Measuring non-intrusively free surface waves with motion capture systems

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Assessment of Wave Properties

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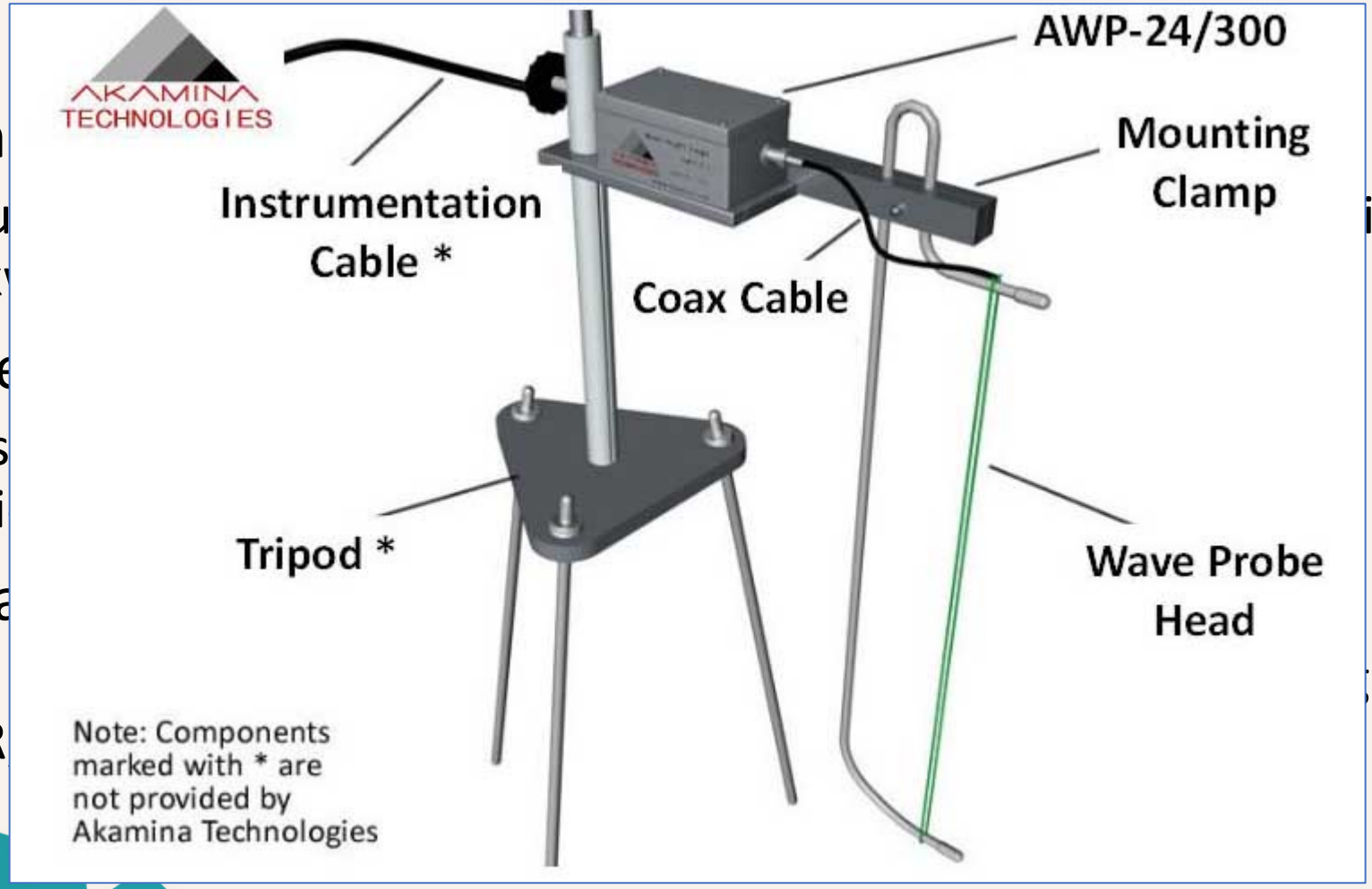


http://www.akamina.com/AWP-300-3.html

Assessment of Wave Properties

- Knowledge of wave kinematics
  - Free surface
  - Orbital velocities
  - Particle accelerations
  - Pressure distribution
  - Orbital excursions
  - Non-linearities
  - Principles of superposition
  - Directionality
  - Spreading
  - …

$$\phi(x,z,t) = \frac{ga}{\omega}\frac{\cosh[k(z+d)]}{\cosh(kd)}\sin(\theta)$$

$$u(x,z,t) = \frac{gak}{\omega}\frac{\cosh[k(z+d)]}{\cosh(kd)}\cos(\theta) \;\; ; \;\; w(x,z,t) = \frac{gak}{\omega}\frac{\sinh[k(z+d)]}{\cosh(kd)}\sin(\theta)$$

$$a_x(x,z,t) = gak\frac{\cosh[k(z+d)]}{\cosh(kd)}\sin(\theta) \;\; ; \;\; a_z(x,z,t) = -gak\frac{\sinh[k(z+d)]}{\cosh(kd)}\cos(\theta)$$

$$A = \text{horizontal axis} = a\frac{\cosh[k(z_o+d)]}{\sinh(kd)} \;\; ; \;\; B = \text{vertical axis} = a\frac{\sinh[k(z_o+d)]}{\sinh(kd)}$$

$$\frac{\omega^2}{k} = g\tanh(kd) \; ; \; C = \frac{gT}{2\pi}\tanh(kd) \;\; ; \;\; C = \sqrt{\frac{gL}{2\pi}\tanh(kd)} \; ; \; L = \frac{gT^2}{2\pi}\tanh(kd)$$

https://cavity.caee.utexas.edu/kinnas/wow/public_html/waveroom/linthe/node25.html

Assessment of Wave Properties

Input

Wave Theory

- [x] 1. Order Stoke
- [x] 5. Order Stoke
- [x] Stream Function Theory

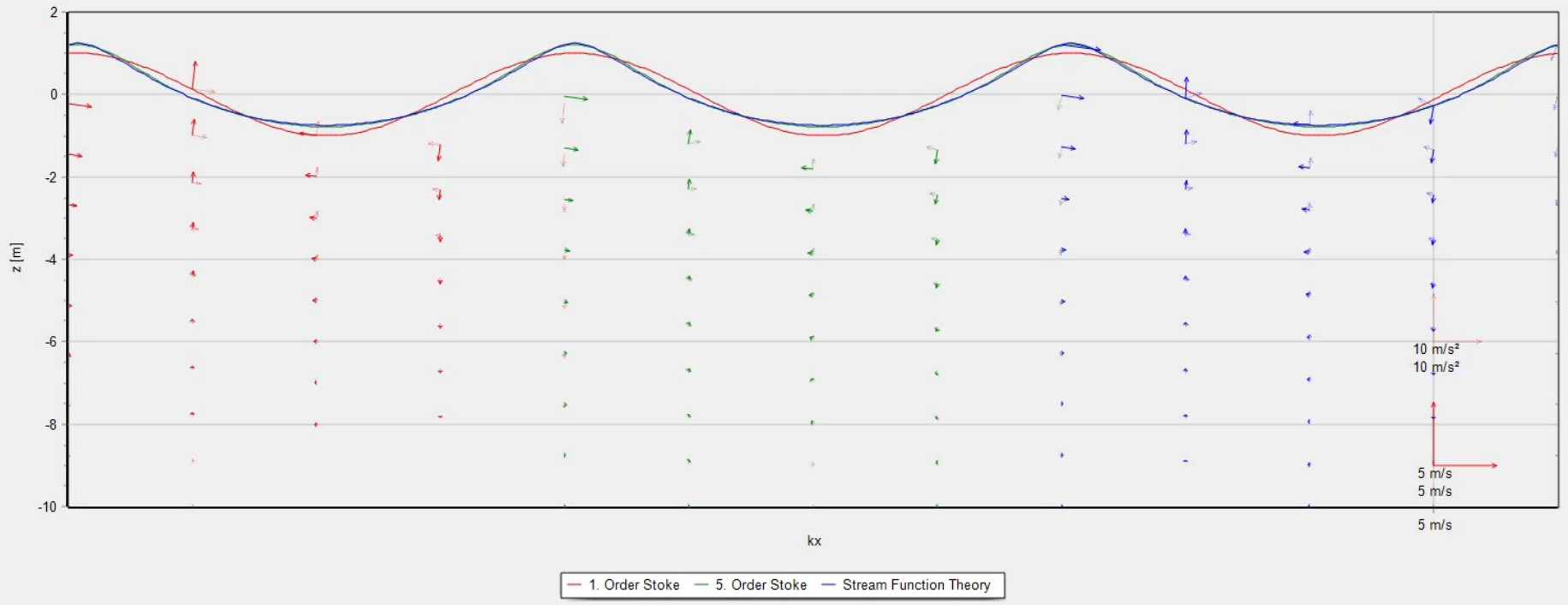
Water Depth [m]	10
Wave Period [s]	3
Wave Height [m]	2
Type of calculation	Current (U) given
U [m/s]	0

Start Calculation

Advanced Options

Output

Parameter	1. Order Stoke	5. Order Stoke	Stream Function Theory
Wavelength (L) [m]	14.055	16.184	16.288
Wave number (k=2·pi/L)	0.447	0.388	0.386
Current Discharge Q [...	1.059	0.893	0.841



Assessment of Wave Properties

Input

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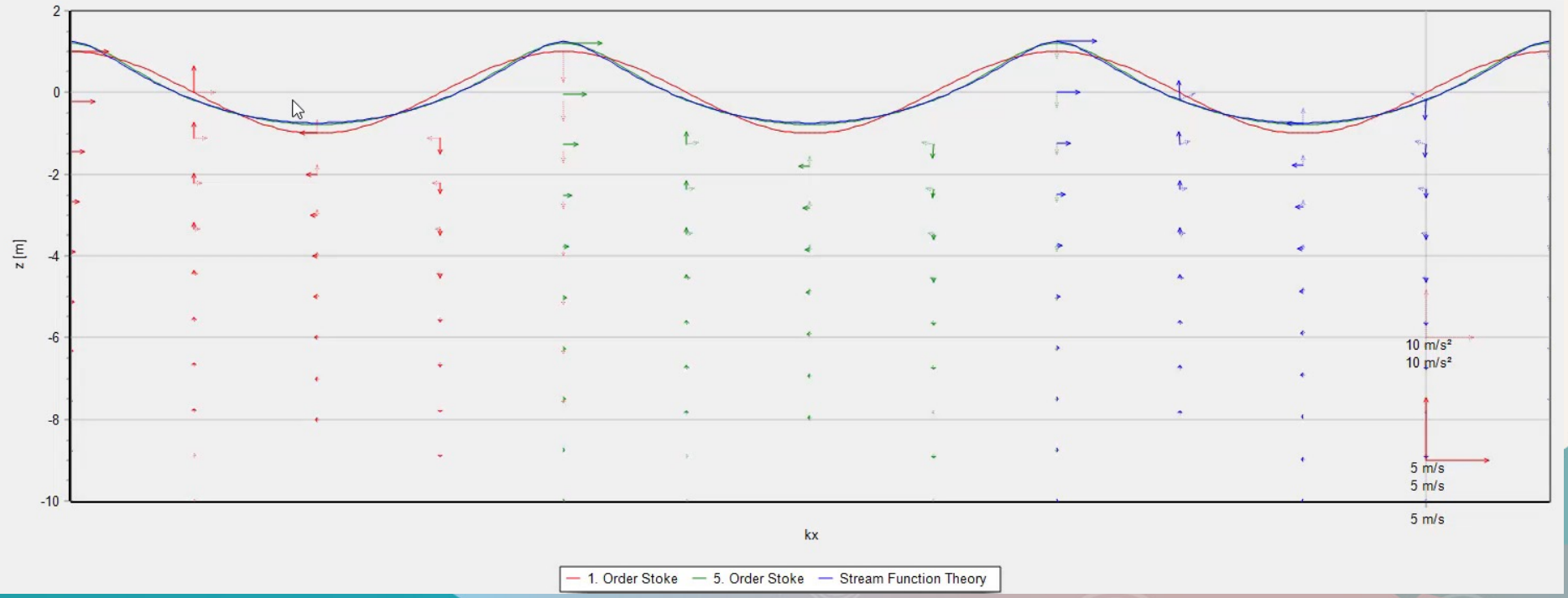
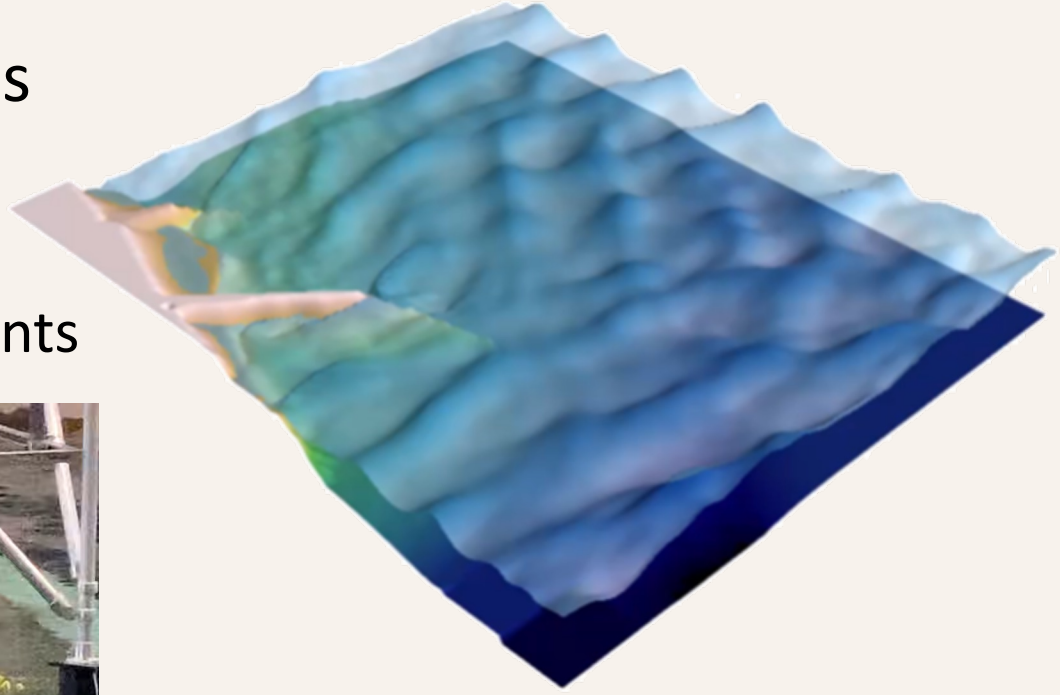
Wavelength (L) [m]	14.055	16.184	16.288
Wave number (k=2·pi/L)	0.447	0.388	0.386
Current Discharge Q [...	1.059	0.893	0.841
kx	2.820	2.820	2.820
z [m]	-0.170	-0.170	-0.170
eta [m]	-0.949	-0.755	-0.724
u [m/s]	Out of Range	Out of Range	Out of Range
w [m/s]	Out of Range	Out of Range	Out of Range
du/dt [m/s²]	Out of Range	Out of Range	Out of Range
dw/dt [m/s²]	Out of Range	Out of Range	Out of Range
pd [Pa]	Out of Range	Out of Range	Out of Range
p [Pa]	Out of Range	Out of Range	Out of Range

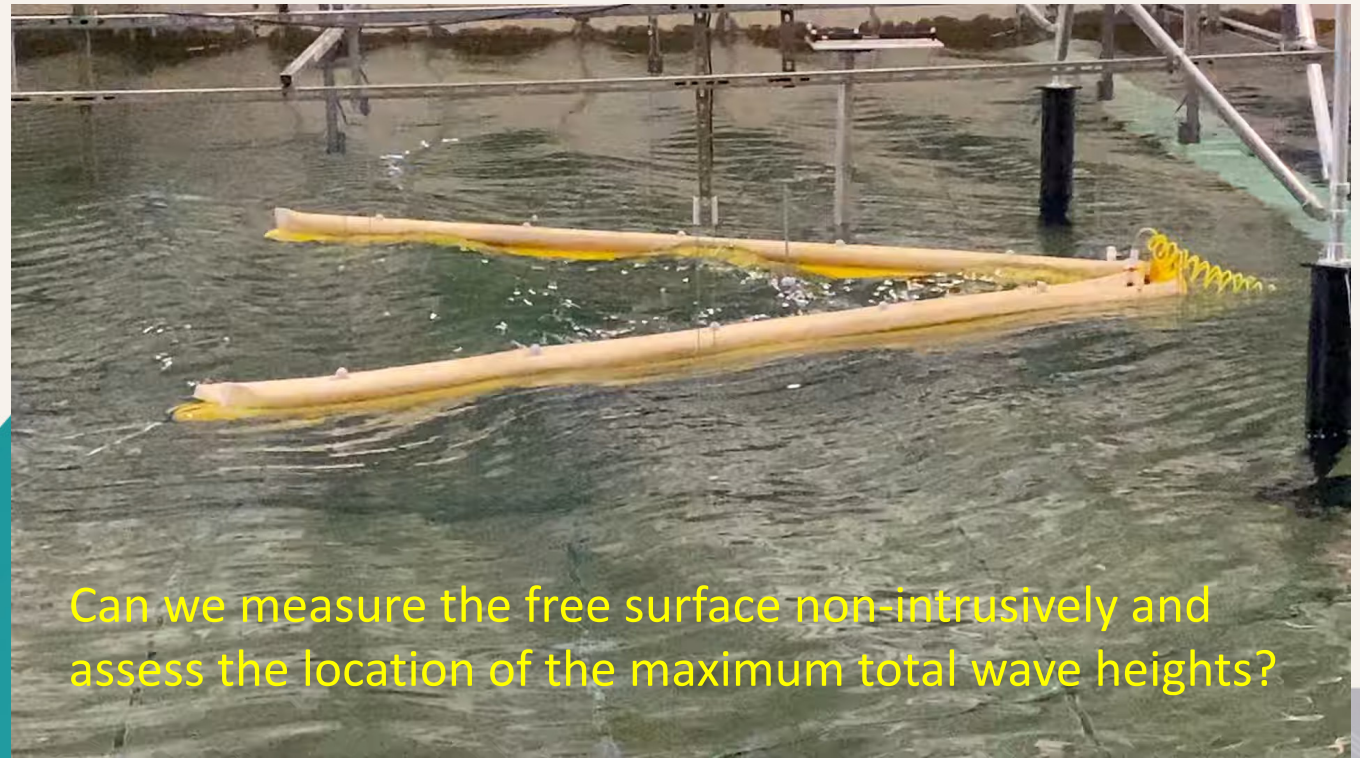


Assessment of Wave Properties

- Limitations on free surface measurements
  - Complex and highly variable 3D wave fields
  - Incompatibility with floating devices
  - Interference of intrusive hardware/instruments



https://jbpacific.com.au/projects/coastal-hazards/diatreme-barge-landing-facility-coastal-assessment-qld/



Can we measure the free surface non-intrusively and assess the location of the maximum total wave heights?

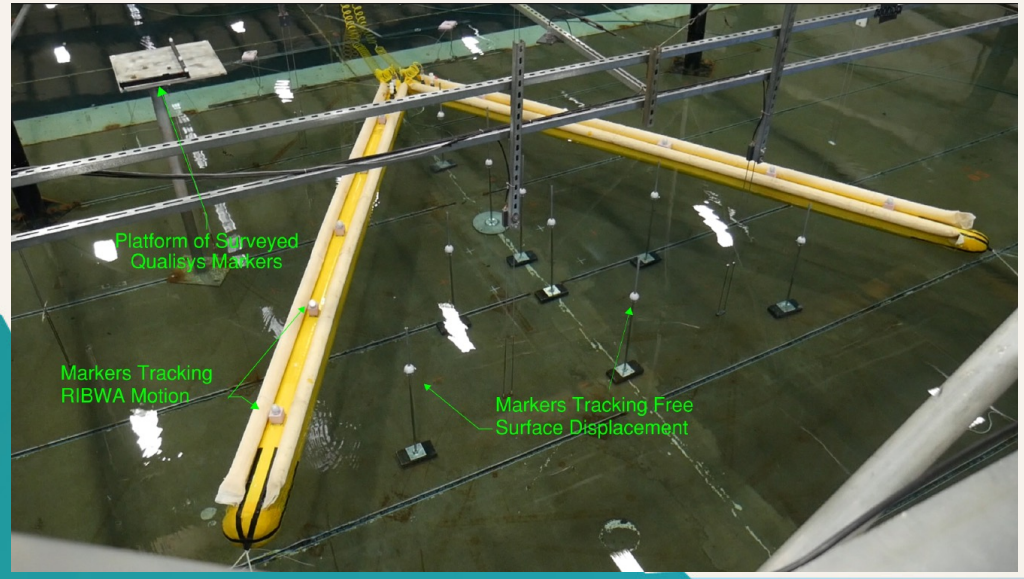
Mocap – Motion Capture System

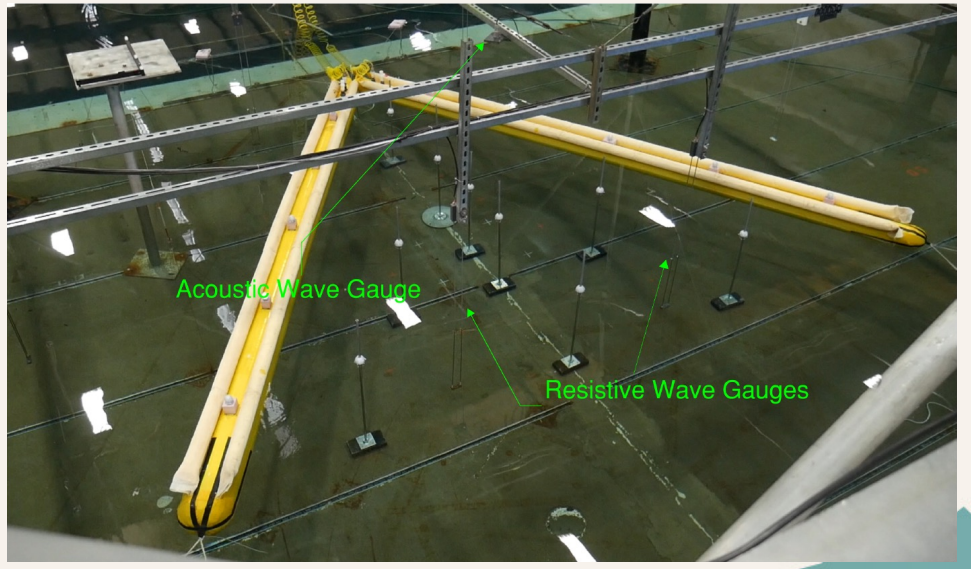
- Registering the motion of objects
- Non-intrusive
- Use of cameras
- Use of passive or active markers
- Capturing the 3D coordinates with a high sampling rate
- Applications in marine engineering, coastal engineering, health science, video game industry, movies, …

https://www.youtube.com/watch?v=qtXz6qocciM

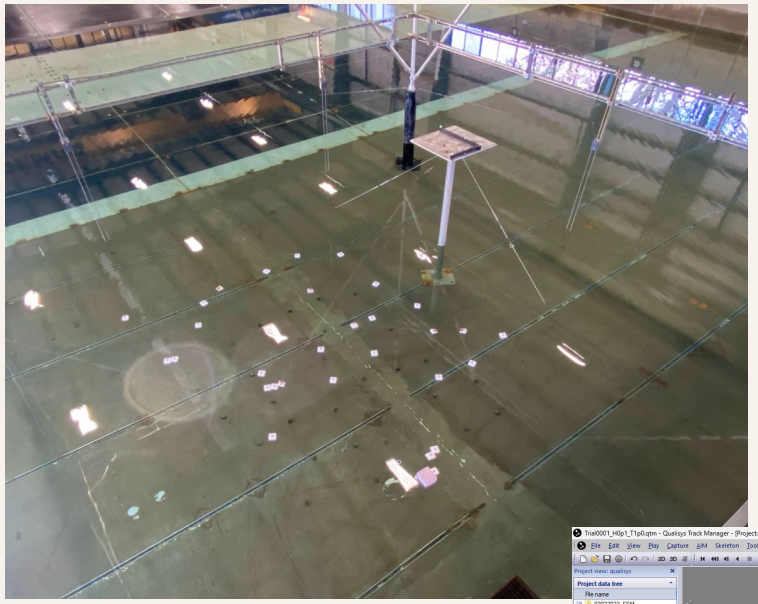
TEAMER - Rapidly Installed Breakwater for WEC Enhanced Performance

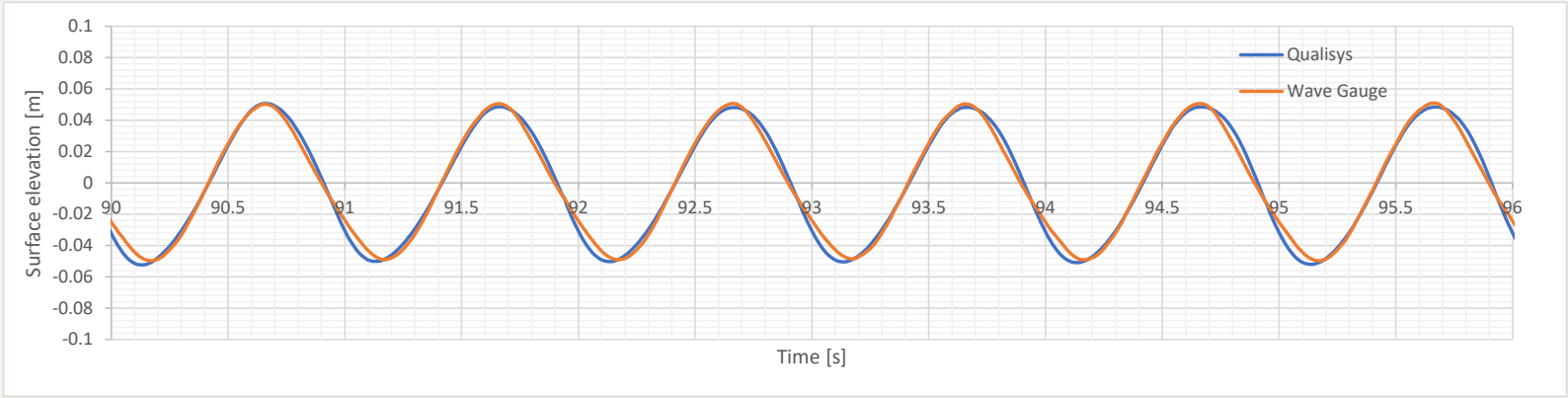
- Experiments presented in UMERC 2023
- Qualisys Motion Capture:
  - RIB/WA motions and deformations
  - Free surface tracking



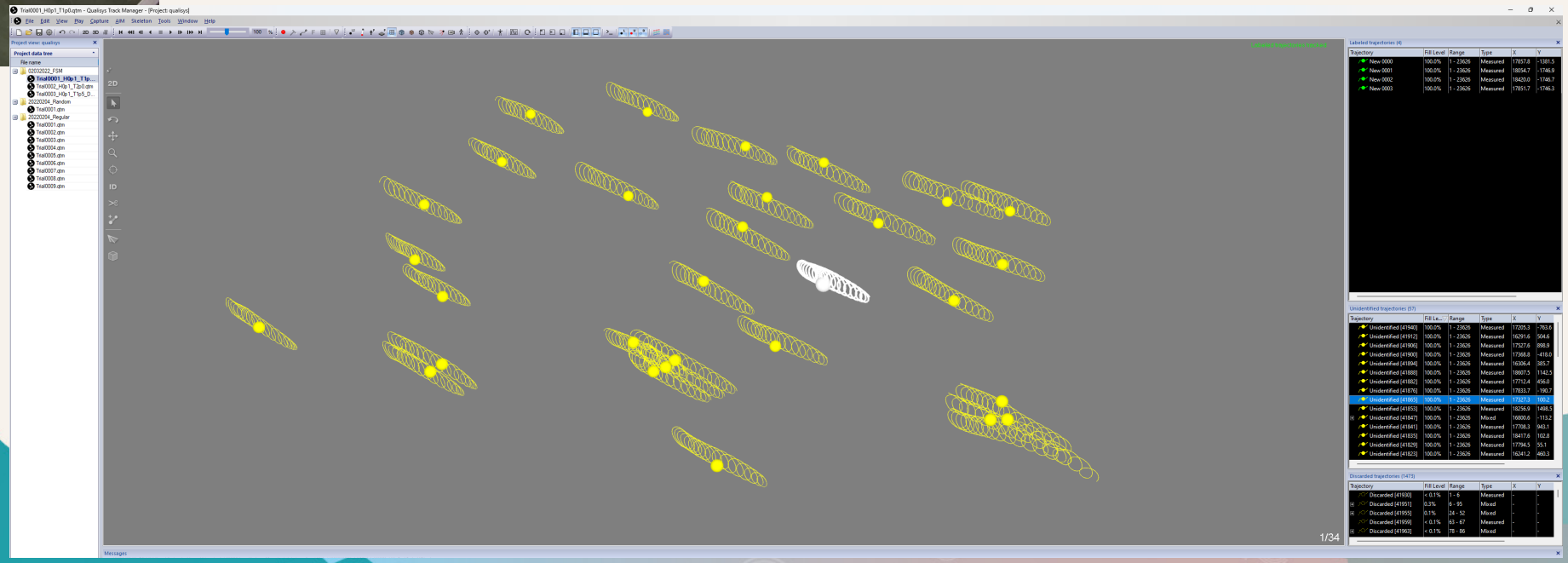


Undisturbed conditions (no RIB/WA)



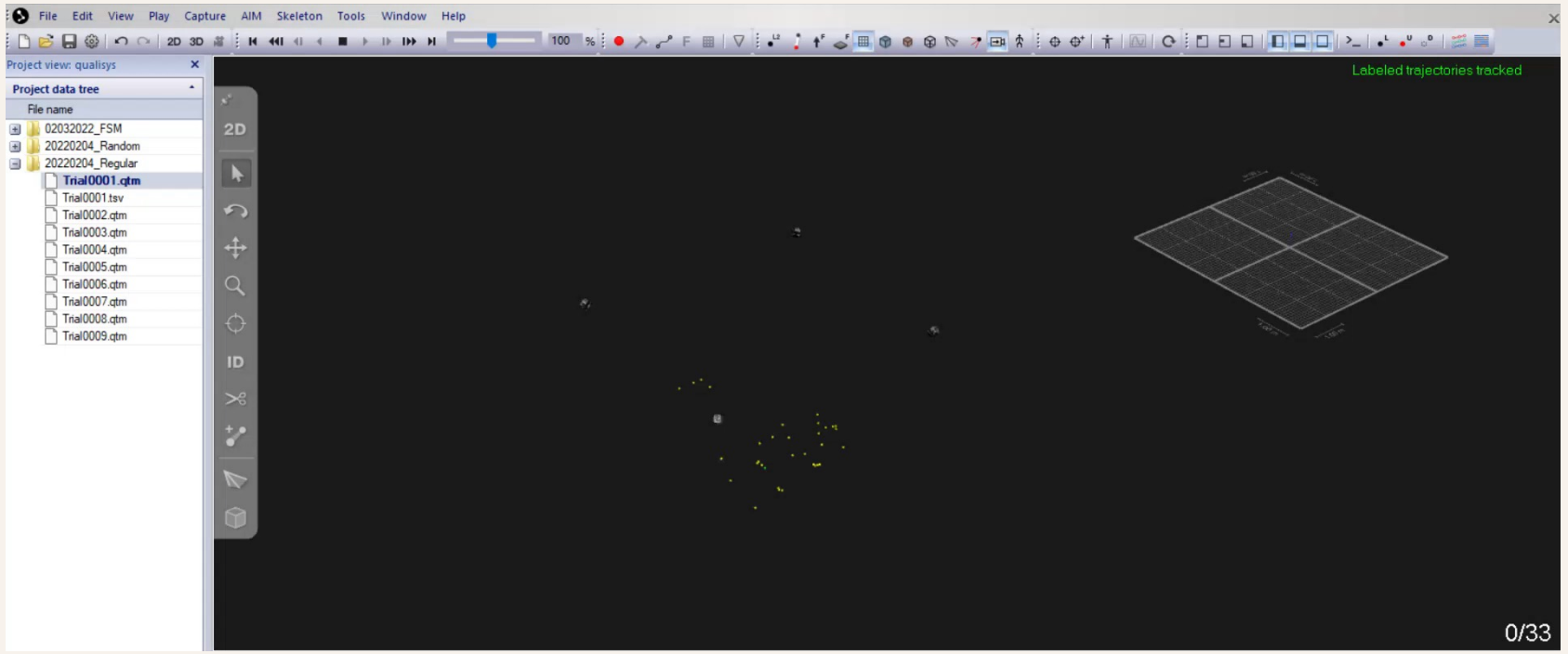


Wave gauge: H=0.096 m, T=1.0 s
Qualisys: H=0.097 m, T=1.002 s

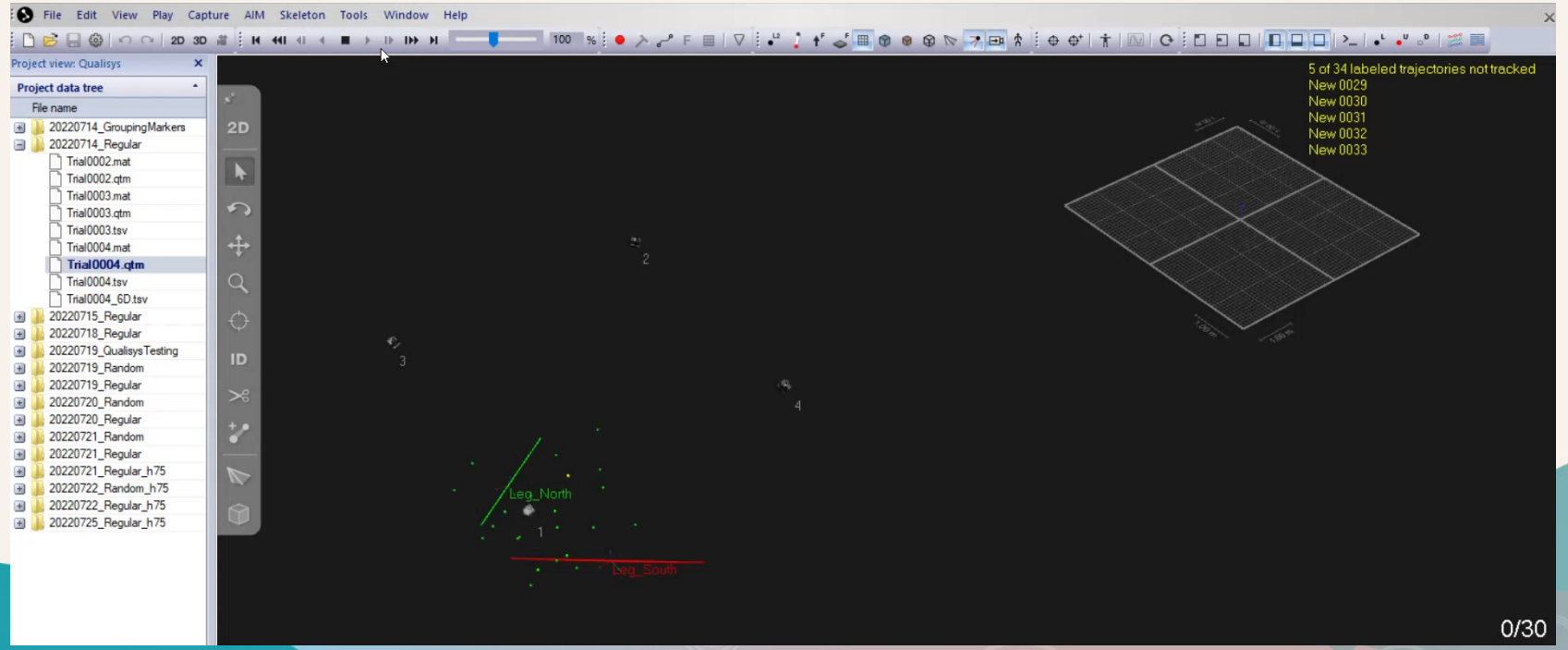


RIB/WA effect

Undisturbed



RIB/WA



Conclusions

- Motion capture with floating markers is an alternative to measure non-intrusively free surface waves
- Complex and highly-variable 3D free surface waves can be measured accurately
- Standard time- and frequency-domain techniques should be adapted to pseudo-Lagrangian measurements
- Multi-directional wave analysis remains another application of Mocap measurements
- Drifting and clustering of markers requires additional improvement for broader applications
- Shallow water measurements and wave breaking remain another aspect for future testing