

A GIS pre-processor for pollutant transport modelling

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Abstract

A GIS pre-processor was developed to produce bathymetric grids and shorelines for open and closed boundary as input to a three-dimensional hydrodynamic/pollutant transport model to simulate the currents and pollutant transport in lakes and coastal areas. The pre-processor operates within ArcView GIS and can read hydrographic files in different formats. The use of this GIS module facilitates the implementation of different pollutant transport scenarios, which in turn can significantly contribute to the decision-making process concerning one of the most contemporary environmental problems. The applicability of the pre-processor is illustrated through a case study on Suda Bay, located in Crete, Greece.

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Keywords: GIS; ArcView; Tecplot; 3D Hydrodynamic model; Pollutant transport

Software availability

Name of software:	Digital Bathymetry Model (DBM)
Developer:	S. Naoum and I.K. Tsanis
First available:	May 2003
Hardware requirements:	PC
Software requirements:	ArcView GIS 3.2
Program language:	AVENUE
Program size:	1000 lines
Availability:	free

1. Introduction

Most of today's models require as input a gridded dataset giving a complete model of the spatial distribution of each input parameter. Along the same line, numerical grid generation is becoming a fairly common tool for use in the numerical solution of partial differential equations on arbitrarily shaped regions. It is the function of the grid to make the best use of the number

of points (sampling stations) that are available. Numerically generated grids have provided the key to removing the problem of boundary shape from finite difference methods. The numerical solution of partial differential equations requires some discretization of the field into a collection of points or elemental volumes (cells). The discretization must conform to the boundaries of the region in such a way that boundary conditions can be accurately represented (Thompson et al., 1985). Geographic Information Systems (GIS) are considered to be efficient tools for this specific purpose by using the Barrier argument to specify the location of linear features (such as shorelines) to interrupt the surface (such as a depth grid) continuity. Barriers are set to limit the input sample points used to interpolate the depth values to only those samples on the same side of the barrier. Input sample points that lie exactly on the barrier line are included in the sample set for both sides of the barrier. However, when barriers are specified, processing time is significantly extended.

In this paper, an ArcView GIS project is developed and used to prepare ASCII input files representing the bathymetric grid and shorelines necessary for running the 3D hydrodynamic/pollutant transport model and for post-processing purposes (represented in this case by the graphics package Tecplot for visualizing). The

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depths of the different locations in the domain are spatially interpolated from contours and/or spot depths. This GIS pre-processor helped to overcome the problems encountered when using conventional methods. In addition to saving time in generating input files, it provides higher spatial accuracy, since all themes are geographically referenced, which eliminates the possibility of overlapping or misplacing. It also shows great flexibility in generating grids of different cell sizes, interpolation techniques, and spatial extents. These elements are vital for research, such as trial and repetition, to better evaluate results. Transferability of the project between users and terminals makes it accessible, and, consequently, more favorable. The AVENUE scripts (ArcView programming language) provide the continuous potential for development by customizing the project according to the need. In addition, this language also provides a menu-driven graphic interface, which makes it possible to guide a user with prompts and explanations throughout the application. ArcView Extensions, such as Dialog Designer and Spatial Analyst, are loaded at the start of the ArcView project, adding more functions and enabling users to create their own dialogs and deal with grids, surfaces, and TINs.

2. ArcView GIS project

The ArcView project, in its basic format, is a collection of views, tables, scripts, layouts, and charts. The saved project, with all its contents, is transferable under the condition that the source location of the themes displayed in the views is transferred along with it. Upon opening the project, all information is retrieved and redisplayed in the same fashion.

The GIS module developed can read digital hydrographic files, which represent the definition of the bathymetry of the computational domain. Since the hydrographic files are in decimal degrees (geographic projection), projecting them in the appropriate projection is the first step in order to properly link all details and any additional information. Upon completing projection, the files are: (1) converted to ArcView shapefiles; (2) filtered to remove any information that, for this application, is deemed irrelevant (for example, rivers); (3) edited to fix any errors and erase any unnecessary features (i.e. moving any spot depths points to inside the shoreline, trim shoreline, ... etc.); and (4) manipulated to match the desired features by the module to generate grids (i.e. convert contours to points, convert shoreline from polygon to polyline, merge islands and shoreline, ... etc.).

The written scripts are then run consecutively to perform the grid generation, which has also been designed to prompt the user with dialogs and messages for guid-

ance and interaction. The depth grids may be defined for either a subarea or the full extent of the available input data. They can also be generated for open or closed boundary conditions. The module also allows the user to specify both the grid cell size and the type of interpolation technique.

After collecting all necessary information from the user through prompts and messages, the program starts executing the task of generating the depth grid. The execution time depends exclusively on the type of interpolation technique used, the extent of the area, and the cell size. Larger areas and smaller cell size definitely increase execution time. Kriging interpolation, for example, normally requires more time than Spline and IDW. The user is informed of the completion of the operation when a message is displayed on the screen. The ASCII file is then generated, together with a visual presentation of the grid. Finally, another process initiates by running a series of ArcView scripts that convert the shoreline (including islands, if they exist) to points separated at user-specified spacing. The text file is then generated.

3. 3D hydrodynamic/pollutant transport model

The IDOR3D hydrodynamic/pollutant transport model is a multi-layer research model that has been developed at McMaster University and has been successfully applied to many areas, such as Lake Ontario (Shen et al., 1995) and Hamilton Harbor (Tsanis and Wu, 2000). Shen et al. (1995) concluded that IDOR3D was able to reproduce wind-induced horizontal circulation and the vertical structure in large water bodies such as Lake Ontario. Predictions of lake circulation patterns and conductivity were in good agreement with field measurements. In another study, Tsanis and Wu (2000) stated that field data collected in the Hamilton Harbor case was used for model calibration and verification of IDOR3D. The simulated currents were compared with current-meter data and the simulation results were in good agreement with the drogoue experimental data. These comparisons demonstrated that IDOR3D can simulate the major features of the water currents and level changes in Hamilton Harbor.

3.1. Governing equations

Three-dimensional governing equations for wind-induced circulation were derived from the Navier–Stokes equations by using the following assumptions:

- Shallow water assumption: the vertical accelerations are small enough to be ignored, which results the hydrostatic pressure distribution.

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