



## MIKE 21/3 Coupled Model FM

Step-by-step training guide: Coastal application



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## 1 Introduction

This Step-by-step training guide relates to Torsminde Harbour on the west coast of Jutland, Denmark, see Figure 1.1 and Figure 1.2.



Figure 1.1 Torsminde Harbour, Denmark. View towards north



Figure 1.2 Map of the North Sea area. Torsminde is located in the western part of Jutland, Denmark



## 1.1 Background

Torsminde fishery harbour is located at a tidal inlet on the west coast of Jutland, Denmark, on one of the narrow tidal barriers which divide coastal lagoons from the sea. The port is located at the entrance to the coastal lagoon Nissum Fjord. Sluices regulate the water exchange between the lagoon and the sea.

Up until the 1980's, i.e. for about 100 years, critical parts of the coast were protected by traditional structures such as groynes. A comprehensive nourishment scheme was established in the mid-eighties. Nourishment of about 3 million m<sup>3</sup>/year along a stretch of approximately 115 km has now stabilised the beach at critical stretches, while other stretches have been left to retreat as part of an overall shoreline management plan prepared and controlled by the Danish Coastal Authority.

Torsminde harbour is located in the central part of a very exposed stretch, where the net littoral drift is southward with an order of magnitude of 0.4 million m<sup>3</sup>/year, but where the gross transport is several times larger.

As a result severe sedimentation and shoaling problems affected the harbour entrance and a need for alternative layout of the harbour made it necessary to make preliminary investigations of the sediment transport pattern in the area.

## 1.2 Objective

The objective of this Step-by-step training guide is to set up a model simulating the morphology for the Torsminde harbour and the adjacent coastal areas from scratch and to calibrate the model to a satisfactory level.

The coupled model setup involves the following MIKE 21 modules:

- MIKE 21 Flow Model FM, Hydrodynamic Module
- MIKE 21 Spectral Wave Module
- MIKE 21 Flow Model FM, Sand Transport Module

Attempts have been made to make this exercise as realistic as possible although some short cuts have been made with respect to the data input. This mainly relates to quality assurance and pre-processing of raw data to bring it into a format suitable for the MIKE Zero software. Depending on the amount and quality of the data sets this can be a tedious, but indispensable process. For this example the 'raw' data has been provided as standard ASCII text files.

All files used in this Step-by-step training guide are a part of the installation. You can install the examples from the MIKE Zero start page.

**Please note** that all future references made in this Step-by-step guide to files in the examples are made relative to the main folders holding the examples.

User Guides and Manuals can be accessed via the MIKE Zero Documentation Index in the start menu.

If you are familiar with importing data into DHI's file system, you do not need to generate all the MIKE Zero input parameters yourself from the included raw data. All the MIKE Zero input parameter files required to run the example are included and the simulation can be initiated right away.



## 2 Creating the Computational Mesh

Creation of the mesh file is a very important task in the modelling process.

The mesh file couples water depths with different positions and contains the following information:

- 1. Computational grid
- 2. Water depths
- 3. Boundary information

Creation of the mesh requires an xyz file(s) for positions of land-boundaries and an xyz file(s) that couples geographical positions with water depths. A data file including a bathymetry can also be used as an alternative to an xyz file with water depths.

Creation of the computational mesh typically requires numerous modifications of the data set, so instead of explaining every mouse click in this phase, the main considerations and methods are explained in the MIKE FM HD document:

MIKE 21 & MIKE 3 Flow Model FM, Hydrodynamic Module, Step-by-Step Training Guide,

which can be accessed via the MIKE Zero Documentation Index in the start menu.

When creating the computational mesh you should work with the mdf file, which contains information about settings for the mesh. Focus in this example is on Sand Transport Module (ST), so both the necessary xyz files and the mdf file and a mesh file are already supplied with the example, so that the remaining time can be spent on specific ST subjects. Two mesh files are supplied with the example: a coarse mesh and a fine mesh. Using the coarse mesh will reduce simulation time as fewer calculations are needed and the time step may be increased.

An outline of the properties for the two bathymetries is given in Table 2.1.

	Fine mesh	Coarse mesh
No. of elements	7876	3674
No. of nodes	4211	1997
Minimum element length	4.8 m	11.8 m
Maximum element length	214.8 m	241.0 m
Minimum element area	13 m <sup>2</sup>	107 m <sup>2</sup>
Maximum element area	21980 m <sup>2</sup>	28648 m <sup>2</sup>

#### Table 2.1Mesh bathymetry properties

Figure 2.1 shows the fine mesh, which is used in this example, and Figure 2.2 shows a graphical presentation of the mesh of the Torsminde area as it can be displayed with MIKE Animator.





Figure 2.1 The Torsminde area computational mesh and bathymetry as it can be presented with the Data Viewer tool



Figure 2.2 The Torsminde area computational mesh and bathymetry as it can be presented with the MIKE Animator tool



## 3 Creating Various Input Parameters to the MIKE 21/3 Coupled Model FM

Before the MIKE 21/3 Coupled Model FM complex can be set up, the input data must be generated from the measurements.

The following measurement data are used:

- 1. Water levels at the northern jetty in the period from 1997 to 1999
- 2. Wave model results from the North Sea
- 3. Measured pre- and post storm bathymetric survey data in the harbour entrance. The surveys were carried out on 16 October 1997 and 27 October 1997, respectively
- 4. Measured survey lines along the west coast from 1998
- 5. Measured local survey lines from 1999

The bathymetric survey data in the harbour entrance form the basis of calibrating the ST model. Thus it is chosen to start the simulation period at 16/10 1997 00:00 and end it at 27/10 1997 00:00:00 (i.e. 11 days).

The measured data is included in the MIKE Zero Examples folder:

.\MIKE\_21-3\_Integrated\_Models\CoupledModel\_FM\Torsminde\data

Preparation of input data is made by using various tools in MIKE Zero. Therefore reference is also made to the MIKE Zero User Guide, which can be accessed via the MIKE Zero Documentation Index in the start menu:

MIKE Zero Pre- and Postprocessing, Generic Editors and Viewers, User Guide

## 3.1 Water Level Boundary Conditions

Measured water level recordings from Torsminde harbour are available.

The Torsminde model is forced with water level boundaries and wave radiation stress. Unfortunately there are no measurements of water levels at the boundary, so the correct variation along the boundary is not known. Therefore the boundary is specified as a time series (dfs0 type file) constant along the boundary. Because of the open area and relatively small domain of the model, the water levels measured at Torsminde harbour are selected as boundary conditions for the entire model.

**Please note** that the time series must have equidistant time steps. That means that if the raw data have time gaps without measurements, the gaps in the raw data must be filled before importing it, or the time series must be interpolated from a non-equidistant time series after importing it. In this case we will do the latter.



## 3.1.1 Importing measures water levels to time series file

The file 'Torsminde\_levels.txt' containing measured water levels can be found in the folder:

.\MIKE\_21-3\_Integrated\_Models\CoupledModel\_FM\Torsminde\Data\Boundary\_Conditions

Note that the measured values are stored in unit cm, see Figure 3.1.

Torsminde_Levels.txt - Notepa	
File Edit Format View Help	p
Water Level recordings	from Torsminde
Time Elevation	
1997-01-01 00:00:00	-83
1997-01-01 00:15:00	-84
1997-01-01 00:30:00	-83
1997-01-01 00:45:00	-82
1997-01-01 01:00:00	-79
1997-01-01 01:15:00	-77
1997-01-01 01:30:00	-77
1997-01-01 01:45:00	-74
1997-01-01 02:00:00	-71
1997-01-01 02:15:00	-71
1997-01-01 02:30:00	-69
1997-01-01 02:45:00	-66
1997-01-01 03:00:00	-66 +

Figure 3.1 ASCII file with water level recordings from Torsminde

🚰 New File x Product Types: Documents: 🕀 🗁 MIKE Zero - C MIKE HYDRO Profile Series (.dfs1) - 🛅 MIKE 11 Data Manager (.dfsu,.mesh,.dfs2,.dfs3) - 🛅 MIKE 21 🕞 Grid Series (.dfs3,.dfs2) 🛅 MIKE 3 📥 Plot Composer (.plc) - MIKE 21/3 Integrated Models 📥 Result Viewer (.rev) 🛅 LITPACK 📥 Bathymetries (.batsf) MIKE FLOOD Climate Change (.mzcc) 🛅 MIKE SHE Ecolab (.ecolab) Auto Calibration (.auc) EVA Editor (.eva) 📥 Mesh Generator (.mdf) 📥 Data Extraction FM (.dxfm) 💧 MIKE Zero Toolbox (.mzt) Time Series OK Cancel

Open the Time Series Editor in MIKE Zero (File→New→File), see Figure 3.2.

Figure 3.2 Starting the Time Series Editor in MIKE Zero



Select the ASCII template. Open the text file 'Torsminde\_levels.txt'. Change the time description to 'Non-Equidistant Calendar Axis' – uncheck the 'Delimiter between time and first item' box and press OK, see Figure 3.3. Then right click on the generated data and select properties change the type to 'Water Level', see Figure 3.4.

Save the data as 'WaterLevels\_NonEq.dfs0'.

me Series Editor: Impo	rt from ascii			
Description				
File name: dels\Cou	pledModel_FM\Ta	orsminde\data\bound	ary_conditions\Torsminde_Levels.txt	
Delimiter: Tab	•	Time description:	Non-Equidistant Calendar Axis	•
Treat consecutive of	lelimiters as one	Start Time:	28-03-2014 08:22:37	
🔲 Ignore delimiters in t	egining of line	Time Step:	0 [days]	
🔲 Delimiter between ti	me and first item		00:00:10 [hour:min:sec]	
Delete value:	-1e-030		0 [fraction of sec.]	
			Time Series Export ASCII Format	
			Time Seles Export ASCI Pointat	
Time Elevation 1997-01-01 00:00:00 1997-01-01 00:15:00 1997-01-01 00:30:00 1997-01-01 00:45:00 1997-01-01 01:00:00 1997-01-01 01:15:00	-83 -84 -83 -82 -79 -77			
Time	Elevation			
1997-01-01 00:00:00				
1997-01-01 00:15:00				
1997-01-01 00:30:00 1997-01-01 00:45:00				
1997-01-01 00:45:00				
1997-01-01 01:15:00				
	_ ··· ]			
	0	K Ca	ancel	

Figure 3.3 Time Series Editor Import Template



Title:		Water Lev	el recordings from Torsmina	le			ОК
							Cancel
Axis Informa	ation						Help
Axis Type:		Non-Equid	istant Calendar Axis 🔻				
Start Time:		01-01-199	7 00:00:00				
Time Step:			0 [days]				
		00:1	5:09 [hour:min:sec]				
		0.41	0332 [fraction of sec.]				
No. of Time	esteps:	10	3483	Axis Units:		-	
tem Informa	ation						
	Γ	Name	1	Гуре		Unit	
	Eleva	ition	Water Level		-	meter	
1			Water Flow		*		
1			Water level change Water Level				
1							
1			Water Ouality				
1			Water Quality Water Volume Error				

Figure 3.4 Time Series Properties

## 3.1.2 Create equidistant time axis

The time series file created has a number of gaps in the time series. For example, on 1/7 1997 the recordings stop at 17:30 and are first resumed at 09:00 the next day.

To obtain an equidistant time series for the simulation you should use the MIKE Zero Tool *Interpolate Time Series*.

Open the MIKE Zero Toolbox in MIKE Zero (File $\rightarrow$ New $\rightarrow$ MIKE Zero Toolbox). Select *Interpolate Time Series* in the *Time Series* group, see Figure 3.5.



nztl	
Concatenation   Extraction   File Converter   GIS   Hydrology   Statistics   Time Series   One Year Summary   Preprocessing Temporal Data   Sorting Temporal Data   Time Series Batch Conversion   Transformation	
Tool List Setup List	
New Edit Delete Up	Down Run



Press the New button and follow the dialogues.

Select the file 'WaterLevels\_NonEq.dfs0' as the input file. In the next dialogue box, please define the interpolation parameters as shown in Figure 3.6. The time step is set to 900 s (i.e. 15 minutes).

Interpolation N	lethod and Subseries Selection	×
On this p	olation Method and Subseries bage you specify the interpolation method to use and the start and end time of the tion period. You also specify the timestep interval.	
Type of i	nterpolation Linear -	
Interpola	tion Period	
Start:	01-01-1997 00:00:00 🔄 💌 End: 26-12-1999 05:00:00 📚 💌	
Interval	[8]	
— Data	a Information	
Start:	1997/01/01 00:00:00 End: 1999/12/26 05:00:00	
Interval	941076 [8]	
	< Back Next > Cancel Hel	p

Figure 3.6 Specifying interpolation parameters in Interpolate Time Series tool



Save the data as 'WaterLevels\_Eq.dfs0'. Press execute and finish to interpolate the data.

Open the file in the *Time Series Editor* and use the Calculator to multiply the data values with 0.01 to specify the data as unit metres, see Figure 3.7.



Figure 3.7 Time Series Editor with imported Water Levels from Torsminde

#### 3.1.3 Filtering time series

To obtain a smooth variation of water levels, the measured water level recordings from Torsminde must be low pass filtered. If you do not filter the time series, the numerical simulation may become unstable.

To filter the time series use the MIKE 21 Tool FFT Filtering of Time Series.

Open the MIKE 21 Toolbox in MIKE Zero (File $\rightarrow$ New $\rightarrow$ File), see Figure 3.8.

Rew File		
Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 3 MIKE 21/3 Integrated Models MIKE 21/3 Integrated Models MIKE FLOOD MIKE SHE	Documents: Flow Model (.m21) Flow Model FM (.m21fm) Spectral Waves FM (.sw) Boussinesq Waves (.bw) Elliptic Mild Slope Waves (.ems) Parabolic Mild Slope Waves (.pms) Non-Cohesive Sediment Transport (.st2) Curvilinear Flow Model (.m21c) MIKE 21 Toolbox (.21t)	
MIKE 21 Toolbox		-
	OK	Cancel

#### Figure 3.8 Selecting the MIKE 21 Toolbox in MIKE Zero

Select the tool FFT Filtering of Time series in the Waves group, see Figure 3.9.







Press the *New* button and follow the dialogues. Select the file 'WaterLevels\_Eq.dfs0' as the input file. In the next dialogue box, define the frequency range as shown in Figure 3.10. The maximum frequency of interest is set to 5e-005 Hz, corresponding to 5.5 hours.

Sel	ect Frequency Range	×
	Select Frequency Range. On this page you specify lower and upper frequencies of interest. If the wave spectrum corresponding to the time series after removal of the specified waves is to be saved, you should enter a name for the file.	
	Specify Frequency Range:	
	Minimum Frequency of Interest: 0 [Hz]	
	Maximum Frequency of Interest: 5e-005 [Hz]	
	Save Resulting Energy Spectrum:	
	No     No	
_		
	< Back Next > Cancel Help	p

#### Figure 3.10 Specifying frequency range in FFT Filtering of Time Series tool

Save the data as 'Waterlevels\_Torsminde.dfs0'1. Press 'Execute' and then finish.

Now you are ready to use this file as boundary conditions for the flow simulation.

#### 3.1.4 Plot time series file

To make a plot of the water level time series, please open the Plot Composer in MIKE Zero, see Figure 3.11.

<sup>&</sup>lt;sup>1</sup> Please note that data files supplied with the installation are write-protected. This means that these files must be renamed or saved to a different folder.

eries (.dfs0) Series (.dfs1) Aanager (.dfsu,.mesh,.dfs2,.dfs3) eries (.dfs3,.dfs2) omposer (.plc) Viewer (.rev) metries (.batsf) e Change (.mzcc) (.ecolab)
alibration (.auc) ditor (.eva) Senerator (.mdf) :xtraction FM (.dxfm) :ero Toolbox (.mzt)
E

Figure 3.11 Starting the Plot Composer in MIKE Zero

Select 'plot'  $\rightarrow$  'insert a new plot object' and select 'Time Series Plot', see Figure 3.12. Right click on the plot area and select properties, if the GUI is not opened automatically.

Insert Plot Object		<b>—</b> X—
Insert		
Single Plot Maximized		
Single Plot Sized:	w: 100 [mm] h: 100	[mm]
O Multiple Plots Tiled:	nx: 2 ny: 2	
Standard Graphics     Dfsu Plot     Grid Plot     Profile Plot     Marced Graphics     Advanced Graphics     Advanced Graphics     Advanced Flot     Advanced Graphics     Advanced Flot     Advanced Plot     Advanced Plot     Marced Plot     Advanced Plot		
	ОК	Cancel

Figure 3.12 Insert a new Plot Object as Time Series in Plot Composer

Add the actual time series file to the Plot Composer by clicking and selecting the file. It is possible to add more than one time series to the same plot. In the 'Time Series Plot



Properties' dialogue it is possible to change some of the properties for the plot such a item names, colours of curves, etc. (see Figure 3.13).

Time	Series P	lot Properties			×		
Item	Items X-Axis Y-Axis Curves Text Annotations						
	tem Defi	nition					
					<b>× →                                   </b>		
		Item name	Items	File name	Item type		
	1	Elevation	Elevation	C:\Data\Examples.Rel201	Water Level		
	2	LP/HP filtering of Elevation	LP/HP filtering of Elevation	C:\Data\Examples.Rel201	Water Level		
	•				•		
			ОК	Cancel Apply	Help		

## Figure 3.13 Plot Composer Time Series Plot Properties dialogue for selecting time series files and adjusting scales, curves, etc.

The resulting plot of the water level variation at the boundary during the simulation is shown in Figure 3.14.



Figure 3.14 Water level variation in time, before and after low pass filtering



## 3.2 Wave Boundary Conditions

Wave conditions are available from a regional model<sup>2</sup>. Because of the open area and relatively small domain of the present model the wave conditions are set as constants along the offshore (west) boundary.

The north and south boundaries are selected to be lateral, as these are far away from the area in focus.



Figure 3.15 shows the wave conditions during the simulation period.

Figure 3.15 Time series of significant wave height and mean wave direction

In the beginning of the period there are fairly small waves from SW. After almost 4 days the wave direction shifts to NW and the wave height increases.

## 3.3 Initial Conditions (Hydrodynamic Module)

The initial surface level is estimated to be 0.0 m over the whole domain. Using the soft start facility the water level will adapt to the measured water level in Torsminde harbour within an hour.

## 3.4 Wind Forcing (Hydrodynamic Module)

Wind recordings from Torsminde Harbour will form the wind forcing as time series constant in space.

The wind recordings from Torsminde harbour have been loaded into the Time Series Editor and saved in 3-hour intervals in the file Wind\_Torsminde\_3h.dfs0.

Time series of the wind speed and direction are shown in Figure 3.16.

<sup>&</sup>lt;sup>2</sup> See e.g. www.waterforecast.com





Figure 3.16 Wind speed and direction from Torsminde Harbour during the simulation period

A more descriptive presentation of the wind can be given as a wind speed (or wind rose) diagram. Figure 3.17 shows the wind rose for Torsminde Harbour.



Figure 3.17 Wind rose from Torsminde Harbour for the simulation period as it can be illustrated in the Plot Composer. The dominating wind direction is northwest



## 3.5 Sediment Data

#### 3.5.1 Sediment properties

The sediment properties are assumed to be constant over the area. The median grain size is 0.3 mm and the sediments are well sorted with a spreading of 1.45.

#### 3.5.2 Generating sediment transport tables

Prior to execution of the Sand Transport Module, quasi-3D sediment transport look-up tables have to be generated. The extension of the tables must be such that the possible parameters from the simulation are covered.

The necessary extension of the transport tables is not known a priori the simulation. However, an educated guess can be made on basis of the boundary conditions, information about the area and previous experience.

To generate a transport table, please open the *MIKE 21 Toolbox* in MIKE Zero, select the *Generation of Q3D Sediment Tables* and press *New*, see Figure 3.18 and Figure 3.19.

🚰 New File		×
Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 21/3 Integrated Models LITPACK MIKE FLOOD MIKE SHE MIKE 21 Toolbox	Documents: Flow Model (.m21) Flow Model FM (.m21fm) Spectral Waves FM (.sw) Boussinesq Waves (.bw) Elliptic Mild Slope Waves (.ems) Parabolic Mild Slope Waves (.ems) Non-Cohesive Sediment Transport (.st2) Curvilinear Flow Model (.m21c) MIKE 21 Toolbox (.21t)	
	ОК	Cancel

Figure 3.18 Starting the MIKE 21 Toolbox in MIKE Zero



Environmental Hydrodynamics Morphology Sediments Extension of Q3D Sediment Tables Extension of Sediment Tables Generation of Q3D Sediment Tables Generation of Sediment Tables Generation of Stoms Generation of Stoms Sediment Discharge Calculation Seismology Tidal Waves Wind Tool List Setup List	21T2			
Morphology Sediments Extension of Q3D Sediment Tables Extension of Sediment Tables Generation of Q3D Sediment Tables Generation of Sediment Tables Integration of Stoms Sediment Discharge Calculation Seismology Tidal Waves Wind		Environmental		
Sediments Extension of Q3D Sediment Tables Extension of Sediment Tables Generation of C3D Sediment Tables Generation of Sediment Tables Sediment Discharge Calculation Seismology Tidal Waves Wind				
<ul> <li>Extension of Q3D Sediment Tables</li> <li>Extension of Sediment Tables</li> <li>Generation of Sediment Tables</li> <li>Generation of Stoms</li> <li>Sediment Discharge Calculation</li> <li>Seismology</li> <li>Tidal</li> <li>Waves</li> <li>Wind</li> </ul>				
<ul> <li>Extension of Sediment Tables</li> <li>Generation of Q3D Sediment Tables</li> <li>Generation of Sediment Tables</li> <li>Integration of Stoms</li> <li>Sediment Discharge Calculation</li> <li>Seismology</li> <li>Tidal</li> <li>Waves</li> <li>Wind</li> </ul>				
Generation of Q3D Sediment Tables Generation of Sediment Tables Integration of Stoms Sediment Discharge Calculation Seismology Tidal Waves Waves Wind		Q	.0	
<ul> <li>Integration of Stoms</li> <li>Sediment Discharge Calculation</li> <li>Seismology</li> <li>Tidal</li> <li>Waves</li> <li>Wind</li> </ul>		$\simeq$	es	
Seismology Tidal Waves Wind		Seneration of Sediment Tables		
Beismology Tidal Waves Wind		Integration of Storms		
Tidal ₩ Waves Wind		<u> </u>		
₩wes Wind				
Wind				
Tool List Setup List				
Tool List Setup List				
Tool List Setup List				
Tool List Setup List				
	Tool	List Setup List		
	· · · · · · · · · · · · · · · · · · ·			
			1 <b>5</b> - <b>2</b>	
New Edit Delete Up Down Run	New	Edit Delete Up	Down Run	

Figure 3.19 Selecting tool for generation of transport tables

Follow the tutorial, rename the setup and continue to the dialogue containing General Parameters and Additional Parameters. Press next for each to accept the default values. In the 'Wave Parameters' dialogue change the wave theory to Stokes 1<sup>st</sup> order, see Figure 3.20.

Wave Parameters	۲.
Select Wave Parameters On this page you specify the wave theory used to describe the time variation of the near-bed velocity and the value of the breaking wave parameters.	
Wave theory:       Breaking wave parameters:         Image: Stokes       Gamma 1:       1         Image: Choidal       Gamma 2:       0.8         Image: Voccidal       Image: Gamma 2:       0.8         Image: Doering & Bowen       Order of solution:       1	
< Back Next > Cancel Help	

Figure 3.20 Selecting wave theory for transport tables



In the 'Sediment Transport Tables Axes' dialogue, the extension of the tables is defined, see Figure 3.21.

( united			Sediment table axis				
Sediment table axis           First value         Spacing         No of point							
15	0.15	0.01	Current speed				
Wave height         0.2         0.25         18							
11	1	5	Wave period				
Wave height/water depth 0.05 0.05 20							
13	30	0	Angle current/waves				
1	2.000	0.300	Grain Size				
1	0.15	1.45	Sediment grading				
1		0	Bed slope, curr. direction				
1	0.02	0					
1	0.001	10	Centrifugal acceleration				
Sediment grading         1.45         0.15         1           Bed slope, curr. direction         0         0.01         1           Bed slope, normal to curr.         0         0.02         1							

#### Figure 3.21 Defining the extension of the transport tables

Insert the values given in Figure 3.21, press next and continue to give the sediment transport tables a descriptive title. Go on with saving the setup and press 'Execute' to the tool in order to generate the sediment transport tables. Two ASCII files will be generated with the extensions .lon and .crs, respectively.

As generating sediment transport tables is computationally demanding, sediment transport tables for this example have been provided with the setup.





## 4 Setup of MIKE 21/3 Coupled Model FM

## 4.1 Specifications

We are now ready to set up the model using the Torsminde mesh with the pre-storm water depths, boundary conditions and forcings as described in Chapter 3.

In Table 4.1, the parameters applied for the simulation are listed in short.

Table 4.1	Specifications	for the	calibration	simulation
-----------	----------------	---------	-------------	------------

Parameter	Value
Specification file	Sim1.mfm
Mesh and bathymetry	FineBathy.mesh 4211 Nodes, 7876 elements or CourseBathy.mesh 1997 nodes, 3674 elements
Simulation period	1997-10-16 00:00 – 1997-10-27 00:00 (11 days)
Time step interval	1800 s
No. of time steps	528
Module selection	Hydrodynamics (HD) Sand Transport (ST) Spectral Waves (SW)
HD: Solution technique	Low order, fast algorithm Minimum time step: 0.1 Maximum time step: 1800 Critical CFL number: 1
HD: Flood and dry	Standard flood and dry
HD: Initial conditions	Constant 0.0 m
HD: Wind forcing	Wind_SimulationPeriod.dfs0 soft start: 3600 s wind friction varying with wind speed
HD: Wave radiation	Wave radiation from SW simulation
HD: Water level boundaries North and south West boundary	Waterlevels_Torsminde.dfs0 Include radiation stress correction, soft start 3600 s Exclude radiation stress correction, soft start 3600 s
HD: Eddy viscosity	Smagorinsky formulation, Constant 0.28 m²/s
HD: Bed resistance	Manning number, FineManning.dfsu or CourseManning.dfsu
HD: Coriolis forcing	None
ST: Model type	Wave and current
ST: Sediment transport table	QsTable.lon / QsTable.crs
ST: Time step factor	2
ST: Sediment properties	Constant, d50=0.3 mm, spreading 1.45
ST: Forcings	Wave field from SW simulation



Parameter	Value		
ST: Morphology	Include feedback on hydrodynamic, wave and sand transport calculation		
ST: Boundaries	Zero sediment flux gradient for outflow, zero bed change for inflow		
SW: Basic equations	Spectral: Directionally decoupled parametric formulation Time: Quasi-stationary formulation		
SW: Discretization	Type: directional sector 14 directions with a minimum value of 135 degrees and a maximum value of 45 degrees.		
SW: Solution technique	Newton-Raphson iteration Tolerance: 1.0·10 <sup>-5</sup>		
SW: Water level conditions	Water level variation from HD simulation		
SW: Current conditions	Current variation from HD simulation		
SW: Wind forcing	Wind_SimulationPeriod.dfs0		
SW: Wave breaking	Constant gamma value: 0.8		
SW: Bottom friction	Constant Nikuradse roughness, $k_N$ : 0.01 m Include effect on mean wave frequency		
SW: Initial conditions	Type: Zero spectra		
SW: North & south boundary	Lateral boundary		
SW: West boundary	Varying in time, constant along line File: NSW_timeseries_okt97.dfs0		
Result files	HD_results.dfsu, SW_results.dfsu, ST_results.dfsu		
Simulation time	About 27 minutes with a 2.2 GHz PC, 8 GB RAM, 4 cores, using the coarse bathymetry About 2.0 hours with a 2.2 GHz PC, 8 GB RAM, 4 cores, using the fine bathymetry		

In the following screen dumps, the individual input pages are shown and a short description is provided.

Additional information about the modules can be found in the User Guides listed below, which can be accessed via the MIKE Zero Documentation Index in the start menu:

MIKE 21 Flow Model FM, Hydrodynamic Module, User Guide

MIKE 21 Flow Model FM, Sand Transport Module, User Guide

MIKE 21 SW, Spectral Waves FM Module, User Guide

## 4.2 Specifications for Basic Parameters

To create a new setup file, open the MIKE Zero shell and select File $\rightarrow$ New $\rightarrow$ File, MIKE 21/3 Integrated Models $\rightarrow$ Coupled Model FM. Specify the bathymetry and the mesh file FineBathy.mesh in the 'Domain' dialogue, see Figure 4.1. The projection zone has already been specified in the mesh generation process as UTM-32. In the mesh file, each



boundary has been given a code. In this example the North Boundary has 'Code 2', the West Boundary has 'Code 3' and the South Boundary has 'Code 4'. Rename the boundary 'Code 2' to 'North', 'Code 3' to 'West' and 'Code 4' to 'South' in the 'Boundary Names' dialogue.

**Please note** that you can see a graphical view of the computational mesh and the boundaries by selecting 'Boundary Conditions' in the Hydrodynamic Module. Here you can also view the code values (second item), see Figure 4.2.







Figure 4.2 Computational mesh and code values of the boundaries



In the MIKE 21/3 Coupled Model FM the modules run simultaneously, allowing feedback of the results between the involved modules at a frequency determined by the overall time step.

Set the start date to 1997-10-16 00:00:00, specify the time interval to 1800 s and the number of time steps to 528 in order to simulate a total period of 11 days, see Figure 4.3.

Sim1.mfm					
MIKE 21/3 Coupled Model FM	Time				
Module Selection	Simulation period				
Hydrodynamic Module     Sand Transport Module	No. of time steps 528				
🗄 🗹 Spectral Wave Module	Time step interval 1800 [sec]				
	Simulation start date 16-10-1997 00:00:00 🔄 💽 [dd-mm-yyyy hh:mm:ss]				
	Simulation end date 27-10-1997 00:00:00 [dd-mm-yyyy hh:mm:ss]				
Navigation					
Validation / Simulation					

#### Figure 4.3 MIKE 21/3 Coupled Model FM: Simulation period

For this example include the 'Hydrodynamic', 'Sand Transport' and 'Spectral Waves' modules in the 'Module Selection' dialogue, see Figure 4.4.

Sim1.mfm	
MIKE 21/3 Coupled Model FM	Module Selection
	Module Selection   Hydrodynamic  Transport  ECO Lab / Olispill  Mud Transport  Particle Tracking  Sand Transport
	Spectral Waves
Navigation	ton /

Figure 4.4 MIKE 21/3 Coupled Model FM: Module Selection



## 4.3 Specifications for the Hydrodynamic Module

The shallow water equations are solved using 'Low order, fast algorithm' for both time integration and space discretization, see Figure 4.5.

The minimum time step is set to 0.1 s to ensure that the CFL number always is less than the critical CFL number of 1. The maximum time step is set to the overall time step of 1800 s.

Sim1.mfm			- • ×
MIKE 21/3 Coupled Model FM	Solution Technic	que	
Module Selection	Shallow water equation	s	
Hydrodynamic Module	Time integration	Low order, fast algorithm 👻	
	Space discretization	Low order, fast algorithm 🔹	
	Minimum time step	0.1 [sec]	
Bed Resistance	Maximum time	1800 [sec]	
Coriolis Forcing     Wind Forcing	Critical CFL number	1	
✓ Ice Coverage ✓ Tidal Potential	Transport equations		
Precipitation - Evaporat	Minimum time step	1 [sec]	
Sources	Maximum time	1800 [sec]	
	Critical CFL number	1	
Boundary Conditions     Decoupling			
🗄 🗹 Outputs			
Sand Transport Module     Spectral Wave Module			
III → II			
Navigation			
	on /		

Figure 4.5 MIKE 21/3 Coupled Model FM, Hydrodynamic Module, Solution Technique

In this example the standard flooding and drying should be included (see Figure 4.6), because the tidal variation of the water level will cause part of the beach to dry out and flood during the simulation. If you choose not to include flooding and drying, the model will blow up in situations with dry areas.

In our case select a drying depth of 0.005 m and a flooding depth of 0.05 m. The wetting depth should be 0.1 m. These are default values.



Sim1.mfm				
MIKE 21/3 Coupled Model FM	Flood and Dry			
Module Selection	Include flood and dry		_	
Solution Technique	Drying depth	0.005		
✓ Depth     ✓ Flood and Dry	Flooding depth	0.05	[m]	
- Density	Wetting depth	0.1	[m]	
Eddy Viscosity				
🖌 🖌 Ice Coverage				
Tidal Potential     Precipitation - Evaporat				
Wave Radiation				
Sources				
🗈 🗹 Boundary Conditions				
🗈 🗹 Spectral Wave Module				
Navigation				
Validation / Simulation	on /			

#### Figure 4.6 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Flood and Dry

As the density variation is not taken into account in this example, the density should be specified as 'Barotropic', see Figure 4.7.

Sim1.mfm		
MIKE 21/3 Coupled Model FM	Density	
Module Selection Hydrodynamic Module	Density type Barotropic	
···· ✓ Depth ···· ✓ Flood and Dry ···· ✓ Density ···· ✓ Eddy Viscosity	Reference temperature     10 [°C]       Reference salinity     32 [PSU]	
✓ Bed Resistance     ✓ Coriolis Forcing     ✓ Wind Forcing		
···· ☆ Ice Coverage ···· ☆ Tidal Potential ····· ☆ Precipitation - Evaporat		
····· ☆ Wave Radiation ····· ☆ Sources ····· ☆ Structures		
Initial Conditions     Soundary Conditions     Soundary Conditions     Decoupling		
Navigation		
	n_/	

#### Figure 4.7 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Density specification

The default setting for the Horizontal Eddy Viscosity is a Smagorinsky formulation with a coefficient of 0.28, see Figure 4.8.



Sim1.mfm		
MIKE 21/3 Coupled Model FM	Edd. After states	
Domain	Eddy Viscosity	
✓ Time     ✓ Module Selection	u a dellar a	
	Horizontal Eddy Viscosity	
Hydrodynamic Module	Eddy type	Smagorinsky formulation
M Solution rechnique	Eddy type	Smagorinsky formulation
Flood and Dry	Smagorinsky formula	tion data
Density	onagonnon, ronnala	
Eddy Viscosity	Format	Constant
Bed Resistance	Constant value	0.28
Coriolis Forcing		
🗈 🗹 Wind Forcing	Data file and item	Select
Ice Coverage		Item: View
<ul> <li>Tidal Potential</li> <li>Precipitation - Evaporat</li> </ul>		
Waye Badiation		
Sources	Eddy parameters	
🗄 🖌 Structures		
🚽 🖌 Initial Conditions	Minimum eddy viscos	ity 1.8e-006 [m²/s]
😥 🗹 Boundary Conditions	Maximum eddy visco	sity 10000000 [m <sup>2</sup> /s]
🗹 🗹 Decoupling		
🗄 🖬 Outputs		
Navigation		
,,		
Validation Simulation	1	

#### Figure 4.8 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Eddy Viscosity (Horizontal)

The Bed Resistance will be given as a Manning map, see Figure 4.9. The Manning number is  $40^{1/3}$ /s in the overall area, but smaller at the south and north boundaries to avoid instabilities during simulation.

🔵 Sim1.mfm			- • •
MIKE 21/3 Coupled Model FM	Bed Resistance	9	
Module Selection ✓ Hydrodynamic Module	Resistance type	Manning number	
Solution Technique	Manning number data		
Flood and Dry	Format Constant value	Varying in domain   32 [m^(1/3)/s]	
Eddy Viscosity	Data file and item		Select
		Item: Manning number	View
Wave Radiation			
Boundary Conditions     Gecoupling     Outputs			
Sand Transport Module			
Navigation			
Validation (Simulation	on /		

Figure 4.9 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: The Bed Resistance is specified as Varying in domain: FineManning.dfsu

The format must be set as 'Varying in domain' in order to specify the bed resistance by a 2D data file (dfsu or dfs2).

Click Select ... to select the data file in the open file window that appears.



Sim1.mfm		
MIKE 21/3 Coupled Model FM	Wind Forcing	
Module Selection	V Include	
Hydrodynamic Module	Format	Varying in time, constant in domair 💌
✓ Depth     ✓ Flood and Dry	Speed Direction	0 [m/s]
Eddy Viscosity	Direction	VTorsminde\Data\Wind\Wind SimulationPeriod.dfs0 Select
Bed Resistance	Data file and items	Item: Wind speed View
Wind Forcing     Vice Coverage		Item: Wind direction
Tidal Potential	Neutral pressure	1013 [hPa]
Wave Radiation	Soft start interval	3600 [sec]
Structures		
Boundary Conditions		
Outputs     Sand Transport Module		
Sand Hansport Module     Spectral Wave Module		
Navigation		
Validation Simulation	1	
	1	

The Wind Forcing will be included as a time series file, see Figure 4.10.

#### Figure 4.10 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Wind Forcing

The format must be set as 'Varying in time, constant in domain' in order to specify the wind conditions by a time series file. A soft start of 3600 s is applied.

Click Select ... to select the data file in the Open File window that appears.

The Wind Friction type is set to 'Varying with Wind Speed' with the default values, see Figure 4.11.

🔵 Sim1.mfm			- • ×
MIKE 21/3 Coupled Model	Wind Friction		
Module Selection	Friction		
Hydrodynamic Module	Friction type	Varying with Wind Speed 🔹	
Flood and Dry	Constant	0.001255	
Eddy Viscosity	Linear variation using	Speed         Friction           7         [m/s]         0.001255	
Coriolis Forcing		25 [m/s] 0.002425	
Wind Friction			
Tidal Potential			
✓ Wave Radiation ✓ Sources			
Decoupling     Outputs			
Sand Transport Module +			
Navigation			
	1		

Figure 4.11 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Wind Friction



Please note that this example **does not** include the parameters of the following subjects:

- Coriolis Force
- Ice Coverage
- Precipitation-Evaporation
- Sources
- Tidal Potential
- Structures
- Decoupling

and the associated dialogue pages are not considered.

The wave radiation should be specified in the 'Wave Radiation' dialogue. In this case the flow, wave and sediment modules are executed in coupled mode, so you should select the type 'Wave radiation from SW simulation', see Figure 4.12.

Sim1.mfm			
MIKE 21/3 Coupled Model FM	Wave Radiatio	n	
Module Selection	Type Wave rad	liation from SW simulation	
⊟ ✓ Hydrodynamic Module	Wave radiation		
	Format	Varying in time and domain	
✓ Density ✓ Eddy Viscosity	Data file and items		Select
Bed Resistance		Item: Item:	View
		Item:	
<ul> <li>✓ Tidal Potential</li> <li>✓ Precipitation - Evaporat</li> </ul>	Soft start interval	0 [sec]	
····· ✔ Wave Radiation ···· ✔ Sources			
Boundary Conditions			
🗈 🗹 Spectral Wave Module			
Navigation			
Validation Simulation	n /		

Figure 4.12 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Wave Radiation

Now you should check the boundary conditions at the simulation start time to estimate the initial surface level. In this case we will use a constant level of 0.0 m, which is the measured value in Torsminde harbour 1 hour after the start of the simulation, see Figure 4.13.



Sim1.mfm MIKE 21/3 Coupled Model FM	Initial Condition			
	Initial Conditions	5		
✓ Time ✓ Module Selection	Trees			1
	Туре	Constant	•	J
Hydrodynamic Module     Solution Technique	Initial data			
M Solution rechnique	Surface elevation	0 [m] u-velocity	0	[m/s]
Flood and Dry	Surface elevation	·		
✓ Density		v-velocity	0	[m/s]
Eddy Viscosity				
✓ Bed Resistance				
Coriolis Forcing	Data file			Select
🕀 🖌 Wind Forcing	Surface elevation item	Item:		View
🚽 🖌 Ice Coverage	Velocity items	Item:		
🗹 🗹 Iidal Potential	velocicy icents	Item:		
Precipitation - Evaporat		Item:		
Wave Radiation				
Sources				
Structures				
M Initial Conditions				
Boundary Conditions     Decoupling				
Navigation				

#### Figure 4.13 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Initial Conditions

In the 'Boundary Conditions' dialogue, the boundary conditions should be specified for the boundary names, which were specified in the 'Domain' dialogue, see Figure 4.1. There is a North Boundary, a West Boundary and a South Boundary, and the time series that were generated in Chapter 3 should be used on all three boundaries.

In this example the boundary type is 'Specified Level' (Water Level), because only Water Level measurements are available. 'Specified Level' means that the Water Levels are forced at the boundaries and the discharge across the boundary is unknown and estimated during simulation.

The boundary format must be set as 'Varying in time, constant along boundary' in order to specify the boundary as a time series file (dfs0).

Click Select ... to select the data file in the Open File window that appears.

At the North and South boundary you must select the 'Include radiation stress correction'. This automatically changes the water level at the boundary to include the water level setup caused by the breaking waves. There is no reason to this correction for the West Boundary as the wave setup here is negligible.

It is a good practice to use a soft start interval. In our case 3600 s is suggested with a reference value corresponding to the initial value of 0.0 m. The soft start interval is a period in the beginning of a simulation where the effect of the boundary water levels does not take full effect.

In the beginning of the soft start period the effect of the specified Boundary Condition is zero. The effect increases gradually until the boundaries have full effect in the model at the end of the soft start interval period. See Figure 4.14.

**Please note** that an easy way to see the boundary data file is to simply click \_\_\_\_\_\_ in the 'Boundary' dialogue.



Sim1.mfm				E	- • •
MIKE 21/3 Coupled Model 🔺	North				<u> </u>
Module Selection	Type Specified Boundary data	level 🔻	·		
Solution Technique	Format	Varying in time, const	ant along boundary	·	
	Data file and item		ions\Waterlevels_Torsmin		E
	Type of vertical profile	Item: LP/HP filtering	of Elevation	View	
	Soft start Type Sinus var Time interval Reference value	iation 3600 [sec] 0 [m]	Interpolation type In time Linear In space Normal	•	
South So					
Validation (Simulation	ı /				

# Figure 4.14 MIKE 21/3 Coupled Model FM, Hydrodynamic Module. The Boundary Conditions for the North Boundary are specified as constant along the boundary: Waterlevels\_Torsminde.dfs0

Now you may specify one output as an area series (2D) and also specify the resulting output file name, see Figure 4.15. Specify the file name HD\_results.dfsu for the first simulation.

🧶 Sim1.mfm	
MIKE 21/3 Coupled Model A	Output 1
	Geographic View Output specification Output items Data Field type 2D (horizontal)   Output format Area series
✓ Density ✓ Eddy Viscosity	Output file HD_Results.dfsu Treatment of flood and Only real wet area
	Time step First 0 Last 528 Frequency 2 Area series
✓ Wave Radiation ✓ Sources ↔ Structures	Map projection UTM-32  Import from file
<ul> <li>✓ Initial Conditions</li> <li>→ ✓ Boundary Conditio</li> </ul>	Easting Northing Layer no. Name
Decoupling	1 443757.10636 6244949.8366
□ ✓ Outputs	2 443757.10636 6250066.4987
✓ Output 1	3 445762.67241 6250066.4987
🗈 🖌 Sand Transport Module 👻	4 445762.67241 6244949.8366
Navigation	n /

#### Figure 4.15 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Output type and location. Results can be specified as point, line or area series

Reduce the output size for the area series to a reasonable amount by selecting an output frequency of 3600 s, which is a reasonable output frequency for a tidal simulation. As our time step is 1800 s, the specified output frequency is 3600/1800 = 2. As default, the full area is selected.





Pick the parameters to include in the output file as shown in Figure 4.16.

Figure 4.16 MIKE 21/3 Coupled Model FM, Hydrodynamic Module: Output items

## 4.4 Specifications for the Spectral Wave Module

In this simulation waves derived from a regional numerical model act as boundary conditions for the local wave simulation.

The time formulation is selected as quasi-stationary formulation. This has been chosen because of the limited size of the area. Also the simulation time for the quasi-stationary simulation is much smaller than for the instationary simulation.

The spectral formulation of the wave model is selected as directionally decoupled parametric formulation, see Figure 4.17.






The start time step for the wave calculations is specified in the 'Time parameters' dialogue. The time step for the wave simulation is defined by the overall time step.

The wave simulation should start at the same time as the hydrodynamic simulation, e.g. start time step is 0 as shown in Figure 4.18.

Sim1.mfm		
MIKE 21/3 Coupled Model FM  Module Selection  Mo	Time parameters         Start time	
Validation / Simulat		

#### Figure 4.18 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Time parameters

In the 'Spectral Discretization' dialogue you specify the spectrum from which the wave simulations are based. Specify the values as given in Figure 4.19.

**Please** note that increasing the number of directions will give more accurate results, but also longer simulation time. If the expected wave directions fall within a pre-defined range



of directions, the choice of a directional sector type of discretization is recommended to reduce the computational time.

Sim1.mfm			
MIKE 21/3 Coupled Model FM	Spectral Discretization		
Module Selection	Frequency Discretization Discretization type logaritmic	Number of frequencies	25
Spectral Wave Module     Sectral Wave Module     Sectors     Time parameters		Minimum frequency Frequency factor	0.055 [hz]
Solution Technique     Solution Technique     Solution Technique     Solution Technique     Solutions     Solutions     Solutions	Directional Discretization Discretization type Directional sector	Number of directions	14
<ul> <li>✓ Wind Forcing</li> <li>✓ Ice Coverage</li> <li>✓ Diffraction</li> <li>✓ Wave Breaking</li> </ul>		Minimum direction Maximum direction	135 [deg] 45 [deg]
	Separation of wind sea and Swell Type of separation No separation	Ţ	
Navigation			

#### Figure 4.19 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Spectral Discretization

In the 'Solution Technique' dialogue you specify the method as Newton-Raphson iteration. Specify the values as given in Figure 4.20.

Sim1.mfm			
MIKE 21/3 Coupled Model FM	Solution Technique		
Module Selection	Quasi stationary formulation Output of convergence	information	
Sand Transport Module     Spectral Wave Module	Geographical space discretization	Low order, fast algorithm	•
Basic Equations	Frequency discretization	Low order, fast algorithm	-
Spectral Discretization	Directional discretization	Low order, fast algorithm	·
Water Level Conditions ✓ Current Conditions	Method	Newton-Raphson iteration	•
✓ Wind Forcing	Max. number of iterations	500	
✓ Diffraction     ✓ Wave Breaking	Tolerance (RMS-norm of residual)	1e-005	
Bottom Friction	Tolerance (Max-norm of change in sig. wave height)	0.001 [m]	
Structures	Relaxation factor	0.1	
Initial Conditions     Soundary Conditions			
🗄 🗹 Outputs			
Navigation			
	n /		

#### Figure 4.20 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Solution Technique

In the 'Water Level Conditions' dialogue you specify the type as 'Water level variation from HD simulation', see Figure 4.21.



• Sim1.mfm			• 🔀
MIKE 21/3 Coupled Model FM	Water Leve	el Conditions	
✓ Time ✓ Module Selection	Туре	Water level variation from HD simulation	
Hydrodynamic Module     Sand Transport Module			
Spectral Wave Module     Basic Equations			
Time parameters			
Vater Level Conditions			
✓ Current Conditions ✓ Wind Forcing			
✓ Ice Coverage ✓ Diffraction			
✓ Wave Breaking ✓ Bottom Friction			
Boundary Conditions			
Navigation			
Validation / Simulati	on /		

### Figure 4.21 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Water Level

Likewise, in the 'Current Conditions' dialogue you specify the type to be 'Current variation from HD simulation', see Figure 4.22.

Sim1.mfm			
MIKE 21/3 Coupled Model FM	Current (	Conditions	
wf Time         wf Module Selection         wf Hydrodynamic Module         wf Sand Transport Module         wf Spectral Wave Module         wf Spectral Wave Module         wf Spectral Discretization         wf Spectral Discretization         wf Spectral Discretization         wf Solution Technique         wf Water Level Conditions         wf Uter trace Conditions         wf Uter trace Conditions         wf Uter trace Transport         wf Diffraction         wf Diffraction         wf Diffraction         wf Boundary Conditions         wf Initial Conditions         wf Boundary Conditions         wf Outputs         Navigation	Туре	Current variation from HD simulation 🔹	
	on /		



The Wind Forcing is included as a time series file similar to the input for the Hydrodynamic module, see Figure 4.23.



Sim1.mfm	
MIKE 21/3 Coupled Model FM	
	Wind, speed and direction
🗈 🗹 Sand Transport Module 🥼 Wind data	
Spectral Wave Module     Format	Varying in time, constant in domair 💌
Time parameters Speed	0 [m/s]
Spectral Discretization	0 [deg]
Water Level Conditions Data file and items	4\Torsminde\Pata\Wind\Wind_SimulationPeriod.dfs0
Wind Forcing	Item: Wind speed View
✓ Diffraction Soft start     ✓ Wave Breaking	0 [sec]
Bottom Friction – Wind Generation F	ormula
Initial Conditions Wind Generation	n formula SPM84 🔹
Boundary Conditions	
Navigation	
Validation Simulation	

Figure 4.23 MIKE 21/3 Flow Model FM, Spectral Wave Module: Wind Forcing

In this example 'Ice Coverage' and 'Diffraction' are not included and the dialogue pages are is not explained.

Use the default values in the 'Wave Breaking' dialogue, see Figure 4.24.

🔵 Sim1.mfm		
MIKE 21/3 Coupled Model FM	Wave Breaki	ng
Module Selection	Model	Wave breaking
i Sand Transport Module i Spectral Wave Module	Type of gamma	Specified gamma 🔻
Basic Equations	Gamma data	
Spectral Discretization	Format Constant value	Constant   0.8
Water Level Conditions     Gurrent Conditions     Wind Forcing     Ge Coverage	Data file and item	Select Item: View
✓      ✓      Øffraction     ✓      Wave Breaking     ✓      Øctom Friction     ✓      Structures     ✓      finial Conditions     ④      ✓      Boundary Conditions	Alpha Gamma (wave ste	epness) 1 on mean wave frequency
Navigation		
	n /	

Figure 4.24 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Wave Breaking

In the 'Bottom Friction' dialogue, the model for the friction is selected to Nikuradse roughness,  $k_N$ . The bottom friction is set to a constant value of 0.01 m. As default the effect on mean wave frequency is included, see Figure 4.25.



Sim1.mfm		
MIKE 21/3 Coupled Model FM	Bottom Friction	
√ Time		
Module Selection	Model	Nikuradse roughness, kn 🔻
⊕ ✓ Hydrodynamic Module     ✓ Sand Transport Module	Nikuradse roughness o	data
Spectral Wave Module     Sectral Wave Module     Sectral Wave Module	Format	Constant 💌
Time parameters	Constant value	0.01 [m]
Spectral Discretization	Data file and item	Select
Water Level Conditions		Item: View
✓       Current Conditions         ✓       Wind Forcing         ✓       Ice Coverage         ✓       Diffraction         ✓       Bottom Friction         ✓       Structures         ✓       Initial Conditions         E       ✓         Ø       Outputs	Current friction	0 mean wave frequency
Validation Simulation	1	



In this case the directionally decoupled parametric formulation is started as a cold-start simulation. Select Zero spectra in the 'Initial Conditions' dialogue, see Figure 4.26.

In this example 'Structures' is not included and the dialogue page is not described.

In the 'Boundary Conditions' dialogue, the boundary conditions should be specified for the boundary names, which were specified in the 'Domain' dialogue, see Figure 4.1. There is a North Boundary, a West Boundary and a South Boundary.

• Sim1.mfm	
MIKE 21/3 Coupled Model FM Module Selection Module Selection Mod	Initial Conditions         Type       Zero Spectra         Use initial conditions for all time steps
	<u></u>

### Figure 4.26 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Initial Conditions

In this example, the waves on the West boundary are defined by a time series file whereas the North and South boundary are defined as Lateral, see Figure 4.27. As the lateral boundary conditions is an approximation, inaccurate results near the boundary may be expected, but as the area of interest is well inside the model domain it is assumed that this will have no effect on the conclusive results.



Sim1.mfm				
MIKE 21/3 Coupled Model FM	Boundary Conditi	ons		
✓ Time ✓ Module Selection	Geographic View List vie	M		
Hydrodynamic Module	Geographic view			
🗈 🗹 Sand Transport Module	Boundary Name	Format	Edit	
🖻 🗹 Spectral Wave Module	North	Lateral boundary	Go to	
Basic Equations	West South	Wave parameters (version 1) Lateral boundary	Go to	
Spectral Discretization	South	Lateral boundary	Go to	
Solution Technique				
Water Level Conditions				
Wind Forcing				
✓ Ice Coverage				
Diffraction				
✓ Wave Breaking ✓ Bottom Friction				
Bottom Friction     Structures				
🖌 Initial Conditions				
Boundary Conditions				
South				
v West				
🕀 🖌 Outputs				
Navigation				
Validation Simulation				

### Figure 4.27 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Boundary Condition List

The time series of waves for the West boundary is obtained from a previous simulation as described in Chapter 3. The type is Wave Parameters (Version 1) and the boundary format must be set as 'Varying in time, constant along boundary' in order to specify the boundary as a time series file (dfs0).



Click Select ... to select the data file in the Open File window that appears.

In this case the waves at the start of the simulation are small so it is assumed that a soft start interval is not necessary, see Figure 4.28.

MIKE 21/3 Coupled Model FM         Module Selection         Module Selectal Wave Module         Module Selectal Wave Selectal Wave Module         Module Selectal Wave Selectal Wave Selectal Wave Selectal Waves WSW_timeseries_okt97.dfs0         Module Selectal Wave Selectal S	• Sim1.mfm	x
Image: Sectal Wave Bold   Image: Sectal Wave Module   Image: Sectal		
Initial Conditions     Soft start     Interpolation type     Interpolation type     Interpolation type     In time Linear     In space     Normal     ✓     Mest     Reference significant     Formal	✓       Time         ✓       Module Selection         ✓       Module Selection         ✓       Module Selection         ✓       Module Selection         ✓       Spectral Wave Module         ✓       Spectral Discretization         ✓       Spectral Discretization         ✓       Spectral Discretization         ✓       Spectral Discretization         ✓       Varying in time, constant along line         ✓       Spectral Discretization         ✓       Spectral Discretization         ✓       Varying in times, constant along line         ✓       Spectral Discretization         ✓       Module Select         ✓       Spectral Discretization         ✓       Current Conditions         ✓       Item: MWD         ✓       Defaction         ✓       Diffraction         ✓       Mave Breaking         ✓       Bottom Friction	
	✓       Initial Conditions         ✓       Boundary Conditions         ✓       Soft start         Type       Linear variation         ✓       Noth         ✓       West         @       Outputs         Navigation       0 [m]	

Figure 4.28 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Boundary Conditions

The output of the wave simulation is defined as an area series (2D), see Figure 4.29. Reduce the output size for the area series by selecting an output frequency of 3600 s, similar to the HD output. As default, the full area is selected.

Pick the parameters to be included in the output file as in Figure 4.30.



Sim1.mfm	
MIKE 21/3 Coupled Model FM Model Selection Model Select	Output 1         Geographic View       Output specification       Integral wave items       Model items       Input items         Field type       Parameters       Output format       Area series       Imput items         Output file       SW_Results.dfsu       Treatment of flood and       Only real wet area       Imput items         First       0       Last       528       Frequency       2         Area series       Map projection       UTM-32       Import from file         Import from file       Import from file       Import from file         1       443757.10636       6244949.8366       Easting         2       443757.10636       6244949.8366       Easting       Name         1       443757.10636       6249066.4987       Easting       Hame         1       443757.10636       6249499.8366       Easting       Easting         3       445762.67241       6249499.8366       Easting       Easting         4       445762.67241       6249499.8366       Easting       Easting
	_1



Sim1.mfm			
MIKE 21/3 Coupled Model FM	Output 1 Geographic View Output specific	cation Int	tegral wave items Model items Input items
M Module Selection     M Module Selection     M Module Module     M Sand Transport Module     M Sand Transport Module     M Spectral Wave Module     M Spectral Discretization     M Spectral Discretization     M Selection Technique     M Water Level Conditions     M Current Conditions     M Vind Forcing     M Vind Forcing     M Vind Forcing     M Vind Forcing     M Selection     M Wave Breaking     M Seturctures     M Structures     M Structures     M Structures	Parameters           Significant wave height           Maximum wave height           Peak wave period           Wave period           Wave period           Directional standard deviation           Wave velocity components           Radiation stresses           Particle velocities           Wave power		
Boundary Conditions	Type of spectrum Whole spectrum Frequency range Minimum 0.055 [hz] Maximum 0.5959088 [hz] Directional range Minimum 135 [deg Maximum 45 [deg		Separation of wind sea and swell Dynamic threshold frequency, version 2  Distance above bed for particle 0 [m]
Validation / Simulation	n /		

Figure 4.30 MIKE 21/3 Coupled Model FM, Spectral Wave Module: Output items



## 4.5 Specifications for the Sand Transport Module

In the 'Model Definition' dialogue you select the 'Model type' to *Wave and current* as the sediment transport calculations in this simulation are based on the simultaneous calculation of waves and currents, see Figure 4.31.

To limit computational time, the sediment transport rates for this model type are found by interpolation in a table containing sediment transport rates for an array of representative events. The method of generating such a sediment transport table is described in Chapter

3. Click \_\_\_\_\_\_ to select the sediment transport table 'QsTable.lon' in the Open File window that appears.

Sim1.mfm	
MIKE 21/3 Coupled Model FM	Model Definition
✓ Time ✓ Module Selection ↔ ✓ Hydrodynamic Module → ✓ Sand Transport Module	Model type Wave and current
Model Definition	Model description
✓ ✓ Time parameters     ✓ ✓ Sediment properties     ✓ ✓ Forcings     ✓ ✓ Morphology     ✓ ✓ Outputs	Warying layer thickness     0.0005     [m]     Image: Comparative of the second seco
i∄- 🖌 Spectral Wave Module	Pure current description     Transport description       Transport description     Number of       Equilibrium     Image: Constraint of the second secon
	Wave and current description Sediment transport table
	Data file d_Models\CoupledModel_FM\Torsminde\Data\Tables\QsTable.lon
Navigation	
Validation Simulation	un /



The time step for the sediment calculations is specified in the 'Time parameters' dialogue. The time step for the ST simulation is defined in relation to the overall time step.

The sediment transport simulation should start at the same time as the hydrodynamic simulation, i.e. start time step is 0. The time step for the ST simulation should be defined such that the update of the sediment transport rates reflects the bathymetric changes. In this case an update frequency of  $\frac{1}{2}$  hour is chosen, hence the time step factor must be set to 1 (1800 s), see Figure 4.32.

**Please note** that decreasing the time step factor may increase the simulation time.



🔵 Sim1.mfm		
MIKE 21/3 Coupled Model FM	Time parameters	
	Time step factor 2	
Navigation		
	n /	

#### Figure 4.32 MIKE 21/3 Coupled Model FM, Sand Transport Module: Time parameters

The sediment properties must be defined in the 'Sediment Properties' dialogue. Per default the porosity is set to 0.4.

**Important**: The specified grain diameter or grading coefficient must be contained in the sediment transport table. If the sediment data is outside the limits of the table, the simulation will stop!

In this case the sediment data in the area is specified as Constant with a mean Grain diameter of 0.3 mm and a Grading coefficient of 1.45, see Figure 4.33. (It is the type of sediment, which is described in the 'Sediment transport table' in Figure 4.31).

Sim1.mfm			
MIKE 21/3 Coupled Model FM	Sediment properties		
	Porosity Porosity 0.4		
Model Definition	Sediment data		
···· ✓ Sediment properties 	Format Constant	▼	
Morphology		[mm]	
🗄 🗹 Spectral Wave Module	Grading coefficient 1.45		
	Data file and items	Select .	_
		View	
	Relative density 2.65	]	
Navigation	1		

Figure 4.33 MIKE 21/3 Coupled Model FM, Sand Transport Module: Sediment properties



In this simulation it is implicit that the current fields are found from the ongoing HD simulation. In the 'Waves' dialogue you specify the type as 'Wave field from SW simulation', such that you use the results from the ongoing SW simulation, see Figure 4.34.

Sim1.mfm		
MIKE 21/3 Coupled Model FM	Waves	
	Type Wave field from SW simulation 🔻	
	n /	



The focus of this simulation is to model the morphological evolution during a storm period, i.e. bathymetry changes. In the 'Model Definition' dialogue you select to include the feedback on hydrodynamic, wave and sand transport calculation. This enables a dynamic update of the bathymetry that effects the future calculations, see Figure 4.35.

Set the maximum bed level change to 2 metres/day to avoid instabilities in the simulation because of abrupt changes at the boundaries.

Sim1.mfm		
MIKE 21/3 Coupled Model FM	Model definition	
Module Selection	Max bed level change 2 [m/day]	
Sand Transport Module	Speedup factor 1	
More parameters     More parameters     More parameters     More parameters     More parameter     More	☑ Include feedback on hydrodynamic, wave and sand transport calculation	
	ion /	

Figure 4.35 MIKE 21/3 Coupled Model FM, Sand Transport Module, Morphology: Model Definition

The time step for the morphological update is the same as the time step for the sediment calculations, i.e. the speed-up factor is 1.



You can start the morphological update of the bathymetry at a later time than the start of the sediment transport calculations, but in the present case you should set the start time step to 0, see Figure 4.36.

Sim1.mfm			
MIKE 21/3 Coupled Model FM	Time paran	neter	
M Time     Module Selection     M Hydrodynamic Module     M Hydrodynamic Module     M Gall Definition     M Time parameters     M Sediment properties     M Forcings     M Morphology     M Morphology     M Morphology     M Bank Erosion     Bank Erosion     M Spectral Wave Module	0		
Navigation			
Validation Simulat	ion /		

#### Figure 4.36 MIKE 21/3 Coupled Model FM, Sand Transport Module, Morphology: Time parameter

Bank erosion is not included in the model as the focus area is in front of the harbour entrance where no slope failure mechanisms will influence the result.

In the 'Boundary Conditions' dialogue, the boundary conditions should be specified for the boundary names, which were specified in the 'Domain' dialogue, see Figure 4.1. There is a North Boundary, a West Boundary and a South Boundary.

Select the boundary type for all three boundaries as shown in Figure 4.37.

🔵 Sim1.mfm		
MIKE 21/3 Coupled Model FM & Domain & Domain & Domain & Module Selection & Module Selection & Module Selection & Model Definition & Model	North Type Zero sediment flux gradient for outflow, zero bed change for inflow	
	<u>"'</u>	

Figure 4.37 MIKE 21/3 Coupled Model FM, Sand Transport Module, Morphology: Boundary conditions



The output of the sediment transport simulation is defined as an area series (2D), see Figure 4.38. Select an output frequency of 3600 s, twice the time step of the HD simulation. As default, the full area is selected.

Sim1.mfm	
MIKE 21/3 Coupled Model FM	Output 1         Geographic View       Output specification         Data         Field type       2D (horizontal)         Output file       ST_Results.dfsu         Treatment of flood and       Only real wet area
B - xf Morphology	Time step First 0 Last 528 Frequency 2 Area series Map projection UTM-32  Import from file Map Frequency 2
	Easting Northing Layer no. Name
	1 443770.51765 6245046.3359
	2 443770.51765 6249810.7596
	3 445762.53963 6249810.7596
	4 445762.53963 6245046.3359
	)
Navigation	
////	

Figure 4.38 MIKE 21/3 Coupled Model FM, Sand Transport Module: Output type and location

Pick the parameters to include in the output file as in Figure 4.39.

MIKE 21/3 Coupled Model FM         Image: Selection         Module Selection         Model Definition         Model Selection         Selection         Selection         Selection         Depth avera	Sim1.mfm		
Navigation	MIKE 21/3 Coupled Model FM Domain Module Selection Module Selection Module Selection Module Definition Module Definition Morphology Morphology Morphology Morphology Morphology Spectral Wave Module	Output 1         Geographic View       Output specification       Output items         Basic variables       Image: Component in the specification is t	
Validation Simulation			







# 5 Model Calibration

In order to calibrate the model, some measurements are required inside the model domain.

## 5.1 Measured Bathymetries

In this example, the bed level in front of the harbour entrance has been surveyed on 16/10 and 27/10 1997, respectively. These two dates are the beginning and end of the simulation period. The findings are shown in Figure 5.1 as maps of the survey data.

The maps show that two areas in front of the harbour entrance are significantly more shallow than the surroundings. One area is an isolated outer bar, positioned 300 m from the coastline. Another area is an inner bar located close to the northern jetty, extending in front of the harbour entrance.

Before the storm, on 16 October, 1997, the outer bar extended 100 in the north-south direction and 50 m in the west-east direction. It rose up to -3.0 m in an area where the bed levels were below -4 m. The inner bar extended 200 m along the coast and 50 m across. The southern 100 m of the bar was located just in front of the harbour entrance. The bar rose to above -2 m in an area where the bed generally was between -4 m and - 5 m.

After the storm, on 27 October, 1997, the outer bar remained in its general appearance. However, it seems like the most shallow area did migrate a bit northwards. The inner bar now stretches even further across the entrance towards the south, though the top level of the bar has decreased.

These bathymetry changes can be related to the hydrodynamic conditions. In the beginning of the period, the fairly small waves from southwest would generate a northbound littoral drift. On 20 October 1997 the wave direction shifted to northwest and the wave height increased thus generating a larger south-bound littoral drift. In total this would cause the sediment in the area to move towards south, as seen for the inner bar.

In reality the sluice inside the harbour was closed during the storm and reopened after the storm, but before the post-storm measurement. The influence of the outflow on the bed level change can be seen as the two seawards extensions on the inner bar.







Figure 5.1 Measured bed level in front of harbour entrance. Upper: measured 16/10 1997 Lower: measured 27/10 1997



## 5.2 Comparison of Measured and Calculated Bathymetries

Use the Data Viewer to plot the initial bathymetry and the calculated bed level after the 11 days of simulation. A comparison can easily be made by applying a colour legend that resembles the scanned map.

Figure 5.2 shows the measured and simulated bathymetries before and after the storm event.

It is seen that the bar in front of the harbour entrance in the simulation shows the same tendency of southward migration as observed in nature. However, the form of the bar is different. This is probably because the outflow due to the opening of the sluices in the harbour at the end of the storm period is not considered in the simulation.



Figure 5.2 Comparison of measured and simulated bathymetries in front of harbour entrance. Upper: measured Lower: calculated

## 5.3 Line Series Extraction

The development of the inner bar can be reviewed in detail by extracting lines from the result file.

To extract lines from a dfsu file, use the Data Extraction FM tool in MIKE Zero, see Figure 5.3.



MIKE 11 MIKE 21 MIKE 3 MIKE 21/3 Integrated Models LITPACK MIKE FLOOD MIKE SHE	Profile Series (.dfs1) Data Manager (.dfsu,.mesh,.dfs2,.dfs3) Grid Series (.dfs3,.dfs2) Plot Composer (.plc) Result Viewer (.rev) Bathymetries (.batsf) Climate Change (.mzcc) Ecolab (.ecolab) Auto Calibration (.auc) EVA Editor (.eva) Mesh Generator (.mdf) Data Extraction FM (.dxfm) MIKE Zero Toolbox (.mzt)	
Data Extraction FM		

### Figure 5.3 Starting the Data Extraction FM tool in MIKE Zero

In the 'Input' dialogue specify the name of the file containing the simulation results, see Figure 5.4.

📥 ExtractLineData.dxfm		
Data Extraction FM	Input	
🖾 🖌 Outputs	File name ledModel_FM\T	orsminde\simulation1\Sim1.mfm - Result Files\ST_Results.dfsu
	File information	
	Map projection :	UTM-32
	X min, X max :	443790.047273, 445743.010000
	Y min, Y max :	6245093.045909, 6249764.049545
	Z min, Z max :	-14.293978, 7.838003
	Number of dimensions :	2
	Number of layers :	0
	Time step interval :	3600.000000 second
	Number of timesteps :	265
	Start date :	16-10-1997 0:00:00
	End date :	27-10-1997 0:00:00
Navigation		
Validation Simulat	ion /	

Figure 5.4 Selecting input file

In the 'Output' dialogue you define an output file for each line you want to extract, see Figure 5.5.

In this case three lines are defined as listed in Table 5.1.



Table 5.1	Extraction lines from the Output dialogue
-----------	---

Lines	Start	End	Description
Line 1	(445100, 6247880)	(445300, 6247880)	North cross-shore line
Line 2	(445100, 6247830)	(445300, 6247830)	South cross-shore line
Line 3	(445200, 6248050)	(445200, 6247750)	Longshore line

The lines are outlined in Figure 5.6.

📥 ExtractLineData.dxfm				
Data Extraction FM	Output 1			
	Geographic View Output specification Output items Data Field type 2D (horizontal)  Output format Line series			
	Output file \CoupledModeLFM\Torsminde\simulation1\BedLeveLLine_7880.dfs1			
	First     0     Last     264     Frequency     1       Line series       Map projection     UTM-32     Import from file			
	No. of points on line 41			
	Easting Northing z Name			
	First 455100 6247880			
	Last 445300 6247880			
Navigation				
Validation Simulation				



Choose 'Run'  $\rightarrow$  'Start Data Extraction' to extract the line data.





Figure 5.6 Position of extraction lines

The development of the bed level along Line 1, Line 2 and Line 3 are shown in Figure 5.7, Figure 5.8 and Figure 5.9, respectively. Line 3 is positioned to follow the top level of the bar.

It is seen from Figure 5.7 and Figure 5.8 that the bed level does not change significantly in the sheltered area behind the breakwater, i.e. east of position 140 m on the x-axis. Figure 5.7 shows that the inner bar just adjacent to the northern jetty has been subject to some erosion. The contrary is the case for Figure 5.8 where a distinct bar has developed.

Figure 5.9 shows that the existing inner bar has migrated towards south during the simulation, thus covering the harbour entrance entirely. The harbour entrance is positioned between position 150 m and 250 m on the x-axis.













Figure 5.9 Bed level along Line 3: before and after simulation

