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Impact of subgrid-scale ice thickness distribution on heat flux on and through sea ice

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We evaluate the impact of subgrid-scale ice thickness distribution on the heat flux on and through sea ice in a numerical model. An ice-ocean coupled model with a subgrid-scale ice thickness distribution scheme, COCO4.5, is used. The number of the thickness categories is 15. The model is forced by an atmospheric climatology based on the CORE (Common Ocean Reference Experiment) normal year forcing to simulate the present state of the sea ice and ocean. The modeled climatology reproduces the ice cover reasonably well with a realistic ice thickness distribution. The heat flux on and through the sea ice is established using the grid-representative sea-ice and snow-on-ice thickness calculated by some different methods from the results of the identical simulation. When the grid-representative thickness is calculated as a weighted arithmetic mean of the subgrid-scale ice thickness distribution, the conductive heat flux through the ice and snow is underestimated compared with that actually driving the model. The bias is larger in the Arctic basin (approximately 50% underestimation) compared with that in the Southern Ocean (approximately 20%). This underestimation becomes smaller in magnitude when a weighted harmonic mean is employed as the grid-representative thickness. The ratio of the weighted harmonic mean thickness to the weighted arithmetic mean thickness, c_m, is smaller in the Arctic basin compared with that in the Southern Ocean. The smaller c_m in the Arctic basin corresponds to the larger heat flux bias there. The flux underestimation also becomes smaller when the conductive heat flux is calculated using the weighted arithmetic mean thickness multiplied by c_m. The heat flux is also established with using the subgrid-scale ice thickness distribution rearranged to smaller number of the categories than the original. The result shows that the flux bias decreases with an increase in the number of categories. We also perform a sensitivity experiment in which the model is forced by the biased heat flux identified using the arithmetic mean of the ice thickness. A significant decrease in ice volume is found, notably in the Arctic Ocean. These results suggest that sea-ice models without an ice thickness distribution scheme underestimate the conductive heat flux through ice, and thereby the resultant sea-ice thickness, because the ice thickness from these models typically corresponds to the weighted arithmetic mean thickness.