A NEW HYBRID APPROACH IN THE CALIBRATION OF A BREAKING MODEL WITHIN A BOUSSINESQ-TYPE WAVE MODEL

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Motivation

- Can we assure that wave breaking models accurately predict the breaking location and its extension?

  – Usually wave breaking models are calibrated using free surface elevation measurements (η):

    - Schäffer et al. (1993)
    - Kennedy et al. (2000)
    - Tonelli and Petti (2009)
    - Tissier et al. (2012)
    - Cienfuegos et al. (2010)

    Breaking models calibrated/validated using measurements of η

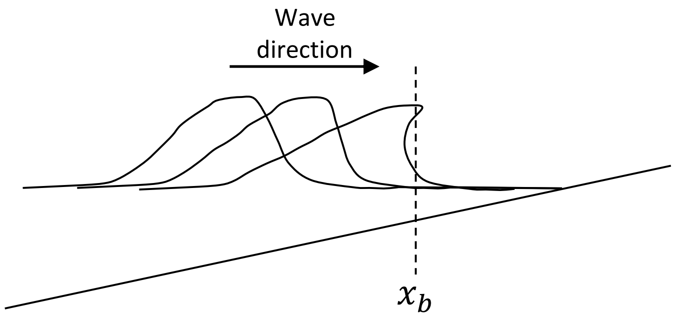
Motivation

- Can we assure that wave breaking models accurately predict the breaking location and its extension?

  - Some researchers have included the breaking location (x_b) as a calibration element:

    - Okamoto & Basco (2006)
    - D'Alessandro & Tomasicchio (2008)

Breaking models calibrated/validated using measurements of x_b



Motivation

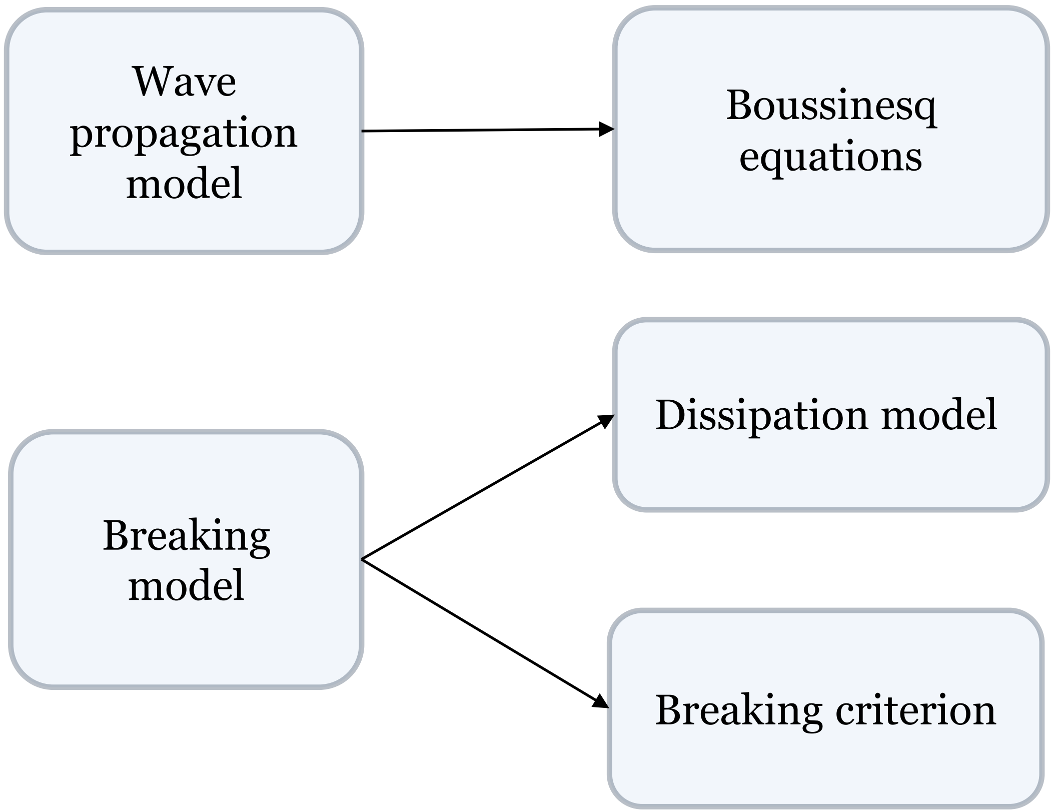
- What about the <u>ending point</u> of the breaking process?
- What about the <u>length</u> of the breaking process?

Objective

Propose a calibration methodology that includes both measurements of η and the breaking process (initial and ending points), and therefore, its length.

Numerical Model

- A 1D wave breaking model for Boussinesq-type equations was used (Cienfuegos et al. 2010)



Wave propagation and dissipation model

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} - D_h = 0$$

$$\frac{\partial u}{\partial t} + \frac{1}{2}\frac{\partial (u^2)}{\partial x} + g\frac{\partial h}{\partial x} + \Gamma_d - \frac{1}{h} D_{hu} = 0$$

Terms associated with wave breaking

h: local depth
u: depth averaged horizontal velocity
g: gravitational acceleration
Γ_d: Boussinesq dispersive terms
D_h, D_{hu}: breaking-induced contributions

- Dissipation model is represented with a parametric eddy viscosity model that acts in D_h and D_{hu}.

Details of the propagation and dissipation model?
See Cienfuegos et al. (2010) or ask me at the end of the session.

Wave Breaking Criterion

A simple breaking slope threshold angle was used as a breaking criterion (Cienfuegos et al., 2010).

- Breaking starts if the frontal angle of the wave exceeds Φ_b:

$$\left|\frac{\partial \eta}{\partial x}\right| > \tan \Phi_b$$

Φ_b: parameter of the calibration

- Breaking stops if the frontal angle of the wave is less than Φ_f:

$$\left|\frac{\partial \eta}{\partial x}\right| < \tan \Phi_f$$

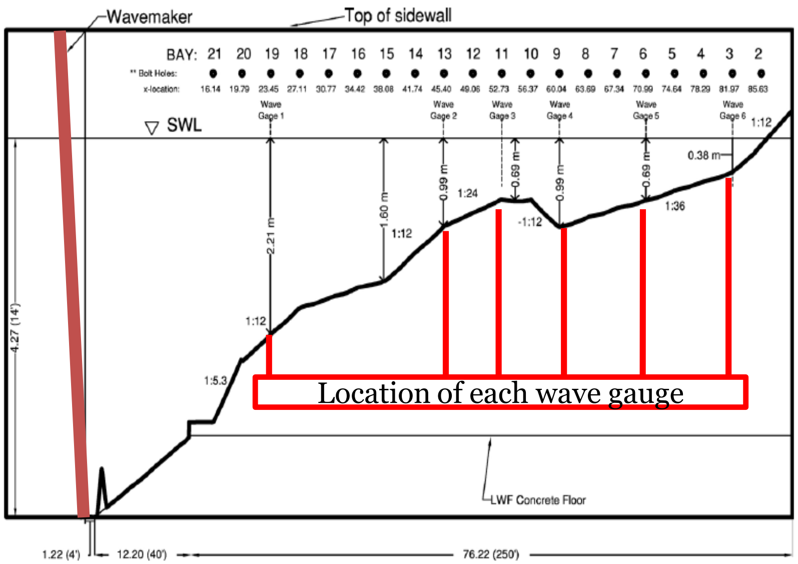
Φ_f: parameter of the calibration

Experimental data

Free surface elevation (η) and the wave breaking location were simultaneously recorded in a barred profile (scale 1:3) at the Large Wave Flume Lab *at Oregon State University* (Catalán & Haller, 2008).

Bathymetry data was recorded from a field experiment in Duck, NC.

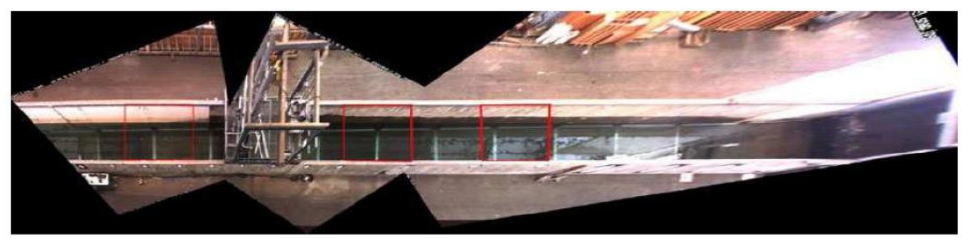
η -> Wave gauges



6 gauges recorded the free Surface elevation (η)

Breaking location -> Video cameras

Visual field of each camera



Top view (corrected) of the cameras

3 video cameras recorded the wave breaking location

Experimental data

- Both a regular and an irregular wave cases were considered.

Wave run case	T_p(s)	H_0 (m)	Breaker
Regular	4.0	0.64	*Spilling*
Irregular	2.7	0.37	*Spilling*

Experimental data

How do we quantify the breaking location and its extension?

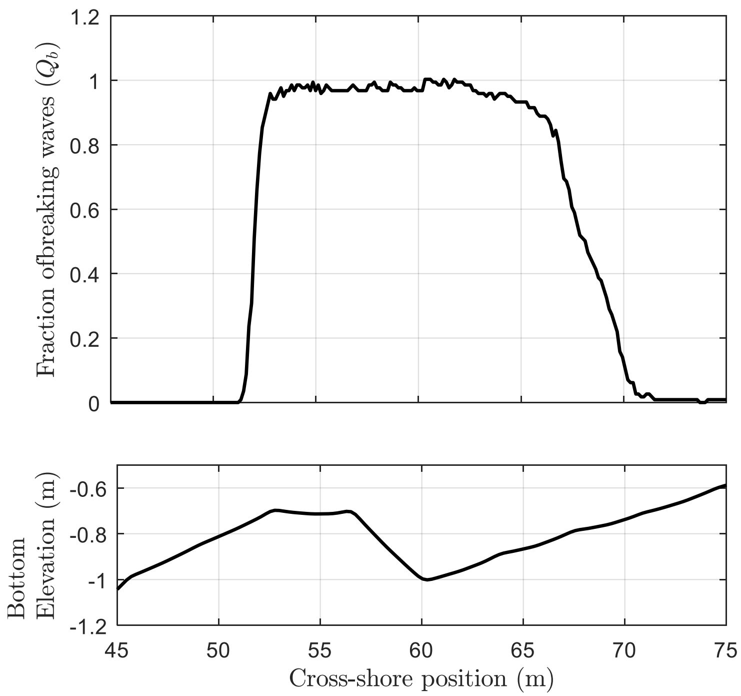
- Fraction of breaking waves $Q_b(x)$, defined as:

$$Q_b(x) = \frac{\#\ breaking\ waves}{\#\ total\ waves}$$

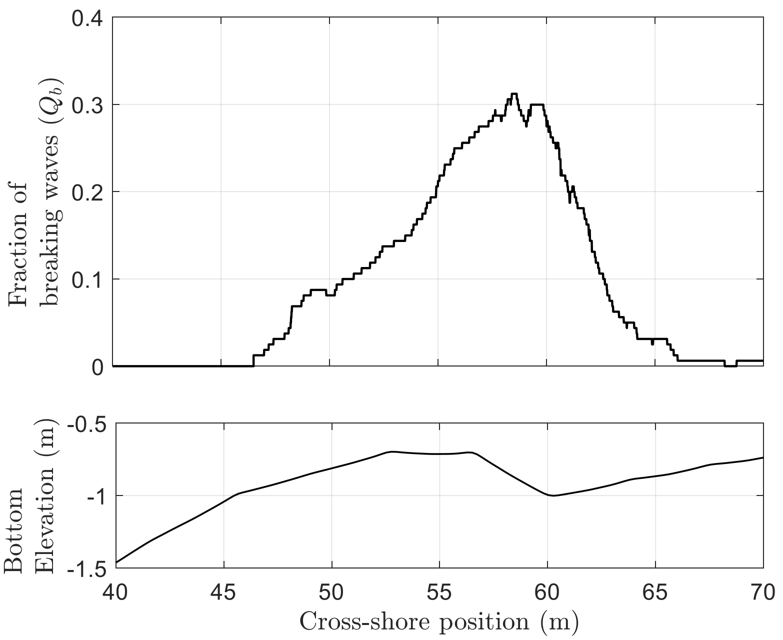
Experimental data

$$Q_b(x) = \frac{\#\ breaking\ waves}{\#\ total\ waves}$$

Regular run



Irregular run



Model calibration methodology

Traditional calibration

Fit:

a) The root mean square of the wave height (H_{rms})

$$H_{rms}(x) = \sqrt{\frac{1}{N_{waves}} \sum_{i=1}^{N_{waves}} \left(H_i(x)\right)^2}$$

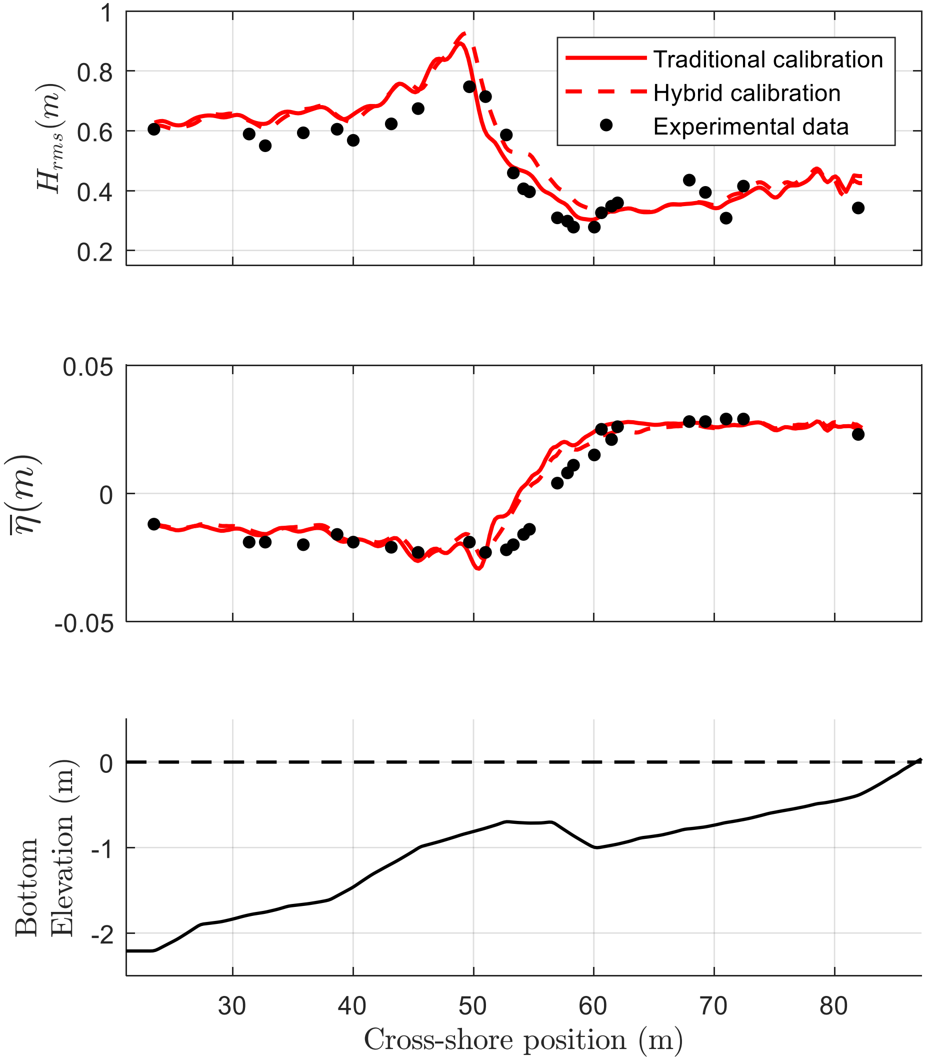
Hybrid calibration

Fit both:

a) The root mean square of the wave height (H_{rms})

b) The fraction of breaking waves (Q_b)

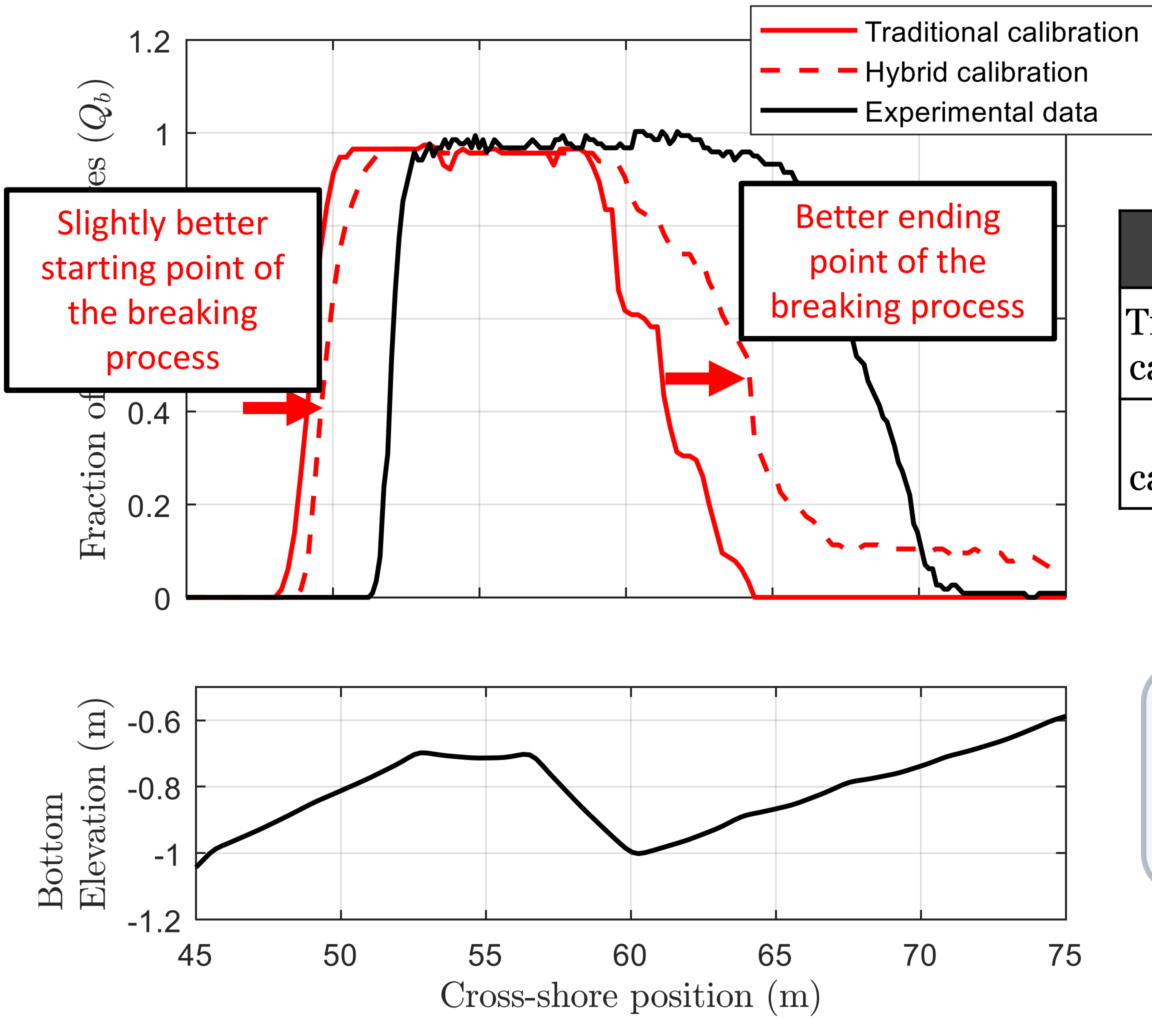
Results and discussion
Regular Waves



	Φ_b	Φ_f
Traditional calibration	42°	9°
Hybrid calibration	44°	8°

Both calibrations seem reasonable

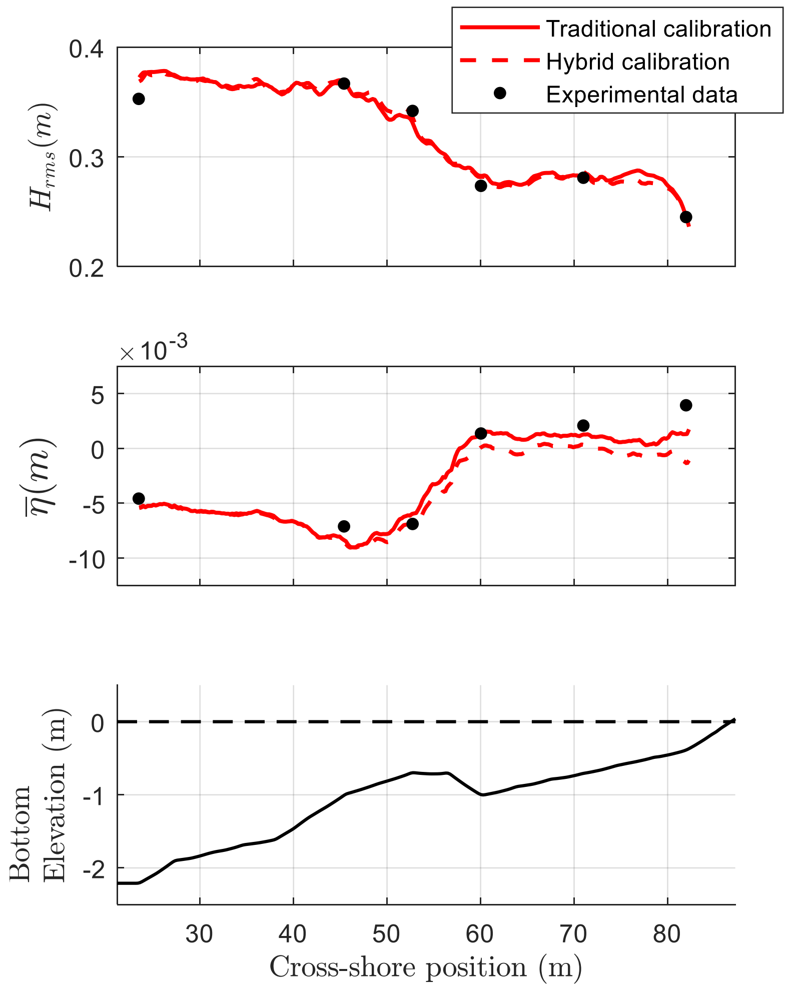
Results and discussion
Regular Waves



	Φ_b	Φ_f
Traditional calibration	42°	9°
Hybrid calibration	44°	8°

Both calibrations do not show the expected agreement

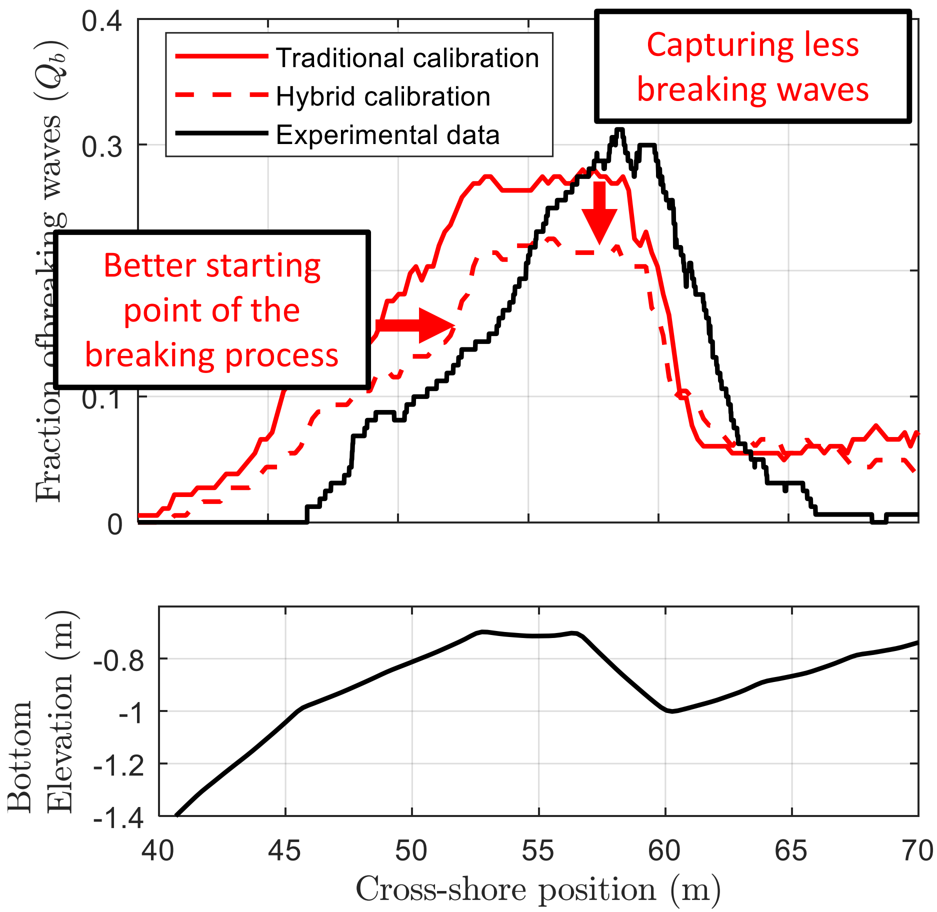
Results and discussion
Irregular Waves



	Φ_b	Φ_f
Traditional calibration	24.5°	8.0°
Hybrid calibration	28°	6.5°

Again, both calibrations seem reasonable

Results and discussion
Irregular Waves



	Φ_b	Φ_f
Traditional calibration	24.5°	8.0°
Hybrid calibration	28°	6.5°

Both calibrations do not show the expected agreement

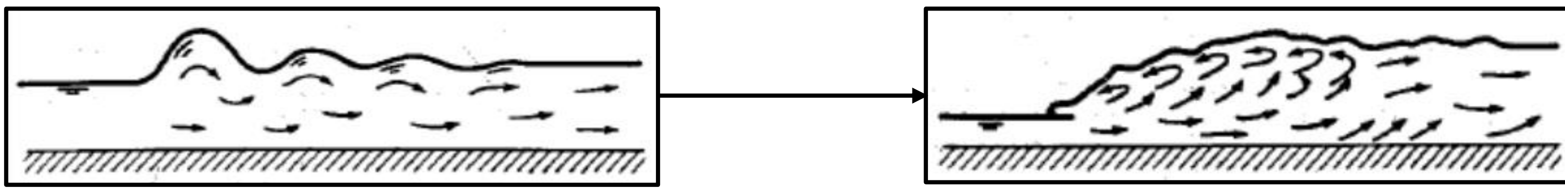
A different wave breaking criterion: Breaking Celerity Index (BCI) (D'Alessandro & Tomasicchio, 2008)

Undular hydraulic jump

Non-breaking wave

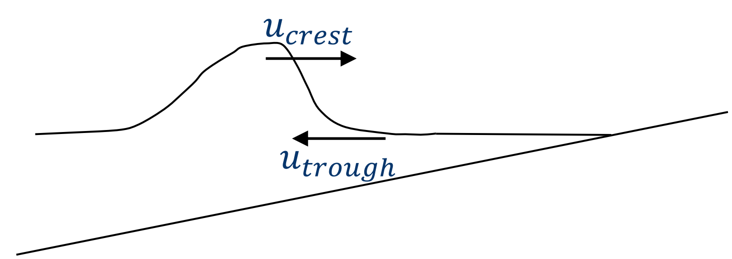
Fully developed hydraulic jump

Breaking wave



- Breaking starts if:

$$\frac{\partial \eta}{\partial t} \geq BCI \qquad BCI = \frac{u_{crest} - u_{trough}}{CTFN}$$



$CTFN$: Critical Trough Froude Number

$CTFN$: parameter of the calibration

A different wave breaking criterion: Breaking Celerity Index (BCI) (D'Alessandro & Tomasicchio, 2008)

- Two different breaking ending criteria were implemented.

1) From Kennedy et al. (2000):

Breaking ends if $\frac{\partial \eta}{\partial t} < \eta_t^*$

$$\eta_t^* = \begin{cases} b_2\sqrt{gh} & t - t_b \geq T^* \\ b_1\sqrt{gh} + \frac{t - t_b}{T^*}(b_2 - b_1)\sqrt{gh} & 0 \leq t - t_b < T^* \end{cases}$$

T^*: Transition time. $T^* = 5\sqrt{h/g}$

t_b: time when breaking was initiated

Calibrate: CTFN, b_1, b_2

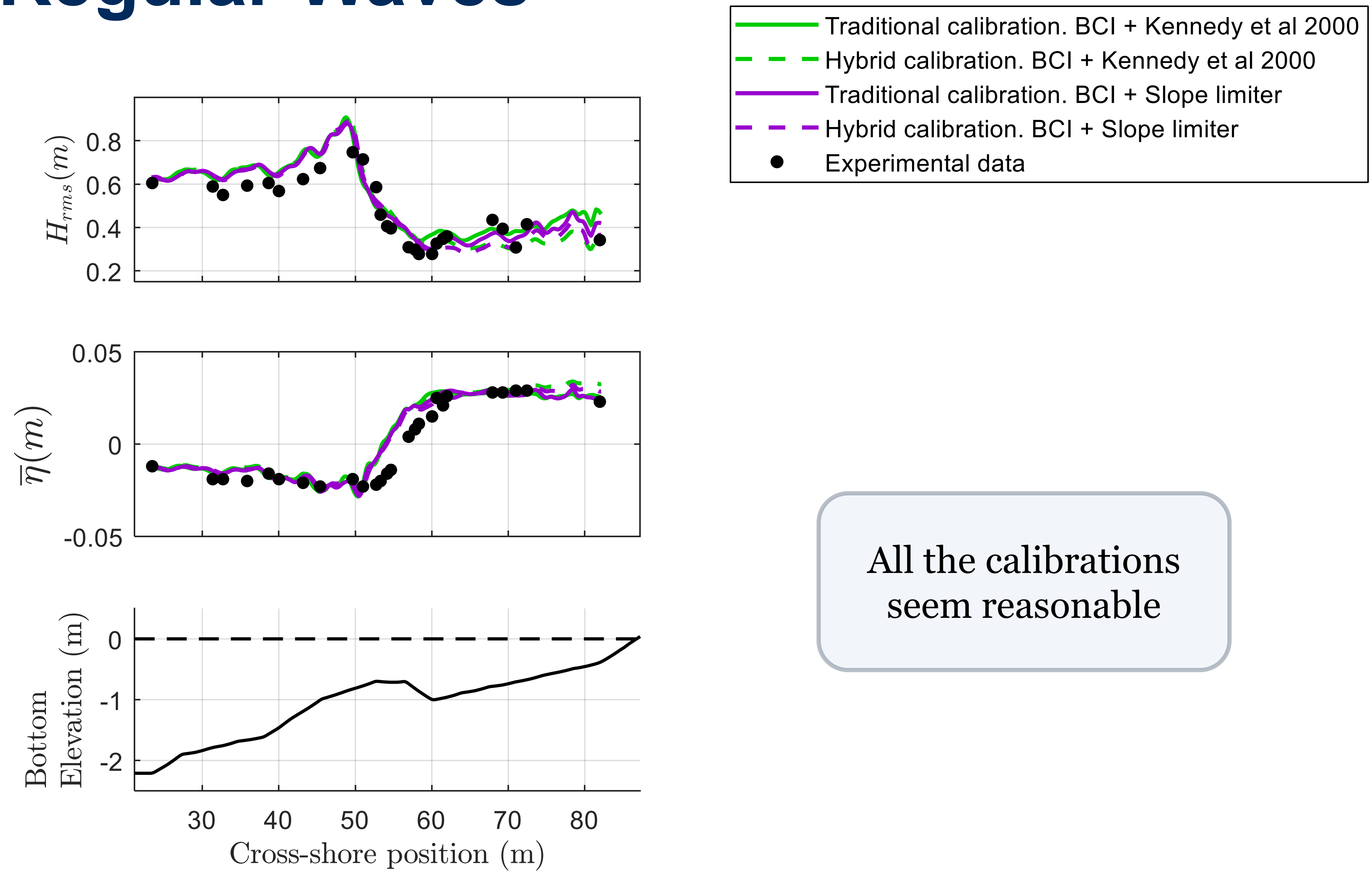
2) Breaking slope threshold angle (Cienfuegos et al., 2010)

Breaking ends if

$$\left|\frac{\partial \eta}{\partial x}\right| < \tan \Phi_f$$

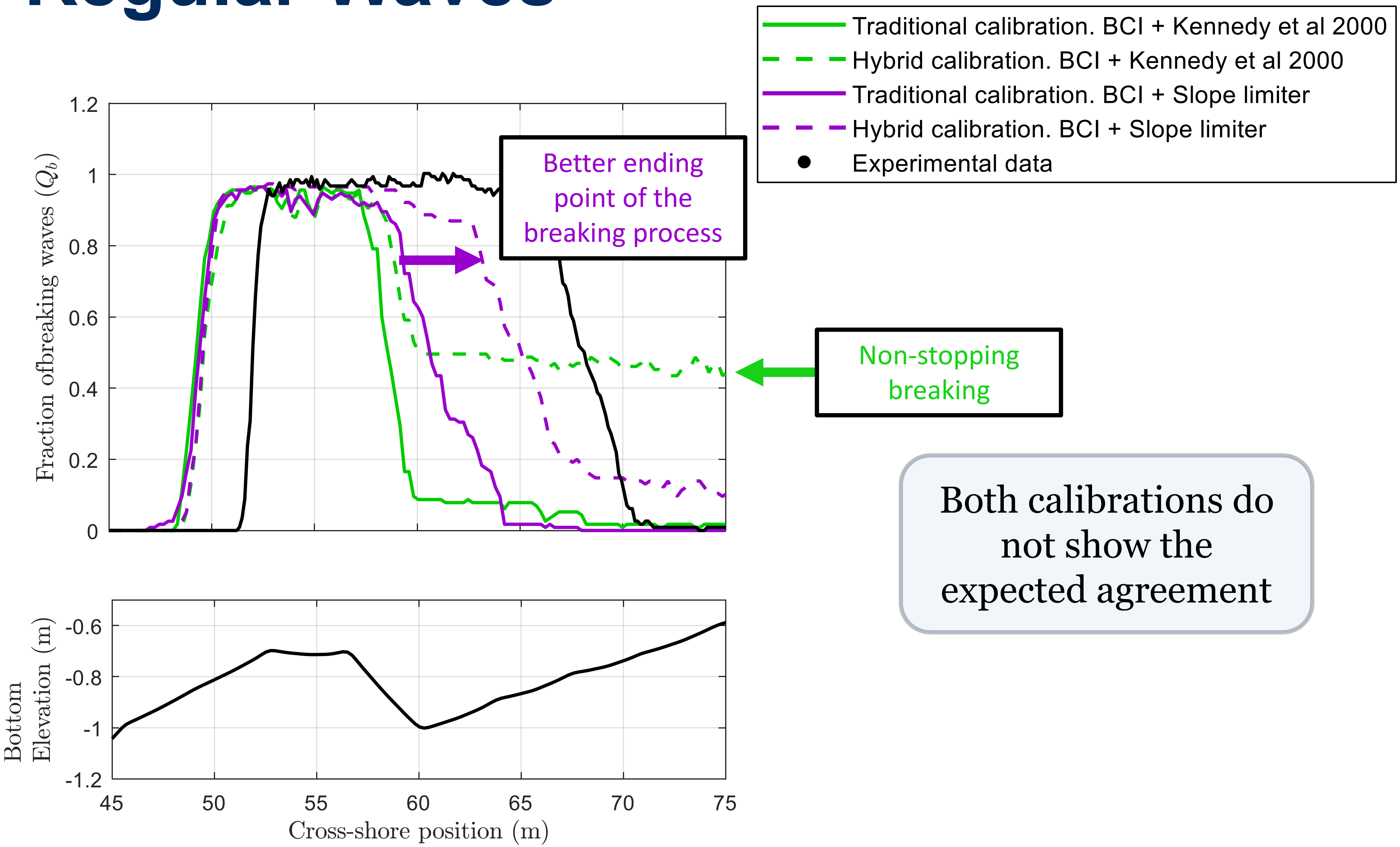
Calibrate: CTFN, Φ_f

Results and discussion
Regular Waves



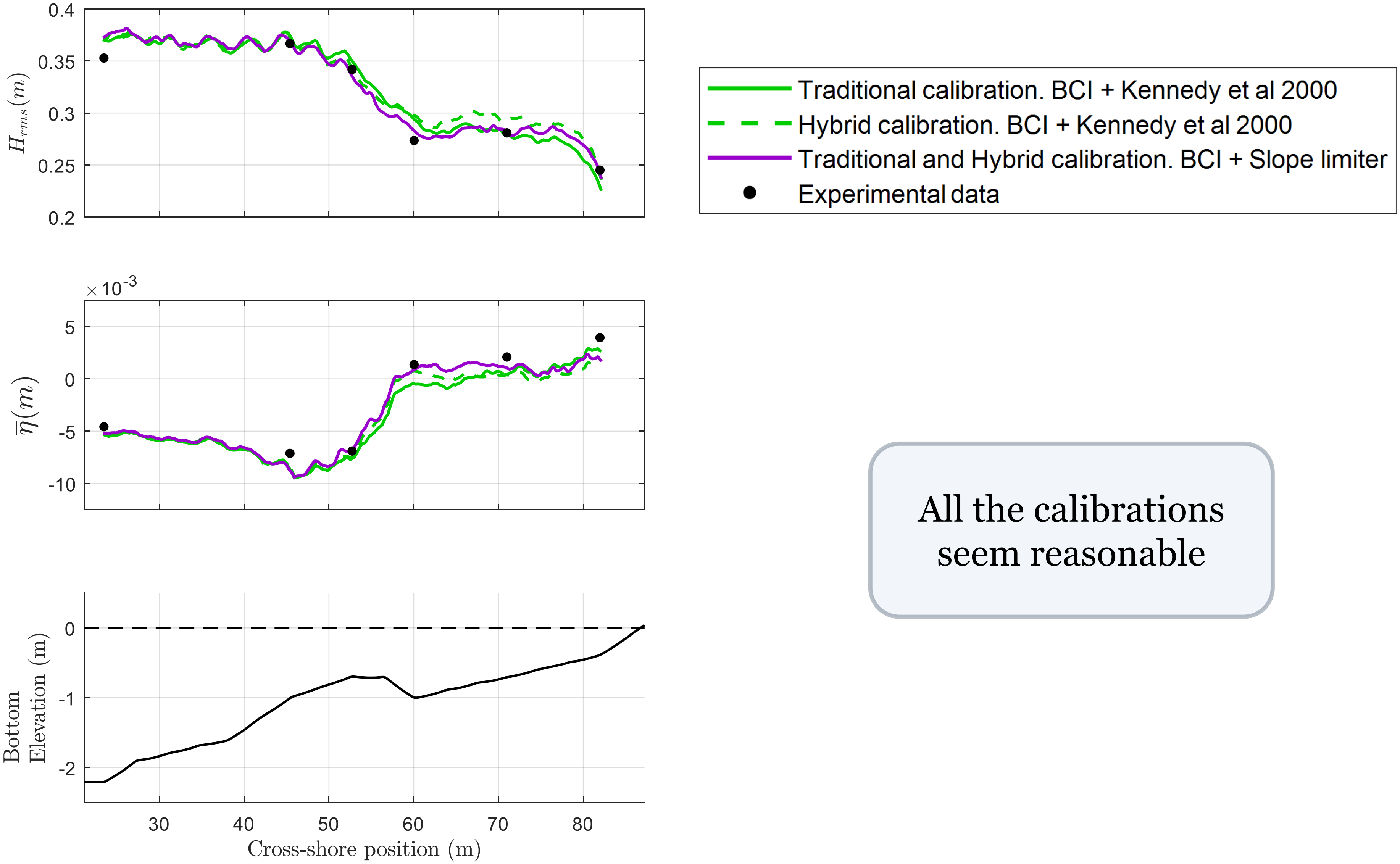
All the calibrations seem reasonable

Results and discussion
Regular Waves



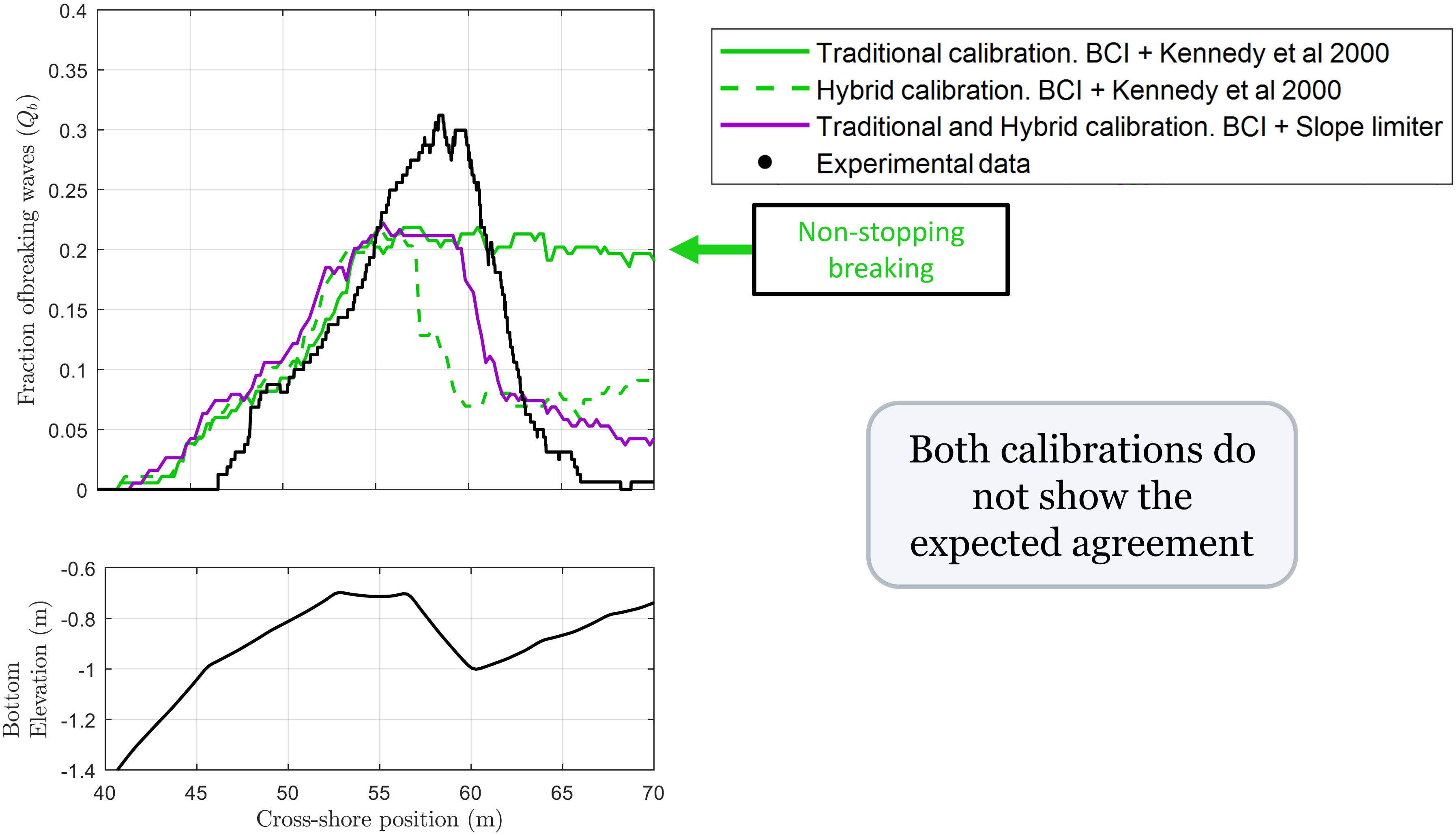
Both calibrations do not show the expected agreement

Results and discussion
Irregular Waves



All the calibrations seem reasonable

Results and discussion
Irregular Waves



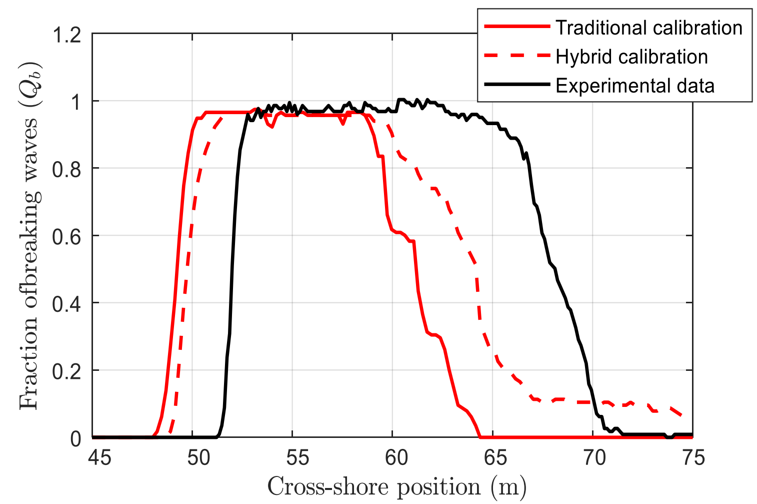
Both calibrations do not show the expected agreement

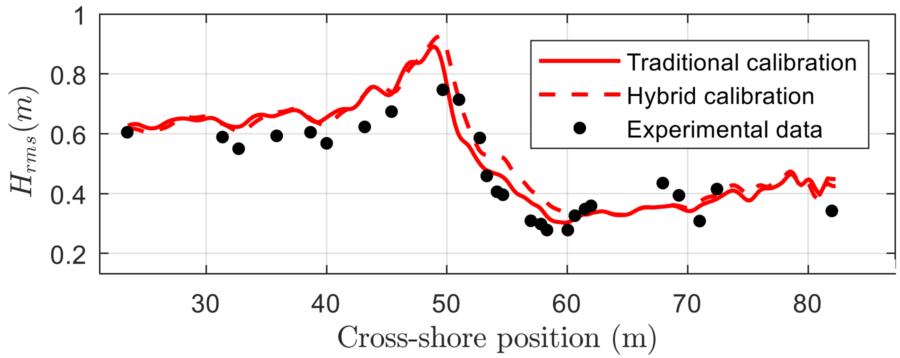
Conclusions

- The hybrid calibration can improve the parameter selection of a breaking model.

- Without the use of the video cameras, irregularities in the location of the breaking process go unnoticed.

- Achieving a good fit of both the water levels and the breaking process is a challenge for the presented breaking models, which might require adjustments on their original formulation.





THANK YOU FOR YOUR ATTENTION