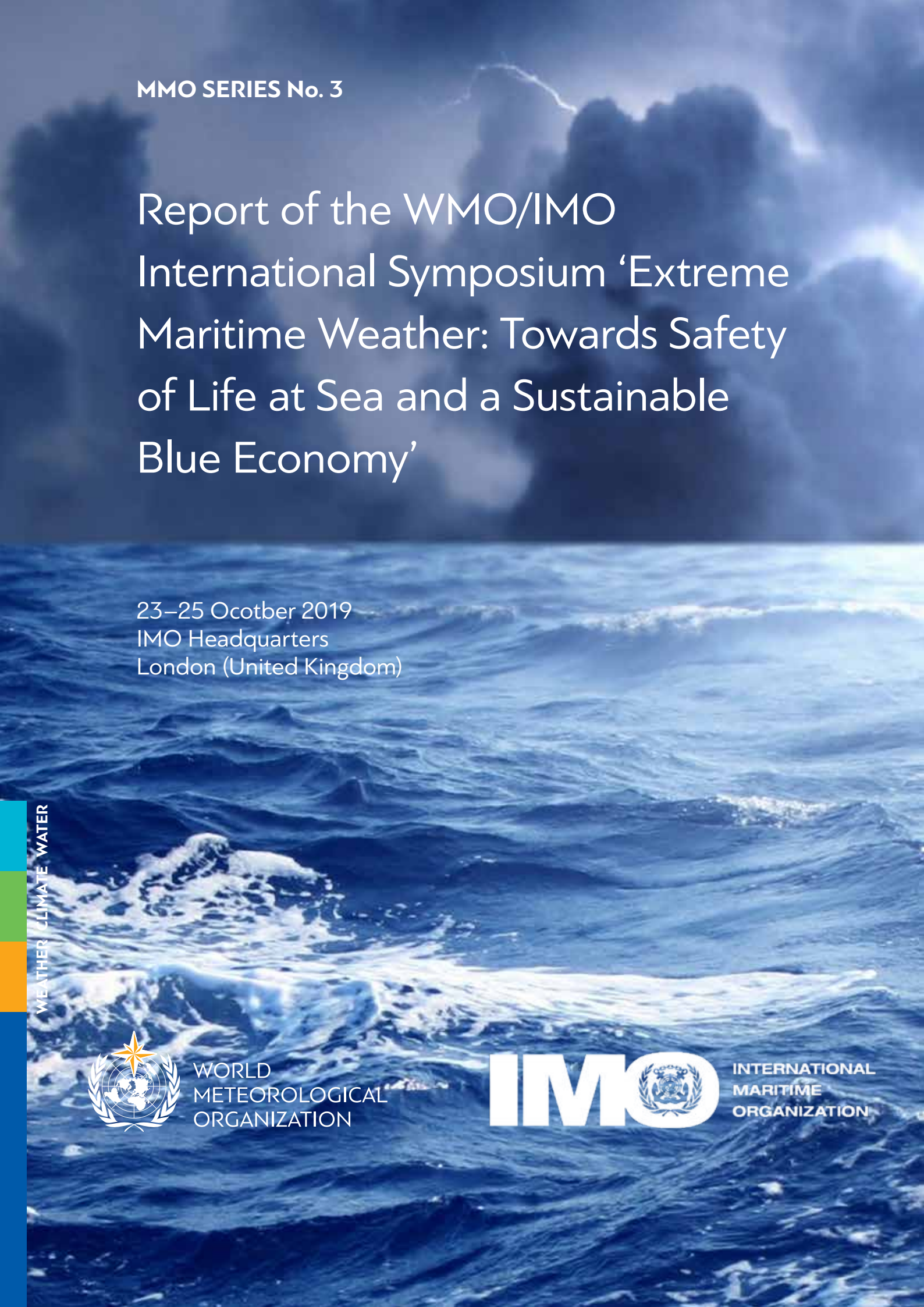

MMO SERIES No. 3

Report of the WMO/IMO International Symposium 'Extreme Maritime Weather: Towards Safety of Life at Sea and a Sustainable Blue Economy'

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Speakers, Moderators and the Organizing Committee at the First WMO-IMO Symposium on Extreme Maritime Weather, October 2019.

The WMO/IMO International Symposium Extreme Maritime Weather: Towards Safety of Life at Sea and a Sustainable Blue Economy

Background

The first International Symposium on "Extreme Maritime Weather: Towards Safety of Life at Sea and a Sustainable Blue Economy" was held in London at the International Maritime Organization (IMO) Headquarters from the 23rd to 25th October 2019. Jointly organized by the World Meteorological Organization (WMO) and the IMO, over 200 participants from over 40 different countries attended, representing both private and public sectors, and including Ministers and Ambassadors. The structure of the Symposium consisted of Plenary Sessions, with invited presentations and panel discussions. The Symposium Programme and presentations are available at https://public.wmo.int/en/events/meetings/londonsymposium.

Executive Summary

Under the Safety of Life at Sea (SOLAS) Convention, the WMO and IMO have collectively worked to reduce the risk and vulnerability of the maritime community in the event of hazardous or extreme maritime weather. Despite this longstanding partnership, there exist areas in which the WMO and IMO can close the gap in understanding between the maritime industry and the metocean[1] community. Topical sessions highlighted the need for educational trainings for both mariners and metocean forecasters that would increase awareness between mariners and forecasters of each community's needs and operational constraints. Specifically, to build a broader understanding among various stakeholders will require forecasters to have a clearer understanding of forecast-dependent maritime operations and decision making and likewise will require mariners to understand the forecasting process.

This Symposium also highlighted the need to tighten connections in the value chain between the collection of metocean data, metocean data assimilation, marine weather forecasting, and the dissemination of marine forecasts and services to users and stakeholders. It also demonstrated the value in looking to the research community to inform operational and policy and decision making, from which the results can in turn inform subsequent research priorities. Participants identified opportunities for increased metocean data collection through the extant WMO Voluntary Observing Ship (VOS) programme as well as private industry (e.g. oil and gas). Participants observed that there is a need for more explicit encouragement for ships to actively participate in programmes as well as an improved understanding of how to better facilitate the onboard collection of metocean data. Moreover, this Symposium demonstrated the need for authoritative data sources officially endorsed to increase confidence in product users and a closer look at data management and dissemination is required to promote the exchange of relevant data.

Finally, the Symposium highlighted a growing demand for marine services that communicate impact-based weather forecasts as well as ancillary support in decision making. Future efforts could include developing vessel class-specific impacts that correspond with varying marine weather conditions. Presenters also highlighted the need for improved forecast portrayal and visualization of weather impacts that would include forecast confidence and uncertainties, thereby shifting the focus of communications from what the 'weather will be' to

[1] Metocean: Meteorology and (physical) Oceanography

instead: 'what it will do'. The definition of impact is dependent on risk, exposure, and vulnerability; therefore, coordination with the maritime industry is necessary to determine individualized impacts resulting from hazardous marine conditions. This Symposium demonstrated that public-private partnerships could most efficiently address this need.

The Symposium concluded that better communication between metocean forecasters and the maritime industry is urgently needed to ensure the safety of life and property at sea while increasing the efficiency of maritime operations. Increased data collection could improve forecasts, which allows marine service providers to tailor and communicate the impacts of hazardous marine conditions on vessels and ports. The implications of a more efficiently and effectively operated value chain would provide wide ranging societal benefits. Examples of such benefits include a reduction in the loss of life and property at sea and along coastlines from the utilization of impact-based marine weather forecasting and real-time conditions in ports and harbours, improved operational efficiency and reduced emissions resulting from optimal voyage routing, environmental monitoring and forecasting to aid coastal management, and more effective search and rescue and environmental emergency response efforts.

Participants observed that a formalized collaboration between WMO and IMO regarding extreme maritime weather issues would help attain the aforementioned needs and goals. Ad hoc thematic entities might be needed to solve specific issues. A WMO-IMO collaboration should endeavour to provide education and training, for improved messaging of metocean conditions for mariners. The next International Symposium on "Extreme Maritime Weather" could be organized jointly with IMO and WMO in two years' time. The date and the place of the next Symposium should be advertised as soon as possible. Between the symposiums, topics addressed in the first International Symposium on "Extreme Maritime Weather: Towards Safety of Life at Sea and a Sustainable Blue Economy" should be discussed in the appropriate IMO, WMO and other relevant bodies.

Opening Session

Mr Thomas Cuff (Office of Observations, National Weather Service, National Oceanic and Atmospheric Administration; Chair, JCOMM Services) opened the Symposium, inviting Mr Hiroyuki Yamada (IMO) and Dr. Xu Tang (WMO) to make opening remarks on the scope and goals of this joint Symposium organized by the IMO and WMO. Participants also heard from Ambassador Peter Thomson (United Nations Secretary General's Special Envoy for the Ocean).

Mr Yamada stated that shipping is the engine that keeps the global economy moving. He posited that to keep that engine running, cooperation between the maritime community, marine weather forecasters, and marine service providers is necessary in order to increase the safety of life and property at sea. Mr Yamada expressed his concerns that a changing climate will present new challenges and risks to vessels. He suggested that the maritime community must mitigate these by means of improved readiness with the use of new technologies and multi-disciplinary collaboration on a global scale. Dr. Tang (WMO) remarked on the increased quality in marine forecasting but commented on the continuation of accidents at sea that occur as a result of severe and extreme maritime weather. Dr. Tang called for the continuation and amplification of marine services to the maritime community to facilitate improved decision making. He tasked the forecasting community to continue developing the most efficient and effective means to deliver marine hazard information to the maritime community. In a recorded message to Symposium participants, Ambassador Thomson commented on the timeliness of the joint Symposium, noting that extreme weather continues

to cause loss of life and cargo, as well as environmental damage. He reasoned that adequate access to metocean forecasts could have prevented many recent losses. Ambassador Thomson also highlighted the importance of scaling up ocean science to meet sustainable development goals (SDGs).

Mr Cuff concluded the opening session, delivering the keynote address, highlighting the great improvements in forecasting accuracy over the last 60 years. However, like the other opening speakers, he posed the question: 'If marine weather forecasts are improving, what factors allow for the loss of life and property due to inclement weather to continue occurring?' Echoing the sentiments of Ambassador Thomson, Mr Cuff noted that as the Global Blue Economy continues to grow, the maritime industry must adapt to adequately balance the cost and ship routing and scheduling against the likelihood of a hazardous maritime weather event. In particular, Mr Cuff expressed his concerns regarding the increase in maritime traffic in response to sea ice loss in a warming world, noting that unlike relatively short-lived extreme weather events, sea ice poses a constant and often hidden threat. He also noted the importance of identifying authoritative data sources in a world where data sources are abundant. Mr Cuff concluded that ultimately, increased meteorological training for mariners and enhanced marine services from forecasters, and the insurance and private sectors can together reduce the loss of life and property at sea.

Session 1 - International regulatory framework

- The WMO and IMO have worked closely together for decades to improve maritime safety under the SOLAS Convention
- International collaboration is requisite in the exchange of meteorological information and the provision of marine services to the maritime community
- In order to provide high quality marine services, greater collaboration between NAVAREA and METAREA coordinators is required

The first session moderated by Mr Thomas Cuff (Office of Observations, National Weather Service, National Oceanic and Atmospheric Administration; Chair, JCOMM Services), provided an overview of current international regulatory framework that guides decision making in the maritime community. Mr Osamu Marumoto (Maritime Safety Division, IMO) opened the session with a discussion of the Safety of Life at Sea (SOLAS) Convention, first adopted in 1914 following the sinking of the *RMS Titanic*. Mr Marumoto also outlined how the SOLAS Convention supports marine meteorology, especially under chapter V: Safety of Navigation. He also discussed the oversight of maritime safety information (MSI), defined under SOLAS, and its distribution through the Global Maritime Distress and Safety System (GMDSS).

Dr. Sarah Grimes (Marine Meteorology and Ocean Affairs (MMO) Division, WMO) continued the discussion of formal and informal contributions of the WMO to the maritime community through interagency partnerships (e.g. The Arctic Council, SENDAI Framework, Intergovernmental Panel on Climate Change, etc.) and through the WMO Marine Meteorology and Oceanography (MMO) Division. Dr. Grimes also emphasized the degree of international collaboration the WMO facilitates for the exchange of meteorological information across international borders. Mr Neal Moodie (Marine Weather Services, Bureau of Meteorology, Australia; Chair, JCOMM WWMIWS-C) concluded the session with an overview of the Worldwide Metocean Information and Warning Service (WWMIWS). Mr Moodie noted that

WWMIWS and its 21 METAREA regional coordinators are responsible for delivering MSI through the GMDSS. Nine of the 21 coordinators presented at this Symposium on several topics. Mr Moodie concluded that there is a need for increased collaboration among NAVAREA and METAREA coordinators.

Session 2: Extreme Maritime Weather - Case Studies

- Forecasting of extreme marine weather events has greatly improved but technological constraints hinder effective deliverance of forecasts to vessels
- There is an increase in demand for impact-based weather forecasting in the maritime community
- Decision support services to the maritime community can contribute towards helping mariners maximize routing efficiency when rerouting due to weather

The second session, moderated by Mr Peter Hinchliffe (Executive Board, Nautical Institute), addressed extreme maritime weather in different ocean basins and demonstrated its impact on the maritime community. Mr Hinchliffe noted that, while much of the conversation surrounding the shipping industry and climate change focuses on the impact of shipping on Earth's climate system, fewer discussions highlight the impact of climate change on the shipping industry. Mr Hinchliffe raised three broad concerns: 1) whether ships are currently designed and constructed to withstand deteriorating weather conditions, 2) the need for continued hydrographic mapping in response to sea level rise, especially in and around ports, and 3) the status of port infrastructure to accommodate rising sea levels and continued vessel access. Speakers in this session presented case studies that emphasize current opportunities to improve communication of marine weather forecasts to the maritime community.

In his presentation, Mr Joseph Sienkiewicz (Ocean Prediction Center, National Weather Service, National Oceanic and Atmospheric Administration) demonstrated that comparing automatic identification system (AIS) vessel tracking with marine warning areas illustrates vessel avoidance practices during hazardous weather conditions. However, he cautioned that although forecasting abilities have improved, the successful receipt at sea of those forecasts vary widely and is dependent on a vessel's technological capacity. Mr Sienkiewicz noted that many vessels still receive Marine Safety Information (MSI) via dot matrix printers that receive text data but are not able to receive forecast visualizations and are not integrated with vessel navigation system. He concluded that this often tasks mariners with deciphering and interpreting forecasts in relation to vessel position.

Ms Nelly Florida Riama (Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG); Vice-Chair JCOMM Expert Team for Disaster Risk Reduction (ETDRR)) reiterated the need to focus on dissemination of forecasts in a way that is accessible to the maritime community. She drew on examples of Indonesian Marine Weather Services that aim to improve the forecast in terms of timeliness as well as effective communication. Ms Riama also stated that an increased demand for impact-based forecasting exists within the maritime community. One of the ways in which Indonesia seeks to fill this gap is through the implementation of a "Fisherman Field School", which works to train fishermen in interpreting weather and climate data for decision-making purposes.

Finally, Ms Petty Leung (StormGeo Ltd.; Member of Nautical Institute) discussed how to address the apparent conflict between safety and economic pressure, where storm avoidance behaviours maximize safety, but often at a higher operation cost. She concluded

her presentation demonstrating the need for decision support services that aid captains in decision-making when rerouting in response to hazardous weather conditions. The session concluded with a discussion that re-emphasized the needed for integrated services that include 1) authoritative weather sources, 2) improved warning communication and visualizations, and 3) auxiliary decision support services.

Session 3: Extreme Maritime Weather - Views from Protection, Indemnity, and Insurance

- Interagency cooperation within a nation can be a valuable resource for implementing protocol changes in response to accidents at sea
- Shipping companies with a stronger safety culture file fewer insurance claims
- Improving operational practices and cargo stowage can reduce loss of life and property at sea

Mr Peter Hinchliffe (Chair, Executive Board, Nautical Institute), opened the third session, which provided an overview of some of the risks associated with extreme maritime weather that result in damage or loss to ships, cargo, and the marine environment (e.g. oil spills). This session featured presentations from the United States Committee on the Marine Transportation System (CMTS) as well representatives from the international marine insurance industry.

Ms Helen Brohl (U.S. Committee on the Marine Transportation System) presented on steps the U.S. CMTS takes to investigate incidents in marine transportation and facilitate interagency cooperation to make recommendations and implement protocol changes where appropriate. She emphasized the need for well-defined weather categories, standardization of electronic chart display and information systems (ECDIS), enhancing real-time weather observations from vessels, and increasing international collaboration and data sharing to improve forecasts.

Mr Marius Schønberg (Loss Prevention and Risk Assessment, Gard AS) presented a comprehensive overview of risk from an insurer's point of view. He discussed the importance of fostering a culture of safety among shipping companies, demonstrating that while most shipping companies had strong safety cultures, those which did not filed a higher frequency of insurance claiMs Mr Sean Dalton (International Union of Marine Insurance) closed the session noting that the overall number of shipping losses has decreased but that has resulted in a larger percentage of losses being a result of weather, highlighting the need for more informative weather forecasts. Mr Dalton stated that many of the losses consist of cargo ships and that as much as 67% of losses are attributable to human error. To reduce the number of losses and incidents, he recommended an increased focus on improving operational practices, an improvement to cargo stowage that would reduce exposure of transported items, and increased transparency in terms of the type of cargo a vessel is transporting.

The session concluded with a discussion on factors that contribute to a vessel's risk in extreme maritime weather. Participants agreed that the timeliness of authoritative weather data is a critical factor in reducing risk and that adjustments could be made to shipboard requirements for the capacity to receive MSI, as is a vessel's sea worthiness, especially in the context of a changing climate that brings more extreme maritime weather.

Session 4: Extreme Maritime Weather - Stakeholder Perspectives

- Marine weather events can result in crew fatigue, oftentimes leading to compromised decision making
- Growth in Maritime Autonomous Surface Ships (MASS) is greatly outpacing the ability to regulate them in the context of SOLAS
- Extreme weather events can damage ports and greatly impact a vessel's ability to access ports

The fourth session, moderated by Mr Nick Ashton (United Kingdom Met Office; Vice-Chair, JCOMM Services), highlighted the impacts of extreme weather events on operational aspects of sea-going vessels, autonomous vehicles, and the broader marine community. This session focused on challenges faced at sea as well as when accessing ports.

Captain Morgan McManus (State University of New York) discussed his experience at sea as master of a training ship, sailing for deep sea oil and gas, and as an instructor of mariners at sea every summer. Captain Morgan emphasized that weather affects everyday operations on a ship, such as regular maintenance and job risk assessment, and that weather induced fatigue often stresses crews, consequently resulting in errors and consequences that can have grave consequences. He also noted that weather routing brings operational efficiency (e.g. speed and fuel consumption) and that captains must balance safe weather routing and maximum efficiency. To do this, he stated the importance of meteorological training for mariners, especially to prepare for cases when technological assistance fails.

Mr Andrew Colenutt (United Kingdom Maritime and Coastguard Agency) demonstrated that autonomous surface ships operating with some degree of independence from humans illustrates the need for better data handling, paired with Geographic Information Systems (GIS) and modelling to gather more marine data. He also cautioned that the implementation of autonomous surface ships is quickly outpacing the regulation of observations collected from them. Mr Colenutt concluded by stressing the need for regulation and data validation soon.

Captain Don Cockrill (UK Maritime Pilots Association) rounded out the session with a discussion of how extreme weather events and changing climate effects port pilotage. He outlined the main factors affecting port accessibility (e.g. wind, visibility, tidal levels, tidal currents, river levels, river currents, and siltation) and provided examples of how weather can compound many of these factors and cause significant damage to ports. Captain Cockrill suggested that ports must begin to consider their vulnerability and implement plans to increase the resilience of their infrastructure and operations.

Session 5: Impact, Value, and Opportunities of the Voluntary Observing Ships and Related Programs

- Multiple opportunities exist for vessels to participate in the voluntary collection of metocean data; however, increased observations from more ships would greatly improve our global observational capacity
- The Global Ocean Observing System is working to expand its capacity to include metocean data as well as biogeochemical and biological data
- As the quantity of data increases, so does the need to validate data and ensure proper use of scientific equipment onboard vessels participating in voluntary observations

Mr Thomas Cuff (Office of Observations, National Weather Service, National Oceanic and Atmospheric Administration; Chair, JCOMM Services) moderated the fifth session, which presented the various ship observation programs currently collecting metocean data. This session also emphasized the need for an improved awareness of the need for voluntary observations from ships and other platforms at sea to increase our global observational capacity.

Ms Emma Steventon (Surface Marine Networks, United Kingdom MetOffice and Member, JCOMM Ship Observations Team) began the session with an overview of the status of the Ship Observations Team (SOT), discussing the Voluntary Observing Ship (VOS) scheme, the Automated Shipboard Aerological Programme (ASAP), and the Ship of Opportunity Programme (SOOP). These programs provide metocean data to modellers and forecasters in real time, enhancing safety services to mariners. Ms Steventon emphasized the need to increase participation in these programs to expand observational capacity globally.

Mr Mathieu Belbeoch (WMO/IOC JCOMMOPS) continued discussing global observations with an overview of the Global Ocean Observing System (GOOS) and its implications for marine operations, climate, and ocean health. Mr Belbeoch noted ways in which GOOS is expanding to include marine meteorology, physical oceanography, biogeochemical oceanography, and biology. He also stated the importance of cooperation with multiple sectors of society, including the private sector, non-governmental organizations, and citizens. Mr Belbeoch also acknowledged the value that partnerships with the shipping industry have in working towards closing gaps in spatial and temporal gaps in observational data. Discussion following the presentations focused on the need to ensure data validity, training ship crews to properly use scientific equipment, and quality control.

Session 6: Weather and Ocean Data to Improve Forecasts at Sea

- The creation of a comprehensive global metocean observation network will require international collaboration, as has been the case in some of the most recent metocean projects (e.g. MOSAiC, Copernicus)
- Metocean data is critical to the planning, construction, and operation of ports
- Metocean data is critical for modelling environmental impacts in marine environments

Mr Thomas Cuff, (Office of Observations, National Weather Service, National Oceanic and Atmospheric Administration; Chair, JCOMM Services) moderated the sixth session, which demonstrated how metocean data are used to generate marine forecasting information and provided examples of how some maritime sectors successfully utilize such data. Examples focused on marine services such as Copernicus and Spain's Meteorological and Oceanographic Support System.

Mr Pierre Bahurel (Mercator Ocean International; Chair, JCOMM Expert Team on Operational Ocean Forecasting Systems (ETOOFS)) began the session highlighting the growth that has occurred in the ocean observations community between one of the earliest expeditions, the Fram expedition in 1893, to the most recent, the MOSAiC Expedition on the German icebreaker Polarstern. Mr Bahurel emphasized the importance of international collaboration in the success of the most recent expedition and noted that the same degree of investment in operational marine services would be of incredible value. He used the operational marine service Copernicus as a successful example of the implementation of such services on regional scale.

Dr. Enrique Alvarez Fanjul (Physical Oceanography Department, Port of Spain; Vice-Chair, JCOMM ETOOFS) continued to demonstrate how information from ocean forecasting is successfully utilized in the maritime community, specifically by port authorities. He explained that ports need metocean data through its entire life cycle, from the design phase to the exploitation phase. He discussed some of the ways in which the Port of Spain utilizes forecast data from its Meteorological and Oceanographic Support System (SAMOA) to support operations. He concluded that monitoring and forecasting the marine environmental is a definitive need for port authorities and that user feedback is a critical component of successful programs to address this need.

Mr David Pino (Technical Management, Port of Barcelona) concluded the session with an overview of how the Port of Barcelona, the fastest growing port in Europe, employs SAMOA to forecast not only meteorological conditions but also environmental information that can help mitigate damage from oil spills and other environmental hazards, especially given that 20 spills occurred in the Port of Barcelona in 2018 alone. The discussion following the presentations highlighted the importance of warnings and actions in ports, not only to notify when port conditions will deteriorate but also when conditions are forecast to improve.

Session 7: Advances in Weather and Ocean Forecasting to Support Decision Making

- Panellists introduced the concept of impact-based forecasting and warnings
- Impact-based forecasting must consider the hazard, exposure, vulnerability, and risk to best suit end users' needs
- Panellists and Symposium participants agreed that increased dialogue between forecasters and mariners is needed in order to best determine risk from a multitude of end user perspectives

The seventh session, moderated by Mr Nick Ashton (United Kingdom Met Office; Vice-Chair JCOMM Services), opened an interactive discussion with participants about probability-based information to support MSI and marine safety products. This session also introduced the concept of an impact-based warning system. Additionally, this session sought to identify ways in which impact-based warnings could contribute to global and local shipping industries. The discussion panel included Mr Neal Moodie (Marine Weather Services, Bureau of Meteorology, Australia; Chair, JCOMM WWMIWS-C), Mr John Parker (Prediction Services Operations – Marine, Ice, and East Division, Meteorological Services of Canada; Vice-Chair, JCOMM WWMIWS-C), and Mr Daniel Peixoto de Carvalho (Navy Hydrographic Center, Brazil; JCOMM WWMIWS-C).

The panel opened the discussion with a brief overview of the current impact-based warning framework. They stated that they key elements to consider in such a system are 1) the hazard, hydrometeorological in nature that poses some level of threat to life, property, or the environment, 2) exposure, who and what a particular hazard will affect, 3) vulnerability, the susceptibility of humans and their livelihoods and property, and 4) risk, the probability and magnitude of harm predicted to impact humans, their livelihoods, and assets to exposure and vulnerability to a particular hazard. Mr Parker used the example of the Canadian Air Force to highlight how forecasts impact their operations globally and notes that users need to be able to toggle different environmental variables (e.g. temperature, wind, etc.) Mr Peixoto de Carvalho reiterated that the key focus should be on the partnership between the maritime and

meteorological communities and uses the occurrence of rare tropical storms in the Southern Atlantic as an example of the importance of conversations between these communities.

Participants engaged in a thorough discussion of best practices for converting forecast variables into vulnerability and exposure information, which can in turn be converted to impact-based forecasts specific to users' needs. Participants also discussed the need to specifically identify the end users of such information: individuals on the bridge, office personal guiding a particular vessel, or perhaps both. Discussants agreed that meteorologists are somewhat familiar with hazards but are not necessarily trained to think about vulnerability, which highlights the need for the maritime community to participate in developing impact-based forecast recommendations. Session participants concluded the discussion considering whether or not observations from nearby vessels could be incorporated into real-time forecasting.

Session 8: Enabling Digital Delivery of Maritime Safety Information

- The IMO's Strategy Implementation Plan endorses the use of the International Hydrographic Organization's S-100 standard for data access and services
- Most MSI is text only and can result in ambiguities about a vessel's location in relation to an extreme weather event
- GMDSS is not currently configured to transmit the amounts of data that visualizations of weather hazards would require

Mr John Parker (Prediction Services Operations – Marine, Ice, and East Division, Meteorological Services of Canada; Vice-Chair, JCOMM WWMIWS-C) moderated the eighth session focusing on ways to improve electronic delivery of ice, weather, and hazard data directly to shipboard navigation systeMs This session also discussed how to increase awareness among users and producers of new digital charting standards for weather and ice information.

Mr Javier Yasnikouski (Operational Safety, Maritime Safety Division, IMO) provided an outline of the IMO's E-Navigation Strategy Implementation Plan (SIP), which began development in 2006 and continues into the present. Mr Yasnikouski presented on the most relevant SIP developments such as the identification of user needs, the gap between cost-benefit and risk analyses, and a potential list of e-navigation solutions. He stated that the SIP had recognized the use of the International Hydrographic Organization's (IHO) S-100 standard as the baseline for creating a framework for data access and services under the scope of SOLAS. Mr Yasnikouski emphasized the importance of the further development of marine services such as MSI services, vessel shore reporting, maritime assistance services, nautical chart and publication services, ice navigation services, and meteorological information services.

Mr Eivind Mong (Electronics and Informatics, Integrated technical Services, Canadian Coast Guard; Chair, IHO Group S-124) continued the discussion presenting on some of the challenges of delivering MSI to Electronic Chart Display and Information System (ECDIS). Mr Mong highlighted the fact that most MSI information is digital but mostly text without visualizations, resulting in ambiguity in the location of extreme weather occurrences, consequently hindering the shipboard decision-making process. Mr Mong stated that one of the largest challenges for improving the delivery of MSI is one of connectivity and bandwidth, as Internet connectivity to ECDIS is not required for system operations and, in many cases,

not implemented because of cost and cyber security concerns. Mr Mong suggested that visualization of MSI is needed and should be harmonized between S-124 and S-412 standards, and that IMO Regulations and Guidance for connecting to ECDIS may require updates.

Dr. Jürgen Holfort (Ice Service and Baltic Sea-Level Service, German Federal Maritime and Hydrographic Agency; Vice-Chair, JCOMM ETSI) extended this discussion to needs in the communication of sea ice data. He noted that the first operational S-411 ice charts were available and viewable in geographic information system (GIS) programs in 2013 but that there is still no available S-411 capable ECDIS, though test systems currently exist. Dr. Holfort discussed some of the challenges in creating S-411 capable ECDIS and thoughts towards portrayals that would include vessels ice capabilities and WMO ice concentration and stages of development coded with different colours.

Mr Joseph Sienkiewicz (Ocean Prediction Center, National Weather Service, National Oceanic and Atmospheric Administration) concluded the session with an overview of standards for wind, wave, and weather hazards. Mr Sienkiewicz stated that a major goal is to develop a navigation safety S-100 based product specification for weather information for use in Electronic Chart Systems (ECS), including ECDIS. He also proposed the use of wave and weather polygons that would reduce confusion regarding the location of potential marine weather hazards. He noted that some of the challenges to consider include coordination amongst METAREA providers, dissemination, and implementation (training and collaboration). Another concern raised is that GMDSS is not currently configured to receive the amount of data that visualizations can include.

Session 9: Decision Support Services in Polar Regions

- Support for navigation in ice-covered waters comes from many different sources in different manners
- An international effort to standardize sea ice information transmitted to vessels would greatly increase safety for vessels traveling in Polar Regions
- Incorporating ice charts into shipboard ECDIS could increase safety for vessels traveling in Polar Regions

Mr Helge Tangen (Development Centre for Weather Forecasting, Norwegian Meteorological Institute; JCOMM WWMIWS-C) moderated the ninth session focusing on decision support services in Polar Regions. This session described how metocean data is delivered in Polar Regions and how meteorological services are working with gaps in metocean data to improve forecasts at sea. This session also established a broader understanding of the Polar Code, operational services, and long-range services available to stakeholders in Polar Regions.

Mr Keld Qvistgaard (Greenland Ice Service, Danish Meteorological Institute; JCOMM Expert Team on Sea Ice (ETSI)) opened the session discussing how the Polar Code applies to maritime navigation and operations. Mr Qvistgaard stated that support for navigation in ice-covered waters is found through SOLAS, government tasks and national regulations, WMO resolutions, and the Polar Code. However, he noted that a major challenge for delivering ice navigation services is the highly variable nature of ice itself. He cited changes in the timing of operations due to a changing climate, increased vessel traffic and class variability, and the differing requirements dependent on proximity to ice as other potential challenges. Mr

Qvistgaard highlighted the Danish National Ice Services as an example of a marine service that incorporates standards agreed upon and approved by the JCOMM ETSI to deliver ice information to ships via GMDSS.

Mr John Parker (Prediction Services Operations – Marine, Ice, and East Division, Meteorological Services of Canada; Vice-Chair, JCOMM WWMIWS-C) summarized the state of extended range sea ice forecasting by drawing on examples from Argentina, Norway, Finland, Canada, and the United States. Mr Parker demonstrated that a temporal range of forecasting exists, from seasonal to ten-day forecasts for sea ice. Mr Parker emphasized the need for a coordinated international effort to develop and standardize the communication of sea ice information to vessels.

Mr Thomas Cuff (Office of Observations, National Weather Service, National Oceanic and Atmospheric Administration; Chair, JCOMM Services) closed the session presenting on the work of the International Ice Charting Working Group (IICWG), established in 1999, as a forum for coordinating sea ice and iceberg service matters and is an important advisory committee. Mr Cuff recounted the sinking of M/S Hans Hedtoft as an example of where services of the like provide by IICWG could save lives. Mr Cuff indicated that particularly as sea ice extent continues to decline, an increase in vessel traffic will bring more mariners in contact with ice covered waters. He presented the International Ice Patrol (IIP) as an example of one way monitoring for icebergs can provide relevant warning products to the maritime community. Mr Cuff ended the presentation with a few ideas to work towards in the future, including incorporating ice chats into shipboard ECDIS, approve established standards for ice forecasters and analysts, and improving iceberg models to predict location, drift, and deterioration.

Session 10: Voyage Routing Optimization

- Routing optimization services can help ships balance the demands between the most efficient shipping routes and potentially hazardous weather conditions
- Improved routing optimization can help ships increase operational efficiency and simultaneously reduce emissions
- A shift to wave power, which considers both wave height and swell, could improve our ability to understand the changing sea state in various regions

Captain. Nick Nash (P&O Princess Cruises, Carnival Group; President, The Nautical Institute) moderated this session, which aimed to motivate a dialogue on route optimization services, including issues of lost time to companies, potential products that companies can use, and a discussion to learn further about the gaps and needs of the industry.

Mr Gavin Roser (Large EU Freight Network) began the session with an overview of European Freight and Logistics. He stated that the goals of Freight and Logistics are to improve communication and understanding between supply chain professionals. Mr Roser emphasized that they offer services that are driven by manufacturers and that their participation includes consultation about key shipper concerns such as supply chain disruption (e.g. airfreight options, geopolitics, volcanic eruptions, etc.). He concluded his discussion with some of Freight and Logistics' goals for the future, which include initiating and supporting new ideas through dialogue, and introducing new ideas in the community through supporting speakers, visits, and webinars.

Mr Charles Wyng (Voyage Solutions, Wärtsilä Voyage) presented on Sea Traffic Management (STM), which works to provide information from stakeholders that is then integrated into traffic management software. Mr Wyng stated that some of STM's primary goals include reducing emissions, providing better voyage plans, and enhancing maritime safety. He argued that efficient routing is a major component of achieving STM's goals because it allows for fuel reduction, port synchronization, and integrates ECDIS into its operations. He also recommended replacing the phrase "estimated time of arrival" with "planned arrival time" to reduce some of the pressure placed on mariners to arrive at a particular time.

Mr Huw Davies (StatrumFive, Ltd.; Member of Nautical Institute) continued with a discussion of how weather-related issues can add additional pressure to chartered vessels. He described how charterers pay for fuel while the vessel performance is ensured by the owner. Mr Davies noted that the result creates a situation where ship owners are incentivized to over exaggerate their vessel's performance, masters are under pressure to perform and exaggerate the weather conditions experienced and weather and routing companies are incentivized to underestimate the weather conditions that ultimately leads to sub-optimal decision making in terms of ship safety. To address this, Mr Davies suggested that vessel progress should be monitored to ensure it is taking the most efficient route and that upon completion of the voyage, a report should be generated that compares planned speed and fuel consumption to actual speed and consumption.

Dr. Gianandrea Mannarini (Applications Research, OPA Division, Euro-Mediterranean Centre on Climate Change) concluded the session focusing on the role of metocean forecasts in ship routing to work towards the IMOs decarbonisation goal. Dr. Mannarini proposed that shifting from using wave height and wave period as independent metrics to using wave power could greatly assist in this effort, which is sensitive to both extreme wave height and swell. He demonstrated there have been statistically robust observed wave power changes from 1985 to 2008, where wave power in the northern hemisphere has generally decreased and in the southern hemisphere it has increased. In the Arctic, Dr. Mannarini noted that a significant reduction in sea ice has resulted in an enhancement of sea state and potentially greater wave heights in some Arctic regions. He concluded that operational energy efficiency measures for ship routing are the only means of emissions reduction until it is possible to develop a low-carbon fleet of significant size.

Session 11: Decision Support for Passenger Ship Navigation

- The architecture of cruise ships exposes them to wind forces that can exceed the power of engine thrusters
- Passenger ships have the additional economic pressure of entertaining passengers and meeting their experience expectations
- High-resolution forecasts and authorized weather apps, particularly in high-latitude routes, could greatly enhance the ability of passenger ship captains to assess potentially hazardous conditions

Ms Petty Leung (Storm Geo Ltd; Member, Nautical Institute) moderated this session, which highlighted needs in passenger ship navigation and how decision support services can be improved. Presenters distinguished between controllable and uncontrollable factors and

how support services can help reduce risk in the cruise industry while minimizing the economic impact.

Captain. Nick Nash (P&O Princess Cruises, Carnival Group; President, Nautical Institute) opened the session discussing the impact of wind force on cruise ships, which even on a large cruise ship can be greater than 200 tonnes at just 35 knots. He stated that this is problematic because conventional thrusters can only handle up to 150 tonnes. He suggested that the WMO should consider accrediting web based programs such as Windfinder, Accu-Weather, and Windy to ensure staff is able to appropriately provide weather guidance in the marine context. He also noted that in addition to the economic pressures that the shipping community must consider in decision making, the cruise industry must also consider passenger satisfaction.

Mr Thomas Bøggild (Greenland Pilot Service) concluded the session with a discussion of the Greenland Pilot Service, which was established in Nuuk, Greenland to deliver licensed pilots to passenger vessels in Greenland waters. Mr Bøggild noted that Greenland Pilot Service provides decision support both before and during pilotage. However, he emphasized that high winds, restricted visibility, and bergy waters can certainly complicate this effort. He outlined areas of improvement that can reduce risk, such as the availability of high-resolution forecast.

Session 12: Decision Support for Offshore Industry

- One of the biggest risks to the offshore community is the risk of wave-in-deck
- The effect of warming oceans on waves, especially in extra-tropical regions, is one of primary areas of concern for the offshore industry
- The development of medium and long-range forecasts can improve risk-based decision making in the offshore industry

The twelfth session, moderated by Mr Tero Jokilehto (MMO, WMO), focused on perspectives from the offshore industry (i.e. oil and gas) and their needs for meteorological and oceanographic information as well as improved decision support services.

Mr John Upton (Shell U.K. Limited; Member of International Association of Oil and Gas Producers) opened the session with a summary of the needs of the oil and gas industry to plan for extreme maritime weather events. Mr Upton highlighted how the International Association of Oil and Gas Producers (IOGP) works with oil and gas companies to promote safe, responsible, and sustainable exploration and production practices. He noted that IOGP has a meteorology and oceanography committee whose objectives are to ensure best practices, safety and efficiency, codes and standards, innovation, and collaboration. Mr Upton stated that one of the biggest risks in offshore product is wave-in-deck loading, which has increased, particularly in extra-tropical regions. He emphasized the use of probabilistic forecasting to improve risk-based decisions to minimize subjectivity in the forecasts. He also emphasized the need for historical re-analyses and an analysis of how changing climate is likely to affect operations. He concluded that the development of medium and long-range forecasts, sharing of data, methods, best practices and collaboration within oil and gas companies can improve risk-based decision making in the offshore industry.

Mr Jacob Sørenson (Danish Hydraulic Institute) concluded the session presenting on metocean data provision and support services for operation and design of offshore energy development. He underlined the need for channel optimization and presented NCOS Online,

a digital model of ports to support strategic and operational needs, environmental modelling (e.g. hydrodynamics, waves, wind, and sediment transport), vessel response, and external data. Mr Sørenson noted challenges to decision support tools for risk-based assessment include harsh environmental conditions, uncertain forecasts of many parameters, uncertain processes, and complex decisions.

Dr. Øyvind Breivik (Norwegian Meteorological Institute) concluded that the effect of trends in 20th and 21st century climate, particularly sea surface temperatures, on waves must be further considered to adequately prepare coastal and offshore operations. He mentioned the Intergovernmental Panel on Climate Change (IPCC) models have varied effects on wind and waves. Average wind speed and wave height are projected to decrease, but extreme storms are not projected to decrease, variance increases while the mean goes down. Half of the world's coastlines are at risk of a robust change in at least two of the parameters (wave height, wave direction, wave period), which will lead to increased coastline erosion.

Session 13: Maritime Safety and Other Concerns

- Recommendations for wave-based vessel classes were established in 1986 and likely require updating
- Machine learning may enable the maritime sector to forecast vessel traffic in open water
- Expansion in marine services can greatly improve operational efficiency and safety of life and property at sea and in ports

Dr. Sarah Grimes (MMO, WMO) moderated session thirteen, which considered perspectives on maritime safety and other concerns, and how decision support services can be improved while considering potential areas for improvement in the provision of metocean information for stakeholders.

Mr Håvard Austefjord (International Association of Classified Societies), opened the session with a discussion of the role of the International Association of Classified Societies (IACS) in the maritime industry, including defining technical rules with which ships must comply (e.g. defining what types of waves different vessels can withstand). Mr Austefjord referenced Recommendation No. 34, where standard wave data includes a scatter diagram defining sea states used to determine the lifetime evaluation of ship loads and response. He pointed out that this recommendation is based on visual observations from ships in the BMT Atlas (1986) and archived by WMO. However, Mr Austefjord cautioned that this recommendation may be outdated and challenges the validity of outdated data in a changing climate. He concluded emphasizing the importance of an array of observational methods, including voluntary ship observations and hindcast modelling, opining that greater participation will greatly improve marine weather forecasts.

Mr Jani Poutiainen (Finnish Meteorological Institute) continued the discussion with the introduction of machine learning in the context of railway traffic with implications for forecasting maritime traffic. Mr Poutiainen explained that informed railway operation centres can take several actions to increase its workforce, reduce train shifts, and improve communication. He also emphasized the importance of meteorological data in forecasting railway traffic and delays. Mr Poutiainen asserted that similar methods can be employed in the maritime sector and applied to forecast vessel traffic delays in open water, with considerations for establishing a database for actual deviations from original estimated time of arrival and safety related

decision making. He concluded with the thought that similar methods may also be applicable for forecasting port activities.

Mr Thomas Bruns (Marine-Meteorological Services, Deutscher Wetterdienst; JCOMM ETDRR) concluded the session with a presentation summarizing the challenges and opportunities surrounding wave forecasting. He demonstrated that Deustcher Wetterdienst (DWD) participates in numerous types of marine services, including participation in VOS and ASAP programs, archiving and disseminating quality controlled observational data, running operational wave forecasting models, and providing meteorological services for ships. In addition, DWD offers weather routing services and are currently supporting German research vessels. Mr Bruns echoed the sentiment of several Symposium participants that the services, including onboard route optimization and shore-based routing from ensemble forecasting and metocean experts, can greatly improve route optimization and safety of life and property at sea.

Session 14: Search and Rescue (SAR) and Environmental Emergency Response

- Accurate metocean forecasting is imperative in search and rescue operations for recovery as well as operational safety
- Examples of support services for SAR and environmental emergency response in Belgium, Canada, China, France, Indonesia, Italy, Japan, Norway, and the United States are highlighted
- Metocean forecasting is a critical component to modelling the spread and mutation of environmental disasters

Mr Javier Yasnikouski (IMO) moderated session fourteen, which heard multiple perspectives from the Search and Rescue (SAR) and environmental emergency and disaster entities. Presenters discussed preventing and responding to maritime disasters and identified challenges and areas for improvement in collect metocean data and communication of extreme marine weather.

Ms Nelly Florida Riama (Indonesian BMKG; Vice-Chair JCOMM ETDRR) discussed the role of national weather services on maritime search and rescue in Indonesia. She outlined how BMKG facilitates users integrating products into SAR operational systems, and further stated that the effectiveness of SAR depends almost entirely on accurate maritime weather and ocean forecasting (e.g. how drift direction can impede SAR operator's ability to locate distressed vessels). She highlighted aviation incidents of Air Asia in 2014 and Lion Air in 2018 to demonstrate the need of accurate meteorological and oceanographic forecasting in recovering the wreck sites. She concluded that shifting to a common platform would better facilitate integration with systems that stakeholders use to receive such information.

Mr Giovanni Coppini (Ocean Predictions and Applications, OceanLab, Euro-Mediterranean Centre on Climate Change; Chair, JCOMM Expert Team Marine Environmental Emergency Response (ETMEER)) presented on support services for SAR and environmental emergency response in Belgium, China, Japan, France, Italy, Canada, and Norway. He outlined the range of services that such organizations have been able to provide in SAR and environmental response operations.

Mr Clement Chazot (IMO) closed the session focusing on marine environmental emergency response. He presented the adoption, in 1990, of the International Convention on

Oil Pollution, Preparedness, Response and Cooperation (OPRC) following the Exxon Valdez accident in Prince William Sound, Alaska. This convention notably emphasizes the importance of developing pollution emergency plans for ships, offshore units, sea ports and oil handling facilities, as well as reporting requirements and adequate response capacity. The convention also provides a framework for mutual aid and international cooperation. Mr Chazot explained that the weather could not only be the cause of a maritime incident, it could also impact the mounting of a response effort to a marine pollution. In that regard, Mr Chazot stressed the importance of weather considerations, and highlighted the decision-support role of forecasting models. Forecasting models can indeed assist in simulating temporal and spatial surface, sub-area, and atmospheric mobility of a pollutant, understanding the amount and rate of evaporation, and predicting a change in properties (e.g. emulsification). Mr Chazot concluded that these services are particularly useful in remote locations, or when aerial surveillance of a pollution incident is limited.

Session 15: Open Discussion – Gaps, Actions, Next Steps

- Educational trainings for mariners and forecasters could help close gaps in communication between these communities
- The establishment of accredited forecast sources could increase confidence in marine hazard forecasts from such sources
- Strengthening of public-private partnerships can help increase observational data and help improve forecast products

Mr Nick Cutmore (Secretary General, International Maritime Pilots Association) moderated the final session, closing the Symposium with a discussion of the topics presented over the course of the three days. Mr Cutmore emphasized the need to consider the next steps forward in order to ensure that the goals outlined for the Symposium are translated into actionable iteMs Symposium participants outlined numerous areas where joint efforts could reduce the risk of loss of life and property at seas.

One key area where increased collaboration could benefit the maritime community is with educational training for both mariners and forecasters, to help each group better understand the needs and capabilities of the other. For example, mariners would benefit from training that demonstrates how to properly interpret and use marine weather forecasts. Conversely, forecasters would benefit from training that helps them identify the constraints and risks associated with vessel operations in hazardous conditions that would better inform communications of hazardous weather conditions. Furthermore, participants discussed the unique challenge of safety in ports, given that ports are not under IMO jurisdiction, yet vessels are vulnerable to hazards that exist inside harbours.

Participants also discussed the need to publicly recognize the value of vessels voluntarily collecting observational data and connect their participation to its impacts in the weather forecasting community. Furthermore, participants emphasized the need to then accredit authoritative sources of weather forecast information to reduce the reliance on less reliable forecast data. Continuing the conversation surrounding data, participants also identified the need to further develop stronger relationships between public and private sectors in order to better utilize proprietary data from private business. Finally, participants highlighted the need to consider new platforms for the delivery of MSI (e.g. satellite internet) while considering the limitations and challenges of implementing new technology.

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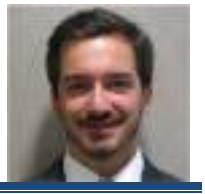

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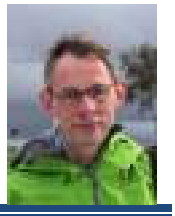

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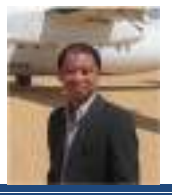

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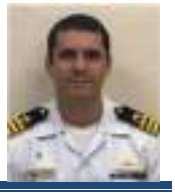

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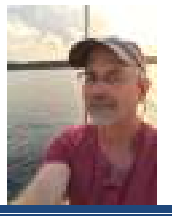

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List of Acronyms

List of Acronyms

AIS	Automatic Identification System
ASAP	Automated Shipboard Aerological Programme
BMKG	Meteorology, Climatology, and Geophysical Agency, Indonesia
BMT	British Maritime Technology
CLIA	Cruise Lines International Association
CMA-SAMOA	Environmental Control Panel-Meteorological and Oceanographic Support System of the Port Authority (Spanish)
CMCC	Euro-Mediterranean Centre on Climate Change
CMEMS	Copernicus Marine Environment Monitoring Service
CMTS	Committee on the Marine Transportation System
CWAM	Coastal Wave Model
DHI	Danish Hydraulic Institute
DMI	Danish Meteorological Institute
DWD	Deutscher Wetterdienst
ECDIS	Electronic Chart Display and Information System
ETA	Estimated Time of Arrival
ETDRR	JCOMM Expert Team for Disaster Risk Reduction
ETOOFS	JCOMM Expert Team on Operational Ocean Forecasting Systems
ETMEER	JCOMM Expert Team Marine Environmental Emergency Response
ETSI	JCOMM Expert Team on Sea Ice
FMI	Finnish Meteorological Institute
GDPFS	Global Data-Processing and Forecasting System
GIS	Geographic Information System
GMDSS	Global Maritime Distress Safety System
GOOS	Global Ocean Observing System
GT	Gross Tonnage
GWAM	Global Wave Model
IACS	International Association of Classification Societies
IAEA	International Atomic Energy Agency
ICOADS	International Comprehensive Ocean-Atmosphere Data Set
IHO	International Hydrographic Organization
IICWG	International Ice Charting Working Group

IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOGP	International Oil and Gas Producers
IPCC	Intergovernmental Panel on Climate Change
JCOMM	the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology
JCOMMOPS	JCOMM in situ Observation Support Center
LNG	Liquefied Natural Gas
MASS	Maritime Autonomous Surface Ships
metocean	Meteorology and (physical) Oceanography
MMO	Marine Meteorology and Ocean Affairs Division at WMO
METAREA	Geographical sea region for the purpose of coordinating the transmission of meteorological information to mariners on international voyages through international and territorial waters
MOSAiC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
MSI	Maritime Safety Information
NAVAREA	Geographical sea region for the purpose of coordinating the transmission of navigational information to mariners on international voyages through international and territorial waters
NMHS	National Meteorological and Hydrological Services
OPRC	International Convention on Oil Pollution, Preparedness, Response and Cooperation
PIANC	the World Association for Waterborne Transport Infrastructure
SAR	Search And Rescue
SDGs	Sustainable Development Goals
SIP	IMO's E-Navigation Strategy Implementation Plan
SOLAS	International Convention for Safety of Life at Sea
SOT	Ship Observations Team
SOOP	Ship of Opportunity Programme
STM	Sea Traffic Management
UNESCO	United Nations Educational, Scientific and Cultural Organization
VOS	Voluntary Observing Ship
WMO	World Meteorological Organization
WWMIWS	the IMO/WMO World Wide Met-Ocean Information & Warning Service

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