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Gaussian Process emulation of multi-model ice sheet and glacier projections

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The land ice contribution to global mean sea level rise has not yet been predicted with ice sheet and glacier models for the latest set of socio-economic scenarios (SSPs), nor with coordinated exploration of uncertainties arising from the various computer models involved. Two recent international projects (ISMIP6 and GlacierMIP) generated a large suite of projections using multiple models, but mostly used previous generation scenarios and climate models, and could not fully explore known uncertainties.

Here we estimate probability distributions for these projections for the SSPs using Gaussian Process emulation of the ice sheet and glacier model ensembles. We model the sea level contribution as a function of global mean surface air temperature forcing and (for the ice sheets) model parameters, with the 'nugget' allowing for multi-model structural uncertainty. Approximate independence of ice sheet and glacier models is assumed, because a given model responds very differently under different setups (such as initialisation).

We find that limiting global warming to 1.5°C would halve the land ice contribution to 21st century sea level rise, relative to current emissions pledges: the median decreases from 25 to 13 cm sea level equivalent (SLE) by 2100. However, the Antarctic contribution does not show a clear response to emissions scenario, due to competing processes of increasing ice loss and snowfall accumulation in a warming climate.

However, under risk-averse (pessimistic) assumptions for climate and Antarctic ice sheet model selection and ice sheet model parameter values, Antarctic ice loss could be five times higher, increasing the median land ice contribution to 42 cm SLE under current policies and pledges, with the 95th percentile exceeding half a metre even under 1.5°C warming.

Gaussian Process emulation can therefore be a powerful tool for estimating probability density functions from multi-model ensembles and testing the sensitivity of the results to assumptions.

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