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Bayesian Statistical Analysis of Historical and Late Holocene Rates of Sea-Level Change

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A fundamental concern associated with climate change is the rate at which sea levels are rising. Studies of past sea level (particularly beyond the instrumental data range) allow modern sea-level rise to be placed in a more complete context. Considering this, we perform a Bayesian statistical analysis on historical and late Holocene rates of sea-level change. The data that form the input to the statistical model are tide-gauge measurements and proxy reconstructions from cores of coastal sediment. The aims are to estimate rates of sea-level rise, to determine when modern rates of sea-level rise began and to observe how these rates have been changing over time. Many of the current methods for doing this use simple linear regression to estimate rates. This is often inappropriate as it is too rigid and it can ignore uncertainties that arise as part of the data collection exercise. This can lead to over confidence in the sea-level trends being characterized.

The proposed Bayesian model places a Gaussian process prior on the rate process (i.e. the process that determines how rates of sea-level are changing over time). The likelihood of the observed data is the integral of this process. When dealing with proxy reconstructions, this is set in an errors-in-variables framework so as to take account of age uncertainty. It is also necessary, in this case, for the model to account for glacio-isostatic adjustment, which introduces a covariance between individual age and sea-level observations. This method provides a flexible fit and it allows for the direct estimation of the rate process with full consideration of all sources of uncertainty.

Analysis of tide-gauge datasets and proxy reconstructions in this way means that changing rates of sea level can be estimated more comprehensively and accurately than previously possible. The model captures the continuous and dynamic evolution of sea-level change and results show that not only are modern sea levels rising but that the rates of rise are continuously increasing. Analysis of the a global tide-gauge record (Church and White, 2011) indicated that the rate of sea-level rise increased continuously since 1880AD and is currently 2.57mm/yr (95% credible interval of 1.71 to 4.35mm/yr). Application of the model a proxy reconstruction from North Carolina (Kemp et al., 2011) indicated that the mean rate of rise in this locality since the middle of the 19th century (current rate of 2.66 mm/yr with a 95% credible interval of 1.29 to 4.59mm/yr) is in agreement with results from the tide gauge analysis and is unprecedented in at least the last 2000 years.