

Surf Wave Dynamics in the Coastal Environment

Re-scaling the Battjes-Janssen Model for Depth-induced Wave-breaking

Wednesday 2nd November
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Environmental Fluid Mechanics

Motivation

- Scaling Battjes-Janssen model generally OK, except over reefs, tidal flats and lakes.
- Alternative scalings improve some cases at the expense of others.

Methodology

- Try alternative scalings on large number of laboratory and lake observations.
- On this basis develop new scaling.
- Calibrate and verify this new scaling on laboratory, lake and complex field cases.

Summary of Conclusions

- New γ -scaling unifies a number of concepts in literature and is dependent on slope, n and normalized depth, kd .
- New scaling generally OK including over reefs, tidal flats and lakes.



How can we model wave breaking?

- Battjes and Janssen, 1978:

$$\varepsilon = -\frac{1}{4} \alpha \bar{f} Q_b \rho g H_m^2$$

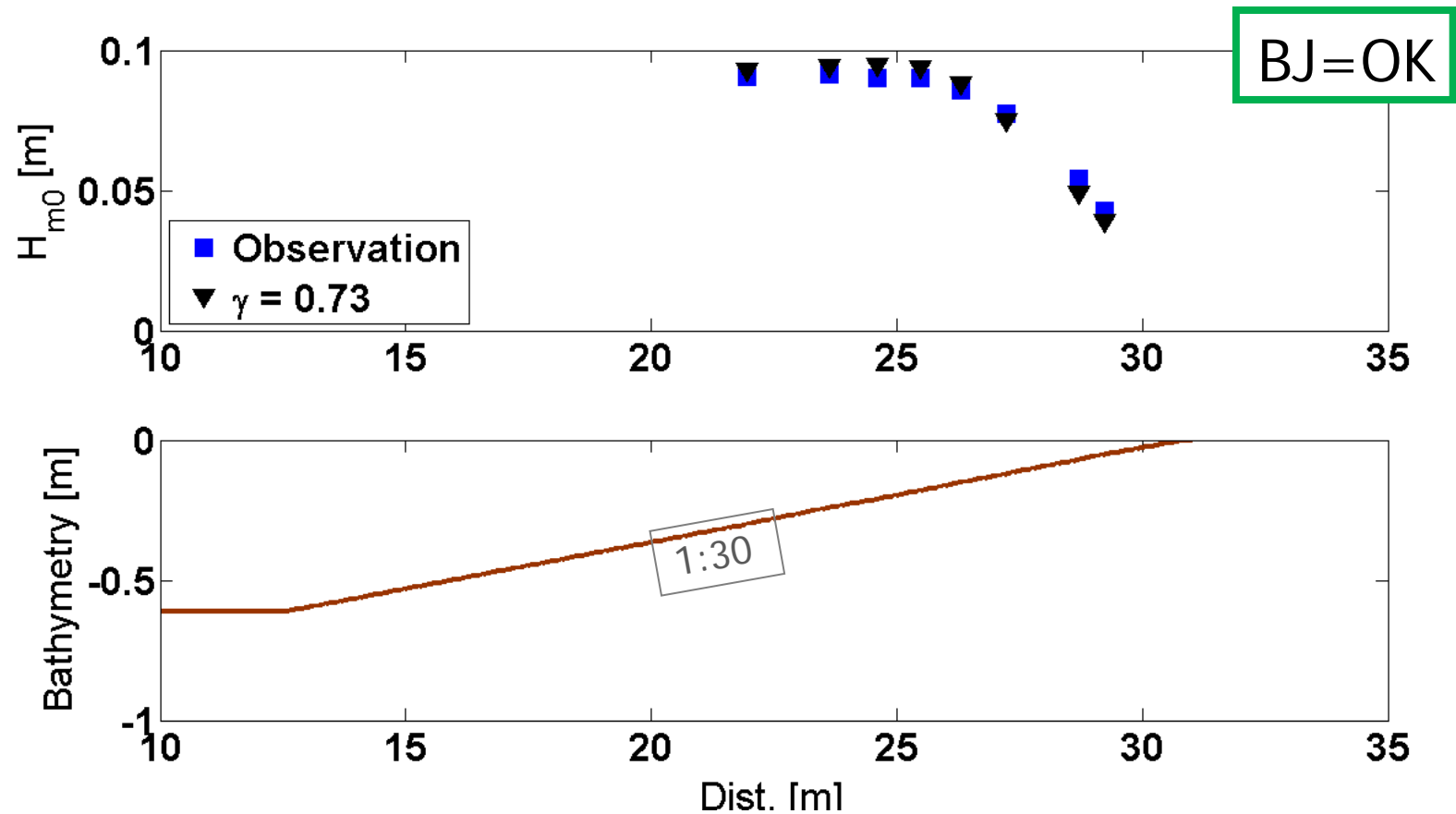
$$H_m = \gamma d$$

- Default in SWAN:

$$\alpha = 1.00 \quad \gamma = 0.73$$

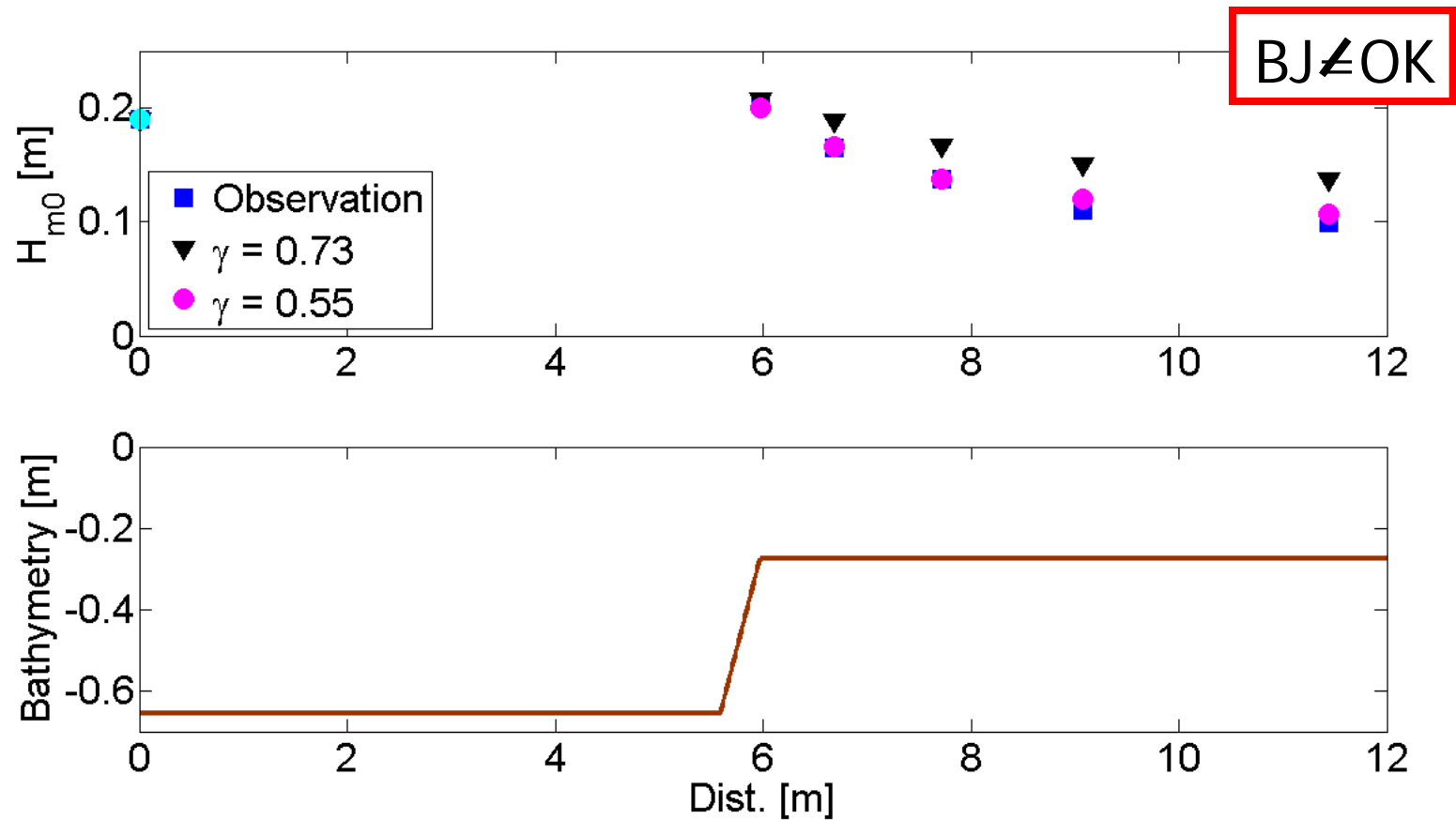
Performance of default SWAN 40.81

Constant slopes – Smith(2004)



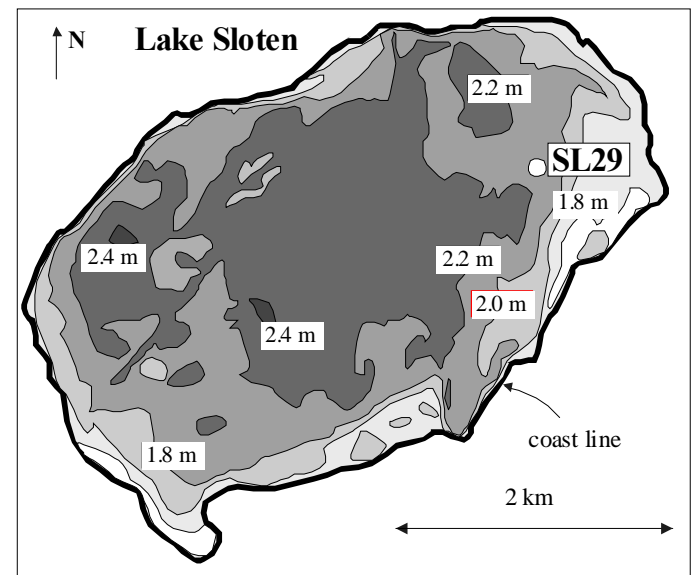
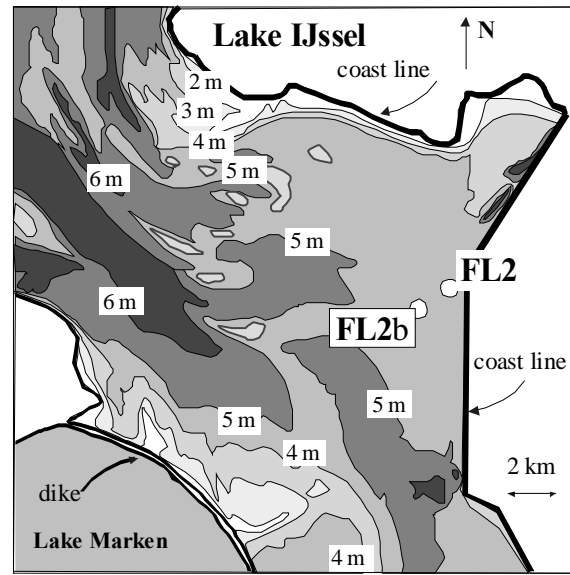
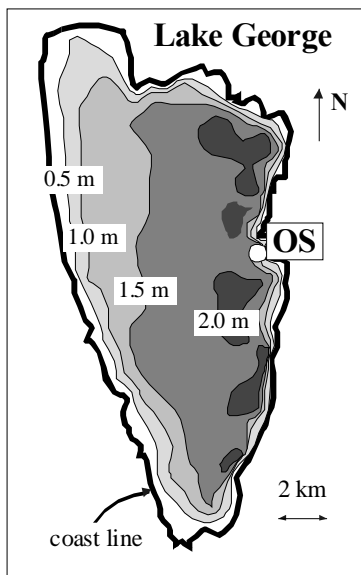
Performance of default SWAN 40.81

Horizontal bottom – Jensen(2002)



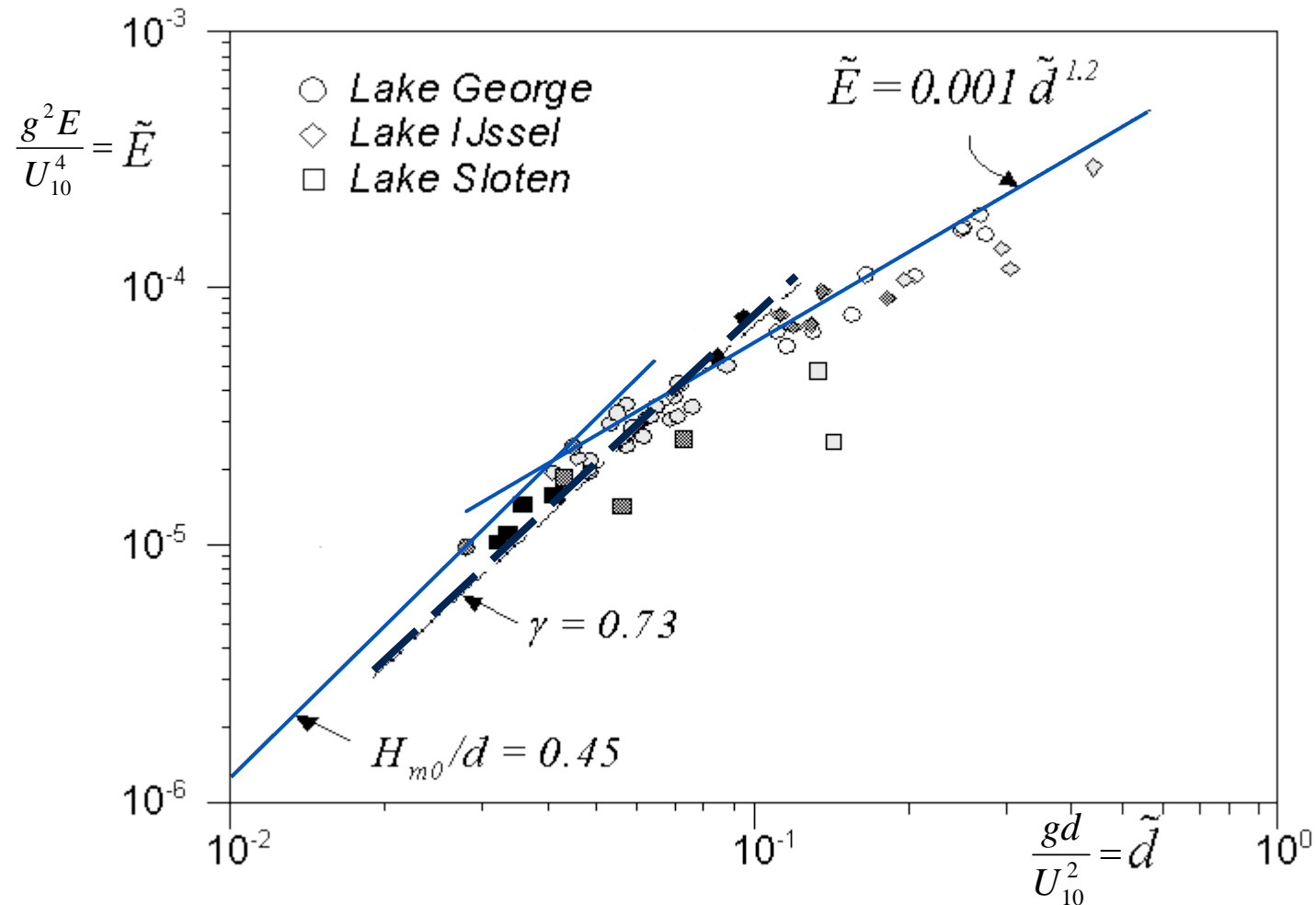
Performance of default SWAN 40.81

Locally generated wind waves over shallow flat bottoms



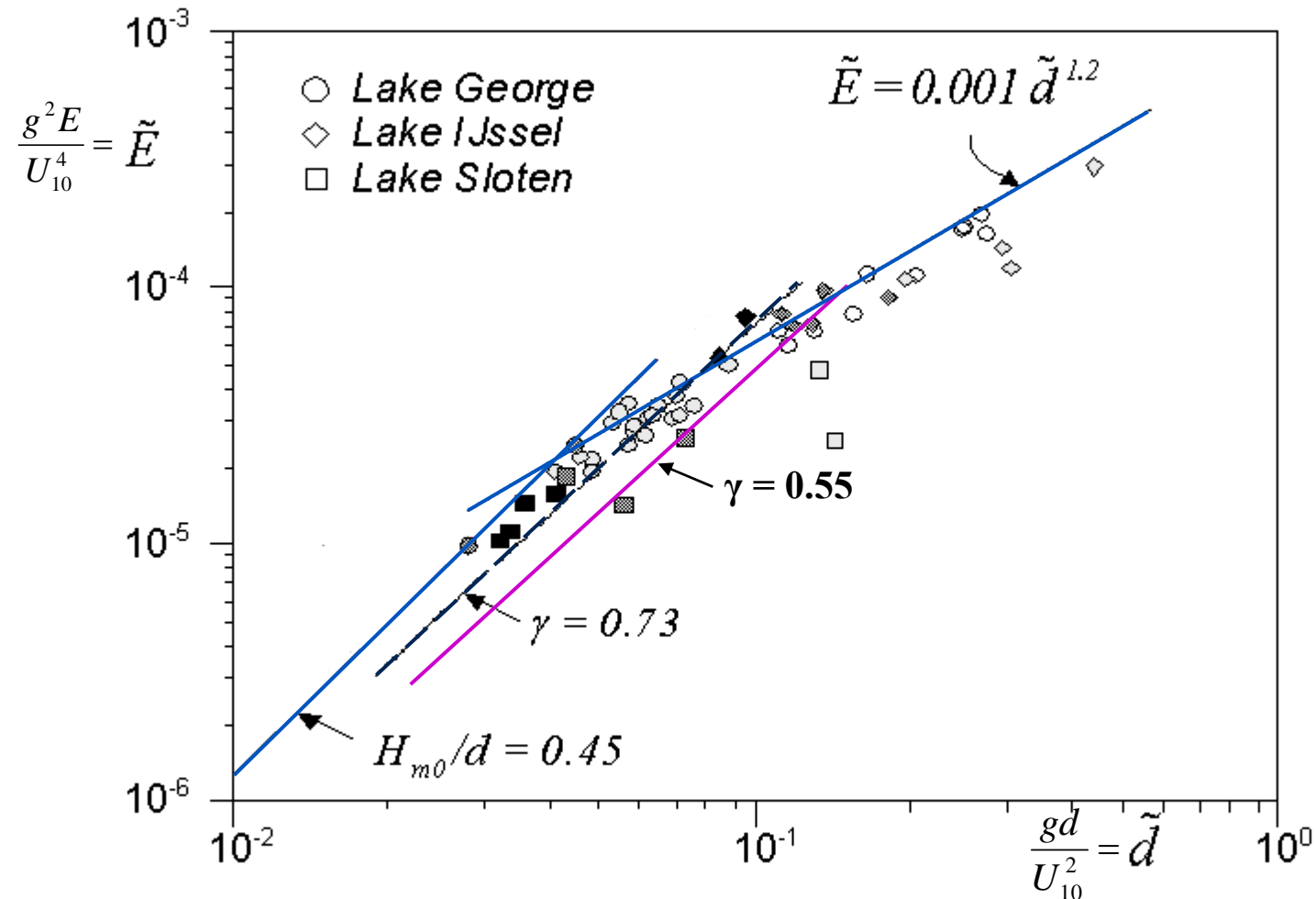
Performance of default SWAN 40.81

Locally generated wind waves over shallow flat bottoms



Performance of default SWAN 40.81

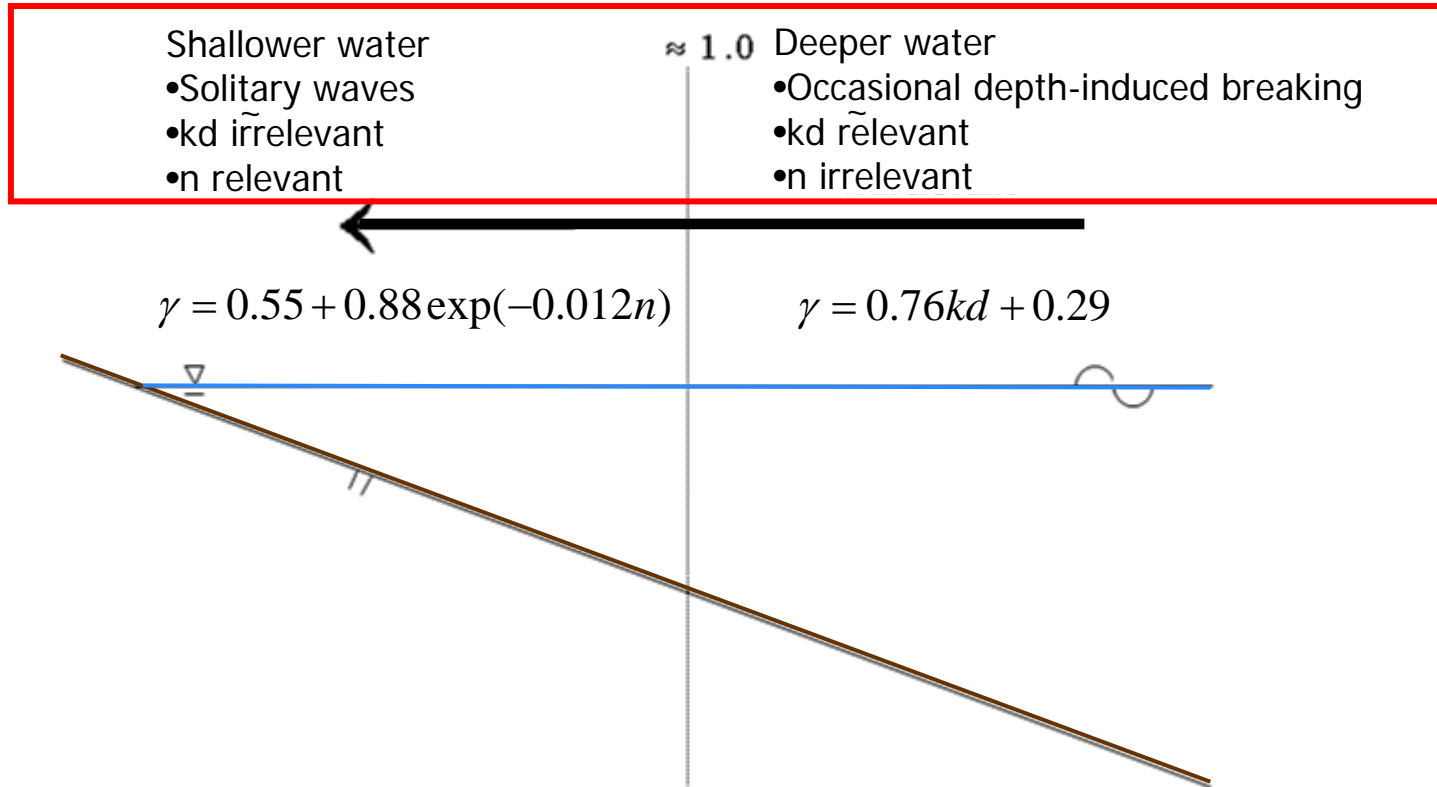
Locally generated wind waves over shallow flat bottoms



γ -scaling in Literature

- Battjes and Janssen (1978)
- Battjes and Stive (1985)
- Nelson (1997)
- Ruessink et. al. (2003)
- Raubenheimer et. al. (1996)
- Goda (2010)

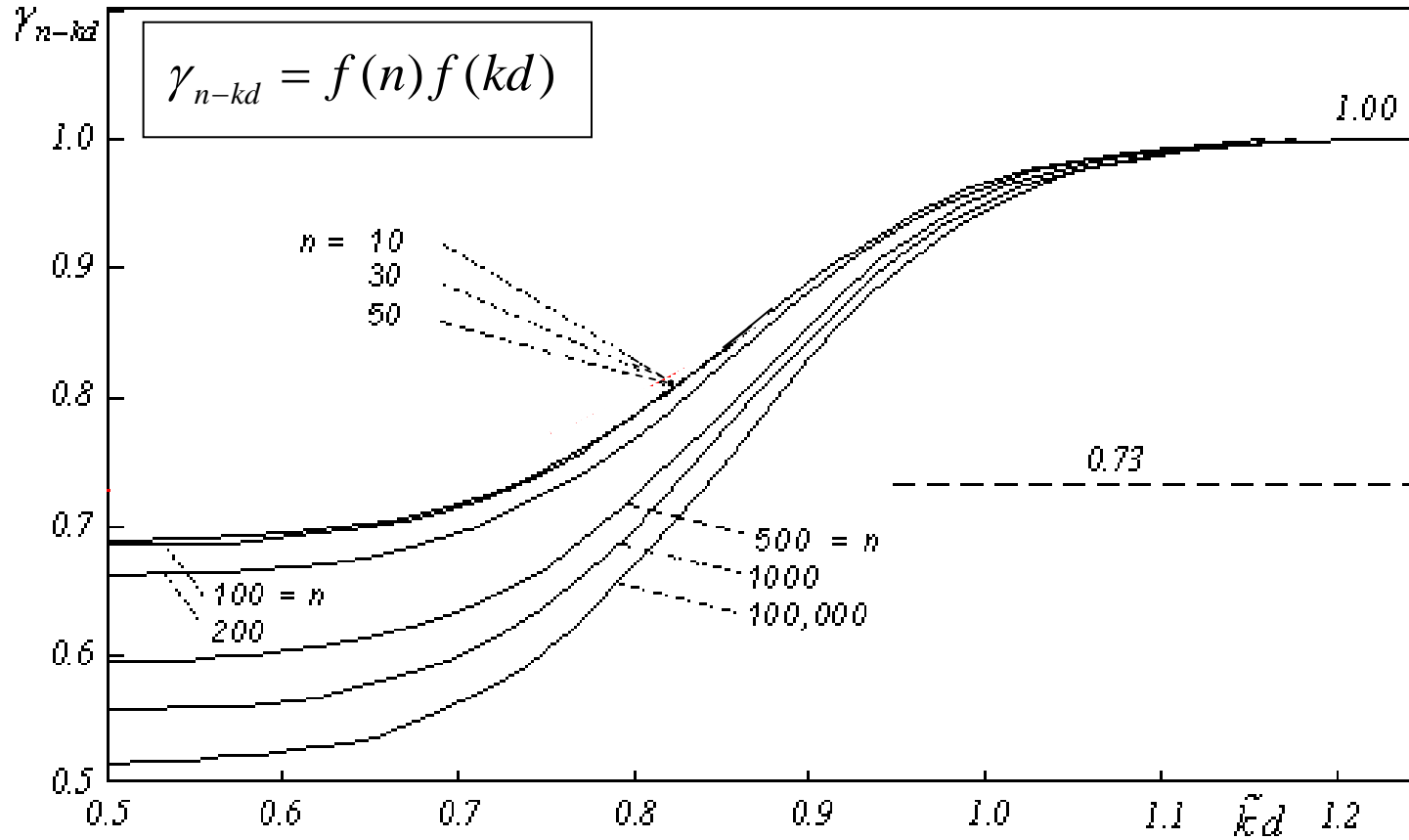
Proposed 'n-kd' γ -scaling



- $\gamma_{n-kd} = f(n)f(kd)$

Proposed 'n-kd' γ -scaling

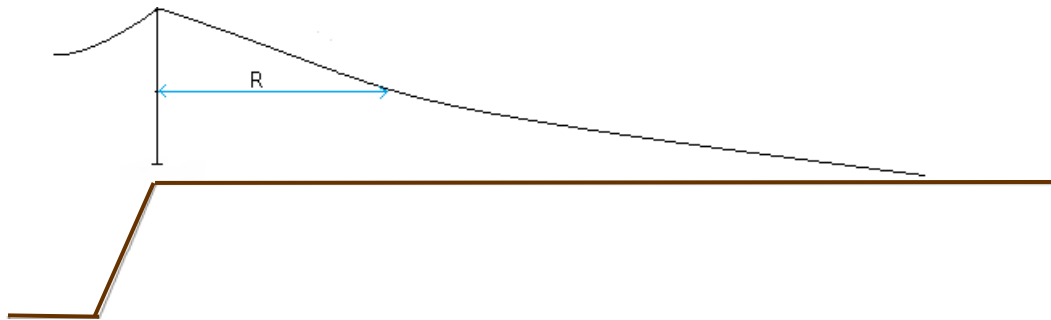
Shallower water •Solitary waves •kd irrelevant •n relevant	$kd \approx 1.0$	Deeper water •Occasional depth-induced breaking •kd relevant •n irrelevant
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Relaxation

- Wave breaking persistence
- Relaxation model (economy):

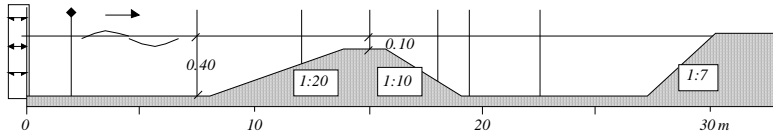
$$\frac{d\gamma_*}{ds} = \frac{1}{R} (\gamma_{n-kd} - \gamma_*)$$



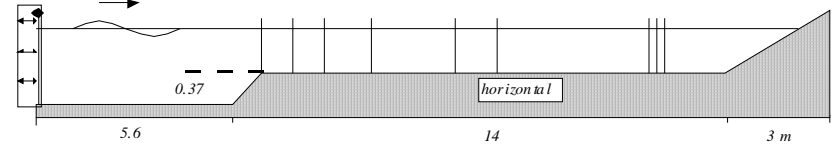
Calibration

$$SI = \frac{\sqrt{\frac{1}{N} \sum (H_{m_0,obs} - H_{m_0,sim})^2}}{H_{m_0,obs}}$$

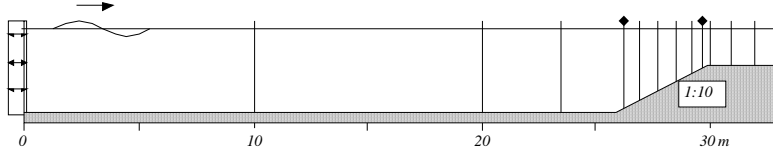
Delft Hydraulics



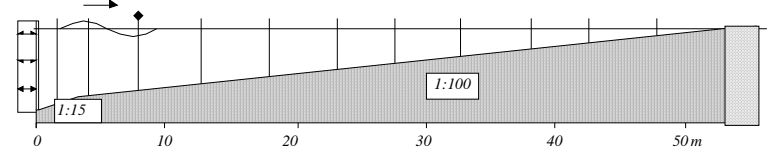
Aalborg University



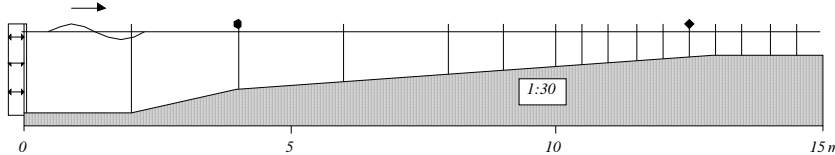
HR Wallingford



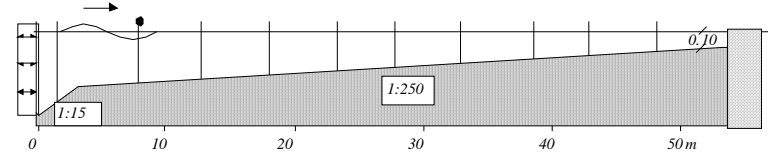
Imperial College



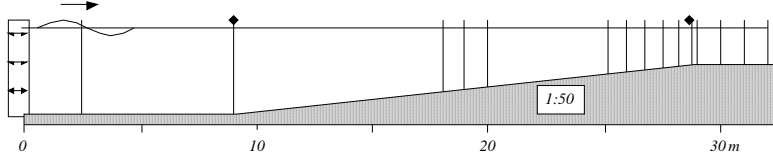
HR Wallingford



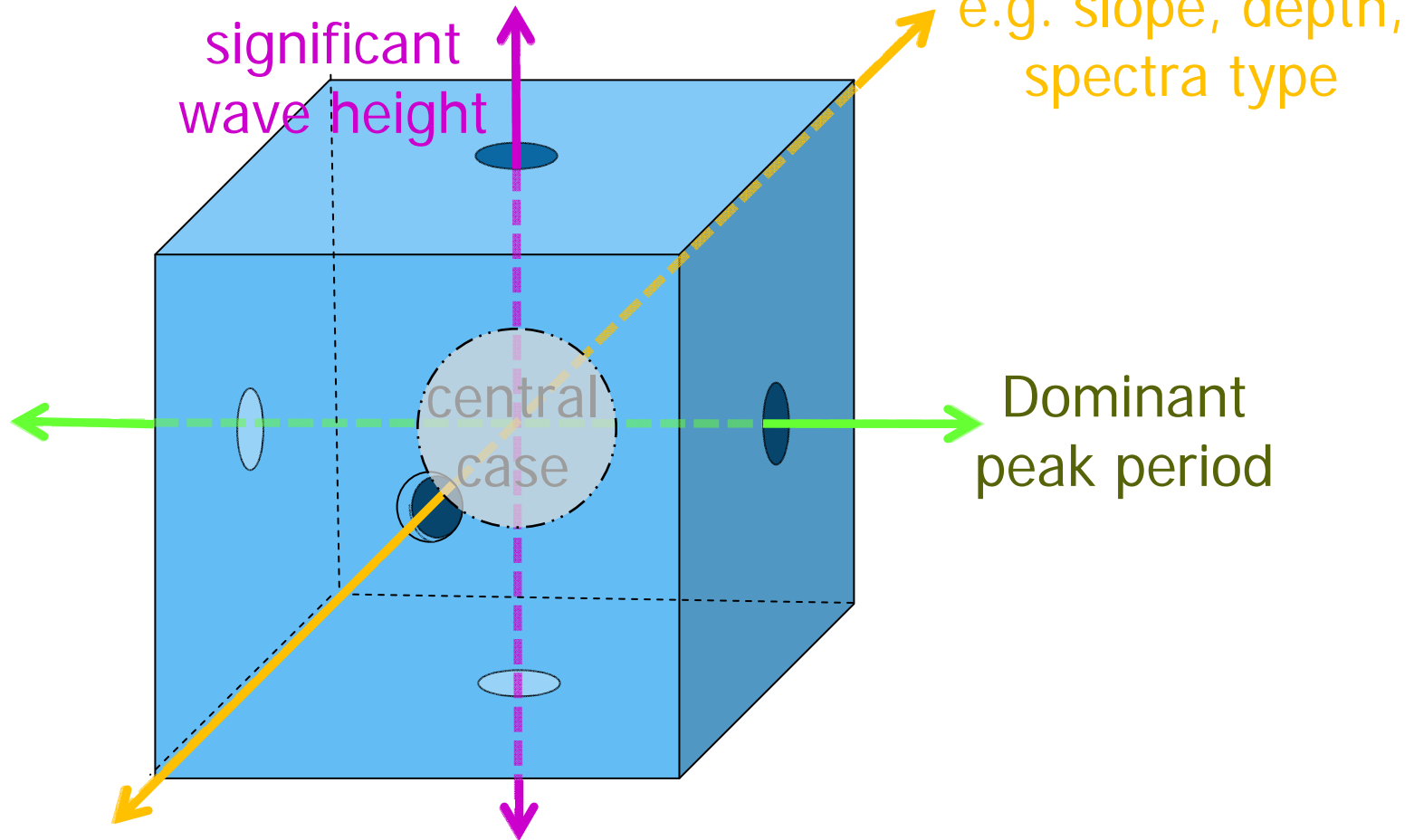
Imperial College



HR Wallingford



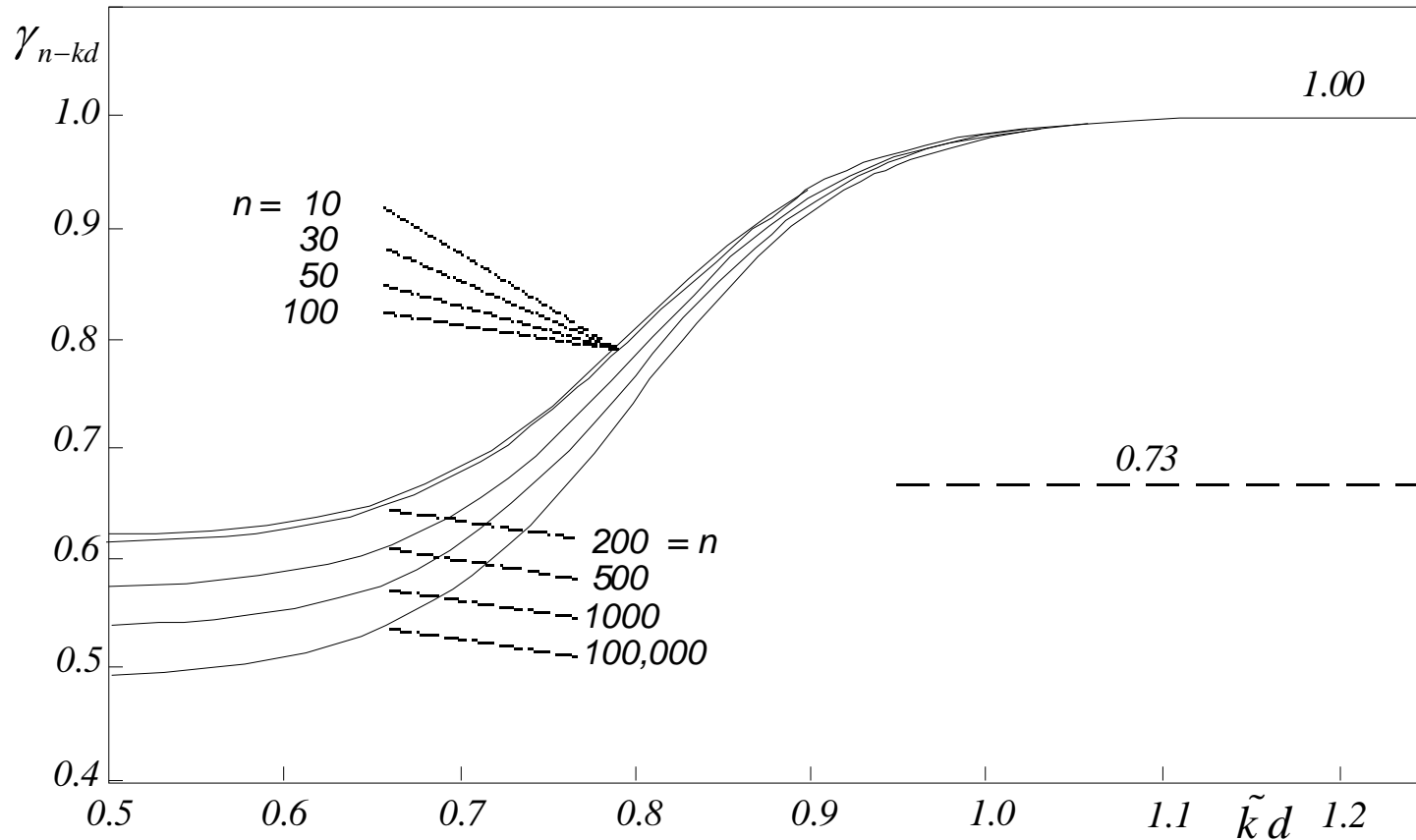
Calibration



- Results in 5 cases per selection parameter

Calibration

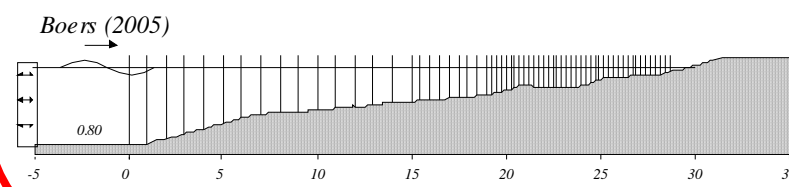
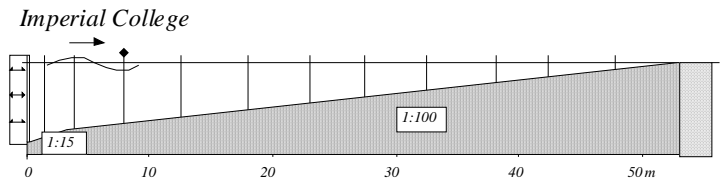
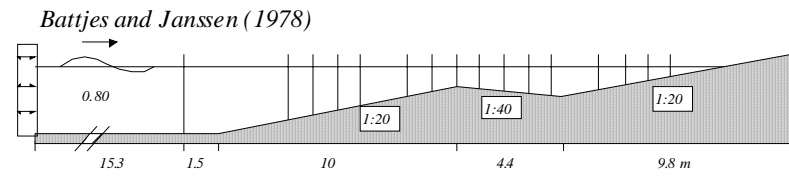
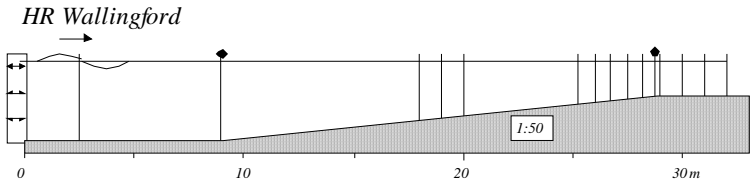
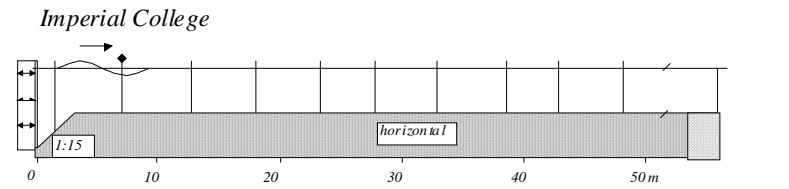
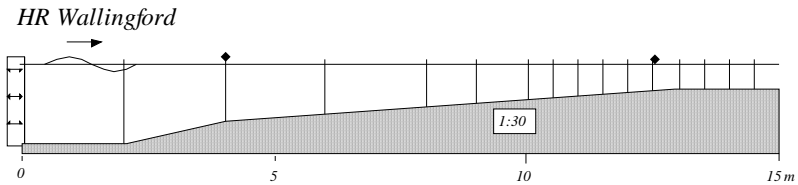
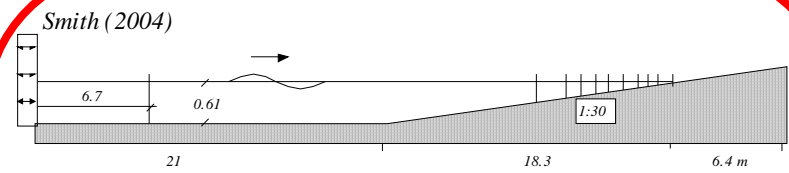
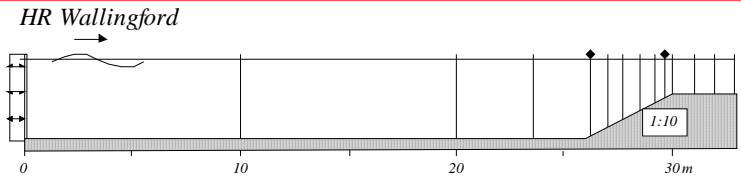
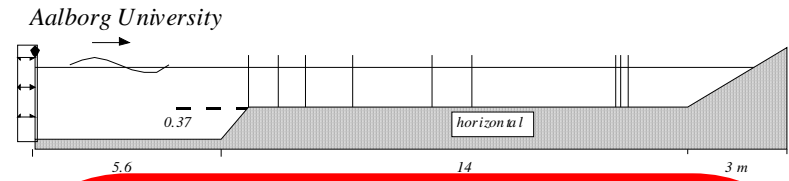
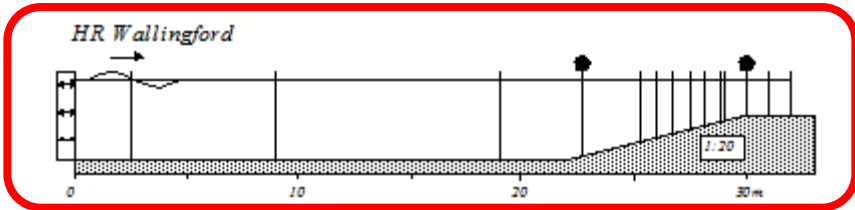
$$SI = \frac{\sqrt{\frac{1}{N} \sum (H_{m_0,obs} - H_{m_0,sim})^2}}{H_{m_0,obs}}$$



- From 80 out of 121 possible cases

Verification Laboratory & Field

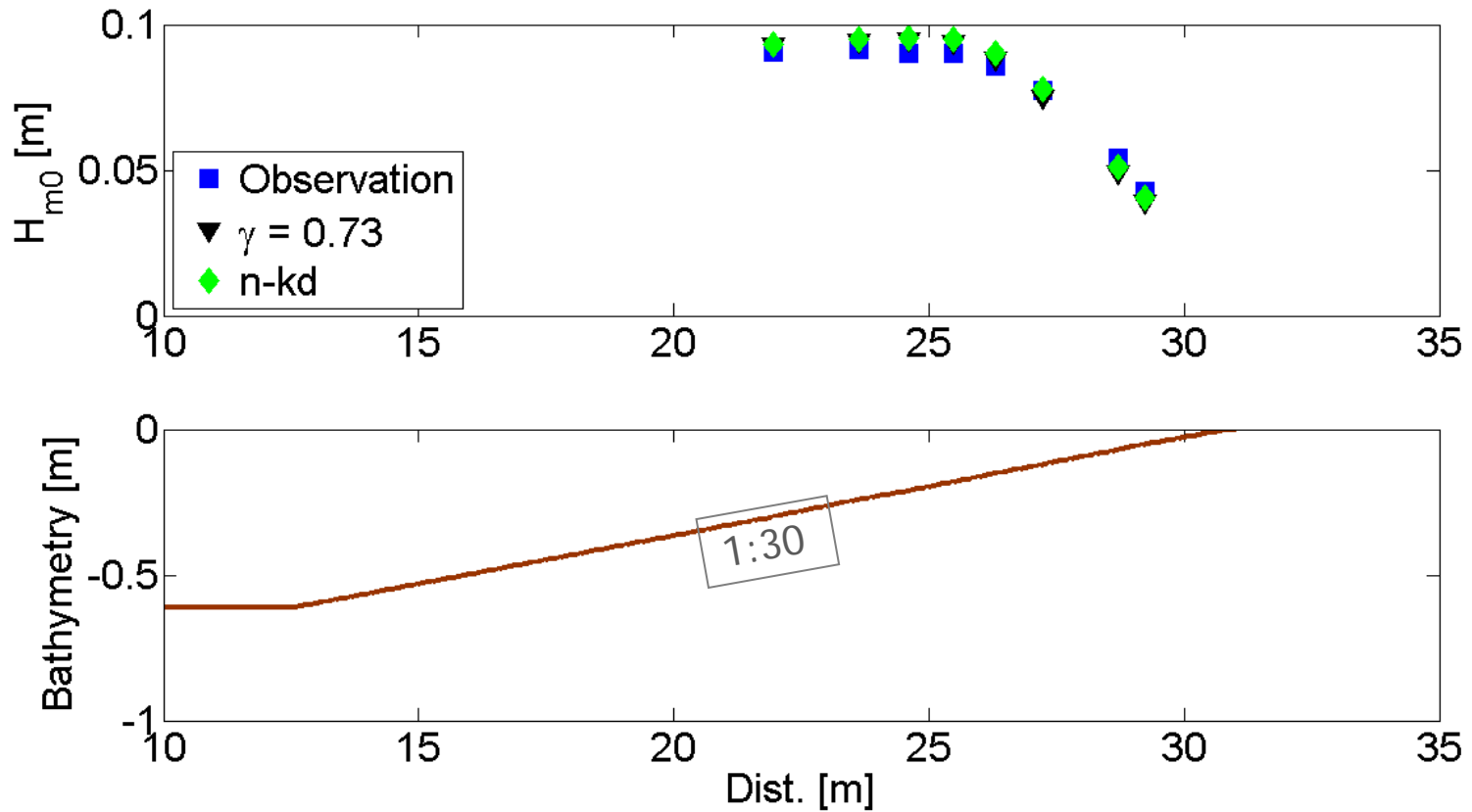
Verification - Laboratory



• 124 cases were used

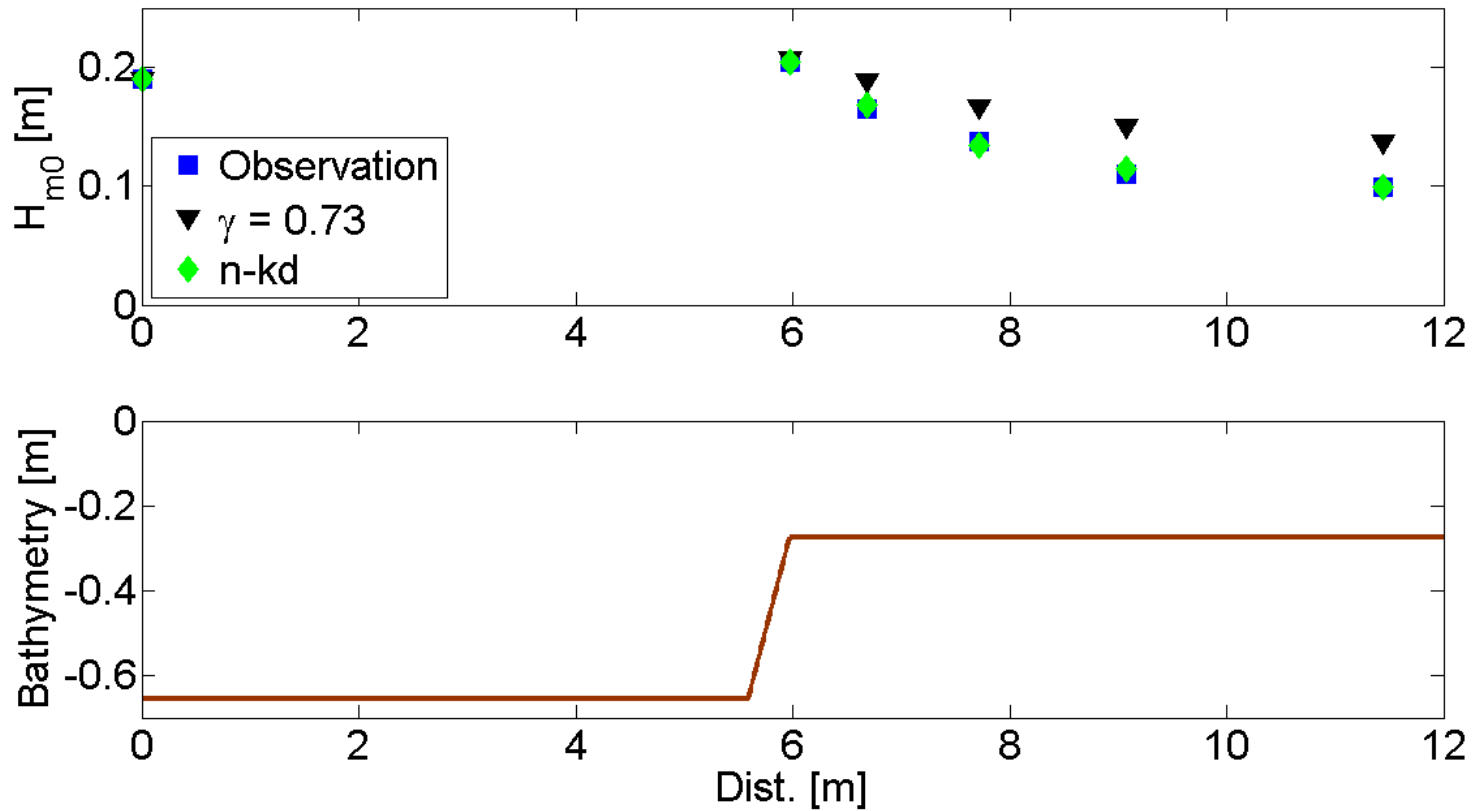
Verification

Smith V01	Scatter Index
$\gamma = 0.73$	0.045
'n-kd' γ -scaling	0.046

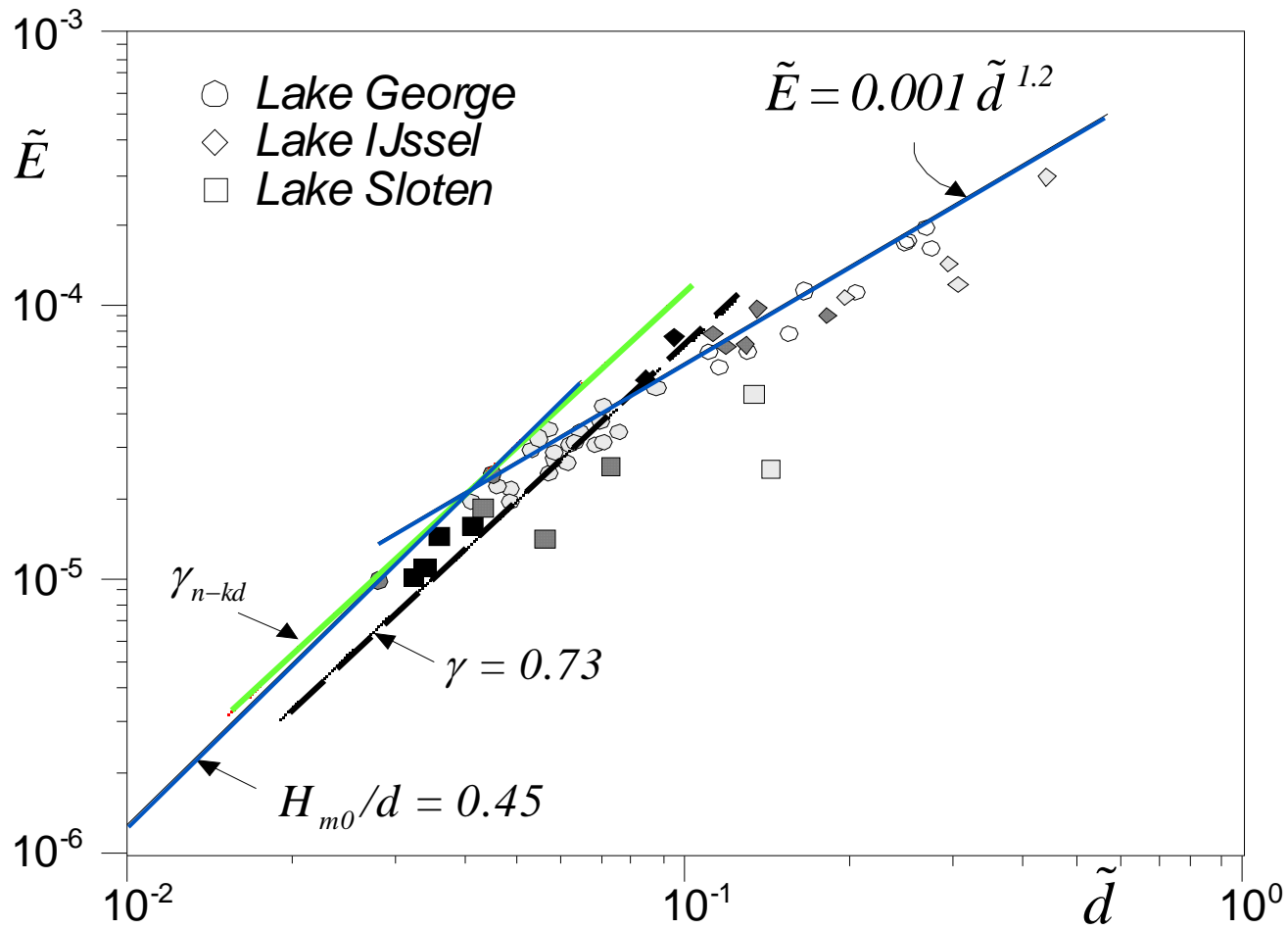


Verification

Jensen V01	Scatter Index
$\gamma = 0.73$	0.212
'n-kd' γ -scaling	0.022



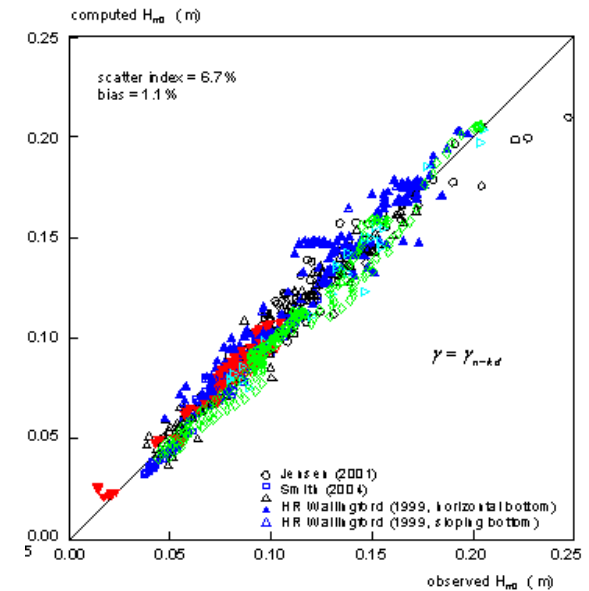
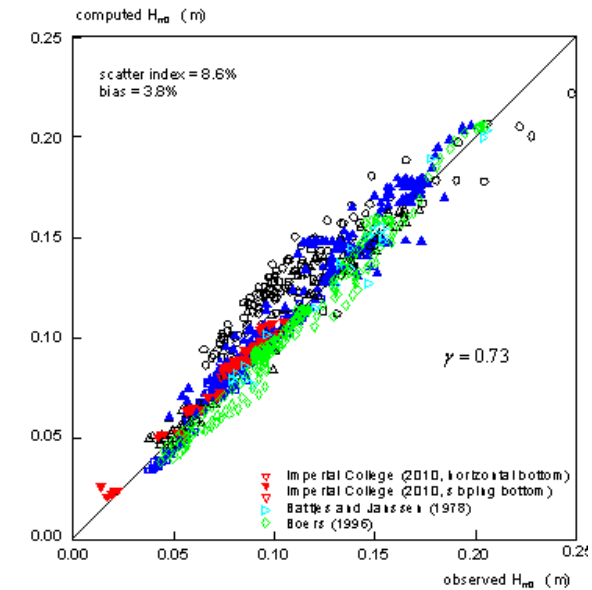
Verification



Verification

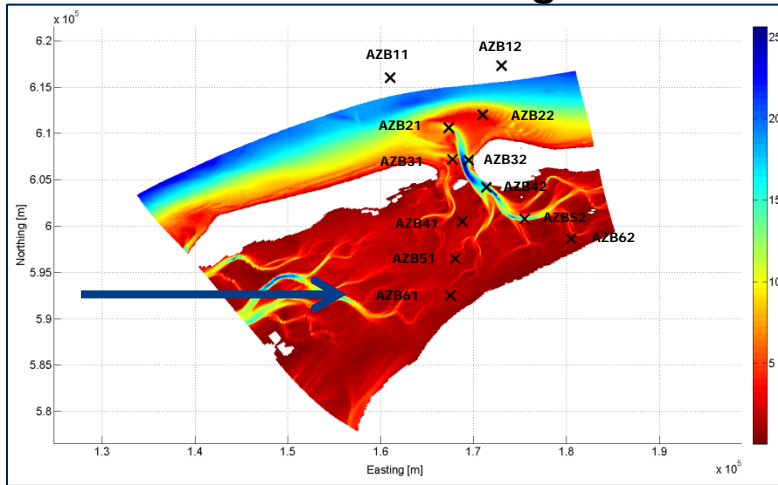
	No. Cases	$\gamma = 0.73$	n-kd
<u>horizontal bottom</u>			
Wallingford	25	0.076	0.070
Imperial College	5	0.060	0.039
Aalborg University	25	0.205	0.077
Flat Bottom Lakes	3	0.165	0.015
	average	<u>0.127</u>	<u>0.050</u>
<u>sloping bottom</u>			
Wallingford	25	0.077	0.076
Imperial College	7	0.106	0.104
Smith	31	0.059	0.059
Boers*	3	0.057	0.056
Battjes-Janssen*	2	0.050	0.055
	average	<u>0.070</u>	<u>0.070</u>
Overall Average		0.099	0.060

- * Bar-trough profiles

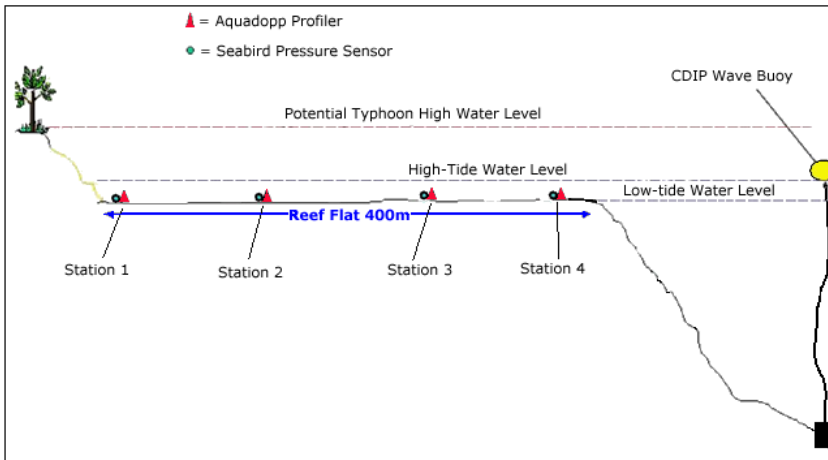


Verification - Field

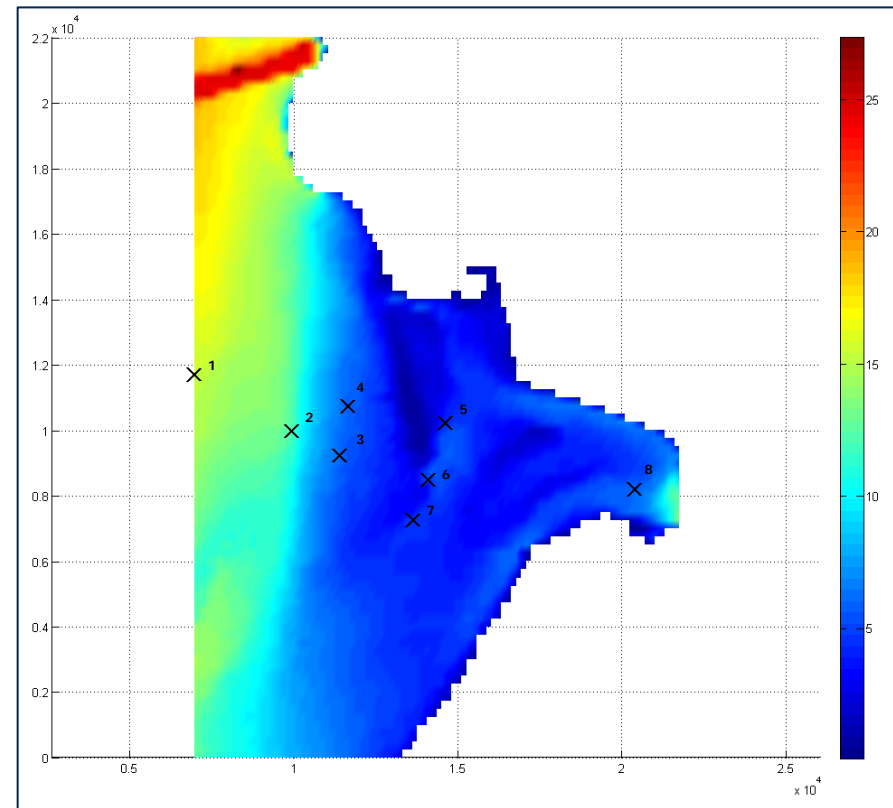
Amelander Zeegat



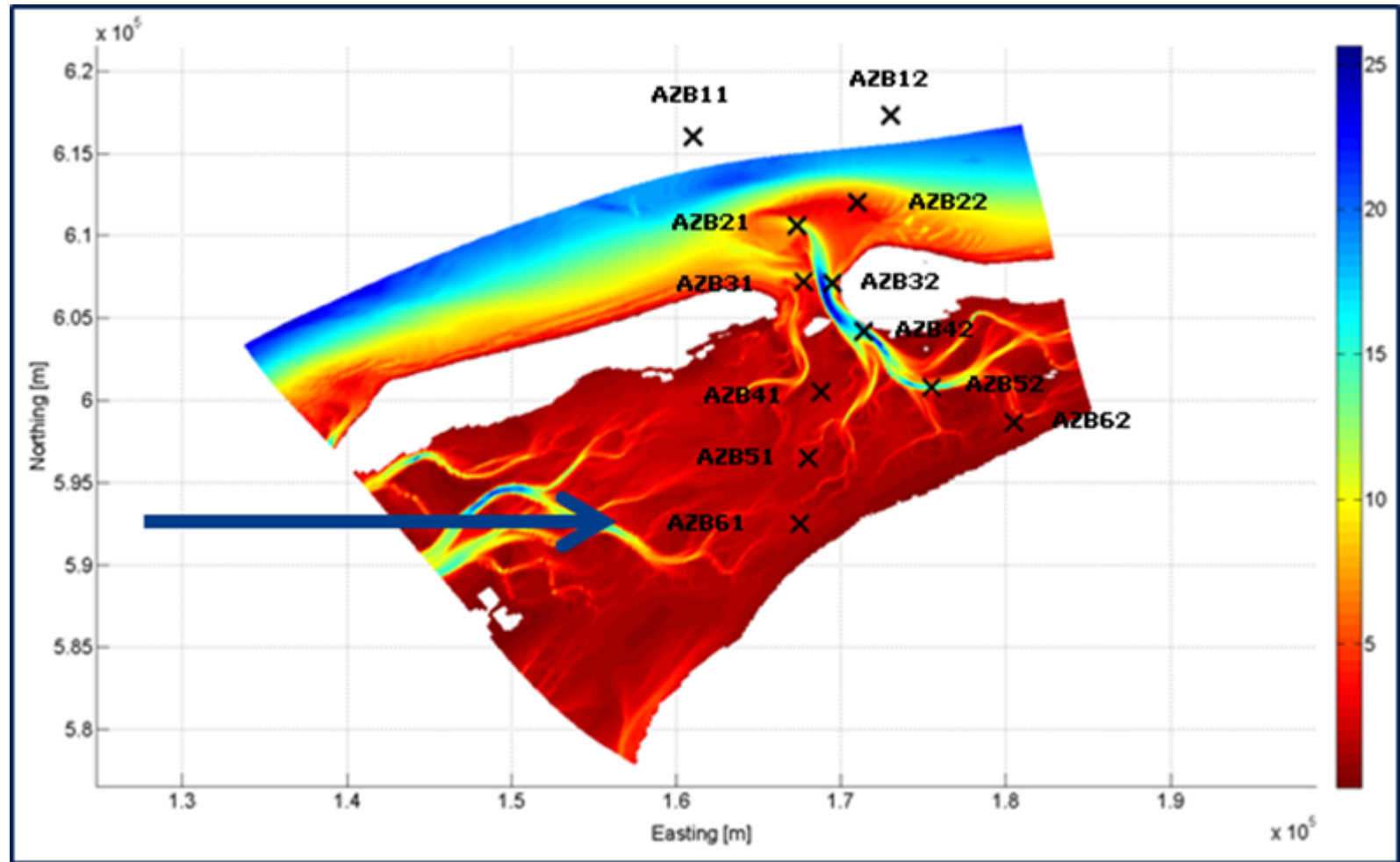
Guam



Haringvliet



Verification - Field



Verification

AMG V01 (E)

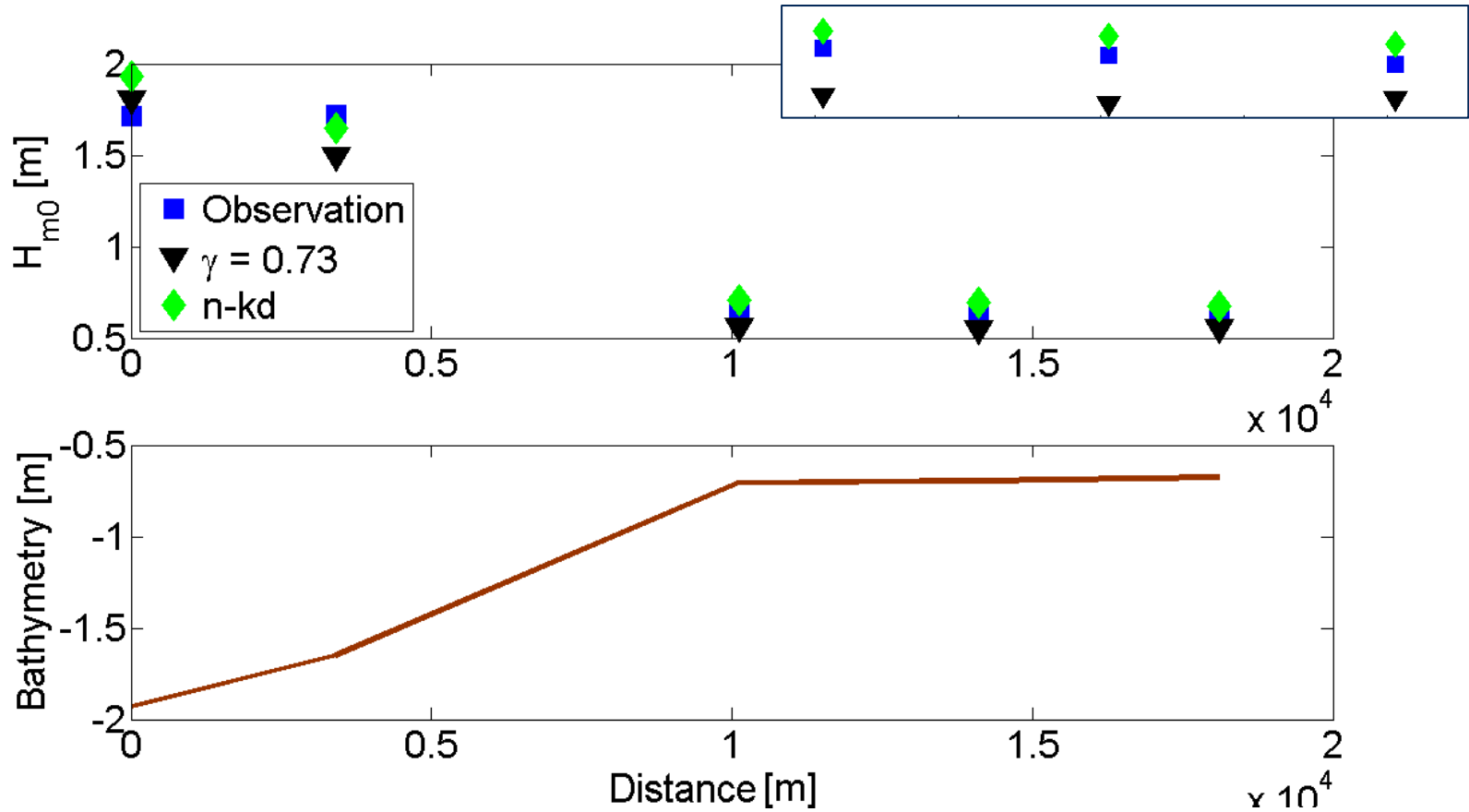
Scatter Index

Default SWAN

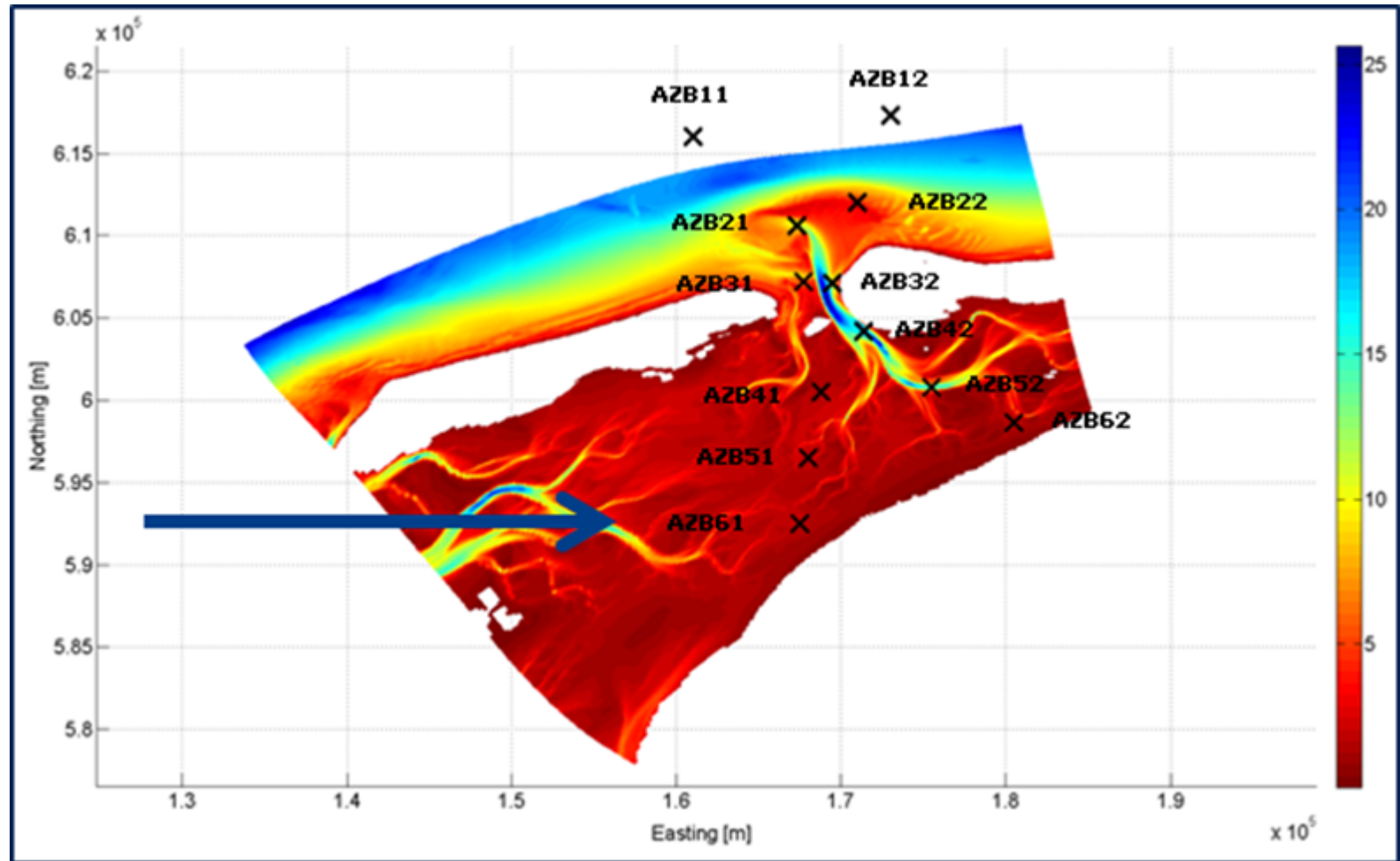
0.218 (0.175)

'n-kd' γ -scaling

0.101 (0.095)



Verification - Field



Verification

AMG V01 (W)

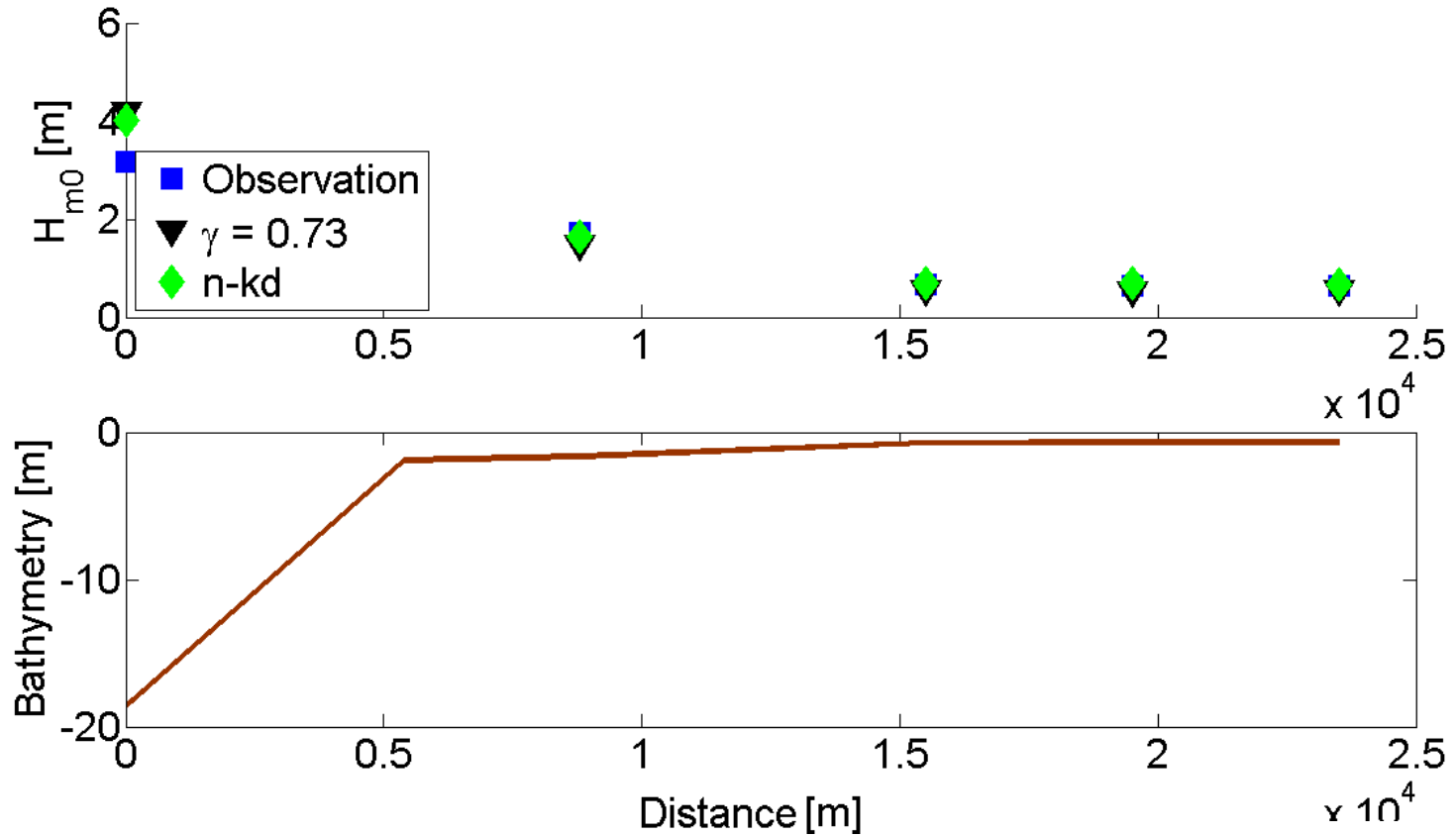
Scatter Index

$\gamma = 0.73$

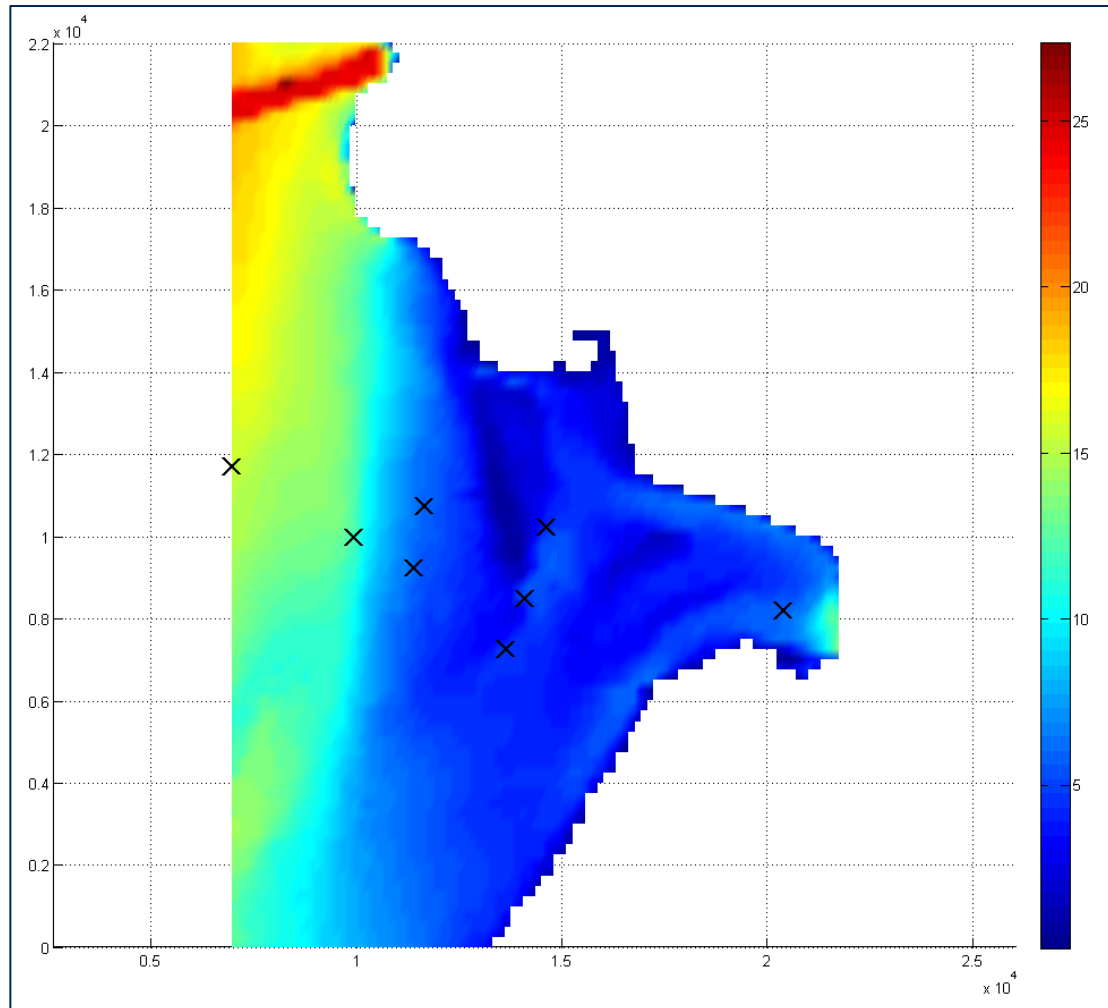
0.123 (0.175)

'n-kd' γ -scaling

0.089 (0.095)



Verification - Field



Verification

Har V02

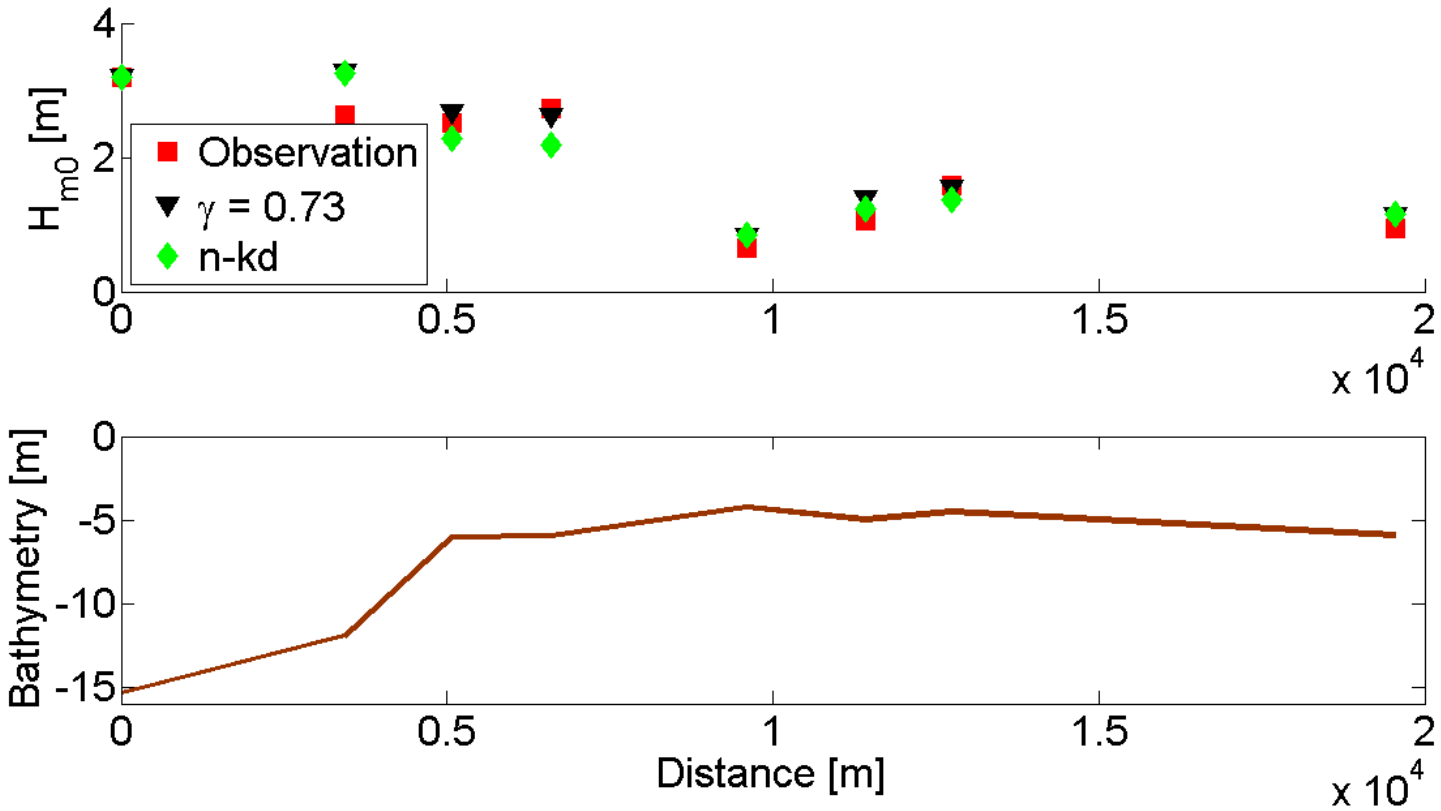
Scatter Index

$\gamma = 0.73$

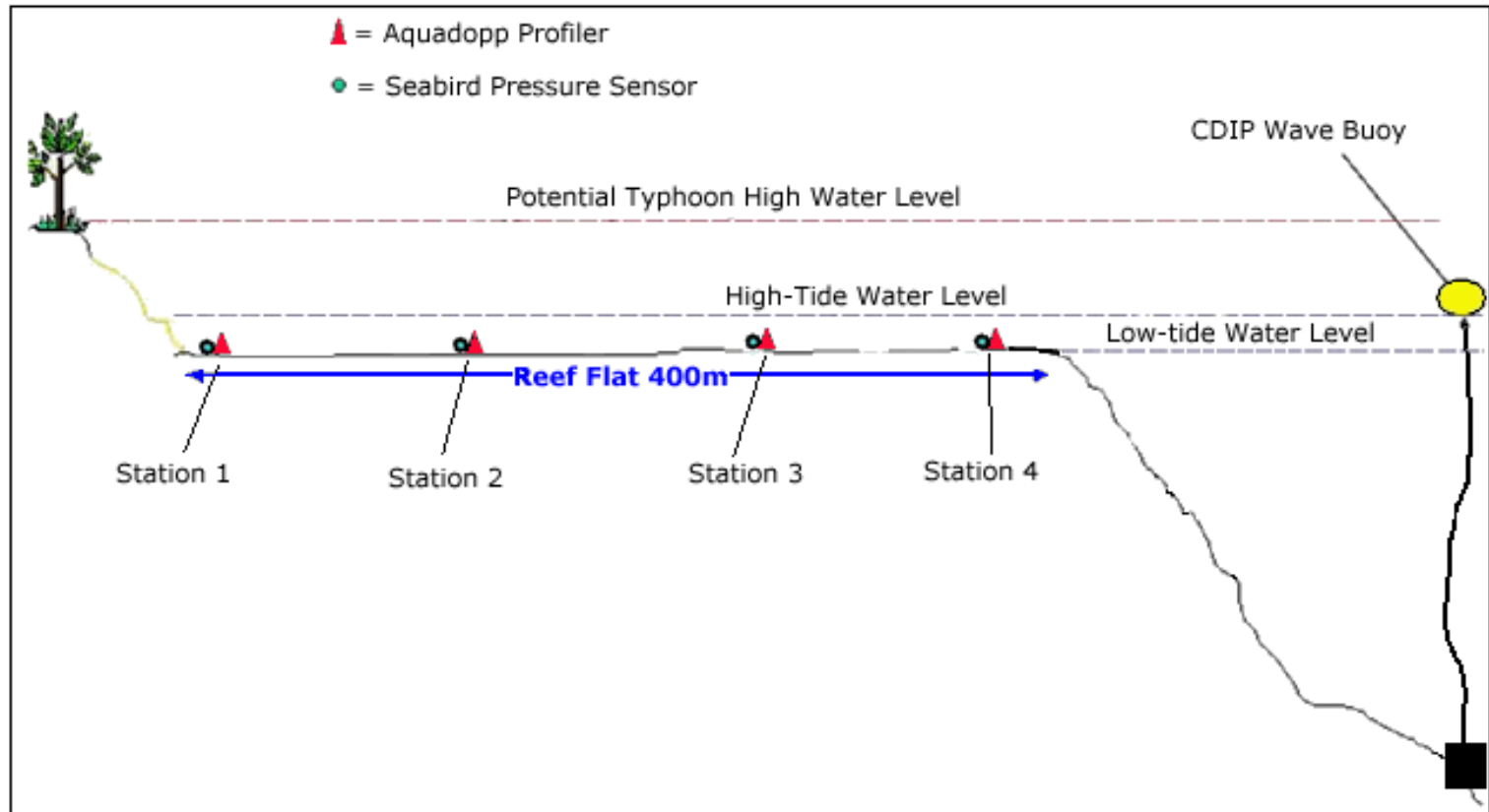
0.218

'n-kd' γ -scaling

0.204



Verification - Field



Verification

Guam V01

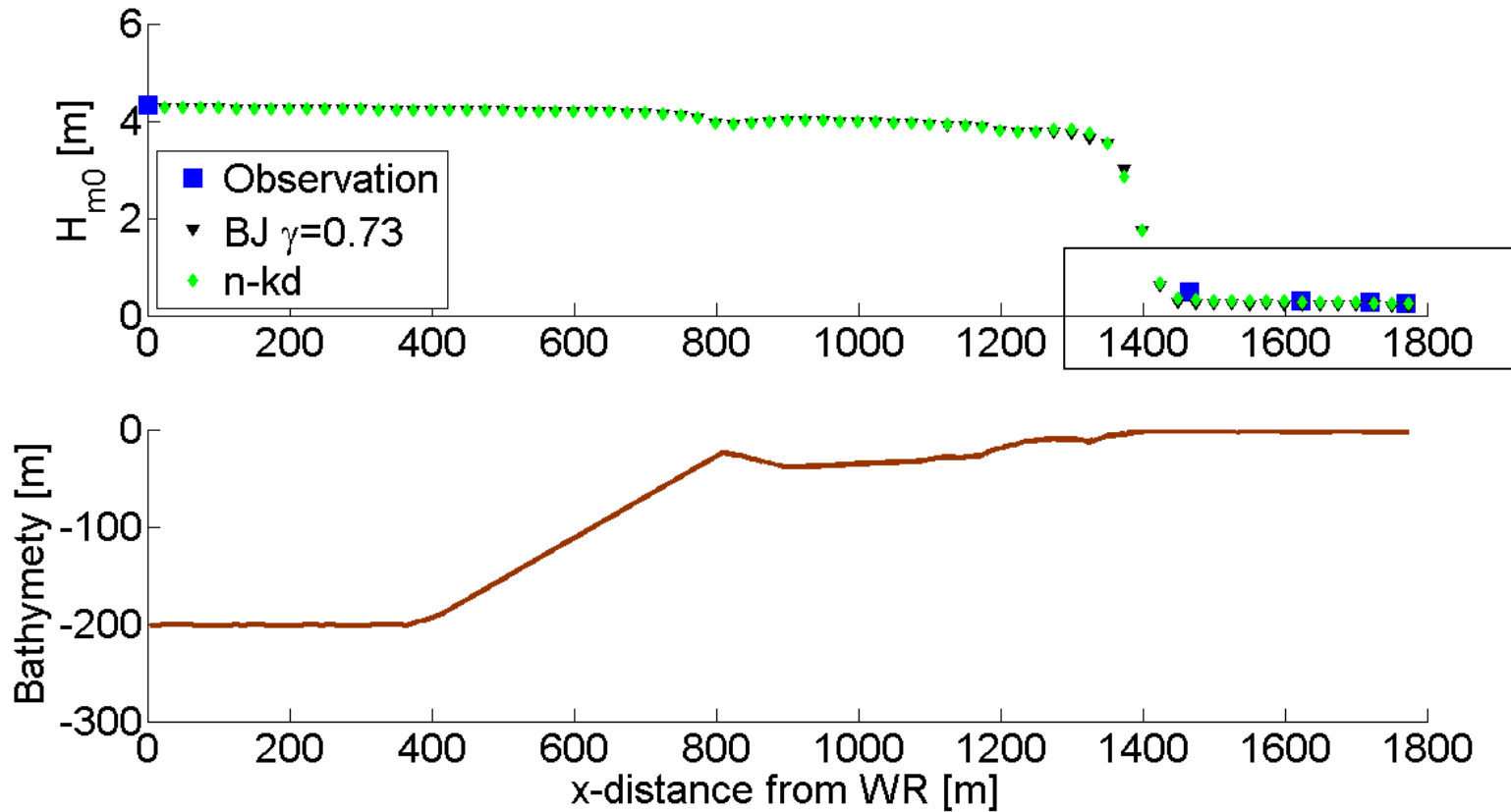
Scatter Index

$\gamma = 0.73$

0.382

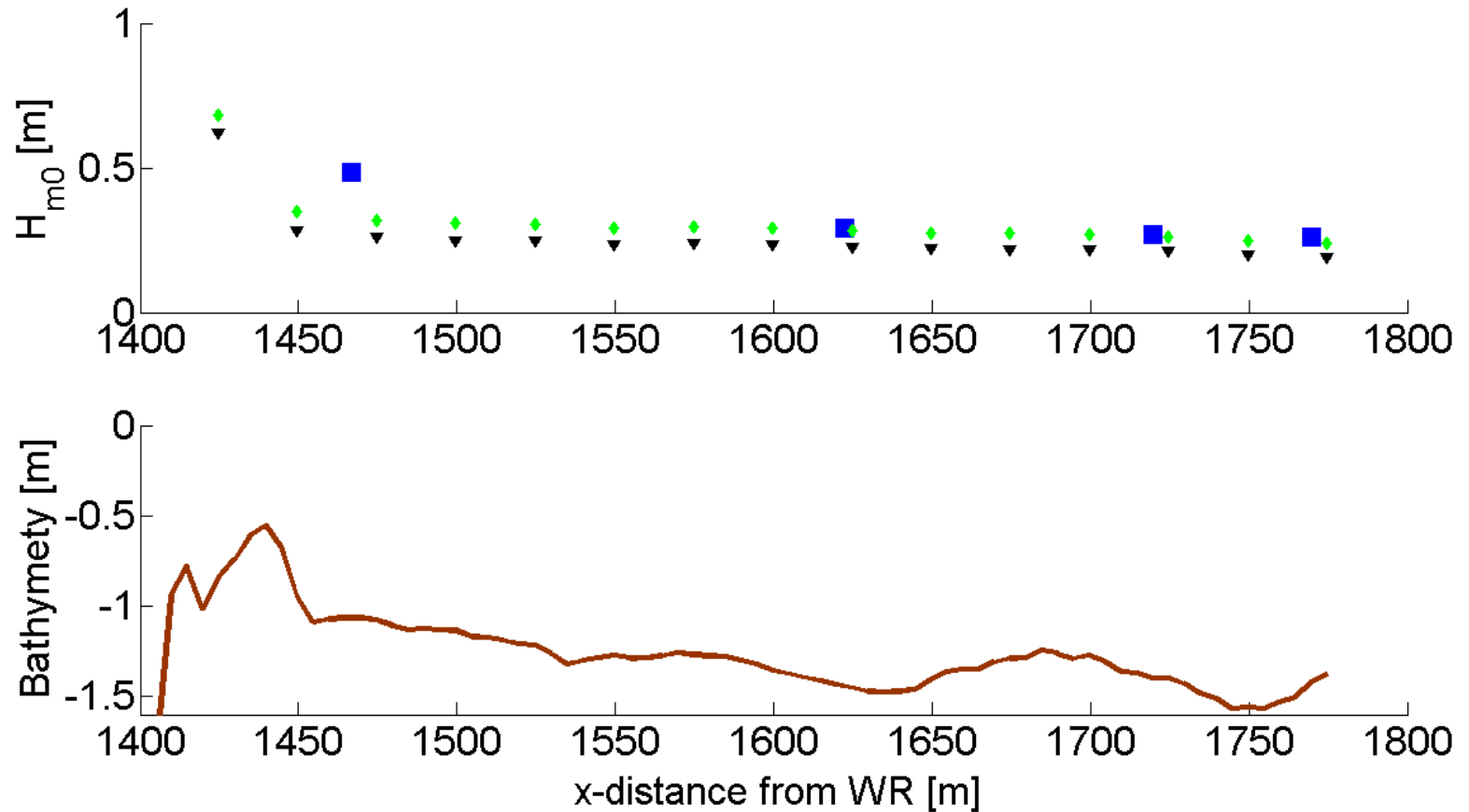
'n-kd' γ -scaling

0.254



Verification

Guam V01	Scatter Index
$\gamma = 0.73$	0.382
'n-kd' γ -scaling	0.254



Verification - Field

Location	No. Cases	$\gamma = 0.73$	n-kd
Amelande Zeegat (2007)	3	0.142	0.091
Haringvliet (1987)	2	0.200	0.152
Guam (2006)	4	0.435	0.327
Average		0.259	0.190

Concluding Remarks

- New γ -scaling unifies a number of concepts in literature and is dependent on slope, n and normalized depth, kd .
- New scaling generally OK including over reefs, tidal flats and lakes.

An aerial photograph of a tropical beach. The water is a vibrant turquoise color, transitioning to a deeper blue further out. The beach is a wide, white sand strip. The sky is a pale, hazy blue. The text "Thank You!" is centered over the image in a large, black, sans-serif font.

Thank You!