A parameterization of flow separation

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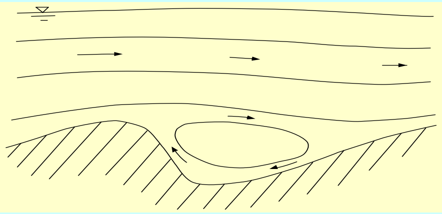
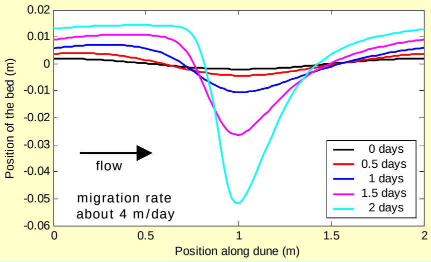
1. Introduction

During floods, dunes develop on the river bed as a result of the increasing discharge. To predict water levels during floods, it is essential to be able to predict the dimensions of those dunes, and their resulting roughness.

During their development, the lee-side of dunes may become so steep that the flow separates over the top of the dune.



A model is available which can simulate the initial development of dunes, when no flow separation occurs. It is based on hydrostatic equations, and uses a partial slip boundary condition at the bed.



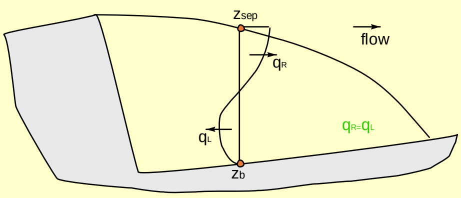
Small initial disturbance in small waterdepth (10 cm). Model and code used: Van den Berg & Van Damme.

To include flow separation in this model, a parameterization of the flow separation zone (FSZ) is proposed.

2. Method

Kroy et al. (2002) state that formation and migration of aeolian sand dunes do not very sensitively depend on the details in the FSZ. Since there is flow recirculation in the FSZ, it might be sufficient to only compute the flow field above the separating streamline. Therefore, we propose a parameterization of this separating streamline.

In the literature, data from various experiments on flow separation behind dunes and steps can be found. We extracted the separation streamline from this data by assuming recirculation in the flow separation zone:



$$q_{fsz} = \int_{z_b}^{z_{sep}} u(z)dz = 0$$

q is specific discharge

The main concepts of the parameterization are:

- Shape of separation zone independent of flow conditions
- 3rd order polynomial: $s(x) = s_3(x^*)^3 + s_2(x^*)^3 + s_1(x^*) + s_0$
- Length of separation zone can be found from:

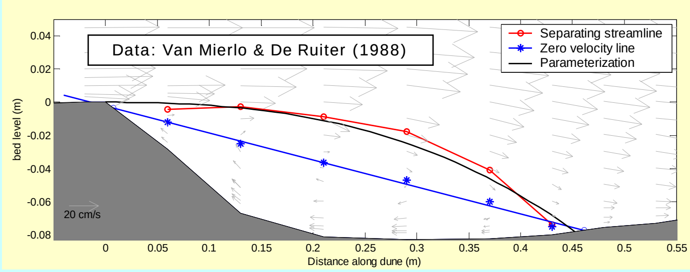
$$\frac{L_{fsz}}{H_{dune}} = 0.19\alpha_s + 5.66$$

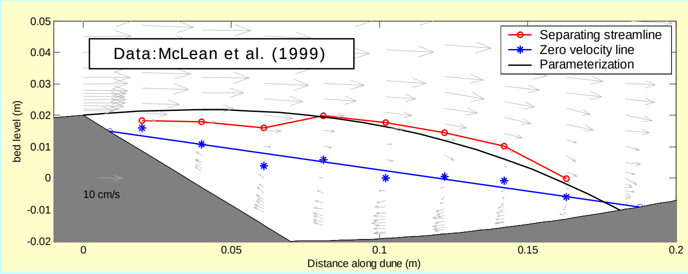
with L_{fsz} the FSZ-length, H_{dune} the dune height at separation and α_s the local bed slope at separation (degrees).

- Smooth connection at separation point gives s_1 and s_0
- Reattachment at an angle of about 25°

3. Results

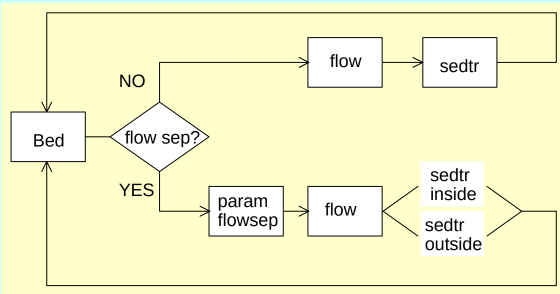
The results of this parameterization are compared with data:





4. Conclusions

The parameterized separating streamline coincides very well with the data. The parameterization is simple to apply. Now, its functioning has to be tested in a dune development model:



5. Discussion and future work

- What is the required boundary condition above the FSZ?
- What are the implications for bed shear stress?
- What about sediment transport in the FSZ?
- What is the influence of turbulence generated in the FSZ on the rest of the flow field?

Acknowledgements

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