Consensus Statements

Planning for Sea Level Rise: An AGU Talk in the Form of a Co-Production Experiment Exploring Recent Science

David Behar[1], Robert Kopp[2], Rob DeConto[3], Christopher Weaver[4], Kathleen White[5], Kris May[6], Robert Bindschadler[7]

[1] San Francisco Public Utilities Commission; [2] Rutgers University; [3] University of Massachusetts, Amherst; [4] US Global Change Research Program; [5] US Army Corps of Engineers; [6] Silvestrum Climate Associates; [7] NASA Emeritus

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Introduction

Evolving science provides new observations, models, and understanding of land, ice, and ocean dynamics that can increase clarity about the nature of projected sea level rise (SLR) but also in many ways increase uncertainty about how decision makers, planners, and engineers should use or adopt the latest science in SLR adaptation efforts. Two important studies, different in kind but dominating the conversation about SLR adaptation planning today, were targeted by this author group for a "co-production" process with a goal of creating common understandings between scientists and decision makers. First, DeConto and Pollard (2016)[1] suggested the potential for significantly higher upper end projections for Antarctic ice sheet melt, which increase both global and regional SLR above most previously assumed upper limits. Second, probabilistic projections using model output and expert elicitation as presented in Kopp et al (2014)[2] are increasingly appearing in federal reports, scientific assessments, and SLR guidance documents. These two papers are excellent examples of research that is pushing the boundaries of the science-to-planning interface, while the ultimate application of this work as actionable science is far from settled.

This white paper (and the accompanying presentation) presents the outcome of recent conversations seeking to co-produce common understandings among our diverse author team. The authors are engaged in SLR science and planning related contexts from many angles and perspectives and include the aforementioned Kopp and DeConto as well as representatives of the City of San Francisco, Army Corps of Engineers, US Global Research Program, and consultant community. This collaboration demonstrates co-production in process, featuring topics about which the authors reached consensus on the subject of the application of probabilistic projections. This process provided significant learning opportunities for each author, and enhanced each author's respective understanding of the perceived knowledge gaps in translating SLR science into action. The authors have recommended a series of potential next steps and plan to continue their beneficial co-production efforts.

Background and motivation for our process

As coastal communities increasingly invest resources to assess vulnerability and implement adaptation strategies in response to sea level rise, projections of SLR under climate change are evolving to better support SLR planning decisions. Past sources of SLR information drawn upon by decision makers include: semi-empirical methods (Rahmstorf 2007[3]); scenario approaches (Parris et al 2012[4]); expert surveys (Horton et al 2014[5]); expert elicitation techniques (Bamber and Aspinall 2013[6]); literature syntheses (NRC 2012[7]); approaches that combine model output, expert opinion, and other techniques to generate likely SLR outcomes without characterizing extremes (Church et al 2013[8]); and most recently, Bayesian probabilistic projections that present quantified probabilities of SLR for the full range of outcomes, including extremes, using a combination of model output, expert elicitation, and other techniques (Kopp et al 2014[9]).

This last approach has been increasingly recommended for use in scientific assessment reports produced for coastal planners (i.e. for Boston,[10] New Jersey,[11] New York City[12] Southeast Florida,[13] the Olympic Peninsula,[14] Oregon,[15] and California[16]). This trend may lead to a de-emphasis on using traditional scenario planning approaches within vulnerability and risk assessments, which several of our authors have used in their jurisdictions to justify and prioritize adaptation efforts, in favor of selecting specific probabilistic levels of SLR in planning adaptation solutions. While probabilistic projections are sought proactively by some (e.g. the Risky Business Project[17]), in many instances they are arriving on the desks of planners, engineers, and decision makers who have little background in the methodologies used. Furthermore, the scientific reports generally do not explain, or explain in only a cursory fashion, the techniques used to generate the probabilistic projections they present and the assumptions and uncertainties they may contain, do not provide clear explanations as to the differences between Bayesian probabilities and frequentist probabilities, and do not provide sufficient guidance on how to use them in a planning, decision making, or adaptation design context.[18]

The author team spans multiple discrete sectors engaged in an ongoing examination of this issue, including the science, coastal planning, federal agency, and consulting communities. At the outset, we presented varying opinions as to the “actionable science” value of probabilistic SLR projections. Generally, authors with broad experience in applying SLR projections in a planning and design context (Behar, White, May) were skeptical of the use value of Bayesian probabilities, while authors in the science community (Kopp, Weaver, DeConto, Bindschadler) were more supportive of their use in decision making.

This author team came together based on our mutual interest in understanding the interface between science and decision making. Our goal is to bridge what we perceive as a gap between the growing prominence of probabilistic projections of SLR developed by the science community and the preparedness of decision makers to understand and incorporate this work into planning and design. By convening multiple times in advance of the AGU Fall Meeting, the authors attempted to co-produce common understandings to address this gap and provide value in advancing the use of cutting-edge science in decision making.

Consensus agreement #1: The need for greater co-production

Science is necessary but not sufficient for decision making under deep uncertainty. We believe that decision effectiveness using best available science is improved if the appropriate community of decision-makers, scientists, and those that span the boundaries (e.g., translators of user needs into science questions, and of science into information appropriate for use in engineering decisions or policy) co-produce a suite of decision-support products (e.g., reports, tools, datasets, guidance) tailored to the context in which this information will be used. It is the consensus observation of our author team that rigorous co-production efforts related to new SLR science – including probabilistic projections – can and should be much more widespread than they are today. Greater collaboration between the producers and potential users of new, cutting edge scientific information in general, but the new probabilistic projections in particular, can reduce the dangers of misunderstanding, misapplication, and maladaptation. Co-production efforts can also address some of the gaps noted above in the scientific assessment reports intended for decision makers.

Consensus agreement #2: opportunities associated with Bayesian probabilistic projections

Bayesian probabilistic approaches for producing and providing information about potential future global and local SLR may add value to previous approaches in a least three ways that are potentially useful to decision makers:

a. A Bayesian probabilistic framework in principle allows for a systematic, reproducible integration of diverse lines of scientific evidence, as well as the ability to clearly demonstrate the sensitivity of the resulting distributions to alternative assumptions about the science.

b. Such a framework is one way to support mapping of global and local SLR scenarios to future emissions pathways (though it is not the only way). For example, use of this framework highlights the substantial agreement in SLR projections across the different future emission scenarios through 2050, which provides additional confidence for near-term SLR projections.

c. Probabilistic projections can, in theory, support a variety of decision frameworks. This includes supporting those frameworks that rely directly on Bayesian probability distributions (e.g., expected utility approaches, simplified cost-benefit methods), and providing the underlying information to support alternative quantitative frameworks (e.g., robust decision making, traditional scenario planning, possibilistic frameworks) for characterizing uncertain future outcomes. In practice, decision makers and users of Bayesian probabilistic projections must understand how estimated Bayesian probabilities differ from the frequentist probabilities commonly used by decision makers, such as flood risk analysis around storm return periods (e.g., 1% annual chance event).

Consensus agreement #3: limitations of Bayesian probabilistic projections

The use value of Bayesian probabilities in planning, design, and decision making is subject to some inherent limitations, and can be further diminished by some common pitfalls in their application:

a. There is no consensus on how to meaningfully assign quantitative probabilities for the upper extreme range of potential future global SLR; therefore, a given set of Bayesian probabilistic projections may underestimate or overestimate the SLR contributions due to rapid ice sheet loss after 2050.

b. It is not currently possible to represent uncertainty in future SLR with a single Bayesian probability density function (PDF) after 2050. As highlighted in Consensus Agreement #2, there is substantial agreement in the SLR projections through 2050. However, after 2050, the differences in the projections vary greatly across both emission scenarios and individual scientific assessments. Therefore, multiple analyses and PDFs should be used in any adaptation study considering projections later this century and beyond.

c. The seeming precision of the numbers in a single Bayesian PDF may lead decision-makers to be overconfident about their knowledge of the future. For example, lack of understanding of the true sensitivity of the numbers in the upper-half of the distribution to uncertainties and assumptions may lead to a failure to appropriately consider possible high-end futures, such as extreme SLR that may not be adequately represented in the PDF.

d. Combining Bayesian and frequentist probabilities in a given analysis (e.g., when trying to understand how a historical flood frequency or return period might transform across a distribution of possible future sea levels with differing likelihoods) requires additional nontrivial steps that should be tailored to particular water levels of interest.

e. The use of probabilities may lead decision-makers to believe that quantitative probabilities may appropriately be used in the risk assessment equation commonly employed in the engineering community (Risk = Likelihood x Consequence). Prior to 2050, the agreement among PDFs from different studies may lend confidence to using the probabilities in this manner. However, when assessing longer-term risk after 2050, the use of Bayesian probabilities in this manner requires extreme caution. Multiple PDFs should be used for SLR after 2050. If not adequately represented in the set of PDFs used, supplementary ways of incorporating extreme SLR should also be considered (e.g., discrete, non-probabilistic scenarios), particularly if the timeframe is closer to 2100 or beyond.

Notes on the co-production process and next steps

The author group co-produced the session abstract prior to submission. Between October 13 and December 7, the group convened five conference calls approximately every two weeks. Initially, general principles were discussed, both related to the issues in play and the group's goals in addressing them. Throughout the process, email threads explored relevant approaches and concepts. Journal articles, reports, and other documents were shared to offer support for lines of thinking. About a month into the process, one member produced a draft consensus document based on discussions to that point, and others later amended, edited, and commented on the consensus document. Midway through the process, this white paper took shape, and refining and reaching agreement on the white paper became the primary focus of the group.

The group did not completely fulfill one of its two objectives, the consideration of how DeConto and Pollard (2016), as a defining example of cutting edge science leading to new upper end SLR estimates, can or should be incorporated into planning. Issues associated with the significant uncertainties in upper-end SLR estimates, and the rapidly evolving science in this area, were addressed as part of the extensive discussions around probabilistic projections. Broader issues related to the uptake of emerging upper-end estimates into the full range of decision support products, and over what timescale, remain to be addressed as a key next step for this co-production process.

In addition, other follow on activities are being planned to broaden both the scope of this process and the dissemination of its findings and lessons. These include 1) identifying case studies of the use of probabilistic projections in decision making (and the associated guidance provided in support), and exploring the interplay of the potential benefits and pitfalls highlighted in this white paper; 2) extending this co-production exercise to consider a wider range of approaches for providing future SLR information, including traditional scenario approaches that have been used in a variety of decision contexts to date; and 3) sharing what has been learned through this co-production process with diverse audiences, through the peer-reviewed literature, presentations, and other types of engagement activities.

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