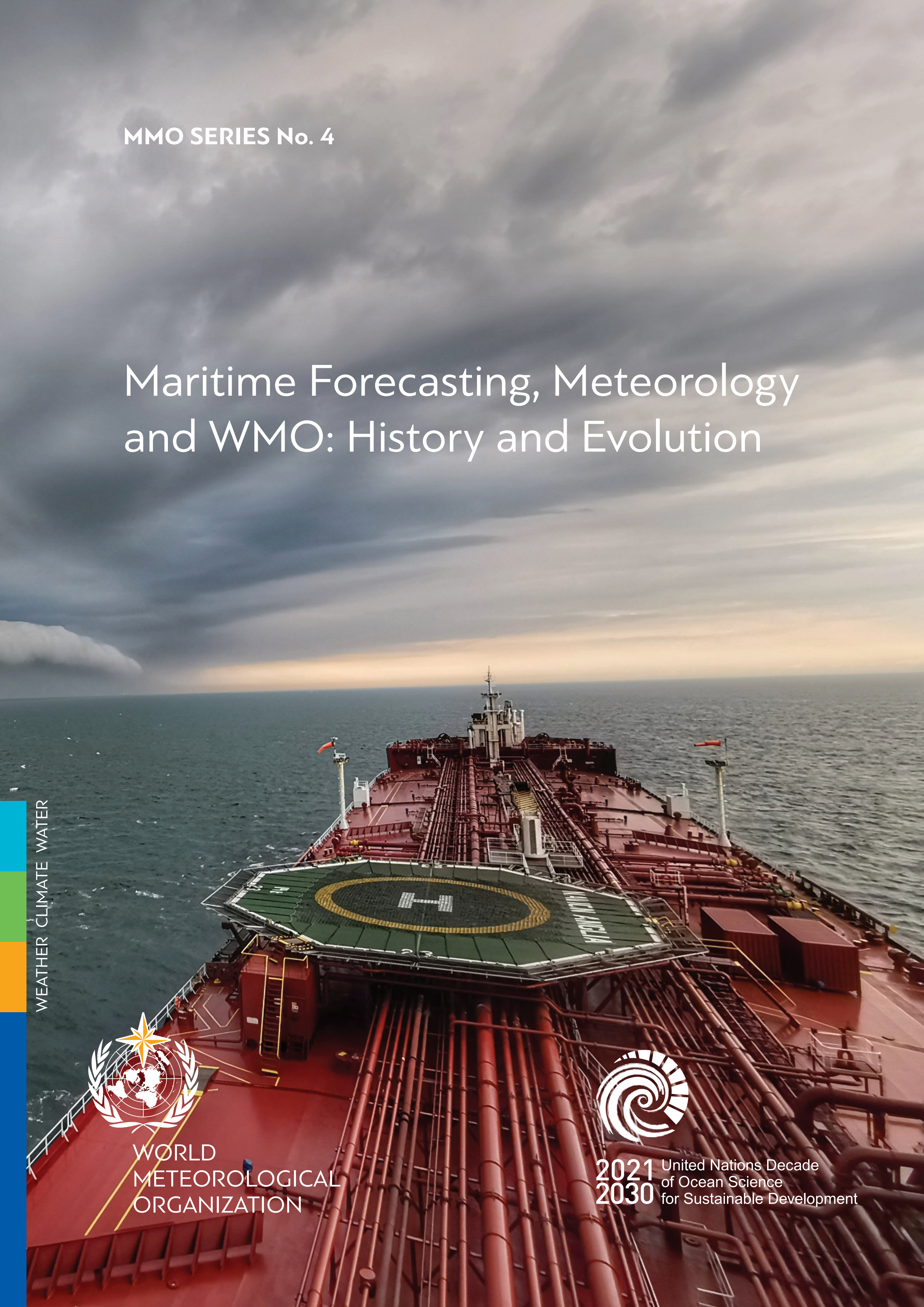
MMO SERIES No. 4

Maritime Forecasting, Meteorology and WMO: History and Evolution



WEATHER CLIMATE WATER

WORLD
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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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FOREWORD

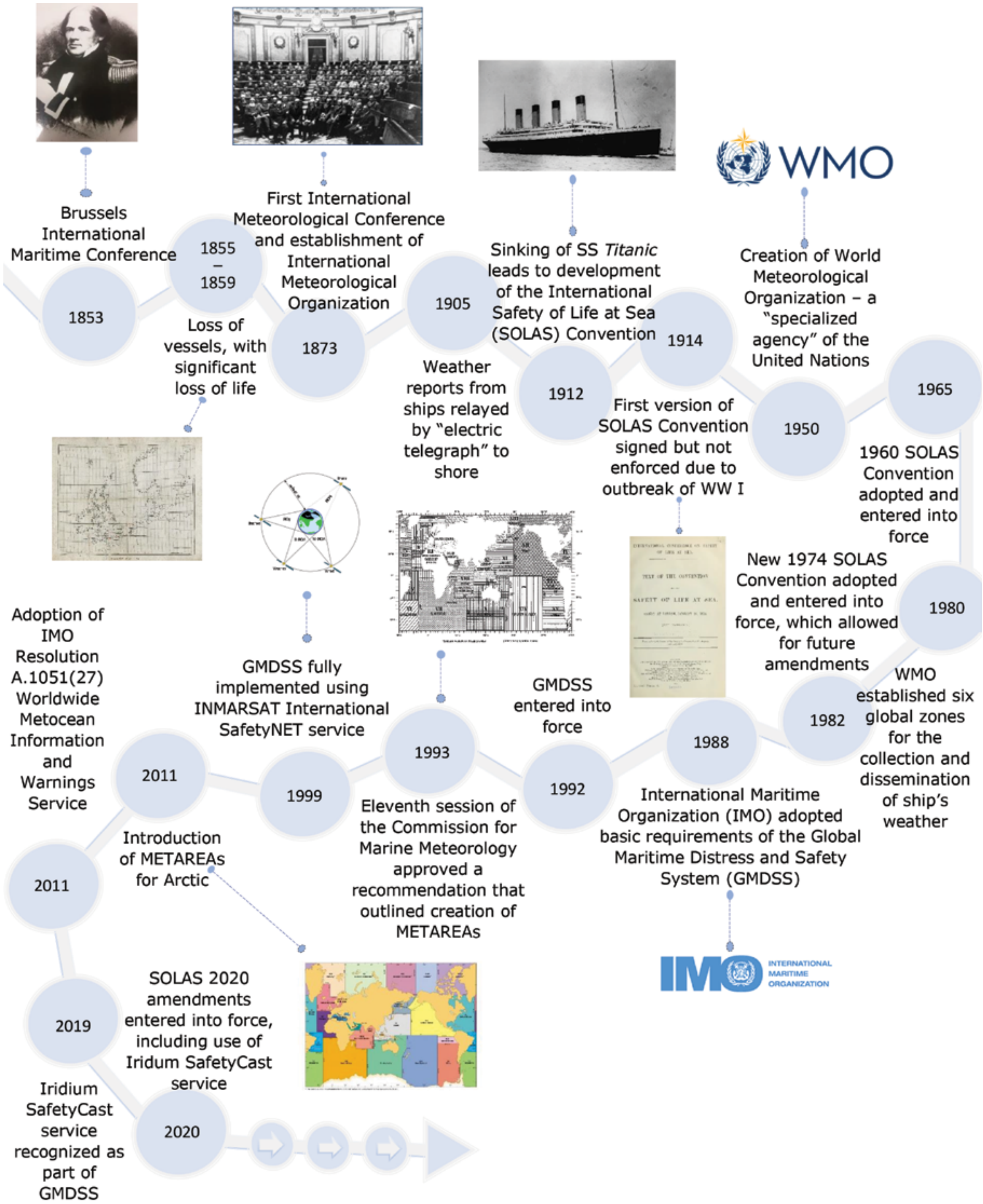
In early 2023, we will mark the 150th anniversary of international meteorological cooperation since the establishment in 1873 of the International Meteorological Organization, the predecessor to the World Meteorological Organization (WMO). This paper, *Maritime Forecasting, Meteorology and WMO: History and Evolution*, reminds us of the critical role that maritime safety has played, and continues to play, in driving international meteorological cooperation.

Marine meteorology has always been crucial to the safety of seafarers and to the economic efficiency of sea voyages.

Technological advancement and strengthening of maritime safety regulations over the decades have improved the reliability and accuracy of meteorological information and its communication for maritime safety. The progress and changes in distribution are fittingly captured in this brief history, highlighting the milestones and actions undertaken by the met-ocean, mariner, maritime safety and satellite communities to enable such developments. It also highlights the importance of collaboration and partnerships to improve maritime safety information and its promulgation.

With the significance of the 150th anniversary of international meteorological cooperation, I am pleased this short history highlights WMO involvement in coordinating the provision of marine meteorological information as we continue to strive towards improving it, while working with partners for its effective delivery. The launch of this paper coincides with the 2022 World Maritime Day. I would like to thank everyone involved in efforts over the years, and also those involved currently, in their work to improve the protection of life and property at sea.

Prof. Petteri Taalas
WMO Secretary-General



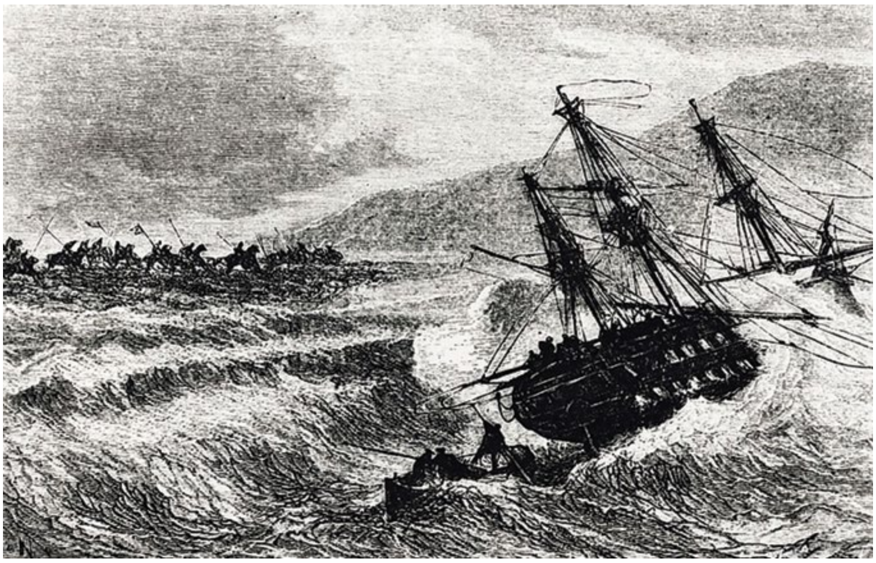
Timeline of key events in the history and evolution of maritime forecasting, meteorology and WMO

INTRODUCTION

Marine weather has had a major influence on human activities for centuries – not only for maritime safety, but also with broader impacts on major historical events.

One early example is the Yuan Dynasty invasions of the Japanese archipelago in the thirteenth century (Turnbull, 2014). Mongol military fleets attacking the Japanese islands were thwarted twice by typhoons, in 1274 and 1281. Storms destroyed hundreds of ships at sea with thousands of lives lost, ultimately limiting the Mongol expansion across east Asia.

Later examples include the sinking of the French Navy ship *Henri IV* during the siege of Sebastopol in November 1854, during the Crimean War. Sunk during an unexpected and fierce hurricane storm, the loss of this ship and a corvette has been widely attributed as the motivation for the start of intense French meteorological research (Hontarrède, 1998). A few months later, in February 1855, a similar weather-related disaster took place between Corsica and Sardinia. The French warship *Sémillante* was wrecked in an unexpected violent storm, resulting in the loss of all 693 soldiers and crew on board (Pierre, 2001; Dexter and Parker, 2009).



Sinking of the *Henri IV* during the siege of Sebastopol, November 1854

Source: Hontarrède (1998); the image was taken from an original sourced at the Musée de la Marine, Paris

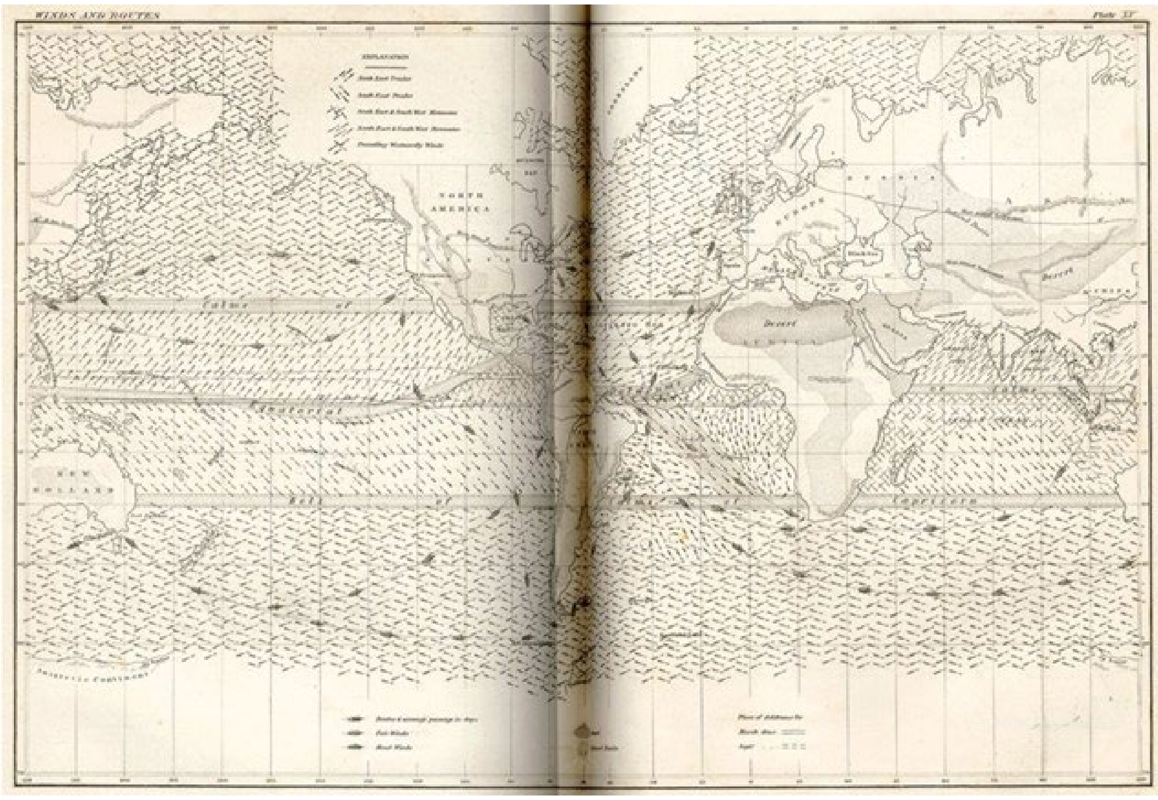
Learning from such incidents and other high-profile maritime disasters, numerous maritime nations around the world have provided and refined the accuracy of forecasts for mariners over many years. Prediction of marine weather for maritime safety, especially military operations at sea, has been a major driver to advance meteorological science (Hontarrède, 1998).

Since the mid seventeenth century, keeping weather records from land-based points was emerging as a popular activity, at least in Europe and possibly also in the Arab world (Met Office, n.d.*a*). Related to wind and impacts on sea state, by the eighteenth century, Daniel Defoe, wrote about a storm in the British Isles in November 1703, entitled *The Storm: Or A Collection of the Most Remarkable Casualties and Disasters Which Happen'd in the Late Dreadful Tempest Both by Sea and Land* (Defoe, 1704). In this, he referred to a 12-point scale "table of degrees… used by our sailors". By the early nineteenth century, Francis Beaufort of the British Royal Navy had devised a different scale for wind force, which became known as the Beaufort Scale. It remains in use today and is considered the standard for maritime wind speed (Royal Meteorological Society, n.d.).

Significant developments started to take place in meteorology and its application to the maritime community from the middle of the nineteenth century. The first uses of the recently invented "electric telegraph" to transmit weather observations in the United Kingdom of Great Britain and Northern Ireland and the United States of America occurred in 1849.

Soon after, in 1853, the landmark Brussels International Maritime Conference became a critical moment in marine meteorology history. The conference came about due to exchanges of official correspondence between the governments of the United Kingdom and the United States of America on the desire to improve the quality and coverage of meteorological observations and data gathered at sea.

Lieutenant Matthew Fontaine Maury of the United States Navy, already prominent and respected for his efforts on ocean currents and winds, had proposed to the United States Government that improved instruments and knowledge of their inherent errors would dramatically improve the quality of observational data used to generate marine forecasts. They could also be used to calibrate and validate the lesser quality data obtained from merchant ships and less-capable observers.



Early depiction of the general directions and strengths of ocean currents and winds

Source: Maury (1855); courtesy of the Smithsonian Libraries and Archives

Initially, this was a bilateral initiative focused on the British and United States navies. However, Maury proposed a more ambitious approach with the convening of an international conference inviting representatives of the main global powers. Although European scientists had been exchanging information for years, the conference brought together 12 mainly naval military experts from 11 different countries. It therefore became the first truly global gathering for international meteorological cooperation, "for the purpose of holding a Conference on the subject of establishing an uniform system of meteorological observation at sea, and of concurring in a general plan of observation on the winds and currents of the Ocean; with a view to the improvement of navigation and to the acquirement of a more correct knowledge of the laws which govern those elements" (Maritime Conference, 1853). For further information, see Hontarrède (1998), Shearman (2003) and Dexter and Parker (2009).

Lieutenant Matthew Fontaine Maury of the United States Navy, the driving force behind convening the International Maritime Conference in Brussels, 1853

Source: WMO

This conference resulted in the initial steps for standardization in the process of recording weather and ocean observations. It was also significant through precipitating momentum for the convening of the First International Meteorological Congress in Vienna in 1873. Ultimately, this triggered the birth of the International Meteorological Organization – the predecessor of the World Meteorological Organization (WMO) (Hontarrède, 1998; Shearman, 2003; Dexter and Parker, 2009; Dexter, 2020).

Participants at the first International Meteorological Congress, Vienna, 1873

Source: WMO

In addition to the significance of the maritime sector driving the start of international cooperation in meteorology, advances in maritime safety were also being made at a national level. For example, in the United Kingdom, the Clipper *Royal Charter*, which had sailed from Australia, hit a severe storm and sank off the coast of North Wales in 1859, killing over 400 people. This tragic incident brought about the introduction of a "warnings service" in 1861 (Met Office, n.d.*b*).

One of the original charts produced by Vice-Admiral Robert FitzRoy to demonstrate his understanding of the storm that sunk the *Royal Charter*

Note: Wind strength is shown by the length of the line; red and blue lines represent pressure and temperature; and weather conditions such as cloud and rain are shown by markings in small boxes.

Source: Met Office (n.d.*b*). © Crown Copyright [1859]. Information provided by the National Meteorological Library and Archive – Met Office, United Kingdom.

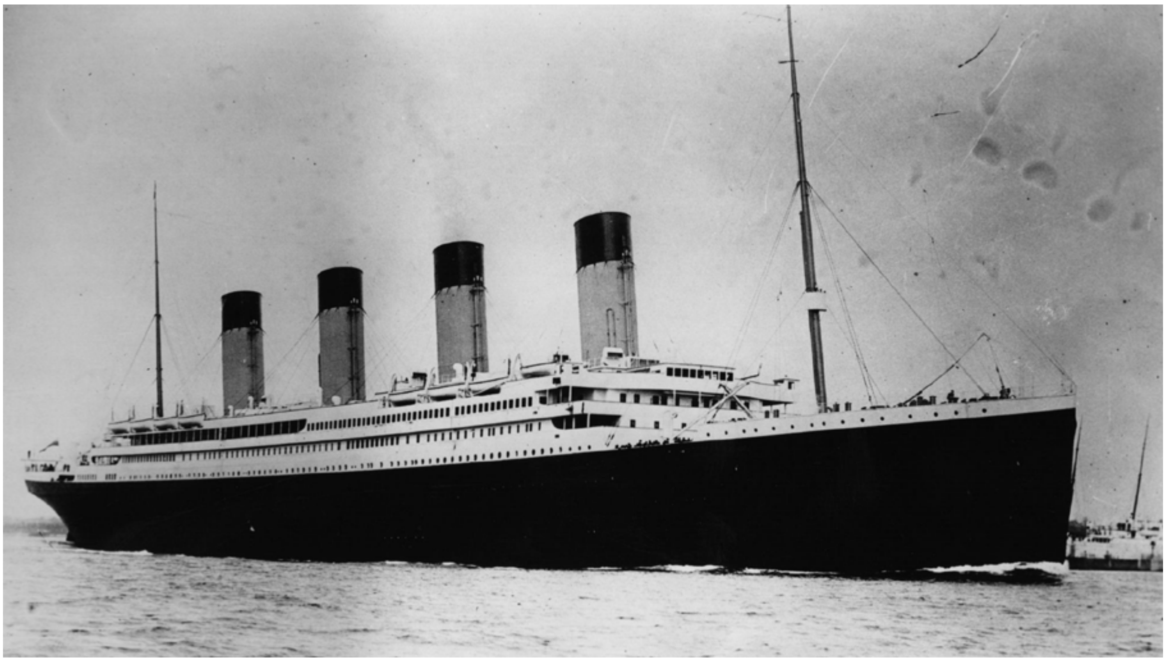
Although this "warnings service" ceased for a period in 1865, it was reintroduced in 1867 and became known as the "Shipping Forecast". This is still a fundamental element of the contribution of the United Kingdom to maritime safety and its obligation as METAREA I in supporting the Global Maritime Distress and Safety System (GMDSS).[1]

Around the same time, Urbain Le Verrier, who established the French meteorological service, saw the potential of the new electric telegraph. He pioneered its use as the main transmission medium of the proposed national meteorological observation network (Dexter and Parker, 2009). This development of "wireless telegraphy" allowed, for the first time, two-way communications with ships at sea. Further developments meant that, in 1905, it was used to relay weather reports from ships at sea to coastal radio stations.

Following this progress, in 1907, the International Meteorological Organization[2] made it obligatory for all ships to transmit weather reports to shore. At the same time, it also established the Commission for Maritime Meteorology, later renamed in 1971 to the Commission for Marine Meteorology, which remained active until 1999 (Dexter and Parker, 2009).

1 METAREAs are explained below.
2 Formed in 1879 until 1950, the International Meteorological Organization was the precursor to WMO, which was formed in 1950 (WMO, 2022*a*).

These developments maintained emphasis on the critical aspects of weather and navigation variables, as well as access to hazard information, for the safety of life at sea. These were brought to the fore with the sinking of the SS *Titanic* in 1912, when the self-proclaimed "unsinkable" passenger liner carrying 2 200 people struck an iceberg in the north Atlantic Ocean, and 1 503 lives were lost.



SS *Titanic*, which sank on her maiden voyage in 1912 after striking an iceberg in the north Atlantic Ocean

Source: Canva Pro

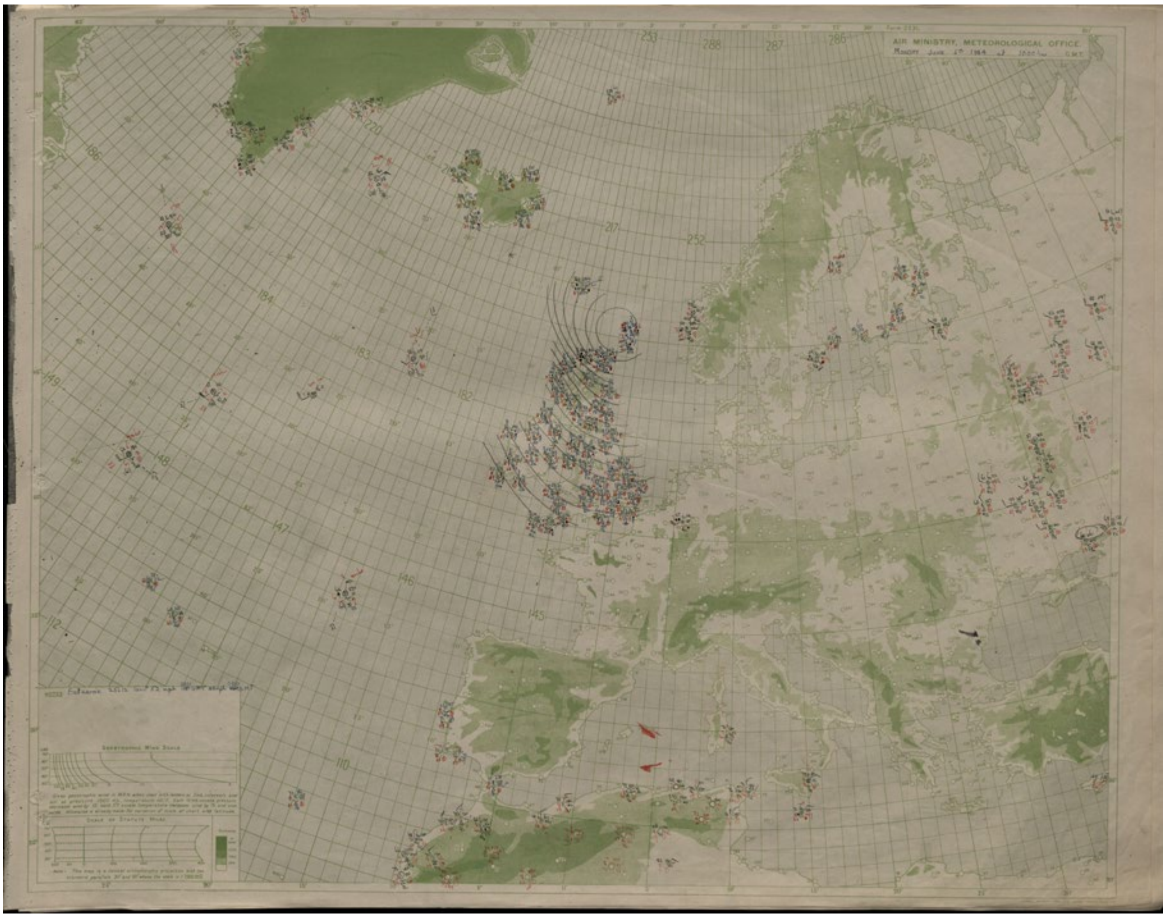
International reaction was swift, with establishment of the International Convention for the Safety Of Life At Sea (SOLAS Convention 1914; International Conference on Safety of Life at Sea (1913-1914 London), 1914), whereby, for the first time, it became obligatory for Contracting Parties to freely provide information on ice. Although initially, information relating to weather was optional, the provision of twice-daily weather bulletins for ships at sea, to help their safe passage, soon became a "cornerstone" of the Convention, and remains in the amended version, SOLAS Convention, 1974 (United Nations, 1974). The *Titanic* disaster also highlighted the dire need for robust and easily available ice charts to help in voyage planning in ice hazard conditions (Deggim, 2021; Wyatt, 2021).

At the end of the nineteenth century, the dominance of sail and wind power shifted to mechanical steam power. As such, it was widely considered that, in the future, maritime transport would become less dependent on meteorological information. Following soon after, the early twentieth century saw the rise of aviation, which then became a significant focus of meteorological services. As a result, traditionally close ties subsided between meteorological services and mariners (Dexter and Parker, 2009).

By the early 1930s, several factors highlighted the continuing need for, and development of, maritime safety information (MSI). A key recognition was that up to 70% of maritime safety incidents were related to the weather. Additionally, there were continuing developments in maritime communications, which permitted more reliable delivery of a broader range of MSI (Dexter and Parker, 2009).

The Second World War highlighted the need for high-quality meteorological and oceanographic information to be available to ships at sea. Prime examples are the Atlantic convoys during the

Battle of the Atlantic (1939–1945) and the Normandy landings (6 June 1944), which in particular required wind speeds of less than 18 knots, clear skies and wave heights below 2 m. Devised by meteorologist and oceanographer Professor Walter Munk, meteorology and swell data for a wave prediction method used by the United States Navy were instrumental in the success of the landings. This is an example of the critical nature and impact of high-quality weather and wave information.



Synoptic working chart for 5 June 1944

Source: Met Office (n.d.*c*). © Crown Copyright [1944]. Information provided by the National Meteorological Library and Archive – Met Office, United Kingdom.

In 1950, the non-governmental International Meteorological Organization became the intergovernmental WMO and a specialized agency of the United Nations. WMO carried forward most of the subsidiary bodies of the defunct International Meteorological Organization, including the Commission for Maritime Meteorology, as well as maintaining the system for the provision of high seas warnings and forecasts in support of the safety of life and property at sea that had been established in the 1940s (Dexter, 2020).

The 1960s saw a growing appreciation within the global meteorological community of the important role played by the ocean in atmospheric processes. This was reflected in the value placed on observations from the oceans and the framework that WMO put into place for the "collection and dissemination" of ship weather reports.

The interests of WMO and national meteorological services were extending rapidly beyond the traditional sea surface winds and waves to more fundamental ocean variables. Through the Commission for Maritime Meteorology, WMO was responding to some of these developments, as was the United Nations Educational, Scientific and Cultural Organization's fledgling Intergovernmental Oceanographic Commission (IOC). IOC established a Working Group on Fixed Ocean Stations as a forerunner to the Integrated Global Ocean Services System.

In 1999, the World Meteorological Congress and the IOC Assembly adopted identical resolutions to formally establish the Joint WMO–IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM). This was a significant, though not unique, event in the United Nations system where two independent intergovernmental organizations jointly established a subsidiary body (Dexter, 2020).

One outcome of this development was a greater ability to concentrate expertise through the establishment of several Expert Teams within JCOMM, made up of experts in particular disciplines from WMO Members and IOC Member States. These Expert Teams included Maritime Safety Services (1999–2017), Sea Ice (1999–2019) and Marine Accident Emergency Support (2005–2012). Alongside these were other teams that effectively supported the delivery of maritime services.[3]

DEVELOPMENT OF SATELLITE COMMUNICATIONS AND THE GLOBAL MARITIME DISTRESS AND SAFETY SYSTEM

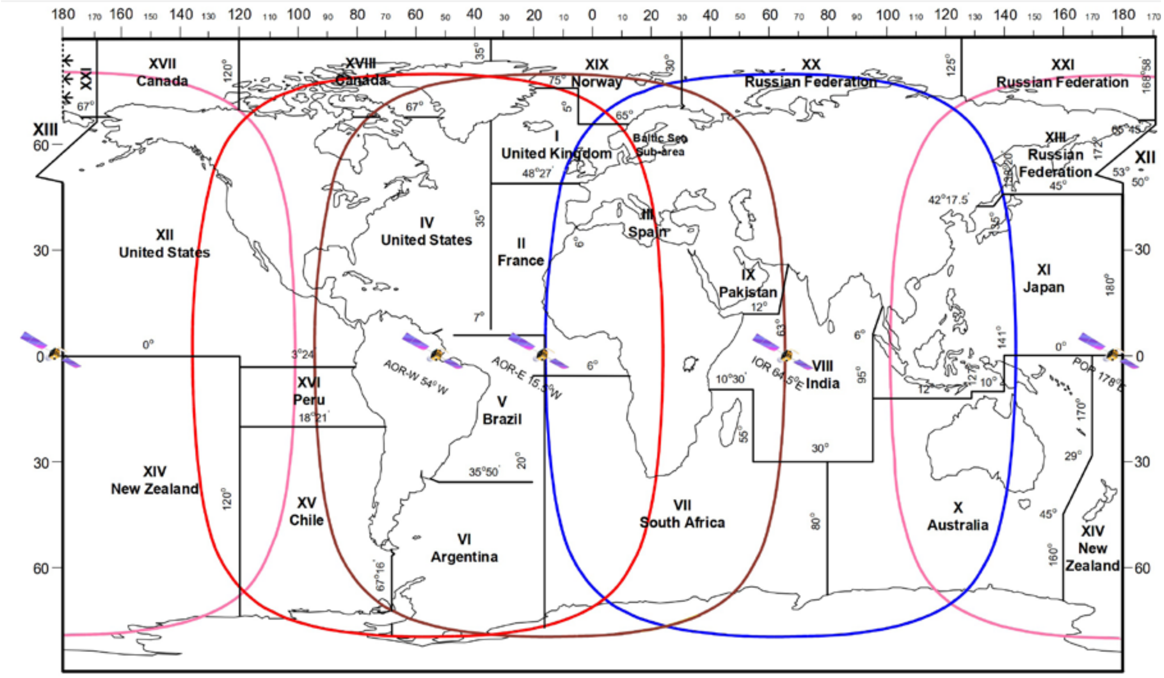
Almost in parallel with the developments between WMO and IOC, developments were also taking place with marine weather broadcasts. In the 1960s, the International Maritime Organization (IMO), recognizing that satellites would play an increasingly important role in search and rescue, established the International Maritime Satellite Organization (INMARSAT) to provide emergency maritime communications.

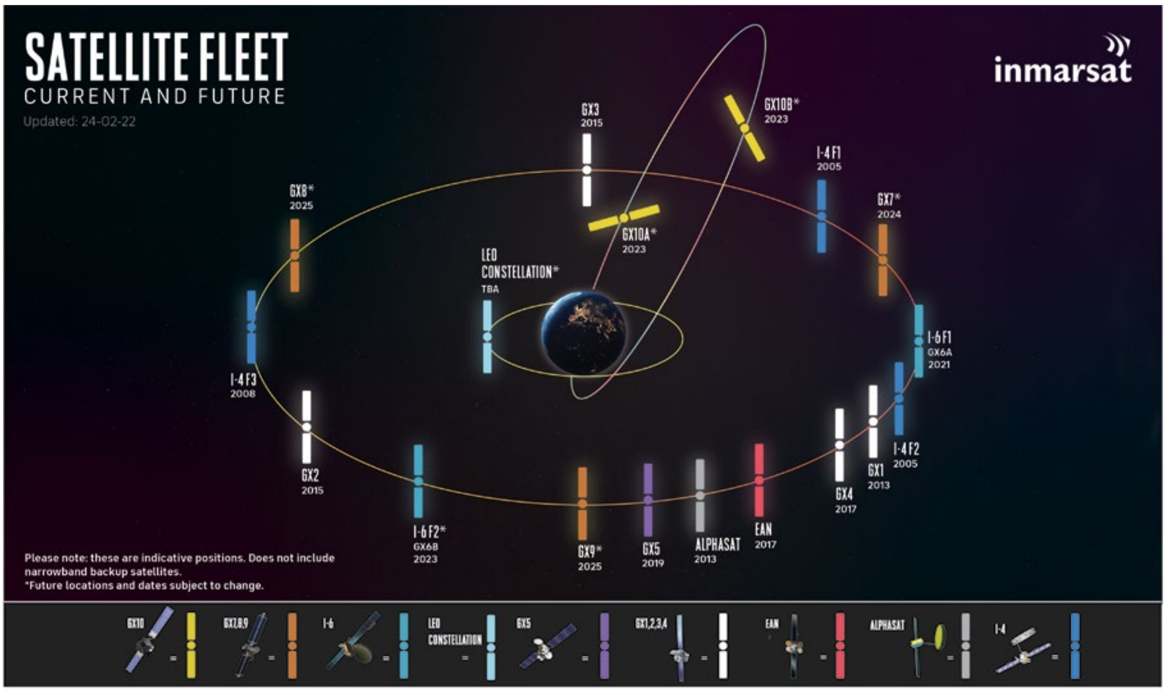
By 1987, interest in NAVTEX[4] was growing, and many countries were introducing operational MSI into their NAVTEX bulletins. In 1988, IMO Member States adopted the basic requirements of GMDSS as a fundamental element of the SOLAS Convention, and the system was gradually introduced from 1992 onward. These SOLAS Convention amendments also included, for the first time, the stated requirement for the broadcast of MSI to shipping on the high seas, including meteorological warnings and forecasts.

Today, GMDSS is an integrated communications system which ensures that no registered SOLAS ship in distress can disappear without trace thus allowing more lives to be saved at sea. Under GMDSS, all ships above 300 gross tonnage are required to be equipped with satellite receivers and NAVTEX receivers to automatically receive MSI, including meteorological warnings and forecasts (Savina, 2006).

[3] For further information about the history of JCOMM and maritime involvement, see Dexter (2020).

[4] NAVTEX is an international, automated, medium frequency, direct-printing service for promulgation of MSI, including navigational and meteorological warnings, meteorological forecasts and other urgent safety-related messages to ships (see IMO (2011*a*) for additional information).





Inmarsat satellite coverage as used in GMDSS: (top) in the late 2000s, Inmarsat-3 coverage with NAVAREAs/METAREAs and (bottom) the 2022 constellation

Source: (top) IMO (2015), © Inmarsat; (bottom) Inmarsat 2022, © Inmarsat

WMO also established and implemented a marine broadcast system for GMDSS (Savina, 2006). This was adopted at the eleventh session of the Commission for Marine Meteorology (WMO, 1993), and, after approval by the WMO Executive Council, was integrated into the *Manual on Marine Meteorological Services* (WMO, 2018*a*). This Manual remains the underpinning document for establishing and monitoring meteorological MSI and the fundamental source of marine meteorology rules and regulations of WMO.

Several other WMO publications complement the Manual, including the *Guide to Marine Meteorological Services* (WMO, 2018*b*), *Sea-ice Information and Services* (WMO, 2021) and *Information for Shipping* (WMO, 2018*c*). Furthermore, IMO, the International Hydrographic Organization (IHO) and WMO have also published the *IMO/IHO/WMO Manual on Maritime Safety Information (MSI)* (IMO, 2014), which was originally published in 1996. This replaced the *IMO/IHO Guide to Drafting Radio Navigational Warnings for the World-Wide Navigational Warning Service* first published in 1993 (IMO, 1993).[5] This joint manual brings together the navigational and meteorological aspects of maritime safety procedures (IMO, 2014).

In the SOLAS Convention, there was, initially, only an obligation on administrations to provide "meteorological forecasts and warnings", with no mention of WMO or National Meteorological and Hydrological Services (NMHSs). However, the hard lobbying at IMO eventually brought an amendment to the GMDSS text in the SOLAS Convention to the effect that administrations should abide by the rules and regulations of WMO in delivering meteorological services to shipping under the SOLAS Convention.

Alongside WMO, IMO and IHO were continuing to progress the evolution of the provision of MSI (Deggim, 2021; Wyatt, 2021). At the seventeenth assembly of IMO, a formal resolution (A.706(17)) was adopted that introduced the World-Wide Navigational Warning Service (WWNWS) to provide navigational warnings across the globe, within the auspices of GMDSS (IMO, 1991*a*). This also introduced the concept of NAVAREA Coordinators for the 16 NAVAREAs.[6]

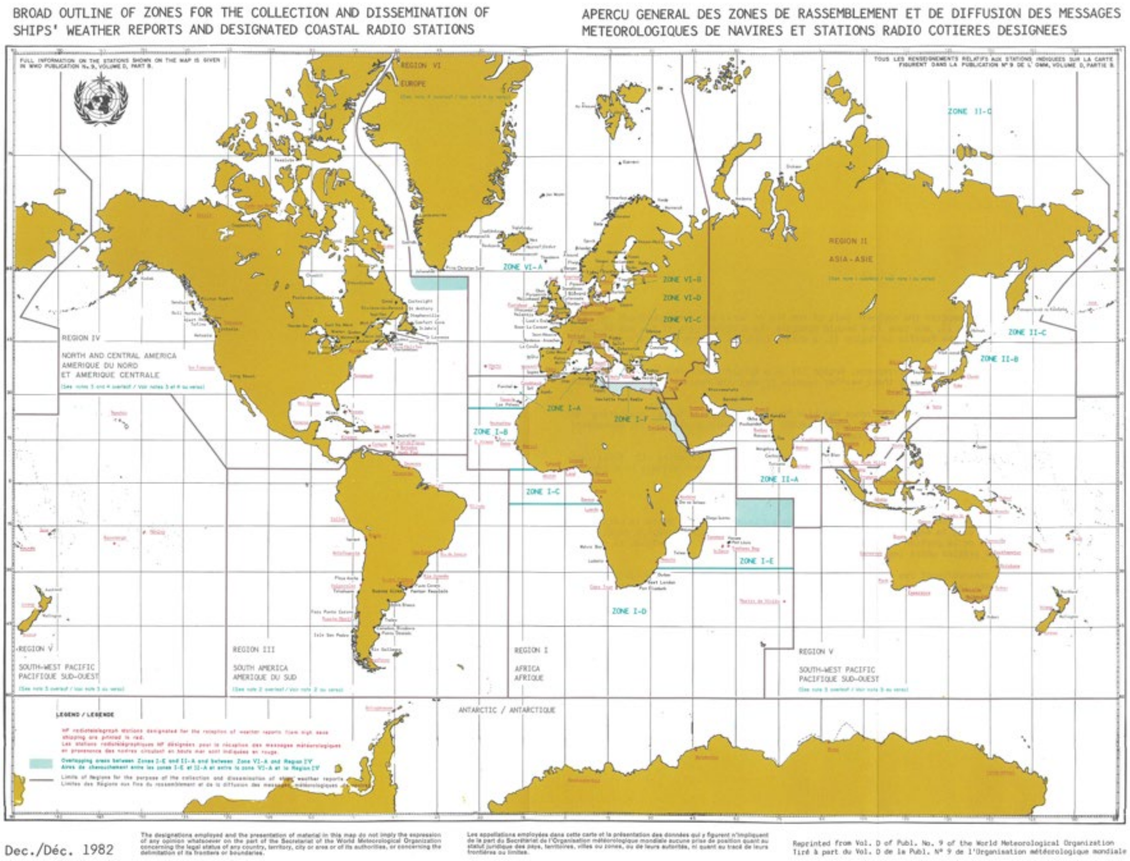
EVOLUTION OF THE ROLE OF WMO IN MARITIME SAFETY ACTIVITIES SINCE THE 1990S

While IHO had a formal system and network for the promulgation and dissemination of navigation warnings since 1991, it was apparent that the WMO system (which had been in use since the 1940s and continued to function satisfactorily) needed a major review (WMO, 1989). This was partly due to developments that had recently occurred or were being implemented.

It was proposed that WMO could develop a similar system and network for the provision of meteorological information. At the eleventh session of the Commission for Marine Meteorology, a recommendation was approved that outlined the role of METAREAs (WMO, 1993). Recommendation 3 stated that "For the purpose of the preparation and issue of meteorological warnings and the regular preparation and issue of weather and sea bulletins, the oceans and seas are divided into areas for which national Meteorological Services assume responsibility" and that "The areas of responsibility together provide complete coverage of oceans and seas by meteorological information contained in warnings and weather and sea bulletins for the high seas." The recommendation also outlined how such information may be disseminated and which INMARSAT Coast Earth Station should be used for each bulletin (Savina, 2006).

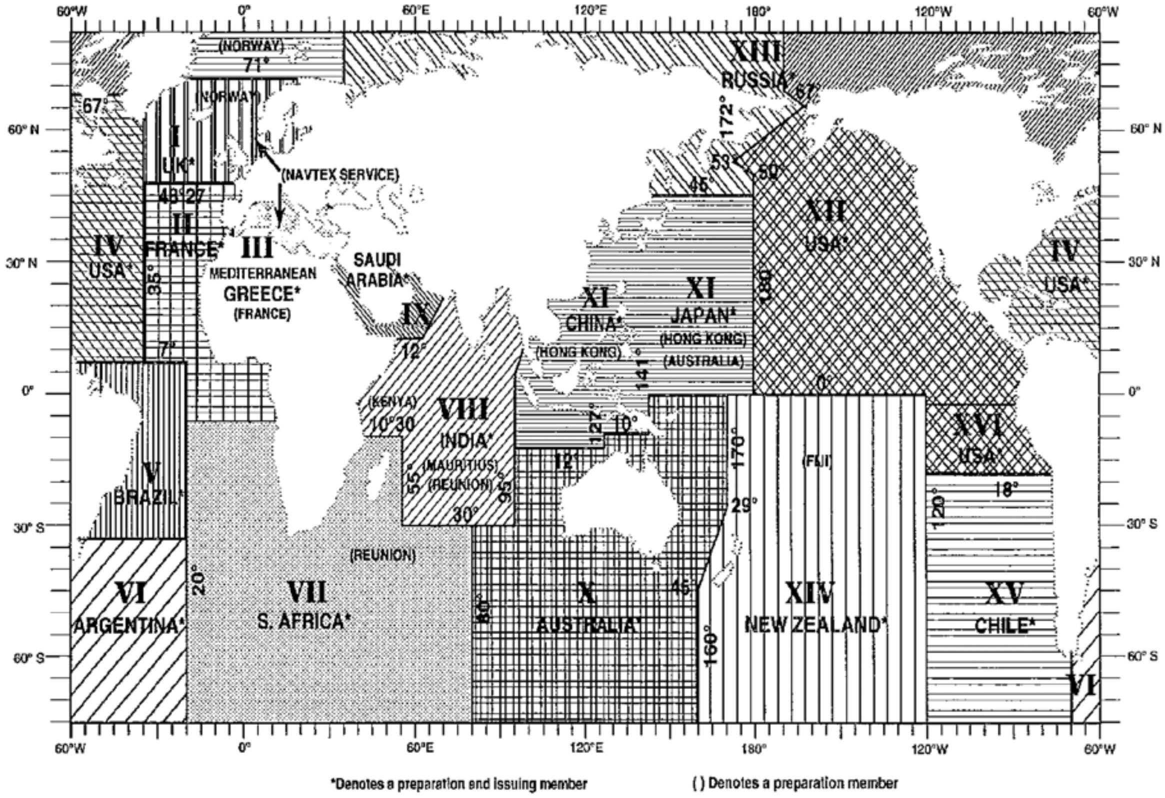
[5] This reference is the first edition – there were several revisions until 1996, after which it was replaced.

[6] A NAVAREA is defined as a geographical sea area established to coordinate the broadcast of navigational warnings. The term "NAVAREA" followed by a roman numeral may be used to identify a particular sea area, with a NAVAREA Coordinator being the authority charged with coordinating, collating and issuing NAVAREA warnings for a designated NAVAREA.



Outline of zones for collection and dissemination of ship weather reports and designated coastal radio stations, December 1982

Source: WMO (1982)



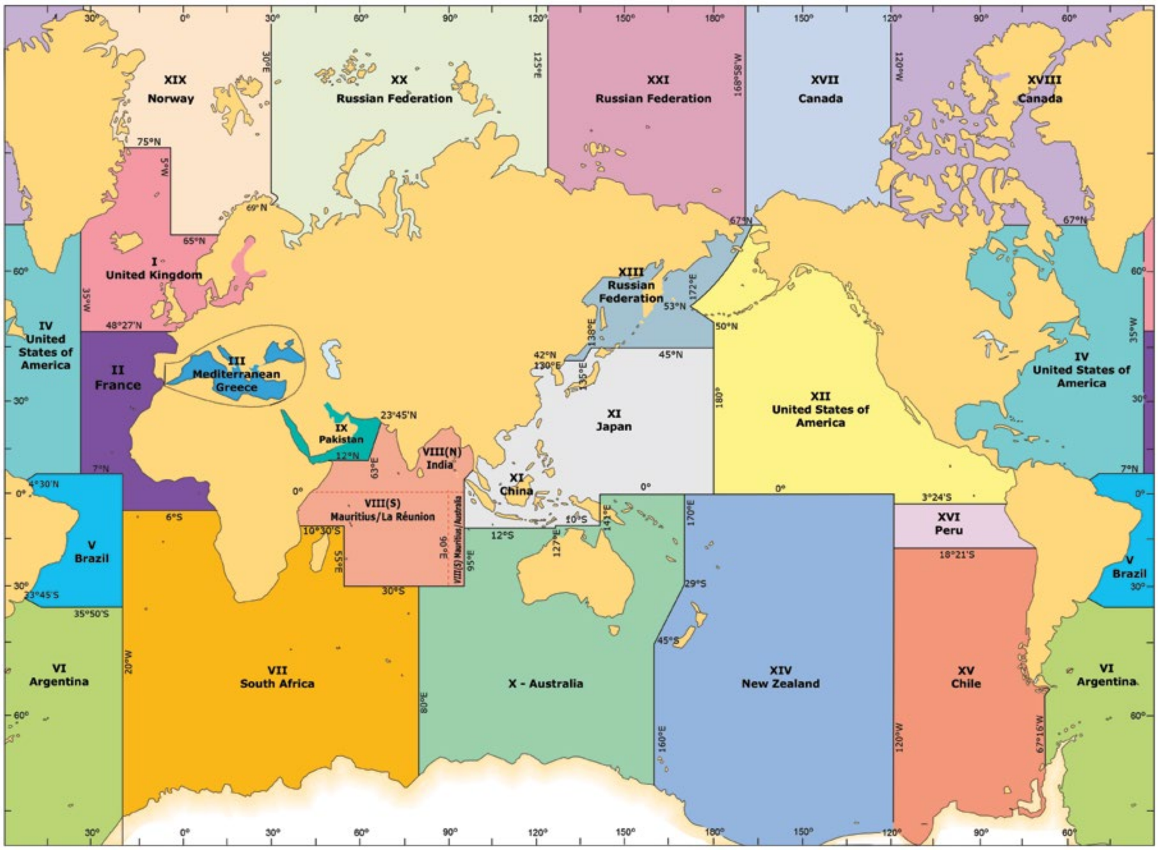
METAREAs as described in Recommendation 3 of the eleventh session of the Commission for Marine Meteorology

Source: WMO (1993)

In the early 1990s, when many NMHSs were facing questions about what their roles should be, and while many of them were already providing services to METAREAs (with at least three Coordinators already in place[7]), there was no formal IMO mandate or framework, equivalent to A.706(17), to guide them in providing these services. Initial informal discussions between some METAREA Coordinators, principally METAREAs I and II, considered the possibility of developing a form of IMO resolution that would mirror the resolutions already in place: A.705(17) (*Promulgation of Maritime Safety Information*; IMO, 1991*b*) and A.706(17) (*World-Wide Navigational Warning Service*; IMO, 1991*a*). These resolutions were amended in later years.

WMO adopted the concept of METAREAs as outlined above. These were equivalent to IHO NAVAREAs and largely mirrored NAVAREAs with one or two exceptions, around China and Japan and the Indian Ocean structure. This framework of parallel NAVAREAs and METAREAs continued largely unchanged until 2011. Then, with shipping increasingly looking to use the Northeast and Northwest Passages around the coasts of Canada and the Russian Federation to reduce fuel costs and with the possibility of climate change making these routes increasingly attractive, five new NAVAREAs and METAREAs were introduced. Services for these areas are provided by Canada, Norway and the Russian Federation.

[7] Initial METAREA coordinating countries in 1993 were France, the United Kingdom and the United States of America.



Limits of METAREAs since 2018

Source: WMO (2018*a*)

Although METAREAS had been originally recognized in 1993, it was only in 2011 that the Worldwide Met-Ocean Information and Warning Service (WWMIWS) was established as a recognized service for the promulgation of meteorological forecasts and warnings at sea. WMO considered that to support this, it would be beneficial to introduce an appropriate resolution to ensure the methodology for applying the content of the above statement was consistent with the methodology adopted for the provision of navigational warnings through Resolution A.706(17), as amended (IMO, 2008*b*).

Following detailed work by the WMO Secretariat and METAREA Coordinators, and with considerable assistance and advice from the IHO Secretariat, a suitable draft resolution was developed that introduced this new WWMIWS.

At its eighty-fifth session, the IMO Maritime Safety Committee had adopted amendments to Resolution A.705(17), including the statement that "Meteorological information shall be provided in accordance with the World Meteorological Organization (WMO) technical regulations and recommendations, monitored and reviewed by the Expert Team on Maritime Safety Services of the Joint WMO/IOC Commission for Oceanography and Marine Meteorology (JCOMM)" (IMO, 2008*a*).

An appropriate resolution was introduced at the IMO Assembly session and was formally adopted by the Organization on 30 November 2011 as Resolution A.1051(27) (IMO, 2011*b*).

Having established a suitable framework within which METAREA Coordinators could work, safety services continued to be provided for some years until further refinements were introduced after 2011. These included establishment of the WWMIWS Committee in 2017 with membership open to all METAREA Coordinator Focal Points (WMO and IOC, 2017). Soon afterwards, an *Operations*

Handbook for METAREA Coordinators (JCOMM, 2019) was finalized to guide Coordinators in their roles and to understand their responsibilities, as outlined in IMO Resolution A.1051(27) (IMO, 2011*b*).

The reform of WMO in 2019 led to disbandment of JCOMM, and establishment of the WMO Commission for Weather, Climate, Water and Related Environmental Services and Applications (SERCOM), in which the Standing Committee on Marine Meteorological and Oceanographic Services (SC-MMO) inherited the responsibility for maritime safety among other marine activities.

SC-MMO has ensured continuation of the METAREA group through the Advisory Group on the WWMIWS Sub-Committee, as well as maritime safety activities, marine environmental emergency response, and search and rescue through other Expert Teams. To emphasize the close parallels between WWMIWS and the navigational WWNWS, joint meetings between the two are convened periodically to provide a forum for both groups of Coordinators to liaise and ensure a common approach to the provision of MSI.

To make meteorological MSI visible, and as a service to users, a website has been available since 2003 (hosted by Météo-France), from where users can access marine forecasts for each METAREA (WMO and Météo-France, n.d.).

It should also be noted that, in addition to the forecasting services provided, WMO also undertakes regular gathering of feedback from users of meteorological MSI via the Marine Meteorological Monitoring Survey. Traditionally, this was done by face-to-face interviews, largely undertaken by Port Meteorological Officers on their regular visits to ships. Recently, with more vessels having access to the Internet, these surveys have been available online, for masters or owners/charterers to complete at their convenience. For more information, including the summary results of previous surveys, see WMO (2022*b*).

LOOKING TO THE FUTURE...

Moving ahead, it seems likely that changes and enhancements to the provision of meteorological MSI will continue in different ways. As the science of meteorology, and particularly marine meteorology, continues to advance, there will be further challenges for marine service providers to meet.

As the saying goes “a picture says a thousand words”, so it is with meteorological information: there will be an increasing need to provide information in graphic formats and other innovative ways. This is already under way in some areas with, for example, the development of services that can complement electronic chart display and information systems (commonly called ECDISs) and associated electronic navigational charts (commonly called ENCs). This is an area of close collaboration with IHO and its Member States. Work is also under way in developing products compatible with the S-100 framework, with the met-ocean specific products including Sea Ice information (S-411) and Weather and Wave Information (S-412 and S-413)

For the traditional sources of information that are regulated by IMO through the SOLAS Convention, there have been moves to introduce other satellite providers. In 2018, IMO Member States therefore decided to introduce additional satellite service providers. In addition to Inmarsat Ltd, in 2018, Iridium was recognized for the provision of satellite services under the SOLAS Convention. IMO remains open to other providers seeking recognition, either on a regional or on a global coverage basis.

Examples of typical systems for receiving satellite services at sea, including Inmarsat (top) and Iridium (bottom)

Source: (top) Inmarsat, © Inmarsat; (bottom) Kyle Hurst © Kyle Hurst

In addition to the expansion of satellite systems and available bandwidth, work within IMO and its Member States, although at an early stage, is progressing on potential systems to replace the ageing analog technology of the NAVTEX system. Recognizing the benefits of the provision of graphic products, the potential of digital terrestrial systems is being assessed for the provision of MSI within coastal regions under individual national authorities. It is anticipated these will also support the S-100-based product specifications being developed.

All these developments will use the same data as currently used, although products will be graphic rather than the current text base. This will pose new challenges to information providers – not necessarily what products to provide, but more how to manage the information data flow so as not to overwhelm the maritime customer. Organizations and authorities will have to further consider customer requirements rather than simply what they can provide. This may require providers, through WMO, to gather more sophisticated feedback from users in addition to the routine surveys currently undertaken.

Looking even further ahead, marine autonomous surface ships (MASS) will have a plethora of sophisticated environmental sensors providing real-time data on which machine operational decisions will be made. These data also have multiple additional uses for populating model databases and early warning systems. If made available, and as meteorological computer modelling becomes more advanced, there is the potential for on-board systems to directly ingest data, such as numerical model output, format them and display them on bridge systems for human portrayal.

Illustrated example of a MASS

Source:

CONCLUSION

While technology continues to advance, the basic tenet of safety and protection – of lives and property at sea – remains the same as it has been for hundreds of years. The cost to saving a life is immeasurable, and thus it is the entrenched public service to ensure that met-ocean information is continuously provided for quality warnings and forecasts. This basic foundation service, on which WMO was built, will continue.

ACKNOWLEDGEMENTS

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REFERENCES

Defoe, D. 1704: *The Storm: Or A Collection of the Most Remarkable Casualties and Disasters Which Happen'd in the Late Dreadful Tempest Both by Sea and Land.* Printed in 1713 for G. Sawbridge and J. Nutt.

Deggim, H., 2021: The IMO and WMO – Providing weather information to support safe navigation. *WMO Bulletin*, 70(1): 10–12.

Dexter, P., 2020: *The Establishment of the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology: A Personal History* (WMO-No. 1250). MMO Series No. 2. Geneva, World Meteorological Organization.

Dexter, P. and P. Parker, 2009: Meteorology and marine transportation. *WMO Bulletin*, 58(2): 111–117.

Hontarrède M., 1998: Meteorology and the maritime world: 150 years of constructive cooperation. *WMO Bulletin*, 47(1): 15–26.

International Conference on Safety of Life at Sea (1913-1914 London), 1914: *Text of the Convention for the Safety of Life at Sea.* London, His Majesty's Stationery Office.

International Maritime Organization, 1991*a*: Resolution A.706(17) Adopted on 6 November 1991: World-Wide Navigational Warning Service. A 17/Res.706. London.

———, 1991*b*: Resolution A.705(17) Adopted on 6 November 1991: Promulgation of Maritime Safety Information. A 17/Res.705. London.

———, 1993: *IMO/IHO Guide to Drafting Radio Navigational Warnings for the World Wide Navigational Warning Service.* 1st edition. Sub-Committee on Radio Communication COM/Circ.124. London.

———, 2008*a*: Amendments to Resolution A.705(17) – Promulgation of Maritime Safety Information. MSC.1/Circ.1287. December 2008. London.

———, 2008*b*: Amendments to Resolution A.706(17) – World-Wide Navigational Warning Service. MSC.1/Circ.1288. 9 December 2008. London.

———, 2011*a*: *Revised NAVTEX Manual.* MSC.1/Circ.1403. London.

———, 2011*b*: Resolution A.1051(27) Adopted on 30 November 2011: IMO/Worldwide Met-Ocean Information and Warning Service – Guidance Document. A 27/Res.1051. London.

———, 2014: *Revised Joint IMO/IHO/WMO Manual on Maritime Safety Information (MSI).* MSC.1/Circ.1310/Rev.1. London.

———, 2015: *Analysis of Information on Developments of Inmarsat Global Limited Sub-Committee on Navigation, Communications and Search and Rescue (NCSR).* NCSR 3/19. London.

Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology, 2019: *Operations Handbook for METAREA Coordinators.* JCOMM Technical Report No. 98. Geneva.

Maritime Conference, 1853: *First International Maritime Conference Held in Brussels in 1853 for Devising a Uniform System of Meteorological Observations at Sea, August and September 1853.* Official report. Brussels.

Maury, M.F., 1855: *The Physical Geography of the Sea*. Sampson, Low, Son & Co.

Met Office, n.d.*a*: Beaufort: National Meteorological Library and Archive Fact Sheet 6 – The Beaufort Scale, https://www.metoffice.gov.uk/research/library-and-archive/publications/factsheets.

Met Office, n.d.*b*: How the Royal Charter gale shaped the shipping forecast, https://www.metoffice.gov.uk/about-us/who/our-history/the-royal-charter-gale.

Met Office, n.d.c: Synoptic working charts for 1941 – 1950, https://library.metoffice.gov.uk/Portal/Default/en-GB/RecordView/Index/626450.

Pierre, N., 2001: *Rethinking France: Les Lieux de Memoire, Volume 2: Space*. University of Chicago Press.

Royal Meteorological Society, n.d.: The Beaufort Wind Scale, https://www.rmets.org/metmatters/beaufort-wind-scale.

Savina, H., 2006: Maritime information for safety at sea. *WMO Bulletin*, 55(2): 96–103.

Shearman, R., 2003: The growth of marine meteorology – A major support programme for the World Weather Watch. *WMO Bulletin*, 52(1): 39–45.

Turnbull, S., 2014: *Genghis Khan and the Mongol Conquests 1190–1400*. Oxford, Osprey Publishing Ltd.

United Nations, 1974: *Safety of Life At Sea Convention*. London.

World Meteorological Organization, 1982: *Guide to Marine Meteorological Services* (WMO-No. 471). Geneva.

———, 1989: *Commission for Marine Meteorology: Abridged Final Report of the Tenth Session* (WMO-No. 716). Geneva.

———, 1993: *Commission for Marine Meteorology: Abridged Final Report of the Eleventh Session* (WMO-No. 792). Geneva.

———, 2018*a*: *Manual on Marine Meteorological Services* (WMO-No. 558). Geneva.

———, 2018*b*: *Guide to Marine Meteorological Services* (WMO-No. 471). Geneva.

———, 2018*c*: *Information for Shipping*, Vol. D (WMO-No. 9). Geneva.

———, 2021: *Sea-ice Information and Services* (WMO-No. 574). Geneva.

———, 2022*a*: History of IMO, https://public.wmo.int/en/about-us/who-we-are/history-IMO.

———, 2022*b*: Marine Meteorological Monitoring Survey (MMMS), https://community.wmo.int/activity-areas/Marine/MaritimeSafety/MMMS.

World Meteorological Organization and Intergovernmental Oceanographic Commission, 2017: *Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology: Abridged Final Report of the Fifth Session* (WMO-No. 1208). Geneva.

World Meteorological Organization and Météo France, n.d.: Worldwide Met-Ocean Information and Warning Service (WWMIWS), http://weather.gmdss.org/.

Wyatt, D., 2021: The IHO and WMO – over a century of collaboration. *WMO Bulletin*, 70(1): 13–14.

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