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Frequently Asked Questions Regarding the New Jersey Science and Technical Advisory Panel (STAP) Study

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Human-caused climate change is accelerating sea level rise in New Jersey and driving increases in coastal flood hazards. In 2016, Rutgers University researchers convened a panel of scientists to assess projections of future sea level and storm changes affecting the Garden State. To ensure the usability of their assessment, the scientists also consulted with state and local practitioners to discuss how they would integrate the science into their decisions to enhance the coastal resilience of New Jersey's people, places, and assets. In 2019 the New Jersey Department of Environmental Protection engaged Rutgers to conduct new consultations with panels of scientists and practitioners to update its 2016 work to reflect the most recent climate science. Key updates in the new report include: the addition of historical sea level rise information for New Jersey; consideration of the latest information related to potential ice-sheet changes and their effect on sea level rise; and assessment of increasing tidal flooding under sea level rise. All of the reports can be found at: https://njclimateresourcecenter.rutgers.edu/resources/nj-sea-level-rise-reports/ [1]

1. What are the New Jersey Science and Technical Advisory Panel (STAP) studies?

The first New Jersey Science and Technical Advisory Panel (STAP) on Sea Level Rise and Coastal Storms was convened by Rutgers University on behalf of the New Jersey Climate Change Alliance in 2015, culminating in a 2016 report that identified consensus science that can inform practitioners' efforts to enhance the resilience of New Jersey's people, places, and assets to sea level rise, coastal storms, and the resulting flood risk (Kopp et al., 2016).

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[1] Citations for the 2019 and 2016 STAP reports are:

- Kopp, R.E., C. Andrews, A. Broccoli, A. Garner, D. Kreeger, R. Leichenko, N. Lin, C. Little, J.A. Miller, J.K. Miller, K.G. Miller, R. Moss, P. Orton, A. Parris, D. Robinson, W. Sweet, J. Walker, C.P. Weaver, K. White, M. Campo, M. Kaplan, J. Herb, and L. Auermuller. New Jersey's Rising Seas and Changing Coastal Storms: Report of the 2019 Science and Technical Advisory Panel. Rutgers, The State University of New Jersey. Prepared for the New Jersey Department of Environmental Protection. Trenton, New Jersey.
- Kopp, R.E., A. Broccoli, B. Horton, D. Kreeger, R. Leichenko, J.A. Miller, J.K. Miller, P. Orton, A. Parris, D. Robinson, C.P.Weaver, M. Campo, M. Kaplan, M. Buchanan, J. Herb, L. Auermuller and C. Andrews. 2016. 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. Prepared for the New Jersey Climate Adaptation Alliance. New Brunswick, New Jersey.

Following the same process, the same team at Rutgers University was engaged by the State of New Jersey Department of Environmental Protection to update the 2016 report based on the most current scientific information. Similar to the inaugural 2016 work, the 2019 STAP was charged with identifying and evaluating the most current and authoritative science on sea level rise projections and changing coastal storms, considering the implications for the practices and policies of local and regional stakeholders, and providing practical options for stakeholders to incorporate science into risk-based decision processes.

The scientists that participated in the STAP were nationally and internationally recognized experts from many institutions and organizations including Drexel University; Princeton University; Rutgers University; Stevens Institute of Technology; U.S. Army Corps of Engineers; U.S. Environmental Protection Agency; the National Oceanic and Atmospheric Administration; the New Jersey Association for Floodplain Management; the New York City Mayor's Office of Resiliency; and Atmospheric and Environmental Research.

Note the STAP report recommends that practitioners and scientists review its sea level rise estimates on a regular basis, not to exceed 5 years as well as after the publication of any global (*i.e.*, International Panel on Climate Change (IPCC)) or national (*i.e.*, National Climate Assessment) assessments related to sea level rise and coastal storms relevant to New Jersey.

2. What were the findings of the 2019 STAP study?

- *Sea level rise* - The 2019 STAP examined both the magnitude (amount) and rate (speed) of sea level rise in New Jersey.
  - Magnitude:
    - Historical sea level rise in New Jersey: sea level in New Jersey rose 17.6 inches (1.5 feet) along the New Jersey coast from 1911 to 2019, compared to a 7.6-inch (0.6 feet) total change in the global mean sea level.
    - Near-term future projections of sea level rise: New Jersey coastal areas are *likely* to experience sea level rise of 0.5 to 1.1 feet between the years 2000 and 2030, and 0.9 to 2.1 feet between 2000 and 2050.
    - Longer term projections of sea level rise:
      - Under a high-emissions scenario, coastal areas of New Jersey are *likely* to see sea level rise between 1.5 to 3.5 feet between the years 2000 and 2070, and 2.3 to 6.3 feet between the years 2000 and 2100.
      - Under a moderate-emissions scenario, coastal areas of New Jersey are *likely* to see sea level rise of 1.4 to 3.1 feet between the years 2000 and 2070, and 2.0 to 5.1 feet between 2000 and 2100.
      - Under a low-emissions scenario, coastal areas of New Jersey are *likely* to see sea level rise between 1.3 to 2.7 feet between the years 2000 and 2070, and 1.7 to 4.0 feet between the years 2000 and 2100.
  - Rate:
    - Over the last forty years, from 1979 to 2019, sea level rose at an average rate of 0.2 inches per year along the New Jersey coast, compared to an average rate of 0.1 inches per year globally.

- Near-term future rates of sea level rise: New Jersey coastal areas are *likely* to experience average sea level rise rates of 0.2 to 0.5 inches per year over 2010 to 2050.
- Longer term future rates of sea level rise:
  - Under a high-emissions scenario, coastal areas of New Jersey are *likely* to see sea level rise rates of 0.3 to 1.1 inches per year over 2060 to 2100.
  - Under a moderate-emissions scenario, coastal areas of New Jersey are *likely* to see sea level rise rates of 0.2 to 0.8 inches per year over 2060 to 2100.
  - Under a low-emissions scenario, coastal areas of New Jersey are *likely* to see sea level rise rates of 0.2 to 0.6 inches per year over 2060 to 2100.

➢ *Coastal storms* – Higher sea levels will increase the baseline for flooding and impacts from high tides and coastal storms (*i.e.,* hurricanes and nor'easters):
- Hurricanes: The 2019 STAP focused on three issues with respect to hurricanes (*i.e.*, tropical cyclones): frequency, intensity and precipitation. While most studies do not project an increase in the global frequency of tropical cyclones, both maximum wind speeds and the rate of rainfall during tropical cyclones are likely to increase. Changes in the frequency, wind speed, and tracks of tropical cyclones remain an area of active research, and there is no definitive consensus at this time regarding such changes specific to New Jersey.
- Nor'easters: The 2019 STAP reviewed the science with regard to the global frequency of nor'easters (*i.e.*, extratropical cyclones), which indicates that such frequency is not likely to change substantially. Although there is some evidence for a decrease in frequency of extratropical cyclones over the North Atlantic as a whole, this is not apparent near the coast. A limited but inconclusive body of evidence suggests the possibility of changes to extratropical storm tracks in the North Atlantic. In general, changes in the frequency, wind speed, precipitation rate, and tracks of extratropical cyclones remain an area of active research; at this time, there is no definitive consensus regarding such changes.

➢ *Tidal flooding* – The 2019 STAP reviewed the science with regard to the frequency of high-tide flooding, also known as "nuisance" or "sunny day" flooding. Between 2007 to 2016, there was an average of eight high-tide flood events in Atlantic City, NJ, with annual event totals ranging between four events in 2007 and 18 events in 2009. This frequency has grown from an average of less than one high-tide flood event per year in the 1950s. The frequency of high tides exceeding the current high-tide flood threshold will continue to increase with sea level rise. For example, based on the *likely* range of sea level rise projections, Atlantic City will experience 17 to 75 days of expected high-tide flooding per year in 2030, and 45 to 255 days per year of expected high-tide flooding in 2050.

3. What is sea level and how is it measured in the STAP report?

Sea level refers to the elevation of the ocean in reference to the shoreline. Land that is higher than the shoreline is above sea level and land that is lower than shoreline is below sea level. Sea level is measured by tide gauges around the world as well as by satellites.

Sea level is not changing at the same rate at all points around the world; in fact, sea level rise in the Mid-Atlantic region of the United States is greater than it is globally. When describing local or regional sea level rise (SLR), the STAP refers specifically to relative sea level rise.

Global mean sea level (GMSL) and local relative sea level (RSL) are determined by several factors (Gregory et al., 2019; Kopp et al., 2015).

- GMSL is determined by the volume of water in the ocean. The two major processes contributing to GMSL are thermal expansion and land ice mass loss, with some additional contribution from changes in the amount of water stored on land in lakes, groundwater, dams, and other surface water bodies.
- RSL is the change in the local height of the sea surface relative to local ground elevation. RSL is affected by the same three factors that contribute to GMSL, as well as other factors that affect the local height of the sea surface and the land. In New Jersey, these factors include:
    - Glacial isostatic adjustment: Sinking of the land due to the ongoing response to the Earth to the melting of the great North American ice sheet after the last ice age contributes about 0.5 in/decade of RSL rise in coastal New Jersey;
    - Long-term sinking of coastal land: Natural sediment compaction and groundwater withdrawal along the Coastal Plain and in the Meadowlands contribute up to about 0.4 in/decade along the Coastal Plain;
    - Ocean physics: Dynamic sea level changes due to changes in ocean circulation, temperature, and salinity may add as much as 1 ft/century in the U.S. Northeast under high-emissions scenarios; and
    - Planetary physics: Changes in Earth's gravitational field, rotation, and crustal shape in response to large shifts of mass from ice to the ocean diminish the effect of Greenland ice sheet and Arctic glacier melt and increase the effect of Antarctic ice sheet melt.

4. How does the 2019 STAP report differ from the 2016 STAP report?

The projections in the 2016 report were produced using the Kopp et al. (2014) framework, which was designed to produce local estimates of sea level probabilities fairly consistent with the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5). As with the AR5, the *likely* sea level projections in the 2016 report did not fully integrate the possible instabilities in the polar ice sheets. As the 2016 STAP noted:

> *These results represent one consistent, scientifically justifiable way of estimating the probability of different levels of SLR. Alternative methods or new science may yield higher or lower estimates of the probability of high-end outcomes. For example, one recent study (Deconto & Pollard, 2016) suggested that physics involving ice cliffs and ice shelves, not previously incorporated into ice sheet models, could render the Antarctic ice sheet significantly more vulnerable to melt within the current century than ice sheet models had previously indicated. Taken at face value, the results of that paper would elevate likely sea level rise for New Jersey in 2100 under high emissions (RCP 8.5) to about 4–8 ft., while having little effect by 2050 or under low emissions. While this is just one study, it highlights the dynamic nature of the scientific knowledge. Accordingly, the STAP advises that extra consideration be given to high-end outcomes when assessing highly vulnerable or highly consequential people, places and assets.*

One key new study since the 2016 report was a structured expert judgement study (Bamber et al., 2019) of potential ice-sheet contributions to sea level rise over the next three centuries.

Structured expert judgement is a formal risk analytic method used for estimating the likelihoods of different outcomes when formal models are inadequate; it has been used for a variety of topics, including nuclear reactor safety, particulate matter pollution, food-borne disease, volcanic hazards, and COVID-19 transmission in schools. It uses a formal method to combine the expertise of experts, weighting their relative contributions to the analysis based on tests of the experts' ability to estimate their own uncertainties as well as correct values for relevant calibration questions to which the correct answers are knowable.

The 2019 STAP report combines the structured expert judgement study of Bamber et al. (2019) with the approach used by the 2016 STAP report. The two approaches complement each other: the 2016 STAP *likely* ranges capture what is represented in the models used by the ice-sheet modeling community, while the Bamber et al. (2019) study uses a formal risk analytic method to incorporate estimates of the factors not in these models.

Because the two approaches give different estimates of likelihoods, the 2019 STAP reports ranges of probabilities: for example, based on both approaches, in a 2°C world, there is a 3-5% chance of exceeding 5 ft of sea level rise by 2100, while in a 5°C world, there is a 12-38% chance of exceeding 5 ft by 2100. The summary table presents bounded probabilities (*e.g.*, less than a 17% chance) that represent the consensus of both approaches (*e.g.*, both approaches agree that, by 2100, there is less than a 17% chance of exceeding 3.9 ft in a 2°C world, 5.1 ft in a 3.5°C world, and 6.3 ft in a 5°C world).

This choice of using ranges of probability is a fairly conservative one, and the panel expects that, as scientific knowledge progresses, estimates of probability from individual future scenarios will vary within the range the STAP report presents.

Other differences from the 2016 report include:

- The use of climate scenarios based on warming levels (*i.e.*, global mean warming by the end of the century of 2°C, 3.5°C or 5°C above pre-industrial levels) rather than Representative Concentration Pathways (RCP) that were used in the IPCC AR5 and have been supplanted by Shared Socioeconomic Pathways (SSP) in the IPCC Sixth Assessment Report (AR6);
- Incorporation of information on historical sea level rise in New Jersey; and
- A focused discussion of tidal flooding.

5. What do the low, high, and moderate emissions scenarios used in the STAP report represent?

Both the 2016 and 2019 STAPs indicate that longer term (post 2050) projections of sea level rise are dependent upon the amount of greenhouse gas emissions in the Earth's atmosphere.

- The low emissions scenario corresponds to a world in which global warming is limited to 2°C above late-nineteenth century levels, consistent with the aspirations of the 2016 Paris Agreement. According to a 2018 Intergovernmental Panel on Climate Change Special Report, limiting global warming to 2°C, consistent with the low scenario, would require a global decline of carbon dioxide emissions of about 25% by 2030 and global net-zero emissions by about 2070.

- The high emissions scenario corresponds to a future with growth in fossil fuel emissions, leading to global warming reaching 5°C by 2100.
- The moderate emissions scenario is halfway between the two and corresponds to a future experiencing warming of about 3.5°C by 2100.

At the time of the writing of the 2019 STAP report, the Climate Action Tracker projected that global climate policies established by December 2018 set the planet on course for a warming of 3.1-3.5°C by 2100, consistent with the STAP moderate emissions trajectory. The Climate Action Tracker is an independent research consortium that estimates the likely temperature increase in the 21st century based on the climate change mitigation targets, policies, and actions of countries.

As of November 2022, the Climate Action Tracker indicated the planet was on course for about 2.7°C of warming by 2100 (Climate Action Tracker, 2022), this is between the STAP low and moderate emissions projections of 2°C to 3.5°C by 2100. This shift in 2022 to about 2.7°C of warming reflects more aggressive Nationally Determined Contribution pledges and targets (such as the U.S. 2021 commitment to achieve net-zero emissions by 2050), the expansion of climate policy in major economies around the world (such as within the U.S.'s Inflation Reduction Act), and refinements in the Climate Action Tracker's methodology (Climate Action Tracker, 2022).

The IPCC AR6 Working Group 3 report (Riahi et al., 2022) and Synthesis Report (SYR; Lee et al., 2023) estimate that a range of possible extrapolations of policies implemented through the end of 2020 lead to a median projected warming of 2.2–3.5°C by 2100, with a central tendency of about 3.2°C. The more recent assessment by Climate Action Tracker, based on policies implemented through November 2022, estimates a warming of 2.7°C [2.2–3.4°C range] by 2100 (Climate Action Tracker, 2022). Note that while the central estimates of these two reports differ, their ranges are similar; their differences can be primarily attributed to differences in the interpretation of climate change policy and recent action and policy as of 2022. Regardless, these warming trajectories (*i.e.*, those from the AR6 Working Group 3 report and SYR, and the Climate Action Tracker) are projected to be lower than the STAP report's moderate scenario (3.5°C) due to, in large part, changes in global climate change policies. Reversals of current global policy, or an important role for feedbacks not represented in climate models, could revise these assessments.

6. What does the STAP report mean when it discusses 'likely' sea level rise?

Following the terminology used by the Intergovernmental Panel on Climate Change, the STAP uses the term 'likely' to mean 'at least a 66% (*i.e.,* two-in-three) chance' that a stated outcome will occur (*e.g.*, there is at least a 66% chance that future sea level will fall within a projected likely range). Note, the "17th-83rd percentile" ranges can be viewed as analogous to a *likely* range. Note also that for any sea level rise estimate, there could be as much as a 17% chance that sea level rise will be above the *likely* range.

7. If sea level rose in NJ at 0.2 inches/year between 1979 and 2019, how can the STAP report project that sea level in 2030 could increase more than 0.5 feet?

The STAP report measures relative sea level change using 19-year averages (tidal epochs) centered on each decade. This approach accounts for the variability in sea level change on a year-to-year basis (See STAP Figure 2a) driven by regional variability in atmosphere and ocean circulation. To measure the actual change in sea level that will occur in 2030, scientists will need to establish a 2030 baseline and compare it to the 2000 baseline. A scientifically comparable 2030 baseline can only be established using tide gauge observations from the 19-year period between 2021-2039. Note, the 2000 baseline is based on tide gauge observations from the 19-year period 1991-2009.

Were the historic rate of sea level change in New Jersey to continue without acceleration, it would indeed yield a projection in 2030 of 0.5 feet above the 2000 baseline. This constitutes the lower end of the *likely* range. However, there is strong evidence for a global acceleration of sea level rise. The IPCC concluded in a 2019 report: "Global mean sea level (GMSL) is rising, with acceleration in recent decades due to increasing rates of ice loss from the Greenland and Antarctic ice sheets (very high confidence), as well as continued glacier mass loss and ocean thermal expansion."

This acceleration is not apparent in local tide gauges over 1979 to 2019 due to the temporary masking effect of regional variability in atmosphere and ocean circulation. The panel expects accelerating global sea level rise to be apparent over the next two decades, trending toward the higher values in the *likely* range for the 19-year tidal epoch from 2021 to 2039 (reported as 2030).

8. How do sea level rise projections in the STAP 2019 study compare with more recent reports such as the IPCC (2021) and the Interagency (2022) reports?

As of April 2023, the latest IPCC report that addresses sea level rise processes and projections is the AR6, the sea level projections of which were described in the Working Group 1 (Physical Science) volume, which was published in 2021 (Fox-Kemper et al., 2021). The federal Sea Level Rise and Coastal Flood Hazard Scenarios and Tools Interagency Task Force released a 2022 report (hereafter referred to as the *Interagency report*) (Sweet et al., 2022) that builds upon the IPCC report.

The STAP and IPCC reports employ similar methodologies but differ in how they incorporate potential rapid ice-sheet loss into their sea level rise estimates: this is because this process is currently the subject of substantial scientific exploration. Certain rapid ice-sheet loss processes are called *'low confidence'* processes by the IPCC, but low confidence does not indicate a lower quality estimate of resulting sea level rise. *Confidence* terms (*e.g.*, low, medium, and high confidence, see Figure 1) are used by the IPCC to define the level of evidence and degree of agreement among scientists around all the processes that are used as inputs into IPCC sea level rise estimates. Confidence increases when there are multiple, consistent, independent lines of high-quality evidence and the agreement among scientists about these processes is high. In the case of sea level rise projections, 'low confidence' processes can also be described as an "unknown likelihood, high-impact process." In other words, a 'low confidence' process like rapid ice-sheet loss has an unknown likelihood of occurring, but if rapid ice-sheet loss does occur, it would have a high impact on sea level rise estimates, and is plausible enough to consider in sea level rise projections.

When the IPCC assigns a confidence to a process, regardless of the level of confidence, this indicates the scientific community thinks the process is sufficiently plausible to warrant consideration in an assessment. As the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate states, "Stakeholders with higher risk tolerance (*e.g.*, those planning for investments that can be very easily adapted to unforeseen conditions) often prefer to use the *likely* range of projections, while stakeholders with a lower risk tolerance (*e.g.*, those deciding on critical infrastructure) also consider global and local mean sea level above the upper end of the *likely* range … and from methods characterized by lower confidence."

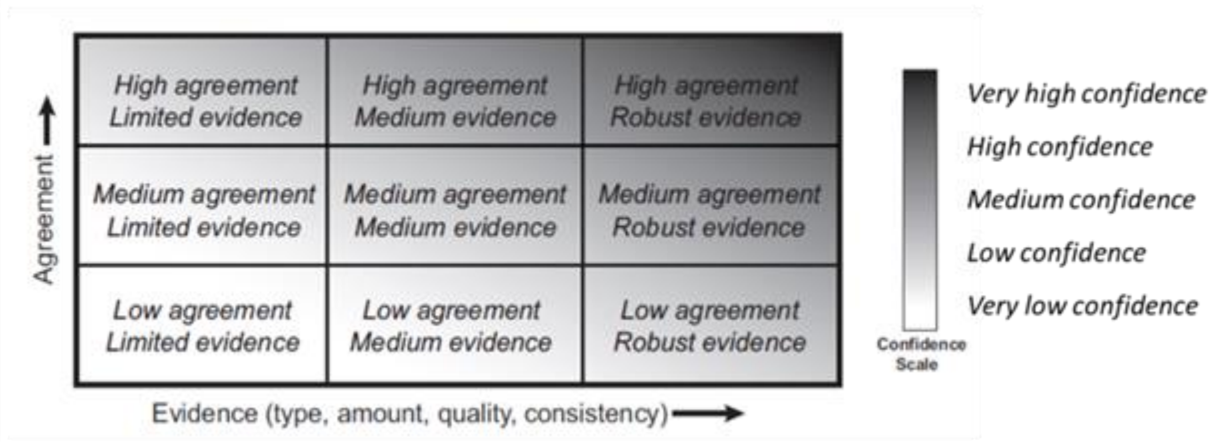

Figure 1. *The schematic used by the IPCC Fifth Assessment Report to help readers interpret the different levels of confidence associated with evidence. This schematic can be used to understand the STAP and IPCC reports. Confidence generally increases toward the top-right corner as suggested by the darker shading. (Modified from Mastrandrea et al. 2010).*

The STAP report incorporates these unknown-likelihood, high-impact processes into its primary projections, while the IPCC presents two kinds of projections: *low confidence* projections that include these processes and *medium confidence* processes that do not include them. The *'low confidence' and 'medium confidence'* labels do not characterize the overall quality of the projections themselves, but indicate whether the projections incorporate rapid ice-sheet loss processes, in which there is currently *low confidence*.

Quantitatively, consistent with this methodological difference, the STAP report projections provide similar estimates of sea level rise to the IPCC projections that include the *low confidence* processes. IPCC *medium confidence* projections estimate lower sea level rise than the STAP and IPCC *low confidence* projections of sea level rise, particularly at the high end of projected ranges. (The difference between (1) the IPCC *medium confidence* projections and (2) the STAP and IPCC *low confidence* projections increases over time and increases with the intensity of warming scenarios (*i.e.,* 2°C of warming compared to 5°C of warming by 2100).)

Note the STAP report and the IPCC report projections that include low confidence processes provide more protective (*i.e.*, higher) estimates of sea level rise than the IPCC report projections that exclude low confidence processes. The IPCC and STAP reports are not directly comparable to the Interagency report due to different framing between report approaches. Additional information on each of these points is provided below.

2019 STAP and the IPCC Report

Table 8.1. Comparison of estimated sea level rise in New Jersey based on the STAP and IPCC AR6 reports. Estimates are organized by: the climate scenario; the report; the degree of warming expected by the end of the century (Degree of Warming °C); and the confidence levels of processes included in each projection. All values are reported in feet (ft), and "—" represents a value that was not assessed in a report.

	New Jersey Sea level Rise Estimates (ft) in 2100 *											
Climate Scenario	STAP Low / IPCC Low (SSP1-2.6)			IPCC Intermediate (SSP2-4.5)			STAP Moderate / IPCC High (SSP3-7.0)			STAP High / IPCC Very High (SSP5-8.5)		
Report	STAP	IPCC AR6		STAP	IPCC AR6		STAP	IPCC AR6		STAP	IPCC AR6	
Degree of Warming (°C)**	2.0	1.8		--	2.7		3.5	3.6		5.0	4.4	
Confidence Levels of Processes Included	Low, Medium, and High	Low, Medium, and High	Medium and High	Low, Medium, and High	***Low, Medium, and High	Medium and High	Low, Medium, and High	***Low, Medium, and High	Medium and High	Low, Medium, and High	Low, Medium, and High	Medium and High
Chance SLR Exceeds												
> 83% chance	1.7	1.9	1.9	--	2.3	2.3	2.0	2.7	2.7	2.3	3.0	3.0
~ 50% chance	2.8	2.5	2.5	--	3.1	2.9	3.3	3.6	3.3	3.9	4.0	3.7
< 17% chance	3.9	3.4	3.2	--	4.4	3.8	5.1	5.1	4.2	6.3	5.9	4.7

** 'Low confidence' does not indicate lower quality than a 'high confidence' estimate of sea level rise: rather, confidence is used to qualify the degree of agreement and level of evidence around the processes that are used as inputs into the sea level rise estimates.*
*** Reported global warming levels are for the end of the 21st century, relative to a late nineteenth century baseline. For the IPCC scenarios, reported warming levels are median projections, while the IPCC sea level projections incorporate the range of possible warming levels consistent with the specified emissions scenario.*
**** IPCC low confidence projections for the intermediate (SSP2-4.5) and high (SSP3-7.0) emissions scenarios are interpolated and are not direct outputs of the IPCC.*

The methodologies used in the STAP and IPCC reports are similar, with updated warming scenarios, climate models, and sea level rise models between the STAP and the IPCC report. As noted above, the reports differ in how they communicate uncertainty: the STAP projections incorporate *low confidence* rapid ice-sheet loss processes in whose rate and magnitude there is currently a low level of agreement among researchers, while the IPCC separately presents projections including or excluding these processes. For scenarios, the IPCC report utilizes the recent Shared Socioeconomic Pathways (SSP) to project warming and sea level rise. These are:

- SSP1-1.9: Very low greenhouse gas emissions, with global net-zero CO_2 emissions around 2050, limiting median projected warming to about 1.5°C above late-nineteenth century levels.
- SSP1-2.6: Low greenhouse gas emissions, with global net-zero CO_2 emissions by about 2075, limiting median projected warming to below 2°C above late-nineteenth century levels.
- SSP2-4.5: Intermediate emissions, consistent with an optimistic interpretation of current global policy, with global emissions slowly rising to about mid-century and then declining. Median warming by 2100 would be approximately 2.7°C.
- SSP3-7.0: High emissions, with continued emissions growth throughout the century, leading to median warming of approximately 3.6°C by the end of the century.
- SSP5-8.5: Very high emissions, requiring sustained growth in fossil fuel use at rates comparable to those of the 1990s and 2000s, leading to a median projected warming of 4.4°C by the end of the century.

To align with the underlying peer-reviewed literature, the IPCC provided *low confidence* projections only for two emissions scenarios: a low emissions scenario (SSP1-2.6), comparable to the STAP low scenario, and a very high emissions scenario (SSP5-8.5), comparable to the STAP high scenario. For purposes of comparison, we interpolate the IPCC *low confidence* projections to yield projections for an intermediate (SSP2-4.5) and high (SSP3-7.0) emissions scenarios, the latter of which is comparable to the STAP moderate scenario.

The STAP projections, IPCC *low confidence* projections, and IPCC *medium confidence* projections are similar and exhibit only limited sensitivity to future emissions through 2050. By 2100, IPCC *low confidence* projections for Atlantic City under the IPCC high emissions scenario (SSP3-7.0) indicate a 17^{th}-83^{rd} percentile range of 2.7 ft to 5.1 ft of sea level rise, similar to the STAP report's moderate emissions scenario *likely* range of 2.0 ft to 5.1 ft of sea level rise. Both scenarios are associated with a similar level of median warming (~3.5 °C) by 2100 and are considered comparable. IPCC intermediate emissions (SSP2-4.5) 17^{th}-83^{rd} percentile range is 2.3 to 4.4 ft of sea level rise, with a median estimate of 3.1 ft: a similar median estimate to the STAP report's moderate scenario (3.3 ft) but with a narrower range (2.0 to 5.1 ft of sea level rise).

Considering only processes in which there is at least *medium confidence* and excluding rapid ice-sheet loss processes in which there is *low confidence*, the IPCC high emissions scenario (SSP3-7.0), with 3.5°C of warming by 2100 yields a *likely* range of 2.7 to 4.2 ft of sea level rise by 2100. The upper bound for this IPCC projection's *likely* range is 0.9 ft lower than the comparable STAP report's moderate projection (2.0 to 5.1 ft of sea level rise) and the corresponding IPCC *low confidence* projection.

2019 STAP and the 2022 Interagency Report

The STAP and IPCC report's projections cannot be compared directly to the Interagency report's scenarios. The STAP and IPCC reports offer scientific projections of future sea level change that result from potential emissions and warming. These reports answer the question: *What is the likelihood of different amounts of sea level rise under different future climate scenarios?* In contrast, the Interagency report offers scenarios of future sea level change to answer the question: *What is the range of plausible future sea level that a decision maker might wish to consider (incorporating both the range of possible emissions and the range of possible physical responses, regardless of whether those ranges are likely)?* Moreover, the Interagency report relies upon the IPCC report to evaluate the likelihood of the Interagency scenario trajectories under different warming levels and does not make an independent evaluation of likelihoods.

While direct comparisons cannot be made between the STAP and IPCC report's projections and the Interagency report's scenarios, the central tendencies (medians) of the Interagency report scenarios range from 2.1 to 7.0 ft of sea level rise at 2100, encompassing the *likely* ranges projected by the STAP and IPCC reports except at the lowest end of the STAP and IPCC low emissions projections. Additionally, the higher Interagency sea level scenarios fall well outside the *likely* range of the STAP low emissions scenario, with the highest Interagency high scenario (median of 7.0 ft rise by 2100) exceeding the upper end of the *likely* range for the STAP high emissions scenario.

9. Was the STAP study built upon peer-reviewed research?

The STAP study is a consensus report in which a panel of experts used a deliberative process that relied on the peer-reviewed literature on sea level rise projections. As was done in the 2016 STAP, the 2019 STAP vetted its preliminary findings with a panel of diverse practitioners to ensure the findings were provided in a manner that was useful and informative in their planning and decision-making practices.

The STAP deliberated upon several peer reviewed studies that provide probabilistic SLR projections for sites around the world, including New Jersey. These studies differ in their treatment of the polar ice sheets, as well as (in some cases) the climate scenarios considered. Examples of studies consulted include:

- Kopp et al. (2014) – This study is the framework used by the 2016 STAP. It is based upon the Representative Concentration Pathway (RCP) emission scenarios (van Vuuren et al., 2011) and yields projections of *likely* GMSL changes broadly consistent with IPCC AR5.
- Rasmussen et al. (2018) – This study is consistent with the framework and basic set of assumptions of Kopp et al. (2014) but employs different climate scenarios. In particular, rather than the RCPs, it uses warming-level scenarios based upon temperature projections for 2100, so that projections are (for example) for 1.5°C and 2.0°C global mean warming scenarios rather than for the RCPs.
- Kopp et al. (2017) – This study replaced the original Antarctic ice-sheet mass loss projections of Kopp et al. (2014) with those from the Antarctic ice-sheet modeling study of DeConto and Pollard (2016). The ice-sheet model incorporated (for the first time in a continental-scale model) the gravitational instability of ice cliffs and exhibited high sensitivity to increasing atmospheric temperatures. This study was considered by the STAP but not integrated into its projections.
- Bamber et al. (2019) – This study replaced the Greenland and Antarctic ice-sheet projections of K14 with projections based on a structured expert judgment (SEJ) study of ice-sheet changes associated with climate scenarios leading to 2°C and 5°C of warming by 2100, and it produced sea level rise projections consistent with these scenarios.

10. Does the STAP study offer policy recommendations?

No. The STAP report is intended to provide a scientific consensus on which policy makers can build their decisions. Discussion as to the use of the STAP report to reflect variable asset life cycles, uncertainty principles, and other applicable decision points are for illustrative purposes.

11. Are other states using the approach that the NJ STAP used?

Yes. Several jurisdictions use an expert-panel-led process to evaluate and produce a determination of the best available science for that jurisdiction. Jurisdictions that have used a similar scientific framework, in part or wholly, as that used in the 2016 STAP and 2019 STAP efforts include: California, Delaware, Maryland, Oregon, Washington, and City of Boston.

12. What uncertainties are included in the STAP report?

The word "uncertainty" itself has slightly different meanings when used in everyday speech versus a scientific context. In scientific discourse, it conveys the extent to which a measurement or projection may be affected by information that is known to be imperfect or incomplete. One can think of it as the range of possible values for that measurement or projection. The STAP communicates uncertainty in their projections using the likelihood and confidence terminologies adopted by the IPCC AR5 Report (Mastrandrea et al., 2010).

13. How often should the expert panel report be updated?

The STAP recommends that SLR projections be revisited periodically not to exceed 5 years, as well as after the release of any relevant reports from the Intergovernmental Panel on Climate Change (IPCC) or the U.S. National Climate Assessment, to assure that the estimates remain consistent with scientific advances.

ADDITIONAL BACKGROUND

14. Why is sea level change in the report measured from the year 2000?

At the time of publication, the National Tidal Datum Epoch is the 19-year tidal cycle centered on 1992 (*i.e.*, 1983 to 2010). For consistency with the sea level projection literature, including most recent federal and state sea level assessments, the baseline tidal epoch for the projections in this report is different from the National Tidal Datum Epoch. It is instead centered on the year 2000; more specifically, it is the average sea level over the 19-year tidal cycle from 1991 to 2009. Users can adjust the STAP projection to the 1983 to 2001 National Tidal Datum Epoch (centered on the year 1992) by adding 1.4 inches (0.1 ft). For example, the STAP central estimate projection for 2050 is 1.4 ft above the 2000 baseline. This is equivalent to 1.5 ft above the 1983 to 2001 National Tidal Datum Epoch (1992). Due to atmosphere and ocean dynamics, the annual average sea level can vary by up to 0.2 ft around the 19-year average sea level centered in the same year.

15. How long has sea level rise been occurring in NJ?

Twenty thousand years ago, a giant ice sheet covered much of North America, extending as far south as northern New Jersey. Between about 18,000 years ago and 7,000 years ago, this giant ice sheet disappeared, and other glaciers and ice sheets around the world shrunk considerably, leading to a rapid rise in global average sea level that was also experienced here in New Jersey. Over the last 4,000 years, the dominant long-term driver of SLR in New Jersey has been the sinking of the land as part of the ongoing response to the disappearance of the North American ice sheet (*i.e.*, glacial isostatic adjustment discussed in question 3 above) .

Geological data indicate that, primarily as a result of land subsidence, sea level in New Jersey rose about 6 inches/century (1.6 ± 0.1 mm/yr) from 0-1900 CE (Kemp et al., 2013; Kopp, Kemp, et al., 2016). Rates in the 20th and 21st centuries recorded by tide gauges are significantly higher (roughly three times higher than before 1900), reflecting a growing contribution from processes related to current, greenhouse gas-driven climate changes. SLR along the Jersey Shore has been consistently faster than at The Battery over this period, a difference predominantly attributed to subsidence associated with groundwater withdrawal (See Figure 2b in the 2019 STAP report).

From 1911 (the start of the Atlantic City tide-gauge record) to 2019, sea level rose 17.6 inches along the New Jersey coast (average rate of 1.7 in/decade [4.2 ± 0.1 mm/yr]) in New Jersey. Sea level rose 13.3 inches at the Battery located at the southern tip of Manhattan Island in New York City (average rate of 1.2 in/decade [3.1 ± 0.1 mm/yr]). Comparatively, GMSL rose 7.6 inches (average rate of 0.7 in/decade [1.8 mm/yr]) (Dangendorf et al., 2019; WCRP Global Sea Level Budget Group, 2018).

Over the last forty years, from 1979 to 2019, sea level rose 8.2 inches along the New Jersey coast (average rate of 2.0 in/decade [5.2 ± 0.2 mm/yr]). Sea level rose 6.5 inches at the Battery over the same period (average rate of 1.6 in/decade [4.1 ± 0.2 mm/yr]). Comparatively, GMSL rose 4.3 inches (average rate of 1.1 in/decade [2.7 mm/yr]) (Dangendorf et al., 2019; WCRP Global Sea Level Budget Group, 2018).

Between the 19-year period centered on the year 2000 (1991-2009) and the 19-year period centered on the year 2010 (2001-2019), sea level rose by 1.5 in (3.8 cm) at the Battery and in New Jersey: 1.7 in (4.2 cm) at Atlantic City, 2.0 in (5.2 cm) at Cape May, and 2.1 in (5.4 cm) at Sandy Hook.

16. How would the projections of the 2016 STAP report translate into the framework of the 2019 STAP report?

The 2016 STAP report used different emissions scenarios than the 2019 STAP report. Rather than the warming level-based projections in the 2019 report, the 2016 report used the more obscurely labeled Representative Concentration Pathways (RCPs) that were the standard emissions scenarios used by the climate modeling community from about 2010 to 2018. However, it is possible to reconstruct what the 2019 STAP would have produced had they chosen to adopt warming level-based scenarios but not been able to draw upon the work of Bamber et al. (2019) to characterize uncertainties not well represented in ice-sheet models. Indeed, these projections were an input (alongside the projections using Bamber et al, 2019) into the 2019 STAP headline numbers.

Had the 2019 STAP chosen to retain the methodology of the 2016 report, which was consistent with the state of knowledge represented in the 2013 IPCC report, the STAP would have projected a *likely* rise in New Jersey by 2100 of 1.7-3.6 feet (instead of 1.7-3.9 ft) in a 2°C scenario, 2.0-4.1 feet (instead of 2.0-5.1 feet) in a 3.5°C scenario, and 2.3-4.7 feet (instead of 2.3-6.3 feet) in a 5°C scenario.

Such ranges would have come with the caveat similar to that the IPCC included with its projections of *likely* sea level change in its 2013 report: “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.” (A tenth of a meter is equal to about a third of a foot.) The approach used by the 2019 STAP allowed that hazard to be quantified and incorporated into key figures and tables using a formal risk analytic method.

17. What critical research is underway to assess risk from sea level rise in the future?

While flood risks are often modeled as independent events, recent research is focusing on modeling compound events. The STAP panel and practitioners discussed the need to move toward models that can represent combined hazards from rainfall and flooding that can co-occur.