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1. Introduction

This report is a result of activity 6.4.1 in the BLAST-programme. The goal is to identify and analyse current climate change scenarios for the North Sea. BLAST is a part of the Interreg IVB NSR-programme.

1.1. Sea level rise, definition and causes

The position of the coastline changes all the time. Long term trends of accumulation or retreat depends on the immediate order of magnitude between eustatic and isostatic conditions. A recent example − in geological terms − is the millenniums after he last Ice Age, where alternate ratios between eustatic and isostatic movements meant changing conditions related to transgression and regression of the sea. Eustatic changes are determined by changes in climate conditions. When global climate gets warmer a transgression is expected to take place and vice versa.

Since 1990 IPCC has published so called assessment reports every 5-6 year updating the results of scientific research worldwide. The reports state expected changes in parameters reflecting the effect of climate change. In the latest assessment report from 2007 IPCC states a global sea level rise (SLR) of 18-59 cm for 2090-2099 depending on the actual emission scenario (the SRES-scenarios are an assembling of different emission scenarios published by IPCC in a special report). The report further explains that understanding of some important effects driving SLR rise is too limited, so the report does not assess the likelihood of SLR. The figures show the model-based projections of global average SLR. The projections do not include uncertainties in climate-carbon cycle feedbacks nor the full effects of changes in ice sheet flow. Therefore the upper values of the ranges are not to be considered upper bounds for SLR. They include a contribution from increased Greenland and Antarctic ice flow at the rates observed for 1993-2003, but this could increase or decrease in the future.

The figures are absolute values. What is important for the individual landowners is how much the sea is expected to rise relative to his property. The relative SLR is affected by regional effects, which indeed contributes to the absolute value, as well as local effects. These effects may add negative as well as positive contributions to SLR.

Regional effects may be changes in wind patterns, changes in sea currents and gravitational forces. Changes in wind patterns specially affect the height of storm surge.

Local effects may play an important role. Isostatic movements as the rebound from the last Ice Age have a positive effect on the rate. Subsidence caused by drainage of the soil may have a negative impact.

It may be useful to distinct between policy and scientific climate change scenarios. Policy scenarios reflect precautionary scenarios that are used for instance for coastal protection constructions and physical planning, i.e. reservation of space behind dikes for future reinforcements. Strategic planning may reflect that climate adaptation is a long-range process and uncertainty exists regarding the pace of impact. Scientific scenarios reflect the best actual insight of the scientific world, although this might differ from one scientific institute to another due to different numerical models, assumptions etc. The IPCC assessment reports reflect a cautious announcement on climate change effects based on the latest accepted research at that moment.

2. Approach

Our actual approach to obtain the required knowledge was to contact persons in the different EU-countries from the network of Danish Coastal Authority and ask for accessible information. In this manner we hope to achieve the latest results of approved SLR rates in the different countries. If our contacts did not acquire the proper knowledge, they did refer to colleagues or contacts of their own. The names of the actual contact persons, which delivered the acquired information, are mentioned in the text.

We also tried to make more official applications to national institutions as for instance the national meteorological institutes. These applications did not add more value to the activity.

Some of the stated rates of SLR indicate official statements of SLR while others use figures from accomplished projects. In this manner they reflect the order of magnitude of the predicted SLR. There may also be differences in the length of time horizon. Some may look approximately 50 years ahead, while other may look forward to 2100.

2.1. Projections of sea level rise

In this chapter the results from the different countries of this survey will be mentioned consecutively. In the end of this chapter, the collected information will be presented in a table.

2.1.1. Belgium

Contact: Dries van den Eynde. Koninklijk Belgisch Instituut voor Natuurwetenschappen

Reference: D. Van den Eynde et al. Evaluation of climate change impacts and adaptation responses for marine activities ”CLIMAR”. Final Report phase 1. Brussels: Belgian Science Policy (2009)

As mentioned in the report, a way of dealing with the uncertainties of possible impacts is to draw a series of climate change scenarios.

Further on from the report: “Five scenarios were drawn for 2040 (mid-term) and 2100 (long-term): two moderate (M, M+) scenarios, two warm scenarios (W, W+) and a worst case scenario (W). In the M and W scenarios, there is no significant change in air circulation patterns, and the precipitation increases both in summer and in winter with about 3 % per °C of air temperature increase. In the M+ and W+ scenarios, there are significant changes in air circulation patterns and the precipitation increases more in winter (about 7% per °C of air temperature increase) and decreases in summer (about 10% per °C of air temperature). This decrease in summer precipitation is mainly attributed to the decrease in the number of rainy days. A strong change in air circulation induces warmer and moister winter seasons and increases the likelihood of dry and warm summer time situations.”

Below “....the five scenarios are presented for 2040 and for 2100. The scenario for 2100 is simply a linear interpolation of the values for 2040.” Further on: “…the SLR in the last improbable “worst case” scenario, accounts for some unexpected effects, such as the massive melting of ice sheets and the stopping of the Thermohaline Ocean Circulation.”

For 2040 the SLR is +30 cm (M-scenarios), +40 cm (W-scenarios) and +100 cm (worst scenario). Similar for 2100 the figures are +60 cm, +93 cm and +200 cm.

2.1.2. Sweden

Contact: Bengt Rydell. Statens Geotekniska Institut

According to Mr. Rydell there are limited national policies specific on climate change and coastal areas. A comprehensive governmental investigation was carried out in 2007 by the Commission on Climate and Vulnerability. The report could be found on http://www.sweden.gov.se/sb/d/574/a/96002. This investigation has been the platform for the ongoing climate adaptation activities on national, regional and local levels and also for a number of assignments to Swedish authorities. After this report was published, new research results and experiences have been developed in Sweden and internationally on climate change. The latest information on climate change including SLR, run-off from rivers, precipitation etc. will be found on the SMHI webpage www.smhi.se.

The report from the Commission on Climate and Vulnerability is mentioned beneath. No projections on SLR was identified from the webpage www.smhi.se.

Reference: Sweden facing climate change - threats and opportunities. Swedish Government Official Report. Ministry of the Environment. The Commission on Climate and Vulnerability (2007).

Quotation from the report: “The level of the seas will continue to rise. The lowest emissions scenario (B1) projects a global average rise between 18 cm and 38 cm, while the highest scenario (A1FI) projects between 26 cm and 59 cm from around 1990 to 2095. The total interval of uncertainty is not directly comparable with figures given in TAR, as a different methodology was used to calculate the uncertainty. These calculations have not included the possibility that the deglaciation processes in Greenland and Antarctica may accelerate as a consequence of the continued global warming. These processes could cause a further rise in sea levels possibly during this century. The increase is expected to continue for several centuries, even if concentrations of greenhouse gases are stabilized. However, it should also be noted that the increase is not spread evenly across the world’s seas. Regionally, e.g. in the Baltic Sea and the North Sea, the rise is expected to be 10−20 cm greater than the global average (IPCC, 2007b).”

2.1.3. Schleswig-Holstein

Contact: Jakobus Hofstede. Ministerium für Landeswirtschaft, Umwelt und ländliche Räume des Schleswig-Holstein.

Reference: Abschlussbericht Projektgruppe Klimaschutz und Klimawandel in Schleswig-Holstein (2007)

In the report projections of different parameters are included. Concerning SLR the projection says from 20 to 60 cm from the period 1961-90 until 2100, plus maximum 20 cm from the melting of the Greenland ice cap. In the long term SLR will accelerate.

2.1.4. Niedersachsen

Contact Frank Thorenz. Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz, (NLWKN).

Reference: Generalplan Küstenschutz Niedersachsen/Bremen – Festland. NLWKN (2007).

According to Mr. Thorenz the state of Lower Saxony issued the above mentioned master plan of coastal defence – for the mainland coast − in 2007. This plan reflects the official policy.

Measurements show secular rise of high tide water level of 25 cm in 100 years. IPCC's latest publication (2007) with global sea level change from 18 to 59 cm until the end of this century is also mentioned. According to Mr. Thorenz the contribution for future SLR of 25cm/100 years since then has been changed to a precautionary factor for climate change of 50 cm/100 years. Due to the uncertainties of effects of climate change on hydrological factors different adaptation measures have been introduced in the design of new dikes.

2.1.5. The Netherlands

Contact: Niels Roode. Rijkswaterstaat Waterdienst

Reference: National Water Plan, 2009-2015 (2006)

Mr. Roode refers to the EU-project SafeCoast from 2006, where similar efforts were performed resulting in a report that can be downloaded on the website:
http://www.safecoast.org/cohesion/common_climate.php

The leading scenarios are based on the KNMI scenarios of 2006, which are reflected in the recent National Water Plan 2009-2015: http://www.verkeerenwaterstaat.nl/english/Images/NWP%20english_tcm249-274704.pdf. KNMI introduces 4 scenarios, two moderate scenarios − G and G+ − with a temperature increase of 2°C in 2100 compared to 1990, and two warm scenarios − W and W+ – with 4°C increase. The index + indicates a change in prevalent wind pattern resulting in milder and wetter winters and warmer and drier summers. The SLR, which only depends on temperature increase, is 35-60 cm in scenarios G's and 40-85 cm in scenarios W's. Corresponding information is specified for 2050 respectively 15-25 cm for the G-scenarios and 20-35 cm for the W-scenarios. KNMI states, that together these four scenarios encompass the greater part of the uncertainty.

The Delta Committee has done its own research in addition to the KNMI scenarios. Quotation from the report: "This incorporates the latest scientific insights and is based on an extreme scenario with a plausible upper limit for the global and regional rise in sea levels, changes in storm conditions over the North Sea and changes in precipitation in the long term. Up to 2050, the climate scenario applied by the Delta Committee remains within the range described by KNMI scenarios. With an average soil subsidence of around 5 cm, the relative rise in sea levels is estimated to be 0.20 to 0.40 m by 2050. In the long-term perspective, the upper limit for the (relative) rise in sea levels by 2100 is higher than that in the KNMI 2006 scenarios: 0.65 to maximum of 1.30 m. The calculations take the effect of soil subsidence into account."

Mr. Roode states, that it is unclear to him whether the Dutch still make policy scenarios or not. He has the impression that the Dutch now only use KNMI 2006, but it is unclear to him, whether the latest scientific KNMI scenarios have now overruled the scenarios mentioned in earlier policy documents.

An elaborating enquiry to another contact person, a senior adviser with respect to climate change issues, did not succeed.

2.1.6. Norway

Contact: John Morten Klingsheim. Kystverket (Norwegian Coastal Administration)

Reference: Hanssen-Bauer et al. Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilplassing, Norsk klimasenter (2009)

The above report gives a scientific base for SLR and other climate changes in different parts of Norway.

Based on relevant data, the model of Ramstorf for predicting global SLR and scenario SRES A2, a SLR of 65 to 110 cm is expected in 2100 in relation to 2000 with mean value 80 cm. Ramstorfs model compares global SLR with rise in global temperature. Calculations indicate a regional contribution of 10 cm in this region, so it ends up with a mean SLR along the Norwegian coast of 90 cm in 2100.

Summed up the SLRs in 2050 is expected to be 23-45 cm, with a mean value of 31cm and in 2100 70-125 cm with a mean value of 90 cm.

With differences in vertical land movement along the Norwegian coast the SLR (max and min values) is specified for five cities: Tromsø, Trondheim, Bergen, Stavanger and Oslo.

2.1.7. United Kingdom

Reference: Lowe et a. UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK (2009)

UK presents three emissions scenarios, which comply with IPCC's SRES scenarios, i.e. a low emissions scenario (SRES B1), a medium emissions scenario (SRES A1B) and a high emissions scenario (SRES A1F1).

Key findings of the analysis give projections of UK coastal absolute SLR for 2095 that range from approximately 12-76 cm representing all three scenarios. Taking vertical land movement into account gives slightly larger SLR projections relative to land in the more southern parts of the UK where land is subsiding, and somewhat lower increases in relative sea level in the north. Projected relative SLRs for different locations in UK are presented, for instance an increase for 1990-2095 of approximately 21-68 cm for London and 7-54 cm for Edinburgh (5th to 95th percentile for the medium emissions scenario).

2.1.8. Denmark

Reference: Strategi for tilpasning til klimaændringer i Danmark (2008). (Governmental strategically adaption to the effects of climate change).

The strategic plan works with three scenarios SRES A2, SRES B2 and EU2°, an EU based scenario, with the target, that global warming only will grow 2° from pre-industrial period to 2071-2100. SLR of 0.45-1.05 m on the Danish North Sea Coast is only mentioned for the A2 scenario up to 2071-2100. In this figure extra storm surge contribution of 30 cm is included.

Reference: DMI. Fremtidens havniveau (2010).

Based on the latest scientific research the Danish Meteorological Institute estimates the SLR around Denmark to be 0.3-1.2 m in 2100. With local effect as geotechnical rebound included this will be 0.1-0.9 m. The similar numbers for the situation in 2050 will be 0.05-0.4 m.

3. Overview

Based on information attained by contact persons of each North Sea country in addition to relevant references the result of the survey is collected in table 1 below.

This survey does not pretend to be a thorough research on SLR rates used in the different countries. Dependant on purpose and attitude these may also differ in each country. Furthermore the figures probably will be outdated as new results from studies using new information and upgraded numerical models will be published. The intention with this survey is just to give a brief overview of realistic rates accepted in the countries surrounding the North Sea either given by single numbers or by intervals.

It is not possible to make a direct comparison between projections of the different countries. The periods used for the projections are not identical, but reflects a kind of 100 years period up to 2100. All though it is not specified in all reports, it is assumed that projections reflect the relative SLR in each country.

The column “Policy” indicates whether the figures are political determined as official values or not.

Country	Sea level rise projections (if not specified in cm)	Policy	Reference	Remarks
Belgium	Scenarios (until 2100) M: 60 | M+: 60 | W: 93 | W+: 93 | WC: 200	-	Project CLIMAR	Do also present scenarios for 2040
Sweden	IPCC´s scenarios Regionally, e.g. in the Baltic Sea and the North Sea, the rise is expected to be 10-20 cm greater than the global average	Yes	Swedish Government Official Report. Ministry of the Environment. The Commission on Climate and Vulnerability	
Schleswig-Holstein	20-60 cm plus max. 20 cm caused by melting of the Greenland ice cap (until 2100)	-	Abschlussbericht Projektgruppe Klimaschutz und Klimawandel in S-H	
Nieder-sachsen	IPCC´s scenarios. Later on a precautionary factor of 50cm/100 years has been introduced.	Yes	NLWKN. Generalplan Küstenschutz Niedersachsen/Bremen – Festland	
The Netherlands	KNMI-scenarios (reference 1990) G: 35-60 | G+: 35-60 | W: 40-85 | W+: 40-85 Delta Committee scenario 65-130 cm	(?)	Dutch Central Government. National Water Plan 2009-2015.	Do also present scenarios for 2050
Norway	65-110 cm, 80 cm as central estimate (reference 2000). Modified sea level calculations based on A2 emission scenario. Regional surplus on 10 cm with central estimate 90 cm	-	Norsk Klimacenter. Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilpasning	Do also present scenarios for 2050
UK	Scenarios (reference 1980-99) (absolute regional figures) High: 15-76 | Medium: 13-61 | Low: 12-48	-	UK Climate Projections. Marine & coastal projections	Presents furthermore local SLR for four cities in UK
Denmark	Scenario (2071-2100) (extra surge included) EU2°: | B2: | A2: 45-105	Yes	Regeringen. Strategi for tilpasning af klimaændringer i Danmark	
	Up to 2100 10-90 cm	No	DMI. Fremtidens havniveau	Do also present scenarios for 2050

Table 1: Sea level rise projections in the North sea countries, its origin and whether it is policy or not (September 2010).

4. References

Dries van den Eynde. Koninklijk Belgisch Instituut voor Natuurwetenschappen. Personal contact

D. Van den Eynde et al. Evaluation of climate change impacts and adaptation responses for marine activities ”CLIMAR”. Final Report phase 1. Brussels: Belgian Science Policy (2009)

Bengt Rydell. Statens Geotekniska Institut. Personal contact.

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Sweden facing climate change - threats and opportunities. Swedish Government Official Report. Ministry of the Environment. The Commission on Climate and Vulnerability (2007).

Jakobus Hofstede. Ministerium für Landeswirtschaft, Umwelt und ländliche Räume des Schleswig-Holstein. Personal contact

Abschlussbericht Projektgruppe Klimaschutz und Klimawandel in Schleswig-Holstein (2007)

Niels Roode. Rijkswaterstaat Waterdienst. Personal contact

National Water Plan, 2009-2015 (2006)

Safecoast website http://www.safecoast.org/cohesion/common_climate.php

John Morten Klingsheim. Kystverket (Norwegian Coastal Administration). Personal contact

Hanssen-Bauer et al. Klima i Norge 2100. Bakgrunnsmateriale til NOU Klimatilplassing, Norsk klimasenter (2009)

Lowe et a. UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK (2009

Strategi for tilpasning til klimaændringer i Danmark (2008). (Governmental strategically adaption to the effects of climate change).

DMI. Fremtidens havniveau (2010).