Guide to Marine Meteorological Services

2018 edition

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 471

Guide to Marine Meteorological Services

2018 edition

WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 471

EDITORIAL NOTE

Typefaces employed in this volume do not signify standard or recommended practices, and are used solely for legibility. The word shall is used to denote practices that are required for data representation to work. The word should denotes recommended practices.

METEOTERM, the WMO terminology database, may be consulted at http://public.wmo.int/en/resources/meteoterm.

Readers who copy hyperlinks by selecting them in the text should be aware that additional spaces may appear immediately following http://, https://, ftp://, mailto:, and after slashes (/), dashes (-), periods (.) and unbroken sequences of characters (letters and numbers). These spaces should be removed from the pasted URL. The correct URL is displayed when hovering over the link or when clicking on the link and then copying it from the browser.

WMO-No. 471

Chairperson, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 81 17
Email: publications@wmo.int

ISBN 978-92-63-10471-1

PUBLICATION REVISION TRACK RECORD

Date	*Part/ chapter/ section*	*Purpose of amendment*	*Proposed by*	*Approved by*

CONTENTS

1. INTRODUCTION

Weather information has always been vital for the safety and efficient operation of marine industries, particularly transport and fishing. Early in the twentieth century, wireless telegraphy allowed regular communication between ship and shore, and weather broadcasts to shipping began. The first International Convention for the Safety of Life at Sea (SOLAS Convention) called for all shipping lanes and fishing grounds to be covered with weather information broadcast by radio; governments agreed to share responsibilities for these broadcasts. The International Maritime Organization (IMO)/WMO Worldwide Met-Ocean Information and Warning Service (WWMIWS) provides uniform coverage of forecasts and warnings to ships traversing the oceans. The IMO Polar Code provides additional guidance on the provision of suitable marine meteorological and sea-ice services to support safe shipping in polar waters.

The availability of marine forecasts and warnings to mariners in coastal waters is vitally important to the ability of National Meteorological and Hydrological Services (NMHSs) to meet the principles of the SOLAS Convention.

Internationally agreed methods of providing services to the marine community around the world are described in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I. The purpose of this Guide is to complement the Manual by:

(a) Describing the requirements for the various types of service;

(b) Explaining the rationale for the agreed methods of providing services;

(c) Giving guidance on how to set up and maintain marine meteorological services.

It follows the same structure as the *Manual on Marine Meteorological Services*.

2. MARINE METEOROLOGICAL SERVICES

2.1 GENERAL

Broadly speaking, marine meteorological services have two functions:

(a) To serve international shipping, fishing and other marine activities on the high seas;

(b) To serve the various activities that take place in coastal and offshore areas, ports, lakes and on the coast.

A marine meteorological programme embraces a wide range of activities. In the preparation of analyses, synopses, forecasts and warnings, knowledge is required of the present state of the atmosphere and the ocean surface, as well as the climate of the region. In addition, other types of forecasts that refer to special elements and phenomena, such as waves, storm surges, sea ice and ice accretion may be based on relevant observational data.

With such a strong dependence on observational data, the recruitment of voluntary observing ships (VOSs) and the training of shipboard and shore personnel in observing techniques comprises an important component of any marine meteorological programme. Additionally, the development of marine communication systems, along with the distribution, reception and archiving of observations must also be considered as a major component of such a programme. These two components in combination thus enable the two aforementioned functions of a marine meteorological service to be fully supported and implemented.

Each part of a marine meteorological programme should also incorporate a monitoring system so that the programme can be evaluated at regular intervals. Monitoring is necessary to ensure that the services provided continue to meet the requirements of users.

2.2 ORGANIZATION OF MARINE METEOROLOGICAL SERVICES

2.2.1 General

Although an NMHS may be organized in various ways, a general approach (based on *Strategy for Service Delivery and its Implementation Plan* (WMO-No. 1129) to the implementation of marine meteorological services can be recommended as follows:

(a) Consult the WMO *Guide to the Implementation of a Quality Management System for National Meteorological and Hydrological Services* (WMO-No. 1100) and consider how the principles of the framework could be applied;

(b) Develop and carry out programmes for the training and competency assessment of marine meteorologists and technical support personnel;

(c) Consider the types of weather-sensitive marine activities such as:

   (i) Fisheries;

   (ii) Recreational boating;

   (iii) Pollution;

   (iv) Hydrofoil, hovercraft or similar services;

   (v) Oil drilling and exploration;

(vi) Coastal structures vulnerable to high waves;

(vii) Harbours subject to seiches and other water-level changes;

(viii) Coasts vulnerable to erosion or rising sea levels;

(ix) Community activities along the coast;

(d) Contact users and in consultation with them identify their requirements; users usually include:

(i) Government department for fisheries;

(ii) Recreational boating organizations;

(iii) Fishing organizations;

(iv) Authorities responsible for safety of life at sea, including coastal waters;

(v) Authorities responsible for combatting marine pollution;

(vi) Operators of ferry, hydrofoil, hovercraft or similar services;

(vii) Oil-drilling and shipping companies;

(viii) Authorities responsible for protection of the coastal populations from, among others, storm surges, high waves and tsunamis;

(ix) Harbour control authorities;

(e) Design a service programme to provide information and products in formats that satisfy the requirements (including review of other products provided by other NMHSs);

(f) Determine the need for any additional data and processing facilities necessary for the preparation of these service products and arrange for their acquisition (including establishment of VOSs);

(g) Arrange for the provision of service products through appropriate communication platforms;

(h) Arrange for a monitoring system to ensure that service products meet the requirements and continue to do so;

(i) Arrange for the collection and checking of meteorological records, the processing of marine climatological data and the identification of statistical information to be supplied;

(j) Arrange for weather observations from ships and vessels;

(k) Identify requirements for additional research into:

(i) Forecast techniques;

(ii) Marine weather and ocean hazards;

(l) Ensure adequate representation of the NMHS in organizations, both national and international, involved in efforts to improve marine services;

(m) Ensure that adequate attention is given to meteorology and elements of physical oceanography in marine navigation schools.

2.2.2 Marine components of the WMO Global Data-processing and Forecasting System

The WMO Global Data-processing and Forecasting System (GDPFS) provides a framework to support service delivery in NMHSs. Members can access information from global, regional or specialized centres through the WMO Information System (WIS). For marine forecasting, there are centres for wave modelling, ocean modelling, numerical weather prediction, marine environmental emergencies and tropical cyclones. The *Manual on the WMO Global Data-processing and Forecasting System* (WMO-No. 485) provides specific details.

2.2.3 Service evaluation

Service evaluation is an important requirement of the WMO Quality Management Framework and the Strategy for Service Delivery. Service evaluation can be undertaken through:

– Conversation with stakeholders;

– Periodic surveys of marine users;

– Measurement of performance metrics;

– Review of feedback;

– Benchmarking against other service providers.

Calculation of performance metrics and reporting on these performance metrics to stakeholders and clients provides accountability and transparency for the forecast and warning services provided. The following list provides guidance on useful metrics:

– Reliability of wind – calculated as the percentage of wind forecasts within 5 knots of the observed;

– Reliability of waves and sea state – calculated as the percentage of wave forecasts within 0.5 metres of the observed;

– Reliability of wave period – calculated as the percentage of wave period forecasts within 2 seconds of the observed;

– Success and misses for wind warnings in areas with adequate observations, such as ports and harbours;

– Success and misses for position of tropical cyclone warnings.

2.2.4 Stakeholder engagement

It is important to provide only those services that are required, as there is no point in providing services for which there is little, if any, demand. National Meteorological and Hydrological Services should establish consultation forums with relevant groups such as port and harbour authorities, ship captains, pilots, dockyard personnel, port works engineers, container terminal and warehouse operators, shipping companies and insurance companies. Based on these consultations, an NMHS will be able to formulate the procedures to provide services of a general nature catering for the majority of the user groups, of a specialized nature tailored to meet any particular need of an individual user group, or both types of service.

Major changes in the issue, form and content of the bulletins, or the discontinuance of a bulletin, should be announced by members well before the effective date of change to enable all users to be notified in time.

2.2.5 Education and communication with users

The SOLAS Convention describes (Chapter V Regulation 34 – Safe navigation and avoidance of dangerous situations, and within Annex A.24 – Voyage planning) how vessels should prepare for their trip and route. The annex specifically outlines for small vessels the importance of:

- Checking the weather forecast for the journey;
- Knowing the tides;
- Knowing the vessel limitations for the expected weather and wave conditions.

Meteorological services should develop educational material that builds on the principles of boating and weather planning outlined in the SOLAS Convention. The material should emphasize the risks associated with weather and wave conditions, and the relationship between meteorological service capability and consequences of weather impacts. For example, the likelihood of getting caught in hazardous conditions may become lower due to improved weather forecast services, but the consequences may still be serious if a vessel is, nevertheless, caught in such conditions.

Meteorological services should educate mariners that not all weather developments can be predicted far in advance. Although the forecast may be favourable when they set out, they still need to listen for warnings that may be issued of imminent adverse weather.

An education programme using clear web pages and publications may be needed to educate mariners on the weather-related hazards they may face. Training courses may be run in conjunction with the rescue authorities that have to take action when these craft get into difficulty.

2.3 SERVICE DESIGN CONSIDERATIONS

2.3.1 Information formats

Weather information may be provided in a number of formats to meet user requirements. The main formats include:

- Maps
- Text
- Voice
- Tables
- Grids

Depending on the dissemination constraints for a marine user, the need to develop products in all formats may not be required. The following descriptions outline some of the benefits and constraints for each format:

- Map displays provide highly detailed information across defined spatial domains, and if provided as a time sequence, a user can study the evolution of the weather and ocean elements during specific time periods. Maps may be produced in an image format, or provided as a gridded or S-100-compatible file for display by on-screen software.

– Text products provide short summaries and broader detail for a defined area and time period. These text products may be simpler to interpret for most users and can be used for marine radio broadcasts. Text products generally have a small file size for Internet dissemination to mariners at sea.

– Voice products may be transmitted as audio or by video accompanied by other formats. There may be time limits imposed for radio broadcasts, and consideration should also be given to the reception quality on board vessels and the impact of broadcasts that are too long on a mariner's ability to interpret the information while doing other duties. These constraints have an impact on the information provided in the text that the voice product is based on.

– Information displayed as a table is usually for a specific location, so a user will get the benefit of detailed information over a period of time for that location but may lose context of what is happening over nearby areas.

– Gridded information may be integrated into decision support systems and situational awareness tools, or interrogated to output customized information for the particular marine activity or operating risk threshold.

2.3.2 Dissemination options

Consideration of the dissemination methods to reach each marine sector is important when designing a service. Some products may not be suitable for delivery to mariners operating well offshore with communication constraints. The following list of dissemination options provides a guide:

Well offshore (sea areas A3 and A4):

– Enhanced Group Call (EGC) System satellite transmissions

– High frequency narrow-band direct printing (HF NBDP)

– HF radio voice services

– HF radiofax graphical services

– HF email

– Internet delivered by satellite providers

Coastal areas (sea areas A1 and A2):

– Very high frequency (VHF)/medium frequency (MF) radio

– NAVTEX

– International NAVTEX

– Internet delivered by mobile network provider

Ports, coastlines and land-based support operations:

– Internet

– VHF radio

– NAVTEX

Internet services via satellite providers may be a very expensive option for mariners to receive information at sea. Consideration should be made in keeping web-page sizes to a minimum. It may be valuable to mariners that an NMHS provides a website to display simple text-only versions of the products for low cost and quick download.

Mariners planning their trip may use a desktop computer or a mobile device to access Internet services. Mariners operating within mobile phone coverage may also access the Internet services using a mobile device or laptop. Consideration should be made to the design and layout of the information to suit devices of various sizes. Mobile phones have compact displays, while laptops and larger screen devices have more room to display information.

Another option is to provide a subscription-based service to receive products via email, using Internet or marine radio transfer platforms, for display on devices while at sea. The subscription service would provide small file sizes for download.

Some mariners plan their activities for the next day based on television weather bulletins or amplitude modulation/frequency modulation (AM/FM) radio programmes. It is important to establish relationships with media presenters to emphasize the important components of the NMHS marine service. This will help ensure that mariners are receiving the same messages about weather-related hazards through all channels.

2.3.3 **Consideration of time and area requirements**

The service design and delivery of marine weather services should take the following characteristics into account:

- The amount of detail required for today and tomorrow versus the next few days:

  - For today and tomorrow, mariners will generally require more specific details about the time of arrival of wind changes, sea breezes or thunderstorms. This information may be presented as specific hours of the day, time periods of 2 to 6 hours, or subsections of the day.

  - For the next few days, mariners will generally require details about changes to wind, wave, sea-ice and weather conditions in broader time descriptors to account for uncertainty in the forecast and also their own planning detail. This information may be presented as time periods of 6 or 12 hours.

- The area coverage of the forecasts and warnings:

  - Mariners often traverse large sections of the coastline or specific shipping lanes, and weather patterns can vary across coastline sections and from the coast to well offshore. It is important to cover all areas of the coastal waters with a weather service that may be used for shipping routes (to comply with the SOLAS Convention Chapter V Regulation 34).

  - It is important to consider how to define the forecast area and any sub-areas to match vessel activity and density. The understanding of these areas is important for mariners reading the text forecast or listening to the forecast on marine radio.

  - The size of the forecast area is an important consideration for the amount of specific meteorological detail that can be described to match the requirements of mariners.

When considering the design of various service components, emphasis should be placed on those activities or user groups that present the biggest risk to their safety and protection. Consideration of how best to emphasize and highlight rare or unusual phenomena to the target groups should be a priority.

2.4 USER REQUIREMENTS

2.4.1 General

In general, the impact that could result from a meteorological condition depends on its severity and on the sensitivity of a particular activity or operation to that condition. Similarly, meteorological phenomena can make recreational activities and the work of fishing and shipping fleets much more difficult or hazardous.

Marine operations are sensitive to environmental conditions. Generally, extreme values of waves, wind and obstructions to visibility increase the risk to the safety of the vessel or sea structure and to the persons involved in their operation. Less extreme values, even if safety is not threatened, will affect the efficiency, effectiveness or comfort of the operation. The usefulness of a warning or a forecast depends on the accuracy of the prediction; the format and communication platform used to deliver the information; its timeliness, that is, the number of hours or days in advance of the event that the forecast can be provided; and the ability of the user to react to the information.

The requirements and importance of the various elements of information may be significantly different between each major user group, including the details of the desired forecast and the time required to take action based on this information. This is important information for service providers to base the design of their services on.

2.4.2 Provision of marine climatological information

The requirements for marine climatological data involve a number of activities ranging from shipping, planning offshore mining and coastal infrastructure, to monitoring services. Climatological information can be expressed in chart, graphic and statistical form.

2.4.3 Specialized services

Meteorological services may be requested to provide a special forecast service, either as a regular activity or to assist in a given operation at sea or on the coast. Regular services may be for a segment of the community or a large number of users, such as recreational boating, heavily congested shipping areas, surf beaches or fishing grounds; or they may be for specific commercial purposes, for example, oil-drilling platforms and hovercraft or hydrofoil services. Services may be required for a limited period, for example for construction activity on or just off the coast, or for a yacht race.

Services provided to a specific organization are usually provided on a commercial basis, whereby the precise service and the associated charges are negotiated with the client.

2.5 REQUIREMENTS FOR EACH SERVICE ELEMENT

2.5.1 Wind

Information about wind is generally considered to be the most important element to a mariner. Mariners are concerned with changes in wind speed and direction throughout the day for the area they are travelling through or operating within.

Critical wind speeds are sometimes lower for smaller craft than for commercial shipping. Smaller vessels are sensitive to gustiness and wind shifts as well as mean wind speed.

Depending on the special national requirements, information about lower wind speeds are important for small vessels and leisure craft. Some vessel operators restrict operations when winds exceed 15 or 20 knots due to the development of wind waves and potential discomfort and safety of crew and passengers.

When determining warning thresholds for national requirements, the frequency of certain wind speeds needs to be considered. For example, warnings of wind speeds that are encountered on most days will be issued so frequently that their effectiveness will be lost.

The wind may exert considerable force on a structure such as a drill rig or vessel. Since the force exerted is proportional to the square of the wind speed, extreme winds are especially critical. High winds also create dangerous working conditions for personnel on exposed decks.

Wind has impacts on exploration platforms with respect to flaring, cargo handling, the helideck, module access and general deck operations.

The identification of a sea breeze developing along the coast is important for coastal and inland communities due to its cooling effects and improvement of human comfort levels, or even the possible development of thunderstorms along the sea-breeze edge.

2.5.2 **Waves**

Wave information is generally the second most important element after wind.

Information about total wave heights (the combination of swell waves and wind waves) and the individual wave components is of importance to a wide range of users. Consideration should be given to providing information about multiple swells of significant size as this is useful for vessels and coastal activities.

Wind waves have significant effects on the headway vessels can make, how fast fish can be found and caught, how productive loading and unloading operations are, and on the transfer of fishing catches to factory ships and other operations. For example, the safety regulations on ves2.6.3sels of the former Soviet fishing fleet stipulated that when wind speeds reached 30 knots (equivalent to 15 metres per second) or when wave heights were over 4 metres, SRT-type vessels (medium fishing trawlers) should cease to make way or should stay in port.

Wind waves, especially high waves with short periods (a choppy sea), and to a lesser extent long swell, can be a danger to small craft. In shallow water areas (such as lakes or island reefs), the wind-wave behaviour and short wavelength are particularly dangerous due to reduced stability for the short-length, flat-bottomed vessels that commonly operate in these areas. Near the coast, where these boats generally operate, wind waves also depend on the irregularity of the coastline, the water depth, and surface currents or tidal streams. Combinations of strong currents, high waves and high winds may create hazardous conditions for rigs and vessels.

For large vessels, information about waves less than two metres high is normally not of concern. Smaller vessels will be concerned with all wave heights. Small vessels on lakes are vulnerable to being swamped by small wave heights with short wave periods.

The rapid arrival of a significant swell train may cause problems to port operators moving vessels into and out of port, and also for vessels that may not be able to take necessary preparatory steps in time. Rapid changes in swell conditions pose direct risks to vessel structural integrity due to enhanced loading on the vessel structure, risks to vessel stability and deck operations due to crew unpreparedness.

Some harbours become difficult to access if high seas and swells are running outside. Tourist resorts with surf beaches may need information about dangerous high swells.

The direction of wave patterns is also of concern to large vessels for fuel consumption management and ship handling. Some large vessels will find ship handling difficult when the swell direction aligns with their direction of travel and the swell height is over four metres. Wave breaking is also a major cause of damage at sea. High waves with very deep valleys may be called "freak" or “rogue” waves because they are dangerous to shipping in terms of direct risks to vessel structural integrity due to enhanced loading on the vessel structure. They are generally caused when waves move against a sea current.

Some coastal and inland areas may be commonly influenced by two swell trains, and information about each individual swell train provides useful information for ports, vessels and coastal users. Information on swell systems that are crossing other systems of wind waves is also important as the confused state of the sea increases risks to vessel stability and crew operations at elevated heights.

Offshore drilling platforms are generally engineered to withstand extreme wave heights and periods that may be expected on average at frequencies exceeding hundreds of years (that is, very rare but statistically and physically possible). As such, companies will require information about extreme wave height and period, particularly associated with tropical cyclones or intense low pressure systems. For some oil operation purposes a complete directional spectral representation of the waves is required.

2.5.3 **Wave period**

Certain structures (coastal and offshore oil operations) are more vulnerable to certain wave periods than others. Longer wave period can restrict ship handling of large vessels, while smaller vessels can be swamped in shorter-period waves. Long-period swells enhance the risks for deck operations at elevated heights. Coastal foreshores may be eroded during long-period swells with high energy.

Harbour masters may close port entrances or deploy additional tugs to safely transit ships into and out of port during long-period swell events. Some ports may be affected by the combined effects of wave direction and long-period swell.

2.5.4 **Surf and breakers**

High breaking waves cause coastal erosion and can damage structures built near the sea. Surf forecasts may be required for popular surfing beaches. A prediction should include maximum height and direction of breakers, together with the wind and tides that affect the way the waves break. When high breakers are predicted, lifeguard stations may assign additional personnel or close the beach. For boaters attempting to exit or enter a coastal river entrance, the behaviour of breaking waves is influenced by the tide conditions and the wave direction. An out-flowing tide generally results in steep waves forming at the river entrance, which present a hazard for boaters.

2.5.5 **Visibility**

Poor visibility is a major hazard to all vessels because of the increased danger of collision. Visibility less than two nautical miles, although not typically hazardous for most shipping operations during the day, nonetheless reduces to some degree the mariner’s ability to manoeuvre safely. Visibility less than one mile, however, poses a hazard to navigation and marine operations such as fishing. For visibility less than half a mile, safe navigation will require vessels to significantly reduce forward speed, or even come to a complete stop until visibility improves. In visibility approaching zero it is hazardous not only for any moving vessels, but also for vessels at anchor or lying to. Reduced visibility can also increase the risk of collision between vessels, drill rigs and icebergs.

Fog and mist are the most common causes of reduced visibility, but snow, thick haze, smoke and heavy rain can also constitute a hazard. The visibility limit requiring a warning should be determined in consultation with users.

2.5.6 **Clouds and precipitation**

Information about cloud cover and sunshine are an important consideration for recreational and leisure boaters in deciding whether to go boating. Generally, more leisure vessels will be on the water during sunny conditions. Information about precipitation is important for recreational boating for passenger comfort, while heavy precipitation may significantly reduce visibility for all marine operations.

2.5.7 **Thunderstorms and squalls**

Ships traversing shipping lanes are especially vulnerable to sudden changes in the weather associated with thunderstorms and violent cold fronts. The rapid development and movement of these phenomena make them an extreme hazard. Large container vessels and cruise ships in port and dense shipping lanes are particularly vulnerable to squalls and sudden thunderstorm gusts due to the long and high sides of these vessels.

Many vessels in coastal waters, particularly small craft, are vulnerable to squalls from thunderstorms and squall lines, waterspouts and severe lightning.

The lightning associated with thunderstorms can be dangerous, since the masts and derricks tower above the water surface. Both heavy rainfall rates and lightning can cause disruption of radio transmissions. Lightning poses a serious hazard to aircraft operations, and may create problems at a drill rig if gas is being burned off at the time. Lightning would also be a serious hazard to exposed personnel in the water.

Rainfall, in general, is not a serious problem, although low visibility may result and decks may become slippery. Also, discomfort or hypothermia may result from wet clothing. Intense rainfall associated with thunderstorms, however, may cause equipment and cargo to be flooded if the drainage design is inadequate.

2.5.8 **Air temperature**

Extreme temperatures, either hot or cold, can reduce the efficiency and accident-avoidance capability in workers exposed to the elements, due to incipient hypothermia or, at the other extreme, heat stroke. Heating, cooling and ventilating the working and living space is important, not only for the well-being of personnel, but also for the operation of electronic control facilities. Air temperature is also a contributing factor to wind chill and spray icing.

The IMO Polar Code defines the operation of shipping in low air temperature as a hazard. The Code defines “low air temperature” as areas of less than or equal to -10 °C.

For ship construction and the operation of equipment in polar conditions, the Polar Code defines the “polar service temperature” as the equivalent of 10 °C below the lowest mean daily low temperature for the area in which the vessel will operate. All exposed operating and communication equipment must be designed to operate in these temperatures.

2.5.9 **Sea temperature**

Minimum, maximum and variability of sea-surface temperature and temperature gradient are important in the selection of materials for equipment used in drilling operations, since many materials lose much of their strength and toughness in very cold or very warm conditions.

Because of the risk of hypothermia, a very cold sea temperature is the critical limit for survival of personnel in the water, without adequate protection. For example, the survival time of a person in water of zero degrees centigrade is of the order of less than 10 minutes.

Water temperature plays an important factor for coastal leisure activities. It also is important for management of fisheries.

2.5.10 **Ocean currents**

Information on ocean currents is used in navigation, fishing operations, and search and rescue operations. The currents also have an impact on the movement of powered and sailing vessels. Fuel consumption management is an important cost factor for marine transportation companies, and details of ocean and tidal currents are a key variable. Knowledge of currents is also particularly vital in modelling the movement of possible oil spills and other contaminants.

Water currents in association with surface winds play a significant role in the movement of sea ice and icebergs.

Bottom currents are of concern for seabed pipelines as they can cause sediment washouts resulting in unsupported pipelines, which consequently become overstressed.

2.5.11 **Rip currents**

The interaction of waves breaking along shorelines and near headlands or other coastal structures can cause rip currents. Rip currents carry water away from the shore, therefore posing a hazard to swimmers. Local lifeguard stations are best placed to identify the potential risk of rip currents due to existing beach characteristics and wave heights, wave direction, and tide and wind conditions.

2.5.12 **Storm induced water-level changes and seiching**

These variations in water level are of great concern for the design of some coastal facilities, and for the operation of shipping in shallow waters. Storm surges and resulting flooding have caused considerable damage and loss of life in coastal communities. Governments may activate community action plans for coastal defence measures and possible evacuation of the population in areas affected.

The most common and most dangerous storm-induced water-level change is the storm surge generated by a tropical cyclone. Storm surges can also be generated by intense extratropical depressions, particularly when the sea is being driven along a narrowing gulf. Lives are more often lost in the flooding of low-lying coastal areas from storm surge than from the destructive winds of the cyclone itself. The low atmospheric pressure itself will cause a rise in water levels.

Government agencies will generally require the time and height of the maximum water level when the surge is expected to arrive. A storm surge arriving at low tide will cause less damage than one at high tide.

Harbour seiches may lead to irregular ship movements, making berthing difficult and increasing the danger of collisions. Abnormally low water levels due to the effects of wind stress – so-called negative surges – may affect marine operations in coastal areas, estuaries or at entrances to harbours. Information is also needed about such deviations in water level.

2.5.13 **Tides**

Tide predictions are generally provided for the lunar-influenced tides. Times of the high and low water level and height for the current day and next few days provide important planning information for vessels and coastal engineers.

2.5.14 **Ice accretion**

The accumulation of ice on the superstructure and deck equipment of vessels, even large ones, may seriously affect safety and operational efficiency. Icing on aerials, for example, may make radio and radar equipment inoperative. On small vessels icing presents a much greater hazard.

The weight of ice reduces freeboard and stability, and in storm conditions leads to a risk of capsizing. Fishing vessels operating in polar seas are especially vulnerable; supercooled drops of rain, drizzle or fog droplets create hazardous working conditions.

Warnings of ice accretion are given when the forecast wind force is Beaufort force 6 or more, the water temperature near freezing and the air temperature well below freezing. Most cases of icing occur with high wind speeds producing sea spray or when vessels are shipping water. “Black frost” resulting from supercooled water droplets (fog) is less frequent but far more dangerous, as the developing ice is compact and very adherent. Black frost is commonly observed with strong winds, fog, low air temperatures and relatively high water temperatures.

2.5.15 **Freezing spray**

Freezing spray is the most dangerous form of icing encountered at sea, and accounts for around 90 per cent of ship icing reports. Spray ice can accrete at rates in excess of several centimetres per hour and is difficult to remove because of its hardness and strong adhesion. Vessels usually generate most spray when headed into the waves, and minimum spray when running with the waves.

Vessel size is also an important factor in icing rates as the average liquid water content of wave-generated spray decreases exponentially with elevation. Most of the spray is confined in a 5–10 metre range above sea level, which means smaller vessels are exposed to considerably more spray than large ships or drilling platforms.

2.5.16 **Sea ice**

Ice conditions not only hamper navigation, but can occasionally lead to damage to vessels. Sea ice can present a hazard to all classes of shipping. Vessels approaching or passing through icy regions must reduce speed, which increases costs and reduces overall voyage efficiency. Ship classifications and hull designs are based on the amount, type and thickness of ice through which a ship can safely navigate.

Stationary structures (drill rigs and platforms) that operate in ice-infested waters must also be designed to withstand ice movement and crushing forces. Ice jamming can occur, causing bridge and harbour damage, and flooding.

The most important features of sea ice that affect marine operations are:

(a) The amount of ice present, usually measured as tenths of the sea surface covered by ice;

(b) Ice thickness, referred to as stage of development, which is related to ice age;

(c) Form of ice, that is, whether it is fast ice or pack ice, floe size, and the amount of ridging;

(d) Ice movement.

2.5.17 **Icebergs**

Icebergs are a major hazard for navigation. Collision may occur in limited visibility or in stormy weather with snowfall.

Information is required on the position of icebergs at specified times and their estimated size, speed and direction of movement. During the ice season the south-eastern, southern and south-western limits of regions of icebergs in the vicinity of the Grand Banks of Newfoundland are monitored for the purpose of informing passing ships of the extent of this dangerous region. The guidelines for this international ice patrol service are laid down in the SOLAS Convention.

2.5.18 **Tropical cyclones**

When fully developed they are accompanied by mountainous, steep, breaking waves and winds of hurricane force. Because of the extremely low pressures in the eye of the cyclone, water levels are raised, and, when coupled with the wind-induced water-level surge together with high seas, these systems can inflict very serious damage to coastal installations, and can occasionally lead to the loss of lives and ships.

The position of the centre of a cyclone (or of an extratropical depression) is usually given in latitude and longitude in high seas warnings designed for large ships at sea; however, for coastal waters position should be given by distance and bearing from well-known coastal locations. This is because fishers and other users of coastal waters forecasts are not so familiar with latitude and longitude. It is important to educate the community and mariners to not simply focus on the centre position of the tropical cyclone, and to be aware that the damaging effects could cover a few hundred kilometres/miles.

2.5.19 **Tsunamis**

Tsunamis are generated by underwater seismic activity. They can cause enormous destruction and loss of life. The warning of a significant tsunami should result in the rapid evacuation of all low-lying areas in its path.

2.5.20 **Humidity**

High humidity may be important in shipping for its potential damaging effect on cargo, particularly when coupled with cold sea-surface temperatures, which results in hull and cargo sweating. Painting operations may be adversely affected by high humidity and the durability of some paint coatings reduced.

Warm temperatures accompanied by high humidity can produce considerable discomfort and, in the extreme, are a hazard to health. Marine operations are affected when physical exertion becomes unpleasant and frequent rest periods become necessary under high humidity and temperatures.

2.5.21 **Wind chill**

Wind chill above certain thresholds is a very important consideration for human comfort. Hypothermia and frostbite may result from wind chill in a very short time, impairing work efficiency and increasing the likelihood of accident. The heavy clothing necessary to withstand the cold also contributes to the possibility of accident. High values of wind chill will also reduce human survival time in the water.

2.6 **REQUIREMENTS FOR SPECIFIC USERS AND APPLICATIONS**

2.6.1 **SOLAS vessels**

The SOLAS Convention defines SOLAS vessels as those being of weight greater than 300 gross tonnes and all passenger vessels navigating international waters. SOLAS vessels generally undertake journeys of days and weeks in duration.

International Convention for the Safety of Life at Sea vessels require information relating to four main activities:

(a) Travel on the high seas;

(b) Travel through shipping lanes, pilotage areas;

(c) Entering and exiting a ports,

(d) At berth, loading and unloading activities.

These vessels are generally built to resist the forces of wind, waves and storms. However, a mechanically driven ship cannot maintain its speed and course in all weather and sea conditions. To prevent a ship from experiencing the excessive shocks of slamming into waves, or excessive rolling in adverse wave conditions, speed has to be reduced or its course changed, or both. In severe storms, speed reductions can be considerable, and a ship may have to ride out the storm without making appreciable headway.

The optimum heading on which a ship should be placed under severe weather conditions depends on the design of the ship, its size, cargo and conditions of loading. A ship with heavy deck cargo is handled differently from, for example, a tanker, while the captain of a passenger ship considers the comfort of passengers and endeavours to reduce the angle of roll. In calculating how to secure and protect the cargo, wave data and the motion of the ship must be taken into account, together with the mass and position of the load.

Cargo shipped by seagoing vessels to distant destinations is always subject to some degree to the effects of meteorological conditions, which often affect the quality of the cargo by causing its deterioration. The types of damage caused by unfavourable meteorological conditions are many and varied: high humidity may cause metal parts to corrode, and when coupled with high temperatures may ruin paint coatings. Specialists in the field attribute 25 per cent of the losses experienced in freight shipments each year to meteorological conditions. More than 90% of the two to three million types and varieties of freight are sensitive to meteorological factors. High humidity directly contributes 10–20% of the losses and spoilage.

Foodstuffs in particular are extremely sensitive to environmental conditions. Approximately 90–95% are temperature sensitive, and 60–70% are sensitive to humidity.

In all cases the expected time of arrival at the destination is important and will be affected by weather conditions. Late arrival carries economic penalties for the shipping company. Some ports can only be reached at high tide, and missing a tide means a wait of 12 hours for the next available window of time. Several hours may be required to prepare a ship at sea for extreme conditions. Outlooks of possible storm developments for a period two to seven days in advance that are updated regularly are welcomed. They enable the ship's captain to take any precautionary measures considered necessary, including altering course to avoid the worst of the weather, and to make appropriate assessments of the expected time of arrival.

The determination of a shipping route across the ocean to maximize efficiency and safety takes into account marine climatological data, load-line rules, ocean currents and medium-range forecasts of wind and wave conditions. One way of reducing costs is the application of meteorology to navigation; this has been applied by ship captains for a very long time. Broadly speaking there are two applications: climatology and specific forecasts at the time of the voyage.

The selection of routes based on climatological reasons can be applied on ocean crossings where the weather is settled for a lengthy period. Generally speaking this will be the case in tropical and subtropical latitudes between about 30°N and 25°S. The actual weather from day to day very often agrees with that expected climatologically for the time of year. The major threat is from seasonal tropical cyclones. In these latitudes, however, there is increasing interest in routing a ship according to the day to day variation in sea currents, as even a small saving in time can be worth a considerable amount of money.

Weather routing services are provided in accordance with SOLAS Convention Chapter V Regulation 34 and IMO Resolution A.893 – Guidelines for voyage planning; and IMO MSC/ Circular 1063 – Minimum standards for provision of weather routeing services, outlines the minimum characteristics for a service. The SOLAS Convention Chapter V Regulation 5 – Meteorological services and warnings, states that marine meteorological services shall be issued by the NMHS, and this would imply that WMO and its Members should oversee weather routing services and standards as well.

Weather services may recommend routes based on anticipated weather conditions, sea ice, ocean determining currents, load-line zones and state of loading. The objectives of weather routing include determining routes designed to minimize crossing time, damage or fuel consumption. For passenger cruise ships weather routing may be used to maximize the amount of sunshine and passenger comfort in avoiding large swells.

Weather routing services provide the following benefits:

(a) Weather routing for the purpose of achieving a least-time ocean crossing also reduces weather damage to ship and cargo;

(b) The greatest benefits are obtained during the winter months of December, January and February in the northern hemisphere, and June, July and August in the southern hemisphere;

(c) Mean time gains on westbound voyages are larger than those on eastbound voyages as following waves, which do not have so much influence on the ship's performance, are predominant on eastbound voyages;

(d) Advised routes depend on the varying weather on, or near, the great circle routes; in summer when waves are predominantly low, the great circle is the most economic route.

The effect of routing on the operational costs of a ship is mainly reflected in fuel and lubricating oil costs. A possible saving of 12 per cent in fuel has been calculated.

2.6.2 **Non-SOLAS vessels**

Non-SOLAS vessels are defined by the SOLAS Convention as being of weight less than 300 gross tonnes; however, the principles of voyage planning and weather risks within the SOLAS Convention regulations still apply. In addition, the carriage of certain radio equipment is related to IMO vessel class standards and IMO definitions for various waters and sea areas. The IMO operating limits for vessels in certain weather and wave conditions are guided by marine meteorological information.

Non-SOLAS vessels require information relating to three main activities:

(a) Travel along coastal shipping routes or on the high seas;

(b) Entering and exiting a port or river entrances;

(c) At berth, loading and unloading activities.

Smaller non-SOLAS vessels are extremely vulnerable to hazardous weather and sea conditions on the high seas. In many cases of sudden deterioration in weather, there is no time to take refuge in a safe port or go to leeward coastal waters. Small vessels do not usually have a dedicated radio-telegraphy operator or satellite reception equipment, and are reliant on radio-telephony for communications. Thus weather and sea bulletins should be broadcast by voice radio-telephony for the benefit of these small craft.

Offshore yachting activities are vulnerable to intense weather patterns. Yachts may be in transit for a number of days at a time. Wind and wave information is highly important to the navigation and capability of the vessel. Weather such as thunderstorms is important for safety of crew and protection of radio equipment. These vessels may not be able to avoid an intense weather pattern and a broken mast or rudder will require a rescue operation to be activated. Offshore yacht skippers access weather information on marine radio or satellite Internet.

2.6.3 **Fishery operations**

Fishers require information relating to the three main activities:

(a) Travel to and from fishing grounds;

(b) Locating and catching fish;

(c) Care and transport of the catches.

The importance of meteorological information depends mainly upon the species fished, the fishing area and methods, and the ship's size and equipment.

Fishing vessels in coastal and offshore waters are usually small. Therefore they are very weather dependent and vulnerable to wind, waves and swell. They are at risk in poor visibility in shallow water or in dense traffic areas. Ice and ice accretion in polar or near-polar areas may affect vessels there. Winds of Beaufort force 6 may be a hazard to small craft.

A large proportion of fishing areas are situated in northern temperate and near-polar regions where there are great dangers in winter from storms, ice accretion on vessels and sea ice. A further danger comes from dense fog banks, mainly in the spring and summer, mostly over cold waters. Moreover, the fishing areas are generally situated far away from the general shipping routes and meteorological observations are usually very sparse.

Information about ocean surface and subsurface temperatures and currents assist in the identification of potential fish sources.

2.6.4 **Recreational boating**

2.6.4.1 ***General***

Recreational boating may include vessels that are powered (motorboats) or non-powered (sailboats or yachts) and is generally a seasonal activity in the mid and higher latitudes. The principles of the SOLAS Convention still apply to these vessels and marine meteorological services should consider their needs. Recreational boating is generally undertaken for periods of a few hours to a day or more in duration. As such, recreational boaters may be able to make decisions on where and at what time of the day they will go boating safely. They may also choose not to go boating if conditions are too dangerous or uncomfortable.

Very small craft are usually used for recreational boating, and these are very weather dependent. Crews of such small craft are often inexperienced and frequently ignore the weather. While much recreational boating takes place in the comparatively sheltered waters of bays and estuaries, strong winds and squalls are still a hazard. Many accidents are due to inexperience and ignorance of the speed with which hazardous weather can arise.

Kayaking and canoeing on enclosed waters and offshore has become a popular recreational activity. These vessels require information about wind waves, winds, gusts and thunderstorms.

Forecasts and warnings for recreational boating should be given wide coverage on suitable communication channels such as marine radio, AM/FM radio and television. Proximity to wide-spread cellular telephone services along the coast now enables many recreational boaters to obtain forecasts and warnings via mobile phone and Internet, and therefore these means of distribution may also be taken advantage of where possible.

Warnings need to be issued of strong winds, and advanced notice of sudden increases in wind gusts, particularly squalls from thunderstorms or fronts.

During sailing regattas the crews are interested in exact wind forecasts as well as actual wind information. Sail craft are particularly sensitive to local wind effects, particularly where the coast is irregular, and very different wind conditions may exist in different areas. Forecasts of wind, gust and expected wind shifts are also of interest. Sometimes the attendance of a meteorologist is requested at a regatta coordination centre to meet specific needs.

2.6.4.2 *Winds and waves*

Boats used for recreation come in many sizes and shapes and are often crewed by people relatively unfamiliar with the dangers inherent in boat operations. Critical wind speeds and wave heights are sometimes lower for these generally smaller craft than for commercial shipping. They are sensitive to gustiness and wind shifts as well as mean wind speed. Wind waves, especially high waves with short periods (a choppy sea), and to a lesser extent long swell, can be a danger to these small craft.

2.6.4.3 *Thunderstorms and squalls*

Small craft are especially vulnerable to sudden changes in the weather associated with thunderstorms and violent cold fronts. The rapid development and movement of these phenomena make them an extreme hazard. Particularly vulnerable are the very small boats on enclosed waters such as bays and harbours.

2.6.4.4 *Fog*

As small craft usually lack radar, poor visibility in fog is a great danger in dense traffic areas such as estuaries, harbours and some coastal areas.

2.6.5 Dynamically supported craft

Dynamically supported craft such as hydrofoil vessels and hovercraft that are operating in coastal and offshore waters are particularly sensitive to changes in wave conditions. Wind also affects operations. The operating limits for wind and waves will vary with the type and size of craft. Because of their higher speed, information on higher ranges of visibility is required.

Fast craft such as hydrofoils, hovercraft and catamarans are more sensitive to wind and waves than ordinary craft of the same size. According to the IMO Code for Safety of Dynamically Supported Craft, the worst intended environmental conditions should be the key threshold for operation of the craft.

Criteria of interest are wave height above 1.3 metres, wind speed above 25 knots (or 13 metres per second) and visibility less than 0.5 nautical miles.

2.6.6 Offshore oil-drilling and mining operations

2.6.6.1 *General*

Offshore operations require highly specialized information, tailored to a particular geographical location and to the kind of operation involved. The marine meteorologist needs to work closely with the operations manager.

Marine meteorological information is important for all four phases of offshore mining:

(a) Site identification and rig design and construction specification;

(b) The drilling from a specially constructed rig;

(c) The construction of offshore platforms;

(d) Operation of the platforms.

2.6.6.2 ***Operations related to oil-drilling platforms***

The interests of the offshore hydrocarbon industry encompass a wide range of activities: geophysical surveys, operation of fixed and dynamically positioned exploration and production platforms, airborne logistic support, monitoring of seabed and overland pipelines, operation of liquefaction plants and port facilities, routing of marine transportation, and possible oil-spill movement, containment and clean-up.

The requirements for information and forecasts for the platform or drilling rig site may include:

(a) Wind direction and speed at 10 metres and at the height of the helicopter deck;

(b) Direction and height of sea and swell;

(c) Periods of sea and swell;

(d) Significant weather phenomena;

(e) Ceiling;

(f) Visibility;

(g) Air temperature;

(h) Sea-surface temperature;

(i) Ice accretion on constructions;

(j) Deviation of tidal heights;

(k) Temperature and current at different depths.

The threshold values for different phases of operations may vary considerably. Seismic survey is weather sensitive because a vessel must make a series of transits of the area in question while towing an acoustic source and a string of hydrophones. There are operational limits to the wind and wave conditions that can be tolerated for both surface and deeper towing.

In addition to forecasts for the platform site, forecasts for the supply service involving helicopters and supply ships are usually needed. The requirements for these services will normally be similar to those of the general aviation and coastal transport in the area.

2.6.6.3 ***Waves and wind***

During drilling the tolerance for side-to-side movement of drilling equipment as the result of wave action is approximately 10% of the water depth. Platforms will move up and down on the larger waves. The period of pitch and roll of a drilling ship is a critical factor, and waves with a period at or near that value can lead to hazardous pitch and roll due to resonance effects.

Wind contributes to the pitch and roll of a drilling rig, and high winds make working conditions difficult. Wind direction may also be an important element as wind shifts may necessitate careful adjustment of anchor cables.

The construction of offshore platforms is particularly vulnerable to winds and waves. Usually the platform is constructed onshore and towed to the site. While underway, waves of 2–3 metres or higher, depending upon the design of the platform, necessitate lowering the legs or taking evasive action by moving the platform to shelter. Advanced notice of a few hours in advance is necessary to permit lowering the legs in time. Lead times of 24 hours or more may be necessary for operational decisions such as when to start the tow to the site. Once on location, the legs are lowered and the structure raised above the direct influence of the waves.

Swell can be as important as wind waves in these operations and information about swell, especially from tropical cyclones, is also required. Swell may impact on the safe connection of the tanker with the oil rig. Extreme waves are a concern for structural integrity of the platform. Advanced notice of severe thunderstorms and squalls are also required, when very strong winds, although of relatively short duration, may cause damage.

Once erected, the operation of the platform usually involves the transport of personnel and equipment by helicopter, and aviation-type forecasts of wind, low cloud, visibility and altimeter setting are required. Advanced notice of gale-force winds and above, and tropical cyclones are necessary as evacuation of all essential or non-essential personnel may be required (by boat or helicopter) before the occurrence of these wind conditions.

2.6.6.4 *Currents and tides*

Information may be required on the sea currents at different depths during drilling in some sea areas, and when platforms are being moved into final positions. Information on bottom currents may be important to assess the pressure on cable and pipe infrastructure. Information on tidal surges may also be important.

2.6.6.5 *Sea ice and icebergs*

Strong winds and currents make icebergs a problem for pipelines and sub-sea well facilities, because these bergs can at times scour the seabed and would tear out anything unprotected or even firmly attached.

In some areas with ice cover the safety of drilling and mining operations is strongly dependent on ice conditions.

If unfavourable ice conditions are expected, one of the following decisions may be taken:

(a) Dismount the drilling unit and withdraw to shelter;

(b) Continue work until some threshold ice load is reached;

(c) Continue work on a stationary platform while undertaking active methods of mitigating ice loads.

2.6.7 Coastal community activities

2.6.7.1 *General*

Coastal areas are often heavily populated, with people being attracted by trade, industry, fisheries, recreation, and, in some countries, retirement to a place near the sea. These communities need protection from the hazards of the sea and its storms.

Coastal community activities affected by weather conditions include:

- Swimming on the coast;
- Outdoor activities;
- Access to facilities or coastal pathways;
- Living in houses or structures on the coast or on low-lying land near the coast;
- Sports and community events;
- Recreational boating or transport by sea (see sections on recreational boating, 2.6.4, and non-SOLAS vessels, 2.6.2).

Considerable amount of engineering activity takes place in the coastal zone. Many coastlines must be protected from erosion and flooding, and this often involves major construction work. The protective sea walls and breakwaters must be designed to withstand extreme wave events with relatively long return periods, so information about these extreme conditions are important for mitigation actions.

2.6.7.2 ***Wind***

Communities located on the coastal interface with the ocean are generally exposed to the full force of wind conditions associated with cold fronts, low pressure systems and tropical cyclones. Activities within the community may be disrupted by these strong wind conditions.

2.6.7.3 ***Storm surges***

Storm surges and resulting flooding of low-lying areas have caused considerable damage and loss of life in coastal communities. When combined with large waves, there may be large impacts on coastal infrastructure and erosion of foreshore areas. Sufficient advance notice is required for coastal defence measures and possible evacuation of the population to be effected.

Abnormally low water levels due to the effects of wind stress – so-called negative surges – may affect marine operations in coastal areas, estuaries or at entrances to harbours. Information is also needed about such deviations in water level.

2.6.7.4 ***Tsunamis***

The warning of a significant tsunami should result in the rapid evacuation of all low-lying areas in its path.

2.6.7.5 ***Surf and breakers***

High breaking waves can cause damage to structures built near the sea and cause coastal erosion. Warnings will be required when such waves are expected to exceed a critical value.

Surf forecasts may be required for popular surfing beaches. A prediction should include maximum height and direction of breakers, together with the wind and tide, which affect the way the waves break. When high breakers are predicted lifeguard stations may assign additional personnel or the beach may be closed.

2.6.7.6 *Rip currents*

These currents and the risks they pose to shoreline users such as swimmers have been previously described in 2.5.11.

2.6.8 Pollution of the sea

Pollution of the sea is the introduction to the sea of harmful substances resulting from human activity. Response agencies may require information on existing and predicted wind, waves and tidal or wind-generated currents to allow the prediction of the spread, movement and concentration of the pollutant. Information may also be required on the areal extent of sea ice and its drift.

The first factor the pollution response authority will want to model will be the likely movement of the pollutant. The meteorological input required by these models includes the forecast surface wind, waves and currents, and air and water temperature.

The wind forecast provides information on the likely natural dispersal of the oil. It may also influence the direction that any odours may travel.

If it is expected that the pollutant will ultimately affect the coast, and perhaps threaten coastal communities and installations, the on-scene commander of the clean-up operations will require forecasts and warnings related to the safe and efficient deployment of the personnel and equipment involved in the clean-up.

Tidal currents may affect the movement of the pollutant.

2.6.9 Power generators and industrial plant cooling systems

Cooling systems on the shore discharge hot water into the sea, relying on its efficient dispersal. Anomalous tides may reduce the capability of cooling systems in the tidal reaches of a coastal area and forecasts of the wind effects on tides may be needed.

2.6.10 Requirements for long-term planning and design information

Long-term planning for marine operations is based on climatological probabilities. For example, a ferry service may not be economically viable if storms and high waves are too frequent. Ships, other marine vessels and marine structures have to be designed to withstand the strongest forces likely to be encountered.

Marine climatological data are required to provide the requisite advice, and consultations should be held between designers and marine meteorologists on the use of climatological data.

2.6.11 Fisheries management

A number of environmental factors affect fish and they must be taken into account in the management and long-term planning of fishing operations. Fisheries research is largely taken up with the investigation of these factors. Environmental factors can affect:

(a) Behaviour, distribution, migration and aggregation of fish;

(b) Yield and catch;

(c) Wintering place;

(d) Fishing period;

(e) Year class strength;

(f) Spawning eggs and larvae.

Among the environmental factors, the following ocean and meteorological factors are important:

(a) Sea-surface temperature;

(b) Sea temperature gradient, both horizontal and vertical;

(c) Salinity;

(d) Temperature/salinity relation;

(e) Oxygen;

(f) Water quality;

(g) Currents;

(h) Water density;

(i) Swell period.

Sea temperature is an environmental factor of great importance for fishing, which in turn determines the commercial viability of fishing grounds. Both the spatial and temporal distribution of surface temperature and water temperature at depth are of great interest, as are the respective variability and any anomalous characteristics. Sudden changes in water temperature lead to stress on fish populations and fish quality.

Some fish species live and feed close to the surface of the sea; others live for the most part on or near the bottom. Some shellfish may be dredged from the bottom. Diving operations to collect some shellfish species, such as abalone, are very sensitive to even low swells. Swell period impacts on water quality and therefore fish quality, as well as reducing oxygen levels and resultant fish survivability.

Winds and waves may impact on operational aspects of fishery management. Currents may increase stress on infrastructure or movement of nutrient-rich water.

Fishery authorities and scientists are very interested in longer-range weather and climate forecasts, particularly of changes in sea-surface temperature and other meteorological and oceanographic parameters that have an impact on:

(a) Fish catches and fish quality;

(b) Fishing grounds;

(c) Distribution of fish;

(d) Fishing periods;

(e) Abundance of species;

(f) Reproductive cycles.

2.6.12 **Ports**

Every port or harbour is different in size, layout and the kind of weather experienced, so that there are a great variety of individual requirements for local marine meteorological services. The provision of marine meteorological services in ports usually involves different organizations, which inevitably leads to different requirements from one port to another.

Marine meteorological services for main ports and harbours usually support the risks of carrying out all, or some, of the following activities:

(a) Ship movements (entering, leaving or moving about the port);

(b) Container handling, container safety and warehousing, including the safety of cranes and lifting gear;

(c) Embarkation/disembarkation of passengers, especially by tender;

(d) Refuelling operations;

(e) Loading of barges;

(f) Dredging or cleaning operations;

(g) Shipbuilding and other construction works;

(h) Port engineering projects;

(i) Icebreaking services in ports and port entrances;

(j) Marine pollution combatting operations in port areas;

(k) Rescue operations;

(l) Industries, commerce, litigation and insurance;

(m) Waterborne recreational activities.

Knowledge of expected winds, sea and visibility helps the planning of movement of ships into, out of, or within the harbour. Weather conditions affect docking operations. When a tropical cyclone is threatening a particular port, the forecast movement of the cyclone will affect a ship captain's decision to take evasive action by going to sea or to ride it out in the harbour.

Cargo handling is affected by high winds, which can damage cranes and lifting gear. Some cargo cannot be handled in rain or in extremes of temperature. General forecasts are not always adequate because local topography tends to have considerable influence on the distribution of wind speeds and precipitation. Although the increasing use of containers has reduced the labour force at many ports, the forecasting service is still important to stevedoring companies in the rostering of their workforce.

Forecasts of wind speed, including gusts, thunderstorms, squalls and the state of the sea are required for the planning of operations such as the loading of barges, dredging and clearing operations, shipbuilding and other construction works, port engineering projects and marine pollution-combatting operations. Most of these operations require warning when wind speeds or waves are expected to exceed some critical value.

Tidal level can be operationally useful for managing under-keel clearance requirements for large ships with deep draughts moving through channels of shallow water. Abnormal water levels sometimes also affect dockyard operations. Information about tidal currents are also relevant.

The planning of icebreaking operations in ports and port approaches is dependent on forecasts of wind, temperature, wave and swell conditions. Severe storms with strong winds and spray in conditions of negative air temperature may lead to rapid ice accretion and cause ships to sink.

Harbour seiches may lead to irregular ship movements, making berthing difficult and increasing the danger of collisions.

Information on visibility or ice conditions in the different approaches to a port, for example, helps ship captains decide the appropriate course to take.

2.6.13 **Search and rescue**

When a vessel is known to have sunk or to be in serious trouble (for example, fire on board a large vessel or engine breakdown on a small craft) a search will be mounted by the appropriate authorities to rescue any survivors. On a large vessel, survivors will have taken to smaller lifeboats.

As small craft will drift with sea and tidal currents, an indication of drift is important in search and rescue operations along with forecasts of winds, waves and visibility. Sea-surface temperature may also be required, as small craft may capsize and this element is an important factor in determining survival time in the water.

2.7 **INTERNATIONAL COORDINATING ARRANGEMENTS**

2.7.1 **General**

The basis of international arrangements regarding the provision of marine meteorological services is given in the WMO *Technical Regulations* (WMO-No. 49), Volume 1, IV, 1 – Meteorological services for marine activities. It is important that shipping operators are able to obtain the same services from different countries in the same way, whether the ship is sailing on the high seas or is in port. The various procedures that should be adhered to are specified in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Parts I and II, which forms part of the WMO Technical Regulations. The Manual contains both standard practices, which are mandatory, with use the verb "shall", and recommended practices, which use the verb "should". International coordination for activities in marine meteorology is shown in the following examples.

2.7.2 **The WMO Voluntary Observing Ships Scheme**

Under the SOLAS Convention ships are required to report any phenomena or weather conditions that constitute a serious hazard to the safety of navigation. Selected ships also contribute, on a voluntary basis, a regular series of weather observations. These observations provide the basis of warnings and weather forecasts of benefit to shipping, and are also used in the compilation of climatological atlases. The VOS Scheme, which is explained in detail in the *Guide to the Global Observing System* (WMO-No. 488), III.4, demonstrates the cooperation between meteorologists and the marine community including shipping and fisheries.

2.7.3 **Methods of observation of marine elements**

There is no doubt that uniformity must exist in the observation of meteorological elements and those of the sea surface. Although instruments used may be different, observing sea stations (mobile ships as well as platforms) should measure exactly the same parameters that describe the state of the atmosphere or ocean at the time of measurement. It is very difficult to meet this requirement in a routine observational programme and, internationally, there must be a regular exchange of information, experiences and views to keep uniformity of measurement at an acceptable level. The requirement also applies to observing stations in coastal and offshore areas. International exchanges of information encourage the use of recent advances in instrument technology, including automation of the measurements. The subject is further explained in the *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8).

2.7.4 Coordination of marine meteorological broadcasts

It is important that the times of broadcast of forecasts be published and known to ships, and that only one broadcast is made to a given area at a time. WMO coordinates the times of broadcast by satellite to various ocean areas. Broadcasts on Global Maritime Distress and Safety System (GMDSS) communication platforms (SafetyNET, NAVTEX, HF NBDP) and marine radio (HF and VHF) should be in accordance with a definitive timetable maintained in *Weather Reporting* (WMO-No. 9), Volume D – Information for Shipping.

It is desirable that the broadcast of meteorological warnings and warnings of navigational hazards in coastal waters be coordinated so that users receive all relevant information on hazards at about the same time. This will require coordination between the NMHS, the authority responsible for issuing navigational warnings and the coast radio station(s).

2.7.5 Port meteorological officers

Port meteorological officers (PMOs) fulfil a highly important role in the liaison between NMHSs and the shipping community. Their functions are truly international in nature – wherever a ship may find itself in the world it must be able to obtain the assistance it needs to serve as a meteorological observing station, and must also be able to obtain information about the marine meteorological services available in the country, region and internationally. International coordination is arranged by WMO, and the roles and responsibilities are described in the *Guide to the Global Observing System* (WMO-No. 488).

2.8 WORLDWIDE MET-OCEAN INFORMATION AND WARNING SERVICE

2.8.1 General

The Worldwide Met-Ocean Information and Warning Service provides maritime safety information (MSI) to mariners in the form of marine forecast and warning products. The Worldwide Met-ocean Information and Warning Service is coordinated across the oceans through 21 defined areas, called METAREAs. Ships receive the MSI products via marine communication systems such as SafetyNet and NAVTEX, which form part of GMDSS. The IMO Assembly Resolution A.1051 – IMO/WMO Worldwide Met-ocean Information and Warning Service guidance document, outlines the functions of WWMIWS.

The MSI products are issued by NMHSs appointed as WWMIWS issuing services. METAREA coordinators are assigned to coordinate provision of the marine services for each area.

To allow mariners all over the world to understand the terminology in weather and sea bulletins, uniformity of terms is highly desirable. A multilingual list of terms used in weather and sea bulletins is included Appendix 2 of the present publication and should provide the necessary guidance to achieve this required uniformity.

2.8.2 Areas of responsibility

The establishment of areas of responsibility is coordinated by the Joint WMO/Intergovernmental Oceanographic Commission (IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM), in consultation with regional associations and approved by the Executive Council.

An issuing service may arrange to receive from other NMHSs forecasts and warnings for part of its area of responsibility for incorporation in the complete forecast for the whole area. These contributing services are known as preparation services.

The issuing service is responsible for composing the complete broadcast bulletins on the basis of input from the relevant preparation services and for monitoring the broadcasts of information to its designated area of responsibility. Where appropriate information, data or advice from a preparation service for a given METAREA is not available, it is the responsibility of the issuing service for that area to ensure that complete broadcast coverage for the area is maintained. An issuing service may agree with a preparation service on an appropriate format for the attribution of the forecast and warning information provided by the preparation service.

The METAREAs are identical to the NAVAREAs used by the International Hydrographical Organization (IHO) for the broadcast of navigational warnings.

An issuing service may extend the area of coverage of weather and sea bulletins beyond its METAREA, if it so wishes, to meet national requirements. In this case, the area of coverage has to be specified in the text of each broadcast so that ships are quite clear as to the area covered by the bulletin. Similarly, a preparation service may extend its area of coverage to meet national requirements, provided the area of coverage is clearly specified in the information supplied to the issuing service.

Whenever an issuing service is no longer able to provide the services for its area of responsibility, the relevant Member should inform the Secretary-General at least six months in advance. Whenever a preparation service is no longer able to provide forecasts and/or warnings for part of a METAREA, it should inform the relevant issuing service, which should try to make alternative arrangements. The Secretary-General should also be informed of changes in preparation services.

Any amendments to the area of responsibility, or proposal for the introduction of a change in an NMHS's responsibility for an area, has to have the approval of the Executive Council based on a recommendation by JCOMM. Before drawing up any such recommendation, the Commission will obtain comments from the NMHSs directly concerned with the proposed amendment as well as comments of the president(s) of the regional association(s) concerned.

Because of the congruence of the METAREAs with the NAVAREAs of IHO it can be hoped that it will not become necessary to amend them.

2.8.3 **About the Global Maritime Distress and Safety System**

The Global Maritime Distress and Safety System has been agreed internationally within IMO by amendment to the SOLAS Convention. For the purposes of the GMDSS communication equipment carriage requirements, the oceans and seas of the world have been divided into four “sea areas”, as follows:

– Sea area A1 – Sea area within the radio-telephone coverage of at least one VHF coast station in which continuous digital selective calling (DSC)[1] alerting is available;

– Sea area A2 – Sea area, excluding sea area A1, within the radio-telephone coverage of at least one MF coast station in which continuous DSC alerting is available;

– Sea area A3 – Sea area, excluding sea areas A1 and A2, within the coverage of approved satellite service providers in which continuous alerting is available;

---

1 DSC is a technique using digital codes enabling a radio station to establish contact with, and transfer information to, another station or group of stations, and complying with the relevant recommendations of the International Radio Consultative Committee.

– Sea area A4 – Sea area outside sea areas A1, A2 and A3, which generally comprise the polar waters.

Ships are required to carry the appropriate equipment for the sea area(s) in which they will be travelling. Most of the high seas areas of the world are in sea area A3.

Under GMDSS, high seas, weather and sea bulletins are broadcast by satellite using the approved satellite service providers with the EGC System. The EGC System allows a bulletin to be broadcast to all ships with the relevant receiving equipment in:

(a) A standard METAREA or coastal area;

(b) A rectangular area delineated by latitude and longitude by the sender;

(c) A circular area delineated by a central point and radius by the sender.

The reader should refer to the IMO *International SafetyNet Manual* for further details.

2.8.4 NAVTEX

Sea area A2 is serviced in some parts of the world (mostly in the northern hemisphere) by the NAVTEX service. This service is the coordinated broadcast and automatic reception on 518 kHz of MSI by means of narrow-band direct-printing telegraphy using the English language. The messages are printed out automatically on receiving equipment on the bridge of a ship.

The reader should refer to the IMO *NAVTEX Manual* for further details.

2.8.5 Other radio communications

Provision is made for broadcast and reception by means of VHF DSC, HF DSC and MF DSC. Full details of the radio communications required internationally in the various sea areas can be found in the SOLAS Convention Chapter IV Regulations 6–11. An NMHS may have to prepare and/or issue warnings and routine forecasts for transmission by an HF direct-printing telegraphy MSI service for areas where such a service is provided for ships engaged exclusively on voyages in such areas. For coastal waters, marine weather bulletins may be broadcast on VHF marine radio services.

As described in the *GMDSS Manual* (http://www.imo.org/en/Publications/Documents/Newsletters%20and%20Mailers/Mailers/IH970E.pdf) Members should be aware of the radio call protocols for meteorological safety information broadcast on marine radio (HF and VHF).

Warnings issued between the times of routine broadcasts of bulletins should be broadcast immediately on receipt by the coast radio station. This particularly applies to the first warning of a tropical cyclone of storm or hurricane intensity. Ships need to be advised immediately of the imminence of dangerous weather.

2.8.6 Provision of information by radio facsimile

Dissemination of weather charts and plain language warnings by radio facsimile is an effective means of serving marine users. The charts provide graphic information on the current and forecast weather situation, which aids comprehension of the forecasts and warnings contained in the text bulletins. The positions of highs, lows and fronts on the analyses provided by radio facsimile should, of course, agree with those described in the bulletin issued at about the same time by the same NMHS.

Detailed schedules of radio facsimile broadcasts are contained in *Weather Reporting* (WMO-No. 9), Volume D – Information for Shipping. This publication gives the particulars of the radio stations, the times of broadcasts, the frequencies used and the areas covered by the charts.

The usefulness of the service depends on strict adherence to the scheduled broadcast times. Some radio-facsimile receivers need manual fine tuning adjustment to ensure optimal reception, and for this reason, ships officers expect transmission to begin at the scheduled time. Some countries use computer control of transmission to ensure accurate timekeeping.

The standard facsimile map displays intended specifically for marine use usually include:

- Surface weather analyses;
- Surface weather prognoses;
- Surface wind-field analyses;
- Surface wind-field prognoses;
- Wave analyses;
- Wave prognoses;
- Sea-surface temperature analyses;
- Sea-surface temperature prognoses;
- Sea-ice and iceberg information;
- Significant weather depiction;
- Ocean current information.

Suitable projections, scales and legends are transmitted, together with recommendations for preparation to ensure maximum clarity on reception.

Members should prepare map displays using the scales along the standard parallels as follows:

(a)	Covering the world:	1:40 000 000
	Alternative:	1:60 000 000
(b)	Covering the hemisphere:	1:40 000 000
	Alternatives:	1:30 000 000
		1:60 000 000
(c)	Covering a large part of a hemisphere or hemispheres:	1:20 000 000
	Alternatives:	1:30 000 000
		1:40 000 000
(d)	Covering a portion of a continent or an ocean, or both:	1:10 000 000
	Alternatives:	1:20 000 000
		1:15 000 000
		1:7 500 000
		1:5 000 000

The following guidelines should be considered when designing a map display for radio-facsimile:

(a) The minimum line thickness should be sufficiently large to ensure clear reproduction;

(b) Lines that are required to be reproduced uniformly should be of uniform width and intensity;

(c) Special marking in heavy print (two or three crosses) of intersections of lines of latitude and longitude should be used;

Note: This will facilitate the use of facsimile charts during periods of poor reception.

(d) The minimum separations of detail in letters, figures, symbols and the like should be sufficient to avoid the unwanted filling of spaces in the reproduction;

(e) Letters, figures, symbols and the like should be drawn as simply as possible;

(f) Models employed in plotting should be as simple as possible.

Standard symbols for the graphic representation of data, analyses and forecasts appear in the *Manual on Codes* (WMO-No. 306), Volume I.1, Attachment IV.

3. SERVICES FOR THE HIGH SEAS

3.1 INTRODUCTION

Typical journeys undertaken on the high seas may last for many days up to a number of weeks. Cruise ships may travel to a number of port destinations with a few days on route between each port. Cargo ships may take a number of weeks between each port. The speed that these vessels travel versus the size of some weather patterns means that it might take a few days to move to safer waters. Generally, the size of vessels operating on the high seas are designed to handle reasonably rough conditions; however, extreme conditions present significant risk and danger to these larger vessels. Cruising yachts also operate on the high seas, and these boats are more vulnerable to damage from rough conditions.

Ship captains are interested in the synoptic weather pattern of the current and forecast positions of depressions and fronts. Although the marine forecasts describe the expected weather, wind and sea conditions, many ship captains wish to know the actual weather, wind and sea conditions experienced in nearby areas. When a storm area is approaching a ship, it is useful for the captain to know the wind speed and the sea and swell in that area so that they can navigate with greater assurance by allowing for the roll and pitch movements that are expected. Ship captains take notice of wind warnings and will avoid the areas affected.

Similarly, captains need to be informed of the actual boundaries of fog areas over cold currents or advection fog near continents in order to make some assessment of probable delays and late arrival in port.

Observations are of great importance to ship captains. These reports should include time of observation, cloudiness, wind, visibility, present and past weather, air temperature and pressure, and sea and swell.

The SOLAS Convention requires meteorological services to be disseminated to vessels on SafetyNET and NAVTEX in accordance with the GMDSS Master Plan (see the IMO *GMDSS Manual*). Members should disseminate meteorological services by marine radio frequencies (for example, MF, HF or VHF) or HF NBDP telegraphy for areas where such a service is provided for ships engaged exclusively on voyages in those areas.

3.2 SERVICE DESCRIPTIONS

Marine meteorological services for the high seas form part of WWMIWS and include provision of:

(a) Meteorological warnings;

(b) Marine forecasts;

(c) Sea-ice information services.

Refer to the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Part I for details on procedures and format requirements.

In accordance with the principle of starting with the most important information, weather bulletins for the high seas have the following mandatory format:

– Part 1 – Warnings

– Part 2 – Synopsis of major features

– Part 3 – Forecasts

The most important element in the bulletin is the warnings, which must indicate clearly the area to which each warning applies. When there is no warning in effect, that fact must be mentioned in part 1 of the bulletin by the statement "Warning nil" or "No warnings". Thus the recipient is in no doubt as to whether a warning is, or is not, current.

The synopsis in part 2 usually gives a description of the position and movement of weather systems for the entire area of responsibility. The synopsis should also describe the limit of all known ice extents. In subtropical and tropical regions, where the general weather situation often shows a seasonal pattern that remains unchanged for a number of days or longer, the synopsis is often reduced to a simple indication, for example "north-east trade flow". Due to the use of different units of measurement applied in various national jurisdictions for wind speed, visibility and wave heights, it is important that the quantitative unit must be included in the text of the message so that the recipient is in no doubt about the magnitude of the element.

It is usual for the area of responsibility to be subdivided, as this aids clarity to the recipient and allows concentration on the area where the ship happens to be. The subdivisions may vary with the weather situation, or be fixed in every bulletin. They may be indicated by latitudes and longitudes, or fixed areas may be indicated by names or numbers, which shortens the message and aids comprehension by the reader. Sub-areas may refer to designated areas defined by IMO such as “shipping lanes”, “particularly sensitive sea areas”, and “vessel traffic management areas”. However, fixed names or numbers need to be well publicized so that all mariners know the areas to which they refer. Sub-areas and their indications are shown for each country in *Weather Reporting* (WMO-No. 9), Volume D – Information for Shipping.

Some issuing services divide their METAREA into subdivisions and issue a complete bulletin of parts 1, 2 and 3 for each subdivision. This may well be the case where preparation services are contributing to the bulletin, as their contributions for particular areas can be incorporated into the complete bulletin with the minimum of delay.

Some issuing services may elect to issue a separate bulletin containing sea ice information and forecasts. This may be useful to reduce the length of a bulletin and also to provide flexibility for dissemination.

Warnings must be issued immediately when the need becomes apparent, without waiting for the next routine forecast. Thus, warnings may be issued separately from a routine forecast.

4. SERVICES FOR COASTAL, OFFSHORE AND LOCAL AREAS

4.1 INTRODUCTION

While the major concern of marine meteorology is the safe passage of ships in transit, meteorological services have become increasingly important for operations and vessel-traffic management in ports and harbours. This is because many activities within these infrastructures are weather sensitive and the increasing turnaround of ships in port means that delays due to weather must be kept to a minimum. Ports most in need of meteorological services are those with a relatively high proportion of adverse weather – fog, gales, swell, rain and squalls – and with a high volume of traffic leading to congestion in the harbour area and approaches.

Coastal areas geographically constitute a transition between land and sea. The areas are not defined in terms of exact geographical boundaries, as they depend on the topography inland and out to sea. At many coasts the meteorological conditions are different from those experienced further inland. Within coastal waters, the influence of the coast, as well as the relative shallowness of the waters, give rise to changes of atmospheric and ocean conditions that can be hazardous to the safety of shipping and small craft.

Forecasts for coastal waters not only serve the national community but also international shipping that may make use of them as well. At the other extreme, recreational boating in very small open boats is subject to hazards from wind and waves that are of no concern to large vessels.

Services are required not only for ocean waters but also for people living right on the coast who are subject to a greater frequency of strong winds and gales than those living even a short distance inland. They need to be warned of storm surges and tsunamis, and are also interested in being informed about surf conditions on open beaches and conditions at harbour entrances.

4.2 SERVICE DESCRIPTIONS

The procedures that should be followed when providing marine meteorological services for coastal, offshore and local areas are described in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Part II.

4.2.1 Areas and boundaries for bulletins

Because of the variation in winds, waves and weather in coastal waters, the weather and sea bulletins cover finer details than those issued for the high seas, which cover far greater areas. The landward boundary of an area for which a coastal bulletin is given is usually the coastline itself. But this line may be very irregular, and bays, estuaries, island barriers or reef barriers may make it hard to define just where the coastline is. A practical approach is to divide the coastal area into a number of sub-areas that are of significance to the local traffic. For instance, one sub-area could cover the approaches to an important harbour, while another could cover local fishing grounds. Significant differences in meteorological conditions would also constitute an important factor in determining the sub-areas. Consideration for the number of sub-areas should also account for how the information will be disseminated through marine radio or other communication platforms. There may be time constraints on marine radio that limit the number of feasible sub-areas to broadcast.

Seaward boundaries of coastal areas are not defined in any general way. They depend on a number of factors, such as the extent to which coastal traffic and activities extend out into the sea or ocean, the vicinity of other countries, the weather and sea conditions themselves and other considerations of a practical and sometimes legal nature. For this reason, the *Manual on*

Marine Meteorological Services does not specify seaward boundaries, but rather their specification is left to the country concerned. Each Member, therefore, in notifying WMO of its programme of coastal weather and sea bulletins, should include in the specifications of this programme the exact boundaries of the area or sub-area of coastal waters for which a particular bulletin is issued. These areas are usually indicated on a map published in *Weather Reporting* (WMO-No. 9), Volume D – Information for Shipping.

4.2.2 **Content of bulletins**

Although coastal bulletins may be issued primarily for national interests, they are also used by international shipping, and for this reason in the *Manual on Marine Meteorological Services*, Volume I, Part II, 3, the contents of coastal weather and sea bulletins are specified. Coastal bulletins do not have to be divided into parts 1, 2 and 3, but they should still follow the order of presentation of information: warnings, synoptic situation, forecasts. There should, as far as possible, be consistency between the forecasts and warnings for the coastal waters and the relevant high seas area. Naturally the forecast for coastal waters gives more detail for the smaller area than the high seas forecast.

Some NMHSs may elect to issue a separate bulletin containing sea ice information and forecasts. This may be useful to reduce the length of a bulletin and provides flexibility for dissemination.

Due to the effect of the coast itself and its topography, winds on the coast and over near-coastal waters often differ markedly from those over the open sea, so it may be important to define the boundaries and scales to users for terms for areas such as offshore, inshore, near shore and coastal.

It is not usually possible to forecast the precise wind and wave conditions in every bay or gulf along the coast, both for reasons of length of the forecast, and of inability to forecast the differences due to the topography. It is important to educate and advise small craft operators that they need to use their own local knowledge to determine the likely conditions in such areas given the general forecast for the coastal section.

It is important to determine, by consultation with representatives of user communities, the thresholds of meteorological and sea wave parameters to be used as criteria for the issue of warnings (beyond those agreed for storms and gales) or be mentioned in the forecast, for example wind speed, strength of gusts, wave height, swell period and direction, visibility and squalls.

Due to the use of different units of measurement applied in various national jurisdictions for wind speed, visibility and wave heights, it is important that the quantitative unit be included in the text of the message so that the recipient is in no doubt about the magnitude of the element.

Warnings of hazardous meteorological phenomena are essential for the safety and security of all kinds of marine activities. Warnings need to give essential information, but not be overlong; most are read out over radio or automatic telephone. There is a limit to how much information can be absorbed by the listener. As stated in the *Manual on Marine Meteorological Services*, "Warnings shall be as brief as possible and, at the same time, clear and complete" (Part I, 2.2.3.9).

Users also like to know how long the dangerous conditions are expected to persist. Thus, formulas such as "moderation is expected tonight", or "strong winds are expected to continue for another two days" should be included if possible.

5. MARINE METEOROLOGICAL SUPPORT FOR MARITIME SEARCH AND RESCUE

5.1 GENERAL

Under GMDSS, Joint Rescue Coordination Centres (JRCCs) are responsible for coordinating search and rescue of ships in distress in each NAVAREA. The success of a search and rescue operation depends to a large extent on the meteorological information available to the JRCC. Survivors may be aboard an small open boat that will drift with the wind, waves, tides and currents, and search areas may be extensive if the position of the survival craft is not known with any degree of accuracy. It may be extremely difficult to see a small craft in conditions of poor visibility or choppy waves. Water temperatures provide guidance to JRCCs on potential survival times of persons in the water.

The use made of meteorological information by a JRCC is described in the IMO *International Aeronautical and Maritime Search and Rescue Manual*.

5.2 SERVICE REQUIREMENTS

The procedures that should be followed when providing marine meteorological services to maritime search and rescue operations are described in the *Manual on Marine Meteorological Services* (WMO 558), Volume I, Part III.

In an emergency situation, meteorological information will be required quickly and procedures should be in place for an NMHS to provide the required information to a JRCC as quickly as possible when a request is received. This requires the JRCC to be kept informed of the addresses of relevant forecasting centres and the available means of communication. It is recommended that there is agreement between the NMHS and the JRCC on the standard format of the information that is required. This saves time when a request is initiated.

It is useful practice to supply the JRCC with routine weather and sea bulletins so that, in an emergency, the JRCC has at least a general forecast of the weather in the area while waiting for the response to a request for more specific advice. On many occasions, when the weather is benign, the routine bulletins will be sufficient for JRCC purposes.

6. SERVICES IN SUPPORT OF THE WORLDWIDE NAVIGATIONAL WARNING SYSTEM

6.1 GENERAL

Maritime safety information is promulgated in accordance with the requirements of IMO Resolution A.705(17) – Recommendation on the promulgation of maritime safety information, as amended. Navigational warnings are issued under the auspices of the IHO/IMO Worldwide Navigational Warning Service in accordance with the requirements of IMO resolution A.706(17) – Worldwide Navigational Warning Service, as amended.

Navigational warnings are issued in response to SOLAS Chapter V Regulation 4 –Navigational warnings, and carry information which may have a direct bearing on the safety of life at sea. Some of the subjects of concern for navigational warnings rely on sources from NMHSs. Appropriate coordination and information-sharing agreements should be established with NAVAREA coordinators to facilitate an effective warning service.

6.2 SERVICE REQUIREMENTS

Full details of navigational warnings are described in the *Joint IHO/IMO/WMO Manual on Maritime Safety Information*, and procedures which should be followed are described in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Part IV.

Particular support arrangements are required for the following navigational hazards:

- NAVAREA warning type 5 – Drifting hazards:
  - Icebergs;
  - Volcanic activity, resulting in heavy ash or floating pumice;
- NAVAREA warning type 12 – Significant malfunction of radio or satellite communication services;
- NAVAREA warning type 16 – Tsunamis and other natural phenomena, such as abnormal changes to sea level:
  - Tsunami risk;
  - Abnormal water levels.

7. SERVICES IN SUPPORT OF MARINE ENVIRONMENTAL EMERGENCY RESPONSE

7.1 GENERAL

There are a number of IMO conventions and resolutions concerned with preventing pollution at sea. The main one is the International Convention for the Prevention of Pollution from Ships (MARPOL Convention).

Incidents involving the spilling of oil or other pollutants constitute a hazard for coastal areas and communities. Actions necessary to contain the area of pollution, to minimize its effects and to clean up the affected area require meteorological services of a special form. Such pollution incidents usually call for immediate action and it is essential that prearrangements be made between the meteorological service and the pollution control authority so that the NMHS can be alerted and the required information provided with minimum delay.

Maritime countries may designate a responsible authority for marine pollution, or groups of expertise that can provide the appropriate advice as required. This may be done in support of national planning for prevention of marine pollution, or for operations purposes, such as the guidance of oil tankers or to assist other marine activities constituting a pollution threat. NMHSs may be required to provide advice in the formulation of such national plans to prevent and control marine pollution.

7.2 SERVICE REQUIREMENTS

The procedures that should be followed are described in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I.

A framework exists to support Members in developing and enhancing capacity to provide a consistent level of marine meteorological information and drift information in the event of a range of marine environmental incidents, including:

– Spills of oil and other noxious substance;

– Radioactive material discharges in marine and coastal zones;

– Other marine environmental hazards (for example, harmful algal blooms).

Marine pollution drift and dispersal models combine the attributes of the pollutant with the environmental conditions. These models may be operated by the meteorological authority, or by the pollution control authority according to national arrangements.

8. TRAINING IN THE FIELD OF MARINE METEOROLOGY

8.1 INTRODUCTION

The types of personnel requiring training in marine meteorology are:

(a) Meteorological personnel engaged in observational, forecasting and climatological duties for marine purposes;

(b) PMOs;

(c) Seafarers.

Each class of marine meteorological personnel requires training both in general and marine meteorology up to the various standards required for their particular tasks. The classification and educational requirements for meteorological personnel, including the syllabi for training, are fully detailed in *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I – Meteorology. The WMO competency framework for marine meteorological and oceanographic services (*Technical Regulations* (WMO-No. 49), Volume I, Part V can be used for assessing the suitability of forecasting staff.

8.2 TRAINING PRINCIPLES AND PROCEDURES

The principles and procedures governing the training of all classes of meteorological personnel engaged in marine meteorological activities, together with those pertaining to PMOs and seafarers, are described in the *Manual on Marine Meteorological Services* (WMO 558), Volume I, Part VI. Other examples include the need for special training centres, the importance of trained specialist instructors, the involvement of universities and guidance available from WMO publications. Staff involved in the provision of training should refer to the *Guidelines for Trainers in Meteorological, Hydrological and Climate Services* (WMO-No. 1114).

In addition, the standards set by the relevant international authorities for the training of ship officers must be considered, such as the IMO International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, which sets the training requirements in marine meteorology for captains and chief mates of ships of 200 gross registered tons or more. The IMO Polar Code also provides guidelines for training seafarers operating in polar waters.

9. SERVICES FOR MARINE CLIMATOLOGY

9.1 INTRODUCTION

9.1.1 General purpose of marine climatology and societal applications

Note: General information on the purpose of marine climatology and societal applications can be found in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Part VII. In addition, a comprehensive account of the uses of marine climatology can be found in the *Guide to the Applications of Marine Climatology* (WMO-No. 781) (1994) and in this latter Guide's dynamic part, *Advances in the Applications of Marine Climatology*, JCOMM Technical Report No. 13 (WMO/TD-No. 1081) (see JCOMM, 2003*a*, 2005, 2011 – see reference list for web links).

Marine climatology today provides data, information and products about marine meteorological conditions to a wide range of research and science applications in support of industry and national interests in the coastal and offshore regions. Examples of applications and their use of marine meteorological and oceanographic climatological information are detailed in the table below.

Examples of applications and their use of marine meteorological and oceanographic climatological data and information (additional variables not relevant to the Marine Climate Data System (MCDS), and not included in the table, may be required).

Applications	*Examples of use of marine climatological information*	*Marine climatological data and information required*
Maritime transportation	– Ship routing (for example, saving fuel, or making the shipping of perishable goods more expeditious), fleet management and ship design	Winds, currents and sea-state conditions; air and sea-surface temperature, sea ice, parameters of special interest (for example, occurrence of unusual waves, underwater earthquakes)
Natural resources exploitation, including oil and gas production Engineering and construction of coastal and offshore infrastructures	– The systems must often be capable of functioning and surviving in a variety of environments, from the tropics to ice-covered polar regions. The equipment and operations must satisfy the safety and other regulatory requirements of many nations, but also those of classification societies and insurers, whose area of operation is global. Basic to these requirements is that climate, especially extremes, should be adequately considered. – Offshore platform and coastal infrastructure architecture and design – Estimating endurance, required maintenance and operations costs of the infrastructures	Winds, currents, and sea-state conditions, sea-surface temperature, air temperature, and sea ice

Fisheries and aquaculture	– Fishery managers and researchers can use climate information to infer causes of changes in fish populations and to study a variety of physical, chemical and biological marine processes:
	  – Ship and fleet operations
	  – Identification of best aquaculture sites
	  – Classify fish habitat
	  – Compute fish distributions
	  – Fish stock assessment
		Sea-surface temperature, currents, sea-surface height, waves and sea state, wind direction/speed, currents, nutrients, ocean colour, chlorophyll concentration, phyto/zooplankton biomass, photosynthetic radiation, carbon, oxygen, alkalinity, salinity, and turbidity

Applications	*Examples of use of marine climatological information*	*Marine climatological data and information required*
Power generation	– Sizing and design of electric power generators at sea, and estimation of the expected electric power to be generated by them based on the marine climatological conditions	Depending on the energy source used: winds, tides or currents, water temperature gradient, and waves
Tourism	– Providing information to the tourism industry and tourists about local marine meteorological and oceanographic conditions for their activities, for example, sailing, boat trips and beach activities, including surfing	Average climatological conditions, and probability of occurrence of extreme weather and marine meteorological events
Insurance	– Calculation of the cost of insurance against inclement weather and marine conditions for activities in the marine and coastal environment (for example, sports and other media events, and offshore infrastructure such as wind turbines, oil rigs and moorings)	Probability of occurrence of extreme weather and marine meteorological events Historical record of actual occurrences of extreme weather and marine meteorological events
Coast management	– Design and maintenance of coastal infrastructures – Land management on coasts	Average climatological conditions, and probability of occurrence of extreme events
Disaster risk reduction	– Evaluation of the vulnerability of coastal areas which are the most impacted by extreme events – Planning of rescue operations at sea or in coastal regions potentially affected by extreme events	Probability and impact of relevant marine meteorological events (for example, extreme atmospheric and oceanic events)
Prevention and mitigation of marine pollution	– Planning of responses to environmental emergencies such as oil spills	Average marine climatological conditions (winds, currents, sea state, waves), sea ice, probability and impact of marine meteorological events (for example, extremes)
Search and rescue	– Planning of search and rescue operations, taking into account the marine climatological conditions	Average marine climatological conditions (winds, currents, sea state, waves, sea ice)
Climate modelling	– Data assimilation – Evaluation of ocean and atmosphere models – Calibration and validation of satellite data using in situ measurements	All marine climatological data
Climate change studies	– Studies of climate change and air-sea interaction – Climate monitoring – Climate change assessment studies – Climate reanalysis	All marine climatological data, including Global Climate Observing System essential climate and ocean variables

9.1.2 Modernization of the Marine Climatological Summaries Scheme

The former Marine Climatological Summaries Scheme (MCSS) was established in 1963 by the Fourth World Meteorological Congress to provide international exchange of marine meteorological data and for the preparation of marine climatological summaries.

Preparation of climatological charts and atlases for oceans became possible in the second half of the nineteenth century when observations from ships, recorded in logbooks or in special "abstract" meteorological logs, started to become available in rapidly increasing numbers – and, critically, with increasing amounts of instrumental data recorded following the landmark Brussels

Maritime Conference of 1853 (WMO, 2004; Woodruff et al., 2005). For over 100 years, these charts and atlases, mainly for use by shipping, were prepared nationally, obliging countries to ask for observations stored in other countries to supplement their own datasets.

The objective of MCSS was to establish a joint effort of all maritime nations in the preparation and publication of global climatological statistics and charts for the oceans. The underlying idea was that all marine meteorological observations collected from ships of whatever nationality should be included. Eight countries, each with a specific ocean area of responsibility, were designated to process the data in prescribed forms and regularly publish the climatological summaries. Two Global Collecting Centres were established in 1993 to improve the flow of the observational data, in particular concerning ship observations.

However, starting around the early 1980s, the need to take into account new sources of marine meteorological and oceanographic data (for example, from satellites, moored and drifting data buoys, and profiling floats) increased, and with the improvement of computer power and graphic capabilities new techniques and practices for processing and presenting marine climatological data and products appeared, such that the preparation of climatological charts and atlases now only forms a small component of the research, and educational and commercial applications of marine climatological data (see table in section 9.1.1).

This led to the decision by JCOMM to initiate a modernization of MCSS, which resulted in the formal establishment of the Marine Climate Data System (MCDS) by JCOMM at its fourth session and by the Executive Council at its sixty-fourth session. MCDS replaces MCSS, which is now obsolete, and will contribute to the WMO Global Framework for Climate Services.

9.1.3 Introduction to the Marine Climate Data System

Note: General information on and introduction of the MCDS can be found in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Part VII.

The Marine Climate Data System essentially provides for standard and recommended practices and procedures, together with non-regulatory guidance assuring the collection, rescue, digitization, exchange, data processing, quality control (QC), value adding and data flow of marine meteorological and oceanographic climate data and products from various sources. Real-time (RT) and delayed-mode (DM) data are collected through a network of specialized centres, and ultimately aggregated at the WMO/IOC Centres for Marine Meteorological and Oceanographic Climate Data (CMOCs), which are meant to provide higher-level QC and deliver the consistent data and products needed for a wide range of marine climatological applications.

Basic sources of data include in situ observations, for example from ships, moored and drifting data buoys, tide gauges, expendable bathythermographs (XBTs), profiling floats, surface and subsurface gliders, as well as remote sensing data from satellites, aircrafts and a few other specialized sensing systems such as land-based HF radars.

See section 9.3 for more information on MCDS.

9.1.4 Other marine climatology activities

Many marine climatology activities currently fall outside the formal framework of MCDS, largely relating to the provision of data, information, products and expert advice to serve the needs of end user applications such as those listed in the table in section 9.1.1. Ultimately, for a complete and comprehensive MCDS, the activities falling outside the current MCDS structure should ideally be formalized under and contribute to MCDS.

Prominent among these activities are the International Comprehensive Ocean-Atmosphere Data Set (ICOADS), focused on surface marine meteorological data and products; and the World Ocean Database (WOD), focused on subsurface physical oceanographic data and products –

both discussed further in section 9.3.6. Owing to the central roles of these two programmes internationally, it is envisioned that their activities can be transitioned under the formalized MCDS umbrella in due time.

The IOC International Oceanographic Data and Information Exchange (IODE) has established a network of Global Data Assembly Centres (GDACs), which are also contributing to MCDS. A centre can act as a JCOMM GDAC, an IODE GDAC, or both, while avoiding overlaps and providing assurance the work is complimentary to the functions of both groups.

9.2 BEST PRACTICES

9.2.1 General guidance

Note: Adherence to international standards and best practices helps ensure uniformity in data and metadata collection, QC, and the generation of community-produced observational data and climate products – which in turn helps ensure seamless user access to data and products from the full range of ocean platforms, and encourages a wide scope of operational and research applications.

To achieve the highest quality climate data and products, Members of MCDS should closely follow, or propose where not available, appropriate international standards and best practices – applicable to the full range of marine meteorological and oceanographic data-processing activities including data rescue, collection, QC, documentation, archival, distribution, and mirroring of data, metadata and products.

Note: Besides those documented in WMO Manuals and Guides, and JCOMM technical reports (for example, JCOMM, 2017), best practices related to ocean and marine meteorological data and products have been established through the JCOMM-IODE Ocean Data Standards and Best Practices Project (ODSBP), which provides guidance to international data managers. For example, ODSBP has promoted standards for "date and time" (IOC, 2011) and QC flag standards (IOC, 2013).

Members enquiring about standards and best practices should refer to relevant WMO Manuals and Guides, JCOMM Technical Report No. 85 (JCOMM, 2017), the MCDS website (under development), the ODSBP repository (which includes ODSBP publications), JCOMM Catalogue of Practices and Standards (JCOMM, 2015*a*), and JCOMM *The Oceanographer's and Marine Meteorologist's Cookbook for Submitting Data in Real Time and in Delayed Mode* (JCOMM, 2014) for additional information and guidance.

9.2.1.1 *Retaining the original data*

9.2.1.1.1 Members should record and report, in DM, the original data values, where DM reports are available. Where only RT or near-RT reports are provided, they should be permanently preserved in their original format as well. Varying national observing practices, instrumentation, and data-recording technologies frequently result in marine climate data undergoing some changes between observation time and data delivery. For example, cloud cover may be observed in oktas, but circulated over the Global Telecommunication System (GTS) in BUFR format in tenths of sky cover. Automated weather systems may measure the wind every 10 seconds, but the reported value is a 2-minute average once every hour. When discrepancies are discovered in the reported data (for example, values vary from near neighbours, data spikes) the best method to determine the problem is to view the original observation as it was collected (manually or by an instrument). Efforts should be made to retain all source data received at all levels of MCDS in national repositories.

9.2.1.1.2 Where records, publications, logbooks or other sources of data and metadata have been identified, efforts should be made to preserve the data in their original form, or (for original paper records) scanned into archival-quality digital forms, for eventual digitization. In cases where resources are not immediately available for data rescue or digitization, sources of data should be formally documented, to include detailed inventories as practical, and information made publically available through the International Data Rescue (I-DARE) Portal (http://www.idare-portal.org).

9.2.1.2 *High-resolution and high-accuracy data*

9.2.1.2.1 Many modern marine climate applications require observations to be collected at time intervals ranging from seconds to minutes. These high-resolution observations support studies of energy, moisture and gas exchanges between the ocean and atmosphere, evaluations of numerical oceanic and atmospheric models, and calibration and evaluation of satellite observations. When deploying automated weather systems, Members should consider collecting and archiving data at high sampling rates. High-resolution data should be provided by Members in DM when collected.

9.2.1.2.2 The marine climate community also requires traceable observations of known uncertainty and, as much as possible, of high quality. Minimizing uncertainties relies on managing observing systems from instrument selection through the delivery of data. This starts by selecting sensors that meet or exceed standards, properly siting and exposing the instruments, and providing routine maintenance and calibration as set out in WMO (2008). Maintaining and reporting metadata (for example, sensor calibration, sensor type/make/model, data conversion algorithms, sensor locations) along with the data supports evaluation of uncertainty in the observations, including bias estimation. Information on metadata can be found in section 9.2.3.

Note: Examples of the need for high resolution and accurate data may be found in reports from the Workshops on the Advances in Marine Climatology (CLIMAR) (JCOMM, 2003b; Parker et al., 2004; JCOMM, 2008, 2015*b*) and in *Advances in the Applications of Marine Climatology* (JCOMM, 2011).

9.2.2 General guidance on the application of quality control and monitoring

In 1993, two VOS Global Collecting Centres (GCCs) were established by WMO Recommendation 11 (CMM-XI) – Modification to the Marine Climatological Summaries Scheme, (of the former WMO Commission for Marine Meteorology) to facilitate and enhance the flow and QC of marine meteorological data. Specifically, VOS GCCs have evolved into VOS GDACs in the MCDS framework, and are responsible for collecting, processing and distributing DM marine VOS data.

There is a range of activities for RT and DM QC and monitoring.

Real-time monitoring and quality control

A set of QC tools has been developed by Méteo France to monitor European Meteorological Services Network (EUMETNET) E–Surfmar observation networks.[1] The QC checks are mainly based on comparisons with model outputs and can be applied to any marine observing platform that reports on GTS. Reports are generated monthly on network data availability, timeliness and overall quality as compared to previous months and designated targets.

Additionally, the Met Office of the United Kingdom of Great Britain and Northern Ireland hosts a Regional Specialized Monitoring Centre[2] for VOS data and a Real-time Monitoring Centre[3] for VOS Climate Project (VOSClim) fleet data quality monitoring that complement the duties performed by Méteo France. Monthly reports, including monitoring statistics and suspect ship reports, are produced and made available online.

---

[1] http://www.meteo.shom.fr/qctools/.

[2] http://research.metoffice.gov.uk/research/nwp/observations/monitoring/marine/.

[3] http://research.metoffice.gov.uk/research/nwp/observations/monitoring/marine/VOSClim/index.html.

Delayed mode quality control

Minimum QC standards (MQCSs)[4] maintained by VOS GDACs (JCOMM, 2017) provide a basic level of QC on the VOS data and assure consistency in DM exchanges.

Higher QC Standards (HQCSs), as detailed in JCOMM (2017), are being developed to further enhance the VOS data. HQCSs are a modernization of MQCSs with additional checks, such as for climatological and spatial consistency; high resolution checks for 1-minute data and 0.01-degree land masks; and various checks for ranges and internal consistency. Referring to IOC (2011), ODSBP has established a common set of quality flags to assist with mapping between different marine meteorological and oceanographic dataset quality flags. This is a two-tiered flag system. The lower tier is the quality flag system used by the particular group. There are no restrictions on this flag system as long as the flag values are well documented, although the preference is for a 1–4-byte alphanumeric code. The higher tier is a 1-byte flag with values 1 (good), 2 (not evaluated or unknown), 3 (questionable, suspect), 4 (bad) or 9 (missing data). This higher tier is for the general user who wants a QC flag but is not interested in the specific reasons for the flagging. The lower tier should provide more detail on the reasons for the QC flag. More details on the flagging system can be found in IOC (2013).

9.2.3 Metadata: Observational and discovery

Metadata, both observational and discovery, are essential for (a) discovering and accessing observations and data of interest, and (b) correctly interpreting those data. Similarly, metadata on the processing applied to those data are critical for ensuring data provenance and traceability, with the ability to access the original data preserved. Within the context of the Global Ocean Observing System, Snowden et al. (2010) define and discuss the importance of these metadata. For meteorological and climate applications the minimum required set of metadata is defined within the WMO Integrated Global Observing System (WIGOS) Metadata Standard. This includes metadata at the instrument and platform levels, basic processing information and discovery metadata.

Historically, the metadata have not been reported, or reportable, alongside the observations on GTS nor in DM due to format limitations. This began to change in 2003 with the inclusion of VOSClim fleet metadata within the DM reporting formats. This will improve additionally with the development of BUFR marine templates. Thus, as required, Members (and other contributors) should regularly contribute and update observational metadata for all platforms that they operate to the appropriate international repository. For those programmes coordinated under JCOMM, such as under the Ship Observations Team and the Data Buoy Cooperation Panel, the repositories are, or will be, managed by the JCOMM In Situ Observations Programmes Support Centre (JCOMMOPS). In turn, these repositories are linked to the WMO Observing Systems Capability Analysis and Review Tool database. For other programmes, such as Argo and OceanSITES, GDACs typically manage the observational metadata. Metadata at the discovery and processing levels are also of critical importance but typically stewarded at a higher level in MCDS. Thus, Members and other contributors should actively cooperate with Data Acquisition Centres (DACs), GDACs and CMOCS in the generation and management of these higher-level forms of metadata.

9.2.4 Data (and metadata) rescue

National and international activities to recover data and metadata from historical ship logbooks and other international marine meteorological and oceanographic data types (for example, early buoy networks) remain critical to enhance climate databases, and should be promoted and further enhanced internationally. The WMO Commission for Climatology Expert Team on Data Rescue oversees I-DARE (see 9.2.1.1.2), and in the oceanographic data domain the IOC/IODE

[4] http://www.wmo.int/pages/prog/amp/mmop/documents/MQCS-7-JCOMM-4.pdf.

Global Oceanographic Data Archaeology and Rescue Programme rescues oceanographic data. Additionally, the Atmospheric Circulation Reconstructions over the Earth initiative coordinates global data rescue efforts.

9.2.5 Elimination of duplicates and tracking data provenance

One of the difficult problems faced by marine meteorological data providers is to match RT and DM versions of the same original data. Typically, the RT version can contain uncertainties or inaccuracies both in positions and times and may contain un-calibrated data. The DM data often have these errors corrected and so matching RT to DM data is not simply a matter of matching ship identifier, position and time.

Several marine climate programmes have developed methods to compare RT and DM marine meteorological reports to support duplicate elimination. The Global Temperature and Salinity Profile Programme (GTSPP) has developed and tested a procedure to generate unique data tags for original ocean profile data by using the cyclic redundancy check algorithm and successfully incorporated this algorithm into its daily data-processing stream. The International Comprehensive Ocean-Atmosphere Data Set also employs a complex duplicate elimination process (ICOADS, 2016) and takes advantage of unique record identifiers to track the provenance of related RT and DM reports.

In the future, WIGOS identifiers, as mentioned in section 9.2.3, will be helpful in tracking the provenance of platforms providing RT and DM reports and efforts should be made to provide a minimum required set of metadata as defined within the WIGOS Metadata Standard.

9.3 MARINE CLIMATE DATA SYSTEM

9.3.1 Marine Climate Data System description

9.3.1.1 The JCOMM MCDS provides routine and standardized collection of RT and DM climatological data and metadata. It includes both marine meteorological and oceanographic data made available through a network of CMOCs, promoting the sharing, collection, recording, mirroring and exchange of data and metadata for all types of end users.

9.3.1.2 Marine Climate Data System DACs receive data directly from JCOMM observing platforms within the scope of the DAC, data being in agreed formats and provided in DM and RT, by:

(a) Receiving data from a specific data source in DM, applying agreed minimum QC, investigating problems when required; the data are then forwarded to the appropriate GDAC;

(b) Receiving data from all RT sources through existing GTS Centres , applying agreed minimum QC, investigating problems when required; the data are then forwarded to the appropriate GDAC.

9.3.1.3 Select GDACs combine agreed streams of data received from DACs within the scope of the GDACs. Their role is to establish a complete dataset (including metadata), perform agreed quality checks and forward the data and metadata (both observational and discovery) with flags to the CMOC in agreed formats. DM observations should be complemented with RT data, compared, and duplicates removed where possible. It is recommended that the GDACs be interoperable with WIS and/or IODE Ocean Data Portal (ODP).

9.3.1.4 All data (original and quality controlled) and metadata received from GDACs are forwarded to the suitable CMOC. CMOCs act as specialized centres, applying HQCSs and bias correction as required, making datasets and products available to the MCDS user interface and advising Members/Member States when appropriate (see CMOC terms of reference for further information (Recommendation 2 (JCOMM-4), Annex 2)). Data and metadata are stored in line with defined JCOMM standards to ensure data integrity and universal interoperability.

9.3.1.5 Searching, downloading, displaying and analysis of data and products will be undertaken through links provided on the MCDS user interface and additionally through WIS and/or IODE ODP discovery portals.

9.3.1.6 The Centres for Marine Meteorological and Oceanographic Climate Data act as specialized centres ensuring integrated datasets and products are made available through WIS and/or IODE ODP.

9.3.1.7 A detailed schematic of the MCDS dataflow, including IOC components, is shown in the figure below.

9.3.2 **Ship Observations**

9.3.2.1 Voluntary observing ships provide meteorological and/or oceanographic observations manually, generally using electronic logbook software, for example, TurboWin in DM or automatically in RT. An increasing number of automated systems are installed on VOS supplying data in RT.

While most research vessels report high-resolution RT data only to archives and injected into MCDS at the CMOC level, some low-resolution reports are distributed on GTS and captured by GTS collection DACs.

9.3.2.2 Voluntary observing ship DACs are responsible for collecting VOS data from their recruited vessels, applying MQCS4 and forwarding the quality-checked data to the two VOS GDACs on a quarterly basis in an agreed data format (currently international maritime meteorological tape (IMMT)).[5] This comprises traditional manual DM observations as well as data received in RT from automated systems.

The Members operating automated systems on board VOSs should also prepare these data by applying MQCS4 and metadata supplements and redistribute them in the agreed data format for DM processing to GDACs.

Additionally, an RT DAC acquires and forwards VOS observations from GTS and prepares the data for further processing by applying MQCS4, reformatting and adding supplementary metadata.

All DACs should provide feedback on any data quality issues to VOS or PMOs.

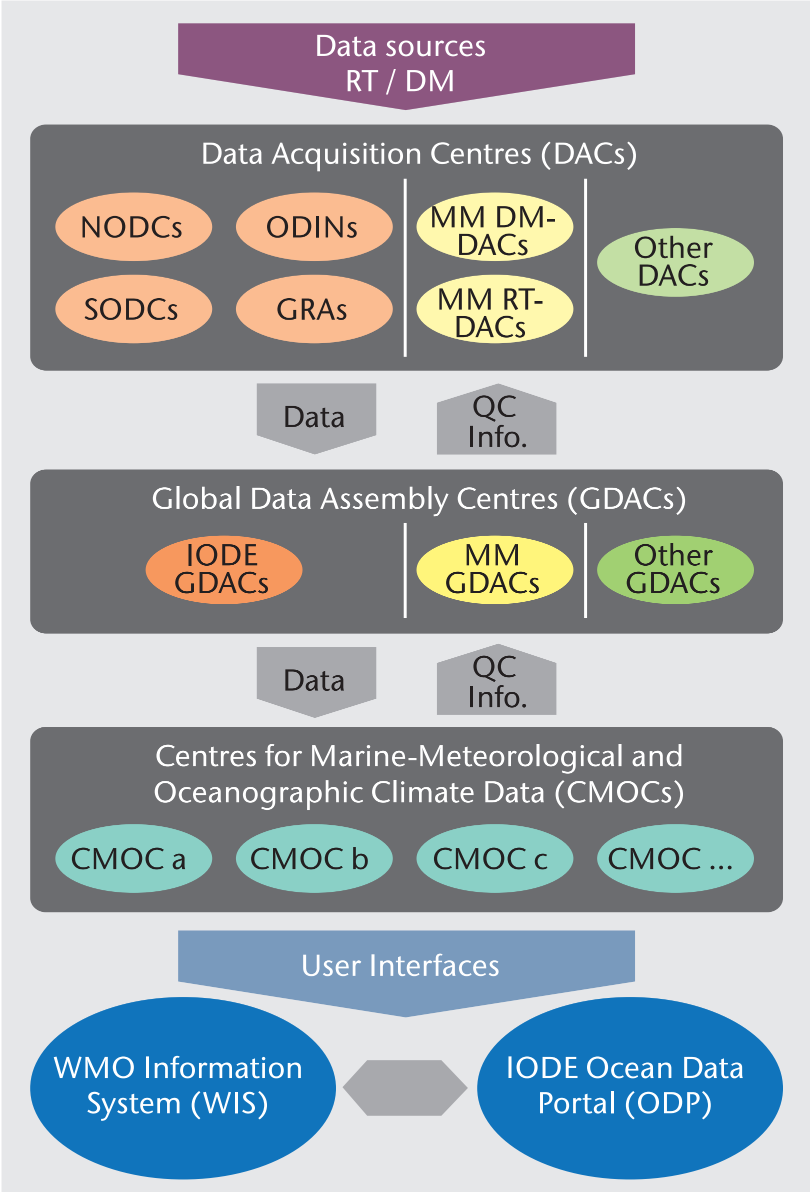
9.3.2.3 Within MCDS, two VOS GDACs are responsible for the management of DM data received from VOS DACs. The VOS GDACs operate in parallel, mirroring each other.

The VOS GDACs should ensure MQCS4 is applied to all incoming data streams notifying respective VOS DACs of any issues. Discovery metadata is made available via WIS and/or IODE ODP. All data (original and quality controlled) and associated metadata with flags should be forwarded in an agreed data format (currently IMMT5) to the appropriate CMOC.

9.3.2.4 The VOS GDACs should also complement the DM data with RT data from the GTS data streams prepared by RT VOS DACs. Aggregated near-RT data products from different data sources can then be developed at the CMOC level.

---

5 https://www.wmo.int/pages/prog/amp/mmop/documents/IMMT-5-JCOMM-4.pdf.



Key:

DM	= Delayed mode data	ODINs	= Ocean Data and Information Networks
GRAs	= GOOS Regional Alliances	QC	= Quality Control
MM	= Marine-Meteorological	RT	= Real-time data
NODCs	= IODE National Oceanographic Data Centre	SODCs	= IODE Specialized Ocean Data Centre

Marine Climate Data System data flows, from source to users

9.3.3 **Data buoys**

9.3.3.1 Data buoys, moored (for example, the Global Tropical Moored Buoy Array) or drifting (for example, the Global Drifter Program), provide meteorological and/or oceanographic observations automatically. Drifting data buoys (DDBs) transmit their data in RT to their owner agencies via a satellite system and value-added resellers generally reformat and transmit some, or all, of the data on GTS. Moored data buoys (MDBs) also transmit their data in RT, but generally store more data on board and so may provide additional data in DM to local or national agencies, if and when recovered.

9.3.3.2 The DDB and MDB DACs are responsible for collecting data from the respective buoy type that they operate or have links to, applying QC and forwarding the quality-checked data to the DDB and MDB GDACs on a yearly basis. They should also provide feedback on any data quality issues to the JCOMMOPS technical coordinator of buoy operations.

9.3.3.3 The DDB and MDB GDACs are responsible for the integration of all DAC data received from their respective platform types. There are two DDB GDACs that ensure QC, notifying data quality issues to the JCOMMOPS technical coordinator of buoy operations. Operating in pair, the DDB GDACs compare data holdings frequently to identify missing data streams, so that eventually they may both acquire identical data on a routine basis. All data (original and quality controlled) and associated metadata with flags should be forwarded to the appropriate CMOC. Discovery metadata is made available via WIS and/or IODE ODP where possible.

9.3.4 High-resolution automated systems

Advanced technology has led to an increased number of automated weather systems being deployed on VOSs, rigs, platforms and coastal stations, along with emerging technologies such as gliders and autonomous surface vessels. In some cases, these systems are implemented by NMHSs or national ocean services (for example, the land-based marine observing coastal stations and meteorological measurements associated with international tide gauge networks) while others are essentially implemented by the research community (for example, autonomous surface vessels and gliders) or private-sector industries (for example, offshore oil platforms or wind turbines). These data may or may not be transmitted via GTS, thus some of these data do not follow this pathway to the specialized data centres within MCDS. Members hosting a system or data collection centre that specializes in data from high-resolution automated systems should support the submission of these data in DM to an appropriate GDAC or CMOC.

9.3.5 Ocean data

Note: There are many sources for subsurface profile data. In near RT (usually within 48 hours), data from the Argo profiling float programme are made available through the Coriolis (France) and Global Ocean Data Assimilation Experiment DACs. Data from XBTs through the Ship-of-opportunity Programme, gliders, conductivity-temperature-depth (CTD) instruments, and pinniped-mounted profilers are pulled from the GTS and uploaded to the GTSPP Continuously Managed Database. Data with a higher level of QC are available through GTSPP from partners around the world for XBTs; from CLIVAR and the Carbon Hydrographic Office and the Biological and Chemical Oceanography Data Management Office for CTD instruments and bottle water samplers; the (newly formed) Animal Telemetry Network Data Assembly Center for pinniped-mounted profilers; three regional glider data assembly centres (in the United States of America, European Union and Australia) for gliders; and OceanSites for deep-water moored buoys. There are other sources for subsurface data, especially CTD instruments, bottle water samplers, and XBT from research cruises, usually held by primary investigators or institutions. All of these sources are ingested, with original QC, into WOD. WOD makes the data available in a uniform format with an additional set of uniform QC flags. WOD and many of the sources make their data available to IODE ODP.

For new data sources, centres should make efforts to distribute RT data through GTS so that centres around the world have instant access to the data. For DM data collection, the programmes mentioned may provide a suitable archive for the new DM data source; or the new programme/platform should collaborate with an existing GDAC when setting up a similar data retrieval/archival process in order to learn from previous experiences and to avoid any duplication of efforts.

9.3.6 Major marine climatology programmes

The ICOADS programme (http://icoads.noaa.gov) is focused on the stewardship of surface marine meteorological data and products. An international partnership now manages ICOADS with eight signatories from Germany, the United Kingdom and the United States (Freeman et al., 2016).

The ICOADS programme offers surface marine data spanning the past three centuries, and simple gridded monthly summary products for 2° latitude x 2° longitude boxes back to 1800 (and 1° x 1° boxes since 1960) – these data and products are freely distributed worldwide. As it contains observations from many different observing systems encompassing the evolution of measurement technology over hundreds of years, ICOADS is probably the most complete and heterogeneous collection of surface marine data in existence.

Similarly, WOD is a collection of quality-controlled ocean profile data, extending from the 1800s to the present day, and updated routinely with modern and rescued data (Boyer et al., 2013).

World Ocean Atlas (WOA) products based on WOD include a set of objectively analysed (1°-grid) climatological fields of in situ temperature, salinity and other oceanographic variables. The World Ocean Atlas also includes associated statistical fields of observed oceanographic profile data interpolated to standard depth levels on 5°, 1° and 0.25° grids. While linked with IODE and the Global Oceanographic Data Archaeology and Rescue Programme, the WOD and WOA activities are operated primarily by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) (https://www.nodc.noaa.gov/OC5/indprod.html).

Satellites provide an additional data source that should be included in MCDS in order to compliment the in situ observing platforms of the system and to provide additional climatological data for long-term use.

9.3.6.1 ***Observational data formats for archival and user access***

The International Comprehensive Ocean-Atmosphere Data Set utilizes the International Maritime Meteorological Archive (IMMA) format. The IMMA format (Woodruff, 2007; Smith et al., 2016) is used to store and provide ICOADS observational data to users, and also to permanently archive the data and metadata in a technologically stable and readily exchanged form. The IMMA format is ASCII based, containing a core section including date, time, location and identification information along with commonly reported meteorological variables and associated metadata, followed by an arbitrary number of "attachments" to meet more specific data or metadata requirements. While the IMMA format is complex and not easily readable by the human eye, Web-based user interfaces can produce spreadsheet and other customized formats. A netCDF version of ICOADS has been developed and will be accessible in 2017.

Similarly, WOD utilizes a custom ASCII format that was constructed to save space and therefore is not easily readable by the human eye. Software is publicly available to convert the native format into formats that are more easily readable and usable in common software. Additionally, WOD data output can be in netCDF format from WODselect (https://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html).

Additional agreed data formats will be used within MCDS, and will be thoroughly documented and compatible between operating centres to ensure harmonious flow of data through MCDS.

9.3.6.2 ***Access to data and products***

The International Comprehensive Ocean-Atmosphere Data Set makes available individual observations and monthly summary products to users from multiple access points at United States partner organizations, the National Center for Atmospheric Research, NCEI and NOAA's Earth System Research Laboratory, each with slightly different options designed to serve different user groups. The ICOADS products web page (http://icoads.noaa.gov/products.html) links to full information and data distribution websites.

World Ocean Database data and WOA products are accessible from NCEI, with current data and product versions (2013) available from locations https://www.nodc.noaa.gov/OC5/WOD13/ and https://www.nodc.noaa.gov/OC5/woa13/.

Additional agreed products will be generated within MCDS, and will be thoroughly documented and accessible to ensure harmonious flow of data through MCDS. All data and products will be discoverable through WIS and/or IODE ODP through the CMOC network and will contribute to the WMO Global Framework for Climate Services.

9.3.7 Application procedure and evaluation process for establishing a centre within the Marine Climate Data System

9.3.7.1 The governance for defining the functions and designation of each type of MCDS Centre – DAC, GDAC or CMOC – is defined (for DACs and GDACs) in Appendix 1, paragraph 3.1 of the present Guide, and (for CMOCs) in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Appendix VII.1.

9.3.7.2 The application procedure for establishing an MCDS centre (DAC, GDAC or CMOC) is as follows:

(a) The host of the candidate MCDS Centre will describe the extent to which it will be addressing requirements of scope, capabilities, functions, and data and software policy of the proposed MCDS Centre.

(b) Once the host of the candidate MCDS Centre has established that it meets the requirements to a sufficient extent, the IOC action addressee of the country, or the Permanent Representative with WMO of the country, as appropriate, will write to the IOC Executive Secretary or the WMO Secretary-General, respectively, to formally state the offer to host and operate the MCDS Centre on behalf of WMO and IOC, and to request that the centre be evaluated and added to the list of MCDS Centres. In so doing, the host of the candidate MCDS Centre will also provide a statement of requirements, scope, capabilities, functions, and data and software policy relevant to the MCDS Centre terms of reference (DAC, GDAC or CMOC as appropriate). The letter should be copied to the appropriate JCOMM co-president, and, for CMOC applications, also to the relevant president of the WMO regional association or chair of the IOC regional subsidiary body in the case where the MCDS Centre is only providing data corresponding to a specific geographic region.

(c) The IOC or WMO Secretariat will then request the appropriate JCOMM co-president to take action through the relevant JCOMM body to evaluate and verify compliance with requirements of the proposed centre.

(d) The designated JCOMM body will evaluate the request and advise in writing whether the MCDS Centre application should be endorsed. The designated body may wish to delegate this work to individuals and/or groups acting on its behalf (for example, one of the component teams, depending on the nature of the proposed centre), but any advice and proposal to JCOMM should still be assessed by and come through the designated body. JCOMM will also conduct reviews of performance and capabilities at the required intervals.

(e) If endorsed by the designated body, and depending on timing, the body will make a recommendation to the JCOMM Management Committee and invite them to provide further advice to JCOMM.

(f) If not endorsed by the designated body or the Management Committee, the JCOMM co-president should advise the candidate about areas in which the candidate centre can be improved to meet requirements. Candidates can reapply at a later date once changes have been made to meet these criteria.

(g) If endorsed by the Management Committee, a recommendation to include the candidate MCDS Centre in the list of such centres in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I (for CMOCs) or the present Guide (for DACs and GDACs) is passed to the next JCOMM session, or, depending on timing, directly to the WMO Congress or Executive Council and the IOC Executive Council or Assembly following JCOMM consultation in writing.

(h) If recommended by JCOMM, a resolution for the proposed change in the *Manual on Marine Meteorological Services* or the present Guide will be proposed to the WMO Congress or Executive Council and a corresponding decision proposed to the IOC Executive Council or Assembly for including the candidate in the list of MCDS Centres.

Note: It is expected that this process, from submission of the MCDS Centre proposal to the JCOMM co-president, to formal approval by the WMO and IOC executive bodies, may take from 6 months to 2 years.

9.3.7.3 At times it may be necessary for a centre to be withdrawn from the MCDS Centre role. The approach proposed by JCOMM is the following:

(a) The body designated by JCOMM should review each centre for necessary capabilities and performance once every five years. If the review is favourable then the MCDS Centre can continue its role as before. If the review is not favourable then the JCOMM Data Management Coordination Group (DMCG) must insist on improvements to be made and these must be reviewed within one year. If the second review is still not favourable then the MCDS Centre role will be withdrawn from the centre through a recommendation by JCOMM and subsequent decision by the WMO Executive Council and IOC Assembly.

(b) If a centre no longer wishes to carry out the functions of a MCDS Centre, JCOMM should be advised immediately through the Secretariat.

9.3.7.4 Appendix 1 provides a summary of the scope, designation and evaluation of MCDS Centres. The detailed process of designation and evaluation criteria for establishing MCDS Centres and regularly evaluating their performances is provided in JCOMM (2017).

REFERENCES

Boyer, T.P., J.I. Antonov, O.K. Baranova, C. Coleman, H.E. Garcia, A. Grodsky, D.R. Johnson, R.A. Locarnini, A.V. Mishonov, T.D. O'Brien, C.R. Paver, J.R. Reagan, D. Seidov, I.V. Smolyar and M.M. Zweng, 2013: *World Ocean Database 2013* (S. Levitus, ed.; A. Mishonov, technical ed.). Series NOAA Atlas NESDIS 72. Silver Spring, MD, National Oceanographic Data Center, http://doi.org/10.7289/V5NZ85MT.

Freeman, E., S.D. Woodruff, S.J. Worley, S.J. Lubker, E.C. Kent, W.E. Angel, D.I. Berry, P. Brohan, R. Eastman, L. Gates, W. Gloeden, Z. Ji, J. Lawrimore, N.A. Rayner, G. Rosenhagen and S.R. Smith, 2016: ICOADS release 3.0: A major update to the historical marine climate record. *International Journal of Climatology*, 37(5):2211–2232 (doi:10.1002/joc.4775).

International Comprehensive Ocean-Atmosphere Data Set, 2016: R3.0-dupelim, http://icoads.noaa.gov/e-doc/R3.0-dupelim.pdf.

Intergovernmental Oceanographic Commission, 2011: Ocean Data Standards: Recommendation to adopt ISO 8601:2004 as the standard for the representation of dates and times in oceanographic data exchange. *IOC Manuals and Guides 54*, 2, https://www.iode.org/index.php?option=com_oe&task=viewDocumentRecord&docID=6665.

———, 2013: Ocean Data Standards: Recommendation for a Quality Flag Scheme for the exchange of oceanographic and marine meteorological data. *IOC Manuals and Guides 54*, 3, https://www.iode.org/index.php?option=com_oe&task=viewDocumentRecord&docID=10762.

Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology, 2003*a*: *Advances in the Applications of Marine Climatology – The Dynamic Part of the WMO Guide to the Applications of Marine Climatology*. JCOMM Technical Report No. 13 (WMO/TD–No. 1081). Geneva, World Meteorological Organization.

———, 2003*b*: *Proceedings of CLIMAR 99. WMO Workshop on Advances in Marine Climatology*. JCOMM Technical Report No. 10 (WMO/TD No. 1062). Geneva, World Meteorological Organization.

———, 2005: *Advances in the Applications of Marine Climatology – The Dynamic Part of the WMO Guide to the Applications of Marine Climatology*. JCOMM Technical Report No. 13 (WMO/TD–No. 1081). Revision 1, June 2005, https://www.wmo.int/pages/prog/amp/mmop/documents/J-TR-13-REV1.html; see also *Special Issue: Advances in Marine Climatology, International Journal of Climatology*, 25(7):821–1022.

———, 2008: Third JCOMM Workshop on Advances in Marine Climatology (CLIMAR-III) (Gdynia, Poland, 6–9 May). MeteoWorld, https://www.jcomm.info/index.php?option=com_oe&task=viewEventRecord&eventID=176.

———, 2011: *Advances in the Applications of Marine Climatology – The Dynamic Part of the WMO Guide to the Applications of Marine Climatology*. JCOMM Technical Report No. 13 (WMO/TD–No. 1081). Revision 2, June 2011, https://www.wmo.int/pages/prog/amp/mmop/documents/J-TR-13-REV2.html; see also *Special Issue: Achievements in Marine Climatology, International Journal of Climatology*, 31(7):949–1098.

———, 2014: *An Oceanographer's and Marine Meteorologist's Cookbook for Submitting Data and Metadata in Real Time and in Delayed Mode*. JCOMM Technical Report No. 72. World Meteorological Organization, Geneva.

———, 2015*a*: JCOMM Catalogue of Standards and Best Practices, http://www.jcomm.info/index.php?option=com_content&view=article&id=159&Itemid=23#catalogue.

———, 2015*b*: *Proceedings of the Fourth JCOMM Workshop on Advances in Marine Climatology (CLIMAR-4) and of the First ICOADS Value-added Database (IVAD-1) Workshop (Asheville, North Carolina, 9–13 June 2014)*. JCOMM Technical Report No. 79. Geneva, World Meteorological Organization, https://www.jcomm.info/index.php?option=com_oe&task=viewDocumentRecord&docID=15293.

———, 2017: *The JCOMM Marine Climate Data System (MCDS)*. JCOMM Technical Report. Geneva, World Meteorological Organization (in preparation).

Parker, D., E. Kent, S. Woodruff, D. Dehenauw, D.E. Harrison, T. Manabe, M. Mietus, V. Swail and S. Worley, 2004: The second JCOMM Workshop on Advances in Marine Climatology (CLIMAR-II). *WMO Bulletin*, 53(2).157–159.

Smith S.R., E. Freeman, S.J. Lubker, S.D. Woodruff, S.J. Worley, W.E. Angel, D.I. Berry, P. Brohan, Z. Ji, E.C. Kent, 2016: The International Maritime Meteorological Archive (IMMA) Format, http://icoads.noaa.gov/e-doc/imma/R3.0-imma1.pdf.

Snowden, D., M. Belbeoch, B. Burnett, T. Carval, J. Graybeal, T. Habermann, J. Snaith, H. Viola and S.D. Woodruff, 2010: Metadata management in global distributed ocean observation networks. In:

Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2) (Venice, Italy, 21–25 September 2009) (J. Hall, D.E. Harrison and D. Stammer, eds). ESA Publication WPP-306, http://www.oceanobs09.net/proceedings/cwp/cwp84/index.php.

Woodruff, S.D., 2007: Archival of data other than in IMMT format: The International Maritime Meteorological Archive (IMMA) Format. In: Second Session of the JCOMM Expert Team on Marine Climatology, (Geneva, 26–27 March 2007), JCOMM Meeting Report No. 50, Appendix A to Annex VII, 68–101, http://www.wmo.int/pages/prog/amp/mmop/documents/JCOMM-MR/J-MR-50_ETMC-II.pdf.

Woodruff, S.D., H.F. Diaz, S.J. Worley, R.W. Reynolds and S.J. Lubker, 2005: Early ship observational data and ICOADS. *Climatic Change*, 73(1–2):169–194.

World Meteorological Organization, 1994: *Guide to the Applications of Marine Climatology* (WMO-No. 781). Geneva.

———, 2004: *An International Seminar to Celebrate the Brussels Maritime Conference of 1853: An Historical Perspective of Operational Marine Meteorology and Oceanography Under the High Patronage of HM King Albert II of Belgium – Proceedings* (WMO/TD-No. 1226). JCOMM Technical Report No. 27. Geneva.

———, 2008: *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8). Geneva.

APPENDIX 1. MARINE CLIMATE DATA SYSTEM CENTRES (SCOPE, DESIGNATION AND EVALUATION)

1. **INTRODUCTION**

	DAC	*GDAC*	*CMOC*
Capabilities	Each centre must have, or have access to, the necessary infrastructure, facilities, experience and staff required to fulfil the approved functions		
		Each centre is recommended to be interoperable with WIS and/or IODE ODP	Each centre's data system must be interoperable with WIS and/or IODE ODP
	Each centre must be able to apply defined WMO and IOC international standards applicable for data and quality management	Each centre must be able to apply defined WMO and IOC international standards applicable for data and quality management or document current procedures as being utilized in MCDS.	Each centre must be able to apply defined WMO and IOC international standards applicable for data and quality management
			Mirroring CMOCs must be able to actively and reliably "mirror" (i.e., maintain mutually consistent) data, metadata, and products, as agreed within the CMOC
	The JCOMM DMCG must assess each centre at least once every five years to verify it meets the necessary capabilities and performance indicators as agreed by the Commission		
Functions and tasks	Each centre, within the confines of its agreed scope, must contribute to WMO and IOC applications by collecting and processing worldwide marine meteorological and/or oceanographic data and metadata (and optionally by mutually agreed CMOC-DAC products, e.g. regional statistics) as documented in appropriate WMO and IOC publications	Each centre, within the confines of its agreed scope, must contribute to WMO and IOC applications by collecting and processing worldwide marine meteorological and/or oceanographic data and metadata (and optionally by mutually agreed CMOC-GDAC products) as documented in appropriate WMO and IOC publications (and to the extent that these functions are not already carried out by other existing data centres, but are complimentary to the functions of these centres)	Each centre, within the confines of its agreed scope, must contribute to WMO and IOC applications (if appropriate in collaboration with DACs/GDACs), e.g. by rescuing, collecting, processing, archiving, sharing and distributing worldwide marine meteorological and/or oceanographic data and metadata, and to the extent that these functions are not already carried out by other existing data centres, but are complimentary to the functions of these other centres

	DAC	*GDAC*	*CMOC*
Functions and tasks			Each centre must provide advice to Members/Member States internationally in response to enquiries regarding standards and best practices, e.g. on data rescue, collection, processing, archival, and distribution of marine meteorological and/or oceanographic data, metadata and products, preferably by referring to the JCOMM/IODE ODSBP (pilot) project and its publications and/or the MCDS website
	Each centre, within the confines of its agreed scope, must receive and gather meteorological and/or oceanographic data (RT or DM) and metadata directly from the observation platforms	Each centre, within the confines if its agreed scope, must receive and assemble meteorological and/or oceanographic data (RT or DM) and metadata from the appropriate DAC	
		Each centre should identify duplicates within the dataset and ensure that they are resolved	Each centre should identify duplicates within the dataset and ensure that they are resolved, when not performed at the GDAC level
		Each centre should compare both RT and DM data streams, where they exist and are part of the scope of the GDAC	Each centre should compare both RT and DM data streams, where they exist, when not performed at the GDAC level
	Each centre must forward the data and metadata to the appropriate GDAC(s) in agreed format(s) within defined timescales	Each centre must forward the data and metadata to the appropriate CMOC(s) in agreed format(s) within defined timescales	
		Each centre is recommended to be interoperable with WIS and/or IODE ODP in order to make discovery metadata available	Each centre must make datasets, and corresponding metadata, within the confines of its scope, available and discoverable through WIS and/or IODE ODP

	DAC	*GDAC*	*CMOC*
Functions and tasks	Each centre must communicate and liaise within the DAC network and the wider MCDS		Each centre must communicate and liaise closely within the CMOC network and the wider MCDS; and particularly on the development and application of quality processes and procedures and on progress with their defined tasks
	Each centre must operate appropriate data-processing and agreed QC procedures within its scope as documented in appropriate WMO and IOC publications		Each centre must operate appropriate data-processing and higher QC procedures, and generate the required products within its scope
	Each centre must provide feedback to the platform operators if data problems are encountered	Each centre must provide feedback to the DACs on data quality issues	
			Mirroring CMOCs will mirror data, metadata, products and processes at defined timescales; the method of mirroring will be agreed upon among mirroring centres
			Data (e.g. instrumental metadata) and products managed within a CMOC will be subject to version control, and metadata history will be preserved, using procedures agreed upon within the MCDS
	Each centre should report on an annual basis to the JCOMM Management Committee through DMCG on its status and the activities carried out; JCOMM in turn should keep the Executive Councils of WMO and IOC informed on the status and activities of the DAC network as a whole, and proposed changes, as required	Each centre should report on an annual basis to the JCOMM Management Committee through DMCG on its status and the activities carried out; JCOMM in turn should keep the Executive Councils of WMO and IOC informed on status and activities of the GDAC network as a whole, and proposed changes, as required	Each centre should report, on an annual basis, to the JCOMM Management Committee through the DMCG on the services offered to Members/ Member States and the activities carried out; JCOMM in turn should keep the World Meteorological Congress and IOC Assembly informed on the status and activities of the CMOC network as a whole, and propose changes, as required

2. DATA ACQUISITION CENTRES

2.1 Terms of reference

2.1.1 A global network of appointed DACs will receive and gather meteorological and/or oceanographic data (RT or DM) and metadata directly from the observation platforms and then forward to the relevant GDAC.

2.1.2 Governance for defining the functions and designation of DACs is defined in the *Manual on Marine Meteorological Services* (WMO No. 558), Volume I, Appendix VII, 2, and paragraph 9.3.7 of the present Guide.

2.1.3 To meet MCDS requirements, DACs must have the following:

Scope:

Each DAC will define its scope of activities, that is, the types of observing platform(s) for which data shall be collected; whether these are collected nationally, regionally and/or from a specific ocean region of interest; and what QC standard is being applied to the data.

Capabilities:

(a) Each Centre must have, or have access to, the necessary infrastructure, facilities, experience and staff required to fulfil the approved functions;

(b) Each Centre must be able to apply defined WMO and IOC international standards applicable for data and quality management;

(c) The JCOMM DMCG must assess each centre at least once every five years to verify it meets the necessary capabilities and performance indicators as agreed by the Commission.

Corresponding functions and tasks:

(a) Each centre, within the confines of its agreed scope, must receive and gather meteorological and/or oceanographic data (RT or DM) and metadata directly from the observation platforms;

(b) Each centre must forward the data and metadata to the appropriate GDAC(s) in agreed format(s) within defined timescales;

(c) Each centre must have documented data-processing and QC procedures within its scope;

(d) Each centre must provide feedback to the platform operators if data problems are encountered;

(e) Each centre, within the confines of its agreed scope, must contribute to WMO and IOC applications by collecting and processing worldwide marine meteorological and/or oceanographic data and metadata (and optionally by mutually agreed CMOC-DAC products, for example regional statistics) as documented in appropriate WMO and IOC publications;

(f) Each centre must communicate and liaise within the DAC network and the wider MCDS;

(g) Each Centre should report on an annual basis to the JCOMM Management Committee through DMCG on its status and the activities carried out; JCOMM in turn should keep the Executive Councils of WMO and IOC informed on the status and activities of the DAC network as a whole, and proposed changes, as required.

Data policy and software licensing usage rights requirements:

A DAC must be committed to make all the data, metadata and products falling within the scope of the DAC network available to the international research community in a way consistent with WMO Resolution 40 (Cg-XII) – WMO policy and practice for the exchange of meteorological and related data and products including guidelines on relationships in commercial meteorological activities, and IOC Resolution IOC-XXII-6 – IOC oceanographic data exchange policy. Where applicable, software should also be shared.

2.2 List of established Data Acquisition Centres within the Marine Climate Data System

As part of the modernization of the former MCSS, now replaced by MCDS, the former MCSS contributing and responsible Members listed in the table below have been given the indicated DAC role in MCDS. Other former MCSS Members are expected to be confirmed upon approval.

Country DAC operated by	*Role in MCDS*
Germany	Contributing Member migrated to DAC for DM VOS data
Hong Kong, China	Contributing Member migrated to DAC for DM VOS data
India	Contributing Member migrated to DAC for DM VOS data in India's former area of responsibility in MCSS
Japan	Contributing Member migrated to DAC for DM VOS data
Russian Federation	Polar sea ice
United Kingdom	Contributing Member migrated to DAC for DM VOS data
United States	DAC for VOSClim Contributing Member migrated to DAC for United States DM data DAC for RT marine data from GTS

2.3 Evaluation criteria

	Criteria	*How do you meet the requirement?*
1	Centre must have, or have access to, the necessary infrastructure, facilities, experience and staff required to fulfil the approved functions	
2	Centre must be able to apply defined WMO and IOC international standards applicable for data and quality management	
3	Scope of the activities of the Centre to receive and gather meteorological and/or oceanographic data (RT or DM) and metadata directly from the observation platforms	
4	Centre must forward the data and metadata to the appropriate GDAC(s) in agreed format(s) within defined timescales	
5	Centre must have documented data-processing and QC procedures within its scope	
6	Centre must provide feedback to the platform operators if data problems are encountered	
7	Centre, within the confines of its agreed scope, must contribute to WMO and IOC applications by collecting and processing worldwide marine meteorological and / or oceanographic data and metadata (and optionally by mutually agreed CMOC-DAC products) as documented in appropriate WMO and IOC publications	

	Criteria	*How do you meet the requirement?*
8	Centre must communicate and liaise within the DAC network and wider MCDS	
9	Centre should report, on an annual basis, to the JCOMM Management Committee through DMCG on its status and the activities carried out. JCOMM in turn should keep the Executive Councils of WMO and IOC informed on status and activities of the DAC network as a whole, and proposed changes, as required	

3. GLOBAL DATA ASSEMBLY CENTRES

3.1 Terms of reference

3.1.1 A global network of appointed GDACs will assemble and perform QC on meteorological and/or oceanographic data (RT or DM) and metadata received from the appropriate DACs and then forward to relevant CMOC(s).

3.1.2 Governance for defining the functions and designation of GDACs is defined in the *Manual on Marine Meteorological Services* (WMO No. 558), Volume I, Appendix VII, 3, and paragraph 9.3.7 of the present Guide.

3.1.3 To meet MCDS requirements GDACs must have the following:

Scope:

Each GDAC will define its scope of activities, that is the types of observing platform(s) for which data shall be collected and compiled, and what QC standard is being applied to the data before submission to a CMOC.

Capabilities:

(a) Each centre must have, or have access to, the necessary infrastructure, facilities, experience and staff required to fulfil the approved functions;

(b) Each centre must be able to apply defined WMO and IOC international standards applicable for data and quality management;

(c) The JCOMM DMCG must assess each centre at least once every five years to verify it meets the necessary capabilities and performance indicators as agreed by the Commission;

(d) Each centre should be interoperable with WIS and/or IODE ODP, where feasible.

Corresponding functions and tasks:

(a) Each centre, within the confines if its agreed scope, must receive and assemble meteorological and/or oceanographic data (RT or DM) and metadata from the appropriate DAC;

(b) Each centre should identify duplicates within the dataset and if possible resolve duplication under agreed processes;

(c) Each centre, where both RT and DM data streams exist, should compare DM with RT data sources, and rectify any differences and/or duplicates between the different sources;

(d) Each centre must have documented data-processing and higher QC procedures within its scope;

(e) Each centre must provide feedback to DACs on data quality issues;

(f) Each centre should make discovery metadata available to WIS and/or IODE ODP, where feasible, noting that this is recommended but not mandatory;

(g) Each centre must forward the data and metadata to the appropriate CMOC(s) in agreed format(s) within defined timescales;

(h) Each centre, within the confines of its agreed scope, must contribute to WMO and IOC applications by collecting and processing worldwide marine meteorological and /or oceanographic data and metadata (and optionally by mutually agreed CMOC-GDAC products) as documented in appropriate WMO and IOC publications (and to the extent that these functions are not already carried out by other existing data centres, but are complimentary to the functions of these centres);

(i) Each centre must communicate and liaise within the GDAC network and the wider MCDS;

(j) Each centre should report on an annual basis to the JCOMM Management Committee through DMCG on its status and activities carried out. JCOMM in turn should keep the Executive Councils of WMO and IOC informed on status and activities of the GDAC network as a whole, and proposed changes, as required.

Data policy and software licensing usage rights requirements:

A GDAC must be committed to make all the data, metadata and products falling within the scope of the GDAC network available to the international research community in a way consistent with WMO Resolution 40 (Cg-XII) and IOC Resolution IOC-XXII-6. Where applicable, software should also be shared.

3.2 List of established Global Data Assembly Centres within the Marine Climate Data System

The following centres have been given the indicated roles as GDACs in MCDS:

GDAC	*Role in MCDS*
Specialized Oceanographic Centre for Drifting Buoys (France)	GDAC for RT drifting buoys
IODE Responsible National Oceanographic Data Centre for Drifting Buoys (Canada)	GDAC for DM drifting buoys
WMO GCCs (Germany and United Kingdom)	GDAC for DM VOS data

3.3 Evaluation criteria

	Criteria	*How do you meet the requirement*
1	Centre must have, or have access to, the necessary infrastructure, facilities, experience and staff required to fulfil the approved functions	
2	Centre must be able to apply defined WMO and IOC international standards applicable for data and quality management	
3	Centre should be interoperable with WIS and/or IODE ODP, where feasible; however this is not mandatory	

	Criteria	*How do you meet the requirement*
4	Scope of the activities of the centre as an MCDS GDAC	
5	Centre, within the confines if its agreed scope, must receive and assemble meteorological and/or oceanographic data (RT or DM) and metadata from the appropriate DAC	
6	Centre should identify duplicates within the dataset and if possible resolve duplication	
7	Each centre, where both RT and DM data streams exist, should compare DM with RT data sources, and rectify any differences and/or duplicates between the different sources	
8	Centre must have documented data-processing and higher QC procedures within its scope	
9	Centre must provide feedback to the DACs on data quality issues	
10	Centre should make discovery metadata available to WIS and/or IODE ODP, where feasible; however this is not mandatory	
11	Centre must forward the data and metadata to the appropriate CMOC(s) in agreed format(s) within defined timescales	
12	Centre, within the confines of its agreed scope, must contribute to WMO and IOC applications by collecting and processing worldwide marine meteorological and /or oceanographic data and metadata (and optionally by mutually agreed CMOC-GDAC products) as documented in appropriate WMO and IOC publications (and to the extent that these functions are not already carried out by other existing data centres, but are complimentary to the functions of these centres)	
13	Centre must communicate and liaise within the GDAC network and wider MCDS	
14	Centre should report on an annual basis to the JCOMM Management Committee through DMCG on its status and activities carried out. JCOMM in turn should keep the Executive Councils of WMO and IOC informed on status and activities of the GDAC network as a whole, and proposed changes, as required	

4. CENTRES FOR MARINE METEOROLOGICAL AND OCEANOGRAPHIC CLIMATE DATA

4.1 Terms of reference and evaluation criteria

The terms of reference and evaluation criteria of CMOCs are provided in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Appendix VII.

4.2 Governance

Governance for defining the functions and designation of CMOCs is defined in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Appendix VII, 4.

4.3 Centres for Marine Meteorological and Oceanographic Climate Data (established and proposed) within the Marine Climate Data System

CMOC	*Scope of duties within the MCDS*
CMOC-China	– Integrate marine meteorological and oceanographic climate drifting-buoy data and metadata, and actively conduct high-level QC and produce specialized datasets of essential climate and ocean variables – Actively participate in the research and development of oceanographic and marine meteorological products, and their related services: climate statistical products and reanalysis products – 7 X 24 operation website to provide free services to users, and mirroring with other CMOCs when possible – Provide technical training, and carry out capacity-building activities for countries in the region
CMOC-WOD (application being prepared for submission)	– Collection, archive and management of global profile observations from multiple sources including DACs and GDACs within the MCDS – Monthly summary statistics and climate products – Development and advice to other Members

APPENDIX 2. MULTILINGUAL LIST OF COMMON TERMS USED IN MARINE METEOROLOGICAL SERVICES

LISTE MULTILINGUE DES TERMES UTILISÉS DANS LE CADRE DES SERVICES DE MÉTÉOROLOGIE MARITIME

LISTA MULTILINGÜE DE TÉRMINOS UTILIZADOS EN LOS SERVICIOS METEOROLÓGICOS MARINOS

МНОГОЯЗЫЧНЫЙ ПЕРЕЧЕНЬ ТЕРМИНОВ, ИСПОЛЬЗУЕМЫХ В МОРСКОМ МЕТЕОРОЛОГИЧЕСКОМ ОБСЛУЖИВАНИИ

English	*Français*	*Español*	*Русский*
Standards of time	Unités de temps	Unidades de tiempo	Единица времени
Universal time coordinated (UTC)	Temps universel coordonné (UTC)	Tiempo universal coordinado (UTC)	Всемирное скоординированное время (ВСВ)
Zone time	Heure du fuseau	Zona horaria	поясное время
Summer time	Heure d’été	Hora de verano	летнее время
Local time	Heure locale	Hora local	местное время
Periods of time	Périodes de temps	Períodos de tiempo	Периоды времеии
Six hours	Six heures	Seis horas	шесть часов
Twelve hours	Douze heures	Doce horas	двенадцать часов
Eighteen hours	Dix-huit heures	Dieciocho horas	восемнадцать часов
Twenty-four hours	Vingt-quatre heures	Veinticuatro horas	двадцать четыре часа
Thirty-six hours	Trente-six heures	Treinta y seis horas	тридцать шесть часов
Forty-eight hours	Quarante-huit heures	Cuarenta y ocho horas	сорок восемь часов
Today	Aujourd’hui	Hoy	сегодня
Tomorrow	Demain	Mañana	завтра
Next few days	Les prochains jours	Los próximos días	следующие несколько дней
Morning	Matin	Mañana	утро
Evening	Soir	Tarde, noche	вечер
Midday	Midi	Mediodía	полдень
Afternoon	Après-midi	Tarde	после полудня
Day	Jour	Día	день
Night	Nuit	Noche	ночь
Sunrise	Lever du soleil	Orto ó amanecer	восход
Sunset	Coucher du soleil	Ocaso	заход
Preliminary terms	Termes préliminaires	Términos preliminares	Предварительные термины
Forecast	Prévision	Previsión, pronóstico	прогноз
Further outlook	Tendance ultérieure	Evolución probable Perspectivas futuras	вероятная эволюция, дальнейшие перспективы

English	*Français*	*Español*	*Русский*
General inference	Situation générale et évolution	Situación general y evolución	общий вывод
General statement	Situation générale	Situación general	общее описание положения
Long-range forecast	Prévision à longue échéance	Previsión a largo plazo	долгосрочный прогноз
Medium-range forecast	Prévision à moyenne échéance	Previsión a medio plazo	среднесрочный прогноз
Short-range forecast	Prévision à courte échéance	Previsión a corto plazo	краткосрочный прогноз
Synoptic situation	Situation synoptique	Situación sinóptica	синоптическое положение, синоптическая ситуация
Warning	Avis	Aviso	предупреждение
Terms of position	Termes de position	Términos de posición	Термины положения
Degrees	Degrés	Grados	градусы
Latitude	Latitude	Latitud	широта
Longitude	Longitude	Longitud	долгота
Quadrant	Quadrant	Cuadrante	квадрант
Hemisphere	Hémisphère	Hemisferio	полушарие
North	Nord	Norte	север
South	Sud	Sur	юг
East	Est	Este	восток
West	Ouest	Oeste	запад
District	District	Distrito	район
Parallel	Parallèle	Paralelo	параллель
Meridian	Méridien	Meridiano	меридиан
Square	Carré	Cuadrado	квадрат
Bearing	Relèvement	Rumbo	пеленг
Direction	Direction	Dirección	направление
Track	Trajectoire,route	Trayectoria	путь, траектория
Area	Zone	Área,zona	область, район
Line	Ligne	Línea	линия
Storm warnings	Avis de tempête	Avisos de temporales	Штормовые предупреждения
Gale warning	Avis de coup de vent	Aviso de viento duro	штормовое предупреждение
Storm warning	Avis de tempête	Aviso de temporal	штормовое предупреждение
Hurricane warning	Avis d'ouragan	Aviso de huracán	предупреждение об урагане
Blizzard	Blizzard	Blizzard, ventisca	близзард
Tropical storms	Cyclones tropicaux	Ciclones tropicales	Тропические штормы
Tropical cyclone	Cyclone tropical	Ciclón tropical	тропический циклон
Hurricane	Ouragan	Huracán	ураган
Typhoon	Typhon	Tifón	тайфун
Baguio	Baguio	Baguio	багуйо
Pressure systems	Systèmes de pression	Sistemas de presión	Барические системы
Area of low pressure	Zone de basses pressions	Área de bajas presiones	область пониженного давления

English	*Français*	*Español*	*Русский*
Low	Dépression	Depresión barométrica	циклон
Trough	Creux	Vaguada	ложбина
Area of high pressure	Zone de hautes pressions	Área de altas presiones	область высокого давления
High	Anticyclone	Anticiclón	антициклон
Ridge of high pressure	Dorsale, crête barométrique	cresta de alta presión	гребень высокого давления
Belt of high pressure	ceinture de hautes pressions	cinturón de altas presiones	пояс высокого давления
Belt of low pressure	ceinture de basses pressions	cinturón de bajas presiones	пояс низкого давления
Col	col barométrique	collado	седловина
Hyperbolic point	Point hyperbolique	Punto hiperbólico	гиперболическая точка
Cyclolysis	cyclolyse	ciclólisis	циклозиз
Cyclogenesis	cyclogenèse	ciclogénesis	циклогенез
Anticyclolysis	Anticyclolyse	Anticiclólisis	антициклолиз
Anticyclogenesis	Anticyclogenèse	Anticiclogénesis	антициклогенез
Air mass nomenclature	Nomenclature des masses d'air	Nomenclatura de las masas de aire	Классификация воздушных масс
Air mass	Masse d'air	Masa de aire	воздушная масса
Stable air mass	Masse d'air stable	Masa de aire estable	устойчивая масса
Unstable air mass	Masse d'air instable	Masa de aire inestable	неустойчивая масса
Cold air	Air froid	Aire frío	холодная масса
Arctic air	Air arctique	Aire ártico	арктический воздух
Antarctic air	Air antarctique	Aire antártico	антарктический воздух
Polar air	Air polaire	Aire polar	полярный воздух
Warm air	Air chaud	Aire caliente, aire cálido	теплый воздух
Tropical air	Air tropical	Aire tropical	тропический воздух
Subtropical air	Air subtropical	Aire subtropical	субтропический воздух
Equatorial air	Air équatorial	Aire ecuatorial	экваториальный воздух
Maritime air	Air maritime	Aire marítimo	морской воздух
Continental air	Air continental	Aire continental	континентальный воздух
Winter monsoon	Mousson d'hiver	Monzón de invierno	зимний муссон
Summer monsoon	Mousson d'été	Monzón de verano	летний муссон
Front nomenclature	Nomenclature des fronts	Nomenclatura de los frentes	Классификация фронтов
Front	Front	Frente	фронт
Polar front	Front polaire	Frente polar	полярный фронт
Cold front	Front froid	Frente frío	холодный фронт
Secondary cold front	Front froid secondaire	Frente frío secundario	вторичный холодный фронт
Warm front	Front chaud	Frente caliente	теплый фронт
Occlusion	Occlusion	Oclusión	окклюзия
Cold occlusion	Occlusion à caractère de front froid	Oclusión fría	окклюзия по типу холодного фронта
Warm occlusion	Occlusion à caractère de front chaud	Oclusión caliente	окклюзия по типу теплого фронта
Upper front	Front en altitude	Frente en altura	верхний фронт

English	*Français*	*Español*	*Русский*
Intertropical front	Front intertropical	Frente intertropical	внутритропический фронт
Frontal wave	Onde frontale	Onda frontal	фронтальная волна
Frontogenesis	Frontogenèse	Frontogénesis	фронтогенез
Frontolysis	Frontolyse	Frontólisis	фроптолиз
Weather	Temps	Tiempo	Погода
Precipitation	Précipitation	Precipitación	Осадки
Rain	Pluie	Lluvia	дождь
Freezing rain	Pluie verglaçante	Lluvia engelante	переохлажденный дождь
Rain and snow	Pluie et neige mêlées	Lluvia y nieve mezcladas	дождь со снегом
Supercooled rain	Pluie surfondue	Lluvia subfundida	переохлажденный дождь
Snow	Neige	Nieve	снег
Snow pellets	Neige roulée	Nieve granulada	снежная крупа
Snow grains	Neige en grains	Cinarra, gragea	снежные зерна
Drizzle	Bruine	Llovizna	морось
Hail	Grêle	Granizo	град
Diamond dust	Poudrin de glace	Polvillo de hielo	алмазная пыль
Ice pellets	Granules de glace	Gránulos de hielo	ледяной дождь
Small hail	Grésil	Granizo menudo	ледяная крупа
Shower	Averse	Chubasco	Ливень
Tornado	Tornade	Tornado	торнадо
Willy-willy	Willy-willy	Willy-willy	вилли-вилли
Visibility	Visibilité	Visibilidad	Видимость
Fog	Brouillard	Niebla	туман
Mist	Brume	Neblina	дымка
Haze	Brume sèche	Calima	мгла
Duststorm	Tempête de poussière	Tempestad de polvo	пыльная буря
Sandstorm	Tempête de sable	Tempestad de arena	песчаная буря
Spray	Embruns	Rociones	водяная пыль
Drifting snow	Chasse-neige basse	Ventisca baja	поземок
Blowing snow	Chasse-neige élevée	Ventisca alta	низовая метель
Miscellaneous	Divers	Misceláneos	Дополнительные термины
Cloud	Nuage	Nube	облако
Clearing up	Se dissipant	Despejando(se)	прояснение
Squall line	Ligne de grains	Turbonada en línea	линейный шквал
Whirlwind	Tourbillon de vent	Remolino de viento	вихрь
Water spout	Trombe marine	Tromba marina	смерч
Frost, freezing	Gelée, gel	Helada	мороз, заморозок
Rime	Givre blanc	Cencellada blanca	изморозь
Glaze	Givre transparent	Cencellada transparente	ледяной налет
Smoke	Fumée	Humo	дым
Thunderstorm	Orage	Tormenta	гроза
Thunder	Tonnerre	Trueno	гром
Lightning	Éclair	Relámpago	молния
Wind	Vent	Viento	Ветер
General terms	Termes généraux	Términos generales	Общие термины

English	*Français*	*Español*	*Русский*
Beaufort scale	Échelle Beaufort	Escala Beaufort	шкала Бофорта
Calm	Calme	Calma	штиль
Light air	Très légère brise	Ventolina	очень слабый ветер
Light breeze	Légère brise	Flojito (viento), brisa muy débil	слабый ветер
Gentle breeze	Petite brise	Flojo (viento), brisa débil	ветер от слабого до умеренного
Moderate breeze	Jolie brise	Bonancible (viento), brisa moderada	умеренный ветер
Fresh breeze	Bonne brise	Fresquito (viento), brisa fresca	свежий ветер
Strong breeze	Vent frais	Fresco (viento), brisa fuerte	сильный ветер
Near gale	Grand frais	Frescachón, viento fuerte	очень сильный ветер
Gale	Coup de vent	Viento duro	штормовой ветер
Strong gale	Fort coup de vent	Viento muy duro	шторм
Storm	Tempête	Tormenta, tempestad, temporal	сильный шторм — буря
Violent storm	Violente tempête	Temporal duro, orrasca	жестокий шторм
Hurricane	Ouragan	Huracán	ураган
Gust	Rafale	Ráfaga, racha	порыв
Squall	Grain	Turbonada	шквал
Sea breeze	Brise de mer	Brisa de mar	морской бриз
Land breeze	Brise de terre	Brisa de tierra	береговой бриз
Prevailing wind	Vent dominant	Viento dominante	господствующий ветер
Shift of wind	Saute de vent	Salto de viento	поворот ветра
Veering (clockwise change in direction)	Virant/Rotation du vent (dans le sens des aiguilles d'une montre)	Cambio de dirección (en el sentido de las agujas del reloj)	менять направление по часовой стрелке
Backing (anticlockwise change in direction)	Revenant/Rotation du vent (dans le sens contraire des aiguilles d'une montre)	Cambio de dirección (en el sentido contrario de las agujas de reloj)	менять направление против часовой стрелки
Local names	Noms locaux	Nombres locales	Местные названия
Trade winds (trades)	Alizés	Vientos alisios (alisios)	пассаты
Bora	Bora	Bora	бора
Mistral	Mistral	Mistral	мистраль
Sirocco	Sirocco	Siroco	сирокко
Gregale	Grégal	Gregal	грегаль
Levanter	Levante	Levante	левантин, южный ветер
Norther	Norther	Nortada	северный ветер
Ice	Glace	Hielo	Лед
(See: *Sea-ice Nomenclature* (WMO-No. 259) for a complete glossary)			
Bergy bit	Fragment d'iceberg	Tempanito	обломок айсберга
Brash ice concentration	Concentration en brash (sarrasins)	Concentración de escombro de hielo	ледяная каша — сплоченность
Past ice	Banquise côtière	Hielo fijo	припай
First-year ice	Glace de première année	Hielo del primer año	однолетний лед
Flaw	Brèche de séparation	Grieta	полоса тертого льда

English	*Français*	*Español*	*Русский*
Floe	Floe	Bandejón	ледяное поле
Frazil	Frasil	Cristales de hielo	иглы
Grease ice	Sorbet	Hielo grasoso	ледяное сало
Grey ice	Glace grise	Hielo gris	серый лед
Grey-white ice	Glace blanchâtre	Hielo gris blanco	серо-белый лед
Growler	Bourguignon	Gruñón	кусок айсберга
Hummocked ice	Glace hummockée	Hielo amonticulado	торосистый лед
Iceberg	Iceberg	Témpano	айсберг
Ice boundary	Ligne de démarcation de glaces	Frontera del hielo	ледовая граница
Ice edge	Lisière de glace	Borde del hielo	кромка льда
Ice field	Champ de glace	Campo de hielo	скопление дрейфующего льда
Ice limit	Limite des glaces	Límite del hielo	крайняя граница льда
Ice patch	Banc de glace	Manchón de hielo	пятно льда
Ice rind	Glace vitrée	Costra de hielo	склянка
Ice shelf	Plateau de glace	Meseta de hielo	шельфовый ледник
Level ice	Glace plane	Hielo plano	ровный лед
New ice	Nouvelle glace	Hielo nuevo	начальные виды льда
Nilas	Nilas	Nilas	нилас
Pack ice	Banquise	Hielo a la deriva	дрейфующий лед
Pancake ice	Glace en crêpes	Hielo panqueque	блинчатый лед
Polynya	Polynie	Polinia	полынья
Rafted ice	Glace entassée ou empilée	Hielo sobreescurrido	наслоенный лед
Shore lead	Chenal côtier	Canal costero	прибрежная прогалина
Shuga	Shuga	Shuga	шуга
Slush	Gadoue	Pasta o grumo	снежура
Young ice	Jeune glace	Hielo joven	молодой лед
Miscellaneous nautical terms	Termes nautiques divers	Términos náuticos diversos	Разные морские термины
Sea	Mer	Mar	море
Sea level	Niveau de la mer	Nivel del mar	уровень моря
Horizon	Horizon	Horizonte	горизонт
Tsunami	Tsunami	Tsunami	цунами
Swell	Houle	Mar de fondo	зыбь
Tide	Marée	Marea	морской прилив и отлив
Surge, storm surge	Lame de fond	Oleada, ola de tormenta	крутое волнение
Surf	Déferlement	Resaca	прибой
Breakers	Brisants	Rompientes	буруны
Wave	Vague	Ola	волна
Wavelet	Vaguelette	Ola pequeña	небольшая волна
General descriptive terms	Termes descriptifs généraux	Términos descriptivos generales	Общие писательные термины
Slight	Faible (léger)	Leve	незначительный
Moderate	Modéré	Moderado	умеренный
Violent	Violent	Violento	жестокий
Heavy	Fort (gros)	Fuerte	тяжелый

English	*Français*	*Español*	*Русский*
Strong	Fort	Fuerte	сильный
Dry	Sec	Seco	сухой
Damp	Humide	Húmedo	влажный
In patches	Par plaques, en bancs	En bancos	в кусках, разрывной
Extensive	Étendu	Extenso	обширный, пространный
Low	Bas	Baja	низкий
High	Haut, élevé	Alta	высокий
Rough	Forte	Duro	бурный
Recurve	Se recourber	Recurvarse	поворачивать
Quickly	Rapidement	Rápidamente	скоро
Slowly	Lentement	Lentamente	медленно
Filling up	Se comblant	Llenándose	заполнение
Increasing	Croissant, augmentant	Aumentando	увеличение
Decreasing	Décroissant, diminuant	Disminuyendo	уменьшение
Breaking up	Se dissolvant	Disipándose	разрушение
Poor	Mauvais	Malo	плохой
Good	Bon	Bueno	хороший
Spreading	S’étendant	Extendiéndose	распространение
Occasional	Occasionnel	Ocasional	случайный
Continuous	Continu	Continuo	непрерывный, продолжительный
Intermittent	Intermittent	Intermitente	прерывистый
At times	De temps à autre	A veces	иногда, по временам
Immediately	Immédiatement	Inmediatamente	немедленно, непосредственно
Early	Tôt	Temprano	рано
Late	Tard	Tarde	поздно
Later	Plus tard, par la suite	Luego, más tarde	позже

For more information, please contact:

World Meteorological Organization

7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland

Communication and Public Affairs Office

Tel.: +41 (0) 22 730 83 14/15 – Fax: +41 (0) 22 730 80 27

Email: cpa@wmo.int

public.wmo.int

JN 18695