Parameterization of wave orbital motion and its effect on long-term morphological development in the nearshore

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River and delta morphodynamics

Introduction

Waves approaching intermediate and shallow water start interacting with the bottom changing their shape and orbital motion (Figure 1). This transformation creates non-linearities on orbital velocities and consequently on sediment transport.

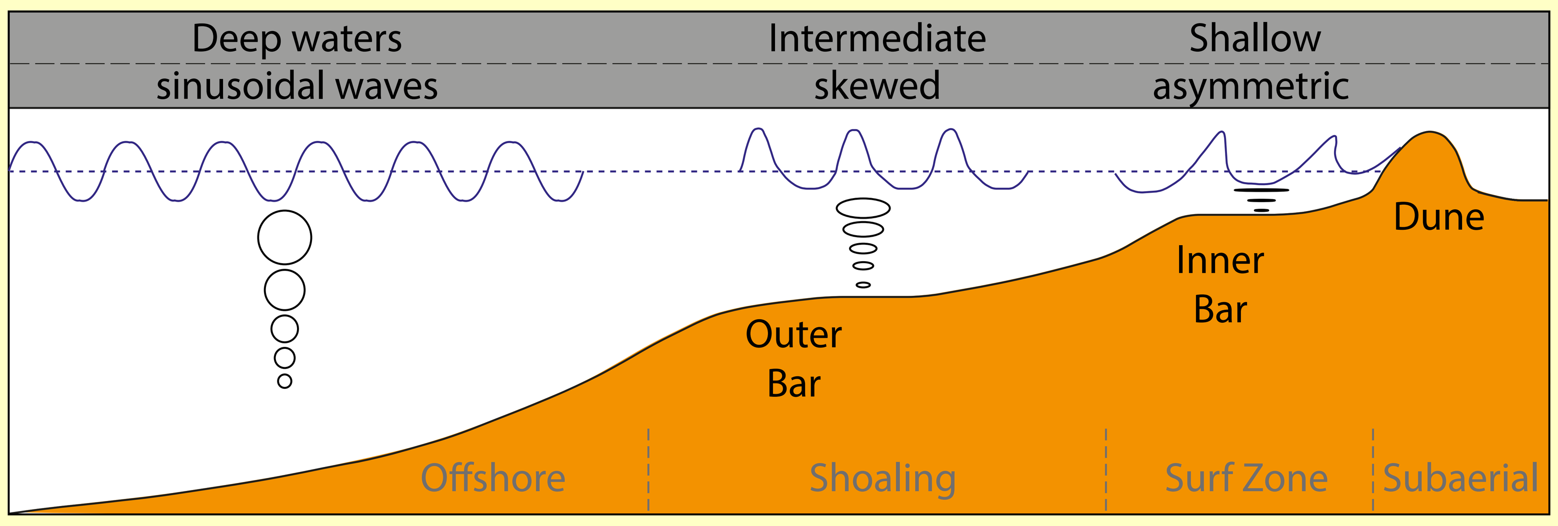
For reasons of computational efficiency, the orbital velocities are often parameterized in morphodynamic simulations. The parameterization simplifies the wave shape and velocities with higher harmonics, for example.

The risk is that this simplifies the nearshore hydrodynamics such that the lack of proper phenomena or even a small errors in wave-shape prediction leads to large net sediment transport and, in the long term (*i.e.* months to decades), unrealistic morphology.

To overcome these assumptions, detailed model calibration is needed for coastal modelling with wave processes included. Especially cross-shore modelling is known for its lacks of physical processes and reproducing observed morphology.

Our objective is to assess effects on long-term morphodynamics of the differences between the wave parameterization methods described in Ruessink *et.al.* (2012) and Isobe & Horikawa (1982) in a 2DH hydrodynamic and morphological model.

Figure 1: Wave transformation along a schematized coastal profile. Towards the coast line the wave shape and orbital motion changes from sinusoidal into skewed within the shoaling zone and asymmetric further into the surf zone. See Figure 2 for theoretical orbital velocity wave shape.



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Theory & Methods

- Isobe & Horiwaka Method [IH]

Hybrid wave theory combining 5th order Stokes and 3rd cnoidal wave theory. The method computes skewness and has a very broad application. Although, it cannot account for asymmetry. Therefore this method tends to overestimate onshore transport in shallow water.

- Ruessink *et.al.* Method [RUE]

Computes the total non-linearity based on Ursell number. The method quantifies the total non-linearity and introduces a new phase and amplitude into the wave shape. The parameterization derived from extensive field data for a large range of wave climates

Figure 2: Orbital velocities derived from RUE method showing the 3 types of wave shapes: sinusoidal, skewed and asymmetric.

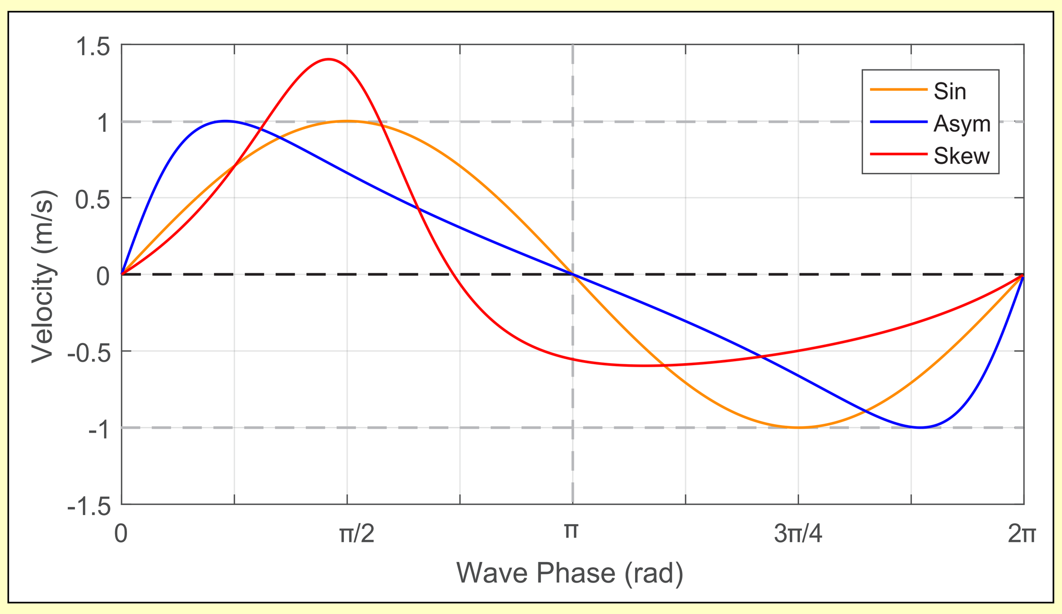
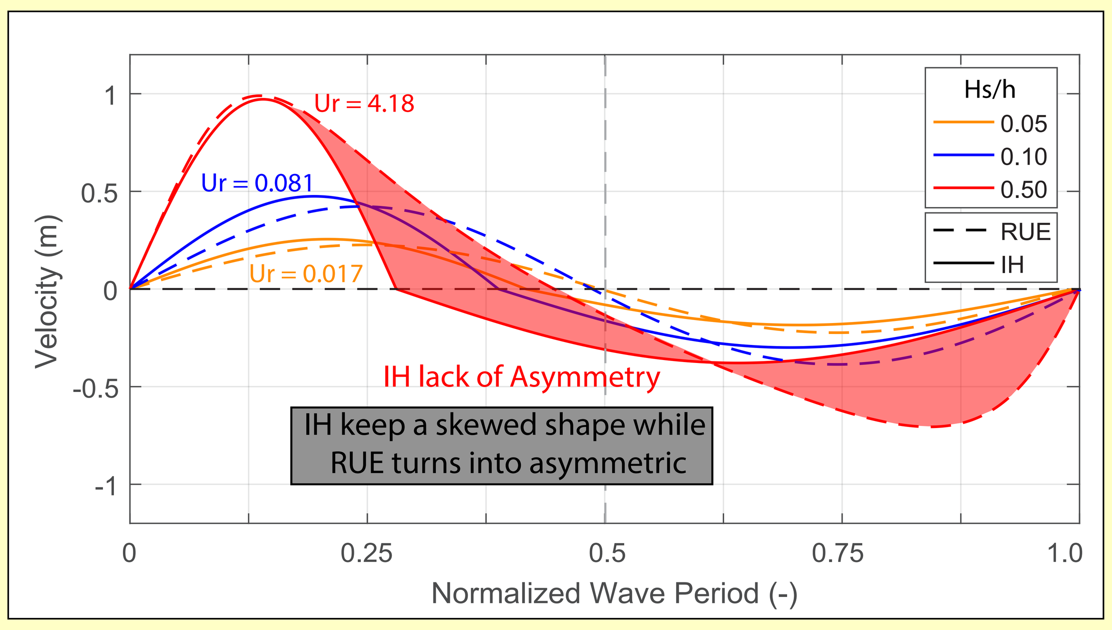


Figure 2 shows theoretical wave shapes from deeper to shallow waters and Figure 3 compares the wave transformation computed with IH and RUE along the profile shown at Figure 5.

Figure 3: Orbital velocities parameterized with IH and RUE for different ratios of wave height vs depth showing the lack of asymmetry for IH formulation.



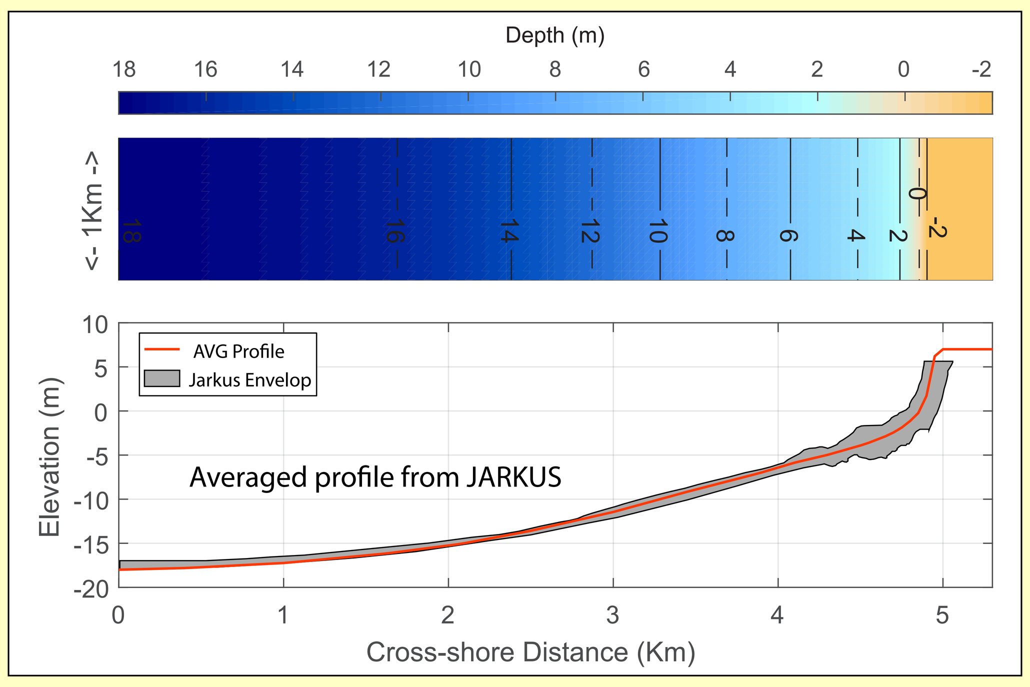
Workflow:

- Implementation of RUE into D3D source code;
- Systematic 1D profile analysis of wave shape, sediment transport and morphology of RUE and IH varying Fwbed calibration parameter;
- Overall morphological comparison of modelled results with field measured data;

Delft3D 2DH model setup

- Harmonic tides (2 meters)
- Wave coupling with SWAN
  - 1 meter / 8 sec / perpendicular
- Bathymetry from Jarkus (Figure 4)
- Sand 250 µm - Van Rijn 2004 (TRANSPOR)
- Morfac 120 (~10 morphological years)
- Fcbed = Fcsus = 1 ; Fwsus = 0
- Fwbed range: 0.2 - 1.4

Figure 4: Model domain applying a time and space averaged profile from JARKUS near Katwijk.



Hydrodynamics & Morphology

Figure 5: Wave height and orbital velocities transformation along the beach profile.

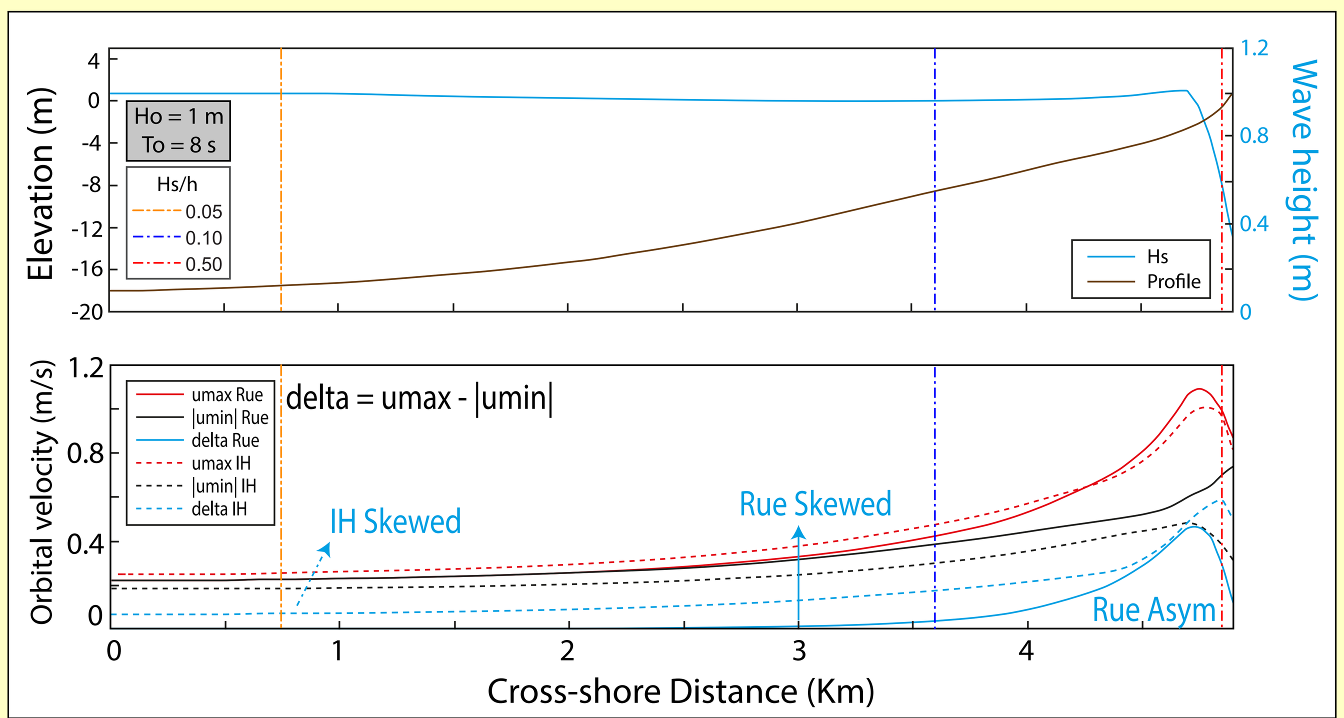


Figure 7: Sediment transport along (and integrated over) the profile for different Fwbed values.

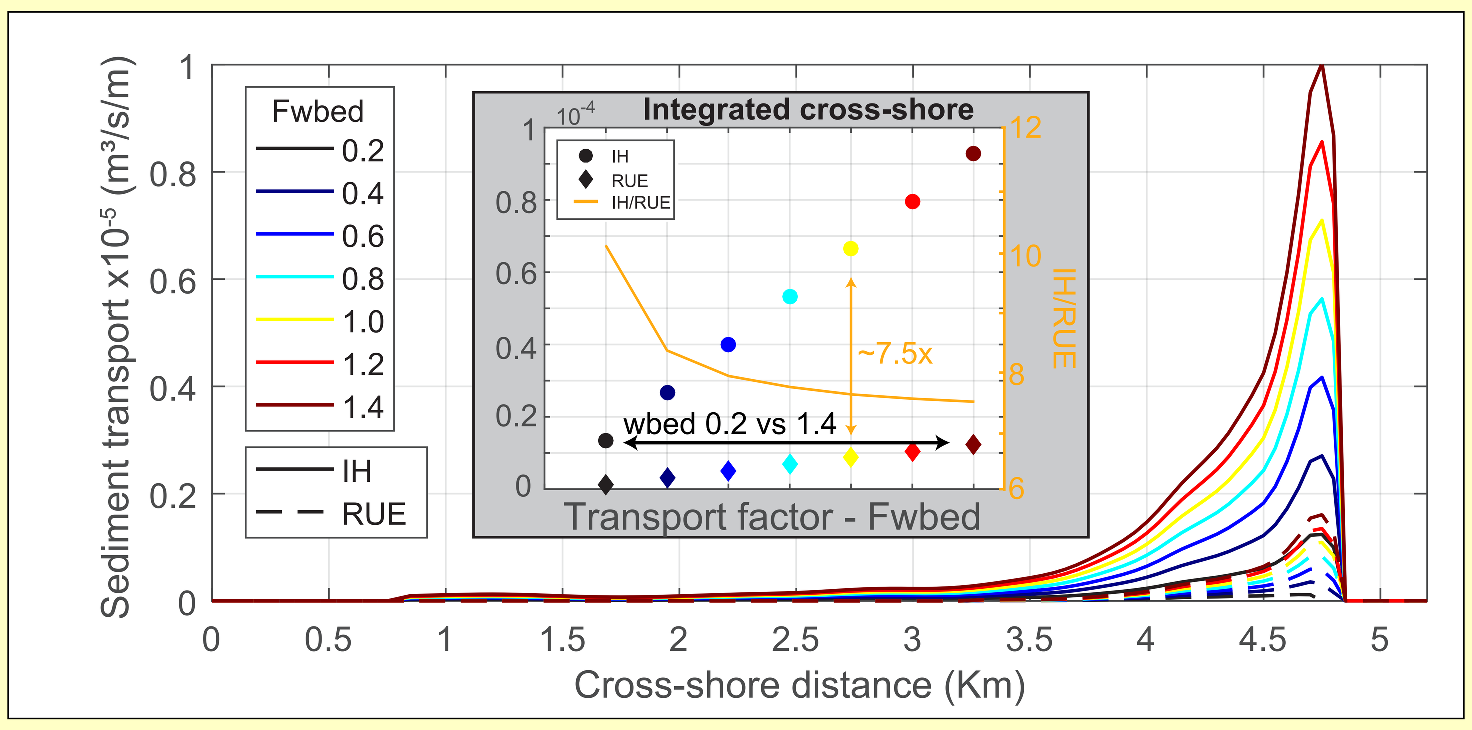


Figure 6: Intra-wave orbital velocity difference (RUE-IH) along the profile.

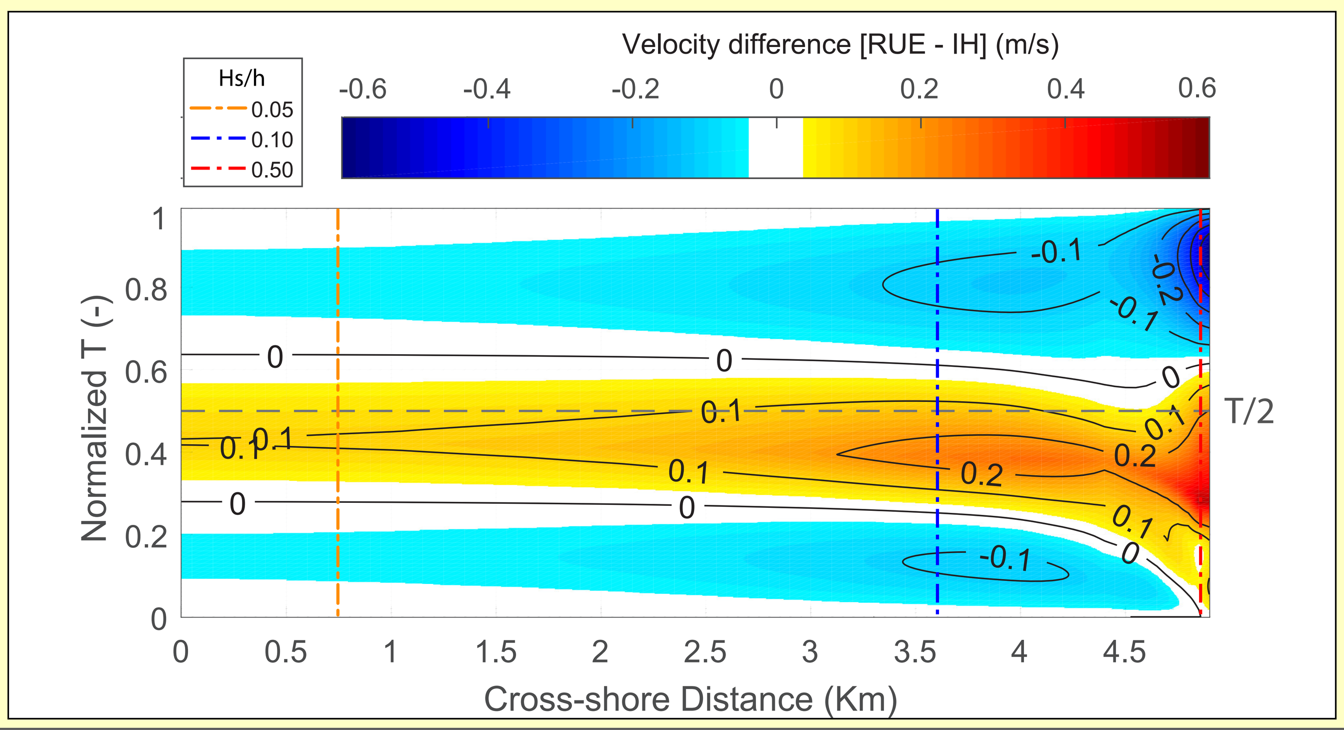
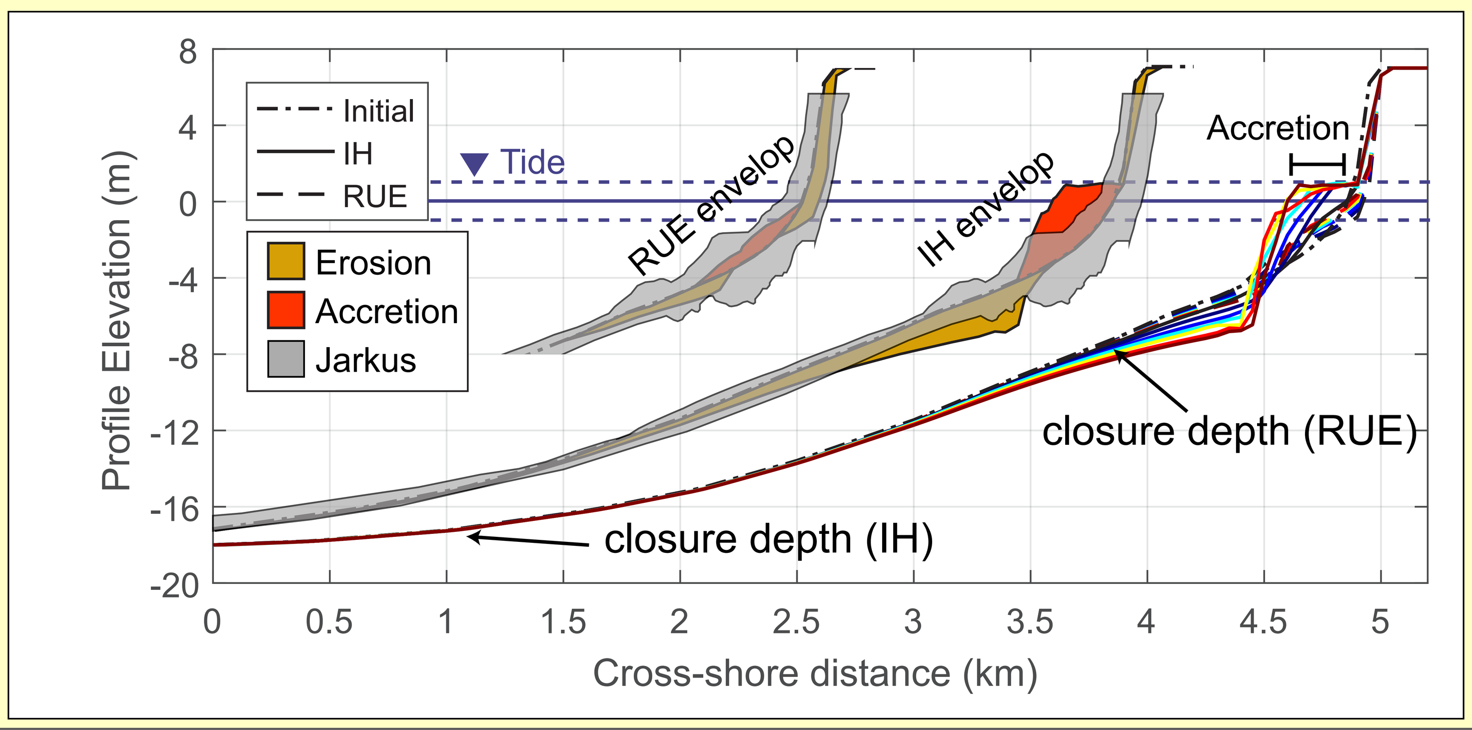


Figure 8: Morphological evolution after 10 yrs comparing IH & RUE and measured profile envelop.



Conclusions

The parameterization of intra-wave orbital velocity has large impacts on long-term morphodynamics.

HYDRODYNAMIC

- IH does not reproduce asymmetric (saw-tooth) shape (Figure 3)
- IH produces skewed shape from relatively deeper water (Figure 5)
- RUE produces skewed and asymmetric wave shape (Figure 2 & 3)
- RUE transforms the wave shape only in intermediate and shallow waters (Figure 5)
- RUE and IH shows larger differences towards the shoreline (Figure 6)

SEDIMENT TRANSPORT & MORPHOLOGY

- IH overestimates onshore sediment transport and shoreline progradation (Figure 7 & 8)
- For our simulated wave, IH/RUE has a sed. transp. factor of 7.5 for default values (Figure 7)
- IH shoreline progradation does not agree with measured data (Figure 8)
- RUE shows morphological development within the measured envelop (Figure 8)
- As a consequence, strong calibration is needed when using IH, *e.g.* Fwbed <= 0.2

For long term morphodynamic models RUE shows better agreement with hydrodynamic processes and final overall morphological development.

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Isobe, M., Horikawa K., 1982. Study on water particle velocities of shoaling and breaking waves. Coastal Engineering in Japan 25: p.109–123.
Ruessink, B.G., Ramaekers G., Van Rijn, L.C., 2012. On the parameterization of the free-stream non-linear wave orbital motion in nearshore morphodynamic models. Coastal Engineering, 65, p.56-63