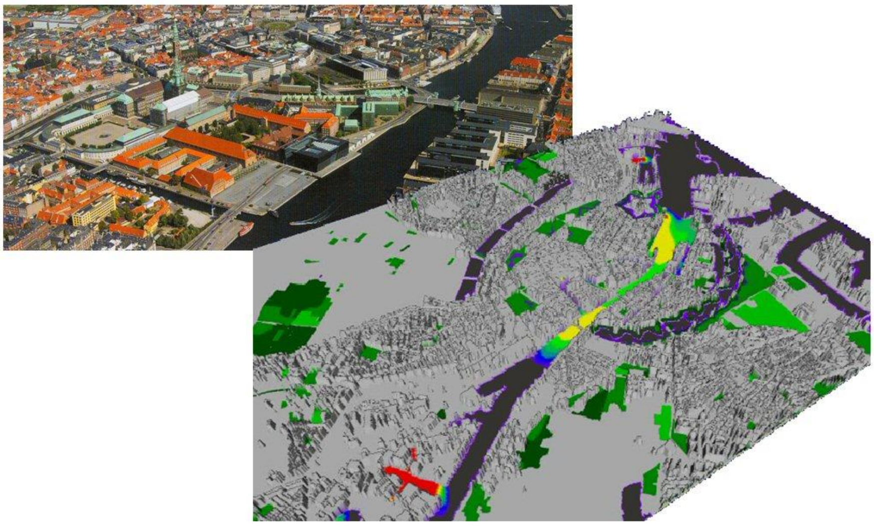

MIKE 21 & MIKE 3 Flow Model FM

Transport Module

Short Description

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MIKE 21 & MIKE 3 Flow Model FM - Transport Module

The Transport Module simulates the spreading and fate of dissolved or suspended substances in an aquatic environment under the influence of the fluid transport and associated dispersion processes. The substance may be of any kind, conservative or non-conservative, inorganic or organic. Non-conservative substances are distinguished by the manner in which they decay. Examples of linearly decaying substances are tracers that are absorbed to particulate matter.

The hydrodynamic basis for the Transport Module is calculated with the Hydrodynamic Module (HD). The hydrodynamic modules can be applied for both barotrophic (constant density) or baroclinic flows. In the latter case, the effect of variable density on the flow is included by solving the transport equations for salt and temperature. The viscosities or diffusivities in the hydrodynamic module are described either as simple constant or calculated using state-of-the-art turbulence models.

Application Areas

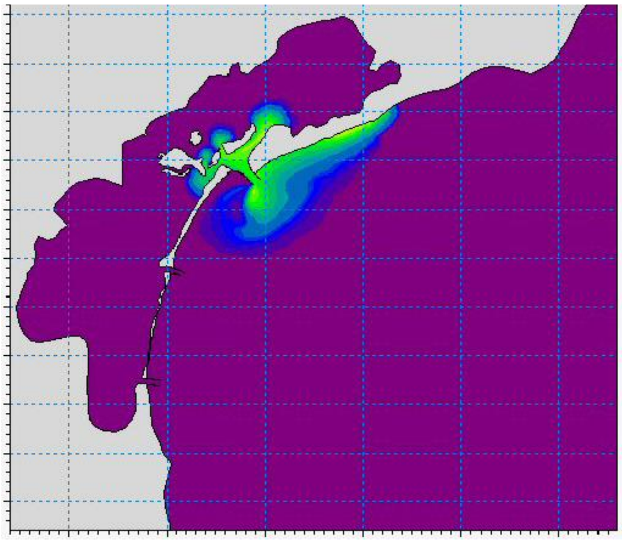
The Transport Module can be applied to a wide range of hydraulic and related phenomena. The application areas are generally problems where flow and transport phenomena are important with emphasis on coastal and marine applications, where the flexibility inherited in the unstructured meshes can be utilised.

Typical substances, which are modelled using the Transport Module are:

- Tracers
- Coliform bacteria
- Xenobiotic compounds

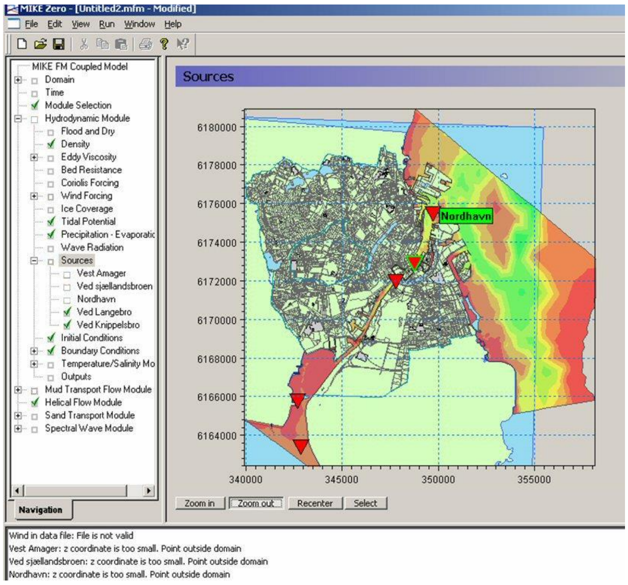
Typical applications include flushing studies, tracer simulations and simple water quality studies. In relation to point pollution sources the Transport Module can be used for conservative approximations of transport and dispersion of e-coli bacteria provided sufficient choice of decay coefficient.

The Ecology and Water Quality Module (ECO Lab) is closely integrated with the Transport Module and the Hydrodynamic Module. ECO Lab simulates reaction processes in multi-compound systems or of substances with a more complex decay than linear, i.e. decay of substances that also depend on light intensity like e-coli. This enables complex ecosystem studies in coastal areas, estuaries and lakes.

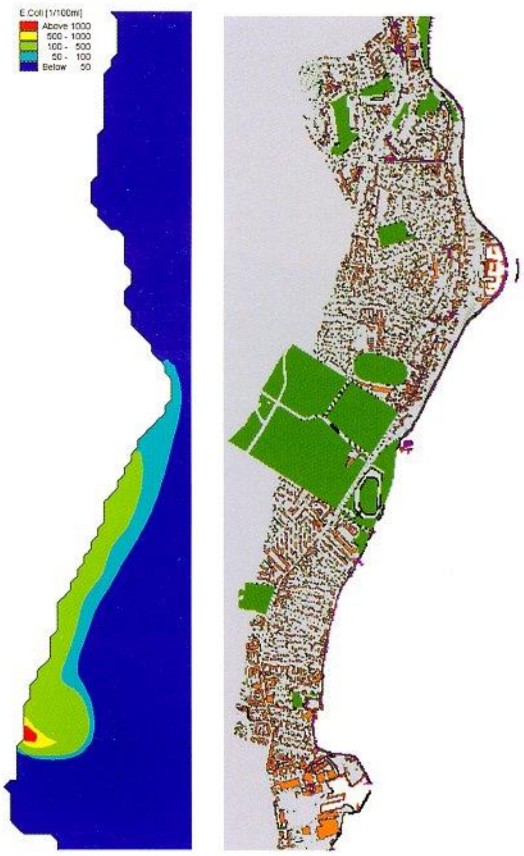


Typical applications with the MIKE 21 & MIKE 3 Flow Model FM Transport Module include tracer studies as shown above in the Venice lagoon

Example of plumes from outfall with colours indicating different concentrations



Example of user interface where sources from CSO's are specified to be used in model simulations to compare different abatement schemes, or online as input to forecasts of water quality



Example of bathing water quality forecasts from a municipality north of Copenhagen. The forecasts are made available on a dedicated bathing water quality webpage

Computational Features

The main features of MIKE 21 & MIKE 3 Flow Model FM – Transport Module are as follows:

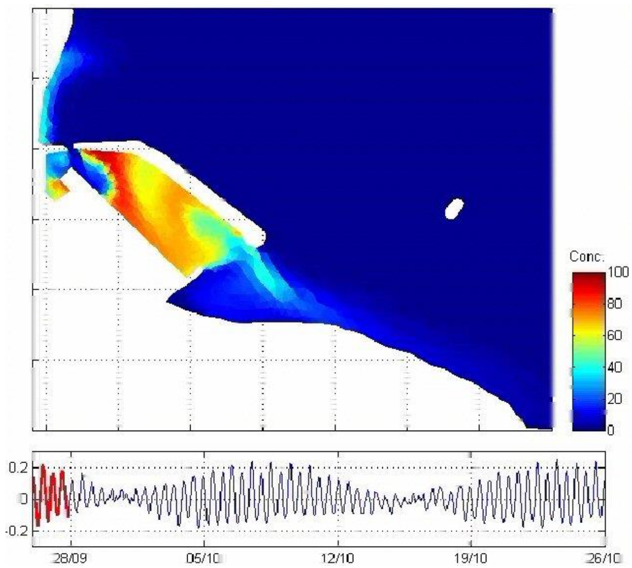
- Conservative substances
- Linear decay
- Sources and sinks (mass and momentum)

Model Equations

MIKE 21 & MIKE 3 Flow Model FM Transport Module is dynamically linked to the Hydrodynamic Module.

The modelling system is based on the numerical solution of the two/three-dimensional incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and of hydrostatic pressure. Thus the model consists of continuity, momentum, temperature, salinity and density equations and it is closed by a turbulent closure scheme. The density does not depend on the pressure, but only on the temperature and the salinity.

For the 3D model, the free surface is taken into account using a sigma-coordinate transformation approach.



Flushing study example from a harbour on Tahiti.
Top: An initial concentration field is placed in the harbour and the dilution due to advection-dispersion processes are then simulated with the HD-TR modules.
Bottom: Time series of tidal elevations

Scalar quantity

The Transport Module can calculate the transport of a scalar quantity. The conservation equation for a scalar quantity is given by

$$\frac{\partial C}{\partial t}+\frac{\partial uC}{\partial x}+\frac{\partial vC}{\partial y}+\frac{\partial wC}{\partial z}=F_C+\frac{\partial}{\partial z}\left(D_v\frac{\partial C}{\partial z}\right)-k_pC+C_sS$$

The horizontal diffusion term is defined by

$$F_C=\left[\frac{\partial}{\partial x}\left(D_h\frac{\partial}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_h\frac{\partial}{\partial y}\right)\right]C$$

For 2D calculations, the conservation equation is integrated over depth and defined by

$$\frac{\partial h\bar{C}}{\partial t}+\frac{\partial h\bar{u}\bar{C}}{\partial x}+\frac{\partial h\bar{v}\bar{C}}{\partial y}=hF_C-hk_p\bar{C}+hC_sS$$

Symbol list

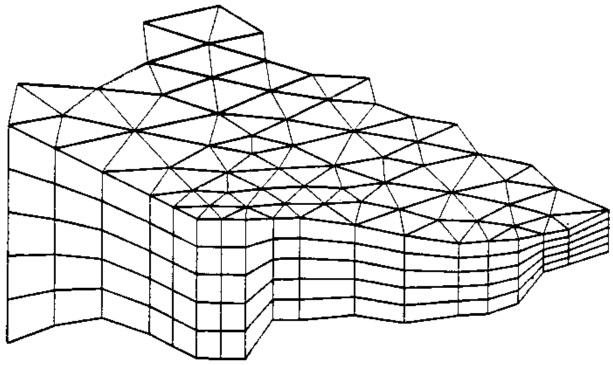
t	time
x, y, z	Cartesian coordinates
D_v	vertical turbulent (eddy) diffusion coefficient
S	magnitude of discharge due to point sources
F_c	horizontal diffusion term
D_h	horizontal diffusion coefficient
h	depth
$\bar{u}$, $\bar{v}$	depth-averaged velocity components
C	concentration of scalar quantity
k_p	linear decay rate of scalar quantity
C_S	concentration of scalar quantity in source

Solution Technique

The solution of the transport equations is closely linked to the solution of the hydrodynamic conditions.

The spatial discretization of the primitive equations is performed using a cell-centred finite volume method. The spatial domain is discretized by subdivision of the continuum into non-overlapping elements/cells. In the horizontal plane an unstructured mesh is used while in the vertical domain in the 3D model a structured mesh is used. In the 2D model the elements can be triangles or quadrilateral elements. In the 3D model the elements can be prisms or bricks whose horizontal faces are triangles and quadrilateral elements, respectively.

The time integration is performed using an explicit scheme.

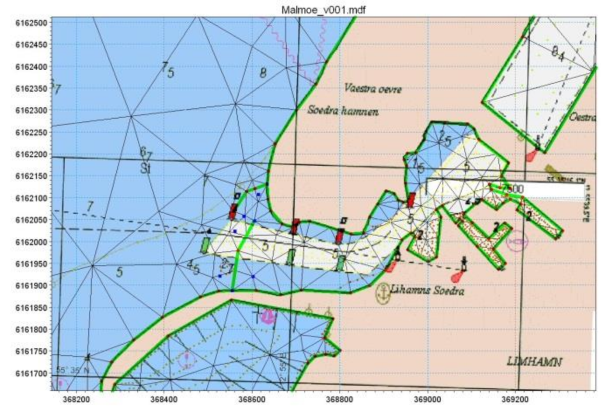


Principle of 3D mesh

Model Input Data

The necessary input data to the transport model is, besides the input for the hydrodynamic model alone, information about the components to simulate:

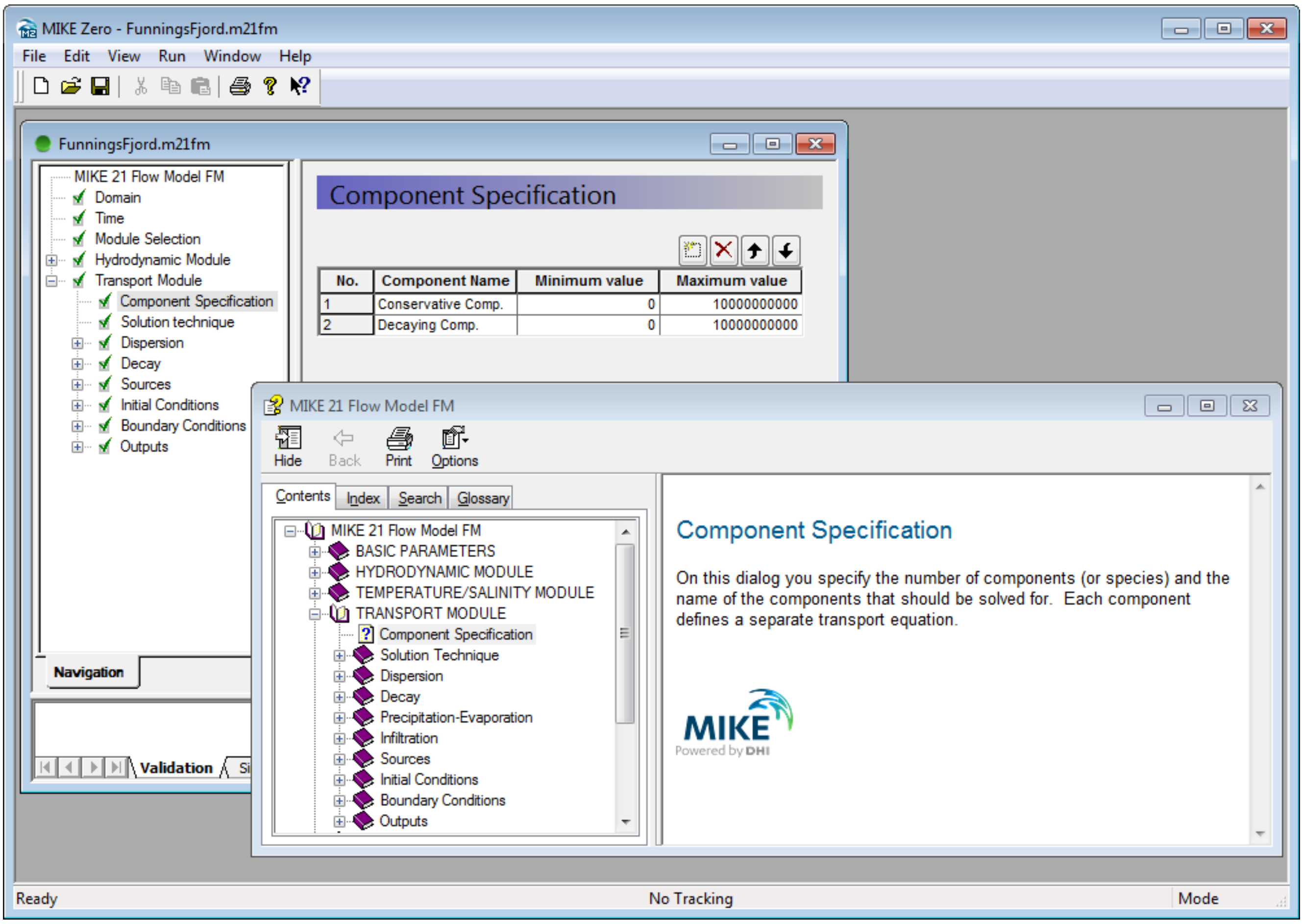
- Component type
- Dispersion coefficients
- Decay information
- Initial conditions
- Boundary conditions



Example of Flexible Mesh generated for a flushing study in Port of Malmoe, Sweden. The background image is from MIKE C-Map which enables extraction of land contours and water depths from digitized Admiralty Charts provided by Jeppesen Norway

Model Output Data

The output from the model includes the concentrations of the given components.
It is possible to specify the format of the output files in MIKE 21 & MIKE 3 as times series of points, lines, areas and volumes (three-dimensional calculations only).

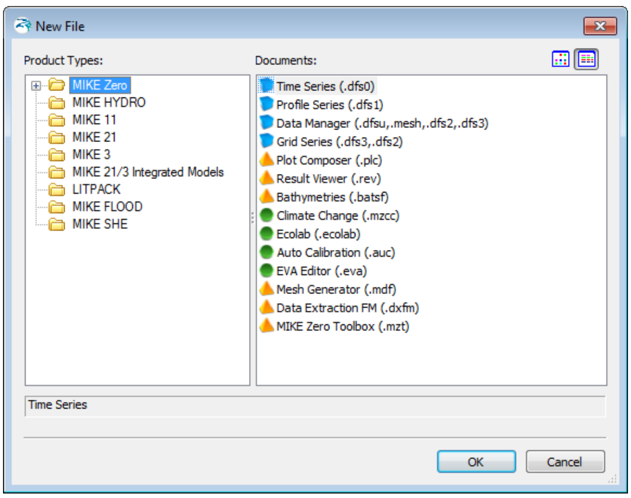


Graphical user interface of the MIKE 21 Flow Model FM, Transport Module, including an example of the Online Help System

Graphical User Interface

The MIKE 21 & MIKE 3 Flow Model FM, Transport Module is operated through a fully Windows integrated Graphical User Interface (GUI). Support is provided at each stage by an Online Help System.

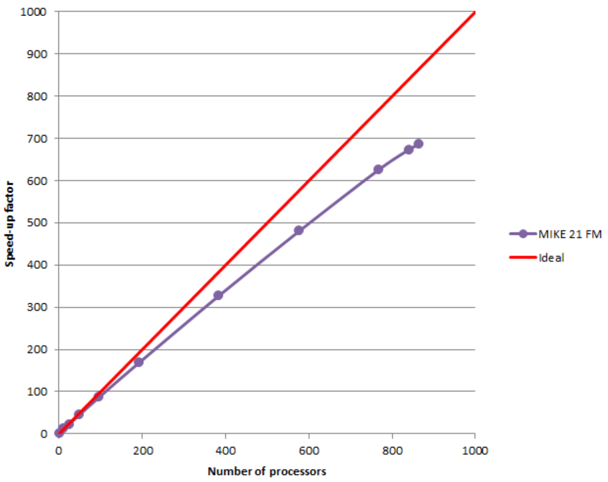
The common MIKE Zero shell provides entries for common data file editors, plotting facilities and a toolbox for/utilities as the Mesh Generator and Data Viewer.



Overview of the common MIKE Zero utilities

Parallelisation

The computational engines of the MIKE 21/3 FM series are available in versions that have been parallelised using both shared memory (OpenMP) as well as distributed memory architecture (MPI). The result is much faster simulations on systems with many cores.



MIKE 21 FM speed-up using a HPC Cluster with distributed memory architecture (purple)

Hardware and Operating System Requirements

The MIKE 21 & MIKE 3 Flow Model FM Transport Module supports Microsoft Windows 7 Professional Service Pack 1 (32 and 64 bit), Windows 8.1 Pro (64 bit), Windows 10 Pro (64 bit) and Windows Server 2012 R2 Standard (64 bit). Microsoft Internet Explorer 9.0 (or higher) is required for network license management as well as for accessing the Online Help.

The recommended minimum hardware requirements for executing the MIKE 21 & MIKE 3 Flow Model FM Transport Module are:

Processor:	3 GHz PC (or higher)
Memory (RAM):	4 GB (or higher)
Hard disk:	160 GB (or higher)
Monitor:	SVGA, resolution 1024x768
Graphic card:	64 MB RAM (256 MB RAM or higher is recommended)

Support

News about new features, applications, papers, updates, patches, etc. are available here:

www.mikepoweredbydhi.com/Download/DocumentsAndTools.aspx

For further information on MIKE 21 & MIKE 3 Flow Model FM software, please contact your local DHI office or the support centre:

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Documentation

The MIKE 21 & MIKE 3 Flow Model FM models are provided with comprehensive user guides, online help, scientific documentation, application examples and step-by-step training examples.