Project plan for implementation of interfacing between Baltic scale models to local (coastal area) models

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Project plan for implementation of interfacing between Baltic scale models to local (coastal area) models

(HORIZONTAL COUPLING OF BALTIC SEA MODELS)

T. Soomere[1], S. Dick[2], M. Gästgifvars[3], V. Huess[4], J.W. Nielsen[4]

[1] Marine Systems Institute, Tallinn University of Technology (MSI), Estonia
[2] Federal Maritime and Hydrographic Agency (BSH), Germany
[3] Finnish Environmental Institute (SYKE), Finland
[4] Danish Meteorological Institute (DMI), Denmark

This report describes possibilities of coupling of circulation, water level, wave and ecological models with different resolutions and/or based on different descriptions of the underlying physical processes. Existing experience of one-way and two-way coupling in operational oceanographic models is discussed. Details of models that may be used as the large-scale counterparts of the Baltic Sea basin as well as planned local operational models are listed. Areas that may need two-way nesting are identified. Some advanced techniques for model coupling and their relevance for the Baltic Sea conditions are discussed.

Contents

1. Introduction: what is horizontal coupling

Owing to the limited capacity of even the most contemporary and future computers, it apparently remains impossible to cover the whole ocean with a high-resolution model with a grid step that is necessary to resolve sea state properties in the small subbasins or straits with a complex geometry and bathymetry. This feature dictates that, inevitably, modellers working for the needs of specific sea areas must use coupling and nesting schemes in both scientific and operational models. Large basins (where the sea state properties either vary insignificantly of where the detailed information about their behaviour is not needed) are covered with a coarse grid whereas in areas of particular interest much better resolution might be necessary. The factual choice of the resolution and the quality of input information for each counterpart reflects the balance between the cost of computations, the resolution required and the operational needs.

A more fundamental problem is that in different scales different physical processes may prevail. This is a built-in problem in atmospheric models where discussions between the hydrostatic and non-hydrostatic approach have a long history (e.g. Männik et al., 2003). In circulation models sometimes it may be reasonable to construct only two-dimensional model for large basins with relatively flat bottom, but three-dimensional effects must be included into sensible coastal models. The behaviour of single wave crests is irrelevant in large-scale spectral wave models but frequently decisive in coastal applications.

In order to account for this feature of the dynamics of marine systems, models containing either different parametrizations of physical processes or even based on fundamentally different descriptions of certain mechanisms may be necessary to adequately represent several features of the behaviour of oceanographic variables. Information exchange between models of different type is a completely nontrivial question. However, it seldom arises in operational oceanography and is not discussed in this report.

Another argument for horizontal coupling is that some countries located in specific parts of the Baltic Sea may consider not reasonable to construct and run its own large-scale models (that must be feeded with relevant data from other regions anyway). Within the Baltic-wide cooperation, it might be much more beneficial to use data from operational Baltic Sea models run in other countries or institutions, and to run its own model in some limited sea area. Such a cooperation might greatly reduce costs of operational forecast in countries with relatively small extension of coastal line (Lithuania, St. Petersburg region). Also, this scheme might be useful in case when high-resolution model is needed only in some emergency cases.

2. Possibilities of horizontal coupling

A classical example of horizontal coupling is a nesting scheme. Typically, the sea state over a maximally large area is first calculated with the use of a relatively coarse grid. Based on these results, input information for another model (normally but not necessarily) of the same type but with a higher resolution and covering a specific sea area is constructed. This procedure is sometimes repeated 4-5 times until the necessary resolution is achieved.

Models with a variable grid size or, more generally, using unstructured grids, may, under some conditions, also be called coupled models. This approach is mostly use to-day in scientific models (e.g., Albiach et al., 2000; Hagen et al., 2001). However, we do not consider this type of models because there is no specific interface between model counterparts.

In operational models run for the whole Baltic Sea area, it is typical that the models (1) are of the same type; (2) no open boundaries within the Baltic Sea areas are used and (3) mostly, one-way information flow exists (except possibly for circulation models in the Danish Strait area).

However, for scientific purposes many other schemes are known. Models are not necessarily of the same type. For example, in many cases large-scale circulation model of the whole Baltic Sea is 2D whereas local models are 3D (Elken, 2001). In some studies, wave model WAM is implemented in the two first steps of a model hierarchy (with grid step of 3 nm for the whole Baltic Sea and 1 nm for the eastern sector of the Baltic proper). The third step is the NSW model from MIKE 21 and the fourth step is the Boussinesq model from MIKE 21 (Soomere, 2001; Liiv and Liiv, 2001).

3. Experience of PAPA partners with horizontally coupled operational models

To-day, horizontally coupled operational models are routinely in use in four parnter institutions (Table 1). The details of this models are listed in Appendix (Table A1).

Table 1. Horizontally coupled operational models

Institution	Circulation models	Output to	Wave models	Other	Input from
BSH	BSHcmod (BSH circulation model)			BSHdmod (BSH dispersion model)	
RDANH			Wave model		
SMHI	3D circulation	SYKE			
DMI	BSHcmod		WAM cycle 4		
FIMR			WAM cycle 4	Water level	
SYKE	OpHespo circulation				SMHI

4. Experience with two-way coupling of circulation models at BSH

The BSH has run an operational hydrodynamic circulation model of the North Sea and Baltic Sea, with two-way nesting in the German Bight and western Baltic, since early 1992. Until then, the model resolution in the transition area between the North Sea and Baltic Sea had been 6 nautical miles. As the width of the Danish Straits varies from 0.5 to 7 nautical miles, the formerly used resolution allowed only coarse modelling of the water exchange between North Sea and Baltic.

In 1992, a one-nautical-mile resolution was introduced covering the area of Little Belt and Great Belt, which in 1999 was extended further north and east to include the Sund area as well. In other parts of the Baltic Sea, a grid spacing of 6 nautical miles was maintained. Two-way nesting means that data on water levels, transports, salinity, temperature and ice properties are exchanged between both grids at every time step (Dick et al., 2001).

Comparisons of measurements and model data have shown that the higher resolution of the Danish Straits has led to a qualitative improvement of water exchange simulations of the area between the North Sea and Baltic which, consequently, has also improved the quality of water level predictions for the western Baltic. It is obvious that many topographic features have been resolved by the smaller grid spacing which had not been reproduced by the 6 nm grid used in the past. Figure 1 shows an example of computed surface currents and water levels on 25 March 2004, 03:00 MET. Southerly surface currents of up to 1 m/s caused by fresh northerly winds had been computed for the Great Belt area. The model also simulates several eddies in small bays and represents the high horizontal velocity shear in the straits more realistically. Both features of the current field have a major influence on dispersion processes. A correct computation is important when simulating the drift and dispersion of pollutants like oil or disolved chemicals.

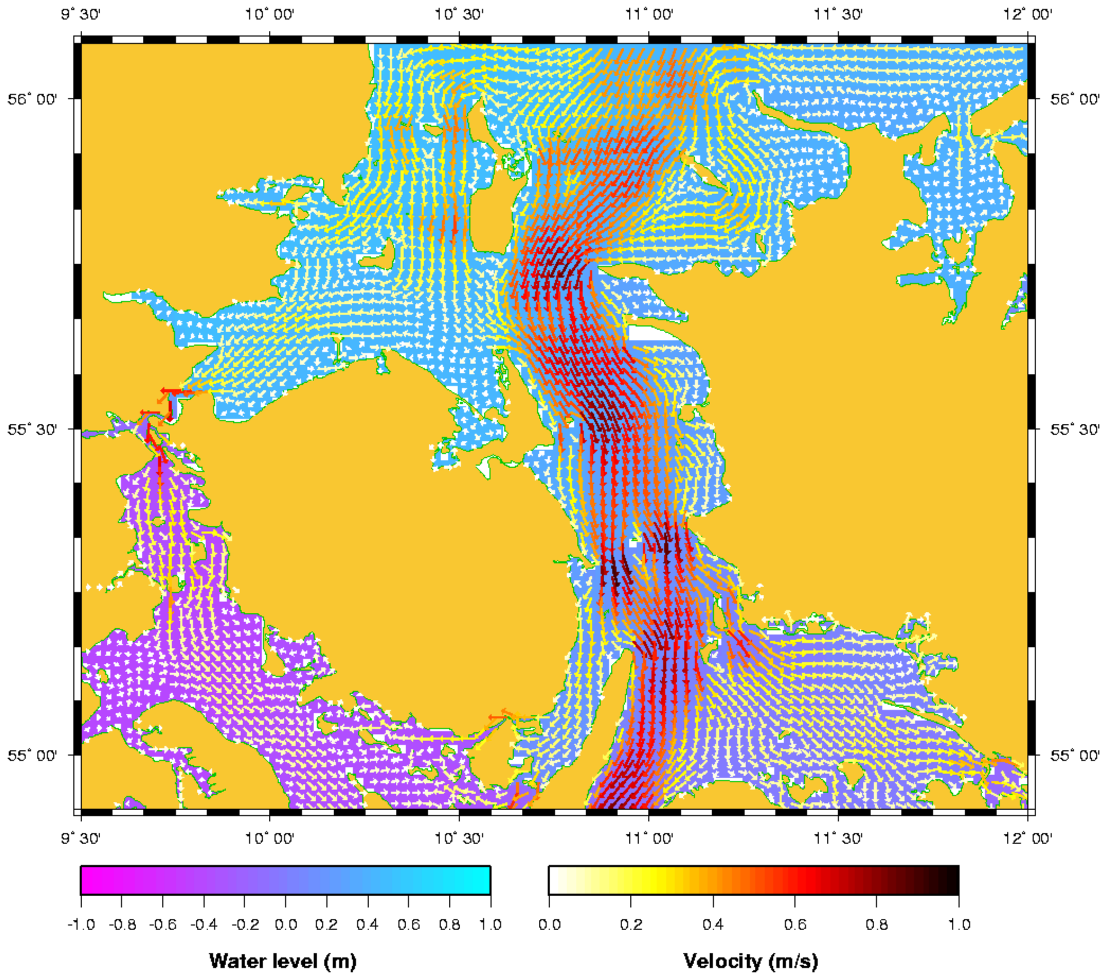

Fig. 4.1. Computed water levels and surface currents of BSH circulation model in the Danish Belt area (nested 1 nm grid) for 25.03.2003, 03:00 MET.

On the other hand, Figure 1 reveals that there still is a need for an even higher resolution. Especially the Little Belt is represented by just a few grid cells, which causes high artificial friction and a reduction of current velocities. A comparison of measured and computed velocities at the Danish station 'W26' shows that in the Great Belt area, the mean currents and current directions generally are predicted quite well by the BSH model. However, the model tends to underestimate current velocities. To improve the results, the BSH is now working on a new model version with 0.5 nautical mile grid spacing in the nested areas which will also better resolve the complex topography in the Danish straits.

5. Experience with one-way coupled wave model in DMI

The DMI has run an operational wave model of the North Sea - Baltic Sea since 1999, with a spatial resolution of 1/6°. The model is WAM Cycle4, a 3rd generation wave model that is being used in operational and scientific applications throughout the world.

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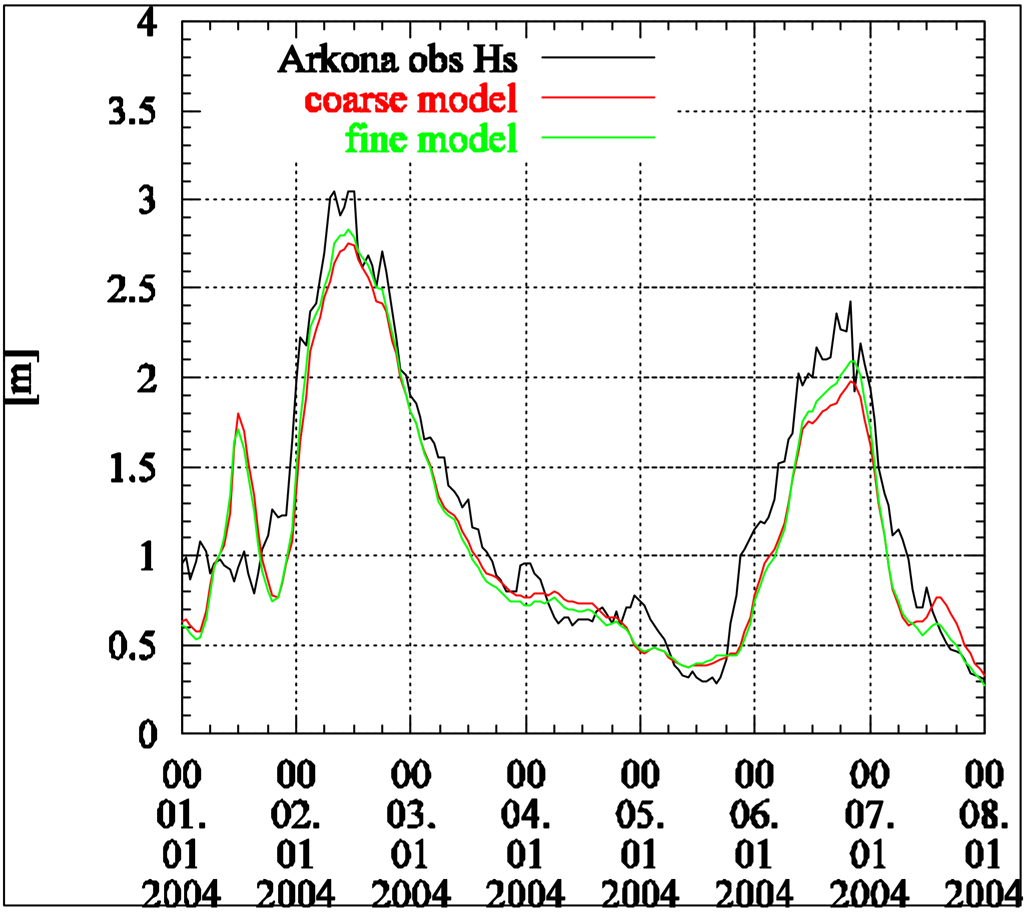

Fig. 5.1. Observed and predicted significant wave height in the Arcona basin

In order to eliminate a negative wave height bias in the North Sea (She and Nielsen 1999), the regional model was extended northwards from 61°N to 68°N and embedded into a mesoscale model covering the North Atlantic north of 30°N.

In the more enclosed waters of the Baltic, and in particular the Transition Area, the rather coarse model setup proved inadequate in cases where the fetch was badly described. A further nesting level, with 1/30° resolution in the nearby Danish waters, was applied to overcome this problem by more accurately resolving the coastline.

The present model set-up thus has 3 nesting levels. The nesting technique is one-way nesting where the fine grid models do not feed back on the coarse grid models. The full wave spectra along the coarse grib model's interior boundary is interpolated to the fine grid points, ensuring complete transfer of wave energy.

An example of the improvement of running a local fine grid model, is shown in the Figure. Observations from the German buoy station located in the Arkona Bassin (54°43.0' N; 13°44.6' E) are plotted for one week of data. A small improvement in the model predictions is seen for both the significant wave height (Fig. 5.1) and the mean wave period (Fig. 5.2) from the fine model compared to the coarse model.

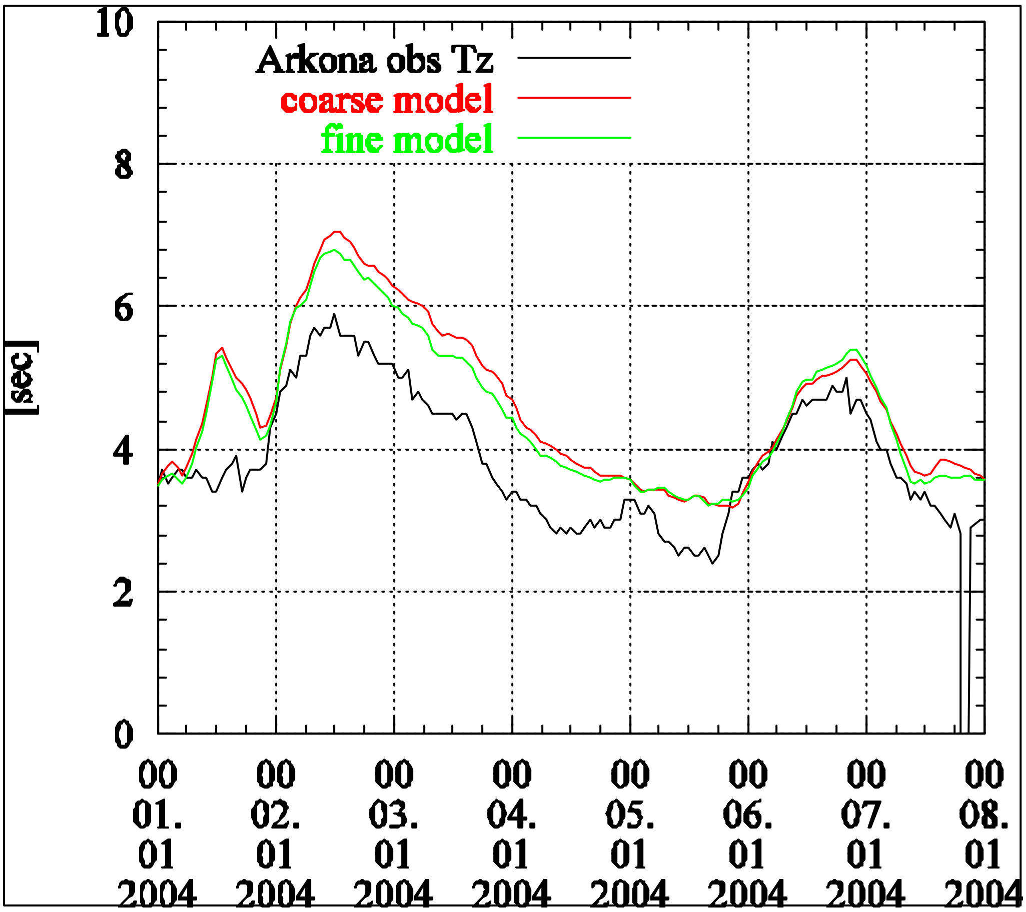

Fig. 5.2. Observed and predicted mean wave period in the Arkona basin.

6. Experience with a local model in one institution that uses input data computed in a Baltic-scale model run in another institution

Operational OpHespo drift prediction system serves as an example of ongoing co-operation within the BOOS and PAPA activities. It represents the basic philosophy of horizontal coupling of large-scale and local circulation models consisting in saving resources through running large-scale models in a few locations and operationally passing relevant information to various local applications.

The main goal in running a local drift model system is to enable drift prediction calculations in the Finnish fragmented archipelago and coastal areas where the resolution of Baltic scale models is not high enough. OpHespo hydrodynamic model has an open boundary in the Gulf of Finland entrance and the information produced by SMHI and the Baltic Sea wide HIROMB model is utilized at the model boundary. Coupling of two models saves expensive computing resources.

Between HIROMB model and OpHespo local model exists one-way information flow. OpHespo uses HIROMB water level forecasts from three different positions as boundary conditions. The water level forecasts from HIROMB are adjusted with the water level observations from Hanko mareograf before used as input for local model calculations. Within the OpHespo hydrodynamic model communication between different grid resolutions is two-way coupling i.e. coarser grid affects finer one and vice versa. HIRLAM wind forcing from Finnish Meteorological Institute (FMI) is used in the hydrodynamic and drift models. During winter period ice observations are incorporated to the model having an effect to the current and drift calculations.

SYKE, FMI and FIMR are responsible of maintaining and developing the model system. Model validation eg. with drift experiments and current measurements as well as inter comparison of modelling results with other models needs to be continued.

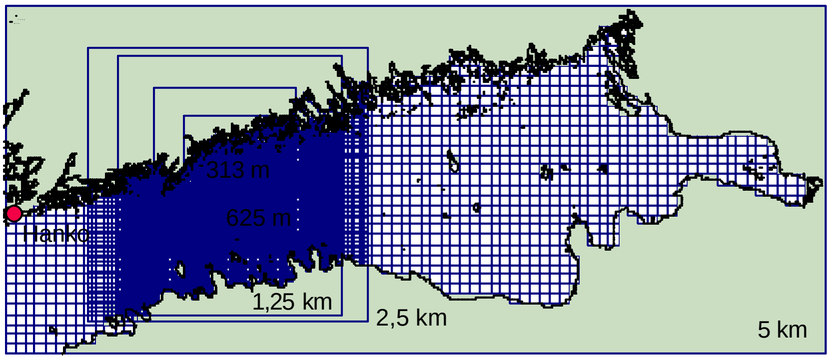

Figure 6.1. The nested calculation grid resolutions of the OpHespo hydrodynamic model.

7. Advanced coupling schemes

Generally, information from a larger scale model is passed as an one-way flow to smaller scale models. This is typical for information exchange between models of the North Atlantic and the North Sea, and have been used, e.g. in the above-described wave model in DMI.

It is typical to use an one-way coupling scheme (nesting) for wave models where only a few other designs have been reported in literature (e.g. Albiach et al., 2000). The basic reason is that information about small-scale nonhomogeneites of the wave field is lost fast owing to certain lateral propagation of wave energy that happens owing to a finite spectral width of realistic wave fields. Another reason for the one-way scheme is that there is no substantial wave energy flux through the Danish Straits. Below we shall describe two areas where two-way nesting of wave models may be necessary.

A specific region in circulation models is the area of the Danish Straits where all horizontally coupled circulation models use two-way coupling schemes. The experience with one example - the BSH circulation model - has been described above. This model uses an elaborated two-way-nesting between the nested area covering the German Bight, Danish Straits and the Western Baltic and the adjacent area. Water levels and mass transport into and out of the fine grid is linked in a two-way communication whereas, a “radiation condition” is applied in order to prevent reflection at the nesting boundaries. Salinity and water temperature data are exchanged between coarse and fine grid in both directions.

SMHI uses mostly one-way communication between the grids for all parameters at the boundary, except for salinity and temperature which have a two-way communication.

Currently, many different quantities of largely different nature are modelled operationally: circulation (incl. water level), waves and ice. From these parameters, wave field may strongly depend on the presence of sea ice and, in specific regions and time intervals, on water level. Therefore, there exists an urgent necessity to include operational ice hind- now- and forecast (from, e.g., circulation models) into wave models.

Several coupling schemes of such models have been reported in Tuomi et al. (2003) As a first step, it is a one-way coupling that basically reduces to changes of the land-sea mask for waves. Output from wave models might be useful for estimates of the erosion rate of ice-covered area. In the future, the ice-induced changes of surface rougness (or of some atmospheric parameters) might be important for the athmosperic part of the vertically coupled wave-atmosphere models.

Another coupling scheme that is only important in emergency cases consists in the use of sea surge information in wave models in areas where substantial changes of water level may occur (St. Petersburg, Pärnu). Loose coupling of models of various sea parameters have shown clear improvement of the results as reported in, e.g., (Choi et al., 2002).

Owing to specific features of wave models, two-way information exchange between such models might be feasible for a part of wave spectrum or for certain wind conditions only.

In the future, a certain coupling scheme of circulation and wave models may be feasible. Such models might improve forecast of the vertical structure of hydrophysical fields in specific areas.

8. Two-way coupling

Two-way coupling is a conceptually nontrivial and technically complex technique, because typically a number of problems must be solved:

- reflection of some (high-frequency) processes (that cannot be resolved in the coarse grid) from the boundary;
- possible necessity to repeat the main model runs after assimilating information from the fine grid area (that may lead to considerable additional computational costs that is not necessarily balanced by the improvement of quality of the modelled information in remote areas);
- in cases of models containing different physical mechanism, boundary information must be built in a specific way.

Owing to the listed (and some other) reasons, the two-way nesting scheme is used in operational models only if seriously motivated by some local reasons. For the Baltic Sea conditions, variations of this technique are generally in use for modelling circulation in regions embracing the Danish Straits. The processes in this area are critical for the whole Baltic Sea and they must be represented as accurately as possible.

Although the geometry of Baltic Sea is very complex, there are only a few other areas that might need two-way coupling schemes for specific purposes.

The entrances of the Bothnian Sea and the Gulf of Finland might need two-way coupling of wave models, because locking of wave propagation direction in these narrow sea areas may frequently occur. These areas may contain specific types of wind wave fields characterised by a well-defined peak in wave spectrum for waves propagating along the axis of the Gulf of Finland or the sea area between Aland and Sweden. This peak emerges in slanting fetch conditions when strong wind blows along a relatively large angle with respect to the axis of a narrow basin (Pettersson et al., 2003; 2004). Wind conditions favourable for such type of wave spectra frequently occur in the Gulf of Finland (Soomere and Keevallik, 2003).

The resulting structure of the wind wave field should be calculated with high-resolution models (possibly based on exact nonlinear computation of wave-wave interactions) and apparently cannot be represented by operational wave models. The reason is that, additionally to a coarser resolution, contemporary operational wave models are based on certain approximations of the nonlinear energy transfer (Komen et al., 1994) that work well for typical ocean wave spectra but may be even theoretically unable to represent certain specific features of the wave field.

Running of a high-resolution local wave model accounting for all quadruplet wave-wave interactions in this area for certain wind conditions and incorporating the results into Baltic-scale wave models might impove model performance for a part of wind directions. Doing this might considerably improve the wave forecast in terms of wave spectrum. In particular, it would be possible to more accurately foresee situations of increased navigational risk by predicting when and where two intense wave systems propagating in different directions simultanously occur in certain areas of the Baltic Proper.

Also, in some areas of the central part of the Gulf of Finland relatively large-scale peninsulas of the southern coast may considerably affect wave field in the central part of the gulf for some wind directions. In order to account for possible variations of wave fields in the northern part of the gulf, a two-way scheme of operational wave forecast might be reasonable in certain situations.

9. Model coupling through an assimilation sheme of modelled data

A specific feature of the cooperation in operational modelling in the Baltic Sea area is that modelling centres are typically located in different countries. As different from the issues of vertical coupling (where normally models are either run in one centre or ven in one computer), the horisontal coupling frequently aims to connecting of results from spatially and politically separated modelling centres. This feature results in severe stability problem of the whole system.

Although it is technically possible to reliably pair spatially separated computers, hardly any institution carrying national responsibility for Baltic-wide operational forecast would take risk of losing a vital part of forecast (or boundary data) owing to technical or political problems in connections between modelling systems in two countries. This situation makes difficult rigid coupling of models to-day and prescribes that certain less rigid or 'loose' techniques of coupling should be used.

A promising technology consists in using of various data assimilation schemes. Instead of a direct use of exact boundary data from local models in two-way coupling systems, such data from a coarse or local model could be treated as measured data. There exist many assimilation schemes that accept data measured at arbitrary time instants. In this way, each model is protected against occasional failures in both the other counterpart or in the connection system. If the boundary data are received correctly, they are used as boundary information. If the data flow ceases, the other model runs with just less accurate boundary data.

10. Planned operational Baltic-scale and local models.

RDANH and MSI reported plans of local models based on boundary information from the existing Baltic-wide models (Table A2). FIMR has developed a water level model that uses data from the Danish Straits and is in a pre-operational stage today.

As for such a plan in Estonia, it probably will not be realized within the PAPA duration. However, it might be wise to build up an implementation plan for local area models of the eastern part of the Baltic Proper, having in mind rapid development of physical marine sciences at the eastern coast of the Baltic Sea.

The model owners prefer data exchange via the existing ftp-boxes that obviuosly is reasonable.

Only a few of the existing (only model by SYKE today) or planned models have open boundaries (that might need input information from other models) within the Baltic Sea basin. This is natural, because the Baltic Sea basin is closed from the eastern side.

11. Summary

Owing to specific geometry of the Baltic Sea and its connections with the Atlantic Ocean, horizontal coupling of operational models of different resolution (or possibly of different types) is a highly actual question. Moreover, two-way coupling of many models is necessary. Most of the circulation models already use two-way nesting schemes, at least, for certain parameters.

As different from the issues of vertical coupling, the horisontal coupling frequently aims to connecting of results from spatially and politically separated modelling centres. On the one hand, this feature results in severe stability problems of the whole system. On the other hand, it serves as a challenge for the future.

There are many different models in operational use, thus, it is impossible to recommend one particular type of interface. For one-way nesting scheme, interpolation of data from coarse models and a proper choice of the boundary of the local model is a classical procedure. For possible two-way coupling scheme, the data from local models may be treated as fictitious measured data for a proper assimilation procedure.

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13. Appendix: Details of operational Baltic-scale models containing horizontal coupling (Tables A1 and A2)

Table A1. Details of models containing horizontally coupled constituents

Institution	*DMI*		*RDANH*	*SMHI*	*BSH*	*FIMR*	*SYKE*
Model	BSH 3D circulation model	wave model WAM cycle 4	wave model Mike 21 OSW – WAM model with modified bottom friction scheme and 2nd order Lagrangian propagation.	3D circulation	BSH circulation North Sea and Baltic Sea, prognostic (BSHcmod)	wave model WAM cycle 4	OpHespo circulation model
Area	North-Atlantic - Baltic		North Sea - Baltic		North Atlantic - Baltic	Baltic - Gulf of Finland	Gulf of Finland
Main prognostic parameters		wave field	wave field	circulation, water level, sea ice	circulation, water level, sea ice, temperature, salinity		circulation, water level
Type of grid	Regular spherical grid	Regular spherical grid	Planar grids defined in UTM projection zone 32. Algoritms for converting to/from lat-lon may be provided by RDANH, or use KMSTrans http://www.kms.dk/	Regular spherical grid		Regular rotated spheric grid; the same rotation as in the FMI-HIRLAM. Location of the shout pole 0, -30.	Regular rectangular grid
Number of nesting steps	3	3	3	3	3	2	5
Time step				600 s			
Step 1		North Atlantic	Large-scale		NE Atlantic	Baltic Sea	Gulf of Finland
Extension or corner		69W–30E; 30N–75N;	South-west corner 50.63195 N, 2.01140 W	NW corner 65°52'00"N; 04°06'40"W	21W–14E; 47N–66N;	Western/easternmost longitude 3.4/18.0, southern/northernmost latitude -8.0/9.0.	23°00´W -30° 20´W 59°15´N- 60°40´N

Grid points			E-W×N-S: 39×34,	105 E-W×88 N-S	52 E-W×46 N-S		
Grid step		1/2°;	50004m × 50004m,	12 nm 20' E-W; 12' N-S	24 nm	0.2° (~22km)	
Time step		600s		600s			
Step 2		North Sea - Baltic	Danish Territorial		North Sea and Baltic	Gulf of Finland	see Fig. 6.1
Extension or corner	see BSH 14 vertical layers; z-level thickness [m]: 8, 4, 4, 4, 4, 6, 10, 10, 25, 25, 50, 50, 50, 900.	20W–30E; 36N-68N space 1/6 deg; time 4 min	SW corner 53.26742 N, 3.33292 E	NW corner 65°53'30"N; 05°55'50"E	NW corner 65°51’00’’N 04°05'00’’W Northern boundary in the North Sea: 59°15’ N (row no. 67; row1=northernmost) Up to 14 fixed depth layers, (see DMI)	Regular rotated spheric grid nested in the Baltic Sea 0.2° grid.11.2E-14.8E, 1.0N-3.8N Shout pole 0, -30. Boundary points from coarser grid latitude 1.0-3.8 degrees, at longitude 11.2.	
Boundary information			Grids 2 and 3 have open north-south boundaries (for nested forcing) through the Bornholm Basin and the Arkona Basin respectively	Information from the 12 nm grid along the western boundary 05°55'50"E			
Grid points			51 E-W × 42 N-S:	294E-W×253N-S	207E-W×174N-S		
Grid step			16668m × 16668m	3 nm 5' E-W+3' N-S	6 nm 10' E-W×6' N-S	0.05° (~5km)	
Time step	90s			600 s			
Step 3		Danish Waters	Inner Danish		German Bight + Western Baltic	-	see fig.6.1

Extension or corner		7E–6E 53N–60N	South-west corner 53.85117 N, 9.33782 E	NW corner 65°53'30"N; 09°22'30"E	NW corner: 56°23’30’’N 06°10’50’’E Northern boundary in the North Sea: row 43 Same depth levels as in the coarse grid.		
Boundary information				Information from the 3 nm grid along the western boundary 09°22'30"E.			
Grid points			E-W×N-S: 45×51,	752 E-W×735N-S	312 E-W×191N-S		
Grid step		1/30°	5556m × 5556m,	1 nm 1,67' E-W+1' N-S	1 nm 1'40" E-W+1' N-S		
Time step		1 min		600s			
Type of external forcing	DMI-HIRLAM, hourly values: wind 10m, mslp, T 2m, Q 2m, cloud coverage, river run-off	DMI-HIRLAM, hourly values: wind 10m	Forced by 10-m wind from DMI-Hirlam provided by DMI every 6 hours	Air pressure, x- and y-components of wind, air temperature, specific humidity, total cloud cover	The 84-hour forecast data from the GME (global, 31 layers, grid ~55 km) and LM (local, 35 layers, grid ~7 km) atmospheric models of the German Weather Service DWD; hourly values: mean sea level pressure, total cloud cover, wind calculated for 10 m height based on stability conditions within the Prandtl layer, bottom layer (35 m) air temperature and humidity; interpolated to the circulation model.	Wind speed and direction at 10m height from FMI HIRLAM; time step is 1 hour. The grid and the resolution of the FMI-HIRLAM model are the same as in the wave model (for the whole Baltic Sea)	

Information exchange between the blocks; **0ne/two way communication**	Two-way for velocity, temperature and salinity	One-way (wave spectra passed)		One-way communication between the grids for all parameters at the boundary, EXCEPT two-way communication for salinity and temperature	Two-way-nesting between Step 2 & Step 3: water levels and mass transport into and out of the fine grid, a radiation condition is applied in order to prevent reflection at the nesting boundaries. At the open boundaries in the North Sea external surges are provided by a NE Atlantic model (2-dimensional, 24 nm grid spacing).	Standard WAM one-way nesting	Receives water level information from SMHI via ftp-box
Calculated parameters for each grid point	As output + turbulence parameters	Spectral wave energy	Discrete wave spectra 0.05 to 0.4 Hz, 16 directions	x- and y-components of currents, salinity, temperature, water level, ice concentration, total ice thickness, snow depth on ice, snow temperature on ice, ice drift velocity components	Current velocity components u, v, w, water level elevation ? (ref. to zero water level ?= 0), temperature, salinity, ice thickness and compactness. Reference locations of the parameters according to the Arakawa C grid configuration. Output levels from surface to bottom: 3 x 8 m, 26 m, 4 x 50 m, remainder Output time step is 15	For the whole model area: significant wave height, mean wave direction, mean wave period, peak wave direction, peak wave period, friction velocity, stokes drift, wave stress, drag coefficient For selected points: wave spectra with 24 direction and 35 frequencies starting from 0.041772 Hz	x- and y-components of currents, water level

					minutes for currents and water level, 60 minutes for temperature, salinity and ice data. The forecast interval is 72 hours starting at 00Z every day, based on the 12Z-analysis and forecast run of the DWD-models from the day before. Output data is available after 06:00 a.m.		
Parameters passed between the blocks				x- and y-components of ocean velocity for all depths, salinity and temperature for all depths. Ice drift velocity components, water level, ice thickness, ice concentration, and snow depth on ice, along the western boundaries.			x- and y-components of currents, water level
Standard output parameters	Sea level (90 sec) Hourly values for: ice concentration, ice thickness, T, S, u, v, w	Hourly values for: Significant wave height, mean wave direction, dominant wave period, mean wave period, swell height, swell direction, swell period, Charnock number.	Hm0 (Hs), Tp (peak period), T01(period from 1st spectral moment), T02 (2nd spectral moment), PWD(peak direction), MWD(mean direction), DSD directional spectral width), U,V (10m wind forcing).	At the surface: Water level, ice concentration, total ice thickness, ice drift velocity components. All vertical levels: x- and y-components of current, salinity, temperature.	see above		x- and y-components of currents, water level

Parameters that could be passed into nested models, if different from above			Discrete wave spectra 0.05 to 0.4 Hz, 16 directions.	All standard output parameters; see above.				
Preference for passing information to local nested models	ftp-box	ftp-box	1. Output interpolated to points specified by the requester, or limited to surrounding grid points. This in needed in order to reduce the bandwidth. 2. Data published on own ftp-box (e.g. like ftp://ftp.frv.dk/papa/forecast/) 3. Provide output from our future wave model WaveWatch-III	ftp-box	ftp-box favoured, e-mail is also possible if the data set is small	ftp-box		
Other planned models					New model version (V4) with higher horizontal and vertical resolution: North Sea and Baltic Sea Model: E-W grid step 3' N-S grid step 5' (about 3 nm) Coastal model: E-W grid step 0.5' N-S grid step 50'' (about 0.5 nm)	Model with an increased resolution for the Baltic Sea (operational by the end of 2004) The whole Baltic Sea area in rotated grid with 0.1° (~11km) resolution. Same rotation as in the FMI HIRLAM. Westernmost longitude 3.4, easternmost longitude 18.0, southernmost latitude -8.0 and northernmost latitude 9.0. Shout pole 0, -30.	Development ideas: adding of temperature, salinity, turbulence and river flows to the model calculation, redefine the calculation grid to achieve better horizontal resolution evenly in the whole gulf, running of several model copies with different wind input	

Planned major changes of external forcing					New atmospheric models at DWD in 2004: Global: 40 vertical layers, bottom layer 10 m (exact 10 m wind), grid spacing 40 km Local: 40 layers, grid spacing 7 km, covering the whole of Europe		

Table A2. Planned operational models containing horizontally coupled constituents

Institution	RDANH	MSI	FIMR
Planned model type	3-D circulation and mixing	Wave model	water level
Planned model area	North Sea - Baltic	Gulf of Finland, Moonsund, northwestern part of the Baltic Proper	Baltic Sea
Grid parameters of the whole model area (grid step in N-S and E-W directions, or algorithm of generating the grid points, whatever is relevant; if a multi-step nested approach is planned, please describe shortly the nesting scheme)	Lat-lon grid. 1 latitude minute X 5/8 longitude minute matching the 1 nm grid of HIROMB	1*1 nm in the open sea area incl Gulf of Finland and Gulf of Riga; additionally nested to 1/2…1/4 nm in Moonsund, Pärnu Bay and possibly in some areas of the Gulf of Finland; generally one-way nesting scheme except for specific wind directions	9.5E-29.0E, 54.0N-66.0N. grid step 0.25° N-S 0.5° E-W.
Planned standard output parameters	Temperature, salinity, 3-d velocity, surface elevation and turbulence parameters in all 3-d cells. Output timestep not decided.	Significant wave height, dominating wave period, wave propagation direction, certain spectral parameters	
Planned external forcing	Forced by surface conditions of DMI-Hirlam provided by DMI every 6 hours	HIRLAM	Either atmospheric pressure at the boundary to define the water level at the Danish straits; or water level forecasted by BSH
Planned location of horizontal boundaries	North-south along 3 W (approx), west-east along 60 N (approx) west of Norway	N-S along 21°E, E-W along 57°N + 61°N (approx. Liepaja - Utö line)	Danish straits
Parameters planned to extract from large-scale models	Surface elevation and barotropic current from Atlantic model adding astronomical tides. 3-d baroclinic data interpolated from a monthly climatology. 3-d boundary conditions from Atlantic model if available.	Wave spectrum along the western boundary, gridded wind field for the model sea area	Water level at the Danish Straits
Preference for receiving the boundary information (ftp-box, e-mail, others)	1. Data available on providers ftp-box 2. Output interpolated to points specified by us, or limited to surrounding grid points.	ftp-box	ftp-box