Deltares

Enabling Delta Life

Model development for flood forecast improvement in the Netherlands

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with thanks to colleagues

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Contents:

- The newly created Deltares
- Present NL flood forecasting system
- Considerations for a new system
- Water level model – DCSMv6
- Calibration approach - OpenDA
- Wave model – SWAN_NorthSea
- Time schedule of Implementation / Operation

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Deltares : four institutes are pooling strengths

The Netherlands is built on "water and soft soil"

- **WL | Delft Hydraulics**
  - hydraulic engineering and integrated water management
- **GeoDelft**
  - geo-engineering
- A part of **TNO Built Environment and Geosciences**
  - soil and groundwater
- Sections of **Rijkswaterstaat**
  (**study departments** RIKZ, RIZA and DWW)
  - integrated water management and hydraulic engineering.

→ Deltares = Combination of above institutes
"staff of ~800 / combined history > 400 years"

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Deltares : implications for you and me?

- 1-1-2008: Creation of Deltares
- A “not-for-profit” foundation under Dutch law
- Stronger emphasis than before on the public task to maintain the integrated knowledge base for the civil protection and management of the wet / soil infrastructure of the Netherlands
- The “programme responsibility” for this public task has been transferred to Deltares; external review at 5 year intevals (?)
- So…..
    - Continuation of international outlook
    - Stronger R&D, next to Special Projects
    - But no operational tasks
- And….
    - Our commitment to research will not change
    - Increased cooperation with universities worldwide

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NL Flood forecasting: Dutch coast in 6 sectors

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Flood (Pre-) Warning and Alarm levels

Frequency		2/year	1/year	1/5year
Sector	**Basis station**	**pre-W-level**	**W-level**	**A-level**
Scheldt	Flushing	310	330	370
W Holland	Hook of Holland	200	220	280
Dordrecht	Dordrecht	-	-	250
Den Helder	Den Helder	-	190	260
Harlingen	Harlingen	-	270	330
Delfzijl	Delfzijl	260	300	380
Storm Surge Barriers				
SVKY	Krimpen a/d IJssel	210*	-	-
SVKO	Eastern Scheldt	275	300*	-
SVKW	Rotterdam Waterway	-	250	300*

*) level when storm surge barriers will be closed

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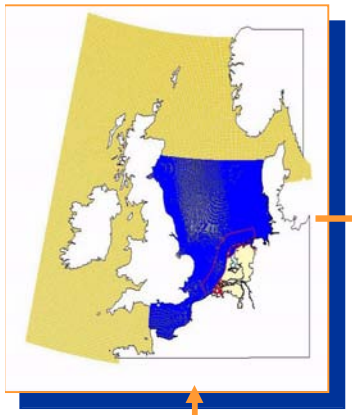
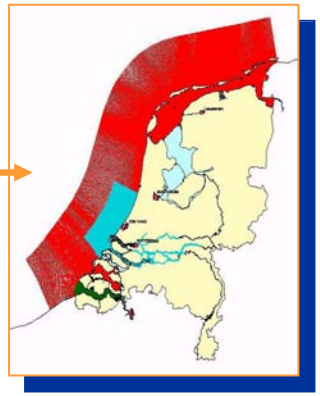
Set up of present Flood Forecasting Models

A system of 4 nested 2D water level forecast models:

(1) DCSM → (2) ZUNO → (3) COASTZONE → (4) RHINE+ROFI



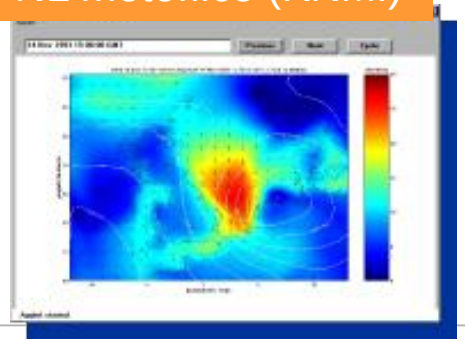


SIMONA
(/ Delft)
model code

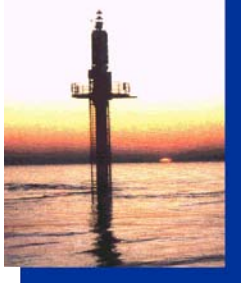
Kalmanfilter
for
Data
assimilation

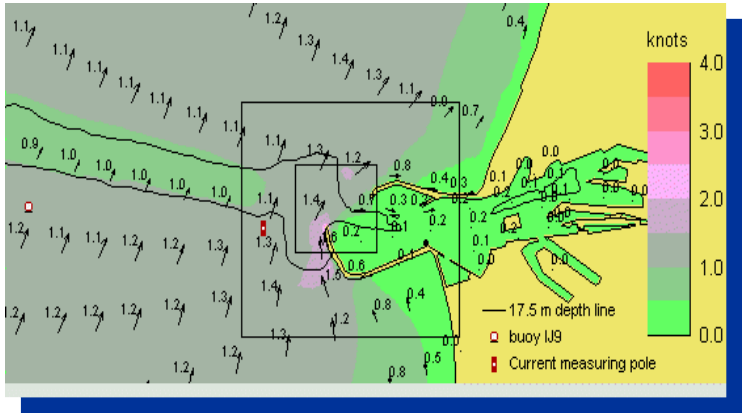
Water level forecasts,
Currents,
Salinity

Meteo-forecasts
NL metoffice (KNMI)



Monitoring





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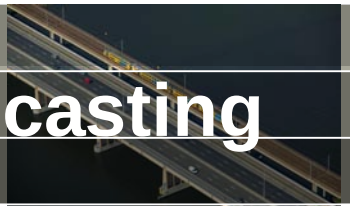
Present operational flood forecasting



- DCSMv5 domain beyond shelf; 1/12^{o} NS by 1/8^{o} EW (~9.3 km)
- COASTZONE (boundary fitted) : ~200m by ~300m along coast to ~100m in estuaries
- COASTZONE: various local models are nested in COASTZONE
- Operationally: 4 times/day T=36 hrs; HIRLAM 11 by 11 km winds
- Forecasts are prepared for 6 main stations / sectors,
- Kalman filtering for forecast improvement (Steady state approach);
- Man machine mix in fixing the official forecasts and warnings
- Status calibration : 1998; including limited altimeter data
- Only water level forecasts –"best guesses" added for wave effects

- → Present DCSMv5 model is at the end of its life cycle

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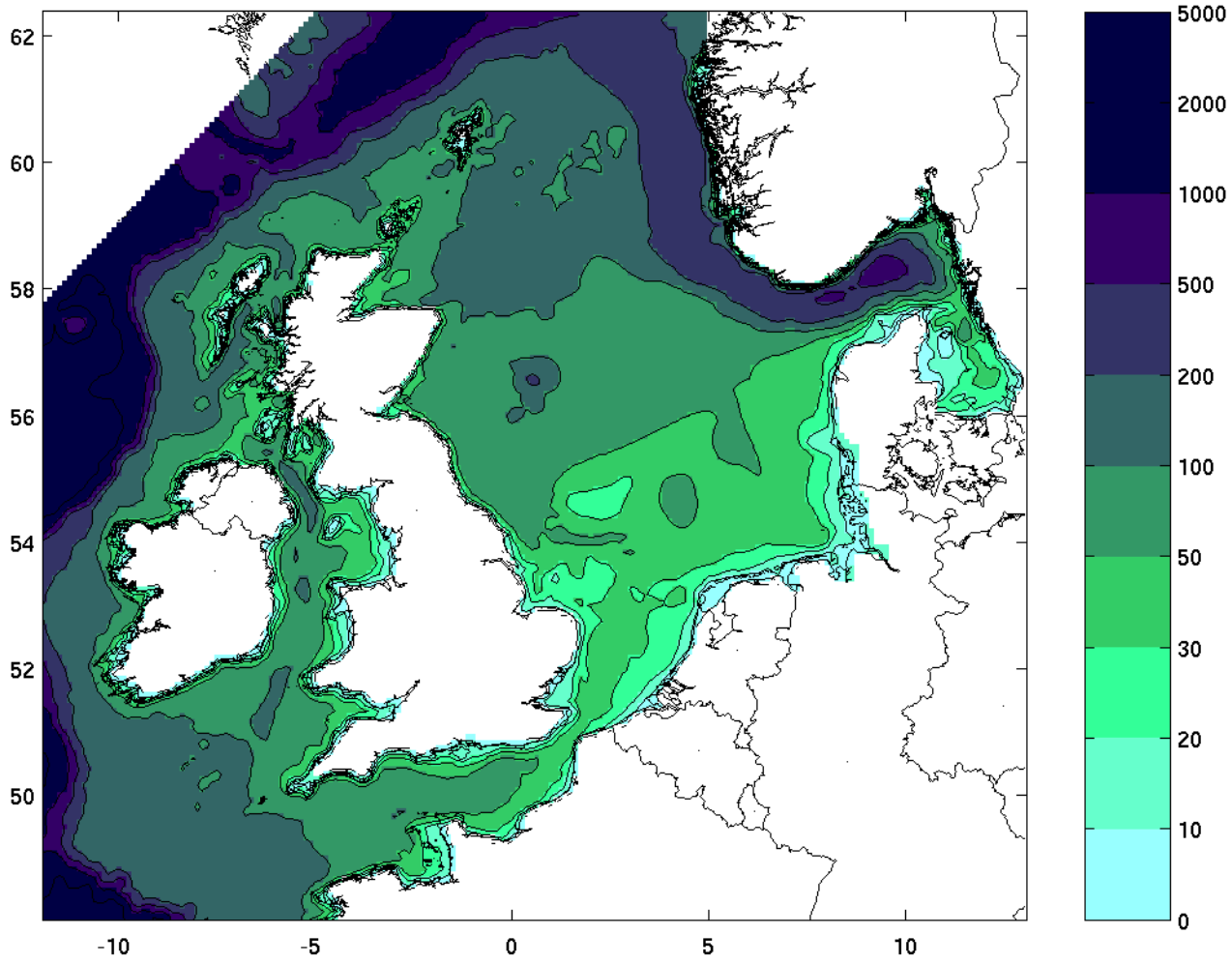
DCSMv5 model: 1/12º NS by 1/8º EW (~9.3 km)



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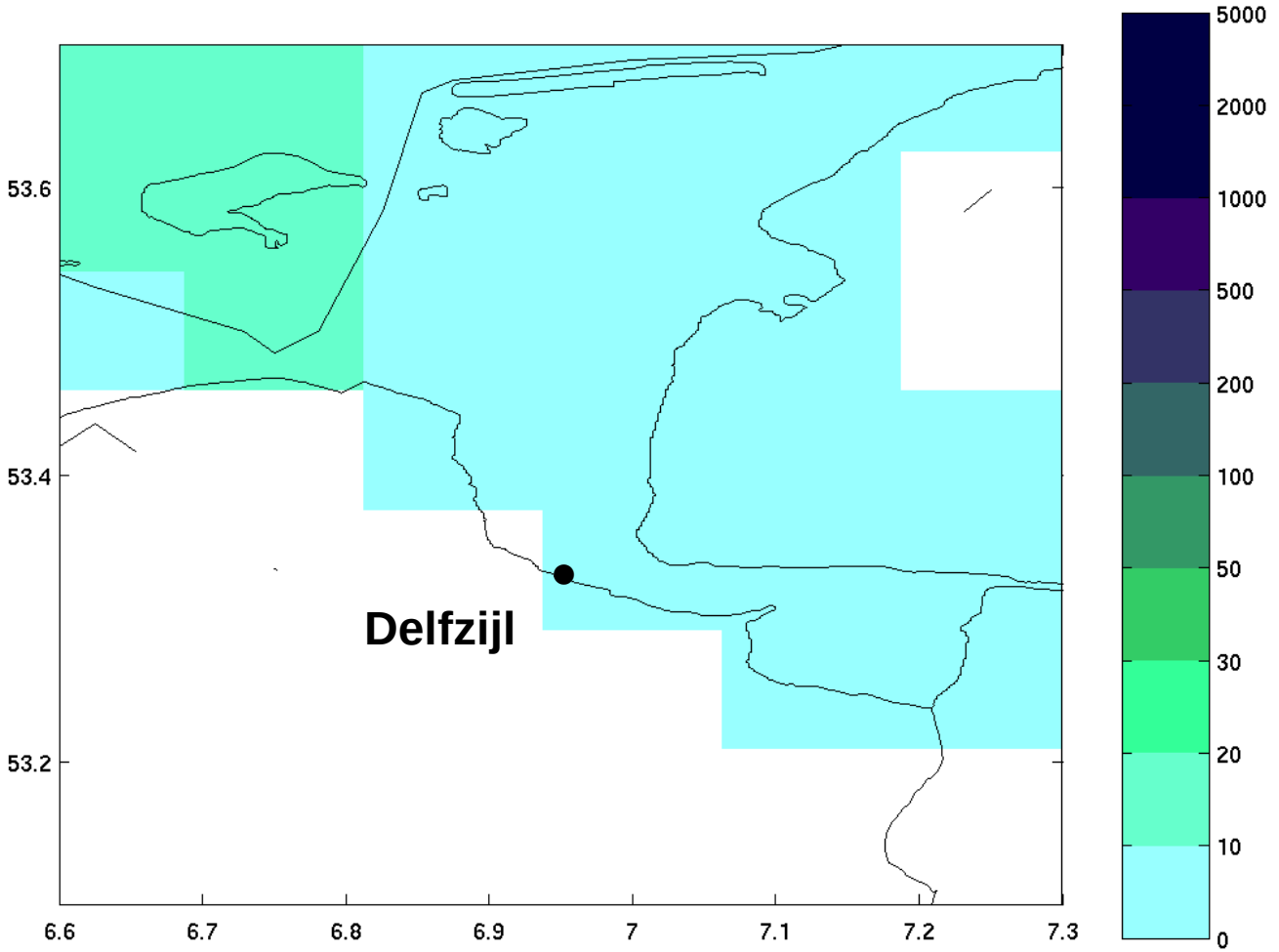
DCSMv5: very low resolution in the Delfzijl inlet



Resolution of DCSMv5: overall ~9.3 km

Resolution of COASTZONE : locally ~200 – 300m

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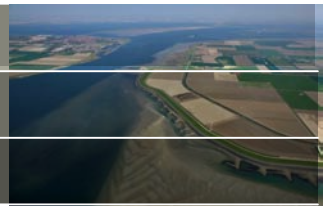
Considerations for a new system



- NOOS: inter-agency exchange of operational forecasts
- NOOS cooperation: new bathymetry data for North Sea domain
- Awareness of the importance of wave forces
- Awareness of the varying quality of sea defences
- → Can we predict the hydraulic loads per sea defence section?
- Effect of Katrina: Longer forecast window / evacuation?
- System at end of life cycle; computational efficiency
- Key staff will reach retirement age over next 5 years

- → Early 2006: proposal: “Improvement flood forecast models”
- → All Saints storm of 1 November 2006 confirmed the weaknesses of the present forecast system
  - Delfzijl: $H_{peak/obs}$ = 483 cm; $H_{peak/forecast}$ = 400 cm: ΔH_{peak} = -83 cm

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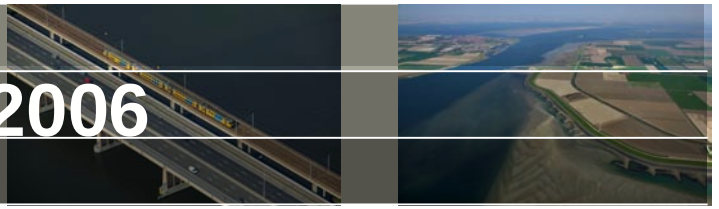
All Saints Storm 1 November 2006



sector	station	datum 2006	astronomisch HW		SVSD verwach-ting	opgetreden HW		scheve opzet op HW	VW / W / A *	tijdstip geven waarschuwing / alarmering
			tijd	stand		tijd	stand			
West Holland	Hoek van Holland	31 okt	22h26	+108	+240	22h40	+247	139	W	31 okt 16h30
Den Helder	Den Helder	1 nov	02h24	+78	+220	02h30	+238	160	W	31okt 20h30
Harlingen	Harlingen	1 nov	04h24	+105	+320	04h00	+326	221	W	31 okt 22h00
Delfzijl	Delfzijl	1 nov	07h00	+138	+400	06h40	+483	345	A	31 okt 23h30

sector station date T_{HW} H_{HW} (tidal part) FC T_{obs} H_{obs} H_{surge} $T_{warning}$

→ warnings in time; ΔH_{peak} = - 7 cm, + 18 cm, - 6 cm, - 83 cm, respectively

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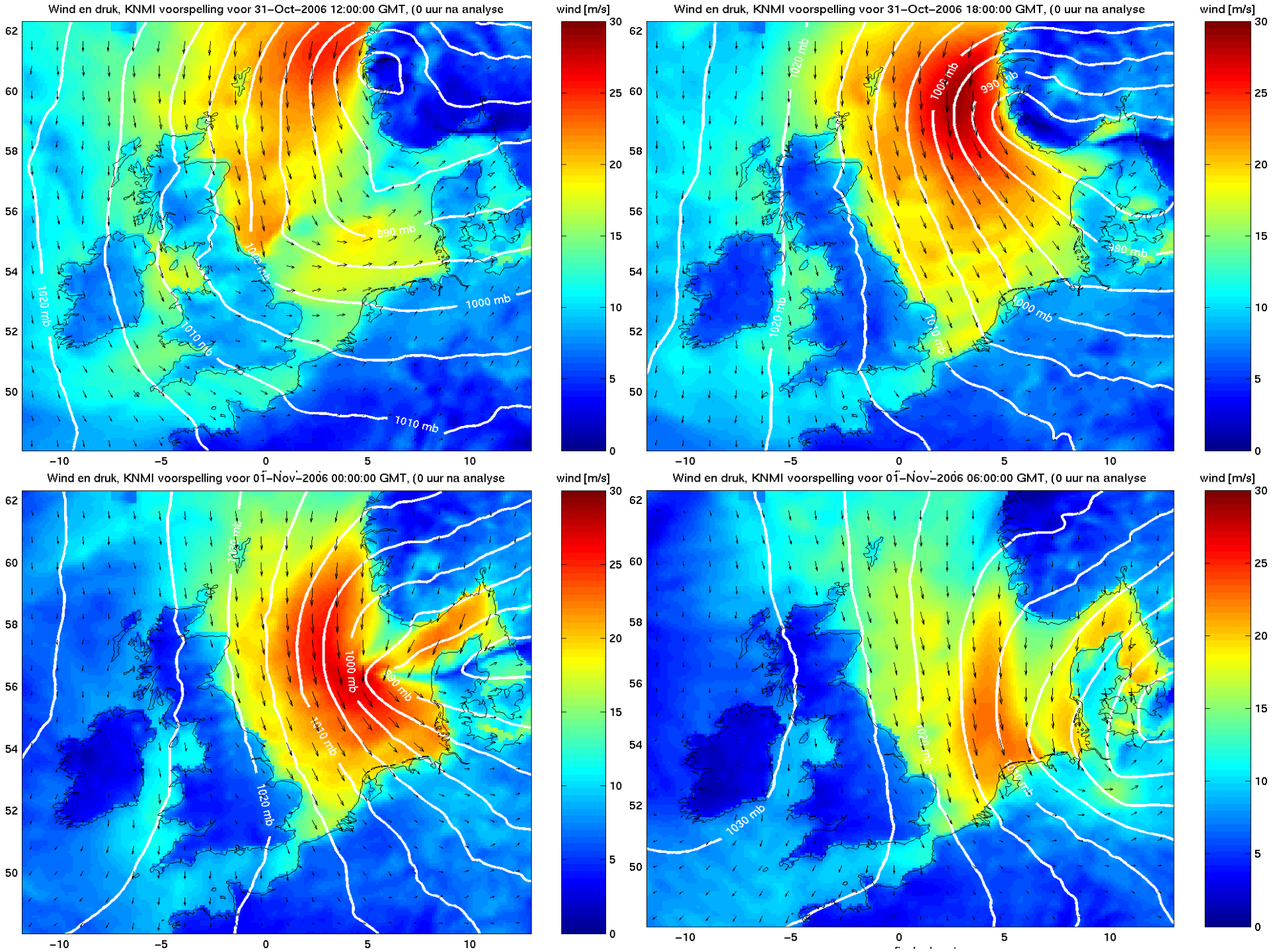
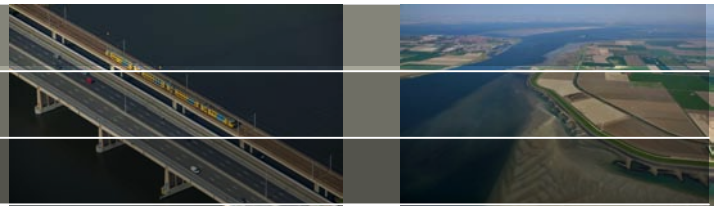

Wind en druk, KNMI voorspelling voor 31–Oct–2006 12:00:00 GMT, (0 uur na analyse
Wind en druk, KNMI voorspelling voor 31–Oct–2006 18:00:00 GMT, (0 uur na analyse
Wind en druk, KNMI voorspelling voor 01–Nov–2006 00:00:00 GMT, (0 uur na analyse
Wind en druk, KNMI voorspelling voor 01–Nov–2006 06:00:00 GMT, (0 uur na analyse
wind [m/s]
990 mb
1000 mb
1010 mb
1020 mb
1030 mb

Water level model – DCSMv6



- Spherico-curvilinear grid approach; yet 2D physics
- Larger domain for DCSMv6:
  - 5x5 refinement of resolution to 1/60^{o} by 1/40^{o};
- ZUNOv4: 3x3 refinement: = resolution COASTZONE
- Domain decomposition: double-domain approach;
- based on detailed 1 km (NOOS) bathymetry
- Inclusion of Tide Generation Forces
- Including diagnostic salinity distribution (MDT proxy)
- Tidal boundary forcing: 12 constituents
  - SA, SSA, MF, MM, Q1, O1, P1, K1, N2, M2, S2, K2
- Initial tidal forcing estimate:
  - from a blending of T/P data and GOT.02 results

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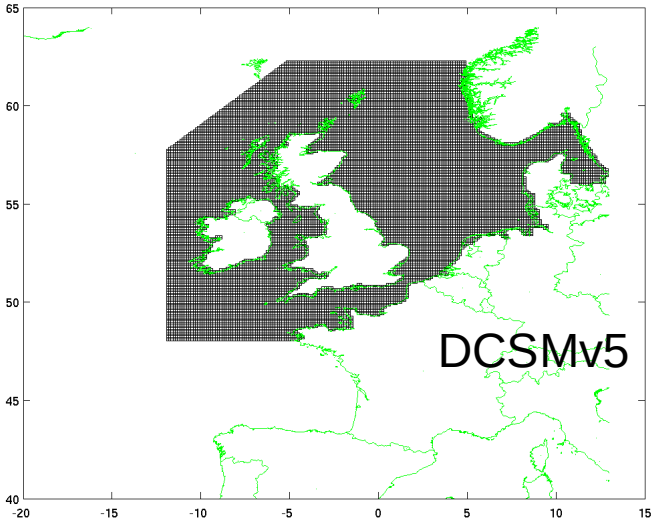
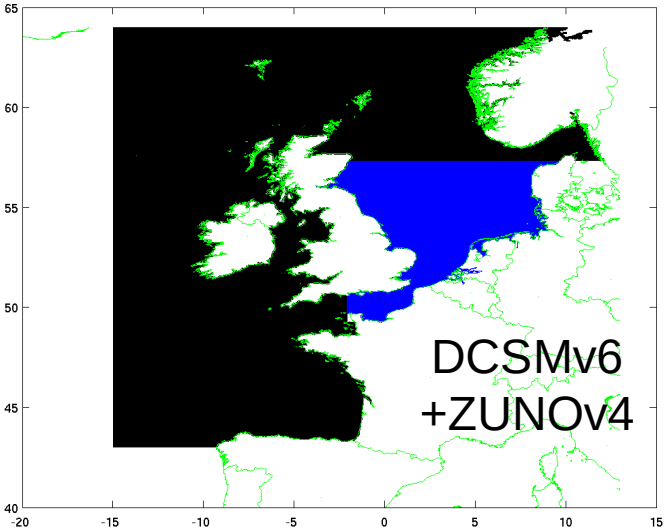
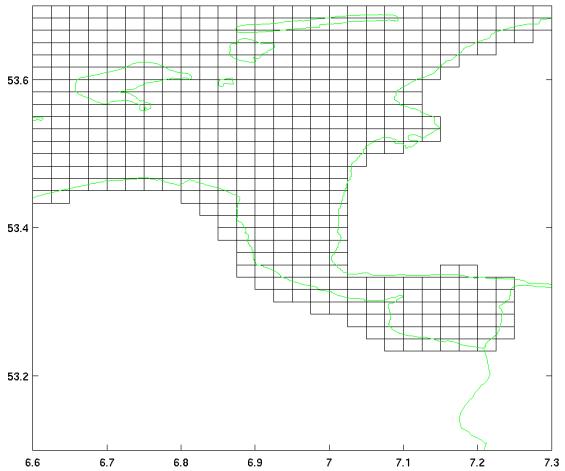
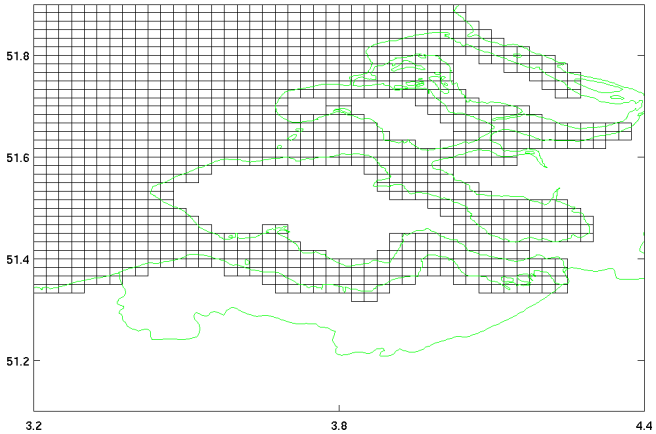
Water level model – DCSMv6







DCSMv6 local resolution



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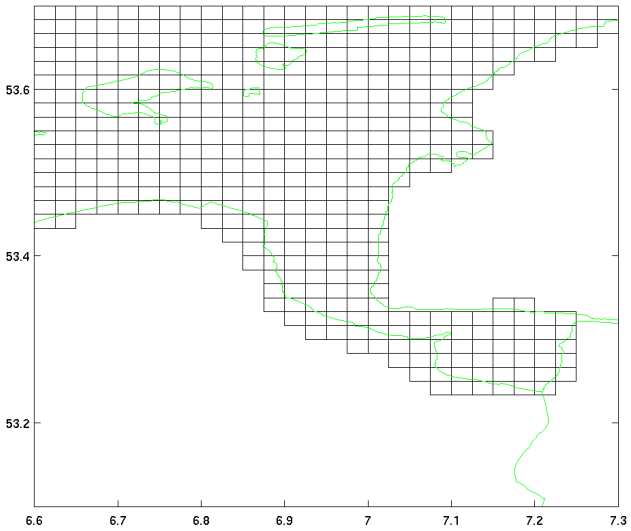
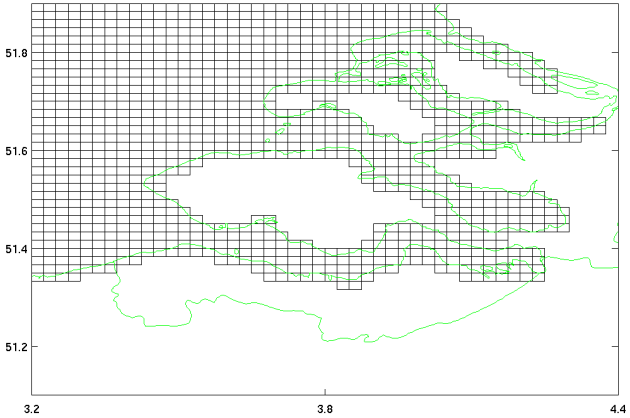
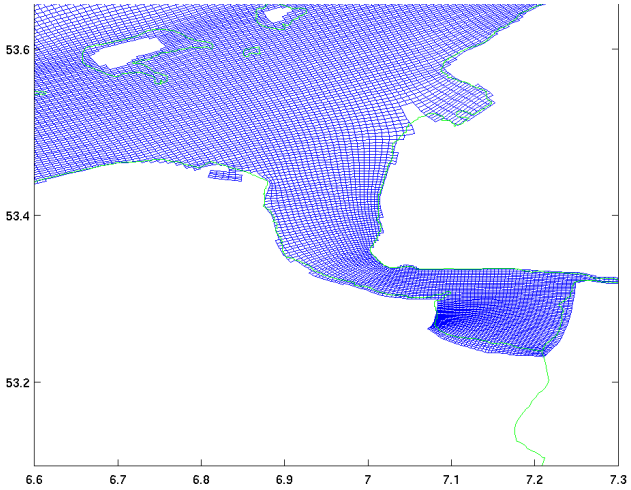
Water level model – DCSMv6 + ZUNOv4

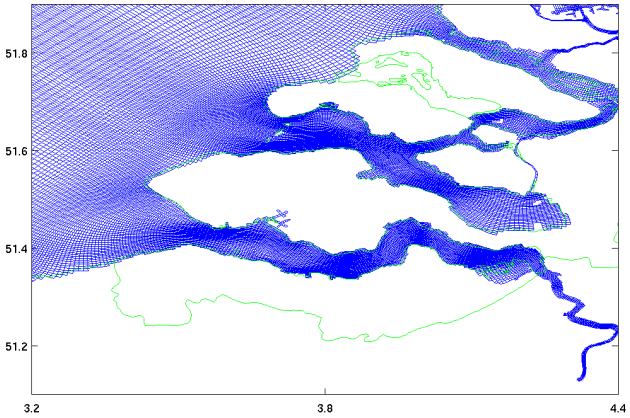


DCSMv6 local resolution





ZUNOv4 local resolution



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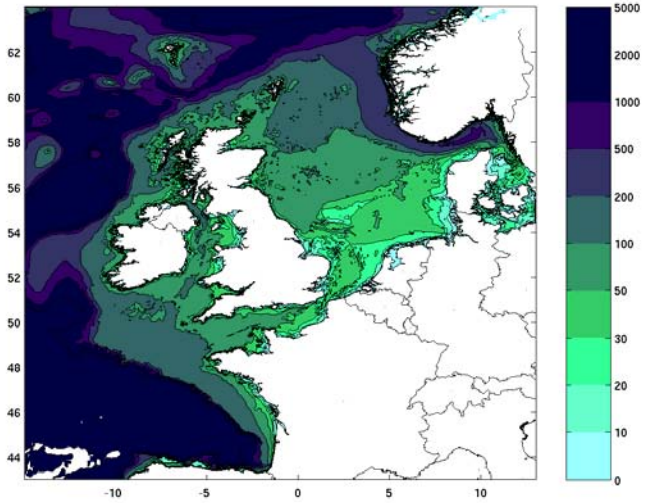
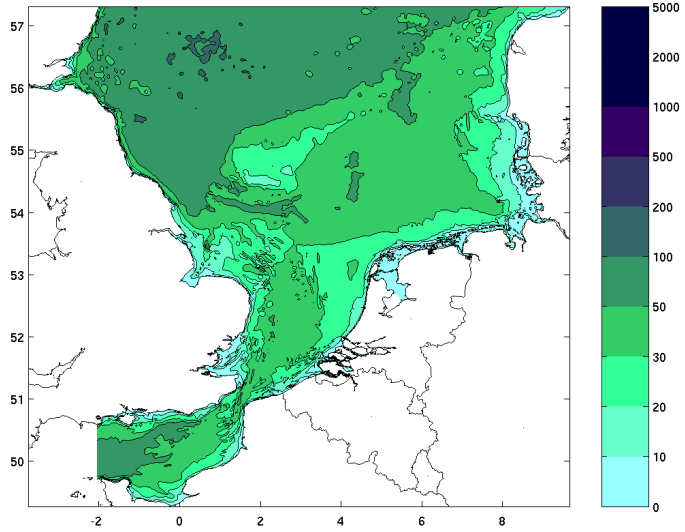
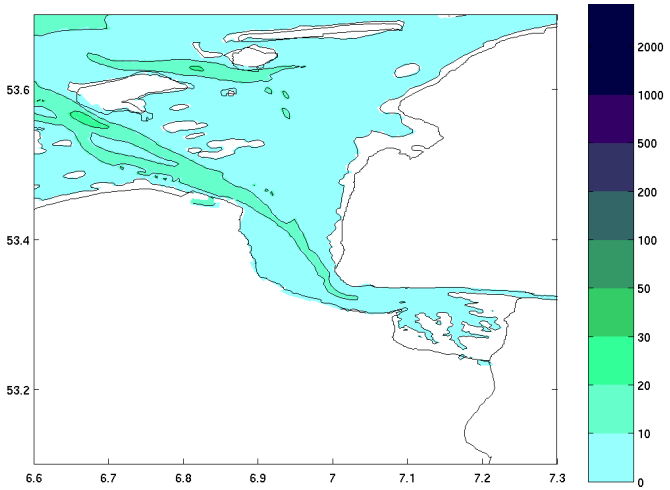
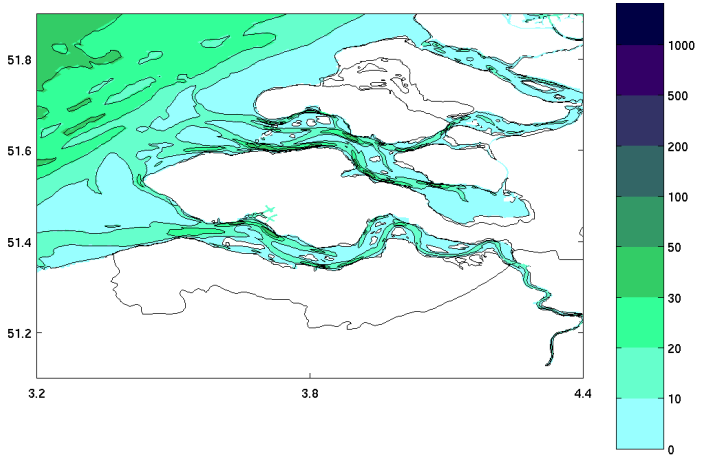
Bathymetry model – DCSMv6 + ZUNOv4









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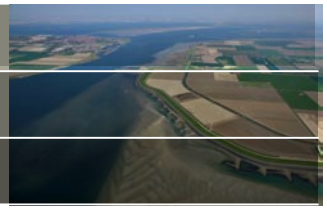
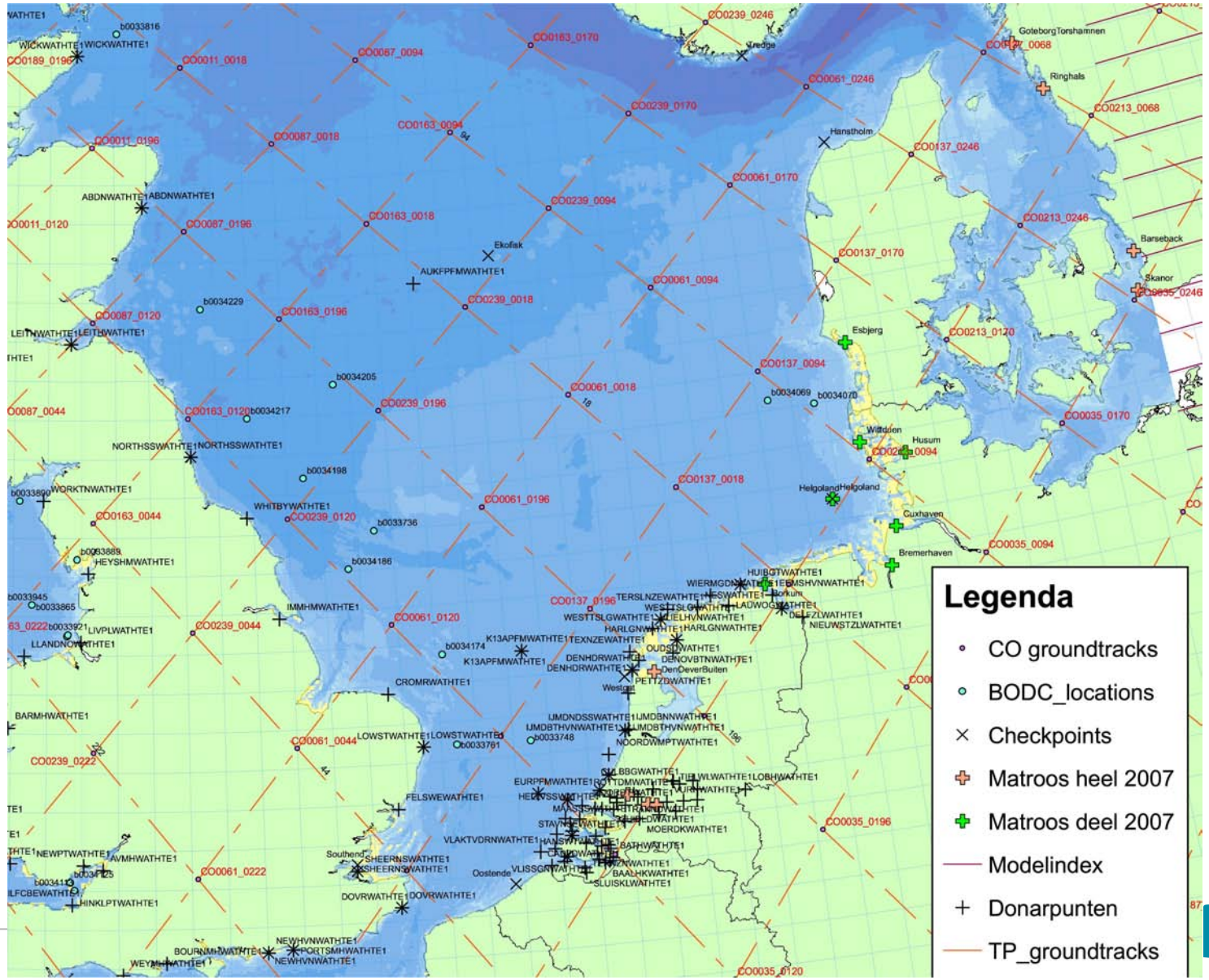
Calibration approach:



- On tidal water levels (year 2007):
  - NOOS exchange stations;
  - historic project data (e.g. Conslex-82);
  - T/P and Jason altimetry (Cross-overs)
- "Telescoping":
  - from overall response to detailed distribution
- Use of OpenDA portable data assimilation environment
- Optimisation techniques: DUD, Simplex, Powell
- Includes constraints and provides uncertainty bands
- BC's + sub-regional area-mean depths / bed friction
- Sub-region by subregion: from outer to inner
- Last: calibration of air-sea exchange parameterisation

North Sea part, stations and T/P – Jason tracks



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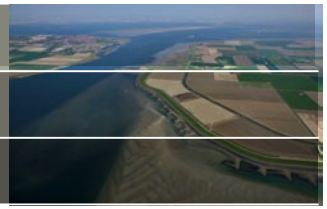
Calibration approach: OpenDA



- OpenDA : merging of DATools and COSTA developments
- Generic approach for “wrapping” process models with OpenDA
- OpenDA also features options for Uncertainty Analysis
- Coupling to other models (MIKE21, CARDINAL): straightforward
- Intended for wide user community of non-specialists:
  - sofar: 3 types of filters plus 3 calibration routines
  - more will be added (TUDelft and wider academia)
  - including features to offset often limited monitoring data
  - much attention to uncertainty prescription
  - much attention to postprocessing of results
  - detailed user documentation
- Calibration applications sofar: mainly in wave modelling (SWAN)
- Improvement of operational forecasts since 2006, e.g. in FEWS

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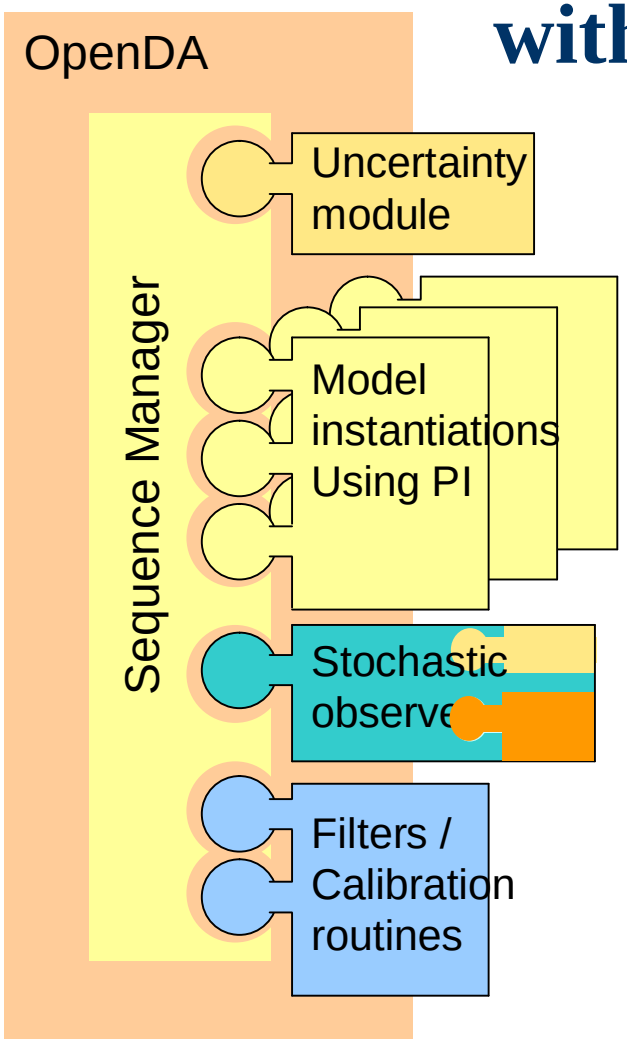
OpenDA data assimilation environment

Portable - generic coupling with process models



- DUE (Data Uncertainty Engine)
- DUE/WL (μ, σ)

- Sobek/CF, Sobek/RE (River flows)
- HBV, REW, HYMOD (Rainfall Runoff)
- *Delft3D-FLOW* *(3D flows)*
- SWAN, SIMONA (waves, 3D flows)

- PI Time Series
- Map Files
- OpenMI-wrapped state

- Particle Filter / SIR, …
- Ensemble Kalman Filter, RRSQRT
- DUD, Powell, Simplex

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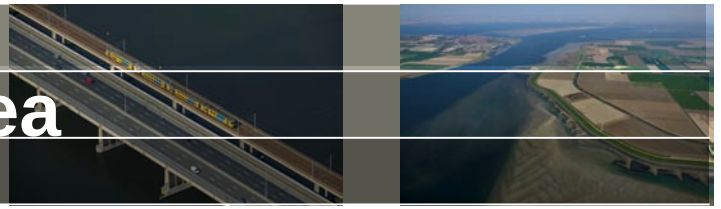
Wave model – SWAN_NorthSea



•During storms, waves strongly contribute to forces on the sea defence in terms of

- wave run-up, slamming and overtopping

•In shallow water, wave-driven currents strongly add to the tide and surge induced currents (and erosion, etc.)

→ Simulate SWAN deep water physics on the DCSMv5 grid (~9.3 km) (driven by boundary forcing from ECMWF model)

→ From ~20m contour: full non-linear SWAN physics on the ZUNOv4 grid

2D spectra provide $H_{ms}, T_{m-1,0}, \theta, H_{ms} * T_{m-1,0}$ and $\sqrt{H_{ms}} * T_{m-1,0}$

•Parameters of interest at toe: $H_{ms} * T_{m-1,0}$ (overtopping) and $\sqrt{H_{ms}} * T_{m-1,0}$ (damage due to wave attack/ forces/ slamming)

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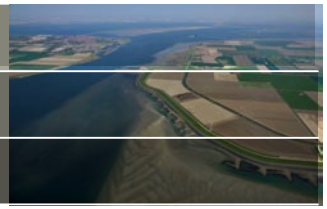
SWAN: 3rd generation wave model



Phase-averaging model that solves the spectral action balance equation, in Cartesian or spherical coordinates, without any *ad hoc* assumption on the shape of the wave spectrum.

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(c_x N\right)+\frac{\partial}{\partial y}\left(c_y N\right)+\frac{\partial}{\partial \sigma}\left(c_\sigma N\right)+\frac{\partial}{\partial \theta}\left(c_\theta N\right)=\frac{S_{tot}}{\sigma}$$

S_{tot} =wind input+
wave-wave non-linear interactions (quadruplets &/+triads)+
whitecapping + bottom friction+ depth induced wave breaking

Some of SWAN's source terms can be chosen from a couple of options.

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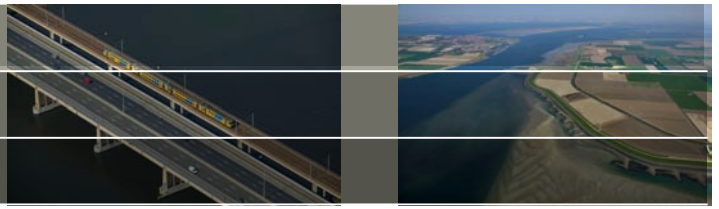
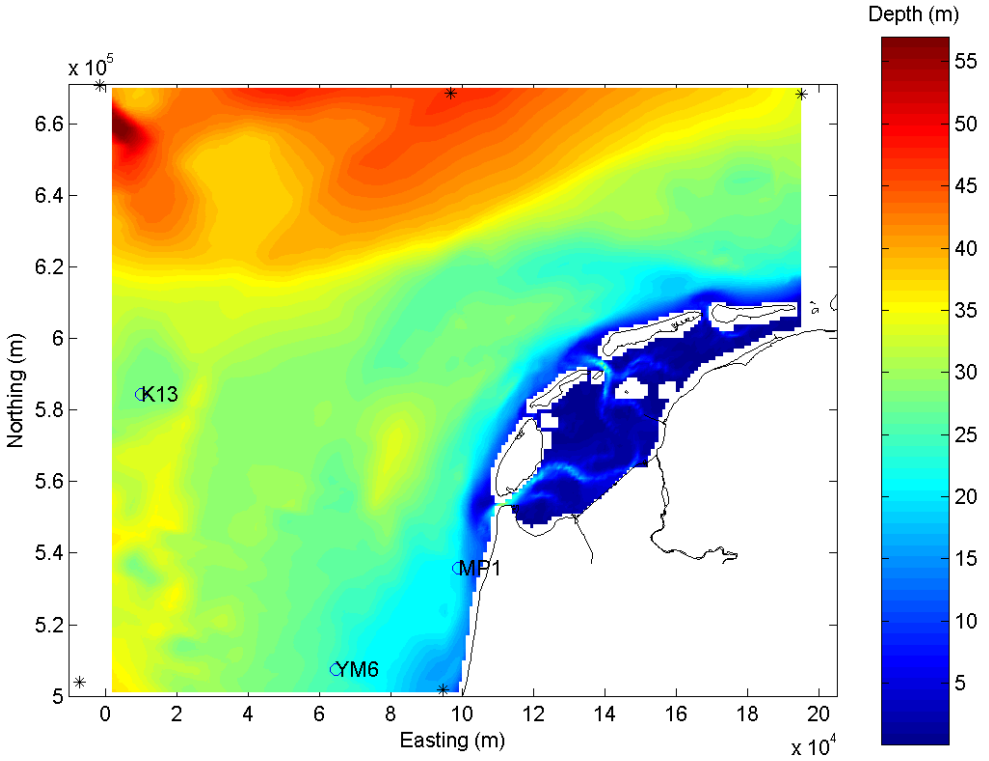
SWAN: test case North Sea



Test set-up
(here: steady state
SWAN approach):



- •directional resolution of 10 degrees
- •37 frequencies between 0.03 and 1 Hz.
- •BSBT numerical scheme with 5 min time step
- •Comparison with field data → presently limited data close to coast
- •Calibration (2009): → via OpenDA

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Time schedule of implementation / operation

- April 2009?: DCSM 2-domain calibration completed
- April 2009?: SWAN calibration completed
- July 2009?: Setup of operational environment:
  → time stepping of SWAN and DCSM in parallel
  → data exchanges through OpenDA
  (much re-use of interfacing software; modular set up)

- 15 September 2009?: pre-operational testing of new system in "shadow mode"
- 15 September 2010?: parallel operational use
- 15 September 2011?; acceptance test completed and discontinuation of DCSMv5

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