



# National Transportation Safety Board

Washington, DC 20594

## Safety Recommendation Report

### Tropical Cyclone Information for Mariners

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<b>Accident Number:</b>	DCA16MM001
<b>Vessel:</b>	SS <i>El Faro</i>
<b>Owner/Operator:</b>	TOTE Maritime Puerto Rico/TOTE Services, Inc.
<b>Location:</b>	40 nautical miles northeast of Acklins and Crooked Islands, Bahamas
<b>Date:</b>	October 1, 2015
<b>Adopted:</b>	June 20, 2017

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The National Transportation Safety Board (NTSB) is providing the following information to urge the National Oceanic and Atmospheric Administration (NOAA), the National Weather Service (NWS; a component of NOAA), and the US Coast Guard to take action on the safety recommendations in this report. The recommendations address, in the interest of mariner safety, the development of tropical cyclone information and its availability to mariners. The recommendations derive primarily from factual information gathered during the NTSB's ongoing investigation into the sinking of cargo vessel *El Faro* on October 1, 2015.

The factual data revealed that critical tropical cyclone information issued by the NWS is not always available to mariners via well-established broadcast methods. The data also suggest that modifying the way the NWS develops certain tropical cyclone forecasts and advisories could help mariners at sea better understand and respond to tropical cyclones. Further, factual data on the official forecasts for Hurricane Joaquin and other recent tropical cyclones suggest that a new emphasis on improving hurricane forecasts is warranted.<sup>1</sup>

The NTSB has yet to determine the probable cause of, or contributing factors in, *El Faro's* sinking. Nevertheless, based on the meteorological facts gathered thus far, plus discussions with the NWS and the Coast Guard, the NTSB makes ten recommendations in this report.<sup>2</sup> Two recommendations are addressed to NOAA, seven to the NWS, and one to the Coast Guard.

## Accident

On Thursday, October 1, 2015, about 0715 eastern daylight time (EDT), the Coast Guard received distress alerts from the 790-foot roll-on/roll-off container ship *El Faro*. The US-flag vessel, owned by TOTE Maritime Puerto Rico and operated by TOTE Services, Inc. (hereinafter, TOTE) was 40 miles northeast of Acklins and Crooked Island, Bahamas, and close to the eye of Hurricane Joaquin.<sup>3</sup> The ship was en route from Jacksonville, Florida, to San Juan, Puerto Rico,

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<sup>1</sup> The data include official forecasts for Joaquin (and the system that was to become Joaquin) before it was classified as a hurricane.

<sup>2</sup> The Meteorology Group Factual Report (and associated attachments) for this accident may be found at <https://dms.nts.gov/pubdms/search/hitlist.cfm?sort=0&order=1&CurrentPage=1&EndRow=15&StartRow=1&docketID=58116&txtSearchT=meteorology>.

<sup>3</sup> All miles in this report are nautical miles (1.15 statute miles).

with a cargo of containers and vehicles. Just minutes before the distress alerts were received, the *El Faro* captain had called TOTE's designated person ashore and reported that a scuttle had popped open on deck no. 2 and that there was free communication of water into the no. 3 hold. He said the crew had controlled the ingress of water but that the ship was listing 15 degrees and had lost propulsion. The Coast Guard and TOTE were unable to reestablish communication with the ship. Twenty-eight US crewmembers, including an off-duty engineering officer sailing as a supernumerary, and five Polish workers were on board.

The Coast Guard, US Navy, and US Air Force dispatched multiple assets to the ship's last known position, but the search was hampered by hurricane-force conditions on scene. On Sunday, October 4, a damaged lifeboat and two damaged liferafts were located. The same day, the Coast Guard found a deceased crewmember wearing an immersion suit. A Coast Guard rescue swimmer placed a self-locating buoy next to the body and left to investigate reported signs of life elsewhere. No signs of life were found, and the previously located body could not be found again. On Monday, October 5, a debris field and oil slick were discovered. The Coast Guard determined that *El Faro* was lost and declared the accident a major marine casualty. At sundown on Wednesday, October 7, the Coast Guard suspended the search for survivors.<sup>4</sup>

On October 31, 2015, a Navy ship fitted with underwater detection equipment located the wreckage of *El Faro* at a depth of about 15,000 feet. In April 2016, a research vessel from the National Science Foundation and Woods Hole Oceanographic Institution located *El Faro*'s voyage data recorder (VDR) but did not have equipment on board that could safely retrieve it. Four months later, the Navy ship revisited the site of the sinking and location of the VDR. On August 8, the Navy recovered the VDR capsule, which yielded 26 hours of data, including audio recordings of conversation that took place on *El Faro*'s bridge.

## Discussion

*El Faro* departed Jacksonville on its final voyage shortly before 2300 EDT on September 29, 2015. At 2253 EDT that evening, the National Hurricane Center (NHC) issued a Tropical Cyclone Forecast/Advisory for Tropical Storm Joaquin, placing its center at that time roughly 180 miles northeast of San Salvador Island, Bahamas. Maximum sustained surface wind was estimated at 60 knots, and the storm was described as moving west-southwest at 4 knots.<sup>5</sup> The storm's center was forecast to come within about 45 miles of San Salvador Island by 0800 EDT on October 1.<sup>6</sup> When *El Faro* sank (about 0740 EDT on October 1), the center of the hurricane was 104 miles south of the position forecast for 0800 EDT that day and had an intensity 35 knots greater than what had been forecast in the NHC advisory issued 33 hours earlier, on September 29.<sup>7</sup>

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<sup>4</sup> More information about this accident can be found in the NTSB public docket for the *El Faro* investigation, located at <http://dms.nts.gov/pubdms/search/hitlist.cfm?docketID=58116>.

<sup>5</sup> A *knot* is a unit of speed equal to one nautical mile per hour (about 1.15 statute miles per hour).

<sup>6</sup> The NHC's 2253 EDT Tropical Cyclone Forecast/Advisory predicted Joaquin's center to be near 24.8°N, 74.1°W (roughly 45 miles north-northeast of San Salvador Island) at 0800 EDT on October 1, with maximum sustained winds of 80 knots.

<sup>7</sup> This assessment is based on the NHC's post-storm "best track" for Joaquin. The forecast had a forecast period of 36 hours.

In January 2016, the NHC published a tropical cyclone report (TCR) that included a critique of the center's forecasting for Hurricane Joaquin.<sup>8</sup> The TCR stated that mean official track forecast errors for Joaquin "were lower than the mean official errors for the previous 5-yr period at 12 [hours] but were higher between 24 and 120 [hours]. In fact, official forecast track errors between 72 and 120 [hours] were more than double the mean official errors for the previous 5-yr period." As reported in the TCR, the NHC's mean 5-year forecast track error for the 36-hour forecast period was 60.4 miles, and the mean intensity error was 11.5 knots.

The TCR further stated: "Much of the error in the forecast track resulted from Joaquin's atypical southwestward motion toward the Bahamas from 0000 UTC 28 September through 1800 UTC 1 October.<sup>9</sup> . . . Most of the models, as well as the official forecast, indicated that Joaquin would move northwestward or westward once it became a tropical cyclone, and they were late in showing the southwestward motion that persisted for several days." With regard to intensity, the TCR stated: "Official forecast intensity errors were greater than the mean official errors for the previous 5-yr period at all forecast times."

A NOAA Service Assessment, "The Historic South Carolina Floods of October 1–5, 2015," provided further analysis of model performance during the forecasting of Joaquin, stating: "The GFS [Global Forecast System model] had a very difficult time capturing [Joaquin's] initial track. This resulted in less warning given to the Bahamas, where significant storm impacts occurred."<sup>10</sup>

In conversation after the TCR's release, NHC staff told NTSB staff that Joaquin was one of the most challenging storms for forecasting track. In particular, the computer models appear to have had difficulty defining the cyclone's vertical structure (system depth). According to the NHC, Joaquin in its early stages existed in a northerly wind shear environment. Early model solutions for Joaquin indicated that the shear would be too strong for significant cyclone development and that Joaquin would remain relatively weak and move to the west and northwest. However, Joaquin strengthened, became a deep system, and moved southwest.

During public testimony in May 2016 at the Coast Guard's second Marine Board of Investigation (MBI) for the *El Faro* accident, the branch chief of the NHC's Hurricane Specialist Unit stated:

We know that when there's a lot of wind shear that it's pretty easy to predict the behavior of a tropical cyclone. . . . We also have a pretty good handle on things when the wind shear is very low . . . one of our biggest challenges is trying to sort out what's going to happen at intermediate levels of shear . . . the tropical cyclone is trying to keep the storm vertically coherent, wind shear is trying to tear it apart, and the forecaster has to decide based on the guidance that he has which of those two competing factors is going to win. And in those situations, the – getting the intensity forecast right and getting the track forecast right really go hand [in] hand. If you don't get the intensity right you're probably not going to get the track right because the storm is now going to be steered by a flow at a different layer of the

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<sup>8</sup> See [http://www.nhc.noaa.gov/data/tcr/AL112015\\_Joaquin.pdf](http://www.nhc.noaa.gov/data/tcr/AL112015_Joaquin.pdf).

<sup>9</sup> UTC = coordinated universal time, 4 hours ahead of eastern daylight time.

<sup>10</sup> See [http://www.weather.gov/media/publications/assessments/SCFlooding\\_072216\\_Signed\\_Final.pdf](http://www.weather.gov/media/publications/assessments/SCFlooding_072216_Signed_Final.pdf).

atmosphere. So that was certainly the problem in the first few forecast[s] for Joaquin where we were expecting very high levels of shear. We expected that the storm was not going to handle that shear very well and basically become very shallow and move off to the west and northwest in the shallow flow. Joaquin didn't cooperate with that particular line of thinking. It, for whatever reason and to this day [I] can't really tell you why it did so, but that storm was particularly resistant to the wind shear. Now maybe we – maybe there was less shear out there than we thought. Or perhaps there was something about the dynamics of that particular storm that allowed it to resist. But that was the basic challenge in trying to figure out how that storm was going to respond to the shear that was being imposed on it. And that affected both the intensity forecast and the track forecast.<sup>11</sup>

In further MBI testimony, when the Coast Guard asked if there was anything he believed could help forecasters in the NHC's Hurricane Specialist Unit with tropical cyclone forecasts, the branch chief stated:

[An] improved basic understanding of how tropical cyclones behave . . . the physical problem that we were dealing with in Joaquin was how was this particular tropical cyclone going to respond to shear that was not too strong and not too weak but somewhere in the middle . . . Joaquin's a real good example of how far we still have to go.

Recent difficulty with forecasting tropical cyclones in sheared environments is not limited to Joaquin. Earlier in 2015, the NHC had forecast that Tropical Storm Erika, then located about 140 miles southeast of Puerto Rico, would reach hurricane strength 4 days later, when it was forecast to be near West Palm Beach, Florida. Instead, Erika dissipated 40 hours later near the eastern tip of the island of Hispaniola. The TCR for Erika noted the effects of shear on Erika's intensification and stated: "The mean official forecast track errors [for Erika] were greater than the mean official errors for the previous 5-yr period at all forecast intervals."<sup>12</sup> Further: "Official forecast intensity errors [for Erika] were lower than the mean official errors for the previous 5-yr period at the 12- through 48-[hour] forecast interval, and greater than the 5-yr mean at 72 [hours]." In correspondence with the NTSB, the NHC stated that its best regional model "under-did" the disruptive effects of the sheared environment.

More-recent examples of difficulty in forecasting tropical cyclones in sheared environments are Hurricane Matthew and Tropical Storm Julia, both occurring in 2016.

*Hurricane Matthew.* On the morning of Friday, September 30, 2016, when Hurricane Matthew's maximum sustained wind was assessed at 85 knots, an NHC Tropical Cyclone Discussion stated: "It is notable that the rapid intensification [of Matthew] has occurred despite an ongoing 20 kt [knots] of southwesterly vertical wind shear . . . The intensity forecast is very problematic. The ongoing shear has so far done little to keep Matthew from intensifying. Despite this, the intensity guidance is in unanimous agreement that the cyclone should weaken from 12–48 hours, most likely due to shear." Six hours later, while discussing the storm's continued strengthening, a

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<sup>11</sup> A transcript of the branch chief's testimony (which took place during the second day of the Coast Guard's second MBI for the *El Faro* accident) may be found in the NTSB public docket for this investigation.

<sup>12</sup> The TCR for Tropical Storm Erika may be found at [http://www.nhc.noaa.gov/data/tcr/AL052015\\_Erika.pdf](http://www.nhc.noaa.gov/data/tcr/AL052015_Erika.pdf).

new NHC Tropical Cyclone Discussion stated: “[Matthew’s] intensification has occurred despite analyzed southwesterly shear of around 20 kt. The SHIPS model output shows this shear continuing for the next 36 hours or so, and as a result, the SHIPS and LGEM models show Matthew weakening during this time. This weakening trend is also shown by the HWRF and COAMPS-TC hurricane models.”<sup>13</sup> Six hours later, as Matthew became a major hurricane despite the model guidance and forecasts, a new NHC Tropical Cyclone Discussion stated: “Matthew has continued to rapidly strengthen at a remarkable rate today.” The discussion noted the “lack of skill of the intensity guidance thus far.” Over the next 36 hours, Hurricane Matthew maintained a maximum sustained wind speed of at least 125 knots.<sup>14</sup>

*Tropical Storm Julia.* In correspondence with the NTSB, the NHC noted that the disturbance that ultimately became Tropical Storm Julia was expected to move inland over Florida and not become a tropical cyclone. However, it moved to the right of the model guidance, an error most likely due to an asymmetry in the system’s convection caused by westerly shear. The disturbance stayed close to the east Florida coast as it moved northward and eventually became a tropical storm. According to correspondence with the NHC, residents had very little advance warning of the formation of Julia.<sup>15</sup>

Although accurate tropical cyclone forecasting is critical to protecting lives and property on land, mariners at sea must be particularly aware of a tropical cyclone’s strength and anticipated path. According to the NHC, “Hurricanes have been the cause of many maritime disasters and unfortunately, there is no single rule of thumb that can be used by mariners to ensure safe separation from a hurricane at sea. Instead, constant monitoring of hurricane potential [and] continual risk analysis when used with some fundamental guidelines become the basic tools to minimize a hurricane's impact to vessels at sea or in port.”<sup>16</sup> An accurate forecast is fundamental to assessing the strength, position, and potential movement of a hurricane; to conducting an effective risk analysis; and to improving mariners’ safety.

In 2009, NOAA established the Hurricane Forecast Improvement Project (HFIP), a 10-year effort aimed (in part) at accelerating improvements in forecasting hurricane track and intensity and reducing the uncertainty in hurricane forecasts. According to the HFIP’s 5-year strategic plan, “HFIP provides the basis for [NOAA] and other agencies to coordinate hurricane research needed to significantly improve guidance for hurricane track, intensity, and storm surge forecasts . . . The goals of the HFIP are to improve the accuracy and reliability of hurricane forecasts . . .”<sup>17</sup>

In its fiscal year 2015 (FY2015) budget summary, NOAA stated that “HFIP has achieved many of its goals, to date.”<sup>18</sup> In its FY2017 budget summary, NOAA indicated that “NWS will shift focus away from existing R2O [research to operations] efforts, such as the [HFIP] program, that are highly specialized. However, improvements made from HFIP will be maintained and

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<sup>13</sup> Full names of the forecasting models are as follows: SHIPS = Statistical Hurricane Intensity Prediction Scheme; LGEM = Logistic Growth Equation Model; HWRF = Hurricane Weather Research and Forecasting; COAMPS-TC = Coupled Ocean/Atmosphere Mesoscale Prediction System-Tropical Cyclone.

<sup>14</sup> For more information, see <http://www.nhc.noaa.gov/archive/2016/MATTHEW.shtml>.

<sup>15</sup> For more information, see <http://www.nhc.noaa.gov/archive/2016/JULIA.shtml>.

<sup>16</sup> See <http://www.nhc.noaa.gov/prepare/marine.php>.

<sup>17</sup> See [http://www.hfip.org/documents/hfip\\_strategic\\_plan\\_yrs1-5\\_2010.pdf](http://www.hfip.org/documents/hfip_strategic_plan_yrs1-5_2010.pdf).

<sup>18</sup> See [http://www.corporateservices.noaa.gov/nbo/fy15\\_bluebook/FY2015BudgetSummary-small.pdf](http://www.corporateservices.noaa.gov/nbo/fy15_bluebook/FY2015BudgetSummary-small.pdf).



improvements to hurricane forecasting will continue within other modeling efforts.”<sup>19</sup> Despite HFIP’s success in achieving many of its goals, forecasting for storms in some sheared environments, as highlighted by the four tropical cyclones from 2015 and 2016 described earlier, is still a significant issue. The NHC has stated that moderate-shear environments pose some of the most significant challenges for tropical cyclone forecasting and are prone to causing large forecast errors. The NTSB is not aware of any NOAA modeling effort aimed specifically at improving how forecast models handle tropical cyclones in moderate-shear environments, and believes that such a focus might lead to relatively quick success in this critical area.

The NTSB concludes that specific improvement of tropical cyclone forecasting in moderate-shear environments would lead to better model performance/guidance and improved mariner safety. Therefore, the NTSB recommends that NOAA develop and implement a plan specifically designed to emphasize improved model performance in forecasting tropical cyclone track and intensity in moderate-shear environments.

An additional (but related) activity that could improve the forecasting of tropical cyclones that affect mariners at sea would be to develop technology allowing NWS hurricane forecasters to quickly sort through large numbers of tropical cyclone forecast model ensemble members.<sup>20</sup> Such technology would identify clusters of solutions among ensemble members and either automatically, or with forecaster intervention, correlate the clusters against a set of standard parameters (vertical wind shear, environmental moisture, vortex depth, etc.). Knowing which factors lead to particular clusters could help forecasters choose the best model guidance for a particular forecast. NHC staff told the NTSB that this capability could have made a difference in the forecasting for Joaquin.

Another example of where such technology might have benefited forecasters is Tropical Storm Debby (2012). According to the TCR for the storm, during the early stages when Debby was located in the central Gulf of Mexico, “track guidance indicated a dichotomy in the model forecast tracks, with almost as many model solutions taking Debby toward the Texas coast as solutions showing a northeastward track toward north Florida. The European Centre for Medium-Range Weather Forecasting [ECMWF] model and its ensemble members largely favored a track toward Texas . . . while the GFS and a majority of GFS ensemble members were directed toward northern Florida and the western Atlantic.”<sup>21</sup> In correspondence with the NTSB, the NHC stated: “There was a very definite split between the ECMWF ensembles and the GFS ensembles, and early on we chose wrong.” The TCR reported that NHC official forecast track errors for Debby “were larger than the mean official errors for the previous 5-yr period at all forecast times through 72 [hours], and considerably so after 24 [hours]. Official track errors were about double the 5-yr mean at 36–48 [hours] and triple that at 72 [hours]. There were no verifying forecasts at 96 [hours] and 120 [hours].”

Another recent example is 2016’s Hurricane Matthew. According to the NHC, as Matthew approached Florida from the southeast, and even as it continued northward along the east coast of

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<sup>19</sup> See [http://www.corporateservices.noaa.gov/nbo/fy17\\_bluebook/FY17\\_BB\\_Final\\_508.pdf](http://www.corporateservices.noaa.gov/nbo/fy17_bluebook/FY17_BB_Final_508.pdf).

<sup>20</sup> An *ensemble* is a collection of forecasts all valid at a particular time. Typically, the term refers to a group of forecasts formed by running an individual model repeatedly using slightly different initial conditions, although such a collection can also comprise forecasts from separate, independent models (the latter is normally referred to as a “multi-model ensemble”).

<sup>21</sup> See [http://www.nhc.noaa.gov/data/tcr/AL042012\\_Debby.pdf](http://www.nhc.noaa.gov/data/tcr/AL042012_Debby.pdf).

Florida and northeastward toward South Carolina, forecast model ensemble members diverged on the storm's track. Some took Matthew eastward past the North Carolina coast and out to sea, while others turned Matthew south and southwestward back toward Florida and the Bahamas. The official NHC forecasts for Matthew followed the south/southwestward track option for a while, which highlighted the potential for Florida to have to deal with Matthew a second time in about a week. Instead, Matthew's track more closely followed the forecast models that took Matthew past the North Carolina coast and eastward out to sea.

The NTSB notes that in the 5-year strategic plan for the HFIP, responsibility for the "Development of New Tools for Evaluation of Hurricane Forecasts" fell to the HFIP's verification team. One milestone under this task was to "develop, implement, and enhance tools for evaluation of TC [tropical cyclone] ensemble forecasts," with dates of completion listed as both 1–2 years and 3–5 years. The development of technology as described above would have fallen under this item, and the NTSB is aware that some development work did begin on such a program. A display system has been developed, but it is not yet capable of performing the correlation analysis described above. According to the NHC, no further funding has been allocated to develop this analysis capability, and in its current state the display system does not have a forecast application.

The NTSB concludes that technology that would allow NWS forecasters to quickly sort through large numbers of tropical cyclone forecast model ensembles, identify clusters of solutions among ensemble members, and allow correlation of these clusters against a set of standard parameters would significantly improve official forecasts for tropical cyclones that affect mariners at sea. Therefore, the NTSB recommends that NOAA develop and implement technology that would allow NWS forecasters to quickly sort through large numbers of tropical cyclone forecast model ensembles, identify clusters of solutions among ensemble members, and allow correlation of those clusters against a set of standard parameters.

Although more accurate forecasting of tropical cyclones would surely improve marine safety, mariners at sea must be aware of and receive critical weather forecasts and advisories. The VDR on *El Faro*'s bridge recorded numerous discussions about Joaquin, its current position and forecast track, and products or systems that delivered the information.<sup>22</sup>

One means by which the *El Faro* crew remained aware of the changing position, forecast intensity, and forecast track of Joaquin was through Inmarsat-C SafetyNET (SAT-C) text broadcasts of NHC weather products, which were delivered to the vessel's bridge.<sup>23</sup> The NHC product received via SAT-C that delivered (with limited delay) the most current information on Joaquin's position and forecast track and intensity was the Tropical Cyclone Forecast/Advisory.<sup>24</sup>

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<sup>22</sup> For the transcript of the VDR audio recordings, see the NTSB docket at <https://dms.nts.gov/public/58000-58499/58116/598645.pdf>.

<sup>23</sup> Further discussion of the Inmarsat-C SafetyNET service and the specific products and times of their availability during *El Faro*'s final voyage are found in the Meteorology Group Factual Report (see footnote 2). Text products received via SAT-C are printed on paper and can also be read on a SAT-C terminal monitor. The SAT-C alert tone and the sound of the printer functioning on the *El Faro*'s bridge were documented in the VDR transcript.

<sup>24</sup> Although an NWS High Seas Forecast is available from SAT-C and carries some of the NHC's most recently issued tropical cyclone information, it is expected to be received via SAT-C roughly 90 minutes after the Tropical Cyclone Forecast/Advisory.

The NHC issues this advisory four times a day for active tropical cyclones.<sup>25</sup> The NTSB identified five instances in the *El Faro* VDR transcript (“sound of SAT-C terminal receiving incoming message”) where the SAT-C terminal on the vessel’s bridge likely received a Tropical Cyclone Forecast/Advisory. These five instances occurred about 0638, 1057, 1654, and 2253 EDT on September 30 and 0447 EDT on October 1.

About the same time the NHC issues a Tropical Cyclone Forecast/Advisory, it also issues a Tropical Cyclone *Public* Advisory (hereafter, Public Advisory/Advisories). Though it provides no detail about forecast storm positions and intensities, the Public Advisory gives the current center position of a storm as well as its maximum sustained winds, current movement, and minimum central surface pressure.<sup>26</sup> When coastal tropical storm or hurricane watches or warnings are in effect, NWS Instruction (NWSI) 10-601 calls for *Intermediate* Public Advisories to be issued at 3-hour intervals between the regularly scheduled Public Advisories, even if the coastal watches or warnings are issued by another country’s government (for example, the Bahamas).<sup>27</sup> The Public Advisories, *including* the Intermediate Public Advisories, are not available to mariners via SAT-C, nor are they required to be.<sup>28</sup>

According to the *El Faro* VDR transcript, at 2057 EDT on September 30, the third mate indicated that he had expected the NHC to issue its next advisory at 2000 EDT:

**Third Mate**     *the National Hurricane Center was supposed to issue  
20:57:02.5     their– next advisory at– eight. how long that takes ‘em to–  
work its way through the system– get to us.*

It is possible that the third mate had expected a 2000 EDT NHC update on Joaquin based on what he had seen on The Weather Channel.<sup>29</sup> The Weather Channel had prominently displayed the next expected NHC update/advisory in its programming earlier in the day, and the NTSB believes that those displays would have occurred through the evening programming. An NHC advisory issued at 2000 EDT could only have been a scheduled Intermediate Public Advisory or an unscheduled Special Advisory (discussed later).

Though the third mate did not specify that the next advisory was expected via SAT-C, *El Faro*’s VDR recorded the following just over an hour and a half later:<sup>30</sup>

22:37:17.0     *[sound of SAT-C terminal receiving incoming  
message.]*

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<sup>25</sup> The NHC nominally issues its Tropical Cyclone Forecast/Advisory products at 0500, 1100, 1700, and 2300 EDT.

<sup>26</sup> The Public Advisory contains a brief discussion and “48-hour outlook” for a storm.

<sup>27</sup> When required, Intermediate Public Advisories are issued at nominal times of 0200, 0800, 1400, and 2000 EDT. NWSI 10-601 stipulates that an additional requirement for issuing an Intermediate Public Advisory is when “a tropical cyclone is over land at tropical storm strength or greater.” NWSI 10-601 may be found at <http://www.nws.noaa.gov/directives/sym/pd01006001curr.pdf>.

<sup>28</sup> The Intermediate Public Advisory is disseminated with the same alphanumeric text header as the Public Advisory.

<sup>29</sup> The third mate mentioned information gleaned from The Weather Channel four times during his watch.

<sup>30</sup> It is believed that the SAT-C message delivered to *El Faro* at 22:37:17.0 EDT on September 30 was a tropical cyclone product applicable to the eastern Pacific and not to *El Faro*’s region. The following excerpts from the *El Faro* VDR transcript are abridged and leave out identification of certain sounds on the bridge during these times.



22:37:28.4 [sound of SAT-C terminal printer printing.]

**Third Mate** (the weather/hello).  
22:38:09.8

**Third Mate** (I don't know) it's for the Pacific unfortunately.  
22:38:15.1

About 15 minutes later, *El Faro*'s VDR recorded the following:

22:53:24.5 [sound of SAT-C terminal receiving incoming message.]

**Third Mate** all right– this should be the one. maybe.  
22:53:27.0

22:53:35.1 [sound of SAT-C terminal printer printing.]

**Third Mate** hey captain sorry to wake ya.  
23:05:08.7

**Third Mate** naw– nothin' and uh the latest weather just came in.–  
23:05:12.0 and umm– thought you might wanna take a look at it.

The advisory received at 2253 EDT was the Tropical Cyclone Forecast/Advisory regularly disseminated every 6 hours.<sup>31</sup> As noted earlier, Public Advisories for a particular storm are not disseminated via SAT-C. Therefore, the Intermediate Public Advisories for Joaquin were never received on *El Faro*'s bridge through SAT-C. The 2000 EDT Intermediate Public Advisory would have advised the bridge that during the past 3 hours, the center of Joaquin had moved 20 miles south-southeast and had increased in intensity to about 90 knots.<sup>32</sup> This Intermediate Public Advisory was possibly the “next advisory” expected by the third mate. In addition, based on remarks by the chief mate earlier in the voyage, it appears that the chief mate thought (incorrectly) that the ship was receiving new weather information every 3 hours instead of every 6 hours.<sup>33</sup>

At 0120 EDT on October 1, the second mate called the captain to suggest an alternative route, after which the second mate indicated to a helmsman that the captain wished to stay on the planned route. About 10 minutes later, the NHC issued an Intermediate Public Advisory (not received on board *El Faro*) indicating that Joaquin had moved southwest over the past 3 hours. That was about when *El Faro* completed a planned course change from 150 degrees true to 116 degrees true. At 0135 EDT, with *El Faro* heading 113 degrees true, Joaquin's center position, according to the just-issued Intermediate Public Advisory, was 71 miles from *El Faro*, at 7 degrees

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<sup>31</sup> This advisory was disseminated by the NHC at 2249 EDT (4 minutes before *El Faro*'s receipt).

<sup>32</sup> The 1700 EDT Tropical Cyclone Forecast/Advisory had forecast Joaquin's next position (at 0200 EDT on October 1) to be about 45 miles southwest and its intensity at that time to be 85 knots.

<sup>33</sup> A statement by the chief mate to that effect appears at 06:38:56.9 EDT on September 30 in the *El Faro* VDR transcript.

to port.<sup>34</sup> This advisory would have identified to the crew that *El Faro*'s current course was taking them almost directly toward the center of the southwest-moving hurricane.

An additional product the NHC can issue to deliver important information about a tropical cyclone between regularly scheduled products is the Tropical Cyclone Update.<sup>35</sup> These updates are not available to mariners via SAT-C, nor are they required to be. The NTSB notes, however, that there are supplemental sources for the Intermediate Public Advisories and Tropical Cyclone Updates, and that SAT-C is not required for onboard access to these products, assuming certain other capabilities. One supplemental source is discussed later in this report.

The NTSB is concerned that while coastal tropical cyclone watches or warnings are in effect, the NHC disseminates authoritative, up-to-date information (the Intermediate Public Advisory) on a tropical cyclone's position, intensity, and movement that is not available to mariners via SAT-C. The NTSB is further concerned that Tropical Cyclone Updates are also not available to mariners via SAT-C. Although the Intermediate Public Advisory and Tropical Cyclone Update may be available through other onboard communication devices, such as open internet browsing or the email-based FTPmail system (discussed later), the NTSB considers SAT-C an important option for mariners to receive weather information. Moreover, as part of the Global Maritime Distress and Safety System (GMDSS), SAT-C is required equipment for many vessels and a source for mandatory monitoring of weather information.<sup>36</sup>

The NTSB concludes that mariners using only SAT-C miss important tropical cyclone information found in the Intermediate Public Advisories and Tropical Cyclone Updates. Therefore, the NTSB recommends that the NWS work with international partners to develop and implement a plan to ensure immediate dissemination to mariners, via SAT-C (and appropriate future technology), of the Intermediate Public Advisories and Tropical Cyclone Updates issued by the NWS, in a manner similar to the current process of disseminating the Tropical Cyclone Forecast/Advisory.

The NTSB is further concerned that, in accordance with NWSI 10-601, Intermediate Public Advisories are issued only when a hurricane threatens land areas. As a result, updated information on tropical cyclones that could affect mariners at sea may not be generated unless watches and warnings for coastal areas are in effect. Although the Intermediate Public Advisory is currently the method used to relay updated storm information between regularly scheduled advisories, in the future, the Tropical Cyclone Updates could be issued in addition to the Intermediate Public Advisory, or in lieu of the Intermediate Public Advisory (when it is not required). Such updates

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<sup>34</sup> According to the VDR data, at 0135 EDT, *El Faro*'s heading was about 113 degrees true, with a course over ground of 115 degrees true.

<sup>35</sup> The NHC issues Tropical Cyclone Updates to inform users of significant changes in a tropical cyclone *between* regularly scheduled Public Advisories.

<sup>36</sup> For further information on the GMDSS, see <http://www.navcen.uscg.gov/?pageName=GMDSS>. With regard to Federal Communications Commission requirements (established in Title 47 *Code of Federal Regulations* 80.1123) for monitoring weather information via an Inmarsat ship Earth station, the Coast Guard has stated that, "[Vessels] are required to monitor the Inmarsat ship Earth station for shore-to-ship distress alerts without limitation, including but not limited to weather-related alerts. Only GMDSS vessels that travel in Sea Area A3, more than 100 nautical miles from shore, are required to carry an Inmarsat ship Earth station."

are critical, particularly when a storm does not behave according to its forecast track or intensity in the 3 hours after a forecast is issued.

The NTSB concludes that current NWS policy for the issuance of an Intermediate Public Advisory may prevent the generation of important new information about a tropical cyclone that does not pose an immediate threat to land. The NTSB believes that in consideration of the marine community, updated storm information should be generated and disseminated regardless of storm watch/warning status for land areas, and that the dissemination products should be available to mariners via SAT-C (as recommended in this report), through protocols that minimize additional forecaster workload and do not detract from the generation of other public tropical cyclone products. Therefore, the NTSB recommends that the NWS modify its directives to ensure, for all tropical cyclones of tropical storm strength or greater within its jurisdiction, that its facilities issue, at the 3-hour interval between regularly scheduled Tropical Cyclone Forecast/Advisories, an Intermediate Public Advisory, a Tropical Cyclone Update, or another product available (or expected to be available) to mariners via SAT-C (and appropriate future technology), and that the product include coordinates of current storm center position, maximum sustained surface winds, current movement, and minimum central pressure.

The Tropical Cyclone Forecast/Advisory issued by the NHC contains text that advises users of when to expect the “next advisory” for a particular storm. When an additional advisory is anticipated, the next advisory time is always indicated as 6 hours following the current Tropical Cyclone Forecast/Advisory. Although the NTSB recognizes that the “next advisory” time is intended to indicate when to expect the next Tropical Cyclone Forecast/Advisory, some users might be misled into believing that no new storm information of any type will be available until then. The NTSB notes that the regularly scheduled NHC Public Advisories identify when the NHC will next issue “intermediate” and “complete” advisories.

The NTSB concludes that the “next advisory” time identified in the Tropical Cyclone Forecast/Advisory products for a particular storm could mislead some users as to when new storm information of any type for that storm will become available from the NWS. Therefore, the NTSB recommends that the NWS modify its directives to ensure that the “next advisory” time in a Tropical Cyclone Forecast/Advisory clearly indicates when to expect the next update of “current” or forecast information for that particular tropical cyclone.

According to NWSI 10-601, Special Advisories for a tropical cyclone are issued whenever an “unexpected significant change” occurs or when US watches or warnings are to be issued between regularly scheduled advisories.<sup>37</sup> When a Special Advisory is required, an entire Special Advisory package is issued.<sup>38</sup> According to NWS 10-601, “when the special advisory package is issued only for a watch or warning, it will contain the track and intensity forecast from the previous regularly scheduled advisory with only the initial position and intensity updated. When the special advisory is issued for an unexpected change, the previous track and intensity forecast will be updated to reflect the unexpected change.”

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<sup>37</sup> No current criterion defines “significant” in this regard.

<sup>38</sup> A Special Advisory package includes the Public Advisory, the Tropical Cyclone Forecast/Advisory, the Tropical Cyclone Discussion, the Aviation Tropical Cyclone Advisory, and a suite of graphics.

Despite Joaquin's repeated tendency during the days before *El Faro* sank to move south of its short-term forecast track, as well as two periods of stronger-than-expected short-term intensification, the only Special Advisory package for Joaquin was issued at 1200 EDT on October 3, 2015. That was 2 days after the sinking, when the NHC adjusted Joaquin's initial and forecast intensity. Further, when deviations in a storm's track (relative to its forecast track) occur after an official forecast is released, graphics issued by the NHC can deliver potentially confusing information to a mariner or other user.

Figures 1–4 show NHC Tropical Cyclone Track Forecast Cone and Watches/Warnings graphics issued for Hurricane Joaquin, Hurricane Matthew, and Tropical Storm Erika. In these graphics, three of which were issued to represent the information available when an Intermediate Public Advisory was released, the storm's current movement (labeled "Movement" in the information block at the bottom center of the figures) is in a direction notably different from what the illustrated forecast track suggests will be the average/overall movement in the following hours (in figures 1–4, we see direction differences of about 45 degrees, 90 degrees, 135 degrees, and 180 degrees between the reported current movements and the storm's next forecast position). The forecast track is simply a curve drawn from the storm's current position to a forecast location 6 or 9 hours in the future; in addition, a current motion in a direction other than toward the next forecast point does not necessarily indicate that the forecast position will be wrong. However, the identification of a storm's current movement (in the text at the bottom of the figures) as being different from its near-term forecast movement (depicted in the track/positions in the graphics themselves) can confuse mariners who look at the product to follow a storm's near-term progress. For the NHC, the divergence can also highlight situations where a new forecast track may be needed.

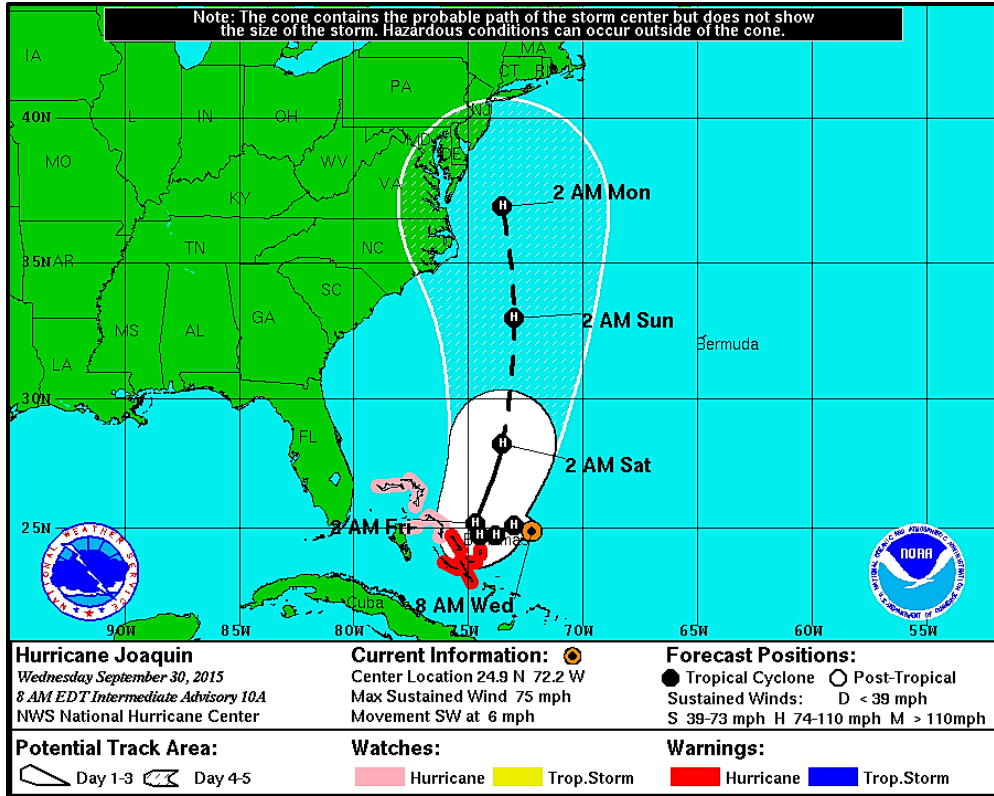


Figure 1. NHC tropical cyclone track forecast cone and watches/warnings graphics issued for Hurricane Joaquin at 0800 EDT on September 30, 2015.

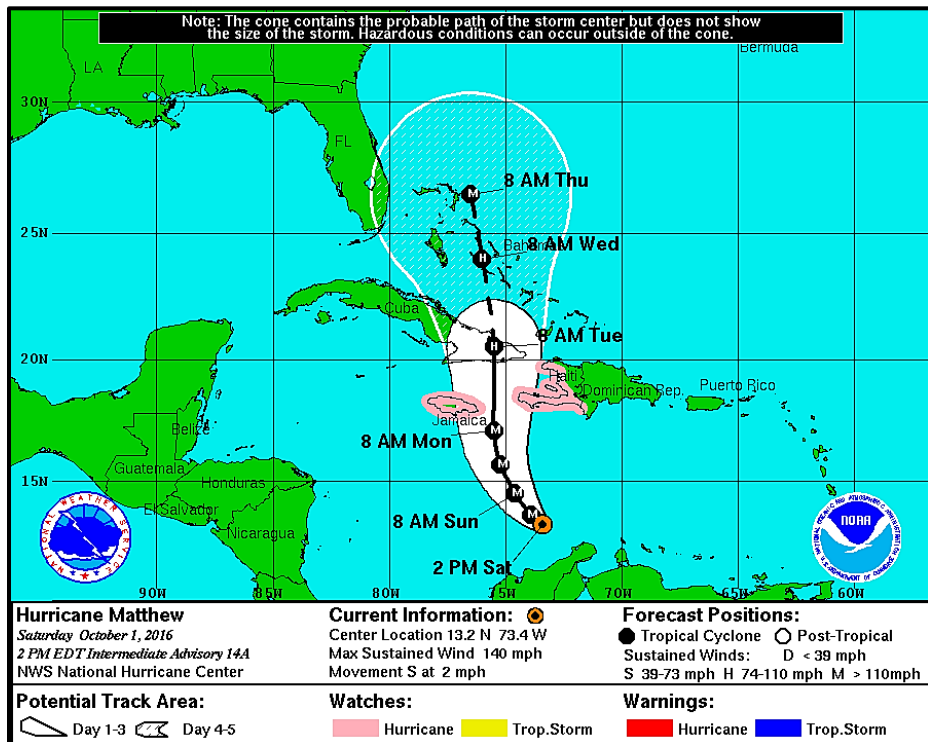


Figure 2. NHC tropical cyclone track forecast cone and watches/warnings graphics issued for Hurricane Matthew at 1400 EDT on October 1, 2016.



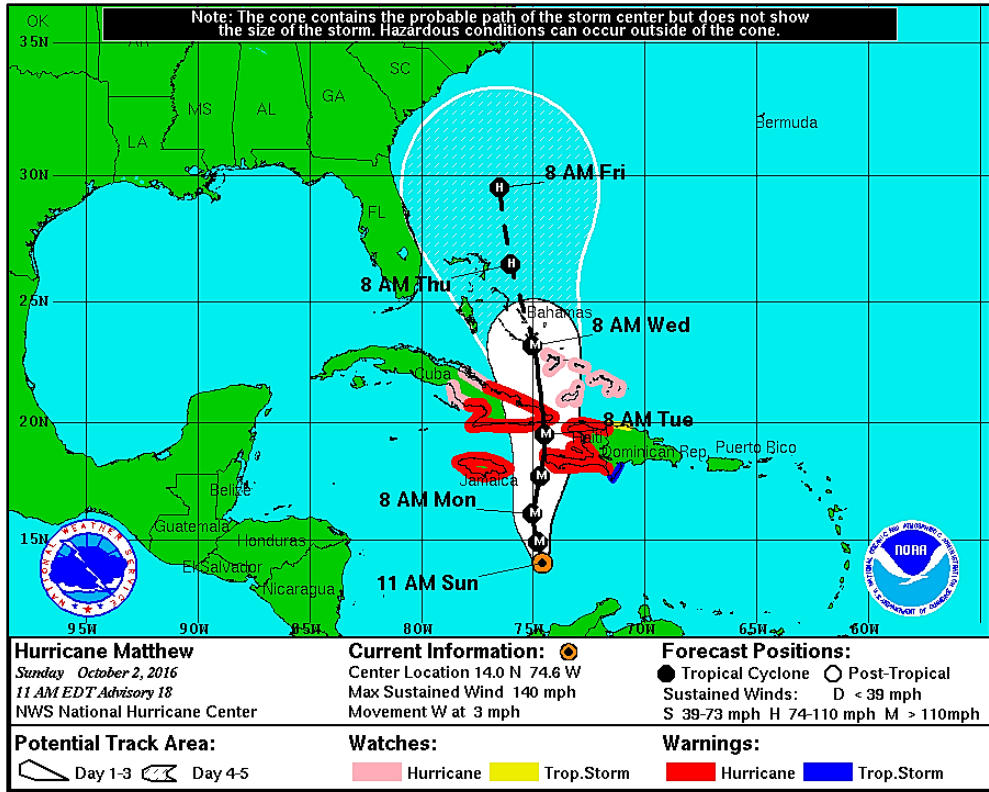


Figure 3. NHC tropical cyclone track forecast cone and watches/warnings graphics issued for Hurricane Matthew at 1100 EDT on October 2, 2016.

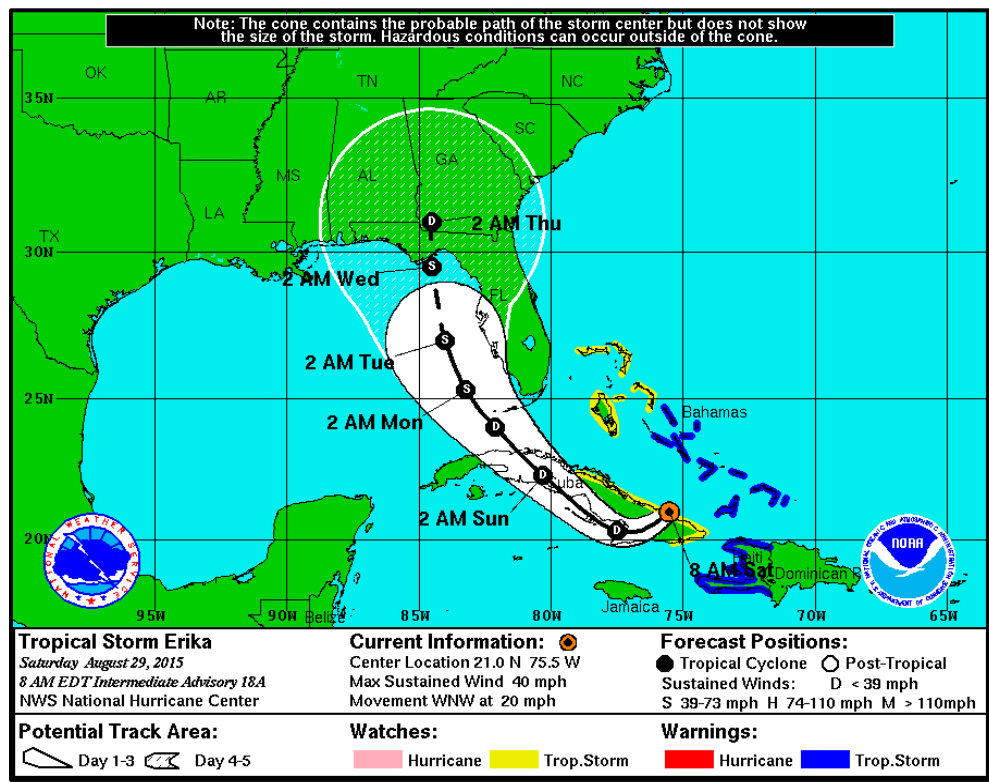


Figure 4. NHC tropical cyclone track forecast cone and watches/warnings graphics issued for Tropical Storm Erika at 0800 EDT on August 29, 2015.

When asked at the second MBI hearing about the apparent confusing presentation on Joaquin's movement in figure 1, the branch chief of the NHC's Hurricane Specialist Unit responded: "That looks odd, I concede." In later correspondence with the NTSB, the branch chief indicated that one benefit of issuing a Special Advisory package for an "unexpected change" in a storm is that all graphics associated with that particular storm are reissued. If a new forecast track that is more consistent with a storm's current movement is deemed appropriate, that could eliminate the apparent inconsistency in the Tropical Cyclone Track Forecast Cone and Watches/Warnings graphics.

According to the NHC, informal protocol dictates that if new data become available suggesting that a 12- or 24-hour forecast for a tropical cyclone's intensity is going to be low by at least 10 or 15 knots, a Special Advisory package will be issued. However, there are no criteria that would guide the issuance of a Special Advisory package for an unexpected change in a tropical cyclone's track. Further, NWSI 10-601 does not define what is meant by an "unexpected change" or an "unexpected significant change" regarding a tropical cyclone's expected behavior.<sup>39</sup> The NTSB recognizes that it can be difficult for forecasters to determine whether a forecast departure observed during the hours immediately after the release of an official forecast represents a trend significant enough to warrant a Special Advisory. The NTSB concludes that although NWS facilities are required to issue Special Advisories when an unexpected significant change is believed to occur in a tropical cyclone, no formal guidance exists for forecasters to define significant change. Therefore, the NTSB recommends that the NWS quantitatively define "significant change" in terms of both the track and intensity of a tropical cyclone to guide the issuance of Special Advisory packages.

The Coast Guard broadcasts NWS information applicable to mariners through technology such as medium-frequency navigational TELEX (NAVTEX), a major element of the GMDSS. Other radio broadcasts of NWS information come from the Coast Guard through high-frequency (HF) voice broadcasts (also known as VOBRA) and HF Simplex Teletype Over Radio (SITOR). Not all NAVTEX, HF VOBRA, and HF SITOR broadcasts include the Tropical Cyclone Forecast/Advisory, Public Advisory (including Intermediate Public Advisories), and Tropical Cyclone Update products, however.

The NTSB realizes that the NWS does not control whether or how the Coast Guard broadcasts its weather products. Further, the NTSB recognizes that the Coast Guard Communications Command, which coordinates broadcasts of weather information from Coast Guard infrastructure, receives NWS weather products directly from the Navy. A group called the Coast Guard-NOAA/NWS Coordination Liaison Group (UNCLOG) allows the Coast Guard and the NWS to "promote and positively affect the safety of mariners and the safe and efficient conduct of commerce in the US waters" cooperatively.<sup>40</sup> Through UNCLOG, the NWS can make recommendations to the Coast Guard as to what NWS products should be delivered to mariners through Coast Guard broadcasts in different locations.

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<sup>39</sup> NWSI 10-601 section 6.2.2.2 gives an example of a significant change as "a tropical cyclone's intensity category is upgraded or downgraded." It should be noted that a change in a tropical cyclone's intensity category can occur with as little as a 5-knot change in the maximum sustained wind between advisories.

<sup>40</sup> For further information about UNCLOG, see <http://www.nws.noaa.gov/os/marine/uscgmoa2010.pdf>.

The allocated windows for broadcasting weather information via NAVTEX, HF VOBRA, and HF SITOR are near or at saturation; additional broadcasts of weather information using those methods may require delicate coordination between Coast Guard broadcast facilities. The addition of weather information to the broadcasts may be a goal not easily achieved. However, it is important that mariners receive timely and comprehensive tropical cyclone information, and the NTSB believes that efforts should be made to provide it via the aforementioned methods, with appropriate guidance to mariners on Coast Guard broadcast times for all disseminated weather products.

The NTSB concludes that timely dissemination of NWS Tropical Cyclone Forecast/Advisories, Intermediate Public Advisories, and Tropical Cyclone Updates to mariners in all regions via NAVTEX, HF VOBRA, and HF SITOR would help mariners remain informed about tropical cyclones. Therefore, the NTSB recommends that the Coast Guard, in collaboration with the NWS, provide timely broadcasts of the Tropical Cyclone Forecast/Advisories, Intermediate Public Advisories, and Tropical Cyclone Updates to mariners in all regions via NAVTEX, HF VOBRA and HF SITOR, or appropriate radio alternatives (and appropriate future technology).

The NWS “FTPmail” system, which has been available since 1997, allows users to access NWS real-time text and graphics by standard email.<sup>41</sup> Mariners who can connect to email (for example, via satellite) but cannot access the internet (web-browse) are identified as the ideal users of the FTPmail system. *El Faro* was one such vessel. Weather information is accessed via FTPmail when the user sends an email to ftpmail@ftpmail.nws.noaa.gov, with a series of specific commands in the email body. Once the request is received, the NWS server runs the commands and returns the results (requested weather data as an attachment or text) in an automated email back to the requestor’s email account. FTPmail is not designed to allow users to schedule recurring data delivery. Rather, an individual request must be made each time weather information is desired.

As discussed earlier, *El Faro* did not receive the NHC Intermediate Public Advisories via SAT-C. Assuming that all NWS systems and *El Faro*’s email arrangements (including satellite connectivity) were working properly, the Intermediate Public Advisories would have been available in near-real time through FTPmail.<sup>42</sup> The FTPmail system allows mariners to obtain an extremely large amount of text and graphic weather information, provided that users understand the request syntax and how to identify the alphanumeric text headers for the products they want.

The NWS warns users of FTPmail against relying on the internet for weather information: “The Internet is not part of the National Weather Service’s operational data stream and should never be relied upon as a means to obtain the latest forecast and warning data. Become familiar with and use other means, such as NOAA Weather Radio, to obtain the latest forecasts and warnings.” Nevertheless, the NTSB views FTPmail as an important supporting source of weather information for vessels on which crewmembers can send and receive email. As discussed in this report, NWS products that relay important information about tropical cyclones are not available

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<sup>41</sup> The NWS includes a disclaimer that reads (in part): “Check time and date of forecasts. Downloaded data may not represent the latest forecast.” According to the NWS, after products are generated, it typically takes 1 to 5 minutes before they appear on the FTPmail server. Availability is product-specific, and urgent products, such as warnings, have higher priority and are available on the server sooner than routine products.

<sup>42</sup> There is no evidence that anyone on board *El Faro* during the accident voyage used FTPmail to access weather information.

via well-established means such as Inmarsat-C SafetyNET, NAVTEX, and Coast Guard HF radio. Further, even if a product is available, its broadcast or availability may be delayed. FTPmail may be the most efficient means by which to supplement the receipt of those products on vessels whose crews have access to email but not to the open internet.

The NTSB notes that FTPmail is popular, typically receiving requests from between 1,000 and 2,000 individual users a month. During his testimony to the MBI for the *El Faro* accident, a former Sea Star Line captain stated: “FTP[mail], it was good. It was a good improvement as information that we had not had. And it was outstanding.”<sup>43</sup> The NTSB is pleased to learn that the NWS recently upgraded its FTPmail server and that security has also been upgraded. According to the NWS, “FTPmail is here to stay for a while.”

However, the NTSB believes that FTPmail can be improved. One improvement would be to include tropical cyclone graphic products issued by the NHC, the Central Pacific Hurricane Center (CPHC), the Guam Weather Forecast Office (WFO), and the Navy’s Joint Typhoon Warning Center and Fleet Weather Center–Norfolk.<sup>44</sup> Another improvement would be to allow users to schedule recurring, automated deliveries of specific products.<sup>45</sup> To make this improvement, significant software development might be required.<sup>46</sup>

The NTSB concludes that certain enhancements to the NWS FTPmail service would assist mariners in remaining cognizant of weather information not available in a timely manner, or not available at all, via other onboard weather information receipt vehicles. Therefore, the NTSB recommends that the NWS ensure that tropical cyclone graphic products issued by entities such as the NHC, the Central Pacific Hurricane Center, the Guam Weather Forecast Office, the Joint Typhoon Warning Center, and Fleet Weather Center–Norfolk are made available in near-real time via the FTPmail service. Further, the NTSB recommends that the NWS allow users to schedule recurring, automated receipt of specific NWS products through an enhanced FTPmail service (and appropriate future technology).

This report identifies improvements that would provide mariners with better weather information and give them better access to that information. The report is based on factual information the NTSB has gathered during its investigation into the *El Faro* sinking, as well as additional discussions with the NWS and the Coast Guard. The NTSB recognizes that to continue

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<sup>43</sup> A transcript of the former Sea Star Line captain’s testimony (which took place during the second day of the Coast Guard’s second MBI for the *El Faro* accident) may be found in the NTSB public docket for this accident.

<sup>44</sup> Some of these products had reportedly been available via FTPmail in the past. The products include, from the NHC: the Tropical Cyclone Track Forecast Cone and Watches/Warnings graphic, the Tropical Cyclone Surface Wind Speed Probabilities (34, 50, and 64 knots) graphics, the Two-Day Graphical Tropical Weather Outlook graphic, the Five-Day Graphical Tropical Weather Outlook graphic; from the CPHC: the Track Forecast Cone and Watch/Warning graphic, the Wind Speed Probabilities graphics, the Wind History graphic, the Surface Wind Field graphic, the Tropical Weather Outlook graphic; from the Guam WFO: the HURREVAC Forecast Track Error and Forecast Uncertainty graphics; from the US Navy: all graphic products. The Navy’s Fleet Weather Center–San Diego should also be considered because it provides backup services.

<sup>45</sup> Some vessels/companies may incur costs associated with each incoming email, which might discourage their use of a subscription option.

<sup>46</sup> The NWS may be reluctant to allow this capability if it is identified as a *list serve*, and may need to require that individual subscriptions for emailed data expire quickly to limit multiple subscriptions for the same vessel due to crew turnover.

to make improvements, agencies such as NOAA, the NWS, and the Coast Guard must remain connected to marine users, both to identify changing user needs and to assess the effect of changes in the agencies' services.

NTSB staff has discussed the issue of feedback from marine users with the NWS and the Coast Guard. NTSB staff is unaware of any broad surveys since 2007 aimed at soliciting responses from the marine user community about NWS capabilities and services.<sup>47</sup> Discussions with NWS staff have, however, identified a desire for new feedback on mariner decision-making with regard to NWS weather information. Specific needs expressed by NWS staff include (1) understanding what weather information mariners use in their decision-making, (2) understanding when that information is used, (3) understanding whether certain NWS products are useful, and (4) developing opportunities to hear directly from ship masters.

The NTSB believes that future improvements to NWS services for mariners could be greatly aided by improved solicitation of mariner feedback to the NWS. To help accomplish that goal, support to the NWS could be provided by the Coast Guard. The NTSB concludes that future improvements to NWS weather services for mariners could be greatly aided by improved NWS solicitation of mariner feedback. Therefore, the NTSB recommends that the NWS develop and implement a plan for soliciting feedback from the marine user community, particularly ship masters, about the accuracy, timeliness, and usability of weather services to mariners.

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<sup>47</sup> In 2007, a request for public comment on questions asked in the *Federal Register* gave mariners 120 days to comment on their use of Coast Guard HF broadcasts and other resources, the impact that discontinuance might have on their operations, and the alternatives that they might consider in case of discontinuance. For a Coast Guard report on the findings, see <http://www.navcen.uscg.gov/pdf/deliverable%20final%20report.pdf>. In February 2017, the Coast Guard provided the NTSB with the results of a long-range communications survey distributed to vessels in 2016. The survey asked about usage and quality of NAVTEX, HF SITOR, HF VOBRA, and weather information sent by facsimile. The results can be found in an addendum to the NTSB Meteorology Group Factual Report for the *El Faro* investigation. In March 2017, the Committee on the Marine Transportation System (a federal cabinet-level, interdepartmental committee chaired by the Secretary of Transportation) discussed an Extreme Weather Task Force that is currently surveying federally owned, civilian-manned ships. The US Maritime Administration is working to get an exemption to the Paperwork Reduction Act for the project so that all US operators can subsequently be surveyed.



## Findings

1. Specific improvement of tropical cyclone forecasting in moderate-shear environments would lead to better model performance/guidance and improved mariner safety.
2. Technology that would allow National Weather Service forecasters to quickly sort through large numbers of tropical cyclone forecast model ensembles, identify clusters of solutions among ensemble members, and allow correlation of these clusters against a set of standard parameters would significantly improve official forecasts for tropical cyclones that affect mariners at sea.
3. Mariners using only Inmarsat-C SafetyNET miss important tropical cyclone information found in the Intermediate Public Advisories and Tropical Cyclone Updates.
4. Current National Weather Service policy for the issuance of an Intermediate Public Advisory may prevent the generation of important new information about a tropical cyclone that does not pose an immediate threat to land.
5. The “next advisory” time identified in the Tropical Cyclone Forecast/Advisory products for a particular storm could mislead some users as to when new storm information of any type for that storm will become available from the National Weather Service.
6. Although National Weather Service facilities are required to issue Special Advisories when an unexpected significant change is believed to occur in a tropical cyclone, no formal guidance exists for forecasters to define significant change.
7. Timely dissemination of National Weather Service Tropical Cyclone Forecast/Advisories, Intermediate Public Advisories, and Tropical Cyclone Updates to mariners in all regions via medium-frequency navigational TELEX (NAVTEX), high-frequency voice broadcasts (HF VOBRA), and high-frequency simplex teletype over radio (HF SITOR) would help mariners remain informed about tropical cyclones.
8. Certain enhancements to the National Weather Service FTPmail service would assist mariners in remaining cognizant of weather information not available in a timely manner, or not available at all, via other onboard weather information receipt vehicles.
9. Future improvements to National Weather Service weather services for mariners could be greatly aided by improved National Weather Service solicitation of mariner feedback.

## Recommendations

As a result of this report, the National Transportation Safety Board makes the following safety recommendations:

### **To the National Oceanic and Atmospheric Administration:**

Develop and implement a plan specifically designed to emphasize improved model performance in forecasting tropical cyclone track and intensity in moderate-shear environments. (M-17-8)

Develop and implement technology that would allow National Weather Service forecasters to quickly sort through large numbers of tropical cyclone forecast model ensembles, identify clusters of solutions among ensemble members, and allow correlation of those clusters against a set of standard parameters. (M-17-9)

### **To the National Weather Service:**

Work with international partners to develop and implement a plan to ensure immediate dissemination to mariners, via Inmarsat-C SafetyNET (and appropriate future technology), of the Intermediate Public Advisories and Tropical Cyclone Updates issued by the National Weather Service, in a manner similar to the current process of disseminating the Tropical Cyclone Forecast/Advisory. (M-17-10)

Modify your directives to ensure, for all tropical cyclones of tropical storm strength or greater within your jurisdiction, that your facilities issue, at the 3-hour interval between regularly scheduled Tropical Cyclone Forecast/Advisories, an Intermediate Public Advisory, a Tropical Cyclone Update, or another product available (or expected to be available) to mariners via Inmarsat-C SafetyNET (and appropriate future technology), and that the product include the coordinates of the current storm center position, maximum sustained surface winds, current movement, and minimum central pressure. (M-17-11)

Modify your directives to ensure that the “next advisory” time in a Tropical Cyclone Forecast/Advisory clearly indicates when to expect the next update of “current” or forecast information for that particular tropical cyclone. (M-17-12)

Quantitatively define “significant change” in terms of both the track and intensity of a tropical cyclone to guide the issuance of Special Advisory packages. (M-17-13)

Ensure that tropical cyclone graphic products issued by entities such as the National Hurricane Center, the Central Pacific Hurricane Center, the Guam Weather Forecast Office, the Joint Typhoon Warning Center, and Fleet Weather Center–Norfolk are made available in near-real time via the FTPmail service. (M-17-14)

Allow users to schedule recurring, automated receipt of specific National Weather Service products through an enhanced FTPmail service (and appropriate future technology). (M-17-15)

Develop and implement a plan for soliciting feedback from the marine user community, particularly ship masters, about the accuracy, timeliness, and usability of weather services to mariners. (M-17-16)

**To the US Coast Guard:**

In collaboration with the National Weather Service, provide timely broadcasts of the Tropical Cyclone Forecast/Advisories, Intermediate Public Advisories, and Tropical Cyclone Updates to mariners in all regions via medium-frequency navigational TELEX (NAVTEX), high-frequency voice broadcasts (HF VOBRA), and high-frequency simplex teletype over radio (HF SITOR), or appropriate radio alternatives (and appropriate future technology). (M-17-17)

**BY THE NATIONAL TRANSPORTATION SAFETY BOARD**

**ROBERT L. SUMWALT III**  
Acting Chairman

**CHRISTOPHER A. HART**  
Member

**EARL F. WEENER**  
Member

**T. BELLA DINH-ZAHR**  
Member

**Adopted June 20, 2017**