The National Decommissioning Centre
Innovation through Partnership

University of Aberdeen

Net Zero Technology Centre
Technology Driving Transition

DEPLOYMENT FEASIBILITY STUDIES OF VARIABLE BUOYANCY ANCHORS FOR FLOATING WIND APPLICATIONS

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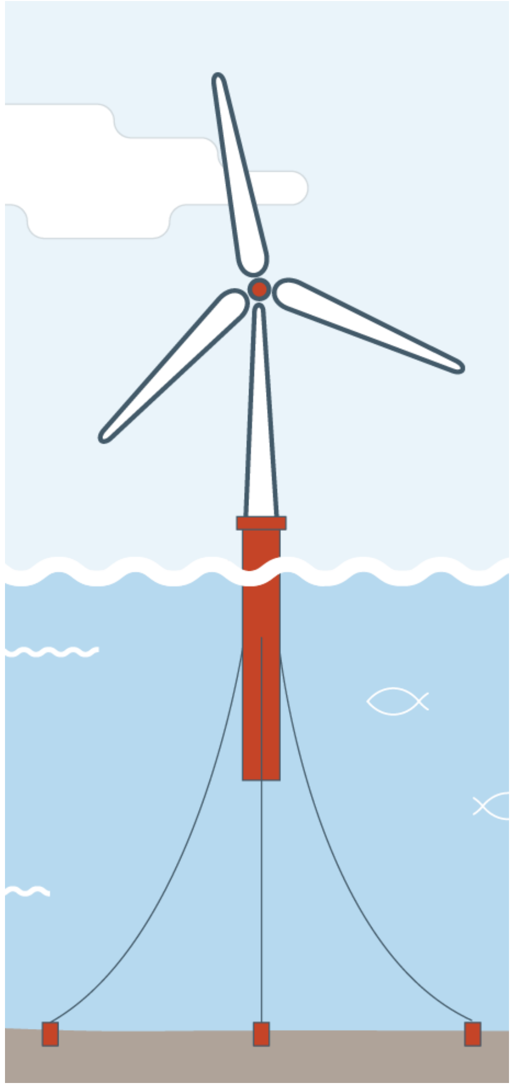
Research rationale

- Motivation:
  - To simplify the installation and reduce costs of floating offshore wind turbines.
- Proposed solution:
  - Liquid Anchor technology, that delivers improved anchor holding capacity and thereby reduced installation costs.
  - A variable buoyancy anchor towed and installed from smaller vessel without the need of heavy lift equipment.
  - Virtual field trials ahead of offshore deployments through multi-physics simulations under controlled multi-variables conditions: waves, currents, wind, drag & lift forces and more.



The simulator

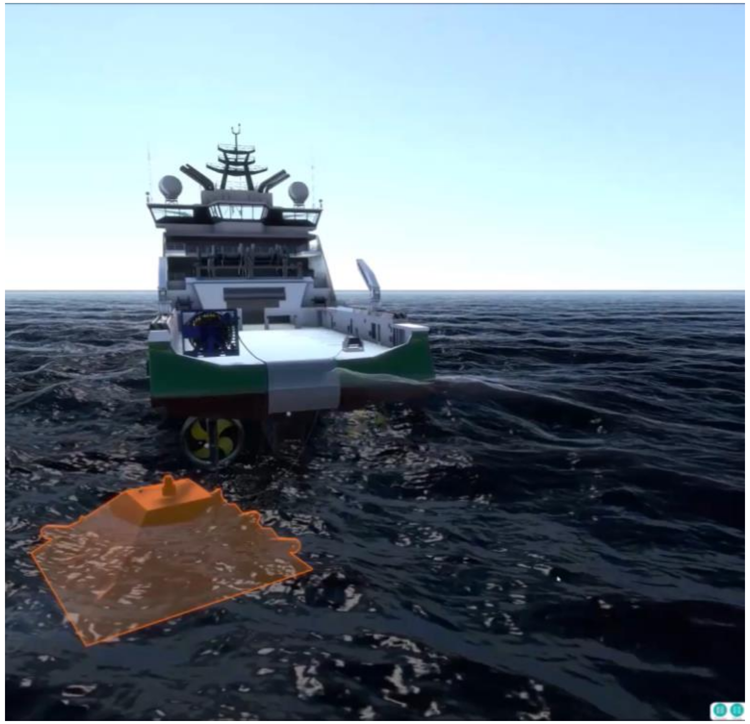
- A walk-in 300-degree visual immersive environment
- 4 stations with ability to assign control of any object/asset in the scene to one of the stations (chairs) for example ROVs, cranes, personnel, vessels etc.
- All simulation based on real time physics calculations
- Ability to place objects and modify simulation parameters in runtime
- All objects within scene have full effect from user-controlled environment, for example vessels are affected fully by waves, current, wind etc.
- Delivered with a library of ships, ROVs, cranes and objects (jackets, containers etc.)
- Ability to import CAD data to the simulator system.

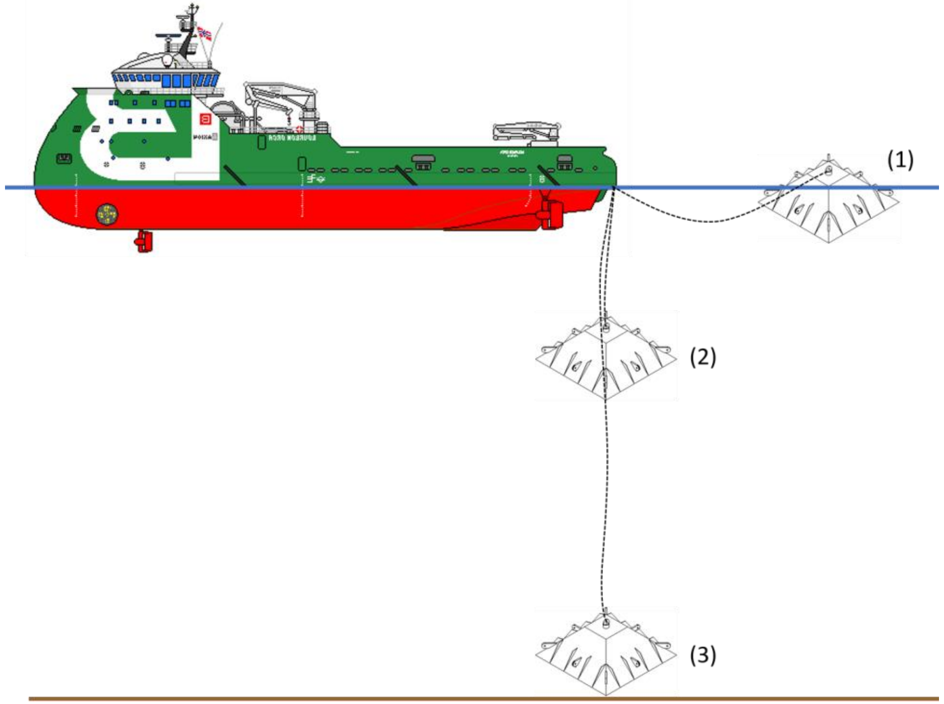
- Real-physics simulations allows for realistic tests that would otherwise be highly expensive.
- Aside from visually appealing, data is exported for analysis and support the decision-making process.

Deployment process

- Deployment in 100 meters water depth
- Irregular waves with a JONSWAP spectrum
- Significant wave height (H_s) ranging from 1 to 5 meters
- Peak period (T_p) of 10s for all H_s values.
- Current of 0.1 knots

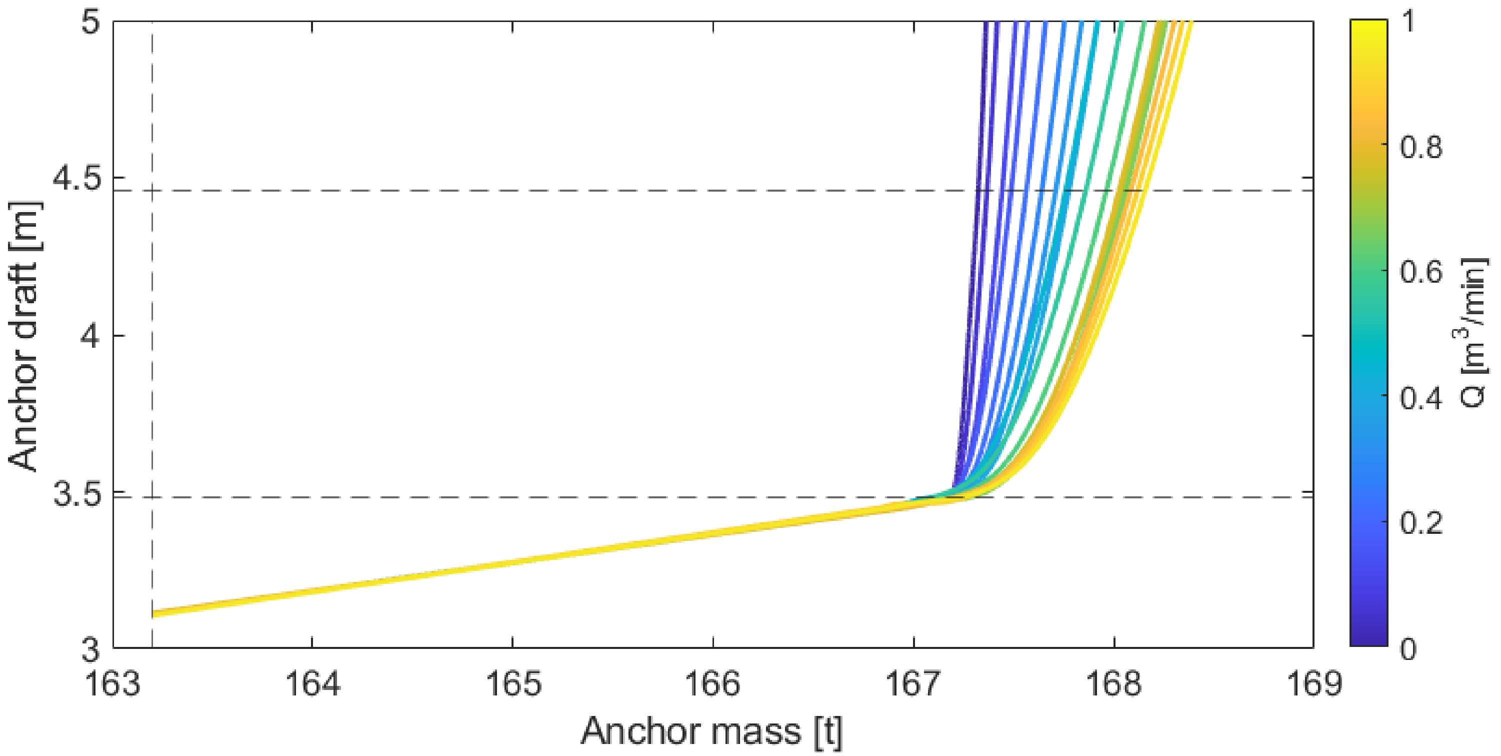
1. The ballast fluid is pumped into the anchor.
2. The anchor positions itself under the stern of the vessel, hanging from the winch cable
3. Controlled descent to the seabed guided by the winch.





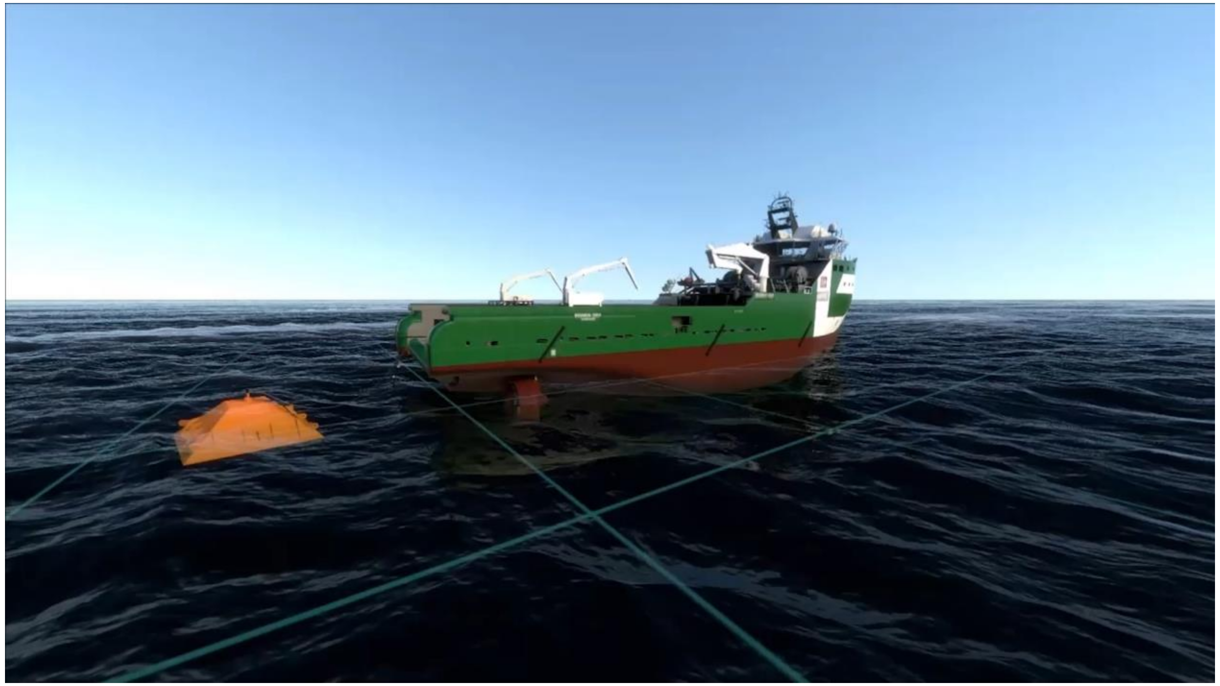
1. Buoyancy tests

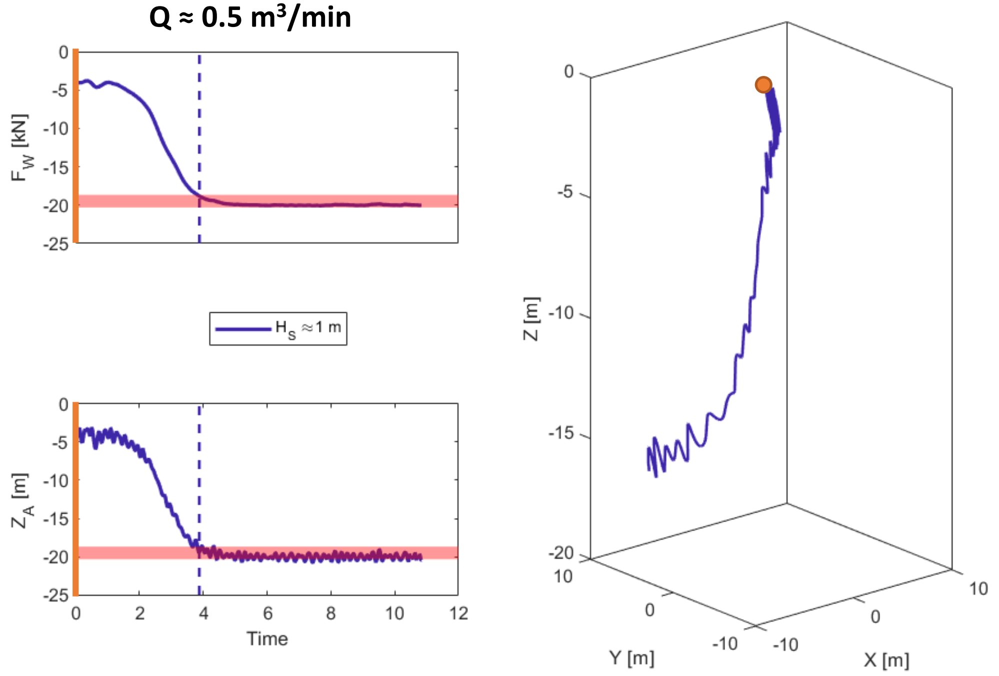
- Once the anchor is towed into place, liquid ballast is pumped into the anchor.
- Different pump rates are investigated.
- The amount of ballast needed for the anchor to fully submerge is between 4 and 5 tonnes, depending on the pumping rate.



Positioning under vessel

- Once the anchor has negative buoyancy, it starts descending to position itself under the stern of the vessel.
- The anchor settles under the vessel effectively hanging from the winch cable.
- The force settles once all the ballast has been pumped.





3. Descent to seabed

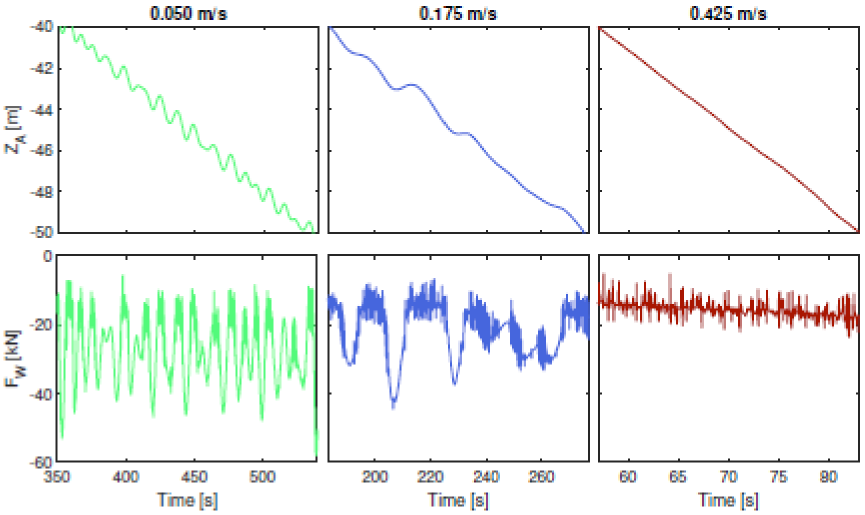


Figure 12: Effect of waves on the anchor and winch forces. Top: Anchor vertical position Z_A. Bottom: Winch force F_W. For three different winch velocities V_W.

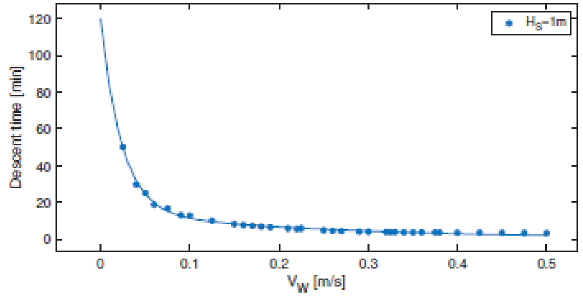


Figure 13: Descent time as a function of winch velocity.

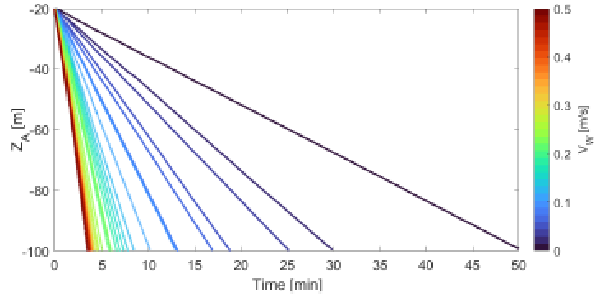


Figure 14: Variation of the anchor's vertical position with time for $H_S = 1$ m.

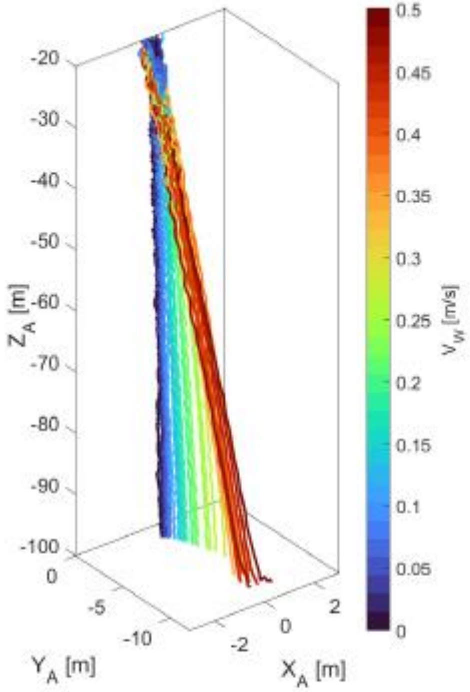
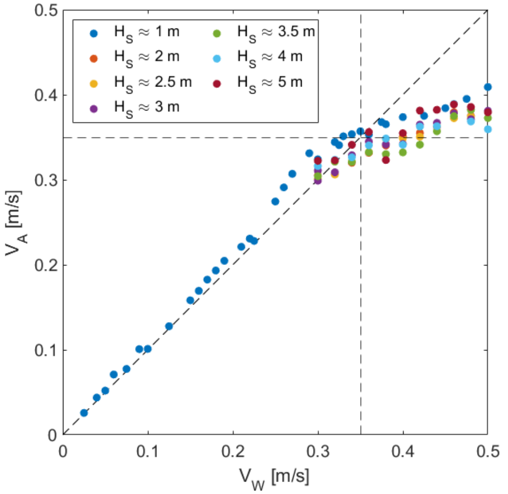


Figure 16: 3D descent trajectory of the anchor for wave case $H_S = 1$ m.



- At winch speed V_W=0.35 m/s the anchor velocity (V_A) stops increasing at the same rate (1:1) as V_W.
- Similar behaviour for all wave cases.

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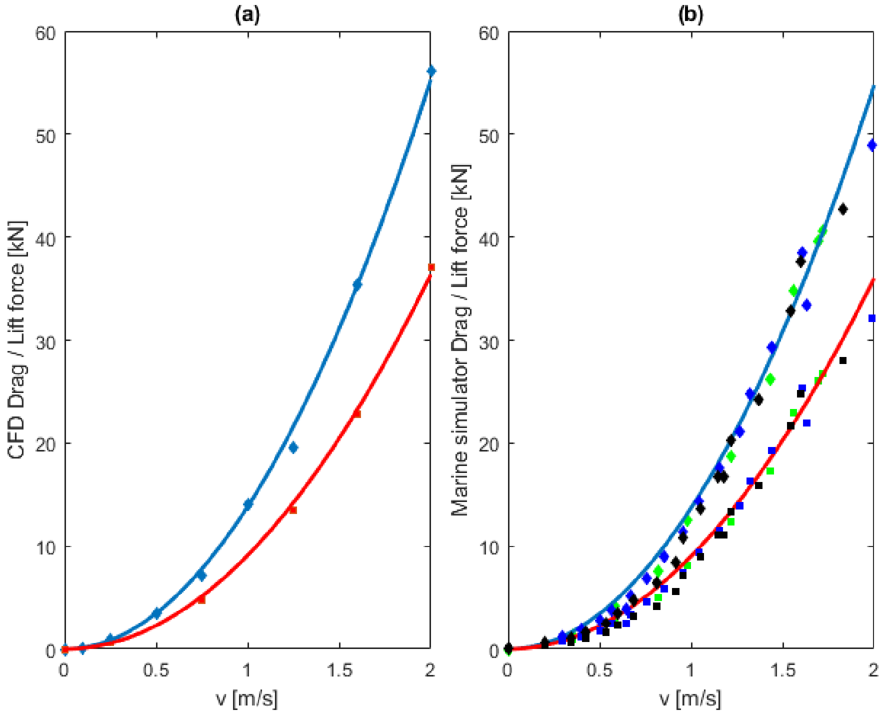
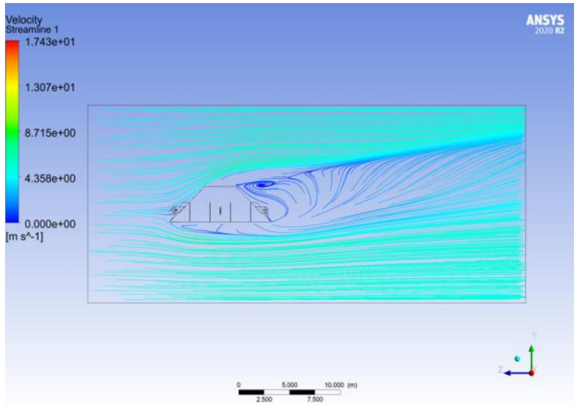
Current effect





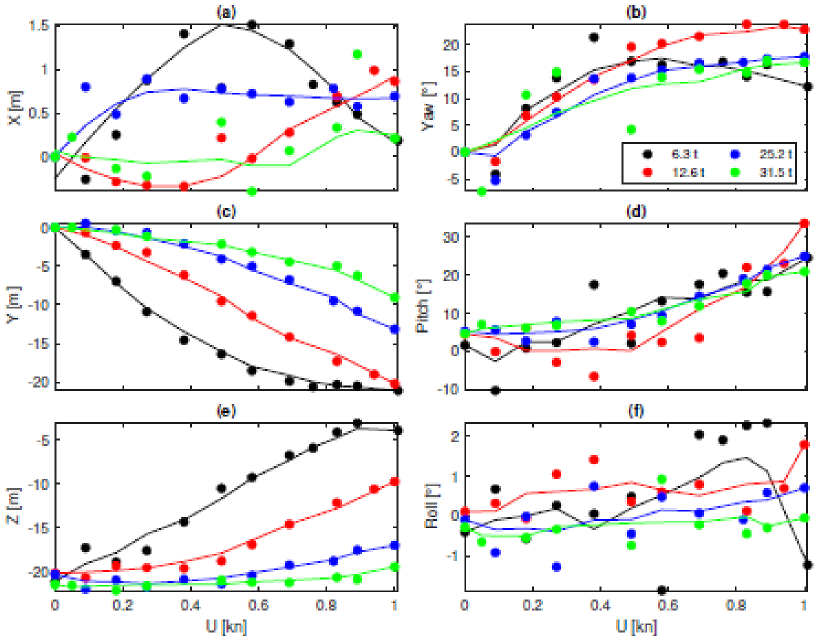
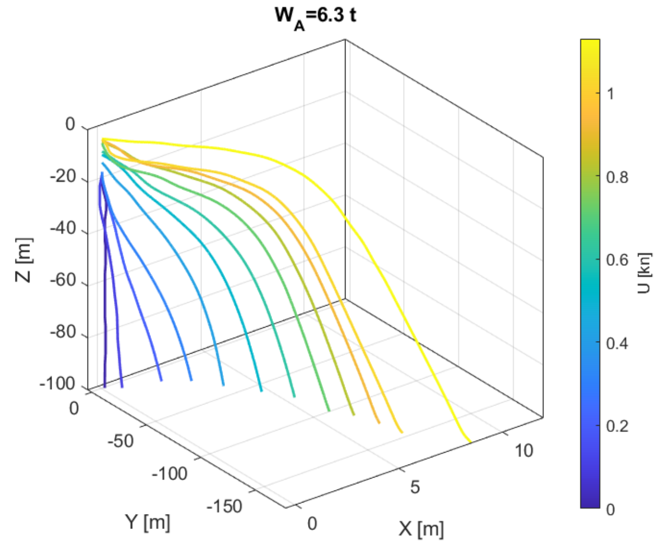
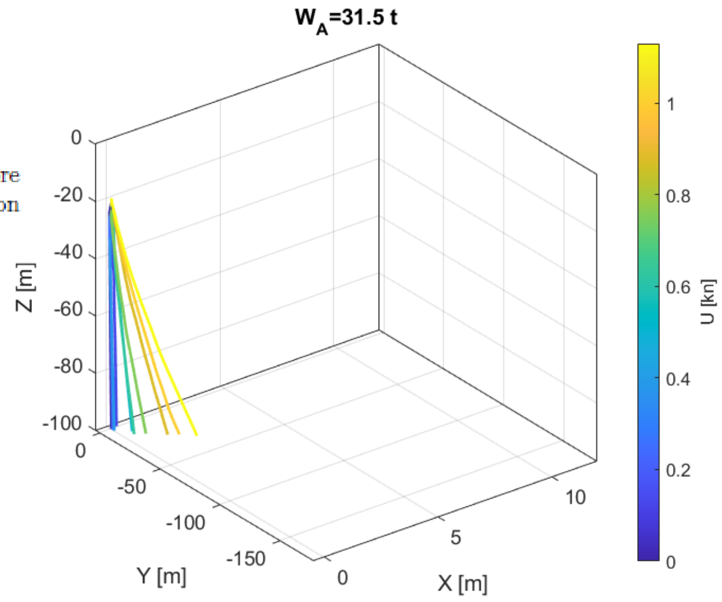
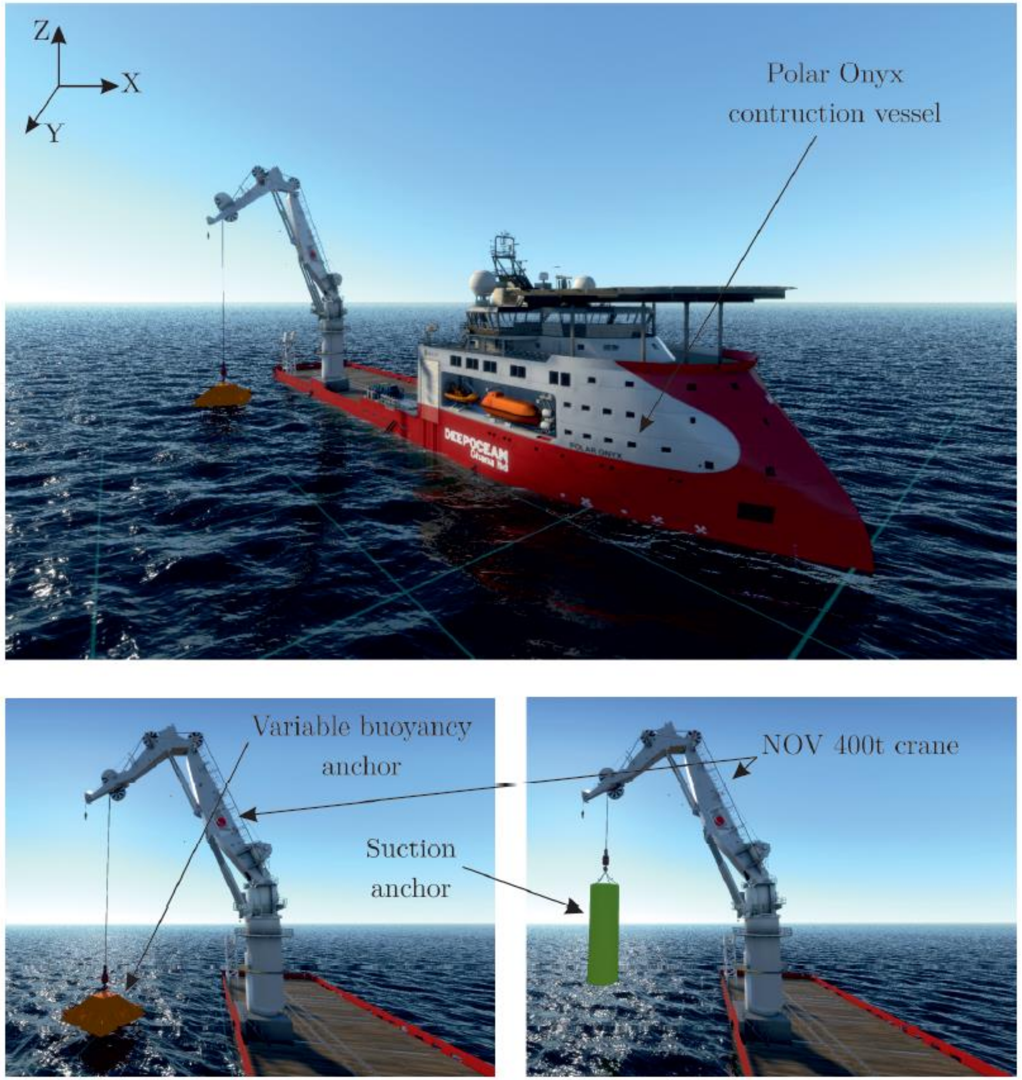


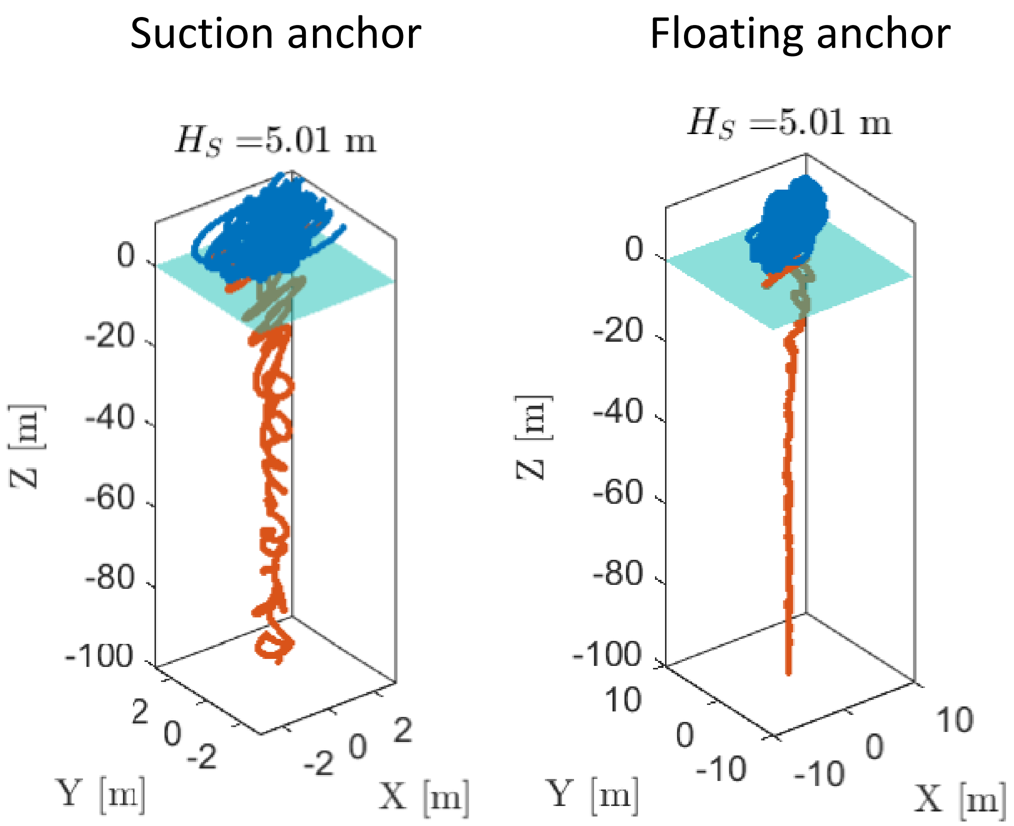
Figure 34: Left column: Variation of the anchor's position (Y, X and Z) before releasing thew winch with U. Right column: Variation of the anchor's orientation (yaw, pitch and roll) before releasing the winch with U





4. Suction vs floating anchors





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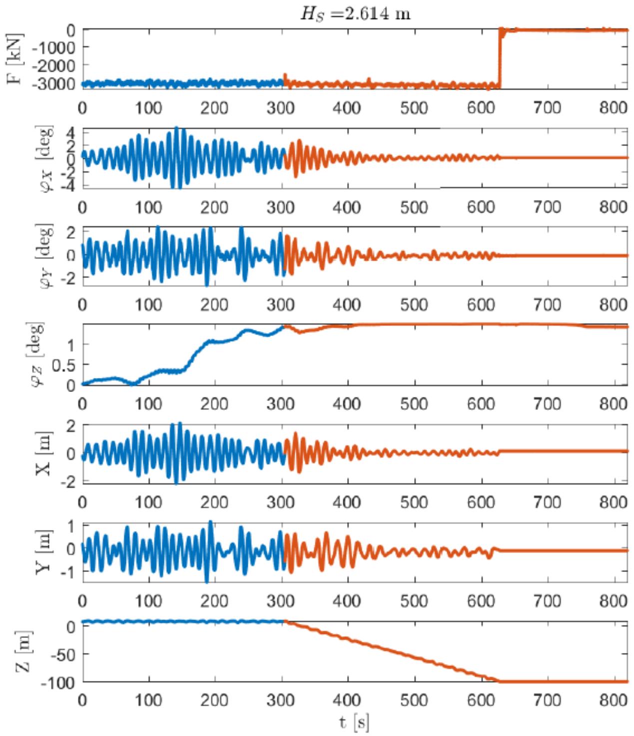


Figure 40: Example time histories for significant wave height of $H_S = 2.61\,\mathrm{m}$ for crane force F, angular displacements (pitch, roll, yaw) of the suction anchor, φ_X, φ_Y, φ_Z and displacements of the variable buoyancy anchor along X, Y, and Z axes, respectively. Note, that time histories shown in blue correspond to anchor hanging on the crane and those shown in orange correspond to deployment stage with crane winch speed of $V_W = 0.35\,\frac{\mathrm{m}}{\mathrm{s}}$.

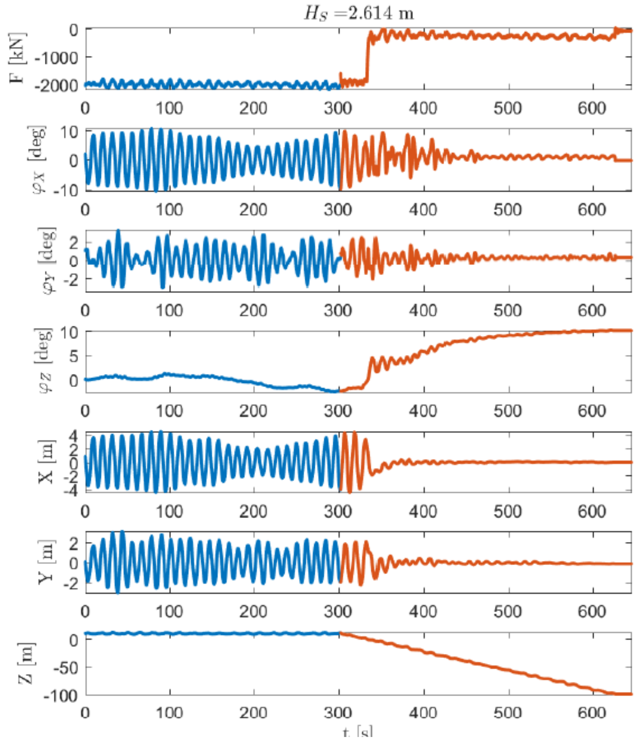
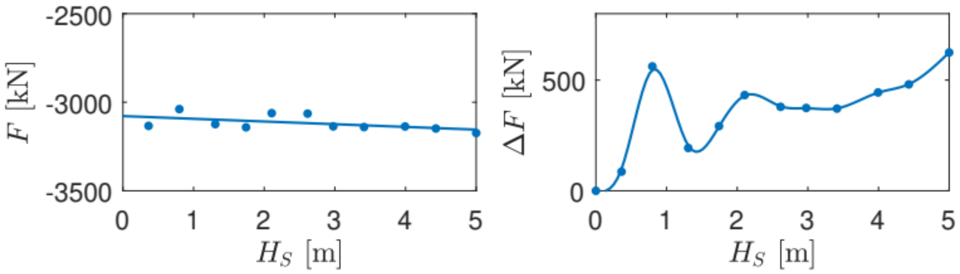
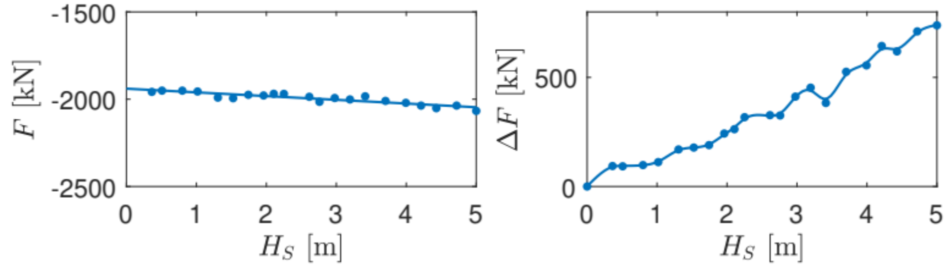


Figure 49: Example time histories for significant wave height of $H_S = 2.61\,\mathrm{m}$ for crane force F, angular displacements (pitch, roll, yaw) of the variable buoyancy anchor, φ_X, φ_Y, φ_Z and displacements of the variable buoyancy anchor along X, Y, and Z axes, respectively. Note, that time histories shown in blue correspond to anchor hanging on the crane and those shown in orange correspond to deployment stage with crane winch speed of $V_W = 0.35\,\frac{\mathrm{m}}{\mathrm{s}}$.

Suction anchor



Floating anchor



Conclusions

- The anchor requires approximately 4 tonnes of ballast to start its descent.
- Positioning under the vessel takes under 5 minutes for $Q>0.5m^3/min$.
- Higher pumping rates limit the wave-induced oscillations on the anchor’s orientation.
- Descent to seabed takes between 3.5 and 4 minutes, depending on the winch velocity V_W.
- After V_W=0.35m/s, the anchor descent velocity remains constant, meaning the anchor is fully controlled by the winch.
- Ballast weight limits the impact currents have on the anchor’s drift.
- Compared to a generic suction anchor, the proposed anchor generates less loads on the winch and the descent is more controlled.