Probabilistic Projections of Sea-Level Change

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The New York City Panel on Climate Change's 2013 study pioneered bottom-up, probabilistic, regional sea-level projections, combining probability distributions separately estimated for the principal contributors to sea-level change. Ref. 1 built upon this approach and extended it to the global scale. Other authors have subsequently adopted similar approaches.

Ref. 1 combines multiple lines of information to construct probability distributions for key contributors to global-mean sea-level (GMSL) and relative sea-level (RSL) change. It employs distributions derived from global climate models for thermal expansion and ocean dynamics and from a surface-mass-balance model for glacier contributions. It projects anthropogenic land-water storage based upon historical relationships with human population. Regional contributions of non-climatic processes are based upon statistical analysis of tide-gauge data. Ice-sheet contributions are derived from the IPCC AR5 expert assessment and a structured expert elicitation. Land-ice projections are translated into RSL changes using static-equilibrium fingerprints.

An alternative probabilistic approach is based upon semi-empirical models. For example, ref. 2 developed a model for GMSL calibrated to global mean temperature change and GMSL reconstructions for the last two millennia. Most recent publications using semi-empirical models have yielded 21st century projections similar to bottom-up probabilistic approaches, as well as to the IPCC AR5. While this agreement could be viewed as corroborating bottom-up projections, this agreement could also be viewed as reflecting a historical bias in bottom-up projections.

Despite the efforts discussed above, sea-level rise is an area of deep uncertainty: there is no single, unique probability distribution for future sea-level change. Recent ice-sheet modeling studies indicating a potential >1 m GMSL contributions from Antarctica in the 21st century (e.g., 3) suggest current approaches may significantly underestimate GMSL rise. Such studies have not yet been conducted in a probabilistic manner, so it is not possible to revise probability estimates based upon them. However, we can explore the consequences of substituting projections that account for mechanisms such as ice-shelf hydrofracturing and ice-cliff collapse into a probabilistic framework. Initial explorations indicate substantial effects on the sensitivity of projections to emissions and the extent to which observations of current sea-level change can constrain future sea-level change.

Given this deep uncertainty, end users should consider applying adaptive management and/or robust decision frameworks appropriate for deeply uncertain contexts. One simple tool is provided by the sea-level rise allowance framework, which combines the epistemic uncertainty of sea-level projections and aleatoric uncertainty of flood return periods, allowing probability distributions to be collapsed to single numbers that reflect an end-user's degree of flood tolerance, time frame of interest, and confidence in sea-level projections (4).

(1) Kopp et al (2014). Earth’s Future 2, 287–306. (2) Kopp et al. (2016). Proceedings of the National Academy of Sciences 113, E1434-E1441. (3) DeConto and Pollard (2016). Nature 531, 591-597. (4) Buchanan et al. Climatic Change 137, 347-362.

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