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Assessing the history of global sea level from noisy and incomplete observations of local sea level

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The last interglacial (LIG) is an analogue for contemporary global-warming scenarios. Geological records show local sea level (LSL) in the LIG generally higher than today, but the mapping from global sea level (GSL) to LSL is modulated by the solid Earth. LSL is a function of both time since and location relative to the source of the melting events that define GSL. We determine the posterior pdf of GSL (and ice volume) through time in the LIG, from a database of sparse and scattered, noisy measurements of LSL. Noise is present in both the dependent and independent variables, sea level and age. Both posterior and prior pdfs are assumed to be Gaussian. By Gaussian process regression, we might approach this as a space-time interpolation/inversion problem, but absent large numbers of precise measurements, we need simulation to obtain the covariance of LSL and GSL. The covariance expresses the Earth system response through the sea-level equation. We use the solver developed by Mitrovica, modelling eustatic, gravitational, deformational, and rotational effects of melting ice sheets. To construct a prior, we average LSLs and GSL over multiple alternative ice sheet histories run through this forward model. The histories themselves are sampled from two underlying pdfs: one for global ice volume from isotopes and another for individual ice sheet volumes based upon random perturbations of last-glacial-maximum-to-present models. Two more Gaussian terms are added to approximate thermosteric effects and small contributions from unaccounted sources such as small mountain glaciers. To construct the posterior we start by estimating it at the points included in our database, and then interpolate to calculate values elsewhere, as in the covariance we have incorporated the full physics of the problem without constraining it to fit a particular forward model. First, we correct measurements of LSL for tectonics. Second, we employ Gaussian process regression to estimate the true sea levels. Third, we use the Metropolis-Hastings algorithm to draw a new sample of the ages, based upon the measured ages and the current estimate of the true sea levels. Repeating this Gibbs sampling sequence many times we obtain the posterior pdf for LSL and GSL in a way that satisfies the measurements. With 95% probability GSL peaked at least 6.6 m higher than today during the LIG. This highlights the vulnerability of ice sheets to even relatively low levels of sustained global warming.