Physical modelling of landslide generated tsunamis around a conical island: Recent developments

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- New experiments with moveable wave gauges
    - k-f analysis for the analysis of the trapped waves
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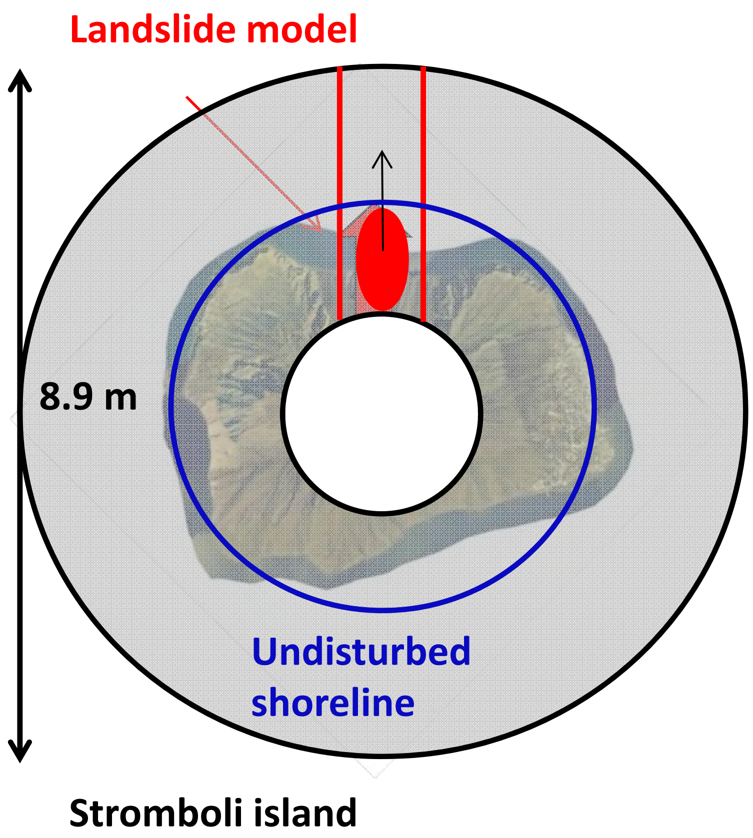
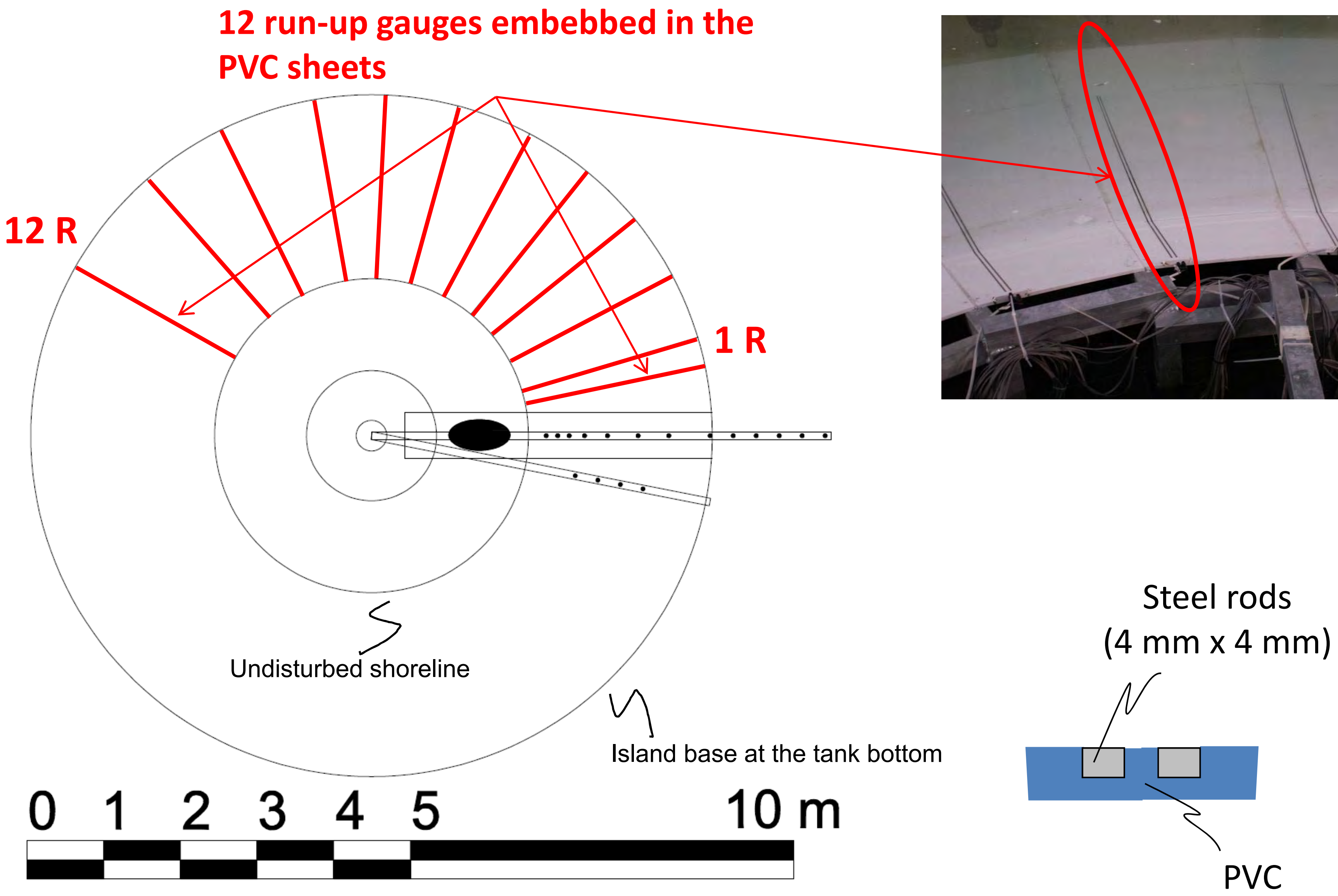
The conical island: a small simplified Stromboli

The physical model represents a truncated conical island (base radius 4.45 m). The slope of the island's flanks is 1:3 (1 vertical, 3 horizontal). A flat slope (0.5 m wide) allows the model to slide along the flank and to enter the water. The physical model roughly reproduces the small volcanic island Stromboli (South Tyrrenian Sea, Italy) in a Froude law scale (1:1000).

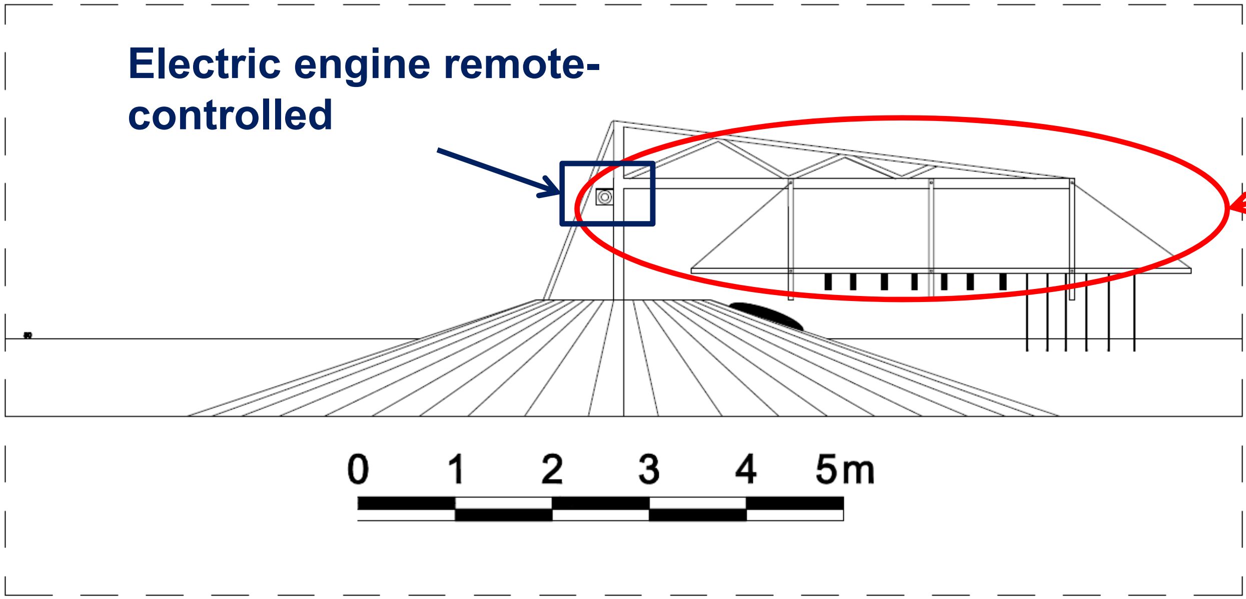


The run-up gauges

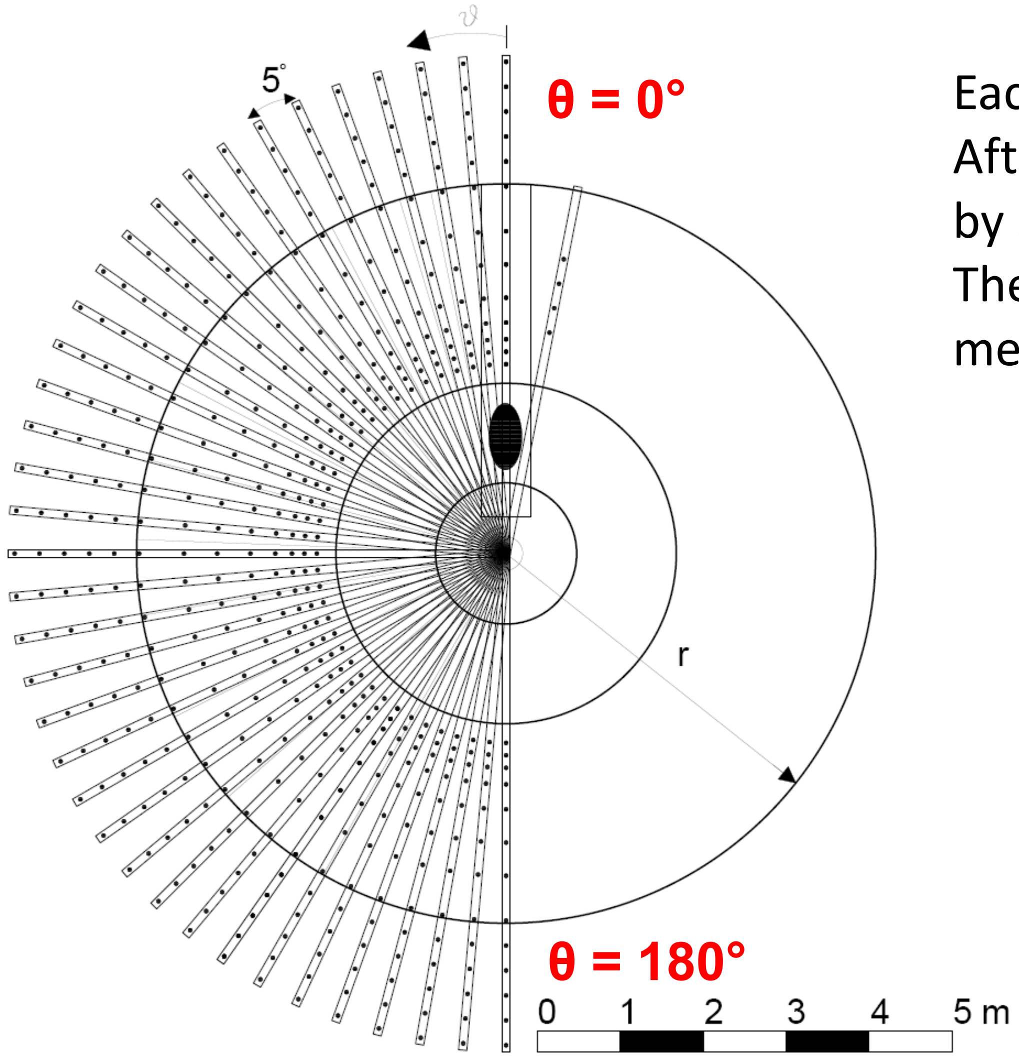


A movable arm to change the position of wave gauges

13 wave gauges are installed on a rotating arm, which is placed at the island center. An electric engine, remotely-controlled rotates it along an angular sector of **180°**, with steps of **5°**.



A movable arm to change the position of wave gauges

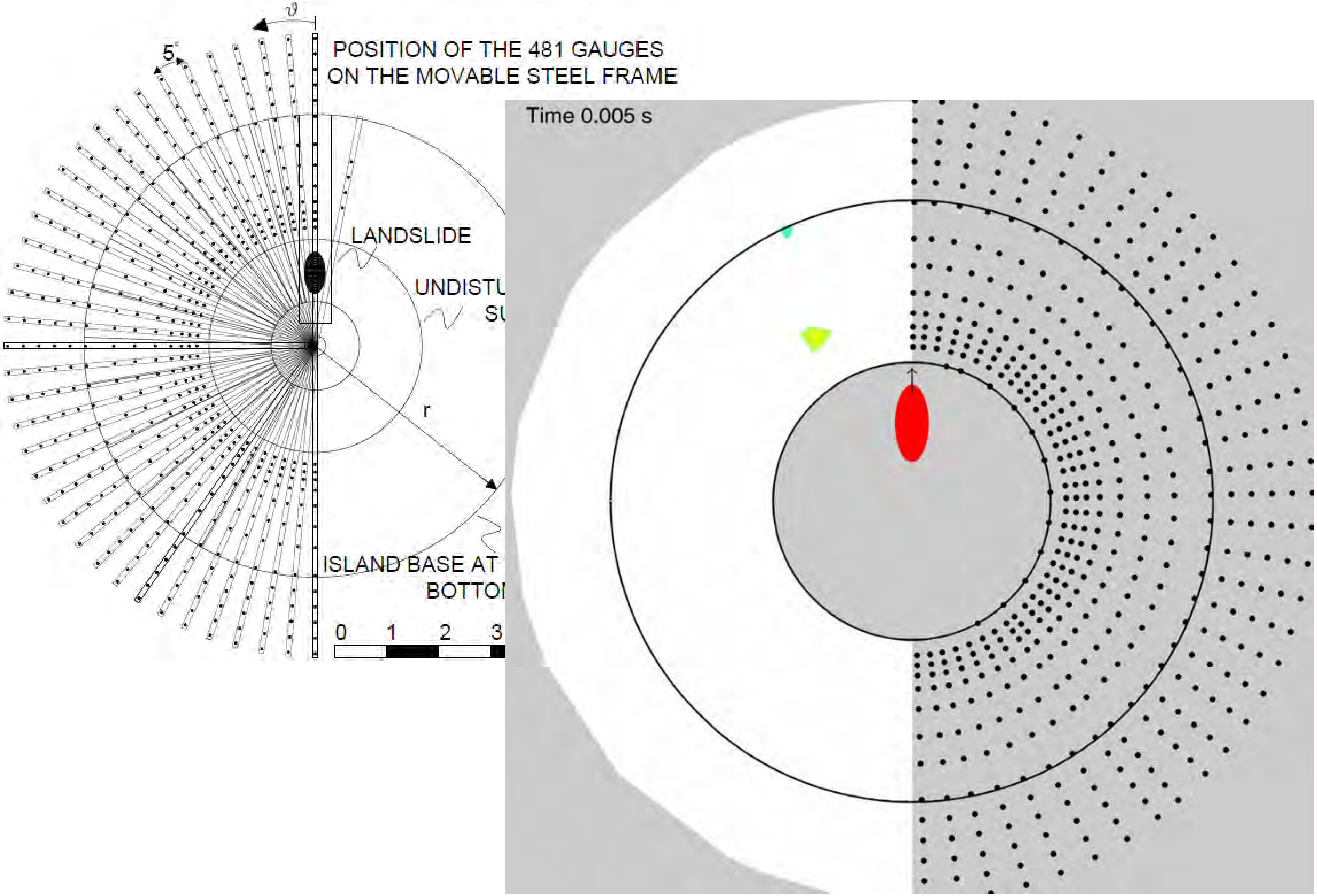


Each experiment is repeated 37 times.
After each test the arm has been rotated by 5°.
The arm position has been carefully measured by a theodolite.

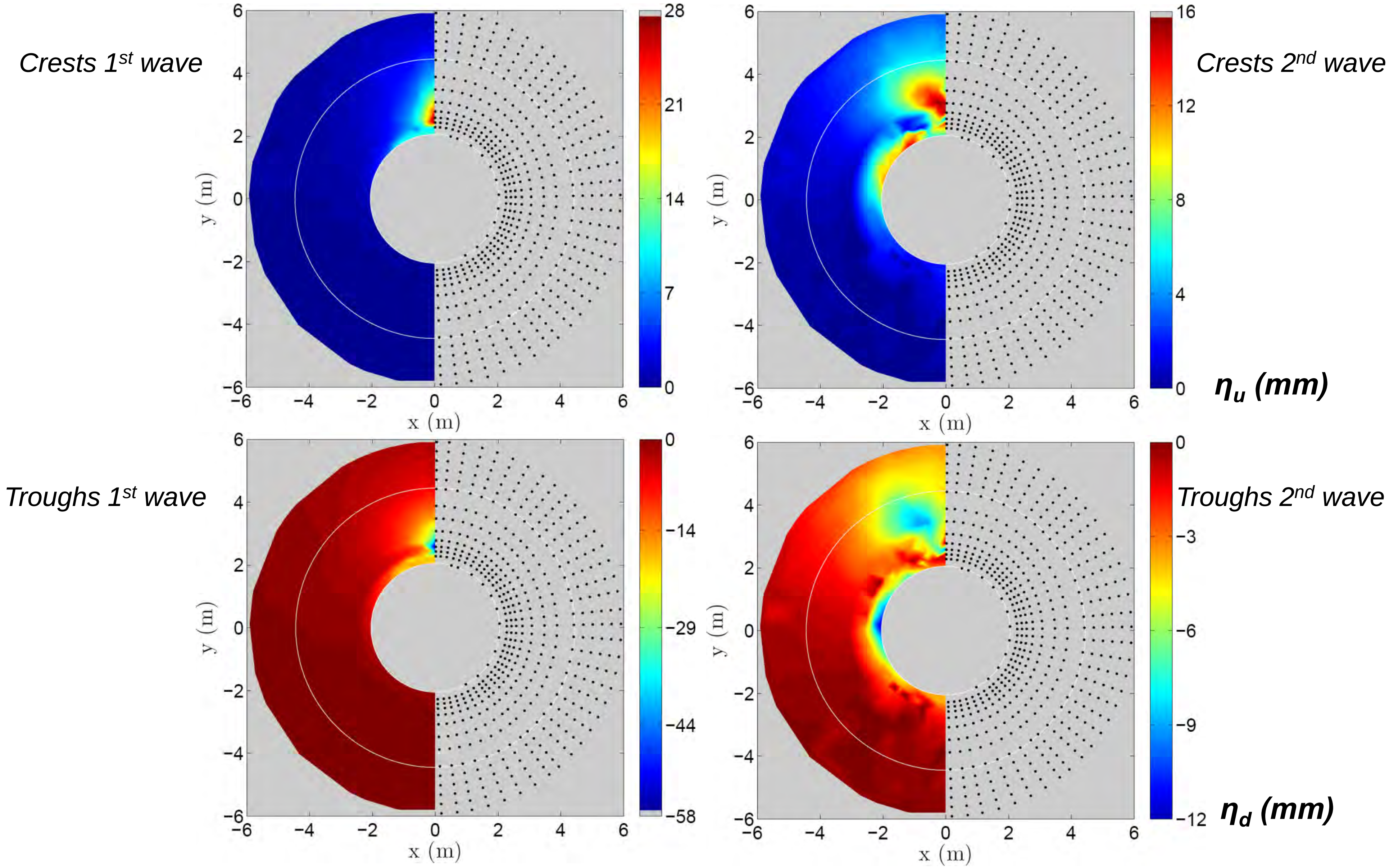
Once the repeatability of the experiments is ensured, more than **500** punctual free surface elevation time series are available

θ = Angle between the path of the landslide and the rotating arm

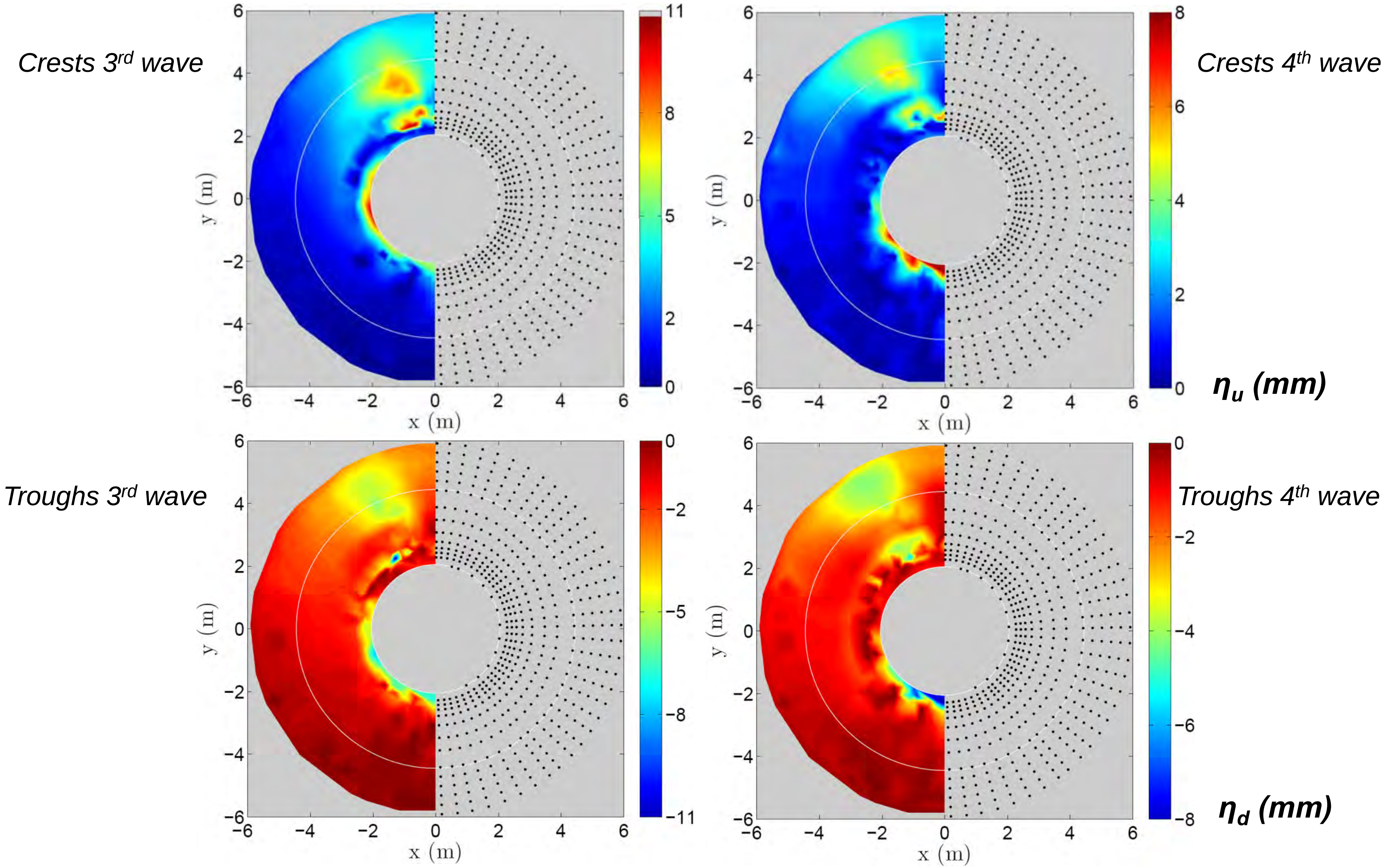
Animation of the results



Crest and trough elevation, first and second waves

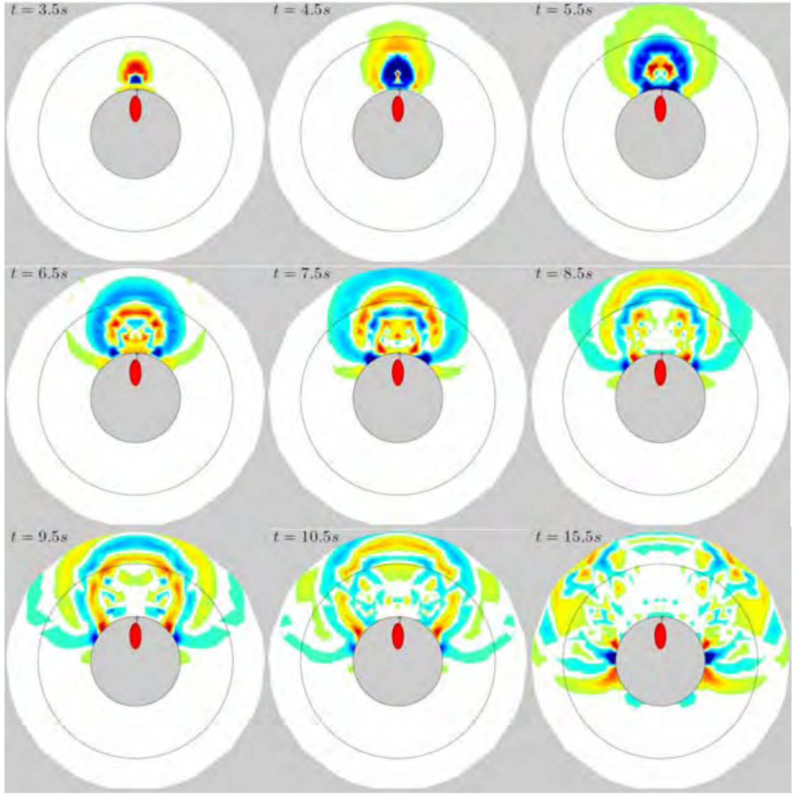


Crest and trough elevation, third and fourth waves

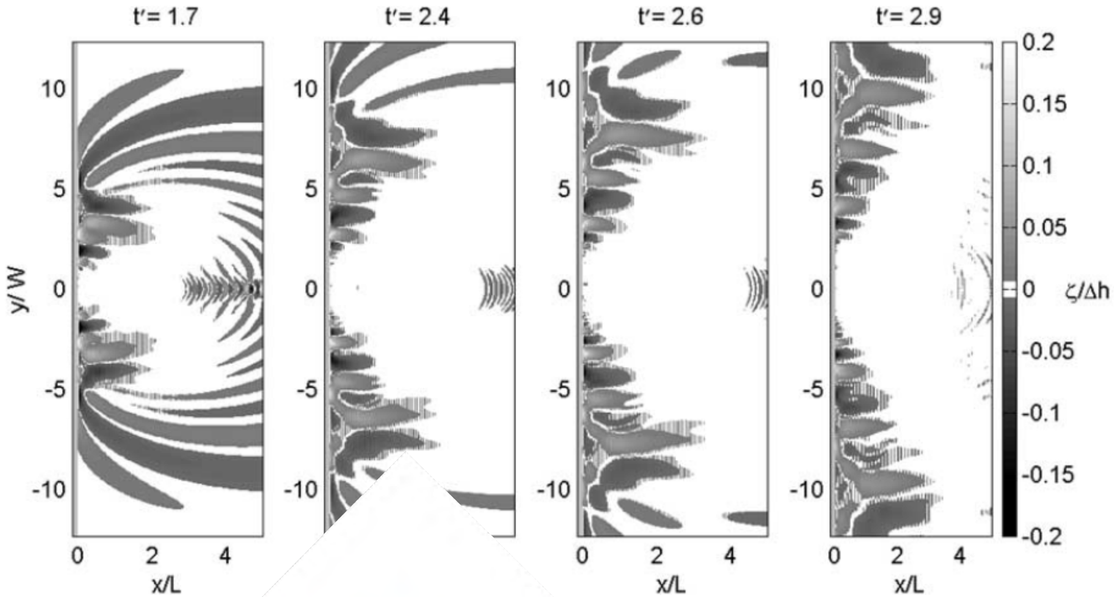


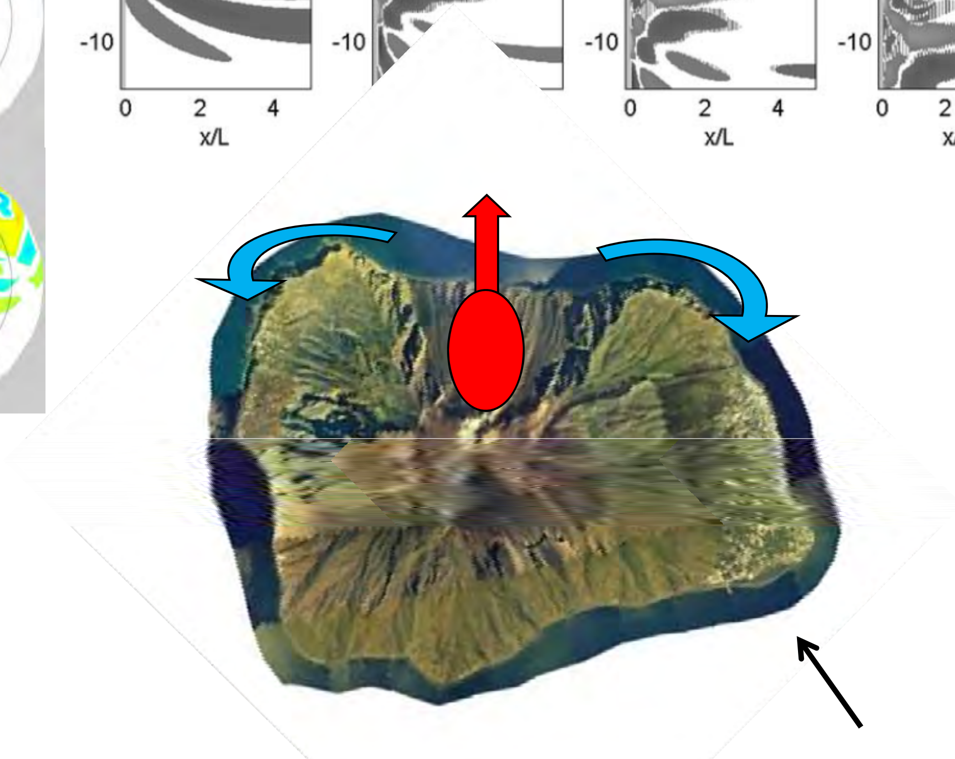
Wavenumber-frequency (k-f) analysis of the results

Present experimental results



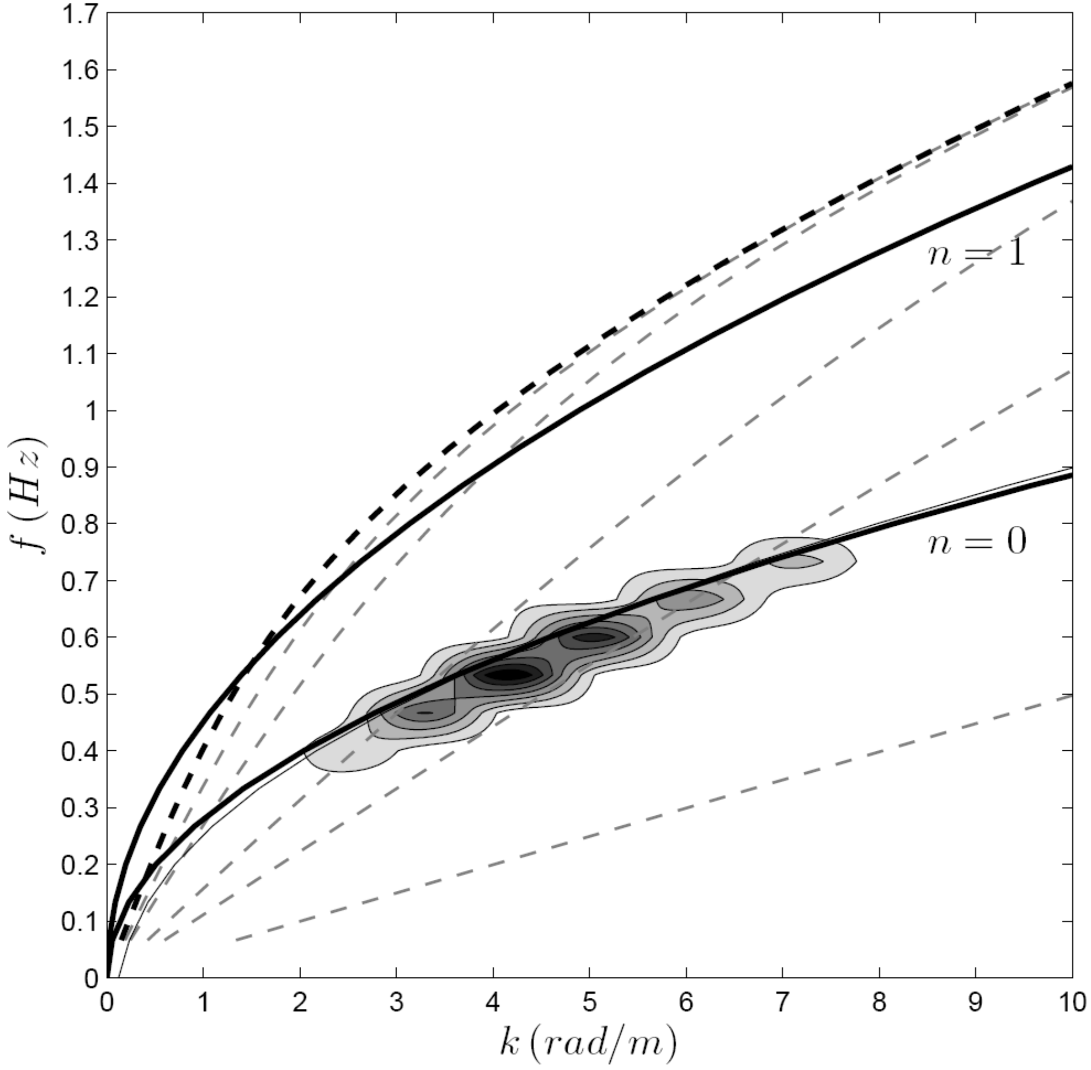
Lynett & Liu (2005)





Wavenumber-frequency (k-f) analysis of the results

The 1D k-f, applied to the run-up time series, shows that the waves propagate along the shore as a **0^{th}-order edge waves packet** or Stokes edge waves (*Ursell, 1952*).



Dispersion relationships:

- Deep water limit
- Edge waves (n = 0, 1)
- Edge waves (circular shoreline)
- Small amplitude waves

Edge waves (*Ursell, 1952*)

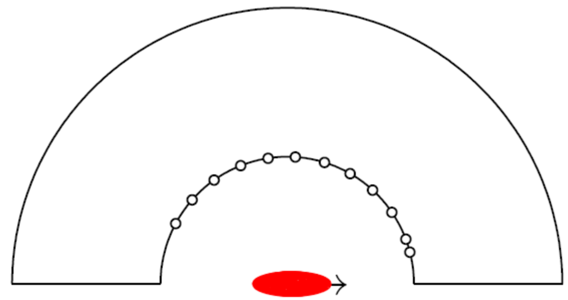
$$\omega^2 = g\,k\,\sin\left[(2n+1)\,\beta\right]$$

Edge waves (circular shoreline, *Smith & Sprinks, 1975*)

$$\omega^2 = g\,k\,\tan\beta\left[1 - \frac{1}{4}(k\,r_s)^{-1}\right]^2$$

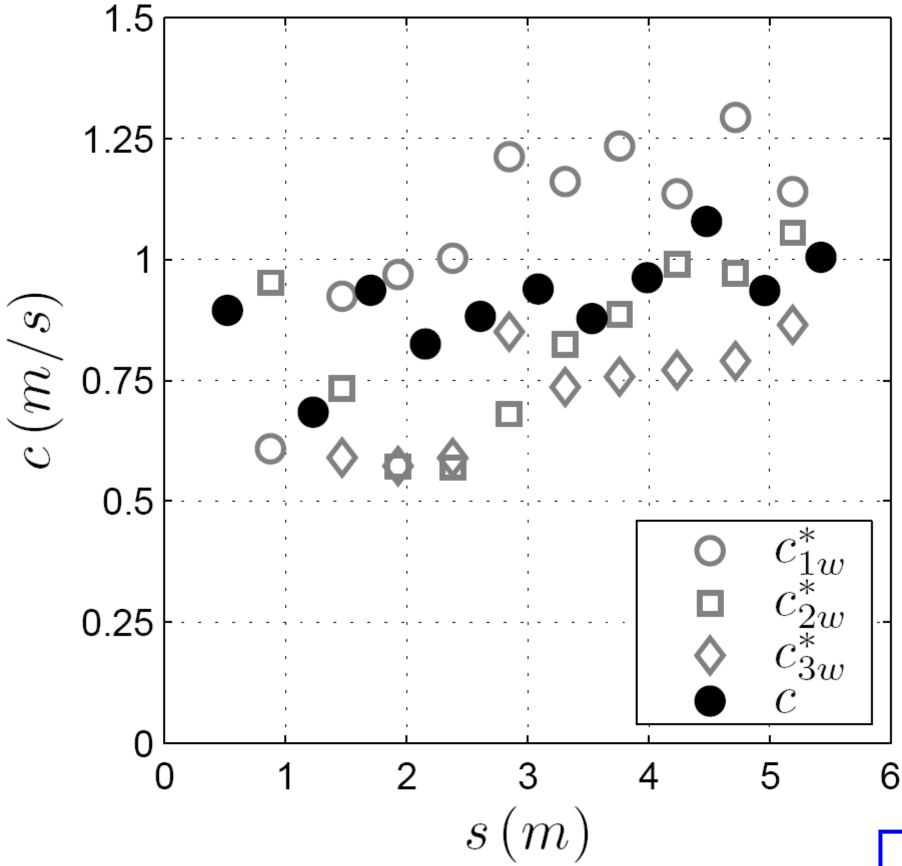
Small amplitude waves

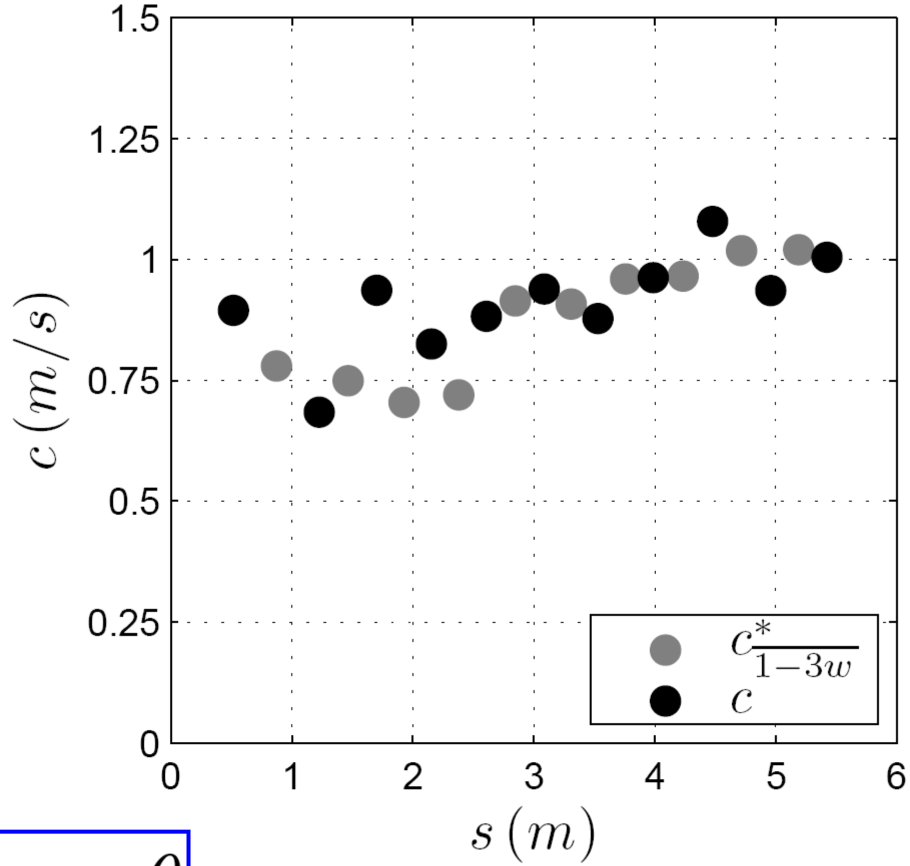
$$\omega^2 = g\,k\,\tanh\left(kh\right)$$



Estimate of the wave phase celerity

The experimental phase wave celerity of the first three waves that form the packet (c^*_{1w}, c^*_{2w}, c^*_{3w}) has been calculated as from the zero-crossing analysis, while the theoretical one has been obtained (*c*) by the edge waves dispersion relation.

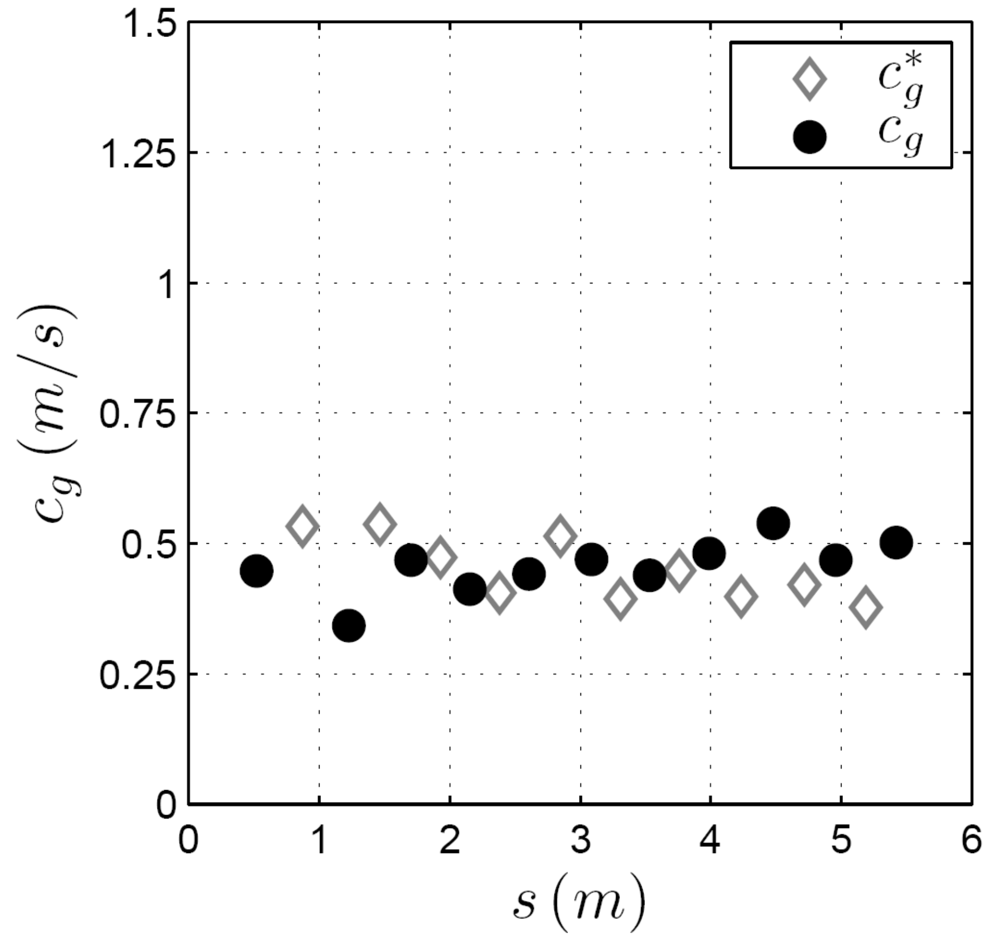




$$s = r\,\theta$$

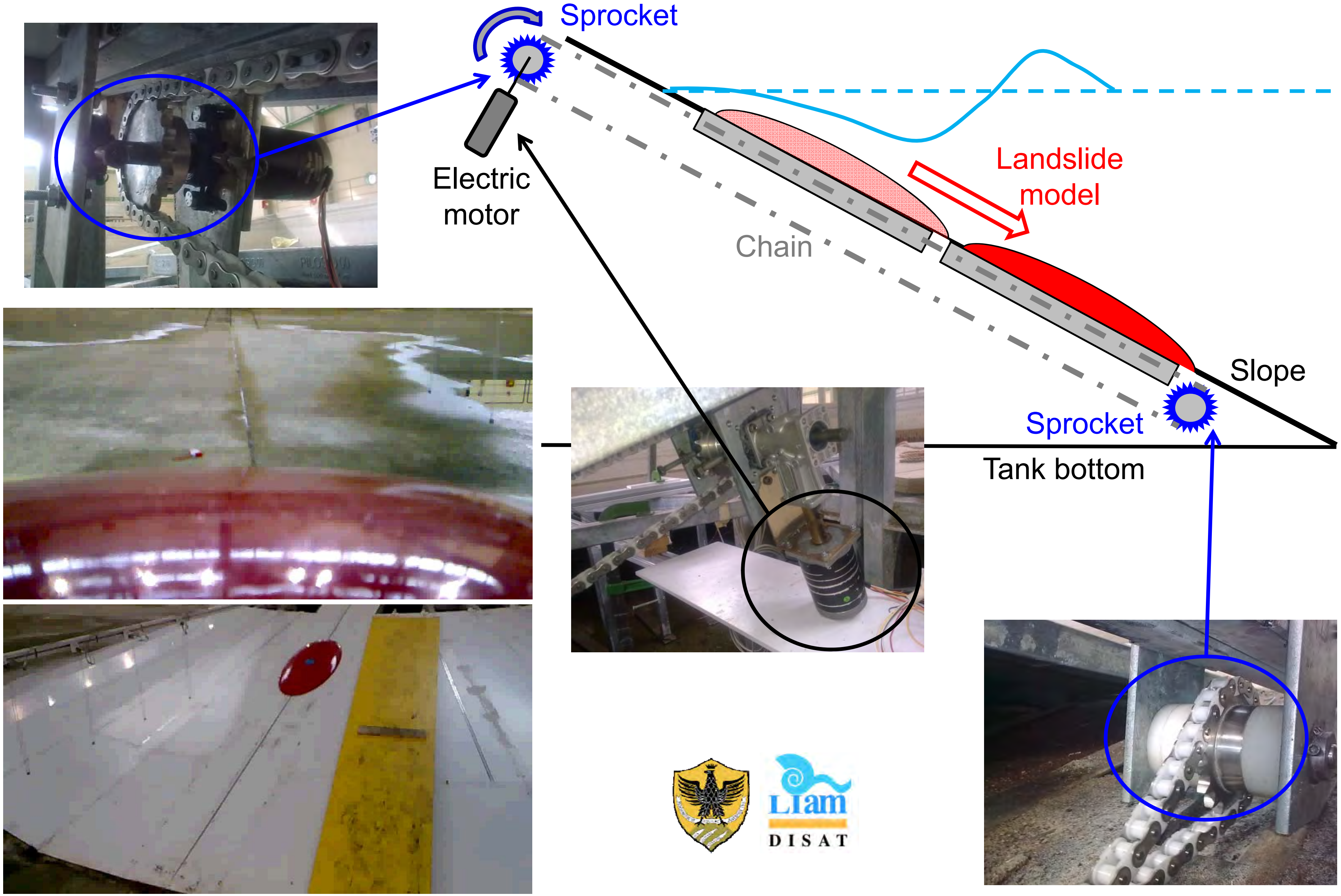
Estimate of the wave group celerity

The theoretical group wave celerity, as from the edge waves theory for the 0-th mode, is in very good agreement with the experimental one.



$$s = r\,\theta$$

The new tests with submerged landslides



Landslide motion (controlled by the motor)

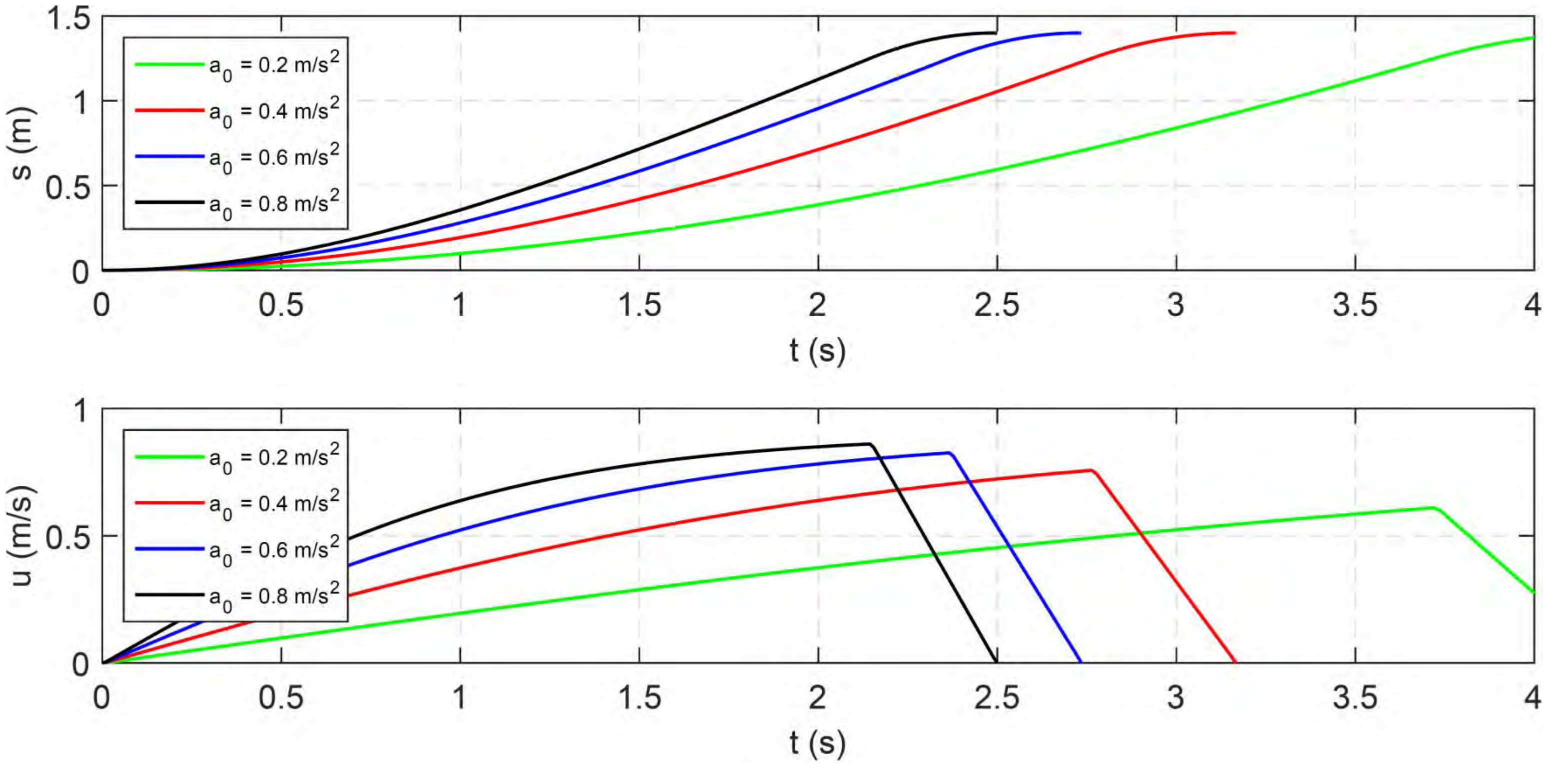
The landslide laws of motion has been obtained by the analytical solutions by Watts (1998) and Pelinovsky & Poplavsky (1996). The initial acceleration has been varied parametrically.

$$\begin{cases} s(t) = \frac{u_t^2}{a_0} \ln \left[\cosh \left(\frac{a_0 t}{u_t} \right) \right] \\ u(t) = \frac{ds(t)}{dt} = u_t \tanh \left(\frac{a_0 t}{u_t} \right) \end{cases}$$

Watts (1998); Pelinovsky & Poplavsky (1996)

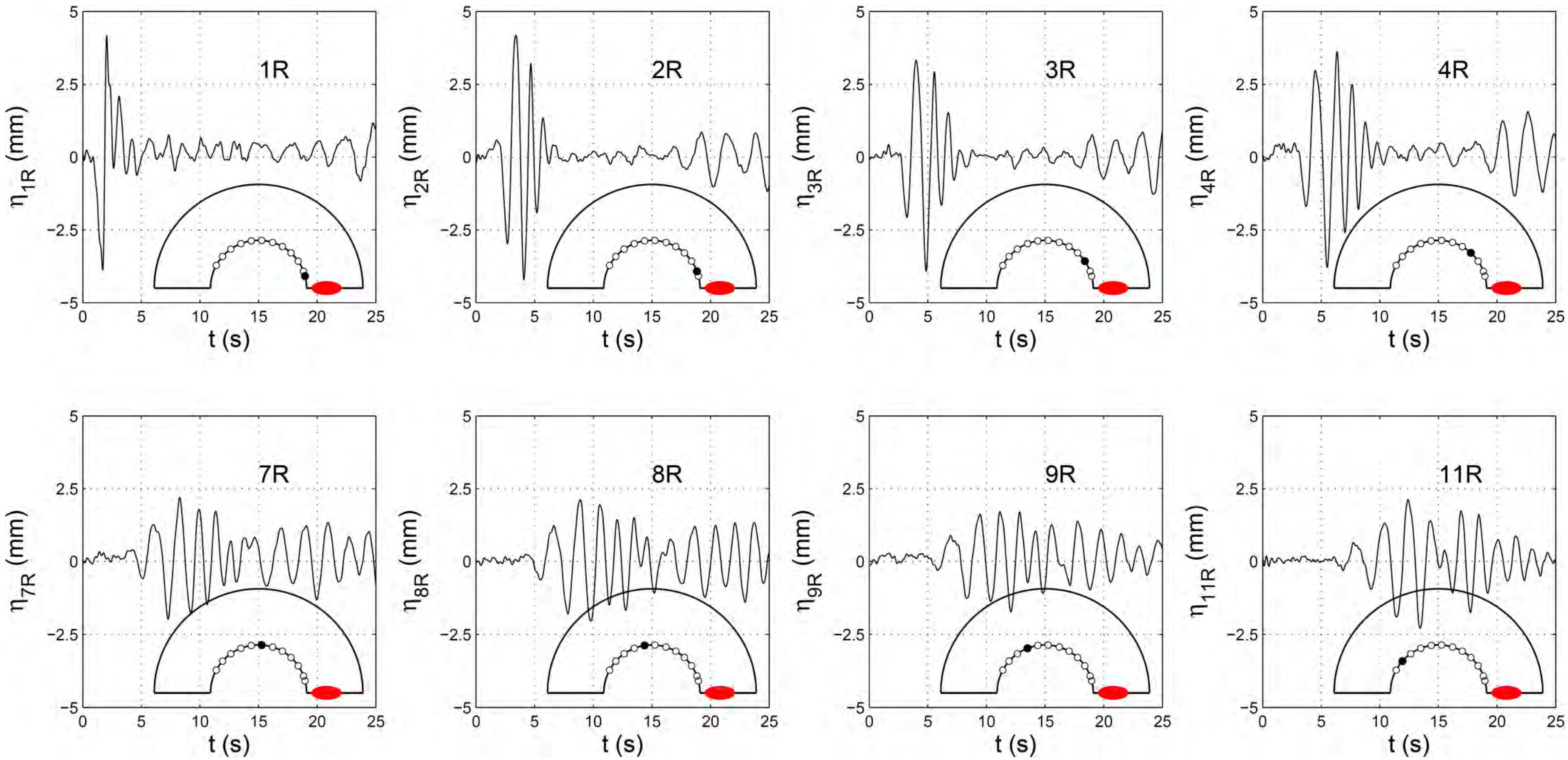
a_0 (m/s^2)	0.2	0.4	0.6	0.8

The gravity-driven initial acceleration for LS1 as estimated from experimental parameters is $a_0 = 0.47$ m/s^2



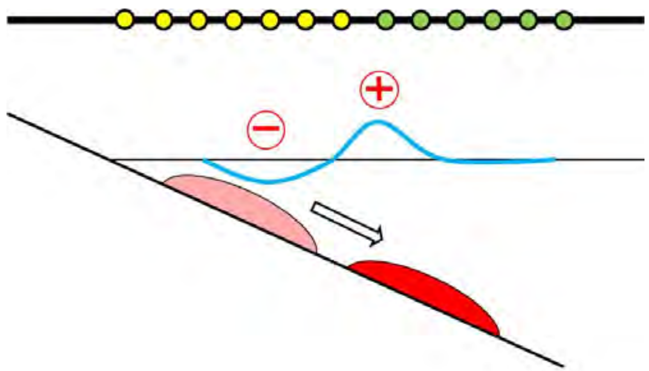
Results for submerged landslide: wave run-up features

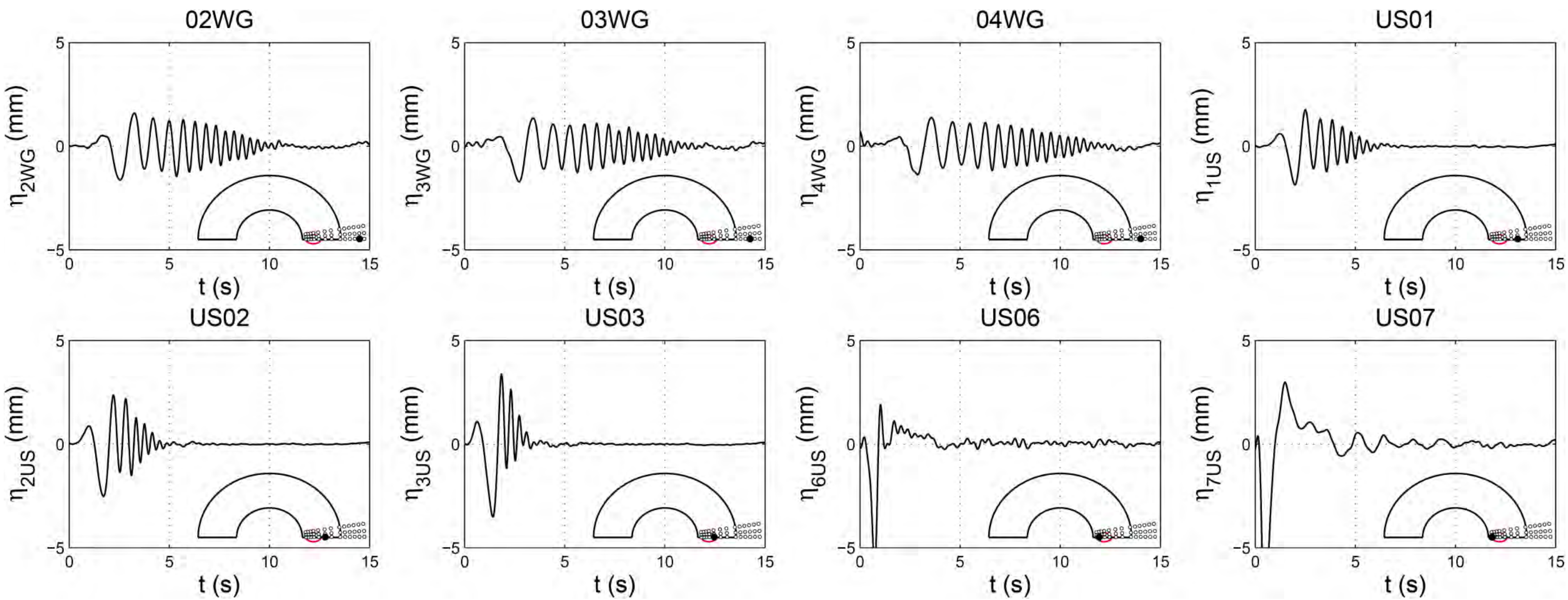
Run-up time series (a_0 = 0.8 m/s^2) along the shoreline of the island.



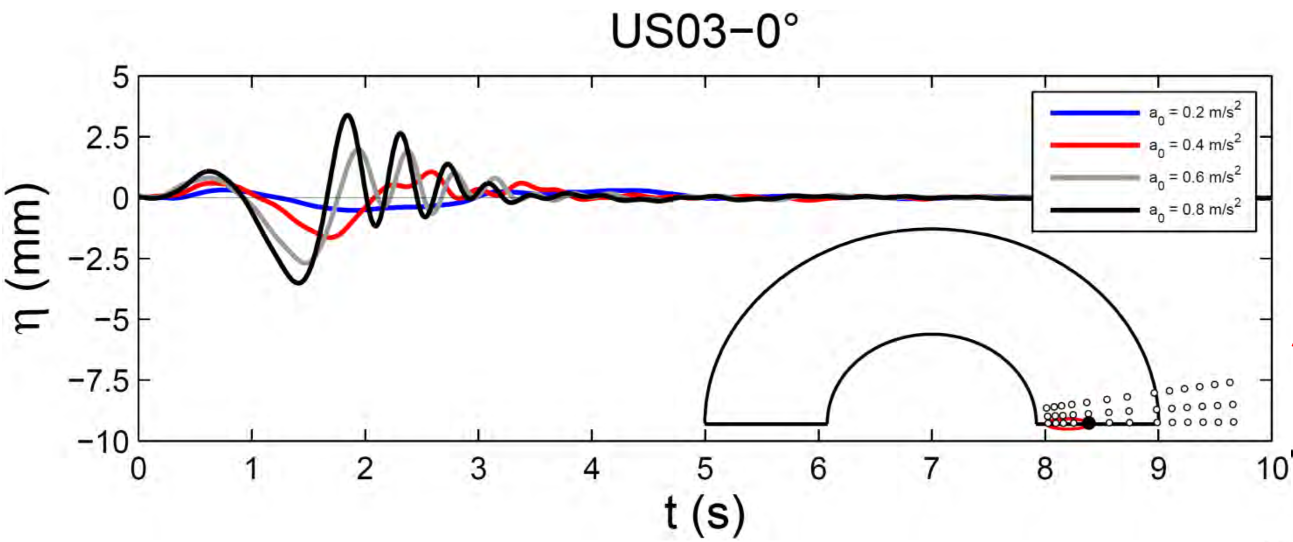
Results for submerged landslide: near field waves

Free surface elevation time series in the near field (a_0 = 0.8 m/s^2) evaluated at different positions along the landslide path.

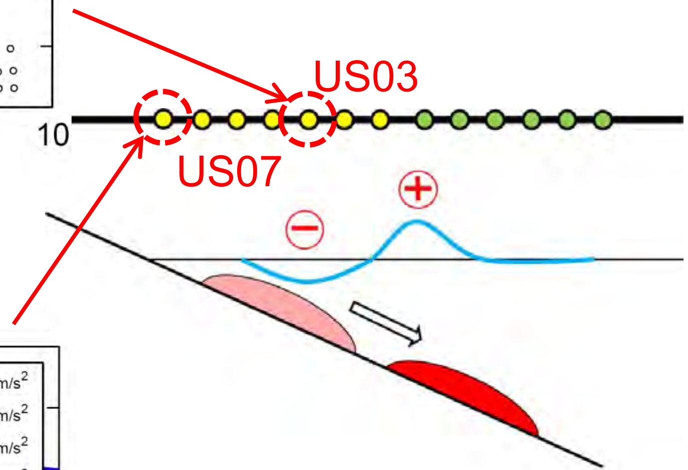


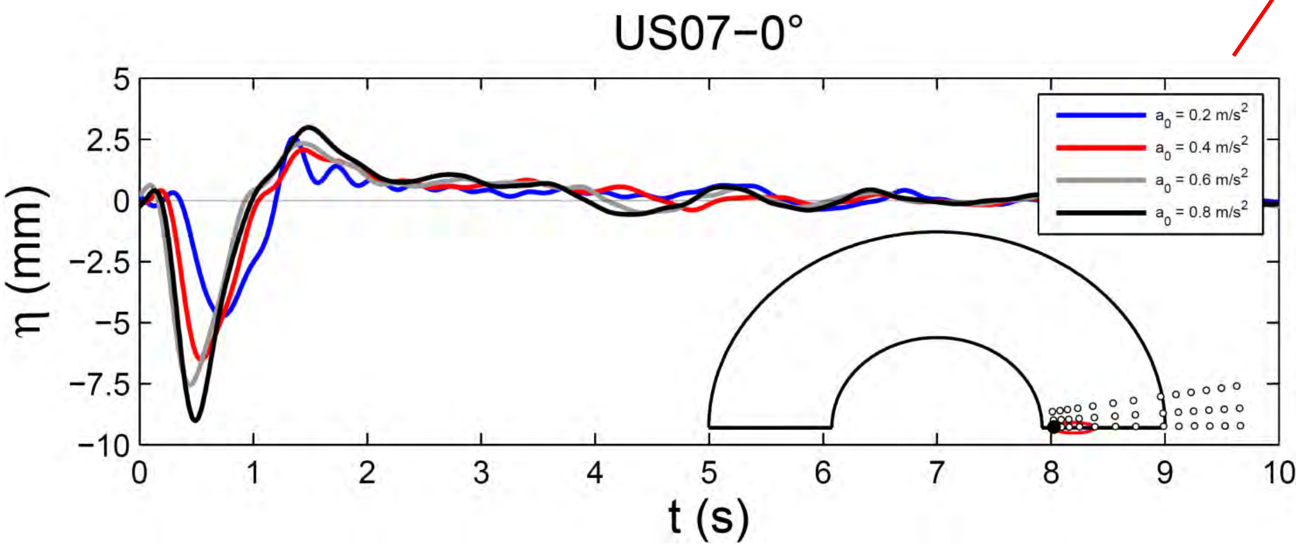


Results for submerged landslide: near field waves



Free surface elevation time series in the near field as a function of the initial acceleration a_0.





Conclusions and references

Movable arm experiments:
Romano A., M. Di Risio, G. Bellotti, M. G. Molfetta, L. Damiani, P. De Girolamo (2016). Tsunamis generated by landslides at the coast of conical islands: experimental benchmark dataset for mathematical model validation. Landslides, pp. 1-15.
Benchmark data available for distribution

k-f analysis:
Romano A., Bellotti G., Di Risio M. (2013). Wavenumber–frequency analysis of the landslide-generated tsunamis at a conical island. Coastal Engineering, vol. 81, pp. 32-43.

EOF analysis:
Wavenumber-frequency analysis of the landslide-generated tsunamis at a conical island. <u>Part II: EOF and modal analysis</u> (in preparation)

Submerged landslides:
Tsunamis generated by submerged landslides at a conical island: experimental and numerical analysis (in preparation)