Implementation of the *Verduin and Backhaus* seagrass-current interaction into the General Ocean Turbulence Model (GOTM). A short feasibility study

by HANS BURCHARD AND KARSTEN BOLDING

The seagrass-current interaction has been successfully simulated by *Verduin and Backhaus* [1998] by means of coupling an ocean circulation model (HAMSOM) and a Lagrangian tracer model. The model set-up was basically two-dimensional with a vertical and a horizontal coordinate. A harmonic swell wave travelling into the direction of the positive x-coordinate had been specified at one open boundary.
The seagrass was represented by passive Lagrangian tracers which freely followed the flow as long as they were located inside prescribed excursion limits. The movement was simply frozen when the excursion limit was reached and the flow tendency was to carry them even further out. Only in that situation, the seagrass tracers had an effect on the current speed by exerting a quadratic friction on the flow.
The basic result of *Verduin and Backhaus* [1998] for a location inside the seagrass meadow was, that the mean kinetic energy had a local maximum just above the upper reach of the seagrass. That was found to be in good agreement with field measurements.
The basic assumption which leads to the idea of implementing this concept into a one-dimensional model with only a vertical coordinate is, that horizontal gradients of relevant quantities are neglegable. Here, the concept of *Verduin and Backhaus* [1998] is implemented into the General Ocean Turbulence Model (GOTM, see *Burchard et al.* [1999]), which includes a number a number of different turbulence closure models. The advantage of this one-dimensional approach is that a higher vertical resolution and a higher number of different model runs can be achieved. The disadvantage, of course, is the lower generality. Processes typical for the lateral edges of seagrass canopies can for example not be examined.
In this one-dimensional approach, the sea surface elevation ζ and its gradient have to be prescribed. According to *Verduin and Backhaus* [1998] we use the following formula:

$$\zeta(x,t) = A\sin\left(\frac{2\pi}{\lambda}x - \frac{2\pi}{T}t\right) \tag{1}$$

with the amplitude $A = 0.15$ m, the wavelength $\lambda = 100$ m and the period $T = 15$ s. The horizontal gradient $\partial_x\zeta$ is calculated from (1) as well.
The basic equations used here are the momentum equation,

$$\partial_t u - \partial_z(\nu_t\partial_z u) = -g\partial_x\zeta - C_f u|u|, \tag{2}$$

and the tracer equation for seagrass:

$$\partial_t x = \begin{cases} u & \text{for } |x| < x_{\max} \text{ or } x\cdot u < 0, \\ 0 & \text{else.} \end{cases} \tag{3}$$

The seagrass friction coefficient C_f is only non-zero at heights where seagrass tracers are at their excursion limits:

$$C_f = \begin{cases} C_f^{\max} & \text{for } |x| = x_{\max}, \\ 0 & \text{else.} \end{cases} \tag{4}$$

The maximum excursion limits $x_{\max}$ and the friction coefficients $C_f^{\max}$ are given in figures 1 and 2.

As a turbulence model, the k-ε two-equation model as presented by *Burchard et al.* [1999] has been chosen here. The production of turbulence is calculated here as the sum of shear production and friction loss at the seagrass leaves:

$$P = \nu_t(\partial_z u)^2 + \alpha C_f |u|^3. \tag{5}$$

Here, $0 \leq \alpha \leq 1$ gives the efficiency of turbulence production caused by friction between current and seagrass leaves.
Two experiments are performed:

A: Now extra turbulence is produced by leaf-current friction, $\alpha = 0$.

B: All friction losses between leaves and current are converted to turbulence, $\alpha = 1$.

The result for the two runs are shown in figures 6 - 7. The sensivity to α seems to be small, only the profiles of averaged turbulent kinetic energy are significantly influenced. The results of *Verduin and Backhaus* [1998] are basically reproduced. Especially, the local maximaum of mean kinetic energy just above the upper reach of seagrass is well simulated. The only striking difference is that in our model the seagrass shows an asymmetry for the excursion which is following the residual transport caused by the waves travelling from left to right. *Verduin and Backhaus* [1998] found an asymmetry into the other direction. This difference might be caused by the neglect of horizontal processes such as momentum advection or inhomogeneities in the seagrass meadow in our one-dimensional model.

Bibliography

[1] Burchard, H., K. Bolding, and M.R. Villarreal, GOTM - a general ocean turbulence model. Theory, applications and test cases. Report EUR 18745 EN, European Commission, 103 pp., 1999.

[2] Verduin, J.J., and J.O. Backhaus, Dynamics of plant-flow interactions for the seagrass *Amphibolis Antarctica*: Field observations and model simulations, *Estuarine Coastal and Shelf Science, 50*, 185-204, 2000.

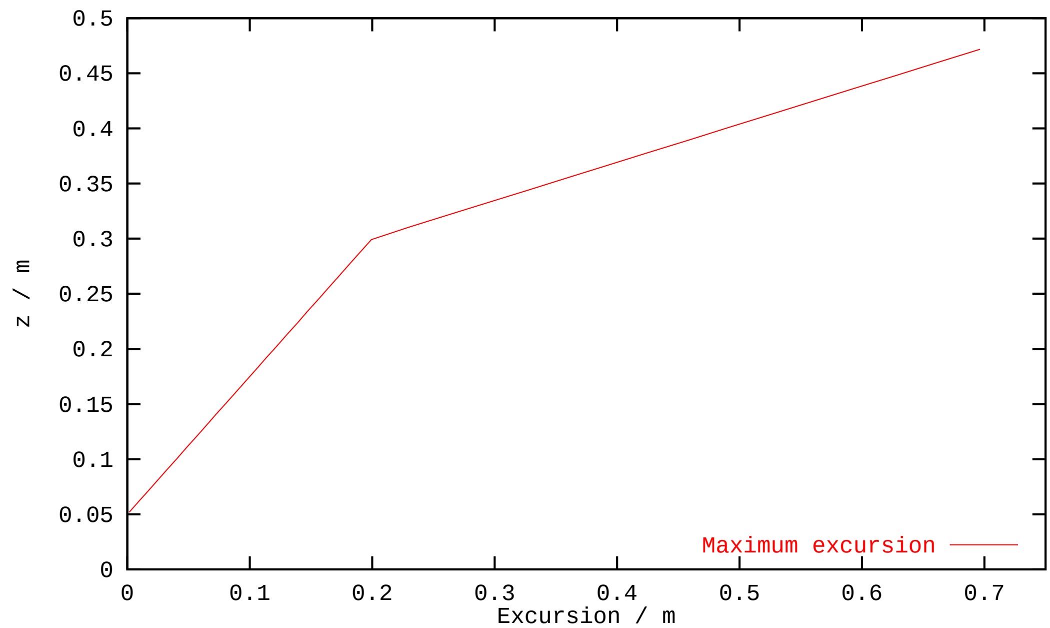

Figure 1: Maximum lateral excursion for the seagrass tracers.

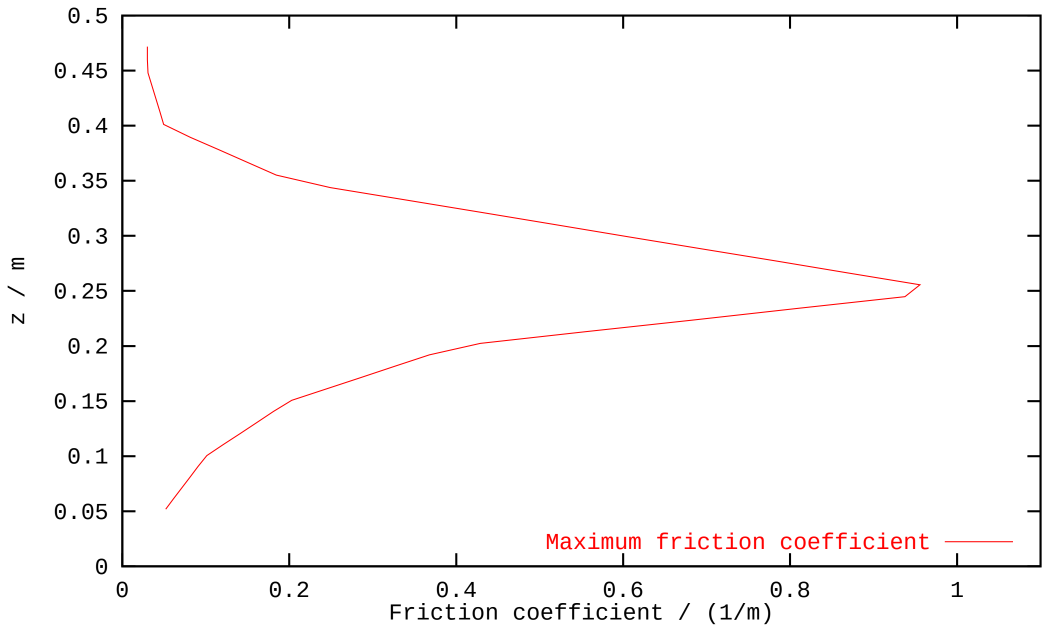

Figure 2: Friction coefficient which the seagrass exerts on the flow in the case of maximum lateral excursion.

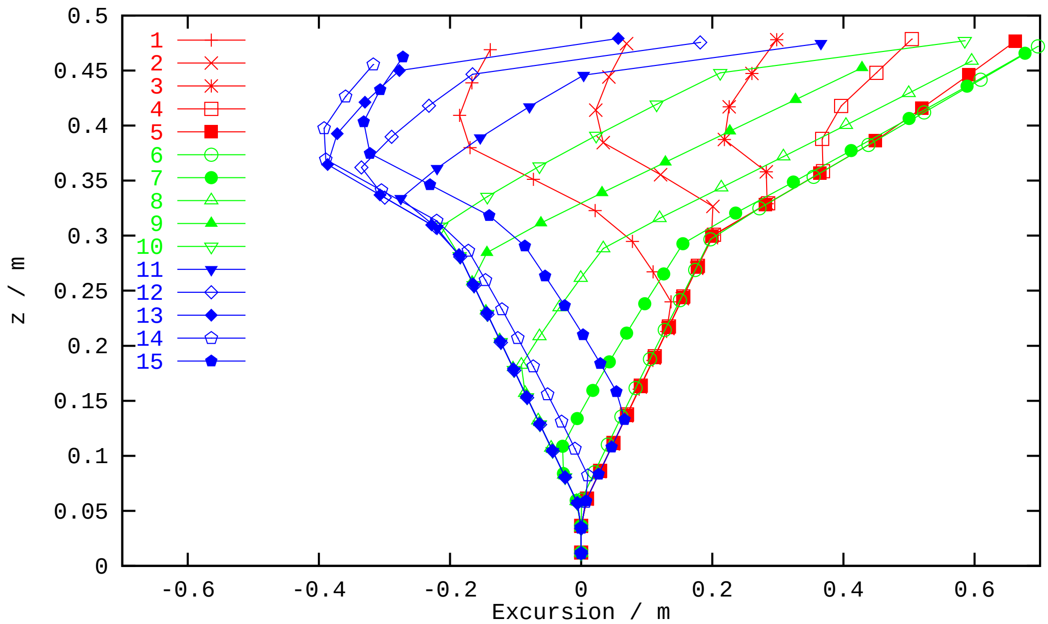

Figure 3: Excursion profiles of the seagrass tracers for experment A during one wave period, the time step between two subsequent profiles is 1 s.

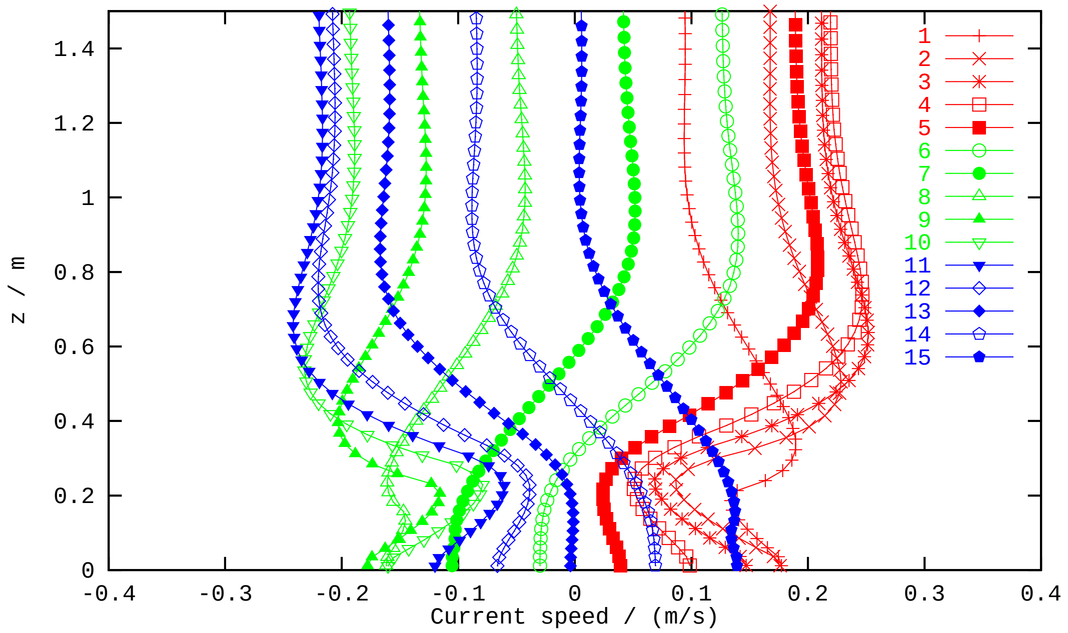

Figure 4: Velocity profiles for experment A during one wave period, the time step between two subsequent profiles is 1 s.

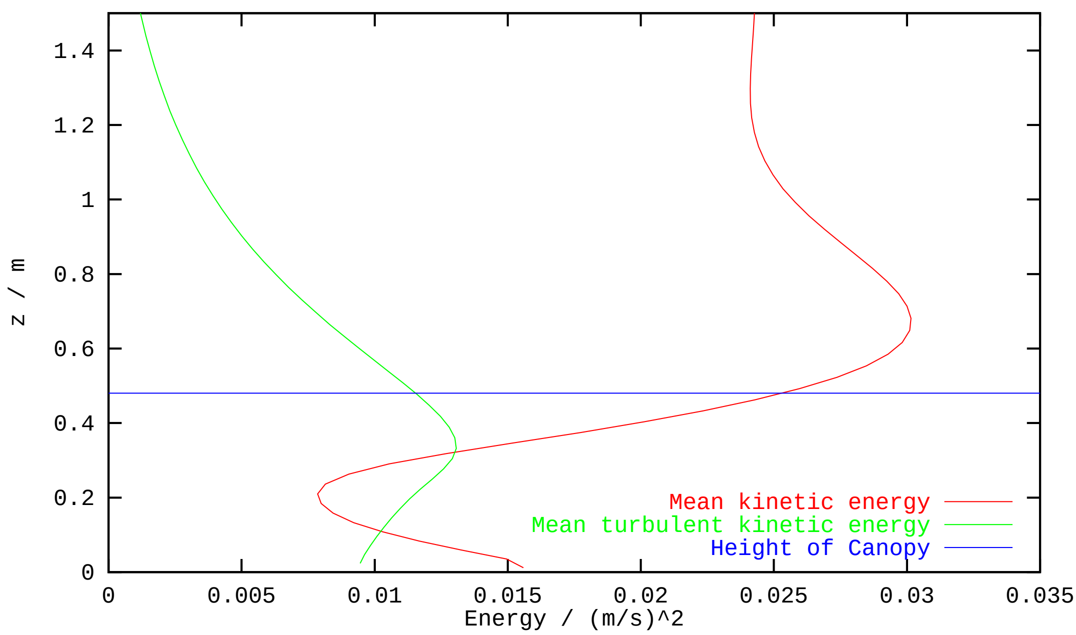

Figure 5: Mean kinetic and turbulent kinetic enery profiles for experment A averaged over one wave period.

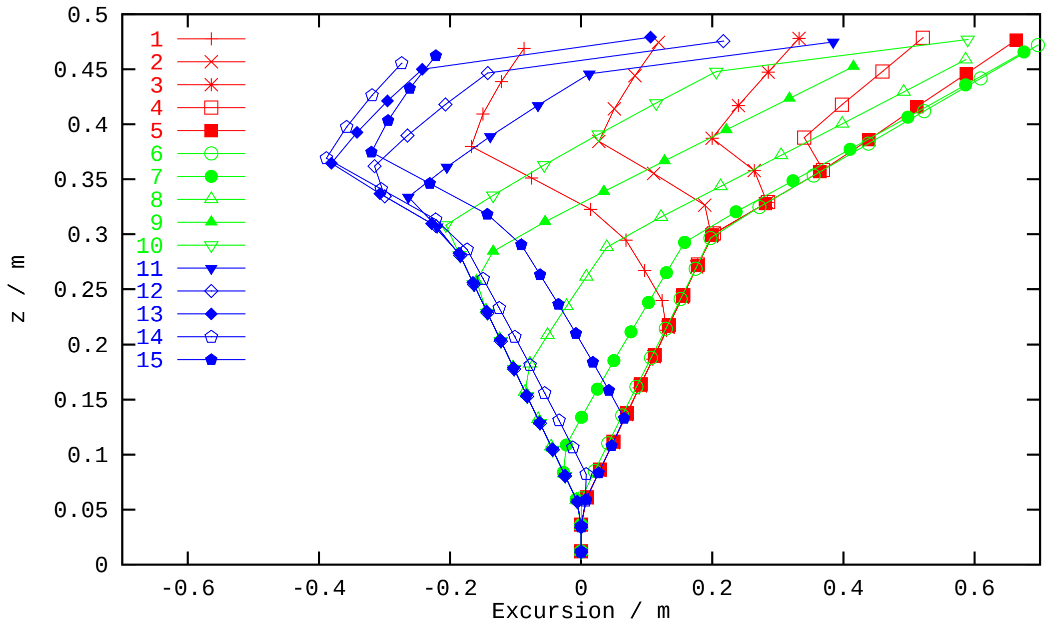

Figure 6: Excursion profiles of the seagrass tracers for experment B during one wave period, the time step between two subsequent profiles is 1 s.

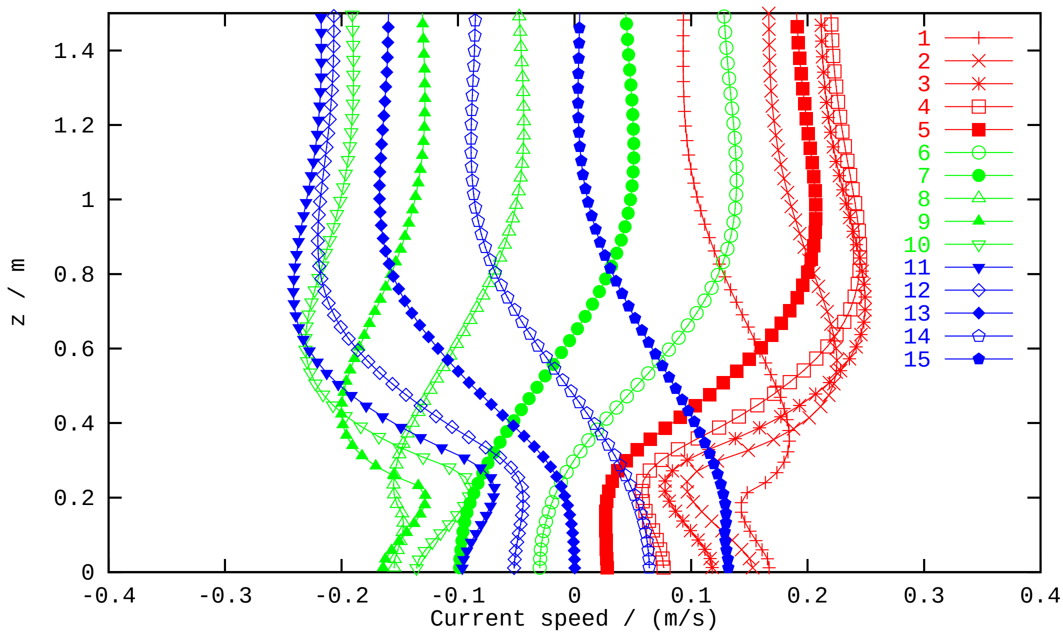

Figure 7: Velocity profiles for experment B during one wave period, the time step between two subsequent profiles is 1 s.

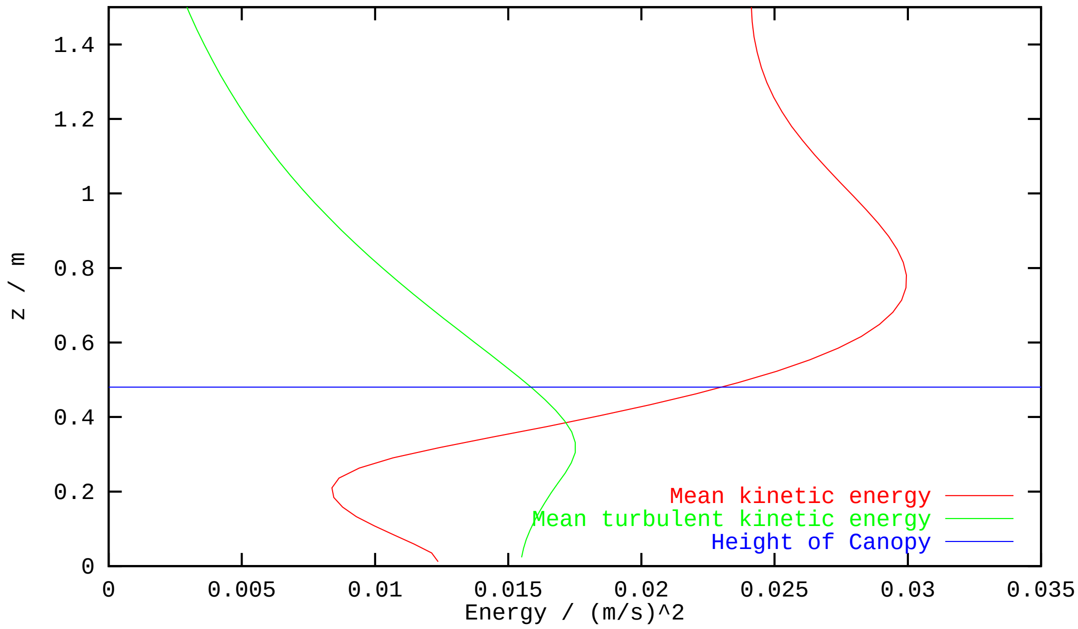

Figure 8: Mean kinetic and turbulent kinetic enery profiles for experment B averaged over one wave period.