



MIKE 3 Flow Model FM MIKE ECO Lab Module Step-by-step training guide



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1 Introduction

This Step-by-step training guide relates to the Odense Estuary (see Figure 1.1), which is situated on the island 'Funen' in Denmark.



Figure 1.1 Odense Estuary, Denmark

1.1 Background

The Odense Estuary has been under surveillance by the Danish authorities for a number of years as part of the Danish Monitoring Program NOVA. The eutrophication of the estuary is affected by the diffuse runoff of nutrients from the agriculture surrounding the estuary and also a number of point sources discharging to the estuary.

The Funen Powerplant is located in the inner part of the estuary, see Figure 1.2. The powerplant has an intake of cooling water in Stavids Stream and the cooling water is in average heated by approximately 2 degrees Celcius in the powerplant and diverted to Odense River. The effects on the Estuary of cooling water from the powerplant have been assessed using numerical modelling describing hydrodynamics and eutrophication.





Figure 1.2 Funen Powerplant

The possible effects on the ecosystem of Odense Estuary from the cooling water include increased mortality of phytoplankton and zooplankton in the cooling water itself. This effect is not assessed in the present example though. Also the change in salinity and temperature in the inner part of the estuary, as a result of the diversion of the cooling water, could change ecosystem habitats. Another effect could be that salinity plumes might have a blocking effect of the entrance to Odense River for fish migrating between the Estuary and Odense River.

1.2 Objective

The objective of this Step-by-step training guide is to set up a MIKE 3 Flow Model FM ECO Lab model for Odense Estuary.

The focus is on MIKE ECO Lab in this example and it is assumed that the reader is familiar with setting up a hydrodynamic MIKE 3 Flow Model FM. If not please refer to the PDF document: MIKE 21 & MIKE 3 Flow Model FM Step-by-step training guide for Øresund for a guide that goes through the process of creating a computational mesh and setting up a MIKE 3 Flow Model FM hydrodynamic model.

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 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. You can install the examples from the MIKE Zero start page.

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



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

A MIKE ECO Lab eutrophication simulation usually covers the dynamics of a growth season. Therefore two simulation examples are included: one with a simple mesh and one with a fine resolution mesh.

A 3D model covering both hydrodynamics and eutrophication usually requires a very long simulation time. This fact is hard to comprehend in a training guide. Even with the rough model it takes a long time to cover a season. Therefore the season has been divided into sub periods, which can be started independently of each other. The model with the fine mesh only covers a short period and is only included to illustrate the benefits and disadvantages of refining the computational mesh to higher resolutions: the cost in CPU time and how much it improves the results.





2 Creating the Computational Mesh

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

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

- 1. Computational Grid
- 2. Water Depths
- 3. Boundary Information

Creation of the mesh requires a xyz file for positions of land-boundaries and a xyz file that couples geographical positions with water depths. An old MIKE 21 & MIKE 3 bathymetry can also be used as an alternative to a xyz file with water depths.

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

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

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

When creating the computational mesh you should work with the mdf-file, which contains information about settings for the mesh. Focus in this example is on MIKE ECO Lab, so both the necessary xyz files and the two mdf-files and mesh-files for both a rough and a fine mesh are already supplied with the example, so that the training time can be spent on specific MIKE ECO Lab subjects.







The fine mesh and the rough mesh that are used in the example are shown in Figure 2.1 and Figure 2.2. Figure 2.3 shows a graphical presentation of the fine mesh of Odense Estuary as it can be displayed with MIKE Animator.



Figure 2.2 The rough Odense Estuary computational mesh as it can be presented with the Data Viewer tool



Figure 2.3 The fine Odense Estuary computational mesh as it can be presented with the MIKE Animator tool



3 Creating the Parameters to the MIKE 3 Flow Model FM

Before the MIKE 3 Flow Model FM can be set up, the input data to the model must be generated from the data collected. **Note** that the data requirements would have been the same if the model was set up for MIKE 21 Flow Model FM ECO Lab. Both the raw data and the data after importing the raw data into MIKE Zero format files are available in the example. You can choose to generate the MIKE Zero input parameters yourself, as part of the training. If you are already familiar with importing data into MIKE Zero Format files, you may not want to do the full exercise and simply use the input data files that have already been made instead of making them yourself.

The following data has been collected for this example:

- 1. Bathymetric data in the form of a xyz file from a local survey. The positions of the land boundaries are taken from MIKE C-MAP
- 2. Hydrodynamic boundary data: The water levels are measurements from a monitoring station near 'Gabet' at the entrance to the Estuary. The salinities and temperatures at the boundary are taken as model output from a larger regional hydrodynamic model
- Hydrodynamic forcings: measurements of wind, air temperature and clearness coefficient
- 4. Hydrodynamic sources: measurements of discharges and precipitation. Also the excess temperature in connected source/sinks from Funen Powerplant
- 5. Hydrodynamic initial conditions: salinity and temperature are given as model output from a previous MIKE 3 simulation for January 2002
- MIKE ECO Lab boundary data: concentrations at the boundary of the advective state variables in the MIKE ECO Lab template are taken as model output from a larger regional model
- MIKE ECO Lab forcings: measurements of solar radiation in the active photosynthetic spectrum of light (E/m2/d)
- MIKE ECO Lab loadings: concentrations in sources and precipitation of the advective state. Some are measured and some are estimated
- MIKE ECO Lab initial conditions of MIKE ECO Lab state variables are given as model output from a previous MIKE 3 simulation for January 2002
- 10. Calibration data; measurements from two monitoring stations of salinity, temperature, chlorophyll-a, Total N, Total P, inorganic P, inorganic N.

Figure 3.1 shows a map of the Odense Estuary with the positions of the sources and monitoring stations.





Figure 3.1 A map of Odense Estuary and the position of sources and monitoring stations

3.1 Generating Hydrodynamic Boundary Data

The water levels at a monitoring station at the entrance to the Estuary have been measured.

As the entrance to the estuary where the boundary is placed is rather narrow, the water levels along this boundary are not expected to have significant variation. Therefore it is assumed that it is sufficient to have only one measurement station for the water levels at this boundary.

The salinities and temperatures at the boundary are taken as model output from a larger regional hydrodynamic model.



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. Select the ASCII template. Open the text file 'waterlevel_gabet.txt', see Figure 3.3. Change the time description to 'Equidistant Calendar Axis' and press OK, see Figure 3.4.

😚 New File			ĸ
Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 21 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		OK Cancel	

Figure 3.2 Starting the Time Series Editor in MIKE Zero

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.

🝺 waterlevel_gabet.txt - Notep		
File Edit Format View Help		
Water Level recordings Time Elevation 2002-01-01 00:00:00 2002-01-01 00:15:00 2002-01-01 00:30:00 2002-01-01 00:45:00 2002-01-01 01:15:00 2002-01-01 01:30:00 2002-01-01 01:45:00	from St Gab 0.369 0.351 0.329 0.306 0.281 0.247 0.216	et 📕
2002-01-01 02:00:00 2002-01-01 02:15:00	0.182 0.156	





Description File name: C:\MIKEZero\dev\source\Example\MIKE_FM\EL\Odense_Estuary\Data\Ascii\watr Delimiter: Tab Time description: Equidistant Calendar Axis Treat consecutive delimiters as one Start Time: 7/21/2004 6:46:04 PM Ignore delimiters in begining of line Time Step: 0 [days] Delimiter between time and first item 00:00:10 [hour:min:sec] Delete value: -1e-030 0 [fraction of sec.]
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Ignore delimiters in begining of line Time Step: 0 [days] Delimiter between time and first item 00:00:10 [hour:min:sec] Delete value: -1e-030 0 [fraction of sec.]
Delimiter between time and first item 00:00:10 [hour:min:sec] Delete value: -1e-030 0 [fraction of sec.]
Delete value: -1e-030 [fraction of sec.]
Ime Series Export ASUI Format
Preview
Water Level recordings from St Gabet
I me Elevation 2002-01-01_00:00:00 0_369
2002-01-01 00:15:00 0.369
2002-01-01 00:30:00 0.351
2002-01-01 00:45:00 0.329
2002-01-01 01:15:00 0.281
2002-01-01 00:00:00 0.369
2002-01-01 00:15:00 0.359
2002-01-01 00:45:00 0.329
2002-01-01 01:15:00[0.261
OK Cancel

Figure 3.4 Time Series Editor Import Template

Then right click on the generated data and select properties change the type to 'Water Level', see Figure 3.5.

Save the data in:

 $. \label{eq:linear} \label{e$

The resulting time series can be seen in Figure 3.6.



e Properti	ies					?
-General Ir	nformation —					OK
Title:	W	/ater Level reco	ordings from St Gabe	t		Cancel
-Axis Inforr	mation					Help
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	Ē	00:15:00	[hour:min:sec]			
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		Water Level	abanan		Þ	
Inse	ert	Append	Delete		Item Filtering	







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



New File Product Types: MIKE Zero MIKE HYDRO MIKE 11 MIKE 21 MIKE 21 MIKE 3 MIKE 21/3 Integrated Models LITPACK MIKE FLOOD MIKE SHE	Documents: Time Series (.dfs0) Profile Series (.dfs1) Data Manager (.dfs1,.mesh,.dfs2,.dfs3) Grid Series (.dfs3,.dfs2) Plot Composer (.plc) Result Viewer (.rev) Bathymetries (.batsf) Climate Change (.mzcc) Escilable (.arclab)	 Auto Calibration (.auc) EVA Editor (.eva) Mesh Generator (.mdf) Data Extraction FM (.dxfm) MIKE Zero Toolbox (.mzt) 	
Plot Composer	< <u> </u>	OK	► Cancel

Figure 3.7 Starting the Plot Composer in MIKE Zero

Insert Plot Object		×
Insert Single Plot Maximized Single Plot Sized: Multiple Plots Tiled:	w: 100 [mm] h: 100 [m nx: 2 ny: 2	ım]
Metafile Plot Polar Plot Profile Plot Slice Plot Time Series Direction Plot Time Series Plot Track Flow Visualization Wind/Current Rose Plot		
	OK Cance	el

Figure 3.8 Insert a new Plot Object as Time Series in Plot Composer

If necessary, right click on the plot area and select properties. 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 property dialogue it is possible to change some of the properties for the plot, such a colours, etc. (see Figure 3.10).



Look ir My Recent Documents	x 🔁 Gabet 💽 🔶 🖆 📰+	
Desktop My Documents		
My Computer		
My Network Places	File name: waterlevel.dfs0	
	Select Item Period Info. Item Info. Constraints Info.	
	Title: Water Level recordings from St Gabet	
	File Type: Equidistant Time Axis	
	Any Item Type Elevation 🔽	Cancel QK

Figure 3.9 Selection of time series files in Plot Composer

e Serio	e <mark>s Plot Properti</mark> X-Axis Y-Axis I	es Curves	Text Annotati	ons				
-Item [Definition							
							🖹 🗙 🗲	• F
	Item name	Items	File name	Item type	Unit	Glb min	Glb max	Simp
1	Elevation	Elev	C: WIKEZero\	Undefined	undefined	-0.810999989	1.136999964	Float
								Þ

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





Figure 3.11 shows the measured water levels at the boundary in Plot Composer.

Figure 3.11 The measured water levels at the boundary plotted with Plot Composer

3.1.2 Density variation at the boundary

The salinity and temperature model boundaries are extracted from a larger MIKE 3 model and therefore the format of the extracted data is a MIKE Zero Grid Series file (dfs2). This format is the same format as MIKE 3 Flow Model FM uses on the boundaries with spatial variation. So the data needs no data processing.

An alternative could have been using the frequent measurements at the boundary, but it is difficult to measure a complicated salinity boundary correctly. If you want to create your own boundaries of salinity and temperature, it can be done in two ways:

- Create a new Grid Series and enter the data manually in the Grid Editor tool. There are different interpolation tools available in the Grid Editor that are useful. New → File→Grid Series → Blank Grid
- 2. Create an Ascii file with your boundary data and import it into a Grid Series. New → File → GridSeries → From Ascii File. You can for instance use a spreadsheet to create the ASCII file with your data following a specific format. After the mandatory header, the profile measurements are grouped in a x-z matrix for each item and time step. The first 13 lines in the ASCII file constitute a mandatory header containing information about:
 - title
 - dimension
 - UTM zone
 - start date and time
 - No. of time steps
 - time step in seconds
 - No. of x points and z points
 - x and z-spacing in meters
 - name, type and unit of item in file
 - delete value



Note that different online operational forecast models covering large regions are being developed these years (also by DHI), and maybe one of these models covers the area you are interested in, so that you can get boundary data from it.

The file 'sali_temp.dfs2' containing the salinity and temperature boundary conditions can be found in the folder:





Figure 3.12 Snapshot of Grid Series Boundary file of salinity at the Gabet Boundary



3.2 Generate Hydrodynamic Forcings

The measurements of wind, air temperature and clearness coefficient should be entered in MIKE Zero format.

3.2.1 Wind forcing

Wind recordings from Odense will form the wind forcing as time series constant in space. Load the time series editor and import the ASCII file 'wind.txt' with equidistant calendar axis, see Figure 3.13. Save the file in 'wind.dfs0'. Time series of the wind speed and direction can be illustrated with the Time Series Direction Plot in Plot Composer, see Figure 3.14.

📕 wind.txt - Notepad					
File Edit Format View Help					
Wind Odense Time Wind Speed	wind D	irection			_
Unit 100274 2000	0	100003	2401	0	
2002-01-01 00:00:00 2002-01-01 01:00:00	5.1 4.3	277.0 292.0			
2002-01-01 02:00:00	3.8	303.0			
2002-01-01 03:00:00	3.8	289.0			
2002-01-01 05:00:00	3.3	1238.0 .531 0			
2002-01-01 07:00:00	4.5	234.0			
2002-01-01 08:00:00	6.2 7.6	243.0 248.0			
2002-01-01 10:00:00	8.4	253.0			
<u> </u>					• //





Figure 3.14 Wind speed and direction in city Odense as it can be illustrated in the Plot Composer with the Time Series Direction Plot template



3.2.2 Air temperature, clearness coefficient and precipitation forcings

The heat exchange module in MIKE 3 Flow Model FM uses information about air temperature and clearness of the sky to estimate the temperature in the model. In our case both the air temperature and clearness coefficient are available as measurements.

Continue to generate time series with the Time Series Editor by importing ASCII files with measurements of air temperature (Deg. Celcius) and clearness coefficient (%).

The ASCII files are named:

- temp.txt
- clear.txt

Save the files as temp.dfs0 and clear.dfs0 in the folder:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Heat

Measurements of air temperature and clearness of the sky are illustrated with time series plots in the Plot Composer, see Figure 3.15 and Figure 3.16.



Figure 3.15 Air temperature measured near Odense Estuary illustrated with time series plot in the Plot Composer





Figure 3.16 Clearness (%) of the sky near Odense Estuary illustrated with time series plot in the Plot Composer

The precipitation has also been measured and is available as raw data in the ASCII file: • precipitation.txt.

Generate a time series with the Time Series Editor by importing the ASCII file and save the file as precipitation.dfs0 in the folder:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Forcings

The file is seen in the Plot Composer as in Figure 3.17.



Figure 3.17 Precipitation in the Odense Estuary area illustrated with time series plot in the Plot Composer



3.3 Generate Hydrodynamic Sources

There are 13 sources in Odense Estuary. Sources are often an essential part of MIKE ECO Lab studies. So even if the hydrodynamic sources have no significant effect on the hydrodynamics itself in an area, they must be included because they are important for the MIKE ECO Lab loadings. The best thing is to get the data as frequent measurements, or as model of the stream in question, but sometimes no data exist and you have to make qualified guesses of the discharges in a stream or other source.

No.	Name of source	Discharge Raw data file	Discharge File name
1	Stavids Stream	stav.txt	stav.dfs0
2	Odense River	odense.txt	odense.dfs0
3	Lunde Stream	lu_n.txt	lu_n.dfs0
4	Vejstrup Stream	vejr.txt	vejr.dfs0
5	Geels Stream	gel.txt	gel.dfs0
6	U_48	u_48.txt	u_48.dfs0
7	Fjordmarken South	fj_s.txt	fj_s.dfs0
8	Fjordmarken North	fj_n.txt	fj_n.dfs0
9	U_46	u_46.txt	u_46.dfs0
10	Krags Stream U_27	u_27.txt	u_27.dfs0
11	U_28	u_28.txt	u_28.dfs0
12	U_29	u_29.txt	u_29.dfs0
13	Funen Powerplant	fynsv.txt	fynsv.dfs0

 Table 3.1
 List of hydrodynamic sources and the names of the raw data and the time series after importing into MIKE Zero

Table 3.1 lists the names of the sources and the ASCII files with raw data. You can also see the names of the source files after importing the ASCII files to MIKE Zero time series.

Generate the source files with the Time Series Editor by importing the ASCII files and saving them with the names as shown in Table 3.1 in the folder:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Sources

An example of the annual cycle of flow in one of the sources (Odense River) is seen in the Plot Composer in Figure 3.18.





Figure 3.18 The flow discharge in Odense River 2002 illustrated with time series plot in the Plot Composer

3.4 Generate Hydrodynamic Initial Conditions

Salinity and temperature are given as model output from a previous MIKE 3 simulation for January 2002. They are delivered as dfs3 files:

- salinity.dfs3
- temperature.dfs3

MIKE 3 Flow Model FM can interpolate initial conditions directly from dfs3 files, so in this case it is easy to generate the hydrodynamic initial conditions for salinity and temperature.

Please note that it is wise to check how well the dfs3 file is interpolated into the mesh (especially in the bottom layer): See the first time step in one of your dfsu result files. The bottom layer should not have negative values for salinity. Sometimes it is necessary to edit the dfs3 file and add some values to get a better interpolation.

Snapshots of the temperature and salinity files for the top layer can be seen in Figure 3.19 and Figure 3.20.

It is especially important with salinity to have hot initial conditions in systems with high retention times, because if the model is cold-started with salinity, this variable can take a long time to find the right level. If no data of initial conditions are available and no other model output can be used, you should run a long warm-up period first.

The initial conditions for the water level is simply a guess based on the measurements at the boundary. Therefore we will choose an initial surface elevation of 0.369 m.





Figure 3.19 Temperature initial condition uses Grid Series Format dfs3 from another MIKE 3 model of the area



Figure 3.20 Salinity initial condition uses Grid Series Format dfs3 from another MIKE 3 model of the area



3.5 Generate MIKE ECO Lab Boundary Data

Concentrations at the boundary of the advective state variables in the MIKE ECO Lab template are in this case taken as model output from a larger regional model. An alternative would have been to use frequent measurements at the boundary. Often they are not measured so frequently for the variables that are modelled with MIKE ECO Lab, and therefore the best boundary data are often those that are extracted from large regional models. Please note that different online operational forecast models covering large regions are being developed these years (also by DHI), and maybe one of these models covers the area you are interested in, so that you can get boundary data from it.

The model boundaries are in this case extracted from a larger MIKE 3 ECO Lab eutrophication model and therefore the format of the extracted data is a MIKE Zero Grid Series file (dfs2). This format is the same format that MIKE 3 Flow Model FM uses on the boundaries. So the data needs no data processing.

An alternative could have been using frequent measurements at the boundary, but it is difficult to measure a complex MIKE ECO Lab boundary correctly. If you want to create your own boundaries of MIKE ECO Lab boundaries, it can be done in two ways:

- Create a new Grid Series and enter the data manually in the Grid Editor tool. There are different interpolation tools available in the Grid Editor that are useful. New → File→ GridSeries → Blank Grid
- 2. Create an ASCII file with your boundary data and import it into a Grid Series. New → File→ GridSeries → From ASCII File. You can for instance use a spreadsheet to create the ASCII file with your data following a specific format. After the mandatory header, the profile measurements are grouped in a x-z matrix for each item and time step. The first 13 lines in the ASCII file constitute a mandatory header containing information about:
 - title
 - dimension
 - UTM zone
 - start date and time
 - no. of time steps
 - time step in seconds
 - no. of x points and z points
 - x and z-spacing in meters
 - name, type and unit of item in file
 - delete value

The files for the boundary conditions for this example are found in the folder:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Boundary_Conditions\Gabet



The file names are the following:

- phytoplankton_c.dfs2
- phytoplankton_n.dfs2
- phytoplankton_p.dfs2
- chlorophyll_a.dfs2
- zooplankton_c.dfs2
- detritus_c.dfs2
- detritus_n.dfs2
- detritus_p.dfs2
- inorganic_n.dfs2
- inorganic_p.dfs2
- dissolved_oxygen.dfs2

An example of a snapshot of the dissolved oxygen boundary file for Gabet boundary can be seen in Figure 3.21.







3.6 Generate MIKE ECO Lab Constants

For some constants in MIKE ECO Lab it is relevant to specify them with a spatial variation:

Measurements of:

30 20 10

0

40 60 (Grid spacing 150 meter)

1/1/1990 12:00:00 PM, Time step: 0, Layer: 0

20

. 80

- dry weight of sediment
- sediment bulk density
- sediment iron content

have been created and interpolated into dfs2 files using the Grid Series Editor, see Figure 3.22:

- dry_weight_sediment.dfs2
- sediment_bulk_density.dfs2
- sediment_fe_content.dfs2



8e-005 - 0.00016 Below 8e-005



In the calibration phase (see Chapter 4.2) it was also decided to use a spatial variation of the following parameters:

- background light extinction
- sedimentation rate shallow water

These files are specified in the files:

- light_extinction_background.dfs2
- sedimentation_rate_shallow_water.dfs2

3.7 Generate MIKE ECO Lab Forcings

Measurements of solar radiation in the active photosynthetic spectrum of light (E/m2/d) are available.

Generate the MIKE ECO Lab forcing for light with the Time Series Editor by importing the ASCII file: light.txt.

Save the generated time series file as 'light.dfs0' in the folder:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Forcings

The seasonal variation in solar radiation is shown with the Plot Composer in Figure 3.23.



Figure 3.23 Measurements of solar radiation in the active photosynthetic spectrum of light (E/m2/d) in 2002 illustrated with time series plot in the Plot Composer



3.8 Generate MIKE ECO Lab Source Concentrations

Concentrations C (mg/l) in sources of the advective MIKE ECO Lab state variables must be specified.

Combined with the discharges Q specified under hydrodynamics they form the loading of a source.

Loading = Q*C

The best thing is to get the data as frequent measurements, or as output from another model (MOUSE, or MIKE 11) of the point source in question, but sometimes no data exist and you have to make qualified guesses of the concentrations in a stream.

The quality of these data is often very critical for the accuracy of the MIKE ECO Lab model. Therefore the estimation and specification of loadings can take very much time in a MIKE ECO Lab study. Make sure you have all the data you can get of point sources and make a proper assessment of the diffuse loading.

It is important not to 'forget' any significant loadings to the ecosystem.

In our case some sources are measured and some are estimated.

In Table 3.2 there is a list of names of the sources and the ASCII files with raw data of MIKE ECO Lab concentrations in the sources. You can also see the name of the source files after importing the ASCII files to MIKE Zero time series. Generate the source files with the Time Series Editor by importing the ASCII files and saving them with the names as shown in Table 3.2 in the folder:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Sources

The seasonal variation in the Odense River MIKE ECO Lab concentrations of inorganic Nitrogen and Phosphorus is shown with the Plot Composer in Figure 3.24.



Figure 3.24 Measurements of MIKE ECO Lab concentrations (mg/l) in Odense River in 2002 illustrated with time series plot in the Plot Composer. Inorganic N is on the left axis and Inorganic P is on the right axis.



Table 3.2	List of data with MIKE ECO Lab concentrations in the sources and the names of the
	raw data and the time series after importing into MIKE Zero

No.	Name of source	Raw data ASCII file	Loading Time series Filename	
1	Stavids Stream	l_stav.txt	l_stav.dfs0	
2	Odense River	I_oden.txt	l_oden.dfs0	
3	Lunde Stream	l_lun.txt	l_lun.dfs0	
4	Vejstrup Stream	l_vejr.txt	l_vejr.dfs0	
5	Geels Stream	I_geel.txt	l_geel.dfs0	
6	U_48	l_u48.txt	l_u48.dfs0	
7	Fjordmarken South	l_fj_s.txt	l_fj_s.dfs0	
8	Fjordmarken North	l_fj_n.txt	l_fj_n.dfs0	
9	U_46	l_u46.txt	l_u46.dfs0	
10	Krags Stream U_27	l_u27.txt	I_u27.dfs0	
11	U_28	l_u28.txt	I_u28.dfs0	
12	U_29	l_u29.txt	I_u29.dfs0	

3.9 Generate MIKE ECO Lab Initial Conditions

Initial conditions of MIKE ECO Lab state variables must be specified. If the retention time in the system is high, the initial conditions are quite important, and should be measured. If the retention time is low, the initial conditions are not so important for the advective state variables, because the system will quickly 'flush' the system anyway, and the concentrations will be in balance after a 'warm up' period. Also the 'not-moveable' state variables (fixed) are often quite important to measure. These could for example be maps of benthic vegetation, benthic fauna, etc.

Initial conditions for MIKE ECO Lab state variables are given as model output from a previous MIKE 3 simulation for January 2002. They are delivered as dfs3 files:

- phytoplankton_c.dfs3
- phytoplankton_n.dfs3
- phytoplankton_p.dfs3
- chlorophyll_a.dfs3
- zooplankton_c.dfs3
- detritus_c.dfs3
- detritus_n.dfs3
- detritus_p.dfs3
- inorganic_n.dfs3
- inorganic_p.dfs3
- dissolved_oxygen.dfs3



- macroalgae_c.dfs2
- macroalgae_n.dfs2
- macroalgae_p.dfs2
- rooted_vegetation_biomass.dfs2
- rooted_vegetation_shoot_density.dfs2
- sediment_ammonia.dfs2
- sediment_iron_adsorped_p.dfs2
- sediment_nitrate.dfs2
- sediment_organic_n.dfs2
- sediment_phosphate.dfs2
- sediment_organic_p.dfs2

MIKE 3 Flow Model FM can interpolate initial conditions directly from dfs3 files, so in our case it is easy to generate the hydrodynamic initial conditions for the MIKE ECO Lab state variables. If no data exist of initial conditions, you should run the model with a long 'warm up' period first. An example of an initial condition for 'Rooted vegetation shoot density' is shown in Figure 3.25.







3.10 Generate Calibration Data

The calibration data might be measurements from different monitoring stations. They are used for comparing simulated values with measured values. So these data are important for documenting the capability and quality of the model.

Measurements from two monitoring stations of salinity, temperature, chlorophyll-a, Total N, Total P, inorganic P, and inorganic N are available in our case.

Generate time series with the Time Series Editor by importing ASCII files with the measurements. The ASCII-files are named:

- st17_waterquality_variables_top.txt
- st17_waterquality_variables_bottom.txt
- st17_temperature.txt
- st17_salinity.txt
- st8_waterquality_variables.txt
- st08_temperature.txt
- st08_salinity.txt

Save the files as dfs0-files with the same names as the txt-files in the folder:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Measurements

In Chapter 4, we will use the measurements to compare the measured time-series with the simulated time series.





4 MIKE 3 Flow Model FM – Setup of MIKE ECO Lab

4.1 Specifications of the MIKE 3 Flow Model FM

We are now ready to set up a MIKE 3 Flow Model FM ECO Lab model using the input parameters, which were generated in Chapters 2 and 3.

First, a MIKE ECO Lab template containing a mathematical description of the ecosystem should be specified in the dialogue shown in Figure 4.2. A predefined DHI MIKE ECO Lab template describing eutrophication inclusive nutrient dynamics in the sediment and benthic vegetation was found suitable for describing the ecosystem of Odense Estuary and the state variables relevant in the surveillance program of the Odense Estuary. See details about the mathematical description in the scientific documentation of the MIKE ECO Lab template:

DHI Eutrophication Model 1 incl. sediment and benthic Vegetation, MIKE ECO Lab Template, Scientific Description,

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

The example has been divided up into 6 simulations. The first two specification files do not require much simulation time and they use the fine mesh for simulating two consecutive periods. They cannot be used for comparing with measurements because the simulated periods are too short. However, you can specify a longer simulation period and compare with measurements yourself (if you have time). The other four specification files use a rough mesh and simulate longer periods. One of them also covers a whole season. The other three cover smaller consecutive periods.

The consecutive specification files can be launched with the enclosed bat script without opening the dialogues:

Fine mesh:	run_warmup_period1.bat
Rough mesh:	run_warmup_period1_period2.bat

If you want to skip the warm up period you can launch Period 1 (or Period 2) without running the warm up period first, because the initial conditions for both periods are enclosed in the example.

Please note that once you start the warm up period simulation you will overwrite the initial conditions for Period 1, and then it has to finish before you can run Period 1.

The fine mesh would be preferred in most projects where more time is available for the execution than during training.

Therefore we will go through the dialogues with the fine mesh. In the end of the chapter we will look at the results from a whole season with the rough mesh and compare them with measurements.



Table 4.1 Summary of setups

Parameter	#	Value		
Specification File	1	Odense_Estuary\Fine\Calibr_1\Warmup\odense_rough.m3fm		
2		Odense_Estuary\Fine\Calibr_1\Period_1\odense_rough.m3fm		
3		Odense_Estuary\Rough\Calibr_1\Warmup\odense_rough.m3fm		
	4	Odense_Estuary\Rough\Calibr_1\Period_1\odense_rough.m3fm		
	5	Odense_Estuary\Rough\Calibr_1\Period_2\odense_rough.m3fm		
	6	Odense_Estuary\Rough\Calibr_1\Season\odense_rough.m3fm		
Computational Mesh and No.	. of	odense.mesh, 10 vertical equidistant layers		
layers		odense_rough.mesh, 7 vertical layers		
Simulation Period:				
Fine, Warm	n up	2002-01-01 00:00 – 2002-01-01 01:00	(1 hour)	
Fine, Peric	od 1	2002-01-01 01:00 - 2002-01-01 05:00	(4 hours)	
Rough, Warm	n up	2002-01-01 00:00 - 2002-01-03 00:00	(2 days)	
Rough, Peric	od 1	2002-01-03 00:00 – 2002-01-15 00:00	(12 days)	
Rough, Peric	od 2	2002-01-15 00:00 – 2002-03-01 00:00	(1½ months)	
Rough, Full Pe	riod	2002-01-01 00:00 - 2002-12-15 00:00	(almost 1 year)	
Time Step:				
Fine mesh set	ups	2.5 s		
Rough mesh setups		10 s		
ECO Lab update frequency		300 s		
Simulation Time:				
Fine, Warm up		About 1 min. with a 2.2 GHz PC, 8 GB RAM, 4 threads in 1 domain		
Fine, Period 1		About 4 min. with a 2.2 GHz PC, 8 GB RAM, 4 threads in 1 domain		
Rough, Warm up		About 2 min. with a 2.2 GHz PC, 8 GB RAM, 4 threads in 1 domain		
Rough, Period 1		About 14 min. with a 2.2 GHz PC, 8 GB RAM, 4 threads in 1 domain		
Rough, Period 2		About 49 min. with a 2.2 GHz PC, 8 GB RAM, 4 threads in 1 domain		
Rough, Full Sea	son	About 3 hrs. with a 2.2 GHz PC, 8 GB RAM, 4 threads in 1 domain		

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


4.1.1 MIKE 3 Flow Model FM specifications of domain, time steps, and modules

Start by clicking New \rightarrow MIKE 3 \rightarrow Flow Model FM, see Figure 4.1.

😚 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:	w Model FM (.m3fm) MIKE 3 Toolbox (.3t)	
Flow Model FM		ОК	Cancel

Figure 4.1 Starting MIKE 3 Flow Model FM in MIKE Zero

Specify the bathymetry and mesh file 'odense.mesh'. The projection zone shall be set to UTM-33. You should specify 10 equidistant vertical layers, see Figure 4.2.



Figure 4.2 MIKE 3 Flow Model FM: Specify Domain



The mesh file contains information about boundaries. In this case there are only one boundary (code 2), and you have the option to give the boundary a more describing name than a number. Name it 'Gabet', see Figure 4.3.

MIKE Zero - [odense.m3fmRea	d Only - Modified] lelp	_ D × _ B ×
Mavigation	Normain Mesh and Bathymetry Domain specification Boundary names Boundary Hame Code 2 Gabet Code 2 Gabet Gabet Gabet	4
Ready	Pointer outside model area	Mode //

Figure 4.3 MIKE 3 Flow Model FM: Specify Boundary Names: For instance Gabet

Specify a time step that resolves the ecological and hydrodynamic phenomena of interest. The specified time step is the maximum time step during simulation. During simulation, the time step is reduced if necessary to keep Courant numbers less than 1.0. Start with a time step of 25 s. The time step range must be specified to 144 time steps in order to simulate a total period of 1 hour, see Figure 4.4. Set the start date to 01.01.2002 00:00:00.

MIKE Zero - [odense.m3fmRead Only - Modified]		
휹 File Edit View Run Window Help	<u>s</u> ×	
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Mike 3 Flow Model FM Image: Construction of the section Image: Construction		
Ready Pointer outside model area Mode		

Figure 4.4 MIKE 3 Flow Model FM: Simulation period



Next you should include MIKE ECO Lab in the simulation by choosing it in the Module Selection Dialogue, see Figure 4.5.

🔵 odense.m3fm		
MIKE 3 Flow Model FM	Module Selection Module Selection Hydrodynamic Transport ECO Lab / Olspill Mud Transport Particle Tracking Sand Transport	
Validation Simulat	on_/	

Figure 4.5 MIKE 3 Flow Model FM: Module Selection

4.1.2 MIKE 3 Flow Model FM specifications of hydrodynamics

Under Solution Technique you should set the maximum time step to 2.5 s as shown in Figure 4.6. Choose Standard flood and dry as shown in Figure 4.7.

🔵 odense.m3fm			- • •
MIKE 3 Row Model FM	Solution Tech	nnique s	
M module detaction M module detaction M detaction Technique M Depth M Flood and Dry M Densty M Eddy Viscosity	Time integration Space discretization Minimum time step	Low order, fast algorithm	
yf Bed Resistance √f Coriolis Forcing ⊕ √f Wind Forcing √f Ice Coverage √f Tidal Potential	Critical CFL number	1	
√ Precipitation - Evaporation √ Infiltration √ Vave Radiation √ Sources √ Sources √ Structures	Minimum time step Maximum time Critical CFL number	0.01 [sec] 2.5 [sec] 1	
Navigation			
Validation / Simulation /			





odense.m3fm MKE 3 Row Model FM ✓ Domain ✓ Time ✓ Module Selection ✓ Density ✓ Density ✓ Density ✓ Density ✓ Corolis Forcing ✓ Vind Forcing ✓ Vind Forcing ✓ Idal Potential ✓ Precipitation - Evaporation ✓ Maxe Relation ✓ Soucces ✓ Soucces ✓ Soucces ✓ Temperature/Salinty Module ✓ Outputs	
Navigation	

Figure 4.7 MIKE 3 Flow Model FM: Flood and Dry specification

The model area is an estuary with several fresh water streams discharging into the estuary, but the estuary is also influenced by saline water from the surrounding waters at the narrow entrance to the estuary. Therefore the water is rather fresh in the inner parts of the estuary, and with higher salinity at the entrance to the estuary. Consequently, density variations are included in the hydrodynamic setup by setting the density type as a Function of temperature and salinity. See Figure 4.8.



Figure 4.8 MIKE 3 Flow Model FM: Density specification



The next dialogue to modify is the Horizontal Eddy viscosity. Choose a Smagorinsky formulation with a constant value of 0.28 m^1/3/s, see Figure 4.9.

MIKE Zero - [odense.m3fmRead	d Only - Modified]	
	₩ N \= # @ □ # ₫ /	
MIKE 3 Flow Model FM	Eddy Viscosity Horizontal Eddy Viscosity Eddy type Smagorinsky formulation Smagorinsky formulation data Format Constant Constant value 0.28 Data file and item Item. Item. View	L¢.
Validation / Simulation /		
Ready	Pointer outside model area	Mode //

Figure 4.9 MIKE 3 Flow Model FM: Horizontal Eddy viscosity specification

The Vertical Eddy viscosity should be specified as type Log Law formulation, see Figure 4.10.

MIKE Zero - [odense.m3fmRea	d Only - Modified]	
R Hie Edit View Run Window F		_ 먼 스
MIKE 3 Flow Model FM MIKE 3 Flow Model FM Mike 3 Flow Model FM Mike 3 Flow Model Selection Mike 3 Koule Selection Mike 3	Eddy Viscosity Eddy Viscosity Eddy type Log law formulation Eddy viscosity Iddy v	
Ready	Pointer outside model area	Mode //

Figure 4.10 MIKE 3 Flow Model FM: Vertical Eddy viscosity specification

The Bed Resistance should be specified with a roughness height of 0.1 m, see Figure 4.11.



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MIKE 3 Flow Model FM	Bed Resistance Resistance type Roughness height Format Constant Value O.1 [m] Data file and item Item: View	
Ready	Pointer outside model area	Mode //

Figure 4.11 MIKE 3 Flow Model FM: Bed Resistance specification

The wind file that we generated in Chapter 3 should be specified as the wind: wind.dfs0 (Varying in time, constant in domain) shall be specified as the Wind Forcing. See Figure 4.12.

MIKE Zero - [odense.m3fmRead	Only - Modified]			_ 🗆 🗡
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	r: r ~ ~ / ~			
MIKE 3 Flow Model FM	Wind Forcing			
Time				
Module Selection				
Solution Technique	Format	Varying in time, constant in domain 💌		
Flood and Dry	Speed	0 [m/s]		
I ✓ Density	Direction	0 [deg]		
Bed Resistance	Data di suddisso		Color 1	
Coriolis Forcing	Data file and items	U: Program Files (DHI (MIKEZero (Examples (MIKE_3))	Select	
the Coverage		Item: Wind Direction		
✓ Tidal Potential		Item:		
🖌 🖌 Precipitation · Evaporat.		, 		
Wave Radiation	Neutral pressure	1013 [hPa]		
Initial Conditions	Soft start interval	100 [sec]		
🗄 🗹 Boundary Conditions				
🕀 🗹 Outputs				
🗄 🗹 ECO Lab Module				
Navigation				
1				
Validation / Simulation /				
Ready		Pointer outside model area		Mode

Figure 4.12 MIKE 3 Flow Model FM: Wind Forcing specification

Specify the Wind Friction as in Figure 4.13.



MIKE Zero - Jodense m3fmRead	Only - Modified]	
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	** № N 102 / 60 □ F# E /	
Image: Section Image: Method of Se	Wind Friction Friction Friction type Varying with Wind Speed Constant 00026 Linear variation using Speed To [m/s] 0.0012 24 [m/s] 0.0025	
Validation Simulation		
Ready	Pointer outside model area	Mode //.

Figure 4.13 MIKE 3 Flow Model FM: Wind Friction specification

The precipitation: precipitation.dfs0 (Varying in time, constant in domain). See Figure 4.14.

Note: The setting for evaporation needs to be carried out after including the heat exchange in the Temperature/Salinity module.

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MIKE 3 Flow Model FM ✓ Domain ✓ Time ✓ Module Selection □ ✓ Hydrodynamic Module	Precipitation Precipitation Specifie		
✓ Solution Technique ✓ Flood and Dy ✓ Flood and Dy ✓ Eddy Viscosity ✓ Eddy Viscosity ✓ Bed Resistance ✓ Cirolis Forcing ✓ Wind Forcing ✓ Wind Friction ✓ Vind Friction ✓ Ice Coverage ✓ Vind Priction	Format Constant value Data file and item Soft start interval	Varying in time, constant in domain Varying in time, constant in domain O [mm/day] C.VProgram Files/DHI/MIKEZero/Examples/MIKE_3X Item: precipitation Item: precipi	
✓ Precipitation = Evaporat. ✓ Wave Radiation ✓ Sources ✓ Initial Conditions ✓ Boundary Conditions ✓ Boundary Conditions ✓ Decoupling ✓ Outputs ✓ Co Lab Module ✓ Navisation	Evaporation Compute	ed evaporation	
Validation & Simulation /			
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Figure 4.14 MIKE 3 Flow Model FM: Precipitation specification

Next the discharges and co-ordinates must be specified for the sources. One of them is the Funen Powerplant.



This source is actually a so-called connected source. In the model it should be described with 5 intakes of water in the Stavids Stream. These intakes should be connected to 5 outfalls in the Odense Stream at different water depths. So in the model the 13 sources should be described with 22 source points. The hydrodynamic source files that we generated in Chapter 3 should be specified as the sources. The file names and positions are given in Table 4.2. Specify them as type 'Simple source, Varying in time', apart from the last 5 where the type is 'Connected source, Constant'. See Figure 4.15 and Figure 4.16.

Table 4.2 List of sources and their positions in the fine mesh

No.	Name of source	Easting (UTM 33)	Northing (UTM 33)	Discharge filename	Layer number
1	Stavids Stream	207764	6151566	stav.dfs0	3
2	Odense River	211281	6151619	odense.dfs0	3
3	Lunde Stream	211955	6157226	lu_n.dfs0	3
4	Vejstrup Stream	213550	6153038	vejr.dfs0	3
5	Geels Stream	215279	6154407	gel.dfs0	3
6	U_48	212040	6157034	u_48.dfs0	3
7	Fjordmarken South	214378	6162797	fj_s.dfs0	3
8	Fjordmarken North	214738	6163049	fj_n.dfs0	3
9	U_46	215891	6158980	u_46.dfs0	3
10	Krags Stream U_27	214774	6153759	u_27.dfs0	3
11	U_28	217079	6156567	u_28.dfs0	3
12	U_29	223273	6159304	u_29.dfs0	3
13	Funen Powerplant Outfall 1	209659	6152351	fynsv.dfs0	6
14	Funen Powerplant Outfall 2	209659	6152351	fynsv.dfs0	5
15	Funen Powerplant Outfall 3	209659	6152351	fynsv.dfs0	4
16	Funen Powerplant Outfall 4	209659	6152351	fynsv.dfs0	3
17	Funen Powerplant Outfall 5	209659	6152351	fynsv.dfs0	2
18	Funen Powerplant Outfall 1	210090	6152099	Connected to 13	6
19	Funen Powerplant Outfall 2	210090	6152099	Connected to 14	5
20	Funen Powerplant Outfall 3	210090	6152099	Connected to 15	4
21	Funen Powerplant Outfall 4	210090	6152099	Connected to 16	3
22	Funen Powerplant Outfall 5	210090	6152099	Connected to 17	2





Figure 4.15 MIKE 3 Flow Model FM: Hydrodynamic Sources specification

MIKE Zero - [odense.m3fmRead Only - Modified]	
Wave Radiation Sources Sources Sources Vestuds Stream Vestuds Stream <th></th>	
Ready Pointer outside model area Mode	





The initial conditions for the warm up period is specified as a constant surface elevation of 0.369 m, see Figure 4.17.

MIKE Zero - [odense.m3fmRead	Only - Modified]		_ D X _ B X
MIKE 3 Flow Model FM MIKE 3 Flow Model FM Module Selection Multicodynamic Module Module Selection Multicodynamic Module Multicodynamic Module Multicodyna	Initial Conditi Type Initial data Surface elevation Data file	Constant) [m/s] [m/s] [m/s] Select
✓ Wind Friction ✓ Ice Coverage ✓ Tidal Potential ✓ Precipitation - Evaporat. ✓ Wave Radiation ✓ Sources	Surface elevation item Velocity items	ltem. Item: Item: Item:	View
	Data file Velocity items	ltem: Item:	Select View
Navigation		Pointer outside model area	Mode //

Figure 4.17 MIKE 3 Flow Model FM: Hydrodynamic Initial Conditions specification

For the Hydrodynamic Boundary Conditions specify the type as specified level, varying in time, constant along boundary. Select the file water_level.dfs0 that was generated in Chapter 3 and define a soft start of 100 s, see Figure 4.18.

MIKE Zero - [odense.m3fmRead	l Only - Modified]	
	₩ N @ # @ □ f* ⊈ /	
MIKE 3 Flow Model FM	Gabet Type Specified level Bounday data Format Varying in time, constant along boundary Constant value 0 (m) Data file and item [C:VProgram Files/DHI/MIKEZero\Examples\MIKE_3\FI Soft start [Item: Boundary lålue Soft start [Item: Boundary lålue Soft start [Item: Boundary lålue Time interval 100 [sec] Reference value 0 [m] Boundary data corrections [In space Normal Include wird correction [Include indication stress correction] Include radiation stress correction [Include radiation stress correction]	
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Figure 4.18 MIKE 3 Flow Model FM: Hydrodynamic Boundary Conditions specification



Range checking of the temperature and salinity can be necessary in order to prevent numerical blow-ups. Therefore specify an acceptable range as in Figure 4.19.

MIKE Zero - [odense.m3fmRea	d Only - Modified]	
	××× ₩	
	Equation Temperature Minimum 2 [°C] Maximum 28 [°C]	
Validation Simulation	1	
Ready	Pointer outside model area	Mode //

Figure 4.19 MIKE 3 Flow Model FM: Temperature/Salinity minimum and maximum values

Please note that you may violate the mass conservation law when the range check option is active. However, if the range checking only is activated in a few points at a few time steps, this solution can be a practical way to overcome numerical instability. See Figure 4.19.

The type of Solution Technique should match the settings in the Hydrodynamic module.

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Image: Second state st	Image: Second		
Navigation			
Validation / Simulation /			
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Figure 4.20 MIKE 3 Flow Model FM: Temperature/Salinity Horizontal Dispersion specification



Specify the Horizontal Dispersion of salinity and temperature as scaled to the eddy viscosity with a Scaling factor of 1, see Figure 4.20.

Specify the Vertical Dispersion of salinity and temperature as scaled to the eddy viscosity with a scaling factor of 0.01, see Figure 4.21.

IKE Zero - [odense.m3fmReal File Edit View Run Window Image: Second sec	ad Only - Modified] Help 3 😽 🕼 🔭 🖉 🖗 🗆 🏂 🖉 /	_ D ×
Wind Forcing Wave Radiation Sources Wind Sources Wave Radiation Sources Wave Radiation Sources Wave Radiation We Rad	Vertical Dispersion Formulation Scaled eddy viscosity formulation Scaling factor 0.01 Dispersion coefficient formulation Format Constant Constant value 0.01 Select Data file and item Item:	
Ready	/ Pointer outside model area	Mode //

Figure 4.21 MIKE 3 Flow Model FM: Temperature/Salinity Vertical Dispersion specification

Include the Heat Exchange and specify the files for air temperature and clearness, which were generated in Chapter 3. Set Relative humidity to 84.22 % while other parameters should be the default values, see Figure 4.22.

Now return to the Precipitation-Evaporation dialogue in the Hydrodynamic module and set the type of evaporation to 'Computed evaporation', see Figure 4.14

The temperature in Precipitation should be specified as ambient water temperature, see Figure 4.23.



🔵 odense.m3fm		
MIKE 3 Flow Model FM		
- 🖌 Domain	Heat Exchange	
- M Time		
Module Selection	Include neat exchange	
Hydrodynamic Module	Latent heat Sensible he	eat Short wave radiation Long wave radiation Atmospheric conditions
Solution Technique		
 M Depth If Food and Day 	Air temperature	
v nood and bry	Format	Varving in time, constant in domain 💌
 Fiddy Viscosity 	- Chinac	
Bed Resistance	Constant value	15 [°C]
- 🖌 Coriolis Forcing	Data file and item	C:\Data\AJS Examples.Rel2016\MIKE 3\FlowModel Select
🗈 🗹 Wind Forcing	a dia the difa item	Item: Air temperature
🚽 🗹 Ice Coverage		Tell. Air teliperature
Tidal Potential		
Precipitation - Evaporation	Relative humidity	
✓ Infiltration		
Wave Hadiation	Format	Constant
Sources	Constant value	82.44 [%]
Structures		Colort
Roundary Conditions	Data file and item	Select
Temperature/Salinity Module		Item: View
✓ Equation		
Solution Technique	Clearness coefficient	
Dispersion		
Heat Exchange	Format	Varying in time, constant in domair 🔻
Precipitation - Evaporation Sources	Constant value	70 [%]
- 🖌 Initial Conditions	Data file and item	C:\Data\AJS_Examples.Rel2016\MIKE_3\FlowModel_ Select
Boundary Conditions		Item: H/H0 View
Decoupling		
ECU Lab / Uispii Module		
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Figure 4.22 MIKE 3 Flow Model FM: Heat Exchange specification

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1		
Validation Simulation	1	
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Figure 4.23 MIKE 3 Flow Model FM: Precipitation temperature specification



The temperature in the sources should for the normal sources be specified as excess temperature and salinity with a constant value of zero. The temperature/salinity specification for the intake of cooling water of the Funen Powerplant is specified, but not used because the discharge in the source is 'negative'. But for the outfall of the cooling water from Funen Powerplant the heating of the water in the powerplant should be specified as an excess temperature. So specify the excess temperature with fynsv.dfs0, item temperature, see Figure 4.24.

MIKE Zero - [odense.m3fmRea	d Only - Modified]			
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	Funen Powers Type of temperature Temperature Format Constant value Data file and item	Varying in time 10 [C] C-Program Files/DHI/MIKEZero/Examples/MIKE_3/ [Item: Temperatur	Select View	<u>*</u>
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Figure 4.24 MIKE 3 Flow Model FM: Source Funen Powerplant Temperature/ Salinity specification

The Initial Conditions for salinity and temperature should be specified with the temperature.dfs3 and salinity.dfs3 files, see Figure 4.25.

Specify Boundary Conditions for temperature and salinity. Remember to specify as soft start period, see Figure 4.26.



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You should save 4 output files:

- 2D output file
- 3D output file
- 2D initial conditions for the Period 1 simulation (Only time step 144 with 4 items: Surface elevation, Total water depth and Depthaveraged velocity in U and V direction)
- 3D initial conditions for the Period 1 simulation (Only time step 144 with 6 items: U velocity, V velocity, W velocity, Density, Temperature and Salinity)

You may also want to include 2 additional output files (for calibration purpose):

- St 8 time series in position UTM 33 (213812, 6154526)
- St 17 time series in position UTM 33 (217662, 6156584)

4.1.3 MIKE 3 Flow Model FM specifications for MIKE ECO Lab

Select the MIKE ECO Lab template:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\ECOLab_Template\EutrophicationModel1Sedi mentBenthicVegetation.ecolab

In the dialogue you can see a short summary of the number of variables defined in the MIKE ECO Lab template.

Set the MIKE ECO Lab update frequency to 24, corresponding to a time step of $25 \times 24 = 600$ s, and select the Euler integration method, see Figure 4.27.

MIKE Zero - [odense.m3fmRead	l Only - Modified]	- O ×
🚒 File Edit View Run Window H	elp	_ & ×
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MIKE 3 Flow Model FM	Model Definition Template Selection From File C:\Program Files\DHI\MIKEZero\Examples\MIKE_3\FlowModeLF Summary 25 State Variables 121 Constants 100 Processes 7 Forcings 3 Derived Outputs	
	1	
Ready	Pointer outside model area	Mode //

Figure 4.27 MIKE 3 Flow Model FM: Model Definition for MIKE ECO Lab specification



The State Variables section should show a summary about the characteristics of the state variables in the MIKE ECO Lab template. These characteristics can only be changed by editing the content of the MIKE ECO Lab template and they cannot be changed in the MIKE 3 Flow Model FM dialogue. The characteristics are about if the state variables are advective or fixed. Furthermore, they specify if the state variable is 2D or 3D, and what unit the state variable has, see Figure 4.28.

- 🖌 Domain - 🖌 Time	State \	/ariables	
- ✓ Module Selection - ✓ Hvdrodvnamic Module	ID Nar	ne Description Transport Spatial va	riation
🖌 🖌 ECO Lab Module	1 PC	Phytoplankton C g C/m3 AD 3D	r
- 🖌 Model Definition	2 PN	Phytoplankton N g N/m3 AD 3D	r
- 🖌 State Variables	3 PP	Phytoplankton P. g P/m3 AD 3D	r
🚽 🖌 Solution technique	4 CH	Chlorophyll-a, q Chl/m3 AD 3D	r
🗸 Constants	5 ZC	Zooplankton C. g C/m3 AD 3D	r
- 🖌 Forcings	6 DC	Detritus C. g C/m3 AD 3D	r
🗄 🖌 Dispersion	7 DN	Detritus N. a N/m3 AD 3D	
표 🖌 Precipitation - Evaporat	8 DP	Detritus P. g P/m3 AD 3D	r
🗄 🖌 Sources	9 IN	Inorganic nitrogen, g N/n3 AD 3D	r
표 🖌 Initial Conditions	10 IP	Inorganic phosphorous, g P/m3 AD 3D	r
🗄 🖌 🖌 Boundary Conditions	11 DO	Dissolved oxygen, g DO/m3 AD 3D	r
🗄 🖌 🖌 Outputs	12 BC	Macroalgea C, g C/m2 2D	C
	13 BN	Macroalgea N, g N/m2/d 2D	c
	14 BP	Macroalgea P, g P/m2/d 2D	- 2
	15 EC	Rooted vegetation, g C/m2 2D	- C
	16 NNE	C Rooted vegetation, number of shoots, no/m2 2D	Г
	17 KDC	X Depth of NO3 penetration in sediment, m 2D	r
	18 SOF	Sediment organic P, g P/m2 2D	ç
	19 FES	Sediment iron adsorped P, g P/m2 2D	ç
	20 SIP	Sediment phosphate, g P/m2 2D	ç
Invigation			



The Solution Technique should match the one used in the Hydrodynamic Module.

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MIKE 3 Flow Model FM	Constants		
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Module Selection			
🗄 🖌 Hydrodynamic Module	No. Description	Туре	Value
🗕 🖌 ECO Lab Module	1 latitu, Latitude	Built-in	
🖌 Model Definition	2 mymd, Pelagic: Growth rate diatoms, 1/d	Constant	0.7 (/d)
— 🖌 State Variables	3 myrng, Pelagic: Growth rate green algae, 1/d	Constant	1.3 (/d)
- Solution technique	4 sida, Phytoplankton: Day no. for change to green algae domination	Constant	90 dimensionless
- 🖌 Constants	5 fac, Phytoplankton: Correction for dark reaction	Constant	1.3 dimensionless
- 🖌 Forcings	6 alfaeu, Phytoplankton: Light saturation intensity, E/m2/d	Constant	15 E/m2/d
吏 🖌 Dispersion	7 tetd, Phytoplankton: Temperature dependency growth rate diatoms	Constant	1.01 dimensionless
🗄 🗹 Precipitation - Evaporat	8 tetg, Phytoplankton: Temperature dependency growth rate green algea	Constant	1.12 dimensionless
🗄 🗹 Sources	9 teti, Phytoplankton: Temperature dependency for light saturation intensity	Constant	1.04 dimensionless
🗄 🗹 Initial Conditions	10 pnmi, Phytoplankton: Min. intracellular concentration of nitrogen, g N/gC	Constant	0.07 g N/g C
🗄 🗹 Boundary Conditions	11 pnma, Phytoplankton: Max. intracellular concentration of nitrogen, g N/g C	Constant	0.18 g N/g C
🗄 🖌 🗹 Outputs	12 ppmi, Phytoplankton: Min. intracellular concentration of phosphorous, g P/g C	Constant	0.002 g P/g C
	13 kc, Phytoplankton: Half-saturation concentration for phosphorus, g P/g C	Constant	0.01 g P/g C
	14 ppma, Phytoplankton: Max. intracellular concentration of phosphorous, g P/g C	Constant	0.01 g P/g C
	15 epsi, Phytoplankton: Specification for nutrient saturation	Constant	0.001 dimensionless
	16 kni, Phytoplankton: N uptake under limiting conditions, g N/g C/d	Constant	0.3 g N/g C/day
	17 kpi, Phytoplankton: P uptake under limiting conditions, g P/g C/d	Constant	0.02 g P/g C/day
1	18 kpn, Phytoplankton: Half-saturation constant for N uptake, g N/m3	Constant	0.05 g N/m3
	19 kpp, Phytoplankton: Half-saturation constant for P uptake, g P/m3	Constant	0.01 g P/m3
	20 sep, Pelagic: Sedimentation rate <2m, 1/d	2D file	0.07 (/d)
Navigation			Þ
Validation Simulation			
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Figure 4.29 MIKE 3 Flow Model FM: Constants in MIKE ECO Lab Specification



The constants defined in the MIKE ECO Lab template can be given a global value in your setup, or be specified with a file describing its spatial variation, see Figure 4.29. A constant can only be specified with a file with spatial variation if the constant is defined as such in the MIKE ECO Lab template. Furthermore, a list of the constants, which all can be modified in the setup, is shown in Figure 4.30 and Figure 4.31. The values are mostly the default values that are read in the MIKE ECO Lab template, but a few are modified. Go through the list and specify the constants with the same values.

Remember to specify the maps:

- dry_weight_sediment.dfs2
- light_extinction_background.dfs2
- sediment_bulk_density.dfs2
- sediment_fe_content.dfs2
- sedimentation_rate_shallow_water.dfs2



No.	Description	Туре	Va	ue	File Name	
1	latitu, Latitude	Built-in				
2	mymd, Pelagic: Growth rate diatoms, 1/d	Constant	0.7	(/d)		
3	mymg, Pelagic: Growth rate green algae, 1/d	Constant	1.3	(/d)		
4	sida, Phytoplankton: Day no. for change to green algae dominati	Constant	90	dimensionl		
5	fac, Phytoplankton: Correction for dark reaction	Constant	1.3	dimensionl		
6	alfaeu, Phytoplankton: Light saturation intensity, E/m2/d	Constant	15	E/m2/d	x	
7	tetd, Phytoplankton: Temperature dependency growth rate diato	Constant	1.01	dimensionl	1 Alexandress of the second se	
8	tetg, Phytoplankton: Temperature dependency growth rate gree	Constant	1.12	dimensionl		
9	teti, Phytoplankton: Temperature dependency for light saturation	Constant	1.04	dimensionl		
10	pnmi, Phytoplankton: Min. intracellular concentration of nitrogen,	Constant	0.07	g N/g C		
11	pnma, Phytoplankton: Max. intracellular concentration of nitrogen	Constant	0.18	g N/g C		
12	ppmi, Phytoplankton: Min. intracellular concentration of phosphor	Constant	0.002	g P/g C		
13	kc, Phytoplankton: Half-saturation concentration for phosphorus,	Constant	0.01	g P/g C		
14	ppma, Phytoplankton: Max. intracellular concentration of phosph	Constant	0.01	g P/g C		
15	epsi, Phytoplankton: Specification for nutrient saturation	Constant	0.001	dimensionl		
16	kni, Phytoplankton: N uptake under limiting conditions, g N/g C/d	Constant	0.3	g N/g C/da		
17	kpi, Phytoplankton: P uptake under limiting conditions, g P/g C/d	Constant	0.02	g P/g C/da		
18	kpn, Phytoplankton: Half-saturation constant for N uptake, g N/m	Constant	0.05	g N/m3		
19	kpp, Phytoplankton: Half-saturation constant for P uptake, g P/m3	Constant	0.01	g P/m3		
20	sep, Pelagic: Sedimentation rate <2m, 1/d	2D file	0.07	(/d)	C:WIKEZero\dev\example\M3\FlowModel_FM\EL\Odense_Estuary\Data\Consta	
21	seve, Pelagic: Sedimentation rate >2m, m/d	Constant	0.1	meter/day		
22	kdma, Pelagic: Death rate phytoplankton, 1/d	Constant	0.01	(/d)		
23	vm, Phytoplankton: Fraction of nutrients released at phytoplankto	Constant	0.3	dimensionl		
24	chmi, Coefficient for chlorophyll-a production, g Chl*m2**d/g C/E	Constant	0.02	g Chl*m2*d		
25	chma, Phytoplankton: Coefficient for max. chlorophyll-a producti	Constant	1	1/(E/m2/da		
26	pla, Pelagic: Light extinction constant phytoplankton, m2/g Chla	Constant	30	m2/g Chl-a		
27	bla, Pelagic: Light extinction background constant, 1/m	2D file		1/m	C:WIKEZero\dev\exampleW3\FlowModel_FM\EL\Odense_Estuary\Data\Consta	
28	dla, Pelagic: Light extinction detritus C, m2/g DC	Constant	0.1	m2/g detrit		
29	sla, Pelagic: Light extinction constant suspended solids, m2/g SS	Constant	0.1	m2/g SS		
30	kgrb, Pelagic: Max. grazing rate, 1/d	Constant	1.5	(/d)		
31	tetz, Phytoplankton: Temperature dependency for max. grazing r	Constant	1.05	dimensionl		
32	kgrs, Phytoplankton: 1. order dependency of grazing rate on alg	Constant	50	(/d)		
33	kgrm, Phytoplankton: 0. order dependency of grazing rate on alg	Constant	5	dimensionl		
34	vefo, Zooplankton: Specific growth, g C/g C	Constant	0.28	g C/g C		
35	vzn, Zooplankton: N to C ratio in zooplankton, g N/g C	Constant	0.07	g N/g C		
36	vzp, Zooplankton: P to C ratio in zooplankton, g P/g C	Constant	0.002	g P/g C		
37	refo, Zooplankton: Respiration constant zooplankton carbon	Constant	0.3	dimensionl		
38	kdzb, Pelagic: Zooplankton death rate 1st order, 1/d	Constant	0.1	(/d)		
39	kdz, Pelagic: Zooplankton death rate 2nd order, m3/g C/d	Constant	12	m3/g C/da		
40	kmdm, Pelagic: Detritus C mineralisation rate, 1/d	Constant	0.1	(/d)		
41	tere, Detritus: Temperature dependency for C mineralisation	Constant	1.08	dimensionl		
42	kmdn, Detritus: propertional factor for release of N from minerali	Constant	1	dimensionl		
43	kmdp, Detritus: Propertional factor for release of P from mineralis	Constant	1	dimensionl		
44	sed, Pelagic: Detritus C settling rate <2m, 1/d	Constant	0.2	(/d)		
45	sevd, Pelagic: Detritus C settling rate >2m, m/d	Constant	0.05	meter/day		
46	mybc, Macroalgae, Production rate at 20 deg., 1/d	Constant	0.27	(/d)		
47	mabce, Macroalgae, growth rate factor,	Constant	1			
48	tmax, Macroalgae, Growth inhibition temperature, C	Constant	30	grader Cel		
49	topt, Macroalgae, Growth optimum temperature, C	Constant	18	grader Cel		
50	lasa, Macroalgae, Lassiter constant	Constant	0.1	dimension		
51	ikb20, Macroalgea: Light saturation intensity at 20 deg., E/m2/d	Constant	20	E/m2/day		
52	inb20, Macroalgea: Light intensity for photo inhibition at 20 deg.,	Constant	25	E/m2/day		
53	tetib, Macroalgea: Temperature dependency for light saturation a	Constant	1.04	dimension		
54	pape, Macroalgea: Minimum biomass of macro algae, g C/m2	Constant	0	g C/m2		
55	vin, Macro algae: Potential N uptake by BC, g N/g C/d	Constant	0.035	gN/gC/day		
56	vip, Macro algae: Potential P uptake by BC, g P/g C/d	Constant	0.01	g P/gC/d		
57	pnma, macro algae: Max. intracelluar conc. of N, g N/g C	Constant	0.2	gN/gC		
58	pnmi, macro algae: Min. intracelluar conc. of N, g N/g C	Constant	0.06	gN/gC		
59	ppma, Macro algae: Max. intracelluar conc. of g P/g C	Constant	0.02	gP/gC		
60	ppmi, macroalgea: Min. Intracellular concentration of phosphorou	Constant	0.002	gP/gC		
61	ккюр, масто algae: Haitsat. conc. for P, g P/g C	Constant	0.005	gP/gC		
62	kon, macroalgea: Hait-saturation concentration for N uptake, g N	Constant	0.2	g N/m3		
63	кор, мастоаlgea: Hait-saturation concentration for P uptake, g P/	Constant	0.08	g P/m3		
64	mia, waeroaigae: Light extinction constant macroalgae, m2/g BC totk, Meeroalgae, & Restad upgetation, Termanetime down	Constant	0.02	m2/g macr		
65	mile. Macroalgea a Rooled vegetation: Temperature dependency	Constant	1.04	a Các2		
00	miller, mael balaca. Thi conola values for sen-shauna di filacru al	CONSTANT	20	IN CALLS		

Figure 4.30 MIKE 3 Flow Model FM: Constants in MIKE ECO Lab Specification for Odense Estuary





67	Italia, Maavaalisaas Classisiaa vata at 30 daawaaa, 4 d	Constant	0.00	(14D)		
67	ksim, Macroalgea: Sloughing rate at 20 degrees, 1/d	Constant	0.02	(/a)		
68	teti, macroaigea: Temperature dependency sloughing rate	Constant	1.03	dimensioni		
59	tets, macro algae, Death rate constant, 1. Order coeff.	Constant	0	amensioni		
70	ws1, Macro algae Death rate constant, 2. Order coeff., 1/m	Constant	3	per meter		
71	roma, macroalgea: Respiration rate at 20 degrees, 1/d	Constant	0	(/a)		
72	vo, Oxygen: Production/consumption relative to carbon, g DO/g	Constant	3.5	gDOIgC		
73	kmsc, Sediment: Proportional factor for sediment respiration	Constant	0.7	aimensioni		
74	Indo, Oxygen: Hait-saturation constant, g/m3	Constant	2	g/m3		
75	Indos, Oxygen: Hait-saturation constant in sediment, g/m3	Constant	2	mg/i		
76	Indo, Oxygen: Coefficient for oxygen dependency	Constant	1	dimensioni		
11	teth, Sediment: Temperature dependency sediment Nirelease	Constant	1.1	dimensioni	N	
78	tetp, Sediment: Temperature dependency sediment P release	Constant	1.09	dimension	k	
79	ters, Sediment: Temperature dependency sediment respiration	Constant	1.07	dimension		
80	kds, Sediment: Depth of modelled sediment layer, m	Constant	0.1	m		
81	vf, Sediment: Sediment bulk density, g/cm3	2D file	2	g WW/cm3	C:WIKEZero\dev\example\M3\FlowModel_FM\EL\Odense_Estuary\Data\Consta	
82	dm, Sediment: Dry weight sediment, g DM/g WW	2D file	0.5	g DM/g W	C:WIKEZero\dev\example\M3\FlowModel_FM\EL\Odense_Estuary\Data\Consta	
83	kfe, Sediment: Fe content sediment, g Fe/g DM	2D file	0.0004	g Fe/g DM	C:WIKEZero\dev\example\M3\FlowModel_FM\EL\Odense_Estuary\Data\Consta	
84	difno3, Sediment: Diffusion constant nitrate, m2/d	Constant	2.4e-005	m2/day		
85	difnh, Sediment: Diffusion constant ammonia, m2/d	Constant	2.4e-005	m2/day		
86	kfip, Sediment: Diffusion constant phosphate, m2/d	Constant	2.4e-005	m2/day		
87	krsn1, Sediment: Mineralisation rate SON, 1/d	Constant	0.0024	(/d)		
88	krsp1, Sediment: Mineralisation rate SOP, 1/d	Constant	0.0144	(/d)		
89	kkdox, rate NO3 penetration into sediment, 1/d	Constant	0.025	1/d		
90	demax, Sediment: Max. denitrification rate at 20 C per m3 active	Constant	0.84	g N/m3/da		
91	knit, Sediment: Max. nitrification rate at 20 C per m3 active sedim	Constant	4.8	g N/m3/da		
92	ksnh0, Sediment: Half-saturation constant ammonia, nitrification,	Constant	0.5	g N/m3		
93	krsn0, Sediment: Fraction of settled N to mineralisation	Constant	0.1	dimensionl		
94	knim, Sediment: N:C ratio of immobile N, g N/g C	Constant	0.064	g N/g C		
95	krsp0, Sediment: Fraction of settled P to mineralisation	Constant	0.2	dimensionl		
96	kpim, Sediment: Fraction of settled P to immobilisation	Constant	0.02	dimensionl		
97	krap, Sediment: 1st order constant iron absorbed P, 1/d	Constant	0.24	(/d)		
98	kfepo, Sediment: Max. Fe-P sorption, g P/g Fe	Constant	0.066	g P/g Fe		
99	khfe, Sediment: Half-saturation constant phosphate, Fe-P sorptio	Constant	0.001	q P/m3		
100	kka. Sediment: Constant 1. oxygen penetration into sediment, m	Constant	N 0 00124	- m		
101	kkb Sediment: Constant 2, oxygen penetration into sediment, m	Constant	Langer and			
102	kkc. Sediment: Constant 3, oxygen penetration into sediment, ma	Constant	Range: 0 -			
102	med. Rooted yea: Specific growth rate at 20 C. shoot biomass	Constant	0.1	(M)		
104	tetal. Rooted ver: Temperature dependency for growth	Constant	1.08	dimension		
104	ibe20. Rooted veg.: Light intensity at 20 C for photoiphibition. Elin	Constant	35	Elm2/d		
105	ike20. Rooted veg.: Light intensity at 20 C for saturation. E/m2/d	Constant	20	Em2/d		
100	ice20, Rooted veg.: Light intensity at 20 C for saturation, L/h2/d	Constant	20	E/m2/d		
107	teto. Rooted veg : Temperature dependency for light compensation, E/m	Constant	1.04	dimension!		
100	medic, Rooted veg. Temperature dependency for light compensation	Constant	0.04	CAD		
109	Intern, Rooted veg., Specific death rate at 20 C, shoot biomass, 1.	Constant	0.01	(/u) dimension		
110	Letw, Rooted veg., Temperature dependency for death	Constant	1.07	dimensioni		
111	ewil, Rooted veg.: 1st death constant shallow waters	Constant	2.5	dimensioni		
112	ewz, Rooted Veg.: 2nd death constant shallow waters	Constant	2	amensioni		
113	jmngr, Rooted veg.: Maximum growth rate at 20 C, humber of sho	Constant Constant	15	numper/m		
114	kioss, Rooted veg.: specific death rate at 20 C, number of shoot	Constant	0.003	(/a)		
115	Itsa, kooted veg.: Fraction of root, veg, to the sediment	Constant	0.9	amension		
116	ecno, Rooted veg.: N to Ciratio, g N/g C	Constant	0.035	gN/gC		
117	ecpc, Rooted veg.: P to C ratio, g P/g C	Constant	0.0045	gP/gC		
118	ken, Rooted veg.: Halfsat. Conc. of IN in the water, g N/m3	Constant	0.2	gN/m3		
119	kep, Rooted veg.: Halfsat. conc. of IP in the water, g P/m3	Constant	0.1	gP/m3		
120	ksen, Half saturation const. SNH uptake by EC, g N/m3	Constant	0.1	g N/m3		
121	ksep, Half saturation conc. SIP uptake by EC, g P/m3	Constant	0.05	g P/m3		

Figure 4.31 MIKE 3 Flow Model FM: Constants in MIKE ECO Lab Specification for Odense Estuary, continued



The user specified forcings defined in the MIKE ECO Lab template must be specified given a global value in your setup, or specified with a file describing its spatial variation, see Figure 4.29. Furthermore, a summary of the forcings that are possible to modify in the setup is shown in Figure 4.32.

Remember to specify the solar radiation with the time series file: • light.dfs0

MIKE Zero - [odense.m3fmRead	Only - Modified]			
	😽 N 🤤 🖉 🚳 🗆 🗚	• • ×		
MIKE 3 Flow Model FM	Forcings			
	No. Description	Туре	Value	File Name
📄 🖌 ECO Lab Module	1 Temperature	Built-in		
🚽 🖌 Model Definition	2 Salinity	Built-in		
🚽 🖌 State Variables	3 Suspended solids	Constant	0 ma/l	
🖌 Solution technique	4 Solar Radiation	TS file	25 E/m2/d C	Program Files/DHIMIKEZero/Examples/MIKE_3/FI
	5 Water depth water column	Built-in		
Forcings	6 Water depth actual layer	Built-in		
표 🖌 Dispersion	7 wsp, Wind speed, m/sec	Built-in		
 Initial Conditions Initial Conditio	4			۲
Ready	Pointe	r outside model av	38	Mide 2

Figure 4.32 MIKE 3 Flow Model FM: Forcings in the MIKE ECO Lab specification

You shall specify dispersion parameters for the advective state variables. For the horizontal dispersion you shall specify it as for the salinity and temperature dispersion specification.

Specify the Horizontal Dispersion of the advective state variables as scaled to the eddy viscosity with a scaling factor of 1, see Figure 4.33.

Specify the Vertical Dispersion of the advective state variables as scaled to the eddy viscosity with a scaling factor of 0.01, see Figure 4.34.



MIKE Zero - [odense.m3fmRea	d Only - Modified]	
File Edit View Run Window F		
MIKE 3 Flow Model FM	Phytoplankton C, g C /m3 Formulation Scaled eddy viscosity formulation Format Constant Constant value Dof (m7/s] Data file and item Item: View	
	1	
Ready	/ Pointer outside model area Mk	de //



🔀 MIKE Zero - [odense.m3fmRea	od Only - Modified]	
Rile Edit View Run Window		
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Domain Module Selection Module Selection Module Selection Module Selection Module Selection Model Definition State Variables Solution technique Constants Model Definition Model Definition	Phytoplankton C, g C /m3 Formulation Scaled eddy viscosity formulation Scaling factor 0.01 Poispersion coefficient formulation Format Constant Constant value 0.01 [m?/s] Data file and item Item: Item: View	
Validation / Simulation	1	
Ready	Pointer outside model area	Mode //,



For precipitation, the atmospheric deposition is considered to be small, so set the concentrations to be zero for all the advective state variables except the dissolved oxygen which can be set as ambient concentration or even better as the saturated oxygen concentration.

Specify the MIKE ECO Lab concentration files, which were generated in Chapter 3 for the sources. See the file names in Table 4.3. The dialogue looks as in Figure 4.35.



In MIKE ECO Lab it is useful to know the exact loading into the system. Use a spreadsheet to determine the loading based on both the hydrodynamic discharge and the MIKE ECO Lab concentration.

The total loadings after doing such an exercise are shown in Table 4.4.

In 2002, the total loadings of N and P to Odense Estuary were:

- 2483 ton N/y
- 72 ton P/y

Table 4.3 List of sources and their concentration files

No.	Name of source	Discharge Filename
1	Stavids Stream	I_stav.dfs0
2	Odense River	I_oden.dfs0
3	Lunde Stream	I_lun.dfs0
4	Vejstrup Stream	I_vejr.dfs0
5	Geels Stream	I_geel.dfs0
6	U_48	I_u48.dfs0
7	Fjordmarken South	l_fj_s.dfs0
8	Fjordmarken North	l_fj_n.dfs0
9	U_46	l_u46.dfs0
10	Krags Stream U_27	I_u27.dfs0
11	U_28	I_u28.dfs0
12	U_29	l_u29.dfs0
13	Funen Powerplant 1	(Constant 0 mg/l)
14	Funen Powerplant 2	(Constant 0 mg/l)
15	Funen Powerplant 3	(Constant 0 mg/l)
16	Funen Powerplant 4	(Constant 0 mg/l)
17	Funen Powerplant 5	(Constant 0 mg/l)
18	Funen Powerplant 1	(Default value)
19	Funen Powerplant 2	(Default value)
20	Funen Powerplant 3	(Default value)
21	Funen Powerplant 4	(Default value)
22	Funen Powerplant 5	(Default value)



Table 4.4Runoff and loadings to Odense Estuary 2002

	Discharge	Nitrogen	Phosphorus
Loading name	10,000 m³/y	Ton N/y	Ton P/y
Fjordmarken North, estimated	880	50.62	1.72
Fjordmarken South, estimated	996	59.09	1.80
Geels Stream, total	1059	59.35	1.19
Lunde Stream, total	2792	158.37	5.80
Odense River, total	24008	1534.44	41.06
Stavis Stream, total	5617	321.44	9.45
U27, total (Krags Stream)	569	33.79	1.03
U28, total	427	25.29	0.77
U29, total	462	27.58	0.83
U46, total	569	33.79	1.03
U48, total	1039	62.00	1.92
Vejrup Stream, total	1978	117.73	3.66
Ejby Mill WWTP*)	2114	57.50	2.03
North-East WWTP*)	358	18.90	0.79
North-West WWTP**)	630	29.00	0.62
Stige island dumping ground*)			
Atmospheric deposits		0.00	0.00
TOTAL	40396	2483.09	71.75

*) Loading included in Odense River

**) Loading included in Stavis Stream



MIKE Zero - [odense.m3fmRea	d Only - Modified]	
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Image: Stream of the strea	Phytoplankton C, g C /m3 Type of variable Specified concentration Format Constant value OI (mp/l) Data file and item C:VProgram Files/DHI/MIKEZero/Examples/MIKE_31 Select Item: pc View	
Ready	/ Pointer outside model area	Mode //

Figure 4.35 MIKE 3 Flow Model FM: Specifying concentrations for the advective MIKE ECO Lab state variables in Stavids Stream

The Initial Conditions for all MIKE ECO Lab state variables should be specified with the files mentioned in Chapter 3.9, see Figure 4.36.

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Initial Conditions Initial Condition	Phytoplankton C, g C /m3 Format Varying in domain Constant value 0.1 [mg/l] Data file and item C:VProgram Files/DH1MIKEZero/Examples/MIKE_33 Select Item: Ptytoplank.C (mg/l) View	
Ready	Pointer outside model area	Mode
	, ontor output alog	1.000

Figure 4.36 MIKE 3 Flow Model FM: Specifying Initial Conditions for the MIKE ECO Lab state variables

The Boundary Conditions for advective MIKE ECO Lab state variables should be specified with the files mentioned in Chapter 3.5 q and with a soft start of 100 s , see Figure 4.37.



IKE Zero - [odense.m3fmRea Image: File Edit View Run Window Image:	d Only - Modified] Help } ₩2] N Tec 2/ 49 □ 1/4 5 / -	
Hydrodynamic Module Vert ECD Lab Module State Variables Solution technique Solution technique	Phytoplankton C, g C /m3 Type Phytoplankton C, g C /m3 Format Varying in time and along boundary Constant value 01 [mg/l] Data file and item C:\Program Files\DHI\MIKEZero\Examples\MIKE_3\Select Type Sinus variation Type Sinus variation Time interval 100 [sec] Reference value 0 [mg/l]	
Ready	/ Pointer outside model area Mode	//,

Figure 4.37 MIKE 3 Flow Model FM: Specifying Boundary Conditions for the advective MIKE ECO Lab state variables

You should save 6 output files:

- 2D output file
- 3D output file
- St 8 time series in position UTM 33 (213812, 6154526)
- St 17 time series in position UTM 33 (217662, 6156584)
- 2D initial conditions for the Period 1 simulation
- 3D initial conditions for the Period 1 simulation

An example of the 3D output file is shown in Figure 4.38.

The 3D parameters to choose from in the specification of a 'Field type 3D' output file can be seen in Figure 4.39.

The 2D parameters to choose from in the specification of a 'Field type 2D' output file can be seen in Figure 4.40.

Save the last time steps of a 2D file and a 3D file. This file can be used as initial condition in another simulation, see Figure 4.41.



MIKE Zero - [odense.m3fmRead	Only - Modified]	
MKE 3 Flow Model FM	3D Geographic View Output specification Output items Data Tield type Image: Compart Files/DHI/MIKEZero/Examples/MIKE_StPlowModeLFMN Output file C.VProgram Files/DHI/MIKEZero/Examples/MIKE_StPlowModeLFMN Image: Compart files/DHI/MIKEZero/Examples/MIKE_StPlowModeLFMN Treatment of flood and dry Only real wet area Image: Compart files/DHI/MIKEZero/Examples/MIKE_StPlowModeLFMN Time step First 0 Last 144 Frequency 36 Volume series Import from file Layer range 1 to 10 Image: Compart file files/DHI/MIKEZero/Examples/DH	
Ready	Pointer outside model area	Mode



🔵 odense_rough.m3fm						•
MIKE 3 Flow Model FM	20					
🗹 Domain	3D					
Time						
Module Selection	Geographic 1	View Output specification Output items				
Hydrodynamic Module					<u> </u>	
Medal Definition	NO	Variable	Include	write	Handle data	<u> </u>
State Variables	1	Phytoplankton C, g C /m3		Current value	Default	
State Valiables	2	Phytoplankton N, g N/m3		Current value	Default	
Solution technique	3	Phytoplankton P, g P/m3	\boxtimes	Current value	Default	
	4	Chlorophyll-a, g Chl/m3	\boxtimes	Current value	Default	=
Forcings	5	Zooplankton C, g C/m3	\boxtimes	Current value	Default	-
🗄 M Dispersion	6	Detritus C, g C/m3	\boxtimes	Current value	Default	
Precipitation - Evaporation	7	Detritus N, g N/m3	\boxtimes	Current value	Default	
Sources	8	Detritus P, g P/m3	\boxtimes	Current value	Default	
🖭 🗹 Initial Conditions	9	Inorganic nitrogen, g N/m3	\boxtimes	Current value	Default	
🗄 🚽 Boundary Conditions	10	Inorganic phosphorous, g P/m3	\boxtimes	Current value	Default	
🚽 🗹 Temperature	11	Dissolved oxygen, g DO/m3	\boxtimes	Current value	Default	
🚽 🗹 Salinity	12	ihb, BC, Light intensity photoinhibition macroalgea corrected f		Current value	Default	
 Density 	13	prpc, Production phytoplankton carbon, g C/m3/d		Current value	Default	
 Wind forcing 	14	odpc, Oxygen production by phytoplankton, g DO/m3/d		Current value	Default	
🖻 🗹 Outputs	15	grpc, Grazing of phytoplankton carbon, g C/m3/d		Current value	Default	
- 🖌 3D	16	depc. Death of phytoplankton carbon. g C/m3/d	- H	Current value	Default	Ŧ
- sf 2D - sf St 8 - sf St 17 - sf 3D hot - sf 2D hot	Enable/d	sable all				
Navigation						
Validation Simulation						

Figure 4.39 MIKE 3 Flow Model FM: Specifying 3D Output parameters for the MIKE 3 FM ECO Lab



MIKE 3 Flow Model FM			_			
Domain	20					
🖌 🖌 Time						
Module Selection	Geographic	View Output specification Output items				
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ECO Lab / Oilspill Module	No	Variable	Include	Write	Handle dat	•
 Model Definition 	1	Macroalgea C, g C/m2	\boxtimes	Current value	Default	
- 🗹 State Variables	2	Macroalgea N, g N/m2/d		Current value	Default	E
 Solution technique 	3	Macroalgea P, g P/m2/d	X	Current value	Default	- L
— 🖌 Constants	4	Rooted vegetation, g C/m2	×	Current value	Default	
- 🗹 Forcings	5	Rooted vegetation, number of shoots, no/m2		Current value	Default	
🗄 🗹 Dispersion	6	Depth of NO3 penetration in sediment, m		Current value	Default	
Precipitation - Evaporation	7	Sediment organic P, g P/m2		Current value	Default	
🗈 🗹 Sources	8	Sediment iron adsorped P, g P/m2		Current value	Default	
🗄 🗹 Initial Conditions	9	Sediment phosphate, g P/m2		Current value	Default	
Boundary Conditions	10	Sediment organic N, g N/m2		Current value	Default	
- 🗹 Temperature	11	Sediment ammonia, g N/m2		Current value	Default	
- 🖌 Salinity	12	NO3-N in Surface sediment pore water, layer (0 - kdo2), g N/		Current value	Default	
— 🗹 Density	13	Sediment P, immobile fraction, g P/m2		Current value	Default	
 Wind forcing 	14	Sediment N, immobile fraction, g N/m2		Current value	Default	
🖻 🖌 Outputs	15	EC0 Biomass rooted venetation EC>=0 o C/m2	- H	Current value	Default	Ŧ
- 🖌 3D	•				F	
w 20 wf 52.8 wf 52.17 wf 30 hot wf 20 hot	Enable/d Stat Add Hyd	isable all tional/derived output aulic vanables				
						_
						_

Figure 4.40 MIKE 3 Flow Model FM: Specifying 2D Output parameters for the MIKE 3 FM ECO Lab

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MIKE 3 Flow Model FM	3D hot Geographic View Output specification Output items Data Detrained of the specification Output formal Period Output formal Volume series Output file CVProgram Files/DHIVMIKEZero/Examples/MIKE_3/FlowModel_FMV Treatment of flood and dry Only real wet area Time step Time step First 144 Frequency Volume series Import from file Ager range to 10 Import from file 1 207515.47287 61548961.8726 2 204515.47287 6151357.0629 2 224374.98778 61548961.8726 4 224374.98778 6154961.8726	
Ready	Pointer outside model area	Mode //

Figure 4.41 MIKE 3 Flow Model FM: Specifying hot data for the 3D Output parameters for the MIKE 3 FM ECO Lab

Reduce the output size for the area series to a reasonably amount by selecting an output frequency of 900 s. As our time step is 25 s then the specified output frequency is 36. As default, the full area is selected.

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





In Figure 4.42 you can see snapshot of simulated output of 'Rooted vegetation, shoot density $(No./m^2)$ ' with the rough mesh.

Figure 4.42 MIKE 3 Flow Model FM: Snapshot of simulated 2D output of Rooted Vegetation [No./m2]



Figure 4.43 shows a snapshot of the simulated top layer of 'Total nitrogen (mg/l)'





4.2 Model Calibration

After the simulation use the Plot Composer (or Grid Editor, Data Viewer) to inspect and present the results. In order to calibrate the model, we need some measurements inside the model domain.

Measurements of Salinity, Temperature, Total N, Total P, Inorganic N and Inorganic P are available from the 2 monitoring stations:

- Station 8: position in UTM 33 (213812, 6154526)
- Station 17: position in UTM 33 (217662, 6156584)

You can choose to create the plots in the Plot Composer yourself, or to use the Plot Composer files already made and enclosed in the example in the Plots folder in each simulation folder.

The calibration of MIKE ECO Lab model means that you change model input or parameters in the setup so that you get a better fit between the measurements and the model output. As you can see in Figure 4.29, you can adjust many parameters. It shall be noted that many of them are not changed so frequently.

When calibrating you should only change one parameter at a time, so that clearly the isolated effect on a state variable from changing a parameter can be seen.

Besides changing MIKE ECO Lab constants, you may need to change other model parameters, such as dispersion parameters, hydrodynamic parameters, loadings, forcings and boundary conditions.

If the simulated output does not match the measurements there can be many reasons. A classic reason is that the boundary and loading data is not measured frequent and accurate enough.



4.2.1 Total nitrogen

A pattern with high Total N values in winter and lower values in summer is modelled well with the model. The high values in winter are caused by the release of inorganic nitrogen from the sediment, see Figure 4.44.

It is also seen that the nitrogen levels are simulated with higher values in the inner part of the estuary.



Figure 4.44 Comparison of measurements and model output for Total Nitrogen



4.2.2 Total phosphorus

A pattern with high Total P values in summer is modelled well with the model. The high values in summer are caused by the release of inorganic phosphorus from the sediment. It is also seen that the phosphorus levels are simulated with higher values in the inner part of the estuary. See Figure 4.45.



Figure 4.45 Comparison of measurements and model output for Total Phosphorus



4.2.3 Inorganic nitrogen

A pattern with high inorganic nitrogen values in winter and lower values in summer are modelled well with the model. It is clear that the primary production in Odense Estuary is limited by inorganic nitrogen as the concentrations drop to very low values in the growth season. The high values during winter are caused by the release of inorganic nitrogen from the sediment. It is also seen that the nitrogen levels are simulated with higher values in the inner part of the estuary. See Figure 4.46.







4.2.4 Inorganic phosphorus

A pattern with high inorganic phosphorus values in summer is modelled well with the model. The high values in summer are caused by the release of inorganic phosphorus from the sediment. It is clear that phosphorus is not the limiting nutrient for the primary production in the growth season. It is also seen that the phosphorus levels are simulated with higher values in the inner part of the estuary. See Figure 4.47.



Figure 4.47 Comparison of measurements and model output for Inorganic Phosphorus



4.2.5 Salinity and temperature

For temperature the calibration looks good for both calibration stations. For station 8, the temperature is a little too warm in the summer. The salinity matches the measurements in a satisfying way for station 8. For Station 17, the model cannot simulate the stratification of salinity and temperature so well. Try reducing the vertical dispersion of salinity to get a better stratification. See Figure 4.48.



Figure 4.48 Comparison of measurements and model output for salinity and temperature

