The 3D Unstructured SCALDIS Model

departement Mobiliteit en Openbare Werken

A New High Resolution Model for Hydrodynamics and Sediment Transport in the Tidal Scheldt

29/06/2015

IAHR Scheldt Session

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Vlaamse overheid

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Overview

- Introduction (framework, why a new model?)
- Calibration strategy
- Results
  - water levels
  - velocities
  - discharges
- Conclusions

Integrated Plan Upper Sea Scheldt

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- Client: W&Z, aZS
- Project “Integrated Plan Upper Sea Scheldt”
  - Improve navigability of the Upper Sea Scheldt
  - Without negative effects on nature and safety against flooding
- Integrated within Flemish-Dutch research programme "Agenda for the Future“(2014-2017)
- Project Partners: INBO, UA-Ecobe, IMDC, Technum, FHR

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Model Purpose

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- HD for scenario analysis from Mouth area to Upper Sea Scheldt
- Include FCA and CRT areas
- Derived products
  - Sediment transport (Mud & Sand) by FHR
  - Ecosystem model (with UA – Ecobe)
  - Ecotope maps (with INBO)
  - Fish migration & Bird abundance with INBO

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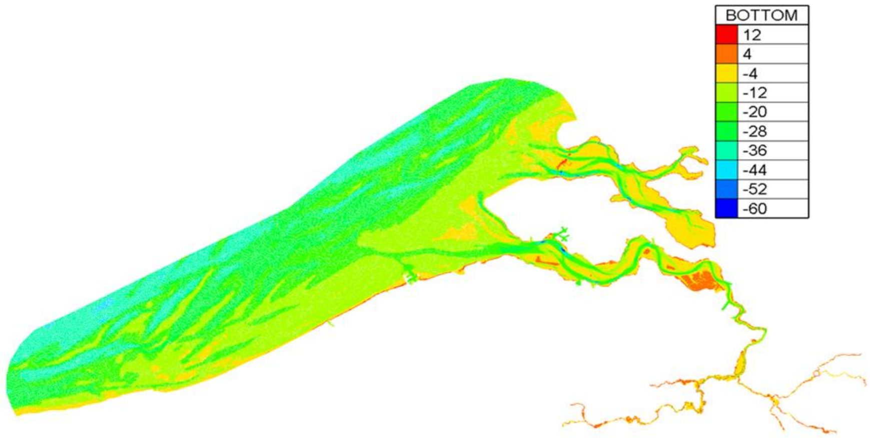
Model domain



Grid & Bathymetry

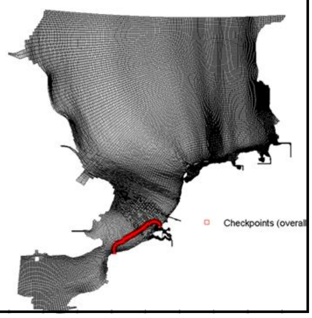
- 200 to **500 m** in North Sea and mouth area
- 200 m in Eastern Scheldt
- 120 m in Western Scheldt
- 7 m in upper Sea Scheldt to **5 m** at upstream boundaries

➔ +430.000 nodes in the horizontal
➔3D in 5 sigma layers
➔+2.150.000 nodes in total

- Bathymetry from 2013-2014

Boundary Conditions Downstream

- Derived from CSM-ZUNO modeling train
- CSMv5 – Continental Shelf Model
  - driven at ocean boundaries by astronomical water levels (tidal components: M2, S2, N2, K2, O1, K1, Q1, P1, NU2, L2, SA)
- ZUNOv3 – Zuidelijke Noordzee Model
  - nested in CSM
- HIRLAM winddata
- ZUNO incl Salinity
- Run for 2013



Boundary Conditions Upstream

- 8 discharge boundaries with **daily averaged discharge** values:
- Merelbeke, Dender, Zenne, Dijle, Kleine Nete, Grote Nete, Channel Ghent-Terneuzen, Channel Bath

Calibration strategy

- Data availability 2013
  - 48 WL stations (10' TS)
  - 58 sailed ADCP campaigns (2005-2014)
  - 11 salinity stations (10' TS)
  - 29 flux transects
- Weighted Dimensionless Cost Function
  - Vertical tide (water levels) 50%
  - Horizontal tide (velocities and discharges) 50%

Weighted Dimensionless Cost Function

$$Cost = \sum_{Factors} \frac{max(Factor_i, Threshold_i)}{max(Factor_{i,ref}, Threshold_i)} * Weight_i$$

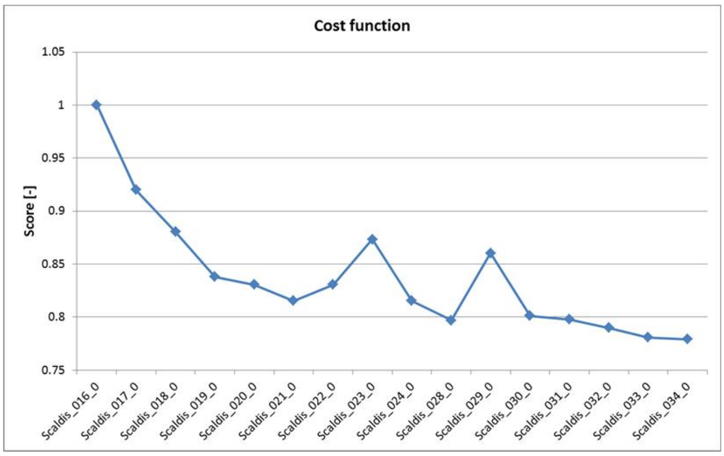
Factor = Error against Measurement

- Vertical Tide
  - RMSE of the water level time series [m]
  - RMSE of high waters [m]
  - Harmonic Analysis: Vector Difference [m]
- Horizontal Tide
  - RMAE of Sailed ADCP transects [-]
  - RMSE of Q measurements [m³/s]
- Measurement Uncertainty through Factor Threshold
- Assessed using VIMM toolbox

Weighted Dimensionless Cost Function

	Zone	Objective Function	Weights [%]		
Vertical Tide (Water Levels)	Western Scheldt	RMSE Time Series	3,50%	14,00%	50%
		RMSE Level High Water	3,50%		
		Vector difference	3,50%		
		delta M2 amplitude	3,50%		
	Eastern Scheldt	RMSE Time Series	1,25%	5,00%	
		RMSE Level High Water	1,25%		
		Vector difference	1,25%		
		delta M2 amplitude	1,25%		
	Lower Sea Scheldt	RMSE Time Series	3,50%	14,00%	
		RMSE Level High Water	3,50%		
		Vector difference	3,50%		
		delta M2 amplitude	3,50%		
	Upper Sea Scheldt	RMSE Time Series	4,25%	17,00%	
		RMSE Level High Water	4,25%		
		Vector difference	4,25%		
		delta M2 amplitude	4,25%		
Horizontal Tide (Velocities and Fluxes)	Western Scheldt	RMAE of Sailed ADCP deep zone	10,00%	13,33%	50%
		RMSE of Discharges	3,33%		
	Lower Sea Scheldt	RMAE of Sailed ADCP deep zone	10,00%	15,83%	
		RMAE of Sailed ADCP shallow zone	2,50%		
		RMSE of Discharges	3,33%		
	Upper Sea Scheldt	RMAE of Sailed ADCP deep zone	15,00%	20,83%	
		RMAE of Sailed ADCP shallow zone	2,50%		
		RMSE of Discharges	3,33%		
			100%	100%	100%

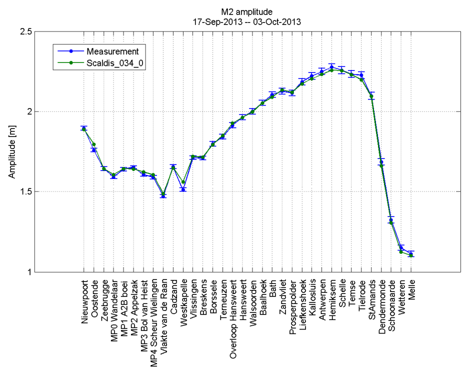
Weighted Dimensionless Cost Function

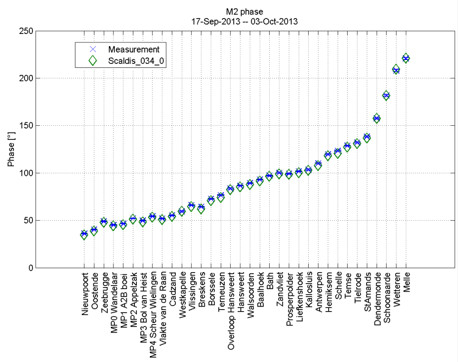


Model performance: WL

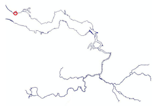
Parameter	Western Scheldt and North Sea	Eastern Scheldt	Lower Sea Scheldt	Upper Sea Scheldt
RMSE time series (m)	0.10	0.09	0.14	0.14
RMSE HW (m)	0.08	0.10	0.13	0.12
RMSE LW (m)	0.07	0.09	0.09	0.11
Bias M2 amplitude (m)	-0.01 to 0.05	-0.01 to 0.03	-0.02 to 0.01	-0.03 to 0
Bias M2 phase (degrees)	-2 to 0	-2 to 4	-2 to -1	-3 to 2

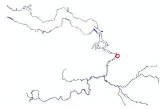
M2 amplitude and phase

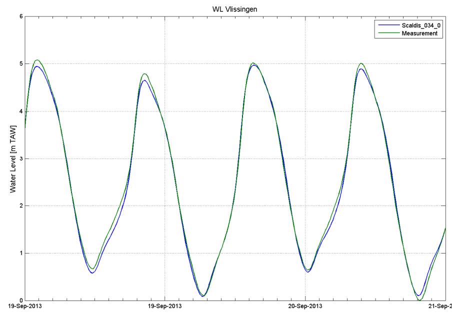


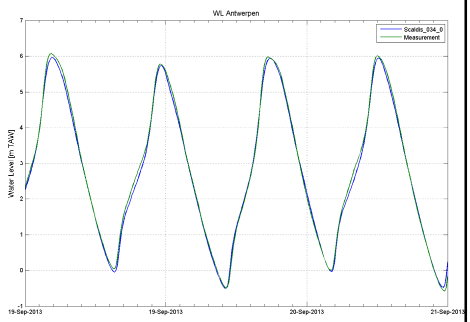


WL history Vlissingen, Antwerpen









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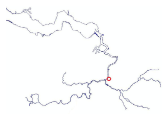
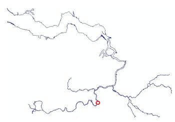
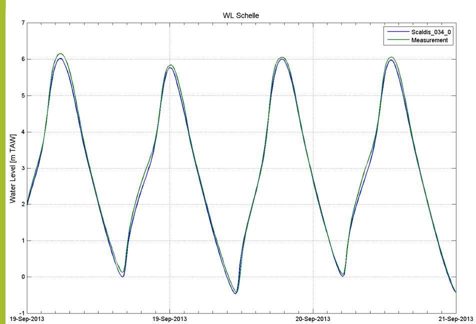
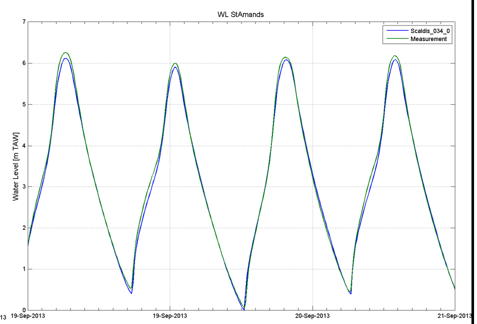
WL history Schelle, Sint Amands









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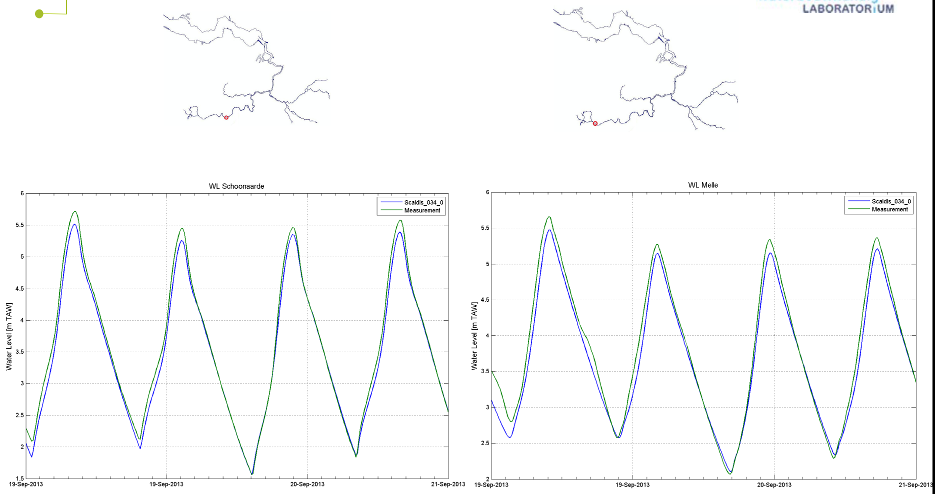
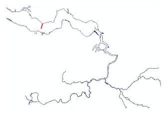
WL history Schoonaarde, Melle

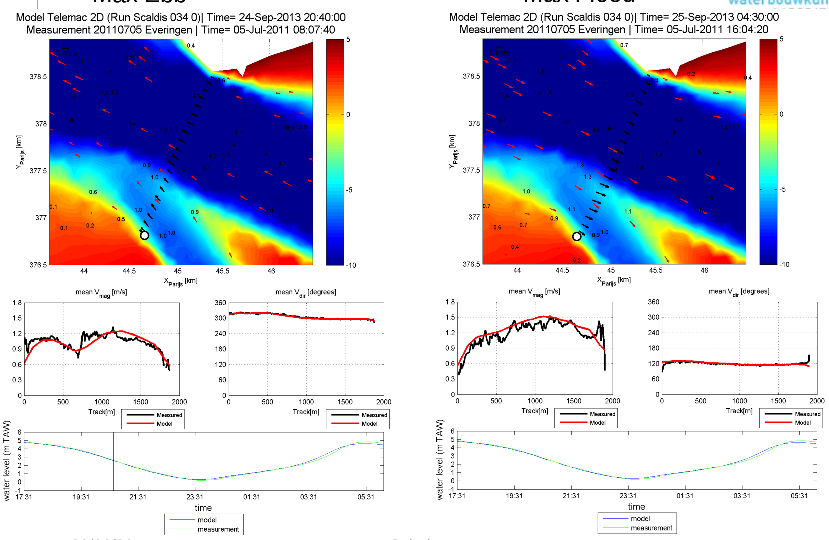


Model performance ADCP Everingen

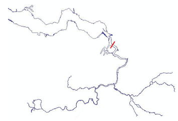


Max Ebb

Max Flood



Model performance ADCP Liefkenshoek

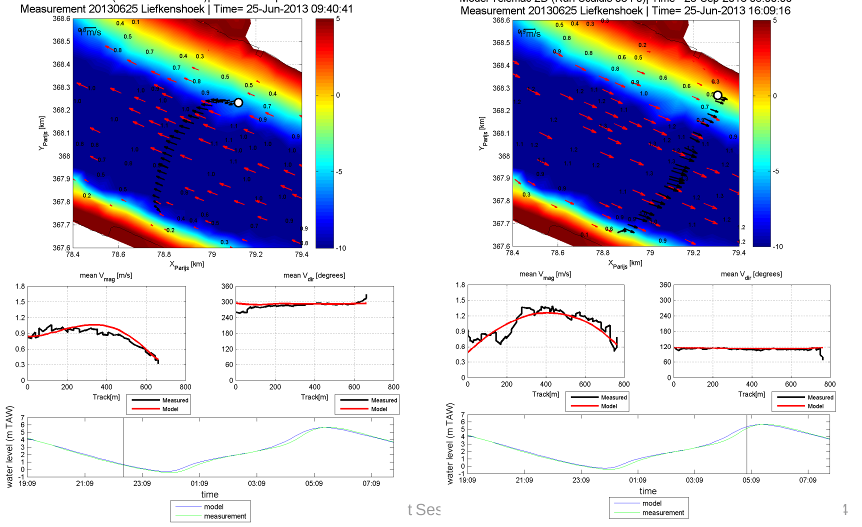


Max Ebb

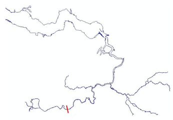
Model Telemac 2D (Run Scaldis 034 0)| Time= 22-Sep-2013 22:30:00
Measurement 20130625 Liefkenshoek | Time= 25-Jun-2013 09:40:41

Max Flood

Model Telemac 2D (Run Scaldis 034 0)| Time= 23-Sep-2013 05:00:00
Measurement 20130625 Liefkenshoek | Time= 25-Jun-2013 16:09:16



Model performance ADCP Schoonaarde

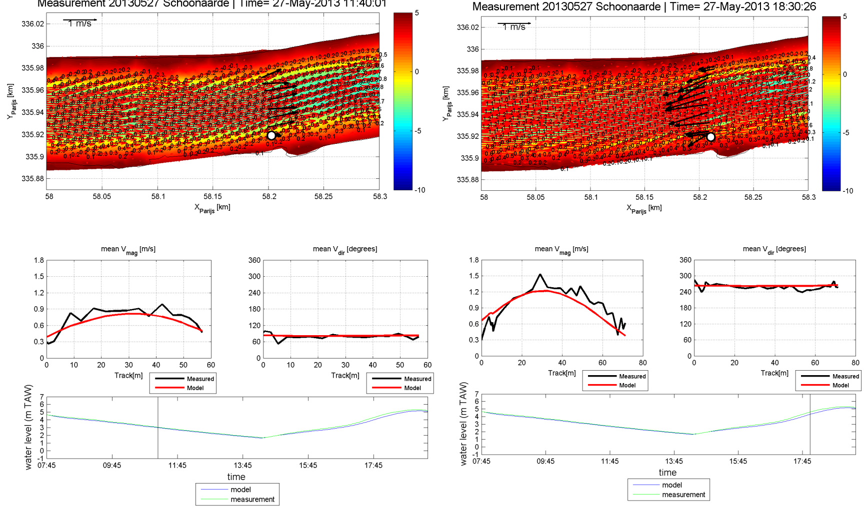


Max Ebb

Model Telemac 2D (Run Scaldis 034 0)| Time= 21-Sep-2013 11:10:00
Measurement 20130527 Schoonaarde | Time= 27-May-2013 11:40:01

Max Flood

Model Telemac 2D (Run Scaldis 034 0)| Time= 21-Sep-2013 18:00:00
Measurement 20130527 Schoonaarde | Time= 27-May-2013 18:30:26



Model performance: velocities

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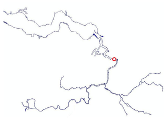
- RMSE of velocity magnitude varies between 12 cm/s and 25 cm/s
- For most transects it is smaller than 20 cm/s

Stationary velocity: deep zone



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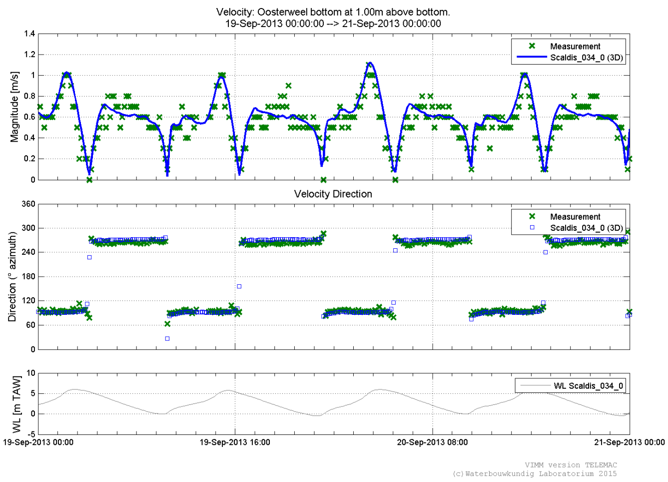
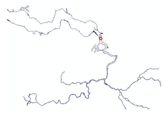
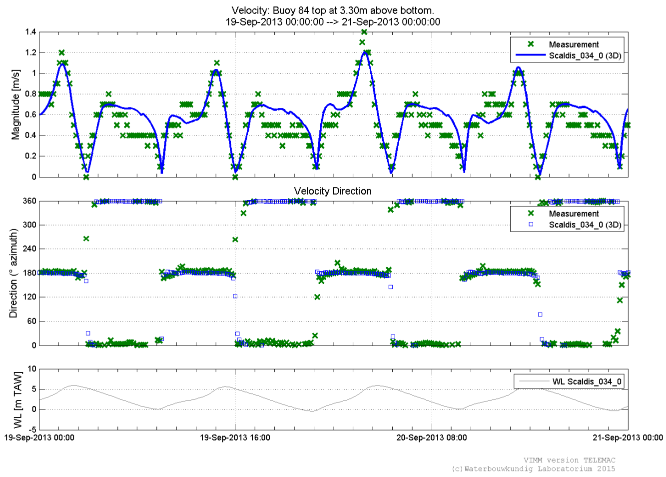


Stationary velocity: deep zone

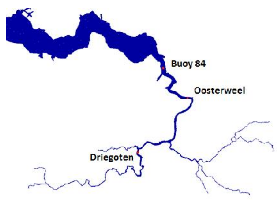




Stationary velocity: deep zone

Location	Analysis vector			Magnitude		Direction	
	MAE TS	RMAE TS	Model qualification	BIAS TS	RMSE TS	BIAS TS	RMSE TS
	[m/s]	[-]	(*Sutherland et al.,* 2003)	[m/s]	[m/s]	[°]	[°]
Buoy 84 bottom	0.13	0.29	good	0.05	0.13	0	21
Buoy 84 top	0.12	0.25	good	0.03	0.13	-1	23
Oosterweel bottom	0.10	0.20	good	0.02	0.10	4	24
Oosterweel top	0.14	0.22	good	-0.07	0.15	2	30
Driegoten (real)	0.16	0.35	good	0.05	0.17	-2	23
Driegoten (proxy)	0.30	0.68	poor	0.29	0.35	1	18
Totaal	0.15			0.05	0.19	0	25

Driegoten real: too shallow in model
Driegoten proxy: too high velocity



Stationary velocity: shallow zone

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Western Scheldt:
- Hooge Platen Noord
- Hooge Platen West
- Plaat van Walsoorden

Sea Scheldt:
- INBO measurements

Stationary velocity: shallow zone

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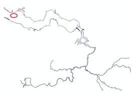
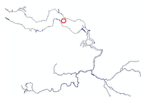
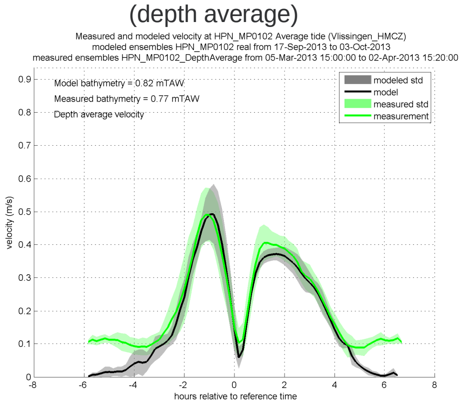
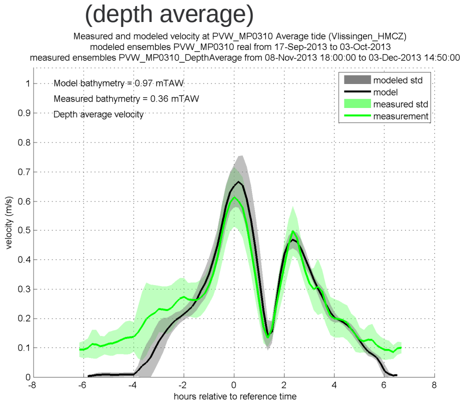




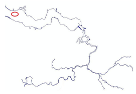
Hooge Platen Noord (depth average)

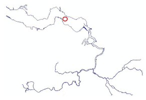


Plaat van Walsoorden (depth average)

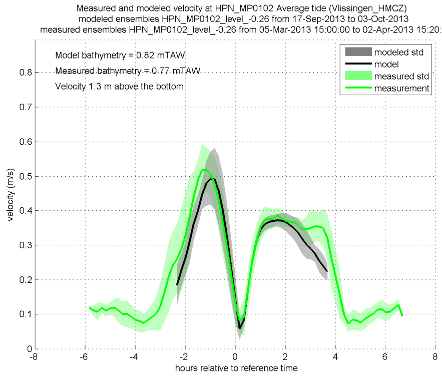


Stationary velocity: shallow zone

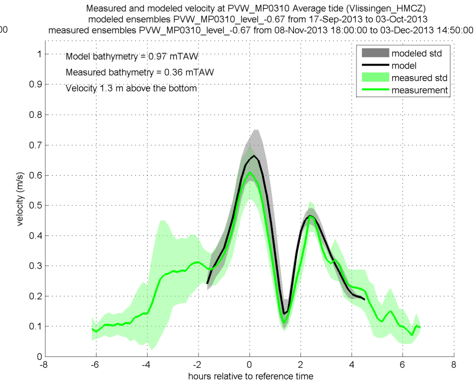




Hooge Platen Noord
(1.3 m above bottom)



Plaat van Walsoorden
(1.3 m above bottom)



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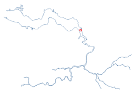
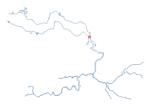
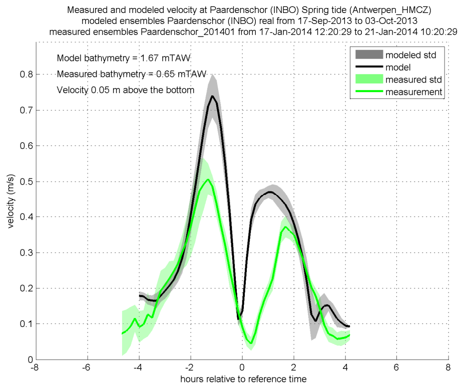
Stationary velocity: shallow zone

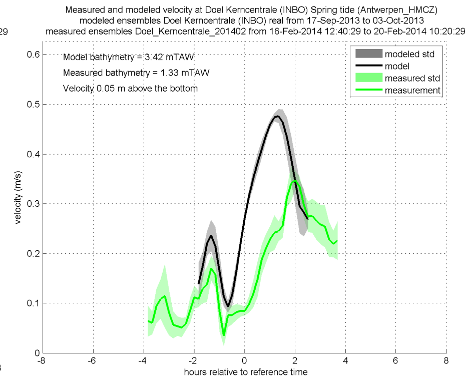




Paardenschor
(0.05 m above bottom)



Doel
(0.05 m above bottom)



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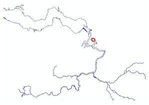
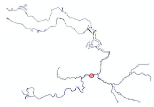
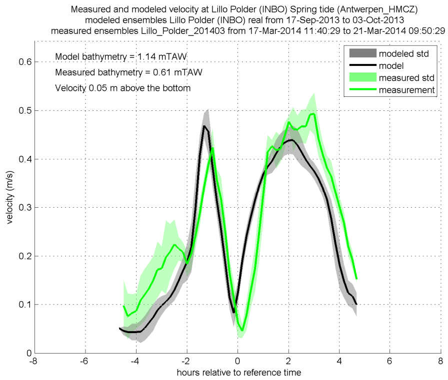
Stationary velocity: shallow zone

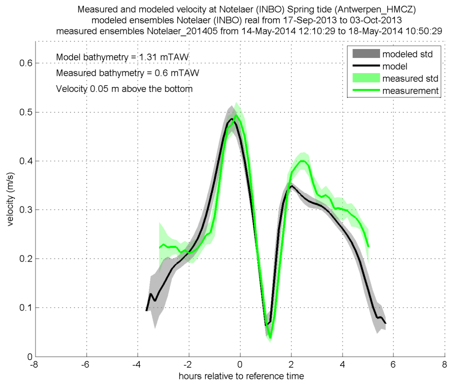




Lillo polder
(0.05 m above bottom)



Notelaer
(0.05 m above bottom)



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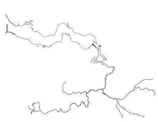
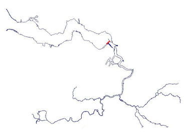
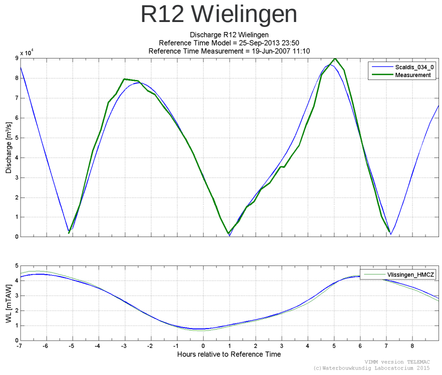
Model Performance: discharges

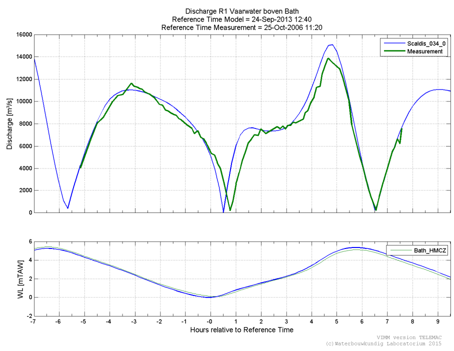




R12 Wielingen



R1 Vaarwater boven Bath



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Model Performance: discharges

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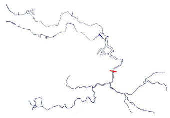
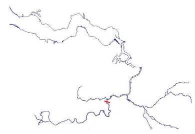
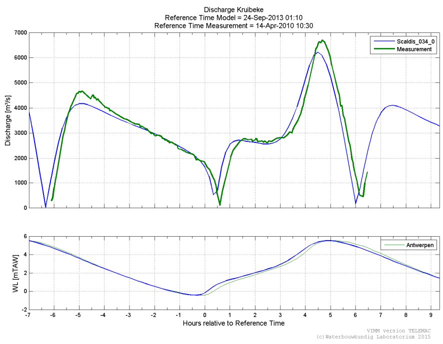
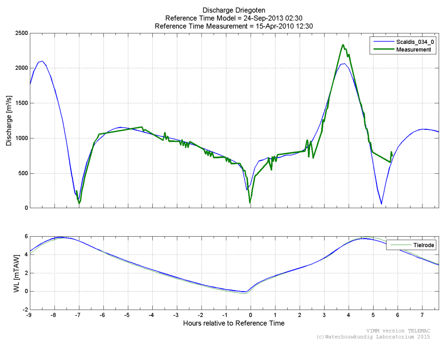


Kruibeke



Driegoten





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Model Performance: Salinity

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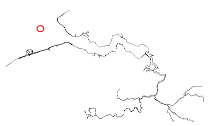

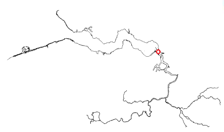

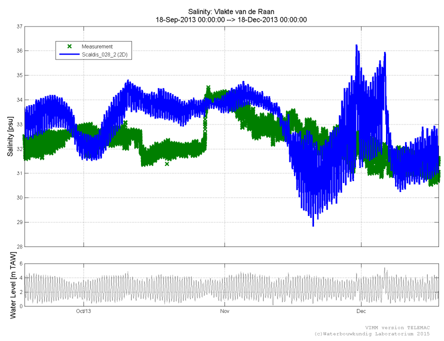

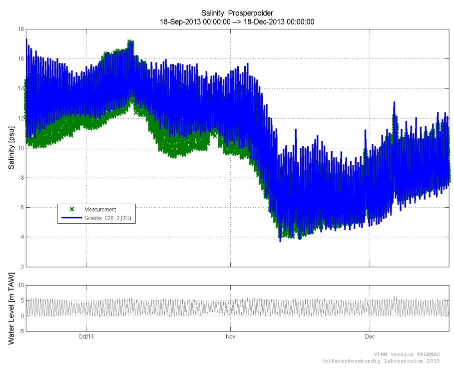

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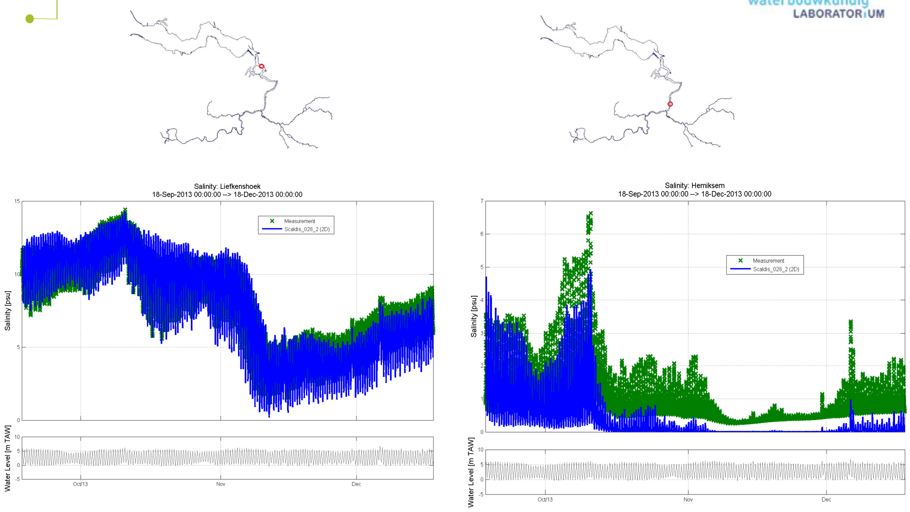
Model Performance: Salinity



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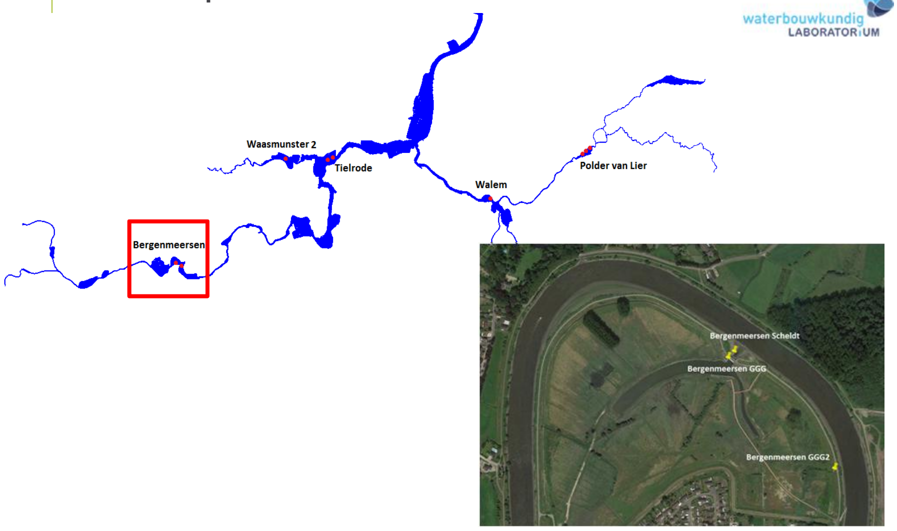
Storm period: flood areas



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Sinterklaasstorm in Bergenmeersen

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Storm period: flood areas

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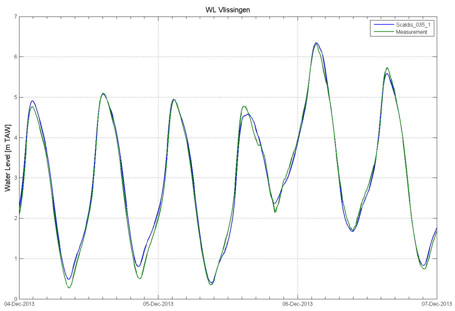
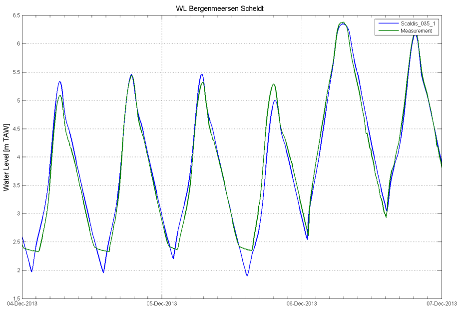
Vlissingen



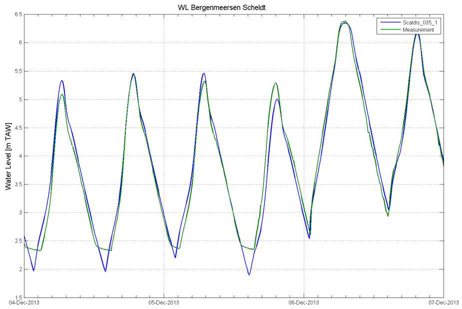
Bergenmeersen Scheldt



Storm period: flood areas

Bergenmeersen GGG

Bergenmeersen Scheldt



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Conclusions

- Assessing model skill
  - Stated model purpose
  - Weighted dimensionless cost function to combine different physical quantities
  - VIMM toolbox (in-house development FHR)
    - Standardised statistics
    - Abstraction layer between model platform, data source and statistical method
    - Deep insight in model performance

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Conclusions

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- Combination of techniques to combine models and measurements
  - Harmonic Analysis of WL
  - Timeseries and extrema of WL
  - Comparable Tide
    - ADCP Sailed transects
    - Q measurements
  - Ensemble Analysis of velocities in shallow areas
  - Timeseries of salinity
  - Timeseries of WL during storm

Conclusions

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- SCALDIS model, a new 3D high resolution hydraulics model
  - +500d of work
  - Let's build exciting new products!
    - Ecosystem model with UA – Ecobe
    - Ecotope maps with INBO
    - Fish migration & Bird abundance with INBO
    - Sediment transport (Mud & Sand) by FHR
    - …
  - Huge added value in multi-disciplinary work

Technical Report

- Smolders, S.; Maximova, T.; Vanlede, J.; Verwaest, T.; Mostaert, F. (2015, in prep). Integraal Plan Bovenzeeschelde: Subreport 1 – 3D Hydrodynamisch model Zeeschelde en Westerschelde. Version 1.0. WL Rapporten, 13_131. Flanders Hydraulics Research: Antwerp, Belgium.

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- OpenEarth initiative for an open access to Rijkswaterstaat bathymetric datasets, and an updated version of the t_tide method