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BONUS briefing

SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

AMBER
Assessment and modelling Baltic ecosystem response

Climate change, nitrogen cycle, and biodiversity loss are all global concerns that have already passed beyond the well-defined thresholds and may result into disastrous consequences for the entire humanity. Being of major relevance for the Baltic Sea area, these major global concerns together with the change in land use are the research foci of the AMBER project. The results by the AMBER scientists show, for example, that the impact of organic matter on near coastal eutrophication is completely underestimated.

OVERVIEW

The general aim of AMBER is the implementation and application of the ecosystem approach to management of the Baltic Sea. It examines two closely intertwined environmental threats, eutrophication and climate change, and their combination with losses in biodiversity and change in land use.

The project focuses on the coastal ecosystem which hosts important ecosystem services for 85 million inhabitants across nine nations over the Baltic Sea catchment. The coastal ecosystem receives most of human-derived nutrient loads from rivers, submarine ground water discharge, atmospheric deposition, and point sources and links the land with the open Baltic Sea.

The coastal ecosystem governs the biogeochemical transformations of phosphorus and nitrogen compounds through close coupling of processes occurring in water and sediments. Furthermore, it is crucial for fish as reproduction area, nursery and grazing ground. In order to implement and apply ecosystem approach to management concept on the coastal ecosystem, the link between the catchment (including groundwater) and the open Baltic Sea must be studied in a holistic manner.

However, separating the signals of climate change from those of the direct impact of human activity is difficult. AMBER has taken an approach of separating climate from human induced signals by means of a combinatorial variation in model's boundary conditions. In this, AMBER uses the output of existing regional climate change scenarios and the output of a watershed model simulating changes in land use.

The project has carried out extensive retrospective analyses on long-term monitoring data sets to identify climate regime shifts and the potential predictability of development of the coastal ecosystem. Furthermore, selected measurements of the key biogeochemical transformation processes in the coastal water of the southern and the boreal northern parts of the Baltic Sea as well as in the groundwater have been carried out to complete the picture of the complex nitrogen cycle. In the concluding stage of the project, models have been applied to generate future projections. In order to reduce the uncertainties in the model-derived projections,

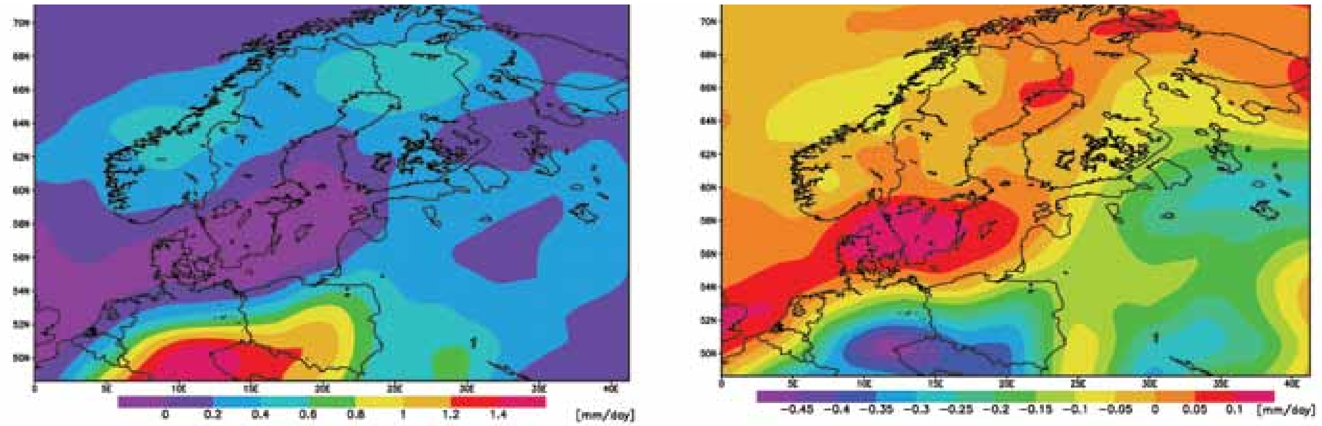

Figure 2. Mean precipitation rate (deviation from long-term climatic mean) during the vegetation periods for the years 1950-1989 (left) and 1990-2010 (right). Data source: NCEP/NCAR)

AMBER scientists have applied the ensemble method based on synthesis of the outputs of several parallel models. The projections constructed by AMBER scientists will constitute the milestones for further development of ecosystem approach to management policy and creating decision advisory tools for the Baltic Sea region.

OUTLINE OF KEY RESULTS

1. COASTAL PROCESSES

AMBER has been able to distinguish the shallow lagoons and the coastal zone (down to 20-25m water depth) from the deep basins of the Baltic Sea in terms of major processes and concentrations of substances. While surface waters of lagoons and coastal zones receive nitrogen and phosphorus with the river loads, the deep basins are mainly influenced by nitrogen captured from atmosphere by cyanobacteria blooms (Figure 1).

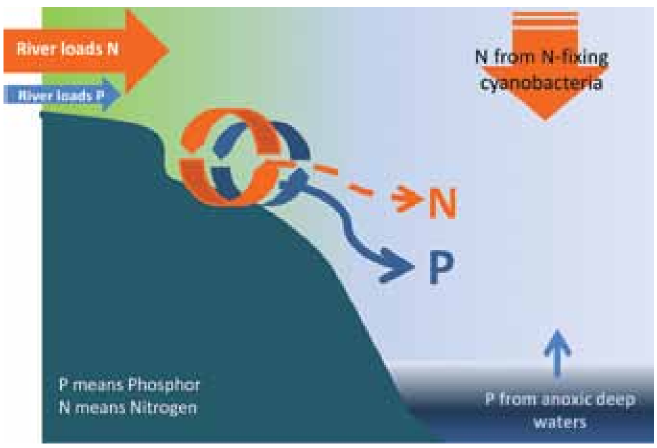

Figure 1. Schematic of coastal zone nitrogen (N) and phosphorous (P) cycling and delivery to the open sea. It is shown that a substantial fraction of the river nitrogen load seems to be lost in the coastal zone which is an important ecosystem service.

These blooms are supported also by phosphorous from oxygen depleted waters below the halocline (80-100m depth). The high river nutrient loads lead to high primary production rates especially in spring during the major flow season. Material settles from the water to the bottom where organic material is decomposed and processed. AMBER scientists observed high removal of nitrogen in sediments of lagoons and at coastal zones. Thus much less nitrogen is exported to the open Baltic Sea than phosphorous. To sustain this important ecosystem service of coastal nitrogen removal, which is similar to what happens in a sewage treatment plant, it is crucially important to prevent oxygen depletion at the coastal zones.

It is well known that nitrogen load from rivers consists of inorganic form (nitrate is usually measured and evaluated) and also of organic forms like terrestrial organic matter. AMBER scientists have been able to demonstrate that the organic nitrogen can act as a significant nutrient source for phytoplankton and bacteria as well. At the same time, climate change projections from the Baltic Sea catchment suggest an increase in precipitation in the northern countries and a decrease in the south. This may lead to increasing loads of terrestrial organic matter to the coastal zone of e.g. the Gulf of Bothnia. Thus the loading of organic substances that have hardly been monitored in the past deserve close attention while designing the future monitoring programmes.

2. EUTROPHICATION AND CLIMATE CHANGE

Climate change projections clearly predict changes in precipitation patterns over the entire catchment. Precipitation will not change uniformly but increase in the north and decrease in the south. Altered precipitation patterns in the Baltic Sea catchment (Figure 2) will lead to an increase in river runoff in the northern boreal watersheds by 20-30% whereas in the southern cultivated watersheds river runoff will decrease by some 20%. As a result, the Gulf of Bothnia will receive significantly higher freshwater inflow and loads of organic matter from forests, wetlands and soils. This in turn will result not only in changes in water salinity and the light conditions in the water, but also in the plankton community at

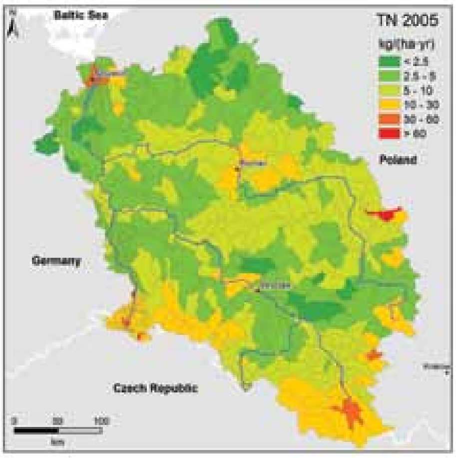

Figure 3. Total nitrogen emission (kg/ha/year) in the year 2005

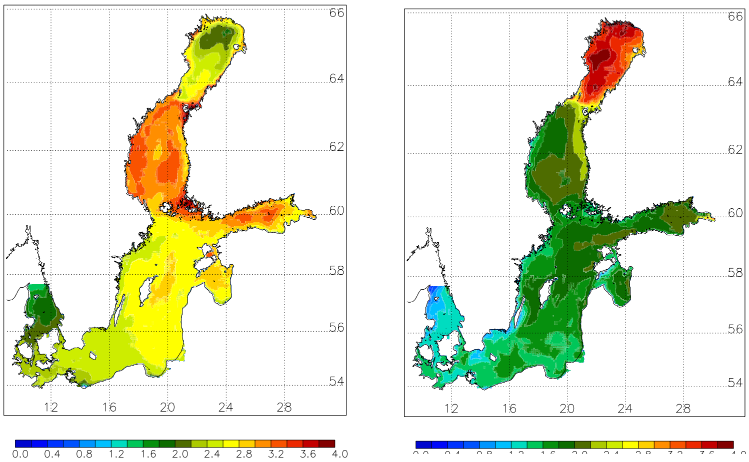

Figure 4. Surface temperature for IPCC Scenario A1B (2070-2099 minus 1970-1999) shows different warming. Left: spring HadCM3; right: summer ECHAM5. (Source: SMHI Report Nr 107, 2011)

the base of the food web and possibly in higher trophic levels too. Lower precipitation in the cultivated watersheds may lead to less emissions and higher natural removal of nutrients from river water during the transport to the Baltic resulting in lower nutrient loads. However, an obvious risk is that increased use of fertilisers and intensified farming practices, including the projected increase in meat consumption, may counteract these projections.

3. BIOTA AND REGIME SHIFT

In interaction with eutrophication and overfishing, climate change may cause rapid non-linear changes leading to ecosystem regime shifts. These ecosystem-wide changes cannot be predicted by the present ecological models. Salinity and temperature are the major hydrographic variables influenced by climate which in turn affect marine biodiversity and the state of commercially important fish species. Zooplankton species are found to be crucial indicators of such abrupt ecosystem changes. Data on zooplankton species can be used in combination with early-warning methods to forecast ecosystem regime shifts. Such a system of indicators including physical, lower trophic levels, holistic ecosystem indicators has been developed for supporting stock trend assessment and management of Eastern Baltic cod.

4. SPECIFIC MANAGEMENT RECOMMENDATIONS

To better cover the coastal zone that hosts important ecosystem services for the community, the EU Water Framework Directive and Marine Strategy Framework Directive need to be harmonised. To improve the management of the Baltic Sea, the basins should be separated into a coastal system and an open sea system. This needs to be considered in future status reports by HELCOM as well. Measures in individual catchments must be taken to reduce the nutrient export to the coastal sea (Figure 3). These may include the improvement of agricultural practices, better nitrogen use efficiencies, a decrease in emissions from point sources and urban areas to achieve scientifically sound reductions to coastal waters.

The monitoring system needs to be improved in order to be able to foresee non-linear ecosystem changes (i.e. regime shifts) and monitoring needs to include suitable indicators in combination with early warning detection method. Furthermore, indicators of the physical and biological environment of commercially important fish species should be included to support fish stock assessment and management, as well as improved zooplankton sampling.

NEXT STEPS AND FUTURE PLANS

Biogeochemistry of coastal zone

Regulation of nitrogen cycling and removal processes in the coastal zone and lagoons is not fully understood and needs to be better studied. Moreover, the role of terrestrially derived organic material in coastal zones that depends on land use and precipitation must be investigated.

Climate response on basin level

Another future step necessary in order to understand Baltic ecosystem response in detail arises from climate change scenarios (Figure 4). It was rather surprising that applying different models to the same IPCC scenario, the Baltic Sea shows different responses in different basins. Hence in the future it is important to investigate the Baltic ecosystem response on a basin level.

IN BRIEF

AMBER
Assessment and modelling Baltic ecosystem response

Climate change, nitrogen cycle, and biodiversity loss together with the change in land use are the research foci of the AMBER project. The results by the AMBER scientists show, for example, that the impact of organic matter on near coastal eutrophication is completely underestimated. Science basis for developing and implementing ecosystem approach to management is imperative in the Baltic Sea region.

KEY RESULTS

- Present and future changes in precipitation patterns over the Baltic Sea catchment will cause a decrease in salinity and a loss of marine biodiversity.
- Coastal areas of the Baltic have specific dynamics in nutrient cycling decoupled from the open sea. While terrestrial organic matter is an important component in river loads, its role is currently grossly underestimated.
- The combination of climate and land use models indicate that it may be a major holdback to fulfil the environmental goals of the Baltic Sea Action Plan, if the demand for humans' animal protein consumption increases as projected.

WHO NEEDS THE INFORMATION

The AMBER results should be of major interest to people involved in administration or legislation. The Baltic Sea Action Plan was historically a milestone, but nevertheless it should be subject of regular inspection and update with respect to new scientific knowledge. Our results may be used for setting quantitative targets for eleven qualitative descriptors of good environmental status as defined by Marine strategy framework directive.

Summerschool in Stockholm 2010

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