PARALLELIZATION TECHNIQUES IN SEDIMENT TRANSPORT MODELING

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Abstract The Curvilinear Hydrodynamic 3-D (CH3D) model has been routinely applied for 3-D hydrodynamic and water quality modeling studies at the Engineering Research and Development Center (ERDC), Mississippi. The original Curvilinear Hydrodynamics in Three-Dimensions (CH3D) can be applied in two vertical resolution modes, Z-grid and Sigma–grid. The Z-grid version is documented in Johnson, et al (1991). The Sigma-grid version, used in this study, is documented in Chapman et al (1996). The basic single-block Sigma-grid model was developed by Sheng (1986) but has been extensively modified over the years, including the development of the Z-grid version. CH3D performs hydrodynamic computations on a non-orthogonal curvilinear or boundary-fitted curvilinear grid. The model solves the 3-D, Navier-Stokes equations with the hydrostatic assumption and the Boussinesq approximation for turbulence closure. The effects of temporal variation, inertia, Coriolis forces, wind stresses, bottom friction, pressure gradients, density gradients, and turbulent momentum fluxes are included in the momentum equations. The CH3D model was generalizing to include mobile-bed processes (such as aggradation and scour, bed-material sorting, and movement of both bedload and suspended load of non-uniform sediment mixtures) by Spasojevic and Holly (1994) under a joint effort by the Hydraulics Laboratory of the U.S. Army Corps of Engineers, Waterways Experiment Station, and the Iowa Institute of Hydraulic Research. The resulting CH3D model was called CH3D-SED. The model was implemented for application to mixed grain size sediments, with appropriate bed material sorting and armoring routines. A unique feature of the mobile bed model, single-block grid CH3D-SED, is the allocation of bed material load for transport as either bed load or suspended load.

The single-block grid CH3D-SED version was then developed to include the evaluation of suspended-sediment transport, bedload transport and the interaction between the two. This single-block grid technology, however, encounters difficulties in long computer processing time as well as large memory storage requirements. For an area with complicated coastlines, the number of active cells (water) used in the calculation is often much smaller than the number of inactive cells (land). To eliminate these problems, many techniques have been introduced over the years. Among these techniques, a combination of data decomposition and Message Passing Interface (MPI) has been used. In this work, a combination of the multi-block grid generation and MPI parallelization techniques was proposed. The advantages of the multi-block grid parallel version of CH3D-SED include 1) the flexibility of site specific horizontal and vertical grid resolution assigned to each grid block, 2) block specific application of the sediment transport, wave radiation stress gradient forcing and computational cell wetting/drying model options and 3) reduced memory and computational time requirements allowing larger computational domains and longer simulation time periods.

To demonstrate the advantages of the multi-block and parallelization capability, hydrodynamic and sediment transport simulations were performed utilizing the existing Berwick Bay, Louisiana computational domain. The purpose of this study was to analyze the shoaling issues on the

Atchafalaya River at Morgan City, LA. In addition, the study was to include testing of proposed solutions to the shoaling problem at Morgan City. Historically, the thalweg of the channel ran along the eastern side of the Atchafalaya River at Morgan City, LA; but in recent years the channel has migrated to the Berwick side of the river and the port on the Morgan City side of the river has begun to shoal heavily. As a result, shoaling requirements have risen significantly.

Comparisons of single-block and multi-block predictions of the velocity field, concentrations, and bed changes time series data at several locations within the model domain are presented. Comparison of wall-clock times and memory requirements between single-block and multi-block grids on several HPC computer systems will also be presented.

REFERENCES

Johnson, B. H., Heath, R. E., Hsieh, B. B., Kim, K. W., and H. L. Butler (1991). “Users Guide for a Three-dimensional Numerical Hydrodynamic, Salinity and Temperature Model of Chesapeake Bay,” Technical Report HL-91-20, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Chapman, R. S., Johnson. B. H., and S. R. Vemulakonda. (1996). “Users Guide for the Sigma Stretched Version of CH3D-WES; A Three-Dimensional Numerical Hydrodynamic, Salinity and Temperature Model,” Technical Report HL-96-21, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Sheng, Y. P. (1986). ``A Three-dimensional Mathematical Model of Coastal, Estuarine and Initials Lake Currents Using Boundary Fitted Grids," Report No. 585, A. R. A. P. Group of Titan Systems, Princeton, NJ.

Spasojevic, M., and Holly, F. M. (1994). ‘‘Three-dimensional numerical simulation of mobile-bed hydrodynamics.’’ *Contract Rep*. *HL-94-2*, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.