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Effects of sea-ice changes on Arctic temperature amplification and climate sensitivity

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Observations show that the greatest warming on Earth in recent decades took place in the Arctic. Also simulations with global climate models, forced with increased greenhouse gas concentrations, agree on enhanced warming in high northern latitudes, called Arctic amplification. The resulting warming for a given forcing is determined by the equilibrium climate sensitivity of the climate system. In the Arctic climate system, sea ice is a key factor. It is therefore imperative to get a better understanding of the effects of northern hemisphere sea-ice changes on Arctic temperature amplification, and on global and Arctic climate sensitivity.

Two aspects of northern hemisphere sea-ice cover are examined using simulations of global climate models: initial sea-ice cover, and sea-ice cover sensitivity to global and Arctic temperature change. In addition, their relation with Arctic temperature amplification and global and Arctic climate sensitivity is investigated. This is done by analysing long-term climate experiments of phase 5 of the Coupled Model Intercomparison Project (CMIP5). The two types of experiments that we used are forced with prescribed CO_2 concentrations: in one scenario CO_2 is increased by one percent per year (simulation length=140 yr) and in the other scenario CO_2 is increased abruptly to four times its initial value (150 yr). As control experiment a pre-industrial forcing scenario is used.
For the one percent per year CO_2 increase scenario, we find a strong relation between the initial state of sea ice and sea-ice sensitivity to both global and Arctic temperature change, suggesting that the sea-ice feedback strength depends on the climate state itself. Furthermore, we computed the equilibrium climate sensitivity of the models using the abrupt 4xCO_2 increase experiment. We find a stronger relation between sea-ice sensitivity to global temperature and global climate sensitivity, than between sea-ice sensitivity to Arctic temperature and Arctic climate sensitivity. Additionally, we did not find a significant relation between sea-ice initial extent, or sea-ice sensitivity, to global or Arctic temperature, and magnitude of Arctic amplification.

These findings might imply that initial sea-ice extent determines the rate at which sea-ice cover declines in response to temperature changes. To get a proper representation of sea-ice evolution in coupled models it is then required to have an accurate sea-ice cover in the initial climate state. It appears that other mechanisms than those related to sea ice determine the magnitude of Arctic amplification and Arctic climate sensitivity in global climate models. Apparently, therefore, the combined effect of other temperature feedback mechanisms is stronger than the ice-albedo feedback alone. Vice versa, the magnitude of Arctic climate sensitivity or Arctic amplification seems to not significantly affect sea-ice sensitivity to temperature change. However, as global climate sensitivity determines the magnitude of warming in response to a greenhouse gas forcing, it does influence the total response of sea ice to the forcing. This study suggests that sea-ice changes depend on climate state, and to a less extent on climate change.