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Contrasting effects of sea ice thinning and retreat on Arctic Ocean momentum influx

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The current thinning and retreat of the Arctic sea ice cover has a non-trivial effect on the momentum transfer into the ocean as decreases of ice concentration and thickness have different consequences. On the one hand, a thinner and thus weaker ice cover is more easily forced by the wind to drift faster, which increases the momentum flux into the ocean. On the other hand, sea ice retreat reduces momentum transfer because the ice surface provides greater drag than the open water surface for common wind speeds. We quantify these effects by analyzing the ocean surface stress from an Arctic-wide coupled sea-ice ocean model simulation covering the period 1979–2012. Over this time span the basin-wide annual mean ocean surface stress has been increasing by 0.004 N/m^2/decade with an even steeper trend of 0.006 N/m^2/decade since 2000. The positive trend is associated with the winter months and caused by the weakening of the ice cover. In summer, however, the ocean surface stress has been decreasing at -0.002 N/m^2/decade. The latter can be attributed to the complete melt of sea ice in vast areas of the Arctic Ocean during recent summers, exposing a generally smoother ocean surface. Note, these trends are not a consequence of a change in available momentum (wind forcing) but rather due to changing momentum transfer.

Further, we introduce the concept of optimal ice concentration, which helps to understand the effect of sea ice retreat: as sea ice provides greater drag than open water, the momentum transfer increases with increasing ice concentration up to a point, the optimal ice concentration, at which further gain of ice compactness is accompanied by exponentially growing frictional losses due to flow interaction. For a common formulation of the ice internal stress a concentration of 80% to 90% yields optimal amplification of the momentum transfer into the ocean. While in the 1980s most of the Arctic Ocean featured ice concentrations of more than 85% even in summer, summer sea ice concentrations are predominantly below this optimal ice concentration during the recent decade.