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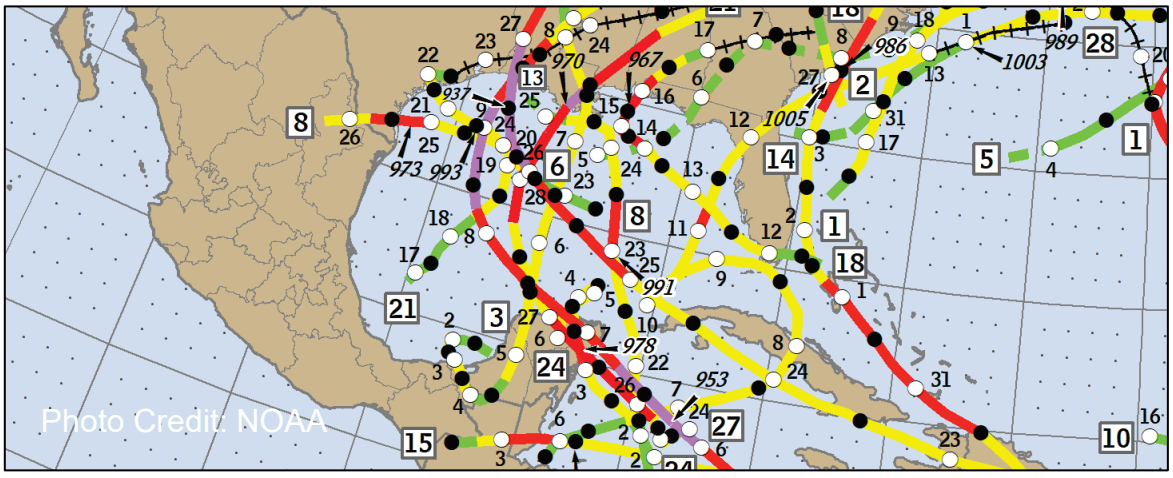
An Examination of Multihazard Marine Transportation System (MTS) Response and Recovery Operations during the 2020 Hurricane Season

Katherine Chambers, Joshua Murphy, Jessamin Straub, Alejandra Enriquez, and the US Committee on the Marine Transportation System Resilience Integrated Action Team

January 2024



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An Examination of Multihazard Marine Transportation System (MTS) Response and Recovery Operations during the 2020 Hurricane Season

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Abstract

The Committee on the Marine Transportation System (CMTS), Resilience Integrated Action Team (RIAT), was established in 2014 to foster the coordination and coproduction 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. The RIAT utilizes this definition of resilience to convene first-responder CMTS agencies to examine challenges and successes and make recommendations about past hurricane seasons. The 2020 hurricane season saw a record-breaking number of storms form in the Atlantic basin during a global pandemic. As a result, federal agencies were challenged to operate in a multihazard posture, and many former lessons learned needed to be adjusted to this unprecedented situation.

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Preface

This study was conducted for the US Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, under Funding Account Code U4368911; AMSCO Code 031391.

The work was performed in part by the Coastal Processes Branch of the Flood and Storm Protection Division, US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL). At the time of publication of this report, Mr. Victor Gonzalez was chief, Coastal Processes Branch; Mr. David May was chief, River and Estuarine Engineering Branch; Ms. Patricia Tolley was acting chief, Flood and Storm Protection Division; Ms. Morgan Johnston was program manager of the Navigation Systems Research Program; Mr. Charles E. Wiggins was the ERDC technical director for Navigation; and Ms. Tiffany Burroughs was chief of the US Army Corps of Engineers (USACE) Navigation Division at Headquarters, USACE.

The deputy director of ERDC-CHL was Mr. Keith Flowers. The director of ERDC-CHL was Dr. Ty V. Wamsley.

This report was prepared by an interagency team entitled the Resilience Integrated Action Team under the US Committee on the Marine Transportation System (CMTS). The interagency team also consisted of members from 12 different marine transportation system agencies. These members contributed content and review for the report, and the report was passed on to the CMTS Coordinating Board for subsequent review and approval. It was initially released online in December 2020. Report development was funded in part by the Navigation Systems Research Program, Project No. 462579; Navigation Systems Resilience. The program manager was Ms. Morgan Johnston.

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The commander of ERDC was COL Christian Patterson, and the director was Dr. David W. Pittman.

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1 Introduction

1.1 Background

The Marine Transportation System (MTS) provides a critical linkage between the United States 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 US 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 broader international, domestic, and inland supply chains.

A significant portion of the US MTS is in low-lying coastal regions, making it susceptible to impacts from hurricanes and other coastal storms. The federal agencies that comprise the US Committee on the Marine Transportation System (CMTS)—most notably the US Army Corps of Engineers (USACE), US Coast Guard (USCG), the US Department of Homeland Security 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 1 June 2020 and 30 November 2020 (NOAA 2021). Twelve storms made landfall on the US coastline, including six hurricanes, resulting in an estimated $37 billion in damages (Masters 2020). 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 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 physically 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. Poststorm 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.

1.2 Objective

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 notes key differences between the 2020 season and previous 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 with the acknowledgement that the key roles of state, local, private, and nonprofit response have not been addressed. It is anticipated that the report will assist the coordination between federal and nonfederal partners' efforts to support the US MTS in its return to normal operations.

1.3 Approach

The US CMTS Resilience Integrated Action Team (RIAT) is a group of federal agencies that have interest in both the MTS, its stakeholders and operators, and its resilience. *Resilience* is defined as the ability to prepare, absorb (resist), recover, and adapt to and from disruptions (PPD 21 2013).

The RIAT addresses the cyclical nature of resilience, convening response and recovery personnel to discuss how best to adapt and evolve between storm seasons. In 2017, the RIAT was tasked with reviewing the impacts of back-to-back Hurricanes Harvey, Irma, and Maria. Since then, the team has published a report summarizing findings from 2017 (CMTS 2018) and a combined report summarizing 2018 and 2019 (CMTS 2020).

During the 2020 season, federal agencies had to respond to a record number of Atlantic storms during a global pandemic. This multihazard scenario uncovered the need for a third follow-on report that would specifically consider the challenges faced during this unprecedented event. Similar to the previous reports, the RIAT convened a virtual workshop with federal agency partners on 10 June 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 later from Hurricane Sally. The names and offices of these agencies are available in the appendix.

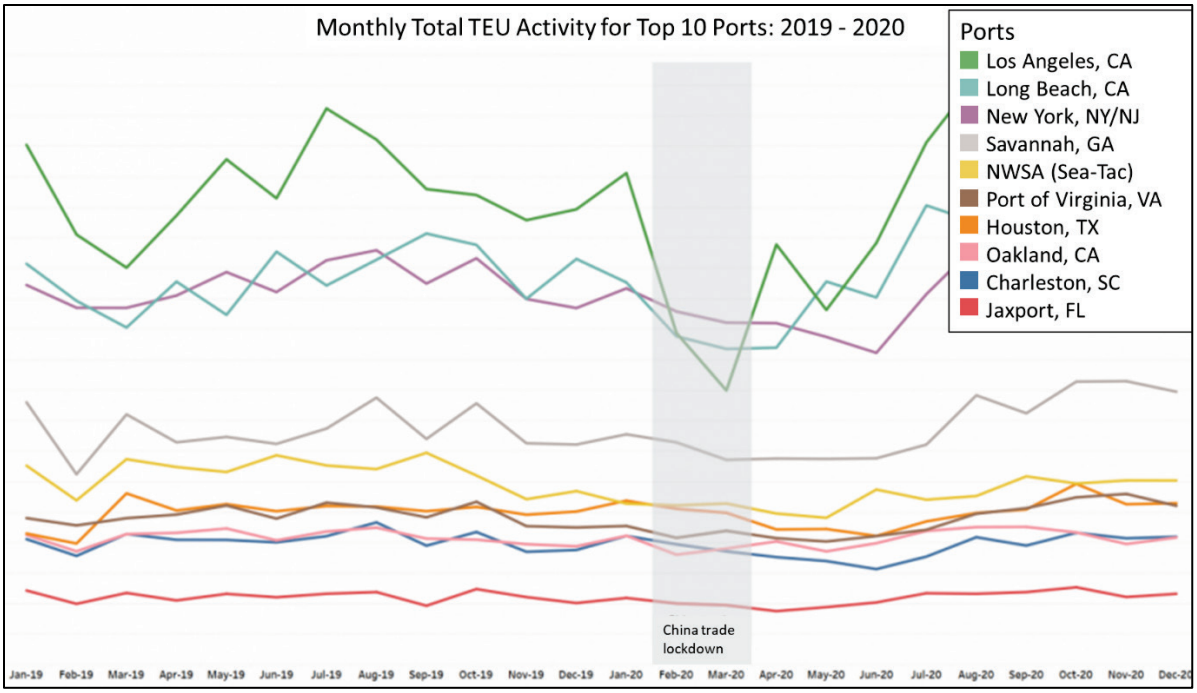
2 Coronavirus Disease (COVID-19) and Preparations for the 2020 Hurricane Season

2.1 COVID-19 Impacts to the Marine Transportation System (MTS)

In early 2020, 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 United States, 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 (CDC 2021). While such actions were necessary from a public health perspective, they also introduced severe restrictions on economic activities. Social distancing and lockdown regulations that resulted in many temporary business closures and a reduction in the production of goods and services (Bauer 2020). The resultant disruption to the supply chain, in turn, caused a reduction in shipping activity across the United States and the globe.

The impact of the COVID-19 pandemic on global shipping and the US MTS varied across different ports and shipping industries. A global study of automatic information system (AIS) data showed a decline in ship mobility during March to June ranging between 5% to 14% for container shipping and between 19% to 42% for the passenger and cruise industry (Millefiori et al. 2021). In the United States, 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 US ports (Northam 2020). 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 1; BTS 2021). 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 US west coast (BTS 2021). 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 late October 2020 (CDC 2022).

Figure 1. Monthly twenty-foot equivalent unit (commonly referred to as TEU) activity for the top-10 US container ports from 2019 to 2020. The *highlighted section* depicts the period of national Chinese trade lockdown during the pandemic. (Image reproduced from BTS 2021. Public domain.)



2.2 MTS Preparation Activities for COVID-19

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 (CMTS 2020). Additional preparation activities included having interagency tabletop exercises to identify known problem areas in local waterways, prepositioning 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, colocating personnel from different agencies within the same facility increased face-to-face communications. In 2020, many of these activities were no longer feasible due to pandemic restrictions. Agencies had to adjust their operations to ensure the continuity given severe limitations of in-person communications and collaboration.

2.2.1 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 (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 Federal Emergency Management Agency (FEMA) National Response Coordination Center was able to support Emergency Support Function #1 (Transportation), the CMTS Executive Secretariat supported maximum telework capacity, the USCG implemented liberal telework for nonessential civilians and military personnel ranked O-4 and below, NOAA's Office of National Marine Sanctuaries (ONMS) and National Marine Fisheries Service 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 canceled 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.

2.2.2 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.

The guidelines published by 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. In addition to following these guidelines, offices implemented alternating team schedules (USCG), robust testing protocols, COVID-19 monitoring, pilot and crew quarantines, shelter-in-place requirements, flexibility for travel authorizations (NOAA Office of Marine and Aviation Operations), or simply standing down teams until back-to-work plans could be established (NOAA Navigation Response Teams and National Geodetic Survey).

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.

3 2020 Hurricane Season Review

3.1 Impacts from the 2020 Hurricane Season

In what was an ominous forerunner 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 30 November, the Atlantic basin experienced 30 named storms, 14 of which developed into hurricanes (NOAA 2021). Twelve storms made landfall in the United States, 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 2). The most destructive hurricane to impact the US in 2020 was Hurricane Laura, which made landfall on 27 August (Masters 2020). The Category 4 storm brought sustained winds of 150 mph* and a surge of over 13 ft, making it the strongest hurricane to strike Southwest Louisiana (NOAA NWS 2020a). Hurricane Laura was also the most expensive storm of 2020, with damages costing $19 billion (NOAA OCM 2020). With 37 billion-dollar weather and climate disasters, 2020 was the sixth consecutive year where 10 or more billion-dollar disaster events occurred in the United States (NOAA OCM 2020).

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 3 depicts these port closures due to those 10 named storms (identified within the column; BTS 2020).

* For a full list of the spelled-out forms of the units of measure and unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248–52 and 345–7, respectively. https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

Figure 2. A map of US hurricane season tracks during the 2020 Atlantic hurricane season. (Image reproduced from NOAA NWS. Public domain.)

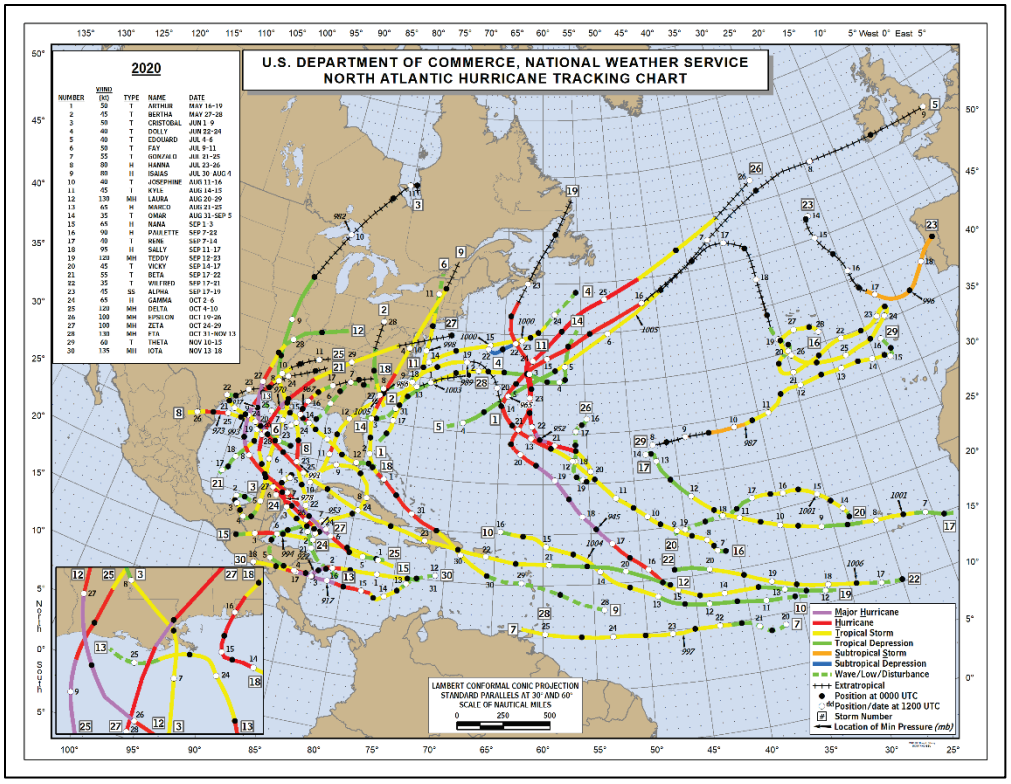
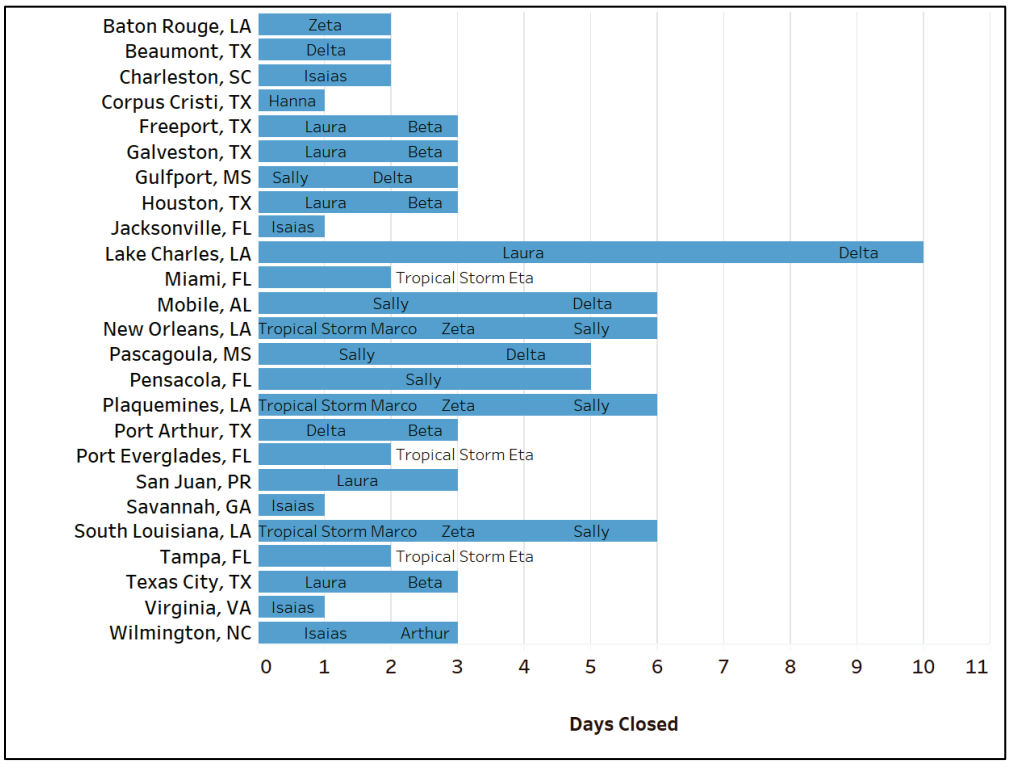


Figure 3. Port closure days for US ports during the 2020 Atlantic hurricane season. (Image reproduced from NOAA NWS. Public domain.)



3.2 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 nonroutine 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 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 and 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.

3.3 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 Scientific Support Coordinators, the Disaster Response Center, 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 versus 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.

3.4 Hurricane Laura

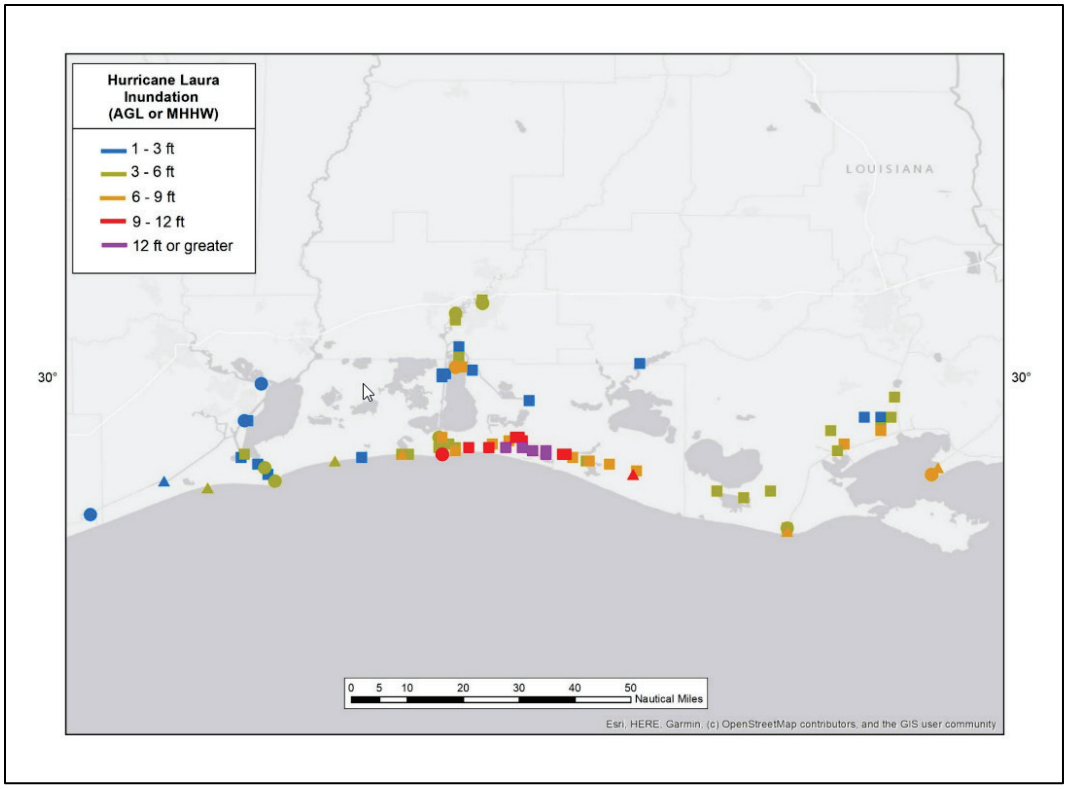
3.4.1 Overview and Impacts

Hurricane Laura formed as a tropical wave to the west of Africa on 16 August 2020. After passing through the Caribbean Sea as a weak tropical storm, Hurricane Laura rapidly intensified within the Gulf of Mexico before making landfall near Cameron, Louisiana on 27 August as a Category 4 storm with peak winds of approximately 150 mph (Pasch et al. 2021). In addition to the heavy winds, the storm brought high levels of coastal inundation, with surge elevations of greater than 12 ft occurring across South Central Louisiana from Atchafalaya Bay to Caillou Bay (Figure 4). 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

† Port conditions are set by the USCG and describe when sustained wind gusts from tropical storms or hurricanes are expected to arrive at the Port: WHISKEY = 72 hr, X-RAY = 48 hr, YANKEE = 24 hr, ZULU =12 hr.

surge destroyed 10,000 homes and damaged several structures in Louisiana (Pasch et al. 2021).

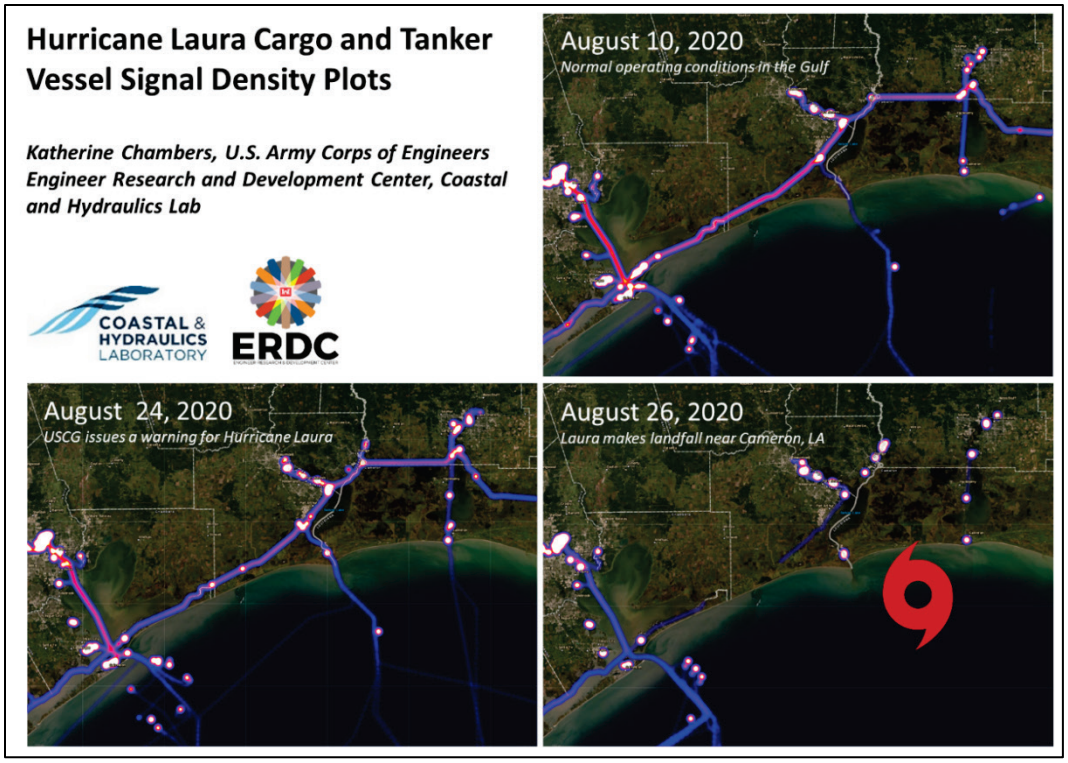
Figure 4. Maximum water level observations in southwest Louisiana where the highest storm surge inundation occurred. Maximum water levels measured from tide and stream gauges (circles), US Geological Survey (USGS) water level sensors (*triangles*), and surveyed high-water marks (*squares*). AGL: above ground level; MHHW: mean higher high water. (Image reproduced from Pasch et al. 2021. Public domain.)



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 US Coast Guard's Captain of the Port sets the following port conditions based on the anticipated arrival time of gale force winds. On 29 August, port condition ZULU was set for the Calcasieu Waterway and the Sabine-Neches Waterway. Condition ZULU remained until 30 August for the Sabine-Neches Waterway, and 31 August for the Calcasieu Waterway (USCG 2020a). On 31 August, port conditions were set to RECOVERY for the Sabine-Neches Waterway; the Gulf Intracoastal Waterway from West Port Arthur to High Island opened to eastbound and westbound inland traffic. The Port of Lake Charles continued to recover and opened as of 2 September 2020 (USCG 2020b). 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 5).

Figure 5. Hurricane Laura cargo and tanker vessel signal density plots. (Image reproduced from USACE-ERDC 2021. Public domain.)



3.4.2 Challenges: Hurricane Laura

As the strongest storm to impact the southwest Louisiana region in over 100 yr, 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 multiweek 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.

- Logistics
  - The sea state offshore of the Hurricane 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 hr on the water, 2 hr in transit to a hotel, and 6 hr processing data overnight.
  - Supply distribution was also an issue. Supplies needed to be driven in from Houston, Texas, or New Orleans, Louisiana.
  - 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 of the Calcasieu Waterway after Hurricane Laura, which required emergency dredging to remove.

3.4.3 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:

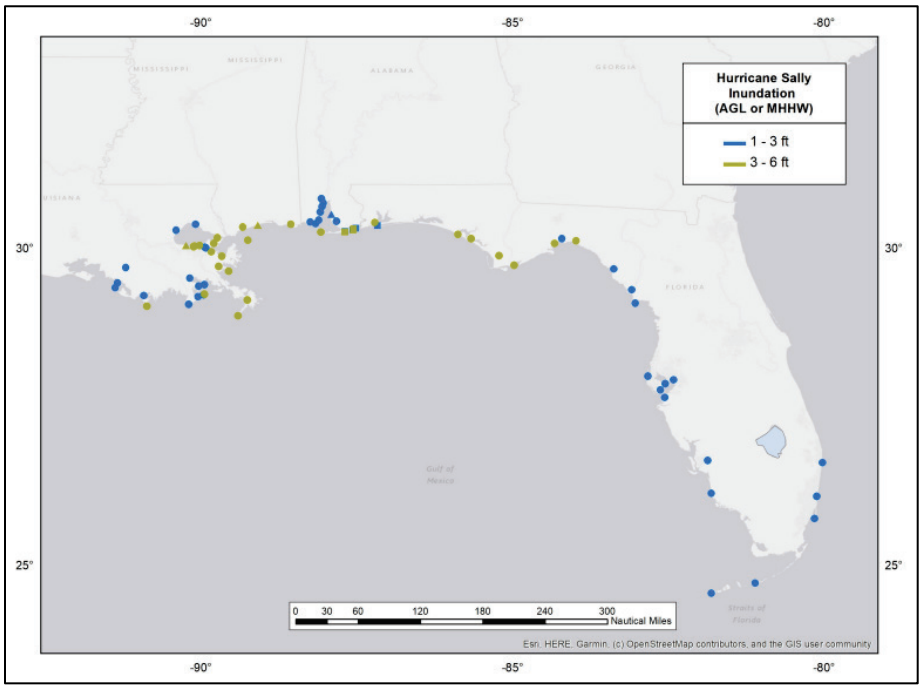
- Coordination and Communication
  - Preseason preparations to identify agency responsibilities was key for an effective response. This was accomplished through intercoordination throughout the year that was ramped up in May through June with Hurricane Team Calls and Harbor Safety Team calls.
- Survey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

3.5 Hurricane Sally

3.5.1 Overview and Impacts

Hurricane Sally made landfall in Gulf Shores, Alabama, on Wednesday, 16 September as a strong Category 2 hurricane with maximum sustained winds of 105 mph (FDEP 2020). Sally produced widespread wind, storm surge, and freshwater flooding across coastal Alabama and the western Florida Panhandle. Flood and wind damage also extended well inland into southwest Alabama and south-central Alabama. Hurricane 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 (Figure 6). Hurricane Sally is responsible for causing $7.3 billion in damage and four fatalities in Florida, Alabama, and Georgia (NOAA NWS 2020b).

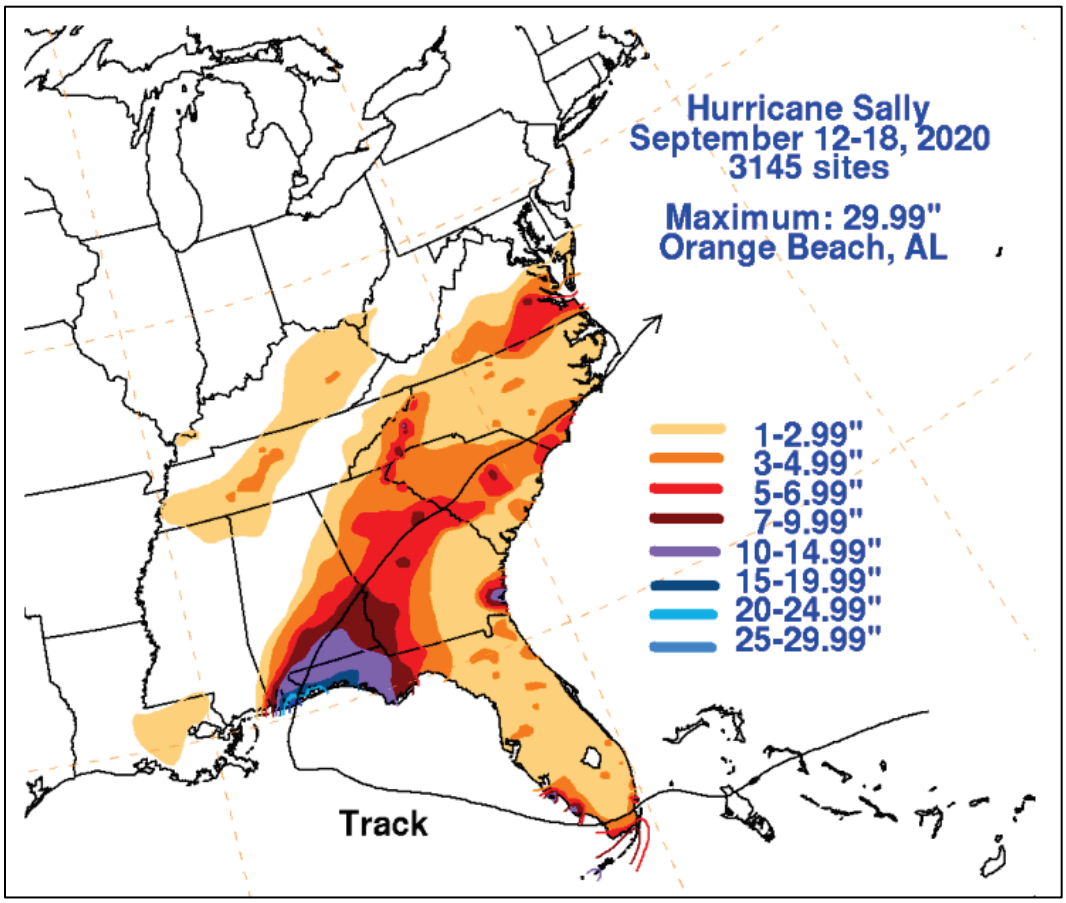
Figure 6. Maximum water levels measured from tide gauges (*circles*), water level sensors (*triangles*), and surveyed high-water marks (*squares*) from Hurricane Sally. Water levels are referenced as feet AGL or above MHHW. (Image reproduced from Berg and Reinhart 2021. Public domain.)



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. Hurricane 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. Hurricane Sally's slow motion while approaching and moving across the northern Gulf coast resulted in high rainfall totals. Rainfall that was upwards of 24–30 in. was recorded in parts of Alabama and the Florida Panhandle (Figure 7).

Figure 7. Track and rainfall accumulations (inches) from Hurricane Sally, 12–18 September 2020. The extratropical track over the United States is partially based on analyses from the National Oceanic and Atmospheric Administration (NOAA) Weather Prediction Center. (Image reproduced from Berg and Reinhart 2021. Public domain.)



3.5.2 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 accounted for.

3.5.3 Successes: Hurricane Sally

Hurricane Sally resulted in several major successes relative to flexible communications and adoption of new technologies to facilitate response actions in a COVID-19 environment.

- Communication and Coordination
    - USCG started Executive Port Coordination and Emergency Operations Center (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 telephone and video conferencing in lieu of in-person networking reduced negative impact.
- Technology
    - The USCG relied on industry partners to identify critical 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 and Marine Environmental Response Teams from the USCG leveraged Unmanned Aircraft Systems for post storm assessments. This expedited the port assessment process and enabled USCG air crews to focus on search-and-rescue mission.

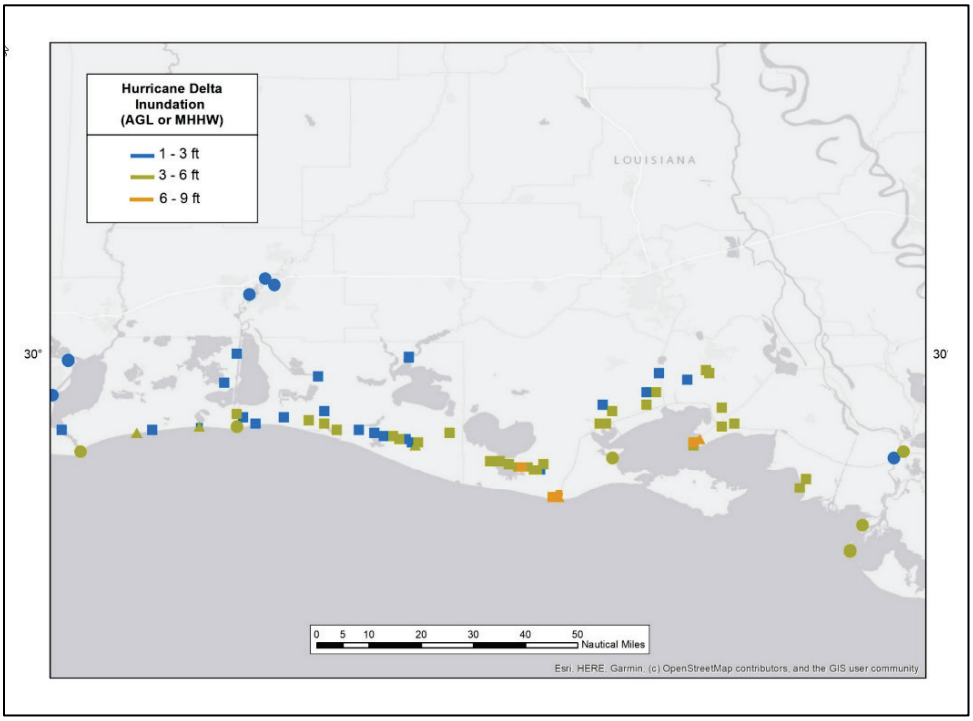
3.6 Hurricane Delta

3.6.1 Overview and Impacts

Hurricane Delta formed as a tropical wave in the Caribbean Sea on 1 October 1 2020, strengthening into a Category 4 hurricane before making an initial landfall on the Yucatan Peninsula on 7 October with a downgraded intensity of Category 2 (NOAA NWS 2020c). Delta then re-emerged into the Gulf of Mexico, making US landfall as a Category 2 hurricane in Southwest Louisiana on 9 October. The impact area was

remarkably close to where Hurricane Laura hit 6 weeks prior, with landfall occurring just 12 miles east. While Hurricane Delta was a weaker storm than Category 4 Hurricane Laura, it still brought winds of over 100 mph and a surge of 6–9 ft (Figure 8) 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 approximately $3 billion (Cangialosi and Berg 2021).

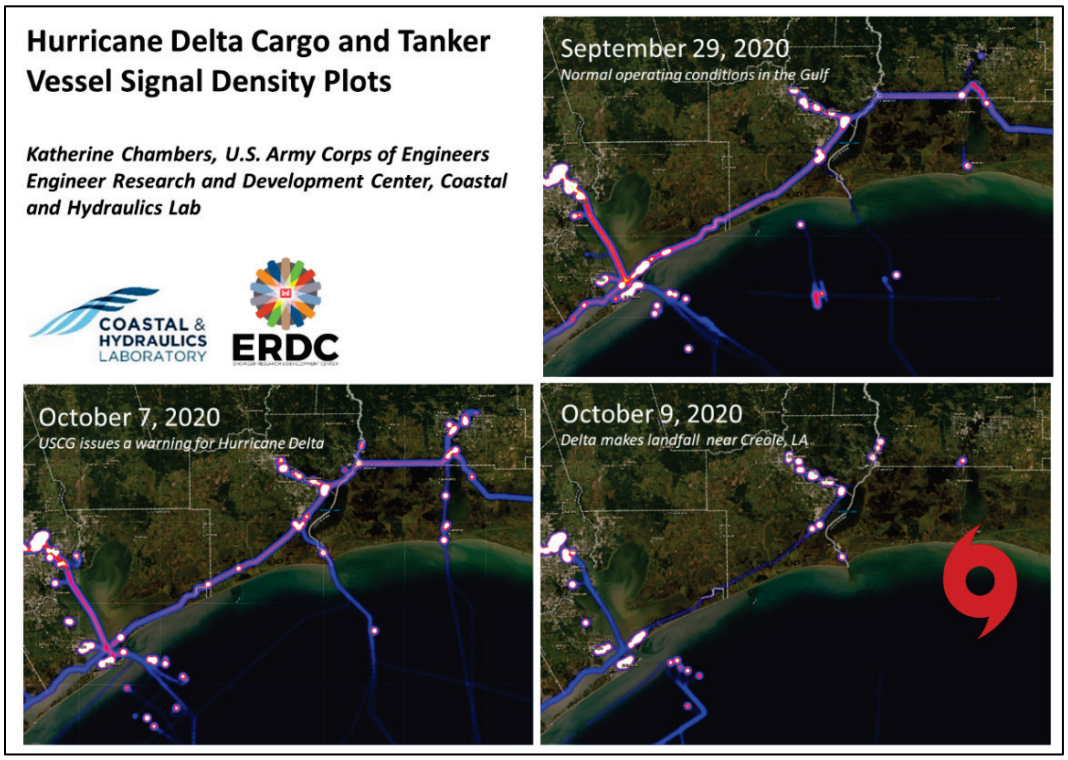
Figure 8. Maximum water level observations in southwest Louisiana where the highest storm surge inundation occurred. Maximum water levels measured from tide and stream gauges (*circles*), USGS water-level sensors (*triangles*), and surveyed high-water marks (*squares*) from Hurricane Laura. Water levels are referenced as feet AGL or above MHHW. (Image reproduced from Cangialosi and Berg 2021. Public domain).



On 7 October, the NWS published an advisory with predicted storm surges of 4–6 ft in southeast Texas and southwest Louisiana coasts. Several ports in the affected region responded to the projected deteriorating conditions, resulting in port closures. On 7 October, the Captain of the Port at Port Arthur set port condition XRAY for ports Beaumont, Port Arthur, Orange, and Sabine, Texas; and Lake Charles, Louisiana. 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 and by 8 p.m. CDT, port conditions were set to condition ZULU (USCG 2020c). On 11 October 2020, port condition ZULU remained for the Calcasieu Waterway, with port conditions RECOVERY for Beaumont, Port Arthur, Orange, and

Sabine, Texas. On 12 October, port condition RECOVERY was set for the Calcasieu Waterway, with Black Bayou Bridge and Grand Lake Bridge resuming their normal 24 hr operations on 13 October. In addition, the Sabine-Neches Waterway opened to traffic with restrictions (USCG 2020d). 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 9).

Figure 9. Hurricane Delta cargo and tanker vessel signal density plots. (Image reproduced from USACE ERDC 2021. Public domain.)



3.6.2 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.

3.6.3 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 hr 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 communication 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.

4 Recommendations and Conclusion

4.1 Summary 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.

4.1.1 Prepare

Most recommendations identified after the 2020 hurricane season involved actions that must be undertaken before any response or recovery actions begin. These actions are related to increased system vulnerability awareness, established relationships and collaboration mechanisms, identifying a process for vetting and releasing information, and implementing technology platforms for remote work where possible. These recommendations and some detailed actions are found in Table 1, which follows.

Table 1. Preparation recommendations based on findings from the 2020 hurricane season.

Preparation Actions	Identify system vulnerabilities ahead of time. • Increase domain awareness through coordination with industries that utilize the MTS. Review blind spots (e.g., unregulated facilities, cold-staked rigs, uninspected barges) and identify who is responsible for each. • Conduct a reality-based assessment of vulnerabilities to identify weaknesses and anticipate potential disruptions (storm surge, power grid, loss of communication, etc.). • Analyze the entire MTS for interdependences across infrastructure sectors and with communities. Such analysis should include close coordination with partners and users. • Work with pilots or other port partners to identify critical ATON before the storm so that assessments and repairs can be prioritized for faster channel reopening. • Hold hurricane preparedness workshops to refresh partners about collaboration methods, identify responsibilities, and outline a *perfect* storm response.
	Ensure close collaboration through tools, regular calls, and established relationships. • For any hurricane event, coordinate requirements and priorities ahead of time. • Continuously maintain relationships with agencies charged with response and recovery operations at all scales. • Conduct teleconferences with teams and stakeholders early and often to ensure common understanding and consistent communication. • Consider establishing a common collaboration tool for agencies (despite likely access hurdles).
	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 rhythm and is accountable. • Establish common data vetting procedures so that data and updates are communicated consistently to managers and decision makers. With multiple sources (e.g., field observations, news media, social media), a process for synthesis and dissemination is critical. • Consider time zones when setting reporting requirements. Different agencies have different time structures and reporting templates (e.g., updates at 1:00 p.m., 9:00 p.m. for one agency, 10:00 a.m. and 10:00 p.m. 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 communication flowing. • Identify virtual collaboration platforms to effectively maintain communication and knowledge sharing during times when in-person work is not feasible or safe. • Ensure that back-up applications and platforms are identified and in place should the primary mechanism for virtual collaboration be unavailable. • Create and maintain agency protocols to ensure availability, training, and maintenance of systems to support emergency response work during a pandemic. These systems could include virtual platforms and protocols for ensuring safety for those in the field.

4.1.2 Absorb and Recover

Recommendations to improve response-and-recovery actions focused primarily on the challenges encountered in the field. In 2020, personnel were required to respond promptly in an environment where great care must be taken to limit the exposure of both the community and response team to COVID. A summary of these recommendations is found below in Table 2.

Table 2. Recommendations for absorbing and recovering from a hurricane during a pandemic.

Absorb (Resist) and Recover Actions	Leverage new technology to quickly reestablish navigation. • Consider e-ATONs as a tool for quickly reestablishing 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.
	Incorporate self-sufficiency into response and recovery operations. • Include the use of mobile housing and on-site power generation to reduce the reliance on the surrounding communities.

4.1.3 Adapt

Adaptive actions recommended by the RIAT included a variety of themes focused on the health, training, and communication abilities of first responders. These actions are summarized in the following Table 3.

Table 3. Actions to adapt between hurricane seasons.

Adaptation Actions	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 Incident Command System positions at smaller units become 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 among 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.

4.2 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.

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Appendix: Agencies and Offices of Workshop Attendees

Department of Defense

US Army Corps of Engineers

Engineer Research and Development Center

Operations and Regulatory Division

US Committee on the Marine Transportation

Secretariat

US Department of Homeland Security

Cybersecurity and Infrastructure Security Agency

US Coast Guard

Headquarters: COVID-19 Response Global Migration Task Force, Maritime Unit

Headquarters: Port Resiliency and Recovery Branch

Atlantic Area Port and Facility Activities

District 8 Contingency Planning Branch

Marine Safety Unit Lake Charles

US Department of Transportation

Bureau of Transportation Statistics

US Maritime Administration

Office of Inland Waterways

Office of Ports and Waterways Planning

National Geospatial Agency

Office of Americas Western Hemisphere

US Department of Commerce

National Oceanic and Atmospheric Administration

National Ocean Service

Office for Coastal Management

Office of Coast Survey

Central Gulf Navigation Services

Office of National Marine Sanctuaries

Florida Keys National Marine Sanctuary

Office of Response and Restoration

Disaster Response Center

Marine Debris

National Weather Service

National Weather Service Southern Region HQ

Abbreviations

AGL	Above Ground Level
AIS	Automatic information system
ATON	Aids to navigation
BTS	Bureau of Transportation Statistics
CDC	Centers for Disease Control
CMTS	Committee on the Marine Transportation System
COVID-19	Coronavirus disease
e-ATON	Electronic aids to navigation
EOC	Emergency Operations Center
ERDC	Engineer Research and Development Center
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
MHHW	Mean higher high water
MTS	Marine Transportation System
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OCS	Office of Coast Survey
ONMS	Office of National Marine Sanctuaries
RIAT	Resilience Integrated Action Team

TEU	Twenty-foot equivalent unit
USACE	US Army Corps of Engineers
USCG	US Coast Guard
USGS	US Geological Survey

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14. ABSTRACT

The Committee on the Marine Transportation System (CMTS), Resilience Integrated Action Team (RIAT), was established in 2014 to foster the coordination and coproduction 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. The RIAT utilizes this definition of resilience to convene first-responder CMTS agencies to examine challenges and successes and make recommendations about past hurricane seasons. The 2020 hurricane season saw a record-breaking number of storms form in the Atlantic basin during a global pandemic. As a result, federal agencies were challenged to operate in a multihazard posture, and many former lessons learned needed to be adjusted to this unprecedented situation.

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