REGIONAL METEOROLOGICAL–MARINE REANALYSES AND CLIMATE CHANGE PROJECTIONS

Results for Northern Europe and Potential for Coastal and Offshore Applications

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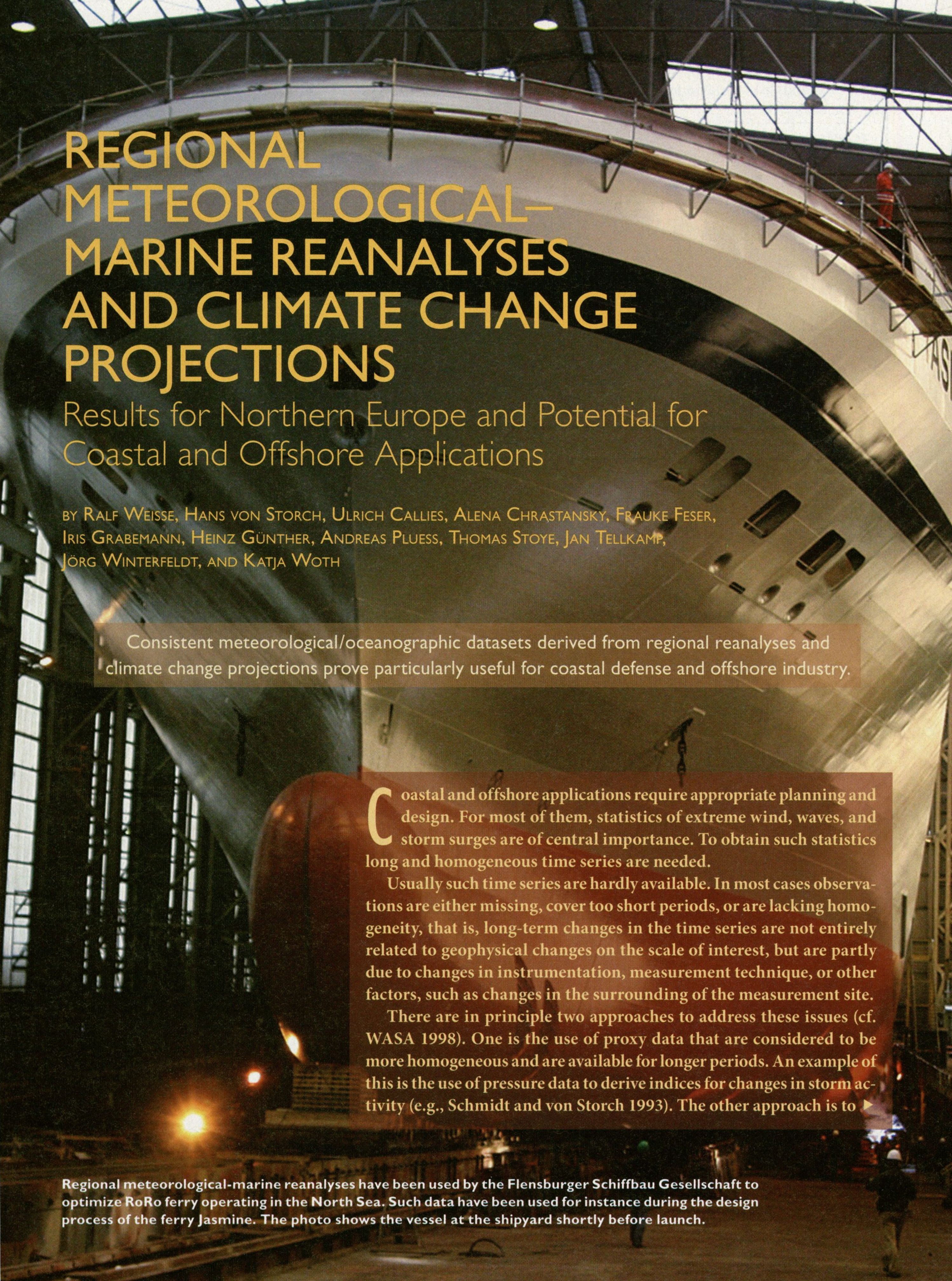
Consistent meteorological/oceanographic datasets derived from regional reanalyses and climate change projections prove particularly useful for coastal defense and offshore industry.

Coastal and offshore applications require appropriate planning and design. For most of them, statistics of extreme wind, waves, and storm surges are of central importance. To obtain such statistics long and homogeneous time series are needed.

Usually such time series are hardly available. In most cases observations are either missing, cover too short periods, or are lacking homogeneity, that is, long-term changes in the time series are not entirely related to geophysical changes on the scale of interest, but are partly due to changes in instrumentation, measurement technique, or other factors, such as changes in the surrounding of the measurement site.

There are in principle two approaches to address these issues (cf. WASA 1998). One is the use of proxy data that are considered to be more homogeneous and are available for longer periods. An example of this is the use of pressure data to derive indices for changes in storm activity (e.g., Schmidt and von Storch 1993). The other approach is to ▶



Regional meteorological-marine reanalyses have been used by the Flensburger Schiffbau Gesellschaft to optimize RoRo ferry operating in the North Sea. Such data have been used for instance during the design process of the ferry Jasmine. The photo shows the vessel at the shipyard shortly before launch.

TABLE 1. List of regional models, model areas, and forcing data used in the coastDat reconstructions and climate scenario simulations referred to in this study. The listing is not exhaustive. For a full list we refer to the coastDat Web page (online at www.coastdat.de).

Model time span	Name (model reference, setup reference)	Model area	Grid distance	Forcing data
Reconstructions				
Atmosphere 1948–2007	**REMO** (Jacob and Podzun 1997; Feser et al. 2001)	Western Europe/adjacent seas	0.5° × 0.5°	NCEP–NCAR reanalyses
Waves 1948–2007	**WAM** (WAMDI Group 1988; Weisse and Günther 2007)	North East Atlantic, North Sea south of 56°N	Two nested grids 50 km × 50 km, 5 km × 5 km	Near-surface wind fields from REMO reconstruction
Tide surge 1958–2002	**TELEMAC2D** (Hervouet and Haren 1996; Weisse and Pluess 2006)	North Sea	Unstructured grid 5 km–80 m (coastal areas)	Near-surface wind and pressure fields from REMO reconstruction
Climate scenario simulations				
Waves 1961–1990, 2071–2100	**WAM** (WAMDI Group 1988; Grabemann and Weisse 2008)	North East Atlantic, North Sea	Two nested grids 50 km × 50 km, 5 km × 5 km	Near-surface wind fields from RCAO (Räisänen et al. 2004)
Tide surge 1961–1990, 2071–2100	**TRIM** (Casulli and Stelling 1998; Woth et al. 2006)	North Sea	10 km × 10 km	Near-surface wind and pressure fields and from RCAO (Räisänen et al. 2004)

use numerical models driven by reanalysis data over sufficiently long periods and at high spatial and temporal resolution (e.g., Günther et al. 1998).

Both approaches have advantages and disadvantages. While proxy data can generally be used to reconstruct indices for rather long time periods (up to centuries), their spatial resolution remains limited and proxy data must be available at sufficient detail and quality. Hindcasts, on the other hand, are limited to periods for which global reanalyses are available (now about 60 yr) and by the quality of the involved models.

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The abstract for this article can be found in this issue, following the table of contents.
DOI:10.1175/2008BAMS2713.1

In final form 20 November 2008

In the following we describe a set of coastal and offshore hindcasts based on global reanalysis data. The hindcasts are complemented with consistent climate change scenarios for the future. Data obtained from these exercises are integrated into a joint database referred to as "coastDat" (available online at www.coastdat.de). In the following the model setup and experimental design are briefly described. Subsequently, some representative examples are provided in which coastDat has been applied for the analysis of recent and potential future changes. Finally, applications are shown in which coastDat has been used to address coastal and offshore problems. An outlook for further applications is offered at the end of this paper.

MODEL SETUP AND SIMULATIONS.

We used the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) global reanalysis (Kalnay et al. 1996) in combination with spectral nudging[1] (von Storch et al. 2000) to first drive a regional atmosphere model (Table 1) for an area covering most of Europe and the adjacent seas. Initially the model was integrated for the years of 1958–2002, with a spatial

[1] Here a height-dependent nudging coefficient was applied to the large scale (>750 km) zonal and meridional wind speed components above about 850 hPa.

grid size of about 50 km × 50 km. The period has been extended later and currently covers the 60 yr of 1948–2007. Full model output is available for every hour within this 60-yr period.

From this atmospheric simulation, near-surface marine wind fields have been used subsequently to drive high-resolution wave and tide surge models (Table 1). While the wave model was run in a nested mode with a coarse grid (about 50 km × 50 km) covering most of the northeast Atlantic and a fine grid (about 5 km × 5 km) covering the North Sea south of 56°N, the tide surge model was run on an unstructured grid with typical grid spacing of about 5 km in the open North Sea and largely increased values (up to 80 m) near the coast and in the estuaries. As for the atmospheric part, full-model outputs have been stored every hour. In this way a high-resolution meteorological–marine (metocean) dataset for the North Sea covering the last six decades of years has been created. Figure 1 shows an example of conditions obtained for 21 February 1993.

An impression of the extent to which this approach is capable of providing a reasonable reconstruction of the observed wind and wave climate is given in Fig. 2. Shown are the observed and hindcast wind speed and direction as well as significant wave height, period, and wave direction for a 3-month period at station K13 (53.22°N, 3.22°E). In principal, a good agreement can be inferred. For instance, the storm event on 21 February, which caused observed significant wave heights of more than 6 m, is reasonably reproduced for all parameters. On the other hand, there are also events with larger discrepancies, such as the one around 1 March for which wave heights are considerably underestimated, which in this case was caused by too-low wind speeds in the atmospheric hindcast. When compared with scatterometer data, the hindcast wind fields in general show a reasonable agreement, and it was found that in coastal areas, especially in such with complex topography, hindcast wind fields are significantly improved compared to those form the driving reanalysis (J. Winterfeldt and R. Weisse 2009, personal communication).

A comparison of observed and hindcast storm indices for Lund in Sweden is shown in Fig. 3. Generally it can be inferred that the observed year-to-year variability is captured reasonably by the hindcast, although some bias may occur. For marine near-surface wind fields, Winterfeldt (2008) demonstrated that, compared to the driving reanalysis,

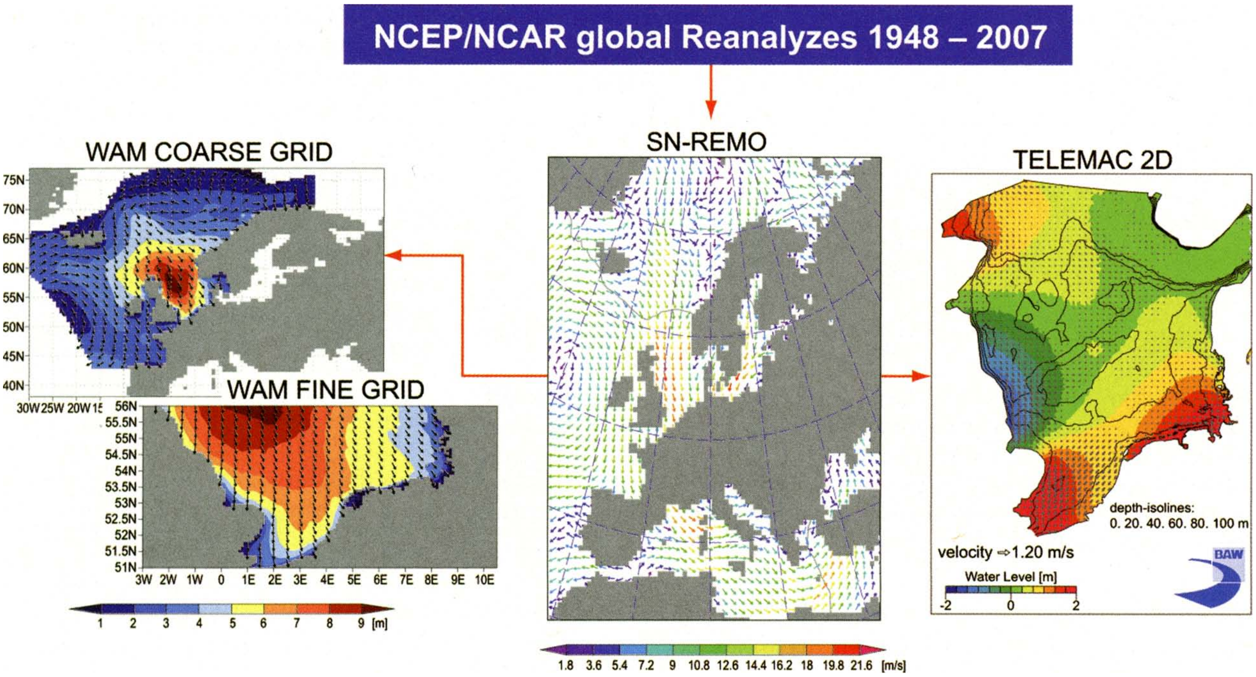

Fig. 1. Layout of the consistent metocean hindcast 1948–2007 for the southern North Sea. From the (middle) regional atmosphere hindcast hourly wind fields were used to force a (right) tide surge and a (left) wave model hindcast. The figure shows an example of consistent metocean conditions obtained from the hindcast for 1200 UTC 21 Feb 1993. (middle) Near-surface (10-m height) marine wind fields (m s^{-1}), and corresponding wind direction obtained from the regional atmospheric reconstruction. (left) Corresponding significant wave height fields (m) and mean wave direction from the coarse and the fine grid wave model hindcast. (right) Tide surge levels (m) from the corresponding tide surge hindcast. After Weisse and Günther (2007).

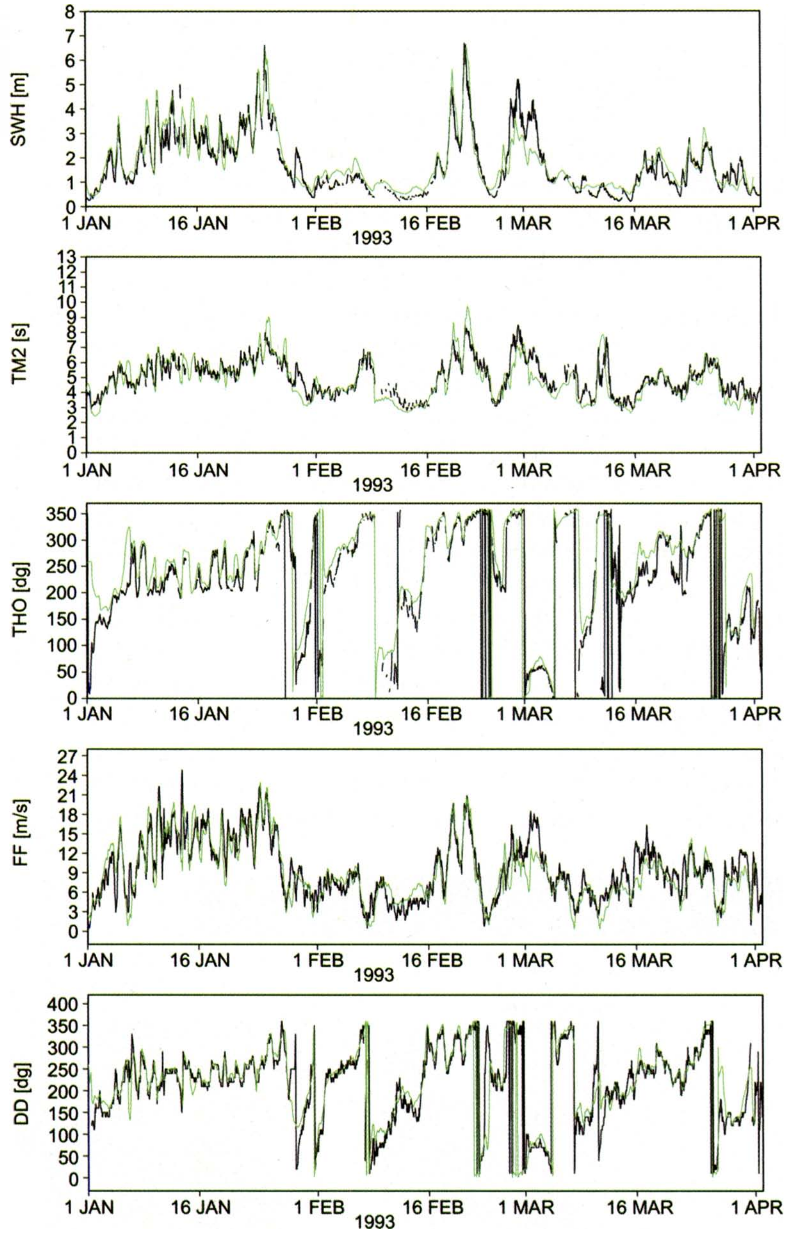

Fig. 2. (from top to bottom) Time series of significant wave height (SWH, m), Tm02 wave period (TM2, s), mean wave direction (THQ, ° coming from) wind speed (FF, m s^{-1}), and wind direction (DD, ° coming from) at K13 for a 3-month period from 1 Jan 1993 to 31 Mar 1993. Observations (black) and model results (green). After Weisse and Günther (2007).

Scenarios for future climate conditions have been obtained in a similar way. Here the global reanalysis has been replaced by an ensemble of different global climate change simulations. We have used four sets of simulations using A2 and B2 emission scenarios[2] for 2071–2100 with two different global climate models. These simulations were downscaled approximately on a 50 km × 50 km grid by the Swedish Meteorological and Hydrological Institute in the framework of the Prediction of Regional Scenarios and Uncertainties for Defining European Climate Change Risks and Effects (PRUDENCE) project (Christensen et al. 2002), with the regional model Rossby Centre Regional Atmosphere–Ocean Model (RCAO) (Räisänen et al. 2004). From these simulations, near-surface wind and pressure fields have subsequently been used to produce high-resolution scenarios of possible wave (Grabemann and Weisse 2008) and storm surge conditions (Woth 2005; Woth et al. 2006) for the North Sea (Table 1). While the size of this ensemble is still somewhat limited because of computational constraints, it allows not only for an estimate of potential future met-ocean conditions, but also for a first rough guess about the underlying uncertainties.

A full listing of regions, parameters, and periods presently contained in coastDat may be obtained from the coastDat Web site (online at www.coastdat.de).

an improvement is obtained mainly in coastal areas. More validation can be found for the atmospheric part in Feser (2006), for the tide surge simulation in Weisse and Pluess (2006), and for the wave model hindcast in Weisse and Günther (2007).

RECENT AND POSSIBLE FUTURE CHANGES. The coastDat dataset was used by Weisse et al. (2005) to analyze long-term changes in storm activity over the North Sea and the northeastern North Atlantic. They found an increase in storm activity from about 1960. Storm activity

[2] Here A2 and B2 refer to scenarios according to the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES; Nakicenovic and Swart 2000) representing a more pessimistic (A2) and a more optimistic (B2) view regarding the development of future greenhouse gas concentrations.

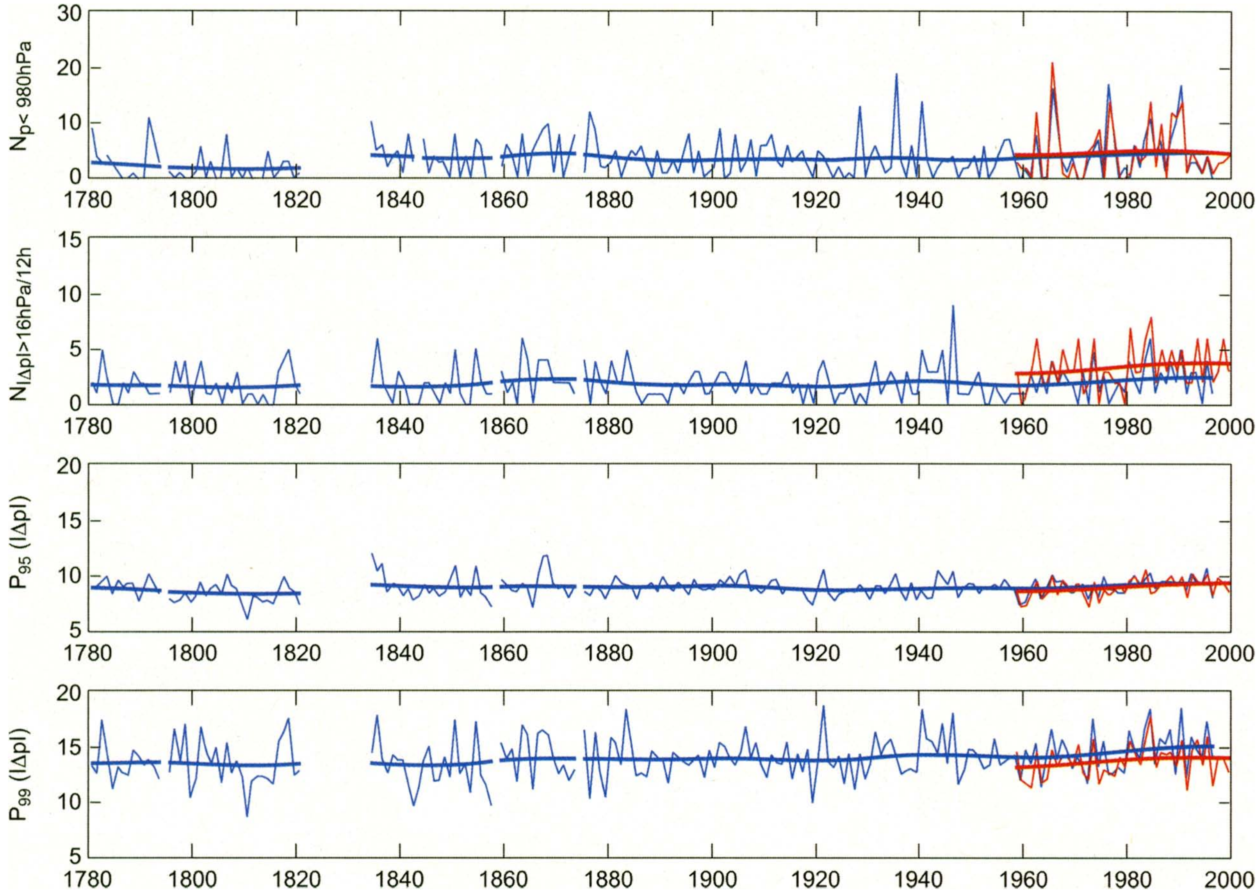

Fig. 3. Comparison between different storm indices for Lund, Sweden. (from top to bottom) Annual number of pressure readings of less than 980 hPa; annual number of strong pressure tendencies exceeding 16 hPa in 12 h; annual 95th and 99th percentiles of strong pressure tendencies. Obtained from observations after data from Bärring and von Storch (2004) (blue), obtained from coastDat (red).

peaked around 1990–95, after which a decrease was inferred. These results are consistent with those obtained from proxy data for the area. For instance, Alexandersson et al. (2000) and an update in Solomon et al. (2007) report a similar behavior based on the analysis of upper-geostrophic wind speed percentiles derived from station pressure data. Covering a longer period than the coastDat hindcasts in particular, these studies showed that the 1960–90 increase in storm activity was not unusual, but that activity levels reached in the mid-1990s were comparable to that at the beginning of the twentieth century. Long-term changes in extreme storm surges and ocean wave heights based on the coastDat dataset were analyzed by Weisse and Pluess (2006) and by Weisse and Günther (2007). In particular, they found that the changes correspond to that of storm activity with increases in storm surges and wave heights between about 1960 and 1990, decreasing thereafter.

Changes of the North Sea storm surge climate in an ensemble of climate change simulations that form part of the coastDat dataset were analyzed by Woth (2005) and Woth et al. (2006). Figure 4 shows the changes in extreme storm surge levels expected toward the end of the century. Although regional details differ among the different models and scenarios, all point toward a moderate increase in severe storm surge levels along most of the Netherland, German, and Danish coast lines. When compared to the natural variability estimated from the coastDat hindcast (Weisse and Pluess 2006), climate change–related increases in storm surge heights are found to be smaller for most of the Netherlands and Danish coast, while they are significantly larger along most of the German coastline (Woth et al. 2006).

Using near-surface marine wind speeds from the same set of scenario simulations, Grabemann and Weisse (2008) performed a similar ensemble of wave model simulations. Although the same wind forcing was used, changes appeared to be more diverse. In particular, regional patterns of changes in severe wave

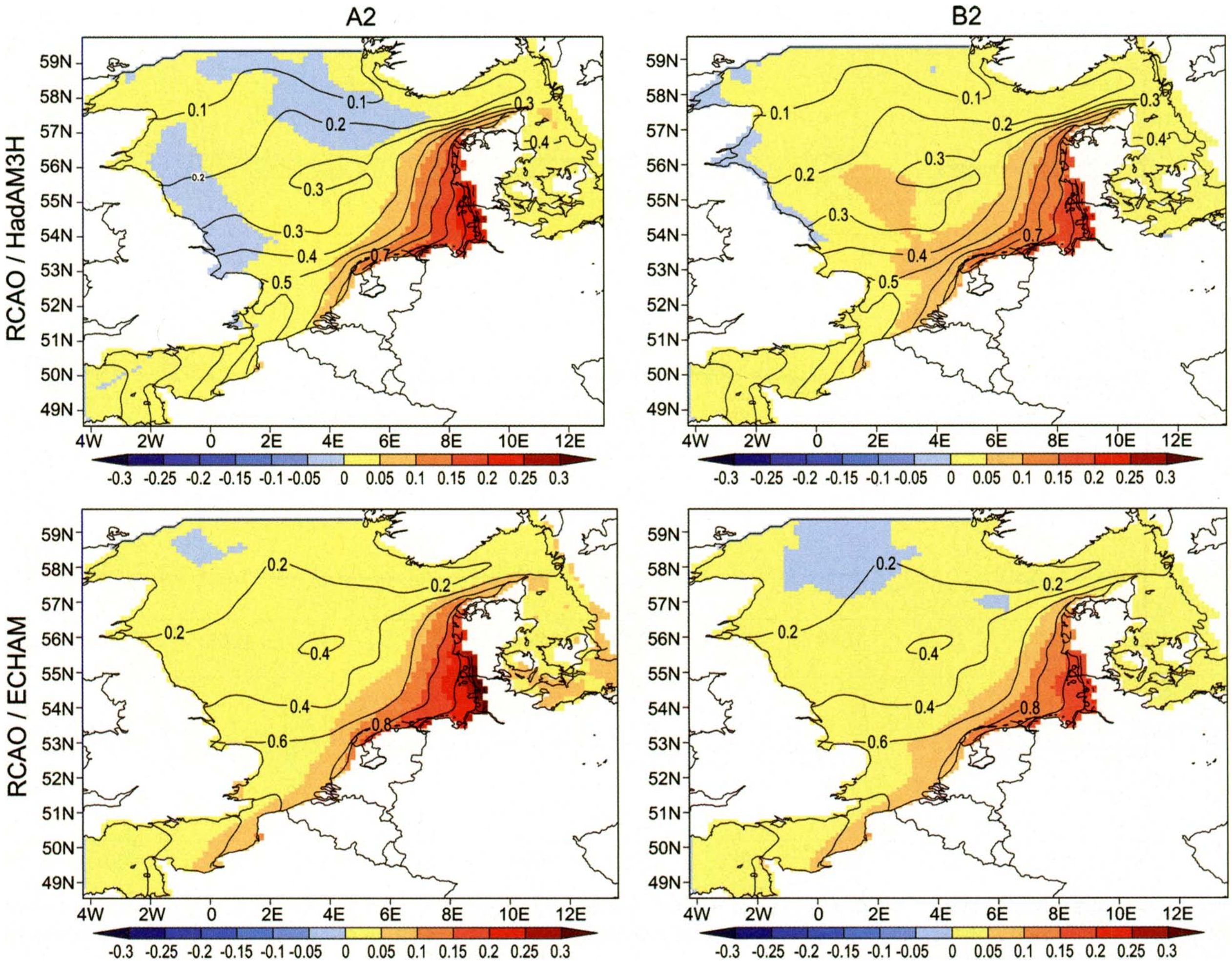

FIG. 4. Differences (colors) of annual 99.5 percentiles of storm surges between possible future (2071–2100) and present day (1960–90, contour lines) weather conditions obtained from tide surge simulations using forcing from different climate models and emission scenarios. (left) Response for the A2 emission scenario. (right) Response for the B2 emission scenario. Storm surge response for near-surface wind speeds from the RCAO regional climate model driven by two different global climate models (top, HadAM3H; bottom, ECHAM5) after data and methods described in Woth (2005) and Woth et al. (2006).

conditions differ and the magnitude of the changes strongly depends on the choice of the atmospheric model from which wind fields have been used.

APPLICATIONS OF COASTDAT. The coastDat dataset has been used for a variety of coastal and offshore applications. This comprises applications in ship design, oil risk modeling and assessment, and the construction and operation of offshore wind farms. In the following a few examples will be provided.

Optimization of ship operation profiles. Operation profiles of RoRo[3] vessels operating on fixed routes in the North Sea were simulated over decades of years with environmental conditions (wind, water depth, sea state) provided by the coastDat dataset (Friedhoff and Maksoud 2005). Operation profiles (such as velocity or power) were varied under the constraint that the operations are time critical, that is, the individual trips need to be finished within a given time window, as long as permitted by safety requirements (weather conditions). Results for a 200-m RoRo vessel operating on a 332-nm round-trip between Zeebrügge, Belgium, and Immingham, United Kingdom, are provided in Friedhoff and Abdel-Maksoud (2005). For the 3,650 trips simulated within a 10-yr period they found fuel consumption to be increased by about 9% when compared to calm weather conditions and attributed

[3] RoRo vessels are ships designed to carry wheeled cargo (cars, trucks, trailers, etc.). The term is used in contrast to vessels that use cranes to load and unload cargo.

the effect to the additional power required to face the environmental conditions caused by wind, waves, and water levels. They also showed that operation profiles may be optimized compared to conventional approaches such that operation costs are reduced and delay becomes minimal. They concluded that databases such as coastDat may provide valuable tools to optimize ship design with respect to the expected environmental conditions on the route.

Environmentally based optimization of ship design. Operability and safety on board, both constrained by severe weather conditions, are important factors for short sea shipping, especially for RoRo and RoPax[4] vessels. In ship design, sea-keeping simulations are used to account for these factors (Cramer et al. 2002). Generally, the motion of a ship in a sea state depends on several design parameters (e.g., hull form, location of the center of gravity, radii of gyration, etc.) and it cannot generally be concluded that a specific sea state is more or less severe for the ship than others. Instead, the reaction of the ship to a design modification has to be determined for each sea state by direct simulations (Cramer et al. 2002). In case the intended operating area and operation schedule are known already during the design phase, this information can be used to simulate the ship's motion in environmental conditions to be expected in the operation area during the lifetime of the vessel and to optimize the design with respect to the intended operational profile. Detailed wind and sea state information over decades of years as given by coastDat are an excellent source of data for this kind of application.

The coastDat dataset has been used by the Flensburger Schiffbau-Gesellschaft to assess and optimize a RoRo ferry operating in the North Sea. Design parameters such as limiting accelerations and roll angles (Henning et al. 2006), slamming impact loads (Stoye et al. 2008), and others have been investigated. When exceedance probabilities of operational limits were found to be unacceptable, design modifications had to be performed. For example, when the occurrences of high roll angles need to be reduced, passive roll-stabilization tanks may be installed to modify the eigenfrequency of the roll motion, making the ship more seaworthy in a given sea state. An alternative is the installation of active fin stabilizers that compensate the roll moment caused by waves up to a certain degree, provided that the ship's speed is sufficient. From coastDat, statistics about weather down times, for example, for operation with or without fin stabilizers, may be derived. The latter provides decision support for the ship operator on whether the improvement of the sea-keeping behavior is worth the investment into a roll stabilization system.

Offshore wind farms. In the North Sea there are presently substantial efforts underway regarding the construction and implementation of offshore wind farms. Design and planning of construction and maintenance, etc., require long and homogeneous environmental data that are seldom available at the site. There is presently considerable interest in the use of statistics derived form coastDat for such purposes. Weisse and Günther (2007) have shown that there is a reasonable agreement of such statistics when estimated from observations and from coastDat data.

Because coastDat data are available for 60 yr at high spatial and temporal resolution, the data are often used to estimate the magnitude of rare events that may have considerable impacts on the site, such as the 50-yr return value for near-surface wind speed or significant wave height. Also, joint probability distributions, such as any combination of wind speed, wind direction, significant wave height, wave periods, and wave direction, are frequently requested and needed during the design process. A unique feature of coastDat is the estimation of duration-related statistics, for instance, how long severe sea-state conditions may last on the site. Similarly, statistics of weather windows may be derived. For instance, the time window within which wave heights, on average, remain below a given threshold (e.g., 2 m) may be required to plan equipment and maintenance schemes, or to estimate whether it would be feasible, at a given probability, to arrange the site within a given time frame, for example, a season.

Coastal protection. On the basis of coastDat local scenarios for future high water levels for coastal tide gauges have been constructed (Grossmann et al. 2007). A statistical relationship was constructed between observed high water levels at the North Sea and the tide gauge Hamburg (St. Pauli) located about 80 km upstream within the estuary of the Elbe. Subsequently, storm surge projections from coastDat were used to elaborate on potential future changes for Hamburg (Fig. 5). According to Grossmann et al. (2007), an increase of the annual maximum high water levels in Hamburg of about 20 ± 20 cm appears possible and plausible for the time horizon of 2030. In 2085, the mean scenario for St. Pauli amounts to an increase of 64 ± 50 cm. These calculations employ

[4] RoPax vessels describe RoRo ships that accommodate passengers, in addition.

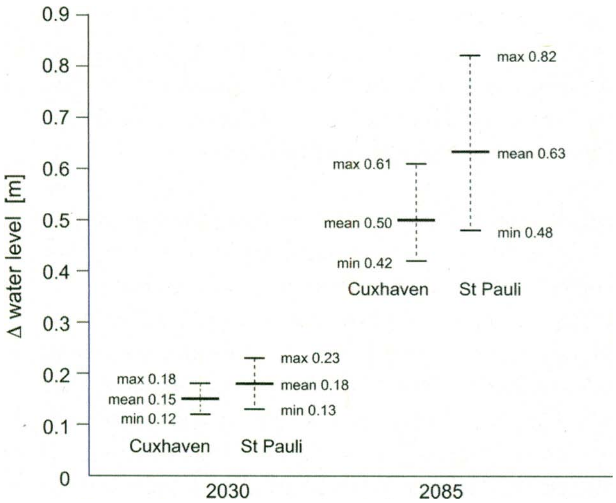

FIG. 5. Projections of climate change–related modifications in extreme high waters in Cuxhaven (North Sea) and Hamburg, St. Pauli (Elbe estuary) in 2030 and 2085 based on coastDat scenarios from different regional models and emissions scenarios. Because the results from the different scenarios do not differ significantly the mean value is indicated across all models and scenarios. The minimum and maximum range for all scenarios and models is shown in addition. A sea level rise of 9 cm by 2030 and of 33 cm by 2085 is included. After Grossmann et al. (2007).

a mean sea level rise of 9 cm for 2030 and of 29 and 33 cm (accounting for different scenarios) for 2085, respectively.

Oil risk modeling. A toolbox [Program for the Evaluation of Lagrangian Ensemble Transport Simulations (PELETS-2d)] for Lagrangian drift modeling based on fields from coastDat has been developed. An oil chemistry model may also be included and wind drift may or may not be taken into account. The latter represents an essential forcing factor when oil spills or drifting materials are considered.

On the basis of coastDat, PELETS-2d has been applied to a number of problems, including the assessment of freshwater signals at Helgoland, the comparison of station data with ship-based measurements, or the assessment of oil-related risks. An example is shown in Fig. 6. Here oil accidents along a major shipping route have been considered based on coastDat. In order to estimate travel time statistics, such oil accidents have been represented by passive tracer simulations initialized once every 28 h over about five decades. Subsequently, potential impacts on different target regions have been examined. Such target regions may be defined, for instance, by their potential sensitivity to the stranding oil. Figure 6b shows an example of a travel time distribution that was obtained from such simulations. It can be inferred that, depending on weather conditions, eventually 65% of all particles reached the target region. The most frequent travel time was found to be about 2–3 days. In some cases, however, travel times could be as small as 12 h. The latter has considerable consequences for emergency concepts to be implemented.

The analysis could be further refined by assuming that the frequency of accidents but also the efficiency of oil fighting may actually depend on the current metocean conditions in each case. All information needed for such studies would again be available from coastDat.

Assessment of chronic oil pollution. The coastDat dataset in combination with PELETS-2d has also been used for the interpretation of chronic oil pollution (Chrastansky et al. 2008). Chronic oil pollution predominantly results from illegal oil dumping and represents a major threat for the marine environment. It is, however, difficult to quantify, and often the number of oil-contaminated beached birds is used as an indirect indicator. It turns out that for trend assessments the latter may be misleading. Chrastansky et al. (2009) show an example of two common seabird species where the variability observed within the number of corpses registered during beached bird surveys for the German coast primarily reflects the interannual variability of prevailing weather conditions (Fig. 7). In other words, variations within the number of beached birds may be at least partially a result of changes and variations in atmospheric wind conditions, and changes over several years are not necessarily a proof that chronic pollution has reduced as a result of the implemented measures. Chrastansky et al. (2008) therefore concluded that atmospheric variability needs to be accounted for in the interpretation of such data.

Assessment of policy regulations. The weather stream generated in coastDat has also been used for an assessment of a policy regulation, namely, the outphasing of lead in gasoline in Europe. After an initial increase until the early 1970s, national and Europe-wide regulations have been adopted, so that since the late 1980s the presence of lead in the atmosphere has been greatly reduced. The questions were as follows: how much lead has been deposited over the past decades in Europe and how successful has the regulation been? To study this, gridded estimates of emissions were derived [for details refer to von Stoch et al. (2003) and references therein], which were transported subsequently using the daily winds available from the coastDat dataset. Finally, the deposition, using in particular the rainfall from the atmospheric coastDat reconstruction, was determined. The result of this exercise were emitter–recipient matrices for all European countries, and estimates of the net input into European marginal seas. As an example, Fig. 8 shows the estimated deposition into the Baltic Sea for the period of 1958–95, which clearly displays the initial phase of growing pollution and then the stepwise reduction. The figure also shows the available estimates from measurements campaigns and their consistency with the model-based reconstruction.

Other applications. There are a number of other applications not addressed in detail here. These include applications related to water quality studies or the definition of safety criteria for navigation. Data may also be used for comparison of in situ data taken at different platforms. For example, data from a fixed station have been compared with measurements taken on a ferry passing nearby. Here, usually a better agreement between observations could be obtained when currents from coastDat were used to simulate water transports between the two observational sites. The time-dependent simulated travel times provided an estimate of the time-dependent time lag that had to be taken into account for a proper comparison of the two observational time series (for more details see www.coastdat.de).

Data from coastDat have also been used for some terrestrial applications. For example, terrestrial biosphere models were driven with atmospheric input from coastDat to analyze gross primary productivity over Europe (Jung et al. 2007) or to examine and assess the European 2003 carbon flux anomaly (Vetter et al. 2008).

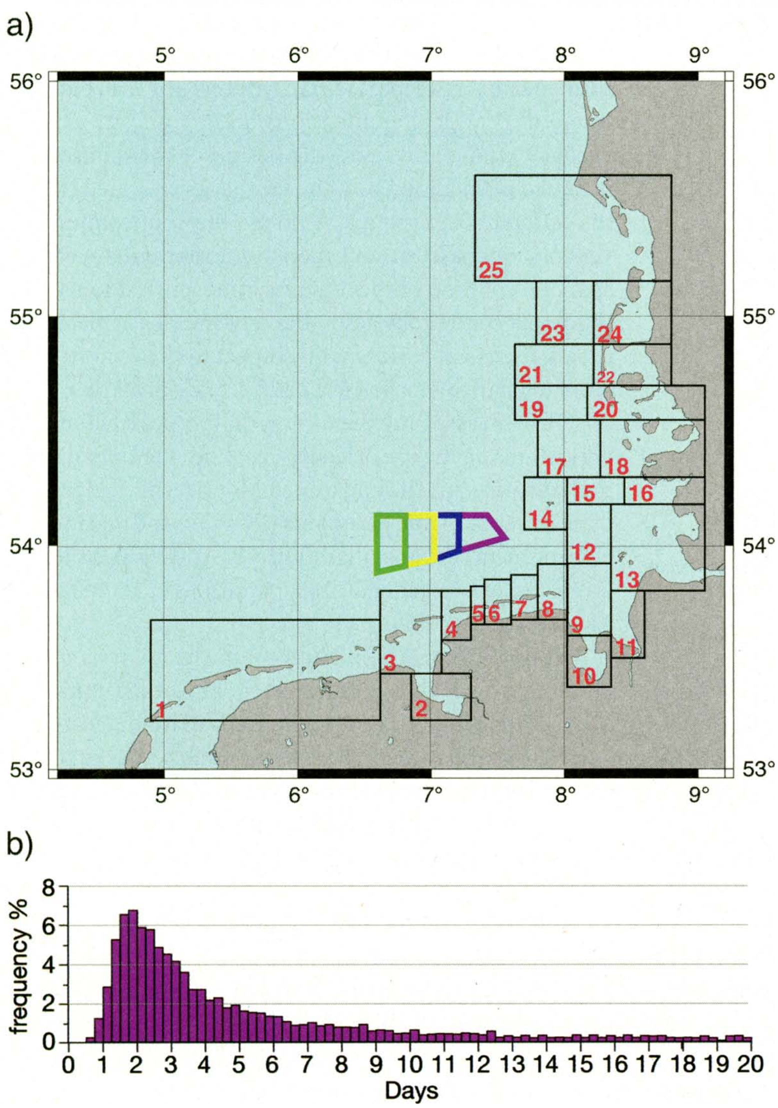

Fig. 6. (a) Section of the North Sea. Green, yellow, blue, and magenta boxes denote areas in the vicinity of major shipping routes in which passive tracer simulations representing hypothetical oil accidents have been initiated. The black boxes labeled with red numbers indicate target regions in which the impact of the accidents has been investigated. (b) Frequency distribution of the travel time that passive tracer particles started within the magenta source region need to reach target region 14 (Helgoland). The analysis is based on 65% of the initial tracer particles that actually affect the target region within 13,615 simulations that were started within the period 1958–99. Weathering of spilled oil was disregarded in this study.

SUMMARY AND OUTLOOK.

The coastDat dataset consists of a set of coastal analyses and scenarios for possible future developments. It constitutes a consistent meteorological–marine (metocean) dataset at high spatial and temporal resolution available for the last 60 yr. It was shown that the statistics of extreme events can be estimated from coastDat at a reasonable degree of approximation. Thus far the dataset has been developed mainly for the North Sea and adjacent areas. Efforts

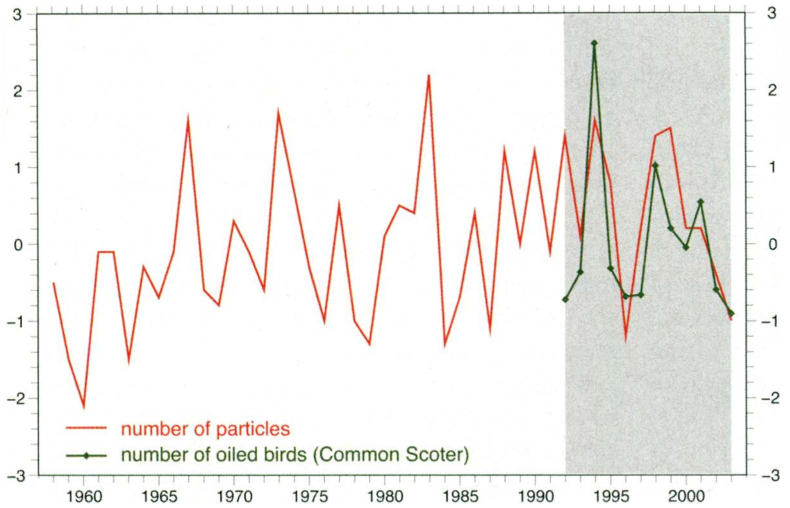

Fig. 7. Number of beached oil-contaminated birds (Common Scoters) observed at the German coast (1992–2003) and number of beached tracer particles simulated with PELETS-2d based on coastDat (1958–2003) assuming a constant level of chronic oil pollution. All data are shown as anomalies normalized by standard deviation. After data and methods described in Chrastansky et al. (2008).

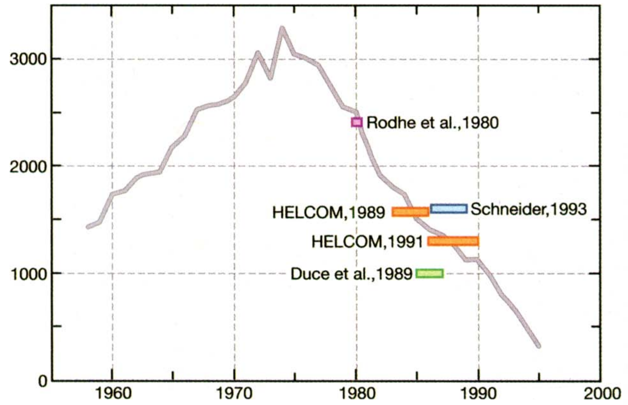

Fig. 8. Annual lead deposition (tons) over the Baltic Sea, from measurement-based estimates (colored bars) and the simulations (gray line) described in von Storch et al. (2003).

are presently underway to transfer the approach to the statistics of polar lows (Zahn et al. 2008) or tropical regions (Feser and von Storch 2008a,b). Other extratropical regions, such as the Baltic Sea, are also considered.

In face of the limited observational material available for many coastal and offshore areas, regional climate datasets such as coastDat may represent particularly useful tools for many applications, if adequately designed. They not only provide some knowledge about the meteorological–marine conditions at places and times at which no measurements have been made, but in the prospect of ongoing and future climate changes such regional climate datasets may serve as a reality substitute within which the robustness of possible (adaptation) options for many applications may be tested. Here we have provided some examples ranging from ship design, to coastal protection, oil risk modeling, or the construction and operation of offshore wind farms.

The purpose of generating and validating regional climate datasets such as coastDat is not to build or to construct a forecast system for the region. Rather, the ultimate goal is to describe and to assess ongoing and possible future climate change and to provide tools and data from which reliable *statistics* of meteorological–marine climate conditions and changes may be derived. We have shown that such information is of particular interest for a broad range of practical applications and, from our experience, the quality and the design of the dataset benefit considerably from the feedbacks provided by the different user groups. Among others, upcoming versions of coastDat will therefore foster enhanced spatial resolution of the regional atmosphere model, improved coastal physics in the wave modeling part, or larger ensemble sizes with respect to the regional climate change scenarios. Further, and similarly to the effort on assessing the success of European Union regulations on the use of leaded gasoline, attempts are underway to simulate and to assess long-term changes of persistent organic pollutants (POPs) in the marine environment, in particular for the North Sea and the Baltic Sea (Aulinger et al. 2007; Matthias et al. 2008; Matthias et al. 2009).

Summarizing, and in addition to the analysis of existing observational data, we believe that comprehensive model-based regional climate datasets such as coastDat may provide a valuable source of information for the analysis of regional changes and the identification of options for actions especially in data sparse coastal or offshore regions.

ACKNOWLEDGMENTS. Figure 3 and the comparison therein were kindly provided by Lars Bärring from the Swedish Meteorological and Hydrological Institute where similar analyses are in progress. Mrs. Gardeike kindly prepared Figs. 5 and 8. We are also grateful for her help in improving the quality of all other figures.

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