Guidebook for Enhancing Resilience of European Maritime Transport in Extreme Weather Events
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### List of abbreviations

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<tr>
<td>C-MAN</td>
<td>Coastal-Marine Automated Network</td>
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<tr>
<td>DART</td>
<td>Deep-ocean Assessment and Reporting of Tsunamis</td>
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<td>DSC</td>
<td>Digital Selecting Calling</td>
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<td>ECMWF</td>
<td>European Center for Medium range Weather Forecasting</td>
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<td>EGC</td>
<td>Enhanced Group Call</td>
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<td>EWENT</td>
<td>Extreme Weather impacts on European Networks of Transport</td>
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<tr>
<td>GFS</td>
<td>Global Forecast System</td>
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<td>GMDSS</td>
<td>Global Maritime Distress and Safety System</td>
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<td>GOES</td>
<td>Geostationary Operational Environmental Satellites</td>
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<td>HSC</td>
<td>High-Speed Craft</td>
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<td>IMCO</td>
<td>Inter-Governmental Maritime Consultative Organization</td>
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<td>IMO</td>
<td>International Maritime Organization</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>JTWC</td>
<td>Joint Typhoon Warning Center</td>
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<td>LNG</td>
<td>Liquid Gas Plant</td>
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<td>MARPOL</td>
<td>International Convention for the Prevention of Pollution from Ships</td>
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<td>MEPC</td>
<td>Marine Environment Protection Committee</td>
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<td>MF</td>
<td>Medium Frequency</td>
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<td>MODU</td>
<td>Mobile offshore drilling unit</td>
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<td>MSI</td>
<td>Maritime Safety Information</td>
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<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<td>NAVTEX</td>
<td>Navigational Telex</td>
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<td>NCOM</td>
<td>Navy Coastal Ocean Model</td>
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<td>NBDP</td>
<td>Narrow Band Direct Printing</td>
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<td>NCEP</td>
<td>National Center for Environmental Prediction</td>
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<td>NDBC</td>
<td>National Data Buoy Center</td>
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<td>NESDIS</td>
<td>National Environmental Satellite, Data, and Information Service</td>
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<td>Abbreviation</td>
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<tr>
<td>NIMA</td>
<td>National Imagery and Mapping Agency</td>
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<td>NLS</td>
<td>Noxious Liquid Substance</td>
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<td>NMC</td>
<td>National Meteorological Center</td>
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<td>NMHS</td>
<td>National Meteorological and Hydrological Services</td>
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<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
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<td>NOGAPS</td>
<td>US Navy Operational Global Atmospheric Prediction System</td>
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<td>NTWC</td>
<td>National Tsunami Warning Center</td>
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<td>NWR</td>
<td>NOAA Weather Radio</td>
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<td>NWS</td>
<td>National Weather Service</td>
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<td>OVR</td>
<td>Optimum Voyage Routing</td>
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<td>PTWC</td>
<td>Pacific Tsunami Warning Center</td>
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<td>RO-RO</td>
<td>Roll-on/roll-off</td>
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<td>SFV</td>
<td>Safety of Fishing Vessels</td>
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<td>SPOS</td>
<td>Ship Performance Optimisation System</td>
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<td>SPS</td>
<td>Special purpose ship</td>
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<td>SOLAS</td>
<td>International Convention for the Safety of Life at Sea</td>
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<td>SVR</td>
<td>Severe Weather Warning</td>
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<td>TAO</td>
<td>Tropical Atmosphere Ocean</td>
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<td>TOR</td>
<td>Tornado Warning</td>
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<tr>
<td>USCG</td>
<td>United States Coast Guard</td>
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<tr>
<td>VHF</td>
<td>Very high frequency</td>
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<td>VOS</td>
<td>Volunteer Observing Ships</td>
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<td>VTS</td>
<td>Vessel Tracking Service</td>
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<tr>
<td>WMO</td>
<td>World Meteorological Organization</td>
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<tr>
<td>WRF</td>
<td>Weather Research and Forecasting Model</td>
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The MOWE-IT project: The goal of the MOWE-IT project is to identify existing best practices and to develop methodologies to assist transport operators, authorities and transport system users to mitigate the impact of natural disasters and extreme weather phenomena on transport system performance. The project is funded by the European Commission’s 7th RTD framework programme between October 2012 and September 2014. MOWE-IT is co-ordinated by the Technical Research Centre Finland (VTT) and involves 12 European research institutes and companies. For more details please consult our website www.mowe-it.eu.

This document contains draft guidelines and recommendations for the improvement of resilience of maritime transport operations in extreme weather conditions. This guidebook will cover open sea, coastal waters and port operations, which all have different weather conditions as disturbance factors and against which a greater resilience can be built.

A number of recommendations and guidelines for the reduction of weather impacts on maritime transport were synthesised from the experiences collected through site visits and existing literature. Following sections of this guidebook will discuss each situation separately and the guidebook ends with recommendations on long-term and short-term measures on how to improve the resilience.

Open Sea Operations

IMO and other existing regulations and standards

Safety first – this is the main goal of the International Maritime Organization (IMO) through the years. It has always been recognized that the best way of improving safety at sea is by developing international regulations that are followed by all shipping nations and from the mid-19th century onwards a number of such treaties were adopted. Several countries proposed that a permanent international body should be established to promote maritime safety more effectively, but it was not until the establishment of the United Nations itself that these hopes were realized.

Today, IMO standards and instructions are one of the keys to safe and efficient open sea operations.

While there are no universally applicable definitions of ship types, specific descriptions and names are used within IMO treaties and conventions. These are listed in Annex 1 of this guidebook.

In order to meet-up requirements accordingly to various conditions, it is convenient to use determination on sea areas given by the Global Maritime Distress and Safety System (GMDSS) and officially stated in the International Convention for the Safety of Life at Sea (SOLAS). GMDSS sets 4 different areas according to the number and type of radio safety equipment ships have to carry depending upon its tonnage.
Sea Area A1. An area within the radiotelephone coverage of at least one very high frequency (VHF) coast station in which continuous digital selective calling (Ch.70/156.525 MHz) alerting and radiotelephony services are available. Such an area could extend typically 30 nautical miles (56 km) to 40 nautical miles (74 km) from the Coast Station.

Sea Area A2. An area, excluding Sea Area A1, within the radiotelephone coverage of at least one Medium frequency (MF) coast station in which continuous Digital Selecting Calling (DSC) (2187.5 kHz) alerting and radiotelephony services are available. For planning purposes, this area typically extends to up to 180 nautical miles (330 km) offshore during daylight hours, but would exclude any A1 designated areas. In practice, satisfactory coverage may often be achieved out to around 400 nautical miles (740 km) offshore during night time.

Sea Area A3. An area, excluding sea areas A1 and A2, within the coverage of an Inmarsat geostationary satellite. This area lies between about latitude 76 Degree NORTH and SOUTH, but excludes A1 and/or A2 designated areas. Inmarsat guarantees their system will work between 70 South and 70 North though it will often work to 76 degrees South or North.

Sea Area A4. An area outside Sea Areas A1, A2 and A3 is called Sea Area A4. This is essentially the polar regions, north and south of about 76 degrees of latitude, excluding any A1 or A2 areas.

These sea areas are shown in Figure 1.

![Figure 1: Sea areas according to SOLAS.](image)

Weather information from authorities

There is a lot of different weather data that can be obtained in modern world from open and official sources. But which one is officially recognized, reliable, useful and efficient? World Meteorological Organization (WMO) is the key player and recognized supplier of necessary weather information.

The Maritime Safety Information (MSI) service is an internationally co-ordinated network of broadcasts of Maritime Safety Information. This information contains:

- Navigational warnings
- Meteorological information (forecasts and warnings)
- Distress alerts
MSI is part of the Global Maritime Distress and Safety System (GMDSS). Every ship, while at sea, has to be capable of transmitting and receiving maritime safety information. Reception of MSI is free of charge to all ships. MSI is transmitted by a variety of means, using terrestrial and satellite radio communications. The GMDSS supports two independent systems to broadcast Maritime Safety Information (MSI):

- NAVTEX, MF terrestrial radio to cover many coastal areas
- SafetyNET, using the Inmarsat-C Enhanced Group Call (EGC), covering the entire Inmarsat ocean regions including coastal areas

To ensure that the ships know when to receive MSI for a given area and subject, many of the MSI broadcasts are scheduled, under IMO co-ordination, to a particular time, Land Earth Station and Ocean Region.

As per IMO Assembly Resolution A.706(17) adopted 6 November 1991 global ocean is divided on 21 different regions (NAVAREAS or METAREAS) and each government is responsible for navigation and weather warnings (see Figure 2). Necessary information is delivered to recipients via Inmarsat SafetyNET system within the framework of the WMO Marine Broadcast System for the GMDSS in all Sea Areas (A1-A4).

Figure 2: NAVAREA areas

NAVTEX (Navigational Telex) is a major element of the GMDSS. SOLAS mandated certain classes of vessels must carry NAVTEX, beginning August 1, 1993. NAVTEX is an international automated medium frequency direct-printing service for delivery of navigational and meteorological warnings and forecasts, as well as urgent marine safety information to ships. NAVTEX was developed to provide a low-cost, simple, and automated means of receiving this information aboard ships at sea within approximately 370 km (200 nautical miles) off shore. There are no user fees associated with receiving NAVTEX broadcasts, as the transmissions are typically transmitted
from the National Weather Authority (Italy) or Navy or Coast Guard (as in the US) or national navigation authority (Canada).

Radiofax, also known as weatherfax and HF Fax is also a good source of useful and reliable weather information. Radiofax is used worldwide for the dissemination of weather charts, satellite weather images, and forecasts. The oceans are covered by coastal stations in various countries and transmit necessary information as per stipulated schedule on fixed HF frequencies.

Description of navigation systems

IT sector is the one of the fast growing sectors of world economy. So it is completely clear that future navigational systems have to work in synergy between all chains related to utilization of navigational information and be able to issue such kind of “decision makers”. Crew on board should be able to simulate forthcoming condition changes. Such changes are already made and subsequently cooperation would improve only. Such kind of systems can be explored through the example of Ship Performance Optimisation System (SPOS) Onboard system developed by MeteoGroup UK Limited.

SPOS Onboard is the onboard weather routing system. With SPOS Onboard the ship’s route can be optimised, taking into account sea conditions such as waves, currents and swells, and wind and other weather elements.

SPOS has timely updates ensuring crew is always aware of the surrounding and forecasted weather. SPOS is designed to enable captain and crew to adjust route calculations according to the weather information provided and the ship’s specific characteristics. The captain can then chart the optimum route (both in terms of safety and efficiency) for his ship in prevailing conditions.

SPOS onboard ensures vessels navigate the globe safely and efficiently, reducing fuel consumption and contributing to a clean environment.

SPOS has been designed to improve vessel performance and increase safety for crew, vessel and cargo. Instead of providing the master with a predefined route, SPOS provides detailed weather information onboard, as well as advice and support during the planning and execution of ocean voyages. Weather forecasts are received daily via e-mail and weather maps can be displayed on screen or printed. Captain and crew can enter and update vessel and voyage data during transit. Taking into account weather, ocean current and ship characteristics, SPOS calculates the optimum route and sets out alternatives. System allows to save best route and update with the latest weather forecast each day.

However, even WMO has recognized the existence of challenges with the quality and reliability of weather forecasts and that, despite the advances that have been achieved in the field, there is much room for growth and improvement. These challenges are outlined in their 2009 report as well as in World Bank 2013 report. Challenges and solutions listed include the modernization and investment in well-equipped and fully staffed meteorological and hydrological agencies, promotion of cooperation between said agencies, addressing technical and technological challenges such as the quality as well as the spatial and temporal resolution of meteorological data and their dissemination platforms, equipment maintenance or replacement with newer ones, etc.
Weather information provision, from official sources and on-board

A lot of experienced meteorologists all over the world and oceanology experts are talking about global warming. Some people agree, some – no. But everybody admits that weather events have become more sharp, vivid and extreme. European territory is not exclusion. Nonchalance costs are high. From the very beginning ships’ officers trained not only to use simultaneous weather information sources and compare results, but also be able to observe and make conclusions of current weather situation. Such approach was tested by good maritime practice and proved it efficient. Through the last 10-20 years vessels traffic overturn raised up significantly, therefore, ship’s crew could experience great lack of time for necessary weather observations. This argument has no excuses so weather routing systems of new age are going to deliver the most valuable, accurate and useful information with accent on ships technical condition and description. Narrow focus on ships’ seaworth conditions and specialization is going to be a cost efficient choice. Ship’s crew has no time and possibilities to predict and evaluate wave height at their route, but it could be done by a shore provider who has access not only to real-time weather data, but also to the archive of weather event at a particular area. Synergy between crew on board and shore based personnel together with improvement of technical equipment at both parties will enable to create fruitful, efficient and smooth cooperation and make sea not only safer but also more predictable.

There are excellent weather information, forecasting and route planning, services available to assist in navigational decision-making. However, ships’ captains and global shipping companies that utilise them report there are occasions where separate agencies advise contradictory actions; and at the commercial level poor forecasting is seen as the cause of additional costs. Discussing this issue with all parties suggests there is an information gap – reliable observation data.

For example, a vessel has its own wind sensors. It looks at its local data and compares it to the forecast, if the two are in some agreement; there is a level of confidence. However, this is here and now - type of confidence. Envisioning the route and conditions a few hours ahead our confidence gets less and less the further we go forward in time.

Today’s technology allows us to bridge this gap. Observational surface data from vessels can be made available in near real-time to enable ships’ decision makers to see what their fellow mariners are actually experiencing ahead. If we can assure that the observational data collected is reliable quality data, then our decision makers can see when the forecast data they are looking at is compromised. It also means the forecast agencies can see how their current forecasts are performing, enabling them to issue higher quality and more reliable updates.

This model is used with great success in other areas of transport and we have seen significant undisputable forecast accuracy improvement over the years.

Imagine, as an example, you have a Lloyd’s Register ship, and as part of that register the reliability of its wind observation equipment is certified. That could be the ticket which enables your ship’s captain to see a map of near real-time surface observation data from other Lloyd’s Register vessels on the route ahead. This greatly enhances the belief in the weather forecast. With some 4,000 Lloyd’s Register vessels potentially feeding into a reliable map of current and recent surface conditions, the open sea becomes a safer and more economical place to operate.

Similar systems are already available from Vaisala for other transport needs. Vaisala operates a global bureau that centrally collects the observational data (in this case via Inmarsat or similar),
processes the data for quality and reliability, and makes the time-stamped data available to decision makers and forecasters in near real-time. The real-time data is typically plotted over the latest forecast data enhancing forecast confidence, or a call for a forecast model update.

Of course we are not limited to wind data - temperature, humidity, barometric pressure, visibility and precipitation, are all elements of surface weather data that can be automatically collected and disseminated in the open sea environment.

**Presentation of best international practices: U.S. Coast guard; a benchmark of efficiency**

In the U.S., information on weather for the coastal areas is provided by the Marine and Coastal Weather Services Branch of the National Weather Service (NWS). The area of responsibility, apart from the U.S. coastal waters includes offshore waters, the Great Lakes of the American Northeast, and the open oceans.

NWS marine weather forecasters issue wind, sea state, and significant weather warnings, forecasts, and weather statements by using radar, satellite, and in-situ observational data along with the weather analyses and forecast guidance provided by the National Center for Environmental Prediction (NCEP).

Data from the National Data Buoy Center (NDBC), another part of the NWS, are also utilized in coastal weather predictions. Apart from a number of about 90 buoys, the NDBC uses the Coastal-Marine Automated Network (C-MAN) which consists of about sixty stations installed on lighthouses, at capes and beaches, on near shore islands, and on offshore platforms. The stations record atmospheric pressure, wind direction, speed and gust, and air temperature. Some C-MAN stations also provide measurements of sea surface temperature, water level, waves, relative humidity, precipitation, and visibility. All buoys and many C-MAN stations located in offshore areas operate on marine batteries which are charged by solar cells. The acquired data are then ingested into numerical weather prediction computer models where they are processed and transmitted hourly through NOAA Geostationary Operational Environmental Satellites (GOES) to a ground receiving facility at Wallops Island, Virginia, operated by the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS). Additionally, some buoys and C-MAN stations may use the Iridium satellite system to transmit data. The data is recorded and processed by the National Oceanographic Data Center (NDBC). All buoys are serviced about every two years for routine maintenance and to install newly calibrated sensors. The United States Coast Guard (USCG) supplies transportation for buoy deployments, retrievals, and other maintenance.

Further information is provided by the Volunteer Observing Ships (VOS) network which consists of thousands of vessels worldwide which are sending observations every few hours which are then used by marine forecasters and computer modelers to improve the accuracy of the forecasts.

The NWS provides a number of products with information on marine weather to the end user. First and foremost, the warning and forecast program is the core of the NWS’s responsibility to mariners. The Small Craft Advisory forecast winds along with hazardous sea conditions that may affect small craft operations which may be issued up to 12 hours before the onset of adverse conditions and warnings up to 24 hours in advance.
Also, a coastal marine forecast is issued for 5 different areas (East coast, West coast, Gulf, Alaska and Hawaii) four times per day (except Alaska, where it is issued two times per day). The timetable is different for each area, with issuance times being 1 hour later for those states that switch to daylight savings time. A 3-5 days outlook is included. Offshore Forecasts are also issued with effective times being generally the same as those for coastal forecasts. These forecasts, issued by certain NWS offices, are mainly geared to those mariners operating farther offshore, a day or more from safe harbor.

For the needs of the largest ocean-going vessels, a High Seas Warning and Forecast is issued which gives more emphasis on gale force or worse conditions. These are issued four times per day and include the areas of North Atlantic, Tropical Atlantic, East Pacific, North-East Pacific, North Mid-Pacific, South Mid-Pacific, Mexico and Peru High Seas.

The NWS issues Special Marine Warnings for potentially hazardous over-water events, usually of short duration (up to 2 hours), not adequately covered by other marine warnings and forecasts. These events include thunderstorms, waterspouts, squalls, wind shifts, and other short-lived conditions. Special Marine Warnings are issued mainly for the coastal waters but may also be issued for offshore areas. If a tornado or severe thunderstorm is expected to move over coastal waters, NWS issues a Special Marine Warning. If a severe thunderstorm or waterspout is expected to move ashore, NWS issues separate warnings (Severe Weather Warning (SVR) and/or Tornado Warning (TOR)) for land areas. Also, Marine Weather Statements are used to follow up the Special Marine Warnings or to provide information on non-severe conditions such as fog.

Finally, Hurricane and Tropical Storm Advisories are issued for the Atlantic, Pacific, Gulf of Mexico and Caribbean regions as needed by the Tropical Prediction Center in Miami and the Central Pacific Hurricane Center in Honolulu. These advisories are issued at least four times a day during the tropical cyclone season and extend out to 72 hours. For the tropical West Pacific, typhoon and tropical storm advisories are issued when necessary by the Joint Typhoon Warning Center. Tropical Cyclone Public Advisories are issued as needed by the NWS office in Guam. Hurricane warnings are issued for forecast winds of 64 knots or higher associated with a hurricane and Tropical Storm warnings are issued for forecast winds of 34 to 63 knots associated with a tropical storm.

According to the NOAA Website, there are a number of ways to disseminate weather information. Some of them are listed below:

By National Oceanic and Atmospheric Administration (NOAA):

- NOAA Weather Radio (NWR): Marine weather products are widely disseminated via U.S. Coast Guard (USCG) broadcasts, NOAA Weather Radio, Internet and other media. Schedules for marine broadcasts are listed in the National Imagery and Mapping Agency (NIMA) Publication 117 and NWS Marine Weather Service Charts.
- NOAA Telephone Recordings: The NWR network provides voice broadcasts of coastal and marine forecasts on a continuous cycle. This network covers nearly all of the continental United States, Hawaii, the populated Alaskan coastline, Puerto Rico and the Virgin Islands, and Guam and the Northern Mariana Islands. Typical coverage is 25 nm offshore. When severe weather threatens, an alarm tone is sent to automatically turn on compatible NWR receivers in the transmitter’s coverage area.
NOAA HF VOICE: Many NWS forecast offices offer recorded marine and local forecasts by telephone. The numbers are usually listed in the telephone directory under “United States Government, Commerce Department, National Weather Service.”

By the United States Coast Guard (USCG):
- USCG HF Radiofax: NOAA broadcasts offshore forecasts, coastal waters forecasts and storm warnings on 4125 kHz in Alaska.
- USCG VHF VOICE: The USCG broadcasts high seas weather maps, sea surface temperature maps, and text forecasts over HF radiofax. Transmitter sites are located at Boston (NMF), New Orleans (NMG), Kodiak (NOJ), Pt. Reyes (NMC), and Honolulu (KVM-70). The USCG also broadcasts coastal waters forecasts and storm warnings on VHF Channel 22A after an initial call on VHF Channel 16. The USCG VHF network provides near-continuous coverage of continental US coastline, Hawaii, the populated Alaskan coastline, Puerto Rico and the Virgin Islands, and Guam and the Northern Mariana Islands. Typical coverage is 25 nm offshore.
- USCG MF VOICE: USCG broadcasts offshore forecasts and storm warnings on 2670 kHz following an initial call on 2182 kHz.
- USCG HF Voice: USCG voice broadcast of high seas forecasts. Limited offshore forecasts also are available.
- USCG SITOR (NBDP): Also known as Narrow Band Direct Printing is a text broadcast of high seas forecast. Limited offshore forecasts are also available.
- NAVTEX: NAVTEX is a USCG broadcast of offshore warnings and forecasts in text form. Limited coastal forecasts are also available. Typical coverage is 200 nm offshore.

Other:
- INMARSAT-C SafetyNET: This is a broadcast of Maritime Safety Information that includes high seas weather.
- WWV and WWVH (time tick): A summary of Atlantic and Pacific high seas storm information.
- DIAL-A-BUOY: Mariners can obtain the latest coastal and offshore weather observations through a telephone service called Dial-A-Buoy. This service provides wind and wave measurements taken within the last hour at stations located in the Atlantic, Pacific, Gulf of Mexico, and Great Lakes.

Mandate of weather service information provision and at what cost

Open Sea has a lot of difficulties. Extreme weather is one of them and one of the most essential. However, ship’s Officers are not alone fighting wind and waves. Many specialists, such as hydro-meteorologists, oceanologists, voyage reconstructors, are ready to utilize and share their experience and knowledge. This fact gave birth to a new branch of nautical science: weather routing. The key idea of such service is to provide a ship’s crew with authorized, elaborated and most economically efficient decisions related to vessel’s voyage performance and safety.

Optimum Voyage Routing (OVR) is made to conduct safe and efficient operations for a vessel. How does it work? OVR program designed by Aerospace and Marine International. Service can be used as an example. It includes an initial route recommendation sent prior to departure, daily voyage monitoring of vessel, en route weather advisories and route recommendation updates. Route Analysts work with vessel’s shore based operator and Master to ensure safe and economical voyage according to weather and time constrains. Simultaneously, shore side operator
could be provided with up-to-date information about his vessel by using Fleet Status Report. It includes en route weather and sea conditions, updated performance speed calculations, and updated estimate on time of arrival. Once vessel arrives, weather routing company provides a comprehensive End of Voyage Report for review. Such reports are recognized as both reliable and objective. Entire service requires Shipowner to conclude the contract with an ocean routing company.

Sometimes paperwork asks for a lot of time and effort, especially when assistance and advice is needed on urgent basis. Tropical cyclones could be one of them. Due to this fact, Tropical and Heavy Weather Advisory service can be ordered at any time during voyage to assist Masters and to help reduce the chance of cargo and structure damage. This service includes daily voyage monitoring of vessel, en route tropical and heavy weather advisories and route recommendation update. Telephone Consultancy with duty personnel is available 24 hours – 7 days a week as part of the standard service. Team of experienced marine forecasters includes a number of meteorologists highly trained in tropical cyclone forecasting. Staff experience is usually acquired at the Joint Typhoon Warning Center (JTWC) - the Eastern Pacific Hurricane Center, before its’ transfer to the National Hurricane Center in Miami, and in other leading National Meteorological Centers and private Tropical Cyclone Forecast Centers. All these forecasters have extensive operational experience in all the tropical cyclone basins. Forecast products, text, graphics and charts can be sent via email and/or made available on the web-secure client-specific internet delivery site.

Thanks to modern communication systems and synergy between various parties, it is possible to study, utilize and include a large scope of various weather information given by the WMO, land, ship and data buoy observations, observations directly from rigs, platforms, Global weather satellite imagery from both polar orbiting and geostationary satellites, NCEP Global Forecast System (GFS) atmospheric mode output (to 16 days), Quikscat ocean wind analysis data, European Center for Medium range Weather Forecasting (ECMWF) atmospheric model output, US Navy Operational Global Atmospheric Prediction System (NOGAPS) atmospheric model, Japan Meteorological Agency atmospheric model for Northern Asia, Wave Watch 3 third generation, spectral ocean wave model, NOAA and Navy Coastal Ocean Model (NCOM) ocean currents. This is all on board of one particular vessel. We can proudly declare, that in the near future the level of cooperation is going to improve and become deeper and more accurate.

Connections to radars, satellites and other equipment installed on vessel when changing sea region

Bearing in mind latest requirements to GMDSS system and relevant equipment, following changes shall be applied when changing sea region:

- VHF station shall be switched ON not only on channel 16, but also on additional channels/frequencies as per local regulations
- Weather faxsimile frequencies shall be adjusted according to nearest provider with strongest signal
- Ocean region at Inmarsat C system must be relevant to vessels position (as shown in Figure 3)
What can be improved and how?

Fighting wind and waves: for different ship types different challenges

When navigating any ship, the two most prominent external factors affecting sailing are: wind and currents. Currents affect mainly the stability of the ship and its position. They must be taken under consideration especially in cases such as maneuvering in narrow channels, in inland waters or harbors but also in open seas (for safe transport, to minimize transit time and efficient use of fuel). In order to aid the navigator in selecting the fastest and safest routes with regards to the expected weather and ocean conditions, Pilot Charts are provided which, among other information, depict averages in prevailing winds and currents at different times of the year. Usually, the ship is positioned with the current from ship’s ahead; this will reduce the ship’s speed over ground and improve ship’s response to the rudder.

However, while currents affect the ship mostly in definite and predictable ways, wind is more elusive. Wind is not only a factor when one considers the generation of waves but it also directly affects the ship itself, in more ways than one. The way wind affects the movement of a ship is not confined to the size or weight of her. Other factors come at play, such as the freeboard of the ship (Freeboard is the distance from the waterline to the upper deck level, measured at the lowest point of sheer where water can enter the boat or ship). Containers and Roll-on/Roll-off (Ro-Ro) ships have large freeboards and are more affected by winds. More than that, for the same ship, different overall conditions can have different effects: an unloaded ship responds differently to the same wind force than a ship down to her marks or when the windage area (the area of the ship exposed to the wind) changes.

In any case, when navigating a ship under wind conditions, the navigator must be aware of numerous factors that can affect the movement. There are different responses and different effects for different directions of wind: for example, in case of head wind, the stern part (back) of the ship has the tendency to pay off on either sides (a common effect on ships where the accommodation area is at the aft region) but when the wind blows from right astern, steering the ship becomes easy. In case of berthing however, head wind is preferable since it creates a breaking effect.
Knowing factors such as wind speed and direction as well as knowing the ship herself is crucial in order to navigate efficiently.

Concerning waves, there are five major categories: wind-generated, tidal, seiches, tsunamis and pressure induced waves. Wind-generated waves are the most common waves found on the ocean (these are the result from stress on the water surface caused by the wind) and they are the waves that have the greatest impact on ships. Seiches (the sloshing of water back and forth) can also be created by persistent strong winds blowing along the long axis of large water body causing a rise in the water level at the down-wind side and a lowering of the water level at the up-wind end.

Regardless of the creation cause of the wave, wave height is a major factor affecting a ship’s performance, since it creates ship motions that reduce propeller thrust and can cause increased drag from steering corrections. Similar with wind, wave direction and height affects ship motion: a head wave reduces speed; a following wave increases it. During heavy seas, exact performance prediction becomes difficult due to constant corrections to course and ship speed. In any case, again, knowledge of wind height and direction of wave motion is crucial in order to secure shiphandling and comfort.

**What is missing in the on-board technology for wave height measurement?**
Historically, wave data has been available on the open sea via systems designed to work with ships’ radar. Compared to other meteorological data systems such systems have been relatively expensive and have probably been utilised more by oil and gas rigs, and vessels operating helidecks and support operations.

Technology does advance however, and Radac is an example of a company that is working at the pioneering end of such technology; improving accuracy with its state-of-the-art technology approaches, while reducing cost and not interfering with existing ships’ radar.

Given that >90% of the world’s commerce moves by sea, combining Radac equipment and its data into systems, like that offered by Vaisala, will provide value benefits for improved operational decision making that will quickly absorb the initial costs by savings in diesel alone.

**Ice thickness measurement equipment**
For better navigation in the future it will be helpful for safety navigation to use ship navigation radar designed and engineered by the scientists of Odessa National Maritime Academy, which is designed for the detection and recognition of navigation objects like:

- coastline
- ships
- the size and thickness of ice fields
- thrill
- weather events:
  - cyclones,
  - wind speed and direction,
  - precipitation,
  - mist and fog
  - thunderstorm,
  - volcanic dust,
  - temperature and humidity.
The main principles of operation of ship navigation radar system:
The polarization Doppler radar, allowing radiate electromagnetic wave with the given polarization and take two components of the reflected signal by which to automatically compute the polarization properties of objects and their speed.

List of equipment
1. Transmitter - two wave;
2. Receiver - dual channel;
3. Fullpolarized antenna with controllable parameters;
4. Automated computer processing system and presentation of information in acolor image.

A specific issue with ice is the formation of ice at ports, which are close to openings of a river. The formation of ice can be very rapid and push a thick cover of ice from the riverside. Removal of this ice is tricky as it forms very fast and moves with the tide as well. There are several ports in Europe affected by the ice from rivers.

**Coastal operations**

**Relationship between port and local shipping community**

The task of each port is to handle cargo. Ports are interested in optimization of internal procedures and quicker performance related to cargo shipment. Unfortunately, safety of coastal sailing is not a first priority for port executives, because port managers associate them with cargo handling process only and do not care about various traffic participants at outer roads. Local shipping communities could be an element able to fill in the gap between port and others.

The key issue of future and possible cooperation is safety. Safety of vessels in coastal areas means that ships’ crew is fully aware of current weather situation, depths, possible navigational objects and unpredicted extreme weather events. Pleasure crafts, small fishermen boats and even jet ski users must be aware of navigational warnings in related area. But how can it be managed? Odessa port area can be used as an example to on how such exchange is organized. As per law requirements, small vessels prior to sailing must report to local border guards based in the port. Upon receipt of approval from border guards sailors able to go to sea for a strictly allowed period of time accordingly (for example small inflatable crafts are prohibited to sail overnight). Permission can not be obtained if vessel does not comply with various regulations as per SOLAS Convention. Compulsory character of this procedure helps to keep a precise eye on sailing areas, but unfortunately many sailors do not comply with required procedures and proceed to sea on their own risk which in many cases leads to tragedy. Volunteer organizations between local shipping authorities and small craft owners could be a way to achieve mutual agreement between all involved parties. Fishermen’s associations or yacht owners’ clubs help to spread important information between participants and keep all hazards very well known to everyone. Synergy in efforts and responsibility of each member could help to make environment near port waters clean and safe.
Responsibilities of the port in information management

Ports usually have at least a minimum set of equipment to monitor weather developments. They also receive weather updates at least daily from meteorological offices. In addition to this, they can also subscribe to different levels of additional services. Usually, radio frequency and mobile phone technologies are available to ships in coastal waters, both large ships entering and exiting the port as well as ships and yachts sailing in the region for other purposes. As the ports receive information of changes in weather in the case of extreme conditions, they should play a role in informing the users of coastal waters, outside the pilot system targeting port entry and exit only.

However, there are no established mechanisms of information sharing between the port VTS station and coastal water ships. The radio frequency is used in some ports but in others there is no agreed principle on information sharing. This is an area where significant gains in safety can be made relatively quickly and at a low cost by using radio frequency, subscription to SMS service or sirens and other locally devisable warning systems. This can be decided upon by national governments as a practice to be adopted in the country’s ports, depending on the technology available at ports (weather information systems and availability of weather reports and technologies for data provision to coastal water users). Standards in format of sending the information, such as frequency, service subscription (for mobile phone applications) and format of the information provided would help to utilise the data more broadly. In this respect, EU level decisions on responsibilities and data provision would be helpful.

Early warning mechanisms

Early warning is defined as the provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response. This requires four basic parameters: knowing the risk, monitoring and predicting the existence of said risk, disseminating relevant information to the potentially affected areas and responding in order to mitigate disaster. The basic idea behind any early warning and its subsequent steps is that an early and accurate prediction of short- or long-term potential risks stemming from severe weather conditions, will lead to a better management and more successful mitigation of a potential disaster and its impacts on society, economies, and environment.

When it comes to severe weather hazards, two main categories can be discerned: rapid, short term events (such as everyday weather) and long term, “creeping” hazards. Depending on the event, different early warning periods can be defined (as seen in Figure 4).
For both of these categories, the same four-step rule applies: an effective early warning system must include all aspects of emergency management, such as a risk assessment analysis, monitoring and predicting location and intensity of a potential severe weather event, communicating timely alerts to authorities and to those potentially affected and, finally, responding to the disaster. It is not enough to have knowledge of a severe weather warning risk or to accurately predict the time, place and scale of it. If the warning is not made available to the parties concerned or the response is not timely and up to scale then the early warning mechanism has failed.

In order to achieve this, a number of principles for early warning systems must be included and implemented in the design of such a system in order for it to function properly. Such principles include:

- Effective monitoring and predicting any severe weather related event using up-to-date monitoring and prediction systems from multiple sources, if available.
- Balance the trade-off between the amount of warning time available and the reliability of the predictions provided. These two are often conflicted: more prediction time improves accurate knowledge of the event; however it also means less time available to issue warning for the said event.
- When a warning is issued, the message should, above all, be simple and easily understood (in plain language, precise and clear) and, at the same time, communicate the level of uncertainty and expected cost of taking action. An effective communication strategy should be developed in order to avoid refusal to respond to an issued warning.
- The communication infrastructure used to relay a message must be reliable and robust, providing fail safes against collapse that guarantee the eventual arrival and reception of said message by the parties concerned as well as constant communication during the response phase with frequencies and channels reserved and dedicated to such operations. Promote use of easily and timely providers of information such as the Internet or cell phone alerts.
- A clear definition of the areas of responsibility, hierarchy as well as constant interaction and communication between the main actors of the early warning process. Coordination between authorities and public should be strengthened.
- Set priorities based on risk assessment analysis, without sacrificing the ability to respond. Training decision-makers and involved parties in what the received information means and how it should be implemented should not be overlooked.
- Perform gap analysis in the system in order to identify possible shortcomings, critical aspects and future needs.
- Promote cooperation and participation in the development, implementation and research on early warning systems technology and application.

All mariners should have free access to some sort of local weather forecast and warnings produced by national meteorological office. However, it is the larger commercial shipping that is typically under the microscope and which benefits from local port authority, harbour master and pilot scrutiny. This team typically has the benefit of additional local weather stations, possibly additional hydrological forecasts, wave and tide measurement sensors, etc.

This wealth of information has the potential to enable ports to gain greater understanding of its microclimates; the Port of Southampton for example is well catered for. Close to the port itself it has established three zones that are affected differently depending on prevailing winds. Weather stations in each of those zones and at critical points out in the coastal waters themselves enable them to pin-point changes in the waters.

Most ports are happy to make their weather data available to the wider audience and endeavour to do so. Southampton covers a significant coastal area and local mariners including many yachtsmen and women can access data from local weather stations on-line, and hear forecast updates and information on local radio.

**Port operations**

**Preparedness**

Ports come in all shapes and sizes. They can also serve different purposes. With >90% of the world’s commerce moving via its oceans, then a great many are handling vast quantities of commercial cargo. There are those serving passenger and RoRo ferries, many are fishing ports, most also serve recreational sea-goers. There are dedicated oil and gas terminals, etc.

The nature of their business, combined with their local geographical position influences the local business logic and operational codes with respect to the weather they have to manage.

Nevertheless, exposed to full-on Atlantic storms or relatively quiet back-waters they are all affected by the weather and the tides. Wind and waves are the critical factors.

Most, if not all, ports have wind sensors, many have wave and tide sensors, and some have visibility sensors. There are then general meteorological sensors for temperature and humidity, barometric pressure, sea temperature, etc.
Most commercial ports and terminals operate VTS systems. 

All nations provide national weather forecasts for their seas and coastal waters affecting port users. Hydrological offices provide wave and current forecasts. Some ports take additional, more detailed, site-specific forecast information.

…and we humans have been handling the sea and the weather for many, many generations.

In general terms, with our ages of experience and the modern technology available, we manage port activities pretty well in relation to the weather.

We even keep abreast of extreme weather in relation to climate change, we see flood defence systems put into operation, for example, The Thames Barrier - operated by Port of London Authority.

Challenges

Principally, ‘the devil is in the detail’.

Whilst it appears we have a lot of technology to help us; currently, when we get to the detail, we tend to rely more on the experience and professionalism of human beings.

If we accept that all ports have instrumentation providing observational wind data, how many of those ports have accurate, reliable wind data that is providing applicable data for the purposes it is needed? Unfortunately, far too many appear to provide data that potentially compromises the decisions their operatives have to make. At best this means trade is hampered, ships do not enter or leave ports as and when they could. At worst there are accidents.

When the pilots in the port of Limassol are unsure about the wind and ask the Harbour Master for assistance, his nearest point of reference is a meteorological weather station in a nearby car park, compromised by local high buildings. The location at port is shown in Figure 5 below. It is hardly representative of the entrance to the harbour or its berths. In these cases safety has to side with lack of confidence and doubt and the pilot will not take the vessel into harbour.
Figure 5: Positioning of wind metering station at the Port of Limassol.

Not only do we see wind instruments positioned such that they are compromised by surrounding structures, but we see them installed on top of buildings the updraft vortex compromising the measurement of wind direction. There is then the question of maintenance. Mechanical wind sensors rotate on bearings. These mechanical parts wear, further reducing the accuracy of the data. By the time a sensor has ceased up and stopped working, it must surely have been providing compromised data for an extended period previously.

**Aiding technologies**

We are fortunate in the port and near-shore environment that experienced ship Captains are backed up by the advice available from locally experienced Harbour Masters, Pilots and tug operators. From our many interviews, however, we know, that even with this wealth of knowledge and experience there are still times and situations where confidence is not what it should be. Some ports offer a more complex situation than others, but the general picture for aiding technologies is the same.

In the port environment we may typically look at a 16-point compass. Depending on the prevailing wind direction the variance in magnitude and direction of low level winds can vary significantly. To strengthen the confidence of experience, wind-mapping technology is available to provide a pictorial representation of wind flow. Such technology provides three main benefits.

First it provides immediate confidence by backing up that which is already known by our experienced local decision makers.

Secondly, it provides scientific insight into those areas they already know are challenging when the prevailing weather comes from a less favourable direction.
Thirdly, it pinpoints the best locations for wind instruments to be installed such that they are providing an accurate, understandable and representative picture of how these variations manifest to enable confident advising and decision making.

Having established best locations for sensors we must ensure they are installed in positions that minimise any potential compromise. We want to install them above intervening structures. We want to know at what height we are measuring in order the data can be normalised - to suit different sizes of vessels and craft in the area. We also want to minimise maintenance requirements by reducing the wear on mechanical parts. At the moment ultrasonic wind sensors probably provide the optimum solutions. Vaisala’s WMT700 ultrasonic wind sensors have been developed with the harsh maritime challenges in mind.

Having established wind and waves then visibility is usually taken as the next challenge. As humans our confidence grows when we can see what is happening. In some ports our decision makers are not positioned to see everywhere. The operational question is often; “When will this fog lift?” Strategically placed visibility sensors enable us to scientifically measure the visible ranges and in this way we can ‘see’ how fog density is changing and moving across an area.

Lightning Detection and Alarms – fixed on-shore locations that require warning of electrical storms can be catered for by installing independent equipment or via local services (if they already exist). These services typically have associations with EUCLID, the European Cooperation for Lightning Detection.

Where installations are a challenge, for example off-shore and on ships, Vaisala can offer its GLD360 service. Essentially Vaisala has installed a global network of lightning detection equipment that enables it to track electrical storms not just over land, but also over the open sea. For shipping, lightning itself may not be an issue, but the knowledge that the storm associated with it is somewhere ahead can assist in deciding which course to follow.

Manuals/practice

Port operations in the case of natural disasters or extreme weather phenomena need to be administered with the safety-first principle. To collect evidence of current measures in the ports reviewed for the project, two particular concerns were raised:

- Processes for emergency procedures need to be clearly documented and a manual collecting the roles and responsibilities should not only exist but be made available to everyone working at the port and the procedures should be exercised at times;
- Decisions related to closing down the port or preventing entry or exit of ships should rely not on subjective decisions of port authorities but on reliable information, where thresholds for critical levels determine the actions required.

Regarding the existence of manuals for port operations, it appears that the practice is mixed: some ports have the manuals and the staff refers to it in the case of conditions that trigger actions, however, smaller ports do not necessarily have the resources to produce their own manuals. In some ports manuals are produced for separate parts of operations, which can create confusion if multiple procedures are required simultaneously.
Robust decision-making tools and information are needed to support the port VTS and harbour master. In the interviews conducted, most people stated that no data can replace the final judgement by the port professional staff. However, at the same time it was also noted that in many cases there was no data to back up decisions. In cases where accidents had led to court cases, the availability of weather data and communication between vessels and VTS were considered a major advantage for the port in defending its case.

Recommendations:

- Regionalised manuals for port operations should be developed to support the safety in smaller ports
- Decision-making processes on port operations should be developed further to take into consideration the possibility to connect decisions made to robust data rather than human judgement. This would reduce liability and human error possibility

Role of weather information

Weather information in ports is mainly used in two ways: short term (day-to-day) and long term utilization: the former refers to daily and weekly planning in all aspects that affect port operations and the latter is used for future planning of port operations in order for the port to deal with challenges stemming from possible changes in local climate conditions.

Each category presents its own challenge. Extreme weather events such as high winds and severe storms, flooding from tides, river or land water due to high precipitation, snow or ice and temperature extremes could disrupt port operations, create hazards for on-site personnel, affect port infrastructure and create additional costs due to reduced productivity, delays, accidents and insurance costs. Every stage from when a ship enters a port, loads/unloads its cargo and departs, weather can affect the safety, efficiency and cost: For instance, severe wind is the main deciding factor whether bulk gantry and container cranes will operate or not or whether a ship is allowed to dock on a berth or not. High wind speeds could cause delays to arrivals and departures of ships affecting pilot transfers, pilotage and ship handling as well as also cause additional disruption to crane activity, container yard stacking and the mooring of ships. Exposure to extremely high or low temperature is likely to affect the ability of port workers to continue to work safely and without endangering their health and safety. Increases in the amount of rainfall and snow could result in flooding, causing disruption to ‘on site’ port logistics and damages to cargo and infrastructure. Heavy snowfall can cause problems to the shore side straddle carriers for container terminals or interrupt road and rail networks leading to the port. According to the findings of the EWENT Project, cargo handling amounts to 75-90% of port costs, so it is understandable how important the knowledge of possible adverse weather conditions is and how costly an uninformed decision can become.

To that end, day-to-day operations heavily rely on the provision and correct application of accurate and timely weather information. Depending on the nature of the upcoming extreme weather, port authorities usually take such actions as stopping cargo handling, moving and securing large cranes and other port equipment, suspending operations, deploying sandbags and other flood protection measures, evacuate areas, provide workers with suitable wear in cases of extreme temperatures or limit their exposure to open areas. Also, port authorities assist ships arriving or departing from the said port by relaying weather information: Most ports, through their websites, provide not only
weather forecasts (usually derived from local weather stations and services) but also the prevailing weather conditions to that particular port: Data on wind direction and speed, tides and currents, visibility and probabilities of fog, wave height and precipitation, temperature as well as sea surface atmospheric pressure and (in higher latitudes) ice, are the most common weather information provided.

However, the importance of weather information is not restricted to the short-term prediction. Equally important, if not more so, are the long term applications of whether and how the prevailing weather and climate of the port and its surrounding area is going to be affected by future climate change conditions. The severity of how climate change will impact a port depends mostly upon the location and topographical nature of the area in which the port is sited. For instance, ports which are located in low lying geographic areas are vulnerable to risks, such as sea level rise, storm surges and increased storminess which could affect the port’s supporting infrastructure. Even a more moderate shift of current climate conditions could mean an increased occurrence of disturbances of port operations which, in turn, may put the operational and economic position of the port at stake.

Long-term planning requires the knowledge of trend of extreme weather events. Since planning and actual implementation of protective measures is time-consuming as well as expensive, accurate knowledge of the upcoming needs is imperative in order to avoid “regret actions” and unnecessary costs. An adaptation strategy should consider what could be the impact of storm surges, sea level rise, temperature change, rainfall and snow and high winds, identify those events which show positive trends and act accordingly. For instance, for a port that faces ever growing challenges with severe winds, the need to acquire robust quay gantry cranes able to withstand increased wind speed is imperative or, in case of frequent temperature extremes, a port might seek to update its equipment and infrastructure (replace vulnerable tarmac surfaces on the port terminal, or eliminate the use of none air-conditioned vehicles). In any case, a holistic approach should be used, encompassing various aspects of socioeconomic life, infrastructure and broader aspects of incoming climate changes, even ones that are not that obvious such as the opening or Arctic routes which might diminish (or enhance) the geographical position of a port or severe flooding that affects agriculture and adds work stress to a port which must deal with an increased rate of imports.

Wind closing the port is logistics operations’ problem; it is not ship’s problem

Regarding the ports and their present operations and development needs, a number of ports in different parts of Europe were analysed. Depending on the climate zone where the port is situated, the challenges encountered are quite difficult. However, some basic conclusions apply to all the ports studied:

1) Positioning of weather measurement equipment: In all the case study ports, the location of the equipment is not optimal. In other words, the measurement does not capture the conditions of entry to the port, in terms of wind direction and speed. This is a critical factor, as strong wind in itself is not critical as such, but it is equally depending on the direction of the wind.

2) Available measurement technologies: All ports have wind measurement stations, but in addition wave height measurement is desirable, but non-existent in all cases. Wave height, as a consequence of the wind direction, is another critical factor that determines the safe arrival to port.
3) The weather information available is fragmented and filtered from various sources: Ports rely on main weather forecast information and additional information collected on site. Warnings provided by meteorological institutes are used to supplement the standard information. However, decisions on the continuation of operations are based on individuals’ expert assessment, not the data provided. This creates a room for error and possibility for a major accident in the case of misinterpretation of available data.

Preparedness of ports to deal with various extreme weather phenomena varies. In most cases the information available is not sufficient enough to make decisions that are based on weather data evidence, which leaves room for human error.

**Examples of European ports, their challenges and extreme weather preparedness**

**Port of Odessa operations in the case of extreme weather events**

Odessa is situated in an area which climate-wise poses a challenge for port operations. Winter conditions are below zero degrees and the presence of Danube River creates difficult ice conditions.

The port has a manual prepared for various external disruptions, which covers all weather conditions and provides the guidelines for companies which operate the various terminals and services in the port area. In addition, several companies that operate at the port each have specific equipment to deal with maintenance of port areas in the case of extreme weather events. They are used in a collaborative way between various operators, which makes their use effective and reduces need to have similar services available from all service providers for their own operations.

Regarding the weather information services, the port relies only on official daily forecasts from the service provider. The port authorities forward this information to companies operating in the port. In the case of special information this can be provided through a call or e-mail. No equipment exists at the port or coastal waters which could be used to provide additional weather information. The preparedness of the port to tackle with interruptions such as storms is therefore limited in terms of the foresight. In the case of storms, which can arise rapidly the port usually closes the operations but there is no preventive mechanism that could warn the cargo offloading services or ships entering the port at the time. This does pose a potential for hazardous situations and accidents. The port or the companies operating in the port area do not provide additional weather information to fishermen or other boats using the coastal waters. This means that there is no authority with responsibility of oversight of safety in the coastal area waters. This can also be a potential cause of accidents if conditions change suddenly.
The three most severe extreme weather events the Port of Odessa has to deal with are:

- Storms
- Ice
- Rain and wind combination

What is a particular concern at the Port of Odessa is the impact of the river, which in the winter time pushes ice to a thick frontier. The port is struggling to find ways in which the routes to port can be kept open with icebreakers as the wind changes making the ice move constantly, blocking recently opened routes. This is combination of wind changes and the flow of ice from river Danube. For other winter maintenance, including the port ground operations, salt, sand and chemicals are being used. Dedicated areas in the port are designated for vehicles and pedestrians and maintenance is planned accordingly.

Suggested areas of improvement for Port of Odessa:
- Management of ice situation at the port area
- On-time collection of weather-related information on ice situation, wind and storms.

The technologies to manage the information exist, at the moment the challenge is to define which actor should take a responsibility of the information collection and dissemination. This is related to the cost of investment to such systems, if their use is not mandatory, investment decisions should be weighed against gains in safety and accident reduction. In the view of the operations review it appears that such potential gains could be realised and they could be significant.

**Port of Limassol operations in the case of extreme weather events**

The port of Limassol is the main port hub of the Republic of Cyprus, situated in the Eastern Mediterranean. Extreme weather event challenges that the port faces include heat wave conditions during the summer months and low visibility due to fog/dust transport events.

The port of Limassol relies on the Cyprus meteorological service for the provision of official daily forecasts as well as warnings. The former is provided once a day. Furthermore, there is constant information flow through the Meteorological Service’s web page as well as the possibility of further reception and clarification of information through telephone or email. However, the VTS office relies on some additional sources as well such as the Oceanographic Centre of Cyprus for provision of information on sea waves through their website or incoming ships. The dissemination of information is provided through the NAVTEX system and short wave radio.

Coastal waters information to fishermen is provided by the Cyprus Meteorological Service. The relevant information is provided three times per day for an 8-hour period along with warnings (when they exist) through uploads to a Voice Response System. Additional information is provided through telephone if asked.

The three most severe extreme weather events that exist in the port of Limassol are:

- Wind
- Fog/dust transport episodes
- Heat waves

Wind, as always, is the most crucial aspect of port operations. In the case of the Port of Limassol, the port closes and every crane activity stops when the wind gets 7 Beaufort or more. Fog and dust
create problems about 3-4 times per year, the former especially during early summer in the early morning hours. Dust episodes, according to studies performed by the Meteorological Service of Cyprus present a positive trend for the area and might pose a significant problem in the future. Heat waves can also create problems. During the summer months the Department of Labour monitors the Discomfort Index and issues warnings when it considers this appropriate. When such a warning is issued, all activity within the Port area stops for a three-hour period. Trend studies performed by the Meteorological service of Cyprus also present positive trends for Heat discomfort episodes.

Suggested areas of improvement for Port of Limassol:
- Problems cited by the VTS office include the position of the port’s meteorological station as well as the position of the VTS office itself. Both could be positioned on the end of breakwater to provide maximum optimal performance: the former through correct and relevant measurements, the latter through increased sea visibility for the officer in charge. Another problem cited by the VTS office is the lack of sufficient personnel; the office is considered understaffed and many times only one VTS officer is present. Despite the problems VTS faces the port has an exceptionally good record considering accidents: within a timeframe of 8 years, no accidents have been reported.
- Interview with the senior pilot and the VTS officer on site revealed that there is a desire for accurate weather information both for better performance and for the sake of record keeping. Decisions made for the closure of the port or the advises given of whether a ship should enter the port is given through experience; however in case something goes wrong it is desirable to have more concrete evidence for the handling of decisions. The same goes with decision parameters: the senior pilot has cited different criteria and thresholds of weather conditions for each pilot that impact their decisions. A clear regulation that all should follow is deemed desirable.

Southampton operations in the case of extreme weather events

Port of Southampton is the second busiest commercial port in the UK, the busiest cruise terminal and its waters are also home to many yachtsman and sailing events, not to mention the Royal Navy. It of course opens onto one of the world's busiest water motorways The English Channel. Situated half-way along the channel it also has to contend with a double-tide phenomenon.

With such a large number of shipping movements there is limitless experience and local knowledge to rely on. It is a good location to understand that despite this wealth of expertise, technology is an absolute requirement to keep the port operating safely and to its optimum.

With south-westerly winds prevailing across the UK some 70% of the time it is usually clear what approach is required. But the experts there know that when the wind changes direction it can be a game-changer. The Harbour Masters and Hydrography Officer work using three zones to facilitate changing conditions. They have had wind-mapping undertaken to understand the effects of the land situated to the north and east of the port, its associated microclimate experiencing different challenges to its other zones.

The port authorities have a number of maritime weather stations strategically placed to assist with commercial movements, three primary wind stations both onshore and on the water, plus additional stations whose information is available to yachtsmen and other recreational users to
improve their safety. The port is currently upgrading its equipment and adding additional visibility sensors.

**LNG Ports; example of National Grid LNG in UK**

National Grid Grain LNG is the UK’s primary LNG terminal situated in relatively calm waters south east of London. Its approach to safety is second-to-none. Operational procedures are very strict to minimise any risk of accident. Vessels 100s of meters long have to manoeuvre to 1cm accuracy. Accurate knowledge of wind speed and direction is important. The terminal benefits from being situated such that the predominant south-westerly winds push its associated vessels into the terminal. Nevertheless if winds are likely to cross a maximum threshold, vessels are not allowed to proceed and are held out at sea.

The terminal benefits from Vaisala’s state-of-the-art wind and visibility sensors which it hopes to expand to increase coverage and to enable its operational team on the dockside to see applicable real-time data on hand held devices.

Lightning is not so prevalent in the UK, nevertheless in recent years an LNG vessel was hit by lightning while at the terminal. It is comforting to know such importance is placed on safety.

While severe weather is usually defined as weather conditions accompanied by severe rainfall, damaging wind gusts, hail or tornados, lightning (and thunder) is not generally included in the definition of severe weather. However, it does consist of a considerable hazard to both infrastructure and human welfare despite the fact that fatalities attributed to lightning have presented a negative trend in recent decades.

One of the industries affected most by severe weather activity and, especially lightning, is the Natural Gas Industry and, especially, the Liquid Natural Gas (LNG) liquefaction and regasification facilities. In terms of a fire hazard, natural gas is an easily ignitable light hydrocarbon and the storage and process areas should be considered a “Class One” environment where the chance of fire or explosion resulting from a spark is very high. It is evident that any source of ignition should be eliminated from those areas both from a direct strike and lightning’s secondary effects.

Europe is home to a large number of regasification plants, as shown in the figure below. It is evident that lightning activity, especially under global warming conditions is of special interest for the safe and effective operation of such plants both for the sake of safety as well as for Europe’s energy needs.
Generally, Europe is not generally considered a “hotbed” of lightning activity. As shown in the figure below mostly Eastern Europe and the Mediterranean basin are sites of elevated lightning strike density. However, this is still important since (as shown in Fig.1) a large number of LNG plants are located at the shores of the Mediterranean basin.

The relationship between global warming and global lightning activity is of special interest; however it is also quite complex. As seen from Fig. 7, lightning activity is not uniform across earth’s regions but presents a large degree of variability. This is mainly due to the fact that lightning activity depends on a number of factors such as surface temperatures, tropical deep convection, rainfall,
upper tropospheric water vapour and other important parameters that also affect the global climate system.

Upper tropospheric water vapour shows a close correlation to global lightning activity; however, it is difficult to estimate this effect, since the two processes that mainly govern the water vapour content (amplitude of future global warming in response to greenhouse forcing and the transportation of large amounts of water vapour into the upper troposphere by continental deep convective storms) also have a direct effect on global lightning activity.

Several modeling studies over the past 20 years indicate an approximate 10% increase in lightning activity globally for every 1°C global warming, with most of the increase occurring in the tropics. According to the National Institute of Space Research, a 10-20% increase in lightning frequency for each 1°C increase in temperature is expected. This is extremely important for the LNG industry: according to Atherton and Ash (2006) lightning accounts for 61% of all accidents in storage and processing activities, where natural events are identified as the root cause of the incidents and a 15% increase in lightning-related losses has been recorded from 2009 to 2010 (Lloyds Insurance Institute, 2011).

While the majority of lightning occurs in the tropics, there are some hints of increased activity also in Europe. According to the IPCC (2007), annual mean temperatures in Europe are likely to increase more than the global mean: the warming in northern Europe is likely to be largest in winter and that in the Mediterranean area largest in summer and the highest summer temperatures are likely to increase more than average summer temperature in southern and central Europe. Also, annual precipitation is very likely to decrease in most of the Mediterranean area and in central Europe; precipitation is likely to decrease in summer. According to Conedera et al. (2006) during hot and dry summers (such as the drought period in summer 2003) lightning fires became particularly frequent, with a significantly higher burned area and higher fighting costs in the southern Alpine regions. This might indicate that global warming influence could increase the risk of damage caused by lightning in Europe, especially in Central and Southern Europe.

Conclusions and additional research agenda

Maritime weather forecasts

One of the problems most oftenly cited by meteorologists is the available data required in order to actually forecast marine weather. A number of problems ranging from poor selection of locations for weather stations, poor spatial and temporal resolution of the data provided as well as availability and maintenance of weather stations have been noted. Wind data, which are especially essential, as well as live data from bouys covering the area up to a minimum of 8 km from coasts which will provide live data of swell height (significant and instantaneous), frequency and direction are much in need. However, there are problems such as high costs of purchasing, running an maintaining such systems and there are additional problems with coordinating action between national weather services and port authorities due to the increased variability of the nature and structure of the latter (national ports, private ports, ports serving different functions, etc).

As a solution, quality and reliability of wind forecasts could be very much improved by using WRF (Limited Area Model) down to a 2 km resolution. Research should move to the direction of creating...
more durable, cheap and available tools for weather stations on the field as well as bouys. Collaboration between weather services, oceanographic institutes and other shareholders could provide much needed experience and pooling of resources. Legislation from the EU could define more clearly who is responsible for what considering weather stations in ports.

Decision-making regarding safety – IMO/EU/national governments

Regarding the improvements in maritime safety and ships’ on board navigation systems IMO has the role to approve or disapprove any changes proposed. Despite all aspirations to become flexible organization, IMO’s decision-making is still under the hands of bureaucracy. Therefore, it may take a couple of months to register, adopt and implement necessary amendments. Committees and Sub-Committees are empowered to deal on a specific field and precisely certain events, on which IMO’s attention is required. Legal, Technical, Facilitation, Maritime Safety, Marine Environment Protection Committees and their Sub-Comittees act on topics relevant for their purpose. Upon receiving reports and the proposals of the Committees, The Council of IMO, which is the executive body of IMO, submits them to the Assembly and Member States, with comments and recommendations deemed appropriate. Unfortunately, the Council is not able to make recommendations to Governments on maritime safety and pollution prevention. As per Article 15(j) these be made only by IMO Assembly, which meets once every two years. It causes delays and subsequent economic losses. There is a possibility to meet in an extraordinary session if necessary. This mechanism still requires improvement.

Safety-related decisions on ports should never be based on economic rationality but entirely on the anticipated safety impact. Needless to say, this still has to be within the economic feasibility of such investments. It is the best option that national and international regulations on ports will add particular reference to minimum standards for port safety measures, whichever principles of categorisation they made choose to classify the ports. These categories could be based on port size, type of vessels/cargo handled etc.

Authorities should be aware of the best technologies and systems available. At present each port can design and implement its own systems, ranging from impressive self-constructed monitoring systems at Southampton Port to basic equipment used in Port of Limassol. Standards and systems requirements could seriously help quicker adoption of technologies and create a way to enforce the implementation.

Paying for increased safety

One of the critical elements of additional safety gains from investments to new technology is the question who bears the financial responsibility of the investment? The situation is complicated by the various players involved in open sea and port operations. An illustrative example is the London Port Authority, where harbour master is subject Environmental Agency’s instructions when the flooding requires closure of the gates. It is important that the chain of command is very clear on instructions.

Another good example of over-riding safety concerns is the extreme heat conditions in Cyprus; when conditions of heat and other factors reach a critical point, the government prevents any outdoor work due to health hazards. In the recent years this has been a more common challenge
in Port of Limassol, which also forces a port closure at the times of the general warning announced for the entire Cyprus. These examples show that although the port operations are under the control of the harbour master, there are overriding, weather-related processes that directly impact the port operations.

For these processes there is a clear procedure. Same principle should apply to other weather-related issues ports are dealing with, ideally through legislation and nationally administrated procedures. As these come with cost it is necessary to consider who should pay for the investments required.

Some of the potential models of managing the safety investments can be listed as:
- Concession agreement: the port authority defines the service standard including safety equipment and the company managing the port will make necessary instalments;
- Port managed by municipality: Following national guidelines, working with external experts to design the necessary information systems
- Private ports; Following national guidelines, working with external experts to design the necessary information systems

The critical challenge is to identify the potential safety issues and to work with stakeholders on how to overcome them.

**Role of technologies**

Previous sections have highlighted some of the challenges currently faced in port, near-shore, and open sea environments along with technological answers to some of the questions they pose. While working on this project the team has interviewed those involved in maritime professions that are affected by the weather, those that work to assist in mitigating against the effects of the weather, and those that are ultimately affected by those who are trying to assist.

Despite already investing in technologies, sensors, weather forecasting and so on, there is a real gap in both effectiveness and efficiency.

To take wind as a primary example; knowing what the wind is doing is critical. The strength and/or direction of the wind can be an operational threshold at which work stops, vessels are allowed entry, require assistance, etc.

Such operational decisions are often taken by a decision maker taking a look at the current wind data on a display.

Typically what we find is a company has been effective in getting some equipment installed, but not effective enough. The type of sensor chosen may not be fit for purpose; it may be installed in an inappropriate location, and/or is not adequately maintained. This should not be a box-ticking exercise. There should be clearly recognised guidelines and requirements to ensure the correct equipment is installed in suitable locations and it is adequately maintained. Instrumentation should be purchased from reputable companies, such as those with ISO9001 Quality, companies that check and understand the application and which provide suitable guidance and instruction on the effective use of their equipment. Careful choice of sensors, for example in this case, moving to
state-of-the-art ultrasonic sensors further adds to efficiency gains – such sensors have no moving parts like bearings that mechanically wear out and compromise data accuracy.

Looking forward in time brings in weather forecasting. Forecasting agencies provide forecasts for the weather (including winds). Again companies are effective investing in buying forecast products. However, forecasts are purchased with an end result in mind. Is the accuracy of the forecast and therefore quality of decision taken good/effective enough? Decision Makers and Operations Managers display a range of views on how effective the forecast information they receive turns out to be. Taking their mixed evaluation and discussing it with the forecasters, we find a gap in information that potentially reduces the effectiveness of forecasts and therefore efficiency of operations.

Typically, forecasters are doing a good job with the high-tech tools available today. However, to improve the accuracy of their forecasts they require reliable observed data coming back to them to compare against. Forecast models and the parameters that go into them are many and varied. By comparing forecast model output against reliable observed data for the forecast location, the model inputs can be altered to improve accuracy. With empirical comparison available forecasts become more accurate, more effective. Decision makers increase in confidence and make more effective decisions, increasing the efficiency and safety of operations.

Success of this feedback loop typically requires the assistance of a company such as Vaisala that provides and ensures suitable instrumentation is installed in optimum locations. They will take care of collecting the data and provide continuous remote monitoring of sensors and data for reliability and quality and on-going maintenance thereof according to ISO9001 practices. That quality data is then made available to both the Decision Maker and the Forecaster, with observed data graphically portrayed against the forecast. Forecast agencies are often keen to work with performance indicators and such effective/efficient systems ensure it is clear just how good a job they are doing. When poor performance is noted, then there is a real opportunity to understand the reason why and to fix it.

It is important to note that forecasters will not be criticised against data coming from a 10-year old, unloved, mechanical anemometer, mounted on a 10m high pole sitting downwind of a 20m high warehouse. Nor will they be able to improve their forecast service beyond the threshold of uncertainty.

The final connection is with those whose operations depend on the information coming from the forecasters and the decisions made by the port authorities, etc. ‘Time is money’ is an old cliché, but it is often true. This group in particular loses out when forecasts and decisions are not effective/efficient enough.

Of course in all of this it is not just time, but also safety. Technology is there to assist in effective and efficient commerce and it is there to ensure efficient commerce runs at minimum risk. Safety risks due to adverse weather can be efficiently minimised.

Technology already exists and companies are available to ensure reliable quality data is available to ports, and vessels on the open sea; and to their forecast agencies. That collective has the potential to share its data and make our ports and oceans a more effective and efficient place to operate and at lower risk. With >90% of the world’s commerce moving by sea, the costs of
embracing effective technology are a drop in the ocean compared to the enhanced value they bring to effective and efficient operations.
References


Annex – Ship types

The following is a non-exhaustive list of ship types defined in various IMO instruments:

- A passenger ship is a ship which carries more than twelve passengers. (International Convention for the Safety of Life at Sea (SOLAS I/2)
- A fishing vessel is a vessel used for catching fish, whales, seals, walrus or other living resources of the sea. (SOLAS I/2)
- Fishing vessel means any vessel used commercially for catching fish, whales, seals, walrus or other living resources of the sea.
- A nuclear ship is a ship provided with a nuclear power plant. (SOLAS I/2)
- Bulk carrier means a ship which is constructed generally with single deck, top-side tanks and hopper side tanks in cargo spaces, and is intended primarily to carry dry cargo in bulk, and includes such types as ore carriers and combination carriers. (SOLAS IX/1.6)
- Bulk carrier means a ship which is intended primarily to carry dry cargo in bulk, including such types as ore carriers and combination carriers. (SOLAS XII/1.1)
- Oil tanker means a ship constructed or adapted primarily to carry oil in bulk in its cargo spaces and includes combination carriers, any Noxious Liquid Substance (NLS) tanker as defined in Annex II of the present Convention and any gas carrier as defined in regulation 3.20 of chapter II-1 of SOLAS 74 (as amended), when carrying a cargo or part cargo of oil in bulk. (International Convention for the Prevention of Pollution from Ships (MARPOL) Annex I reg. 1.5)
- General cargo ship: A ship with a multi-deck or single-deck hull designed primarily for the carriage of general cargo. (Marine Environment Protection Committee (MEPC).1/Circ.681 Annex)
- High-speed craft is a craft capable of a maximum speed, in metres per second (m/s), equal to or exceeding 3.7 times the one-sixth power of the volume of displacement corresponding to the design waterline (m³), excluding craft the hull of which is supported completely clear above the water surface in non-displacement mode by aerodynamic forces generated by ground effect. (SOLAS X/1.2, High-Speed Craft (HSC) Code 2000 para 1.4.30)
- Mobile offshore drilling unit (MODU) means a vessel capable of engaging in drilling operations for the exploration for or exploitation of resources beneath the sea-bed such as liquid or gaseous hydrocarbons, sulphur or salt. (SOLAS IX/1, MODU Code 2009 para 1.3.40)
- Special purpose ship (SPS) means a mechanically self-propelled ship which by reason of its function carries on board more than 12 special personnel. (SPS Code para 1.3.12)
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