1-25-2023

Evaluating Knowledge Gaps in Sea-Level Rise Assessments From the United States

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Recommended Citation

Garner, A. J., Sosa, S. E., Tan, F., Tan, C. W. J., Garner, G. G., & Horton, B.P. (2023). Evaluating knowledge gaps in sea-level rise assessments from the United States. Earth's Future,11, e2022EF003187. https://doi.org/10.1029/2022EF003187

AGU ADVANCING EARTH AND SPACE SCIENCE

Earth's Future

RESEARCH ARTICLE
10.1029/2022EF003187

Key Points:

- More than half of communities in the United States (U.S.) underestimate the upper end of future sea-level rise (SLR) compared to projections from the most recent Intergovernmental Panel on Climate Change report
- There are no long-term (beyond 2100) projections of SLR from assessment reports in the U.S. South
- Most projections from the U.S. Northeast and West use ranges of SLR; projections from the U.S. South often use single estimates

Supporting Information:
Supporting Information may be found in the online version of this article.

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Citation:
Garner, A. J., Sosa, S. E., Tan, F., Tan, C. W. J., Garner, G. G., & Horton, B. P. (2023). Evaluating knowledge gaps in sea-level rise assessments from the United States. *Earth's Future*, *11*, e2022EF003187. https://doi.org/10.1029/2022EF003187

Received 29 JUN 2022
Accepted 21 NOV 2022

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Evaluating Knowledge Gaps in Sea-Level Rise Assessments From the United States

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Abstract There have been many scientific advances regarding future sea-level projections, however it is unclear if these have been transferred to assessment reports used by stakeholders. Here, we present a first-of-its-kind comprehensive analysis of regional sea-level rise (SLR) assessments for the United States (U.S.). We identify variations in time horizons over which regions plan for SLR, with 25 projections from the U.S. Northeast and West that extend to 2150 or beyond, but no projections from the U.S. South beyond 2100. The majority of 2100 projections from the U.S. Northeast (77%) and West (83%) include ranges of future SLR, while 88% of projections from the U.S. South include only single estimates. At least 56% of U.S. communities in the database underestimate the upper end of future SLR compared to the regional projections of the Intergovernmental Panel on Climate Change Sixth Assessment Report.

Plain Language Summary It is unknown if scientific advances are readily incorporated into local SLR assessments used by the public for decision making. To better understand where knowledge gaps exist in SLR assessments, we construct and analyze a database of the most recent local assessments for the United States (U.S.). We find differences in assessments among regions, including the time horizons used for future projections, and varying preferences for single values of SLR versus ranges that better capture uncertainty. Over half of U.S. communities included in our analysis underestimate the high end of future SLR compared to the Intergovernmental Panel on Climate Change Sixth Assessment Report.

1. Introduction

Despite the threat that rising sea levels present to coastal communities in a warming world, coastal populations and associated economic assets of the United States (U.S.) have increased in recent decades, and are likely to continue to grow in the future (National Oceanic and Atmospheric Administration (NOAA), 2013). By 2100, it is plausible that up to 13 million people within the continental U.S. could live in areas at risk of inundation from rising sea levels (Hauer et al., 2016). Consequently, future sea-level rise (SLR) is a pressing concern for coastal stakeholders (Sweet et al., 2017).

Given the potentially devastating consequences of rising sea levels for coastal communities and ecosystems (Kirwan & Megonigal, 2013; Kulp & Strauss, 2017; Saintilan et al., 2020), it is perhaps unsurprising that research efforts aimed at projecting future sea levels have resulted in numerous scientific advances in the four decades since the first global mean sea level projections were published (Gornitz et al., 1982; B. P. Horton et al., 2020; Kopp et al., 2014; Rahmstorf, 2007; Wigley, 1995). One such advance is the development of regional projections of SLR for the U.S., which can deviate from the global average (Church et al., 2013; Kopp et al., 2014; Slangen et al., 2012, 2014) because of physical processes such as ocean dynamics, gravitational and rotational deformation effects, and vertical land motion (e.g., Church et al., 2013; Couldrey et al., 2021; Ezer et al., 2013; Harvey et al., 2021; B. P. Horton et al., 2018; Love et al., 2016). Other advances have included the development of new approaches (such as probabilistic projections) to better capture uncertainty within SLR projections (A. J. Garner et al., 2018; Kopp et al., 2014); a focus on less likely but highly damaging high-end SLR projections (B. P. Horton et al., 2018; Kopp et al., 2017; Pfeffer et al., 2008); and an expansion of the time horizons for which we project future SLR (Kopp et al., 2017; Levermann et al., 2013; Schaeffer et al., 2012).

Writing – review & editing: Andra J. Garner, Sarah E. Sosa, Fangyi Tan, Christabel Wan Jie Tan, Gregory G. Garner, Benjamin P. Horton

Assessment reports that project and plan for future SLR (Griggs et al., 2017; Hall et al., 2019; R. Horton et al., 2010; Kopp, Andrews, et al., 2019; NAHRIM, 2010; Sweet et al., 2022) for coastal communities and decision makers (Hamlington et al., 2020, 2021) must be cognizant of the latest scientific advances. However, there are many social and economic challenges when it comes to properly planning to protect coastal communities and ecosystems from SLR, due to the deeply uncertain nature of future SLR (especially on longer time horizons) and multiple regional processes that influence sea level (Bongarts Lebbe et al., 2021; Hinkel et al., 2018). These challenges can be amplified by the institutional complexities that inevitably arise when working to implement coastal policies that are supported by the science (Hall et al., 2018; Kopp, Gilmore, et al., 2019). When such challenges persist, it can result in disconnects between the state of the science and the guidance provided to stakeholders in assessment reports (Hall et al., 2018).

Here, we present the first database of current regional SLR assessment reports in the U.S. to evaluate the present state of the scientific guidance and discover potential knowledge gaps that might hinder coastal resilience. We analyze SLR projection methodologies, magnitudes, and timescales from the Atlantic, Gulf, and Pacific coasts of the U.S., and compare current regional guidance from these areas with projections of regional SLR from the Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC AR6; IPCC, 2021). Our work highlights potential scientific and communication gaps that will be critical for local communities to overcome as they seek to prepare for future changes in sea level.

2. The United States Sea-Level Rise Assessment Database

The database of regional SLR assessment reports (hereafter, the database) includes nearly 400 projections from 31 reports for 54 locations in the U.S. and Puerto Rico (Table S1). The database is comprised of the most recent published assessment reports for each location (deadline of 31 December 2021). Information described in the database allows for assessed projections to be classified by region, methodology, end year, and emission scenario (Table 1). Individual assessment reports are crafted by authors from various sectors, including academia, government, industry, and non-profit/charitable organizations.

When describing the database, the terms "lower," "central," and "upper" estimates are used to describe assessed SLR with varying likelihoods (e.g., different percentiles) from a single projection within a report. Alternatively, the terms "low," "moderate," "high," and "combined" are used to describe the emissions scenarios for which a given report provides assessed values of future SLR. As an example, New Jersey's state assessment report includes three sets of assessed projections for the year 2100—one each for low, moderate, and high emissions. Each of these projections includes a lower (5th percentile), central (50th percentile), and upper (95th percentile) estimate in the database (Kopp, Andrews, et al., 2019).

Where feasible, we use the 5th, 50th, and 95th percentiles of assessed SLR projections in the database as lower, central, and upper SLR estimates. However, this is not always possible because some assessed projections define lower, central, and upper estimates differently, and other assessed projections provide only a single value of estimated future SLR, which is listed in the database as a central estimate, since it is both the highest and lowest estimate of SLR available for that location (Table S1).

3. Variations in Regional Sea-Level Rise Assessments From the United States

To identify potential variations in SLR assessment approaches within the U.S., we divide the U.S. into three geographical regions following the Fourth National Climate Assessment (USGCRP, 2018): U.S. Northeast; U.S. South; and U.S. West (Figure 1a; See Section 6).

3.1. Planning for SLR Over Different Time Horizons

Assessments in the database have a variety of time horizons. Factors influencing time horizons include: accepted planning horizons for land-use and infrastructure projects (Caffrey et al., 2018; Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group, 2019); direct feedback from practitioners (Kopp, Andrews, et al., 2019); horizons used in the most recent national/international assessments (Caffrey et al., 2018; Hawai'i Climate Change Mitigation and Adaptation Commission, 2017); and direct charges from political committees commissioning the assessment (North Carolina Coastal Resources Commission Science Panel, 2015). The

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Table 1
Fields Included in the Regional Sea-Level Rise Projection Database

Database field	Units/Notes
Title of the assessment report	–
Region of focus for the projection	–
Broader geographical region for the projection	(U.S. Northeast, U.S. South, or U.S. West)
Latitude	Degrees N/S
Longitude	Degrees E
Lead author	May be individual or organization
Sector(s) with which authors are affiliated	–
Third-party report	Yes (not locally produced) or No (locally produced)
Year the report was published	–
Year the previous iteration of the report was published	–
Methodology of the projection	As in Table 2
Emission scenario used for the projection	–
Baseline year for the projection	–
End year for the projection	–
Lower estimate of SLR	Meters
Definition of the lower estimate of SLR	–
Central estimate of SLR	Meters
Definition of the central estimate of SLR	–
Upper estimate of SLR	Meters
Definition of the upper estimate of SLR	–
SLR projection components: Vertical land motion	Yes (included) or No (excluded)
SLR projection components: Land water storage	Yes (included) or No (excluded)
SLR projection components: Greenland ice sheet	Yes (included) or No (excluded)
SLR projection components: Antarctic ice sheet	Yes (included) or No (excluded)
SLR projection components: Glaciers	Yes (included) or No (excluded)
SLR projection components: Thermal expansion	Yes (included) or No (excluded)
SLR projection components: Ocean dynamics	Yes (included) or No (excluded)
Link to report containing the projection	–
Notes relevant to the projection's database entry	–

total numbers of assessments and individual projections at different time horizons differ substantially by region (Figure 1b).

The U.S. Northeast has the greatest number of individual assessment reports ($n = 11$) in the database compared to the U.S. South ($n = 10$) and U.S. West ($n = 4$) for 2050. The same is true for 2100, where there are 13 assessments for the U.S. Northeast, 10 assessments for the U.S. South, and four assessments for the U.S. West (Figure 1b). The relatively large number of assessments in the U.S. Northeast may be due to the number of individual states within the region, and/or the fact that in this region, some cities such as New York City and Boston produce their own SLR assessments in addition to broader state reports (Gornitz et al., 2019; The Boston Research Advisory Group, 2016).

The U.S. South, however, has the greatest number of assessed projections within assessment reports for 2050 ($n = 59$) and 2100 ($n = 48$) compared to U.S. Northeast ($n = 19$ in 2050 and $n = 35$ in 2100) and U.S. West ($n = 9$ in 2050 and $n = 24$ in 2100; Figure 1b). But, these values come with the caveat that 36 assessed projections for each time horizon in the U.S. South (approximately 61% of 2050 and 75% of 2100) are from a third-party assessment on SLR hazards produced by the National Park Service (NPS; Caffrey et al., 2018), rather than from assessments crafted by and for stakeholders within the local community (see Section 6).

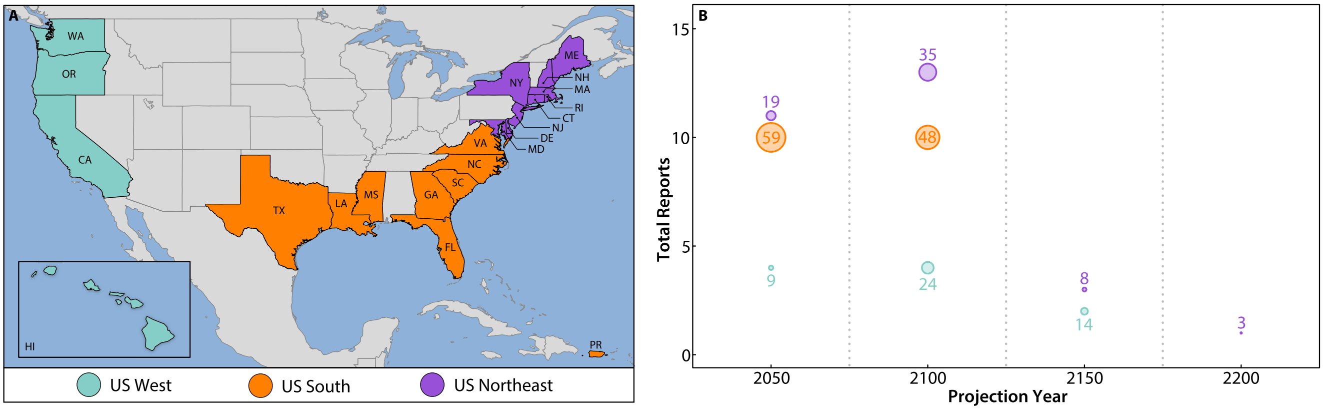

Figure 1. Total Assessment Reports and sea-level rise (SLR) Projections by Region. (a) Map depicting the states with SLR projections included in the database. Colors indicate the geographical region into which each state has been classified: United States (U.S.) Northeast (purple), U.S. South (orange); U.S. West (blue). (b) Total number of SLR reports and projections for year 2050, 2100, 2150, and 2200 in each region. The total number of projections during each time period for each region is indicated by the point size and numbers in (or adjacent to) each point. Note that many individual assessment reports produce multiple projections, including different projections for different emission scenarios. Point colors are used to distinguish different regions: U.S. Northeast (purple), U.S. South (orange); U.S. West (blue).

Over longer time horizons there are significant variations in the availability of assessed SLR projections among U.S. regions. The U.S. Northeast plans for the longest time horizons, with three assessed projections extending to 2200, and eight assessed projections extending to 2150. The U.S. West also has a high number of long-term time horizons, with 14 assessed projections in the year 2150. The U.S. South, however, has no assessed projections available beyond 2100 (Figure 1b).

3.2. Different Approaches to Projecting Future Sea-Level Rise

There are regional differences in methodologies to assess future SLR (Table 2, Figures 2 and 3). The U.S. Northeast has the greatest variety of methods whereas the U.S. West has the least; but in both regions, the dominant methodology is a probabilistic approach (57% and 81%, respectfully). In the U.S. South, probabilistic methodologies are not used at all. Instead, the primary methodology involves adapting IPCC projections (58%)—a method in which assessed projections are based on those from an IPCC report but are adapted in some way to

Table 2
Descriptions of Sea-Level Rise Projection Methodologies

Method	Description
Probabilistic	Projections are taken from a comprehensive probability distribution, and are comprised by estimating individual components
Model synthesis	Models are used to calculate SLR contributions from every component considered, but projections are not taken from a comprehensive probability distribution
Model hybrid	Physical and/or statistical modeling techniques are used to estimate SLR contribution for some components, but not all; projections are not taken from a comprehensive probability distribution
IPCC	Projections are taken directly from an IPCC report
Adapted IPCC	Projections are based on those from an IPCC report, but are adapted in some way to better reflect the hazard for a specific region (e.g., adding vertical land motion)
NOAA 2017	Projections are taken directly from the 2017 NOAA Technical Report, "Global and Regional Sea Level Rise Scenarios for the United States"
Adapted NOAA 2017	Projections are based on those from the NOAA 2017 Report, but are adapted in some way for the specific region
Adapted IPCC/NOAA 2017	Projections are based on a combination those from IPCC reports and those from the 2017 NOAA report
Other	Range of alternative methodologies that do not clearly fit into any of the categories described above.

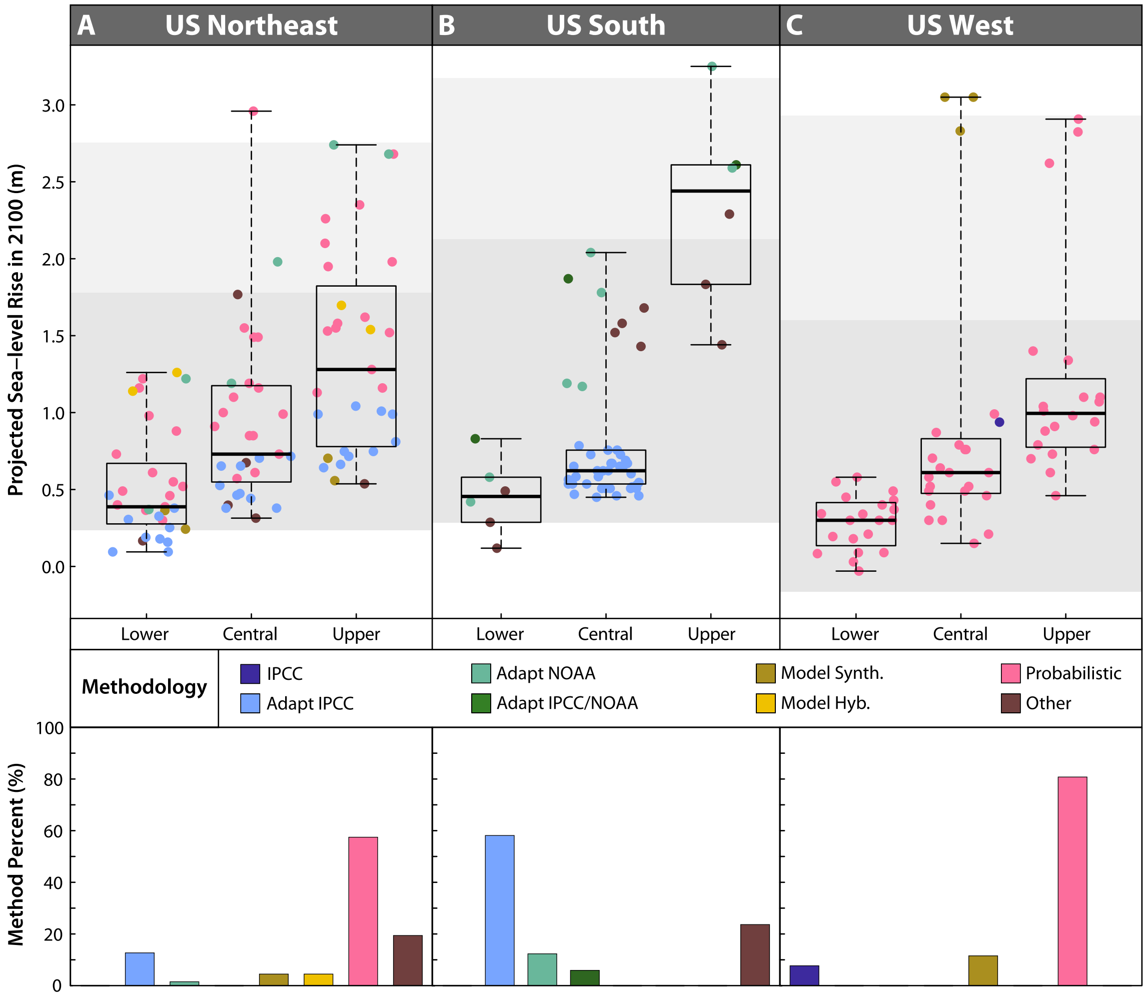

Figure 2. Projected sea-level rise (SLR) by Region and Method. Top: Projected SLR from assessment reports collected from the United States (U.S.) Northeast (a), U.S. South (b), and U.S. West (c). Shown are lower estimates, central estimates, and upper estimates from each region. Box plots show the extreme range of the data for each category (dashed lines), as well as the 25th −75th percentiles (boxes), and medians (sold line within box). Color represents the methodology used to generate SLR projections. Note that SLR projections have been normalized for comparison to one another (see Section 6.3). Shaded area in background shows the 5th percentile of AR6 SSP1-2.6 medium-confidence projections to the 95th percentile of AR6 SSP5-8.5 medium-confidence projections (darkest shading) and additional SLR up to the 95th percentile of AR6 SSP5-8.5 low-confidence projections (lighter shading) for each region as a whole. Bottom: Bar plots showing the percentage of projections using various methodologies for (a) the U.S. Northeast, (b) the U.S. South, and (c) the U.S. West. Bar colors indicate methodology used.

better reflect the hazard for a specific region (e.g., by adding regional estimates of vertical land motion; Table 2, Figure 2b).

While not all assessments go into detail about the reasoning for choosing particular methodologies, some common themes emerge. Many assessments defer to methods and data sources from the most recent IPCC report at the time, citing the IPCC as the world's leading authority on climate change (e.g., Caffrey et al., 2018; Hawai'i Climate Change Mitigation and Adaptation Commission, 2017). Other reports similarly rely upon the IPCC, but also look to national assessments such as those from the NOAA, deferring to not only an internationally recognized authority, but also a leading authority at the national level in scientific analyses of our coasts (e.g., Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group, 2019). Still other assessments opt for methods such as probabilistic approaches described in individual studies from the record of peer-reviewed literature. For example, California's assessment largely relies upon the probabilistic approach from Kopp et al. (2014), with one of the key points from the state's assessment indicating that probabilistic approaches will be best for California's policy needs, since probabilities of specific SLR can help to inform decisions (Griggs et al., 2017).

Approaches to SLR projections in the U.S. also vary by whether the focus is on single values of projected SLR ("central estimates") or ranges of possible future SLR that convey uncertainty at various time horizons. Most

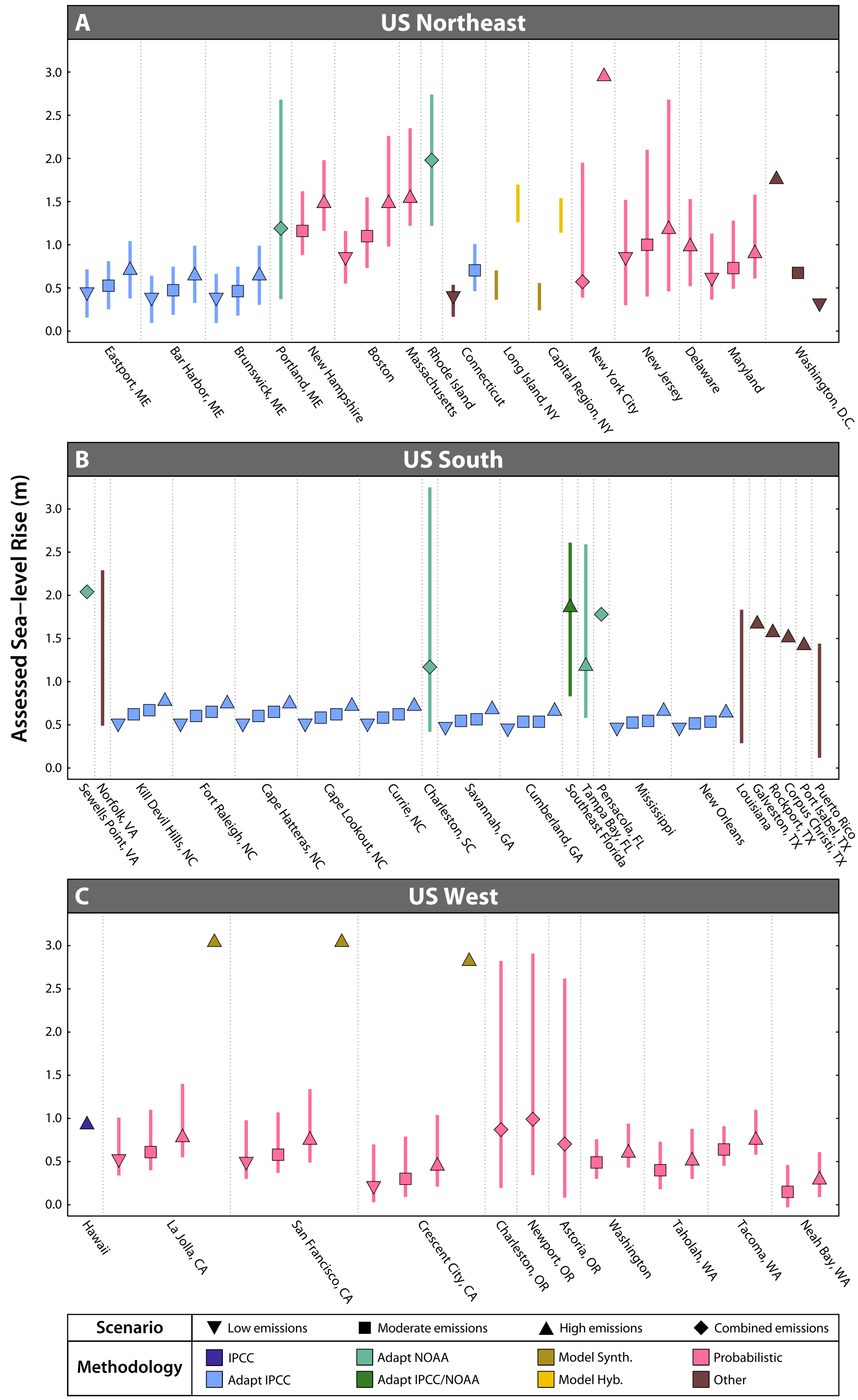

Figure 3. Ranges and Emission Scenarios of Projected sea-level rise (SLR). Assessed SLR from the United States (U.S.) Northeast (a), U.S. South (b), and U.S. West (c). Bars in each plot show the range of projected SLR (from lower estimate to upper estimate); points show the central estimate from each projection. Color of bars and points indicate methodology (as in Figure 2). Point shape indicates whether the projection is for a low emissions scenario (downward triangle), moderate emissions scenario (square), high emissions scenario (upward triangle), or combined emissions scenario (diamond). Some locations do not include central estimates, and thus do not have a point to indicate the type of emissions scenario. These locations are: Long Island NY and Capital Region NY (Model Synthesis projections: Emissions = Combined; Model Hybrid projections: Emissions = High); and Louisiana, Puerto Rico, and Norfolk, VA, all of which use a combined emissions scenario for assessed projections.

projections for SLR in 2100 from the U.S. Northeast (77%) and U.S. West (83%) include lower, central, and upper estimates of future SLR (Figures 2 and 3). This finding is consistent with the dominant methodology in both regions being probabilistic, and suggests some effort to capture the deeply uncertain nature of assessed SLR projections (A. J. Garner et al., 2018; Kopp, Gilmore, et al., 2019; Kopp et al., 2014). In the U.S. South, however, the majority (88%) of 2100 projections include only a single, "central" estimate of future SLR, rather than a projected range that better captures uncertainty (Figures 2b and 3b; Kopp, Gilmore et al., 2019).

Assessed projections for different regions in the U.S. further differ by the types of emission scenarios considered (Figure 3). For instance, the majority of 2100 projections in the database (87%) use "low" (e.g., Representative Concentration Pathway 2.6 (RCP2.6)), "moderate" (e.g., RCP4.5), and/or "high" emission scenarios (e.g., RCP8.5) to generate assessed projections. However, across all regions, some assessments either have no clearly defined emission scenario (e.g., Watson & Knapp, 2021), or opt instead to use a combination of scenarios to generate assessed projections (Figure 3). For example, assessments from New York City (Gornitz et al., 2019), Oregon (Dalton & Fleishman, 2021), and Louisiana (Coastal Protection and Restoration Authority, 2017), all include assessed projections for an emissions scenario defined as a combination of RCP4.5 and RCP8.5 emission scenarios (Figure 3).

Some assessments from each region also include scenarios that are more extreme than a typical high emissions pathway—for example, California includes assessed projections for an H++ scenario (extreme scenario from the Fourth National Climate Assessment; Griggs et al., 2017), New York City includes assessed projections for an Antarctic Rapid Ice Melt scenario (Gornitz et al., 2019), and South Carolina includes assessed projections for the NOAA Extreme scenario (consistent with 2.5 m of global mean SLR by 2100; Watson & Knapp, 2021). Assessment reports for these regions often highlight the deep uncertainty associated with ice loss from Antarctica, and the need to consider extreme scenarios in the face of uncertainty. For example, New York City, New Jersey, and California assessment reports all discuss the potential for large contributions to SLR from Antarctica in the future as a reason for considering relatively high-end scenarios in their assessments (see Section 5; Gornitz et al., 2019; Griggs et al., 2017; Kopp, Andrews, et al., 2019).

Accompanying the range of scenarios and their associated SLR projections, some assessments include guidance on how assessed projections for different scenarios and estimates should be used in decision making. For example, the assessment report for Southeast Florida which focuses only on a high scenario notes that values between the lower estimate and central estimate should be used for most projects with a short-term planning horizon; values in line with the central estimate should be used for critical infrastructure expected to be in service during or after 2070, and values consistent with the upper estimate should be used for projects expected to last beyond 2070 as well as infrastructure that cannot be easily replaced or moved (Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group, 2019). Similarly, an assessment for North Carolina advises users that higher SLR estimates and scenarios will decrease risk for infrastructure projects like roads, bridges, and hospitals (North Carolina Coastal Resources Commission Science Panel, 2015). Alternatively, the New Jersey assessment stresses that users should consider multiple scenarios for their decisions, given the uncertainty of future emissions and associated SLR (Kopp, Andrews, et al., 2019).

3.3. Magnitudes of Projected Sea-Level Rise

Approaches to SLR assessments play an important role in the overall magnitude of assessed SLR projections in each region for different time horizons.

The U.S. Northeast interquartile (25th–75th percentile) ranges for lower, central, and upper estimates of SLR in 2100 are relatively broad (all >0.39 m) with values of 0.28–0.67 m, 0.55–1.18 m, and 0.78–1.82 m, respectively (Figure 2a). In the U.S. South, interquartile ranges are narrower for lower (0.29–0.58 m) and central (0.54–0.76 m) estimates, but the upper estimate is broad and of significantly higher magnitude (1.83–2.61 m; Figure 2b). In the U.S. West, interquartile ranges for lower, central, and upper estimates of SLR in 2100 are consistently narrow at 0.14–0.42 m, 0.48–0.83 m, and 0.78–1.22 m, respectively (Figure 2c). The maximum assessed projections of SLR for 2100 are 2.96 m in the U.S. Northeast (New York City), 3.25 m in the U.S. South (South Carolina), and 3.05 m in the U.S. West (California; Figures 2 and 4).

Cumulative distribution functions (CDFs) constructed by pooling all assessed projections (lower, central, and upper estimates) for each region and time horizon illustrate differences in assessed projection magnitudes among

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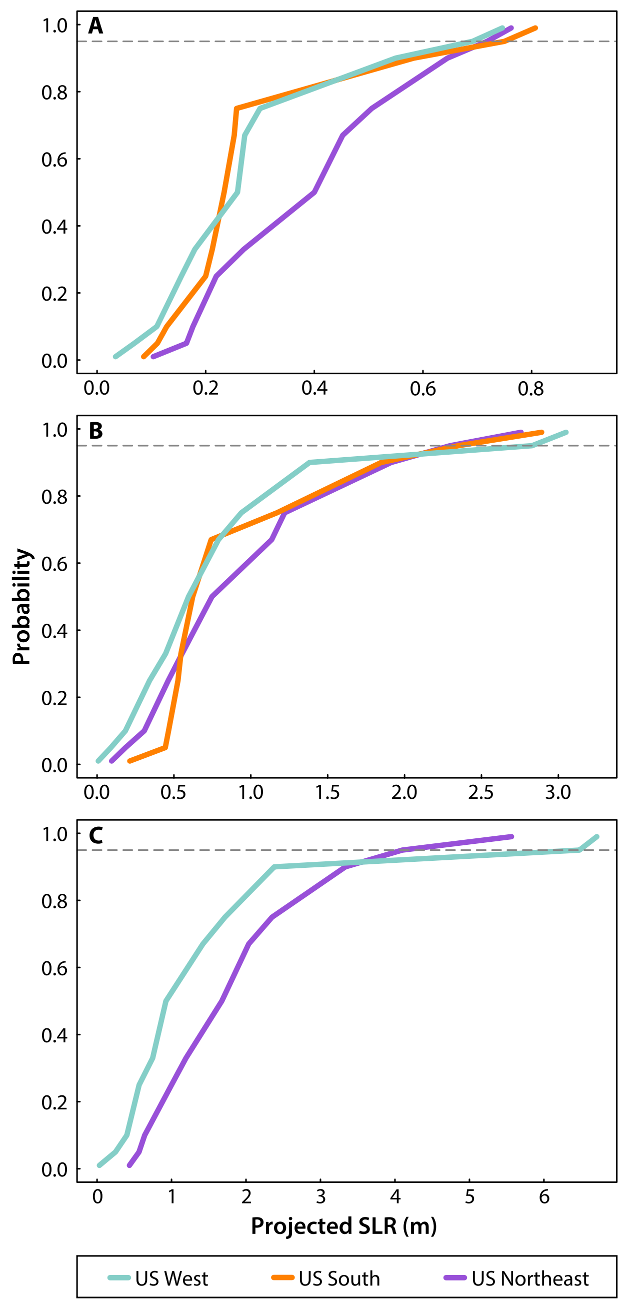

Figure 4. Cumulative Distribution Functions (CDFs) of Projected sea-level rise (SLR) from Assessment Reports in the United States (U.S.). CDFs constructed over the ensemble of normalized assessed projections of SLR (see Section 6.3) for the U.S. Northeast (purple), U.S. South (orange), and U.S. West (blue) in year (a) 2050, (b) 2100, and (c) 2150. Dashed line represents the 95th percentile of the projection ensemble for each time period/region.

regions at different time horizons (Figure 4). For the year 2050, assessed projections from the U.S. Northeast are typically the highest of any region (21 projections greater than 0.4 m), except for the very upper tail of 2050 assessed projections, which tend to be higher in U.S. South (Figure 4a). Assessed projections from the U.S. West are often the lowest in all time periods except the upper tail of assessed projections in 2100 and 2150, with six assessed projections greater than 2 m in 2100, and three assessed projections greater than 3 m in 2150 (Figures 2, 4b, and 4c). The highest projections for the U.S. West in each of these time periods come from the California assessment, which includes assessed median projections for both 2100 and 2150 using the H++ scenario (Figures 2, 4b, and 4c).

Similar patterns emerge for CDFs constructed from assessed projections for different emission scenarios and regions (Figure S1 in Supporting Information S1). For instance, CDFs of assessed projections in the year 2100 for low and moderate emissions scenarios indicate that the U.S. Northeast generally has the highest assessed projections (exceeding 1 m for low scenarios, and 2 m for moderate scenarios), followed by the U.S. West. Most projections from the U.S. South for low and moderate emissions scenarios are very similar to one another, and are all around 0.5 m. For high emission scenarios in 2100, the highest projections from the U.S. West tend to exceed the magnitude of assessed projections for the U.S. Northeast and U.S. South. In cases where a combination of emissions scenarios are used for 2100 projections, assessed projections from the U.S. South tend to be greatest, though all three regions include projections for combined emissions that exceed 2.5 m.

4. Comparing Local Assessment Reports With Regional Projections From the IPCC Sixth Assessment Report

The IPCC Sixth Assessment Report (AR6; IPCC, 2021) includes for the first time easily accessible regional SLR projection data (Fox-Kemper et al., 2021; G. G. Garner et al., 2021). Here, we compare the 95th percentile of Shared Socioeconomic Pathway 5–8.5 (SSP5-8.5) IPCC AR6 regional projections with the highest 2100 SLR estimates for each location in the database to understand which local assessments successfully capture the less likely, but highly damaging upper estimates of SLR that cannot be ruled out by 2100 (Fox-Kemper et al., 2021). In many cases, the highest assessed projection being compared to IPCC values is an upper estimate; however, in some cases (e.g., San Francisco, CA, or Savannah GA), the highest assessed projection for a location is recorded as a central estimate in the database (Figure 3). From a risk-perception standpoint, it is important to understand how the maximum assessed SLR for each location compares with an estimate from the upper tail of the probability distribution of IPCC regional SLR projections since such scenarios would be highly damaging if realized, and successful adaptation measures require sufficient advance planning to be successful (Haasnoot et al., 2019; McEvoy et al., 2021). Comparisons with the 95th percentile of IPCC regional SLR projections are therefore made to whichever assessed projection in the database is highest for each location, regardless of whether that assessed projection is categorized as a "central," or "upper" estimate (see Section 6).

An analysis of the maximum assessed projections for each location in the database suggests that at least 56% of locations underestimate the upper end of future SLR compared to IPCC AR6 regional projections. The highest regional projections from IPCC AR6 are generally found in the U.S. South along the Gulf Coast, followed by the U.S. Northeast, with the lowest SLR projections found in the U.S. West.

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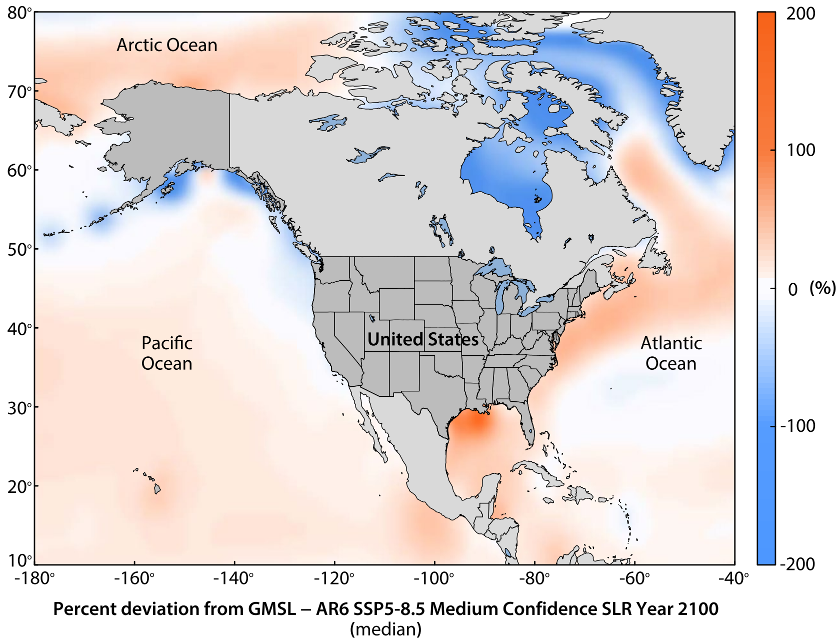

Figure 5. Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC AR6) Global and Regional sea-level rise (SLR). Comparison Maps showing the percent deviation of the IPCC AR6 SSP5-8.5 medium-confidence regional SLR projections from the global mean sea level for the year 2100 at the 0.5 quantile (median).

In the U.S. Northeast, the regional IPCC AR6 projections tend to exceed global mean projections in 2100, with the greatest levels of exceedance in the southern portion of the region along the coasts of Maryland, New Jersey, New York, and Massachusetts (Fox-Kemper et al., 2021; G. G. Garner et al., 2021), due to a combination of vertical land-level subsidence from glacial isostatic adjustment (Love et al., 2016; Walker et al., 2021) and ocean dynamics associated with changes in the strength and/or position of the Gulf Stream (Ezer et al., 2013; Harvey et al., 2021; Love et al., 2016) (Figure 5). The guidance from many assessments in this region is consistent with the IPCC projection of greater future SLR than the global average for 2100. Many locally assessed projections match or exceed the 95th percentile of SSP5-8.5 IPCC AR6 projections (Figures 6a and 6d; Figure S2 in Supporting Information S1; Section 6). Furthermore, several local assessments from this area account for less-likely, but highly damaging future SLR scenarios (e.g., New York City; Gornitz et al., 2019), and therefore have locally assessed projections that are consistent with the SSP5-8.5 IPCC AR6 low-confidence projections (Figures 6a and 6e; Figure S2 in Supporting Information S1; Section 6).

In the U.S. South, the regional IPCC AR6 projections for 2100 typically exceed global mean projections (Figure 5; Fox-Kemper et al., 2021; G. G. Garner et al., 2021). The greatest exceedances are found along Gulf of Mexico coastline, particularly along the coasts of Texas, Louisiana, and Mississippi, where there is substantial subsidence caused by a potential combination of subsurface fluid withdrawal and compaction (Abadie et al., 2020; Harvey et al., 2021; Jankowski et al., 2017; Kolker et al., 2011; Törnqvist et al., 2020). On the U.S. Southeast coast, exceedances tend to be greatest along the shorelines of Virginia and the Carolinas, where vertical land-level subsidence from glacial isostatic adjustment and the Gulf Stream are still important contributors to regional SLR (Ezer et al., 2013). Assessed projections for the U.S. South often fall well below IPCC AR6 estimates, with the greatest deficits in the Mississippi delta region, where assessed projections are up to 1.4 m below the 95th percentile of SSP5-8.5 IPCC AR6 estimates for 2100 (Figures 6b and 6d, Figure S2 in Supporting Information S1). In South Carolina and Florida, however, where we find the highest assessed projections for the region, some assessed values either exceed (South Carolina) or come within 0.1 m (Florida) of the more extreme IPCC AR6 low-confidence estimates (Figures 3, 6b, and 6e; Figure S2 in Supporting Information S1).

In the U.S. West, where tectonics currently causes regional uplift along much of the Washington, Oregon, and northernmost California coast (Harvey et al., 2021), IPCC AR6 projections for 2100 are typically the same as or lower than global mean projections (Figure 5). The exception to this rule is Hawaii, which tends to exhibit

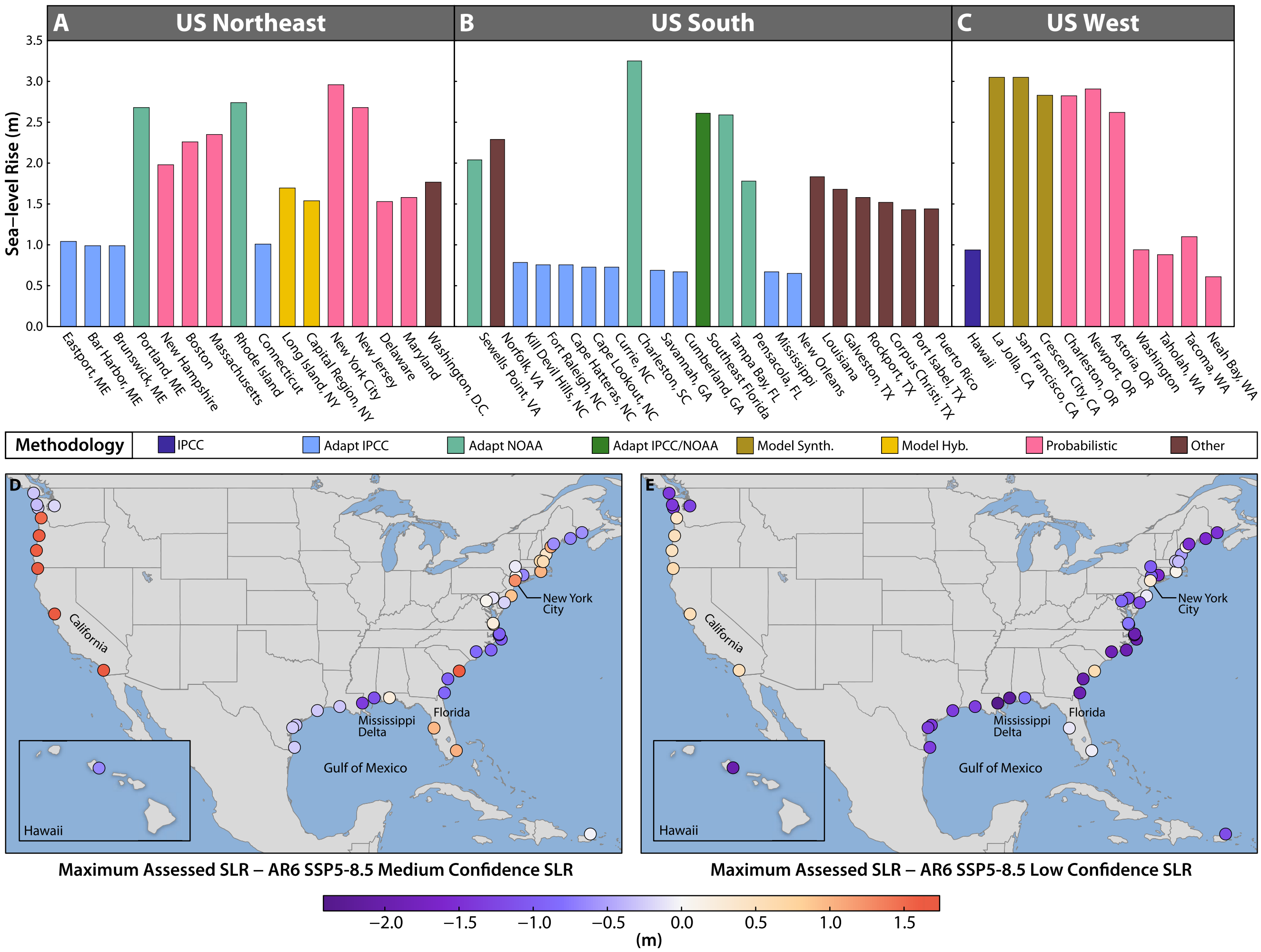

Figure 6. Comparing maximum year 2100 sea-level rise (SLR) estimates from Assessment Reports with Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC AR6) Projections. (a–c) Bar plots showing the magnitude of maximum year 2100 SLR projection at each location in the database for each region, and the method used for that maximum projection (bar color); (d) point-by-point comparison of maximum year 2100 SLR from assessment reports with IPCC AR6 medium-confidence projections, and (e) point-by-point comparison of maximum year 2100 SLR from assessment reports with IPCC AR6 low-confidence projections. Note that maximum year 2100 SLR is simply the maximum assessed SLR recorded for each location in the database, and does not depend on an estimate's classification as "lower," "central," or "upper" (See Sections 4 and 6.4).

higher regional SLR than the global average for most islands for 2100 (Figure 5). Some regional assessments for the U.S. West (Washington, Hawaii) are lower than not only the global average, but also lower than the 95th percentile of SSP5-8.5 IPCC AR6 projections (Figures 6c and 6d; Figure S2 in Supporting Information S1). The lowest regional assessment compared to IPCC AR6 values is from Hawaii, where regionally assessed projections are 0.7 m less than IPCC AR6 estimates for 2100 (Figure 6d). In California, however, where the highest locally assessed projections were developed for the H++ scenario, local assessments exceed even the IPCC AR6 low-confidence values (Figures 6c and 6e, Figure S2 in Supporting Information S1). The same is true in Oregon, where the highest locally assessed projections were developed for the NOAA Extreme scenario.

5. Discussion

Long-term assessments are important to ensure appropriate adaptation planning commitments, in order to avoid more costly retrofitting of infrastructure when higher SLR amounts are inevitably realized (Haasnoot et al., 2021). There are 25 assessed projections for the U.S. Northeast and West that extend to 2150 or beyond; nearly all of these long-term projections exceed 1 m, and several in each location exceed 5 m (e.g., Griggs et al., 2017). However, in the U.S. South, there are only 12 locally produced assessed projections that extend beyond the middle of this century to 2100, and no assessments that extend beyond the end of the century. The lack of long-term, locally produced assessments in any part of the U.S. constitutes an important gap in resiliency planning and community engagement, but may be especially consequential in the U.S. South, where future flood risk has been described as inequitable, and is expected to disproportionately impact minority communities (Wing et al., 2022).

Because different types of decisions have different risk tolerances, it is imperative that uncertainty associated with future SLR be reasonably represented and accounted for in assessments that analyze the future hazard coastal communities face (Hinkel et al., 2019). As a whole, the U.S. South is once again inconsistent with other regions in terms of how uncertainty is handled. In the U.S. Northeast and West, the majority of assessed projections (77% and 83% respectively) provide lower, central, and upper estimates of possible future SLR values. However, many assessments in the database for the U.S. South choose to focus on singular (i.e., central) estimates of future SLR only, rather than ranges (Figures 2 and 3). This indicates a tendency for many decision makers in the U.S. South to embrace a "prediction-first" decision framework (where probability distributions are assessed to choose an optimal value), rather than a more robust "decision-first" framework (where multiple plausible futures are embraced in an effort to better encapsulate all of the available information) (Kopp, Andrews, et al., 2019; Kopp, Gilmore, et al., 2019). Such a tendency is not uncommon among decision makers, who often desire a single value of future SLR, wanting to know "where the line is drawn" so that they can easily provide guidelines to local municipalities (Carlsson Kanyama et al., 2019; Hinkel et al., 2019). This type of "prediction-first" approach may be appealing as a way to simplify planning and policymaking surrounding SLR adaptation; however, it also conceals the deeply uncertain nature of future SLR projections (Kopp, Gilmore, et al., 2019), particularly for projections focused on time horizons beyond the middle of this century (A. J. Garner et al., 2018). Regions that use single values of future SLR for planning may fail to consider less likely but highly damaging possibilities of higher future SLR, leaving them vulnerable to significant hazards if future SLR exceeds the single estimate used in planning (Hinkel et al., 2019; Kopp, Gilmore, et al., 2019). Furthermore, this type of approach shifts the decision problem from the broader group of decision makers that may use the projections in a publicly available, regional assessment to the smaller number of decision analysts that helped to develop the assessment and may not always be stakeholders (G. Garner et al., 2016).

There are regions within the U.S. where the upper end of current local guidance either agrees with or deviates from the current state-of-the-art scientific projections from the IPCC AR6. Six assessment reports in the database (California, New York City, Rhode Island, Maine, South Carolina, and Oregon; Dalton & Fleishman, 2021; Gornitz et al., 2019; Griggs et al., 2017; Gulf of Maine Research Institute, 2018; Roman, 2017; Watson & Knapp, 2021) include high end SLR guidance that either matches or exceeds the less likely, but high impact IPCC AR6 low-confidence projections (Figure 6), while three others (two from Florida, and one from New Jersey; Kopp, Andrews, et al., 2019; Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group, 2019; Tampa Bay Climate Science Advisory Panel, 2019) include high end guidance that comes within 0.1 m of the IPCC AR6 low-confidence projections for 2100. Some of these reports share certain characteristics.

South Carolina (Watson & Knapp, 2021), Oregon (Dalton & Fleishman, 2021), Rhode Island (Roman, 2017), Maine (Gulf of Maine Research Institute, 2018), and Florida (Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group, 2019; Tampa Bay Climate Science Advisory Panel, 2019) assessments include projections that rely on NOAA 2017 scenarios (Roman, 2017; Table S1), basing their highest projections upon either the NOAA "Extreme" scenario (considered an upper limit on future SLR, and consistent with 2.5 m of global SLR), or the NOAA "High" scenario (the second highest in the NOAA report, and consistent with the highest scenario put forward in a 2016 report from the U.S. Department of Defense Strategic Environmental Research and Development Program; John A. Hall et al., 2016; Sweet et al., 2017). All of these regions are highly vulnerable to future SLR—for example, the Gulf of Maine experiences some of the largest tides in the world, (Muis et al., 2020; Pelling & Mattias Green, 2013) and Florida's low-lying elevation and populous coastlines are especially susceptible to higher sea levels (Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group, 2019; Tampa Bay Climate Science Advisory Panel, 2019). Such vulnerabilities may contribute to the choice of assessment reports in these regions to focus on a relatively high future SLR scenario. With the recent publication of the updated NOAA SLR scenarios (Sweet et al., 2022), and the development of visualization tools for these projections through the National Aeronautics and Space Administration (NASA) Sea Level Portal, we anticipate that this methodology will continue to be widely used in future local assessments as well.

The California (Griggs et al., 2017) and New York City (Gornitz et al., 2019) assessments note particular concern about contributions to future SLR from the Antarctic Ice Sheet, and thus include extreme SLR scenarios

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associated with rapid ice melt. The New Jersey assessment also notes several factors that may cause the state to be especially susceptible to future SLR, including vertical land motion, ocean dynamics, and gravitational and rotational deformation effects that amplify SLR associated with the loss of ice from Antarctica (Kopp, Andrews, et al., 2019). The assessment thus uses a probabilistic methodology to account for up to 5°C warming, and incorporates expert elicitation (Bamber et al., 2019a) to assess potential contributions to SLR from ice sheets (Fox-Kemper et al., 2021; Kopp, Andrews, et al., 2019).

Conversely, at over half of the locations in the database, the upper end of assessed projections falls below the upper end of IPCC AR6 projections, including regions that are particularly vulnerable to future SLR. For example, assessed projections in the Mississippi Delta region in the U.S. (a region dealing with substantial subsidence; Abadie et al., 2020; G. G. Garner et al., 2021) as well as assessed projections along the U.S. Southeast coast (where ocean dynamic effects and gravitational and rotational deformation effects from the Greenland Ice Sheet contribute to accelerated SLR; G. G. Garner et al., 2021) are up to 1.4 m lower than the 95th percentile of SSP5-8.5 IPCC AR6 projections. One possible reason for this is that local assessments sometimes produce projections of SLR that do not include vertical land motion (Coastal Protection and Restoration Authority, 2017; Department of Energy and Environment, 2015; Evans et al., 2016; Tetra Tech Inc and State of Hawai'i Dept. of Land and Natural Resources, 2017). For example, the Louisiana Coastal Master Plan calculates subsidence rates, but provides this information as a separate risk factor from local SLR estimates, resulting in an assessed SLR value that does not fully capture relative SLR for a region that is greatly impacted by vertical subsidence (Coastal Protection and Restoration Authority, 2017; Shirzaei et al., 2020; Tay et al., 2022). Furthermore, local assessments are sparse along the Gulf coast and U.S. Southeast coast, with many projections in these regions coming from a report generated by the NPS (Caffrey et al., 2018). The NPS report downscaled regional SLR projections from IPCC 5th Assessment Report (AR5) but provides only single (central) values of SLR, defined as the 50th percentile of SLR from a probabilistic framework. The projections also do not include any extreme SLR associated with accelerated contributions from Antarctica or Greenland (B. P. Horton et al., 2018). From a policy standpoint, the inclusion of projections that are highly uncertain on long timescales, such as those that incorporate accelerated ice sheet loss, can be a challenge; however, if action is not taken in the face of this uncertainty, it could result in fewer and less effective adaptation options later in time (Haasnoot et al., 2019; Hinkel et al., 2019; Kopp, Gilmore, et al., 2019). It may be beneficial, therefore, for local assessments to include such high-risk scenarios for decisionmaker consideration, as coastal communities work to develop adaptive decision mechanisms using emerging policy tools (e.g., Bhave et al., 2016; Haasnoot et al., 2019).

Assessments use a variety of methodologies and produce a wide range of estimated upper bounds of future SLR. The upper bound of projected 2100 SLR varies significantly among sites in the database, with the lowest such projections falling below 1 m, and the highest such projections reaching to 3 m or slightly higher (Figure 6). Many sites that use an IPCC or Adapted IPCC methodology base their projections on global estimates of SLR from IPCC AR5, and thus have maximum projections of ∼1 m (Figure 6; Caffrey et al., 2018; Hawai'i Climate Change Mitigation and Adaptation Commission, 2017). Previous work (A. J. Garner et al., 2018; B. P. Horton et al., 2020) has suggested that IPCC reports have historically provided lower estimates of global mean SLR than the upper bound of global mean SLR reported in individual research studies. This is potentially due to a tendency of past IPCC reports (AR5 and earlier) to err on the side of least drama (Brysse et al., 2013), intentionally providing cautious and conservative estimates of SLR, rather than focusing on less likely extremes that would be of greater consequence should they occur (A. J. Garner et al., 2018). Our analysis indicates that assessments constructed using IPCC-based methodologies that adopt AR5 (Table 2) are consistently lower than projections developed using non-IPCC based methodologies (Figure 6, Figure S3 in Supporting Information S1). Furthermore, many assessed projections that rely upon past IPCC methodologies underestimate future SLR compared to both AR6 medium- and low-confidence regional projections (Figure 6).

As evidenced by the wide variety of assessments and planning approaches described in the database across different regions of the U.S., the question of how to consider SLR in public policy is not straightforward. Policies at the state or even national level tend to be designed to provide certainty for citizens and their communities; but SLR is inherently uncertain, particularly at longer time scales (Lawrence et al., 2018). This means that while the most practical approach from a policy standpoint might be to put relatively static planning guidelines in place, it is nonetheless critical to develop flexible policies and adaptation planning that can be adjusted ahead of damage occurring if dangerous entrenchment due to current policies and guidance is to be avoided (Hinkel et al., 2019; Lawrence et al., 2018). This logic is evident in many of the local assessments in the database, which often include recommendations to review new scientific developments and update the assessment on a regular basis, either at set time intervals, or after the introduction of new national or international reports, such as those from the IPCC (Dalton & Fleishman, 2021; Gornitz et al., 2019; Griggs et al., 2017; Hawai'i Climate Change Mitigation and Adaptation Commission, 2017; Kopp, Andrews, et al., 2019; North Carolina Coastal Resources Commission Science Panel, 2015).

In the past year, new SLR guidance has emerged at both the national level from NOAA, and the international level from the IPCC, which could provide motivation to update guidance and assessments at more local levels. The fully probabilistic regional projection datasets from both NOAA and IPCC AR6 are now freely available (G. G. Garner et al., 2021), along with visualization tools to help interpret these projections through the National Aeronautics and Space Administration (NASA) Sea Level Portal. The open-access nature of these tools that include low-confidence projections with a focus on less likely but highly consequential ice sheet contributions (see Section 6; Fox-Kemper et al., 2021) could provide a valuable tool for developing the next generation of scientifically accurate locally assessed projections.

6. Methods

6.1. Selection of Assessment Reports

With this project, we aimed to produce a database of regional assessment reports that include information on future SLR for locales in the U.S. To this end, we focused on finding and including reports that were designed both by and for stakeholders and decision makers in specific regions, and which included projections of SLR that extended through at least 2100. For example, the database includes major state-wide reports in the U.S. (such as "New Jersey's Rising Seas and Changing Coastal Storms: Report of the 2019 Science and Technical Advisory Panel," prepared for the New Jersey Department of Environmental Protection (Kopp, Andrews, et al., 2019)), as well as major reports produced for smaller regions where possible (e.g., New York City projections of SLR from the "New York City Panel on Climate Change 2019 Report" (Gornitz et al., 2019)). Though substantial effort was made to ensure that all available and relevant assessment reports were included in the database, it is perhaps inevitable that a small number of reports were overlooked and may not be included here.

In some regions, we were unable to find regional assessment reports that met our criteria. In these cases, if possible, we have included reports in the database that provide "third-party" projections of future SLR for the region, which might reasonably be used by coastal decision makers in lieu of a more locally commissioned report. For example, we were unable to find any regional assessment reports for Mississippi, but were able to locate projections relevant for locations within this state in a report produced for the NPS, "Sea Level Rise and Storm Surge Projections for the NPS (Caffrey et al., 2018)"; therefore, we include the NPS report in our database as the source of Mississippi projections. The NPS report projections are also included in the database for Georgia and North Carolina (where the only local assessment reports we were able to locate included projections that extended only to ~2050), and for New Orleans, Louisiana (since these were the only assessed projections we found specifically for the city of New Orleans, which is well-known to be at especially high risk for flood losses associated with rising sea levels (Abadie et al., 2017; Hallegatte et al., 2013; Wong & Keller, 2017)). Finally, for the state of Maine, though we located projections of future SLR for the state from the Gulf of Maine Research Institute website (Gulf of Maine Research Institute, 2018), no official regional assessment report generated by the state was discovered; therefore, our database also includes several projections for the state of Maine that come from a report produced by the Geological Survey of Canada, "Relative Sea-level Projections in Canada and the Adjacent Mainland United States" (James et al., 2014).

We note that there are a number of other sources from which decision makers in a region without a local assessment report might have found SLR projections, such as NOAA's 1° gridded set of scenario-based relative SLR projections (Sweet et al., 2017). However, given that the report associated with these projections leaves it to practitioners to modify and interpret non-climatic background rates of relative SLR for their region (Sweet et al., 2017), we do not include projections from this data set in the database, except for in the various instances where they are used within regional assessment reports (e.g., Gulf of Maine Research Institute, 2018; Southeast Florida Regional Climate Change Compact Sea Level Rise Work Group, 2019) that do meet the criteria we describe above.

Our database was constructed using assessment reports published on or before 31 December 2021.

6.2. Definitions of Geographical Regions

We divide projections/reports into three regions for analysis: the U.S. Northeast, U.S. South, and U.S. West (Figure 1). For the U.S. Northeast, we based our divisions upon those used in the Fourth National Climate Assessment (NCA4), assigning the coastal states of Maryland, Delaware, New Jersey, New York, Massachusetts, Connecticut, Rhode Island, New Hampshire, and Maine to this region (USGCRP, 2018). Additionally, we assigned projections from Washington, D.C. to the U.S. Northeast region for our analysis. For the U.S. South, we include coastal states from NCA4's Southeast region (Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana) as well as Texas (the only coastal state in the NCA4's Southern Great Plains region), and Puerto Rico (USGCRP, 2018). Finally, for the U.S. West, we include the states of Hawaii, California, Oregon, and Washington; Alaska would also normally be included in this region, though we were unable to find any SLR assessment reports for Alaska to be included in this analysis. This region combines coastal states from NCA4's Northwest, Southwest, Alaska, and Hawaii regions (USGCRP, 2018).

6.3. Establishing Time Horizons for Database Entries

Time horizons for projections vary significantly among studies, with end years typically ranging from the early 21st century (e.g., Grannis et al., 2010) to 2200 (e.g., The Boston Research Advisory Group Report, 2016). For most of our analyses, we focus on projections with end years of 2050, 2100, 2150, and 2200. To be counted as one of these categories, projection end years must fall into specific windows: 2040–2060 (for 2050 projections); 2080–2110 (for 2100 projections); 2140–2160 (for 2150 projections); and 2180–2210 (for 2200 projections). When studies use a range for the base or end year (e.g., 2040–2050), we use the central value of this range for our calculations. Some studies include decadal projections; in such cases, only the projection closest to our target end year (2050, 2100, 2150, or 2200) from that particular report is used for analyses at that time horizon.

We consider two different metrics that may offer information about the time horizons over which different regions plan for future SLR: total number of reports for a given end year, and total number of projections for that end year (Figure 1b). The total reports available for a region in the database indicates the total number of unique reports from which SLR projections were available, where only the most recent report for a given location and from a particular source (e.g., New York City Panel on Climate Change) is included in the database. The total projections for a region indicates the total number of projections available across all reports for a region. For example, in New Jersey, there is one report (New Jersey's Rising Seas and Changing Coastal Storms); but, within this report, there are 11 projections included in the database—one projection each for 2030 and 2050, and three projections each for 2070, 2100, and 2150, where different projections for each year assess future SLR under low, moderate, and high emissions (Table S1; Kopp, Andrews et al., 2019).

Most projections in the database have similar baseline years—typically either 1995.5 (the central year from a baseline range of 1986–2005) or 2000. However, there is generally less consistency in the end year of SLR projections. To ensure consistency across projections and reports when comparing total amounts of SLR, we normalize SLR projections (A. J. Garner et al., 2018; B. P. Horton et al., 2018) using the baseline and end years in Equation 1:

$$\mathrm{SLR}_{\mathrm{Norm}} = \mathrm{SLR}\frac{W}{(Y - Y_0)}, \tag{1}$$

where $\mathrm{SLR}_{\mathrm{Norm}}$ is the normalized SLR projection (i.e., rate of expected SLR change), SLR is the SLR provided in the regional assessment report, W is the window-length from the year 2000 to the target year (i.e., 50, 100, 150, or 200), Y is the study end year, and Y_0 is the study baseline year.

6.4. IPCC Sixth Assessment Report Regional Projections

The IPCC AR6 sea-level change projections are provided as two datasets: the medium-confidence projections and the low-confidence projections. The medium-confidence projections use methods and assumptions about the individual processes that contribute to sea-level change that are assessed to have medium-confidence or stronger. The low-confidence projections use methods and assumptions about the individual processes that contribute to sea-level change that are assessed to have low-confidence or stronger, which include those used in the medium-confidence projections. Both the medium-confidence and low-confidence projections are provided at 1,030 tide gauge locations around the world (since tide gauges were used to help inform a Gaussian Process Model to estimate vertical land motion in regional projections), as well as a global 1° × 1° grid. Both the medium-confidence and low-confidence projections are provided in decadal time steps starting in year 2020; however, the medium-confidence projections end at year 2150 whereas the low-confidence projections end at year 2300 (Fox-Kemper et al., 2021; G. G. Garner et al., 2021).

Multiple lines of evidence regarding the treatment of land-ice contributions are used in both the medium-confidence and low-confidence projections. To do so, seven sea-level projection workflows were designed, each using a specific set of contributor methods and assumptions, to generate total integrated sea-level projections. The details of each of these workflows can be found in the main text and supplemental materials for IPCC AR6 Chapter 9 (Fox-Kemper et al., 2021; G. G. Garner et al., 2021). In summary, each workflow contains the same methods for projecting contributions from terrestrial water storage, vertical land motion, thermal expansion, and dynamic ocean processes. The workflows used to generate the medium-confidence projections use a combination of an emulator calibrated to the Ice Sheet Model Intercomparison Project 6 (ISMIP6) and the Glacier Model Intercomparison Project 2 (GMIP2; Edwards et al., 2021), a linear response model fit to ISMIP6 model runs (Levermann et al., 2020), and an extension of the methods used in AR5 (Church et al., 2013) to project the glacier and ice-sheet contributions. The workflows used to generate the low-confidence projections use a combination of those used in the medium-confidence projections as well as projections from an uncertain but potentially high-impact contribution from the Antarctic ice sheet (DeConto et al., 2021) and a structured expert judgment experiment regarding the contributions from both the Greenland and Antarctic ice sheets (Bamber et al., 2019b). The probability distributions produced from each of these workflows are then combined into probability boxes (p-boxes) where the p-box median value is the average of each of the workflows' median values, the p-box percentiles below the 50th percentile are the minimum values across the workflows at the corresponding percentile, and the p-box percentiles above the 50th percentile are the maximum values across the workflows at the corresponding percentile.

To compare assessed projections from local assessments with IPCC values, we compare the maximum assessed projection from each assessment with the 95th percentile of IPCC regional projections. As noted in Section 2, we use the 95th percentiles of assessed SLR projections as upper SLR estimates for the database where feasible—meaning that in many cases, we are comparing a 95th percentile from the local assessment report to the 95th percentile from the IPCC report. However, in some cases, it is possible that the maximum assessed projection for a location is not a 95th percentile, either because the upper estimate is defined differently (e.g., as the 99th percentile, the 90th percentile, or as a value from a NOAA scenario), or because there is only one estimate for the location. For example, in many locations in the U.S. South, only one "central" estimate is provided, and this is often defined as a 50th percentile (Caffrey et al., 2018). In such instances, this central estimate is the maximum available assessed projection for the location, and is thus the estimate that is compared with the 95th percentile of IPCC regional projections. This approach allows for a comparison between the maximum assessed projections included in the database for each location with a value that falls within the less likely, but highly damaging upper tail of the IPCC regional SLR probability distribution.

Data Availability Statement

All data used here is included in Table S1, which is the database of U.S. regional assessment reports used for this analysis. The data set can also be found in an open access repository, here: https://doi.org/10.5281/zenodo.7328629.

Acknowledgments

The authors wish to thank Muhammad Hadi Ikhsan (Earth Observatory of Singapore) for his inputs on figure design. This work was supported by funding from the National Science Foundation awarded to AJG (EAR-1625150). BPH, FT, and CT are supported by the Singapore Ministry of Education Academic Research Fund MOE2019-T3-1-004, the National Research Foundation Singapore, and the Singapore Ministry of Education, under the Research Centers of Excellence initiative and the National Sea Level Program Funding Initiative (Award USS-IF-2020-1), administered by the National Environment Agency, Singapore and supported by the National Research Foundation, Singapore. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not reflect the views of the N.R.F., M.N.D., and N.E.A. This work is Earth Observatory of Singapore contribution 487. We thank the IPCC AR6 SLR projection authors for developing and making the sea-level rise projections available, multiple funding agencies for supporting the development of the IPCC AR6 SLR projections, and the NASA Sea Level Change Team for developing and hosting the IPCC AR6 Sea Level Projection tool.

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