FACULTY OF ENGINEERING
AND ARCHITECTURE

Average and Wave-By-Wave Overtopping Performance of Steep Low-Crested Structures

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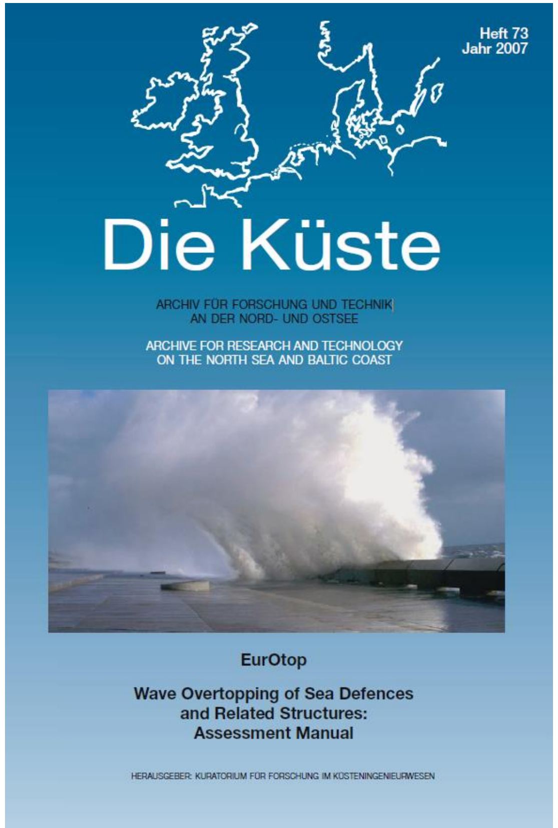
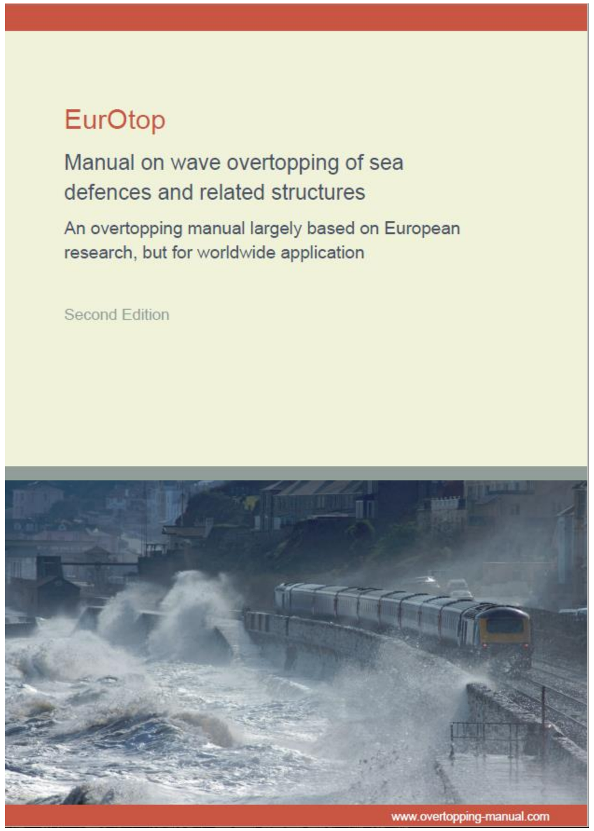
Source: ITV News

EurOtop (2007)

EurOtop 2 (2016)



Major update



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Overview

Literature review

Experimental setup and test programme

Average wave overtopping

Individual wave overtopping

Conclusions

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Average overtopping prediction in the EurOtop manual

EurOtop (2007)

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.2 \exp\left(-2.6 \frac{R_c}{H_{m0}}\right)$$

Not depending on slope angle

Slope	$1 \leq \cot\alpha \leq 4$
Relative freeboard	$0.5 \leq R_c/H_{m0} \leq 3.5$

Not applicable for steep low-crested structures

EurOtop (2016)
from Van der Meer and Bruce (2014)

$$\frac{q}{\sqrt{gH_{m0}^3}} = a \cdot \exp\left(-\left(b \frac{R_c}{H_{m0}}\right)^{1.3}\right)$$

New!

Depending on slope angle

$a = 0.09 - 0.01(2 - \cot\alpha)^{2.1}$ and $a = 0.09$ for $\cot\alpha > 2$

$b = 1.5 + 0.42(2 - \cot\alpha)^{1.5}$ with a maximum of $b = 2.35$

and $b = 1.5$ for $\cot\alpha > 2$

Slope	$\cot\alpha \geq 0$
Relative freeboard	$R_c/H_{m0} \geq 0$

Applicable for steep low-crested structures

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Victor and Troch formula is also applicable for steep low-crested structures

$$\frac{q}{\sqrt{gH_{m0}^3}} = a \cdot \exp\left(-b\,\frac{R_c}{H_{m0}}\right)$$

Relative crest freeboard R_c/H_{m0}

cot α			$0 \leq R_c/H_{m0} \leq 0.8$		$0.8 \leq R_c/H_{m0} \leq 2$
cot α	$0 \leq \cot\alpha \leq 1.5$	Z1	$a = 0.033\cot\alpha + 0.062$	Z2	$a = 0.2$
			$b = 3.45 - 1.08\cot\alpha$		$b = 4.88 - 1.08\cot\alpha$
	$1.5 \leq \cot\alpha \leq 2.75$	Z3	$a = 0.11$	Z4	$a = 0.2$
			$b = 1.85$		$b = 2.6$

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Individual overtopping volumes follow a Weibull distribution

Two-parameter Weibull distribution

$$P_V = \exp\left(-\left(\frac{V}{A}\right)^{B}\right)$$

- P_V: Exceedance probability of volume V
- A: Scale factor A
- B: Shape factor B

B = 2 — Rayleigh distribution

Empirical

$$P_{ow} = \frac{N_{ow}}{N_w}$$

- P_{ow}: Probability of overtopping
- N_{ow}: Number of overtopping waves
- N_w: Number of incident waves

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The existing prediction formulae for individual overtopping are limited

Shape factor B

EurOtop (2007) — $B = 0.75$

Victor et al. (2012) — $B = \exp\left(-2\frac{R_c}{H_{m0}}\right) + 0.15\cot\alpha + 0.56$

Hughes et al. (2012) — $B = \left[\exp\left(-2\frac{R_c}{H_{m0}}\right)\right]^{1.8} + 0.64$

Relative crest freeboard

Slope angle

Probability of overtopping P_{ow}

Van der Meer & Janssen (1994) — $P_{ow} = \exp\left[-\left(0.65\frac{R_c}{H_{m0}}\right)^2\right]$

Victor et al. (2012) — $P_{ow} = \exp\left[-\left((1.4 - 0.3\cot\alpha)\frac{R_c}{H_{m0}}\right)^2\right]$

Slope angle

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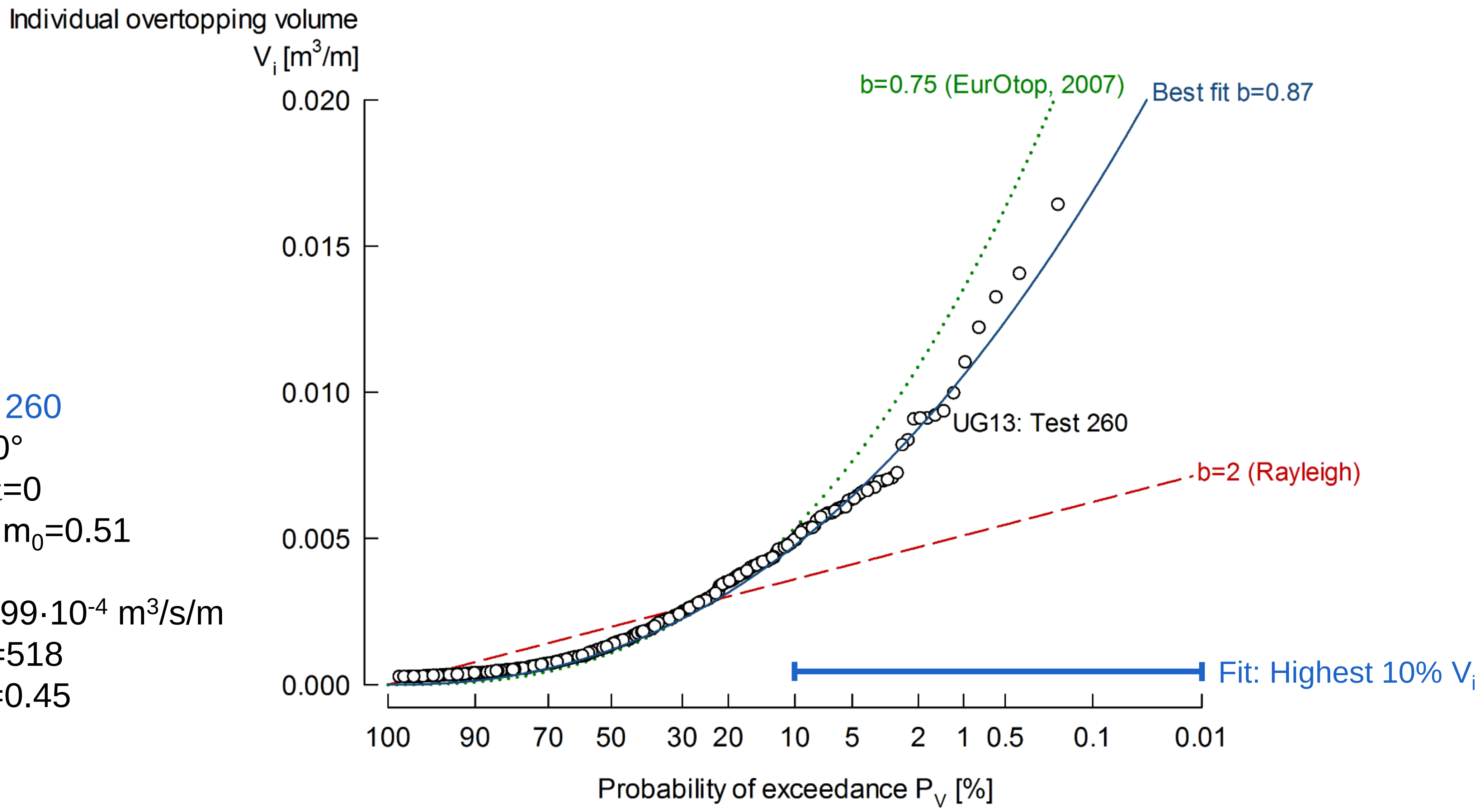
The best Weibull fit
is calculated for every test



Test 260

α=90°

cot α=0

R_c/Hm_0=0.51

$q=7.99 \cdot 10^{-4}$ m³/s/m

N_{ow}=518

P_{ow}=0.45

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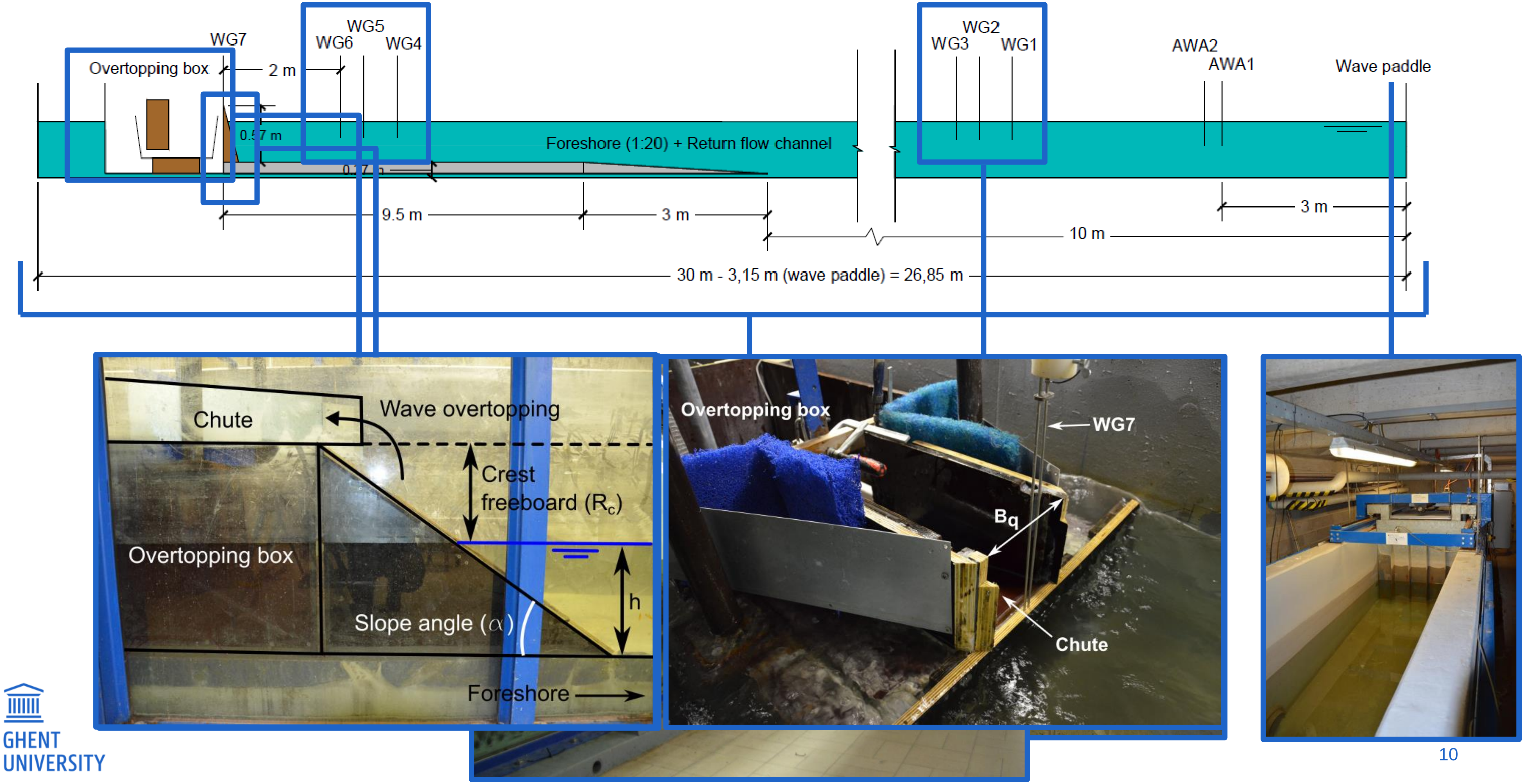
Experimental setup



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More than 900 tests were performed on smooth slopes

	UG10	UG13	UG14	UG15
Slope angle α [°]	20, 25, 30, 35, 40, 45, 50, 60, 70	25, 35, 45, 60, 75, 80, 85, 90	35, 45, 60, 70 75, 80, 85, 90	35, 45, 60, 70 75, 80, 85, 90
cot α [-]	$0.36 \leq \cot\alpha \leq 2.75$	$0 \leq \cot\alpha \leq 2.14$	$0 \leq \cot\alpha \leq 1.43$	$0 \leq \cot\alpha \leq 1.43$
Relative crest freeboard R_c/H_{m0} [-]	0.11 – 1.69	0 – 2.4	0 – 2.9	0.11 – 1.87
Relative wave height H_{m0}/h [-]	0.016 – 0.33	0.03 – 0.2	0.2, 0.3, 0.4, 0.5	0.3, 0.4, 0.5

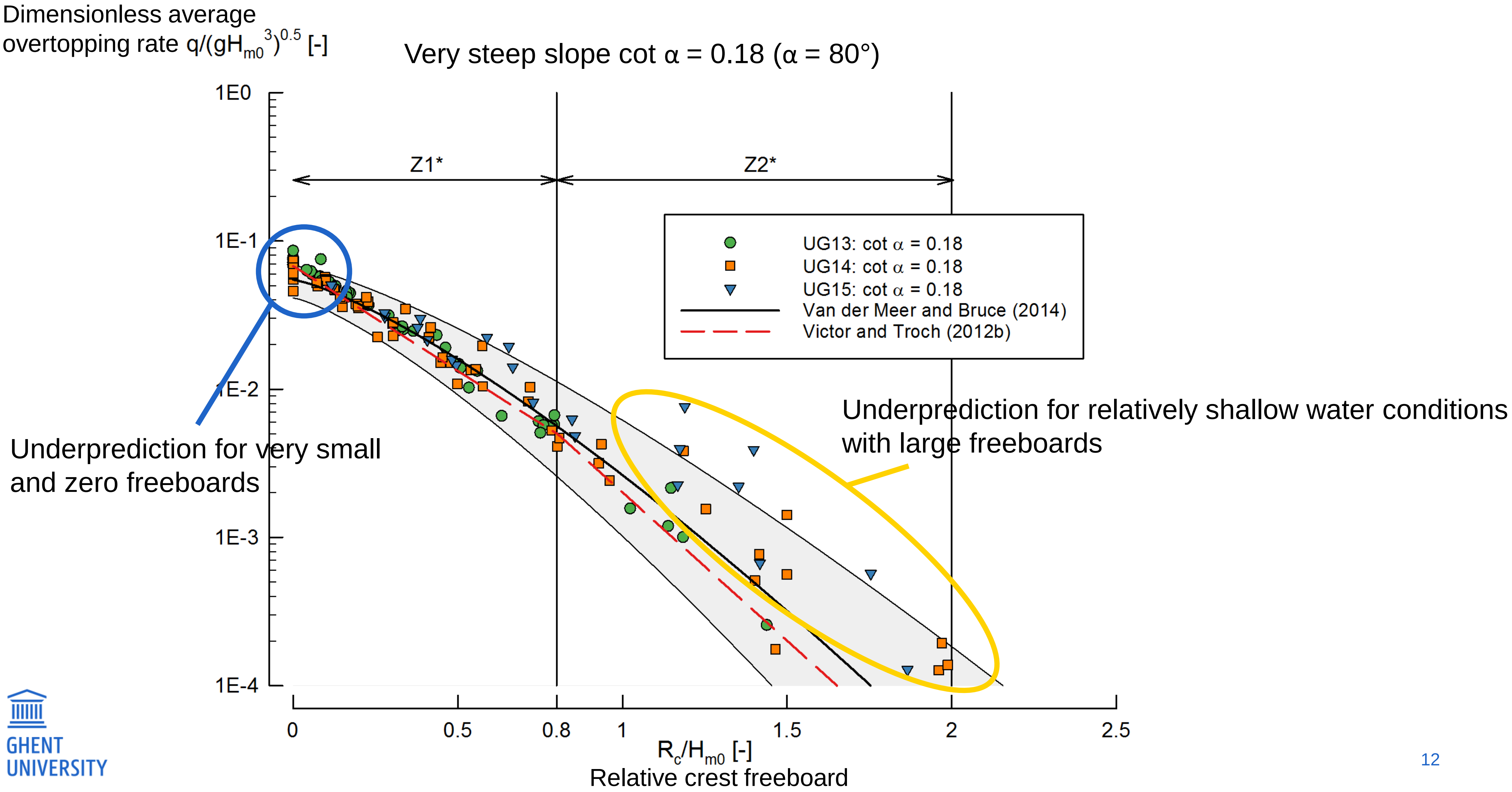
Overlapped tests on deep water

Extension tests on shallow water

Deep water → Shallow water

Shallow water

Average overtopping results



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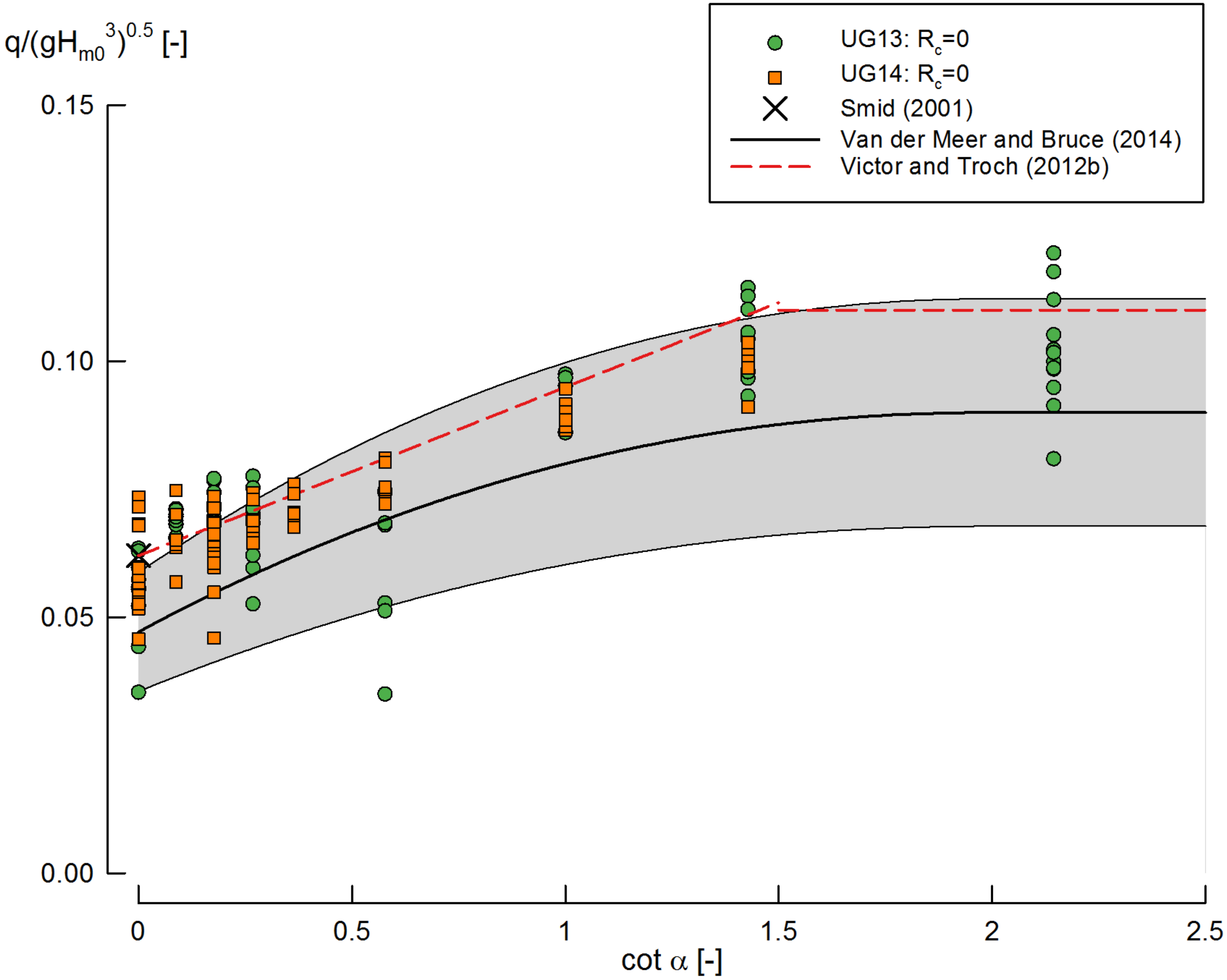
Underprediction for very small and zero freeboards



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New average overtopping prediction

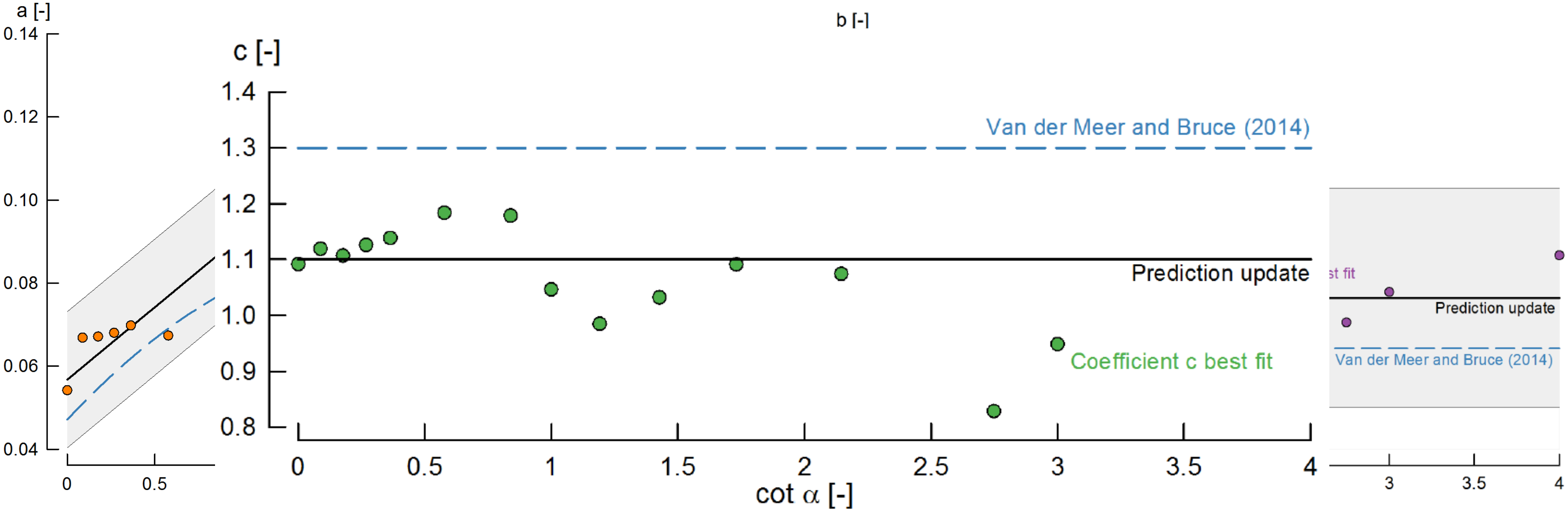
$$\frac{q}{\sqrt{gH_{m0}^3}} = a \cdot \exp\left(-\left(b\frac{R_c}{H_{m0}}\right)^c\right)$$

$a = 0.109 - 0.035(1.5 - \cot\alpha)$ with $a = 0.109$ for $\cot\alpha \geq 1.5$

$b = 2 + 0.56(1.5 - \cot\alpha)^{1.3}$ with $b = 2$ for $\cot\alpha \geq 1.5$

$c = 1.1$

Fitted through UG10, UG13, UG14, UG15 and CLASH



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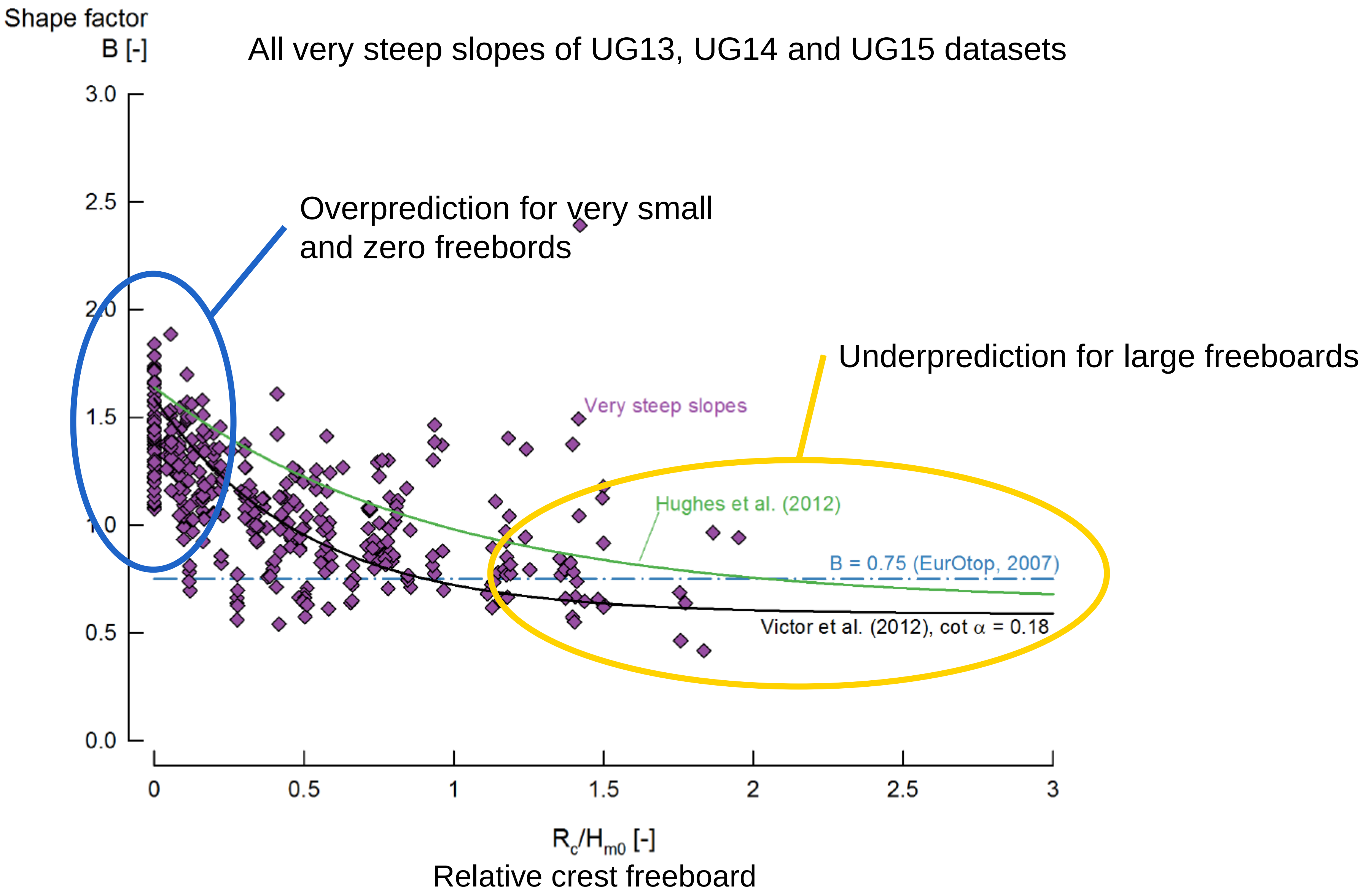
Individual wave overtopping results: shape factor B



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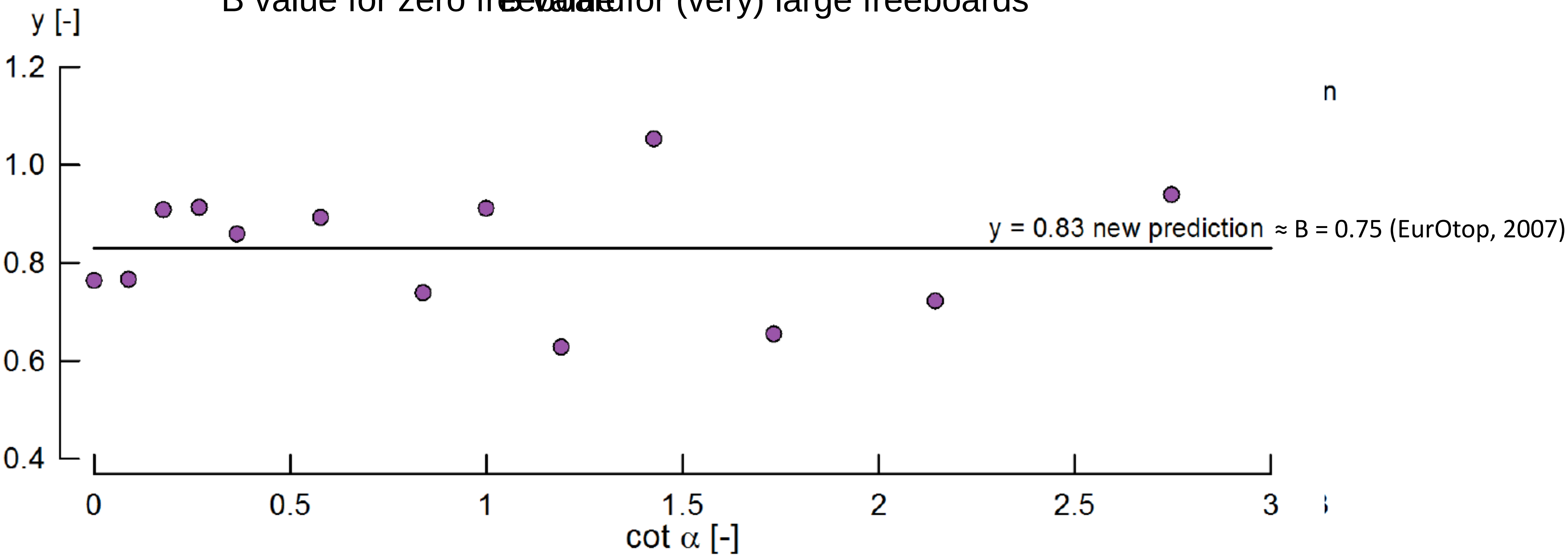
New shape factor B prediction

$$B = w \exp\left(-x \frac{R_c}{H_{m0}}\right) + y \qquad B = (0.59 + 0.23 \cot\alpha) \exp\left(-2.2 \frac{R_c}{H_{m0}}\right) + 0.83$$

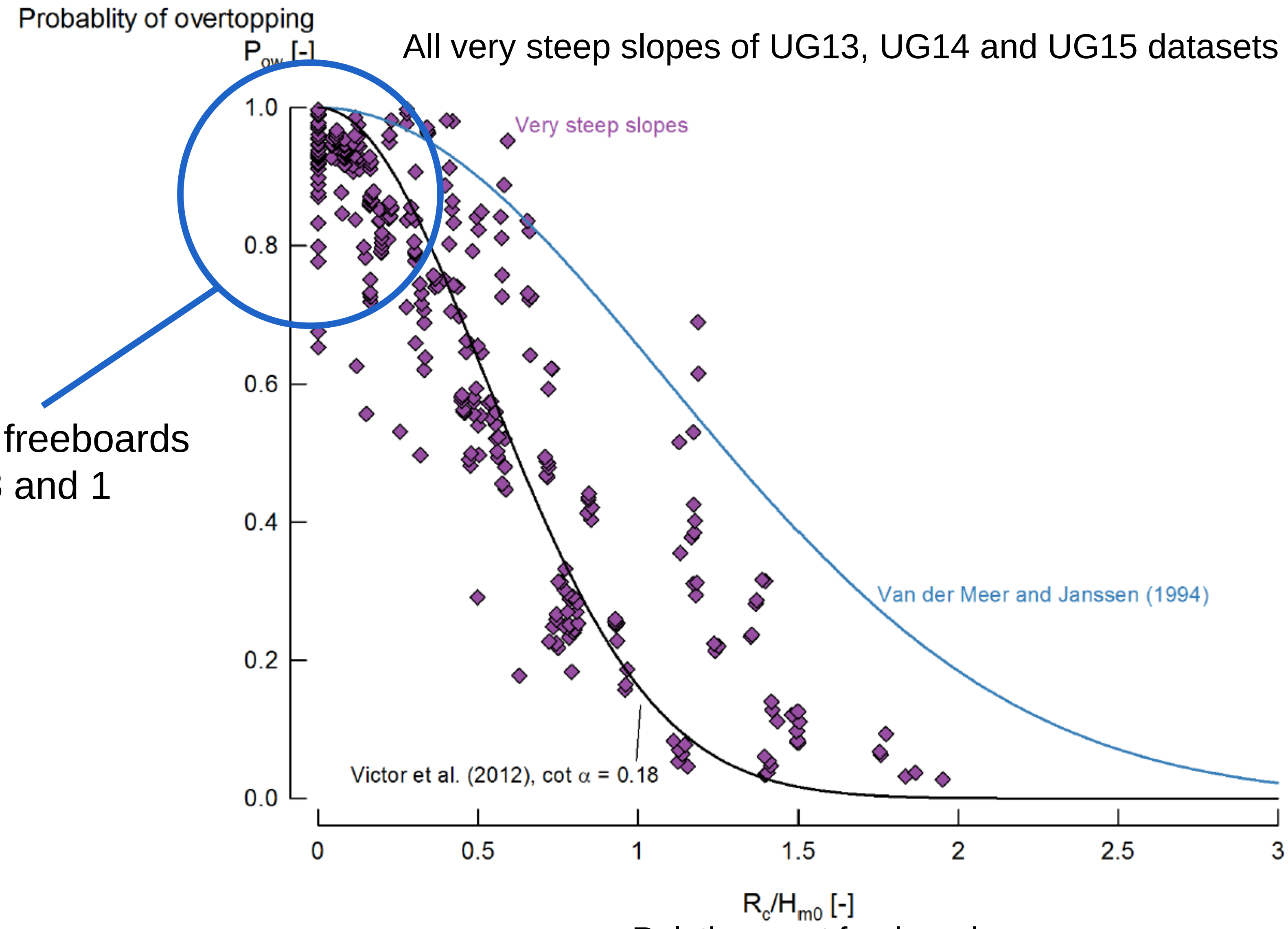
B value for zero freeboard

B value for (very) large freeboards



Individual wave overtopping results: probability of overtopping P_{ow}

All very steep slopes of UG13, UG14 and UG15 datasets



Relative crest freeboard

P_{ow} for zero freeboards between 0.8 and 1

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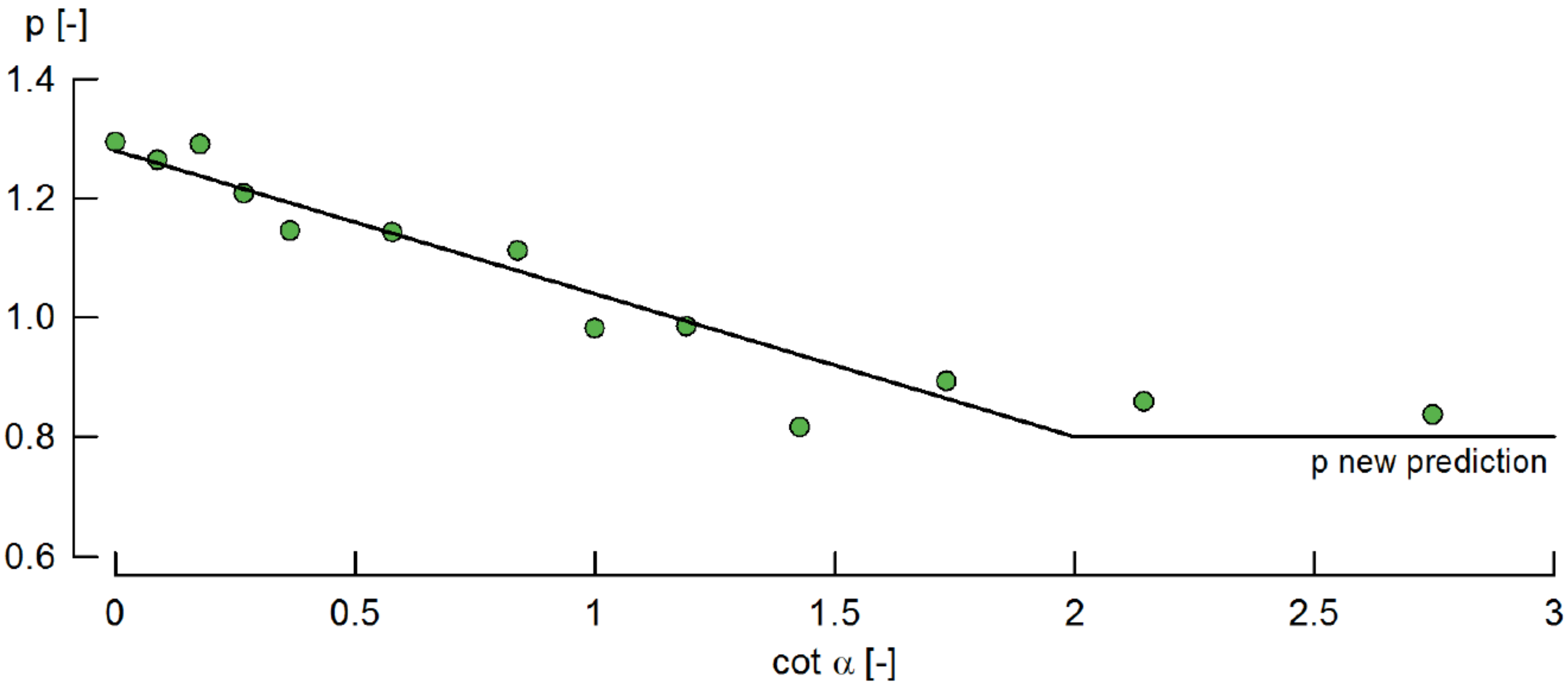
New probability of overtopping P_{ow} prediction

$$P_{ow} = \exp\left[-\left(p\,\frac{R_c}{H_{m0}}\right)^2\right]$$

$$P_{ow} = \exp\left[-\left([0.8 + 0.24(2 - \cot\alpha)]\,\frac{R_c}{H_{m0}}\right)^2\right]$$

with $P_{ow} = \exp\left[-\left(0.8\,\frac{R_c}{H_{m0}}\right)^2\right]$ for $\cot\alpha \geq 2$



Conclusions

Average wave overtopping

Underprediction of very small and zero freeboard of existing formulae.

New average overtopping prediction improves the accuracy for very small and zero relative freeboards while maintaining the accuracy for the rest of conditions.

Individual wave overtopping

Shape factor B

Overprediction of existing formulae for zero freeboards.

New prediction depends on $\cot\alpha$ for zero freeboards and is constant for large freeboards, improving the accuracy.

Probability of overtopping P_{ow}

P_{ow} for zero freeboard is between 0.8 and 1.

New prediction improves the accuracy based on the new Ghent University data.

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