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Contributing processes to Arctic amplification for a range of forcing in MIROC GCM

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It is a robust feature among general circulation models that surface warming in the Arctic exceeds that in lower latitudes under the global warming. While various mechanisms have been proposed, their contributions are hardly quantified systematically. Such diagnosis is an urgent task in order to understand model behaviors and the operating mechanism for the large latitudinal difference. Here we apply a recently proposed feedback analysis technique, Climate Feedback-Response Analysis Method (CFRAM), to a full GCM which includes the hydrological cycle, and quantify the relative contributions under different external forcings. The simulated temperature change by the GCM is reasonably well reproduced by the sum of independently diagnosed CFRAM decompositions. The existing radiative kernel technique was extended to evaluate the radiative components of the CFRAM for the first time, which widens the applicability of the CFRAM considerably. Surface temperature response in the Arctic is amplified by rediative feedbacks of albedo, water vapor, and clouds, and large-scale condensation heating. This diagnosis is consistent with increased moisture transport from lower latitudes, and reduced sea ice cover and consequent increase in evaporation under warming. Enhanced warming near the surface caused by these processes is diagnosed as lapse rate feedback in the conventional analysis of top-of-the-atmosphere radiative effect. Albedo feedback is not always a predominant factor and the change in evaporative cooling equally contributes or exceeds it in some cases in maintaining the anomalous meridional temperature contrast. As a consequence, the sign of the total radiative feedback contribution to the contrast depends on the forcing, but the total non-radiative feedback contribution is consistently positive. Important contribution to the contrast is also made not via ‘dry’ heat transport process but through the hydrological cycle. Similar analysis for other GCMs is strongly encouraged in order to reveal robustness of the results and evaluate uncertainties.