2021 State of High Tide Flooding and Annual Outlook

Myrtle Beach, South Carolina. Photo Credit: mycoast.org

Silver Spring, Maryland
July 2021

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U.S. DEPARTMENT OF COMMERCE
National Ocean Service
Center for Operational Oceanographic Products and Services

Center for Operational Oceanographic Products and Services
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2021 State of High Tide Flooding and Annual Outlook

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NOTICE

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EXECUTIVE SUMMARY

One of the most tangible signs of sea level rise is the increased frequency of high tide flooding (HTF) occurring along the U.S. coastlines. HTF impacts coastal infrastructure and natural systems (e.g., flooding of storm and wastewater systems, roadways, commercial/private property, sandy beaches, and marshes) and typically begins when water levels exceed about 0.5 meter (1.75 feet) above high tide as measured by the National Oceanic and Atmospheric Administration (NOAA) tide gauges. HTF levels are nationally calibrated against NOAA's National Weather Service and local emergency managers' depth-severity thresholds used in weather forecasting and impact communications to provide a consistent coastal-climate resiliency standard. HTF damages infrastructure and creates other economic and ecosystem impacts within coastal communities, which are largely responsible for finding and funding mitigative solutions.

NOAA's National Ocean Service provides annual reports (this is the seventh of an annual series[1]) tracking historical HTF frequency changes, mapping current exposure footprints, and providing next-year outlooks and multi-decadal projections of flood frequency changes. Decadal projections are based upon a range of relative sea level (RSL) rise considered more likely to occur based upon the Fourth U.S National Climate Assessment.[2] These reports are designed to inform the public of the accelerating upward trajectory of climate-driven coastal flooding, and support partners and coastal communities as they plan and make decisions regarding increasingly disruptive and expensive impacts.

In 2020 (May 2020–April 2021), U.S. coastlines continued to experience HTF at a rate (4 days/year—national median) that is twice what it was just 20 years ago. In total, 14 locations tied or broke HTF records along the U.S. Southeast Atlantic and Gulf coastlines due to a combination of effects from a record-breaking hurricane season and/or continued RSL rise (12 locations tied/set records for RSL levels). For perspective, as compared to HTF frequencies typical in 2000, these regions experienced a (median values) 400–1100% increase in 2020 (e.g., 14 and 22 days for Charleston, S.C. and Bay Waveland, Miss. in 2020 versus 2 and 3 days in 2000, respectively). Over 80% of East and Gulf Coast tide gauge locations are now experiencing annual acceleration (nonlinear rise) in HTF frequencies with most others linearly increasing.

For 2021 (May 2021–April 2022), continued acceleration in HTF and its impacts are expected with 3–7 days (national median) of HTF likely under near-neutral conditions of the El Niño Southern Oscillation. The 2021 HTF Outlook is 7–15 days along the Western Gulf, 6–11 days along the Northeast Atlantic, 3–7 days along the Southeast Atlantic and Eastern Gulf, and upwards of 3 and 7 days along the Southwestern and Northwestern Pacific, respectively. No HTF is likely along Hawaii or the U.S. Pacific or Caribbean coastlines. That said, this outlook does not discount that local flooding might occur at water levels less than the HTF height threshold used here, and it does not explicitly account for wave, rainfall, and elevated groundwater effects.

By 2030, the national median HTF frequency rate is likely to increase about 2–3 times (7–15

[1] An interactive map of this year's results is available at https://tidesandcurrents.noaa.gov/HighTideFlooding_AnnualOutlook.html

[2] https://nca2018.globalchange.gov/chapter/appendix-3/

days) without further adaptation measures; by 2050, it is likely to increase 5–15 times higher (25–75 days). In addition to minor flooding events, moderate and major HTF (starting at about 0.8 meter and 1.2 meters [2.75 feet and 4 feet] above high tide), which trigger coastal flood warnings for significant risks to life and property, will become much more commonplace as we approach mid-century.

1. INTRODUCTION

Tide gauge observations of the National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS) along the U.S. coastline are used traditionally to define our nautical boundaries, facilitate safe and effective maritime commerce, establish tidal datums critical to coastal mapping and engineering, and support emergency response preparedness. NOAA's tide gauge data is now increasingly important to achieve coastal resilience through planning for impacts from relative sea level (RSL) rise. Paired with NOAA coastal flood thresholds for local impacts, NOAA tide gauges are documenting a rapid growth in coastal flooding occurring within many U.S. coastal communities (Sweet et al., 2014). Flooding that decades ago happened only during a severe storm can now occur during a full-moon tide or with a change in prevailing winds or currents. Such high tide flooding (HTF) is becoming common and causing concerns within U.S. coastal communities.

HTF begins when coastal water levels exceed about 0.5 m (about 1.75 ft) above the mean higher high water (MHHW) level. At these levels, HTF impacts are typically more minor, with deeper and more severe moderate and major HTF occurring about 0.8 m and 1.2 m (about 2.75 ft and 4 ft) above MHHW, respectively.[3] Site-specific HTF height-severity thresholds vary by a location's tide range (Sweet et al., 2018), which facilitates mapping of potential exposure to these flood categories using NOAA's VDatum model (https://vdatum.noaa.gov/) and best available elevation data provided by NOAA's Digital Coast (Figure 1).

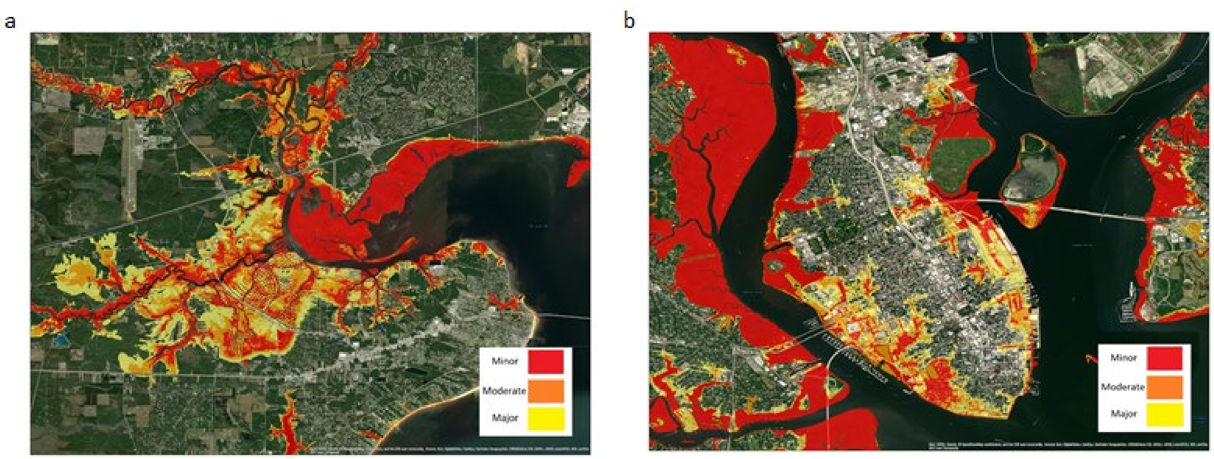

Figure 1. Map for minor (red), moderate (orange) and major (yellow) HTF layers for a) Bay Waveland, Miss. and b) Charleston, S.C. mapped by the same methods as NOAA's Sea Level Rise Viewer.[4] Red is used for the minor HTF layer since it will be flooded under all three HTF categories.

The HTF height-severity thresholds are calibrated to those of NOAA's National Weather Service (NWS) Weather Forecasting Offices and on-the-ground local emergency managers, which are the official thresholds used to communicate imminent flood impacts in weather forecasting and

[3] HTF counts exceeding the minor threshold will also include more severe events; so, although most events are likely less severe, more substantial surge events (e.g., from tropical cyclones or nor'easters) will also be captured.

[4] https://coast.noaa.gov/data/digitalcoast/pdf/slr-high-tide-flooding.pdf

communications (NOAA, 2020). However, the NWS coastal flood thresholds are typically representative for only a particular area and do not exist at all U.S. coastal locations. Therefore, the HTF thresholds, which are a best-fit solution (via linear regression) of the NWS thresholds with tide range, are used to provide a nationally consistent method to define infrastructure vulnerabilities for coastal-climate resilience purposes (Sweet et al., 2018). As such, there are some locations (e.g., the Florida Keys; Honolulu, Hawaii) that might experience minor flooding at heights below the local HTF threshold, and conversely, there are some locations that may not experience flooding (e.g., directly behind the seawalls in St. Petersburg, Fla. or Galveston, Tex.) but still experience subsurface impacts like storm-water infiltration or overland flooding impacts further up- or down-coast.

This past year, there were numerous media reports concerned with RSL rise and impacts ranging from threatening ecosystems[5] to taxpayer-supported mortgages.[6] These media reports add to the growing list of concerns documented over the last several years about the degradation and under-capacity of storm and wastewater systems, as well as flooding of properties, roadways, and businesses—affecting real-estate prices and disrupting commutes and commerce. There were also some exciting advances to help us better understand the spatial footprint of flooding used to calibrate community-scale models for smart planning using citizen science observations.[7]

This report is the seventh in an annual series to assess HTF that occurred last year to raise awareness of the growing impact of RSL rise. It also is to inform decision-making about what to expect, not only next year (e.g., budgeting and allocating for necessary coastal flood responses) but over the longer term (e.g., major infrastructure upgrades and land-use planning) to ensure resilience to sea level rise impacts. Specifically, this report provides an assessment of HTF that occurred in 2020 (May 2020–April 2021) and for the first time, further distinguishes HTF into minor, moderate, and major categories.[8] This report also maps select locations' exposure from minor, moderate, and major HTF and provides a 2021 (May 2021–April 2022) HTF outlook based upon temporal trends and predicted strength of the El Niño-Southern Oscillation (ENSO). Note: the outlook predicts flooding only at or above the minor threshold. This report and accompanying NOAA website[9] also continue to provide projections of HTF by Sweet et al. (2018) based upon the range of RSL rise *likely* (Intermediate Low to Intermediate Scenarios) to occur by 2030 and 2050 using projections of Sweet et al. (2017) adopted by the Fourth National Climate Assessment.

[5] https://theconversation.com/sea-level-rise-is-killing-trees-along-the-atlantic-coast-creating-ghost-forests-that-are-visible-from-space-147971

[6] https://www.politico.com/news/2020/11/30/climate-change-mortgage-housing-environment-433721

[7] https://www.theatlantic.com/science/archive/2020/11/predicting-floods-before-strike/617208/

[8] Data available at https://tidesandcurrents.noaa.gov/api-helper/url-generator.html

[9] https://tidesandcurrents.noaa.gov/HighTideFlooding_AnnualOutlook.html

2. 2020 CONDITIONS

During 2020 (May 2020–April 2021), La Niña conditions prevailed (average Oceanic Niño Index [ONI] value of -0.79[10]) and the U.S. Atlantic experienced a record-setting hurricane season.[11] There were 30 named storms (with top winds of 39 mph or greater) and 12 landfalling storms mostly impacting the Gulf and Southeast Atlantic Coasts. The national (median) number of days with HTF was 4 (Figure 2a), which matches 2019 as the second highest on record. This continued the upward accelerating trend and was within range of last year's outlook (2–6 days; Sweet et al., 2020). Though occurrences of moderate and major HTF are also becoming more likely due to continued RSL rise—some locations set a few records in 2020 (see below)—their national (median value) frequencies are still less than once per year.

Relative sea levels in 2020 were slightly lower than in 2019 as a whole (median difference of ~2.5 cm); however, they were still elevated and attained the second highest level on record with almost 0.3 m (1 ft) rise in the last 100 years (linear trend of 2.7 mm/yr). When viewed regionally and locally (Figure 2b), RSL was slightly lower along most U.S. coasts, which at least along the West Coast was likely in response to La Niña conditions that lower sea levels. There were 12 locations that did, however, break or tie RSL records including locations along the Southeast Atlantic, Eastern Gulf, and along the Hawaiian and Pacific Islands. Though not record-setting, RSLs in 2020 were slightly elevated as compared to 2019 along the Northwest Pacific.

Closer inspection of two locations—Charleston, S.C. and Bay Waveland, Miss.—help illustrate the nature of processes contributing to HTF during 2020 (Figure 2c-d). Both locations were exposed to a varying degree of tropical cyclones, though the storm tracks were generally offshore in the case of Charleston and regionally onshore for the case of Bay Waveland.[12] Both locations set HTF records in 2020 (14 days and 22 days, respectively) and Charleston had record-setting RSLs. Charleston's HTF record was almost completely in response to monthly-scale RSL variability that lifted the astronomical tides above the HTF/minor flood threshold (Figure 2c, green line). On the other hand, of the 22 HTF days at Bay Waveland (Figure 2d), nearly all were due to short-period storm surges, which caused moderate (10 days—broke record) and major (3 days) HTF.

[10] https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

[11] https://www.noaa.gov/media-release/record-breaking-atlantic-hurricane-season-draws-to-end

[12] https://www.nhc.noaa.gov/tafb_latest/tws_atl_latest.gif

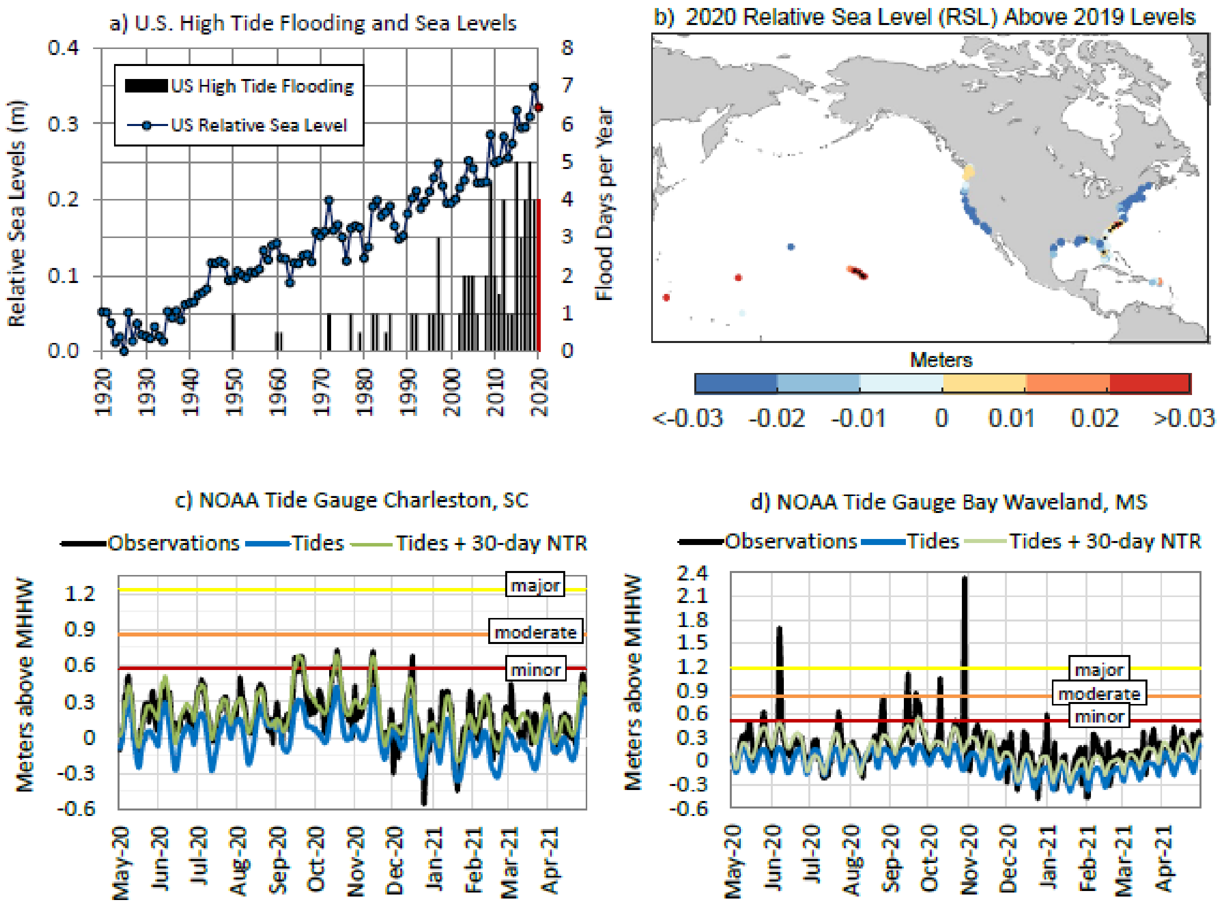

Figure 2. a) Median HTFs per year (black bars) from 1920–2020 with the annual-median rise in RSL (blue line). 2020 sea level and flood frequency values are shown in red. In b) are the individual tide gauge locations showing the difference in RSLs between 2019 and 2020 with black dots denoting those that broke historical RSL records in 2020. In c) is a time series of 2020 daily highest water level observations (black line), the tide component only inherent to the observations (blue line) and a combined tide and 30-day lowpass filtered nontidal residual (green line) time series at the NOAA tide gauge in c) Charleston, S.C. and d) Bay Waveland, Miss. with the minor (red), moderate (orange) and major (yellow) HTF height thresholds.

Along U.S. coastlines (Figure 3), HTF occurred the most along the Western Gulf (17 days, median value) and to a lesser extent, along the Eastern Gulf and Southeast Atlantic Coasts (9 days and 8 days), respectively, related to a combination of high tropical cyclone activity and continued RSL rise. The Northeast Atlantic experienced 6 days (median value) of flooding, and RSLs were generally lower in 2020 relative to 2019 (Figure 2b). No HTF occurred along the Southwest Coast likely due to suppressed RSLs and a northward shift in storm track related to higher near-surface pressures over the Eastern North Pacific due to La Niña conditions (personal communication with Martin Hoerling with NOAA Physical Sciences Laboratory) that contributed to 3 HTF days along the Northwest Pacific. In terms of how observed 2020 HTF days related to the 2020 outlook produced last year (Sweet et al., 2020), most fell within the outlook range (61 locations), with 15 locations below the 2020 outlook (mainly along the Northeast Atlantic and Southwest Pacific) and 20 locations above the outlook (along the Southeast Atlantic and Gulf Coasts).

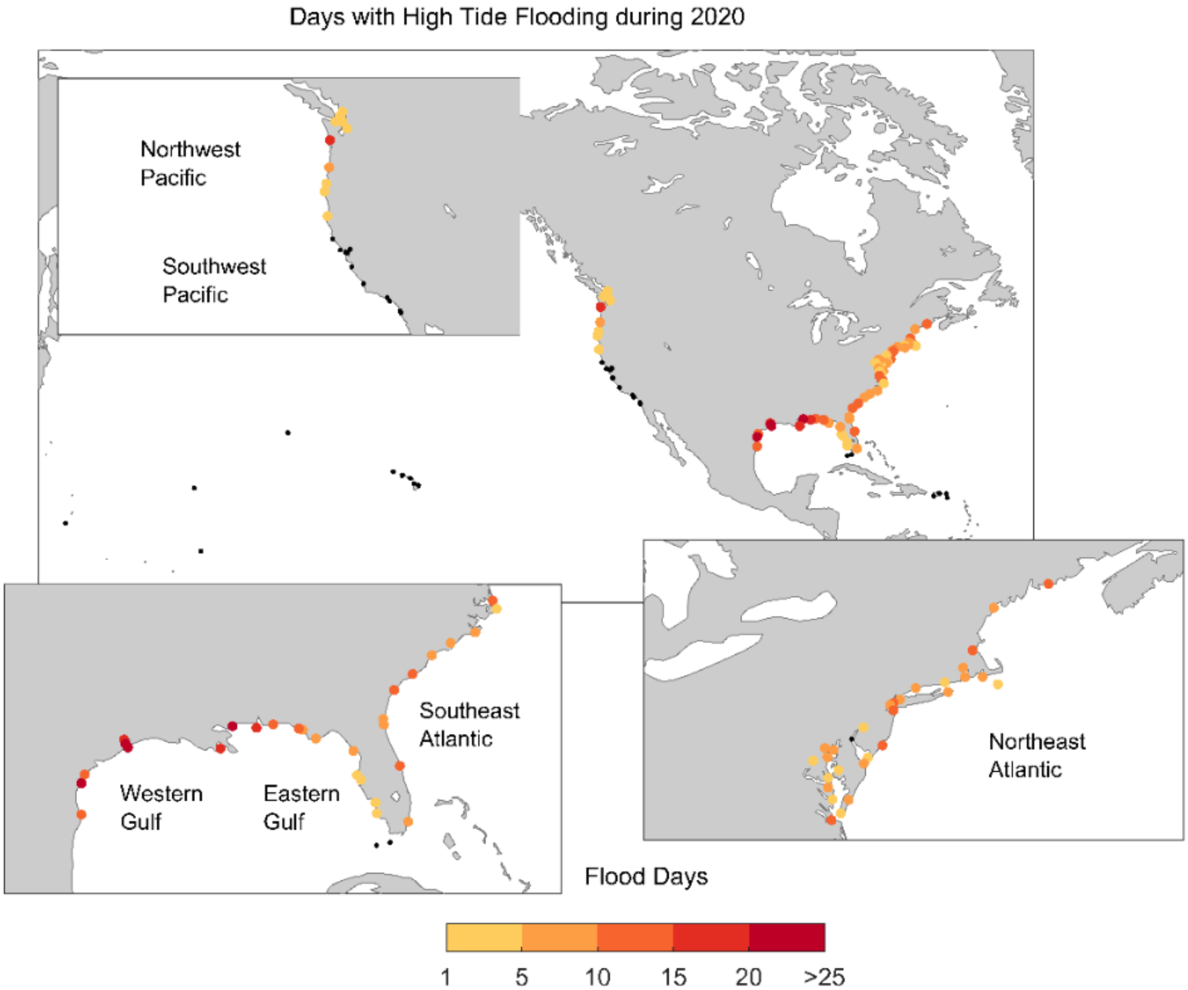

Figure 3. Number of days with HTF in 2020 at 97 NOAA tide gauge locations with values listed in Appendix 1. Black dots identify locations where HTF did not occur during 2020.

Although the Hawaiian Islands hit record RSLs in 2020, no HTF occurred. However, Honolulu experienced more than 45 days when water levels exceeded 0.3 m above MHHW with some local impacts (Habel et al., 2020). The lack of HTF occurrences can be explained in terms of the height of the HTF threshold itself (>0.5 m MHHW) and the fact that Hawaii experiences less overall observed storm-tide variability as compared to a location with a wider and shallower continental shelf, as is found along the Atlantic or Gulf Coasts. Of note, the HTF statistics and outlooks are based upon tide gauge measurements, which generally do not account for wave effects (Sweet et al., 2015). A comparison of daily highest water levels at Honolulu and Charleston during 2020 (Figure 4a) shows higher variability at Charleston, which together with higher RSL rates over the last two decades[13] explains the difference in recorded HTF days in 2020 (Figure 4b). Though there were reports of coastal flooding in Honolulu during 2020 primarily related to wave runup effects,[14] rising seas and rising groundwater tables are posing a

[13] https://tidesandcurrents.noaa.gov/sltrends/sltrends.html

[14] https://www.staradvertiser.com/2020/07/24/breaking-news/king-tide-takes-out-waikiki-lifeguard-tower/

host of other subsurface problems such as wastewater and industrial waste contamination.[15] In general, places with a small range in storm-tides will quickly transition from little overland flooding to chronic flooding as sea levels rise, as would be the case for Honolulu with about 20 cm of additional RSL rise above 2020 levels (Figure 4b).

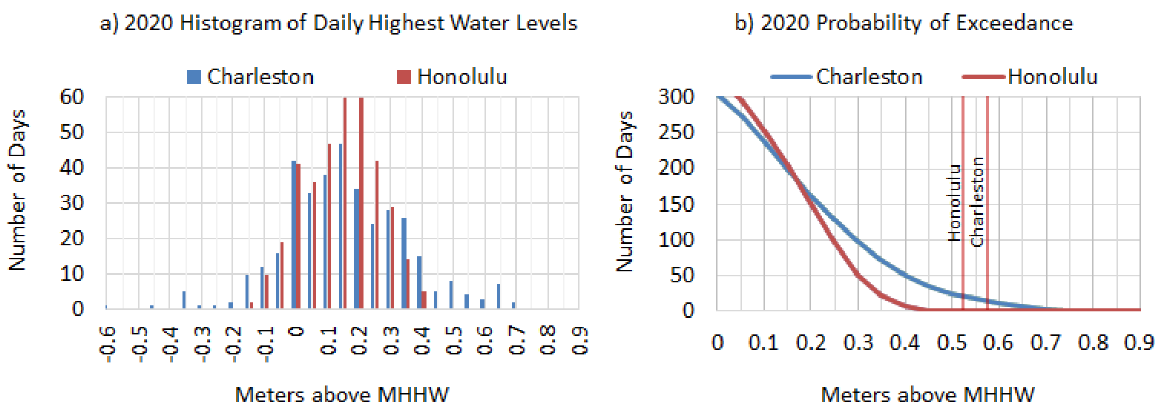

Figure 4. a) Histogram of daily highest water levels and b) exceedance probability for 2020 water levels at Charleston and Honolulu showing the HTF thresholds (red vertical lines) at both locations.

In all, 14 locations broke or tied historical HTF records along the Southeast and Gulf Coasts (Figure 5a) related to high tropical cyclone activity and in some locations, elevated RSLs. HTF records occurred in Galveston, Corpus Christi, and Bay Waveland (>20 days); Dauphin Island, Grand Isle, Pensacola, Trident Pier, Charleston, Port Isabel, Rockport, and Panama City Beach (10–20 days); and Panama City, Fernandina Beach, and Mayport (8–9 days). Compared to trend HTF values in year 2000 (e.g., based upon a trend fit or 19-year average), 2020 was a notable year along the Southeast Atlantic (400% median increase), the Eastern Gulf (600% increase), and the Western Gulf (1100% increase) as illustrated in Figure 5b. In some instances and locations, HTF days actually caused (and are also categorized as) moderate and major HTF (Figures 5c–d) mostly along the Southeast Atlantic and Gulf Coast associated with tropical cyclone activity. The highest number of days with moderate HTF, which also set historical records, occurred in Bay Waveland, Corpus Christi, Galveston, and Eagle Point (5–10 days); of these, major flood thresholds were surpassed on 1–3 days except at Eagle Point, where no major HTF occurred. Exposure associated with the various HTF depth-severity categories is illustrated for Bay Waveland and Charleston in Figure 1.

[15] https://www.hakaimagazine.com/features/the-rising-tide-underfoot/

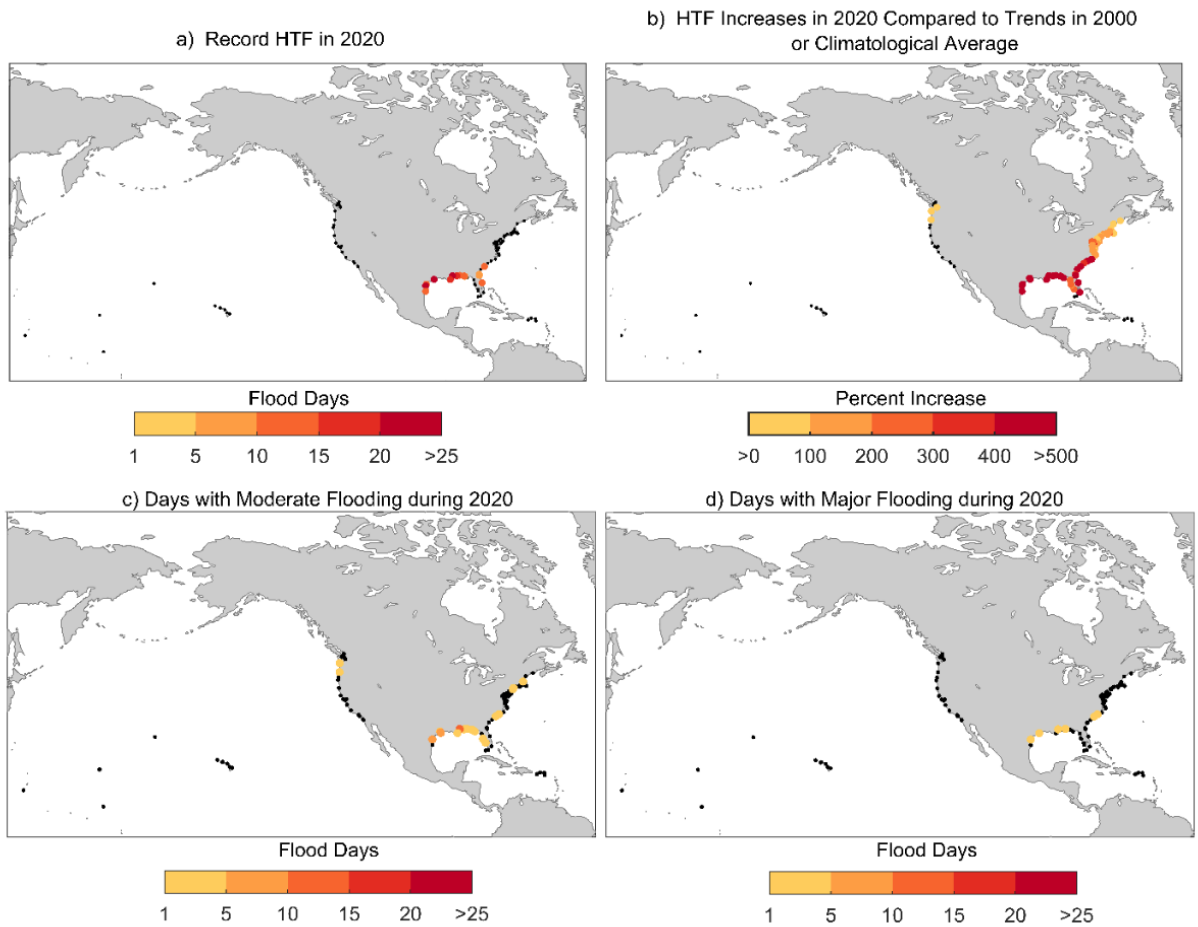

Figure 5. a) Locations where HTF in 2020 either tied or broke all-time records, b) the percent increase in 2020 HTF days as compared to trend values for year 2000 or climatological average where no temporal trends exist. Also shown are days with HTF in 2020 that also reached c) moderate and d) major flood stage.

3. 2021 HIGH TIDE FLOOD OUTLOOK

The basis for the 2021 HTF Outlook, similar to the past outlooks, uses annual counts of HTF days since 1950 through the most recent year (2020 for this report). These data are fit using either a quadratic or linear regression (significance above the 90% level, p values <0.1) or the average over the most recent 19-year period (2002–2020 in this case) (Figure 6a). Where historical ONI values also are significant (Figure 6b), they are included in the model (e.g., bivariate model—time and ONI; or where no temporal trend is present, possibly only an ONI-based regression is included). The outlook is a projection to year 2021 (May 2021–April 2022) and uses ONI values predicted (May 2021 plume) by an international model ensemble;[16] neutral conditions are predicted this coming year (average ONI=-0.04). A quadratic fit is used in 50 of the 61 locations along the Atlantic and Gulf Coasts and one location (San Diego) along the Southwest Pacific Coast. Sixteen locations use a linear trend in their outlook (10 along the Atlantic and Gulf Coasts, four along the West Coast, and two in the Pacific Islands); ONI values are used at 36 locations along the West and East Coasts, with a couple along the Gulf and one in

[16] https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/

the Pacific Islands. This implies that HTF is now accelerating or linearly increasing at all but one East and Gulf Coast location (Key West) with ENSO affecting flood frequencies along portions of most U.S. coastlines.

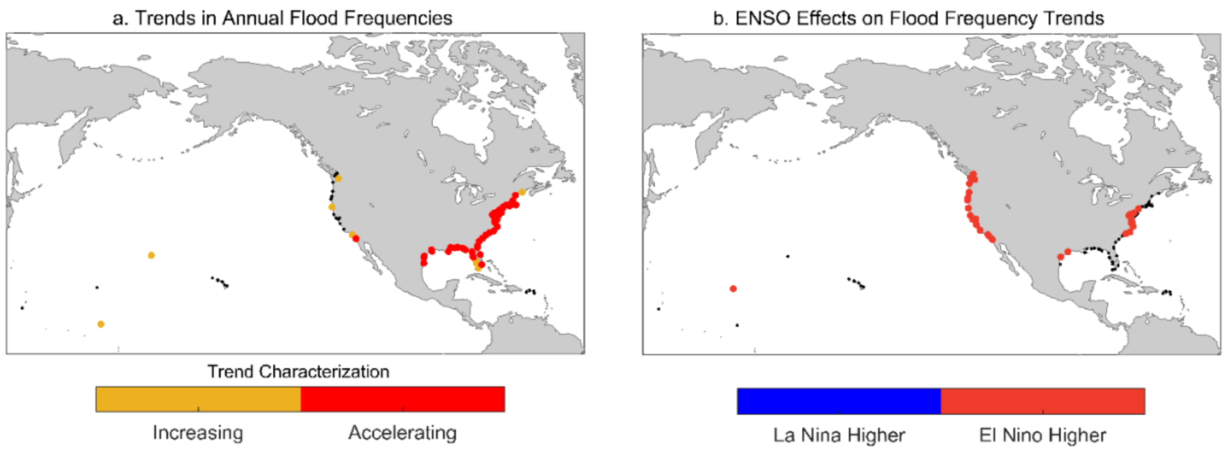

Figure 6. Statistical model type used in the 2021 Outlook showing a) where either a linear or quadratic trend (black dots represent no temporal trend and a 19-yr climatological mean is used as the outlook) and b) if the model fit (e.g., as shown in panel a) includes sensitivity to ENSO; where no temporal trend exists, an ENSO dependency may still exist (e.g., West Coast locations).

In Appendix 1, the 2021 Outlook is the predicted likely range (i.e., ±1 standard deviation) with the median/expected value shown in Figure 7. As a whole (median value of local ranges), U.S. coastlines are projected to experience 3–7 days of HTF. Regionally, the Western Gulf and Northeast Atlantic are projected to experience the most HTF in 2021 (median range values of 7–15 days and 6–11 HTF days, respectively). The Southeast Atlantic and Eastern Gulf are projected to experience 3–7 HTF days, with the Northwest and Southwest Pacific projected to experience 0–7 and 0–3 days, respectively. No HTF days (reaching >0.5 m above MHHW) are projected for Hawaii, the U.S. Pacific, and Caribbean Islands. Again, failing to exceed the HTF thresholds used in this report does not necessarily mean flooding will not occur, as flooding can occur in some places at lower water levels. Since this assessment is based on tide gauge data, generally it does not include flooding from wave runup effects, elevated groundwater tables, or localized rainfall.

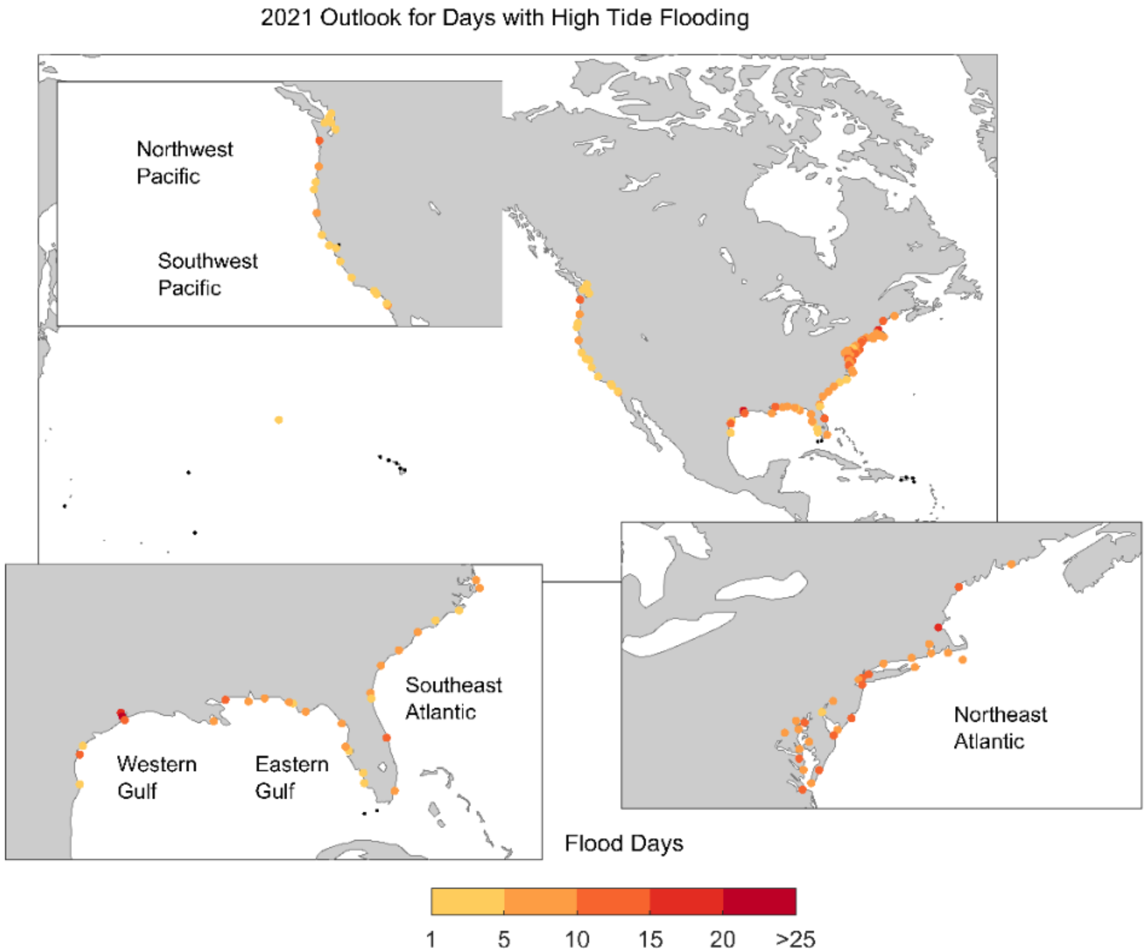

Figure 7. Outlook for the number of HTF days projected to occur in 2021 (May 2021–April 2022) with color-codes associated with the 'expected' value, whereas the actual outlooks are given as a likely range (expected value ±1 standard deviation provided in Appendix 1).

4. Summary

NOAA tide gauges continue to measure an increase in RSL, which is driving greater frequency of HTF along U.S. coastlines. An individual HTF event typically causes minor impacts, which are not overly damaging or of lasting concern if viewed as singular events. However, the cumulative repercussions from rising frequencies and durations of floods are beginning to damage infrastructure and cause other economic and ecosystem impacts within coastal communities, which are largely responsible for finding and funding solutions. Thus, HTF is a growing concern to coastal residents, emergency managers, community planners, and resource managers alike. NOAA intends to continue providing next-year outlooks and projections for the coming decades to support both preparedness and planning.

In 2020 (last year: May 2020–April 2021), U.S. coastlines experienced (median value) 4 days of HTF. The 2020 HTF day count matched that from the year prior (2019) but continues to define an accelerating trend seen over the last several decades. HTF in 2020 was twice the rate normal in 2000 (e.g., the median value of all locations' trend-based values in 2000 was 2 days of HTF).

HTF in 2020 was most prevalent along the Western Gulf, Eastern Gulf, and Southeast Atlantic Coasts (17 days, 9 days, and 8 days—median values, respectively), with 14 locations breaking or tying historic HTF records due to a combination of effects from a record-breaking hurricane season and rising RSLs. In many locations and instances, the HTF that occurred reached the moderate and major HTF levels. Twelve locations broke RSL records, including several in the Southeast Atlantic and the Gulf, but also the Hawaiian Islands coastline, which could be related to the prevailing La Niña conditions. La Niña conditions typically suppress West Coast RSLs and HTF, at least along California coastlines, due to a northward shift in regional coastal storm tracks.

Next year (2021), the acceleration in HTF nationally along U.S. coastlines is expected to continue, with 3–7 days of HTF likely (median of 5 days ±2 days, which is 1 standard deviation). The 2021 Outlook by region is listed below:

- 6–11 days along the Northeast Atlantic
- 3–7 days along the Southeast Atlantic
- 0 days along the Caribbean
- 3–7 days along the Eastern Gulf
- 7–15 days along the Western Gulf
- 0–7 days along the Northwest Pacific
- 0–3 days along the Southwest Pacific
- 0 days along the Hawaiian and Pacific Islands

By 2030, the national HTF frequency is likely to be about 2–3 times greater (national median of 7–15 days) than today without additional flood-management efforts. By 2050, HTF is likely to be 5–15 times higher (national median of 25–75 days), and potentially in some locations reaching nearly 180 days per year, effectively becoming the new high tide. These projections do not consider future floodplain management/adaptation efforts and are based upon those of Sweet et al. (2018) using the relative sea level projections considered likely (Intermediate Low and Intermediate Scenarios) to occur by the Fourth National Climate Assessment (Sweet et al., 2017).

5. Acknowledgements

The authors acknowledge the NOAA Center for Operational Oceanographic Products and Services Data Processing Team for verifying the hourly water level data for the stations presented in this report and Dr. Matthew Widlansky at the University of Hawaii Sea Level Center for information on Honolulu and insightful discussions about Pacific Island flood risk.

6. Data Availability

An interactive map of the outlook can be found at:
https://tidesandcurrents.noaa.gov/HighTideFlooding_AnnualOutlook.html

The high tide flooding data referenced in this report can be accessed via the CO-OPS API at:
https://tidesandcurrents.noaa.gov/api-helper/url-generator.html

High tide flooding and sea level rise inundation layers, digital elevation models and map services are available at:
https://coast.noaa.gov/digitalcoast/tools/slr.html

U.S. sea level rise scenarios of the Fourth National Climate Assessment can be found at:
https://scenarios.globalchange.gov/sea-level-rise

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APPENDIX 1.

Location-specific high tide flood (HTF) occurrences and projections. U.S. Regions, NOAA tide gauges, NOAA minor HTF threshold (meters above MHHW), HTF frequency typical of year 2000 based upon trend fits, historical annual HTF day counts through last year (2019: May 2019–April 2020), number of HTF days during 2020, the moderate and major HTF height thresholds, HTF day counts that also reached the moderate and major levels in 2020, the 2020 Outlook, and HTF range considered likely by 2030 and 2050 (Sweet et al., 2018).

Region	Tide Gauge Location	NOAA ID	HTF Height (m, MHHW)	HTF Typical in 2000 (days/ year)	HTF Record through 2019 (days/ year)	HTF in 2020 (days/ year)	Moderate and Major HTF Heights	Moderate and Major HTF in 2020	HTF 2021 Outlook (days/ year)	2030 HTF (days/ year)	2050 HTF (days/ year)
Pacific Is.	Nawiliwili, HI	1611400	0.522	0	1	0	0.82, 1.19	0, 0	0	0	1-30
	Honolulu, HI	1612340	0.523	0	0	0	0.82, 1.19	0, 0	0	0	2-30
	Mokuoloe, HI	1612480	0.526	0	0	0	0.82, 1.2	0, 0	0	0	3-30
	Kahului, HI	1615680	0.527	0	1	0	0.82, 1.2	0, 0	0	0	4-55
	Kawaihae, HI	1617433	0.526	0	0	0	0.82, 1.2	0, 0	0	0	0-15
	Hilo, HI	1617760	0.529	0	1	0	0.82, 1.2	0, 0	0	0-1	10-65
	Midway Island	1619910	0.515	1	6	0	0.81, 1.19	0, 0	0-2	3-4	8-60
	Apra Harbor, Guam	1630000	0.529	0	1	0	0.82, 1.2	0, 0	0	0	2-45
	Pago Pago, A.S.	1770000	0.497	0	0	---	0.79, 1.17	---	0	0-0	0-2
	Kwajalein Island	1820000	0.548	0	2	0	0.84, 1.22	0, 0	0-1	10-20	40-100

	Wake Island	1890000	0.529	0	2	0	0.82, 1.2	0, 0	0	1-2	6-55
NE Atlantic	Bar Harbor, ME	8413320	0.639	7	30	13	0.9, 1.31	0, 0	4-14	20-35	45-90
	Portland, ME	8418150	0.621	5	21	7	0.89, 1.29	0, 0	7-13	15-30	35-80
	Boston, MA	8443970	0.625	6	22	11	0.89, 1.3	1, 0	11-18	20-35	45-95
	Woods Hole, MA	8447930	0.527	2	10	5	0.82, 1.2	0, 0	3-7	8-20	35-135
	Nantucket Island, MA	8449130	0.544	2	11	3	0.83, 1.21	0, 0	3-7	7-15	30-125
	Newport, RI	8452660	0.547	2	11	6	0.84, 1.22	0, 0	3-7	10-25	40-125
	Providence, RI	8454000	0.559	3	15	8	0.84, 1.23	0, 0	6-11	15-30	40-105
	New London, CT	8461490	0.537	2	10	4	0.83, 1.21	0, 0	3-7	8-15	25-120
	Bridgeport, CT	8467150	0.589	3	11	6	0.87, 1.26	0, 0	6-11	15-30	35-105
	Montauk, NY	8510560	0.531	3	11	6	0.82, 1.2	0, 0	4-7	10-25	40-150
	Kings Point, NY	8516945	0.597	5	15	5	0.87, 1.27	2, 0	7-13	20-35	40-110
	The Battery, NY	8518750	0.562	5	15	13	0.85, 1.23	0, 0	9-14	20-40	50-135
	Bergen Point, NY	8519483	0.567	4	13	7	0.85, 1.24	0, 0	7-12	15-35	45-130
	Sandy Hook, NJ	8531680	0.564	5	20	11	0.85, 1.23	1, 0	10-15	25-45	70-160
	Atlantic City, NJ	8534720	0.556	5	22	11	0.84, 1.23	0, 0	9-15	20-35	65-155
	Cape May, NJ	8536110	0.566	3	14	4	0.85, 1.24	0, 0	5-10	15-30	55-135

	Philadelphia, PA	8545240	0.582	3	12	4	0.86, 1.25	0, 0	4-8	10-20	30-105
	Reedy Point, DE	8551910	0.571	1	5	0	0.85, 1.24	0, 0	1-3	6-15	25-100
	Lewes, DE	8557380	0.557	4	15	8	0.84, 1.23	0, 0	7-12	15-30	50-135
	Cambridge, MD	8571892	0.525	1	11	4	0.82, 1.2	0, 0	5-8	9-20	40-150
	Tolchester Beach, MD	8573364	0.519	2	17	7	0.81, 1.19	0, 0	7-12	15-25	50-160
	Baltimore, MD	8574680	0.520	2	12	7	0.82, 1.19	0, 0	5-9	15-25	50-160
	Annapolis, MD	8575512	0.518	2	18	7	0.81, 1.19	0, 0	7-11	15-25	55-170
	Solomons Island, MD	8577330	0.518	1	11	2	0.81, 1.19	0, 0	5-8	10-20	45-165
	Washington, DC	8594900	0.539	3	22	3	0.83, 1.21	0, 0	5-10	10-20	35-120
	Wachapreague, VA	8631044	0.564	3	17	7	0.85, 1.23	0, 0	8-15	15-25	40-120
	Kiptopeke, VA	8632200	0.536	3	11	4	0.83, 1.21	0, 0	4-8	10-20	40-120
	Lewisetta, VA	8635750	0.518	2	20	5	0.81, 1.19	0, 0	9-14	15-25	50-170
	Windmill Point, VA	8636580	0.532	3	17	1	0.83, 1.2	0, 0	5-11	15-25	45-160
	Sewells Point, VA	8638610	0.534	5	15	14	0.83, 1.2	0, 0	9-14	20-35	65-170
SE Atlantic	Duck, NC	8651370	0.545	5	18	11	0.83, 1.22	0, 0	6-12	20-30	55-135
	Oregon Inlet, NC	8652587	0.514	1	8	2	0.81, 1.18	0, 0	3-6	7-15	35-165

	Beaufort, NC	8656483	0.543	0	10	5	0.83, 1.21	0, 0	2-4	6-15	25-100
	Wilmington, NC	8658120	0.557	1	14	5	0.84, 1.23	1, 1	2-6	4-9	15-65
	Springmaid Pier, SC	8661070	0.568	2	11	9	0.85, 1.24	1, 1	4-9	10-20	30-75
	Charleston, SC	8665530	0.570	2	13	14	0.85, 1.24	0, 0	5-9	10-20	35-90
	Fort Pulaski, GA	8670870	0.591	2	13	12	0.87, 1.26	0, 0	5-9	15-25	40-95
	Fernandina Beach, FL	8720030	0.580	2	9	9	0.86, 1.25	0, 0	3-7	9-15	25-70
	Mayport, FL	8720218	0.557	1	6	8	0.84, 1.23	0, 0	2-4	5-10	20-65
	Trident Pier, FL	8721604	0.537	0	12	14	0.83, 1.21	0, 0	9-14	7-15	25-65
	Virginia Key, FL	8723214	0.518	0	9	6	0.81, 1.19	0, 0	4-7	2-5	10-55
	Vaca Key, FL	8723970	0.512	0	1	0	0.81, 1.18	0, 0	0	1-3	9-65
	Key West, FL	8724580	0.522	0	2	0	0.82, 1.19	0, 0	0	0-2	8-60
Eastern Gulf	Naples, FL	8725110	0.535	1	3	1	0.83, 1.21	0, 0	0-2	2-4	9-55
	Fort Myers, FL	8725520	0.516	1	6	3	0.81, 1.19	2, 0	1-4	3-6	15-80
	St. Petersburg, FL	8726520	0.528	1	4	2	0.82, 1.2	1, 0	2-3	3-7	15-85
	Clearwater, FL	8726724	0.540	1	5	3	0.83, 1.21	0, 0	4-6	2-4	10-55
	Cedar Key, FL	8727520	0.546	2	11	6	0.84, 1.22	0, 0	4-7	5-10	20-70

	Apalachicola, FL	8728690	0.520	1	10	9	0.82, 1.19	1, 0	4-8	4-8	10-50
	Panama City, FL	8729108	0.516	1	7	9	0.81, 1.19	1, 0	2-6	4-7	10-65
	Panama City Beach, FL	8729210	0.517	1	8	11	0.81, 1.19	2, 0	2-7	4-6	10-50
	Pensacola, FL	8729840	0.515	2	10	14	0.81, 1.19	3, 1	3-7	5-8	15-70
	Dauphin Island, AL	8735180	0.512	1	10	18	0.81, 1.18	2, 0	5-11	6-10	30-95
	Bay Waveland, MS	8747437	0.522	3	14	22	0.82, 1.19	10, 3	10-16	25-40	110-205
Western Gulf	Grand Isle, LA	8761724	0.428	0	6	16	0.73, 1.1	2, 0	4-9	9-20	145-270
	Morgans Point, TX	8770613	0.535	2	22	17	0.83, 1.21	3, 0	13-21	30-45	110-215
	Eagle Point, TX	8771013	0.494	0	64	38	0.79, 1.16	5, 0	38-53	---	---
	Galveston, TX	8771450	0.517	3	18	27	0.81, 1.19	5, 1	9-16	15-30	100-215
	Rockport, TX	8774770	0.504	1	7	11	0.8, 1.17	0, 0	2-5	7-15	60-165
	Corpus Christi, TX	8775870	0.529	1	18	22	0.82, 1.2	6, 1	7-15	10-20	55-150
	Port Isabel, TX	8779770	0.517	1	9	12	0.81, 1.19	0, 0	2-6	7-15	40-135
SW Pacific	San Diego, CA	9410170	0.570	2	13	0	0.85, 1.24	0, 0	3-7	10-15	30-60
	La Jolla, CA	9410230	0.565	2	8	0	0.85, 1.24	0, 0	1-4	10-15	25-55

	Los Angeles, CA	9410660	0.567	1	6	0	0.85, 1.24	0, 0	1-3	6-10	15-40
	Santa Monica, CA	9410840	0.566	2	7	0	0.85, 1.24	0, 0	0-3	8-15	20-50
	Port San Luis, CA	9412110	0.565	1	6	0	0.85, 1.24	0, 0	0-2	3-5	8-25
	Monterey, CA	9413450	0.565	1	7	0	0.85, 1.24	0, 0	0-2	3-5	10-30
	San Francisco, CA	9414290	0.571	0	6	0	0.85, 1.24	0, 0	0-1	2-3	6-25
	Alameda, CA	9414750	0.580	1	10	0	0.86, 1.25	0, 0	0-2	1-2	3-15
	Point Reyes, CA	9415020	0.570	2	8	0	0.85, 1.24	0, 0	0-3	4-7	15-40
	Port Chicago, CA	9415144	0.560	1	15	0	0.85, 1.23	0, 0	0-3	2-2	4-15
	Arena Cove, CA	9416841	0.573	2	14	0	0.86, 1.24	0, 0	0-4	5-7	10-30
NW Pacific	Humboldt Bay, CA	9418767	0.584	4	15	4	0.86, 1.25	0, 0	4-10	15-20	45-80
	Port Orford, CA	9431647	0.572	4	23	2	0.85, 1.24	0, 0	0-8	9-15	15-40
	Charleston, OR	9432780	0.593	5	27	3	0.87, 1.26	0, 0	0-8	9-15	15-35
	South Beach, OR	9435380	0.602	7	25	8	0.88, 1.27	1, 0	1-9	15-20	30-50
	Toke Point, WA	9440910	0.609	12	33	16	0.88, 1.28	3, 0	4-16	15-20	20-35
	Port Angeles, WA	9444090	0.586	4	12	2	0.86, 1.26	0, 0	0-5	5-7	8-15
	Port Townsend, WA	9444900	0.604	3	13	3	0.88, 1.27	0, 0	0-4	5-6	9-20

	Seattle, WA	9447130	0.639	2	11	3	0.9, 1.31	0, 0	1-5	5-6	9-20
	Cherry Point, WA	9449424	0.612	3	15	3	0.88, 1.28	0, 0	0-5	4-5	5-10
	Friday Harbor, WA	9449880	0.595	4	17	4	0.87, 1.27	0, 0	0-5	6-7	9-20
Caribbean	Lime Tree Bay, VI	9751401	0.509	0	1	0	0.81, 1.18	0, 0	0	0	0-3
	Charlotte Amalie, VI	9751639	0.510	0	1	0	0.81, 1.18	0, 0	0	0	0-7
	San Juan, PR	9755371	0.519	0	1	0	0.81, 1.19	0, 0	0	0	0-9
	Magueyes Island, PR	9759110	0.508	0	1	0	0.81, 1.18	0, 0	0	0	0-3

ACRONYMS

cm	centimeter
CO-OPS	Center for Operational Oceanographic Products and Services
°C	degree Celsius
ENSO	El Niño Southern Oscillation
ft	feet
HTF	high tide flooding
m	meter
mm	millimeter
MHHW	mean higher high water
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWS	National Weather Service
ONI	Oceanic Niño Index
RSL	relative sea level
yr	year