Mixing contributions from resonant trapped internal waves generated by bottom topography in an estuary

T.M. Wegman[1], J.D. Pietrzak[1], R.J. Labeur[1], W.M. Kranenburg[1,2], M. Verlaan[1,2]

[1]Delft University of Technology, The Netherlands

[2] Deltares, The Netherlands

Corresponding author: t.m.wegman@tudelft.nl

Session: NP7.1 | Extreme Internal Wave Events: Generation, Transformation, Breaking and Interaction with the Bottom Topography

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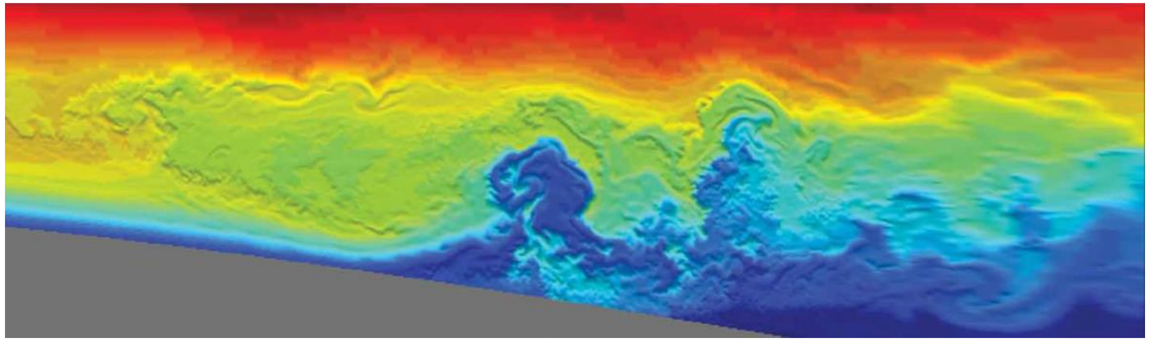
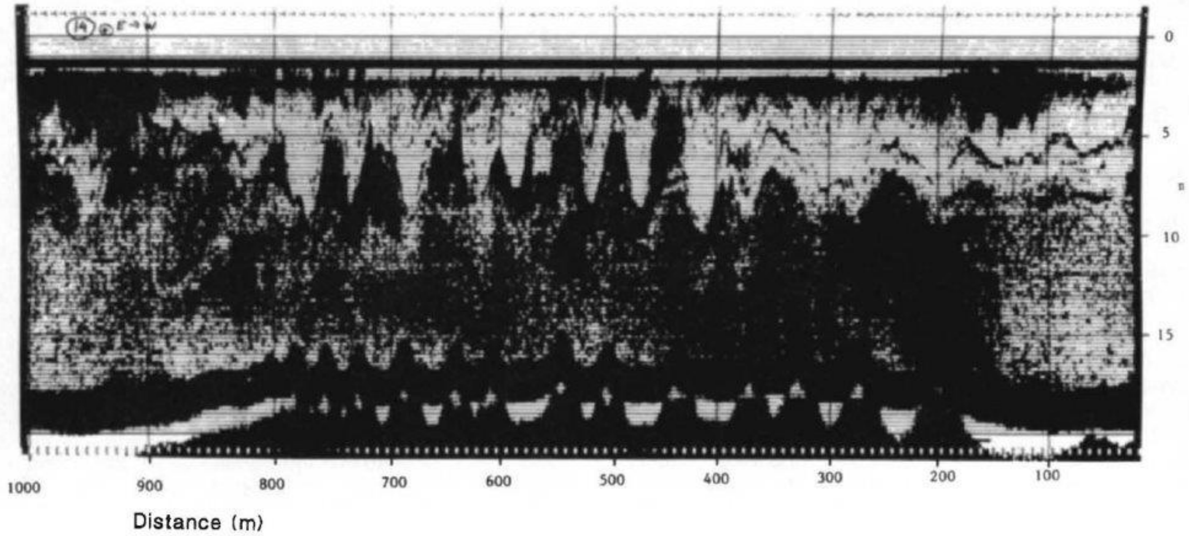
Internal waves in estuaries



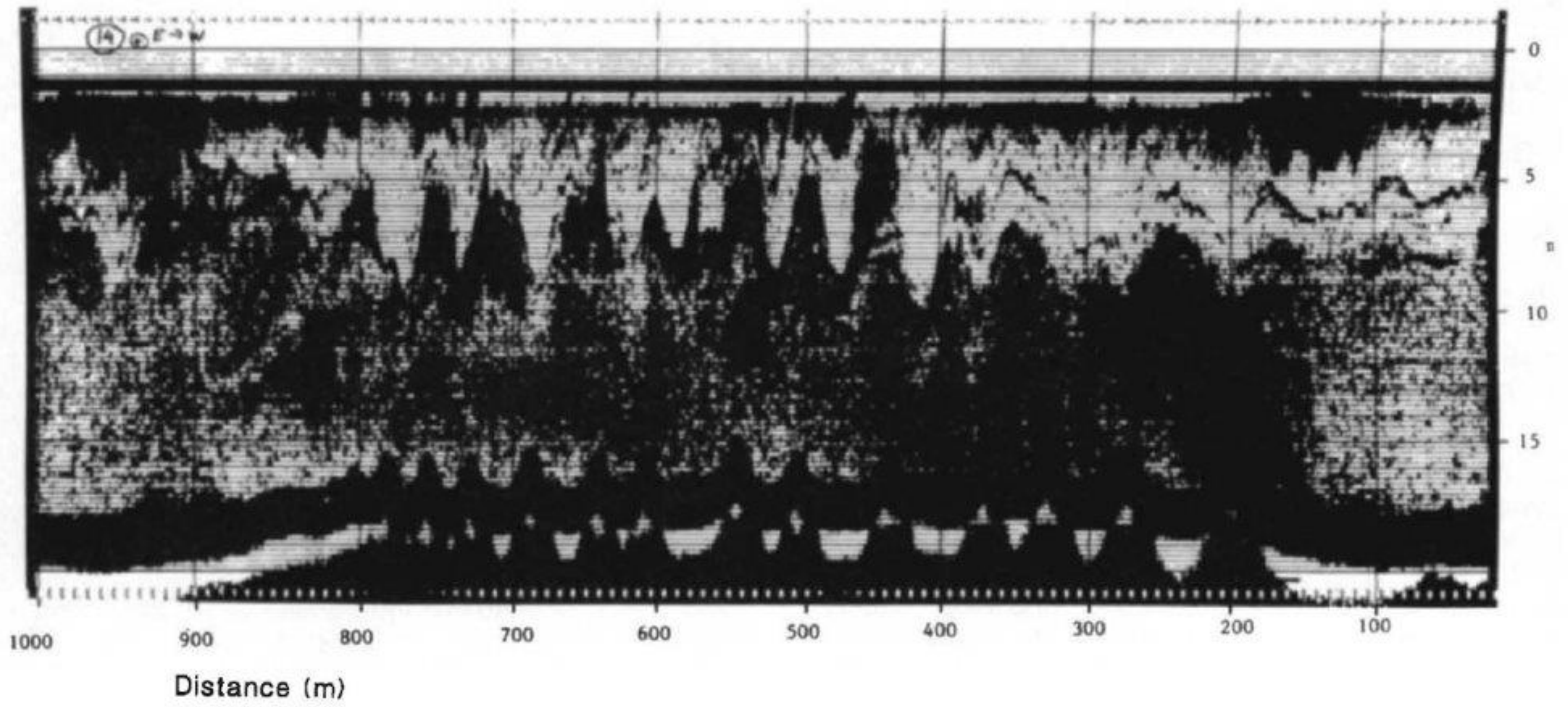


Upper image: Klymak, J., Legg, S., Alford, M., Buijsman, M., Pinkel, R., and Nash, J. (2012). The Direct Breaking of Internal Waves at Steep Topography. *Oceanography*, 25(2):150–159.
Lower image: Pietrzak, J. D., Kranenburg, C. & Abraham, G. (1990). Resonant internal waves in fluid flow. *Nature, Springer Science and Business Media LLC, 344*, 844-847.

Trapped internal waves in the Rotterdam Waterway

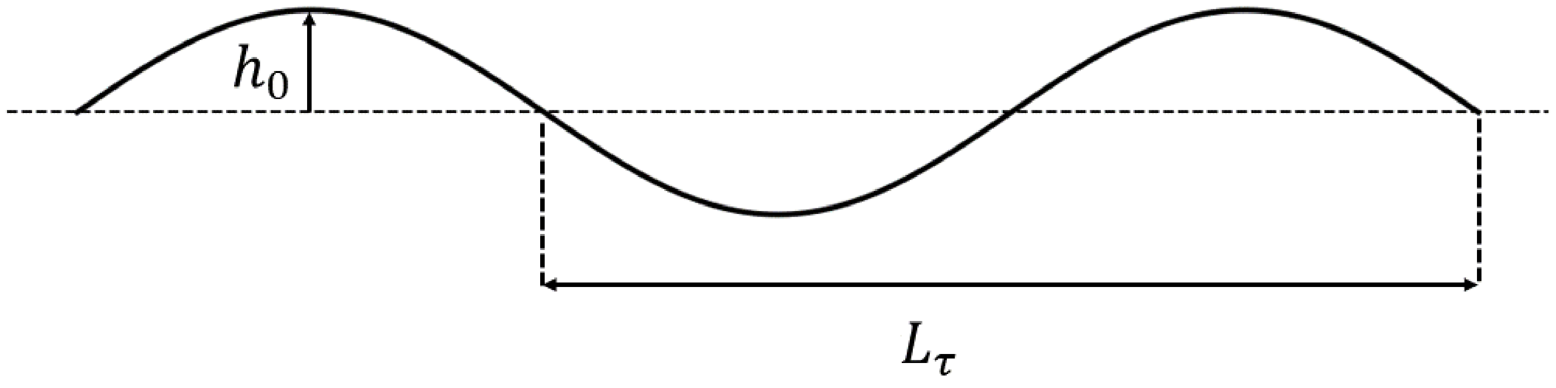
Left image: ZKM. Sattelite image Europe modified Copernicus Sentinel data (2017), processed by Sinergise/ESA.
Right image: Sattelite image of Rhine Meuse Delta. *Source: Displate*

Trapped internal waves in the Rotterdam Waterway



Pietrzak, J. D., Kranenburg, C. & Abraham, G. (1990). Resonant internal waves in fluid flow *Nature, Springer Science and Business Media LLC, 344*, 844-847.

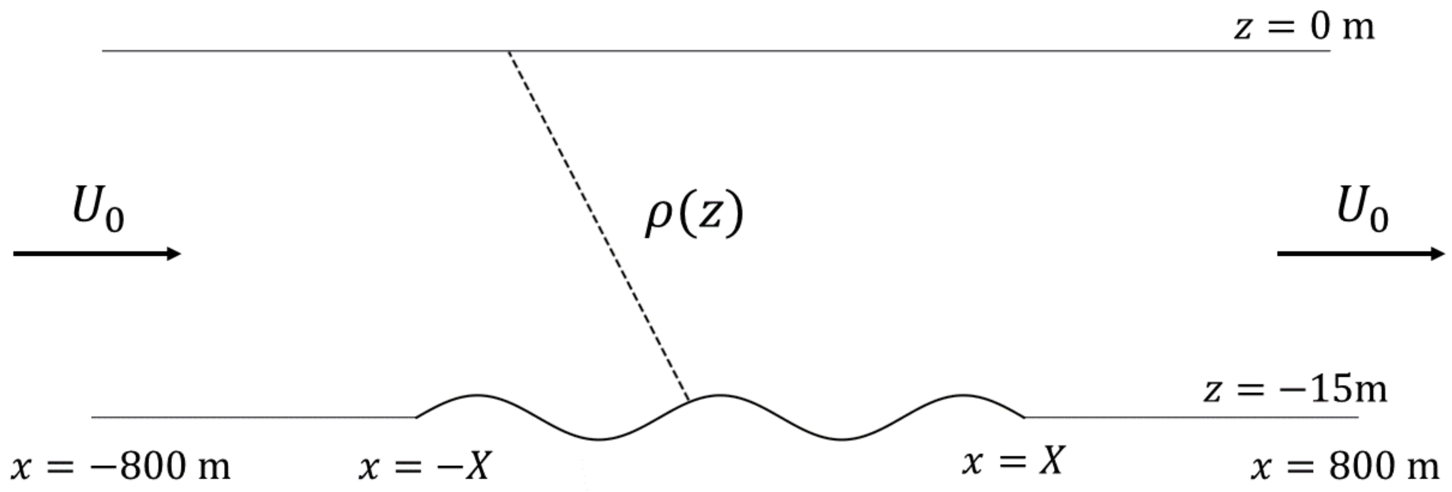
Analytical analysis



- Bottom topography amplitude h_0 → magnitude
- Bottom topography wave length L_τ→ magnitude and resonance condition

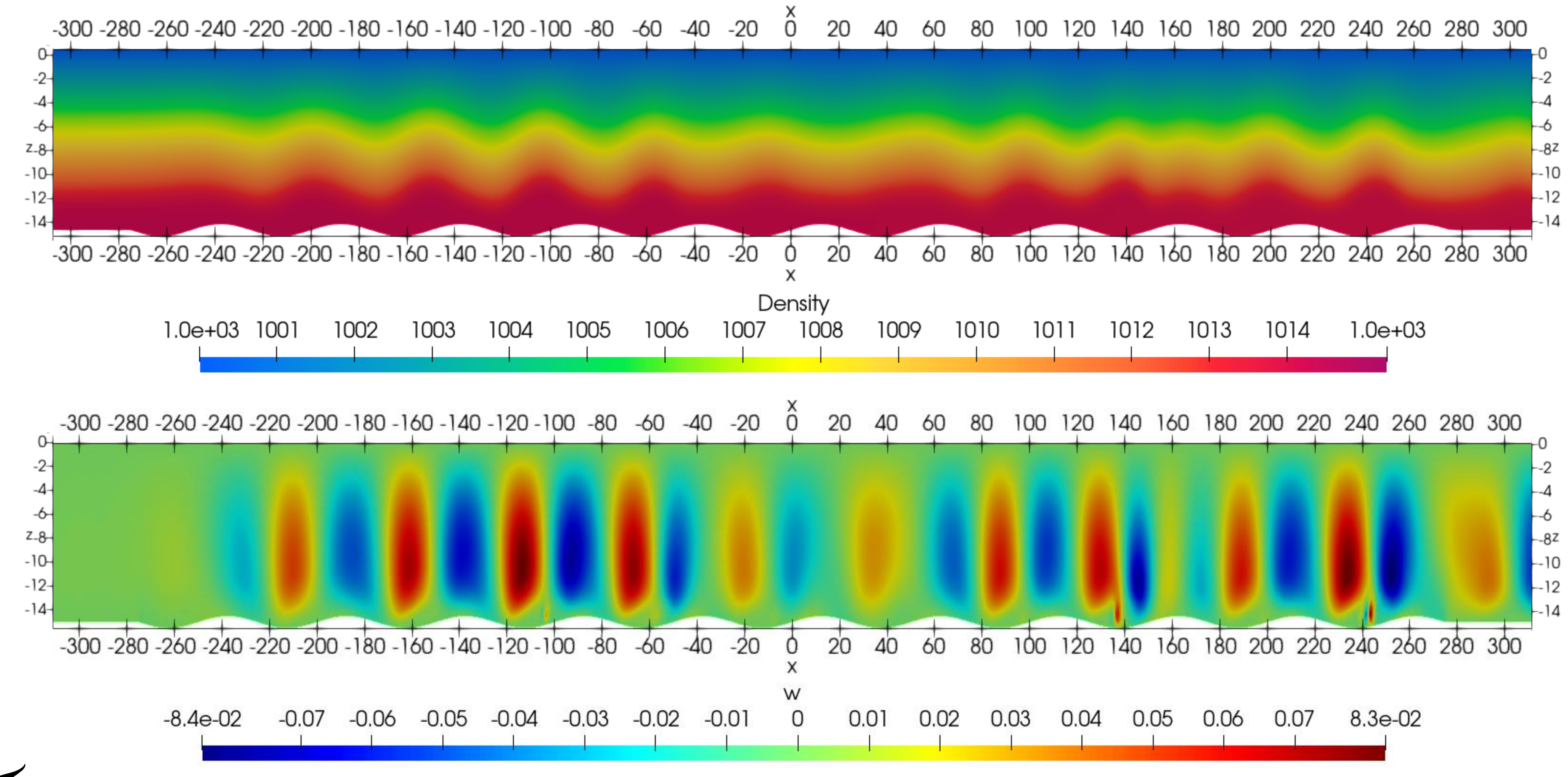
Set-up numerical simulation

- Fully non-hydrostatic finite element model (FINLAB[1])
- 2DV channel with a linearly stratified fluid
- Inflow & outflow boundary condition U_0 increases linearly in time

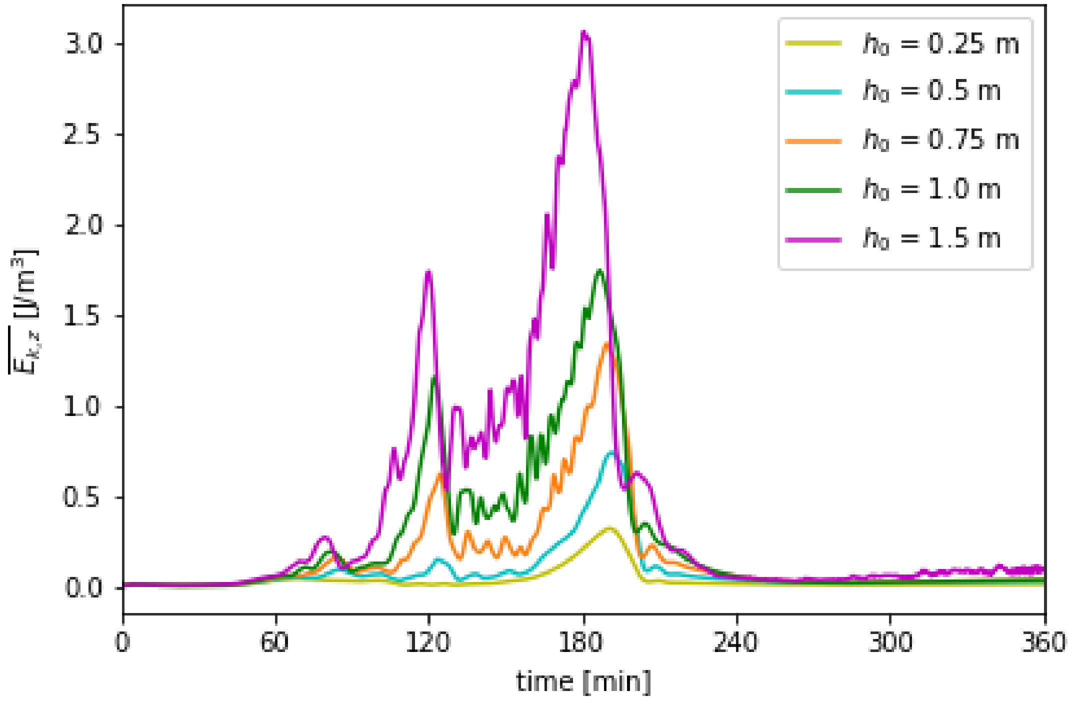


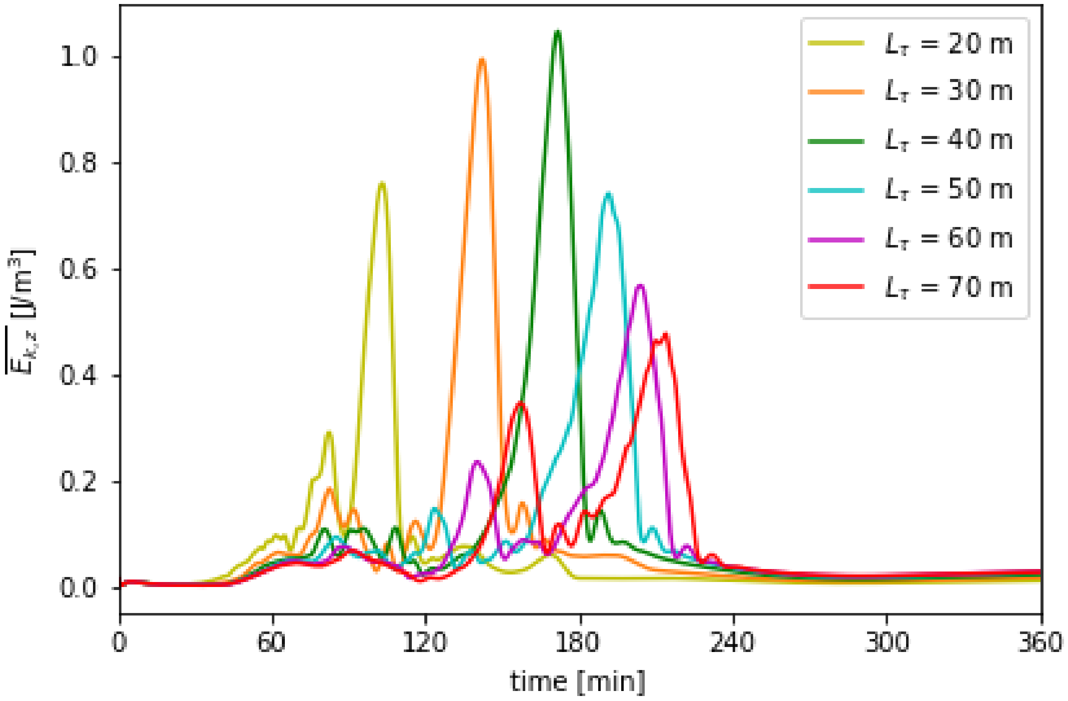
[1] Pietrzak, J. and Labeur, R. J. (2004). Trapped internal waves over undular topography in a partially mixed estuary. *Ocean Dynamics*, 54(34).

Mode 1 response



Variation in bottom topography parameters h_0 and L_τ



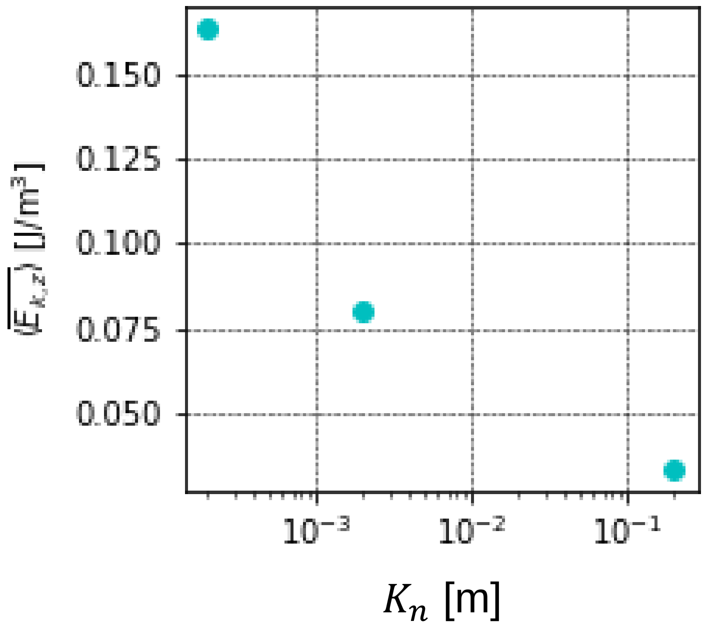


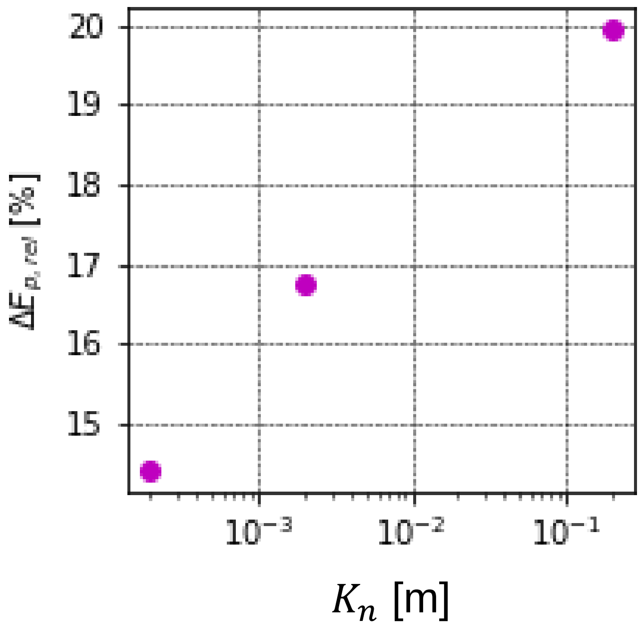
TU Delft

Mixing

Variations in Nikuradse bed roughness K_n

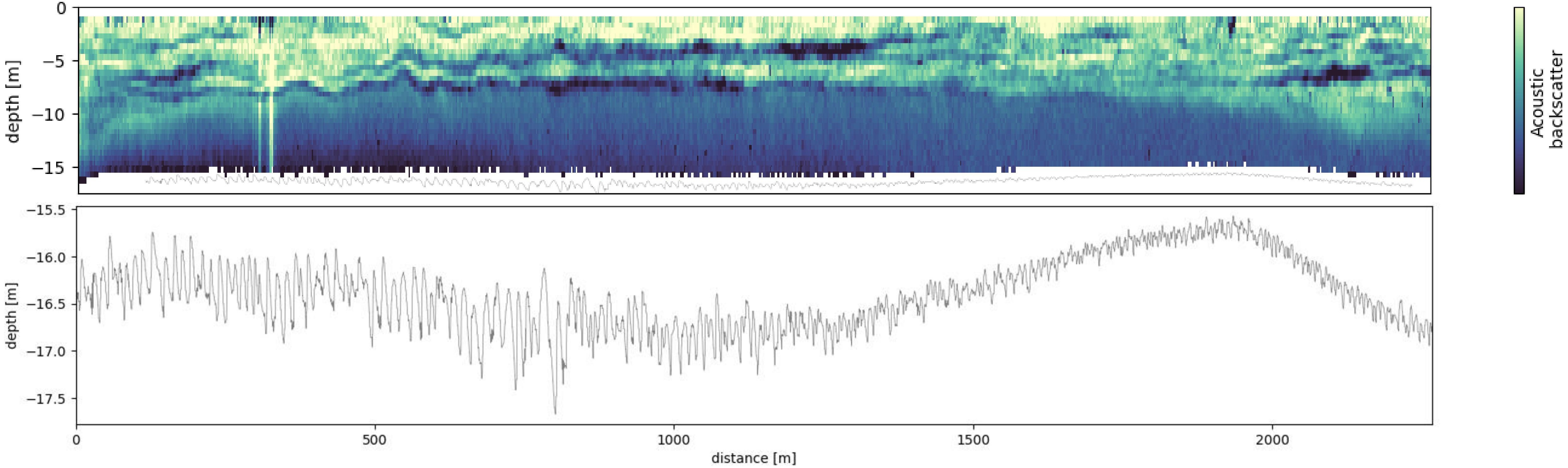
- $K_n \uparrow$ → friction ↑
- $K_n \uparrow$ → IW energy ↓
- $K_n \uparrow$ → $\Delta E_{p,rel} \uparrow$





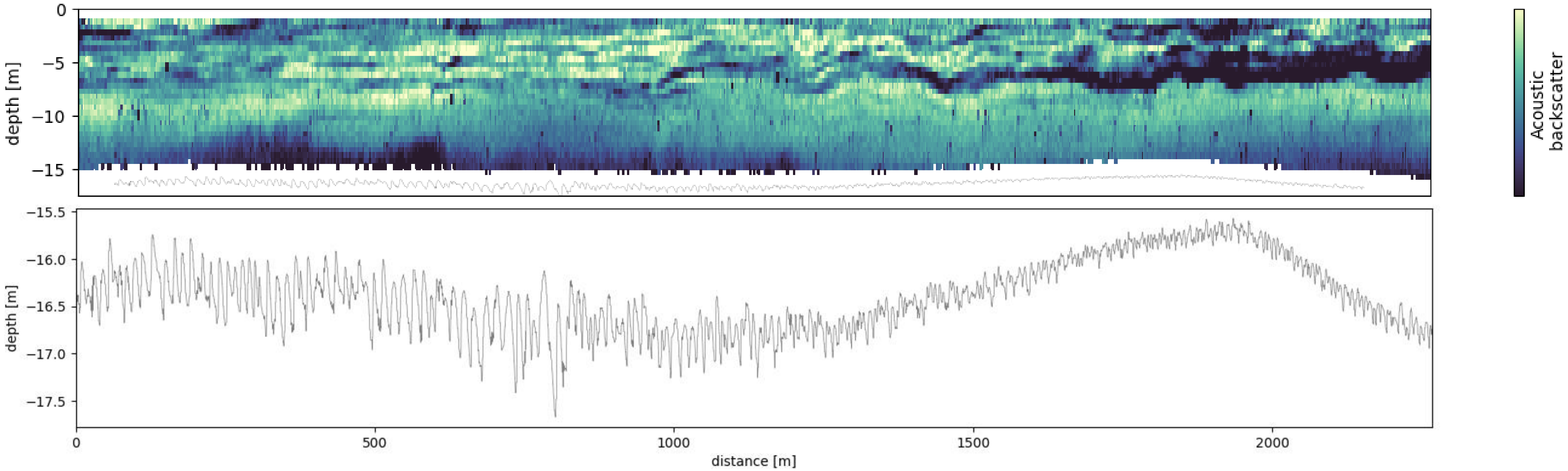
- *Friction has more influence on $\Delta E_{p,rel}$ than internal wave energy*

Measurements in the Rotterdam Waterway



Ebb flow

Measurements in the Rotterdam Waterway



Ebb flow

Conclusions

- For an accelerating flow case:
  - General response well described by analytical analysis;
  - Internal waves have a strong role near the bed due to bed friction;
- Estuarine internal waves observed in region with undular bottom topography.

Future work

- Model case with decelerating flow;
- Mixing contributions from propagating and/or breaking IWs;
- Analysis outside generation area;
- Comparison to field surveys of IWs and turbulent dissipation.

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