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A scaling law for similar ice sheet flow

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The time scales of the flow and retreat of the outlet glaciers draining Greenland and Antarctica and their potential instabilities are arguably the largest uncertainty in future sea-level projections. The associated stress and velocity fields are highly complex. Here we derive an exact scaling law from first principles that shows that the time scale of outlet-glacier flow is related to the inverse of 1) the fourth power of the width-to-length ratio of its topographic confinement, 2) the third power of the confinement depth and 3) the temperature-dependent ice softness. We show that idealized numerical simulations of marine ice-sheet instabilities (MISI) as found in Antarctica follow this theoretical prediction. In a further step we apply the scaling law to observations of different MISI-prone Antarctic outlets to compare their potential instability time scales. The simple scaling relation incorporates the full complexity of the ice stress field of a fast outlet glacier similar to the predictive power of the thermodynamic equations of an ideal gas. In quantifying the non-linear influence of glacier geometry and temperature on the ice dynamicsscaling law allows to investigate similar ice flow under future global warming.