Runup of long waves on composite coastal slopes: numerical simulations and experiment

Ahmed Abdalazeez[1], Ira Didenkulova[1,2], Andrey Kurkin[2], Artem Rodin[2] and Denys Dutykh[3]

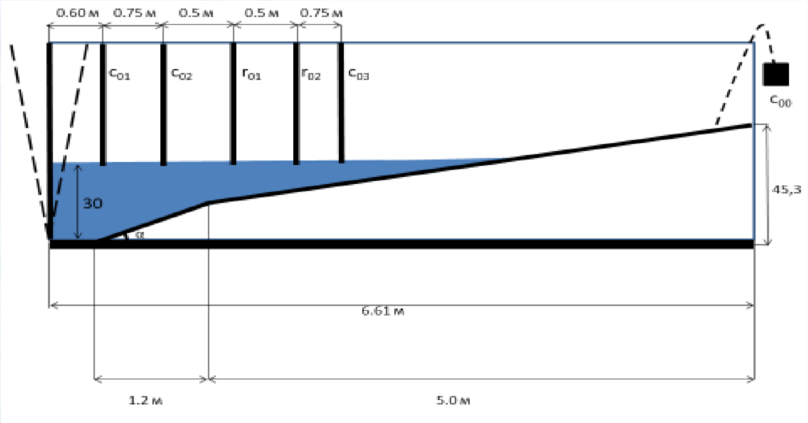
[1]Tallinn University of Technology, Department of Marine Systems, Tallinn, Estonia. (didenkulova@mail.ru), [2]Nizhny Novgorod State Technical University n.a. R.E.Alekseev, Nizhny Novgorod, Russia. [3]Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, LAMA, Chamberi, France.

Experimental setup

- Experiments have been conducted in the hydrodynamic flume of the Nizhny Novgorod State Technical University n.a. R.E. Alekseev. Both composite beach profiles were constructed in 2019.
- The Coastal Slope 1 consists of three parts made of aluminum. The plane beach part of the Coastal Slope 2 is also made of aluminum, and the convex profile consists of two parts made of curved PLEXIGLAS organic glass.

Two types of beach profiles are considered:

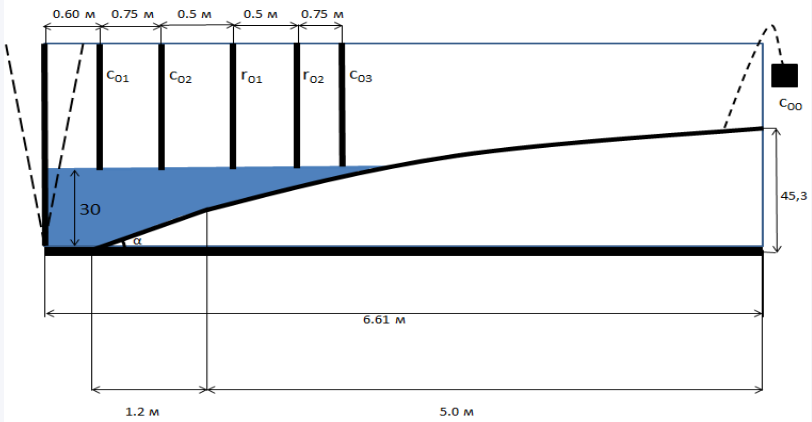
The Coastal Slope 1: consists of two merged plane beaches with lengths 1.2 m and 5 m and beach slopes tan α = 1:10 and tan β = 1:15 respectively.



Scheme of the experiment with a plane-plane beach

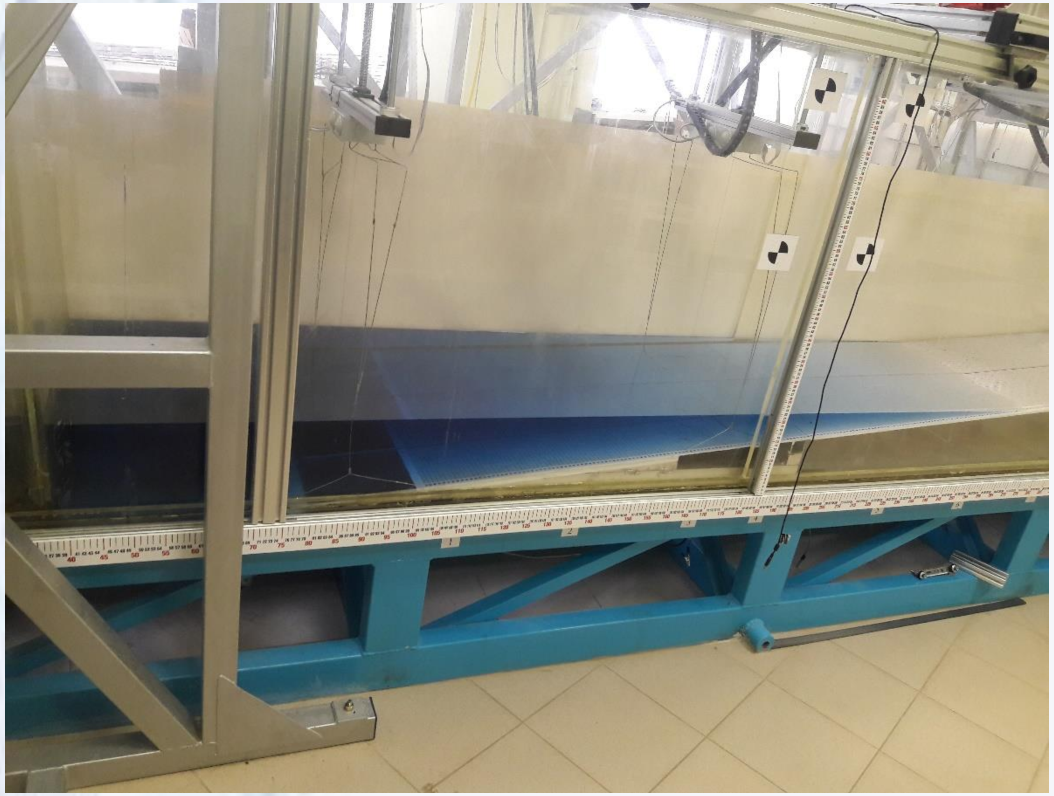
- C00, C01, C02, C03, r01, r02 are capacitive and resistive wave gauges, (meatured the free surface water , mm).
- runup (C00) is measured by a capacitive string sensor installed along the slope.
- The bottom depth was constant for each experiment and was 0.3 meters.

The Coastal Slope 2: consists of two sections: plane beach with length 1.2 m and a beach slope α, which is merged with a convex (non-reflecting) beach. The latter is constructed in the way, that its total height and length remain the same as for the Coastal Slope 1.



Scheme of the experiment with plane-convex beach

Experimental setup



Hydrodynamic flume of the Nizhny Novgorod State Technical University n.a. R.E. Alekseev

Numerical models

1D Nonlinear Shallow Water Equations (NLSW): *[Dutykh et al. 2011]*

$$\left.\begin{aligned} &H_t + (Hu)_x = 0 \\ &(Hu)_t + \left(Hu + \frac{g}{2}H^2\right)_x = gHh_x \end{aligned}\right\}$$

Nondispersive model

Modified Peregrine equations (mPer): *[Durán et al. 2018]*

$$\left.\begin{aligned} &H_t + Q_x = 0 \\ &\left(1 + \frac{1}{3}H_x^2 - \frac{1}{6}HH_{xx}\right)Q_t - \frac{1}{3}H^2 Q_{xxt} - \frac{1}{3}HH_x Q_{xt} + \left(\frac{Q^2}{H} + \frac{g}{2}H^2\right)_x = gHh_x \end{aligned}\right\}$$

Dispersive model

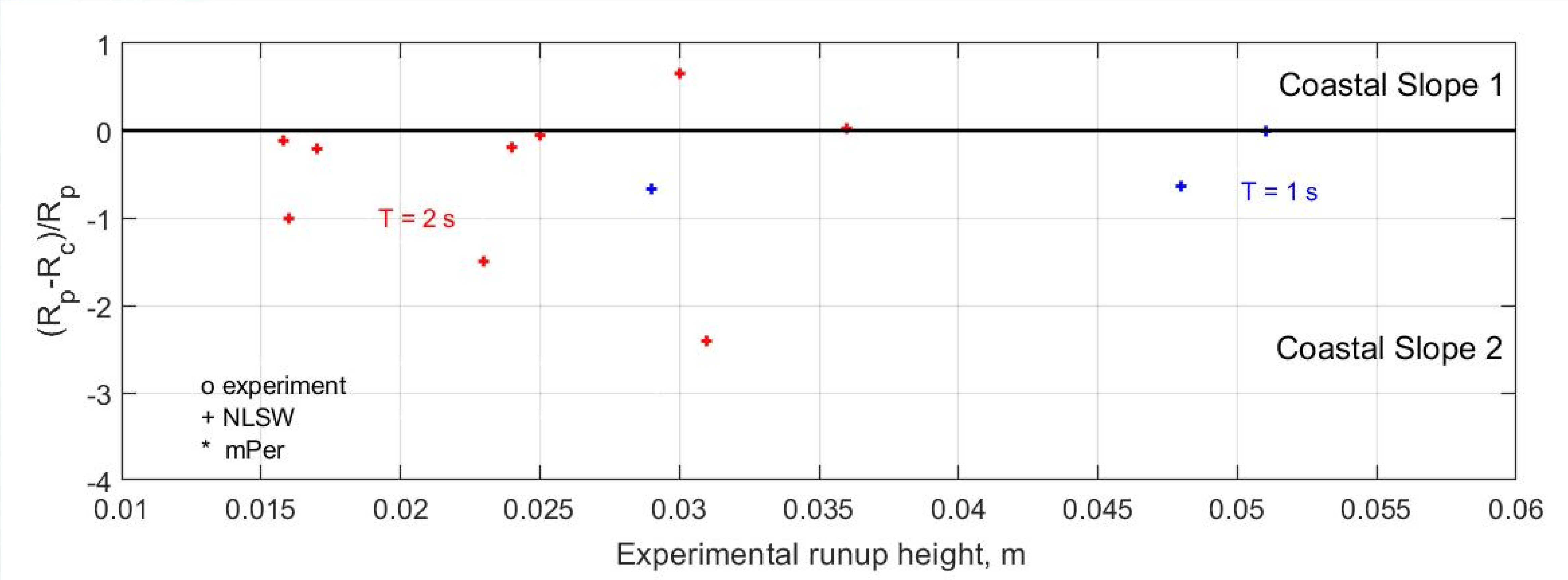
Q is the horizontal momentum

H = *h* + *η* is the total water depth

Experimental data

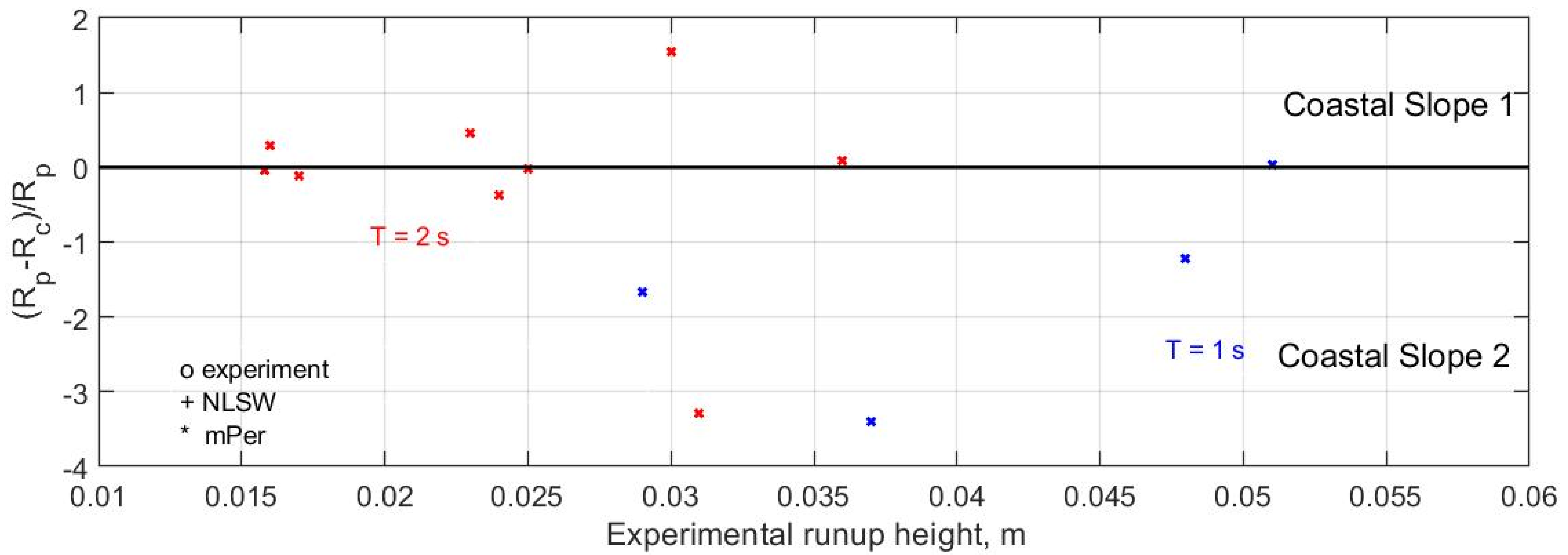
Due to COVID19 outbreak, the experiments were stopped, so we do not have sufficient data .....

Comparison of what we have: NLSW



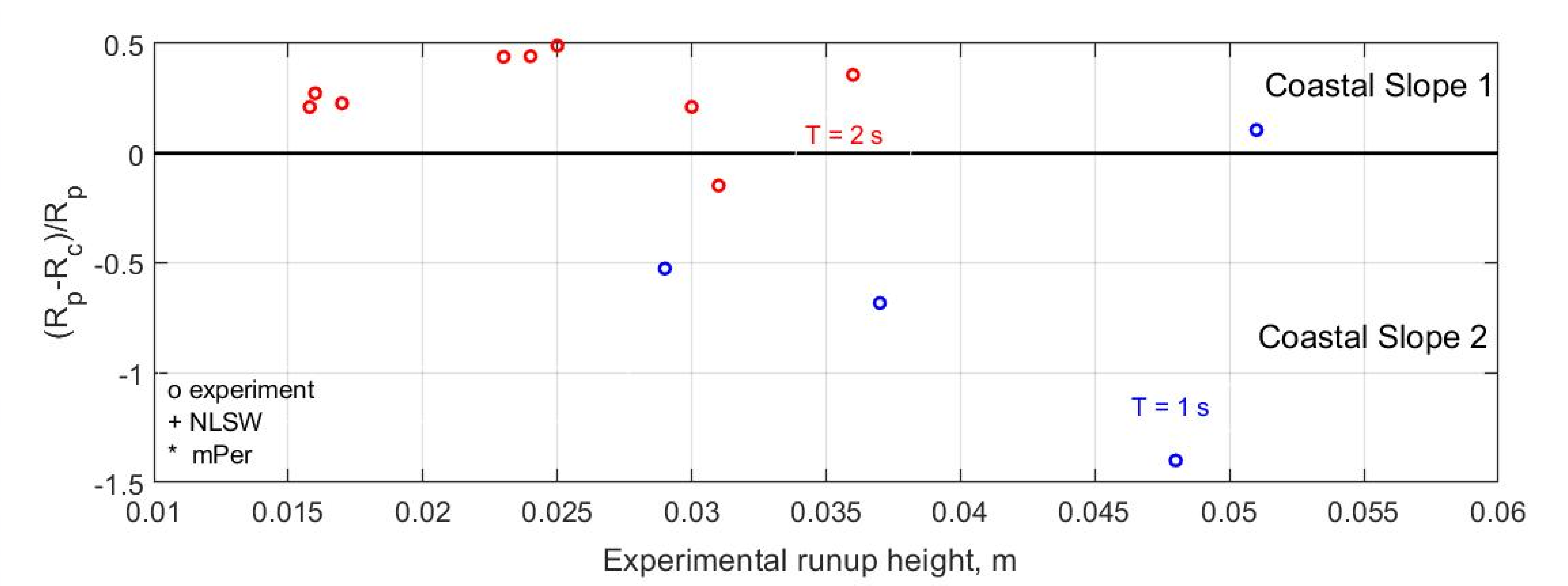
The runup height on the Coastal Slope 2 (plane-convex beach) tends to exceed the corresponding runup height on the Coastal Slope 1 (plane-plane beach), that somehow agrees with previous results for runup on plane and convex beaches *[Didenkulova et al. 2009; Didenkulova et al. 2018]*.

Comparison of what we have: mPer



Taking dispersion into account leads to an increase in the spread in values of the wave runup height. As a consequence, individual cases when the runup height on the Coastal Slope 1 is higher than on the Coastal Slope 2 have been observed

Comparison of what we have: experiment



In experimental data, such cases occur more often, so that the advantage of one slope over another is no longer obvious. Note also that the most nonlinear breaking waves with a period of 1s have a greater runup height on Coastal Slope 2 for both models and most experimental data.

Conclusion

- Shown numerically that, in the framework of the nonlinear shallow water theory, the runup height on the Coastal Slope 2 (plane-convex beach) tends to exceed the corresponding runup height on the Coastal Slope 1 (plane-plane beach), that agrees with *[Didenkulova et al. 2009; Didenkulova et al. 2018]*.
- Taking dispersion into account leads to an increase in the spread in values of the wave runup height. As a consequence, individual cases when the runup height on the Coastal Slope 1 is higher than on the Coastal Slope 2 have been observed.
- In experimental data, such cases occur more often, so that the advantage of one slope over another is no longer obvious. Note also that the most nonlinear breaking waves with a period of 1s have a greater runup height on Coastal Slope 2 for both models and most experimental data.

References

- Didenkulova I, Pelinovsky E, Soomere T (2009) Long surface wave dynamics along a convex bottom. Journal of Geophysical Research – Oceans 114: C07006.
- Dutykh D, Katsaounis T, Mitsotakis D (2011) Finite volume schemes for dispersive wave propagation and runup. Journal of Computational Physics 230(8): 3035–3061.
- Durán A, Dutykh D, Mitsotakis D (2018) Peregrine's System Revisited. In Abcha N, Pelinovsky E, Mutabazi I (eds.) Nonlinear Waves and Pattern Dynamics. p. 3–43, Springer, Cham.
- Didenkulova I, Pelinovsky E, Rodin A (2018) Long wave run-up on plane and "non-reflecting" slopes. Fluid Dynamics 53 (3): 402–408.