A Comparison between the mid-Holocene and the future in the Arctic warming mechanism

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From the climate model simulations, it is projected that the Arctic warming will be strengthened in the future.
However, the degree of projected warming varies with climate models and there are substantial uncertainties in the future projections of Arctic warming.
Shmidt et al.(2013) suggested a possibility of constraining uncertainty in the future climate projections by using information from past periods when the Arctic region was warmer than today. In their study, however, only a statistical correlation between paleoclimate and future climate simulations across models is presented. Therefore, the underlying mechanism causing the correlation is unclear. As they are well aware, the sound physical explanation is necessary in order for us to apply their method to constrain the future climate projections.
The principle aim of this study is to investigate commonality and difference of Arctic warming mechanism in the past and in the future, and to obtain insight into the possibility of constraining uncertainty of future climate projections by using paleo-climate data. We use the outputs of pre-industrial control, the quadruple of atmospheric CO_2 concentration($4\times CO_2$) and mid-Holocene experiments from 11 CMIP5/PMIP3 atmosphere-ocean general circulation models. The mid-Holocene here refers to 6000 years ago and the Arctic region was warmer than today because of the difference in earth’s orbital parameters.
First, we identified predominant processes of Arctic warming in each experiment based on the surface energy balance, and also investigated sea ice, clouds, water vapor and sea surface temperature response. In both experiments, most of the anomalous energy input into the Arctic region in summer is used for melting of sea ice, absorbed into the ocean. Consequently, the surface warming is moderate during summer. Several months later, the heat is released from the exposed warm sea surface and it causes the Arctic warming. In addition, the role and approximate timing of sea ice, clouds and water vapor changes are common in the two experiments. We found that there are many commonality in the Arctic warming mechanism in the future and in the mid-Holocene even though they are caused by completely different external forcing.
Next, we quantified that contribution of individual processes to the inter-model variance of the surface temperature changes in the Arctic region for each experiment. In the $4\times CO_2$ experiment the largest contribution to the variance of annual mean (ANN) surface temperature change is the surface albedo feedback. As to the October - December (OND) mean surface temperature change, on the other hand, it is the heat release from the ocean. In the mid-Holocene experiment the largest contributions to the variance of both ANN and OND surface temperature change in the Arctic region are made by the differences in downward clear-sky longwave radiation. Also, the contribution of the surface albedo feedback to the variance of ANN surface temperature changes and the contribution of the oceanic heat release to the variance of OND surface temperature changes are relatively large and statistically significant. As the surface temperature and near-surface air temperature which determines the downward longwave radiation are tightly coupled, it is expected that constraints of other processes would result in a reduction of total uncertainty. In other words, if the Arctic warming in the mid-Holocene is simulated accurately, the reliability of the model’s representation of surface albedo feedback, the process related to oceanic heat release, and hence the future projections would increase.

Based on the understanding of Arctic warming mechanism from this study, it is considered that paleo-environment information of Arctic Warming in the mid-Holocene is useful for constraining uncertainty in the future projections of Arctic warming.

Keywords: Climate models, Paleoclimate, Future projections