APPLICATION OF GID TO GENERATE THE 3D FINITE ELEMENT MESH FOR THE STUDY OF MARINE CIRCULATION IN THE BAY OF BISCAY

Arnel L. German*, Manuel Espino*, Jordi Blasco†, Manuel Maidana*, Enrique Escolano and Miguel Pasenau****

*Laboratory of Maritime Engineering (LIM)
Universidad Politécnica de Cataluña
Campus Nord UPC, 08034 Barcelona, Spain
e-mail: arnel.german@upc.edu , web page: http://lim-ciirc.upc.es/

† Department of Applied Mathematics I
Universidad Politécnica de Cataluña
Campus Sud UPC, 08028 Barcelona, Spain
e-mail: jorge.blasco@upc.edu , web page: http://www.ma1.upc.edu/˜blasco

**International Center for Numerical Methods in Engineering (CIMNE)
Universidad Politécnica de Cataluña
Campus Nord UPC, 08034 Barcelona, Spain
e-mail: escolano@cimne.upc.edu , web page: http://www.cimne.com/

Key words: Unstructured Mesh Grid, Finite Element Mesh, Vertical Triangular Prism Generation

Abstract. *A 3D finite element mesh has been generated using GID to study the marine circulation in the Bay of Biscay. The surface of the study domain is discretized using unstructured mesh consisting of triangular elements. The triangular elements are then projected vertically to the bottom of the study area to generate vertical triangular prism columns. The lateral faces of the generated prismatic elements are vertical while the superior and inferior bases are not necessarily horizontal. The resulting computational grid describes faithfully the geometric complexities of the study area and at the same time, it complies with the numerical requirements of the ocean model.*

1 INTRODUCTION

Mesh generation is vital in computational field simulation of ocean dynamics because it has a tremendous influence in its accuracy and efficiency. In this context, mesh generation becomes a crucial step in numerical simulation and people from various backgrounds are working to develop meshing software models capable of generating both structured and unstructured meshes. Structured meshes, characterized by its regular connectivity, are ideal for finite difference because this numerical method can take advantage of the regular nature of the grid for fast identification of neighboring cells. Unstructured meshes which have irregular cell arrangements are ideal for finite element simulation of irregular domains and complex geometries similar to coastal areas. With the recent advances in algorithm and computer hardware, unstructured mesh approach has been used for a wide range of ocean dynamics field simulation with better computational accuracy and cost[i,ii,iii].

In this paper, the generation of a three dimensional finite element mesh for a marine environment using GID is presented. In Section 2, we present the geometric requirements and numerical constraints that will govern the mesh construction. Section 3 discusses the methodology used by GID to generate the horizontal and vertical ocean mesh. Some results are presented in Section 4 while Section 5 enumerates the conclusion.

2 STATEMENT OF THE PROBLEM

The objective of this work is to generate a spatial discretization which approximates the geomorphological characteristics of the Bay of Biscay (Figure 1) and complies with the constraints of the governing equation of the numerical model.

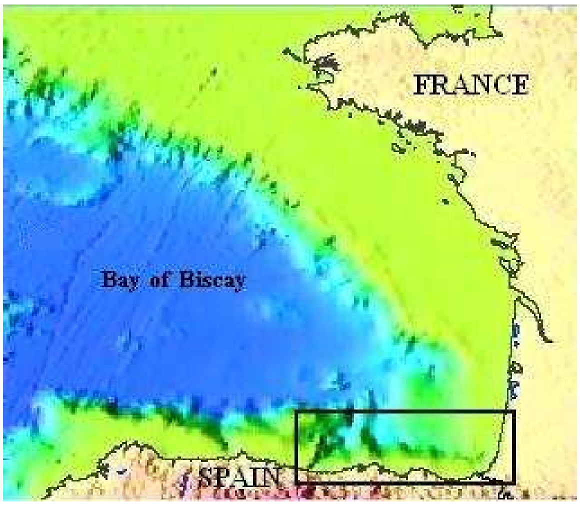

Figure 1: The Bay of Biscay with the location of the study area enclosed in a box

The mesh generation starts with the surface that describes the extent of the domain. While surface grid generation is a simple process, the uneven coastline of the bay has to be represented. The generated surface mesh is extended in 3D and considers the complex bathymetry of the bay in volume mesh generation. The bathymetry is very uneven due to the presence of canyons, sea cliffs and sea mounts.

Volume grid generation can be done using different three dimensional elements but the construction of the mesh in 3D must be given special attention especially with regards to the type of hydrodynamic problem being resolved. Normally for rigid-lid type oceanic problems, 3D mesh generation is constructed using tetrahedral or hexahedral elements. But in barotropic problems, where the free surface elevation is accounted for, or in baroclinic problems where horizontal gradients of density are important, vertical triangular prism elements are needed. For the latter case, the presence of the barotropic term involves volume integral of the product of the derivative of the bidimensional surface shape function and the tridimensional volume shape function. The computation of this integral is done elementwise and this is feasible only if the elements are ordered and stored in vertical columns[iv].

Considering these criteria, the target volume discretization of the study area is an unstructured three dimensional mesh with the horizontal surface, composed of triangles of various dimensions adapted to the irregular geometry of the coastline and for the vertical, layers of vertical triangular prisms.

3 MESH GENERATION

The starting point of mesh generation is the given surface representation of the Bay of Biscay. The underlying principle used by GiD[v], the software used to generate the mesh, is the advancing front method which is widely used for generating triangle and tetrahedral meshes.

The construction of the 3D mesh is done by dropping vertically each node of the previously generated triangles until it reaches the bottom as shown in Figure 2. All lateral faces of the resulting triangular prisms must be vertical to comply with the numerical requirements of barotropic and baroclinic problems. The superior and inferior bases of the generated triangular prisms are not necessarily horizontal.

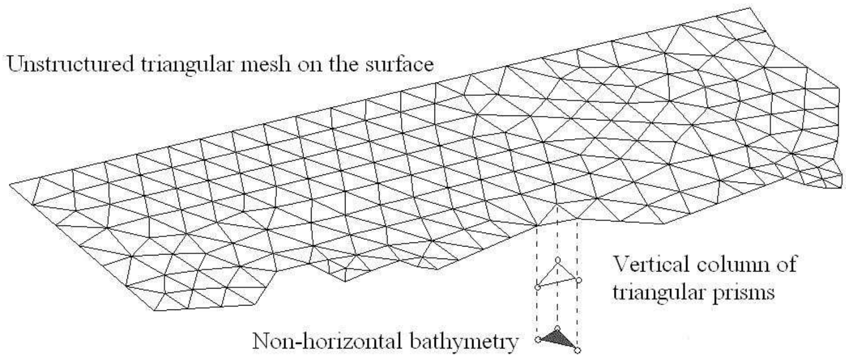

Figure 2: Volume generation using columns of vertical prisms

4 APPLICATIONS

In this section, some initial applications are presented to show the efficiency of the generated 3D mesh. The grid used is composed of 51,996 elements, 33,235 nodes and has four vertical layers. It is utilized to interpolate the initial conditions of temperature, salinity and water density in the Bay of Biscay. These parameters are interpolated in all nodes of the computational grid using known sets of data gathered from specific reading stations. The results for the bottom layer interpolations are shown in Figure 3 together with the computational grid.

5 CONCLUSIONS

An unstructured finite element mesh of the ocean topography of the Bay of Biscay has been presented in this paper. The computational grid is generated using advancing front method to discretize the surface into triangles and the vertical mesh is composed of vertical triangular prisms. The resulting computational grid describes more precisely the geometric complexities of the study area and at the same time, it complies with the numerical requirements of the ocean model. For this reason, it is expected that during the simulation of the marine circulation in the Bay of Biscay, the mesh will be an efficient tool to accurately represent this complex phenomena.

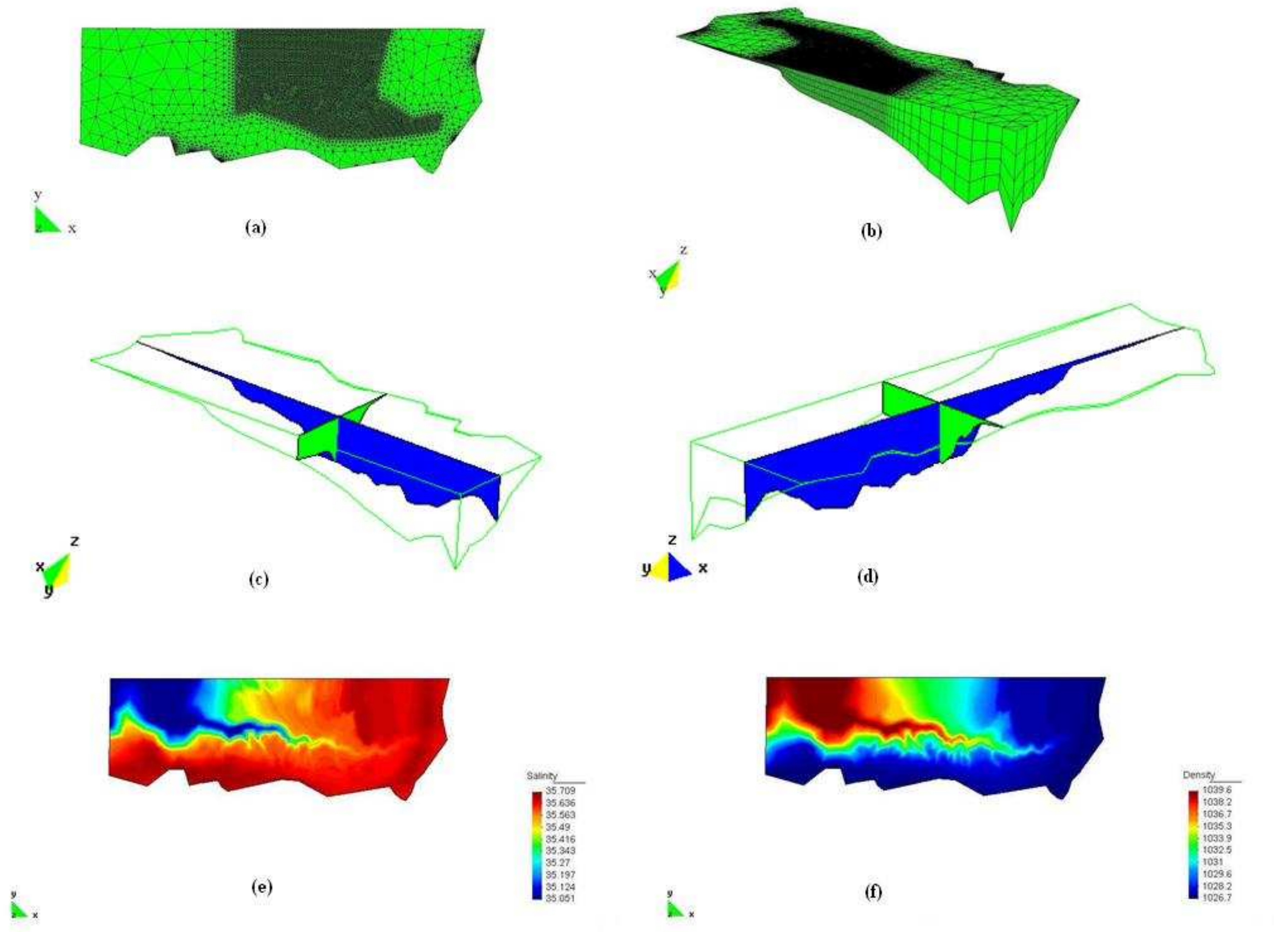

Figure 3: The Bay of Biscay Model: (a) 3D computational mesh; (b) Isometric view; (c) Rear cross section; (d) Front cross section; (e) Salinity and (f) Density at the bottom of the bay

REFERENCES

[i] R.J. Labeur and J.D. Pietrzak. “A fully three dimensional unstructured grid non-hydrostatic finite element coastal model”, *Ocean Modelling*, **10**, 51-67 (2005).

[ii] R.A. Walters. “Coastal ocean models: two useful finite element methods”, *Continental Shelf Research*, **25**, 775-793 (2005).

[iii] R.A. Walters. “Design considerations for a finite element coastal ocean model”, *Ocean Modelling*, **15**, 90-100 (2006).

[iv] M.A. Maidana, *Desarollo de un modelo numérico en elementos finitos para las ecuaciones de Navier-Stokes. Aplicaciones oceanográficas.* Tesis doctoral UPC, (2007).

[v] CIMNE, *GiD the personal pre and postprocessor Reference Manual Version 8*.