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.
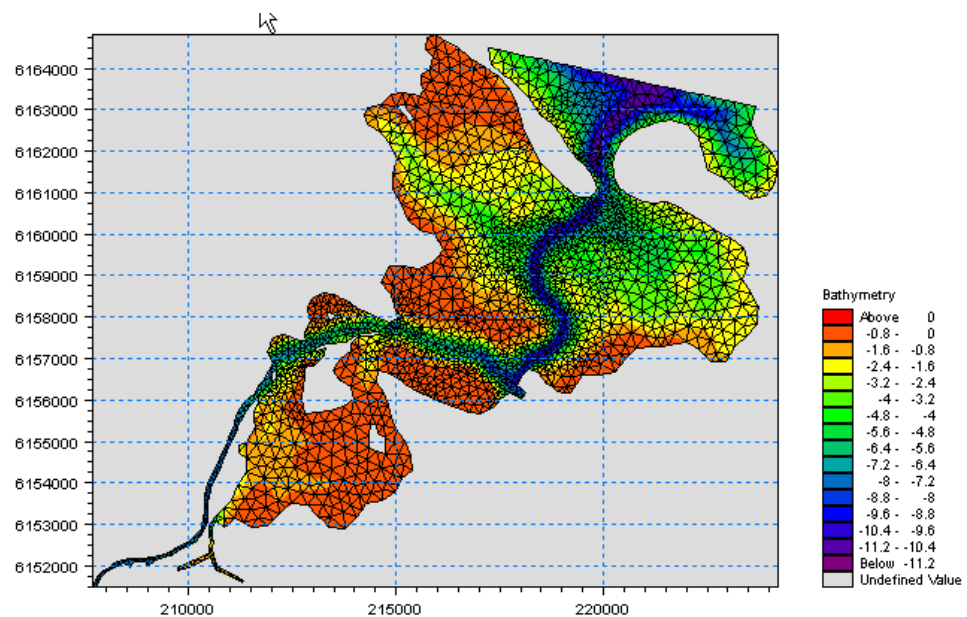
Figure 2.1   The fine Odense Estuary computational mesh as it can be presented with the Data Viewer tool

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.

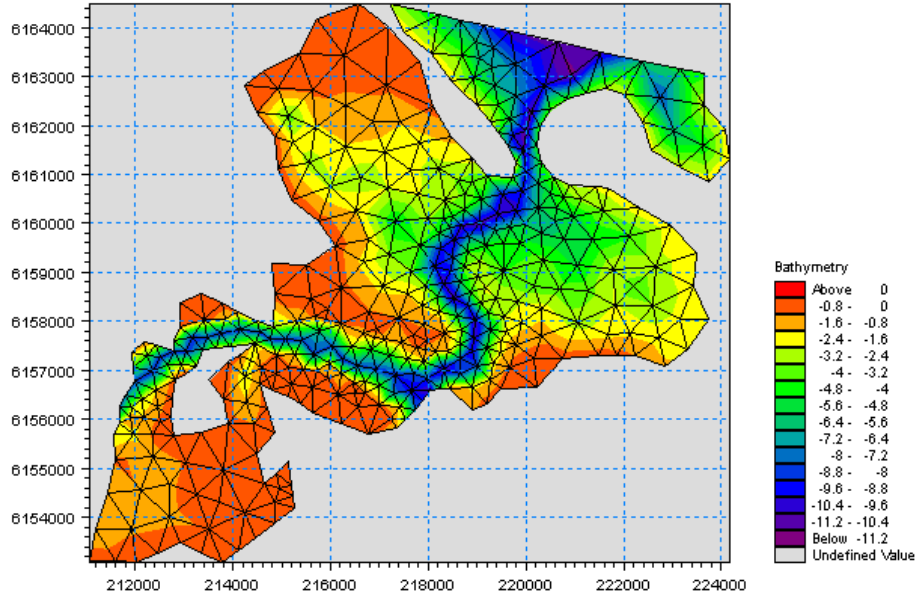Figure 2.2   The rough Odense Estuary computational mesh as it can be presented with the Data Viewer tool
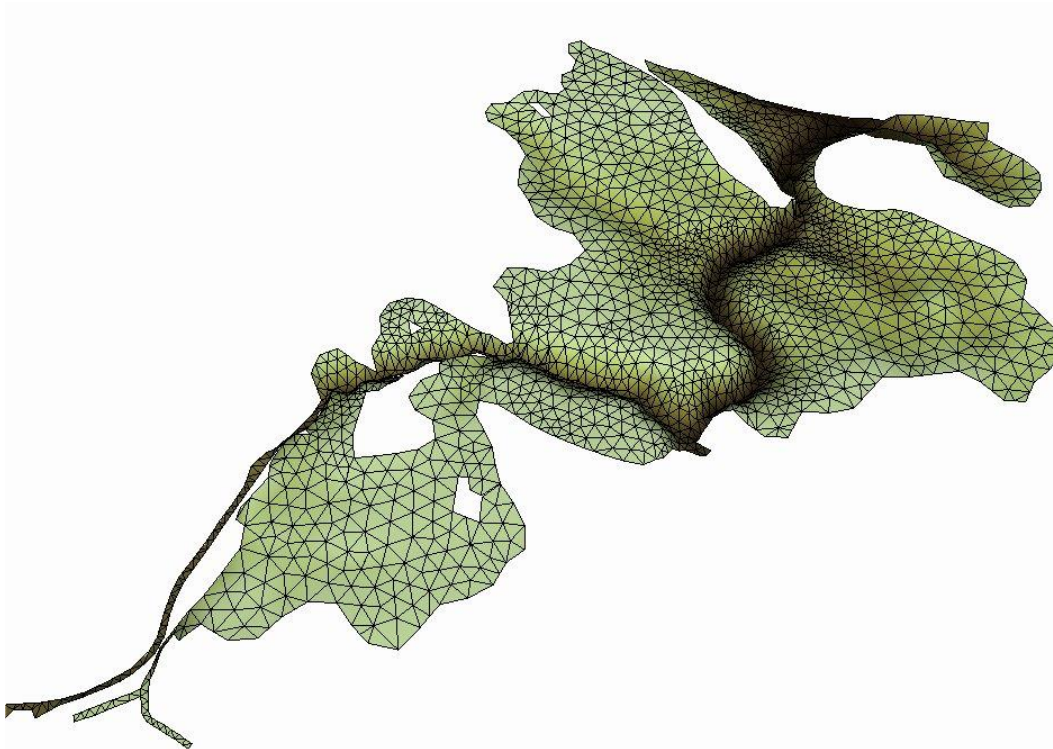

Figure 2.3   The fine Odense Estuary computational mesh as it can be presented with the MIKE Animator tool

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

3. 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

6. 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

7. MIKE ECO Lab forcings: measurements of solar radiation in the active photosynthetic spectrum of light (E/m2/d)

8. MIKE ECO Lab loadings: concentrations in sources and precipitation of the advective state. Some are measured and some are estimated

9. 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→New→File→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.
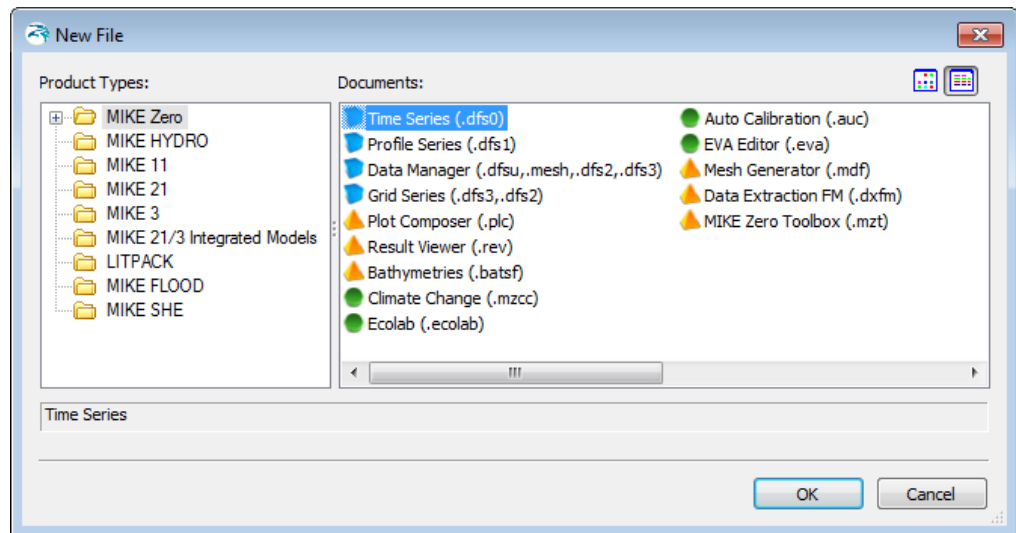

Figure 3.2   Starting the Time Series Editor in MIKE Zero

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.

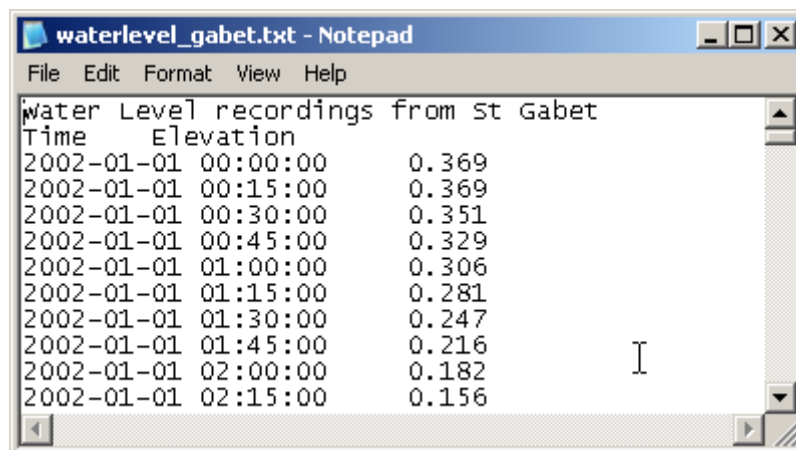

Figure 3.3   ASCII file with water level recordings from Station Gabet
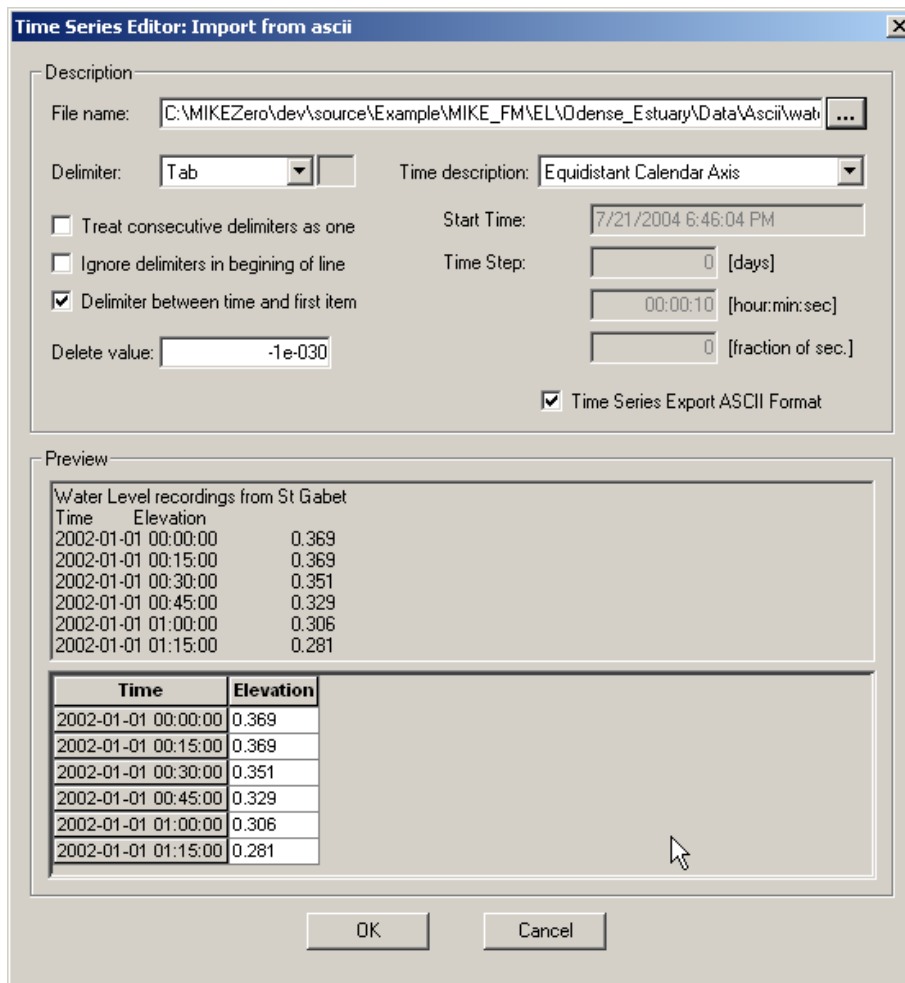
Figure 3.4   Time Series Editor Import Template

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

Save the data in:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Boundary_Conditions\Gabet\waterlevel.dfs0

The resulting time series can be seen in Figure 3.6.
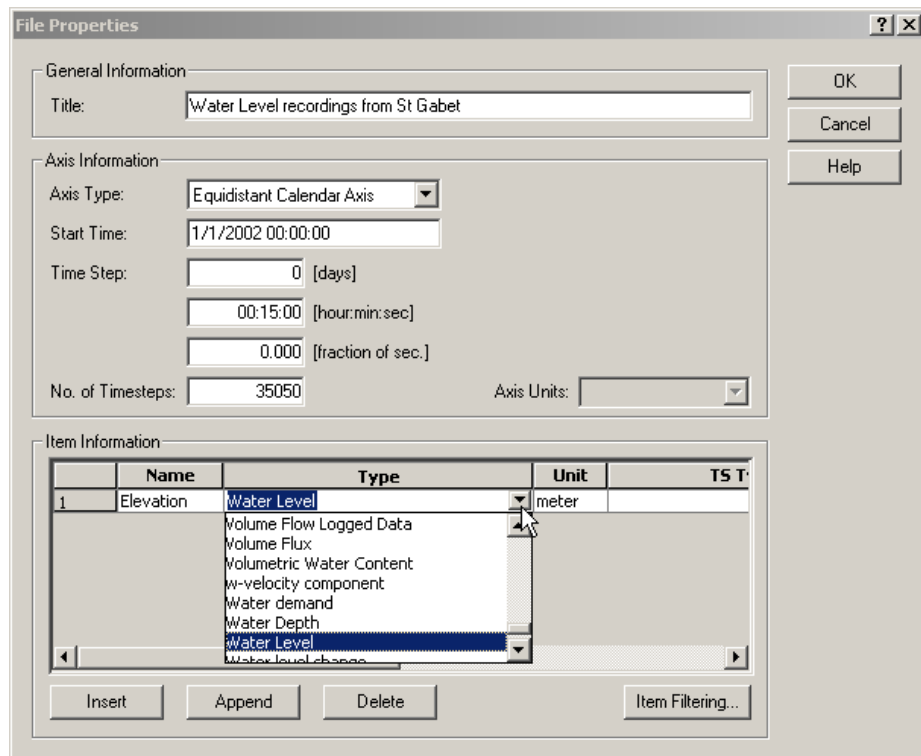
Figure 3.5   Time Series Properties
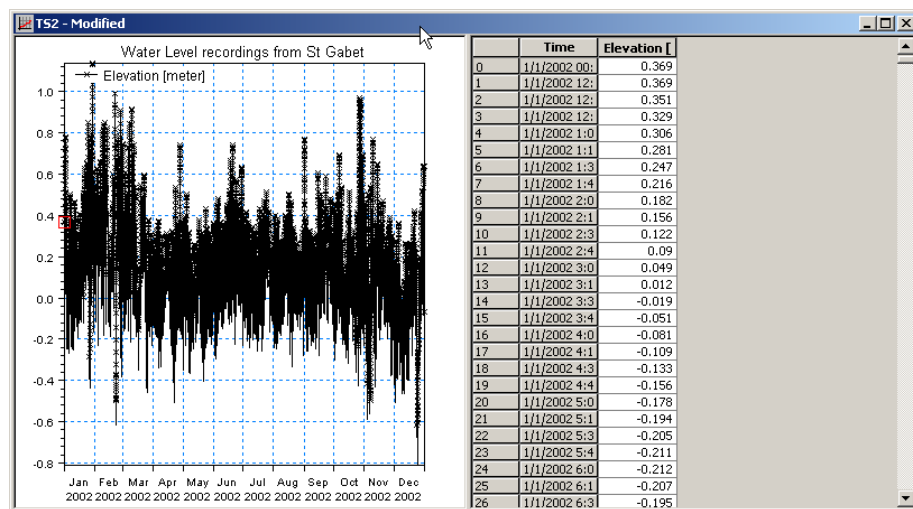
Figure 3.6   Time Series Editor with imported Water Levels from Station Gabet

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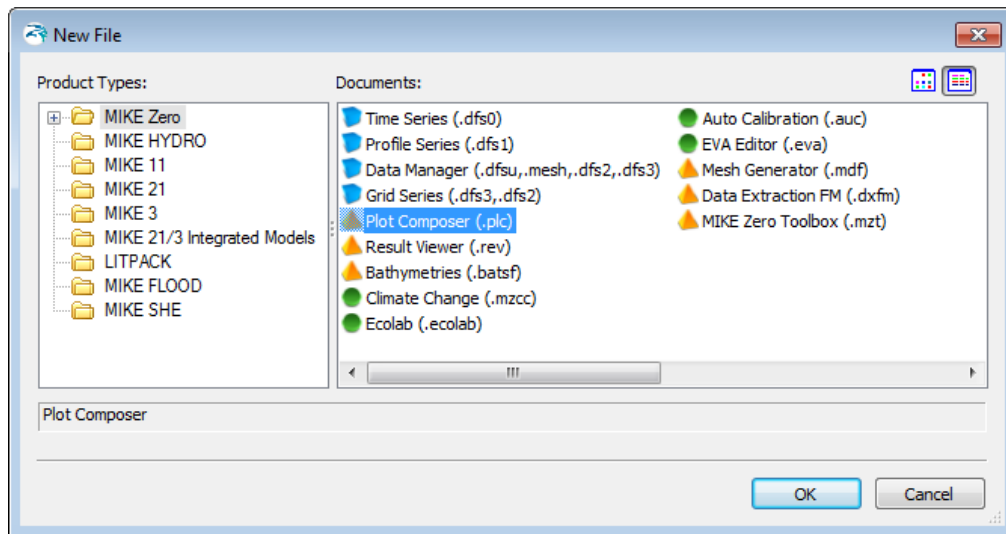
Figure 3.7   Starting the Plot Composer in MIKE Zero
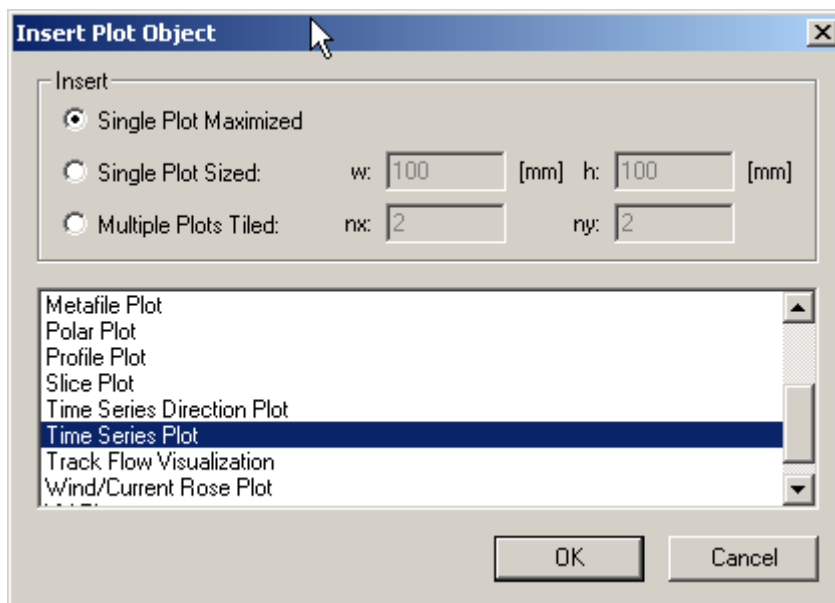
Figure 3.8   Insert a new Plot Object as Time Series in Plot Composer

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).

Creating the Parameters to the MIKE 3 Flow Model FM
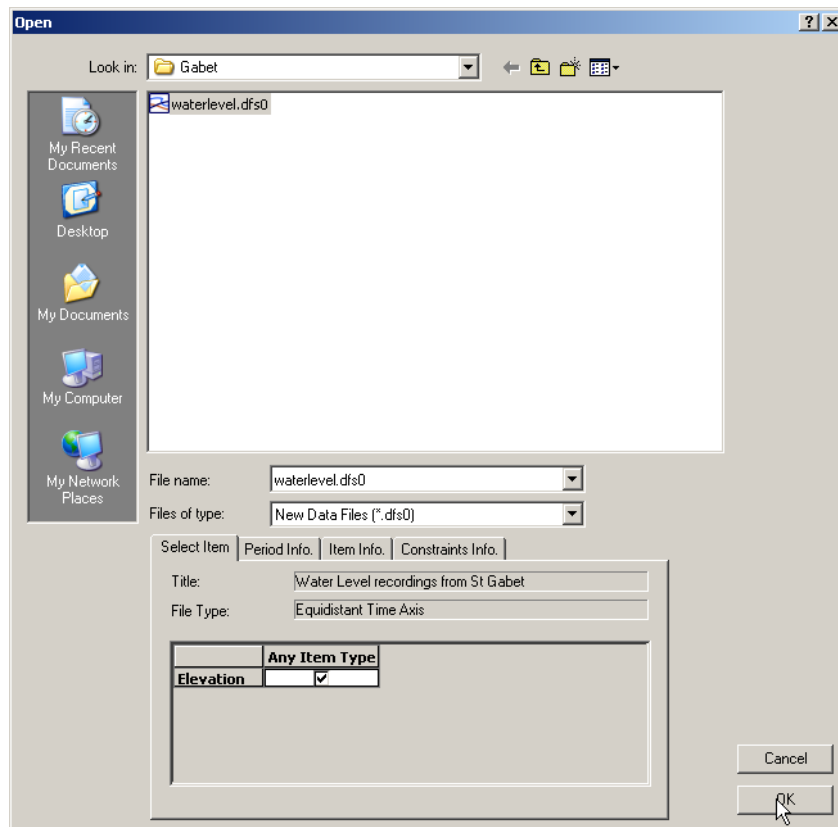
Figure 3.9   Selection of time series files in Plot Composer
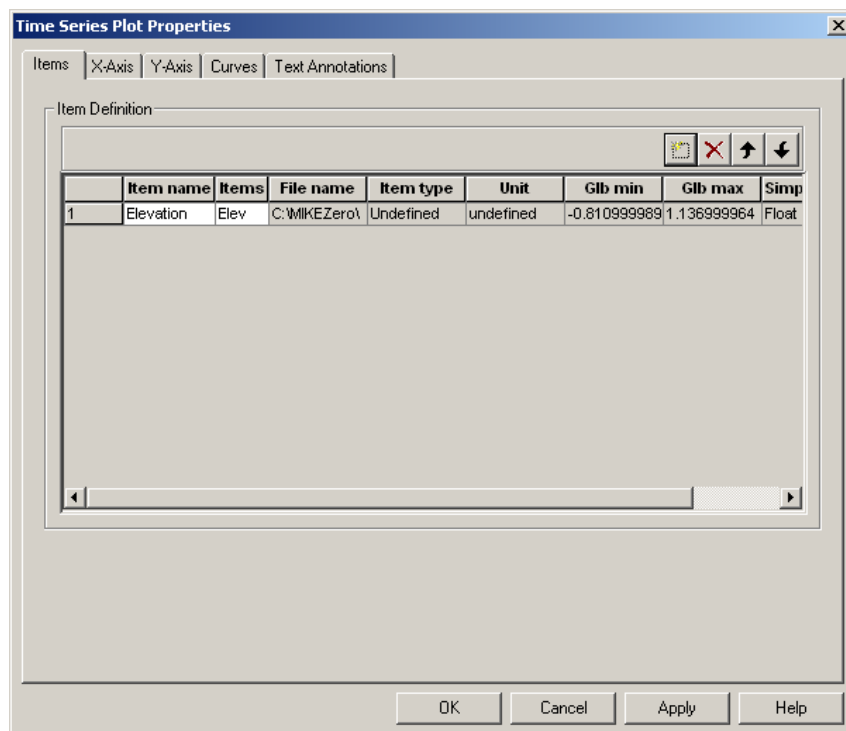
Figure 3.10   Plot Composer Time Series Plot Properties dialogue for selecting time series files and adjusting scales, curves, etc.

Powering WATER DECISIONS   13

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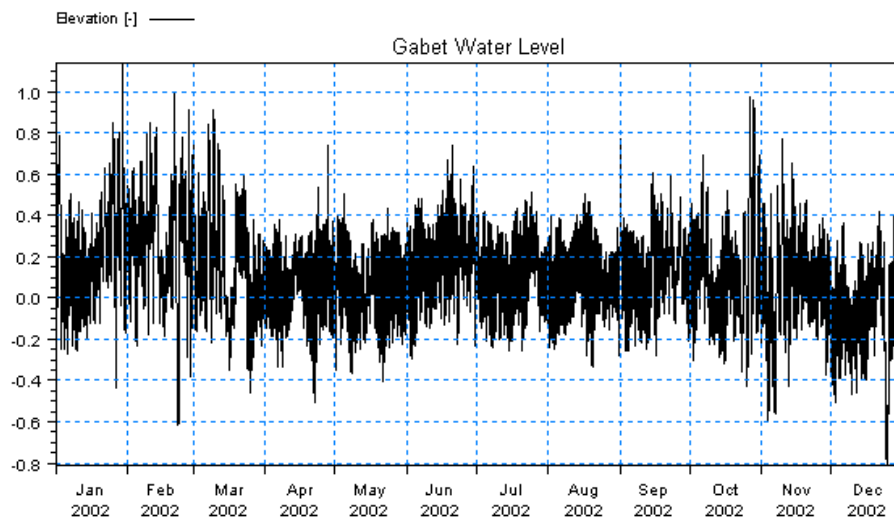
Figure 3.11   The measured water levels at the boundary plotted with Plot Composer

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:

1.   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:

.\MIKE_3\FlowModel_FM\EL\Odense_Estuary\Data\Boundary_Conditions\Gabet
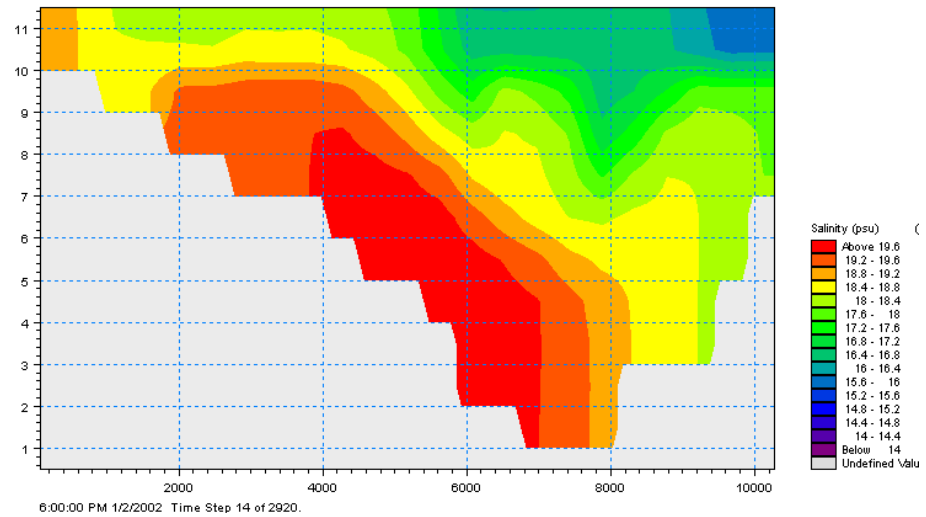
Figure 3.12   Snapshot of Grid Series Boundary file of salinity at the Gabet Boundary

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.
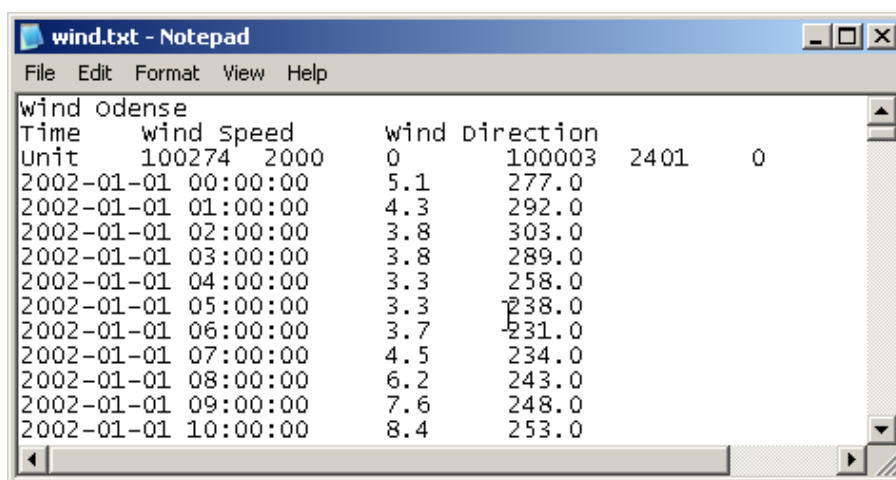
Figure 3.13   ASCII file with wind speed and direction from Odense city
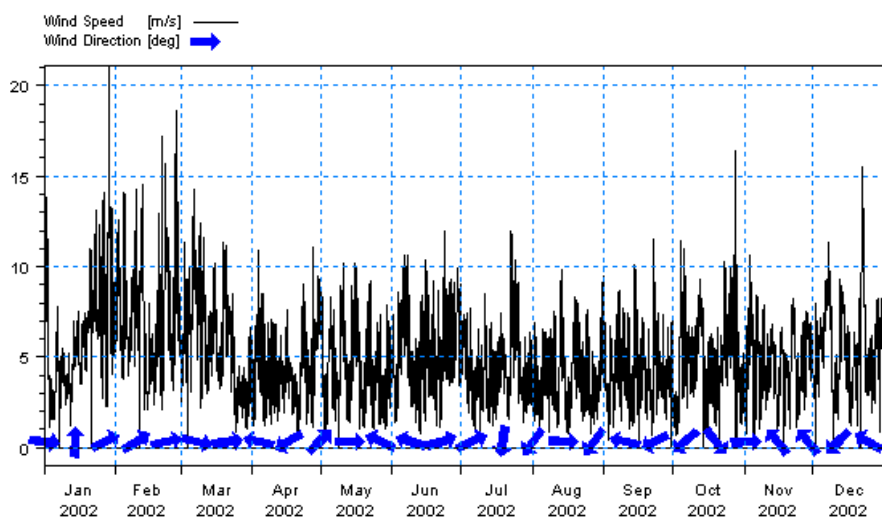
Figure 3.14   Wind speed and direction in city Odense as it can be illustrated in the Plot Composer with the Time Series Direction Plot template

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.
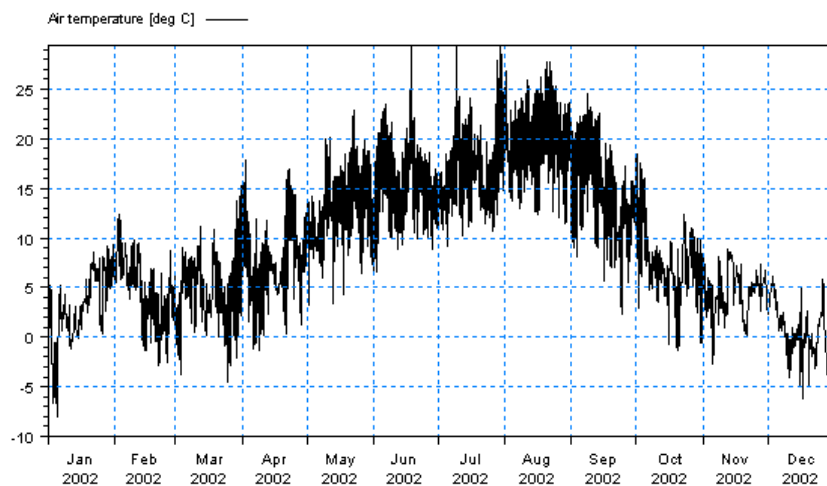
Figure 3.15   Air temperature measured near Odense Estuary illustrated with time series plot in the Plot Composer
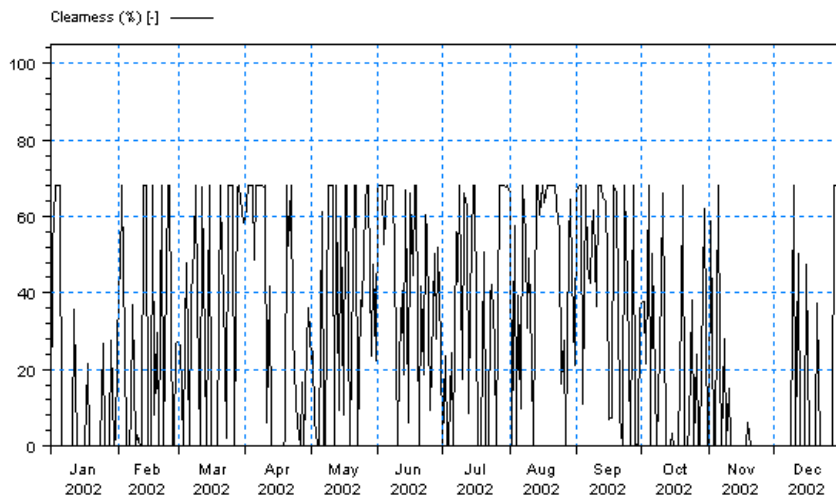
Figure 3.16   Clearness (%) of the sky near Odense Estuary illustrated with time series plot in the Plot Composer

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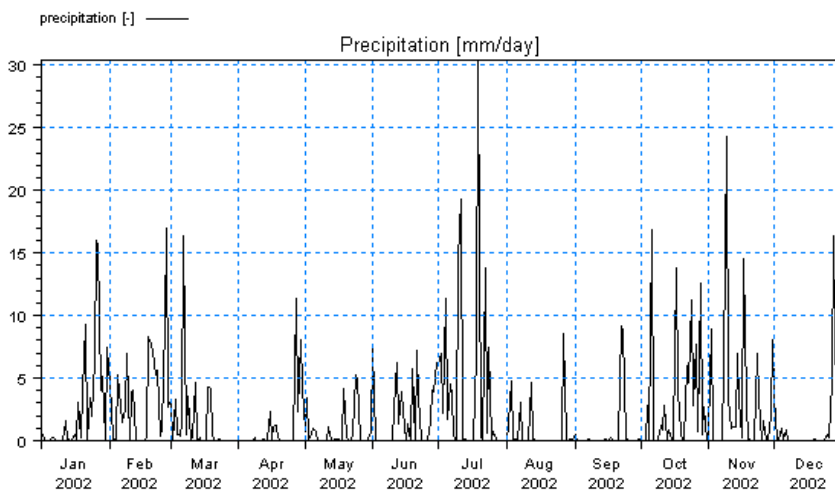
Figure 3.17   Precipitation in the Odense Estuary area illustrated with time series plot in the Plot Composer

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.

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

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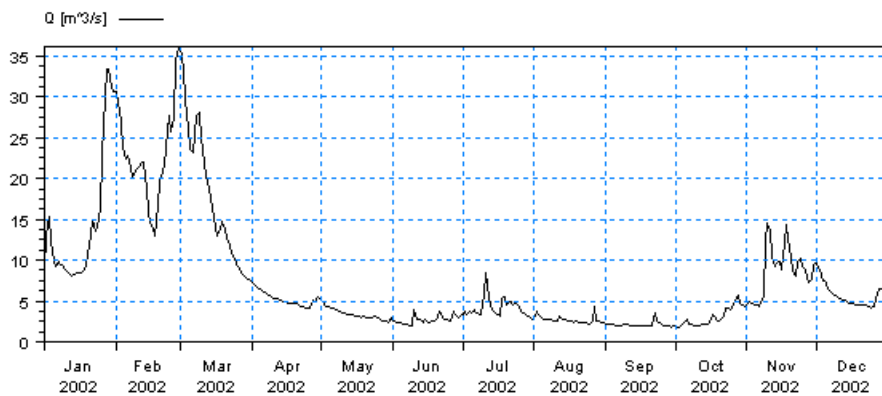
Figure 3.18   The flow discharge in Odense River 2002 illustrated with time series plot in the Plot Composer

## 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

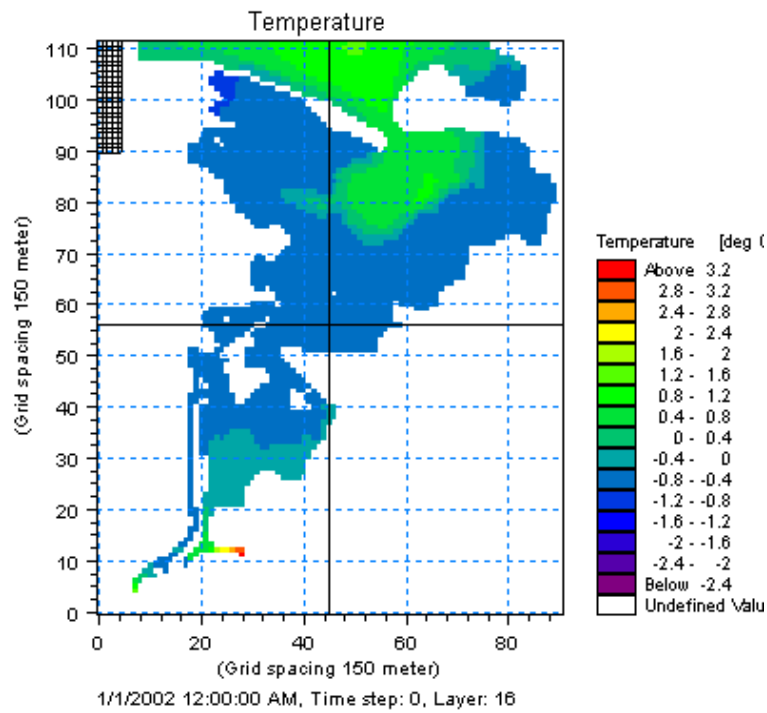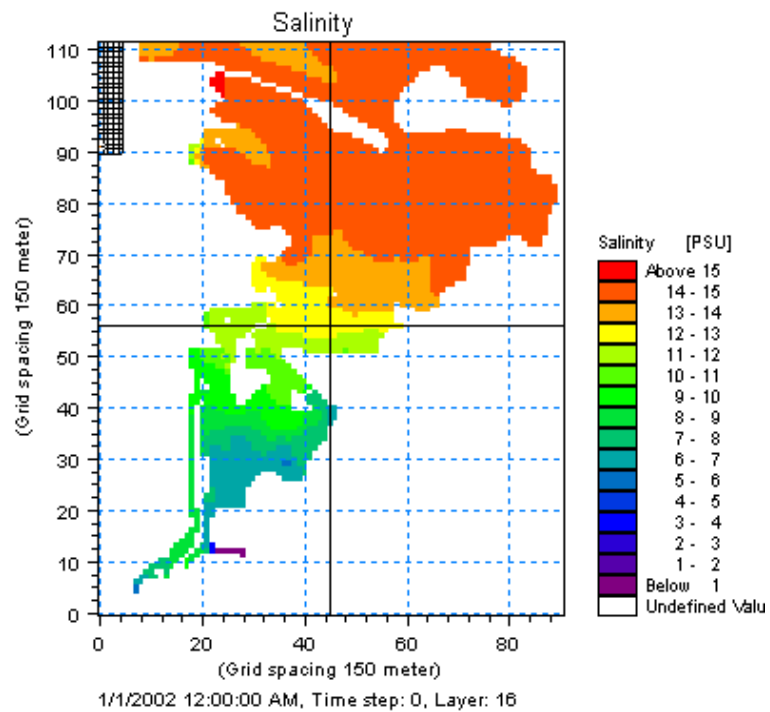Figure 3.20   Salinity initial condition uses Grid Series Format dfs3 from another MIKE 3 model of the area

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:

1.   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.
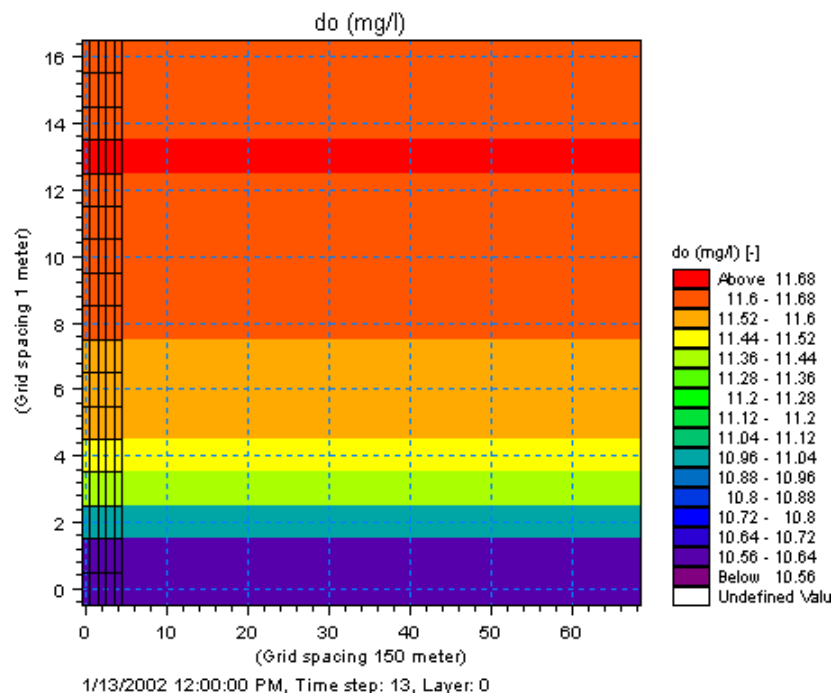
Figure 3.21   An example of a MIKE ECO Lab boundary condition for the state variable dissolved oxygen in dfs2 format. The boundary is called Gabet and the values are taken as model output from another MIKE model. M3FM interpolates the values in the dfs2 file to the correct depths during the simulation

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:
• 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
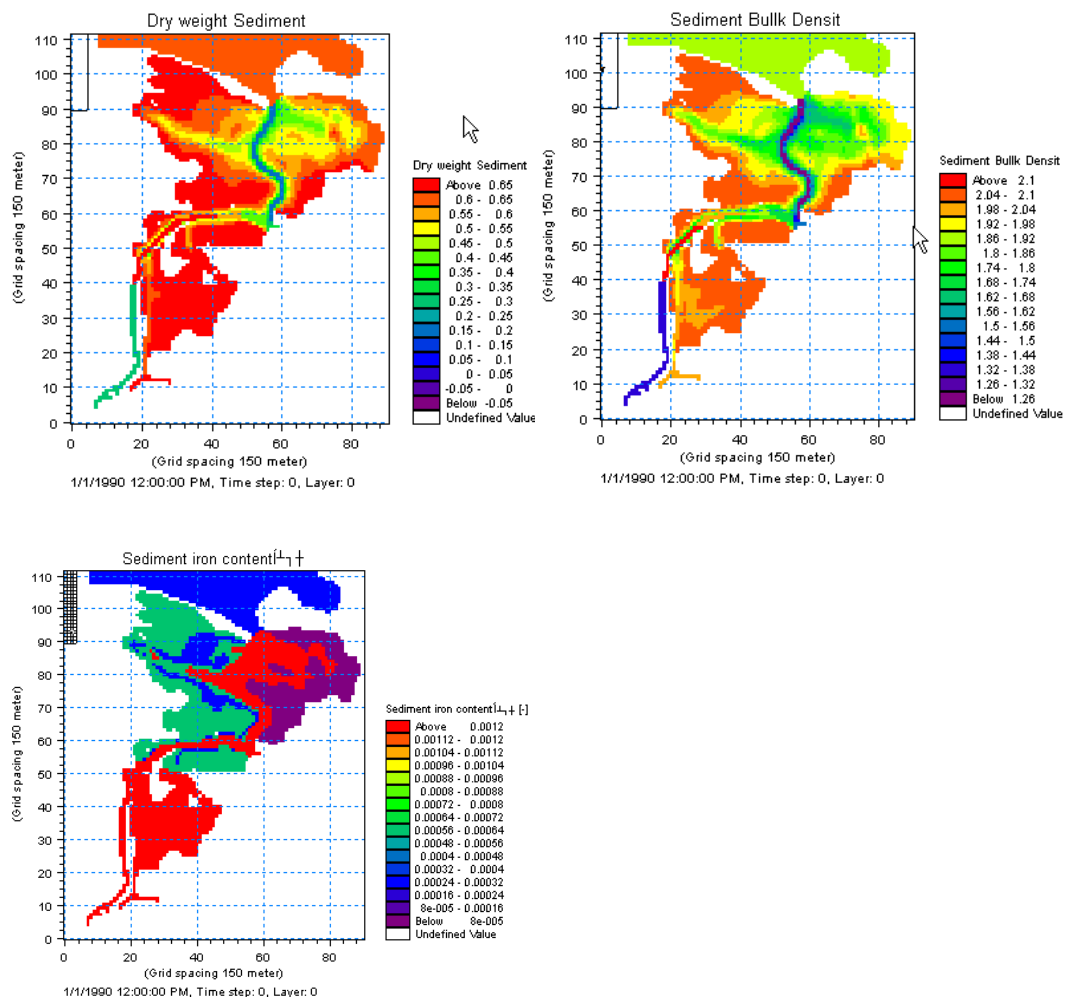
Figure 3.22   Measurements of dry weight of sediment, sediment bulk density and sediment iron contents as used in the model

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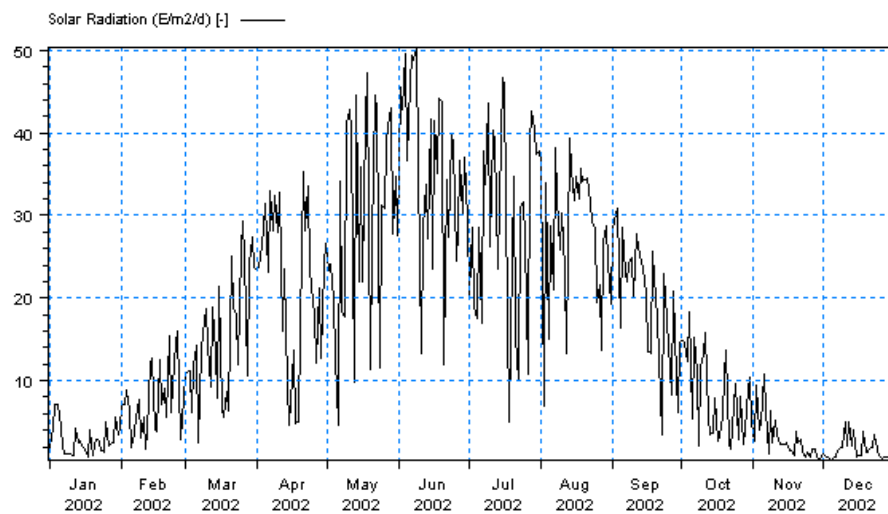
Figure 3.23   Measurements of solar radiation in the active photosynthetic spectrum of light (E/m2/d) in 2002 illustrated with time series plot in the Plot Composer

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.
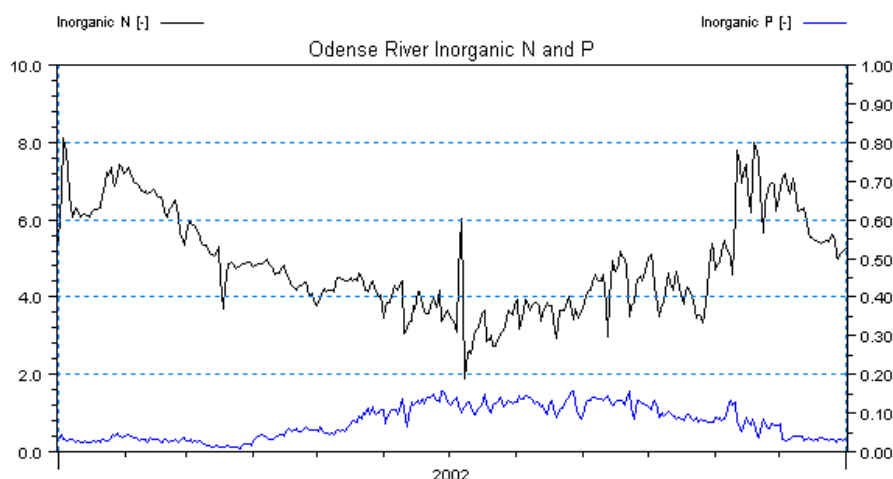

Figure 3.24   Measurements of MIKE ECO Lab concentrations (mg/l) in Odense River in 2002 illustrated with time series plot in the Plot Composer. Inorganic N is on the left axis and Inorganic P is on the right axis.

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	l_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	l_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	l_u27.dfs0
11	U_28	l_u28.txt	l_u28.dfs0
12	U_29	l_u29.txt	l_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.
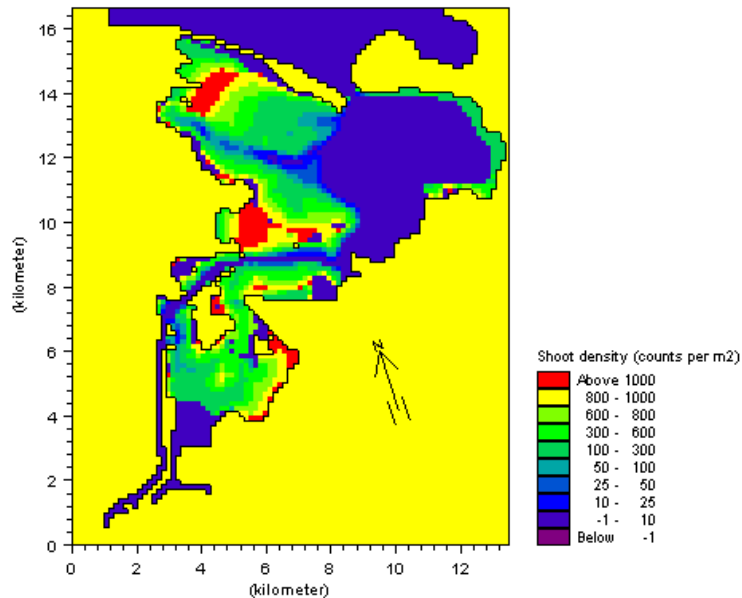

Figure 3.25   Initial conditions for Benthic vegetation shoot density (Counts per m^2) is model output from another MIKE 3 model of the area. M3FM interpolates the dfs2 file into the mesh if it covers the same geographical area. The file is shown with the Grid Plot in the Plot Composer

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 layers		odense.mesh, 10 vertical equidistant layers
		odense_rough.mesh, 7 vertical layers
Simulation Period:		
Fine, Warm up		2002-01-01 00:00 – 2002-01-01 01:00 (1 hour)
Fine, Period 1		2002-01-01 01:00 – 2002-01-01 05:00 (4 hours)
Rough, Warm up		2002-01-01 00:00 – 2002-01-03 00:00 (2 days)
Rough, Period 1		2002-01-03 00:00 – 2002-01-15 00:00 (12 days)
Rough, Period 2		2002-01-15 00:00 – 2002-03-01 00:00 (1½ months)
Rough, Full Period		2002-01-01 00:00 – 2002-12-15 00:00 (almost 1 year)
Time Step:		
Fine mesh setups		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 Season		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 → MIKE 3 → Flow Model FM, see Figure 4.1.
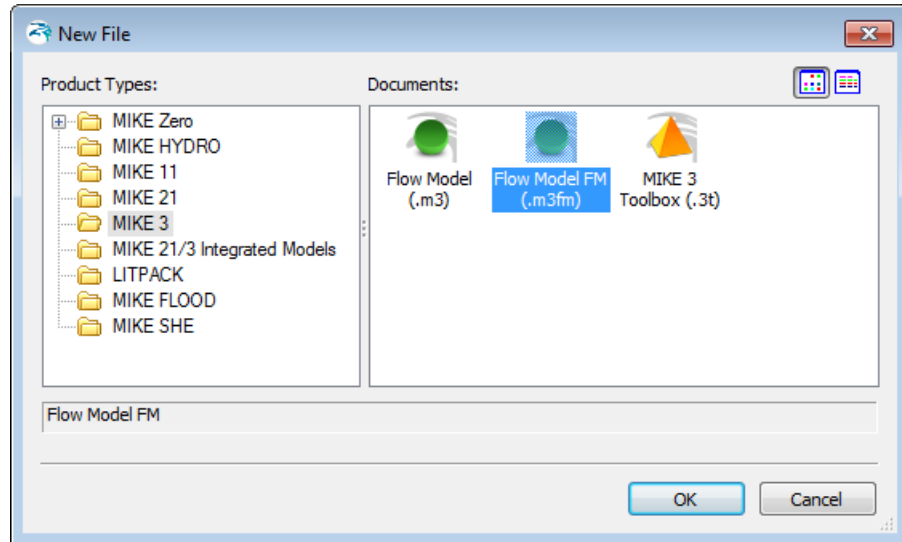

Figure 4.1   Starting MIKE 3 Flow Model FM in MIKE Zero

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.
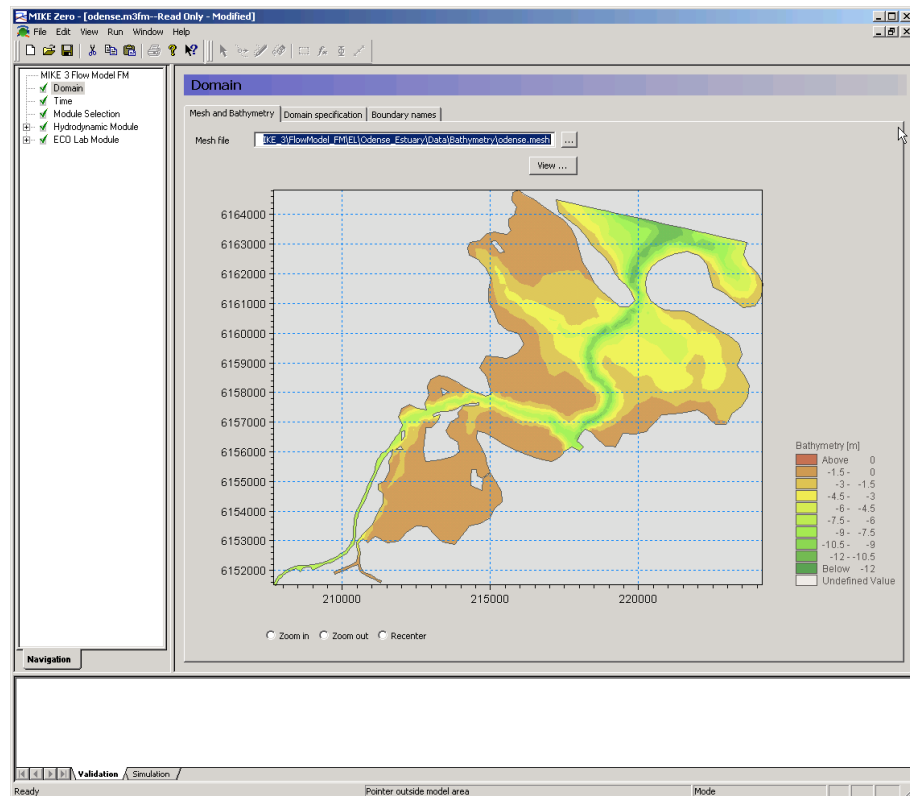

Figure 4.2   MIKE 3 Flow Model FM: Specify Domain

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.
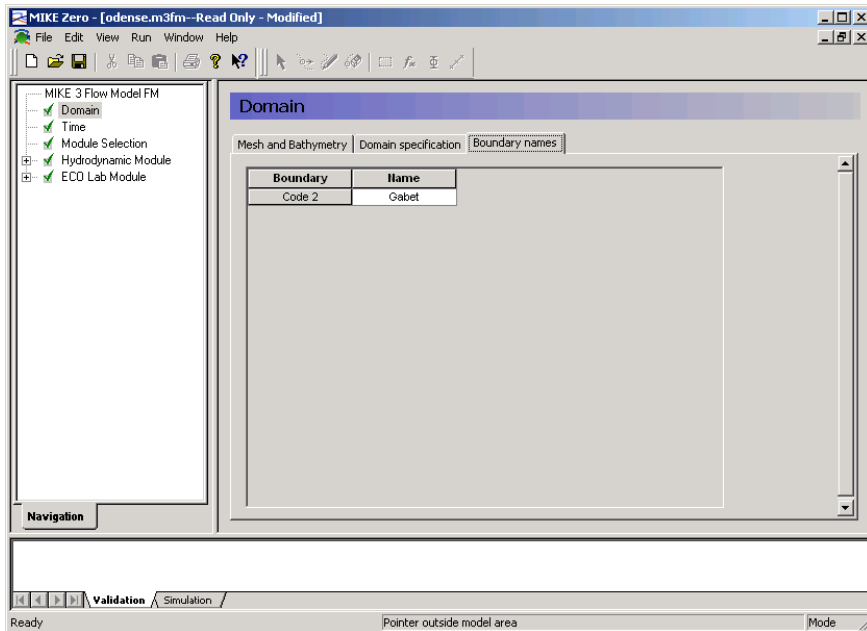

Figure 4.3   MIKE 3 Flow Model FM: Specify Boundary Names: For instance Gabet

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.
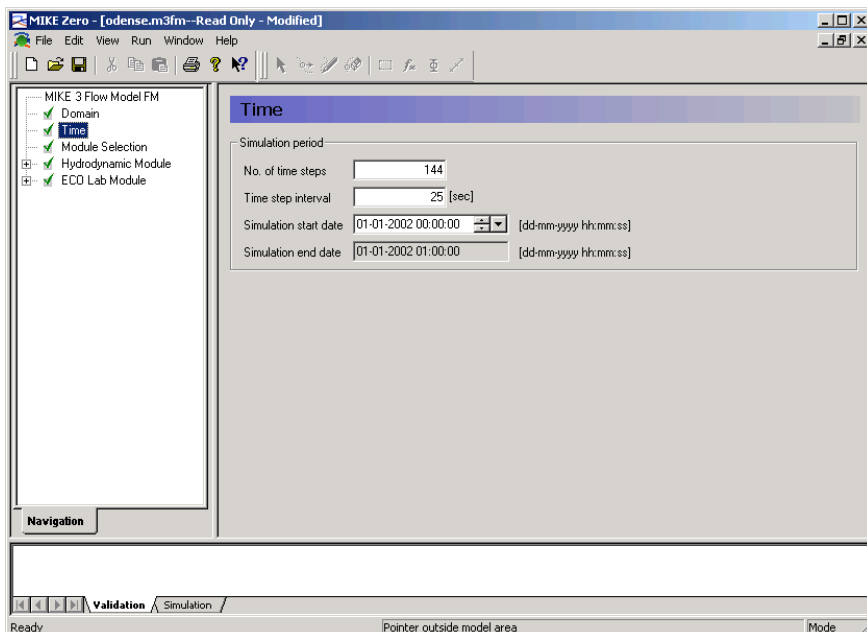
Figure 4.4   MIKE 3 Flow Model FM: Simulation period

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

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.
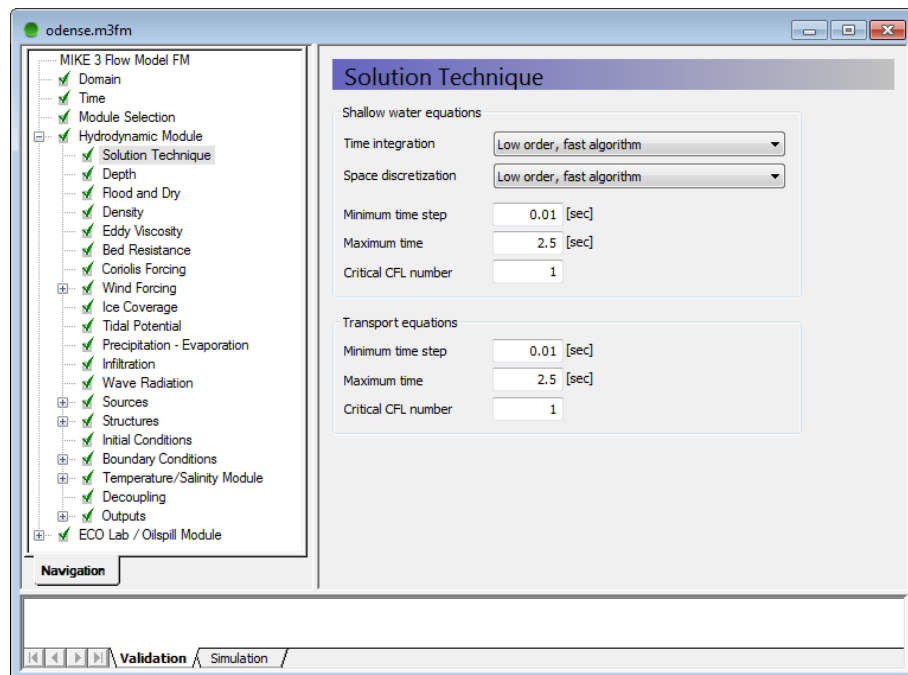
Figure 4.6   MIKE 3 Flow Model FM: Solution Technique
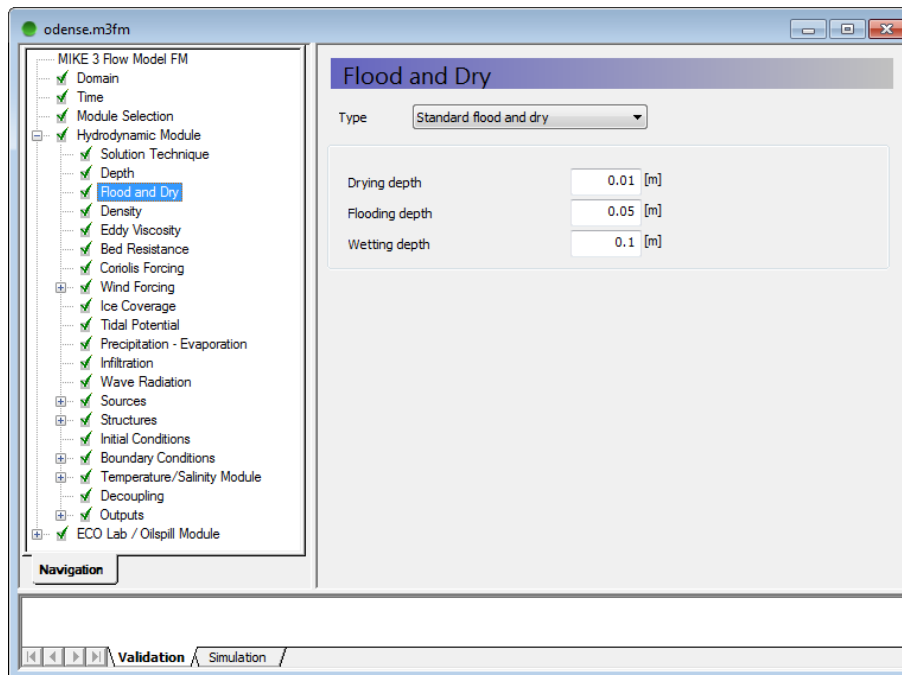
Figure 4.7   MIKE 3 Flow Model FM: Flood and Dry specification

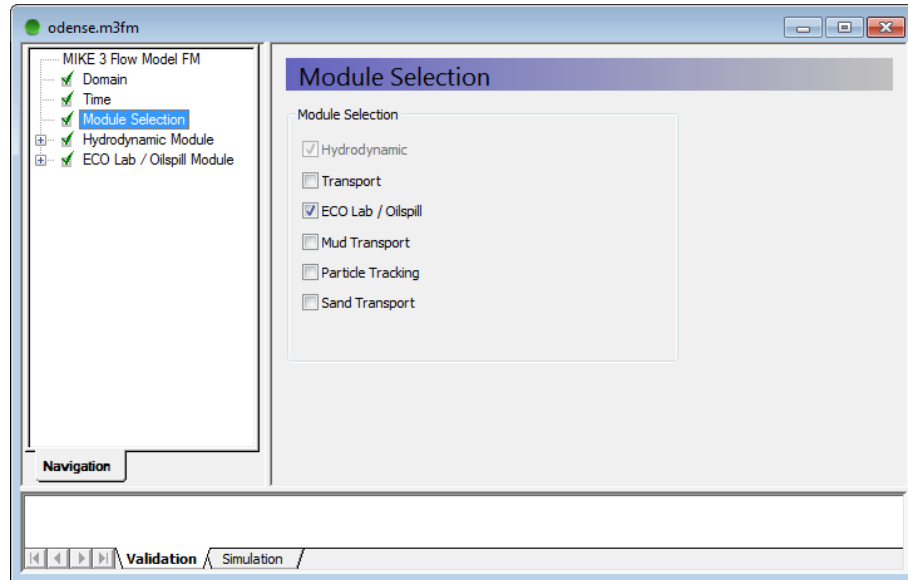The model area is an estuary with several fresh water streams discharging into the estuary, but the estuary is also influenced by saline water from the surrounding waters at the narrow entrance to the estuary. Therefore the water is rather fresh in the inner parts of the estuary, and with higher salinity 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.
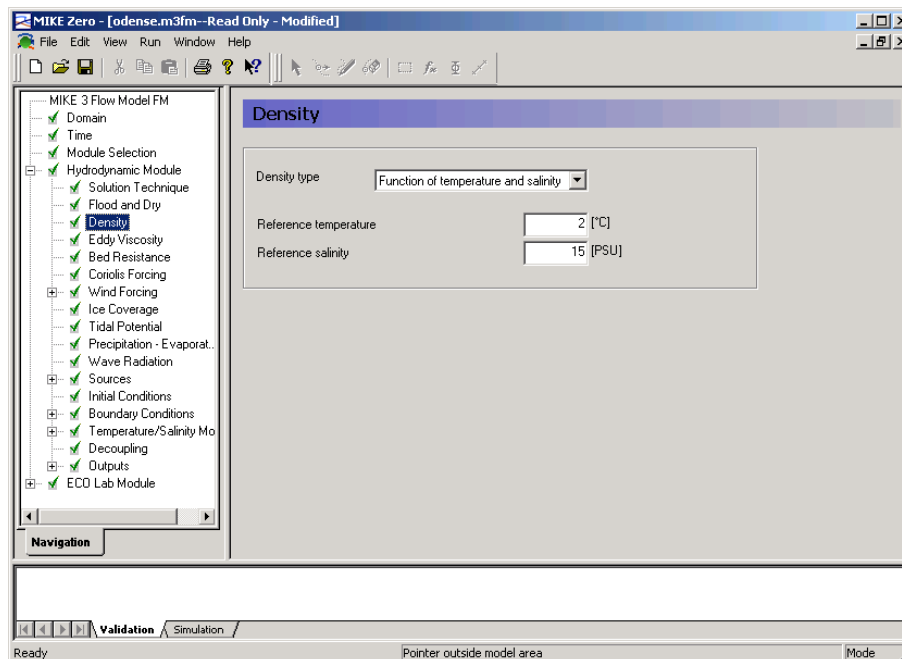
Figure 4.8   MIKE 3 Flow Model FM: Density specification

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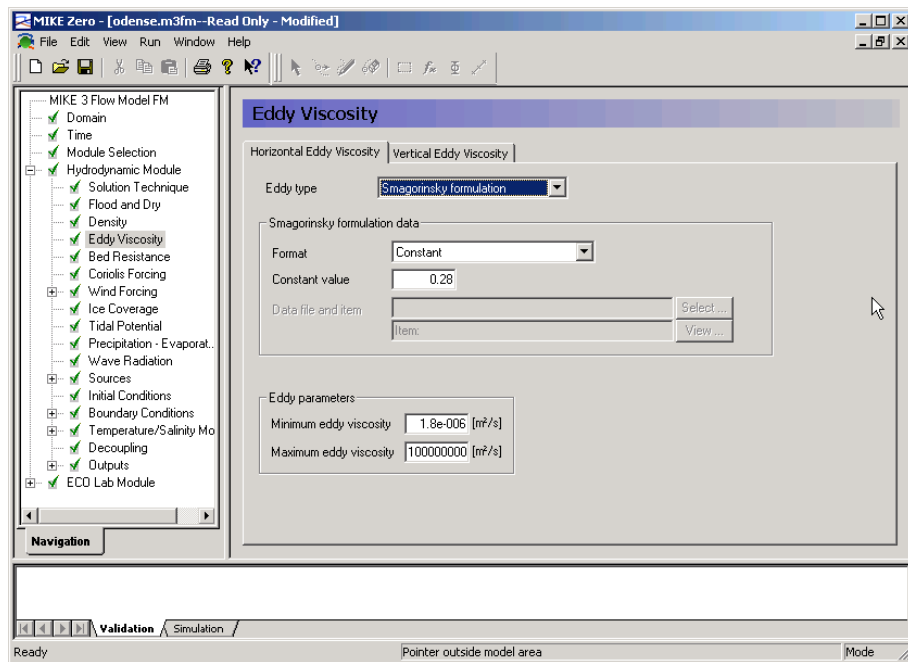
Figure 4.9   MIKE 3 Flow Model FM: Horizontal Eddy viscosity specification

The Vertical Eddy viscosity should be specified as type Log Law formulation, see Figure 4.10.
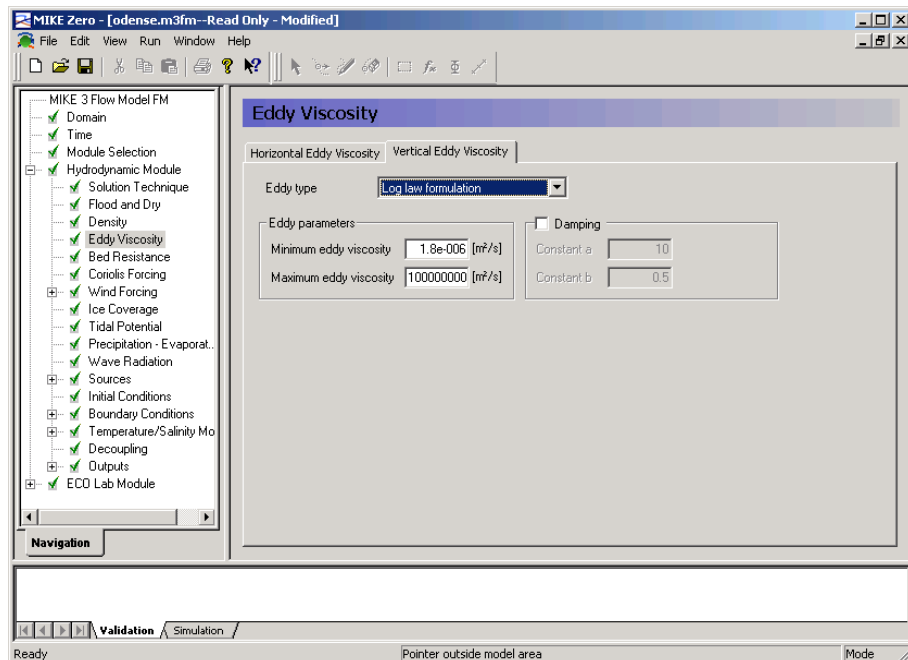
Figure 4.10   MIKE 3 Flow Model FM: Vertical Eddy viscosity specification

The Bed Resistance should be specified with a roughness height of 0.1 m, see Figure 4.11.
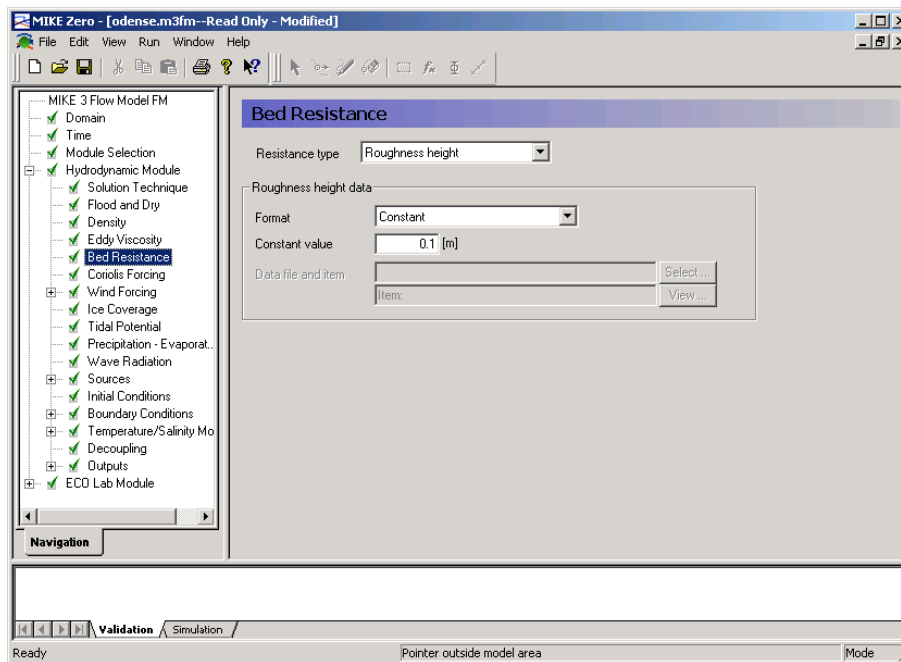
Figure 4.11   MIKE 3 Flow Model FM: Bed Resistance specification

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.
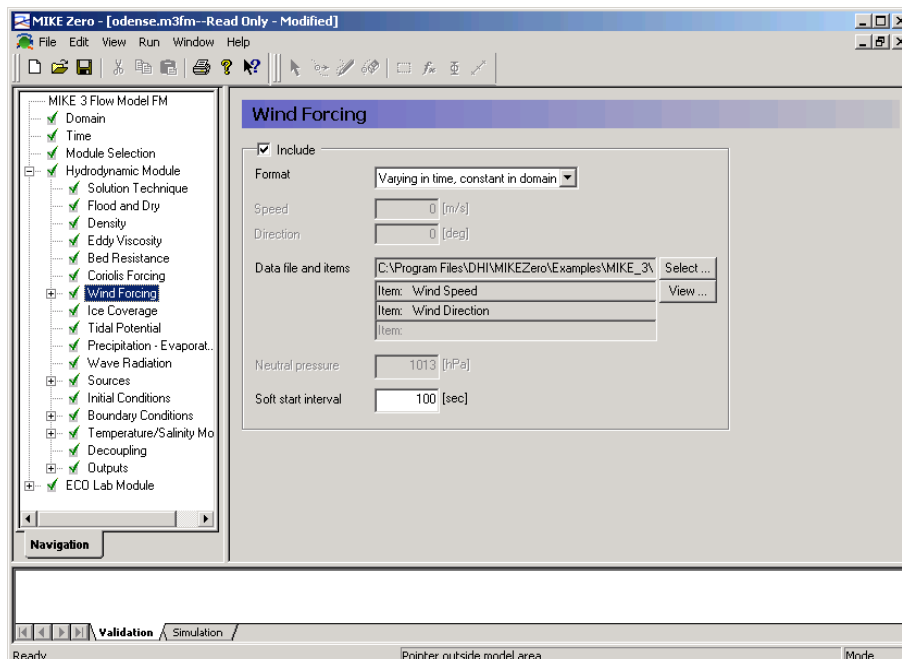
Figure 4.12   MIKE 3 Flow Model FM: Wind Forcing specification

Specify the Wind Friction as in Figure 4.13.
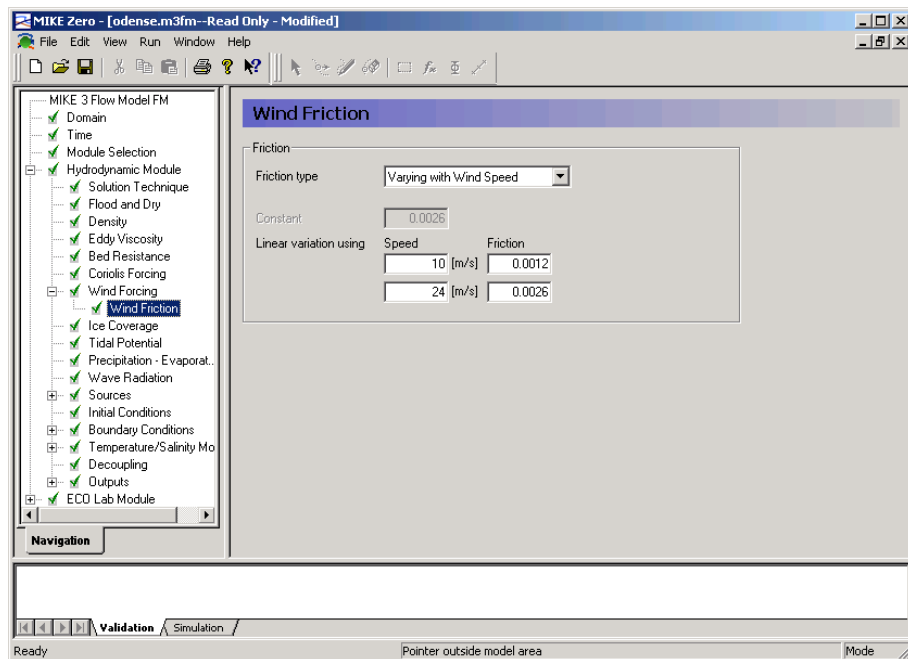
Figure 4.13   MIKE 3 Flow Model FM: Wind Friction specification

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.
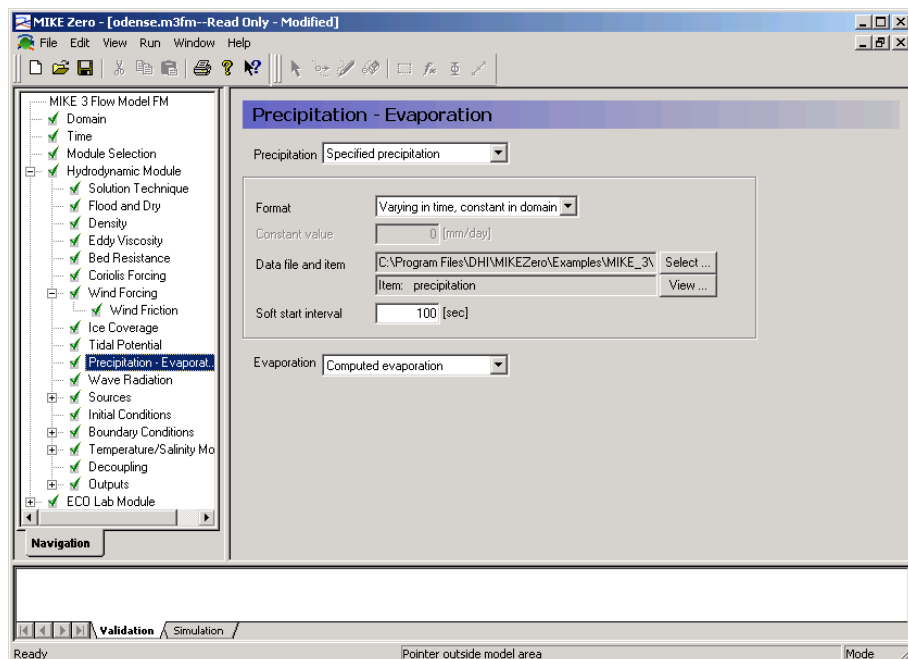
Figure 4.14   MIKE 3 Flow Model FM: Precipitation specification

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
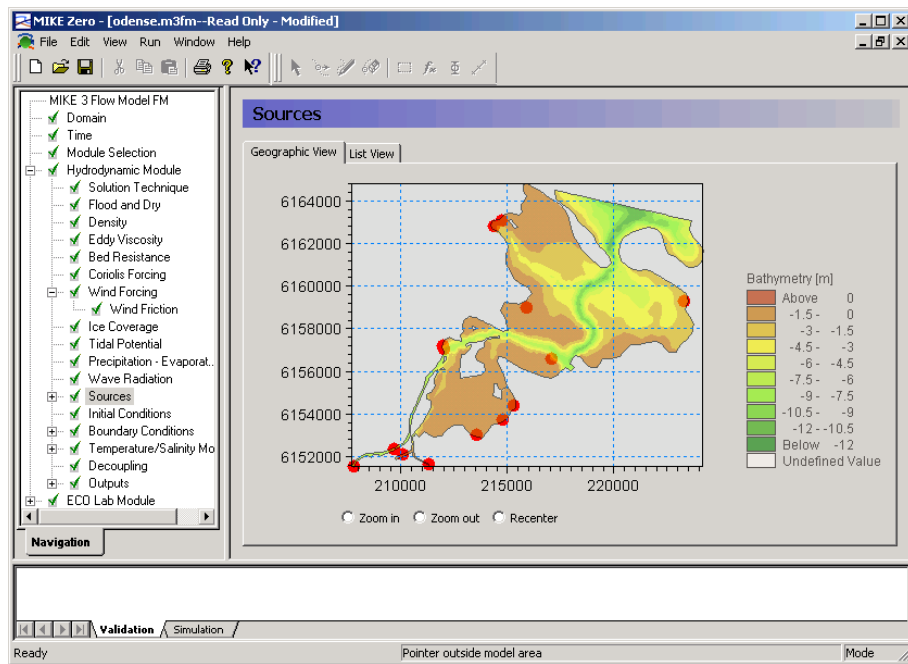
Figure 4.15   MIKE 3 Flow Model FM: Hydrodynamic Sources specification
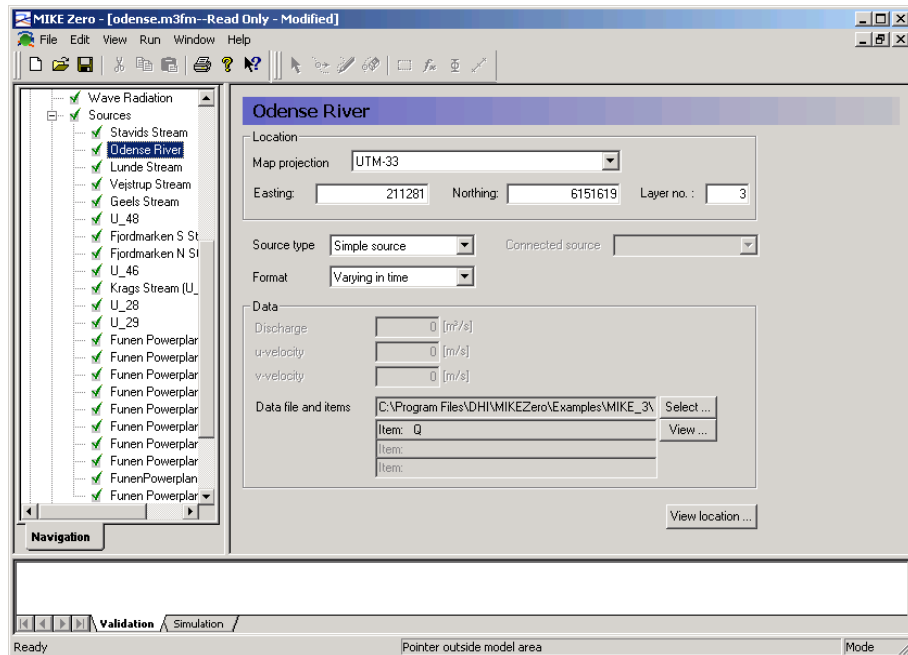
Figure 4.16   MIKE 3 Flow Model FM: Hydrodynamic Sources specification for Odense River

MIKE 3 Flow Model FM

The initial conditions for the warm up period is specified as a constant surface elevation of 0.369 m, see Figure 4.17.
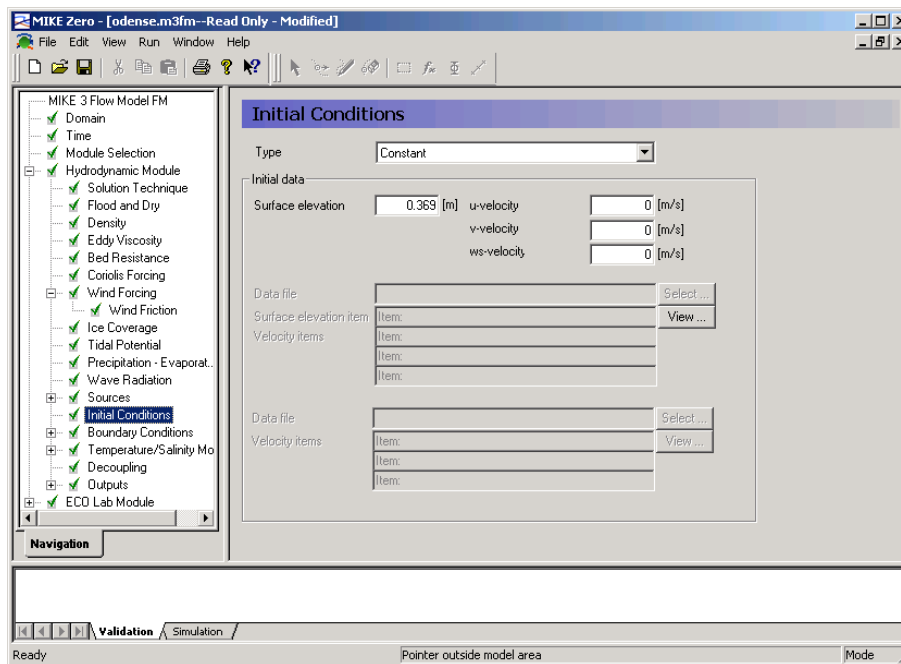
Figure 4.17   MIKE 3 Flow Model FM: Hydrodynamic Initial Conditions specification

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.
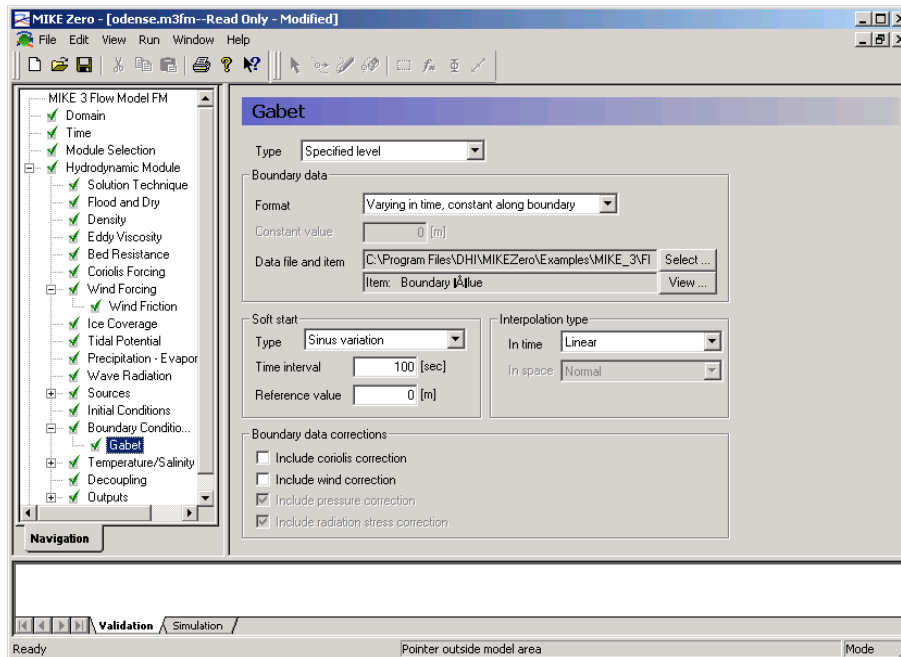
Figure 4.18   MIKE 3 Flow Model FM: Hydrodynamic Boundary Conditions specification

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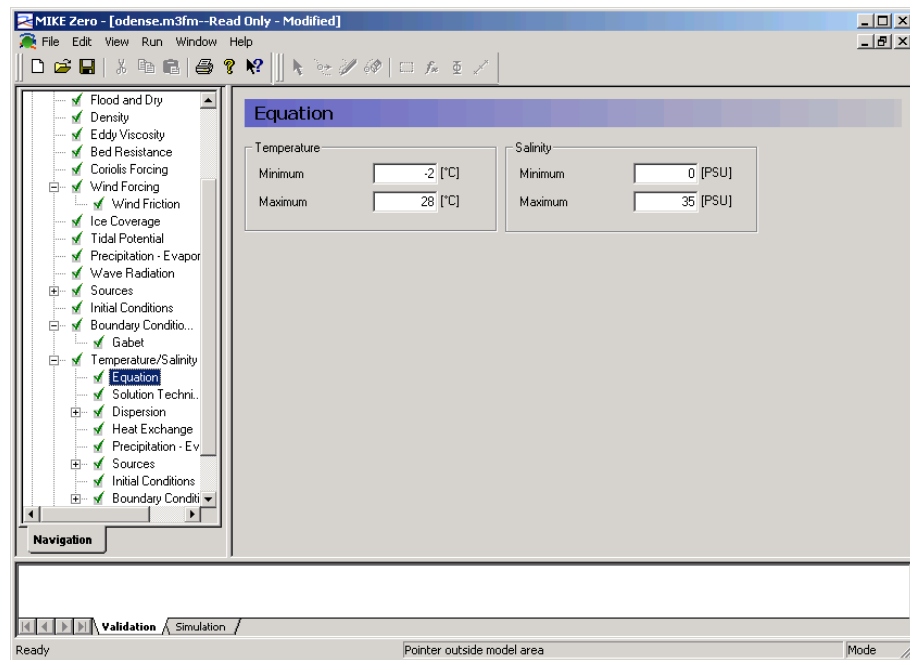
Figure 4.19   MIKE 3 Flow Model FM: Temperature/Salinity minimum and maximum values

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.
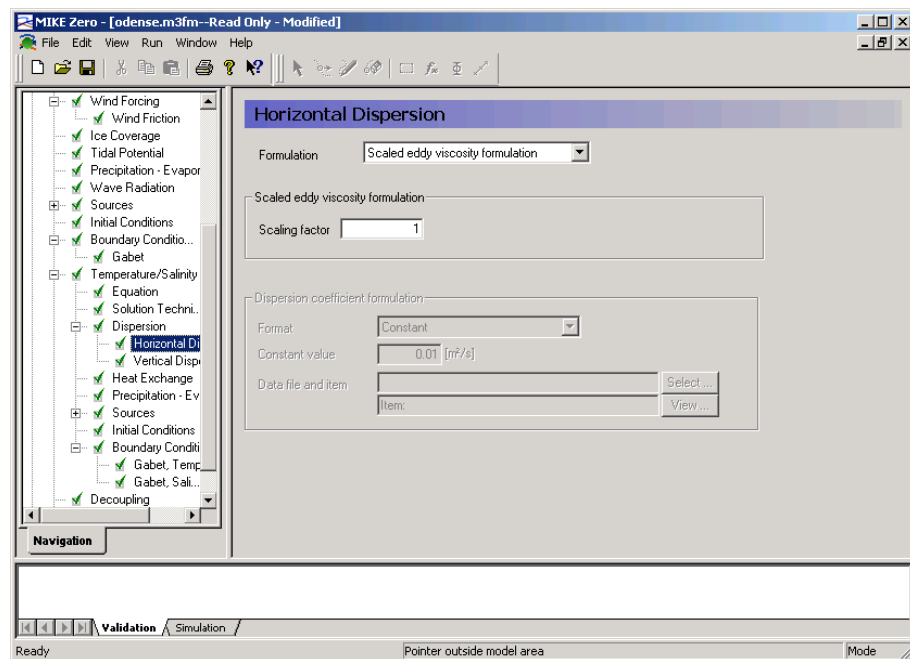
Figure 4.20   MIKE 3 Flow Model FM: Temperature/Salinity Horizontal Dispersion specification

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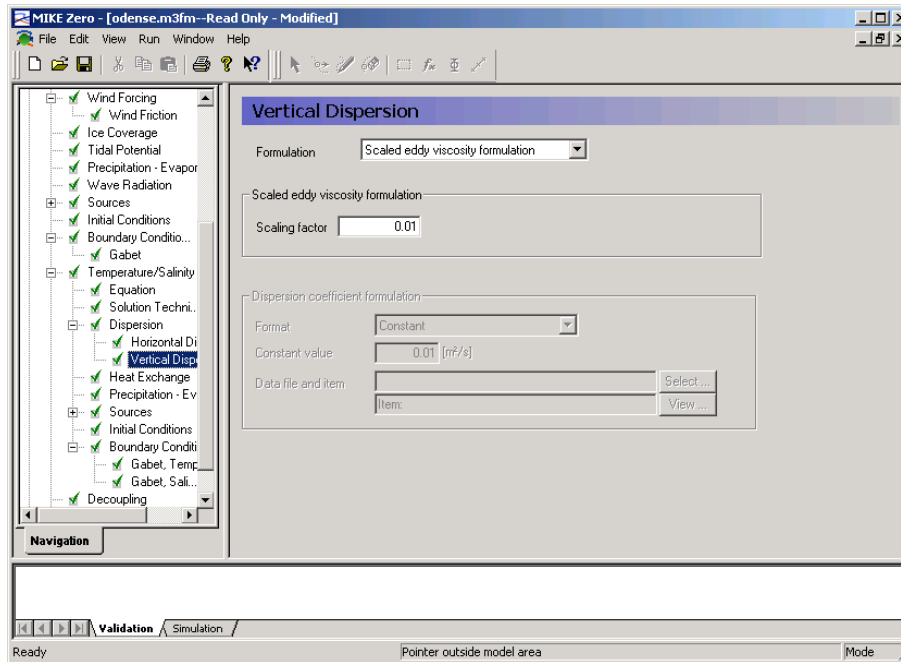
Figure 4.21   MIKE 3 Flow Model FM: Temperature/Salinity Vertical Dispersion specification

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.
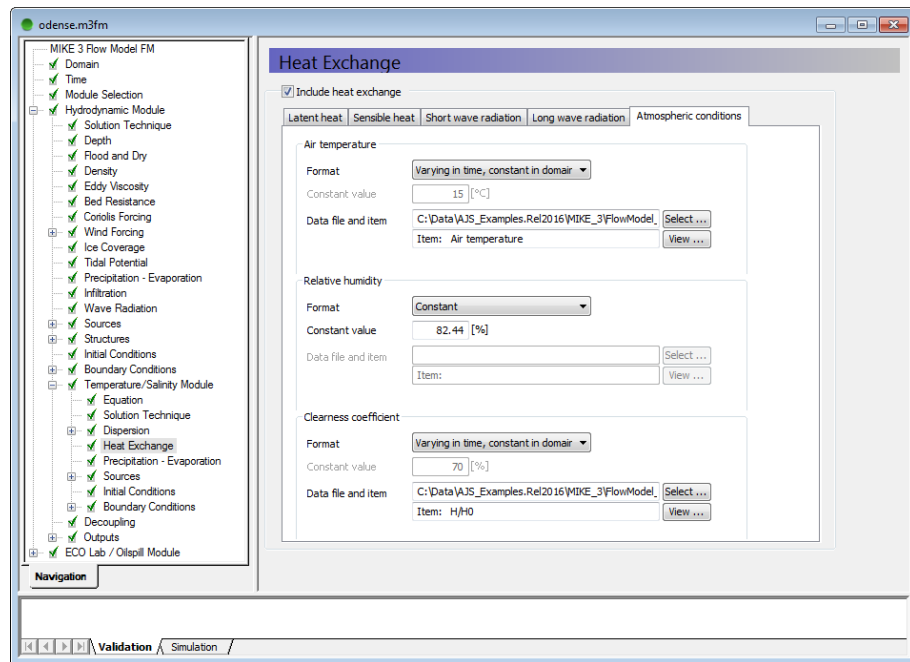
Figure 4.22   MIKE 3 Flow Model FM: Heat Exchange specification
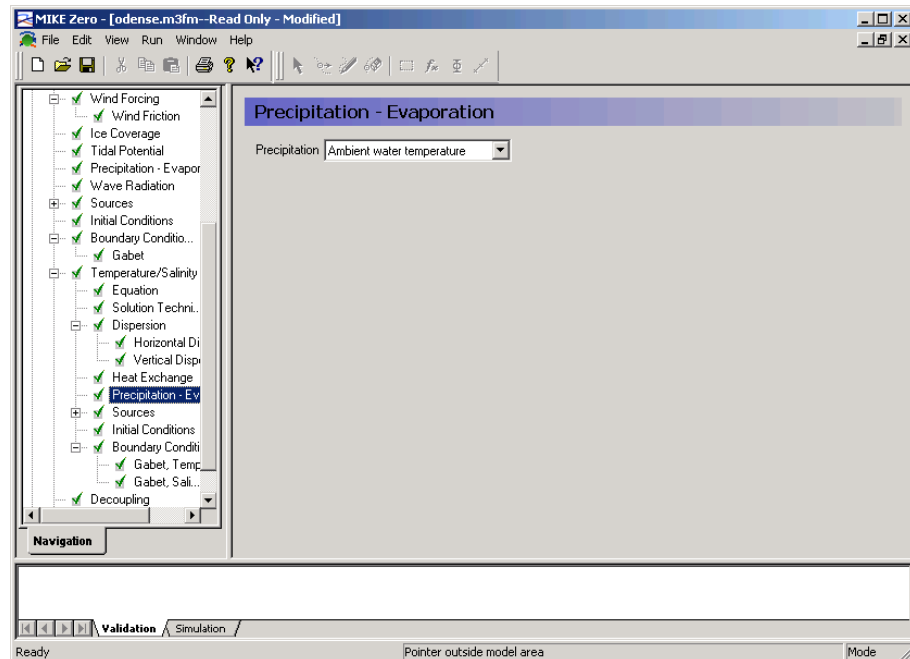
Figure 4.23   MIKE 3 Flow Model FM: Precipitation temperature specification

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.
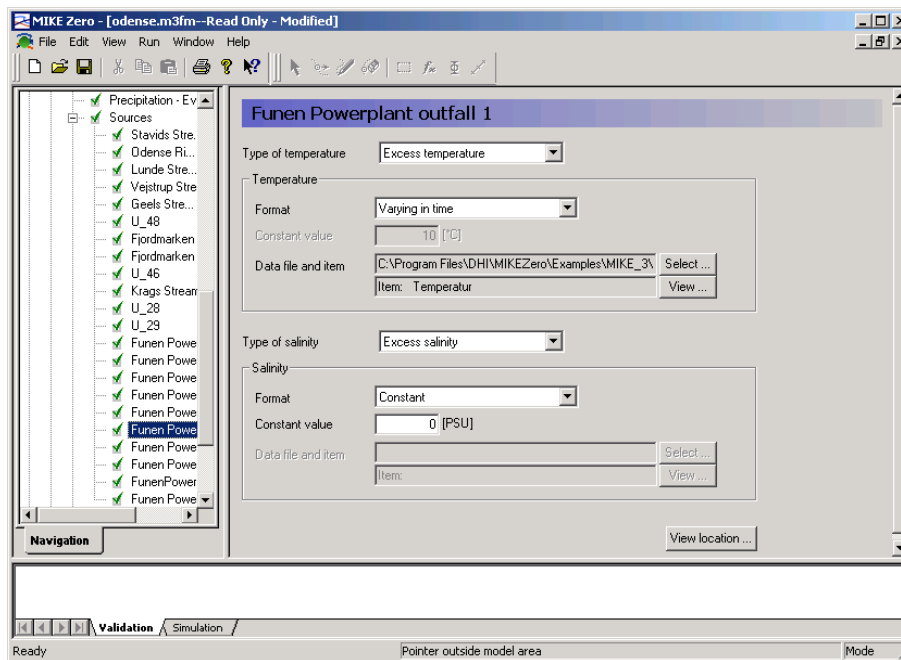
Figure 4.24   MIKE 3 Flow Model FM: Source Funen Powerplant Temperature/ Salinity specification

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.
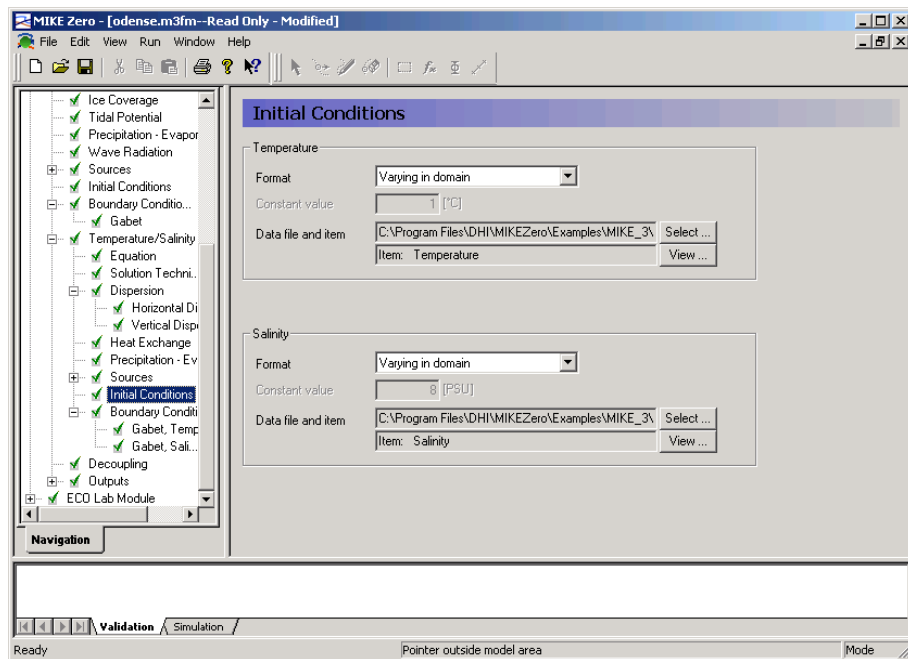
Figure 4.25   MIKE 3 Flow Model FM: Initial Conditions for temperature/salinity specification
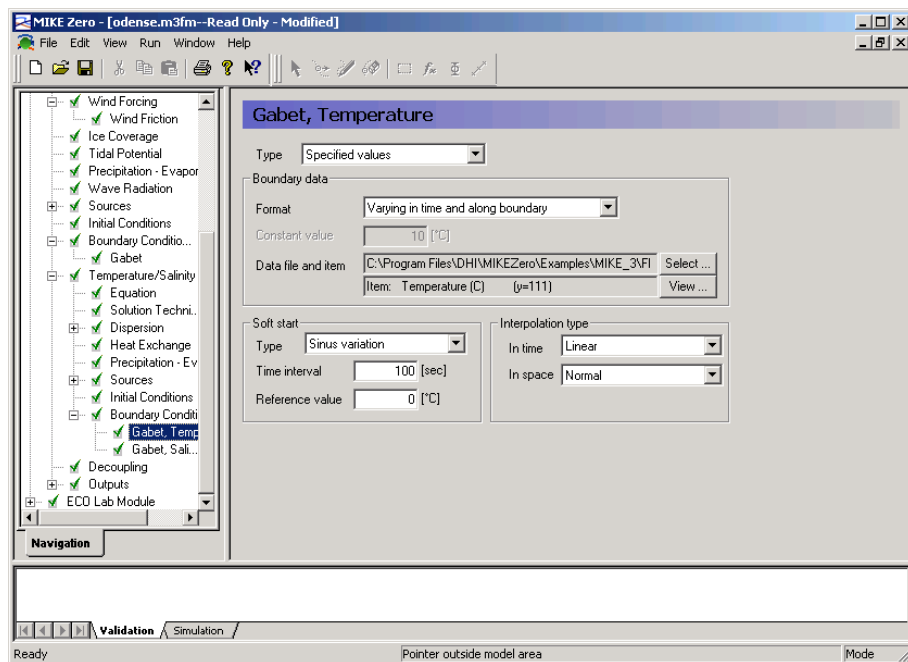
Figure 4.26   MIKE 3 Flow Model FM: Boundary Conditions for temperature specification

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 Depth-averaged 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\EutrophicationModel1SedimentBenthicVegetation.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 x 24 = 600 s, and select the Euler integration method, see Figure 4.27.
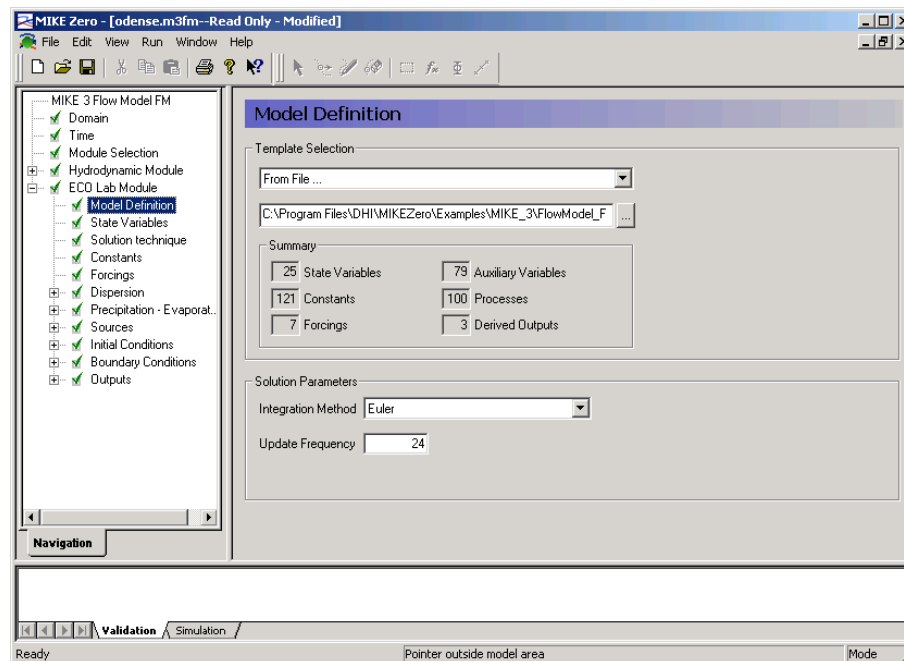
Figure 4.27   MIKE 3 Flow Model FM: Model Definition for MIKE ECO Lab specification

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.
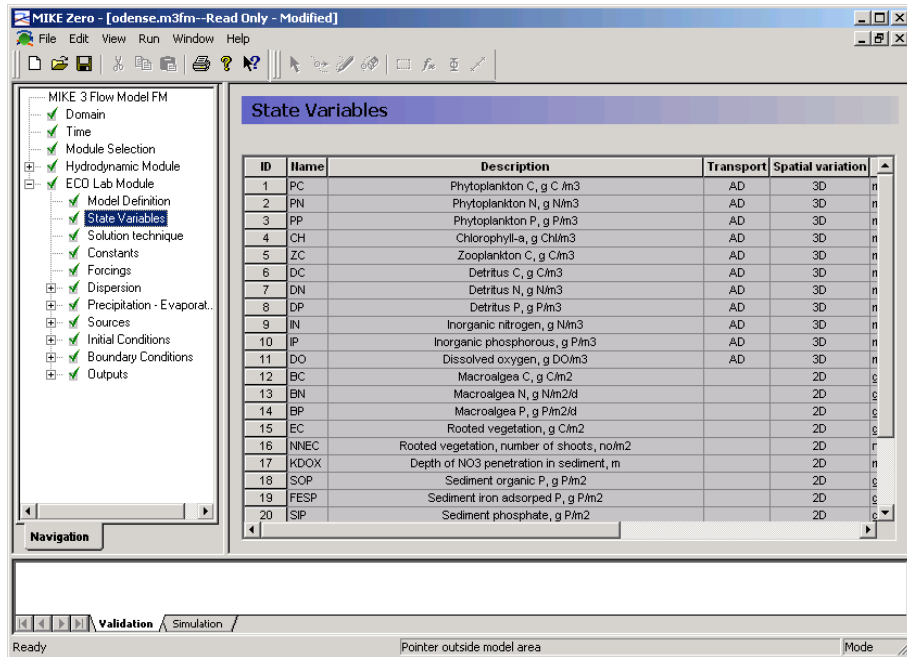
Figure 4.28   MIKE 3 Flow Model FM: State Variables in the MIKE ECO Lab template

The Solution Technique should match the one used in the Hydrodynamic Module.
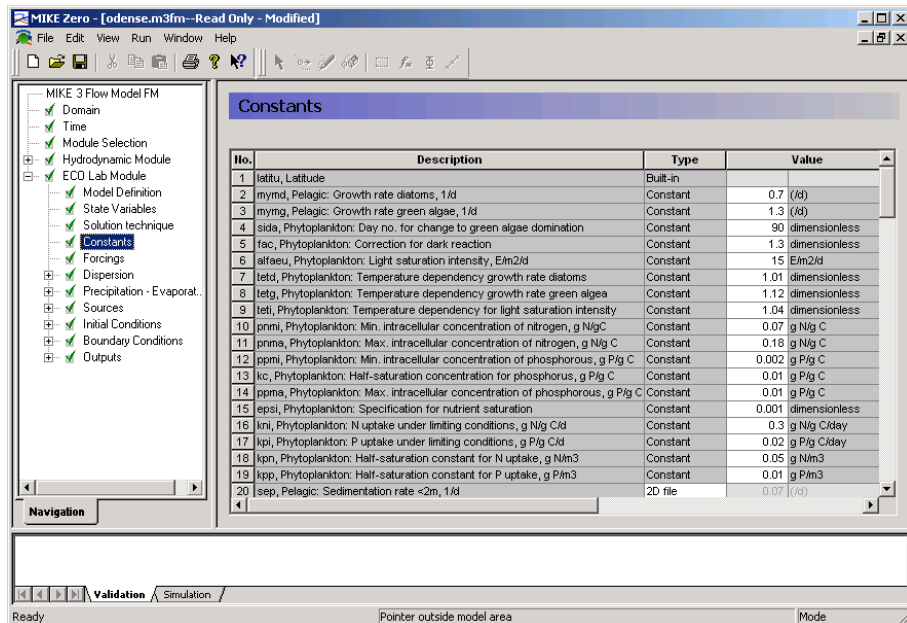
Figure 4.29   MIKE 3 Flow Model FM: Constants in MIKE ECO Lab Specification

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	Type	Value		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		...
7	tetd, Phytoplankton: Temperature dependency growth rate diato	Constant	1.01	dimensionl		...
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:\MIKEZero\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	0.35	1/m	C:\MIKEZero\dev\example\M3\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	dimensionl		...
51	ikb20, Macroalgea: Light saturation intensity at 20 deg., E/m2/d	Constant	20	E/m2/day		...
52	ihb20, Macroalgea: Light intensity for photo inhibition at 20 deg.,	Constant	25	E/m2/day		...
53	tetib, Macroalgae: Temperature dependency for light saturation a	Constant	1.04	dimensionl		...
54	babc, Macroalgae: 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	bnma, Macro algae: Max. intracelluar conc. of N, g N/g C	Constant	0.2	gN/gC		...
58	bnmi, Macro algae: Min. intracelluar conc. of N, g N/g C	Constant	0.06	gN/gC		...
59	bpma, Macro algae: Max. intracelluar conc. of g P/g C	Constant	0.02	gP/gC		...
60	bpmi, Macroalgea: Min. intracellular concentration of phosphorou	Constant	0.002	gP/gC		...
61	kkbp, Macro algae: Halfsat. conc. for P, g P/g C	Constant	0.005	gP/gC		...
62	kbn, Macroalgea: Half-saturation concentration for N uptake, g N	Constant	0.2	g N/m3		...
63	kbp, Macroalgea: Half-saturation concentration for P uptake, g P/	Constant	0.08	g P/m3		...
64	mla, Macroalgae: Light extinction constant macroalgae, m2/g BC	Constant	0.02	m2/g macr		...
65	tetk, Macroalgea & Rooted vegetation: Temperature dependency	Constant	1.04	dimensionl		...
66	mibc, Macroalgea: Threshold values for self-shading of macro al	Constant	20	g C/m2		...

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

67	kslm, Macroalgea: Sloughing rate at 20 degrees, 1/d	Constant	0.02	(/d)		
68	tetl, Macroalgea: Temperature dependency sloughing rate	Constant	1.03	dimensionl		
69	tets, Macro algae, Death rate constant, 1. Order coeff.	Constant	0	dimensionl		
70	ws1, Macro algae Death rate constant, 2. Order coeff., 1/m	Constant	3	per meter		
71	rbma, Macroalgea: Respiration rate at 20 degrees, 1/d	Constant	0	(/d)		
72	vo, Oxygen: Production/consumption relative to carbon, g DO/g	Constant	3.5	g DO/g C		
73	kmsc, Sediment: Proportional factor for sediment respiration	Constant	0.7	dimensionl		
74	mdo, Oxygen: Half-saturation constant, g/m3	Constant	2	g/m3		
75	mdos, Oxygen: Half-saturation constant in sediment, g/m3	Constant	2	mg/l		
76	ndo, Oxygen: Coefficient for oxygen dependency	Constant	1	dimensionl		
77	tetn, Sediment: Temperature dependency sediment N release	Constant	1.1	dimensionl		
78	tetp, Sediment: Temperature dependency sediment P release	Constant	1.09	dimensionl		
79	ters, Sediment: Temperature dependency sediment respiration	Constant	1.07	dimensionl		
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 VWV/cm3	C:\MIKEZero\dev\example\M3\FlowModel_FM\EL\Odense_Estuary\Data\Consta	...
82	dm, Sediment: Dry weight sediment, g DM/g VWV	2D file	0.5	g DM/g VV	C:\MIKEZero\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:\MIKEZero\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	g P/m3		
100	kka, Sediment: Constant 1, oxygen penetration into sediment, m	Constant	0.00124	m		
101	kkb, Sediment: Constant 2, oxygen penetration into sediment, m2	Constant	Range: 0 - 0.1	g DO		
102	kkc, Sediment: Constant 3, oxygen penetration into sediment, m*	Constant	0.1	m d/g DO		
103	megr, Rooted veg.: Specific growth rate at 20 C, shoot biomass,	Constant	0.13	(/d)		
104	tetal, Rooted veg.: Temperature dependency for growth	Constant	1.08	dimensionl		
105	ihe20, Rooted veg.: Light intensity at 20 C for photoinhibition, E/m	Constant	35	E/m2/d		
106	ike20, Rooted veg.: Light intensity at 20 C for saturation, E/m2/d	Constant	20	E/m2/d		
107	ice20, Rooted veg.: Light intensity at 20 C for compensation, E/m	Constant	2	E/m2/d		
108	tetc, Rooted veg.:Temperature dependency for light compensati	Constant	1.04	dimensionl		
109	medr, Rooted veg.: Specific death rate at 20 C, shoot biomass, 1	Constant	0.01	(/d)		
110	tetw, Rooted veg.: Temperature dependency for death	Constant	1.07	dimensionl		
111	ew1, Rooted veg.: 1st death constant shallow waters	Constant	2.5	dimensionl		
112	ew2, Rooted veg.: 2nd death constant shallow waters	Constant	2	dimensionl		
113	mngr, Rooted veg.: Maximum growth rate at 20 C, number of sho	Constant	15	number/m		
114	kloss, Rooted veg.: Specific death rate at 20 C, number of shoot	Constant	0.003	(/d)		
115	fsd, Rooted veg.: Fraction of root. veg. to the sediment	Constant	0.9	dimensionl		
116	ecnc, Rooted veg.: N to C ratio, 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:
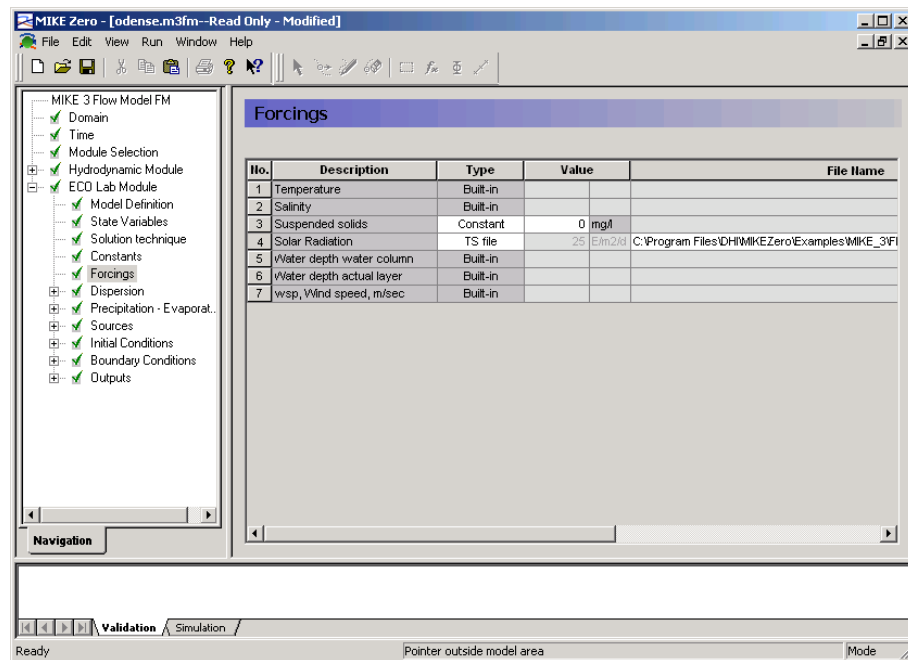• light.dfs0

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.
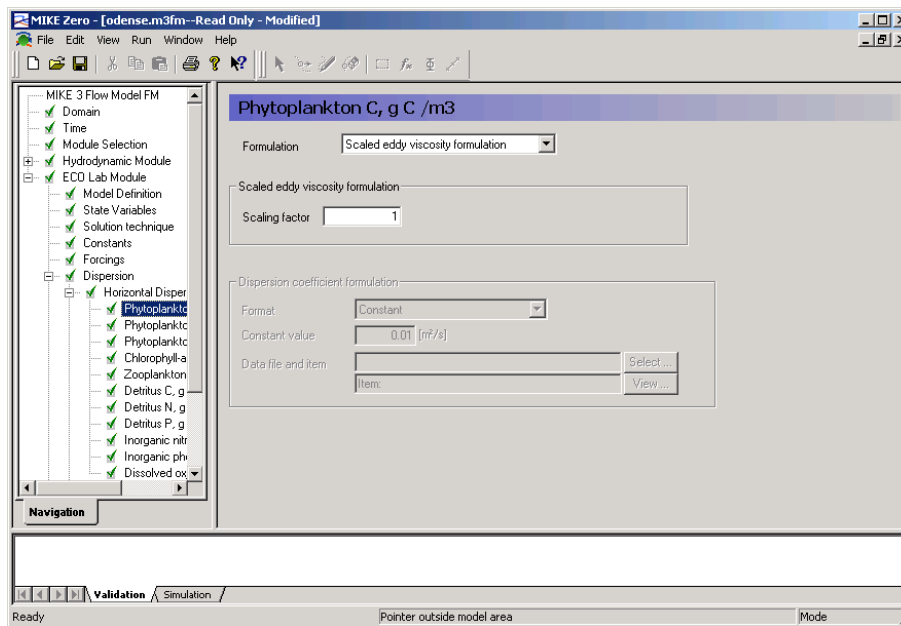
Figure 4.33   MIKE 3 Flow Model FM: Horizontal Dispersion parameters for the advective MIKE ECO Lab state variables
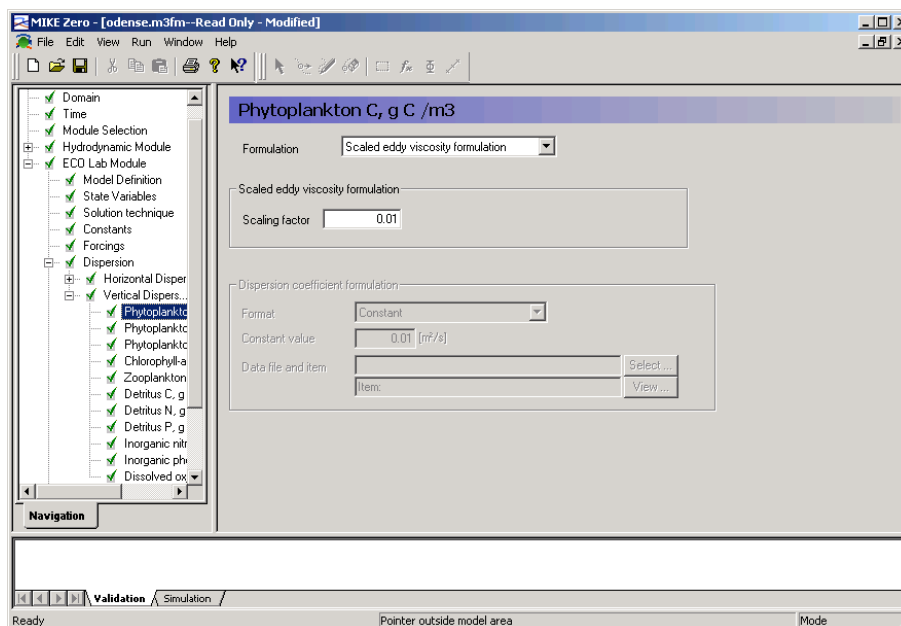

Figure 4.34   MIKE 3 Flow Model FM: Vertical dispersion parameters for the advective MIKE ECO Lab state variables

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	l_stav.dfs0
2	Odense River	l_oden.dfs0
3	Lunde Stream	l_lun.dfs0
4	Vejstrup Stream	l_vejr.dfs0
5	Geels Stream	l_geel.dfs0
6	U_48	l_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	l_u27.dfs0
11	U_28	l_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 4.4   Runoff and loadings to Odense Estuary 2002

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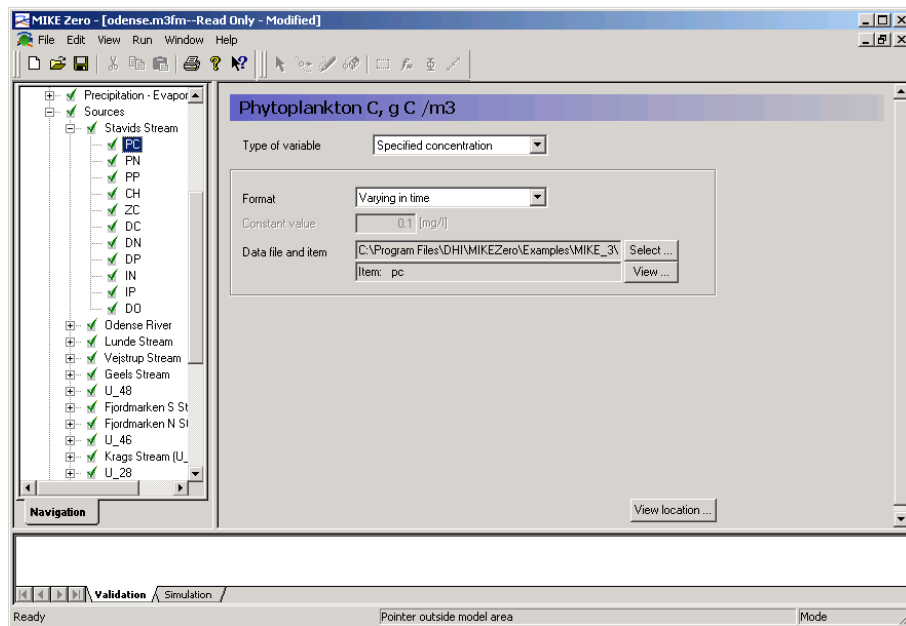
Figure 4.35   MIKE 3 Flow Model FM: Specifying concentrations for the advective MIKE ECO Lab
state variables in Stavids Stream

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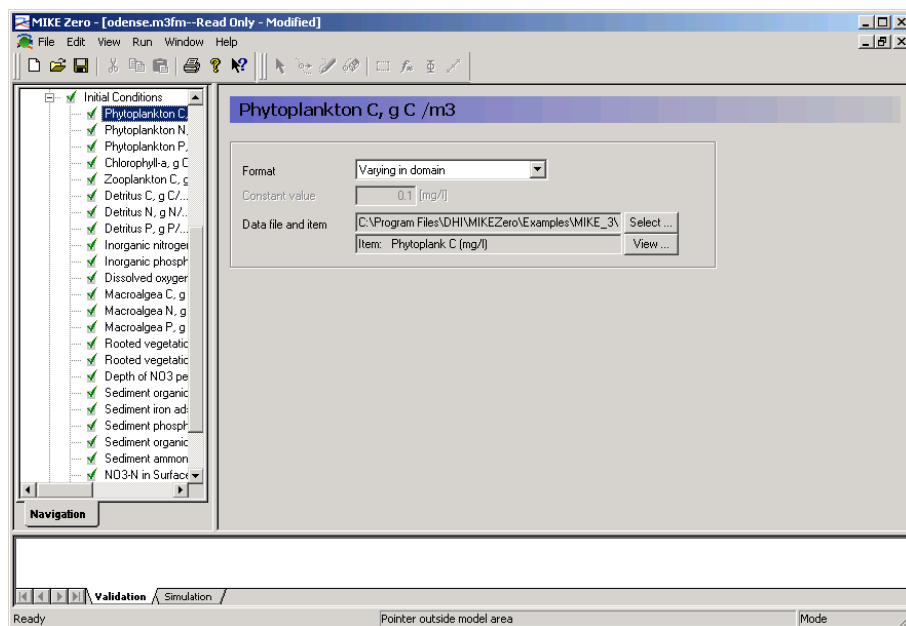files mentioned in Chapter 3.9, see Figure 4.36.

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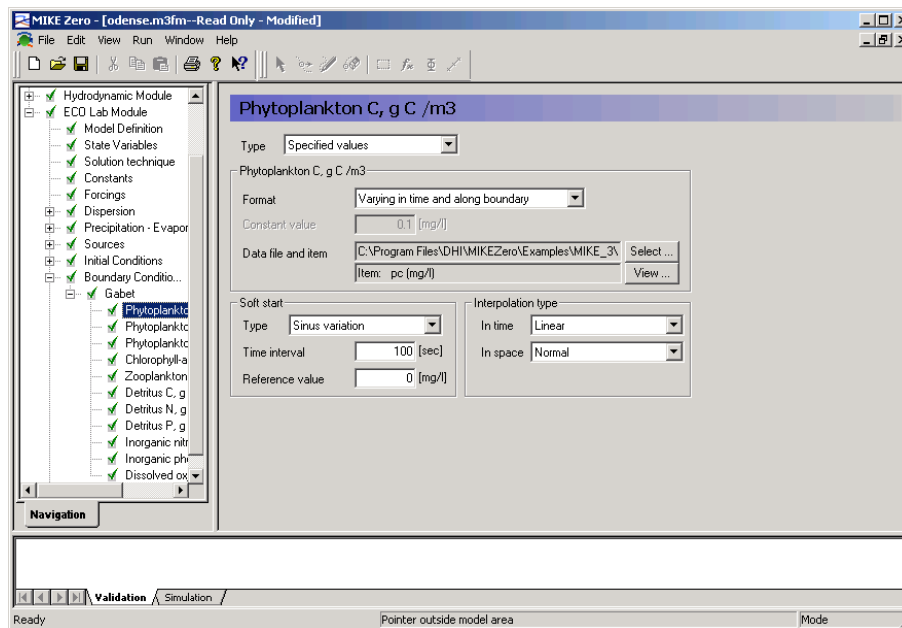
Figure 4.37   MIKE 3 Flow Model FM: Specifying Boundary Conditions for the advective MIKE ECO Lab state variables

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.
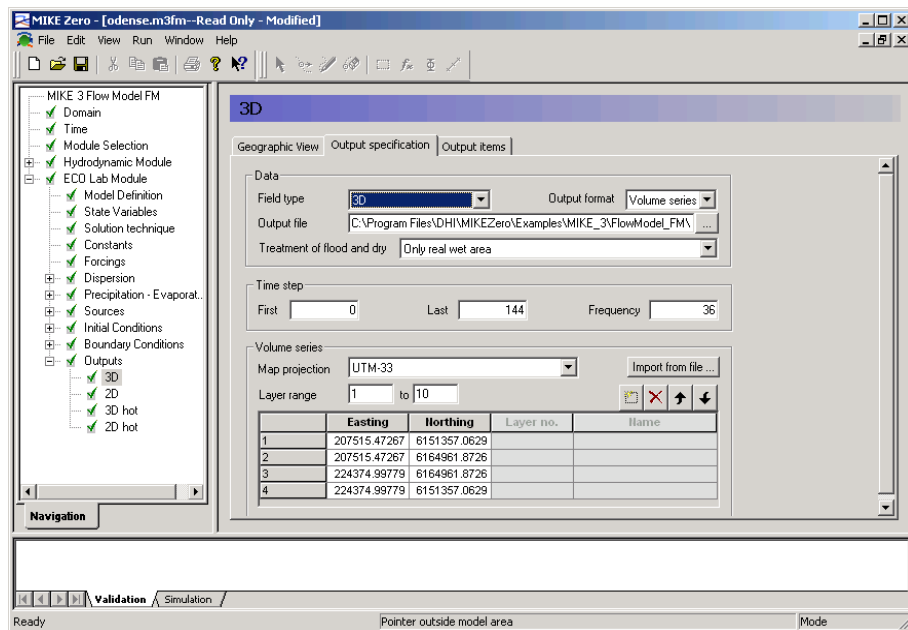
Figure 4.38   MIKE 3 Flow Model FM: Specifying Output file for the MIKE 3 FM ECO Lab
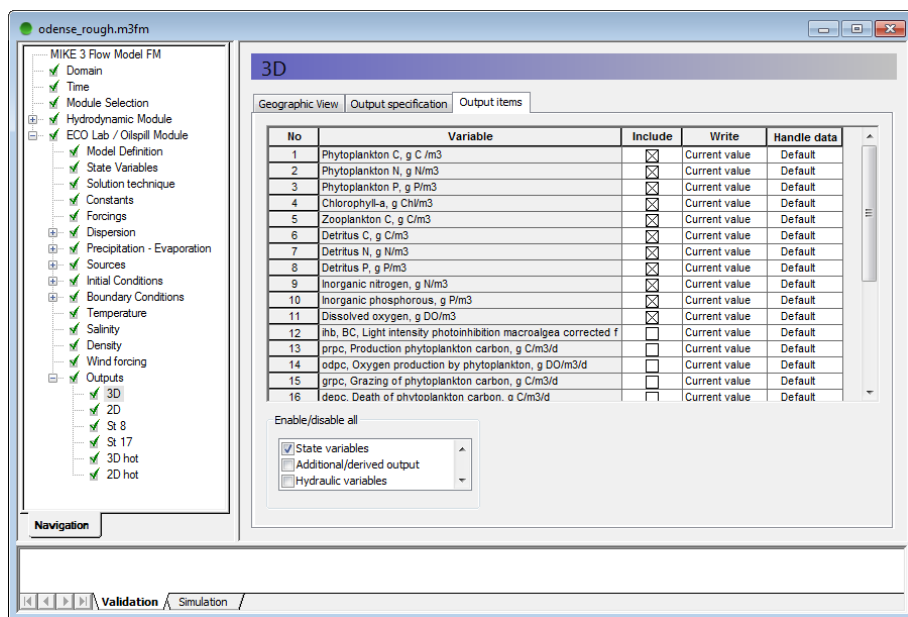

Figure 4.39   MIKE 3 Flow Model FM: Specifying 3D Output parameters for the MIKE 3 FM ECO Lab
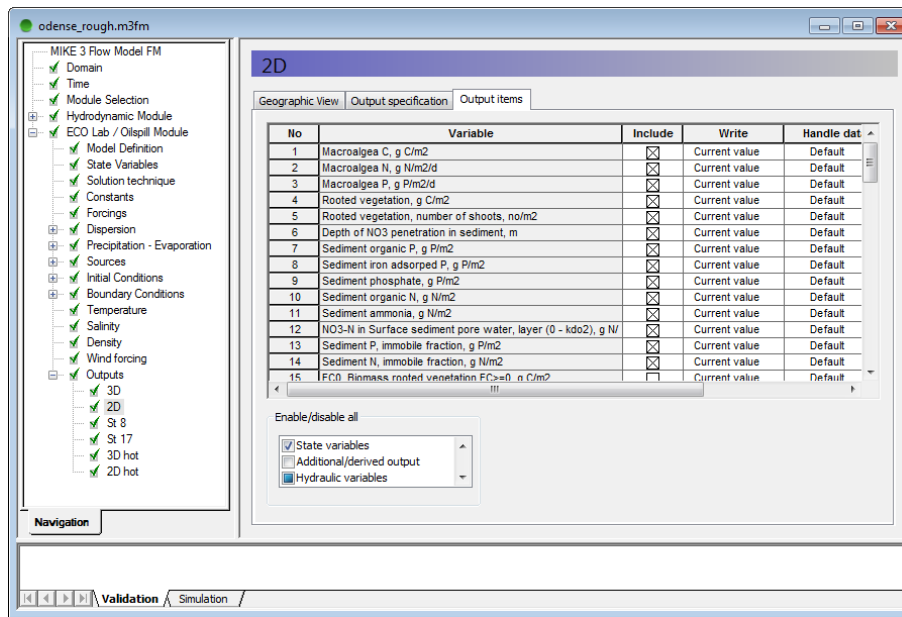
Figure 4.40   MIKE 3 Flow Model FM: Specifying 2D Output parameters for the MIKE 3 FM ECO Lab
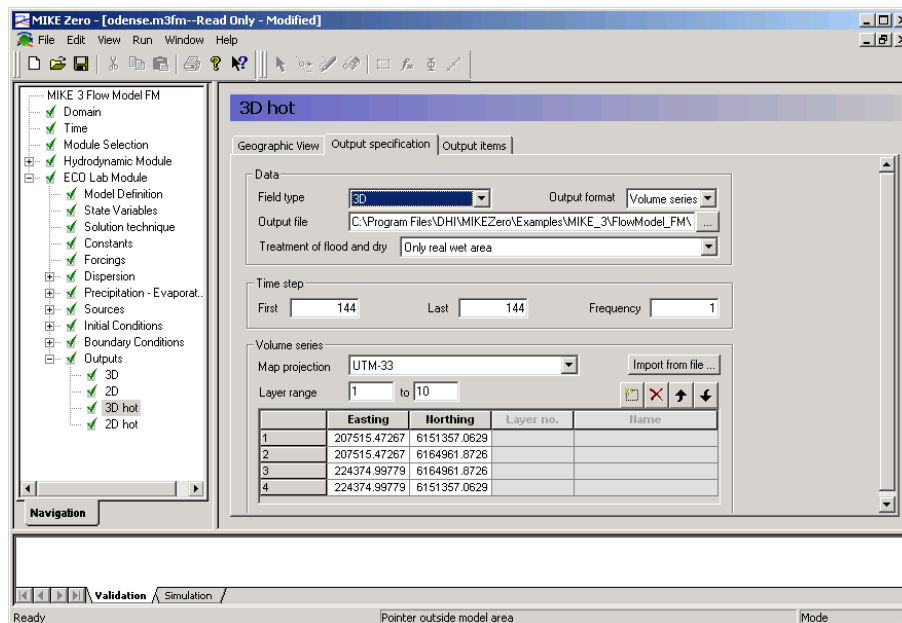

Figure 4.41   MIKE 3 Flow Model FM: Specifying hot data for the 3D Output parameters for the MIKE 3 FM ECO Lab

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.
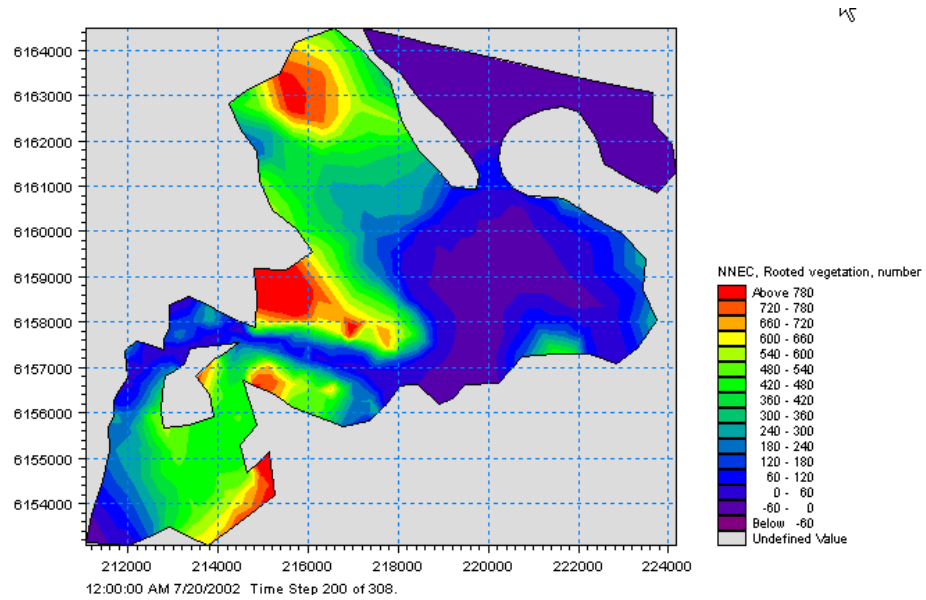

Figure 4.42   MIKE 3 Flow Model FM: Snapshot of simulated 2D output of Rooted Vegetation [No./m2]

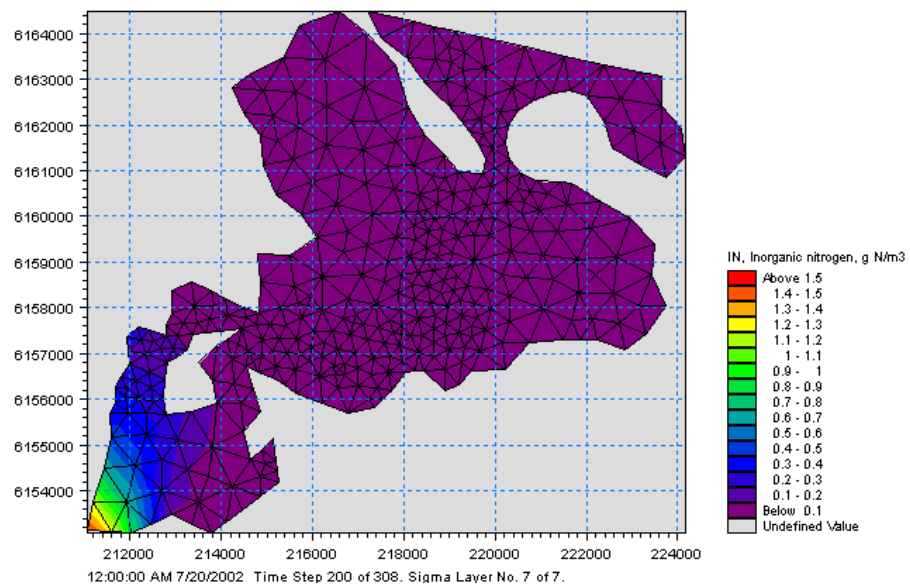Figure 4.43 shows a snapshot of the simulated top layer of 'Total nitrogen (mg/l)'

Figure 4.43   MIKE 3 Flow Model FM: Snapshot of simulated water surface layer of Total Nitrogen

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.
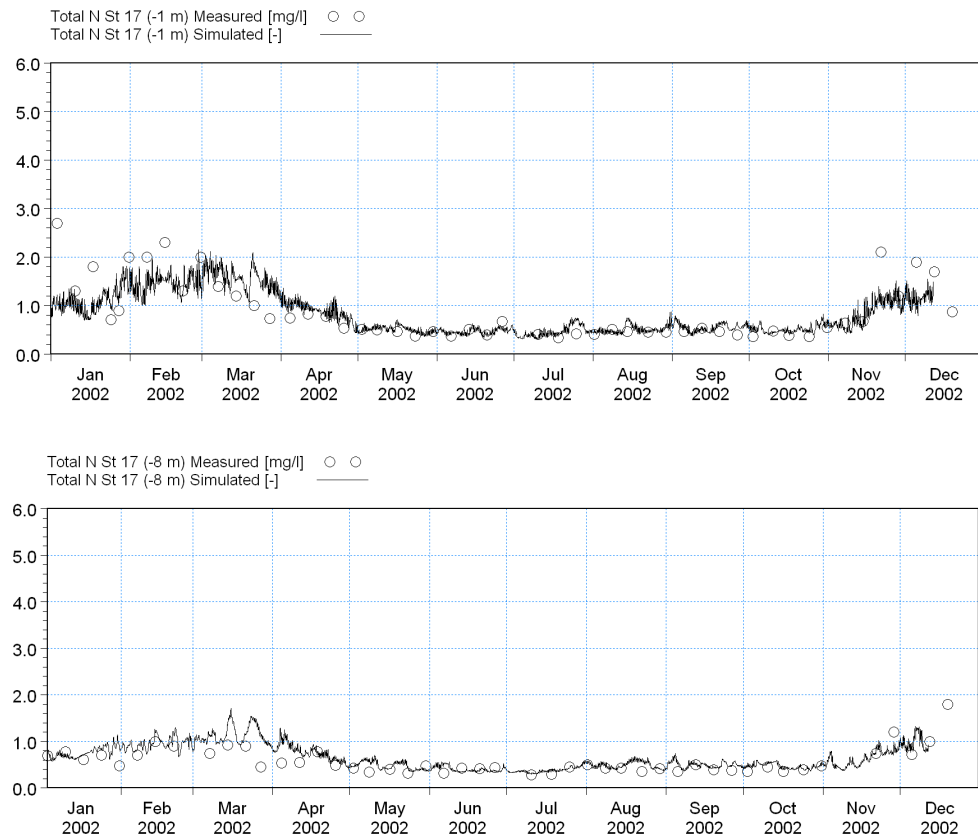

Figure 4.44   Comparison of measurements and model output for Total Nitrogen

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.
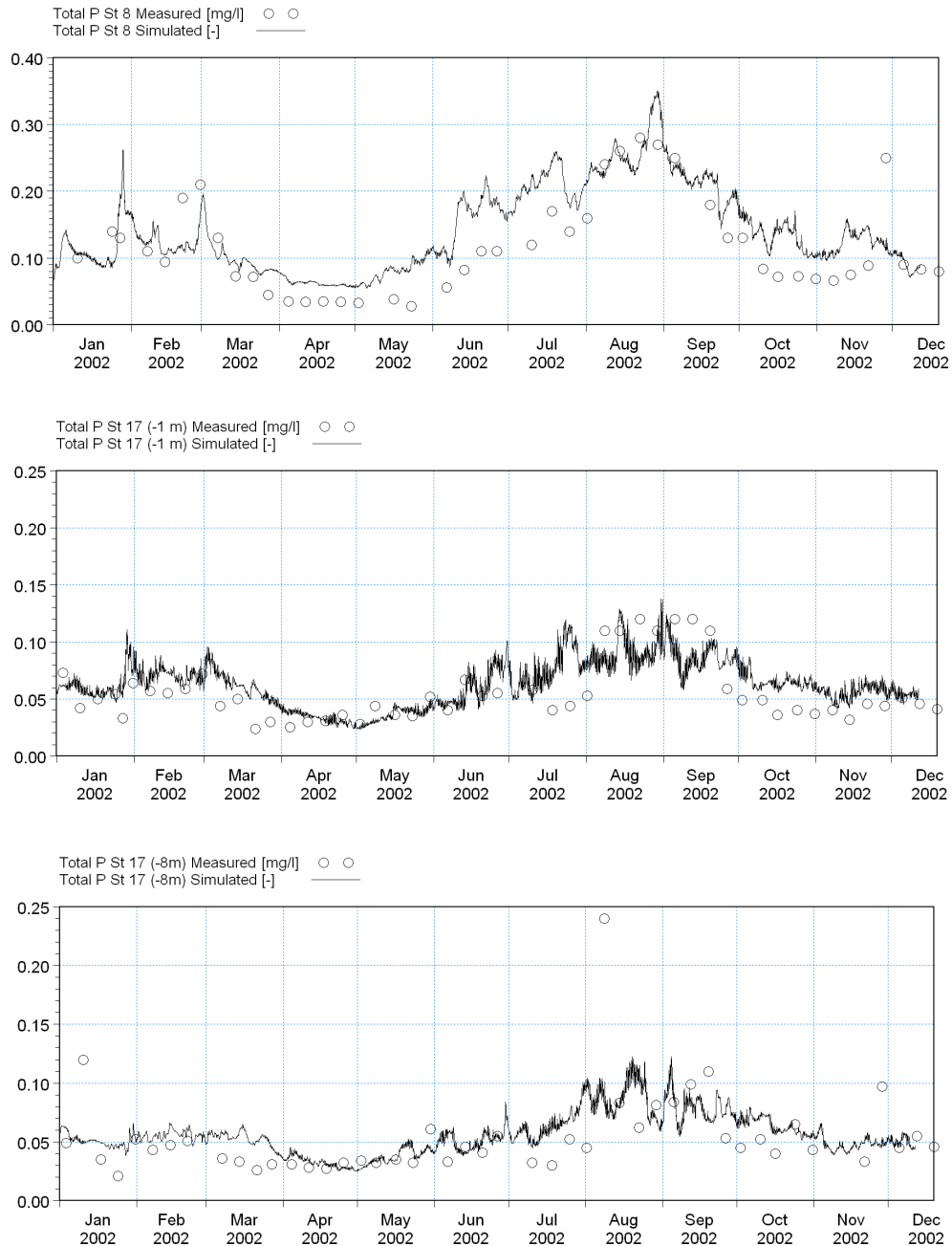
Figure 4.45   Comparison of measurements and model output for Total Phosphorus

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.
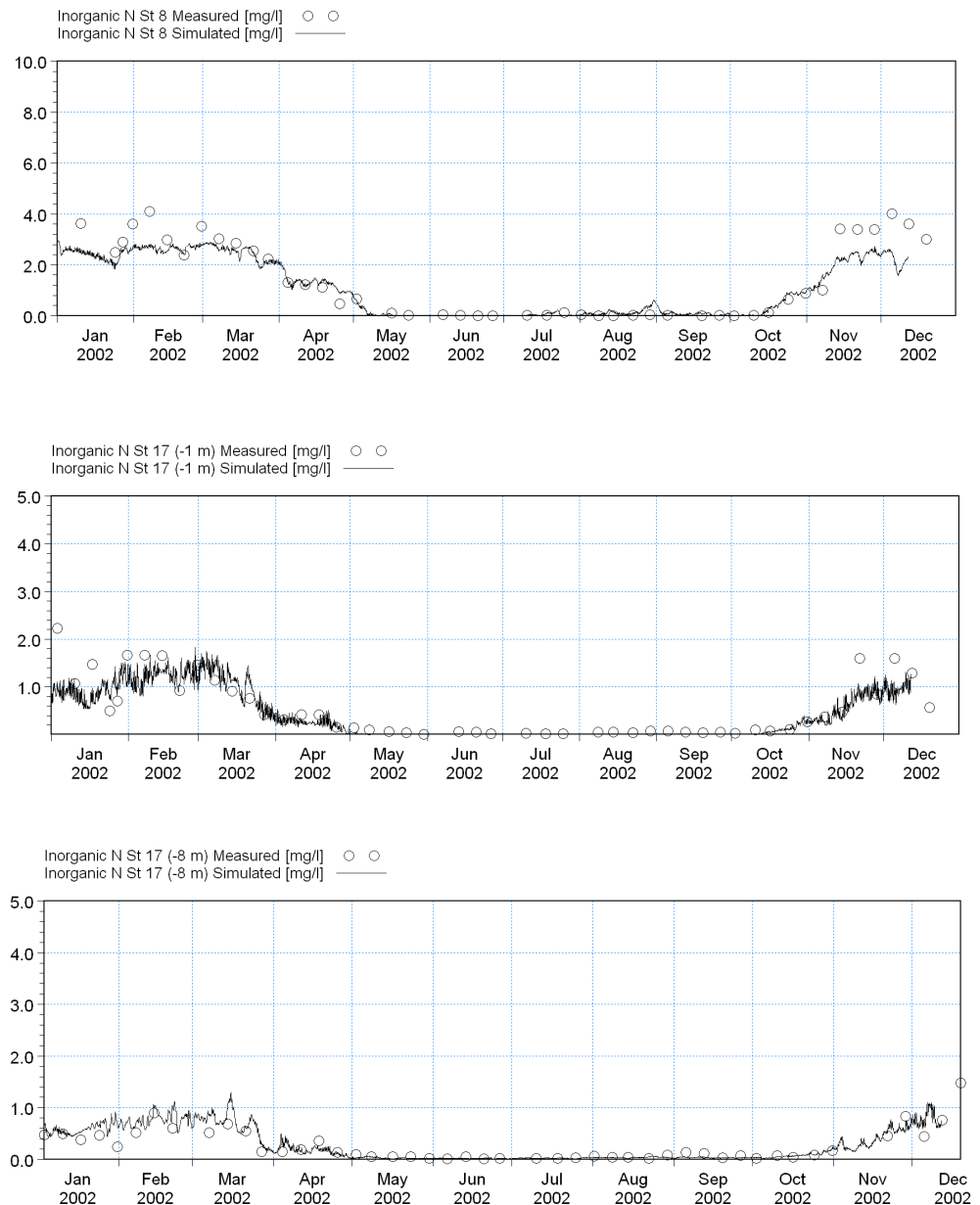

Figure 4.46   Comparison of measurements and model output for Inorganic Nitrogen

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.
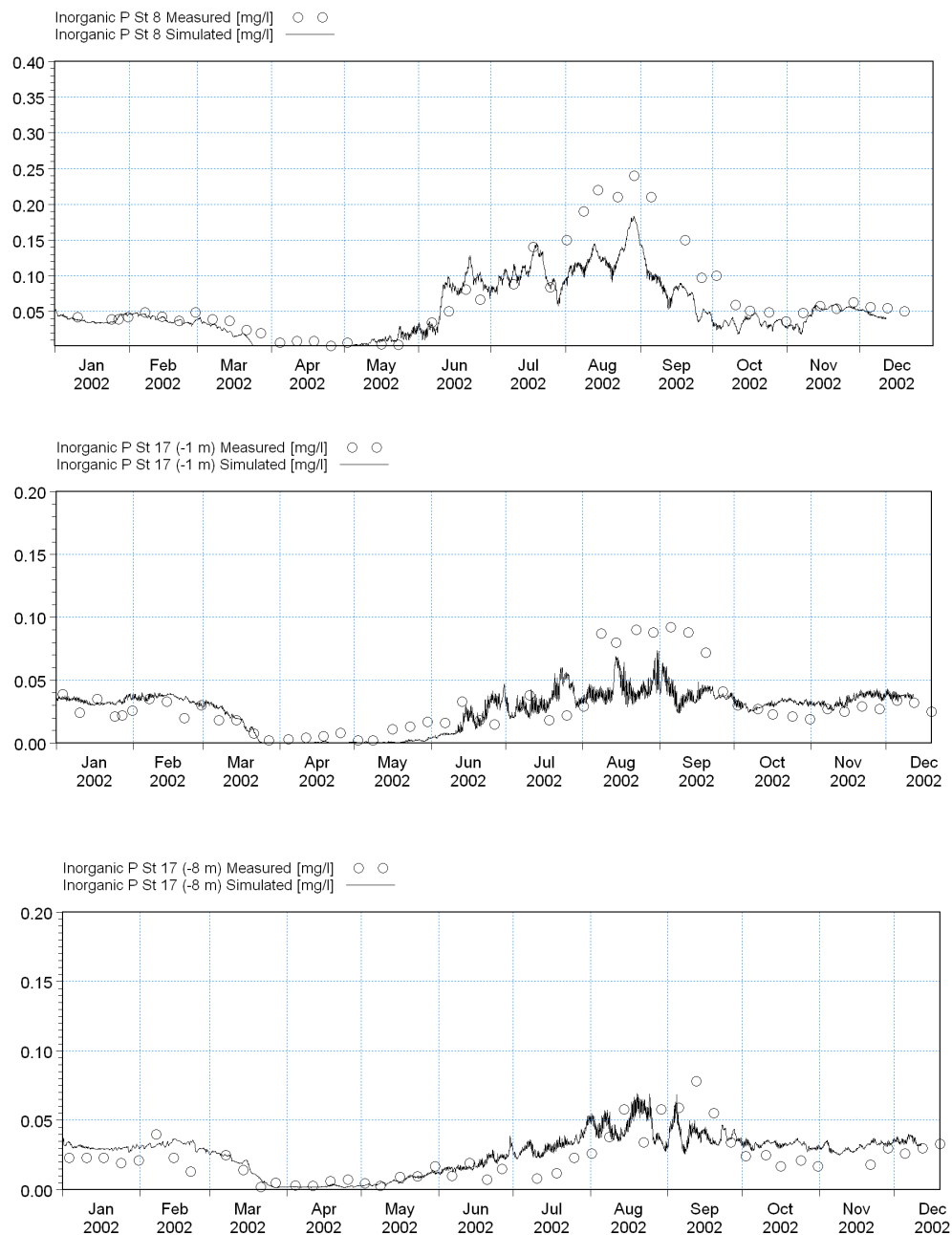

Figure 4.47   Comparison of measurements and model output for Inorganic Phosphorus

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.
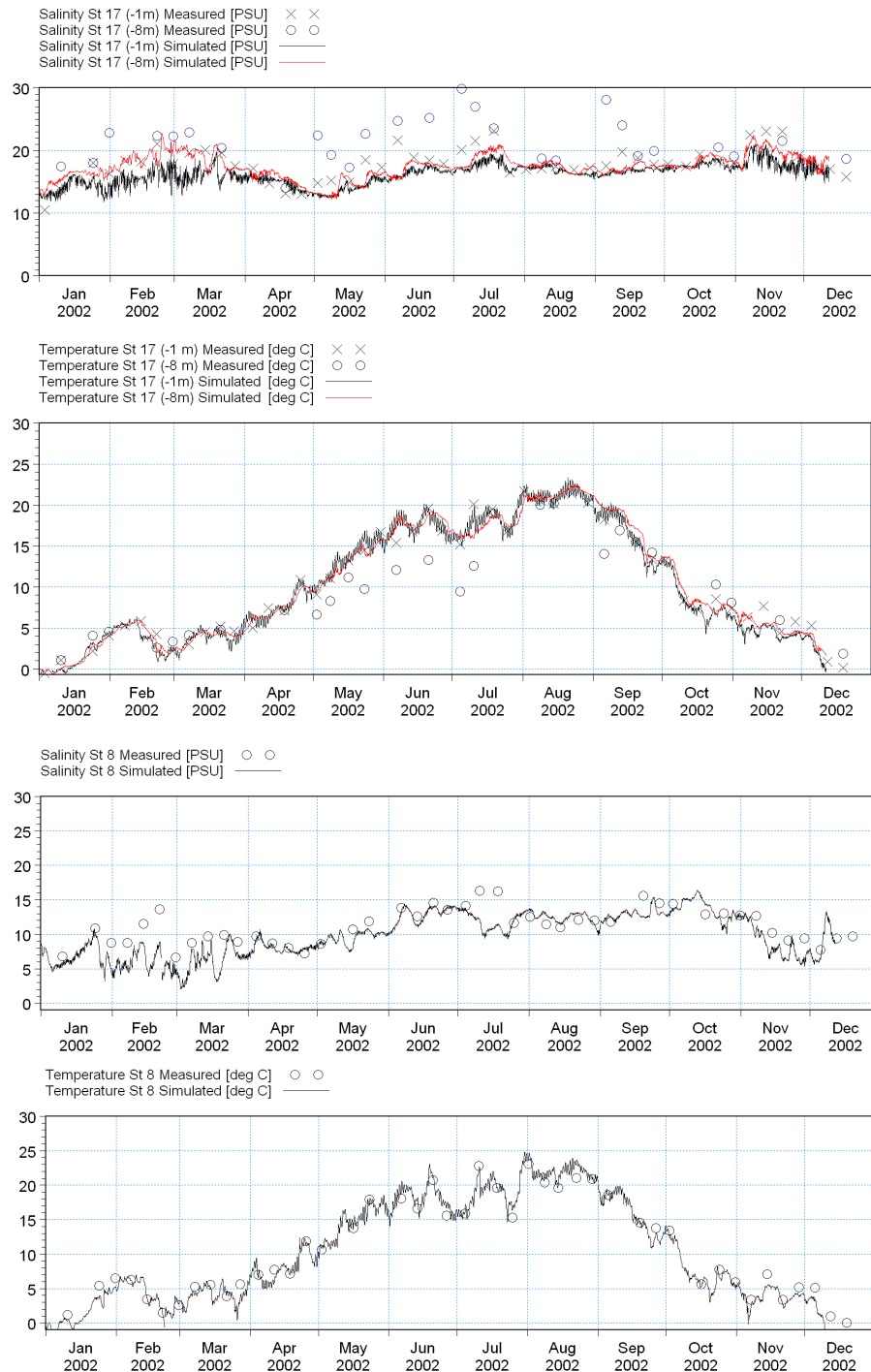

Figure 4.48   Comparison of measurements and model output for salinity and temperature