

Construction of evaluation method for pumping capacity  
and vertical displacement of the wave-powered upwelling pump.

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# 1 Research background

## problem

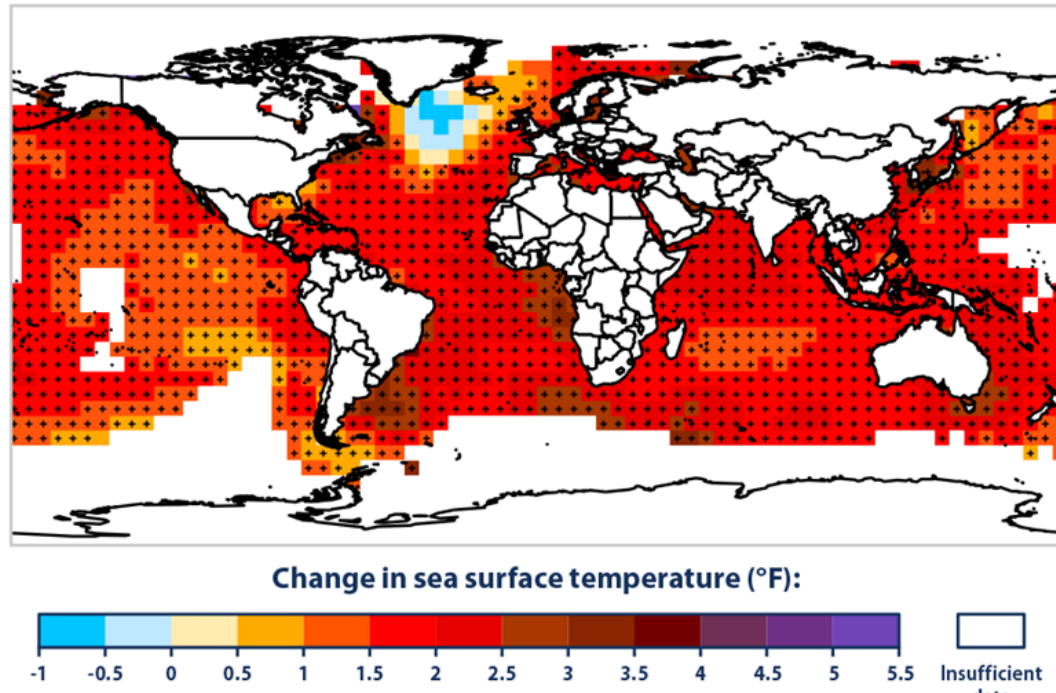


Fig.1 Global sea surface temperature [1]

- Sea surface temperature has been rising in recent years.
- This will cause a decrease in fish catches.

## About upwelling

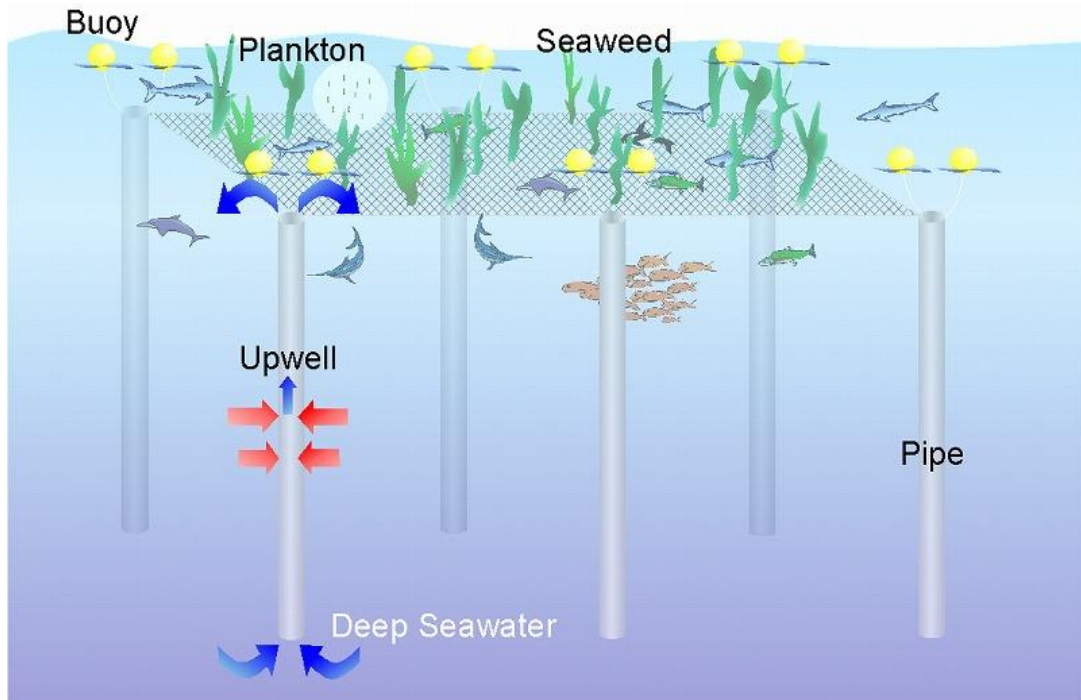


Fig.2 artificial upwelling [2]

- Upwelling is a phenomenon in which deep sea water rises to the surface.
- Artificial upwelling is expected to revitalize marine ecosystems.

## About upwelling pump

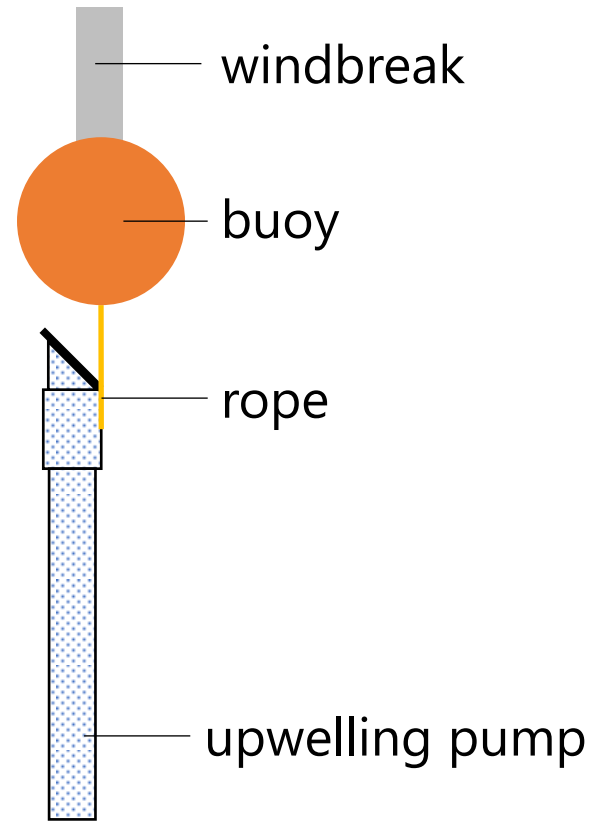


Fig.3 upwelling pump diagram



Fig.4 upwelling pump

## 2 Purpose of research

Measuring the vertical displacement of the upwelling pump.

Analyze the effect of buoy rotation.

## Taking videos



Fig.5 upwelling pump in the sea [3]

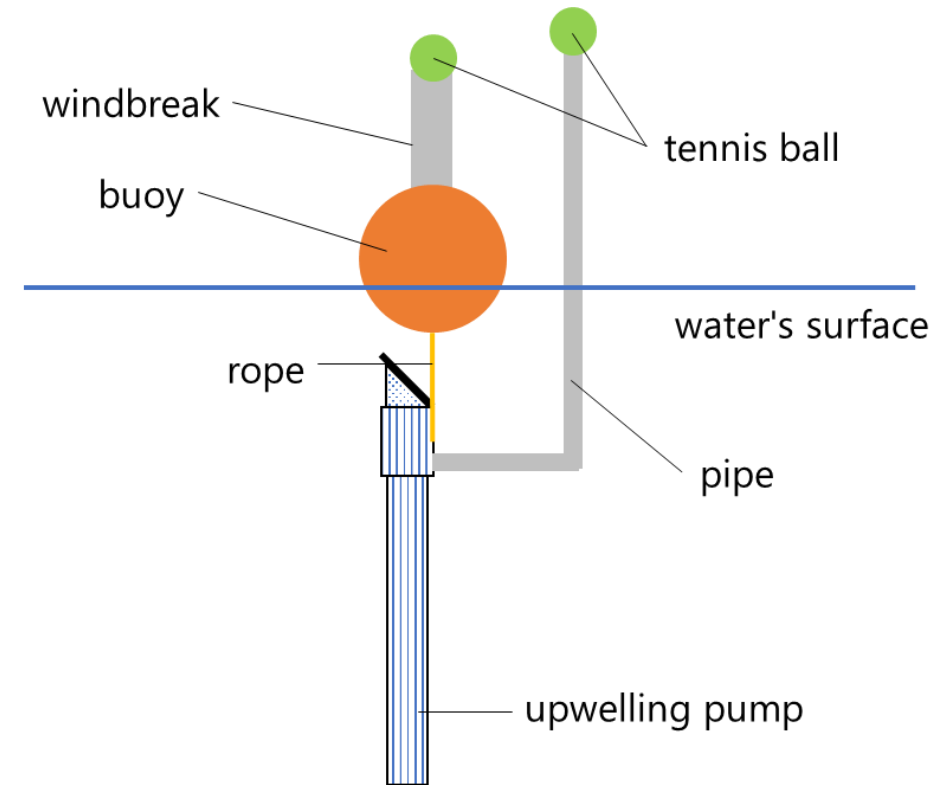
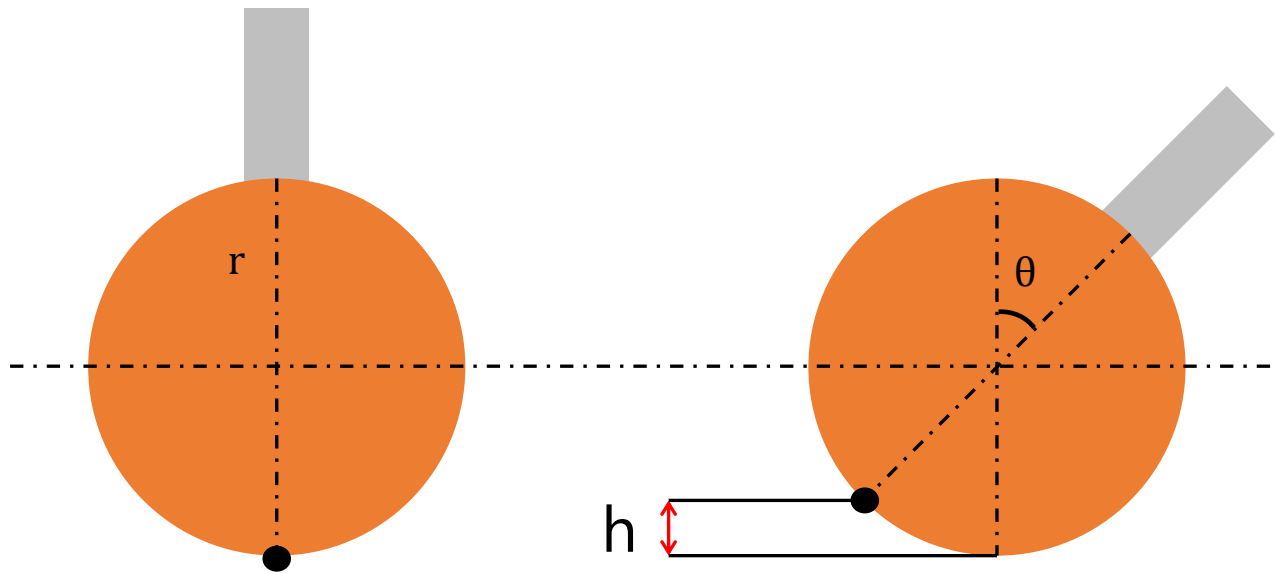


Fig.6 Overall view of the upwelling pump system

## Calculation method



$$h = r - r \cos \theta$$

- $r$  : Radius of buoy[cm]
- $\theta$  : Tilt of the buoy[deg]
- $h$  : Vertical displacement[cm]

Fig.7 Method of calculating vertical displacement

### 3 Analysis method

## Calculation method

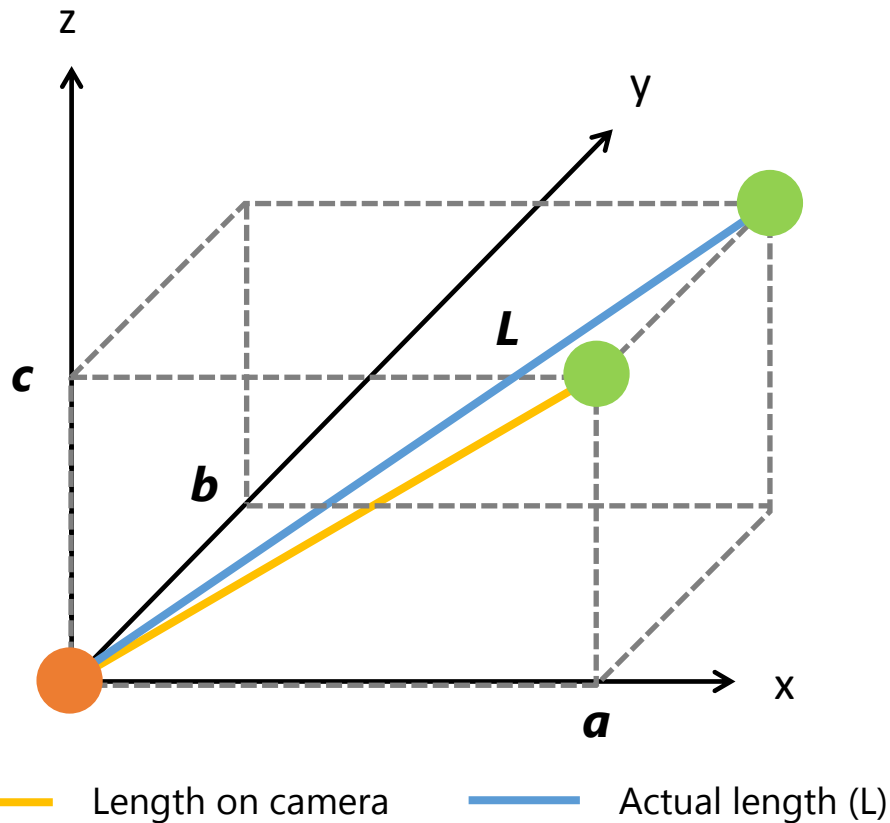
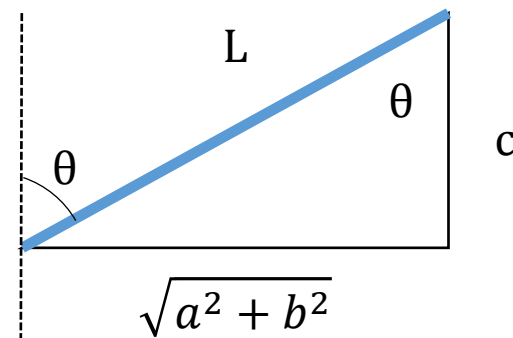


Fig.8 three-dimensional coordinates

1. Determine  $a$  and  $c$  by image analysis.
2. Find  $\theta$  from the below figure.



(Find  $b$  from  $L, a, c$ )

Fig.9 Angle calculation method



## 4 Analysis results

### Center coordinates of the buoy

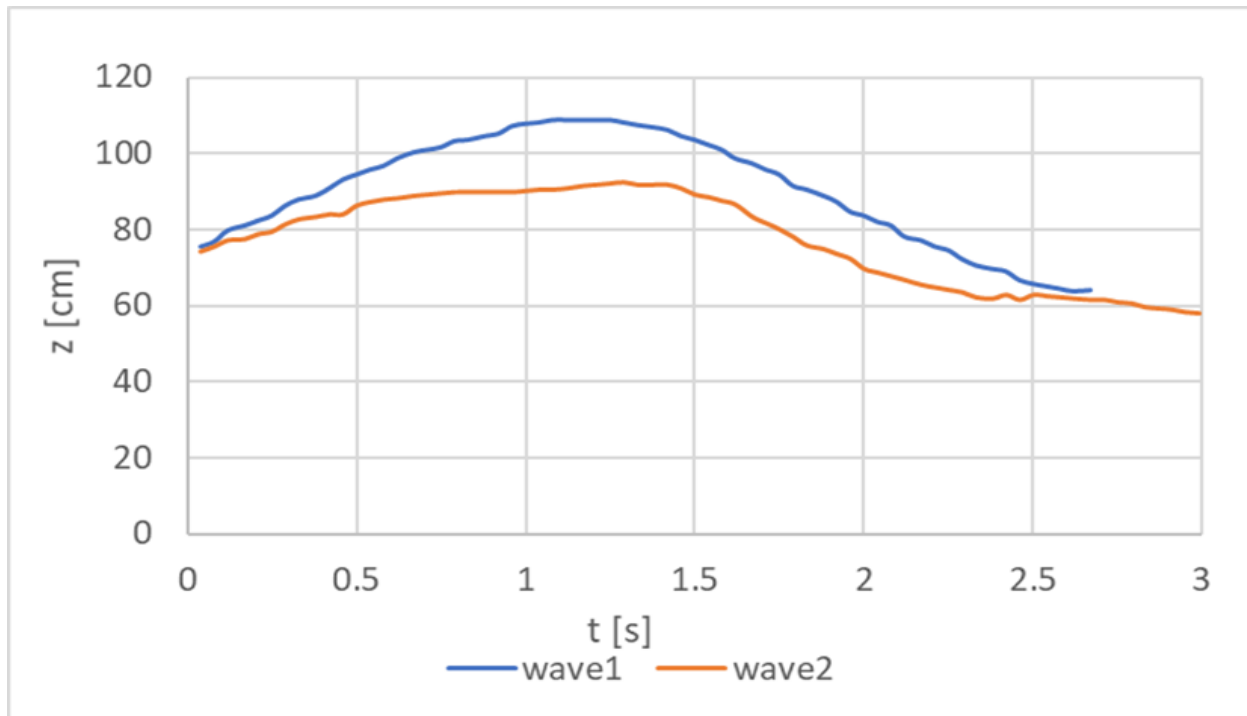
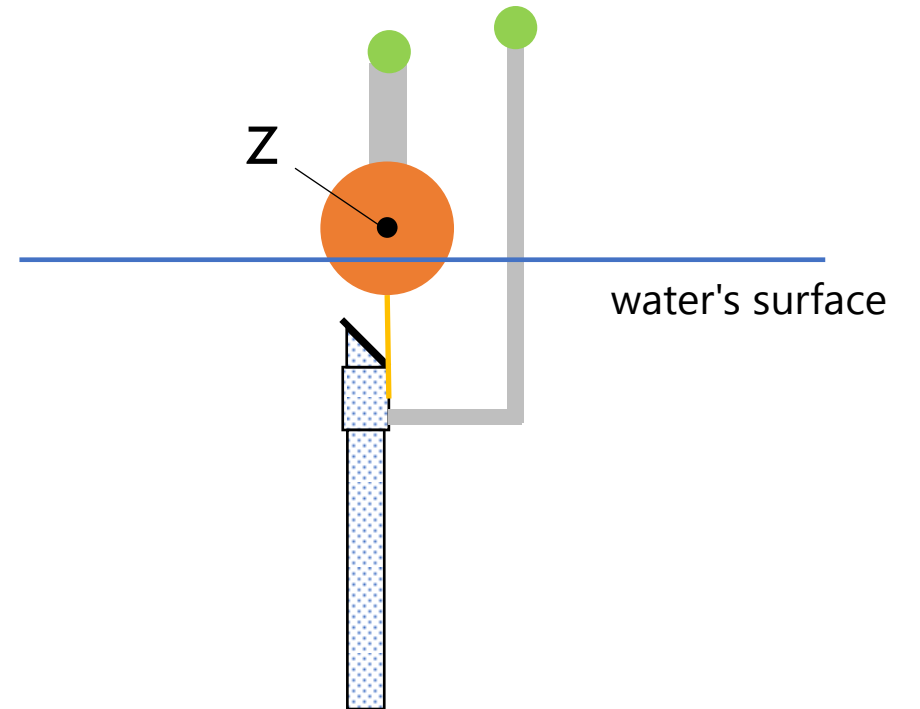


Fig.10 Vertical displacement of the buoy's center coordinates



## Vertical displacement by buoy tilt

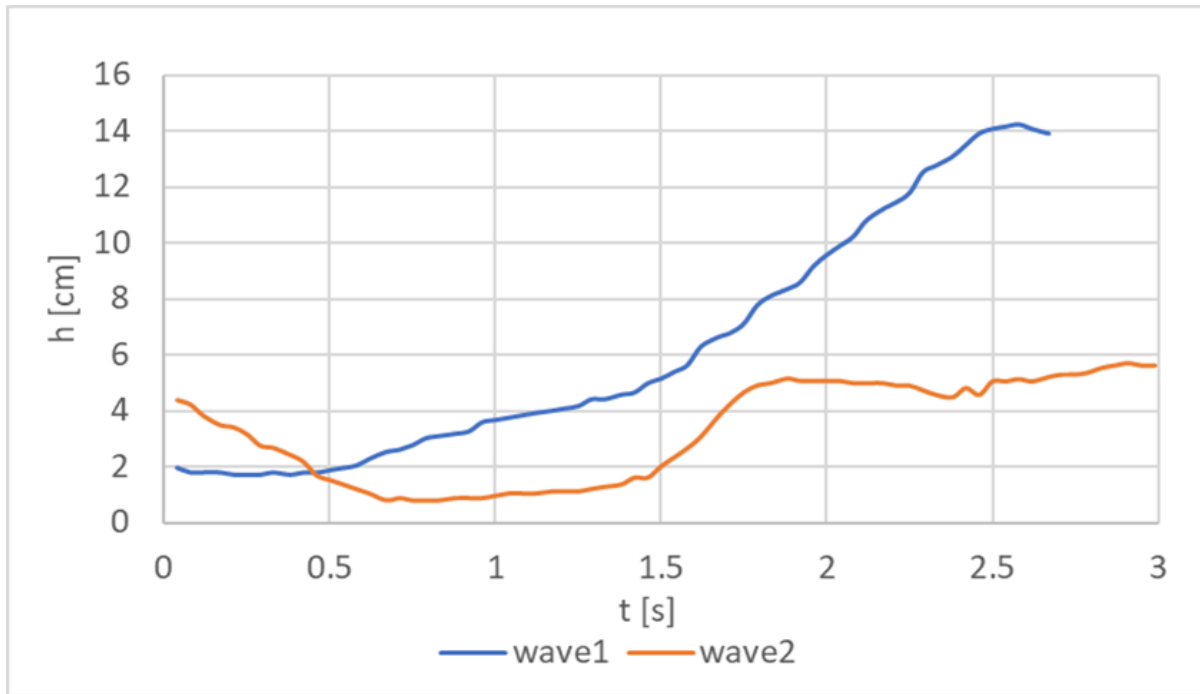
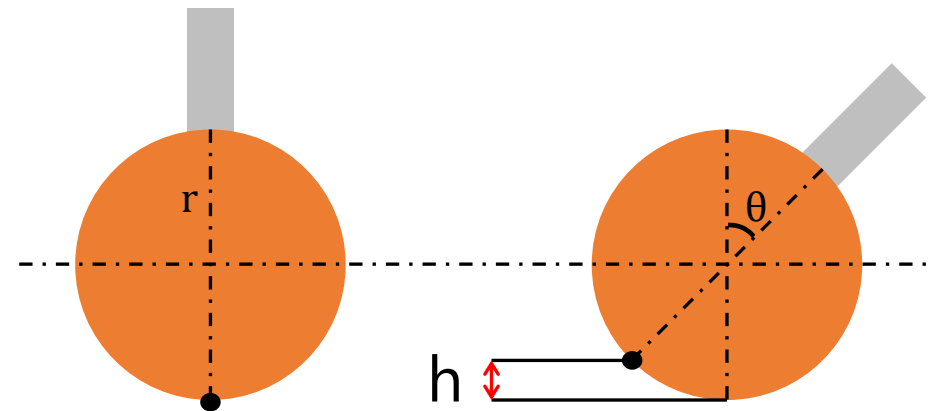


Fig.11 Vertical displacement of connection



$h$  is 15cm at maximum.

## Comparison of vertical displacement

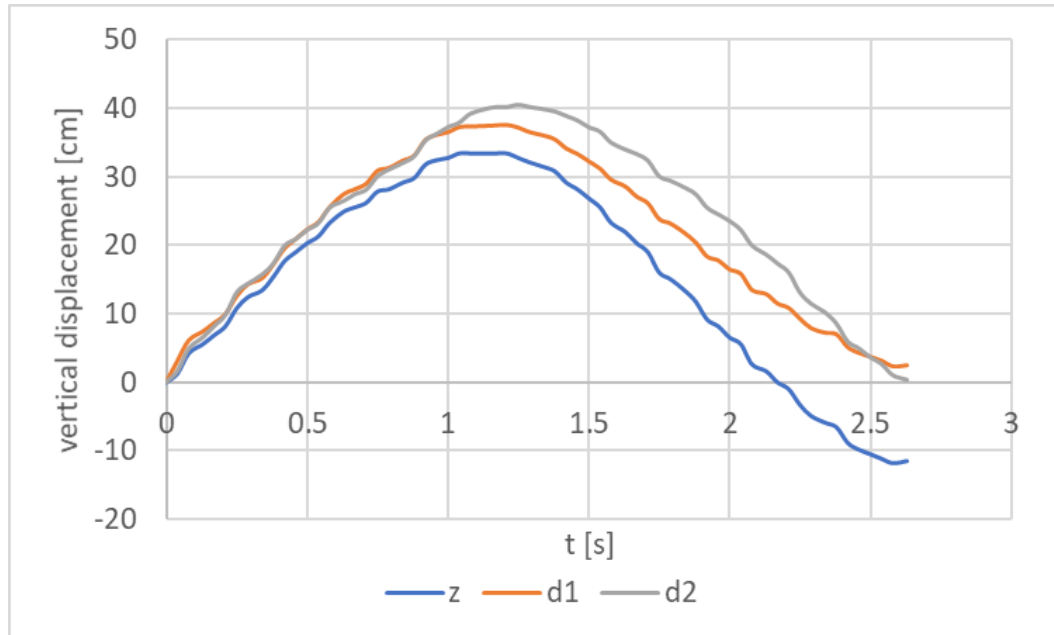
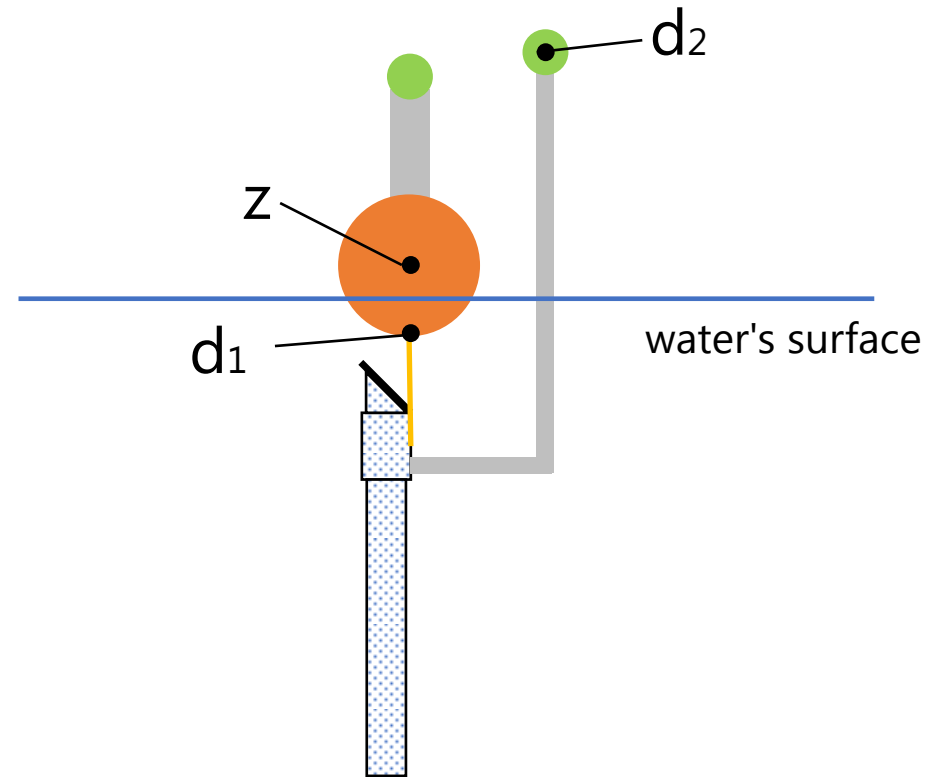


Fig.12 Comparison of displacement (wave1)



## Comparison of vertical displacement

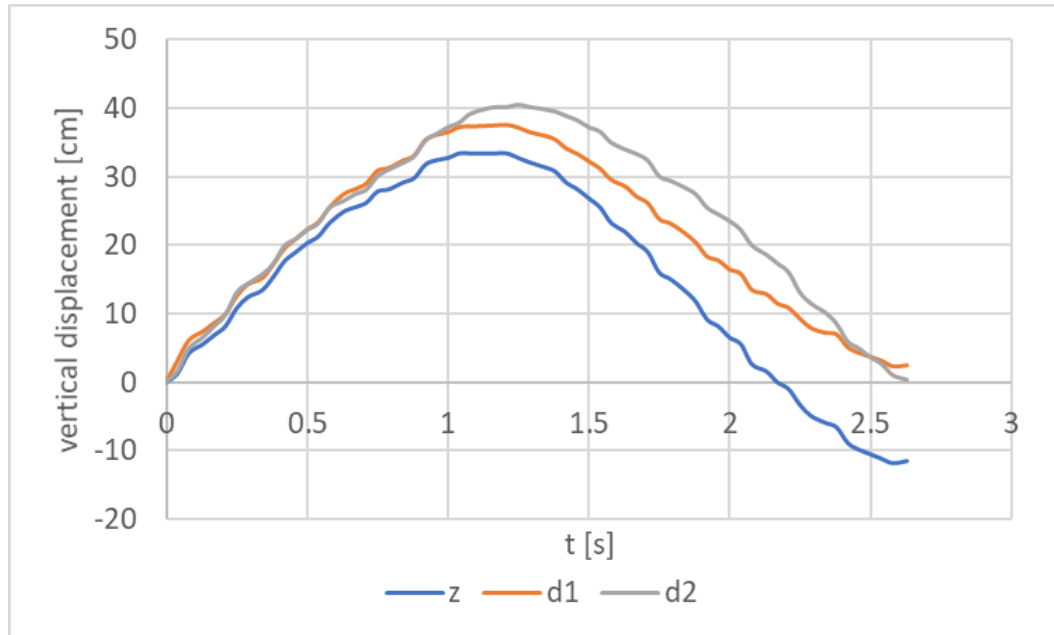


Fig.12 Comparison of displacement (wave1)

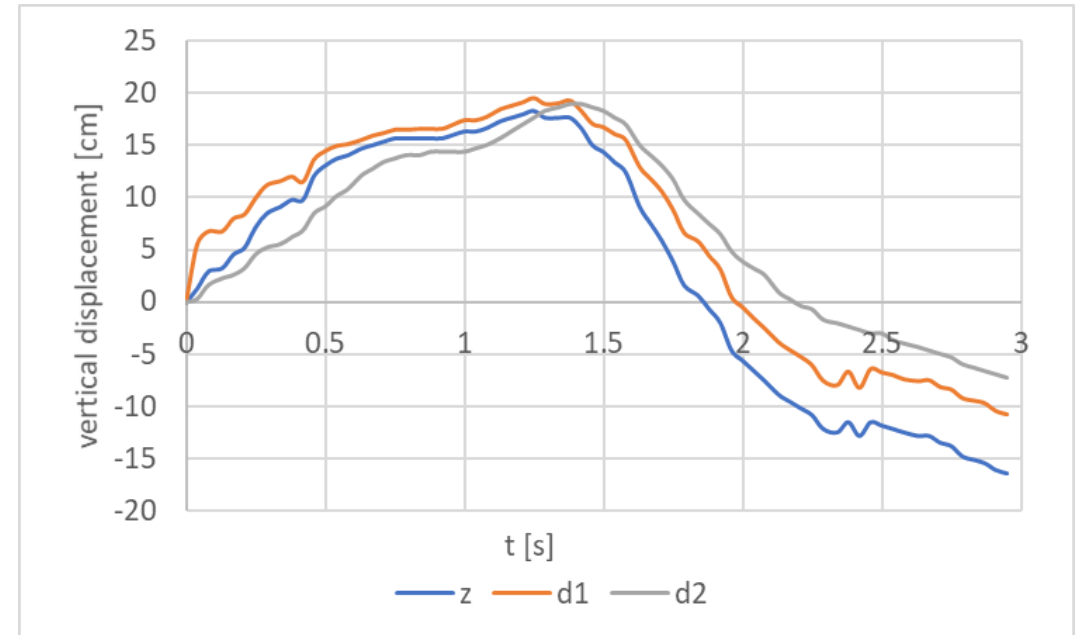


Fig.13 Comparison of displacement (wave2)

## 5 Conclusion

Vertical displacement  
of the upwelling pump  
was measured.

The effect of buoy tilt  
could not be confirmed.

- [1] U.S. Environmental Protection Agency, " Sea Surface Temperature",  
Climate Change Indicators, (2021),  
<https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature>
  
- [2] Institute of Fluid Science, TOHOKU University "LAPUTA project"
  
- [3] NPO ESCOT, <http://npo-escot.org/>