Attachment N

Declaration of Robert Kopp

I, ROBERT KOPP, declare as follow:

PERSONAL BACKGROUND AND EXPERIENCE

1. I received a Bachelor of Science degree in Geophysical Sciences from the University of Chicago in 2002, then received a Master of Science degree in Geobiology from the California Institute of Technology in 2005. I received a Ph.D. in Geobiology from the California Institute of Technology in 2007.
2. Between 2007 and 2009, I was a postdoctoral fellow in geosciences and public policy at Princeton University.
3. Between 2009 and 2011, I was a Science & Technology Policy Fellow at the U.S. Department of Energy Office of Climate Change Policy and Technology.
4. Since 2011, I have been a member of the faculty at Rutgers University-New Brunswick. From 2011 to 2014, I was an assistant professor. From 2014 to 2017, I was an associate professor. Since 2017, I have been a professor.
5. Since 2017, I have also served as director of the Institute of Earth, Ocean, and Atmospheric Sciences at Rutgers University-New Brunswick.
6. Major focuses of my research over the last decade have included past sea-level change, future sea-level change, and climate change adaptation.
7. I have published over 75 peer-reviewed scientific publications since 2003; in the last nine years, almost all of these have related to climate change and sea-level rise.

8. I am one of the lead authors of the *Climate Science Special Report*, which is volume 1 of the US government's Congressionally mandated Fourth National Climate Assessment,[1] and was released in November 2017.
9. I am a lead author of the chapter on Oceans, Cryosphere, and Sea-Level Rise in the forthcoming Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), a contributing author to the IPCC's forthcoming Special Report on the Ocean and Cryosphere in a Changing Climate, and a contributing author to the 2013-2014 IPCC Fifth Assessment Report.
10. I also serve as a member of the National Academy of Sciences' Board on Atmospheric Science and Climate.
11. I am a co-author on the report that developed the sea-level rise projections used in the Fourth National Climate Assessment.[2,3] I chaired the New Jersey Climate Adaptation Alliance's Science and Technology Advisory Panel 2016 report on sea-level rise,[4] and have also served on sea-level rise expert panels for the state of Maryland, the state of California, New York City, and the city of Boston.

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[1] USGCRP, CLIMATE SCIENCE SPECIAL REPORT: FOURTH NATIONAL CLIMATE ASSESSMENT, VOLUME I (Donald J. Wuebbles et al. eds., 2017).
[2] WILLIAM V. SWEET ET AL., GLOBAL AND REGIONAL SEA LEVEL RISE SCENARIOS FOR THE UNITED STATES (2017), https://goo.gl/YUehx6.
[3] These projections update and replace the projections used in the Third National Climate Assessment, developed by ADAM PARRIS ET AL., GLOBAL SEA LEVEL RISE SCENARIOS FOR THE US NATIONAL CLIMATE ASSESSMENT (2012). The scenarios used in the Third National Climate Assessment spanned a range of possible global mean sea-level rises from 0.2 to 2.0 (0.6 to 6.6 feet) over the 21st century. The new projections elevated the lowest scenario to 0.3 m (1.0 feet), based on the historical trend since 1993, and extended the upper range to 2.5 m (8.2 feet), based on a growing body of evidence suggesting that such extreme outcomes are physically possible, although their probability is not currently possible to assess. The new report also added corresponding local projections.
[4] R.E. KOPP ET AL., ASSESSING NEW JERSEY'S EXPOSURE TO SEA-LEVEL RISE AND COASTAL STORMS: REPORT OF THE NEW JERSEY CLIMATE ADAPTATION ALLIANCE SCIENCE AND TECHNICAL ADVISORY PANEL (2016).

Key Messages

12. The *Climate Science Special Report* is an "authoritative assessment of the science of climate change, with a focus on the United States,"[5] constituting volume 1 of the Congressionally mandated Fourth National Climate Assessment. It was written by 51 academic and federal scientists, including 32 lead authors, of which I was one. It underwent an extensive review process involving multiple government agencies, the general public, and the National Academies of Sciences, Engineering, and Medicine. It identified several key findings with respect to sea-level rise.[6] In my expert judgement, these findings continue to provide a concise and accurate summary of the current state of the underlying science. Specifically, the *Climate Science Special Report* found:

> [i.] Global mean sea level (GMSL) has risen by about 7–8 inches (about 16–21 cm) since 1900, with about 3 of those inches (about 7 cm) occurring since 1993 (*very high confidence*).[7] Human-caused climate change has made a substantial contribution to GMSL rise since 1900 (*high confidence*), contributing to a rate of rise that is greater than during any preceding century in at least 2,800 years (*medium confidence*).

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[5] USGCRP, *supra* note 1 at 1.

[6] William V. Sweet et al., *Sea level rise*, *in* CLIMATE SCIENCE SPECIAL REPORT: FOURTH NATIONAL CLIMATE ASSESSMENT, VOLUME I 333–363 (D. J. Wuebbles et al. eds., 2017).

[7] Throughout this declaration, I use the likelihood language adopted by the Intergovernmental Panel on Climate Change and the National Climate Assessment. Specifically, as described by USGCRP, *supra* note 1 at 6: "Likelihood is the chance of occurrence of an effect or impact based on measures of uncertainty expressed probabilistically (based on statistical analysis of observations or model results or on expert judgment)…. Where it is considered justified to report the likelihood of particular impacts within the range of possible outcomes, this report takes a plain-language approach to expressing the expert judgment of the chapter team, based on the best available evidence. For example, an outcome termed *likely* has at least a 66% chance of occurring (a likelihood greater than about 2 of 3 chances); an outcome termed *very likely*, at least a 90% chance (more than 9 out of 10 chances)." The quotations from the National Climate Assessment also use the Intergovernmental Panel on Climate Change's confidence language. Specifically, as described by USGCRP, *supra* note 1 at 6: "Assessments of confidence in the Key Findings are based on the expert judgment of the author team…. Confidence is expressed qualitatively and ranges from low confidence (inconclusive evidence or disagreement among experts) to very high confidence (strong evidence and high consensus)…. Confidence should not be interpreted probabilistically, as it is distinct from statistical likelihood."

[ii.] Relative to the year 2000, GMSL is *very likely* to rise by 0.3–0.6 feet (9–18 cm) by 2030, 0.5–1.2 feet (15–38 cm) by 2050, and 1.0–4.3 feet (30–130 cm) by 2100 (*very high confidence in lower bounds; medium confidence in upper bounds for 2030 and 2050; low confidence in upper bounds for 2100*).[8] Future pathways have little effect on projected GMSL rise in the first half of the century, but significantly affect projections for the second half of the century (*high confidence*). Emerging science regarding Antarctic ice sheet stability suggests that, for high emission scenarios, a GMSL rise exceeding 8 feet (2.4 m) by 2100 is physically possible, although the probability of such an extreme outcome cannot currently be assessed. Regardless of pathway, it is *extremely likely* that GMSL rise will continue beyond 2100 (*high confidence*).

[iii.] Relative sea level (RSL) rise in this century will vary along U.S. coastlines due, in part, to changes in Earth's gravitational field and rotation from melting of land ice, changes in ocean circulation, and vertical land motion (*very high confidence*). In intermediate and low GMSL rise scenarios, RSL rise is *likely* to be less than the global average in much of the Pacific Northwest and Alaska. For high GMSL rise scenarios, RSL rise is *likely* to be higher than the global average along all U.S. coastlines outside Alaska. Almost all U.S. coastlines experience more than global mean sea level rise in response to Antarctic ice loss, and thus would be particularly affected under extreme GMSL rise scenarios involving substantial Antarctic mass loss (*high confidence*).

[iv.] As sea levels have risen, the number of tidal floods each year that cause minor impacts (also called "nuisance floods") have increased 5- to 10-fold since the 1960s in several U.S. coastal cities (*very high confidence*). Rates of increase are accelerating in over 25 Atlantic and Gulf Coast cities (*very high confidence*). Tidal flooding will continue increasing in depth, frequency, and extent this century (*very high confidence*).

[v.] Assuming storm characteristics do not change, sea level rise will increase the frequency and extent of extreme flooding associated with coastal storms, such as hurricanes and nor'easters (*very high confidence*). A projected increase in the intensity of hurricanes in the North Atlantic (*medium confidence*) could increase the probability of extreme flooding along most of the U.S. Atlantic and Gulf Coast states beyond what would be projected based solely on RSL rise. However, there is *low confidence* in the projected increase in frequency of intense Atlantic hurricanes, and the

[8] Projections on sea-level rise trends are generally defined with respect to an average of sea level over a 19-year period, known as a tidal datum epoch. The standard period used in the United States, the National Tidal Datum Epoch, runs from 1983-2001. Projections quoted with respect to the year 2000 are more specifically with respect to the average sea level over 1991-2009. Based on the average rate of sea-level change since 1993, global mean sea level today is about 3 inches higher than the average over the National Tidal Datum Epoch and about 2 inches higher than over 1991-2009.

> associated flood risk amplification and flood effects could be offset or amplified by such factors as changes in overall storm frequency or tracks.[9]

13. Over the current century, even under stringent emissions reductions, sea-level rise over the current century in south Florida, including around Turkey Point is – like global mean sea-level rise – *very likely* (i.e., greater than nine chances in ten) to be faster than the average over the last century.
14. To a first approximation, the amplitude of tidal and storm-driven flooding can be added to average sea level to estimate total water level. Increases in average sea level in south Florida will thus lead to increases in the amplitude of the water levels associated with storms and tides, and increases in the frequency of storm- and tide-driven flooding.
15. Changes in hurricanes and tropical storms under climate change remain a topic of active research, but most experts project that the intensity of hurricanes and tropical storms will increase in a warmer future world. This has the potential to lead to additional increases in the amplitude of storm-driven high water levels in south Florida, although the possibility that climate change will also drive changes in storm tracks make this effect challenging to assess with confidence.

Sea-level rise in south Florida

16. For the remainder of this declaration, I focus on sea-level rise at the Key West tide gauge, which is maintained by the National Oceanic and Atmospheric Administration (NOAA).[10]

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[9] Sweet et al., *supra* note 6 at 333.
[10] https://tidesandcurrents.noaa.gov/stationhome.html?id=8724580

17. Tide gauges measure relative sea level, which is the difference between the height of the land surface and the height of the water surface, and are the main way of observing coastal water levels. The Key West tide gauge, which began recording in 1913, is one of the oldest tide gauges in the country and the longest and most continuous record in southern Florida.

18. Based on the spatial scales of variability of sea level, conclusions drawn from this tide gauge can be reasonably construed to reflect the changes experienced at Turkey Point. As previously recognized by the Nuclear Regulatory Commission, "The Miami Beach station was removed from service in 1981, but trends at Miami Beach are well correlated with trends at the Key West station."[11]

19. Water levels as measured by a tide gauge reflect a superposition of long-term trends, between-year variability, a seasonal cycle, storm-driven surges, and tides. In general, when scientists discuss sea-level change, they are referring to the long-term trend. A conventional way to assess long-term change is to examine changes in 19-year averages of sea level. The 19-year duration is conventionally used to define a tidal datum epoch; the current National Tidal Datum Epoch represents average sea level over 1983-2001.

20. Since the Key West record began in 1913, sea level at Key West has risen by about 9.8 inches, an average rate of about 0.09 inches per year. Due primarily to regional subsidence of the land associated with the ongoing response of the solid Earth to the loss of the Ice-Age ice sheet in North America, this is larger than the global average increase over this time period. This subsidence will continue an approximately constant rate over

[11] *In the Matter of Florida Power & Light Co. (Turkey Point Nuclear Generating Units 6 and 7)*, CLI-18-01, at 25 n. 110 (2018). https://www.nrc.gov/docs/ML1809/ML18095A117.pdf

the next century. Since 1992, the midpoint of the National Tidal Datum Epoch, sea level has risen by about 2.7 inches, an average rate of 0.11 inches per year.

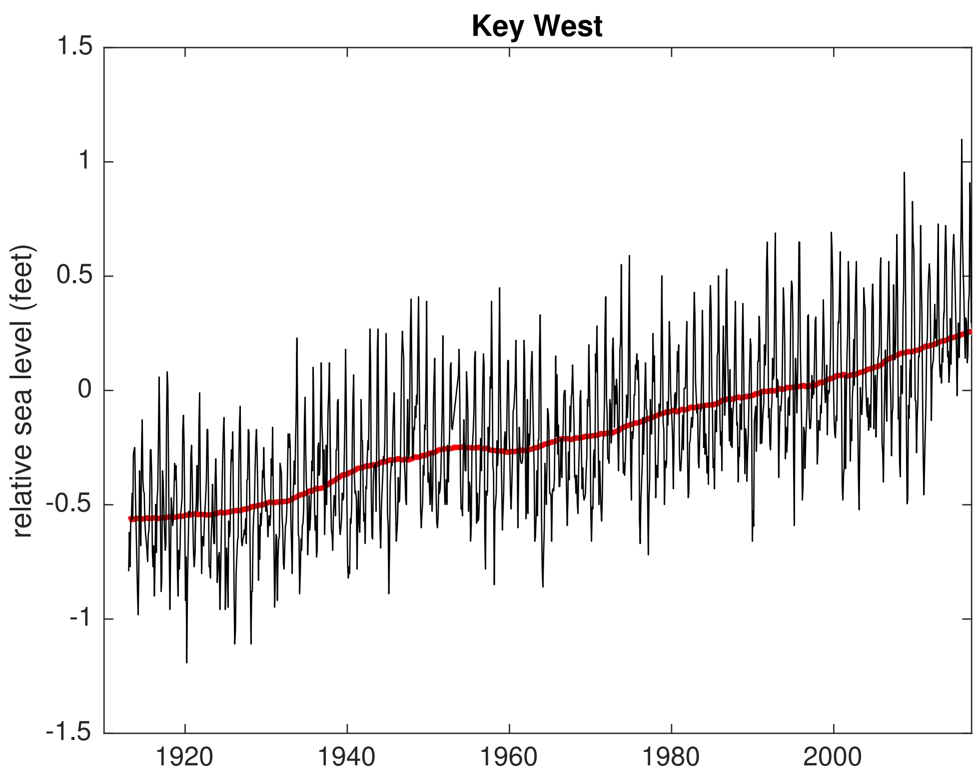

Figure 1: Monthly average sea level at Key West (black) and 19-year running average sea-level (red), both relative to average sea level during the National Tidal Datum Epoch (1983-2001).

21. As globally, sea-level rise is projected to continue to increase, *very likely* with continued acceleration, in south Florida.

22. The projections I present here span a range that arises from a number of different sources of uncertainty. In the near term, this uncertainty range is due primarily to variability in ocean and atmospheric circulation, which is also the primary driver of the year-to-year variability that can be seen in Figure 1. In the second half of the century and beyond, the uncertainty range is due primarily to the range of possible future greenhouse gas

emissions and to the potential for instability in the Antarctic ice sheet. The potential instability of the Antarctic is a topic of very active scientific investigation, and the state of scientific understanding is rapidly changing.

23. To represent this uncertainty range, it is increasingly common to use so-called 'probabilistic' projections of sea-level rise that reflect the probability of reaching different levels of sea-level rise over time, under different greenhouse gas emission scenarios. My collaborators and I have pioneered some of this work.[12] To represent the scientific controversy regarding the instability of the Antarctic ice sheet, our research also recommends using alternative cases for representing Antarctic ice sheet behavior.[13]

24. These sea-level rise projections consider a variety of physical driving factors, including: the global expansion of the oceans with warming; changes in the mass of ice sheets and mountain glaciers; changes in the storage of water on land in groundwater and dams; the effects of changing ice sheets and glaciers on the Earth's gravitational field and rotation; changes in atmospheric and oceanic circulation; and the geological background effect of sea-level rise due to the ongoing effects of the end of the last ice age.

25. For emissions scenarios, we use three global greenhouse gas emissions scenarios that have been defined by the international climate modeling and integrated assessment research communities, known as Representative Concentration Pathways 8.5, 4.5, 2.6. [14] For the remainder of this declaration, we refer to these pathways as High, Medium, and Low emissions scenarios. The High emissions scenario is consistent with unchecked

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[12] Robert E. Kopp et al., *Probabilistic 21st and 22nd century sea-level projections at a global network of tide gauge sites*, 2 EARTH'S FUTURE 383–406 (2014).

[13] Robert E. Kopp et al., *Evolving understanding of Antarctic ice-sheet physics and ambiguity in probabilistic sea-level projections*, 5 EARTH'S FUTURE 1217–1233 (2017).

[14] Detlef P. Van Vuuren et al., *The representative concentration pathways: an overview*, 109 CLIMATIC CHANGE 5–31 (2011).

fossil-fuel-based economic growth, leading to a near-doubling of CO_2 emissions between today and 2050, with continued growth thereafter. The Medium emissions scenario is consistent with a stabilization of CO_2 emissions at near current levels through 2050 and then a decline thereafter. The Low emissions scenario is an aggressive emissions reduction scenario, in which global CO_2 emissions decline to less than one-third of their current level by 2050 and below zero (i.e., net artificial removal of CO2 from the atmosphere) by the end of the century. The Low scenario is the scenario most consistent with the aspirational goals of the Paris Agreement of the United Nations Framework Convention on Climate Change, which include achieving net-zero global greenhouse gas emissions in the second half of this century.[15] Current national policies and commitments through 2030 appear to place global emissions on a trajectory intermediary between Medium and High,[16] but the Paris Agreement is intended to put in place a regular process for assessing and strengthening national commitments over the course of the century, so a 'most likely' scenario cannot be identified on the basis of this observation alone.[17]

26. For Antarctic instability, we consider two cases. These cases can be viewed as the assessments of two idealized experts, one optimistic and one pessimistic. In my expert opinion, most reasonable experts would have an assessment that falls somewhere between the Optimistic and Pessimistic cases. In other words, the combination of

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[15] UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, ADOPTION OF THE PARIS AGREEMENT DECISION 1/CP.21 (2015), https://unfccc.int/sites/default/files/resource/docs/2015/cop21/eng/10a01.pdf.

[16] Joeri Rogelj et al., *Paris Agreement climate proposals need a boost to keep warming well below 2 °C*, 534 NATURE 631–639 (2016).

[17] Assessing the future evolution of low-carbon technologies and of national policies to mitigate emissions is a challenging task that goes well beyond climate science. As NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE, VALUING CLIMATE DAMAGES: UPDATING ESTIMATION OF THE SOCIAL COST OF CARBON DIOXIDE (2017) noted at 76, for this task, "there is no real alternative to relying on the judgment of experts with knowledge of both political and diplomatic processes in the United States and other nations and of technical challenges to reducing emissions."

Optimistic and Pessimistic projections represents a plausible range of expert assessments of Antarctic behaviors, with the future evolution of the science likely to support intermediate assessments. Importantly, each of these cases represents a different estimate of the probability of different Antarctic behaviors over time; they do not represent deterministic scenarios of Antarctic behavior. For example, the Pessimistic projections incorporate a greater probability for rapid Antarctic ice loss, but do not treat this loss as a foregone conclusion.

27. The Optimistic projections follow the Antarctic assumptions of Kopp et al. 2014[18], which are consistent with the Intergovernmental Panel on Climate Change's Fifth Assessment Report.[19] In the Optimistic projections, under the High emissions scenario, it is likely (i.e., about two chances in three) that the Antarctic contribution to global mean sea-level rise over the 21st century will be between a sea-level fall of 8 cm (3 inches; due to increased snowfall, primarily in the East Antarctic) and a sea-level rise of 15 cm (6 inches). It is likely that the total global mean sea-level rise over the 21st century will be between 62 and 101 cm (2.0 and 3.3 feet). The Fifth Assessment Report, on which these estimates are based, did, however, observe its own conservatism. It noted that "Based on current understanding, only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause global mean sea level to rise substantially above the likely range during the 21st century. This potential additional contribution cannot be precisely quantified but there is medium confidence that it would not exceed several tenths of a meter of sea level rise during the 21st century."[20]

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[18] Kopp et al., *supra* note 12.
[19] John A. Church, Peter U. Clark & et al., *Chapter 13: Sea Level Change*, *in* CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS (Thomas F. Stocker, Dahe Qin, & et al. eds., 2013), http://www.ipcc.ch/report/ar5/wg1/.
[20] *Id.* at 1140.

28. Several observational studies following the Fifth Assessment Report have increased the body of evidence for ice-sheet instability in West Antarctica,[21] and several subsequent modeling studies have suggested larger Antarctic contributions, driven by interactions between the warming ocean, the warming atmosphere, unstable floating ice shelves, and the ice sheet.[22] Accordingly, in our second set of sea-level projections, we use Antarctic projections from the modelling study of DeConto and Pollard 2016.[23] In the Pessimistic projections, under the High emissions scenario, it is likely that the Antarctic contribution to global mean sea level rise alone will be between 35 and 134 cm (1.1 and 4.4 feet), and that the total global mean sea-level rise will be between 109 and 209 cm (3.6 and 6.9 feet).

29. Exhibit 1 presents projections of sea-level trends at Key West for the three emissions scenarios and two Antarctic cases. In these figures, the black represents the observed monthly average tide gauge values; the dark red presents the median projection for each scenario and set of Antarctic assumptions; and the light red represents the very likely probable range. That is to say, under the assumptions of each projection, there is a 9-in-10 chance that future 19-year-average sea level at Key West will fall within this range.

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[21] For example, E. Rignot et al., *Widespread, rapid grounding line retreat of Pine Island, Thwaites, Smith, and Kohler glaciers, West Antarctica, from 1992 to 2011*, 41 GEOPHYS. RES. LETT. 3502–3509 (2014); Ian Joughin, Benjamin E. Smith & Brooke Medley, *Marine ice sheet collapse potentially under way for the Thwaites Glacier Basin, West Antarctica*, 344 SCIENCE 735–738 (2014).

[22] For example, Catherine Ritz et al., *Potential sea-level rise from Antarctic ice-sheet instability constrained by observations*, 528 NATURE 115–118 (2015); N. R. Golledge et al., *The multi-millennial Antarctic commitment to future sea-level rise*, 526 NATURE 421–425 (2015); Robert M. DeConto & David Pollard, *Contribution of Antarctica to past and future sea-level rise*, 531 NATURE 591–597 (2016).

[23] DeConto and Pollard, *supra* note 22.

30. Exhibit 2 shows the probability, under each projection, that the 19-year-average sea level at Key West will exceed by given levels the National Tidal Datum Epoch at different points in time. For example:

    a. Through 2060, across emissions scenarios and Antarctic cases, there is between a 68 percent change and a 95 percent chance that average sea-level rise at Key West will exceed 1 foot above the National Tidal Datum Epoch; by 2100, this rises to between 92 and 100 percent.

    b. Through 2060, there is a 10-37% chance that average sea level rise will exceed 2 feet under the High emissions scenario and a 3-8% chance under the Low emissions scenario; by 2100, this rises to 81-100% and 44-56%, respectively.

    c. By 2100, there is a 43-97% chance that average sea level rise will exceed 3 feet under the High emissions scenario and a 11-19% chance under the Low emissions scenarios. There is a 15-83% chance that average sea level rise will exceed 4 feet under the High emissions scenario, and a 3-4% chance under the Low emissions scenarios.

    d. Even higher levels of sea-level rise are possible in this century. For example, by 2100, under the High emissions scenario, there is a 1.5-39% chance that average sea level rise will exceed 6 feet, which is reduced to 0.6-5% under the Medium emissions scenario, and to 0.5% or less under the Low emissions scenario. There is a 0.4-15% chance of exceeding 8 feet under the High emissions scenario, reduced to 0.1% or less under the Medium and Low emissions scenarios.

Extreme water levels in south Florida

31. During high tides and storm events, extreme high water levels arise from the superimposition of tidal and storm influences on top of average sea level. For a given extreme water level, higher average sea levels imply that it takes a less extreme tide or storm to produce the same total water level; correspondingly, a tide or storm of a given magnitude will produce a more extreme total water level than it would have with lower average sea level.

32. Based on the more than 100-year long tide-gauge record at Key West, it is possible to estimate the probability of different extreme water levels that arise from the effects of storms and tides acting on top of average sea level.[24] NOAA estimates that the 1% annual probability high-water level (also known as the 1-in-100 year high-water level) is 62 cm (2.0 feet) above contemporary Mean Higher High Water. (Mean Higher High Water is the average height of the higher of the two daily tides.) The 10% annual probability high-water level is 44 cm (1.4 feet) above Mean Higher High Water, the 50% annual probability high-water level is 30 cm (1.0 feet) above Mean Higher High Water, and the 99% annual probability high-water level is 18 cm (0.6 feet) above Mean Higher High Water.

33. The highest water level on record at Key West was 91 cm (3.0 feet) above contemporary MHHW,[25] during Hurricane Wilma on October 24, 2005; however, this strong storm exhibited considerable regional variability. At Vaca Key[26], this same storm peaked at 174

[24] https://tidesandcurrents.noaa.gov/est/stickdiagram.shtml?stnid=8724580
[25] https://go.usa.gov/xUXBg
[26] https://go.usa.gov/xUXB4

cm (5.7 feet), and at Virginia Key[27], 75 cm (2.5 feet) above MHHW. Despite this difference in expression of the highest historical water level, estimates of the probability of lower water levels are similar at Key West and Vaca Key: at Vaca Key[28], the NOAA-estimated 99%, 50% and 10% annual probability water levels are 20 cm (0.7 feet), 29 cm (1.0 feet), and 46 cm (1.5 feet) above contemporary MHHW, essentially indistinguishable from the extreme water levels at Key West. (The Virginia Key record is too short to perform a comparable analysis.) The Hurricane Wilma high water level at Vaca Key can thus be interpreted as a caution that, for an intense with an appropriate track, extreme water levels well above the highest observed historically at a particular site are well within the range of possibility.

34. As noted previously, to a first approximation, the effects of sea-level rise can be added to these numbers. Thus, for instance, 1.0 feet of average sea-level rise turns the current 50% annual probability high-water level (1.0 feet above Mean Higher High Water) into the new average higher high-water level and the current 1% annual probability high-water level (2.0 feet above Mean Higher High Water) into the new 50% annual probability high-water level. 2.0 feet of average sea-level rise turns the current 1% annual probability high-water level into the new average higher high water level. The effects of this cannot be understated: at Key West, 3.0 feet of sea-level rise is sufficient to turn the highest water level experienced to a flood level expected to be exceeded, on average, half of the days of the year.

35. This first approximation may be modified by the non-linear interaction of sea-level and surge: for example, sea-level rise may change the shape of the basin over which a storm

[27] https://go.usa.gov/xUXB2
[28] https://tidesandcurrents.noaa.gov/est/stickdiagram.shtml?stnid=8723970

pushes water, thus altering the way sea level and surge combine. However, detailed hydrodynamic modeling studies have shown that the linear approximation is a good approximation in many regions.

36. These first approximations may also change if the character (e.g., intensity, frequency, or tracks) of tropical storms and hurricanes change, as may be expected in a warmer climate. The effect of this is difficult to assess quantitatively, however, as noted by the Climate Science Special Report's fifth Key Message on sea-level change[29]:

> Assuming storm characteristics do not change, sea level rise will increase the frequency and extent of extreme flooding associated with coastal storms, such as hurricanes and nor'easters (*very high confidence*). A projected increase in the intensity of hurricanes in the North Atlantic (*medium confidence*) could increase the probability of extreme flooding along most of the U.S. Atlantic and Gulf Coast states beyond what would be projected based solely on RSL rise. However, there is *low confidence* in the projected increase in frequency of intense Atlantic hurricanes, and the associated flood risk amplification and flood effects could be offset or amplified by such factors as changes in overall storm frequency or tracks.

Summary

[29] Sweet et al., *supra* note 6 at 334.

37. The projections presented above and summarized below are consistent with the assessment presented in the Fourth National Climate Assessment and, based on the peer-reviewed scientific literature, reasonably represent the range of possible future sea-level change in south Florida.

38. Even under a low-emissions scenario and with a relatively stable Antarctic ice sheet, it is likely (greater than two chances in three) that sea-level rise will exceed 1 foot in south Florida by 2060, and very likely (greater than nine chances in ten) that it will do so by 2090.

39. Substantially larger levels of sea-level rise are possible by 2060, especially under higher emissions scenarios. Under a high-emissions scenario, it is very likely that south Florida sea-level rise will exceed 1 foot by 2060, and there is between about a 1-in-10 chance (with a relatively stable Antarctic ice sheet) and a 1-in-3 chance (with a pessimistic model of Antarctic instability) that it will exceed 2 feet by 2060. With high emissions, there is between about a 1-in-200 and a 1-in-40 chance that south Florida sea-level rise will exceed 3 feet by 2060. A moderate-emissions scenario reduces the chances of exceeding 2 feet by 2060 to between about 1-in-25 and 1-in-7, and a low-emissions scenario reduces these chances further, to between about 1-in-33 and 1-in-13. The chances of exceeding 3 feet by 2060 are 1-in-300 or less in both moderate- and low-emissions scenarios.

40. Substantially larger levels of sea-level rise are possible later in the century, particularly under higher emissions scenarios, and particularly if Antarctica behaves in a manner consistent with the most pessimistic peer-reviewed models of ice-sheet instability. Under a pessimistic model of Antarctic instability and a high emissions scenario, sea-level rise

in Florida is likely to exceed 4 feet by 2100, and there is a greater than 1-in-100 chance of exceeding 10 feet by 2100. By 2120, these chances rise to nearly 100% for 4 feet and to nearly 1-in-3 for 10 feet. Under a pessimistic model and a moderate emissions scenario, the chances of exceeding 4 feet are about 1-in-25 by 2100, growing to about 1-in-7 by 2120; the chances of exceeding 6 feet are about 1-in-20 by 2100, growing to about 1-in-4 by 2120.

41. By comparison, a continuation of the historic trend of sea-level rise observed over the last century would yield a south Florida average sea level that is about 6" above the average sea level of the National Tidal Datum Epoch (1983-2001) by 2060, about 10" by 2100, and about 1 foot by 2120.

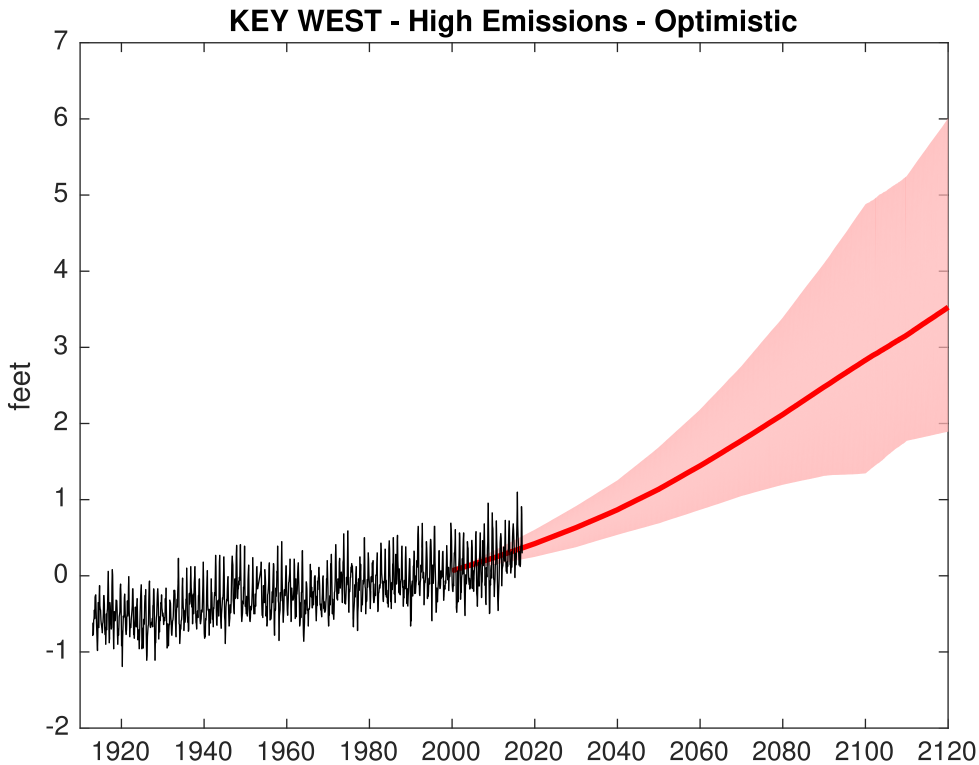
I declare under penalty of perjury under the laws of the United States that the foregoing is true and correct to the best of my knowledge.

Dated: July 26, 2018

Robert Kopp

Exhibit 1: Projections of sea-level rise at Key West under different scenarios and treatments of Antarctica

The figures below show historical monthly average sea level (black) and projected 19-year average sea-level (red) under three greenhouse-gas emissions pathways (High, Medium, and Low, corresponding to the standardized Representative Concentration Pathways 8.5, 4.5, and 2.6) and two different cases for Antarctic ice sheet behavior (Optimistic and Pessimistic). The dark red lines represent median projections (i.e., there is an estimated 50% chance the true value will be above, and a 50% chance the true value will be below), and the light red shaded areas represent the 90% probable range (i.e,. there is an estimated 9-in-10 chance the true value will fall in the range, for the specific emissions scenario and Antarctic case).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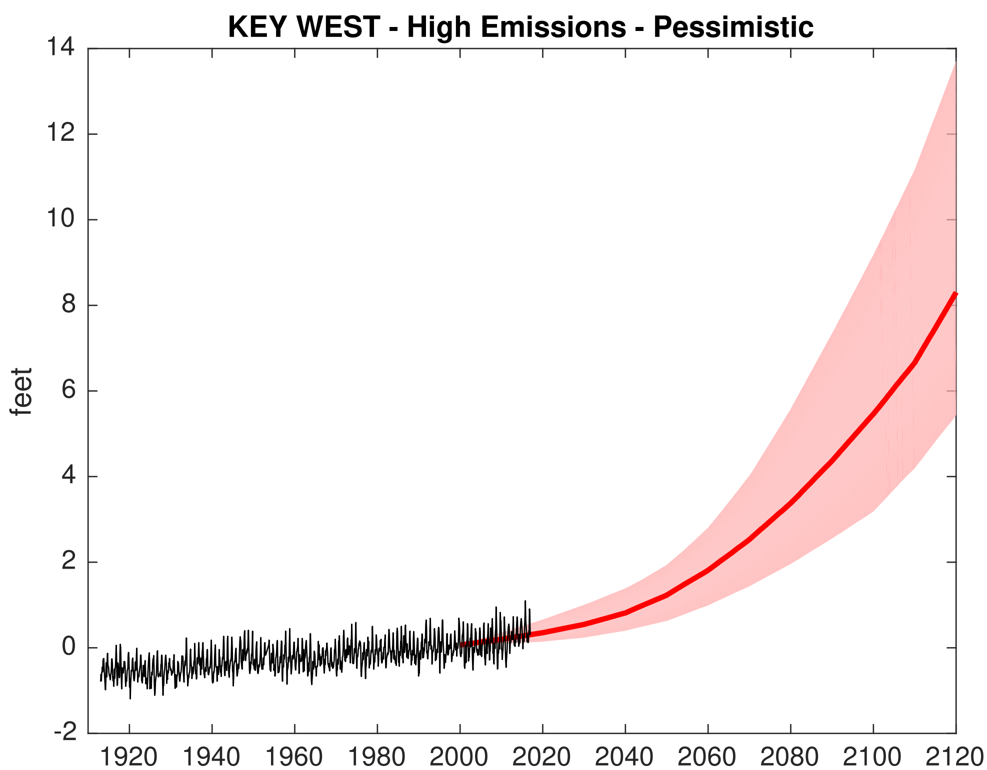
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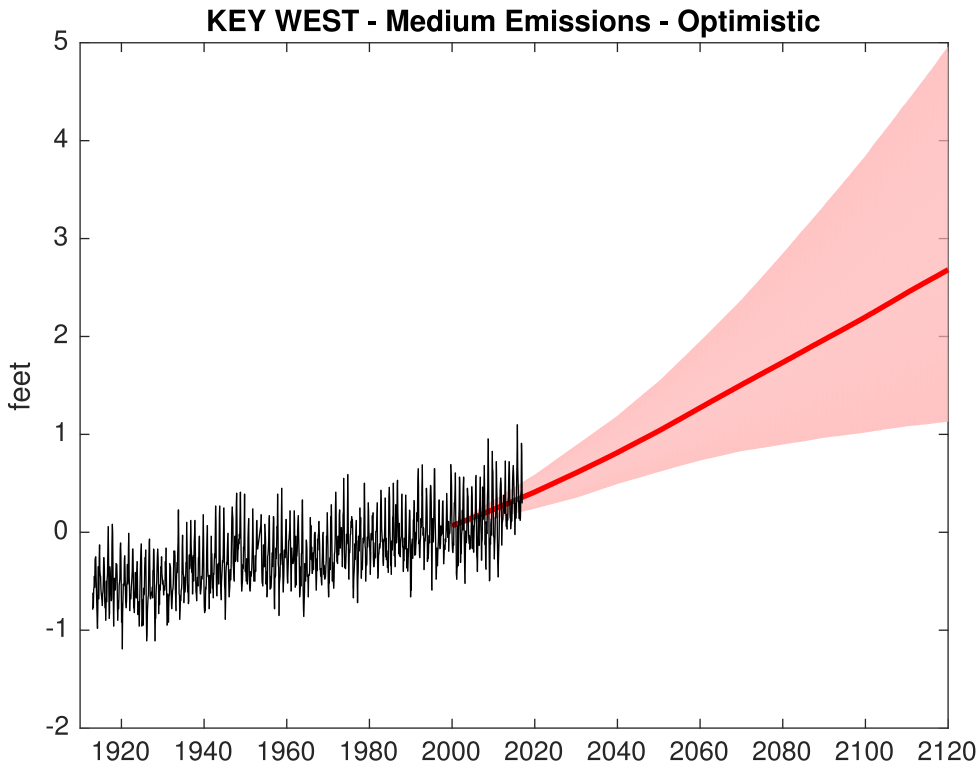
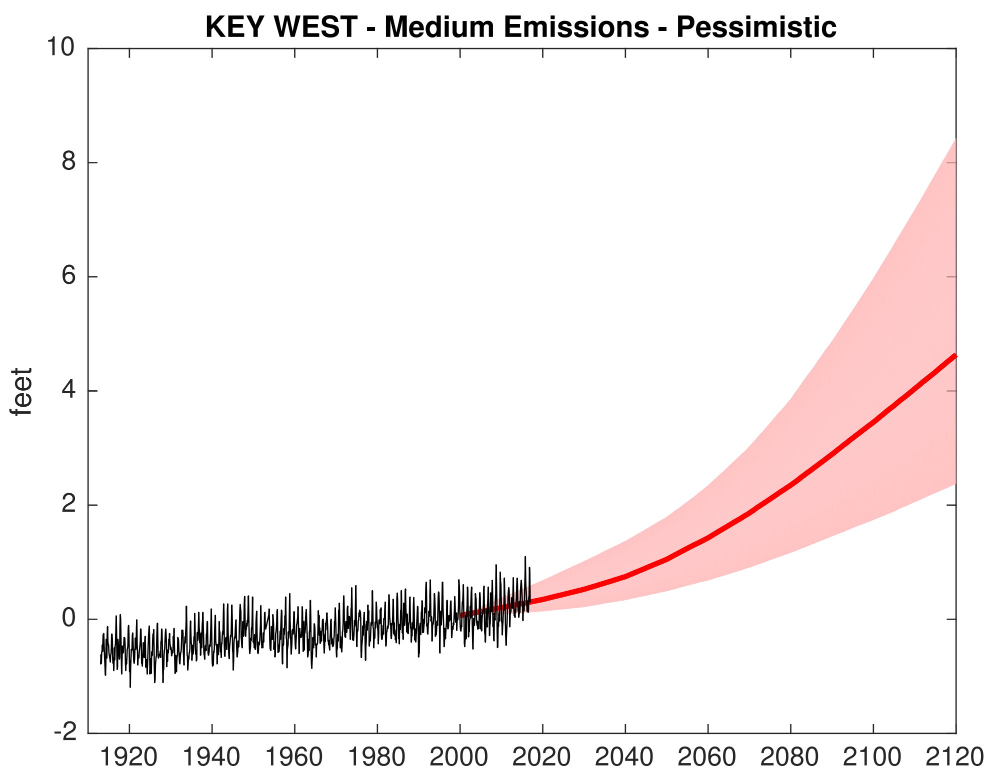
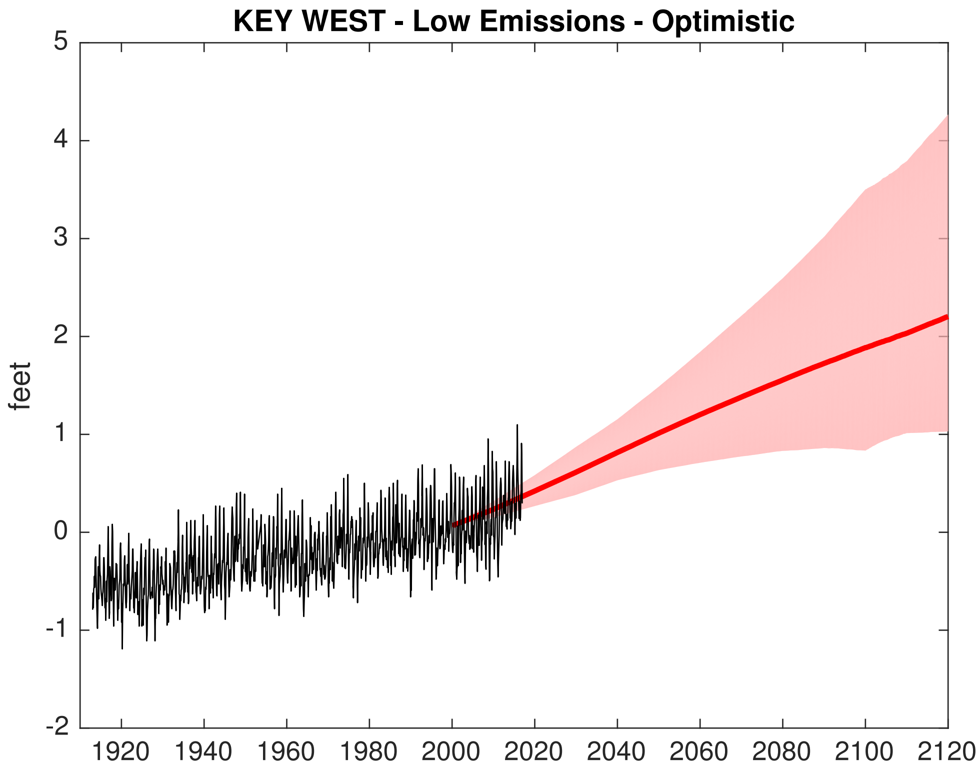
2120


KEY WEST - Medium Emissions - Optimistic
feet
5
4
3
2
1
0
-1
-2
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120


KEY WEST - Medium Emissions - Pessimistic
feet
10
8
6
4
2
0
-2
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120


KEY WEST - Low Emissions - Optimistic
feet
5
4
3
2
1
0
-1
-2
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120

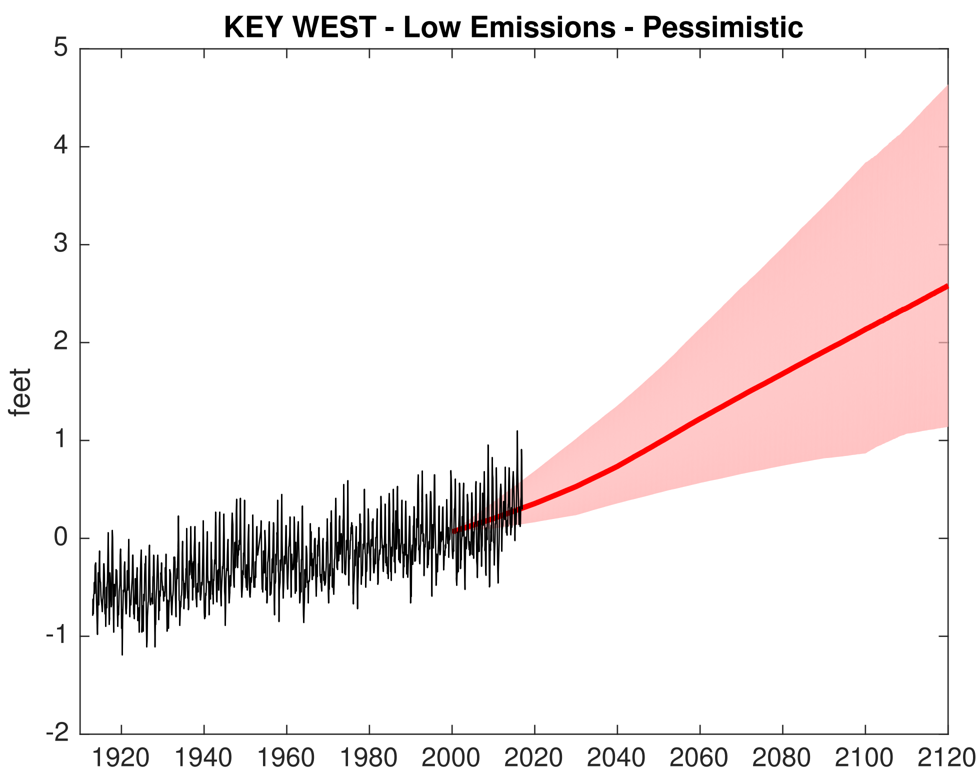

KEY WEST - Low Emissions - Pessimistic
feet
5
4
3
2
1
0
-1
-2
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120

Exhibit 2: Probability that 19-year-average sea level will exceed different thresholds over time under different scenarios and treatments of Antarctica

The tables below show the estimated probability that the 19-year average of sea-level rise at Key West will exceed the stated under three emissions scenarios (High, Medium, and Low) and two different cases for Antarctic ice-sheet behavior (Optimistic and Pessimistic) considered. The thresholds are expressed in feet above the average sea level of the National Tidal Datum Epoch (1983-2001). Each table corresponds to a specific threshold; each row to a specific combination of emissions scenario and Antarctic ice-sheet cases; each column to a 19-year average centered on a stated year; and each cell to the estimated probability that the threshold will be exceeded in the given year, under the specified emissions scenario and Antarctic case. For a particular emissions scenario, the range of probabilities across Antarctic cases approximately represents the range of probability estimates that different reasonable experts might estimate.

1 foot above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	2.1%	27.0%	68.2%	89.4%	96.0%	97.7%	98.2%	98.3%	99.6%	99.7%
High	Pessimistic	5.1%	28.3%	71.6%	94.8%	99.6%	100.0%	100.0%	100.0%	100.0%	100.0%
Medium	Optimistic	1.4%	19.2%	54.8%	78.9%	88.8%	92.6%	94.4%	95.3%	96.1%	96.5%
Medium	Pessimistic	5.7%	23.5%	55.1%	81.4%	92.8%	97.4%	99.1%	99.6%	99.8%	99.9%
Low	Optimistic	1.1%	16.8%	52.0%	74.0%	84.4%	89.2%	91.2%	91.6%	95.9%	96.1%
Low	Pessimistic	5.7%	23.2%	47.8%	68.4%	80.9%	87.3%	90.9%	92.4%	96.4%	97.2%

2 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.1%	1.2%	9.9%	32.7%	57.6%	73.4%	81.0%	91.2%	93.7%
High	Pessimistic	0.0%	0.0%	3.9%	36.5%	77.6%	94.3%	99.3%	99.9%	100.0%	100.0%
Medium	Optimistic	0.0%	0.1%	0.6%	4.2%	15.4%	32.3%	47.9%	60.0%	68.7%	75.0%
Medium	Pessimistic	0.0%	0.0%	2.2%	14.3%	41.2%	67.6%	84.0%	91.5%	95.6%	97.9%
Low	Optimistic	0.0%	0.1%	0.5%	3.0%	9.6%	21.0%	33.2%	43.7%	52.8%	59.4%
Low	Pessimistic	0.0%	0.0%	1.9%	7.5%	19.1%	32.8%	45.9%	55.9%	64.1%	70.1%

3 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.0%	0.1%	0.5%	2.9%	11.2%	26.9%	43.2%	57.0%	68.4%
High	Pessimistic	0.0%	0.0%	0.0%	2.4%	28.5%	64.9%	87.7%	96.8%	99.9%	100.0%
Medium	Optimistic	0.0%	0.0%	0.1%	0.3%	1.0%	3.7%	9.2%	18.3%	28.6%	38.4%
Medium	Pessimistic	0.0%	0.0%	0.0%	0.1%	5.5%	22.2%	45.8%	65.8%	79.9%	87.7%
Low	Optimistic	0.0%	0.0%	0.1%	0.3%	0.9%	2.2%	5.1%	10.5%	14.5%	20.7%
Low	Pessimistic	0.0%	0.0%	0.0%	0.0%	1.1%	4.7%	10.5%	18.5%	26.2%	35.9%

4 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.0%	0.0%	0.1%	0.5%	1.8%	5.9%	15.4%	22.0%	34.5%
High	Pessimistic	0.0%	0.0%	0.0%	0.0%	5.2%	30.9%	60.9%	82.9%	96.8%	99.9%
Medium	Optimistic	0.0%	0.0%	0.0%	0.1%	0.3%	0.7%	1.7%	4.1%	8.2%	14.2%
Medium	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	3.8%	15.7%	33.3%	51.0%	66.7%
Low	Optimistic	0.0%	0.0%	0.0%	0.1%	0.2%	0.6%	1.2%	2.8%	4.0%	6.5%
Low	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	3.6%	7.2%	11.3%

5 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.0%	0.0%	0.0%	0.1%	0.5%	1.5%	4.4%	6.7%	13.6%
High	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.1%	11.4%	34.7%	60.4%	82.6%	98.1%
Medium	Optimistic	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	1.2%	2.7%	4.9%
Medium	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	4.1%	13.2%	27.5%	42.0%
Low	Optimistic	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.5%	1.1%	1.5%	2.6%
Low	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.5%	2.4%

6 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.6%	1.5%	2.3%	5.0%
High	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	19.5%	39.1%	62.3%	87.6%
Medium	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	1.1%	2.0%
Medium	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	4.9%	12.9%	25.1%
Low	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.5%	0.9%	1.3%
Low	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%

7 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.7%	1.0%	2.1%
High	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	7.6%	25.9%	44.1%	69.7%
Medium	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	1.1%
Medium	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	5.9%	14.0%
Low	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.4%	0.8%
Low	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

8 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.4%	0.6%	1.2%
High	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	14.9%	31.4%	54.3%
Medium	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.4%	0.6%
Medium	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	7.2%
Low	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.5%
Low	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

9 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%	0.6%
High	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	6.0%	23.6%	40.9%
Medium	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%
Medium	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	2.7%
Low	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.3%
Low	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

10 feet above National Tidal Datum Epoch

Emissions	Antarctic	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120
High	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.2%	0.4%
High	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	13.8%	31.4%
Medium	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%
Medium	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Low	Optimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%
Low	Pessimistic	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%