U.S. Seaports Face Elevated Risks in a Warmer World with Higher Seas

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U.S. commercial maritime ports will likely face substantial challenges associated with climate change throughout this century. If the effects of rising sea levels and increased temperatures increasingly stall port operations or cause infrastructure deterioration, they can pose a risk to trade flows. This Executive Briefing on Trade examines a recent set of climate change projections, focusing on continental U.S.-specific trends that pose the greatest risks to seaports.

Seaports handle over two-thirds of the tonnage of all U.S. merchandise trade.[1] Foreign container trade is concentrated on the Atlantic and Pacific coasts, processing 17 million and 15 million twenty-foot equivalent units in 2019, respectively, while the Gulf seaports handle the majority of waterborne petroleum and food trade that is primarily carried in bulk vessels.[2] Because of the intrinsic position of seaports along open coasts or within low lying tidal estuaries, this substantial volume of trade is directly exposed to rising sea levels and more extreme coastal weather associated with climate change.

The Intergovernmental Panel on Climate Change's Sixth Assessment Report, Working Group I contribution (WGI report) captures current international scientific consensus regarding historical and projected global climate change and specific physical impacts.[3] The WGI report presents its findings within the context of a broad range of possible scenarios based on different levels of greenhouse gas emission intensity. All scenarios project increased global mean temperatures, causing further melting of glaciers and ice caps and thermal expansion of the oceans and resulting in global sea level rise. The WGI report found that when emissions are most intensely mitigated, sea levels around the continental United States would rise by about 10–30 centimeters (cm) between 2021–2040 and by about 40–90 cm by the end of the century. Scenarios with status quo or increased emissions intensity predict even greater sea level increases.

U.S. seaports are vulnerable to extreme sea levels (ESLs) and dangerous storms. Coastal storms and associated storm surges present direct challenges to port operation and infrastructure due to the potential for heavy flooding of low-lying areas and wind damage. Hurricane Sandy provides a recent example of how a storm capable of creating ESLs can impact port infrastructure and operations.[4] An in-depth analysis of the impact of Hurricane Sandy on Red Hook Terminal in Brooklyn showed that the storm damaged berths, power equipment, buildings, terminal equipment, and cargo.[5] Combined with closures of New York Harbor, this storm prevented any cargo vessel from accessing the terminal for over one week.

Although tropical storms have made landfall within the United States many times over the last twenty years, only a few have created storm surges like Hurricane Sandy's that led to ESLs inundating major U.S. ports.[6] As sea levels rise, however, that risk will increase, especially when compounded with the greater

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[1] USDOC, "Maritime Services," accessed November 22, 2021. A seaport includes the harbors, docks, container berths, intermodal terminals, administrative structures, and other physical infrastructure required for operation.
[2] USACE, "Waterborne Commerce," accessed December 1, 2021.
[3] IPCC, "Climate Change 2021," 2021; IPCC, "IPCC AR6-WGI Atlas," accessed November 30, 2021. Quoted values are median projected changes under an SSP1-2.6 scenario from 1995–2014 baseline levels, using the CMIP6 model.
[4] ESLs are defined as coastal sea levels statistically expected to occur only once every hundred years.
[5] Ryan-Henry and Becker, "Port Stakeholder Perceptions of Sandy Impacts," October 2, 2020.
[6] NOAA, "Extreme Water Levels," accessed November 23, 2021.

precipitation and storm intensity that are also predicted to result from rising temperatures. Additional climate-associated factors, such as coastal erosion, will also undermine the physical infrastructure of seaports as well as surrounding coastal communities. The WGI report indicates that the likelihood of ESL events from tropical storms will be greater especially along the U.S. Atlantic and Gulf coasts.

One study cited by the WGI report provides highly localized ESL predictions under different conditions.[7] These projections show that, even under a moderate climate change scenario, there would likely be more frequent intense coastal flooding. For example, ESL events previously expected to occur every 100 years in New York are expected to occur every 81 years by 2050, accelerating to every 19 years by 2100. For Los Angeles and Houston, baseline ESLs would occur every 67 and 80 years by 2050 and every 7 and 25 years by 2100. Major seaport infrastructure will thus be increasingly subject to these shifts over the coming decades.

U.S. seaports are also exposed to climate change effects by their links with other types of transportation infrastructure. Even sub-ESL flooding associated with higher high tides may periodically prevent vehicles and trains from moving along low-lying roads and railways connected to seaports.[8] In recent years, such high tide flooding has been expected in fewer than ten days per year in all U.S. regions. However, when such floods change from being occasional disruptions to regular occurrences, they can severely impede the flow of commerce to ports. One recent analysis found that if global sea levels rise consistent with low-emissions scenarios, high tide flooding by 2050 will occur on average between 13–17 days per year along the Pacific coast, 23–80 days per year along the Gulf coast, and 26–44 days per year along the Atlantic coast.[9] These frequencies will accelerate through 2100, with Atlantic and Gulf coastal areas projected to experience high tide flooding most days each year.

Extreme heat events can place structural strain on seaport infrastructure, including thermal expansion of bridge joints, reduction of pavement integrity, and deformation of rail track. Inland flooding caused by rains can impede upstream transportation, while coastal erosion of barrier island systems can reduce the viability of intercoastal waterways.[10] According to the WGI report, these climatic impacts are likely to intensify in most regions of the continental United States, which may create bottlenecks in the flow of cargo to and from seaports that can reduce their overall utility within supply chains even if they remain physically intact.

Mitigating the future risks posed by climate change to seaport operations requires investments in port resiliency and preparedness. For example, Hurricane Sandy inspired the Port of New York and New Jersey and its tenants to upgrade preparedness plans, retrofit buildings, and acquire deployable flood barriers. More challenging and costly infrastructure investments, such as physically raising critical infrastructure and building drainage systems, have also been proposed.[11] The specific strategy and costs faced by each port will depend on the local geography, infrastructure needs, and specific impacts of climate change on that coastline.

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[7] Vousdoukas et al., "Global Probabilistic Projections," 2018; Vousdoukas et al., "Global Extreme Sea Level Projections dataset," 2018; additional data provided by the author.
[8] Moftakhari et al., "What Is Nuisance Flooding?," 2018; TRB, "Potential Impacts," July 16, 2008.
[9] Sweet et al., "Patterns and Projections," February 2018.
[10] TRB, "*Potential Impacts*," July 16, 2008; Forzieri et al., "Escalating Impacts," January 1, 2018.
[11] Leonard, "As Storms Become More Frequent and Volatile," June 8, 2021.