ICCE 2018
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018

Validation Of A Buoyancy-Modified Turbulence Model By Numerical Simulations Of Breaking Waves Over A Fixed Bar

Brecht DEVOLDER[1,2], Peter TROCH[1], Pieter RAUWOENS[2]

[1]Ghent University, Department of Civil Engineering, Belgium

[2]KU Leuven, Department of Civil Engineering, Technology Cluster Construction, Belgium

36th International Conference on Coastal Engineering (ICCE 2018)

July 30 – August 3, 2018, Baltimore, Maryland, United States of America

GHENT UNIVERSITY

KU LEUVEN

fwo

FACULTY OF ENGINEERING AND ARCHITECTURE

Department of Civil Engineering


UNIVERSITEIT
GENT

Overview

- **CFD numerical wave tank**

- **RANS turbulence modelling**
  - Wave propagation
  - Wave breaking

- **Breaking waves over a fixed bar**

- **Conclusions**

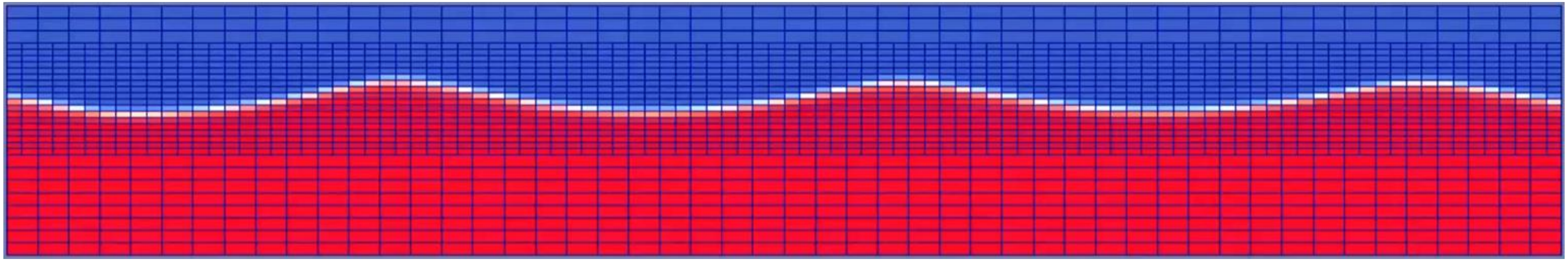
CFD numerical wave tank

- Non-linear viscous numerical wave tank in OpenFOAM
  - = box filled with water (red) and air (blue)
  - *p* and *U* : Navier-Stokes equations
  - volume fraction *α* : Volume of Fluid (VoF) method

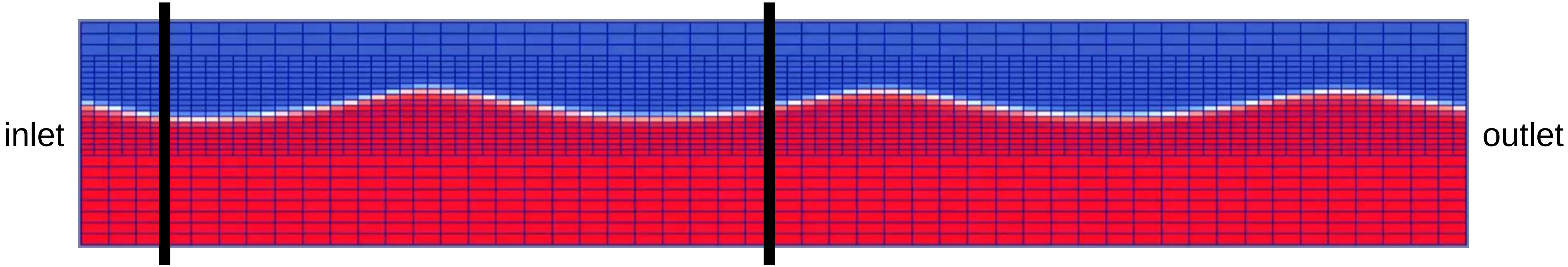
OpenFOAM
The OpenFOAM Foundation

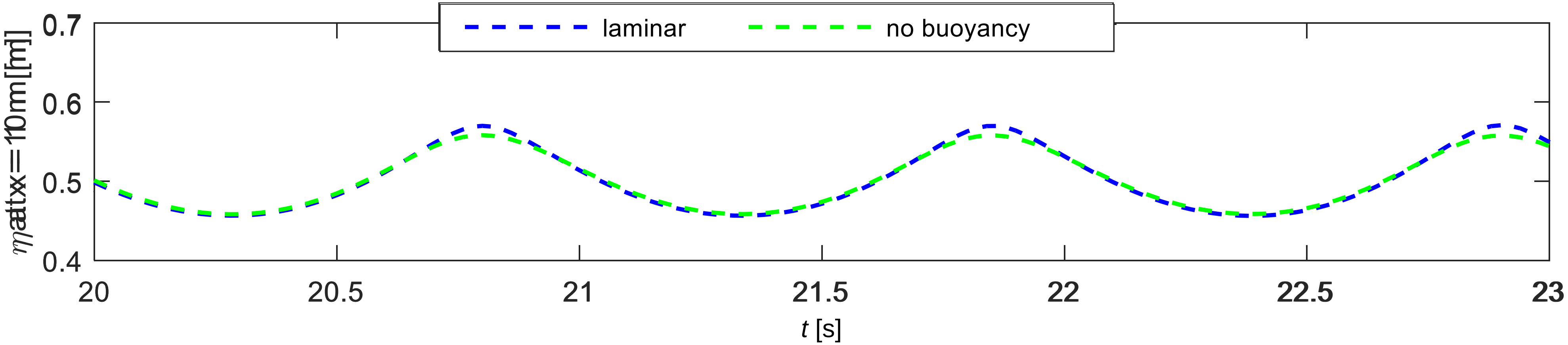
- Boundary conditions for wave generation and wave absorption

IHFOAM

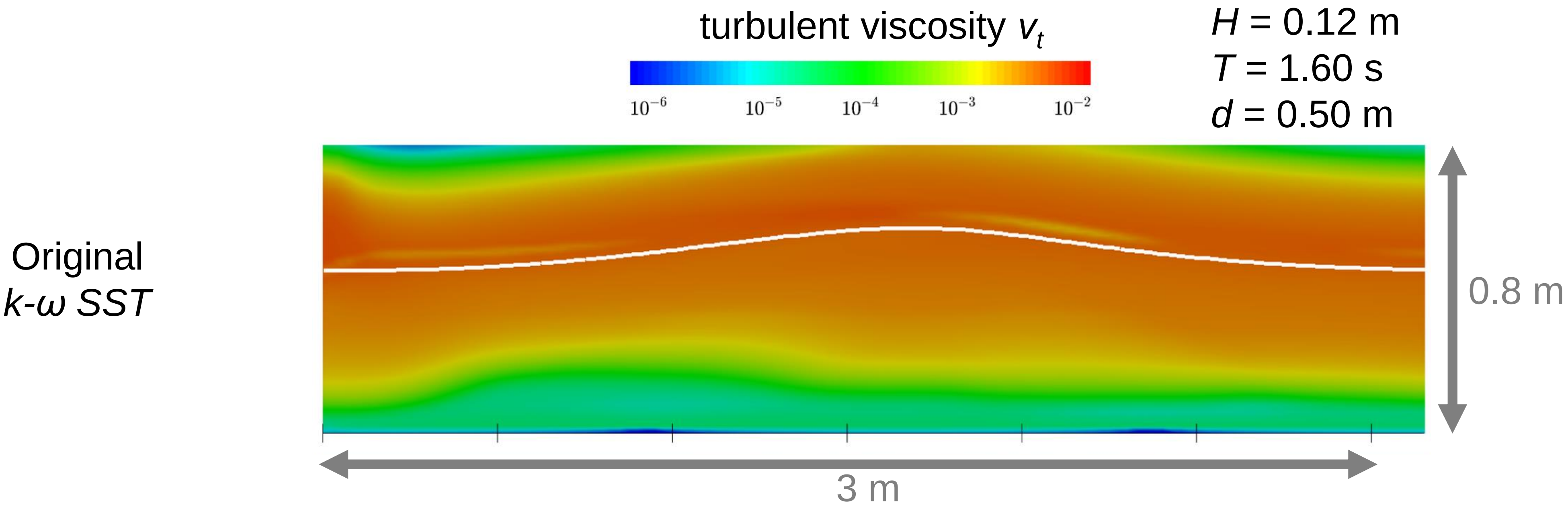


Wave damping due to RANS turbulence modelling





Wave damping due to RANS turbulence modelling



$$\frac{\partial k}{\partial t} + \frac{\partial u_j k}{\partial x_j} - \frac{\partial}{\partial x_j}\left[(\nu + \sigma_k \nu_t)\frac{\partial k}{\partial x_j}\right] = P_k - \beta^* \omega k \qquad P_k = \min\left(\nu_t \frac{\partial u_i}{\partial x_j}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right), 10\beta^* k\omega\right)$$

$$\frac{\partial \omega}{\partial t} + \frac{\partial u_j \omega}{\partial x_j} - \frac{\partial}{\partial x_j}\left[(\nu + \sigma_\omega \nu_t)\frac{\partial \omega}{\partial x_j}\right] = \frac{\gamma}{\nu_t} G - \beta\omega^2 + 2(1 - F_1)\frac{\sigma_{\omega 2}}{\omega}\frac{\partial k}{\partial x_j}\frac{\partial \omega}{\partial x_j}$$

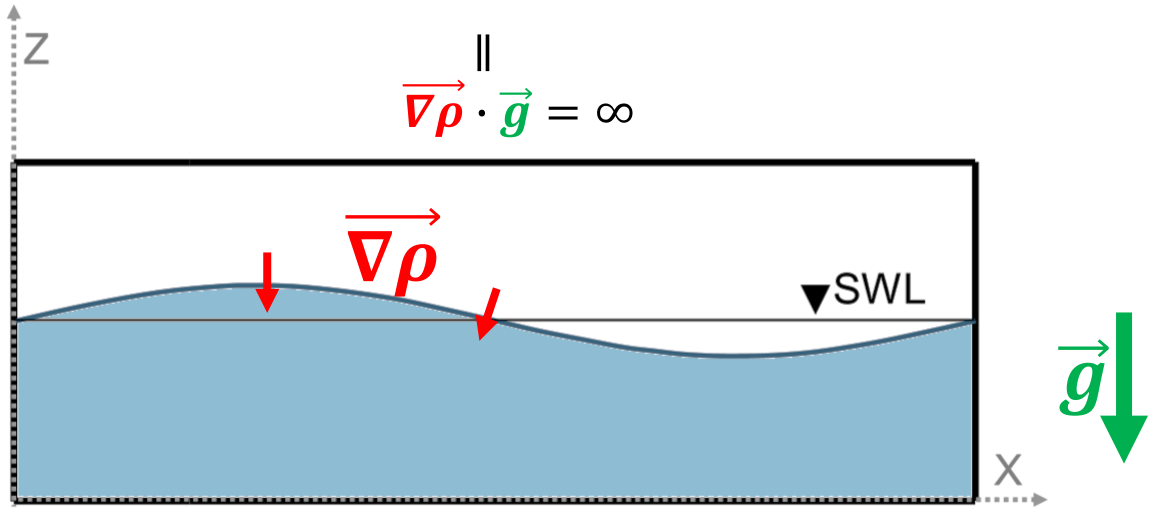
$$\nu_t = \frac{a_1 k}{\max(a_1 \omega, S F_2)}$$

Buoyancy-modified turbulence model

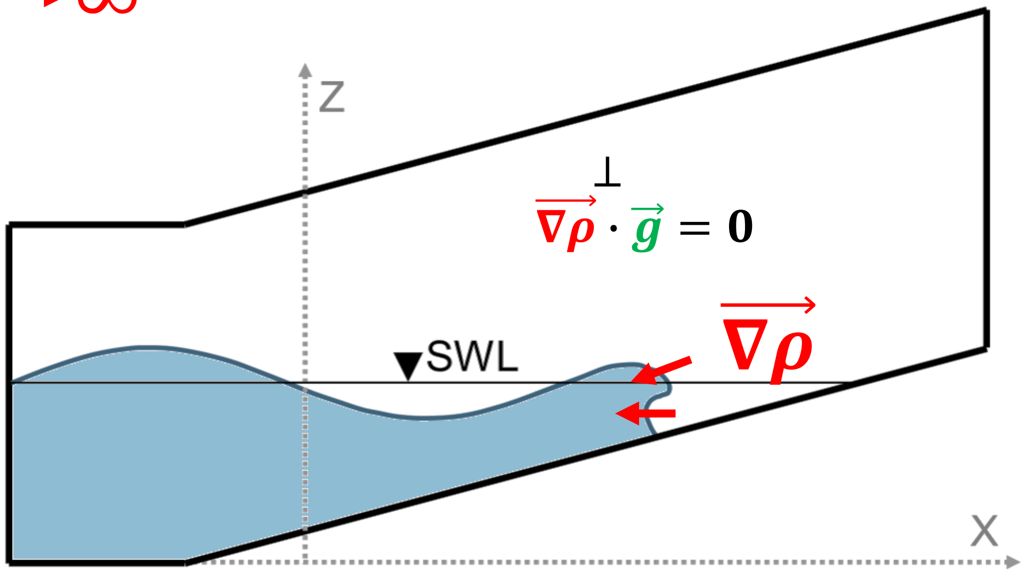
- Density included in the *k*-equation and *ω*-equation for *k-ω* and *k-ω SST*
- Buoyancy source term G_b in the *k*-equation (implicitly implemented):

$$G_b = -\frac{\nu_t}{\sigma_t}\overrightarrow{\nabla\rho}\cdot\vec{g}$$

↳ ∞



wave propagation: $\nu_t \rightarrow 0$

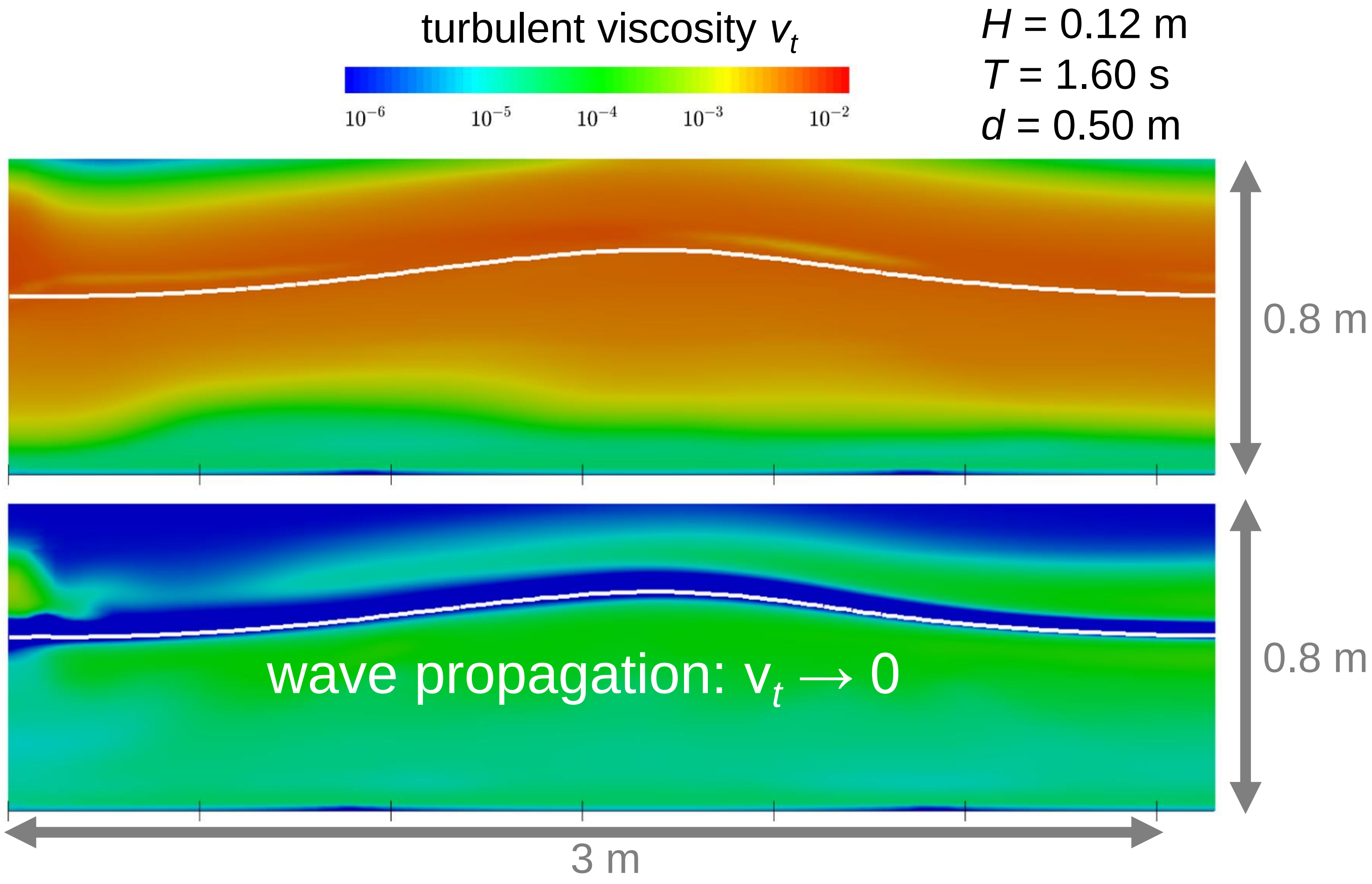


wave breaking : $G_b \rightarrow 0$

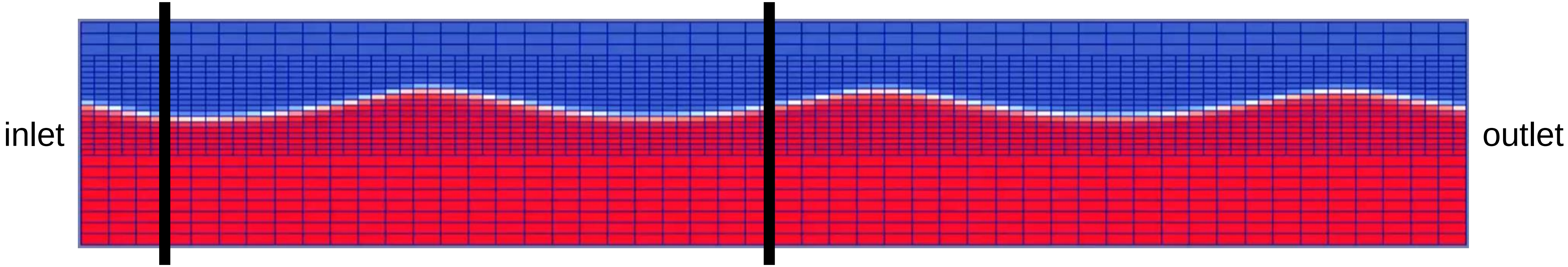
Wave damping due to RANS turbulence modelling

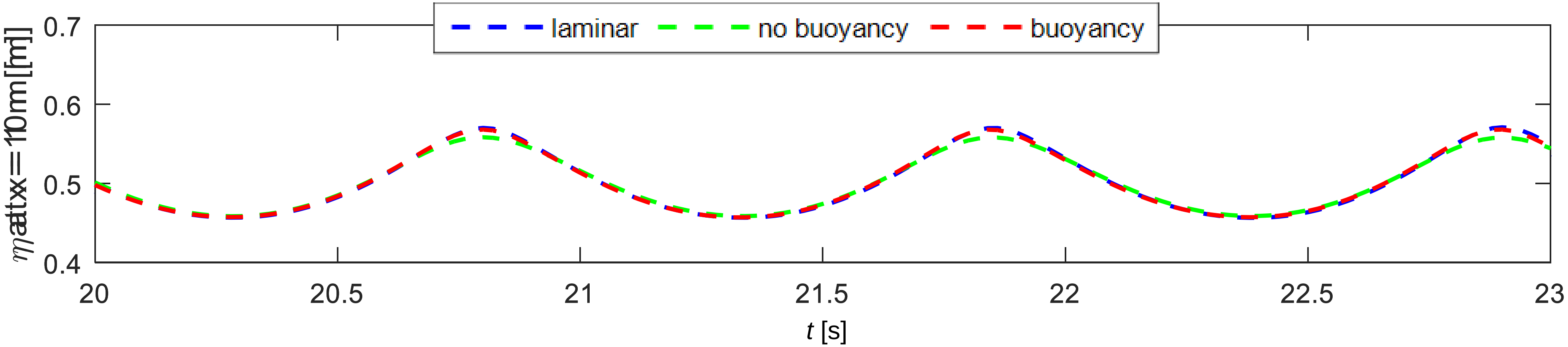
Original
k-ω SST

Buoyancy-modified
k-ω SST



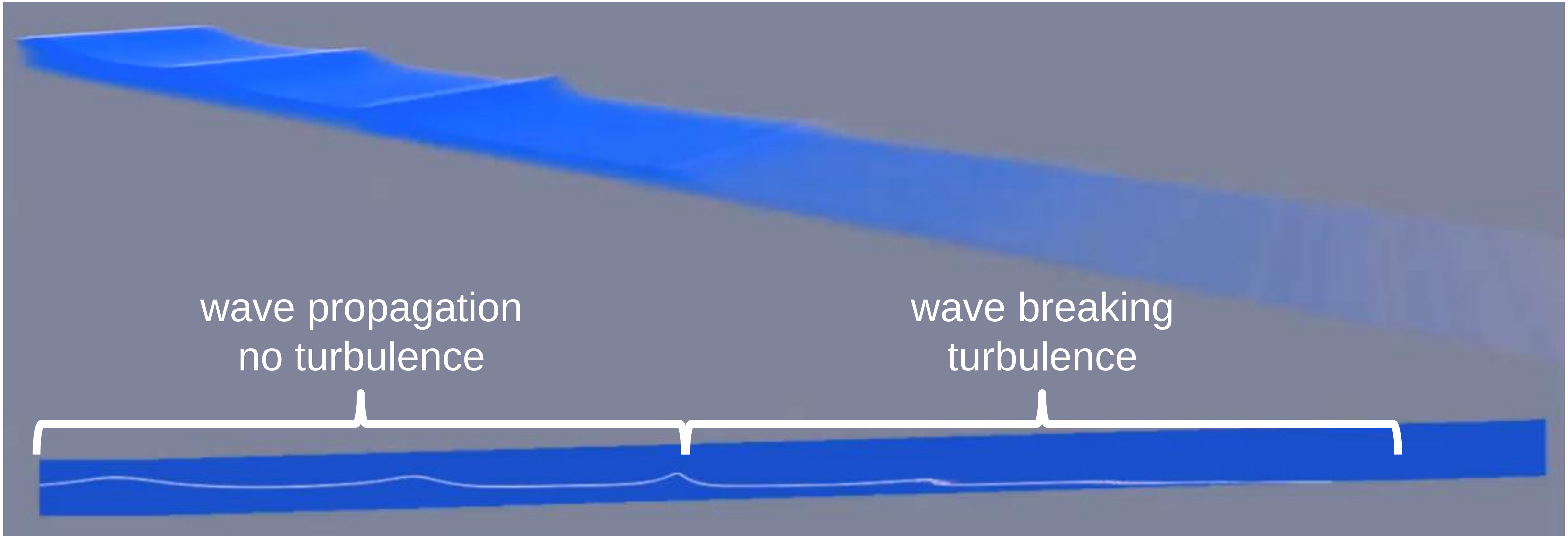
Wave damping due to RANS turbulence modelling





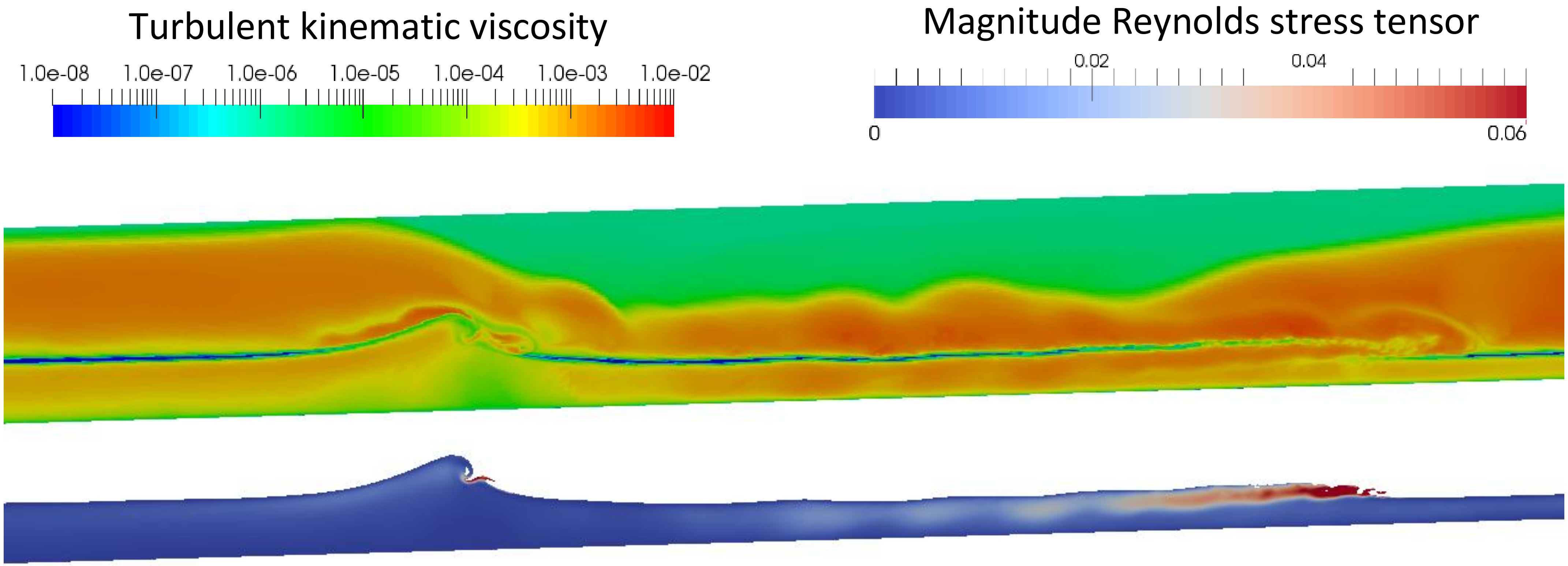
Wave breaking (spilling)

Experiments: F.C.K. Ting, J.T. Kirby, Observation of undertow and turbulence in a laboratory surf zone, Coastal Engineering 24 (1994) 51–80.



Wave breaking (spilling)

Experiments: F.C.K. Ting, J.T. Kirby, Observation of undertow and turbulence in a laboratory surf zone, Coastal Engineering 24 (1994) 51–80.

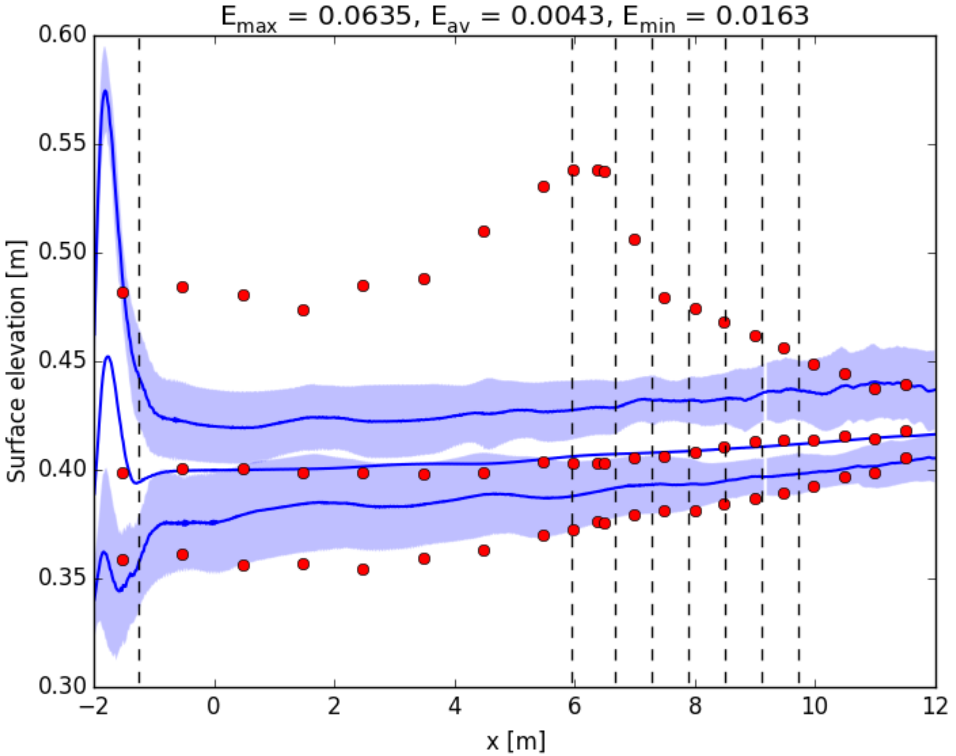


wave breaking : $G_b \rightarrow 0$

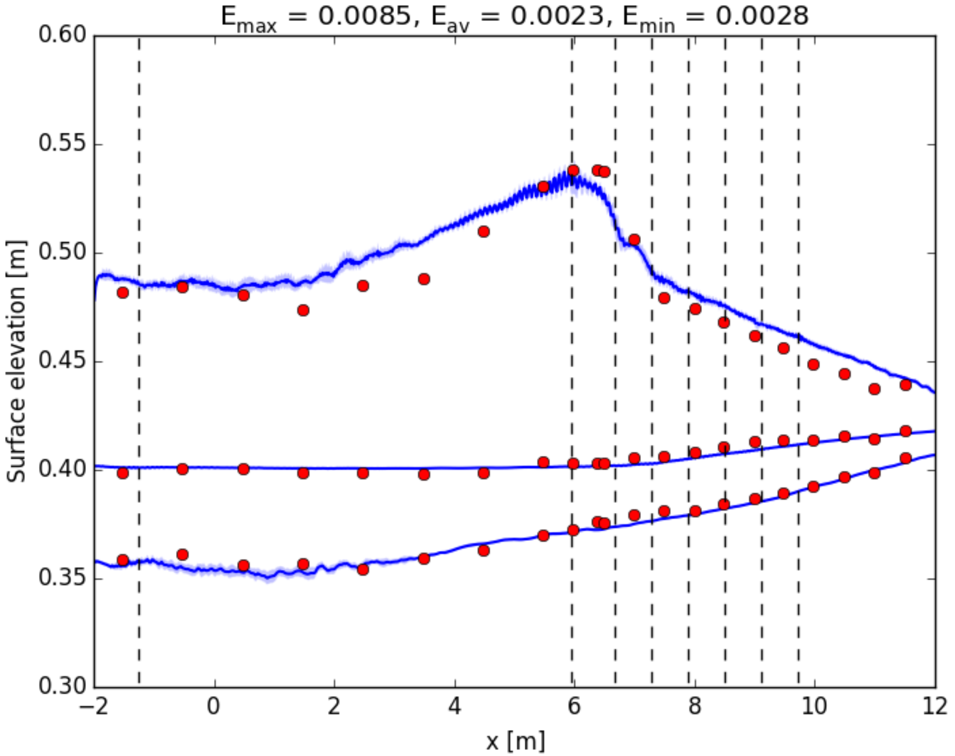
Wave breaking (spilling)

Experiments: F.C.K. Ting, J.T. Kirby, Observation of undertow and turbulence in a laboratory surf zone, Coastal Engineering 24 (1994) 51–80.

original *k*-*ω* model



buoyancy-modified *k*-*ω* model

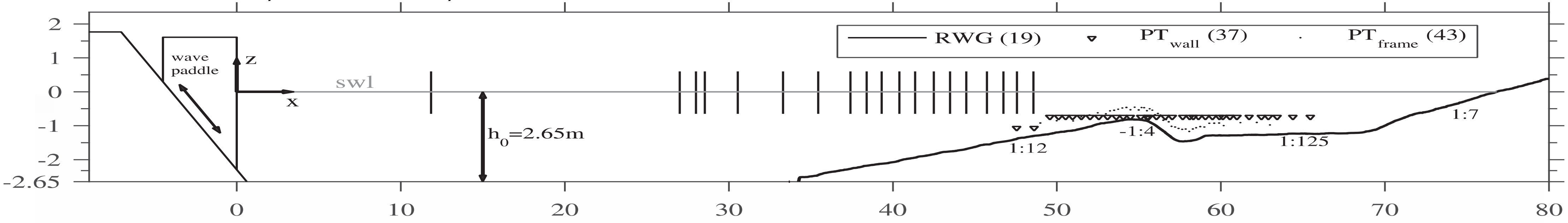


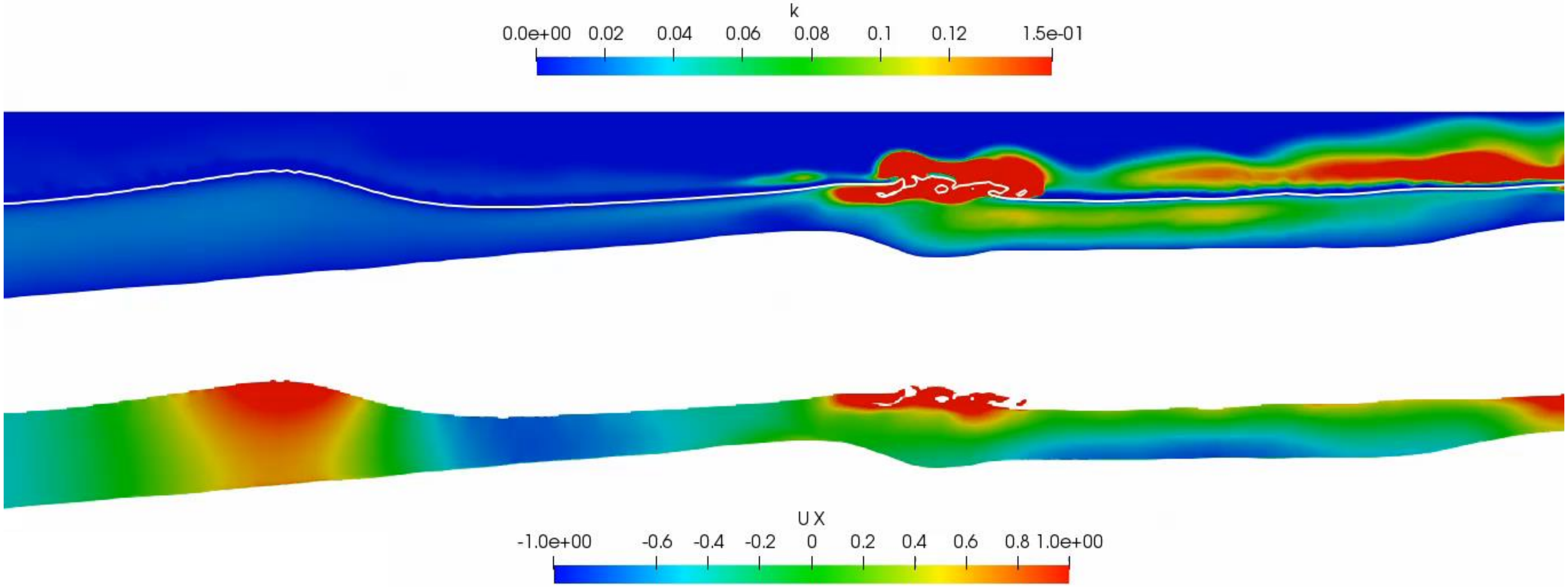
https://github.com/BrechtDevolder-UGent-KULeuven/buoyancyModifiedTurbulenceModels

Breaking waves over a fixed bar (plunging)

Experiments: van der A et al. (2017): Large-scale laboratory study of breaking wave hydrodynamics over a fixed bar, Journal of Geophysical Research: Oceans, vol. 122, pp. 3287–3310.

H = 0.85 m ; T = 4.00 s ; d = 2.65 m

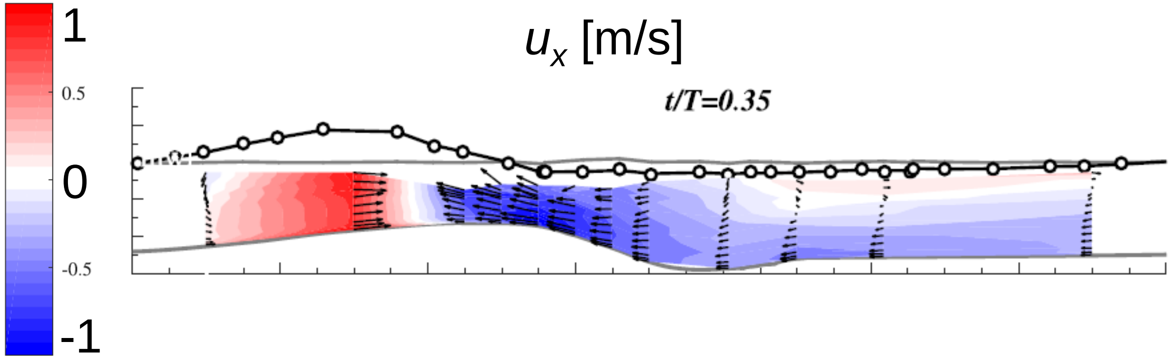
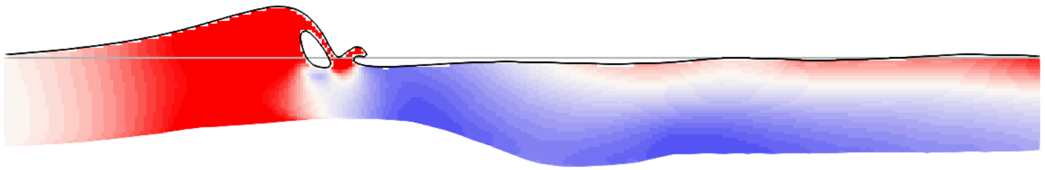
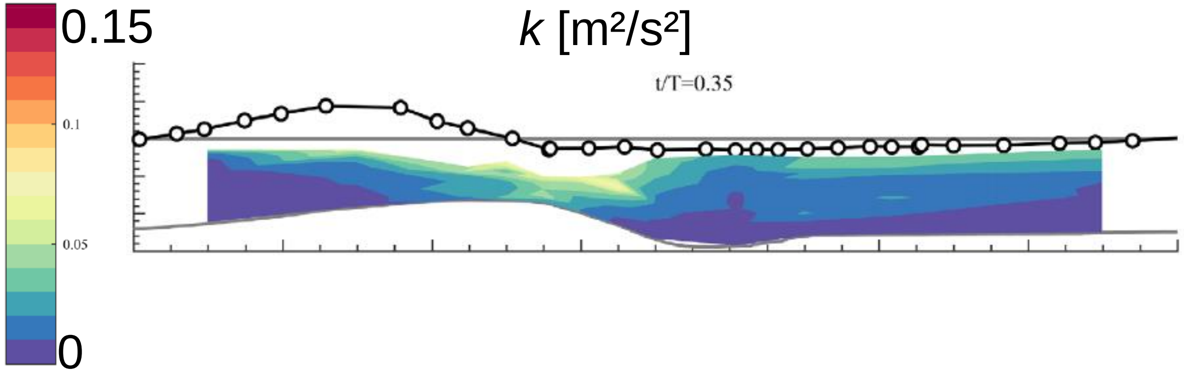
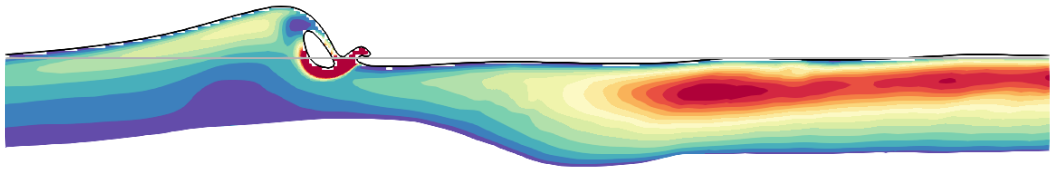




Breaking waves over a fixed bar (plunging)

Experiments: van der A et al. (2017): Large-scale laboratory study of breaking wave hydrodynamics over a fixed bar, Journal of Geophysical Research: Oceans, vol. 122, pp. 3287–3310.

Outlook: validation of surface elevations, velocity profiles and turbulent quantities

Experiments	CFD simulation
u_x [m/s]	u_x [m/s]
	
k [m²/s²]	k [m²/s²]
	

Conclusions

- Enhanced wave modelling using buoyancy-modified RANS turbulence models
- No wave damping due to RANS turbulence modelling using a two-phase fluid solver
- More accurate predictions of the turbulent quantities in the flow field under breaking waves

Brecht DEVOLDER (MS, PhD)

Researcher
Department of Civil Engineering
Ghent University and KU Leuven
Brecht.Devolder@UGent.be
Brecht.Devolder@KULeuven.be

GHENT UNIVERSITY
KU LEUVEN
fwo
FACULTY OF ENGINEERING AND ARCHITECTURE
Department of Civil Engineering