Storm and Surge Climate in the North Sea Area: Changes in the Past Century.

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Abstract

The observational record of the storm climate (approximately 100 years) in the North Sea area is analysed.

A major methodical obstacle for the assessment of systematical changes in the intensity of storm events are the inhomogeneities of the observational record, both in terms of local observations and of analysed products (such as weather maps), which usually produce an artificial increase of extreme winds. To overcome these obstacles, robust indicators, such as annual distributions of geostrophic wind speeds or of high-pass filtered sea level variations (storm surges) are developed and analysed. According to these indicators, the storm climate in the near-coastal areas of Northwest Europe has not systematically worsened in the past century.

A statistical model is built which relates intramonthly quantiles of high-frequency water level variations to seasonal mean air pressure maps over the North Atlantic. This model confirms the absence of a marked roughening of the storm climate (even though there was such a trend in the last few decades). This statistical model is also used for deriving a scenario for the time of expected doubling of atmospheric carbon dioxide at about the year 2035: it indicates a moderate increase of storm surge height in the German Bight.

1 Background

In the public debate concerning climate change due to increasing emissions of radiatively active gases into the atmosphere many people are concerned about the possibility of an intensification of extratropical storms. Even though the IPCC took a cautious stand in this matter because of lack of evidence, a mixture of indirect evidence (van Hoff, 1993; Hogben, 1994) and misleading scientific statements (Schinke, 1992) created a substantial uneasiness in the public. The offshore oil industry in the North Sea was confronted with reports about extreme waves higher than ever observed. The insurance industry organized meetings with scientists because of greatly increased storm-related damages. The Northern European newspapers were full of speculations about the enhanced threat of extratropical storms in the early part of 1993.

In this situation the Norwegian Weather Service organized two workshops "Climate Trends and Future Offhsore Design and Operation Criteria", in Reykjavik and Bergen, and brought together people from the oil industry, certifying agencies and scientists to discuss the reality of a worsening of the wave and storm climate. The workshops did not create definite statements but the general impression that hard evidence for a worsening of the storm and wave climate was not available (for a summary see von Storch et al., 1994). A group of participants then established the "WASA project".[1]

Parallel to the WASA project, the question whether the storm surge climate in the North Sea would have changed, and may possibly change in future, was pursued with funding by the German Ministry of Science and Technology (BMBF).

In the present paper conclusions from both projects are summarized. First, the results concerning the storm climate, deduced from various atmospheric parameters in WASA, and results deduced from changes in the high-frequency statistics of storm surges at the North Sea (BMBF), are presented - these data unequivocally indicate no change in storminess (Section 2). Then, in Section 3 a statistical model is designed which relates intramonthly quantiles of surge statistics at one location to the monthly mean air-pressure field over the Northeast Atantic and Europe. This statistical model is fitted to 1970 - 1988 data of high water levels in Cuxhaven (a harbour in the German Bight at the mouth of the river Elbe; Section 4; for more details, refer to von Storch and Reichardt, 1996) and tested with independent data since 1900. The model is used for deriving a scenario of future surge statistics in Cuxhaven at the expected time of doubled CO_2 concentrations around 2035.

2 Analysis of the Observational Record of Storminess

When assessing the temporal evolution of the storm climate, in principle two different types of data may be considered. One source of information could be the archive of weather maps, which covers more than hundred years. Indeed, several attempt have been made to count the number of storms, stratified after the minimum core pressure, in the course of time (Schinke, 1992; Stein and Hense, 1994). These studies are useful in describing the year-to-year fluctutions in the past, say, 10 years. However, for the longer perspective this approach renders inconclusive simply since the quality of the weather maps has steadily improved. Thus any creeping worsening of the storm climate apparent in the weather maps (as reported by Schinke, 1992) might reflect a real signal or a result of the ever increasing quality of the operational analyses due to more and better observations, more powerful diagnostic tools and other improvements in the monitoring of the state of the troposphere. A more detailed mapping of the pressure distribution, however, automatically yields deeper lows.[2]

The inhomogeneity problem is illustrated by Figure 1 in which the ratio of high-pass filtered standard deviations of air-pressure variations in winter in the decade 1984-93 and in the decade 1964-73, as derived from the DNMI analyses[3], is plotted. Obviously is the variability greatly enhanced since the 1960's in areas where little or no in-situ observations are routinely available; this increase is likely spurious. In the

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[1] Preliminary summaries of the WASA project are offered by WASA (1994,1995). A major part of WASA deals with the assessment of the wave climate - first results will be published in near future by WASA Wave Group (1997).

[2] This problem is severe for (daily) weather maps; when dealing with monthly mean maps, the inhomogeneity becomes less significant.

[3] The Norwegian Weather Servcie DNMI has prepared 6-hourly high resolution air pressure analyses from 1955 until today. Until 1982 the analyses were done manually with a resolution of 150 km; after that time an objective technique was used and the product became available on a 75 km grid. Commonly, these analyses are considered as the best product for the region.

area marked in Figure 1, between 70° N and 50° N and east of $20^\circ W$ the bias seems less severe. For this area slightly more storms were found in the 1984-93 decade than in the previous decades (348 as opposed to 339, 336 and 330). We do not know to what extent changes in the analysis scheme are responsible for the changing storm numbers in that area, therefore the result of this storm count should be taken as an upper bound of an increase of storm frequency and intensity.

Any analysis of changes of the storm climate should be supported by an analysis of local observations which are unaffected by improvements in the process of mapping the weather.[4] A good parameter would be wind-speed, since it relates directly to damages and impact of waves and surges. However wind observations - either determined instrumentally or estimated - are usually of limited value due to inhomogeneities such as the change of scale, change of observer, change of surroundings etc. (cf. Peterson and Hasse, 1987).

Therefore one must look for other and more homogeneous proxies for storminess. An obvious choice is to base these on station air pressure, the time series of which are considered to be rather homogeneous because more or less the same instrument (mercury barometer) and procedures have been used throughout the entire observation period.

From air-pressure two proxies for storminess may be formed, namely the annual (seasonal, monthly) distribution of the geostrophic wind speed derived from three stations in a triangle (Schmidt and von Storch, 1993; see Section 2.1) or the annual (seasonal, monthly) distribution of the pressure tendency, possibly after suppressing the non-synoptic variations by means of a digital filter (Schmith, 1995) (see Section 2.2). Another homogenous proxy data time series is provided by high-frequency sea level variations at a tide gauge. The variance of such variations is controlled by the variance of the synoptic atmospheric disturbances (see Section 2.3).

These proxy data geostrophic wind, high-frequency pressure tendency and sea level variations, can not be used to reliably estimate actual wind speeds; however, changes of the annual (monthly) distributions are connected with similar changes in the distributions of the wind speed (cf. WASA (1995)).

2.1 Geostrophic Wind Analyses

For a number of 15 stations, situated in Northwestern Europe and the Northeast Atlantic, an uninterrupted pressure record for about the last 100 years of three or four daily observations were identified in the WASA project, which could be homogeneized (Alexandersson, 1986).

With these stations, triangles were set up and daily geostrophic winds were derived. Here, the results for two such triangles are shown: one over Denmark and one over southern Sweden.

For the Danish triangle, annual distributions of geostrophic winds speeds were derived, and from each annual distribution the annual 50%, 90% and 99% quantiles were determined.[5] The resulting time series of the annual quantiles Figure 2 show no significant upward or downward trend but some interdecadal variability.

A similar result is obtained for the Swedish triangle Göteborg-Visby-Lund. This time, the result is presented by plotting the annual number of cases with geostrophic wind speeds exceeding 25 m/s per year. Figure 3 indicates that there may have been a weak reduction of the number of such cases in the past.

Also the analysis of other triangles offers no evidence of a ongoing worsening of the European storm climate.

2.2 Pressure Tendency Analysis

Large air pressure tendencies are indicative for major baroclinic developments so that large wind speeds are likely to occur somewhere in the neighborhood. Therefore Kaas et al. (1995) suggested the use of the absolute value of the 24-hourly pressure tendency as another possible proxy for storminess. They investigated the record of two stations, namely Fanø in Denmark and Thorshavn on the Faroer Islands

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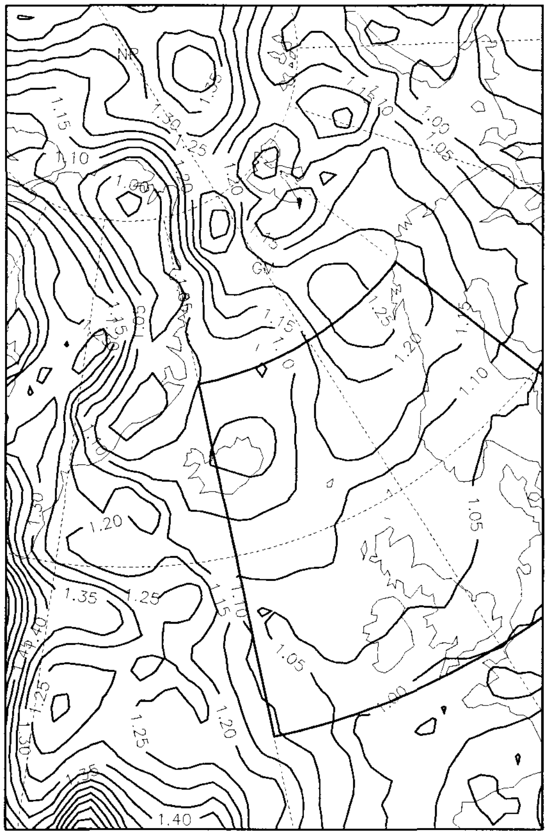
[4] According to "van Loon's Rule", this advice is almost universal - results obtained from analysed products should be checked with the help of local data.

[5] The 90% *quantile* of a distribution X is that number $x_{90\%}$ so that the probablity to observe any realization of $X < x_{90\$}$ is 90%. In case of distributions formed from 365 daily geostrophic wind speeds during one year, the actual geostrophic wind is at 36 days equal or larger than the 90% percentile.
Quantiles are often called *fractiles* or *percentiles*.

Figure 1: *Ratio of synoptic scale standard deviation of air pressure variations in winter (DJF) as derived from DNMI analyses in the decade 1984-93 and in the decade 1964-73. The analyses in the marked area south of 70° N and east of 20° W seem to be relatively homogeneous.*
Courtesy: Viasheslav Kharin.

SLP STD ratio (band-pass filtered)



Data: DNMI 1984-93 vs. 1964-73, DJF

Figure 4: *Time series of percentiles of the absolute value of the 24-hour pressure tendencies over Denmark Units: 0.1 hPa/3 hrs.*
Courtesy: Torben Schmith.

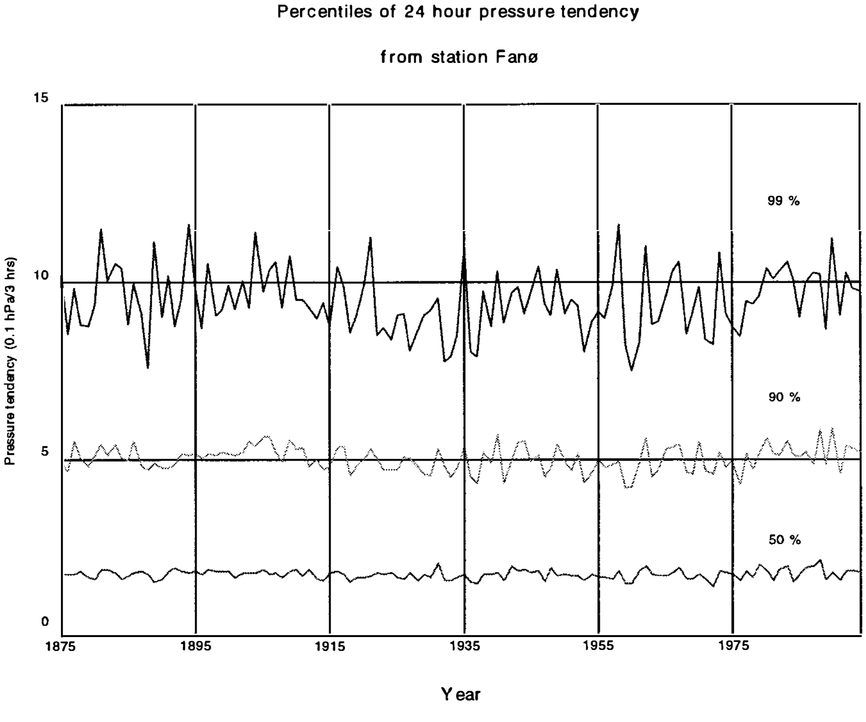


Figure 2: *Time series of percentiles of geostrophic wind speed over Denmark. Units: m/s. Courtesy: Torben Schmith.*

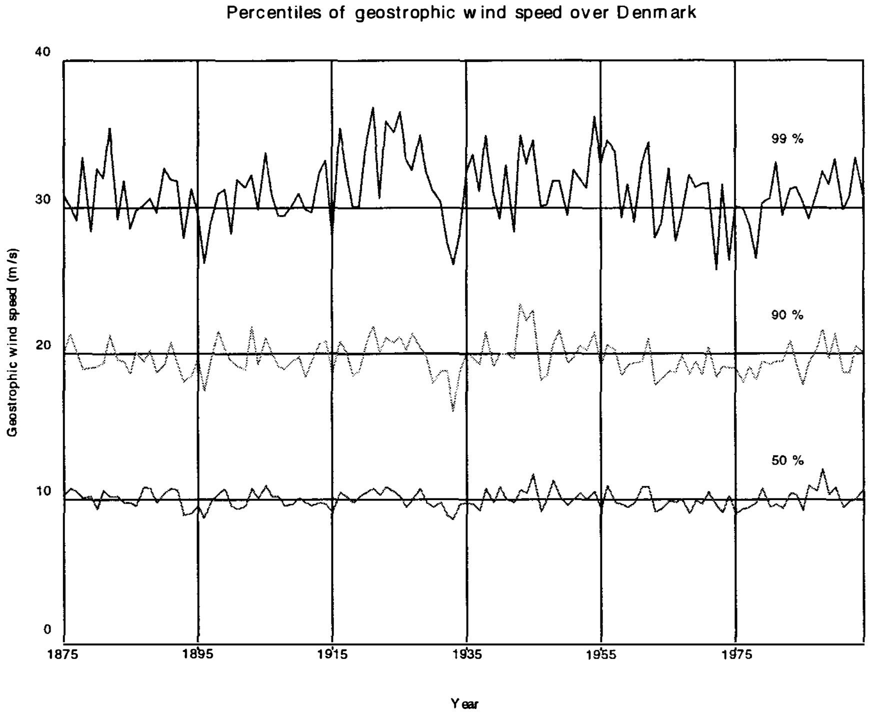


Figure 3: *Time series of number of daily geostrophic wind speeds exceeding 25 m/s, derived from the triangle Göteborg-Visby-Lund in Southern Sweden. The solid line represents a low-pass filter. Courtesy: Hans Alexandersson*

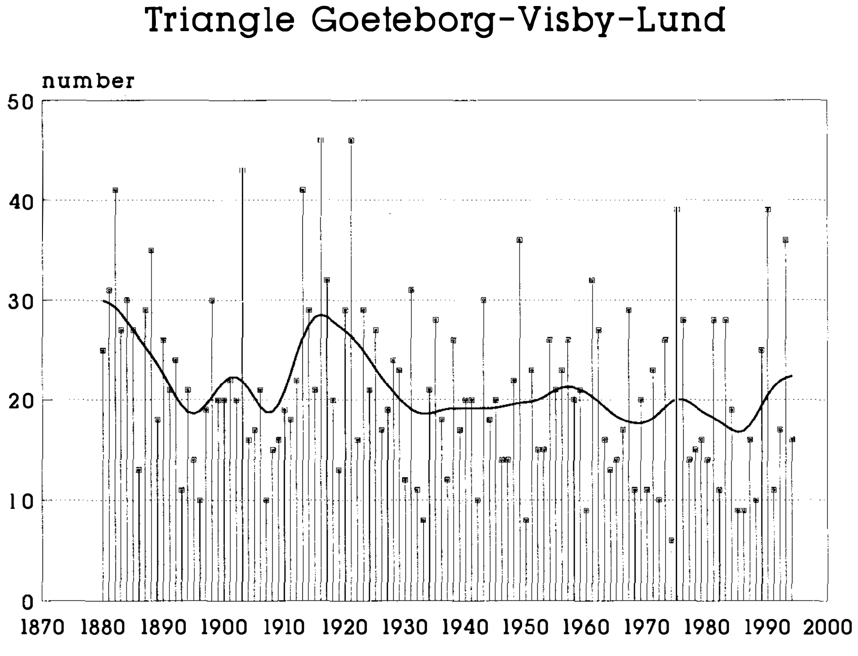
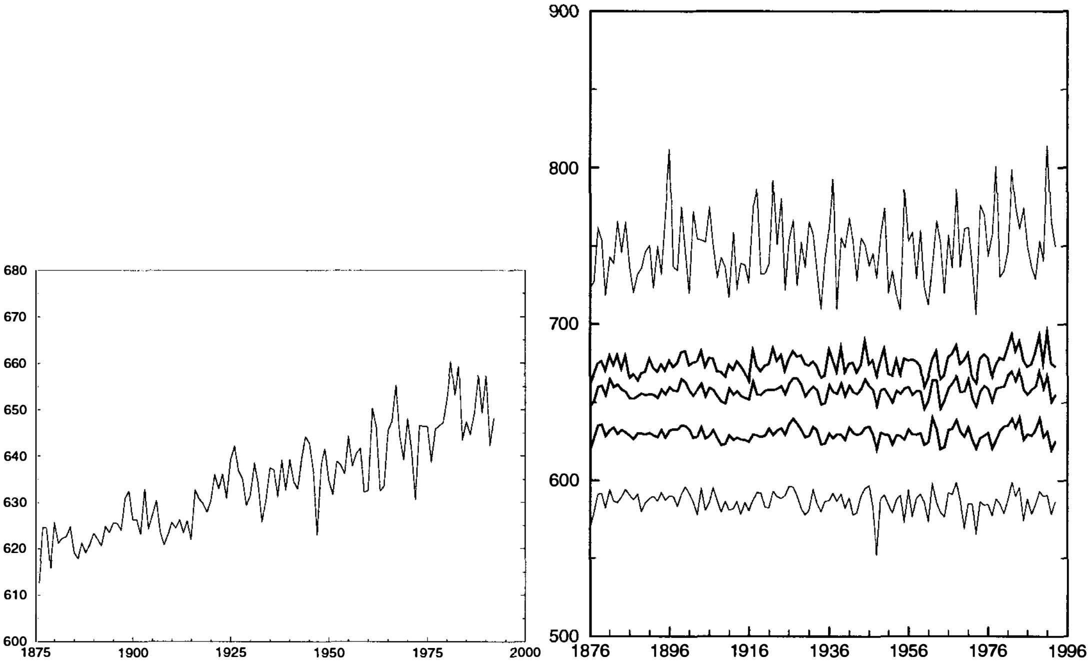


Figure 5: *Time series of the annual mean of the sea level reported by the Cuxhaven (German Bight) tide gauge (left), and the time series of various annual percentiles (10%, 50%, 90%, 99% from bottom to top) of sea level relative to the annual mean (right). Units: cm*



in the North Atlantic. In both cases no systematic increase of the 50%, 90% and 99% percentiles of the annual distributions of the pressure tendencies were found, as is exemplified in Figure 4 for Fanø. In the later years,. since about 1970, an increase is present for all three tide gauges, but this increase does not appear as alarming when comapred to earlier time-limited trends. The recent trend may well be linked with the intensification of the North Atlantic Oscillation in the past decads (Hurrell, 1995), and it is certainly required to closely monitor the future development.

2.3 Highfrequency Sea Level Variations

The idea to use high-frequency variations of sea level as a proxy for storm activity was suggested by de Ronde (cf. von Storch et al., 1994), who analysed data from Hoek van Holland. To do so, the annual mean water level is subtracted from the data, because changes in the mean water level are thought to reflect processes unrelated to the storm activity, such as local anthropogenic activity (e.g., harbour dredging), mean sea level rise or land sinking. After subtraction of the annual mean, intraannual distributions of the water level variations are formed, like in the case of geostrophic winds discussed above, and intraannual quantiles are determined.

The time series of annual mean sea level[6] as well as the time series of intraannual quantiles at Cuxhaven (German Bight, at the mouth of the river Elbe) are displayed in Figure 5. The mean water level has risen by about 30 cm/100 years, but the storm related intraanual quantiles have remained almost constant.[7]

By now, the observational record at several tide gauges around the southern und eastern North Sea has been examined. As for Cuxhaven, at the other locations no increase of the storm-related intraannual quantiles were found. As examples, we present the time series for Den Helder (The Netherlands) and Esbjerg (Denmark) in Figure 6.

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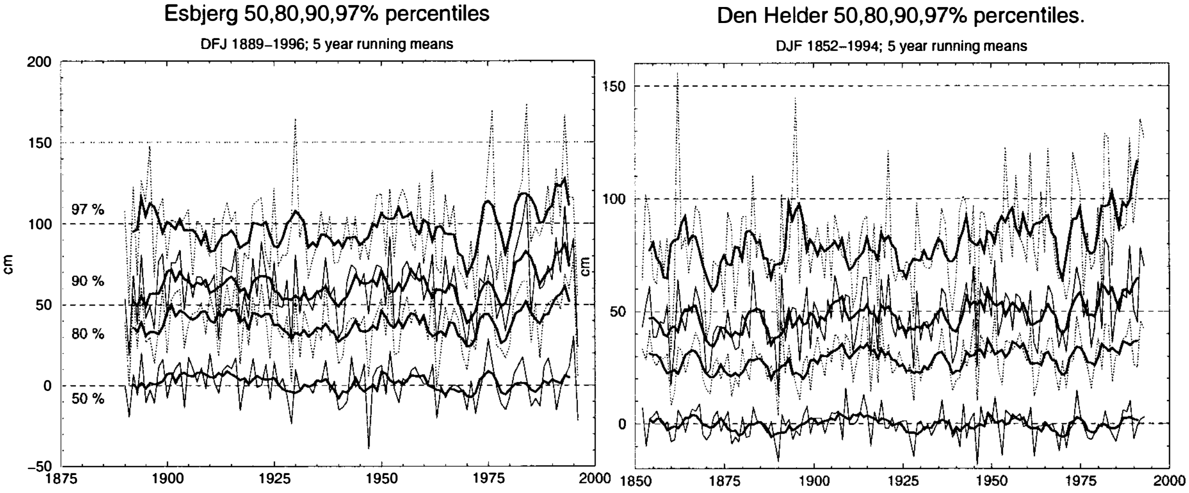
[6] Here given as the height of the high tide, which takes place about twice daily.

[7] Note that the effect of unchanged storm-related variations and a rise of the mean water level leads to a significant increase of the height of storm surges!

Figure 6: *Time series of the intraannual quantiles of storm-related water level variations (defined as deviation from the annual mean) at the gauges in Den Helder and Esbjerg. The den-Helder time series has been corrected for systametic changes induced by the dam construction closing the Ijsselmer in the 1930s. Units: cm*


Esbjerg 50,80,90,97% percentiles
DFJ 1889-1996; 5 year running means
Den Helder 50,80,90,97% percentiles.
DJF 1852-1994; 5 year running means

3 The Empirical Model Linking Intramonthly Percentiles and Mean Air Pressure Distributions

The empirical model is based on a Canonical Correlation Analysis which links two sets of random vectors $\vec{\mathbf{S}}_t$ and $\vec{\mathbf{Q}}_t$ (Barnett and Preisendorfer, 1987; von Storch, 1995). Both vectors are assumed to be centered, i.e., their time means are subtracted prior to the analysis. Also, a data compression with the help of EOFs is done prior to the analysis in order to avoid artificially enhanced correlations.

In the cases considered below, one vector time series, $\vec{\mathbf{S}}_t$, represents the winter (DJF) monthly mean air-pressure distributions. The other vector time series, $\vec{\mathbf{Q}}_t$, is formed by a few quantiles of the intramonthly distributions of our local parameter of interest. In case of storm-related water level distributions, the 50%, 80% and 90% quantiles are considered so that[8]

$$\vec{\mathbf{Q}}_t = \begin{pmatrix} q_{50\%} \\ q_{80\%} \\ q_{90\%} \end{pmatrix}_t \tag{1}$$

The result of a CCA are pairs of vectors $(\vec{p}^{\,s;k}, \vec{p}^{\,q;k})$ and time coefficients $\alpha_{s;k}(t)$ and $\alpha_{q;k}(t)$ so that

$$\begin{aligned} \vec{\mathbf{S}}_t &= \sum_k \alpha_{s;k}(t)\vec{p}^{\,s;k} \\ \vec{\mathbf{Q}}_t &= \sum_k \alpha_{q;k}(t)\vec{p}^{\,q;k} \end{aligned} \tag{2}$$

The $k = 1$ coefficients share a maximum correlation ρ_1, the $k = 2$ coefficients another maximum correlation ρ_2 obtainable under the constraints of being uncorrelated with the $k = 1$ coefficients and so forth.

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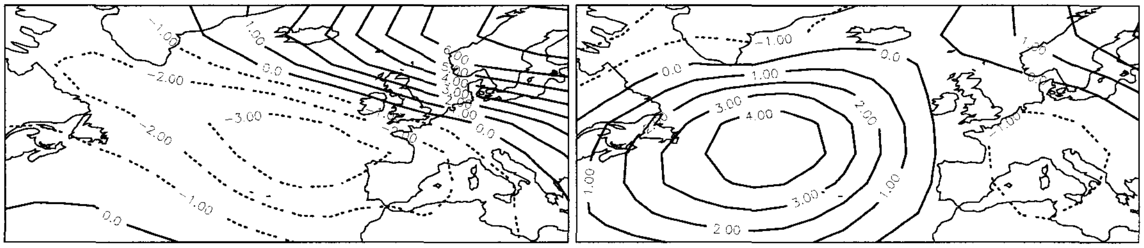
[8] Note that the quantiles are also centered, so that the vector $\vec{\mathbf{Q}}$ is composed of *anomalies*.

Figure 7: *Two characteristic patterns* $\vec{p}^{\,s;1}$ *(left) and* $\vec{p}^{\,s;2}$ *(right) of monthly mean air pressure anomalies over the Northeast Atlantic. The coefficients of these CCA vectors share a maximum correlation with the coefficients of Cuxhaven water level percentile patterns given in Table 1. Units: hPa.*



The pattern are eigenvectors of a matrix essentially featuring the cross-covariance matrix between $\vec{\mathbf{S}}$ and $\vec{\mathbf{Q}}$. The CCA coefficients $\alpha_{s;k}$ are determined as least square fit by minimizing

$$\| \vec{\mathbf{S}}_t - \textstyle\sum_{k=1}^{K} \alpha_{s;k}\vec{p}^{\,s;k} \| \tag{3}$$

The coefficients are normalised to one

$$\mathrm{VAR}(\alpha_{q;k}) = \mathrm{VAR}(\alpha_{s;k}) = 1$$

so that the three components of $\vec{p}^{\,q;k}$ may be interpreted as anomalies which occur typically together with the "field distribution" $\vec{p}^{\,s;k}$.

The downscaling model which relates the large-scale air-pressure information to the local-scale storm-related water level information is a regression model $\alpha_{q;k} = \rho_k\alpha_{s;k}$ for the CCA-coefficients $\alpha_{s;k}$ and $\alpha_{q;k}$ with a reconstruction in the three-dimensional space using (2):

$$\hat{\vec{\mathbf{Q}}}_t = \widehat{\begin{pmatrix} q_{50\%} \\ q_{80\%} \\ q_{90\%} \end{pmatrix}}_t = \sum_{k=1}^{K} \rho_k \alpha_{s;k}(t)\vec{p}^{\,q;k} \tag{4}$$

The regression model (4) may be applied to anomalies of observed or simulated air pressure fields $\vec{\mathbf{S}} = \sum \alpha_{s;k}\vec{p}^{\,s;k}$.

The success of the reconstruction of observed intramonthly water level percentiles is quantified by two measures of skill, namely the correlation skill score ρ_κ and the percentage of represented variance ϵ_κ for $\kappa = 50\%, 80\%$ and 90% (Livezey, 1995):

$$\begin{aligned} \rho_\kappa &= \frac{\mathrm{COV}(\hat{q}_{\kappa;t}, q_{\kappa;t})}{\sqrt{\mathrm{VAR}(\hat{q}_{\kappa;t})\mathrm{VAR}(q_{\kappa;t})}} \\ \epsilon_\kappa &= 1 - \frac{\mathrm{VAR}(\hat{q}_{\kappa_t} - q_{\kappa;t})}{\mathrm{VAR}(q_{\kappa;t})} \end{aligned} \tag{5}$$

where $\hat{q}_{\kappa:t}$ is the estimated κ percentile in the month t.

In the following Section 4 we show and discuss the resulting patterns $\vec{p}^{\,q;k}$ and $\vec{p}^{\,s;k}$ and their relationship for the case $\vec{\mathbf{S}}$ = *monthly mean air pressure distribution* and $\vec{\mathbf{Q}}$ = *intramonthly quantiles of observed high-pass filtered high water levels in Cuxhaven,.*

4 The Downscaling Model for Water Level Quantiles

Before calcuating for each winter month the intramonthly quantiles, first the annual means are computed and subtracted from the data. Then, the CCA is done with the 18-year subset of data December 1970 to February 1988. The remaining data, prior to 1970, are kept as independent data for verifying the statistical model.

Table 1: *Characteristic anomalies of intramonthly percentiles of storm-related water level variations in winter (DJF) at Cuxhaven.*
The k-row is the k-th CCA vector $\vec{p}^{\,q;k}$. *This vector represents* ϵ_k *of the variance of* $\vec{\mathbf{Q}}$ *within the fitting interval December 1970 - February 88. Its coefficient* $\alpha_{q;k}$ *shares a correlation of* ρ_k *with the coefficient of the air-pressure pattern* $\vec{p}^{\,s;k}$ *within the fitting interval.*

$\kappa =$	50%	80%	90%	ϵ_k	ρ_k
k		[cm]		[%]	
1	-21	-16	-18	83	0.89
2	-10	1	10	13	0.32

Table 2: *The correlation skill* ρ_κ *and the percentage* ϵ_κ *of the month-to-month variability of the intramonthly percentile* q_κ *represented by the regression model ((4)), determined from independent data (1899 - 69).*

	correlation skill score ρ_κ				represented variance ϵ_κ			
K	$\kappa =$	50%	80%	90%	$\kappa =$	50%	80%	90%
1		.75	0.73	0.69		53 %	50 %	45 %
2		.79	0.72	0.63		62 %	50 %	40 %

The two largest correlations amount to 0.89 and 0.32 (see Table 1) The first two CCA patterns of air pressure distributions are shown in Figure 7 and the associated anomalies of storm related intramonthly water level percentiles are given in Table 1.

The first air pressure anomaly pattern, $\vec{p}^{\,s;1}$, describes a southeasterly flow across the North Sea, which is connected with a almost uniform decrease of all three considered percentiles of -20 cm. This CCA pair describes the dominant atmospheric control of water level variations - as much as 83% of the variance of of month-to-month variability of intramonthly percentiles is represented by this first pair of patterns. From the distributions shown in Figure 7 and an analysis of the characteristic pattern of high-pass filtered air pressure variance (see von Storch and Reichardt, 1996) we conclude that the first CCA pattern encompasses two factors affecting water level variations; first, there is a weakened mean northwesterly flow; secondly, this pattern reduces the formation of synoptic disturbances which travel in a southeasterly direction into the North Sea, where they pile up water in the German Bight.

The second air pressure pattern, $\vec{p}^{\,s;2}$, is less important for the variations of Cuxhaven water levels, since it represents in the fitting interval no more than 13% of the variance of the combined vector of percentile anomalies. Its link to water level variations is rather different from that of the first CCA pattern: The 50% percentile is lowered by 10 cm, the 80% percentile is almost unchanged and the 90% percentile is lifted by 10 cm. Thus, the water level distribution becomes markedly broader if this air pressure distribution prevails; if the sign of air pressure anomaly is reversed then the water level distribution tends to be narrower than on average. Also the second pair of CCA pairs is physically plausible. The anomalous air-pressure distribution of $\vec{p}^{\,s;2}$ in Figure 7 does not cause an additional accumulation of water in the German Bight. Indeed the mean air flow across the North Sea is southeasterly and, consistently, the 50% percentile is reduced. However, this pattern steers ocassionally energetic synoptic disturbances into the area of the North Sea (see von Storch and Reichhardt, 1996) so that the higher percentiles are enhanced.

The regression model (4) has been used for estimating intramonthly percentiles for Cuxhaven for the winters 1899 to 1988. The skill of the model (4) is summarised in Table 2. The inclusion of the second canonical pair improves the skill for the 50% percentile but deteriorates the skill for the 90% percentile. We include it in the regression model to have more degrees of freedom when designing the scenario below.

As in most cases with statistical models, a marked percentage of variance is *not* represented by the model. This "failure" matters if the goal of the model is to reproduce the details of a development. In the present case, however, these details do not matter; instead, all what is needed is the statistics of storm-related

Figure 8: *Time series of 80%-percentiles of intramonthly storm-related water level variations in Cuxhaven as derived from in-situ observations (solid) and estimated from the monthly mean air-pressure field through (4) (dashed).Units: cm*

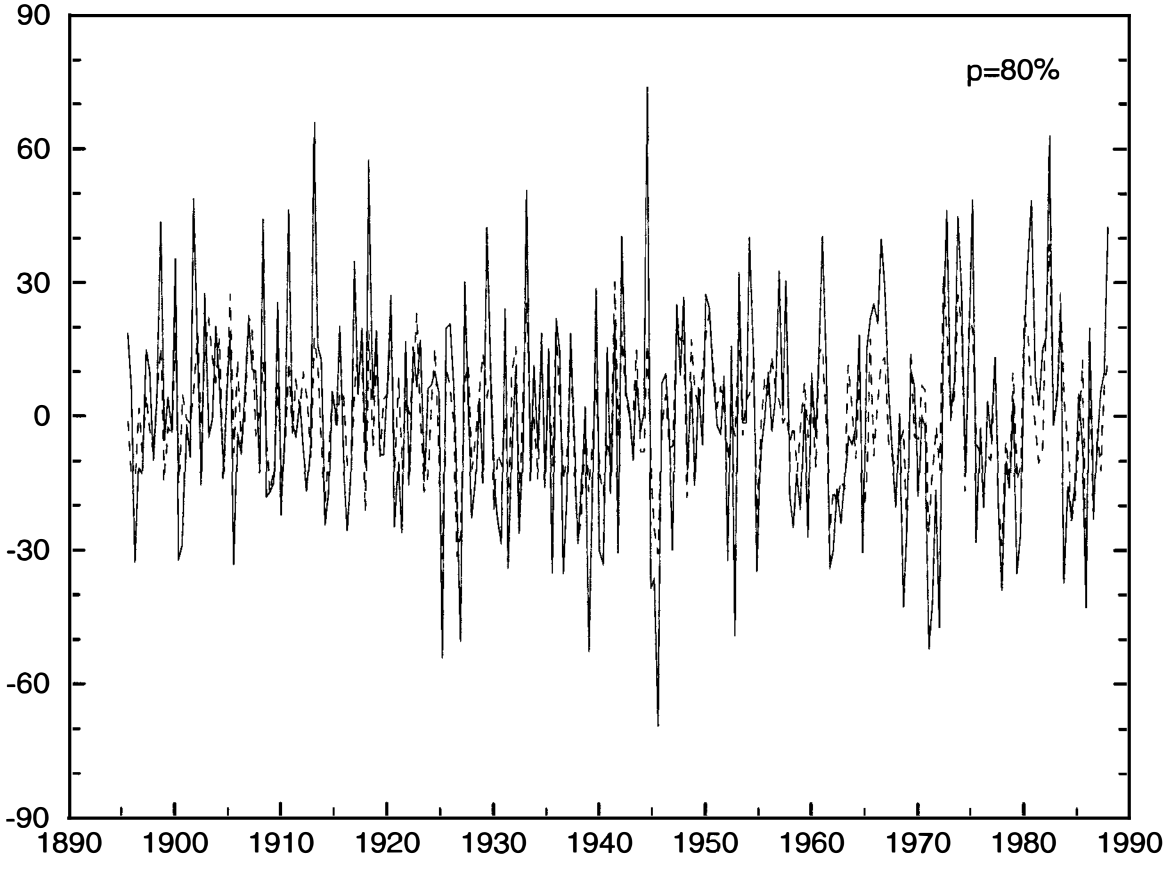
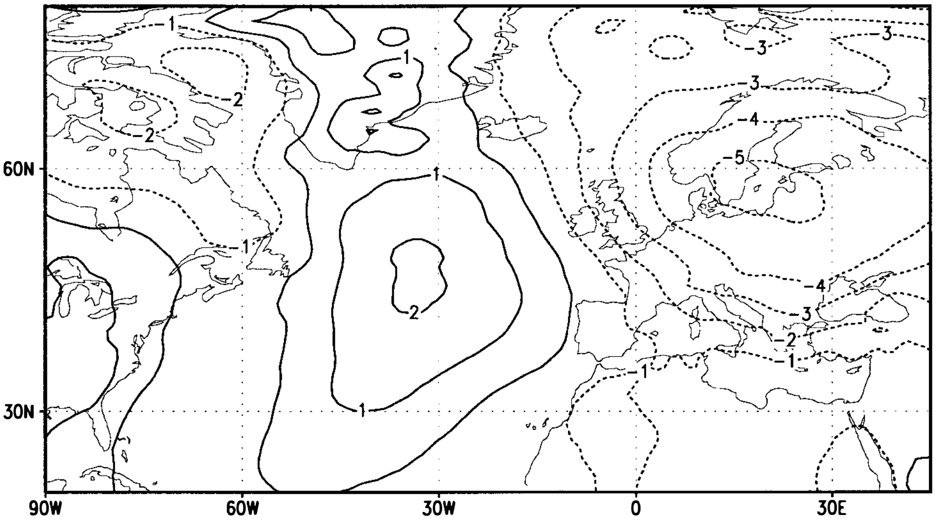


Figure 9: *Simulated atmospheric response to doubled carbon dioxide concentrations, as derived from a T106 time slice experiment. The variable shown in air pressure at sea level, given in hPa.*



water level variations. The achievement of this goal is demonstrated by Figure 8 which displays the time series of the 80% quantiles as derived from the detrended in-situ observations and as reconstructed by the regression model (4). The differences between the in-situ data and the indirectly derived data appear as mostly irregular, while the low-frequency variations are captured remarkably well.

In order to determine a consistent scenario of expected future storm-related water levels in Cuxhaven, the mean difference field of air pressure in a paired "$2 \times CO_2$"/"control" ***time slice experiment*** with a T106 atmospheric GCM is determined and plugged into the regression model (4). In these time slice experiments, the atmospheric GCM simulates the equilibrium reponse to present day sea surface temperature and sea ice distribution and present carbon dioxide concentrations. For the "$2 \times CO_2$" experiment, SST and sea ice distributions from a simulation with a coupled low-resolution atmosphere-ocean GCM with gradually increasing carbon dioxide concentrations are determined from the time of doubled carbon dioxide concentrations at about the year 2035 (Cubasch et al., 1992). These SST and sea ice distributions are then used as specified, time constant lower boundary conditions for the T106 atmospheric GCM. Additionally, the carbon dioxide concentrations are doubled. For more details, refer to Bengtsson et al. (1995, 1995) or Cubasch et al. (1996). Beersma et al. (1997) found the wind climate in the doubled carbon dioxide world insignificantly changed when compared to the control run.

The resulting change in the air pressure distribution is plotted in Figure 9. When fed into the regression models for anomalies of intramonthly quantiles of high tide levels in Cuxhaven a slight increase of about 7 *cm* for all three quantiles is found.

5 Conclusions

The storm and surge climate along the North Sea coasts has not roughened in the past hundred years. This result is consistent with findings for other European coasts and other analyses. For instance, Jónsson (1981) studied the number of "storm days" on Iceland, as defined by local observations, and found no systematic changes (cf. von Storch et al., 1994). The Koninklijk Nederlands Meteorologisch Instituut published an official assessment on the state of climate and its change for the territory of the Netherlands (KNMI, 1993). According to that report the maximum windspeeds observed during severe storms have not been increased between 1910 and today.

Thus, results derived from analysed products (weather maps) who allude to a roughening of the storm climate, seem to be misleading, since a significant part of the identified signal is due to changes in the observational, reporting and analysing procedure.

Our study has a number of *caveats*. The analysis of geostrophic winds, pressure tendencies and high-frequency sea level variations covers only the near-coastal areas of Northern Europe, and no robust analysis is available for the open ocean regions. Also, one may speculate whether the link between these proxy data and the wind speeds holds for extreme wind speeds.

Our scenario for the expected time of doubled carbon dioxide concentrations points to moderate increases of surges in the German Bight. This scenario is consistent with, and within the range of previously observed variations. As such, it is plausible. However, it depends crucially on the validity of the driving GCM experiments; if these GCM simulations turn out being inadequate then also our numbers are inadequate. Thus, not too much informational weight should be given to this scenario.

Also, no error bars are given for the scenarios. Such error bars are often demanded as indispensibly by physicists, but can not be given with any degree of confidence. The expected error is composed of many factors, ranging from natural variability in the system to proper descriptions of the various parameterizations in the used climate model. Since the climate models are tuned ot the observational record, and only one such record exists, rigorous statements about errors can not be made.

In the present analysis, the aspect of wave heights, and the reports about increasing weave heights in the past dacades (Neu, 1984, Carter and Draper, 1988, Bacon and Carter, 1991, van Hoff, 1993, Hogben, 1994, Buows et al., 1996) has not been considered since a detailed publication about these matters is to be expected in near future (WASA Wave Group, 1997; see also WASA 1994 and 1995).

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