An Examination of Multi-Hazard Marine Transportation System (MTS) Response and Recovery Operations During the 2020 Hurricane Season

Report by the CMTS Maritime Resilience Integrated Action Team

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U.S. Coast Guard
U.S. Committee on the Marine Transportation System Executive Secretariat
U.S. Department of Homeland Security
U.S. Department of Transportation
U.S. Environmental Protection Agency
Maritime Administration
National Geospatial-Intelligence Agency
National Oceanic and Atmospheric Administration
U.S Department of the Navy
U.S. Transportation Command

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Table of Contents

Executive Summary

The U.S Committee on the Marine Transportation System (CMTS) Resilience Integrated Action Team (RIAT) was established in 2014 to foster the coordination and co-production of knowledge that incorporates the concepts of resilience into the marine transportation system (MTS). The RIAT defines resilience as a four-phase cycle that incorporates preparation, response, recovery, and adaptation activities to minimize disruption to the MTS, as a whole. Since the unprecedented 2017 hurricane season, which saw significant impacts to ports and the MTS across the U.S. Gulf, Atlantic, and Caribbean coasts, the RIAT has produced an annual report that takes input from CMTS member agencies and uses it to examine challenges and successes in MTS preparation, response, and recovery. These reports also include a discussion on potential recommendations that could be enacted by CMTS member agencies and their partners to increase resilience. The scope of this report examines the 2020 hurricane season, which saw a record-breaking number of storms form in the Atlantic basin during a global pandemic. As a result, federal agencies that are charged with MTS preparation, response, and recovery activities were challenged to operate in a multi-hazard posture.

In general, the 2020 hurricane season came with many challenges. This included issues with logistics, such as trouble with transportation to and from affected areas, issues with communication due to the need to shift to virtual meetings, and the need to balance protecting communities from hurricanes while ensuring the virus did not spread. However, even with the added challenge of the COVID-19 pandemic on MTS hurricane response and recovery operations, there were several successes noted by CMTS member agencies. For example, the rapid adoption of virtual meetings and calls allowed response and recovery entities to continue to "see" their partners and collaborators increasing confidence and trust while maintaining social distancing guidelines. There were also lessons learned from previous hurricane seasons that were used during the 2020 hurricane season, such as the use of recreational vehicles to house staff closer to the impacted areas while maintaining isolation from the affected communities.

Three storms were examined in-depth, due to their impacts on the MTS: Hurricanes Laura, Sally, and Delta:

- Hurricane Laura was a Category 4 storm that impacted the coast of South-Central Louisiana in August, 2020. Some of the challenges encountered during this hurricane included multiple power outages where distribution and transmission systems needed to be rebuilt, logistic problems such as lodging issues and supply distribution, and various obstructions which shut down marine transportation. Even with these challenges, there were several successes during this hurricane, which included pre-

season preparation that helped set the stage for coordinated response, and rapid survey results despite channel obstructions.

- Hurricane Sally was a Category 2 storm, which primarily impacted the Gulf Coast from Mississippi to the Florida Panhandle in September, 2020. Some of the challenges from Hurricane Sally were like those of Hurricane Laura, including restrictions from COVID-19 and repeated damage creating several problems with response, along with staffing and travel issues. However, there were also various successes. This included early coordination for port calls which ensured ports were prepared and synced, and Port Emergency Action Teams (PEAT) and Marine Environmental Response Teams (MER) from the Coast Guard using technology to expedite port assessment and shift focus to search and rescue missions.
- Hurricane Delta was a Category 2 storm that impacted some of the same portions of the Southern Louisiana coastline that had been impacted by Hurricane Laura a little over a month prior. The challenges faced during the response to Hurricane Delta mirrored those from Hurricane Laura. This included logistical and survey challenges, such as finding proper housing for response and recovery staff. Some of the successes during this hurricane included the use of recreational vehicles to combat significant transit times to and from the impacted regions.

As a result of the discussions from the recovery and response efforts, several recommendations were made for improving resilience in the future. These recommendations were categorized into three parts: preparation, absorption, and adaptation. For preparation, some of the recommendations highlighted the need to communicate early and often, such as holding workshops, analyzing the entire system for vulnerabilities by working with port authorities and users, and identifying who is responsible for certain domains in case they impact shipping channels. For absorption/recovery, recommendations included ensuring collaboration through regular calls and establishing common collaboration tools, creating data vetting procedures for information dissemination, and leverage existing virtual tools and platforms for communication while ensuring backup platforms exist should the primary method be unavailable. In addition, leveraging new technologies to re-establish navigations (such as electronic aids to navigation (e-ATONs)), increasing communications that focus on essential support functions, and establishing ways to become self-sufficient were suggested. Finally, for adaptation, recommendations included communicating with port partners and other stakeholders using a common communication tool, provide resources for personnel health and safety, and make after-action reviews a priority.

The results of this report provide a framework for future actions to minimize disruptions via the recommendations and will, therefore, increase MTS resilience in the future.

Introduction

The Marine Transportation System (MTS) provides a critical linkage between the United States (U.S.) and the global economy, facilitating the movement of imports and exports across the nation's borders, domestic cargo along its coasts and inland waters, and serving as a major economic engine for the U.S. supply chain. Increasing efficiencies by manufacturers, coupled with growing demand for consumer goods, has furthered the need for effective and predictable marine transportation. Disruption to any part of the MTS and its network of navigation channels, ports, intermodal connections, and supporting infrastructure, can quickly ripple through the broader international, domestic, and inland supply chain.

A significant portion of the U.S. MTS is located in low-lying coastal regions, making it susceptible to impacts from hurricanes and other coastal storms. The federal agencies that comprise the U.S. Committee on the Marine Transportation System (CMTS) – most notably the U.S. Army Corps of Engineers (USACE), U.S. Coast Guard (USCG), the U.S. Department of Homeland Security (DHS) and its agencies, and the National Oceanic and Atmospheric Administration (NOAA) – work with state and local counterparts in port communities to respond to and recover from the effects of storms and other natural and man-made disruption to marine navigation. Their actions, including emergency channel surveys, the identification and removal of obstructions, and maintenance and replacement of aids to navigation (ATON), among many others, effectively ensure the return of the safe and efficient flow of goods and services.

The 2020 hurricane season was record-breaking, with 30 named storms forming in the Atlantic basin between June 1 and November 30[1]. Twelve storms made landfall on the U.S. coastline, including six hurricanes, resulting in an estimated $37 billion in damages[2]. Three hurricanes in particular, Hurricane Laura in August 2020, Hurricane Sally in September 2020, and Hurricane Delta in October 2020, impacted similar regions adjacent to the Gulf of Mexico –areas that play a key role in the transport and manufacture of petroleum products. In all three instances, CMTS member agencies supported response and recovery efforts to minimize impacts to navigation.

Under regular circumstances, the record-breaking events of the 2020 hurricane season would stand out compared to previous years. However, a global pandemic resulting from an outbreak of a novel Coronavirus disease (COVID-19) provided an especially challenging period for the MTS and its port communities, affecting the ability of federal agencies to support the hurricane response and recovery effort. In-person communication and coordination activities that

[1] Record-Breaking Atlantic Hurricane Season Draws to an End | National Oceanic and Atmospheric Administration. www.noaa.gov/news/record-breaking-atlantic-hurricane-season-draws-to-end.
[2] A Look Back at the Horrific 2020 Atlantic Hurricane Season. Yale Climate Connections, 1 Dec. 2020, yaleclimateconnections.org/2020/12/a-look-back-at-the-horrific-2020-atlantic-hurricane-center/

typically occur both within and between agencies and partners had to transition to virtual information sharing platforms. For those who could not work remotely, detailed, careful plans for testing and operating while isolated had to be developed. Onboard equipment and software checks on agency response vessels were postponed, leading to unforeseen issues that could not be addressed ahead of time. Post-storm field deployments became logistically difficult due to the need to limit the exposure of impacted communities and the massive amounts of survey and infrastructure recovery work that needed to be completed in the region. In many cases, response and recovery staff were also personally affected by the hurricanes which limited their availability to respond and communicate. Despite these challenges, MTS response and recovery operations adapted nearly "on-the-fly" to ensure that they could continue to fulfill their roles during the hurricane season.

The purpose of this report is to describe the impacts, challenges, and successes from the 2020 hurricane season and to examine the impact of the global COVID-19 pandemic on MTS preparation, response, and recovery operations. The report reviews changes in response practices between storm seasons and makes overall recommendations to enhance the future resilience of the MTS. The audience for these recommendations is federal agencies with a major role in MTS recovery planning and efforts. However, it is important to note the critical role that non-federal stakeholders play in ensuring the continued operation of the MTS from response and recovery efforts. A large portion of disaster recovery is the responsibility of state and local governments, nonprofits, and private industry. It is anticipated that the report will assist the coordination between federal and non-federal partners' efforts to support the U.S. MTS in its return to normal operations.

Background

Resilience is defined as the ability to prepare, absorb, recover, and adapt to and from disruptions (Presidential Policy Directive 21, 2013). This work employs a four-phase resilience cycle to conceptualize resilience, gather information, and analyze impacts and changes through time (Figure 1, The Resilience Cycle). By utilizing these four phases, it is possible to identify improvements in response and recovery efforts and make recommendations to increase adaptive capacity and preparation activities to advance the resiliency of the MTS to future events.

Figure 1. The cycle of the fundamental actions found in nearly all resilience definitions: prepare, absorb, recover, and adapt[3].

Critical to resilience is the ability to adapt between events to be better prepared so that future events will result in lower impacts and faster recoveries. One key part of adaptation is learning from the past, and the CMTS Resilience Integrated Action Team (RIAT) has intervened as a platform to convene Federal agencies to share and discuss their experiences and potential improvements with their partners. The RIAT is a consortium of Federal agencies that manage, operate, or are stakeholders in the MTS and have interests in increasing its resilience. The CMTS RIAT was established in 2014 and has served as a platform to gather federal agencies to foster collaborations, improve understanding of emerging challenges, and to determine impacts, best practices, and lessons learned after disruptive events.

In 2017, the Coordinating Board of the CMTS tasked the RIAT with identifying the best practices and lessons learned from the 2017 hurricane season. The ensuing report, "The 2017 Hurricane Season: Recommendations for a Resilient Path Forward for the Marine Transportation System", outlines challenges, successes, and recommendations for increasing resilience based upon

[3] Rosati, J.D., K.F. Touzinsky, and W.J. Lillycrop, 2015. "Quantifying coastal system resilience for the U.S. Army Corps of Engineers." Environment Systems and Decisions, 35(2):196-208

reported experiences of responding and recovering to hurricanes Harvey, Irma, and Maria[4]. Following recommendations to continue post-storm interagency collaboration, the RIAT developed a companion report that examined the federal agency response during the 2018 and 2019 hurricane seasons including hurricanes Florence, Michael, and Dorian[5].

The 2020 season, during which federal agencies had to respond to a record number of Atlantic storms during a global pandemic, pointed to the need for a third follow-on report that would specifically look at the challenges faced during this unprecedented multi-hazard environment. Similar to previous hurricane reports, the RIAT convened a virtual workshop with federal agency partners on June 10, 2021 to capture input on the impacts, challenges, and best practices of the 2020 hurricane season and address the impact of COVID-19. Input was provided by Federal agency personnel located in field offices and directly responsible for response and recovery actions, with a specific focus on Hurricanes Laura and Delta with additional information added, at a later date, from Hurricane Sally.

[4] U.S. Committee on the Marine Transportation System (CMTS). 2018." The 2017 Hurricane Season: Recommendations for a Resilient Path Forward for the Marine Transportation System", U.S. Department of Transportation, Washington, D.C. https://www.cmts.gov/downloads/CMTS_RIAT_2017Hurricanes.pdf

[5] U.S. Committee on the Marine Transportation System (CMTS). 2020. "A Resilient Path Forward for the Marine Transportation System: Recommendations for Response and Recovery Operations from the 2017-2019 Hurricane Seasons", U.S. Department of Transportation, Washington, D.C. https://www.cmts.gov/downloads/CMTS_RIAT_Hurricanes_Report_FINAL.pdf

COVID-19 and Preparations for 2020 Hurricane Season

COVID-19 Impacts to the MTS

In early 2020, a novel Coronavirus (COVID-19) quickly swept across the globe, causing many countries to implement measures to protect human health and minimize the spread of the airborne respiratory virus. Within the U.S., the President declared a national emergency in March of 2020, with many states and local jurisdictions shutting down to try and combat the spread of the virus.[6] While such actions were necessary from a public health perspective, they introduced a severe economic downturn. Social distancing and lockdown regulations that were put in place resulted in many temporary business closures and a reduction in the production of goods and services.[7] The resultant disruption to the supply chain, in turn, caused a reduction in shipping activity across the US and the globe, which had significant impacts on the MTS.

An examination of the impact of the COVID-19 pandemic on global shipping and the U.S. MTS shows an unevenness across different ports and shipping industries, with the most severe declines occurring in the first half of 2020. A global study of Automatic Information System (AIS) data showed a decline in ship mobility during March to June ranging from between 5 and 14% for container shipping and between 19 and 42% for the passenger and cruise industry.[8] In the U.S., demand for petroleum dropped dramatically but a corresponding drop in production lagged. This resulted in surplus supply that was loaded onto oil tankers that were then anchored off major U.S. ports.[9] Container shipping also saw a decrease in the first half of 2020, resulting in reduced port calls and service cancellations ("blank" or "void sailings"). However, it quickly rebounded with the opening of Chinese ports in summer months (Figure 2). As a result, container vessel operators utilized larger vessels and extra voyages during the second half of 2020 that caused increased congestion at ports along the U.S. west coast.[10] The cruise industry was hit hardest, with the Centers for Disease Control (CDC) issuing a "No Sail" order in March, 2020 that effectively shut down the industry until it was conditionally lifted in October 2020.[11]

[6] CDC. "CDC Museum COVID-19 Timeline." Centers for Disease Control and Prevention, 4 Aug. 2021, www.cdc.gov/museum/timeline/covid19.html.
[7] Bauer, Lauren, et al. "Ten Facts about COVID-19 and the U.S. Economy." Brookings Institution, 17 Sept. 2020, www.brookings.edu/research/ten-facts-about-covid-19-and-the-u-s-economy/
[8] Millefiori, Leonardo M., et al. "COVID-19 Impact on Global Maritime Mobility." Scientific Reports, vol. 11, no. 1, 10 Sept. 2021, p. 18039, http://www.nature.com/articles/s41598-021-97461-7, 10.1038/s41598-021-97461-7.
[9] "COVID-19 and Oil Transport: The Issue with Too Much Oil." Friends of the Earth, 10 July 2020, foe.org/blog/covid-19-oil-transport-issue/.
[10] BTS Port Performance Program
[11] CDC. "CDC COVID-19 Orders for Cruise Ships" www.cdc.gov, 5 May 2021, www.cdc.gov/quarantine/cruise/covid19-cruiseships.html.

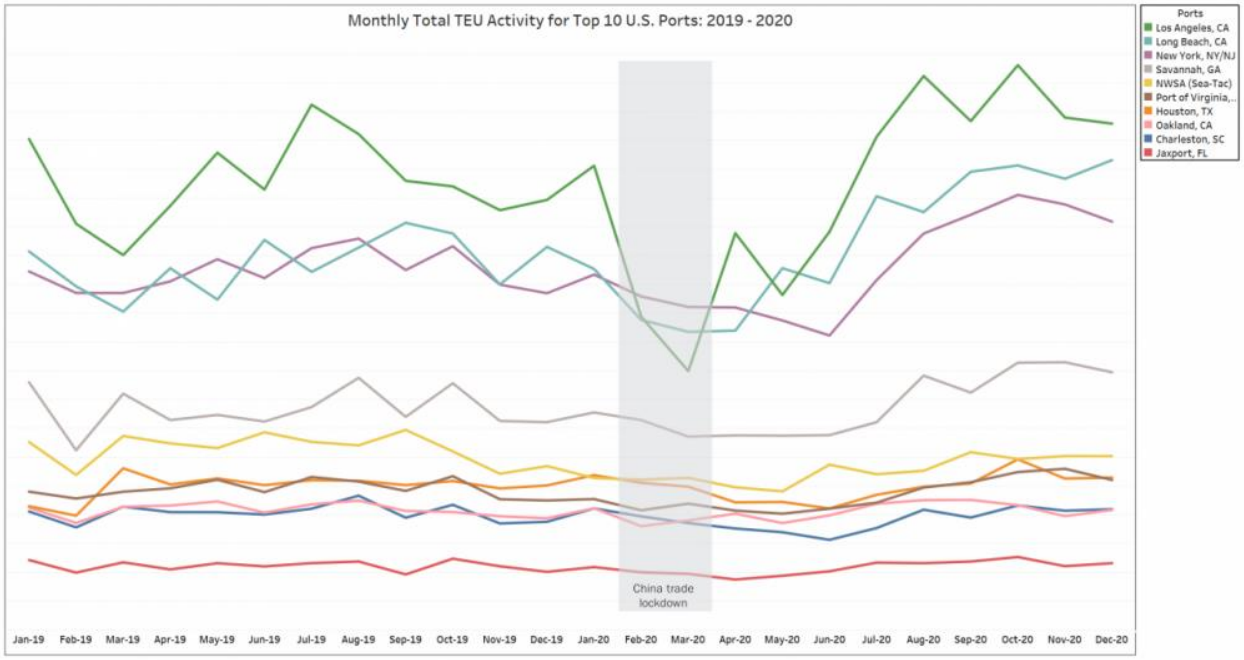


Figure 2. Monthly TEU activity for the top 10 US container ports from 2019-2020. The highlighted section depicts the period of national Chinese trade lockdown during the pandemic.

Source: Bureau of Transportation Statistics. "Resumed Trade with China and Consumer Activity in Late Quarters Leaves Top U.S. Container Ports with Solid 2020." 11 March 2021.

COVID-19 Impacts on MTS Preparation Activities

The COVID-19 pandemic posed several challenges for MTS preparation, recovery, and response operations in 2020. Traditional workforce protocols were modified to adapt to a safe, mainly virtual format. In the 2018 and 2019 hurricane seasons, federal agency preparation activities included hosting early-planning meetings, communicating between agencies, centralizing information distribution, and maintaining or updating existing response plans.[12] Additional preparation activities included having inter-agency tabletop exercises to identify known problem areas in local waterways, pre-positioning vessels and providing contract support for bar surveys to expedite channel surveys, and an increased coordination among representatives from different transportation modes (road, rail, marine), to procure resources for specific areas. For recovery and response, co-locating personnel from different agencies within the same

[12] U.S. Committee on the Marine Transportation System (CMTS). 2020. "A Resilient Path Forward for the Marine Transportation System: Recommendations for Response and Recovery Operations from the 2017-2019 Hurricane Seasons", U.S. Department of Transportation, Washington, D.C. https://www.cmts.gov/downloads/CMTS_RIAT_Hurricanes_Report_FINAL.pdf

facility increased face-to-face communications. In 2020, many of these activities had to be adjusted due to pandemic restrictions. In particular, many agencies had to ensure the continuity of operations with the limitations of in-person communications and collaboration.

Office Work Changes

Among MTS agencies there were two general types of employees that needed to be accommodated quickly during the early COVID-19 response. Put simply, these were employees that could accomplish their job remotely and those that could not.

For those that could work entirely remotely, MTS agencies had a variety of actions that swiftly increased telework flexibility, including liberal (or mandatory) telework posture, transferring workplace interactions (training, collaboration, etc.) to virtual-only, and employing new tools to aid in the sudden workplace transition from the office to home.

New technology and techniques for communication were critical during this time as increased communication both internally and externally was key for successful telework. Regularly scheduled virtual meetings helped to ensure continuity at agencies like NOAA. There were also some challenges with this as some agencies, particularly the USCG and USACE had security issues with several virtual platforms hosted by outside agencies. Across the entire RIAT, the following tools were used:

- Zoom, WebEx, Microsoft Teams, Defense Collaboration System (USCG)
- Google Suite for internal comms, wide variety of other platforms and video calls for outside comms (NOAA)
- Adobe Connect/Homeland Security Information Network (HSIN) (USCG)
- CVR Teams Environment, Webex (USACE)

While the adjustment took a little time initially, MTS agencies successfully transitioned and were able to fulfill their missions while following CDC and their own agency guidance. For example, the FEMA National Response Coordination Center was able support Emergency Support Function #1 (Transportation), the CMTS Executive Secretariat supported max telework capacity, the USCG implemented liberal telework for non-essential civilians and military personnel ranked O-4 and below, NOAA's Office of National Marine Sanctuaries (ONMS) and National Marine Fisheries Service (NMFS) were on mandatory telework and any access to field sites needed to be cleared through ONMS director, and the USACE quickly expanded VPN capacity so that all employees could access the network.

Hurricane preparations looked different during COVID-19 as many preparation exercises were cancelled due to in-person restrictions. Later, as technology became more widely available and personnel felt more comfortable, video exercises and virtual meetings were utilized to continue

the trainings. To maintain training and qualifications, virtual classes were completed via either existing platforms like the Commerce Learning Center (NOAA) or via virtual calls and webinars. Some in-person training was unavoidable (i.e., vessel-based training) and occurred with additional restrictions like required isolation periods, social distancing, masks, and limited group numbers.

Field Work Changes

While many offices began with full telework, they needed to quickly develop a back-to-work plan for the second category of employees that must work in the field or office.

- Guidelines from the CDC were mentioned by RIAT agency members several times as a means for planning office returns – incorporating temperature checks, masks, and social distancing within the office.
    - When the USCG needed to return to the office followed CDC and USCG telework guidelines and returned to work in alternating teams
- Travel and teamwork within the field or on vessels was more complicated.
    - After initially standing down, NOAA Navigation Response Teams and National Geodetic Survey (NGS) had to develop a back-to-work plans for survey teams.
    - NOAA Office of Marine and Aviation Operations (OMAO) protocols were developed from the CDC and Public Health Advisor officers assigned to NOAA. These protocols and subsequent back-to-work plans included a robust testing protocol, flexibility for changing travel authorizations and approvals, shelter-in-place requirements, COVID monitoring, and pilot/crew workforce quarantines.
    - NOAA's Office of Coast Survey (OCS) implemented the use of travel trailers for field responders to impacted communities, field bases controlled by known MTS partners, and testing protocols upon entry and exit of an area for deployed personnel. There was a major challenge with trying to limit the exposure of the community to first responders from different areas. This was addressed by implementing very long hours and residency in an area for first responders; making their jobs far more difficult. In addition, any responders needed to be totally self-sufficient so that they would not have to rely on resources in the impacted area.

2020 Hurricane Season Review

Impacts from the 2020 Hurricane Season

In what was an ominous signal to the record-breaking season to come, the 2020 hurricane season began prior to the traditional June start date, with Hurricane Arthur forming in mid-May. At the conclusion of the season on November 30, the Atlantic basin experienced 30 named storms, 14 of which developed into hurricanes[13]. Twelve storms made landfall in the U.S., where almost the entire Gulf and East coasts were placed under a tropical cyclone watch or warning at some point during the active season (Figure 3). The most destructive hurricane to impact the U.S. in 2020 was Hurricane Laura, which made landfall on August 27.[14] The Category 4 storm brought sustained winds of 150 miles per hour and a surge of over 13 feet, making it the strongest hurricane to strike Southwest Louisiana. [15] Laura was also the most expensive storm of 2020, with damages costing $19 billion[16]. With over 20-billion-dollar weather and climate disasters, 2020 was the sixth consecutive year where 10 or more billion-dollar disaster events occurred in the U.S.[17]

The impacts of the 2020 hurricane season on the MTS extended beyond Southern Louisiana and the Gulf of Mexico region. Ten of the thirty named storms that formed within the Atlantic basin during 2020 resulted in port closures, with the average length of closure of 1.75 days (Figure 4).[18]

[13]National Oceanic and Atmospheric Administration. "Record-Breaking Atlantic Hurricane Season Draws to an End | National Oceanic and Atmospheric Administration." www.noaa.gov, www.noaa.gov/news/record-breaking-atlantic-hurricane-season-draws-to-end.

[14] National Oceanic and Atmospheric Administration. "A Look Back at the Horrific 2020 Atlantic Hurricane Season» Yale Climate Connections." Yale Climate Connections, 1 Dec. 2020, yaleclimateconnections.org/2020/12/a-look-back-at-the-horrific-2020-atlantic-hurricane-center/.

[15] US Department of Commerce, NOAA. "Tropical Weather." Www.weather.gov, www.weather.gov/lch/2020Laura.

[16] Office for Coastal Management. "Hurricane Costs." Noaa.gov, 2017, coast.noaa.gov/states/fast-facts/hurricane-costs.html.

[17]Office for Coastal Management. "Hurricane Costs." Noaa.gov, 2017, coast.noaa.gov/states/fast-facts/hurricane-costs.html.

[18] Bureau of Transportation Statistics "Tropical Storm Elsa Makes Landfall in Florida; BTS Map Shows U.S. Ports Affected by 2020 Named Storms." www.bts.gov, www.bts.gov/data-spotlight/tropical-storm-elsa-makes-landfall-florida-bts-map-shows-us-ports-affected-2020.

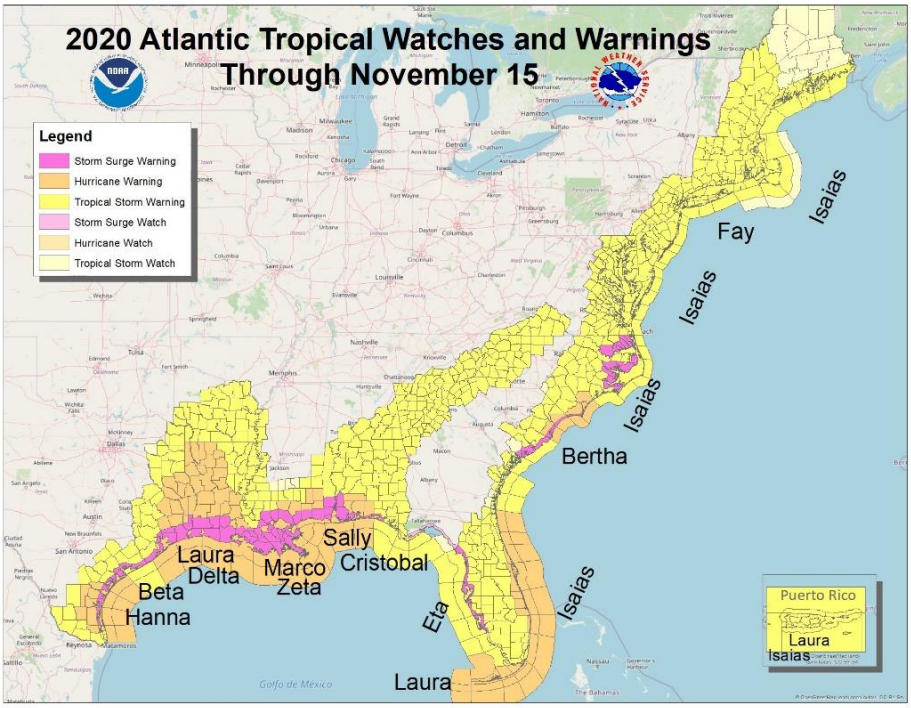


Figure 3. A map of U.S. tropical system watches and warnings during the 2020 Atlantic hurricane season.

Source: NOAA National Weather Service Forecast Office Corpus Christi

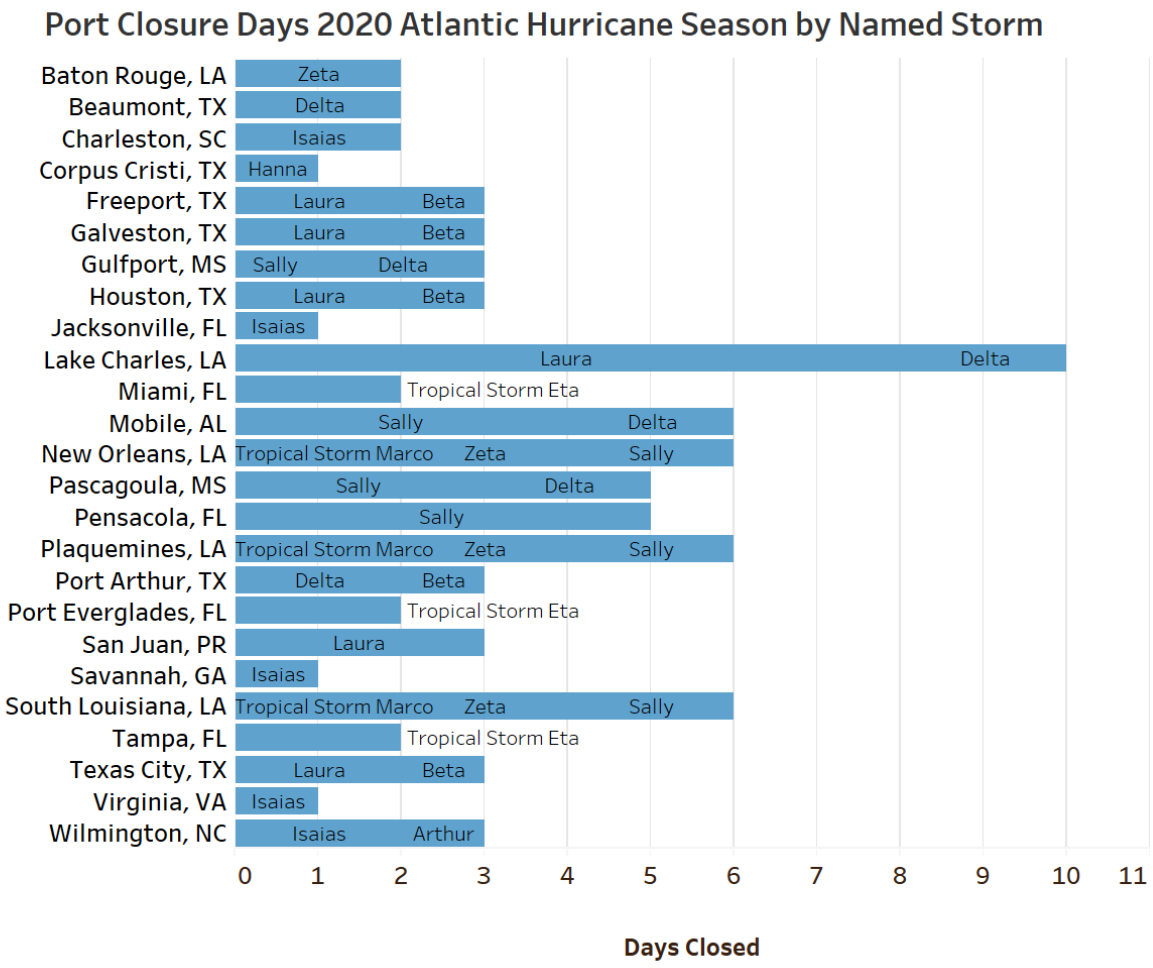


Figure 4. A chart depicting port closures for U.S. ports during the 2020 Atlantic Hurricane Season

SOURCE: Port Impacts: U.S. Department of Transportation, Bureau of Transportation Statistics analysis, based on the U.S. Coast Guard, Port Conditions and port authority websites. Hurricane paths: based upon track data published by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Hurricane Center.

General Challenges

Many of the challenges faced by MTS response and recovery during the 2020 hurricane season can be directly attributed to the COVID-19 pandemic and the associated public health regulations and protocols.

- Logistics:
    - Many residents did not evacuate the impacted areas, with state emergency managers placing those who stayed into hotels instead of shelters due to COVID-19 protocols. This severely limited traditional lodging options for MTS response

and recovery crews, resulting in field crews having to incur long transit times to and from the survey sites. Furthermore, the crews had to logistically plan for gas shortages within the affected areas.

  - The time limitations due to the longer commutes resulted in very difficult conditions for crews (working at night was too dangerous).
  - Due to a reduction in non-routine operations and maintenance, response boats were prone to have issues that could not be dealt with ahead of time.
  - The National Weather Service (NWS), for example, relies on marine observations from a variety of vessels. Not being able to regularly visit these vessels to replace batteries or check on software and hardware of the NWS-installed observation systems resulted in some systems going offline, which necessitated emergency visits in several cases.
  - The lack of in-person preparation and exercise time resulted in lost muscle memory for operations.
  - Because of telework, some employees that would traditionally be working in the field were working remotely. As a result, securing operations and facilities were more difficult with reduced on-site manpower.

- Coordination and Communication:
  - There was confusion within agency teams about who was dealing with storm preparation issues due to the lack of the usual face-to-face coordination that would typically occur.
  - As with any storm, widespread power and cell tower outages were experienced by MTS response and recovery crews, making communications more difficult. In one instance, a storm tracked over a Continuity of Operations (COOP) site, which lost power.
- Protecting Vulnerable Communities:
  - There was a major challenge with trying to limit the exposure of the community to first responders from different areas. This was addressed by implementing very long commuting hours and residency in an area for first responders.
  - Hurricane Laura caused widespread/intense damage within the Southwest Louisiana impact area. This caused both a challenging work environment for MTS response and restoration crews who had to deal with massive power and water outages.

- Power, water, and road outages resulted in cascading failures – especially in the case of power restoration slowing the ability to recover significantly damaged portions of Western Louisiana.
- In several instances, MTS response and recovery staff were personally impacted by the storms. It was noted by several agencies that response and recovery staff impacted by storms could not efficiently respond to the same storm.

General Successes

While the COVID-19 pandemic exacerbated the traditional challenges faced by MTS response and recovery crews, there were numerous instances of successes that were articulated by CMTS member agencies. In several cases, these successes were the result of lessons learned from previous hurricane responses, or adjustments made within the same season.

- Coordination and Communication:
  - NOAA reported receiving MTS-related priorities from NOAA Navigation Managers, NOAA Office of Response and Restoration (OR&R) Scientific Support Coordinators (SCCs), the Disaster Response Center (DRC), and federal partners USCG, USACE and FEMA
  - USACE response, both internally and with external entities such as the USCG, pilots, and ports, was well coordinated with effective communication. Restrictions to exposure to outside parties was minimized. Entry and exit from the affected areas were done quickly and efficiently.
  - While remote support brought some unique challenges to field activities, it also provided some advantages to collaboration activities. Virtual meetings and calls allowed response and recovery entities to "see" some customers and other coworkers in other offices. This, in turn, led to more trust and confidence by being able to talk to people directly vs. only via voice chat. In some instances, remote support increased relationship building.
  - USCG Executive Port Coordination calls started earlier to get pulse and status reports. As storm tracks shifted, external port partners were included on decisions to set port condition Zulu in Mobile.
  - USCG also reported that they met with all port partners prior to the COVID-19 pandemic, which helped them to build and maintain relationships during the 2020 hurricane season.

- Logistics:
    - To overcome some of the commuting and travel issues associated with storm response, NOAA's Mobile/Pensacola Navigation Response Teams rented a trailer to place onsite during the Hurricane Laura response and repeated it with Delta. Other agencies rented RVs to get response and recovery staff closer to the site without long transits – something that was learned during the Hurricane Ike response in 2008.
    - As in previous hurricane seasons, USCG and USACE survey assets were staged in advance of weather arrival, which allowed them to rapidly coordinate the survey of impacted waterways.

Hurricane Laura

Overview and Impacts

Hurricane Laura formed as a tropical wave to the west of Africa on August 16, 2020. After passing through the Caribbean Sea as a weak tropical storm, Laura rapidly intensified within the Gulf of Mexico before making landfall near Cameron, Louisiana on August 27th as a Category 4 storm with peak winds of approximately 150 mph.[19] In addition to the heavy winds, the storm brought high levels of coastal inundation, with surge elevations of greater than 12 feet occurring across South Central Louisiana from Atchafalaya Bay to Caillou Bay (Figure 5). Almost a foot of rain fell in Southwest Louisiana, causing flooding in low-lying areas of Calcasieu, Acadia, and Natchitoches Parishes. The human and economic toll of Hurricane Laura was significant, with 47 direct deaths in the US and Caribbean region and over $19 billion in damages. The force of the hurricane's winds and surge destroyed 10,000 homes and damaged several structures in Louisiana.[20]

[19] J. Pasch, Richard, et al. "National Hurricane Center Tropical Cyclone Report: Hurricane Laura." NOAA National Hurricane Center, 26 May 2021.
[20] J. Pasch, Richard, et al. "National Hurricane Center Tropical Cyclone Report: Hurricane Laura." NOAA National Hurricane Center, 26 May 2021.

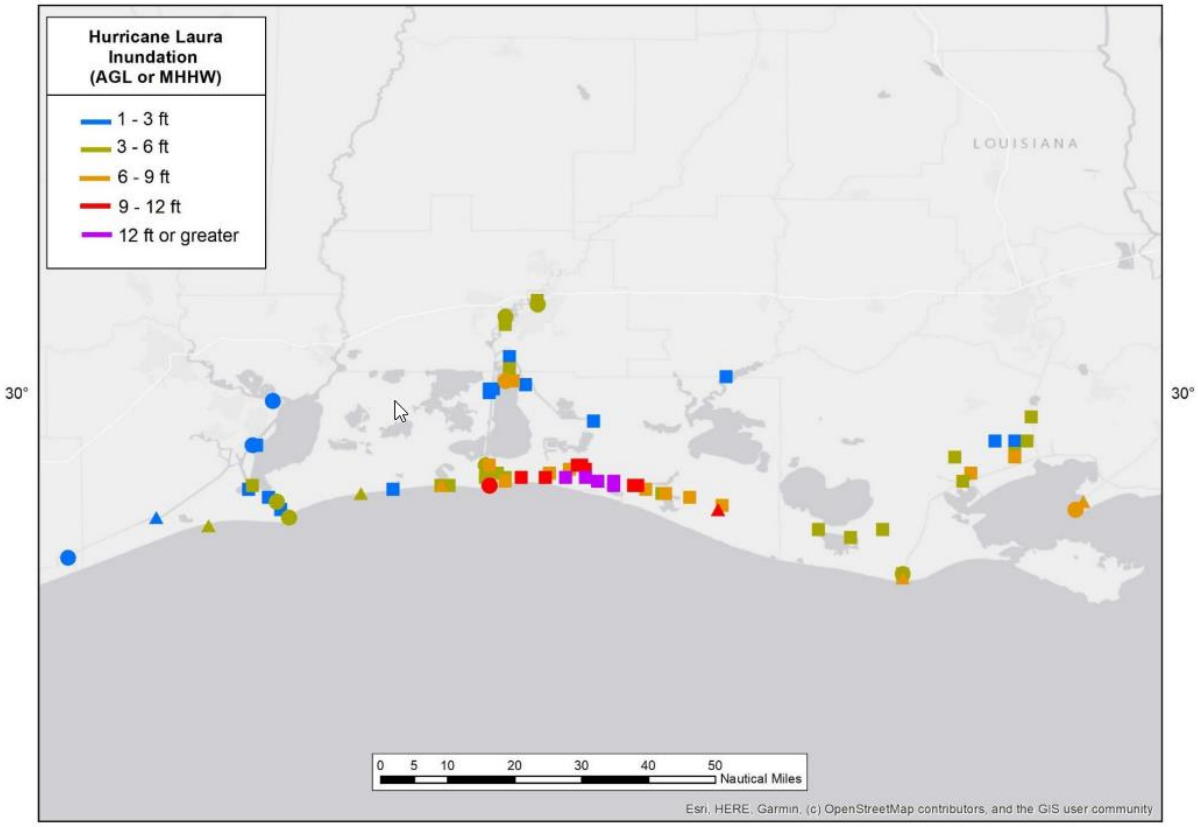


Figure 5. Maximum water level observations in Southwest Louisiana where the highest storm surge inundation occurred. Maximum water levels measured from tide and stream gauges (circles), USGS water level sensors (triangles), and surveyed high water marks (squares) from Hurricane Laura.

Source: Richard J. Pasch, Robbie Berg, David P. Roberts, and Philippe P. Papin "National Hurricane Center Tropical Cyclone Report", 20-29 August 2020, National Hurricane Center, 26 May 2021.

The Southwest Louisiana coastline is home to ports and waterways that support the region's petrochemical industry. When approaching storms threaten to disrupt port operations, the U.S. Coast Guard's Captain of the Port sets the following port conditions based on the anticipated arrival time of gale force winds (gale force defined as above 39 mph): WHISKEY – 72 hours, X-RAY – 48 hours, YANKEE – 24 hours, ZULU – 12 hours. On August 29th, port Condition ZULU was set for the Calcasieu Waterway and the Sabine-Neches Waterway. Condition ZULU remained until August 30th for the Sabine-Neches Waterway, and August 31st for the Calcasieu Waterway.[21] On August 31st, port conditions were set to RECOVERY for the Sabine-Neches Waterway; The Gulf Intracoastal Waterway from the West Port Arthur (Highway 87) Bridge

[21] US Department of Homeland Security, "Marine Safety Information Bulletin, Hurricane Laura" US Coast Guard, 2020.

west to High Island opened to eastbound and westbound inland traffic. The Port of Lake Charles continued to recover and opened as of September 2, 2020.[22] The impacts of these port conditions on vessel movements in the affected region can be seen on AIS vessel signal density plots from before, and during landfall (Figure 6).

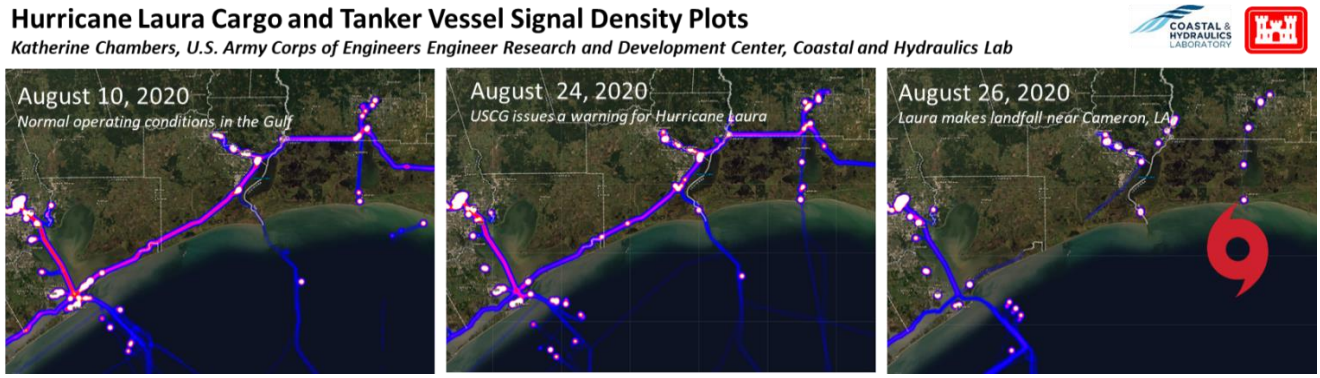


Figure 6. Hurricane Laura Cargo and Tanker Vessel Signal Density Plots. Heatmaps indicate vessel densities of cargo, tanker, towing, and tug vessels.

Source: Data furnished by the US. Coast Guard and compiled via the Engineer Research and Development Center's Automatic Identification System Analysis Package (AISAP).

Challenges: Hurricane Laura

As the strongest storm to impact the Southwest Louisiana region in over 100 years, Hurricane Laura caused significant damage to the coastline and coastal communities. This, along with the public health restrictions enacted to combat the spread of the COVID-19 pandemic, introduced some significant challenges to the MTS response and recovery effort:

- Critical Infrastructure Dependencies
    - Hurricane Laura caused widespread damage to energy infrastructure. Hardest-hit areas, where distribution and transmission systems needed to be rebuilt, experienced multi-week power outages. This impacted restoration efforts of other critical infrastructure.
    - The heavy devastation to the region resulted in significant power outages and limited road access

[22] US Department of Homeland Security. "Marine Safety Information Bulletin, Hurricane Laura" US Coast Guard, 2020.

- Logistics
    - The sea state offshore of the Laura impact area required the use of larger response vessels to cover the 30+ miles of waterway offshore of the Southwest Louisiana coastline
    - Lodging challenges combined with extensive survey needs led to exhaustion for survey teams as they spent 12 hours on the water, 2 hours in transit to a hotel, and 6 hours processing data overnight
    - Supply distribution was also an issue. Supplies needed to be driven in from Houston or New Orleans
    - Getting an effective response as fast as possible and removing survey staff from the area quickly reduced exposure and downtime off boat. The exit plan needed to be well laid out and understood.
- Survey
    - There were multiple channel obstructions that posed unique challenges to navigational survey crews. This included multiple rock barge obstructions within the Calcasieu Waterway that shut down marine traffic.
    - Eight feet of shoaling occurred in the inland reach after Hurricane Laura, which required emergency dredging to remove

Successes: Hurricane Laura

Despite the unprecedented challenges encountered during the Hurricane Laura response in the middle of a pandemic, there were several successes that were identified by MTS response and recovery agencies:

- Coordination and Communication
    - Pre-season preparations to identify agency responsibilities was key for an effective response. This was accomplished through inter-coordination throughout the year that was ramped up in May through June with Hurricane Team Calls and Harbor Safety Team calls.
- Survey
    - Even with channel obstruction removal being a huge focus and providing a reprieve on the need to rapidly conduct surveys, 60 miles of channel from inland into the Gulf took only 4 days to survey following both hurricanes.

Hurricane Sally

Overview and Impacts

Hurricane Sally made landfall in Gulf Shores, AL on Wednesday, September 16, 2020 as a strong Category 2 hurricane with maximum sustained winds of 105 mph[23]. Sally produced widespread wind, storm surge, and freshwater flooding across coastal AL and the western Florida Panhandle. Flood and wind damage also extended well inland into Southwest Alabama and South-Central Alabama. Sally was an extremely slow-moving hurricane, which prolonged and exacerbated the local impacts. The storm was moving at less than 5 mph at the time of landfall, resulting in a long duration of tropical storm and hurricane force winds, storm surge, and torrential rainfall. Sally is responsible for causing 7.3 billion USD in damage and four fatalities in Florida, Alabama, and Georgia[24].

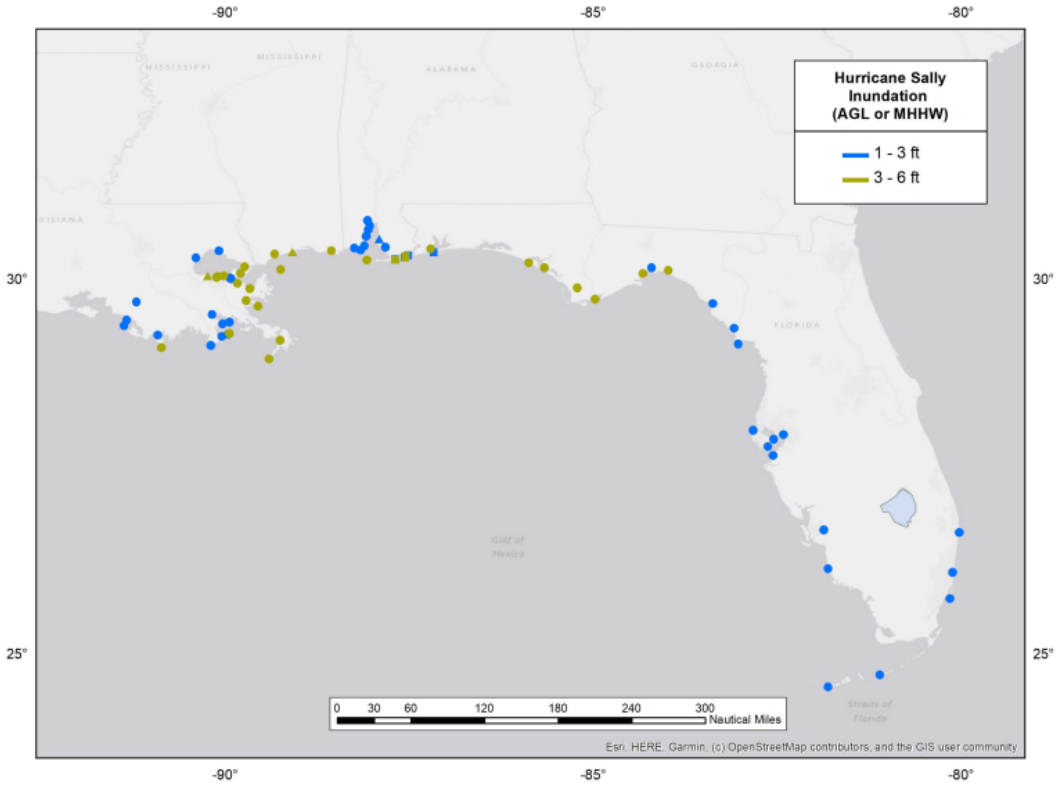


Figure 7. Maximum water levels measured from tide gauges (circles), water level sensors (triangles), and surveyed high water marks (squares) from Hurricane Sally. Water levels are referenced as feet above

[23] Office of Resilience and Coastal Protection, "Hurricane Sally Post-Storm Beach Conditions and Coastal Impact Report", November 2020, https://floridadep.gov/sites/default/files/Hurricane-Sally-Report_11-2020.pdf
[24] Robbie Berg and Brad J. Reinhart, "National Hurricane Center Tropical Cyclone Report", 11-17 September, National Hurricane Center, 12 April, 2021, https://www.nhc.noaa.gov/data/tcr/AL192020_Sally.pdf

ground level (AGL) or above Mean Higher High Water (MHHW), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline.

Source: Robbie Berg and Brad J. Reinhart, "National Hurricane Center Tropical Cyclone Report", 11-17 September, National Hurricane Center, 12 April 2021, pp. 59.
https://www.nhc.noaa.gov/data/tcr/AL192020_Sally.pdf

Hurricane Sally was an erratic hurricane, both in its track and intensity. Early models had the storm tracking with a left-of-track (west) bias towards Southeast Louisiana. Two days before landfall the storms track shifted towards Alabama. Sally's erratic track near the shoreline produced a multifaceted storm surge event, with some areas experiencing flooding followed by a period of abnormally low water due to offshore winds on the backside of the hurricane. Sally's slow motion while approaching and moving across the northern Gulf coast resulted in high rainfall totals. Upwards of 24-30 inches of rain was recorded in parts of Alabama and the Florida Panhandle.

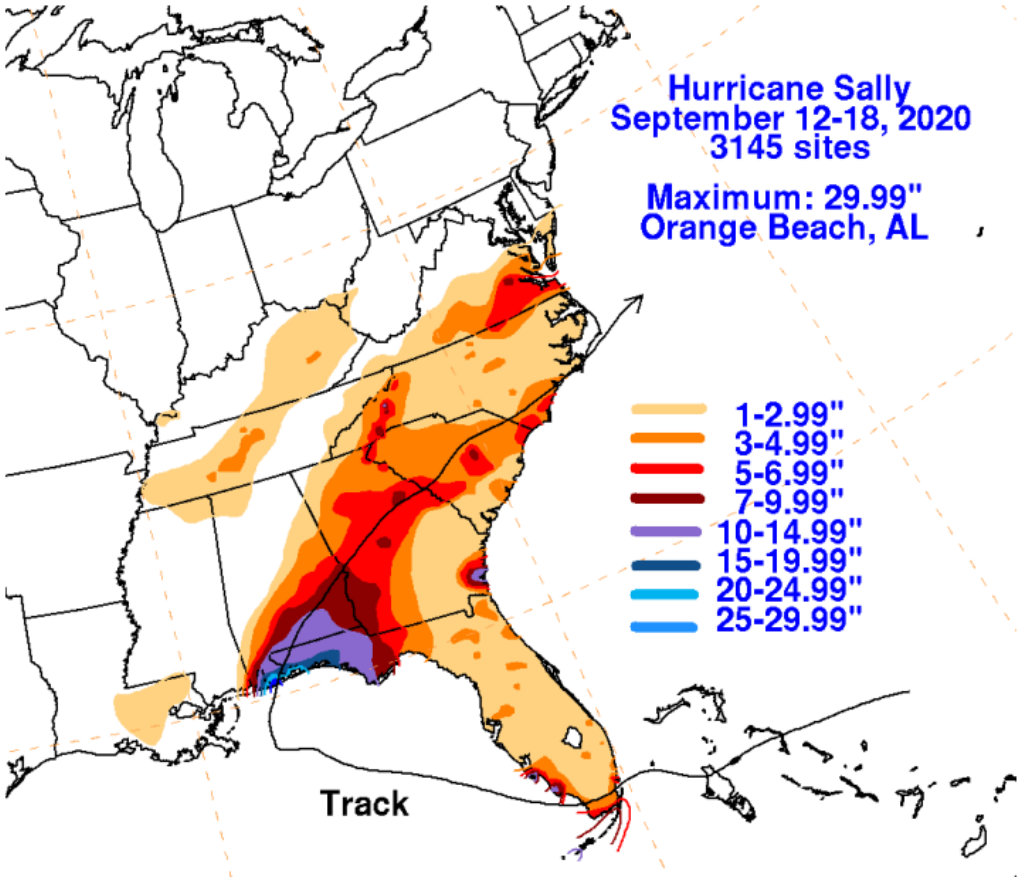


Figure 8. Track and rainfall accumulations (inches) from Hurricane Sally, 11-17 September 2020. The extratropical track over the United States is partially based on analyses from the NOAA Weather Prediction Center.

Source: Robbie Berg and Brad J. Reinhart, "National Hurricane Center Tropical Cyclone Report", 11-17 September, National Hurricane Center, 12 April, 2021, pp 61.
https://www.nhc.noaa.gov/data/tcr/AL192020_Sally.pdf

Challenges: Hurricane Sally

Many of the challenges identified for Hurricanes Laura and Delta were also experienced during Hurricane Sally. The erratic nature of the storms track and intensity produced significant preparation challenges. This, along with the public health restrictions enacted to combat the spread of the COVID-19 pandemic, provided additional challenges to the MTS response and recovery effort:

- Logistics
    - Surge staffing experienced travel issues as the local airport was closed. This required additional administrative planning that was not planned for.

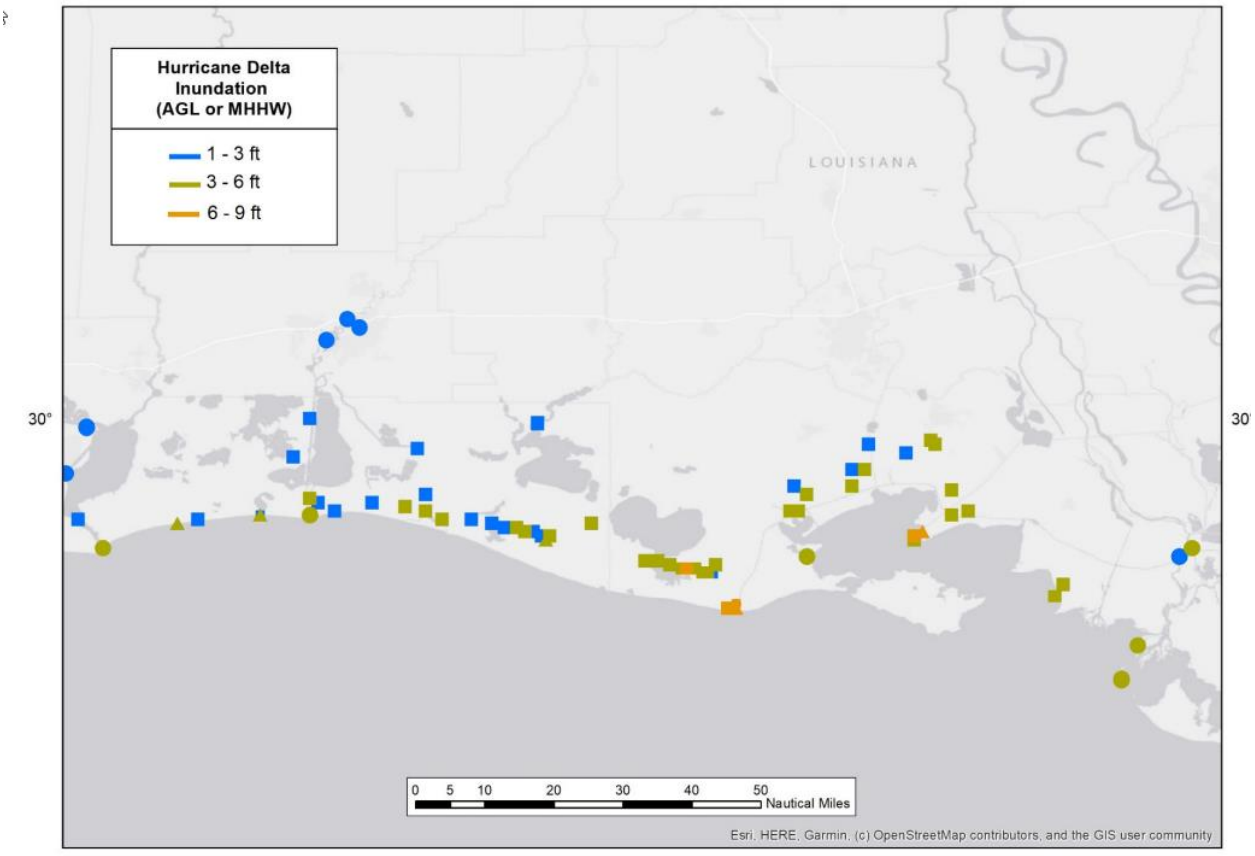
Successes: Hurricane Sally

- Communication and Coordination
    - USCG started Executive Port Coordination/EOC Coordination Calls early. This ensured ports were prepared and synced as the storm's trajectory shifted eastward.
    - The COVID-19 pandemic impacted the traditional preparation cycle of building relationships prior to the hurricane season. Expanded use of tele/video conferencing in lieu of in-person networking reduced negative impact.
- Technology
    - The USCG relied on industry partners to identify critical aids to navigation (ATON). This enabled the USCG to activate only the essential electronic aids to navigation (e-ATON) to prevent bogging down the system
    - Port Emergency Action Teams (PEAT) and Marine Environmental Response Teams (MER) from the USCG leveraged Unmanned Aircraft Systems (UAV) for post storm assessments. This expedited the port assessment process and enabled USCG air crews to focus on search and rescue (SAR) mission.

Hurricane Delta

Overview and Impacts

Hurricane Delta formed as a tropical wave in the Caribbean Sea on October 1, 2020, strengthening into a Category 4 hurricane before making an initial landfall on the Yucatan Peninsula on October 7 with a downgraded intensity of Category 2. Delta then re-emerged into the Gulf of Mexico, making U.S. landfall as a Category 2 hurricane in Southwest Louisiana on October 9th[25]. The impact area was remarkably similar to that of Hurricane Laura six weeks prior, with landfall occurring just 12 miles east. While Hurricane Delta was a weaker storm than Category 4 Laura, it still brought winds of over 100 miles per hour and a surge of 6-9 feet (Figure 7) to an area that was still heavily damaged from the previous storm. The storm and its aftermath caused four deaths in Florida and Louisiana with economic damages estimated to be around $3 billion[26].



[25] US Department of Commerce, NOAA. "Tropical Weather." www.weather.gov, www.weather.gov/lch/2020Delta.
[26] P. Cangialosi, John. "National Hurricane Center Tropical Cyclone Report: Hurricane Delta." NOAA National Hurricane Center.

Figure 7. Maximum water level observations in southwest Louisiana where the highest storm surge inundation occurred. Maximum water levels measured from tide and stream gauges (circles), USGS water level sensors (triangles), and surveyed high water marks (squares) from Hurricane Laura.

Source: John P. Cangialosi and Robbie Berg, "National Hurricane Center Tropical Cyclone Report", October 4-10 2020, National Hurricane Center NOAA, April 19, 2021.

On October 7, 2020, the National Weather Service published an advisory with predicted storm surges of 4-6 feet in southeast Texas and Southwest Louisiana coasts. Several ports in the affected region responded to the projected deteriorating conditions, resulting in port closures. On October 7, the Captain of the Port at Port Arthur set port condition XRAY for ports Beaumont, TX, Port Arthur, TX, Orange, TX, Sabine, TX, and Lake Charles, LA. At 8:00 a.m. CDT, October 8, 2020, port conditions were set to Condition Yankee for these ports, including all connecting waterways and tributaries.[27] By 8 p.m. CDT, port conditions were set to Condition ZULU[28]. On October 11, 2020, Port Condition ZULU remained for the Calcasieu Waterway, with port conditions RECOVERY for Beaumont, Port Arthur, Orange, and Sabine, TX. On October 12th, Port Condition RECOVERY was set for the Calcasieu Waterway, with Black Bayou Bridge and Grand Lake Bridge resuming their normal 24-hour operations on October 13th. In addition, the Sabine-Neches Waterway opened to traffic with restrictions.[29] The impacts of these port conditions on vessel movements in the affected region can be seen on AIS vessel signal density plots from before, and during landfall (Figure 8).

[27] *Marine Safety Information Bulletin, Hurricane Delta*, US Department of Homeland Security US Coast Guard, 2020.

[28] Port Conditions are set by the U.S. Coast Guard and describe when sustained wind gusts from tropical storms or hurricanes are expected to arrive at the Port: WHISKEY = 72 hours; X-RAY = 48 hours, YANKEE = 24 hours, ZULU = 12 hours.

[29] *Marine Safety Information Bulletin, Hurricane Delta*, US Department of Homeland Security US Coast Guard, 2020.

Figure 8. Hurricane Delta Cargo and Tanker Vessel Signal Density Plots. Heatmaps indicate vessel densities of cargo, tanker, towing, and tug vessels.

Source. Data furnished by the US. Coast Guard and compiled via the Engineer Research and Development Center's Automatic Identification System Analysis Package (AISAP).

Challenges: Hurricane Delta

Many of the challenges incurred during the MTS response had to do with the fact that the impacted area was still recovering from impact of Hurricane Laura. In addition, the same logistical and survey challenges remained from the Laura response – most notably the need to house response and recovery staff at a significant distance from survey sites or bring their own temporary housing.

Successes: Hurricane Delta

While the spatial proximity of the impact zones from Hurricane Laura and Hurricane Delta contributed to challenges faced during the Delta response, the temporal proximity resulted in the opportunity to directly apply lessons learned and best practices from the Laura response:

- Logistics
    - To avoid staff exhaustion experienced during Hurricane Laura, NOAA OCS flew data processing staff to hotel rooms 2 hours away from the survey sites. Survey teams were in RVs close to the operational areas and a data runner was employed to move data from survey vessels to the data processing staff.
- Coordination and Communication
    - Operational battle rhythms were established during the Hurricane Laura response that led to better communications and alignment of regional stakeholders and interagency partnerships. The USCG was holding teleconference calls with USACE, pilots and regional and local partners twice a day to make sure that information was being effectively passed along to stakeholders

Summary of Findings

Recommendations to Increase Resilience

The following recommendations were identified by staff from federal MTS response and recovery organizations during a workshop to review the impacts of the 2020 hurricane season on the MTS. They are organized into the four-step cycle of resilience that has been adopted by

the CMTS RIAT. Ideally, these recommendations will be incorporated into future MTS response and recovery activities, so that disruption to navigation can be minimized – effectively enhancing the resilience of the system at-large.

Prepare

- Identify system vulnerabilities ahead of time.
    - Domain awareness should be increased through enhanced coordination with industries that use the MTS. This includes identifying blind spots like unregulated facilities, cold-staked rigs, uninspected barges. There is a need to know who is responsible in case they should impact the shipping channel.
    - Conduct a reality-based assessment of vulnerabilities so that the weaknesses of the MTS (port and waterways) are well known and potential disruptions are anticipated (storm surge, power grid issues, loss of communication, etc.).
    - The entire MTS and its dependencies should be analyzed to identify interdependencies across infrastructure sectors. Such an analysis should include close coordination with industry partners and users. For example, with Hurricane Harvey there were huge refinery complexes that were difficult to access which resulted in explosions. In Florida, leadership did not realize the dependence on ports for fuel (90% comes from ships).
    - Work with pilots or other port partners to identify critical ATONS before the storm so that assessments and repairs can be prioritized for faster channel reopening.
    - Hold hurricane preparedness workshops to remind everyone about collaboration tools, identify who is responsible for what, and outline what a "perfect" storm response will look like.
- Ensure collaboration through tools, regular calls, and established relationships
    - For any hurricane event, coordinate requirements and priorities ahead of time
    - Interacting, coordinating, and identifying responsibilities is key in getting the job done and identifying the type of response necessary. Thus the establishment and maintenance of relationships with those agencies charged with response and recovery operations at all scales should be a continuous practice.
    - Conduct teleconferences with teams and stakeholders early and often. It's key to get stakeholders on the same page and ensure consistent communication.

- Having a common collaboration tool would be a huge help but there will be major hurdles to get access to a common tool that can be implemented across all agencies and stakeholders.
- Set realistic expectations within hurricane-impacted areas regarding the ability of federal agencies to rapidly deliver a product or service.

- Establish processes for releasing vetted and valuable information
  - Ensure that there is a process for reporting and releasing information that fits into the local response and is accountable. Decision makers in the middle of the crisis may not have time to make sure that everything is communicated clearly.
  - Establish common data vetting procedures so that data and updates are communicated consistently. With information streaming in from multiple sources (e.g. field observations, news media, social media), it is necessary for those who are responsible for the synthesis and dissemination of information to managers and decision-makers to get on the same page.
  - Consider time zones when setting reporting requirements. Different agencies have different time structures and reporting templates (ex. Updates at 1PM, 9PM for one agency, 10AM and 10PM for another). There may be a mismatch on new and old information across time zones and agencies that leads to confusion.

- Leverage technological platforms to maintain relationships and keep the communication flowing
  - While the health and safety protocols put in-place to combat the COVID-19 pandemic limits in-person collaboration activities, virtual collaboration platforms can and should continue to be incorporated to effectively build and maintain the relationships that are critical to effectively sharing local knowledge and best practices during hurricane response. Ensure that back-up applications and platforms are identified and in-place should the primary mechanism for virtual collaboration be unavailable.

Absorb/Recover

- Leverage new technology to quickly re-establish navigation
  - Consider electronic aids to navigation (e-ATONs) as a tool for quickly re-establishing a ship channel.

- Start coordination calls early and leverage information about vulnerabilities and identify cross-essential support functions.

- Set up Executive Port Coordination and EOC Coordination Calls – start them early to get a pulse and status of the port, including "blind spots" and vulnerabilities. Leverage industry partners when necessary or needed.
- Increase communication about issues that cross essential support functions, like sunken vessels.

- Identify lodging and staging requirements ASAP
  - Set up reservations at hotels days or weeks in advance and identify where to stand up post-storm operations.
- Incorporate self-sufficiency into response operations
  - The devastation caused by Hurricanes Laura and Delta, coupled with the unique emergency management challenges introduced by the COVID-19 pandemic resulted in significant logistical challenges for navigation survey crews. Response and recovery activities should incorporate self-sufficiency into their field operations to reduce the travel burden on staff. This could include the use of mobile housing and on-site power generation to reduce the reliance on the surrounding communities.

Adapt

- Provide adequate resources for personnel to ensure they are trained and healthy
  - Provide and remind personnel about mental health resources
  - Provide training for personnel and ask for help when gaps in ICS positions at smaller units becomes apparent
- Communicate with partners
  - Meet all port partners prior to the hurricane season
  - Ensure that there is proper representation at state and local EOCs.
  - Share insights between agencies on how the response and recovery effort is being tracked and collaborated because each agency is unique.
  - Identify a single collaboration tool to standardize these efforts, right now the response is complicated by too many tools that partners are using.
- Review the successes and failures of past hurricane response
  - Make after-action reviews a priority and commit to actions that can improve future preparation, response and recovery operations before the next hurricane season

Conclusion

While the MTS has faced many recent challenges due to hazardous weather conditions, 2020 introduced a new test for response and recovery agencies: how to conduct operations during a global pandemic. However, when faced with this new multi-hazard environment, response and recovery efforts effectively pivoted to minimize disruption to the MTS during a historic hurricane season. Federal agencies quickly learned new methods and implemented innovative solutions for ensuring continued collaboration and communication during unprecedented circumstances. As we look to the future, it is critical that these entities continue to integrate these methods with past lessons-learned to minimize disruptions from natural and man-made hazards. These adaptations will, in turn, ensure a more resilient MTS.