Role of the changing river runoff in the Arctic ocean stratification

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Abstract

We investigate the effects of increasing river runoff – the largest freshwater source to the Arctic with a clear, increasing trend (Rawlins et al, 2010) – on Arctic water mass properties.

The trivial result of the surface freshening and the stronger stratification appears to be counteracted by thinning of the surface layer and the halocline, and diminishing of the cold halocline.

Methods

For the extensive perturbation tests with changing river runoff we use modified version of 1DICE Arctic ocean – ice – air column model (Björk, 1989). In addition we perform a perturbation test with doubled Arctic river runoff with 3D ice-ocean model. We use the NorESM platform with MICOM coupled to CICE. The system is forced with the CORE-II normal year forcing and the grid setup is bipolar with the north pole over Greenland resulting to 1° resolution in general (see also Bentsen et al, 2012).

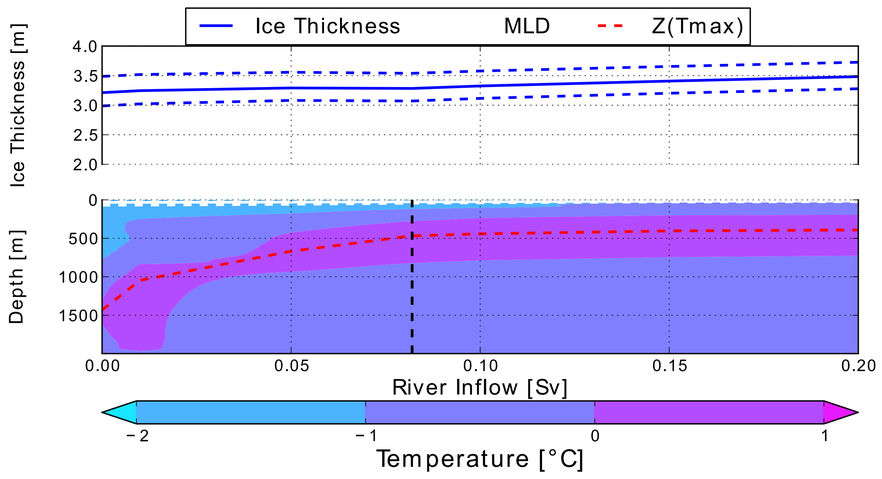

Figure 1. Ice Thickness and temperature changes in the water column. Red dashed line is the maximum temperature in the water column and black dashed line denotes the river runoff in the present climate (also in Figures 2 & 3).

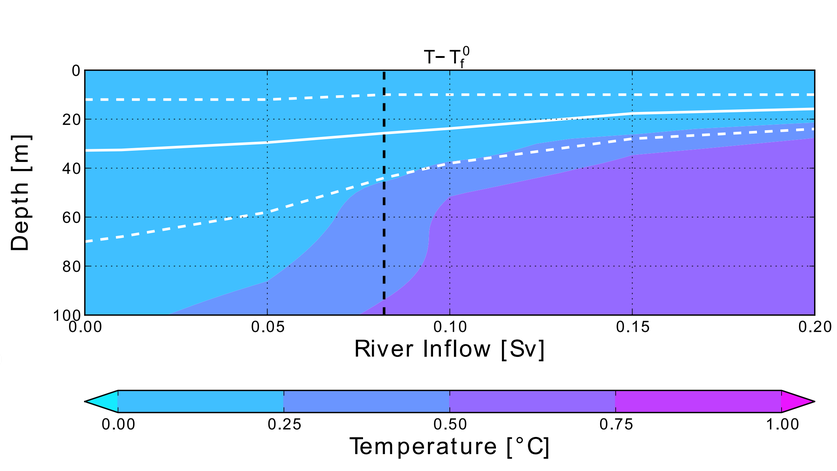

Figure 2. Temperature of the water column compared to freezing point temperature at the surface. White dashed line is the mixed layer depth (as in Figure 1).

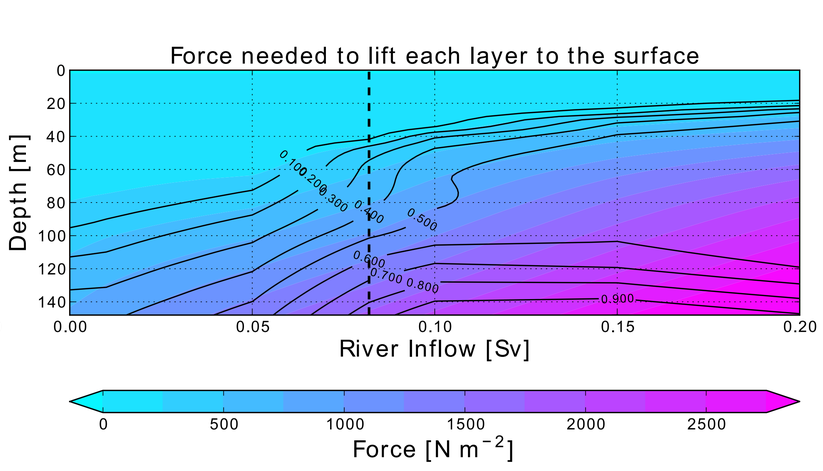

Figure 3. Filled contours show how large force has to be used to lift each layer to the surface. The contour lines on top show the temperature of the water column compared to the surface freezing point temperature.

Results

We find that while the surface stratification strengthens with the increasing runoff, the surface mixed layer thins and warmer water is found closer to the surface (Figures 1 and 2). However, there is little change in the force needed to mechanically mix the warm waters toward the surface, against the stronger stratification. This is seen in Figure 3 as just below the surface mixed layer temperature contours mostly follow the isolines of the force needed to mix the waters to the surface. As a result the effect on the sea ice thickness remains small in the 1D simulations (Figure 1).The column model reproduces previous theoretical considerations (Rudels, 2010) on the Arctic freshwater content and outflow: freshwater content increases as the surface salinity decrease dominates over the thinning of surface mixed layer.

In the 3D simulations we find similar warming of the subsurface layers as in the 1D simulations (Figure 6). In addition we find changes in the cold halocline as the increasing runoff alters shelf convection processes (Figures 4-6). Doubling the river runoff results to very fresh waters at the shelves restricting the convection to shallow surface layer. Consequently the Arctic halocline is degrading and the temperatures just below the surface mixed layer increase over 0.5 °C (Figure 6)

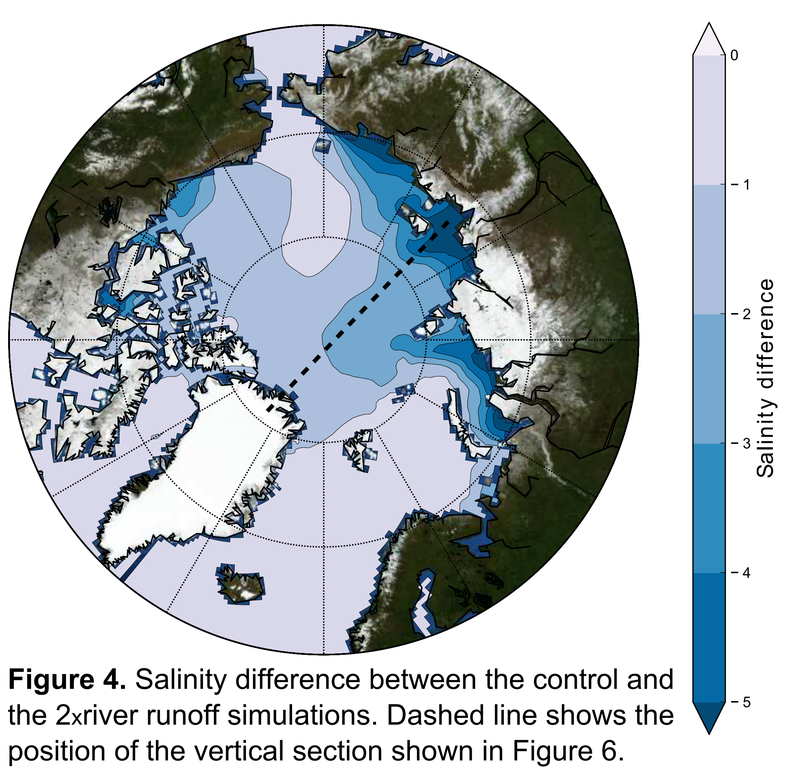

Figure 4. Salinity difference between the control and the 2xriver runoff simulations. Dashed line shows the position of the vertical section shown in Figure 6.

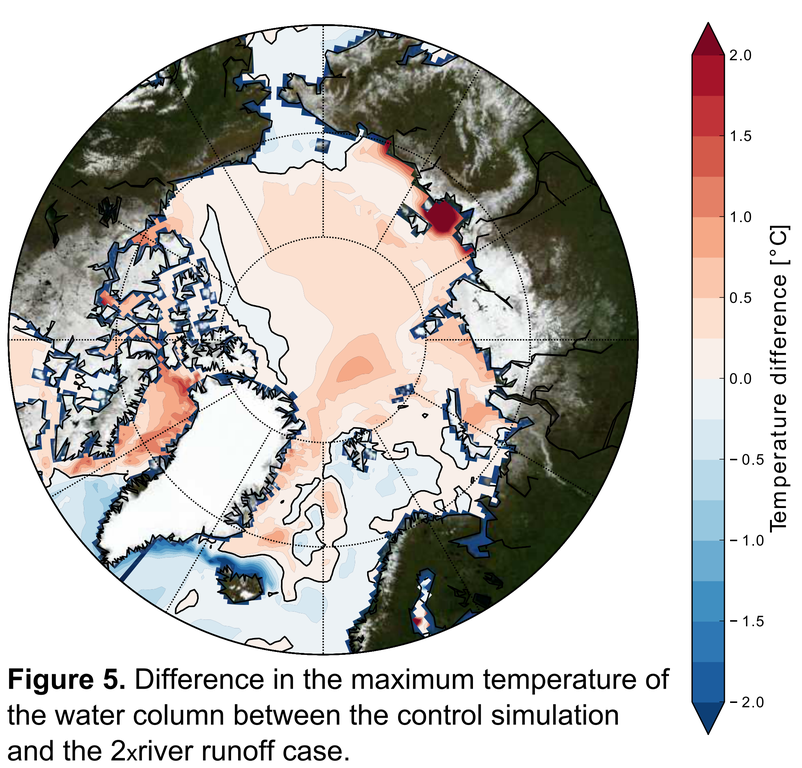

Figure 5. Difference in the maximum temperature of the water column between the control simulation and the 2xriver runoff case.

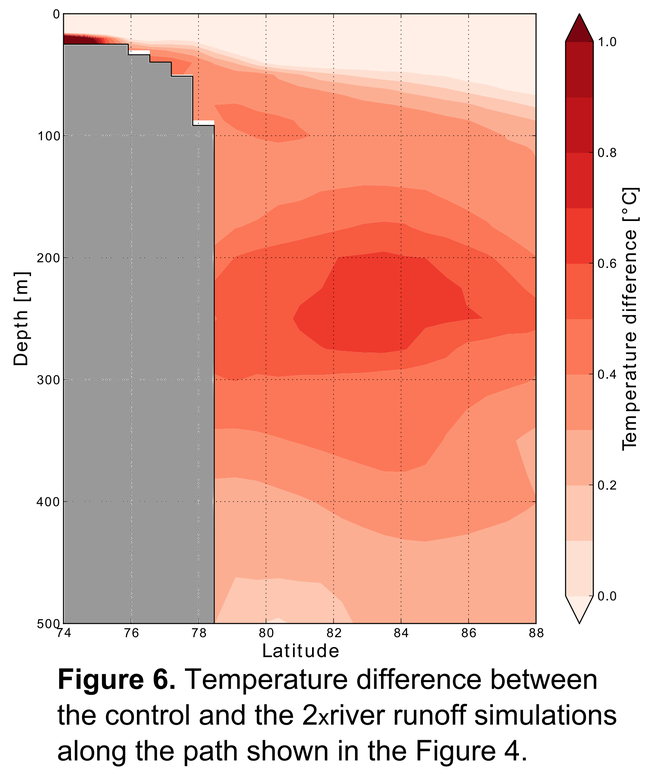

Figure 6. Temperature difference between the control and the 2xriver runoff simulations along the path shown in the Figure 4.

Conclusion

Increasing Arctic river runoff has small positive effect on the sea ice thickness. However the related changes in subsurface stratification are notable and can have further implications together with other changes in the warming climate.

References

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