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Impact of variable atmospheric and oceanic form drag on simulations of Arctic sea ice

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Over Arctic sea ice, pressure ridges, floe and melt pond edges all introduce discrete obstructions to the flow of air or water past the ice, and are a source of form drag. In current climate models form drag is only accounted for by tuning the air-ice and ice-ocean drag coefficients, i.e. by effectively altering the roughness length in a surface drag parameterization. The existing approach of skin drag parameter tuning is poorly constrained by observations and fails to describe correctly the physics associated with the air-ice and ocean-ice drag. Here we combine recent theoretical developments to deduce the total neutral form drag coefficients from properties of the ice cover such as ice concentration, vertical extent and area of the ridges, freeboard and floe draft, and size of floes and melt ponds. We incorporate the drag coefficients into the CICE sea ice model and show the influence of the new drag parameterization on the motion and state of the ice cover, with the most noticeable being a depletion of sea ice over the west boundary of the Arctic Ocean and over the Beaufort Sea. The new parameterization allows the drag coefficients to be coupled to the sea ice state and therefore to evolve spatially and temporally. We find that the range of values predicted for the drag coefficients agree with the range of values measured in several regions of the Arctic. Finally we discuss the implications of the new form drag formulation for the spin-up or spin-down of the Arctic Ocean.