

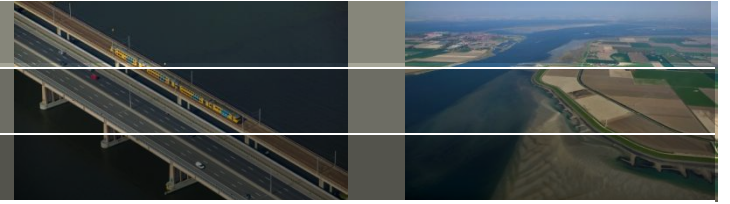


Modeling of flow in intertidal basins using an unstructured grid

Arnold van Rooijen, Arthur van Dam, Gerben de Boer,
Jebbe van der Werf, Herman Kernkamp

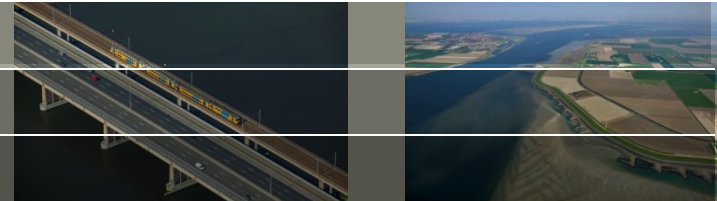
19 mei 2014

Outline



- Introduction
- Methodology
- Results
- Conclusions
- Next steps and future perspectives

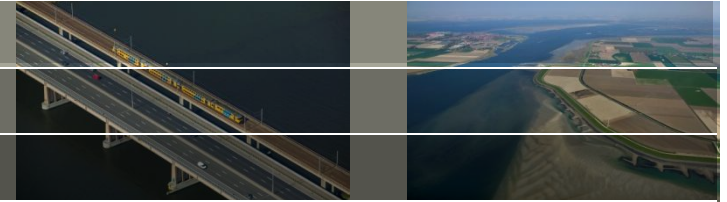
Introduction



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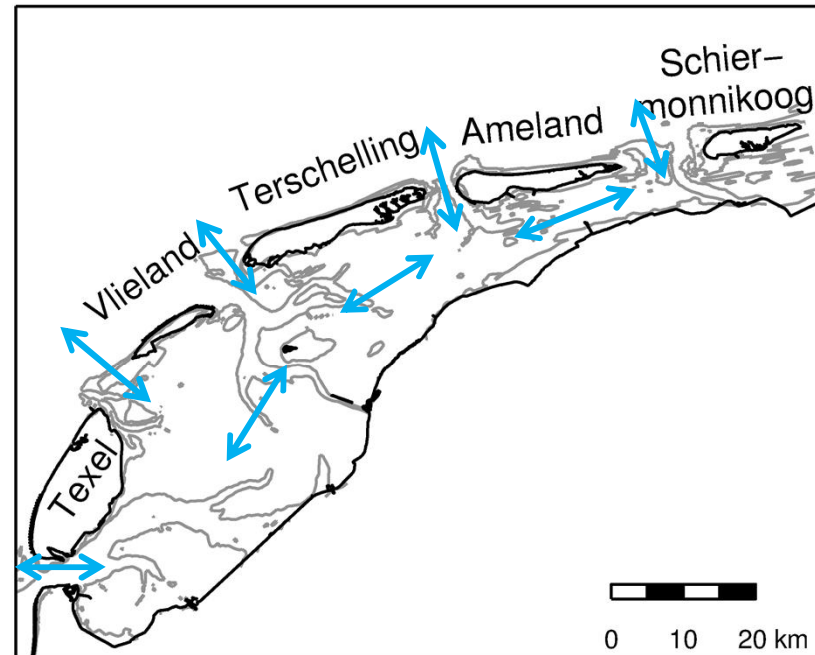
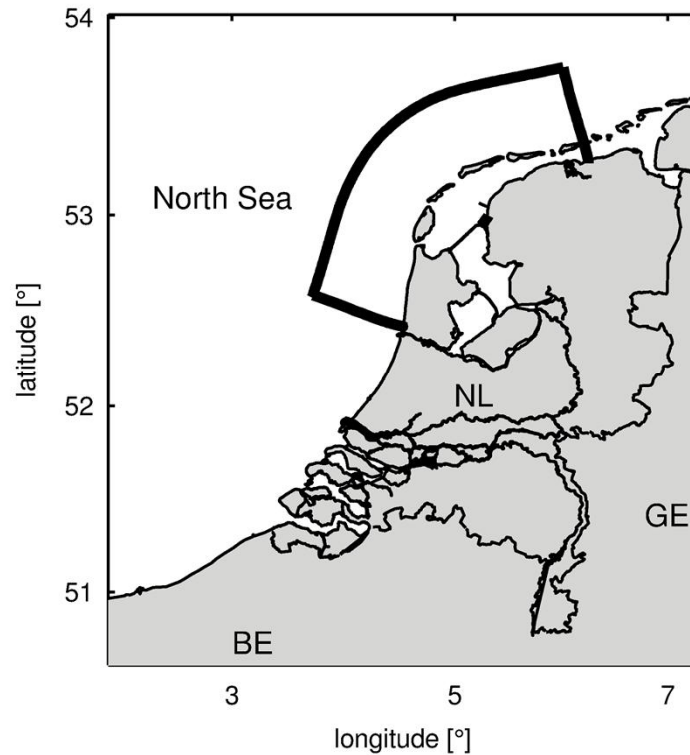
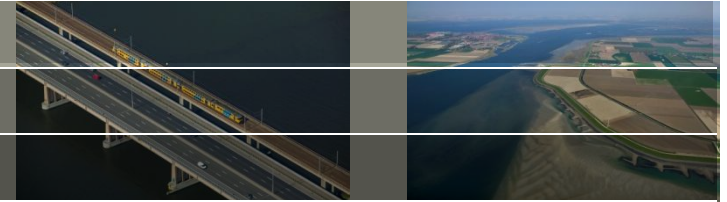
Deltares

Introduction



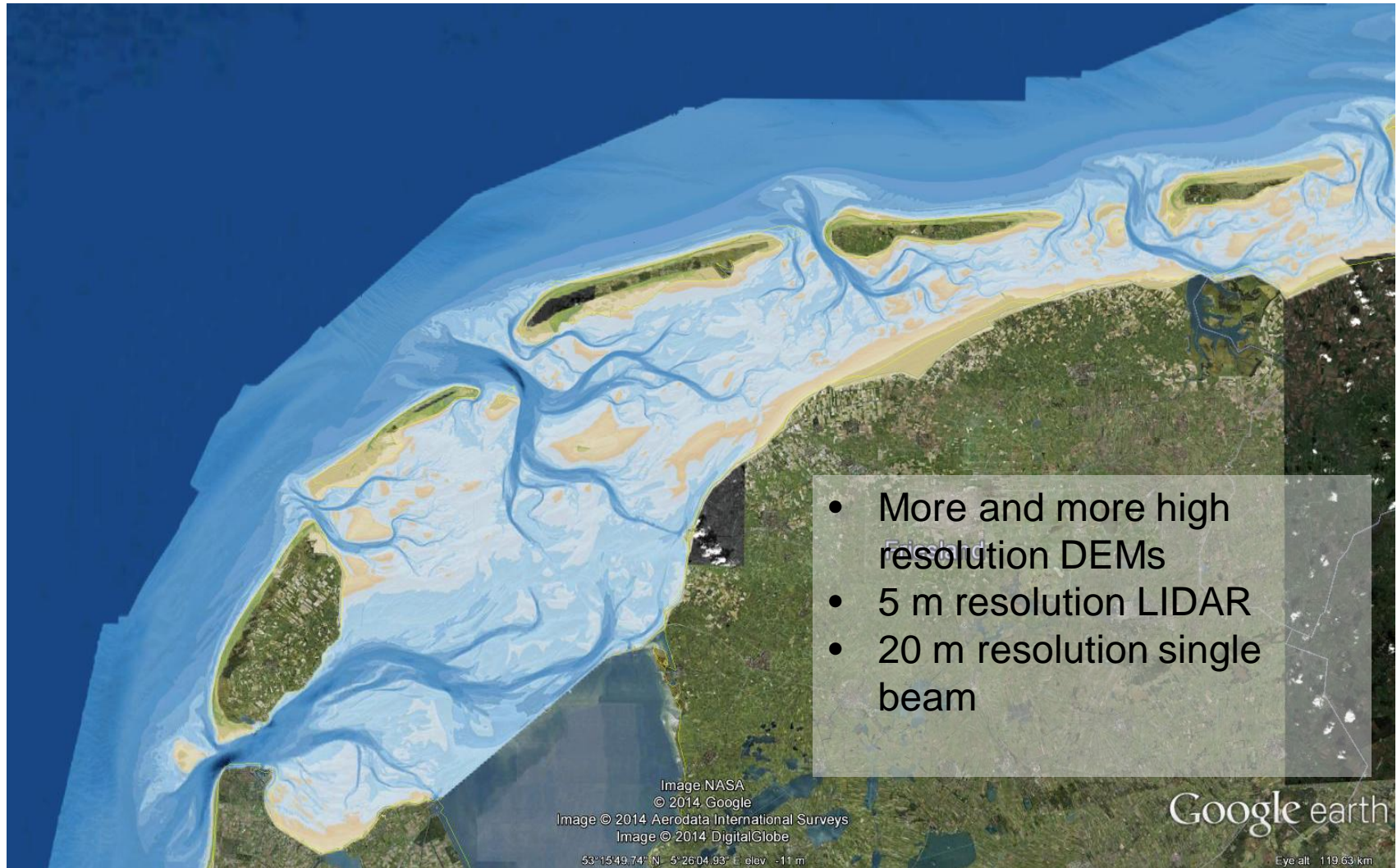
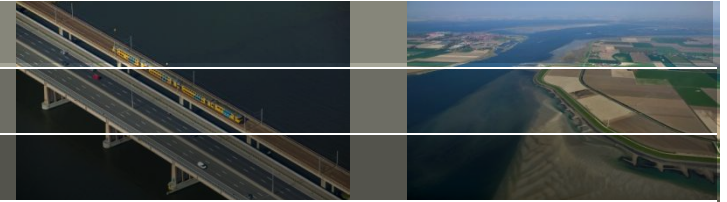
- 2400 km²
- Large biodiversity
- 10-12 million migratory birds per year
- UNESCO World Heritage Site since 2009

Introduction

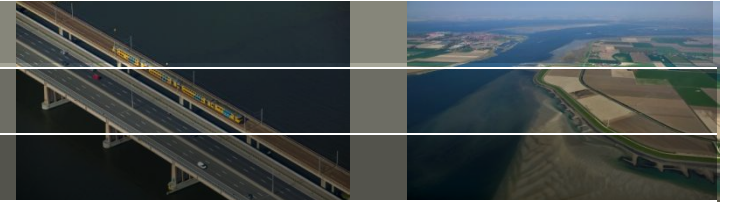


- Sediment fluxes
 - Sediment import through inlets
 - Sediment exchange between basins
 - Sediment deposition
- Study effect of SLR on sediment fluxes

Introduction



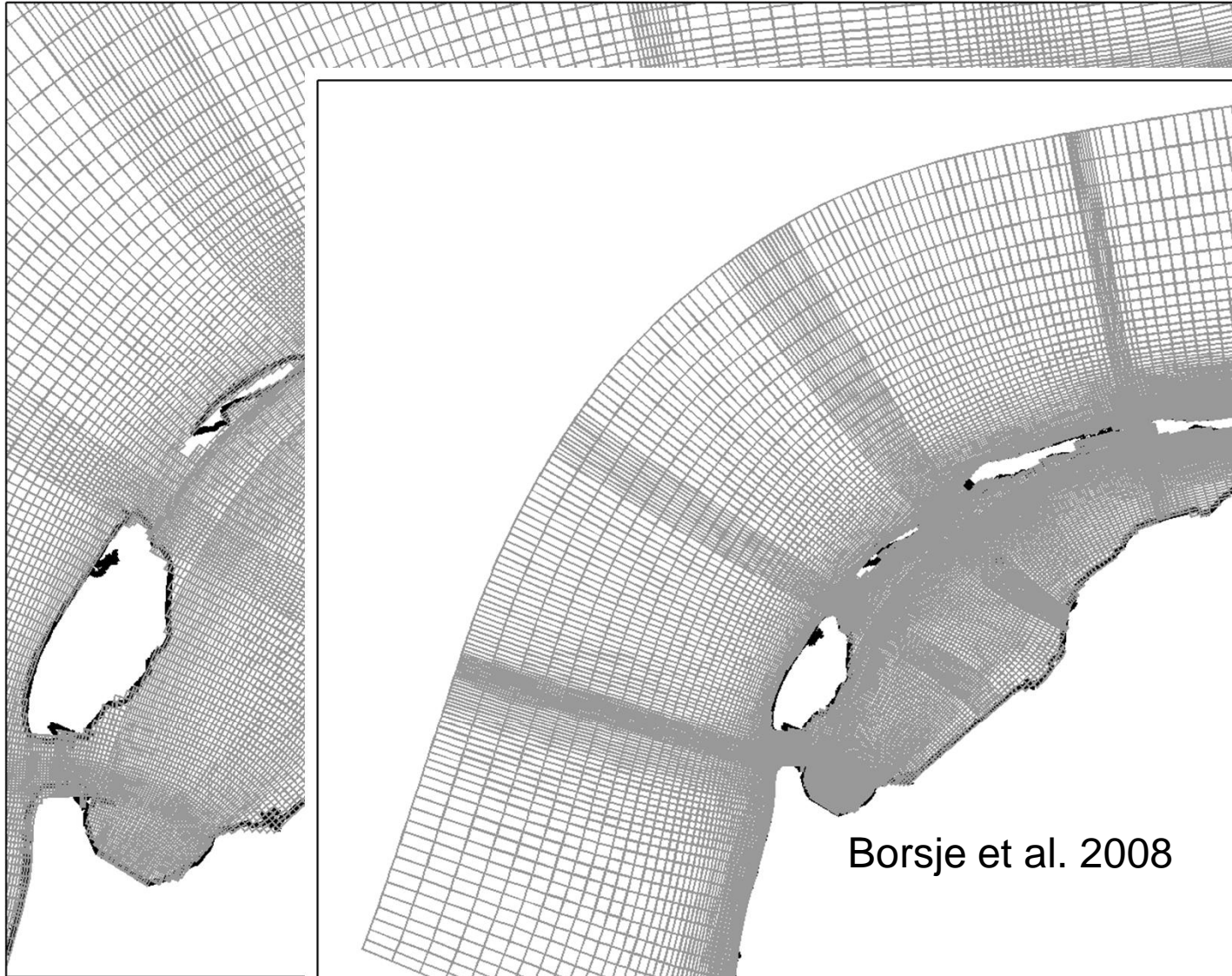
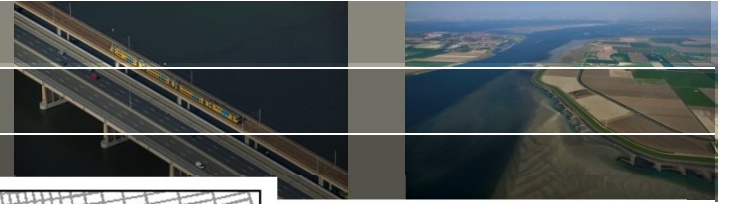
Introduction



Models used before

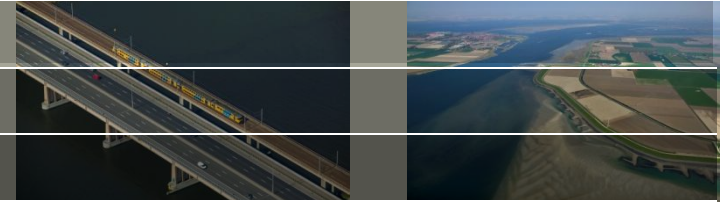
Study	Resolution	Type
Borsje et al. (2008)	500 m	curvilinear
Duran-Matute et al. (2014)	200 m	rectilinear
Elias et al. (2006)	80-120 m	curvilinear

Introduction



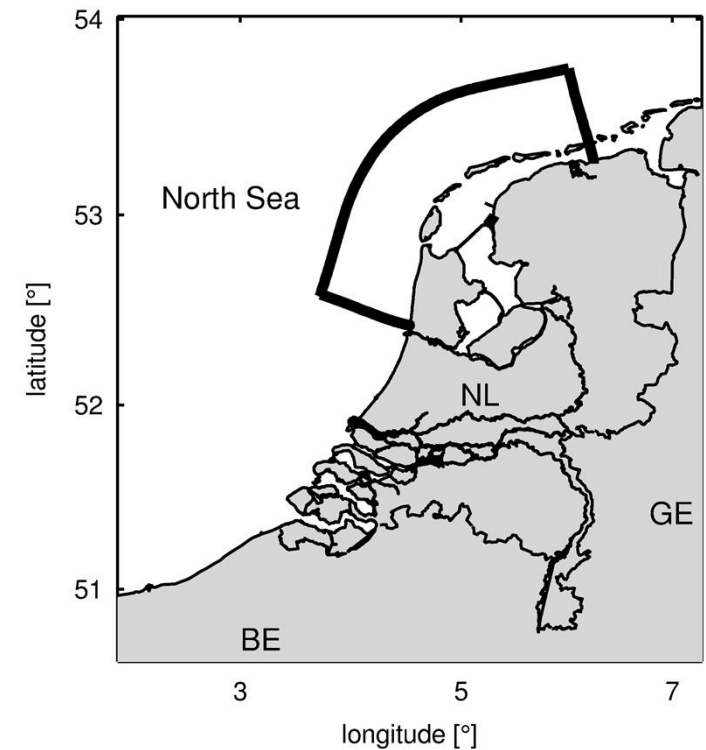
Borsje et al. 2008

Methodology

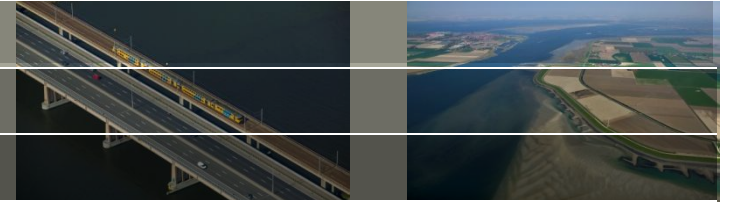


	Grid	Time step
Delft3D	curvilinear	1 min
D-Flow CL	curvilinear	1 min
D-Flow FM	unstructured	≈ 20 sec (CFL-condition based)

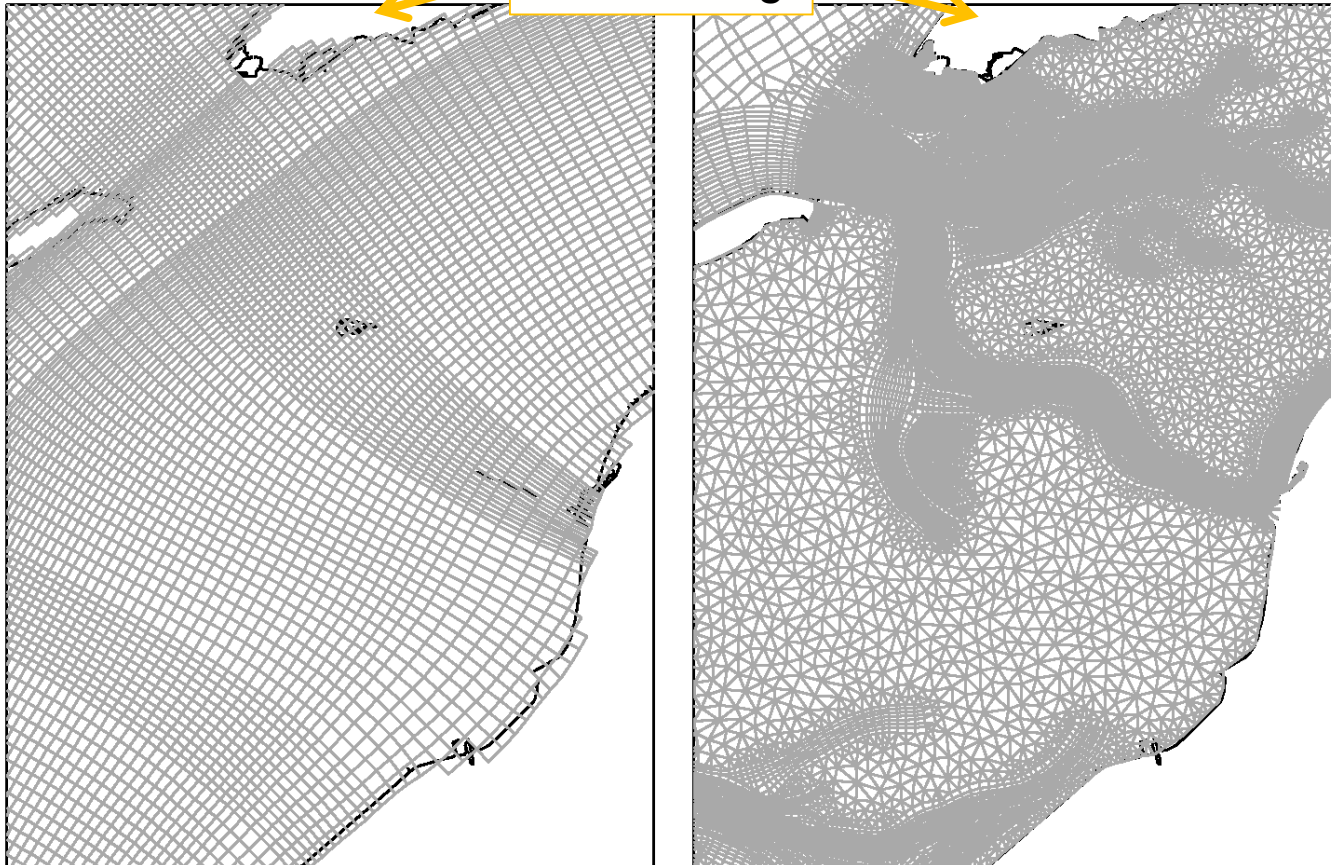
- Depth-averaged (2DH)
- 3 months simulation (May 1 – Aug 1 2010)



Methodology



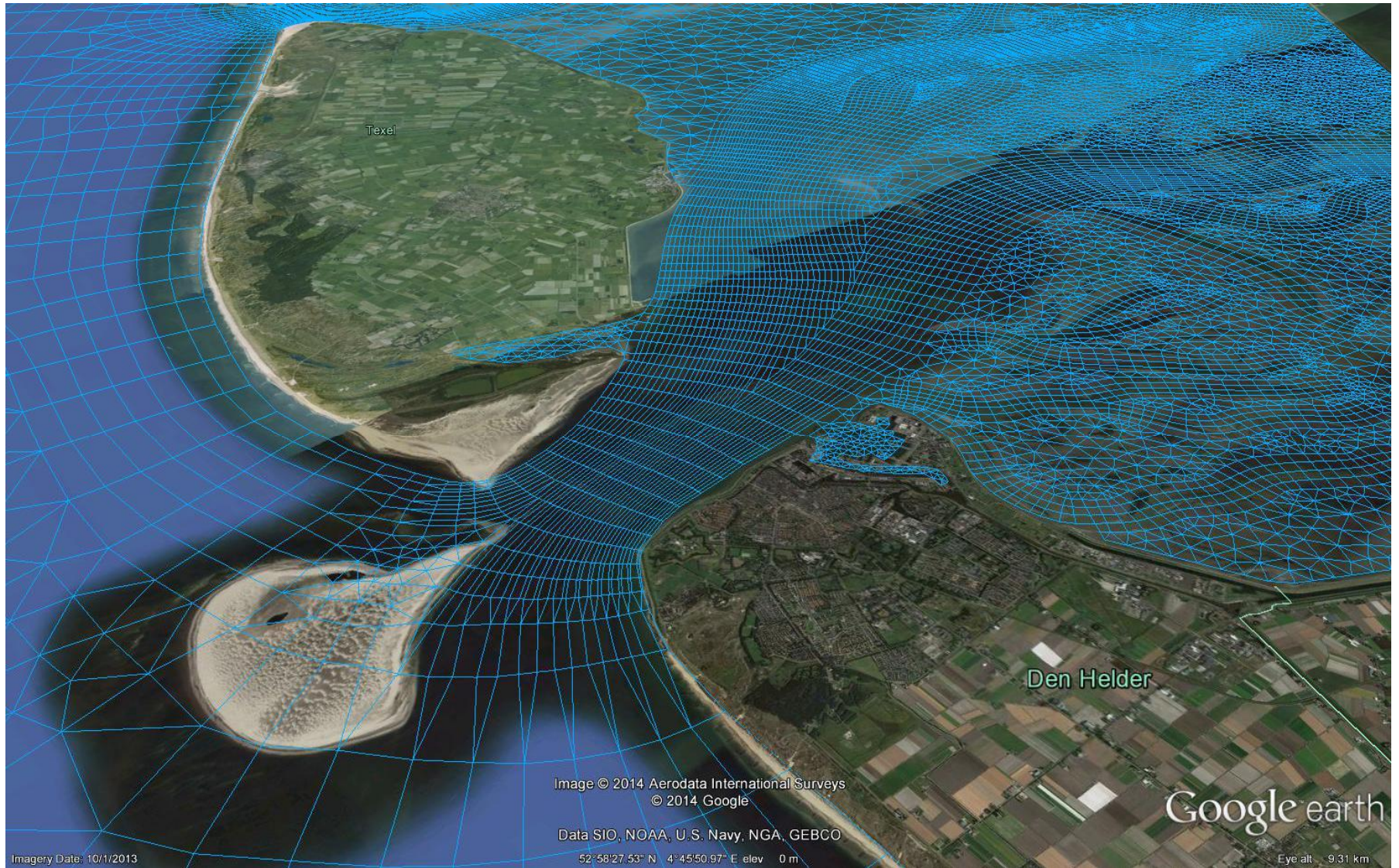
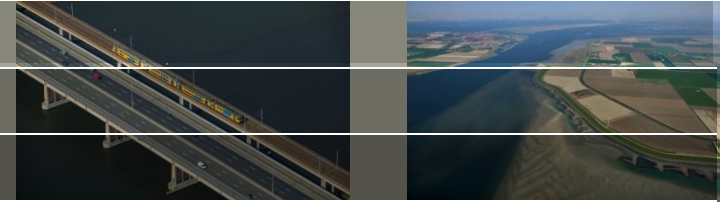
Terschelling



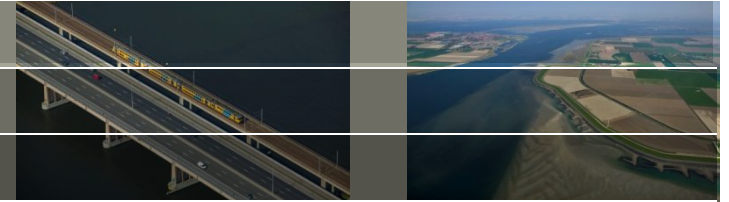
Curvilinear grid
(Borsje et al. 2008)

Unstructured grid

Methodology



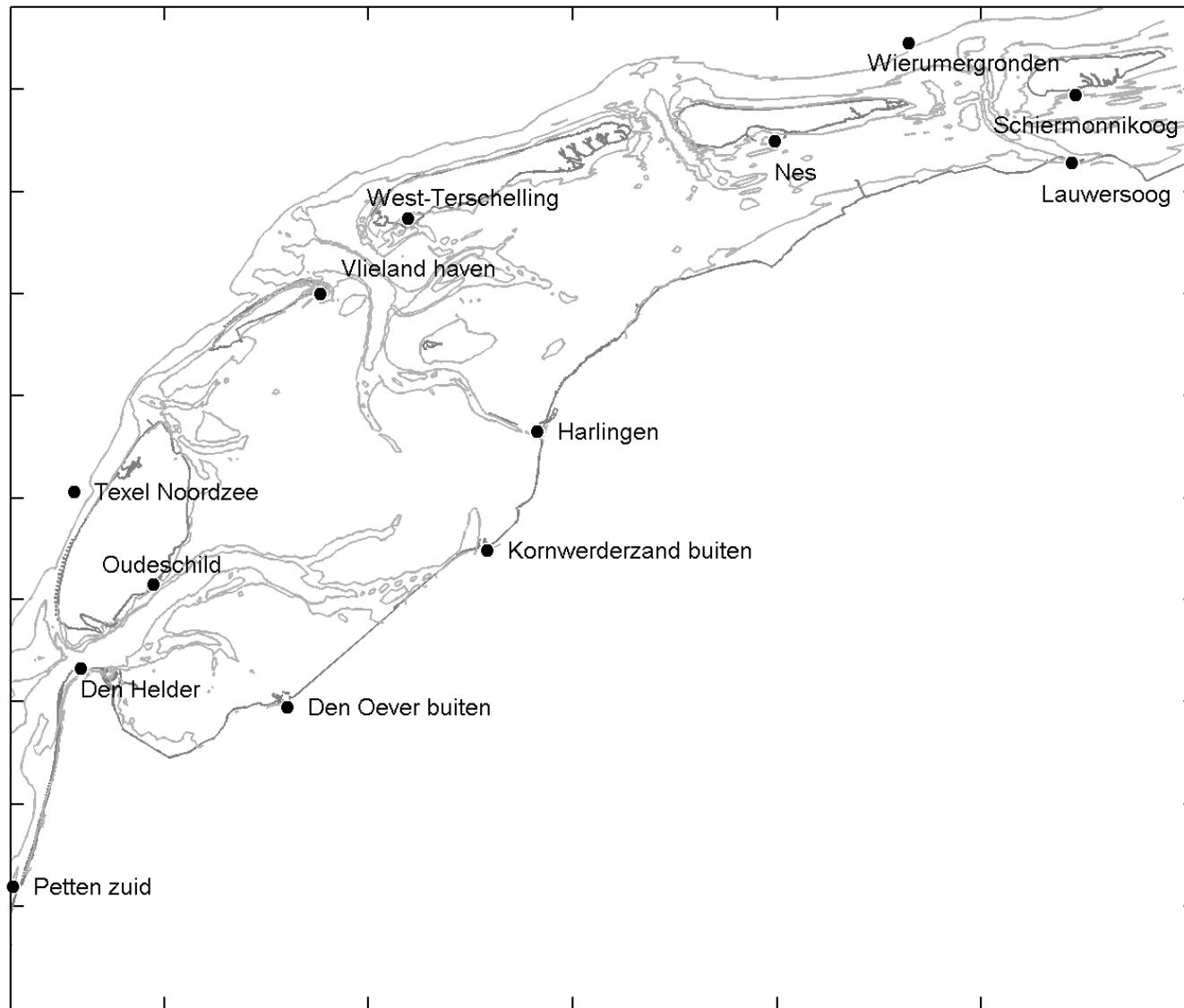
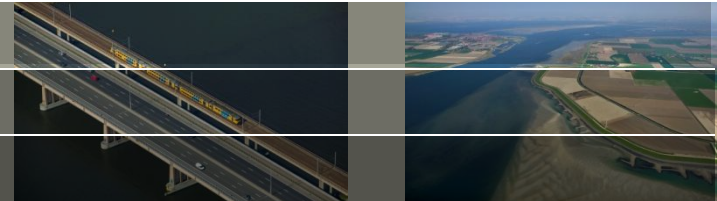
Methodology



Boundary conditions

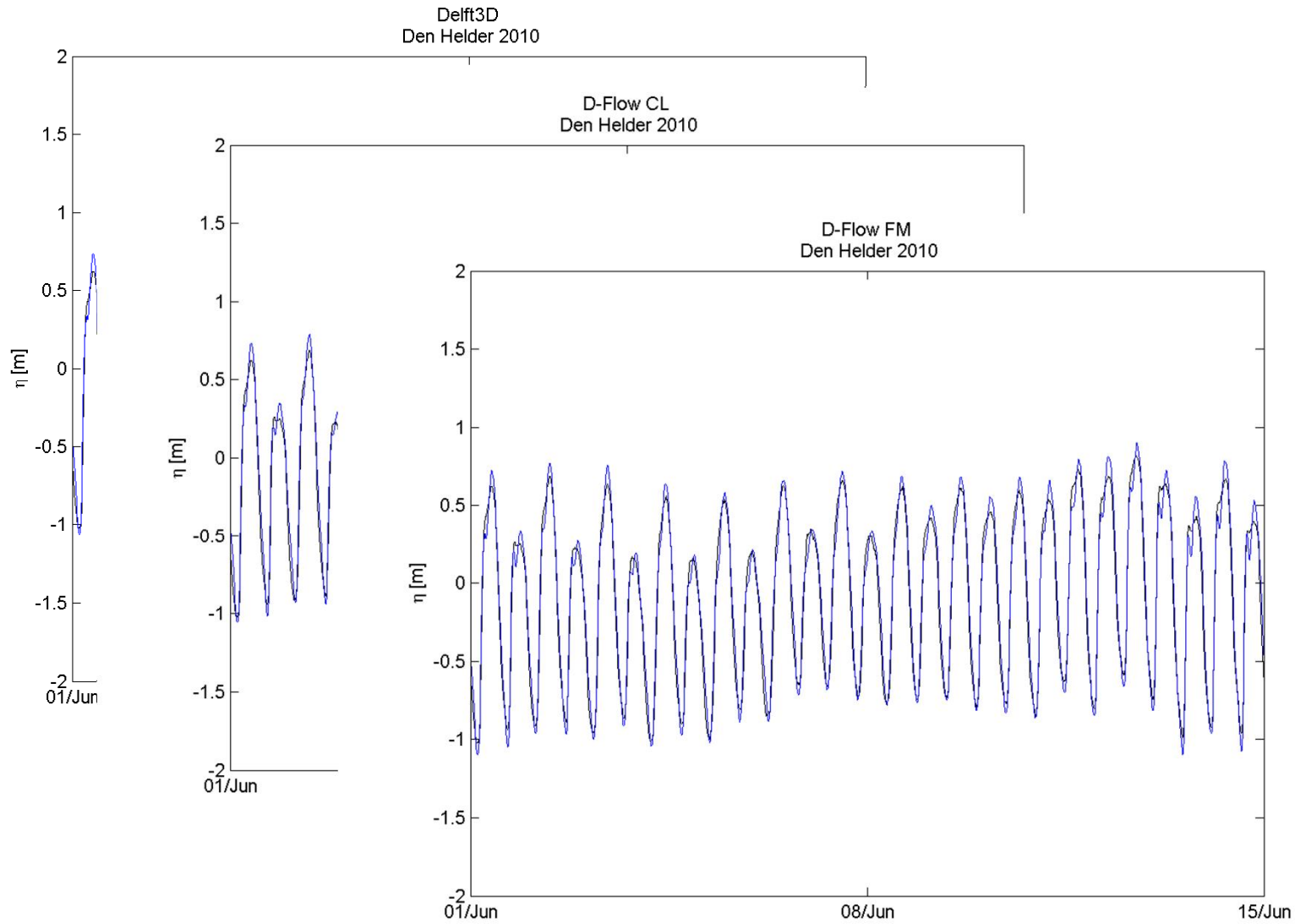
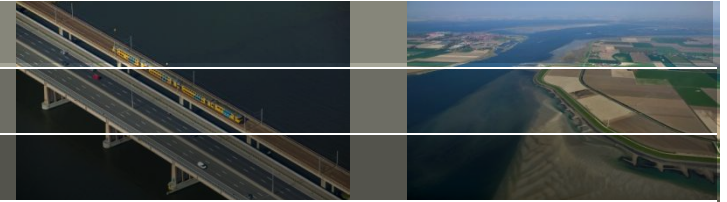
- Only wind and water levels
- Water levels from Dutch operational model for storm surge forecasting (Rijkswaterstaat)
- Wind from KNMI (Royal Dutch Meteorological Institute)
 - Estimated/corrected (potential wind)
 - Station Vlieland
 - Apply spatially uniform wind field

Observation stations

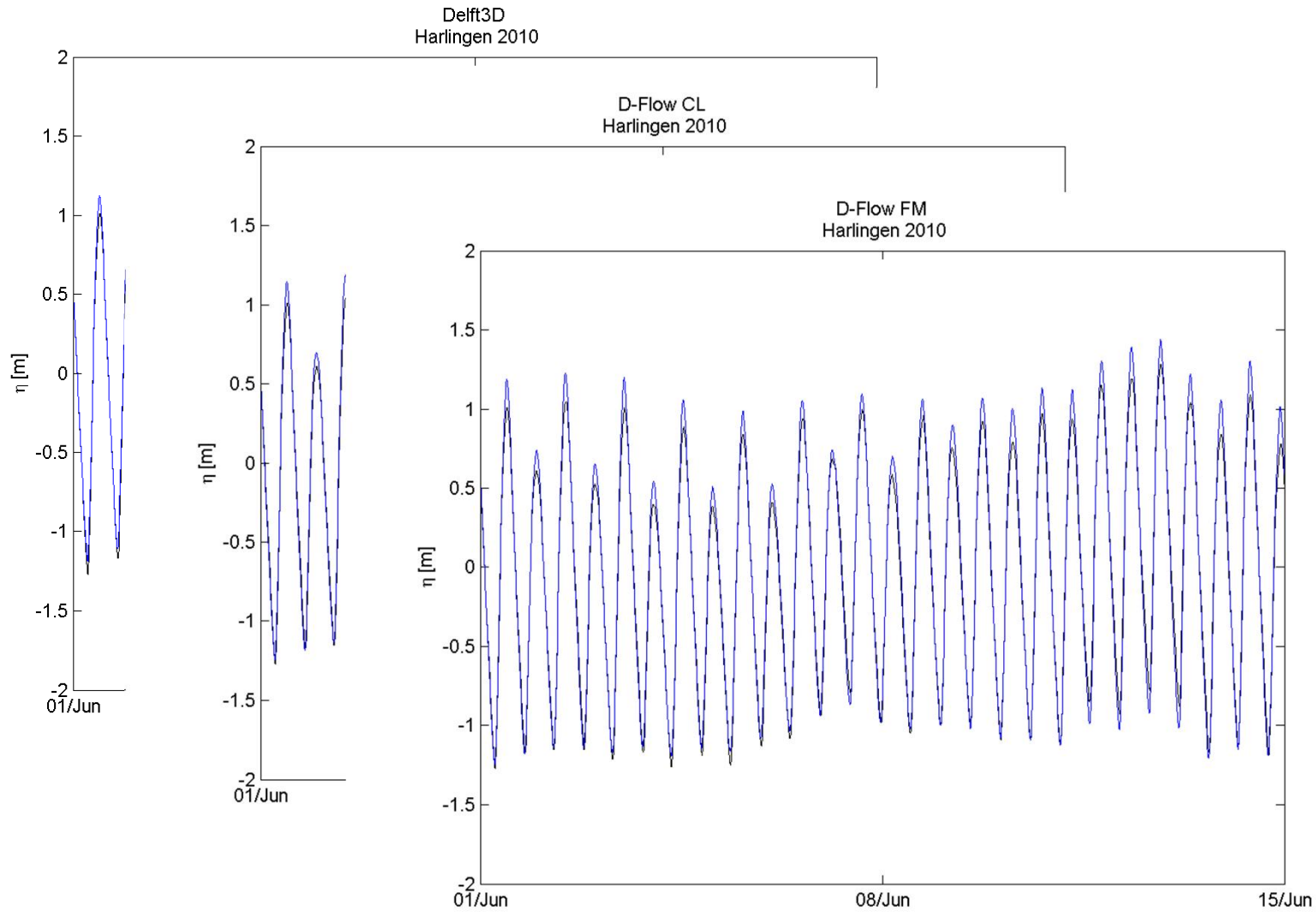
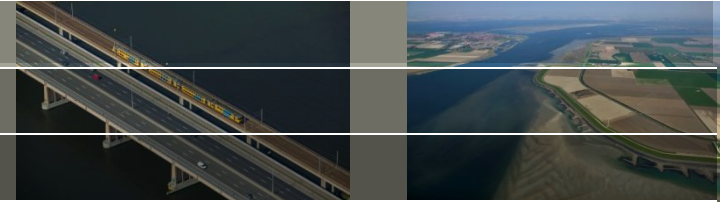


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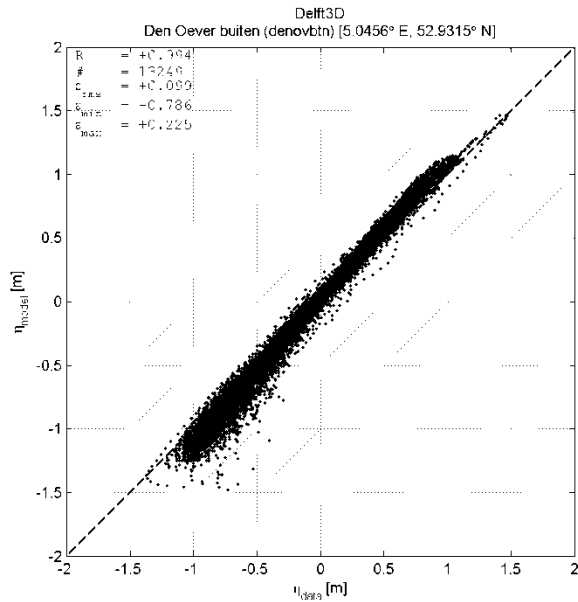
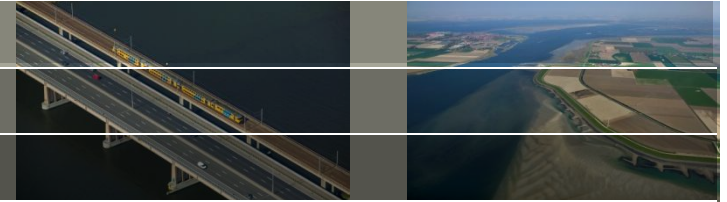
Results: Den Helder



Results: Harlingen

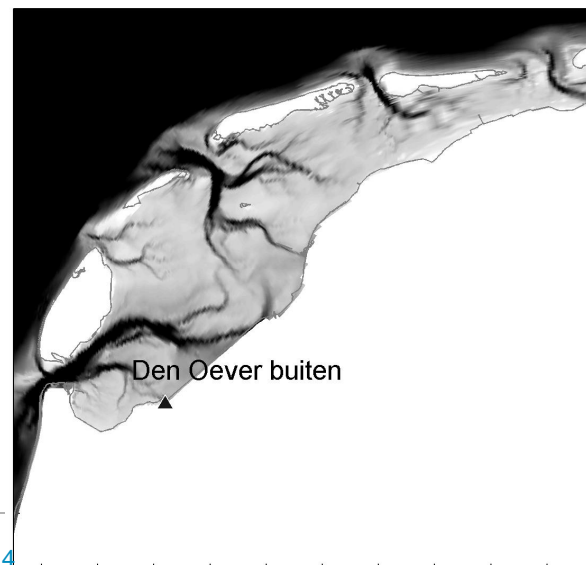


Results: Den Oever



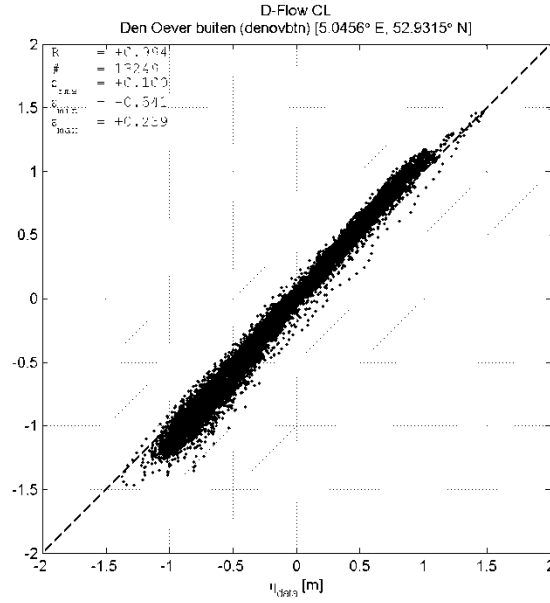
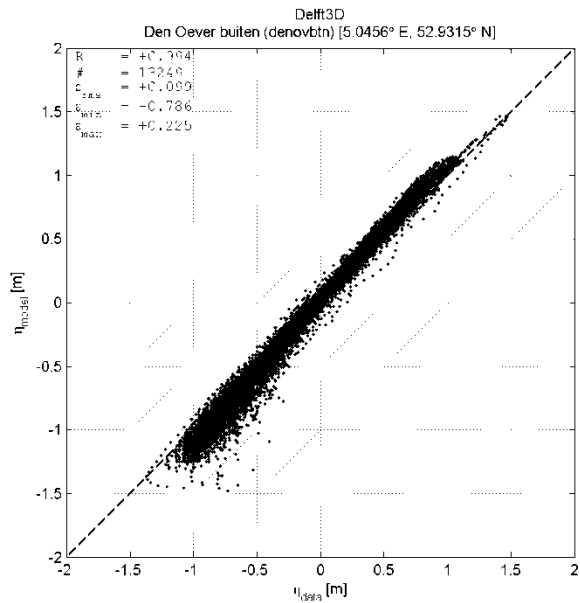
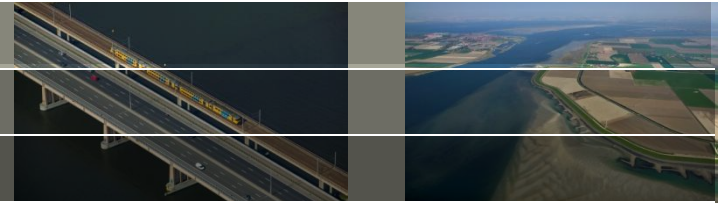
	RMSE (cm)	R (-)
D3D	9.9	0.994
DCL		
DFM		

Location Station Oudeschild



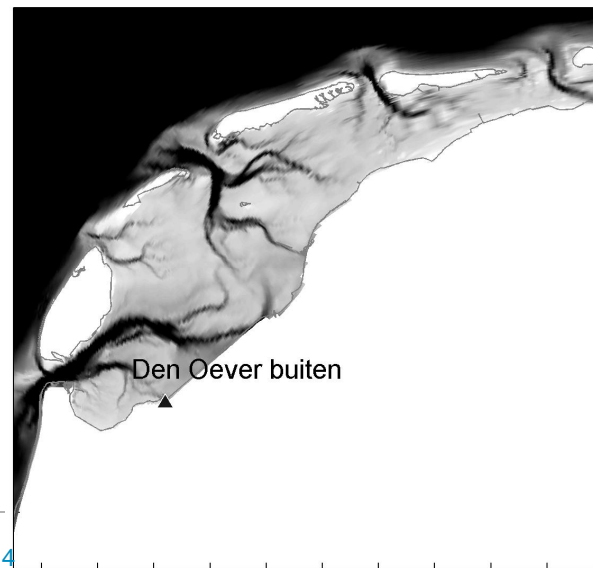
19 mei 2014

Results: Den Oever



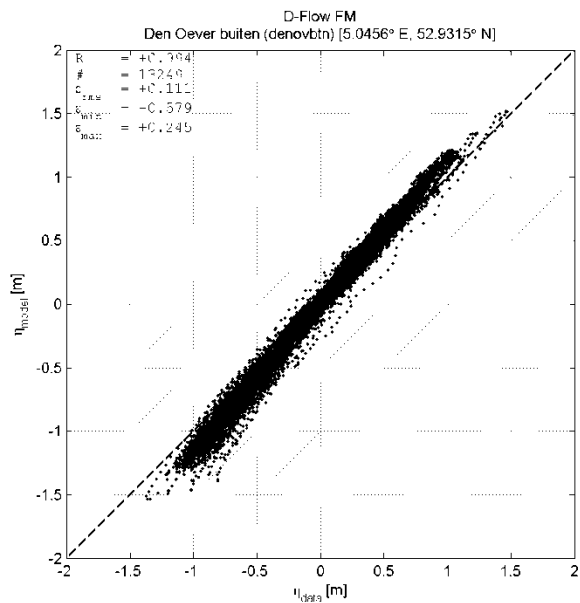
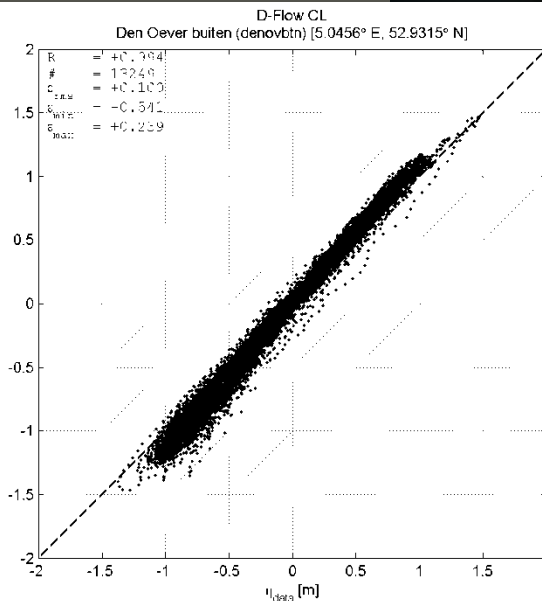
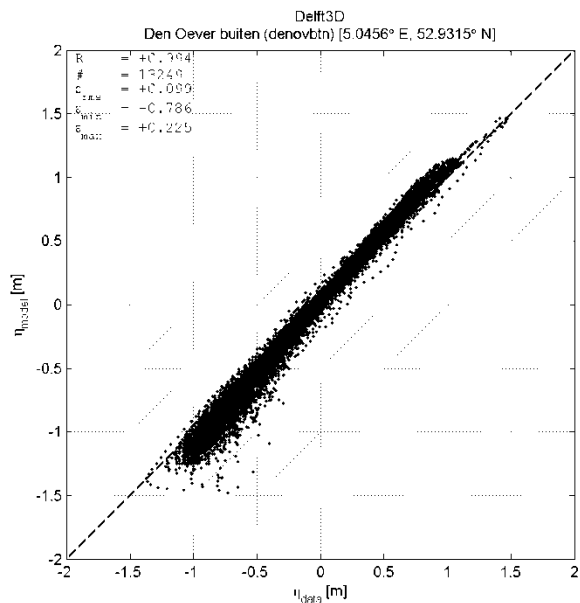
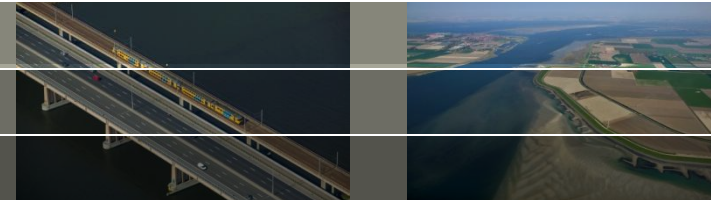
	RMSE (cm)	R (-)
D3D	9.9	0.994
DCL	10.0	0.994
DFM		

Location Station Oudeschild

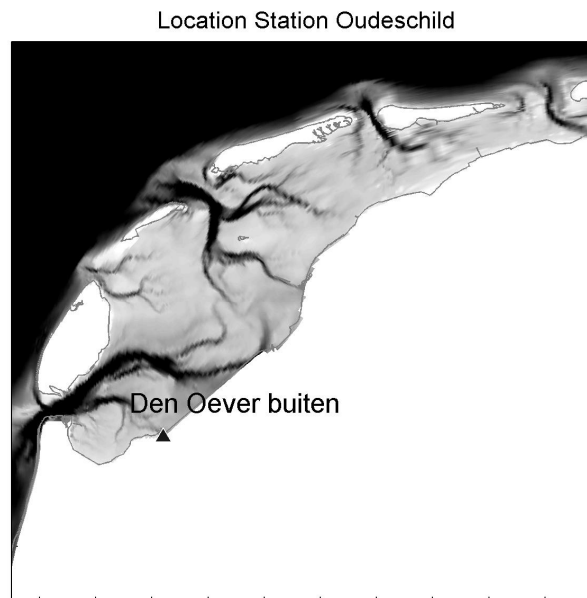


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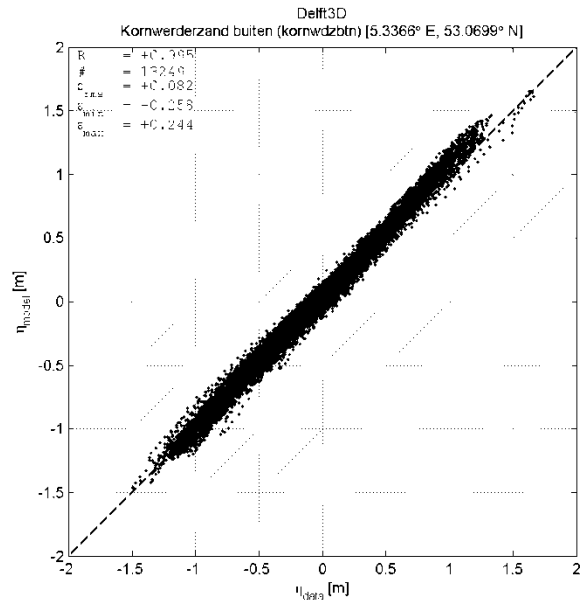
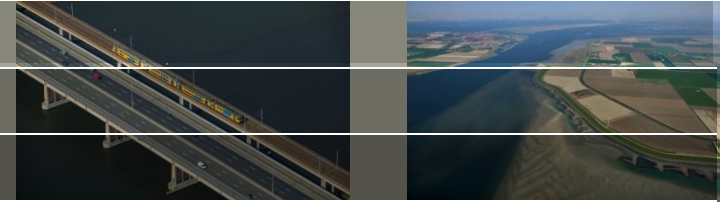
Results: Den Oever



	RMSE (cm)	R (-)
D3D	9.9	0.994
DCL	10.0	0.994
DFM	11.1	0.994

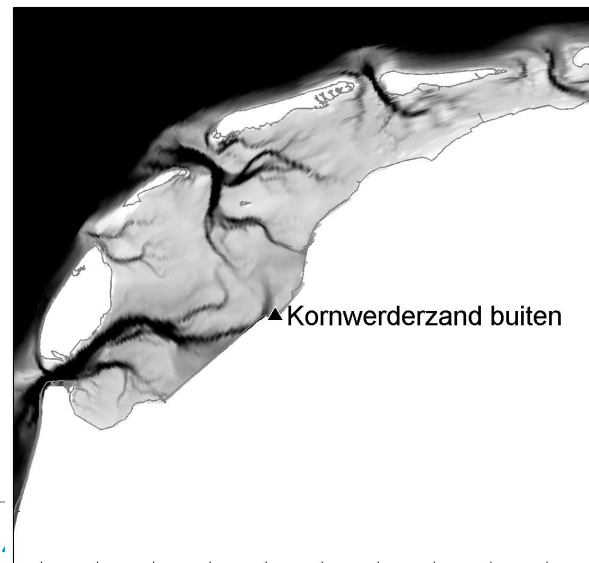


Results: Kornwerderzand



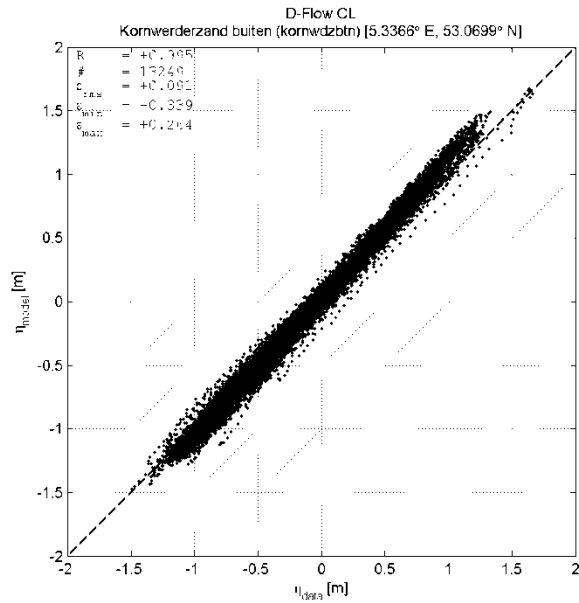
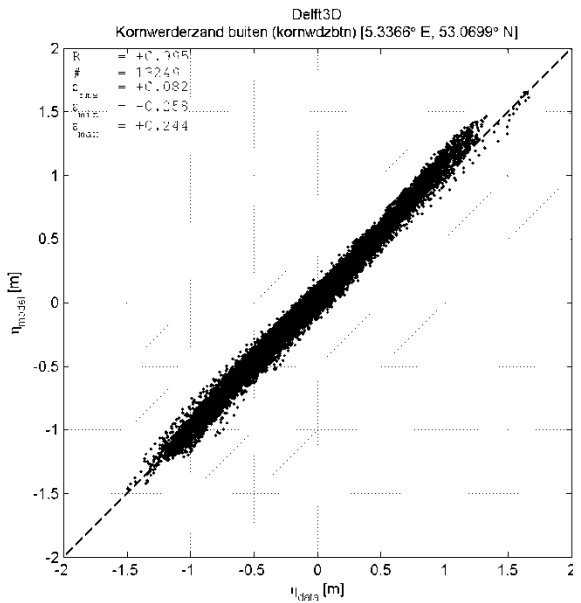
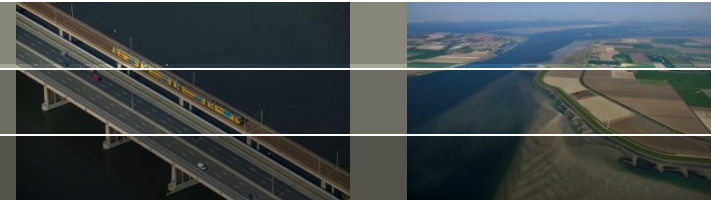
	RMSE (cm)	R (-)
D3D	8.2	0.995
DCL		
DFM		

Location Station Kornwerderzand



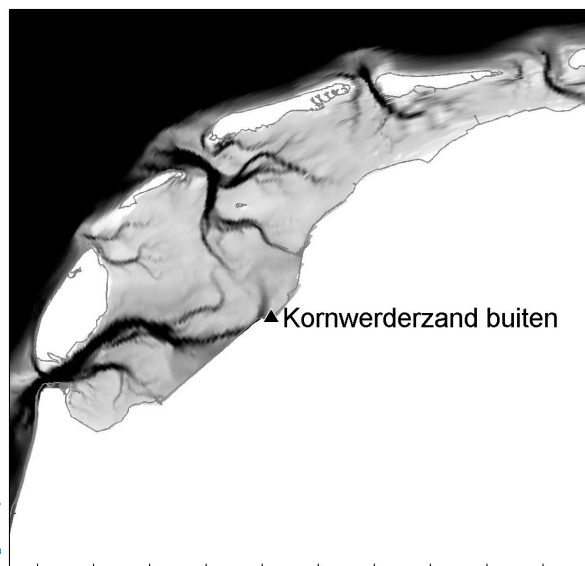
19 mei 2011

Results: Kornwerderzand

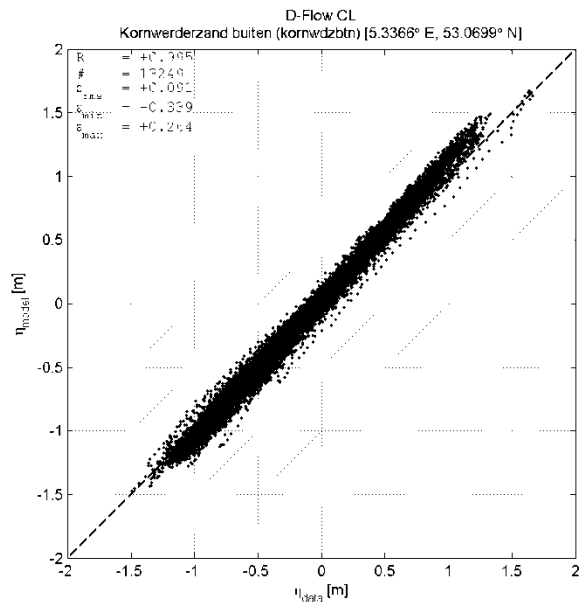
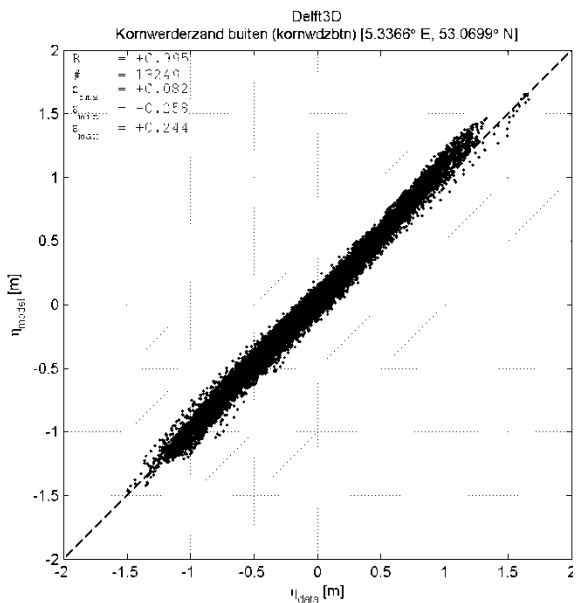
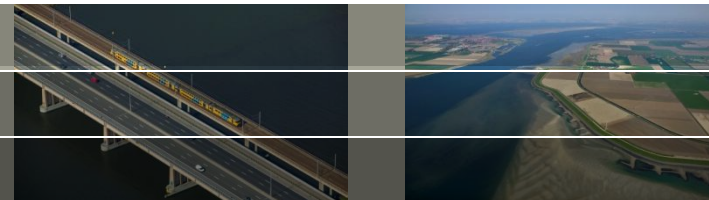


	RMSE (cm)	R (-)
D3D	8.2	0.995
DCL	9.1	0.995
DFM		

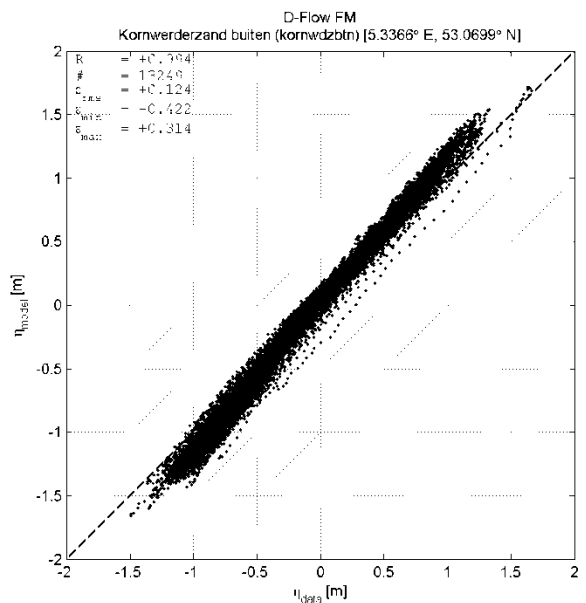
Location Station Kornwerderzand



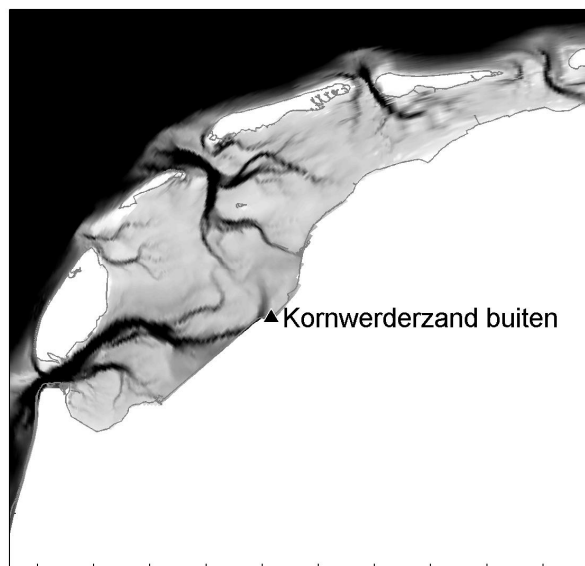
Results: Kornwerderzand



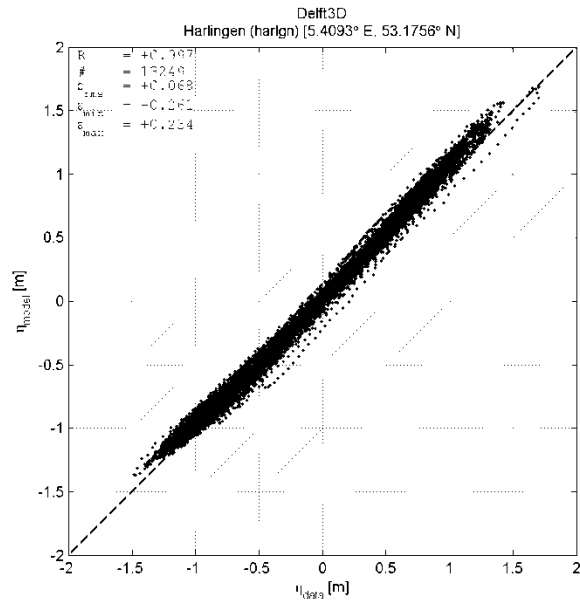
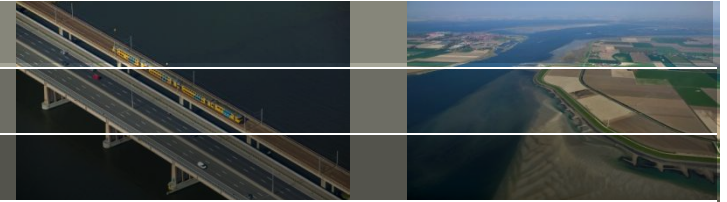
	RMSE (cm)	R (-)
D3D	8.2	0.995
DCL	9.1	0.995
DFM	12.4	0.994



Location Station Kornwerderzand

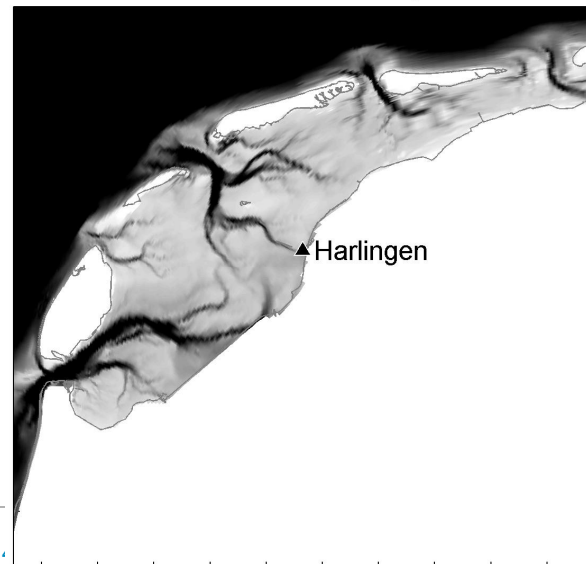


Results: Harlingen



	RMSE (cm)	R (-)
D3D	6.8	0.997
DCL		
DFM		

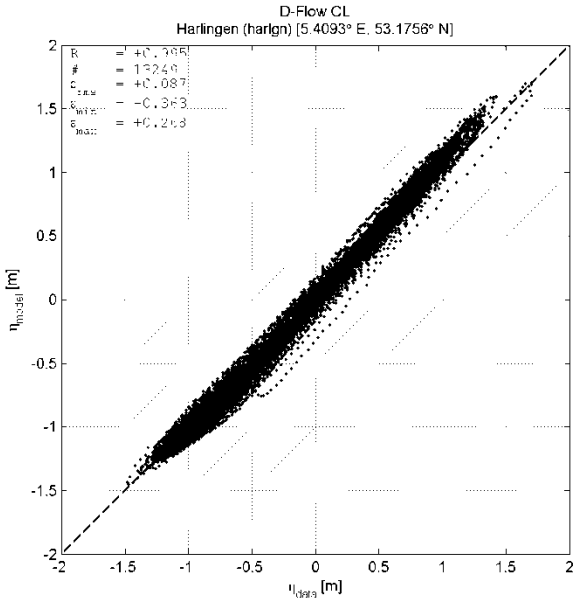
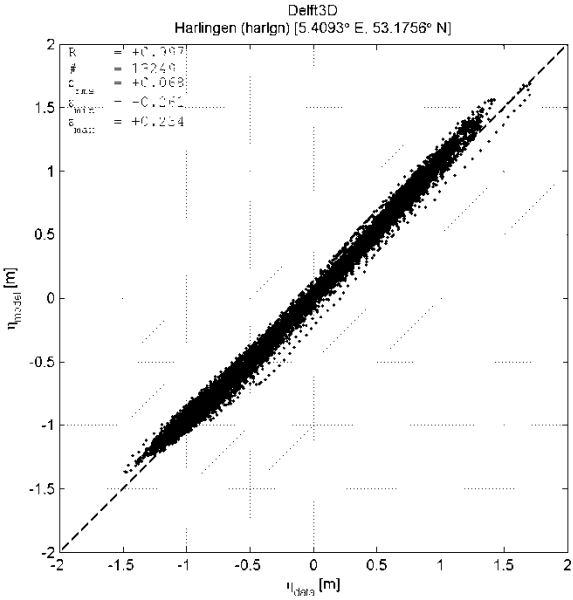
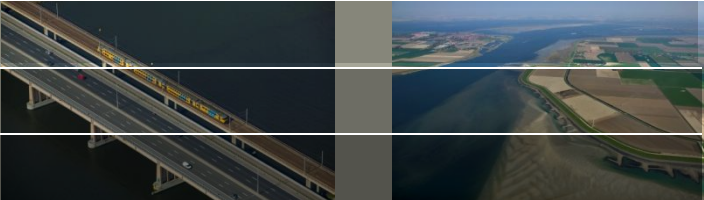
Location Station Harlingen



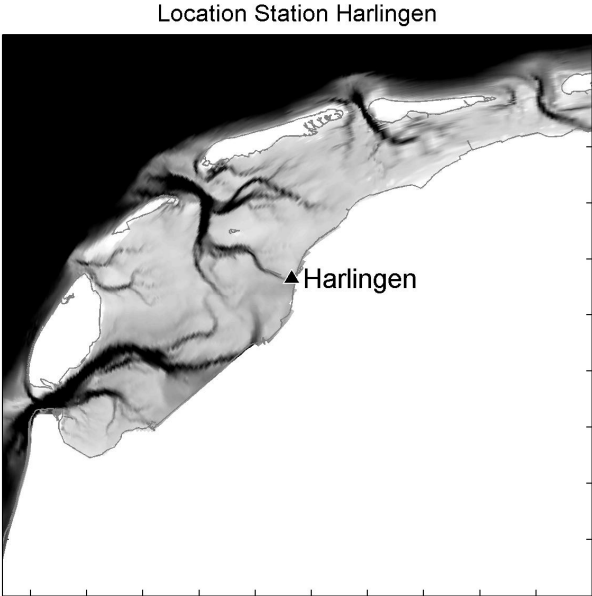
19 mei 201

Deltares

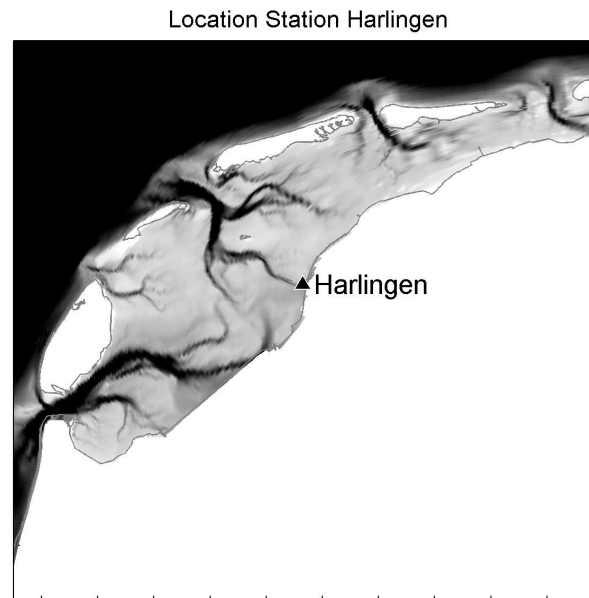
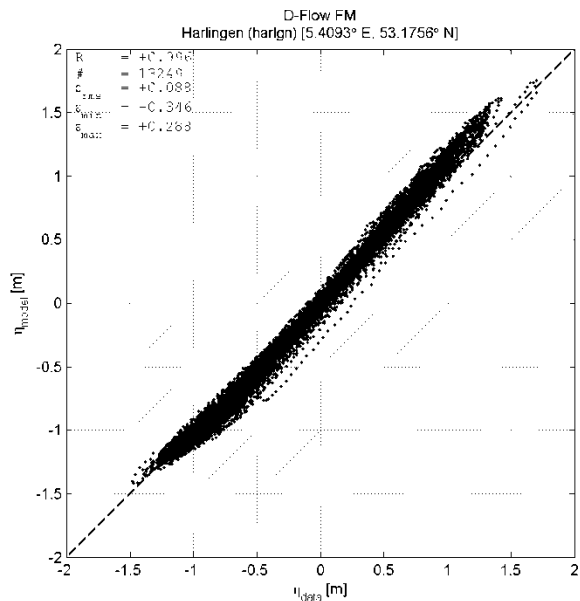
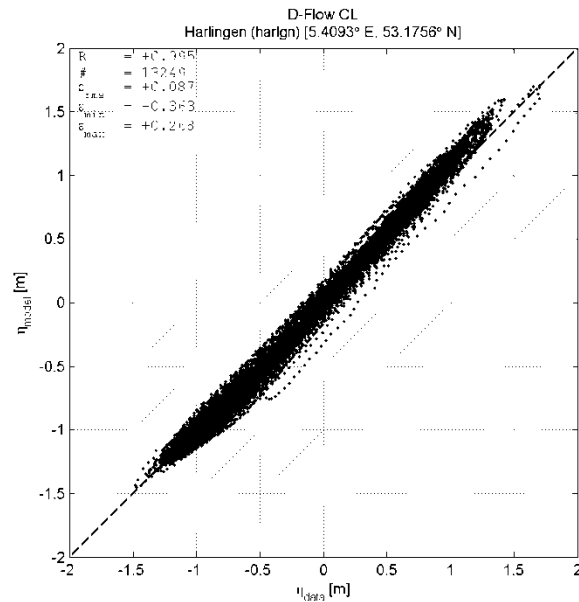
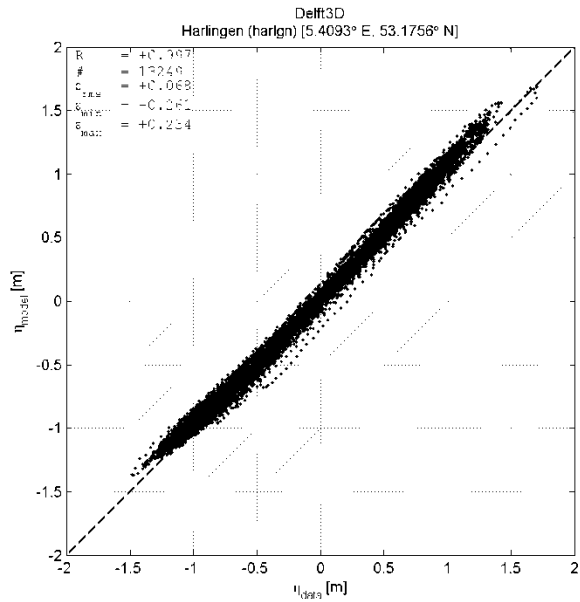
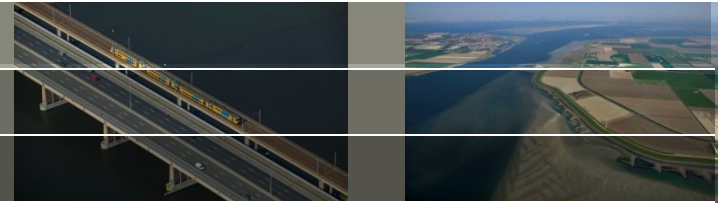
Results: Harlingen



	RMSE (cm)	R (-)
D3D	6.8	0.997
DCL	8.7	0.995
DFM		

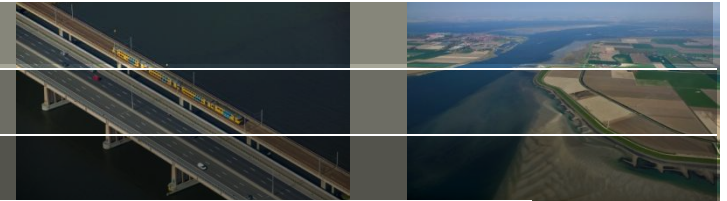


Results: Harlingen

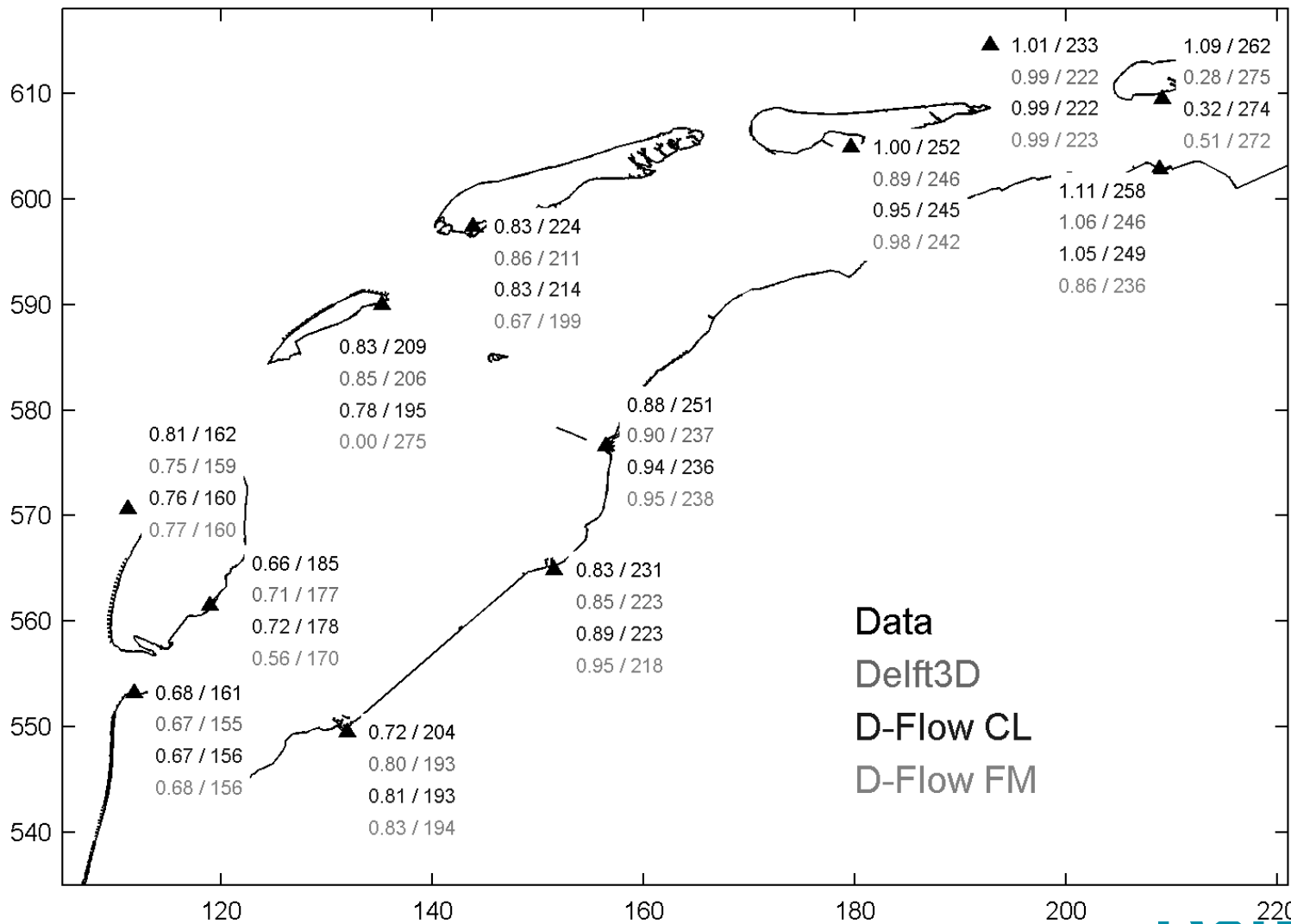


	RMSE (cm)	R (-)
D3D	6.8	0.997
DCL	8.7	0.995
DFM	8.8	0.996

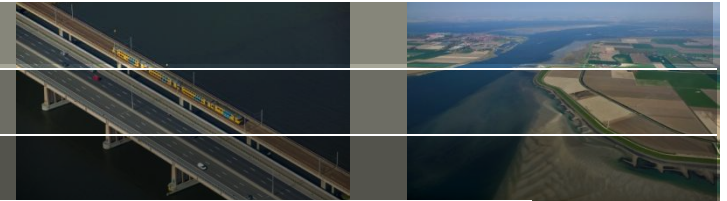
Results: Tidal propagation



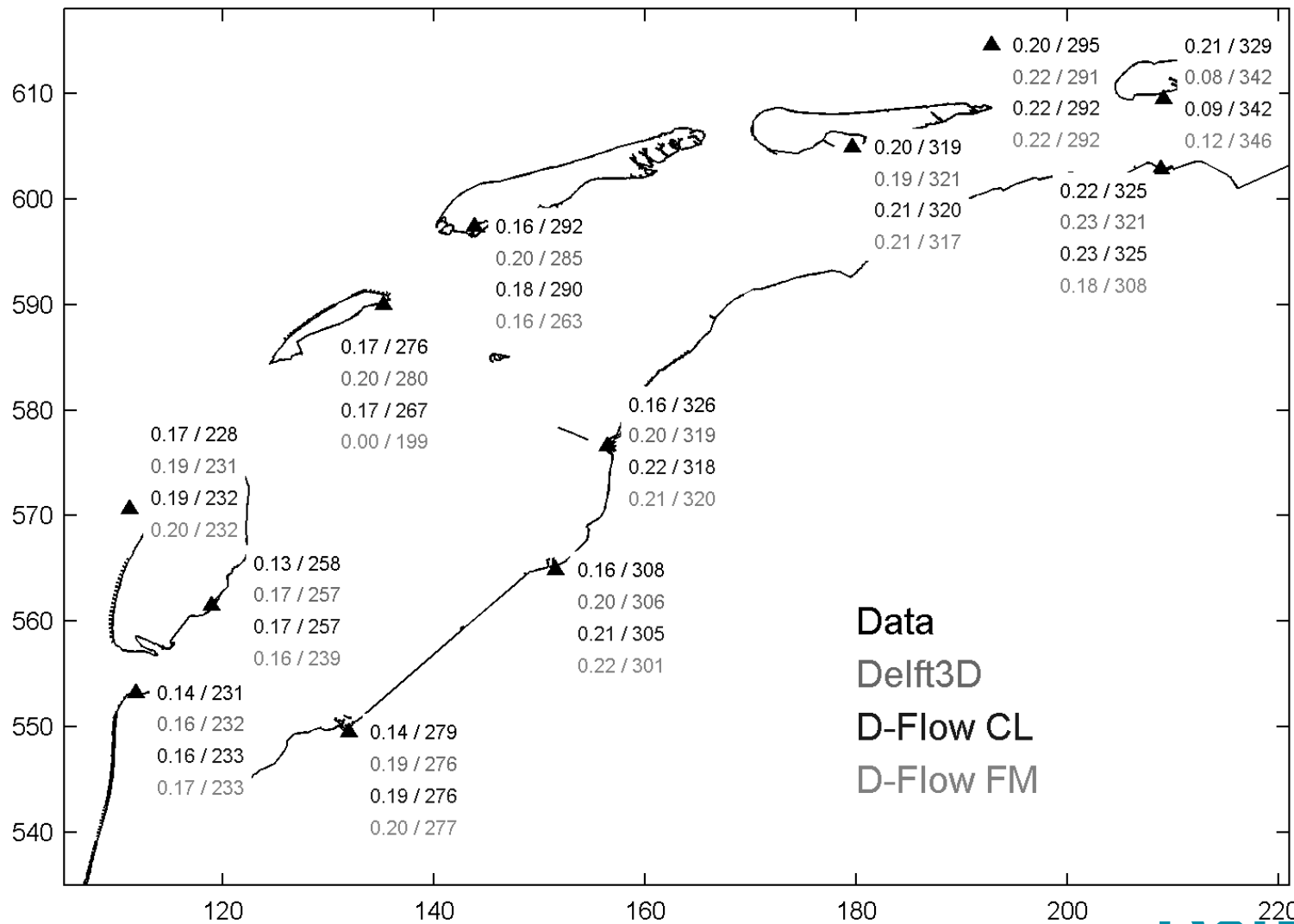
M2 amplitude/phase



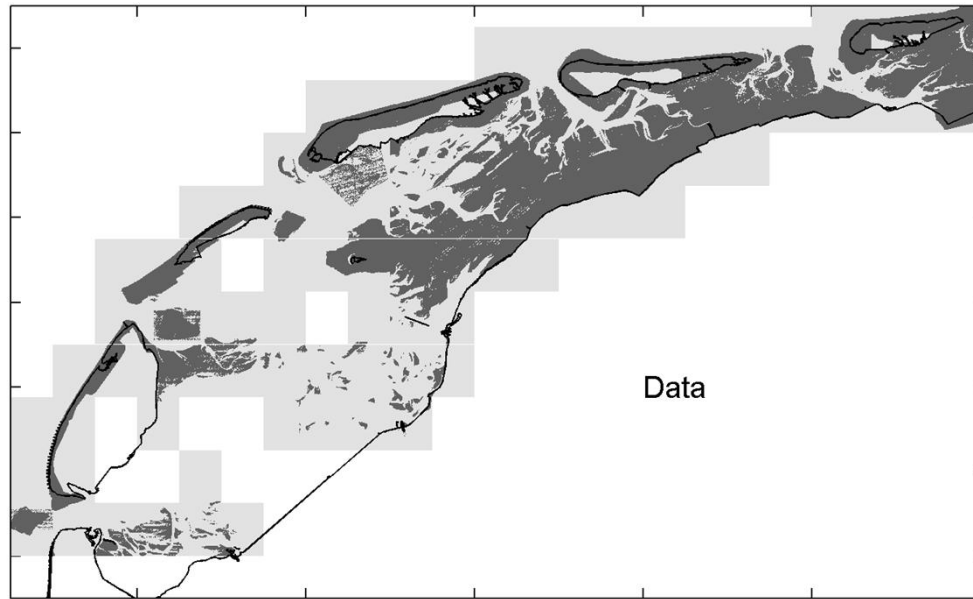
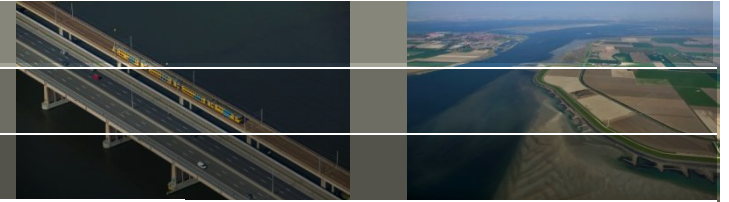
Results: Tidal propagation



S2 amplitude/phase

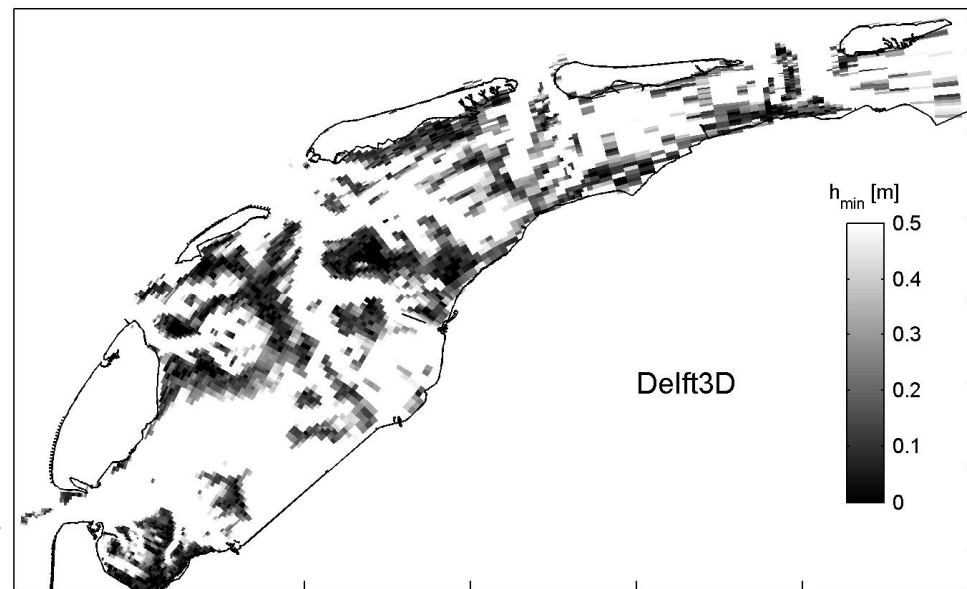
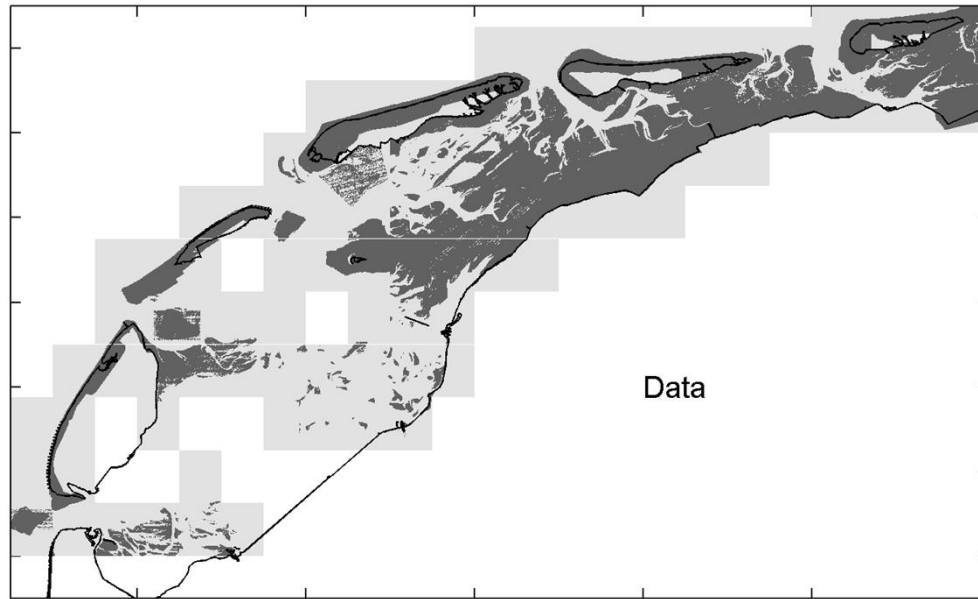
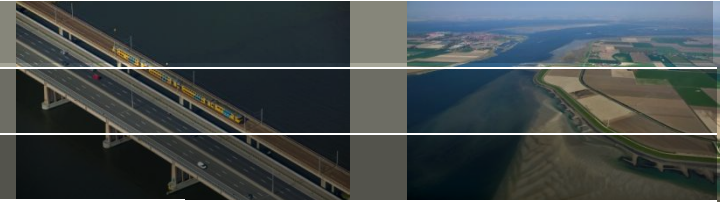


Drying and flooding

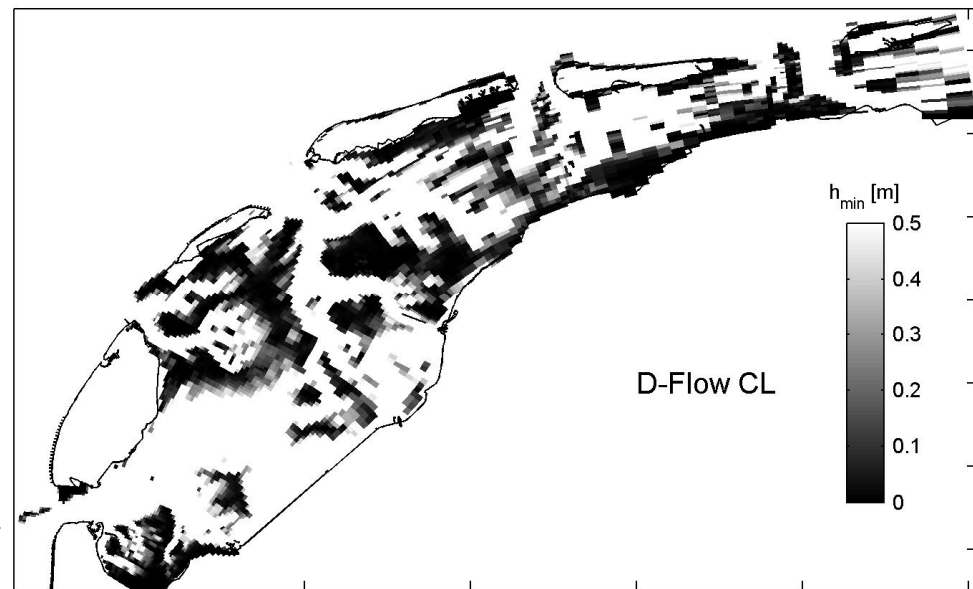
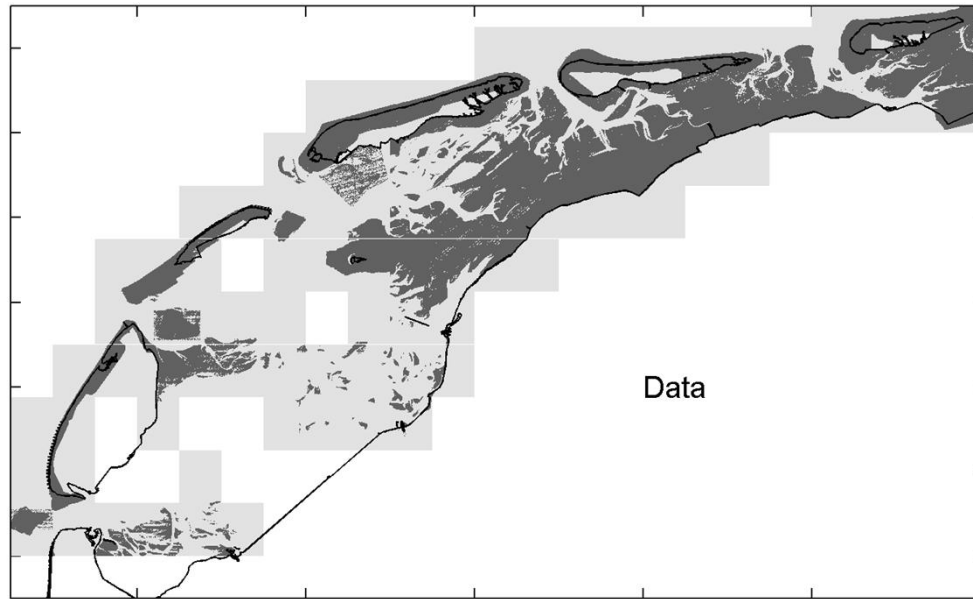
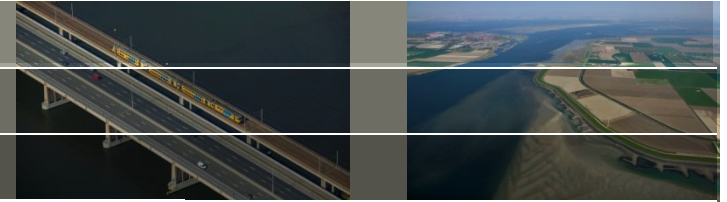


- Lidar measurements (Dutch government)
- Dataset 1996 – 2011
- Bathymetry measured during LLWS (lower low water spring)

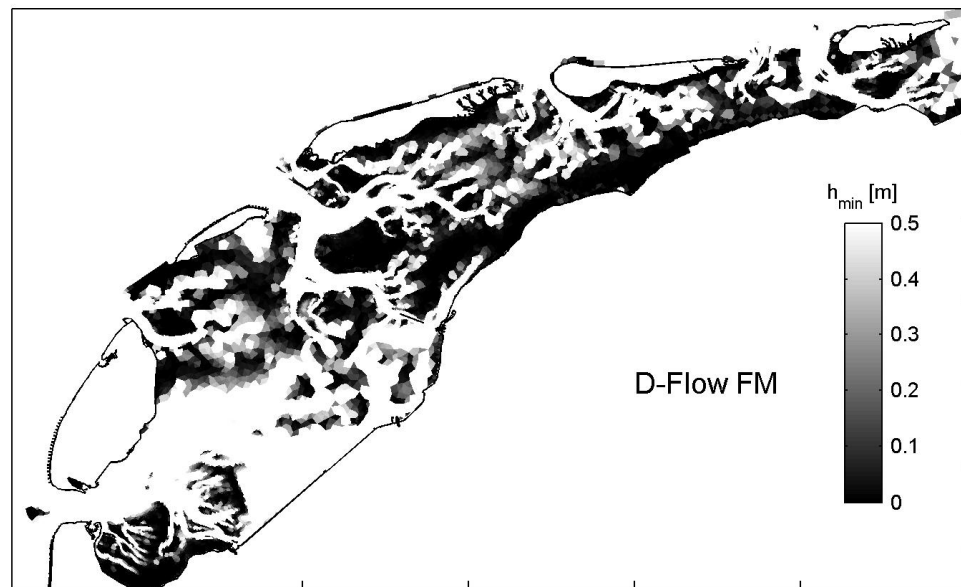
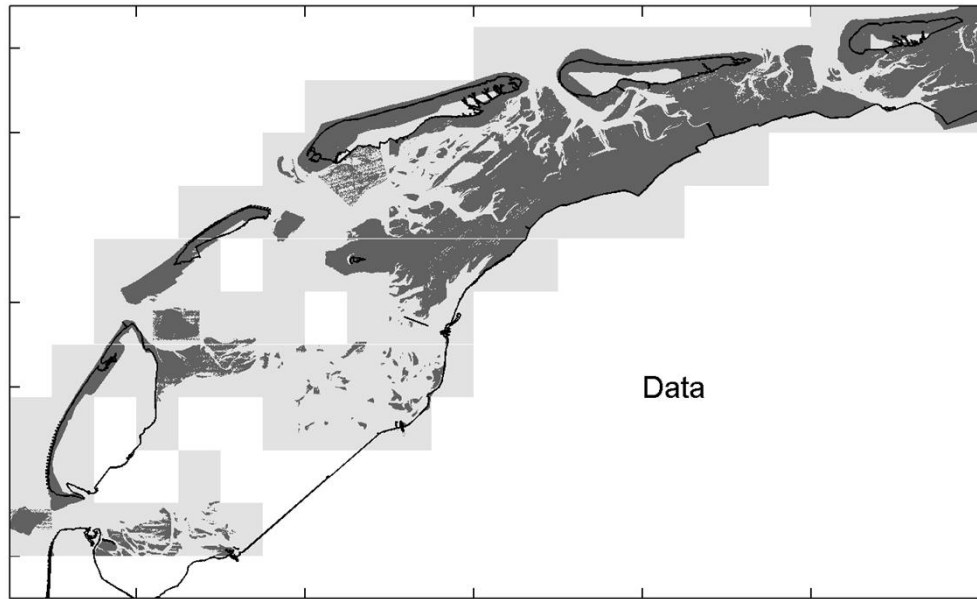
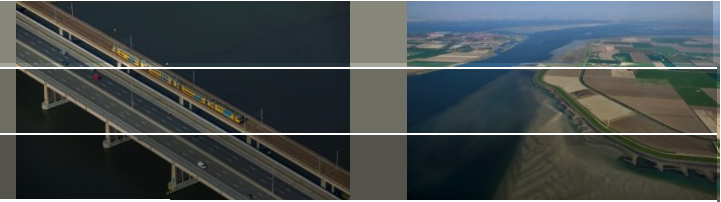
Drying and flooding



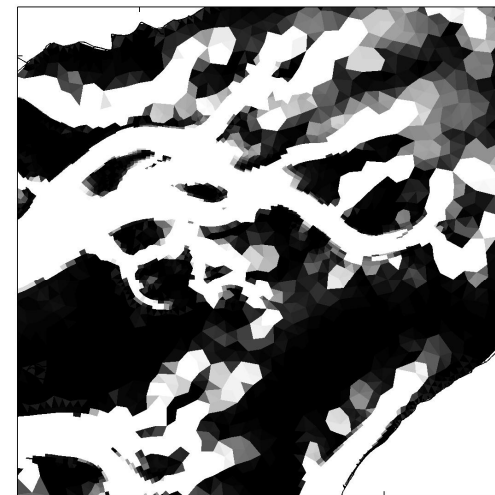
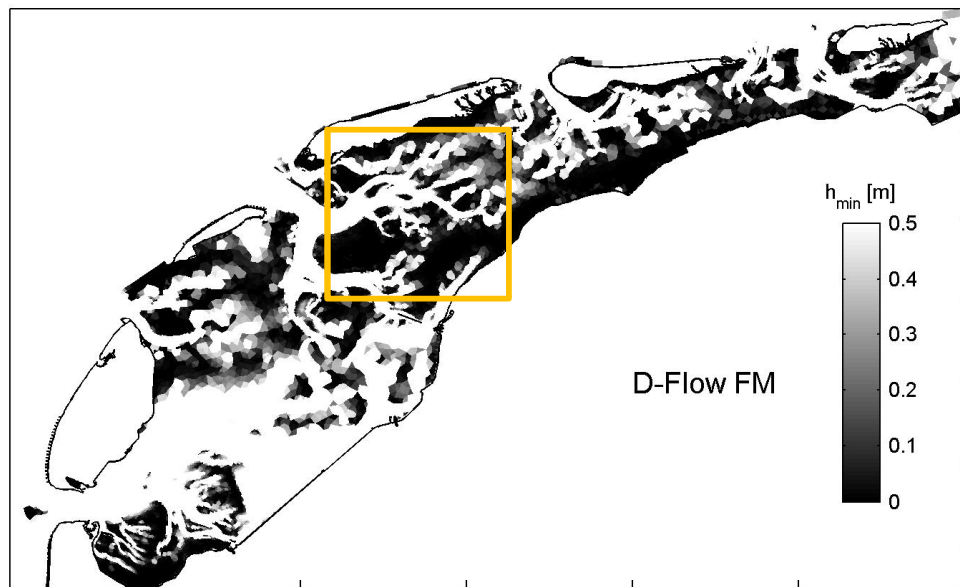
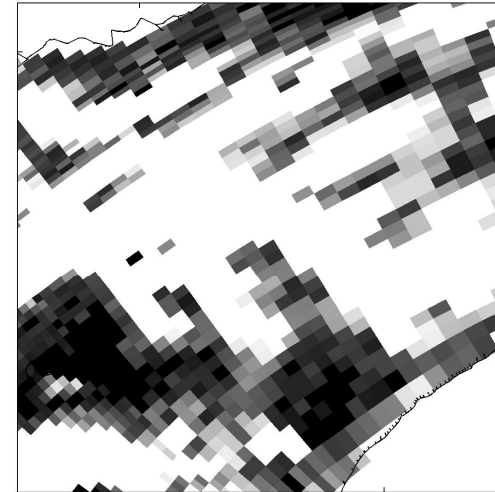
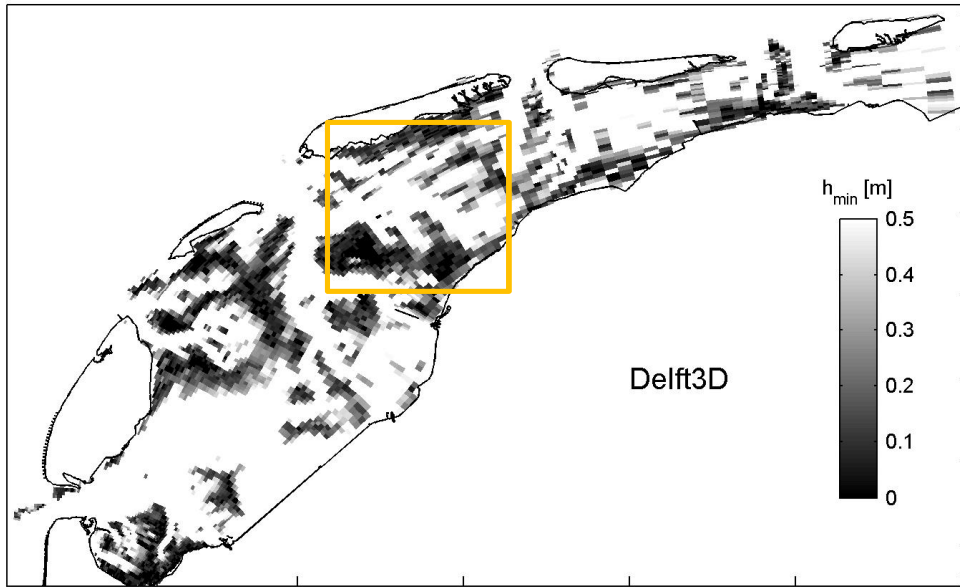
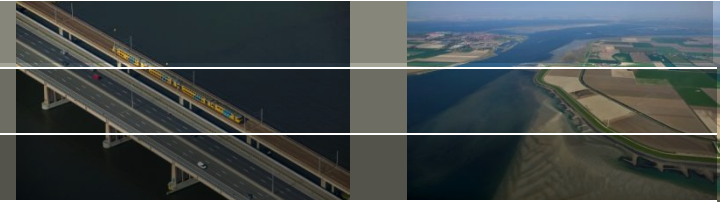
Drying and flooding



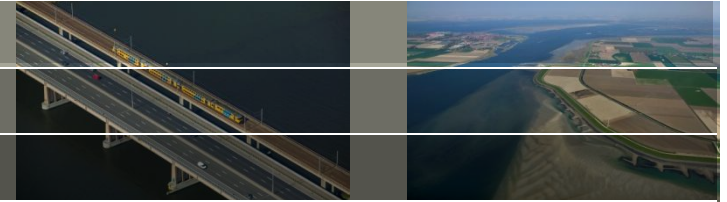
Drying and flooding



Drying and flooding



Performance comparison



3 month model runs on a i7 quad core desktop PC.

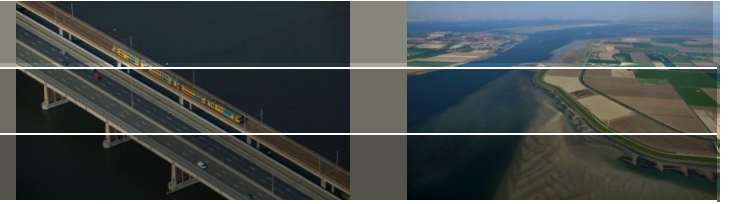
- Delft3D: curvilinear grid, fixed $\Delta t = 1$ min
- D-Flow FM on same curvilinear grid ($\Delta t = 1$ min)
- D-Flow FM unstructured grid ($\Delta t \approx 20$ s)

Model run	Wall clock time	# time steps	# grid cells
Delft3D	8591 s	175680	20829
D-Flow CL	3785 s	187073	20829
D-Flow FM	27862 s	602283	45134

Conclusion:

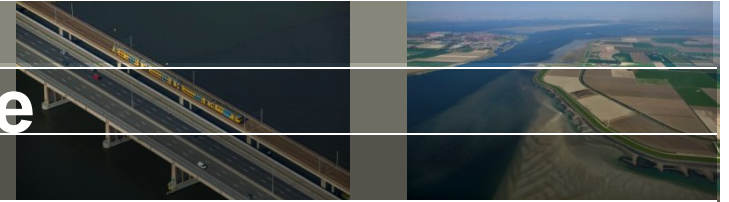
- On identical grids: FM 2.5 x as fast (a.o. thanks to OpenMP multicore)
- On unstructured grid: +- 8 times slower (due to # grid cells + time step)

Conclusions



- We set up three different models for modeling 2DH flow in the (Dutch) Wadden Sea (Delft3D, D-Flow CL, and D-Flow FM)
- The (calibrated) Delft3D model is most accurate
- D-Flow FM seems to predicts drying of tidal flats better
- FM code computationally more efficient

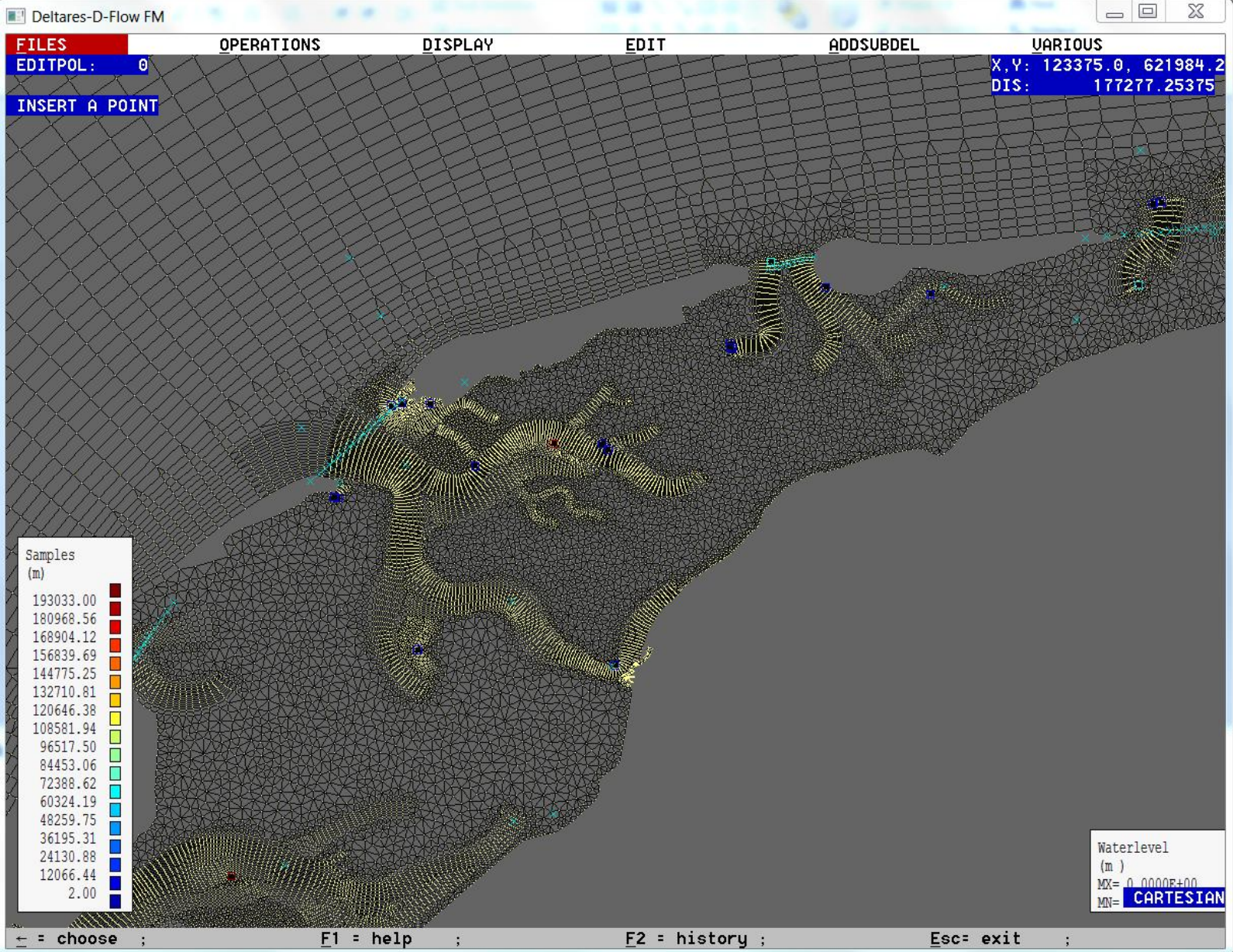
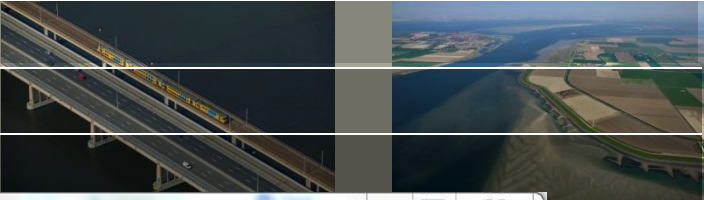
Next steps / future perspective



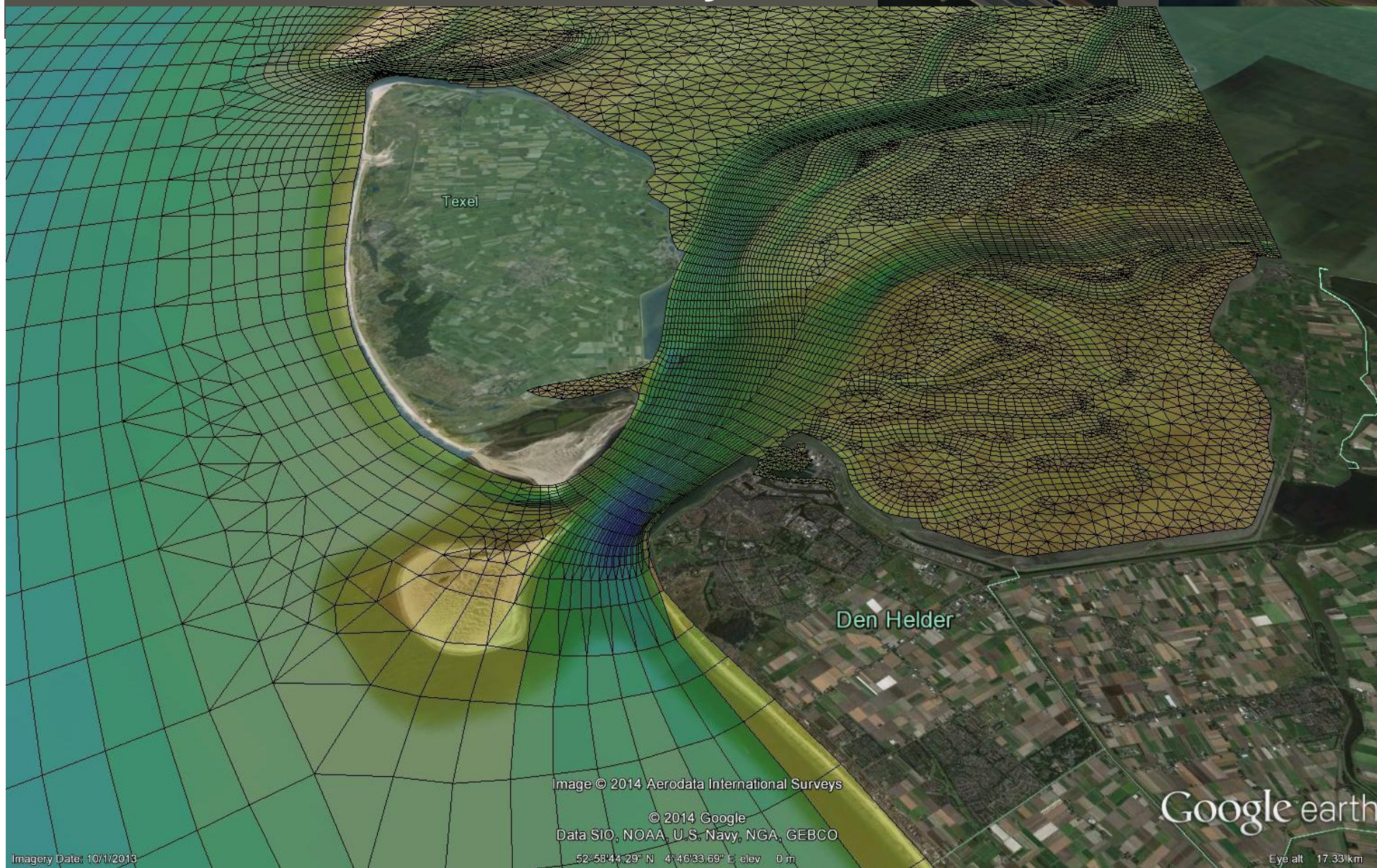
- Calibrate D-Flow FM models
- Optimize D-Flow FM unstructured grid
- Look at drying/flooding processes at a more local scale

- 3D modeling
- Add sediment transport

Optimizing D-Flow FM grid



Thank you!



Imagery Date: 10/1/2013

19 mei 2014

Deltares