

# State Climate Summaries: Tidal Flood Analyses and Additional Projections

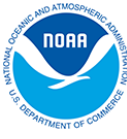
## Overview

This document provides additional information on the annual number of nuisance-level flood days for the observed record and projections for these events through the end of this century. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance flooding has increased in all U.S. coastal states, with more rapid increases along the East and Gulf Coasts. Nuisance flooding events (or tidal flooding) are defined as water levels, measured by National Oceanic and Atmospheric Administration (NOAA) tide gauges (<http://tidesandcurrents.noaa.gov/>), above the local NOAA Weather Service (NWS) threshold for minor impacts (<http://water.weather.gov/ahps>), such as road closures and overwhelmed storm drains, established for emergency preparedness. **In contrast to the figures shown in this technical document, the tidal flood figures in the 2019 revision of the State Climate Summaries have been updated to use a nationally consistent set of derived NOAA flood thresholds, as described below.**

## Data and Methods

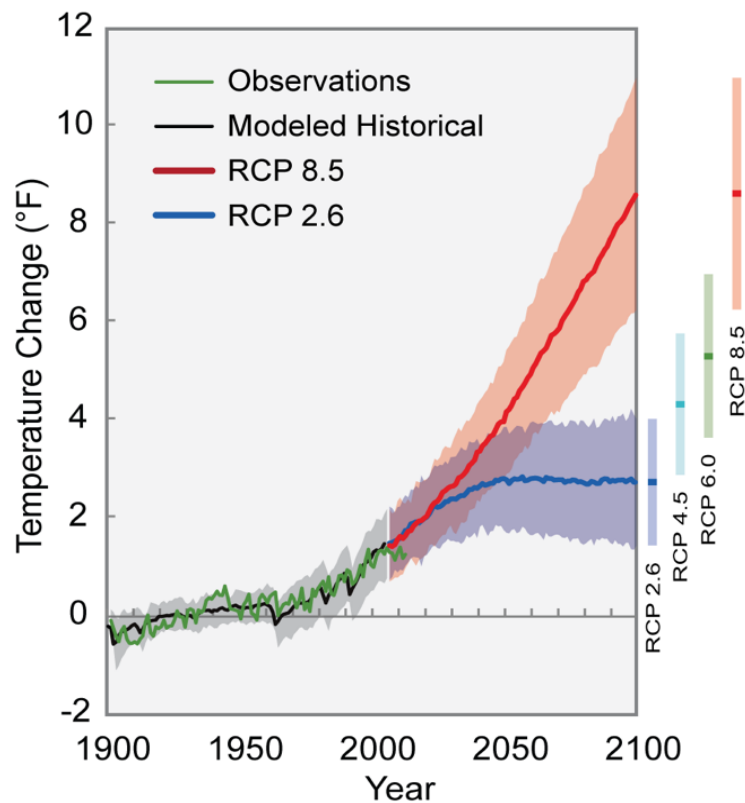
For the figures in this technical document, observed data were derived from counting daily-maximum water levels each year for individual NOAA gauges that exceed specific elevation thresholds for “minor” coastal flooding (Sweet et al. 2014). A year is defined in terms of a meteorological year (May–April). Tidal flood projections were derived from the projections of mean sea level of Kopp et al. (2014), who used outcomes of the Coupled Model Intercomparison Project Phase 5 (CMIP5). The CMIP5 simulations use a set of scenarios called Representative Concentration Pathways (RCPs; Figure 1). These are based on radiative forcing trajectories over time and are named according to the radiative forcing level at 2100 (Moss et al. 2010). From the projection of future mean sea level, local (probabilistic) projections of mean sea level were used to derive future annual frequencies of tidal flooding (Sweet and Park 2014).

Figures 2–18 show the full suite of tidal flooding scenarios as described in Sweet and Park (2014). They feature four RCPs: 2.6, 4.5, 6.0, and 8.5, with the numbers representing the 2100 radiative forcing increase relative to preindustrial levels in  $\text{Wm}^{-2}$ . The carbon dioxide ( $\text{CO}_2$ ) concentrations for RCP4.5 and RCP6.0 cross over at around 2060; before then, the radiative forcing is larger for RCP4.5. The concentration for RCP2.6 is also slightly higher than RCP6.0 early in the 21st century. The lowest concentration pathway, RCP2.6, assumes immediate and rapid reductions in emissions and would result in about  $2.5^\circ\text{F}$  of warming in this century. The highest pathway, RCP8.5, roughly similar to a continuation of the current path of global emissions increases, is projected to lead to more than  $8^\circ\text{F}$  warming by 2100, with a high-end possibility of more than  $11^\circ\text{F}$ .

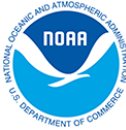


## 2019 Updates

While projections are still based on the CMIP5 RCP scenarios, the tidal flood figures in the 2019 revision of the State Climate Summaries use an updated methodology. As described in Sweet et al. (2018), a tidal flood day occurs when water levels exceed the derived NOAA threshold for minor (high tide) flooding, which is consistent across all locations. Using this new definition, the threshold level has increased for most stations. The tidal flood figures in the 2019 revised State Climate Summaries include projections under the RCP 4.5 (lower emissions) and RCP8.5 (higher emissions) scenarios only.

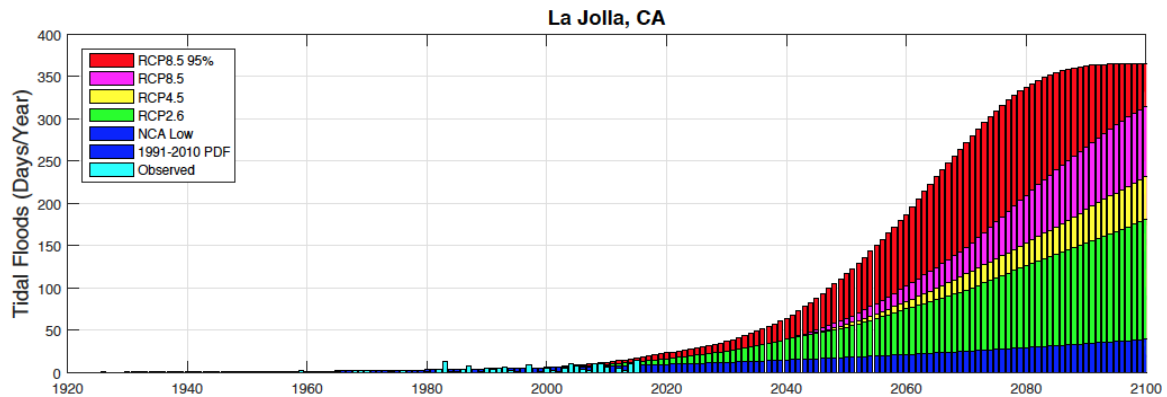


**Figure 1:** Observed and projected global average temperature change, relative to the 1901–1960 average. Lines represent observed (green), modeled historical (black), and projected changes (red and blue) in temperature. Projections are shown for two CMIP5 Representative Concentration Pathways (RCPs)—RCP2.6 and RCP8.5. Shading indicates the range (5th to 95th percentile) of results from a suite of climate models. Projections in 2099 for additional emissions pathways are indicated by the bars to the right of the panel. Source: Adapted from Melillo et al. 2014.

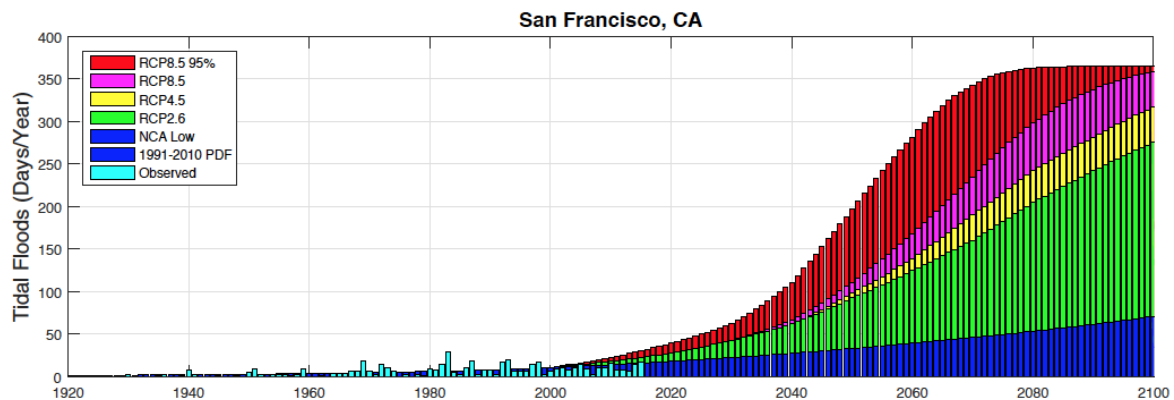


## Observed and Projected Annual Number of Tidal Floods for La Jolla and San Francisco, CA

(a)



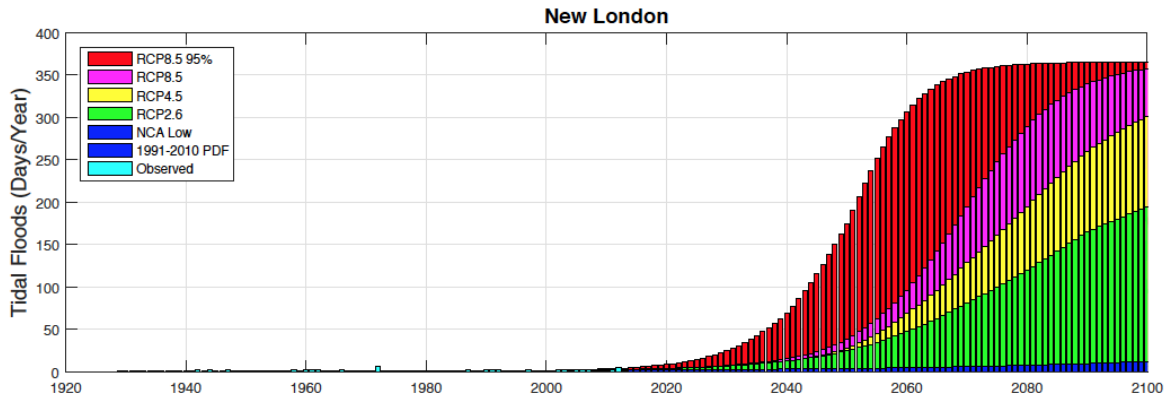
(b)



**Figure 2:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for (a) La Jolla and (b) San Francisco, CA. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance-level threshold) occurred in 2015 at La Jolla and in 1983 in San Francisco. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



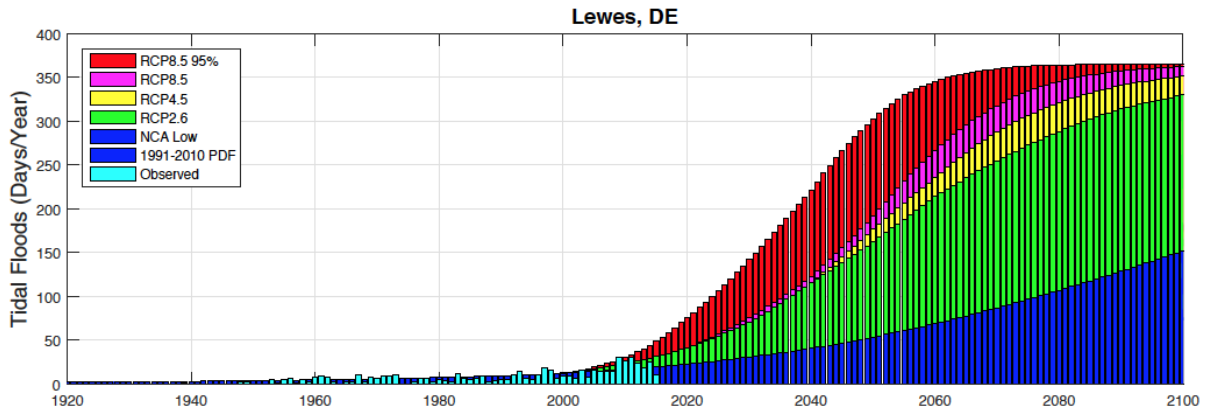
### Observed and Projected Annual Number of Tidal Floods for New London, CT



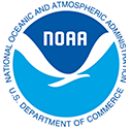
**Figure 3:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for New London, CT. The 95th percentile of model simulations under the RCP8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance-level threshold) occurred in 1972 and 2012 at New London. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



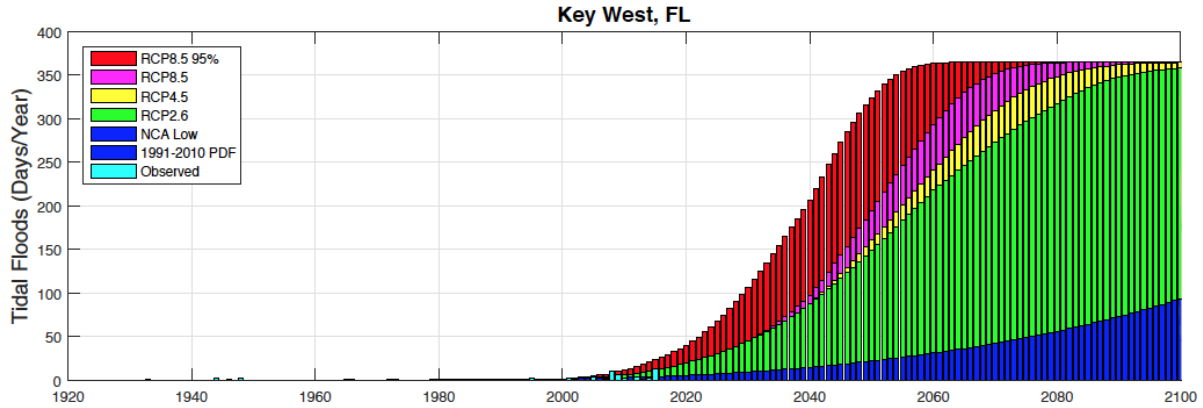
### Observed and Projected Annual Number of Tidal Floods for Lewes, DE



**Figure 4:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Lewes, DE. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2009 and 2011 at Lewes. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



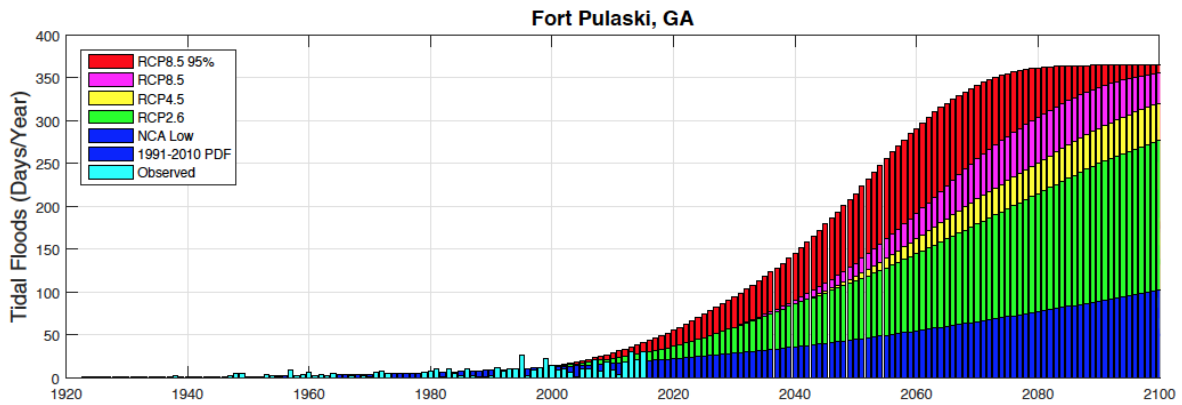
### Observed and Projected Annual Number of Tidal Floods for Key West, FL



**Figure 5:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Key West, FL. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2015 at Key West. Projected increases are large even under a lower emissions pathway. Near the end of the century, under both lower and higher emissions pathways, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



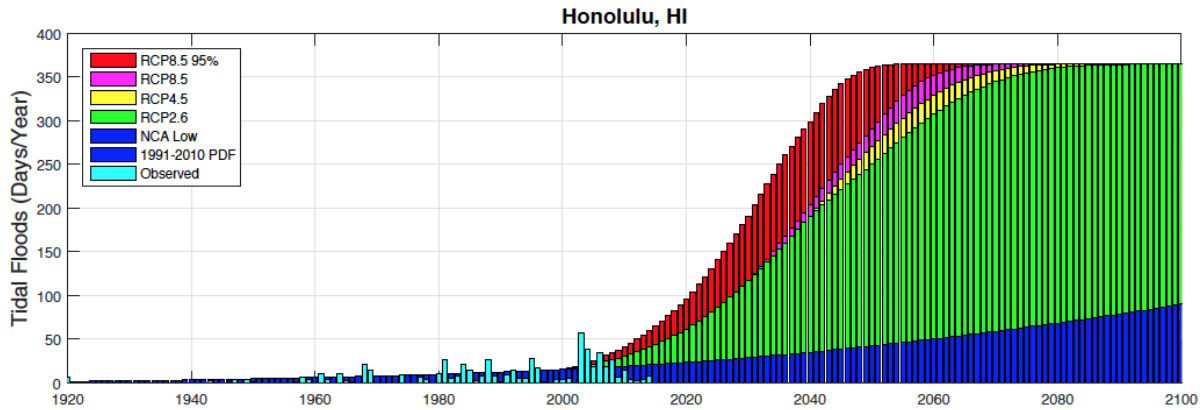
### Observed and Projected Annual Number of Tidal Floods for Fort Pulaski, GA



**Figure 6:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Pulaski, GA. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2013 and 2015 at Pulaski. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



### Observed and Projected Annual Number of Tidal Floods for Honolulu, HI

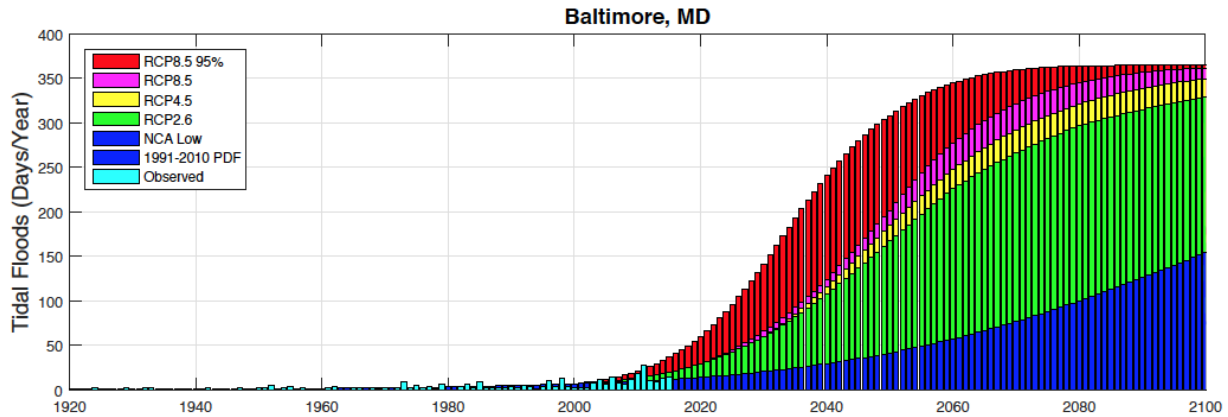


**Figure 7:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Honolulu, HI. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2002 and 2003 at Honolulu. Projected increases are large even under a lower emissions pathway. Near the end of the century, under both lower and higher emissions pathways, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.





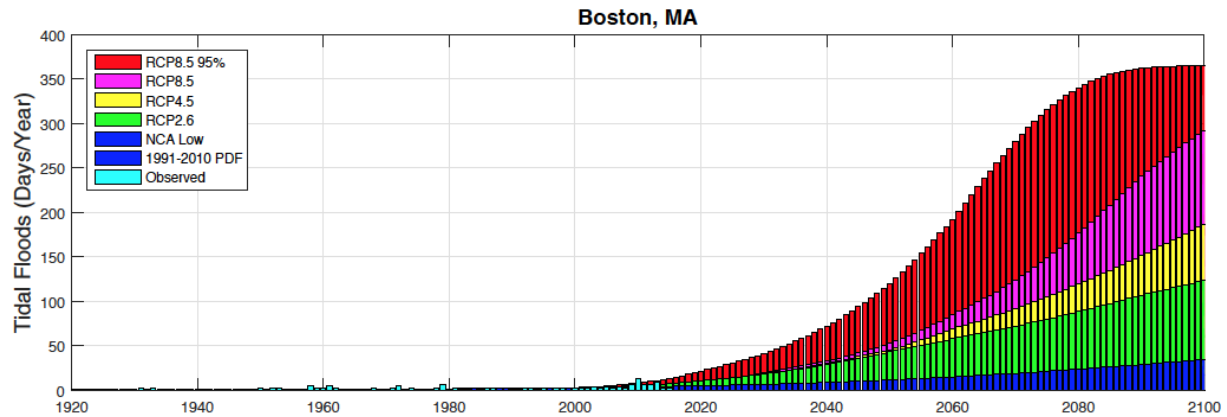
### Observed and Projected Annual Number of Tidal Floods for Baltimore, MD



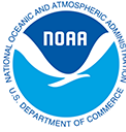
**Figure 8:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Baltimore, MD. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2011 at Baltimore. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



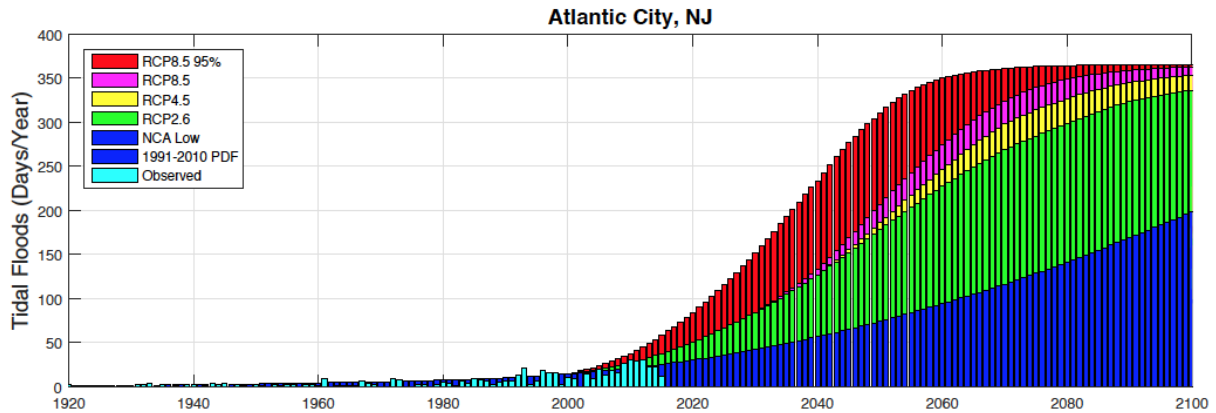
## Observed and Projected Annual Number of Tidal Floods for Boston, MA



**Figure 9:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Boston, MA. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2011 at Boston. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, some models project tidal flooding will occur nearly every day of the year. Source: NOAA NOS.



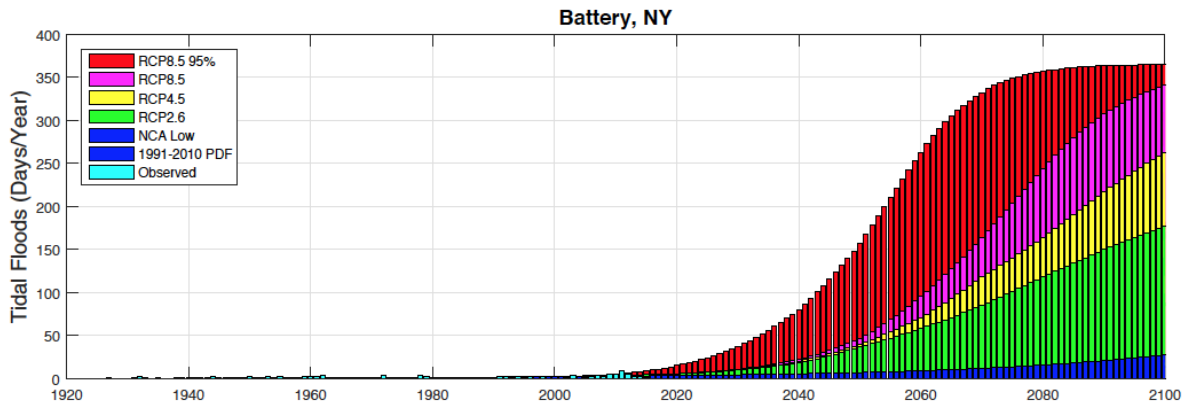
### Observed and Projected Annual Number of Tidal Floods for Atlantic City, NJ



**Figure 10:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Atlantic City, NJ. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2010 and 2012 at Atlantic City. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



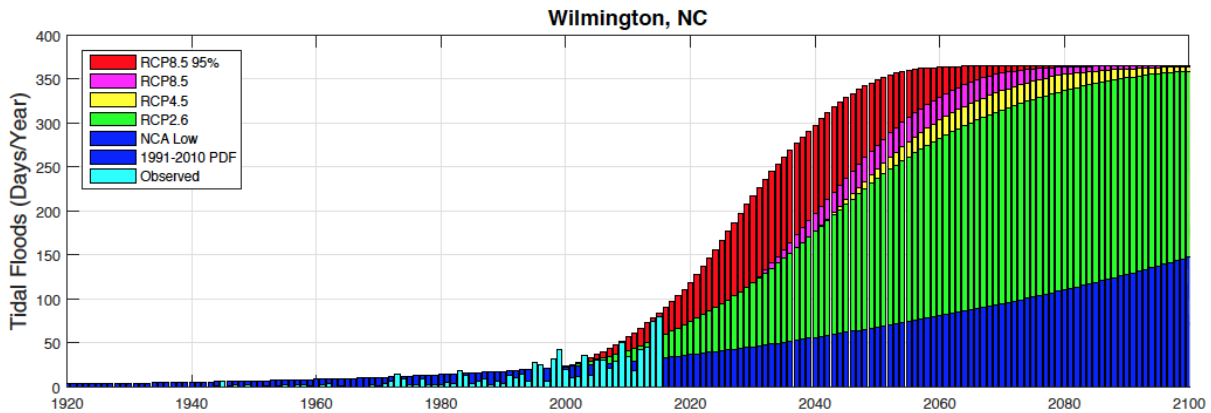
### Observed and Projected Annual Number of Tidal Floods for Battery Park, NY



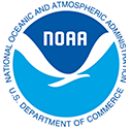
**Figure 11:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Battery, NY. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2011 at Battery. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, some models project tidal flooding will occur nearly every day of the year. Source: NOAA NOS.



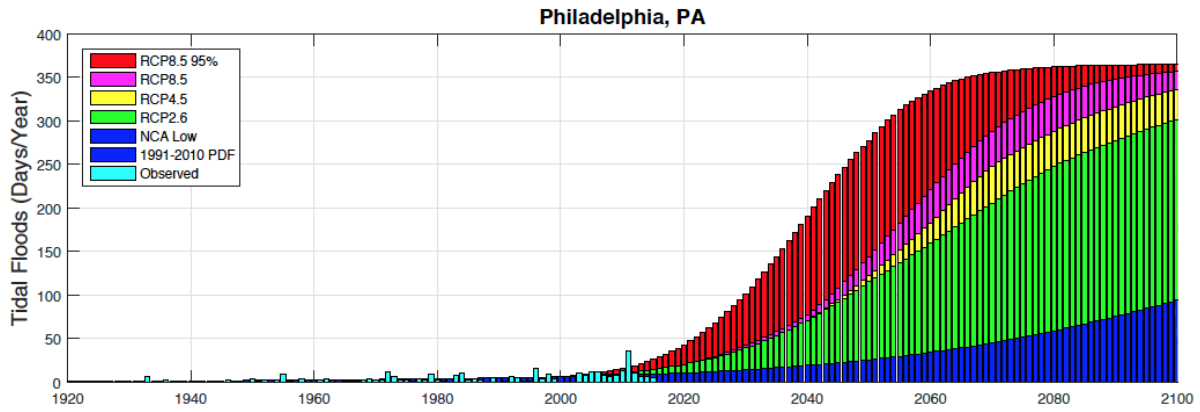
## Observed and Projected Annual Number of Tidal Floods for Wilmington, NC



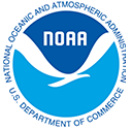
**Figure 12:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Wilmington, NC. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2014 and 2015 at Wilmington. Projected increases are large even under a lower emissions pathway. Near the end of the century, under both lower and higher emissions pathways, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



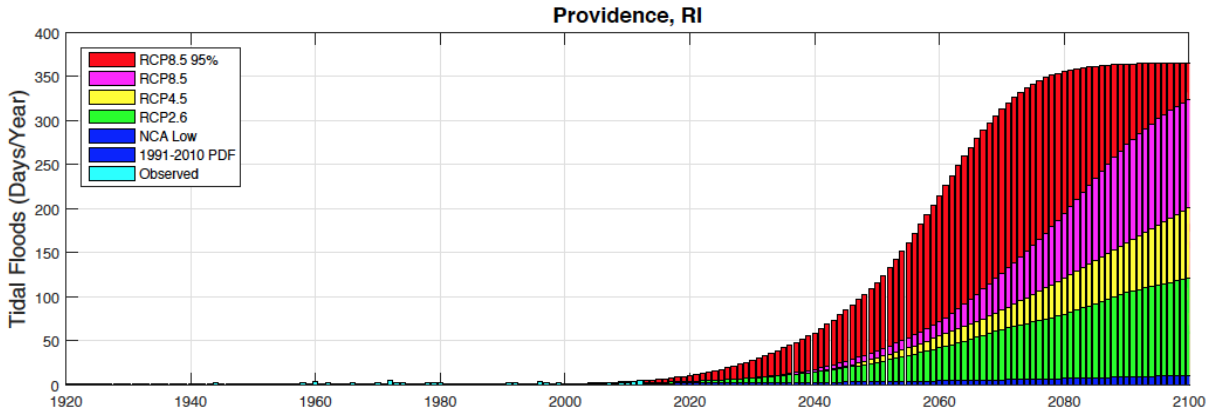
## Observed and Projected Annual Number of Tidal Floods for Philadelphia, PA



**Figure 13:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Philadelphia, PA. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2011 at Philadelphia. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



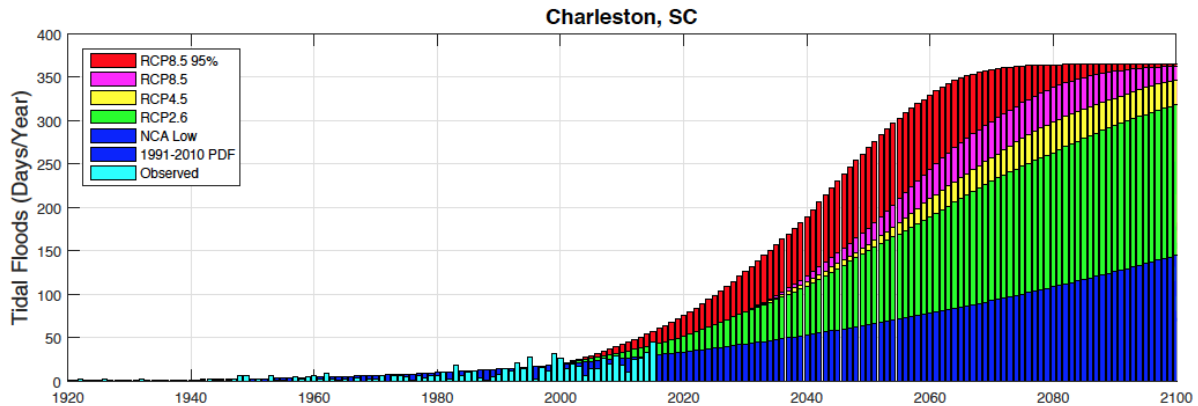
### Observed and Projected Annual Number of Tidal Floods for Providence, RI



**Figure 14:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Providence, RI. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 1972 and 2012 at Providence. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, some models project tidal flooding will occur nearly every day of the year. Source: NOAA NOS.



## Observed and Projected Annual Number of Tidal Floods for Charleston, SC

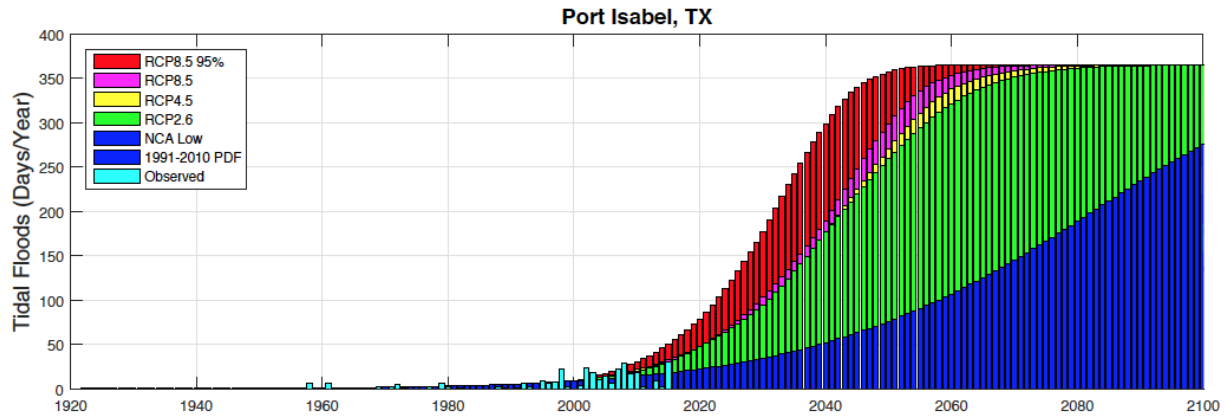


**Figure 15:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Charleston, SC. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2015 at Charleston. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.

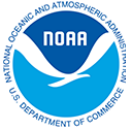




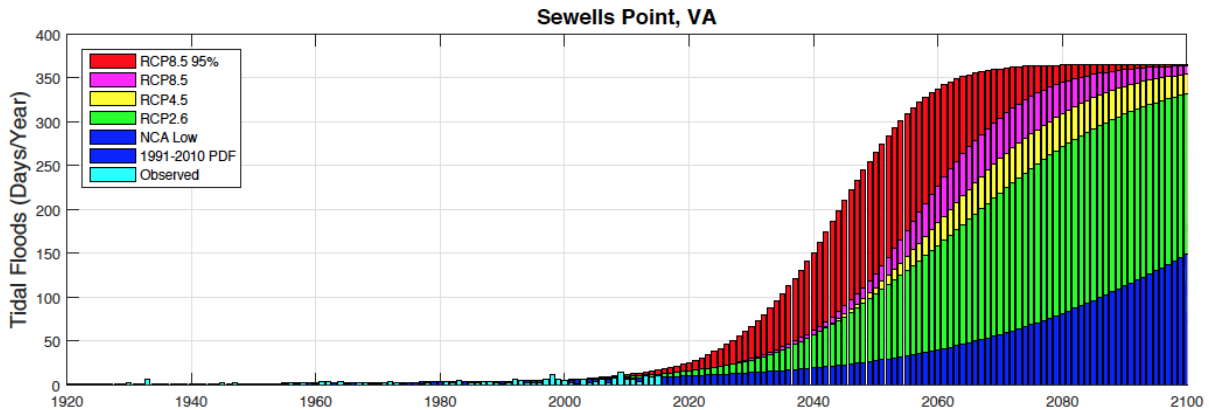
### Observed and Projected Annual Number of Tidal Floods for Port Isabel, TX



**Figure 16:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Port Isabel, TX. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2008 and 2015 at Port Isabel. Projected increases are large even under a lower emissions pathway. Near the end of the century, under both lower and higher emissions pathways, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



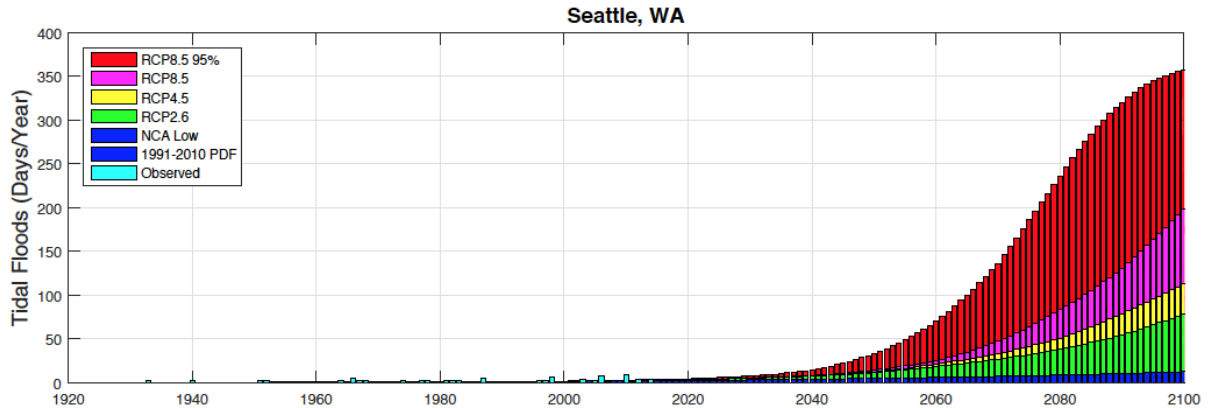
## Observed and Projected Annual Number of Tidal Floods for Sewell Point, VA



**Figure 17:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Sewells Point, VA. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2007 at Sewells. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur nearly every day of the year. Source: NOAA NOS.



### Observed and Projected Annual Number of Tidal Floods for Seattle, WA



**Figure 18:** Number of tidal flood days per year for the observed record (light blue bars) and projections for four possible futures: simple extrapolation ["NCA Low"] of the recent global sea level rise of 3.2 mm per year (blue), much lower emissions [RCP2.6] (green), lower emissions [RCP4.5] (yellow), and higher emissions [RCP8.5] (pink) per calendar year for Seattle, WA. The 95th percentile of model simulations under the RCP 8.5 scenario is shown in red. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 2010/11 at Seattle. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, tidal flooding is projected to occur 150 days or more every year. Source: NOAA NOS.



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