Application of a Trajectory model to select Areas of High Risk of Pollution

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Increased shipping activities have made the already environmentally sensitive Baltic Sea and its coastal areas at risk for pollution and the unintended introduction of invasive species. The BONUS+ BalticWay project attempts to identify the regions that are associated with increased risk to other sea areas and to propose ways to reduce risk of being polluted in the Baltic Sea by placing activities in other areas that may be less affected.

A solution to this inverse problem is sought by means of statistical analysis of a large pool of solutions to an associated direct problem of current-driven transport of adverse impact. A generic example of an adverse substance is an oil spill; however, the results can be used even more adequately for adverse impacts that are distributed over (or carried by) water masses (such as toxic substances or nutrients). It is the intention that using the results of modelling of current-driven transport in combination with statistical analysis, optimum routes for shipping that limits the effect of pollution, can be proposed.

We report results of the analysis of a large ensemble of Lagrangian transport paths of water and pollution particles. The trajectories are calculated with the use of TRACMASS code (Döös, 1995, de Vries and Döös, 2001) from pre-computed velocity fields. This study employs three-dimensional current velocity fields calculated by the Rossby Centre global circulation model (Regional Ocean model, RCO) with a resolution of 2×2 nautical miles.

These trajectories are calculated based on a linear interpolation of the velocity field in each point of selected grid cells.. The position of these trajectories is then updated every six hours. The user has the power to input the source point where the pollution may have been started (the initial position and depth of the trajectories) and at what time (starting and ending time of propagation). It is also possible to make backwards integration of trajectories, that is, to determine where a pollution may have originated given that there is information on where the pollution was sighted.

In this paper we investigate a pool of trajectories covering several years for the Gulf of Finland and for the northern Baltic Proper. The goal is to evaluate the basic parameters of current-driven transport that cannot be extracted directly from the velocity data, such as the average net transport rate in different directions and the ratio of average net and bulk transport (equivalently, the ratio of the final displacement and the length of the trajectories). These parameters allow estimating whether or not the proposed approach would lead to substantial benefit in a given area and the time scales involved.

The currents field, salinity, temperature, density, wind field, average net transport rate, and ratio of average net and bulk transport were analyzed yearly and seasonally. Comparison of the average net transport with the velocity field data allows us to identify the areas that may have very strong (or weak) flow and the direction of such flows. As expected the yearly averaged results show at the entrance of the Gulf of Finland in the surface layer a strong saline inflow of current frequently occurs progressing on southern side of the Gulf of Finland whilst a strong less saline outflow is usually present on the northern Gulf of Finland. These results coincide well with previous studies performed on the Gulf of Finland for example in Andrejev et al. (2004). The results however when averaged seasonally over several months showed a substantial variation. In some years a strong across axis current and coastal currents are present. These seasonal patterns occur frequently but not always every year. Thus there exists some uncertainty for when these patterns may be present. However their existence is of importance especially with respect to identification of areas of high and low risk.

Similar patterns in the ratio of average net and bulk transport allow us to identify the areas of fast moving flow but also the areas where possible mostly local eddy-driven circulation may exist. These results are useful for when identifying suitable pathways for areas of high and low risk. We demonstrate that, for certain seasons, fast pathways of transport may also exist perpendicularly to the Gulf of Finland.

Further analysis of the trajectories allows identifying the typical time scale it takes for pollutants to hit the coastal zone and the areas that are at high and low risk from the viewpoint of coastal protection. The time scale is analysed for three “alert levels”: reaching of pollutants to a distance of 6, 4 or 2 nautical miles from the coast. The pollutant is inserted into all open sea grid cells of the Gulf of Finland and simulations with a duration of about 20 days are made from a variety of starting moments. A count is then made on the number of trajectories that hits the coastal zone and how long it would take for the trajectories to reach the buffer zone. We present here preliminary results for the year 1987 for a duration after 7 to 10 days at particular seasons of the year.

As a practical application of the technology, we demonstrate the calculation of the equiprobability line of hitting opposite coasts by pollution for the conditions of the Gulf of Finland. For wider sea areas it is shown that there exist regions, propagation of pollution from which to any of the coasts is unlikely. The combination of the axis of such areas and the equiprobability line is the first approximation of a safe pathway for shipping.

Thus utilizing a trajectory model combined with relevant statistical analysis serves as a feasible method to determine areas of high and low risk in terms of coastal pollution in the Baltic Sea. Also it can be used in the event that an oil spill/ accident occur to determine where the pollutants may travel to and how long it may take to reach the coastal areas.

References

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