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The State of the Art and Science of Coastal Engineering

A new and fully automatic procedure for the identification and coupling of the overtopping events

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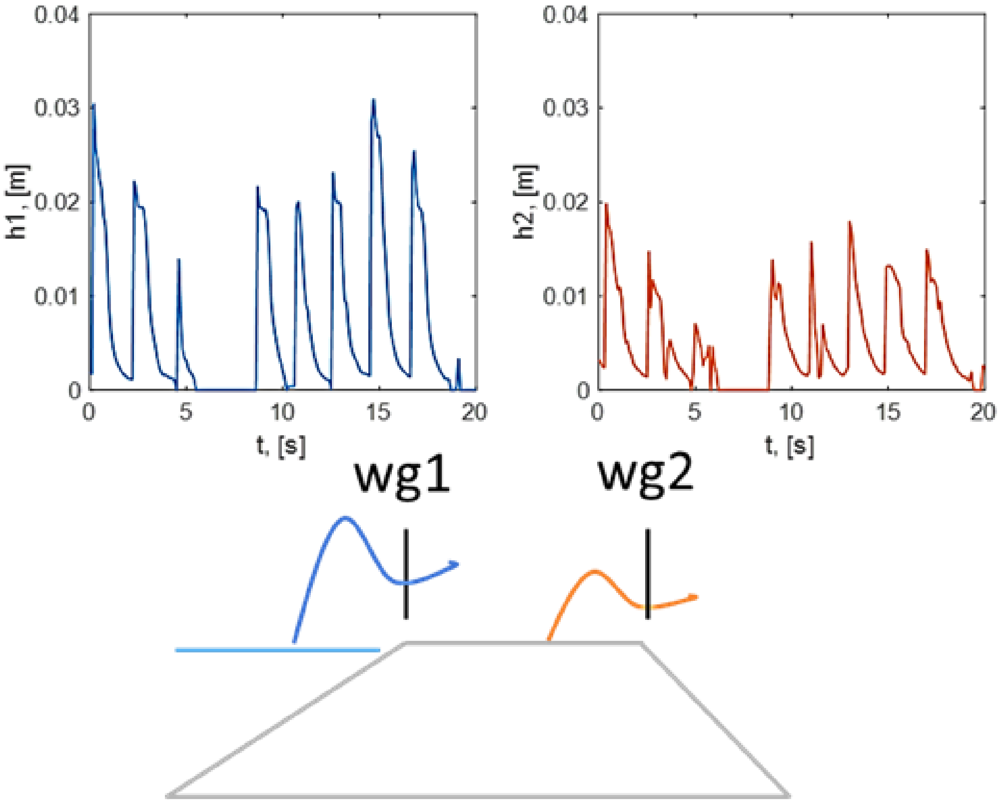
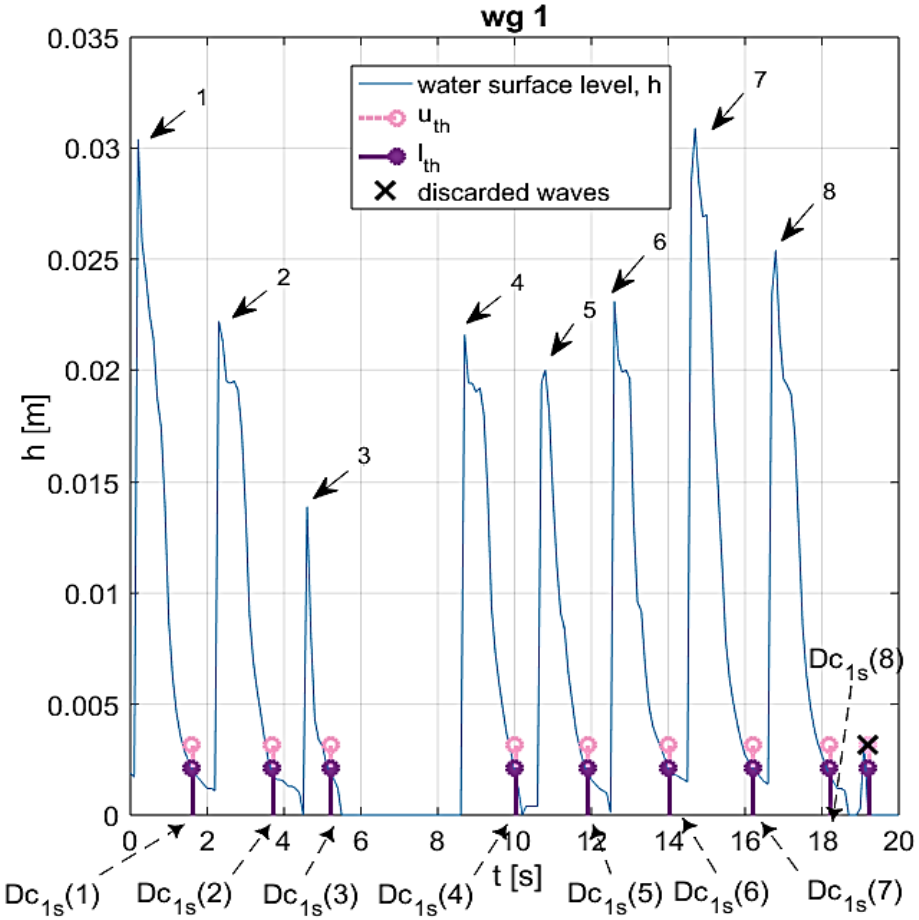
Motivations and background

- Prediction of individual wave overtopping volumes
- Determination of the overtopping flow characteristics across the structure crest
- Assessment of the maximum loads
- Average overtopping discharge

Motivations and background

- Unaffordable inaccuracy of the existing automatic procedures (Hughes & Thornton, 2016)
- No procedure for the coupling of the overtopping events at consecutive gauges exists so far

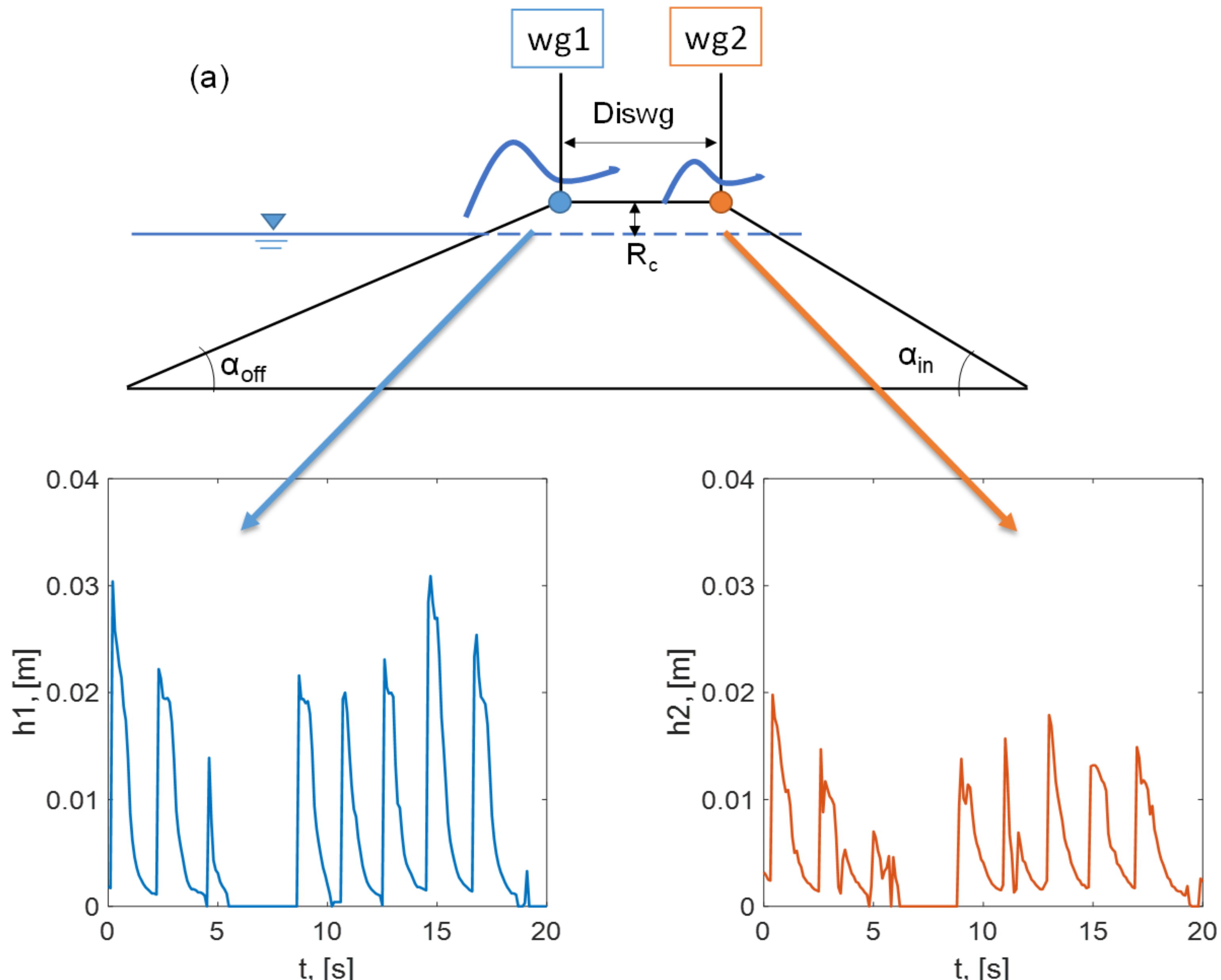




Outline

- Presentation and description of the new procedure
  - First algorithm: the wave identification
  - Second algorithm: the wave coupling
- Benefits and limits of the procedure
  - Rare and frequent overtopping
  - Permeable structures and percolation
- Verification of the procedure
- Applications of the procedure
  - Determination of the extreme wave overtopping volumes
  - Wave celerities
- Conclusions

Scheme and parameters



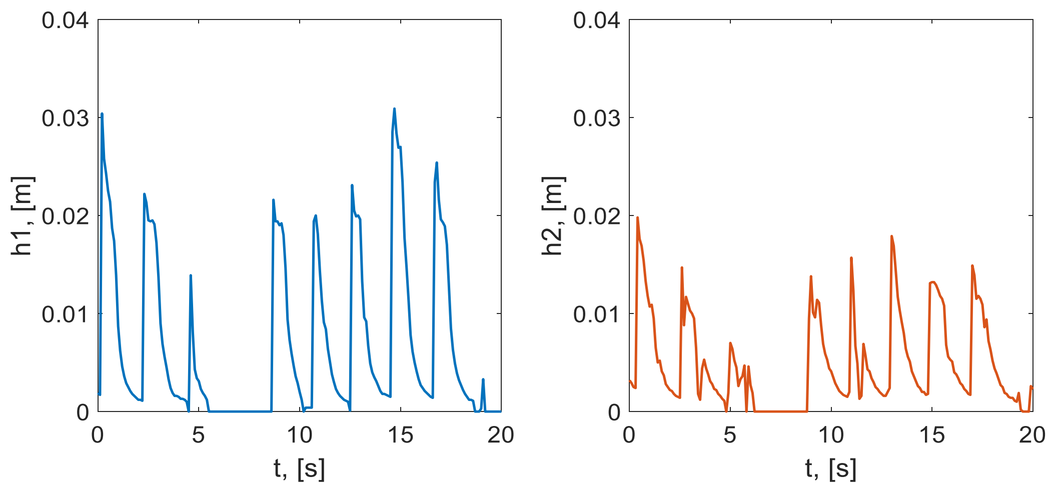
1° step of the procedure: wave identification

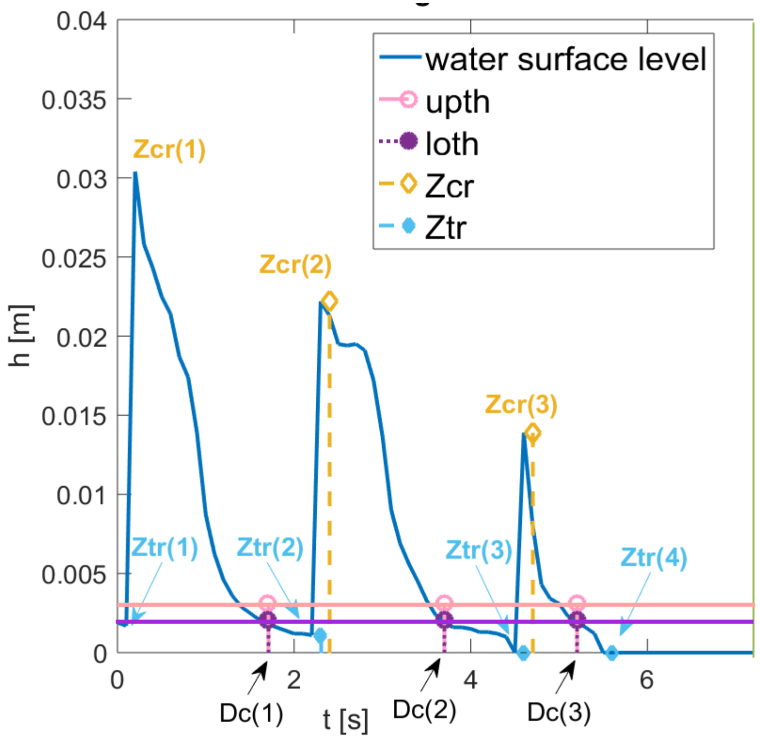
Input 1° step:
h_1, h_2 [m]

Definition of the
2 thresholds based on:
H_s, R_c and diswg

Output 1° step

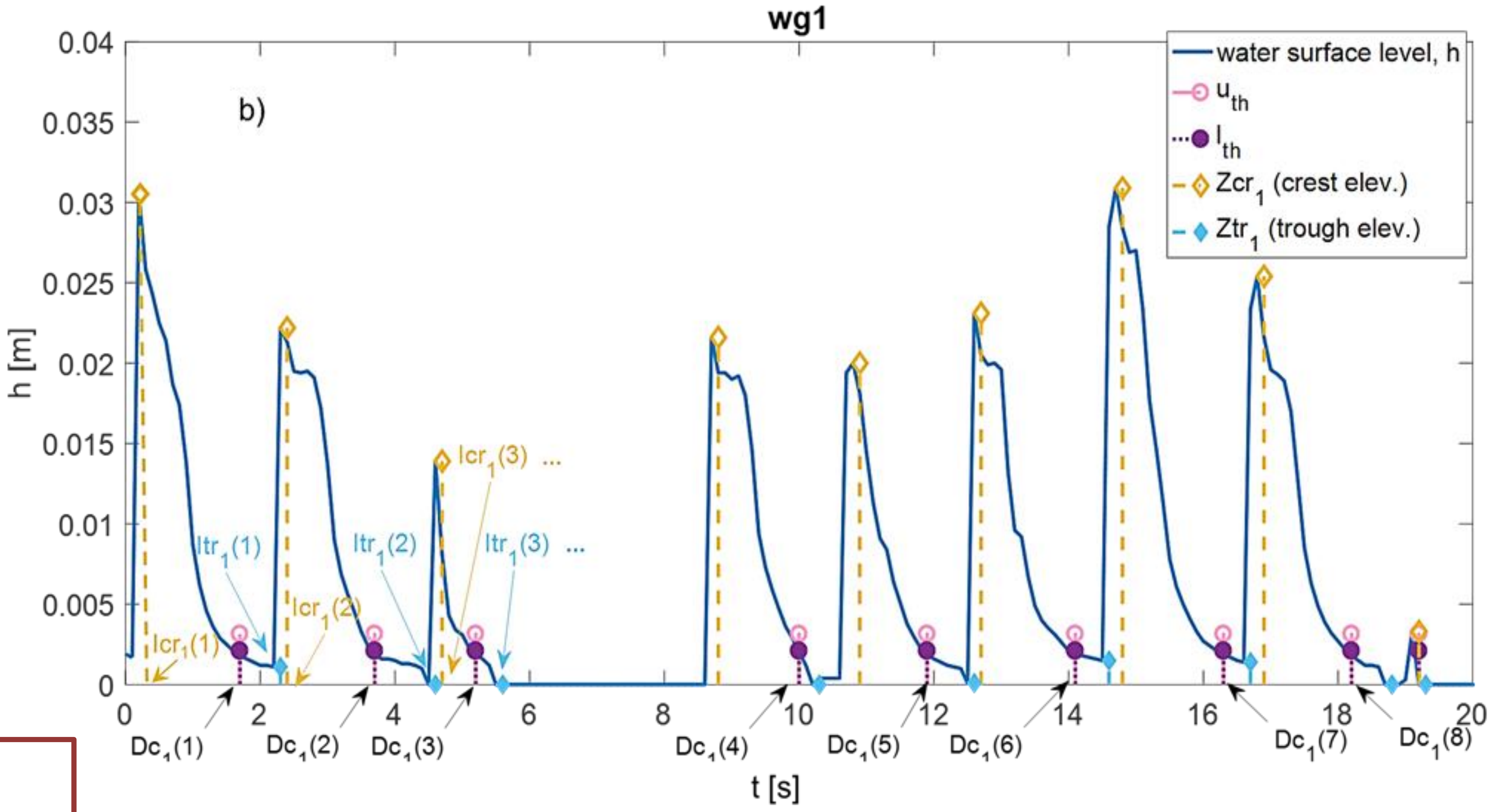
- Dc_1, Icr_1, Itr_1 [s] and Zcr_1, Ztr_1 [m]
- Dc_2, Icr_2, Itr_2 [s] and Zcr_2, Ztr_2 [m]





Wave identification: the outputs

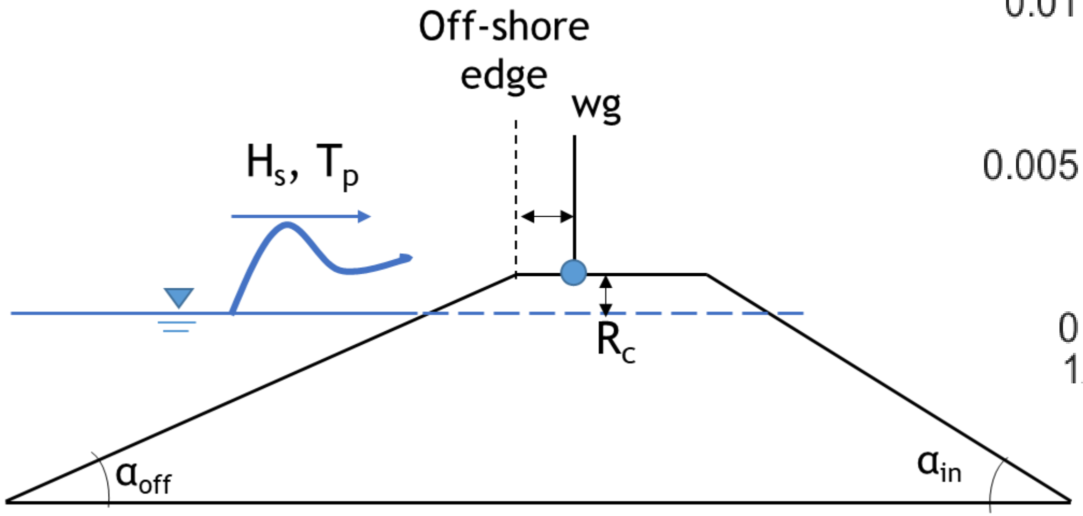
- The outputs of the 1st step are the time ordered sequences of:
  - the instants of zero-down-crossing (Dc [s])
  - the instants of occurrence of the wave crests and troughs (Icr, Itr [s])
  - the wave crest and trough heights (Zcr, Ztr [m])

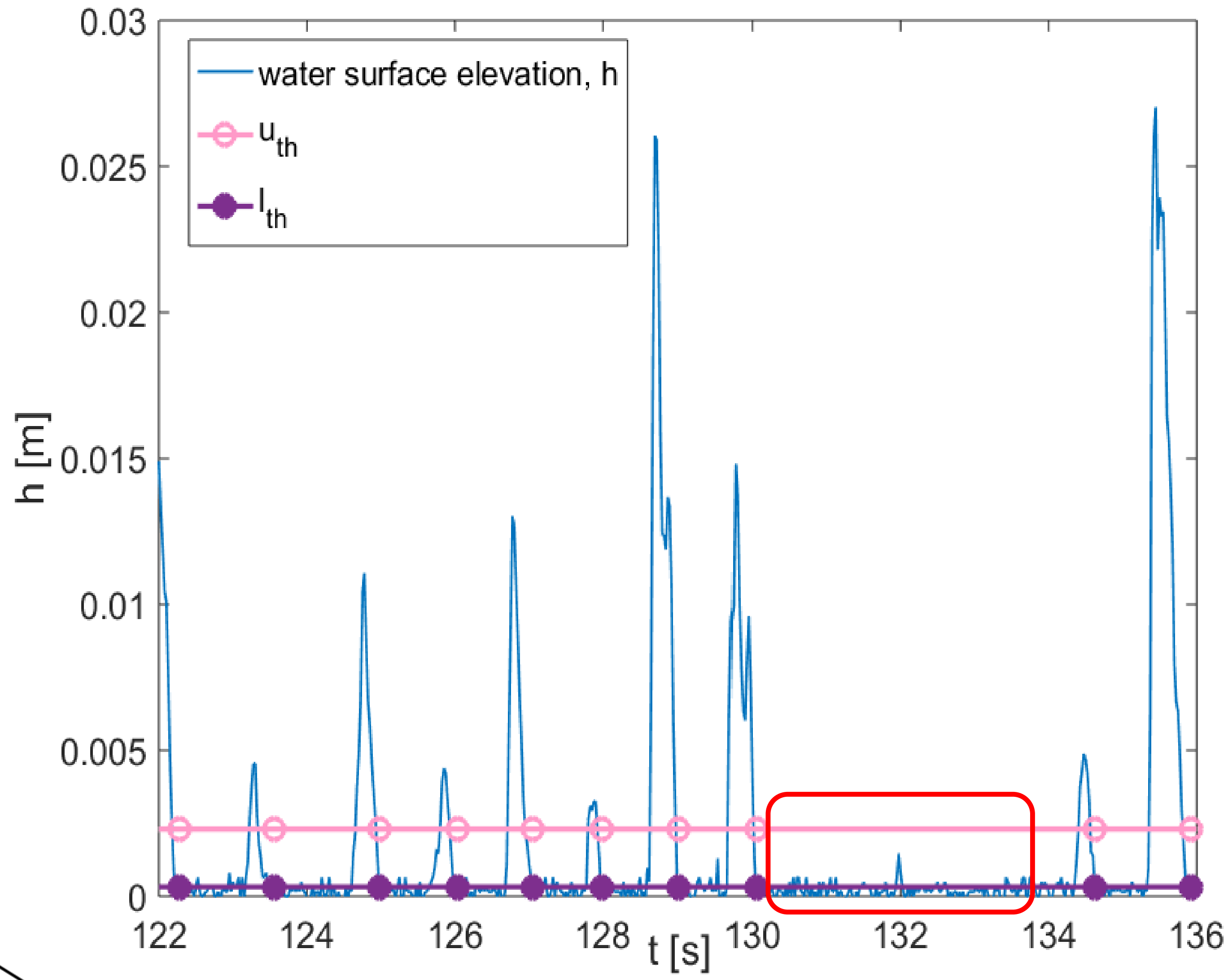


$$H(i)=Zcr(i)-Ztr(i)$$
$$T(i) = Dc(i)-Dc(i-1)$$

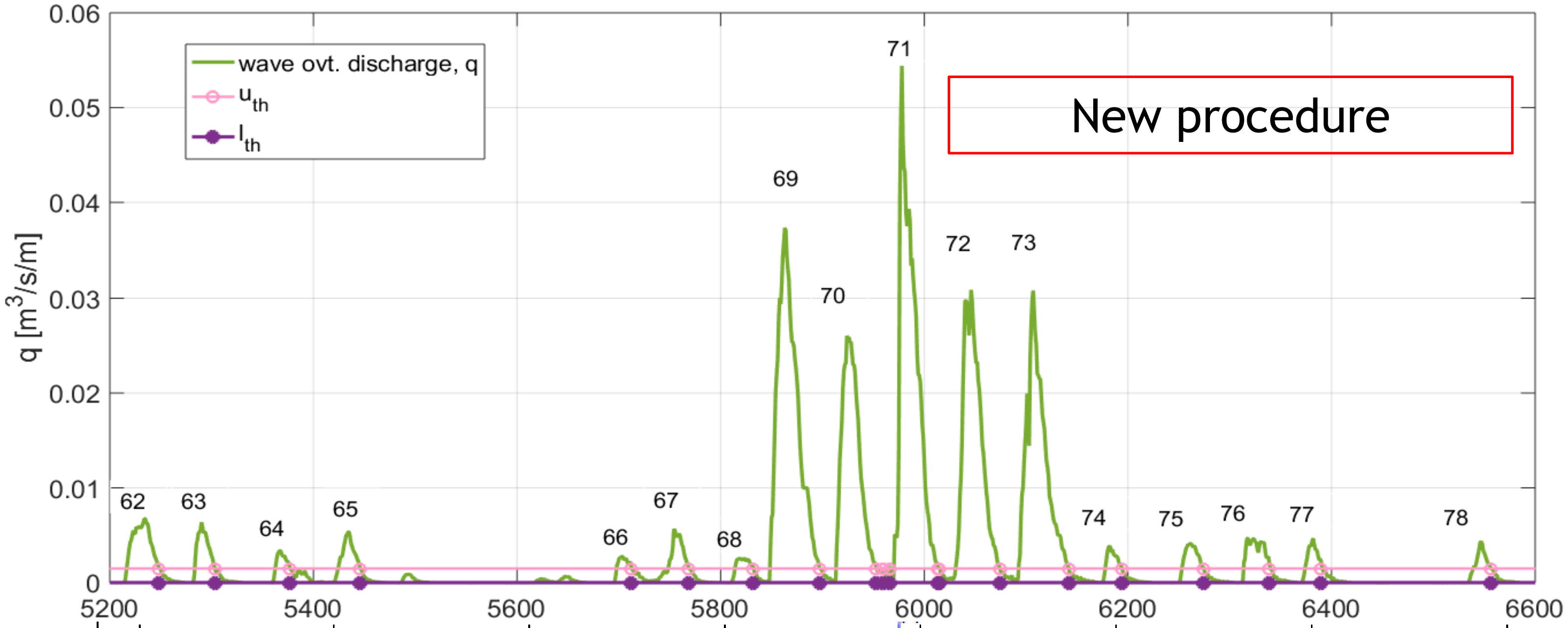
Wave identification: definition of the thresholds

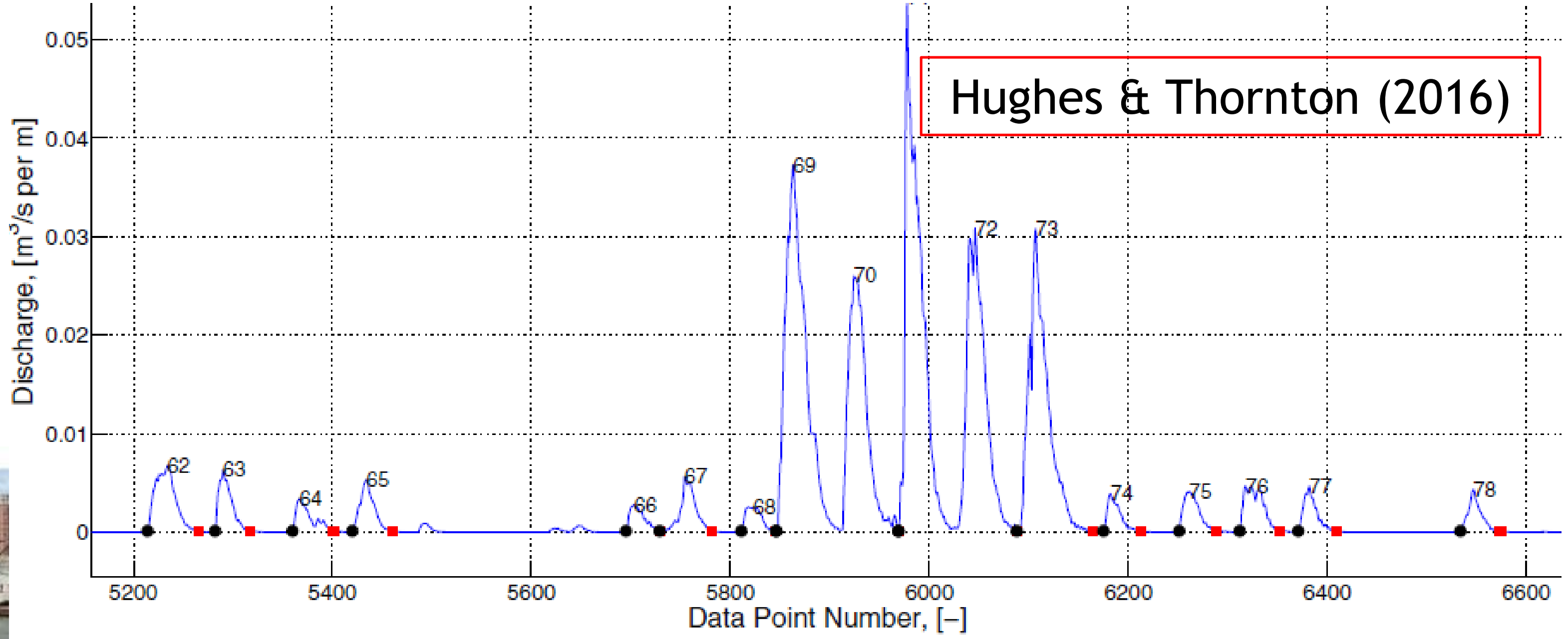
- The thresholds vary with:
  - The structure freeboard (R_c)
  - The wave characteristics (H_s and T_p)
  - The distance of the wg from the dike off-shore edge





Verification of the identification step





Verification of the identification step

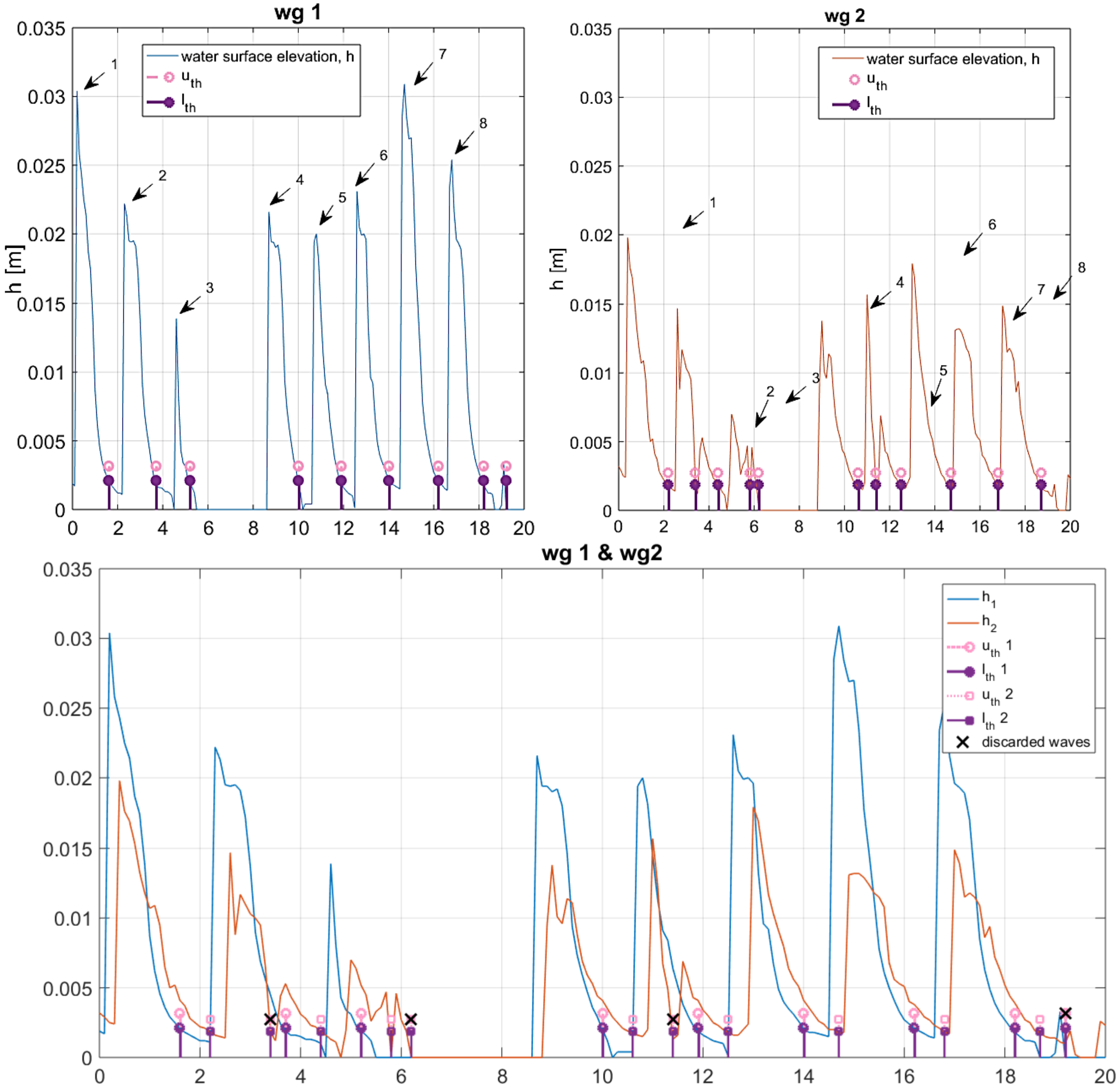
Tests parameters				Hughes & Thornton procedure					New procedure		
Test ID	H_{m0} [m]	$T_{m-1,0}$ [s]	Nw [-]	Auto. V	Man. V	Total V_{HT}	Auto/Total V_{HT}	P_{ovt}	Auto. V	Auto/Total V_{HT}	P_{ovt}
0198	0.103	1.619	1180	486	177	663	73%	56%	636	96%	54%
0199	0.094	1.164	1102	211	235	446	47%	40%	356	80%	31%
0200	0.15	1.96	1276	453	361	814	56%	64%	839	103%	66%
0201	0.148	1.379	1150	254	493	747	34%	65%	680	91%	59%
0451	0.09	1.555	1097	535	46	581	92%	53%	621	107%	57%
0453	0.122	1.663	1120	726	142	868	84%	78%	931	107%	83%
0456	0.157	1.936	1093	617	275	892	69%	82%	904	101%	83%
0457	0.141	1.373	1116	521	267	788	66%	71%	794	101%	71%

2° step of the procedure: wave coupling

Input 2° step:
Dc_1 [s] and Zcr_1 [m]
Dc_2 [s] and Zcr_2 [m]

Definition of the maximum and minimum time lags based on:
H_s, T_p, R_c, diswg, sf

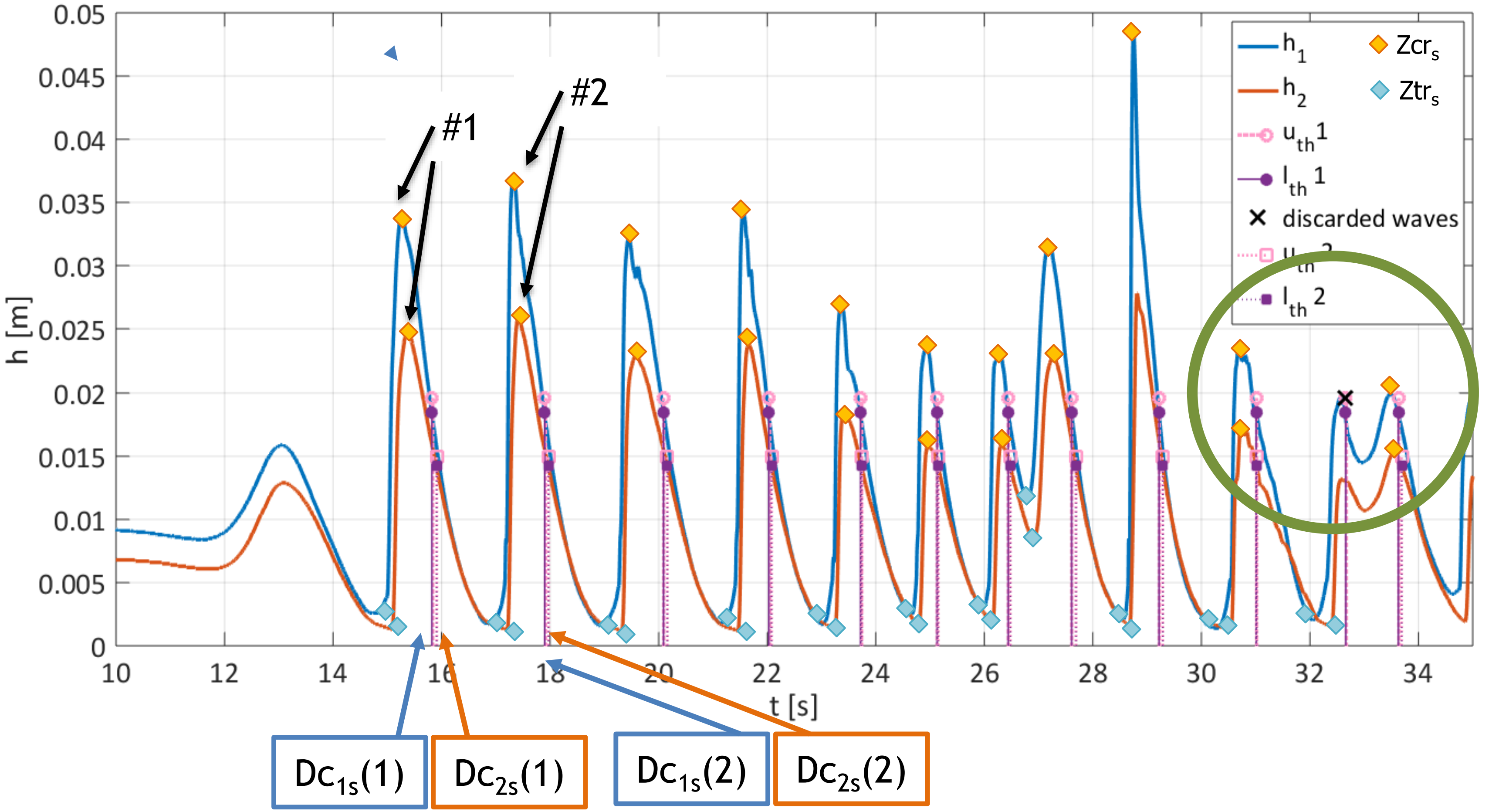
Output 2° step
Dc_{1s}, Dc_{2s} [s]
Zcr_{2s}, Zcr_{2s} [m]
c [m/s]



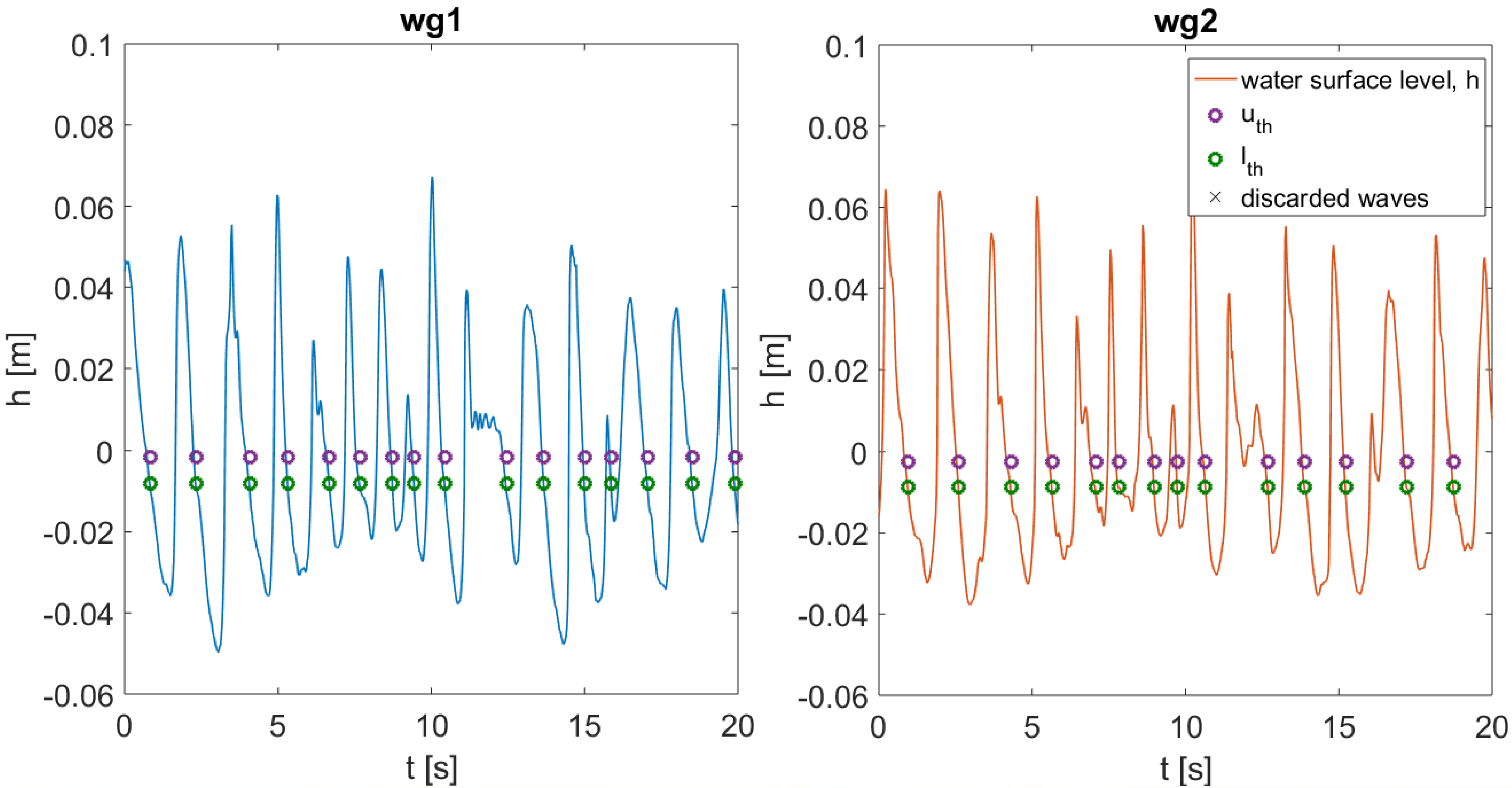
Wave coupling: the outputs

- The outputs of the 2nd step are the time ordered sequences of:
  - the instants of zero-down-crossing (Dc_{1s}, Dc_{2s} [s])
  - the instants of the wave crests and troughs (Icr_{1s}, Itr_{1s}, Icr_{2s}, Itr_{2s} [s])
  - the wave crest and trough heights (Zcr_{1s}, Ztr_{1s}, Zcr_{2s}, Ztr_{2s} [m])

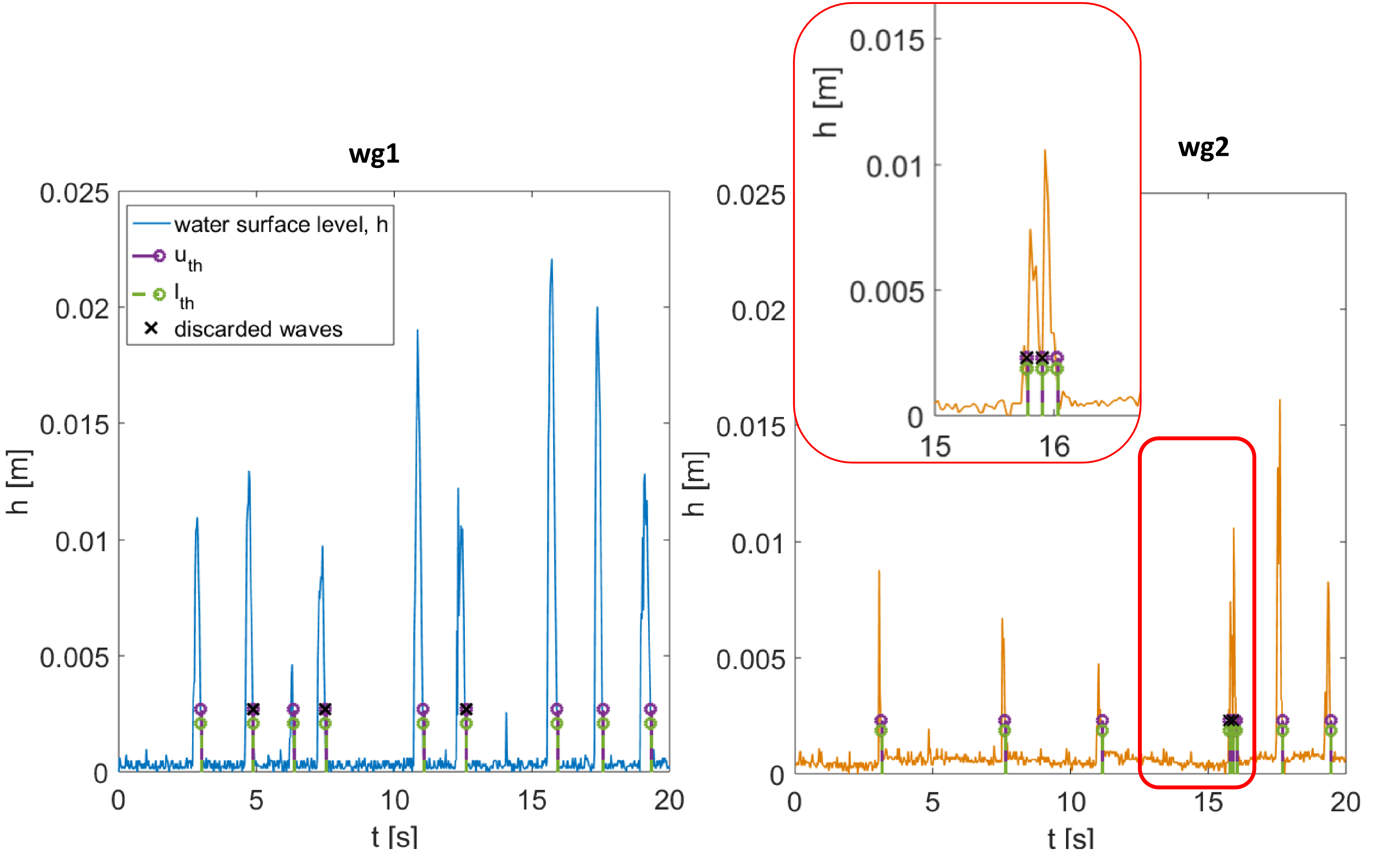
  of the coupled events at wg1 and wg2



Frequent overtopping



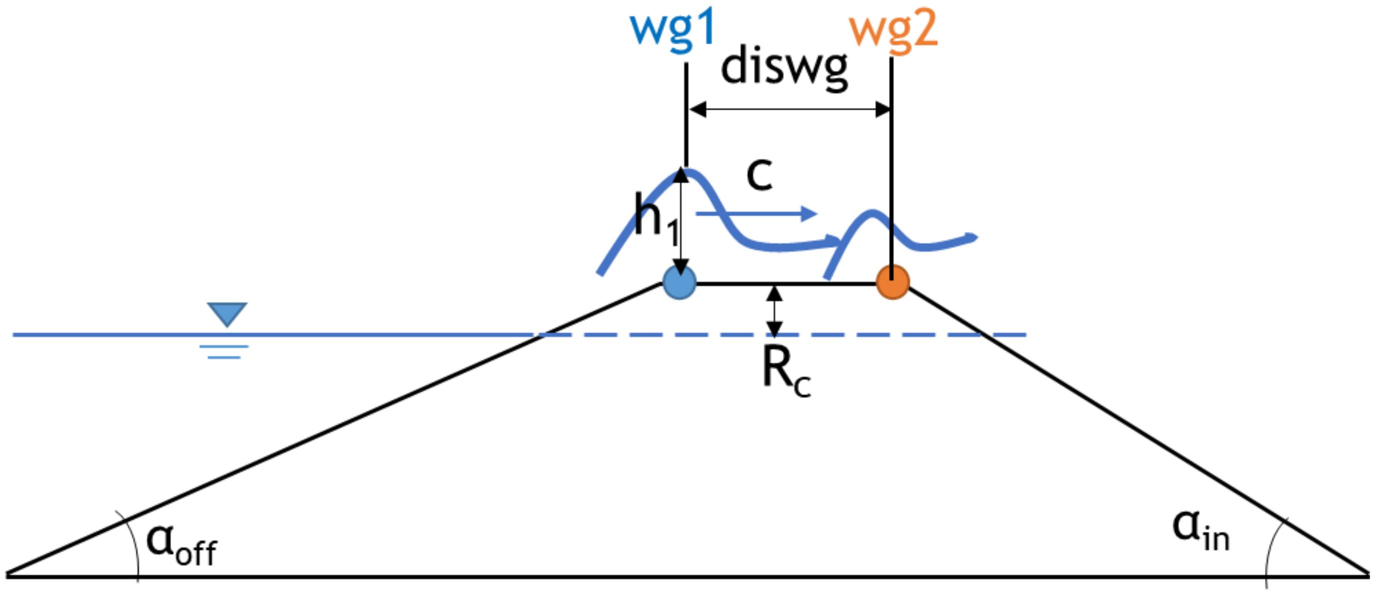
Rare overtopping and percolation



Wave coupling: definition of the time lags

- The max and min time lags vary with:
    - the distance between wg1 and wg2 (diswg, [m])
    - the celerity of the single waves (c, [m/s]); theoretically:
      c_{max} in deep water → dt_{min}
      c_{min} in shallow water → dt_{max}
    - the sample frequency of the signals (sf, [Hz])

$$
\begin{cases}
dt_{min} = \max\left(\dfrac{diswg}{c_{dw}}; \dfrac{1}{sf}\right), & \text{with } c_{dw} = \dfrac{L_p}{T_p} \\
dt_{max} = \dfrac{diswg}{c_{sw}}, & \text{with } c_{sw} = \min\left(\sqrt{gh_1}\right)
\end{cases}
$$



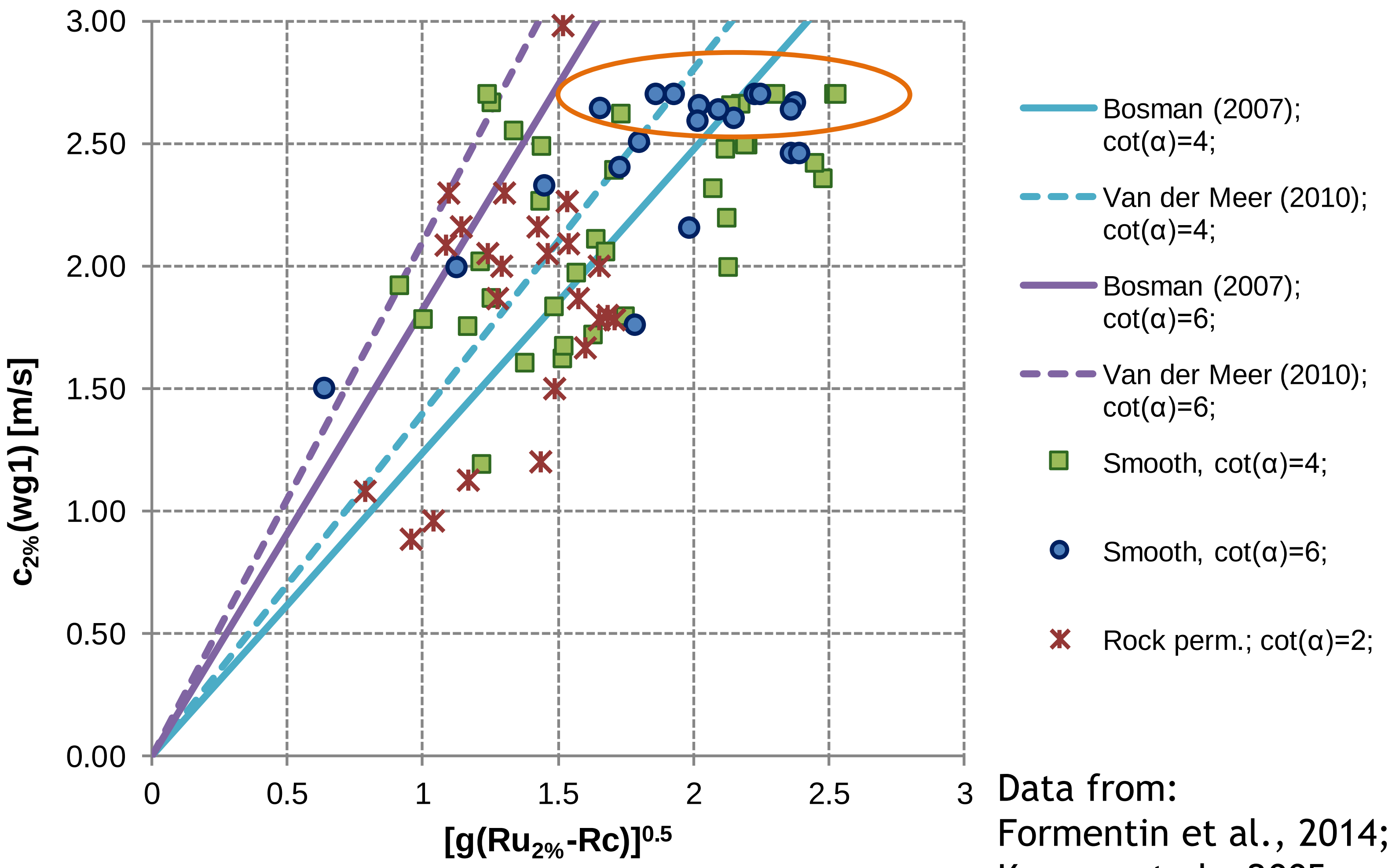
Verification of the coupling step

- Determination of the wave celerities:

$$c(i) = \frac{diswg}{Dc2s(i) - Dc1s(i)}$$

- Comparison of the estimated $c_{2\%}$-values with:
    - Bosman et al. (2007);
    - Van der Meer et al. (2010)

$$u_{2\%}(x_c) = c_u \cdot [(R_{u,2\%} - R_C)]^{0.5}, \quad R_C \geq 0$$

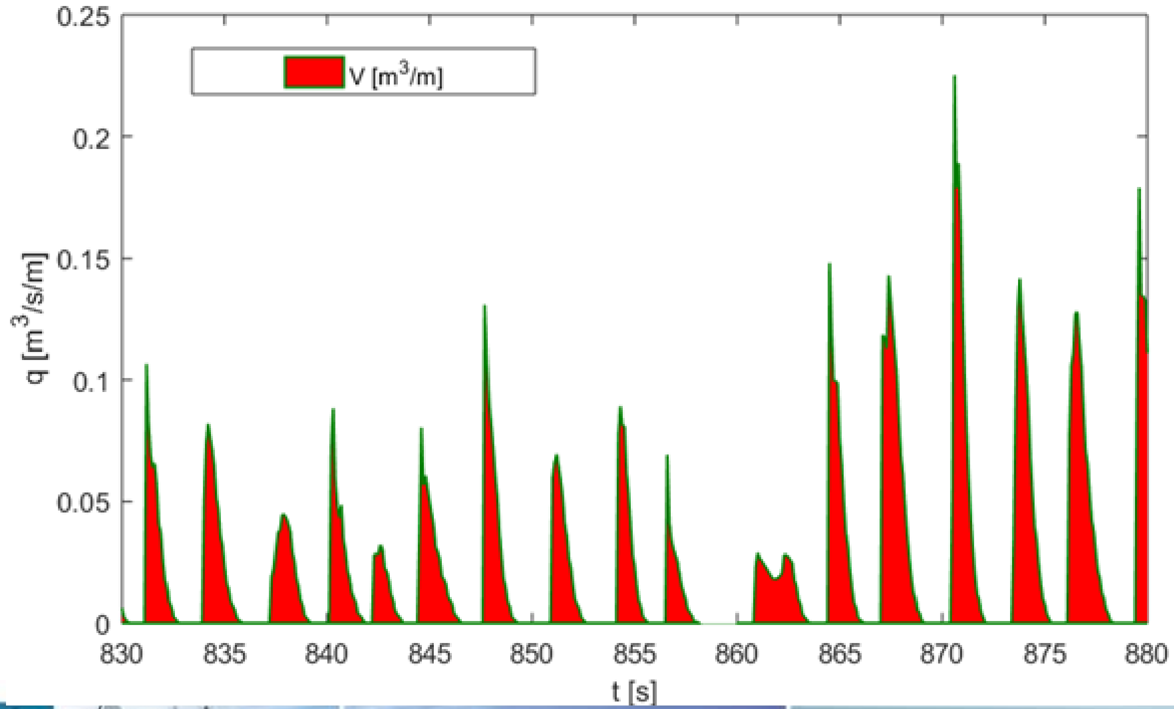


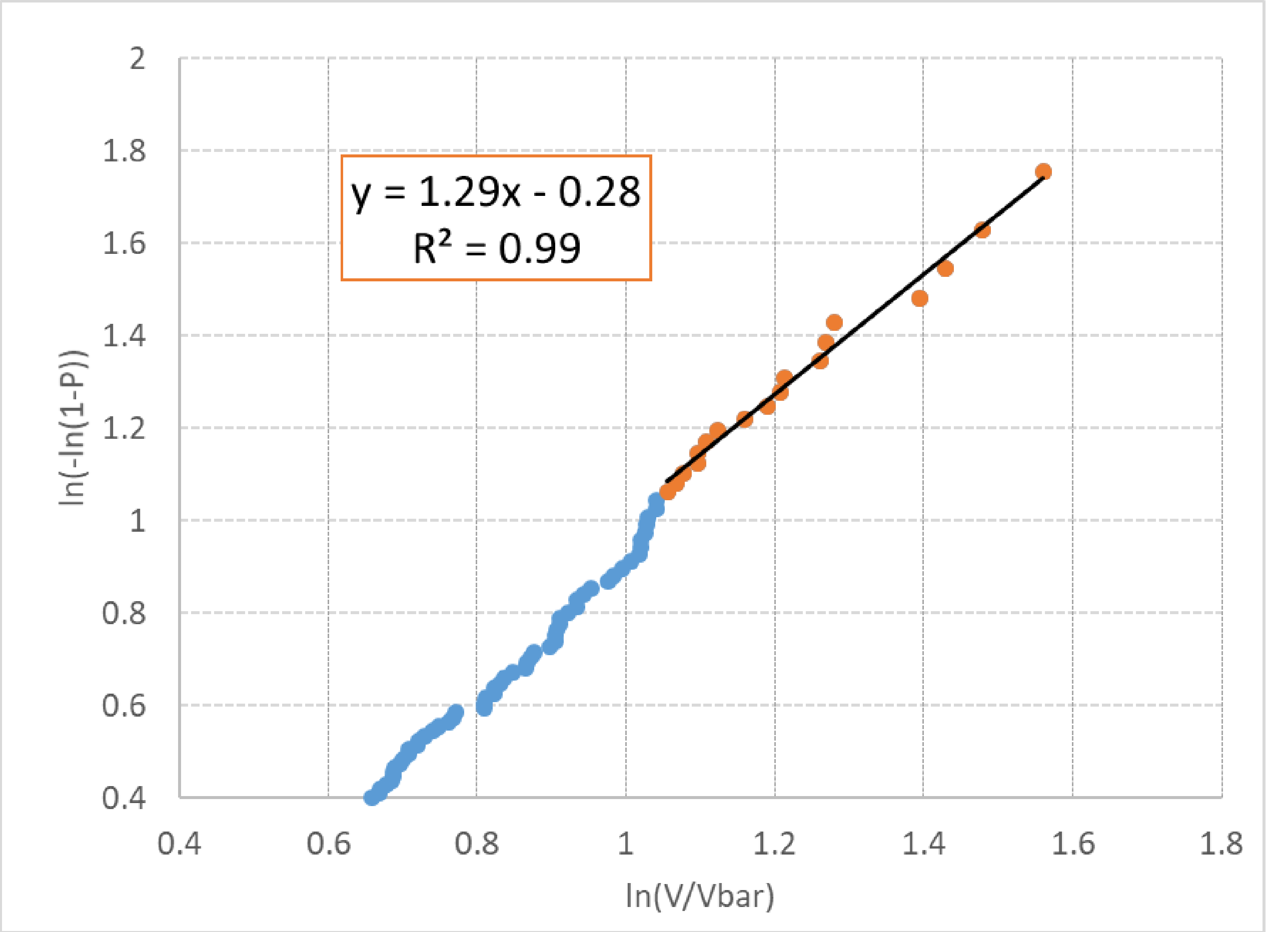
Data from:
Formentin et al., 2014;
Kramer et al., 2005.

Applications: extreme overtopping volumes

- Determination of the Weibull's shape parameter b:

$$P(V_i \geq \overline{V}) = \exp\left(-\left(\frac{V}{a}\right)^{b}\right)$$





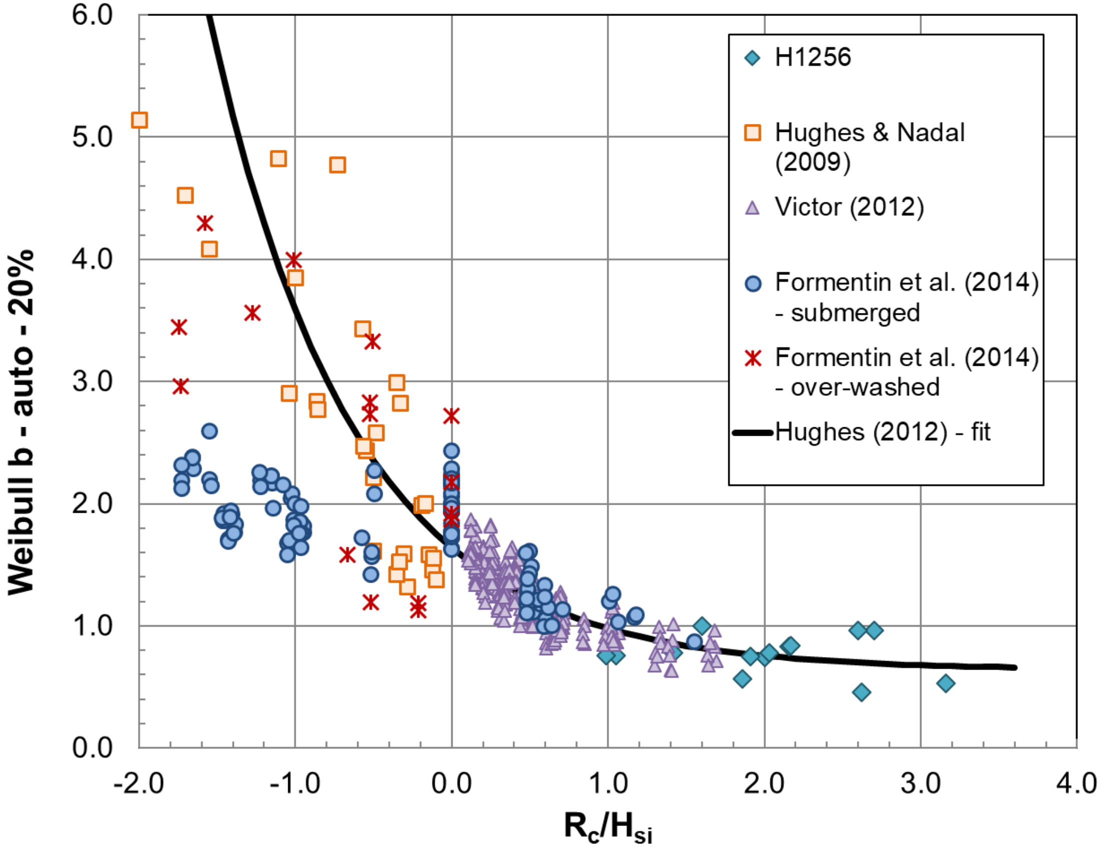
Applications: extreme overtopping volumes

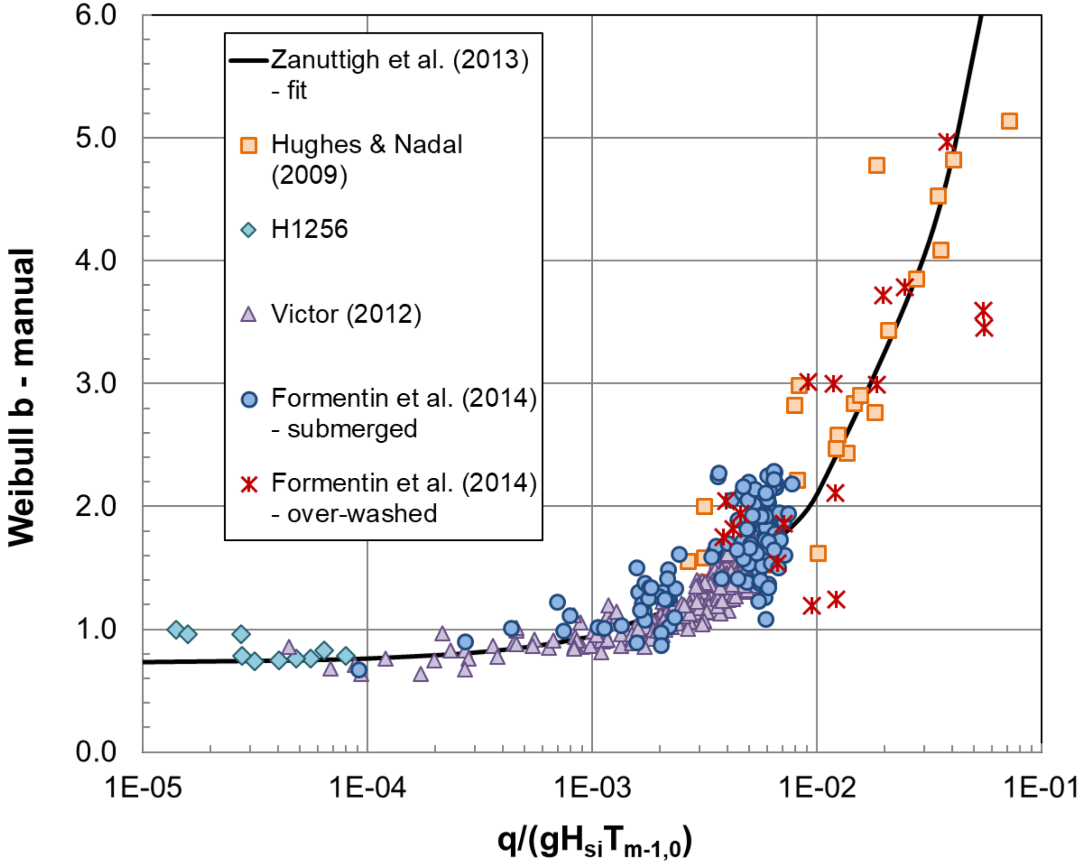
Hughes et al. (2012)

$$b=\left(\exp\left(-0.6\frac{R_C}{H_S}\right)\right)^{1.8}+0.64$$

Zanuttigh et al. (2013)

$$b=0.73+55\cdot\left(\frac{q}{gH_S T_{m-1,0}}\right)$$





Conclusions

- A new procedure has been developed for the identification and the coupling of the individual wave overtopping events
- The procedure is fully automatic and its accuracy is comparable to the accuracy of a manual analysis of the signals
- The procedure can process any kind of oscillatoriy signal in the time domain and can be applied to any structure type and structure emergence
- The wave identification algorithm can be applied to the processing of the discharge signals to reconstruct the distribution of the overtopping volumes
- The coupling algorithm allows the estimation of the wave celerities and the study of the evolution of the wave characteristics over the structure crest
- The main limit of the procedure is represented by the sample frequency of the input signals, i.e. a constraint independent of the procedure itself

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Thank you for your attention!

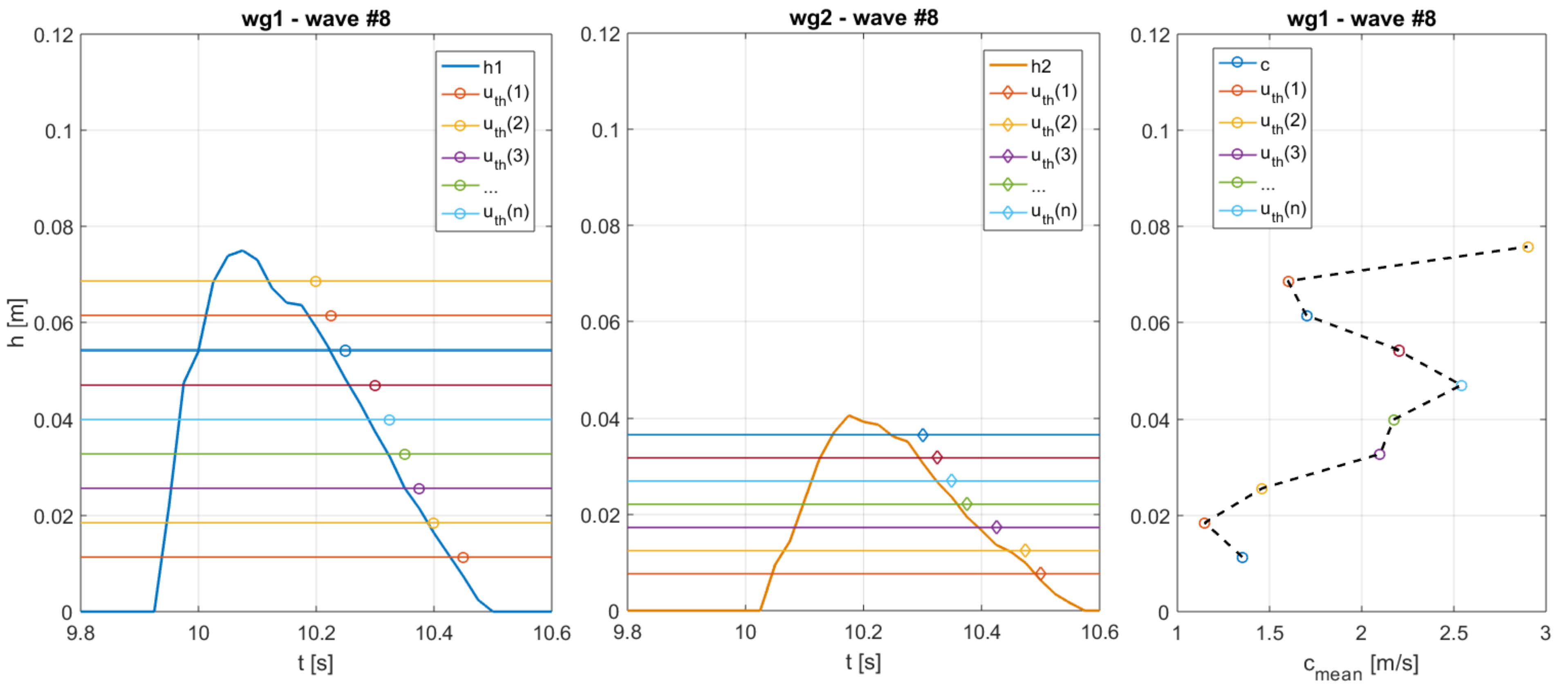



Wave coupling: the wave celerities

- For each i-th wave propagating from wg1 to wg2:

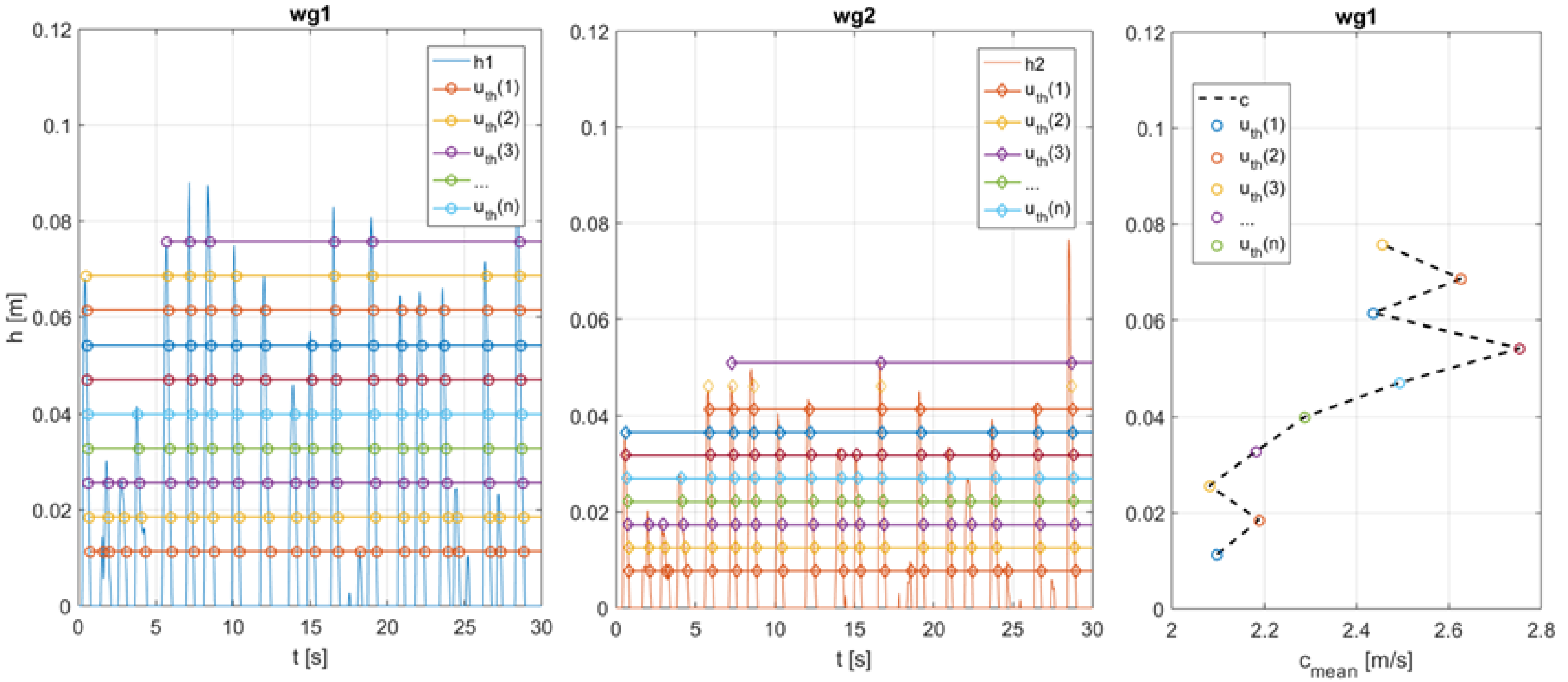
$$c(i) = \frac{diswg}{Dc2s(i) - Dc1s(i)}$$

- *c* can be computed at different elevations, reconstructing the instantaneous vertical profile of c



Wave coupling: the wave celerities

- Extraction of the statistics of the distribution of the c-values (mean, median, extreme quantiles, etc.)
- Reconstruction of the vertical profile of mean c



Applications: extreme overtopping volumes

		Hughes & Nadal (2009)	Experimental
$H_s/L_{m-1,0}$	0.02; 0.03; 0.04	0.02; 0.03; 0.04	0.03; 0.04
H_s [m]	2	2	0.8; 1.0; 1.2
h [m]	7.5; 8.5	7.5; 8.5	[5.2; 7]
R_c [m]	0; 0.5	0; 0.5	0; 0.5
R_c/H_s	-1.5; 1.5	-1.5; 1.5	[0.67; 1.8]
$\cot(\alpha_{off})$	2; 3; 4	2; 3; 4	2; 4
G_c [m]	3; 6; 9	3; 6; 9	3; 6
#	91	91	113