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A particle model applied to the Western Scheldt

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Abstract

The model is based upon the idea of Maier-Reimer[6] of applying particle simulation making use of velocity fields computed by hydrodynamic-numerical models of water movement. Just as in the examples presented by Maier-Reimer[6,7,8,9], the models for the simulation of the water movement and the dispersion are both two-dimensional. For this reason it is essential that the Western Scheldt is a well mixed estuary so that strong effects of density distribution upon currents and mixing do not occur.

The velocity fields are computed by a hydrodynamical model based upon the work of Leendertse[2,3,4,5]. Up to now, all fields used were cyclic repetitions of one complete cycle of the dominant tidal component (M2), thus, for the time being, neglecting lower frequencies. The water movement model includes the flooding and drying of tidal flats, which is a necessity for obtaining acceptable results in an estuary like the Western Scheldt.

In the present model, simulations only apply to completely passive dispersants. Applications till now have been for instantaneous releases only but the programme provides for continuous sources as well. The application of the model to the Western Scheldt was initiated by the need for a so called calamity model, especially to be used in case of accidents with ships carrying harmful substances. In these cases the practical need for predictions of the fate of the pollutant is limited to relatively short periods (hours to a few days). Such predictions can be made with the present model in a few minutes, provided that the velocity histories from the water movement model are on file. For best results, these files should cover various tidal and meteorological conditions.

The model has been calibrated and verified by means of field data from tracer experiments. The quick dilution in the first hours implies that after a short period the simulated dispersion process is increasingly dominated by

the detail in the velocity field of the water movement model with its rather fine mash of 400 m. For obtaining correct concentrations also in the first few hours, use could be made of the concept of a "scaled" random walk (allowing for the scale effect of turbulent diffusion) as already proposed in Maier-Reimer's first presentation[6]. However this concept was modified with a brake mechanism (governed by one or two extra parameters) to prevent too great an increase of dispersion rate in the phase where the given velocity field gradually takes over the spreading mechanism and after some time becomes the main dispersing agent. In general, this happens the sooner, the finer the mash of the given velocity field is. From these considerations it also follows that tracer experiments are only needed on relatively small time scales if one can be confident in the reliability of the velocity field on the scale of the grid on which it has been computed.

The dispersion simulations with the modified Maier-Reimer concept are most satisfactory in the present application, but physically the concept of a random step that increases with time is not quite satisfying because it implies that the particles would have a memory (as to their "age"). For this reason, the work is continued on an alternative concept, based upon a prescribed "turbulent" velocity field[1]. One reason not to use this with the present application, is its greater consumption of computing time. Furthermore the physical objections against increasing random steps have small or negligible effect upon practical results, especially with instantaneous sources. Certainly with the "brake" provisions, the effects are mainly limited to the subgrid range and even there they will probably remain invisible in most cases. This is also due to other "impurities" in the simulation, due to small scale unbalance in the subgrid velocity field (obtained by interpolation), naturally evolving from the fact that in the water movement computation only the balance of the exchange of water between entire grid boxes is guaranteed. Unbalances tend to be greatest along closed boundaries where interpolation of velocities to some extent has to be replaced by extrapolation.

Particles crossing closed boundaries as a consequence of the finite length of time steps, are "returned" by a set of simple reflection precepts. It seems that this concept works well and that artefacts near closed boundaries are always related to the inter(extra)polated velocity field. These effects were studied in some detail in a model for a closed area (a lake) and a stationary velocity field.

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