

Experimental investigation of the statistics of extreme waves and wave forces on top of and behind a shoal

Karsten Trulsen

and experimental work by

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and numerical work by

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UiO : **Department of Mathematics**
University of Oslo

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Invitation to Benchmark Workshop on Numerical Wave Modelling

Dear Colleague,

MARIN has been working on the modeling of wave-structure interaction for more than 75 years and is continuously aiming at improving its knowledge on waves. Therefore, we organize a workshop devoted to numerical modeling of waves. We invite you as an expert in this field to carry out some calculations on a few benchmark cases and to share your expertise in the workshop where we will compare the different methodologies, compare the calculated results to experimental data and discuss the possible differences.

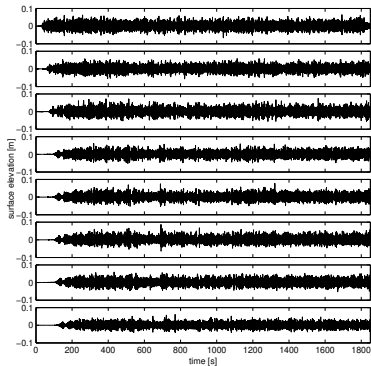
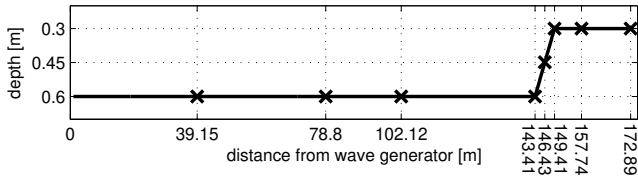
The benchmark will consist of approximately 5 cases (laboratory measurements of long-crested waves) with variations in bottom topography and wave steepness. Some cases will be blind and for some cases the entire dataset will be provided to you. It is assumed that you can initialize your simulations with the measured motions of the wave generator or the measured wave elevation at a point in the basin. The workshop will then focus on the accuracy of the predicted waves at other points in the basin.

- Meet your colleagues to exchange and share ideas and insights
- Keep track of up-to-date developments in this field
- Establish networks

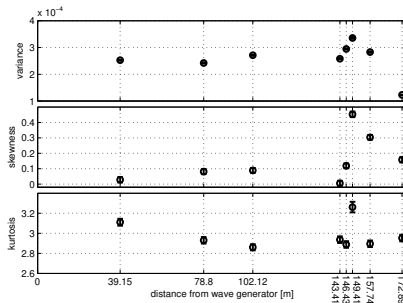


Experiment at Marin 2010

Bottom profile and location of wave probes



Experiment at Marin 2010 — Statistics case 3

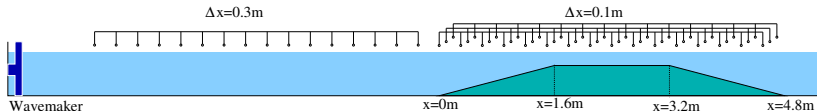


First surprise! The skewness and kurtosis of surface elevation has a local maximum at the front end of the shoal — significantly more extreme than Gaussian statistics!

published in

Trulsen, Zeng & Gramstad (2012) “Laboratory evidence of freak waves provoked by non-uniform bathymetry” *Phys. Fluids* **24**, 097101

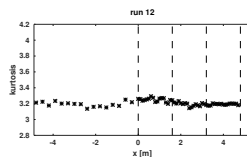
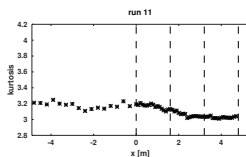
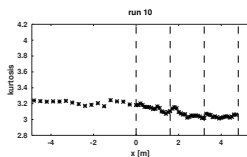
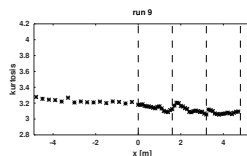
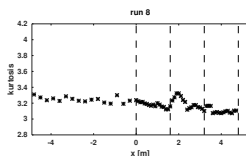
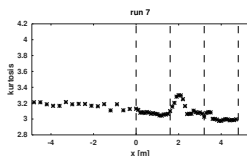
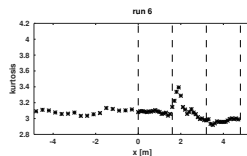
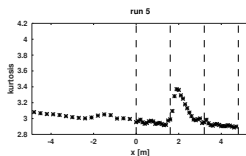
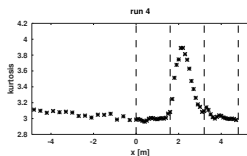
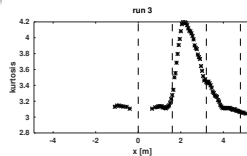
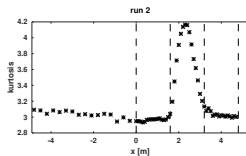
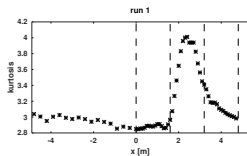
We need more experiments!



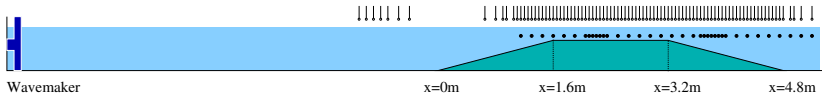
- 2013–2014: Anne Raustøl — master thesis
“Freak waves over variable depth”
- 2013–2014: Lisa Bæverfjord Rye — master thesis
“Freak waves in crossing sea with counterpropagating wave systems”



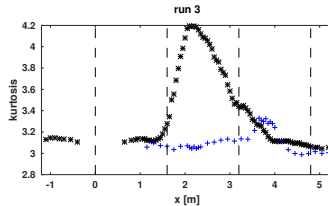
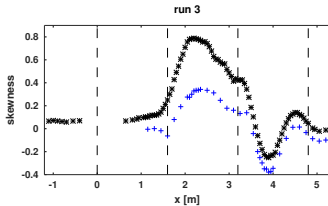
Experiments of Anne Raustøl : kurtosis



How about wave kinematics?



2018: Stian Jorde: master thesis: “Kinematics of waves over a shoal”



Black : surface elevation
Blue : horizontal velocity

Second surprise! The kurtosis of surface elevation and horizontal velocity are completely different! The velocity field has maximum kurtosis behind the shoal!

Published in

Trulsen, Raustøl, Jorde & Rye (2020) “Extreme wave statistics of longcrested irregular waves over a shoal” J. Fluid Mech. **882**, R2.

Data published together with paper — downloaded many times and used by many in new publications

How well is this phenomenon captured numerically?

Reproduced by Boussinesq equation, e.g.

- Gramstad, Zeng, Trulsen & Pedersen (2013)

Reproduced by fully nonlinear methods etc. by many, many, e.g.

- Lawrence, Trulsen & Gramstad (2021)

Not reproduced by nonlinear Schrödinger equations???

- Zeng & Trulsen (2012)
- 2008–2012: Huiming Zeng — Ph.D. thesis

“Evolution of statistics of weakly nonlinear unidirectional waves over a sloping bottom”

- 2018–2021: Christopher Lawrence — Ph.D. thesis

“Extreme wave statistics of surface gravity waves over bathymetry”



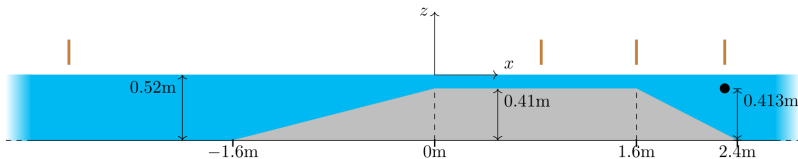
Karsten Trulsen



Statistics of extreme waves on top of and behind a shoal

We wanted more experiments, especially for the kinematics

(But in the mean time the old symmetric shoal made of plywood had decayed so we made a new asymmetric one of Plexiglas)

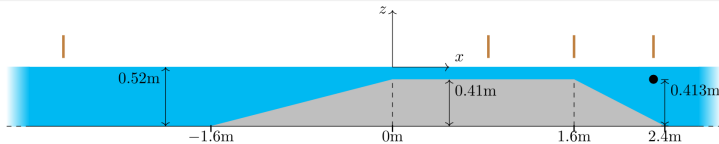


- 2020–2022: Eva Charlotte Berner — master student
“A Statistical Analysis of Rouge Waves”
- 2021–2022 : Karen Samseth — master student
“Freak forces on cylinder behind a shoal”

Karen Samseth and Eva Charlotte Berner cleaning the tank



Does the maximum of kurtosis of velocity have implications for the force experienced by a horizontal cylinder?



- 2021–2022 : Karen Samseth — master student
“Freak forces on cylinder behind a shoal”
- 2023–2027 : Karen Samseth — Ph.D. student

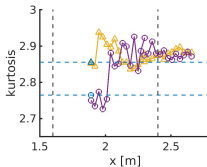
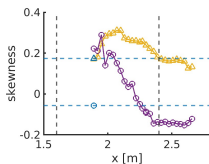


Karen Samseth with horizontal cylinder in tank

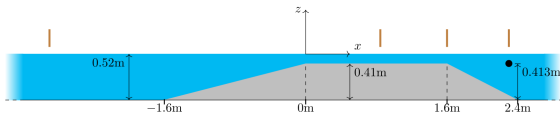
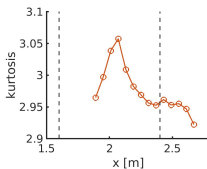
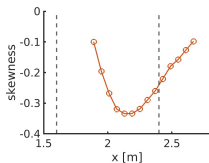


Skewness and kurtosis of forces vs. velocity

Forces:



Horizontal velocity:



Third surprise! Skewness and kurtosis of force are different from those of surface elevation and velocity.

Published in

SAMSETH, K. & TRULSEN, K. 2025 Extreme statistics of wave forces on a horizontal cylinder behind a shoal. *J. Fluid Mech.* **1007**, A59 (20 pages).