

Nonlinear wave group shoaling

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Collaborative work with

- Olivier Kimmoun, *Aix Marseille University*
- Hungchu Hsu, *Tainan Hydraulics Laboratory*
- Stefano Trillo, *University of Ferrara*

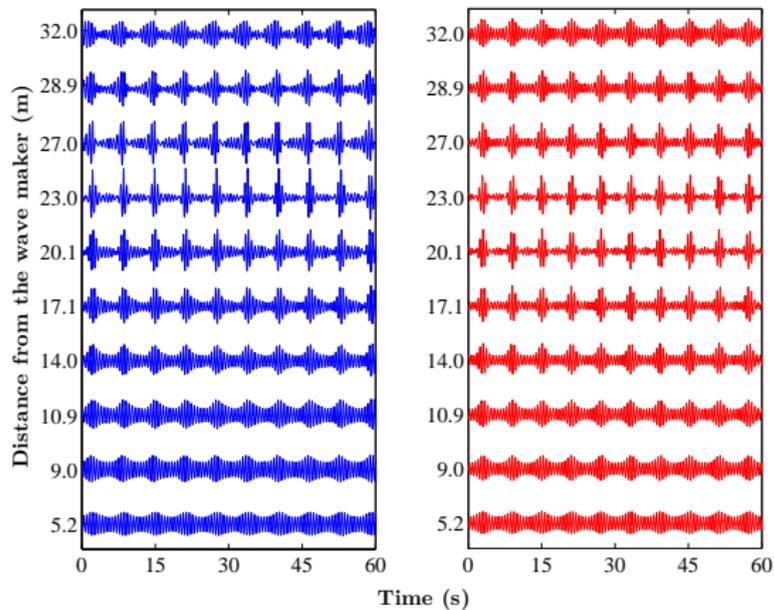






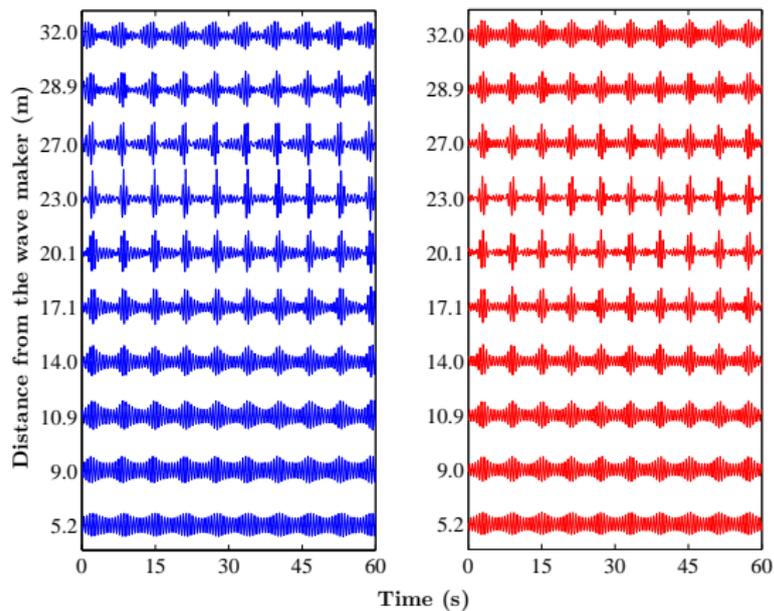
J. M. Dudley, G. Genty, A. Mussot, A. Chabchoub and F. Dias, Rogue waves and analogies in optics and oceanography, *Nat. Rev. Phys.* **1**, 675-689 (2019)

Modulation instability



Modulation instability

$$a = 1 \text{ cm}$$
$$ak = 0.10$$



Modulation instability

$$i \left(\frac{\partial A}{\partial x} + \frac{1}{C_g} \frac{\partial A}{\partial t} \right) = +\lambda \frac{\partial^2 A}{\partial t^2} + \nu |A|^2 A$$

$$\lambda = \frac{1}{2C_g \omega_0} \left[1 - \frac{gh}{C_g^2} (1 - kh\sigma) (1 - \sigma^2) \right]$$

$$\nu = \frac{\omega_0 k^2}{16C_g \sigma^2} \times$$

$$\left[9 - 10\sigma^2 + 9\sigma^4 - \frac{2C_g^2 \sigma^2}{gh - C_g^2} \left(4 \frac{C_p^2}{C_g^2} + 4 \frac{C_p}{C_g} (1 - \sigma^2) + 4 \frac{gh}{C_g^2} (1 - \sigma^2) \right) \right]$$

H. Hasimoto and H. Ono, *J. Phys. Soc. Jpn.* **33** (1972)

Laboratory observations of wave group evolution, including breaking effects

By MARSHALL P. TULIN AND TAKUJI WASEDA†

Ocean Engineering Laboratory, University of California Santa Barbara, CA93106

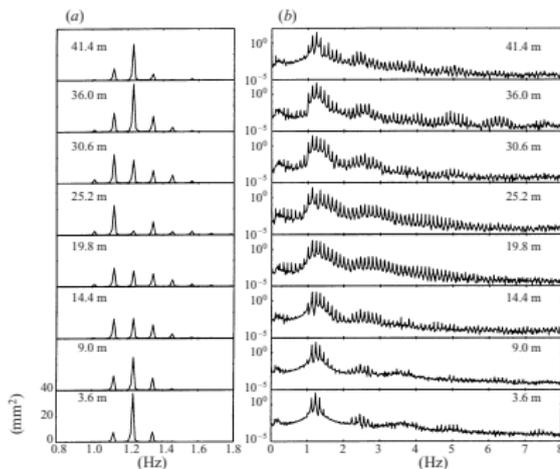
(Received 17 October 1997 and in revised form 11 August 1998)

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Feature Article:

DOI. No. 10.1109/MAES.2017.170062

OTH Radar Phenomenology: Signal Interpretation and Target Characterization at HF

Stuart Anderson, University of Adelaide, Adelaide, Australia

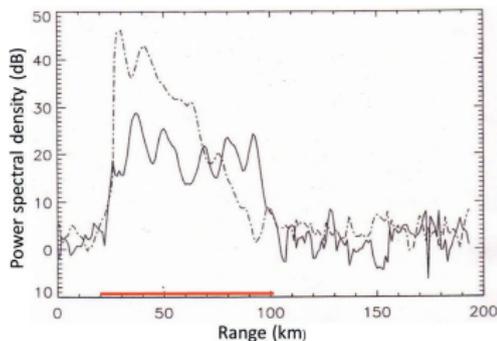
Modulation instability

Feature Article:

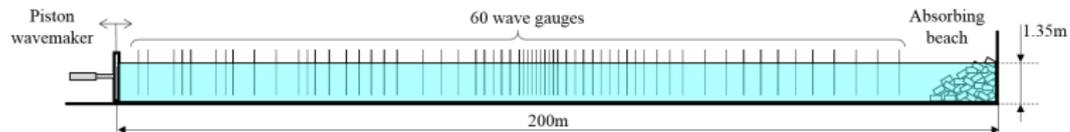
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OTH Radar Phenomenology: Signal Interpretation and Target Characterization at HF

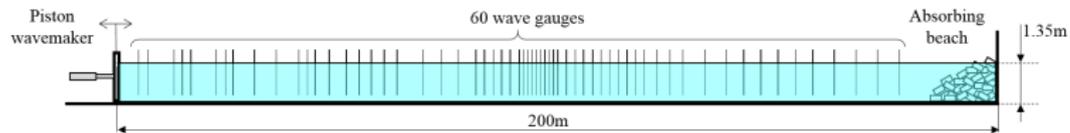
Stuart Anderson, University of Adelaide, Adelaide, Australia



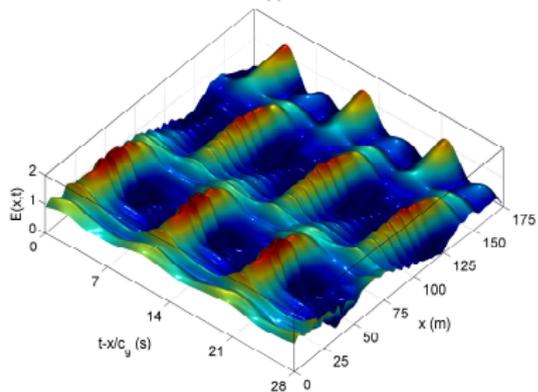
Modulation instability



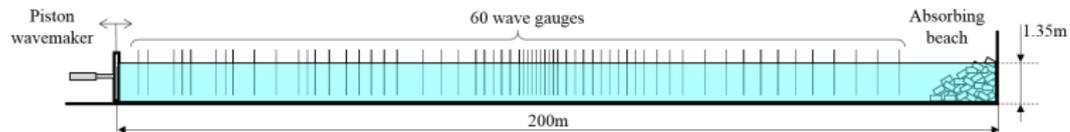
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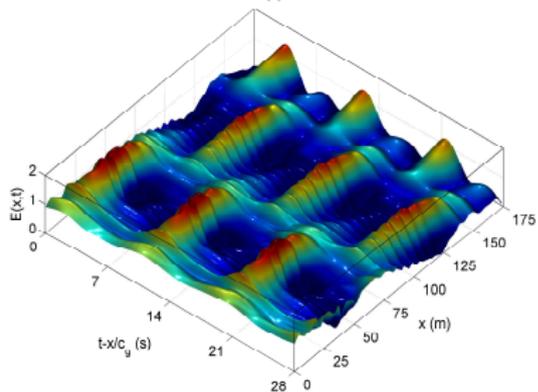
(a)



Modulation instability

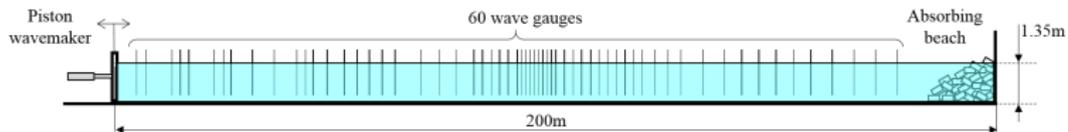


(a)

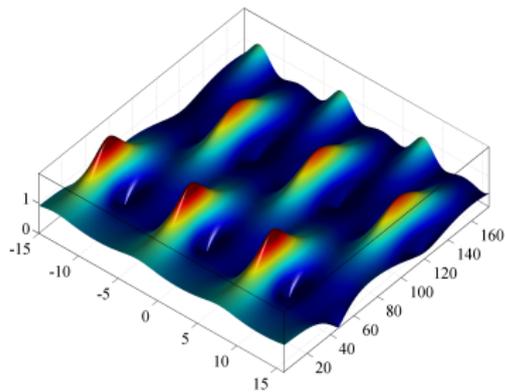
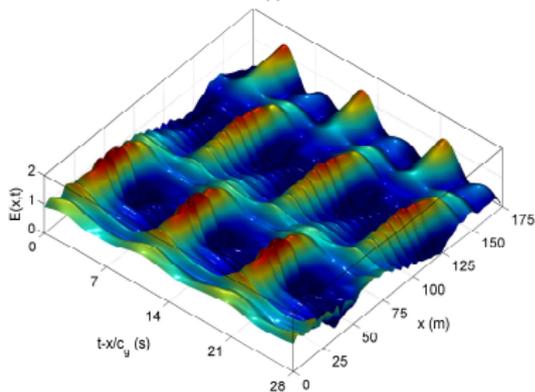


$$iq_x + q_{tt} + 2|q|^2q = iDq$$

Modulation instability

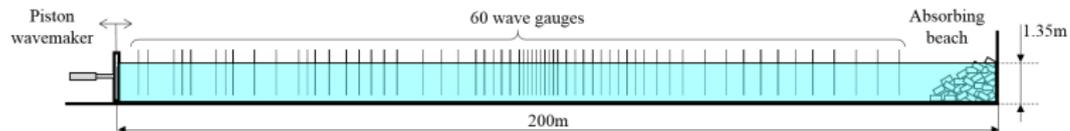


(a)

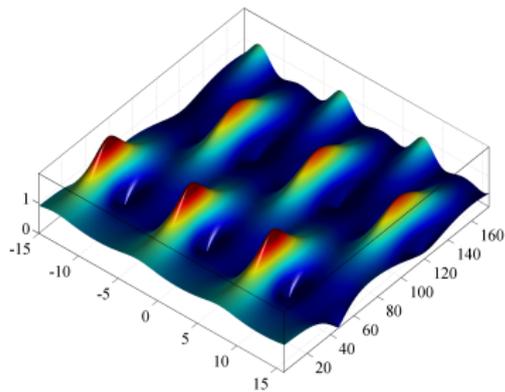
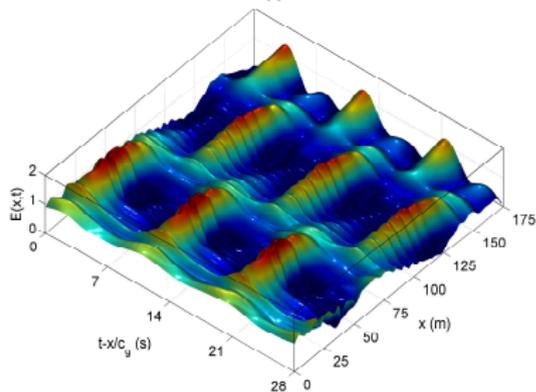


$$iq_x + q_{tt} + 2|q|^2q = iDq$$

Modulation instability



(a)



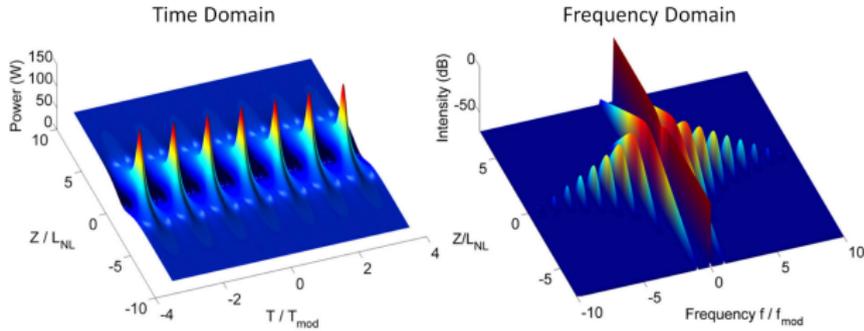
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OPEN **Modulation Instability and Phase-Shifted Fermi-Pasta-Ulam Recurrence**

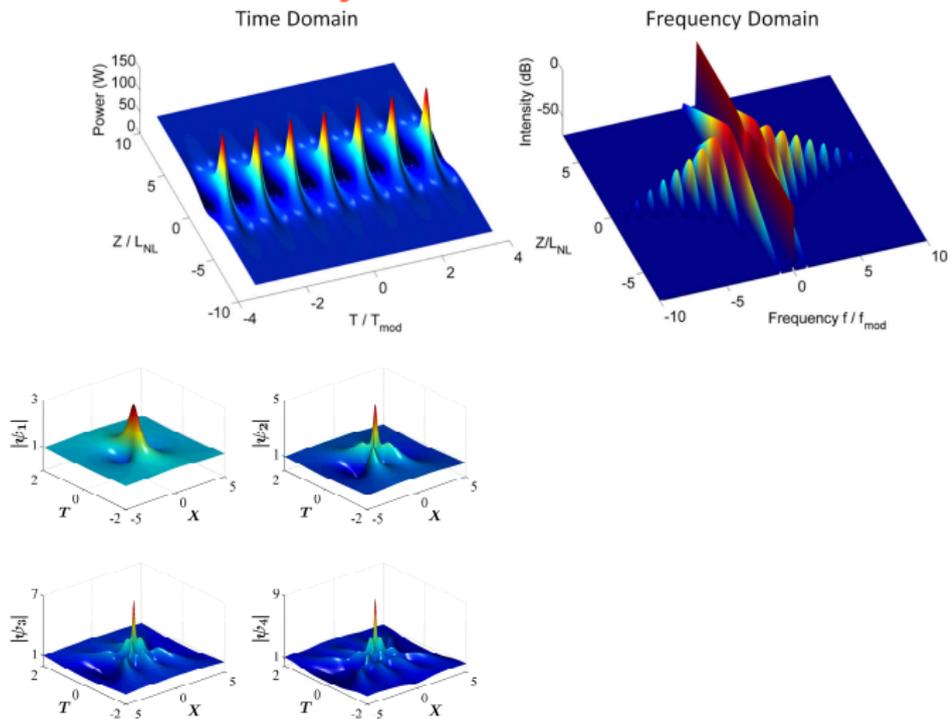
Received: 13 March 2018
Accepted: 20 May 2018
O. Kimmoun¹, H. C. Hsu², H. Branger², M. S. Uj¹, Y. Y. Chen¹, C. Kharif¹, M. Onorato¹, E. J. R. Keebler³, B. Kibler³, N. Akhmediev⁴ & A. Chabchoub^{1,4}

$$iq_x + q_{tt} + 2|q|^2q = iDq$$

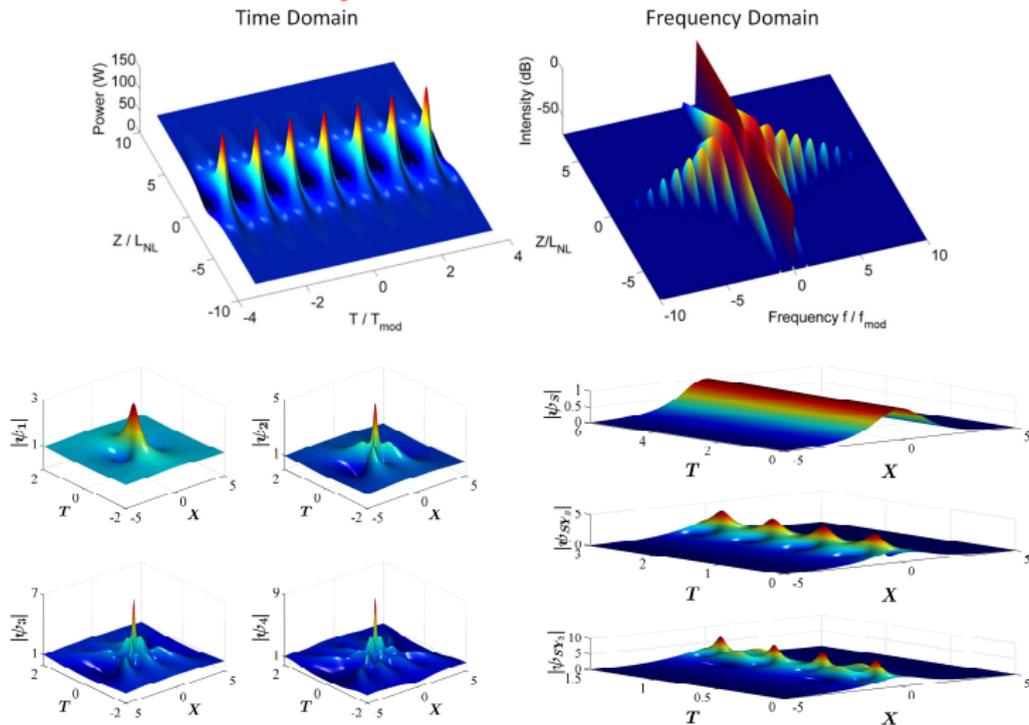
Modulation instability



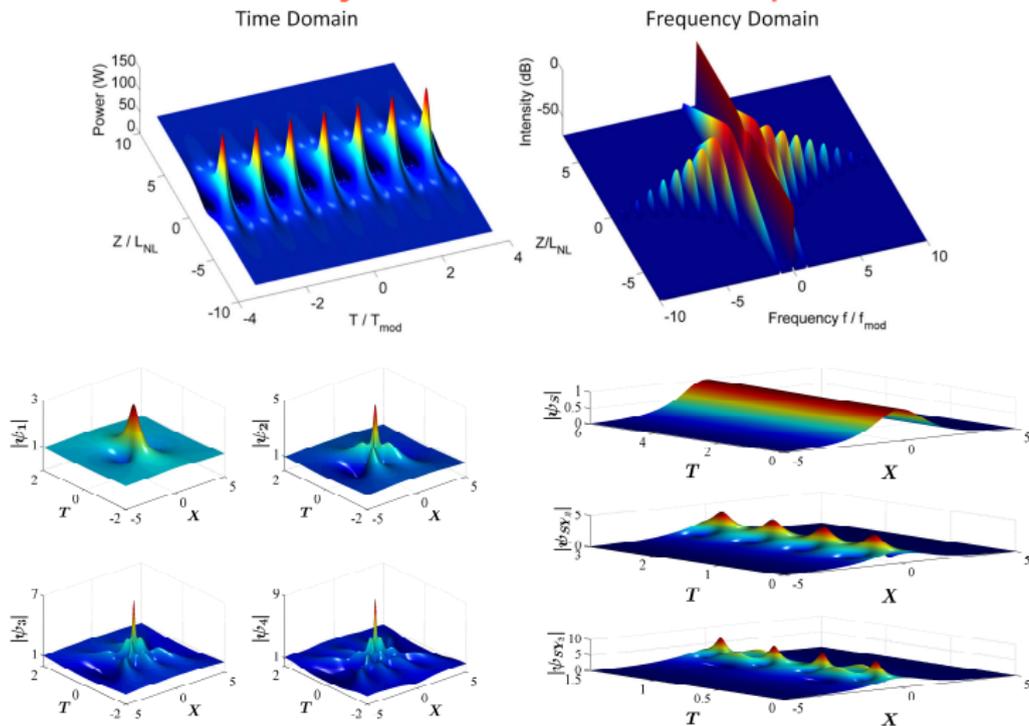
Modulation instability



Modulation instability



Modulation instability - Nonlinear wave packet interaction



Modulation instability - Nonlinear wave packet interaction

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Experiments on Spontaneous Modulation Instability in Hydrodynamics

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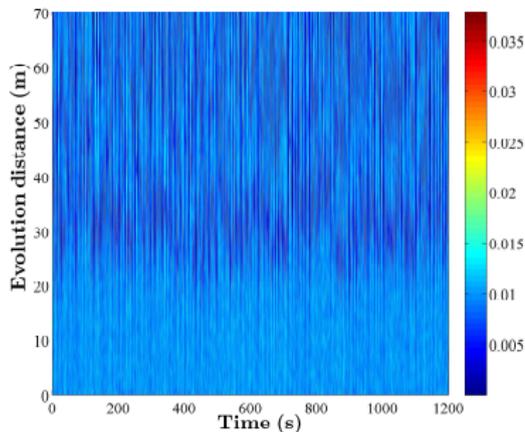
²Graduate School of Frontier Sciences, The University of Tokyo, Chiba, Japan

³School of Civil Engineering, The University of Sydney, Sydney, NSW, Australia

⁴Department of Physics, Tampere University of Technology, Tampere, Finland

⁵Institut FEMTO-ST, UMR 6174 CNRS-Universit  de Franche-Comit e, Besan on, France

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Modulation instability - Nonlinear wave packet interaction

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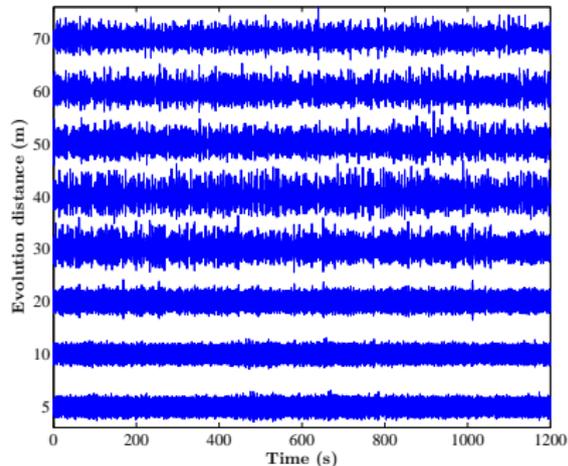
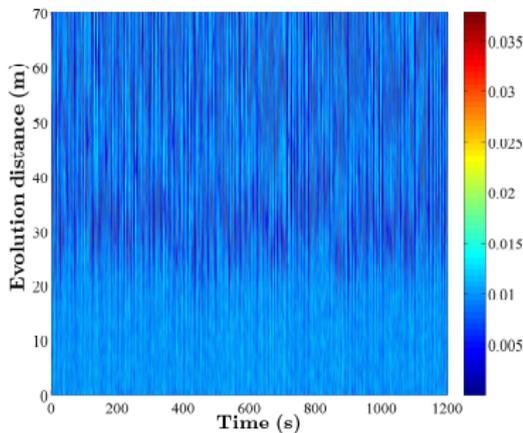
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Modulation instability - Nonlinear wave packet interaction

BREAKING OF OCEAN WAVES AND DOWNSHIFTING

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Modulation instability - Nonlinear wave packet interaction

BREAKING OF OCEAN WAVES AND DOWNSHIFTING

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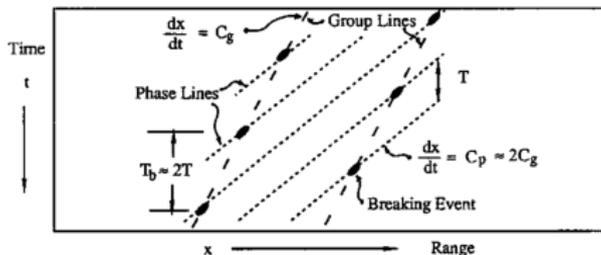
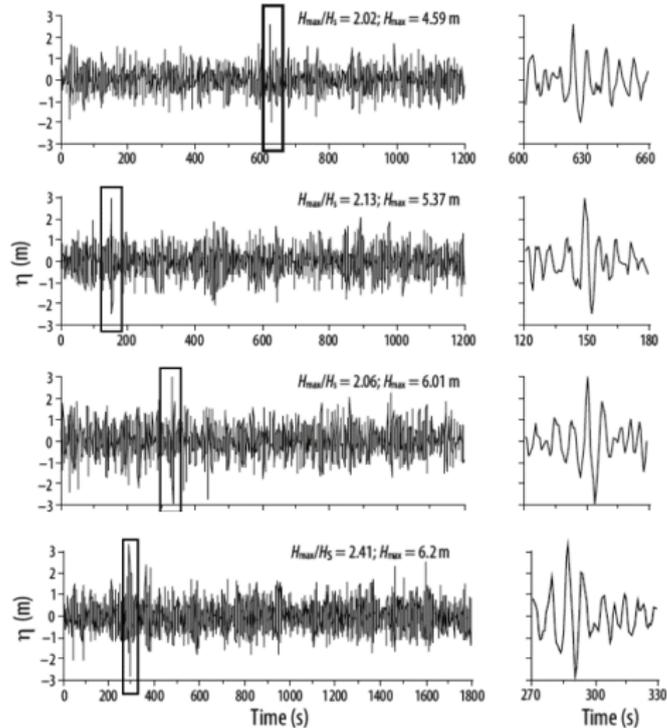
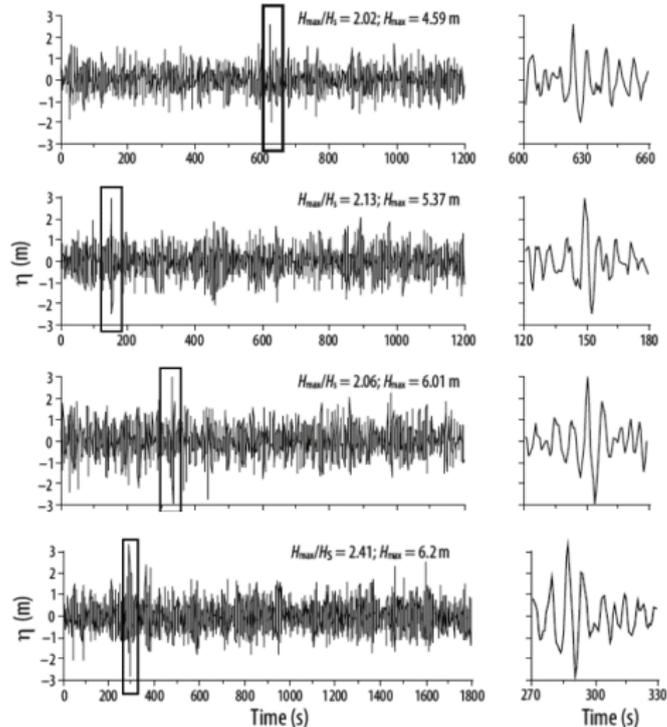


Figure 1: Wave groups delineated by breaking events.
Schematic of low grazing radar observations.

Nonlinear wave group shoaling



Nonlinear wave group shoaling

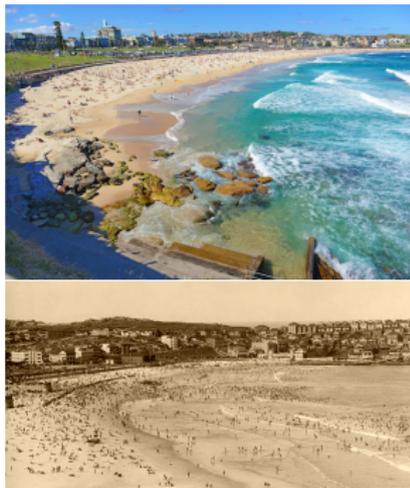


W. Sulisz et al., Cienc. mar. 42 (2016)

Nonlinear wave group shoaling



Nonlinear wave group shoaling



Nonlinear wave group shoaling



Nonlinear wave group shoaling

$$i \left(\frac{\partial A}{\partial x} + \frac{1}{C_g} \frac{\partial A}{\partial t} \right) = -i \mu \frac{d(kh)}{dx} A + \lambda \frac{\partial^2 A}{\partial t^2} + \nu |A|^2 A + i \frac{\sigma}{C_g} A$$

$$\mu = \frac{(1 - \sigma^2)(1 - kh\sigma)}{\sigma + kh(1 - \sigma^2)},$$

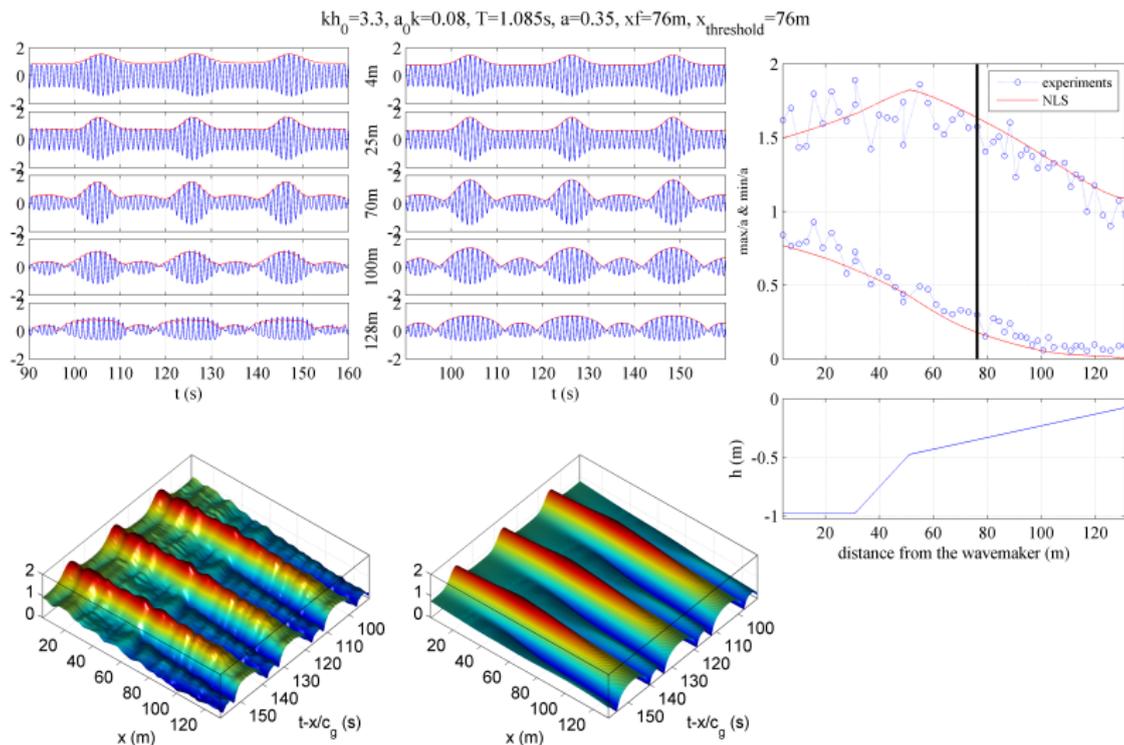
$$\lambda = \frac{1}{2C_g\omega_0} \left[1 - \frac{gh}{C_g^2} (1 - kh\sigma)(1 - \sigma^2) \right]$$

$$\nu = \frac{\omega_0 k^2}{16C_g \sigma^2} \times$$

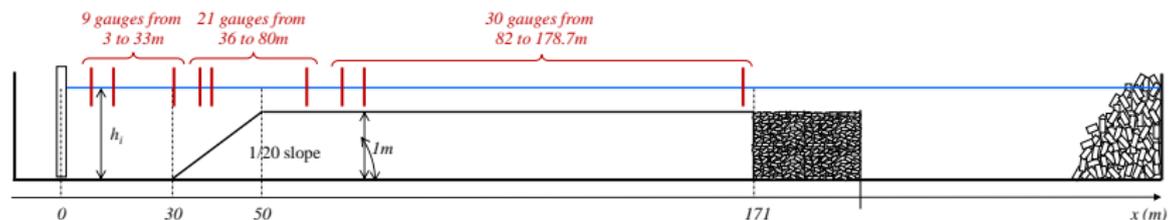
$$\left[9 - 10\sigma^2 + 9\sigma^4 - \frac{2C_g^2 \sigma^2}{gh - C_g^2} \left(4 \frac{C_p^2}{C_g^2} + 4 \frac{C_p}{C_g} (1 - \sigma^2) + 4 \frac{gh}{C_g^2} (1 - \sigma^2) \right) \right]$$

V. D. Djordjevic and L. G. Redekopp, *J. Phys. Oceanogr.* **8** (1978)

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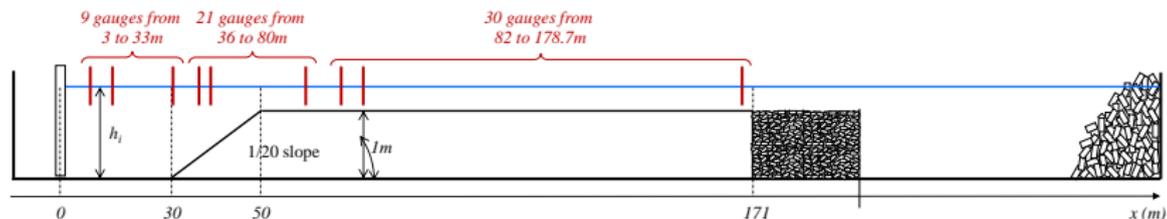


Nonlinear wave group shoaling



Nonlinear wave group shoaling

Unstable wave dynamics over variable bottom topography





Article

Statistics of Extreme Waves in Coastal Waters: Large Scale Experiments and Advanced Numerical Simulations

Jie Zhang ^{1,2}, Michel Benoit ^{1,2,*} , Olivier Kimmoun ^{1,2}, Amin Chabchoub ^{3,4} and Hung-Chu Hsu ⁵

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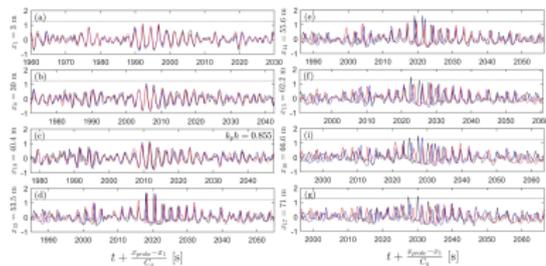
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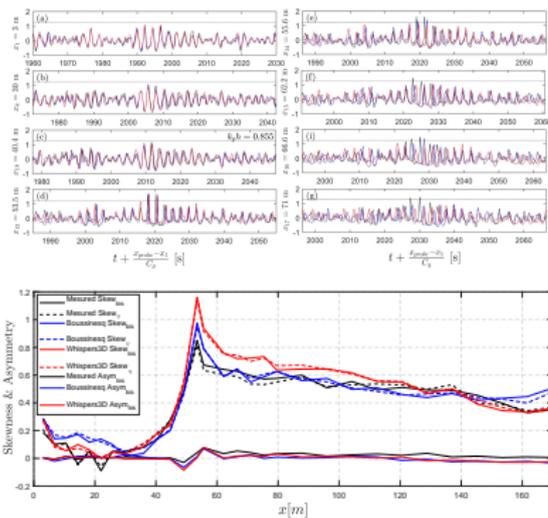
H. B. Bingham et al. *Coast. Eng.*, **56**, 467-478 (2009)

M. L. Yates et al., *Int. J. Numer. Methods Fluids*, **77**, 616-640 (2015)

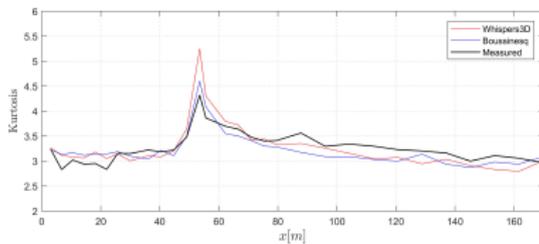
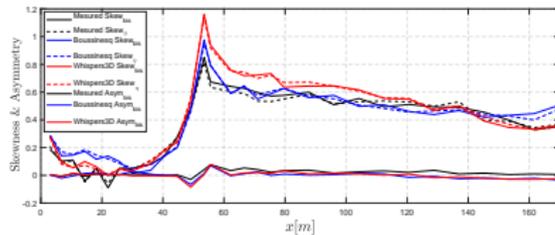
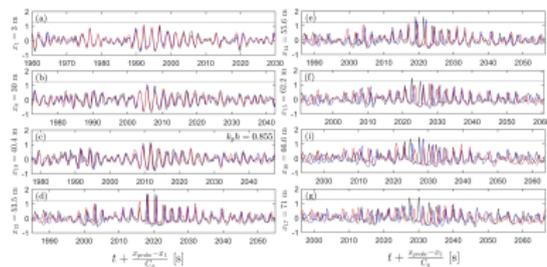
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Thank you! Questions?

