



# MIKE 21 & MIKE 3 Flow Model FM

Hydrodynamic Module

Step-by-step training guide



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## 1 Introduction

This Step-by-step training guide relates to the fixed link across the Sound (Øresund) between Denmark and Sweden.



Figure 1.1 Øresund, Denmark

### 1.1 Background

In 1994 the construction of a fixed link between Copenhagen (Denmark) and Malmö (Sweden) as a combined tunnel, bridge and reclamation project commenced. Severe environmental constraints were enforced to ensure that the environment of the Baltic Sea remains unaffected by the link. These constraints implied that the blocking of the uncompensated design of the link should be down to 0.5 %, and similarly maximum spillage and dredging volumes had been enforced. To meet the environmental constraints and to monitor the construction work a major monitoring programme was set-up. The monitoring programme included more than 40 hydrographic stations collecting water level, salinity, temperature and current data. In addition intensive field campaigns were conducted to supplement the fixed stations with ship-based ADCP measurements and CTD profiles. The baseline monitoring programme was launched in 1992 and continued into this century.

By virtue of the natural hydrographic variability in Øresund the blocking of the link can only be assessed by means of a numerical model.

Amongst the comprehensive data sets from the monitoring programme, which form a unique basis for modelling, a three-month period was selected as 'design' period such that it reflected the natural variability of Øresund. The design period was used in the detailed planning and optimisation of the link, and to define the compensation dredging volumes, which were required to reach a so-called Zero Solution.



### 1.2 Objective

The objective of this Step-by-step training guide is to set-up both a MIKE 21 Flow Model with Flexible Mesh (MIKE 21 Flow Model FM), and a MIKE 3 Flow Model FM for Øresund from scratch and to calibrate the model to a satisfactory level.

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 readily accepted by the MIKE Zero software. Depending on the amount and quality of the data sets this can be a tedious, time consuming but indispensable process. For this example guide the 'raw' data has been provided as standard ASCII text files.

The files used in this Step-by-step training guide are a part of the installation and located in the default installation folders:

.\Examples\MIKE\_21\FlowModel\_FM\HD\Oresund

.\Examples\MIKE\_3\FlowModel\_FM\HD\Oresund

You should install the examples from the MIKE Zero start page in your own folder.

**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 already familiar with importing data into MIKE Zero format files, you do not have to generate all the MIKE Zero input parameters yourself from the included raw data. All the MIKE Zero input parameter files needed to run the example are included and the simulation can start immediately if you want.



## 2 Creating the Computational Mesh

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.

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

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

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

Please also see the User Guide for the MIKE Zero Mesh Generator, 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

### 2.1 General Considerations before Creating a Computational Mesh

The bathymetry and mesh file should

- 1. describe the water depths in the model area
- 2. allow model results with a desired accuracy
- 3. give model simulation times acceptable to the user

To obtain this, you should aim at a mesh

- 1. with triangles without small angles (the perfect mesh has equilateral triangles)
- 2. with smooth boundaries
- 3. with high resolutions in areas of special interest
- 4. based on valid xyz data

Large angles and high resolutions in a mesh are contradicting with the need for short simulation times, so the modeller must compromise his choice of triangulation between these two factors.

The resolution of the mesh, combined with the water depths and chosen time-step governs the Courant numbers in a model set-up. The maximum Courant number shall be less than 0.5. So the simulation times dependency on the triangulation of the mesh, relates not only to the number of nodes in the mesh, but also the resulting Courant numbers. As a result of this, the effect on simulation time of a fine resolution at deep water can be relatively high compared to a high resolution at shallow water.

### 2.2 Creating the Øresund Computational Mesh

A chart of the area of interest in this example is shown in Figure 2.1. It covers the Sound between Denmark and Sweden. Based on a chart (e.g. from MIKE C-map), xyz data for



shorelines and water depths can be generated. In this example xyz data for shorelines and water depths have already been generated. See Figure 2.14.



Figure 2.1 Chart covering the area of interest: Øresund, the Sound between Denmark and Sweden



### 2.2.1 Creating a mdf- file from the raw xyz data

The mesh file containing information about water depths and mesh is created with the Mesh Generator tool in MIKE Zero. First you should start the Mesh Generator (File $\rightarrow$ New $\rightarrow$  File $\rightarrow$ Mesh Generator). See Figure 2.2.

After starting the Mesh Generator you should specify the projection system as UTM and the zone as 33 for the working area. See Figure 2.3.

🗟 New File		×
Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 3 MIKE 21/3 Integrated Models LITPACK MIKE FLOOD MIKE SHE	Documents: Time Series (.dfs0) 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)	
Mesh Generator		
	ОК	Cancel

Figure 2.2 Starting the Mesh Generator tool in MIKE Zero

Workspace projection	×
Please, specify the map projection	
Projection	
UTM-33	
OK Cancel Help	

Figure 2.3 Defining the projection of the work space

The resulting working area is shown in Figure 2.4.





Figure 2.4 The work space as it appears in the Mesh Generator after choosing projection and before adding xyz data

Import digitise file: land.xyz).	d shoreline c See Figure 2	ata from an ASCII file (Data→Import Boundar) 2.5.	y →Open X
Open XYZ File			? ×
Look in:	C Ascii	▼ ← 🖻 💣 ⊞•	
My Recent Documents Desktop My Documents	<mark>⊯land</mark> ▶ water		
My Computer			
9	File name:	land 🗾	Open
My Network Places	Files of type:	XYZ Files (*.xyz)	Cancel

XYZ

Figure 2.5 Import digitised shoreline data

Remember to convert from geographical co-ordinates: Choose Longitude/Latitude after importing shoreline date. See Figure 2.6.



Boundary Properties	×
Please specify the layout of the data file, the proj a single arc or multiple arcs.	jection of the data and whether the points in the data constitute
Column sequence	Arc definition <ul> <li>Add all vertices to one arc</li> <li>Use connectivity information</li> </ul> Discard arcs with less than: 2 vertices
Projection LONG/LAT Unit of X and Y: degree	▼ Data info
Unit of Z: meter	OK Cancel Help



The resulting workspace with the imported shoreline data will appear in a so-called Mesh Definition File (mdf-file) as shown in Figure 2.7.







The next step is to transform the raw data set, into a data set from which the selected domain can be triangulated.

### 2.2.2 Adjusting the boundary data into a domain that can be triangulated

This task should result in a file with boundary- and water boundaries (the green arcs) - forming a closed domain that can be triangulated.

Start by deleting the shoreline vertices and nodes (the red and blue points) that are not part of the shoreline of the area that you want to include in the bathymetry. This includes the nodes on land that you see in Figure 2.7.

Define a northern and southern boundary between Denmark and Sweden by adding arcs between 'Danish' nodes and 'Swedish' nodes. The boundaries should be placed near the co-ordinates for the boundary measurements given in Table 2.1.

Mark the North Boundary arc and choose properties. Set the arc attribute to 2 for the northern boundary. Mark 3 for the southern boundary arc. See Figure 2.8 and Figure 2.9.. These attributes are used for the model system to distinguish between the different boundary types in the mesh: the North Boundary (attribute 2) and the South Boundary (attribute 3). The land/water boundary (attribute 1) is automatically set by the Mesh Generator.

		Position	
Station	Data File	Easting (m)	Northing (m)
WL13 Viken	waterlevel_viken.txt	349744	6224518
WL14 Hornbæk	waterlevel_hornbaek.txt	341811	6219382
WL19 Skanør	waterlevel_skanor.txt	362748	6143316
WL20 Rødvig	waterlevel_rodvig.txt	333191	6126049

#### Table 2.1Measured water level data





Figure 2.8 Selecting the arc for the northern boundary (purple arc) for editing properties (right click with mouse)



Figure 2.9 Editing the northern boundary arc properties

Now you have a closed area that can be triangulated, but first you should go through and smooth all the shorelines. It should be noted that the triangulation of the domain starts from the boundary polygon, thus the number of elements generated by the triangulation process are very dependent of the number of nodes and vertices on the shoreline.

You can use the tool for redistributing the vertices along an arc to form a more uniform shoreline. In areas of special interest you can redistribute the vertices along the land boundary with a shorter distance between them. You might consider not including the bathymetry in inner harbours and lagoons, if they do not have significant effect on the results in the areas, where you do have interest.



After editing all the shorelines you might end up with an mdf-file similar to the one found in this example called: oresund.mdf. See Figure 2.10. Use this file for the further work with this example.

### 2.2.3 Triangulation of the domain

The next step is to triangulate the domain. First you mark the closed areas (islands) that should not be triangulated as polygons (green marks).



Figure 2.10 The mdf-file as it appears in the Mesh Generator after modifying Boundary xyz data to form a closed area surrounded by boundaries ready for triangulation



Try to make the first triangulation (Mesh→Generate Mesh). Use the triangulation option settings as in Figure 2.11. You can see that in this example, the area of interest has a higher resolution than the rest of the mesh. You might also consider refining the mesh in specific areas. You can do that by adding a polygon in the area of interest and giving the polygon local properties (add green mark in polygon and right click the mark for defining its properties).

Mesh Generation		×
Triangular mesh options Maximum element area: Smallest allowable angle: Maximum number of nodes:	[m <sup>2</sup> ] 30 6000	Generate Close Help
Mesh Progress Number of elements: Number of nodes:	0	

Figure 2.11 The triangulation options as they are set in this example

After the triangulation you can use a tool for smoothing the mesh (Mesh $\rightarrow$ Smooth Mesh). In this example the mesh has been smoothed 100 times. The resulting mesh will look as in Figure 2.12.

First import the xyz-file containing the water depths (Data $\rightarrow$ Manage Scatter Data $\rightarrow$ Add $\rightarrow$ water.xyz. Specify projection as Long/Lat for the 1993 data and UTM 33 for the 1997 data. The ASCII files are found in the folders:

.\Data\1993\Ascii\water.xyz

(for MIKE 21 modelling)

.\Data\1997\Ascii\water.xyz

(for MIKE 3 modelling)







Afterwards you have to interpolate the water depths in the appropriate xyz data file into the mesh: water.xyz (Mesh→Interpolate). See Figure 2.13.

**Please note** that the water depths are different in the MIKE 21 FM example and the MIKE 3 FM example, because they cover two different years, so the morphology has changed. The resulting mdf-file for the MIKE 21 bathymetry for 1993 will look as in Figure 2.15.



Interpolation					×
		Coofiguro			
Set value from scatte	er data	Maximum	100		
Triangle Interpolation Me	thod		,		
Interpolation Method	Natural Neighbour	•			
Extrapolate beyond o	onvex hull of scatter of	data			
Size of bounding 1	000 % beyond co	nvex hull			
Inverse distance strength	h 2				
Extrapolation					
Constant value	0				
C Inverse distance v	veighted				
Quadrangular Gridded Ar	reas				
Name	Interpo	plation Specification	n	Zoom	
Program					
Progress					- 1
					-11
		1		1	

### Figure 2.13 Interpolating water depths into the domain from imported XYZ file

📗 water.xyz - Noi	tepad		_ 🗆 🗵
File Edit Format	View Help		
Lat         Pointat           \$\$\frac{1}{2}\$.16805         \$\$12.16609           \$\$12.16637         \$\$12.16749           \$\$12.16972         \$\$12.17084           \$\$12.17168         \$\$12.17140           \$\$12.17196         \$\$12.17264	56.17699 56.17715 56.17762 56.17808 56.17871 56.18011 56.18011 56.18011 56.18011 56.17933 56.17855 56.17855	-20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00	<sup>3</sup>
12.17304 12.17420 12.17364 12.17252 12.16805 12.15742 12.15994 12.16106 12.16441 12.16525 12.16553 12.16357	56.17793 56.17762 56.17730 56.17699 56.17637 56.17637 56.17637 56.17606 56.17481 56.17419 56.17309 56.17169	-20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00 -20.00	3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3

Figure 2.14 ASCII file describing the depth at specified geographical positions (Longitude, Latitude and Depth). Please note that if MIKE C-map is used you are not allowed to view the data in a text editor because the data is encrypted





Figure 2.15 The mesh as it appears in the Mesh Generator after interpolating water depth xyz data into the mesh

Now you are ready to export the data set into a mesh file that can be used in MIKE 21 & MIKE 3 Flow Model FM (Mesh $\rightarrow$ Export Mesh). Save the file as oresund.mesh.



You can view (and edit) the resulting mesh file in the Data Viewer (Figure 2.16) or view it in MIKE Animator Plus (Figure 2.17).



Figure 2.16 The Øresund mesh file as it appears in the Data Viewer





Figure 2.17 The Øresund mesh as it can be presented with the MIKE Animator Plus tool



## 3 Creating the Input Parameters to the MIKE 21 Flow Model FM

Before the MIKE 21 Flow Model FM can be set up, the input data must be generated from the measurements. Measurements for 1993 exist for

- Water levels at the boundaries
- Wind at Kastrup Airport (Copenhagen, Denmark)

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 Generate Water Level Boundary Conditions

Measured water level recordings from four stations located near the open model boundaries are available for the Øresund model, see Figure 3.1.



Figure 3.1 Map showing the water level stations at the open boundaries: Hornbæk, Viken, Skanör, and Rødvig



The Øresund model is forced with water level boundaries. The water level measurements indicate that the variations along the boundaries are significant, so the water level boundaries should be specified as line series (dfs1 type data file) containing an interpolation between the two measurements at each boundary.

In the following, two line series (dfs1 type data file) with water level variations will be created on basis of measured recordings from four stations on two boundaries. The locations of the four stations are listed in Table 2.1

### 3.1.1 Importing measured water levels to time series file

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

🗟 New File		×
Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 3 MIKE 21/3 Integrated Models LITPACK MIKE FLOOD MIKE SHE	Documents: Time Series (.dfs0) 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)	
Time Series	ок	Cancel

Figure 3.2 Starting the Time Series Editor in MIKE Zero

Select the ASCII template. Open the text file waterlevel\_hombaek.txt shown in Figure 3.3. Change the time description to 'Equidistant Calendar Axis' and press OK, see Figure 3.4. Then right click on the generated data in the Time Series Editor and select properties, see Figure 3.5. Change the item type to 'Water Level', see Figure 3.6, and finally, save the data in waterlevel\_hombaek.dfs0.

Repeat these steps for the remaining three stations.

**Please note** that time series must have equidistant time steps in the present version of MIKE 21 & MIKE 3 Flow Model FM. That means that if the raw data have time gaps without measurements, the gaps in the raw data must be filled (e.g. by interpolation) before importing it.



//////////////////////////////////////	hornbaek.txt -	Notepad	
File Edit Form	nat View Help		
Water leve time El 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02 1993-12-02	l recording evation 00:00:00 01:00:00 01:00:00 02:00:00 02:00:00 03:00:00 03:30:00 04:30:00 04:30:00 05:30:00 05:30:00 06:00:00 06:30:00 07:00:00	s from St Hornbaek -0.33 -0.362 -0.3965 -0.3929 -0.4278 -0.4378 -0.4393 -0.473 -0.4984 -0.4977 -0.4941 -0.4797 -0.5139 -0.4961 -0.4671	



	010					1.1.1			
File name:	C:\Oresi	und\Data\1	993\Ascii	\waterlevel	_homba	ek.bd			
Delimiter:	Tab	<b>_</b>		Time descr	iption:	Equidistant Ca	lendar A	xis	•
Treat cons	ecutive	delimiters as	one	Start	Time:	05-09-2	013 11:3	39:38	_
🗌 Ignore delii	miters in	begining of l	ine	Time	Step:		0	[days]	
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Water level re	cordings	from St Hon	nbaek						
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1993-12-02 00	00:00	-0.3	5 62						
1993-12-02 01	1:00:00	-0.3	965						
1993-12-02 01	1:30:00	-0.3	929						
1993-12-02 02	2:00:00	-0.4	278						
1993-12-02 02	2:30:00	-0.4	378						
time		Elevation							
1993-12-02 0	0:00:00	-0.33							
1993-12-02 0	0:30:00	-0.362							
1993-12-02 0	1:00:00	-0.3965							
	1:30:00	-0.3929							
1993-12-02 0	2:00:00	-0.4278							
1993-12-02 0 1993-12-02 0		0.4070							
1993-12-02 0 1993-12-02 0 1993-12-02 0	2:30:00	-0.4378							
1993-12-02 0 1993-12-02 0 1993-12-02 0	2:30:00	-0.4378							







Figure 3.5 Time Series Editor with imported Water Levels from Station 1: Hornbæk

Properties				?
General Information	ı ———			ОК
Title:	Water level reco	ordings from St Hornba	ek	
				Cancel
Axis Information				Help
Axis Type:	Equidistant Cale	endar Axis 💌		
Start Time:	02-12-1993 00:0	00:00		
Time Step:	0	[days]		
	00:30:00	[hour:min:sec]		
	0.000	fraction of sec 1		
	0.000	[indenoirior see.]		
No. of Timesteps:	577		Axis Units:	
Item Information —				_
Nan	ne 🗌	Туре	Unit	
1 Elevatio	n Water Lev	el	meter Instanta	
•			Þ	

Figure 3.6 Time Series Properties



To make a plot of the water level time series open the Plot Composer in MIKE Zero, see Figure 3.7. Select 'plot'  $\rightarrow$  'insert a new plot object' and select 'Time Series Plot' (see Figure 3.8).

🗟 New File		x
Product Types:	Documents: Time Series (.dfs0) Profile Series (.dfs1) Data Manager (.dfsu,.mesh,.dfs2,.dfs3) Geid Series (.dfs2,.dfs3)	
MIKE 3 MIKE 21/3 Integrated Models MIKE FLOOD MIKE SHE	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)	
Plot Composer		
	ОК	Cancel

Figure 3.7 Starting the Plot Composer in MIKE Zero

Insert  Single Plot Maximized  Single Plot Sized: w: 100 [mm] h: 100 [mm]  Multiple Plots Tiled: rx: 2 ny: 2  Find Standard Graphics	×
Single Plot Sized: w: 100 [mm] h: 100 [mm]     Multiple Plots Tiled: nx: 2 ny: 2	aximized
E	red: w: 100 [mm] h: 100 [mm] Tiled: nx: 2 ny: 2
Grid Plot     Grid Plot     Grid Plot     Advanced Graphics     Advanced Graphics     ADCP 2D Plot     Annotation Plot     Grid Plot     Grid Plot     Metafile Plot	iraphics lot ot Plot eries Plot Graphics 2D Plot stion Plot bisualization h Plot Plot e Plot Plot e Plot V

Figure 3.8 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, see Figure 3.9. 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 as colours, etc. (see Figure 3.10).

a Open		×
Look in:	Boundary Conditions	
<u> </u>	Name A V Date modified V Type V	
	waterievel_nornbaek.dtsu 27-09-2012 20:16 TimeSeries.Docu	
Recent Places	waterlevel_touvig.dis0 27-09-2012 20:16 TimeSeries.Docu	
	waterlevel_skandr.cnso 27-09-2012 20:16 TimeSeries.Docu	
Deskton		
Computer		
Network		
	File name: waterlevel_hombaek.dfs0	
	Files of type: New Data Files (*.dfs0)	
	Select Item Period Info. Item Info. Constraints Info.	
	Title: Water level recordings from St 1	
	File Type: Equidistant Time Axis	
	Any Item Type	
	ST 1: WL (m)	
	С	ancel
		ок

Figure 3.9 Selection of time series files in the Plot Composer



Time Seri	es Plot Propertie X-Axis   Y-Axis   C	es urves   Text Anno	tations					×
_ Item I	Definition							
						<b>*</b> ×	<b>+ +</b>	
	Item name	Items	File name	Item type	Unit	Glb min	Glb m	
1	ST 1: WL (m)	ST 1: WL (m)	C:\Oresund\D	Water Level	meter	-0.57990002	6 0.57169	
I					1		×	
			(	ок	Cancel	Apply	Help	

Figure 3.10 Plot Composer Time Series Plot Properties dialogue for selecting time series files and adjusting scales, curves, etc.

Figure 3.11 and Figure 3.12 show the measured water levels at the two boundaries.





Figure 3.11 Combined time series at the North Boundary, Stations 1 and 2: Hornbæk and Viken



Figure 3.12 Combined time series at the South Boundary, Stations 3 and 4: Skanör and Rødvig

### 3.1.2 Creating boundary conditions

The next step is to create line series from the generated time series. Load the Profile Series in MIKE Zero and select 'Blank ...', see Figure 3.13.

Fill in the required information as shown in Figure 3.14:

#### **North Boundary**

- Start date 1993-12-02 00:00:00
- Time step: 1800s
- No. of time steps: 577
- No. of grid points: 2
- Grid Step: 9200m (width of boundary, actually not necessary, because MIKE 21 & MIKE 3 Flow Model FM interpolates the line series to the boundary nodes without respect to this distance, see the MIKE 21 and MIKE 3 Flow Model FM User Guides:
  - MIKE 21 Flow Model FM, Hydrodynamic Module, User Guide
  - MIKE 3 Flow Model FM, Hydrodynamic Module, User Guide



🗟 New File		<b>—</b> ×
Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 21 MIKE 21/3 Integrated Models LITPACK MIKE FLOOD MIKE SHE Profile Series	Documents: Time Series (.dfs0) 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)	
	ОК	Cancel

Figure 3.13 Starting the Profile Series Editor in MIKE Zero

Properties						?
General Information	n	0				ПК
Title:	Wat	er Level North Boundary [m]				Cancel
Axis Information-						Help
Axis Type:	Equ	idistant Calendar Axis 🛛 🔻				
Start Time:	12/	2 /1993 12:00:00 AM 🕂 🔽				
Time Step: (sec)	180	 0 Nu	imber of Grid Points	: 2	_	
No. of Timesteps:	577	Gr	d Step: (m)	9200		
	<u> </u>					
Item Information		Tune	Unit	Min		
1 DAL Nort	h Bou	Nater Level	▼ meter	0		
<u>                                     </u>						
Insert	4	Append Delete		Item Filter	ing	
	_					





Load Station Hornbæk (waterlevel\_hornbaek.dfs0) and copy and paste the water levels to the profile Series Editor at point 0. Next load Station Viken (waterlevel\_viken.dfs0) and copy and paste the levels into point 1 (see Figure 3.15). Save the profile series as waterlevel\_north.dfs1 (see Figure 3.16).



Figure 3.15 Copying water levels from Station 1 (Hornbæk) into the Profile Series Editor (Ctrl V)



Figure 3.16 Water level line series at the North Boundary

Repeat the same step with the southern boundary with the similar information except the grid step and using the recorded water levels at Station Rødvig (waterlevel\_rodvig.dfs0) and Station Skanör (waterlevel\_skanor.dfs0) and save the resulting file as waterlevel\_south.dfs1.



### **South Boundary**

- Start date 1993-12-02 00:00:00
- Time step: 1800s
- No. of time steps: 577
- No. of grid points: 2
- Grid Step: 33500m (actually not necessary, because MIKE 21 & MIKE 3 Flow Model FM interpolates the line series to the boundary nodes without respect to this distance)

### 3.2 Initial Conditions

The initial surface level is calculated as a mean level between the northern and the southern boundary at the beginning of the simulation. Load the two boundary files and approximate a mean level at the start of the simulation. We will use -0.37 m.

### 3.3 Wind Forcing

Wind recordings from Kastrup Airport will form the wind forcing as time series constant in space. Load the time series editor and import the ASCII file 'wind\_kastrup.txt' with equidistant calendar axis. Save the file in 'wind\_kastrup.dfs0'. Time series of the wind speed and direction is shown in Figure 3.17.

A more descriptive presentation of the wind can be given as a wind-speed (or wind-rose) diagram. Start the 'Plot Composer' insert a new plot object, and select 'Wind/Current Rose Plot' and then select properties and select the newly created file 'wind\_kastrup.dfs0' and change the properties of the plot as you prefer with respect to appearance (colours, etc.). The result is shown in Figure 3.18.

🝺 wind_kastrup.txt - Notepad				
File Edit Format View Help				
<pre>wind data Time Speed Direct Unit 100002 2000 1993-12-02 00:00:00 1993-12-02 01:00:00 1993-12-02 01:30:00 1993-12-02 02:00:00 1993-12-02 02:30:00 1993-12-02 03:00:00 1993-12-02 03:30:00 1993-12-02 04:00:00 1993-12-02 04:30:00</pre>	ion 9.294 10.066 10.655 11.22 11.802 11.202 10.367 9.659 9.011 8.401	100003 184.26 186.689 189.167 191.531 193.665 193.254 192.226 189.522 186.016 181.983	2401	0
<b>▲</b>				

Figure 3.17 ASCII file with wind speed and direction from Kastrup Airport





Figure 3.17 Wind speed and direction from Kastrup Airport as it can be illustrated in the Plot Composer (Time Series Direction plot control)



Figure 3.18 Wind rose from Kastrup Airport as it can be illustrated in the Plot Composer and South Boundary



## 4 Creating the Input Parameters to the MIKE 3 Flow Model FM

Before the MIKE 3 Flow Model FM can be set up, the input data must be generated from the measurements. Measurements for 1997<sup>1</sup> exist for

- 1. Water levels at the boundaries
- 2. Salinity at the boundaries
- 3. Temperature at the boundaries
- 4. Wind at Ven

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

### 4.1 Generate Boundary Conditions

### 4.1.1 Water levels

Measured water level recordings from four stations located near the open model boundaries are available for the Øresund model, see Figure 4.1.



Figure 4.1 Map showing the water level stations at the boundaries: Hornbæk, Viken, Skanör, and Rødvig

<sup>&</sup>lt;sup>1</sup> Measurements for 1993 were used for the MIKE 21 Flow Model example in Chapter 3



The Øresund model is forced with water level boundaries. The water level measurements indicate that the variations along the boundaries are significant, so the water level boundaries should be specified as line series (dfs1 type data file) containing an interpolation between the two measurements at each boundary.

In the following, two line series (dfs1 type data file) with water level variations will be created on basis of measured recordings from the four stations on the two boundaries. The locations of the four stations are listed in Table 2.1.

### 4.1.2 Importing measured water levels to time series file

Open the Time Series Editor in MIKE Zero (File $\rightarrow$ New $\rightarrow$  File $\rightarrow$ Time Series), see Figure 4.2. Select the ASCII template. Open the text file waterlevel\_rodvig.txt shown in Figure 4.3. Change the time description to 'Equidistant Calendar Axis' and press OK, see Figure 4.4. Then right click on the generated data in the Time Series Editor and select properties, see Figure 4.5. Change the item type to 'Water Level', see Figure 4.6, and finally, save the data in waterlevel\_rodvig.dfs0.

Repeat these steps for the remaining three stations.

**Please note** that time series must have equidistant time steps in MIKE 21 & MIKE 3 Flow Model FM. That means that if the raw data have time gaps without measurements, the gaps in the raw data must be filled before importing it.

🗟 New File		×
Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 3 MIKE 21/3 Integrated Models LITPACK MIKE FLOOD MIKE SHE Time Series	Documents: Time Series (.dfs0) 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)	
	ОК	Cancel

Figure 4.2 Starting the Time Series Editor in MIKE Zero



📕 waterlevel_rodvig.txt - Notej	pad			<u> </u>
File Edit Form& View Help				
Water Level recordings	from st.	20	Rodvi	g 🔺
Time Rodvig WL				
1997-09-01 00:00:00	0.120			
1997-09-01 00:30:00	0.120			
1997-09-01 01:00:00	0.120			
1997-09-01 01:30:00	0.120			
1997-09-01 02:00:00	0.120			
1997-09-01 02:30:00	0.130			
1997-09-01 03:00:00	0.120			
1997-09-01 03:30:00	0.120			
1997-09-01 04:00:00	0.120			<b>_</b>
•				



Time Serie	s Editor: Imp	ort from as	cii		2
- Descripti	on				
File nom	er CAProg	ram Eilee\DHI\	\MIKEZero\Eusmoles\Mik	E 2\ElowModel EM\U	
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				Time Series Export	ASCII Format
Preview-					
Water L Time	evel recording. Bodvia WI	is from st. 20 R	Rodvig		
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1997-09	3-01 00:30:00 3-01 01:00:00	0.120	J 1		
1997-09	3-01 01:30:00	0.120	Ĵ		
1997-09	3-01-02:00:00 3-01-02:30:00	0.120	) 1		
1007-00	-01 02.30.00	0.130	,		
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1997-0	9-01 00:30:00	0.120			
1997-0	9-01 01:30:00	0.120			
1997-0	9-01 02:00:00	0.120			
1997-0	9-01 02:30:00	0.130	]		
· ·					
				ancel	



Time Series Editor: Import from ascii





Figure 4.5 Time Series Editor with imported water levels from Station: Rødvig

e Properties							? ×
- General Infor Title:	mation	ter Level rec	ordings from st. 20 R	odvig			ОК
-Axis Informati	ion						Lancel Help
Axis Type:	Equ	uidistant Cale	ndar Axis 📃 💌				
Start Time:	9/1	/1997 00:00	00				
Time Step:		0	[days]				
		00:30:00	[hour:min:sec]				
		0.000	[fraction of sec.]	$\searrow$			
No. of Times	steps:	5856		Axis Units:		~	
- Item Informati	ion						
	Name		Туре	Unit		TS T	
<u>1 Ro</u>	dvig WL	Water Leve	;I	meter	Instantaneo	us	
			Delete		Item Filte	<b>F</b>	
Insert		Append	Delete		Item Fil	te	tering

Figure 4.6 Time Series Properties

To make a plot of the water level time series open the Plot Composer in MIKE Zero, see Figure 4.7. Select 'plot'  $\rightarrow$  'insert a new plot object' and select 'Time Series Plot' (see Figure 4.8).


New File  Product Types:  MIKE Zero  MIKE HYDRO  MIKE 11  MIKE 21  MIKE 21/3 Integrated Models  LITPACK  MIKE FLOOD  MIKE SHE  Plot Composer	Documents: Time Series (.dfs0) 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)	
	ОК	Cancel

Figure 4.7 Starting the Plot Composer in MIKE Zero

Insert Plot Object	<b>N</b>	×
- Insert	•	1
<ul> <li>Single Plot Maximized</li> </ul>	t	
C Single Plot Sized:	w: 100 [mm] h: 100 [mm]	
C Multiple Plots Tiled:	nx: 2 ny: 2	
Metafile Plot Rolar Plot	<u> </u>	
Profile Plot		
Slice Plot		
Time Series Direction Plot		
Track Flow Visualization Wind/Current Rose Plot	<b>•</b>	
	OK Cancel	





🔂 Open		<b>x</b>
Look in:	🕌 Boundary_Conditions 🔹 🌀 🎓 🔛 🛪	
Recent Places Desktop Libraries Computer	<pre>waterlevel_hornbaek.dfs0 waterlevel_rodvig.dfs0 waterlevel_skanor.dfs0 waterlevel_viken.dfs0</pre>	
Network	File name:     waterlevel_rodvig.dfs0       Files of type:     New Data Files (*.dfs0)	
	Select Item       Period Info.       Item Info.       Constraints Info.         Title:       Water Level recordings from st. 20 Rodvig         File Type:       Equidistant Time Axis         Any Item Type	
		Cancel OK

Figure 4.9 Plot Composer properties select time series to plot

Add the actual time series file to the Plot Composer by clicking and selecting the file, see Figure 4.9. It is possible to add more than one time series to the same plot. You might also change some of the properties for the plot, such as colours, etc. (see Figure 4.10).

fime 9	Series P	lot Properti	es							×
Items	Items X-Axis Y-Axis Curves Text Annotations									
_ It	em Defir	nition ———								
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	<u>.</u>								×	
					0K	Ca	ncel /	Apply	Help	

Figure 4.10 Plot Composer Time Series Plot Properties dialogue for selecting time series files and adjusting scales, curves, etc.





Figure 4.11 Combined Time Series at the North Boundary, Stations 1 and 2: Hornbæk and Viken





Figure 4.12 Combined Time Series at the South Boundary, Stations 3 and 4: Skanör and Rødvig

### 4.1.3 Creating boundary conditions

The next step is to create line series from the generated time series.

Load the Profile Series in MIKE Zero (File $\rightarrow$ New $\rightarrow$  File $\rightarrow$ Profile Series) and select 'Blank ...'. Use default values for the geographical information in the first dialogue.

In the next dialogue, fill in the required information listed below and as shown in Figure 4.13:

### North Boundary

- Start date 1997-09-01 00:00:00
- Time step: 1800s
- No. of time steps: 5856
- No. of grid points: 10
- Grid Step: 1000m (actually not necessary, because MIKE 21 & MIKE 3 Flow Model FM interpolates the line series to the boundary nodes without respect to this distance)

Load Station Viken (waterlevel\_viken.dfs0) in the Time Series Editor and copy and paste the water levels to the profile Series Editor at column 0 and 1. Next load Station Hornbæk (waterlevel\_hornbaek.dfs0) and copy and paste the levels into column 8 and 9 (see Figure 4.14). This way the water levels are kept constant close to the coast, where the current velocities are expected to be low due to bottom friction. Interpolate the columns 2-7 using the values in columns 1 and 8 (Tools→Interpolation).

Save the profile series as waterlevel\_north.dfs1 (see Figure 4.15).



Axis Inform	mation					Help
Axis Type	e: Equidi	stant Calendar Axis	<u> </u>			
Start Time	e: 9/1/	/1997 12:00:00 AM 🚊	•			
Time Step	p: (sec) 1800		Number o	of Grid Points:	10	
No. of Tir	mesteps: 5856		Grid Step	: (m)	1000	
item Inforr	mation					
	Name	Туре	Unit	Min	Max	
1	North Boundary	Water Level	meter	0	0	





Figure 4.14 Copying Viken water levels into Profile Series Editor



waterlevel_north.dfs1							
Time Step: 01/09/97 00:00:00		Time	0	1	2	3	4 🔺
1.2 Noth Imster	0	01/09/97 00:00:00	-0.0390	-0.0390	-0.0404	-0.0419	-0.04
• Notar [meter]	1	01/09/97 00:30:00	-0.0490	-0.0490	-0.0519	-0.0547	-0.057
	2	01/09/97 01:00:00	-0.0590	-0.0590	-0.0619	-0.0647	-0.067
	3	01/09/97 01:30:00	-0.0590	-0.0590	-0.0619	-0.0647	-0.067
	4	01/09/97 02:00:00	-0.0590	-0.0590	-0.0619	-0.0647	-0.06
0.8	5	01/09/97 02:30:00	-0.0490	-0.0490	-0.0519	-0.0547	-0.05;
	6	01/09/97 03:00:00	-0.0490	-0.0490	-0.0504	-0.0519	-0.05
	7	01/09/97 03:30:00	-0.0390	-0.0390	-0.0419	-0.0447	-0.04
0.6	8	01/09/97 04:00:00	-0.0390	-0.0390	-0.0419	-0.0447	-0.047
	9	01/09/97 04:30:00	-0.0390	-0.0390	-0.0419	-0.0447	-0.047
0.4	10	01/09/97 05:00:00	-0.0290	-0.0290	-0.0319	-0.0347	-0.03;
	11	01/09/97 05:30:00	-0.0190	-0.0190	-0.0204	-0.0219	-0.02(
	12	01/09/97 06:00:00	0.0010	0.0010	-0.0019	-0.0047	-0.007
0.2	13	01/09/97 06:30:00	0.0110	0.0110	0.0096	0.0081	0.006
	14	01/09/97 07:00:00	0.0210	0.0210	0.0196	0.0181	0.016
0.0 1	15	01/09/97 07:30:00	0.0310	0.0310	0.0281	0.0253	0.02
	16	01/09/97 08:00:00	0.0310	0.0310	0.0281	0.0253	0.02:
	17	01/09/97 08:30:00	0.0310	0.0310	0.0281	0.0253	0.02:
-0.2	18	01/09/97 09:00:00	0.0410	0.0410	0.0381	0.0353	0.03;
	19	01/09/97 09:30:00	0.0410	0.0410	0.0367	0.0324	0.028
-0.4	20	01/09/97 10:00:00	0.0310	0.0310	0.0268	0.0225	0.018
	21	01/09/97 10:30:00	0.0210	0.0210	0.0167	0.0124	300.0
	22	01/09/97 11:00:00	0.0110	0.0110	0.0039	-0.0033	-0.01(
-0.6	23	01/09/97 11:30:00	-0.0190	-0.0190	-0.0261	-0.0333	-0.04( 👻
0.0 2.0 4.0 6.0 8.0	•						▶ <i>[li</i>

Figure 4.15 Water level line series at the North Boundary

Repeat the same step with the southern boundary with a similar approach.

Load Station Rødvig (waterlevel\_rodvig.dfs0) in the Time Series Editor and copy and paste the water levels to the profile Series Editor at column 0 and 1. Next load Station Skanör (waterlevel\_skanor.dfs0) and copy and paste the levels into columns 16 to 19 (Because of a larger area with shallow water near the Swedish coast at the southern boundary). This way the water levels are kept constant close to the coast, where the current velocities are expected to be low due to bottom friction. Add values in columns 2-15 by interpolating the data (Tools→Interpolation). Save the resulting file as waterlevel\_south.dfs1.

### **South Boundary**

- Start date 1997-09-01 00:00:00
- Time step: 1800s
- No. of time steps: 5856
- No. of grid points: 20
- Grid Step: 1600 m (actually not necessary, because MIKE 21 & MIKE 3 Flow Model FM interpolates the line series to the boundary nodes without respect to this distance)

## 4.2 Initial Conditions

The initial surface level is calculated as a mean level between the northern and the southern boundary at the beginning of the simulation. Load the two boundary files and approximate a mean level at the start of the simulation. We will use 0 m.



# 4.3 Wind Forcing

Wind recordings from Ven Island will form the wind forcing as time series constant in space. Load the time series editor and import the ASCII file 'wind\_ven.txt' as equidistant calendar axis (See Figure 4.16). Save the file in 'wind\_ven.dfs0'. Time series of the wind speed and direction is shown in Figure 4.17.

📕 wind_ven.t	xt - Notepad				_ 🗆 ×	1
File Edit Forr	mat View Help					
Wind Ven Time Sp Unit 10 1997-09-03 1997-09-03 1997-09-03 1997-09-03 1997-09-03 1997-09-03 1997-09-03 1997-09-03 1997-09-03 1997-09-03	eed Direc 0274 2000 13:00:00 14:00:00 15:00:00 16:00:00 17:00:00 19:00:00 20:00:00 21:00:00 22:00:00 23:00:00	tion 4.87 4.7 4.61 4.79 5.27 4.78 3.91 3.11 2.64 2.61 0.44	100003 322 314.6 322.7 322.9 318.4 319.9 320.7 326.9 287.1 282.3 313	2401	0	]
<						

Figure 4.16 ASCII file with Wind speed and direction from Ven Island in Øresund

A more descriptive presentation of the wind can be given as a wind - speed diagram. Start the 'Plot composer' insert a new plot object select 'Wind/Current Rose Plot' and then select properties and select the newly created file 'wind\_ven.dfs0' and change properties to your need. The result is shown in Figure 4.18.



Figure 4.17 Wind Speed and Direction from Ven Island as it can be viewed in the Plot Composer







## 4.4 Density Variation at the Boundary

As the area of interest is dominated with outflow of fresh water from the Baltic Sea and high saline water intruding from the North Sea, measurement of salinity and temperature has taken place at the boundaries. You can use two methods to generate a grid series boundary files from the measurements. You can for instance use a spread sheet to create an ASCII file from the raw data to import in MIKE Zero. In that case you must follow the same syntacs as the ASCII file in Figure 4.19. The first 13 lines in the ASCII file constitute a header containing information about for instance:

- 1. Title
- 2. Dimension
- 3. UTM zone
- 4. Start date and time
- 5. No. of time steps
- 6. Time step in seconds
- 7. No. of x points and z points
- 8. x and z-spacing in meters
- 9. Name, type and unit of item in file
- 10. Delete value

After the mandatory header, the profile measurements are grouped in an x-z matrix for each item and time step.

Another option is to enter the data manually directly in a new Grid Series file in MIKE Zero, see Figure 4.20. The choice of method depends on the amount of data, their format, and the users own experience with data processing, but both methods can be quite time



consuming<sup>2</sup>. In this example the ASCII files to import in MIKE Zero, containing the vertical profile values of the measurements for every 900 metres along the boundary, are already made and given in the ASCII files named:

- salinity\_north\_boundary.txt
- salinity\_south\_boundary.txt
- temperature\_north\_boundary.txt
- temperature\_south\_boundary.txt

An example is shown in Figure 4.19. You should import these ASCII files with the Grid Series editor and save the files with the same name but with extension dfs2. A plot of a grid series boundary file for salinity is shown in Figure 4.20.

**Note** that if the boundary condition has a fluctuating and complicated spatial variation it is difficult to measure and therefore generate correct boundary conditions. In that case it is often a good strategy to extend the model area so that the boundaries are placed at positions where the boundaries are less complicated and therefore easier to measure.

SalinityNorthBoundary.txt - Notepad	. 🗆 🗙
File Edit Format View Help	
"Title" " Salinity Profile st.55 " "ofm" 2 "Geo" "UTM-30" 0 0 0 "Time" "EqudistantTimeAxis" "1997-09-05" "08:00:00" 4328 1800 "NoGridPoints" 13 40 "Spacing" 900 1 "NoStaticItems" 0 "NoDynamicItems" 1 "Item" "Salinity" "Salinity" "PSU" NoCustomBlocks 1 "M21_Misc" 1 7 0 0 0 0 0 0 0 "Delete" -1E-030	
"tstep" 0 "item" 1 "layer" 0 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 16.9557 16.7755 16.5954 16.4152 16.415 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 16.9557 16.7755 16.5954 16.4152 16.415 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 16.9557 16.7755 16.5954 16.4152 16.415 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 16.9557 16.7755 16.5954 16.4152 16.415 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 16.9557 16.7755 16.5954 16.4152 16.415 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 17.1358 17.0326 16.9594 16.8261 16.7229 16.722 18.0102 18.0102 18.0102 18.0102 18.0102 18.0102 18.0102 17.6884 17.3666 17.0447 16.7229 16.722 20.644 20.644 20.644 20.644 20.644 20.644 20.644 12.6637 18.6835 17.7032 16.7229 16.722 91.6722 20.644 20.644 20.644 20.644 20.644 20.644 20.644 12.6437 18.6835 17.7032 16.7229 16.722 91.6722 20.644 20.644 20.644 20.644 20.644 20.644 20.644 12.6432 18.6037 18.6835 17.7032 16.7229 16.722 91.6722 20.644 20.644 20.644 20.644 20.844 20.844 20.844 11.6432 22.6424 23.6416 24.6408 24.6408 24.640 31.3508 31.3508 31.3508 31.3508 31.3508 31.3508 31.3508 31.3508 31.9168 32.79958 26.3183 24.6408 24.640 33.5182 33.5182 33.5182 33.5182 33.5182 33.5182 33.5182 33.4513 31.72 22.9989 32.8258 32.8258 33.5182 33.5182 33.5182 33.5182 33.5182 33.5182 33.5182 33.4496 33.461 33.425 33.4039 33.403 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.6467 33.5657 33.4848 33.9019 33.901 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.7212 33.8548 33.9184 33.9819 33.981 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.7276 33.8433 33.959 34.0746 34.1903 34.1903 34.190	2 1 2 1 2 1 9 1 9 1 9 1 9 1 8 2 9 3 8 3 9

Figure 4.19 Measured transect of temperature at the North Boundary

<sup>&</sup>lt;sup>2</sup> DHI's MATLAB DFS function (see http://www.mikepoweredbydhi.com/download/mike-by-dhi-tools may be another option



SalinityNorthBoundary.dfs2						_ 🗆 ×
Salinity		0	1	2	3	4 🔺
	39	19.5914	19.5914	19.5914	19.5914	19.
	38	19.5914	19.5914	19.5914	19.5914	19.
35	37	19.5914	19.5914	19.5914	19.5914	19.
	36	19.5914	19.5914	19.5914	19.5914	19.
	35	19.5914	19.5914	19.5914	19.5914	19.
	34	24.056	24.056	24.056	24.056	24
	33	24.056	24.056	24.056	24.056	24
a 25 Salinit	y [PSU] 32	24.9016	24.9016	24.9016	24.9016	24.
	Above 27 31	24.9016	24.9016	24.9016	24.9016	24.
	26 - 27 30	25.3404	25.3404	25.3404	25.3404	25.
	24 - 25 29	25.3404	25.3404	25.3404	25.3404	25.
	23 - 24 28	25.4328	25.4328	25.4328	25.4328	25.
5 <sup>15</sup>	21 - 22 27	25.4328	25.4328	25.4328	25.4328	25.
	20 - 21 26	25.6794	25.6794	25.6794	25.6794	25.
10	18 - 19 25	25.6794	25.6794	25.6794	25.6794	25.
	17 - 18 24	25.74	25.74	25.74	25.74	2
	15 - 16 23	25.74	25.74	25.74	25.74	2
	14 - 15 22	26.2109	26.2109	26.2109	26.2109	26.
	Below 13 21	26.2109	26.2109	26.2109	26.2109	26.
0	Undefined Value 20	26.2109	26.2109	26.2109	26.2109	26.
0 5 10	19	27.4426	27.4426	27.4426	27.4426	27.
(Grid spacing 900 meter)	18	27.4426	27.4426	27.4426	27.4426	27.
9/26/1997 6:30:00 AM, Time step: 1005, Laver: 0	<b>I</b>					
jk-Projection						

Figure 4.20 Grid Series Boundary file of salinity at the North Boundary



# 5 Set-Up of MIKE 21 Flow Model FM

# 5.1 Flow Model

We are now ready to set up the MIKE 21 Flow Model FM<sup>3</sup> model using the Øresund mesh with 1993 water depths, and boundary conditions and forcing as generated in Chapter 3. Initially we will use the default parameters and not take into account the effect of the density variation at the boundaries. The set-up in the first calibration simulation consists of the parameters shown in Table 5.1.

Parameter	Value
Specification File	oresund.m21fm
Mesh and Bathymetry	oresund.mesh (1993) 2057 Nodes in file
Simulation Period	1993-12-02 00:00 – 1993-12-13 00:00 (11 days)
Time Step Interval	120 s
No. of Time Steps	7920
Solution Technique	Low order, fast algorithm Minimum time step: 0.01 s Maximum time step: 120 s Critical CFL number: 0.8
Enable Flood and Dry	Drying depth 0.01 m Flooding depth 0.05 m Wetting depth 0.1 m
Initial Surface Level	-0.37 m
Wind	Varying in time, constant in domain: wind_kastrup.dfs0
Wind Friction	Varying with wind speed: 0.001255 at 7 m/s 0.002425 at 25 m/s
North Boundary	Type 1 data: waterlevel_north.dfs1
South Boundary	Type 1 data: waterlevel_south.dfs1
Eddy Viscosity	Smagorinsky formulation, Constant 0.28
Resistance	Manning number. Constant value 32 m <sup>1/3</sup> /s
Result Files	flow.dfsu ndr_roese.dfs0
CPU Simulation Time	About 25 minutes with a 2.4 GHz PC, 512 MB DDR RAM

### Table 5.1 Specifications for the calibration simulation

<sup>&</sup>lt;sup>3</sup> The MIKE 21 Flow Model FM, Hydrodynamic Module, User Guide can be accessed via the MIKE Zero Documentation Index in the start menu



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

The dialogue for setting up the MIKE 21 Flow Model FM is initiated from MIKE Zero, see Figure 5.1 (File $\rightarrow$ New $\rightarrow$  File $\rightarrow$ MIKE 21 $\rightarrow$ Flow Model FM).

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

Figure 5.1 Starting MIKE 21 Flow Model FM in MIKE Zero

Specify the bathymetry and mesh file oresund.mesh in the Domain dialogue, see Figure 5.2. A graphical view of the computational mesh will appear. The projection zone has already been specified in the mesh as UTM-33. In the domain file each boundary has been given a code. In this Øresund example the North Boundary has the code 2 and the South Boundary has the code 3. Rename the boundary 'Code 2' to 'North' and 'Code 3' to 'South' in the 'Boundaries' window in the Domain dialogue, see Figure 5.3.

Specify an overall time step of 120 s in the Time dialogue. The time step range must be specified to 7920 time steps in order to simulate a total period of 11 days. See Figure 5.4.













🬉 oresund.m21fm		
Oresund.m21fm     MIKE 21 Flow Model FM     ✓ Domain     ✓ Time     ✓ Module Selection     ✓ Hydrodynamic Module	Time         Simulation period         No. of time steps       7920         Time step interval       120 [sec]         Simulation start date       02:12:1993 00:00:00         Simulation end date       13:12:1993 00:00:00         Idd-mm-yyyy hh:mm:ss]	
Navigation Navigation Simula	tion /	

Figure 5.4 MIKE 21 Flow Model FM: Simulation period

In the Module Selection dialogue it is possible to include the 'Transport Module', the environmental 'ECO Lab Module', the 'Mud Transport Module', the 'Particle Tracking Module' and the 'Sand Transport Module'. Furthermore, it is possible to select 'Inland Flooding', see Figure 5.5.

oresund.m21fm			
MIKE 21 Flow Model FM	Module Selection Module Selection Hydrodynamic Transport ECO Lab / Oilspill Mud Transport Particle Tracking Sand Transport	DN	
Validation / Simulation	on_/		

Figure 5.5 MIKE 21 Flow Model FM: Module Selection



In this example, only the Hydrodynamic Module will be used. Please see the Step-by-Step guides for the other Modules if you want to extend your hydrodynamic model with any of these modules.

In the Solution Technique dialogue set the minimum and maximum time step to 0.01 and 120 s, respectively. The critical CFL number is set to 0.8 to ensure stability of the numerical scheme throughout the simulation.

🥃oresund.m21fm		<u>- 0 ×</u>
Oresund.m21fm      MIKE 21 Flow Model FM     ✓ Domain     ✓ Time     ✓ Module Selection      ✓ Hydrodynamic Module     ✓ Solution Technique     ✓ Flood and Dry     ✓ Density     ✓ Eddy Viscosity     ✓ Eddy Viscosity     ✓ Bed Resistance     ✓ Coriolis Forcing     ✓ Lice Coverage     ✓ Tidal Potential     ✓ Precipitation - Evaporation     ✓ Sources     ✓ Initial Conditions     ✓ Foundary Conditions	Solution Technique         Shallow water equations         Time integration       Low order, fast algorithm         Space discretization       Low order, fast algorithm         Minimum time step       0.01 [sec]         Maximum time step       120 [sec]         Critical CFL number       0.8         Transport equations       0.01 [sec]         Maximum time step       0.01 [sec]         Outline time step       0.01 [sec]         Maximum time step       0.02 [sec]         Outlined CFL number       0.8	<u>-   ×</u> T
Boundary Conditions     Source of the second s	Critical CFL number 0.8	

Figure 5.6 MIKE 21 Flow Model FM: Solution Technique

In the Depth dialogue it is possible to include a spatially varying depth correction. In this example, the bathymetry is kept as constant.

In the Flood and Dry t is possible to include flood and dry, see Figure 5.7. In our case select a Drying depth of 0.01 m and a Flooding depth of 0.05 m. The Wetting depth should be 0.1 m.

In this example the flooding and drying in the model should be included, because some areas along the shores of Saltholm will dry out during the simulation. If you choose not to include flooding and drying, the model will blow up in situations with dry areas. Including flooding and drying can however influence stability of the model, so if the areas that dry out are not important for the model study, you might consider not including flooding and drying. In that case you should manipulate the mesh file and make greater depths in the shallow areas to prevent those areas from drying out, and then run the model without flooding and drying.

As the density variation is not taken into account in this example the density should be specified as 'Barotropic' in the Density dialogue, see Figure 5.8.



MIKE Zero - [oresund]	
Image: Construction of the second	
Validation	
Ready No Tracking	11.

Figure 5.7 MIKE 21 Flow Model FM: Flood and Dry

🔀 MIKE Zero - [oresund]		
Tile Edit View Run Window	Help	_ 8 ×
0 🗳 🖬 🐇 🖿 📾 👹	<b>?</b> ₩	
MIKE 21 Flow Model FM MIKE 21 Flow Model FM Module Selection Module Selection Mod	Pensity       Density type       Barotropic       Reference temperature       10       Reference salinity       32       [PSU]	
Navigation		
Ready	No Tracking	

Figure 5.8 MIKE 21 Flow Model FM: Density specification



The default setting for the Horizontal Eddy Viscosity is a Smagorinsky formulation with a coefficient of 0.28, see Figure 5.9.

oresund	
oresund MIKE 21 Flow Model FM ✓ Domain ✓ Time ✓ Module Selection Flood and Dry ✓ Density ✓ Eddy Viscosity ✓ Bed Resistance ✓ Coriolis Forcing ✓ Vind Forcing ✓ Ice Coverage ✓ Tidal Potential ✓ Precipitation - Evaporatic ✓ Wave Radiation ✓ Sources ✓ Initial Conditions Flood and Dry ✓ Decoupling U outputs	Eddy Viscosity  Horizontal Eddy  Eddy type Smagorinsky formulation Smagorinsky formulation Smagorinsky formulation data Format Constant Constant Constant value 0.28 Data file and item Item: View  Eddy parameters Minimum eddy viscosity 1.8e-006 [m²/s] Maximum eddy viscosity 100000000 [m²/s]
Navigation	

Figure 5.9 MIKE 21 Flow Model FM: Eddy Viscosity

The default Bed Resistance with a value given as a Manning number of 32  $m^{1/3}$ /s will be used for the first calibration simulation. In later calibration simulations this value can be changed, see Figure 5.10.

Even though there are often strong currents in Øresund, the effect of Coriolis forces is not so significant, because the strait is rather narrow.

However, Coriolis is always included in real applications. Only for laboratory type of simulations Coriolis is sometimes not included, see Figure 5.11.



oresund		<u>_     ×</u>
MIKE 21 Flow Model FM	Bed Resistance	
Module Selection Hydrodynamic Module Flood and Dry	Resistance type Manning number	
<ul> <li>✓ Density</li> <li>✓ Eddy Viscosity</li> <li>✓ Bed Resistance</li> <li>✓ Catiolic Foreign</li> </ul>	Format Constant Constant value 32 [m^(1/3)/s]	
	Data file and item Select Item: View	
Martin Malidation		



oresund		
MIKE 21 Flow Model FM	Coriolis Forcing	
	Coriolis type Varying in domain  Reference latitude  (deg)	
	k	
<ul> <li></li></ul>		
Navigation		
Validation /		

Figure 5.11 MIKE 21 Flow Model FM: Coriolis Forcing



To use the generated wind time series specify it as 'Variable in time, constant in domain' in the Wind Forcing dialogue, and locate the time series wind\_kastrup.dfs0. It is a good practice to use a soft start interval. In our case 7200 s should be specified. The soft start interval is a period in the beginning of a simulation where the effect of the wind does not take full effect. In the beginning of the soft start interval the effect of the specified Wind Forcing is zero and then it increases gradually until it has full effect on the model at the end of the soft start interval period. Specify the Wind friction as 'Varying with Wind Speed' and use the default values for the Wind friction. See. Figure 5.13.

**Note** that an easy way to see the wind data file is to simply click \_\_\_\_\_\_ in the Wind Forcing dialogue, see Figure 5.12.

oresund			_ <b>_ _ _</b> ×
MIKE 21 Flow Model FM MIKE 21 Flow Model FM Module Selection Hydrodynamic Module Module Selection Medule Selection	Wind Forcing Format Speed Direction Data file and items Neutral pressure Soft start interval	Varying in time, constant in domain ▼         0 [m/s]         0 [deg]         C.\Program Files\DHI\MIKEZero\Examples\MIKE_21         Item:       Seed         Item:       Direction         1013       [hPa]         7200       [sec]	łect iew
Validation			

Figure 5.12 MIKE 21 Flow Model FM: Wind Forcing



around			
MIKE 21 Flow Model FM MIKE 21 Flow Model FM Module Selection Module Selection Flood and Dry Media Flood and Dry Media Resistance Coriolis Forcing Media Presistance Media Precipitation - Evaporatic Media Potential Merican Mave Radiation Media Precipitation - Evaporatic Media Precipitation - Evaporatic Media Precipitations Media Precipitations Media Decoupling Decoupling Decoupling Media Precipitations	Wind Friction Friction type Constant Linear variation using	Varying with Wind Speed         0.001255         Speed       Friction         7 [m/s]       0.001255         25 [m/s]       0.002425	
Validation			

#### Figure 5.13 MIKE 21 Flow Model FM: Wind Friction

In this example

- Ice Coverage is not included
- Tidal Potential is not included
- Precipitation-Evaporation is not included
- Infiltration is not included
- Wave Radiation is not included
- Structures are not included
- Decoupling is not included

The discharge magnitude and velocity for each source and sink should be specified in the Sources dialogue. But, because the sources in Øresund are too small to have significant influence on the hydrodynamics in Øresund they are not included in this example. So since we do not have any sources, leave it blank. See Figure 5.14.

After inspection of the boundary conditions at the simulation start time decide the initial surface level. In this case we will use a constant level of -0.37m, which is the average between our North and South Boundary at the start of the simulation, see Figure 5.15.



oresund		
MIKE 21 Flow Model FM	Sources	
✓ Module Selection     ✓ Hydrodynamic Module     ✓ Flond and Dry	Geographic View List View	
Density     Eddy Viscosity     Ged Besistance	Ho. Hame Include Edit	
Coriolis Forcing		
<ul> <li>✓ Wind Prictori</li> <li>✓ Ice Coverage</li> <li>✓ Tidal Potential</li> <li>✓ Potential</li> </ul>		
Wave Radiation		
Boundary Conditions		
	Edit source New source Delete source	
Navigation		
Validation		



oresund				
MIKE 21 Flow Model FM	Tpitial Condit	long		
II ✓ Domain		IULIS		
Module Selection	Туре	Constant	•	
🖹 🖻 🖌 Hydrodynamic Module	– Initial data			
→ Flood and Dry → ✓ Density	Surface elevation	-0.37 [m] u-velocity	0 [m/s]	
🗹 Eddy Viscosity		v-velocity	0 [m/s]	
Bed Resistance				
G Wind Forcing				
Wind Friction	Data file		Select	
✓ Ice Coverage	Surface elevation item	Item:	View	
Precipitation - Evaporatic	Velocity items	Item:		
		Item:		
Initial Conditions				
🗈 🗹 Boundary Conditions				
Decoupling				
Navigation				
, <u> </u>				
1				
1				
KANN Validation				





In the Boundary Conditions dialogue, the boundary conditions should be specified for the boundary names, which were specified in the Domain dialogue. There is a North Boundary and a South Boundary and the line series that were generated in Chapter 3 should be used. See Figure 5.16.

oresund.m21fm				• ×
Flood and Dry	North			
Consty     Sed Resistance     Consis Forcing	Type Specified Boundary data	level 🔻	]	
Wind Forcing	Format	Varying in time and alo	ng boundary 🔻	
Tidal Potential	Constant value	<b>0</b> [m]		E
Precipitation - Evapor	Data file and item	C:\Data\Examples.Rel	2012\MIKE_21\FlowModel_FM\HI Select	
Sources		Item: North WL	View	
	Type of vertical profile	Uniform profile	<b>v</b>	
Boundary Conditio	Soft start		Interpolation type	
South	Type Sinus var	iation 🔻	In time Linear 🔻	
Decoupling	Time interval	7200 [sec]	In space Reverse order 🔹	
🕂 🗹 Outputs 👻	Reference value	-0.37 [m]		
				+
Validation (Simulation	י_/			

# Figure 5.16 MIKE 21 Flow Model FM. The Boundary Conditions for the North Boundary are specified as waterlevel\_north.dfs1

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

The boundary format must be set as 'Variable in time and along boundary' in order to specify the boundary as a line series file (dfs1).

Click Select ... and select the appropriate data file in the Open File window that appears, see Figure 5.18.

For the North Boundary select the waterlevel\_north.dfs1, and for the South Boundary select waterlevel\_south.dfs1.

**Please note:** when specifying a line series at the boundary it is important to know how MIKE 21 FM defines the first and last node of the boundary. The rule is: follow the shoreline with the discretised domain on the left hand side, see Figure 5.17. When a boundary is reached, this is the first node of the boundary.

In Section 3.1.2 the data for the north boundary was generated using data from Hornbæk in the first grid point and data from Viken in the last grid point of the boundary line. This is





opposite the way MIKE 21 FM defines the direction of the boundary, and thus, the interpolation type for the north boundary should be set to reverse.



Use a soft start interval of 7200 s and a reference value corresponding to the initial value of -0.37 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 interval the effect of the specified Boundary Condition is zero and then the effect increases gradually until the boundaries has full effect on the model at the end of the soft start interval period.

The boundary data corrections due to Coriolis and wind are omitted because the spatial extension of the boundary is relatively small.

Note that an easy way to see the boundary data file is to simply click View... in the Boundary dialogue.



ි Open	×
Look in: 🔒 Boundary_Conditions 💽 🌀 🏂 📂 🖽 🗸	
waterlevel_north.dfs1   waterlevel_sor   waterlevel_sor   Desktop   Libraries   Computer   Vetwork	
File name: waterlevel_north.dfs1	
Files of type: Profile files (*.dfs1)	
Select Item Period Info. Item Info. Constraints Info.	
Title: North Boundary Water Level	
File Type: Equidistant Time Axis	
Level North WL	
	Canad
	ОК



Specify one output as area series and specify the resulting output file name, see Figure 5.19. Specify the file name flow.dfsu for our first simulation. Make sure the required disk space is available on the hard disk. Reduce the output size for the area series to a reasonably amount by selecting an output frequency of 3600 s which is a reasonably output frequency for a tidal simulation. As our time step is 120 s, the specified output frequency is 3600/120 = 30. As default, the full area is selected.

Pick the parameters to include in the output file as in Figure 5.20.

Also specify an output file as point series at the calibration station at Ndr. Roese, see the position in Table 5.2. You might consider saving other time series from neighbouring points, so that you can see how much the results vary in the area near the monitoring station.



MIKE 21 Flow Model FM	Area Serie	s					
<ul> <li>✓ Time</li> <li>✓ Module Selection</li> <li>✓ Module Selection</li> <li>✓ Module Selection</li> <li>✓ Solution Technique</li> <li>✓ Eddy Viscosity</li> <li>✓ Bed Resistance</li> <li>✓ Coriolis Forcing</li> <li>✓ Idd Potential</li> <li>✓ Tidal Potential</li> <li>✓ Precipitation - Evaporation</li> <li>✓ Wave Radiation</li> <li>✓ Sources</li> <li>✓ Initial Conditions</li> <li>✓ Boundary Conditions</li> </ul>	Geographic View Data Field type Output file Treatment of fi Time step First Area series Map projection	Output specifice 2D (horizon AlKE_21\Fic ood and dry 0 0 1 UTM-33	tion Output ite al) wModeL_FM\HD nly real wet area Last	ms   Ou \Oresund\Calil 7920	tput format oration_1\C Frequ	Area series	₹ 30
South		Easting	Northing	Layer no.		Name	
	1	322028.77431	6127731.4889				
E Vitputs	2	322028.77431	6224518.3037				
🖳 🖌 Ndr Roese	3	378689.6147	6224518.3037				
🖌 🖌 Area Series	4	378689.6147	6127731.4889				
Navigation							









### Table 5.2Measurements at Ndr. Roese

		Position		
Station	Data Files	Easting (m)	Northing (m)	
Ndr. Roese	waterlevel_ndr_roese.txt currents_ndr_roese.txt	354950	6167973	

Now we are ready to run the MIKE 21 Flow Model FM. (Run→Start simulation...).

The specification file for this example has already been made:

.\Calibration\_1\oresund.m21fm

**Please note** that if you experience an abnormal simulation, you should look in the log file (shown in the simulation tabs in the GUI) to see what causes the problem. Alternatively, you can use (File $\rightarrow$ Recent log file list) to select and open the log file in a separate window.

After the simulation use the Plot Composer (or Data Viewer) to inspect and present the results. In the following Figure 5.21 and Figure 5.22 two plots are shown; one with currents towards North and one with currents towards South.

The simulation data can be manipulated and extracted directly from dfsu result files by use of the Data Manager or the Data Extraction FM tool:

$$\label{eq:File} \begin{split} & \mathsf{File} \rightarrow \mathsf{New} \rightarrow \mathsf{File} \rightarrow \mathsf{MIKE} \ \mathsf{Zero} \rightarrow \mathsf{Data} \ \mathsf{Manager} \\ & \mathsf{File} \rightarrow \mathsf{New} \rightarrow \mathsf{File} \rightarrow \mathsf{MIKE} \ \mathsf{Zero} \rightarrow \mathsf{Data} \ \mathsf{Extraction} \ \mathsf{FM} \end{split}$$

The Post Processing Tools (statistics, etc.) that are developed for the dfs2 and dfs3 formats can also be used for dfsu files. It requires a conversion of the dfsu file to a dfs2 or dfs3 file first. There is a tool available for that conversion:

 $\mathsf{File} \rightarrow \mathsf{New} \rightarrow \mathsf{File} \rightarrow \mathsf{MIKE} \ \mathsf{Zero} \rightarrow \mathsf{Grid} \ \mathsf{Series} \rightarrow \mathsf{From} \ \mathsf{Dfsu} \ \mathsf{File}$ 









Figure 5.22 Current speed and water level during current towards South



### 5.2 Model Calibration

In order to calibrate the model we need some measurements inside the model domain. Measurements of water level and current velocities are available, see Table 5.2.

### 5.2.1 Measured water levels

Measurements of water level are given at Station Ndr. Roese (waterlevel\_ndr\_roese.txt). Import this ASCII file using the Time Series Editor (how to import ASCII files to time series, see Section 3.1.1). The water levels at Ndr. Roese are shown in Figure 5.23.



Figure 5.23 Ndr. Roese: Measured water level

### 5.2.2 Measured current velocity

Measurements of current velocities are given at station Ndr. Roese (currents\_ndr\_roese.txt). Import this file with the Time Series editor. Plots of current velocity and current speed and direction are shown in Figure 5.24, Figure 5.25 and Figure 5.26.



Figure 5.24 Ndr. Roese: Measured current velocity East and North component





Figure 5.25 Ndr. Roese: Measured current speed and direction



Figure 5.26 Ndr. Roese current rose, as it can be viewed with the Plot Composer



### 5.2.3 Compare model result and measured values

Use the Plot Composer to plot the simulated and measured water level and current. A Plot Composer file for this purpose is already made in this example. Open the file ndr\_roese.plc in:

.\Calibration\_1\Plots

to see a comparison of measurements and model output of water levels and currents at Ndr. Roese. Plots as shown in Figure 5.27 will appear (only if your simulation was successful).

The comparisons between measured and calculated water level and currents indicate that calibration might improve the results.

Try changing the Bed Resistance to a Manning number of 45 m<sup>1/3</sup>/s and the Eddy Viscosity to a Smagorinsky value of 0.24 m<sup>1/3</sup>/s and run the set-up again. Now the model output fit the measurements better, see Figure 5.28.

Try to calibrate further by changing the Manning number and the Eddy Coefficient with your own values. For each calibration simulation compare the results with the measurements. You should only change a single parameter at a time and track the changes in a log. Also be careful not to give values outside a realistic range.

**Note** the way the folders are organised in the example: You can simply copy the Calibration\_2 folder and rename it to Calibration\_3. This way the Plot Composer file will also work for the new calibration simulation, because the path to the files in the Plot Composer file are relative to the present folder. If you are making many simulations this trick can save a lot of time.





Figure 5.27 Comparison of measurements and model output of water levels and currents at Ndr. Rose with default parameters





Figure 5.28 Comparison of measurements and model output of water levels and currents at Ndr. Rose after calibration



# 6 Set-Up of MIKE 3 Flow Model FM

# 6.1 Flow Model

We are now ready to set up the MIKE 3 Flow Model FM<sup>4</sup> model using the Øresund mesh with 1997 water depths, and the boundary conditions and forcings that were generated in Chapter 4.

The example has been divided into three sub periods:

- 1. A warm up period (3 days simulation used to warm up the model)
- 2. Period 1 (6 days simulation)
- 3. Period 2 (12 days simulation)

It is possible to open a specification file for each period, so that the example will not be too time consuming. The 'hot' initial conditions from the previous period to period 1 and period 2 are already supplied in the example. This way period 2, for instance, can be run without running period 1 first.

It is recommended that you start working with the warm up period first in this example. Afterwards start looking at period 1 and 2.

For the purpose of training do not start by opening the included specification files, but make your own specification files. The included specification files can be used for comparison.

The data material in this example allows the user to make a new simulation period 3 up until December 1997.

**Hint** for advanced users: Note that the total of 21 days can be simulated without opening the included specification files. Simply click on the bat file:

.\Calibration\_1\run\_warmup\_period1\_period2.bat

The trick with bat files can be useful when making many simulations. Starting the bat file will however overwrite the included hot initial conditions for period 1 and 2. So only start the bat job if it is intended to run the whole 21-day period. Otherwise open each specification file in the MIKE 3 Flow Model FM dialogues.

Table 6.1 gives a summary of the set-ups:

<sup>&</sup>lt;sup>4</sup> The MIKE 3 Flow Model FM, Hydrodynamic Module, User Guide can be accessed via the MIKE Zero Documentation Index in the start menu



### Table 6.1 Summary of set-ups

Parameter	Value
Specification File	oresund.m3fm
Mesh and Bathymetry	oresund.mesh (1997), 2090 Nodes in file, 10 vertical equidistant layers
Simulation Period (Warm up) (Period 1) (Period 2)	1997-09-06 00:00 - 1997-09-09 00:00(3 days)1997-09-09 00:00 - 1997-09-15 00:00(6 days)1997-09-15 00:00 - 1997-09-27 00:00(12 days)
Time Step Interval (Warm up) (Period 1) (Period 2)	7.2 s 7.2 s 108 s (Period 2)
No. of Time Steps (Warm up) (Period 1) (Period 2)	36000 72000 9600
Solution Technique (Warm up) (Period 1) (Period 2)	Critical CFL number: 1.0 Critical CFL number: 1.0 Critical CFL number: 0.8
Enable Flood and Dry	Drying depth 0.01 m Flooding depth 0.05 m Wetting depth 0.1 m
Initial Surface Level(Warm up)Initial Temperature(Warm up)Initial Salinity(Warm up)Initial Conditions(Period 1)Initial Conditions(Period 2)	0.0 15.0 deg. C From file: salinity_sept_6_1997.dfs3 Hot started from warm up period simulation Hot started from period 1 simulation
Wind	Varying in time, constant in domain: wind_ven.dfs0
Wind Friction	Varying with Wind Speed: 0.0015 at 0 m/s, 0.0026 at 25 m/s
North Boundary Water Level Temperature Salinity	Type 1 data: waterlevel_north.dfs1 Type 2 data: temperature_north.dfs2 Type 2 data: salinity_north.dfs2
South Boundary Water Level Temperature Salinity	Type 1 data: waterlevel_south.dfs1 Type 2 data: temperature_south.dfs2 Type 2 data: salinity_south.dfs2
Result Files	2D_ndr_roese_flow.dfs0 (Time series) 3D_ndr_roese_flow.dfs0 (Time series) 2D_flow.dfsu (2D result file) 3D_flow.dfsu (3D result file) Hot files
CPU Simulation Time (Warm up) (Period 1) (Period 2)	About 3½ hours with a 2.4 GHz PC, 512 MB DDR RAM About 7 hours with a 2.4 GHz PC, 512 MB DDR RAM About 15 hours with a 2.4 GHz PC, 512 MB DDR RAM



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

The dialogue for setting up the MIKE 3 Flow Model FM is initiated from MIKE Zero, see Figure 6.1. (File $\rightarrow$ New $\rightarrow$ File $\rightarrow$ MIKE 3 $\rightarrow$ Flow Model FM)

🚰 New File			<b>×</b>
Product Types:	Documents:		
	Flow Model (.m3)		
MIKE 21			
MIKE 21/3 Integrated Models			
Flow Model FM			
		ОК	Cancel

Figure 6.1 Starting MIKE 3 Flow Model FM in MIKE Zero

Specify the bathymetry and mesh file oresund.mesh in the Domain dialogue, see Figure 6.2. The projection zone has already been specified in the mesh as UTM-33. You should specify sigma mesh type and 10 equidistant vertical layers in the 'Vertical mesh' window. See Figure 6.3

The mesh file contains information about boundaries. In this case there are 2 boundaries, and it is possible to give the boundaries more describing names than numbers. In this Øresund example the North Boundary has the code 2 and the South Boundary has the code 3. Rename the boundary 'Code 2' to 'North' and 'Code 3' to 'South' in the dialogue Boundary Names, see Figure 6.4.

Specify the time step in the Time dialogue to 7.2 s. The time step range must be specified to 36000 time steps in order to simulate a total period of 3 days. See Figure 6.5.





### Figure 6.2 MIKE 3 Flow Model FM: Specify Domain

oresund.m3fm		
Domain	Domain	
Time		
Module Selection	Mesh and Bathymetry Domain specification Vertical mesh Boundary names	
		Â
	Type of Mesh Sigma 🔻	
	Sigma	
	Number of layers 10 Sigma depth 0 [m]	
	Turos of distribution	
	Layer 1 2 3 4 5 6 7 8 9 10	
	Thickness 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1	
	z-level	=
	Number of layers 10	
	Type of distribution	
	Constant grid spacing 0 [m]	
	Layer 1 2 3 4 5 6 7 8 9 10	
	Thickness 0 0 0 0 0 0 0 0 0 0 0	
	,	
	Type of Simple adjustment	
	Minimum layer thickness 0 [m]	
Navigation		•
, <u> </u>		
Validation Simulation	1	

Figure 6.3 MIKE 3 Flow Model FM: Specify number of layers


oresund.m3fm		. <u> </u>
MIKE 3 Flow Model FM     ✓ Domain     ✓ Time     ✓ Module Selection     ✓ Hvdrodvnamic Module	Domain Mesh and Bathymetry   Domain specification   Boundary names   GIS background	
	Boundary Name Code 3 South Code 1 North	
Navigation	,	
Validation		

## Figure 6.4 MIKE 3 Flow Model FM: Specify Boundary Names: For instance North and South Boundary

🔵 oresund.m3fm	
● oresund.m3fm MIKE 3 Flow Model FM	Time         Simulation period         No. of time steps       36000         Time step interval       7.2 [sec]         Simulation start date       06-09-1997 00:00 (dd-mm-yyyy hh:mm:ss]         Simulation end date       09-09-1997 00:00:00         [dd-mm-yyyy hh:mm:ss]
Navigation	on /

#### Figure 6.5 MIKE 3 Flow Model FM: Simulation period

In the Module Selection dialogue it is possible to include the 'Transport Module', the environmental 'ECO Lab Module', the 'Mud Transport Module', The 'Particle Tracking' Module or the 'Sand Transport' Module, see Figure 6.6.



In this example, only the Hydrodynamic Module will be used. Please also see the relevant step-by-step training guides if you want to extend your hydrodynamic model with an ecological model, or a mud model.

🥰 oresund.m3fm		- 🗆 🗵
MIKE 3 Flow Model FM Domain Module Selection Hydrodynamic Module Navigation	Module Selection Module Selection  Hydrodynamic  Transport EC0 Lab Mud Transport Particle Tracking Sand Transport	
Validation / Simulation	1	

Figure 6.6 MIKE 3 Flow Model FM: Module Selection

In the Basic Equations dialogue the Shallow Water Equations should be selected, since the non-hydrostatic pressure, which is the assumption in the Navier-Stokes Equations, has no significant impact on the modelling results for this example.

In the Solution Technique dialogue the maximum time step is set to the overall time step. For the Warm up period and Period 1, the overall time step is small, itself ensuring a stable solution. Thus, the critical CFL number is set to 1.0. For Period 2, the overall time step is large. In this case the critical CFL number is set to 0.8 to ensure stability. Specify ('Lower order, fast algorithm') as the solution method and set the minimum time step (0.01s).

In the Depth dialogue it is possible to include a spatially varying depth correction. In this example the bathymetry is kept as constant.

In this example the Flooding and Drying in the model should be included, because some areas along the shores of Saltholm will dry out during the simulation. If you choose not to include Flooding and Drying, the model will blow up in situations with dry areas. Including Flooding and Drying can however influence stability of the model, so if the areas that dry out are not important for the model study, you might consider not including Flooding and Drying. In that case you should manipulate the mesh file and make greater depths in the shallow areas to prevent those areas from drying out, and then run the model without Flooding and Drying. In our case Flooding and Drying is included, so select a Drying depth of 0.01 m, a Flooding depth of 0.05 m, and a Wetting depth of 0.1 m, see Figure 6.7.



oresund.m3fm			
MIKE 3 Flow Model FM Domain Module Selection Hydrodynamic Module Flood and Dry Eddy Viscosity Ged Resistance Coriolis Forcing Wind Forcing Floe Coverage Mind Forcing Mind Forcing	Flood and Dry ✓ Include flood and dry Drying depth Flooding depth Wetting depth	0.01 [m] 0.05 [m] 0.1 [m]	
Validation			

Figure 6.7 MIKE 3 Flow Model FM: Flood and Dry specification

Øresund is situated in a transition zone between the brackish Baltic Sea to the South and the more saline Kattegat to the North. Therefore, Øresund is often stratified with dense, saline water from Kattegat in the lower part of the water column and the brackish water from the Baltic Sea in the upper part of the water column. A sill across Øresund called Drogden allows the saline plumes from north to only pass the sill under certain long periods of uniform wind conditions. These wind conditions are rather rare and therefore large-scale intrusion of the saline Kattegat water across Drogden into the Baltic only happens every 7 years in average.

In this example we will try to describe the salinities and temperatures in Øresund. Therefore the density should be specified as 'Function of temperature and salinity', see Figure 6.8.

Specify the Horizontal Eddy Viscosity as Smagorinsky formulation with a constant value of 0.1, see Figure 6.9.



oresund.m3fm		
MIKE 3 Flow Model FM MIKE 3 Flow Model FM Module Selection Mytodynamic Module Mytodynamic Mytodynamic Module Mytodynamic Mytodynamic Module Mytodynamic Mytodynamic Module Mytodynamic Mytodynamic Mytodyna	Density         Density type         Function of temperature and salinity         Reference temperature         15         Reference salinity         22         IPSU]	
Validation		



oresund.m3fm		
MIKE 3 Flow Model FM	Eckdy Viscosity         Horizontal Eddy         Eddy type       Smagorinsky formulation         Smagorinsky formulation data         Format       Constant         Constant value       0.1         Data file and item       Select         Item:       View         Eddy parameters       Minimum eddy viscosity         Maximum eddy viscosity       0 [m²/s]	
Module Selection  Module Selec	Horizontal Eddy       Vertical Eddy         Eddy type       Smagorinsky formulation         Smagorinsky formulation data         Format       Constant         Constant value       0.1         Data file and item       Select         Item:       View         Eddy parameters         Minimum eddy viscosity       0 [m²/s]	





Choose a two-equation turbulence model for the Vertical Eddy Viscosity. This formulation implies that the Turbulent Kinetic Energy must be determined with the Turbulence Module, see Figure 6.10.

🔵 oresund.m3fm	- • ×
MIKE 3 Flow Model FM  Domain Eddy Viscosity	Â
Module Selection Horizontal Eddy Viscosity Vertical Eddy Viscosity	
Basic Equations Eddy type Two-equation turbulence	e model 🗸 🗸
Copeth     Eddy parameters     Flood and Dry     Minimum addu vircenity     1 90.05 [m3/c]	
Density         Immunited y viscosity         1.0000 µm /sj           Weight of the state of t	
Coriolis Forcing	
····✓ Ice Coverage ····✓ Tidal Potential	
Infiltration	
Sources V	
Navigation <	> V
Validation Simulation	

Figure 6.10 MIKE 3 Flow Model FM. Vertical Eddy Viscosity specification

Next the Bed Resistance should be specified. In general the reasons for experiencing blow-ups are numerous.

Two strategies can often be used to prevent instabilities:

- 1. Increasing the Eddy Viscosity will 'smoothen' the values and can sometimes solve instability problems
- 2. Increasing Bed Resistance can 'smoothen' Water Levels, and it can also dampen instabilities in some situations.

It is best to solve the problem locally around the area causing problems, so that the trick of solving an instability problem does not significantly influence the calibration of results in other areas.

A roughness height specified as a constant of 0.1 m is used, see Figure 6.11.



MIKE 3 Flow Model FM MIKE 3 Flow Model FM	
✓ Time     ✓ Module Selection     Resistance type     Roughness height       ✓ Hydrodynamic Module     ✓ Flood and Dry     Roughness height data	
B- ✓       Wind Forcing       C:\Program Files\DHI\MIKE_ars_Select         M       Ice Coverage       Item: temperature (z=40)         Wave Radiation       Yiew         M       Sources         M       Initial Conditions         B- ✓       Boundary Conditions         B- ✓       Turbulence Module         W       Decoupling         B- ✓       Dutputs	
Navigation	

Figure 6.11 MIKE 3 Flow Model FM. Bed Resistance specification

Even though there are often strong currents in Øresund, the effect of Coriolis forces is not so significant, because the strait is rather narrow. However, Coriolis is always included in real case applications. Only for laboratory type of simulations Coriolis is sometimes not included. So there is no reason for excluding Coriolis Forcing, because the effect on simulation time is small, see Figure 6.12.

To use the generated wind time series you should specify it as 'Variable in time, constant in domain' in the Wind Forcing dialogue, and locate the time series wind\_ven.dfs0.

**Note** that an easy way to see the Wind data file is to simply click View... in the Wind Forcing dialogue, see Figure 6.13.

It is often a good practice to use a soft start interval. In our case 7200 s should be specified. The soft start interval is a period in the beginning of a simulation where the effect of the wind does not take full effect. In the beginning of the soft start interval the effect of the specified Wind Forcing is zero and then it increases gradually until it has full effect on the model at the end of the soft start interval period.



oresund.m3fm			<u>- 0 ×</u>
MIKE 3 Flow Model FM	Coriolis Ford	ing	
<ul> <li>✓ Module Selection</li> <li>✓ Hydrodynamic Module</li> <li>✓ Flood and Dry</li> <li>✓ Densitu</li> </ul>	Coriolis type	Varying in domain	
✓ Eddy Viscosity     ✓ Eddy Viscosity     ✓ Bed Resistance     ✓ Coriolis Forcing	Reference latitude	56 [deg]	
<ul> <li>✓ Wind Forcing</li> <li>✓ Ice Coverage</li> <li>✓ Tidal Potential</li> </ul>			
<ul> <li>✓ Precipitation - Evaporatic</li> <li>✓ Wave Radiation</li> <li>✓ Sources</li> <li>✓ Initial Conditions</li> </ul>			
Er of Boundary Conditions Er of Temperature/Salinity Mo Er of Turbulence Module			
<ul> <li>✓ Decoupling</li> <li>⊕ ✓ Outputs</li> </ul>			
Navigation			
Validation			



oresund.m3fm			<u>- 0 ×</u>
MIKE 3 Flow Model FM	1412 1 2 1		
🛛 🚽 🖌 Domain	Wind Forcing	J	
🛛 🗹 Time			
Module Selection			
Hydrodynamic Module	Format	Varying in time, constant in domain 💌	
Flood and Dry			
🖌 🖌 Eddu Viscositu	Speed	U [m/s]	
✓ Bed Besistance	Direction	0 [deg]	
🖌 🖌 Coriolis Forcing			
🖃 🖌 🖌 Wind Forcing	Data file and items	C:\Program Files\DHI\MIKEZero\Examples\MIKE_3\ Select	
🚽 🖌 Wind Friction		Item: Speed View	
🚽 🖌 Ice Coverage		Item: Direction	
🚽 🗹 Tidal Potential		Item:	
Precipitation - Evaporatid			
	Neutral pressure	1013 [n=a]	
✓ Initial Conditions	Soft start interval	7200 [sec]	
🛨 🖌 Boundary Conditions	Contonant in Norman		
😥 🗹 Temperature/Salinity Mo			
🗄 🗹 🗹 Turbulence Module			
🚽 🗹 Decoupling			
🗄 🗹 Outputs			
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Validation			

Figure 6.13 MIKE 3 Flow Model FM. Wind Forcing specification



Wind Friction
✓       Module Selection         ✓       Hydrodynamic Module         ✓       Hydrodynamic Module         ✓       Friction         ✓       Density         ✓       Eddy Viscosity         ✓       Bed Resistance         ✓       Conists Forcing         ✓       Conists Forcing         ✓       Vind Friction         ✓       Sources         ✓       Initial Conditions

Specify the Wind friction as 'Varying with Wind Speed' and use the values for the Wind friction as in Figure 6.14.

Figure 6.14 MIKE 3 Flow Model FM. Wind Friction specification

In this example

- Ice Coverage is not included
- Tidal Potential is not included
- Precipitation- Evaporation is not included
- Infiltration is not included
- Wave Radiation is not included
- Structures are not included

The discharge magnitude and velocity for each Source and Sink should be specified in the Sources dialogue. But, because the sources in Øresund are too small to have significant influence on the overall hydrodynamics in Øresund they are not included in this example. So since we do not have any sources, leave it blank. See Figure 6.15.

After inspection of the boundary conditions at the simulation start time you should decide the initial surface level. In this case we will use a constant Surface Elevation of 0.0 m for the warm up period, which is about the average value between our North and South Boundary at the start of the simulation, see Figure 6.16.

The Period 1 and Period 2 simulations use the 'hot', simulated results from the previous period as initial conditions.



oresund.m3fm		
MIKE 3 Flow Model FM ✓ Domain ✓ Time ✓ Module Selection I → ✓ Hwdrodynamic Module	Sources Geographic View List View	
Flood and Dry     Flood and Dry     Density     Eddy Viscosity     Sed Resistance     Coriolis Forcing     Wind Forcing     M Wind Forcing     M Wind Forcing     M Vind Force     M Vind Force	Source Ho.     Hame     Include     Edit       Edit source     New source     Delete source	
Navigation		
Validation		



oresund.m3fm				
MIKE 3 Flow Model FM	Initial Conditi	ODE		
Time	Initial Conditi	ons		
Module Selection	Туре	Constant	•	
Hydrodynamic Module     Second and Dru	Initial data			
	Surface elevation	0 [m] u-velocity	0 [m/s]	
Eddy Viscosity		v-velocity	0 [m/s]	
		w-velocity	0 [m/s]	
📄 🚽 🧹 Wind Forcing				
Wind Friction	Data file		Select	
✓ Tidal Potential	Surface elevation item	Item: Item:	View	
	velocity items	Item:		
Sources		Item:		
⊞… ✓ Boundary Conditions     √ Temperature/Salinity Mo	Data file		Select	
I Turbulence Module	Velocity items	Item:	View	
Decoupling		Item:		
Validation				





In the Boundary Conditions dialogue the boundary conditions should be specified for the boundary names that was specified in the Domain dialogue, see Figure 6.4. There is a North Boundary and a South Boundary and the line series that was generated in chapter 3 shall be used.

In this case the boundary type is 'Specified Level' (Water Level), because only Water Level measurements are available at the boundaries. 'Specified Level' means that the Water Levels are forced at the boundaries, and the discharge across the boundary is unknown and estimated during simulation. In case you choose the boundary type as 'Specified discharge' the discharge is forced and the water levels at the boundary are unknown and estimated during simulation. A stable model in an area with two boundaries can often be obtained if one boundary is type 'Specified discharge' and another is type 'Specified Level'.

The Boundary Format must be set as 'Variable in time and along boundary' in order to specify the boundary as a line series file (dfs1).

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

For the North Boundary select the waterlevel\_north.dfs1, and for the South Boundary select waterlevel\_south.dfs1.

Note that an easy way to see the Boundary data file is to simply click View ... in the boundary dialogue.



Figure 6.17 MIKE 3 Flow Model FM. The Boundaries are defined by codes in the mesh file. In this case code 3 is South boundary, code 2 is North boundary and code 1 is land boundary



**Please note:** When specifying a Line Series, or an Area Series at the boundary it is important to know how MIKE 21 FM defines the first and last nodes of the boundary. The rule is: follow the shoreline with the domain on the left hand side, see Figure 6.17. When a boundary is reached, this is the first node of the particular boundary.

Use a soft start interval of 7200 s and a reference value corresponding 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 interval the effect of the specified Boundary Condition is zero and then the effect increases gradually until the boundaries has full effect on the model at the end of the soft start interval period. See. Figure 6.18.



Figure 6.18 MIKE 3 Flow Model FM. The Boundary conditions for the North Boundary are specified as 'Variable in time and along boundary': waterlevel\_north.dfs1

The density in this example is a function of salinity and temperature. So the model specifications are enhanced with specifications for modelling salinity and temperature. In case you have any problems with stability of salinity or temperature, you have the option of range checking salinity and temperature in the Equation dialogue. Values outside the specified range are cut off, see Figure 6.19. So you should only use range checking if you cannot manage instabilities of salinity or temperature with other methods, because you may violate the mass budget with this method.



oresund.m3fm				
Flood and Dry Density Coriolis Forcing Wind Forcing Wind Forcing Wind Forcing Wind Forcing Wind Forcing Wave Radiation Precipitation - Evapor Wave Radiation Sources Initial Conditions South North Temperature/Salimity South South Initial Conditions Sources Initial Conditions Sources Initial Conditions Sources Initial Conditions Sources Initial Conditions North Sources Initial Conditions North Sources Initial Conditions Navigation	Equation Temperature Minimum Maximum	0 (°C) (10000000 (°C)	Salinity Minimum Maximum	0 (PSU) (10000000 (PSU)
Validation				

Figure 6.19 MIKE 3 Flow Model FM: Temperature/Salinity module range checking. Values outside the specified range of minimum and maximum values are cut off

Use the same solution technique as in the Hydrodynamic module.

The dispersion settings for the Temperature and Salinity module is for both the horizontal and vertical dispersion specified as Scaled Eddy Viscosity, see Figure 6.20. The horizontal sigma value should be set as 1. The vertical dispersion sigma value should be set as 0.1 to support a stratification of Øresund. Note that the dispersion settings are common for salinity and temperature.

The heat exchange with the surroundings is included to simulate the temperatures better in the model. The default values are used and the air temperature is specified as 'Varying in time and constant in domain'. Use the file: temperature.dfs0. See Figure 6.21.



oresund.m3fm		_ 🗆 🗵
✓ Flood and Dry     ✓ Density     ✓ Eddy Viscosity     ✓ Eddy Viscosity     ✓ Edde Resistance     ✓ Coriolis Forcing     ✓ Wind Forcing	Vertical Dispersion       Formulation       Scaled eddy viscosity formulation	
✓ Wind Friction ✓ Ice Coverage ✓ Tidal Potential ✓ Precipitation - Evapor ✓ Wave Radiation	Scaling factor 0.1	
Sources Sources Soundary Conditions South Vorth Equation Vertical Dispersion Heat Exchange Sources Linitial Conditions Navigation	Dispersion coefficient formulation         Format       Constant         Constant value       0.01 [m²/s]         Data file and item       Select         Item:       View	
Validation /		



🔵 oresund.m3fm - Modified			- • •
MIKE 3 Flow Model FM			^
- v Domain	Heat Exchange		
Madula Salastian	Include beat exchange		
Windule Selection			1
Solution Technique	Latent heat Sensible h	eat Short wave radiation Long wave radiation Atmospheric conditions	
✓ Depth ✓ Flood and Dry	Air temperature		
✓ Density	Format	Varying in time, constant in domair 🔻	
Eddy Viscosity	Constant value	15 [90]	
Bed Resistance	Constant value		
Coriolis Forcing	Data file and item	C:\Program Files (x86)\DHI\2012\MIKE Zero\Example Select	
		Item: Air temperature View	
✓ Tidal Potential			
Precipitation - Evaporat	Relative humidity		
Wave Radiation			=
Sources	Format	Constant	
	Constant value	88 [%]	
Boundary Conditions	Data file and item	Select	
🖃 🗹 Temperature/Salinity Mo	Data no ana tom	Item:	
Equation			
Solution Techniq	-		
Heat Exchange	-Clearness coefficient		
Sources	Format	Constant 👻	
🚽 🖌 Initial Conditions	Constant value	70 [%]	
🗄 🗹 Boundary Conditi	Constant value		
⊞	Data file and item	Select	
Decouping		Item: View	
Navigation		III.	•
Validation Simulation	1		





When starting the simulation from scratch it takes approximately one to two weeks to warm up the salinity and temperature distributions in the Øresund model. Therefore, the results of salinity and temperature for the warm up period and the first part of Period 1 cannot be expected to be right. In simulation period 2 (after 9 days' simulation), the salinity and temperature distributions should be quite 'hot'. This example has already been warmed up for the warm up period and Period 1 and the initial conditions are supplied with this example, so you can start the example for Period 2 with initial conditions as if the model had been running for a period of 9 days.

In the warm up period, the initial conditions are specified as constant of 15°C for Temperature, and a type 3 data file: salinity\_sept\_6\_1997.dfs3 is used for the salinity, see Figure 6.22.

oresund.m3fm			<u>- 🗆 ×</u>
Flood and Dry			
🗹 Density	Initial Condi	tions	
Eddy Viscosity	T b		
✓ Bed Resistance	- i emperature		
Coriolis Forcing	Format	Constant	
Wind Forcing			
Wind Friction	Constant value	15 ['U]	
V Ice Loverage	Data file and item	C:\Program Files\DHI\MIKEZero\Examples\MIKE_3\_Select	
Presimitation		Item: temperature	
Value Rediction		item, temperature	
	L		
Boundary Conditions			
South	Salinity		
🖌 🖌 North	Format	Varving in domain	
🖌 Temperature/Salinity Module	1 onniac		
🖌 🚽 Equation	Constant value	22 [PSU]	
🚍 🗹 Dispersion	Data file and item	C\Program Files\DHI\MIKEZero\Examples\MIKE_3\_Select	
📕 🚽 🖌 Horizontal Dispersion —	Data nie and tem		
📔 🖳 🗹 Vertical Dispersion		Item: Sainity	
🖌 🗹 Heat Exchange			
Sources			
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Validation			

Figure 6.22 MIKE 3 Flow Model FM: Initial Conditions in the Temperature/Salinity module in the Warm up simulation

The file salinity\_sept\_6\_1997.dfs3 is a very rough description of the horizontal distribution of salinity in Øresund in the beginning of September 1997. The dfs3 file was generated from a result file and measured values were interpolated into it. It is based on measurements and it does not contain information about the stratification and the vertical variation.



In the Boundary Conditions dialogue, the boundaries for temperature and salinity should be specified for the boundary names, which were specified in the Domain dialogue, see Figure 6.4. Enable the use of the grid series files that were generated in Chapter 4 by selecting the boundary data format 'Varying in time and along boundary'.

For the south boundary, select the files 'temperature\_south.dfs2' and 'salinity\_south' for the temperature and salinity at the boundary, respectively.

For the north boundary select the files 'temperature\_north.dfs2' and 'salinity\_north' for the temperature and salinity at the boundary, respectively.

**Please note** that for the north boundary, the contents of the dfs2 file are expressed in a west-east direction, i.e. opposite to the default direction of the north boundary. Hence the interpolation type in space must be defined as being in Reverse order.

Use a soft start with a sinus variation and a time interval of 7200 seconds. For the temperature, use a reference value of 15° Celsius, and for the salinity, use a reference value of 22 PSU.

oresund.m3fm			
Wind Forcing     Mind Forcing     Mind Potential     Mecipitation - Evaporation     Mecipitation - Evaporation     Mecipitation - Evaporation     Mecipitation - Evaporation     Mecipitation - Mecipitation     Mecipitation	South, Temperature Type Specified values Boundary data Format Varying Constant value Data file and item a\1997 Item: Type of vertical profile Soft start Type Sinus variation Time interval 720 Reference value	g in time and along boundary 10 [°⊂]  //Boundary_Conditions\temperature_south.dfs Temperature n profile  Interpolation type In time Linear In space Normal Is [°C]	2 Select, View
Validation / Simulation /			•

Figure 6.23 MIKE 3 Flow Model FM: Boundary conditions for temperature at the south boundary in the Temperature/Salinity module



🔵 oresund.m3fm		×
Image: second	North, Salinity         Type       Specified values         Boundary data         Format       Varying in time and along boundary         Constant value       32 [PSU]         Data file and item       id/Data\1997/Boundary_Conditions\salinity_north.dfs2         Select,       Item: Salinity         Type of vertical       Uniform profile         profile       Interpolation type         Type       Sinus variation         Time interval       7200 [sec]         Reference value       22 [PSU]	E
Validation / Simulation /		_

Figure 6.24 MIKE 3 Flow Model FM: Boundary conditions for salinity at the north boundary in the Temperature/Salinity module

On the Equation dialog for the Turbulence Module, the k-epsilon formulation is chosen for Model type. The parameters for the model are kept as default values, see Figure 6.25 and Figure 6.26.

Use the same Solution Technique as in the Hydrodynamic module.

The boundary conditions for turbulence are set as constants, using the default values.



🔵 oresund.m3fm		
Coriolis Forcing	Equation	^
Vice Coverage	Model type k-epsilon formulation	√ nc
Infiltration	Empirical constants	
Sources	c1e 1.44	Prandtl number 0.9
Initial Conditions	c2e 1.92 c3e 0	cmy 0.09
Temperature/Salinity		
Solution Techni	Turbulent kinetic energy	Dissipation of turbulent kinetic energy
Initial Conditio	Minimum 1e-07 [m²/s²] Maximum 100000000 [m²/s²]	] Minimum 5e-10 [m²/s³]
Navigation		~
	<	>
Validation Simulation	n_/	

#### Figure 6.25 MIKE 3 Flow Model FM: Turbulence Equation specifications

Coriolis Forcing  Wind Forcing Dispersion	_
Ice Coverage       Closure coefficients         Precipitation - Evapor       Tubulent kinetic energy         Infiltration       Tubulent kinetic energy         Wave Radiation       Horizontal sigma         Sources       Vertical sigma         Initial Conditions       Vertical sigma         Boundary Conditio       Dissipation of tubulent kinetic energy         Turbulence Module       Vertical sigma         Equation       Vertical sigma         Vertical sigma       1.3	^
Navigation	~

#### Figure 6.26 MIKE 3 Flow Model FM: Turbulence Dispersion specifications

Decoupling is not included in the model.



The Model Output is divided into two groups:

- 3D variables
- 2D variables

2D variables can be specified as Point Series, Line Series or Area Series. 3D variables can be specified as Point Series, Line Series or Volume Series. See example of 3D output in Figure 6.27.

oresund.m3fm	
	3D volume series         Geographic View Output type and location Output items         Data       Image: Closed colspan="2">Image: Closed colspan="2" Image: Closed colspa="2" Image: Closed colspan="2" Image: Closed
✓ Ndr. Roese point	3D range Easting Northing Layer no. Hame
w hot 3D	Min. 322028.77431 6127731.4889 1
Navigation	
<u></u>	
Validation	



Specify 6 output files:

- 1. Volume Series and specify the resulting output file name. Specify the file name: 3D\_flow.dfsu.
- Area Series and specify the resulting output file name. Specify the file name: 2D\_flow.dfsu.
- 3. Time Series at Ndr. Roese: 3D\_ndr\_roese.dfs0
- 4. Time Series at Ndr. Roese: 2D ndr roese.dfs0
- 5. A Hot Volume Series (only the last time step) and save in the Initial\_Conditions folder.
- 6. A Hot Area Series (only the last time step) and save in the Initial\_Conditions folder.

Make sure the required disk space is available on the hard disk. Reduce the output size for the Area Series and the Volume Series to a reasonably amount by selecting an output frequency of 3 hours. As the time step is 7.2 s then the specified output frequency is 10800/7.2 = 1500. Default, the full area is selected for both Area Series and Volume Series.



The output files include a Point series at the calibration station at Ndr. Roese, see the position in Table 6.2. You might consider saving other time series from neighbouring points, so that you can see how much the results vary in the area near the monitoring station.

Station		Position		
	Data Files	Easting (m)	Northing (m)	
Ndr. Roese	salinity_ndr_roese_2.9.txt	354950	6167973	
	salinity_ndr_roese_5.9.txt	354950	6167973	
	salinity_ndr_roese_10.6.txt	354950	6167973	
	temperature_ndr_roese_2.9.txt	354950	6167973	
	temperature_ndr_roese_5.9.txt	354950	6167973	
	temperature_ndr_roese_10.6.txt	354950	6167973	
	u_velocity_ndr_roese_3.0.txt	354950	6167973	
	u_velocity_ndr_roese_6.0.txt	354950	6167973	
	u_velocity_ndr_roese_10.5.txt	354950	6167973	
	v_velocity_ndr_roese_3.0.txt	354950	6167973	
	v_velocity_ndr_roese_6.0.txt	354950	6167973	
	v_velocity_ndr_roese_10.5.txt	354950	6167973	
	waterlevel_ndr_roese.txt	354950	6167973	
		354950	6167973	

#### Table 6.2 Measurements at Ndr. Roese

Pick the 3D parameters to include in the output files as shown in Figure 6.28 and the 2D parameters as shown in Figure 6.29.





Figure 6.28 MIKE 3 Flow Model FM: The 3D Output Parameters specification



Figure 6.29 MIKE 3 Flow Model FM: The 2D Output Parameters specification

Now we are ready to run the MIKE 3 Flow Model FM.

The specification files for this example have already been made:

.\Calibration\_1\Varmup\oresund.m3fm



.\Calibration\_1\Period\_1\oresund.m3fm

.\Calibration\_1\Period\_2\oresund.m3fm

After the simulation, you should use the Plot Composer (or Grid Editor or Data Viewer) to inspect and present the results. Two plots are shown below; one top view with salinities and vectors for current speed and direction (Figure 6.30) Another plot is a side view showing a profile along a line through the middle of Øresund from North to South (Figure 6.31).

The Post Processing Tools (data extraction, statistics, etc.) that are developed for the dfs2 and dfs3 formats can also be used for dfsu files. It requires a conversion of the dfsu file to a dfs2 or dfs3 file first. There is a tool available for that conversion:





Figure 6.30 Top view with salinities and vectors for current speed and direction







### 6.2 Model Calibration

In order to calibrate the model we need some measurements inside the model domain. Measurements of water level, current velocities, salinities, temperatures at Ndr Roese are available for different depths, see Table 6.2.

#### 6.2.1 Measurements of water levels, salinities, temperature and currents

Measurements of water levels are given at Ndr. Roese. Import this ASCII file using the Time Series editor. See Figure 6.32.



Figure 6.32 Ndr. Roese Measured Water Level

The salinities, temperatures and current velocities are given at 3 depths at station Ndr. Roese, see Table 6.2. Import these files with the Time Series editor.

#### 6.2.2 Compare model result and measured values

Compare the simulated values at Ndr. Roese with measured values. Use the Plot Composer to plot the simulated and measured values of water level, currents, salinity, and temperature for both the Period 1 and Period 2.

The comparison is shown in Figure 6.33 and Figure 6.34for water levels at Ndr. Roese in Period 1 and Period 2. The water levels look reasonable.









Figure 6.34 Water level comparison at Ndr. Roese. Period 2

The Current comparison for Ndr. Roese is shown in Figure 6.35 and Figure 6.36. For Period 2, the model seems to be 'hot' and the results look good.





Figure 6.35 Current Velocity North comparison at Ndr. Roese. Period 1



Figure 6.36 Current Velocity North comparison at Ndr. Roese. Period 2



# For the temperature results comparison at Ndr. Roese, see Figure 6.37 and Figure 6.38, the model results look good for Period 2, in particular.



Figure 6.37 Temperature comparison at Ndr. Roese. Period 1









For the salinity results comparison at Ndr. Roese, see Figure 6.39 and Figure 6.40, the model results look reasonable for Period 1. However, for Period 2, where the paradigm changes from a well-mixed water column with salinities around 21 PSU to a well-mixed water column with salinities around 11 PSU, the transition from one system to the other is not described with great accuracy. The end levels are correct though.







Figure 6.40 Salinity comparison at Ndr. Roese. Period 2

You could try calibrating the Dispersion properties of salinity to get a better agreement of the salinity in Period 2.

For each calibration simulation compare the results with the measurements. You should only change a single parameter at a time and track the changes in a log. Also be careful not to give values outside a realistic range.

**Note** the way that the folders are organised in the example: You can simply copy the Calibration\_2 folder and rename it to Calibration\_3. This way the Plot Composer file will also work for the new calibration simulation, because the paths to the files in the Plot Composer file are relative to the present folder. If you are making many simulations this trick can save a lot of time.

