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Enabling Delta Life

Accurate prediction of salinity intrusion in the Rotterdam Waterway

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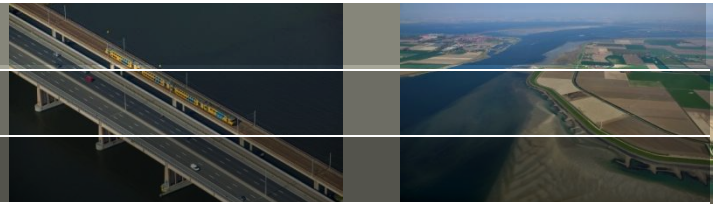
JONSMOD2016, Oslo

Outline



- Salinisation in Rotterdam Waterway
- Problem description: differences between computed salinity intrusion and measurements
- Overview of numerical model schematizations
- Model performance w.r.t. salinisation in Rotterdam Waterway
- Additional analysis for sigma and Z-models
- Conclusions and recommendations

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Salinisation in Rhine Meuse delta

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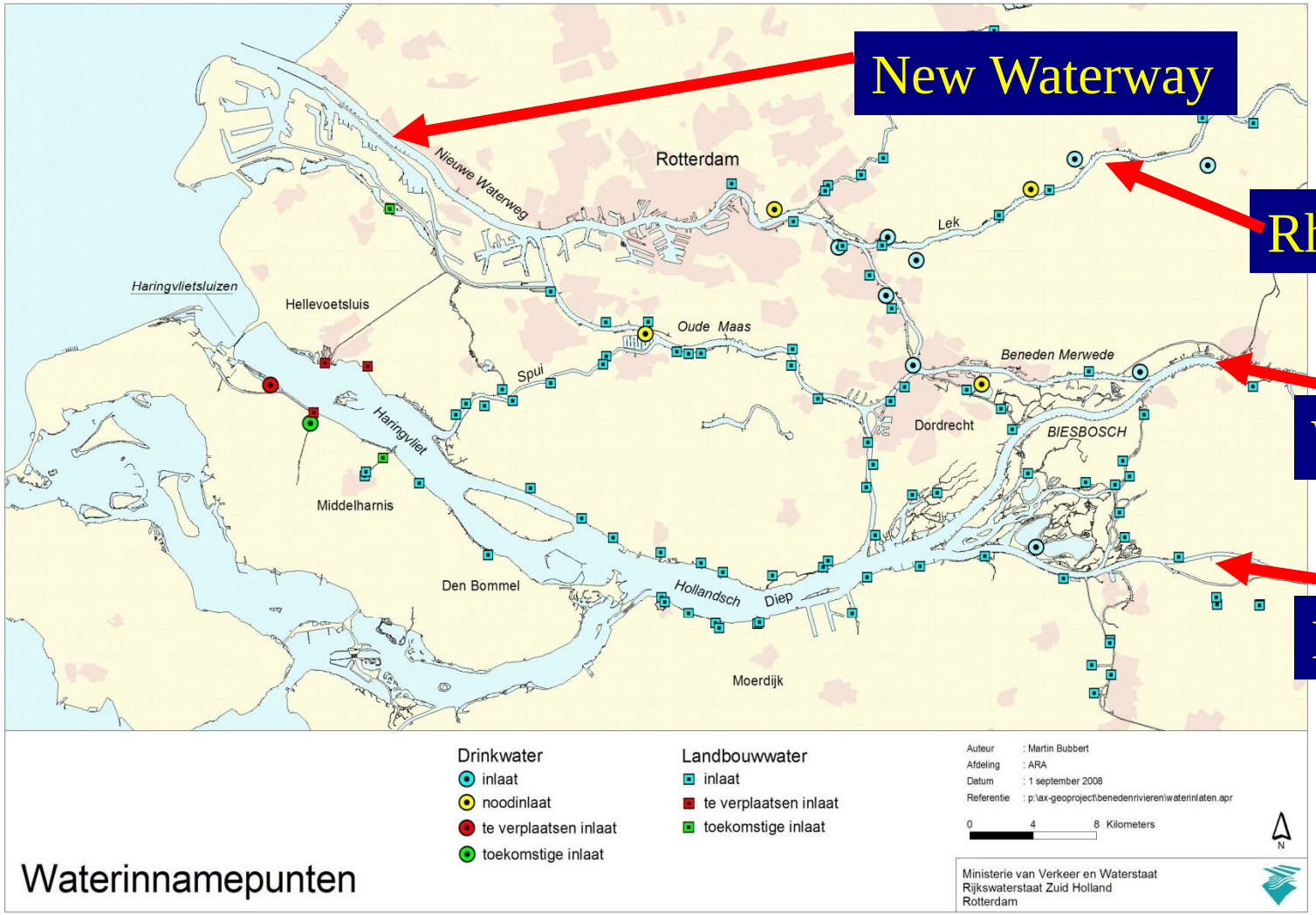
Overview of fresh water intakes

Lobith (German border): 100 mg/l; North Sea 20 g/l
drinking water: < 250 mg/l; agriculture < 700 mg/l



Extreme salinisation in November 2005

1 g/l ≈ 1.8 ppt

Afb. 2: Externe verzilting in november 2005.

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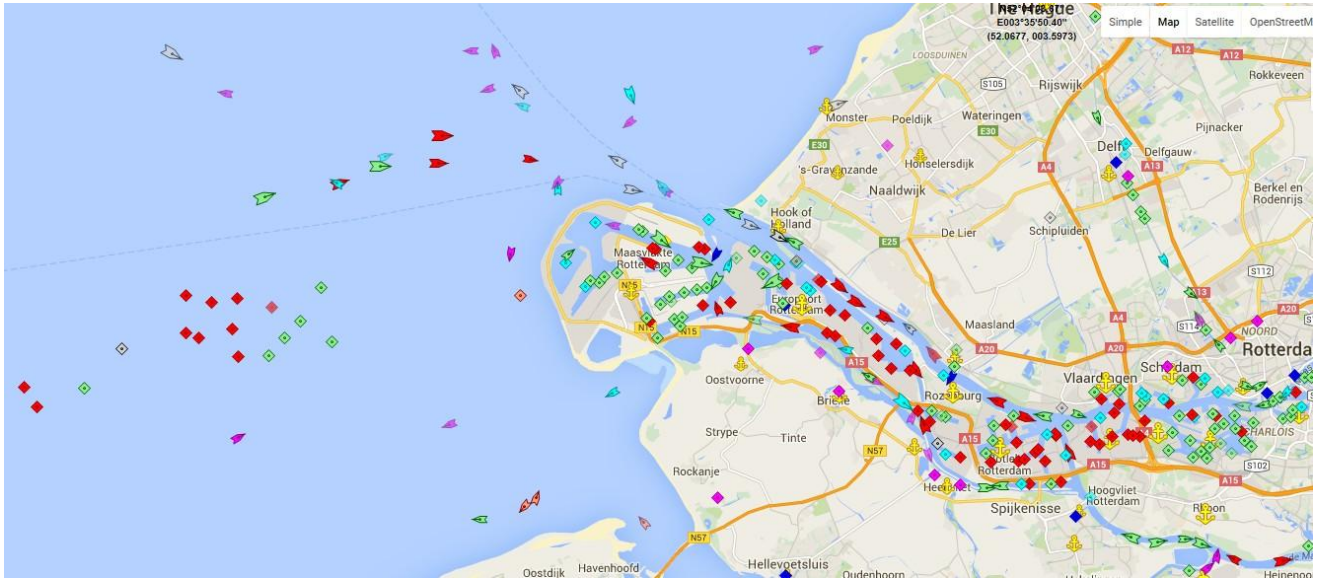
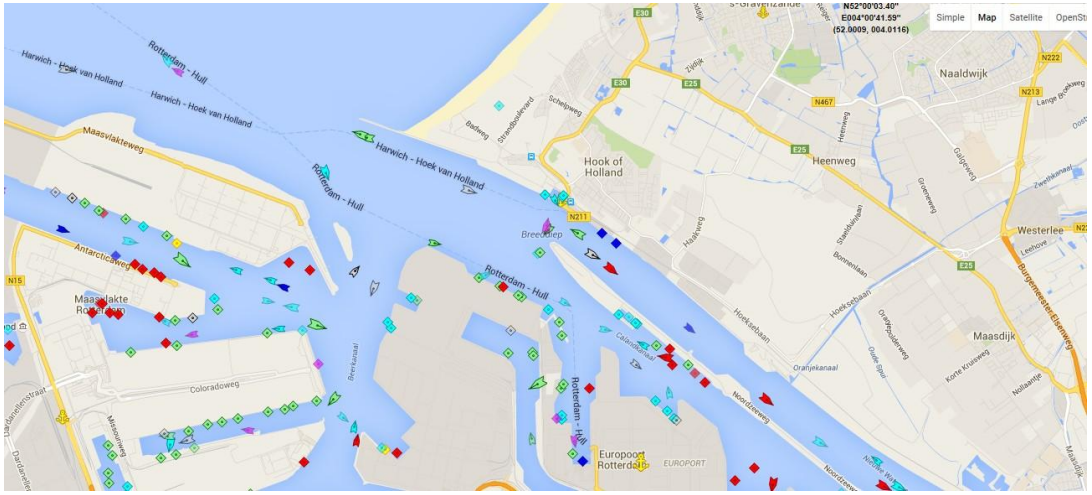
Ship traffic in Rotterdam Harbour (1)



www.marinetraffic.com



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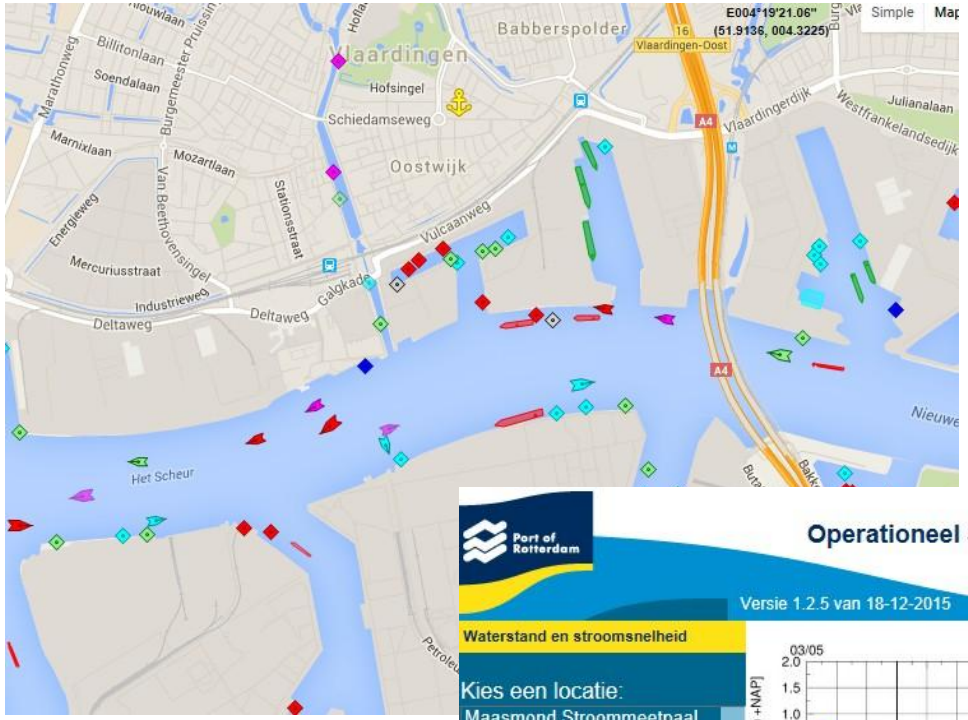
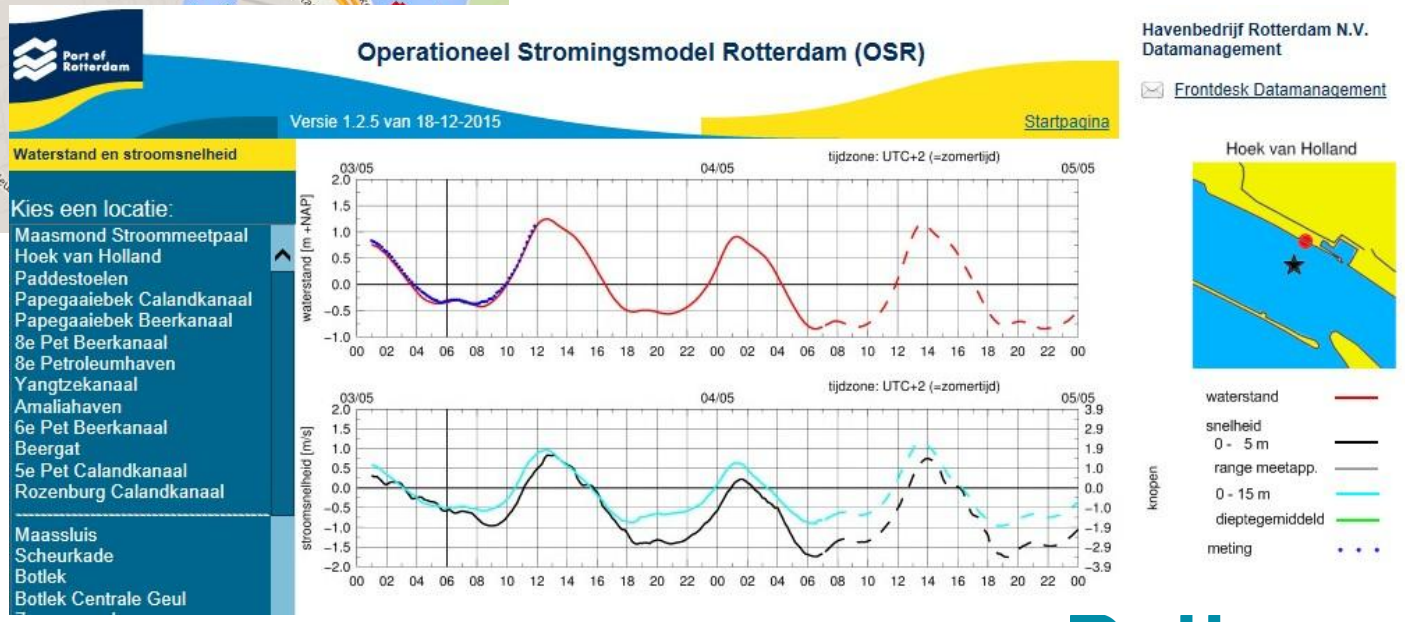
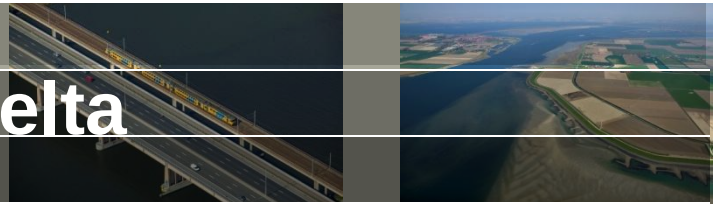
Ship traffic in Rotterdam Harbour (2)



OSR = Operational model for water levels, currents and salinity intrusion in the Rotterdam harbour



Salinisation in Rhine-Meuse delta



- Many issues: deepening New Waterway, Haringvliet sluices partly opened, Deltaprogramme (sea level rise), …

- More detailed questions need more accurate model predictions
- Better substantiation of model choices
- What can models predict and what not?

- Cooperation between Dutch Government en Port of Rotterdam Authority on ‘numerical model development for salinisation’, in consultation with Deltares

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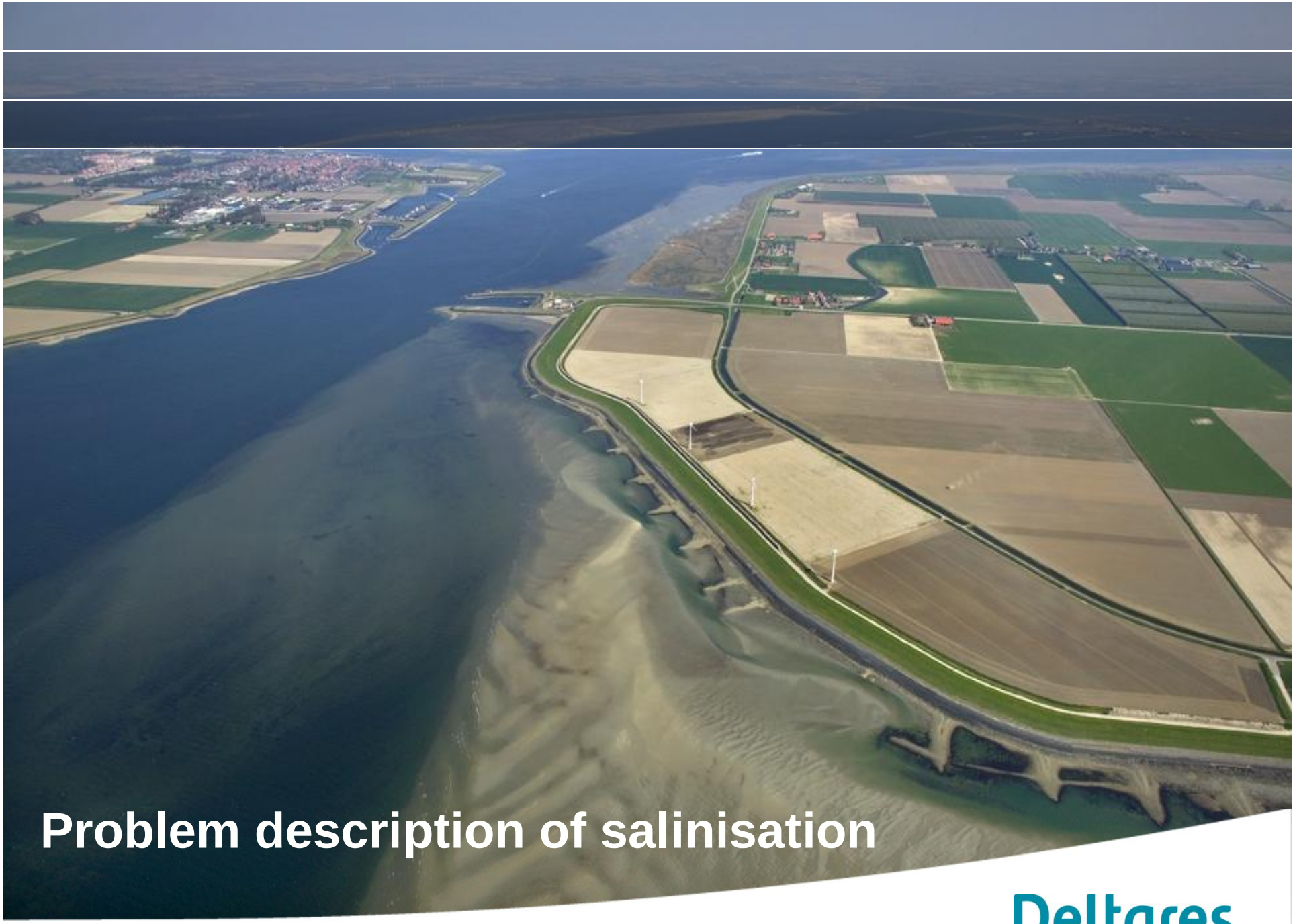

Problem description of salinisation

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Vertical grid concepts

Vertical systems

- surface and bottom following σ-layers
- fixed horizontal z-layers

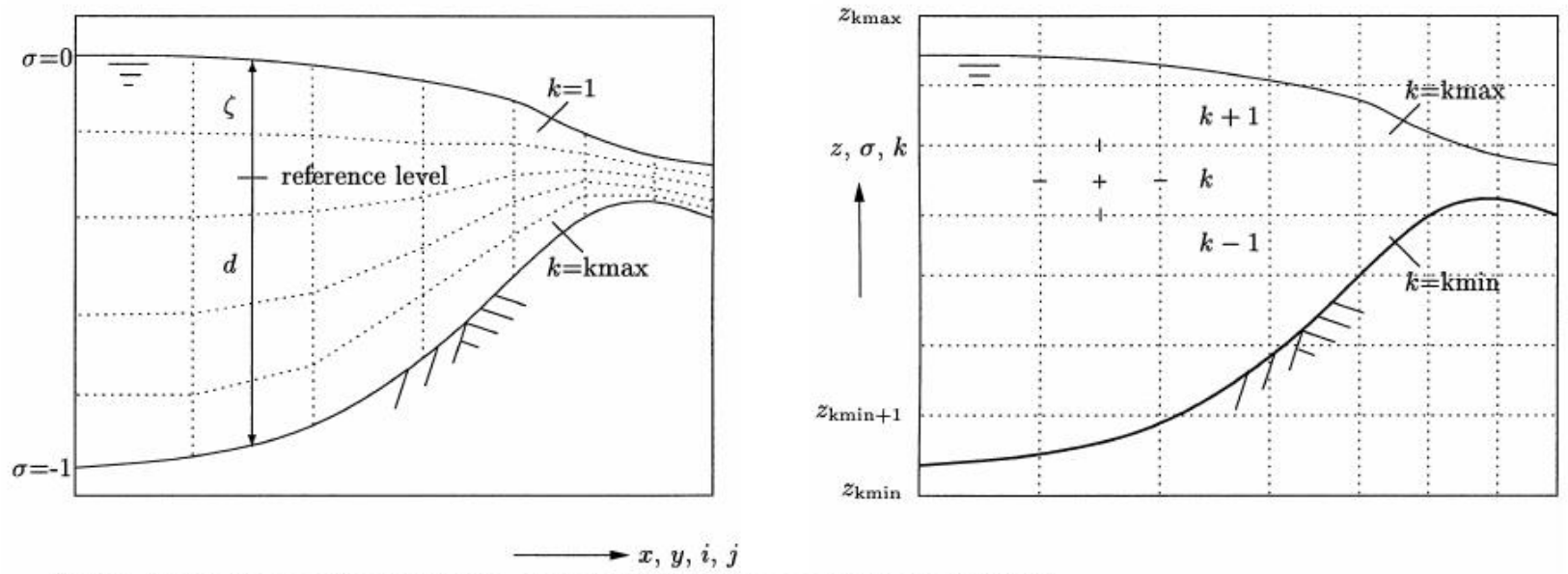

Figure 1.3. Vertical grid concepts: the σ–model (left) and z-coordinate model (right)

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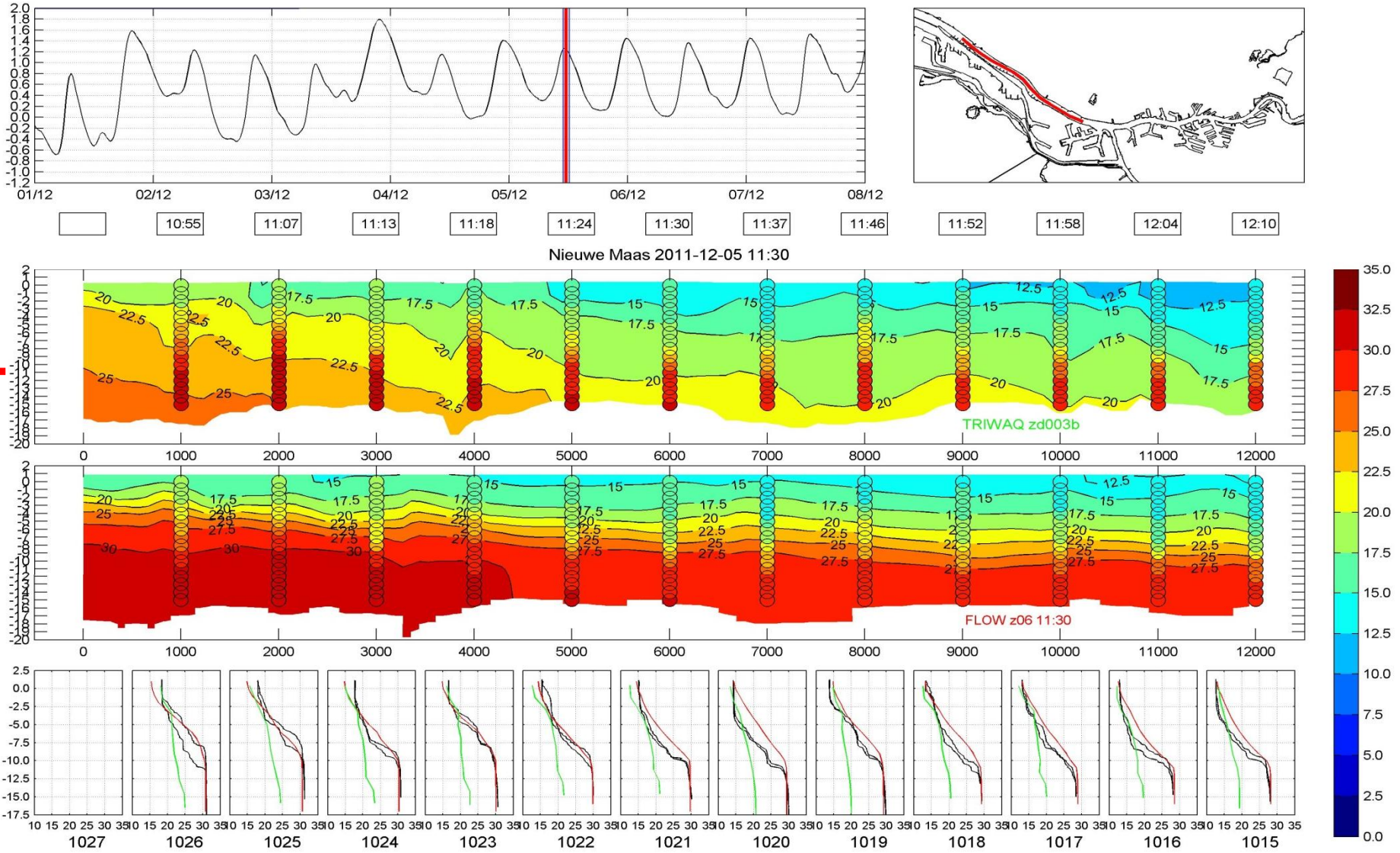
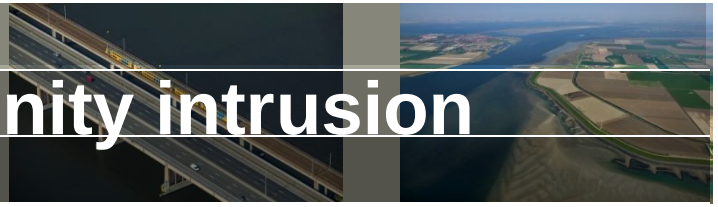
Salinity intrusion for December 2011 storm



Problem description w.r.t. salinity intrusion



Salinity intrusion differs with respect to:

- model schematizations;
- horizontal grid resolution;
- vertical grid layering concept; and
- software codes

- In general for sigma models reasonable to good agreement with measurements under normal conditions. However, large differences for December 2011 storm situation. What is the reason for this?

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Model schematizations

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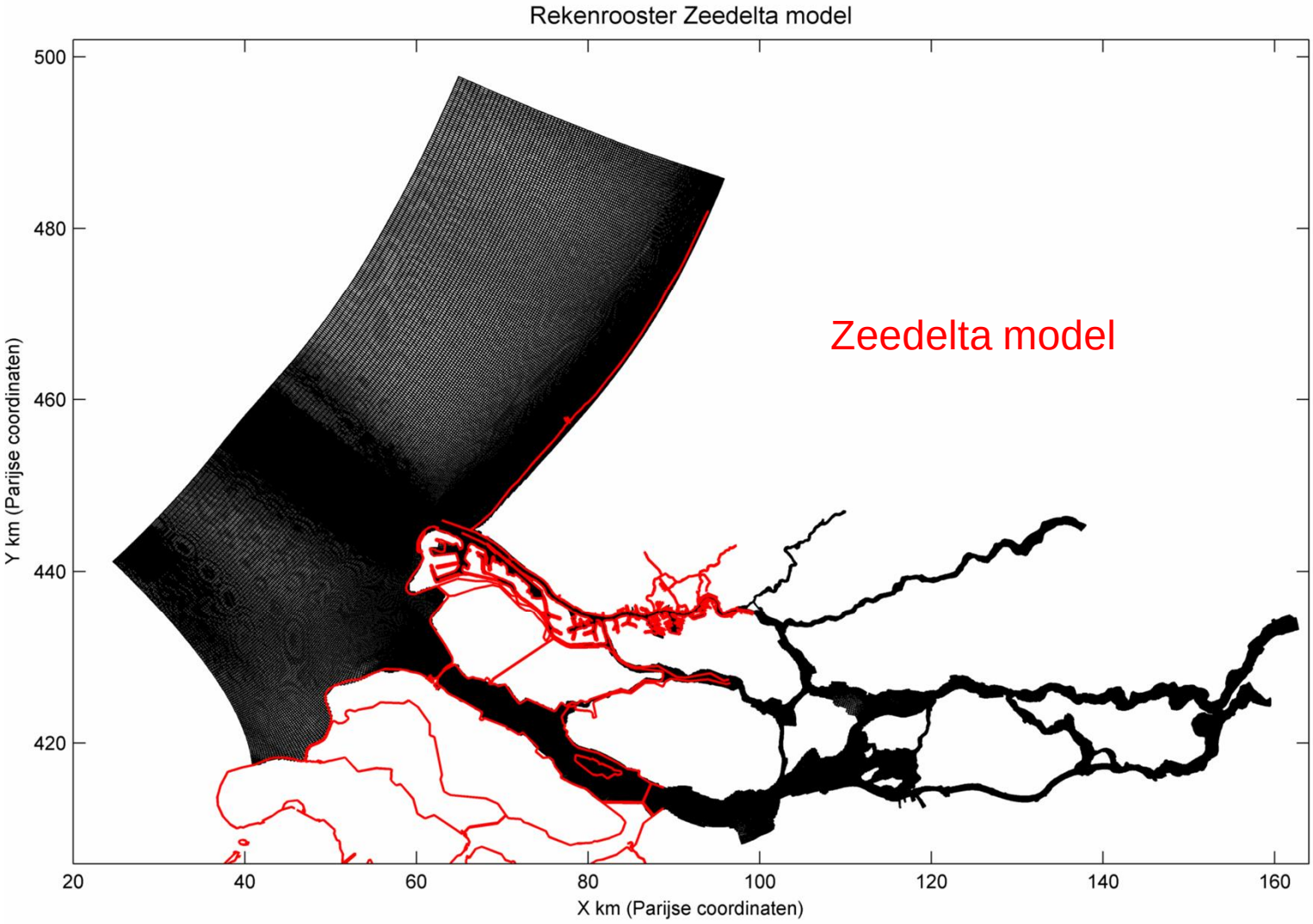
3D models for Rhine Meuse delta



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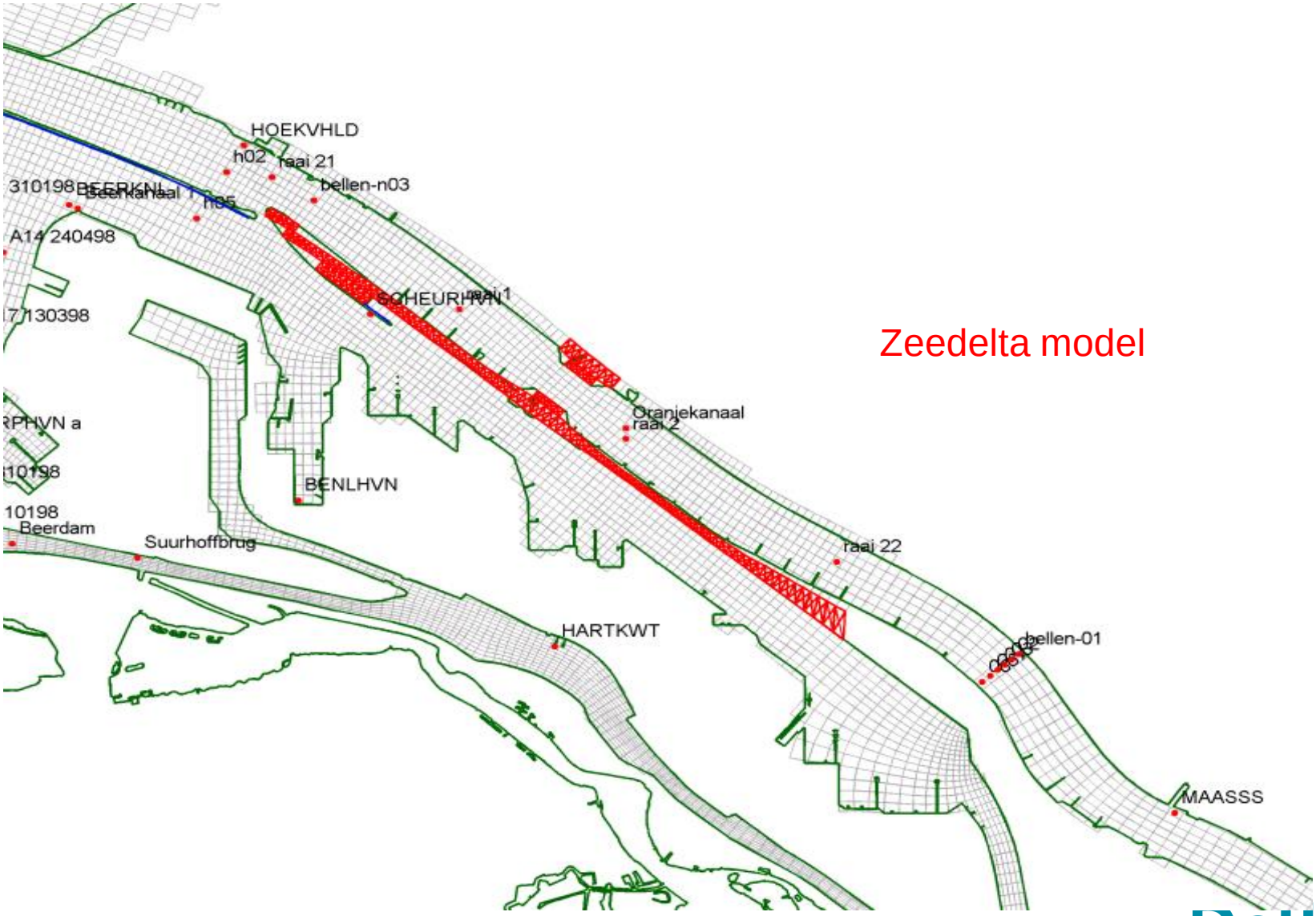
Detailed view of model grid for New Waterway



Zeedelta model

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Detailed view of model grid for Rotterdam harbour

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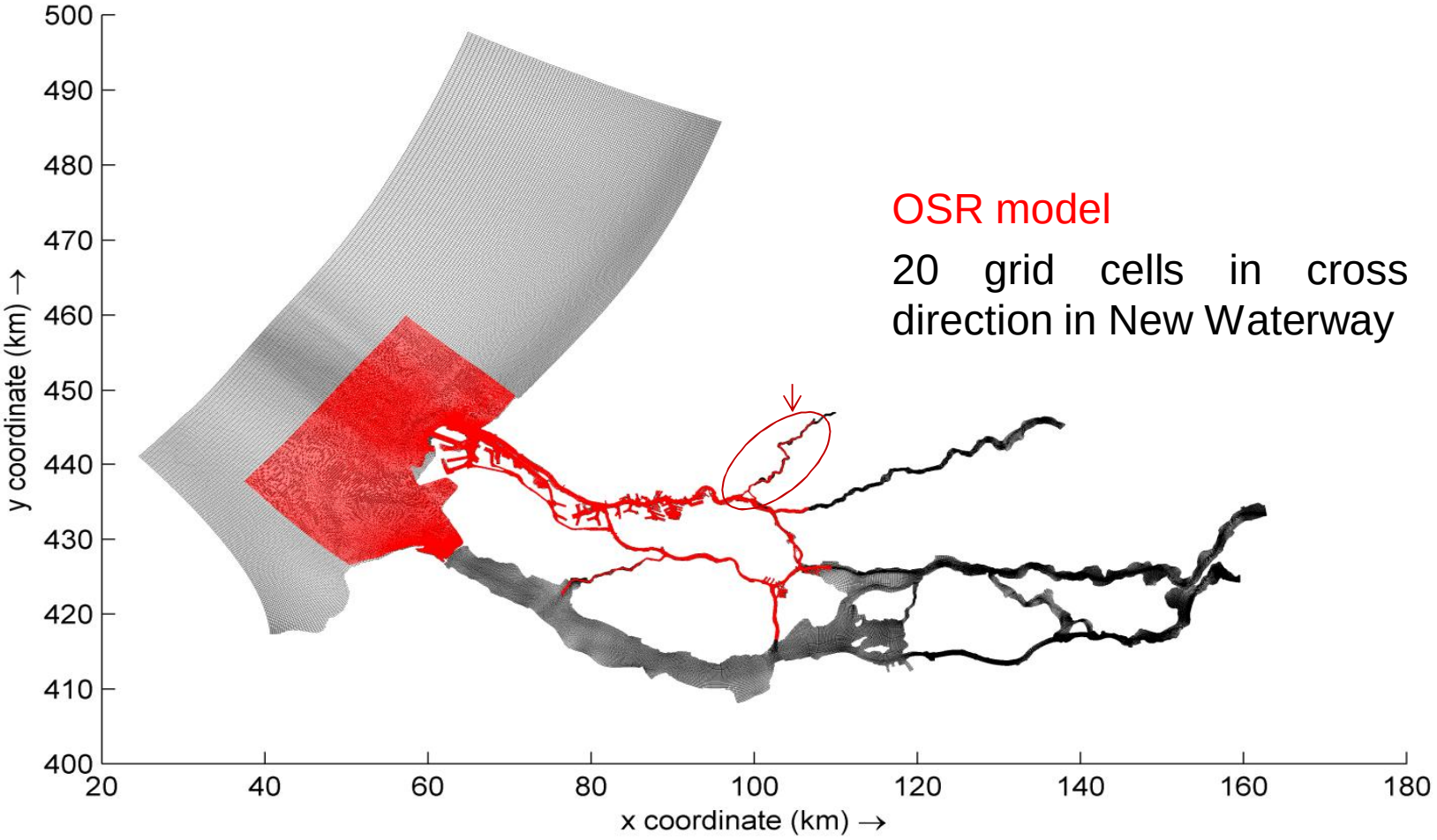
OSR (operational) model

2D outer domain (in black) and 3D inner domain (in red), via nesting



OSR model

20 grid cells in cross direction in New Waterway

Model performance w.r.t. salinity intrusion

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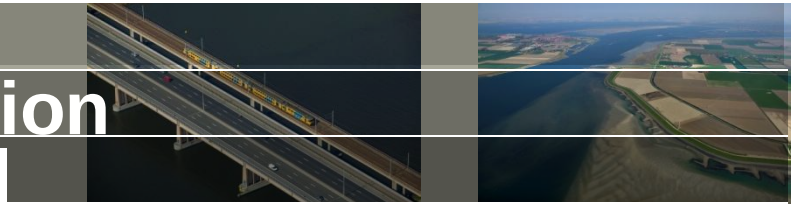
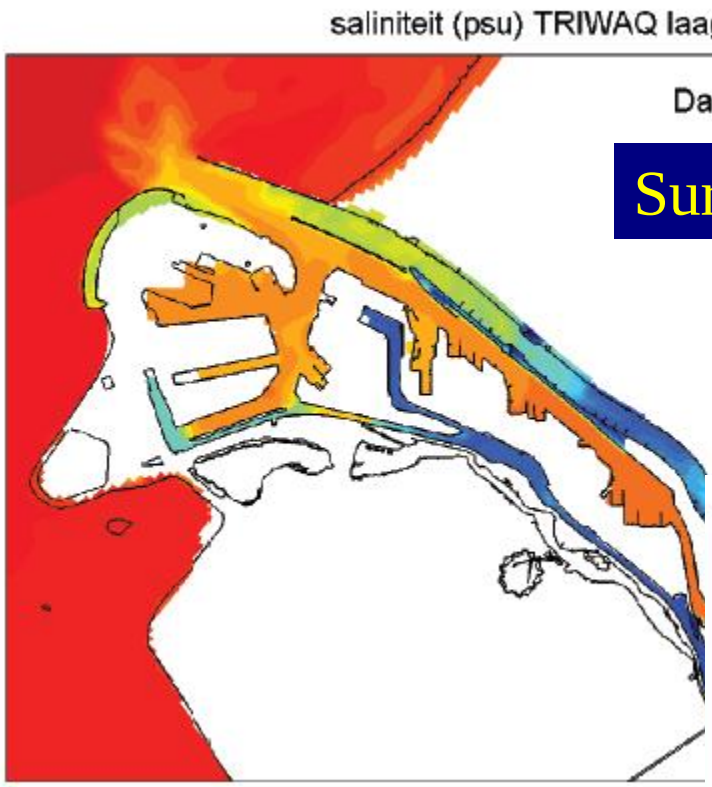
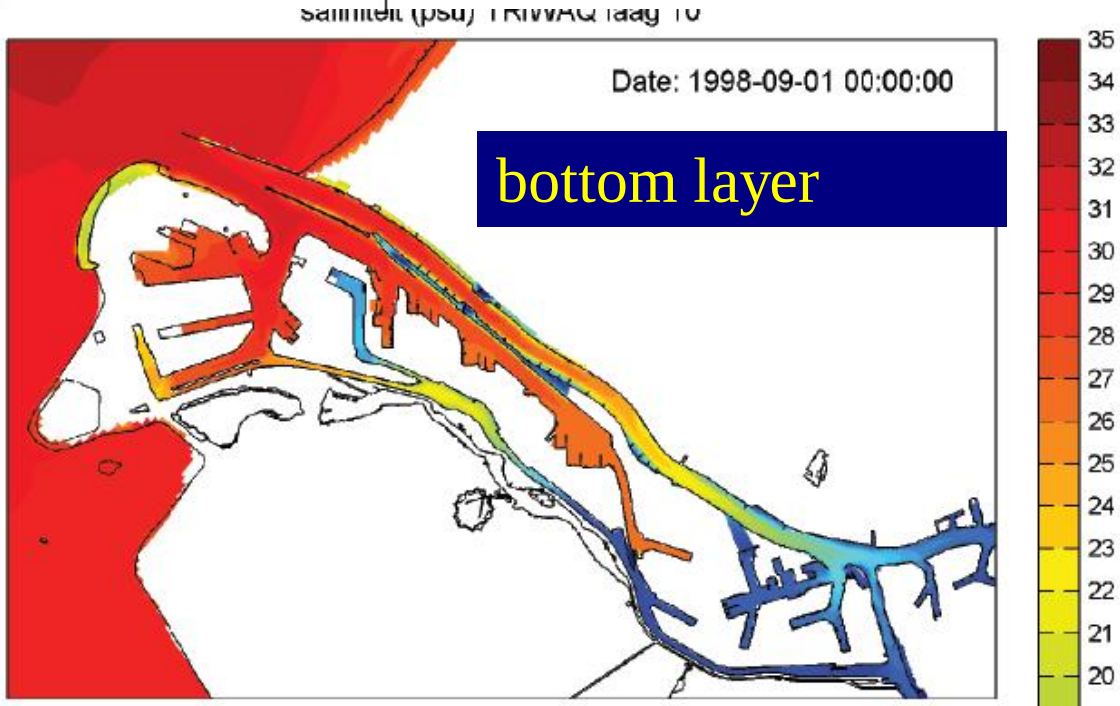
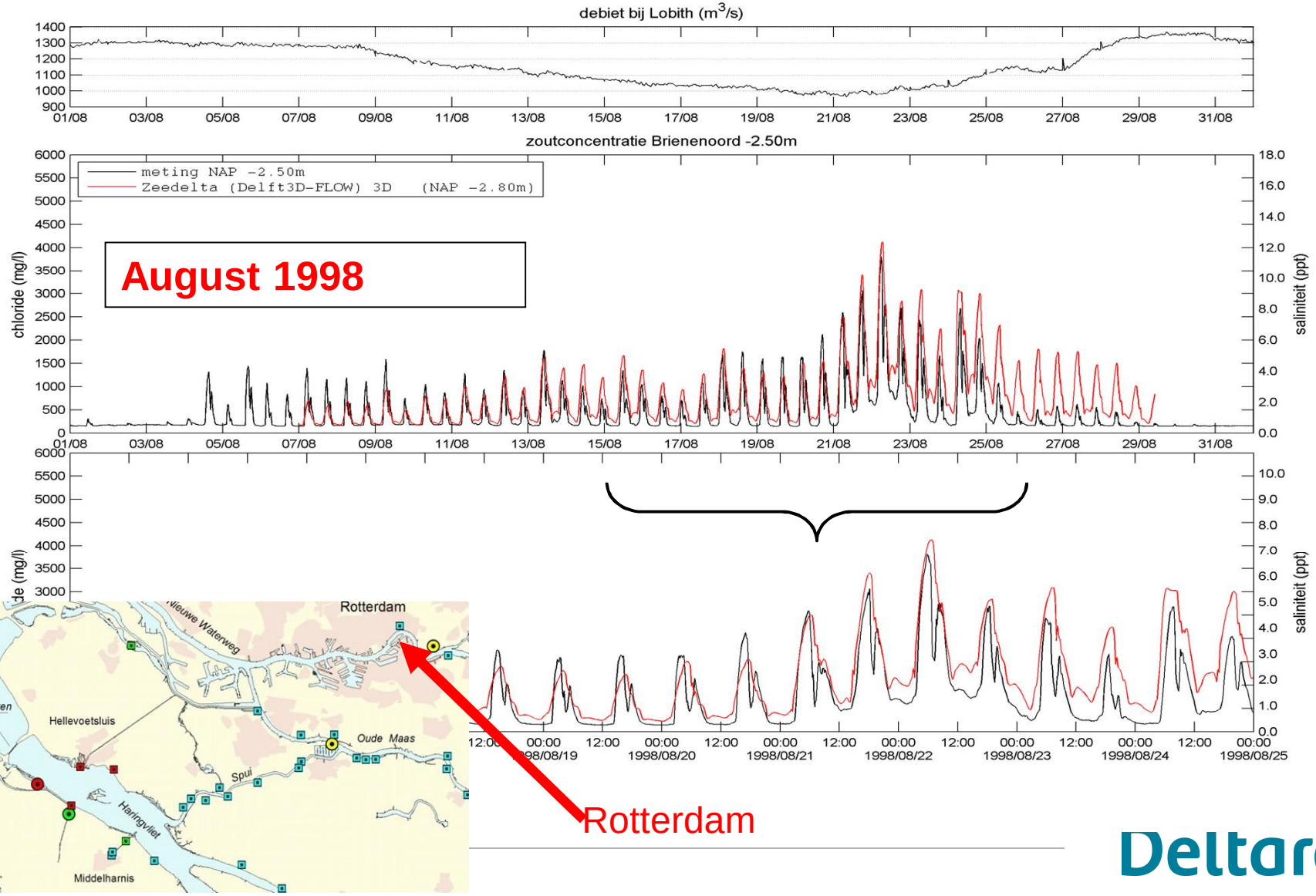
Illustration of salinity intrusion







Validation Zeedelta model for low river discharge (1)



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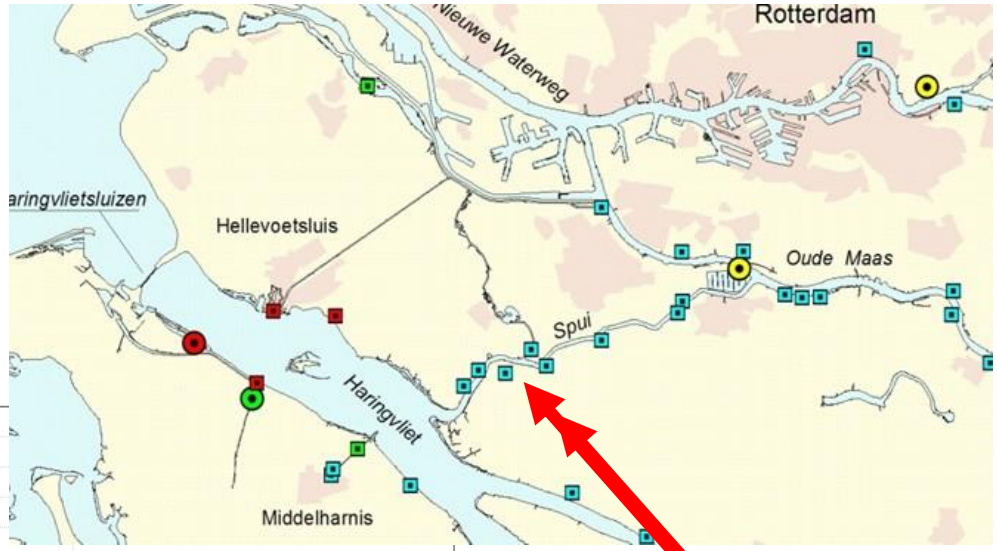
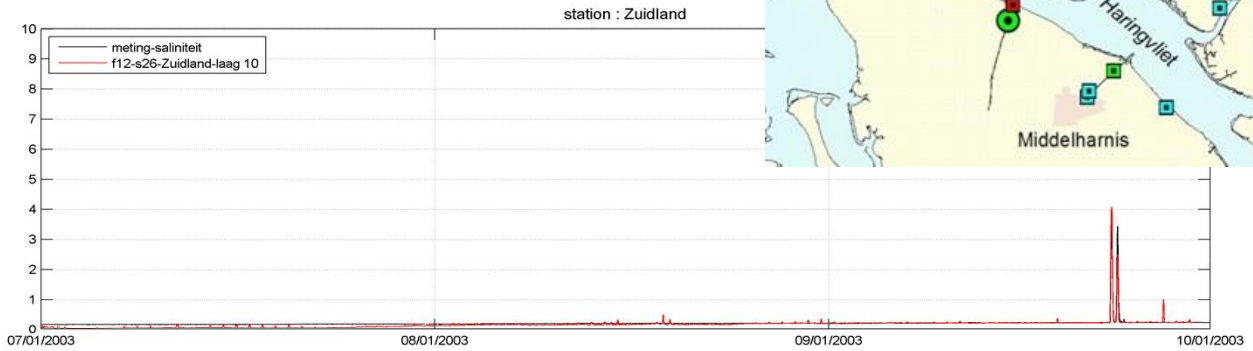
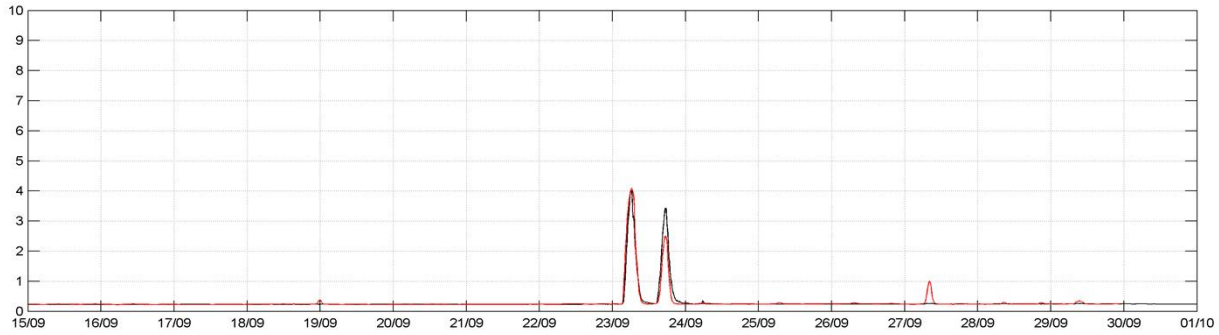
Validation Zeedeltamodel for low river discharge (2)





Zuidland



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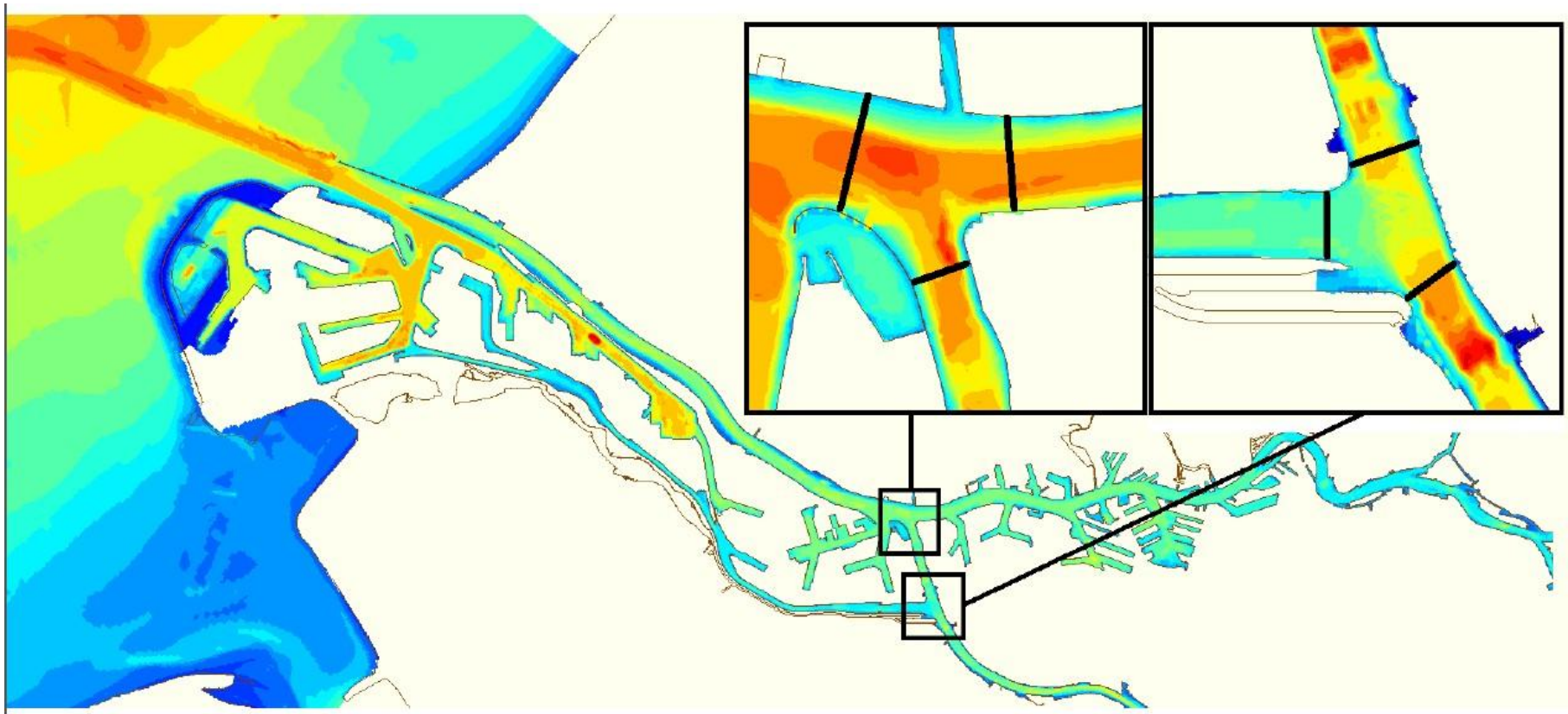
Validation by Port of Rotterdam Authority (1)



- Twee splitsingspunten: 1) Hartelkanaal - Oude Maas
  2) Nieuwe Waterweg - Oude Maas - Nieuwe Maas

M.Sc. thesis of Merel Verbeek

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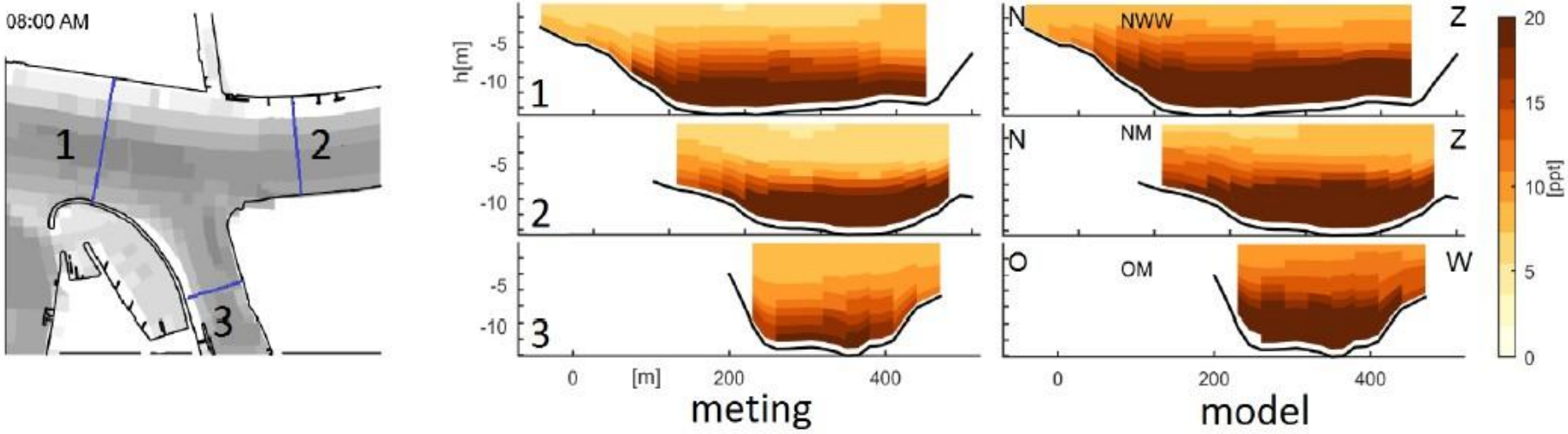
Validation by Port of Rotterdam Authority (2)

- Saliniteit



Mean error: 0.1 - 2 ppt

Correlation r = 0.5 and 0.9

Overestimation of salinity intrusion

Overestimation of stratification

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Additional simulations

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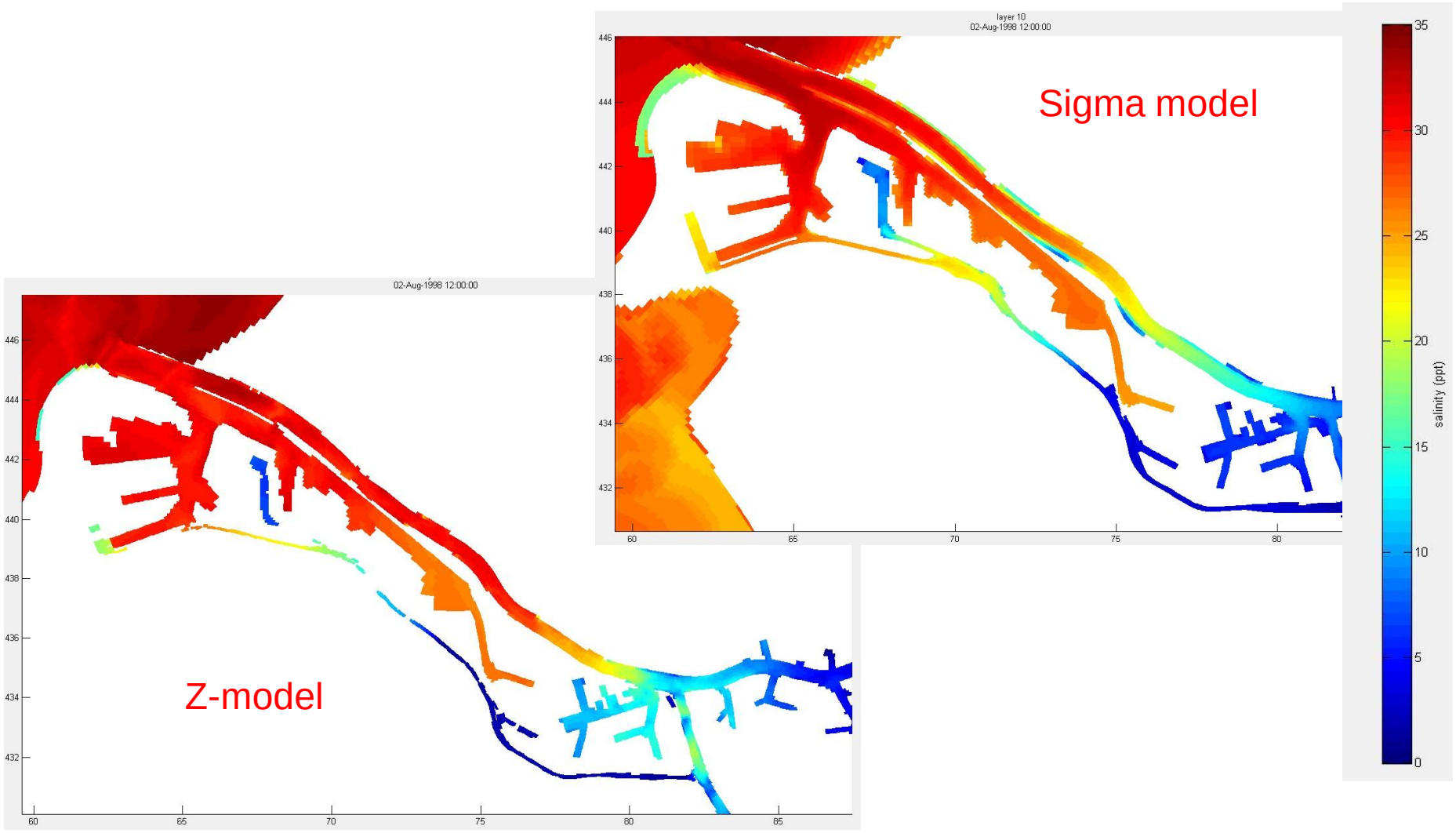
Sigma model versus Z-model



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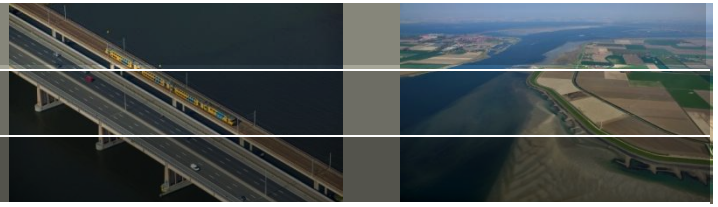
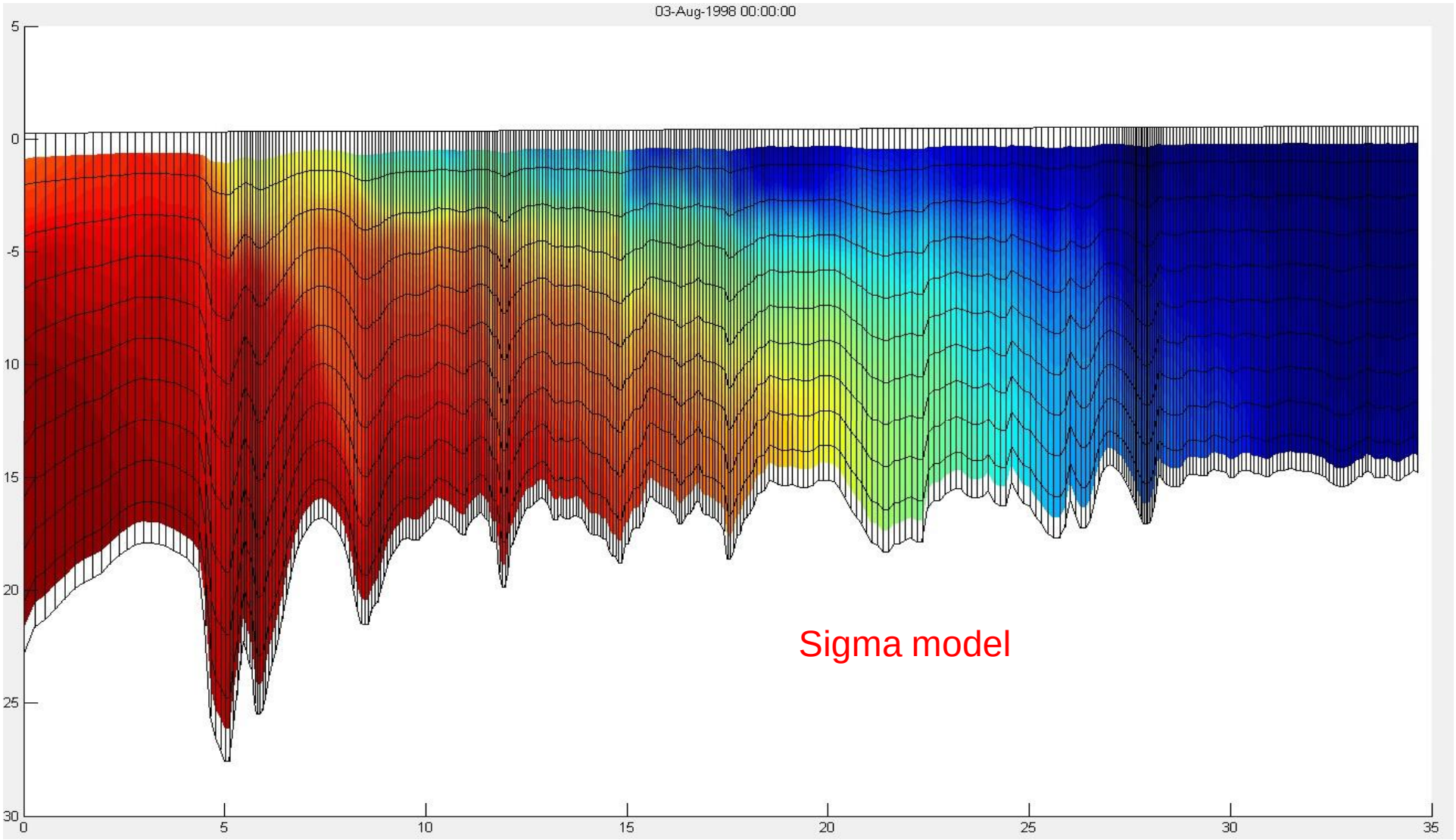
Sigma model (after two days)





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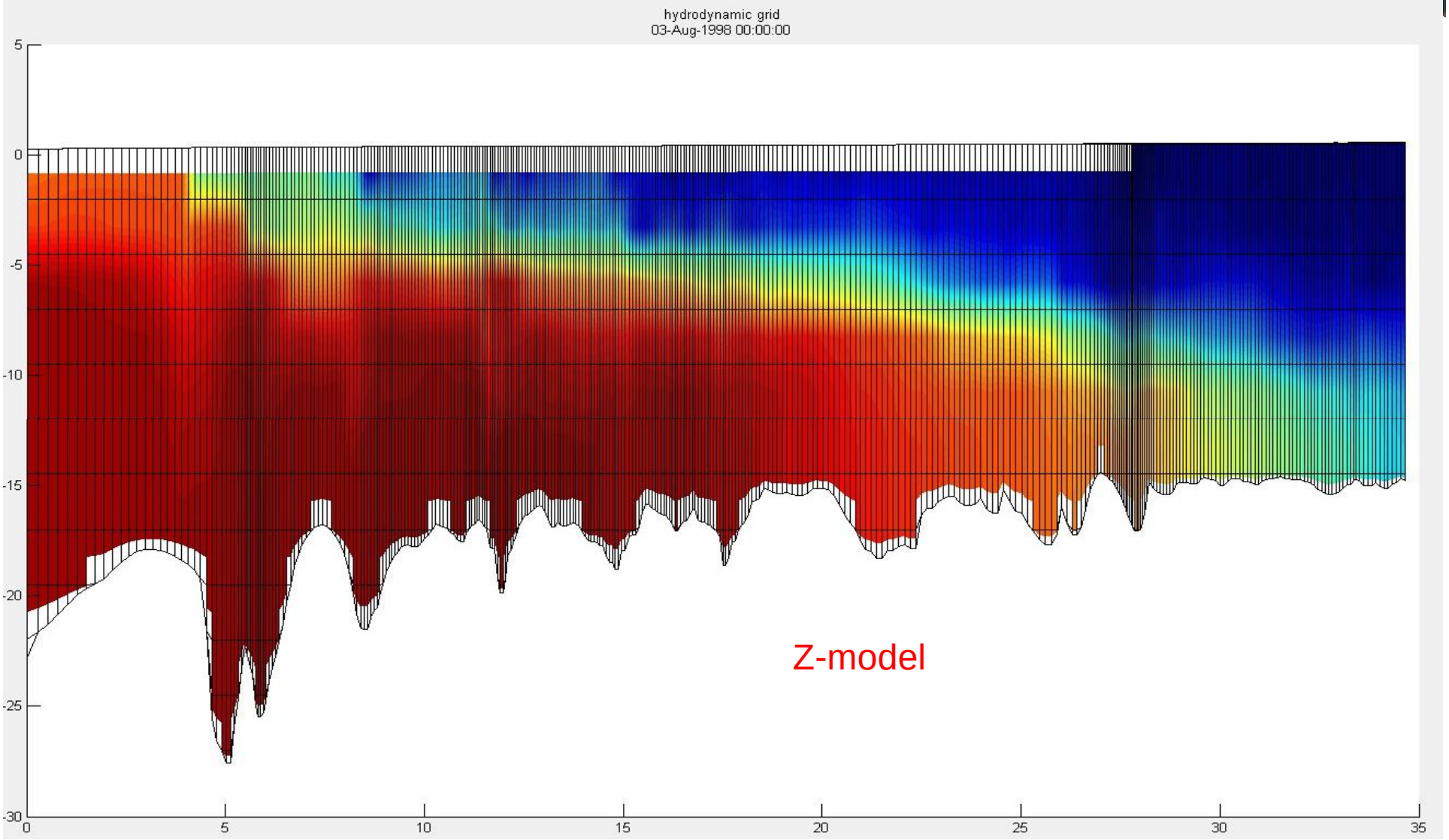
Z-model (after two days)



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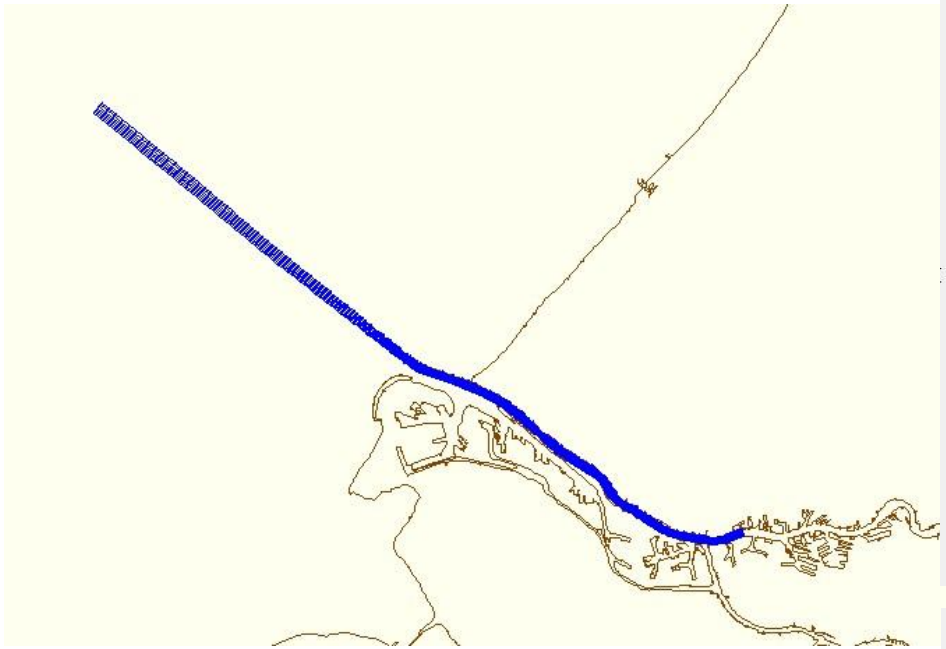
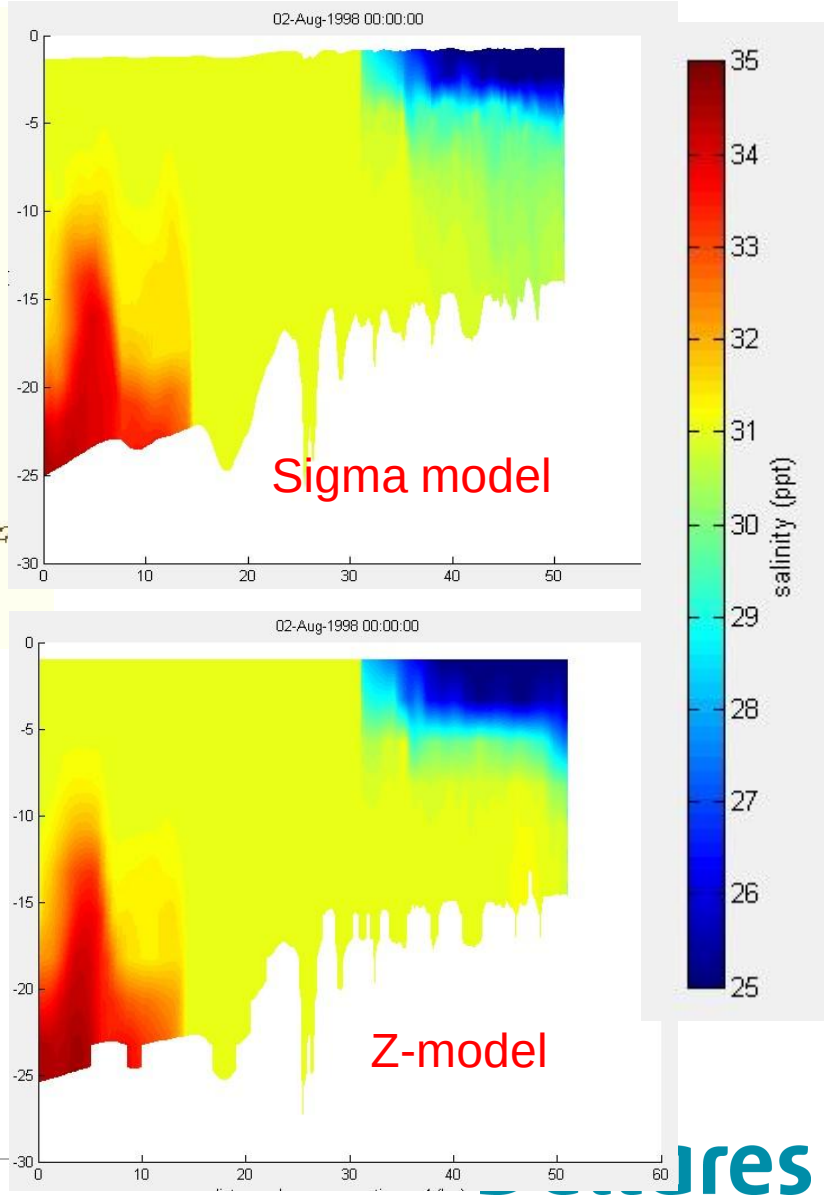
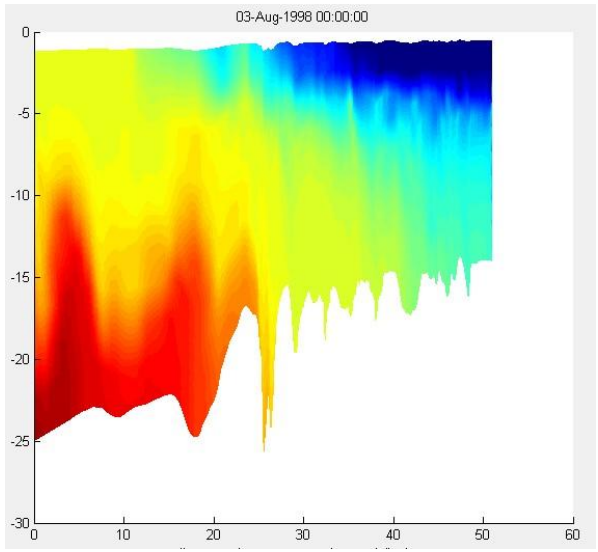
Schematized model

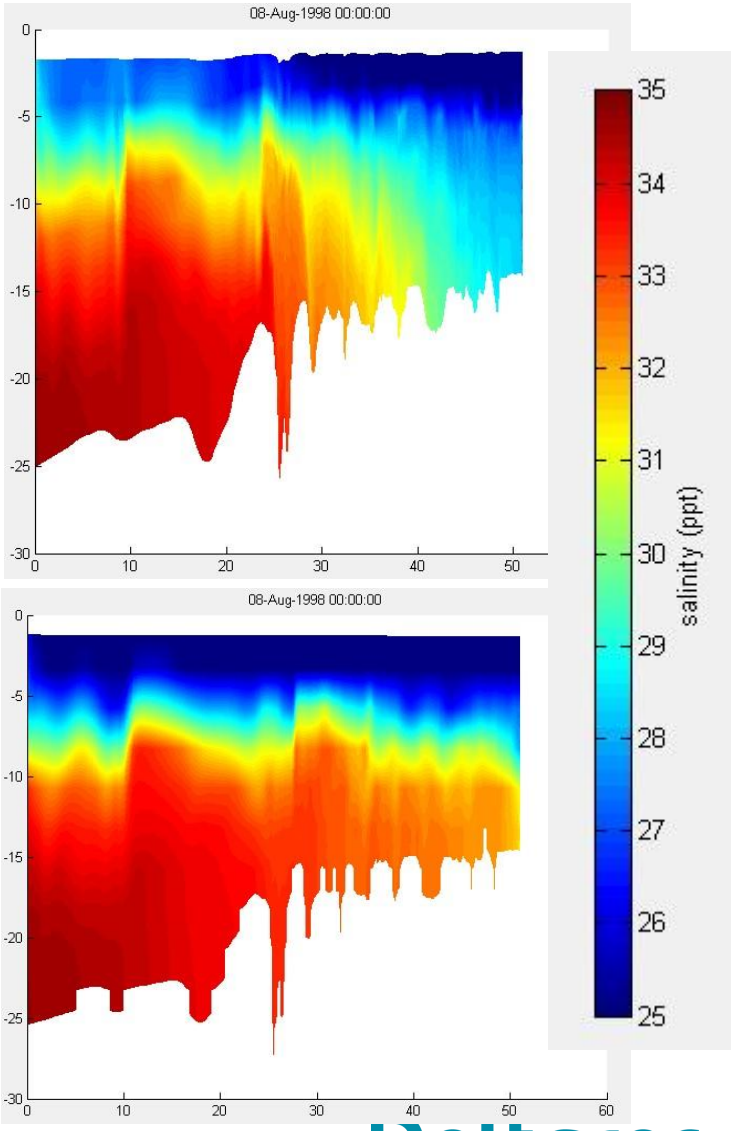


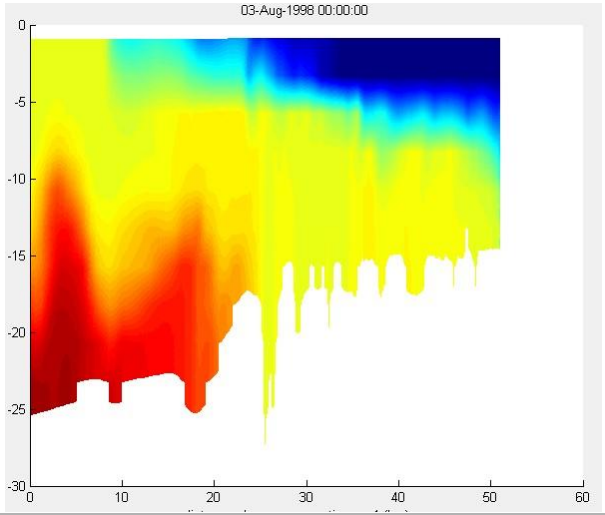


Schematized model (left=2 days; right=7 days)



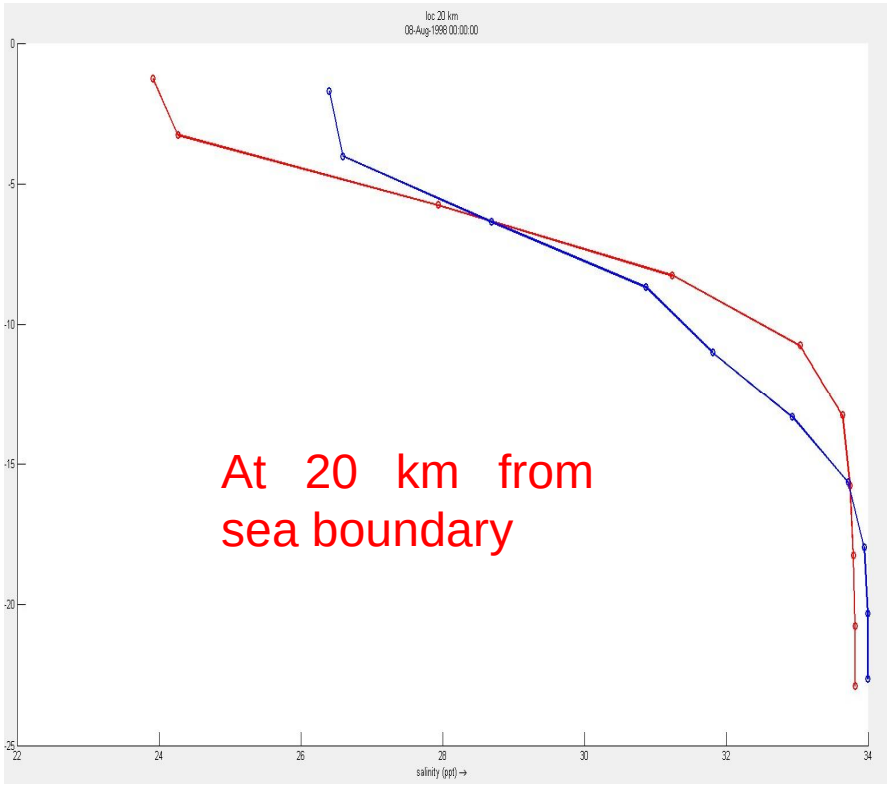
Sigma model



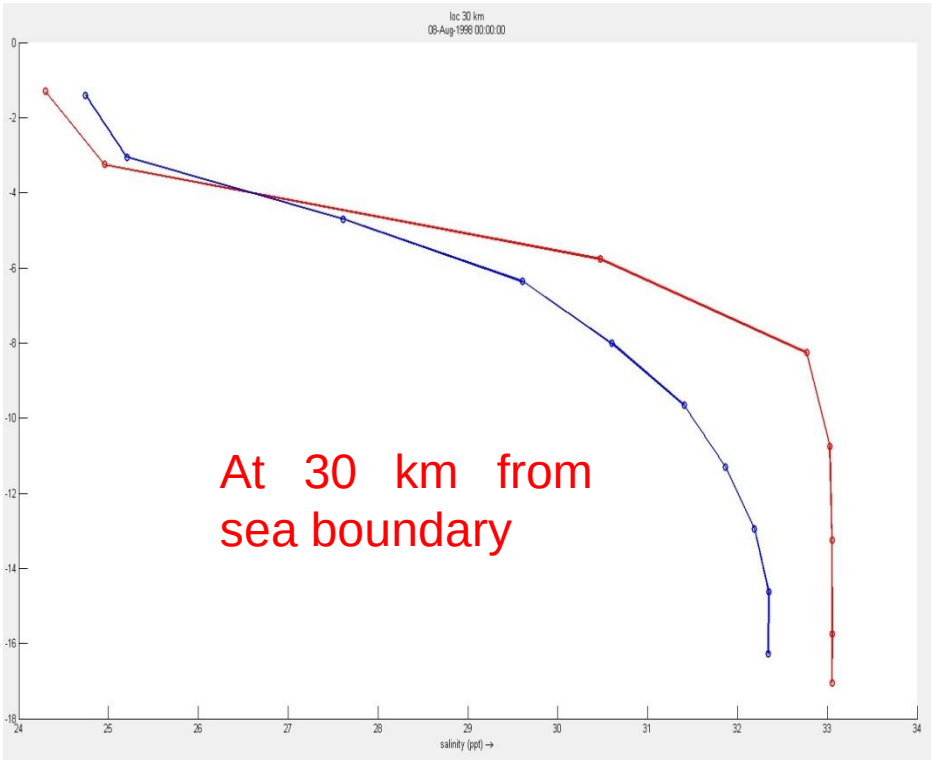


Z-model

Vertical profiles after 7 days



At 20 km from sea boundary



At 30 km from sea boundary

Red = Z-model

Blue = sigma model

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Software systems

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Dutch hydrodynamic modules for 2D/3D

- Delft3D 4 modelling suite (structured grid modelling), with hydrodynamic module Delft3D-FLOW

- Simona modelling suite (structured grid modelling), with hydrodynamic module WAQUA/TRIWAQ

- Delft3D Flexible Mesh suite: combination of unstructured and structured grid modelling with hydrodynamic module D-Flow Flexible Mesh https://www.deltares.nl/en/software/delft3d-4-suite/

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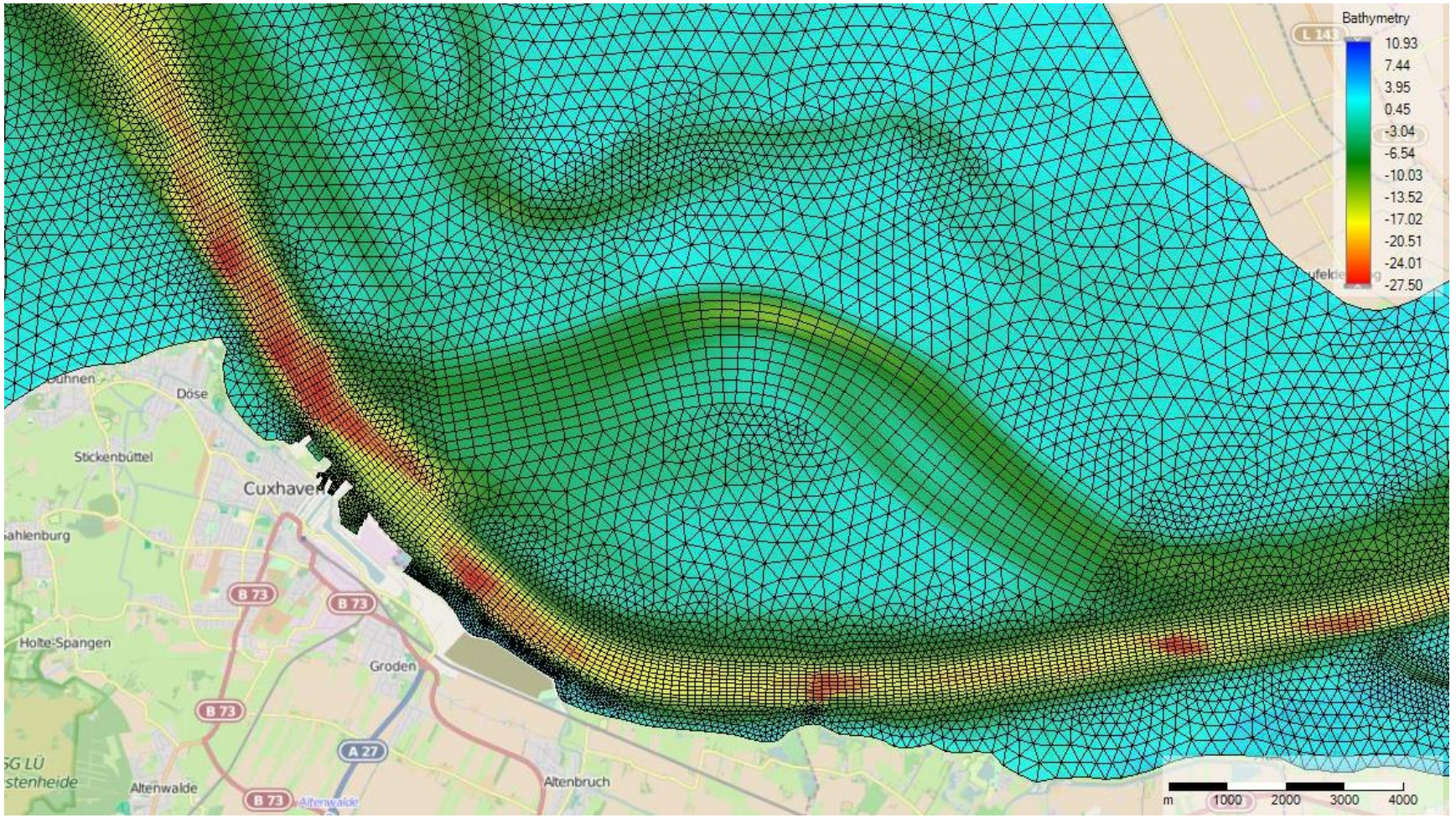
Elbe estuary (Cuxhaven) with Delft3D FM



From Aissa Sehili (BAW, Germany)

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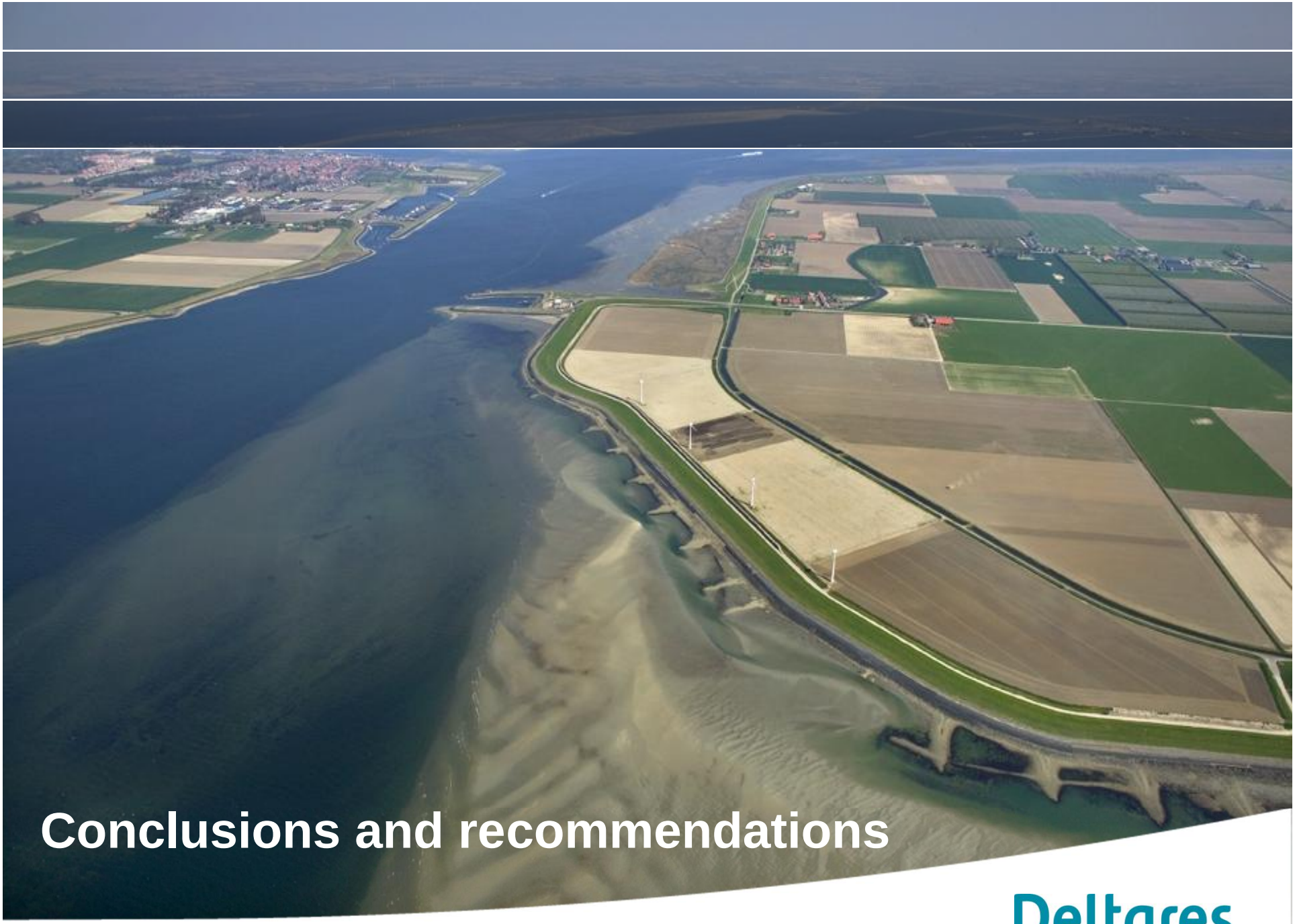

Conclusions and recommendations

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Conclusions w.r.t. prediction of salinisation (1)

- Satisfying model results for salinity intrusion, except for ‘storm December 2011’
- Validated software (both for sigma and Z-model)
- World wide accurate results w.r.t. salinity and temperature stratification in hundreds of applications since 1995

- Difficult to compare sigma and Z-models because of different vertical resolution; only one comparison yet for real-life application
- Salinity is an ‘integrated’ parameter (differences once introduced will remain and will increase)
- Both high and low salinity concentrations are important
- No grid convergence in vertical resolution; k-ε turbulence model optimized for 10-20 layers

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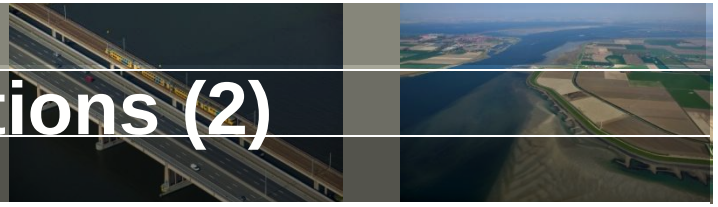
Conclusions and recommedations (2)



- Difference not due to software but to model parameters such as model forcing and grid resolution
- No preference for sigma or Z-model yet
- Model forcing seems to be the main cause of the mismatch in salinisation for December 2011 storm

- (Recom. 1) Measurements at more locations at the same time (in combination with ferry measurements?)
- (Recom. 2) Sensitivity analysis with Delft3D Flexible Mesh (because of sigma and Z-model and combination of sigma and Z)
- Continued cooperation between Dutch government, Port of Rotterdam authority and Deltares

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