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Rate and state sea ice friction

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The distribution of ice thicknesses in the Arctic is a function of the ice deformation which occurs through ridging, rafting and sliding of ice floes. To determine the relative importance of each of these forms of deformation, it is crucial to have a good model of ice friction. We present data on ice-ice friction from a series of large ice-tank experiments, undertaken at the HSVA ship testing facility in Hamburg, Germany. We focus on the impact of varying the sliding rate, and the hold-time before commencing sliding, following the work of Ruina (1983). We move a 2m square floating ice block, of thickness 25cm, under horizontal normal stress, and detail the force required to move the block and hence the implied friction coefficient ?. Loads are of the order 1kN. We find that the time-averaged friction coefficient shows slight rate-dependence, and ? = 0.3-0.4 for a variety of rates (from 1-10cm/s). However, the detailed sliding mechanism varies with rate, and stick-slip behaviour is observed at low rates. The state-dependence is found to be a crucial factor in determining the load required to initiate movement of the ice block. To test for state dependence we apply the side load for a given time interval (the hold time) before starting to move the block. With a hold time of 1000s, the forces are an order of magnitude greater than with a hold time of 10s, and we present data for hold times from 1- 1000s. This work has important implications for sea ice rheology components within global climate models, particularly given that recent satellite observations show that almost all the deformation of Arctic sea ice is due to in-plane frictional sliding. The results outlined above suggest that the static contact time between ice floes may be the key parameter influencing the ensemble movement of sea ice. The work also has value for smaller-scale modelling of sea ice for engineering purposes, for example in predicting forces on offshore structures. As well as presenting our results, we will discuss possible further experiments to extend the range of validity of the work.