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

BalticWay

Full Research Plan submitted to the BONUS+ Call for Proposals 2007

Public information

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1. Concept, objectives and expected outcome of the project

The BalticWay proposal aims at a substantial decrease of industry-induced remote environmental risks (e.g. ship-caused pollution that frequently affects vulnerable areas far from the accident site) by minimizing the consequences of potential accidents. Our approach is based on a *smart use of the existence of statistically heterogeneous semi-persistent current patterns*, which considerably affect pollution propagation as well as drift of various items such as vessels without propulsion, rescue boats or lost containers. Such patterns were recently identified for the Gulf of Finland (Andrejev et al. 2004a,b) and evidently exist in other parts of the Baltic Sea. 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. The existing data suggest that for certain regions (called *areas of reduced risk*) this probability is relatively small, while the (re)-direction of activities to these areas incurs very limited additional costs. These areas of reduced risk are consequently the best candidates for fairways and locations of high-risk offshore structures.

Pursuing the *long-term outcome* of a *substantial decrease of the anthropogenic impact on bio-diversity, particularly on fragile eco-systems*, and greatly reduced costs of accidents, 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*, based on minimising the probability of adverse effects hitting highly valuable areas.

The *major practical targets of the project* are:

(i) to identify areas of reduced risk and establish their basic properties (persistence, seasonal and interannual variability, etc.) in target regions;

(ii) to provide a prototype of the environmental management technology using the concept of areas of reduced risk in a specific setting;

(iii) to formulate a concrete implementation plan for the practical adoption of the technology as well as blueprints for further research and development;

(iv) to develop an independent method for assessing whether such a technology is applicable and economically feasible for a given sea area.

The existence and location of *areas of reduced risk* induced by favourable current patterns will be established through the use of massive numerical simulations, with specifically designed in situ experiments to verify their results. Computer simulations provide detailed information about water motions that allows it to identify some features of transport, which can be inferred neither from theoretical analysis nor from even massive measurements. Novel mathematical methods will be applied to identify the persistence, properties, and potential effect of such areas of reduced risk, and to establish generic criteria for their existence in different sea regions.

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 (IMO 2002). Since their outcome is not always explicit, one of the major challenges implicitly addressed in this proposal consists in further developing methods and technology for the use of statistical information in solving dynamical problems.

With different sea areas having frequently different "value" and/or vulnerability, *the cost* of the consequences (e.g. of a ship accident) and accompanying oil pollution *substantially depends on which place it hits*. In what follows we use the classical *definition of risk* (e.g. of sailing of tankers along a given route) expressed in terms of the probability (of occurrence of a disaster) and the consequences (of this disaster):

$$\text{Risk} = \text{probability} \times \text{(cost of the) consequences}.$$

The goal is to decrease the "probability" factor specifically for high-cost areas. Of the three widely used risk categories: (i) safety of people (loss of life, limb and health); (ii) economical risk (damage to ship, equipment and cargo, etc.); (iii) environmental risk, incl. risk of third persons (damage to ecosystems, coastal pollution, decrease of fish stocks, influence on tourist industry, etc.); we address here the *environmental risk*.

The scope of the proposed project activities has been limited to produce a feasible proof of concept within the time and budget constraints, focussing on specific areas in the Baltic, one generic cost function, one single adverse effect, and one activity to manage.

Since the entire Baltic Sea is too large to reproduce the current patterns with the necessary accuracy, we concentrate on *two target regions*: the Gulf of Finland and the western Baltic Sea. The former is the most vulnerable area hosting extremely heavy ship and tanker traffic. The Belt Sea and the Arkona Basin are the areas where all the ships travelling into/from the North Sea have to pass through. In the Baltic Sea (incl. Kattegat) about 76 ports handle more than 1 million tonnes of cargo per year. The busiest port is St. Petersburg with >14,500 ships visits per year. The number of ship operations (voyages, excluding ferry traffic) in the Baltic is estimated at 150,000 per year (Gollasch and Leppäkoski 2007), and it is assumed to considerable increase in the future.

There exists a natural division of confined seas into open sea and coastal areas. The coastal areas are generally the major life reproduction areas and thus play a major role in restoring the fish stock. Combating oil pollution on open sea is generally much more effective and less expensive than in shallow coastal areas; thus keeping the oil spill or a damaged ship in open sea causes the least damage. Therefore the coastal areas are used as a generic example of "high-value" sea regions. We intentionally leave aside the definition of the factual cost (of the environmental consequences) of accidents. The relevant estimates are usually strongly site-specific and the formal value may substantially depend on political decisions. Doing so causes no loss of generality, because the proposed approach is independent from the particular form of the cost function used.

We mostly consider only one single adverse effect – current-induced drift of oil pollution released in a ship accident. This allows the formulation of mathematical, engineering and technological problems in a language understandable for a wide pool of experts to identify clearly the expected environmental gain. The relevant risk categories are widely known and the benefits of our approach can be compared with existing concepts and results. Yet we emphasize that the method is fairly generic: another obvious application being to influence the strategy where to tow a damaged ship to buy some time that can be crucial for the attempts of limiting the accident's effects, either to ensure the most favourable location of leaking oil or to avoid grounding as long as possible.

While the approach is clearly also relevant for managing activities like the location of off-shore structures, only the problem of ship routing, i.e. environmentally advantageous fairway design, will be treated in the foreseen prototype.

2. State of the art, theory and methods

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It was recognised in the mid-1990s that the geography of shipping routes (and their optimisation, Lo and McCord 1995), ship types and cargoes are major components of the environmental management of shipping (Smith 1995; see also the Tanker Risk Analysis Project, Judson 1997). Although the basic risk, e.g. of the transportation of oil products (Iakovou 1999), is a coastal crash and the related pollution, the benefit of smart ship routing is normally formulated in economical categories (see, e.g., the SEAROUTES project). Only the issue of whales in the North Atlantic and in the Mediterranean has been considered in some environment/ecosystem-based risk categories (Ward-Geiger et al. 2005, Panigada et al. 2006). The central problem in a marine environment is that such risks may have a substantial remote influence (Soomere 2005). The first developments systematically accounting for this aspect are probably the U.S. Patents No. 6171021 and 7082355, which describe solutions that favour avoiding the remote influence of dangerous waves.

Major progress in the environmental management of anthropogenic pressure has now become feasible due to recent major advances in marine sciences, concerning computational facilities, circulation modelling, new technologies for *in situ* and satellite observations, an ever increasing flow of real-time information about the sea state, as well as increasing experience in operational oceanography (oil spill monitoring and forecasting), and in the accuracy of meteorological forecasts. Successful efforts towards solving the direct problem of (oil) pollution transport have led to harmonised and standardised capacities for oil pollution detection, monitoring, combating, and information reporting, including many consortium partners (IoC, SMHI, SYKE, DMI).

There are still very few examples of operational models specifically targeted at *preventive reduction of environmental risks*. One is the system of dynamical relocation of tugboats along the Norwegian Atlantic coast run by Det Norske Veritas (Lehmann and Sørgård 1999). The reason for such a limited use is that the details of current patterns are still difficult to forecast and that solution methods for the inverse problem, which are necessary for an adequate estimate of the best ship locations, are underdeveloped.

The movement of the surface layer and the accompanying drift are jointly governed by three factors: currents, wind and waves. The transport induced by the latter two mostly mimics the behaviour of the wind and wave patterns. In the absence of currents, the probability of hitting a vulnerable area is roughly inversely proportional to its downwind/wave distance from the location of the pollution release. The solution to the problem of finding the area of least risk is straightforward: it is just as far "upwind/wave" from the location as possible.

The situation for the current-induced transport is fundamentally different. The instantaneous field of currents is an integral reaction of water masses to a variety of forcing factors. It is a highly nontrivial, anisotropic, inhomogeneous, non-stationary system with large spatial variation, even for practically stationary wind events, and frequently even in antiphase with wave- and wind-induced transport features (e.g. Andrejev et al. 2004a, Gästgifvars et al. 2006). The inadequate current forecast is probably the main reason why the forecast of current-induced transport of an oil spill is much less reliable compared to the description of wind- and wave-induced transport.

Marine science has only recently reached the situation where the development of mathematical models, the accuracy and reliability of circulation modelling, the computational facilities and the quality of information about forcing factors allow addressing the problem of current-induced pollution transport in a dependable way.

3. Innovation and new approaches, progress beyond the state-of-the-art

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The proposal's *major target for innovation* is a low-cost but effective technology for environmental management based on the wise use of intrinsic properties of sea currents.

We aim at *substantial progress in*: (a) numerical identification of areas of reduced environmental risk, combined with an analysis of the applicability, reliability and accuracy of the relevant inverse modelling procedures; (b) establishing the geometry, persistence, and temporal scales of such areas; (c) estimation of the potential benefit of such areas; (d) developing a platform for a technology prototype for environmentally friendly management of shipping and offshore activities, and (e) developing generic methods for identifying the feasibility of the use of this technology.

Relevance to the topic of the call

The research is targeted at minimizing the impact of potential disasters beforehand, by optimising the location in terms of environmental risks. This is in line with the experience that a gain in environment-based management typically does not mean making profit, but avoiding the disastrous consequences of making a bad choice. The project contributes specifically to reducing anthropogenic risks to the marine environment associated with the maritime industry. It will become possible to adjust ship routes, offshore or coastal structures so that the consequences of an accident are minimal.

The project efforts contribute to a scientifically justified platform for environment- and ecosystem-based management, offering the best available science to policy-makers for legislative issues (for example the possible re-routing of ships through national waters) and to decision-makers in industry for practical use in day-to-day operations.

The by-products in the form of developing risk analysis methodologies are of clear value for environmental safety, as an inherent component of the total socio-economic system embracing infrastructures, decision support and validation tools. Another by-product is the increase of awareness of society and stakeholders about preventive solutions of this type and about the potential of marine science in general. The project will also contribute towards the increase of the predictive capacity of contemporary circulation models, overcoming the gap in real-time initial data and resulting uncertainties, by constructing a solution based on a statistical approach and the far reaching use of novel mathematical methods.

4. Themes and key research issues of the BONUS-169 Science Plan addressed. Relevance for the management of the Baltic Sea – relation to themes 1 and 7

The project aims at providing cutting edge technology for the increased protection of the marine environment, while still keeping up the economic value of the marine industry and sea transport, thus integrating marine ecosystem management with other needs of society (Theme 7), and linking scientists, stakeholders and decision-makers in the process of elaborating a scientific base for political decisions. A key idea is that a considerable decrease of risks is manageable by means of fairly minor investments, thus providing a cost-effective ecosystem-based management technology towards mitigation of environmental problems and risk. The consortium will also strive for better synthesizing and disseminating research outcomes at all levels for bridging the gap between science and users, for improved receptivity and utilization in policy and decision-making, and to increase the usability of research products (Theme 1).

The uptake of the concept is only possible by linking science and policy through the creation of the necessary societal, economical, legal and political framework for the real implementation after the end of the project (Theme 1). Mapping out the future steps to be taken in this regard is therefore an important ingredient of the project (Theme 7.4); for the production of this roadmap an active role of the Project Advisory Board of stakeholders (see Section 7) will be crucial.

We employ a highly interdisciplinary approach involving the cooperation of scientists from different areas. The hydrodynamic research is expected to substantially improve our understanding of the semi-persistent 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 (Theme 2.2 and 2.3). This will be achieved by developing and applying knowledge systems for effectively tracking huge amounts of information by means of inverse modelling technologies. This knowledge will be applied to assess environmental risks and to construct an optimum response strategy (Theme 2.4).

Practical implementation of the project results is expected to substantially decrease the impact of maritime transport and industry on bio-diversity, particularly on fragile eco-systems (Theme 5).

It will indirectly contribute to sustainable fishing through better protection of key areas of fish stock reproduction (Theme 4). Although preventing pollution (Theme 6) is not directly addressed, the proposed concept is a novel scientific strategy for improving assessment and management of potential pollution (Theme 4.3) based on investigations how natural forcing modifies the transport and dispersion of pollutants (Themes 6 & 2).

The project is to address effectively and in a coherent and holistic manner the Baltic's transboundary environmental problems caused by industrial activities. It is important that this project is not 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.

5. Contribution in producing deliverables described in the BONUS-169 Science Plan

Linking science and policy. The results will contribute to a better capacity to predict and mitigate environmental risks in a coherent and holistic manner (D1), by bridging between science and policy (D2). The project focuses on the increase of the usability of research results from the Baltic Sea science community for wider society (D1). Its ambition is to establish a novel research area through integration of transnational research outputs across several disciplines of natural, technological, and economic sciences, and to develop a method not only applicable in the Baltic Sea area, but in other European regional seas and regional seas elsewhere (D2, D3). The proposed concept can only be the necessary first step on the long way to an uptake of the relevant technology in practice, but the consortium is convinced that the time is ripe to take this step now. The results will directly provide specific support for integrated coastal zone management (D4).

Large scale ecosystem threats, responses and mitigation. The core target is the introduction of a novel, scientifically robust method for environmental risk assessment and management (D3). The proposed studies offer novel analyses and models of the potential impact of human activities on the Baltic Sea ecosystem (D4) and ways to their mitigation. The fairway design prototype is relying on a cost-benefit analysis of environmental factors and a dynamical risk model, offering a cost-efficient abatement and remedial measures (D5). The approach offers new scientific support for effective and adaptive management, regulatory and mitigation measures to achieve sustainable fisheries and protect biodiversity through mitigation of the consequences of pollution events (D6).

Strengthening collaboration and use of common resources. We expect that, as a by-product of the proposed research, a large number of international scientific publications on Baltic Sea environmental issues will be published (D1). Collaboration and co-funding of joint activities with the running Marie Curie projects CENS-CMA and SEAMOCS will be active until their end in 2009 and with the Future and Emerging Technologies grant GSD (which is just about to start) for 2008-2010 (D3). This will provide more effective exploitation and dissemination of scientific results as well as training opportunities for young researchers. The consortium is going to organise an international Advanced Study School, specifically designed for young scientists and reflecting the project's activities in an interdisciplinary manner (D4). The teams have a demonstrated ability of networking, knowledge dissemination and communication to wider society (see Section 6), and these qualities will be further developed through this cooperation (D5). We will definitely contribute the entire wealth of the project databases created during the project to openly accessible, common databases (D8).

Transnational added value and international cooperation beyond the project

The project is to tackle a major goal with an effort that could never be mustered in one country alone. To reach a feasible solution tight networking of the various scientific teams is necessary through Baltic-wide transboundary and interdisciplinary research consultation, planning, coordination and concerted action, including synthesizing and combining the data and information sources from the entire Baltic area. The teams cover all Baltic countries with strong research efforts in the particular subject. The involvement of strong marine research institutions and modelling groups in Poland and Russia would not, to our understanding, add complementary expertise to the pool of competence of the existing consortium. The cutting edge marine scientific activities in Latvia and Lithuania are out of the scope of this project. We consider, however, inviting their representatives to the Advisory Board to match also their needs and keep them informed about the project and its outcomes.

The direct societal benefit in all Baltic Sea countries created by a reduction of the potential environmental impact is obvious through the *improved (albeit implicit) protection of vulnerable parts of the marine ecosystems* (in particular, the coastal life reproduction areas), whereas only small additional expenses for the marine industry are expected. The largest immediate benefit will result for the two target areas, all of which border several countries. An obvious short-term benefit is to avoid or greatly *reduce the consequences of ecological disasters* like the pollution caused by the tankers “Erika” and “Prestige”. Further basin-wide economic benefit will arise through *better-protected development of the fishing and tourist industry*.

Extensive interaction is expected in the course of the project between ship experts, marine boards, experts in navigation, ship routing and classification, specialists in pollution detection, monitoring and combating, marine scientists and national decision-makers. The project will *foster long-term durable cooperation between scientists, engineers, policy-makers and society in general*, in particular, through the activities of the Project Advisory Board.

Such an interdisciplinary chain evidently *increases personal and collective capacity and competitiveness*, leads to better collaboration among the teams also in the future, and, in general, contributes to further structuring of Baltic-wide marine research, strengthening its excellence through extensive joint activities of experts in different fields as well as through establishing further co-operation and co-ordination of efforts in marine science and (industrial) society. We foresee extensive technology transfer between the consortium partners. This will ensure a more balanced distribution of efforts and foster effective collaboration.

Extensions of the proposed technology can be used in fairly general activities to decrease adverse environmental effects. Developing the approach for two different target areas will provide blueprints how to approach the study of other areas; once elaborated for the Baltic conditions, it can be easily used in other surveillance and assessment systems for any semi-enclosed or coastal seas. The project results apparently are applicable in other regional seas; for example, the Adriatic Sea, or the Bay of Burgas and the Bay of Varna (Black Sea). This feature suggests that the results can generate much wider international cooperation within the consortium as well as trigger joint endeavours of single partners with third parties. Last but not least, a successful use of the potential of areas of reduced risk would serve as an example on a global scale, making the Baltic Sea community the trailblazer and thus the frontrunner in this approach of limiting the adverse environmental impacts for other European regional seas and in the wider global scale.

6. Dissemination plan

The dissemination activities are considered to be of great importance for this project and are envisaged to take place on three different levels: (i) to the scientific community through regular channels of scientific publications and presentations at conferences, (ii) to the public in general, and (iii) specifically to societal, economical, legal and political stakeholders. We foresee a separate task, and single out a member of the IoC team (Ewald Quak) as Dissemination Manager, so that he takes special responsibility for this aspect of the project and coordinates and supervises the efforts of the whole consortium. He is also charged with the correct supervision of the IPR handling (see Section 7). Although commercial exploitation is certainly not the main concern of the project, partial results may still warrant an examination concerning a possible (commercial) exploitation, and patenting of certain steps of the technologies for increased protection of marine environment is also not excluded.

The Project Advisory Board will point to the right persons and channels to involve various (societal, economical, legal and political) stakeholders. At the project end, the future steps for the practical implementation are expected to be mapped (WP 7), and the involved stakeholders should already be informed about the project results and recommendations.

The partners already now spend a lot of effort on raising wider public awareness and understanding through the dissemination and popularisation of research on coastal environment, ecological marine issues, ship-traffic-induced adverse effects and ways of their neutralising, by means of public lectures, articles in popular science journals, web-pages, TV appearances, radio broadcasts, and daily newspapers. For example, for his efforts in explaining to the public the scientific background of the devastating storm "Gudrun" hitting the Baltic Sea in January 2005, the project coordinator Tarmo Soomere was elected Person of the Year 2005 by Estonia's oldest newspaper *Postimees* (Scholl 2006). Special efforts for dissemination to and training of younger scientists are described in Section 10.

7. Participants and management of the project

The project is intrinsically of a highly multidisciplinary character. Teams representing very different fields are brought together to achieve the project goals, while keeping a reasonable balance between fundamental and applied science, experience in operational services, knowledge in environmental management, and providing powerful computational tools. The technical roles of the partners are described in Section 11. The partners basically represent two categories:

(i) Highly qualified research teams from universities and specialised research institutes: *Institute of Cybernetics, Dept. of Meteorology (Univ. of Stockholm), Institute for Coastal Research, Leibniz Institute of Marine Sciences (IFM-GEOMAR, Univ. of Kiel).*

(ii) Leading public and private organisations wholly or partially specialising in services towards marine safety, such as operational oceanographic services or manufacturers of pollution detection and monitoring instruments: *Swedish Meteorological and Hydrological Institute, Finnish Institute for Marine Research, Laser Diagnostic Institute, Danish Meteorological Institute*.

The coordinating team **IoC** (Leader WP8) forms a part of the Centre for Nonlinear Studies, an Estonian Centre of Excellence in Research. The justification of the project being co-ordinated by IoC is manifold: (a) the potential of the effect of specific current structures for the transport of pollution was first recognized there (Soomere 2006, Soomere and Quak 2007); (b) the risk of a major oil pollution in the Gulf of Finland is rather high and its effects would be most devastating on the Estonian coast, leading to a high public and political awareness for this subject; (c) IoC has the senior personnel with the necessary experience of handling such an endeavour; (d) the cost level in Estonia makes it financially advantageous to locate the management activities there.

IoC also takes part in the production of initial and forcing data sets and, as Leader of WP6, *contributes specific expertise concerning the analysis of dispersion properties of (quasi) 2D flows, in mathematics of inverse problems, and in the mathematical description of the geometry of current patterns, their basic features and persistency*.

SYKE is a governmental research institute, with the responsibility to produce objective and trustworthy information about the marine environment for Finland. *The SYKE team specifically contributes by high-resolution circulation modelling in the Gulf of Finland.* Other important tasks of SYKE are measurements of the surface and subsurface currents (Leader WP5) and contribution to the forcing data, synthesis, and applications.

MISU was founded by Carl-Gustaf Rossby in 1947 and presently comprises dynamical meteorology, chemical meteorology, atmospheric physics and physical oceanography. The team contributes unique competence in *calculations of trajectories of pollution paths, experiments* *with drifters* (Leader WP3)*, and mathematics of circulation* (WP6). The team is also strongly involved in the validation through experiments (WP5).

SMHI is the Swedish governmental agency for meteorology, hydrology and oceanography. The team for BalticWay represents the SMHI RTD division that supports the institute with research and development of new production tools. The *SMHI team specifically contributes high-resolution simulations of current patterns for the entire Baltic Sea in ice and changing climatic conditions* (Leader WP2). Its role also includes production of forcing fields (WP1), performing the analysis of uncertainties and of the robustness of the applications (WP4).

The main objectives of **DMI** are: to make observations, to provide forecasts and other information of weather, sea state, climate, and related environmental conditions in the atmosphere, over land and in the sea, to communicate these to the public, to contribute to the development of geophysical sciences. The team for BalticWay represents the DMI Centre of Ocean and Ice, and *specifically contributes Baltic Sea oil spill models, and ship routing technology experience* (Leader WP7). DMI also contributes through the compilation of datasets of weather forcing (WP1), running a high-resolution Baltic Sea oil spill model (WP3) for comparisons with currents-induced drift models (WP4), and running 'simulated ship routing experiments'.

The Institute of Coastal Research **ICR** at GKSS is responsible for the proper *collection of forcing and boundary data* (Leader WP1) and specifically contributes to the *validation of the results of circulation modelling* by runs with a generic ocean model (WP2, WP3, WP5, WP6, WP7)

The main research topics of **IFM-GEOMAR** are mostly focussed on the ocean circulation and climate dynamics, marine biogeochemistry, marine ecology, and dynamics of the ocean floor. *The IFM-GEOMAR team specifically contributes to high-resolution circulation modelling for the entire Baltic Sea but in particular for the western Baltic including Belt Sea* (WP2); it also will provide observational data for the Baltic Sea (WP1) and is responsible for the synthesis activities (Leader WP4). Model runs and data analysis will be performed on HPC facilities of Kiel University.

LDI is an Estonian private enterprise that holds key competence and numerous patents concerning scanning-lidar-based oil pollution detection techniques, including remote detection of the position, features and components of an oil spill. *The LDI team specifically contributes the expertise in the detection of oil pollution and the identification of oil types* (WP5); it also has a role in the collection of forcing data (WP1).

Several partners (SMHI, DMI, SYKE) are committed to make observations in meteorology, hydrology and oceanography, and to provide forecasts for the entire community. DMI is the initiator, co-founder and leader of the Baltic Operational Oceanographic System (BOOS).

All partners possess the experience for collaborative activities in strongly interdisciplinary and intersectorial fields. All team leaders have experience in leading quite large enterprises, departments, working groups, and/or large field cruises. For example, laser, remote and in-situ sensing techniques developed at LDI have been used in studies in a number of EC projects, and in a number of service contracts in Europe and North America.

The consortium is designed to ensure that results are "the best marine science can give to society." We believe (i) that the consortium involves the necessary combination of expert-level scientists, advanced computing facilities and software, (ii) that the features of marine dynamics are known to a level that is sufficient to find a robust and reliable solution of the desired kind, and (iii) that we have gathered a critical mass of researchers in order to not just give a proof of concept, but to get a clear view of how to continue the effort all the way to a meaningful prototype and to convince stakeholders of the uptake of the entire concept at a large scale.

The project will be divided into Work Packages (WP) and these in turn into Tasks. Each partner leads one WP (except for the coordinating partner IoC that also leads WP6, and LDI that cannot provide senior resources for WP leadership). The *WP Leaders* provide the technical leadership and practical management for each WP, coordinate the activities of *Task Leaders* (to be appointed at the kick-off), ensuring that the foreseen work is indeed carried out, with the expected quality, on time and on budget. *The Managing Board,* composed of the WP Leaders and a representative of LDI (and thus representing all partners), is chaired by the coordinator, and is the ultimate managing, decision-making and arbitration body. It will be in charge of the overall direction of the project; controls the technical implementation of the project work and proposes corrective actions when necessary. It will also finally define *deliverables and milestones* to assure proper project execution. These have already been formulated by the consortium but cannot all be listed here due to lack of space.

The *Project Coordinator* will implement an efficient management and coordination of the research and is charged to supervise the scientific, technical, financial and administrative progress of the project, and be the communication channel to the BONUS Secretariat. The *Dissemination Manager* will be responsible for IPR matters, the activities on dissemination and exploitation, especially emphasizing stakeholders like end users, policy makers, and the non-specialist public.

A *Project Office* will be established at IoC, providing assistance in the performance of day-to-day tasks. It will manage the administrative, financial and other non-technical aspects of the project; assist the Coordinator and the Dissemination Manager in their duties; and act as the secretariat of the Managing Board.

To ensure the uptake of the technology of smart use of areas of reduced risk and the further development of the outcomes, the consortium realizes the need to include representatives of major stakeholders already during the running of the project as members of the *Project Advisory Board*. The board's key role is to monitor the general progress of the project, and giving recommendations on the direction of the activities. The Advisory Board will give regular feedback to the Managing Board. We have already received positive responses from H. Dahlin (EuroGOOS), E. Buch (BOOS), M. Stankiewicz (HELCOM) and J. Engelbrecht (President of ALLEA). Additionally, a representative of the shipping industry, a representative from a state maritime board, and a representative from a ministry of environment will be invited into the Board, also some representatives of Baltic Sea countries not represented in the consortium.

It is of course hoped for that conflicts that arise are typically resolved in a way that enables consensus-oriented solutions. Still conflict resolution procedures will be part of the Consortium Agreement, which will also cover Intellectual Property Rights (IPR) and the handling of pre-existing knowledge. For matters of major importance, the advice of the BONUS Secretariat will be sought.

8. Budget requested from BONUS+

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Personnel costs form about 70% of the total budget (Euro 1 615 554). Several partners (IoC, ICR, DMI, IFM-GEOMAR) will recruit either a PhD student or a postdoctoral researcher, while MISU, SYKE, SMHI and LDI prefer to contribute a part of the workload of their experienced researchers.

IoC will employ a Project Manager and Dissemination Manager (both part-time). They will be especially important at the start of the project, when a communication network will not just be set up between people, but also the computational infrastructures need to be linked. Since it is essential to keep the foreseen schedule, the involved people must meet face-to-face regularly to coordinate their efforts, address deviations and stay up-to-date on the overall progress. It is assumed that technical meetings and co-located sessions of the Managing Board will take place at least twice a year.

The costs of experiments (in WP5) are currently included in the budget of the coordinator but will be distributed between the partners as occasion requires. The rent of a ship and organization of field works is estimated as Euro 95,000 and purchasing of drifters as Euro 50,000.

The involved institutions will provide, as **in-kind contributions,** the accumulated know-how, models and computing resources of their teams.

9. Significant facilities and large equipment available for the project

Each team provides its own model, software, technology, and equipment. Four different Baltic Sea circulation models and two operational oil spill models have been thoroughly tested. The partners own extensive computing facilities, some of which are top-of-the-line not only in the Baltic Sea region, but also on the European level. For example, DMI uses the Cray XT5 supercomputer with 3600 processors, and a XT4 supercomputer. IFM-GEOMAR has access to HPC facilities at Kiel University, with NEC SX-8 vector computers perfectly suited for ocean circulation model runs, and has large electronic data storage capacities for the huge amount of model data. SMHI has access to computational resources of the Swedish Infrastructure for Computing, a dedicated Swedish computer for climate science, and an own computer cluster. SMHI is also shareholder in a currently built Linux cluster with ~3000 processor cores. The cluster will enable high-resolution simulations of centennial scale length and is well suited for multi-tracer runs with biogeochemical models. At IoC a cluster of 98 Opteron 2216 CPU processor cores was just launched. Thus, there are enough computational resources available for the project.

Although several partners own research vessels, we plan to use either the small research vessel *Salme* (Tallinn University of Technology) or vessels of the Estonian Maritime Academy in order to keep the budget reasonable and to ensure that the work will be done in due time. Still there may arise the necessity to use other ships for some of the experiments.

10. Researcher exchange and training. Advanced Study School

Most of the teams have been active and successful in researcher exchange and transfer of competence to new generations of scientists; for example, IoC is the key organizer of a series of international Advanced Study Schools in marine and coastal sciences. Intense joint training and exchange of young scientists has already been established between IoC and SMHI in the framework of the Marie Curie RTN SEAMOCS (2005-2009). Frequent senior researcher exchanges (for periods ranging from weeks to months) involve several partners (IoC, ICR, SYKE, IFM-GEOMAR). DMI, SMHI, SYKE and the coordinator (for IoC) have successfully worked together in the Baltic-wide EU network PAPA (2002-2005), etc.

The project will be featured in training activities for young researchers (Master and PhD students, Post Docs), in which many of the partners are involved. Specifically, an international Advanced Study School will be organised on project topics. This school will target young PhD level researchers employed by the partners, but will be open for the wider community.

In order to get maximum impact from this event, it is foreseen to publish a tutorial book (suitable for teaching purposes) on the interdisciplinary approach of the project. The book will be based on invited school lectures covering the following subjects:

- preconditions (high-resolution circulation models, operational drift & oil spill models);
- forcing factors (river discharge, atmospheric forcing, open boundaries, etc.);

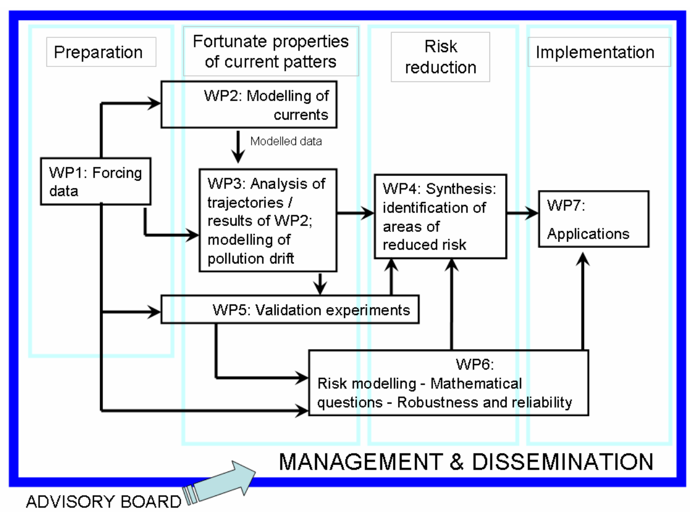
- technologies of massive & long-term calculations of velocities of water particles, and determination of particle trajectories;
- analysis of the set of trajectories for different seasons, years, ship tracks, etc.;
- methods of compilation of maps of probabilities & time scales for hitting vulnerable areas;
- various possibilities for cost functions, methods of estimating risks and relevant costs, identification of areas of minimum risk;
- combination of the results with the existing ship routing systems.

Ewald Quak (IoC) has just been an editor of such a collection of tutorials, which may serve as a kind of template (Hasle, Lie and Quak 2007). We also foresee the integration of project material into standard courses given by team members, e.g. in the course of coastal processes given by the IoC team. As several PS teach at universities, we plan an intensive involvement of graduate students in the project. At least four PhD students will be financed from the project, thus an equal or even larger number of PhD topics and theses will be generated.

11. Work plan

(Published as a short version)

The activities consist of four major groups (see flow chart) that are (i) launched subsequently, (ii) run in parallel later on, (iii) reflected through dissemination activities, and (iv) accompanied by the analysis of applicability and reliability of the methods in use.



Flow chart of the project activities

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WP1 Forcing and boundary data – Leader: ICR

Objective: Gathering, unification, recalculation and proper formatting of the initial, boundary and forcing data for the circulation, oil spill, and risk models.

Description of work and role of participants. The necessary data is scattered between different databases, formatted differently and generally not accessible on-line. Experience has shown that considerable efforts in reanalysis and reformatting are necessary prior to running the circulation models. These efforts will be concentrated in Estonia due to low labour costs. The major contribution of DMI, SMHI, SYKE, and ICR consists in providing access to their databases and work experience with large amounts of data.

WP2 Circulation modelling in the target areas – Leader: SMHI

Objective: To provide a high-resolution database of 3D current fields with long temporal coverage for the target areas, for the subsequent identification of the favourable current patterns and current-induced transport both on the sea surface and in the subsurface layer.

Description of work and role of participants. The circulation modelling efforts are crucial for the success of the project. A large time interval (>20 years) is a precondition for a reliable resolution of effects of seasonal variability and interannual variability of forcing and ice conditions.

WP3 Particle trajectory and oil spill modelling - Leader MISU

Objective: Conversion of the results of the 3D current simulations into practically usable data sets, from which proceeds the calculation of realistic patterns of (pollution) transport on and below the water surface in the identified target areas.

WP4 Synthesis: identification of areas of reduced risks – Leader: IFM-GEOMAR

Objective: Generalisation of the results of all modelling activities and validation experiments to derive practically usable results and suggestions.

WP5 Validation experiments – Leader SYKE

Objective: To provide *in situ* and remote sensing data for the validation of results extracted from numerical calculations.

WP6 Risk analysis and mathematics of inverse problems – Leader: IoC

Objectives: quantification of the gain from using the proposed technology in terms of environmental risks; estimates of the reliability of the approach; providing tools identifying the applicability of the approach.

Description of work and role of participants. For an uptake of the technology the guess that environmental risks are at minimum level for accidents that occur within the areas of reduced risk has to be validated in both qualitative and quantitative terms. The studies of applications will be limited to the particular case of oil discharge from ships.

WP7 Applications – Leader: DMI

Objectives: Development of a prototype of the technology for fairway design based on the environmental risk approach for the Gulf of Finland, implementation plans for its application, and identification of potential applications in other aspects of environmental management.

WP8 Management and dissemination – Leader: IoC

Objectives: to establish and maintain a strong cooperation between partners; to ensure coordination of the partner efforts and optimal use of the project resources; to ensure that the project proceeds as anticipated; to ensure that the project tasks and deliverables are completed in a timely and orderly fashion as foreseen in the project plan; to provide all documentation to the BONUS secretariat.

Description of work and role of participants. The management, dissemination and exploitation activities, and the IPR management will last for the whole duration of the project. The work is led by the Project Coordinator and Dissemination Manager, with active participation of all partners, WP and Task leaders.

12. List and timing of different Work Packages and Tasks

Work Package		*Year 1: Months 1–12*				*Year 2: Months 13-24*				*Year 3: Months 25–36*			
Leader	*Task*	*1 2 3*	*4 5 6*	*7 8 9*	*A B C*	*1 2 3*	*4 5 6*	*7 8 9*	*A B C*	*1 2 3*	*4 5 6*	*7 8 9*	*A B C*
WP1	**Forcing and boundary data**												
ICR	*Metocean data*												
	Data for risk model												
	Weather & radiation stress												
WP2	**Circulation modelling**												
SMHI	*Entire Baltic Sea*												
	High resolution target areas												
	Validation												
WP3	**Trajectory and oil spill**												
MISU	*Implementation of method*												
	Trajectories												
	Oil drift												
WP4	**Synthesis**												
IfM	*Reduced risk areas*												
	Uncertainties & seasonal patterns												
	Effects of wind and waves												
	Subsurface patterns												
WP5	**Validation experiments**												
SYKE	*Baltic Proper*												
	Gulf of Finland												
	Remote & oil spill tracking												
WP6	**Risk and mathematics**												
IoC	*Risk modelling*												
	Water age												
	Probabilistic approach												
	Mathematical problems												
WP7	**Applications**												
DMI	*Prototype of technology*												
	Implementation plan and gain												
	Legal aspects												
WP8	**Dissemination & management**												
IoC	*Tasks 8.1 – 8.3*												
	Advanced Study School												

13. Plan of submitting project data to some common database

The ultimate use of the project results is of course the development of the concept of areas of reduced risk into a technology usable in practice. Still the unified set of *initial, boundary, and forcing data* (wind, water level, river discharge, etc.) for the models for the simulation period as well as the systematised input data necessary for running the risk model is of clear value for the scientific community and definitely will be made available.

The collection of databases (of currents, particle trajectories, etc.) generated within the project will provide a wealth of resources for further research by the consortium partners, and also for further studying and dissemination. The intention is to make as many parts of them accessible and usable by the whole scientific community as possible. The partners are also very willing to explore the possibilities of co-operating with other BONUS project consortia in sharing project data, whenever possible.

14. Ethical issues and gender aspects

No ethical issues are expected to arise during this project. In particular, we do not use informed consent, any personal data nor do we use animals or human embryonic stem cells. The proposed research does not exploit any local resources of developing countries. The studies have no military or terrorist application.

Given the traditional under-representation of women in research and development activities within traditional marine sciences and offshore engineering, it is a positive sign that the teams involve several high-qualified female experts. The female researchers involved in the project will be fully integrated into the project teams and into the team and project management. Particular attention will be paid to provide possibilities for flexible working hours for those team members that have young children, as is already the policy of the participating institutions. In general audience related dissemination activities that target schools and universities, the teams will make special efforts to make sure that schoolgirls and female students are represented in the audience in order to help to attract more women to a career in science and technology.

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