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BONUS briefing

SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

BALTICWAY

The potential of currents for environmental management of the Baltic Sea maritime industry

The ever increasing impact of the marine industry on vulnerable sea areas such as the Baltic Sea, and the increase in risks associated with potential oil pollution from ship traffic or oil platforms, calls for novel methods for mitigating beforehand the impact of risks on vulnerable areas. BALTICWAY develops methods for preventive reduction of offshore environmental risks caused by the maritime industry that are transported by surface currents to the coasts. The BALTICWAY scientists are characterising systematically the damaging potential of the Baltic Sea areas in terms of their potential transport to vulnerable regions if faced by an oil spill or other pollution. This way, by placing maritime activities in the safest offshore areas, the consequences of potential accidents can be minimised before they occur.

OVERVIEW

Traditionally risks of maritime industry are associated with possible accidents (ship collisions or grounding, etc.) that may lead to loss of lives or property, or to environmental pollution; the management of environmental risks in turn is typically focussed on small areas around the installation or the ship in question.

However, the technological progress has led to a new paradigm in the treatment of such risks. Namely, by-products such as exhaust emissions, external noise or dangerous waves are no more located in small areas. The amounts of oil spills or other harmful substances potentially released to the sea by some ships or specific offshore infrastructures have increased to a level that are of acute danger to the ecosystem and to society, even in seemingly remote and safe locations. Especially the currents can transport different impacts over hundreds of kilometres and may provide extremely large risks to some regions over a substantial time period, as demonstrated, for example, by the recent Gulf of Mexico oil spill. This component of environmental risk is exceptionally important in particularly vulnerable sea areas that host intense ship traffic such as the Baltic Sea (Figure 1).

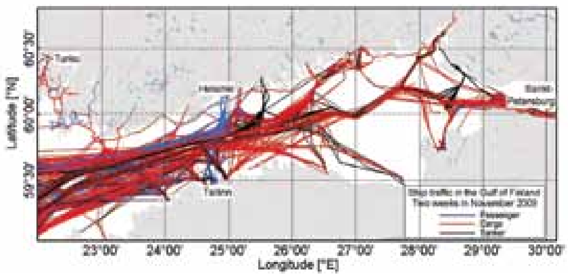

Figure 1. Sailing lines of ships in the Gulf of Finland in a two week period (Nov 2009).

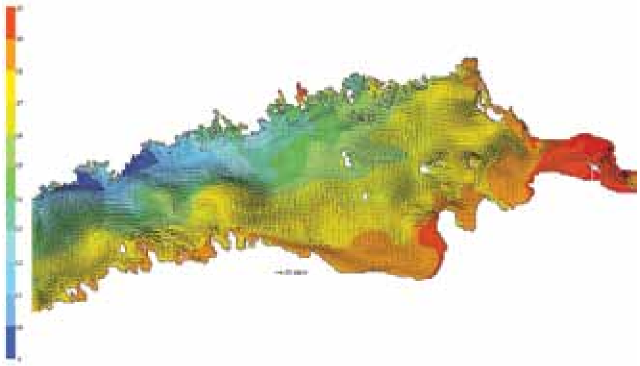

Figure 2. A snapshot of the current system (arrows) and sea surface temperature (color code) for the Gulf of Finland in 0.25 nautical mile (ca 470 m) resolution (O.Andrejev, Helsinki).

BALTICWAY's approach is based on a smart use of the existence of semi-persistent favourable current patterns which affect considerably pollution propagation as well as drift of various items such as vessels without propulsion, rescue boats or lost containers. These patterns make the probability of transport of dangerous substances or undesired items from different open sea areas to vulnerable sections (such as spawning, nursing or also tourist areas) highly variable. For certain areas of reduced risk this probability is relatively small and re- or directing activities to these areas would appear to be feasible as well with very limited additional costs. Hence, these areas are the best candidates for fairways and locations of high-risk offshore structures.

The core objective of BALTICWAY is to establish key components of a reliable, robust and low-cost technology for the environmental management of shipping, offshore, and coastal engineering activities. Integrating marine ecosystem management with other needs of society, and linking scientists, stakeholders and decision-makers in the process of elaborating a scientific base for political decisions is the key.

While addressing effectively and in a coherent and holistic manner the Baltic's transboundary environmental problems caused by industrial activities, it is also important for BALTICWAY not to be driven by the needs of scientific research alone; rather it is an initiative of the scientific community reflecting the cooperative research needs towards sustainable development and effective stewardship of the Baltic Sea.

The entire research under the BALTICWAY umbrella is highly interdisciplinary. The hydrodynamic studies have substantially improved our understanding of the patterns of currents in the Baltic Sea, thus leading to better knowledge of geophysical forcing of pollution transport and contributing to the predictive capacity of circulation and operational models. In parallel, the project has developed and applied knowledge systems for effectively tracking huge amounts of information concealed in current-driven transport. This knowledge is applied in a generalised form to assess environmental risks and to construct an optimum response strategy.

OUTLINE OF KEY RESULTS

The existence and location of areas of reduced risk have been established through the use of massive numerical simulations supported by specifically designed in situ experiments to verify their results. The method used contains four key components: (i) an eddy-resolving circulation model, (ii) a scheme for tracking of (Lagrangian) trajectories of water or pollution particles, (iii) a technique for the calculation of quantities characterising the potential of different sea areas to supply adverse impacts, and (iv) routines to construct the optimum fairway. The gain is expressed in terms of the probability of pollution transport to the vulnerable areas and the time pollution takes to reach these areas. As a first approximation, coastal areas are used as a generic model for valuable regions.

Computer simulations with a resolution necessary for adequately resolving the key features of current systems provide detailed information about the extreme complexity of water motions in natural current systems (Figure 2). This complexity calls for the use of non-traditional and novel mathematical methods to identify the persistence, properties, and potential effect of favourable current patterns, and to establish generic criteria for the existence of areas of reduced risk in different sea regions.

The quantification of the potential of different offshore domains to serve as a source of danger to the coastal environment through current-driven transport involves solving an inverse problem of pollution propagation. Such problems are frequently mathematically ill-posed and no universal method exists for solving them. 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 (so-called Lagrangian trajectories, Figure 3).

The entire approach is intrinsically based on certain statistical features of current-induced transport. The importance of statistical methods in marine design and operation is now generally acknowledged. Since their outcome is not always explicit, one of the major challenges implicitly addressed by the BALTICWAY team consists in

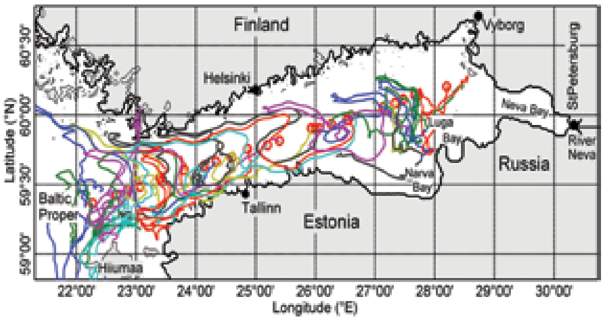

Figure 3. A selection of trajectories of water particles in the Gulf of Finland.

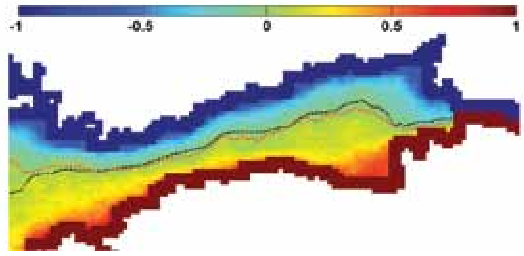

Figure 4. Distribution characterising the probability of hitting the northern and southern coasts of the Gulf of Finland for the years 1987–1991 based on simulations with the Rossby Centre model with a spatial resolution of 2 nautical miles (M.Meier, Norrköping) and the TRACMASS code for Lagrangian trajectories (K.Döös, Stockholm). Black and red lines indicate the equiprobability lines for two slightly different methods (B.Viikmäe, Tallinn).

further developing methods and technology for the use of statistical information in solving dynamical problems. These methods allow to identify a number of concealed features of transport which can be inferred neither from theoretical analysis nor from even massive measurements.

There is a variety of different approaches to define the optimum fairway or location of other potentially dangerous activities. The 'fair way' of dividing the risks equally between the opposite coasts is a local solution that does not normally provide the minimum level of risk for the entire water body (Figure 4).

Alternatively, better approximations to characterise the potential of each sea point in terms of its ability to create danger to the vulnerable regions are, for example, the average probability of the transport of pollution released at this point to a coast, or the time it takes for the impact to reach the vulnerable area (Figure 5).

The use of fairways roughly following the minima for probabilities of coastal hit or the maxima for the time it takes for the potential pollution to reach the coast (Figure 6) are most promising in the context of the optimisation of ship routes in terms of minimising the risk of coastal pollution. In the Gulf of Finland, as part of the Baltic Sea, the gain from the use of the optimum fairway is about 40% in terms of the decrease in probability of coastal pollution. In addition, the use of the optimum fairways may almost double the typical time it takes the released pollution to reach the coast.

NEXT STEPS AND FUTURE PLANS

The information derived using the developed technology is of vital importance for institutions responsible for environmental protection (national ministries of environment, national and regional environmental agencies) and maritime spatial planning. It is directly usable in the decision-making process in a crisis situation, e.g., about different search-and-rescue issues. The ultimate goal is to have the technology used by maritime boards for a new generation of fairway and ship routing services.

Practical implementation of the project results is expected to substantially decrease the impact of maritime transport and industry on biodiversity, particularly on fragile ecosystems.

The project will also indirectly contribute to sustainable fishing through better protection of key areas of fish stock reproduction. The method developed by BALTICWAY can also be used as a tool supporting decisions about how far the fairway for ships carrying dangerous cargo should be located from the coast (or from vulnerable areas) facing the open ocean.

Linking science and policy through the creation of the necessary societal, economical, legal and political framework for the real implementation of the research results is the key. For this reason, the consortium will strive for better synthesising and disseminating research outcomes at all levels for bridging the gap between science and users, for improved receptivity and utilisation in policy and decision making, and to increase the usability of research products.

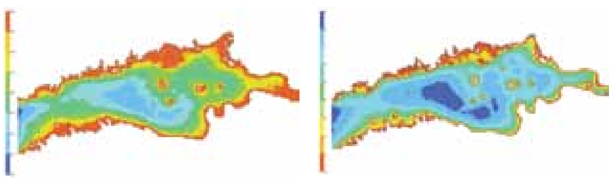

Figure 5. Probability for the beaching of the pollution within 10 days (left) and the time it takes for the pollution to reach the coast (right) in the Gulf of Finland simulated for the period of 1987–1991 (O.Andrejev, Helsinki)

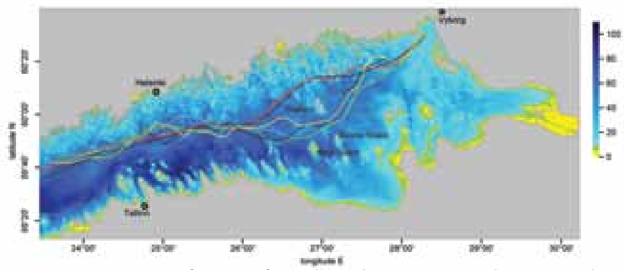

Figure 6. Optimum fairways from the Baltic Proper to Vyborg according to the spatial distributions of the probability for coastal hits (solid lines) and of the particle age (dashed lines) at resolutions of 2 nm (red and black), 1 nm (green and cyan) and 0.5 nm (yellow and white). The depth scale to the right of the map is given in metres.

IN BRIEF

BALTICWAY
The potential of currents for environmental management of the Baltic Sea maritime industry

By studying surface currents in the Baltic Sea, BALTICWAY has developed a new method to determine how shipping as well as offshore and coastal engineering activities can be made environmentally safer. This research identifies areas that are safer to use, distinguishing them from those where marine activities are better avoided because dangerous substances (e.g. oil spills) are likely to be washed to the most vulnerable areas of the Baltic Sea.

KEY RESULTS

- Development of a technique for environmental management of offshore sea areas that minimises current-driven risks for coastal regions.
- Development of algorithms for the identification of the environmentally safest fairways.
- Mapping of long-term behaviour and dispersion properties of surface currents in the Baltic Sea with the use of autonomous drifters.
- Quantification of spatial and temporal variability of properties of the Baltic Sea wave fields.

WHO NEEDS THE INFORMATION

The derived information is of vital importance for institutions responsible for environmental protection (ministries of environment, national and regional environmental agencies) and maritime spatial planning. It is directly usable in the decision-making process in crisis situations, e.g., about different search-and-rescue issues. The ultimate goal is to have the technology used by maritime boards for a new generation of fairway and ship routing services.

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