Climatic Change (2008) 87:1–6
DOI 10.1007/s10584-007-9368-7

BALANCE: an attempt to assess climate change impacts in the Barents Sea Region

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Received: 13 November 2007 / Accepted: 13 November 2007 / Published online: 22 December 2007

1 Introduction

The term climate change (and also the broader term global change that includes climate change) has today almost become a common household term. Most people can relate one way or the other to varying climate conditions and what they may mean to them. However, it is usually not before some "bad weather" hits a region that people start to realize that climate, climate variability and climate change may have very concrete consequences for their daily life.

No later than at this point, questions are raised about the more concrete causes and consequences of climate change. And these questions are equally asked and discussed by politicians, the business community and the public at large. It is these questions that have driven climate science for the last few decades. While the initial emphasis has been on the "global picture," there has been an increasing urge to narrow the focus down to regional or even sub-regional investigations and assessments. Even more so as we began to realize just how different the manifestations of climate changes and their impacts are, depending on the particular region one looks at. Another important observation has been that "climate science" needs to include more than the physical sciences it started from. This recognition stems from the realization that the climate system goes far beyond the physical world and include societal processes that change, for example, the atmosphere's composition and land surface. Moreover, when it comes to addressing the consequences of climate change and possible mitigation and adaptation, disciplines such as economics or sociology have to be consulted to come up with results that are more than "academic."

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2 Overview

Having these considerations in mind the BALANCE project (BALANCE stands for Global Change Vulnerabilities in the **Ba**rents Region: **L**inking **A**rctic **N**atural Resources, **C**limate Change and **E**conomies) was initiated in 2002. The project was carried out by a consortium of 15 partners from six European countries and consisting of a group of interdisciplinary scientists. The study area covers the Barents Sea, the White Sea, Northern Fennoscandia, Northern Russia including the Kola Peninsula, the Archangelsk region, Svalbard, Franz-Josef-Land and Novaya Zemlya. The time frame addressed spans approximately the next 80 90 years.

This issue of Climatic Change starts off with an overview paper by Lange, presenting a detailed account on the BALANCE project, its history, its basic methodologies and its major results achieved by the participating research groups of the consortium.

3 BALANCE modeling framework

The overall goal of BALANCE lies in an assessment of present and future vulnerabilities of the Barents Sea Region to climate change. Vulnerability in this context refers to the extent to which climate change may damage or harm environmental or human systems in the Barents Sea Region; it is a function of both sensitivity to climate and the (autonomous) ability to adapt to new conditions.

The assessment is based on a framework of individual models describing selected environmental and societal components of the Barents Region and their responses to climate change (impact models). We assessed the impacts of climate change by comparing baseline and future climate change scenarios that were generated by the models employed in the project at a number of different time slices around 1990, 2020, 2050 and in cases feasible 2080 (Lange 2008).

Climate scenarios for the individual impact models were obtained by a regional climate model (REMO) of the Max Planck Institute for Meteorology in Hamburg, Germany (Jacob and Podzun 1997; Jacob 2001). REMO was forced by output of a global climate model that was driven by the SRES B2 scenario (Nakicenovic and Swart 2000).

Göttel et al. (2008) describe REMO and its application to the vegetation model LPJ-GUESS (Smith et al. 2001) that was used in the BALANCE project. Their study investigates the vegetation feedback on climate change. Results of the study demonstrate that this feedback is one order of magnitude smaller than the effects of greenhouse-gas-forcing on climate alone.

The results of the vegetation model (LPJ-GUESS) indicate an increase in boreal needle-leaved evergreen forest as a consequence of a migration northwards and upwards in the mountain areas (Wolf et al. 2008a). Wolf et al. (2008b) also test the sensitivity of the ecosystem model to changes in hydrology and temperature. They suggest that soil parameters need to be considered more precisely in future studies.

With regard to forest ecosystems in Fennoscandia, Wolf et al. (2008c) find that background insect herbivory is a likely cause for significant changes in future forest composition. In addition, Kozlov (2008) demonstrates the dependence of endemic insect herbivory damage on latitude. There seems to be a positive correlation between increasing latitude and the degree birch forests are damaged by insects, with northern trees being affected significantly more strongly than birch trees at more southern locations.

Vegetation changes resulting from climate change as indicated in the papers briefly described above will have significant consequences for biodiversity and species distribution in the Barents Sea Region as described by Zöckler et al. (2008). This is mainly due to the limited autonomous adaptation capacity to changing climatic conditions of tundra bird species. As projected by the LPJ-GUESS model, present tundra area will decrease by 14 and 19% new tundra will develop on presently Arctic desert areas, thus resulting in a net gain in tundra area as a result of climate change. However, it is uncertain, if the newly developed tundra will serve the same functions as the lost habitat. Zöckler et al. conclude that the net impact of a change in climatic conditions on the considered indicator bird species will be a loss in habitat and thus a decline in population numbers of these birds in the Barents Sea Region.

River discharge and freshwater runoff to the Barents Sea under changing climate was investigated by Dankers and Middelkoop (2008). The results of their model (BarentsFlow) clearly indicate that the hydrological characteristics of the sub-arctic environment studied will change considerably. This is mainly due to a reduction of the snow season by 30 to 50 days and increased evapotranspiration in the summer.

Marine ecosystems are equally likely to transform as a consequence of climate change. To assess these changes, Ellingsen et al. (2008) use a complex physical/biological coupled ocean model that utilizes the climate scenarios as derived from REMO (Göttel et al. 2008). The results of this study demonstrate an increase in water temperatures of the Barents Sea and a corresponding decrease in sea ice cover. Changes in the physical conditions will have impacts on the marine ecosystem: although primary production will slightly increase, the production of zooplankton species will decrease. This is due to a comparative advantage of Atlantic zooplankton species over Artic zooplankton species.

The results of this study are subsequently used as input to an individual-based model of capelin, a key species of the Barents Sea ecosystem (Huse and Ellingsen 2008). The model simulations show that the spawning area of capelin is going to shift eastwards towards a region along the western coast of Novaya Zemlya. Spawning will take place earlier in the year due to the increase in water temperatures. The mainly adult capelin population will migrate towards the north-eastern part of the Barents Sea.

4 Climate change impacts on selected economic sectors

As stated above, the BALANCE project also aims to assess the vulnerabilities of major economic sectors in the Barents Sera region. We looked at three sectors, two of which are of clear economic significance (fishery, forestry), whereas one (reindeer herding) is not only of economic importance, but also because of its cultural and traditional value for the Sami population in northern Fennoscandia and north-western Russia.

Rees et al. (2008) investigate the likely response of reindeer herders to changes in both climate as well as in socio-economic and/or political conditions in the four countries considered in BALANCE and for a time frame of 1990 to 2080. Although the projected changes in climate in the study region as given by the REMO model (Göttel et al. 2008) lead to changes in vegetation cover that have an impact on reindeer husbandry, they appear less significant compared to other drivers. Moreover, the adaptive capacity of reindeer herders that is largely based on their past experiences seems to be outweigh a significant part of the adverse effects of climate change impacts. In comparison, the potential impacts of changes on the subsidy regime and the impacts of losses of pasture as a result of enhanced industrial activities, increased, forestry and farming and environmental contamination are significantly larger. Furthermore, changes in the socio-economic and political conditions together with climate change may lead to synergistic effects increasing impacts on the reindeer herding economy. The study by Rees et al. (2008) demonstrates that the adaptive capacity of reindeer herders to such impacts and thus their vulnerability varies considerably between the four countries (Norway, Sweden, Finland and Russia) considered in BALANCE.

Keskitalo (2008) comes to similar results in her study that deals with forestry and forestry communities in the Barents Sea region. In looking at the Pite River Basin in northern Sweden, the study reveals that impacts to climate change on the level of selected communities varies significantly, thus confirming the hypothesis that adaptive capacities and therefore vulnerabilities are strongly location-specific. Keskitalo's analysis (2008) also demonstrates that current socio-economic conditions and possible transition processes will have a more significant bearing on the vulnerability of a community than the projected changes in climatic conditions. This notwithstanding and somewhat depending on the primary economic activity pursued, future changes in climate will enhance the burden on already vulnerable communities in northern Fennoscandia.

Lundmark et al. (2008) used a modified employment model to estimate the effects of projected climate changes on regional employment in forest-resource based communities in Norrbotten, Sweden, Finnish Lapland and the Arkhangelsk oblast in Russia. Confirming the results of Rees et al. (2008) and Keskitalo (2008) Lundmark et al. demonstrate that the vulnerabilities to changing environmental conditions on the local to regional scale are significantly location dependent. Mainly due to the sole dependence of the economy on renewable natural resources in combination with a limited adaptive capacity, the Archangelsk oblast appears to be more vulnerable to climate change than Norrbotten and Finnish Lapland.

Eide (2008) simulates the effect of different management regimes on the Norwegian cod fisheries in the presence of changes in physical and biological conditions as caused by projected climate change. The findings support the results of earlier studies and support the hypothesis that different management regimes are of significantly more importance to the economic performance of the fishery industry in the Barents Sea for the next 25 years than the impacts of climate change.

5 Model integration

Bernard and Ostländer (2008) combined the BALANCE Spatial Data Infrastructure and a Geographic Information System to derive an Assessment and Decision Support System on the basis of the various individual results obtained in BALANCE. This System is to be used by the different stakeholder groups of the Barents Region form the fishery and forestry industry, from reindeer herders but also by regional political decision makers, scientists and the public at large.

The paper by Roderfeld et al. (2008) aims to summarize and quantify the potential impact of climate change on selected ecosystems in the BALANCE study area. Changes in climatic parameters are represented by means of assigning individual/altered climate classes as based on the Köppen climate classification (Köppen 1923). More specifically, Roderfeld at al. attempt to integrate the impacts of climate change as derived from the different impact models within BALANCE for individual terrestrial and marine ecosystems. A major tool employed for this purpose is a Geographical Information System that enables a standardized visualization of potential climate change impacts in the study region. The maps thus derived demonstrate that the integrated impacts of climate change on individual terrestrial and marine ecosystems will vary significantly between the two chosen time slices at 2050 and 2080.

6 Conclusions

This Special Issue of Climatic Change is devoted to papers that report major results of the BALANCE project (*Global Change Vulnerabilities in the Barents Region: Linking Arctic Natural Resources, Climate Change and Economies*). While quite extensive, the contributions cover but a fraction of the most interesting and substantial findings gained in the course of this project. This notwithstanding, we trust that the papers presented here will enable insights into important aspects of climate change and its impacts in the European North. We hope that this may provide guidance and insight to those who will have to cope with the impacts of climate change in years to come.

Acknowledgement We would like to thank the European Commission for financial support for BALANCE and the responsible officers, Drs. Denis Peter and Maria Yeroyanni for guidance and advice. We acknowledge countless comments and suggestions offered to us by our colleagues and insightful – though sometimes surprising – advice and suggestions presented by stakeholders and administrators in the region. Last but not least, we would like to thank Climatic Change and its editor Stephen Schneider for providing us with an excellent platform to publish some of our results.

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