Geophysical Research Abstracts,
Vol. 11, EGU2009-3210, 2009
EGU General Assembly 2009

Sediment dynamics in a single particle framework

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Sediment dynamics in ocean/coastal models are usually modelled using an advection/ diffusion equation for the concentration of one or more sediment classes coupled to the hydrodynamical part of the numerical model. The numerical solution of these additional partial differential equations unavoidably introduces an artificial numerical diffusion leading to the smearing of sharp gradients, the possible occurrence of artificial oscillations and non-positivity. Furthermore there are also restrictions in the number of sediment classes and important diagnostics like residence/settling times or individual tracks are not feasible.

A Lagrangian particle-tracking model has been developed to simulate short term sediment dynamics in the East Frisian Wadden Sea (southern North Sea). The numerical treatment of individual sediment particles allows a straightforward physical interpretation of the processes involved, automatically accounting for suspension and bedload. In order to achieve a comparable accuracy to the concentration-based models, a Lagrangian model must track a large number of independent particles. With the highly efficient parallelisation of particle tracking on modern high performance computer clusters the use of large numbers of particles is feasible.

The movement of the particles (here up to 50 million in total) is described by a stochastic differential equation, which is consistent with the advection-diffusion equation. The particles are advected by the 4-D currents. Turbulent horizontal diffusion is implemented by a random walk process that is related to the shear of the velocity field. In the vertical the particle velocities are computed as a combination of the sinking velocity of each particle, the background fluid velocity and again a random walk, that is now related to the vertical eddy diffusivity. Resuspension and deposition depend on the particle diameter, particle density, and a ratio of bottom shear stress to a critical bottom shear stress.

A severe winter storm (Storm “Britta” in November 2006) is used for validation. Here the model results show good agreement with observations. The flexibility of the Lagrangian approach for simulating non-cohesive single/mixed sediments and its potential to include other processes like fragmentation and clustering, tracking biological species or reactive chemical containments will be illustrated.