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Relative contribution of feedback processes to Arctic amplification of temperature change in MIROC GCM

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The finding that surface warming over the Arctic exceeds that over the rest of the world under global warming is a robust feature among general circulation models (GCMs). While various mechanisms have been proposed, quantifying their relative contributions is an important task in order to understand model behavior and operating mechanisms. Here we apply a recently proposed feedback analysis technique to a GCM under different external forcings including elevated and lowered CO_2 concentrations, and increased solar irradiance. First, the contribution of feedbacks to Arctic temperature change is investigated. Surface air temperature response in the Arctic is amplified by albedo, water vapor, and large-scale condensation feedbacks from that without a feedback although a part of it is suppressed by evaporative cooling feedback. Second, the contribution of feedbacks to Arctic amplification (AA) relative to global average is investigated. Under the positive radiative forcings, the albedo feedback contributes to AA predominantly through warming the Arctic more than the low latitudes while the evaporative cooling feedback contributes to AA predominantly by cooling the low latitudes more than the Arctic. Their relative effects vary with the applied forcing, however, and the latter dominates over the former in the increased solar irradiance and lowered CO_2 experiments. The large-scale condensation plus evaporative cooling feedback and the dynamical feedback contribute positively and negatively to AA, respectively. These results are consistent with an increase and a decrease of latent heat and dry-static energy transport, respectively, into the Arctic under the positive radiative forcings. An important contribution is thus made via changes in hydrological cycle and not via the ‘dry’ heat transport process. A larger response near the surface than aloft in the Arctic is maintained by the albedo, water vapor, and dynamical feedbacks, in which the albedo and water vapor feedbacks contribute through warming the surface more than aloft, and the dynamical feedback contributes by cooling aloft more than the surface. In our experiments, ocean and sea ice dynamics play a secondary role. It is shown that a different magnitude of CO_2 increase introduces a latitudinal and seasonal difference into the feedbacks.

Keywords: Arctic amplification, global climate model