ARCHER2 Celebration of Science
7th - 8th March 2024

HEC-WSI
a High End Computing Consortium for Wave Structure Interaction

University of Plymouth
University of Exeter
Manchester Metropolitan University
University of Bath
City University London
Manchester 1824 The University of Manchester
Newcastle University
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Introduction to the HEC-WSI

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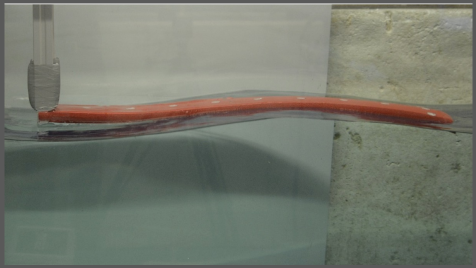
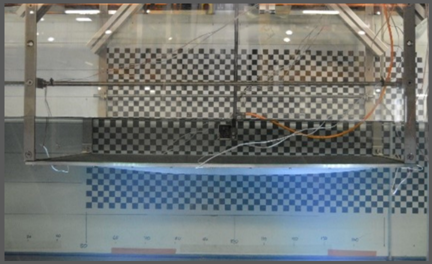
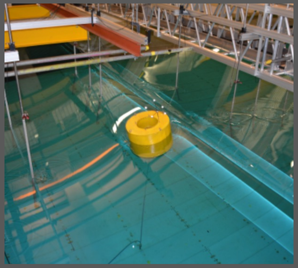
1. Science and Technology Facilities Council (STFC) , Hartree Centre
2. Science and Technology Facilities Council (STFC), Scientific Computing Department

Prof. Deborah Greaves
University of Plymouth, Centre for Coastal and Ocean Science and Engineering







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High end computing consortium for wave structure interaction (HEC-WSI)

- **Started:** 3rd January 2023
- **Ends:** 2nd January 2027
- **Funded by:** Engineering and Physical Sciences Research Council (EPSRC) [EP/X035751/1]
- **Motivation:** A new/emerging consortium to support the WSI community which is seeing rapidly increasing benefit from the use of HPC for modelling and simulation
- **Aims to:**
  - **Build a network** of computational researchers, and wider WSI community members, to **facilitate** world-class high end computing research in the field of WSI;
  - **Provide leadership** in developing strategic agendas for the WSI community;
  - **Enhance** the suitability of WSI software for high end computing;
  - **Provide a forum** to share knowledge and expertise;
  - Provide central core resource and **maximise community involvement** through inclusive and flexible access, opportunities and support.

HEC-WSI Management Group

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HEC-WSI Chair: Prof. Deborah Greaves (University of Plymouth)

University of Exeter · Manchester Metropolitan University · University of Bath · City University of London (Est 1894)

The University of Manchester (1824) · Newcastle University · UKRI Science and Technology Facilities Council

HEC-WSI Project Partners

The University of Edinburgh
Swansea University / Prifysgol Abertawe
Maynooth University / National University of Ireland Maynooth
Lancaster University
CIMNE — International Centre for Numerical Methods in Engineering
HydroWing
engys
National Research Council of Italy
AquaSpira
ARUP
JUST
Dalian University of Technology
Cardiff University / Prifysgol Caerdydd
University of Oxford
CCFE — Culham Centre for Fusion Energy
University of Stuttgart Germany
Kyoto University — Founded 1897
University of Cambridge
UKacm — UK Association for Computational Mechanics
Catapult — Offshore Renewable Energy
Warwick — The University of Warwick
University of Strathclyde Glasgow
University of Southampton
OpenCFD®
Indian Institute of Technology Madras
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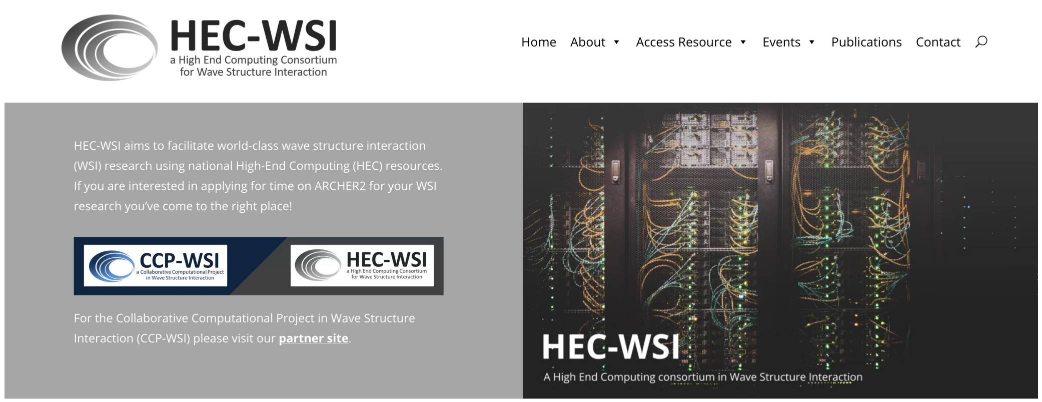
HEC-WSI Activities

- **Website:** https://hec-wsi.ac.uk/
- **Mailing List:** https://hec-wsi.ac.uk/contact/ (combined CCP-WSI, HEC-WSI, SIG-WSI list)



CoSeC
Computational Science Centre for Research Communities
www.cosec.stfc.ac.uk

- **Role of CoSeC in HEC-WSI**
  - Provide computational science support to the entire community (e.g. Scientific software development, HPC application engineering, Training)
  - Helping to enable computational infrastructure (e.g. website, data collation)
  - Undertaking specific workplan within the project

CoSeC Activities

CoSeC
Computational Science Centre for Research Communities
www.cosec.stfc.ac.uk

- **Programme of Work:**
  - WP1: Porting, Optimisation and code developments for WSI
    - Looking at key codes like OpenFOAM, ParaFEM, FEniCS and performing WSI-specific profiling on ARCHER2, looking at developments in GPU acceleration and sharing best practices and directly optimising WSI community codes.
  - WP2: Scientific use case development and sharing
    - **Fully-coupled use case – floating offshore wind turbine (FOWT)**
    - Showcase and provide a demonstrator for developments made in WP1
    - Openly accessible and shared as a benchmark
    - Used to explore machine learning techniques for low-cost surrogate model solutions
  - WP3: HPC Access Management
  - WP4: Training and Dissemination

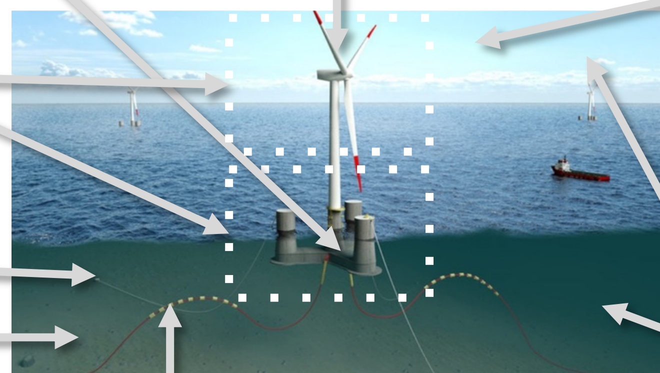
Coupled Multi-physics WSI Problem Definition: Floating Offshore Wind Turbine (FOWT)

Rigid Floating Body

Flexible Structure

Atmospheric Modelling

Near-field: multi-phase fluid dynamics and single phase aerodynamics



Anchors

Sea bed (soil mechanics)

Far-field: Potential flow for fluid dynamics and aerodynamics

Flexible tethering

https://www.ccp-wsi.ac.uk/data_repository/test_cases/test_case_015

Coupling Framework

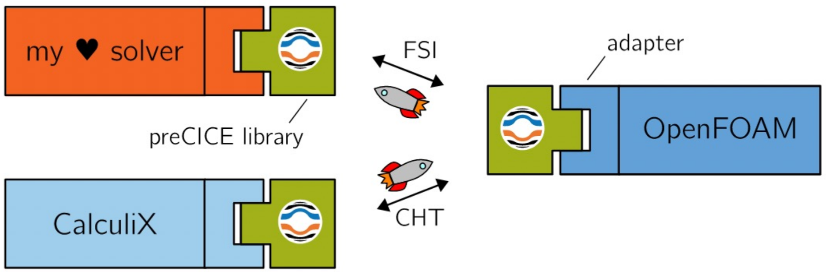
Monolithic approach

Pros	Cons
No communication overhead between solvers since both set of equations are solved as one linear system for each time step.	Require significant modification to existing solver to couple another set of equations for a different physics
No coupling iteration required for each timestep but solving the fully coupled linear system may require more iterations	Nature of coupling approach provides a tightly coupled and two way coupled system which may not be required

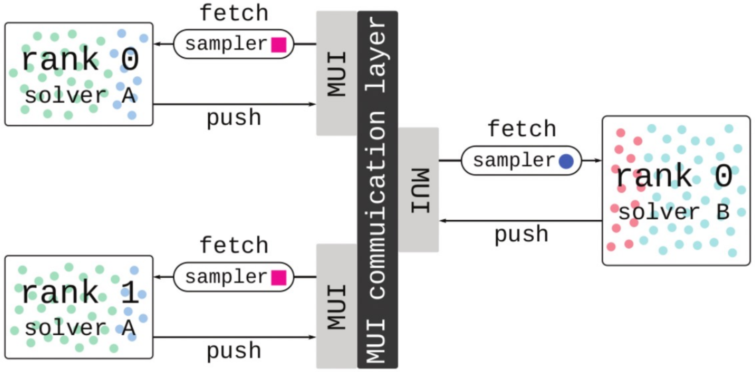
Partitioned approach

Pros	Cons
Choice of explicit or implicit coupling depending on the physics of the problem	May incur significant computational cost due to the coupling iteration between solvers in the case of implicit coupling
Use of existing specialized solver to solve the physical problem considered	May incur significant communication overhead between solvers depending on size of interface boundary (e.g. volumetric coupling)

Coupling Framework

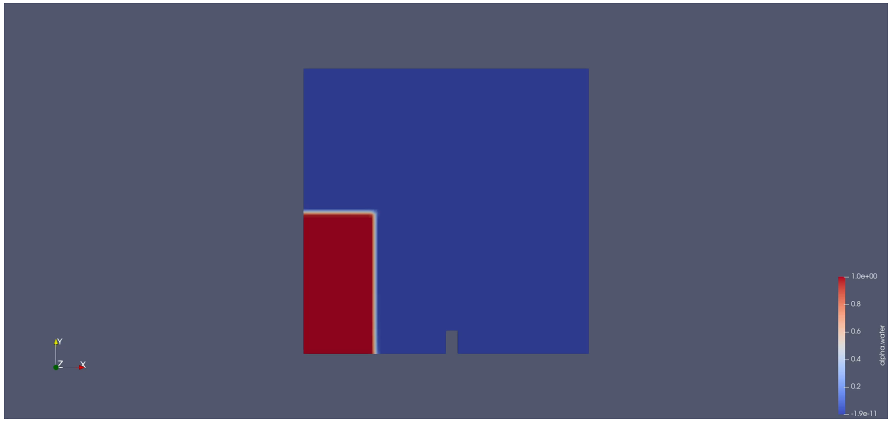


https://precice.org/



https://mxui.github.io/

2D flexible Dambreak



WP3: HPC Access Management

HEC-WSI Access Modes

- The HEC-WSI currently offers 3 access modes (plus a dedicated allocation for early career researchers (ECRs) incl. training and support):
  - Porting & Benchmarking (PB) (< 3 months);
  - Code Development (CD) (< 6 months);
  - Project Access (PA) (< 12 months);
  - ECRs Access (< 12 months).
- Open to international and industry collaborators provided the ARCHER2 usage aligns with the aims of the HEC-WSI

https://hec-wsi.ac.uk/access-resource/access-modes/

WP4: Training and Dissemination

Recent Training Activities

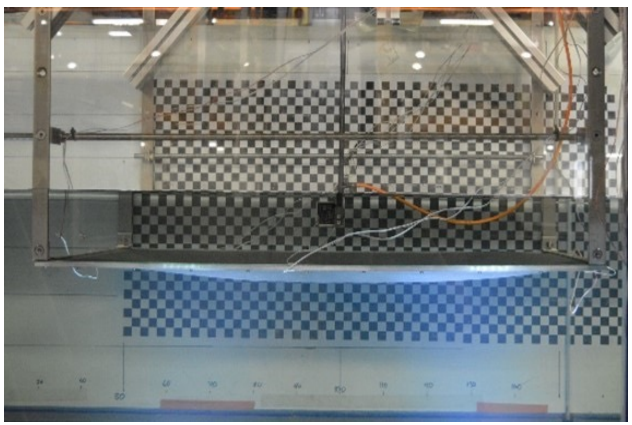
- CCP/HEC-WSI Code Coupling hackathons – June/July 2022

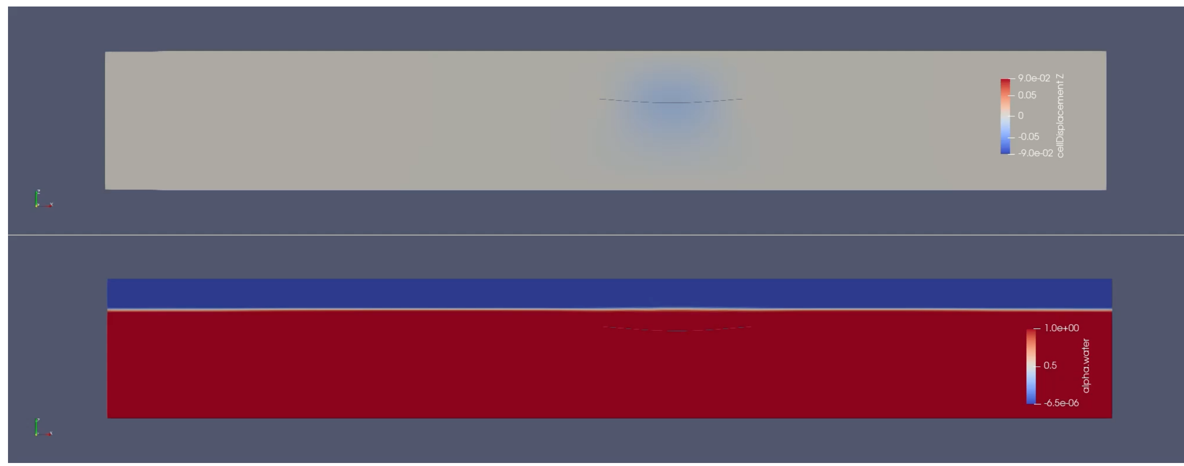
- CCP/HEC-WSI OpenFOAM Training workshop – June 2023

Recent HEC-WSI Supported Examples

Focused Wave Interactions with a submerged flexible membrane (CCP-WSI Blind Test 4)

- Understand how thin flexible membrane displaced under equilibrium and focused wave conditions
- Benchmarking two way coupled FSI Model on Archer 2 HPC





Experimental figure is obtained from https://www.ccpwsi.ac.uk/data_repository/test_cases/test_case_014

Recent HEC-WSI Supported Examples

Investigating flow field characteristics around Artificial reefs (Reef Cube®)

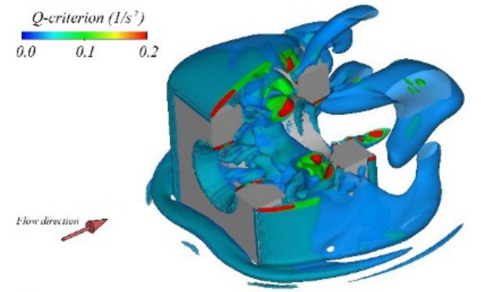
Amir Bordbar[1], Vasilios Kelefouras[1], Yeaw Chu Lee[1]

[1]University of Plymouth

Access mode: HEC-WSI partner (UoP)

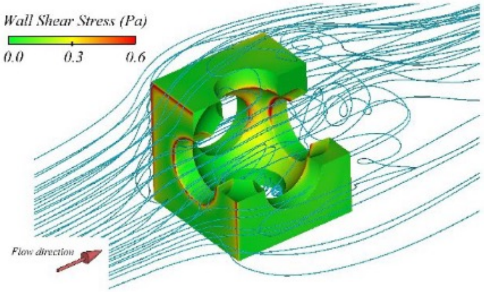
- Funded by R&D solution fund (university of Plymouth) and ENGYS Ltd.
- Supported by ENGYS Ltd. and ARC Marine
- Numerical investigations into flow field characteristics both around and within these structures using OpenFOAM.
- Various configurations and orientations are explored to identify the most suitable structures in terms of flow velocities for marine organisms and assess the positional stability of these cubes.
- This research aims to optimize the artificial reef environment for marine life.

(a) Artificial reefs attract fish and other aquatic organisms.



(c) Formation of vortices and eddies in the presence of the reef cube.

(b) In favorable condition, marine organisms grow on artificial reefs.



(d) Shear stress on reef surface and flow field around it using streamlines.

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engys
Open-source CFD for Enterprise

ARC Marine

Recent HEC-WSI Supported Examples

CFD investigation of an isolated surging wind turbine rotor and a surging wind turbine rotor in a wake

Aleksandr Tsvetkov[1]

[1]University of Plymouth

Access mode: HEC-WSI partner (UoP)

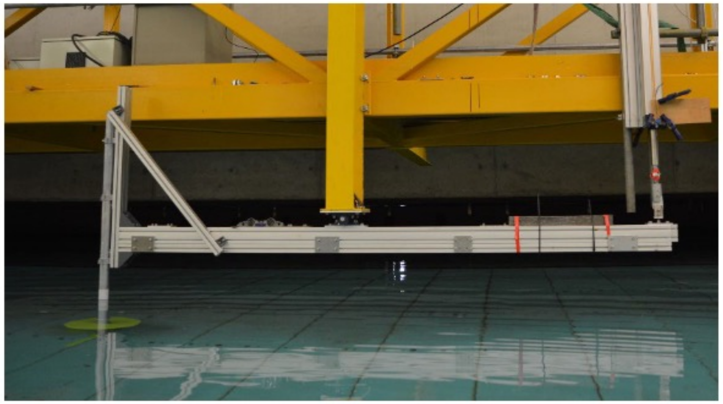
- MSc Dissertation project (Offshore Renewable Energy Engineering, University of Plymouth - Supervised by Dr Edward Ransley)
- Blade resolved wind turbine simulation using OpenFOAM
- Prescribed surge motion
- Isolated and in wake (cyclic boundary condition)

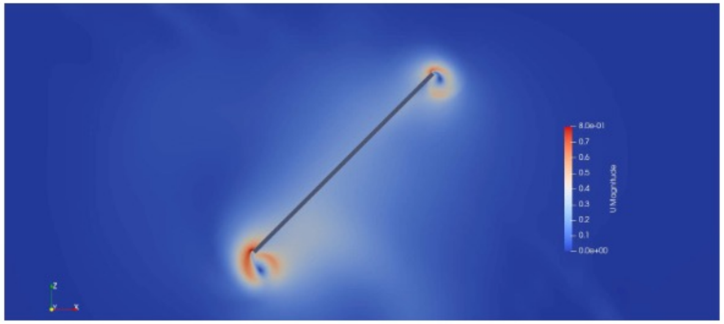
Recent HEC-WSI Supported Examples

Motion reduction strategies for SSP foundations for FOWT

Ignacio Pregnan Johannesen[1], Edward Ransley[1], Martyn Hann[1], Shanshan Cheng[1], Deborah Greaves[1]

[1]University of Plymouth, UK





Access mode: HEC-WSI partner (UoP)

- PhD project (University of Plymouth)
- Focusing on pitch motion (rotation).
- Additional surfaces to: increase viscous damping forces on the platform; increase added mass effects and shift the platform's natural frequency to enable smaller lightweight platform concepts.
- Simulations using OpenFOAM.

Recent HEC-WSI Supported Examples

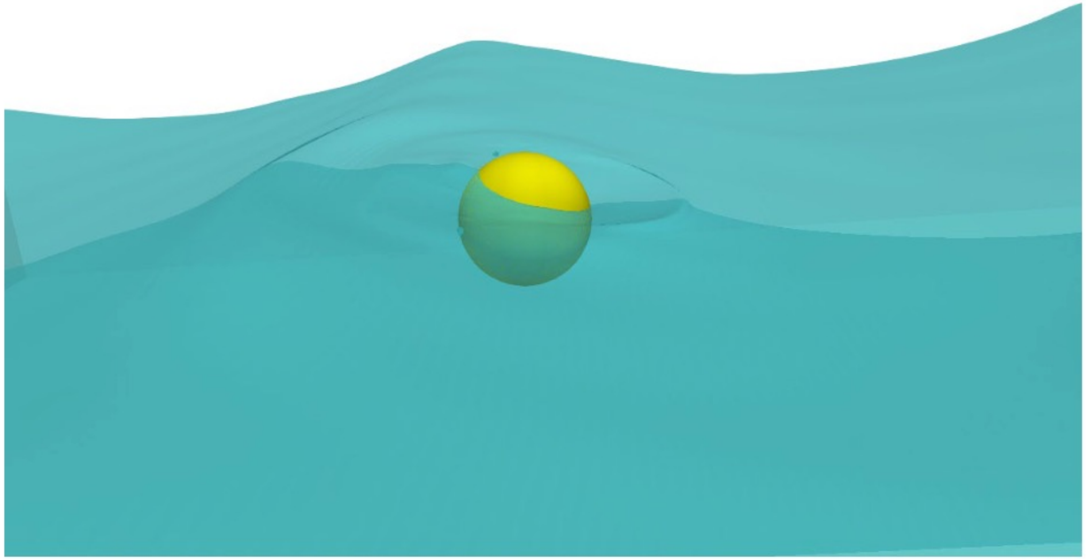
IEA OES Task 10 – ‘Kramer Sphere’ w. excitation force

Scott Brown[1], Edward Ransley[1]

[1]University of Plymouth, UK

Access mode: HEC-WSI partner (UoP)

- University of Plymouth’s contribution to the IEA OES Task 10 on WEC Modelling Verification and Validation
- Simulations using OpenFOAM



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OES OCEAN ENERGY SYSTEMS

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