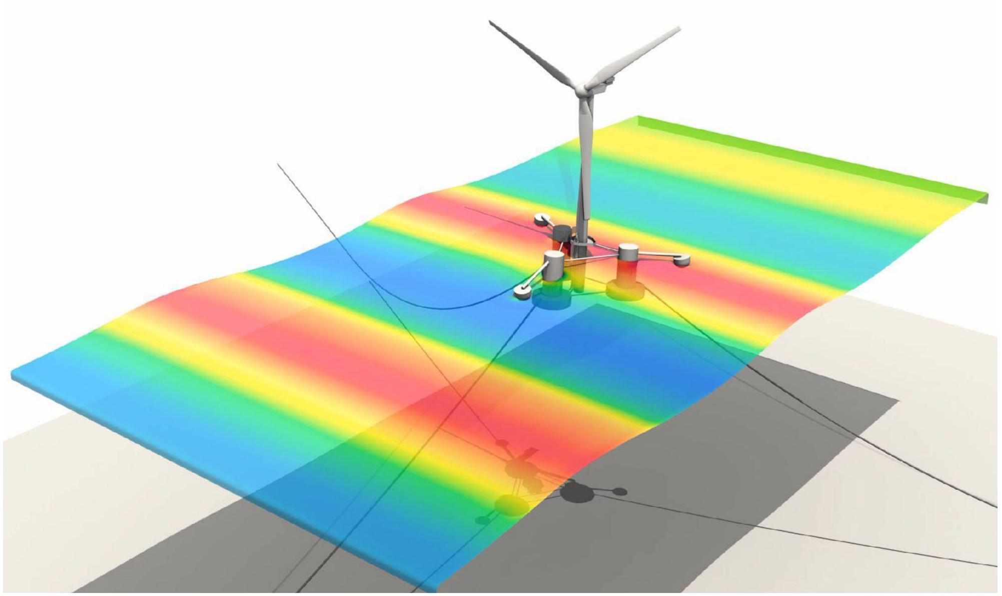
High-Performance Computing to Support Wave Energy Development



Moncho Gómez Gesteira
EPHYSLAB Environmental Physics Laboratory
CIM Centro de Investigación Mariña, Universidade de Vigo

ACKNOWLEDGEMENTS

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KU LEUVEN

Wave Energy

La energía undimotriz puede ser relevante en el futuro.

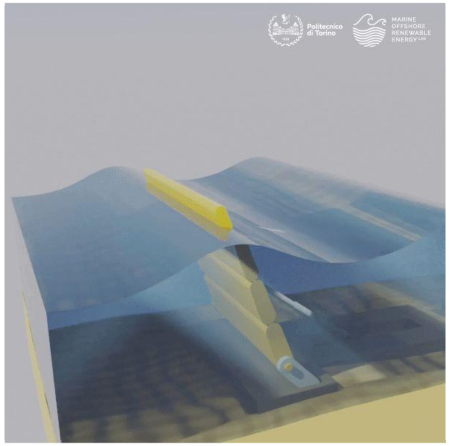
- La energía undimotriz tiene un potencial enorme, con una **densidad energética** considerablemente mayor que la de la eólica y la solar.
- Los convertidores de energía undimotriz pueden operar hasta el **90 % del tiempo**, en comparación con el 20–30 % de los dispositivos eólicos y solares..
- La energía undimotriz muestra una **buena correlación con la demanda**, ya que alrededor del 37 % de la población mundial vive a menos de 90 km de la costa..

Sin embargo

- La energía undimotriz tiene que competir contra tecnologías más maduras en las que la inversión ya está realizada.
- Existen multiple tecnologías.

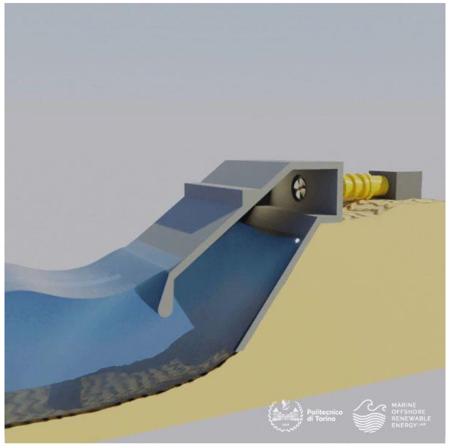
VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

Point Absorber

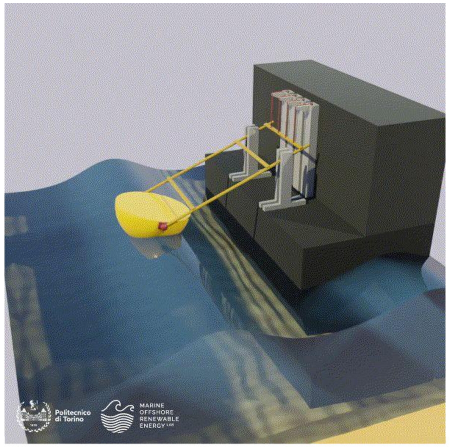


Oscillating Wave Surge Converter

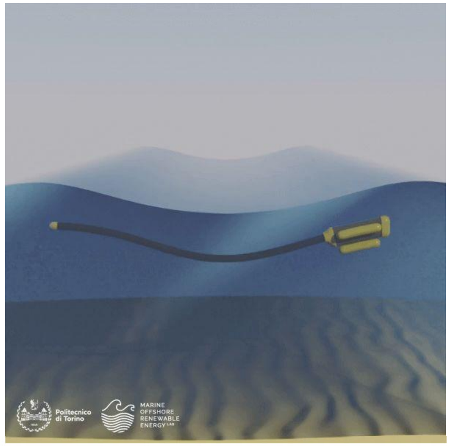
Surface Attenuator



Oscillating Water Column



WaveStar-type WEC

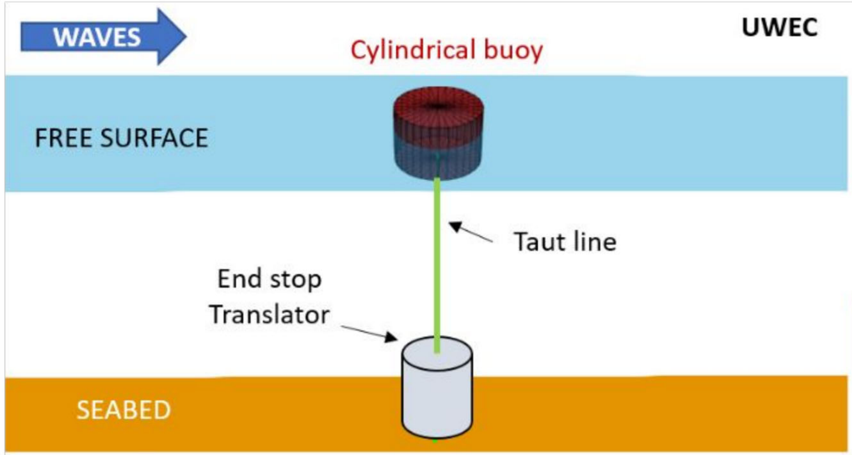


Flexible Pressure Differential

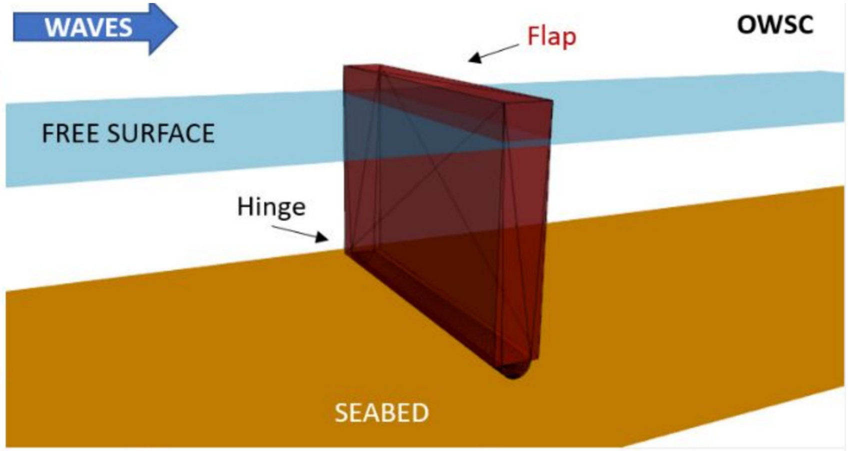
TRL	Descripción general	Ejemplo en energía undimotriz
1	Principios básicos observados	Identificación del potencial energético de las olas y conceptos físicos iniciales.
2	Formulación de la tecnología	Desarrollo de ideas de dispositivos (absorbedores puntuales, columnas de agua oscilante, etc.).
3	**Prueba de concepto analítica o experimental**	**Modelos matemáticos y pruebas de laboratorio a escala reducida en canal de olas.**
4	**Validación en laboratorio**	**Prototipos a pequeña escala probados en tanque de olas bajo condiciones controladas.**
5	**Validación en entorno relevante**	**Prototipos a escala intermedia en instalaciones de ensayo costeras o de laboratorio avanzado.**
6	Demostración de sistema en entorno relevante	Dispositivo a escala reducida desplegado en mar real con condiciones controladas (puerto, bahía protegida).
7	Demostración de sistema en entorno operativo	Prototipo a escala real instalado en mar abierto bajo condiciones operativas.
8	Sistema completo y cualificado	Dispositivo a escala real probado de manera sostenida, validando rendimiento, fiabilidad y mantenimiento.
9	Sistema probado en operación comercial	Planta undimotriz en operación comercial conectada a red eléctrica y en funcionamiento continuo.

VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

Uppsala Point Absorber

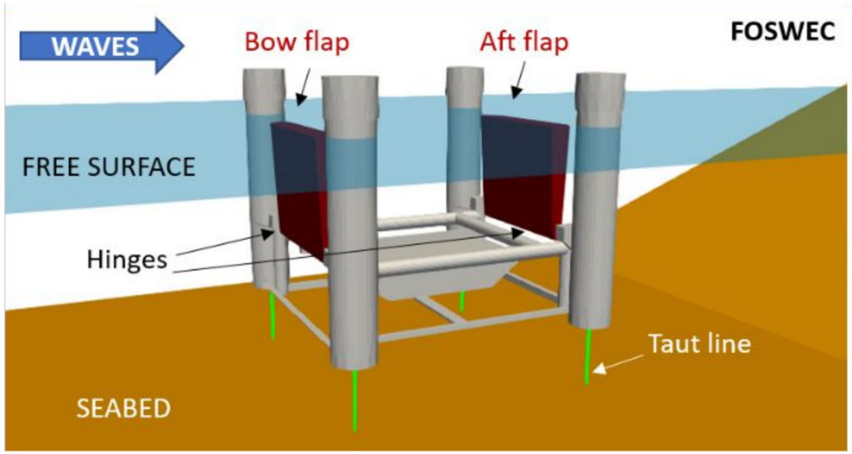


Oscillating Wave Surge Converter

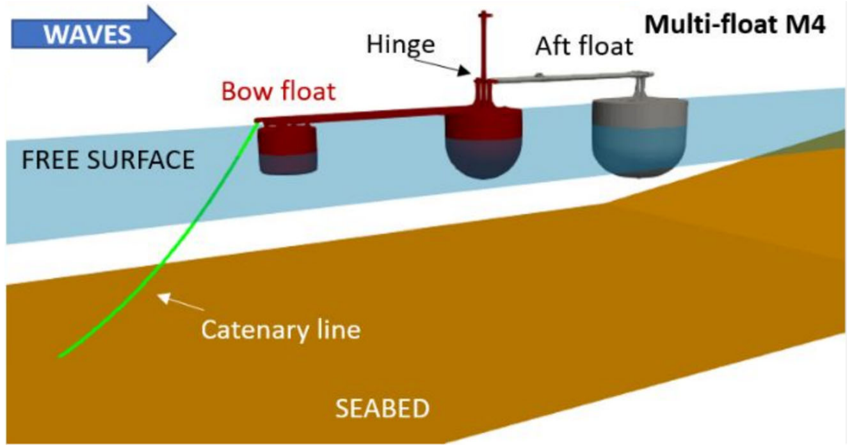


cpu gpu
DualSPHysics

Floating Oscillating Surge WEC



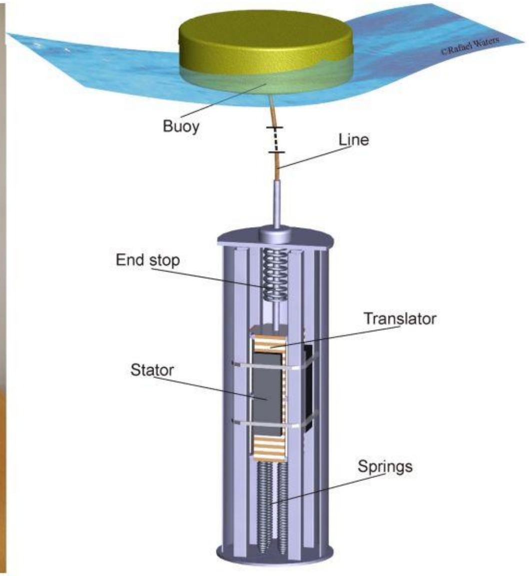
Multi-float M4



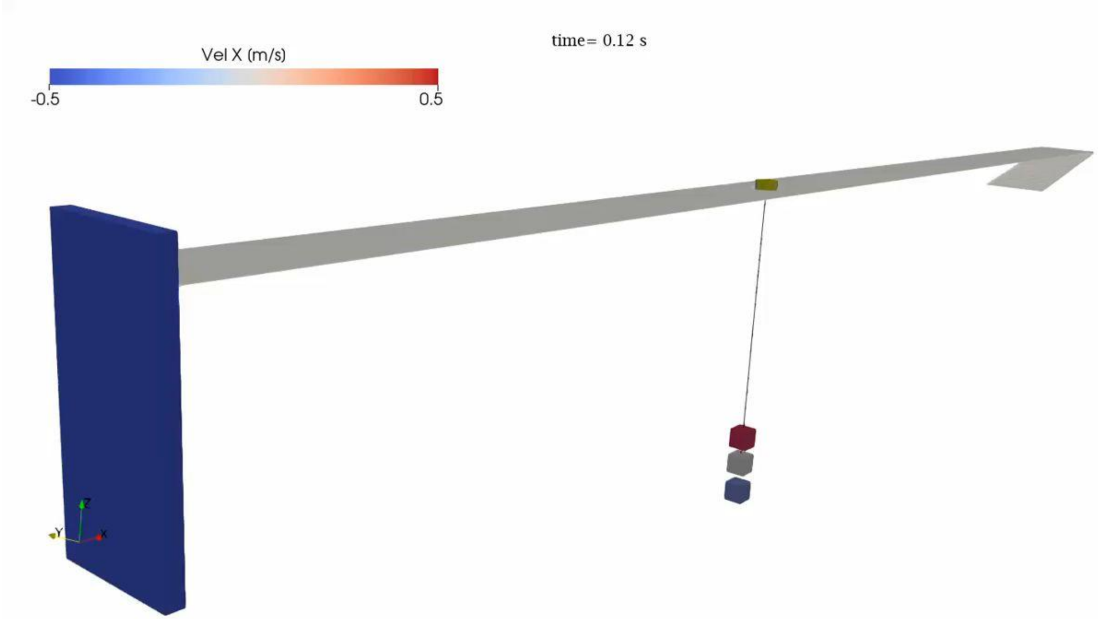
VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

Uppsala Point Absorber

- **Floating buoy** and a linear magnet generator (PTO) **connected via a line**.
- The generator is attached on a **ballasted platform** fixed at the seabed.



Source: Göteman et al., 2015

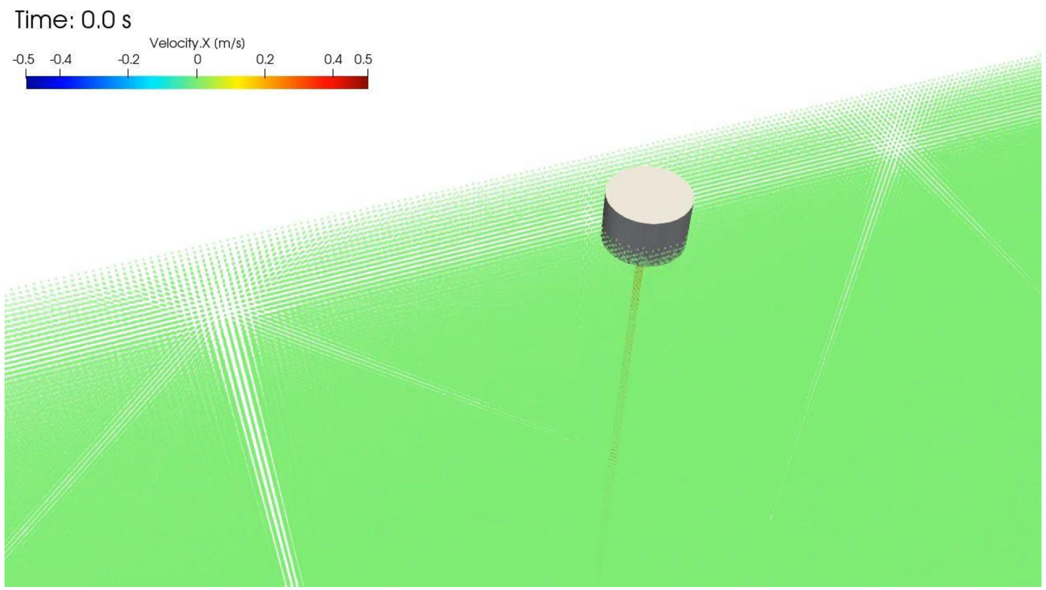


The model is asserted by friction brakes acting on the translator → PROJECT CHRONO

A taut mooring line transmits the rectified motion of the buoy to the translator → MoorDyn+

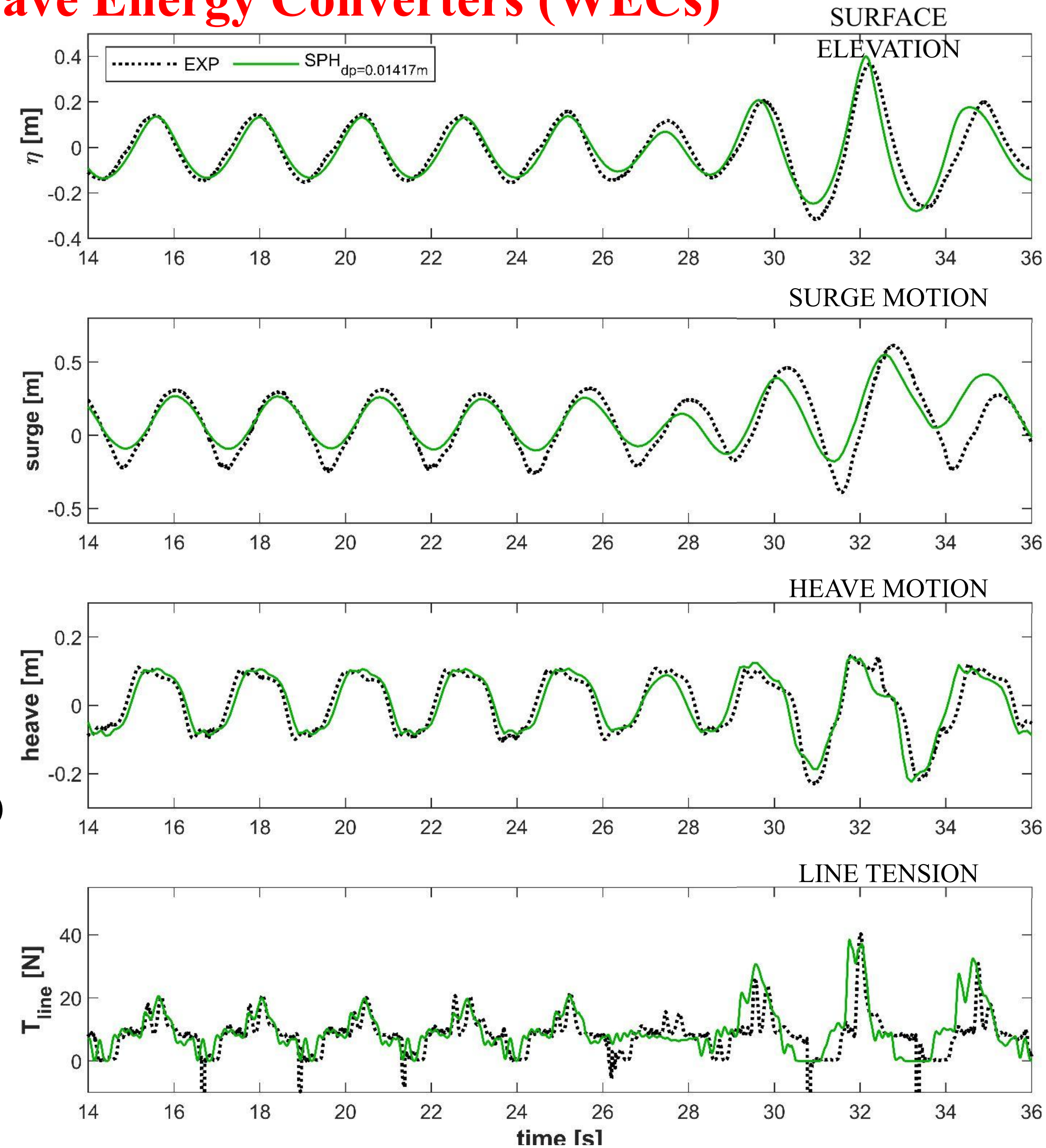
VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

Uppsala Point Absorber



Focused wave train (**H_{focus}=0.38 m**, **T_{focus}=2.604 s**)
embedded into regular wave background (**H=0.27 m**, **T=2.4 s**)
PTO configuration with only internal **damping (2.79 Ns/m)**

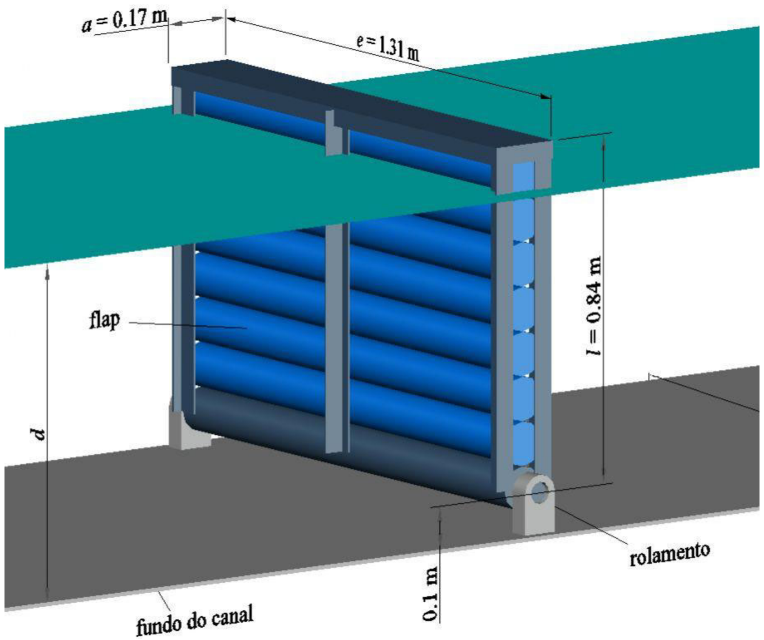
dp [m]	**0.0425**	**0.02125**	**0.01417**
H/dp	8.47	16.94	25.41
particles	$2.03\cdot10^5$	$1.89\cdot10^6$	$6.43\cdot10^6$
runtime	1.0 h	10.6 h	48.3 h
runtime/second	1.5 min	16.8 min	1.3 h



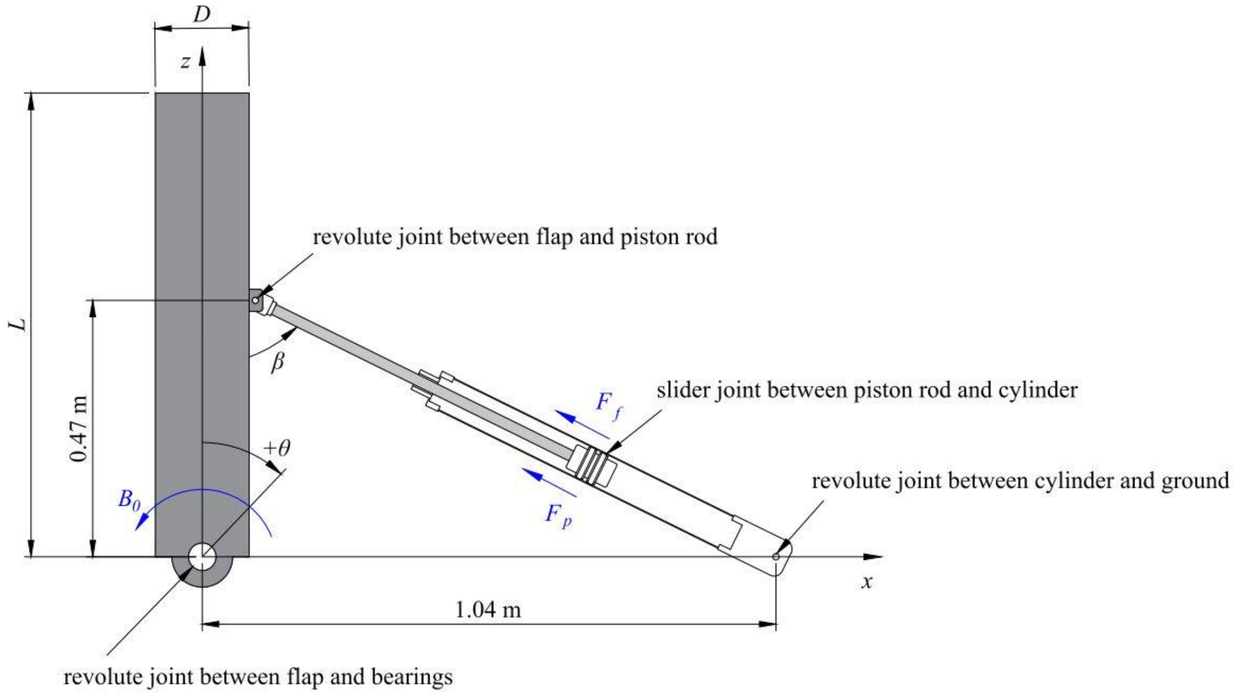
VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

Oscillating Wave Surge Converter

- OWSCs are designed to **harness wave energy** nearshore through the **oscillatory pitch motion of a flap**.
- The **flap** consists of PVC tubes joined by a stainless-steel frame, and a bearing, and it is **hinged width-wise above the bed**.



Source: *Brito et al., 2017*



The PTO system: equivalent torque (to the one on the revolute joint) generated by a linear force following a Coulomb damping behaviour

VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

Oscillating Wave Surge Converter

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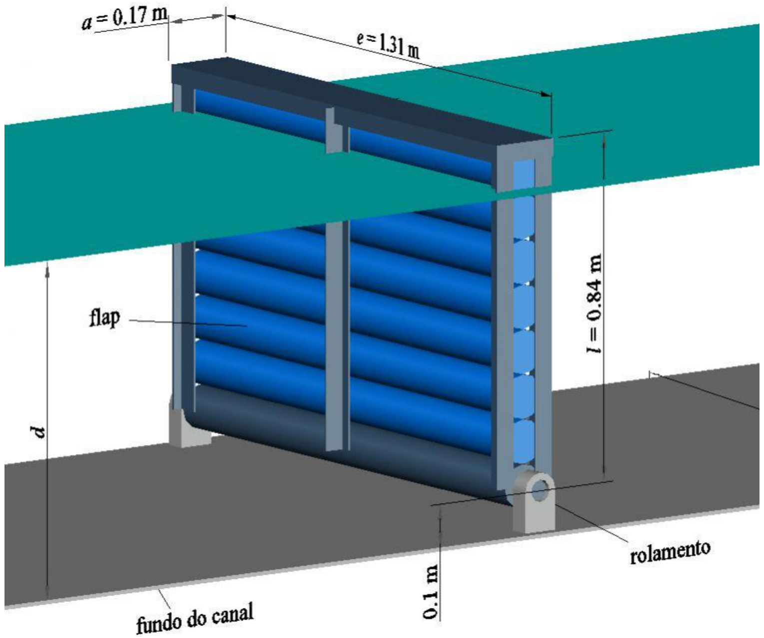

Source: *Brito et al., 2017*

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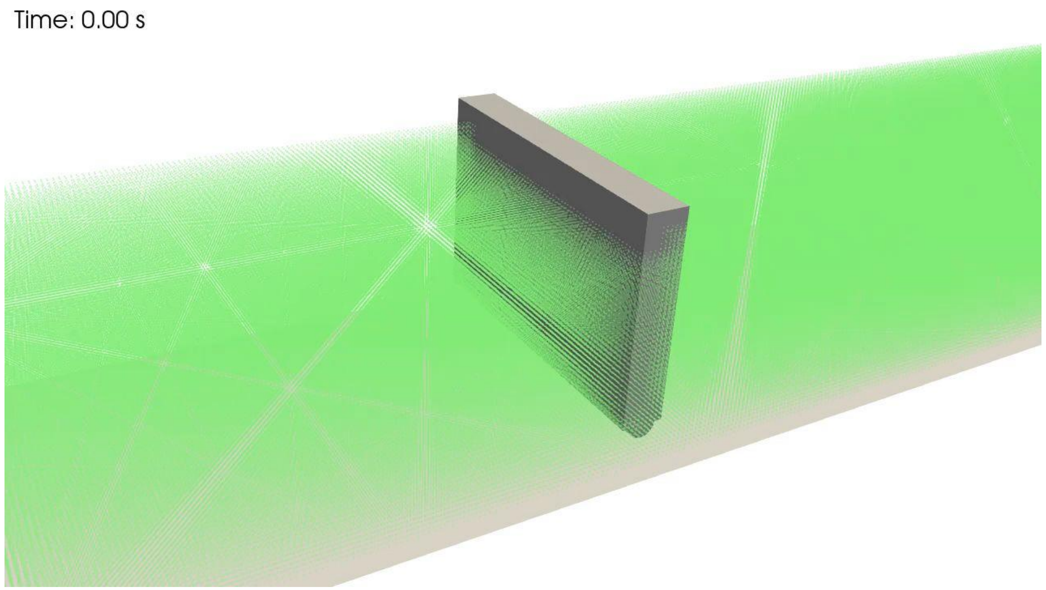
PROJECT CHRONO

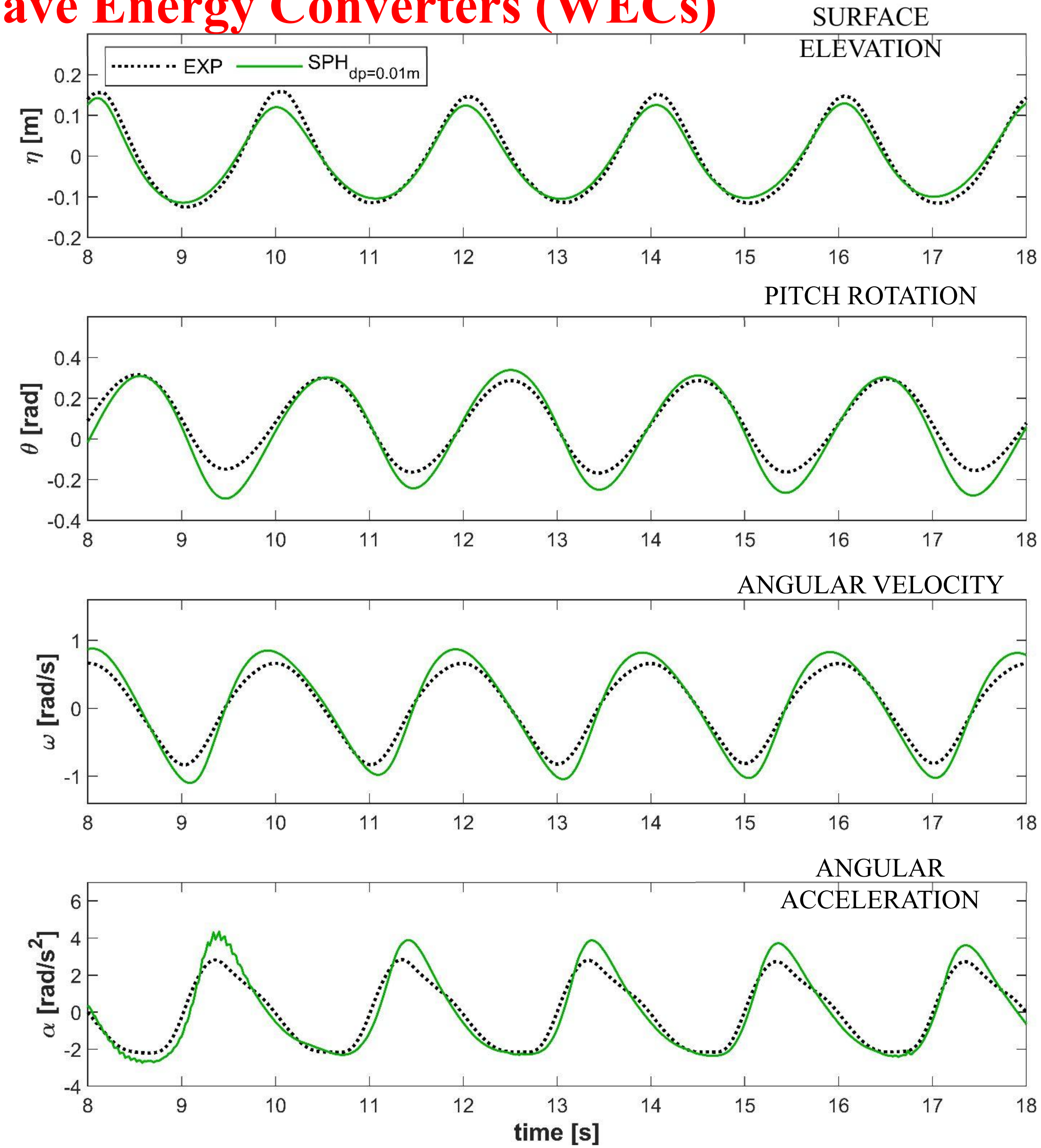
VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

Oscillating Wave Surge Converter



Regular wave (***H*=0.25 m**, ***T*=2 s, depth=0.825 m**)

dp [m]	**0.03**	**0.02**	**0.01**
H/dp	8.33	12.50	25.00
particles	$1.20 \cdot 10^6$	$3.87 \cdot 10^6$	$2.92 \cdot 10^7$
runtime [h]	1.4 h	6.4 h	91.2 h
runtime/second	4.2 min	16.9 min	4.6 h

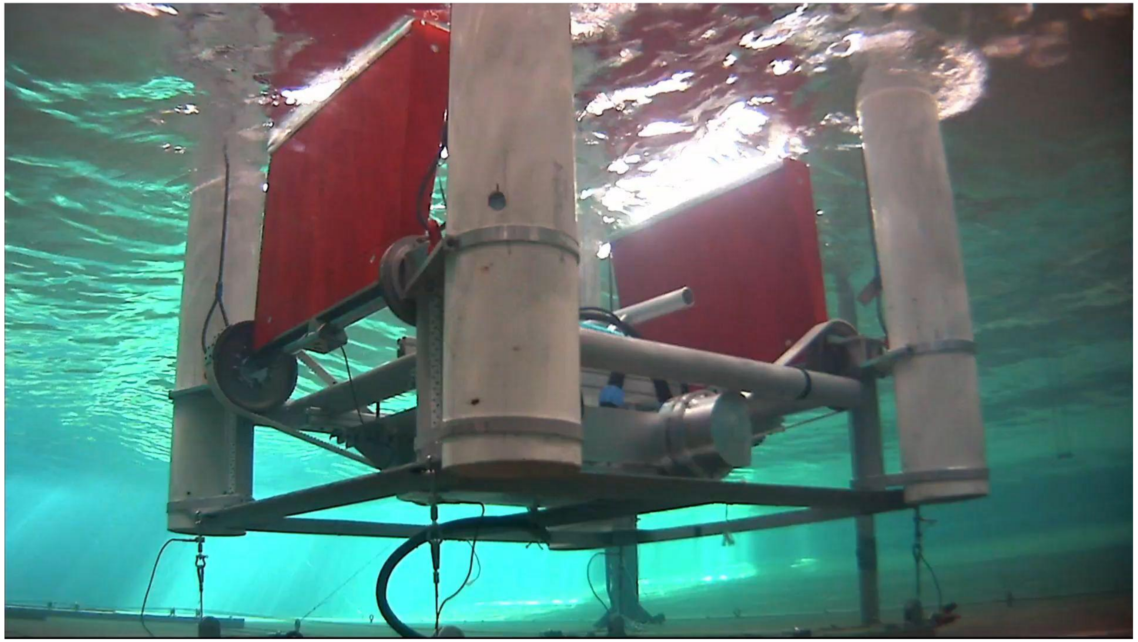


VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

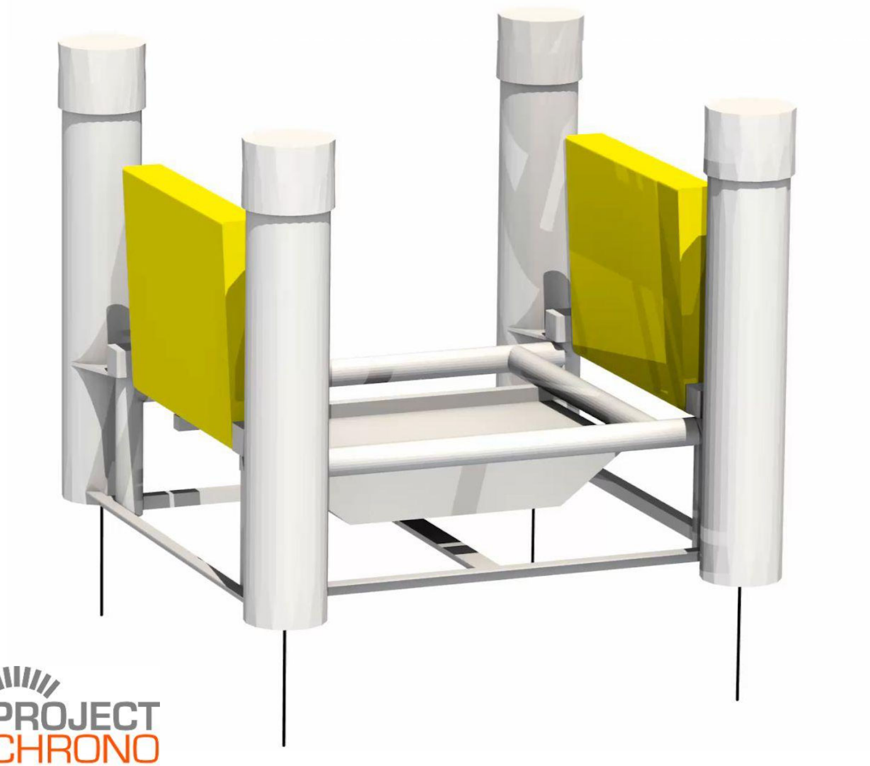
Sandia National Laboratories

Floating Oscillating Surge Wave Energy Converter (FOSWEC)

- FOSWEC is a **dualflap** device with a submerged central platform serving as the host for the two flaps.
- The flaps are hinged **to pivot around shafts** mounted to the hull and are controlled by independent motors (PTO).



https://youtu.be/OUxbaEC2K6Y

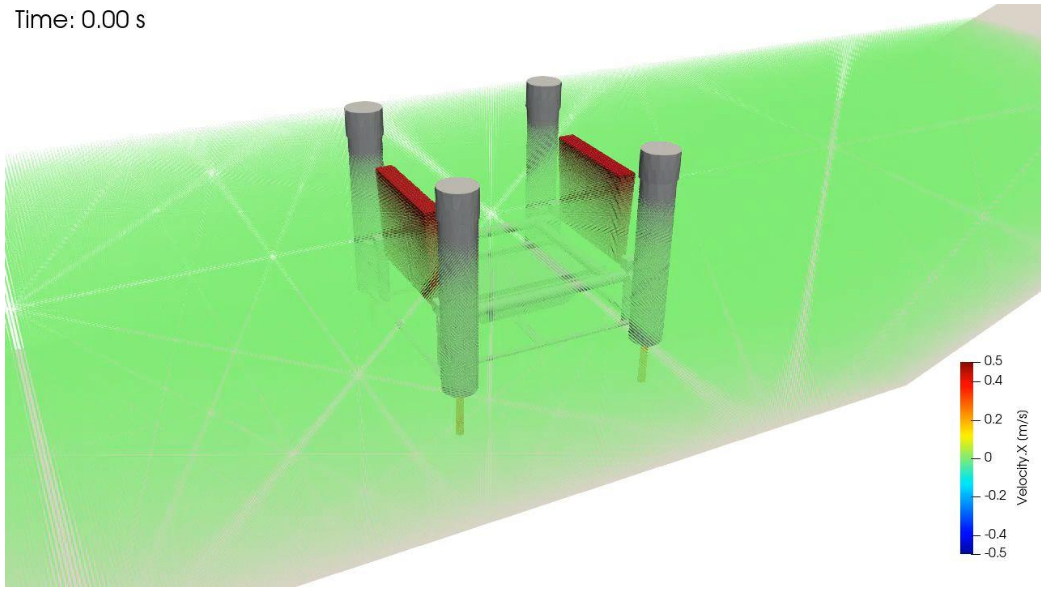


Stiffness and damping coefficients of the PTO system → PROJECT CHRONO

The hull is anchored by 4 mooring taut vertical lines → MoorDyn+

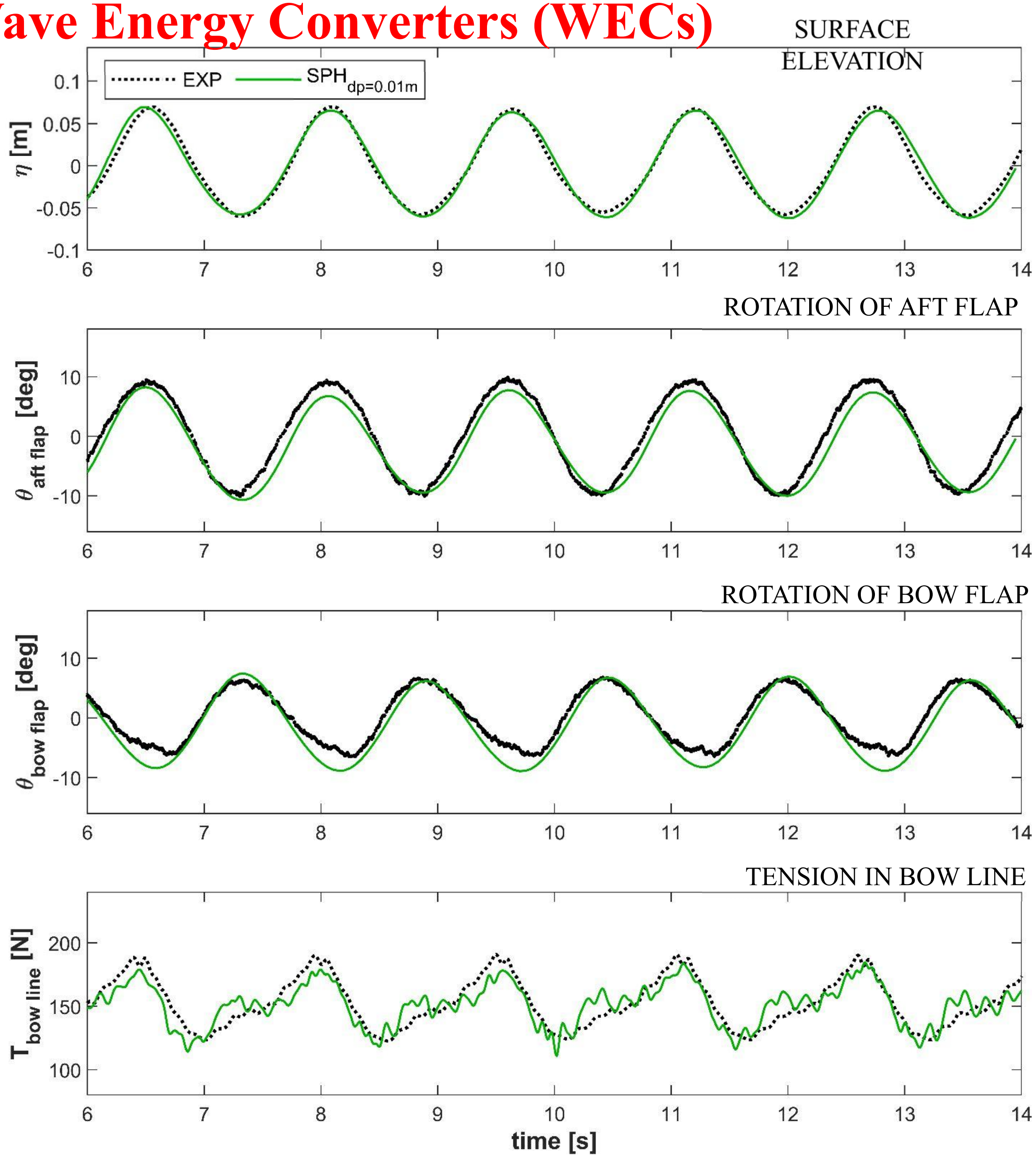
VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

FOSWEC



Regular wave (***H*=0.136 m, *T*=1.5625 s, depth=1.36 m**)

dp [m]	**0.03**	**0.02**	**0.01**
H/dp	4.53	6.80	13.60
particles	$1.45\cdot10^5$	$4.78\cdot10^6$	$3.68\cdot10^7$
runtime	1.4 h	6.5 h	100.9 h
runtime/second	6.1 min	28.0 min	7.2 h

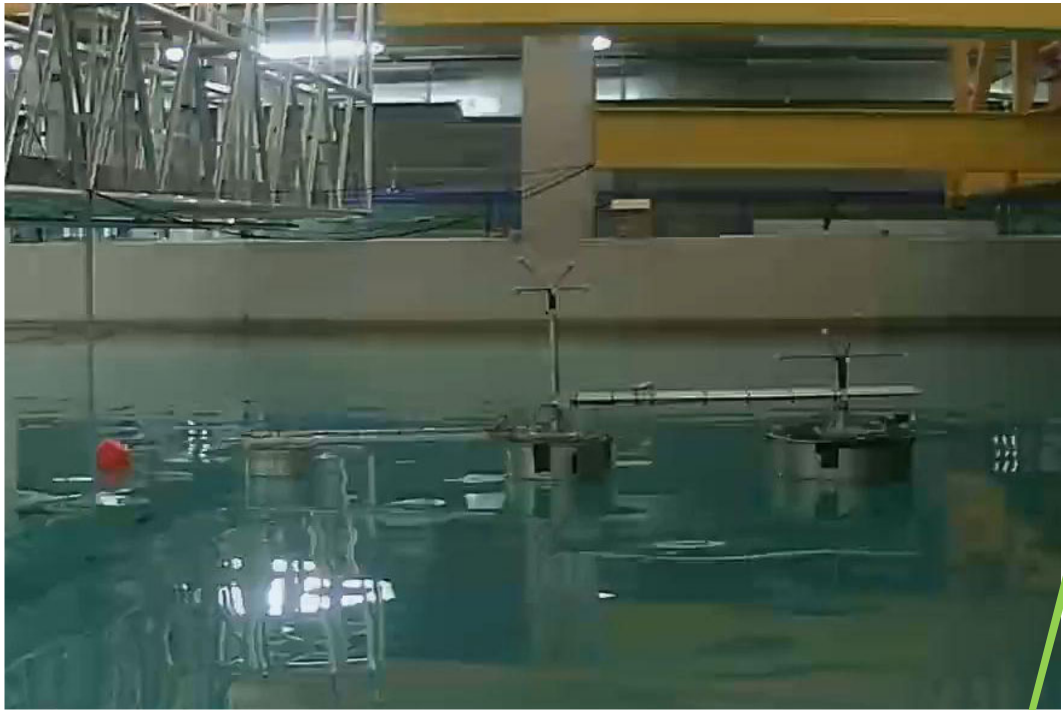


VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

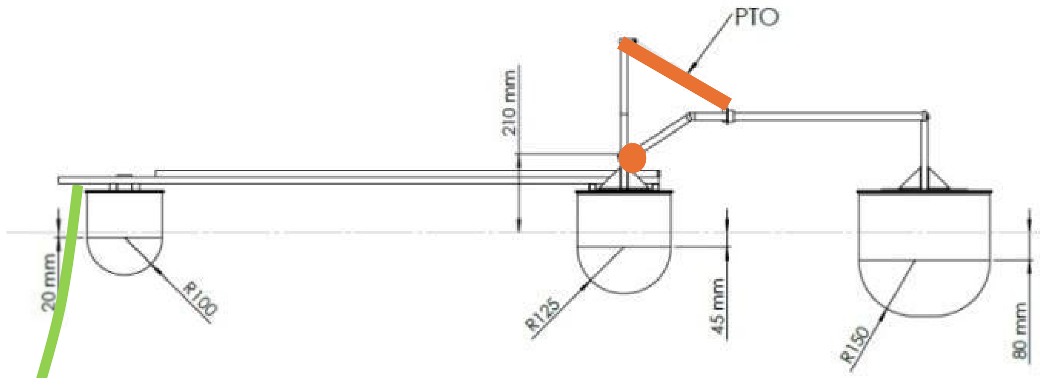
MANCHESTER 1824
The University of Manchester

Multi-float M4

- The multi-float M4 comprises several floats with **multi-mode forcing**.
- The cylindrical **floats have different diameters and drafts** with hemispherical bases.
- The diameters of the floats and their drafts **increase from bow to aft to facilitate the alignment** with the wave direction.



Source: *Santo et al., 2017*

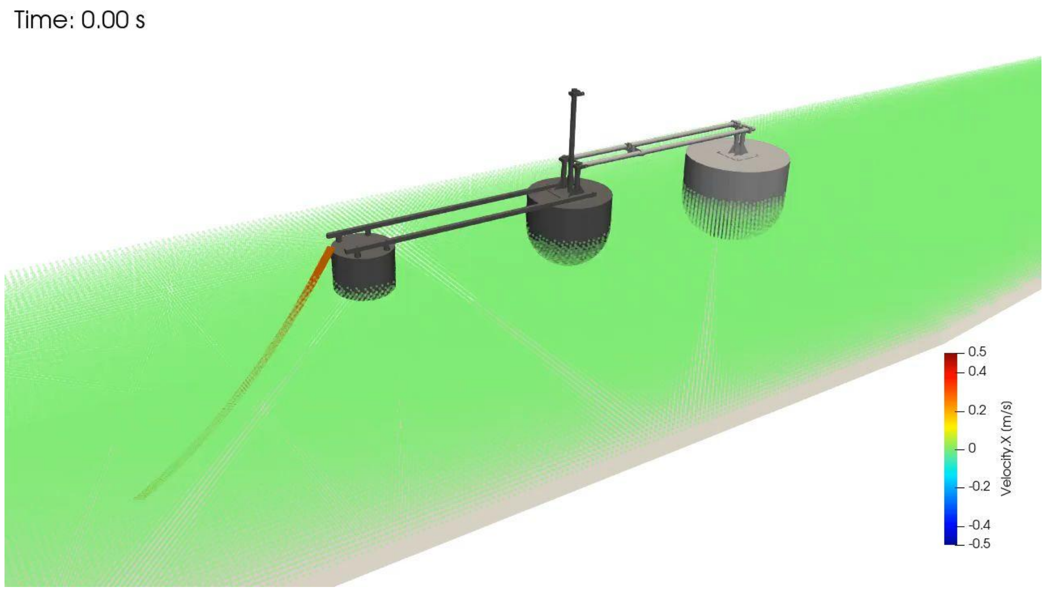


Interaction wave-WEC **SPH**
Mooring line **MoorDyn+**
Mechanical constraint "hinge"
Pneumatic actuator or damper

PROJECT CHRONO

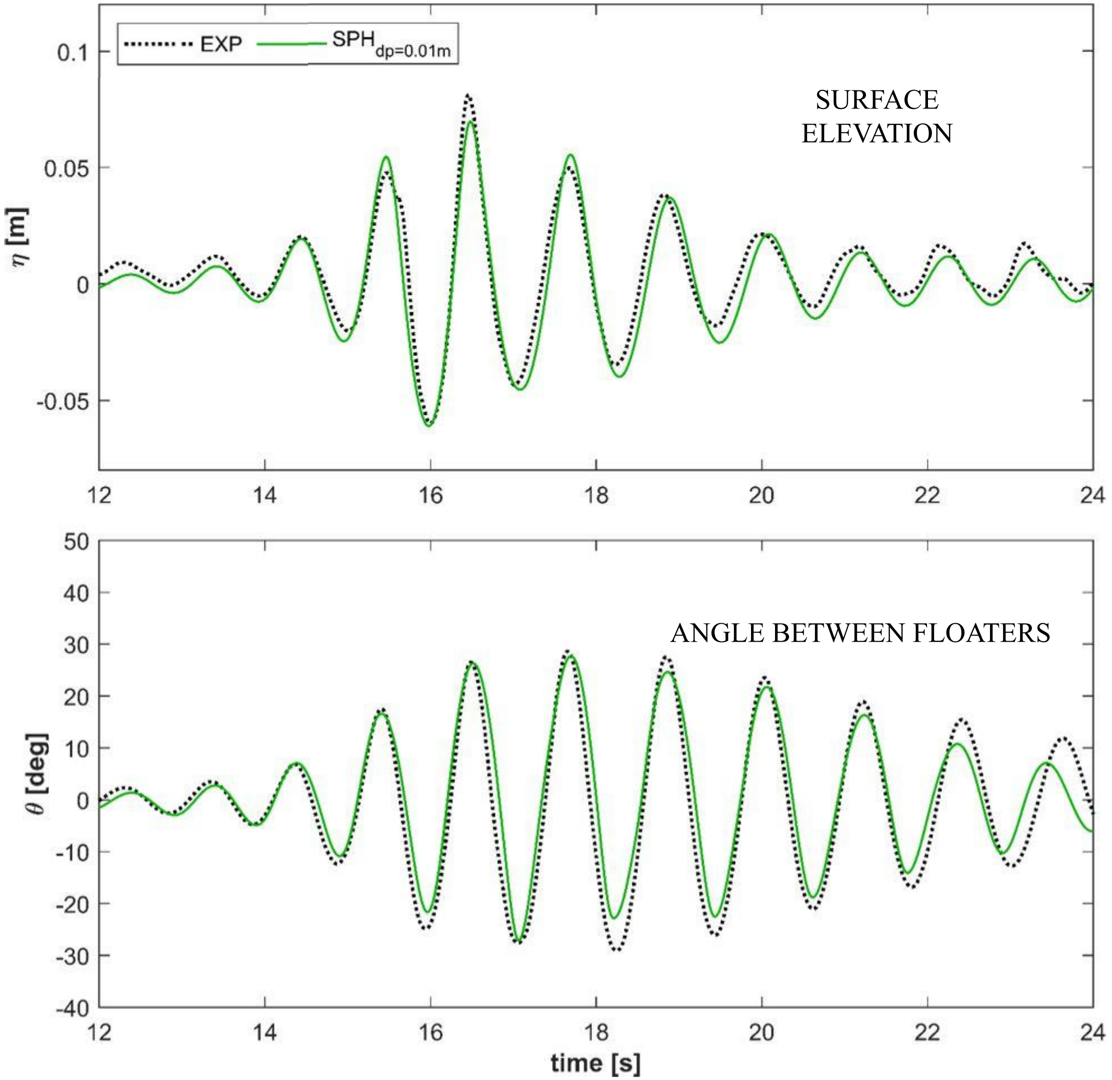
VALIDATIONS AND APPLICATIONS: Wave Energy Converters (WECs)

Multi-float M4



Focused wave (H_{focus}=**0.16 m**, T_{focus}=**1.1 s, depth=0.6 m)**

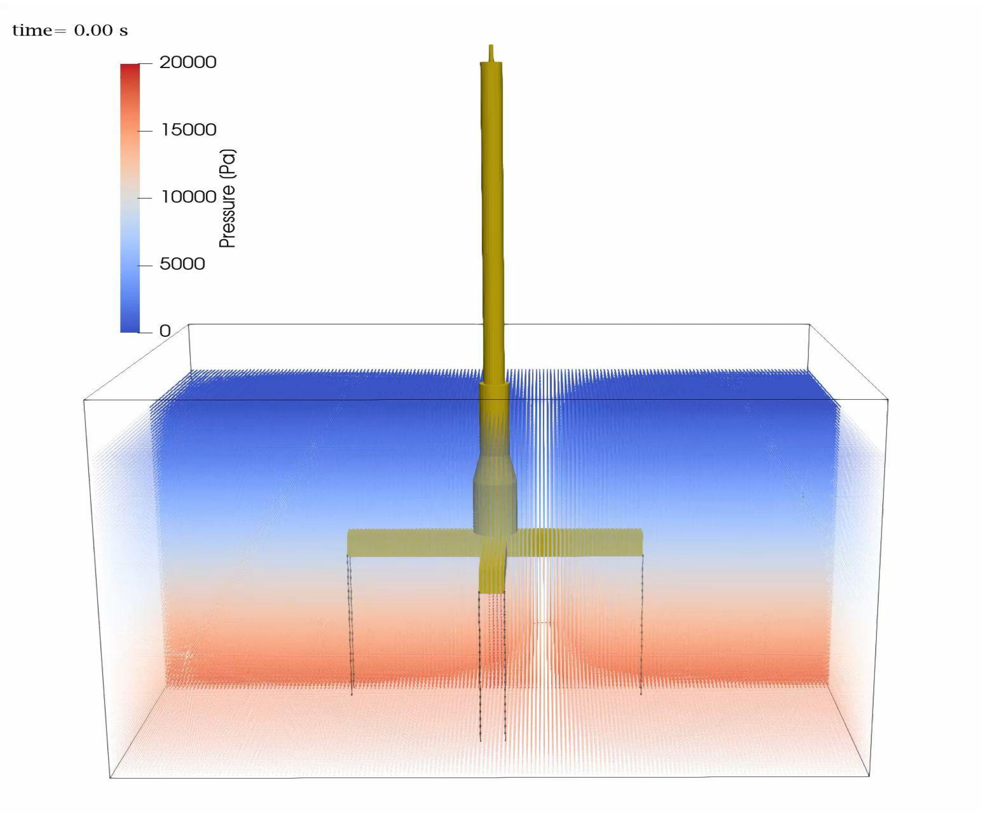
dp [m]	**0.03**	**0.02**	**0.01**
H/dp	5.33	8.00	16.00
particles	$3.30\cdot10^5$	$1.20\cdot10^6$	$7.46\cdot10^6$
runtime	0.6 h	2.1 h	24.9 h
runtime/second	1.4 min	4.9 min	59.6 min

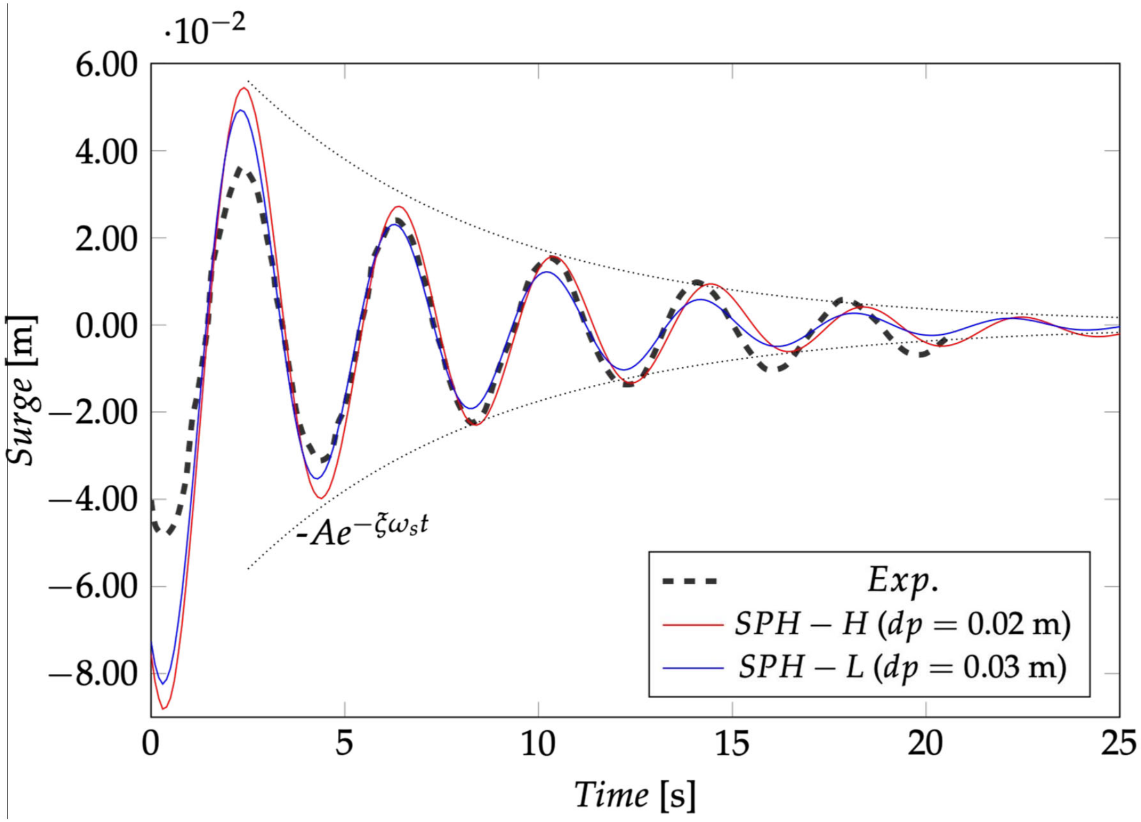


VALIDATIONS AND APPLICATIONS: Floating Offshore Wind Turbines (FOWTs)

Tension-Leg platform

SURGE DECAY



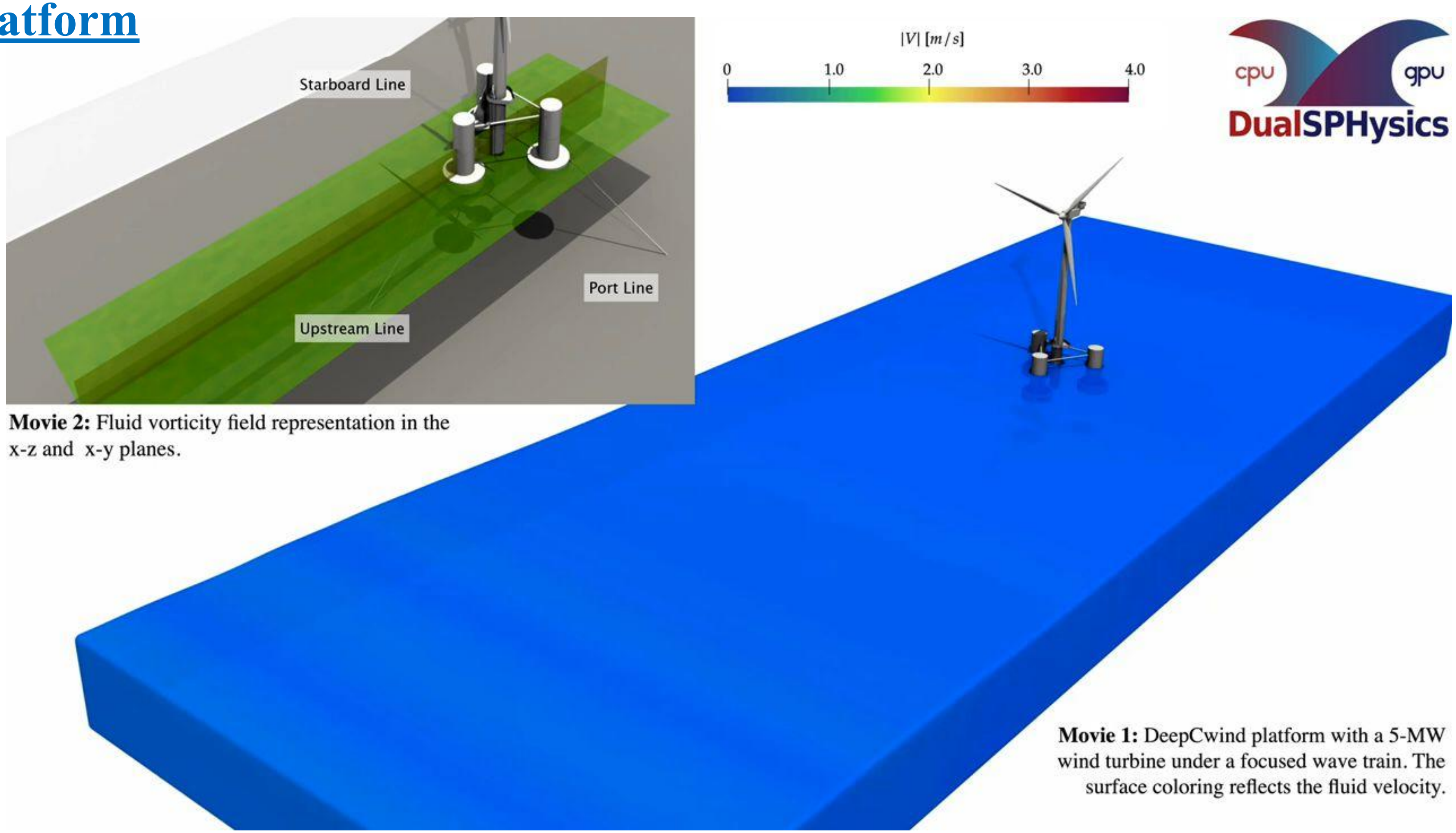


Tagliafierro et al., 2022. Numerical assessment of a Tension-leg platform wind turbine in intermediate water using the Smoothed Particle Hydrodynamics method. Energies, 15(11), 3993.

QUEEN'S UNIVERSITY BELFAST

VALIDATIONS AND APPLICATIONS: Floating Offshore Wind Turbines (FOWTs)

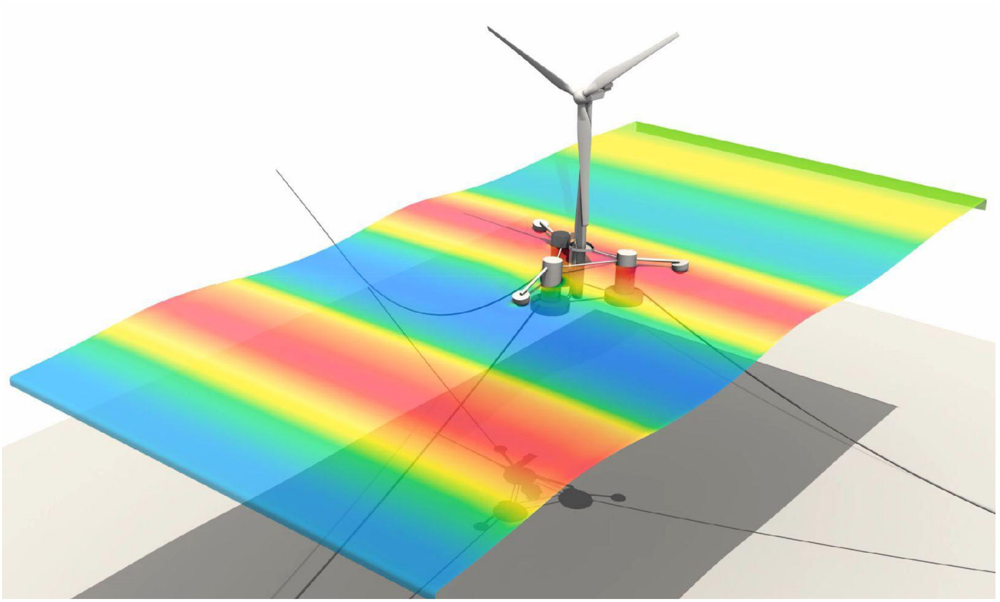
DeepCwind platform



Movie 2: Fluid vorticity field representation in the x-z and x-y planes.

Movie 1: DeepCwind platform with a 5-MW wind turbine under a focused wave train. The surface coloring reflects the fluid velocity.

Tagliafierro et al., 2023. Numerical validations and investigation of a semi-submersible floating offshore wind turbine platform interacting with ocean waves using an SPH framework. Applied Ocean Research, 141, 103757.



DeepCwind platform & Wave Star wave gennerator

Gracias por su atención

AWESDI: Atlantic Wave Energy Sustainable Deployment Initiative

Interreg Atlantic Area

Co-funded by the European Union

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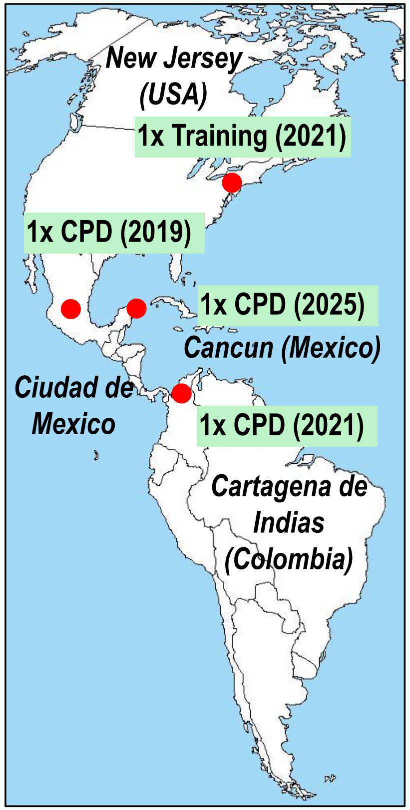

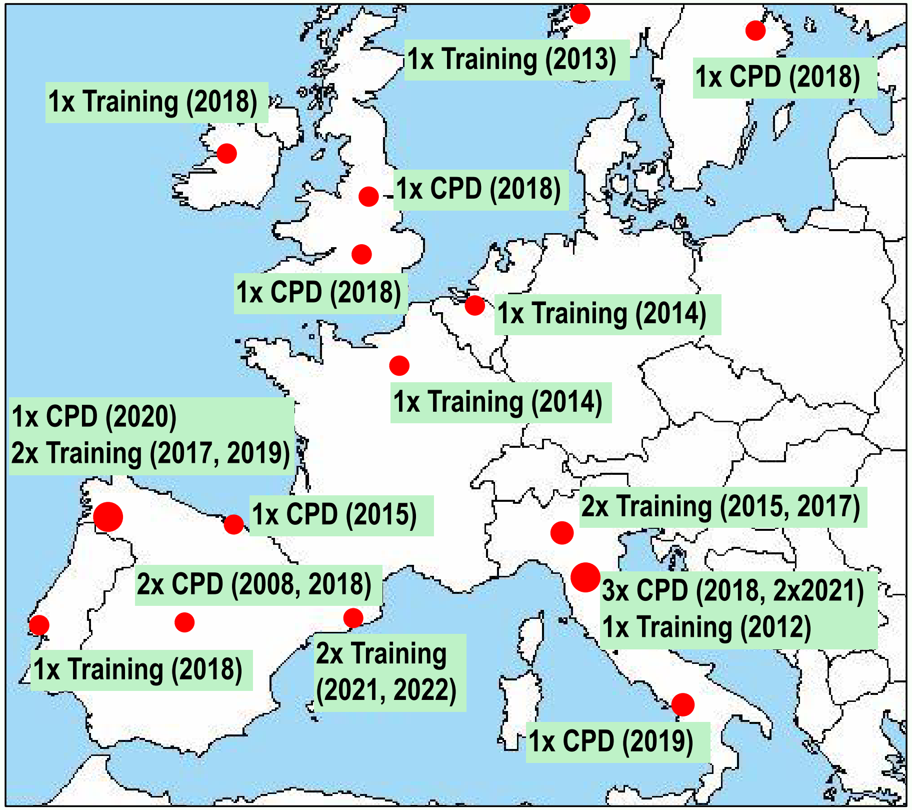

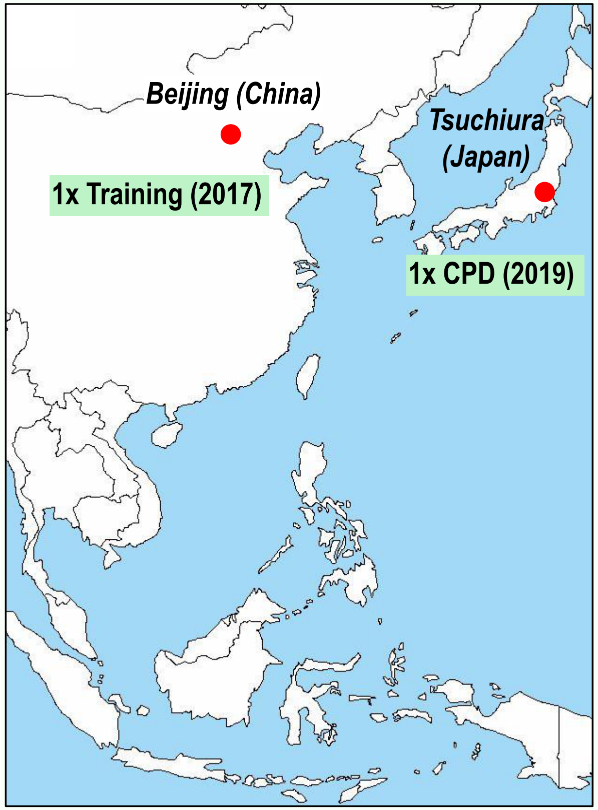

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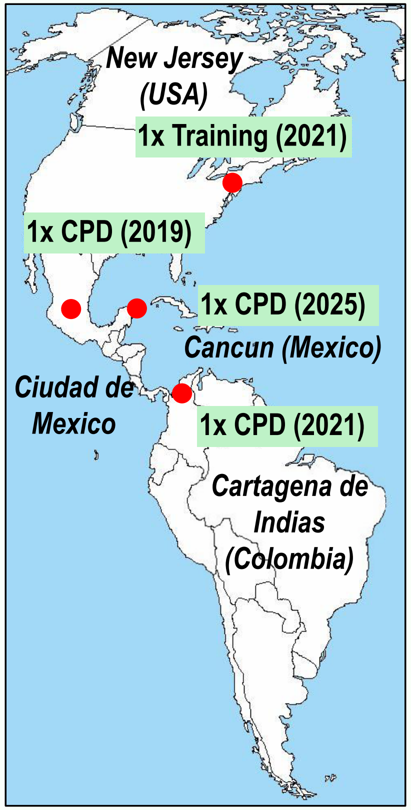

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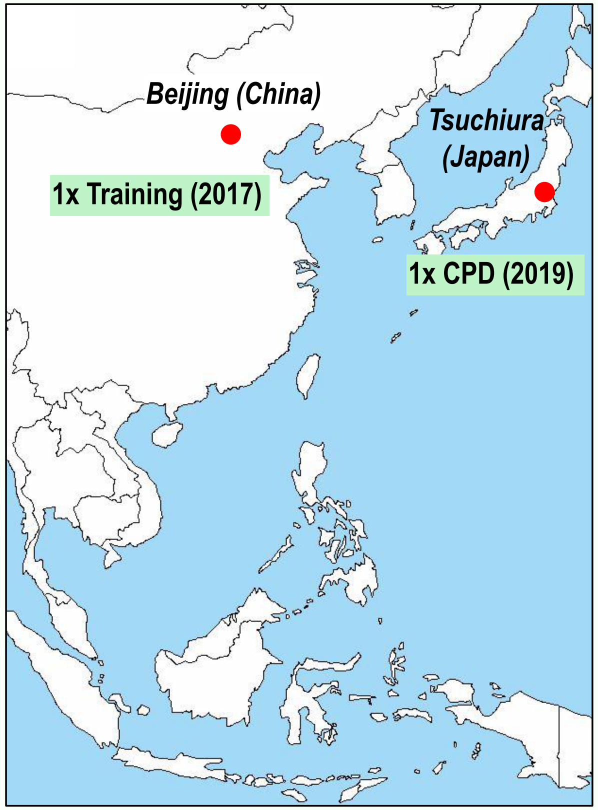
MEXICO: Ciudad de México, Cancún

COLOMBIA: Cartagena de Indias

CHINA: Pekín

JAPAN: Tsuchiura



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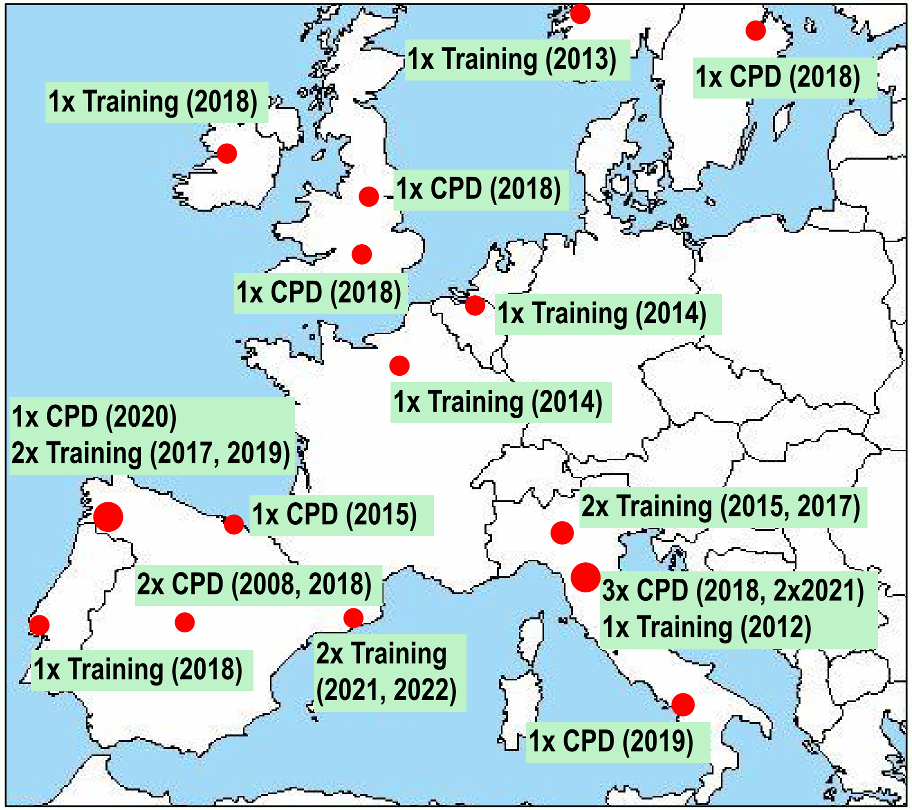

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NORWAY: Trondheim

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GERMANY: Braunschweig (Next month)

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