The Coastal Research Program

at the Institute for Coastal Research,

GKSS Research Center, Germany

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The following is a general report about the research program of the GKSS Institute for Coastal Research. It has been written for scientists interested in the institute, specifically for visitors. The report describes the situation in early 2004.

First the object "coast" is defined; next the three key research questions are listed and discussed. The major part of the report is used to provide examples of specific research done – as a demonstration that the research program is not just fine words at the strategic level but reflects serious and relevant work at the nuts and bolts level. In the Appendix, information is provided about the infrastructure, the organizational structure, "white" publications as well as national and EC funded projects in 2003.

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The Institute for Coastal Research Ifk[2] was formed in the year 2001 by combining and focusing environmental research activities at GKSS, namely the Institutes for Hydrophysics, Atmospheric Physics and Chemical and Physical Analytics, on the challenge of monitoring, assessing, and predicting the environmental state of the coastal zone.

The object of research, the coast, is understood first as a significant component of the Earth System. As such, the IfK is engaged in understanding the sensitivity of the coastal environment to global change, and the role of coastal processes on the functioning of the global Earth system. For the Earth system the coast is of particular importance as it is the boundary between terrestrial and marine fluxes of matter; the coast also represents the most productive ecosystems in estuaries and shallow coastal seas.

The coastal zone is also understood as an outstanding landscape because it is under the continuous pressure of both heavy usage and constant modifications by humans for a variety of goals as well as violent natural forces. As such, being vulnerable, this landscape needs to be managed, and coastal research provides tools, assessments, and scenarios for doing so.

The deliverables of this research is the understanding of the role of the coastal system in the global context, the assessment of the state and sensitivity of the coastal system and the capability to picture possible futures with the help of scenarios.

GKSS is pursuing its research in the framework of the MARCOPOLI program, which is a joint effort with the Alfred-Wegener Institute for Polar and Marine Research. The work done at IfK is also closely linked to the research done at the Zentrum für Marine und Atmosphärische Wissenschaften (ZMAW) in Hamburg, and at the Forschungs- und Technologiezentrum Westküste (FTZ Büsum) of the University of Kiel. Fruitful cooperation is also arranged with the universities in Oldenburg and Lüneburg, with the Institute for Baltic Sea Research IOW and with the German Climate Computer Center, with various European partners in the EU Framework Programs, and with many other partners all over the world.

The MARCOPOLI-coastal research is part of the German contribution to the LOICZ themes: “River basin and human dimension”, “Fate and transformation of materials in coastal and shelf waters”, “System sustainability and resource management”, and “Coastal change and people”. The other important international framework the IfK program is contributing to the IPCC Fourth Assessment.

1 THE COASTAL LANDSCAPE

Coasts may be viewed as boundaries between land and sea or as wide transition zones between continents and the open ocean, including drainage basins, coastal lowlands, islands, and shelf seas till

[2] A schematic representation of the organizational structure of the IfK is provided in the Appendix of this report. In addition, a list of JCR publications in 2003 as well as a list of national and EC funded projects is given.
The institute contains also a group dealing with aspects of global climate in historical times; since this is only loosely related to coastal aspects, the work of this group is not covered by this overview. The group takes part in the global marine research program of MARCOPOLI.

the continental margin. Coastal areas are sensitive to global change, and are zones of particular interference between natural processes and human activities. There is use of geological and living resources as well as of energy, use of the coast for shipping, recreation, and waste disposal, while residual natural areas are preserved or restored at developed coasts. Driving pressures on the usage of coastal areas are high with an increasing percentage of the world population living at the coast and faced with an ongoing sea level rise.

During the past decades, coastal zones have experienced a tremendous increase in population and utilization by men. In many areas, such as in the North Sea and Baltic Sea, coasts are no more a natural environment but heavily affected and modified by past and ongoing human activities: exploitation of gas and oil, shipping and industry, offshore wind-farming, utilization of marine resources and mariculture, and tourism with all kinds of construction work including protection of coastal settlements. Coastal zones are subject to environmental threats that endanger the human population, economic activities, and the ecosystem. Examples of such threats are weather extremes such as storm surges, flooding, and wave activity. Ongoing climate change will enhance some of these risks. Other examples of anthropogenic threats are related to water quality such as contamination by hazardous substances, eutrophication, and oil spills.

Concurrently, many coastal zones are areas of high productivity and biological richness. They are important if not absolutely vital breeding and feeding grounds for many marine organisms and migrating birds. Because of this fact and its value for recreation, many coastal zones are protected areas. As an example, most of the German North Sea coast has been declared National Park with different zones of utilization. A sustainable use of coastal zones requires a rational management, balancing the various human activities and the natural developments in the framework of democratically formulated goals. Thus, the main challenge and task of coastal research is to provide policy makers and society at large with the required knowledge about the functioning and potentials of the system “coast” as the basis for an Integrated Coastal Zone Management. This knowledge consists of understanding of the relevant dynamical processes, the ability to monitor and interpret the environmental state and ongoing change, the documentation of long-term change and of scenarios of possible future developments.

In practice, the width of the coast will depend on the questions and problems to be treated. In the IfK program, the coast is considered as the part affected by human use, including the coastal lowlands and estuaries to the shallow shelf sea. A regional emphasis on the German coasts is combined with a global perspective from polar to tropical coastal regions.

2 THE GKSS RESEARCH

Key research questions addressed by the GKSS research program are

1. How is global change affecting the coastal system?
2. What is the present state and present change of the coastal zone?
3. How can we reliably and cost-effectively monitor coastal states and processes?

Further problems are addressed as well; in particular with respect to the competing public perceptions of coasts ("images of the coast"), and projects dealing with specific needs of authorities and commercial companies.

In the following, we will briefly sketch how these questions are approached; examples in Section 3 will illustrate what is done.

2.1 How does global change affect the coastal system?

Global change – that is, among others, change in climate, changing patterns of release of chemical substances, and changing the socio-economic pressure on the coast. There are several topical and typical problems addressed. Which new substances will be released in future into the fluvial and marine environment? How harmful may these substances be? What are the risks of alien species imported from other areas by shipping? How will different patterns of "spatial" usage (e.g. by large-scale offshore-wind energy parks effect) affect regional ecosystems? What will be the effect of changing weather patterns (i.e., climate) on storm surges, ocean waves, and coastal erosion?

In the following section we will present results from two studies in this field; the first deals with scenarios of changing storm surge statistics in the North Sea (section 3.1.1). The storm surge statistics is determined by the regional meteorological conditions; these are expected to change in the coming decades following the steady anthropogenic increase of radiatively active substances, in particular greenhouse gases like carbon dioxide and methane. The other example is dealing with the changing pattern of shipping (section 3.1.2); a major characteristic of globalization is the intensification of the exchange of products – which to large extent is taking shipping. Also, the use of fossil fuels will likely continue to grow, as envisaged by all IPCC scenarios at least until about 2050. Thus, the risk of oil spills will remain significant for coastal seas; also, the phenomenon of the arrival and spread of foreign species by ballast water will be a prevailing risk. The last case, in section 3.1.3, provides an example how European environmental legislation may change environmental conditions in estuaries and coastal seas.

2.2 What is the present state and present change of the coastal zone?

Methodically, this task amounts to combine sensibly observational data with adequate modeling capabilities, which allow for a holistic view of the system.

Different time scales have to be considered; time scales of hours to several days, and time scales of decades of years.

For the *short* time scale, of hours to a few days, the task is to provide decision makers, such as operators of harbors, offshore activities, or ships, with nowcasts and short term forecasts. The task for science is here to provide users with a methodology, which can be used in a regular, operational manner. A major goal of this activity is the construction of an "operational" model of the North Sea, comprising both the abiotic as well as the biotic environment. So far, suitable components for the hydrodynamics are readily available, but significant efforts are needed for the modeling of the ecosystem; also, the process of assimilating data into such a model (which is a standard process in the related problem of weather forecasting) needs significant R&D efforts. A further yet significant unsolved complication is the impact of anthropogenic impacts on the coastal ecosystem. These impacts need to be understood and quantified before they can be modeled in a reliable and realistic way.

The example presented in the next section demonstrates a methodology, which has been designed to advice captains and pilots about regional current, wind and wave conditions in the wider entry of a harbor (section3.2.1).

For the *long* time scales, the task is to assess slow changes, which may be related to, for instance, climate change, to regulations such as the banning of lead in gasoline or the gradual improvement of river and coastal waters by waste water treatment. Such an assessment is needed to identify adverse developments, allow for timely re-definitions of thresholds, and for the a-posteriori assessment of the effect of political regulations. Obviously, these efforts are methodologically close to the task of building scenarios.

Here, two examples are presented. The first deals with the assessment of the marine wind- and wave statistics as well as long-range transport of hazardous substances in Europe (section 3.2.2); the second is an analysis to what extent the fluvial load with heavy metals in the river Elbe has changed as a response to the abrupt change of economic activity in Eastern Germany and the introduction of efficient water treatment plants (section 3.2.3).

2.3 How can we reliably and cost-effectively monitor coastal processes?

The aforementioned tasks can be achieved only when sufficient data are available. The problem is that collecting data representative for the state of the coastal environment is a costly and demanding task. Recording hydrodynamic parameters in coastal areas is in most cases no longer a challenge; but recording parameters describing the chemical and ecological state is not yet solved in a manner that allows a routine reliable and affordable monitoring practice. The challenge is multiple – it is related to the selection of parameters to be measured; the analytical procedures to do the measurement; the technology of recording and transmitting; the conceptual approach of contextualizing the data.

Three examples are shown in Section 3.3. The first is on in-situ technology to determine the chemical and ecological quality of sea water; the technology is mounted on a ferry; the second deals with the changing bathymetry, which is monitored by a radar technique (section 3.3.1); the third is a remote-sensing technology which allows the determination of the concentration of suspended matter and other parameters in the upper layers of the coastal sea (section 3.3.2). The sensor is mounted on the European satellite ENVISAT.

3 EXAMPLES

In this section, we present a series of examples for the general research questions raised in the previous section. In many cases, the studies were made in a European consortium funded by the European Commission (see Appendix 5.4.2).

The overall strategic approach has been spelled out in the previous section; also the significance of the various examples to follows has been explained there. In this section, we want to present our work with some technical detail. Because of the complexity of the coastal system, both in terms of its dynamics and it utility, such a series of examples will necessarily raise with some readers the impression of a shopping list. However, a comparison of the examples with the overarching objectives of the programs reveals that the selection of cases is not arbitrary but an adequate attempt to cover the breadth of the topic.

3.1 Global change and the coast

In this section a number of research examples engaged in estimating and assessing coastal impacts of global change is presented. As for other low lying coastal regions the North Sea coast experiences a particular threat from storm surges which represent a major risk for human safety. In the first example new scenarios of future storm surge statistics under increased greenhouse gas concentrations are presented (section 3.1.1). The second example is related to the risk from oil spills. This risk may increase in the future in particular in the North Sea and the Baltic Sea where intensive shipping is confronted with numerous plans for future offshore-wind farms many of them in the vicinity of major shipping routes (section 3.1.2). The third example is related to riverine deliveries to the coastal zone and the related human dimension. It demonstrates that coastal systems are affected not only directly but also indirectly by changes occurring in the river catchments (section 3.1.3).

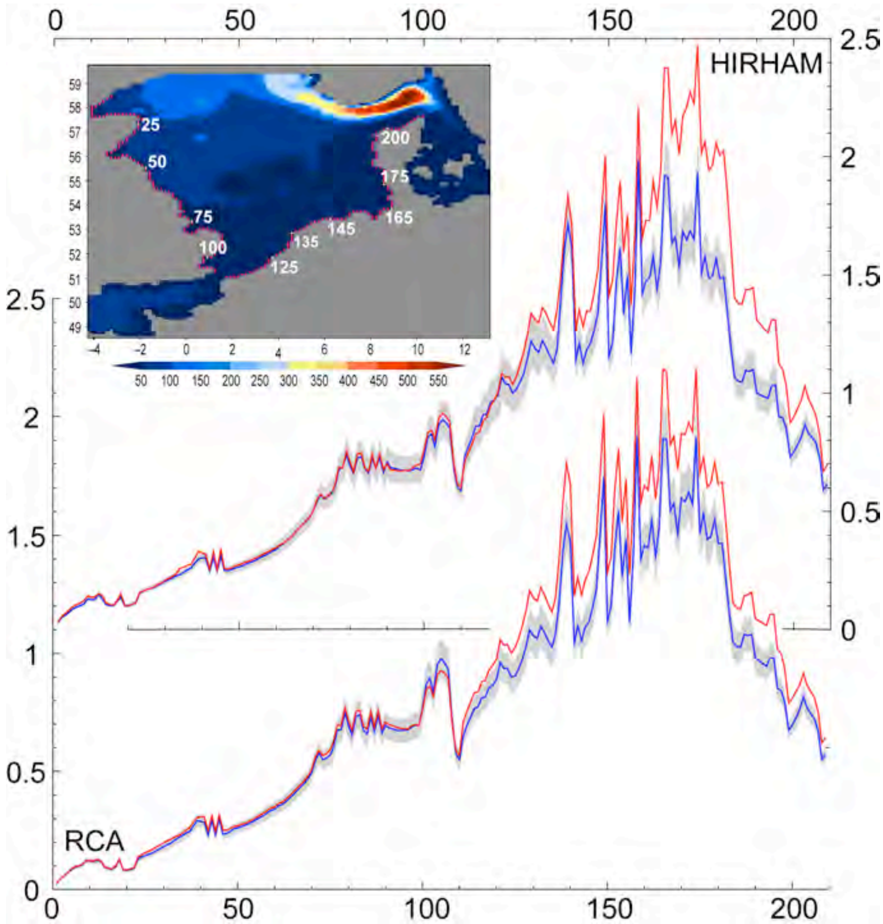

Figure 1: Mean of winter maximum surge levels (unit: meter) from 30 years control run (blue line) and A2 scenario (red line) for near-coastal locations along the North Sea coast (as indicated as red points in the inset). Top: HIRHAM model, bottom: RCAO model. Shaded area: 90% confidence interval for present natural variability.

3.1.1 Future storm surge statistics for the North Sea coast

Obviously, the threat of storm surges is a serious environmental problem for low lying coastal regions. Kauker and Langenberg (2000) and Langenberg et al. (1999), among others, have shown that the statistics of storm surges can satisfactorily be modeled with hydrodynamical models.

Apart of the reconstruction of the past history of water level variations and storm surges along the North Sea coast, another application of such models is the estimation of possible future storm surge statistics (e. g. Kaas et al., 2001). Scenarios are obtained by running the hydrodynamic model twice. First, many years of wind and pressure data, simulated by a high-resolution global climate model under "control conditions" (i.e. with present day atmospheric greenhouse gas loadings) were administered; in a second run the same variables were used, but from a time slice in the future, simulated by the same model this time forced with some anticipated future atmospheric greenhouse gas concentration.

In the WASA[3]project (Langenberg et al., 1999; WASA, 1998) the wind and pressure data originated from a couple of two 5-years simulations; in STOWASUS (Kaas et al., 2001) 30-year time slices were used. In the present PRUDENCE project, a hydrodynamic model is used to simulate "control" and "climate change" conditions for the North Sea. The inset of Figure 1 shows the integration area, the bathymetry as well as the coastal grid points.

The study differs from the previous approaches first by a dynamical downscaling of the regional wind and pressure conditions. An original global simulation describes the evolution under a 1961-2100 emission scenario[4]. The years 1961-1990 serve as control time slice, the years 2071-2100 as "climate change scenario". The global simulations are downscaled by a series of regional models to a much finer grid of about 50 x 50 km_. The various project partners, among them also GKSS, all run their regional models for this purpose.

The changes in storm surge statistics caused by the meteorological conditions were described i.e. as changes in percentiles of high water elevations. Since most impact damage is expected in the coastal zone the storm surge residuals were analyzed focused on near coastal grid cells along the North Sea coast. Figure 1 shows a comparison between the modeled surge forced with data coming from simulations with two regional atmospheric models (Danish HIRHAM and Swedish RCAO) for present-day conditions (blue curve) and the climate chance scenario (red curve) along 209 extracted near coastal cells. The winter maximum of the modeled surge of each year was selected and averaged across each of the two 30-year periods. The shaded grey band around the control blue line indicates the 90% confidence interval. Along the UK coast, the red curve remains within the grey band, indicating that no significant change in surge statistics is happening there. Nevertheless at about 50% of all locations, namely those along the Dutch, German and Danish coast, the red curve is outside the grey band, showing a noticeable increase of the mean maximum winter surge for the scenario. For the HIRHAM forcing the increase is up to almost 60 cm whereas in the RCAO the increase is only about up to 20 cm. The effect of general increase of the sea level is not included in this analysis.

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[3] WASA, STOWASUS and PRUDENEC are names of EU funded projects.

[4] The global model is HAdAm3 for the Hadley Center; the scenario is SRES A2.

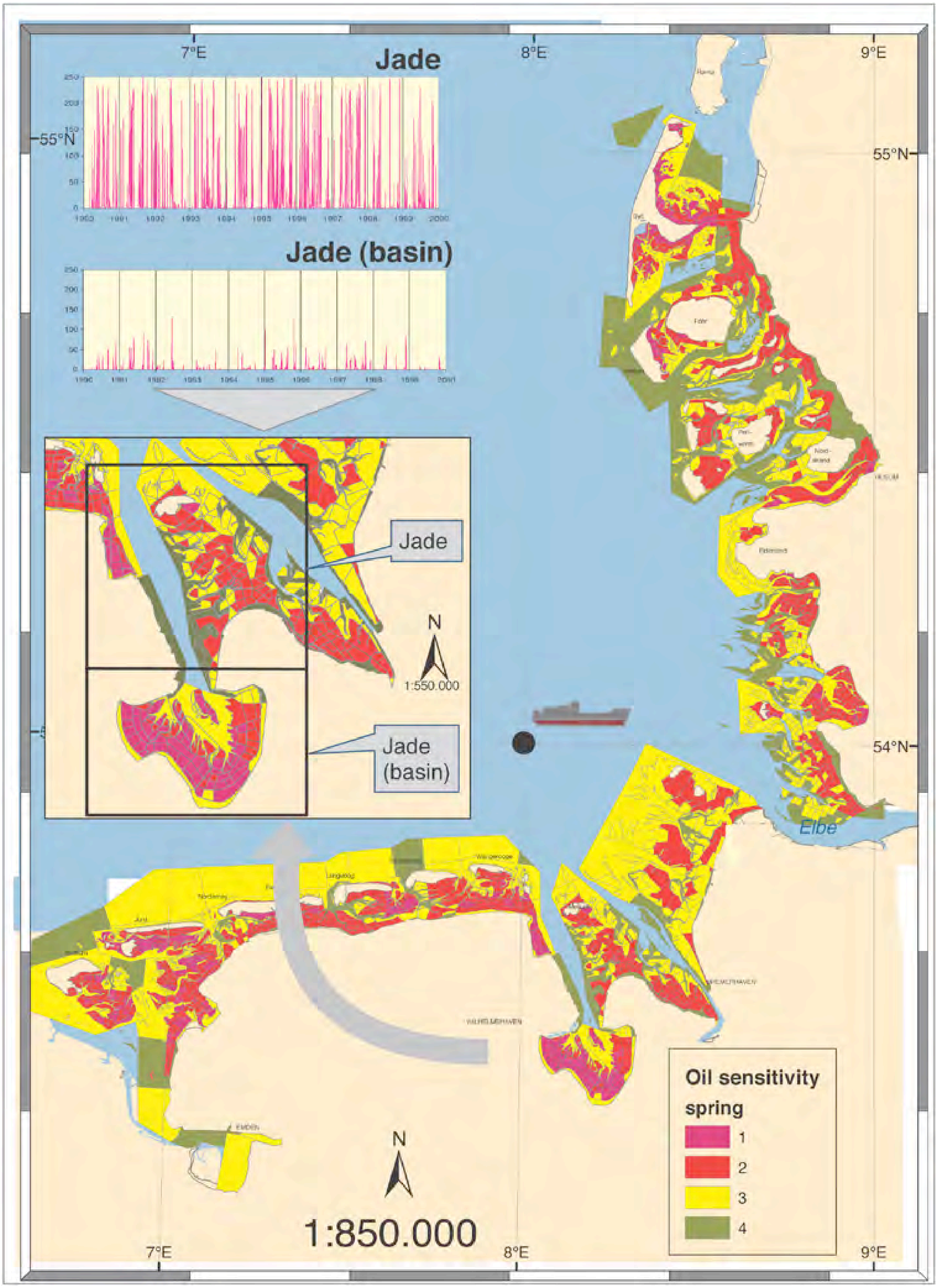

Figure 2: Simulations based on a 10 years period of reconstructed weather conditions: Number of particles that would have reached the Jade region and the inner Jade basin, respectively, if a hypothetical oil spill event (represented by 250 released particles) had taken place at the indicated location. Oil sensitivities of the ecosystem are labelled between 1 (high) and 4 (low).

3.1.2 Intensive shipping and risk of oil spills

The “Wadden Sea”, a contiguous region of tidal flats, barrier islands, alluvial terrestrial zones and salt marshes, extends along the North Sea coast of Germany, The Netherlands and Denmark. It is about 450 km long and up to 20 km wide. It is of enormous value as a cleansing site for the coastal water, as a nursery for young fish, and as a feeding and nesting ground for wading birds and waterfowl. The German part became a national park in 1985/86. The proximity of important shipping routes and ports is a permanent threat.

There are plans to build offshore wind-energy parks in the German Bight not far from these shipping routes. An important question is whether the presence of wind turbines would significantly increase the risk of ship collisions and a subsequent oil pollution of the Wadden Sea coast. Large quantities of crude oil, which can spread over wide areas by tides and winds, present not only the danger of temporary damage but rather of permanent harm, since oil, bound to the sediment, is released very slowly .

At GKSS, detailed reconstructions of meteorological and hydrodynamic conditions in the past decades (cf. Section 3.2.2) are used for a comparative assessment of different locations that are considered for the installation of the wind-energy parks. In combination with coastal environmental sensitivity maps for oil spills, produced by GKSS within the project “Thematic mapping and oil spill sensitivity study” for the national contingency plan (van Bernem et al., 2000), these detailed long term simulations, which explicitly resolve natural variability, provide valuable information far beyond prototypical studies based on few selected characteristic weather situations. They improve the basis for a reliable assessment of the efficiency of implemented response measures and provide important input for the optimization of response strategies with regard to the protection of the most vulnerable coastal areas. As an example, Figure 2 presents results of a detailed simulation of consequences of a hypothetical oil spill event as function of time and the exact location of the coastal area to be protected.

3.1.3 River basin deliveries to the coastal zone and human dimensions

Coastal areas are impacted by human activities that originate in the “hinterland”. Activities in river catchments determine the horizontal flow of materials to the coast with impacts on coastal morphology (e.g., sediments) or the ecosystems (e.g., nutrients and contaminants).

In trying to provide options for managers, science has to take into consideration that there are large regional differences in definitions of ’natural’ or ’acceptable’ environment conditions. These differences also have a cultural background biasing society’s perception of the coastal zone and its value functions. Thus, rather than to define standards it is our aim to provide the sound scientific information to do so. Science can be seen as having a narrative role here, showing the trajectory of change along the basins systems, providing projections into the future, and highlighting the critical system switch points for decision and intervention.

The challenge is to bring together the combined expertise of natural and social sciences to study the river basin and coastal zone as one system; recognizing that while the major impacts are at the coast, part of the solution lies within the river basin.

As one of the first attempts to meet this challenge and to provide better science for improvement of management, the EUROCAT EU project (jointly coordinated by GKSS and the Vrije Universiteit

Amsterdam) has been launched (Figure 3). The overall goal of the EUROCAT project is the preparation of concepts for an integrated catchment management and for a sustainable use of water resources at a catchment scale. Using the unifying framework of Driver-Pressure-State-Impact-Response (DPSIR), the response of the coastal zone to changing material fluxes is connected back to the individual socio-economic drivers at the catchment scale (Nunneri et al., 2002). The results of the study are useful to develop better management solutions and strategies in some of the main river basins in Europe, including implementation of the Water Framework Directive (Hofmann et al., 2003).

The pressures affecting catchment-coastal zone systems vary across Europe because of differences in geography as well as in economic and social conditions. In order to identify these differences and their relevance for a better management strategy at the catchment level, the EUROCAT regional studies deal with Mediterranean Sea, Baltic Sea, and North Sea, and eight associated catchments characterized by relevant environmental and management issues.

The EUROCAT approach is now extended to other continents in the framework of LOICZ basins.

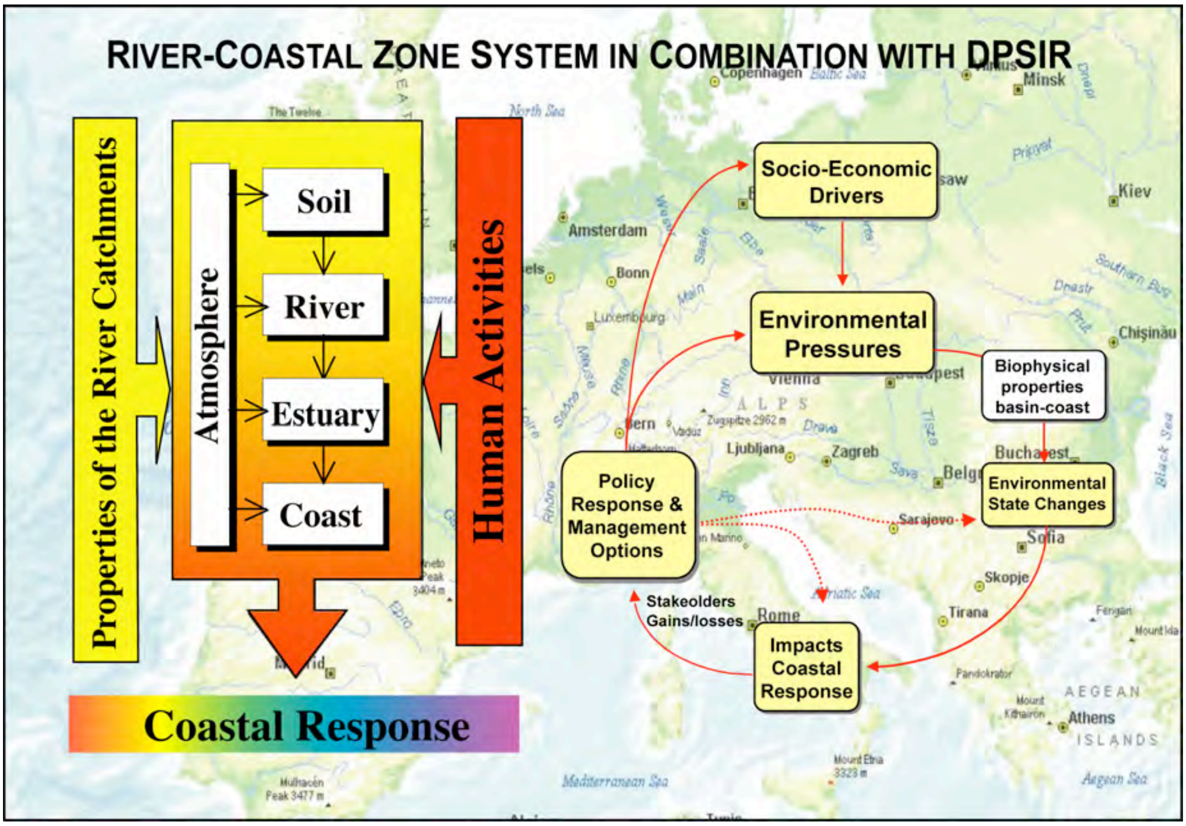

Figure 3: The EUROCAT (European catchment changes and their impact on the coast) approach to catchment/coast interaction.

3.2 Present change: Short term und long-term assessment

As already outlined, we face two challenges. The operational short term assessment and forecast needs to be repeated regularly. It serves the needs of practitioners in companies and authorities. The other type of assessment is the analysis of long term statistics and change needed for the determination of risks and for the evaluation of the success or failure of changing usage or of modifications of the coastal environment.

In this section, we present three examples. The first is related to monitoring waves and currents for shipping. A methodology and a demonstration study are presented that provide support to ship traffic and enhance safety by providing real-time data of wind, wave and currents in nautically difficult waters (section 3.2.1). The second and the third example deal with longer time scales. In one case, incomplete observational data were processed with detailed environmental models to reconstruct environmental conditions during the past 5 decades of years in some detail (section 3.2.1). The last case is an example of fist setting up a dedicated long-term observational campaign for assessing long-term change (section 3.2.3).

The strategic value of such analyses is double. The first example addresses obvious operational needs for managing coastal activities. The latter assess the present state including that range of variability – which allows the assessment of past regulations and environmental legislation and the detection and attribution of anthropogenic change. Also, analysis of ongoing long-term changes and present changes provide the backbone for assessing potential future changes.

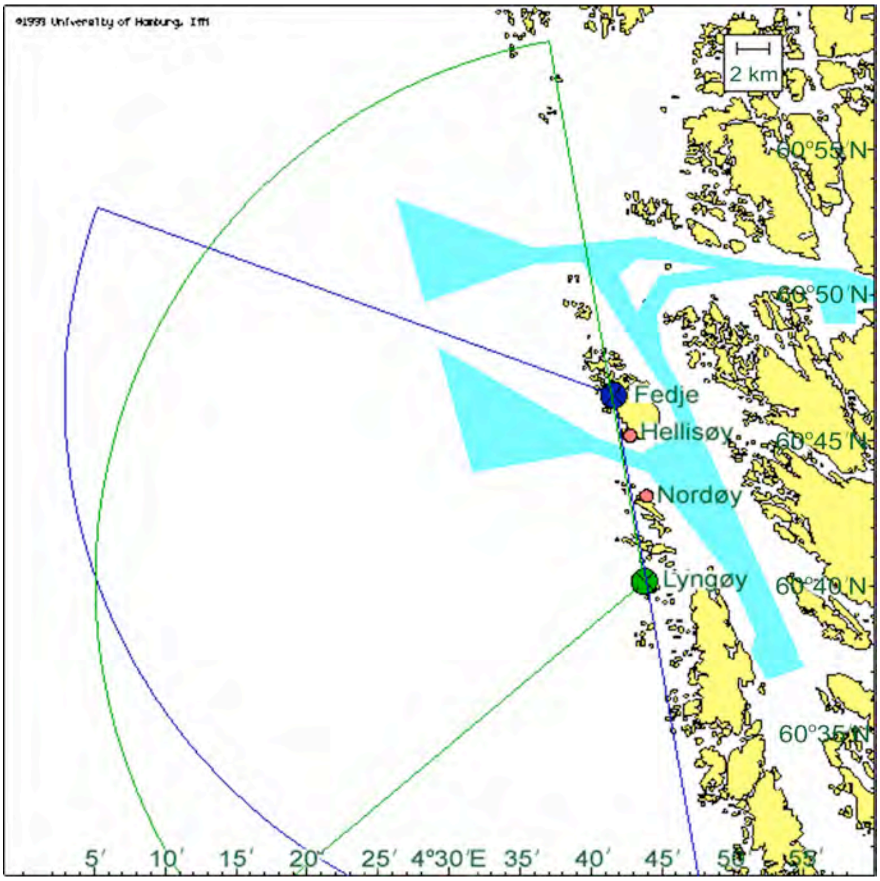

Figure 4: The area in front of the passage south of Fedje (near Bergen, Norway) was observed by two WERA HF Radars sited at Fedje (blue) and Lyngøy (green), and by two WaMoS Radars (red) sited at Hellisøy and Nordøy. This map gives an overview on the area and shows the ship ways (light blue) and the estimated coverage of the WERA radars.

3.2.1 Monitoring waves and currents for shipping

In the perspective of the Global Ocean Observing System (GOOS) an important goal is to develop operational tools for those in charge of safety and regulation for coastal marine operations and constructions, as well as for the protection of the marine environment.

The primary objective of the European Radar Ocean Sensing (EuroROSE) project (Guddal et al., 2000) was to provide monitoring and short-term forecasts of winds, waves, and currents, to support the ship traffic management in port approaches.

The methodology was to combine by data assimilation area covering remote sensing data and high-resolution numerical forecast models (Breivik, 2001) and to display the data in VTMS (Vessel Traffic Management Services) centers.

The full EuroROSE system was scientifically validated and successfully tested in two field experiments. Currents and wave fields of the Atlantic coasts of Norway and Spain have been measured and modeled during two experiments. (See Figure 4; Essen et al., 2003; Wyatt et al,. 2003).

The close co-operation between the scientific and end-user community, and the data quality achieved by combining numerical models and real-time ground based radar measurements resulted in a high acceptance of the systems for operational applications.

3.2.2 Regional environmental history 1958-2002

Lay people would conjecture that weather, wave conditions and aerial transport in Europe would be well known since everything has been "measured". This is a misconception as the state of the atmosphere, the coastal sea or the transport of matter is never measured but needs to be "analyzed", which means that the local data are extrapolated to a complete quasi-continuous description with the help of models. Since the models are improved in the course of time and since the observational technology and network change in time, the result of this changes is that the record of analyzed weather (and other variables) is not homogeneous but contains to some - mostly unknown - extent not only physical signals but also non-meteorological effects. However, the derivation of trends and proper extreme values statistics require homogeneous analysis.

At GKSS we are engaged in preparing such homogeneous analyses. Apart of being homogeneous, the result is better than conventional products as it provides spatial and temporal detail needed for impact studies, such as ocean wave conditions.

A spatially and temporally detailed reconstruction of the European weather of the last decades was calculated (Feser et al., 2001). It used the coarse-scale weather analysis by NCEP, which were fed into the regional atmospheric model SN-REMO using the spectral nudging technique (von Storch et al., 2000). This exercise resulted in a presentation of the weather stream for all of Europe from 1958 until 2002 on a 50 by 50-km^2 grid once an hour. A validation for wind conditions over the sea gave favorable results (Garcia-Sotillo, 2003; Feser et al., 2003, Koch et al., 2003). The data (until 1997) are available at the German Climate Computer Center for public use.

These wind analysis have been used for calculating wave conditions in the European coastal waters for the entire period, 1958-2002. This was done in the European project HIPOCAS (Soares et al., 2003), and the quality of the wave data were found to be very good. Extreme value statistics derived from these data are now used as background for the planning of off-shore activities, and for assessing ongoing climate change. Figure 5 shows the changing significant wave heights in the Southern North Sea in 1958-1998. For most part of Northern European Seas, there was a tendency towards more storms until the early 1990s, but more stationary conditions since then.

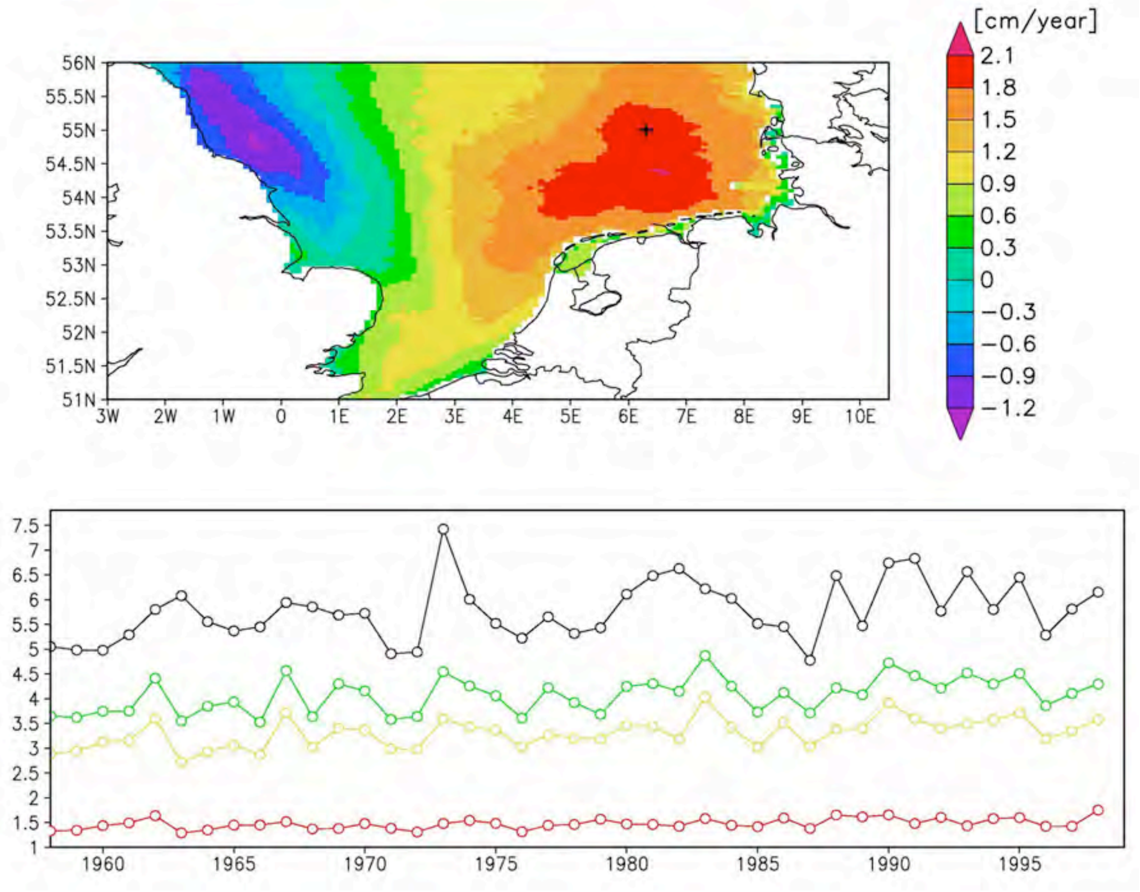

Figure 5: Linear trend of the intra-annual 99 percentile of the total significant wave height in cm/year as obtained from a multi-decadal wave hindcast 1958-1998 for the North Sea south of 56 North (upper). The resolution of the wave model simulation is about 5.5 km. Time series of the intra-annual 50, 90, 95 and 99%-tile (from bottom to top) are shown in the lower panel. The location of the grid point is indicated by the black cross in the upper panel.

The data have been used for more applications; for instance, the currents and water level variations in the North Sea have been calculated; also suspended matter conditions and possible pathways of oil slicks in case of accidents are considered.

The wave and current data are exploited for assessments of the present situation by a variety of user, both from governmental agencies such as BSH, BAW or ALR but also from commercial consortia.

Due to changes in industrial production pathways, environmental awareness and legislation, consumer demands and the development of new chemicals, the pressure on coastal ecosystems based on anthropogenic substances also undergoes long-term changes. A reduction of industrial or private usage of substances can, but does not necessarily result in lower exposition risks for humans and ecosystems.

This is also dependent from the decomposition behavior and transport pathways of the substances in the environment. The joint application of sophisticated numerical models and analytical measurement techniques enables the assessment of reduction scenarios for hazardous chemicals.

An extensive analysis was made with gasoline lead, of which larger and larger amounts were emitted until the 1970s (von Storch et al., 2003, Hagner, 2000). In the 1970ies and 80ies lead was gradually phased-out from gasoline. This resulted in a decrease of atmospheric loads and to a lesser degree in the accumulation of lead in terrestrial ecosystems and humans (Hagner, 2002; von Storch and Hagner, 2004). In coastal marine ecosystems however, a decrease of lead concentrations could hardly been detected (Hagner, 2002).

Also, the pathways and depositions of mercury have been dealt with extensively. 40% of the European emission sources for mercury were located in the Elbe drainage basin and have contributed significantly to the deposition into the North Sea. At the beginning of the 1990ies emissions from this region have been reduced significantly due to political changes and the immediate shut-down of production facilities such as caustic soda and acetaldehyde plants in East Germany. Spatial and temporal variability of atmospheric mercury has been assessed by a combination of field measurements and numerical models, resulting in high resolution deposition fields. (Schmolke and Petersen, 2003, Ebinghaus et al., 2002).

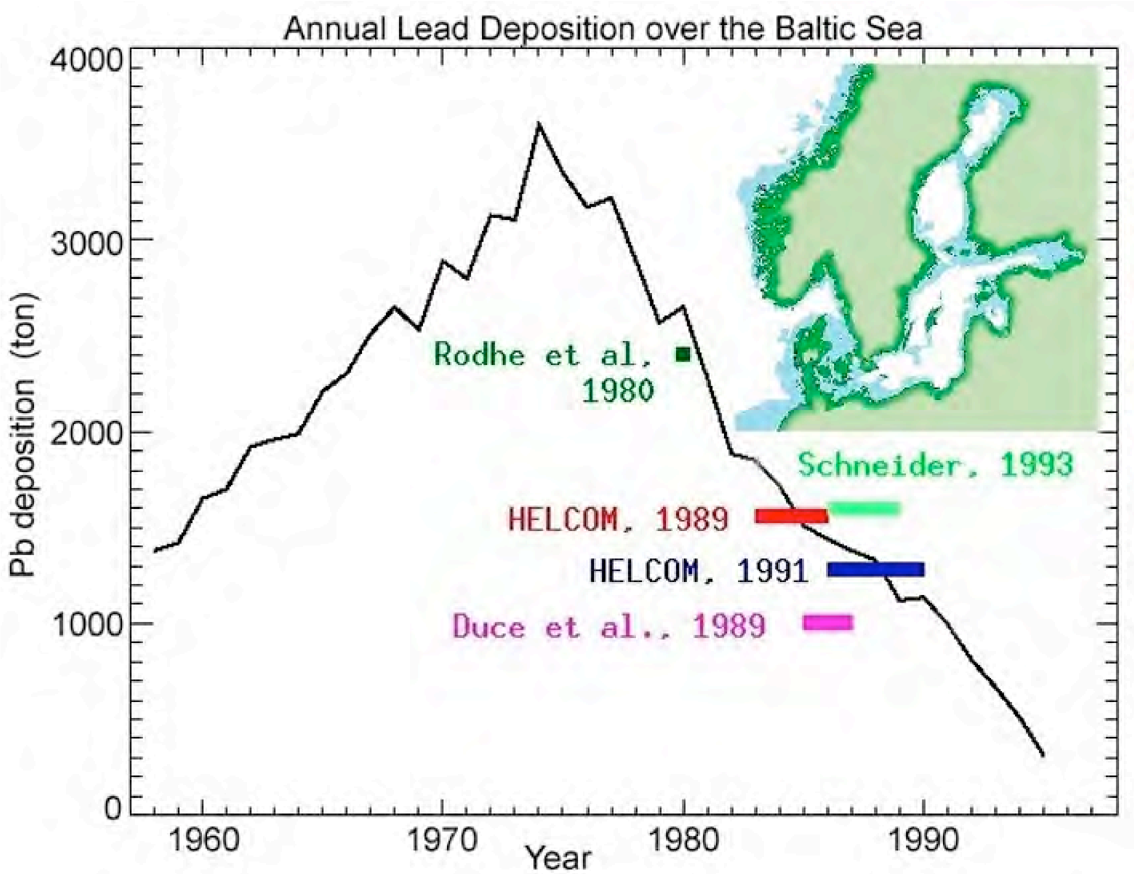

Figure 6: Lead deposition as estimated with a model, using estimates of emissions and detailed weather information 1958-1995, and several estimates derived from observations. (von Storch et al., 2003).

The same approach of strong interplay between model application and field measurements is presently implemented for multi-compound group of Persistent Organic Pollutants POPs. Present environmental concern is very much focused on perfluorinated organic compounds (PFOCs) in marine ecosystems, a substance group used for a variety of consumer products and applications for the past 50 years. Although produced in huge quantities (globally: 5 mio kg/year) and known adverse effects on human and ecosystem health, information on the occurrence and trends of these highly persistent and bioaccumulative substances in the North Sea do not yet exist. PFOCs substances are nowadays partially phased out. In close cooperation with BSH and FTZ Büsum concentrations are determined in the North Sea (water and atmosphere) and in North Sea seals.

The reconstruction of the history of coastal climate and coastal pollution as exemplified here is a fundamental requirement to evaluate the present state and present change of the coastal zone (one of the program's key research questions) and to derive science-based needs for future monitoring.

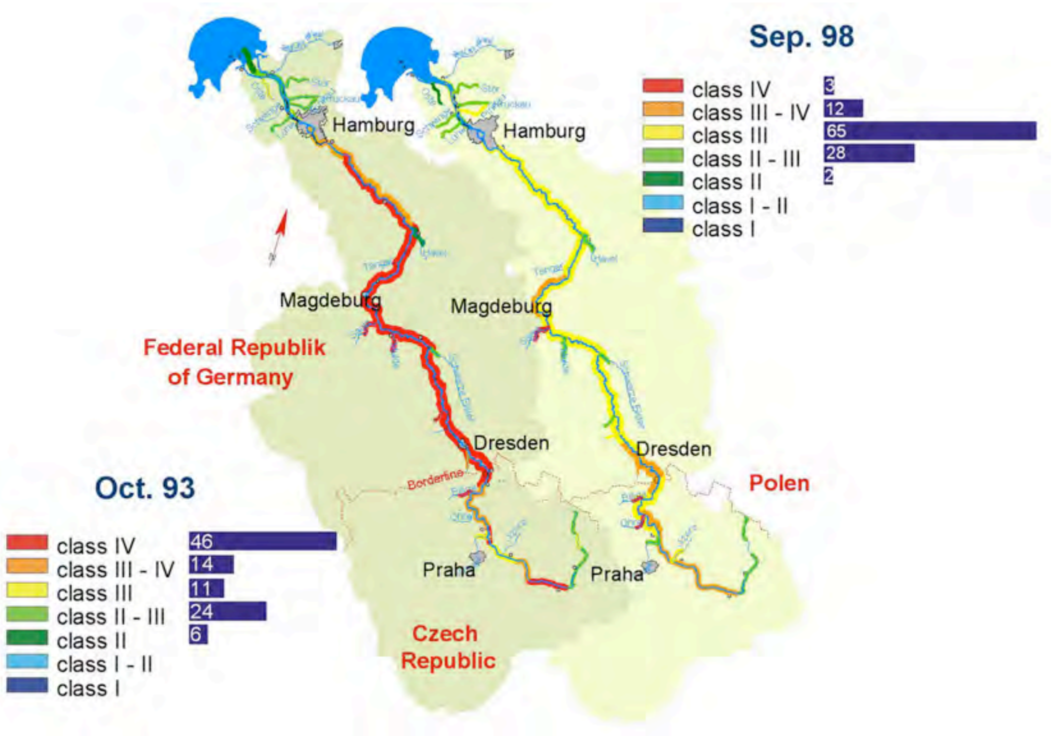

Figure 7: Comparison of the quality state of mercury concentrations in suspended particulate matter of the River Elbe in October 1993 and September 1998. Along almost the entire German part of the rive Elbe the water quality has improved by one class, from red to yellow (classification scheme of the ARGE Elbe).

3.2.3 Assessment of water quality in the Elbe after the political changes in East Europe

At the beginning of the nineties, the river Elbe was one of the most polluted rivers in Europe. With its length of 1091 km and a catchment area of 148268 km^2 the river significantly affected the coastal area of North Sea by its outflow into the German bight. However, after the political changes in East Europe great effort was laid on improving this situation (see also Section 3.2.1).

After reunification, it became possible for the first time to monitor the actual state of contamination of the entire river Elbe from the source to the mouth. To verify the success of the initialized action, above all the assessment of the temporal trend of the elemental charge and its state at the end of the nineties was a matter of interest. For that purpose several sampling campaigns have been carried out between 1992 and 2002, where samples out of the river water and the sediment have been taken in an almost instantaneously along the longitudinal profile of the river Elbe from the mouth at the North Sea in Germany to the spring in Krokonse Mountains in the Czech Republic (Prange et al., 1995). This has been done in close cooperation between GKSS and official national water institutions of the Czech Republic (Povodi Labe, Hradec Kralove and VUV, Praha) as well as German water regulatory authorities such as the "Wassergütestelle Elbe" in Hamburg and other institutions. Apart of assessing the changing water quality of the river, another goal was to use this information to develop scientifically-based strategies for targeted and cost effective river monitoring programs in the future and for the initiation of effective remediation measures (Prange et al., 1997).

Today the water quality of the river Elbe has improved significantly due to the changes in industrial production lines, the closing-down of chemical factories and the installation of more than 30 water treatment plants. It has reached a state comparable to that of the river Rhine approximately 10 years ago. Figure 7 demonstrates significant improvements on the example of Mercury. Nevertheless, anthropogenic and xenobiotic substances such as e.g. hexachlorohexane still pose a serious problem for the water quality of the river Elbe, e.g. for the use of drinking water and for the ecological functioning. Point sources do not play the major role any more. Instead, diffuse run-offs are of increasing predominance. Of ongoing concern, however, is the continuing wash-out of abandoned polluted areas of former industrial sites near the city of Bitterfeld and the mining areas of the Erz Mountains. Highly contaminated water is still transported via the tributary river Mulde into the river Elbe (Aulinger et al., 2002).

3.3 Monitoring technology and methodology

The backbone of any integrated coastal management is scientifically based information about the state and trends of the coastal environment and about options for managing its development and utilisation in a sustainable and safe manner. Advanced and efficient monitoring techniques are necessary to sample data, which are representative in time and space and which capture also extreme events. To achieve this goal it is not only necessary to develop the necessary equipment but also tools for data management and processing as well as strategies, which allow us to adapt these techniques to the special scales of an area and period on which changes are expected or to events such as accidents, where a quick availability of information is needed.

The main emphasis will be placed on issues related to water quality, maintenance of marine and coastal biodiversity and habitats. We will address the effect of wind, waves and currents on coastal habitats, ship traffic and offshore activities, coastal protection and possible accidents.

In our research program we focus our work on (1) the development of automatic in situ measurement systems, which are operated either from ships of opportunity (ferry-box) or buoys or measurement poles in case of shallow water, (2) on remote sensing techniques, which are operated from ground, aircraft or satellite, and (3) on models for combining the results from different sources and for interpolating gaps in the data. Furthermore, statistical methods are used to analyze the data and to develop or adapt strategies for sampling. Finally geo-information techniques are used and further developed to maintain data bases and retrieve and visualize the information.

For improving the monitoring potential of data from remote sensing and automatic measurement systems, we have to identify proxy and indicator variables for which the relationship to those variables of interest have to be determined, which cannot be observed directly by using the automatic and remote sensing techniques.

3.3.1 In-situ technology

One of the observation methods mentioned above is an in-situ technology for the measurement of chemical and biological parameters, which control the quality of seawater. In order to reduce the running costs the system is mounted on ferry boats as instrument carrier - in contrast to moored buoys which need costly research ships for maintenance. The autonomous FerryBox system consists of a flow-through unit with sensors for temperature, salinity, oxygen concentration, turbidity, pH, chlorophyll (fluorescence), algal groups and nutrient concentration (ammonia, nitrate/nitrite, o-phosphate, silicate). A GPS receiver gives the exact position of the ship (Figure 8).

The system is controlled by an industrial PC which is in connection with the land station via cellular phone. Whereas most marine in-situ measuring system, e.g., on buoys, have many problems with bio-fouling the FerryBox has an integrated anti-fouling system: By pressure-cleaning of the sensors in combination with rinsing with diluted acid no bio-fouling occurs.

The system is mounted on a ferry from Cuxhaven to Harwich (UK) since November 2000 measuring the water quality of the southern North Sea. In contrast to fixed mooring the system has to main advantages: 1) Less maintenance costs, and 2) regular profile data over a large distance. The project is integrated in the EU project "FerryBox" in which 8 ferry systems will be compared and applied to different scientific questions (e.g., water quality, eutrophication, sediment-/ water transport)

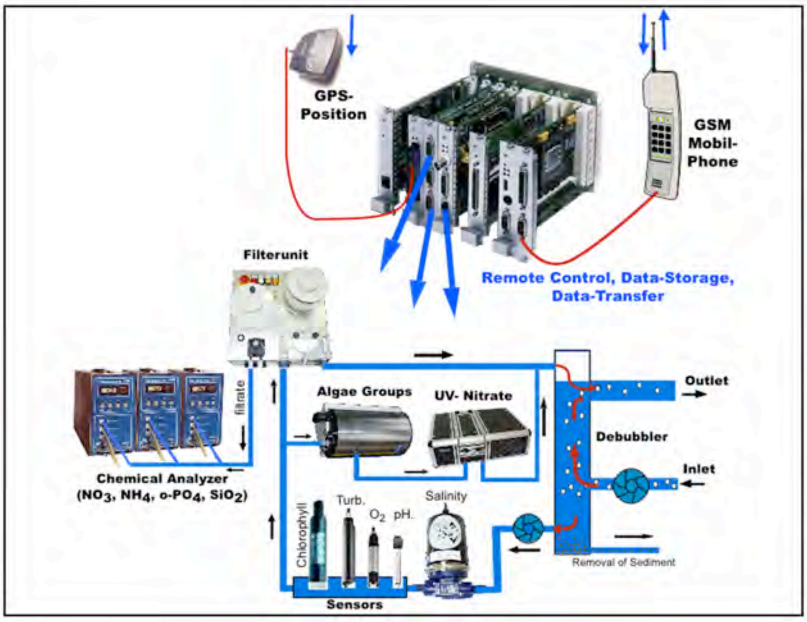

Figure 8: Schematic drawing of the FerryBox system.

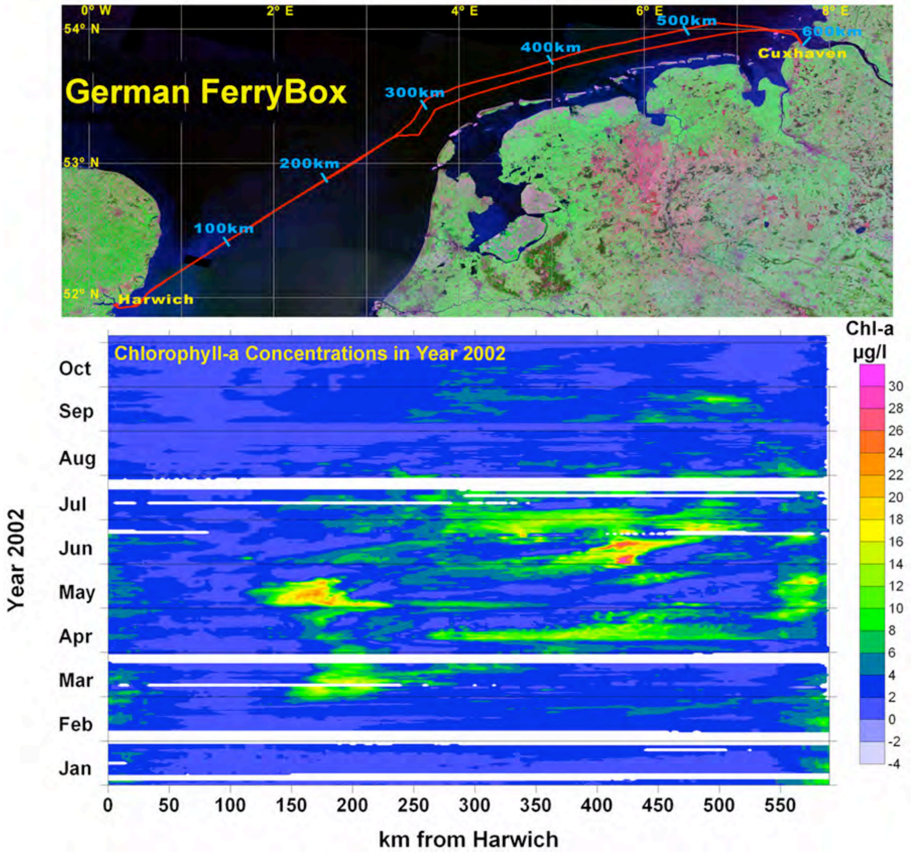

Figure 9: Measurement of chlorophyll-a along a transect from Cuxhaven to Harwich (Ferry route).

Figure 9 shows as an example a contour plot of the chlorophyll concentrations .On the vertical axis the time is depicted; the horizontal axis shows the distance from Harwich. The chlorophyll concentrations are color-coded from small values (blue; 2-6 µg/l) to large values (red; 16-22 µg/l). Until the end of February no algal growth exists. This starts between km 180 and km 220 in early March. Later in April plankton growth occurs along the whole Dutch and German coast. In early May this bloom breaks down, leaving only the patches at km 150 and km 560.

The diagram displays only conditions along the ferry transect. The decrease of chlorophyll concentrations along the Dutch and German coast may reflect a break-down of algal populations or the large "algae patch" may have drifted out of this transect. In order to get more information on the distribution of chlorophyll in larger parts of the North Sea as well as information on the movement of chlorophyll patches satellites are needed. In the near future not only remote sensing data but hydrographical modeling will be used for a better interpretation of the FerryBox data.

This example shows that by using the innovative FerryBox approach it is possible to collect chemical-biological parameters which describe the state of coastal waters in a better and less costly way.

Another monitoring approach makes use of radar hydrography, which allows monitoring hydrodynamic parameters extending across large areas.

An example of the successful use of such technology is an application to coastal protection. Beach nourishment is the most valuable measure to conduct coastal protection. To keep control of the sand brought into the near shore environment monitoring of the bathymetry is required. Ground based radars may be used to this end. This can be achieved by Inverse modeling of the bathymetry by the refraction of the near shore wave field (Senet et al., 2001, 2004): The model uses the wave refraction depending on the local water depth. Figure 10 shows the bathymetric change determined between 2001 and 2003 for an area off the island of Sylt. Close to shore loss of sand is obvious, whereas a broad stripe between 200 m and 800 m distance from shore shows a significant increase of sand. Another sand reduction zone is at a distance of around 1000 m. These results have been verified by conventional observations.

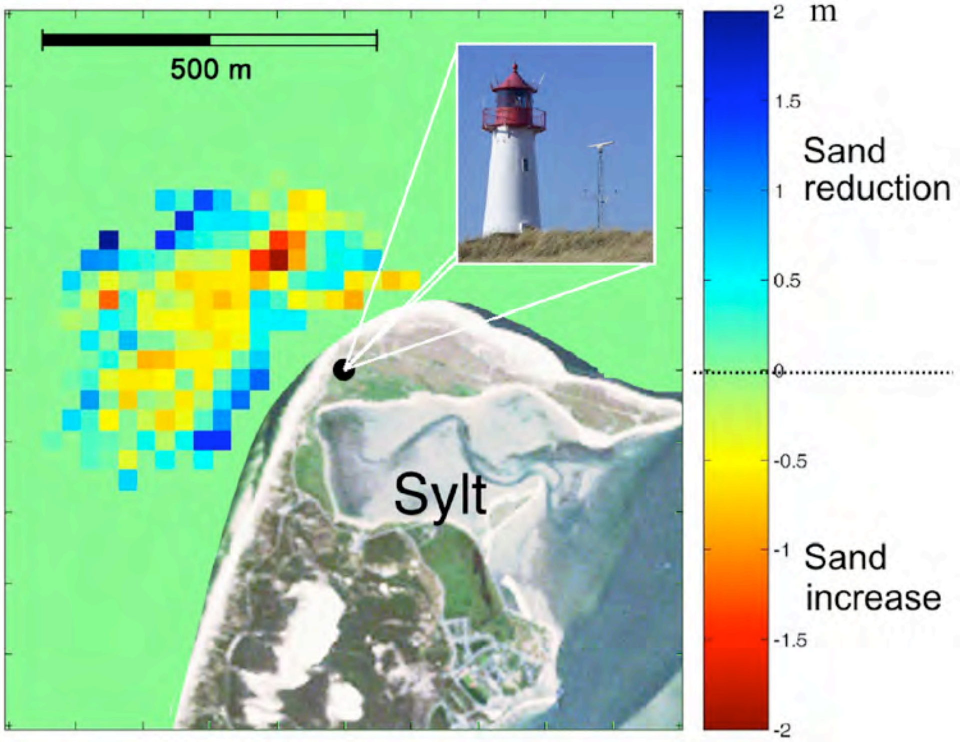

Figure 10: Change of bathymetry off Sylt 2001-2003.

3.3.2 Space-born technology

With the launch of the Earth observation satellite ENVISAT of the European Space Agency (ESA) on March 1, 2002, also a new perspective for the scientific observation and monitoring of coastal zones has emerged. With MERIS, the Medium Resolution Imaging Spectrometer, it is now possible to map the horizontal distribution of suspended matter, phytoplankton and humin substances with a spatial resolution of 300 m and a revisit cycle in mid latitudes of 1-2 days (Rakst and Bezy, 1999). Figure 11 shows the Elbe and Weser estuaries and the Helgoland Bight in form of a RGB image computed from the 15 spectral bands of MERIS. The complex distribution of suspended matter along the coast and the turbidity zone in the Elbe estuary can clearly be monitored using MERIS data. The algorithms to retrieve the concentrations from the reflectances measured in 15 spectral bands are based on neural network technology and radiative transfer simulations (Schiller and Doerffer, 1999). GKSS developed it for ESA; it is now part of the ground segment.

Figure 11: RGB image computed from the 15 spectral bands of MERIS showing the Weser and Elbe estuaries.

The Advanced Synthetic Aperture Radar (ASAR) with different spatial resolutions down to 10 m enables us to study wind and wave fields even in lagoons (Horstmann et al. 2002, Lehner et al. 2001) as well as the movement of sandbanks and underwater structures and the distribution of oil in cases of accidents. Further instruments on ENVISAT, which contributes to an observing system are the AATSR (Advanced Along Track Radiometer), which is used to determine the sea surface temperature with an accuracy of 0.2 –0.3 deg and RA-2, the Radar Altimeter for determining waves and partly currents.

Since all instruments fly on one platform, it is of interest to use their synergy. Within the HGF project ENVOC (ENVISAT Operational Oceanography), with AWI, DLR, GFZ and GKSS as partners, first case studies have been carried out to combine the data from different instruments by using models. One example is the improvement of the suspended matter transport model, which has been developed at GKSS ((Pleskaschevski et al 2004). The transport of SPM and the surface concentration in a shallow water region such as the Southern North Sea is mainly determined by vertical turbulence, which in turn depends on wind and wave conditions. Thus, for this purpose, the vertical mixing rate in the model was determined and tuned in such a way that the surface distributions as measured by the satellite could be reproduced for different conditions (water depth, wind and waves, type of bottom sediment). Figure 12 shows a comparison between the model results and data of MOS for a case of high wind conditions. The imaging spectrometer MOS was build and operated by DLR.

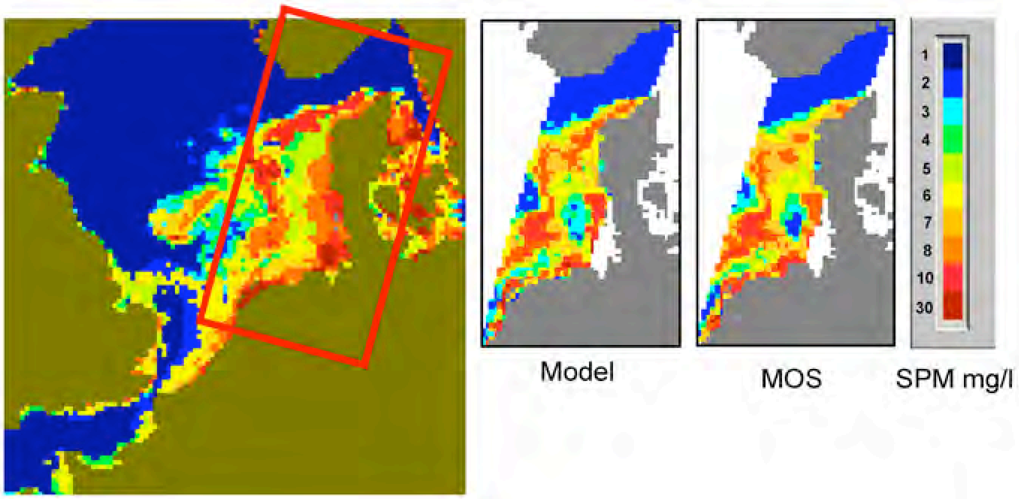

Figure 12: Comparison of results of a suspended matter (SPM) transport model with data remotely sensed by the MOS sensor. Left to right: model region, SPM concentration from model and remotely sensed.

Another example is the determination of primary production in shallow coastal seas. For this purpose information about (1) the concentration of phytoplankton chlorophyll and the vertical irradiance attenuation (both from MERIS), (2) depth of the thermocline from wind and temperature data (ASAR and AATSR) and (3) the daily course of solar attenuation by clouds (from METOSAT data, Schiller, 2001)) have to be combined as input to a primary production model.

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5 APPENDIX

5.1 Infrastructure

The institute supplies internal and external research groups with a series of platforms and measuring systems for campaigns and operational measurements. The platforms are specifically adapted to operate in the near coast shallow waters.

	"Ludwig Prandtl"	"Storch"
Length o.a.:	32.5 m	11.00 m
Beam:	7.50m / 6.35 m	3.55 m
Draught:	1.50 m	1.00 m
Power:	2 x Diesels (375 kW)	2 x 164 kW
Speed:	11 kn	20 kn
Electric:	2 generators 24V, 220V, 380V	8 kW generator 24V, 220V
Maneuvering:	2 Schottel-pumpjets (120 kW); computer controlled dynamical positioning system	nautical radar, river radar, UKW, GPS, 2 echo sounders, bow derrick, A-frame, 1 hydraulic crane, dinghy, winches,
Class:	German Lloyd 100A4k	
Special feature:	suited for resting upon mud flats	
Equipment:	nautical radar, river radar, UKW, GPS, 2 echo sounders, A-frame, hydraulic crane, dinghy, winches, 2 moon-pools, electronic and wet lab for 4-6 scientists,	nautical radar, river radar, UKW, GPS, echo sounder, 1 hydraulic crane, winch

5.1.1 Research vessels

The IfK operates two research vessels: the "Ludwig Prandtl" and a smaller research boat "Storch" (Figure 13, Table). As a standard, both vessels can be equipped with a multibeam echo sounder system, acoustical Doppler current profiler (ADCP) and they provide facilities to operate vertical profiler systems up to depths of 60 m and to collect bed sediment samples. In the portable lab-container on-board "Ludwig Prandtl", a version of the "ferry-box"-system can be installed and samples from the water column and bed sediments prepared and analyzed. In addition, "Ludwig Prandtl" can be precisely maneuvered by means of a computer controlled dynamical positioning systems on predefined courses.

5.1.2 Automatic stand alone systems

On several locations along the German North Sea and Baltic Sea coasts, stand-alone measuring devices are operated: wave rider buoys, wave radar and pole systems (Figure 14). They are installed each year over the ice-free season to acquire long-term data sets on the hydrodynamics and sediment dynamics in the main research areas of the IfK. Continuous data transfer to the IfK proceeds via telephone communication and allows monitoring of the system functioning and to present the data in near real-time to the general public via an internet portal.

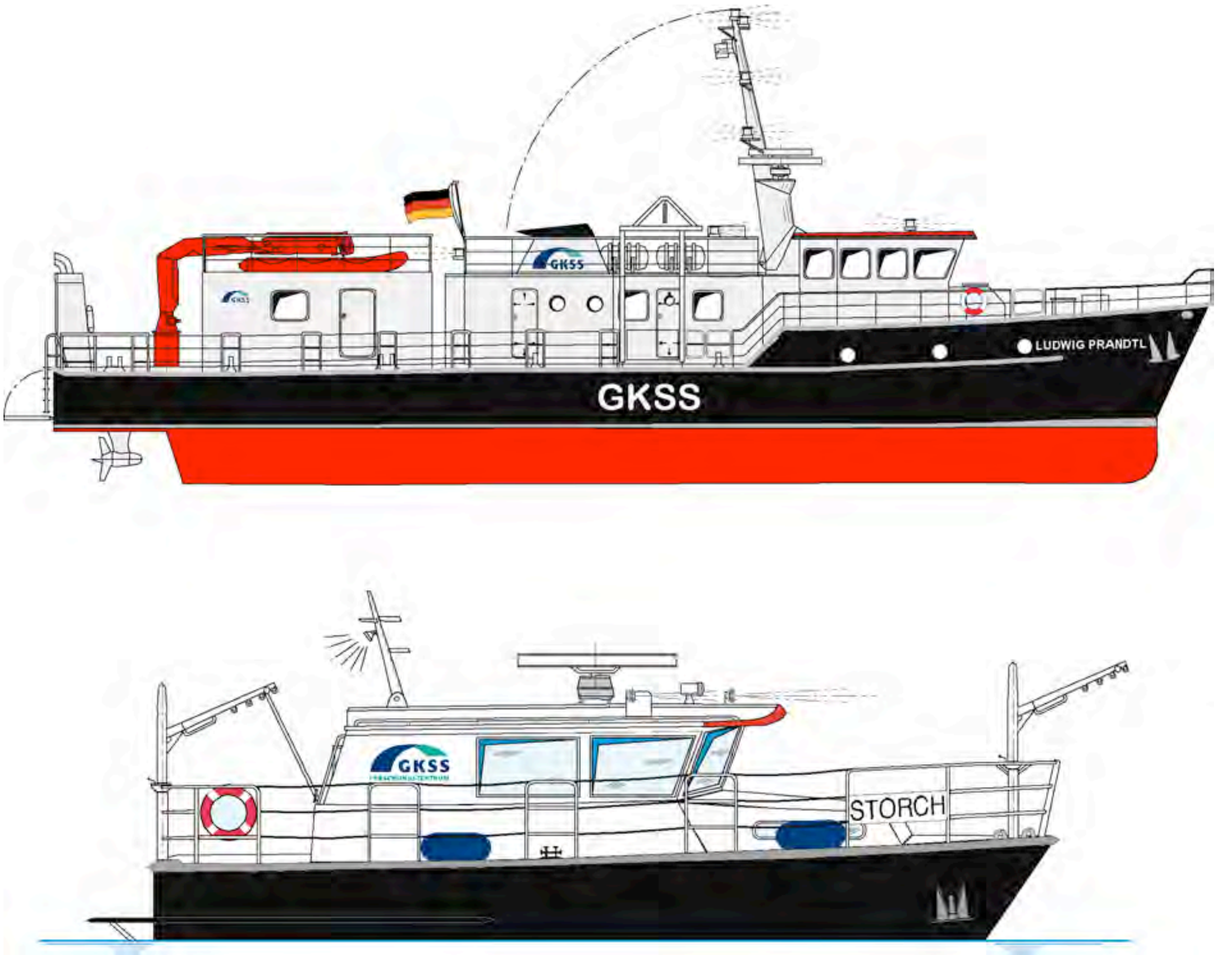
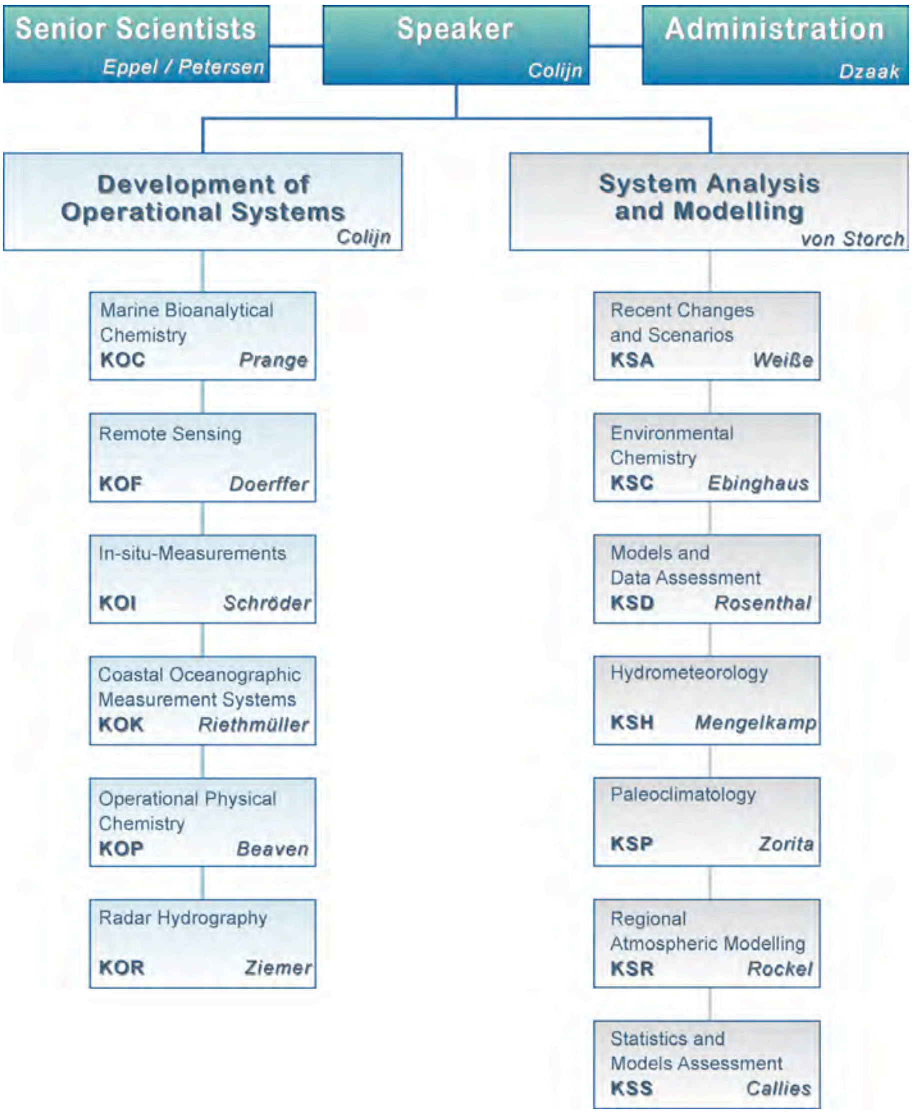


Figure 13: Research Vessel “Ludwig Prandtl” and Research boat “Storch”.

Figure 14: Wave rider buoy (left), wave radar system WAMOS (middle) and measuring pole (right).

5.2 Organizational



Organizational structure of the Institute for Coastal Research as of January 2004.

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5.4 National and European Projects

Performing R&D projects at the national or European level has a year-long tradition at Institute of Coastal Research of GKSS. The following pages review EC- and BMBF[5]-funded projects[6] with GKSS

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[5] BMBF is he German federal Ministry for Education and Research.

acting as either the project coordinator or a participant. A list of partner institutions in EU funded projects completes this chapter.

5.4.1 BMBF-funded Projects

BIOSENS II:	Optimierung und Erprobung eines miniaturisierten Analysesystems zur Messung von Nährstoffen in Ästuar- und Küstengebieten
Watthydrodynamik	Die hydrodynamische Belastung von Wattgebieten
Wattenmeersedimente	Sedimentinventar nordfriesisches Wattenmeer
DATUN	Simulation des europäischen Klimas in der instrumentalen Periode mit der DATUN Methode (Data-assimation through upscaling and nudging)
EVA-GRIPS	Regionale Verdunstung auf der Gitterpunkt/Pixel-Skala über heterogenen Landoberflächen
KRIM	Klimawandel und präventives Risiko- Küstenschutzmanagement an der deutschen Nordseeküste
ENVOC	ENVISAT will be used for various tasks including improvement of wind, wave and sea ice measurements as well as water constituent, hydrobiological and geochemical monitoring
MOSES:	Modelling the medium-term seastate climate in the German North Sea coastal area

5.4.2 EC-funded Projects

EUROCAT	European catchments – Catchment changes and their impact on the coast
NAOC	Neural network algorithms for ocean colour
HIPOCAS	Hindcast of dynamic processes of the ocean and coastal areas of Europe
PRUDENCE	Prediction uncertainties describing European climate change and effects
OROMA	Operational radar and optical mapping in monitoring hydrodynamic, morphodynamic and environmental parameter for coastal management
REVCAMP	Regional validation of MERIS chlorophyll products in North Sea coastal waters
HIMOM	A system of hierarchical monitoring methods for assessing changes in the biological and physical state of intertidal coastal zones
i-MARQ	Information System for Marine Aquatic Resource Quality
DISMAR:	Data integration system for marine pollution and water quality

[6] Including projects related to global climate in historical times

FLOODRELIEF	Real-time flood decision support system integrating hydrological, meteorological and remote sensing technologies
FERRYBOX	From on-line oceanographic measurements to environmental information
SOAP	Simulations, observations and paleoclimate data: Verifying climate models over the last 500 years
MaBene	Managing Benthic ecosystems in relation to physical forcing and environmental constraints
BRIMOM	Biofouling resistant infrastructure for measuring, observing and monitoring
GLIMPSE	Global implications of Arctic climate processes and feedbacks
ALP-IMP	Multi-centennial climate variability in the ALS based on instrumental data, model simulations and proxy data
EVISA	The European Virtual Institute for Speciation Measurements
ENSEMBLES	Ensemble-based predictions of climate changes and their impacts
SEAROUTES	Advanced decision support for shiprouting based on full-scale ship-specific Responses as well as improved sea and weather forecasts including synoptic, high precision and realtime satellite data.
MaxWave	Maximum Waves

EC-project Partners

Germany	Alfred-Wegener-Institut für Polar- und Meeresforschung AWI, Bremerhaven Forschungs- und Technologiezentrum Westküste FTZ, Büsum Universities in Hamburg, Kiel, Oldenburg, Lüneburg, Bremen, Hannover and Münster Max-Planck-Institut für Meteorologie, Hamburg ZMAW, Hamburg Institut für Ostseeforschung, Warnemünde Forschungszentrum Jülich H JENA engineering GmbH Freie Universität Berlin PIK Potsdam Bolding and Burchard Hydrodynamics GbR Carsten Brockmann Consult Amt für ländliche Räume Husum Freie Universität Berlin Deutsches Zentrum für Luft- und Raumfahrt e.V. Technische Universität Berlin, Deutscher Wetterdienst
France	CNRS - Centre National de la Recherche Scientifique THALES S.A.

	Universities de Pau et des Pays de l'Adour , and Pierre et Marie Curie Institut Francais de Recherche pour l'Exloitation de la Mer IFREMER Institut Oceanographique Paul Ricard ACRI SA Météo France
Slovakia	Jozef Stefan Institute
Austria	Technical University Vienna
Norway	Norwegian Meteorological Office University of Tromsø and Oslo Norwegian Institute for Water Research Det Norske Veritas AS
Denmark	Danish Meteorological Institute Danmarks Miljøundersoegelse NERI Danmarks Jordbrugs Forskning Risø National Laboratory København Universitet
Sweden	Swedish Meteorological and Hydrological Institute Lund University
Finland	University of Lapland, Rovaniemi Finnish Environmental Institute Finnish Meteorological Institute Finnish Institute for Marine Research
United Kingdom	University of Glasgow Chelsea Instruments Ltd, West Molesey Universities of London, East Anglia, Edinburgh, Wales-Bangor, Southampton, Dundee, Reading and St. Andrews. UK Met. Office National Environmental Research Council BMT Marine Information Systems Ltd. ABP Marine Environmental Research Ltd. Natural Environment Research Council University of St. Andrews Meteorological Service European Centre for Medium-Range Weather Forecasts Satellite Observing Systems (SOS) Southampton Oceanographic Centre Proudham Oceanographic Lab
The Netherlands	Netherlands Organisation for Applied Scientific research TNO, Delft Oceanographic Company of the Netherlands B.V. Delft Vrije Universiteit Amsterdam Royal Netherlands Academy of Arts and Science, Netherlands Institute of Ecology University of Groningen Royal Netherlands Institute for Sea Research, Texel
Portugal	Instituto Superior Tecnico Universidade de Lisboa Instituto Nacional de Engenharia e Tecnologia Industrial Instituto de Meteorlogia

Spain	Consejo Superior de Investigaciones Cientificas Universitites Complutense de Madrid, and Politécnica de Madrid Instituto Espanol Oceanografia
Poland	Institutes of Meteorology and Water Management , Wroclaw and in Warszawa Institute of Hydroengineering, Polish Academy of Sciences
Belgium	Royal Belgian Institute for Natural Sciences Ministry of the Flemish Community, Brussels Katholieke Universiteit Leuven
Greece	National Technical University of Athens (NTUA) National Centre for Marine Research, Athens
Irland	National University of Ireland
Switzerland	Eidgenössische Technische Hochschule ETH Universities of Fribourg and Bern
Estonia	Institute for Marine Research