Supporting Information for "Assessing Climate Impacts and Risks of Ocean Albedo Modification in the Arctic"

N. Mengis[1], T. Martin[1], D.P. Keller[1] and A. Oschlies[1,2]

Corresponding author: N. Mengis, Helmholtz Centre for Ocean Research Kiel (GEOMAR), Düsternbrooker Weg 20, 24105 Kiel, Germany. (nmengis@geomar.de)

[1]Helmholtz Centre for Ocean Research Kiel (GEOMAR), Düsternbrooker Weg 20, 24105 Kiel, Germany

[2]Kiel University, D-24098 Kiel, Germany

Appendix A: Tracer Analysis

A virtual dye tracer was implemented in the whole Arctic basin north of 70°N over all depth levels, where it was set to the value 1, at the beginning of the experiment in 2020. To calculate the mean temperature of the water masses that enter the Arctic Ocean, defined as the ocean area north of 70°N, we started by tracking the dilution of the dye tracer. In order to being able to use this information we subtracted 1 from the tracer field and take the absolute value. This enables us to investigate where water masses entered the Arctic Ocean. The mean temperature of the water masses entering the Arctic Ocean, was then calculated as a weighted mean of all temperatures in the Arctic Ocean marked by the tracer with respect to the grid box volume and the dye tracer concentration.

$$T_{mean,entering}(x,y,z,t) = mean_{x,y,z}[T(x,y,z,t) * t_{inv}(x,y,z,t) * V(x,y,z)]/ mean_{x,y,z}[t(x,y,z,t) * V(x,y,z)]$$

T is the ocean temperature, t_{inv} is the inverted tracer concentration with values in $[0,1]$, and V is the volume of the grid box. Figure S5, shows the mean temperature of entering water masses in the Arctic Ocean over time. Note, that the deep convection events in the default RCP4.5 and RCP8.5 simulations are also detectable in this time series, since these events act to cool the entering water masses.

For the calculation of the vertical temperature profiles as shown in Figure 5b, we did not integrate over z.

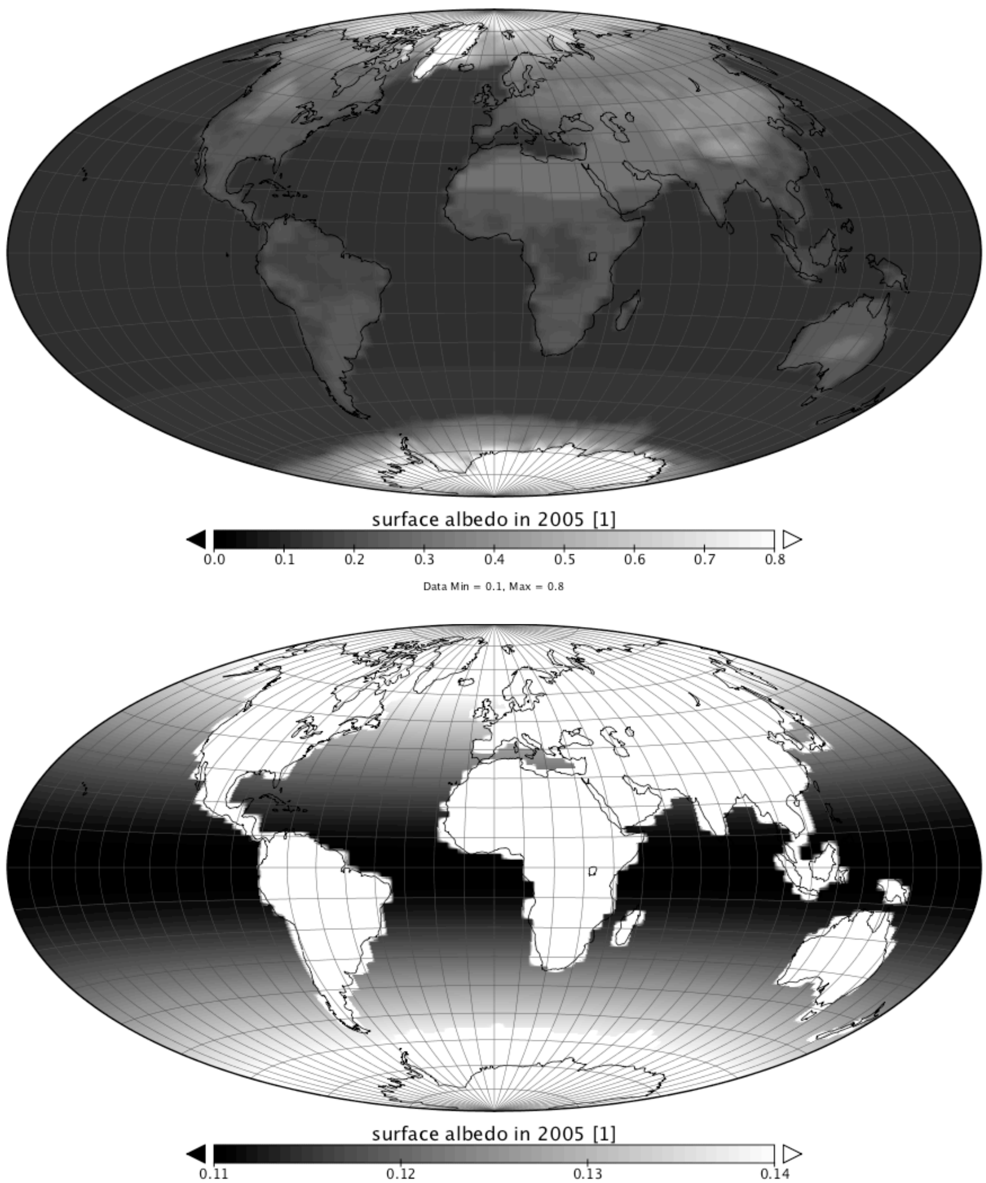

Figure S1. Regional distribution of the surface albedo in UVic ESCM in 2005. top: For a global perspective with colour axis from 0 to 0.8; bottom: For an oceanic perspective with colour axis from 0.11 to 0.14.

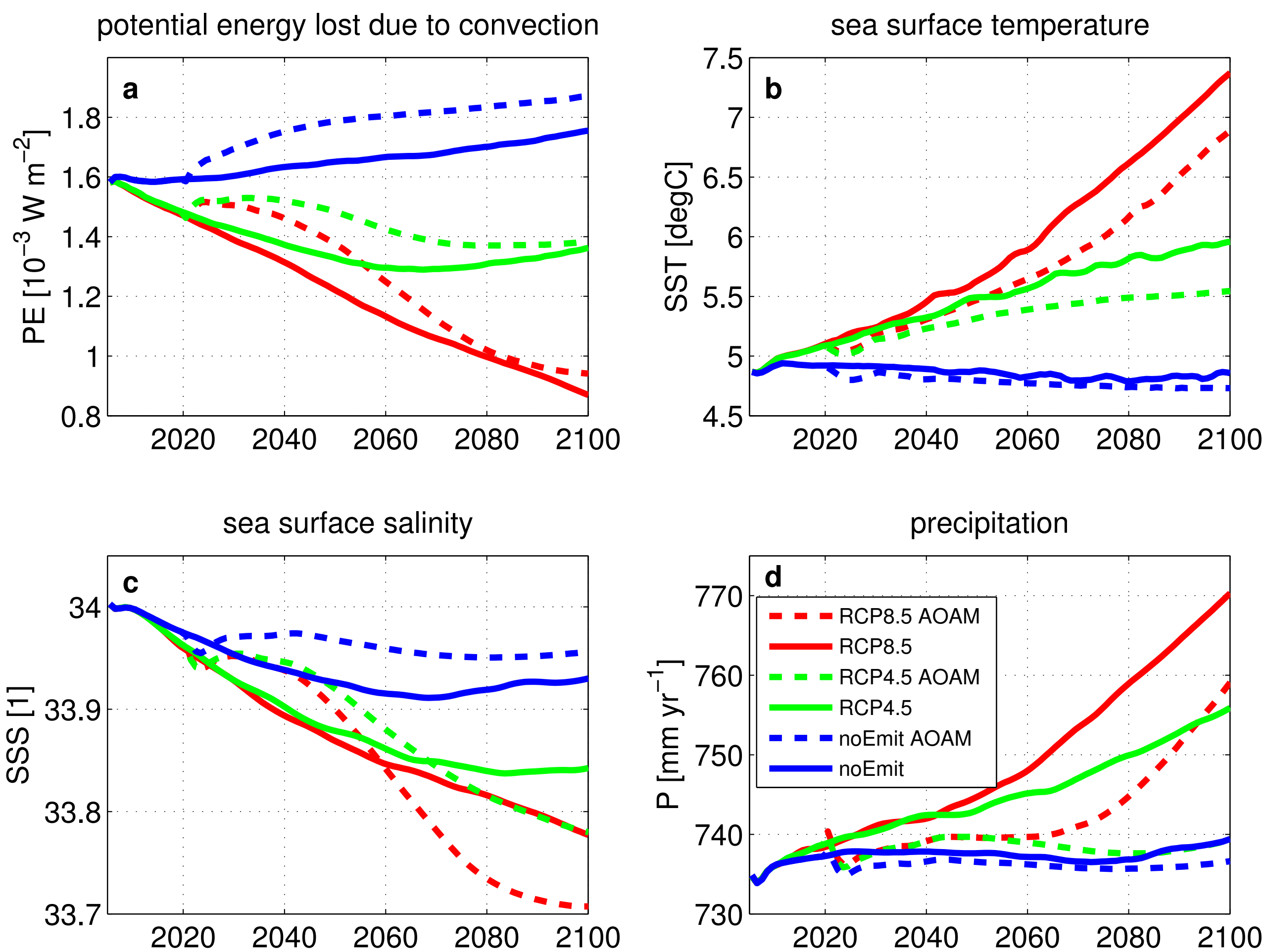

Figure S2. Annual average properties of the Atlantic ocean surface between 50 to 70°N. a) Potential energy lost to convection; b) sea surface temperature; c) sea surface salinity; and d) precipitation.

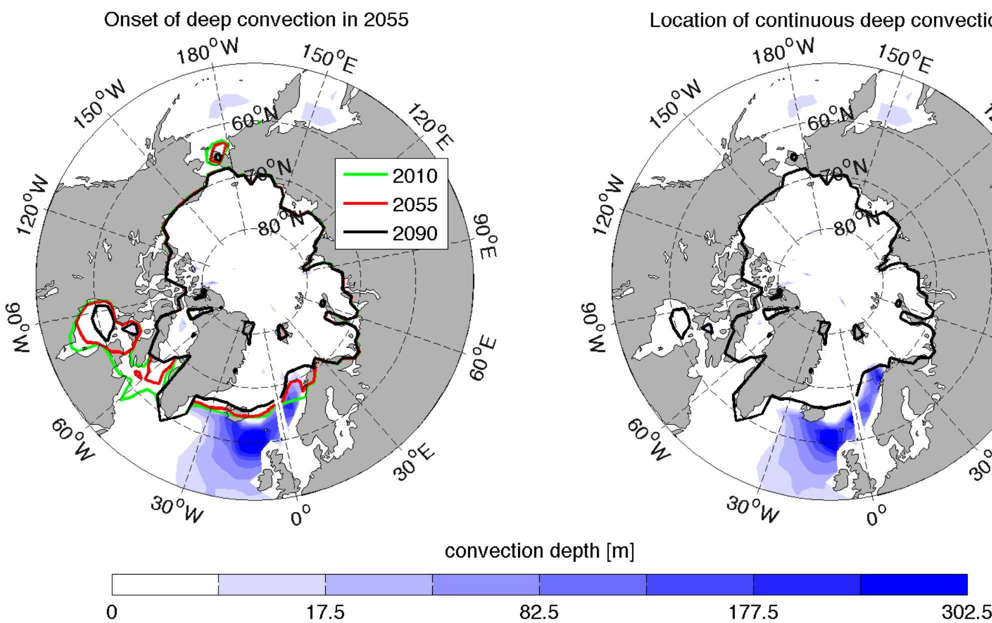

Figure S3. left: Location of deep convection areas in 2055, when deep conception is starting to emerge north of 65°N in the RCP8.5 experiment, as an exemplary temporal snap shots. Shown are annual mean sea ice edges for 2010 (green), 2055 (red) and 2090 (black), to show the ice edge location before and with fully developed deep convection.

right: The location of the newly formed continuous deep convection sites in the Nordic seas in the RCP8.5 simulation averaged over 2090-2100. Shading indicates the average number of convected levels and the black contour is the mean ice edge.

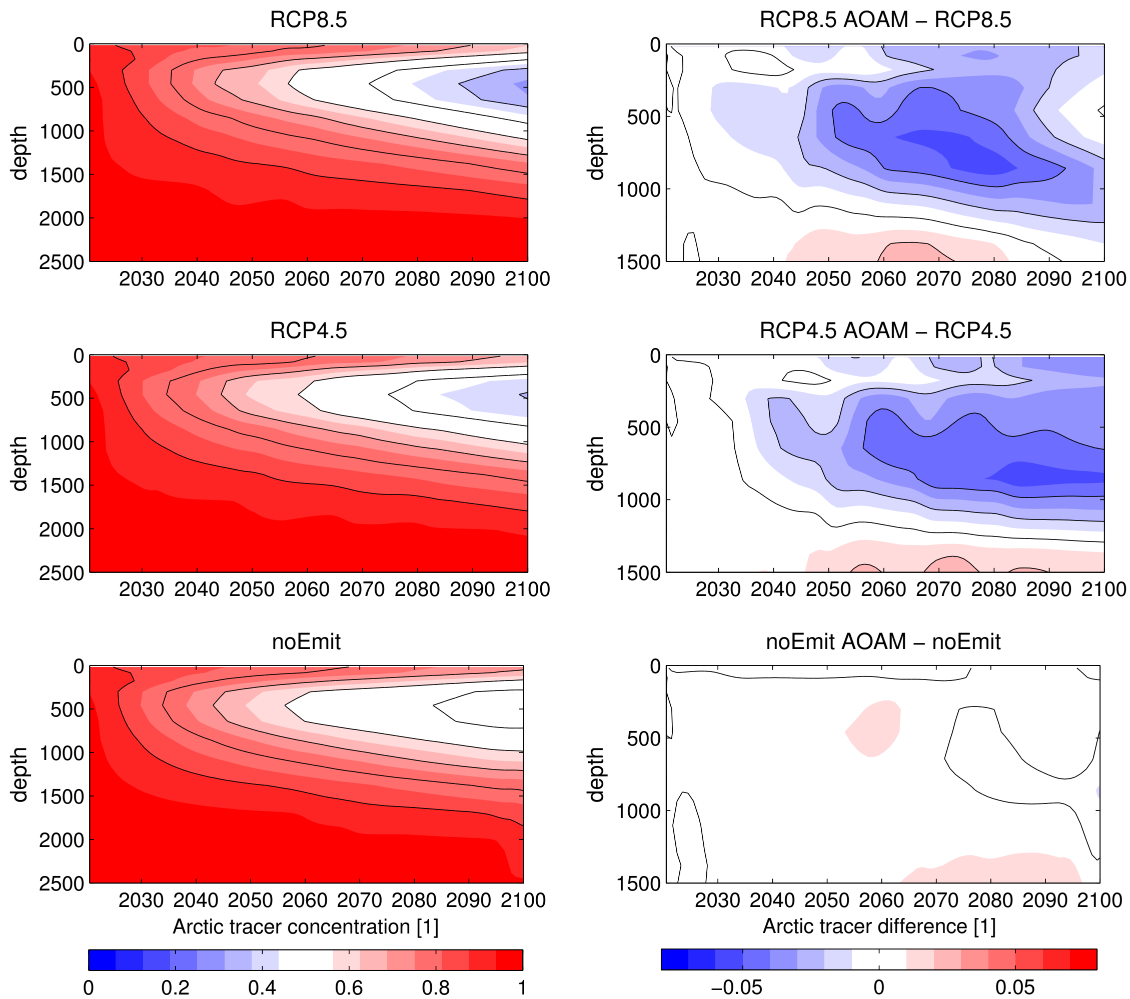

Figure S4. left: Hovmöller diagrams of the Arctic tracer for the three default scenarios; right: Hovmöller diagrams of the impact of the AOAM implementation on the mean Arctic vertical tracer concentration.

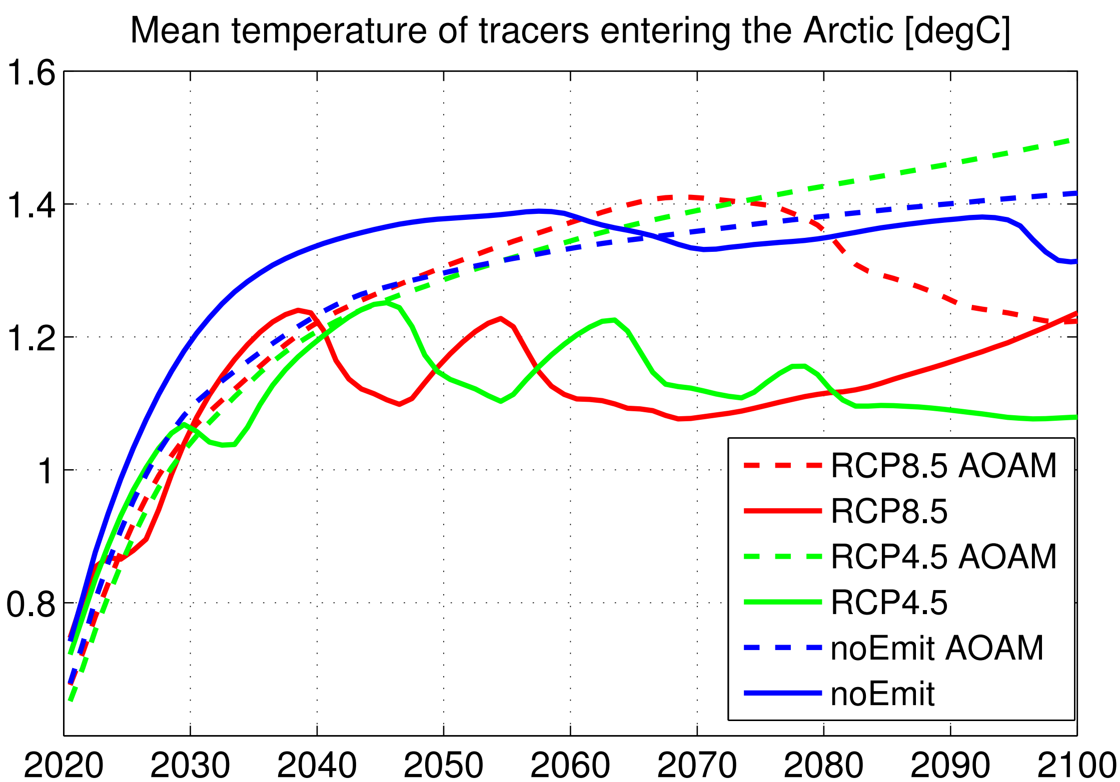

Figure S5. Time series of mean temperature of traced water masses entering the Arctic Ocean, calculated as described in Appendix A. Note, that this display includes both, changes in the dye tracer volume as well as changes in the temperature of the traced water masses.

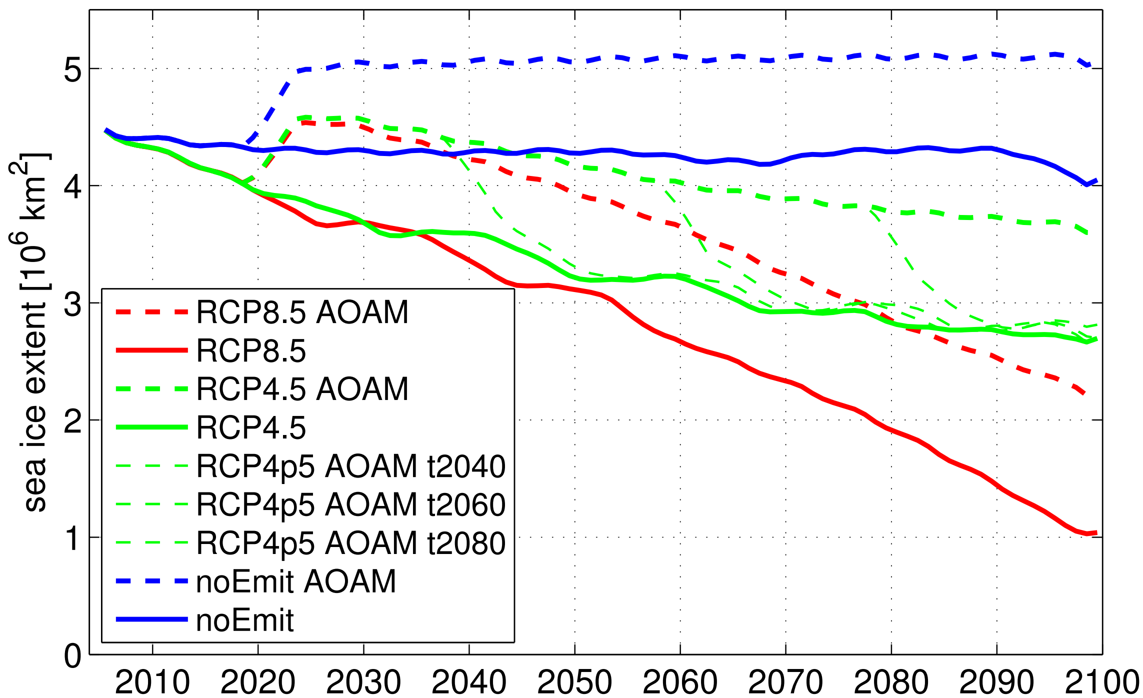

Figure S6. Northern Hemisphere annual minimum sea ice extent for the different forcing scenarios, see legend. Same as Figure 2a of the main article, with the addition of three termination experiments in the RCP4.5 AOAM simulation starting in 2040 (RCP4p5 AOAM t2040), 2060 (RCP4p5 AOAM t2060) and 2080 (RCP4p5 AOAM t2080).

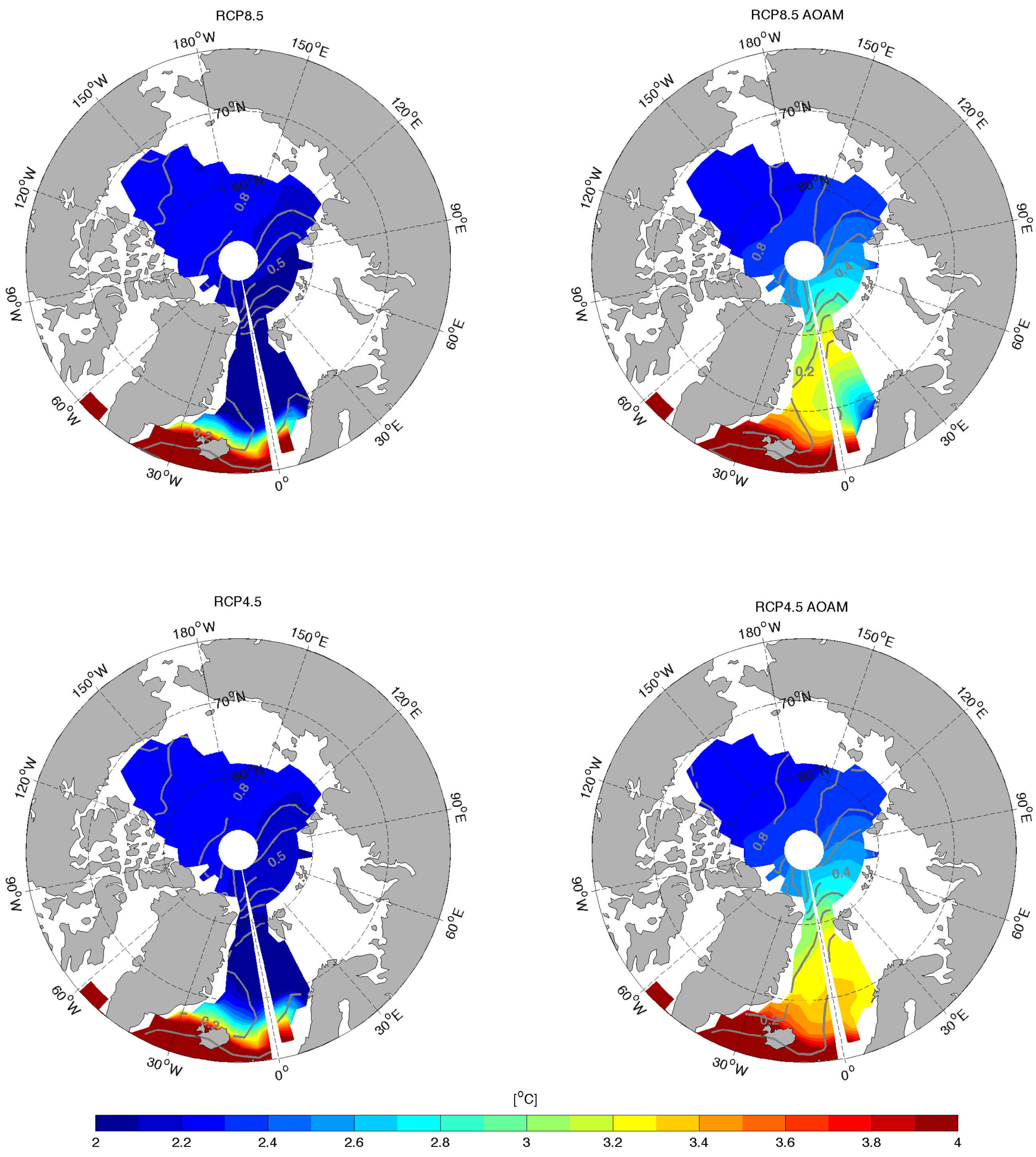

Figure S7. Arctic ocean temperatures in 2070 at about 850m depth for four experiments. The grey contours show the tracer concentration after 50 years of integration.