American Geophysical Union, Ocean Sciences Meeting
San Diego, California, February 9-13, 1998

Coupling of Hydrodynamics and Water Quality in Numerical Simulations

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It is readily apparent that hydrodynamics plays a significant role in the transport, mixing, resuspension and sedimentation of nutrients and micro-organisms in lakes, rivers and tidal estuaries. It is less obvious that the biology can modify the hydrodynamics in a manner that may impact biological productivity. A simple example is seen in the Swan River in Western Australia, where macroalgae can blockade shallow regions, effectively damping the propagation of surface waves inshore of the algae, providing a quiescent environment suitable for enhanced macroalgae growth. To investigate the importance (or unimportance) of the coupling between hydrodynamics and biogeochemistry, we are conducting a series of studies using idealized domains and the ELCOM and CAEDYM numerical simulation codes developed a the Centre for Water Rsearch. ELCOM (Estuary, Lake and Coast Ocean Model) simulates three-dimensional hydrodynamic transport and mixing through solution of the Navier-Stokes equations and scalar transport equations. Baroclinic and barotropic effects are included through resolving large scale (hydrostatic) free surface motion and transport of temperature and salinity scalars for the density field. CAEDYM (Computational Aquatic Ecosystem Dynamics Model) provides an integrated suite of biogeochemistry models that are directly coupled to the flow solution in ELCOM. Our approach is to examine processes and interactions in relative isolation so that an understanding of the individual interactions can be obtained. Typical studies include (1) phytoplankton growth comparisons between one-dimensional and three-dimensional simulations, (2) effects of phytoplankton self-shading on mixed layer depth, heat budget and productivity, (3) development of local density currents and phytoplankton transport due to phytoplankton shading and horizontal gradients of temperature, and (4) nutrient transport/depletion in macroalgae beds. Through examination of simulation results we are able to identify areas where coupling between hydrodynamics and biology can be neglected, where coupling is vital, and where further research and validation through field studies and laboratory experiments is necessary.

Acknowledgements
This research was conducted with the support of the Centre for Environmental Fluid Dynamics (CEFD) at the University of Western Australia. Model development was supported in part by the Western Australia Estuarine Research Foundation and the Western Australia Waters and Rivers Commission.

Citation
Hodges, B.R., M. Herzfeld, K. Winters, and D. Hamilton (1998), "Coupling of hydrodynamics and water quality in numerical simulations," *EOS Trans*. AGU, 79(1) Ocean Sciences Meet. Suppl. OS11P-1, 1998.