HYDRODYNAMICS AND WATER QUALITY MODELING OF SINGAPORE AND JOHOR STRAITS WITH SLON MODEL

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SLON (Sigma Layers Offing Numerics) model is being developed in TMSI, NUS as the further evolution of the numerical model THREETOX, developed in the Institute of Mathematical Machines and System Problems (Kiev, Ukraine) by Margvelashvili et al. (1997). SLON is a multidisciplinary model including hydrodynamics, water quality and suspended sediments simulations.

Hydrodynamics of SLON is governed by 3-D free-surface hydrostatic equations written in double sigma coordinate system in vertical direction and Cartesian coordinates horizontally. Model physics is similar to the well-known POM (Princeton Ocean Model), Blumberg, A.F. and Mellor, G.L. (1987), but it has some different physical approaches.

Vertical viscosity and diffusivity coefficients are calculated according to the k/ε turbulence model of Burchard and Petersen (1999). Because state variables in coastal areas often strictly depend on each other, SLON includes coupled calculation of temperature, salinity, water quality parameters and suspended sediments concentrations. Feedback influence of these parameters on hydrodynamics allows a wider range of phenomenon modeling, for example, effect of self-shading for phytoplankton. Implemented advanced schemes of heat, momentum and mass fluxes through the water surface use standard meteorological conditions over water surface for model forcing. These meteorological parameters include wind speed, wind direction, air temperature, air humidity, cloudiness and air pressure. Short wave Sun radiation is treated as the internal source of heat due to light extinction. Water transparency is assumed to be variable both in space and time as the function of modeled water quality parameters.

SLON's equations are written in double sigma vertical coordinate system, which gives significant advantage for modeling of stratified flows in areas with complex bottom topography in comparison with the single terrain-following sigma coordinate system used in POM. It is especially effective for salinity and temperature modeling in coastal regions with artificial ship channels, underwater walls and other man-made constructions. Models with a single vertical sigma coordinate system, are failing to simulate adequately a lot of important phenomena inherent to such areas, such as salt intrusion.

SLON uses staggered grids for scalars (temperature, salinity, etc.) and velocity components. Advection scheme for a scalar is based on van Leer scheme as in Lin et al. (1994). This scheme is formally of the second order accuracy except near sharp fronts, where a special filter is applied to prevent spurious oscillations. The recently developed advection scheme using staggered grids for horizontal velocity components and based on van Leer scheme ensures the same properties as the latter for a scalar. Leap-frog scheme for velocity component advection, used in POM, is conservative, second order accuracy, but it can produce spurious oscillations in the case of high horizontal velocity gradients, which are typical in Singapore waters. The new scheme ensures the absence of oscillations. Furthermore, it does not require additional advection subroutines in program code caused by staggered grids.

Complexity of shelf topography and coastal line often requires fine horizontal and vertical numerical resolution, which can be practically achieved using multiprocessor systems. Low-cost parallelization is realized in SLON via horizontal domain decomposition and using MPI (Message Passing Interface) for data exchange on each integration time step, as it was done in POLCOMS (Proudman Oceanographic Laboratory Coastal Ocean Modelling System), Souza et al. (2002). In such a way calculation can be run in network of PC, which is affordable for small companies and institutions in contrast to extremely expensive supercomputers.

At present SLON is intensively used for a variety of applications in Singapore waters as a research and forecasting tool. Model is constantly being calibrated taking into account the local features of this region. Due to the lack of information about mangrove areas, additional specific efforts are necessary for model calibration for these regions. However comparison of simulation results with measurements proves model efficiency and accuracy.

Further development of SLON will include implicit numerical scheme for calculation of surface elevation, non-hydrostatic version of the model, employment of sigma-z vertical co-ordinate system, improvement of turbulence model, coupling with surface wave model, optimizations of parallel computation, and application in web forecast system.

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