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Messaging the Rip Current Threat from Distant Tropical Cyclones in the Carolinas

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ABSTRACT

Rip currents are the number one weather-related killer in the Carolinas, and rip currents generated by swells from distant tropical cyclones pose a unique messaging challenge for the National Weather Service (NWS). A database of surf fatalities from Atlantic basin tropical cyclones was compiled, with 87 surf fatalities along the continental United States coastline between 2000 and 2022 attributed to distant storms, where direct impacts from the storm remained far from the local area. Hurricane Lorenzo in 2019 led to eight drownings along the United States East Coast despite remaining more than 3110 km (1680 n mi) offshore in the central Atlantic. The rip current impacts from Lorenzo led to efforts to increase communication and improve several products from the NWS offices in Wilmington and Morehead City, North Carolina. Efforts have also been made to increase the NWS reach into underserved communities and vulnerable populations, including translating rip current briefings into Spanish and developing a partnership with the North Carolina Division of Services for the Deaf and Hard of Hearing. In the last few years, NWS Wilmington has begun messaging rip current outbreaks similar to other weather threats, such as potential severe weather events.

1. Introduction

Rip currents are the deadliest and most common hazard people encounter at the beaches of North and South Carolina, and along most of the coastlines worldwide (Arozarena et al. 2015; Brewster et al. 2019; Brighton et al. 2013; Gensini and Ashley 2010). Rip currents are narrow, seaward flowing currents extending from near the shoreline out through the surf zone (Castelle et al. 2016). They form as incoming waves push water up the slope of the beach and, to remain in balance, excess water building in the surf zone seeks the path of least resistance as a rip current. Figure 1 shows the basic structure of a rip current with three main components: feeders, neck and head. The neck of the rip current is where the speeds are the strongest and where swimmers can get into trouble. Rip currents are often likened to treadmills and are capable of carrying people away from the shoreline and into deeper water. The United States Lifesaving Association estimates that rip currents are responsible for more than 100 drownings each year in the United States and contribute to more than 80% of lifeguard surf rescues (Brewster et al. 2019). The National Weather Service (NWS) Weather Forecast Office in Wilmington, North Carolina, has maintained a local database of confirmed rip current drownings in North and South Carolina since 2000, and is a more complete record than the NWS Storm Events Database. Based on these local records, 180 rip current drownings occurred in North and South Carolina between 2000 and 2022. This is more than the combined death toll from tornadoes, flooding, lightning, and wind recorded in both states during the same period, making rip currents the foremost weather threat to life in the Carolinas (NCEI 2023).

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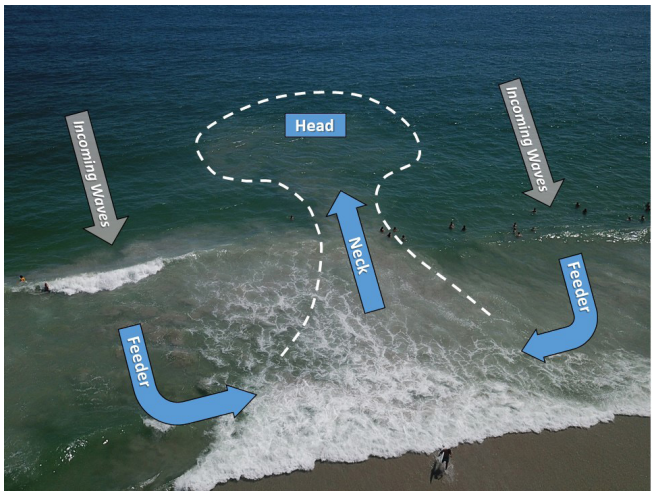


Figure 1. Basic structure of a rip current. Incoming waves pile water up at the shoreline. Feeder currents flow along the shoreline, converge, and form the offshore-directed neck of the rip current. The head of the rip current is past the breaking waves where the current dissipates and disperses. [Background image courtesy of Wrightsville Beach Fire Department (WBFD)]. *Click image for an external version; this applies to all figures hereafter.*

A wide variety of weather conditions can create life-threatening rip currents along the beaches, and the surf can be especially primed for rip current development from tropical cyclones (Gensini and Ashley 2010). Strong winds from a tropical cyclone can generate high-energy waves that pose a significant hazard to mariners and coastal areas. For example, Hurricane Lorenzo, a powerful Category 5 hurricane in the central Atlantic, generated large waves and long-period swells that propagated across most of the North Atlantic basin in late September and early October in 2019. These swells, roughly 15 m (50 ft) in height near the storm's center, arrived at the East Coast with wave heights of 0.9 to 1.2 m (3 to 4 ft) and periods of 13 to 16 seconds (NHC 2019). Roughly 6% of fatalities in the United States directly attributed to Atlantic tropical cyclones between 1963 and 2012 were caused by rough surf, including rip currents (Rappaport 2014). Research analyzing national rip current drownings from 1994 to 2012 by Paxton and Collins (2014) estimated that 9% of the drownings were associated with tropical cyclone swells. Similarly, records for the Carolinas reveal that 10% of rip current drownings between 2000 and 2022 were directly associated with tropical cyclones (NWS Wilmington 2022, unpublished data). There is also a peak in strong rip current occurrences reported by Wrightsville Beach Ocean Rescue (WBOR) in North Carolina during the month of September, correlating with the peak of the Atlantic hurricane season (Wrightsville Beach 2004-2022, personal communication).

Perhaps the most dangerous rip current scenario is associated with distant tropical cyclones. A distant storm is any storm that leads to only marine and surf impacts locally, either causing additional impacts elsewhere or remaining at sea. Waves created by tropical cyclones propagate far from the storm and impact coastlines hundreds or even thousands of kilometers (miles) away. As the waves break along the coast, they can produce rough surf and deadly rip current outbreaks that impact a large swath of beaches along the coast. Rip currents generated from offshore storms are significantly stronger, with strengthened channelized rip currents and an increase in the occurrence of flash rips (S. Proffitt, WBOR, 2024, personal communication; Castelle et al. 2016). According to Carolina Beach Ocean Rescue (CBOR), distant tropical cyclones pose the worst case scenario as the long period swell from the storms adds more natural energy and contributes to the flow strength of the rip currents (S. Kelly, CBOR, 2024, personal communication). While direct tropical cyclone impacts, such as rain and wind, associated with these scenarios typically remain far offshore, the local beach weather may create inviting and pleasant conditions for beachgoers. As a result, individuals engaging in recreational activities in the surf zone are likely to underestimate the rip current risk created by the swells originating from a distant tropical cyclone (Rappaport 2000).

Distant tropical cyclones pose a unique messaging challenge for the NWS and other partners in the community that aim to protect life and promote beach safety. It is difficult to communicate the significance of the hazardous conditions along the coast when the originating storm is far away and the local weather is benign. This became apparent in the Fall of 2019 when Hurricane Lorenzo generated swells that resulted in eight surf-related fatalities along the East Coast despite remaining more than 3110 km (1680 n mi; Fig. 2) from the United States (NHC 2019). During the Lorenzo swell event, a prolonged High Rip Current Risk was issued by the NWS along a large segment of the United States East Coast. In addition, multiple local, regional, and national news outlets highlighted the impending threat from Lorenzo's swells along the coast. Despite these efforts, multiple drownings from Florida to Rhode Island still occurred. The impact from Hurricane

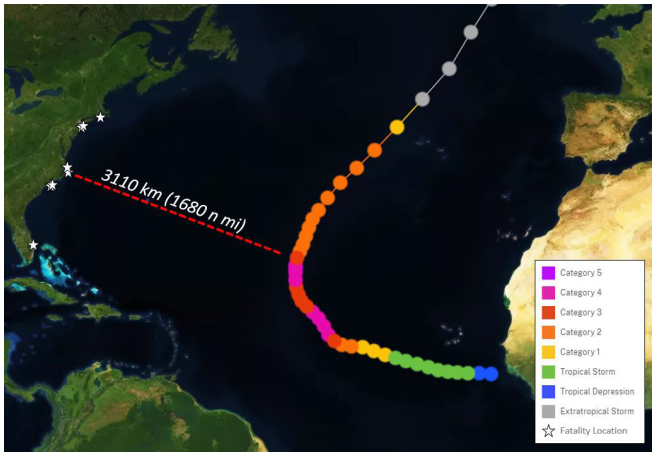


Figure 2. Track and intensity of Hurricane Lorenzo (2019) in the eastern and central Atlantic Ocean with a notation of Lorenzo's closest approach to the United States of 3110 km (1680 n mi). Lorenzo briefly strengthened to a Category 5 hurricane at 0300 UTC on 29 September 2019 near where the storm made its closest approach. The locations of the eight surf fatalities attributed to Lorenzo are marked along the East Coast. Track image from NOAA Historical Hurricane Tracks database [Available online at coast.noaa.gov/hurricanes/].

Lorenzo led to increased efforts within the NWS to improve communications for these meteorological situations, including increasing rip current education efforts and working with coastal and inland partners to reduce loss of life in future events (Oliva et al. 2021).

Weather forecasts, including rip currents, are only valuable if they are received and understood by those that need the information, whether it is decision makers or the public. To achieve this, the NWS embraced the Impact-Based Decision Support Services (IDSS) approach as early as 2011, as highlighted by Uccellini and Ten Hoeve (2019). Even though a formal update to the NWS Mission Statement to include IDSS principles was not made until 2021, local NWS offices increased IDSS services through the 2010s. IDSS focuses on delivering forecast information and interpretative services to NWS partners to safeguard life and property, utilizing tools such as email briefings, conference calls, or on-site support (e.g., decision support provided by NWS meteorologists deployed to an Emergency Operations Center). Improving forecasts represents just a segment of the broader strategy, with the NWS continuously exploring methods to effectively convey the forecasts and hazards to decision-makers before and throughout events, thereby empowering them to prepare for and respond to extreme weather, water, and climate events.

A primary communication challenge is reaching the inland population with rip current forecasts and safety information. People from across the country visit Carolina beaches, and exposure to rip current safety information for the inland demographic is typically minimal. As a result, these visitors may be less familiar with the rip current hazard, making them less likely to know how to respond if they find themselves caught in a rip current or witness someone struggling in the surf. In addition, tourists are more likely to choose swimming locations based on convenience versus safety (i.e., choosing the beach closest to their location rather than seeking out a lifeguarded one) and may also underestimate their risk in favor of enjoying their vacation (Menard et al. 2018; Williamson et al. 2012). Between 2000 and 2022, 51% of the rip current drownings in the Carolinas involved non-residents (i.e., individuals from outside North Carolina and South Carolina), with only 19% of the fatalities residing in the coastal counties of the Carolinas (NWS Wilmington 2022, unpublished data). Thus, there is a need to increase rip current education and awareness nationwide, including landlocked states, to better prepare vacationers before they visit the beach.

Another communication challenge for the NWS for all weather hazards is reaching historically underserved and socially vulnerable communities (HUSVC). This challenge arises from a combination of factors, including language barriers and historically limited direct communication with these communities. As a result, reaching HUSVCs can be difficult, especially when there are currently little to no established connections. The Department of Commerce (DOC) Equity Action Plan (2022) identified ways to create a more equitable and inclusive economy by addressing key barriers for HUSVCs. Within the plan, the National Oceanic and Atmospheric Administration (NOAA) was tasked with "enhancing community engagement to ensure HUSVCs can access data and programs needed to build climate resilience." As part of NOAA, the NWS has been working hard in recent years to build partnerships with HUSVCs to promote inclusive weather resiliency in all communities.

2. Atlantic tropical cyclones and surf fatalities

To better quantify the surf impact from tropical cyclones, particularly distant storms, a database was compiled of surf fatalities attributed to Atlantic basin

tropical cyclones in the continental United States (CONUS) using data from 2000 to 2022. To do this, information was pulled from the National Hurricane Center (NHC) Tropical Cyclone Reports (TCR), National Centers for Environmental Information (NCEI) Storm Events Database, and media articles. Fatalities included in the study were those clearly linked to a tropical cyclone event, ruled as an accidental drowning, and limited to people within the surf zone. To have a clear link to a tropical cyclone, the surf fatality had to either be explicitly mentioned in a TCR, connected to a storm in the Storm Events Database narrative, or occurred as tropical swells were impacting local waters per NWS forecast products. Fatalities involving vessels such as boats or jet skis were excluded. It is worth noting that the cause of all surf drownings cannot be determined, especially as a large percentage of drownings occur when no lifeguards are present, and thus may lack eyewitnesses or may be observed by untrained people (Brewster et al. 2019). In addition, not all drownings are reported by the media, and some may remain unknown to the NWS and therefore are undocumented. Even though the database created may not be comprehensive, it provides important statistics that can be used to enhance outreach and education efforts regarding the surf hazards associated with tropical cyclones.

A total of 147 surf fatalities related to Atlantic basin tropical cyclones between 2000 and 2022 occurred along the continental United States coastline. Figure 3 shows a breakdown of the fatalities by year and classified by whether the fatality was rip current related and/or caused by a distant storm. In this study, a distant storm is any storm that led to only maritime and surf impacts at the fatality location, either causing additional impacts elsewhere in the United States or remaining out at sea. Of the 147 known fatalities, 103 were attributed to rip currents, with 44 drownings related to other hazardous surf conditions (e.g., large breaking waves). In 2020, there were more surf fatalities due to Atlantic tropical cyclones than in any other year, with a total of 18 deaths from 10 different storms. This increase occurred during the most active Atlantic hurricane season on record (NOAA 2020).

Demographics, circumstances, and location of each recorded fatality were documented (Table 1). Out of the 147 fatalities, 129 (88%) were male, reflecting the common demographic trend among coastal drowning victims. Most drowning victims are male due to their likeliness to engage in water activities, increased confidence in swimming abilities, increased use of alcohol, and greater willingness to conduct a rescue (Driscoll et al. 2004; Gensini and Ashley 2010; Howland et al. 1996; Lawes et al. 2020; McCool et al. 2008; Moran and Stanley 2013). Similar to local and national drowning statistics, 50% of the fatalities in this study were out-of-state visitors. Figure 4 is a map of the hometown locations (if known) of the Atlantic tropical cyclone-related surf fatalities from 2000 to 2022, showing a large spread inland and even internationally.

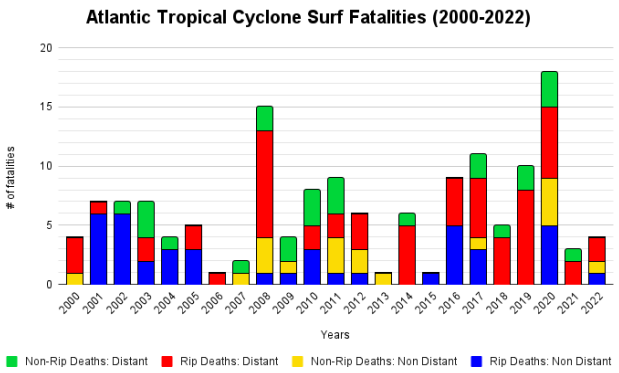


Figure 3. Annual distribution of surf fatalities along CONUS coastline associated with Atlantic basin tropical cyclones from 2000 to 2022. Fatalities are characterized by rip current and non-rip current incidents, in addition to whether the fatality was caused by local or distant tropical cyclones. Database was compiled using data from NHC (2023), NCEI, and media reports.

Table 1. Demographic and geographic analysis of Atlantic basin tropical cyclone surf fatalities between 2000 and 2022. Demographic statistics shown are gender, residency status relative to drowning location, and whether victim was a bystander attempting a rescue. Also shown is whether the tropical cyclone was distant or not (relative to drowning location) and a state breakdown of fatality locations. Database was compiled using data from NHC (2023), NCEI, and media reports.

Atlantic Tropical Cyclone Surf Fatalities				
	Total	**Percentage**	**States**	
Male	129	88%	FL	62
Female	18	12%	NJ	19
			NC	19
Out of State	74	50%	AL	9
			TX	8
Bystander	20	14%	NY	7
			RI	6
Local Storms	60	41%	SC	6
Distant Storms	87	59%	LA	4
			MD,CT,MA,ME,VA	1

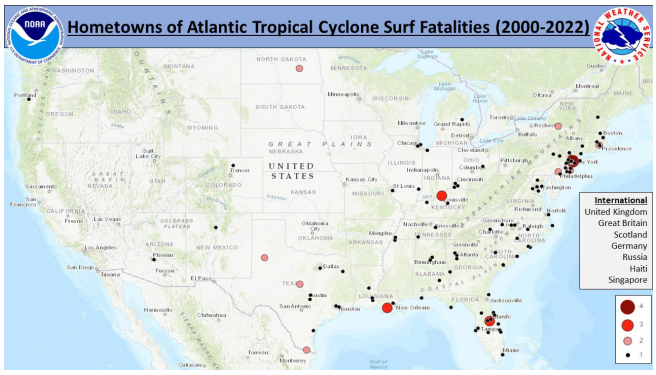


Figure 4. Map of hometown locations of surf fatalities attributed to Atlantic basin tropical cyclones from 2000 to 2022, with marker size and color corresponding to the number of fatalities from that location. Map highlights the distribution of affected individuals far from the coastline, including a number of international hometowns listed. Hometowns were recorded using data from NHC (2023), NCEI, and media reports.

Individuals who reside inland but visit the beach for recreation are at an increased risk of drowning due to rip currents and other beach hazards.

As expected, Florida recorded more surf fatalities linked to Atlantic basin tropical cyclones than any other state. Several factors contribute to this trend, including Florida's long and extensive coastline, a thriving tourism industry, its characteristic warm air and sea surface temperatures, and its susceptibility to storms in both the Gulf of Mexico and the Atlantic Ocean. There are four main hotspot regions for East Coast and Gulf of Mexico surf fatalities due to Atlantic basin tropical cyclones: the Florida panhandle and Alabama beaches, Florida's eastern coast, North Carolina, and the New York-New Jersey region.

Another important fact is a tropical cyclone does not have to reach hurricane strength to generate hazardous surf. Of the 147 known fatalities, 44 were attributed to tropical storms. Although tropical storms are less likely to be considered distant threats because their winds lack the intensity to produce powerful swells over long distances, additional factors such as storm size, history, and background synoptic conditions can contribute to the surf impacts from a storm. A strong tropical storm can still create hazardous surf conditions hundreds of miles away from its center, underscoring the need to continuously monitor potential coastal impacts.

Although significant attention is typically given to tropical cyclones forecasted to make landfall or approach the coastline, a distant tropical cyclone often receives less public attention, leading to a reduced awareness of potential threats. As indicated in Table 1, 87 (59%) of the surf fatalities resulting from Atlantic basin tropical cyclones were associated with distant storms. As mentioned before, a distant storm is any storm that led to only marine and surf impacts at the fatality location, either causing additional impacts elsewhere in the United States or remaining out at sea.

To further break down the data, 45 (31%) of the fatalities were attributed to cyclones where there were no local impacts besides hazardous surf and marine conditions, but the storm impacted elsewhere in the United States. For instance, Hurricane Delta in 2020 made landfall in southwestern Louisiana but led to two surf drownings in the Florida panhandle, more than 482 km (300 mi) to the east. Additionally, 42 (29%) of the fatalities were linked to truly distant tropical cyclones, mostly hurricanes. In this case, truly distant tropical cyclones are storms that had no impact on the United States except for hazardous marine and surf conditions, with Hurricane Lorenzo in 2019 and Hurricane Fiona in 2022 as prime examples. Figure 5 shows drone footage captured at Wrightsville Beach, North Carolina showing numerous strong rip currents along the coastline created by swells from Fiona.

3. Hurricane Lorenzo (2019)

Hurricane Lorenzo was a powerful tropical cyclone in the eastern and central Atlantic from 22 September 2019 through 4 October 2019. At its peak, Lorenzo was a 72 m s-1 (140 kt), Category 5 hurricane on the Saffir-Simpson Scale, the highest wind speed for any hurricane east of 50°W in the Atlantic hurricane database dating back to 1851 (NHC 2019). From 26-30 September 2019, Lorenzo maintained its intensity as a Category 2 or stronger hurricane. During this time frame, Lorenzo was either moving directly toward the United States (i.e., west-northwestward) or moving slowly. This was key to the generation of impressive long period swells that traversed the Atlantic, reaching the East Coast approximately four days later with wave heights of 0.9 to 1.2 m (3 to 4 ft) and periods of 13 to 16 seconds.

The long-period swells from Hurricane Lorenzo led to a deadly rip current outbreak along the United States East Coast, with strong rip currents and hazardous surf conditions along much of the coastline. During the period from 30 September 2019 to 3 October 2019, a total of eight lives were lost, with six of these fatalities attributed to rip currents. These incidents occurred from

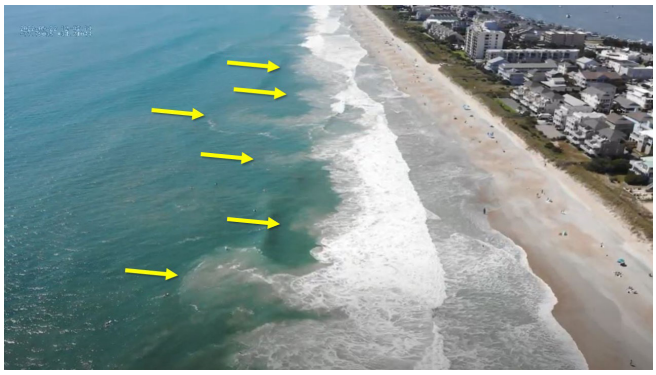


Figure 5. Drone footage capturing numerous rip currents at Wrightsville Beach, North Carolina, created by swells from Hurricane Fiona, more than 805 km (500 mi) away, in September 2022. Arrows point to several of the individual rip currents seen along the coastline. (Image courtesy of WBFD).

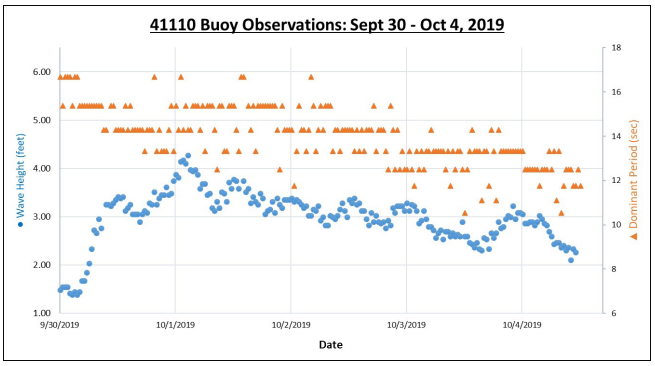


Figure 6. Observations from Buoy 41110 (Masonboro Inlet, ILM2) showing wave height (ft) and dominant period (seconds) during the peak of Hurricane Lorenzo swells from 30 September to 4 October 2019, located 10 km (6.2 mi) southeast of Wrightsville Beach, North Carolina (data from NDBC).

Florida to Rhode Island (Fig. 2), with four fatalities recorded in North Carolina alone. What made this situation particularly noteworthy was that Hurricane Lorenzo never approached closer than 3110 km (1680 n mi) to the East Coast. Despite its distant location, Lorenzo was responsible for more surf-related fatalities than any other tropical cyclone since Hurricane Gabrielle in 1989, which also claimed eight lives along the Northeast United States Coast (Rappaport 2000).

Multiple factors contributed to the significant loss of life caused by Hurricane Lorenzo. The most important factor was the swell generated by the storm. Low wave height, high period swell events are especially dangerous along the coast, as they can create deceptive lulls in the wave sets, making the surf look inviting to beachgoers at times. Figure 6 shows observations from the University of North Carolina Wilmington's (UNCW) Coastal Ocean Research and Monitoring Program (CORMP) buoy 41110, located 10 km (6.2 mi) southeast of Wrightsville Beach, North Carolina, with multiple days of 0.61 to 1.2 m (2 to 4 ft) long period swells (NDBC 2019).

Another contributing factor was the anomalously warm weather that coincided with the arrival of Lorenzo's swells along the East Coast. Surface analyses from the NOAA/NWS Weather Prediction Center (not shown) revealed a ridge of high pressure situated along the East Coast from 30 September through 1 October, shifting southward on 2 October. This contributed to above-normal air temperatures at many East Coast locations during this period. In addition, in southeastern North Carolina, the water temperature at Wrightsville Beach was between 27°C and 28°C (80°F and 82°F), which is more typical for mid-July through early September (NOAA Center for Operational Oceanographic Products and Services 2019; NWS Wilmington 2019). The combination of warm air and sea water temperatures created pristine late-season beach conditions, potentially giving the public a false sense of security because of Lorenzo's offshore trajectory. It is also worth noting that the beach season had already ended for many North Carolina lifeguards as beach attendance typically decreases beyond early September.

The Surf Zone Forecasts issued by NWS offices along the East Coast forecasted a High Rip Current Risk between 30 September and 3 October due to the arrival of Lorenzo's swells. Hazardous surf conditions and dangerous swells were also messaged through multiple NWS social media platforms and included in the NHC Public Advisories for Lorenzo. Several national news outlets, such as CNN and The Weather Channel, along with numerous local and regional media partners, highlighted the surf hazard from Hurricane Lorenzo in their coverage. Despite accurate forecasting, considerable messaging, and widespread media attention, eight drownings occurred within four days, all attributed to Lorenzo, demonstrating that forecast information is only valuable if it is received and acted upon by those who need it.

The impact of Hurricane Lorenzo became a catalyst for an increased focus on the threat posed by distant tropical cyclones within the NWS. Subsequent efforts have been made to bolster communication and enhance messaging before and during dangerous surf conditions associated with distant tropical systems, including the development of specialized, dedicated weather briefings.

Additionally, there has been an expansion and increased frequency of outreach and education initiatives aimed at raising awareness to these hazards among the public, especially within HUSVCs and those located inland, during pre-season hurricane presentations.

4. Recent IDSS successes

One of the main principles of IDSS is providing actionable forecast information to core partners and decision makers to enhance decision-making, promote safety and awareness, and maximize the reach of critical information aimed at protecting lives and livelihoods, and enhancing the national economy. In the years since Hurricane Lorenzo, both NWS Wilmington and NWS Newport/Morehead City, North Carolina, have ramped up their communication efforts with partners and the public whenever a distant tropical cyclone is forecasted to produce dangerous surf conditions along local beaches. In 2020, the offices instituted a new policy to create dedicated one-page briefings before and during these events, with an example shown in Fig. 7. These briefings are disseminated via email to partners (e.g., emergency managers, media, universities, and beach rescue) and made available on the forecast offices' websites, with partners helping to force multiply awareness of the threat within their communities. Additionally, there has been an increased emphasis on leveraging social media channels to broadcast alerts when there is the potential for a rip current outbreak at local beaches, especially in cases involving distant tropical cyclones. Figure 8 shows two examples of social media posts created by NWS Wilmington highlighting the surf threat from Hurricanes Earl (2022) and Lee (2023), with both posts reaching roughly 30 000 people each per Facebook analytics. In some respects, NWS Wilmington has adopted a similar approach to communicating rip current threats as it does for other weather-related hazards, such as potential severe weather outbreaks.

In 2021, the Carolinas experienced the impacts of three offshore hurricanes that led to rip current outbreaks: Henri, Larry, and Sam. Henri initially formed as a strong tropical storm in the western Atlantic and transitioned into a hurricane as it moved northward, tracking a few hundred miles east of North Carolina. Larry and Sam, on the other hand, were hurricanes that formed in the deep tropics of the Cape Verde region in the eastern tropical Atlantic and reached Category 3 and 4 strength, respectively, before turning northward east

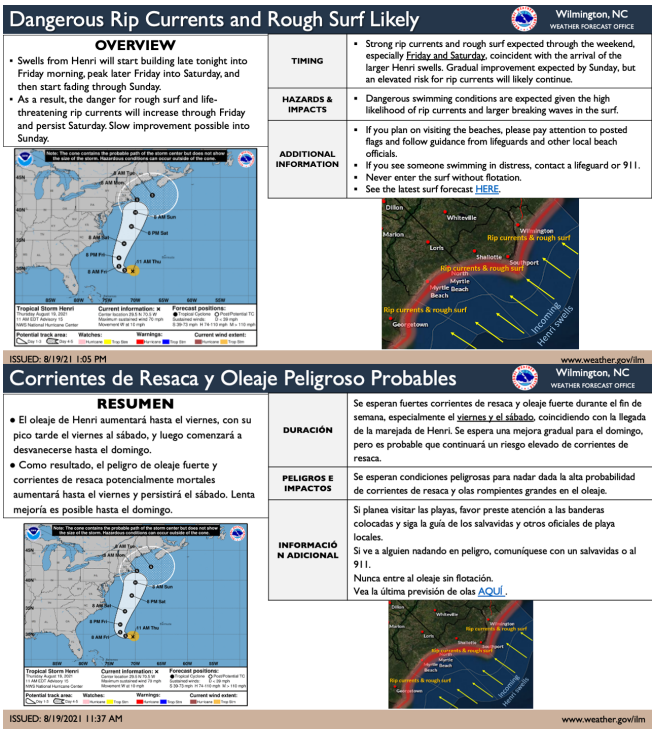


Figure 7. Briefing issued by NWS Wilmington, North Carolina, highlighting dangerous surf conditions expected from Hurricane Henri, distributed on 19 August 2021 in English (top) and Spanish (bottom).

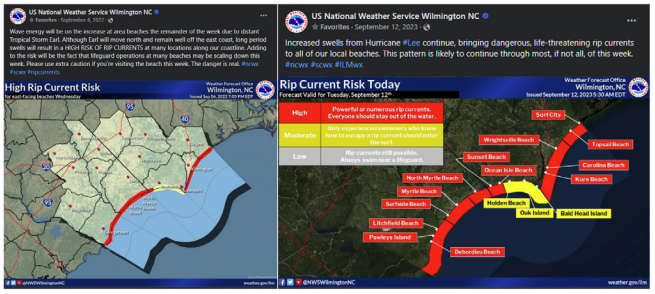


Figure 8. Social media posts created by NWS Wilmington highlighting the local surf threat created by distant tropical cyclones, namely the high rip current risk, for the majority of beaches across southeastern North Carolina and northeastern South Carolina. Left: Post from 6 September 2022 for Hurricane Earl (still a tropical storm when post was created). Right: Post from 12 September 2023 for Hurricane Lee.

of Bermuda. These three storms all generated strong rip currents and high surf conditions along the beaches of New Hanover County, North Carolina (where the city of Wilmington and Wrightsville Beach are located), leading to numerous rescues. Notably, on 2 October 2021, with Hurricane Sam well offshore, Wrightsville Beach Ocean Rescue reported 30 rip current rescues,

marking the highest number of single-day rescues in the month of October since NWS Wilmington began collecting data from Wrightsville Beach in 2004. Unfortunately, one local fatality was reported in North Myrtle Beach, South Carolina, as a result of rough surf caused by Hurricane Larry, which was also responsible for two rip current drownings, one in Florida and one in Virginia.

The following year, the Carolinas experienced the impacts of two distant hurricanes. Hurricane Earl (Category 2) and Hurricane Fiona (Category 4) moved across the western Atlantic more than 1287 km (800 mi) and 805 km (500 mi) east of the Carolinas, respectively, in September 2022. Both storms resulted in the formation of strong rip currents and rough surf at local beaches. There were no fatalities in the Carolinas from either of these storms, though it is understood that it is impossible to connect the reduction of surf fatalities attributed to tropical cyclones in the Carolinas in the last few years to any specific reason, including increased NWS efforts.

Several one-page briefings were created for each of the aforementioned storms to highlight the expectancy of dangerous rip currents and rough surf. These briefings were sent to partners of NWS Wilmington, North Carolina, who, in turn, disseminated the messages within their communities and organizations for further distribution. Overwhelming positive feedback was received from these partners in response to these briefings. A local TV station expressed its appreciation for the forecasts and briefings related to distant hurricanes, as it made it simpler for their team to repackage the information and communicate timing and impacts across their news and weather platforms. UNCW reported that the notifications allowed their team to effectively inform the campus community of the dangerous surf conditions. They forwarded the briefings to more than 16 000 students, faculty, and staff, and utilized the information campus-wide to enhance safety measures and protect the community.

To reach additional community members, NWS Wilmington, North Carolina, enlisted the support of the NWS Multimedia Assistance in Spanish (MAS) team. The MAS team, comprising Spanish-speaking NWS employees on a volunteer basis, were available to assist an NWS office based on its specific needs during events (Bermudez and Zeitler 2018; Torres 2018). They generously volunteered their time to translate materials, create talking points, and conduct Spanish-language interviews during significant weather events. During distant tropical cyclone events, the MAS team played a vital role in translating NWS Wilmington briefings into Spanish (refer to Fig. 7). These translated briefings were subsequently shared with partners and posted on social media platforms to more effectively reach non-English speaking residents in the local population. Translated versions of the briefings were distributed to various organizations, including New Hanover County Emergency Management, the North Carolina Latino Alliance, and the Latino Center at UNCW, among others. The United States Census Bureau (2022) estimates that 12.3% of North Carolina's population speaks a language other than English at home, with 7.6% in South Carolina, and the NWS strives to reach these communities whenever possible.

Additional service equity community engagement efforts have been conducted by NWS Wilmington to help educate the local deaf and hard of hearing community through a partnership with the North Carolina Division of Services for the Deaf and Hard of Hearing (NC DSDHH). In 2020, NWS Wilmington teamed up with NC DSDHH to host a virtual webinar to discuss rip current basics and life-saving information. This webinar included American Sign Language (ASL) interpreters via webcam, as well as captioning services during the live presentation, with the purpose of reaching members of the community that might have been physically unable to participate in similar outreach events in the past. In 2022, during an annual Beach Hazards and Rip Current Workshop hosted by NWS Wilmington and NWS Newport/Morehead City for core partners, an ASL interpreter was available throughout the two-day virtual event to extend the reach to partners within the deaf and hard of hearing community.

As roughly 30% of the rip current fatalities in the Carolinas involved residents from inland parts of North and South Carolina, coastal Carolina NWS offices have started to work closely with neighboring inland forecast offices to enhance the communication with their communities. This includes sharing rip current and beach safety information with the public and their partners before and during the beach season. Inland offices proactively send emails to their partners, providing timely information about the rip current threat along the coast resulting from distant hurricanes. Additionally, they are more actively raising awareness through social media channels and share informative posts from coastal offices.

There have also been several NWS product enhancements in recent years, which help improve IDSS

during potential rip current outbreaks. In 2020, NWS Wilmington, in collaboration with several other East Coast NWS offices, initiated an experiment involving enhanced wave terminology in local Coastal Waters Forecasts (CWF) available on the web (Fig. 9), an effort that began at NWS Eureka, California, (Scalora et al. 2023). The project's objective was to incorporate wave detail components into NWS forecasts, highlighting multiple wave systems present within the local waters. This additional information provided valuable insights for marine customers, especially those vulnerable to particular sea states. The new marine forecast product highlighted significant wave events, including those that might lead to dangerous rip current outbreaks, by presenting essential data such as wave height, wave period, and wave direction information in both time and space. The wave detail experiment became operational in the spring of 2024 for all coastal NWS offices, with the exception of Alaska.

In the summer of 2021, NWS Wilmington launched an Experimental Surf Forecast Matrix product, making it accessible to both partners and the public on the web (Fig. 10). The official Surf Zone Forecast (SRF) issued by NWS offices contains a full two-day forecast, providing a single forecast for each day per coastal county. However, surf zone conditions can change throughout the day and vary along the coastline. Leveraging recent advancements in wave modeling and rip current forecasting, NWS Wilmington developed surf forecast matrices with parameters similar to the operational SRF product. These matrices provide 6-day forecasts, broken down into 3-hourly and 6-hourly increments, and there is an individual matrix available for popular beaches within the Wilmington, North Carolina, forecast area. This experiment aims to equip decision-makers and the public with the information they need to plan for potentially hazardous surf conditions. Since 2021, the Experimental Surf Forecast Matrix product has expanded to a few other East Coast and Gulf Coast offices, including NWS Wakefield, Virginia, with further expansions planned for the future.

The NWS is also actively working to improve the prediction of rip currents. NOAA launched the first national rip current forecast model in 2021. This model utilizes input from the Nearshore Wave Prediction System (NWPS) to predict the likelihood of hazardous rip currents. Since then, the Meteorological Development Laboratory (MDL) has contributed by providing probabilistic rip current forecast guidance to NWS offices using regional and seasonal logistic regression equations, calibrated to local conditions with input from local lifeguard reports (Im et al. 2021). These advancements aim to refine rip current forecasting at both the national and local levels.

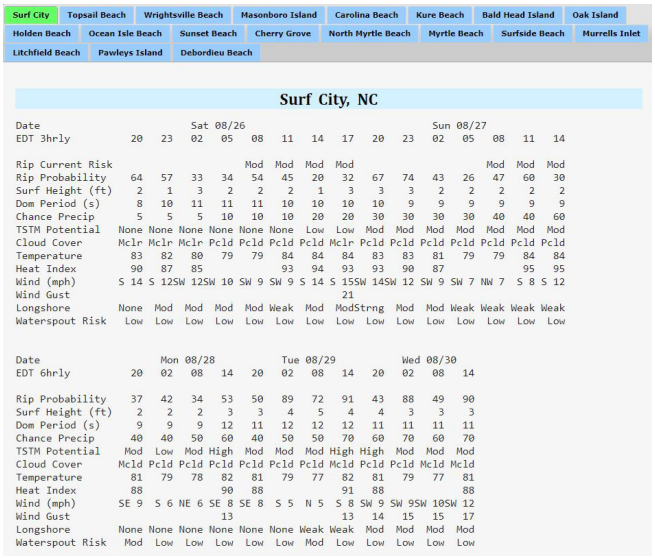
AMZ250-261400-
Coastal waters from Surf City to Cape Fear NC out 20 nm-
942 PM EDT Fri Aug 25 2023

.THROUGH 7 AM...S winds 10 to 15 kt with gusts up to 20 kt. Seas 2 to 3 ft. Wave Detail: E 3 ft at 13 seconds and E 2 ft at 7 seconds. Isolated showers.
.TODAY...S winds 5 to 10 kt, increasing to 10 to 15 kt with gusts up to 20 kt in the afternoon. Seas 2 to 3 ft. Wave Detail: E 3 ft at 13 seconds and E 2 ft at 7 seconds. Isolated showers.
.TONIGHT...S winds 10 to 15 kt. Gusts up to 20 kt in the evening. Seas 3 ft. Wave Detail: E 3 ft at 8 seconds and SE 2 ft at 11 seconds.
.SAT...SW winds 5 to 10 kt, increasing to 10 to 15 kt with gusts up to 20 kt in the afternoon. Seas 2 to 3 ft. Wave Detail: SE 3 ft at 10 seconds and SW 2 ft at 3 seconds. A slight chance of showers and tstms in the afternoon.
.SAT NIGHT...SW winds 10 to 15 kt with gusts up to 20 kt, diminishing to 5 to 10 kt after midnight. Seas 2 to 3 ft. Wave Detail: E 3 ft at 10 seconds and SW 2 ft at 3 seconds. A slight chance of showers and tstms in the evening, then a chance of showers and tstms after midnight.
.SUN...W winds 5 to 10 kt, becoming S in the afternoon. Seas 2 to 3 ft. Wave Detail: E 2 ft at 9 seconds and SE 1 ft at 10 seconds. A chance of showers and tstms.

Figure 9. Experimental Coastal Waters Forecast (CWFILM) text product issued by NWS Wilmington, North Carolina, for 25 August 2023, which includes information on multiple wave systems in addition to the standard wind, seas and storm chances in the operational CWF product. The wave detail experiment became operational in the Spring of 2024 for all coastal NWS offices, with the exception of Alaska.

5. Discussion

Nearly 90% of all tropical cyclone related deaths are water related: storm surge, rain and inland flooding, hazardous surf, and rough marine conditions (Rappaport 2014). Of these water related hazards, the hazardous surf threat can easily be overlooked or underestimated, especially when it is the result of a distant hurricane. It is more likely for the public to disregard, or misjudge, the threat from a storm hundreds or thousands of miles away versus a tropical cyclone forecasted to directly impact their location with rain, wind, and/or surge. The database of surf fatalities from Atlantic basin tropical cyclones shows that the threat to life from distant storms is real, with 87 surf fatalities along the continental United States coastline between 2000 and 2022 attributed to distant storms. In recent years, NWS Wilmington and NWS Newport/Morehead City, North Carolina, recognized more could be done by the NWS



Surf City | Topsail Beach | Wrightsville Beach | Masonboro Island | Carolina Beach | Kure Beach | Bald Head Island | Oak Island
Holden Beach | Ocean Isle Beach | Sunset Beach | Cherry Grove | North Myrtle Beach | Myrtle Beach | Surfside Beach | Murrells Inlet
Litchfield Beach | Pawleys Island | Debordieu Beach

Surf City, NC

Date			Sat 08/26								Sun 08/27				
EDT 3hrly	20	23	02	05	08	11	14	17	20	23	02	05	08	11	14
Rip Current Risk					Mod	Mod	Mod	Mod					Mod	Mod	Mod
Rip Probability	64	57	33	34	54	45	20	32	67	74	43	26	47	60	30
Surf Height (ft)	2	1	3	2	2	2	1	3	3	3	2	2	2	2	2
Dom Period (s)	8	10	11	11	11	10	10	10	10	9	9	9	9	9	9
Chance Precip	5	5	5	10	10	10	20	20	30	30	30	30	40	40	60
TSTM Potential	None	None	None	None	None	None	Low	Low	Mod	Mod	Mod	Mod	Mod	Mod	Mod
Cloud Cover	Mclr	Mclr	Mclr	Pcld	Pcld	Pcld	Pcld	Mclr	Pcld	Pcld	Pcld	Pcld	Pcld	Pcld	Pcld
Temperature	83	82	80	79	79	84	84	84	83	83	81	79	79	84	84
Heat Index	90	87	85			93	94	93	93	90	87			95	95
Wind (mph)	S 14	S 12	SW 12	SW 10	SW 9	SW 9	S 14	S 15	SW 14	SW 12	SW 9	SW 7	NW 7	S 8	S 12
Wind Gust								21							
Longshore	None	Mod	Mod	Mod	Mod	Weak	Mod	ModStrng		Mod	Mod	Weak	Weak	Weak	Weak
Waterspout Risk	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

Date		Mon 08/28			Tue 08/29				Wed 08/30		
EDT 6hrly	20	02	08	14	20	02	08	14	20	02	08	14
Rip Probability	37	42	34	53	50	89	72	91	43	88	49	90
Surf Height (ft)	2	2	2	3	3	4	5	4	4	3	3	3
Dom Period (s)	9	9	9	12	11	12	12	12	11	11	11	11
Chance Precip	40	40	50	60	40	50	50	70	60	70	60	70
TSTM Potential	Mod	Low	Mod	High	Mod	Mod	Mod	High	High	Mod	Mod	Mod
Cloud Cover	Mcld	Pcld	Pcld	Pcld	Pcld	Pcld	Pcld	Mcld	Pcld	Pcld	Mcld	Mcld
Temperature	81	79	78	82	81	79	77	82	81	79	77	81
Heat Index	88			90	88			91	88			88
Wind (mph)	SE 9	S 6	NE 6	SE 8	SE 8	S 5	N 5	S 8	SW 9	SW 9	SW 10	SW 12
Wind Gust				13				13	14	15	15	17
Longshore	None	None	None	None	None	None	Weak	Weak	Mod	Mod	Mod	Mod
Waterspout Risk	Mod	Low	Low	Low	Low	Low	Mod	Low	Low	Low	Low	Low

Figure 10. Experimental Surf Forecast Matrix issued by NWS Wilmington, North Carolina, on 26 August 2023, with detailed surf and weather forecast information every 3 to 6 hours for the next six days. A separate matrix is included for popular beaches within the NWS Wilmington forecast area. [Product available online at www.weather.gov/ilm/surfmatrices].

to mitigate the loss of life from distant storms, and both offices began ramping up messaging before and during rip current outbreaks created by distant tropical cyclones to introduce greater visibility to the threat.

Enhanced messaging is just one aspect of the challenge. Ensuring that vital and potentially lifesaving information reaches underserved and vulnerable populations is equally important, in addition to reaching beachgoers from inland areas. Collaboration between the NWS and social scientists are underway to develop and refine strategies for reaching these communities effectively. The NWS must do more than just tailor messages; local forecast offices need to establish robust communication and outreach strategies, such as creating dedicated briefings for potential rip current outbreak events. The imperative is to ensure that all beachgoers, regardless of their origin or background, receive timely and actionable information and are well-informed about potential hazards before venturing into the ocean. Working with local partners or using NWS resources, such as NC DSDHH and the NWS MAS team, can assist with reaching additional community members. Coastal NWS offices must also continue to work with inland forecast offices to expand beach safety communication efforts beyond the coastline. This may include inviting inland NWS partners to beach hazards workshops hosted by coastal NWS offices, or working with inland NWS offices to share hazardous surf forecasts with their communities. In addition, improved rip current forecasts and enhanced messaging are only as good as the action taken by those that receive them. If a potential beachgoer does not take action, despite knowing the potential risks, then any messaging becomes ineffective. This is especially true for tourists who may be more focused on enjoying their vacation rather than following any advice to stay out of the ocean.

Another piece of the puzzle that warrants discussion is the presence of lifeguards. It is well documented that most surf zone drownings occur either on unguarded beaches or when lifeguards are off duty (Arozarena et al. 2015; Brewster et al. 2019; Hartmann 2006), and the United States Lifesaving Association has calculated that the chance of a person drowning while lifeguards are present is 1 in 18 million (Branche and Stewart 2001). Almost half of the surf fatalities due to Atlantic tropical cyclones since 2000 (71 out of 147, or 48%) occurred during the months of September to November, which is late in the year with respect to the typical beach season. Particularly for beaches in the Mid-Atlantic and the Northeast, water temperatures cool and beach populations decrease after Labor Day, and lifeguard presence after early September varies from beach to beach. Although there are numerous challenges related to lifeguard staffing and scheduling, as well as whether an area is guarded or unguarded in the first place, beaches that are more likely to experience late season rip current outbreaks from tropical cyclones would benefit from having plans in place to protect beachgoers during these hazardous events.

6. Conclusions

Distant tropical cyclones pose a unique and often underestimated threat to beachgoers due to the deceptive combination of potentially benign local weather and powerful swells generated hundreds or even thousands of kilometers (miles) away. These swells can create dangerous rip currents and rough surf conditions, catching people off guard. Fifty-nine percent of known surf fatalities along the CONUS coastline attributed to Atlantic basin tropical cyclones were linked to distant storms, defined as those causing only marine and surf impacts at the fatality location, with the rain and winds associated with the tropical cyclone remaining far from land.

The wake-up call came in 2019 when Hurricane Lorenzo, despite maintaining a distance of more than 3110 km (1680 n mi) from the United States East Coast, claimed eight lives due to rip currents and rough surf. This tragic event prompted a concerted effort within the NWS to improve the communication and messaging of these often-overlooked threats. At a local level, dedicated briefings are now issued and disseminated to partners along the coastal Carolinas in anticipation of and during rip current outbreaks caused by distant tropical cyclones. Moreover, an increased presence on social media platforms has helped to amplify messaging to increase awareness of the dangerous threat.

NWS efforts to actively address the surf threat posed by tropical cyclones, particularly distant storms, are relatively new and still evolving. It is difficult, if not impossible, to measure the success of enhanced messaging and product improvements in recent years with only a handful of storms to evaluate. The more people that can be reached before and during rip current outbreaks, and the more information decision-makers have to prepare and respond to events, the better the chances lives can be saved. Looking ahead, the hope is for rip current outbreaks, particularly those originating from distant storms, to receive the same level of attention and preparedness as other well-publicized weather threats, such as severe weather outbreaks. By doing so, the NWS and its partners can aim to protect the public more effectively and work towards a reduction in surf-related fatalities.

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