

AN INTERACTIVE PROGRAM FOR THE INITIALIZATION OF AN AQUATIC ECOSYSTEM MODEL

Peeter ENNET^a and Nijad KIBAR^b

^a Estonian Marine Institute, Paldiski mnt. 1, EE-0001 Tallinn, Estonia; e-mail: peeter@sea.ee

^b National Council For Scientific Research, MRC, Jounieh, Lebanon; e-mail: rsensing@cnrs.edu.lb

Received 24 March 1997, in revised form 8 October 1997

Abstract. An interactive program applied in the user interface for the aquatic ecosystem model FinEst is presented. The aim of the interactive user interface is to make the complex aquatic ecosystem model flexible and easy to use and simulate different situations without any changes in the model code. The software for model grid creation and setting of initial fields of model state variables is a component of the user interface in the FinEst model. This software has common features and it can be used for any hydrodynamic or aquatic ecosystem model. As an illustration, the initialization of the model grid and the setting of the initial fields for model state variables for two regions in the southeastern part of the Mediterranean Sea are shown.

Key words: aquatic ecosystem model, interactive user interface.

INTRODUCTION

Mathematical modelling is widely used to describe physical and biochemical processes in an aquatic ecosystem, to analyse the state of the environment, and to find ways how to manage our marine resources in the future.

In this paper an interactive program used in the user interface for the aquatic ecosystem model FinEst is presented. The main principles of the FinEst model were published by Tamsalu & Ennet (1995). The aim of the interactive user interface is to make the complex aquatic ecosystem model flexible and easy to use and simulate different situations without any changes in the model code. This interactive dialogue gives user-friendly support during model initialization and

visualization. It offers information on the model, allows the user to set the model state variables, coefficients, and initial conditions, to choose the model input/output parameters, to change the structure of the model (user can choose different methods to describe chemical and biological processes, to include/exclude bottom sediments, to choose the list of model state variables), to continue the run of some previously used version, to visualize the results, etc.

The software for model grid creation and setting initial fields of model state variables is as a component of the user interface in the FinEst model. This software has common features and it can be used for any hydrodynamic or aquatic ecosystem model. The software is written in C and FORTRAN languages. In this paper, as illustration, the initialization of a model grid and setting the initial fields for model state variables for two regions in the southeastern part of the Mediterranean Sea are shown.

MAIN PRINCIPLES OF THE AUTOMATIC GRID CREATION PROGRAM

To apply the model in a new area, one of the first tasks is to develop the horizontal grid of the model. The program of the automatic grid creation, presented in this paper, can be used separately or as a subroutine inside the main user interface of the model. For example, to use this program of automatic grid creation in the FinEst model user interface, we choose item "Set" in the main dialogue panel and then we select "Grid creation" (Fig. 1).

In Fig. 2 the principal scheme of the program for the creation of the horizontal orthogonal model grid with interpolated depths is shown. The program has an interactive user interface, which makes it easy to introduce the grid parameters and to correct the results.

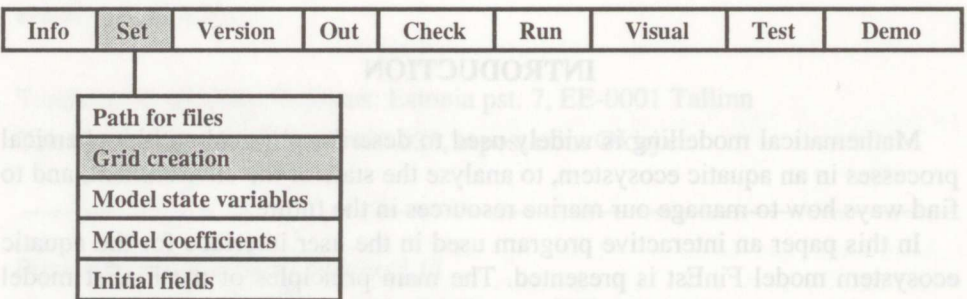


Fig. 1. Selection of automatic grid creation in the FinEst model user interface.

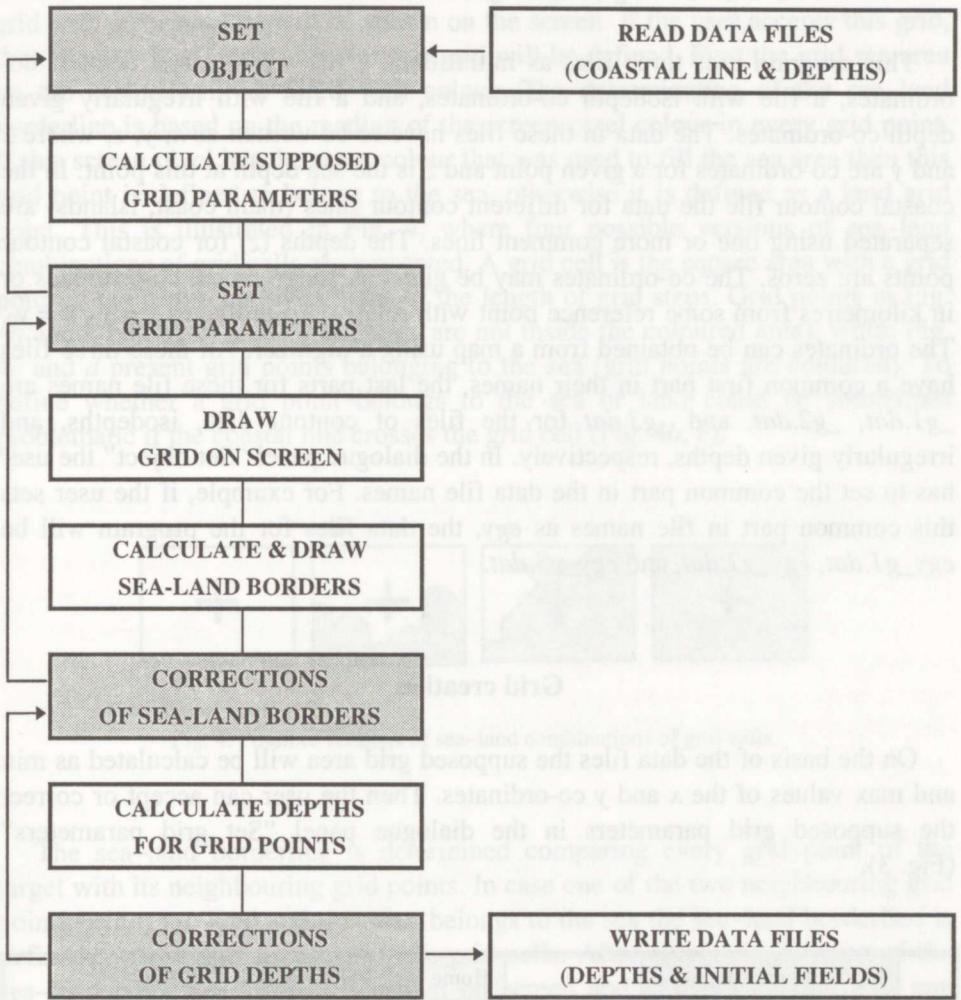


Fig. 2. Principal scheme of the program for the model grid creation. Program parameters can be evaluated and corrected in shaded boxes. The arrows show where the user can go to some previous program dialogue panel.

The data introduced by the user will be checked and in case of logical errors the error message will appear on the screen. In the first dialogue page the user gives the common part of file names.

Setting of the object and initial data

This program uses three files as initial data: a file with coastal contour co-ordinates, a file with isodepth co-ordinates, and a file with irregularly given depth co-ordinates. The data in these files have to be written as x, y, z , where x and y are co-ordinates for a given point and z is the sea depth at this point. In the coastal contour file the data for different contour lines (main coast, islands) are separated using one or more comment lines. The depths (z) for coastal contour points are zeros. The co-ordinates may be given as geographical co-ordinates or in kilometres from some reference point with relative co-ordinates $x = x_0, y = y_0$. The ordinates can be obtained from a map using a digitizer. All these three files have a common first part in their names, the last parts for these file names are *_g1.dat*, *_g2.dat*, and *_g3.dat* for the files of contour data, isodepths, and irregularly given depths, respectively. In the dialogue panel "Set object" the user has to set the common part in the data file names. For example, if the user sets this common part in file names as *egy*, the data files for the program will be *egy_g1.dat*, *egy_g2.dat*, and *egy_g3.dat*.

Grid creation

On the basis of the data files the supposed grid area will be calculated as min and max values of the x and y co-ordinates. Then the user can accept or correct the supposed grid parameters in the dialogue panel "Set grid parameters" (Fig. 3).

Next dialogue page	Home	PgUp	PgDn	End
Set grid parameters				
Grid step, km	12.00			
Grid start in X-direction, km	0.00			
Grid start in Y-direction, km	0.00			
Grid end in X-direction, km	600.00			
Grid end in Y-direction, km	192.00			

Fig. 3. Dialogue panel "Set grid parameters".

After the grid parameters are set in the dialogue panel “Set grid parameters”, a grid with a coastal line will be shown on the screen. If the user accepts this grid, then the sea–land borderline for this grid will be defined. First the grid sea area on the screen will be filled with colour. The determination of the sea–land borderline is based on the reading of the screen pixel colour in every grid point. If this screen pixel has the same colour that was used to fill the sea area then this grid point is defined to belong to the sea, otherwise it is defined as a land grid point. This is illustrated in Fig. 4, where four possible versions of sea–land combinations of grid cells are presented. A grid cell is the square area with a grid point in the centre and with sides of the length of grid steps. Grid points in Fig. 4a and b belong to land (grid points are not inside the coloured area), while Fig. 4c and d present grid points belonging to the sea (grid points are coloured). To define whether a grid point belongs to the sea or land could be sometimes problematic if the coastal line crosses the grid cell (Fig. 4b, c).

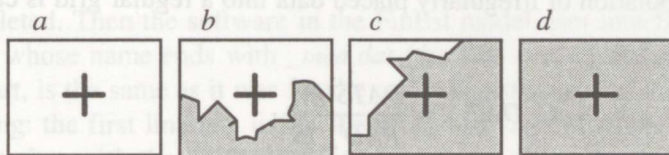


Fig. 4. Possible versions of sea–land combinations of grid cells.

The sea–land borderline is determined comparing every grid point of the target with its neighbouring grid points. In case one of the two neighbouring grid points belongs to land and the other belongs to the sea the sea–land borderline is defined as the common side of these grid cells. After automatic defining of the sea–land borderline it will be drawn on screen and if necessary the user can easily correct this borderline on the screen.

Interpolation of depths from irregularly given data into the regular grid

Inside the grid area the depth data are interpolated for every grid point. The area around the target grid point is divided into four quadrants. In every quadrant the N (the value of N can be changed in program) closest to the target grid point is searched. The smallest number of N is 1 (1 data point in every quadrant around the target point). Figure 5 explains why data from the four quadrants around the target point are chosen. In every quadrant around the target grid point X we are looking for N irregularly placed data points closest to the target point.

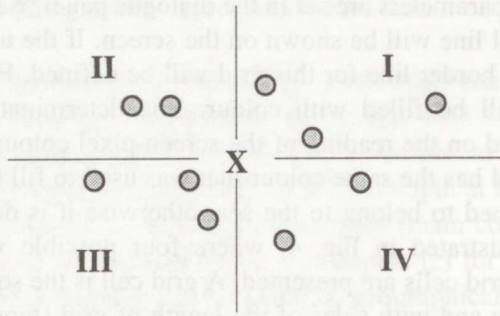


Fig. 5. Irregularly placed data points around the target grid point X.

The interpolation of irregularly placed data into a regular grid is calculated as follows:

$$G_DAT_{I,J} = \frac{DATSUM}{RAD_IS}, \quad (1)$$

where $G_DAT_{I,J}$ is the interpolated value for the regular grid point I,J ;

$$DATSUM = \sum_{L=1}^4 \sum_{M=1}^N \frac{RAN_DAT_{M,L}}{(R_IDK_{M,L})^P}, \quad (2)$$

- where
- L quadrant, $L = 1, 2, 3, 4$
 - N depth data taken into account in every quadrant
 - P weight factor
 - $RAN_DAT_{M,L}$ value of a random data point M in the quadrant L from the regular grid point I,J
 - $R_IDK_{M,L}$ distance of randomise data point M in the quadrant L from the regular grid point I,J

and

$$RAD_IS = \sum_{L=1}^4 \sum_{M=1}^N \frac{1}{(R_IDK_{M,L})^P}. \quad (3)$$

This method of interpolation is used also for handling the FinEst model input data and for plotting and visualization of model results. Some other method of interpolation can also be used inside this program (e.g., the method of splines,

described by Vager & Serkov, 1987). After interpolation the user can see the results on the screen with numerical values of the interpolated depths in grid points. If necessary, the user can correct the interpolated depths. After the user has accepted the grid, the interpolated depths will be written into a file as a matrix where in the sea grid points are the depths and in the land grid points are zeros. Also a file with the sea-land mask for a chosen grid area will be created.

INITIAL FIELDS FOR THE MODEL STATE VARIABLES

An aquatic ecosystem model has numerous state variables (physical variables like water temperature, salinity, etc.; chemical variables like phosphorus and nitrogen compounds; biological variables like autotrophs and heterotrophs, etc.). The initial fields of these model state variables can be set on the basis of measurement data. To set the initial fields, first the creation of the model grid has to be completed. Then the software in the FinEst model user interface will look for the file whose name ends with *_mea.dat* (the first part of the file name, the common part, is the same as it was for the grid). The structure of this data file is the following: the first line is a list of the measured variables and then one line for every station with the date, measurement station co-ordinates (in the same co-ordinate system as the grid data files), and measurement results. The measurement results will be interpolated into the model grid. Choosing in the user menu in the panel "Set" the item "Initial fields" (Fig. 1), the user will get on the screen a list of variables from this measurement data file. After selecting the name of a measured variable on the screen the distribution of this parameter inside the model grid area will be seen. These interpolated into the model grid data can be used as the initial field for this model state variable.

RESULTS

Below, as illustration, the results of using this software for two areas are presented. In the first example the application of the FinEst model in the southeastern part of the Mediterranean Sea is presented. For the creation of the model grid the grid parameters were set as in Fig. 3. The reference point ($x = 0$; $y = 0$) for the grid co-ordinates was chosen as the lower left grid corner point with geographical co-ordinates 29.0° E and 20.7° N. On the basis of the coastal line co-ordinates, the model grid (with 50×16 grid points) was created as shown in Fig. 6.

In Fig. 7 the sea depths inside the model grid sea area are presented. These depths were calculated using interpolation of sea depths taken from a map as irregularly given data.

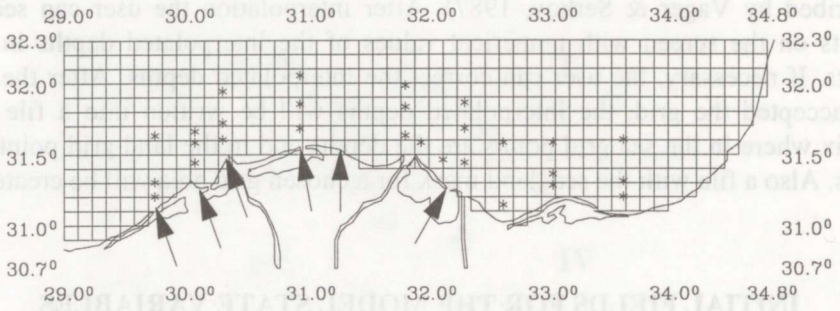


Fig. 6. Model grid created for the Mediterranean coast of Egypt. The arrows show the load sources and stars designate the locations of measurement stations.

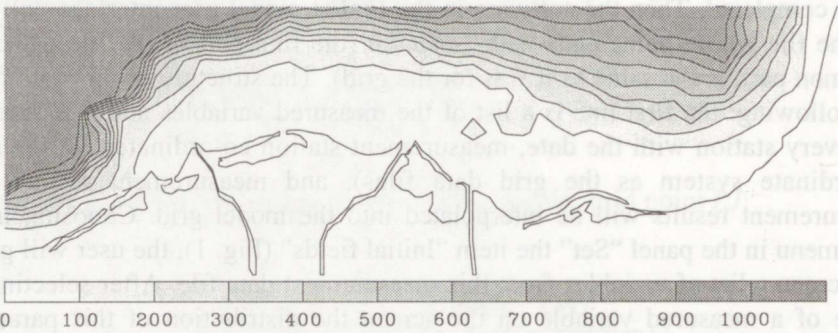


Fig. 7. Calculated sea depths (m) inside a model grid. The isodepths are given with a 100 m interval up to 1000 m.

For setting model state variables we used the results of the measurements carried out at the Alexandria University (Dowidar, 1988).

As an example of setting the initial fields of model state variables the distribution of chlorophyll *a* concentrations in spring inside a model grid is presented in Fig. 8. The initial fields in Fig. 8 were created using measurement results. The locations of stations where measurements were made are shown in Fig. 6.

In the other example the influence of grid parameters on the efficiency of the chosen model grid is demonstrated applying this software for the Lebanese coastal area between Beirut and Tabarja (Fig. 9). Two model grids, created for this area, are compared in Fig. 10. As initial data the same files (coastal line coordinates, isodepths, and irregularly given depths) were used. These two grids

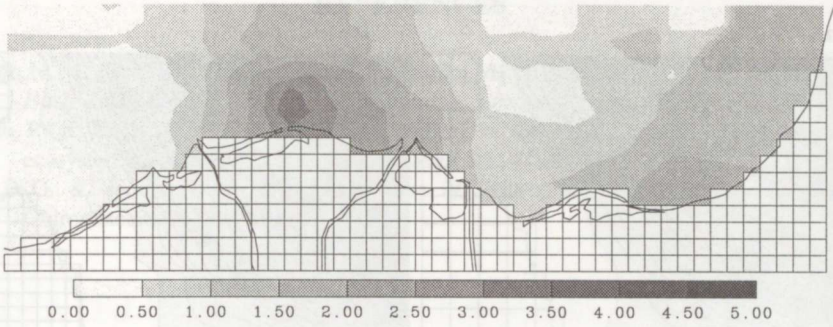


Fig. 8. Distribution of chlorophyll *a* (mg Chl *a*/m³) inside a model grid.

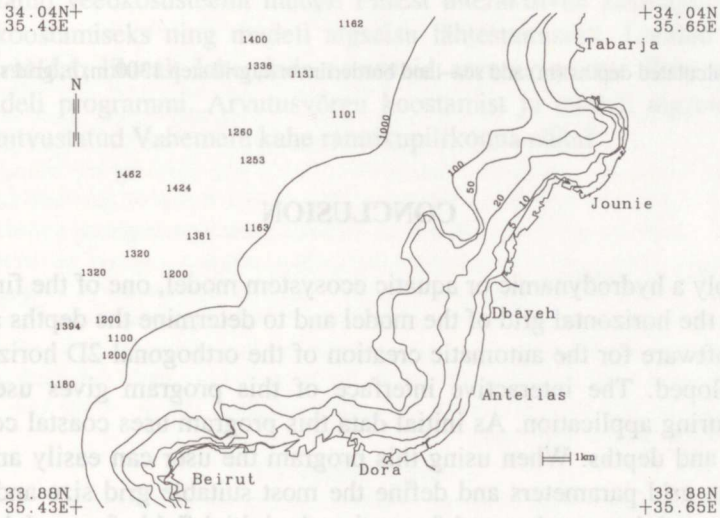


Fig. 9. Lebanese coastal area between Beirut and Tabarja.

cover the same area and the only difference was in the grid step (1300 m for grid in Fig. 10a and 650 m for grid in Fig. 10b). The calculated isodepths are quite similar to original depths in case of both grid steps; however, with increasing grid step some details of the bottom topography will be lost. The same is true for defining the sea-land borderline and determination of initial fields: to include in the model detailed information it is necessary to decrease the grid step. When using this program the user can easily find the most suitable model grid size and location.

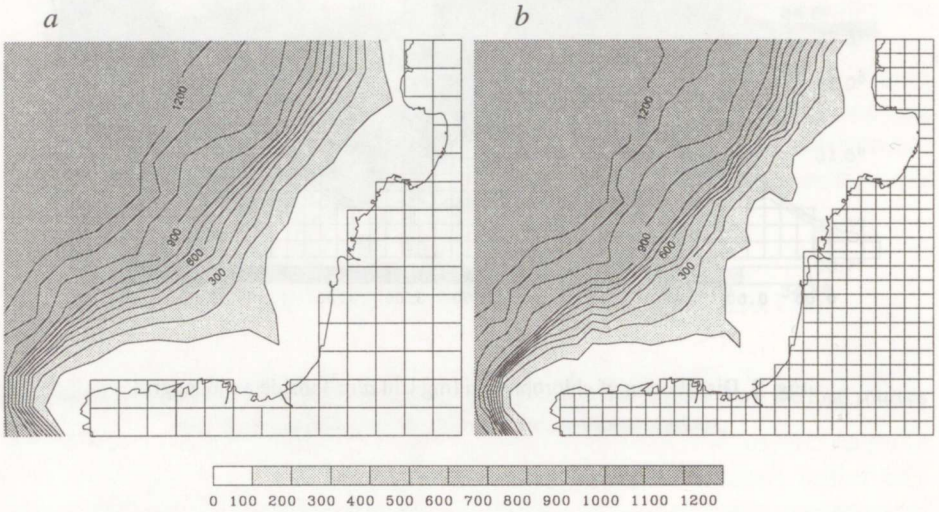


Fig. 10. Calculated depths (m) and sea-land borderlines: *a*, grid step 1300 m; *b*, grid step 650 m.

CONCLUSION

To apply a hydrodynamic or aquatic ecosystem model, one of the first tasks is to choose the horizontal grid of the model and to determine the depths at the grid points. Software for the automatic creation of the orthogonal 2D horizontal grid was developed. The interactive interface of this program gives user-friendly support during application. As initial data this program uses coastal contour coordinates and depths. When using this program the user can easily and quickly modify the grid parameters and define the most suitable grid size and location. Also measured data can be used for setting the initial fields for model variables. This program has common features and it can be used for any hydrodynamic or aquatic ecosystem model.

ACKNOWLEDGEMENT

This software was developed in the International Centre for Scientific Culture, ICSC -World Laboratory, within the Project LAND-3 "Protection of the Coastal Marine Environment in the South Mediterranean Sea".

REFERENCES

- Dowidar, N. M. 1988. Productivity of the Southeastern Mediterranean. In *Natural and Man-Made Hazards* (El-Sabih, M. I. & Murty, T. S., eds.). Alexandria University, 477–498.
- Tamsalu, R. & Ennet, P. 1995. Ecosystem modelling in the Gulf of Finland. II. The aquatic ecosystem model FinEst. *Estuar. Coast. Shelf Sci.*, **41**, 429–458.
- Vager, B. G. & Serkov, N. K. 1987. *Application of Splines in Meteorology and Hydrology*. Gidrometeoizdat, Leningrad.

VEEÖKOSÜSTEEMI MUDELI DIALOGLÄHTESTAMISE PROGRAMM

Peeter ENNET ja Nijad KIBAR

On esitatud veeökosüsteemi mudeli FinEst interaktiivne kasutajaliides arvutusvõrgu koostamiseks ning mudeli algseisu lähtestamiseks. Loodud tarkvarapakett võimaldab lihtsalt lahendada erinevaid arvutusvariante ilma vajaduseta muuta mudeli programmi. Arvutusvõrgu koostamist ja mudeli algseisu lähtestamist on tutvustatud Vahemere kahe rannikupiirkonna näitel.