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Principal investigator: **Dmitry Sein**

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The modern climate run for the period of 1920-2005 according to the AR5 IPCC scenario and the future climate run for the period 2006-2099 according to RCP8.5 IPCC scenario have been performed with regionally coupled ESM ROM and with MPI-ESM having a course resolution (Sein et al., 2015, JAMES). The results of these simulations were used to prescribe boundary conditions and atmospheric forcing for regional eco-hydrodynamic sea model of the Barents, Kara and White Seas (EHBARSEM). The runs with this model were carried out for the period 1966-2099.

According to RCP8.5-runs, the Arctic Ocean's sea ice cover is thinner in ROM than in MPI-ESM, and by 2055 the Arctic Ocean will reach a seasonally ice-free state, long before this happens in MPI-ESM. In the case of the RCP4.5 scenario, neither the global nor the regional model reaches the seasonally ice-free Arctic Ocean until 2100. Both ROM and MPI-ESM show an extensive decrease in winter nutrient concentrations in the North Atlantic, which is caused by the weakening of vertical mixing. In the northeastern Atlantic Ocean, phytoplankton begins to bloom earlier than in the Arctic Ocean, and annual primary production increases at the end of the 21st century. Despite the good qualitative agreement between MPI-ESM and ROM, the climate change signal in ROM shows an increase in regional features.

Analysis of the simulation with the EHBARSEM for the Barents, Kara, and White Seas showed that for the period 1975-2005 an increase in the area of ice was observed and a drop in the total annual primary production (PP), whereas the opposite situation is characteristic of the period 2035–2065. The antiphase in the time course of the total PP and ice area is quite clearly expressed: for years with low ice cover, a high PP is characteristic and vice versa. It should be noted that compared with the period 1975-2005, for 2035-2065 the total PP values are much higher, and the ice area has decreased significantly (fig. 1.). According to the results of the run for 1975-2005 a regression dependence was obtained for the total annual PP on the average annual ice area and the average annual incident short-wave radiation (SWR). The resulting model showed good results on an independent sample for 2035–2065 (the correlation coefficient was 0.95), which justifies the use of this statistical model for the estimation of PP on the area of sea ice and the incident SWR.

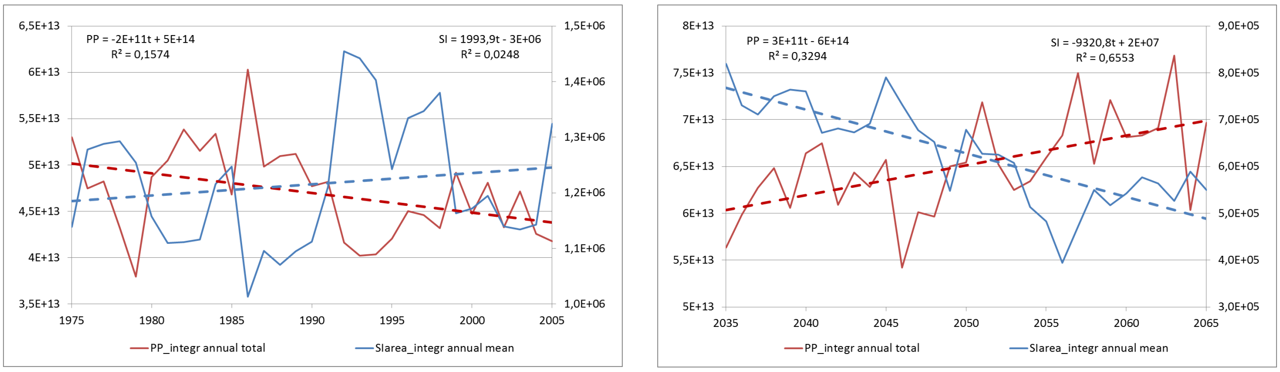

Fig. 1. The interannual variability of the total annual primary production ([g C], left scale) and the average annual ice area ([km^2], right scale) in the model area; left side for the period 1975-2005, right side for 2035-2065.

For the study of the Barents and Kara Seas, we used simulated sea levels from two models, MPI-ESM, and EHBARSEM run for two periods 1933–2005 and 2060–2099 in case of MPI- ESM and 1966–2005 and 2060-2099 in case of EHBARSEM. The MPI-ESM distribution shows better, than EHBARSEM distribution, compliance with a Generalized Extreme Value distribution, approximating the observational data. According to MPI-ESM, the spatial distribution of return levels is characterized by higher values (~ 350 cm) in the western parts of the Barents and Kara Seas coast and lower values (~ 100 cm) in the eastern parts, which indicates two different mechanisms for the occurrence of sea level extremes. The expected change in the future (2060–2099) is from 10 cm (0.1cm/year change) to 60 cm (0.6 cm/year change) (fig.2), with the most substantial change in Pechora Sea which will increase the flooding risk in that region.

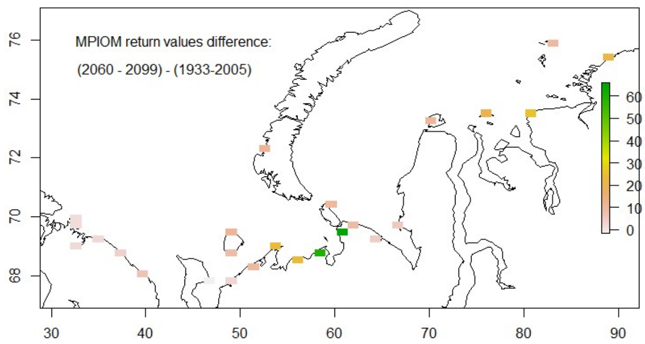

Figure 2. Return levels differences from the MPI-ESM model, period 2060–2099 minus 1933 – 2015.

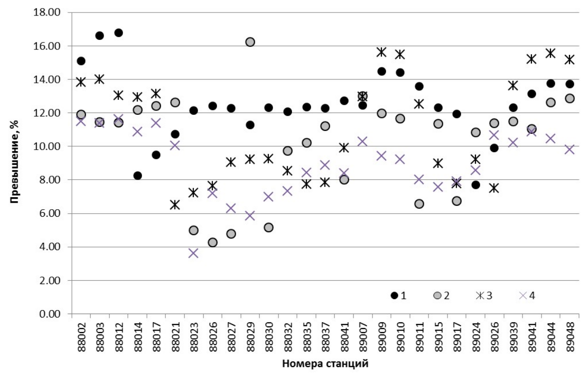

Figure 3. Extreme values of the water surface temperature obtained in the MPI-ESM (1, 2) and EHBARSEM (3.4) models exceeding 1.5 standard deviations for the periods 1966-2005 (1, 3) and 2060-2099 (2, 4) at hydrometeorological stations of the Barents and Kara Seas

A similar analysis of sea surface temperature (SST) at hydrometeorological stations in the Barents and Kara Seas showed that significant SST fluctuations exceeding the standard deviation (SD) over the average value of the period in question, both models reproduce similarly. However, for the climatic period 1966-2005, the MPI-ESM model shows a frequency of small extrema (more than 1.5 SD) in the Barents Sea, 15-17%, which is 3-4% higher than in the EHBARSEM model, and in the eastern part of the Kara Sea - 12- 14%, which is 1-2% lower. At the end of the XXI century, in the western part of the Barents Sea, the frequency of extrema of more than 1.5 SD is almost the same for both models (10–13%), and in the more eastern part, according to the EHBARSEM model, it is 2–4% less, although significant extrema (more than 3 SD) according to this model, appear in the eastern part of the Kara Sea (0.2%), in contrast to the MPI-ESM model, according to which such extremes do not occur at all. If we consider the excess of 2 SD over the average value of the period 1966-2005 to be a significant extreme, then by the end of the century at all stations the maximum SST values for the year will exceed this threshold, and in most cases this will be observed in each year of the simulated period 2060-2099, i.e. with a probability of 100% (Fig. 3).

Summing up the above, it should be noted that the calculations for the climatic period 1966-2005 are in good agreement with the observational data on SST and the area of ice cover. The obtained estimates of the appearance of extreme values of sea level indicate their increase towards the end of the 21st century, especially in the Pechora Sea. According to similar estimates, SST extremes will be observed annually. A decrease in ice cover and an increase in SST will lead to a significant increase in the total annual primary production in the Barents and Kara Seas.