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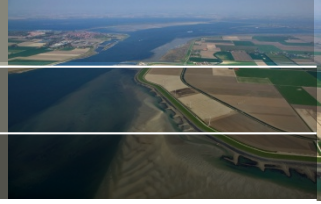
Enabling Delta Life

Modeling the North West European Shelf using Delft3D Flexible Mesh

2nd JCOMM Scientific and Technical Symposium on Storm Surges, 8-13 Nov. 2015, Key West, USA; **Firmijn Zijl**

Outline of this presentation



Modelling the North West European Shelf using Delft3D Flexible Mesh

- Background; Dutch Continental Shelf Model version 6 (DCSMv6)
- Comparsion result HIRLAM vs ECMWF
- Flexible Mesh Grid optimization
- Towards a new 3D transport model for the North Sea …

Background

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Real-time forecasting in The Netherlands

Real-time water level forecasting in the Netherlands

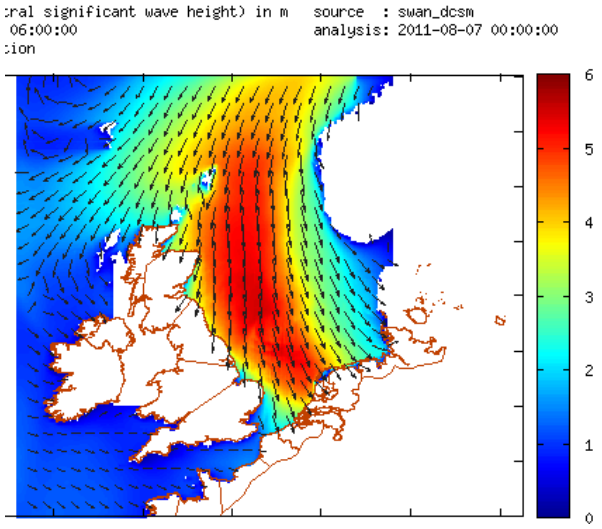
•Need for accurate, real-time operational water level forecasting

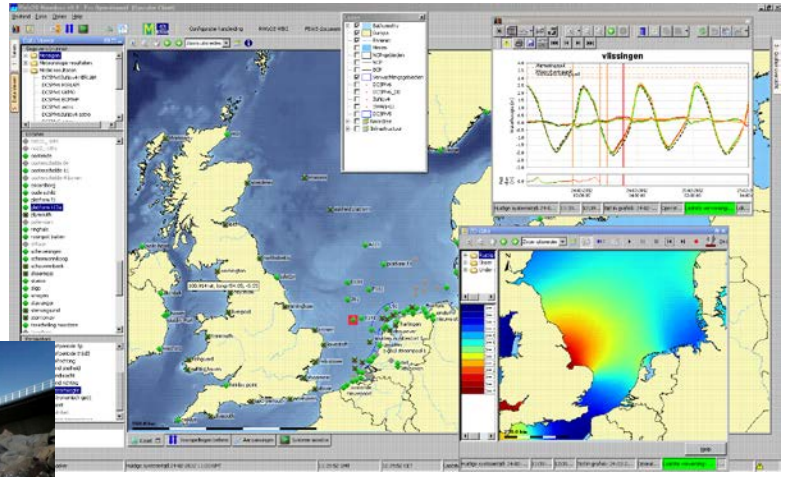
•Water-level forecasts at stations along the Dutch coast are provided every 6 h, with a 48-hour lead time.

• After the November 2006 All Saints storm it was decided that further improvements in model framework were required

• Decision to completely redesign the operational model

• New generation model is part of a comprehensive development to upgrade the operational forecasting system for the North Sea





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DCSMv6 - model setup

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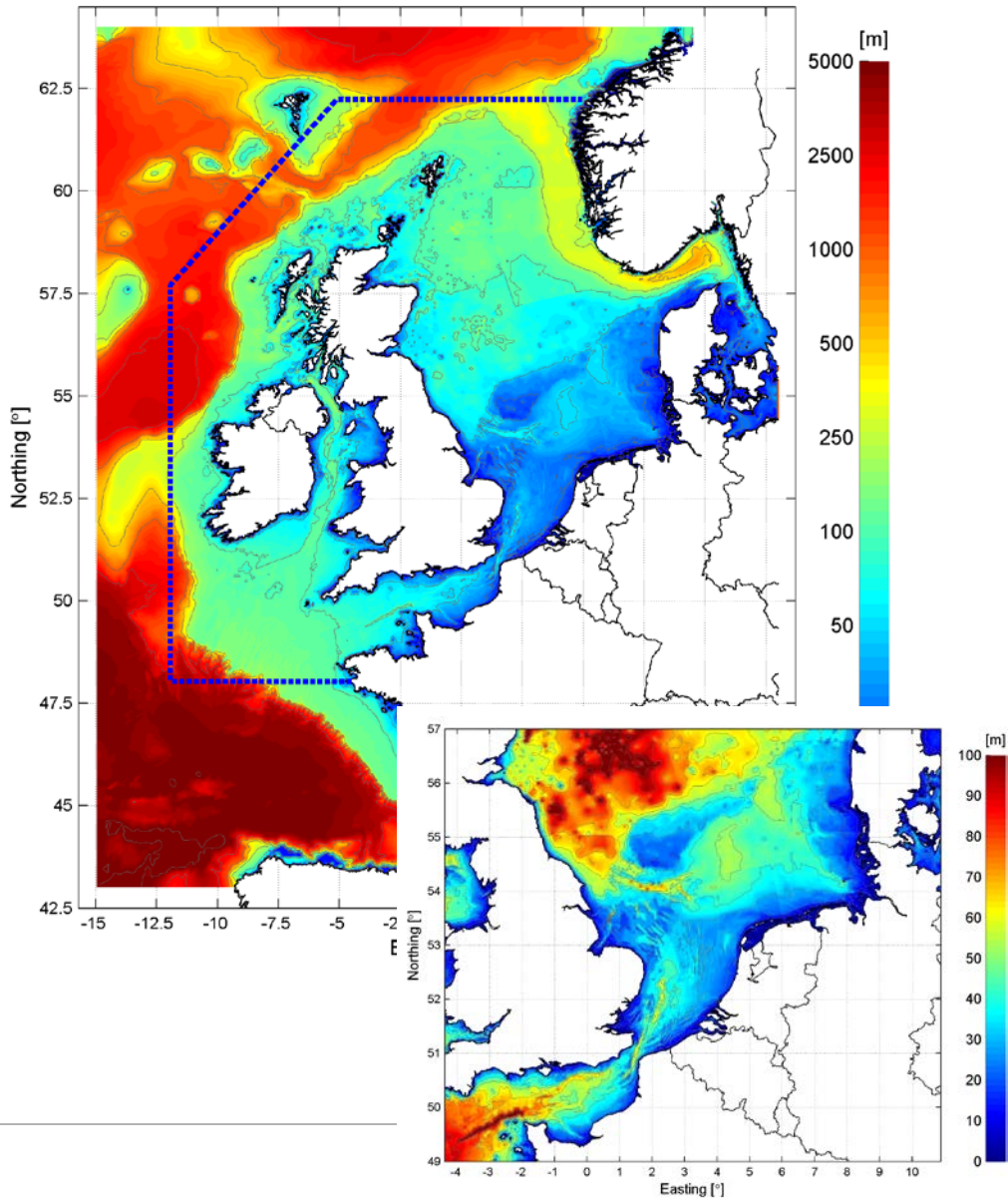
DCSMv6 (model grid and bathymetry)

Model setup - computational grid

- Increased spatial coverage
- Uniform cell size of 1.5’ (1/40°) in east-west direction and 1.0’ (1/60°) in north-south direction (~nautical mile)
- Around 10^6 active grid cells
- With a computational time step of 2 minutes, a 1 day simulation takes approximately 5 minutes on 12 computational cores

Model setup – bathymetry

- Initially based on NOOS gridded bathymetry data set, supplemented by ETOPO2
- Changes made during calibration



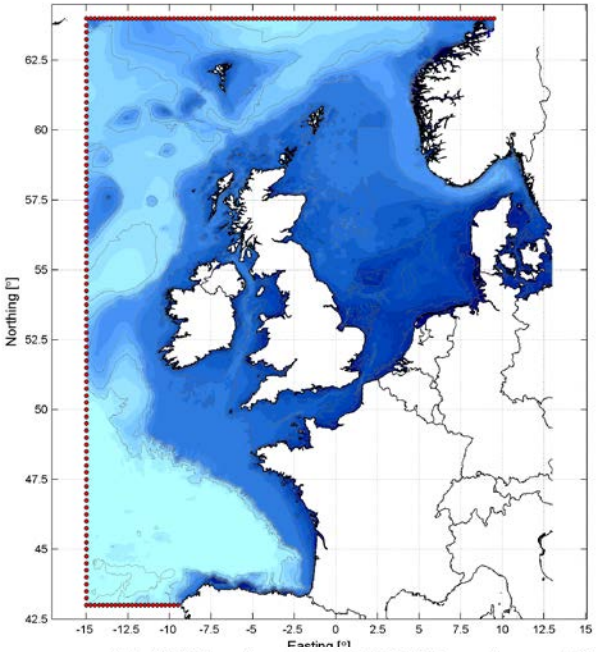
Model setup (boundary forcing)

Model setup - boundary forcing

- Open boundary with 205 sections
- Distinction made between 2 components of the water level elevation:

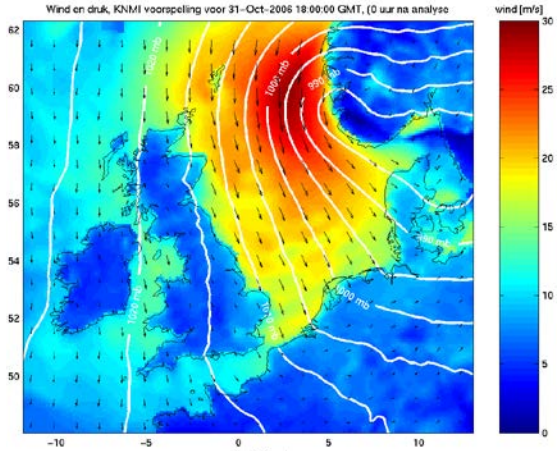
(1)Tide (38 constituents)

(2)Surge, as an inverse barometer correction (IBC) based on time and space varying pressure fields



Model setup - meteo forcing

- Wind speed and air pressure from HIRLAM NWP model provided (operationally) by KNMI
- Sea surface roughness is calculated using the Charnock relation (Charnock parameter 0.025)



- Tide Generating Forces (TGF) included

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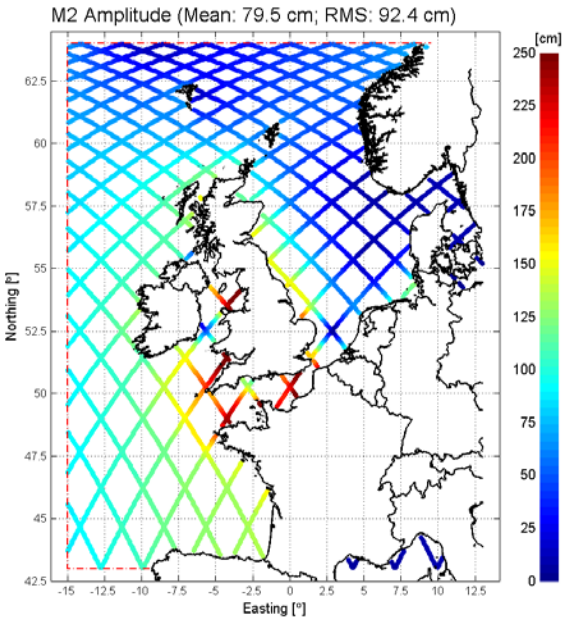
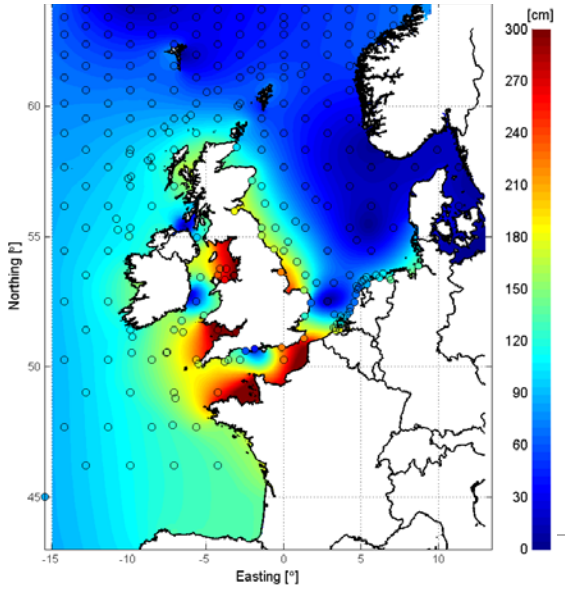
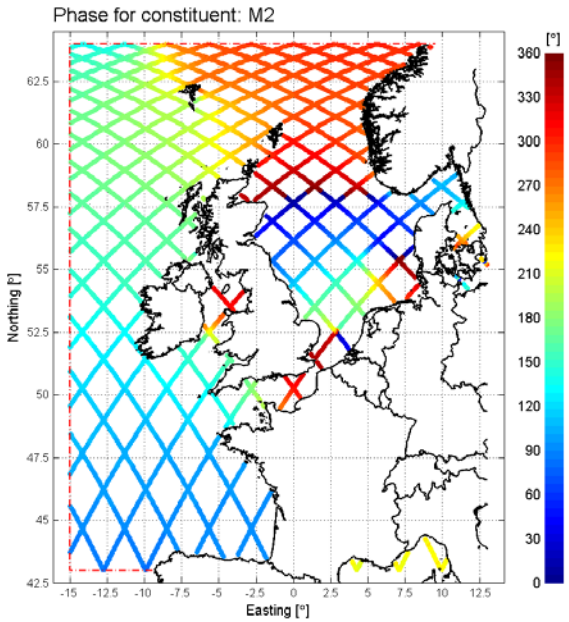
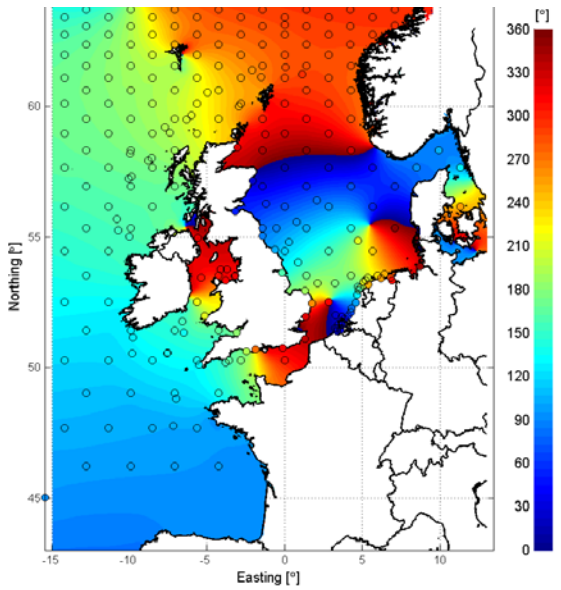
Calibration: DCSMv6 (against satelite altimeter data)

M2 Amplitude









M2 Phase

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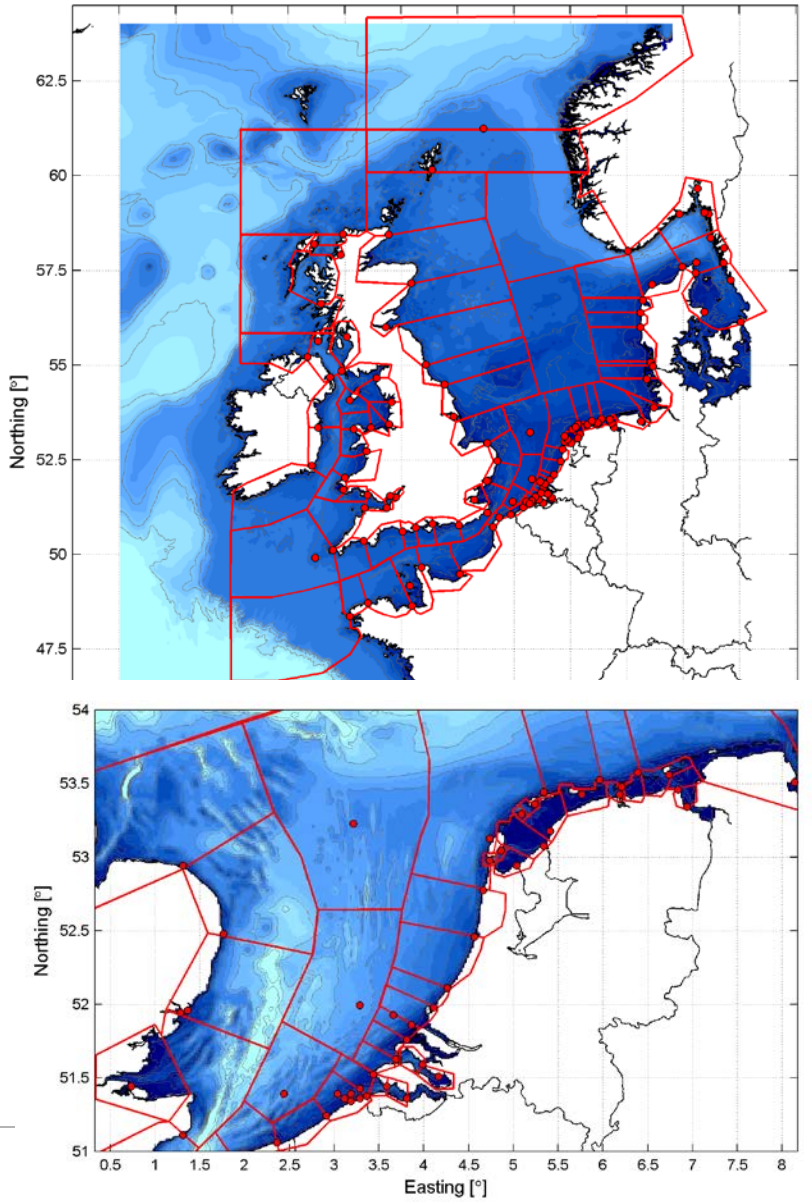
DCSMv6 – calibration

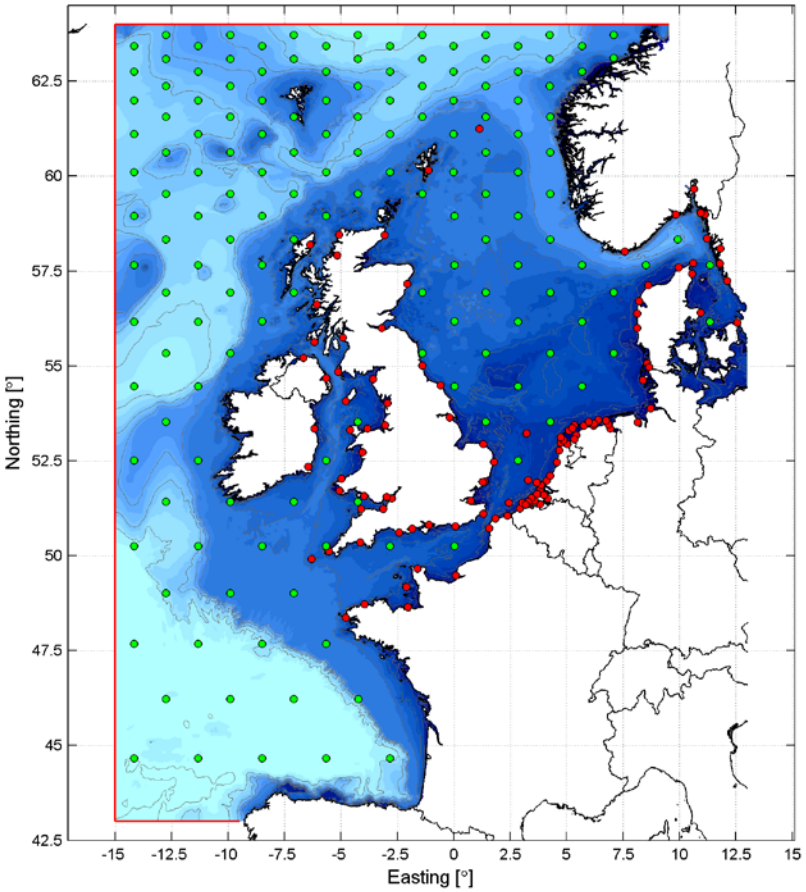
OpenDA-DUD experiment setup and parameters

- Parameters related to prescription at the open boundary excluded from the optimization problem
- Tidal error introduced during the tidal propagation
- Reduction of uncertainty in bottom friction coefficient and bathymetry
- Control parameters defined between measurement locations
- Multiple optimization runs, with increasing length and number of parameters
    - Long period to account for non-stationarity of tidal amplitudes and phases
    - Large area to account for spatial interaction
- Final experiment had 200 control parameters, 12 months, ~100 observations locations



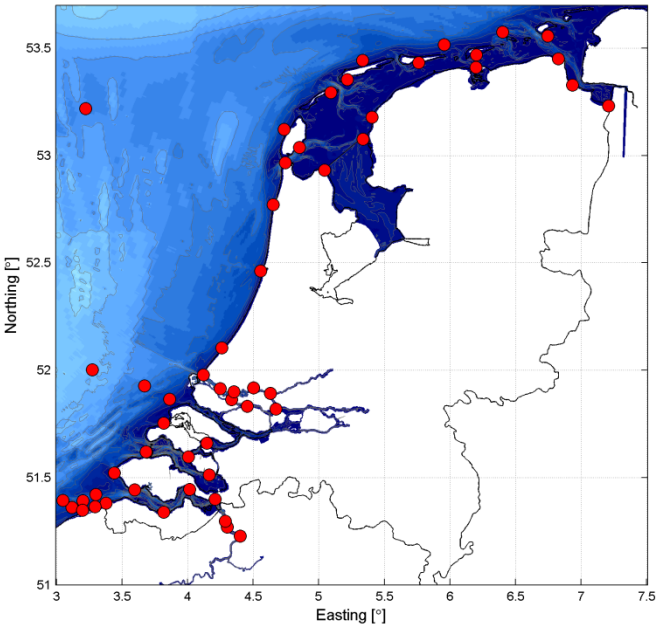
Model calibration

Calibration and validation using tide gauge data at >120 locations



Green dots: radar altimeter cross-over locations

Red dots: in-situ tide-gauge locations



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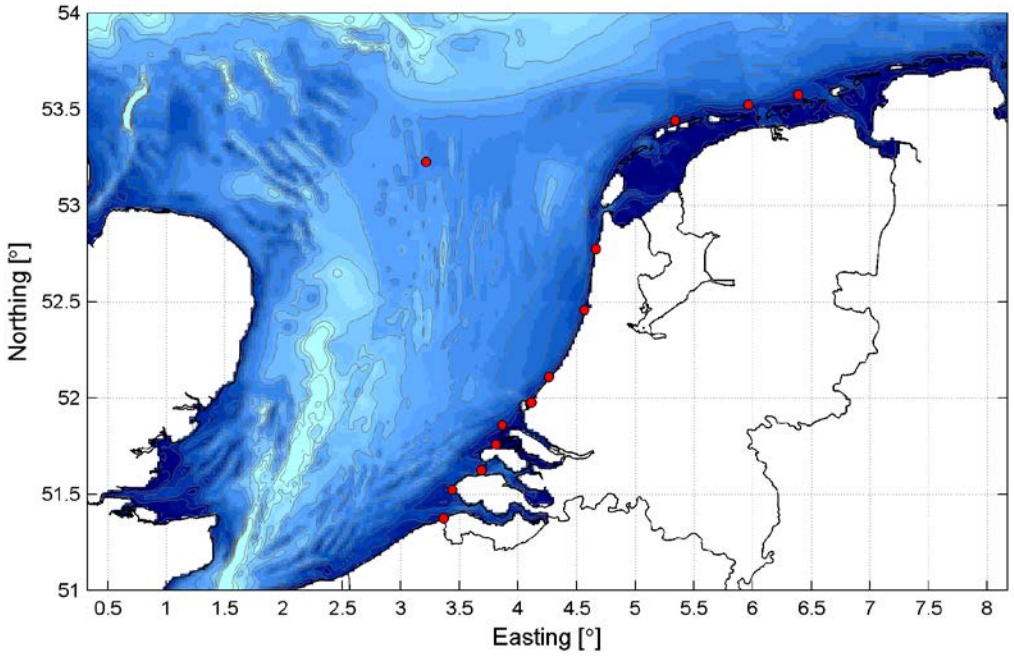
Results: Dutch coastal tide gauge stations

Goodness-of-Fit (in cm) for 13 Dutch coastal stations, 2007

	RMSE (tide)	RMSE (surge)	RMSE (total)	RMSE (high water)	RMSE (low water)
DCSMv5	10.7	7.7	13.1	11.3	11.0
DCSMv6 (Regular mesh)	**3.8**	**5.9**	**7.0**	**6.6**	**7.1**
	-64%	-23%	-47%	-42%	-35%

(harmonic analysis with 118 constituents)



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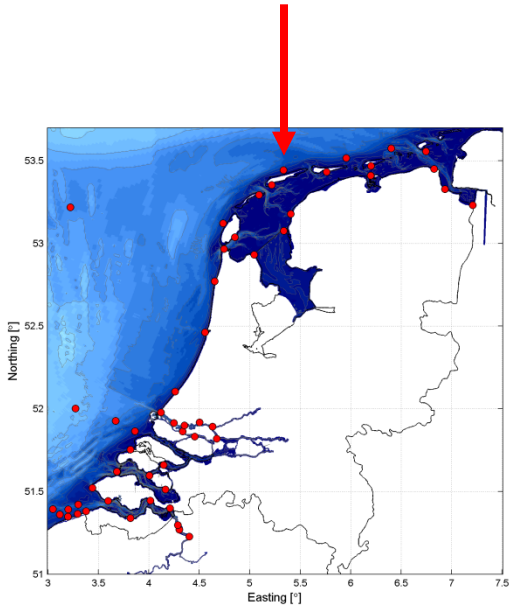
DCSMv6 - results

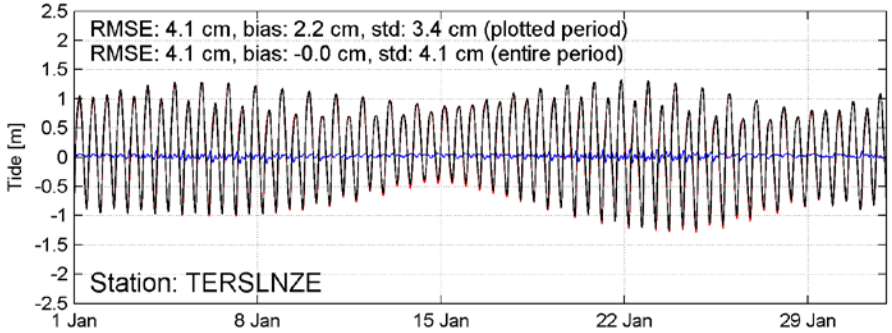
Results for tide, surge and total water level

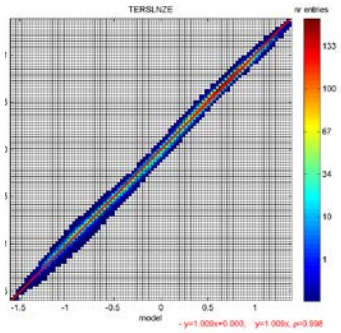


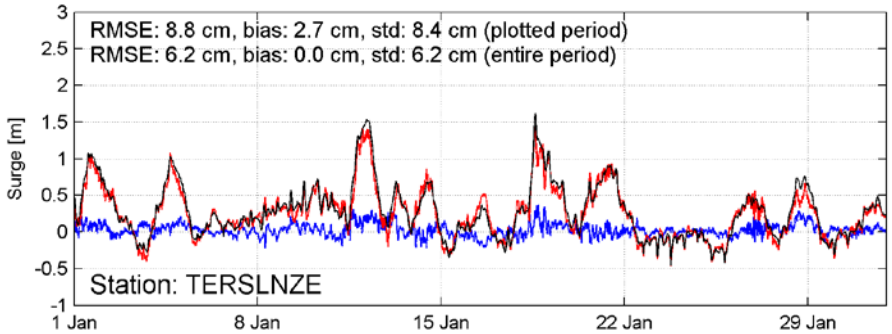
Red: Measurement

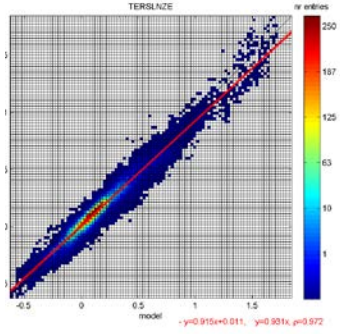
Black: Computation

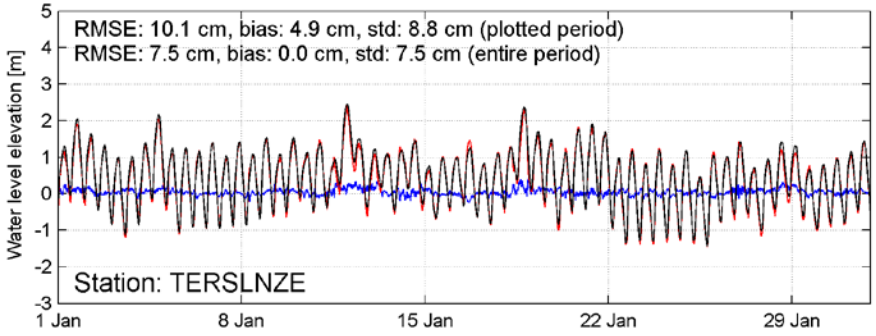
Blue: Residual

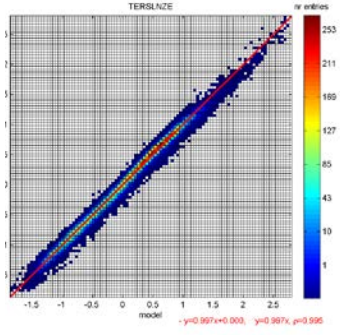












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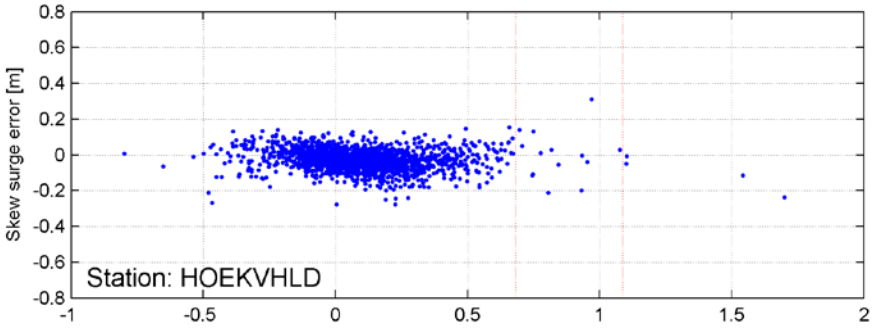
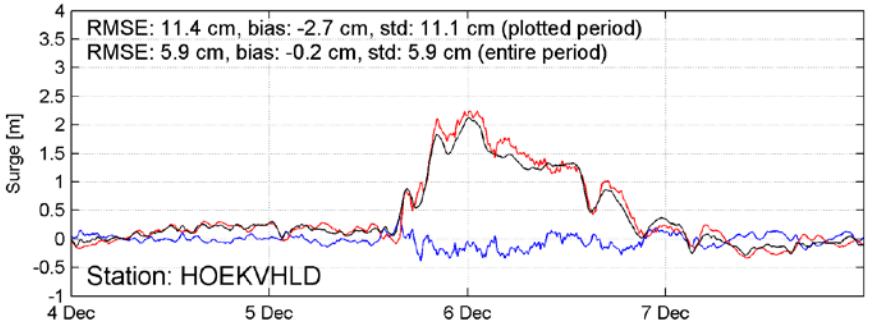
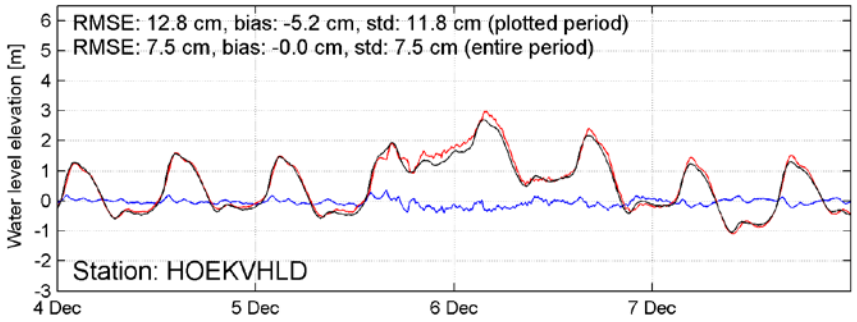
DCSMv6 – Hoek van Holland; HIRLAM vs ECMWF

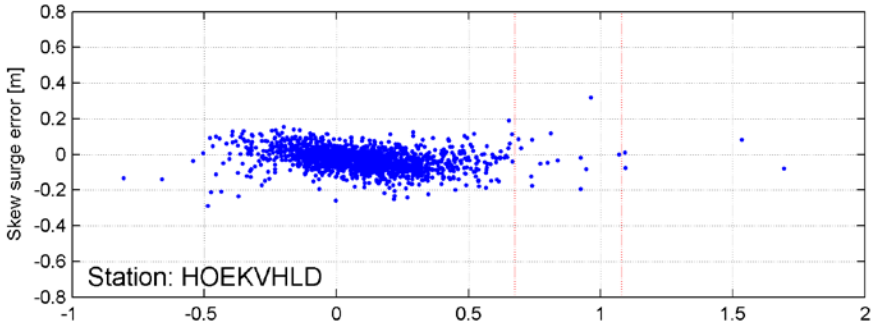
Hirlam

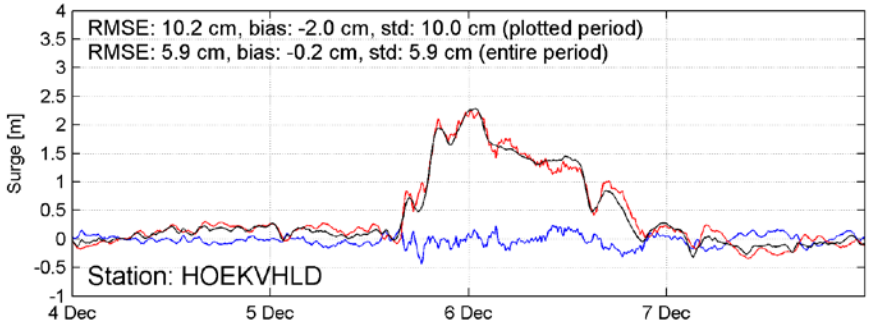


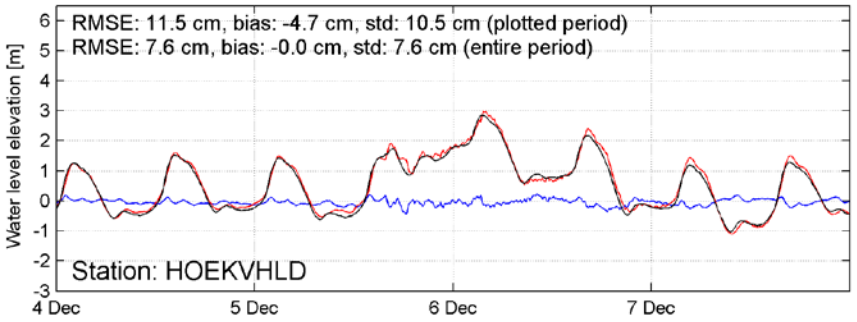




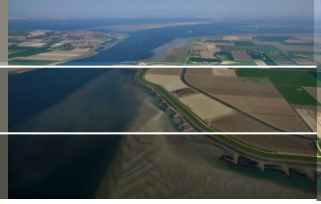
ECMWF







DCSMv6 (Dutch coast)



	RMSE (tide)	RMSE (surge)	RMSE (total)	RMSE (high water)	RMSE (low water)
DCSMv6-Hirlam	**4.6**	**5.9**	**7.3**	**6.7**	**7.0**
DCSMv6-ECMWF	**4.5**	**5.8**	**7.2**	**6.6**	**6.8**

skew surges from 2013-01 to 2015-06

	all skew surges		1% highest skew surges		0.2% highest skew surges	
Model	bias	RMSE	bias	RMSE	bias	RMSE
DCSMv6-Hirlam	1.4	6.2	4.7	14.6	15.7	19.1
DCSMv6-ECMWF	1.4	6.1	4.4	12.4	11.0	13.6

-29%

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VERSION with Flexible Mesh

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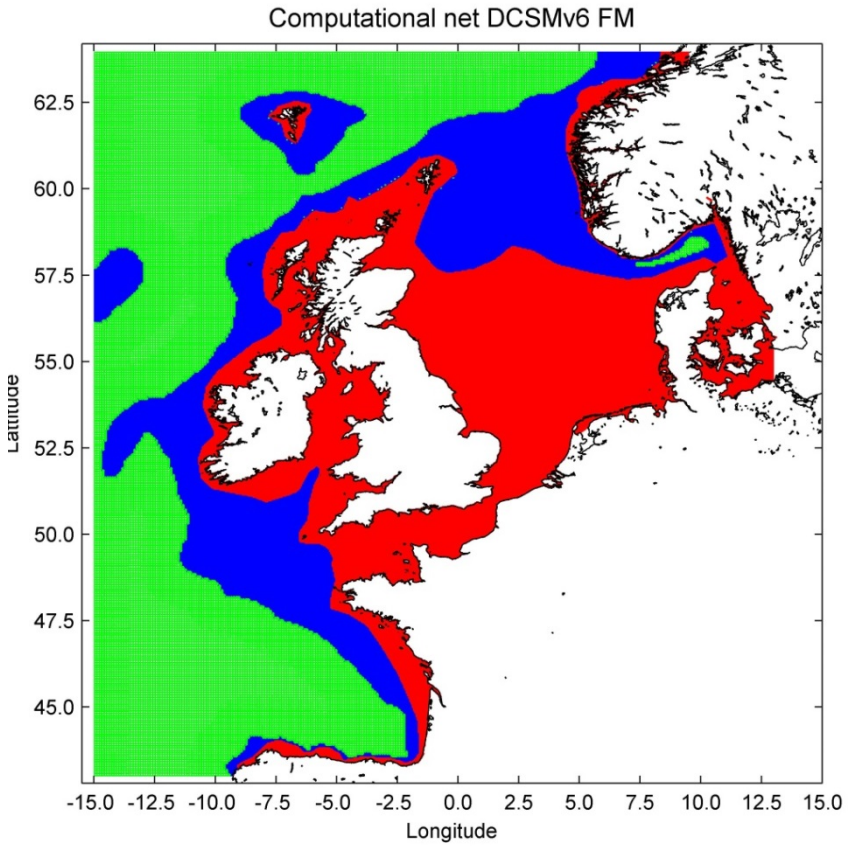
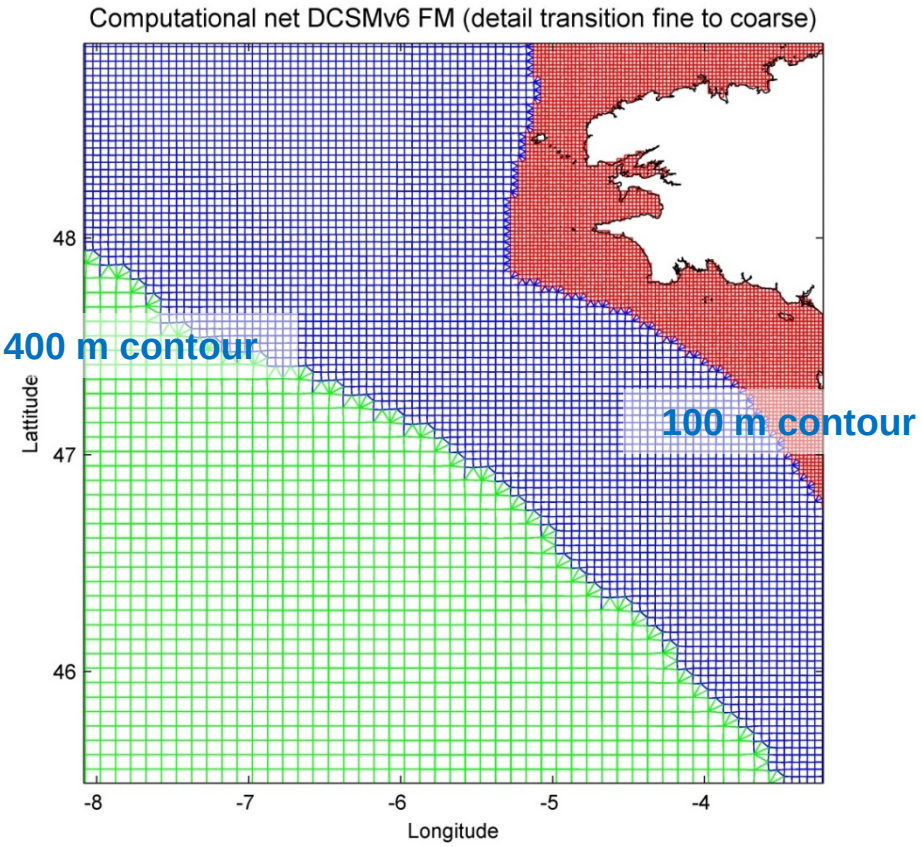
Local grid coarsening





Red: original grid size

Blue: 2x coarsened

Green: 4x coarsened

- # net nodes from 860,000 to 358,000 (factor 2.5)
- # net links from 1,700,000 to 752,000 (factor 2.25)

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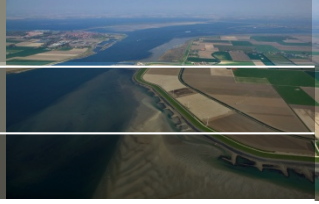
Grid optimization



Numerical time step

- Numerical accuracy is determined by the (wave) Courant number
- As this is proportional to the square root of the depth, with a uniform grid size, the deepest cells are limiting the computational time step.
- Further increase in computational speed by increasing maximum allowed time step from 2 to 3 minutes

With the upgraded flexible resolution grid and increased time step, the model is roughly speaking 3-4 times faster (on one core)

Goodness-of-Fit (in cm) - 13 Dutch coastal stations - entire year of 2007)

	RMSE (tide)	RMSE (surge)	RMSE (total)
Regular mesh	**4.1**	**5.9**	**7.2**
Delft3D FM	**4.9**	**6.0**	**7.7**
Delft3D FM (coarsened)	**5.2**	**6.0**	**8.0**

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