The impact of EXtreme events of future climates on the marine ecOSYSTEM in the Baltic and Barents Sea

(EXOSYSTEM)

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Objectives.

We aim at clarifying the effects of climate change on the frequency and severity of extreme events in the marine environment based on a selection of biotic (algal blooms) and abiotic events (floods, extreme wind waves). The target is the two main types of seasonally ice-covered seas: a semi-closed basin (the Gulf of Finland (GoF), Baltic Sea) and an open sea (the Barents Sea). The central hypothesis is that changes in abiotic drivers (e.g. wind intensity, sea ice cover and river runoffs) due to climate change will affect e.g. the mixed layer depth and near bottom currents in a way that will change notably the occurrence of biotic extreme events such as anoxia and harmful algal blooms in the Baltic Sea and spring blooms in the Barents Sea. The key task is to quantify possible changes in the frequency of these events.

Scientific background.

Climate warming is expected to substantially change the functioning of the seasonally ice-covered seas. In particular, for semi-closed Baltic Sea regional climate models indicate general mildening of winters leading to less ice cover, higher summer temperatures, reduced salinity, and decrease in the relative land uplift (BACC Author Team, 2008,; HELCOM, 2013,). In the case of business-as-usual water quality (measured by bottom oxygen and phytoplankton concentrations, and Secchi depth), will eventually deteriorate in the Baltic Sea (Meier et al., 2012, Climate Dynamics, 39: 2421-2441). In the Arctic global warming is amplified and accompanied by unprecedented sea ice decline. Recently, anomalously large ocean heat transport has reduced sea ice formation in the Barents Sea. In 2050, the Barents Sea is projected to be largely ice-free throughout the year (Smedsrud et al., 2013, Rev. Geophysics, 51, 415–449). The decline and eventual disappearance of ice cover means an increase in the vegetative period and growth of primary production in this most fish-rich sea. Vulnerability of the marine ecosystem strongly depend on the occurrence of both biotic and abiotic extreme events such as harmful algae blooms, storm surges, floods, wave storms, changes in stratification, anomalously warm surface waters or severe ice conditions. The frequency of extreme events is expected to increase. However, presently used scenarios are based on coarse resolution models which are not sufficient for local adaption studies. We aim to fill this gap by using high-resolution circulation models coupled to biogeochemical models. Major gaps exist in the understanding of future frequency and severity of extreme events in seasonally ice covered Northern European seas. This applies to both semi-enclosed basins (such as the Baltic Sea or its sub-basins as the Gulf of Finland) and open seas (such as the Barents Sea). It is not clear whether or how the changes in these two types of seas depend on the isolation (of the Baltic Sea from the Atlantic) or openness (of the Barents Sea) A major shortage of the relevant research is that the processes in each basin have been studied based on the input from different models. Until now all studies of the regional effects of climate change in the Baltic Sea have been limited by mismatched boundary conditions and atmospheric forcing (Meier et al., 2012): the boundary conditions in the Danish straits were taken either from the statistical model (for the sea level), or from observations (for temperature, salinity, biogeochemical variables), whereas atmospheric forcing was taken from global models. In the replication of biotic extreme events a significant role belongs mixing. Its key factors are poorly understood. Most of the vertical turbulence schemes fail to resolve the mixed layer and the density gradient between the surface and bottom layer which is crucial for the algal blooms (Myrberg et al., 2010).

Innovativeness.

The methodological basis is the use of (i) consistent boundary conditions and high-resolution atmospheric forcing (37 km, which is much higher than in commonly used global models 200 km) for both seas taken from the global climate model ROM (Sein et al., 2015, JAMES) and (ii) contemporary high-resolution ocean models for both target areas. The atmospheric forcing is applied directly from the ROM (without downscaling).

Work plan.

WP1. (Led the AWI team with the project coordinator D. Sein). In this WP the simulations based on RCP4.5 and RCP8.5 IPCC scenarios for the period 2006-2099 performed with the global ocean - sea-ice - marine biogeochemistry model (MPIOM/HAMOCC) coupled with the regional atmospheric model REMO and global terrestrial hydrology model HD will be analyzed to find correlations between extreme meteorological situations and marine extreme events (algal blooms, floods, wind waves).

WP2. (Led the FMI team with the leader J. Haapala). The sensitivity of simulation of circulation and hydrography in the GoF to existing vertical turbulence parameterizations will be studied using the NEMO model (Madec, 2008, Institut Pierre-Simon Laplace, France, No 27).

WP3. (Led the SPBIO team with the leader V. Ryabchenko). Direct modeling hydrography, currents, ice conditions, ecosystem and biochemistry in the seas will be implemented using the St.Petersburg Baltic Eutrophication Model (SPBEM) in the GoF and a coupled eco-hydrodynamic model developed in SPBIO (Gorchakov et al., 2012) in the Barents Sea. The corresponding boundary conditions and atmospheric forcing will be prescribed from ROM. The optimal mixing parameterization selected in WP2 will be used in above two models.

WP4. (Led the IoC team with the leader T. Soomere). Comprehensive statistical analysis of results obtained in WP1 and WP3 will be performed. Projections of parameters of the extreme events in question (magnitude, return periods, changes in the frequency of occurrence) will be obtained.