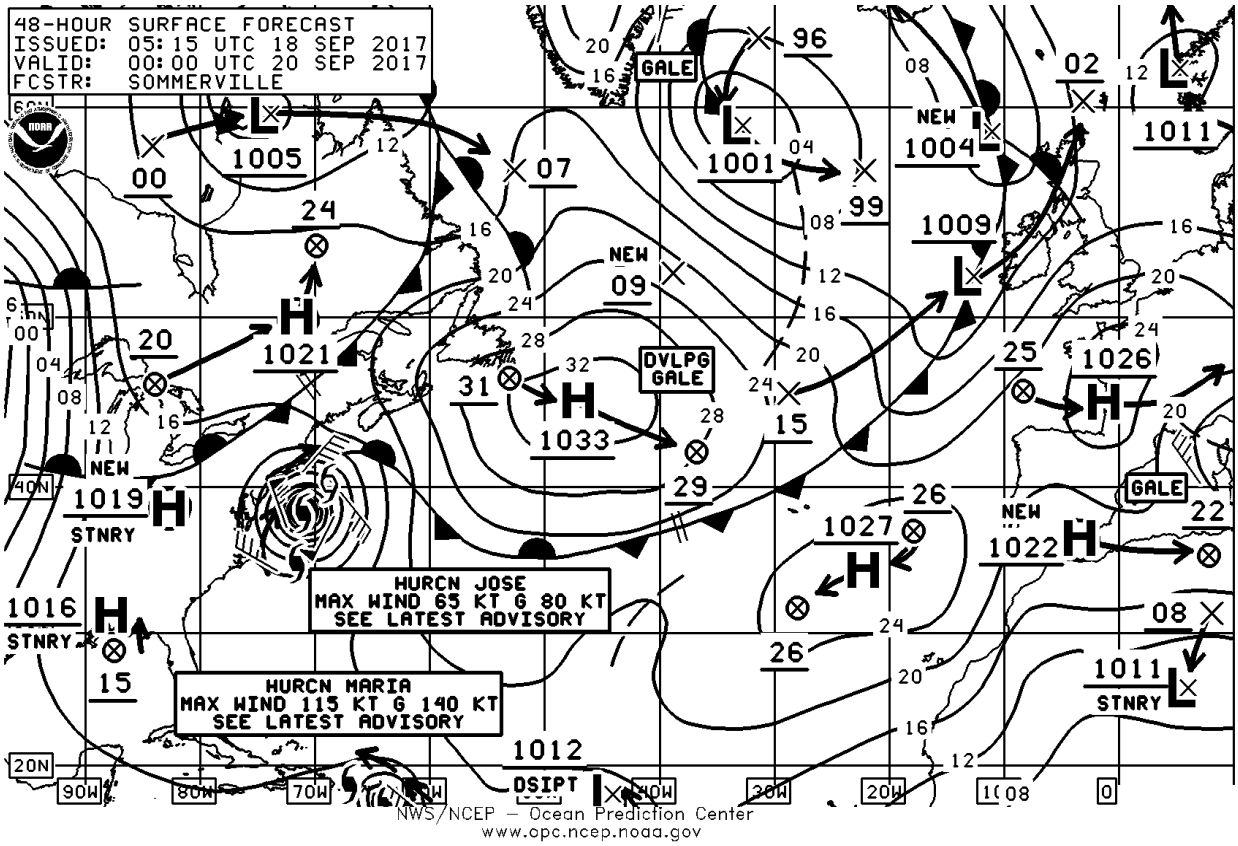
CMTS

U.S. Committee on the Marine Transportation System



Maritime Transportation Extreme Weather Task Force: *A Report to Congress*

February 2018

Maritime Transportation Extreme Weather Task Force: *A Report to Congress (2018)*

This report completes an action directed to the Secretary of Transportation under the National Defense Authorization Act; SEC. 3518. MARITIME EXTREME WEATHER TASK FORCE.

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LIST OF ACRONYMS

AIS	Automatic Identification System
CFR	Code of Federal Regulations
CMTS	U.S. Committee on the Marine Transportation System
ECDIS	Electronic Chart Display and Information System
EMC	Environmental Modeling Center
GFS	Global Forecast System
GMDSS	Global Maritime Distress and Safety System
GT	Gross Tonnage
HF	High Frequency
IHO	International Hydrographic Organization
IIP	International Ice Patrol
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
ISM Code	International Safety Management Code
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
KUP	Knowledge, Understanding and Proficiency
MARAD	U.S. Maritime Administration (Department of Transportation)
METAREA	Meteorological Area
METOC	Meteorological and Oceanographic
MITAGS	Maritime Institute of Technology and Graduate Studies
MMC	Merchant Mariner Credential
MSC	Military Sealift Command
MSI	Marine Safety Information
MF	Medium Frequency
MOVREP	Movement Report
NAIS	Nationwide Automatic Identification System
NAVTEX	Navigational Telex
NHC	National Hurricane Center
NIC	National Ice Center
NDAA	National Defense Authorization Act
Navy	U.S. Navy
NM	Nautical Miles
NMS	National Meteorological Service
NOAA	National Oceanic and Atmospheric Administration
NRF	National Response Framework
NTSB	National Transportation Safety Board
NWS	National Weather Service
OICNW	Officer in Charge of a Navigational Watch
OPC	Ocean Prediction Center

ORM	Operational Risk Management
OTSR	Optimal Track Ship Routine
PMO	Port Meteorological Officer (VOS Program)
PORTS	Physical Oceanographic Real Time System
RSMC	Regional Specialized Meteorological Centers
SMS	Safety Management System
SOCP	Ship Operations Cooperative Program
SOLAS	International Convention for the Safety of Life at Sea
STCW	International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers, 1978, as amended
Task Force	Maritime Transportation Extreme Weather Task Force
TCWC	Tropical Cyclone Warning Centers
USACE	U.S. Army Corps of Engineers (Department of Defense)
USC	United States Code
USCG	U.S. Coast Guard (Department of Homeland Security)
USMMA	United States Merchant Marine Academy
VHF	Very High Frequency
VOS	Voluntary Observing Ship
WFO	Weather Forecast Office
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

Section 3518 of the National Defense Authorization Act (NDAA) of 2017, enacted into law on December 23, 2016, directed the Secretary of Transportation, to establish, not later than 15 days after enactment, "a task force to analyze the impact of extreme weather events, such as in the maritime environment." In response, the Deputy Secretary of Transportation forwarded the directive to the U.S. Committee on the Marine Transportation System (CMTS) to study this issue and prepare a report.

The CMTS Maritime Transportation Extreme Weather Task Force (Task Force) was stood up on January 7, 2017 to include, as directed in the NDAA, the Secretary of Transportation or Secretary's designee, the U.S. Coast Guard (USCG) and National Oceanic and Atmospheric Administration (NOAA). The Task Force also included the Maritime Administration (MARAD), Department of the Navy, U.S. Army Corps of Engineers, Environmental Protection Agency, Department of State, Bureau of Safety and Environmental Enforcement, and National Ocean Council. The report was staffed by the CMTS Executive Secretariat. The Task Force was cognizant that the impetus for the directive in the NDAA stemmed from the tragic sinking of the *El Faro* during Hurricane Joaquin in October 2015 and the battering of the cruise vessel *Anthem of the Seas* during hurricane-force winds in February 2016. Due to the ongoing investigation of the *El Faro*, the National Transportation Safety Board (NTSB) was not a formal member of the Task Force but made their expertise available during the study period.

The Task Force received information for this report from federal agencies, industry representatives via the Ship Operations Cooperative Program (SOCP), a non-profit organization of maritime industry professionals to promote beneficial innovations in vessel and other maritime operations, and from various maritime academies and training institutions. Per the directive in Section 3518(c)(4) of the NDAA, the Task Force found no imminent threats to the safety of an individual on a vessel from extreme weather requiring immediate notification to the Secretary.

To understand available maritime weather prediction, monitoring, and routing technology resources, this report outlines the international framework for maritime weather prediction and monitoring, and the United States' commitment and contribution to this international framework. The National Weather Service (NWS) contributes to the global network of marine weather forecasting centers, and is a key service provider to the International Maritime Organization's (IMO) Global Maritime Distress and Safety System (GMDSS) to transmit weather-related maritime safety information.

The IMO has designated Navigational Telex (NAVTEX), a medium frequency (MF) radio system, as the primary means for transmitting urgent coastal marine safety information (MSI) to vessels. Within the U.S., NAVTEX messages are broadcast from USCG transmitters. Vessels

operating beyond the range of MF radio broadcast range are required to carry Inmarsat satellite equipment. Vessels at sea often rely on broadcasts of alphanumeric and graphical weather information, either via radio broadcast and satellite transmission. GMDSS requirements in the International Convention for the Safety of Life at Sea (SOLAS) Chapter IV specify the equipment necessary to be on board a vessel to receive weather information according to the sea areas in which the vessel operates.

To determine industry practices relating to the response and prevention of marine casualties from extreme weather events, the Task Force identified three key user communities to supplement the Task Force analysis: (1) federal vessel operators, (2) private vessel operators, and (3) maritime academies and training schools. The Task Force joined the SOCP extended industry panel discussion on maritime extreme weather at the SOCP annual meeting held April 5-6, 2017 in Seattle, WA. The Task Force also worked with individual members of the passenger, cargo, and cruise vessel industry, and training and educational organizations. Due to the limited time to develop this report, however, the Task Force was unable to engage industry in a survey tool. The Task Force Report is not a statistical sample of industry practices. As a result, the report is a qualitative, rather than quantitative, report. For a more thorough understanding of industry best practices and the resources used by various maritime sectors, the Task Force recommends a formal survey be implemented in accordance with the Paperwork Reduction Act.

The observations from these engagements, evaluations of the technical capabilities of the federal government in forecasting and disseminating information to mariners regarding extreme weather events, and recommendations provided by the Task Force are summarized below. Details on the recommendations can be found in Section D pages 39-43.

As noted, due to the limited timeline to produce this report, the responses provided herein do not provide a statistical sample of industry practices but provided federal agencies with valuable information from which to make recommendations and report observations.

RECOMMENDATIONS
1) NOAA should seek to harmonize the interpretation of the definition of 'heavy weather' vs 'extreme weather' and engage in efforts to improve the policies that clarify vessel response in circumstances of extreme weather. Specifically, NOAA and the USCG should coordinate and pursue amendments to the International Safety Management Code[1] to require commercial safety management systems to incorporate avoidance policies or procedures for extreme weather.
2) NOAA should continue working with international partners to develop standards for Electronic Chart Display and Information System (ECDIS) weather overlays to

[1] IMO Assembly Resolution A.741(18) (1993).

modernize the dissemination of critical maritime weather information directly to shipboard navigation systems.
3) Leverage federal resources to increase data access, visualization, and intelligence-gathering to better analyze the accuracy of weather forecasts and the effective response of NWS warnings, and provide for enhanced decision support services.
4) NOAA should continue to engage in the Ship Operations Cooperative Program (SOCP) Heavy Weather Working Group and Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) to increase real-time reporting of weather observations from vessels at sea.
5) It is recommended that NOAA increase international collaboration and the sharing of scatterometry data to further enhance the agency's ability to analyze and predict areas of dangerous winds at sea.
6) The Task Force encourages maritime training academies and other schools to review the final *El Faro* report by NTSB to determine where additional risk management training could be incorporated and provided, as appropriate.
7) The Navigation General modules on USCG examinations for deck officer credentials should be reviewed to determine if extreme storm response sections should be modified or enhanced for increased safety of life at sea.
8) Increase public-private engagement between federal agencies and the commercial vessel operator community to focus on increasing the number and quality of weather observations from ships of opportunity.

FOREWARD

"The time for taking all measures for a ship's safety is while still able to do so. Nothing is more dangerous than for a seaman to be grudging in taking precautions lest they turn out to have been unnecessary. Safety at sea for a thousand years has depended on exactly the opposite philosophy."

ADM Chester W. Nimitz, 1944[2]

Mariners must be weather savvy to protect their lives, their vessel, their cargos and the environment. When mariners are at sea, their safety depends on knowledge of the weather and being able to prepare for, and avoid where possible, storms with heavy and extreme weather conditions. Compared to those in peril on land, any emergency assistance at sea is challenged by extreme distances, or other factors, and often complicated by high winds and waves that can persist for several days.

Of course, timely and accurate weather forecasts and observations are just as essential at sea as on land but the ability to collect, analyze, share and receive timely weather information at sea is much more challenging. The use of partnerships among members of the maritime weather enterprise – which includes the marine transportation community, public weather sector, private weather companies, marine interest organizations, such as regional ocean observing systems, and academia – can ensure that the best possible forecasts are developed, hazardous weather warnings are issued, and critical information is communicated in a timely manner. As technologies for communicating marine weather information on the high seas expand and become more accessible, the information available now, along with emerging capabilities and best practices, will enable enhanced situational awareness and augment decision information available to vessels.

In addition to the value of new and expanded technologies related to weather information, the experience and training of mariners remains critical. Optimal bridge management and company-wide best operating procedures is a fundamental component required to make the best use of available technology.

Section 3518 of the National Defense Authorization Act (NDAA) of 2017, enacted into law on December 23, 2016, directed the Secretary of Transportation, to establish, not later than 15 days after enactment, "a task force to analyze the impact of extreme weather events, such as in the maritime environment." In response, the Deputy Secretary of Transportation authorized the directive to the U.S. Committee on the Marine Transportation System (CMTS) to study this issue and prepare a report. The full reference includes:

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[2] https://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/p/pacific-typhoon-18-december-1944/admiral-nimitzs-pacific-fleet-confidential-letter-on-lessons-of-damage-in-typhoon.html

SEC. 3518. MARITIME EXTREME WEATHER TASK FORCE of the National Defense Authorization Act of 2017, enacted into law on December 23, 2016, directed the Secretary of Transportation;

(a) ESTABLISHMENT OF TASK FORCE. —Not later than 15 days after the date of the enactment of this Act, the Secretary of Transportation shall establish a task force to analyze the impact of extreme weather events, such as in the maritime environment (referred to in this section as the ‘‘Task Force’’).

(b) MEMBERSHIP. —The Task Force shall be composed of—

(1) the Secretary or the Secretary's designee; and

(2) a representative of—

(A) the Coast Guard;

(B) the National Oceanic and Atmospheric Administration; and

(C) such other Federal agency or independent commission as the Secretary considers appropriate.

(c) REPORT. —

(1) IN GENERAL. —Except as provided in paragraph (4), not later than 180 days after the date it is established under subsection (a), the Task Force shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives a report on the analysis under subsection (a).

(2) CONTENTS. —The report under paragraph (1) shall include—

(A) an identification of available weather prediction, monitoring, and routing technology resources;

(B) an identification of industry best practices relating to response to, and prevention of marine casualties from extreme weather events;

(C) a description of how the resources described in subparagraph (A) are used in the various maritime sectors, including by passenger and cargo vessels;

(D) recommendations for improving maritime response operations to extreme weather events and preventing marine casualties from extreme weather events, such as promoting the use of risk communications and the technologies identified under subparagraph (A); and

(E) recommendations for any legislative or regulatory actions for improving maritime response operations to extreme weather events and preventing

marine casualties from extreme weather events.

(3) PUBLICATION. —The Secretary shall make the report under paragraph (1) and any notification under paragraph (4) publicly accessible in an electronic format.

(4) IMMINENT THREATS. —The Task Force shall immediately notify the Secretary of any finding or recommendations that could protect the safety of an individual on a vessel from an imminent threat of extreme weather.

The Maritime Extreme Weather Task Force, here after Task Force, enjoyed broad interagency participation including:

- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Coast Guard (USCG)
- Office of the Secretary of Transportation
- Maritime Administration (MARAD)
- Department of the Navy (U.S. Navy)
- U.S. Army Corps of Engineers (USACE)
- Environmental Protection Agency
- Department of State
- Bureau of Safety and Environmental Enforcement
- National Ocean Council
- CMTS Executive Secretariat

Due to the ongoing investigation by the National Transportation Safety Board (NTSB) regarding the sinking of the *El Faro* on October 1, 2015 during Hurricane Joaquin, NTSB was unable to join the Task Force formally but made their expertise available to the team, as appropriate, during the report development and final reviews.

This report fulfills the requirement to respond to the following statements in paragraph (2) of the NDAA: Per paragraph (4), the Task Force found no imminent threats to the safety of an individual on a vessel from extreme weather requiring immediate notification to the Secretary as required in the directive.

Report Development

The Task Force recognized that the NDAA direction was borne from the extreme weather incidents surrounding the tragedy of the Tote Maritime cargo vessel *El Faro* in October 2015 as well as Royal Caribbean's *Anthem of the Seas* cruise vessel that was battered by a severe hurricane-force storm off Cape Hatteras in February of 2016. The Task Force consulted with the NTSB during pre-report development discussions to consider NTSB information that was publicly available and discuss appropriate report boundaries given the ongoing NTSB investigation into the *El Faro*.

The Maritime Transportation Extreme Weather report would include information related to:

- Available weather prediction, monitoring, and routing technology resources from NOAA;
- Baseline of information regarding the way in which Federal vessel operators receive and respond to extreme weather information;
- USCG mariner credentialing training and examination requirements related to meteorology and oceanography topics;
- Information related to industry practices regarding the receipt of and response to extreme weather information;
- Required and available meteorological and bridge management training through established mariner training academies and facilities.

The consensus of the Task Force was also to mainly focus on vessel operations in near-coastal and oceans waters.

The Task Force also observed that the term "heavy weather" has a broad connotation within the maritime community with no clear definition. For example, the International Maritime Organization (IMO) Maritime Safety Committee refers to heavy weather in the context of both adverse and severe weather. (See e.g., IMO 2008 IS Code, Chapter 5). The Task Force sought to distinguish "heavy" from "extreme" weather, as heavy weather may indicate anticipated adverse conditions at sea. "Heavy weather" is often considered in relation to the impacts of the sea state on the vessel, which is highly dependent on the vessel type. The Task Force reached consensus that "extreme weather" poses greater risk to life and property at sea. The Task Force proposes maritime "extreme weather" be defined as wind and sea state conditions that pose a threat to life and property to *all* vessels.

Due to the limited timeline to produce this report, the responses provided herein do not provide a statistical sample of industry practices. As a result, this is a qualitative, rather than quantitative, report.

[A] AN IDENTIFICATION OF AVAILABLE WEATHER PREDICTION, MONITORING, AND ROUTING TECHNOLOGY RESOURCES;

To understand available maritime weather prediction, monitoring, and routing technology resources, this section begins by outlining the international framework for maritime weather prediction and monitoring, and the United States' commitment and contribution to this international framework. This framework influences the United States' transmission of weather forecasts, via the National Weather Service (NWS) under NOAA, within its international areas of responsibility offshore and on the high seas.

This section continues with an explanation of the forecast process, the environmental data inputs required to produce maritime weather forecasts, and the weather products disseminated by the U.S. government to ensure critical marine weather information is publicly transmitted. The federal government does not provide direct routing services to vessels outside the federal fleet; however, this section includes a brief description of the government-provided resources available to inform vessel routing.

INTERNATIONAL FRAMEWORK FOR MARITIME WEATHER PREDICTION AND MONITORING RESOURCES

The IMO and World Meteorological Organization (WMO) are specialized agencies within the United Nations. These organizations ensure that uniform weather-related maritime safety information is available globally for vessels at sea. The United States is a long-standing member of both organizations.

The IMO provides a regulatory framework for international shipping standards that is intended to promote safety in the maritime domain. One of the most important IMO treaties concerning maritime weather prediction is the International Convention for the Safety of Life at Sea (SOLAS). First adopted in 1914, two years after the sinking of the Royal Mail Steamer (RMS) *Titanic*, SOLAS codifies requirements for hazardous weather warnings. The current version of SOLAS was adopted in 1974, with a series of amendments issued thereafter (most recently in January 2017) to ensure the treaty remains relevant. SOLAS includes provisions for disseminating maritime safety information, such as hazardous navigation and weather warnings.

SOLAS Chapter V addresses safety of navigation. Key regulations regarding maritime weather include:

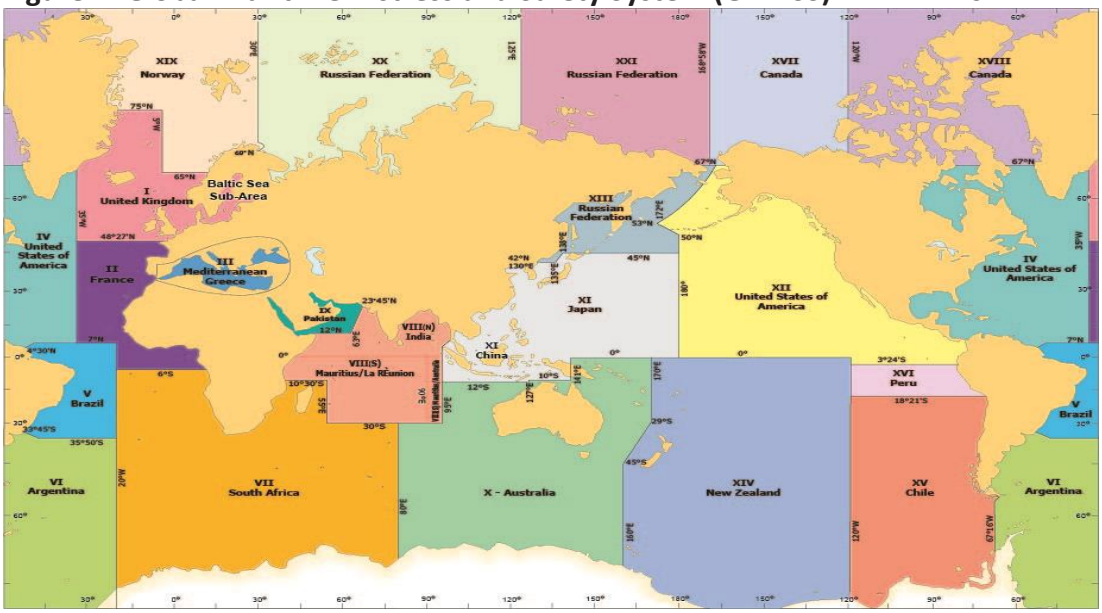
- Regulation 5, Meteorological Services and Warnings
- Regulation 6, Ice Patrol Service
- Regulation 30, Operational Limitations

- Regulation 34, Safe Navigation and Avoidance of Dangerous Situations

The WMO provides a coordinating structure that establishes protocols to ensure coastal nations provide standardized weather information, forecasts, and warnings to ensure the safety of life and property at sea. The WMO Manual on Marine Meteorological Services (WMO No. 558, Volume I) addresses maritime weather services for the high seas, coastal and offshore areas, major ports, and harbors. This includes the requirement that warnings be issued explicitly for tropical cyclones and for wind speeds of gale and storm force intensity. The terms gale and storm are defined as Beaufort wind scale force 8 and 9 (34-47 knots), and force 10 and over (>48 knots), respectively. (See Appendix 1 for the Beaufort Wind Scale). Additional services include warnings for other severe conditions such as, abnormal or rogue waves and restricted visibility resulting from fog and ice accretion. The WMO provides guidance for training in the field of marine meteorology, which pertains to meteorological personnel engaged in national meteorological services (NMSs), Port Meteorological Officers (PMOs), seafarers and marine observers aboard vessels.

Services are prepared and issued by NMSs based on areas of responsibility called meteorological areas (METAREAs) [Figure 1]. The METAREAs closely align with navigational areas, which are used to provide navigational information and warnings to vessels at sea. Weather-related maritime safety information is transmitted to vesels at sea by nations as part of the WMO Marine Broadcast System, which supports the IMO's Global Maritime Distress and Safety System (GMDSS). Countries providing "Issuing Services" are responsible for transmitting hazardous weather warnings and forecasts in METAREAs. Those providing "Preparation Services" contribute forecasts and warnings for transmission by Issuing Services.

Figure 1: Global Maritime Distress and Safety System (GMDSS) METAREAs



Source: WMO (2017)

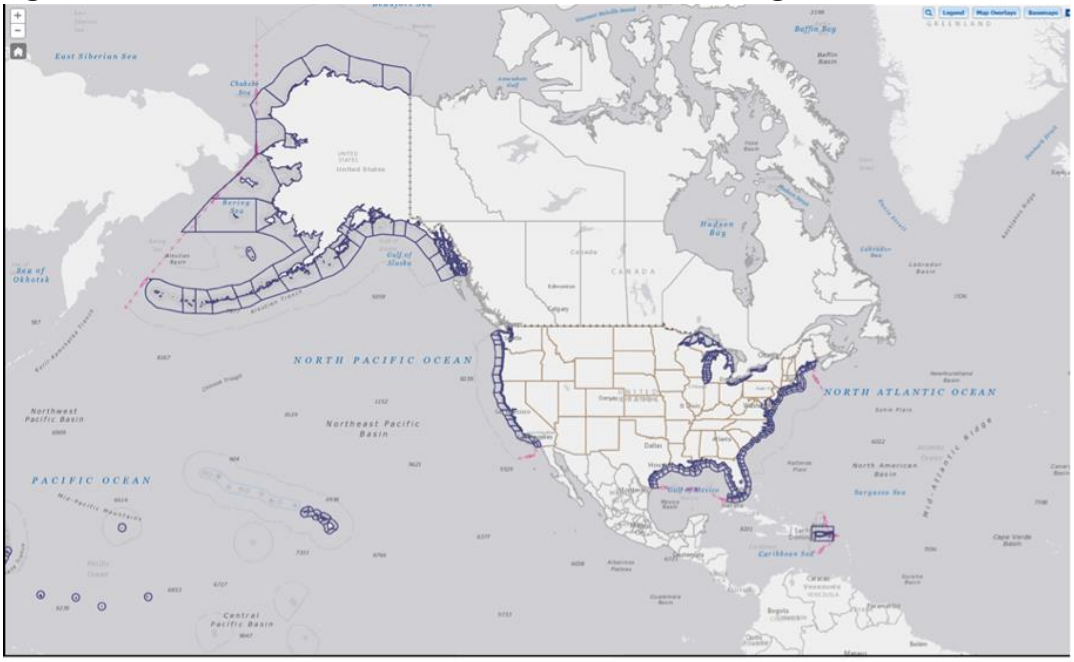
NOAA NATIONAL WEATHER SERVICE: THE U.S. MARITIME WEATHER SERVICE PROVIDER

The United States is one of 185 member states of the WMO and one of its longest-serving members. The NWS, one of six line offices in NOAA under the Department of Commerce, represents the United States in the WMO. The mission of the NWS is to provide weather, water, and climate data, forecasts, and warnings for the protection of life and property and enhancement of the national economy.

The NWS contributes to the global network of marine weather forecasting centers, and is a key service provider to the IMO's GMDSS. The NWS is the responsible "Preparation and Issuing Service" for hazardous weather warnings and forecasts for the high seas in METAREA IV encompassing the western North Atlantic Ocean, Gulf of Mexico, and Caribbean Sea, and METAREA XII encompassing the eastern North Pacific Ocean, including the Bering Sea. Additionally, the NWS is the Preparation Service for U.S. waters in Arctic METAREA XVII, for which Canada is the issuing service. The NWS also issues and broadcasts marine forecasts for U.S. territories in the Western and Southern Pacific Ocean. Other participating countries under the WMO bear responsibility for maritime forecasts in offshore areas outside the purview of the U.S., as shown in Figure 1.

In the NWS, marine forecasts and warnings are categorized as coastal, offshore, or high seas. Nearshore forecasts and warnings are not the subject of this report; however, to gain a comprehensive understanding of the forecast and dissemination process, it is important to note that 47 of the nation's 122 NWS weather forecast offices (WFOs) have responsibility for forecasting on the Great Lakes and along coastal areas, from the shoreline to approximately 50 nautical miles (NM) seaward (varies by NWS region) [Figure 2]. Additionally, the three WFOs in the NWS Alaska Region provide offshore forecasts in addition to coastal forecasts in that region.

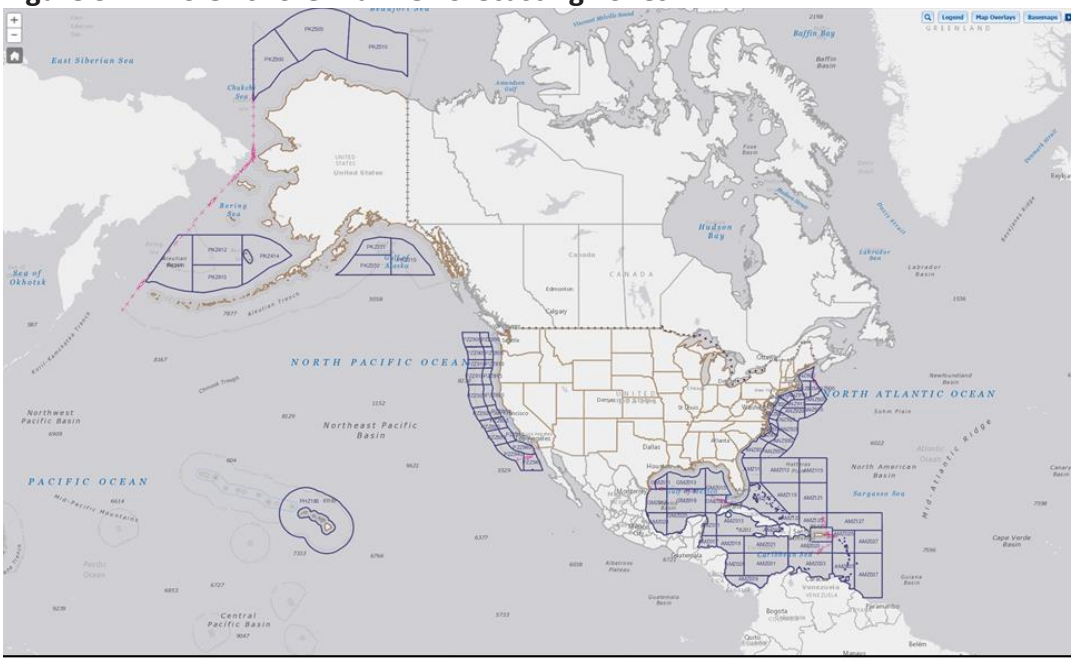
Figure 2: NWS Coastal and Great Lakes Marine Forecasting Zones



NWS Coastal and Great Lakes Responsibility

Source: NOAA NWS (2017)

Figure 3: NWS Offshore Marine Forecasting Zones



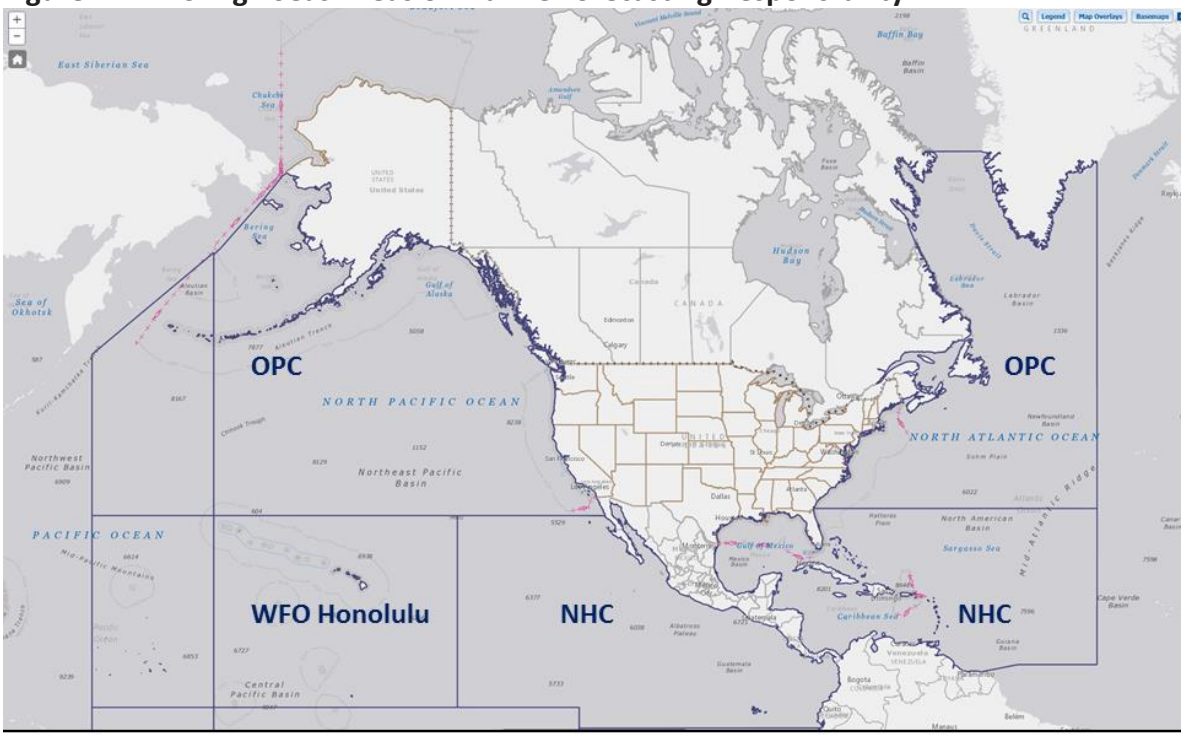
NWS Offshore Waters Responsibility

Source: NOAA NWS (2017)

Offshore forecasts extend approximately 50 to 250 nautical miles (NM) from coastal waters, pending the coastal region [Figure 3]. High seas forecast areas include the offshore zones and extend beyond the limits of the METAREAs [Figure 4]. Forecasts and warnings for the offshore zones and high seas areas are prepared to address GMDSS requirements and disseminated via GMDSS.

Three NWS entities have primary responsibility for providing authoritative maritime hazardous weather warnings and forecasts on the high seas [Figure 4]: the National Hurricane Center (NHC) in Miami, FL, the Ocean Prediction Center (OPC) in College Park, MD; and WFO Honolulu, HI. The OPC provides forecasts and warnings for the Western North Atlantic and Eastern North Pacific Oceans, from approximately latitude 30 degrees N to the Arctic Circle. OPC also provides forecasts for offshore waters of the U.S. East and West coasts. NHC's Tropical Analysis and Forecast Branch provides weather forecasts and hazardous weather warnings not directly associated with tropical cyclones for the high seas of the tropical North Atlantic and Eastern Pacific oceans, as well as offshore forecasts throughout the Gulf of Mexico and Caribbean Sea. The WFO in Honolulu, HI, provides marine forecasts and warnings on the high seas of the central Pacific between latitude 25 degrees S and 30 degrees N, in addition to coastal and offshore forecasts and warnings around Hawaii.

Figure 4: NWS High Seas Areas of Marine Forecasting Responsibility



Source: NOAA NWS (2017)

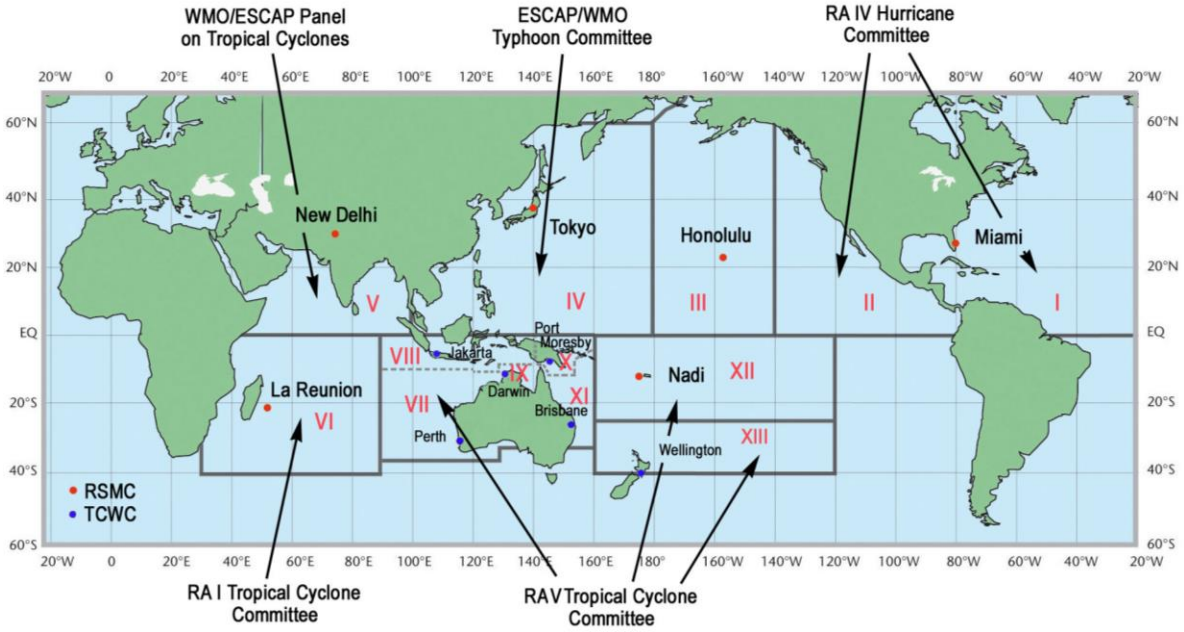
The NWS issues tropical storm and hurricane warnings for predicted wind conditions, as well as warnings for heavy rainfall, flood potential, and storm surge for coastal and inland areas. Tropical cyclones include any cyclone that originates over the tropical oceans and are classified by the intensity of the wind speed produced by the storm. Tropical cyclone classifications include: (1) tropical depression, with winds up to 17 meters per second (34 knots); (2) tropical storm, with winds of 18–32 meters per second (35–64 knots); and (3) severe tropical cyclone, hurricane or typhoon, with winds of 33 meters per second (65 knots) or higher.[3] "Tropical cyclone", "hurricane", and "typhoon" are the regional terms for the highest intensity tropical cyclone classification for a specific geographic region. Specifically, the term "hurricane" is used in the Atlantic and Northeast Pacific, while the same weather phenomenon in the Northwest Pacific is called a "typhoon" and "cyclones" occur in the South Pacific and Indian Ocean.

Mature tropical cyclones can exhibit the highest intensity over the ocean and have the combined destructive-potential of torrential rain, catastrophic winds, and storm surge. Cyclonic storms that do not originate over the tropical ocean are called non-tropical cyclones, extratropical lows, or extratropical cyclones. The term "extratropical" indicates the storm originated outside of the tropics. These cyclonic storms occur in the middle and high latitudes, and have the potential to move rapidly and intensify explosively. These storms often produce large wind fields of 1,500 NM or greater in diameter, and winds of gale-, storm-, or hurricane-force.

Tropical cyclones present a particularly dangerous threat to mariners, in addition to coastal residents, due to the extreme winds and waves produced by tropical cyclones. The WMO coordinates tropical cyclone warning services through six Regional Specialized Meteorological Centers (RSMCs) and three Tropical Cyclone Warning Centers (TCWCs) [Figure 5]. The NHC, as one of the six RSMCs, maintains a continuous watch for tropical cyclones throughout the Atlantic Ocean, Gulf of Mexico, Caribbean Sea, and the eastern Pacific Ocean. WFO Honolulu serves as the Central Pacific Hurricane Center and is also a tropical cyclone RSMC. Both NWS forecast offices issue tropical cyclone forecasts and warnings as needed.

[3] Wind speeds are measured globally at a 10-minute average with a standard anemometer level of 10 meters, except in the United States, where 1-minute average wind speeds are used.

Figure 5: WMO Tropical Cyclone Program RSMCs and TCWCs



Source: WMO (2017)

Additional weather phenomena that produce dangerous maritime conditions include explosively deepening non-tropical cyclones, the funneling of winds between landmasses or mountain ranges, winds parallel to mountainous coastlines, and winds opposing or perpendicular to strong ocean currents, such as the Gulf Stream. Explosively deepening cyclones are frequent, cover large expanses of ocean, and can produce hurricane force winds and waves in excess of 50 feet. These storms often impact the great circle shipping routes across the Pacific and Atlantic. Winds in the vicinity of coastlines with mountains, mountain gaps, and between landmasses can be violent and persistent. The Gulf Stream, due to its' warm temperature and strong current, is fertile for cyclones to develop and intensify. The interaction of the current of the Gulf Stream with opposing strong winds can produce violent destructive waves. Rapidly changing sea ice conditions, such as flash freeze, and the compression of pack ice due to winds and waves also yield extreme weather conditions.

The United States provides additional information and support regarding icebergs, sea ice, and lake ice, which pose additional hazards to shipping. Warning services for these hazards are detailed in SOLAS Chapter V and WMO publication "Sea-Ice Information Services in the World" (WMO No. 574). Ice detection and warning services are provided by the North American Ice Service (NAIS). The NAIS is an international collaboration between the Canadian Ice Service, International Ice Patrol (IIP), the U.S. National Ice Center (NIC), and NWS Alaska Region. Services include iceberg limit and concentrations for the North Atlantic and sea and lake ice analyses for the Arctic, Great Lakes, and Chesapeake and Delaware Bays, when required. Specifically, the NIC, a multi-agency center operated by the U.S. Navy, NOAA, and the USCG, provides global to tactical scale ice and snow products, ice forecasting, and other

environmental intelligence services. The NIC produces a Daily Ice Edge product[4] depicting the daily sea ice pack and the marginal ice zone, which is the transition between open ocean and pack ice and is a significant factor in navigational safety. The IIP, organized under the USCG, monitors iceberg danger in the North Atlantic Ocean and provides relevant iceberg warning products to the maritime community to eliminate the risk of iceberg collision. The IIP activities and responsibilities are delineated in U.S. Code, Title 46, Section 80302 and in SOLAS Chapter V, Regulation 6. The units making up the NAIS also supply detailed and timely information to government vessels operating in ice-impacted waters.

In summary, the NWS issues high seas forecasts in accordance with Regulation 5 of SOLAS and WMO Manual on Marine Meteorological Services (WMO No. 558, Volume I), which explicitly highlights gale (34-47 knots) and storm force (>48 knots) winds, thereby identifying areas with potentially damaging winds and waves for a given vessel. To better highlight threats posed by the most extreme cyclones at sea, the NWS further identifies areas of hurricane-force winds (64 knots and greater) associated with non-tropical cyclones at sea. NWS high seas forecasts are issued every six hours and include any marine warnings for gale, storm, hurricane-force wind, and tropical cyclone conditions.

FORECAST PROCESS

Numerical weather, wave, and ocean prediction models provide guidance to meteorologists that underlie the forecasting process. Weather and ocean forecast models are run two to four times daily using the data collected to make future predictions. These models run on supercomputers that make calculations based on systems of complex differential equations that approximate the physical processes of the atmosphere and its interaction with the oceans and sea ice. Within NWS, the primary source of these model data is the Environmental Modeling Center (EMC). The primary weather and ocean forecasting models run by EMC include the Global Forecast System (GFS) for weather data, and the WaveWatch III for wave height information. These models are run every six hours and are made available to all NWS forecast offices, distributed via the internet, and may be downloaded directly by the public.[5] Other models available for use by NWS maritime forecasters include the U.S. Navy's Global Environmental Models and global models from the Canadian and United Kingdom governments, and the European Center for Medium-range Weather Forecasting.

Experienced marine weather forecasters evaluate all available observations and numerical weather prediction guidance to ensure the atmosphere is being represented as accurately as possible in the model's initial state and to determine where the greatest uncertainties in the

[4] Daily Ice Edge products are available at [http://www.natice.noaa.gov/products/daily_products.html]
[5] Models are available for viewing at http://mag.ncep.noaa.gov/model-guidance-model-area.php

models exist on a given day. Forecasters then prepare and issue their marine weather forecasts, warn for hazardous weather conditions as needed, and send their forecasts for dissemination forecasts via internet, radio, or satellite broadcasts.

WEATHER OBSERVATIONS AS CRITICAL INPUTS TO THE FORECAST PROCESS

Marine forecasters and weather models require satellite, radar, and in-situ (directly measured) observational data to analyze the present state and predict the future environment conditions. Over most land areas, there is a tremendous volume of in-situ weather data available for use by the weather models and forecasters, such as from airports, state and local transportation and environmental systems, and high resolution networks. These data sources complement the weather satellite and radar observations, contributing to a sound understanding of the state of the atmosphere over land at a given time.

To receive practical sea-level observations and ground truth forecasts over the open ocean, the NWS relies on vessel and buoy observations. Over the open ocean, however, in-situ observations from vessels and buoys are limited and cannot provide the coverage density available to meteorologists over land; there simply are not enough vessels transiting the world's oceans to replicate the density of weather observations over land.

SOLAS Chapter V, Regulation 5 requires all states parties, including NMSs, to "encourage" the shipping industry to take, record, and transmit meteorological data and observations. The WMO Voluntary Observing Ship (VOS) scheme organizes and directs the international taking and transmitting of meteorological observations[6]. The NWS manages the U.S. contribution to the WMO VOS scheme, which encourages commercial, federal, and private vessels to submit real-time observations and provides some instrumentation to be placed aboard commercial ships of opportunity. Located in the major ports around the country, NOAA Port Meteorological Officers (PMOs) are the VOS program's field representatives and primary points of contact for vessels, as PMOs perform ship visitations to inspect equipment, repair and replace equipment, adjust equipment to ensure accuracy, and install electronic logging and encoding software.

Throughout the course of a ship visit, PMOs may engage in discussions of weather and provide training in weather observing techniques for VOS, as well as practical applications of meteorological products and services that are available from the NWS for planning safe voyages. Additional discussions and training in basic meteorology to enhance mariners' skill of weather map analysis and interpretation is also part of the PMO ship visit.

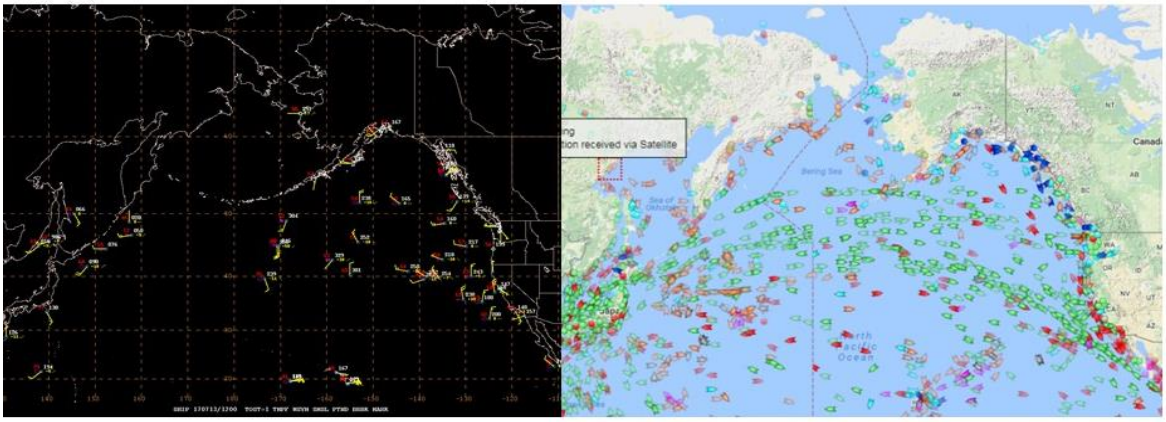
Vessel weather reports, as provided by the WMO VOS scheme, verify and provide observational data, a critical component of the weather forecasting process detailed above. These data assist in updating forecasts for hazardous weather conditions, providing verification of hazardous

[6] See WMO No. 471, Guide to Marine Meteorological Services

weather conditions, and as necessary, adjusting marine weather warnings in real-time.

Despite the language provided in SOLAS Chapter V, Regulation 5 to encourage companies and mariners to report weather observations at sea, comparisons between plots of vessels captured through automatic identification system (AIS) data against shipboard weather reports received in real-time by NWS seem to indicate that few vessels participate in providing observations for use by NMSs, including the NWS. [Figure 6]. Further, the WMO VOS program, consisting of 29 countries, reported only 15% of commercial vessels actively participate in the program and report meteorological observations at the WMO – Intergovernmental Oceanographic Commission (IOC) Joint Technical Commission on Oceanography and Marine Meteorology (JCOMM) SOT-9 conference.

Figure 6: Comparison of received VOS and real-time AIS vessel positions



Comparison of received VOS (left) for 1200 UTC 13 July 2017 and AIS positions of vessels via MarineTraffic.com (right).

To optimize the ocean observing capabilities, the Global Drifter Program of satellite-tracked buoys was established. These small buoys can sense sea surface temperature, sea-level pressure, and surface current via the drift of the buoy. A small percentage of the global drifting buoys are capable of observing wind speed. At present 1,400 buoys are tracked globally with the United States (through NOAA and other sources) contributing to approximately half of the total program worldwide. NOAA Atlantic Oceanographic & Meteorological Laboratory manages the U.S. Global Drifter Program, under the auspices of the Data Buoy Cooperation Panel of the WMO-IOC JCOMM.

Given the scarcity of in-situ observations at sea, marine forecasters rely heavily on remotely sensed data from geostationary and low earth orbiting satellites. Geostationary satellites provide visible and infrared images of clouds and weather systems; water vapor images highlight atmospheric moisture. NWS marine and tropical cyclone forecasters, experts in imagery interpretation, use these data, as well as those measured in other frequency bands to estimate the location and intensity of ocean storms. Tropical cyclone forecasts are often further

supplemented by wind data from instruments on-board or deployed from "Hurricane Hunter" reconnaissance aircraft.

Satellite-based radars, or scatterometers, scan the ocean surface at an angle to measure surface roughness, a proxy for wind speed and direction. Scatterometers can provide indirect measures of wind speeds and directions from near-calm to low-end hurricane force (64 knots or greater). Due to sensor limitations and the spatial scale at which they measure, it is difficult for today's scatterometers to accurately measure the highest winds in hurricanes and the most extreme non-tropical cyclones. These sensors, however, are generally capable of measuring the highest winds in the majority of non-tropical ocean storms. These data are useful in delimiting areas of hazardous winds reaching gale force (34-47 knots) and storm force (48-63 knots).

The primary sources of scatterometer data are polar-orbiting European satellites; at present, there are no U.S. weather satellites with these sensors.[7] Polar-orbiting satellites are not fixed relative to the earth's rotation, causing coverage over a given point not to be continuous. With two polar-orbiting satellites measuring at 12.5-kilometer resolution, a given point over the ocean will typically be measured no more than twice a day. Therefore, if a scatterometer misses a rapidly developing mid-ocean storm or tropical cyclone, there will likely be little to no data available for the weather models or meteorologists or weather models to confirm the existence of dangerous winds for another 12 hours. These data will only be available if a satellite coincidentally passes over the area into which the cyclone has moved.

Wave heights can be determined by altimeters, or satellite radars. Altimeters are acutely accurate downward pointing radars that produce a track line of wave height data, amongst other parameters. At present, there are five altimeters in orbit, two of which are cooperative endeavors between the U.S. (National Aeronautics and Space Administration) and European partners. These satellites, in total, provide global coverage every five days. Similar to the limitations inherent in scatterometers, wave-height inferring satellite altimeters make their precise measurements at a resolution of 4 NM. Repeat measurements for a given point occur as seldom as every three to five days. Therefore, satellites rarely measure the most extreme wave heights associated with oceanic storms.

Maritime forecasters are particularly adept at mining all available data over the ocean, relying on their experience to augment available satellite and in-situ observations to complete the analysis of potential maritime weather hazards.

[7] India successfully launched a scatterometer in 2016 and is expected to make the data operationally available to the U.S. late in 2017.

DISSEMINATION OF MARITIME WEATHER FORECASTS AND WARNINGS

SOLAS Chapter IV generally addresses the dissemination of maritime safety information products via GMDSS. SOLAS Chapter IV applies to all vessels 300 gross tons (GT) and larger. Chapter IV regulations relevant to this report include:

- Part A, Regulation 4, Functional Requirements (for communications).
- Part B, Regulation 5, Provision of Radiocommunication Services.
- Part C, Regulations 7-11, Radio Equipment: General.

To ensure critical marine weather information is transmitted to vessels in a timely manner, NWS marine weather forecasters issue numerous wind, wave height, and significant weather warnings, forecasts, and weather statements. These are made available to mariners and marine service providers around the clock in broadcast, alphanumeric, and graphical forms over the Internet and radio in compliance with SOLAS Chapter IV, Regulation 5. The majority of marine weather information is issued routinely at specified times. Unscheduled hazardous weather warnings, including many tropical weather products and special marine warnings, are issued as conditions are anticipated, imminent, or occurring.

Vessels close to land may be able to access NWS charts on the Internet via cellular phone service and to receive voice broadcasts from the NWS via NOAA Weather Radio. These transmitters operate in the very high frequency (VHF) band, causing their coverage area to be limited by transmitter power, antenna height, and any obstructions between the transmitter and receiver, such as mountains or other natural encumbrance. Reception ranges can vary between 10 and 50 miles or more from the transmitter sites.

More generally, vessels at sea often rely on broadcasts of alphanumeric and graphical weather information, either via radio broadcast or satellite transmission. GMDSS requirements in SOLAS Chapter IV specify the equipment necessary to be on board a vessel to receive weather information according to the sea areas in which the vessel operates. These include, but are not limited to:

- High frequency (HF), and VHF maritime radios.
- HF radiophone or radiotelex (for narrow-band direct printing).
- Medium Frequency (MF) Navigational Telex (NAVTEX) receiver.
- Inmarsat receiver.

The IMO has designated NAVTEX, a MF radio system, as the primary means for transmitting urgent coastal marine safety information (MSI) to vessels. Within the United States, NAVTEX messages are broadcast from USCG transmitters. The NWS prepares coastal and offshore weather forecasts and warnings; these are transmitted via NAVTEX to mariners who operate within approximately 200 NM of the U.S. coast. Transmitters are located near Boston, MA;

Chesapeake, VA; Savannah, GA; Miami, FL; New Orleans, LA; San Juan, PR; Cambria, CA; Pt. Reyes, CA; Astoria, OR; Kodiak, AK; Honolulu, HI; and Guam.

Production delays may cause a product to miss its transmission time due to the fixed-time broadcasts. Shipboard reception or equipment issues may also lead to a vessel missing a disseminated product.

Vessels operating beyond the range of MF radio (NAVTEX) broadcast range are required to carry Inmarsat satellite equipment. Inmarsat-C SafetyNET (Sat-C)[8] is an internationally adopted, automated satellite system for promulgating high seas weather forecasts and warnings, marine navigational warnings and other safety related information to all types of vessels at no-cost. SafetyNET text messages transmitted via Inmarsat can be directed to all vessels in an entire ocean satellite region, and messages with urgency and distress priority will set off audio and visual alarms and be displayed or printed on SOLAS-compliant terminals.

In addition to GMDSS transmissions, many nations operate high frequency (HF) weather broadcasts. Also known as radiofax, HF FAX, radiofacsimile or weatherfax, this is a means of broadcasting graphic weather maps and other images via HF radio. Maps are received using a dedicated radiofax receiver or a single sideband shortwave receiver connected to either an external facsimile recorder or a PC equipped with a radiofax interface. Use of this technology in the United States dates back to 1930, when the U.S. Weather Bureau partnered with Radio Corporation of America to test the technology. While HF reception quality can vary greatly, transmissions in this band offer the ability to reach the open ocean.

As of September 2017, there were 27 radiofax sites operating globally. Five are operated by the United States with charts produced by OPC, NHC, WFO Honolulu, and the NWS Alaska Region sent via USCG transmitters operating in Boston MA, New Orleans LA, Point Reyes CA, Kodiak AK, and Honolulu HI. Monochromatic charts and satellite images are broadcast at fixed times. Therefore, production delays may cause a product to miss its transmission time; network issues can degrade a product to the point of becoming unusable; and shipboard reception, HF propagation, and equipment issues either at the transmission site or receiver can result in a vessel receiving an unreadable product or missing one altogether. There is no alternate source for the broadcast of authoritative weather charts over the open oceans.

Graphical facsimile charts and text bulletins can also be received via either satellite communication or HF via an email request capability called ftpmail. The requestor sends a simple email in a required format to a NOAA server and receives the requested product via email. This is a low-bandwidth capability, making it available on the open seas and on inland

[8] https://www.ntsb.gov/safety/safety-alerts/Documents/SA-065.pdf.

waterways, and has become increasingly popular with those mariners who can afford satellite reception. A similar capability called Saildocs was developed for mariners with limited bandwidth, and includes NOAA graphical products, text bulletins and gridded forecast fields from numerical models and from the National Digital Forecast Database of forecaster derived digital fields. Given the complexity of the number of products, the Task Force developed the following summary matrix [Figure 7].

Figure 7. Representative NOAA Marine Weather Products

Category	Product	Update Frequency	Warning/ Forecast Period	Broadcast	Transmission	Coverage
Text	High Seas Forecast	6 hourly / as needed	2 days	GMDSS Safetynet	Satellite, Inmarsat-C	METAREAs IV and XII
Text	NAVTEX	6 hourly / as needed	5 days	NAVTEX	USCG MF	Coastal and Offshore to the Exclusive Economic Zone
Text	Tropical Cyclone Forecast/ Advisory	6 hourly / as needed	5 days	GMDSS Safetynet	Satellite, Inmarsat-C	North Atlantic Eastern/ Central Pacific
Graphical	Surface Analyses Surface Forecasts	6 hourly 12 hourly	00 hour 24/48/72*/96^ Hour	HF Radiofacsimile	USCG HF	North Atlantic North Pacific
Graphical	Wind/Wave Forecasts	12 hourly	24/48/72*/96^ Hour	HF Radiofacsimile	USCG HF	North Atlantic North Pacific
Gridded Forecasts	Wind speed/direction Wave heights	6 hourly / as needed	7 days 3 hourly (through 72 hours) 6 hourly beyond 72 hours	Available via internet access or email request	N/A	North Atlantic [1] North Pacific [2]

* - 72 hour forecast by NHC and NWS Honolulu
^ - 96 hour forecast by OPC, once per day
[1] – western North Atlantic from OPC, full Atlantic for NHC portion

[2] – eastern Pacific from OPC,NHC, Alaska waters from NWS Anchorage, Juneau, Hawaiian waters
Source: NOAA NWS

ROUTING TECHNOLOGY RESOURCES

While vessel routing services are provided to government-operated vessels, the federal government does not provide routing resources to vessels outside the federal fleet. Weather forecasts and information detailed above, however, are used by private companies to provide routing services to individual vessels by overlaying and analyzing weather forecasts against other environmental conditions affecting maritime navigation, such as ocean currents.

Publicly available resources to inform private vessel routing services include:

- Very Small Aperture Terminal, a two-way satellite ground station used to transmit broadband data to remote locations and for mobile maritime communications.
- The Global Maritime Distress and Safety System (GMDSS) (i.e. NAVTEX, VHF radio, etc.).
- NOAA's National Data Buoy Center website, for real time info from moored weather stations.
- NOAA NWS online products, including NOAA Marine Weather forecasting site, and local NOAA radio weather channels. NOAA NWS Forecast Offices also provide spot-forecasts on an as-needed basis.
- Weather forecast websites and smartphone applications (e.g., federal and private sector weather forecast and vessel routing provider's applications) when cellular mobility allows.
- Numerical model output from regional and global forecast systems such as the NWS High Resolution Rapid Refresh model, the North American Mesoscale model, NWS GFS model, Global WAVEWATCH Model, associated ensemble members of these forecast systems; and Global Real Time Ocean Forecast System ocean model.
- The NWS National Digital Forecast Data base of forecaster enhanced gridded forecast fields.
- Navigation software products that have the ability to overlay forecast information and limited model data on electronic charts in current and future operating areas.
- Coastal webcams if available (visibility, waves).
- USCG Bar Reports (VHF radio), in selected areas.

To fully understand the ways in which the federal routing of marine weather differs from civilian routing, the Task Force compiled the standard operating procedures within the Federal family of vessel operators. The Task Force received information from the U.S. Navy, USCG, Military Sealift Command (MSC), and the NOAA fleet, and this is provided as a suggested best practice in Section B.

[B] AN IDENTIFICATION OF INDUSTRY BEST PRACTICES RELATING TO RESPONSE TO, AND PREVENTION OF MARINE CASUALTIES FROM, EXTREME WEATHER EVENTS

&

[C] A DESCRIPTION OF HOW THE RESOURCES DESCRIBED IN SUBPARAGRAPH (A) ARE USED IN THE VARIOUS MARITIME SECTORS, INCLUDING BY PASSENGER AND CARGO VESSELS;

To determine industry practices relating to the response and prevention of marine casualties from extreme weather events, the Task Force identified three key user communities to supplement the Task Force analysis: (1) federal vessel operators, (2) private shipping operators, and (3) maritime academies and training schools.

The Task Force attended the Ship Operations Cooperative Program (SOCP) extended industry panel discussion on maritime extreme weather at the SOCP annual meeting held April 5-6, 2017 in Seattle, WA. The SOCP is a private non-profit organization that describes its overall objective as improving the safety, productivity, efficiency, security, and environmental performance of U.S. vessel operations. SOCP's membership consists largely of private operators of large, commercial seagoing vessels.

The Task Force also worked with individual members of the passenger, cargo and cruise vessel industry, and training and educational organizations. As noted previously, due to the limited time to develop this report, we were not able to engage industry in a survey tool. The Task Force Report is not a statistical sample of industry practices. For a more thorough understanding of industry best practices and the resources used by various maritime sectors, the Task Force recommends a formal survey be implemented in accordance with the Paperwork Reduction Act.

FEDERAL VESSEL OPERATIONS

The Task Force evaluated best practices by federal vessel operators to better understand and identify their practices related to the response and prevention of marine casualties from extreme weather events. Federal vessel operators include the U.S. Navy, USCG, U.S. Army, USACE, Military Sealift Command (MSC), MARAD, and NOAA. Commander, Naval Meteorology and Oceanography Command, serves as the primary source for timely, relevant and accurate weather and oceanographic information to federal vessel operators. 10 USC §7921 authorizes the U.S. Navy to provide all maritime vessels, aircraft, and forces of the U.S. armed forces, as well as North Atlantic Treaty Organization and coalition forces with maritime environmental safety information, such as weather analyses and forecasts. Other government vessels may also request and receive environmental forecasts, especially when operating in concert with U.S.

Navy forces.

To receive weather and oceanographic support, federal vessel operators submit a Movement Report (MOVREP) message to the U.S. Navy. This message contains future positional information for the vessel. The U.S. Navy Fleet Weather Center located nearest the vessel's area of operations uses this information to issue daily weather forecasts to the vessel, as well as to other vessels listed in the MOVREP, via email through the span of the dates listed. Forecasts are localized for the route or operating area specified by the vessel and are modified as MOVREPS are updated. Vessels receive periodic (daily) forecasts, which also warn of oncoming storms and other potentially hazardous conditions. Vessels eligible for U.S. Navy support can also receive Optimum Track Ship Routing (OTSR) advice from the U.S. Navy in most areas of the world, when requested. OTSR is a Federal advisory service, designed to minimize the risk of damage to vessels at sea from storms, high seas, and sea ice. Routing advice is based on a vessel's operational limits, expressed as the maximum seas ahead, abeam, and astern as well as the maximum sustained wind speed that the vessel can safely sustain without substantial risk of damage to the vessel and cargo. Forecasts and warnings, and OTSR recommendations are received by the vessels via message traffic or email.

Provision of U.S. Navy meteorological and oceanographic (METOC) services begins with specific tasking for support on timescales that range from immediate to long-term planning for days into the future. U.S. Navy METOC personnel collect and consider relevant environmental data from the area of concern on scales ranging from synoptic scale to the micro-scale. Model production centers, primarily at the Fleet Numerical Meteorology and Oceanography Center in Monterey, California and the Naval Oceanographic Office at Stennis Space Center Mississippi**,** produce and distribute various atmospheric, oceanographic, and coupled ocean-atmosphere models to the personnel that are developing weather forecast support to inform their decisions. The result is a weather product to the federal vessel operators that help to inform operational risk decisions and/or exploit favorable weather conditions to carry out operations. The vessel's commanding officer/master, however, retains ultimate responsibility for safe operation of their vessel.

This information may be distributed to federal vessel operators through multiple delivery paths – naval message traffic, email, website post-and-pull, one way and two-way satellite communications paths, PowerPoint briefs, closed-circuit television and voice communications. Due to the wide variety of possible interruptions to data and information delivery, and possible unsafe conditions that could result in the vessel not receiving the information, there is often redundancy in information delivery.

Operational Risk Management (ORM) is a core function of any U.S. Navy command, such as MSC. Commanders are trained to evaluate risk to their units and personnel accomplishing the mission against countless variables impacting operations. Weather is one facet of many considerations balanced during the ORM process. Similarly, the USCG adheres to internal policy

regarding ORM. For example, smaller USCG units have published weather limits and operating outside of those limits requires operational concurrence. The United States National Response Framework (NRF) and local contingency plans are used to prevent, prepare for, respond to, and recover from a variety of incidents, including hurricanes. Information from the NRF and local contingency plans are typically applicable to all Federal operators in coastal and inland waters, and ports.

Throughout the Task Force's evaluation, federal vessel operators reported that safety of personnel is generally prioritized over mission accomplishment. Commanding Officers have operational flexibility in cases of extreme weather, and if the state of the weather is creating an unsafe work environment, can cancel operations. Further, extreme weather often impacts mission success beyond the safety of personnel, and may impact mission effectiveness itself. For example, poor weather often results in poor data collection. Therefore, suspending NOAA-research operations are often preferred over collecting poor quality data.

Federal vessel operations have vessel-specific instructions or standard operating procedures, which expressly describe the weather limits (typically wind and sea state) for a given deployment. For example, NOAA deck officers are a mix of civilian credentialed mariners and NOAA Corps officers. Many NOAA deck officers have extensive training and background in meteorology and can provide crucial information during severe weather risk mitigation. Finally, in military operations impacted by adverse weather, unit Commanding Officers and their higher authority will discuss conditions and may adjust the mission execution parameters accordingly.

INDUSTRY VESSEL OPERATIONS

The International Safety Management Code (IMO Assembly Resolution A.741(18) (1993)) (ISM Code) provides guidance to the international shipping industry in shipboard and shore-based management for the safe operation of vessels and for the prevention of marine pollution. The ISM Code establishes safety management objectives and requires a safety management system (SMS) to be established by individual companies, including any person or manager responsible for operating the vessel. The broad terms of the ISM Code allow for its widespread application in the international context of shipping and maritime operations. However, the broad terms of the ISM Code inevitably leads to a wide range of accepted practices in the maritime industry. The ISM Code does not explicitly require heavy weather avoidance policies or procedures be included in an SMS. This practice and requirement is addressed in the recommendations provided under Section D.

The Task Force found common industry practice for U.S.-flagged vessels for navigating heavy weather. As heard by the Task Force at the SOCP panel, vessel operators use their own company operating criteria and the warnings and forecasts provided by NOAA's NWS to avoid areas of hazardous wind and wave conditions. A company's operations policies are dependent on the type and robustness of their vessels (cargo type, freeboard heights, propulsion systems,

etc.) and whether they are large deep draft vessels or smaller coastal vessels. Private vessel operators reported their policies are to avoid sea states greater than "Beaufort Force 6" (22-27 knots/25-31 mph). For companies operating passenger ferries and coastal towing vessels, including articulated tug and barges, their avoidance threshold of Beaufort Force 6 may be somewhat less than that used for larger vessels. Vessel owners emphasized the need to ensure that early and substantial passage course corrections are made well in advance of developing weather systems to ensure that their vessels avoid adverse sea conditions. It was also stated that if a routing change is made too late, a vessel will not be able to avoid high sea states.

The Task Force learned that private vessel operators emphasize weather routing and passage planning to ensure the safety of the vessel and its crew, passengers, and cargo. Vessel operators reported supplementing government provided weather information, obtained from NAVTEX and weather fax, with information from private sector weather forecasting and vessel routing services. These private services provide vessels with the latest weather information and suggested guidance for optimal routing. On occasion, the routing information provided by the private routing companies will conflict with the government information obtained by NAVTEX or facsimile. When this happens, the vessel's Master must rely on training and experience to reconcile the conflicting information and to determine the vessel's route. A commercial vessel operator related a situation involving conflicting information for routing between two developing storms, the Master had to exercise best judgment in determining the vessel's route. Several companies noted that they coordinate vessel routing with the vessel's Master via email several times a day prior to departure and throughout the voyage to ensure a timely and safe passage.

Industry representatives indicated that it is their general practice to provide their Masters with the discretion to determine their vessels' routes in potentially hazardous seas. Hazardous seas have the potential to damage a vessel and can delay the vessel. Awareness that damage may be occurring to the vessel depends on several factors including the type of vessel, its loaded condition, and the location of its bridge. If the bridge is located near the bow, watch officers may be more aware of the forces acting on the vessel compared to watch officers on a vessel where the bridge is located aft, perhaps 700 feet from the bow. It is critical that the Master and deck officers operate their vessel conservatively in heavy weather. This concept should be spelled out in the company's operating procedures and the company should support Masters who have slowed their vessel in heavy weather. Several operators indicated that they consider the passage of a vessel through Beaufort Force 8 (moderately high, 18 to 25 foot waves) or above to be unacceptable.

As noted, private vessel operators or owners often contract with third party routing services to provide weather information and to suggest the best routing plan for vessels. These routing providers will generally provide client vessels updates several times a day, highlighting areas with current or developing hazardous weather. The vessel uses this information to plan for the next three to four days to avoid hazardous weather. It should be noted that a communications

or hardware failure aboard a vessel may prevent the receipt of timely and accurate forecasts and routing information, this includes failures involving:

- NAVTEX;
- Weather Fax;
- Email connectivity; and
- Inmarsat-C.

MERCHANT MARINER CREDENTIALING

The Task Force collected information regarding the training and examination requirements to qualify for merchant mariner credentials (MMCs) issued by the USCG. The MMCs authorize the mariner to serve upon civilian-manned vessels operated by Federal agencies and by private companies.

Background and Requirements

The USCG has an established program for credentialing merchant mariners serving on a U.S.-flag vessel that is governed by domestic law in the United States Code (USC), titles 5, 14, 33 and 46, and the Code of Federal Regulations (CFR), Title 46, Subchapter B. These regulations and statutes also include the United States' responsibilities for the implementation of the provisions of the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW) 1978, as amended. Through these domestic statutes and regulations, the USCG issues national and STCW officer and rating endorsements to qualified merchant mariners.

The STCW Convention and the STCW Code contain international standards for the qualifications of merchant mariners. The STCW Code includes required standards of competence for deck officers, including the requisite level of knowledge, understanding and proficiency (KUP).

Under U.S. regulations, STCW applies to all U.S. vessels operating outside the "boundary line" or on international voyages. All mariners serving on seagoing U.S. vessels subject to the STCW must meet the STCW's required competency standards. The regulations that implement STCW include the requirements for STCW endorsements for Officer in Charge of a Navigational Watch (OICNW) of vessels of 500 GT or more, Chief Mate and Master for vessels of 3,000 GT or more, and Chief Mate and Master for vessels of 500 GT or more and less than 3,000 GT.

Operational Level Deck Officers

Mates other than chief mates on vessels subject to STCW must meet the requirements for OICNW in 46 CFR 11.309. This includes meeting the STCW standard of competence and the following KUPs:

- Ability to use and interpret information obtained from shipboard meteorological instruments;
- Knowledge of the characteristics of the various weather systems, reporting procedures, and recording systems; and
- Ability to apply available meteorological information.

To achieve these KUPs, mariners who will serve as the OICNW must complete USCG-approved training in Basic Meteorology (46 CFR 11.309(a)(4)(xiii)). This training is typically one week long and is substantially similar to the meteorology module IMO Model Course 7.03, *Officer in Charge of a Navigational Watch*. This course includes characteristics of weather systems; ocean current systems; weather charts and reports; and tides and tidal currents. To pass the course, mariners must demonstrate that they have achieved the required KUPs through the written examinations and practical demonstrations.

In addition to the training and practical tasks required for an STCW endorsement, Mates on vessels 500 GT or more (including 2nd and 3rd Mates) must pass a professional examination that will include questions on the following subjects identified in 46 CFR 11.910:

- Characteristics of Weather Systems;
- Ocean Currents;
- Weather Charts and Reports; and
- Heavy Weather Operations.

<u>Management Level Deck Officers</u>

Masters and chief mates serving on any vessel of 500 GT or more, subject to the STCW, must meet the requirements in 46 CFR 11.305, 11.307, 11.311, or 11.313, as appropriate. Mariners must meet the following KUPs associated with the competence *forecast weather and oceanographic conditions*:

- Ability to understand and interpret a synoptic chart and to forecast area weather, taking into account local weather conditions and information received by weather fax;
- Knowledge of the characteristics of various weather systems, including tropical revolving storms and avoidance of storm centers and the dangerous quadrants;
- Knowledge of ocean current systems;
- Ability to calculate tidal conditions; and
- Use all appropriate nautical publications on tides and tidal currents.

These KUPs are achieved by completion of required training in Advanced Meteorology. This course is typically one week long and is substantially similar to the meteorology module of IMO Model Course 7.01, *Master and Chief Mate*. Student knowledge is assessed by the written

examinations in the course, and ability to apply the knowledge is demonstrated through a series of practical demonstrations, including forecasting expected weather for a 24 or 48-hour period.

Mariners seeking STCW endorsements as Master or Chief Mates are also required to demonstrate the KUP *management and handling of ships in heavy weather*. This is met by completing USCG-approved training for Advanced Shiphandling.

In addition to the STCW requirements above, mariners serving as chief mate and master are examined on their knowledge of meteorology, heavy weather vessel handling, and tropical cyclones on the written examination required for their national officer endorsement (license).

Training

Required training for merchant mariners is conducted by maritime academies and other training schools, including for-profit commercial schools, vessel operators, and maritime labor unions. The Task Force sought background on course requirements and curriculum for heavy weather preparedness and response at the maritime academies and at other training institutions. The Task Force received input from the State University of New York Maritime College, Great Lakes Maritime Academy, Maine Maritime Academy, the United States Merchant Marine Academy (USMMA), Texas A&M Maritime Academy, Maritime Institute of Technology and Graduate Studies (MITAGS), Pacific Maritime Institute (PMI), and Calhoon Marine Engineers' Beneficial Association Engineering School.

Maritime Academies

Maritime academies are academic institutions that provide USCG-approved comprehensive training programs leading to credentials as Third Mate or Third Assistant Engineer, and also an academic Bachelor's degree.

At the maritime academies, deck cadets and midshipmen must complete the required training and assessments for an STCW endorsement as OICNW on vessels of 500GT or more described above. This training and assessment is accomplished and reinforced throughout the academies' four-year curricula. In addition to classroom and practical training ashore, cadets and midshipmen receive shipboard training on commercial vessels, the academies' training vessels, or a combination of both. This experience at sea provides an invaluable opportunity to learn and experience the actual shipboard environment.

NOAA's Vessel Observing System (VOS) PMOs have been providing meteorological training and support to the maritime academies. The PMO serves as a "Sea Term" instructor. The VOS program maintains close relationships with the academies in order to introduce the VOS program. The PMO stresses the importance of reporting marine weather observations to the

cadets. At sea, the PMO provides formal classroom instruction designed to enhance the cadet's ability to determine the expected weather conditions, and to make, record, and transmit an accurate weather observation.

At the USMMA, midshipmen are taught to appreciate the forces created upon the vessel by increasing sea states. Mariners' "rules-of-thumb" are stressed to firmly ingrain the concepts. Emphasis is placed on the operational considerations for navigating in the vicinity of tropical cyclones. The midshipman is taught to understand and appreciate the difference between the forecasted "significant wave height" and the highest wave heights that might be expected, the significant wave height represents the average of the highest one-third of waves, and larger waves will be encountered. Class discussions incorporate recent scientific analysis of extreme occasional wave heights (rogue waves) and vessel operational considerations.

Some maritime academies expressed concern that that the extensive training required for merchant mariner credentials limit the time that can be devoted to meteorology in a 4-year curriculum leading to merchant mariner credentials and an academic degree.

Training Institutions Other Than Maritime Academies

Training schools other than the maritime academies provide comprehensive programs and individual courses for all levels of mariner credentials. These schools are operated by labor unions, vessel owners and operators, and by for profit commercial entities.

Training institutions that responded to the Task Force stated that they provide the USCG-approved training in "Basic Meteorology" and "Advanced Meteorology" required for STCW endorsements at the operational and management levels described above. These meteorology courses will vary by institution, but all must meet the same standards for course content and student proficiency in order to obtain USCG approval.

In addition to meteorology training, these schools offer training in "Advanced Shiphandling" that will include training in handling a vessel in heavy weather. As described to the Task Force, heavy weather vessel operations and storm avoidance include procedures to maneuver safely away from heavy seas or storms and to mitigate the damage to vessels in adverse conditions, such as potentially slowing to avoid slamming into seas or steering directly into heavy seas to reduce heavy rolls. Re-routing or slowing progress through a storm are the primary strategies for safely navigating in or around adverse conditions.
MITAGS and PMI emphasized to the Task Force the need to connect weather scenarios to topics across a full maritime training curriculum. MITAGS and PMI stressed the value of recording observations at sea and building experience with data interpretation, such as use of synoptic scale charts, to allow students to better understand weather phenomena.

Military Training and Practices

Marine meteorology and heavy weather operations training in the U.S. military includes training for deck officers as they gain experience operating in various weather conditions. Every vessel and shore installation has heavy weather procedures designed to prepare the unit for operations in heavy weather. Shipboard personnel are trained to take and report weather observations. Afloat and ashore units are trained annually in hurricane/typhoon preparedness. Large-scale exercises are conducted to train and refresh all afloat and shore commands in preparedness for heavy weather in port and to potentially depart from port well ahead of dangerous wind, sea, or storm surge conditions.

Military personnel selected to command positions receive maritime weather training. All Deck Watch Officers, and Quartermasters of the Watch complete weather training as part of their qualification processes.

[D] RECOMMENDATIONS FOR IMPROVING INDUSTRY MARITIME RESPONSE OPERATIONS TO EXTREME WEATHER EVENTS AND PREVENTING MARINE CASUALTIES FROM EXTREME WEATHER EVENTS, SUCH AS PROMOTING THE USE OF RISK COMMUNICATIONS AND THE TECHNOLOGIES IDENTIFIED UNDER [A]

The Task Force reviewed comments and recommendations received from federal and non-federal stakeholders at varying times during the reporting period. The Task Force reflected upon the findings by the NTSB in the Safety Recommendation Report; these are not addressed in this report, as agencies will respond to the NTSB separately.

Based on comments and recommendations received, the Task Force makes the following specific recommendations and opportunities for improving industry response and policies regarding extreme weather events and preventing marine casualties from extreme weather events. The order of the recommendations provided in this report does not indicate priority.

Recommendation 1. NOAA should seek to harmonize the interpretation of the definition of 'heavy weather' vs 'extreme weather' and engage in efforts to improve the policies that clarify vessel response in circumstances of extreme weather. Specifically, NOAA and the USCG should coordinate and pursue amendments to the ISM Code[9] to require commercial safety management systems incorporate avoidance policies or procedures for extreme weather.

The Task Force observes that the term 'heavy weather' has a broad connotation within the maritime community with no clear definition. For example, the IMO Maritime Safety Committee refers to heavy weather in the context of both adverse and severe weather. (For example, see IMO 2008 Code on Intact Stability for All Types of Ships Covered by IMO Instruments (IS Code), Chapter 5). Meanwhile, no formal or customary definition of the term 'extreme weather' exists within the maritime industry.

The Task Force recommends distinguishing 'heavy' from 'extreme' weather. Heavy weather broadly indicates adverse conditions at sea, the impacts of which are highly dependent on vessel type and size. For example, a large cargo vessel may transit safely through an area of gale force winds, 'heavy weather' conditions are likely to be quite hazardous to a cabin cruiser, and a smaller boat would clearly want to avoid such conditions. However, regardless of vessel size or type, a hurricane poses a grave hazard to any vessel and would therefore be considered 'extreme weather.' The Task Force reached consensus that 'extreme weather' poses a greater risk to life and property and proposes maritime extreme weather be defined as wind and sea state conditions that pose a threat to life and property to *all* vessels at sea.

[9] IMO Assembly Resolution A.741(18) (1993).

Traditionally, NOAA NWS issues warnings for gale, storm, and hurricane force conditions for non-tropical storms and tropical storm and hurricane conditions for tropical cyclones. NOAA considers hurricane conditions to be extreme weather. The capabilities to predict extreme weather events at sea have increased worldwide, and should influence vessel operators to take measures to avoid extreme weather to improve vessel and personnel safety. The Task Force recommends NOAA harmonize the interpretation of the definition of 'heavy' weather' vs 'extreme weather' and engage in efforts to improve the policies that clarify vessel response in circumstances of extreme weather. One specific policy recommendation offered by the Task Force is for NOAA and the USCG to coordinate and pursue amendments to the International Safety Management Code to require commercial safety management systems incorporate avoidance policies or procedures for extreme weather.

Recommendation 2. NOAA should continue working with international partners to develop standards for Electronic Chart Display and Information System (ECDIS) weather overlays to modernize the dissemination of critical maritime weather information directly to shipboard navigation systems.

The WMO and IMO ensure that uniform weather-related maritime safety information is available globally for vessels at sea. GMDSS requirements, regulated under the IMO, mandate all ocean-going passenger and cargo vessels of 300 GT and greater be equipped with radio equipment to improve the safety of international voyages. GMDSS specifically require vessels to receive broadcasts of authoritative maritime safety information, including weather forecasts and warnings, to prevent the occurrence of distress at sea. Authoritative weather forecasts and warnings are disseminated via NAVTEX, Inmarsat, and facsimile in accordance to WMO and IMO GMDSS standards.

Given the range of factors in routing a vessel across the sea, individual vessel routes must consider weather forecasts in the context of other environmental conditions affecting maritime navigation. The suite of products transmitted over the GMDSS cause those responsible for a vessel's navigation to cross-reference and combine information received from multiple text messages manually.

NOAA is working with international partners through the JCOMM and International Hydrographic Organization (IHO) to develop standards for an ECDIS weather overlay, to facilitate the real-time dissemination and display of hazardous weather warnings directly to the electronic navigation systems aboard vessels. ECDIS is a required computer-based navigation system under IMO with the potential to facilitate the real-time dissemination and display of hazardous weather warnings directly aboard vessels. This will integrate authoritative hazardous weather information onto the vessel's single navigation picture to ensure the information provided on the vessel's bridge is consistent with that available ashore.

The Task Force recognizes these efforts to modernize the dissemination of critical maritime

weather information and recommends that NOAA continue working with international partners via JCOMM and IHO to develop standards for disseminating weather hazard information for ECDIS.

Recommendation 3. Leverage federal resources to increase data access, visualization, and intelligence-gathering to better analyze the accuracy of weather forecasts and the effective response of NWS warnings, and provide for enhanced decision support services.

Regulation 19 of SOLAS Chapter V sets the requirements for vessels to carry and use Automatic Identification System (AIS) equipment as part of their navigation equipment. AIS transmissions include a variety of parameters including vessel name, identifier, position, speed, course, heading, vessel type, and voyage information. AIS data is becoming more accessible shoreside via VHF and satellite receipt of the messages. Utilization of AIS data by NOAA weather centers responsible for offshore and high seas forecasts would enhance situational awareness concerning weather avoidance practices by vessels, give forecasters the ability to see the impacts of heavy and extreme weather on marine operations, and allow for enhanced decision support services for vessels in harm's way.

The Task Force recommends that government agencies with requirements for real time access and application of AIS data leverage their resources for data access, visualization, and intelligence gathering to better analyze the accuracy of weather forecasts and the effective response of NWS warnings.

Recommendation 4. NOAA should continue to engage in the Ship Operations Cooperative Program (SOCP) Heavy Weather Working Group and JCOMM to increase real-time reporting of weather observations from vessels at sea.

SOLAS Chapter V, Regulation 5 encourages companies and mariners to report weather observations at sea. However, comparisons between plots of vessels captured through automatic identification system (AIS) data against shipboard weather reports received in real-time by NWS indicate that few vessels participate in providing observations for use by national meteorological services, including the NWS. Further, the WMO VOS scheme, consisting of 29 countries, recently reported that just 15% of commercial vessels actively participate in the program and report meteorological observations in real time. Increasing the voluntary participation in VOS is an initiative encouraged under the new SOCP Heavy Weather Working Group. NOAA is engaging with the working group to develop options for improving the participation rate to increase the receipt of observational weather data at sea. NOAA is also actively engaging the JCOMM, which manages the international VOS scheme, with the same objective.

The Task Force recommends NOAA continue to engage in these bodies to improve the participation of commercial vessels in the reporting of real-time weather observations at sea.

Recommendation 5. It is recommended that NOAA increase international collaboration and the sharing of scatterometry data to further enhance the agency's ability to analyze and predict areas of dangerous winds at sea.

Data from scatterometers flown onboard polar-orbiting satellites provide sea surface wind speeds and directions at a far greater horizontal resolution and coverage than possible with buoys and vessels alone. However, the number of satellites with scatterometers, the coverage of the scatterometers, and the latitude on the ocean surface determine how often a given point on the ocean will be measured. The two operational European satellites optimally measure any given point twice per day for the mid latitudes, more than twice daily at high latitudes, and less than twice per day in the tropics. This leaves the ocean largely unobserved most of the day. Due to latitudinal location, tropical cyclones and other dangerous oceanic storms are often unmeasured each day.

The Task Force recommends NOAA continue to identify and exploit international sources of scatterometry data. As additional scatterometers become available, the greater availability of these data will further enhance the agency's ability to analyze and predict areas of dangerous winds at sea, providing more frequent assessments of cyclone storm structure and intensity while increasing the volume of ocean wind data available for numerical weather models

Recommendation 6. The Task Force encourages maritime academies and other schools to review the final *El Faro* report by NTSB, upon its release, to determine where additional risk management training could be incorporated and provided, as appropriate. Companies are also encouraged to require continuing education in meteorology for their existing credentialed mariners.

Recommendation 7. The Navigation General modules on USCG examinations for deck officer credentials should be reviewed to determine if extreme storm response sections should be modified or enhanced for increased safety of life at sea.
The USCG is currently working with industry representatives to complete a review of all merchant mariner credentialing examination questions. This review includes all examination questions covered under the meteorology and oceanography topics required by 46 CFR 11.910. The SOCP's Marine Heavy Weather Best Practices/Training Subcommittee is encouraged to participate in this effort.

Recommendation 8. Increase public-private engagement between federal agencies and the commercial vessel operator community to focus on increasing the number and quality of weather observations from ships of opportunity.

The Task Force recommends that increased engagement between federal agencies and the maritime community through Federal Advisory Committee Act committees (for example the Merchant Marine Personnel Advisory Committee) and other opportunities focus on increasing the number and quality of weather observations from ships of opportunity through automation, utilizing AIS messages to transmit weather observation data, investigate and recommend training material content for heavy and extreme weather, and facilitate the sharing of best practices by shipping companies for heavy and extreme weather avoidance.

Identified Opportunity for Improvement 1: During discussions regarding the way in which industry receives extreme weather information, the SOCP expressed their concern that ECDIS overlays may be subject to cyber invasion and that vessel operators may benefit from additional prevention measures**.** ECDIS overlays must be protected from cyber security incidents. SOCP reported concern with incidental cyber interferences such as reported cases of seaman plugging a phone into an information port on an ECDIS and crashing the ECDIS.

The Task Force recognizes that ECDIS overlays for weather can be interrupted or disrupted by cyber incidents from private sector industry practices. However cyber incidents related to standard operating procedures and security practices are not under the Task Force directive and will be forwarded to the Department of Homeland Security National Cybersecurity and Communications Integration Center and the USCG National Maritime Security Advisory Committee. This notation has also been forwarded to MARAD Office of Safety, Security, and Environment to consider as part of their ongoing engagement with company security officers. In addition, weather information is generally available in alternative methods such that backup sources can be accessed.

Identified Opportunity for Improvement 2*:* In general discussion about extreme weather operations, SOCP members stated that side-launch lifeboats may cause casualties with davits and parting of the falls. The Task Force has forwarded this to the USCG.

[E] RECOMMENDATIONS FOR ANY LEGISLATIVE OR REGULATORY ACTIONS FOR IMPROVING MARITIME RESPONSE OPERATIONS TO EXTREME WEATHER EVENTS AND PREVENTING MARINE CASUALTIES FROM EXTREME WEATHER EVENTS.

At this time, the Task Force does not have any recommended legislative or regulatory actions.

APPENDIX 1 - BEAUFORT WIND SCALE

Beaufort Wind Scale with Corresponding Sea Code[10]						
Beaufort Number	**Wind Velocity (knots)**	**Wind Velocity (mph)**	**Wind Description**	**Sea State Description**	**Sea State**	
					Term and Height of Waves (feet)	**Condition Number**
0	< 1	< 1	Calm	Sea surface smooth and mirror-like	Calm, glassy 0	0
1	1-3	1-3	Light Air	Scaly ripples, no foam crests		
2	4-6	4-7	Light Breeze	Small wavelets, crests glassy, no breaking	Calm, rippled 0 - 0.3	1
3	7-10	8-12	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Smooth, wavelets 0.3 - 1	2
4	11-16	13-18	Moderate Breeze	Small waves, becoming longer, numerous whitecaps	Slight 1 - 5	3
5	17-21	19-24	Fresh Breeze	Moderate waves, taking longer form, many whitecaps, some spray	Moderate 4 - 8	4
6	22-27	25-31	Strong Breeze	Larger waves, whitecaps common, more spray	Rough 8 - 13	5
7	28-33	32-38	Near Gale	Sea heaps up, white foam steaks off breakers	Very rough 13 - 20	6
8	34-40	39-46	Gale	Moderately high, waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks		
9	41-47	47-54	Strong Gale	High waves, sea begins to roll, dense streaks of foam, spray may reduce visibility		
10	48-55	55-63	Storm	Very high waves, with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	High 20 - 30	7
11	59-63	64-72	Violent Storm	Exceptionally high waves, foam patches cover sea, visibility more reduced	Very high 30 - 45	8
12	64 and over	73 and over	Hurricane	Air filled with foam, sea completely white with driving spray, visibility greatly reduced	Phenomenal 45 and over	9

[10] *The New American Practical Navigator: An Epitome of Navigation* Vol. I ch. 40 (2017), p.672.

APPENDIX 2 – NATIONAL WEATHER SERVICE VOLUNTARY OBSERVING SHIP PROGRAM MARINE INFORMATION GUIDE

The NWS Voluntary Observing Ship Program Marine Information Guide is developed by the Port Meteorological Officer to as means to provide practical applications and knowledge of meteorological products and services that are available from the NWS for planning safe voyages.

The guide is continually updated and can be available for mariners to download at http://www.vos.noaa.gov/vos_resource.shtml.

The following key information is provided in the guide;

- Ocean Area Warnings
- High Seas Forecast
- U.S. Offshore Waters Forecast
- U.S. Coastal & Offshore Waters Forecast (NAVTEX)
- U.S. High Frequency Voice Broadcast For Offshore Waters
- GMDSS Safetynet Services WorldwideTransmission Schedules
- Tropical Cyclone Reference Guide 2016
- Tropical Cyclone Centers and their Regions
- Northwall Effect - U.S. East Coast Vicinity Gulfstream
- U.S. Marine Radio Facsimile Broadcasts
- NWS Radio Facsimile Weather Charts by E-Mail
- NOAA/NWS Chart Terminology & Weather Symbols
- Weather Chart legend
- Worldwide Radiofacsimile Broadcast Locations
- Worldwide METAREAS
- Ocean Current Map
- U.S. PORTS® (Physical Oceanographic Real-Time System)
- nowCOAST (Real-Time Coastal Observations, Forecasts & Warnings)
- NOAA Weather Radio
- WMO Pub 9 - Weather Reporting Vol D - Information for Shipping
- Marine Internet Weather Links
- U.S. Port Meteorological Officer