

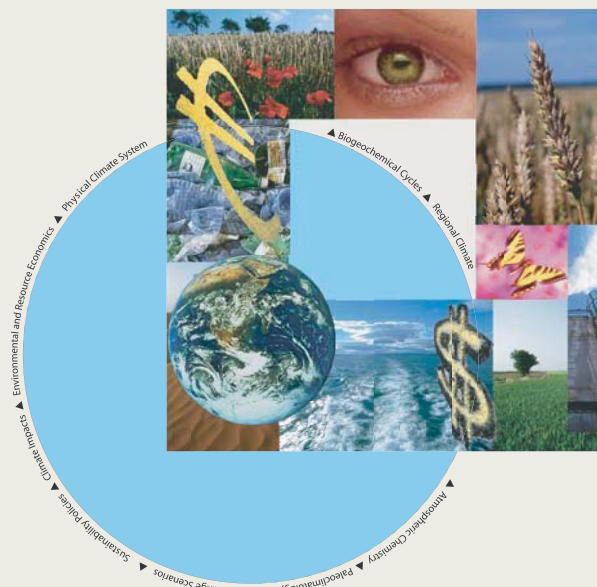


International Max Planck Research School on EARTH SYSTEM MODELLING

Modeling the economic impacts of changes in thermohaline circulation with an emphasis on the Barents Sea fisheries

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Summary

Anthropogenic climate change can trigger a strong decline in strength of the Atlantic thermohaline circulation (THC). Such weakening will have a wide range of impacts, which are not limited to the physical environment of the affected regions, but are likely to affect biodiversity, ecosystem stability, economic activities, water resources, and human energy consumption as well. To improve possibilities for successful adaptation to these altered environmental conditions, it is important to know which regions and societal sectors will be most affected, and how large damages of a THC shutdown turn out to be. This thesis addresses these issues using specifically designed simulation models that are capable of dealing with scenarios of environmental change caused by a weakening of the THC.

In the introductory chapter 1, the concepts of THC weakening, integrated assessment modeling and bioeconomic fisheries modeling are introduced. Furthermore, the bioeconomic simulation model used in this thesis is described in detail.

The first part of the thesis looks at the overall socioeconomic impacts of a reduction in THC strength. An initial assessment of these impacts of a THC shutdown is conducted in chapter 2, using the integrated assessment model *FUND 2.8*. Two cases are compared: one in which the THC weakens by less than a third and later recovers and one in which the THC shuts down almost completely. The results show that the consequences for the North Atlantic region are less pronounced when occurring in the context of global warming than if the THC shutdown had occurred without the background of anthropogenic climate change. The overall and marginal impacts of climate change are negative regardless of the fate of the THC. However, total damages incurred from THC change amount to only a few per cent of GDP in the regions most affected by a THC breakdown, so the overall extent of damages stemming from a THC collapse is fairly limited.

The *FUND* model is improved for the simulations presented in chapter 3 to resolve the socioeconomic impacts of changes in THC strength on a country level. Monetized market and non-market impacts of changes in environmental conditions following a THC collapse are determined for 207 individual countries. Eight different response patterns can be identified. The most frequent pattern observed is one in which a THC shutdown has an offsetting effect on the underlying warming trend. Depending on whether the impacts of warming are initially

beneficial or detrimental, the economic effects of a THC collapse are quite heterogeneously distributed geographically. The analyses indicate that the most important economic sectors affected by an altered THC strength are water resources and energy consumption. Among health related impacts, the changes in the spread of cardiovascular and respiratory diseases are of particular significance. The maximum national impact of a collapse of the THC turns out to be of the magnitude of a few per cent of GDP, whereas the global impact is much smaller. Considering the low probability of occurrence, the scenario of a THC shutdown does not call for drastic action at present.

The second part focuses on the marine fisheries of cod (*Gadus morhua*) and capelin (*Mallotus villosus*) in the Barents Sea region, an important economic sector that is assumed to be particularly affected by changes in the Atlantic THC. In chapter 4, the economic impacts of changes in THC strength on these fisheries are explored using a bioeconomic simulation model. In this assessment, the fishermen follow an adaptive harvesting strategy. A shutdown of the THC is represented by a sudden reduction of the environmental carrying capacities or productivities of the species. The simulations show that in the long run reduced productivity or carrying capacities lead to lower stock sizes and consequently to smaller catches. During the first few years after the change in population dynamics, however, the fisheries are hardly affected. For large changes in productivity or carrying capacity, the cod fishery becomes completely unprofitable. The reduction in economic success is less pronounced for the capelin fishery than for the cod fishery, as the capelin stock can benefit to some extent by a release of predation pressure due to a smaller predator stock size of cod, leaving more capelin to be harvested.

The bioeconomic model is further extended in chapter 5 to allow vessels to enter the fisheries in very profitable periods or to exit if the fishery has become unprofitable. Furthermore, management measures by means of total allowable catches were incorporated. The same scenarios of changes in population dynamics were applied to the improved model version, and simulations were conducted with fisheries using profit-maximizing harvesting strategies. The analyses demonstrate that small changes in population dynamics have only little economic impact. A strong reduction in productivity or carrying capacity, however, has a lasting negative impact on long-term stock development, leading to lower overall catch sizes and consequently to lower income from fishing. Here, the decline in economic activity is particularly significant for the cod fishery not only due to the higher value of the fish but also

because of the much larger amount of capital invested in the operation of the fishery. Generally, a lower productivity has a more profound economic impact than a lower carrying capacity.

Simulations with the bioeconomic fisheries model coupled to scenarios of THC change are performed in chapter 6. The model setup is adjusted to incorporate the influence of temperature and THC strength on recruitment success and natural survival rates of the species. Comparisons of landings and returns from fishing in the scenarios with a stable THC and the THC breakdown scenario yield insights about the success of the fleets and their harvesting strategies in case of altered circulation patterns in the North Atlantic Ocean. The simulations demonstrate that a substantial weakening of the THC leads to impaired cod stock development because of lower survival rates of the youngest age classes. This causes the associated fishery to become unprofitable in the long run. Simultaneous improvements in capelin stock development help the capelin fishery, but are insufficient to offset the losses incurred by the cod fishery.

The final chapter 7 summarizes the findings, discusses the relevance of the results and points to areas of socioeconomic impact assessment of THC change that may prove worthwhile subjects of further research.