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Inventory of climate change scenarios applied in the North Sea countries

Desk study report

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Abstract

In the framework of the project Safecoast an inventory has been carried out of climate change scenarios that are available for the North Sea countries The Netherlands, Belgium, Denmark, Germany and the United Kingdom. The inventory concerned both the scientific climate change estimates in each of these countries (based on measurements and climate change models) as well as scenarios applied in governmental policies.

References

- Request for proposal Climate Change Scenarios in email of October 3, 2005
- Proposal number A1583P1r2 of Alkyon, October 12, 2005
- Contract 71051081, October 12, 2005

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Executive's summary

In the framework of the project Safecoast an inventory has been carried out of climate change scenarios that are available for the North Sea countries The Netherlands, Belgium, Denmark, Germany and the United Kingdom. The inventory has been carried out with the help of the Safecoast partners in the North Sea countries and with a review of available publications.

A distinction has been made between climate change estimates and climate change scenarios. The scientific climate change estimate is defined as an estimate that has been determined on the basis of climate change research. This can be done on the basis of historical measurements or investigations with climate change models. Policy scenarios of climate change are interpretations of the scientific estimates and prescriptions of which scenarios should be considered in coastal zone projects. The availability of the estimates and scenarios are presented in the Tables 4.1 and 4.2 respectively. The actual values of the estimates and scenarios have been presented in the Tables 2.10 and 3.5.

Most of the publications for the North Sea countries present single climate change estimates or scenarios. For the Netherlands and the United Kingdom some different estimates and policy scenarios have been presented. The Netherlands presents three scenarios and estimates to be applied in coastal studies. The 'Low scenario' should be considered for projects with a lifespan in the order of a few years, the 'Medium scenario' for projects with a longer lifespan and 'High scenario' for projects that require extra safety. The climate change estimates presented for the United Kingdom are based on four different greenhouse gas emission scenarios.

Most climate change scenarios focus on the absolute and relative sea level rise. Not much attention is given to other important parameters like the increase of storm surge, wave height, etc. This is mostly due to the fact that predictions of changes in future occurrence of storms, extreme wind and wave conditions are not considered to be very much reliable. In scientific climate change estimates most attention is given to absolute sea level rise scenarios. This is due to the fact that most climate change research is carried out on a global scale. Some countries (The Netherlands, Denmark and the United Kingdom) pay attention to the impact of tectonic movements on the relative sea level rise.

It has been concluded during the review of the available scientific and policy documents that inconsistency can be found in the way that parameter value changes due to climate change are presented. After the start of the IPCC in 1988 and their First Assessment Report (IPCC, 1988) most climate changes parameters have been presented as the change since the year 1990. Care should be taken that the IPCC climate change parameters for, for instance the year 2100, cannot be interpreted as the value change per century. Also some of the publications do not consistently indicate whether their sea level rise values are absolute or relative.

For the construction of new protection works we recommend to use the design sea level at the starting date of the construction and to consider the climate change scenarios in value per unit of time in order to come to the value of the design lifespan. We, therefore, recommend focusing on climate change scenario values per unit of time instead of focussing on the actual values to be expected in the year 2050.

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1 Introduction

1.1 Safecoast

The recent Asian tsunami and flooding of New Orleans due to the Katrina hurricane have again demonstrated the vulnerability of low-lying coastal areas. Storm surges also represent a major natural hazard in the North Sea region. A cumulative low-lying area of about 40,000 km^2 in located in the North Sea countries the Netherlands, Germany, Belgium, Denmark and the UK. Without proper coastal defence measures this area, with a population of approximately 16 million people, would be flooded from time to time. A prerequisite for social progress and economic development in this area is a safe coast. Due to climate change and spatial developments, most experts agree that the risk of flooding will increase in the coming decades and that it is essential to start thinking about alternative and innovative ways to keep our feet dry in a sustainable manner.

A team of coastal managers from the Netherlands, Germany, Belgium, Denmark and the UK have started to cooperate in the joint project Safecoast, which aims to learn from each other about coastal risk management. Safecoast considers the question: ‘How to manage our North Sea coasts in 2050?’ and focuses on the consequences of climate change and spatial developments with respect to safety against flooding. Safecoast will continue until the middle of 2008 and is co-financed by the European Union in the framework of the Interreg 3b North Sea programme for transnational projects. The progress of the project can be monitored on www.safecoast.org

Knowledge on how to manage the safety against flooding is widespread across the North Sea region. Different countries focus on different aspects of policies and strategies in order to stay safe from flooding. In the preceding project Comrisk it has been concluded that not so much a transnational harmonisation of policy is needed, but further mutual understanding and learning is important to improve national policies. This counts for both technical aspects and aspects such as risk communication, awareness, and crisis management. Moreover, the prospect of climate change, economic and spatial developments give rise to similar management questions.

The Safecoast project is divided into work packages called actions. Depending on their goals these actions are either comparisons between countries (cohesion actions), translating knowledge into pilot site risk assessments or plans (focused actions) or converging the knowledge and lessons learnt in the different countries into a synthesis (synthesis action). The main products of Safecoast are:

- An inventory of climate change and spatial development scenarios;
- Risk communication methods;
- Comparison of different flood risk assessment methods;
- An integrated master plan for Flanders coastal safety;
- Flood risk assessments for now and in 2050 in different pilot sites;
- Consolidation of findings into adaptive strategies in an integrated coastal management framework.

1.2 Background

In spatial plans for the coastal zone it is common to consider the future development of boundary conditions for a long time frame. Also for the design of flood protection measures it is important to consider the change of boundary conditions like water level and external forces on the constructions. So far it is not possible to accurately predict future climate changes. It is therefore common to use climate change scenarios in the planning process. These climate change scenarios can contain, for instance, expected values of future sea level rise, wave amplitudes for several percentages of storm frequencies and (sometimes) the storm duration.

Climate change researchers have determined scientific predictions of future changes of certain parameters. This is normally done on the basis of the output of climate change models. The predictions with such type of models are normally involved with large uncertainties. The output of this type of models consists of large ranges of parameter values. In IPCC (2001), for instance, a large range of expected sea level rise (0.09 to 0.88 m) is presented for the period 1990 – 2100. Policy makers, therefore, need to translate the scientific predictions into values to be considered in coastal studies. For this reason it is possible that differences occurs between climate scenarios based on climate change research and climate change scenarios that prescribed in coastal policies. Moreover, it is also possible that different translations of the scientific scenarios into scenarios prescribed in coastal policies have been made in the different North Sea countries.

It appears, furthermore, that certain climate parameters are not yet considered in the climate change scenarios. An example is the storm duration and the wave period. Climate change experts indicate that it is not yet possible to provide any insight in the future changes of these parameters. These are, however, important parameters to be considered in studies related to long-term coastal protection schemes. In the Netherlands this omission is compensated by sensitivity analyses in which assumptions are made of the change of these parameters.

1.3 Objective

The objective of the inventory that has been carried out by Alkyon Hydraulic Consultancy & Research is to provide a comparison of the climate change scenarios that are available for the North Sea countries The Netherlands, Belgium, Denmark, Germany and the United Kingdom. These climate change scenarios should concern both the scientific climate change scenarios (based on measurements and climate change model predictions), as well as scenarios prescribed in governmental policies. This difference should be clearly considered in the inventory.

At least the following climate change parameters should be included:

- Relative sea level rise;
- Extra storm surge;
- Wave height;
- Rise of the coastal cross-sections under influence of sea level rise.

1.4 Approach

The inventory of climate change scenarios has been started by contacting the international partners outside the Netherlands that are involved in the Safecoast project:

Germany

Ministry of the Interior of the Land Schleswig-Holstein
Coastal Defence Division, Emergency Planning & Disaster Management Division
Contact: *Jacobus Hofstede*

Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency, NLWKN, Division Norden – Norderney.
Contact: *Holger Blum*

Belgium

Ministerie van de Vlaamse Gemeenschap
AWZ (Afd. Waterwegen en Zeewezen), CEL KUST

Contact: *Stefaan Gysens*

Ministerie van de Vlaamse Gemeenschap
AWZ (Afd. Waterwegen en Zeewezen),
Waterbouwkundig Laboratorium en Hydrologisch Onderzoek
Contact: *Toon Verwaest*

Denmark

Danish Coastal Authority (DCA)
Kystdirektoratet
Contact: *Thorsten Piontkowitz*

United Kingdom

Environment Agency
National Flood Risk Management Policy Team
Contact: *Paul Miller*

With these project partners the possible ways to obtain information of available climate change scenarios for their countries has been discussed. Based on the discussion additional sources of information have been contacted.

With the information and documents provided by the Safecoast partners a review has been made of available publications concerning climate change scenarios in the North Sea countries.

1.5 Set-up of the report

The result of this work is provided in this report. The results for the scientific estimates and governmental scenarios are presented in Chapter 2 and 3 respectively. Chapter 4 concludes with some general conclusions and recommendations.

2 Estimates based on scientific research

This chapter aims at providing insight in the different scientific climate change estimates that have been determined for the different North Sea Countries. First of all the estimates presented by the IPCC and by each of the countries will be presented. In Paragraph 2.7 a table will be presented in which all data are gathered so that a comparison can be made.

2.1 The Intergovernmental Panel of Climate Change, IPCC

Projections of global average sea level rise from 1990 to 2100, using a range of Atmosphere-Ocean General Circulation Models (AOGCMs) following the IS92a emission scenario (scenario of the Second IPCC Assessment assuming the "best estimate" values of climate sensitivity and of ice melt sensitivity to warming, and including the effects of future changes in aerosol concentrations), lie in the range 0.11 to 0.77 m (IPCC, 2001). This range reflects the systematic uncertainty of climate change modelling. The main contributions to this sea level rise are:

- A thermal expansion of 0.11 to 0.43 m, accelerating through the 21st century;
- A glacier contribution of 0.01 to 0.23 m;
- A Greenland contribution of -0.02 to 0.09 m;
- An Antarctic contribution of -0.17 to +0.02 m.

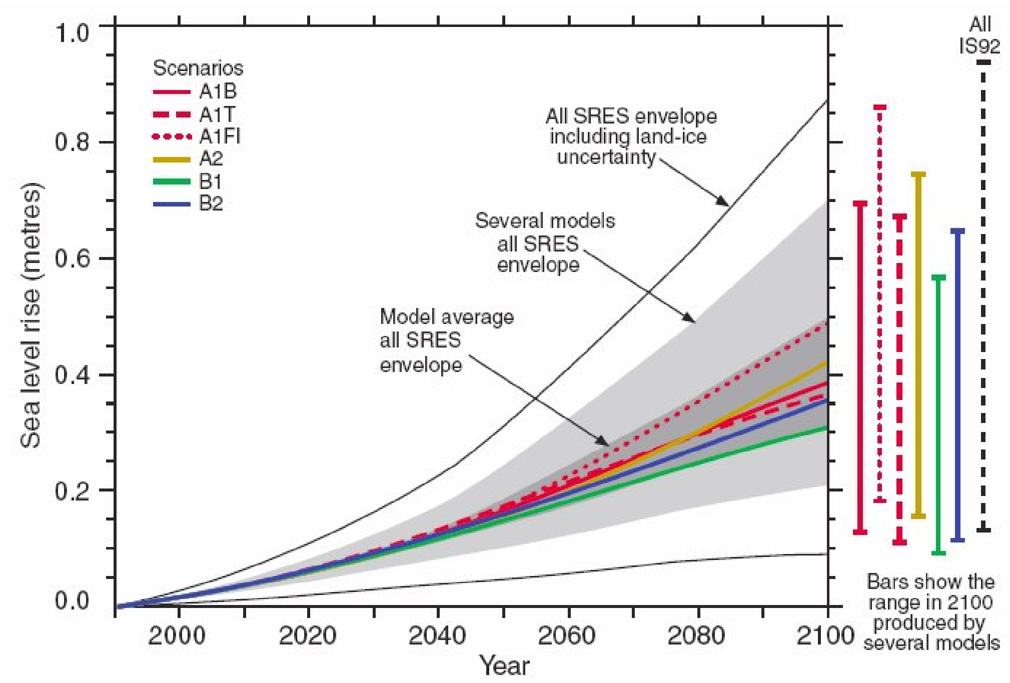

Figure 2.1 Sea level rise scenarios presented by IPCC (2001)

Also included in the computation of the total climate change are smaller contributions from thawing of permafrost, deposition of sediment, and the ongoing contributions from ice sheets as a result of climate change since the Last Glacial Maximum. To establish the range of sea level rise resulting from the choice of different scenarios presented in the IPCC Special Report on Emissions Scenarios (SRES) (IPCC, 2000), results for thermal expansion and land-ice change from simple models tuned to several AOGCMs are used.

IPCC (2001) states that the global mean sea level is projected to rise by 0.09 to 0.88 m between 1990 and 2100. The central value is 0.48 m, which corresponds to an average rate of about two to four times the rate over the 20th century. For the period 1990 to 2025 and 1990 to 2050, the projected rises are 0.03 to 0.14 m and 0.05 to 0.32 m respectively (IPCC, 2001). Significant regional differences are to be expected.

Models agree on the qualitative conclusion that the range of regional variation in sea level change is substantial compared to global average sea level rise. However, confidence in the regional distribution of sea level change from AOGCMs is low because there is little similarity between models, although nearly all models project greater than average rise in the Arctic Ocean and less than average rise in the Southern Ocean. Further, land movements, both isostatic and tectonic, will continue through the 21st century at rates that are unaffected by climate change. It can be expected that by 2100, many regions currently experiencing relative sea level fall will instead have a rising relative sea level. Lastly, extreme high water levels will occur with increasing frequency as a result of mean sea level rise. Their frequency may be further increased if storms become more frequent or severe as a result of climate change (IPCC, 2001).

IPCC (2001) states that several studies have attempted to quantify the consequences of changes in storm climatology for the northwest European continental shelf using regional models of the atmosphere and ocean. Using five-year integrations of the ECHAM T106 model for present and doubled CO2, Von Storch and Reichardt (1997) and Flather and Smith (1998) did not find any significant changes in extreme events compared with the variability of the control climate (see also WASA Group, 1998). However, Langenberg et al. (1999) reported increases of 0.05 to 0.10 m in five-winter-mean high-water levels around all North Sea coasts, judged to be significant compared with observed natural variability.

Lowe et al. (2001) undertook a similar study using multi-decadal integrations of the Hadley Centre regional climate model for the present climate and the end of the 21st century (Figure 2.2), finding statistically significant changes of up to 0.2 m in five-year extremes in the English Channel. Differences between these various results relate to the length of model integration and to systematic uncertainty in the modelling of both the atmospheric forcing and the ocean response.

Changes in wind forcing could result in changes to wave heights, but with the short integrations available, the WASA Group (Rider et al., 1996) were not able to identify any significant changes for the North Atlantic and North Sea for a doubling of CO2. Günther et al. (1998) noted that changes in future wave climate were similar to patterns of past variation.

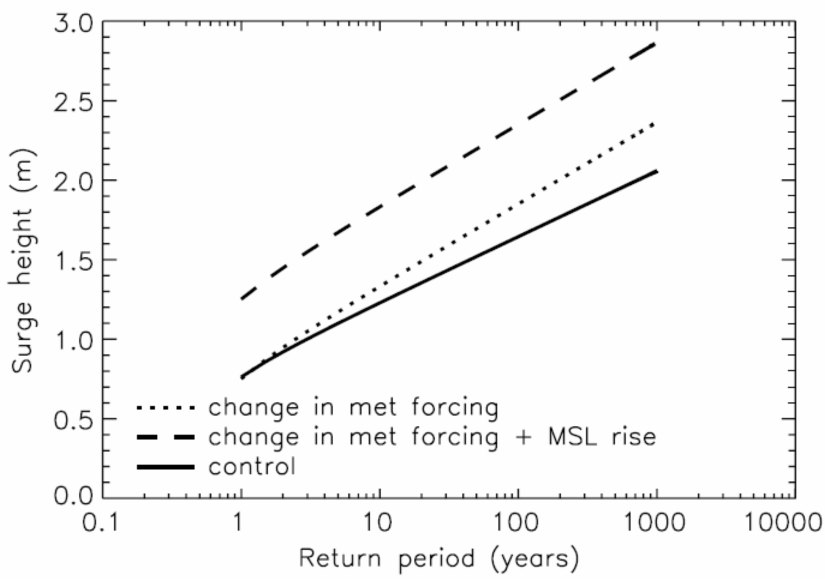

Figure 2.2 Frequency of extreme water level, expressed as return period, from a storm surge model for present day conditions (control) and the projected climate around 2100 for Immingham on the east coast of England, showing changes resulting from mean sea level rise and changes in meteorological forcing. The water level is relative to the sum of present day mean sea level and the tide at the time of the surge (From Lowe et al., 2001).

2.2 The Netherlands

The division Climate Research and Seismology (KS) of the Royal Dutch Meteorological Institute (KNMI) is responsible for the research of the climate and climate changes and for delivery of information and recommendation concerning climate policy in The Netherlands. The climate research at the KNMI aims at observing, understanding and predicting changes in the climate system. The choice of research topics has been based on the state of the art in the (inter)national climate research and on the questions that are asked by the government and society. The research focuses on the role of the oceans and the influence of the interaction between air and water, border layer processes, cloud coverage and radiation, the variability and the foreseeability of the climate, the chemical composition of the atmosphere and the influence of this on the climate, climate change and seismology (earthquakes, core explosions).

A number of publications of the KNMI discuss estimates for the expected change of hydraulic parameters due to climate change. The most recent publications are Beersma et al. (2001), Können (2001) and Verbeek (2003). Beersma et al. (2001) state that, based on the IPCC third assessment (IPCC, 2001), an absolute sea level rise of 0.1 to 0.9 m is to be expected in the 21st century. Table 2.1 and 2.2 present the values published by Können (2001) for the expected absolute sea level rise, the absolute rise of the high and low tide. Können advises to apply a margin in wind speed and gale (storm) intensities. This because the global climate change models do not provide a clear answer for this parameter.

	Low estimate	Central	High estimate

Absolute sea level rise (m)	0.10	0.25	0.45
Absolute rise high tide (m)	0.125	0.275	0.475
Absolute rise low tide (m)	0.075	0.225	0.425
Wind speed and gales (%)	±5	±5	±5

Table 2.1 Climate change estimates 1990 - 2050 for The Netherlands (Können, 2001)

	Low estimate	Central	High estimate
Absolute sea level rise (m)	0.20	0.60	1.10
Absolute rise high tide (m)	0.25	0.65	1.15
Absolute rise low tide (m)	0.15	0.55	1.05
Wind speed and gales (%)	±5	±5	±5

Table 2.2 Climate change estimates 1990 – 2100 for The Netherlands (Können, 2001)

Verbeek (2003) presents climate change estimates for the Netherlands. This author makes a distinction between a low, middle and a high estimate of expected climate changes. In his translation of the IPCC (2001) climate change data for the Dutch situation he assumes an average subsidence of 10 cm per century. Verbeek (2003) presents a relative sea level rise of 0.2, 0.6 and 1.1 m for the low, middle and high estimates in the period 1990 to 2100 respectively. These are the same values as presented by Können (2001) and presented in Table 2.2.

Changes have indeed been observed in the tidal characteristics. From historical water level measurements it has been concluded that the high tide water levels have risen 5 cm per century more quickly than the average sea level (WKB, 1997). The low tide water levels rose on average 5 cm per century less than the average water level. These differences, however, were mostly related to human interference. The construction of the Afsluitdijk, for instance, the Delta works and the development of polders had great impact on the tidal characteristics along the Dutch coast.

Deepening of channels for navigation purposes also induced an increase of tide differences (difference between high and low tide). In the Ems-Dollard, for instance, the water level at high tide rises on average approximately 10 cm more quickly than the average sea level. In the Western Scheldt the high tide water level rises 10 cm per century more quickly and at Bath 30 cm per century more quickly than the average sea level rise.

Tectonic movements of the soil result in local changes of the land elevation. According to the Working Group Climate Changes and Land Subsidence the northwest part of The Netherlands subsides with 7 to 8 cm per century at maximum (WKB, 1997). The southeast part of The Netherlands experiences an uplift of 7 to 8 cm per century at maximum.

2.3 Belgium

In their estimate of the absolute sea level rise in Belgium, Schoeters and Vanhaecke (1999) propose to apply a value between 40 and 70 cm for the period 1990 to 2100. Their estimate is based on IPCC (1995, 1997) and UK Climate Change Review Group (1996).

Van Cauwenberghe (1999) analysed historical water level data for the monitoring station Oostende. His conclusions are presented in Table 2.3.

Water level	Observed relative rise (in mm/yr)

High tide level	2
Mean sea level	1.5
Low tide level	1

Table 2.3 Observed relative sea level rise in the historical data of the Oostende monitoring station in Belgium (Van Cauwenberghe, 1999)

Van Cauwenberghe (1999) concluded that the Oostende measurements do not indicate an acceleration of the sea level rise.

D'Ieteren et al. (2003, 2004) and Den Ouden and Vanderstraeten (2004a and 2004b) base their expectation of an absolute sea level rise of 0.09 to 0.88 m along the Belgian coast in the period 1990 to 2100 on IPCC (2001). The values of the expected absolute rise of the high tide, the mean sea level and the low tide for the period 2000 to 2050 that have been published by WLH (2000) are presented in Table 2.4.

Water level	Absolute rise from 2000 to 2050 (in m)
High tide level	0.3
Mean sea level	0.225
Low tide level	0.15

Table 2.4 Expected absolute rise of high tide, the mean sea level and the low tide in Belgium for the period 2000 to 2050 (WLH, 2000)

D'Ieteren et al. (2004) indicate that the sea level rise in Belgium is expected to increase by a factor 2 to 5 in comparison with the last hundred years.

2.4 Denmark

No official climate change estimates have been determined for the North Sea coast of Denmark. At this moment the Danish Ministry of Environment is establishing an expert group. This expert group consists of representatives from relevant organisations (nature protection, spatial planning, coastal protection, tourism, agriculture, etc.). The task of this expert group is to come up with recommendations for a national strategy to cope with climate change and its consequences. The expert group will present different realistic climate change estimates for Denmark, which, eventually, will be transferred into regulations applied in coastal zone policies.

The Danish Coastal Authority (DCA) has determined climate change estimates within an internal research project. The objective of this project was to quantify the impact of climate change on the Danish North Sea coast. The parameter values and estimates presented in Table 2.5 are still preliminary and represent the DCAs "interpretation" of the IPCC (2001) report. The estimates considered by the DCA are based on the IPCC A1 and B2 emission scenarios, which are considered to be the most realistic scenarios for Denmark.

	Scenario A2 (IPCC 2001)	Scenario B2 (IPCC 2001)
Absolute sea level rise by 2050 (m)	0.13	0.13
Extra storm surge (m)	-	-
Increase of wave height (%)	2	1
Extra sediment transport (North Sea coast	5.1	2.5

to DK) (%)		
Elevation of transverse profile (m)	0.03	0.03

Table 2.5 Preliminary climate change estimates for the period 2005 to 2050 considered by the Danish Coastal Authority for Denmark (DCA, verbal communication)

The tectonic movement in Denmark depends on the geographical location within the country. Denmark is tilting along an axis in Northwest - Southeast direction. For the central part of the Danish North Sea coast a tectonic uplift of approximately 3 cm should be considered by 2050 (DCA, verbal communication).

2.5 Germany

In Germany research on future climate change is carried out at the German Climate Computing Centre (DKRZ). The DKRZ is the national German service centre for climate researchers. By its article of association, DKRZ is responsible to install and operate a high performance computer system for basic as well as applied research in the field of climatology and related disciplines. Its basic task is the provision of computer power for quantitative computation of complex processes in the climate and earth system with sophisticated, realistic numerical models. The Shareholder Board of DKRZ consists of the Max Planck Society, Freie und Hansestadt Hamburg (represented by the Hamburg University), the Alfred-Wegener-Institute for Polar and Marine Research and GKSS Research Center Geesthacht.

The Max Planck Institute has developed models and measurement techniques to analyze the natural variability in the atmosphere, the ocean and the biosphere, and to assess how the system is affected by changes in land-use, industrial development, urbanization, and other human-induced perturbations. Advanced numerical earth system models are used to simulate the behaviour of the atmosphere, the ocean, the cryosphere and the biosphere, and the interaction between these different components of the Earth’s system.

The interdisciplinary joint KRIM project in Germany aims to provide answers to the question “*What demands are made on future coastal protection that is to be included in integrated coastal zone management due to an accelerated rise in the sea level and greater frequency and intensity of extreme events and what social interpretation patterns and decision-making procedures influence this process*?”. The KRIM project applies the climate change estimates developed by the earlier KLIMU (Climate Change and Weser Estuary Region) project.

While the estimate data for temperature, precipitation, wind and wind-related high water level were obtained from a coupled atmosphere/ocean model (ECHAM 4/OPYC 3) via downscaling, assumptions regarding the rise in sea level and tidal range still have to be specified. Taking into account the experience from KLIMU, the KRIM project assumes a 55 cm absolute sea level rise in the period 1990 to 2050 (Grabemann et al., 2005). A 25 cm rise in tidal range is also assumed. This is expressed as an additional increase of the mean high tide water level with +10 cm and a reduction of the mean low tide water level with -15 cm. Furthermore, it is assumed that the wind will increase with 7% during extreme events and that it will have a tendency to shift from a Northwest to a North direction. The KRIM climate estimate for the period 1990 to 2050 is presented in Table 2.6.

	Absolute rise in the period 1990 to 2050
High tide level (m)	0.65
Mean sea level (m)	0.55
Low tide level (m)	0.40
Wind velocity (%), changing from NW to N	7

Table 2.6 Absolute rise of the sea level and wind velocity in the period 1990 to 2050 in Germany (Grabemann et al., 2005)

Scientists from the Institute for Coastal Research of the GKSS Research Centre Geesthacht in Germany have analysed the past history of storms and storm floods in the North Sea region, and used models to investigate future changes. In their press release of October 30, 2005 (GKSS, 2005) GKSS presents information on the expected future sea level rise along the German coast and the impact of future storm surges. In this press release an average sea level rise of 0.2 m in 2030 and 0.7 m in 2085 is presented. On top of this GKSS states that in the period 2070 to 2100 the maximum water levels during storm conditions will increase with 20 to 40 cm along the German coast due to storm surge (see Table 2.7 and Figure 2.3).

	Absolute rise in the period 2005 to 2030	Absolute rise in the period 2005 to 2085
Mean sea level (m)	0.2	0.7
Additional water level rise under storm conditions (m)		0.2 – 0.4

Table 2.7 Absolute rise of the mean sea level between 2005 and 2030 and between 2005 and 2085 in Germany (GKSS, 2005)

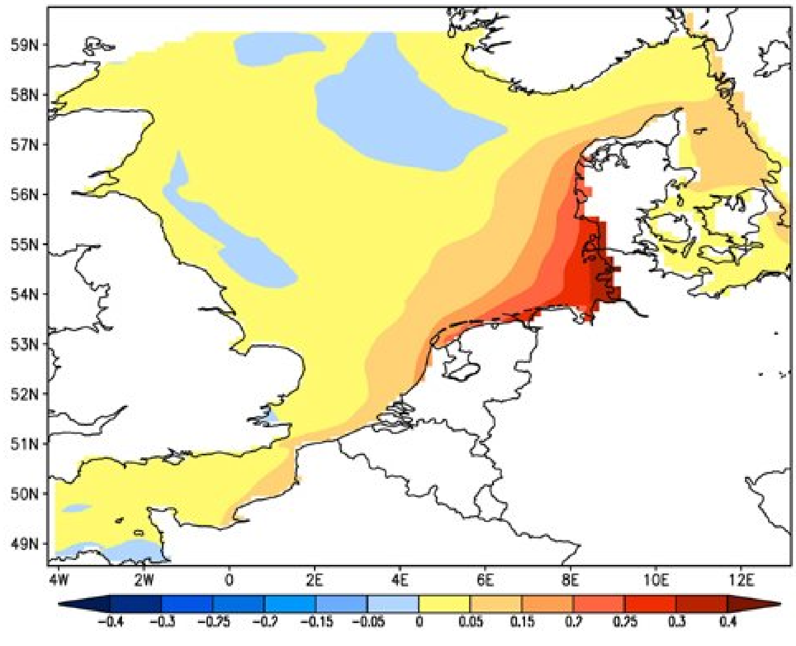

Figure 2.3 Expected change of annual maximum wind induced water levels between 2071 and 2100 (GKS, 2005)

2.6 The United Kingdom

The UK Climate Impacts Programme (UKCIP) provides estimates that show how the climate might change and co-ordinates research on dealing with the future climate in the United Kingdom. Set up in April 1997, UKCIP is funded by the Department for Environment, Food & Rural Affairs (Defra) and based at the University of Oxford. UKCIP works with their stakeholders and co-ordinates research on how climate change will have an impact at regional and national levels. This means that the stakeholders or partners in the United Kingdom commission the research and determine the research agenda, ensuring that it meets their needs. UKCIP provides support and guidance throughout the process for both stakeholders and researchers, and provides a bridge between researchers and decision-makers in government organisations and business. UKCIP has been the catalyst for a range of regional and sectoral studies into the impacts of climate change.

An important publication of the UKCIP is Hulme et al. (2002), which is also called the UKCIP02 publication. Table 2.8 shows the globally averaged sea level rise with respect to the 1961-1990 average calculated using the Hadley Centre models for each of the four UKCIP02 emission scenarios and for the three 30-year periods – the 2020s, 2050s and 2080s. The Hadley Centre models have been developed by the Hadley Centre for Climate Prediction and Research, which is part of the UK Met Office. The differences in sea level rise between the four scenarios are small during the first half of the twenty-first century, but thereafter the projections start to diverge. By the 2050s, the range is only from 14 to 18 cm, yet by the 2080s this range has widened to 23 (Low Emissions scenario) to 36 cm (High Emissions).

UKCIP02 Scenario	2020s (m)	2050s (m)	2080s (m)
Low emissions	0.06	0.14	0.23
Medium-Low emissions	0.07	0.15	0.26
Medium-high emissions	0.06	0.15	0.30
High emissions	0.07	0.18	0.36

Table 2.8 Global average sea level rise relative to the 1961-1990 average in the United Kingdom (Hulme et al., 2002)

The change in the average level of the sea relative to the land will not be the same everywhere because of natural land movements and regional variations in the rate of climate-induced sea level rise. The main reasons for regional land movements in the UK are on-going readjustment of the land to the de-glaciation that followed the last ice age and localised sediment consolidation brought about, for example, by groundwater extraction. In consequence of the former factor, much of southern Britain is sinking and much of northern Britain is rising relative to the sea (Figure 2.4). This means that the relative, or net, change in average sea level around the UK coastline will vary, even if the climate-induced change in sea level were the same everywhere. This is illustrated in Table 2.9 for various regions of the country for the two most extreme UKCIP02 scenarios. The effects of sediment consolidation are not included in these regional estimates, since they are highly localised and can vary over relatively short stretches of coastline.

Regional variations in climate-induced sea level rise occurs because the warming of ocean water is not uniform and neither therefore is the expansion of ocean water. Changes in ocean circulation and atmospheric pressure will also affect the distribution of sea level rise. These regional differences in climate-induced sea level rise can be quite substantial and can vary by up to approximately 50 per cent of the change in the global average (Hulme et al., 2002). In principle, therefore, these regional variations should be taken into account in the UK sea level rise estimates. However, apart from one or two regions of the world's oceans – mostly in the Southern Hemisphere – there is little agreement between different models about these regional patterns of sea level rise. Hulme et al. (2002) have therefore decided to use only the global-average rise as the basis for the UKCIP02 scenarios. For sensitivity studies, however, it is advisable to consider changes in sea level for each scenario that are approximately 50 per cent of those shown in Table 2.8, including those for the full IPCC range. One should also of course include the natural rates of land movement, as illustrated in Table 2.9.

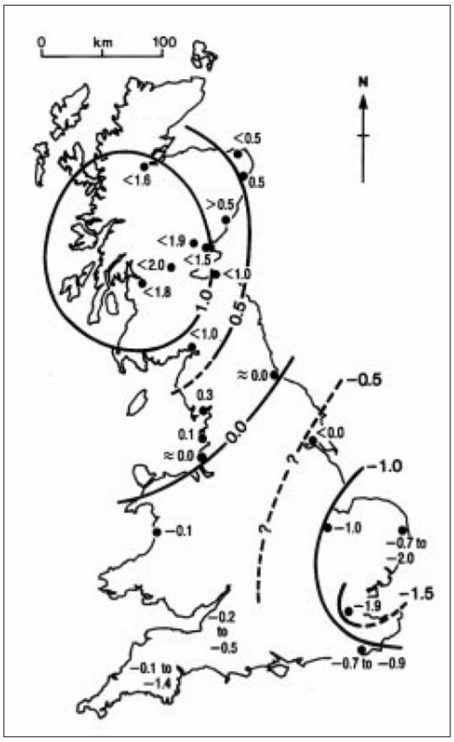

Figure 2.4 Estimates of present (late Holocene) rates of relative land changes (mm/yr). Positive values indicate relative land uplift, negative values are relative land subsidence (Shennan, 1989 in Hulme et al., 2002)

	Regional isostatic uplift or subsidence (mm/yr)	Net Sea level Change 2080s (cm) Relative to 1961-1990	
		Low Emissions scenario	High Emissions scenario
NE Scotland	+0.7	1	61
SE Scotland	+0.8	0	60
NE England	+0.3	6	66
Yorkshire	-0.5	15	75
East Midlands	-1.0	20	80
Eastern England	-1.2	22	82
London	-1.5	26	86
SE England	-0.9	19	79
SW England	-0.6	16	76
Wales	-0.2	11	71
Northern Ireland	N/a	-9	-69
NW England	+0.2	7	67
SW Scotland	+1.0	-2	58
NW Scotland	+0.9	-1	59
Orkney & Shetland	N/a	-9	-69

Table 2.9 Rate of vertical land movement due to isostatic adjustment (Hulme et al., 2002)

Storm surges are temporary increases in sea level, above the level of the astronomical tide, caused by low atmospheric pressure and strong winds. They occur in shallow water regions, such as on the continental shelf around the UK and, in some places, their height may be increased by the funnelling effect of the coastline. The surges are most damaging when they occur at high tide; regular flooding around much of the UK coast is only prevented by flood defences. Future changes in the extreme sea levels associated with storm surges will occur if there are changes in the number, location, or strength of storms and also, of course, as a result of increases in average sea level.

Regional climate models cannot yet produce simulations of storm surge height directly because they do not have an ocean component. Instead, the atmospheric winds and pressure from the regional climate change model of the UK Hadley Centre (HadRM3) have been used to drive a separate high-resolution (30 km) model from the Proudman Oceanographic Laboratory (POL) of the shelf seas around the UK. Statistical distributions have been fitted to the simulated extreme storm surges and these allow estimates to be made of changes in the 50-year return period storm surge heights. The height of storm surges simulated by the surge model are generally below those measured using tide gauges. This is not surprising given that the surge model averages over a 30 km region, while tide gauge measurements are made at a single coastal location. Nevertheless, the geographical pattern of simulated surges for present-day climate, with elevated values at the southern end of the North Sea, compares well with the observations and provides some confidence in the model simulations.

Using the POL surge model and HadRM3, changes in storminess alone suggest that the largest increases in surge height around the UK coastline might occur off the southeast coast. In contrast, a decrease in the storm surge height is simulated for the Bristol Channel. It should be kept in mind, however, that the resolution of the storm surge model is small with grid cells of 30 x 30 km and that the output of the model is not realistic for the relatively narrow Bristol Channel. When the rise in global-average sea level for the central estimate of the Medium-High Emissions scenario is included in this analysis (an additional 30 cm) the increase in the height of the 50-year return period extreme water level, relative to present day, is also raised by this amount.

The simulated changes in the 50-year return period water levels around the UK coastline when all three factors are included (change in storminess, rise in global sea level and vertical land movements) are shown in Figure 2.5 for three different global sea level rise estimates. The largest rise in surge height, up to 1.4 m for the High Emissions scenario high estimate, occurs along the southeast coast of England. This area experiences both the largest change in surge height due to changes in storms (see above) and also the one of the largest regional subsidence rates (Figure 2.4). It is important to note, however, that the modelling uncertainties involved here are very large. Different patterns and magnitudes of change in surge height to those shown in Figure 2.4 can be produced either by using changes in climate extracted from a different climate model to HadRM3, or by using the same changes in climate but applying them to a higher resolution (12 km) surge model. Earlier modelling work completed using the 12 km POL surge model, for example, found that the rise in the 50-year return period surge height off southeast England was much less than that shown in Figure 2.5 (Hulme et al., 2002). Therefore the results of these patterns and magnitudes of change in storm-surge height should be used with great care.

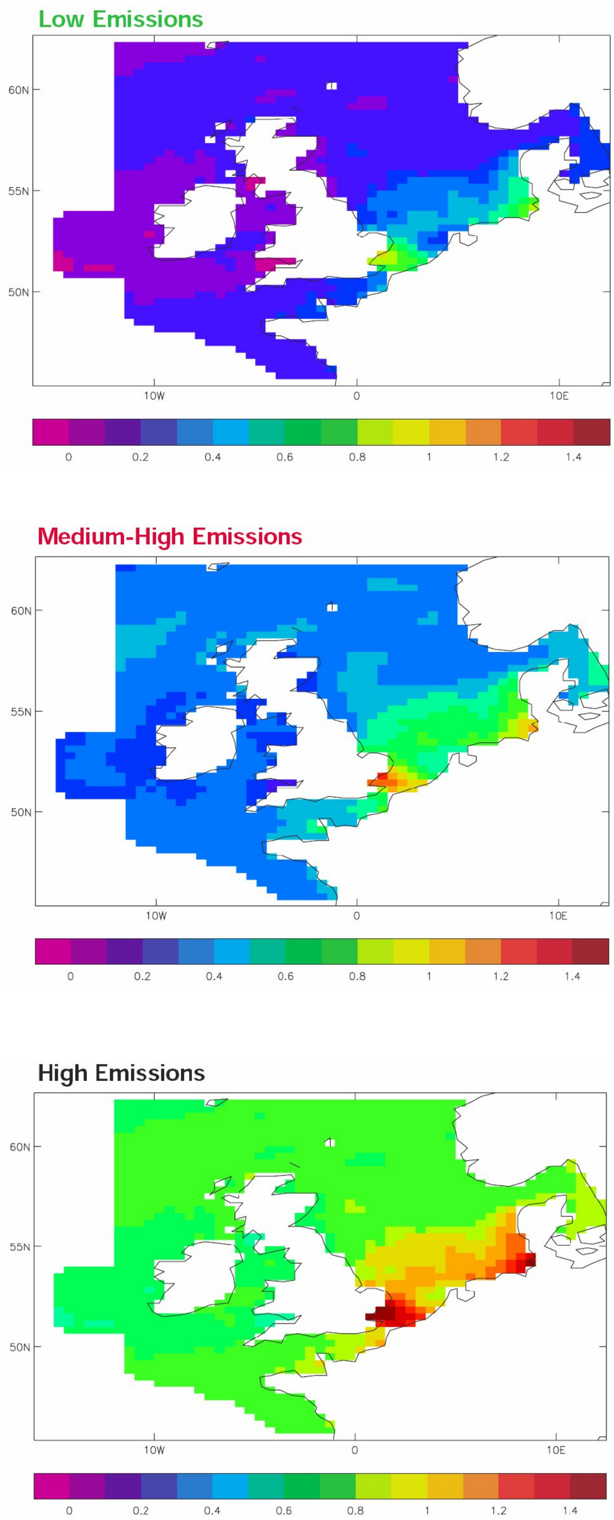

Figure 2.5 Change in 50-year return period surge height (in metres) for the 2080s for three different emission scenarios. The combined effect of global average sea level rise, storminess changes and vertical land movements are considered (Top: 9 cm, middle 30 cm and bottom 69 cm sea level rise) (Hulme et al., 2002)

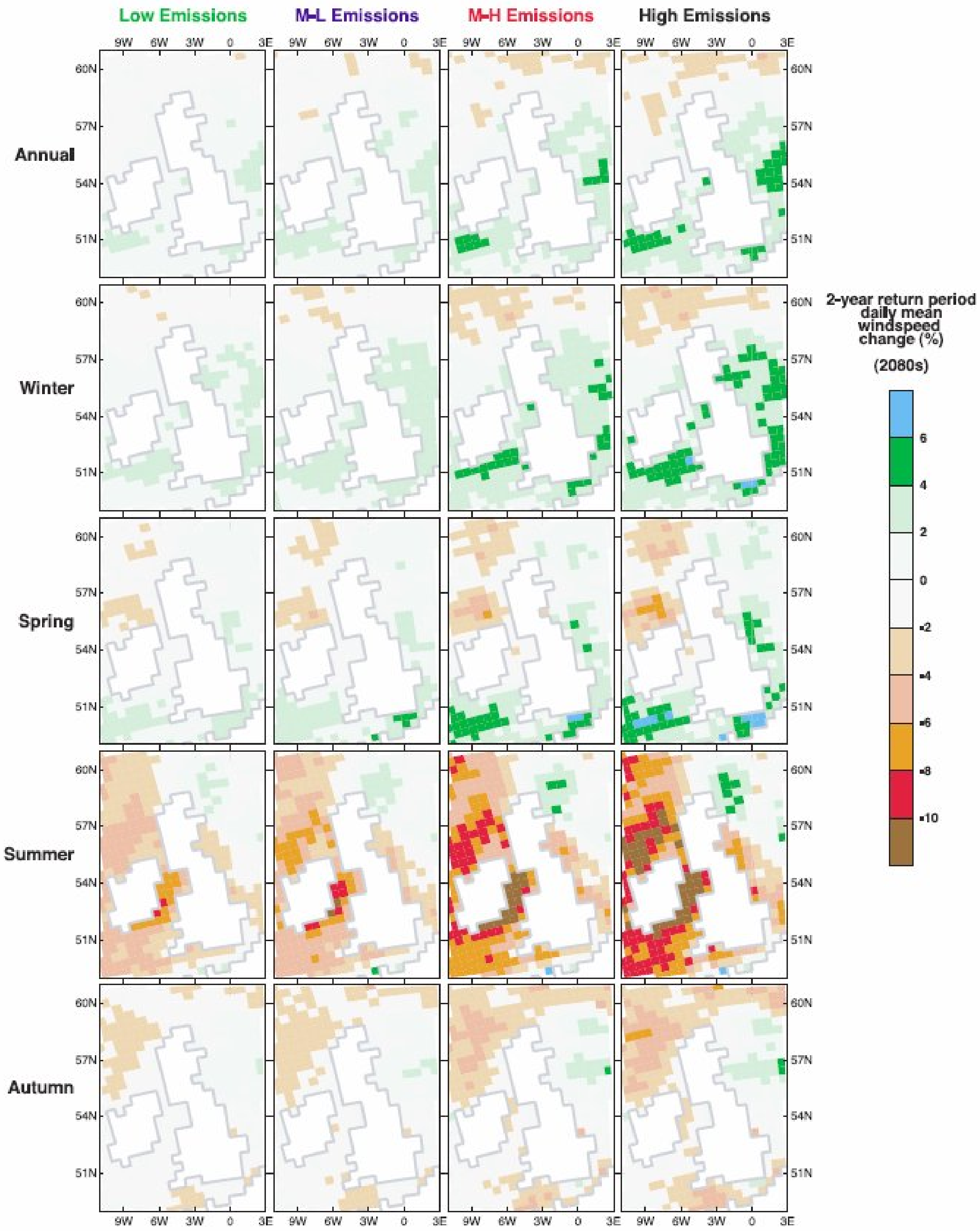

Figure 2.6 Per cent change for the 2080s in the daily-average wind speed, which can be expected, on average, once every 2 years (Hulme et al., 2002)

The heights of offshore waves depend on the strength of the wind and on both the distance and the length of time over which the wind acts on the ocean surface. In addition, swell waves can travel huge distances away from the windy region in which they were generated so that strong winds on the western side of the Atlantic can affect the heights of waves in UK coastal waters. In future, because average wind speeds and wind extremes are expected to change (for example, see Figure 2.5), the height of offshore waves around the UK could also change.

Changes in offshore wave climate and wind direction are not well quantified for the UK. For this reason Hulme et al. (2002) do not present quantitative estimates. The few modelling studies that have tried to quantify these effects have not been conclusive and vary widely from model-to-model. Equally, on the basis of observational evidence Hulme et al. (2002) state that the role of the North Atlantic Oscillation in influencing wave heights is important, and their estimates suggest that the Oscillation may tend towards higher (more westerly) index values in the future. More detailed studies in the future will use winds from long regional climate model simulations to drive detailed models of ocean waves around the UK.

Changes in wind speeds over ocean areas will be an important factor driving the changes in extreme sea levels analysed above. Figure 2.5 shows the change in 2-year return period daily-average wind speed over the seas around the British Isles. The areas off the south and east coasts of England see the largest wind speed increases in winter and spring, between 2 and 8 per cent by the 2080s depending on the chosen scenario. Around most of the rest of the British Isles, however, there are few changes in these seasons. In summer and autumn, the wind speed decreases as climate warms, especially off the west coast of the British Isles where reductions are up to 10 per cent.

2.7 Summary

The different values of climate change estimates that have been presented in the foregoing paragraphs have been put together in Table 2.10. Some remarks should be made for the interpretation of the presented parameter values. Table 2.10 makes a distinction between a Low estimate, Medium estimate and High estimate. This is due to the fact that many publications present ranges of values (for instance IPCC (2001). These ranges are introduced due to the fact that in the climate change model investigations different assumptions have been made for future changes in greenhouse gas emissions or in the impact of these greenhouse gasses on climate change. Other publications present three estimates (Beersma et al., 2001, Können, 2001 and Verbeek, 2003) or even four estimates (Können, 2001, Hulme et al., 2002) for certain parameters. Table 2.10 presents a low a medium and a high estimate for the climate impact. The values for the two estimates 'medium-low' and 'medium-high' emission as presented by Hulme et al. (2002) have been averaged and presented as the medium estimate in the table.

The IPCC as well as most of the other countries present values of the absolute sea level rise, whereas publications for the Netherlands normally present values of the relative sea level rise. This is most probably due to the fact that the tectonic movement in the Netherlands is quite constant all along the Dutch Coastal zone, whereas for instance in the United Kingdom large regional difference can be observed (see Table 2.9). Absolute sea level rise values have been determined for the Netherlands (see Table 2.10) so that a comparison could be made between the different North Sea Countries. These values have been determined by combining the published values of the relative sea level rise with the tectonic movements.

The value of the rise of the coastal cross-section in the Netherlands is always equal to the relative sea level rise. This is due to the assumption that the present coastal profile will shift landwards with a rise of the sea level. In the Dutch coastal zone policy it is stated, however, that at critical locations the coastline should be kept at a prescribed location (the basic coast line or BKL). This is achieved by rising the coastal cross-section with the speed of the observed relative sea level rise.

	Parameter	IPCC	The Netherlands	Belgium [c]	Denmark [c]	Germany [c]	United Kingdom
Low estimate	Absolute sea level rise (m)	0.05	0.06 – 0.065 [a]	-	-	-	0.14
	Absolute rise high tide (m)	-	0.085 – 0.09 [a]	-	-	-	-
	Absolute rise low tide (m)	-	0.035 – 0.04 [a]	-	-	-	-
	Relative sea level rise (m)	-	0.1	-	-	-	-0.09 - +0.26
	Relative rise high tide (m)	-	0.125	-	-	-	-
	Relative rise low tide (m)	-	0.075	-	-	-	-
	Wind speed and gales (%)	-	±5	-	-	-	0 – 4 [e]
	Storm surge increase (m)	0 – 0.1 [b]	-	-	-	-	0 – 1.1
	Wave height increase (%)	-	-	-	-	-	-
	Tectonic movement (m/50yaers)	-	-0.035 to -0.04	-	-	-	-0.075 - +0.05
	Rise of coastal cross-section (m)	-	0.1	-	-	-	-
Medium estimate	Absolute sea level rise (m)	0.18	0.21 – 0.215 [a]	0.225	0.13	0.55	0.15 [f]
	Absolute rise high tide (m)	-	0.235 – 0.24 [a]	0.30	-	0.65	-
	Absolute rise low tide (m)	-	0.185 – 0.19 [a]	0.15	-	0.40	-
	Relative sea level rise (m)	-	0.25	0.075 [g]	0.10	-	-
	Relative rise high tide (m)	-	0.275	0.10 [g]	-	-	-
	Relative rise low tide (m)	-	0.225	0.05 [g]	-	-	-
	Wind speed and gales (%)	-	±5	-	-	7	0 – 6 [e,f]
	Storm surge increase (m)	0 – 0.1 [b]	-	-	-	2.0 [d]	0.2 – 1.4 [f]
	Wave height increase (%)	-	-	-	1 – 2	-	-
	Tectonic movement (m/50years)	-	-0.035 to -0.04	-	0.03	-	-0.075 to +0.05
	Rise of coastal cross-section (m)	-	0.25	-	-	-	-
High estimate	Absolute sea level rise (m)	0.32	0.41 – 0.415 [a]	-	-	-	0.18
	Absolute rise high tide (m)	-	0.435 – 0.44 [a]	-	-	-	-
	Absolute rise low tide (m)	-	0.385 – 0.39 [a]	-	-	-	-
	Relative sea level rise (m)	-	0.45	-	-	-	0.69 - +0.86
	Relative rise high tide (m)	-	0.475	-	-	-	-
	Relative rise low tide (m)	-	0.425	-	-	-	-
	Wind speed and gales (%)	-	±5	-	-	-	0 – 8 [e]
	Storm surge increase (m)	0 – 0.1 [b]	-	-	-	-	0.7 – 1.5
	Wave height increase (%)	-	-	-	-	-	-
	Tectonic movement (m/50years)	-	-0.035 to -0.04	-	-	-	-0.075 to +0.05
	Rise of coastal cross-section (m)	-	0.45	-	-	-	-

[a] Calculated from relative sea level rise and tectonic movement

[b] 50% of the value presented for 2100

[c] For Belgium, Denmark and Germany only one estimate is available. This is considered as the medium estimate.

[d] For the storm surge Germany applies the storm surge that was measures during the occurrence of the deep depression “Anatol” that moved across the North Sea and Denmark.

[e] No value available for 2050. This value is the daily mean wind speed change in 2080.

[f] For the UK four estimates are presented by Hulme et al. (2002) available. This central estimate is the average value of the estimates “medium-low emission and medium-high emissions presented in that publication.

[g] Based measurements published by Van Cauwenberghe (1999)

Table 2.10 Available climate change estimates for the period 1990 – 2050 based on measurements and climate change research

The values of increased storm in 2050 presented in Table 2.10 are determined by using 50% of the maximum storm surge increase values presented by IPCC (2001).

For Belgium, Denmark and Germany only one estimate is available. No distinction has been made between low medium or high greenhouse gas emissions. Therefore, the published climate change estimates for these countries have been presented as the Medium Estimate.

3 Scenarios applied in coastal zone policies

This chapter aims at providing insight in the different climate change scenarios that are applied in coastal zone policies within the different North Sea countries. It is important to acknowledge the fact that policy makers apply climate change scenarios that are different from the scenarios that have been developed on the basis of historical measurements or climate change research. Policy makers make an interpretation of the scientific data for their climate change scenarios. Also, for instance in the Netherlands, different scenarios can be applied for studies that are related to projects with different (time)scales or different risks. First of all the available policy scenarios will be presented for each of the countries. In the summary, a table will be presented in which all data have been combined so that a comparison can be made.

3.1 The Netherlands

The Netherlands has a Law on Flood Protection Schemes (Wet op de Waterkeringen) (Tweede Kamer der Staten-Generaal, 2006) in which the safety is prescribed for each of the dike rings in The Netherlands. This law states that every five years the actual safety provided by the primary flood protection schemes should be tested for each of the dike rings against the safety prescribed by the law. The safety is prescribed as a risk of failure. The law does not state which assumptions should be made with respect to clime change scenarios in case of the design of new projection works.

For The Netherlands a number of policy documents are available in which different climate change scenarios have been presented:

- Third Coastal Note (Derde Kustnota) (MinV&W, 2000);
- Advise of the Committee on Water Management in the Twenty-first Century (CWB21, 2000);
- Technical Advise Committee for the Flood Protection Works, Background document for sea level rise and climate changes with respect to coastal zone management and coastal zone policies (TAW, 2002).

Three types of scenarios have been prescribed for the Dutch coastal protection works, a minimum, middle and a maximum scenario. A minimum scenario is applied for flood protection works with relatively short life spans (approximately 5 years), for instance beach nourishments. In this scenario it is assumed that the protection work will 'grow' with the assumed relative sea level rise of 20 cm per century. A medium estimate is applied for the design of coastal protection works with a lifespan in the order of 50 to 100 years. In the case that land is to be reserved for future sea level rise a margin is applied in the maximum scenario that should be able to cope with 200 years of sea level rise (see Table 3.1).

Table 3.1 presents the parameter values that are presented in the above mentioned Dutch policy documents. It is striking that the unit of the climate change scenarios presented in these policy documents are different from the units applied in the climate change research scenarios (Chapter 2). Most of the climate change parameters published by climate change researchers are absolute values of parameter changes in comparison with the value in 1990 (see Table 2.10). The reason for this is the fact that the Intergovernmental Panel on Climate Change (IPCC) was established in 1988 and published their First Assessment Report in 1990 (Houghton et al, 1990). In this IPCC publication all climate changes were compared to the situation in the year of the publication, 1990. So far, the later IPCC publications always updated the values presented by Houghton et al. and therefore continued to present climate changes since the year 1990. The Dutch policy documents (MinV&W, 2000, CWB21, 2000 and TAW, 2002), on the contrary, presented climate change values per unit of time (50, 100 or 200 years). TAW (2002) has presented the most elaborate climate change scenarios. CWB21 (2000) deviates in some regards from the other two Dutch policy documents.

Estimation of data for 2050	MinV&W, 2000	CWB21, 2000	TAW, 2002

Minimum scenario:			
Relative sea level rise in 50 / 100 / 200 years	- / 0.20 / -	0.10 / 0.20 / -	0.10 / 0.20 / 0.40
Extra storm allowance	-	-	-
Wave height	-	-	-
Increase of wind	-	-	-
Elevation of transverse profile	- / 0.20 / -	0.10 / 0.20 / -	0.10 / 0.20 / 0.40
Middle scenario:			
Relative sea level rise in 50 / 100 / 200 years	- / 0.60 / -	0.25 / 0.60 / -	0.30 / 0.60 / 1.20
Extra storm allowance	-	-	-
Wave height	-	-	-
Increase of wind	-	-	-
Elevation of transverse profile	- / 0.60 / -	0.25 / 0.60 / -	0.30 / 0.60 / 1.20
Maximum scenario:			
Relative sea level rise in 50 / 100 / 200 years	- / 0.85 / -	0.45 / 1.10 / -	0.45 / 0.85 / 1.70
Extra storm allowance	-	-	0.40 / 0.40 / 0.40
Wave height	-	-	5% / 5% / 5%
Increase of wind	10%	-	10%
Elevation of transverse profile	- / 0.85 / -	0.45 / 1.10 / -	0.45 / 0.85 / 1.70

Table 3.1 Climate change scenarios presented in three policy documents in The Netherlands (values of the sea level rise are relative

3.2 Belgium

IMDC (2005) recently published the hydraulic boundary conditions for the Flemish Coast. This document should be considered during the design of constructions along the Belgium coast. IMDC states that a relative rise of the mean sea level of 22 cm is to be expected in the coming 50 years (2005 to 2055). For design purposes, however, the rise of the high tide level is more important. IMDC (2005) suggest to consider a relative rise of the high tide level of 30 cm and a rise of the mean sea level of 25 cm in the coming 50 years (2005 to 2055).

Water level	Relative rise from 2005 to 2055 (in m)
High tide level	0.3
Mean sea level	0.25

Table 3.2 Climate change scenario for the period 2005 to 2055 for Belgium (IMDC, 2005)

3.3 Denmark

So far no official climate change scenarios have been published in coastal zone policies or applied in governmental regulations in Denmark. The Danish Ministry of the Environment has recently put together an expert group in order to present different realistic climate change scenarios for Denmark. Eventually these scenarios will be transferred into regulations applied in coastal zone policies.

3.4 Germany

The Federal Republic of Germany consists of fifteen states. Two of these states (Niedersachsen and Schleswig-Holstein) are directly located along the North Sea. Each of these states is obliged to their own coastal zone policy.

Schleswig-Holstein has published a policy document related to coastal zone protection schemes (Ministerium für ländliche Räume, Landesplanung, Landwirtschaft und Tourismus des Landes Schleswig-Holstein, 2001). In this document a simple climate changes scenario has been assumed: 0.5 m absolute sea level rise in the period 2001 – 2100. This publication refers to IPCC (2001) on the basis of which they assume that no changes will occur in storm surges.

For Niedersachsen a similar policy document is available (Bezirksregierung Weser-Ems, 1997). In this document it is stated that for design purposes an absolute sea level rise of 0.6 m per century should be assumed for Niedersachsen. In addition to this it is stated that a subsidence of 6 to 10 cm per century should be assumed for the coastal zone of Niedersachsen. The Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN) is currently preparing an update of (Bezirksregierung Weser-Ems, 1997).

Table 3.3 summarises the policy scenarios applied in Germany.

Change	Schleswig-Holstein	Niedersachsen
Absolute sea level rise	0.5 m (between 2001 and 2100)	0.6 (m/century)
Subsidence (m)		0.06 – 0.10

Table 3.3 Climate change scenario for the Schleswig-Holstein and Niedersachsen, Germany

3.5 The United Kingdom

PPG25 (ODPM, 2001) is the national policy document on climate change and flood risk in the United Kingdom. This document is currently being updated and will be circulated as a consultation document shortly. This guidance explains how flood risk should be considered at all stages of the planning and development process in order to reduce future damage to property and loss of life in the UK. With respect to climate change ODPM (2001) states that currently the best estimate for absolute sea level rise in the UK is 0.21 m between 2000 and 2050. ODPM declares that this estimate is very uncertain and that it could be as low as 0.1 m and as high as 0.55 m, depending on the future level of greenhouse gas emissions and the sensitivity of the climate system. The best-estimate sea level rise is based on central estimates of each of these. To the climate-induced sea level rise has to be added the movement of land, which is generally falling in the southeast and rising in the north and west (ODPM, 2001).

The rise in sea level will change the frequency of occurrence of high water levels. For example, the current 1-in-100-year high-water level on the east coast may be expected to be exceeded every 20 years on average by 2050, assuming no change in storminess. There may also be secondary impacts such as changes in wave heights due to increased water depths, as well as possible changes in the frequency, duration and severity of storm events. It should be recognised, however, that while sea level rise and climate change could have a significant impact on levels of risk, current information suggests that the actual areas at risk are not expected to increase significantly (ODPM, 2001).

The Department of Environment, Food and Rural Affairs has more recently published a guidance how the UK Climate Impacts Programme 2002 climate changes scenarios should be applied in flood and coastal defence studies in the United Kingdom (DEFRA, 2003). The scenarios of mean sea level rise were based on an average predicted absolute sea level rise of 4.5 mm per year over the next 40-50 years combined with the postulated rates of large-scale land movement. The DEFRA (2003) climate scenario is presented in Table 3.4.

Parameter	DEFRA (2003)
Relative mean relative sea level rise	• 6 mm per year in Anglia, Thames, Southern and North East UK (South of Flamborough Head) • 5 mm per year in the South West UK and Wales • 4 mm per year in the North West and North East UK (North of Flamborough Head)
Storm surge (extreme sea level)	Not to be considered
Medium wave height	5% (in 2080)
Extreme wave conditions	Wave height: +10% (in 2080) Wave period: +5% (in 2080)

Table 3.4 Guidance for the use of the UKCIP02 climate change scenarios in the United Kingdom (DEFRA, 2003)

3.6 Summary

The different values of climate change scenarios that have been presented in policy documents that have been described in the foregoing paragraphs have been put together in Table 3.5. It is obvious that not many coastal zone policies are available in which a prescription is given of the climate change scenarios to be applied in coastal zone studies. Only the Netherlands applies three different scenarios for projects with

	Parameter	The Netherlands	Belgium	Denmark	Germany		United Kingdom (*)
					Schleswig-Holstein	Niedersachsen	
Low estimate	Absolute sea level rise (m)	-	-	-	-	-	-
	Absolute rise high tide (m)	-	-	-	-	-	-
	Absolute rise low tide (m)	-	-	-	-	-	-
	Relative sea level rise (m)	0.10	-	-	-	-	-
	Relative rise high tide (m)	-	-	-	-	-	-
	Relative rise low tide (m)	-	-	-	-	-	-
	Wind speed and gales (%)	-	-	-	-	-	-
	Storm surge increase (m)	-	-	-	-	-	-
	Wave height increase (%)	-	-	-	-	-	-
	Tectonic movement (m/50years)	-	-	-	-	-	-
	Rise of coastal cross-section (m)	0.10	-	-	-	-	-
Medium estimate	Absolute sea level rise (m)	-	-	-	-	0.30[b]	0.21 [c]
	Absolute rise high tide (m)	-	-	-	-	-	-
	Absolute rise low tide (m)	-	-	-	-	-	-
	Relative sea level rise (m)	0.30	0.25 [f]	-	0.25[a]	-	0.20 - 0.30 [d] (0.35-0.425) [g]
	Relative rise high tide (m)	-	0.30 [f]	-	-	-	-
	Relative rise low tide (m)	-	-	-	-	-	-
	Wind speed and gales (%)	-	-	-	-	-	- (+10%)
	Storm surge increase (m)	-	-	-	-	-	-
	Wave height increase (%)	-	-	-	-	-	H: +10%; T:+5% [e]
	Tectonic movement (m/50years)	-	-	-	-	-0.03 - -0.05 [b]	-
	Rise of coastal cross-section (m)	0.30	-	-	-	-	-
High estimate	Absolute sea level rise (m)	-	-	-	-	-	-
	Absolute rise high tide (m)	-	-	-	-	-	-
	Absolute rise low tide (m)	-	-	-	-	-	-
	Relative sea level rise (m)	0.45	-	-	-	-	-
	Relative rise high tide (m)	-	-	-	-	-	-
	Relative rise low tide (m)	-	-	-	-	-	-
	Wind speed and gales (%)	10	-	-	-	-	-
	Storm surge increase (m)	-	-	-	-	-	-
	Wave height increase (%)	5	-	-	-	-	-
	Tectonic movement (m/50years)	-	-	-	-	-	-
	Rise of coastal cross-section (m)	0.45	-	-	-	-	-

Table 3.5 Available climate change scenarios for 2050 in available policy documents

* Update March 6, 2007: Flood and Coastal Defence Appraisal Guidance, Supplementary note to Operating Authorities - Climate Change Impacts, DEFRA, October 2006

a 50% of the value presented for 2100.

b 50% of the value in m/century.

c Based on ODM (2001).

d Based on 4 - 6 mm/yr relative sea level rise (DEFRA, 2003).

e Presented by Defra (2003) for 2080. H is wave height, T is wave period.

f Presented in m per 50 years (for the period 2005 to 2055)

g Based on 7 – 8.5 mm/yr relative sea level rise (DEFRA, 2006) different life spans. The increase of wind speed and wave height is only considered in the high estimate that is applied for projects with a very long time span.

Belgium, The United Kingdom and the state Schleswig-Holstein have a single scenario for the sea level rise. The United Kingdom assumes an increase of the wave height and period in the year 2080.

So far, no policy document is available for Denmark.

4 Conclusions and recommendations

An inventory has been carried out by Alkyon Hydraulic Consultancy & Research in the framework of the international project Safecoast of available climate change scenarios applied in the North Sea countries The Netherlands, Belgium, Denmark, Germany and the United Kingdom. In this inventory a distinction has been made between the scientific climate change scenarios and the scenarios applied in coastal zone policies.

In this respect the scientific climate change estimate is defined as an estimate that has been determined on the basis of climate change research on the basis of historical measurements or climate change models. Policy scenarios of climate change are interpretations of the scientific estimates and prescriptions of which scenarios should be considered in coastal zone projects. The availability of the estimates and scenarios are presented in the Tables 4.1 and 4.2 respectively. The actual values of the estimates and scenarios have been presented in the Tables 2.10 and 3.5.

Most of the publications for the North Sea countries present single climate change estimates or scenarios. For the Netherlands and the United Kingdom some different estimates and policy scenarios have been presented. The Netherlands presents three scenarios and estimates to be applied in coastal studies. The ‘Low scenario’ should be considered for projects with a lifespan in the order of a few years, the ‘Medium scenario’ for projects with a longer lifespan and ‘High scenario’ for projects that require extra safety.

Most climate change scenarios focus on the absolute and relative sea level rise. Not much attention is given to other important parameters like the increase of storm surge, wave height, etc. This is mostly due to the fact that predictions of changes in future occurrence of storms, extreme wind and wave conditions are not considered to be very much reliable. Some countries, however, have presented scenarios for these values. In scientific climate change scenarios most attention is given to absolute sea level rise scenarios. This is due to the fact that most climate change research is carried out on a global scale. Some countries (The Netherlands, Denmark and the United Kingdom) pay attention to the impact of tectonic movements on the relative sea level rise.

It has been concluded during the review of the available scientific and policy documents that inconsistency can be found in the way that parameter value changes due to climate change are presented. After the start of the IPCC in 1988 and their First Assessment Report (IPCC, 1988) most climate changes parameters have been presented as the change since the year 1990. Care should be taken that the IPCC climate change parameters for, for instance the year 2100, cannot be interpreted as the value change per century. Also some of the publications do not consistently indicate whether their sea level rise values are absolute or relative. It is suggested to consistently mention this when presenting sea level rise values.

For the construction of new protection works we recommend to use the mean sea level at the starting date of the construction and to consider the climate change scenarios in value per unit of time in order to come to the value of the design lifespan. We therefore recommend focusing on climate change scenario values per unit of time instead of focussing on the actual values to be expected in the year 2050.

	The Netherlands	Belgium	Denmark	Germany	United Kingdom
Absolute sea level rise	High, medium and low estimates available, based on relative SLR and subsidence values	One estimate available	One estimate available, not yet officially published	One estimate available	Estimates available for 4 emission scenarios
Relative sea level rise	High, middle and low estimates available.	Estimate available based on measurements	One estimate available, not yet officially published		Ranges for high and low estimates for different locations in the UK
Change of the tide	High, middle and low estimates available for the change of high tide, low tide and mean sea level	Estimates available for changes in high tide, low tide and mean sea level		Estimates available for the change in high tide, low tide and mean sea level	
Wind speed	Estimate of wind speed increase is available			Estimate of wind speed increase is available	High, medium and low estimate ranges available for different locations in the UK
Storm surge intensity				Estimate available for the increase in storm surge	High, medium and low estimate ranges available for different locations in the UK
Wave height			One estimate is available, but not yet published		
Tectonic movement	One estimate range is available		One estimate is available		Estimates of the tectonic movement is available for different locations in the UK
Rise of coastal cross-section	Considered to be equal to the relative sea level rise				

Table 4.1 Availability of climate change estimates in the North Sea countries

	The Netherlands	Belgium	Denmark	Germany	United Kingdom
Absolute sea level rise				One absolute sea level rise scenario available for Niedersachsen	One absolute sea level rise scenario available
Relative sea level rise	High, middle and low scenarios available			One scenario available for Schleswig-Holstein	Range of relative sea level rise available
Change of the tide					
Wind speed	One wind speed increase scenario available to be considered in projects with a lifespan of more than 100 years				
Storm surge intensity					
Wave height	One wave height increase scenario available to be considered in projects with a lifespan of more than 100 years				One scenario available for the increase of the wave height and wave period
Tectonic movement				Range available of the tectonic movement in the policy document for Niedersachsen	
Rise of coastal cross-section	Considered to be equal to the relative sea level rise				

Table 4.2 Availability of climate change scenarios in policy documents of the North Sea countries

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