II - 94 Simulation of the Dynamical Processes in the Opunohu Bay

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1. Introduction. A numerical model was applied to simulate the dynamical processes in the Opunohu Bay, Moorca (Figure 1). The three-dimensional Navier-Stokes equations were solved together with transport equation of heat and salinity by a Multi-layered model. The real upper boundary conditions with the absorption of net radiation at the surface, the turbulent transfer of sensible heat, and latent heat together with the wind drag were incorporated.

2. Governing Equations. The governing equations are the Navier-Stokes equations and equations of the transport of heat and salinity written in tensor form as follows

$$\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} + = -\frac{1}{\rho}\frac{\partial P}{\partial x_i} + K_{mj}\frac{\partial^2 u_i}{\partial x_j^2} + F_i \tag{1}$$

$$\frac{\partial u_j}{\partial x_j} = 0 \tag{2}$$

$$\frac{\partial S}{\partial t} + u_j \frac{\partial S}{\partial x_j} = K_{sj}\frac{\partial^2 S}{\partial x_j^2} \tag{3}$$

$$\frac{\partial T}{\partial t} + u_j \frac{\partial T}{\partial x_j} = K_{Tj}\frac{\partial^2 T}{\partial x_j^2} \tag{4}$$

where x_i and u_i are the Cartesian coordinates and corresponding velocity components respectively; t is the time, P the pressure, F_i the volume force related with the inhomogeneous distribution of temperature and salinity, S the salinity concentration of the salinity, T the water temperature and K_{mj}, K_{sj} and K_{Tj} are the eddy viscosity and diffusivities of salinity and temperature, respectively. The water density was considered dependent on the salinity and temperature $\rho = \rho(S,T)$. The static distribution of the pressure was assumed as follows

$$P = \rho g(\eta - z) \tag{5}$$

where η is the water surface elevation.

3. Numerical Solution. A numerical scheme was developed to integrate equations (1-4) to get the velocity, temperature and salinity field. First, the flow domain was divided into layers in the vertical direction. The governing equations then were integrated in the

direction. The governing equations then were integrated in the vertical direction in layers and the resulting equations were discritized on staggered grid (Patankar, 1980) in the horizontal directions. The use of the staggered grid can avoid the grid scale oscillation of the pressure field. A first order upwind scheme was used for the advection terms and an explicit scheme was used for the time. At every time step, the continuity was enforced by solving the integrated form of the continuity equation to get the free water surface elevation.

4. Initial and Boundary Conditions.

The free surface boundary condition is the heat and momentum flux. The heat fluxes at the surface are the absorption of net radiation, sensible and latent heat.

$$K_{Tz}\frac{\partial T}{\partial z} = Rn + LE + H \tag{6}$$

where Rn, LE and H are the net radiation, latent heat and sensible heat, respectively. The momentum flux is the wind drag force acting on the surface.

$$K_{mz}\frac{\partial V}{\partial z} = \rho_a C_D V_a^2 \tag{7}$$

where V is the water velocity vector, ρ_a the air density, C_D the drag coefficient and V_a the wind velocity, respectively. The initial temperature, salinity and velocity were obtained from the measured data.

5. Results and Discussions.

Figures 2 depicts the water velocity field at different depths during a storm with the wind blow in the offshore direction. In the surface layer there is an offshore flow due to the wind drag force while at the bottom a compensate inshore flow exists results in an uppwelling region in the nearshore.

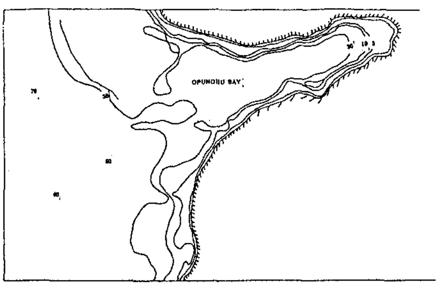

Figure 1. Opunohu Bay

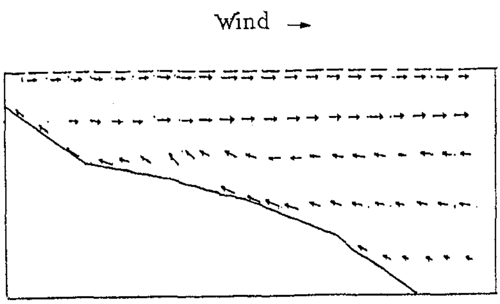

Figure 2. Velocity Field During a Storm

5. Reference.

Patankar S.V. 1980. Numerical Heat Transfer and Fluid Flow. Hemis. Pub. Corp. 197 pp.