

Harnessing ocean wave energy

Why? How? What next?

University of Western Australia
Wave Energy Research Centre

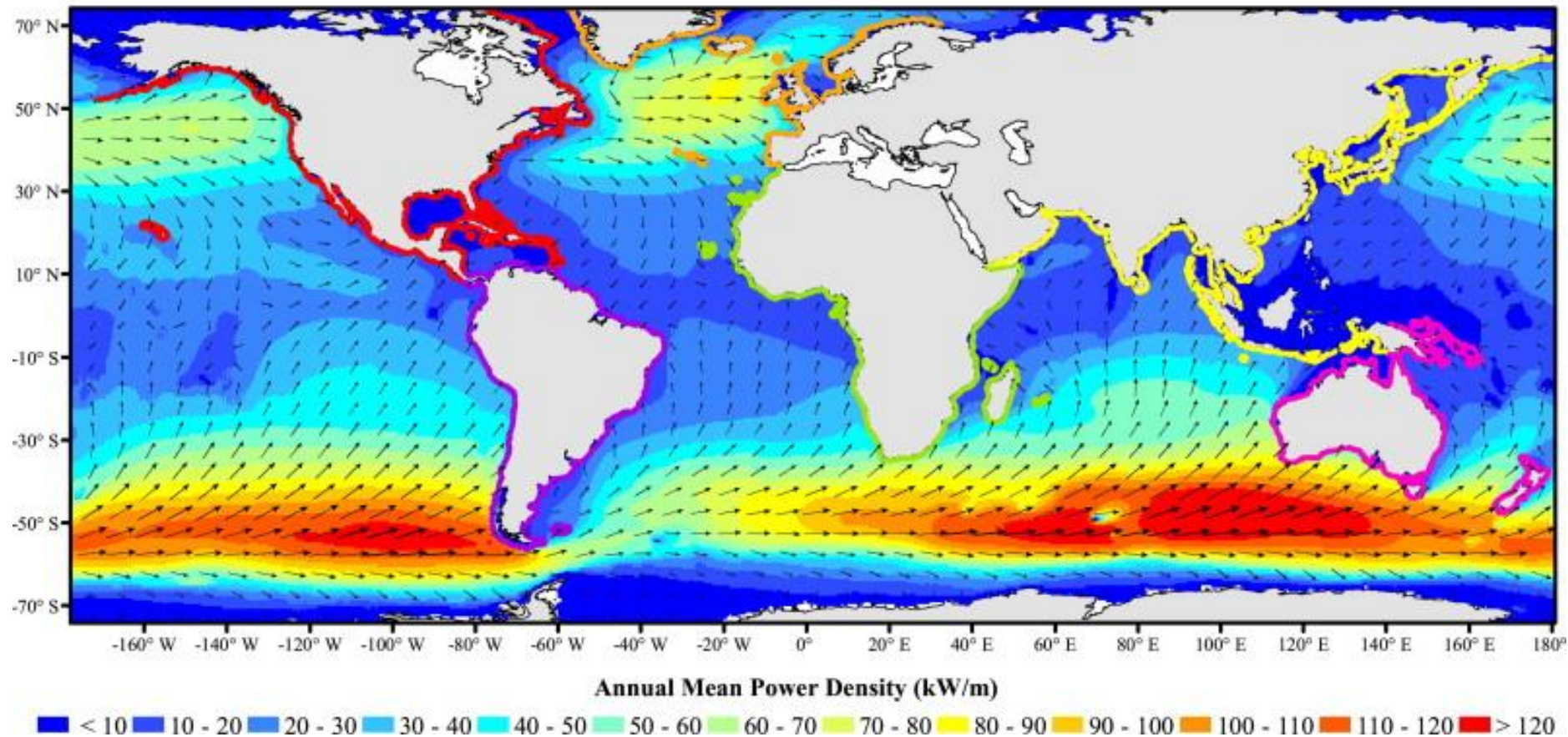
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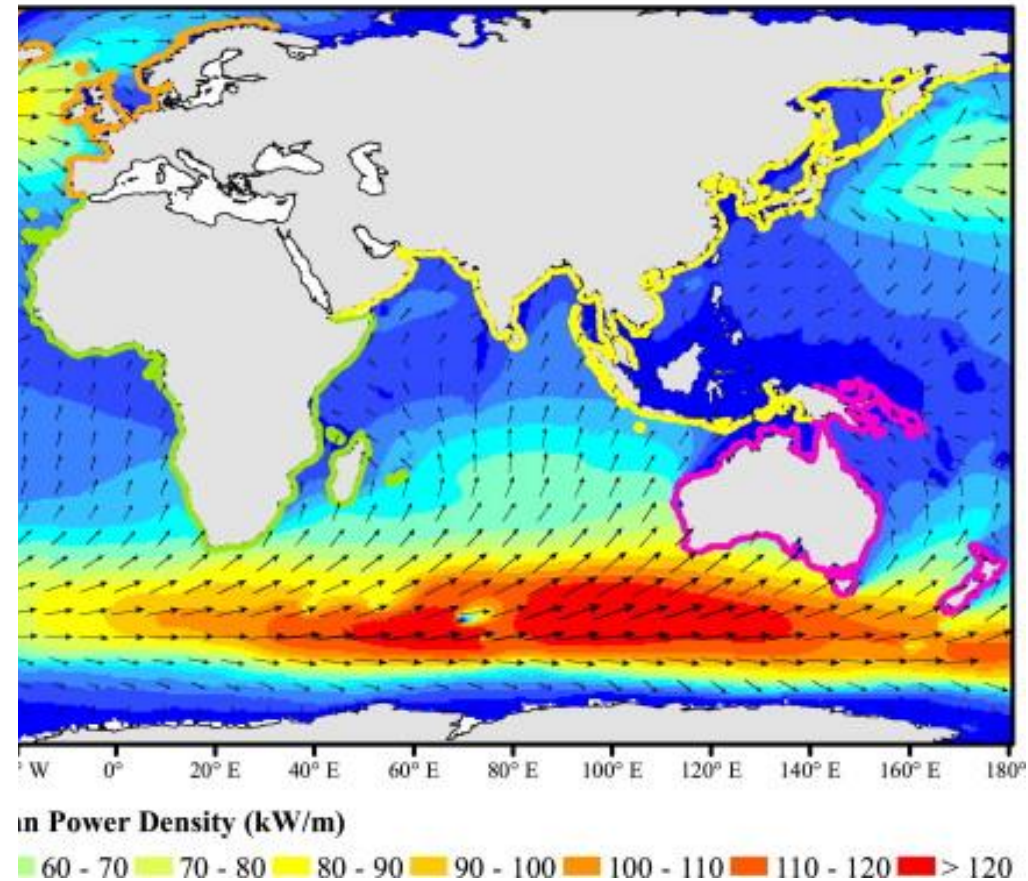
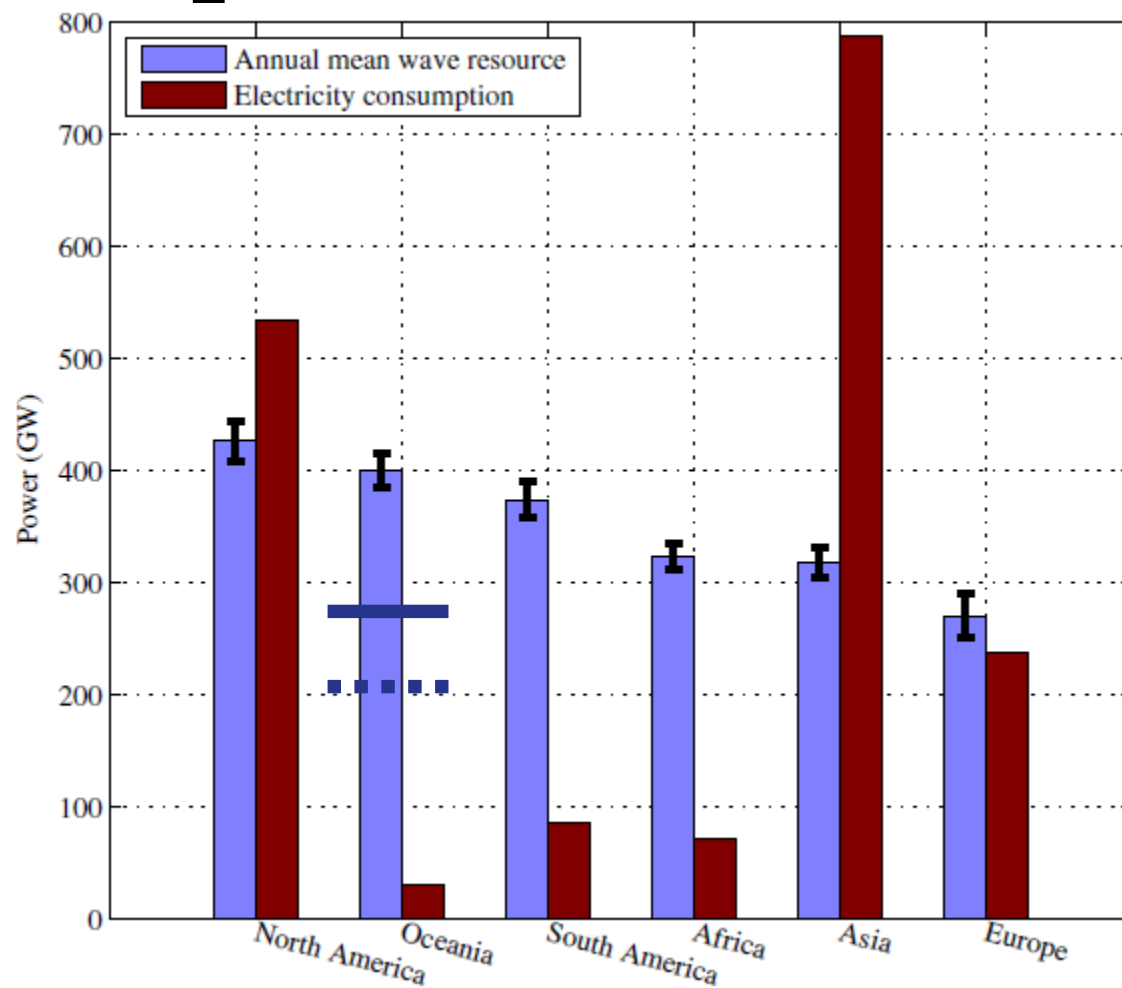
21st April 2021

Why ocean wave energy?

- Enormous resource



Why ocean wave energy?



- Enormous resource
- Wave power (deep water)

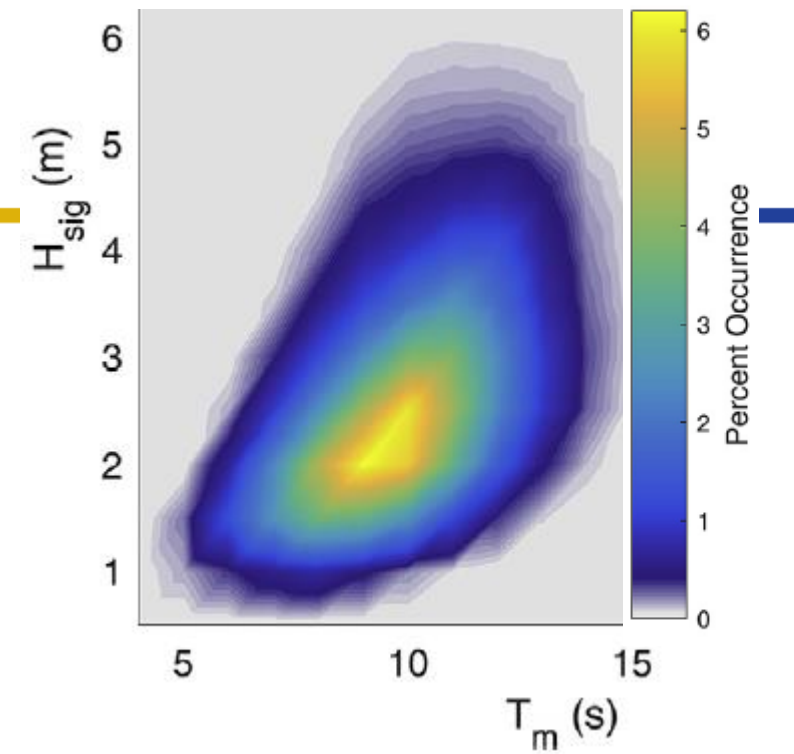
$$P = \frac{\rho g^2}{64\pi} T_e H_s^2 \quad (\text{in W/m})$$

$$\approx \frac{1}{2} T_e H_s^2 \quad (\text{in kW/m})$$

Wave energy

- Enormous resource
- Wave power (deep water)

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Energy flux of sea state with 2 m and 10 s waves (each m of wavefront)

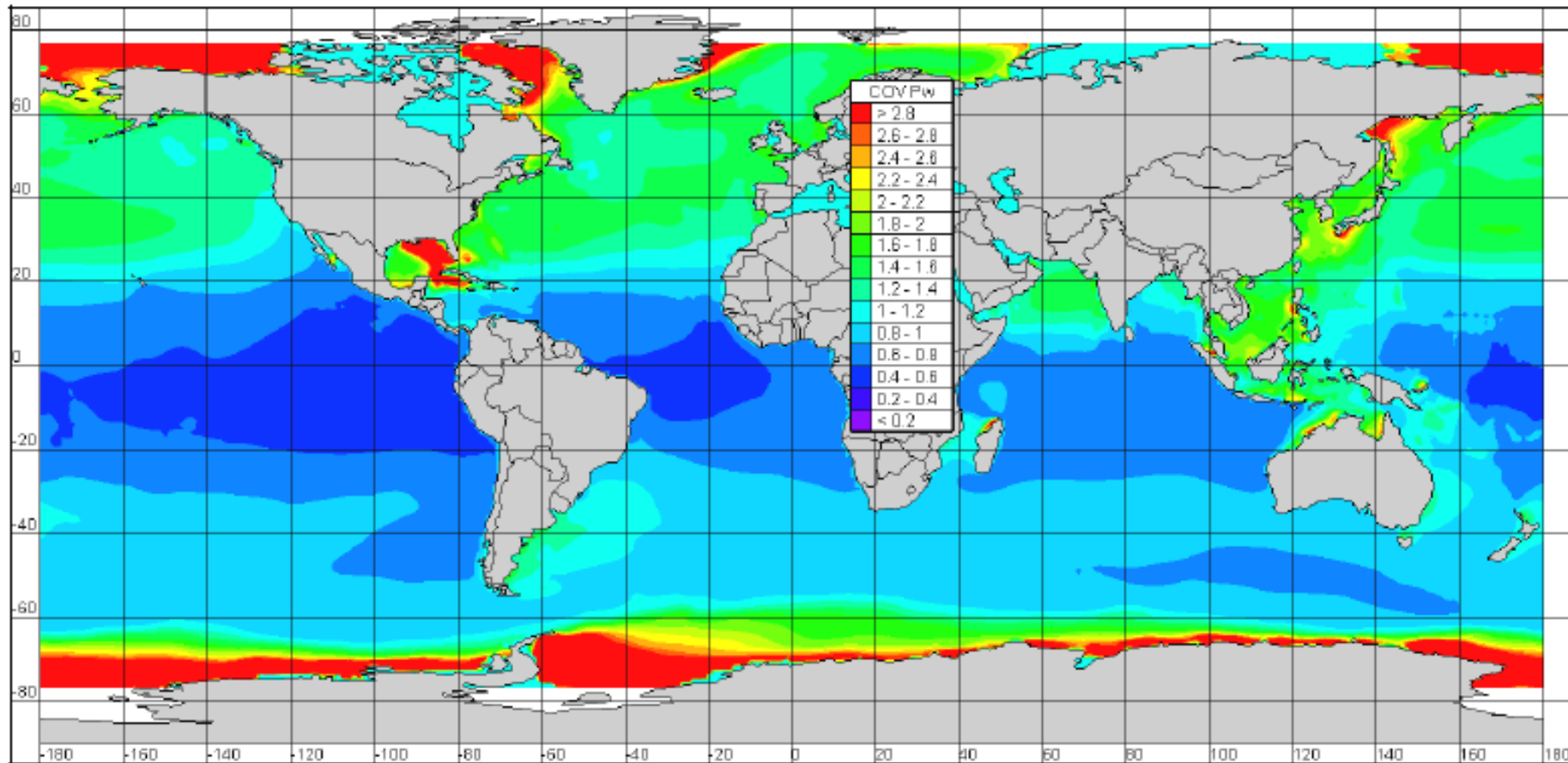
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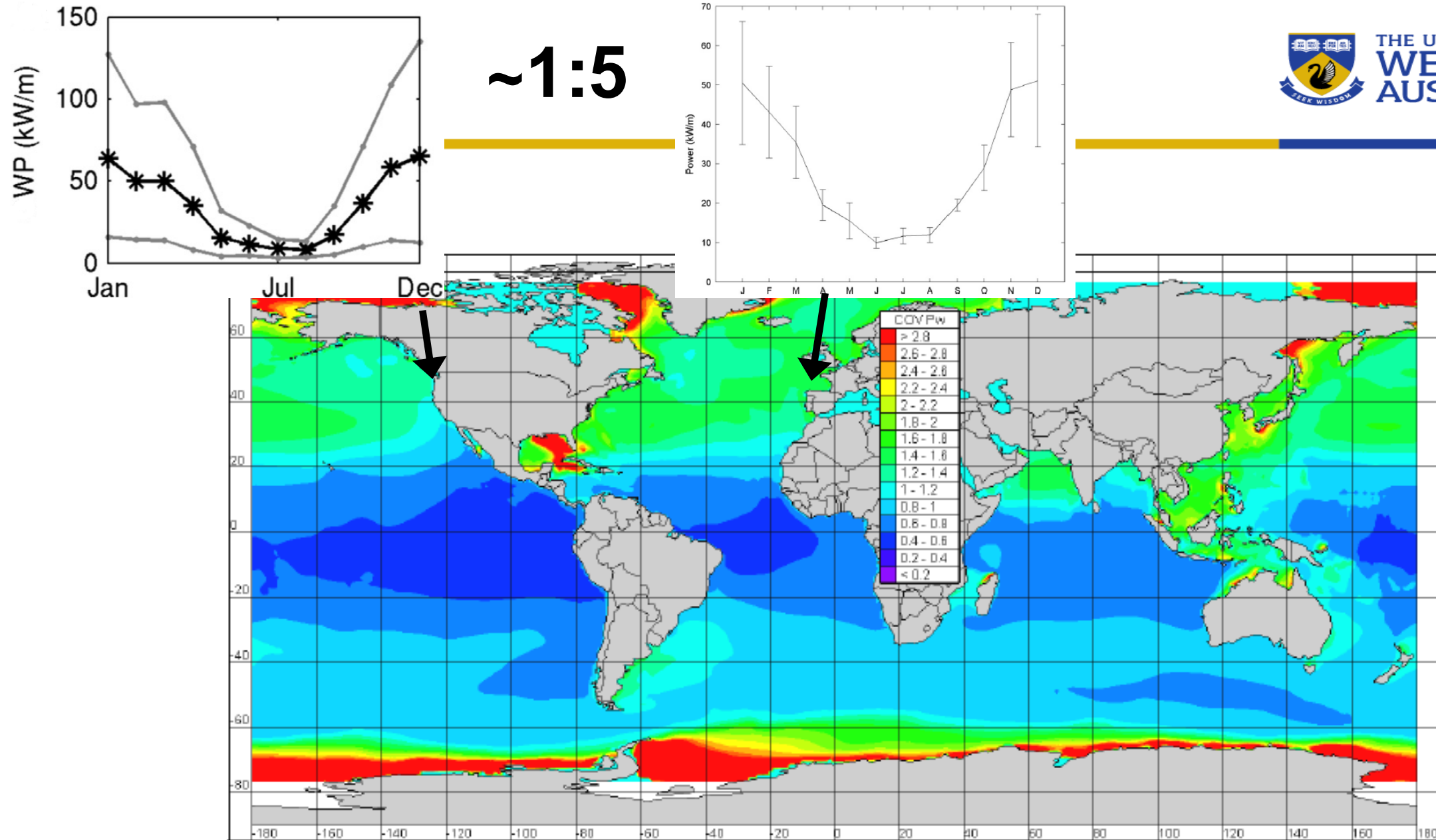
average energy consumption rate of 20-40 households

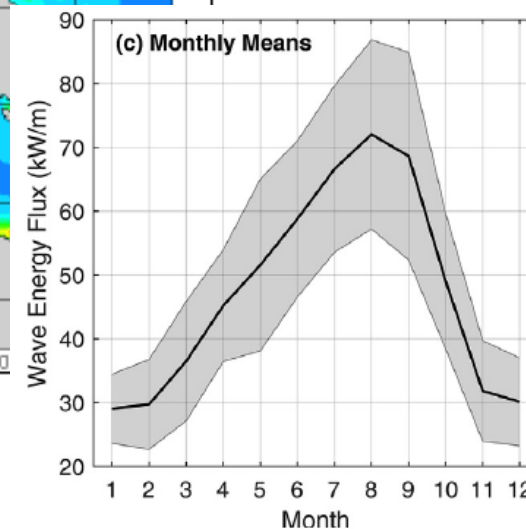
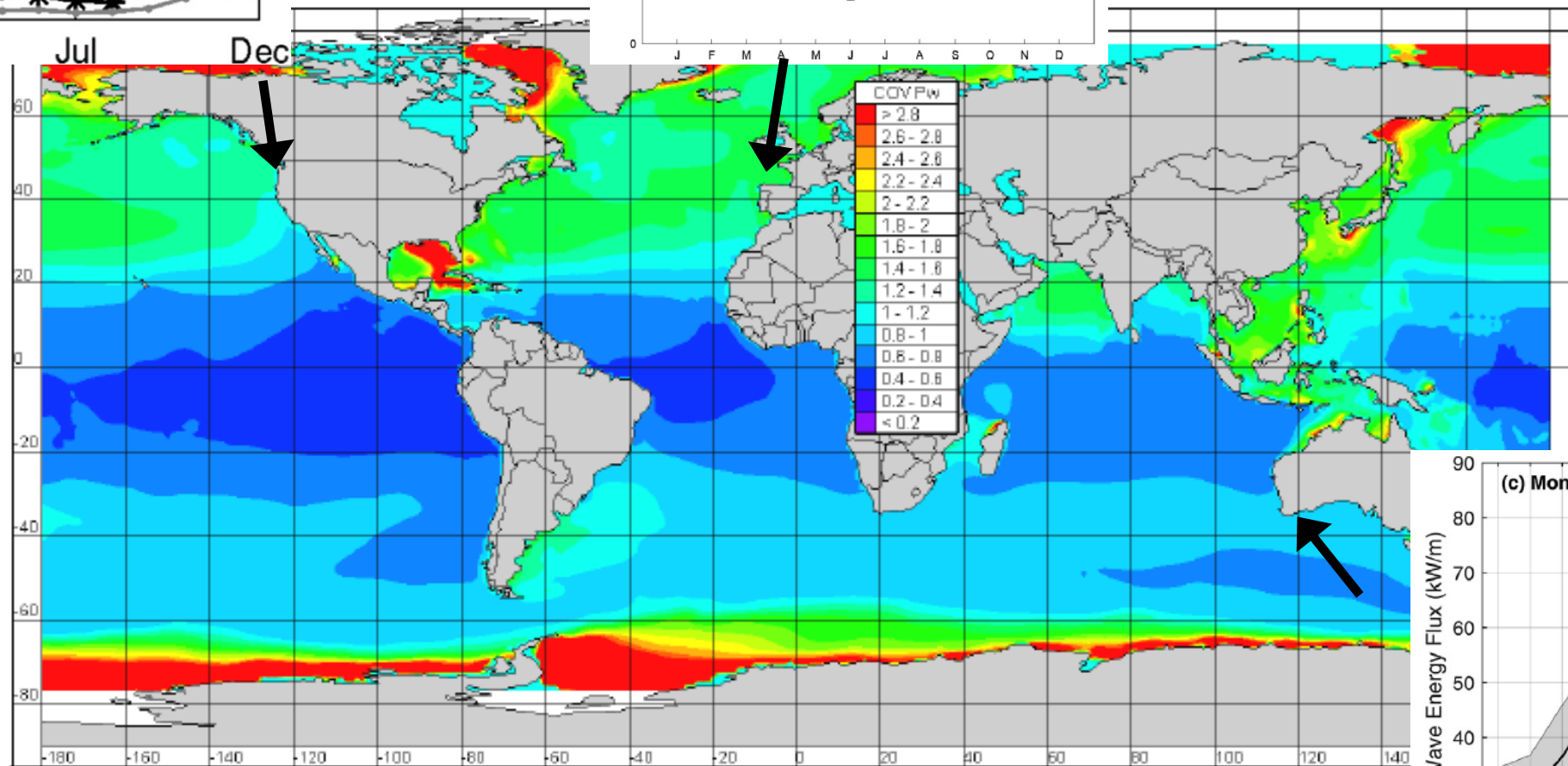
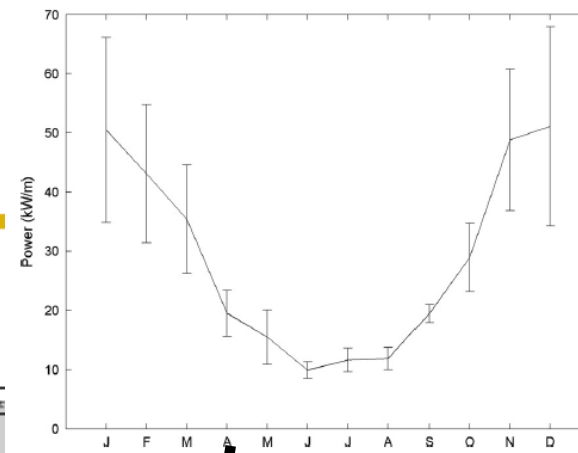
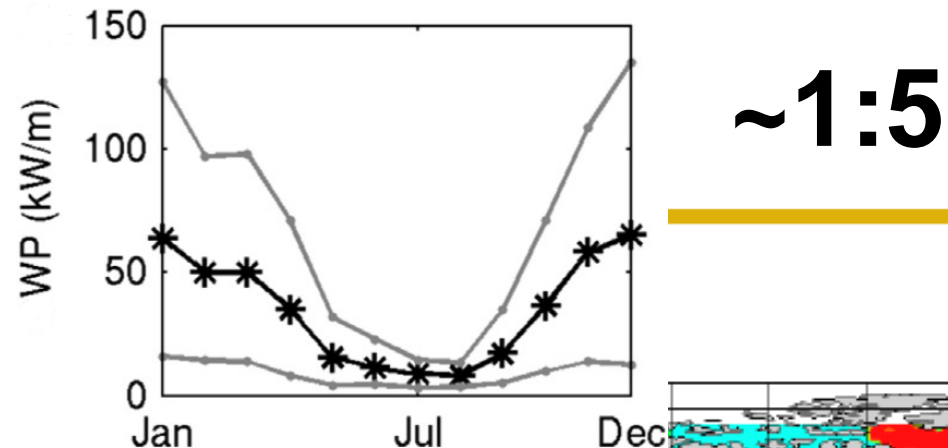
- Temporal variability matters!

Wave energy

- Coefficient of variation

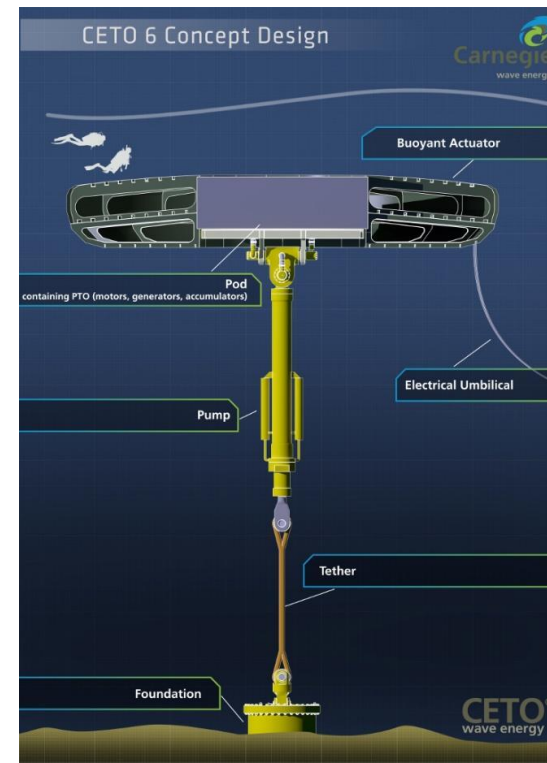






Wave energy converters WECs

- Oscillating bodies



Wave energy converters WECs

- Oscillating bodies

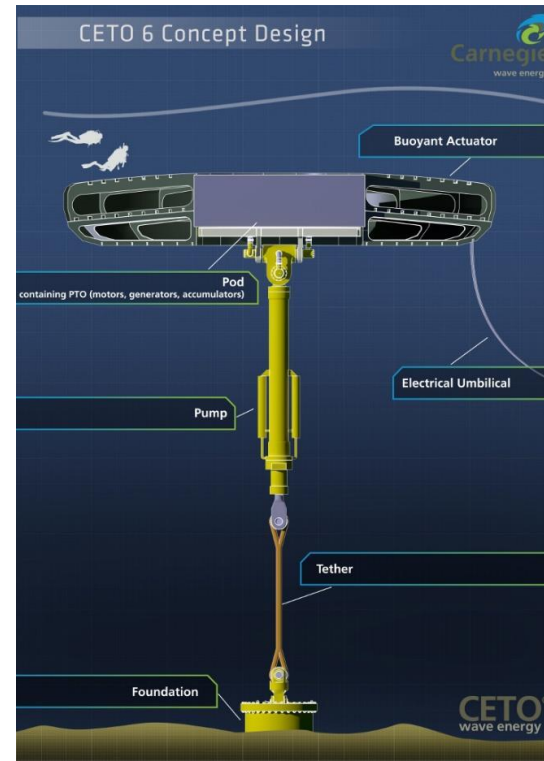
Wave
mechanical
energy



WEC
mechanical
energy



Electricity



Wave energy converters WECs

- Oscillating bodies

Wave
mechanical
energy



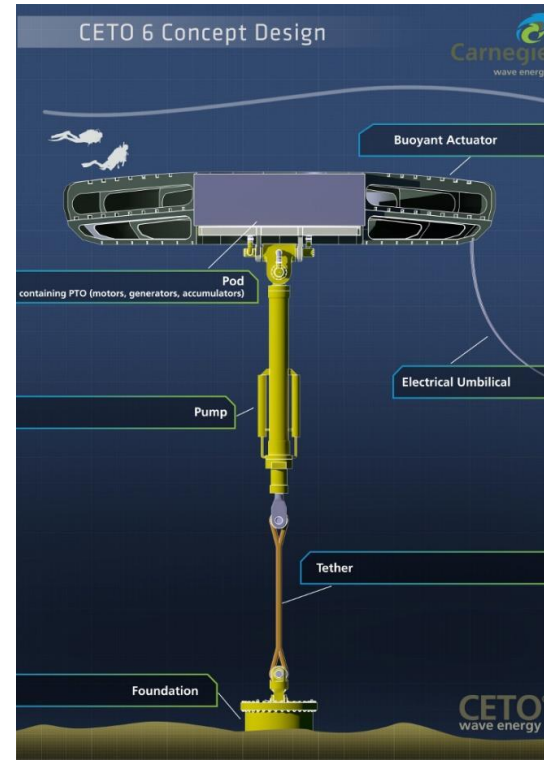
WEC
mechanical
energy



Electricity

energy
capture

wave-structure
interaction

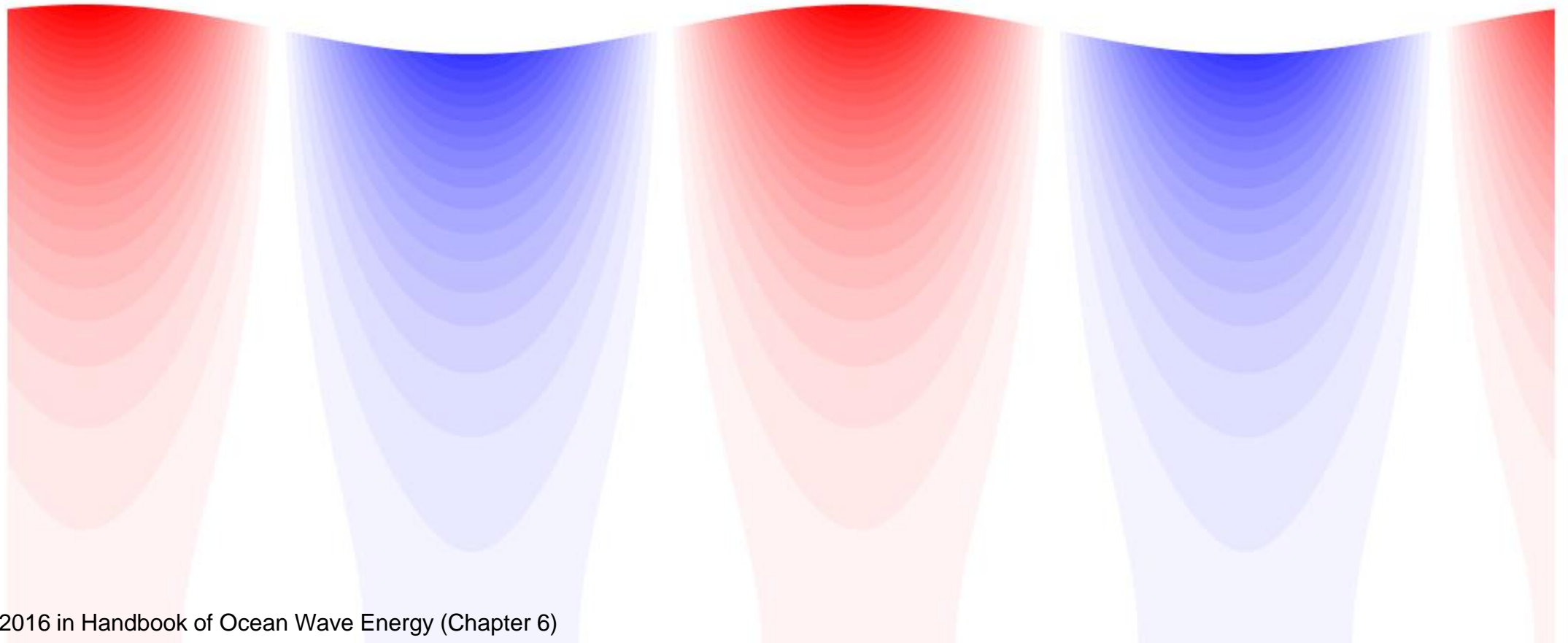
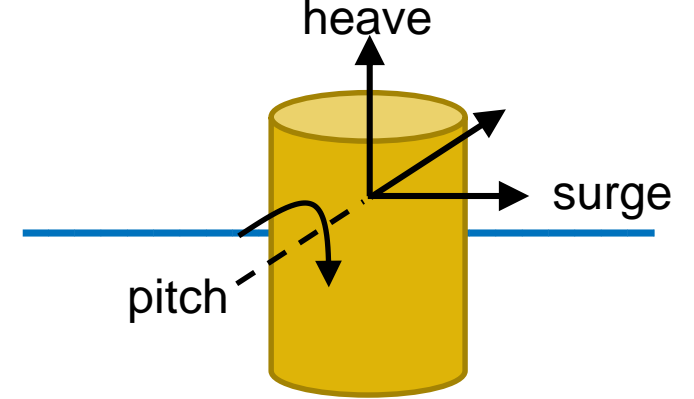


energy
conversion

power take-off

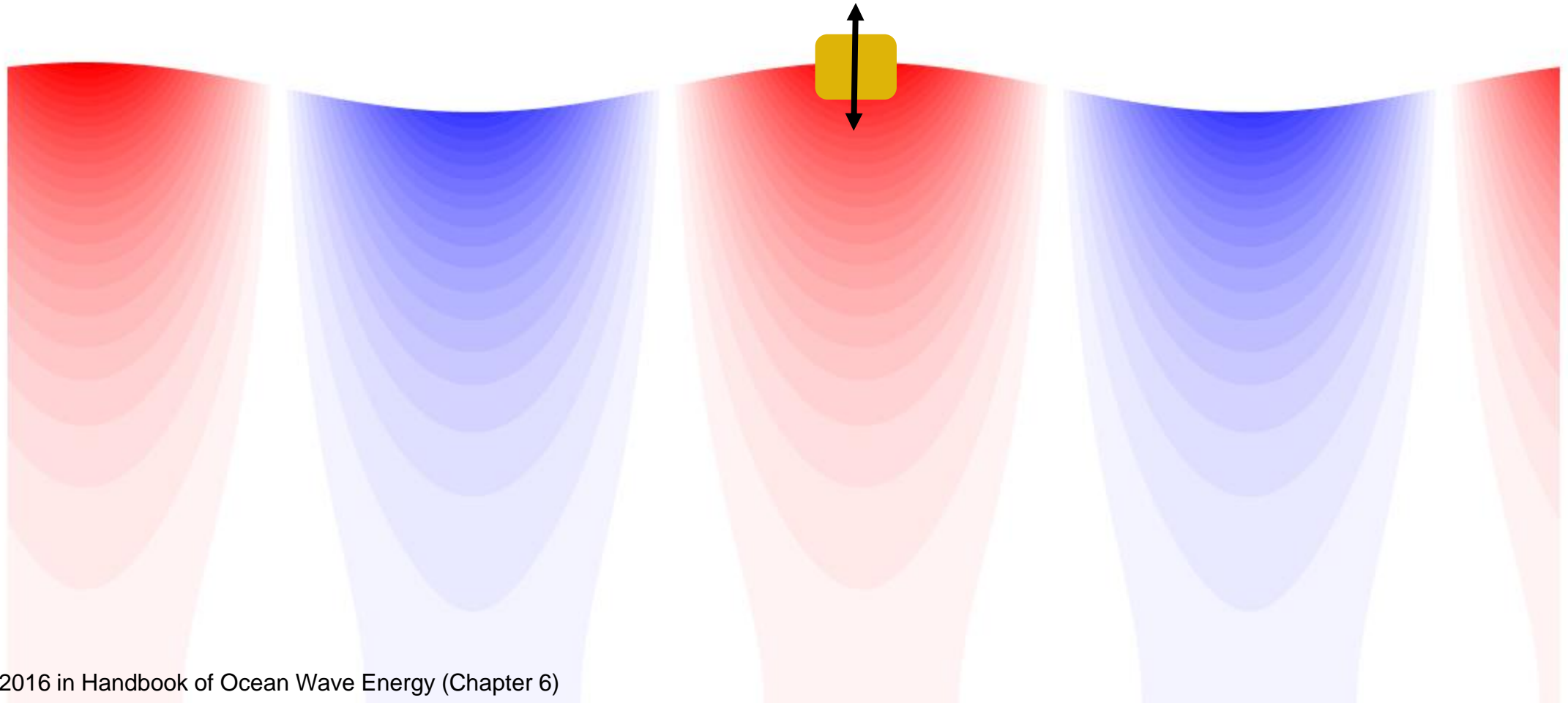
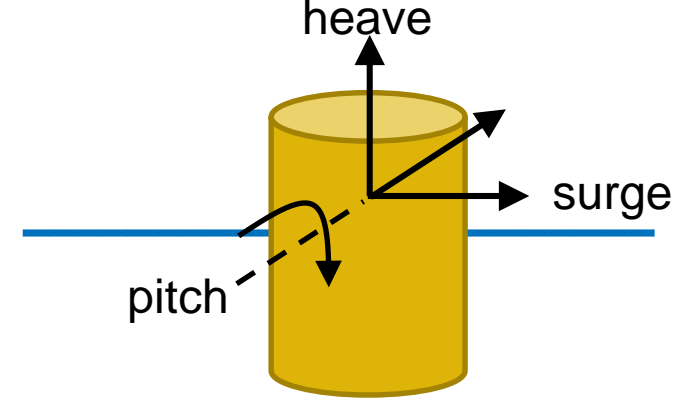
Hydrodynamic design of WECs

- Strong interaction – what shape, size, position, motion?



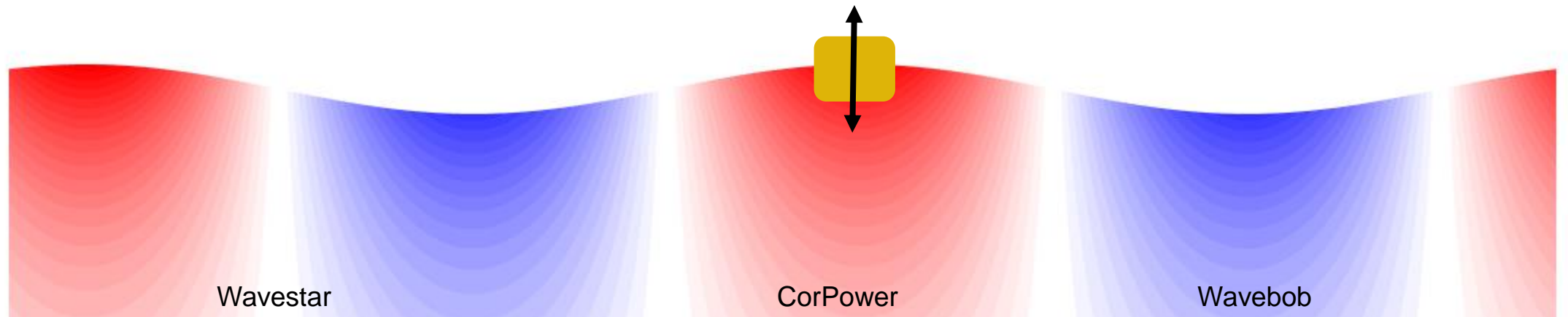
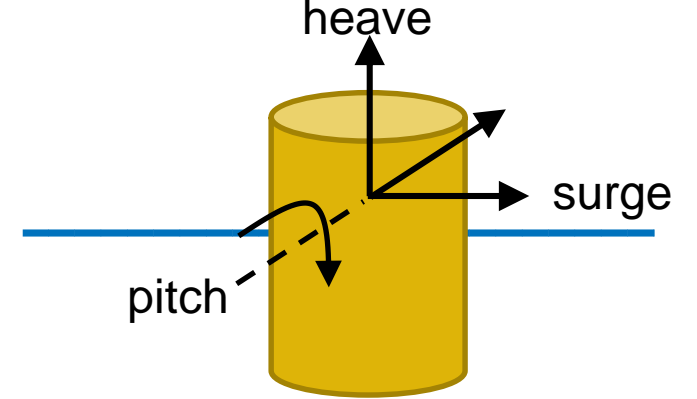
Hydrodynamic design of WECs

- Small low-draft heaving body

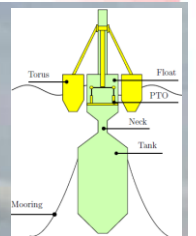
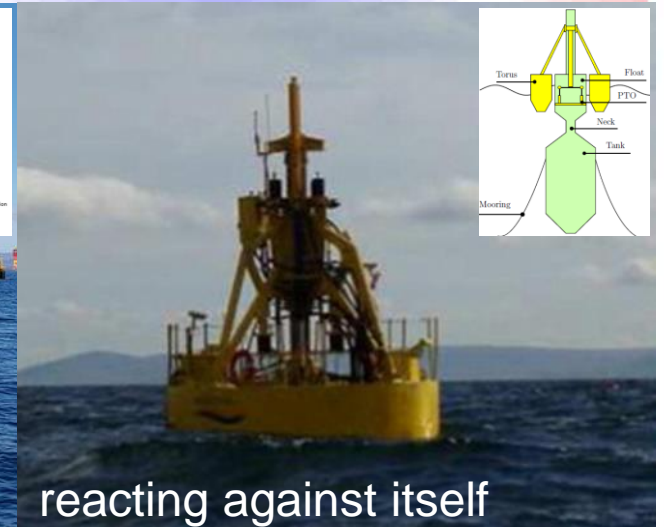
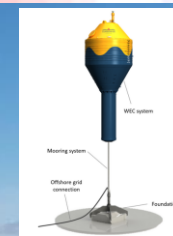
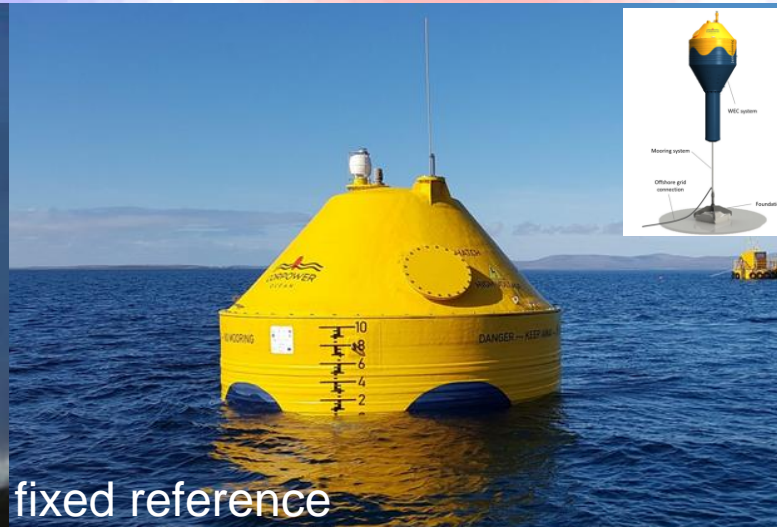


Hydrodynamic design of WECs

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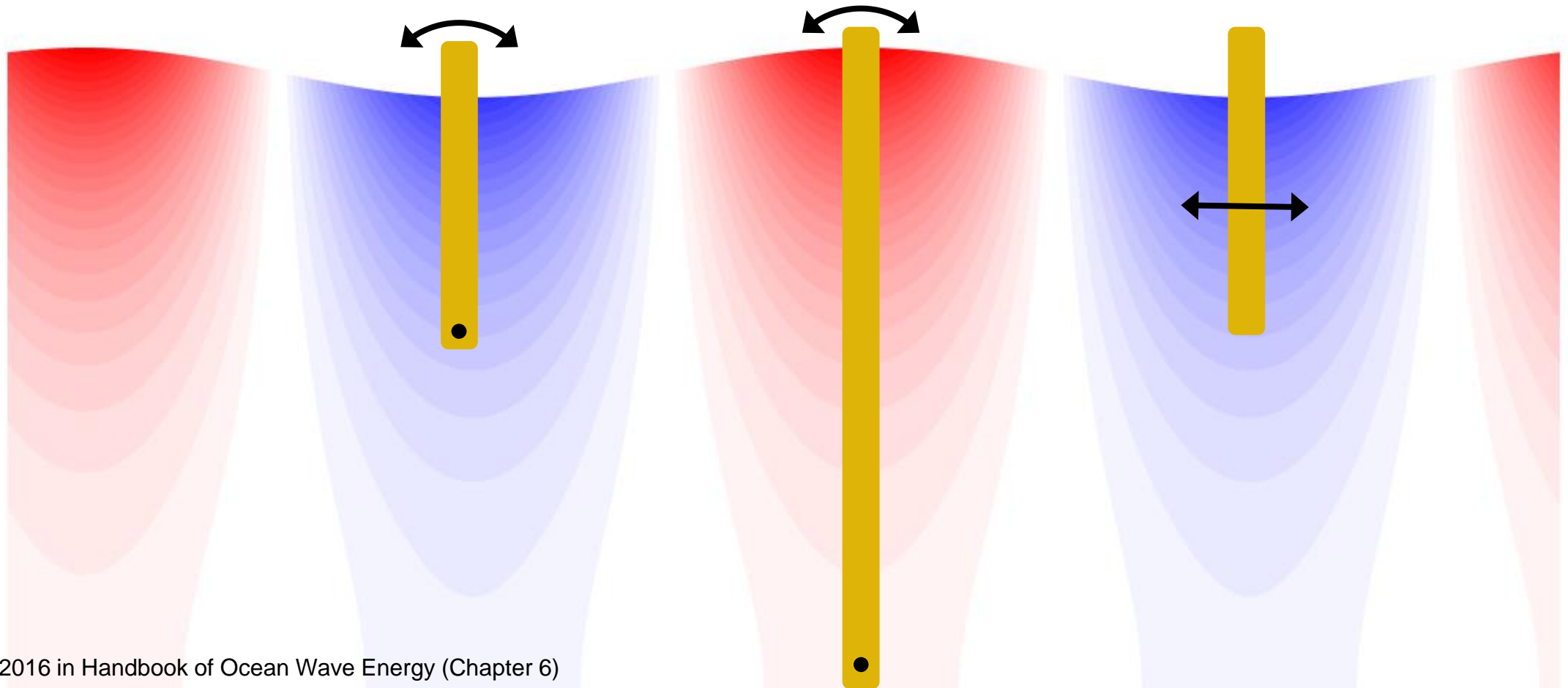
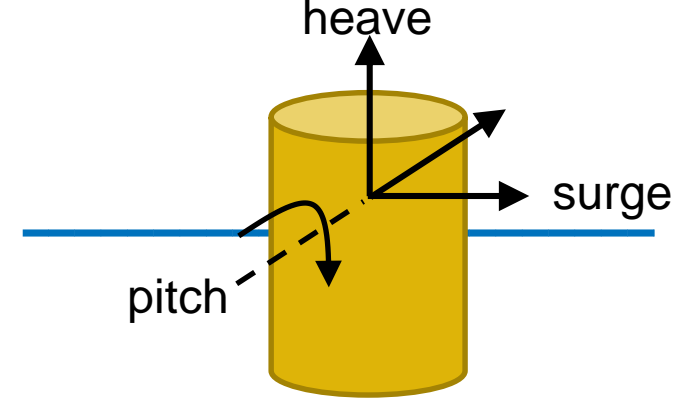
reacting against fixed reference



reacting against itself

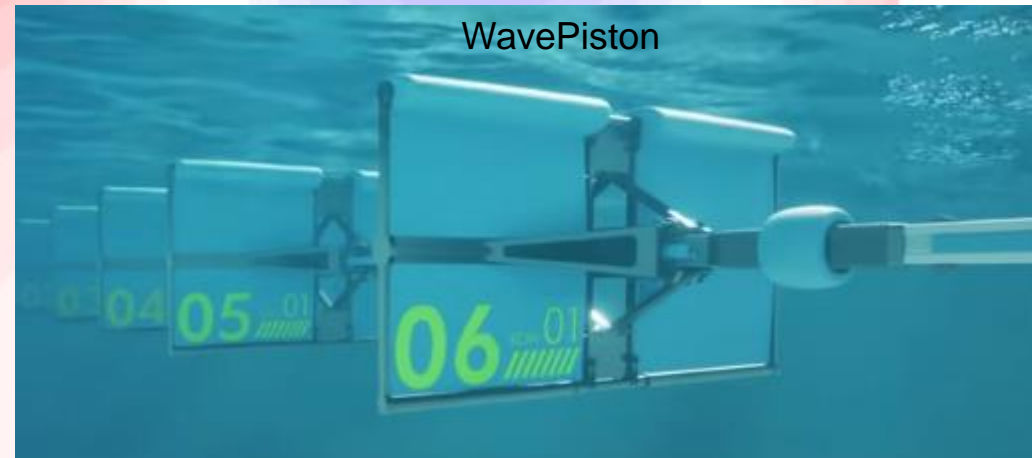
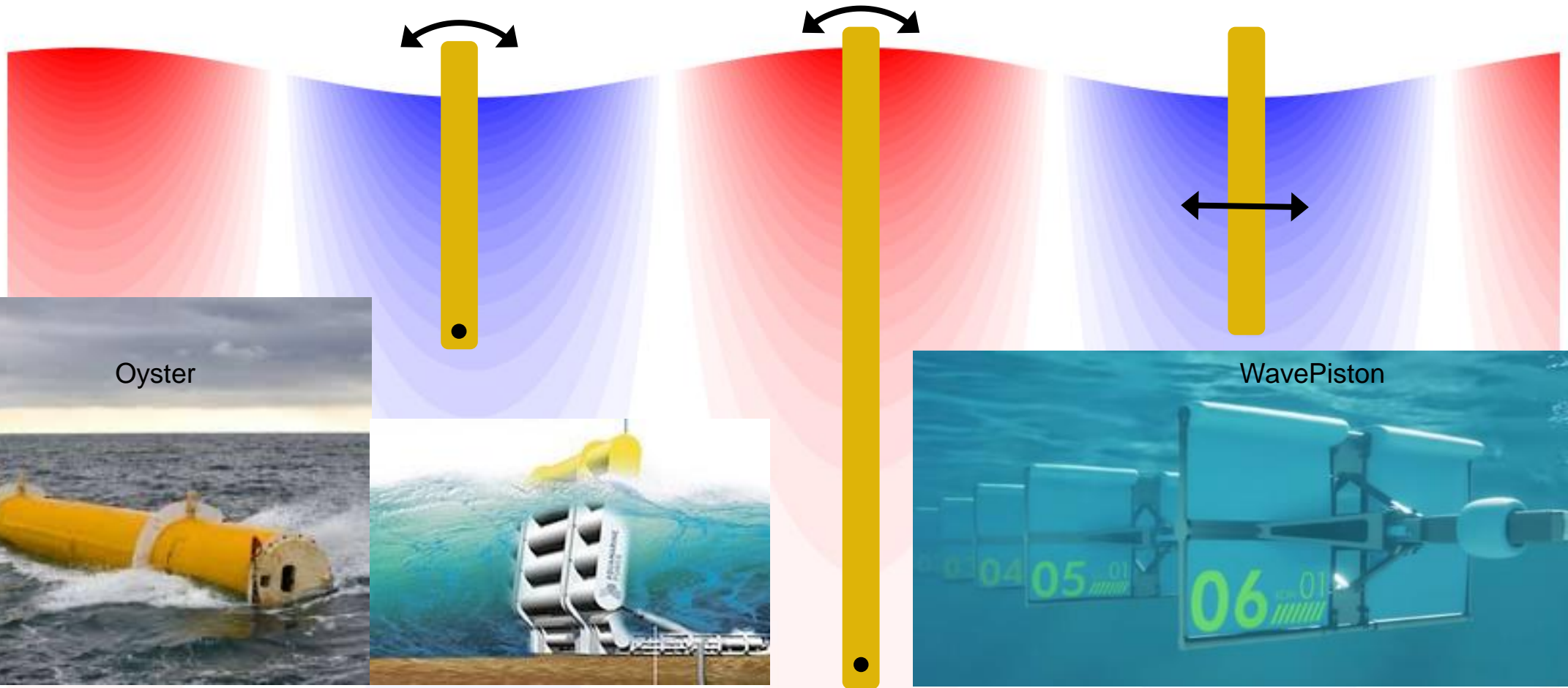
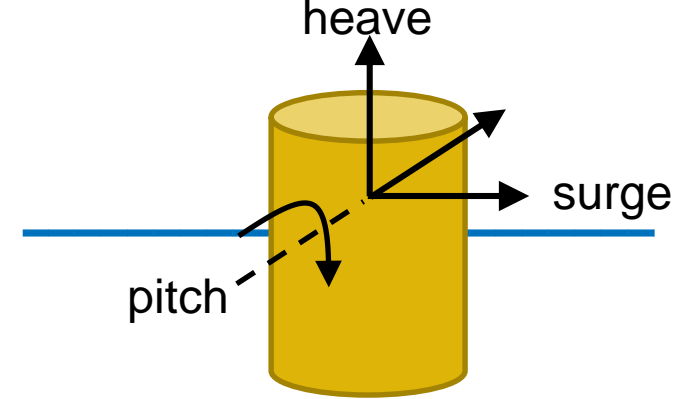
Hydrodynamic design of WECs

- Surface-piercing flap and piston



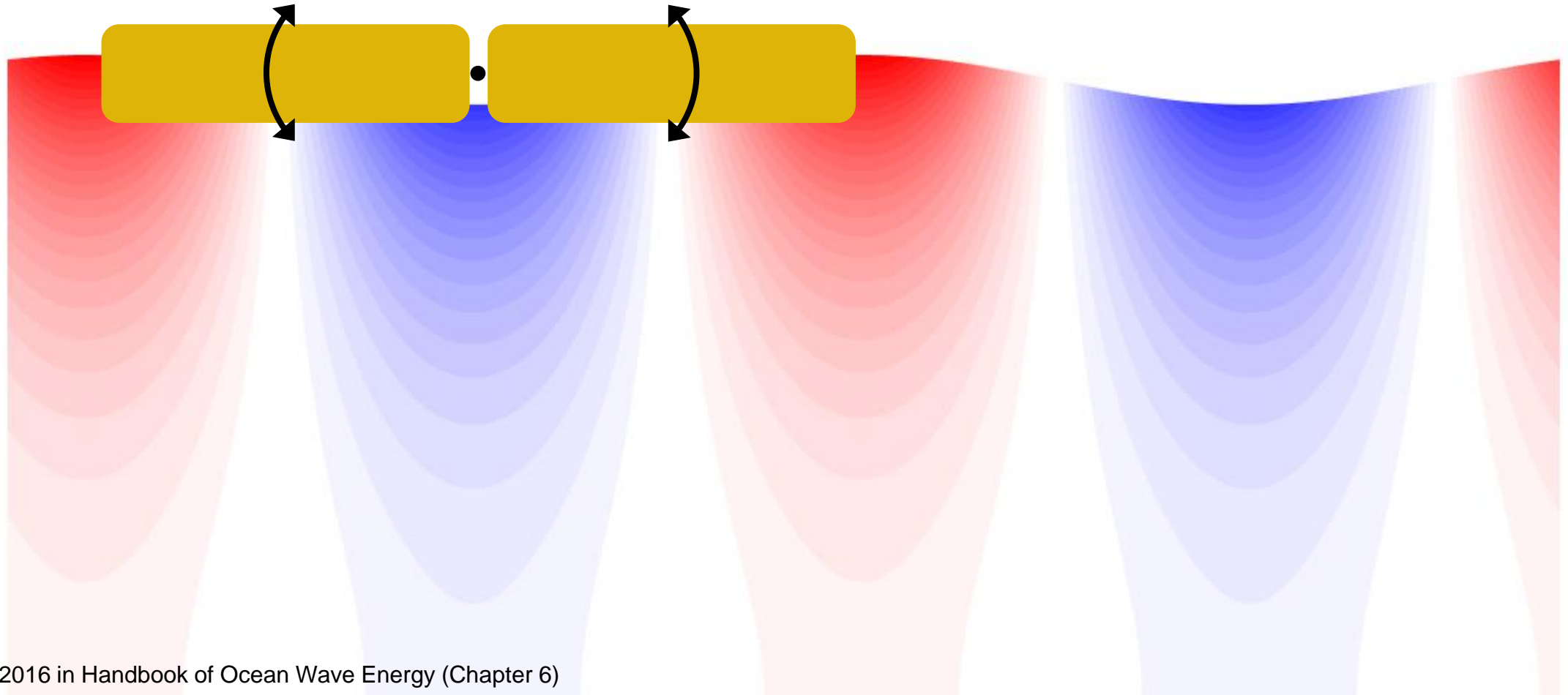
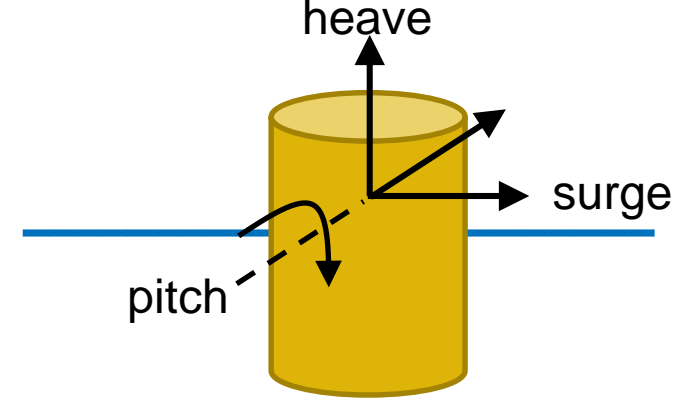
Hydrodynamic design of WECs

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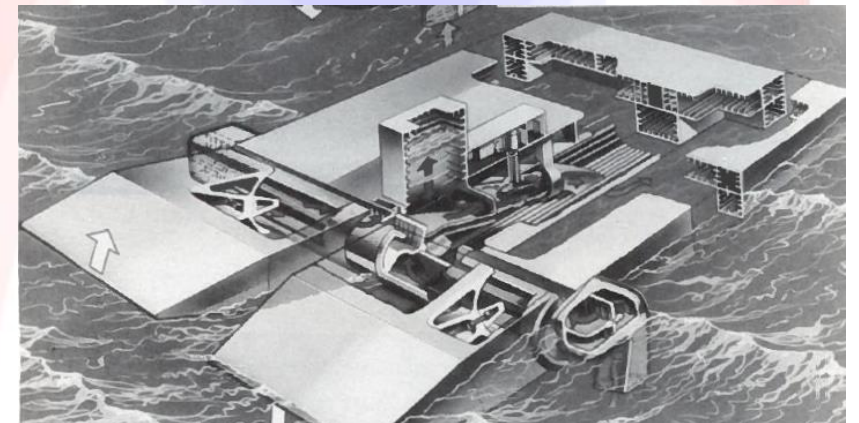
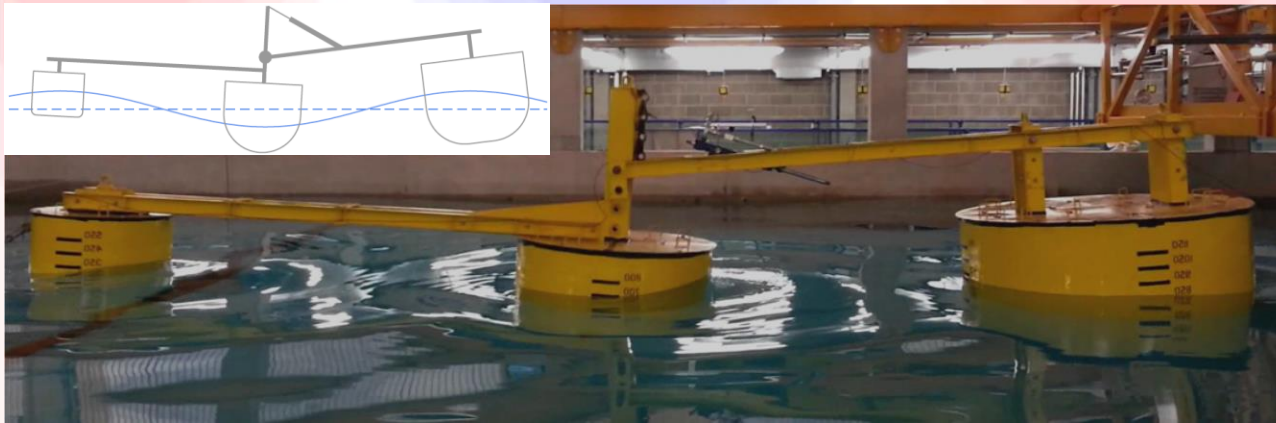
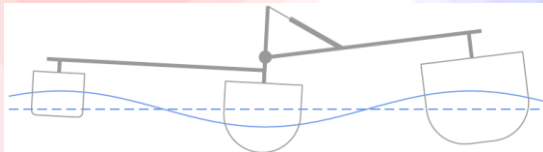
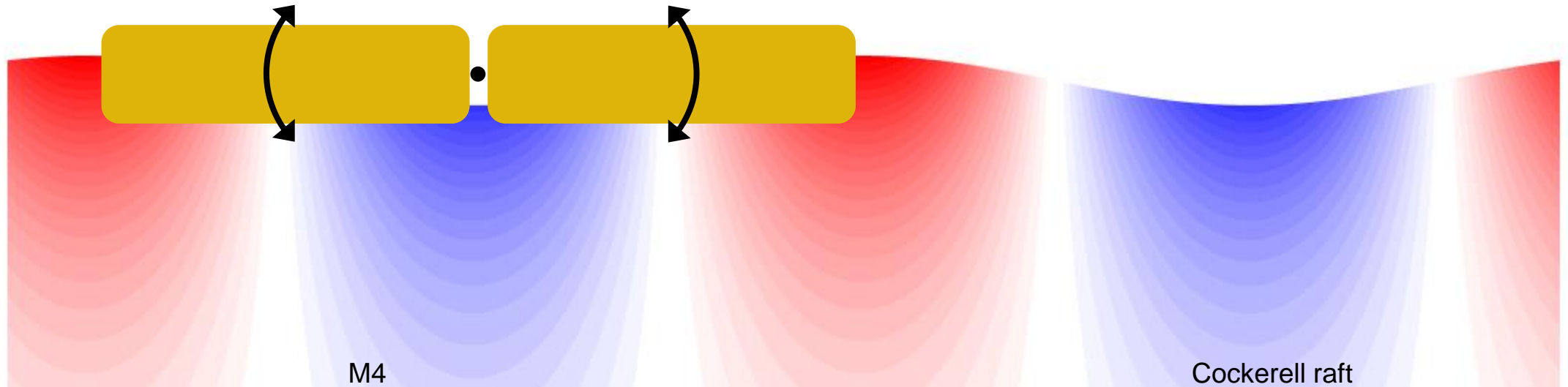
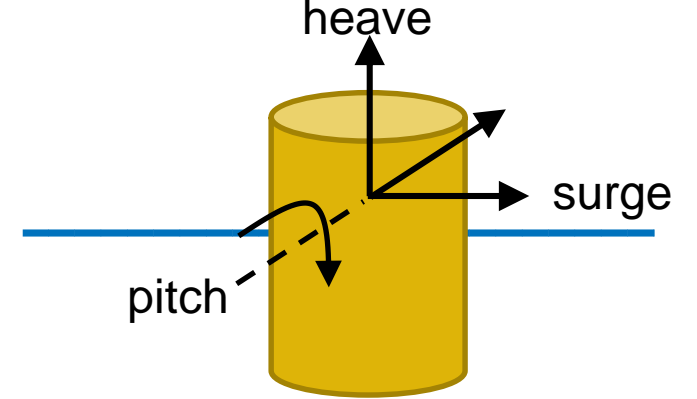
Hydrodynamic design of WECs

- Large articulated bodies



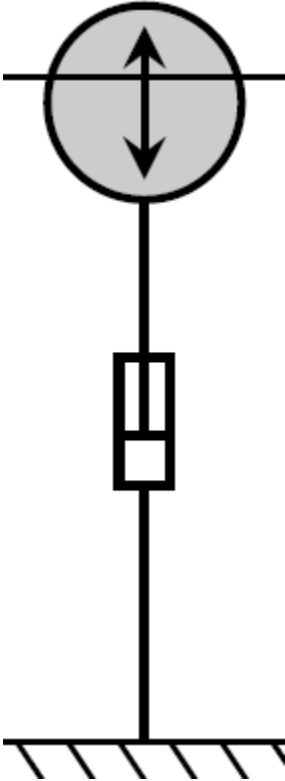
Hydrodynamic design of WECs

- Large articulated bodies



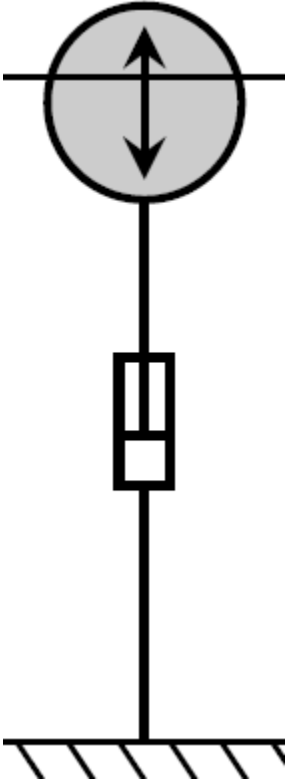
$$(m + m_r)\ddot{Z} + (B + b_r)\dot{Z} + (K + \rho g A_w)Z = F_{exc} \cos(\omega t)$$

- Strong wave-WEC interaction (large excitation / efficient wavemaker)
- Optimal WEC motion for wave energy capture:
 1. Tune natural frequency to match waves (**resonance**)
 - depends on inertia and stiffness properties
 - adjust power take-off stiffness K
 2. Alter damping to maximise power absorption
 - adjust power take-off damping B



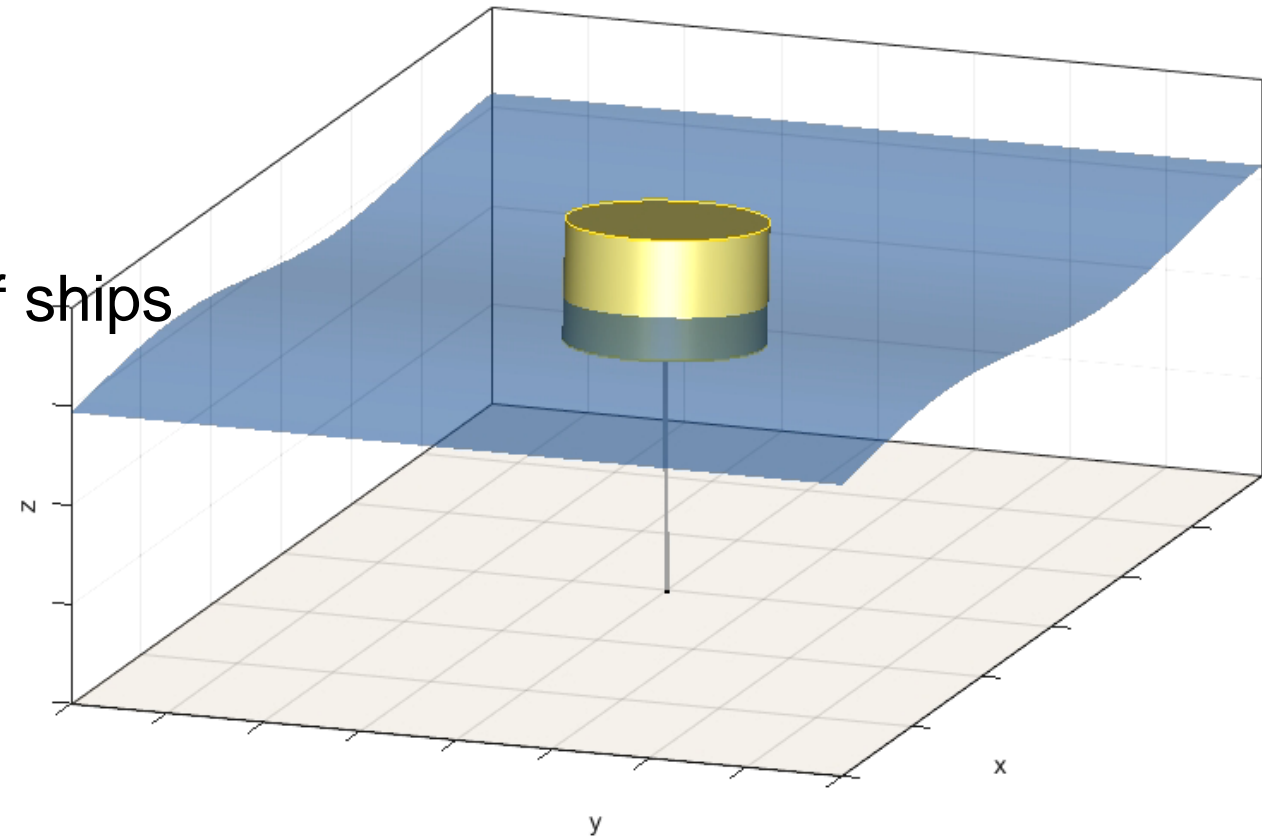
Understanding full WEC dynamics

- Design focus on **productive** mode(s) of motion.
- **BUT** other modes of motion matter
 - important for the overall dynamics
 - can be excited parametrically (**dynamic instability**)

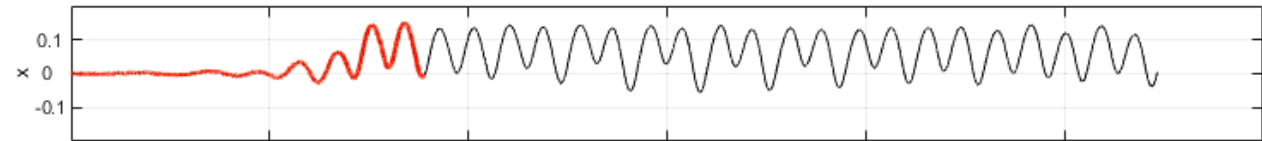


Dynamic instabilities in WECs

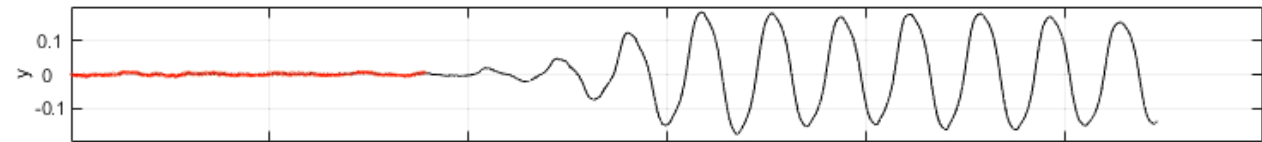
- same mechanism as parametric roll of ships
- increased fatigue loads
- decreased power performance
- need efficient advanced models



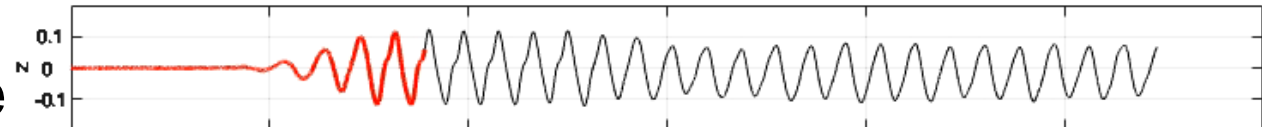
surge



sway

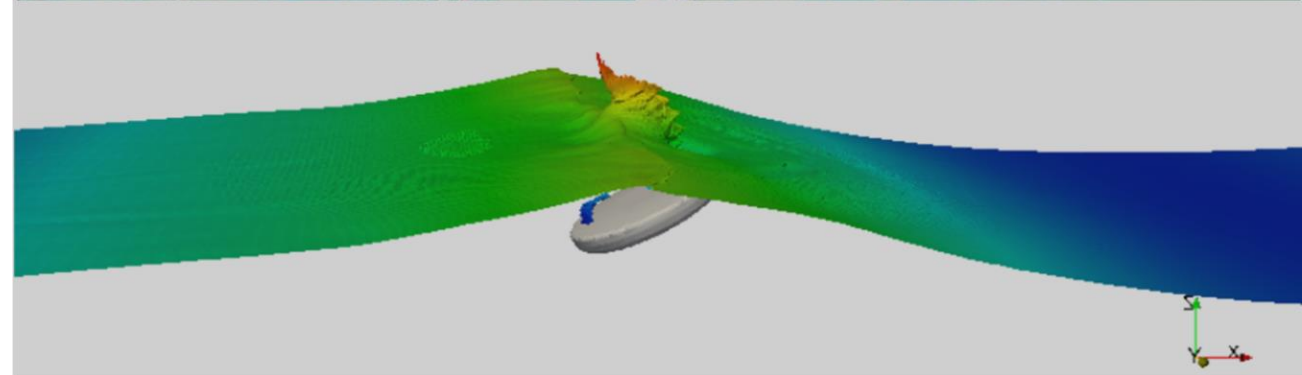
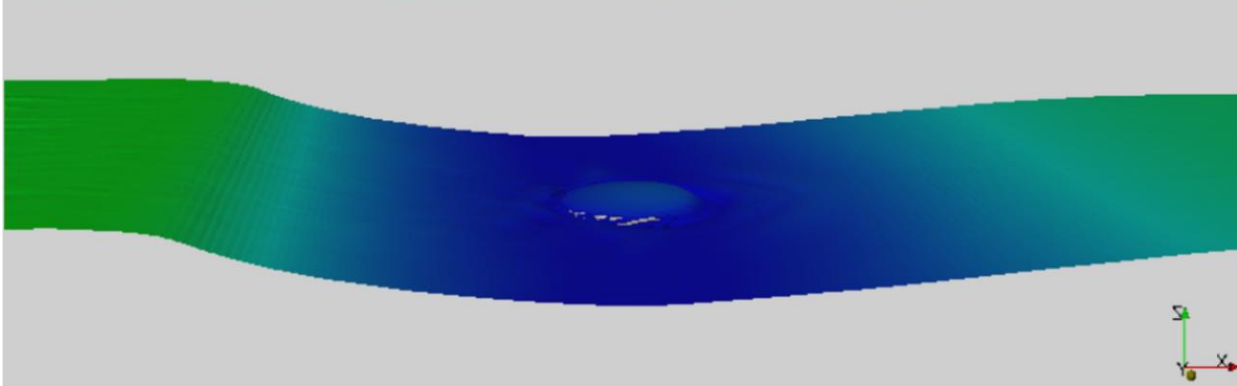


heave

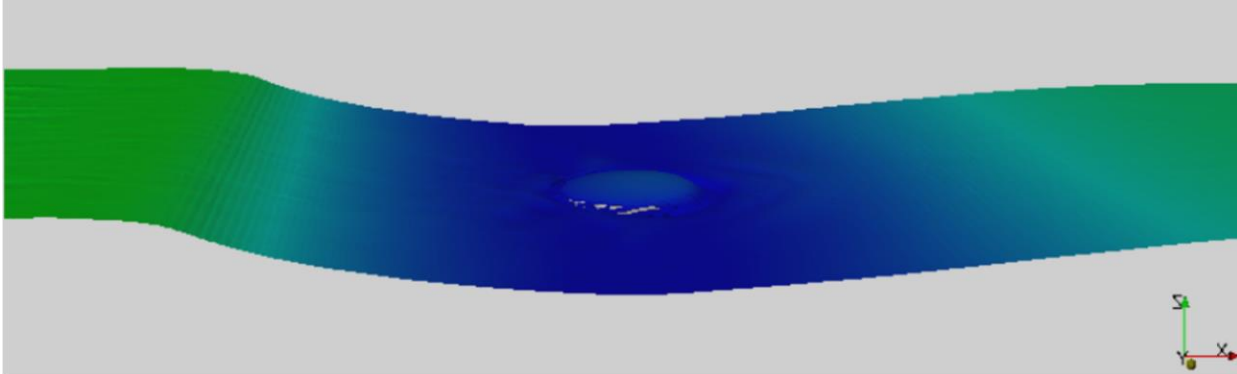


- WEC economics:
 - mild/moderate sea states = income
 - maximise energy capture and conversion efficiency
 - severe sea states = cost
 - minimise motions and loads
- Violent wave-WEC interactions need experiments and sophisticated (computationally demanding) models

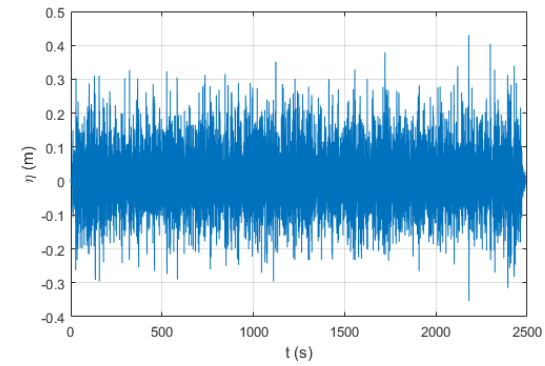
Survivability of WECs and extreme responses



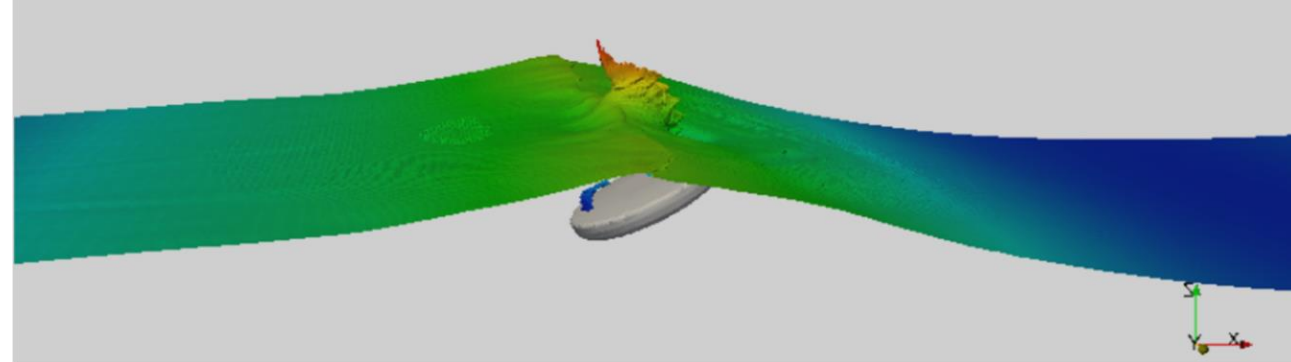
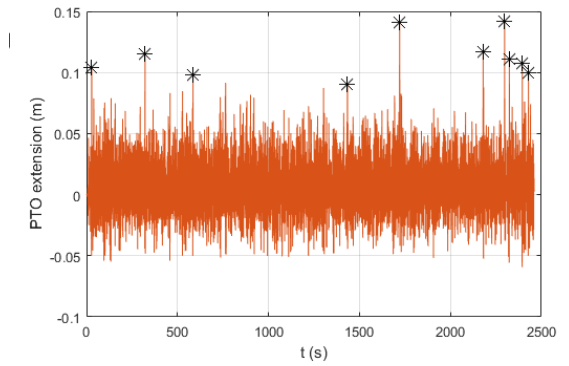
Survivability of WECs and extreme respo



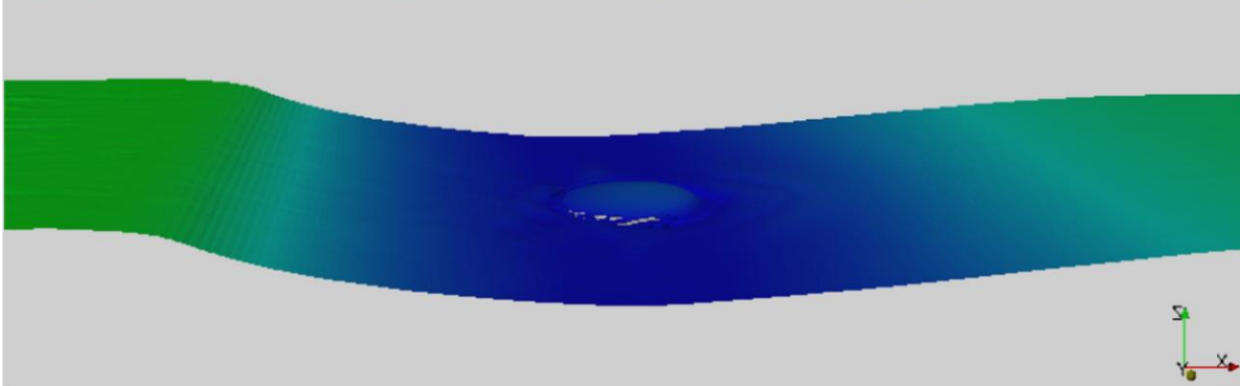
waves



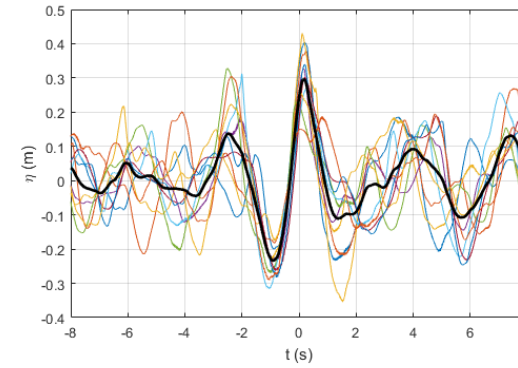
response



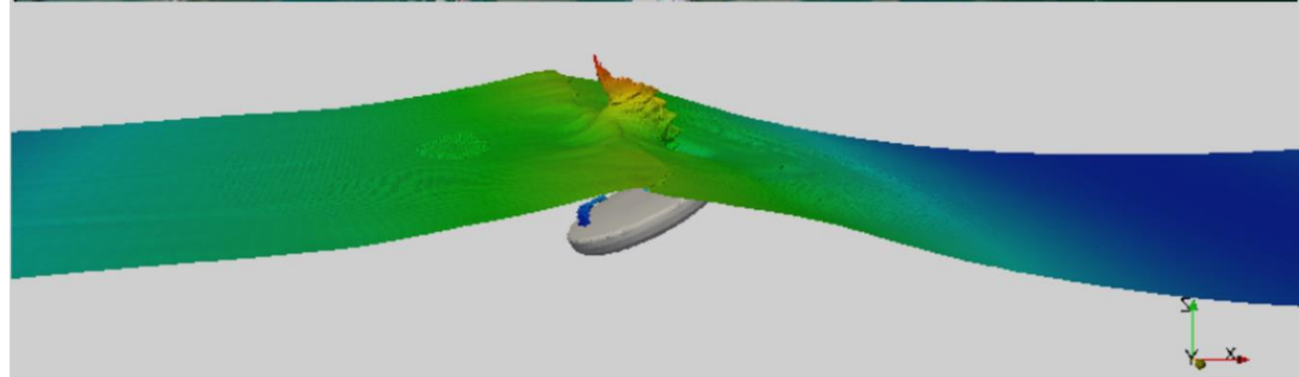
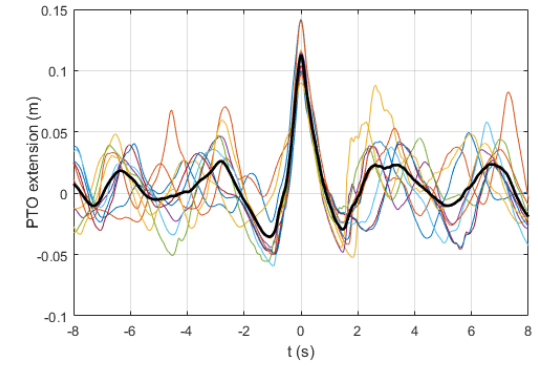
Survivability of WECs and extreme respo



waves



response



Potential markets and latest developments



- Marine aquaculture - Blue Economy CRC
- Remote coastal/island communities - WaveSwell at King Island, Tasmania
- Desalination
- Ocean observation and navigation
- Automated / unmanned / remotely operated vehicles
- Offshore data centers



- Wave energy resource and its potential.
- Hydrodynamic principles of energy capture.
- Current research topics and future markets/opportunities for WECs.

Thank you.



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