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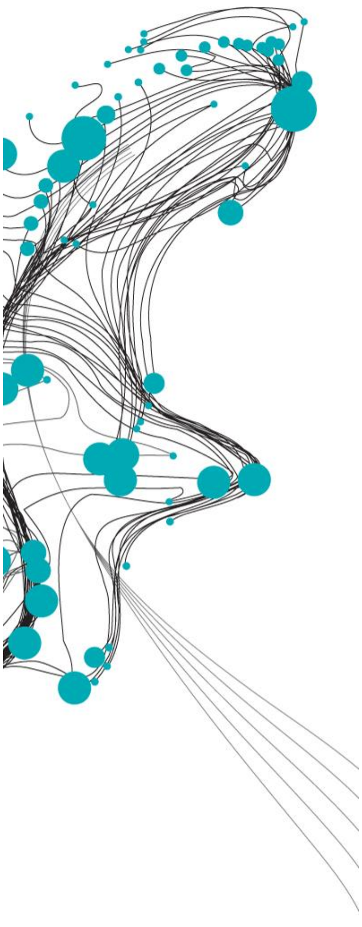

TIME-DEPENDENT LINEARIZED FRICTION: A DEVELOPMENT ON LORENTZ' ENERGY ARGUMENT

In 1918 the State Committee, chaired by professor Hendrik Antoon Lorentz, was commissioned to investigate the consequences of constructing the Dutch closure dam the Afsluitdijk. The Committee's assignment was to determine to what extent one may expect the water levels to rise during storm events. The Committee developed a process-based one-dimensional network model simulating separately the tidal and surge water levels. Essential was the energy argument applied to linearize the quadratic bottom stress parametrization of the tidal model. Lorentz determined a steady friction coefficient by equating the linearized energy dissipation to the quadratic.

Recently, Reef et al. (2016) continued the State Committee's pioneering work by reconstructing their storm model and extending it to a non-stationary model which simulates the time-dependent forcing in the frequency domain. Concluding their research, Reef et al. argue that when the flow velocity is lower than the maximum velocity, their steady friction model overestimates energy dissipation. They proposed for future research a time-dependent friction coefficient, in which a varying velocity scale may be better suited with the varying wind stress and tidal forcing.

This study implemented a time-dependent friction coefficient. The coefficient is specified such that the instantaneous frictional energy dissipation integrated over the channel length is identical for both the linearized and quadratic parametrization, which is determined in an iterative way. Implementation in the frequency domain produces a convolution sum of friction coefficient and velocity in the momentum equation. This couples each frequency in the spectrum, implying interaction between frequencies (e.g. the interaction between tide and surge).

We have performed simulations for an idealized single channel and the Wadden Sea network (see Figure 1). The qualitative behaviour is good. The single channel simulations show that when the steady friction coefficient overestimates energy dissipation, the time-dependent friction model feels less friction. The steady friction simulations display overdamping and a phase lag compared to the time-dependent friction model. We observe significant interaction between tide and surge. The peak surface elevation of the simultaneously forced model is nearly 20% lower than when forced separately. The reduction is likely to be a result of the larger tidal velocities, which in turn result in more friction. The simulations for the Wadden Sea network are performed for the 2013 Sinterklaasstorm. The simulations are in good agreement with measurements. The differences are often within 10 centimetres. During storm there are some outliers of at most 30 centimetres.

The solution method developed in this study is promising, especially for research on interaction (e.g. tidal constituents or tide and surge) with idealized analytical network models.

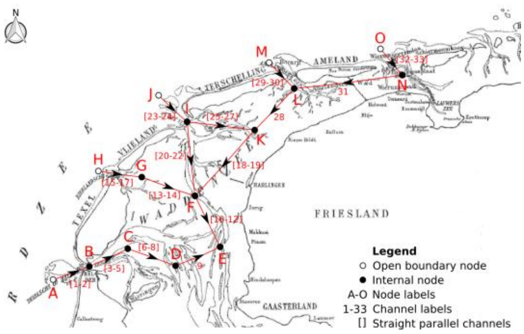

Figure 1: The Wadden Sea tidal channel network used in this study. *Nineteenth century underlying map by the State Committee (1926).*

K.R.G. Reef, P.C. Roos, G. Lipari, and S.J.M.H. Hulscher. In the footsteps of Lorentz: extending the network model of the Wadden Sea - Poster presentation. In PECS Conference 9-14 October, 2016.

State Committee. Verslag van de Staatscommissie - Gevolg van de afsluiting van de Zuiderzee. Technical Report September, 1926.