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Grand designs: quantifying many kinds of model uncertainty to improve projections of sea level rise

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In the EU Horizon 2020 project PROTECT, we have performed around 5000 simulations of the Greenland and Antarctic ice sheets and the world's glaciers to predict the land ice contribution to sea level rise up to 2300. Unlike previous international model intercomparison projects (Edwards et al., 2021; IPCC Sixth Assessment Report, 2021), this is a "grand ensemble" sampling every type of model uncertainty – plausible structures, parameters and initial conditions – and is performed under many possible boundary conditions (climate change projected by multiple global and regional climate models). The simulations also start in the past, unlike the previous projects, to assess the impact of these uncertainties on historical changes.

We use probabilistic machine learning to emulate the relationships between model inputs (climate change; ice sheet and glacier model choices) and outputs (sea level contribution), so we can make predictions for any climate scenario and sample model uncertainties more thoroughly than with the original physical models. We try multiple machine learning methods that have different strengths in terms of speed, smoothness, interpretability, and performance for categorical uncertainties (Gaussian Processes, random forests).

The design of the grand ensemble allows the influence of all these uncertainties to be captured explicitly, rather than treating them as simple noise, and the earlier start date allows formal calibration (Bayesian or history matching) with observed ice sheet and glacier changes, to improve confidence (and typically reduce uncertainties) in the projections. Here we show preliminary projections for global mean sea level rise up to 2300 using these advances, and describe challenges and solutions found along the way.

EU PROTECT project: Scientists of the EU Horizon 2020 project PROTECT: see https://protect-slr.eu for more details.