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Observation-Consistent Nonlinear Ice Melt Contribution to Sea Level Rise and its Implications for Sea-Level Projections

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Sea level rise is a major result of climate change that threatens coastal communities and has the potential to incur significant economic damage. Projecting sea level rise as temperatures rise is therefore crucial for policy and decision-making.

The two modelling methods currently used to project future sea level change are process-based and semi-empirical. Process-based models rely on combining outputs from coupled atmosphere/ocean models for each component of sea level rise. Semi-empirical models calculate sea level as an integrated response to either warming or radiative forcing, using parameters constrained from past observations.

Historically, there is disagreement in sea-level projections between different modelling methods. One source of the discrepancies is uncertainty in land ice response to warming; although nonlinearities exist within processes affecting this response, most existing semi-empirical models treat the relationship between warming and ice-melt as linear.

Non-linear ice melt processes may have not yet affected the observational record (such as tipping points as future warming crosses some threshold) or may have already occurred (such as non-linear effects that apply across all levels of warming, or for which the threshold has already been passed). Here, we examine the effect on semi-empirical projections of sea level rise of nonlinearities in ice melt that have already affected the observed sea level record, by adding a nonlinear term to the relationship between warming and the rate of sea level rise within a large ensemble of historically constrained efficient earth systems model simulations.

Projections reach a median sea level rise of 1.3m by 2300 following SSP245, and 2.6m by 2300 following SSP585. Results suggest that nonlinear interactions can be sub-linear, super-linear or 0, with a mainly symmetrical distribution. This includes high-impact, low-probability super-linear interactions that lead to significantly larger high-end sea level rise projections than when nonlinear interactions are not included. It is key to note that nonlinear interactions that have not yet occurred but that may occur in the future, are not considered – these will lead to an increased projection of sea level rise.