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

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Introduction

Although hydrodynamics at individual river junctions have been extensively researched, this is not the case for multiple junctions or networks. However, the tidal propagation of tides and discharge distribution 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 through the network and the behaviour of the tidal wave at junctions.

Aim: to understand tidal wave propagation through the Rhine-Meuse tidal river network.

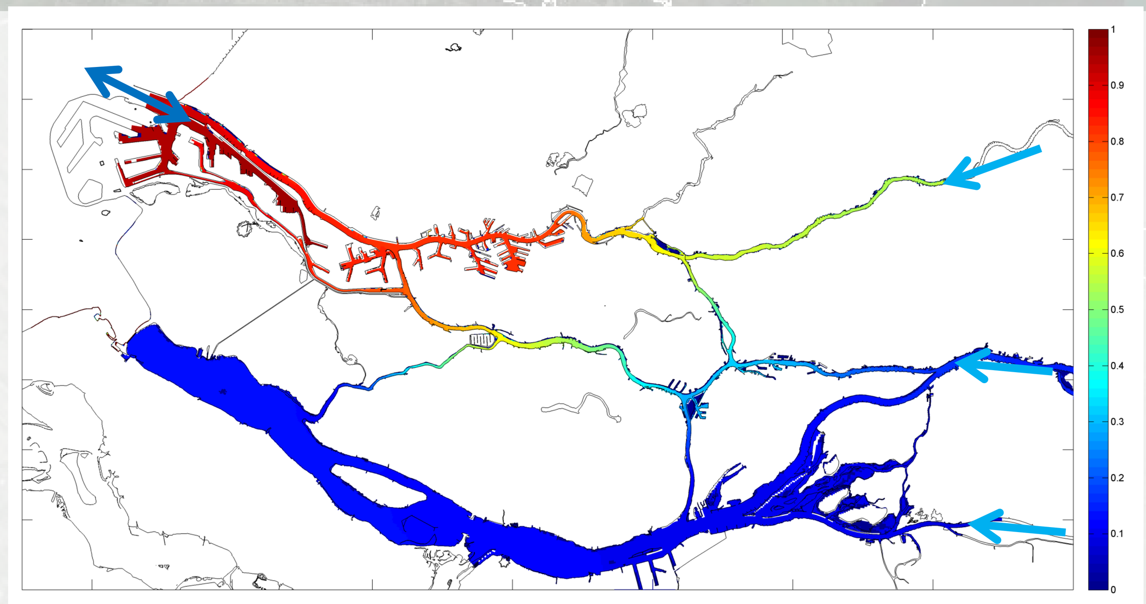
Measurements & model

A fully calibrated 3D model is employed to analyse flow at a fine spatial and temporal scale. 13-hour measurements of flow velocity at 12 junctions throughout the network have been analysed (see below)

Rhine-Meuse tidal river network

In the western Netherlands, the Rhine and Meuse rivers form a channel network. Tidal energy can enter from the north-west, but the southern estuaries of the system have been closed off and now form almost stagnant freshwater lakes. River flow enters through three river branches from the east.

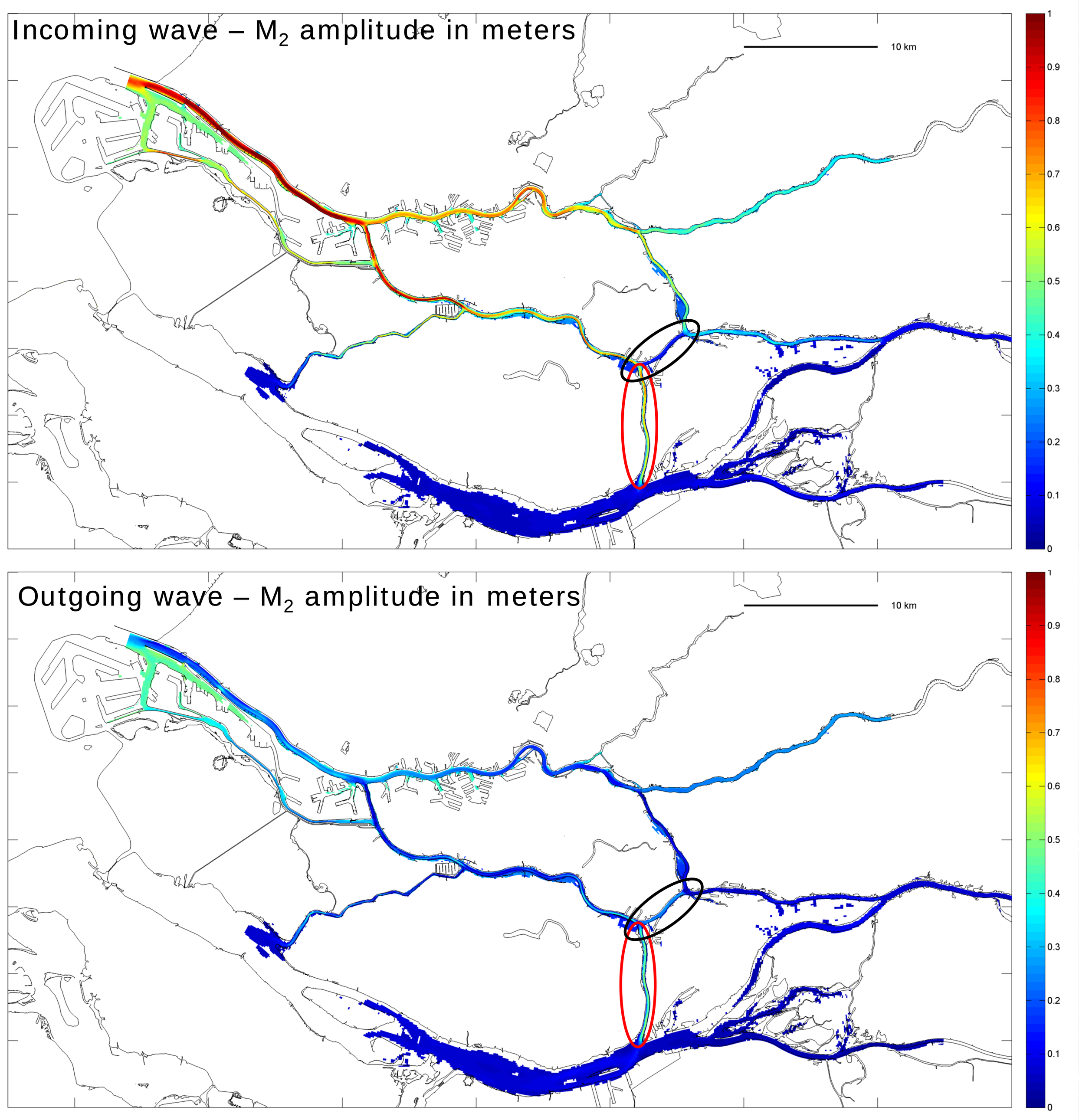
M_2 tidal amplitude in meters,
blue arrows depict river or tidal (dark) flow →



Splitting the tidal wave

We decompose the tidal wave in the estuary in an incoming and an outgoing constituent. A large outgoing wave indicates reflection or a 'backwards' flowing tidal wave. This decomposition is applied to calibrated model results to achieve a full spatial coverage. The in- and outgoing wave amplitudes and phases help to explain observed phase differences between branches at junctions.

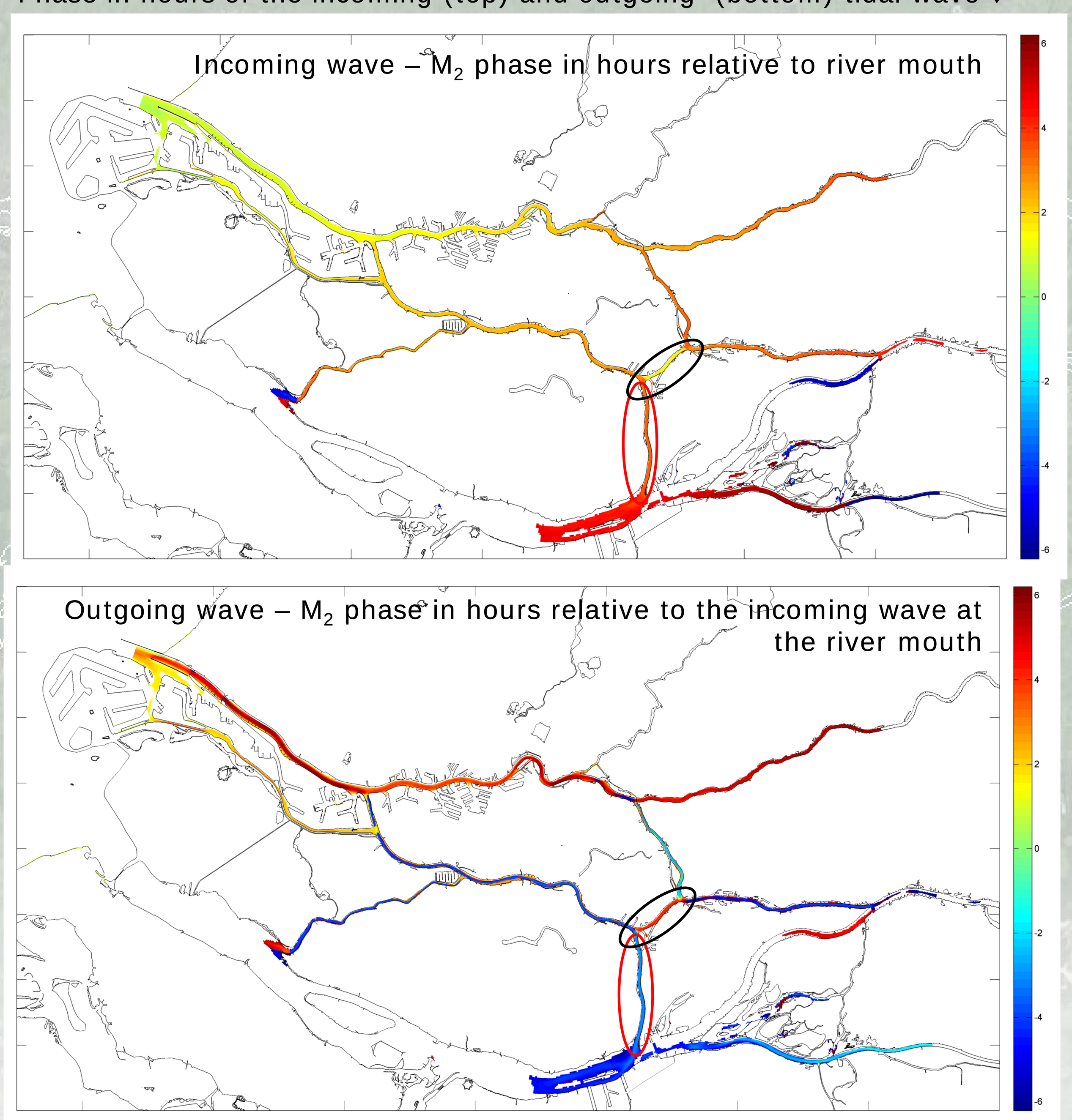
Water levels of the in- and outgoing waves are defined as $\eta_{in} = \frac{1}{2}(\eta + \sqrt{h/g}u)$ and $\eta_{out} = \frac{1}{2}(\eta - \sqrt{h/g}u)$, in which η is water level, h is water depth and u is flow velocity. The amplitudes and phases of η_{in} and η_{out} are further analysed →

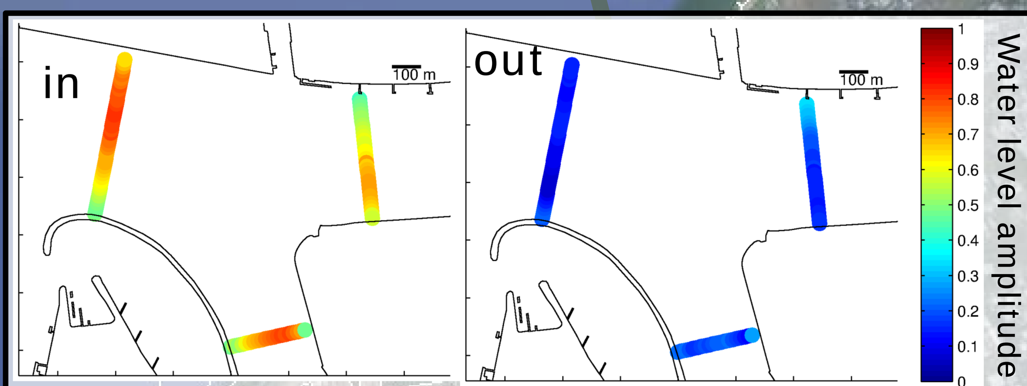


Amplitude of the incoming and outgoing tidal wave, in meters ↑

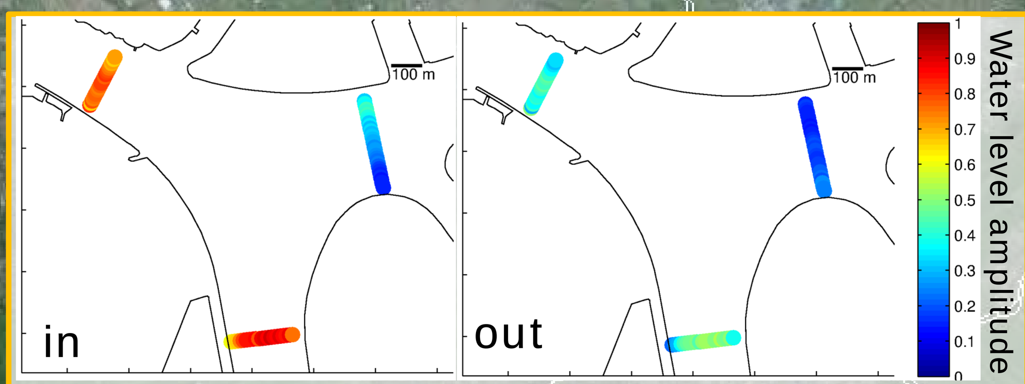
Incoming wave amplitude generally decreases, while the phase increases when moving upstream. The outgoing wave characteristics change between branches. In the red circled channel, the outgoing wave amplitude is large relative to the incoming wave, which may be attributed to reflection at the lake in 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.

Phase in hours of the incoming (top) and outgoing (bottom) tidal wave ↓



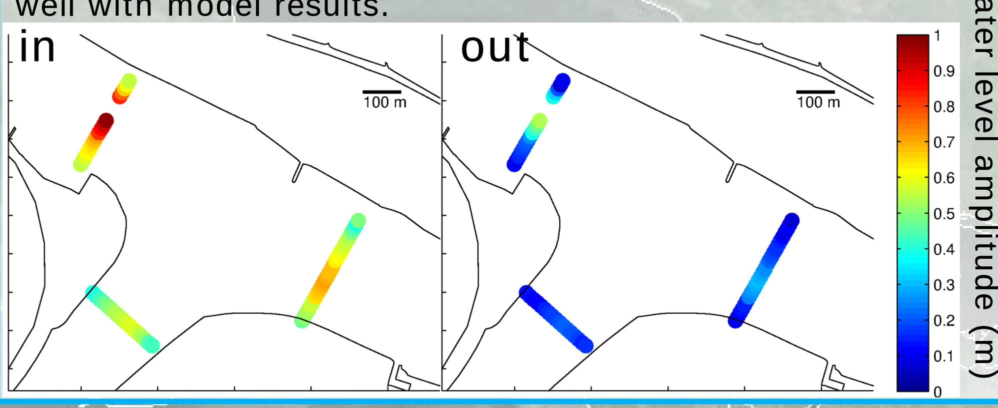


The incoming and outgoing wave amplitudes of the measurements show large lateral gradients, as opposed to 1D network theory. Near sea, outgoing wave amplitude is small.



At this junction, large phase differences between η and u were observed. This may be explained by large differences between incoming and outgoing waves between the branches. The tidal wave does not split at the junction, but propagates from west to south, where it reflects.

At this junctions, measurements show high reflection (high outgoing wave amplitude) in the western branch, but hardly any reflection in the other branches. This agrees well with model results.



Conclusion: Tidal wave propagation paths in the Rhine-Meuse river network have been unravelled.

Splitting the tidal wave in an incoming and outgoing wave demonstrates wave propagation paths and tidal wave reflection. The results agree well with measurement data and explain observed phase differences between branches at junctions.