Longer waves modulation on short waves dissipation source term

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1. Introduction

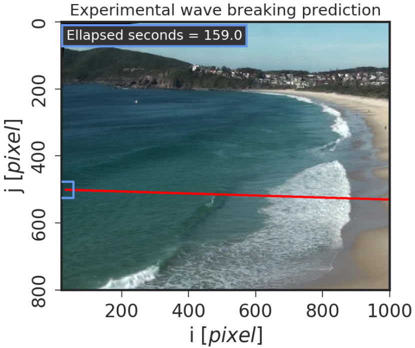
Why do waves break?

Breaking results from an instability that develops near the wave crest when the orbital velocity approaches the phase speed.

- *This criterion gives a maximum possible wave steepness that is:*

$$H_{max}/L \simeq 0.14 \tanh(kd)$$

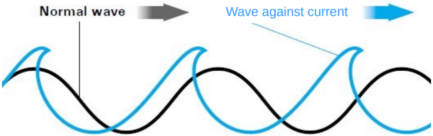
Miche (1944)



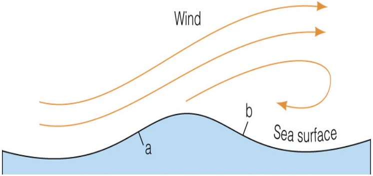
Stringari (2018), PyWaveLearn: Machine learn for wave science

1. Introduction

Wave breaking in deep water

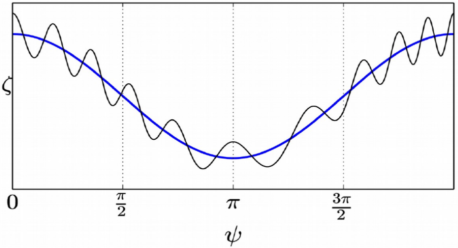


Wave-current interaction



Wind-wave interaction

Long wave modulation



1. Introduction

Wave-by-wave Vs. Statical approach

Banner et al. (2000)

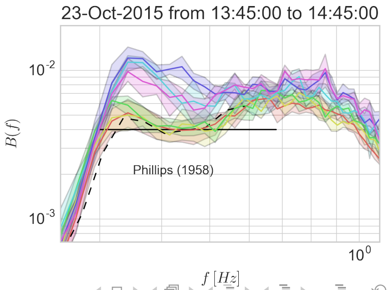
Dissipation is a quase-linear function of the saturation of the spectrum.

$$S_{dis}(\boldsymbol{k}) = \sigma \frac{C_{ds}}{B_r}\left[\delta_d \max\{B(\boldsymbol{k}) - B_r, 0\}^2\right] N(\boldsymbol{k})$$

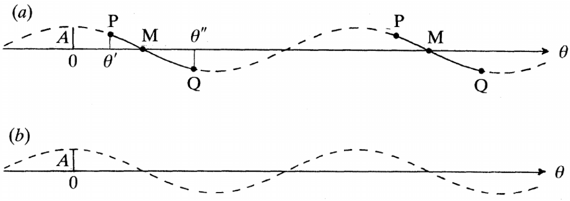
Phillips (1958,1985)

link between wave breaking and spectrum shape. Breaking probability is a function of 'saturation spectrum'

$$B(f) = \frac{(2\pi)^4}{g^2} f^5 E(f)$$



2. Background



Time-history of short waves on uniform train of long waves (Longuet-Higgins, 1991). The dash line indicate the interval where the short waves are breaking. (a) $\Omega < 1$, (b) $\Omega \geqslant 1$

$$\Omega = \frac{(\beta/\sigma)}{\gamma KA}$$

Keller and Wright (1975) introduced the idea of modulation transfer function (MTF), to define how much dominant waves can modulate SWs

$$M_Y = \frac{\widehat{Y}}{A_l k_l \overline{Y}}$$

2. BACKGROUND

Modulation of the wave action

$$N = \overline{N} + \delta N$$

$$\delta N = N' = \overline{N} \sum_{k_l} M_N(k_l) k_l A_l e^{i(\mathbf{k_l} \cdot \mathbf{x} - \omega_l t)}$$

Longuet-Higgins and Stewart (1960) and Phillips (1977)

$$N, k \longrightarrow \begin{cases} \partial_t N' + \partial_x \left[\left(\frac{c'}{2} + U_l \right) N' \right] = 0 \\ \partial_t k' + \partial_x \left[\left(c' + U_l \right) k' \right] = 0 \\ c' = \sqrt{\frac{g}{k'}} \end{cases}$$

$$B \qquad\qquad B'$$

$$B(k) = k^3 E(k)/\omega \quad B' = \overline{B}(1 + \varepsilon M_B \cos \phi)$$

ε is the LW steepness ($k_l A_l$) and

$\phi = \theta_s - \theta_l$

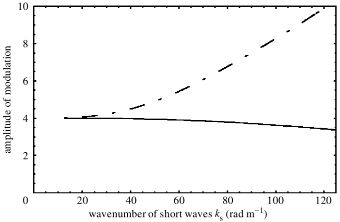
First order MTF

Longuet-Higgins and Stewart (1960)

$$M_B = 4$$

Elfouhaily et al. (2001)

$$M_N = -4 \frac{\omega_1 - i\mu_s}{\omega_1^2 + \mu_s^2} \omega_l \cos^2(\theta_s - \theta_1)$$



This research aims:

- To improve the saturation-based dissipation by taking into account longuer waves modulations effect.

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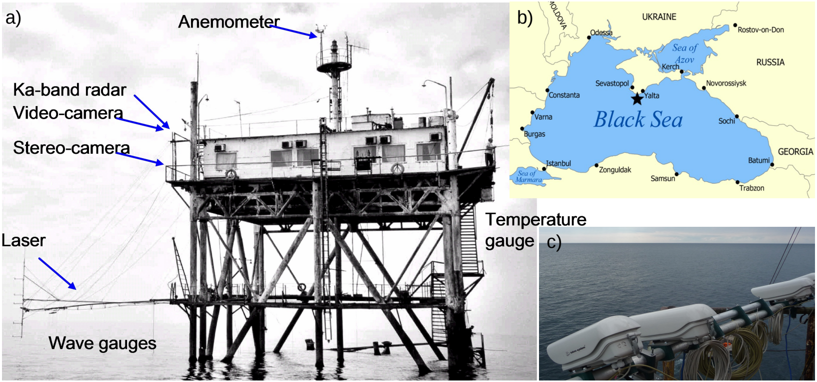
- To improve the saturation-based dissipation by taking into account longuer waves modulations effect.

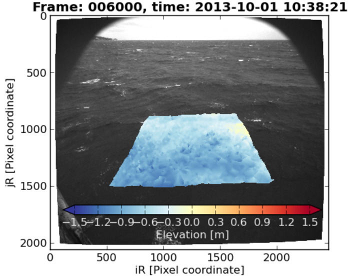
- Short wave breaking modulation by longer waves observed by stereo video system
- Maximum saturation level instead of the mean saturation in WW3 model

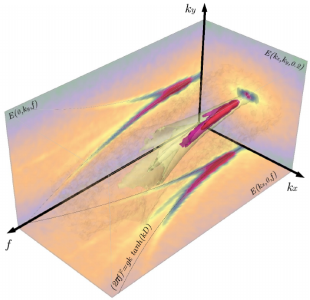
3. Observations



a) Research platform of the Marine Hydrophysical Institute; b) Position of the research platform; c) WASS cameras in the center and DIACAM.

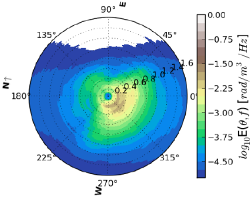
3. OBSERVATIONS



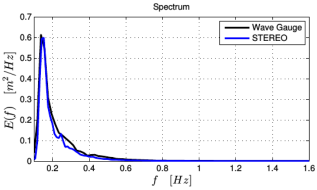


(a) $E(k_x, k_y, f)$

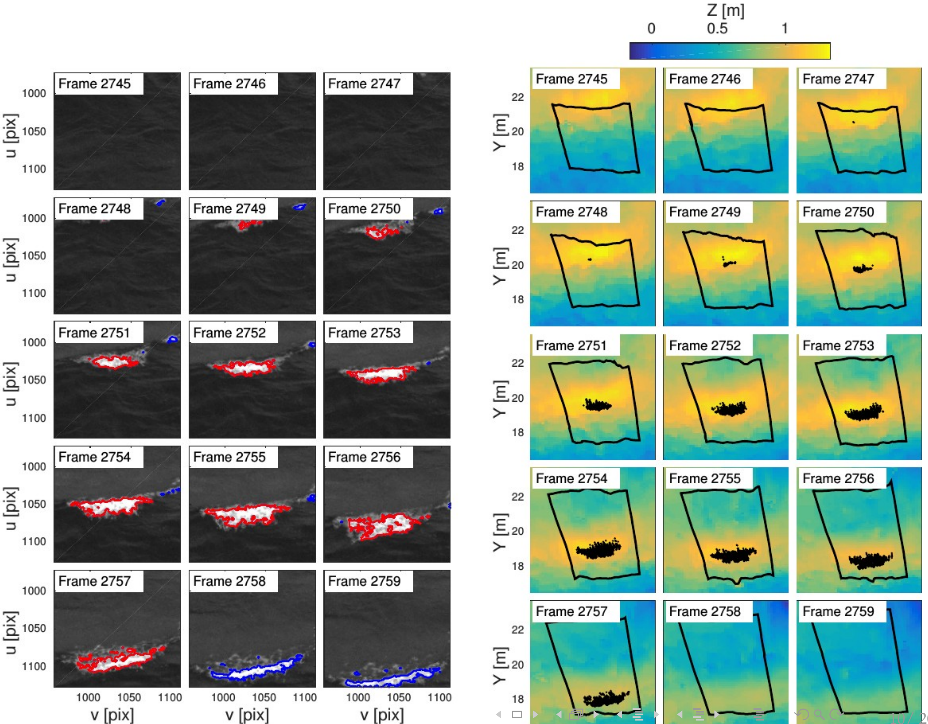
Sea surface elevation and wave spectrum from stereo video.



(b) $E(f, \theta)$

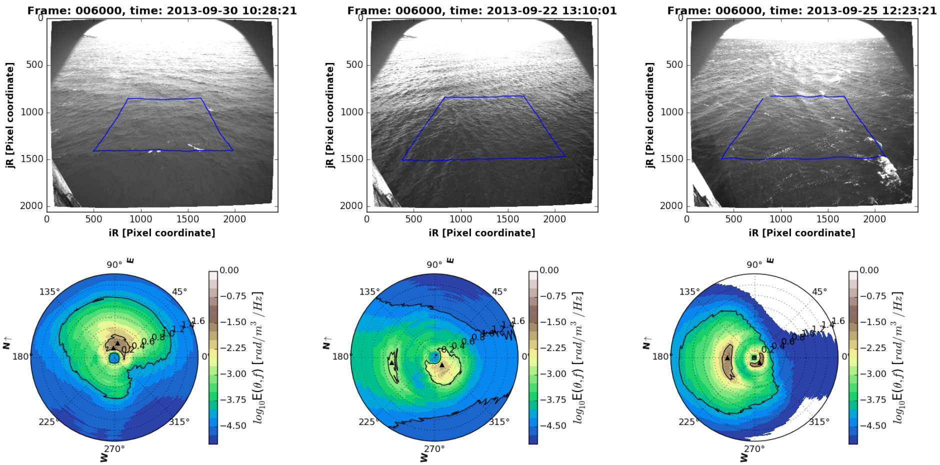


(c) $E(f)$


Z [m]
0
0.5
1
Frame 2745
Frame 2746
Frame 2747
Frame 2748
Frame 2749
Frame 2750
Frame 2751
Frame 2752
Frame 2753
Frame 2754
Frame 2755
Frame 2756
Frame 2757
Frame 2758
Frame 2759
u [pix]
1000
1050
1100
v [pix]
Y [m]
22
20
18

3. Observations

SC1 SC2 SC3

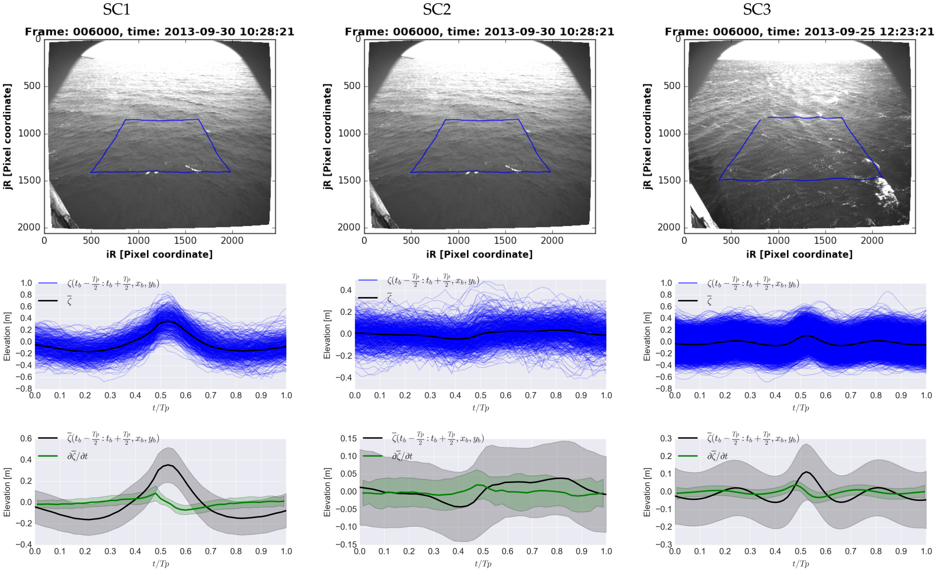


$H_s = 0.66m$ / $T_p = 4.3s$ $H_s = 0.41m$ / $T_p = 4.1s$ $H_s = 0.65m$ / $T_p = 5.7s$

$H_{s2} = 0.35m$ / $T_{p2} = 3.0s$ $H_{s2} = 0.11m$ / $T_{p2} = 1.2s$ $H_{s2} = 0.32m$ / $T_{p2} = 1.8s$

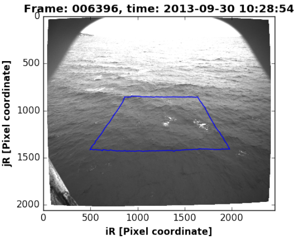
$U_{10} = 8.7m/s$ / E $U_{10} = 6.1m/s$ / N $U_{10} = 15.2m/s$ / N

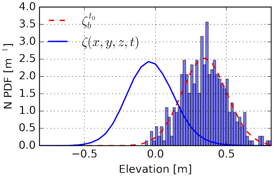
3. Observations



3. Observations

SC1

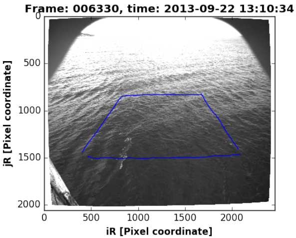


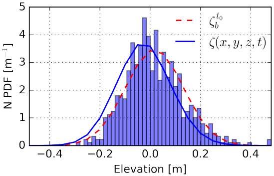


$H_s = 0.66m$ / $T_p = 4.3s$
$H_{s2} = 0.35m$ / $T_{p2} = 3.0s$
$U_{10} = 8.7m/s$ / E

$M_N = 3.77$

SC2





$H_s = 0.41m$ / $T_p = 4.1s$
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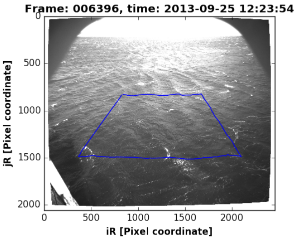
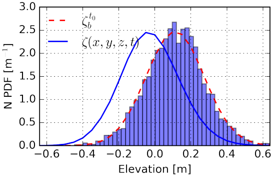
$M_N = 1.67$

SC3





$H_s = 0.65m$ / $T_p = 5.7s$
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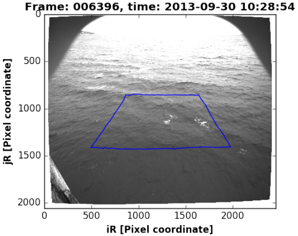
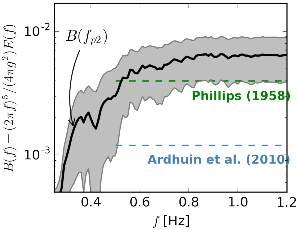
$M_N = 1.98$

3. Observations

SC1





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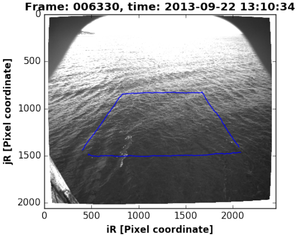
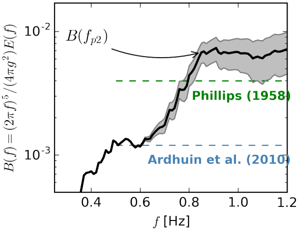
SC2





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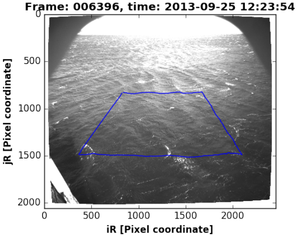
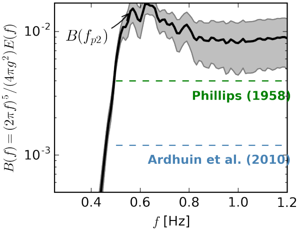
SC3





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4. NUMERICAL MODELLING

WAVEWATCH® III numerical model

$$\partial_t N + \boldsymbol{\nabla} \cdot (\dot{\boldsymbol{x}} N) + \boldsymbol{\nabla}_{\boldsymbol{\kappa}} . (\dot{\boldsymbol{\kappa}} N) = S$$

$$S(\boldsymbol{\kappa}) = S_{in} + S_{ds} + S_{nl} + ...$$

S_{in} and S_{ds} Ardhuin et al. (2010),
S_{nl} Webb-Resio-Tracy (WRT), Hasselmann (1962, 1963a,b)

S_{ds}: Breaking probability is based on a threshold on the saturation of the spectrum (B)

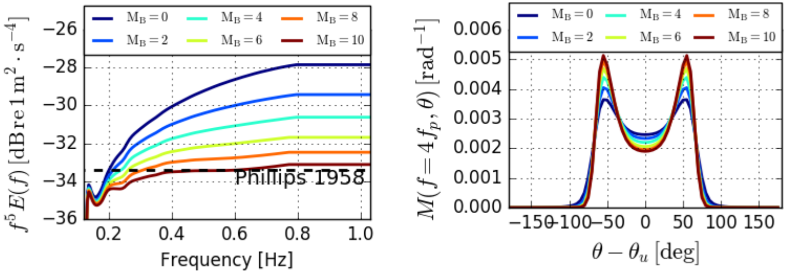
$$B(k, \theta) \rightarrow \boxed{B(k, \theta)[1 + 2M_B \sqrt{mss_l(k, \theta)}]}$$

$$mss_l(k, \theta) = \cos^2(\theta - \theta_l) \int_0^{k/2} k^2 E(k) dk$$

4. Numerical modelling

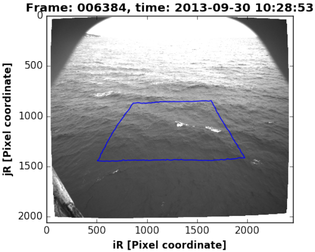
Simplified test case

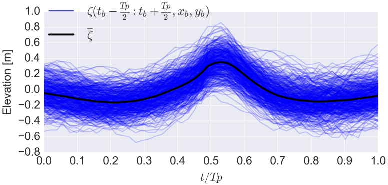
Homogeneous test case of WW3, with 128 freq and 72 directions, 0.04 < f < 1.9 Hz, U10 = 12m/s

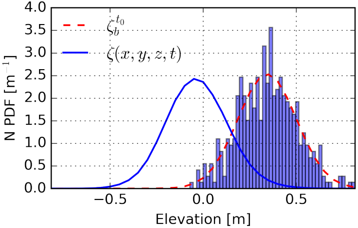


5. CONCLUSIONS

- In this work we explored observational and numerical aspects of short wave dynamic and dissipation.







- Stereo video observations and breaking detection

- Short wave breaking modulation by longer waves

5. Conclusions

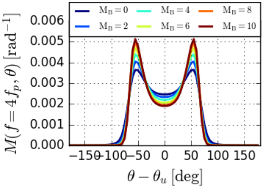
- We propose an extension to the saturation-based dissipation

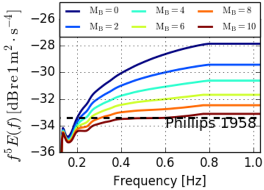
  $B(k,\theta) \rightarrow$

  $$\boxed{B(k,\theta)[1 + 2M_B\sqrt{mss_l(k,\theta)}]}$$

- The results are more consistent with strong bimodality when wind and dominant waves are aligned

- and can also produce the observed $f^5E(f)$ spectral shapes





PERSPECTIVES

- Obtain a more correct M_B
- Phase-resolving simulations using a HOS (Ducrozet et all, 2016)
- Test the source therms on realistic cases

THE END

Thank you!