EPSRC Marine Wave Energy Programme

New Generation Modelling Suite for the Survivability of Wave Energy Convertors in Marine Environments (WavE-Suite)

for Supergen ORE Hub Assembly Jan 2022

Research Team

Investogators			
Title	Name	Role in the project	Organisation
Prof.	Qingwei Ma (QM)	PI, overall management of project	City, University of London
Dr.	Shiqiang Yan	Co-I, leading WP1 and 5	City, University of London
Prof.	Vengatesan Venugopal	Co-I, leading WP4	University of Edinburgh
Prof.	Christopher Pain	Co-I, co-leading WP2 and WP1	Imperial College London
Dr.	Rossella Arcucci	Co-I, leading WP2	Imperial College London
Dr	Jun Zang	Co-I, leading WP3	University of Bath
Dr.	Zhihua Xie	Co-I, co-leading WP3 and WP5	University of Cardiff
Dr.	David Pizer	Project Advisor	Consultant Scientist
Researchers			
Dr.	César Quilodrán Casas	Named researcher	Imperial College London
Dr.	Haoyu Ding	Researcher	University of Bath
Dr.	Roman Gabl	Researcher	University of Edinburgh

Advisory Board

Advisory Board for WavE-Suite				
Title	**Name**	**Role in the board**	**Expertise**	**Organisation**
Dr. and FREng	RV Ahilan	Chair and partner member	hydrodynamics and, offs	AqualisBraemar LOC
Dr.	Chris Retzler	Partner member	Wave energy;	Mocean Energy Ltd
Dr.	Jørgen Hals Todalshaug	Partner member	Wave energy;	CorPower Ocean
Dr.	Yago Torre-Enciso	Partner member	Wave energy;	BiMEP
Dr.	Jon Lekube Garagarza	Partner member	Wave energy;	BiMEP
Prof.	Decheng Wan	Partner member	Numerical modelling	Shanghai Jiaotong Univ
Dr.	Songwei Sheng	Partner member	Wave energy;	Guangzhou Institute of Energy Conversion
Dr.	V Sriram	Partner member	Hydrodynamics and num	IIT Madras
Dr.	Hakim Mouslim	Partner member	Offshore renewable ener	INNOSEA with ABL LOC
Prof. and FREng	Alistair BORTHWICK	invited member	Hydrodynamics and num	University of Edinburgh
Prof.	Andrew Moore	invited member	Data Assimilation and c	University of California Santa Cruz
Prof.	Paul Taylor	invited member	Wave dynamics and appl	University of West Australia
Prof.	Nigel Barltrop	invited member	Offshore engineering	university of Strathclyde

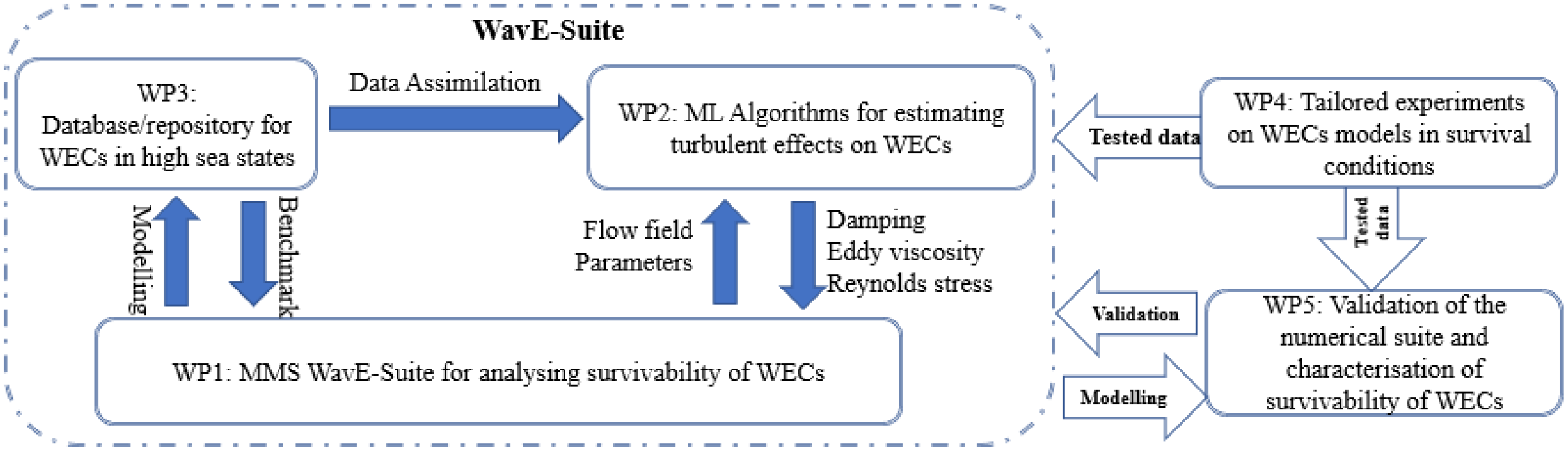
Objectives

Main Objectives:

- Develop a new numerical modelling suite (WavE-Suite) equipped with advanced machine leaning algorithms by coupling five individual numerical models that are suitable for physics of different scales and nature, supported by dedicated databases.
- Realise that WavE-Suite has the ability to deal with irregular waves together with current and to simultaneously capture both large and small-scale physics.
- Validate the WavE-Suite by bespoke experiments and sea trial data.
- Demonstrate WavE-Suite to be able to identify the survival conditions and quantify extreme loads and motions of WECs

Workpackages

- WP1: MMS modelling software for analysing survivability of WECs
- WP2: ML Algorithms for estimating turbulent effects on WECs
- WP3: Databases and repository for WECs in high sea states
- WP4: Tailored model tests on WECs in survival conditions
- *WP5: Validation of WavE-Suite and* characterisation of survivability



Work Plan

	Year 1				Year 2				Year 3				Milestones and PDRA allocations (PDRA time is given in months (m))
	1	2	3	4	1	2	3	4	1	2	3	4	
WP1: MMS WavE-Suite for analysing survivability of WECs													**M1**: Couple ESBI with QALE-FEM; **M2**: Couple QALE-FEM with INS and create the UnifWSI; **M3**: Couple UnifWSI with NS2P; **M4**: Couple ESBI with SWAN; **M5**: Develop algorithm for auto-switch models (*PDRA1* 7-33 m; *CUL PhD student*)
1.1	M1			M2									
1.2								M3					
1.3		M4											
1.4												M5	
WP2: ML algorithms for estimating turbulent effects on WECs													**M6**: ML-damping, merged into QALE-FEM in M1; **M7**: ML-eddyV, merged into INS in M2; **M8**: ML-Rstress, merged into NS2P in M3; **M9:** Refined ML algorithms and guideline for extending ML-damping (*PDRA2* 1-36 m 40%)
2.1		M6											
2.2					M7								
2.3								M8					
2.4												M9	
WP3: Database & repository for WECs in high sea states													**M10**: Database (DB) of eddy viscosity for M7; **M11**: DB of Reynolds stress for M8; **M12**: DB on viscos damping for M6; **M13**: Repository for survivability of WECs (*PDRA3* 1-12 m; *PDRA4* 7-18 m)
3.1				M10									
3.2						M11							
3.3						M12							
3.4												M13	
WP4: Tailored model tests on WECs in survival conditions (Dashed: to be done by IIT Madras)													**M14**: Model test for OWC; **M15**: Model test for point absorbers; **M16**: Model test for attenuator WEC; **M17**: Scaling effects on point absorber (*PDRA5* 13-24 m, *In-kind contribution by IIT Madras*)
4.1			M14										
4.2					M15	M17							
4.3							M16						
WP5: Validation of the numerical suite and characterisation of survivability of typical WECs													**M17**: Validated WavE-Suite; **M18**: Survival condition of single WEC; **M19**: Survival condition for a WEC array; **M20**: Quantified extreme loading/responses of WECs; **M21**: Characterised flow field for WECs(*PDRA1* 7-33 m, *CUL PhD student*)
5.1								M17					
5.2			M18							M19			
5.3												M20	
5.4												M21	
	+		+*		+		+		+		+	*	Project meeting +; Workshops *

- Last for 36 months
- Clear defined milestones for each WP, corresponding to deliverables
- Project meeting and/or workshops every 6 months;
- Project partners play important role;
- Advice and suggestions from all advisory board members are welcome

WP1: MMS modelling software for analysing survivability of WECs

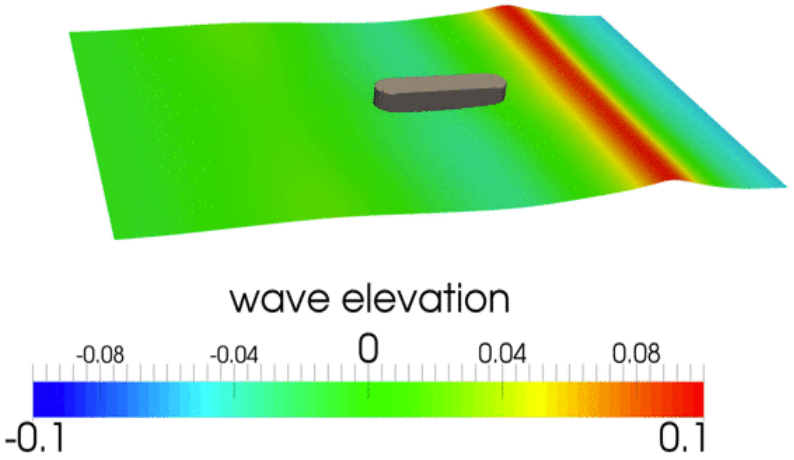
Develop the unified one-phase model for wave-WEC interaction (UnifWSI)

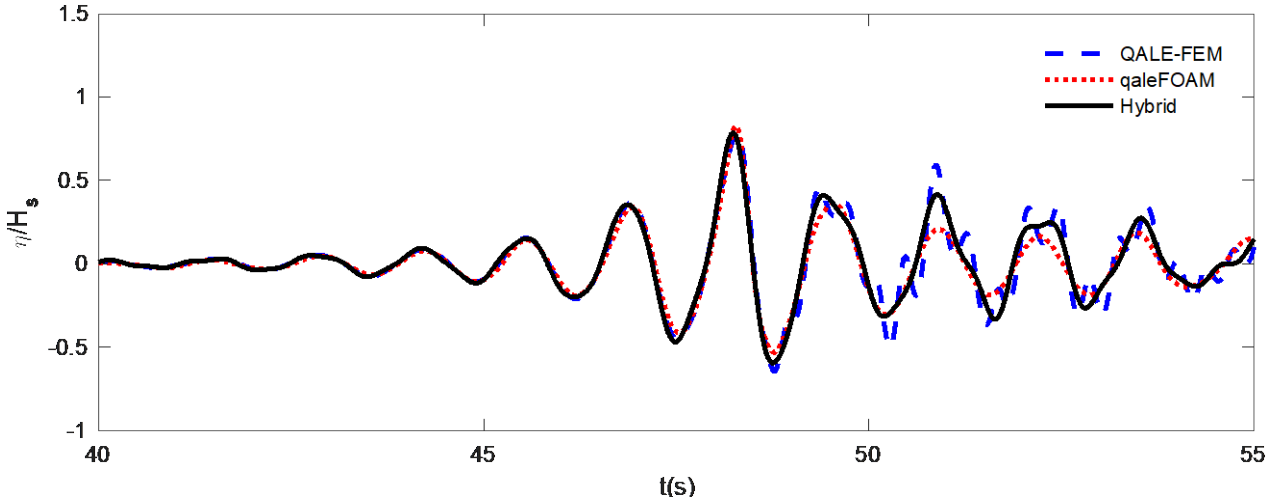
UnifWSI – phase 1

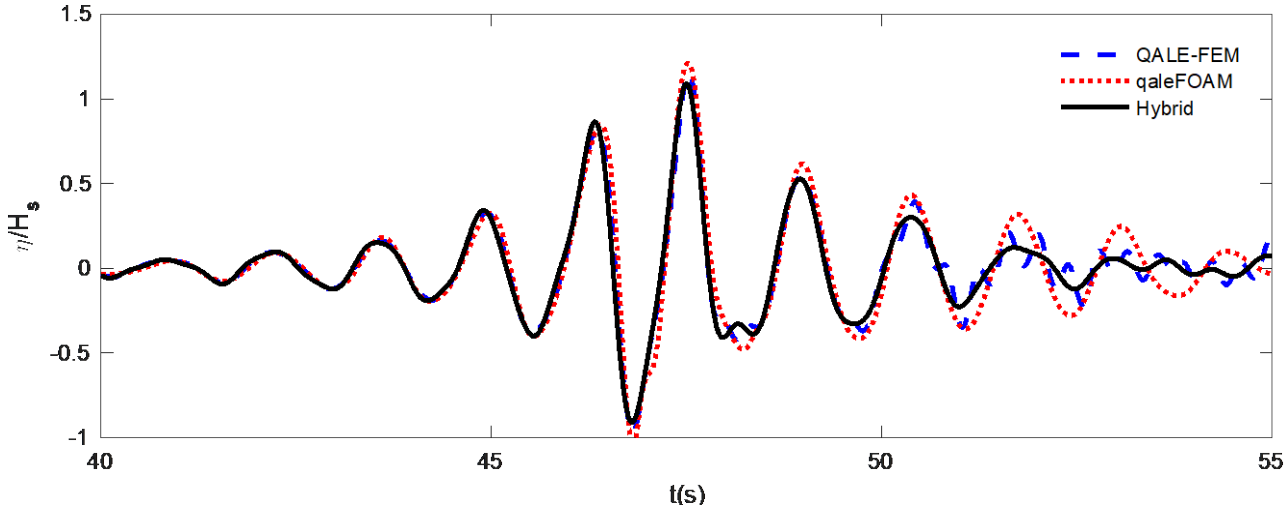
- ✓Coupling the QALE-FEM (potential model) with single-phase FEM based NS model
- ✓Splitting the viscous force through the Projection-based method (fractional step method)
- ✓No need to exchange data between solvers
- ✓No need to decompose the computational domain

WP1: MMS modelling software for analysing survivability of WECs

Preliminary results - model the interaction between focusing waves and floating body







Suspicious high-frequency oscillation supressed in the UnifWSI modelling

WP2: ML Algorithms for estimating turbulent effects on WECs

Methodology for learning turbulent viscosity

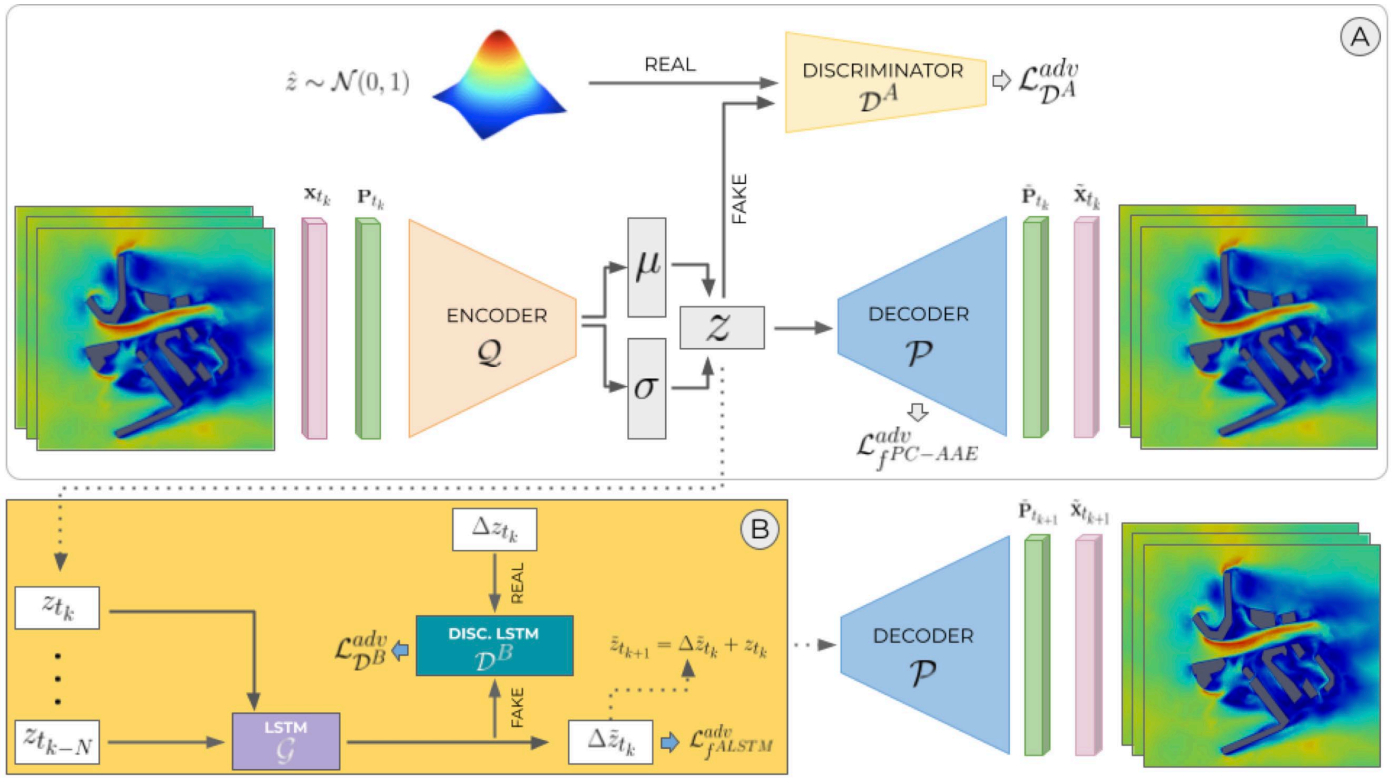
Two-step PC-based adversarial autoencoder (PC-AAE)

Using the input of the unstructured mesh points to achieve first model reduction.

Through the PC-AAE, obtain a latent space representation of the full PC field (second model reduction)

Ensuring that the latent space matches a normal distribution by AAE

Compression of data in Encoder



WP2: ML Algorithms for estimating turbulent effects on WECs

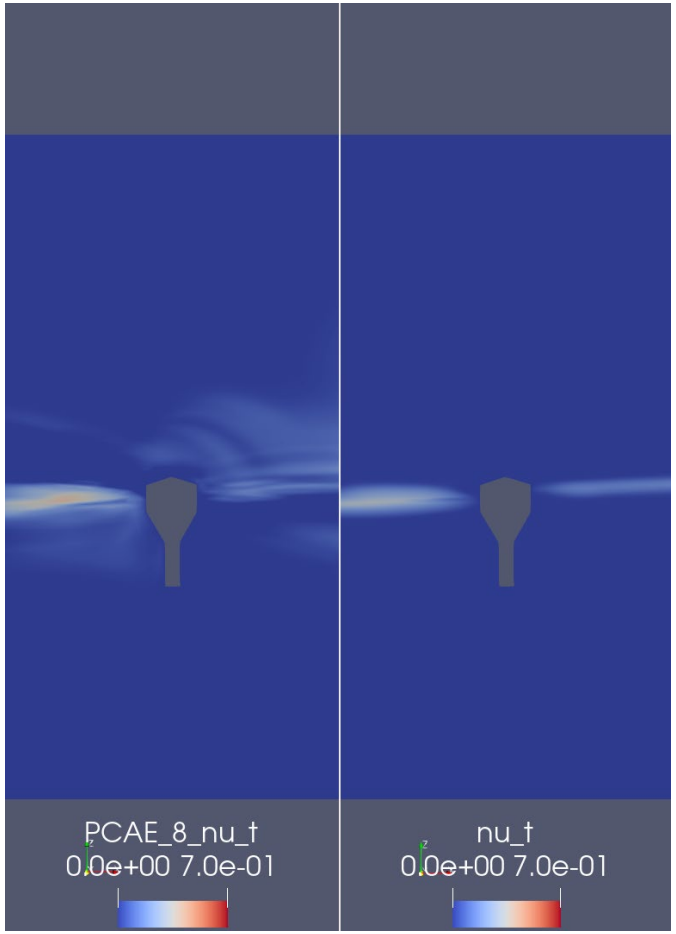
Preliminary results for compression method

PC-AAE compression method developed.

Comparison of viscosity fields obtained by the compression method and original data

Left image: using only 8 dimensions
Right image: the initial ~800k points

Better representation of data with more compression dimensions.



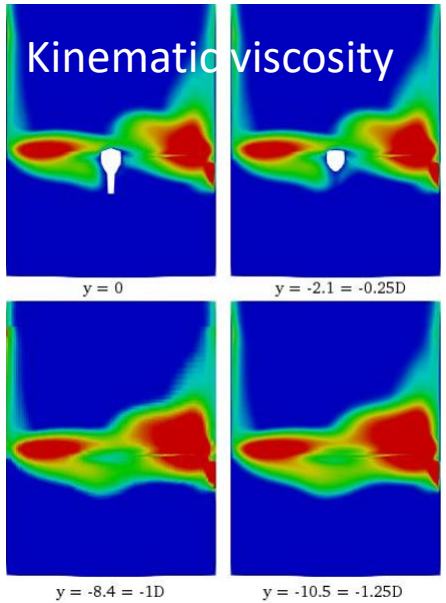
WP3: Databases and repository for WECs in high sea states

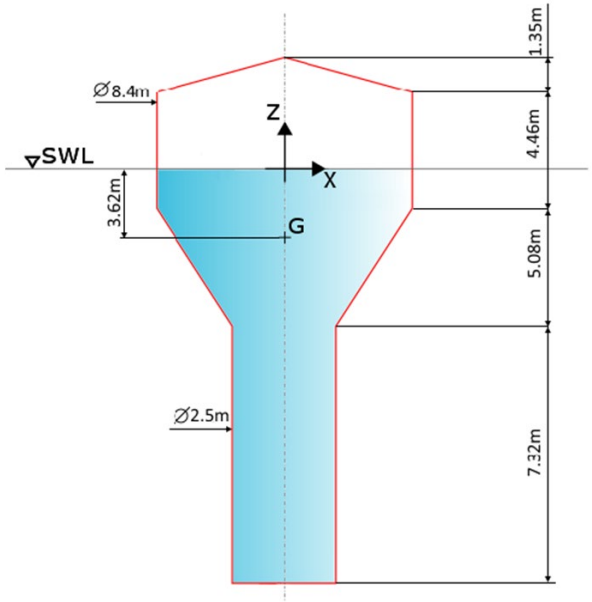
Start to generate database in the following cases

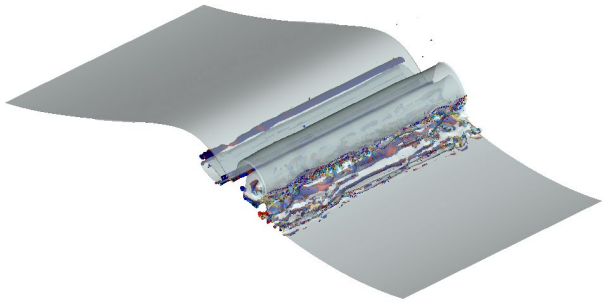
1) Regular wave interaction with a point absorber

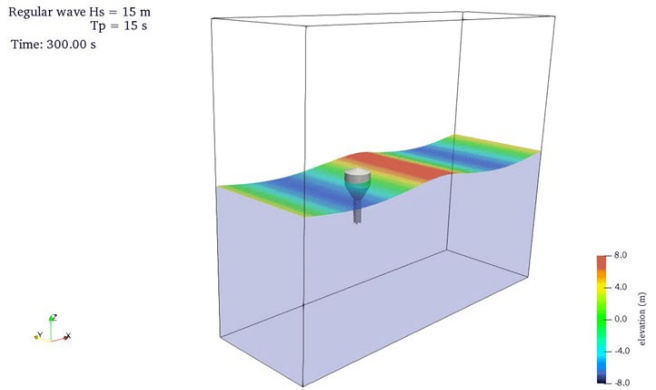
2) NewWave interaction with a point absorber

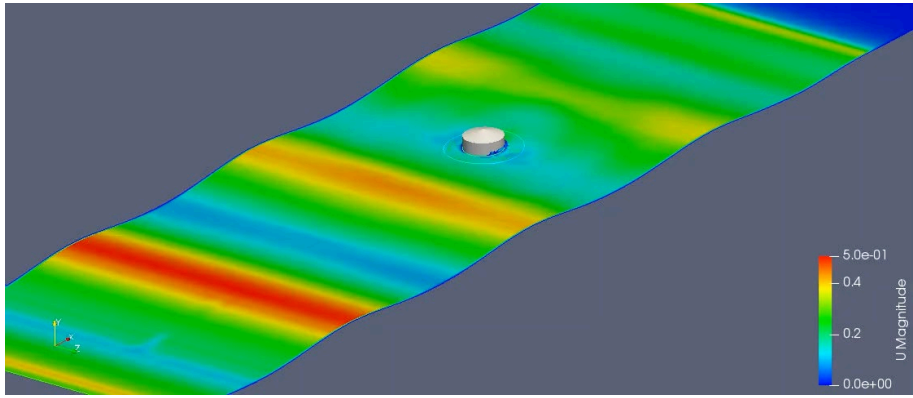
3) Turbulence structures under breaking waves











Summary

- Three months after the start;
- Some progress in WP 1, 2 and 3, following the work plan
- WP1 developed Phase 1 UnifWSI
- WP2 developed PC-AAE compression method for dealing data efficiently.
- WP3 Generated initial results for one WECs and for breaking waves