G. Schernewski & N. Löser (eds.): Managing the Baltic Sea.
Coastline Reports 2 (2004), ISSN 0928-2734
S. 195 - 199

Modelling a future sea level change scenario affecting the spatial development in the Baltic Sea Region – First results of the SEAREG project

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Abstract

This article summarizes the first results of the Interreg IIIB project "Sea Level Change Affecting the Spatial Development of the Baltic Sea Region" (SEAREG). The effects of climate change scenarios have been widely discussed in public and within the scientific community in recent years. The SEAREG project addresses socio-economic and environmental aspects of sea level rise in the Baltic Sea region (BSR) by finding appropriate applications of climate modelling in local and regional planning systems. A rise of the sea level might lead to major flooding events, having severe impacts on the spatial development of cities and regions of the BSR. One basic task in the SEAREG project is to outline the major impact zones caused by sea level rise in the Baltic Sea region by using GIS-based methods. Ocean model and land uplift rate are factors that must be taken into account in addressing flood prone areas. The Swedish Meteorological and Hydrological Institute (SMHI) utilized two emission scenarios (A2 and B2) by IPCC to calculate the RCAO model (Rossby Centre Atmosphere Ocean model). Superimposing this ocean model with a digital elevation model as well as land use data, the effects and spatial extent of sea level change can be evaluated. The results are grid based cartographic presentations showing estimates of sea level changes 100 years after present. In cooperation with spatial planners the e project is developing a Decision Support Frame (DSF) for impact and vulnerability assessment. The DSF will address planning authorities, decision makers and stakeholders in the case study areas and in the BSR cooperation on spatial planning in general.

1 Introduction

Currently it is widely understood that the earth's climate is warming up and the sea levels are rising. The question is, in what speed and to what extent the climate will get warmer. Climate modelers therefore try to inform about the trends in climate change and assist in delineate areas that could be affected by sea level rise and/or flood patterns in 100 years time.

Within the SEAREG project a regional climate model (RCAO-hca2) has been applied to calculate future sea level changes for the Baltic Sea, applying two global general circulation models (GCM) to represent the recent climate (time slice 1961-1990). Applying two control simulations, four future climate scenarios are produced, based on two different emission scenarios called A2 and B2 that predict a time slice 2071 to 2100. The A2 scenario assumes larger and continuously increasing emissions of the major anthropogenic greenhouse gases. The B2 scenario predicts a slower increase of these emissions. In the B2 scenario the air temperature rise amounts to 2.4º and 2.6º C and in the A2 3.3ºC and 3.4ºC, respectively, depending on the global general circulation model used.

In the SEAREG project the following models/ emission scenarios are used:

- HadAM3H from the Hadley Centre (U.K.) (GCM)
- ECHAM4/OPYC3 from the Max Planck Institute for Meteorology (Germany) (GCM)

- RCAO (The Rossby Centre of the Swedish Meteorological and Hydrological Institute (SMHI) produces the regional model used in the SEAREG project. The model is limited to Europe, Fennoscandia (including some parts of the North Atlantic) and the Baltic Sea.)
- A2 and B2 future emission scenarios (provided by the Intergovernmental panel for climate change (IPCC))

The results of the models will be downscaled and plotted into regional and local maps. The maps will be discussed with planners. This dialogue shall lead to a better understanding on both sides with the result that scientists understand how planners can make better use of their models.

1.1 Calculating future sea level change in the Baltic Sea Region up to the year 2100

The two most important factors affecting the mean sea level on the Baltic Sea coast are the land uplift and/or land subsidence on the one hand and the global mean sea level rise (eustatic rise) on the other hand. The relation between these two determines, whether the sea level is generally rising, maintaining stable or lowering in relation to the present coastline (Johansson et al. 2001).

1.2 Baltic Sea wide land uplift

The land uplift data used in the project are based on the research introduced by Ekman in1996. Ekman's consistent map of the recent postglacial rebound of Fennoscandia was constructed on the basis of sea level records, lake level records and repeated high-precision levellings. The sea level records Ekman used are based on 56 reliable tide gauge stations around the Baltic Sea with time series spanning 60 or more years of observation. A fairly smooth apparent uplift (uplift relative to mean sea level) is shown from a maximum rate of 9.0 mm yr-1 in the north of the Baltic Sea to minimum rate of -1.0 mm yr-1 (i.e. land subsidence) in the south (see Figure 1) (Ekman 1996).

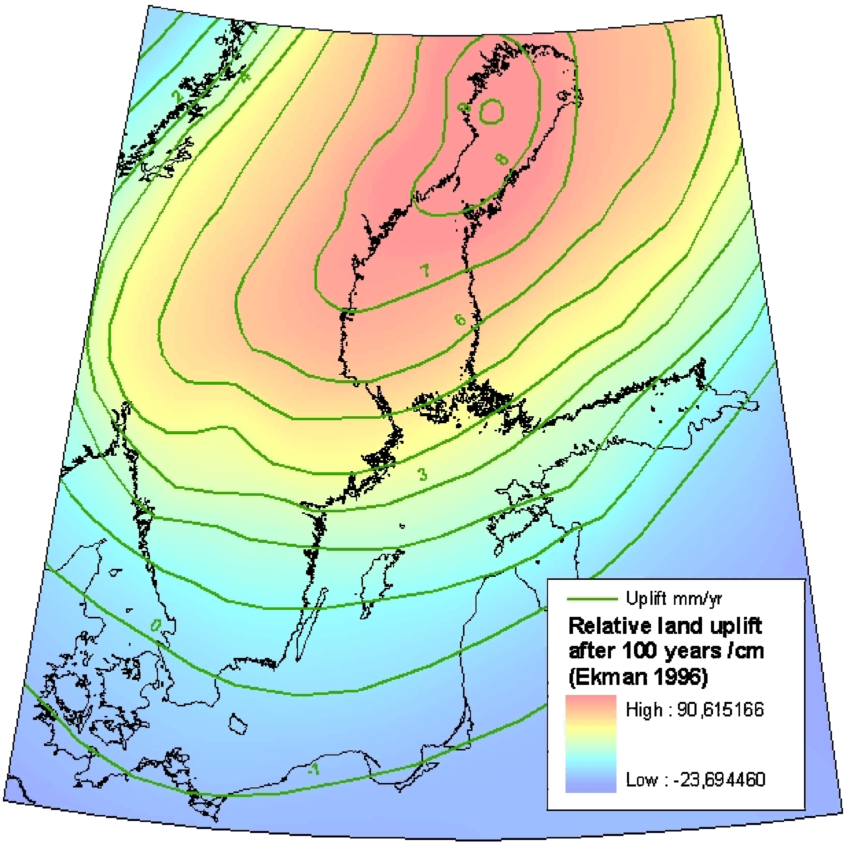

Figure 1: Ekman's consistent map of the recent postglacial rebound of Fennoscandia (1996).

1.3 Changes of the mean sea level

A general rise of the mean sea level is observed since the beginning of the 20th century. This rise has been linear in the limits of observation accuracy (Johansson et al. 2002). The current estimate for the rise amounts to 1-2 mm yr^{-1}, according to Church et al., 2001. The eustatic rise chosen in this project is 1.5 mm yr^{-1} (Gornitz 1995). In the future, the linear behaviour of the global mean sea level might change. According to the Third Assessment Report of IPCC the sea level will rise 9-88 cm from the level of 1990 up to the year 2100 (Church et al. 2001). The RCAO-hca2 average model within the SEAREG project takes into account this past time linear sea level rise as well as the future accelerated rise. The sea level rise, in general, is and will be mainly caused by thermal expansion (Church et al. 2001). The modelled accelerated sea level rise (RCAO-hca2, upper limit) for the Baltic Sea is shown in Figure 2.

To calculate the mean sea level rise up to the year 2100, both, the land uplift layer and the mean sea level rise layer should be converted to represent the situation relative to geoid. The geoid is usually defined as the equipotential surface (level surface) in the Earth's gravity field that coincides with the mean sea level of the ocean. Because mean sea level is almost an equipotential surface but not quite, the national height systems are located in potential surfaces that slightly differ from each other (Ekman, 1994). It is necessary to adopt a height system that is common to the whole area. Ekman presents a unifield height system (NH60) designed for comparisons between geodesy and oceanography for the Baltic Sea area (Ekman et al. 1994).

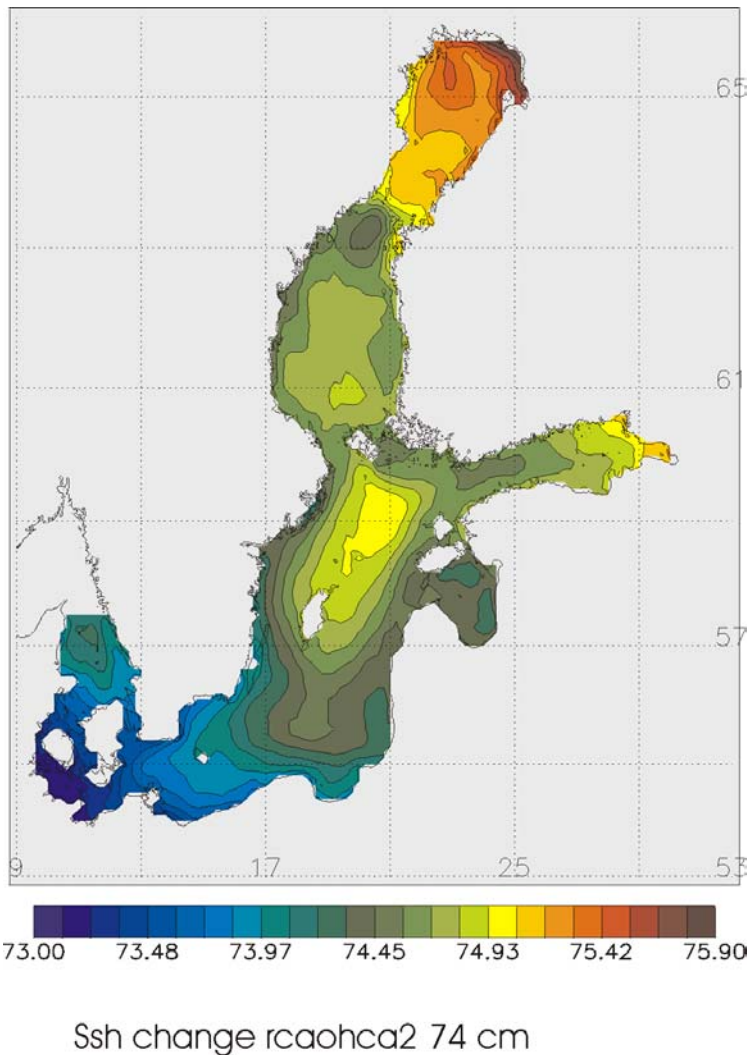

Figure 2: Calculated change of SSH (modelled) for sea level rise up to the year 2100.

2 Results

The sea surface height change (SSH) for the RCAO-hca2 model already has its zero level in the NH60 equipotential surface and there is no need for any conversion. The land uplift was calculated relative to the mean sea level, not the geoid. This leads to a situation where land uplift rate seems to be lower than it really is, because of the continuous rising mean sea level. The following steps were taken to gain the resulting overview map of sea level rise after 100 years in the Baltic Sea Region (Figure 3):

- The land uplift relative to the mean sea level is summed up with eustatic sea level rise to get *the land uplift relative to geoid.*
- *The land uplift relative to geoid* will be subtracted from the SSH change for the RCAO-hca2.

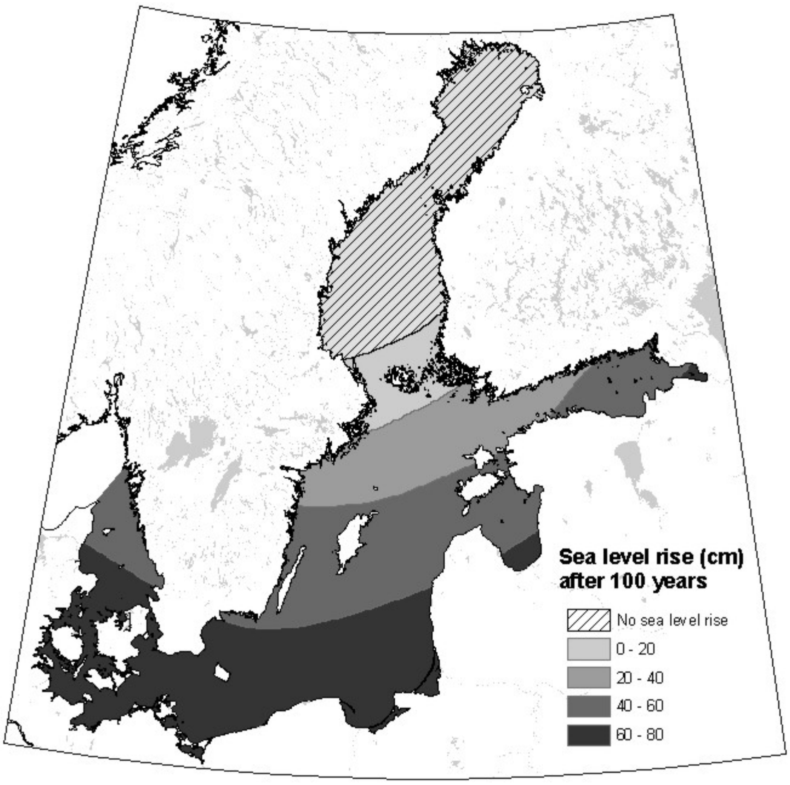

Figure 3: Overview map of sea level change up to the year 2100.

The resulting map shows five major zones illustrating that the future sea level rise in the Baltic Sea is declining form the south coast towards the north. The center of the uplift experiences no sea level rise (Bothnian Sea).

3 Discussion

To estimate the impact of uncertainties of the global and regional model results and of the emission scenarios of anthropogenic greenhouse gases SMHI calculated three sea level scenarios. For the first overview map only the "worst case" scenario was used applying the regional model results with the largest sea level increase (RCO-hca2) together with the upper limit for the global mean sea level rise of 88 cm (Church et al. 2001). However, one should keep in mind that the projected sea level rise in the global IPCC scenarios on the regional scale differs significantly (Church et al. 2001).

As all model predictions of the future, also the downscaling process from the overall BSR model scenario to regional and local scale contains uncertainties. In the several case study areas the different sea level rise scenarios will be applied at local scale (1:10 000). The SEAREG project develops a Decision Support Frame (DSF). This DSF contains a vulnerability assessment that analyses possible impacts of sea level rise, including the coping capacity of the studied areas. The DSF is further described in Klein et al. "Sea Level Change and Spatial Planning in the Baltic Sea Region: findings of the SEAREG project", in this report.

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