15th BIENNIAL CONFERENCE

Joint Numerical Sea Modelling Group

JONSMOD

Delft, The Netherlands

May 10-12, 2010

Venue: Deltares, Rotterdamseweg 185
Tel. (+31)-15-2858585

Programme

and

Book of Abstracts

Delft Canal with Old Church

Organizing Committee:

Prof. Phil Dyke (Plymouth, United Kingdom)
Dr. Alan Davies (Liverpool, United Kingdom)
Dr. Herman Gerritsen (Delft, The Netherlands)

Responsible local organizers:

Dr. Herman Gerritsen
Linda Stuur

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Eml: jonsmod2010@deltares.nl,

Delft, May 2010

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Venue: Deltares, Rotterdamseweg 185
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Scientific Programme

Monday sessions: Auditorium

Tuesday sessions: Auditorium and High Touch

Wednesday sessions: Auditorium

Day 1 - MONDAY 10 May PLENARY SESSIONS AUDITORIUM

08:00 Coach leaves Hampshire Hotel Delft Centre for Deltares
08:30 – 09.20 Registration (Coffee, tea available)
09.20 – 09.40 Welcome (Huib de Vriend, Director Science Deltares and Phil Dyke]

SESSION I – [CHAIR – Erik de Goede, Deltares]

09.40 – 10.00 Speaker 1-1 (Abstract page 1)
Modelling the effects of small scale topography and sub-grid-scale processes upon the larger scale circulation
Alan M Davies National Oceanography Centre, UK
10.00 – 10.20 Speaker 1-2 (Abstract page 2)
Numerical modelling of autumnal circulation over the bay of Biscay Shelf.
Franck Dumas IFREMER, France
10.20 – 10.40 Speaker 1-3 (Abstract page 3)
Influence of high resolution atmospheric forcing on the circulation of the Gulf of Lions (Mediterranean)
Amandine Schaeffer, LSEET, Toulon France.
10.40 – 11:00 Speaker 1-4 (Abstract page 4)
Hydrodynamic Simulations of the European Shelf Sea,
Adolf Stips, JRC, Italy

11.00 – 11.20 BREAK

11.20 – 11.40 Speaker 1-5 (Abstract page 5)
Eddy permitting model of the Gulf of Lion and the Catalan Shelf,
Pierre Garreau, IFREMER, France
11.40 – 12,00 Speaker 1-6 (Abstract page 6)
3-D spatial and temporal structure of temperature and salinity fields in the German Bight: comparison of numerical results with observation.
Johannes Schulz-Stellenfleth, GKKS, Germany
12:20 – 12:40 Speaker 1-7 (Abstract page 7)
The Use of Lagrangian Trajectories for Minimization of the Risk of Coastal Pollution.
Bert Vikmae, Tallinn U of Technology, Estonia
12:40 – 13:00 Speaker 1-8 (Abstract page 8)
Toward multi-scale modelling of the whole hydrosphere: concepts, applications and diagnoses.
Eric Deleersnijder, U Louvain, Belgium

13.00 – 14.20 LUNCH

Day 1 - MONDAY 10 May PLENARY SESSIONS AUDITORIUM
(continued)

SESSION II – [CHAIR – Phil Dyke, University of Plymouth]

14.20 – 14.40	Speaker 2-1 (Abstract page 9) Insights into the structure of the Wyville Thomson Ridge overflow. Vasyl Vlasenko, U Plymouth, UK
14.40 – 15.00	Speaker 2-2 (Abstract page 10) Impact of atmospheric forcing in operational ocean forecasting, Arne Melsom, MetNo, Oslo,, Norway
15.00 – 15.20	Speaker 2-3 (Abstract page 11) Tropical cyclones and associated meteorological tsunami affecting Atlantic Canada, Richard Greatbatch, IFM-Geomar, Germany.
15.20 – 15.40	Speaker 2-4 (Abstract page 12) Numerical Study of Three-Dimensional Circulation and Hydrography in Halifax Inlet Using a Nested-Grid Ocean Circulation Model, Shiliang Shan, Dalhousie U, Canada
15.40 – 16.00	BREAK
16:00 – 16.20	Speaker 2-5 (Abstract page 13) Numerical investigation of the Nordic water overflow in the Faroe-Shetland Channel. Nataliya Stashchuk, U Plymouth, UK
16.20 – 16.40	Speaker 2-6 (Abstract page 14) Comparative quantification of physically and numerically induced mixing in ocean models. Hans Burchard, IOW, Germany.
16.40 – 17.00	Speaker 2-7 (Abstract page 15) Estimation of the Internal Pressure gradient - The Finite Volume. Helene Hisken Pedersen, U Bergen, Norway
17.00 – 17.20	Speaker 2-8 (Abstract page 16) Development of an Operational flood forecasting model for the Firth of Clyde, Scotland Firmijn Zijl, Deltares, The Netherlands
17:30 – 19:00	**Icebreaker: drinks and warm and cold snacks (in/near Deltares Restaurant)**
19:00	Departure of coach from Deltares to Hampshire Hotel Delft Centre

Day 2 - TUESDAY 11 May PARALLEL SESSIONS AUDITORIUM

08:30 (!!!) Coach leaves Hampshire Hotel Delft Centre for Deltares

SESSION III – [CHAIR- Jarle Berntsen, University of Bergen]

09.00 – 09.20	Speaker 3-1 (Abstract page 17) OpenDA, a generic toolbox for data assimilation in numerical modelling Martin Verlaan, Deltares / TUDelft, The Netherlands
09.20 – 09:40	Speaker 3-2 (Abstract page 18) The use of the OpenDA SWAN Calibration Instrument for the Dutch Hydraulic Boundary Conditions. Caroline Gautier, Deltares, The Netherlands.
09.40 – 10.00	Speaker 3-3 (Abstract page 19) Parallel computing and model coupling for data assimilation. Nils van Velzen, VORtech, The Netherlands
10.00 – 10.20	Speaker 3-4 (Abstract page 20) Calibrating the Tidal Prediction of the South China Sea model. Pavlo Zemskyy, NUS / SDWA, Singapore.
10.20 – 10.40	Speaker 3-5 (Abstract page 21) Parameter estimation in a large scale Dutch Continental Shelf Model. Umer Altaf, TUDelft, The Netherlands
10:40 – 11.00	BREAK
11.00 – 11:20	Speaker 3-6 (Abstract page 22) Surge sensitivity to physical parameters through forward and adjoint modelling with MITgcm. Chris Wilson, National Oceanography Centre, UK
11.20 – 11.40	Speaker 3-7 (Abstract page 23) Preparing remotely sensed SPM for data assimilation: Optics, accuracies, and implications for transport models. Marieke Eleveld, IVM, The Netherlands.
11.40 – 12,00	Speaker 3-8 (Abstract page 24) Assimilation of Remote Sensing data in a 3D Suspended Matter Transport Model of the Dutch Coastal Zone. Ghada H El Serafy, Deltares, The Netherlands.
12:20 – 12:40	Speaker 3-9 (Abstract page 35) Improvement of state estimates and numerical model predictions of the German Bight through the assimilation of Ferrybox Data, Joanna Staneva, U Oldenburg, Germany
12-40 – 13.00	Speaker 3-10 (Abstract page 26) Investigating the appearance of SPM in the Rhine river plume on Ocean Color imagery with an idealized numerical model. Gerben J de Boer, Deltares, The Netherlands.
13.00 – 14:20	LUNCH

Day 2 - TUESDAY 11 May PARALLEL SESSIONS AUDITORIUM
(continued)

SESSION IV – [CHAIR - Hans Burchard, Institute for Baltic Sea Research]

14.20 – 14.40	Speaker 4-1 (Abstract page 28) An unstructured shallow flow solver for the North Sea' Herman Kernkamp, Deltares The Netherlands.
14.40 – 15.00	Speaker 4-2 (Abstract page 29) Applications of an unstructured grid model to tidal and tsunami modelling. Julie Pietrzak, TUDelft, The Netherlands
15.00 – 15.20	Speaker 4-3 (Abstract page 30) Modelling the interaction of tides and storm induced currents in shallow water using an unstructured gid finite volume method (FVCOM), Jiuxing Xing, National Oceanography Centre, UK.
15.20 – 15.40	Speaker 4-4 (Abstract page 31) Obtaining spectral consistency among radar altimetric data and the geoid; a prerequisite for data assimilation. Cornelis Slobbe, TUDelft, The Netherlands.
15.40 – 16.00	BREAK
16:00 – 16.20	Speaker 4-5 (Abstract page 32) Model parameters adjustment using an EnKF in a 1-D numerical model of the North Sea CS station. Stephanie Ponsar, MUMM Belgium.
16.20 – 16.40	Speaker 4-6 (Abstract page 33) Model-reduced 4D-Var data assimilation in the phytoplankton bloom prediction in the North Sea' Joanna S Pelc, TUDelft, The Netherlands.
16.40 – 17.00	Speaker 4-7 (Abstract page 34) Estimation of tidal boundary conditions and surface winds by assimilation of high-frequency radar surface currents in the German Bight. Alexander Barth, U Liège, Belgium
17.00 – 17.20	Speaker 4-8 (Abstract page 35) Ensemble prediction of waves and surge for storm conditions, Shunqi Pan, U Plymouth, UK
17:45	Departure of coach from Deltares to Hampshire Hotel Delft Centre
19:00	**Conference dinner** Restaurant De Prinsenkelder, Schoolstraat 11, Delft Distance from hotel: 1.1. km (easy walking distance; see map))

Day 2 - TUESDAY 11 May PARALLEL SESSIONS HIGH TOUCH

<u>08:30 (!!!)</u> Coach leaves Hampshire Hotel Delft Centre for Deltares

SESSION V – [CHAIR- Alan Davies, Proudman Oceanographic Laboratory]

09.00 – 09.20	Speaker 5-1 (Abstract page 37) A convergence study of flow over a backward-facing step using a sigma-coordinate model and a z-coordinate model. Kristin Rygg, U Bergen, Norway
09.20 – 09:40	Speaker 5-2 (Abstract page 38) TVD schemes for shallow seas Christophe Mercier, U. Liège, Belgium
09.40 – 10.00	Speaker 5-3 (Abstract page 39) Development of a finite-element, multi-scale model of the Mahakam delta (Indonesia): Preliminary results. Tuomas Karna, U Louvain, Belgium
10.00 – 10.20	Speaker 5-4 (Abstract page 40) An alternative approach for nonhydrostatic modelling. Knut Klingbeil, IOW, Germany
10.20 – 10.40	Speaker 5-5 (Abstract page 41) Assessing the Far Field Effects of Tidal Power Extraction on the Bay of Fundy using a Nested-Grid Model. Jinyu Sheng, Dalhousie U, Canada
10:40 – 11.00	BREAK
11.00 – 11:20	Speaker 5-6 (Abstract page 42) Modelling near seabed velocities. Oyvind Thiem, U Bergen, Norway
11.20 – 11.40	Speaker 5-7 (Abstract page 43) Investigation of the spreading and dilution of domestic waste water inputs into a tidal bay using the finitevolume model FVCOM. Karsten Lettmann, U Oldenburg, Germany
11.40 – 12,00	Speaker 5-8 (Abstract page 44) Absorbing layers for shallow water models. Axel Modave, U Liège, Belgium.
12:20 – 12:40	Speaker 5-9 (Abstract page 45) Numerical modeling of near bottom currents and food particle transport for cold water reef structures. Tomas Torsvik, U. Bergen, Norway
12-40 – 13.00	Speaker 5-10 (Abstract page 46) Impact of wind gusts on sea surface height in storm surge modelling. Rikke van der Grinten, KNMI, The Netherlands
13.00 – 14:20	LUNCH

Day 2 - TUESDAY 11 May PARALLEL SESSIONS HIGH TOUCH
(continued)

SESSION VI – [CHAIR Herman Gerritsen, Deltares]

14.20 – 14.40	Speaker 6-1 (Abstract page 47) Impact of spatially varying bottom friction coefficient on tidal propagation in the Pertuis Charentais, Bay of Biscay (France). Julien Chalumeau, U La Rochelle, France
14.40 – 15.00	Speaker 6-2 (Abstract page 48) Numerical Studies of Small Scale Eddies behind Headlands in Tidal Inlets. Jarle Berntsen, U Bergen, Norway.
15.00 – 15.20	Speaker 6-3 (Abstract page 49) Tracking of sediment particles in a tide dominated area. Ulf Graewe, IOW Germany
15.20 – 15.40	Speaker 6-4 (Abstract page 50) Numerical studies of dispersion due to tidal flow through Moskstraumen, northern Norway. Birgit Kjoss-Lynge, Bergen Norway
15.40 – 16.00	BREAK
16:00 – 16.20	Speaker 6-5 (Abstract page 51) Dynamical Coupling of a Spectral Wave Model and a 3D Hydrodynamic Model in Highly Variable Tidal Environment. Saeed Moghimi, IOW, Germany
16.20 – 16.40	Speaker 6-6 (Abstract page 53) Modelling wave-tide interactions at a wave-farm in southwest England, Raul Gonzalez, U Plymouth, UK
16.40 – 17.00	Speaker 6-7 (Abstract page 55) Spectral Wave Modelling in Tidal Inlet Seas; Results from the SBW Project. Ap van Dongeren, Deltares, The Netherlands
17.00 – 17.20	Speaker 6-8 (Abstract page 57) Modelling storm surges in the Irish and Celtic Seas using a finite element model (TELEMAC). John Maskell, National Oceanography Centre, UK
17:45	Departure of coach from Deltares to Hampshire Hotel Delft Centre
19:00	**Conference dinner**
	Restaurant De Prinsenkelder, Schoolstraat 11, Delft Distance from hotel: 1.1. km (easy walking distance; see map))

Day 3 - WEDNESDAY 12 May PLENARY SESSIONS AUDITORIUM

08:30 (!!!) Coach leaves Hampshire Hotel Delft Centre for Deltares

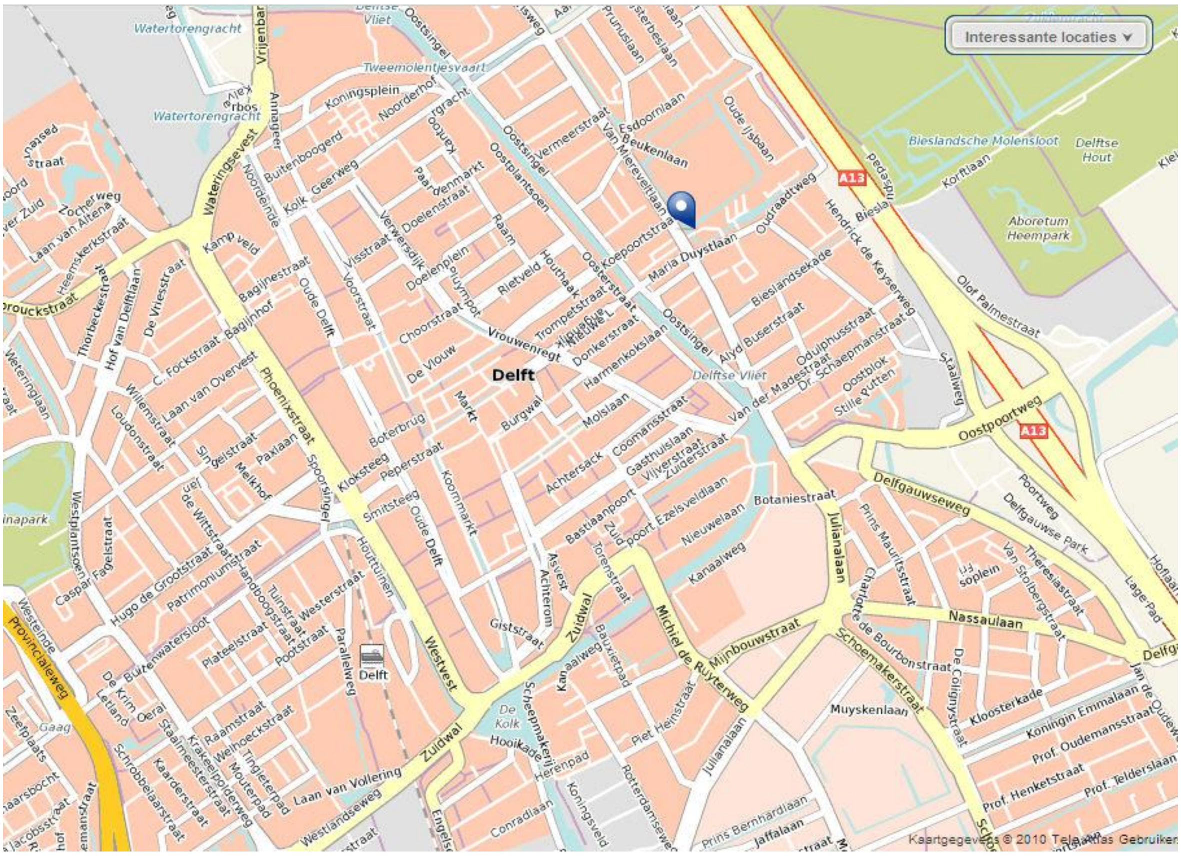
SESSION VII – [CHAIR: Eric Deleersnijder, University of Louvain-la-Neuve]

09.00 – 09.20	Speaker 7-1 (Abstract page 58) Improving Wave Boundary Conditions for a Nearshore Delft3D Forecasting System Jay Veeramony, Naval Research Laboratory, USA
09.20 – 09:40	Speaker 7-2 (Abstract page 59) Decadal long simulations of mesoscale structures in the northern North Sea/Skagerrak using two ocean models Jon Albretsen and Lars-Petter Roed, Met.No, Norway
09.40 – 10.00	Speaker 7-3 (Abstract page 60) Towards a Complete Study of Water Renewal Timescales in the Scheldt Estuary. Benjamin de Brye, U Louvain, Belgium
10.00 – 10.20	Speaker 7-4 (Abstract page 61) Influence of high resolution wind forcing on circulation in a fjord system. Mari Myksvoll, IMR, Norway
10.20 – 10.40	Speaker 7-5 (Abstract page 62) Forcing of mean flow and turbulence by waves in homogeneous zone of Iroise Sea. Guillaume Simon, IFREMER, France
10:40 – 11.00	BREAK
11.00 – 11:20	Speaker 7-6 (Abstract page 64) Effects of Tide Flats on Estuarine Circulation and Plume Dynamics. Zhaoqing Yang, PNNL, USA
11.20 – 11.40	Speaker 7-7 (Abstract page --) *(title: withdrawn; open slot)* *(speaker: withdrawn; open slot)*
11.40 – 12,00	Speaker 7-8 (Abstract page 65) A CO_2 uptake model for the Barents Sea. Marius Arthun, U Bergen, Norway
12:20 – 12:40	Speaker 7-9 (Abstract page 66) Assessment of an oxygen prognosis model for the North Sea - Baltic Sea transition zone. Lars Jonasson, DMI – U Copenhagen, Denmark
12-40 – 13.00	Speaker 7-10 (Abstract page 67) The impact on European shelf tides of future sea level rise Mark Pickering, U Southampton, UK / Deltares, Delft
13.00 – 14:20	LUNCH

Day 3 - WEDNESDAY 12 May PLENARY SESSIONS AUDITORIUM
(continued)

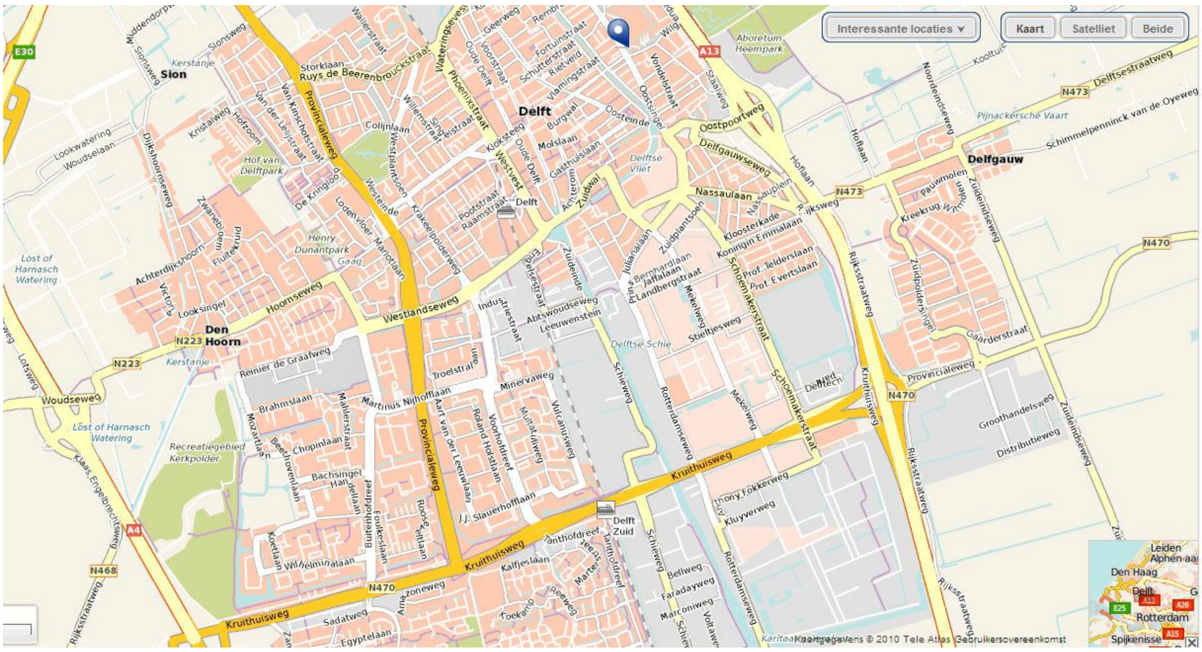
SESSION VIII – [CHAIR: Pierre Garreau, IFREMER]

14.20 – 14.40	Speaker 8-1 (Abstract page 69) Implementation of an operational model to simulate pollutant transfers in the Toulon area, south of France. S. Coudray, IFREMER and Celine Duffa, IRSN, France
14.40 – 15.00	Speaker 8-2 (Abstract page 71) Numerical modelling of organic waste dispersion from a marine fish farm. Alfatih Ali, U Bergen Norway
15.00 – 15.20	Speaker 8-3 (Abstract page 72) Effects of transboundary nutrient transport and riverine nutrient loading from a phytoplankton transport model of the North Sea. Hans Los, Deltares, The Netherlands
15.20 – 15.40	Speaker 8-4 (Abstract page 73) Does turbulence help sinking phytoplankton species to survive? Eric Delhez,U Liège, Belgium
15.40 – 16.00	BREAK
16:00 – 16.20	Speaker 8-5 (Abstract page 74) Water and ecological quality in the Aljezur coastal stream (Portugal). Marta Gomes Rodrigues, Portugal
16.20 – 16.40	Speaker 8-6 (Abstract page 75) Modelled variability of primary and secondary production in the North Sea. Sturla Svendsen, U Bergen Norway
16.40 – 17.00	Speaker 8-7 (Abstract page 76) Comparing the impacts of different atmospheric forcings on the performance of a coupled bio-physical model: A case study for the North and Baltic Sea ecosystem. Ute Daewel, U Bergen, Norway
17.00 – 17.20	Speaker 8-8 (Abstract page 77) A sea drag relation for hurricane wind speeds. Niels Zweers, KNMI, The Netherlands
17.20 – 17.40	Closing remarks – Phil Dyke
17:45	**End of JONSMOD2010**



Map of central part of Delft with locations of:

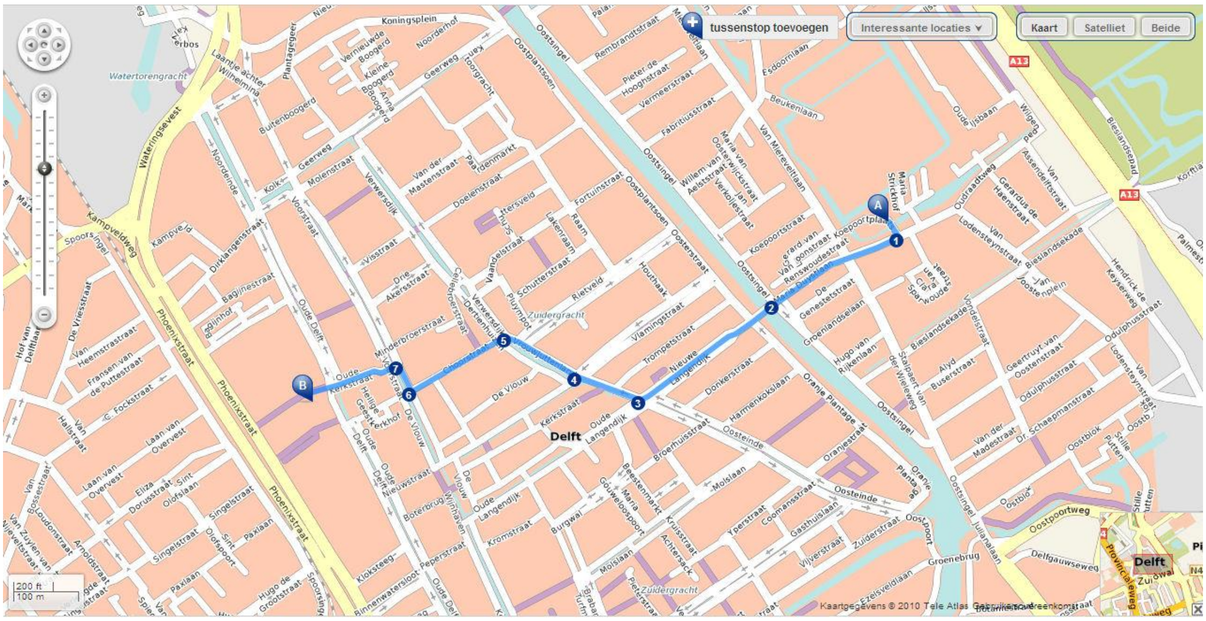
- **Railway Station (note ongoing construction around the railway station)**
- **Hampshire Hotal Delft Centre (arrow); Koepoortplaats 3)**
- **Market square (central on the map; near indication "Delft")**



Map of Delft with location of Hotel, Railway Station and Deltares.

Deltares is the grey block along Rotterdamseweg, between Kluyverweg and Karitaatweg, at the very bottom of the map, featuring canals and ponds
Address: Rotterdamseweg 185; switchboard: +31-15-2858585

See: www.deltares.nl, and attached "DirectionsToDeltares_Roterdamseweg185.pdf"



Map for walking from hotel to restaurant

Restaurant De Prinsenkelder, Schoolstraat 11, Delft
Distance from hotel: 1.1. km

Modelling the effects of small scale topography and sub-grid-scale processes upon the larger scale circulation.

Alan M. Davies, Eric Jones and Jiuxing Xing

National Oceanography Centre
(former: Proudman Oceanographic Laboratory)
6 Brownlow Street, Liverpool L3 5DA, U.K.

Corresponding author, e-mail amd@pol.ac.uk

The problem of resolving or parameterising small scale processes in oceanographic models, and the extent to which small scale effects influence the large scale is briefly discussed . For tides and surges in near shore regions, the advantages of using a graded mesh to resolve coastal and estuarine small scale features is demonstrated in terms of a west coast of Britain unstructured mesh model. The effect of mesh resolution upon the accuracy of the overall solution is illustrated in terms of a finite element model of the Irish Sea and Mersey estuary. For baroclinic motion at high Froude number, the effect of resolving small scale topography within a non-hydrostatic model is illustrated in terms of tidally induced mixing at a single sill, or two closely spaced sills. The question of how to parameterise small scale non-linear interaction processes that lead to significant mixing, in a form suitable for coarser grid hydrostatic models is briefly considered. In addition the importance of topographically induced mixing that occurs in the oceanic lateral boundary layer, namely the shelf edge, upon the large scale ocean circulation is discussed . The use of unstructured grids in these models to enhance resolution in shelf edge regions in a similar manner to that used in storm surge models to enhance near coastal resolution is suggested as a suitable "way forward" in large scale ocean circulation modelling.

Numerical modelling of autumnal circulation over the bay of Biscay Shelf.

F. Dumas and P. Lazure

Ifremer centre de Brest, BP 70, 29280 Plouzané, France

Corresponding author, e-mail fdumas@ifremer.fr

An intense autumnal circulation over the bay of Biscay shelf was highlighted by Lazure et al (2008). Their analysis based on many drifters tracks shows it approximately follows the 100m isobath and its mean velocity magnitude reaches 10 cm/s. SST satellite data show a large warm tongue expending from the south to the north that is strongly correlated with this autumnal current (fig 1).
Both SST pictures and drifters tracks show that this current is likely to have a strong interannual variability. On certain years, the intensification of the circulation even seems to not occur at all.

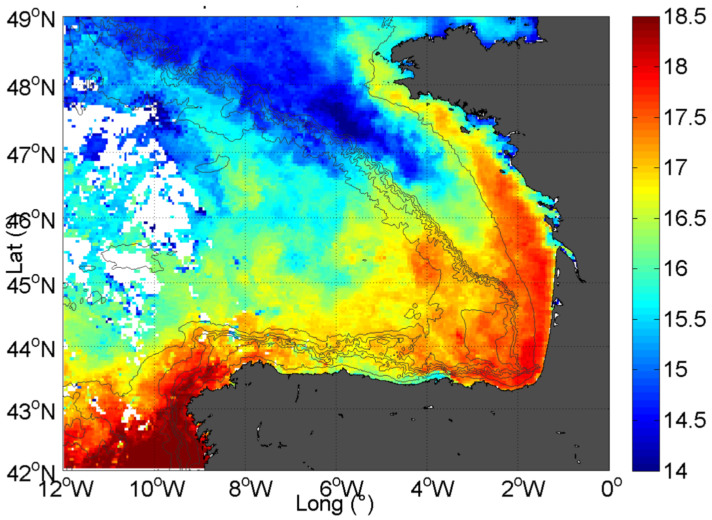


Figure 1 SST scene from MODIS on November 2006, 1st

The authors showed (Lazure et al 2008) that neither the tidal residual currents nor the wind induced circulation can explain this circulation. They pointed out that the bottom front appearing late September (i.e during the fall destratification) is likely to play a major role in driving this current.

The roles of the various mechanisms and their interplay are investigated here thanks to numerical modelling. First, a 2DV assumption is used to identify which of the numerous forcings have a determining impact on the current intensity and its location (slope, initial hydrological structure, tide, wind, thermal fluxes). The numerical parameters and physical parameterisations (resolution, bottom friction, dissipation etc.) are also examined in order to better set up the realistic 3D model of the whole bay of Biscay.

The interannual variability of the autumnal destratification is tackled with the 3D model (MARS, Lazure et Dumas 2008) from 1999 to 2007. Budgets (mass, temperature) at the scale of the whole shelf are performed computed in order to quantify the exchanges between the shelf and the open ocean at this period of the year.

Influence of high resolution atmospheric forcing on the circulation of the Gulf of Lions (Mediterraneen Sea).

A. Schaeffer[(1)], P. Garreau[(2)], A. Molcard[(1)], P. Fraunié[(1)], Y. Seity[(3)], J. Poitevin[(3)]

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(2) Ifremer BP 70 - Technopôle Brest-Iroise 29280 - Plouzané - France
(3) CNRM-GAME, URA1357, CNRS-Météo-France, 42, Avenue G. Coriolis 31057 Toulouse Cedex, France

Corresponding author, e-mail Amandine.Schaeffer@lseet.univ-tln.fr

Atmospheric forcing has been shown to play a major role on hydrodynamic modelling in the western Mediterranean microtidal Sea, in particular wind gusts and curls. New operational forecasting model AROME developed by Méteo France is analysed as atmospheric forcing of the coastal zone in comparison with two other datasets. Its higher spatial and temporal resolution (2.5km and 1 hour respectively compared to 10km and 3h) permits to resolve more precisely small scale structures and diurnal cycles. The impact on the oceanic circulation in the Gulf of Lions is shown to be non negligible on the surface dynamics variability including inertial motion, the mixed layer, internal waves and the upwelling systems.

Acknowledgements:
GIRAC project and Region PACA.

Hydrodynamic simulations of the European Shelf Sea

Adolf Stips*, Elisa Garcia-Gorriz, Svetla Miladinova, Rodrigo Perez

European Commission – DG Joint Research Centre,
Institute for Environment and Sustainability, Global Environment Monitoring Unit,
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We wanted to test the quality of multi-annual simulations of the European Shelf Sea when using a shallow water model. Therefore the European larger Shelf Sea including the North Sea, Irish Sea, Gulf of Biscay and large parts of the Mediterranean Sea was simulated using the 3D hydrodynamical model GETM (General Estuarine Transport Model see http://getm.eu). The turbulence model included is the GOTM model (General Ocean Turbulence Model see http://www.gotm.net). Typical runs were covering the time period from 1985 to 2008, but the period of main interest was from 1998 to 2008. The model was run on spherical grids with different horizontal resolutions the results presented here are from a medium fine resolution setup of 5'x5' (1/12 degree). The area covered extends roughly from 20° West to 10° East and from 30° North to 61° North.
General vertical coordinates using 25 layers were applied. The meteorological forcing was derived from bulk formulae using six-hourly values on a grid from ECMWF interim re-analysis data. Initial and open boundary conditions were derived from the World Ocean Atlas (WOA2005) data. Climatological river runoff from the major rivers in the region of interest is considered in the simulations. The tidal forcing at the open boundaries towards the Atlantic Ocean was constructed from 13 partial tides from the TOPEX-POSEIDON data set. Observed Sea Surface Temperature (SST) data were taken from the NOAA/NASA Ocean Pathfinder satellite, see http://podaac.jpl.nasa.gov/sst.
Results are still preliminary, but it was possible to reproduce the basic circulation patters in the European Shelf Sea in sufficient detail. The prescribed conditions at the open boundaries are very critical for the quality of the simulations.

Eddy permitting model of the Gulf of Lion and the Catalan shelf

Pierre Garreau

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Situated in the North Western Mediterranean Basin, the Gulf of Lions (GOL) and the Catalan Shelf (CS) are two shallow water areas (average depth is 100 m) separated by a very narrow shelf, cut by canyons, off Cap Creus at the border between France and Spain. The aim of the talk is the description of the exchange of water between the both areas using a realistic numerical modelling, in situ measurement (drifting buoys) and remote sensing data (Sea Surface Temperature , chlorophyl, altimetry). Recent progress in numerical operator allows a less viscous representation of the dynamics and realistic eddies are now simulated. The dynamic of the inner shelf exhibits some coastal jets generating eddies behind capes and a thermal front during summer due to the shadowing effect of the Pyrenean Mountains on the wind. Along the shelf break, the North Current or « Liguro-Provençal-Catalan » current flows Southwestward delimiting the open ocean dynamics from the coastal one. This density, slope controlled, current exhibits some instabilities and may also generate onshore anticyclonic eddies (radius in the range of 20 km) that appear often in remote sensing images and are sometimes catch by in-situ data. Despite this dominant Southwestward transportation both numerical modelling and drifting buoys reveal a thin coastal current flowing from the Catalan Sea towards the Gulf Of Lion. Numerical modelling is used to describe the seasonal variability of the dynamics in this zone, to estimate the flux of water and to understand the physics of processes (eddies generations, flux of buoyancy, thermal front generation and local wind effect).

3D-Spatial and temporal structure of temperature and salinity fields in the German Bight: Comparison of numerical model results with observations

Johannes Schulz-Stellenfleth, Joanna Staneva, Sebastian Grayek, Rolf Riethmüller, Emil Stanev

GKSS Research Centre, Institute of Remote Sensing, D-21502 Geesthacht, Germany

Corresponding author, e-mail Schulz-Stellenfleth@gkss.de

Integrated ocean observing systems closely link in-situ and and remote measurements with numerical models enabling the reconstruction and forecast of key state variables with full spatial coverage. One aspect in the set-up of the German COSYNA ("Coastal Observing System for Northern and Arctic Seas") project is to investigate the optimal space-time structure of the observations, their quality, assimilation schemes and numerical model forecast capabilities for the observation area. In its present stage COSYNA focuses on the German Bight including the Wadden Sea and the estuaries of the large rivers. In this study we are presenting first investigations on baroclinic processes in the German Bight. The study is of interest in a wider context, because it gives an idea about the potential of profile measurements in the German Bight in general. This is an important step for the planning of future operational forecast systems, where profile information could be one of the key factors.

The main observational basis was provided by horizontal-vertical transects of the water column on a 20 nautical miles grid within the German Bight. Three surveys were carried out in May, July and September 2009 with “RV Heincke” using a towed undulating vehicle system (“Scanfish” by Eiva Co.). Each survey lasted about a week and yielded cross sections of various parameters like, e.g., temperature and salinity of the German part of the North Sea and give a unique insight into baroclinic processes in this shelf region. Measurements taken at the offshore platform FINO-1 50 km north of the island of Borkum provided the temporal evolution of temperature and salinity profiles at one location.

The three-dimensional primitive equation model GETM (“General Estuarine Transport Model”) is used to hindcast salinity and temperature fields. The model is setup for the German Bight with 1 km horizontal resolution and 21 sigma layers. The open boundary values are taken from the coarser one-way nested North Sea-Baltic Sea model. Data from the German Weather Service (DWD) are used for the metereological forcing.

Three dimensional plots comparing measurements with respective transects through the numerical model are presented. Differences in the stratification between model and measurements are of particular interest, because they give hints concerning possible shortcomings of the model with respect to vertical mixing processes. Temperature-salinity plots of both the model and the measurements are used to identify different water masses and to investigate the stability of the water column for different areas. The evolution of salinity and temperature fields in the period before the observations allows to study the history and origin of the different water masses. The analysis also helps to explain observed differences between model and measurements in particular with respect to mixing and advection processes.

Finally first steps towards the assimilation of the data are taken. Model simulations are analysed using the Scanfish data. The model is then restarted with the analysis and propagated with the metereological and open boundary forcing as before. The assimilation run is compared to the free run in order to study the potential impact of the observations. Of particular interest is the question how long the information from the measurement has an influence on the forecast.

The Use of Lagrangian Trajectories for Minimization of the Risk of Coastal Pollution

Bert Viikmäe, Tarmo Soomere, Nicole Delpeche

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We propose a novel way of utilising the results of circulation modelling for identification of areas of high and low risk for the marine environment. The basic idea takes into consideration statistical properties of large pools of Lagrangian trajectories computed off-line from numerically simulated current fields. As a particular application, we describe first steps made towards creating a technology for identifying such areas for fairway design in the Gulf of Finland.

The basic tool for the analysis of current-driven propagation of adverse impacts (e.g. oil pollution) is a Lagrangian trajectory model, TRACMASS (Döös K. 1995. Inter-ocean exchange of water masses. J. Geophys. Res., 100, C7, 13499–13514) with the use of three-dimensional current velocity fields calculated by the Rossby Centre global circulation model (Regional Ocean model, RCO) with a resolution of 2×2 nautical miles. Trajectories of current-driven pollution are simulated for a few weeks and the simulations for each sea point are repeated over several years.

A central question for narrow basins is how to minimize the joint probability of hitting of either of the coasts. The first order solution is the equiprobability line, the probability of propagation of pollution from which to either of the coasts is equal. This line and/or areas showing the probability of propagation of pollution to the coastal area indicate a safe fairway.

We propose two methods for numerical estimation of the location of the equiprobability line.

The first method consists of the analysis of five trajectories starting from each grid cell. A count is made on if at least 50% of the trajectories travelled to either southern or northern coast. If yes, the cell is marked as being a probable source of pollution for the particular coastal section. If not, the cell is marked as a part of an undefined area, propagation of pollution from which to any of the coasts is unlikely. The separation line for probable sources of pollution to different coasts is interpreted as the estimate of the location of the equiprobability line.

Another method for specification of this line implicitly involves a smoothing process and consists of dividing the sea area into clusters of 3×3 grid cells. By tracing nine trajectories in each cluster (one from each cell) it is established whether the majority of the trajectories end up at one of the coasts or stays in the open sea area.

The equiprobability line was found to be substantially shifted northwards from the axis of the Gulf of Finland. In the western part of the gulf there is a well-defined probability gradient across the gulf, but in the eastern part there is a large area of low risk with respect to pollution affecting the coastal areas. The purpose and meaning of this area is then determined.

Toward multi-scale modelling of the whole hydrosphere: concepts, applications and diagnoses

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The processes taking place in the hydrosphere (sea ice[1], oceans, shelf seas, estuaries, rivers, etc.) are characterised by a wide range of space- and time-scales. Though it is not possible to explicitly simulate all of them, it is our conviction that widening the range of resolved processes, as opposed to parameterised or ignored, will prove fruitful in the long run. To do so, new models are needed that are capable of enhancing the resolution when and where necessary and of representing a large number of physical, chemical and biological processes. Such models are being developed by various teams over the world, one of them being based in Louvain-la-Neuve, Belgium. Their model (SLIM[2]) solves the governing equations by means of the finite-element method on 2D or 3D unstructured meshes. The current status of SLIM will be briefly presented, as well as the developments planned in the future. Some applications will be reported, in particular those pertaining to the land-sea continuum of the Scheldt River[3] (France, Belgium, The Netherlands). Finally, diagnoses of numerical results having recourse to the CART tool box[4] will be discussed.

[1] Although sea ice is usually considered to be a component of the cryosphere, here we place it in the hydrosphere for the sake of convenience.
[2] SLIM = Second-generation Louvain-la-Neuve Ice-ocean Model (www.climate.be/slim)
[3] See www.climate.be/timothy
[4] CART = Constituent-oriented Age and Residence time Theory (www.climate.be/cart)

Insights into the structure of the Wyville Thomson Ridge overflow current from a fine-scale numerical model

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One of the major pathways in the northern part of the Meridional Overturning Circulation (MOC) is that of the deep water in the Nordic Seas that runs through the Faroe-Shetland Channel (FSC) and Faroe Bank Channel (FBC), as well as crossing the Wyville Thomson Ridge (WTR), on its way into the Atlantic Ocean. The WTR overflow cascades down the southern side of the ridge via the narrow Ellett Gully to the Cirolana Deep (CD) which, at 1700 m, is the deepest hole in the extreme north of the Rockall Trough. It accounts for nearly 1/10th of the total Faroe-Shetland Channel Bottom Water (FSCBW) discharged through the Faroese channels and, being about 40\% of the size of the Mediterranean outflow, is an important intermediate water mass in the Rockall Trough.

Over a period of only seven days in April 2003 bottom water temperatures cooled dramatically, from 4.46^{o}C to 3.03^{o}C in the CD and from 3.93^{o}C to 2.54 ^{o}C in the YT. A numerical general circulation model (MITgcm) has been applied to investigate this outflow event. The model revealed the pathway of cold and dense water from the WTR to the CD, and temperature, salinity, and velocity profiles, along with total water transport, were compared to those derived from CTD surveys. The three-dimensional simulations resulted in a fairly good agreement between the observed and modelled cooling.

The most significant results of the numerical experiments were obtained when a passive tracer was included in the model. Analysis of the tracer evolution shows that the mixing process in the modelled downstream gully gravity current is characterized by an explosive detrainment regime. In addition, a complex bottom topography led to the formation in the CD of a pair of eddies with cyclonic and anticyclonic vorticity. A sensitivity analysis revealed that the final depth to which the overflow descends is sensitive to the initial upstream velocity of the overflow, as well as the buoyancy difference. It is argued that models of overflows need to have realistic representations of the density structure of the overflow, and sufficiently fine vertical resolution, for the subsequent fate of the overflow to be accurately represented.

Impact of atmospheric forcing in operational ocean forecasting

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In MyOcean's Arctic Monitoring and Forecasting Centre, an assimilative ocean modelling system is used to produce daily forecasts for sea ice and ocean circulation properties. The assimilation is conducted in a one-week cycle, whereas atmospheric forcing from ECMWF's operational product is updated daily. The forecast range is 10 days, and the weekly updated assimilation is performed for sea ice concentration, sea ice drift (during winter), SST, sea level anomalies and T,S profiles from Argo probes. We present a validation of ocean forecasting results from two sets of ocean circulation forecasts which only differ in the quality of the prescribed atmospheric forcing. We examine the relative impacts of assimilation and atmospheric forcing on the quality of the ocean forecasting results.

Tropical cyclones and associated meteorological tsunami affecting Atlantic Canada

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Unusual and sometimes damaging sea level events at the coast of Newfoundland have been associated with the passage of storms of tropical origin over the neighbouring Grand Banks of Newfoundland. Often the weather at the coast can be fine and pleasant whereas sea level has been reported to rise and fall by a metre or more on time scales of 10's of minutes to half an hour. A feature of the Grand Banks is that the water is shallow (typically 100m depth) so that storms propagating across the Banks can be travelling at speeds comparable to the propagation speed for long surface gravity waves leading to a significant non-isostatic sea level response at the coast (the "meteorlogical tsunami"). Tropical Storm Helene in 2000 is taken as an example. We have used atmospheric forcing derived from an atmospheric model simulation of Helene to drive a realistic, single layer barotropic ocean model. Both wind and atmospheric pressure forcing are found to be important with significant wave refraction (reflection) effects associated with the rapid change in water depth at the shelf break.

Numerical Study of Three-Dimensional Circulation and Hydrography in Halifax Inlet using a Nested-Grid Ocean Circulation Model

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Halifax Inlet is a multi-use estuary with great environmental and economic values. Raw sewage and wastewater, however, have been dumped directly into Halifax Inlet for centuries, leading to poor water quality of this critical coastal system. Better understanding of oceanographic processes is required for pollution control and sustainable development in the inlet. A three-dimensional nested-grid coastal ocean circulation model, known as NCOPS-HFX (Nested Coastal Ocean Prediction System for Halifax Inlet), was used to investigate circulation and hydrography and associated temporal and spatial variability in Halifax Inlet. The NCOPS-HFX is driven by tides, meteorological forcing and buoyancy forcing associated with freshwater discharges. Model performances were assessed by comparing model results with observations including tide gauges and monthly mean climatology of temperature and salinity, which were constructed recently from historical hydrographic observations in the inlet. Model results demonstrate that near-surface currents in the inlet are significantly affected by tides and wind forcing with an intense tidal jet in the Narrows and a weak salinity front in the Bedford Basin. The time-mean circulation produced by the model is characterized by a typical two-layer estuarine circulation. The model also reproduces reasonably well seasonal changes of temperature and salinity distribution in the inlet.

Numerical investigation of the Nordic water overflow in the Faroe-Shetland Channel

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The overflow of dense water from the Nordic Seas through the Faroe-Shetland and Faroe Bank Channels is investigated numerically using Massachusetts Institute of Technology General Circulation Model. The bottom topography along with the initial temperature and salinity distribution were taken from observations. The model is forced by the initial horizontal density gradient applied to the 400-meter layer at the east-northern boundary in the Faroe-Shetland Channel after destruction of a barrier separating different waters. Analysis of the obtained results reveals that the propagating flow is unstable during its adjustment in rotating channel and forms cyclonic and anti-cyclonic eddies. The life-time of some eddies is about 10-20 days. The only permanent feature is the anti-cyclonic eddy with warm core and surface elevation, and is formed before the sill crest of the Faroe Bank Channel. Evidence of this eddy is confirmed experimentally by the tracks of drifters in the area and by temperature and salinity distribution in the Faroese Channels. The model results also show how the part of cold water overflows through the Wyville Thompson Ridge. Temperature, salinity and velocity sections in this area coincide with the recent measurements. The investigation of the hydraulic control around the sills in the Faroe Bank Channel shows very complicated picture of the flow here with some areas where Froude number is larger than one.

Comparative quantification of physically and numerically induced mixing in ocean models

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A diagnostic method for calculating physical and numerical mixing of tracers in ocean models is presented. The physical mixing is defined as the turbulent mean tracer variance decay rate. The numerical mixing due to discretisation errors of tracer advection schemes is shown to be the decay rate between the advected square of the tracer variance and the square of the advected tracer and can be easily implemented into any ocean model.

The applicability of the method is demonstrated for four test cases:
(i) a one-dimensional linear advection equation with periodic boundary conditions, (ii) a two-dimensional flat-bottom lock exchange test case without mixing,
(iii) a two-dimensional marginal sea overflow study with mixing and entrainment, and (iv) the DOME test case with a dense bottom current propagating down a broad linear slope.

The method has a number of advantages over previously introduced estimates for numerical mixing.

This numerical mixing analysis will be demonstrated for a complex numerical simulation of the Western Baltic Sea using GETM (General Estuarine Transport Model). Furthermore, issues of numerical dissipation (numerically induced momentum diffusion) will be discussed.

Estimation of the internal pressure gradient – tuhe finite volume and weighted approaches

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Terrain-following (sigma-coordinate) models are widely used. They are often advantageous when dealing with large variations in topography, and give an accurate representation of the bottom and top boundary layers. However, near steep topography, the use of these coordinates can lead to a large error in the internal pressure gradient force.

Using finite differences is the traditional way of discretising the equations. However, it is possible to integrate over horizontal cells by using a finite volume approach instead. In this work, we will interpret the traditional computation of the internal pressure in the Princeton Ocean Model (Blumberg and Mellor, 1987) as a finite volume method. We will include additional points in the computantional stencil and derive
higher order finite volume methods.

The standard 2nd order POM method will also be combined with the rotated grid approach from Thiem and Berntsen, 2006. We will investigate the possibility of using an 'optimal weighting', with weights that depend on the topography, the stratification, and the grid size. All methods will be applied to an idealised test case - the seamount problem.

Development of an operational flood forecasting model for the Firth of Clyde, Scotland

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The Firth of Clyde is a water body that connects at its southern end to the North Channel. At the northeast, it connects to the Clyde Estuary (which connects to the River Clyde). The dynamics of the system are dominated by the tide as well as meteorologically induced surges. The tide is mainly semi-diurnal with an amplitude of about 1.5 m during spring tide. Under extreme conditions, the surge can reach a height of about 1.5 m or more.

The objective of the study is to develop an operational flood forecasting model that provides water level forecasts with a 36-hour lead-time at the locations of at-risk communities on the shores of the Firth of Clyde and Clyde Estuary. The model also provides the downstream boundary conditions to the fluvial flood forecasting systems for the Clyde and Irvine rivers. The model runs operationally in the national flood forecasting system (FEWS Scotland) maintained by the Scottish Environmental Protection Agency (SEPA).

An orthogonal, curvilinear grid was designed, which is smoothly aligned with shorelines and other distinct features such as the shipping channel through the inter-tidal mud flats near Port Glasgow. The typical grid size in the Firth of Clyde area is about 400 m, decreasing to about 100 m towards the upper Clyde Estuary. A computational time step of 1 minute has been applied. Computing a 36-hour forecast with the Firth of Clyde flood forecasting model takes about 9 minutes on a single 3.6 MHz CPU, which is a suitable run time for operational model simulations.

The model bathymetry is based on high-resolution survey data as well as LIDAR data covering inter-tidal flats near Port Glasgow. At the southern side of the model domain, an open water level boundary consisting of five sections is defined. The prescribed water levels consist of the tidal variation based on 50 prescribed (calibrated) harmonic constituents and the externally generated surge height.

The calibration was done for a one year period (2005), using historical in-situ wind and surge data for model forcing. The rigorous validation has included a one year period (2007-2008) using both (*i*) historical in-situ data and (*ii*) modelled operational data for forcing as well as (*iii*) the modelling of historic storm surges and (*iv*) the assessment of forecast accuracy for various lead times. During the calibration and validation, various Goodness-of-Fit criteria were used to assess model quality in both the frequency and time domain.

The presentation will discuss the model design, the calibration, and the approach and results of the extensive validation in both hindcast and forecast mode.

OpenDA, a generic toolbox for data-assimilation in numerical modelling

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Most applications of data-assimilation make use of a dedicated implementation of the data-assimilation algorithm and processing of the observations. Often, this is not really a problem since implementing an Ensemble Kalman filter for one application is not a huge amount of work. And e.g. 4D-VAR requires an adjoint, and most of the work usually goes into the construction of the adjoint code. However, if one tries to compare several algorithms, develop new algorithms or implement data-assimilation methods for a larger number of models and geographically varying applications, it becomes worthwhile to develop a generic toolbox for data-assimilation.

OpenDA is a flexible toolbox or software environment for data-assimilation.
Openda provides an interface specification of a model and various other components together with the data-assimilation algorithms that use these interfaces to work with the model and observations. In this object oriented framework the algorithms can be programmed independent of any particular model, as they all implement the same interface. Efforts have been made to make coupling of a model to the data-assimilation algorithms efficient and easy. The system also provides methods to handle parallel processing. For some algorithms parallel processing is possible even if the model itself does not provide this feature. It is possible e.g. to distribute the computations of an Ensemble Kalman filter around a cluster, without additional programming for the user. If the model itself can run in parallel then this can be taken into account.

In addition to a reduction of the programming effort, a tool like Openda also increases the reliability of the software because algorithms can easily be tested for many models. Simple tests allow for frequent testing during the development and application to multiple models increase the probability of finding the remaining bugs. It is also intended that the easy use of other data-assimilation algorithms will speed up application of new algorithms.

Openda has been applied to calibration of hydrodynamic models and wave models. In fact, the calibration tool has been constructed such that it can be modified with little effort to any model with ascii input files. OpenDA Kalman filtering has been applied to various hydrodynamic models and an atmospheric chemistry model. Ongoing research efforts aim at including variational data assimilation, model reduction and new Kalman filtering algorithms. At the same time we intend to widen the range of applications, e.g. to rainfall-runoff models, river flow models, ground water models, morphodynamic models and petroleum reservoir models.

Note: OpenDA is the new name for the merger of the COSTA developments initiated by TUDelft and VORtech and the DATools developments started by Deltares/Delft Hydraulics.

From May, 2010, the OpenDA toolbox will be available to interested modellers and assimilation code developers as open source software under LPGL (www.openda.org)

The use of the OpenDA SWAN Calibration Instrument for the Dutch Hydraulic Boundary Conditions

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Introduction

The SWAN wave model computes random waves in coastal regions and lakes. It accounts for wave generation by wind, wave propagation, shoaling, refraction, diffraction and dissipation processes like whitecapping, bottom friction, depth-induced breaking. The source and sink terms contain model parameters, for which default values are available. These are not per definition the optimal settings for a specific area of interest. When wave measurements are available, the parameters can be chosen such that the model approaches the observations best.

Hereto, the SWAN Calibration Instrument is a very useful tool. Even in complicated situations with several observations of various wave parameters in different areas and with several parameters to tune, the SWAN Calibration Instrument helps to find the optimal model settings in an effective way.

The SWAN Calibration Instrument is an OpenDA tool. OpenDA is a strategic software environment for operational data assimilation, model uncertainty analysis and model calibration. It can be linked to any process model.

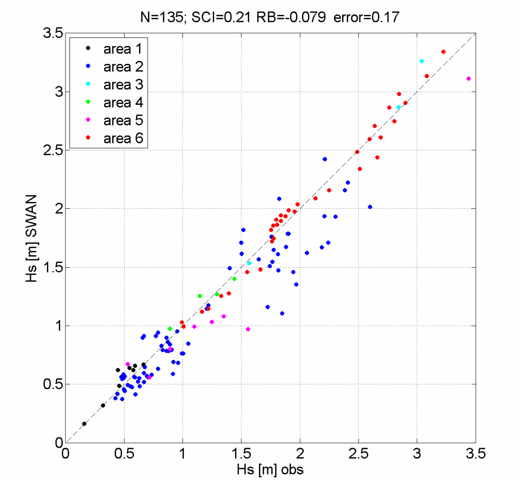
SWAN calibration for the assessment of Dutch Hydraulic Boundary Conditions

Within the process of deriving the Hydraulic Boundary Conditions for the Dutch Wadden Sea coast, SWAN will be used to translate offshore extrapolated wave observations to nearshore locations. The Wadden Sea is an area with complex bathymetry with deep tidal channels and large flats and islands. Since new formulations for wave current interaction and wave breaking have been developed recently in SWAN, it has been decided to calibrate the model.

First of all the parameters to calibrate were chosen, being

- Cds3 — proportionality coefficient in the enhanced dissipation of waves on adverse currents
- $\alpha_{biphasebreak}$ — proportionality coefficient in the biphase breaker model
- Cfjon — friction coefficient
- trfac — proportionality coefficient for the triad LTA method

For the other parameters in SWAN it was decided not to be useful to change them, for several reasons.



Next, suitable observations were selected where the processes of current interaction, breaking, friction or triads occur. Several tests were carried out with different combinations of the four parameters, different weights of the various locations, and different initial values. Finally, the optimal settings were found and validation afterwards does show increased accuracy.

Conclusions

The SWAN Calibration Instrument is a suitable tool to find optimal model settings in an objective, quantitative and reproducible way. Still, use of automated optimization requires sound knowledge of SWAN and wave processes. It is important to select suitable data for the processes of interest, and input parameters like uncertainty parameters, accuracy criteria must be chosen with care.

Parallel computing and model coupling for data assimilation

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Extending an existing (large scale) dynamical model with respect to data assimilation is an elaborate task. This is particularly so because data assimilation schemes, such as Kalman filtering or calibration methods, have consequences for the way in which the model operator is accessed. This usually requires that the data assimilation method is built on top of the existing model code, instead of under the existing code in a library. OpenDA is a generic toolbox that simplifies the application of data assimilation techniques. It provides interfaces between the assimilation algorithms and the model and observation handling code. It provides well-tested implementations of various data assimilation techniques as well. Concepts of object oriented programming are used to define building blocks for data assimilation systems that can exchanged and reused.

In this work we describe OpenDA's parallel computing and model coupling capabilities. Using OpenDA, the parallelization of multiple model runs is provided for free, i.e. does not require additional modification of the existing model code. Further OpenDA provides templates for the easy incorporation of existing model codes that employ parallel computing themselves.

These capabilities are demonstrated by the application of OpenDA to three large scale models in which parallel computing and domain decomposition are used.

Calibrating the Tidal Prediction of the South China Sea model

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Calibrating a hydrodynamic model for tide is typically an engaged and difficult process. This process is complicated further in the vicinity of the South China Sea basin by the tidal flow interactions between the Indian and Pacific Oceans through the Malacca Strait and the Indonesian Through Flows, the complicated combinations of deep and shallow water areas, and the lack of detailed and reliable tidal observation stations across the region. One of the hydrodynamic models used in the Must Have Box (MHBox) study of Sea Level Anomalies (SLAs) and Current Anomalies (CAs) in the South China Sea region is the South China Sea Model (SCS). The SCS has open water boundaries on the Andaman Sea, Sunda Strait, Lombok Strait, Sape Strait, Flores Sea, Celebs Sea, Luzon Strait and Taiwan Strait at which tidal constituents are input for tidal forcing of the model. The SCS was initially calibrated for tide at a particular month. This is typically sufficient for most regions that have a predominant tidal constituent. However a recent re-analysis of the SCS using one year simulation indicates re-calibration is required to be able to use this model for regular tidal forecasting at any time period in any year.

The focus of the present paper is on the full tidal calibration of the SCS through the use of a portable interface for enabling flexible data assimilation and calibration (OpenDA). OpenDA has three methods available for data assimilation and calibration: Doesn't Use Derivative method (DUD), Simplex and Powell methods. Attention is given to the formulation of a well-balanced Goodness-of-Fit criterion for the minimization process, taking into account uncertainty in model and data. The different methods are applied for first estimation of boundary conditions for all 11 open boundaries of SCS. Then the DUD method is used to evaluate and improve the overall response of the SCS by simultaneously varying all the tidal constituents forcing at all the boundaries including the Andaman Sea boundary which has no updated information. In addition OpenDA is used to evaluate and improve local tidal characteristics at particular stations through varying local bed friction or depth. The improvements in parameter settings and tidal constituent results and localized parameters obtained through OpenDA are discussed in terms of sensitivity to overall hydrodynamics and local coastal geometry.

Parameter estimation in a large scale Dutch Continental Shelf Model

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The Dutch Continental Shelf Model (DCSM) is a shallow sea model of entire continental shelf which is used operationally in the Netherlands to forecast the storm surges in the North Sea. The forecasts are necessary to support the decision of the timely closure of the moveable storm surge barriers to protect the land.
A new version of DCSM was developed with higher resolution and larger area as compared to the operational one. Performance of the DCSM regarding the strom surges is influenced by its performance in forecasting the astronomical tides.
In this study, we have implemented a newly developed model calibration method MRVDA (model reduced variational data assimilation) for tidal calibration of the new version of DCSM.
The advantage of this method is that it shifts the minimization into lower dimensional space and avoids the implementation of the adjoint of the tangent linear approximation of the original nonlinear model (Vermeulen and Heemink, 2006; Altaf et al., 2009). The calibration parameter in this study is the model bathymetry. A number of calibration experiments is performed.
The effectiveness of the algorithm is evaluated in terms of the accuracy of the final results as well as the computational costs required to produce these results. In doing so, comparison is made with a traditional method of calibration Dud (Doesn't use derivative), which is already available in OpenDA. Dud is a derivative-free Gauss-Newton algorithm, which makes use of an affine function, instead of tangent function, to approximate the response function (Ralston and Jennrich, 1978).

Keywords—Numerical tidal modeling, Parameter estimation, Proper orthogonal decomposition

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Surge sensitivity to physical parameters through forward and adjoint modelling with MITgcm

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Traditional techniques for estimating storm surge forecast sensitivity to physical parameterisations, such as bottom friction and wind stress, involve perturbed-physics ensembles containing a large number of forward integrations in time. There is an assumption that such ensembles are generated in a way that samples the sensitivity and do not omit regions of parameter space to which the maximum surge elevation is sensitive. To consider the combined sensitivity of multiple physical parameters, there is a need for huge ensembles for a given event, needing huge resources for computation and data analysis.

Adjoint modelling is an alternative tool to estimate such sensitivities using a single model integration where the partial derivatives of model state with respect to each parameter of interest are calculated by linear approximation to the model state space trajectory. The adjoint gives information about the relative importance of multiple physical parameters and can even determine where parameters such as friction are most important, by providing a sensitivity map.
We use MITgcm experiments to compare the ensemble and adjoint techniques for studying surge forecast sensitivity.

Preparing remotely sensed SPM for data assimilation: Optics, accuracies, and implications for transport models

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Remote sensing data have been processed and prepared for input into a data assimilation system to improve cohesive sediment transport modelling and support the Port of Rotterdam (PoR) with assessment of t0 and t1 Suspended Particulate Matter (SPM) conditions in the Dutch coastal waters. Research questions that inevitably came up were: (1) How to select and weigh SPM concentrations derived from remote sensing? (2) How to estimate optical depth, in order to compare with and assimilate into model sigma layers with similar vertical extent? (3) (How) can perturbation in surface SPM concentrations during sand mining be detected?

(1) The remote sensing data has been processed and the SPM and confidence information derived from remote sensing techniques have been analysed. This resulted in a physically based error filtering procedure based on subsequent exclusion of erroneous Inherent Optical properties (IOPs) and radiances in preparation for weighing on standard errors of concentrations.
(2) An equation for estimation of optical depth from the ecological vertical attenuation parameter K_{DPAR} has been derived by combing wave (wavelength) and particle (photon) properties. Yet $1/K_{D560}$ is proposed as the best approximation for optical depth for non-ecological purposes in waters with high sediment load.
(3) In preparation for perturbation detection, variations in concentrations and organic and inorganic components were studied. A successful perturbation detection algorithm comprised the use of anomalies with respect to seasonal and inter-annual variations in SPM concentrations and a statistical outlier detection analysis.

In conclusion, we report on various objective procedures to evaluate performance of SPM from remote sensing and its implications for the assimilation into a coupled numerical hydrodynamic and sediment transport model (Delft-3D). We focus on the processes that regulate surface concentrations in concert with the interpretation of the remote sensing signals and pattern simulation.

Assimilation of Remote Sensing data in a 3D Suspended Matter Transport Model of the Dutch Coastal Zone

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The description of suspended particulate matter (SPM) concentration in a complex dynamical shelf sea can be much improved by integration of remote sensing data into numerical models. This presentation discusses the applicaitn of the Ensemble Kalman Filter (EnKF) data assimilation technique to assimilate SPM data of the North Sea, retrieved from MERIS spectrometer data, into the computational water quality and sediment transport model, Delft3D-WAQ. The SPM data products comprise of SPM concentrations, error information and an approximation of optical depth retrieved from the MERIS recordings using the HYDROPT algorithm. These attributes of the data enable their use in data assimilation. The uncertainty of the transport model, Delft3D-WAQ has been quantified by means of a Monte Carlo approach. A case study covering the first months of 2003 demonstrates that both data and model are sufficiently robust for a successful assimilation. By means of misfit quantification it is discussed to what extent the assimilation improves the spatial and temporal description of SPM in the southern North Sea. Finally, it is discussed how this information can be applied for impact assessments of possibly enhanced turbidity in coastal seas due to large-scale sand-mining operations.

Improvement of state estimates and numerical model predictions of the German Bight through the assimilation of Ferrybox Data

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In this work, we want to quantify the usefulness of and problems associated with the usage of FerryBox along track sea surface temperature (SST) and salinity (SSS) data. We analyse the feasibility of an assimilation of FerryBox data based on data from numerical models, up-to- date remote sensing products, and classical in-situ observation, and give estimates of the corresponding errors. Our analyses show that the variations of SSS along the FerryBox track are too small in comparison to the measurement errors and the errors resulting from the specific FerryBox sampling and can not justify an assimilation under the given circumstances. On the contrary, the assimilation of SST data is possible within an acceptable error range. Output from two model runs of a German Bight 3-D primitive equation numerical model, both assimilating FerryBox data, however one of them with constant relaxation and another one with a variable relaxation based on the temporal and spatial variability of the estimated reconstruction error, are analysed. It is demonstrated that the constant relaxation performs slightly better due to a better compensation of drifting effects in the inner part of the basin, however it produces high errors in the tidal dominated regions near the coast.

Investigating the appearance of SPM in the Rhine river plume on Ocean Color imagery with an idealized numerical model

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River plumes Rivers release significant amounts of freshwater into coastal seas and oceans. After leaving the river mouth this buoyancy input turns anti-cyclonically under the influence of the Earth's rotation and establishes a river plume downstream (to the right on N. Hemisphere, and to left on S. Hemisphere). The Rhine ROFI (Region Of Freshwater Influence) is fed by the Rhine-Meuse system with an average discharge of 2500 m3s-1. The ROFI generally extends 20 to 40 km from the coast, with an occasional outburst of 50 km offshore. Along the coast it can extend over 120 km alongshore to the North. The freshwater significantly affects the current patterns in the ROFI over the vertical, at both tidal and residual time scales. Therefore presence of fresher water is the main agent governing the advection and dispersion of fine sediment in the Dutch Coastal Zone.

Remote sensing of SPM One of the main sources of information on coastal SPM dispersal is remote sensing imagery which provides synoptic data at regular intervals over multiple years. However, the remotely sensed surface SPM images can not directly provide information on the subsurface presence of sediment. Because most of the sediment is actually confined to the bottom layers, this severely limits the use of remote sensing images. Using surface values alone would underpredict the amount of SPM. Furthermore, the Rhine ROFI is frequently stratified. During stratified conditions SPM is trapped even more in the bottom layers. Marine sediments are no longer mixed throughout the water column; due to reduced mixing in and above the pycnocline they are confined to the bottom layers when resuspended. In addition, any riverine sediments leaving the Rhine river mouth, after passing the ETM, will settle from the fresher surface layers. Thus stratification makes the interpretation of surface SPM patterns even more difficult than during normal well mixed conditions. Pietrzak et al. (2010) present an extensive analysis of both NOAA SST and SeaWiFS SPM data for the period 1998-2002. The SST data were used to detect periods of stratification. In stratified plumes atmospheric and solar heat fluxes lead to an extra and fast SST contrast with surrounding waters that make it well-recognizable. In the summer stratified waters exhibit higher surface waters, while in the winter the surface plume temperatures are colder than the surrounding water. The SST data show that the plume exhibits two states: stratified and well-mixed. Pietrzak et al. (2010) linked stratification events as visible with SST to the presence and visibility of SPM. In this study we investigate this phenomenon further using an idealized model of a river plume subject to a Kelvin wave.

Idealized model In addition to SeaWiFS data an idealized numerical model of a river plume is employed to study the distribution of SPM. The goal is to understand the impact of the complex 3D current structure of the river plume on the surface appearance of SPM. The 3D current structure of the Rhine ROFI has been analysed extensively before with this numerical model (De Boer et al. 2006, 2007). In these papers the tidal and residual current patterns were analysed in detail and compared with available in situ data and with SST imagery. After having gained insight in the current structure, the model is now adopted to study the fate of marine and riverine sediments. The findings from this idealized model study help in the interpretation of remote sensing images. The model results are qualitatively compared to available SeaWiFS Ocean Color imagery for 1998 -2002.

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An unstructured shallow flow solver for the North Sea

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Since the mid 1980-ies, Deltares / Delft Hydraulics has been continuously active in the development and validation of a hydrodynamic modelling software for 1D-2D river systems and, separately, one for 3D coastal oceans and estuaries. The two modelling software systems form the cornerstones of the in-house research studies and specialist advice projects, while at the same time they are widely used by researchers and engineers worldwide.

For studies involving both well mixed river flow and stratified estuarine flows, a combination of both packages is desired. To achieve this, an explicit online coupling has been implemented. In practice we find that setting up a combined model and coupling is a time consuming process. Due to their separate development history the look and feel of both user interfaces and their input and output files are quite different.

While both software systems are numerically accurate, robust and efficient, the requirement of strictly orthogonal curvilinear grids has its drawbacks, particularly at smaller spatial scales and increasing resolution. Examples are the well-known ‘staircase’ boundaries or topological restrictions related to connectivity in physical and computational space.

An unstructured grid approach circumvents these problems and offers more flexibility. Therefore, an unstructured flow solver is under development, which builds on the successful concepts of the 1D2D and 3D systems. It features a stable and flexible application of various physical and numerical modeling concepts within one modeling system, with applications ranging from sewer flows, 1D river flows, 2D overland flows and 3D flows in one system.

The system has been tested on its numerical properties, and a variety of validation cases has been conducted. One of the model validation efforts involves the tidal motion on the NW European Continental Shelf.

The presentation will address the major concepts, properties and gained flexibility of the unstructured model code, with a focus on the tidal propagation for an unstructured model network of the NW European Shelf with gridsizes based upon the local waterdepth.

Applications of an unstructured grid model to tidal and tsunami modelling

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Coastal flows are dominated by cross-shore flows in approximate geostrophic balance. For such flows it is important to ensure that the cross-shore region, within a Rossby radius of the coast, is well resolved. The C-grid is known to be a good choice for these types of flow problems. At the same time it is important to resolve the details of the coastline variability and bathymetry, since these too have an important influence on coastal dynamics and wave propagation. Consequently the last few years have seen the development of a large number of unstructured mesh models. Here a C-grid based unstructured mesh semi-implicit finite volume coastal ocean model, Delfin, is briefly described. The staggered C-grid has been adopted by many structured grid models. However, it suffers from one main drawback; that is a Coriolis mode that can be excited when the Rossby Radius is not well resolved. We show how the correct choice of spatial and temporal discretisation can lead to a stable, accurate and efficient unstructured mesh model. The advantages and disadvantages of this modelling approach are discussed in the context of tidal, tsunami and flooding studies. We present high resolution tidal simulations of the southern North Sea. Furthermore, we show the advantages of unstructured meshes over traditional Cartesian based models in resolving the estuaries and inland waterways along the Dutch coast. Some new examples are presented from the Indian Ocean Tsunami, which show excellent agreement with the Jason-1 altimeter track. We also demonstrate the advantages of this approach for simulations dominated by flooding and drying.

Keywords: C-grid, unstructured grid, Southern North Sea, tides, flooding-drying, Indian Ocean tsunami

Modelling the interaction of tides and storm induced currents in shallow water using an unstructured grid finite volume model (FVCOM)

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A three-dimensional unstructured grid finite volume model (FVCOM) of the west coast of Britain is used to investigate the response of the region under idealized storm surge conditions, in particular the interaction between tides and wind-forced currents. The nature of the unstructured grid model permits us to refine the model grid in the near shore regions, e.g., eastern Irish Sea, where the large tidal range in the shallow water generates significant areas of inter-tidal zone. We examine in detail the interaction between tides and wind induced currents, and the maximum bed stress due to tidal and wind forcing. The distribution of the maximum bed stress is dominated by the tidal flow. Nevertheless, the wind forcing can have significant effects, which have implications for pick up, transport and deposition of sediment and pollutants. Using the Mellor-Yamada turbulence closure model, we also investigate the effect of surface breaking wind waves on wind driven currents and the resulting maximum bed stress by including surface wave breaking energetics to modify the turbulence mixing length. Results show complex interactions between tides, wind induced currents and turbulence in the shallow region of the eastern Irish Sea.

Obtaining spectral consistency among radar altimetric data and the geoid; a prerequisite for data assimilation.

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The aim of the project is to estimate a new marine geoid for the North Sea by combining various types of gravity data (satellite, airborne, shipborne, terrestrial), (retracked) radar altimetry data, tide-gauge data, GPS data, and dynamic sea surface topography data provided by the Dutch Continental Shelf Model (DCSM). The DCSM will be used to correct radar altimetry data for the dynamic sea surface topography, which provides geoid heights relative with respect to the adopted reference ellipsoid. However, since the equipotential reference surface of DCSM does not neccesarily coincide with the geoid, a calibration of the model is required, which might in turn result in an improved definition of the reference surface of DCSM. This calibration is based on the iterative assimilation of water levels observed by radar altimetry satellites and tide gauge instruments relative with respect to the best estimate of the geoid.

During the iterative assimilation, radar altimeter data and geoid data will be combined. In practice the spatial resolution of radar altimetry data is much higher than the spatial resolution of the geoid. A pre-requisite for data combination, however, is that the two data sets have the same spectral content, which can be accomplished by low-pass filtering of the radar altimetry data set. The application of standard low-pass filters, such as kernel smoothers, fails, as no radar altimeter data are available on land.

In a recent publication it was suggested that the use of a Slepian basis function representation might overcome the limitations of standard low-pass filters. In a series of experiments we use this representation to filter a MSL signal and compare the performance of this filter with alternative techniques.

Model parameters adjustment using an EnKF in a 1-D numerical model of the North Sea CS station

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The adjustment of model parameters (sea surface drag and solar attenuation coefficient) using an Ensemble Kalman Filter (EnKF) is investigated in a 1-D numerical study of the temperature profile at the North Sea CS station (55°30'N, 0°55'E). This simplified model implementation allows to test many configurations for the sampling of the model error as well as for the adjustment of the parameters. Temperature profiles from thermistor data are assimilated and their effect on the adjustment of the model parameters is studied by comparison of a reference simulation with the model results obtained when assimilating the data with the EnKF.

Model-reduced 4D-Var data assimilation in the phytoplankton bloom prediction in the North Sea

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Phytoplankton blooms, also called algal blooms, are important factors in ecological quality modeling. In order to model algal blooms, algal biomass has to be specified. This is done by measuring the concentration of chlorophyll-a, which provides a reasonable estimate of algal biomass. To model chlorophyll-a concentration the generic ecological model (BLOOM/GEM) (Blauw et al., Hydrobiologia, 2008) is used. The model was developed to simulate nutrients cycle, primary production and ecosystem functioning. Moreover, it consists of detailed underlying hydrodynamics, suspended sediment and river loads, which are required for ecological modeling. A 2D version of this model is used to simulate chlorophyll-a concentration in the southern North Sea.

The ecological model consists of 25 state variables and more than 250 parameters, and it is defined on 8710 grid cells. Since many of the parameters are highly uncertain, the main task of this work is to update the parameter values, such that better model predictions are obtained. Based on the sensitivity analysis 20 parameters have been chosen as the most significant (Salacinska et al., Ecological Modeling, 2009). In this work, based on a number of simulations of the original model, proper orthogonal decomposition (POD) is used to obtain a reduced model (Vermeulen and Heemink, MWR, 2006). This reduced model carries out the most important information with respect to the impact of the parameters on the dynamics of the model. Finally model-reduced 4D variational (4D-Var) data assimilation is performed to estimate the parameters. Since model-reduced 4D-Var is performed in the reduced space, the implementation of the adjoint of the tangent linear approximation of the original model is not required.

The performance of the reduced model, as well as the results of the model reduced 4D-Var data assimilation, are presented. For the data assimilation purposes it is assumed that sattelite data is available. In this work the techniques are tested by means of the twin experiment.

Estimation of tidal boundary conditions and surface winds by assimilation of high-frequency radar surface currents in the German Bight

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Numerical ocean models are affected by errors of various origins: errors in the initial conditions, boundary conditions and atmospheric forcings, uncertainties in the turbulence parametrization and discretization errors. In data assimilation, observations are used to reduce the uncertainty in the model solution. Ensemble-based assimilation schemes are often implemented such that the expected error of the model solution is minimized. It is shown that the observations can also be used to obtain improved estimates of the, in general, poorly known boundary conditions and atmospheric forcings.

An ensemble smoother scheme is presented to assimilate high-frequency (HF) radar surface currents to improve tidal boundary conditions and wind forcings of a circulation model of the German Bight. To create an ensemble of dynamically realistic tidal boundary conditions, a cost function is formulated which is directly related to the probability of each perturbation. This cost function ensures that the perturbations are spatially smooth and that the structure of the perturbations satisfies approximately the harmonic linearized shallow water equations. Based on those perturbations an ensemble simulation is carried out using the full three-dimensional General Estuarine Ocean Model (GETM). Optimized boundary values are obtained using all observations within the assimilation period using the covariances of the ensemble simulation. The approach acts like a smoother scheme since past and future observations are taken into account. The final analysis is obtained by rerunning the model using the optimal perturbation of the boundary conditions. The analyzed model solution satisfies thus the model equations exactly and does not suffer from spurious adjustments often observed with sequential assimilation schemes. Model results are also compared to independent tide gauge data. The assimilation also reduces the model error compared to those sea level observations.

The same scheme is also used to correct surface winds. Surface winds are crucial for accurately modeling the marine circulation in coastal waters. The method is validated directly by comparing the analyzed wind speed to in situ measurements and indirectly by assessing the impact of the corrected winds on sea surface temperature (SST) relative to satellite SST.

Reference

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Ensemble prediction of waves and surge for storm conditions

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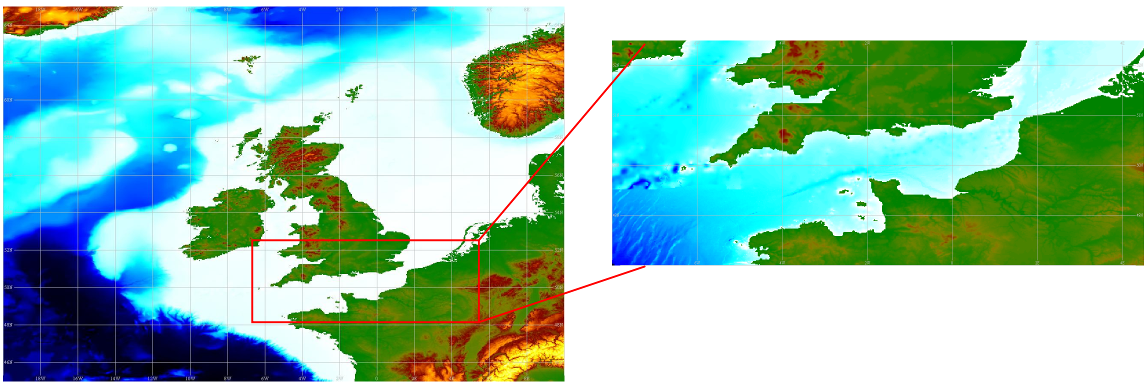
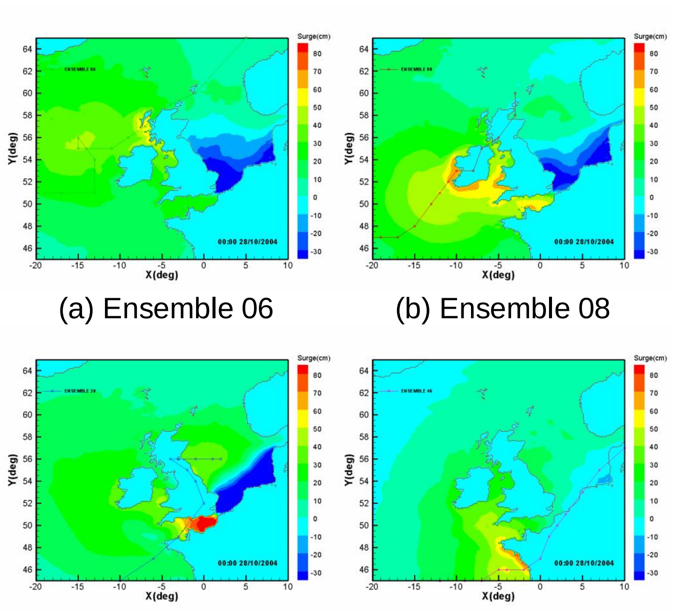
Transforming the meteorological information, such as wind and pressure fields to the ocean base and regional scale waves, tides and surge can commonly be done using deterministic modelling techniques with nested domains. Naturally, the uncertainties from the meteorological information can propagate during the downscaling process, which often affects the accuracy of the predicted waves, tides and surge. Ensemble prediction approach has now been wide used to quantify such uncertainties and their propagation through integrated modelling systems. The model results could significantly improve the assessment of the risk of coastal flood and erosion and provide information for policy makers to reduce or mitigate the possible damages, particularly from the extreme events.

This paper presents the results of the predicted oceanic waves, tides and surge using the ensemble approach with 50 members for the south-west water of the UK, including the English and Bristol Channels from POLCOMS coupled with ProWam, see Figure 1. The results of the predicted waves, tides and surge from the control case and each ensemble member for the storm events in Oct 2004 were analysed and compared with the measurements. The results show that the ensemble averaged predictions in general give good estimation on waves and surge, but considerably improve the predictions of storm peak wave heights and surge when the sort-term (T+2 day) initial conditions before the storm events are used in comparison with those predicted with slightly longer-term initial conditions (T+6 day), Figures 2 & 3.



(a) Coarse domain (b) Fine domain

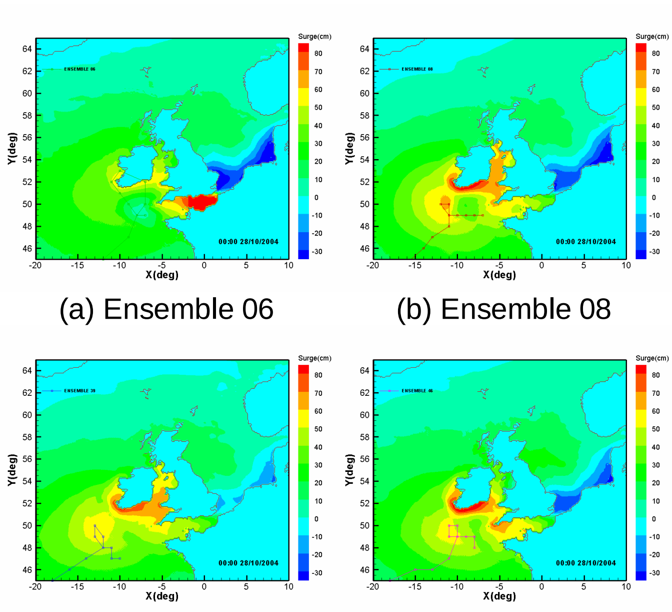
Figure 1 Computational domains



(a) Ensemble 06 (b) Ensemble 08

(c) Ensemble 39 (d) Ensemble 46

Figure 2 Ensemble predicted surge (T+6 day)



(a) Ensemble 06 (b) Ensemble 08

(c) Ensemble 39 (d) Ensemble 46

Figure 3 Ensemble predicted surge (T+2 day)

A convergence study of flow over a backward-facing step using a sigma-coordinate model and a z-coordinate model

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Flow over a backward-facing step is used as a test case to validate computational methods and turbulence models due to its simplicity combined with complex flow patterns. We will present a convergence study using the sigma-coordinate model Bergen Ocean Model (BOM) and the z-coordinate model the Massachusetts Institute of Technology general circulation model (MITgcm) for flow over a backward facing sharp step and a rounded step.

The main focus of the study is the separation point and the reattachment length.
The study shows a shift from stationary flow to time dependent flow for Reynolds numbers larger than 200 for sharp steps, and a corresponding shift,depending of the steepness of the step for rounded steps. For all the time dependent flows, propagating eddies are observed moving downstream with a steady velocity.

Really TVD advection schemes for shelf seas

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During the last decade large efforts have been devoted to the development of high-resolution schemes to solve advection problems. High-resolution conservative numerical schemes satisfying conservative, monotonicity preserving and shock-capturing properties are nowadays widely used in ocean modeling. Among these, TVD schemes, based on the concept of Total Variation Diminishing (TVD), were progressively adopted because of their good behavior that guarantees a solution free from numerical artifacts (no overshooting, no spurious oscillation, small diffusion) that can spoil the physical significance of the results.

Most of the TVD schemes and associated limiters have been originally developed in idealized one-dimensional flows described by a linear advection. In finite volume marine models, one has however often to deal with the depth integrated advection equation. This formulation is usually preferred because of its conservative form that is particularly suited to numerical treatment using a finite volume approach. Conservative numerical schemes can be easily formulated to ensure that the total mass of the advected quantity is conserved. This property is very valuable in the context of environmental studies for which a strict equilibrium of the mass budget of pollutants is often more relevant that the raw accuracy of the integration scheme. In the same context, the numerical scheme should also produce neither new local extremum nor negative concentrations, i.e. it should be monotonicity preserving which is implied by the TVD property.

The development of TVD schemes for the resolution of advection equations written in the conservative form is however not trivial. Numerical experiments show that the blind application to the depth-integrated equation of the usual TVD schemes and associated flux limiters introduced in the context of linear advection can lead to non-TVD solutions in presence of complex geometries. Spatial and/or temporal variations of the local bathymetry can indeed break the TVD property of the usual schemes. Really TVD schemes can be recovered by taking into account the local depth and its variations in the formulation of the flux limiters. Using this approach, a generalized superbee limiter is introduced and validated.

Development of a finite-element, multi-scale model of the Mahakam delta (Indonesia): Preliminary results

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The Mahakam is a 980-km long tropical river flowing in the East Kalimantan province located on the Borneo Island in Indonesia. In this study we focus on the tidally influenced part which extends 365 km upstream from the mouth. The interest of developing a model of such a tropical river lies in the various physical and numerical challenges to take up. In the upstream part of the domain the river flows through a region of three lakes surrounded by peat swamps. Typical to tropical rivers, such swamps act as a buffer for the highly variable discharge regime of the river. In the lowland regions the hydrodynamics of this meandering river is mostly influenced by tides. The tides propagate upstream of the delta, in the main river and its tributaries over a distance exceeding 200 km. Finally the mouth of the Mahakam is a delta exhibiting high number of channels.

The long term scientific objective is mainly the study of sediment transport in the Mahakam river. This river delivers high amounts of sediments to the coastal ocean due to the combination of the high erodibility of tropical soils and the intense rainfall in the equatorial latitudes.

The objective of the present study is to model the flow in the delta channels which is characterised by a very wide range of time and space scales. To be able to capture the different length scales, a depth-integrated version of the unstructured mesh, finite element model SLIM (Second-generation Louvain-la-Neuve Ice-ocean Model) is used. Unstructured grids allow us to refine the mesh in the narrow channels of the delta to conserve a good representation of the hydrodynamics in those areas.

The validation of the tides in the Mahakam delta and the hydrodynamics in the narrow channels will be presented as well as the propagation of the tides upstream from the delta in the river which has been modelled in one dimension. Finally options for the parametrisation of the river-lakes interactions are outlined.

An alternative approach for nonhydrostatic modelling

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The increasing demand for the investigation of nonhydrostatic effects in ocean modelling requires crucial modifications to traditional models applying the hydrostatic pressure assumption. Based on an extensive review of nonhydrostatic solution methods, only two approaches are found to be suitable for the inclusion of the missing nonhydrostatic pressure contribution into an existing hydrostatic model kernel. Since the widespread pressure-correcting projection method requires serious implementational and probably unnecessary computational effort, an alternative approach is successfully revived.

Due to the spatial anisotropy within practical ocean and estuarine applications, the substantial part of the pressure is hydrostatic and the nonhydrostatic pressure contribution would be only a small correction to it. Therefore a straight-forward extension of the traditional hydrostatic procedure is expected to be more efficient than methods adopted from classical engineering tools and based on the inversion of huge algebraic systems. Consequently, within the alternative approach the nonhydrostatic pressure contribution is calculated by an explicit vertical integration of the additional nonhydrostatic terms within the vertical balance of momentum.

To demonstrate the necessary modifications to an explicit mode-splitting hydrostatic model kernel, the extension of the General Estuarine Transport Model (GETM) is outlined. The results of several numerical simulations with the extended GETM, including sloshing basin waves, dispersing interfacial waves, internal lee waves, lock-exchange and buoyancy-driven flows, are presented and compared against analytical theory, laboratory experiments and other numerical simulations. This validation indicates the feasibility of the alternative approach to simulate even strong nonhydrostatic regimes.

Assessing the Far Field Effects of Tidal Power Extraction on the Bay of Fundy using a Nested-Grid Model

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The Bay of Fundy and Gulf of Maine system has a natural resonant period very close to the main semi-diurnal lunar tide. This results in the world's highest tides and strong tidal currents in the Bay of Fundy, particularly in Minas Channel and Minas Basin. A tidal power demonstration facility was recently established in the Minas Basin to test underwater turbines to convert tidal in-stream energy into electricity. The main objective of this study is to quantify the far field effects of tidal power extraction in the Bay of Fundy, the Gulf of Maine and the Scotian Shelf, with a particular focus on tides, tidal current patterns, and the vertical and horizontal distribution of temperature and salinity. The main research tool used in this study is a four-level nested-grid ocean circulation modelling system based on the Princeton Ocean Model (POM). The nested-grid system includes the whole of the eastern seaboard of Canada and the northeast United States at its largest scale with a horizontal resolution of about $1/12^{o}$, and then zooms through two intermediate grids into a high resolution (~1 km) model of the Bay of Fundy. The nested-grid system is forced by tides and meteorological forcing including wind stress, sea level atmospheric pressures and sea surface heat and freshwater fluxes. This presentation will focus on the model performance and main features of simulated three-dimensional circulation and hydrographic distributions in the study region.

Modelling near seabed velocities

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Laboratory experiments have shown that the propagation of a large amplitude internal solitary wave of depression over a flat bottom in a shallow two-layer fluid can generate an unsteady boundary jet along the bed (Carr and Davies 2006). This boundary jet occur after the wave has passed and is in the same direction as the wave.

The laboratory experiment of Carr and Davies (2006) is set up and modeled with use of the Bergen Ocean Model (BOM). The focus is on the sensitivity to the parameters affecting the jet along the bed. The sensitivity of the numerical results to the initial conditions will also be addressed.

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Carr, M. and Davies, P.A. The motion of an internal solitary wave of depression over a fixed bottom boundary in a shallow, two-layer fluid. Physics of Fluids, 18, 016601, 2006.

Investigation of the spreading and dilution of domestic waste water inputs into a tidal bay using the finitevolume model FVCOM

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The 'Jade Bay' is a tidal bay located in the western part of the German Wadden Sea, southern NorthSea coast. During particularly heavy rain falls, rain water mixed with domestic waste water is discharged into the bay due to the limited capacities of the waste water treatment plant of the city of Wilhelmshaven. As the discharge point is located only a few hundred meters from a public bathing beach it is important to know spreading and dilution of the waste waters by tidal and winddriven mixing.

To model the behaviour of the waste water plumes, the unstructured mesh finitevolume model FVCOM (Chen and al., 2003) is used, which allows to cover the large area of the Jade and the nearby North Sea with a relatively high resolution near the point of discharge and a coarser resolution at the outer edges of the study side. We adapted the included sediment module of FVCOM to handle the sedimentation, decay and evolution in the bottom sediments of the discharged waste water particles, especially with respect to bacteria. Furthermore, alternative discharge points located in the interior of the Jade bay were tested, which might be more suited for a faster dilution and a smaller residence time of the waste water particles in the tidal bay.

Absorbing layers for shallow water models

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Open boundaries are often seen as a major source of uncertainty or even error in numerical model simulations. One of the main difficulties is that the boundary conditions must allow the outward propagation of the signal out of the computational domain without creating unphysical reflections. In this presentation, the use of absorbing/sponge layers as boundary conditions is examined in the context of the shallow water equations.
The Flow Relaxation Scheme (FRS) amounts to the introduction of a linear damping term in an absorbing layer bordering the computational domain. This approach is particularly appealing since its numerical implementation is really straightforward. The FRS technique has received new attention with the introduction of Perfectly Matched Layers (PML), first in the context of electromagnetism, then in computational fluid dynamics and, quite recently, in numerical oceanography. Upon introducing extra evolution equations, PMLs enable a clean treatment of waves propagating at any incidence with respect to the boundary.
In both the FRS and PML approaches, an absorption coefficient is introduced that varies from zero inside the model domain to a maximum value at the outer boundary of the absorbing layer, controlling the gradual damping of outgoing waves. Using some simplified model set-up, we show that the performances of these boundary schemes depend critically on the spatial variations of the absorption coefficient and on the spatial resolution within the absorbing/sponge layer. Using the tools of numerical optimization together with some quasi-analytical developments, a nearly optimum law is derived. In a second step, the different types of absorbing layers are compared with each other through the two-dimensional problem of the collapse of a Gaussian-shaped mound of water and its advection by a mean current using the linear and the non-linear shallow water equations.

Numerical modeling of near bottom currents and food particle transport for cold water reef structures

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Lophelia Pertusa is one of a few known reef building cold water corals, and Lophelia reefs are important habitats for fish and benthic organisms. The coral depends on favorable current conditions in order to filter out food particles in the water. However, much is still unknown about the specific conditions that favor settlement and growth of Lophelia Pertusa. Two important factors, the current speed and the shape of the reef itself, have been studied using a numerical particle tracking model.

The current flow has been modeled using the Bergen Ocean Model (BOM), which is based on finite differences on a staggered grid, and with a vertical sigma-coordinate representation. The simulations require a spatial resolution of approximately 1 m, and non-hydrostatic effects have been included. A Lagrangian advection-diffusion model has been integrated in BOM to model the transport of passive, neutrally buoyant tracer particles. Both BOM and the tracking model have been parallelized with MPI.

Simulations have been performed for unidirectional flow over idealized reef profiles, with particles seeded randomly in a region near the bottom. Particles are captured when entering the bottom 25 cm above the sea bed, and this is used to indicate favorable locations for coral settlement and growth. Preliminary tests demonstrate that high resolution in the flow model is essential for an accurate result, whereas high order particle tracking methods do not give significantly different results than simple methods. Effects of different current speeds and reef profiles are demonstrated. The results are consistent with field observations, where it has been observed that the majority of living corals reside on slopes facing the dominating current direction.

Impact of wind gusts on sea surface height in storm surge modeling

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Storm surges are subject of great interest to low laying countries adjacent to oceans. In the Netherlands, modeling of storm induced surges has been performed ever since plans for a closure dike on the 'Zuiderzee' in the early 1920s. Over time, models have become more advanced and surges are better predicted. The shallow water model WAQUA/DCSM (Dutch Continental Shelf Model) is used in The Netherlands for operational forecasting of sea level heights along the Dutch coast. The meteorological input for the model is hourly averaged wind and pressure from HiRLAM (High Resolution Limited Area Model). Because the wind stresses on the surface that drive the model are determined by quadratic velocities, high-frequent variations in the wind velocity contribute to the total driving forces. A better understanding of the way that these variations influence a storm surge is desired.
To assess the importance of these high-frequent variations, gustiness values, obtained from the ECMWF model, have been correlated with the difference between sea level observations and operational model forecasts along the Dutch coast.
To understand more about the way that variations influence the sea level height, a more theoretical case has been investigated. Statistic variations have been added to a uniform wind field in the North Sea. This wind field has been used to drive DCSM. The resulting sea levels are compared to cases without wind disturbances. Wind disturbances have been investigated with different frequencies, temporal and spatial correlation, and variations in the angle and the strength of the wind.

Impact of spatially varying bottom friction coefficient on tidal propagation in the Pertuis Charentais, Bay of Biscay (France)

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The 2D numerical models based on the depth-averaged shallow water equations are now routinely used for modelling tidal propagation in coastal embayments and estuaries. Often, in these models, the sea bottom friction coefficient is supposed to be spatially uniform. In this study, we develop a model of a shallow basin where the spatial variability of the friction coefficient affects noticeably the amplitudes and phases of the semi-diurnal tide and its overtides.
The region under investigation is a semi-closed basin of the Pertuis Charentais situated in the NE Bay of Biscay. A finite-element high-resolution 2D numerical model using the TELEMAC software is developed to simulate tides and surges in the Pertuis Charentais. The spatial variations in the sea bed composition and the distribution of sea bed morphological features (banks, dunes, etc) in the Pertuis are converted into the variations of the sea bottom friction coefficient. Several zones of different friction coefficient are introduced in the model. The magnitude of the friction coefficient in each zone is then determined by fitting the predicted tidal amplitudes and phases to the observed ones using the advanced adjustment techniques.

Numerical studies of small scale eddies behind headlands in tidal inlets

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Inlets in fjords or lochs are natural laboratories for studies of interactions between stratified flow and topography. Measurements, numerical investigations, and analysis have been used to address these interactions.
At tidal inlets, there is a strong transfer of energy from the scales of the incoming barotropic tide towards the scales associated with irreversible mixing. The wide range of spatial and temporal scales involved makes numerical investigations of the flow and processes through narrow channels in fjords very challenging. Many numerical studies have accordingly been undertaken with barotropic depth averaged models.

The use of such models facilitate a high horizontal resolution at the cost of sacrificing vertical resolution and effects of stratification. In order to investigate generation and propagation of internal waves near sills in fjords, two-dimensional vertical slice models are often used. By using this approach, high resolution studies of internal waves and even overturning rolls in the lee of sills have been performed. However, with vertical slice models horizontal eddies that are ubiquitous near narrow channels in tidally driven fjords, are neglected.

Utilisingmassivelyparallel computer systems,fullythree-dimensional studies of the eddies behind a step in the lateral boundary in a tidally driven fjord are undertaken. The sensitivity of the the flow separation behind the step and the properties of the eddies to the grid size is investigated.

Tracking of sediment particles in a tide dominated area

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Sediment dynamics in ocean/coastal models are usually modelled using an advection/ diffusion equation for the concentration of one or more sediment classes coupled to the hydrodynamical part of the numerical model. The numerical solution of these additional partial differential equations unavoidably introduces an artificial numerical diffusion leading to the smearing of sharp gradients, the possible occurrence of artificial oscillations and non-positivity. Furthermore there are also restrictions in the number of sediment classes and important diagnostics like residence/settling times or individual tracks are not feasible.

A Lagrangian particle-tracking model has been developed to simulate short term sediment dynamics in the East Frisian Wadden Sea (southern North Sea). The numerical treatment of individual sediment particles allows a straightforward physical interpretation of the processes involved, automatically accounting for suspension and bedload. In order to achieve a comparable accuracy to the concentration-based models, a Lagrangian model must track a large number of independent particles. With the highly efficient parallelisation of particle tracking on modern high performance computer clusters the use of large numbers of particles is feasible.

The movement of the particles (here in the order of tens of million in total) is described by a stochastic differential equation, which is consistent with the advection-diffusion equation. The particles are advected by the 3-D currents and turbulent horizontal diffusion is implemented by a random walk process that is related to the shear of the velocity field. In the vertical the particle velocities are computed as a combination of the sinking velocity of each particle, the background fluid velocity and again a random walk, that is now related to the vertical eddy diffusivity. Resuspension and deposition depend on the particle diameter, particle density, and a ratio of bottom shear stress to a critical bottom shear stress. Furthermore, the erosion of particles is modelled as stochastic process.

A severe winter storm (Storm "Britta" in November 2006) is used for validation. Here the model results show good agreement with observations. The flexibility of the Lagrangian approach for simulating non-cohesive single/mixed sediments and its potential to include other processes like fragmentation and clustering, tracking biological species or reactive chemical containments will be illustrated.

The tracking system is further used to determine the tidal excursion of particles, and the residence time in the water column. The latter one is an important quantity to estimate oxidation time scales of dissolved matter.

Numerical studies of dispersion due to tidal flow through Moskstraumen, northern Norway.

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The effect of horizontal grid resolution on the horizontal relative dispersion of particle pairs has been investigated on a short time scale, i.e. one M_2 tidal cycle. Of particular interest is the tidal effect on dispersion and transports in coastal water where small scale flow features are important. A three dimensional ocean model has been applied to simulate the tidal flow through the Moskstraumen Maelstrom outside Lofoten in northern Norway, well known for its strong current and whirlpools, Gjevik et al., 1997 and Moe et al., 2002.

Simulations with spatial resolution down to 50 m have been carried out. Lagrangian tracers were passively advected with the flow, and Lyapunov exponents and power law exponents have been calculated to analyse the separation statistics. It is found that the relative dispersion of particles on a short time scale is very sensitive to the grid size, and that the spatial variability is also very large.
This means that models for prediction of transport and dispersion of oil spills, fish eggs, sea lice etc. using a single diffusion coefficient, will be of limited value, unless the models actually resolves the small scale eddies of the tidal current.

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Dynamical Coupling of a Spectral Wave Model and a 3D Hydrodynamic Model in a Highly Variable Tidal Environment

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In this research Dynamical Coupled Marine Model (DYCOM) consist of a spectral wind wave model and 3D hydrodynamic model including a wave-current bottom boundary layer module developed. Wave component of the DYCOM is K-model (GKSS Research Center), conceived as phase-averaged spectral wave models for intermediate and shallow water depths. 3D current field and water elevation has calculated by TRIMPPxzy a parallel nested version of the hydrodynamic model TRIM (Casulli and Cattani 1994, Casulli and Cheng 1992, Eppel et al., 2003). In order to take into account wave-current bottom boundary layer, several time invariant viscosity models e.g. Grant and Madsen, 1979, 1986 (GM86), Styles 2002 (S02), also Van Rijn,1989 (V89) engineering method have been tested and utilized in the DYCOM system. The BBL module appointed to provide improved bottom drag coefficient and bottom dissipation source term to the hydrodynamic and the wave models respectively, based on provided data from above mention models. The modeling system were set up with a spatial resolution of 1600m as coarse grid and 400m as fine grid in German bight and Hoernum inlet respectively. The time period extended from 15 to 25. December 2002, in which measurements for some of required parameters were available. In presence of locally generated wind waves, current velocity at reference level -1 m above the bottom for deeper parts like entrance channel with depth of 21m, is 0.8 m/s but wave orbital velocity is less than 0.2 m/s. Meanwhile shear velocity felt by current (u_{*c}) for S02 and V89 is almost two times of resulted value by GM86 and pure current which is around 2.5 cm/sec. Total shear velocity of wave and current(u_{*cw}) of S02 and V86 are in agreement with an oscillation due to tidal effects. Mean value of both model results are the same as Smith, 1977 and Soulsby, 1997 for wave shear velocity (u_{*w}). The GM86 and equal shear velocity for Γ Hasselmann,1973 show similar smaller values for u_{cw} and u_{w} respectively. In more shallow parts inside the inlet greater orbital velocity reaches to the bottom . So that current velocity and wave orbital velocity are in the same order of magnitude and u_{*c} outcome of S02 and V86 are in agreement, mean while GM86 and pure current shear stress are showing similar results. In this case, methods of S02, V86 and Smith, 1977 producing closer results for u_{cw} . The methods of GM86, equal shear velocity for Γ Hasselmann,1973 and Soulsby, 1997 show less than half of above mentioned results.

For incoming swell condition, even in deeper parts at the entrance of the inlet, wave orbital velocity is greater than current velocity at the reference level. So that u_{*c} of GM86 shows 1 cm/sec more than pure current shear velocity which is around 1cm/sec. Also S02 and V86 are in agreement for producing shear velocity felt by current more than 3.5 cm/sec. In case of u_{cw} , the S02, V86 and Smith, 1977 giving values around 14 cm/sec but the GM86, equal shear velocity for Γ Hasselmann, 1973 and Soulsby, 1997 producing results for this parameter around 5 cm/sec.

Different experiments showed clear effects of wave condition on shear velocity felt by current and total shear velocity. It means in coupling procedure apparent roughness or bottom drag coefficient for hydrodynamic model and bottom dissipation source term for wave model could be improved and affect results considerably. Methods of V86 and S02 are generally in accordance and producing greater values for shear velocity felt by current and total shear velocity. Proposed $\Gamma = 0.038\, m^2 s^{-3}$ by Hasselmann, 1973 to be used in bottom dissipation source term of wave models is in agreement with GM86 in seas and swell condition and generally less than the V86 and S02 methods result. Two way coupling of wave and current, with and without wave current BBL have been investigated through the DYCOM modeling system. Inclusion of BBL methods improves current speed especially in wet and falling dry points. Coupled system prevent dummy high velocity speed in very teen water layer specially in being wet points. Including bed forms in BBL methods will change apparent roughness and bottom stress in current model significantly, especially in shallow areas witch are exposed to swells. Increasing of bottom stress felt by current in water depth below 15 m up to 10 times in more shallow parts of the inlet, showed significant effect on incraesing and decreasing of water coverage in ebb and flow conditions.

Keywords:
Spectral wind waves, Shallow water hydrodynamic, Wave-Current bottom boundary layer, Coupled models

Modelling wave-tide interactions at a wave-farm in southwest England

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1. Introduction

Wave Hub project aims to create the world's largest wave farm for the demonstration and proving of the operation of arrays of wave energy generation devices. Recent studies at the Wave Hub site suggest that wave induced currents are important in controlling sediment movement (SWRDA, 2006). Better understanding of tidal effects on waves and sand transport is crucial to the wave resource characterization and environmental impact assessment of the wave farm at the Wave Hub site.

2. Aims

The aim of this study is to investigate the wave-tide interaction at the Wave Hub site, the final stage of the research consists on the study of waves-tide effects on sediment transport at the wave-farm coast. The results of this study will help the energy wave resource assessment and potential environment impact of the wave farm.

3. Methodology

Coupled wave-circulation-sediment transport models:

i. Nested Wave Watch III and SWAN wave models.
ii. 3-D ocean circulation model ROMS driven by the TMD tidal model at the offshore boundary
iii. Sediment transport model embedded in ROMS
iv. Numerical simulations validated against field measurements at the wave hub site

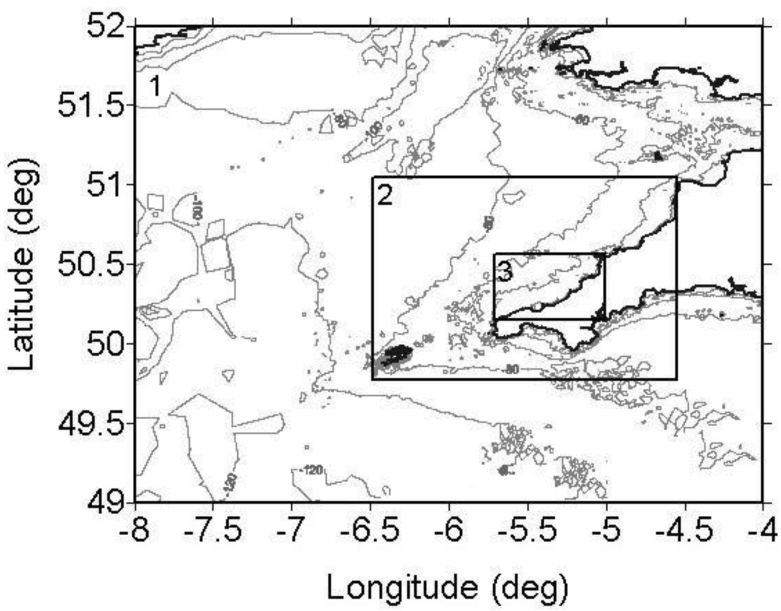

Figure 1. Area of study in the southwest of England, showing the coarse (1), intermediate (2), and fine (3) nested grids, where the 3rd grid is the Wave Hub region.

Wave modelling

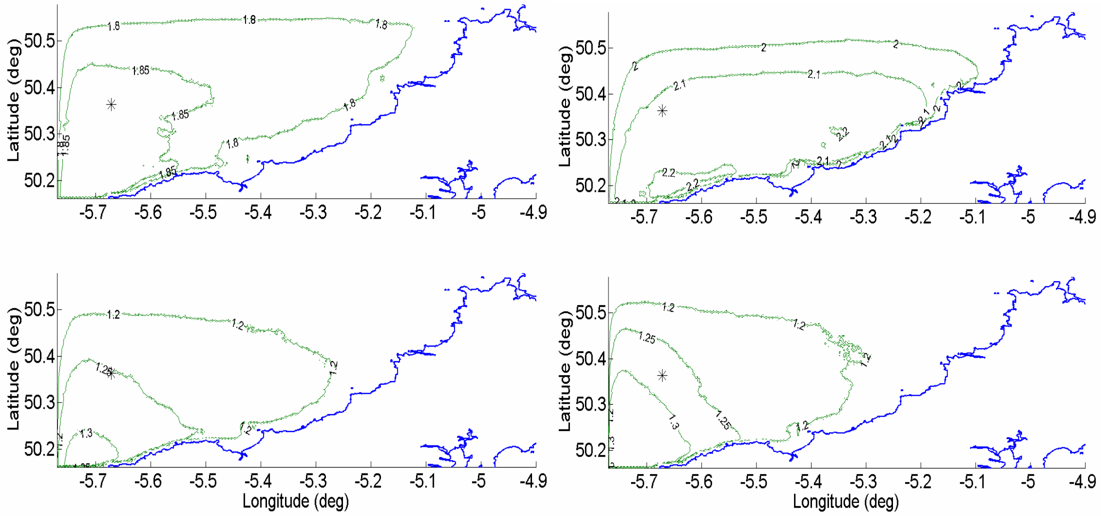

Figure 2. Significant wave height contours (m) for the fine grid domain (3): (Left) with tidal currents, (Right) without tidal currents. (Top) High tide, (Bottom) Low tide. (*) Wave Hub site.

Tidal-current modelling

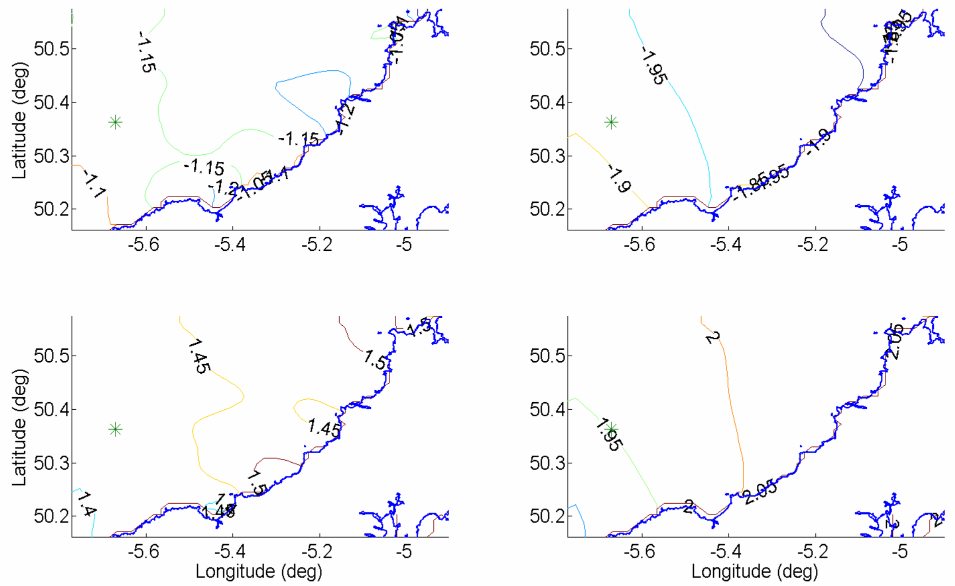

Figure 3. Predicted tide elevation by the circulation model, ROMS, forced by an analytical M_2 tidal solution at the offshore west boundary, (*) indicates the Wave Hub site. (Left) neap, (Right) spring, (Top) low, (Bottom) high tide.

4. Discussion

We found that tide elevations and tidal currents have a significance effect on the wave height at the Wave Hub area.. The incorporation of two-way wave-current coupling is being implemented. Model results will be validated against the wave and current measurements by HF RADAR, ADCP and Directional Waverider buoys during the on-going Wave Hub projects.

5. Reference

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Spectral wave modelling in tidal inlet seas: Results from the SBW project

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1. INTRODUCTION

In compliance with the Dutch Flood Defences Act ('Wet op de Waterkering, 1995'), the safety of the Dutch primary sea defences must be assessed every five years for the required level of protection. This assessment is based onthe Hydraulic Boundary Conditions (HBC) and the Safety Assessment Regulation. In order to compute these HBC at the toe of the dikes and dunes offshore, wave statistics are transformed using the spectral wind wave model SWAN (Booij et al. 1999) which is widely used for the computation of wave fields over shelf seas, in coastal areas and in shallow lakes.

2. PROJECT OBJECTIVES AND APPROACH

At present, there is a large uncertainty regarding the quality of the HBCs that can be obtained by using SWAN in the Wadden Sea, , a complex coastal system in the north of the Netherlands (and extending into northwestern Germany, and western Denmark).. In order to address this issue the SBW (Strength and Loading of Sea Defenses) Wadden Sea project was commenced in 2006 by the Dutch Rijkswaterstaat. In this project, the applicability and quality of the wave transformation model SWAN is evaluated on the basis of a number of storm seasons of measured wave data in two representative areas in the Wadden Sea, one well-shielded by a large ebb tidal delta (the Amelander Zeegat) and one more exposed to North Sea waves (near the Eems Estuary).

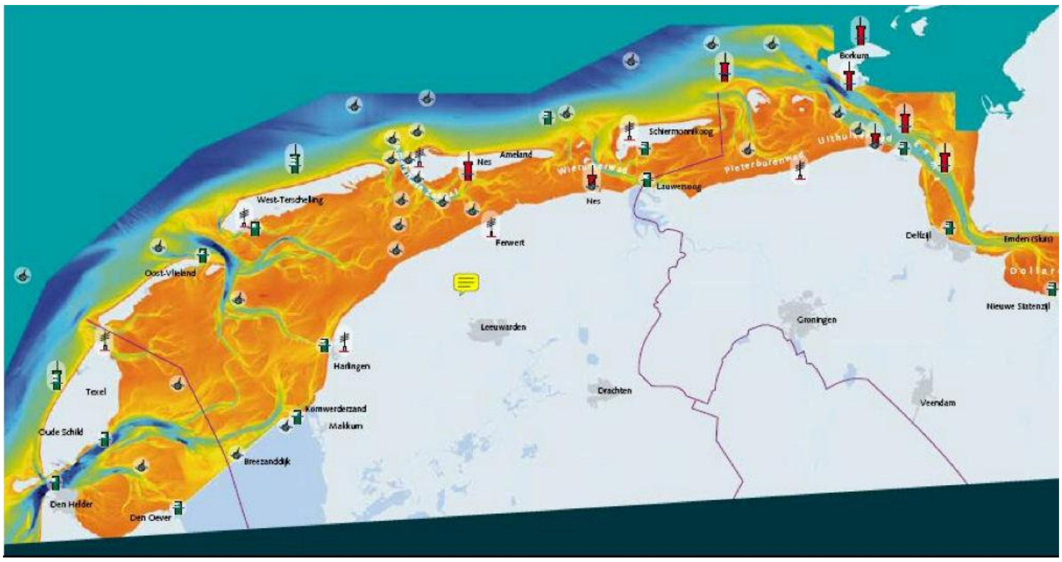

Fig.1 Map of the Dutch Wadden Sea showing measurement stations

Wind, wave, bathymetric and water level data have been obtained in a monitoring program which commenced in 2003. A number of severe storms have passed over the area since that time, providing valuable information to modellers. Hindcast studies based on this data and using SWAN in its default form have confirmed that SWAN accurately simulates the strong dissipation of offshore waves on the ebb tidal delta, so that the wave field in the Wadden Sea interior is dominated by locallygenerated wind sea developing over finite depth. However it was also shown that SWAN

- dissipates low-frequency North Sea waves, penetrating into the interior too strongly, especially when the coasts are not shielded by ebb tidal deltas,
- overestimates wave heights in opposing currents,
- and typically underestimates wave heights and periods over the shallow flats.

3. RESULTS

In the SBW-Wadden Sea project these model deficiencies were analyzed and suggestions for model improvements were proposed. The most important results obtained to date are that

- wave growth is severely affected by currents which means that wave modelling without taking (residual) currents into account will lead to large errors; Including currents resolves this issue.
- a new estimation of the breaker index on the basis of the biphase improves the prediction of wave heights over nearly horizontal beds.
- North Sea waves penetrate further to the main coast in the more exposed areas when the lower value of one of the two default settings of the JONSWAP bottom friction is applied, and refraction is limited for the low-frequency waves. If both modifications are applied the model results almost perfectly match the data at two mainland stations for one particular storm.
- a wave current interaction formulation based on wave steepness improves the results in opposing currents.

ACKNOWLEDGEMENTS

The presented work is part of the SBW (Strength and Loads and Flood Defenses) project commissioned by Rijkswaterstaat Centre for Water Management.

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Presentation title: - Modelling storm surges in the Irish and Celtic Seas using a finite element model (TELEMAC).

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Finite difference models have traditionally been used for operational storm surge forecasting in North West Europe (see Flather, 2000). In comparison to finite element models they were often easier to implement and did not contain spurious modes of sea level elevation and velocity that were often present in finite element solutions. However, these spurious modes have been removed by using simple elements and modified forms of the governing equations (Lynch and Gray, 1979). Finite element models have many potential advantages for storm surge modelling in particular the ability to have a graded mesh with spatially varying grid resolution providing high resolution in shallow water areas where accuracy of the wind stress input is most important and the tide and surge show greatest spatial variability. A finite element model (TELEMAC) of the tides in the Irish and Celtic Seas is used to hind cast a typical storm surge ‘season’ from October 2007 to March 2008 forced by the Met Office’s 12km ‘mesoscale’ weather model. The surge simulated by the TELEMAC model (3AX) could then be compared to observations at tide gauges and to that predicted by the UK operational storm surge model (CS3X). As the meteorological forcing used is the same any systematic improvement could be directly related to enhanced resolution in the TELEMAC model.

The results show that TELEMAC can reproduce the observed surge residuals reasonably accurately with RMS errors between observed and predicted residuals averaging 12cm over the season. It is also shown that on average 80% of the top five observed skew surges and 87% of observed peak residual elevation magnitudes are predicted by TELEMAC. However, there is no systematic improvement compared to the operational model. Both models generally simulate the observed surges with reasonable accuracy but significantly under predict residuals at Liverpool during large surge events. The operational model performs slightly better than TELEMAC in the Bristol Channel as the tide is locally tuned here to give more accurate total water levels. It is apparent that any benefit of resolution increase eventually becomes limited by the resolution of the forcing meteorological data and/or the bathymetry. These limitations are addressed by using high resolution bathymetry in Mersey region and forcing the model with higher resolution (4km) wind fields.

It is found that the pressure induced response of the eastern Irish Sea accounts for less than 20% of the observed surge residuals on average. However, dynamical effects may cause the pressure induced response to become much more significant particularly if the propagation speed of the depression becomes close to that of a shallow water wave and a form of travelling resonance occurs (Lennon, 1963). The dynamical response of the eastern Irish Sea is investigated by manipulating the propagation speed of the depressions in the meteorological forcing data.

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Improving Wave Boundary Conditions for a Nearshore Delft3D Forecasting System

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Delft3D is often used to provide forecasts of nearshore dynamics to US Naval forces. Typically, coupled wave-flow simulations are utilized, and boundary conditions for the wave module are gathered from a regional wave model like SWAN. The disadvantage of prescribing wave boundary conditions based on a regional model is that any error in the regional model is passed to the nearshore model. One way to combat the possibility of passing error to the nearshore model is to correct the regional model given in situ wave measurements. In conjunction with measured wave spectra, an adjoint model of the discretized SWAN equations corrects the boundary conditions of the regional SWAN model and produces a more reliable solution. Therefore, the error passed to the nearshore model is reduced. The advantages of using in situ data and the adjoint regional model to prescribe wave boundary conditions for a nearshore model are shown for an exercise that took place on Santa Rosa Island near Navarre, Florida, USA. A directional wave buoy placed just seaward of the surfzone provides error estimates in the interior of the regional model; the error estimates are propagated back to the boundaries by the adjoint and used to correct the boundary conditions ,thus, improving the regional SWAN model. The improved model provides directional wave spectra at the western offshore corner of the nearshore model domain. These spectra are used to prescribe uniform wave boundary conditions for the nearshore model. A directional wave buoy co-located at the offshore corner of the nearshore model domain confirms improved boundary conditions for the nearshore model. Data-model comparisons for the nearshore model improve significantly when the adjoint is used to improve the regional wave model solution.

Decadal long simulations of mesoscale structures in the northern North Sea/Skagerrak using two ocean models

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We consider results from two 27 year long simulation pairs derived using two different ocean models. We focus on the Skagerrak/North Sea area. Each pair consists of the two terrain-following coordinate models ROMS and MIPOM. The first pair utilizes an eddy-permitting grid, that is, a grid in which the Rossby radius is barely resolved. The second pair utilizes an eddy-resolving grid in which the Rossby radius is truly resolved. The goal is to compare the quality of the two models and the two pairs. To this end we derive statistical properties such as probability density functions and compare them with similar statistics derived from observations. Thereby we obtain insight into whether a truly eddy resolving model is required to realistically capture the mesoscale statistics. We find that eddy resolution is critical to get the mesoscale statistics correct, in particular the strength of the current jets. Our results also indicate that the improvement gained by employing the eddy-resolving grid is mostly due to a better resolved topography. In particular we find that this is the case in areas exhibiting prominent topographic features, such as the deep Norwegian Trench cutting into the heart of the northern North Sea/Skagerrak area. The results also highlights the advantage of first performing quality assurance investigations when implementing a new model for a new area.

Towards a complete study of water renewal timescales of the Scheldt Estuary
A numerical study of water renewal of the Scheldt Estuary

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Making sense of such a huge amount of information contained in present-day model outputs requires specific post-processing approaches presenting the model results in a format that is amenable to analysis. One of the strategies is to compute the timescales associated with the main processes occuring. These timescales synthesize the information hidden in the produced model results, and at the same time they give a quantitative insight into the dynamics and rate of functioning of the system.

In this study we choose to follow this strategy to perform an in-depth analysis of the water renewal processes in the Scheldt Estuary. Applying the Constituent-oriented Age and Residence time Theory (CART, www.climate.be/CART) we compute the following timescales: (i) the age of the different renewing water types, (ii) the residence time, (iii) the exposure time, and (iv) the transit time. The numerical simulations are performed by the finite element model SLIM (www.climate.be/SLIM), which allows the use of a multiscale mesh going from the river scale (10 m) to the continental shelf break (100 km). We investigate the timescales interrelations and investigate how they vary in time and space. In order to further understand this spatio-temporal variability, we try to identify the major drivers of this variability.

Influence of high resolution wind forcing on circulation in a fjord system

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The Porsangerfjord is a broad fjord located in the northern part of Norway at about 70°N. The fjord is 100 km long with a width of 15-20 km and a maximum depth of 230 m. A 60 m deep sill is situated in the inner part, while the outer part of the fjord can communicate freely with the coastal waters. The river input to the system is small compared to the total surface area. Most of the fresh water enters the fjord during the short summer season, contributing to a seasonal stratification from May to October. In this period local wind can cause upwelling/downwelling inside the fjord and set up a cross-fjord gradient.

The Regional Ocean Modeling System (ROMS) is applied to the Porsangerfjord with a 400 m horizontal resolution. 35 vertical sigma layers are included, resulting in a resolution of the surface layer between 28 and 46 cm. The open boundaries are nested one-way with a 4 km operational model run by the Meteorological Institute, together with eight tidal components. The atmospheric forcing is extracted from the ERA interim dataset with a 75 km resolution. An atmospheric downscaling was performed in addition using the atmospheric Weather Research and Forecasting model (WRF) with 1 km resolution in the study area. The influence of high resolution wind forcing on hydrography and circulation will be discussed.

Forcing of mean flow and turbulence by waves in homogeneous zone of Iroise Sea

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The Iroise Sea is located at the western end of Brittany (France). It is a shallow area with a mean depth of 110 m. The study of the surface circulation is motivated by the permanent and high risk of accidental pollution. In Iroise Sea the maritime traffic pass through an area where rough sea states and weather conditions are associated with strong tidal currents: the tidal currents are around 1.5 m/s close to the islands and may reach a maximum of 4 m/s during spring tides. Far from the coast the circulation is dominated by wind stresses and waves. The phenomenon is amplified when the water column is stratified. We want to look at the relations between waves, currents and vertical turbulence. Our study focuses on an area of 120 m water depth west of Ushant island (48°28'N and 5°30'W) where currents are homogeneous in the horizontal directions away from bathymetric asperities.
For validating the model we use surface velocities measured by HF radar. Antennas of radar HF are localized at Porspoder and Cléden Cap Sizun (visible on figure 1). A homogeneous zone add been previously analysed by F. Ardhuin and al. [1]. Compared to other apparatus, radar HF gives an accurate measure of the surface velocity: what we are looking. Radar data had been compared to numerical simulation by H. Muller and al. [4][5]and they found some differences when looking at the Lagrangian velocity.

In order to improve the numerical simulation we focus on:
- Stokes-Coriolis effect (Hasselmann force [3]) on the mean current.
- Surface boundary condition on the mean flow parameterized by waves age and direction.
- Production of turbulence induced by the vertical structure of the Stokes velocity in the TKE equation.
- Wave breaking parameterized through surface fluxes of TKE in the prognostic k-equation.

This model is inspired from the approach of N. Rascle and F. Ardhuin [6] which is adapted to Gaspar, Grégoris and Lefevre 1990 [2]turbulence closure. We use an algebraic formulation of the energy flux from waves to turbulence and take into account the production of turbulence induced by the Stokes drift. The Gaspar, Grégoris and Lefevre turbulence closure was chosen because it was proven by H. Muller et al. [4] to be well suited to the Iroise sea oceanic flow conditions. Interactions of this parametrisation with other turbulence model (up to two-equation model) were also tested and results will be briefly described.
The wave effect on circulation is greatly influenced by the thermal stratification: for have several cycle of stratification we perform a two year simulation. Current time series are analysed by the help of rotary spectra. Results of the 1D vertical simulation, full 3D simulation and radar data are compared. The over estimation of inertial frequency in 1D vertical models is illustrated and some parameterization proposed. We show that the Hasselmann force, waves breaking and production of TKE by Stokes velocity significantly increase the simulated surface velocities.

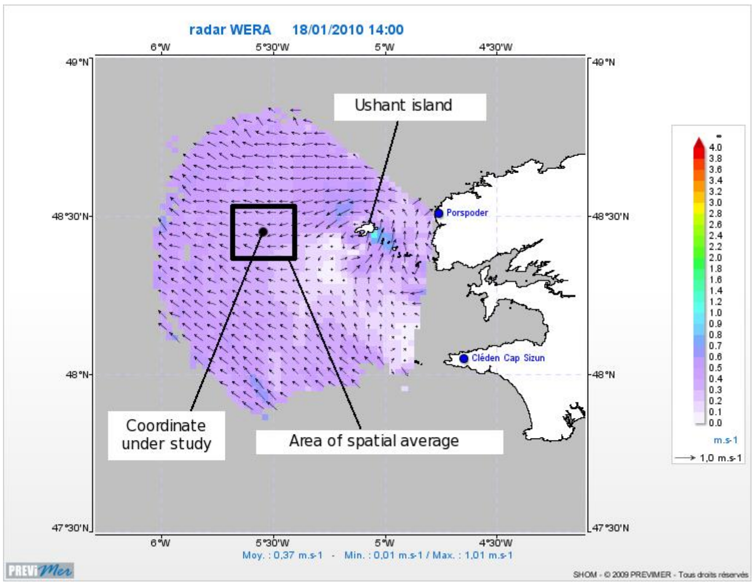

Figure:Intensity and direction of the current measured by HF radar. The HF radar antennas are located at Porspoder and Cléden Cap Sizun (blue dots). Picture from http://www.previmer.org and data from SHOM (french hydrographic service).

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Effects of Tide Flats on Estuarine Circulation and Plume Dynamics

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Tide flats near the mouths of estuaries play an important role in mixing, stratification and estuarine circulation. However, investigating the effect of tide flats on estuarine circulation and plume dynamics with field data or numerical models remains a challenge. It is difficult to accurately characterize the bathymetry and geometric features of small scale tidal channels in tide flats. The rapid development of advanced unstructured-grid coastal ocean models in recent years along with availability of high resolution Lidar bathymetry data makes it possible to characterize the complex geometry in estuarine tide flats accurately. In this paper, we present a high resolution hydrodynamic model developed using the 3-D unstructured grid finite volume coastal ocean model (FVCOM) to study the estuarine circulation and plume dynamics in the Whidbey Basin of Puget Sound in the northwest coast of North America. Whidbey Basin consists of three largest rivers in Puget Sound and associated large tide flat regions present near the mouths of the estuaries. The model was calibrated with observed data for water level, currents, salinity and temperature. The effects of tide flats on estuarine circulation, stratification, and river plume dynamics are investigated with the model. Numerical experiments showed that tide flats play a critical role in controlling the dispersion of river plume, vertical mixing and stratification, and the transverse circulation in the estuaries.

A CO_2 uptake model for the Barents Sea

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The ocean plays an important role in the biogeochemical cycling of carbon. The North Atlantic and the adjacent marginal seas are considered to be a particularly important area for atmosphere-ocean CO_2 fluxes. A significant sink of atmospheric CO_2 are areas of deep water formation and convection. Shelf seas like the Barents Sea have been identified as efficient deep water formation regions due to intense atmosphere-ocean heat exchange and sea-ice formation. The sea-ice formation and consequent brine release produce dense high salinity shelf water (S>34.75 psu), which spills toward the deep sea, thus isolating the absorbed carbon. Recent studies have also showed additional oceanic uptake of dissolved inorganic carbon (C_T) during the sea-ice growth (e.g. Omar et al., 2005).

A new and improved setup of the regional coupled ice-ocean model Hamburg Shelf Ocean Model (HAMSOM) is applied to the Barents Sea for the period 2000-2007. Applying a total variance diminishing (TVD) scheme is shown to improve the model's ability to resolve fronts in temperature and salinity, important for localized water mass modifications. The model also reproduces the Atlantic Water inflow in the south and the cold outflow toward the Arctic Ocean.

To investigate the oceanic CO_2 uptake in the Barents Sea a carbon system module has been implemented, which applies empirical relationships between sea surface temperature and surface water CO_2 fugacity, and between sea surface salinity and total alkalinity. Calculation of the air-sea CO_2 flux was done applying the concentration gradient between the atmosphere and the ocean, and wind-speed. The effect of biology on the carbon system was parameterized using a mean seasonal cycle of nitrate.

Data from the Arctic Ocean (Rysgaard et al., 2009) shows that dissolved inorganic carbon in sea-ice, C_{Ti}, is highly correlated with the bulk salinity, suggesting that C_T is rejected from growing sea-ice into the water column. Based on these data a linear relationship between C_{Ti} and the sea-ice salinity has been formulated and included in the model together with a new time dependent brine rejection scheme.

The present study aims to evaluate the strengths and weaknesses of the simplified carbon system model using available observations. Furthermore, the Barents Sea as a carbon sink is investigated with respect to variability in the air-sea exchange and regional hydrography. Carbon uptake during sea-ice formation is quantified and results are discussed with respect to observed decreasing sea-ice cover in the Barents Sea and Arctic Ocean.

Assessment of an oxygen prognosis model for the North Sea - Baltic Sea transition zone

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The bottom water of the North Sea – Baltic Sea transition zone suffers from seasonal hypoxia, usually during late summer and autumn. These events have large impact on the marine ecosystem and are an important measure of the water quality. However, to model the subsurface dissolved oxygen concentrations is a major challenge. The difficulties originate from both inaccurate descriptions of physical processes such as vertical mixing and deep water flows and from the biogeochemical models having a weak resolution of the oxygen consumption below the euphotic zone. As a step towards improving dissolved oxygen modelling in this area a simple oxygen consumption parameterisation has been implemented into DMI's circulation model CMOD. CMOD is a 3D z-coordinate model covering the North Sea and Baltic Sea with a fine resolution nested domain for the transition zone. The annual oxygen consumption in the parameterisation is determined from the average primary export production in the surface layer and the bioavailable organic material is assumed to be constant through out the year. The oxygen sink is divided into three different temperature dependent processes; pelagic respiration, benthic respiration and diffusive oxygen uptake by the sediment from microbial respiration.

The above forms an oxygen prognosis model which is able to predict the seasonal pattern of the dissolved oxygen. This study provides calibration and a quantitative assessment of the model. The results show that the oxygen depletion events are well described by the model. The areas affected by hypoxia and the timing of these events are in agreement with observations. Interannual variation in oxygen concentrations is resolved with the physical model by water temperature and ventilation of the bottom water through wind mixing and inflowing Skagerrak water. The good agreement between model and observations indicates that the assumption of constant bioavailable organic material in the bottom water is valid for timescales of years. It implies that oxygen conditions in the North Sea – Baltic Sea transition zone is to a large extent regulated by physical processes such as wind, advection and water temperature.

The Impact of future sea-level rise on the European Shelf tides

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Sea-level rise (SLR) presents a challenge for those tasked with predicting extreme water levels at the coastline during the next 100 years. Tides, Storm Surges, Waves and SLR are taken into account when calculating estimates of extreme water levels which are then used to formulate appropriate and cost effective coastal flood defence strategies which ultimately define the design specification of the coastal defences. It is therefore vital that these four variables are properly quantified to ensure accurate estimates of water levels.

This presentation summarises a paper quantifying the effect of SLR on the tides of the Northwest European Continental Shelf. Measurements show sea-level has risen by 1.7mm/yr during the 20th century and 3.1mm/yr during the last decade. Estimates of SLR in the next 100 years have a wide range of uncertainty, with IPCC projections ranging from 0.18-0.59m and other research suggesting an upper limit of 2.0m; as used by the Thames Estuary 2100 project. A 2.0m SLR scenario is therefore tested, along with a 0m control run for the present day tides and a 10m SLR perturbation to test the response of the model.

The investigation uses the Delft3D Dutch Continental Shelf Model (DCSMv5) in depth averaged mode to solve the shallow water equations with the tidal forcing prescribed in deep water along the open boundaries. Simulations were made with tidal forcing for the M2 constituent only and for a set of 10 tidal constituents from the semidiurnal and diurnal species. Additional validation of the DCSMv5 was performed by comparison with cotidal charts based solely on observations. To assess the change in amplitude of the M2 tide with SLR coamplitude plots from the different scenarios were compared. The coamplitude difference plots show both increases and decreases in tidal range across the domain. An individual SLR scenario showing both increases and decreases in tidal range suggests an alteration to the spatial characteristics of the energy dissipation. Comparing the cophase plots shows migration of the tidal amphidromes with SLR, some near shore amphidromic points transition from rotary to degenerate and vice versa. The migration of these amphidromic points results in changes in tidal range at the coastline and can be explained by the changing balance between friction and the Coriolis force. The faster wave propagation due to the increased depth can be seen in the changes in tidal phase with SLR. Under the 2m SLR scenario particularly significant decreases in tidal amplitude were found in the Gulf of St. Malo and the River Severn, with increases in the southern German Bight and the WaddenSea. It is proposed that the changing tidal amplitudes are the result of changing energy dissipation due to bottom friction and changes in wavelengths altering the tidal resonance characteristics.

These changes in tidal range with SLR have implications for regional extreme water levels, directly in terms of the increased or decreased tidal range and indirectly by affecting the regional surge characteristics through the non-linear tide-surge interaction. Currently the majority of coastal impact studies incorporate SLR in their assessment by adding it in a linear way after estimating the other variables. This paper puts into question the validity of this approach as tidal amplitudes are shown to be dependant on the SLR according to a non-linear and spatially variable relationship.

Further implications of these changes in tidal range with SLR can be conceived including alterations to the kinetic energy available for tidal power generation, alterations to the sediment dynamics impacting on a port's dredging requirements, ecological impacts on the shoreline through changes to the height and range of the intertidal zone and changes to the tidally induced fronts impacting primary productivity offshore.

The presentation will conclude by looking briefly at some of the ongoing research on this topic including: the response of the global tides to SLR, the importance of including coastal recession and non-uniform SLR in the simulations as well as further understanding of the mechanisms behind the changing tides.

Implementation of an operational model to simulate pollutant transfers in the Toulon area, south of France

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The bay of Toulon is located south of France. Its geographic and bathymetric configuration gives it a specific hydrodynamic behaviour: an enclosed and not very deep basin (Petite Rade) separated by a semi-closed seawall from an external basin (Grande Rade), open to the Mediterranean Sea coastal circulation and connected to deep water through a canyon at its Southern boundary (Figure 1).

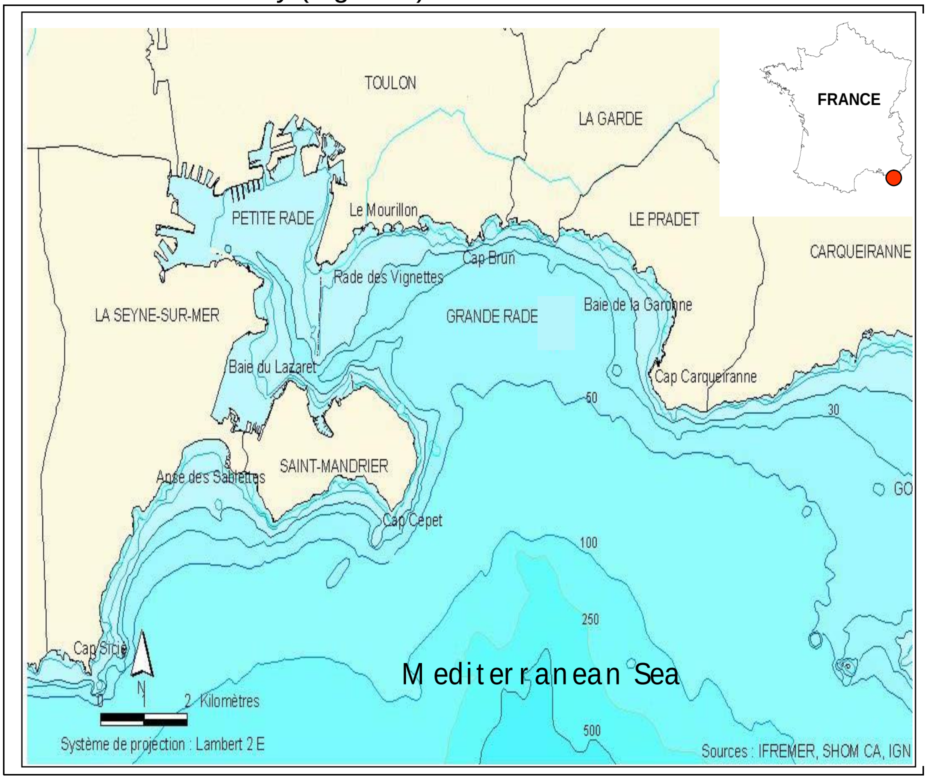

Figure1 : Toulon bay situation

Chronic or accidental inputs of pollutants can occur in this marine environment. French institutes IRSN (Institut de Radioprotection et de Sureté Nucléaire) and IFREMER (Institut Français de Recherche pour l'Exploitation de la Mer) jointly develop an operational tool to simulate the marine dispersion and accumulation of specific pollutants (due to urban contaminants inputs or accidental radioactive release originating from Toulon military harbour) in this area.
Hydrodynamic forecasts are performed using the MARS3D model (Lazure et Dumas, 2008). The model is implemented on a 100*100 meters grid on the horizontal, with 30 vertical sigma levels. Initial and boundary conditions are generated from the 3-hourly outputs of the operational MARS3D configuration of the Western Mediterranean Sea (1.2 km grid). Waves are modelled on the 100m grid with the SWAN model (Booij et al., 1999). Wave's boundary conditions are calculated with the WW3 model (Tolman, 2002). The sediment behaviour modelling is coupled with MARS3D, based on the model proposed by F. Dufois (2008) for the gulf of Lion. Finally, radionuclide decay and partitioning between water and suspended matter are modelled in the water column.

The first modelling results lead us to choose a measurement strategy in order to fit and validate local hydrodynamic and wave models. Two current profilers were installed to perform a record of water current velocities and directions along a vertical profile, and of wave heights, periods and directions. Current measurements transect at southern boundary were also performed to evaluate fluxes. Few model adjustments were found to be necessary when comparing the first results.
One of the model's applications concerns the modelling of radionuclide dispersion. Different accidental release scenarios are taken into account, by bringing atmospheric or liquid discharge off into local marine waters. The model is used to predict radionuclide spatial and temporal dispersion and sediment accumulation for a set of realistic meteorological situation. The first simulations underline the trapping function of the 'Petite Rade' sediments for the most reactive radionuclides, and the importance of the forcing by the bathymetry and the wind. Such results have to be analyzed and conclusions included decision-making support usable in post-accidental situation.

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Numerical modelling of organic waste dispersion from a marine fish farm *

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The impact of organic waste from the marine fish farming on the marine ecosystem has become a concern that needs to be addressed to ensure sustainable and environmentally friendly aquaculture production. Good modelling tools for studying, managing, assessing, and predicting this impact are still not available for the fish farm industry and the associated area planning.

In this study a three-dimensional particle tracking routine is coupled to a terrain following model to investigate the deposition of fish farm particulate matter on the seabed, mainly uneaten food and fish faeces. The particle tracking model uses the local computed flow field for advection of particles and random movement to simulate the turbulent diffusion. Each particle is given a settling velocity drawn from a normal distribution according to sinking velocity measurements of faecal and feed pellets. An idealized fjord is the model domain with a single fish farm. The model is forced by tidal currents.

Features of the deposition footprint such as its shape/size, and the maximum accumulation due to variations in bottom topography will be presented.

Effects of transboundary nutrient transport and riverine nutrient loading from a phytoplankton transport model of the North Sea

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The transport of watermasses, nutrients and the consequent growth and decay of phytoplankton are part of the fundaments of the marine ecosystem. Understanding these processes and their interrelations is therefore key to effective and sustainable management of shelf seas such as the North Sea. Numerical models that describe these processes are a powerful tool in gaining insight in the functioning of the coastal system, as well as providing the basis for policy advice. One organisation that is explicitly also using numerical models as input to quality status reports and policy design for mitigating eutrophication of the North Sea is OSPAR.
In this presentation, the numerical phytoplankton and waterquality Delft3D BLOOM is applied to assess the impact of various reduction scenarions of riverine nutrient concentrations for the OSPAR Eutrophication Committee. This leads not only to well-founded advice but also to more scientific insight in the combined effect of turbidity, nutrient concentrations, residual transport and vertical mixing on the phytoplankton abundance.
Extension of the model with a tagging functionality enables to identify substances by their location of entrance in the model domain. From this functionality additional insight is gained in the relative importance of various nutrient sources to the nutrient pool, plankton community and sedimentary system. In the presentation, for example, the differences between the fates of phosphorus and nitrogen are discussed. Also the differences between various areas within the North Sea and between seasonal cycles are considered.

Does turbulence help sinking phytoplankton species to survive?

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A long-standing issue of biological oceanography is the question as to how sinking phytoplankton species manage to persist. The present study focuses on one of the numerous aspects of this puzzle, i.e. the role of turbulent mixing. In this respect, under the assumption that hydrodynamics is horizontally homogeneous and time independent, we consider the downward flux of particles with negative buoyancy leaving the euphotic layer. The direct — or forward — mathematical model thereof is believed to admit no closed-form solution. However, the adjoint problem allows for various timescales to be derived rather easily. The latter depend on the vertical coordinate only. One of these timescales may be viewed as the residence time, i.e. the time needed to hit for the first time the boundary of the domain of interest. A second timescale, termed "exposure time", is a measure of the time spent in the euphotic layer. The relevance of these timescales for addressing the abovementioned issue is discussed in detail, leading to the conclusion that estimating the exposure time is probably the best approach. Interestingly, the exposure time increases if the eddy diffusivity increases, indicating that turbulence causes settling particles to stay longer in the domain of interest.

It may be even more appropriate to evaluate the amount of light that sinking particles are exposed to. This approach, which is rather novel as opposed to estimating residence or exposure times, relies on a slight modification of the adjoint problem from which the previous timescales are obtained. Analytical solutions are established, showing that the radiative energy received increases as turbulence intensity is enhanced.

All of the theoretical results obtained suggest that turbulence definitely helps sinking phytoplankton species to survive.

Water and ecological quality in the Aljezur coastal stream (Portugal)

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Water and ecological quality in coastal areas is a matter of concern in Europe and worldwide, as reflected in some European Directives (e.g. European Water Framework and Bathing Water Directives). Therefore, integrated tools that allow the evaluation of the water and ecological quality of surface water bodies are useful to support their sustainable management. This study aims at extending, validating and exploring a water quality and ecological model (ECO-SELFE, Rodrigues et al., 2009) to understand the dynamics of the Aljezur coastal stream (southwest coast of Portugal), focusing on different water quality parameters and taking advantage of four recent detailed field campaigns that included synoptic measurements of physical (water levels, currents, salinity, temperature and bathymetry), chemical (dissolved oxygen, ammonium, phosphate, nitrate and silicate) and biological quantities (chlorophyll a, Escherichia coli and enterococcus).

ECO-SELFE is a coupled 3D hydrodynamic and ecological model which targets river to ocean scales (Rodrigues et al., 2009). Previous versions of ECO-SELFE include the simulation of the carbon, nitrogen, phosphorous, silica and iron cycles for several variables (zooplankton, phytoplankton, dissolved organic and inorganic matter, inorganic nutrients and dissolved inorganic carbon), but the oxygen cycle was not explicitly solved by the model. Thus, the first extension of the model included the oxygen cycle, since dissolved oxygen is one of the main indicators for the evaluation of the quality of water bodies. To allow the simulation of this cycle, two new state variables - dissolved oxygen and chemical oxygen demand - were added to the model. The processes considered in the oxygen cycle are: the gross primary production, the respiration of the community (zooplankton, phytoplankton and bacterioplankton), the pelagic chemical reactions and the reaeration. Because the study area is used for recreational purposes, fecal contamination is also a matter of concern in the study of the water quality of the stream. Therefore, a second extension of the model for the inclusion of a new module for fecal contamination simulation was done, which can run together or independently of the ecological module. For the simulation of the fecal contamination two new state variables were added – Escherichia coli and enterococcus. Several hypotheses for the simulation of these microorganisms were evaluated in the model, which was done in parallel with recent laboratory studies of the mortality of Escherichia coli and enterococcus.

The extended ECO-SELFE was validated in the Aljezur coastal stream (SW Portugal) using different measurement periods (September and May), which allowed the evaluation of different environmental and seasonal conditions. The evaluation of the spatial dynamics was also possible since data were measured at several stations located along the stream, from freshwater to marine conditions. Results illustrate the robustness and validity of the model and allow for a preliminary analysis of the water quality dynamics of this system, in particular of the influence of the marshes.

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Rodrigues, M., Oliveira, A., Queiroga, H., Fortunato, A.B. and Zhang, Y.J. (2009). Three-dimensional modeling of the lower trophic levels in the Ria de Aveiro (Portugal), Ecological Modelling, 220 (9-10), 1274-1290.

Modelled variability of primary and secondary production in the North Sea

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The North Sea has for a long time been recognized as a productive area in terms of biomass, and as important fisheries for the countries bordering the North Sea. There is therefore a strong interest in understanding the North Sea ecosystem and the variability of the ecosystem. Since oceanic observations are time consuming and expensive, ocean models are important to supplement the knowledge gained from observations. The same applies to the marine ecosystems. The lowest trophic levels are, at least compared to higher trophic levels, simple to model because they to a good approximation can be modelled as passive drifting particles.

The 3-D coupled physical-biological model ECOSMO(ECOSystem MOdel) has previously been used to study the seasonal cycle of primary and secondary production and biomass in the North Sea. The model was found to be able to describe both temporal and spatial features satisfactory.
Knowing that the model performs reasonably on a seasonal scale, it is now used to study interannual variability. Skogen et al. estimated an interannual variability of annual primary production of about 15 percent, with locally higher values. To investigate the interannual variability the ECOSMO was integrated from 1980 to 2004, with a five year spin-up period.

The first model experiment was done by re-initialising the biological and chemical variables to climatological values at the beginning of each year. However, with this setup the interannual variability is very low. This lead to a second experiment, where the model run was performed continuously, which increased the interannual variability. The difference between the two setups were found to be significant. However, when using North Sea averages, the auto-correlation is low for phytoplankton and zooplankton biomass, both for yearly and monthly anomalies. but some features of the biological or chemical characteristics of the North Sea ecosystem must be retained from one year to the next.

To further increase the interannual variability, as well as the complexity of the model, the remineralization of dead organic material was made temperature dependent using a Q10 parameterisation of the temperature dependence. Since the degree of freedom increased with this approach, a parameter or sensitivity test was performed by using two extremes of the remineralization rate, yet still within the estimates given in literature. The results indicated strong sensitivity of primary and secondary production with respect to the remineralisation rate.

Comparing the impacts of different atmospheric forcings on the performance of a coupled bio-physical model: A case study for the North and Baltic Sea ecosystem

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A coupled bio-physical model (ECOSMO) was applied to the North and Baltic Sea system in order to identify the importance of abiotic and biotic interactions on the seasonal and inter-annual dynamics of lower trophic level dynamics. Since long-term variability of both, North and Baltic Sea ecosystems, has been shown to be strongly related to climate variability, it is obvious that ecosystem components are influenced by atmospheric parameters either directly (e.g. temperature, solar radiation) or indirectly (e.g. wind forcing). Previously performed what-if scenario runs with the model emphasized specifically changes in short wave radiation and the wind forcing to impact spatial and temporal pattern in primary production of the North Sea. Where a 20 % change in short wave radiation caused a change in average primary production of up to 30 % during the summer month.

Hence the choice of the atmospheric model forcing might become crucial for simulating ecosystem dynamics. Two different reanalyses, one from the National Centre for Environmental Prediction/National Centre for Atmospheric Research (NCEP/NCAR) and one from the European Centre for Medium-Range Weather Forecasts (ECMWF), are typically used in equivalent model studies. Both datasets provide atmospheric parameters for the last centuries beginning in 1958. The quality of both datasets was previously assessed in a number of studies, and comparisons indicating reasonable differences especially in radiation parameters and precipitation rather than in 2m air temperature.

In this study we will i) assess the differences between the two re-analyses for the relevant parameters in the North and Baltic Sea area and ii) present results from long-term hind casts (1959-2009) model simulations utilizing each of the two atmospheric datasets. The focus of the analysis will specifically be on the underlying processes that link atmospheric parameters to lower trophic level dynamics and how the inter-annual variability in the simulation results is related to trends in the respective atmospheric dataset.

A sea drag relation for hurricane wind speeds

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Numerical weather prediction models generally use the traditional bulk relation for wind stress, which is characterized by a drag coefficient. Computation of the drag coefficient is usually based on the Charnock relation, which has been proven to be an accurate formulation for many meteorological as well as oceanographic applications. According to the Charnock relation the magnitude of the commonly used 10-meter drag coefficient increases monotonically for increasing 10-meter wind speed. However, recent observations indicated that the magnitude of the drag coefficient levels off from a wind speed of about 30 m/s and then decreases with further increase of the wind speed. The reason for this is that for very high wind speeds the stress above the air-sea interface starts to saturate. It is argued that the effects of sea spray are responsible for this phenomenon.

In this study the drag formulation by Makin (2005) is tested, which incorporates the decrease in the drag coefficient from a wind speed of ~30 m/s. This parameterization is based on the Charnock formulation, however, with a correction term that represents the reducing effects of sea spray. The parameterization is implemented in the atmospheric model HIRLAM. With HIRLAM the tropical storms Katrina and Ivan in the Caribbean are simulated, with both the standard and the changed drag relation. Results from both simulations are compared with observational data in order to verify whether the adjusted drag relation is an improvement for hurricane modeling. Furthermore, with the meteorological data from HIRLAM the two tropical storms are simulated with the Delft3D storm surge model. Hence, criteria for comparison are the 10-meter wind speed, the sea level pressure and the hurricane track but also the sea level height and surge from Delft3D.

List of participants in alphabetical order
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Julien Chalumeau	6-1	47	University of La Rochelle	France
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