Shape of vertical sediment concentration profiles under waves

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1. Objectives

Process-based modeling of sediment concentrations under waves requires a description of the vertical sediment mixing, which is usually parameterized as the sediment diffusivity, $\varepsilon_{s,z}$. We analyze the distribution using new full-scale measurements, bed states and sediment concentrations obtained with a triple-frequency Acoustic Backscatter Sensor. We then compare the obtained $\varepsilon_{s,z}$ profiles to existing formulations.

2. Introduction

➢ Sediment concentrations under waves decrease with height above the bed…

BUT HOW?

➢ Process-based models: $C\, dC/dz = F(\varepsilon_{s,z})$

➢ Various shapes and models suggested for $\varepsilon_{s,z}$ [m^2/s], see Figure 1 and 2.

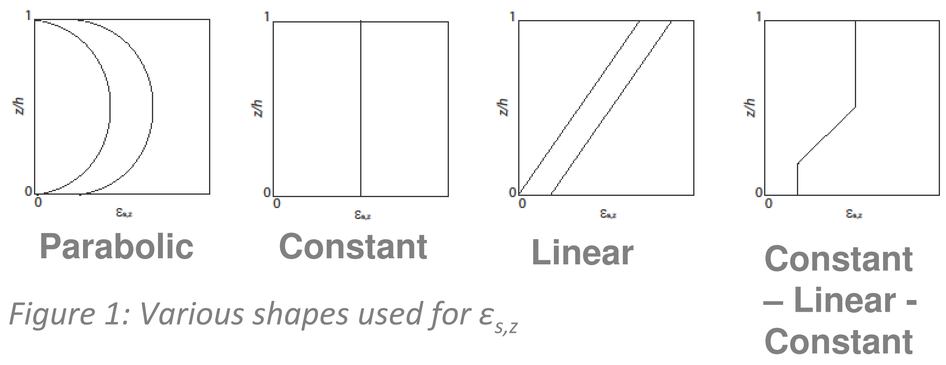

Figure 1: Various shapes used for $\varepsilon_{s,z}$

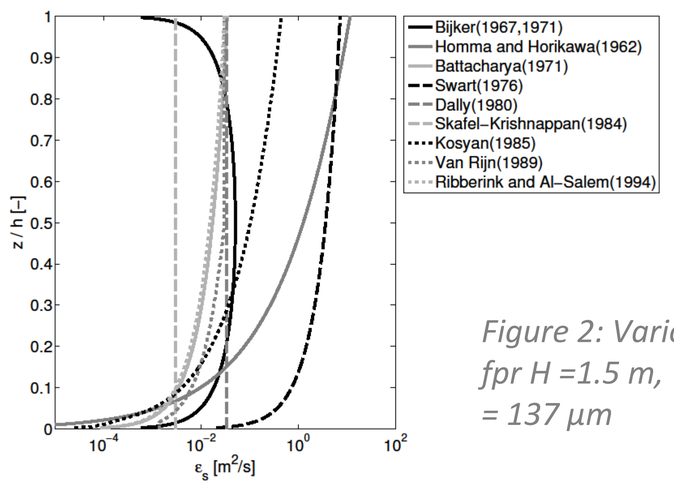

Figure 2: Various models used for $\varepsilon_{s,z}$, fpr H =1.5 m, T=6.5 sec, h=3.5 m, D_{50} = 137 µm

3. Experimental set up

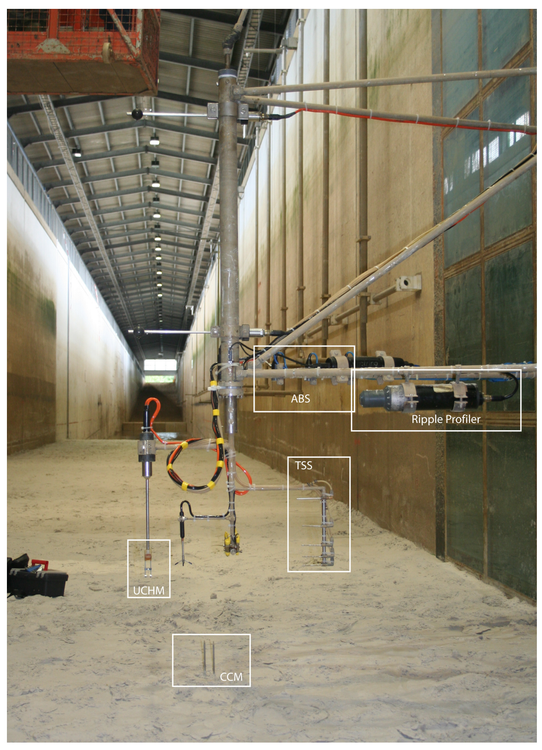

Figure 3: 'Twente-Utrecht' Wallframe in the Großer Wellen Kanal, Hannover, Germany (GWK) with length = 300 m, depth = 7 m and width = 5 m. Used instruments on the frame to measure sediment concentrations: a triple frequency Acoustic Backscatter Sensor (ABS) at 80 cm above the initial bed, a Transverse Suction System (TSS) and Ultra High Concentration Meter (UHCM).

- **Two bed sediments:**
  - Fine: D_{50} = 137 µm, $D_{50,suspended}$ = 118 µm
  - Coarse: D_{50} = 256 µm, $D_{50,suspended}$ = 106 µm
- **Hydrodynamical conditions:**
  - Ripple and sheet flow regime expected; nonetheless ripples did not form in the fine sediments
  - Period T = 6.5 sec, Water depth h = 3.5 m
  - Various wave heights H = [0.7-1.5 m]

4. Results and observations

- Shape of $\varepsilon_{s,z}$ profile for coarse- and fine-grained conditions (A,C) is comparable under high-energetic conditions.
- $\varepsilon_{s,z}$ profiles increase more gradually for the low-energetic conditions (B,D) compared to high-energetic conditions (A,C), possibly due to vortex induced mixing in the ripple regime.
- Parabolic shape in upper-part of the $\varepsilon_{s,z}$ profiles is enforced by the assumption in ABS processing that concentrations go to zero between the bed and the ABS.
- Magnitude of observed $\varepsilon_{s,z}$ for fine-grained conditions (A,B) a factor 10 higher than for coarse-grained experiments (C,D), possibly due to large difference between D_{50} and $D_{50,suspended}$.
- The shape and magnitude of the lower-part of the observed $\varepsilon_{s,z}$ profiles are predicted well by the formulation of Bijker (1971), especially for fine-grained conditions (A,B).

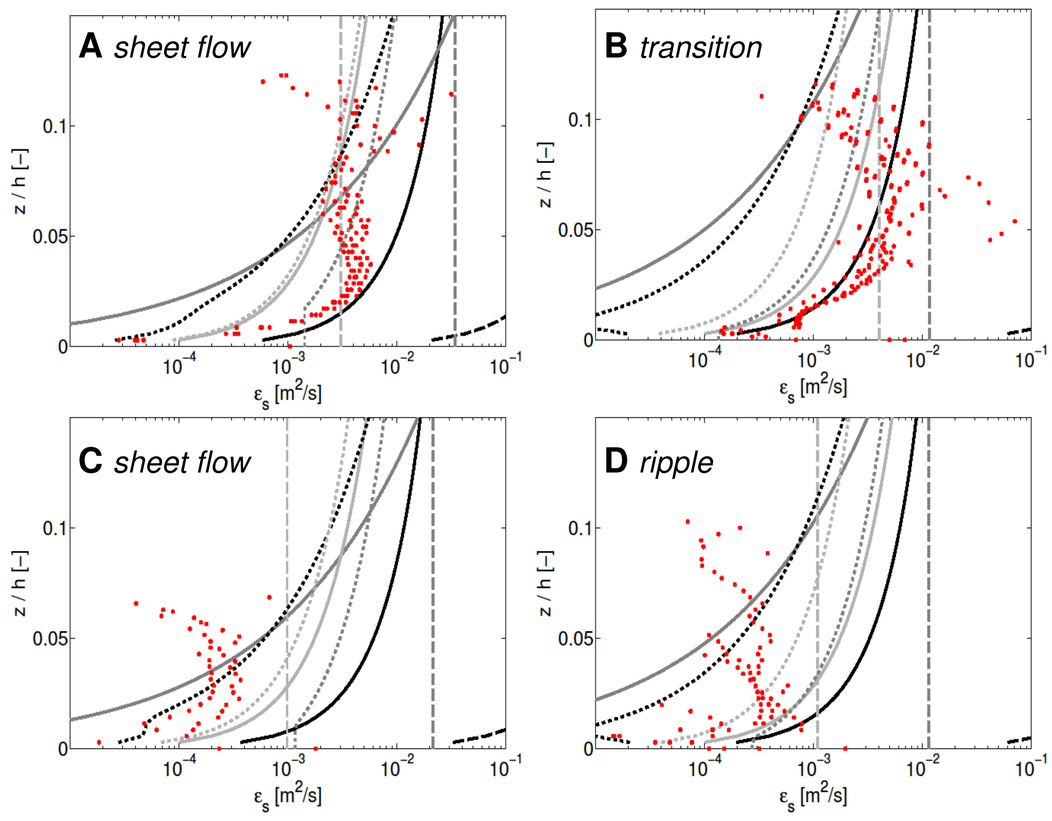

Figure 4: Modelled (lines) and observed (red dots) sediment diffusivities for high- and low energetic conditions. A) H = 1.5 m, fine. B) H = 0.7 m, fine. C) H = 1.5 m, coarse. D) H = 0.7 m, coarse.

5. Conclusions

- **Shape of observed $\varepsilon_{s,z}$ profiles is slightly parabolic under all conditions.**
- **Observed $\varepsilon_{s,z}$ profiles are in the same range as those predicted by existing formulas and are predicted well by the formulation of Bijker (1971).**

Acknowledgements:

Dr. J. Ribberink (Twente University, Enschede), Drs. J.L.M. Schretlen (Twente University, Enschede), Technicians Physical Geography (Utrecht University).