Utrecht University

Faculty of Geosciences
Department of Physical Geography

Hydrodynamics of tidal waves in the Rhine-Meuse river delta network

Nynke Vellinga (n.e.vellinga@uu.nl); Maarten van der Vegt (m.vandervegt@uu.nl) Ton Hoitink (ton.hoitink@wur.nl)

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Introduction

Tidal dynamics in single-threaded estuaries have been researched extensively, but this is not the case for tidal river networks. However, the tidal propagation of tides and energy dissipation through networks determines salinity intrusion, which is increasingly important in the subsiding and heavily engineered Rhine-Meuse delta.
Field measurements combined with three-dimensional modelling, can provide insight in the propagation paths of the tidal wave throughout the network and energy dissipation in channels and at junctions.

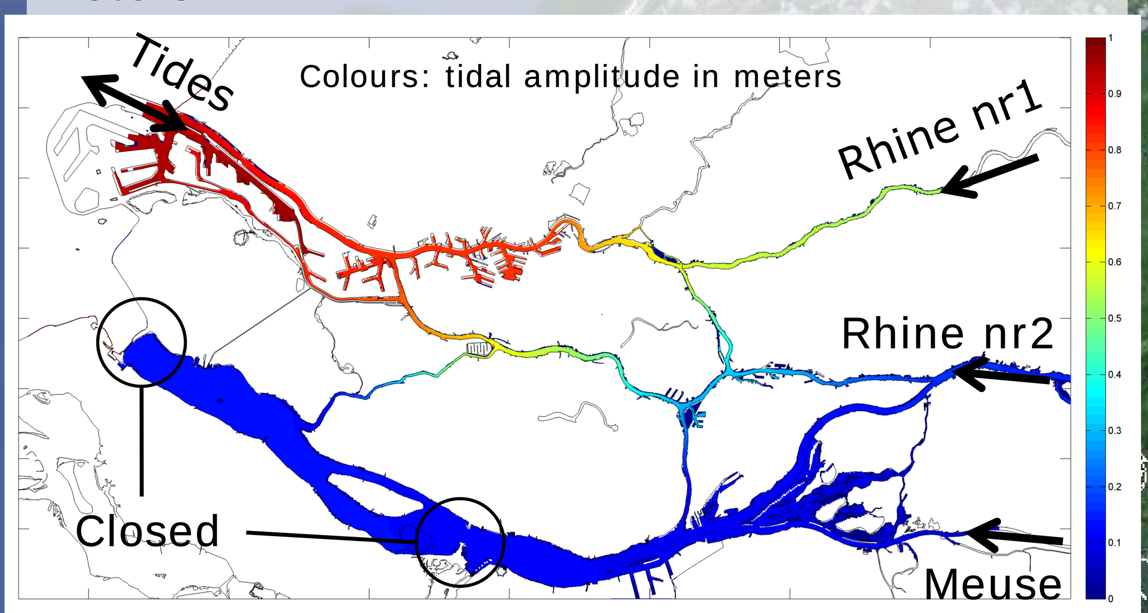
Aim: to understand tidal wave propagation, tidal energy fluxes and energy dissipation through the Rhine-Meuse tidal river network.

Measurements & model

A fully calibrated 2D model is employed to analyse flow at a small spatial and temporal scale. The model is validated with 13-hour measurements at 12 different tidal junctions in the network.

Rhine-Meuse tidal river network

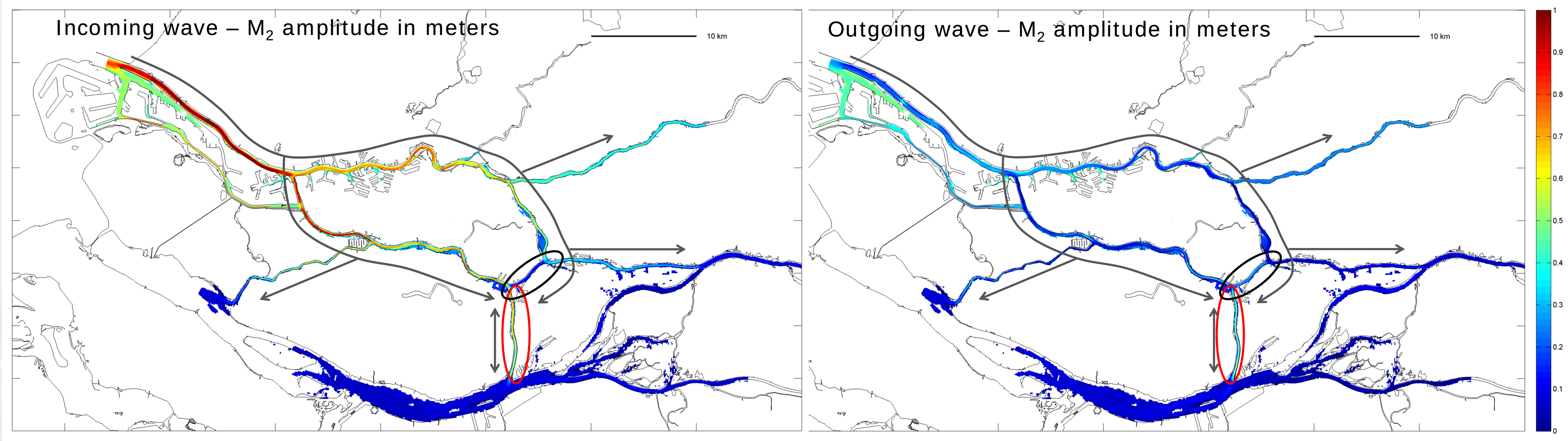
Overview of the network, with tidal amplitude in meters:



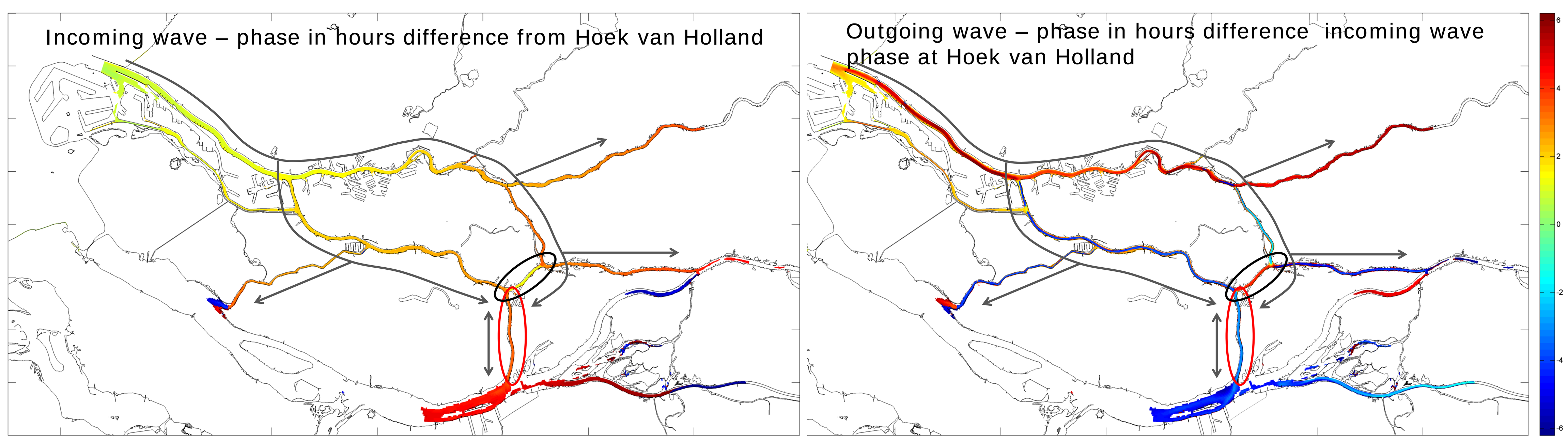
Tidal propagation in a network: splitting the tidal wave

To obtain insight in tidal wave propagation, we decomposed the tidal wave in an incoming and an outgoing constituent.
Water levels of the in- and outgoing waves are defined as $\eta_{in} = \frac{1}{2}\left(\eta + \sqrt{h/g}\,u\right)$ and $\eta_{out} = \frac{1}{2}\left(\eta - \sqrt{h/g}\,u\right)$; η is water level, h is water depth and u is flow velocity.

If η_{out} = 0 → propagating wave
If η_{out} = η_{in} → standing wave
If η_{out} > η_{in} → wave propagating backwards

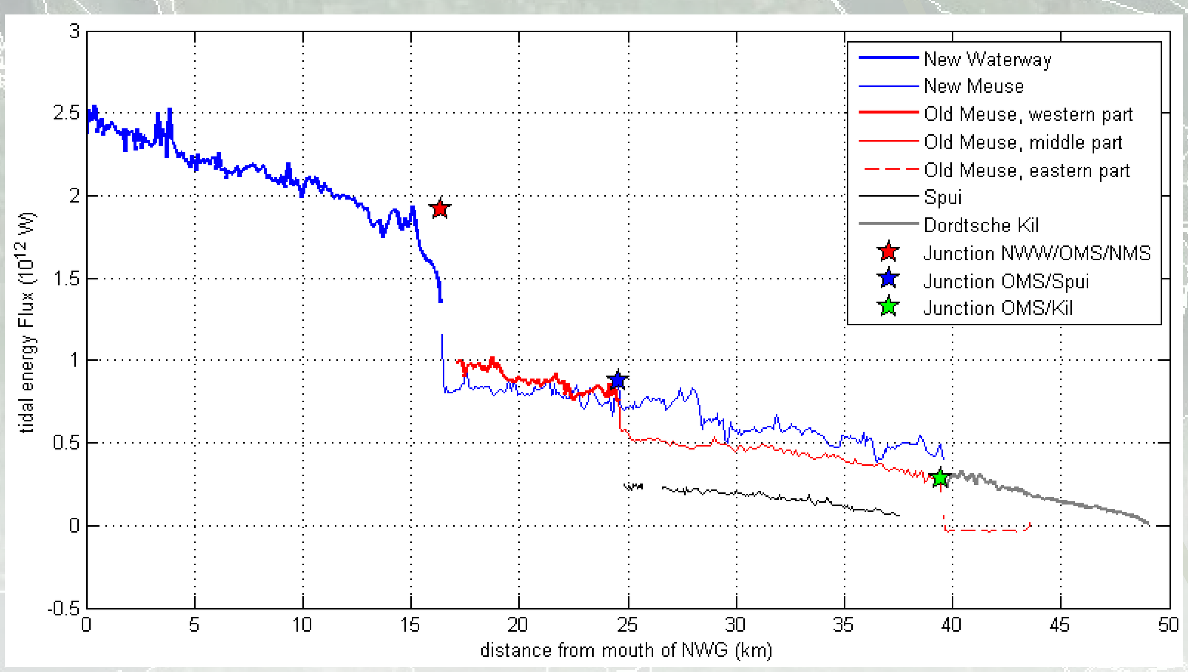


Incoming wave **amplitude generally decreases**, while the **phase increases** when moving upstream. The outgoing wave characteristics change between branches. In the red circled channel, the outgoing wave amplitude is of the same order as the incoming wave, which is attributed to **reflection** in the south. The tidal wave **moves 'backward'** in the black circled channel, first having propagated via the northern and eastern part of the network first.
The junction between the Old Meuse and the Dordtsche Kil forms a tidal divide in the network.



Energy dissipation

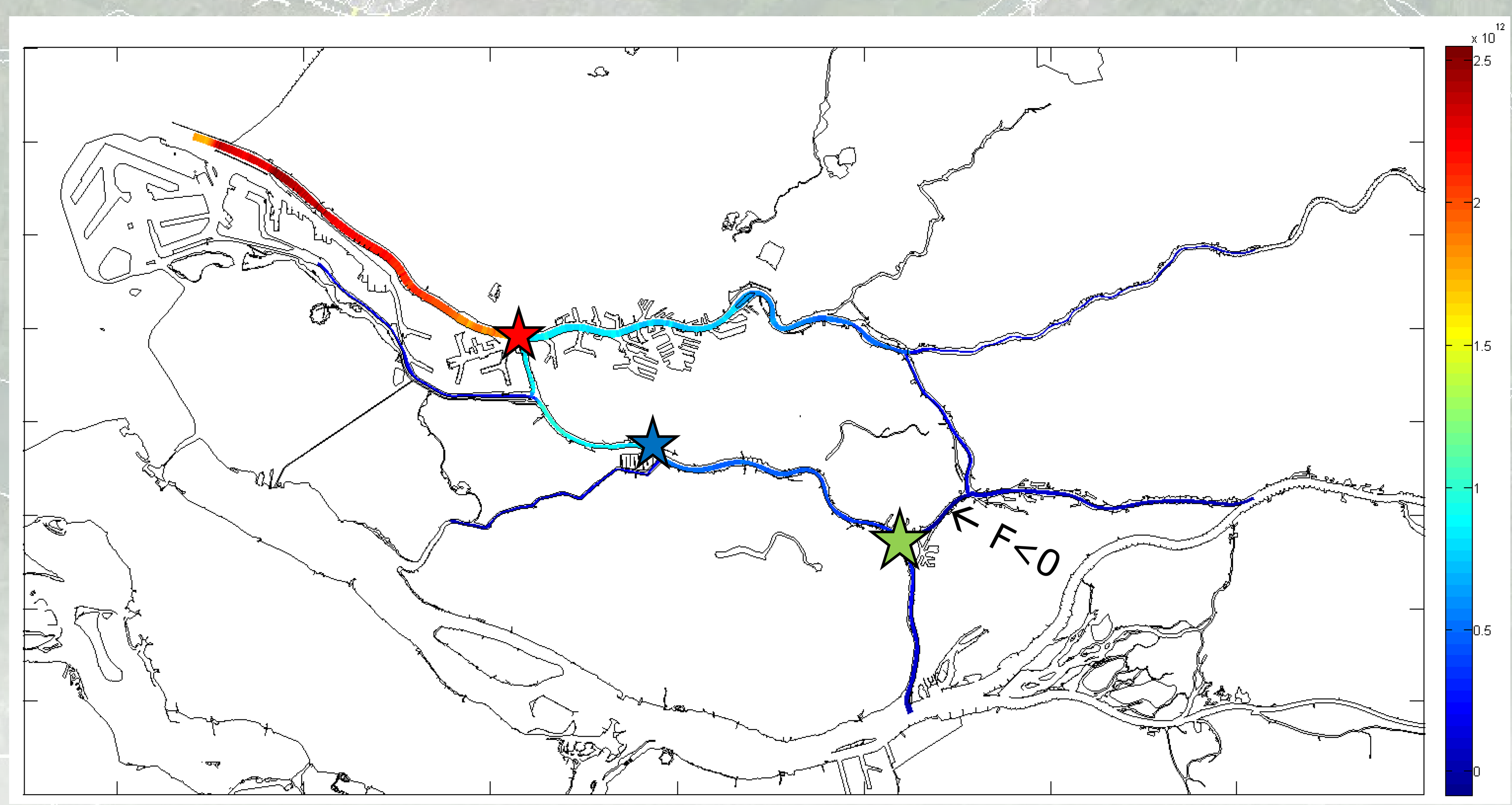
Tidal energy dissipates due to friction at the bed.
When plotting the tidal energy flux as a function of along channel distance, we see that **dissipation varies only slightly** between channels. However, channel widths do vary, so dissipation per square meter also differs. At junctions, energy splits evenly over the branches. In contrast with literature sources, **no energy is dissipated at junctions.**
Further research is needed to assess energy dissipation in detail, especially at junctions.



Tidal energy flux

To obtain a complete picture of the tides in the network, tidal energy flux is calculated:
$F = \iint \rho_0 (h+\eta)\left(0.5|\vec{U}|^2 + g\eta\right)\vec{U}\,dw\,dt$; ρ_0 is denstiy, η is water level, h is water depth, U is depth-averaged flow velocity and g is gravitational acceleration. F is integrated over a 24.8-hour period (two semidiurnal periods) and the width of each channel.

F **decreases** moving upstream. In the eastern part of the Old Meuse, *F* is **negative.**



Conclusion: We unravelled tidal wave propagation and tidal energy fluxes in the Rhine-Meuse network

The tidal wave has two main propagation paths. From the 1st junction one path north, one south. With one path being longer then the other, the waves meet at the Dordtsche Kil. Further research will shed more light at tidal energy dissipation.