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

Maersk oil&gas, 2016

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
Why Basilisk for ocean waves?

- 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?

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

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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>
<thead>
<tr>
<th>Spectrum</th>
<th>Spreading factor s</th>
<th>Linear amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>uni-directional</td>
<td>20, 40 and 52 mm</td>
</tr>
<tr>
<td>B</td>
<td>s=4</td>
<td>20, 40, 55, 70 and 78 mm</td>
</tr>
<tr>
<td>D</td>
<td>uni-directional</td>
<td>20, 40, 55, 61 mm</td>
</tr>
<tr>
<td>D</td>
<td>s=4</td>
<td>20, 55, 70, 85 and 93 mm</td>
</tr>
</tbody>
</table>

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)

*OMAE 2018-78288 – Propagation of steep and breaking short-crested waves – A comparison of CFD codes*
Ex1: Spectrum D, spreading s=4, Linear ampl 93m – at the very breaking limit
Ex1: Spectrum D, spreading s=4, Linear ampl 93m – at the very breaking limit
Ex2: Spectrum D, uni-directional, Linear ampl 61mm – at the very breaking limit

- **X = 4.8 m**
- **X = 5.5 m**
- **X = 6.3 m**
- **X = 6.7 m**

**Graphs:**
- Wave Elevation (mm) vs. Time (s)
- **Second order Theory**
  - **Modeltest**
Ex2: Spectrum D, uni-directional, Linear ampl 61mm – at the very breaking limit

- Second order Theory
  - Modeltest
  - ComFlow
  - Basilisk (AMR)
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

- 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

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

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**ComFLOW:**
- One-phase flow (water only), Cartesian grid with local refinement, maxcellsize: 8.69m, mincellsize: **2.17m**, ~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
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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