

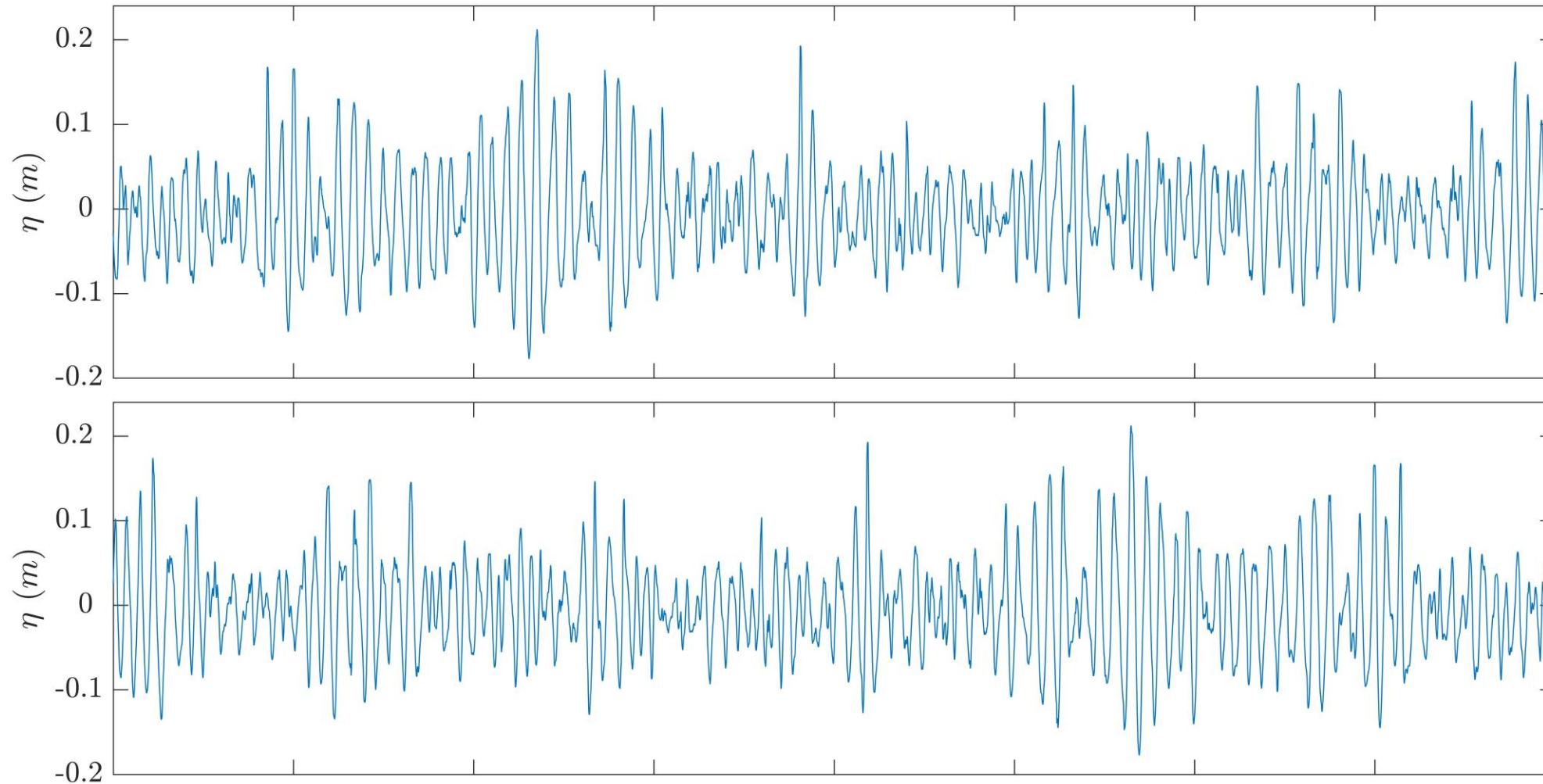
# On the Averaged Shape of Large Water Waves in Flumes and in Open Ocean

Tianning Tang (Tim)

Supervised by Thomas Adcock

05/09/2022

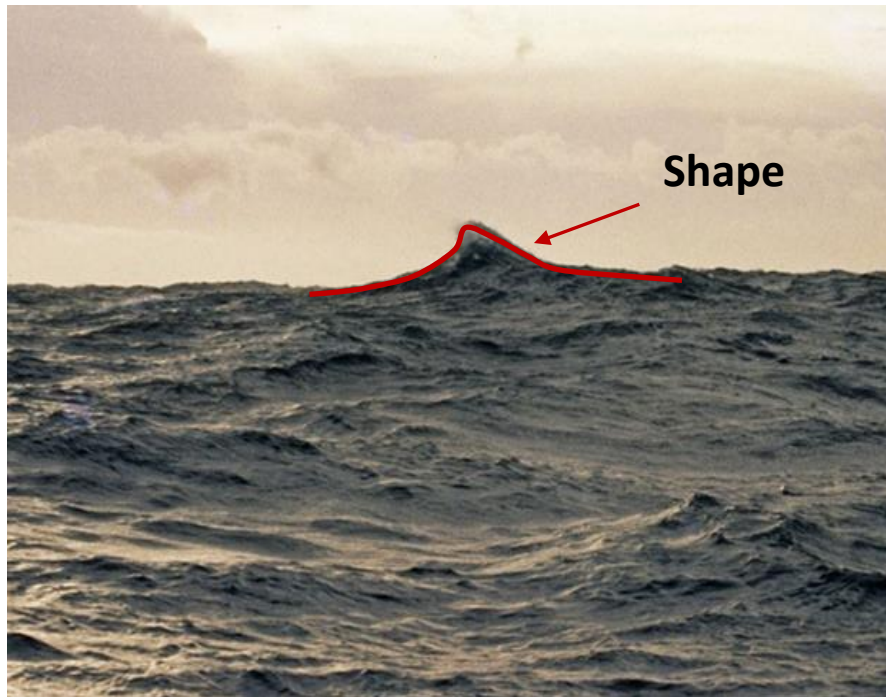
# Quiz...



# Objective

Most probable **shape** of extreme waves

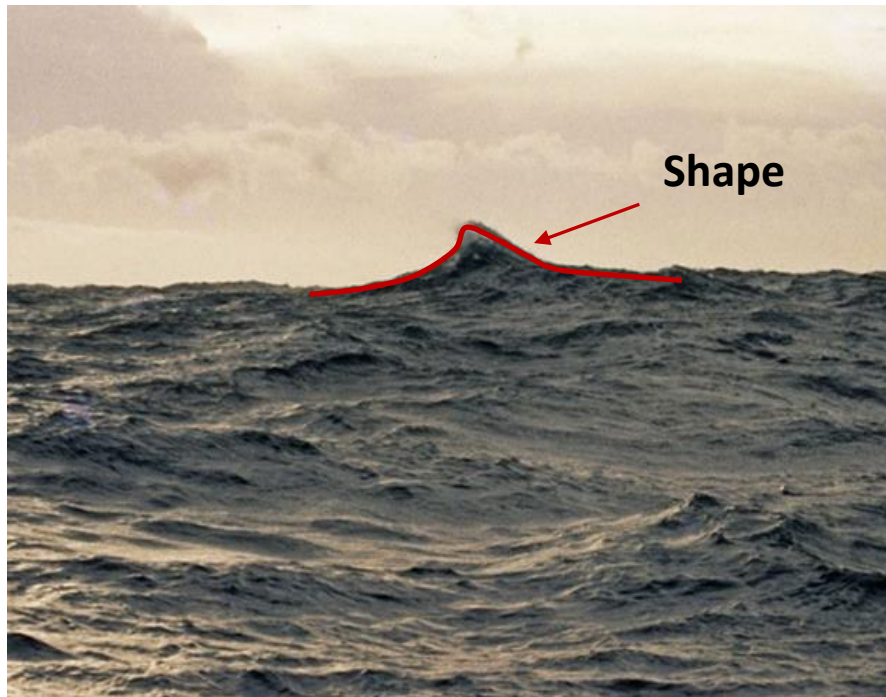
- Wave experiments in wave tank
- Wave records in field data



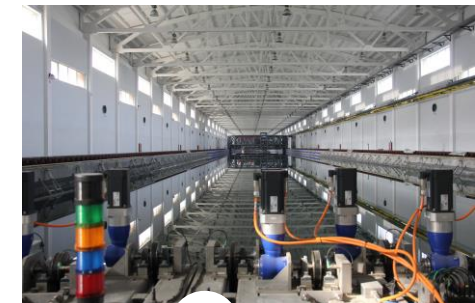
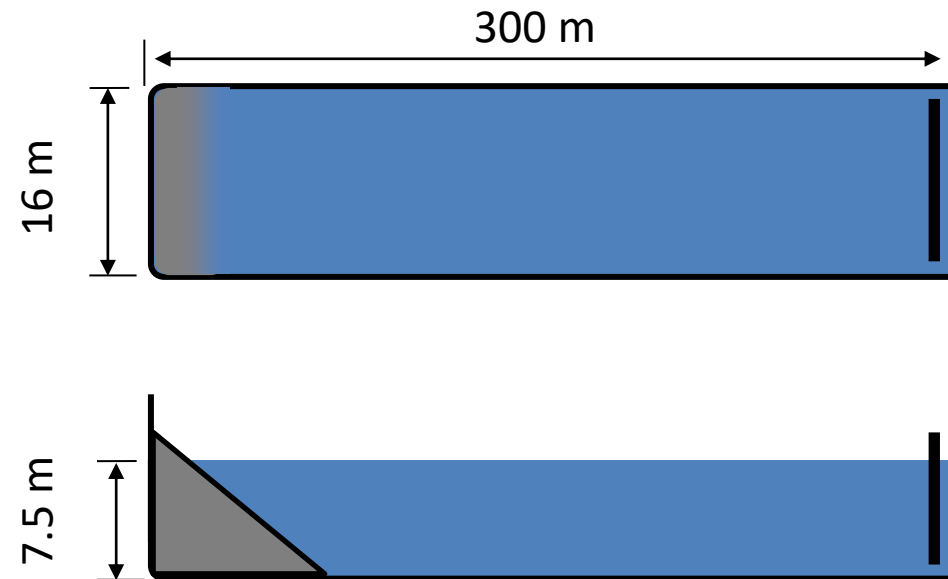
# Objective & Methodologies

Most probable **shape** of extreme waves

- Wave experiments in wave tank
- Wave records in field data



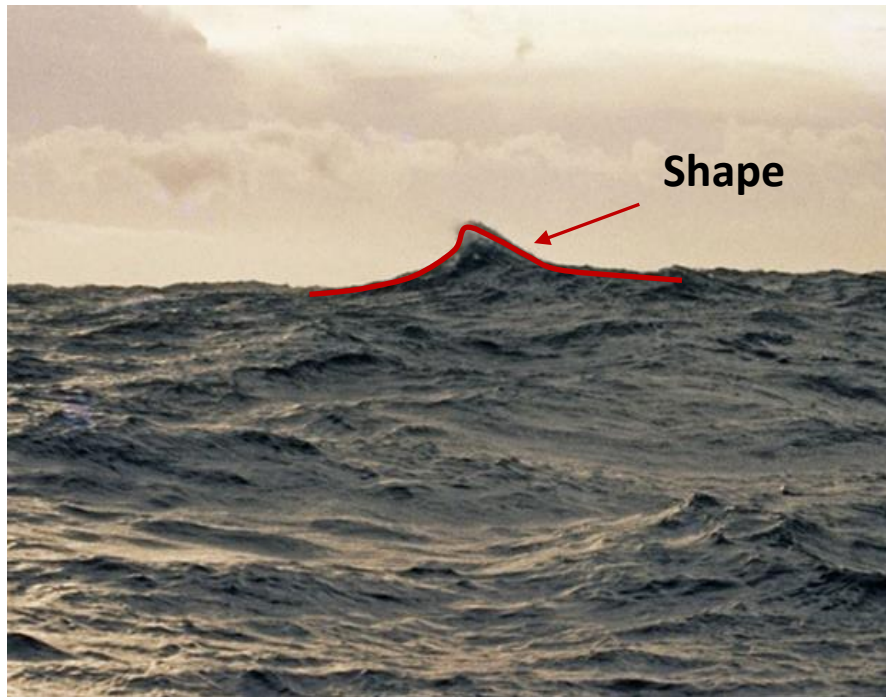
## Wave Experiments at SJTU



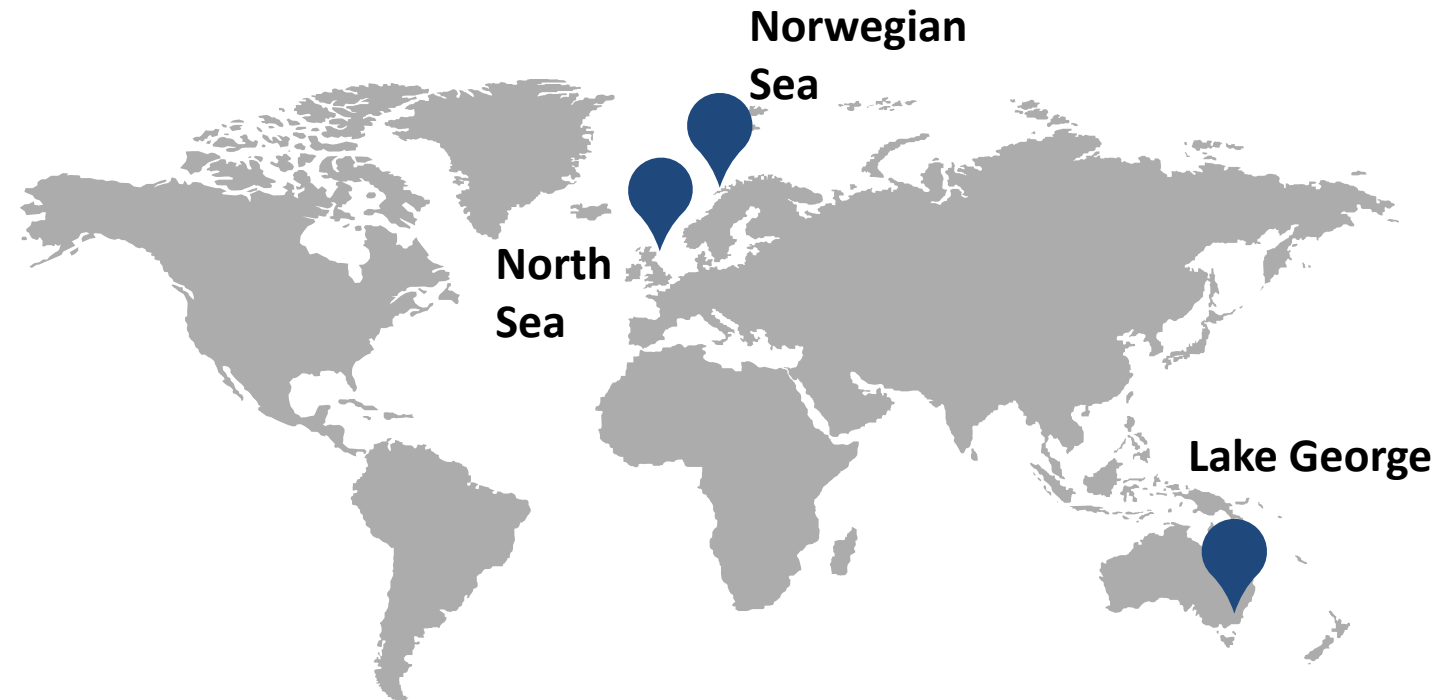
# Objective & Methodologies

Most probable **shape** of extreme waves

- Wave experiments in wave tank
- Wave records in field data



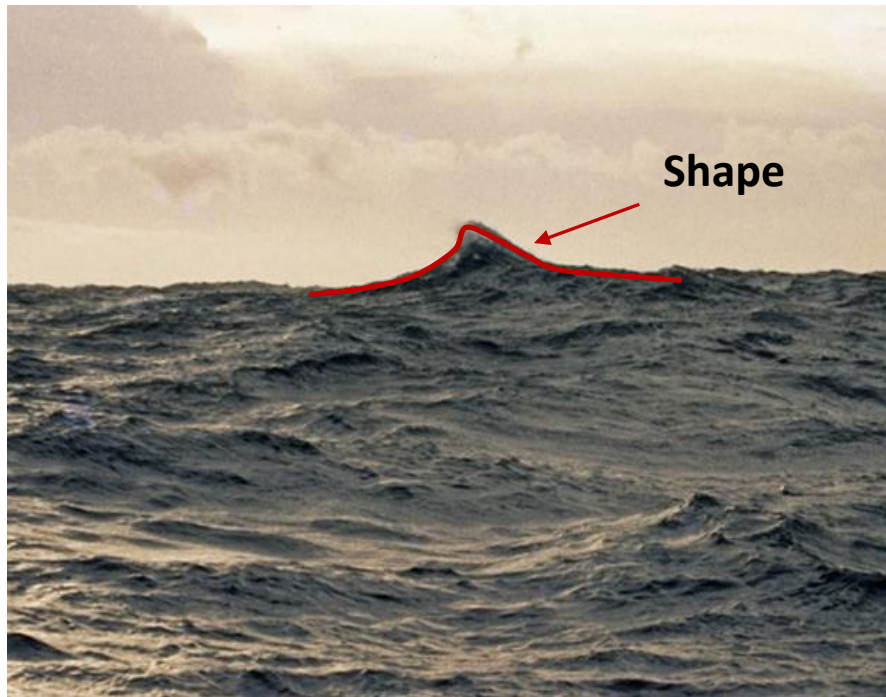
Field data analysis from three datasets



# Objective & Methodologies

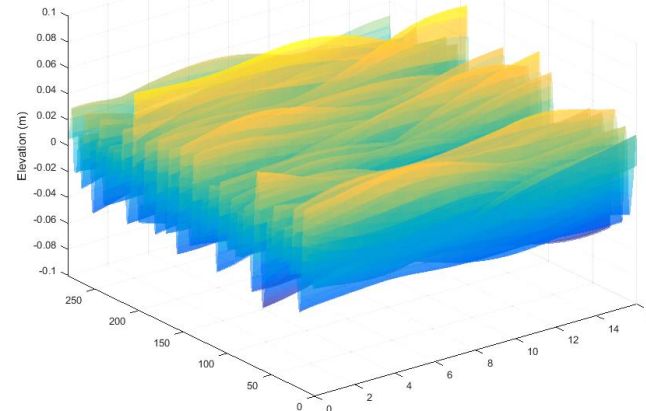
Most probable **shape** of extreme waves

- Wave experiments in wave tank
- Wave records in field data

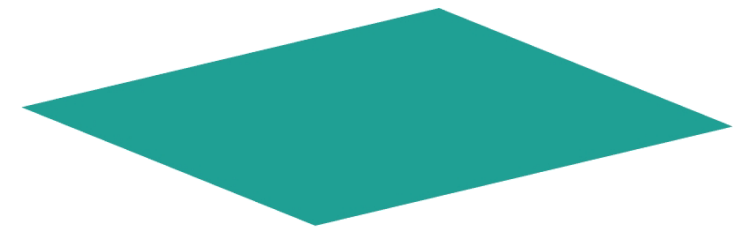


Numerical simulations from two models

**Modified nonlinear  
Schrödinger equation (MNLS)**



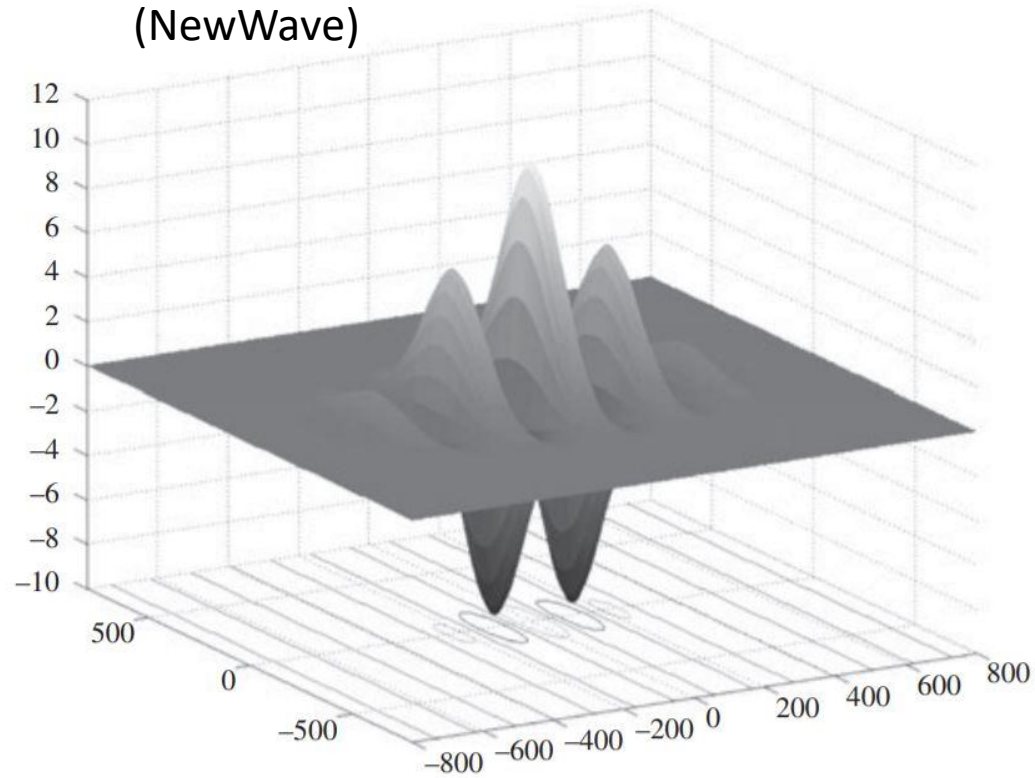
**Fully nonlinear  
potential flow**



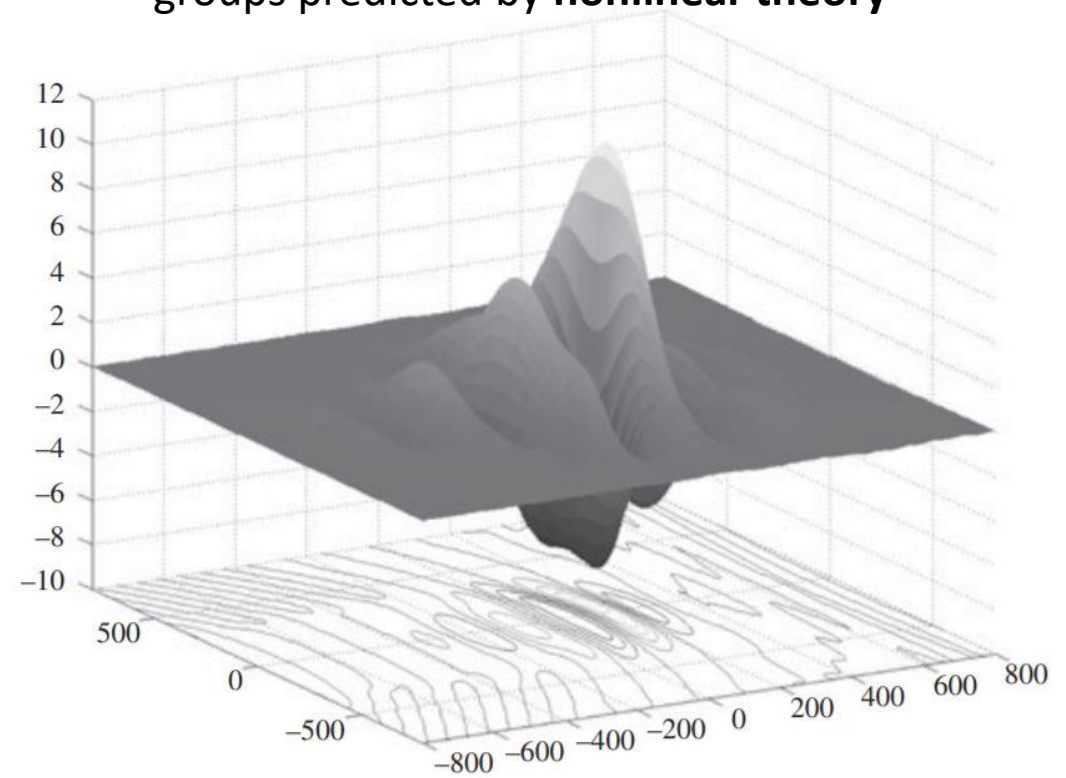
# Wave Groups

- **Lateral expansion**
- **Contraction** in mean wave direction
- Largest wave moves to the **front**

(a) Most probable shape of large wave groups predicted by **linear theory** (NewWave)

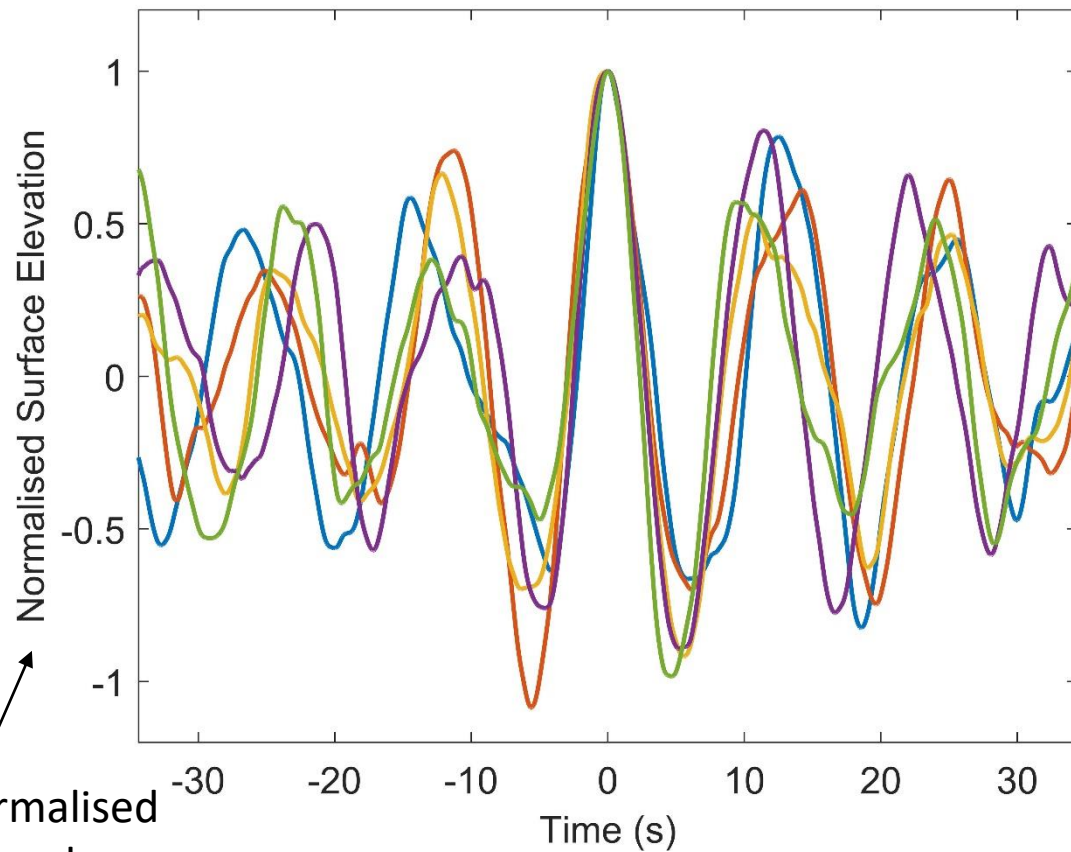


(b) Most probable shape of large wave groups predicted by **nonlinear theory**



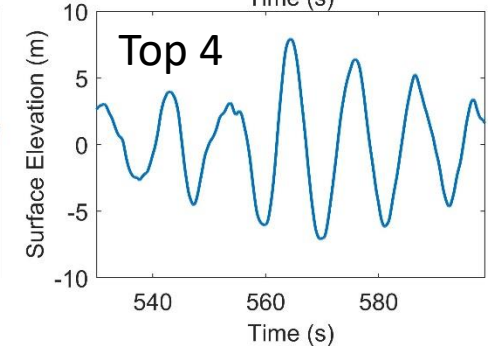
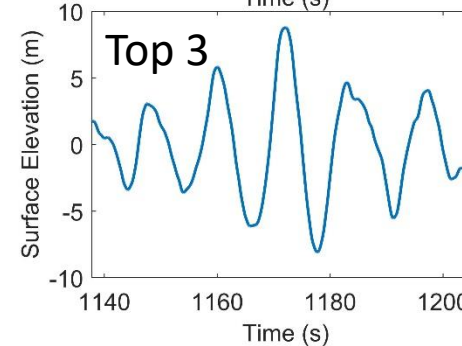
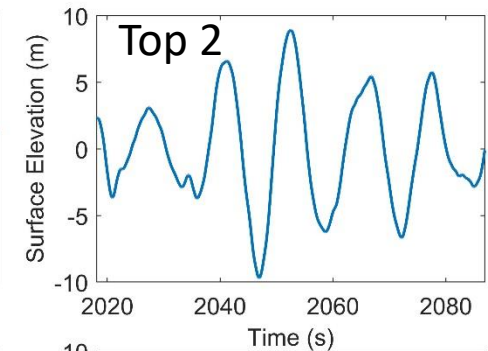
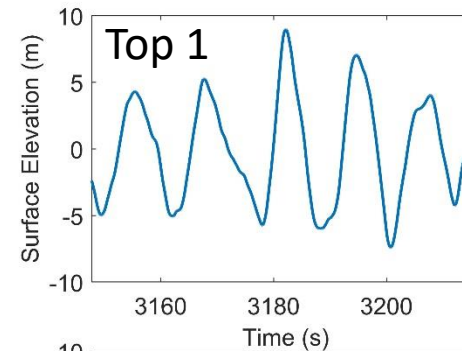
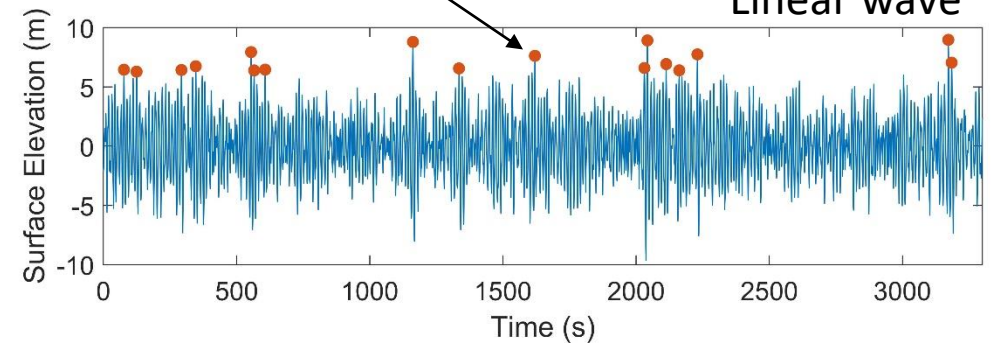
# Shape of Extreme Events

**Extreme waves centred at peak position**



Take an  
average

**Top 17 largest waves**



Normalised  
by peak  
amplitude



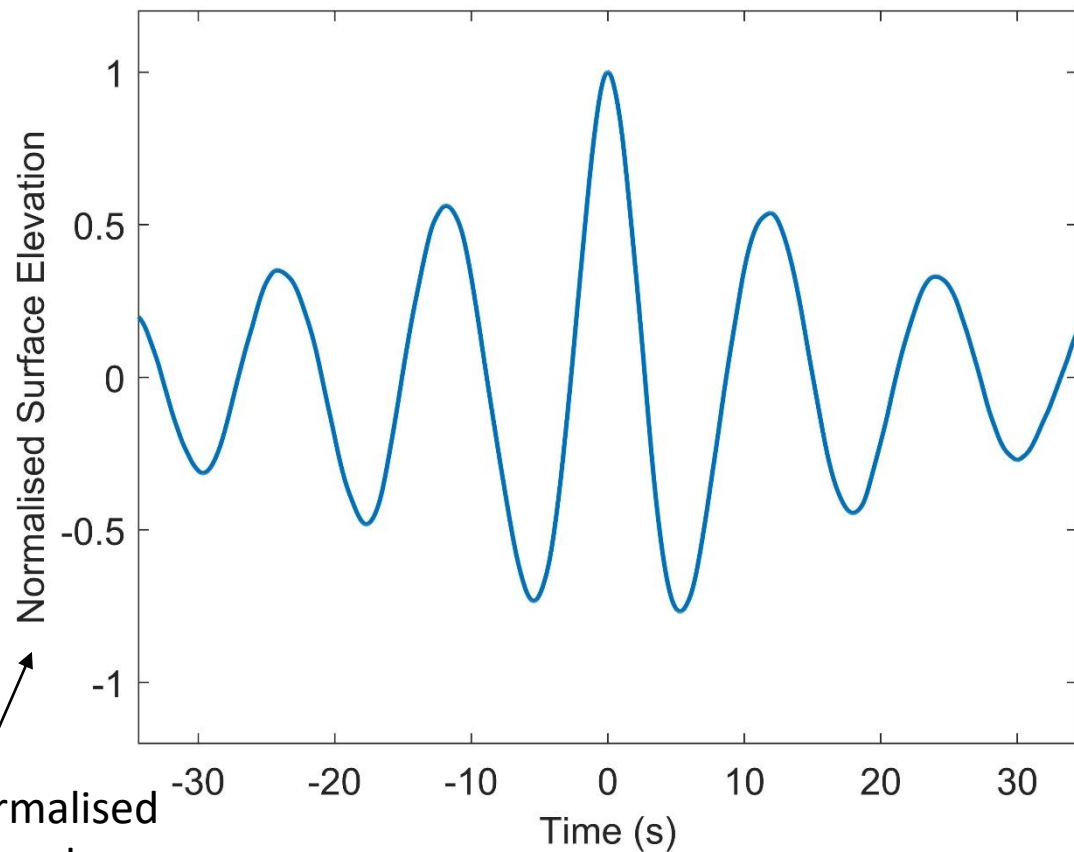
# Shape of Extreme Events



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**ENGINEERING  
SCIENCE**

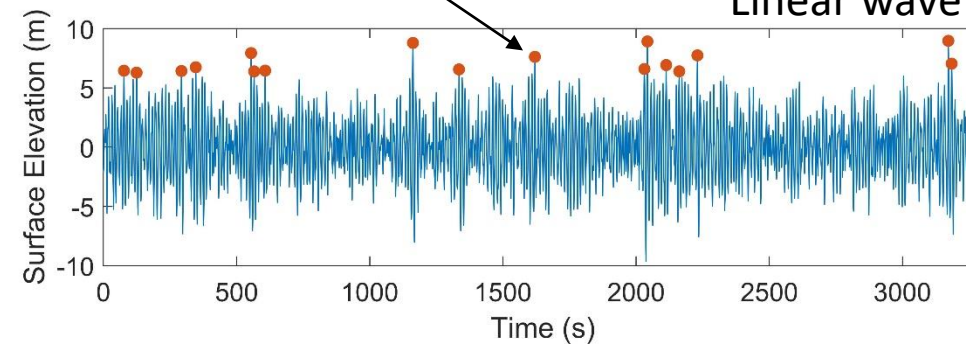


### Averaged extreme wave profile

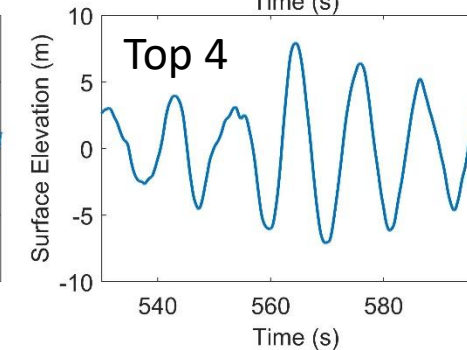
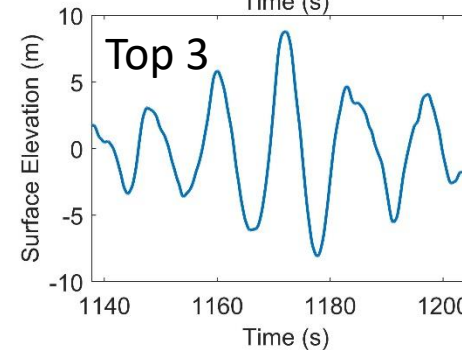
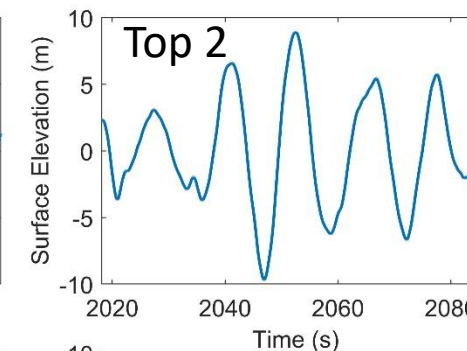
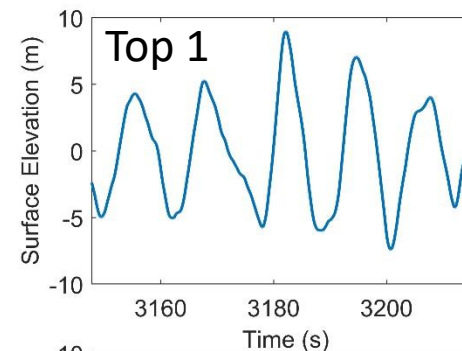


Take an  
average

### Top 17 largest waves



### Linear wave

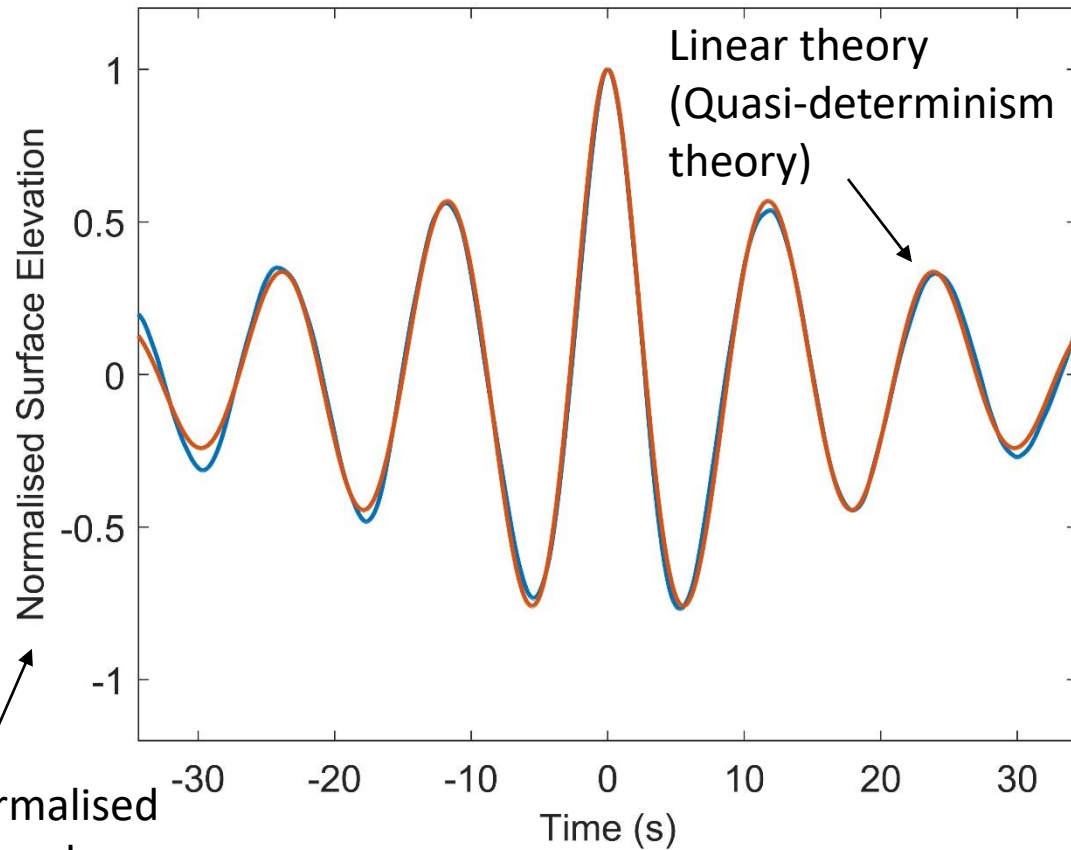


Normalised  
by peak  
amplitude

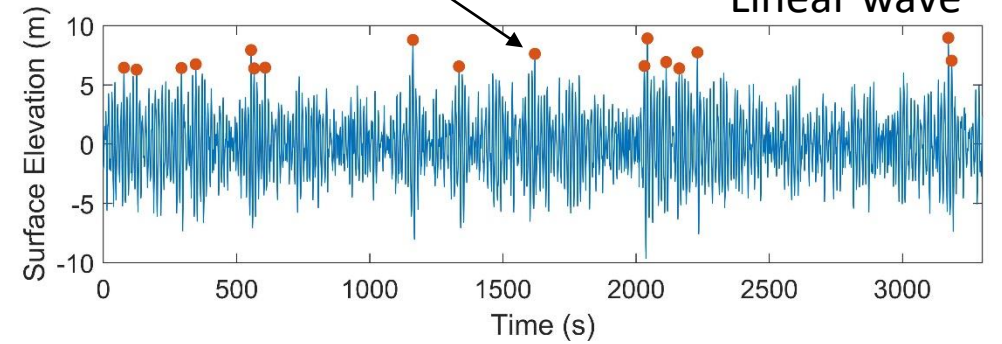
# Shape of Extreme Events



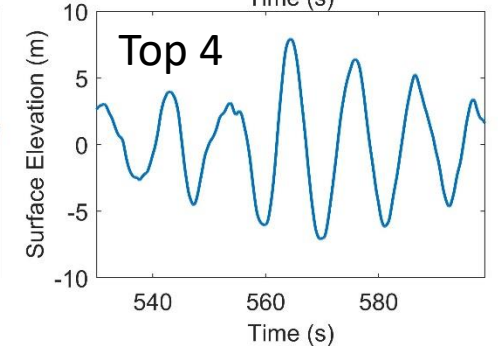
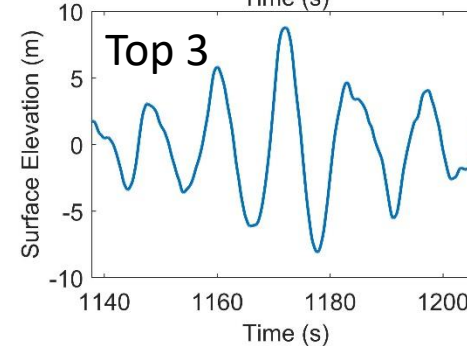
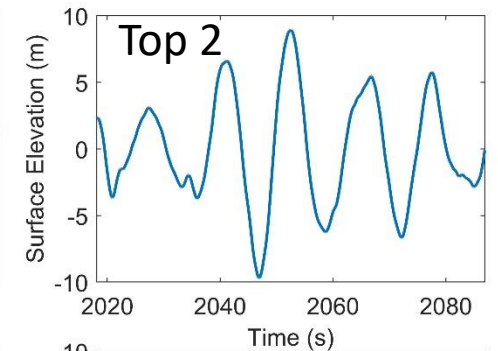
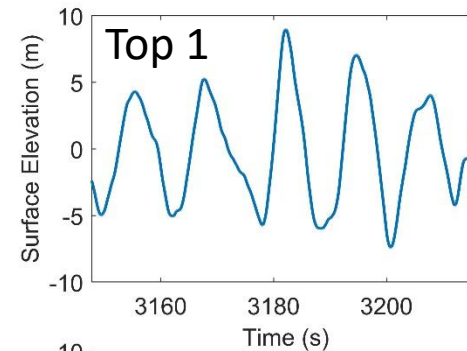
### Averaged extreme wave profile



### Top 17 largest waves

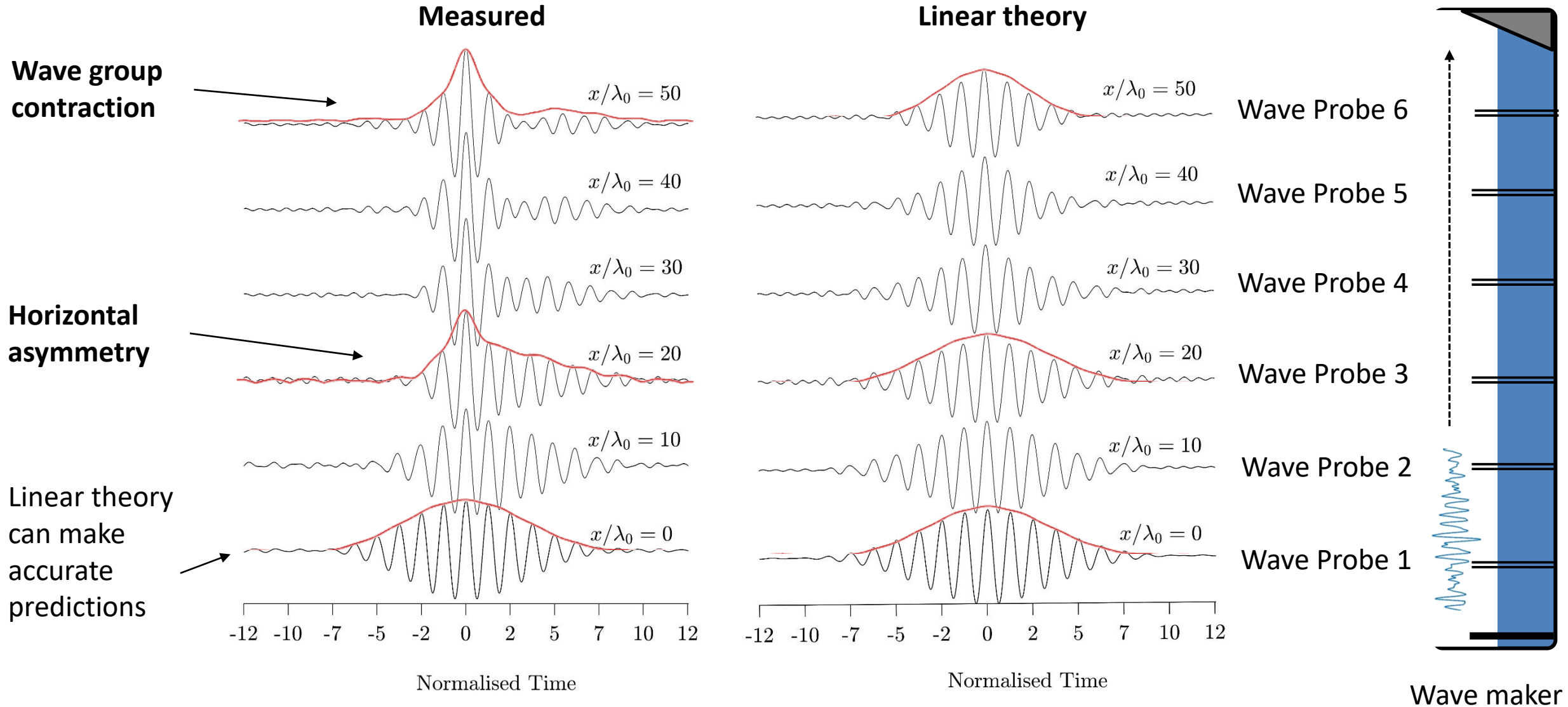


### Linear wave



Normalised  
by peak  
amplitude

# Shape of Extreme Events



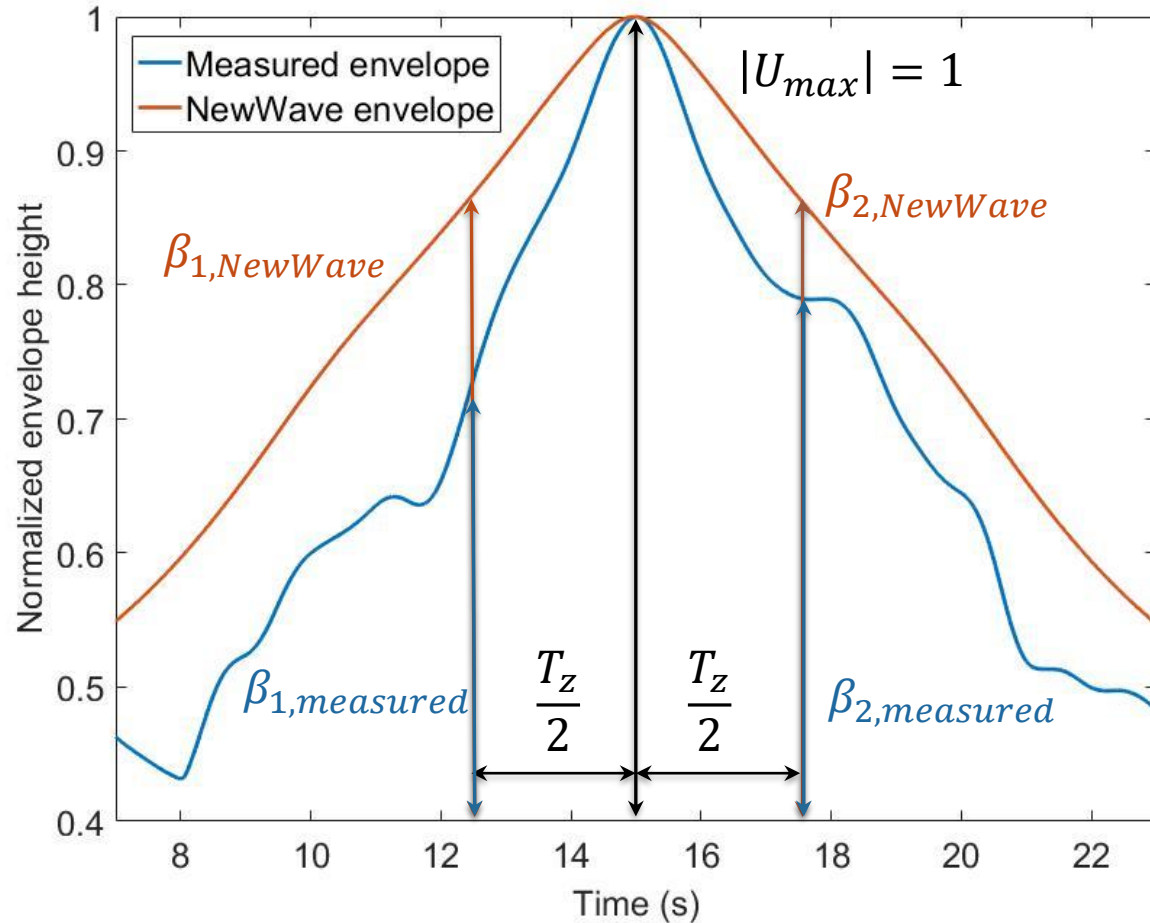
# Quantify the wave group changes

$$\frac{\beta_{2,measured}}{\beta_{2,NewWave}} - \frac{\beta_{1,measured}}{\beta_{1,NewWave}}$$

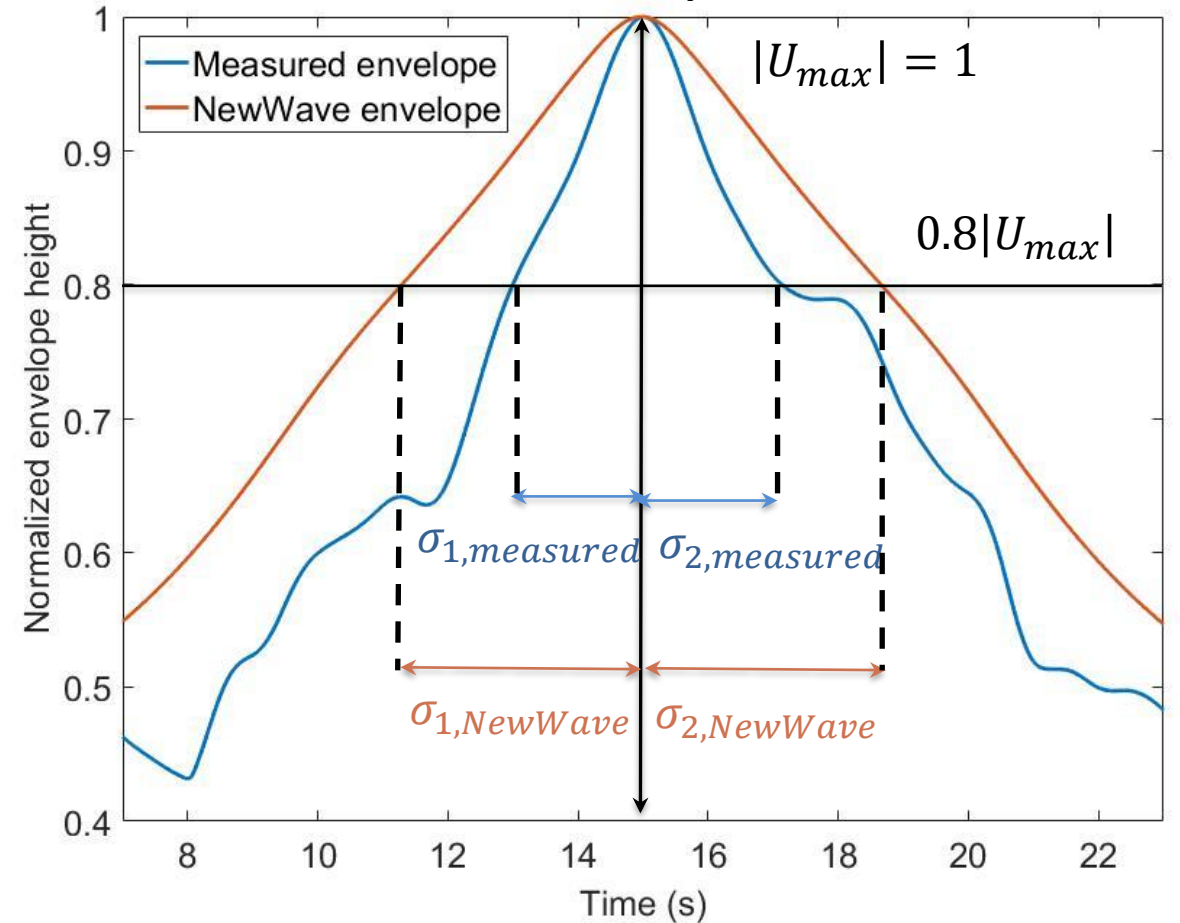
$$1 - \frac{\sigma_{1,measured} + \sigma_{2,measured}}{\sigma_{1,NewWave} + \sigma_{2,NewWave}}$$



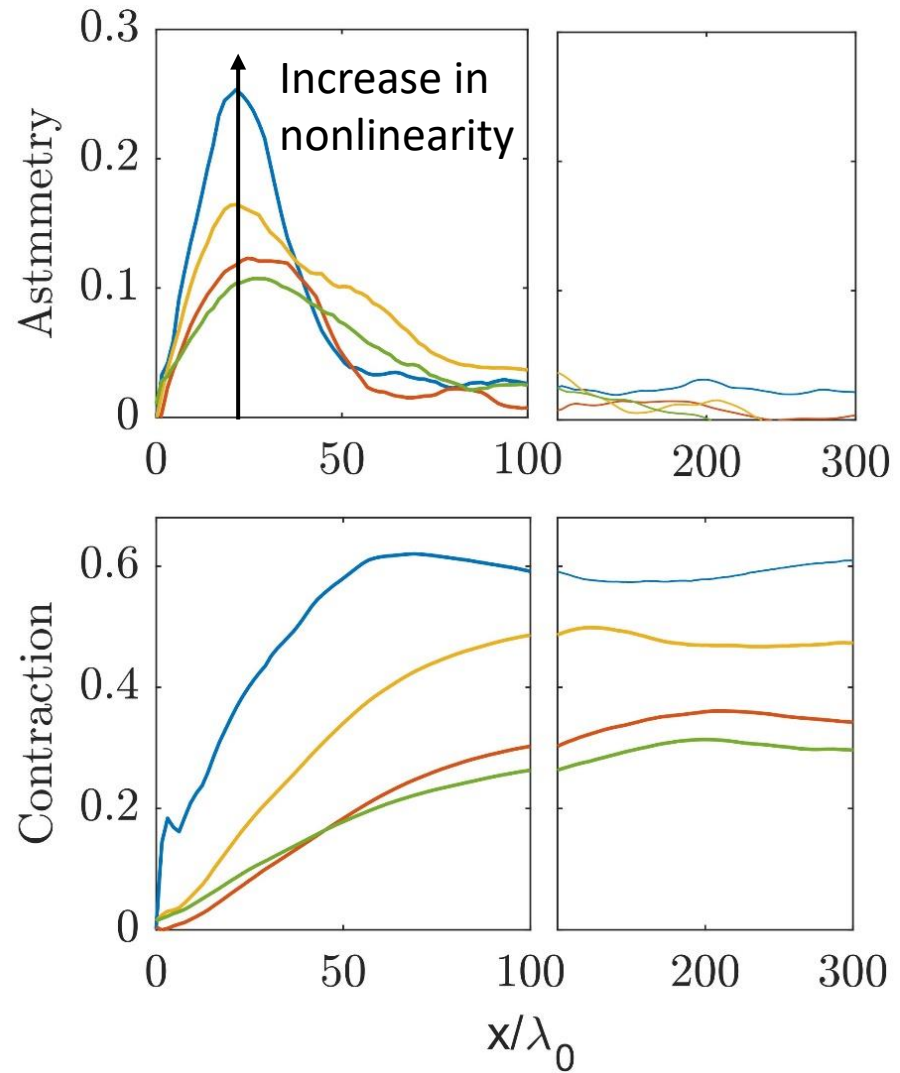
### Horizontal Asymmetry



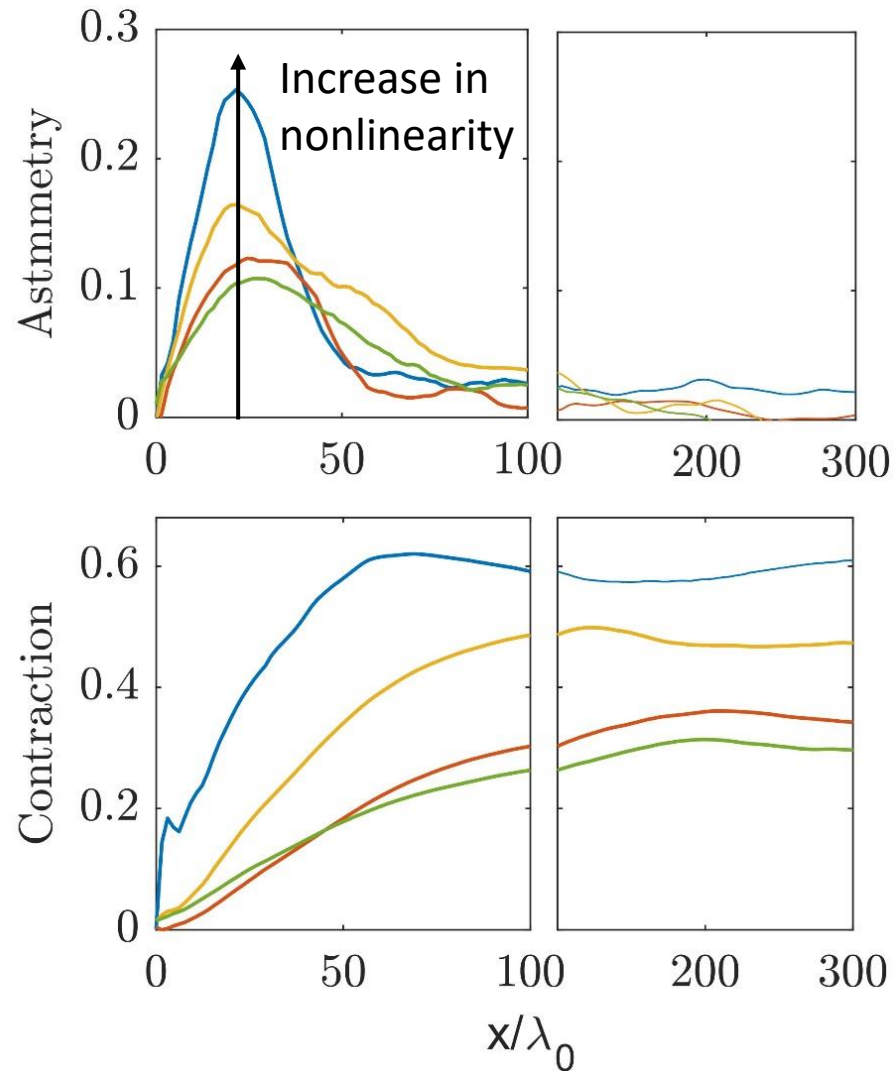
### Wave Group Contraction



# In the flume



# In the flume & Field data



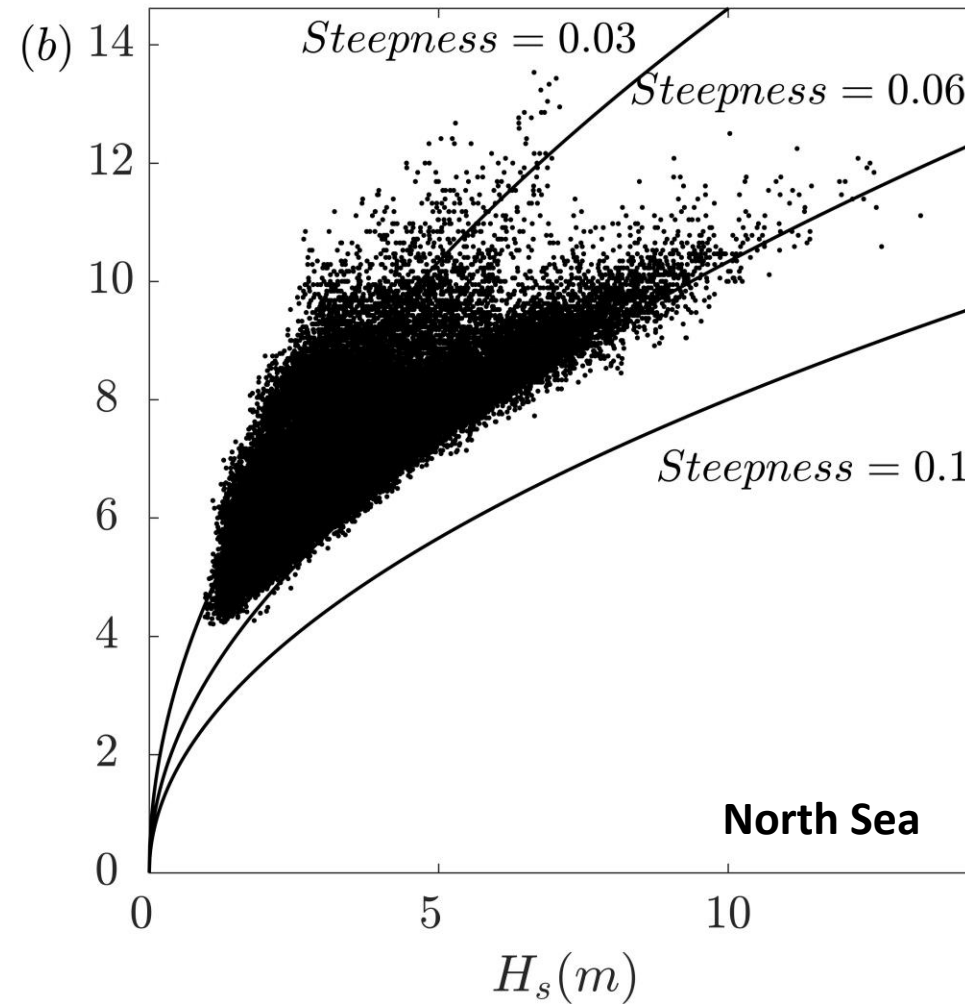
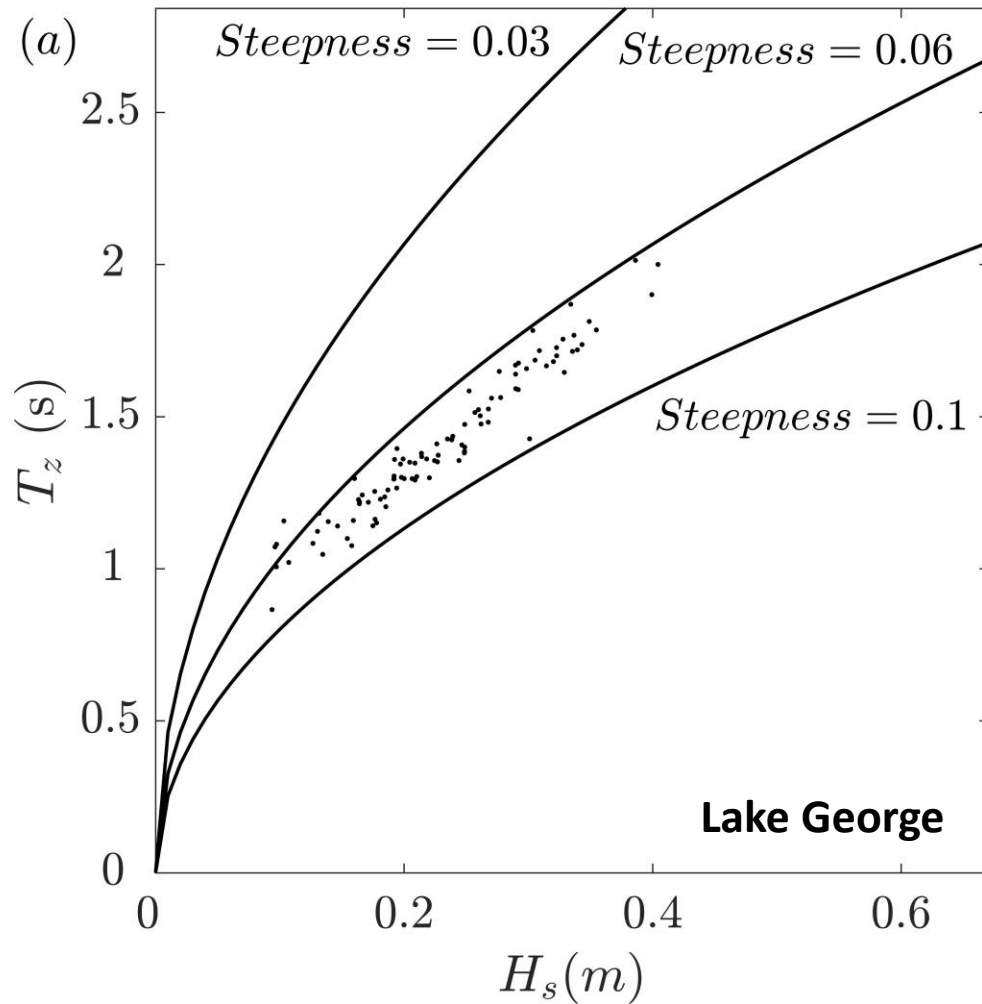
# Field data

$$\text{Steepness} = 2\pi H_s / g T_z^2$$

$T_z$ : Zero-crossing period

$H_s$ : Significant wave height

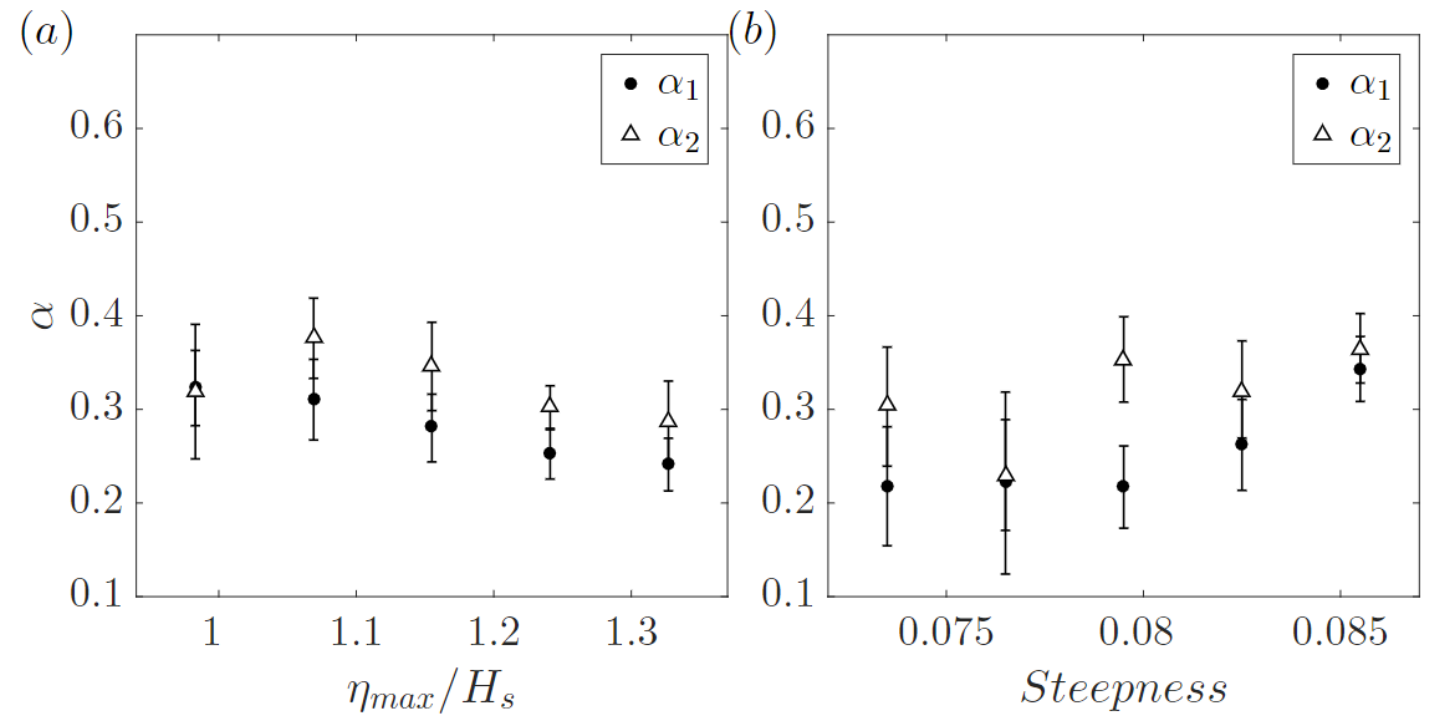
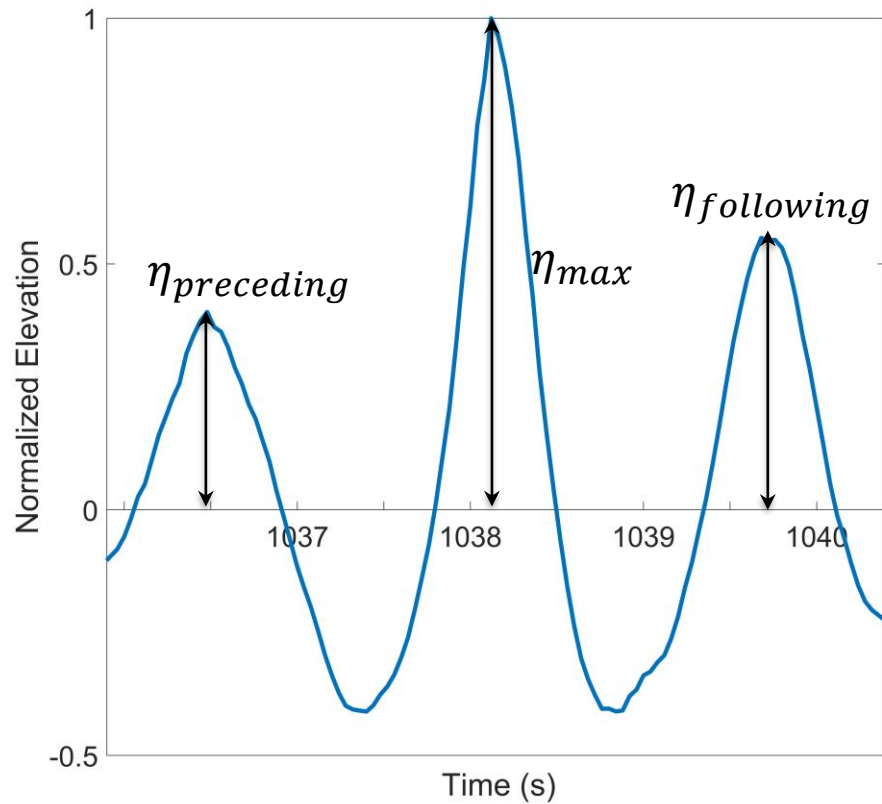
$g$ : Gravitational acceleration



# Asymmetry – Lake George

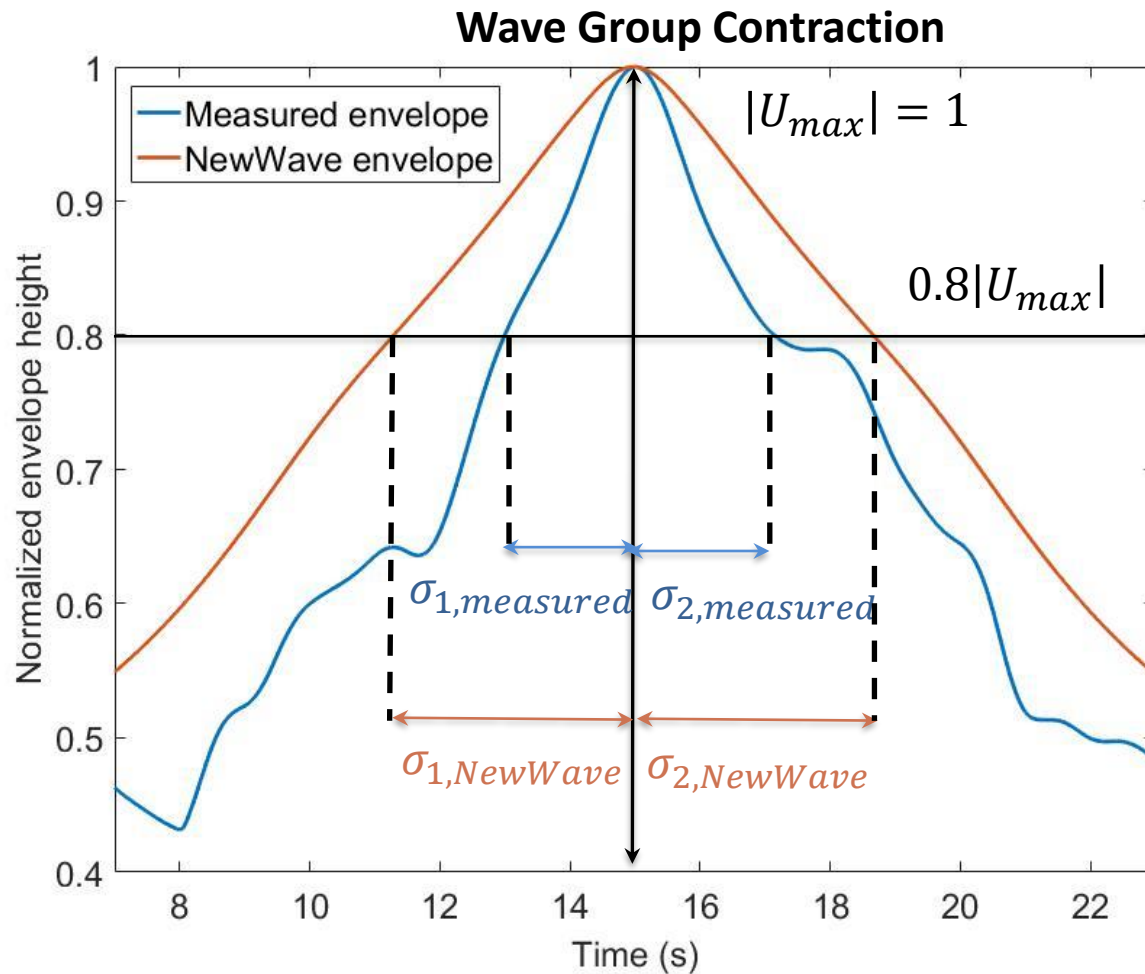
$$\text{Step preceding} = \alpha_1 = \frac{\eta_{\text{preceding}}}{\eta_{\text{max}}}$$

$$\text{Step following} = \alpha_2 = \frac{\eta_{\text{following}}}{\eta_{\text{max}}}$$





# Quantify the wave group changes



NewWave based  
envelope width half  
period before:

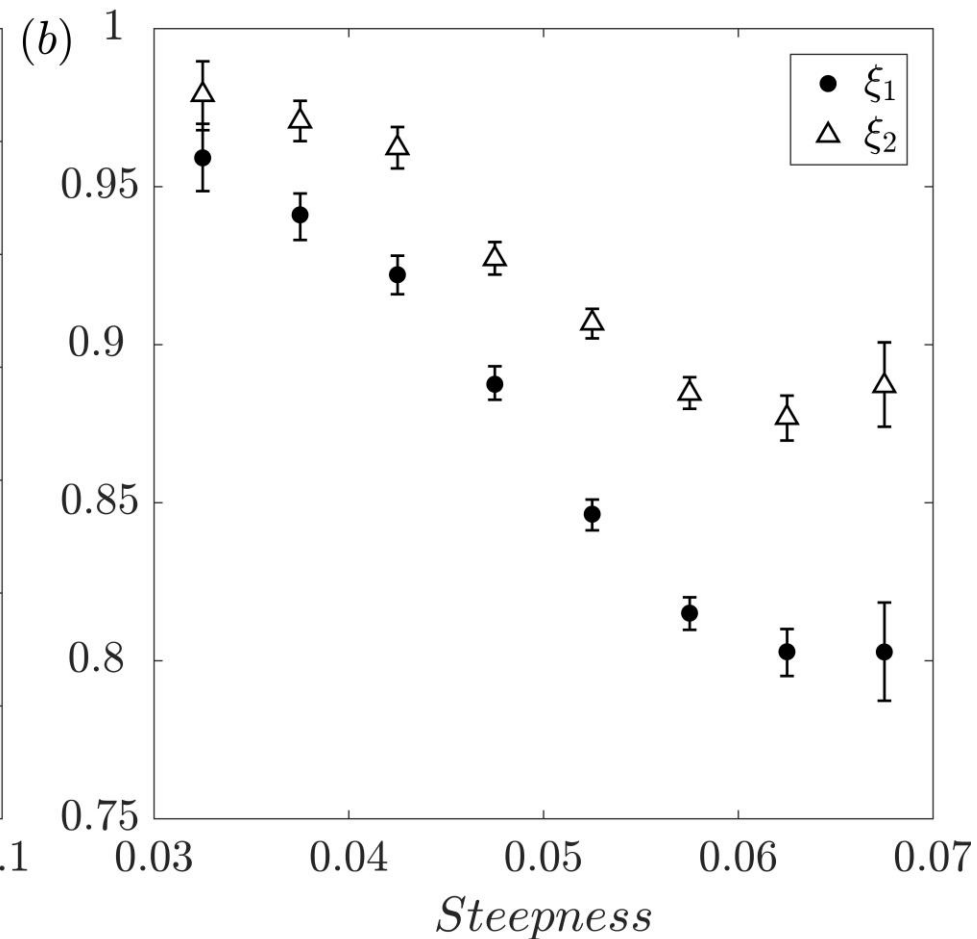
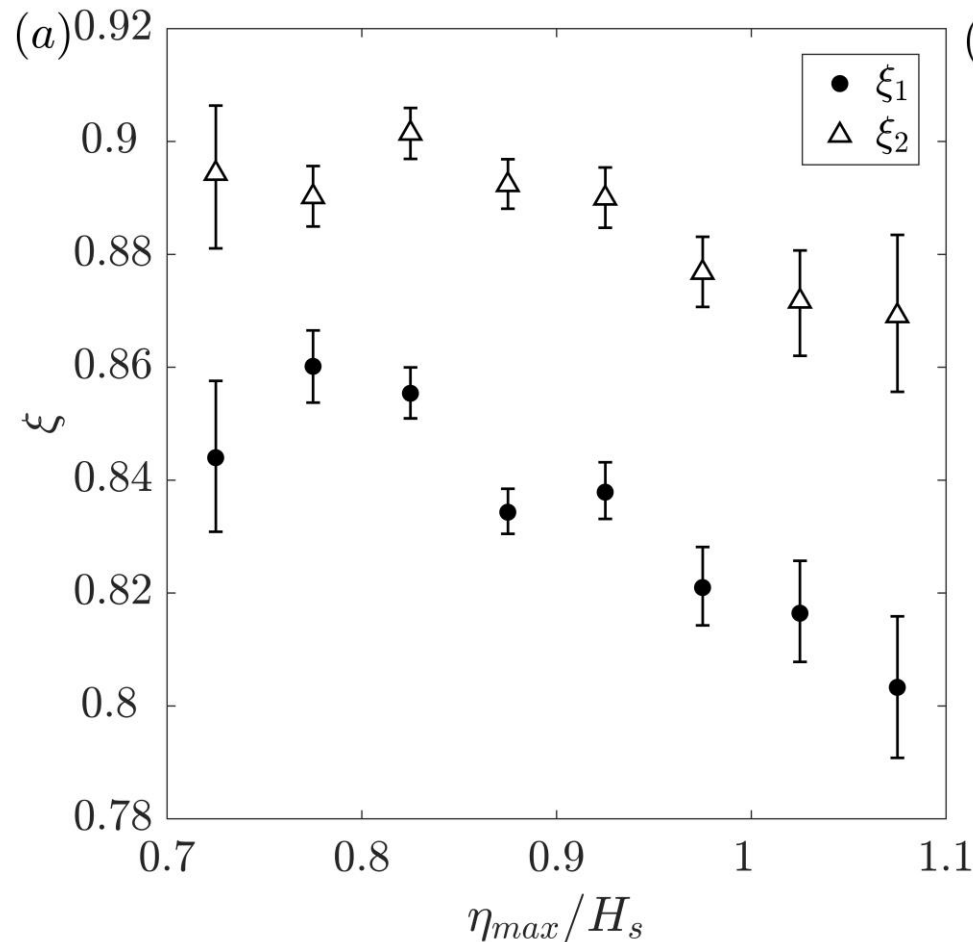
$$\xi_1 = \frac{\sigma_{1,measured}}{\sigma_{1,NewWave}}$$

NewWave based  
envelope width half  
period later:

$$\xi_2 = \frac{\sigma_{2,measured}}{\sigma_{2,NewWave}}$$



# Group Contraction - North Sea



NewWave based  
envelope width half  
period before:

$$\xi_1 = \frac{\sigma_{1,measured}}{\sigma_{1,NewWave}}$$

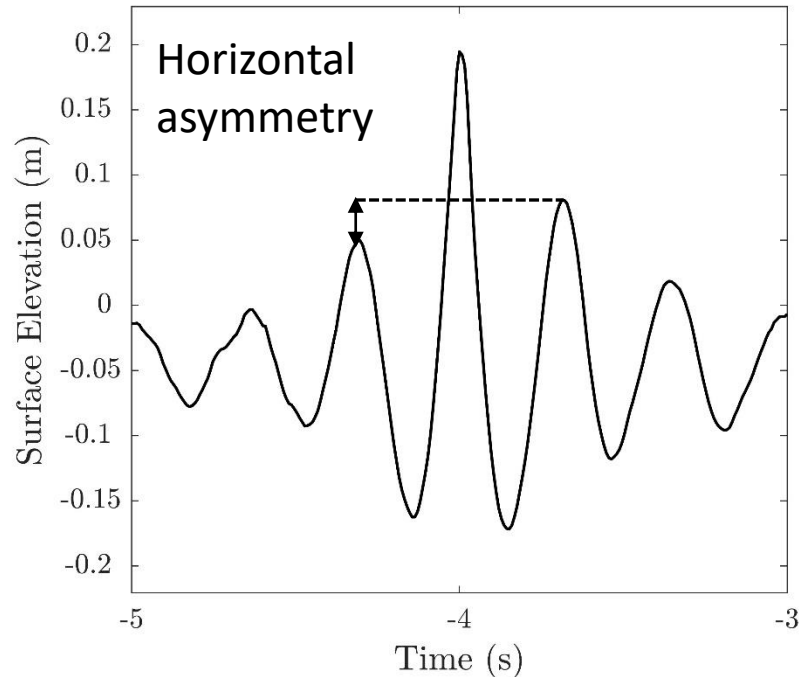
NewWave based  
envelope width half  
period later:

$$\xi_2 = \frac{\sigma_{2,measured}}{\sigma_{2,NewWave}}$$

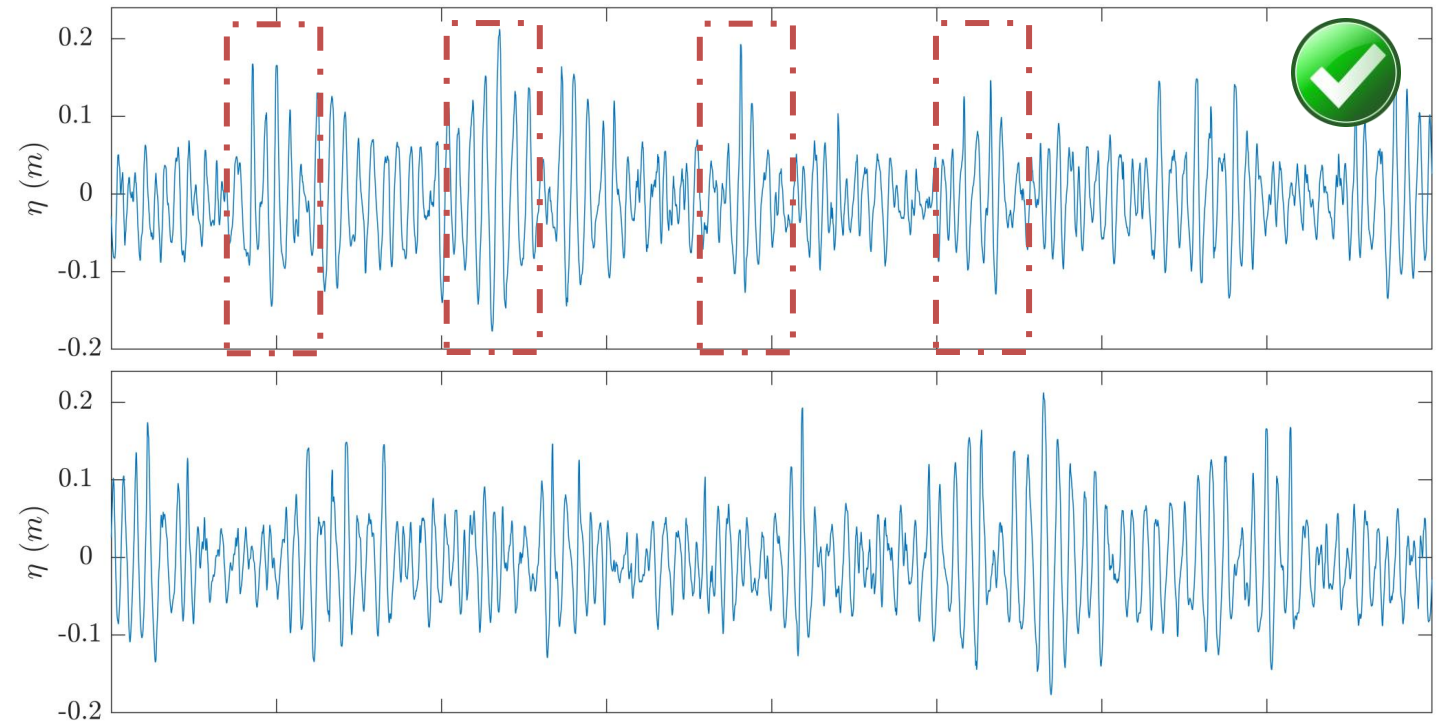
# Conclusion

## Averaged Shape of extreme events:

- The largest crest in the wave group tends to show *horizontal asymmetry* in natural occurring water waves.
- Wave envelope tend to *contract* in the mean wave direction.



## Quiz Answer



- T. Tang, P. Tromans, T. A. A. Adcock, (2019) Field measurement of nonlinear changes to large gravity wave groups. Journal of Fluid Mechanics, 873, 1158-1178. doi: 10.1017/jfm.2019.454
- T. Tang, W. Xu, D. Barratt, H.B. Bingham, Y. Li, P.H. Taylor, T. S. van den Bremer, T.A.A. Adcock (2020) Spatial evolution of the kurtosis of steep unidirectional random waves, Journal of Fluid Mechanics. 908, A3.
- T. Tang, M. J. Yelland, T. A. A. Adcock (2019) The average shape of large waves in the Norwegian sea -- is non-linear physics important? 38th ASME International Conference on Ocean, Offshore and Arctic Engineering



Thank you!

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