Basilisk from an industrial perspective

Extreme wave loads on offshore structures

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Basilisk from an industrial perspective

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  - Safety & integrity of structures at sea
- Section: Environmental Loading & Response

- Extreme wave loads on offshore structures

http://kobiecarouthers.weebly.com/uploads/1/8/2/3/18237875/9209698_orig.jpg

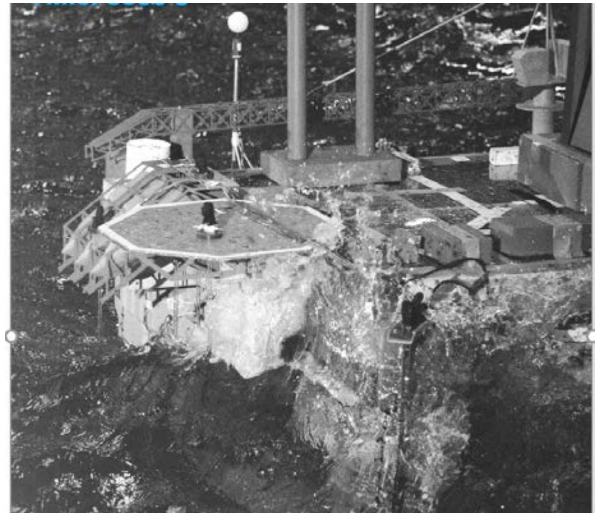
Maersk oil&gas,2016

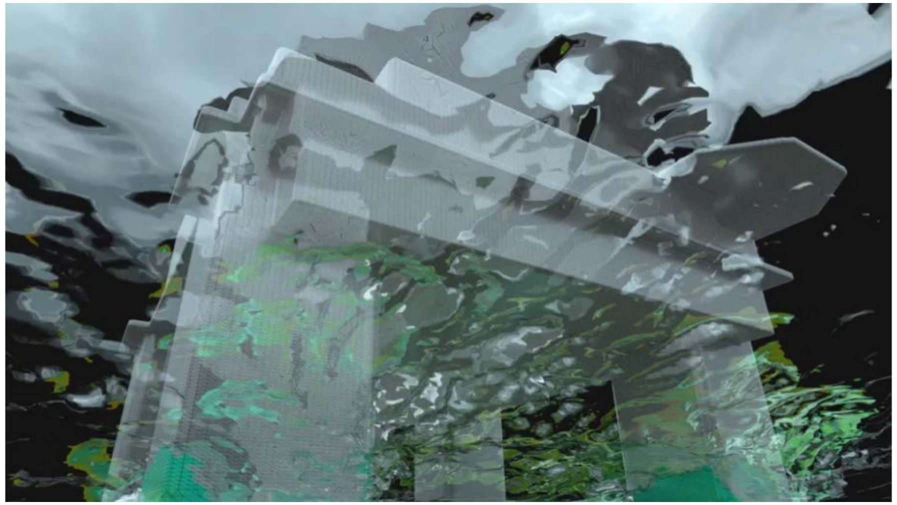
BBC News 2015 (https://youtu.be/D2dv57CpT-s)

Extreme wave loads on offshore structures: Two main challenges

- 1. The modelling of breaking waves
  - Model testing
  - CFD
- 2. The statistical problem
  - Which wave shall we model? (how high, steep, shape, etc)
  - What is the probability of a wave breaking exactly where my structure is standing?
  - Target: wave load with annual probability 10^-4

- Our goal with Basilisk: Run 100’s of wave simulations



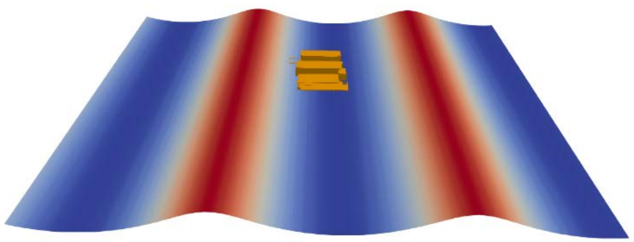


Modelling of realistic ocean waves in a numerical environment – Indeed a challenge

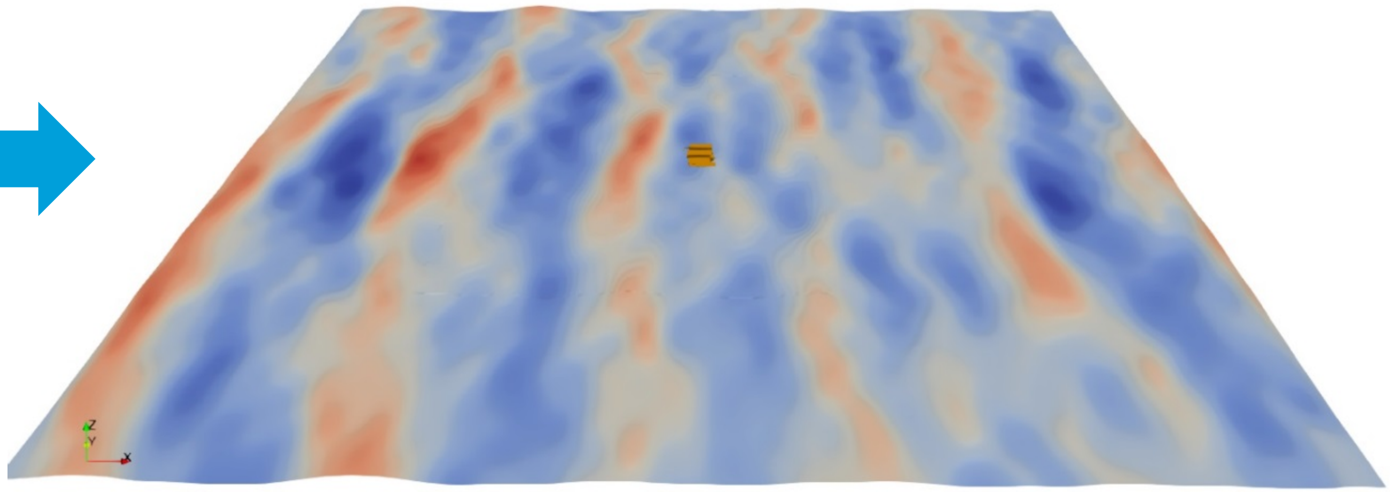
- Important factors which influences crest heights, wave shape and breaking limits
  - Short-crestedness
  - Irregularity
  - Wave evolution (breaking)

Typical simulation requirements:

1.5 x 1.5 km domain, 60-80 sec



The past

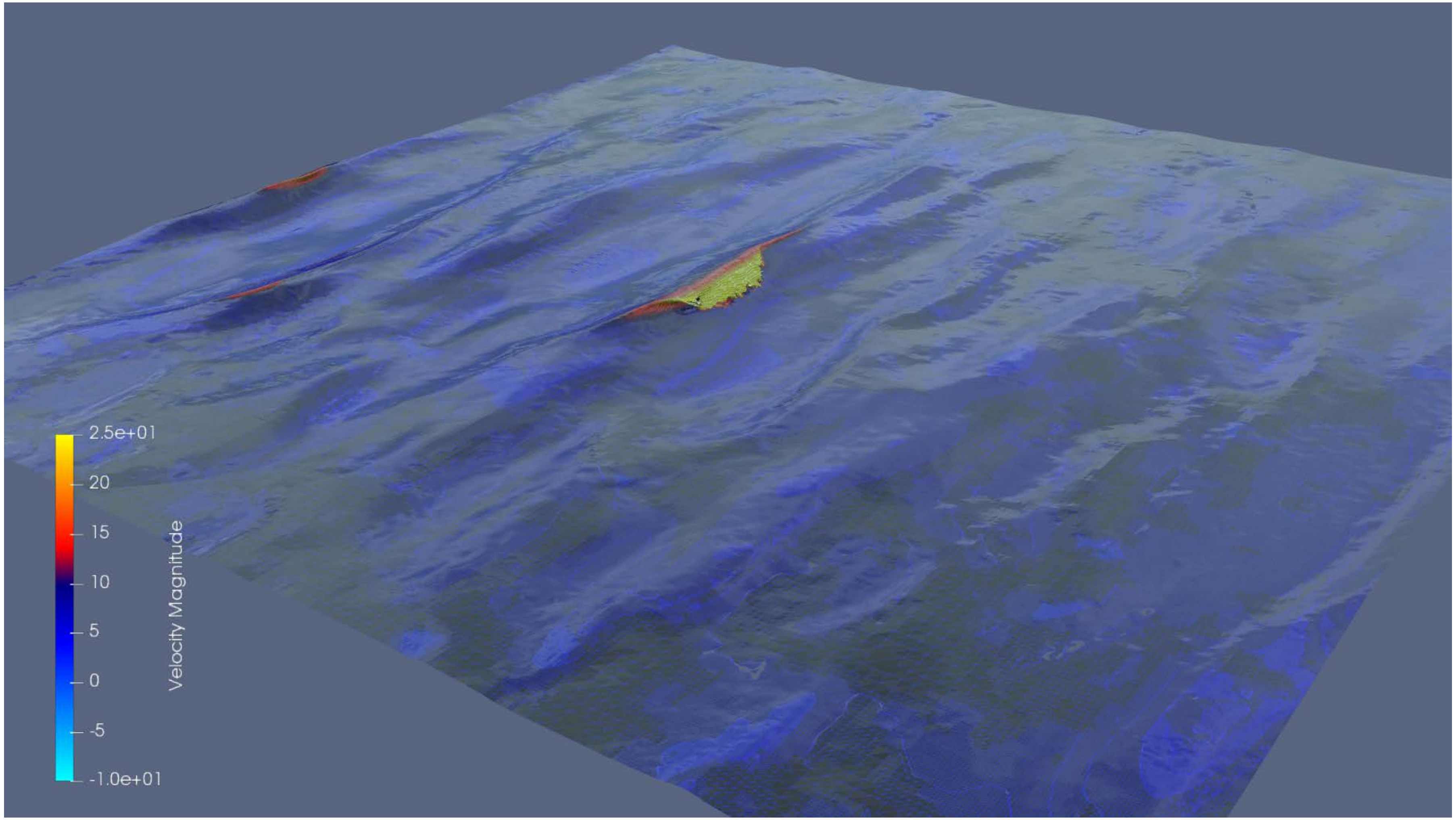


The present

Why Basilisk for ocean waves?

https://youtu.be/1KRlpboGX-A

- The vital components for successfully and effective modelling ocean waves
  - A good numerical implementation
  - **AMR**
  - **Octree mesh**
  - Accurate numeric implementation
  - Geometric VOF (PLIC or more advanced)
  - Momentum advection (in case of two-phase flow)
  - “reduced gravity approach”
- Tailor-made for wave propagation?



Basilisk OpenMP, rendered in Paraview & Blender

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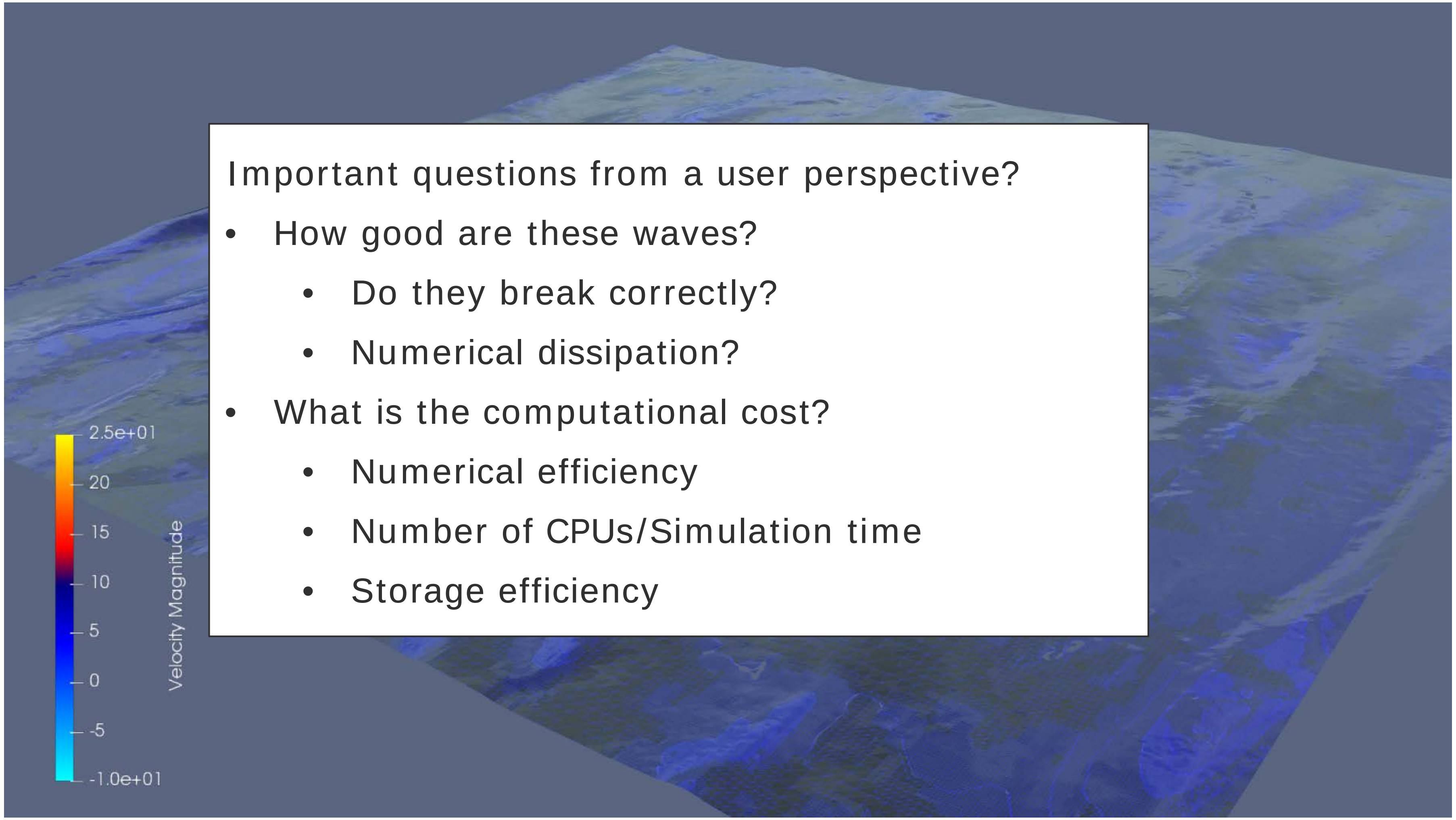


Important questions from a user perspective?

- How good are these waves?
  - Do they break correctly?
  - Numerical dissipation?
- What is the computational cost?
  - Numerical efficiency
  - Number of CPUs/Simulation time
  - Storage efficiency

Basilisk OpenMP, rendered in Paraview & Blender

Validation of CFD results

- model test of a wide range of irregular focused wave groups, with variation of
  – Wave spectrum
  – directional spreading
  – steepness
- Linear wave input known
  – Used as input to CFD, corrected to second order
  – **No tuning!**
- Measurements:
  – Wave elevation (various locations in the basin)
  – Particle velocity (LDA)

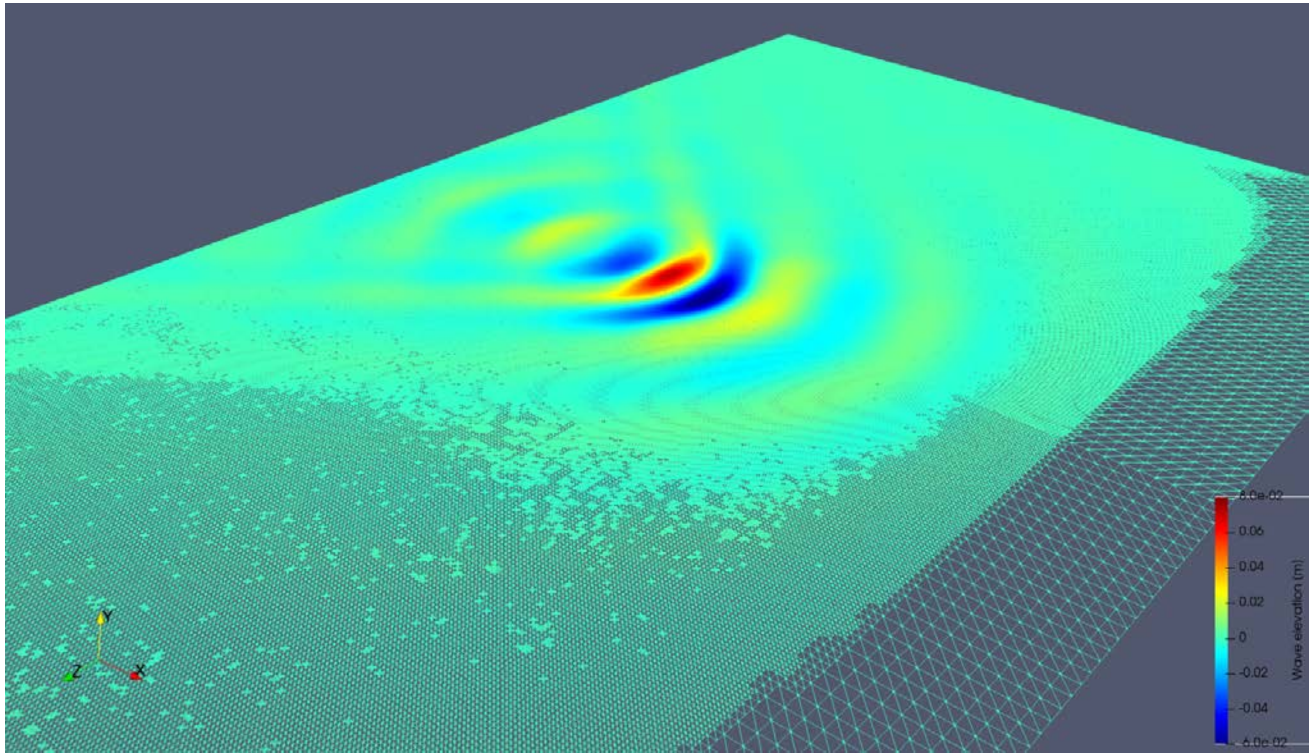
Table 3 Events simulated in CFD

Spectrum	Spreading factor s	Linear amplitude
B	uni-directional	20, 40 and 52 mm
B	s=4	20, 40, 55, 70 and 78 mm
D	uni-directional	20, 40, 55, 61 mm
D	s=4	20, 55, 70, 85 and 93 mm

OMAE 2018-78288 – *Propagation of steep and breaking short-crested waves – A comparison of CFD codes*

Comparison example

- OMAE 2018-78288 – *Propagation of steep and breaking short-crested waves – A comparison of CFD codes*
  - *Comflow and Basilisk*
- Example:
  - Spectrum D (narrow banded)
  - Spreading s=4
  - Linear amplitude 93mm (at the very limit where breaking was observed)



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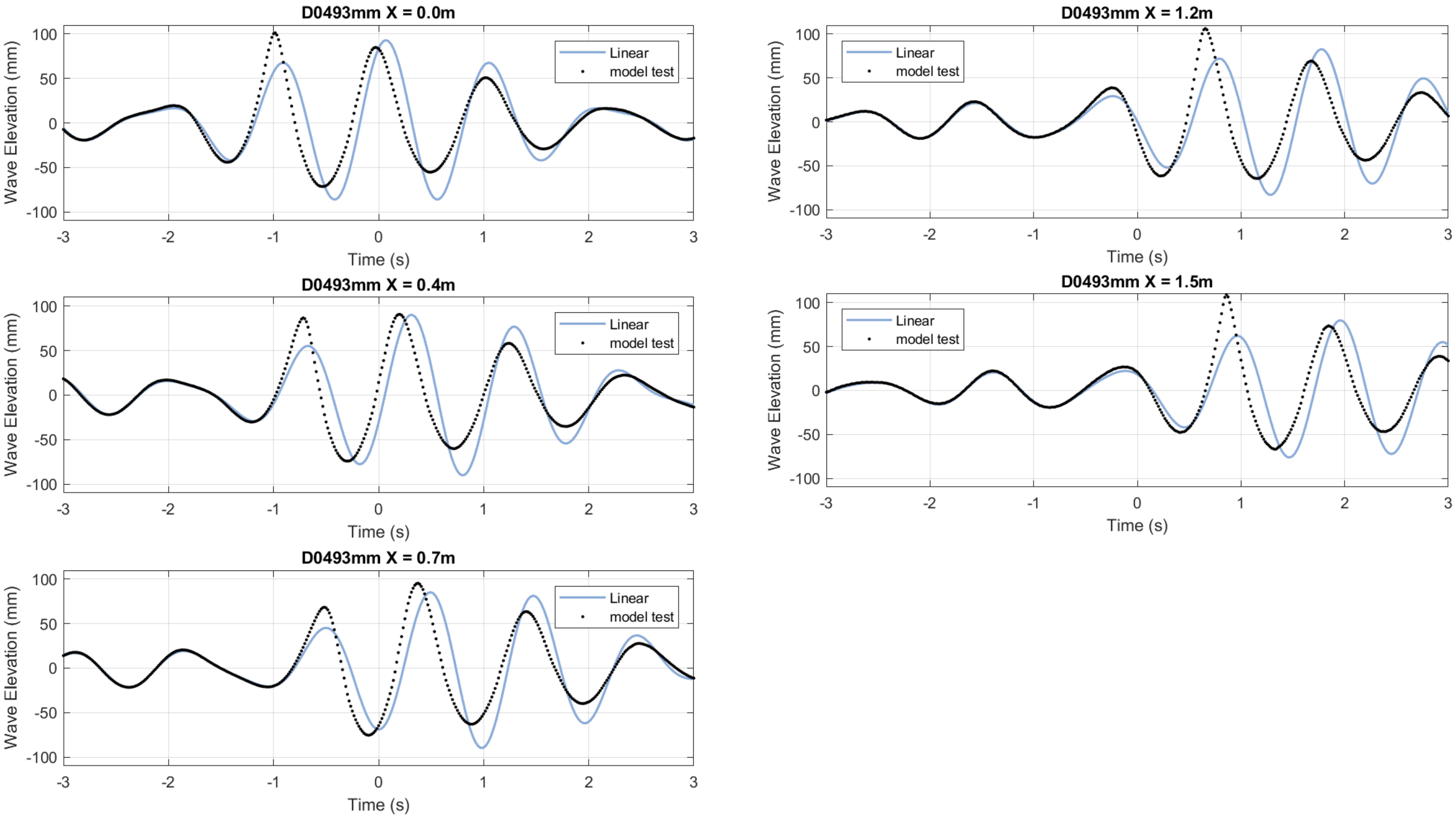
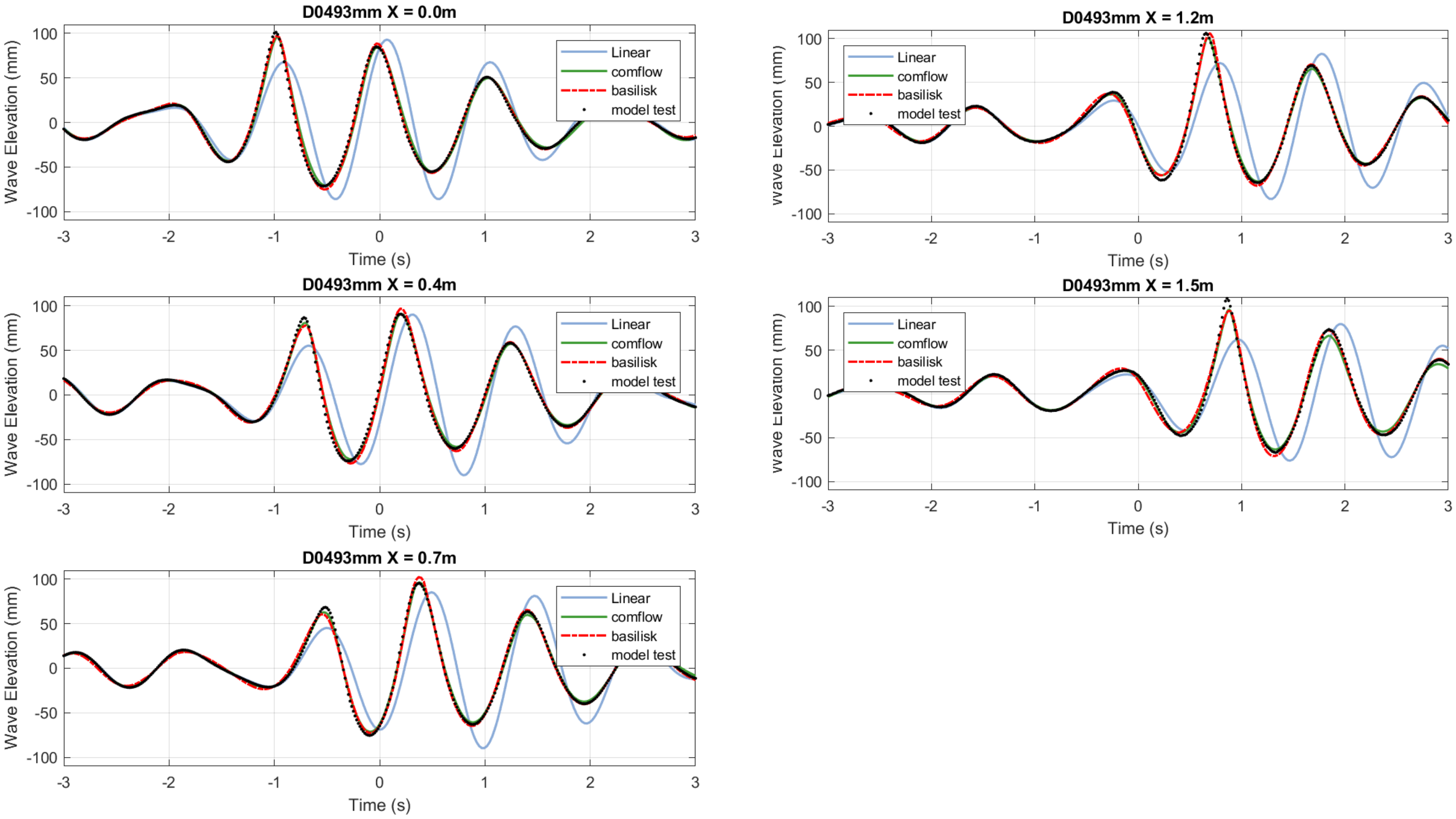
Ex1: Spectrum D, spreading s=4, Linear ampl 93m – at the very breaking limit



DNV·GL

Ex1: Spectrum D, spreading s=4, Linear ampl 93m – at the very breaking limit



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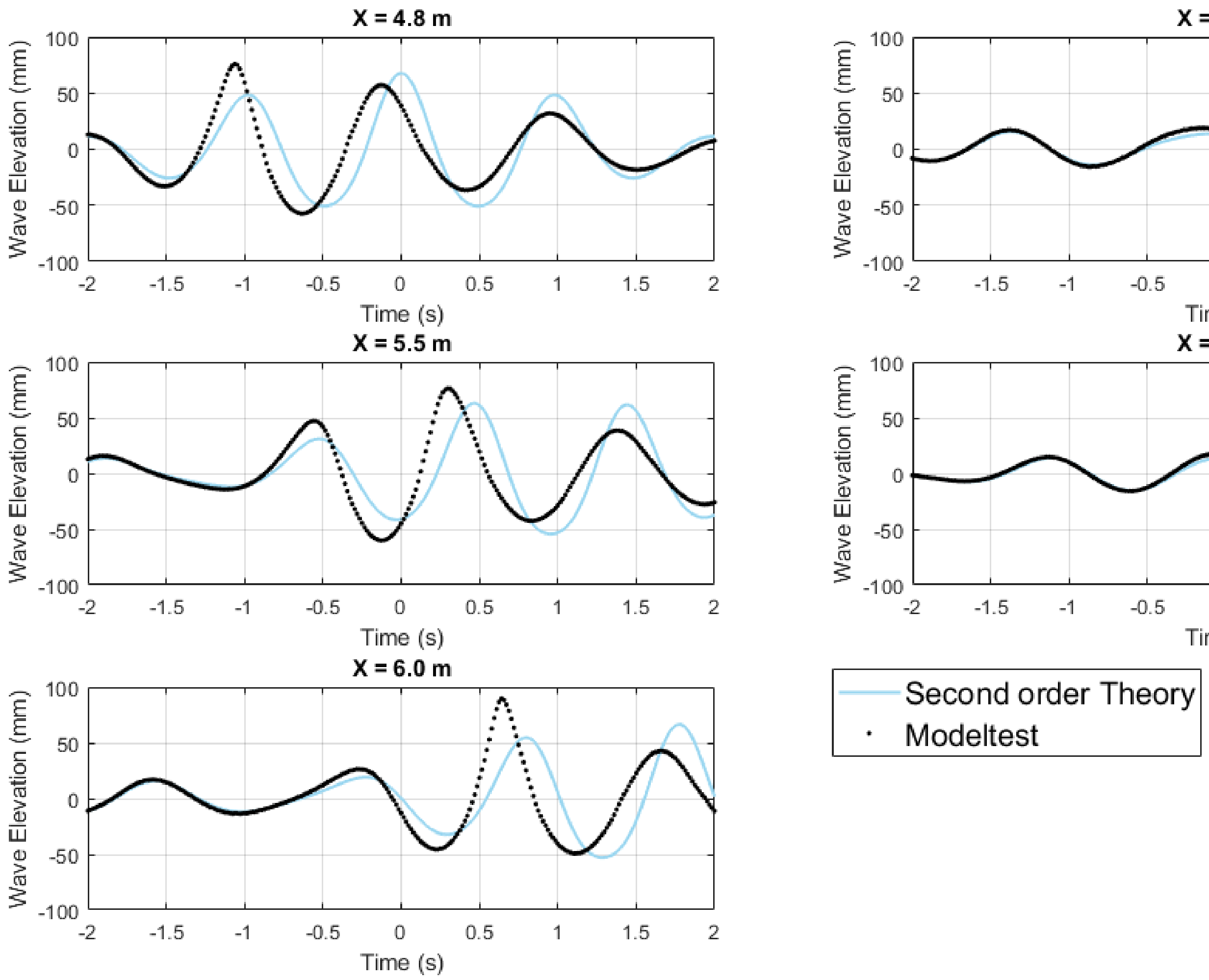
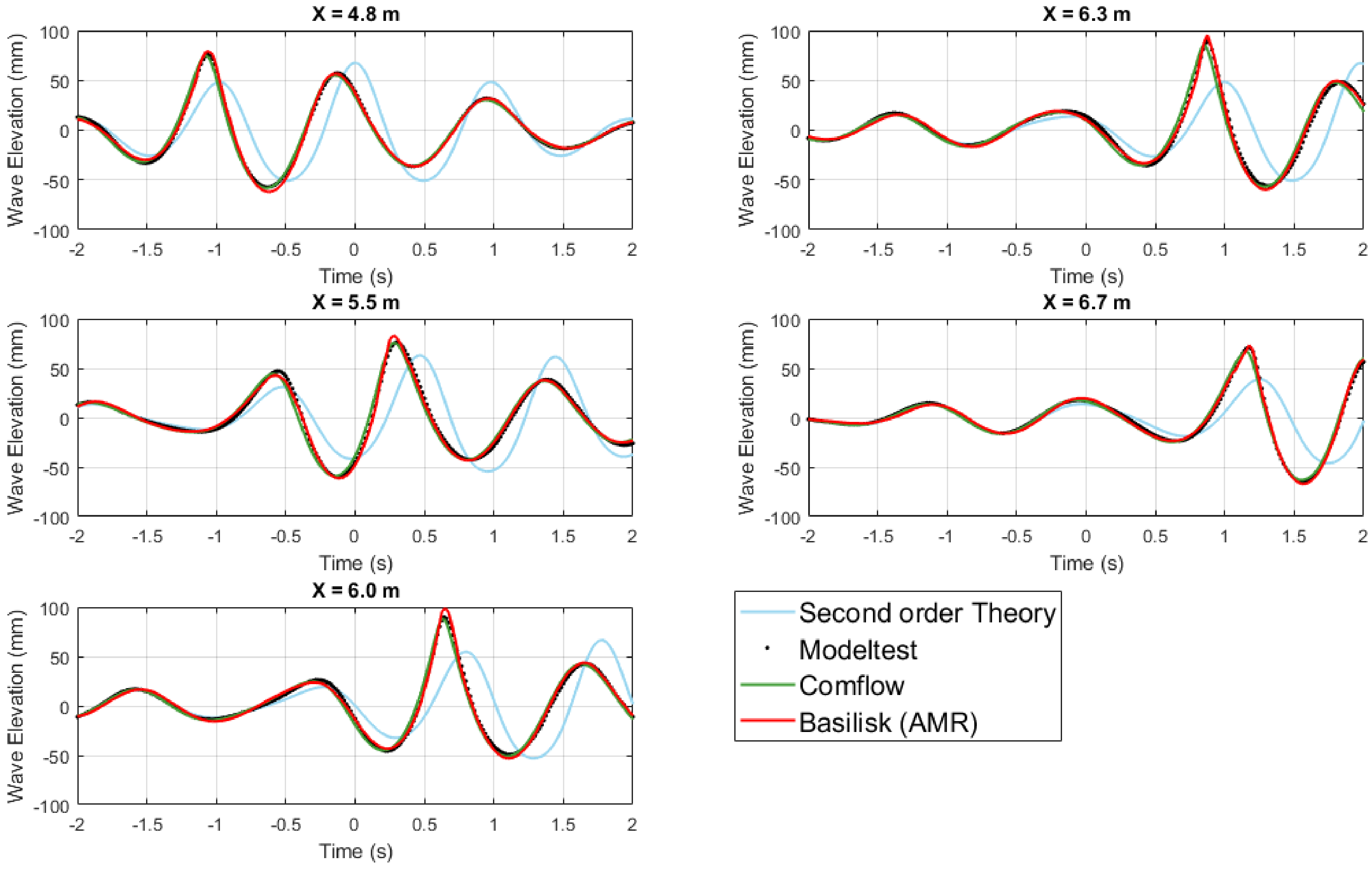
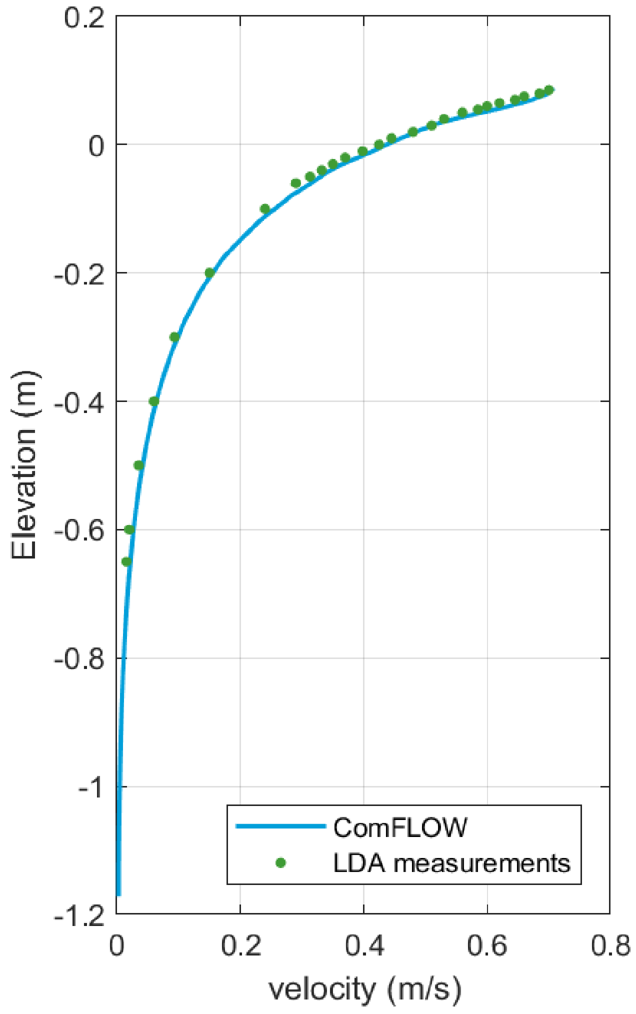
Ex2: Spectrum D, uni-directional, Linear ampl 61mm – at the very breaking limit



Ex2: Spectrum D, uni-directional, Linear ampl 61mm – at the very breaking limit





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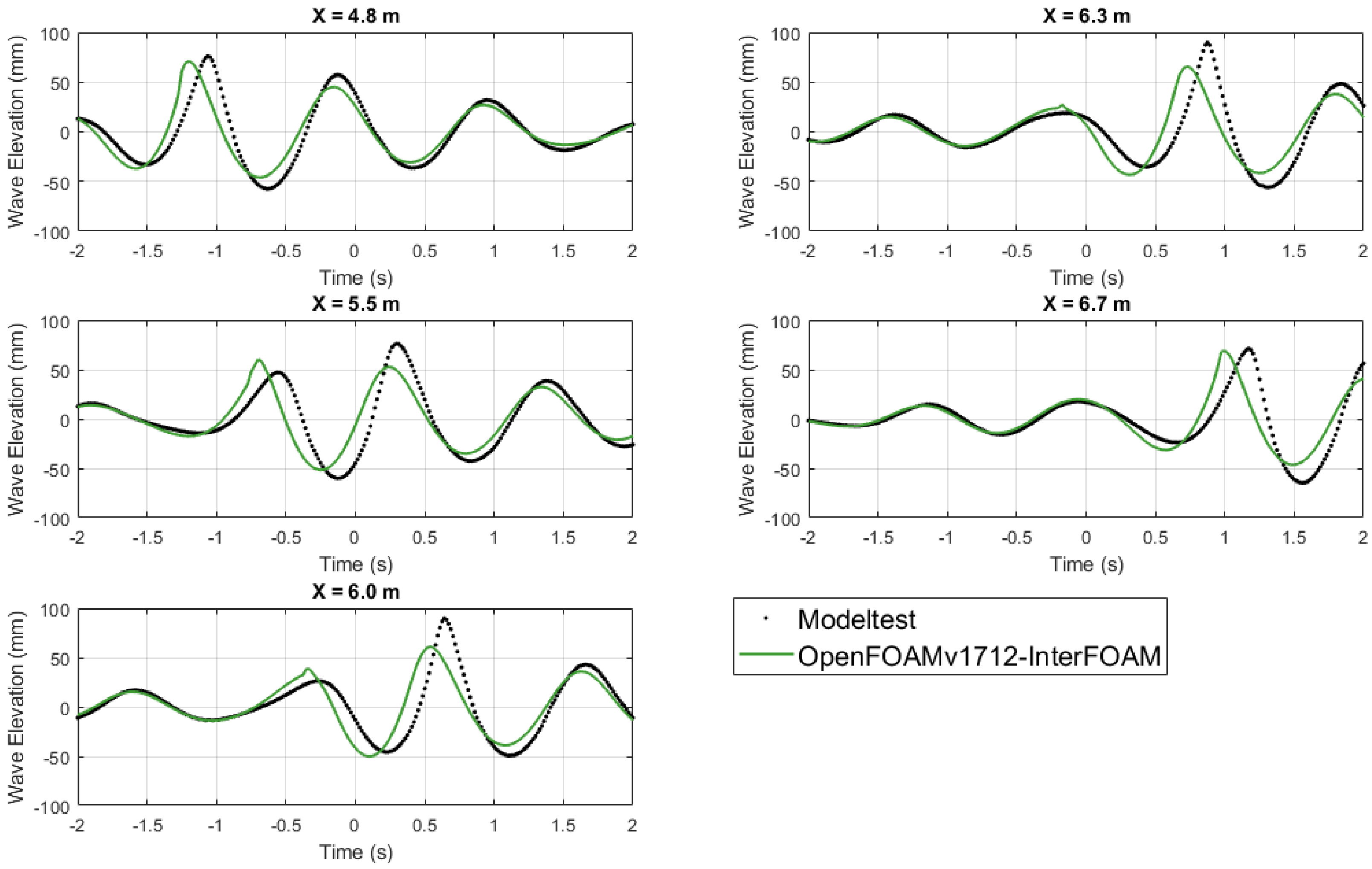
Example of failure to recreate model test wave:



- Works for lower amplitudes but steep waves break to early
- Large range of schemes and grid size attempted

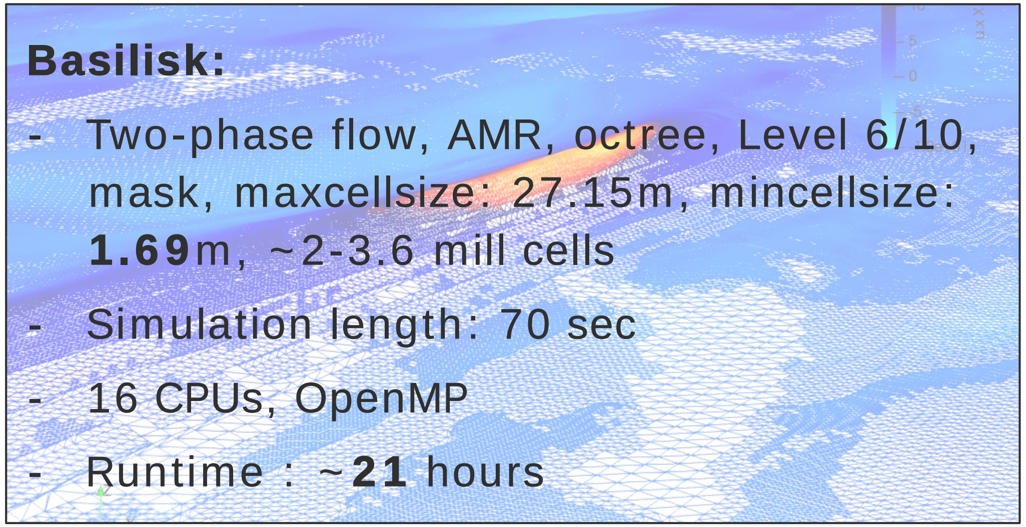
Comparison conclusion:

- The two codes (ComFLOW & Basilisk) evaluated in the paper seem to be very capable of propagating waves
  - Captures the non-linearities very well
  - Numerical energy dissipation – very little (provided the correct schemes are used)
  - Waves do not break prematurely

Performance

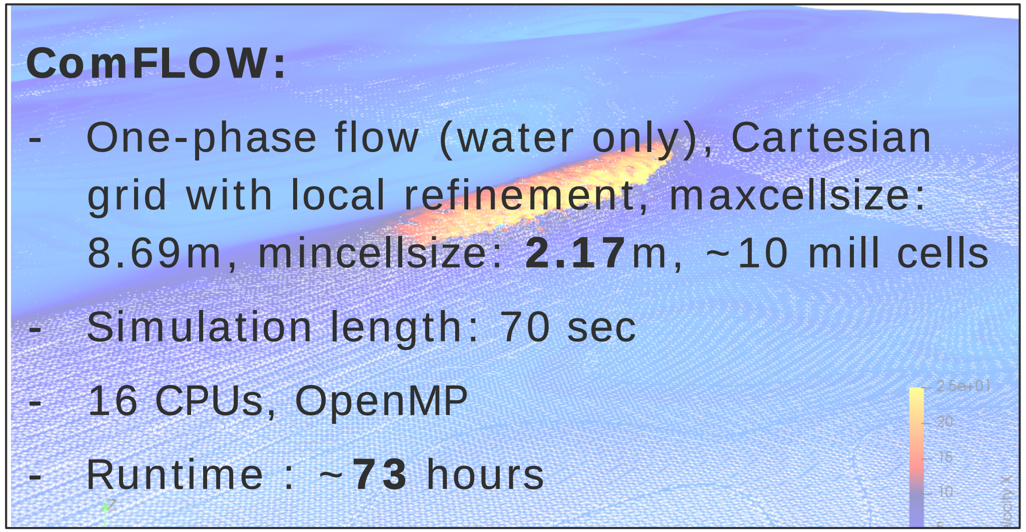
- Comparison to other codes
  - ComFLOW http://poseidon.housing.rug.nl/sphinx/index.html
  - Basilisk http://www.basilisk.fr/

- The big difference: Octree/AMR
  - Improves accuracy at desired locations
  - Reduced number of cells
    - Reduces calculation time and cost
    - Reduces storage cost
  - Expect runtime to come down with a better chosen AMR criteria



Basilisk:

- Two-phase flow, AMR, octree, Level 6/10, mask, maxcellsize: 27.15m, mincellsize: **1.69**m, ~2-3.6 mill cells
- Simulation length: 70 sec
- 16 CPUs, OpenMP
- Runtime : ~**21** hours

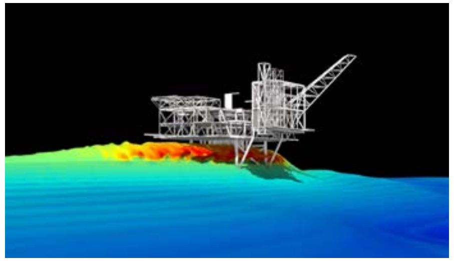


ComFLOW:

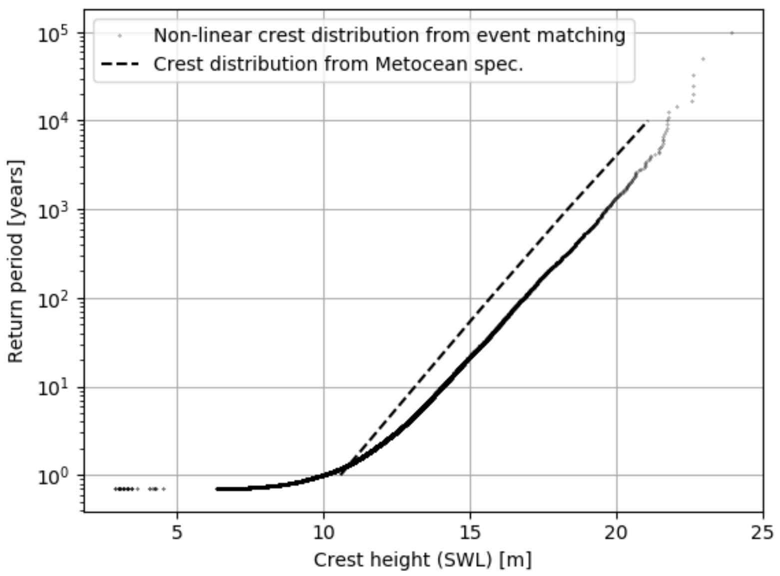
- One-phase flow (water only), Cartesian grid with local refinement, maxcellsize: 8.69m, mincellsize: **2.17**m, ~10 mill cells
- Simulation length: 70 sec
- 16 CPUs, OpenMP
- Runtime : ~**73** hours

Long term statistics of breaking wave properties

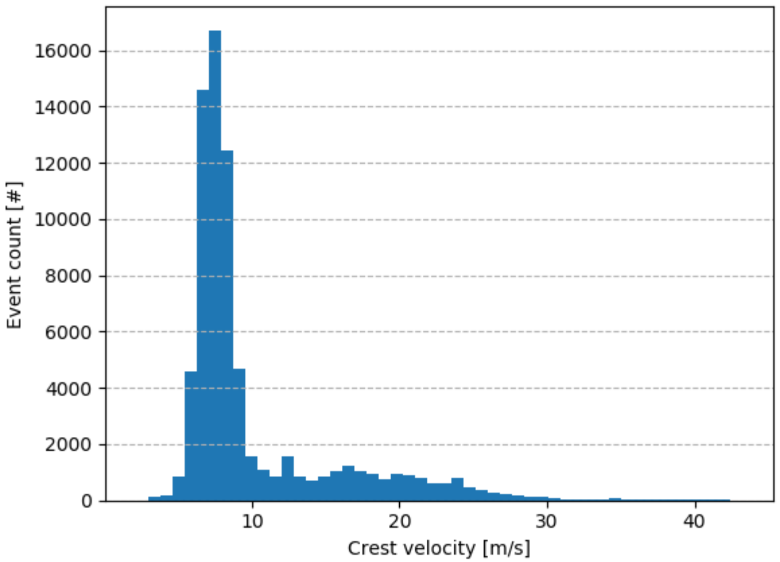
- Capable of running 100’s of events -> Statistics
- *OMAE 2018-78283: Long-term analysis by Event Matching*
  – Running a subset of events in CFD (100 or more), and use the stored kinematics to populate the long term distribution



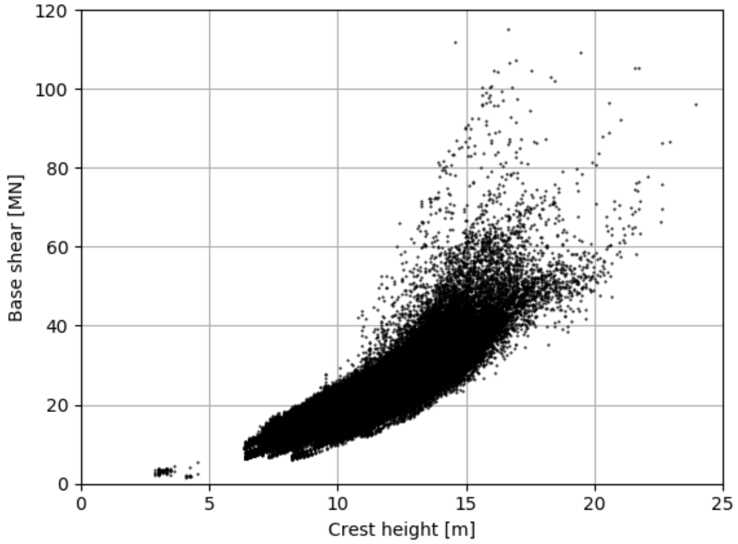
Long-term crest distribution



Distribution of crest velocity

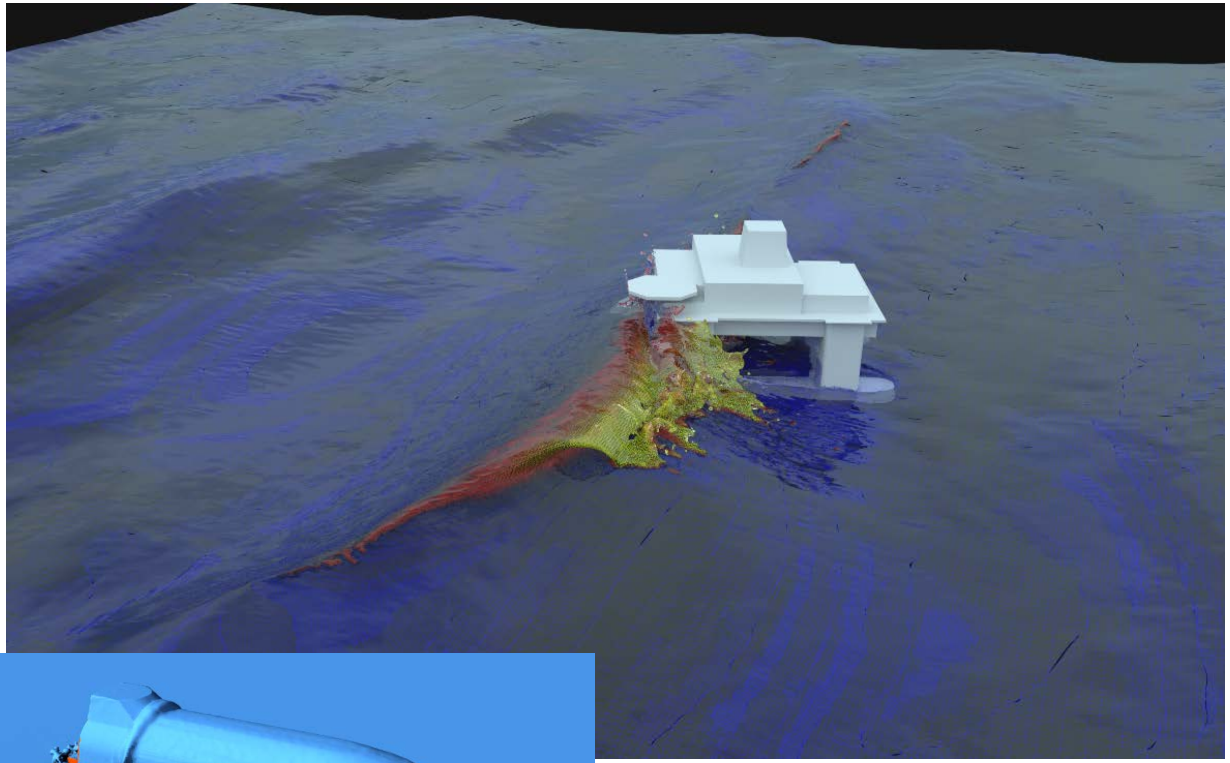


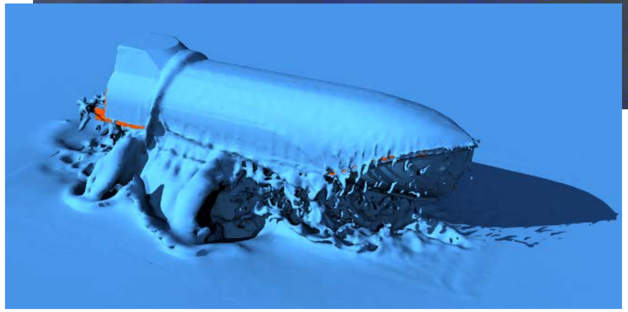
Distribution of wave load (base shear force)



Summary

- Large progress has been made in the modelling and understanding of breaking waves in the ocean thanks to modern CFD codes such as Basilisk
- Thumps up for embedded boundaries!





Questions?

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