CME 193 Final Project Write Up

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Introduction

Nowadays numerical simulation method has already become one of the most common ways to study hydrodynamic problems of ocean, estuaries and rivers. Compared to physical experiments and field measurements analysis, numerical modeling method is more effective to study ocean problems with different scenarios with less cost and more flexibility. While being applied to simulate free surface and velocity field under varied conditions, hydrodynamic model is further extended to simulate the problem of salinity or contaminant transport, and even sediment transport. Therefore, for this final project, we will generate a python code to simulate 2D (x,z) flow problem with the modeling of velocity field and passive scalar field under tidal and inflow boundary conditions.

Numerical Model

In order to simulate 2D flow, a simplified two-dimensional Navier-Stokes equations with the Boussinesq approximation are solved by this final projects.

$$\frac{\partial u}{\partial t} = -\frac{g}{\rho_0}\frac{\partial h}{\partial x} - \frac{\partial}{\partial z}(\nu_v \frac{\partial u}{\partial z}) \tag{1}$$

$$\frac{\partial u}{\partial x} + \frac{\partial w}{\partial z} = 0 \tag{2}$$

$$\frac{\partial h}{\partial t} + \frac{\partial}{\partial x}(\int_{-d}^{h} u\, dz.\ ) = 0 \tag{3}$$

$$\frac{\partial s}{\partial t} + u\frac{\partial s}{\partial x} + w\frac{\partial w}{\partial z} = \frac{\partial}{\partial z}(\nu_s \frac{\partial s}{\partial z}) \tag{4}$$

in which u represents horizontal velocity, h is the free surface height, d denotes the water depth, g is gravity acceleration, ρ_0 denotes water density, ν_v represents the vertical momentum diffusion coefficient, s represents the passive scalar concentration in water, x, z are the two dimensional coordinate and t is time. These simplified equations ignore momentum advection, coriolis force, hydrodynamic pressure, baroclinic pressure and horizontal momentum and scalar diffusion, because these terms are all negligible for a two-dimensional channel flow problem. All the equations are discretized and solved according to the SUNTANS model (Fringer, 2006).

Code Setup

This final project includes six files, including 2dflow.py, grid.py, phys.py, scalar.py, initial.py and boundary.py. They have different functionalities:

(1) 2dflow.py: The main function of all codes with input of basic parameters including channel length, grid resolution, time step size and the number of total time steps.

(2) grid.py: Generate the grid information to discretize the calculation domain.

(3) phys.py: The primary function includes the main loop to calculate free surface height, velocity and scalar field for different time steps. It will also plot the final results.

(4) scalar.py: Solve the passive scalar transport equation (4) to get the new scalar field.

(5) initial.py: Setup the initial condition for the domain.

(6) boundary.py: Setup the boundary condition for the domain.

Example Results

In this section, I use an example problem to illustrate the functionality of this project. In the example problem, I assume the downstream of a river channel is the ocean with tides, while the upstream of the channel is closed without any inflow or outflow. All the parameters are shown in Table 1. L represents channel length, nc and nk are the number of horizontal and vertical cells, T denotes tidal period, dt is time step size, s_0 is the scalar concentration of ocean side. At first, there is no passive scalar in the whole channel. However, during spring tide, passive scalar in the ocean side will be transferred into the channel. Fig. 1 and Fig. 2 clearly illustrate the results for initial condition and at 0.375 tidal cycle.

Parameter	L	nc	nk	T	dt	s_0
Value	$10km$	100	10	$1hr$	$1s$	1

Table 1: Parameters for the example problem

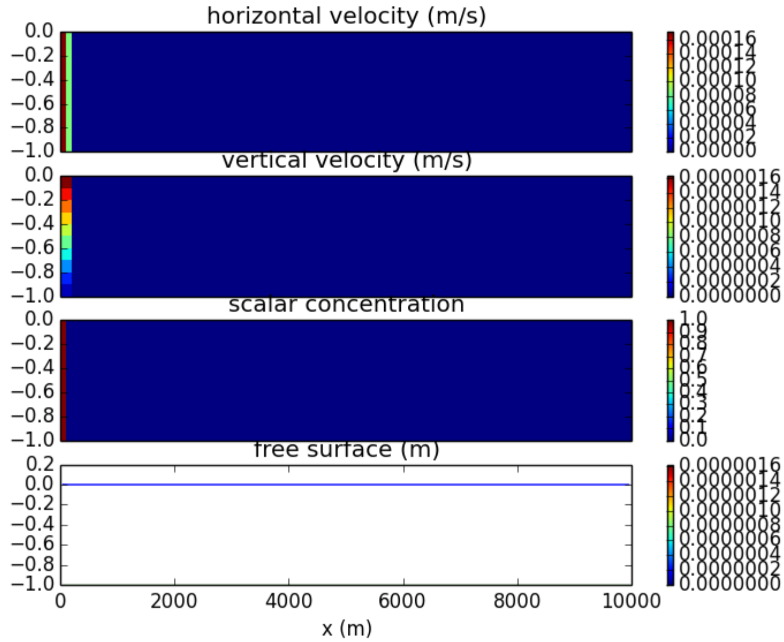

Figure 1: The results for the example problem for initial condition

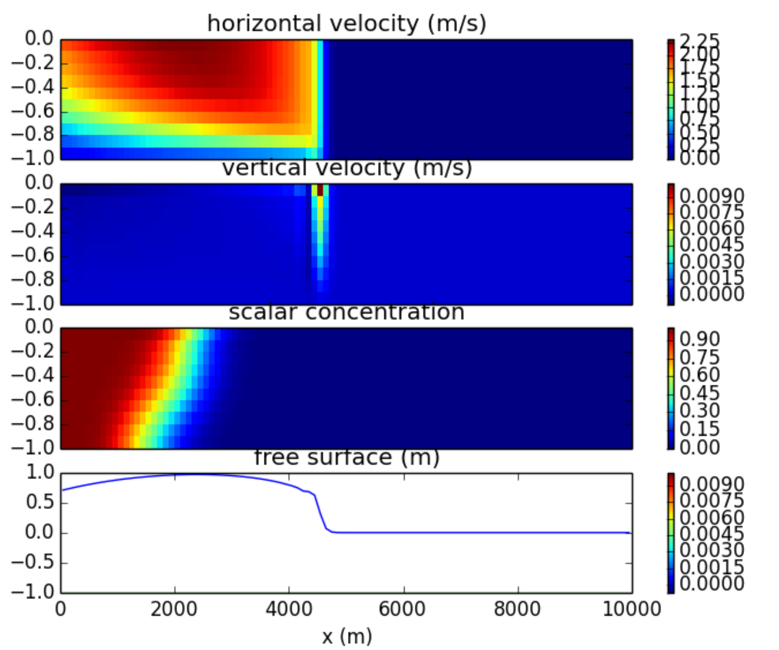

Figure 2: The results for the example problem after 0.375 tidal cycle.

Reference

Fringer, O., M. Gerritsen, and R. Street (2006), An unstructured-grid, finite-volume, nonhydrostatic, parallel coastal ocean simulator, *Ocean Modell.*, 14, 139-173.