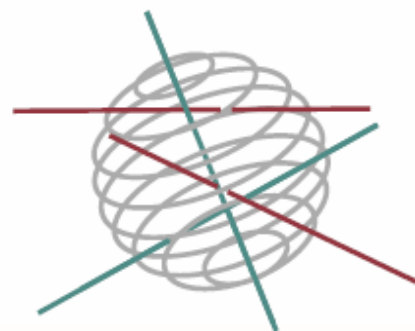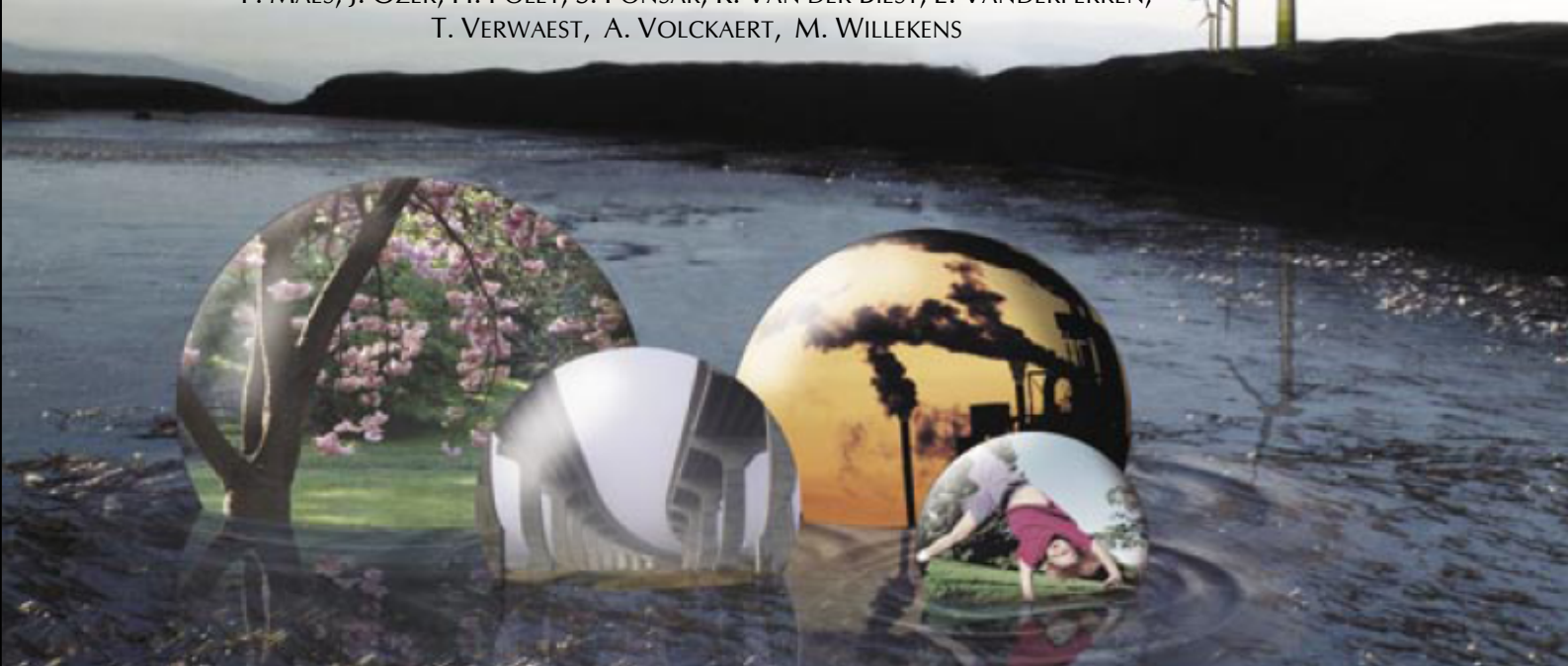# SSD

SCIENCE FOR A SUSTAINABLE DEVELOPMENT

EVALUATION OF CLIMATE CHANGE IMPACTS AND ADAPTATION RESPONSES FOR MARINE ACTIVITIES

CLIMAR project

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ENERGY
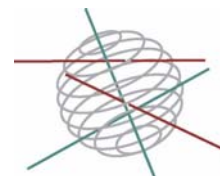
TRANSPORT AND MOBILITY

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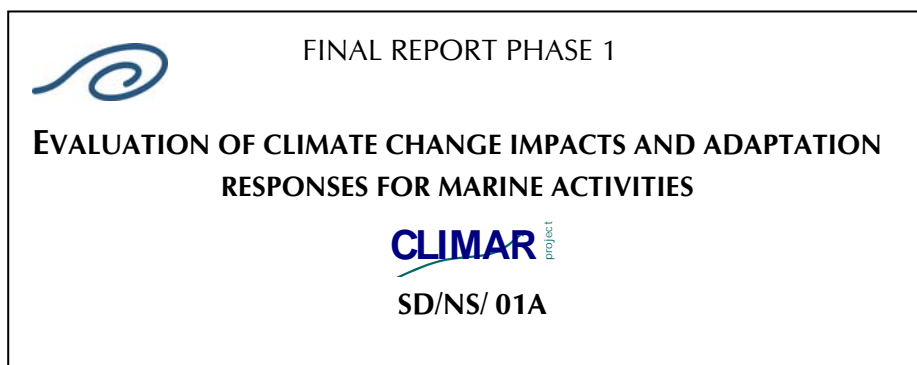
HEALTH AND ENVIRONMENT

CLIMATE

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SCIENCE FOR A SUSTAINABLE DEVELOPMENT (SSD)

North Sea

FINAL REPORT PHASE 1

EVALUATION OF CLIMATE CHANGE IMPACTS AND ADAPTATION RESPONSES FOR MARINE ACTIVITIES

CLIMAR project

SD/NS/ 01A

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BELGIAN SCIENCE POLICY

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Context

Following the IPCC recommendations, the Kyoto Protocol and relevant national strategic documents, it has been necessary to carry out scientific research to determine the impact of global climate changes and, more specifically, the impact on the particularly vulnerable marine environment and its users. While preventive measures, such as the reduction at source of greenhouse gas emissions are required to deal with the problem in the long term, it will also be necessary to envisage adaptive measures to manage the primary and secondary impacts on the North Sea. Furthermore, tools allowing these adaptive measures to be assessed as regards their sustainability, their impact on marine activities and their relationship with preventive measures and the sectorial policy, must be developed.

During the CLIMAR project, a framework was developed, which allows the adaptive measures to be assessed for the ecological, sociological or economic aspects of the Belgian zone of the North Sea.

Primary effects

In the first phase of research, the primary effects of climate change were clarified. They include a rise in sea level, the frequency and intensity of storms, the possible increase in precipitation and changes in temperature and salinity, and spatial variations in erosion and sedimentation.

A study of the literature showed a clear influence of climate change on the physical parameters. However, there are still so many uncertainties surrounding the results of the climatic models regarding the exact determination of local effects, that it is still difficult to provide forecasts on the level of the Belgian continental shelf. As regards the effects of climate change on the chemical and biological parameters, another study of the literature revealed their complexity. Changes in temperature have an influence at different levels of the trophic chain, on the availability of food for various species and on the distribution and life cycle of certain species. Furthermore, changes in the ecosystem can be very abrupt, thus making forecasts even more difficult.

In order to determine the primary effects on Belgian maritime waters, a certain number of series of measurements taken over time were analysed. Linear regression of the sea level at Ostend from 1927 to 2006 showed that, for this period, the sea level increased 1.69 mm a year, a higher value than those values reported up until now. Other models of regression show a possible acceleration in the increase of the sea level over the last few decades. Since 1992, an increase of 4.41 mm a year has been observed.

Significant measurements of wave height between 1978 and 2007, and wind speed from 1980 to 2007 were analysed, at the same time as wind fields at the Norwegian Meteorological Institute. No clear trend was revealed in these time series. There seems to be a slight decrease in the significant wave height at Westhinder, but the time series are too short to provide a definitive answer. In the same way, the wind speed on the Belgian coast shows a slight reduction, especially since 1990-1995. This complies with recent research that seems to indicate a reduction in the frequency of storms in the southern bay of the North Sea.

The analysis of temperature data (World Ocean Database, 2005) shows an increase varying from 0.023°C a year in the north to 0.053°C a year in the central and southern parts of the North Sea.

Based on the study of the literature, the analysis of the data and the scenarios developed in neighbouring countries, different scenarios were developed for Belgium. These range from a moderate scenario, with an increase in the sea level of 60 cm by 2100, to an extreme scenario with an increase in the sea level of 2 m by 2100 and an 8 % increase in wind speed.

The hydrodynamic models of waves and the transport of sediments were adapted in order to assess the impact of these different scenarios on, for instance, the strongest currents around port areas, the

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silting up of channels and waves on the beaches. The results show that currents could increase by 10 % around Nieuwpoort and that waves close to the beach could increase significantly. In the second phase of the project, these impacts will be quantified in more detail.

<u>Secondary impacts</u>

The secondary impacts of these climate changes were then determined, both for the North Sea's ecosystem and socio-economic activities, such as fishing, tourism, port and transport activities, dredging works, offshore wind farms and the risk of flooding. Within the framework of CLIMAR, research is mainly focused on the risks of flooding and on the fishing sector, although the tourism sector is also the subject of a detailed study.

<u>Compilation</u>

First of all, a general terminology was established. Different categories of effects were highlighted. Each category includes a set of effects. An effect gives a more detailed description of the impact due to climate change. While the categories of effects are common to all sectors, the effects are specific to each sector. On an ecological level, the categories of effects are, for instance, water quality, changes in habitat and biodiversity. On an economic level, for instance, there will be production changes and economic damage. Safety, job security and health are categories of social effects.

Based on the categories of effects, the effects specific to the different sectors, such as the protection of the coastline, fishing and tourism, were developed. The relations between the primary impacts and the secondary impacts, as well and the natural link between the secondary impacts, were established. Furthermore, the importance of these impacts for the sector and the priority impacts were estimated. A priority index is attached to the various impacts. During the elaboration of these priority indexes, the risks run, the possible critical thresholds and the time needed to implement an elaboration plan were taken into account. The relative importance of the impacts due to climate change compared with the impacts due to other possible evolutions, such as demographic changes or changes to market prices, were also put into perspective. This information for the different sectors is summarised in the impact tables.

Concerning the protection of the coastline, the most important primary effects are the increase in sea level and a possible increase in the intensity and/or the frequency of storms. The possible consequences for the ecosystem are, among other things, a change in water quality, and changes regarding habitat and biodiversity. On an economic level, this relates to damage linked to an increased risk of flooding. The secondary social impacts are safety, job security or a change in the attraction of the coastline. The erosion of the beaches could reduce the attraction of the coastline, while management of this retreat could have a positive impact both on biodiversity and attractiveness.

As for fishing, the greatest primary impact is the change in sea water temperature. Variations in the intensity and/or the frequency of storms can also have consequences on this sector. More than 50 secondary effects were identified. The ecological impacts are strongly interconnected and illustrate the complex nature of the ecosystem. The change in temperature of the sea water has effects on all levels of the trophic chain. It can lead to the geographic displacement of fish species and provoke changes in the food chain. The economic effects are linked to production changes, which are closely linked to changes in fish stocks or a change in the number of fishing days.

An impact table was also elaborated for tourism. It provides a complete overview of the potential secondary impacts such as the disappearance of the beaches, new forms of ecotourism and the effect of flooding.

Quantification

Description of the sectors

In order to assess the cost of adaptive measures, the impacts must be both specified and quantified. First of all, an in-depth qualitative knowledge of the sector is required. For this purpose, a document describing the sector in depth was drawn up for the three sectors examined.

For the protection of the coastline, maps of land use and the infrastructures in the areas subject to a risk of flooding were elaborated. This information can be used to assess damage due to flooding.

The fishing sector is described in a separate document. The number of fishing boats only reached 102 at the end of 2007, 93 % of which are used for trawling mainly plaice and sole. The Belgian fleet is active in different ICES zones and not only in the Belgian zone of the North Sea. It brings in approximately 20,000 tons of fish a year. The study reveals that it is external factors in particular (the price of fuel, fish, international rules, etc.) that have a very strong influence.

Three major groups have been identified in the tourism description: leisure tourism (holidays by the sea, water sports, etc.), commercial tourism and other more negligible forms such as culture and well-being.

Socio-economic scenarios

External factors such as demographic evolution or the evolution in fuel prices are also very important for the quantification of secondary impacts or the assessment of adaptive measures. We are therefore obliged to make assumptions on the evolution of these socio-economic factors for the defined periods of time. Considering that there is also a high level of uncertainty, different scenarios have been developed. During the elaboration of these scenarios, the 'Environment Report for Flanders' scenarios and the socio-economic scenarios for the neighbouring countries will be used.

Quantification of the secondary impacts

The quantification of the secondary impacts was determined with the help of a certain number of indicators used to estimate the risks and level of vulnerability. For each indicator, an 'Indicator Fact Sheet' was established, in which the indicator was defined, and its importance demonstrated. The variations in these indicators are described for the current situation and for the scenarios linked to climate change. The socio-economic scenarios will also be taken into account for the assessment of the variations in these indicators.

For the protection of the coastline, the indicators are coastal erosion, damage and the number of victims in case of flooding. The values of these indicators are determined for the current situation, the average scenario and the worst-case scenario in 2100. We believe that following a rise in sea level, approximately 17 % of the beaches in the average scenario, and 50 % in the worst-case scenario, will disappear. Damage and victims were determined according to an extreme storm whose period of occurrence is 1/17,000 years. The 'Durosta' model is used to estimate the erosion of the beaches and dunes as well as the risk of the formation of breaches. In this model, the Belgian coast is divided into 256 sections, 300 m wide. In each section, at least one profile is taken into account. In total, the calculations are based on 380 profiles. The 'Mike Flood' model is used to calculate the speed of propagation and the extent of floods, while the 'Latis' software program has been adapted to estimate the damage and number of victims. In the current situation, three weak points have been identified: Mariakerke, Ostend and Wenduine. The most critical point is Ostend because of a greater concentration of buildings and population. In case of an extreme storm, the damage is estimated at EUR 4.1 10^8 and the number of victims at 10. In the worst-case scenario for 2100, we expect the formation of breaches in more than 50 % of profiles. The total damage is estimated at EUR 1,7 10^{10} and there could be up to 6,700 victims.

For the fishing sector, the greatest change will be experienced in terms of dispersion and the relative density of commercial fish stocks. The effect of climate change is complex; it can be direct and indirect and occur at different biological levels (individual, population, ecosystem). Moreover, the effects can be different depending on the region, the species in question and its stage of development. Other factors, such as the pressure of fishing, have an influence on the final answer (e.g. changes in growth, mortality, reproduction, growth and the structure of the population, relative density, dispersion, etc.). In the North Sea, distribution changes resulting from climate change are heterogeneous and result from a combination of different migration patterns, such as displacement to areas approximately 3.6 m deeper per decade and displacement in latitude. The effects on different varieties of fish have been described in detail. A summary of the effect on three different species of fish that are important to the fishing sector, i.e., sole, cod and red mullet, is included as an example in this document.

As regards the tourism sector, the greatest risks and their indicators have been described. In a separate document, coastal erosion indicators, the presence of marine mammals, the attractiveness of the coast and new commercial activities such as ecotourism, are described.

Elaboration of adaptive measures

Adaptive measures can be defined and implemented to counter the impacts of climate change or take advantage of it. Adaptation strategies are a combination of different measures to tackle a determined risk in an integrated manner.

Different types of adaptive measures can be defined. First of all, the population can be insured against losses. Some effects can be fought in a more proactive way. For instance, the Flemish government is currently elaborating an integrated plan to protect the coast against floods up until 2050, while the operational running of the fishing fleet can be adapted to diminish or take advantage of climate changes. Measures can also be taken at a legislative or policy level to counter the effects of climate change. Furthermore, it is clear that climate changes can also offer new opportunities.

Finally, additional research and raising awareness among the population are very important. Different possible adaptive measures for the protection of the coastline were defined, such as setting up artificial islands, artificial reefs, active breakwaters, huge sea walls. The positive and negative aspects of these adaptive measures were also examined. It would therefore seem that there are a number of uncertainties surrounding the setting up of artificial islands in terms of coastal erosion and cost.

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Artificial reefs can be used to absorb the energy of the waves and thus limit the erosion of the dunes and the beaches. This is not particularly easy to implement on the Belgian coast where the tide can reach up to 3 metres. The active breakwaters can possibly offer a solution to this. Huge sea walls can significantly lessen the risk of flooding but require a lot of space. For the time being, in the Netherlands, the installation of a 'sand engine' is envisaged, for which a considerable quantity of sand will have to be extracted. Finally, the controlled permanent flooding of certain areas or raising awareness among the population with regard to flooding, must also be considered.

For the fishing sector, the choice of other species or the adaptation of fishing methods have already been taken into account. It is clear that it is crucial for the government to support the adaptive measures. The international rules, such as fishing quotas, will continue to be very important for the sector.

During the elaboration of the adaptive measures and strategies, the participation of all involved parties is very important. Within the framework of the CLIMAR project, two workshops have been organised on the implementation of adaptation strategies for the two case studies: the protection of the coast and the fishing sector.

Assessment of adaptation strategies

In the second phase of the project, a method will be developed and implemented, for instance, on the basis of a multi-criteria or cost-benefit analysis to assess the adaptation strategies elaborated. It is indeed clear that appropriate measures for one sector can have negative effects on another one. Furthermore, the legal and international aspect of different adaptive measures will be taken into account.