\left(\kappa_k h\right)$$

[4]

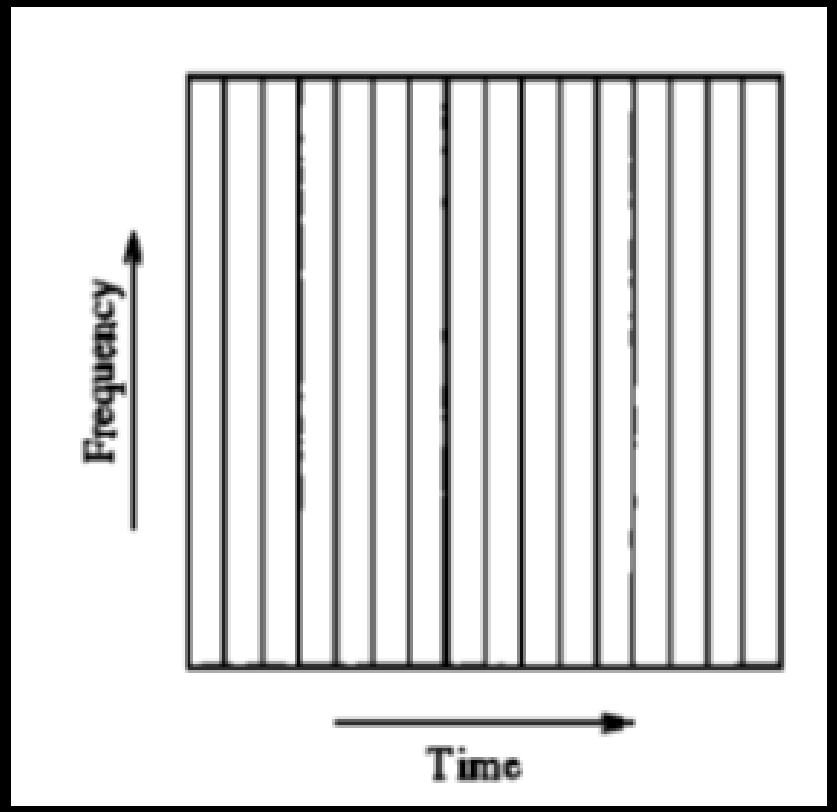
$$\hat{x}_k = \Delta t \sum_{n=1}^{N} x_n e^{-i2\pi f_k n \Delta t}$$

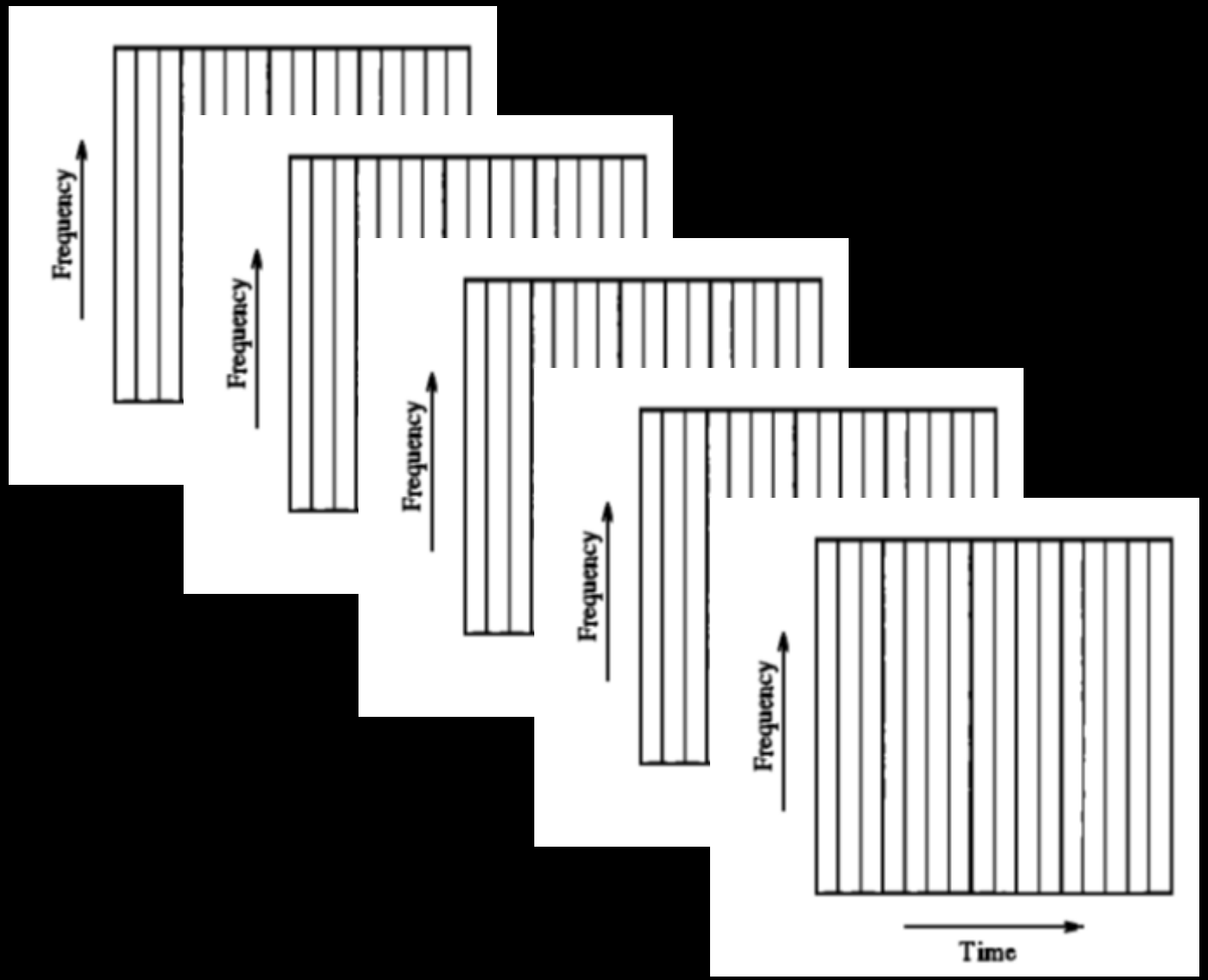
$$E\left(f_k\right) = \mathrm{E}\left[\hat{x}_k \hat{x}_k^*\right]$$

[5]

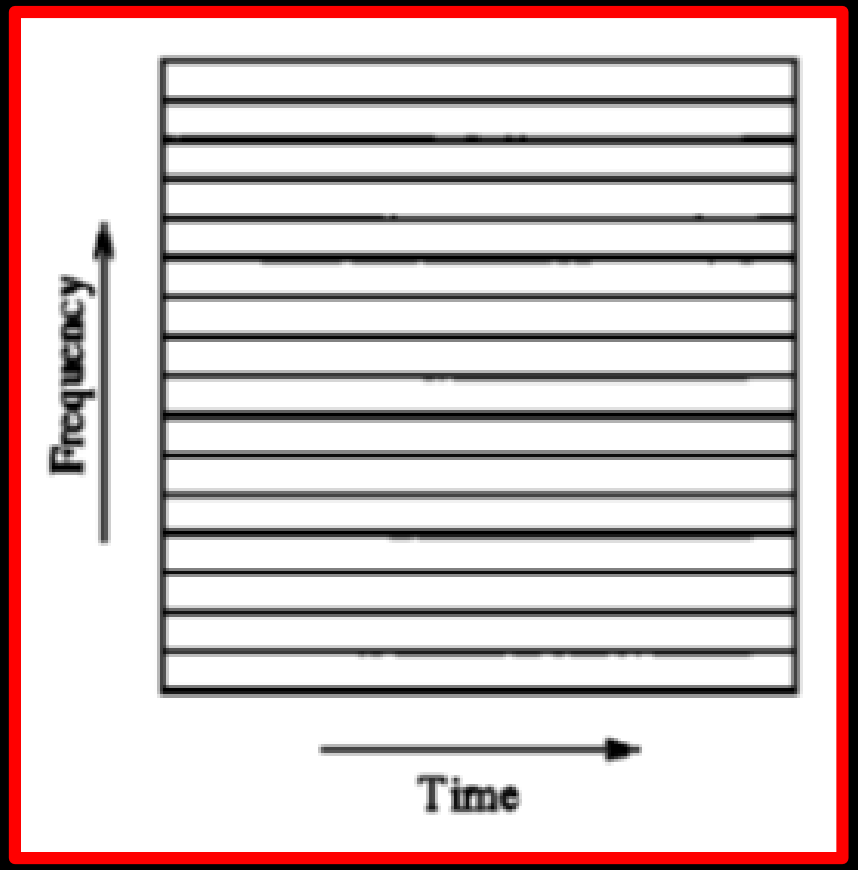
TIME PLANE

$$x_n$$

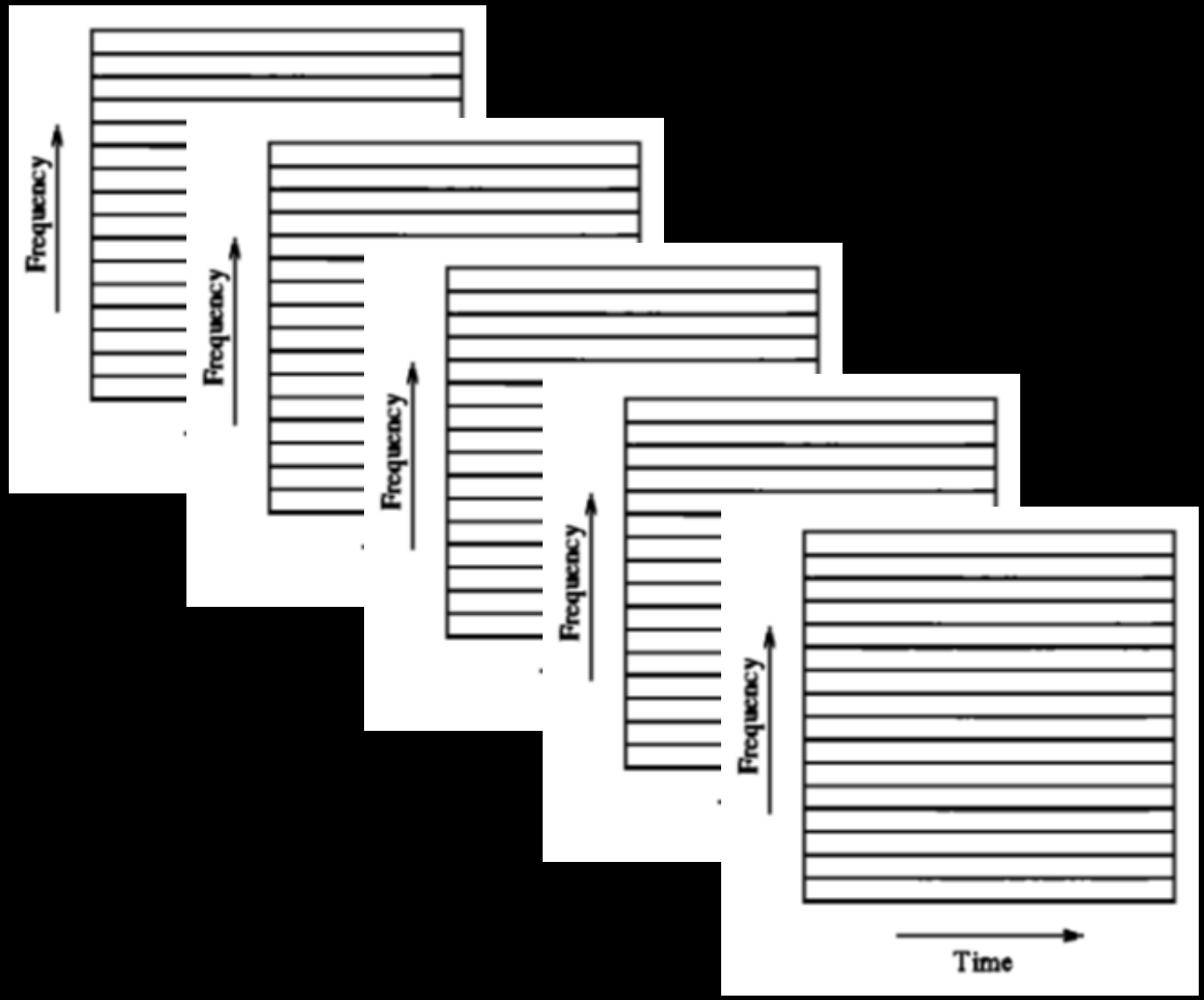


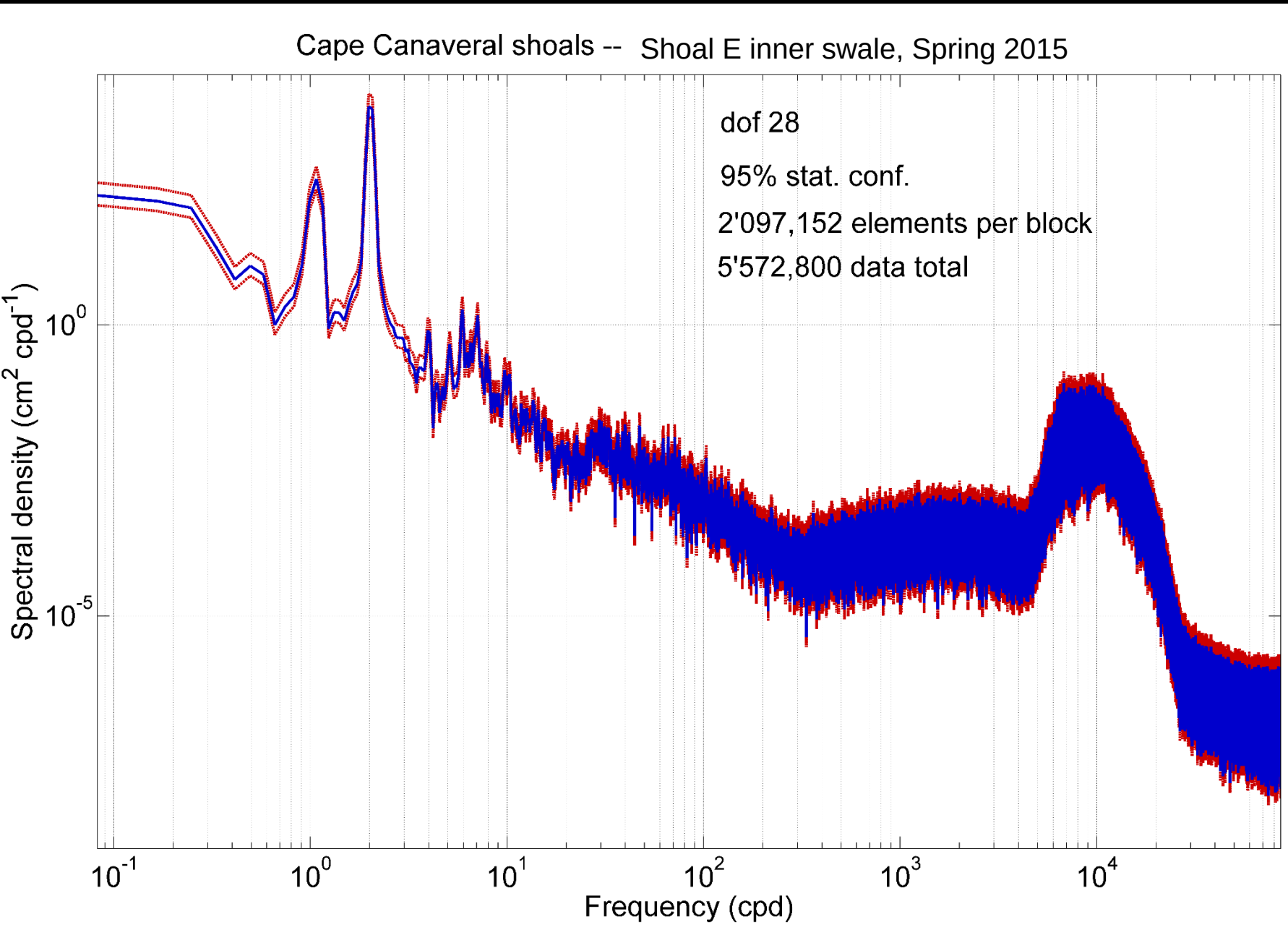


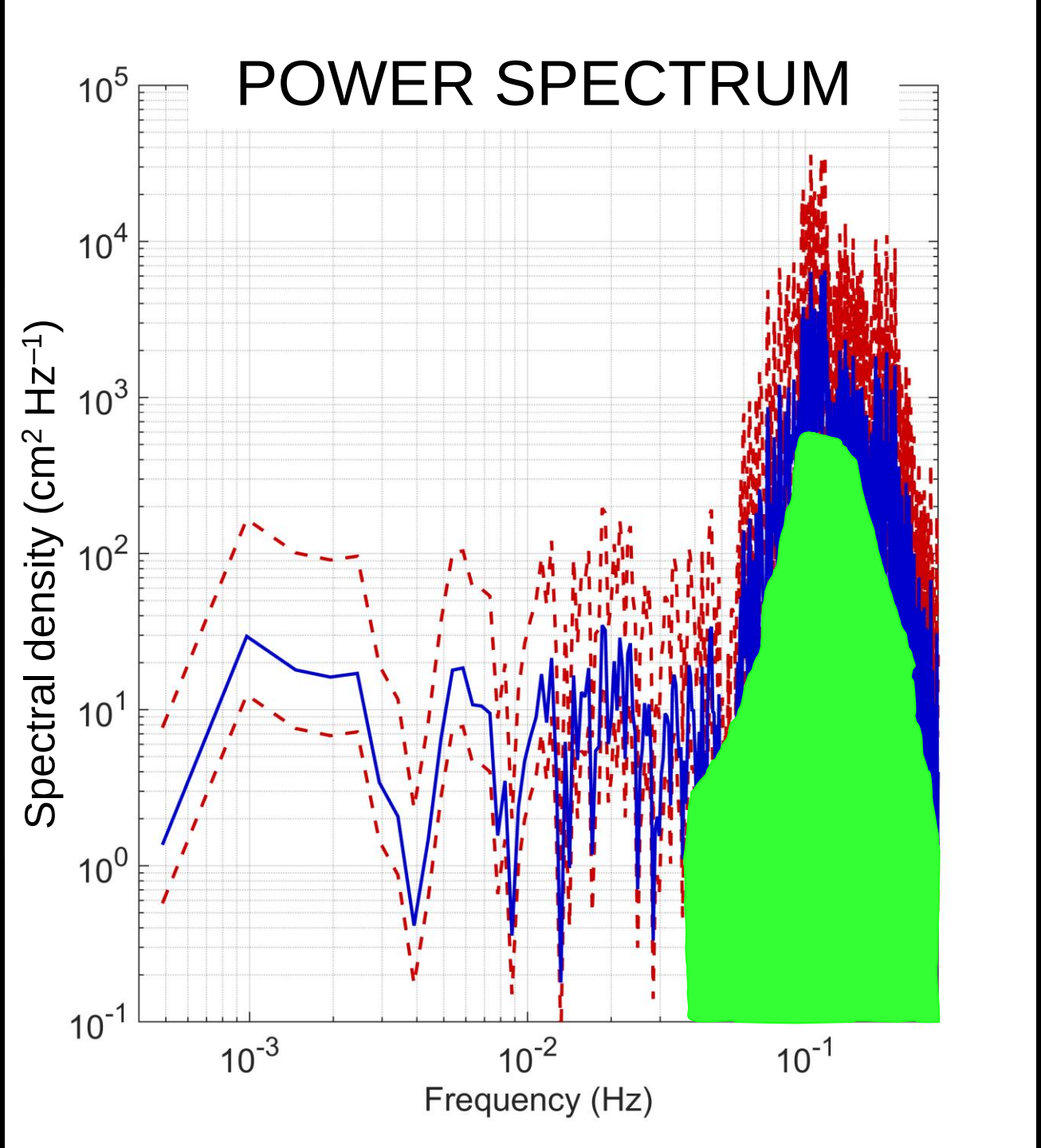
FREQUENCY PLANE
(Power spectrum)



$$E\left(f_k\right) = \mathrm{E}\left[\hat{x}_k \hat{x}_k^*\right]$$

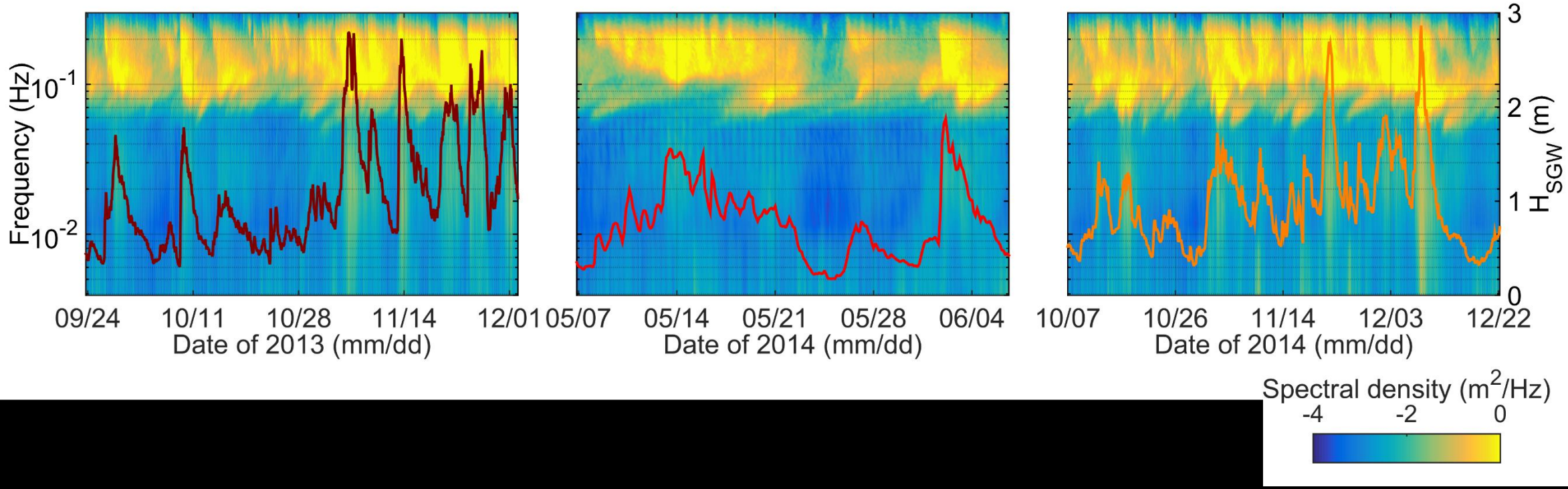



Cape Canaveral shoals -- Shoal E inner swale, Spring 2015
dof 28
95% stat. conf.
2'097,152 elements per block
5'572,800 data total
Spectral density (cm2 cpd-1)
10^0
10^-5
10^-1
10^0
10^1
10^2
10^3
10^4
Frequency (cpd)



VARIANCE
Sea-swell

SPECTROGRAPHS



$$W_n(s) = \sum_{k=0}^{N-1} \hat{x}_k \hat{\psi}^*(s\omega_k)\, e^{i\omega_k n \Delta t}$$

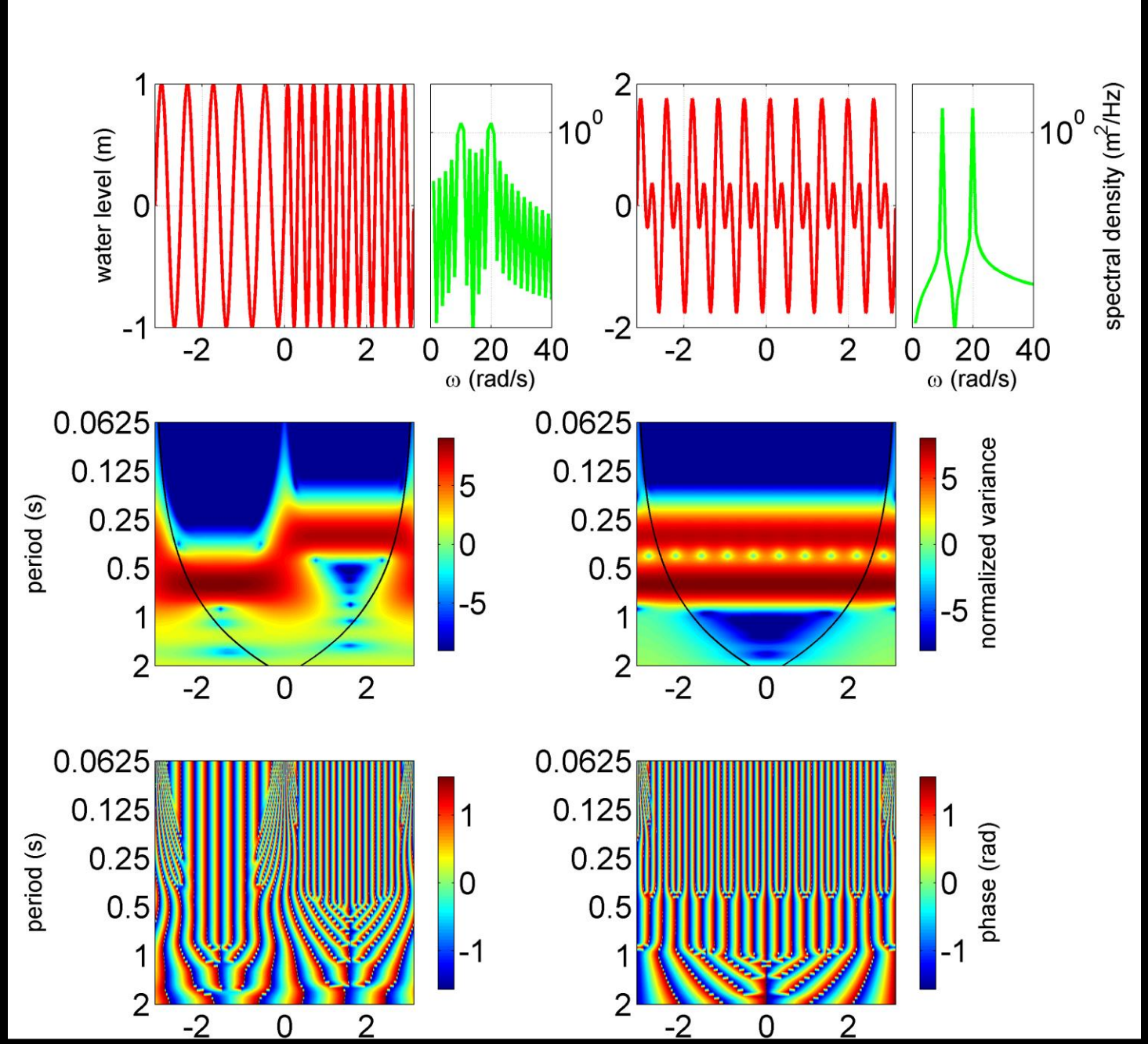
SCALE (FREQUENCY)

FREQUENCY

[6]

$$f_1 = \sin(10t)$$

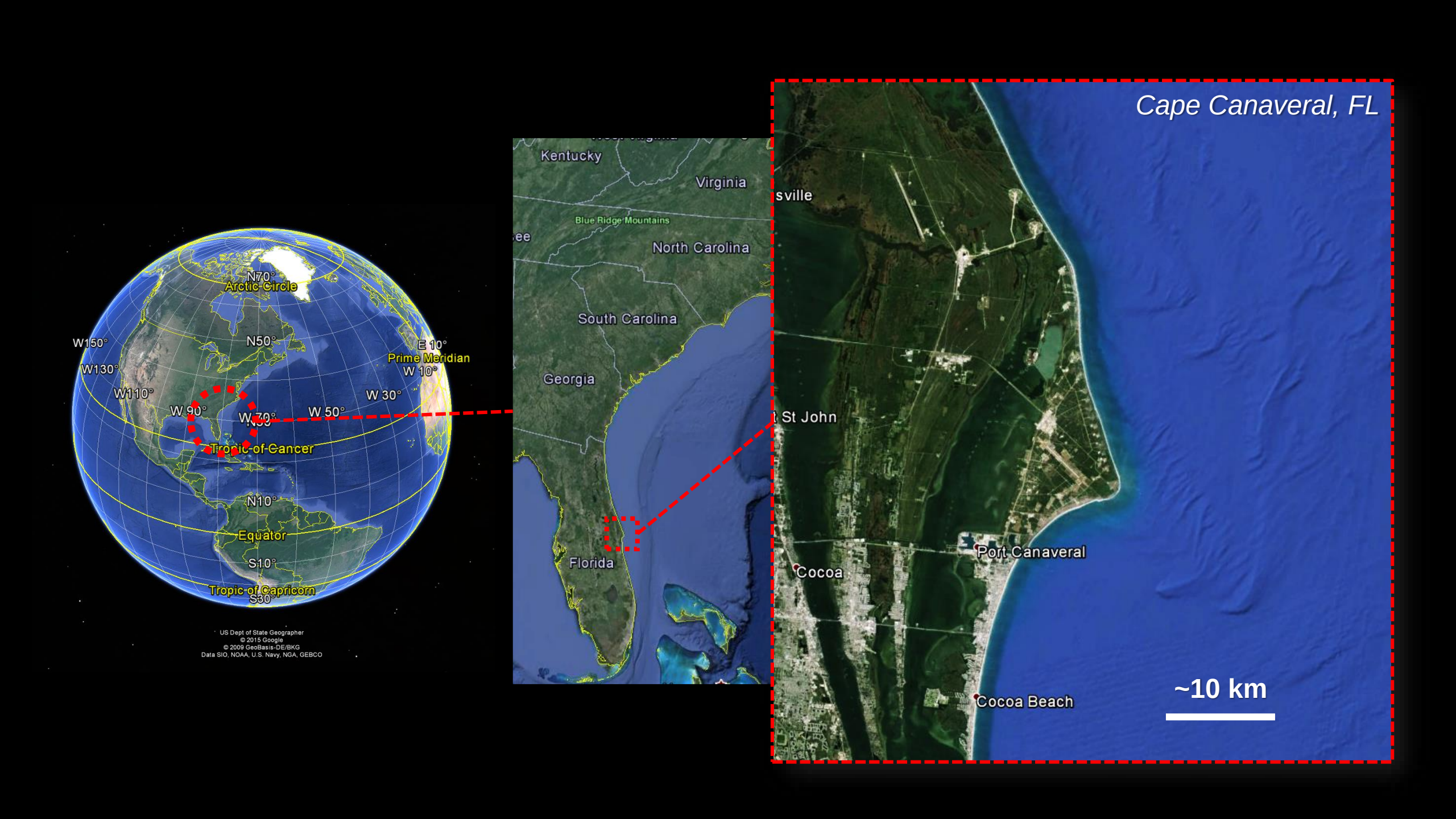
$$f_2 = \sin(20t)$$



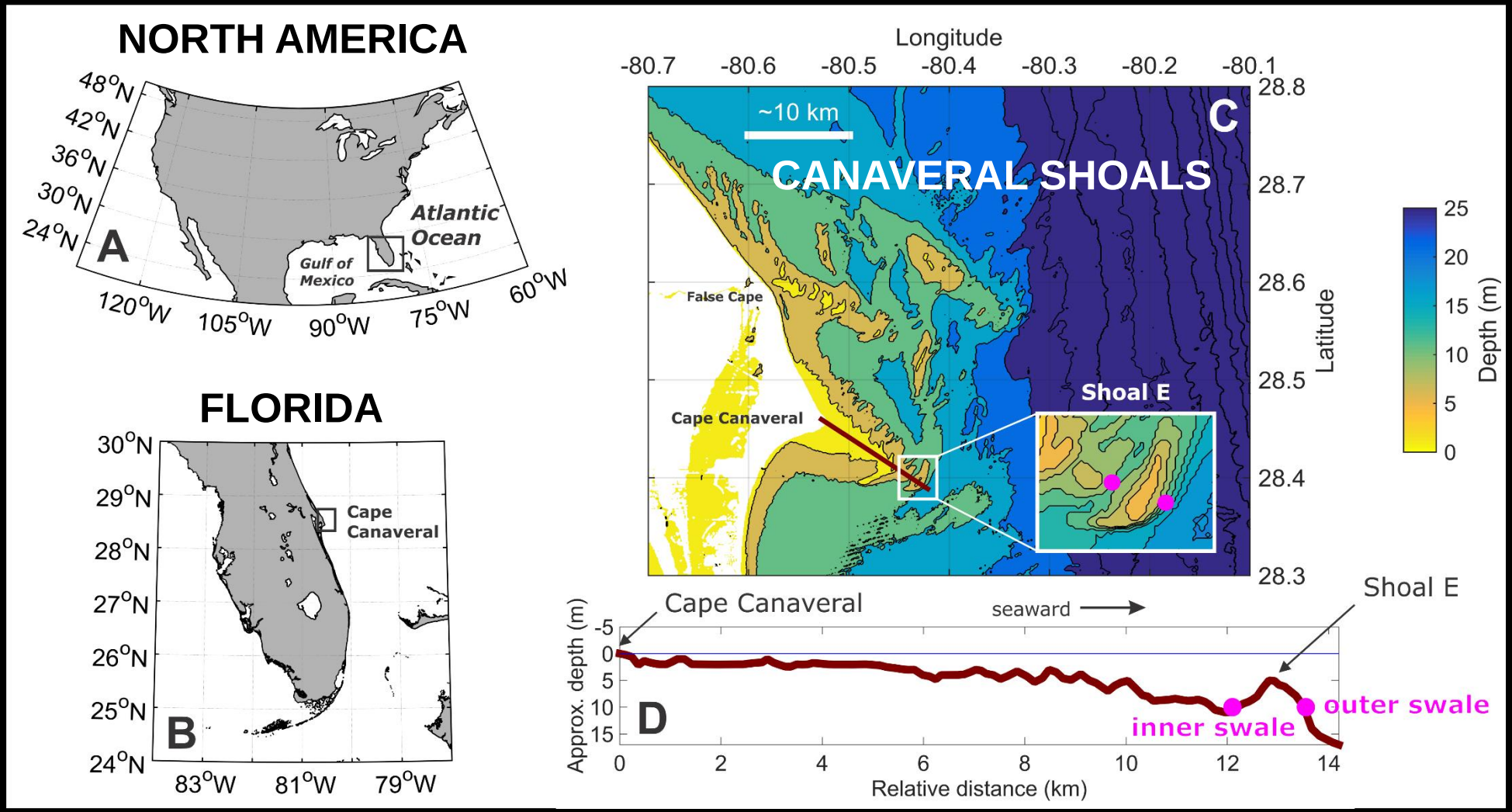
$$f_3 = \sin(10t) + \sin(20t)$$

5

Application to wave transformation over Cape Canaveral shoals

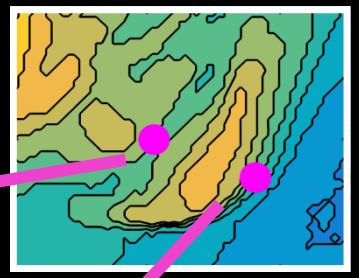

Cape Canaveral, FL
W150°
W130°
W110°
W 90°
W 70°
W 50°
W 30°
W 10°
E 10°
Prime Meridian
N70°
Arctic Circle
N50°
Tropic of Cancer
N10°
Equator
S10°
Tropic of Capricorn
S30°
US Dept of State Geographer
© 2015 Google
© 2009 GeoBasis-DE/BKG
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Kentucky
Virginia
Blue Ridge Mountains
North Carolina
South Carolina
Georgia
Florida
sville
St John
Port Canaveral
Cocoa
Cocoa Beach
~10 km

http://www.gserentals.co.uk/details.aspx?product=192



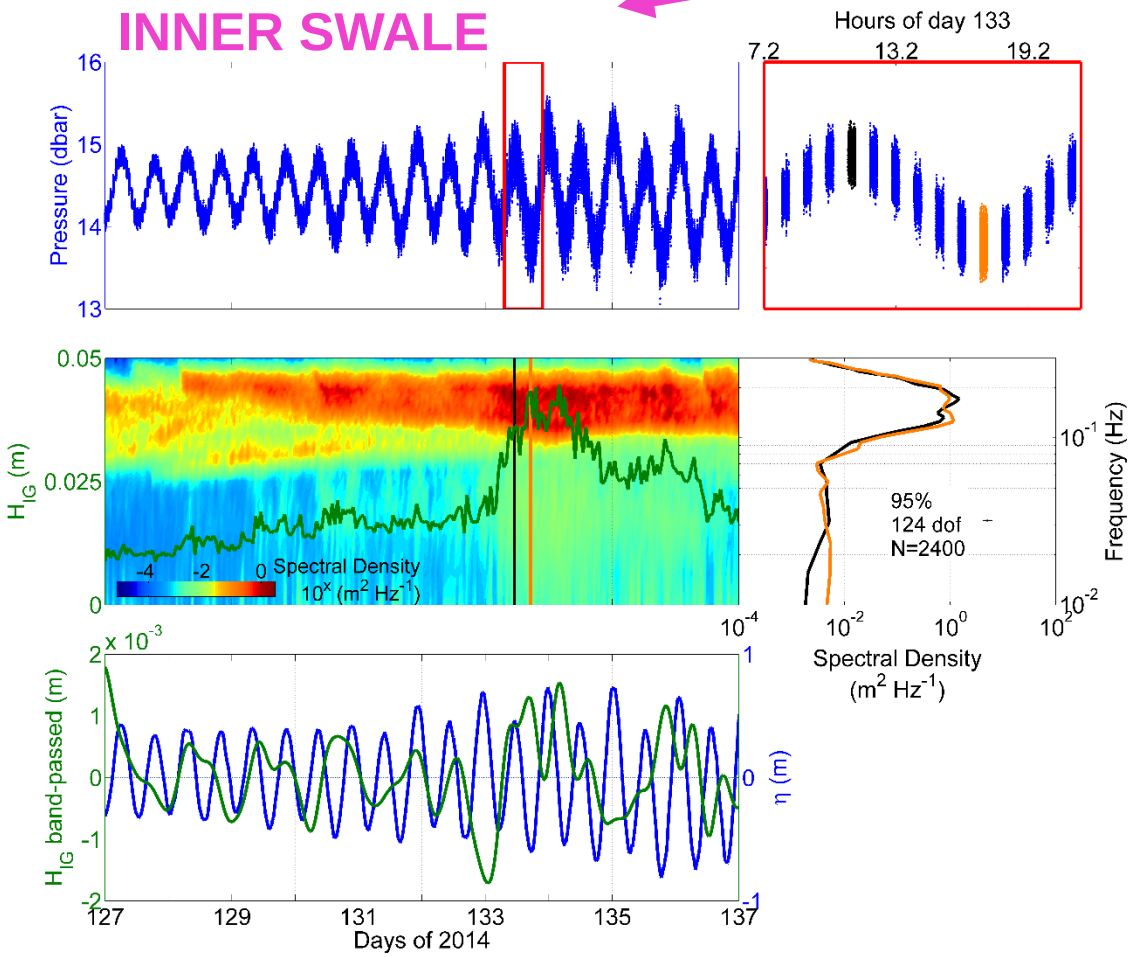
ADCP
Acoustic Doppler Current Profiler with **Pressure sensor**

13 ADCP campaigns between **Fall 2013 and Fall 2016**

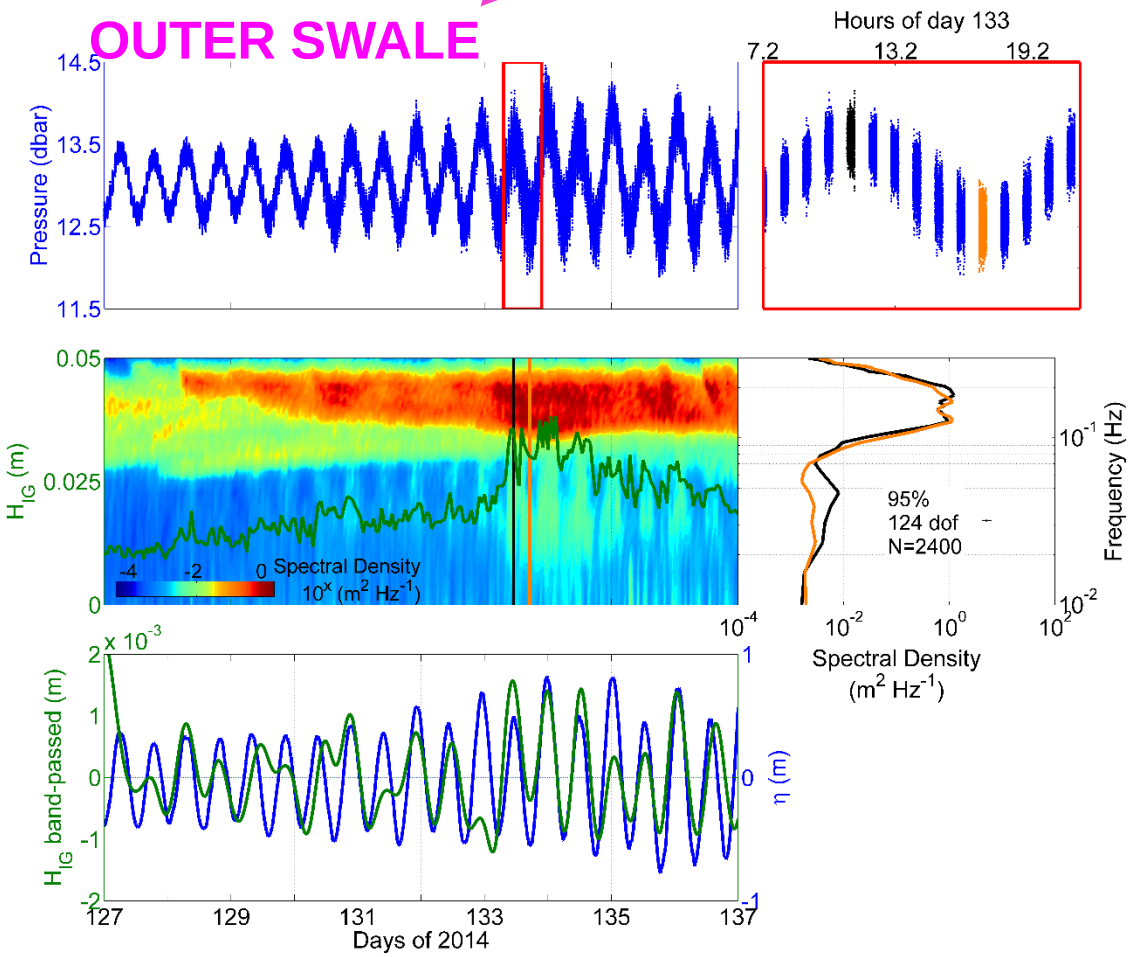


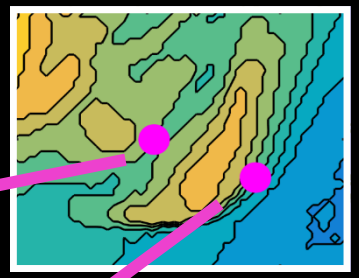
Shoal E

INNER SWALE



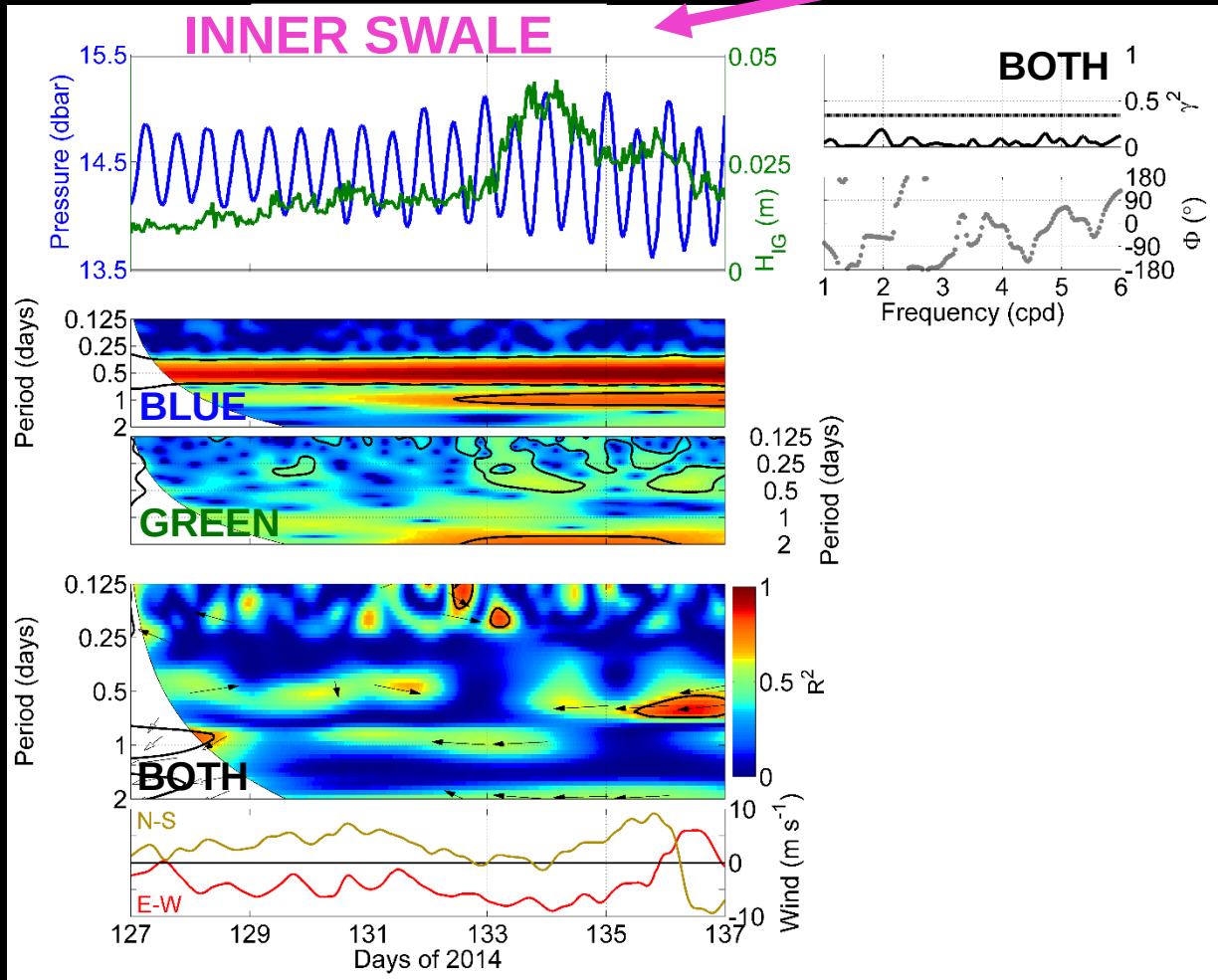
OUTER SWALE



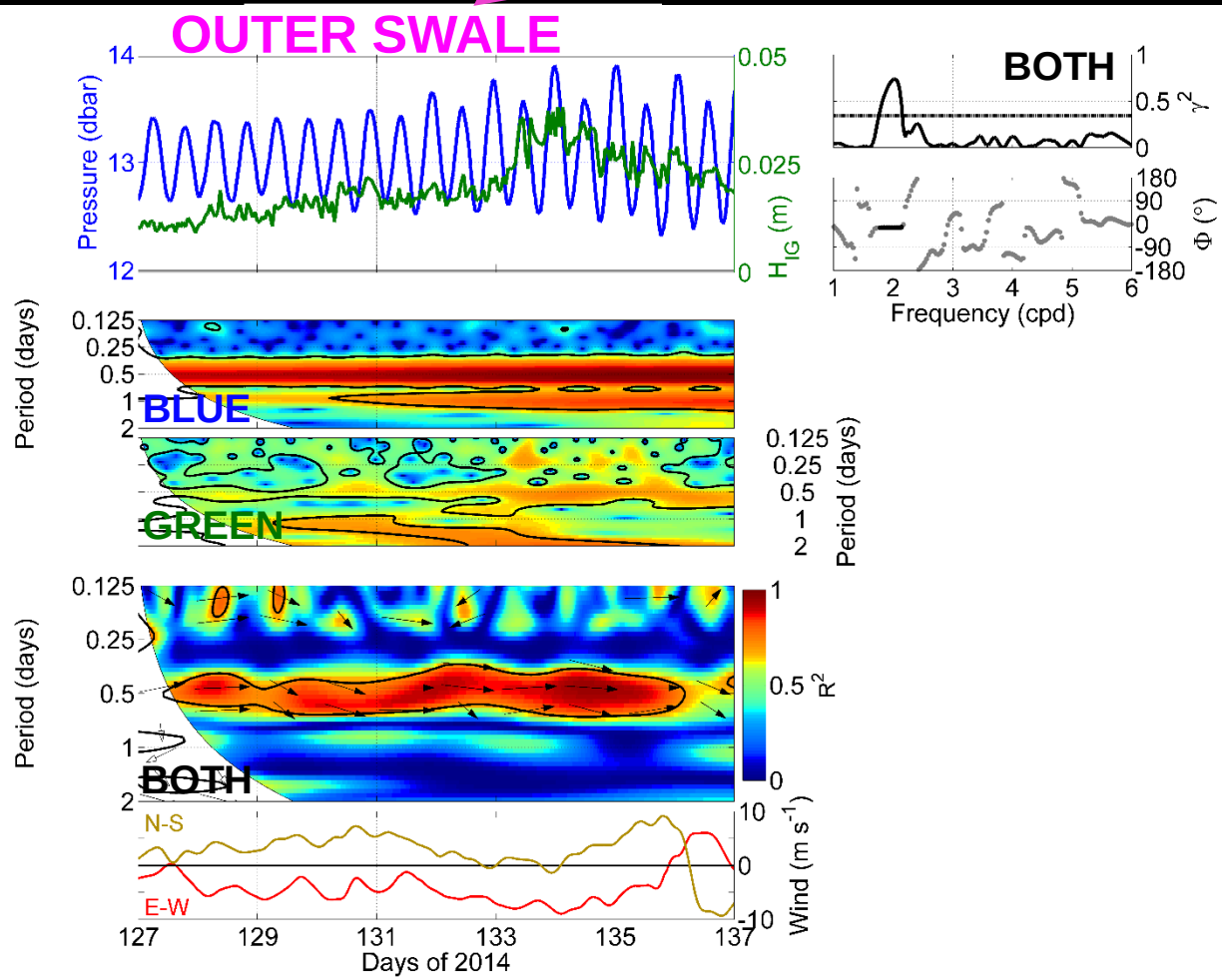


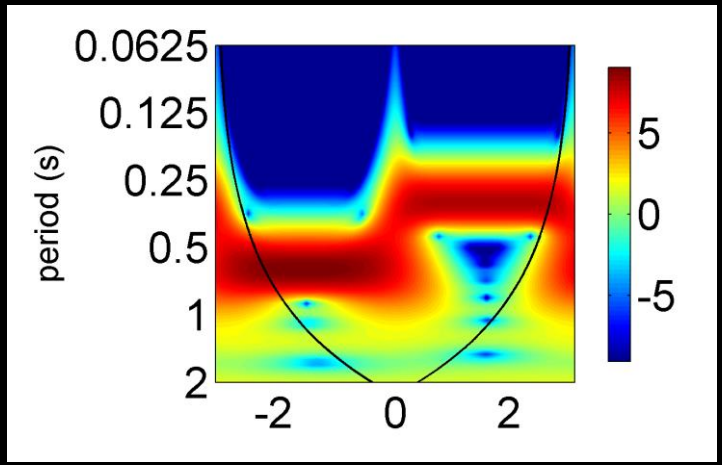
Shoal E

INNER SWALE



OUTER SWALE



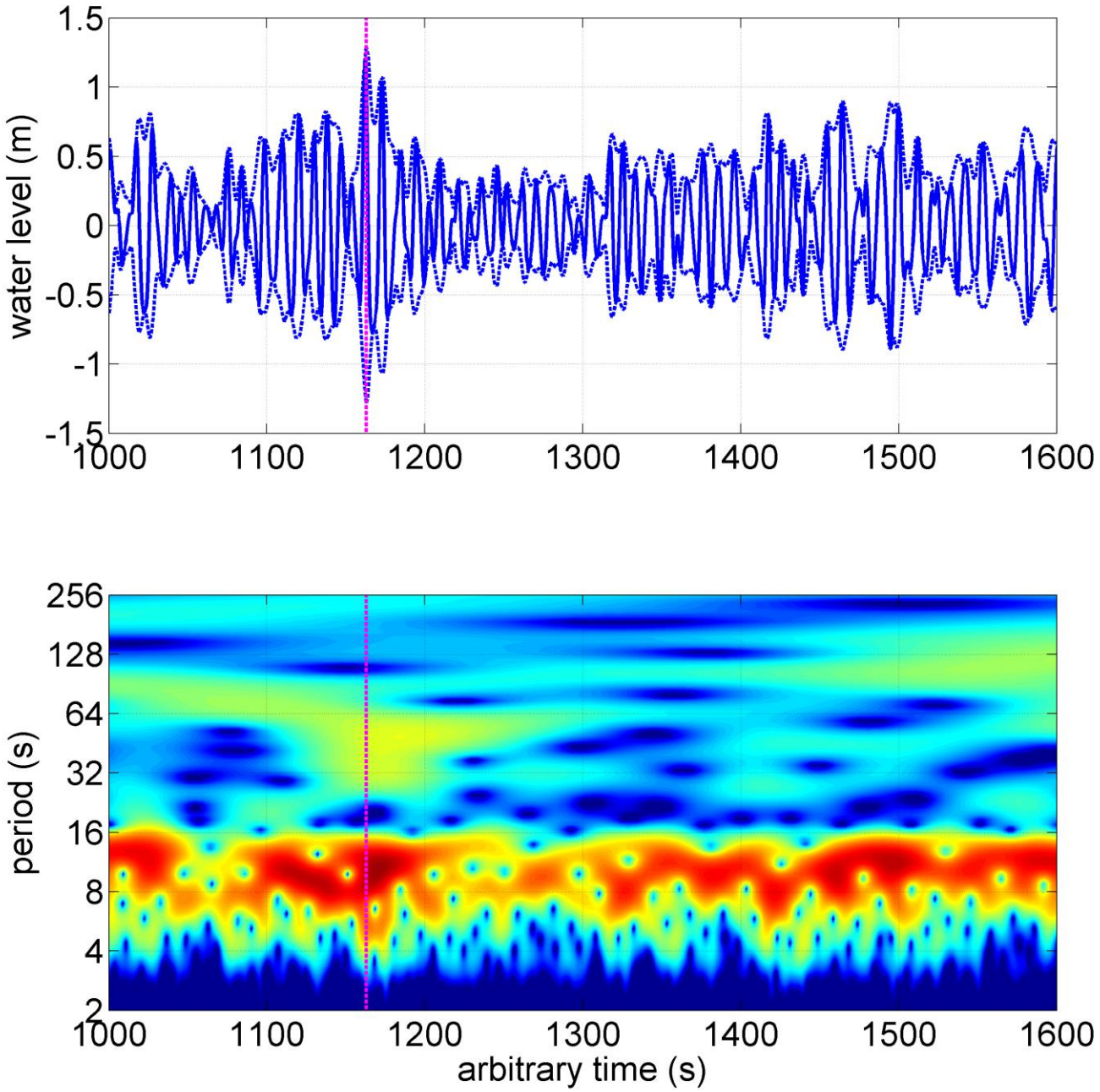


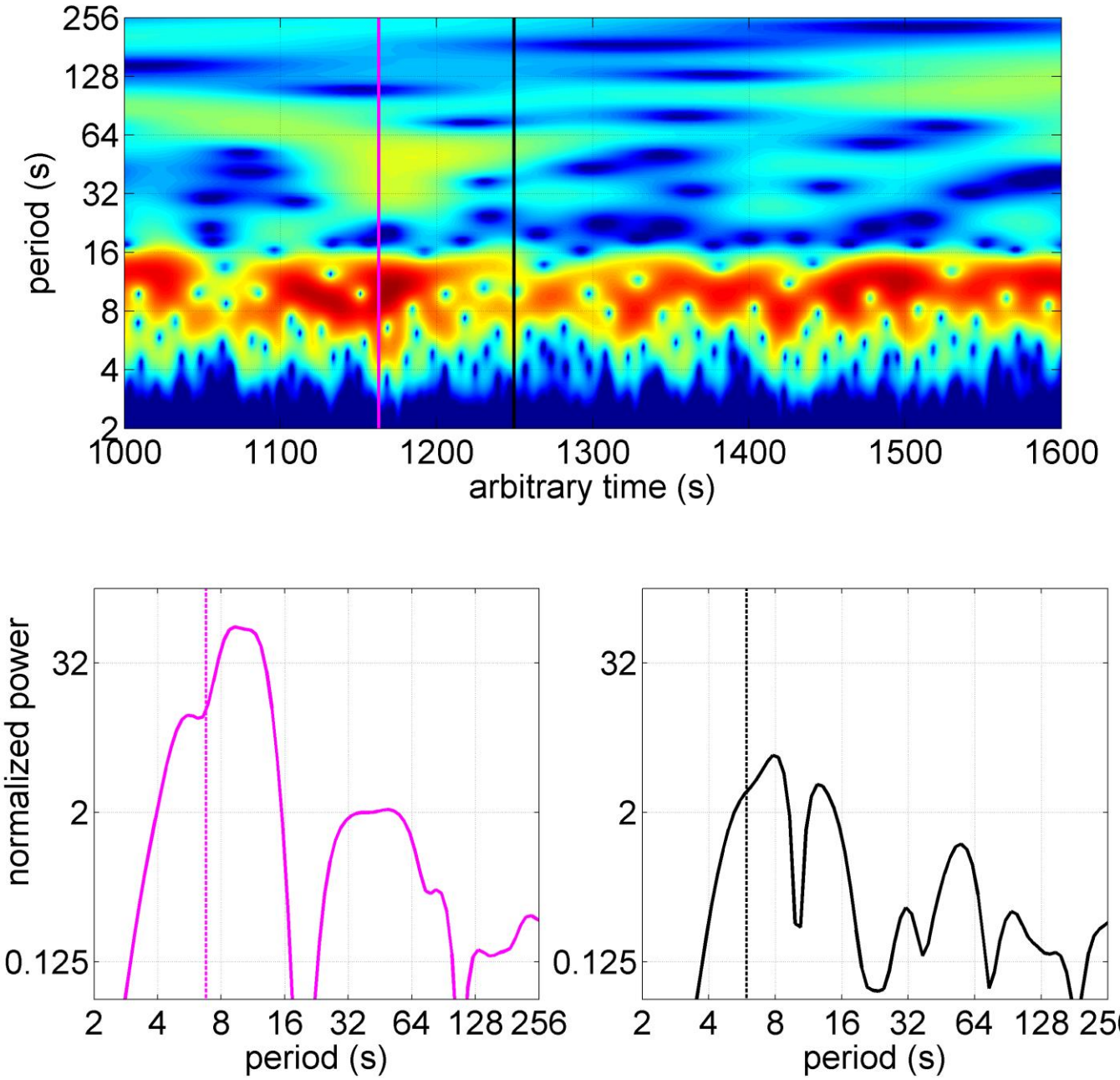
DYNAMIC

$$a\omega^2 > \gamma g$$

γ = 0.103

[7, 8]


1.5
1
0.5
0
-0.5
-1
-1.5
water level (m)
1000
1100
1200
1300
1400
1500
1600
256
128
64
32
16
8
4
2
period (s)
1000
1100
1200
1300
1400
1500
1600
arbitrary time (s)


256
128
64
32
16
8
4
2
period (s)
1000
1100
1200
1300
1400
1500
1600
arbitrary time (s)
normalized power
32
2
0.125
2
4
8
16
32
64
128
256
period (s)
32
2
0.125
2
4
8
16
32
64
128
256
period (s)

6

Appendix: Stokes solution to KdV

$$\eta_t + c_0 \left(1 + \frac{3}{2}\frac{\eta}{h_0}\right)\eta_x + \gamma\eta_{xxx} = 0$$

$$\frac{\eta}{h_0} = \zeta = \epsilon\zeta_1(\theta) + \epsilon^2\zeta_2(\theta) + \epsilon^3\zeta_3(\theta) + O\left(\epsilon^4\right)$$

$$\epsilon = a/h_0$$

$$\theta = \kappa x - \omega t$$

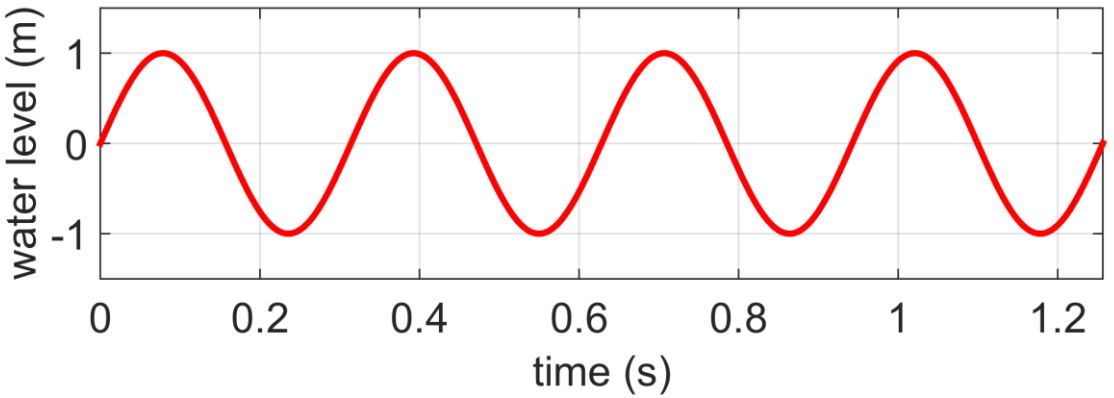
[9]

$$\omega = \omega_0 + \epsilon\omega_1 + \epsilon^2\omega_2 + O(\epsilon^3)$$

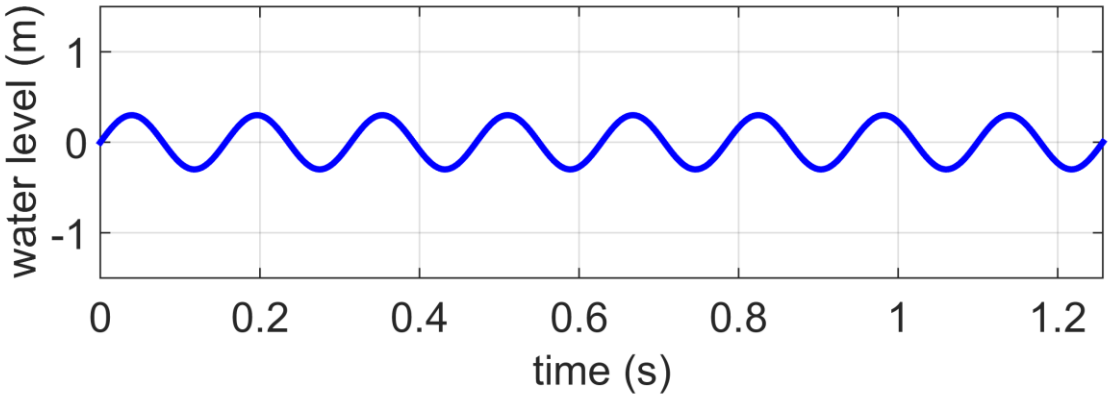
$$\zeta_1 = \cos\theta$$

$$\zeta_2 = \frac{c_0}{8\gamma\kappa^2}\cos(2\theta)$$

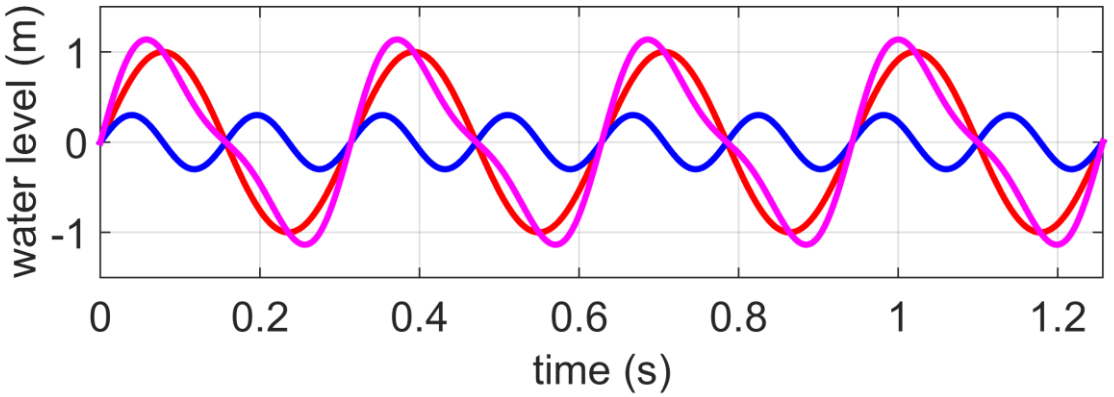
$$\zeta_3 = \frac{3c_0^2}{256\gamma^2\kappa^4}\cos(3\theta)$$



$$\eta_1 = \sin(20t)$$



$$\eta_2 = 0.3\sin(40t)$$



$$\eta_3 = \eta_1 + \eta_2$$

[1] Davidson-Arnott, R. (2010), *Introduction to Coastal Processes and Geomorphology*, Cambridge University Press.

[2] Mei, C. C., M. Stiassnie, and D. K.-P. Yue (2005), Theory and Applications of Ocean Surface Waves. Part 1: Linear Aspects. *Advanced Series in Ocean Engineering*, vol. 23, World Scientific.

[3] Kumar, P., and E. Foufoula-Georgiou (1997), Wavelet analysis for geophysical applications. *Reviews of Geophysics*, 35(4), pp. 385-412.

[4] Elgar, S., and R. T. Guza (1985), Observations of bispectra of shoaling surface gravity waves, *Journal of Fluid Mechanics*, 161, 425–448.

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[6] Torrence, C. and G. P. Compo (1998), A practical guide to wavelet analysis. *Bulletin of the American Meteorological Society*, 79(1), pp. 61-78.

[7] Liu, P. C., and A. V. Babanin (2004), Using wavelet spectrum analysis to resolve breaking events in the wind wave time series. *Annales Geophysicae*, 22: 3335-3345.

[8] Holthuijsen, L. H., and T. H. C. Herbers (1986), Statistics of Breaking Waves Observed as Whitecaps in the Open Sea. *Journal of Physical Oceanography*, Vol. 16, pp. 290-297.

[9] Whitham, G. B. (1999), *Linear and Nonlinear Waves*, Pure and Applied Mathematics, John Wiley & Sons, Inc.