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Quantification of the potential of offshore areas in terms of Lagrangian transport of danger to vulnerable regions

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We present a novel method for the quantification of the potential of different offshore domains to serve as a source of danger to the coastal environment in case when an adverse impact is released to these domains. In general, one has to solve an inverse problem of pollution propagation in order to gather progress in this direction. Although many trajectory-tracking models are invertible, such problems are frequently mathematically ill-posed and no universal method exists for their solving. The relevant methods and technologies are, however, of great practical importance for particularly vulnerable seas or coastal regions of relatively small size. An approximate solution to this problem can be obtained by means of statistical analysis of a large number of solutions of the associated direct problem of propagation of water particles. This approach, based on a pool of relatively short (about 10 days) Lagrangian trajectories has highlighted the presence of very rich, usually concealed internal structure of semi-persistent transport patterns in certain sea areas.

The method contains an eddy-resolving circulation model, a scheme for tracking of Lagrangian trajectories and a technique for the calculation of quantities characterising the potential of different sea areas to supply adverse impacts. The starting point form the numerically simulated velocity fields in the sea area in question over a long time interval. The velocity data are used for the calculation of Lagrangian trajectories of selected water particles. These are used for the construction of quantities that characterize the distribution of the level of environmental risk associated with different sea points. Differently from various direct methods of estimates of environmental risks, the resulting quantities are associated with the points of release of adverse impacts rather than with the vulnerable areas. Finally, the spatial distributions of these quantities are used for the identification of the optimum site of any potentially dangerous activity. The potential of each sea point in terms of its ability to supply danger to the vulnerable regions is to a first approximation quantified with the use of the relevant probabilities. A much richer in content variable is the time (particle age) it takes for the impact to reach the vulnerable area.

We show that particular methods used within each step are largely independent of each other and may be tuned or improved separately without the loss of generality for the entire procedure. The entire method is computationally relatively expensive and, at present, its use seems to be only feasible for relatively small sea areas. However, if the calculations have been once performed for a particular region with necessary resolution and accuracy, the resulting maps have a long term value and can be used for various exercises of maritime spatial planning.

The key contribution from methods of this type is the possibility of extracting and visualising important information that usually remains concealed in classical methods of the analysis of ocean currents. Finally, we demonstrate the potential of the use of this method in the context of optimisation of ship routes in the Gulf of Finland, the Baltic Sea, in terms of minimising the risk of coastal pollution. The gain from the use of the optimum fairway is about 40% in terms of the decrease in the probability of coastal pollution. Moreover, the use of the optimum fairways almost doubles the typical time during which the released pollution reaches the coast.