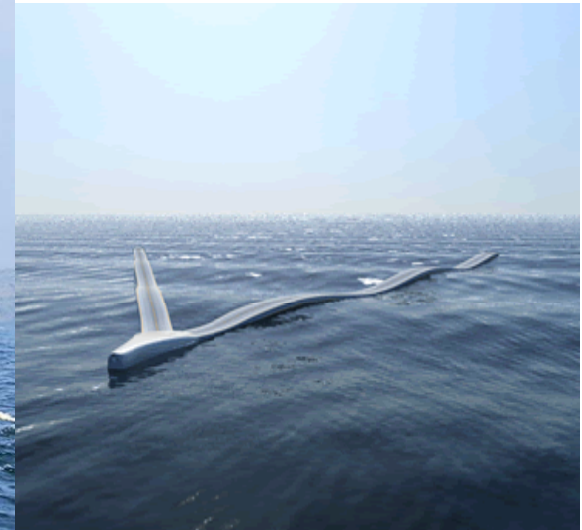
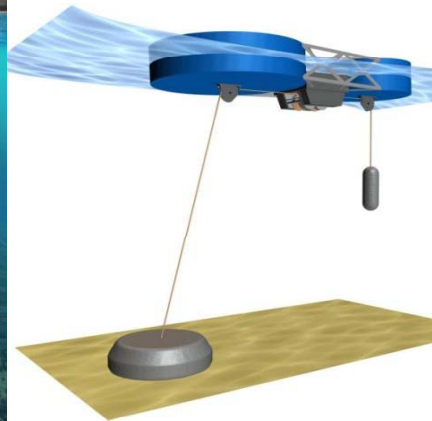
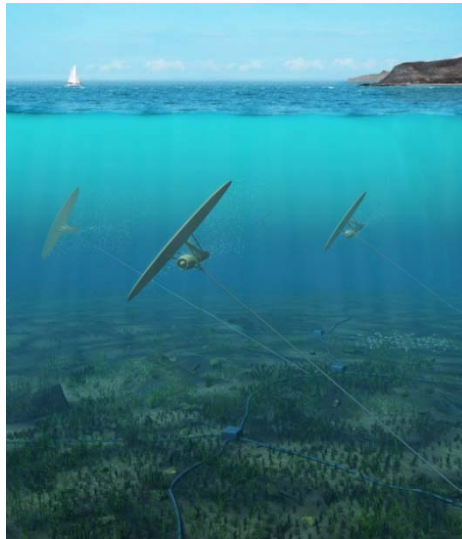


# Mooring wave energy devices non-linear effects

Research topic for a PhD student in the





# Research tasks for student

- Hydrodynamic modelling of moored floating wave energy converters
- Central aims
  - effects of mooring on power capture
  - WECs in violent seas; reducing mooring peak loads and to predict fatigue of mooring lines.
- Focus on numerical modelling with CFD and development of numerical tools for mooring

Research should be generic

Tutor: Claes Eskilsson

Way back in 1976

We started work on  
wave energy in  
Göteborg

In Chalmers we  
were very  
sceptical but  
were gradually  
convinced

*First Symposium on  
Wave Energy Utilization*

*Gothenburgh  
30 October–1 November 1979*



*Proceedings*

Organizing, Editorial and Programme Committee:  
Karl-Gustav Jönsson, Chalmers University of Technology,  
Johannes K Lunde (Chairman), The Group for Wave Energy  
Research, Chalmers University of Technology,  
Thomas Rindøy, The Group for Wave Energy Research,  
Chalmers University of Technology.

# Linear theory

- All the work we did was based on linear theories and superposition
- Preliminary experiments in small tanks
- Field tests first in a lake and later at sea
  
- Appropriate for energy capture then
- Not OK for design forces



IPS-buoy  
Elskling

Gamla Gumman  
1980 – 1981

<http://www.youtube.com/user/Waves4Power>



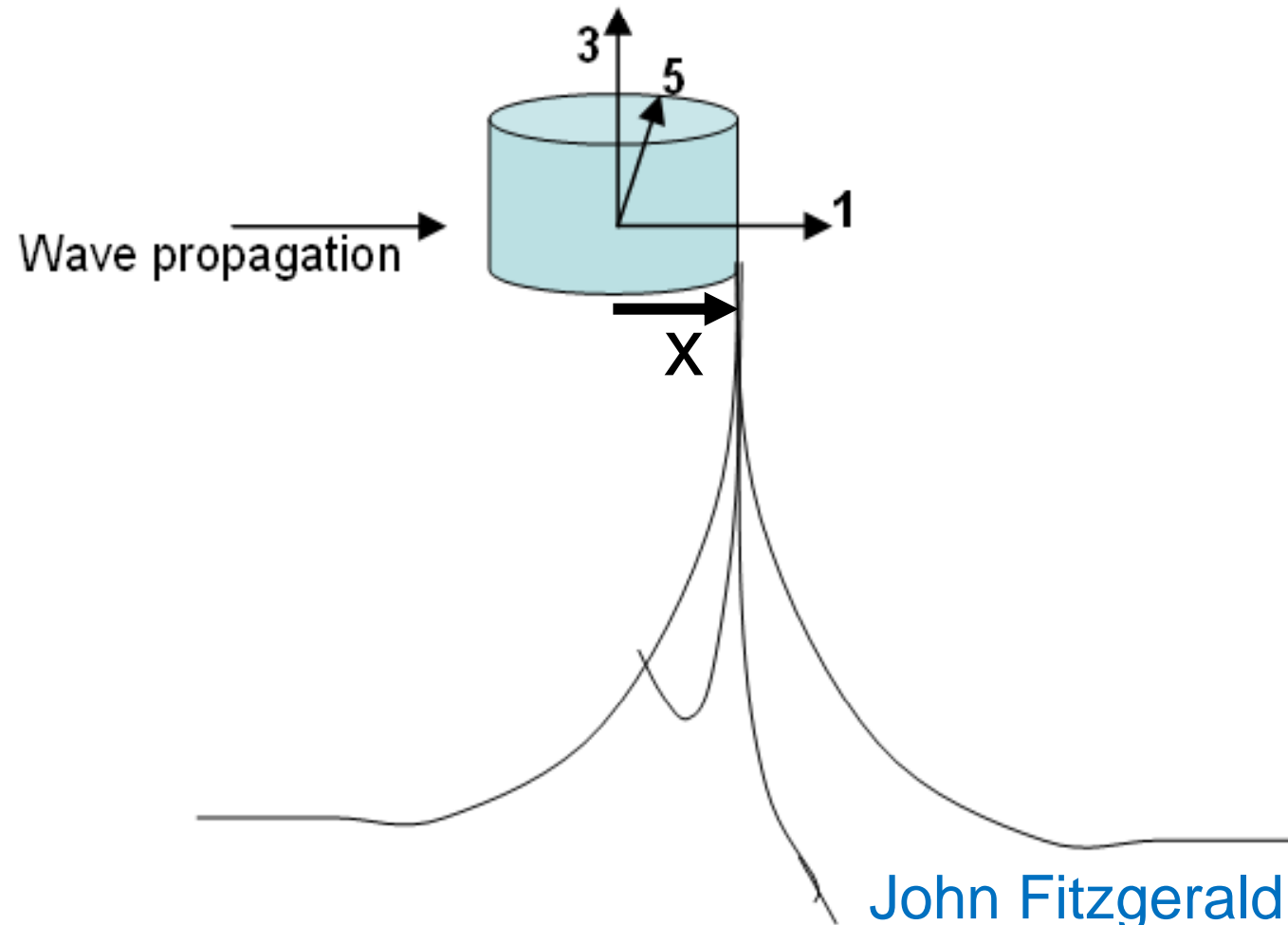
# Waves4Power *Göteborg*



# Non-linear phenomena

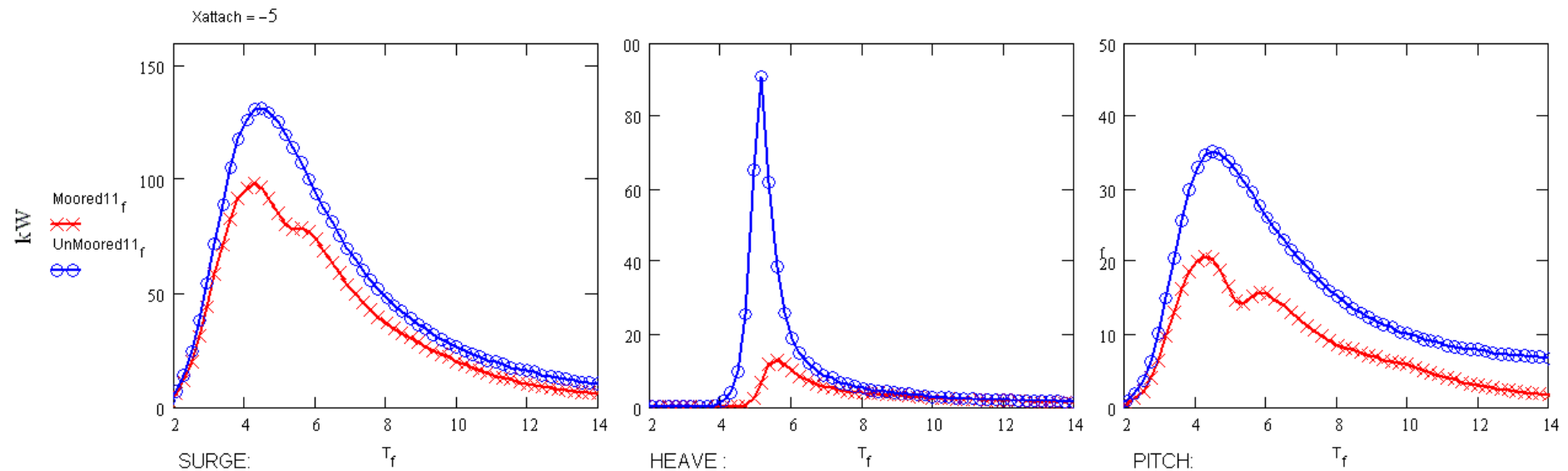
- Problems
  - Highly energetic sea states
  - Resonant motions
  - Large motions even larger than the wave motion
  - Nonlinear loads and damping
- Effects on energy capture
  - Moorings will affect motions
  - Eddy damping and nonlinear motion not negligible

# Example: Power take-off as a function of position of mooring attachment



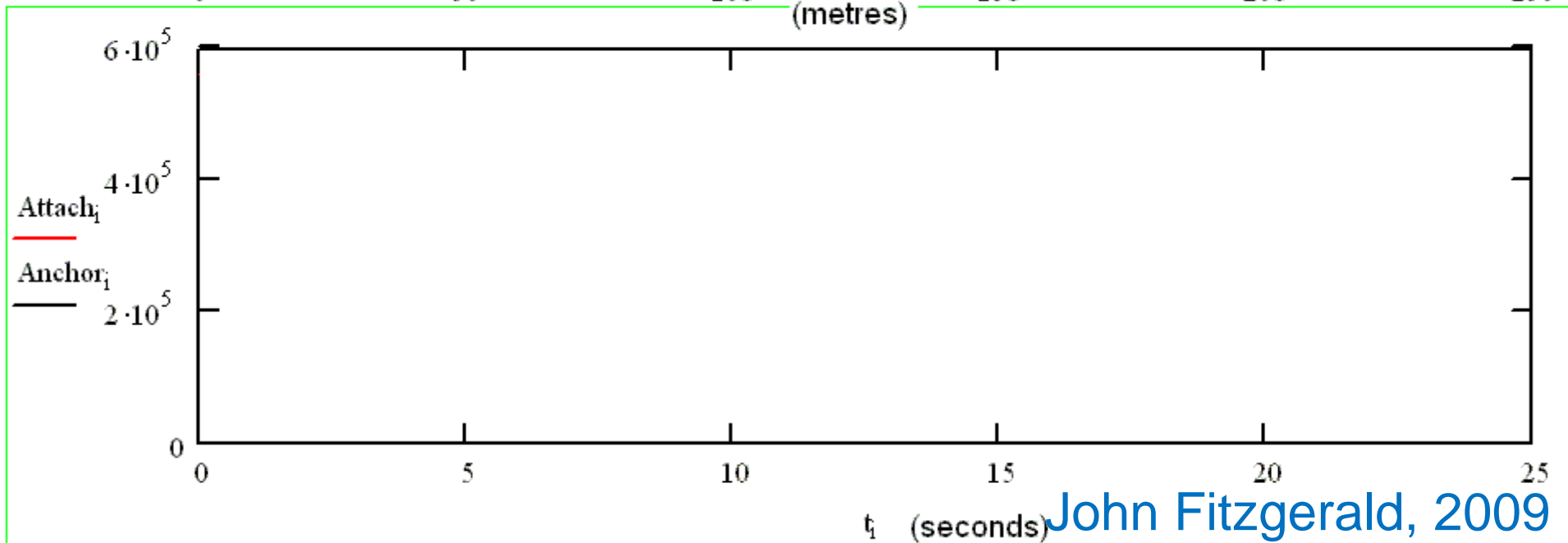
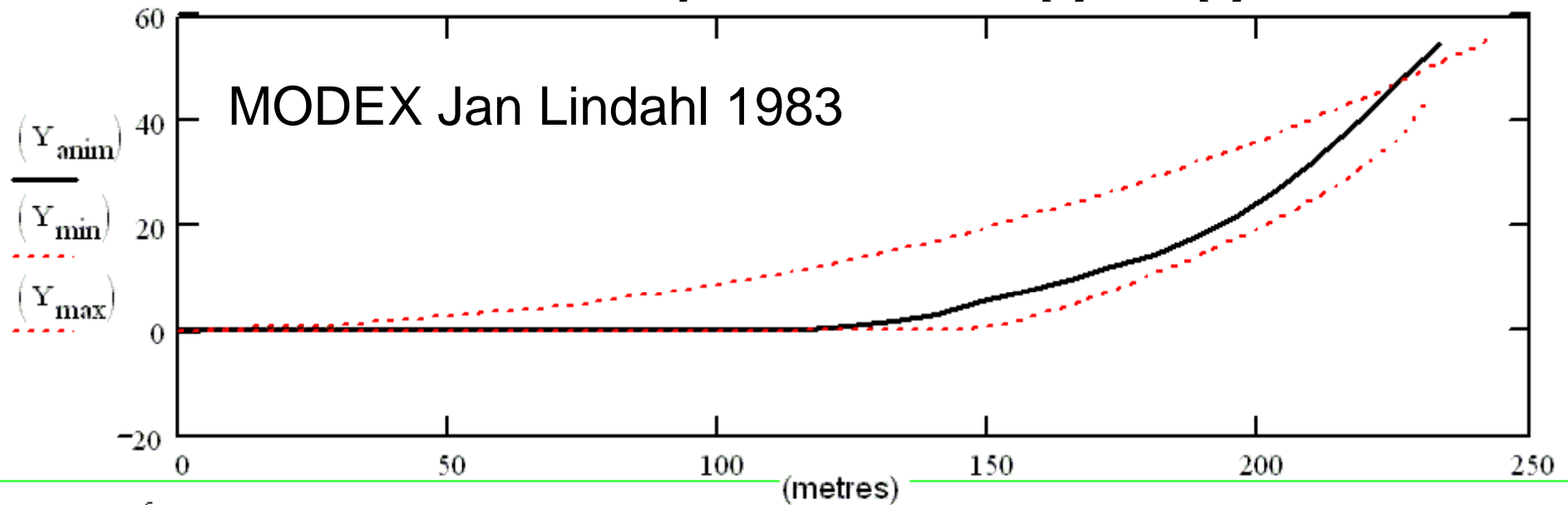
John Fitzgerald, 2009

# PTO as a function of attachment position



John Fitzgerald, 2009

# Catenary mooring leg



# Parallel finite element simulation of mooring forces on floating

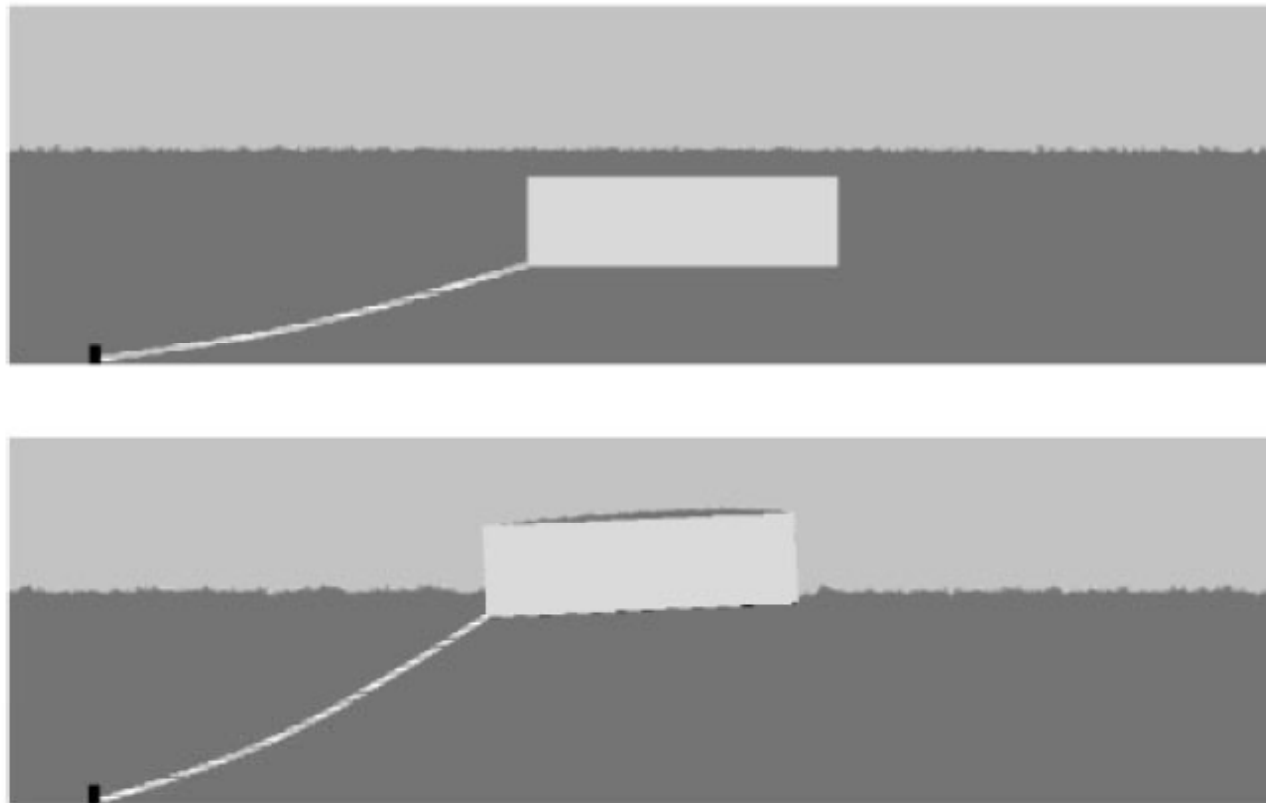
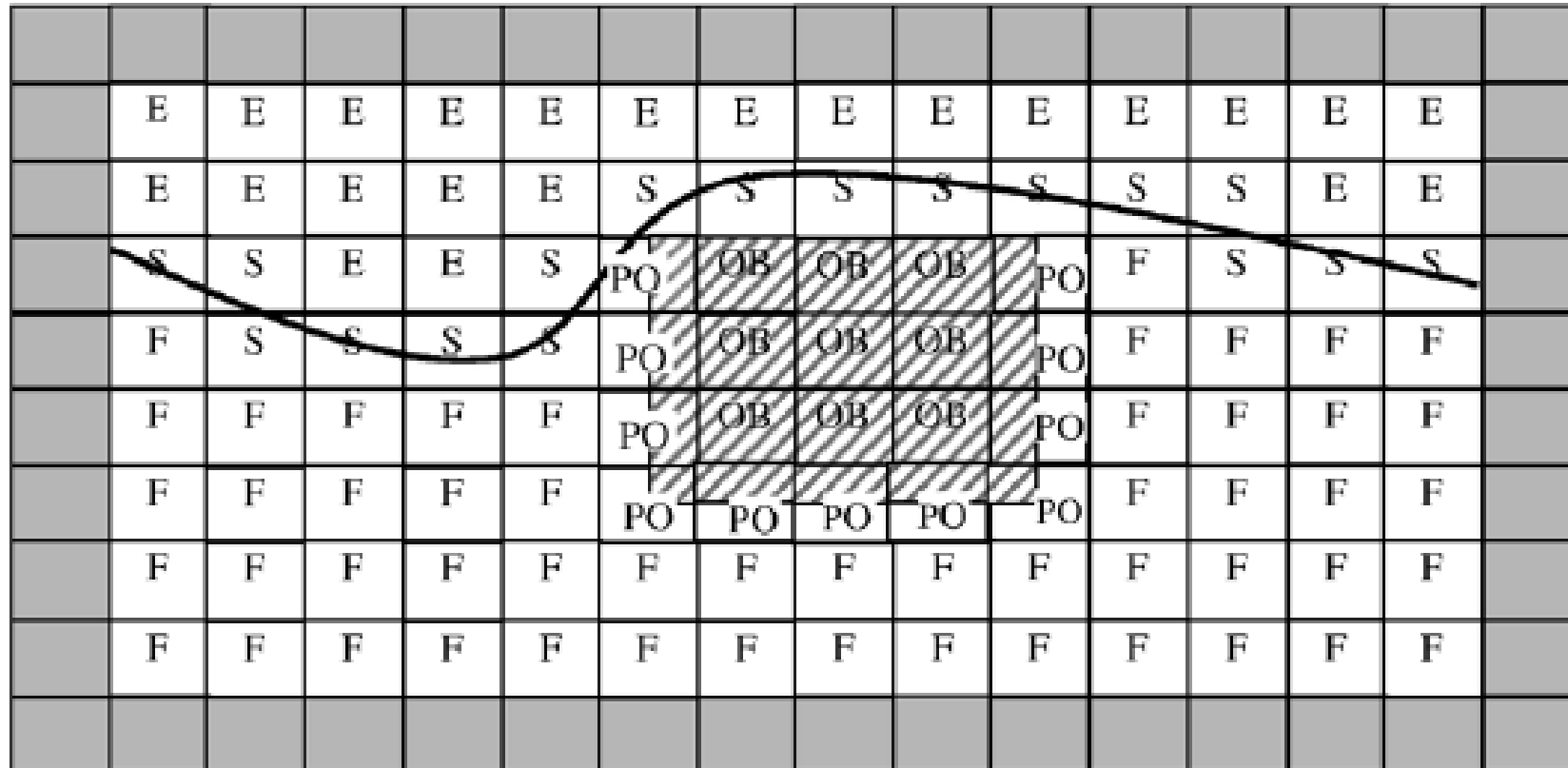


Figure 3. *Buoyancy effect on floating object under water.* Figure shows the cross section from the computational domain at  $z=0.0$  and for times at 0.1 (top) and 2.1 (bottom). Here, the tint shows the water (dark) and air (light) for the *non-linear-fine* solution.

Aliabadi  
Abedi  
Zellars

Bergdahl

# VoF cells



*E = Empty cell, S = Surface cell, F =Fluid cell, OB=Obstacle cell, PO=Partially obstacle cell*

Fig. 4. Free surface geometric model of VOF method and porous body model.

# Experiments with straight mooring legs

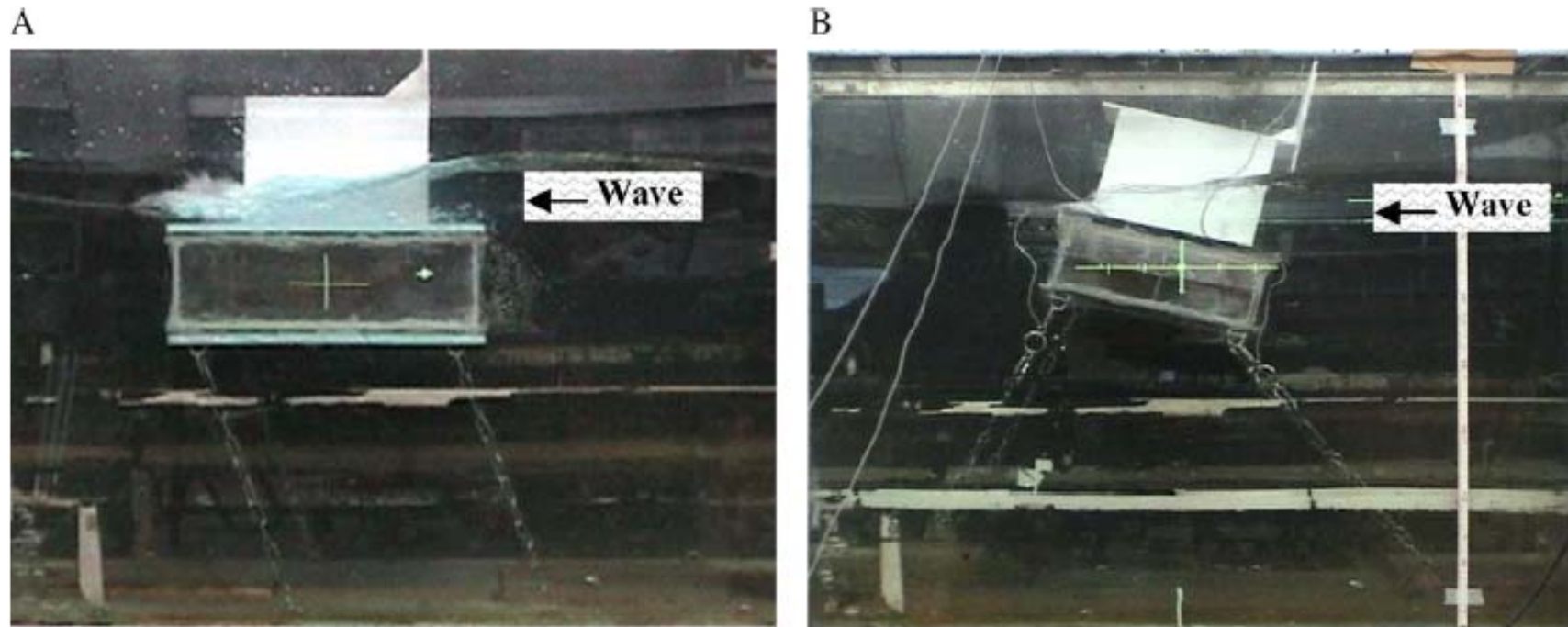
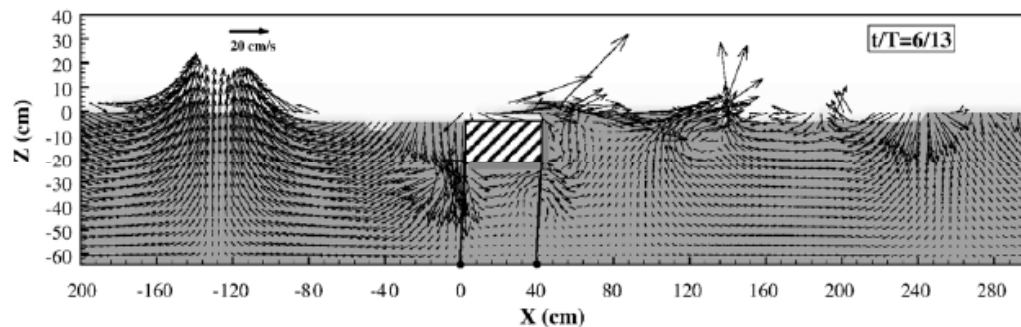
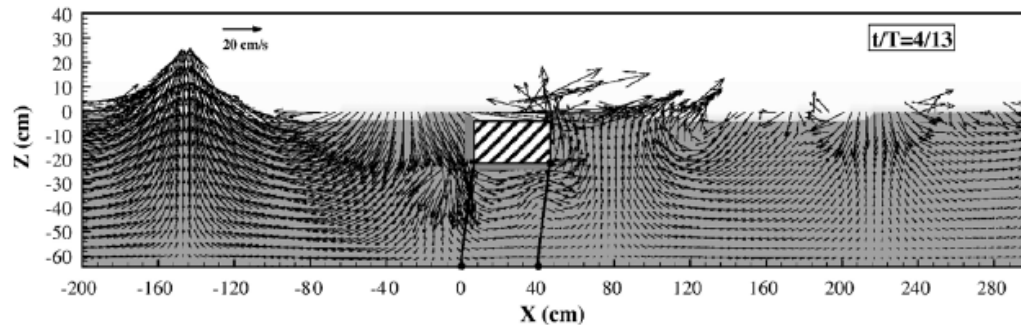
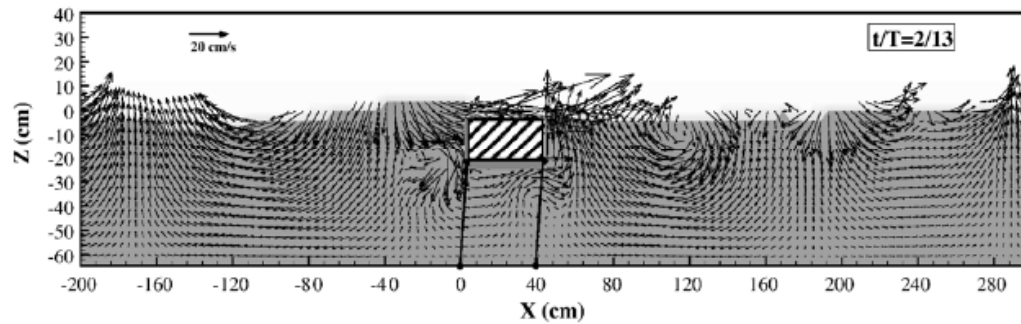
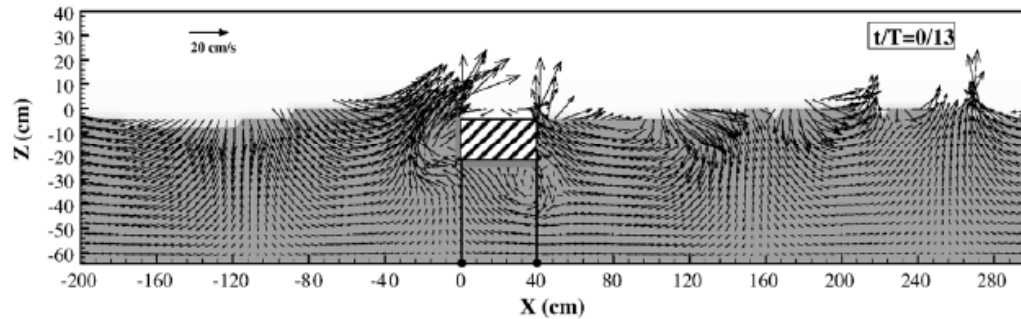
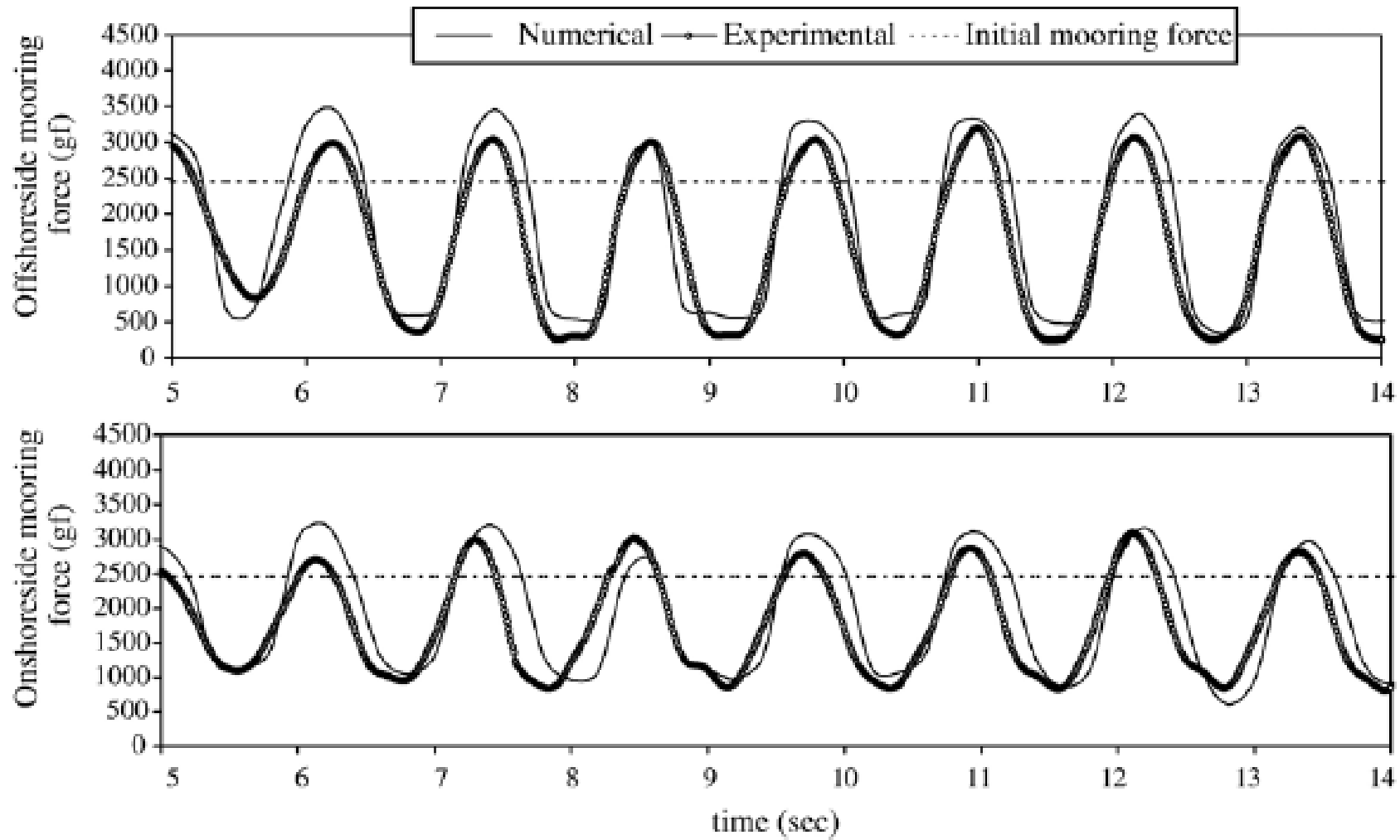


Fig. 7. Side view of the floating body set up at the wave tank during experimental run (A) vertical mooring,  $\theta = 90^\circ$ ; (B) inclined mooring,  $\theta = 60^\circ$ .



# Fluid velocities around the body

# Measured and simulated cable



# OEC tasks in mooring systems

- How do moorings alter capture of wave energy
  - Mooring line model with weights and buoys
    - To be developed in open source FEM toolkit Nektar++
  - Coupled to hydrodynamic 6 dof. model of device
    - Existing OpenFOAM RANS VOF solver for the device, being in the water surface, submerged or emerged
  - Study effects of mooring system arrangements on energy capture
  - Benefits: New rules of thumb and free numerical tools



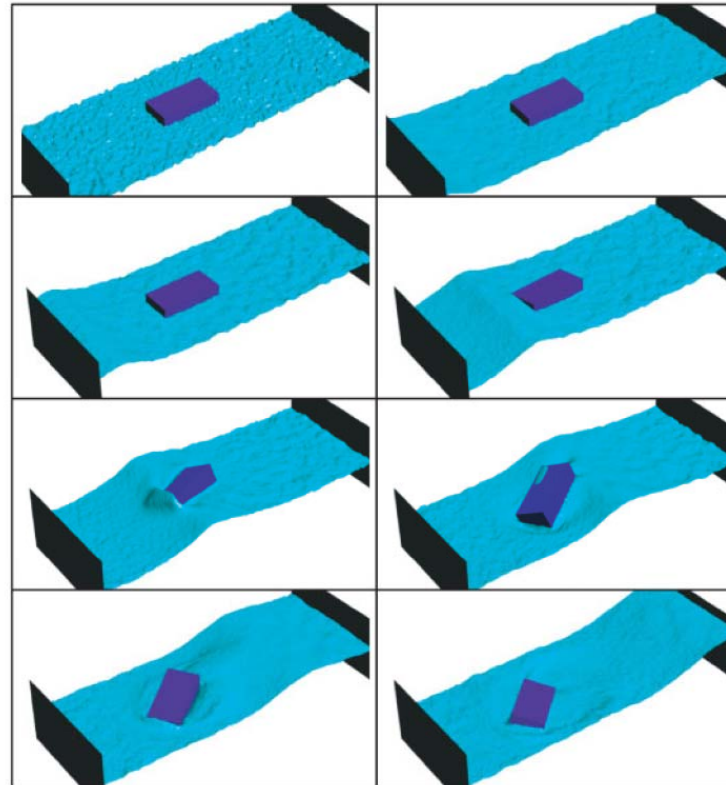


Plate 1. *Water wave impacting on a moored floating box.* The series of the frames (from left to right, top to bottom) show the time history of wave generation, two sides of the container, the free-surface of water, the position of the floating box as water wave impact on it at every 0.167 s intervals beginning at  $t = 0.0$  s.

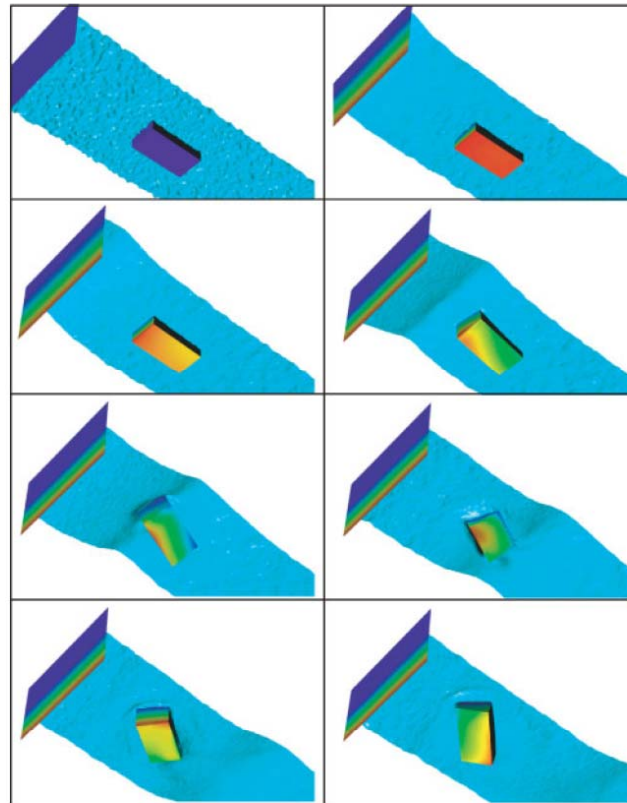


Plate 2. *Water wave impacting on a moored floating box.* The series of the frames (from left to right, top to bottom) show the time history of wave generation and wave impacting on the floating box at every 0.167 s intervals beginning at  $t=0.0$  s viewed from the bottom of the box. The colours on the box represent the pressure distribution.