Future of International Cooperation in Meteorological and Related Services

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In thinking about this paper, I was struck by the words “future” and “international”. For an ideal global society, the benefits of sharing knowledge and data should be universally accepted; however, in the real world, nationalism, competing jurisdictions, economic and technical inequalities, language and cultural barriers all can skew such an obvious desire. The problems and challenges related to social needs, both on a routine and long term basis, require international cooperation for their solution. For international cooperation to work, all partners need to achieve some visible and tangible benefit from working together. For the past century and a half international cooperation in meteorological services has fit the ideal solution. Will it continue into the future?

Addressing the future brought to mind a paper published in the May, 1939 Bulletin of the American Meteorological Society by W. C. Devereaux. In 1938, Dr. Willis Gregg (Director of the Weather Bureau and President of the AMS) wrote to many leading meteorologists and asked about their view of what a meteorological service would look like in another 50 years (i.e. 1988). Gregg died late in 1938 and had not completed a paper that analyzed the responses he received. The paper was to form the major topic for his presidential address to the AMS in January, 1939 in Richmond. Because of the interesting and fascinating information that was contained in the responses, the officers of the society decided to ask Deveraux to review the thirty reports sent to Gregg and prepare a paper. Deveraux quickly recognized that each of the reports would be a interesting study alone; however, he did agree to be a collaborator and provide an extract from each report in his paper.

I mention this because the reports in many cases verified in the late twentieth century the meteorological services provided by our science. For example, many of the reports indicated that the future would benefit in large part from improvements in “radio” and communication related technology. Regarding upper air measurements from the early version of the radiosonde (radiometorograph) one report suggested the future would allow for, “records to be flashed to all parts of the world …rather than a series of dashes to one station only.” Another report suggested that, “Practical meteorology depends to a large extent on the efficiency of communication systems in both the collection of data and the distribution of weather information and forecasts. …At the present time experiments are being conducted in a general distribution of the weather map by printed radio so that it can be received by the aviator in the air, the farmer in the country, or any other person…”

One report noted that meteorology was behind classical physics in recognizing the fourth dimension (called by the writer a “space-time-continuum”). It suggested that, “the weather map is dead matter, but the forecaster would give it life by converting the indications into active energy, and forecast the storm movement and direction and time. It was also suggested that the time-space or matter-force continuum will be solved with mathematical precision in the future." Dr. Charles F. Brooks, then Secretary of the Society, had several ideas of the future which include the following: "use of ultra-high frequency radio transmissions to determine continuously, by means of recorders at different distances from the stations, the changes taking place in the layer structure of the atmosphere;" and "I believe that the use of forecasts placed on phonograph records which may be obtained by telephone will spread to this country and be generally available. The forecast will be changed at least every six hours and in periods of rapidly changing weather every hour."

A report by J. Cecil Alter of Utah suggests remote sensing from space; "Sky-sweeping robots of electric-eyes will explore the upper atmosphere for air mass demarcations, depths, direction and velocity movement, moisture content, and other factors. Zig-zag tracings or photographic replicas, automatically registered, will be made of the shape of the course of the refracted ray from the electric eye, as it passes through different air masses." Interestingly, Alter included a poetic comment by George P. Murphy of the Salt Lake City Weather Bureau Office in his report;

"O'er land and sea, desert and polar space
Observations without man shall soon take place
That fly through air with speed of light
To guide both Man and Weatherman aright.
No longer shall we guess to save our face,
But snap, and there's the weather any place."

Most of the reports sent to Gregg appear to have been quite accurate in depicting the meteorological service of the late 1900s. Further it appears that two common factors seem to have been driving forces. First, scientific development grew at a reasonably rapid pace; and second, improvements in communication related technology often proved to be major keys to advancement. The remainder of this paper will not be as bold as many of the scientists reporting to Gregg, but will rely on extrapolation of current meteorological services to estimate the future.

Considerations for the Future

Meteorology by its very nature has always been a global or international science. But, for meteorology to have become truly an operationally effective world science, improvements, qualitatively and quantitatively, had to be made in the global observation of the condition of the atmosphere. A concomitant improvement was also needed in the transmission of data and the distribution of service information to "users."

For purposes of this paper, services will be considered as the timely availability of information regarding the present and future state of the atmosphere and/or ocean to all or a selective part of the public. Information would include data itself, analyses, and prediction. Because the atmosphere and ocean are global fluids and thus under-go changes on every timescale, it has been necessary to incorporate international cooperation in observing, forecasting, and dissemination of information. As a point of interest, it is probably incorrect to suggest that research provides no service. Conversely, it must also be recognized that in providing meteorological services, there is a built-in research component that provides enhanced scientific understanding. As a result, programs discussed in this paper emphasize service aspects, but do contain research contributions. Similarly, there are research programs, not discussed here, that provide a meteorological service to society.

There are a considerable number of atmospheric and oceanic services available on a nearly continuing basis that require international cooperation. These use large infrastructures that are maintained by intergovernmental and international bodies such as WMO, ICAO, IMO, IOC, and IAEA (many of these infrastructures have been reported in the papers of the first panel). The services generally support public activity such as the safety of life and property, efficiency of transportation, and protection of environmental quality. From an economic point of view, most governments in calculating the costs of their national Meteorological Service assume that the international cooperation component will remain unaltered in the future allowing for a continued free and open exchange of data and information. It is estimated that the value of this international component is worth between 5 and 10 billion dollars annually.

Most would agree, that over the next several decades, the need to support forecast and warning of tropical cyclones both at sea and at land-fall in terms of position and meteorological parameter intensity (e.g. wind speed, storm surge, surface wave spectra, precipitation amount, etc.) will continue, and may require additional accuracy. Support to the safety and efficiency of aviation will continue to require improved quality in order to accommodate both new types of aircraft and the increase in the population of flight air space. Similarly the same kind of improvements in service will be needed to support marine and maritime transportation. The risk of release of hazardous material into the environment will likely increase, requiring both forecasts and assessments of the atmosphere and ocean in order to reduce impact to society. Other potential international meteorological services in the future could provide new or enhanced support to public health, food production, and water resources. Another common aspect of the future will involve the methods used to deliver services to the user. Since this paper is intended to provide background information, the panel may wish to discuss some of these postulates in considerin future enhanced international cooperation in meteorology.

Tropical Cyclone Warning and Forecast Services

Hurricanes, such as “Katrina” and “Rita”, continue to show the value of warning and forecast services in saving lives and protecting property. Similar stories have been documented regarding typhoons in the western Pacific as well as tropical cyclones in the Indian Ocean basin. Several aspects of the international cooperation responsible for these services are noteworthy. The basis for most of this international cooperation lies within five regional tropical cyclone organizations closely aligned to the World Weather Watch (Discussed in Panel one) established by the WMO and other international organization partners.

Each tropical cyclone organization has a major regional numerical forecast center, called a Regional Specialized Meteorological Center (RSMC) which provides a focus for carrying out many services. These six centers (see figure 1) include the: US, Miami National Hurricane Center (Caribbean Sea, Gulf of Mexico, North Atlantic and Eastern North Pacific); Japan, Tokyo Typhoon Center (Western North Pacific and South China Sea); India, New Delhi Tropical Cyclone Center (Arabian Sea and Bay of Bengal); France, La Reunion Tropical Cyclone Center (South-West Indian Ocean); Fiji, Nadi Tropical Cyclone Center (South-West Pacific) and US, Honolulu Hurricane Center (Central North Pacific).

These RSMCs are responsible for coordinating tropical cyclone forecast and warning services for their respective international areas. These services include, providing both numerical model and subjective forecast guidance to each member country regarding the issuance of advisories and warnings; the assignment of storm “names” that have been previously agreed to by the regional body; the coordination of awareness and preparedness education; and the activation of special observing systems, frequencies, or periods. There is an expected continued increase of development in the coastal zones of many countries and the enhanced use of marine oriented recreation in the coming decades. As a result, there is a continuing need for international cooperation in providing tropical cyclone warnings and forecasts that will be most important to the safety of life and property as well as the development of many national economies.

Aviation Forecasting and Warning Services

In many parts of the world, aviation is probably the largest user of meteorological services. One of the early motivations for a weather forecasting and warning service just after the turn of the twentieth century was the support for the fledgling growth of commercial and general aviation. The extreme weather sensitivity of the aircraft employed in the early stages of air navigation can be seen by the records of 1918. Despite the introduction of primitive meteorological services, emergency landings occurred with an average of one per 1300 kilometers flown and the life expectancy of an Air Mail pilot was about four years. In fact in 1921 no fewer than 89 planes crashed and 19 pilots were killed. In contrast, just a few years later improvements in techniques and enhanced international cooperation provided a more mature service and allowed for the famous Lindbergh solo flight from New York to Paris.

Both enroute and terminal weather forecasting have become an integrated part of national and international regulations governing flight and operations at airports and aerodromes. Weather warning and forecast services have become an important part of the safety of aviation operations and have also contributed significantly to the efficiency of commercial flight. Coupled with new and improved satellite navigation, weather forecast services have refined flight plans that are accurate to within minutes even for durations of thousands of miles. This is an important aspect with regard to reducing fuel use and limiting green house gases in the environment.

International and intercontinental flights form a majority of commercial passenger flight miles and thus require international cooperation in the supporting meteorological services. At the turn of the twenty first century, international cooperation in weather forecasting and warning support to aviation made a significant step forward with the start of the World Area Forecast System (WAFS). WAFS is based on the preparation of digital forecasts prepared at just two numerical forecast centers (Washington & Bracknell) for the entire earth (see figure 2). The forecast models at each center are similar and serve as back-up to each should one facility become inoperative. The digital, gridded, and analog forecast services are broadcast by a series of geostationary satellites to the ICAO designated meteorological authority in each country around the world. The weather services provided are required by commercial aviation under the joint regulations established by the ICAO and WMO.

During the next few decades there will be continued pressure for growth in both commercial and general aviation. Society will need to deal with more crowded skies and larger airports as well as the need to decrease impacts on environmental quality and climate change. This growth will not only require the ongoing level of meteorological support, but most likely additional services with enhanced precision and accuracy.

Marine Forecasting and Warning Services

The oceans of the world have long been one of the principal links between countries, both in terms of communication and transportation. Warning, forecasting and climatological services for ocean areas and maritime activities are considered as the start of meteorological services, particular on an international basis. The need can be seen by the fact that more than 4000 ships were lost at sea between 1852 and 1856 entailing approximately 3600 deaths. Not surprisingly, the first large international scientific conference convened was concerned with maritime meteorological matters, the International Conference of 1853 and leading later to the Conference of 1873. At the Conference in 1873 the International Meteorological Organization was established and 20 national meteorological services agreed to cooperate on an international basis. International maritime meteorological service was initiated because of the development of the radio (wireless) telegraph which allowed for both the transmission of observations from ships, and the return transmission of weather conditions. Since its inception, the sharing and exchange of responsibility, information, and data among mariners, maritime nations, and other related international groups has been an important part of making transportation on the high seas safer and more efficient.

Today, the international cooperation for marine weather warning and forecast services is a part of the new satellite based Global Maritime Distress and Safety System (GMDSS) included as a part of the Safety of Life at Sea Convention (SOLAS) administered by the International Maritime Organization, the International Hydrographic Organization, and the World Meteorological Organization. Providing weather warning and navigational information on a timely basis to ships at sea and others is a shared responsibility among several maritime nations (see figure 3). Instead of nations serving ships under their own "flag", the responsibility is divided up into 16 Navareas with just one nation providing the leadership in making available weather warnings and forecasts on at least a 12 hour basis and also providing updates on navigational matters.

At the turn of the twenty first century, global marine weather forecasts and warnings underwent a major change that significantly enhanced the quality and accuracy of the maritime meteorological service. These improvements, cast as part of the new GMDSS, included (1) new highly reliable communications via a dedicated satellite system called INMARSAT, (2) Precise information regarding navigational positioning through GPS and other navigational satellites, (3) Timely information on hazardous weather conditions including the development and movement of extratropical and tropical storms through a global system of weather geostationary satellites, and (4) Improved accuracy of weather forecasts based on more precise and higher resolution numerical forecasting models, better data from satellites and buoys, use of ensemble techniques, and major increases in computer processing capability.

It is expected that maritime transportation will continue to grow in the coming decades as it offers the ability to move large amounts of commodities at relatively low cost with little impact from green house gas emissions. During this time frame, there is a need to improve longer range forecasts, so that evasive measures from storms and other natural hazards can be taken in a timely manner both at sea and at terminus of voyages.

Other Meteorological and Oceanic Services

There are other meteorological and oceanic services, not discussed above, which use and require continuous international cooperation. The topic of transboundary meteorological services across national boundaries (e.g. USA – Canada) involve a great deal of international cooperation and coordination is not discussed in this paper. The Tsunami Warning System in the Pacific brings together international cooperation amongst all the island and coastal nations of the Pacific rim. The cooperation includes "real-time" sharing of tide and seismic data so that information can be quickly analyzed and tsunami warning guidance can be issued to all affected nations. This watch and warning guidance is provided by a global center in Hawaii and several regional centers such as those at Palmer, Alaska and Tokyo. Meteorological support to chemical and hazardous spills in high seas areas is provided under the similar structure used for marine warning and forecast services with a designated focus for coordinating meteorological service support to spills and releases in each Navarea. Similarly, designated international regional support prediction centers have been designated to support releases of nuclear materials, volcanic ash and other hazardous materials into the atmosphere. It should be pointed out the regional centers in tsunami warning, ocean spill and atmosphere release support and other warning and advisory support is provided to national focal points that further disseminate the information nationally and directly to users. A combined research/services program that is expected to continue and most likely expand in the next several decades is the Global Atmospheric Watch (GAW), that monitors green house gases and other chemical constituents in the atmosphere. GAW also includes the monitoring and periodic analysis of stratospheric ozone. As a service, periodic routine bulletins are issued on the state of ozone in the atmosphere. While meteorological support to agriculture is largely a national activity, there is international cooperation in specific areas such as Africa, where regional centers have been established to provide meteorological services support to agriculture regarding drought, desertification, and locust migration. Finally there is a potential for new or enhanced meteorological services that will require international cooperation. For example, increased understanding into biometeorology and bioclimatology may well generate an international service on human health and climate or weather. During the last decade, interseasonal and intraseasonal forecasting has become more and more important. Most of this activity has been provided on a cooperative research institution basis and a formalized intergovernmental program has yet to be realized.

Summary

The scientific literature describes most of the planned international field and numerical experiments that have been accomplished from the International Polar and Geophysical years until the present. Less visible to many has been the continuing international cooperative meteorological services that support many of the aspects that define the quality of life. In particular, the quality of our environment, the safety and efficiency of our transportations systems, the safety of the public living in high risk areas from natural hazards, and the understanding of our climate and its changes. The challenge is great and based on the current growth the world population will reach 10 billion by the year 2050. This new millennium will witness an increased demand for food production, deforestation, increasing desertification, population growth in urban areas and of human settlements in risk prone areas such as coastal lowlands, river valleys, and arid and semi-arid lands. Most of the international meteorological infrastructure set up to provide this support is expected to continue well into the future with changes relating to improvements in technology and additional understanding gained from science. I would expect that most would agree with this forecast; however, it should be pointed out that the rate of improvement could largely be govern by political decisions made nationally and internationally. Questions that could arise would effect future international cooperation including the desire of nations to continue to share the necessary resources to provide services and the potential effects of globalization and trade. Assuming that the socio-economic-political aspects remain relatively stable, I would expect that the trends of future international cooperation in meteorological services would (1) improve with enhance communication technology that deals in large part with users (e.g. cell phones, "blackberries", etc.), (2) increasingly use of consensus assessment techniques (e.g. IPCC method, ensemble forecasting, etc.) for prediction services on all time scales, and (3) embrace new formal services such as biometeorology and climate.

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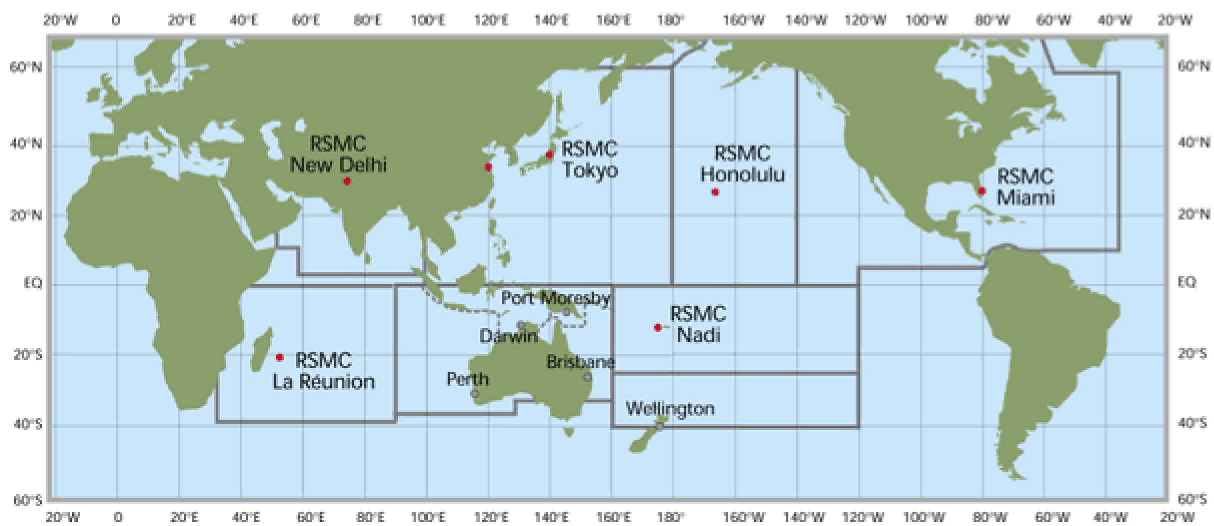
Figure 1

List of Tropical Cyclone RSMCs



Caribbean Sea, Gulf of Mexico, North Atlantic and eastern North Pacific Oceans:
RSMC Miami-Hurricane Center/NOAA/NWS National Hurricane Center, USA.

Western North Pacific Ocean and South China Sea:
RSMC Tokyo-Typhoon Center/Japan Meteorological Agency.

Bay of Bengal and the Arabian Sea:
RSMC-tropical cyclones New Delhi/India Meteorological Department.

South-West Indian Ocean:
RSMC La Réunion-Tropical Cyclone Centre/Météo-France

South-West Pacific Ocean:
RSMC Nadi-Tropical Cyclone Centre/Fiji Meteorological Service

Central North Pacific Ocean:
RSMC Honolulu-Hurricane Center/NOAA/NWS, USA.

Figure 2
World Area Forecast System (WAFS)

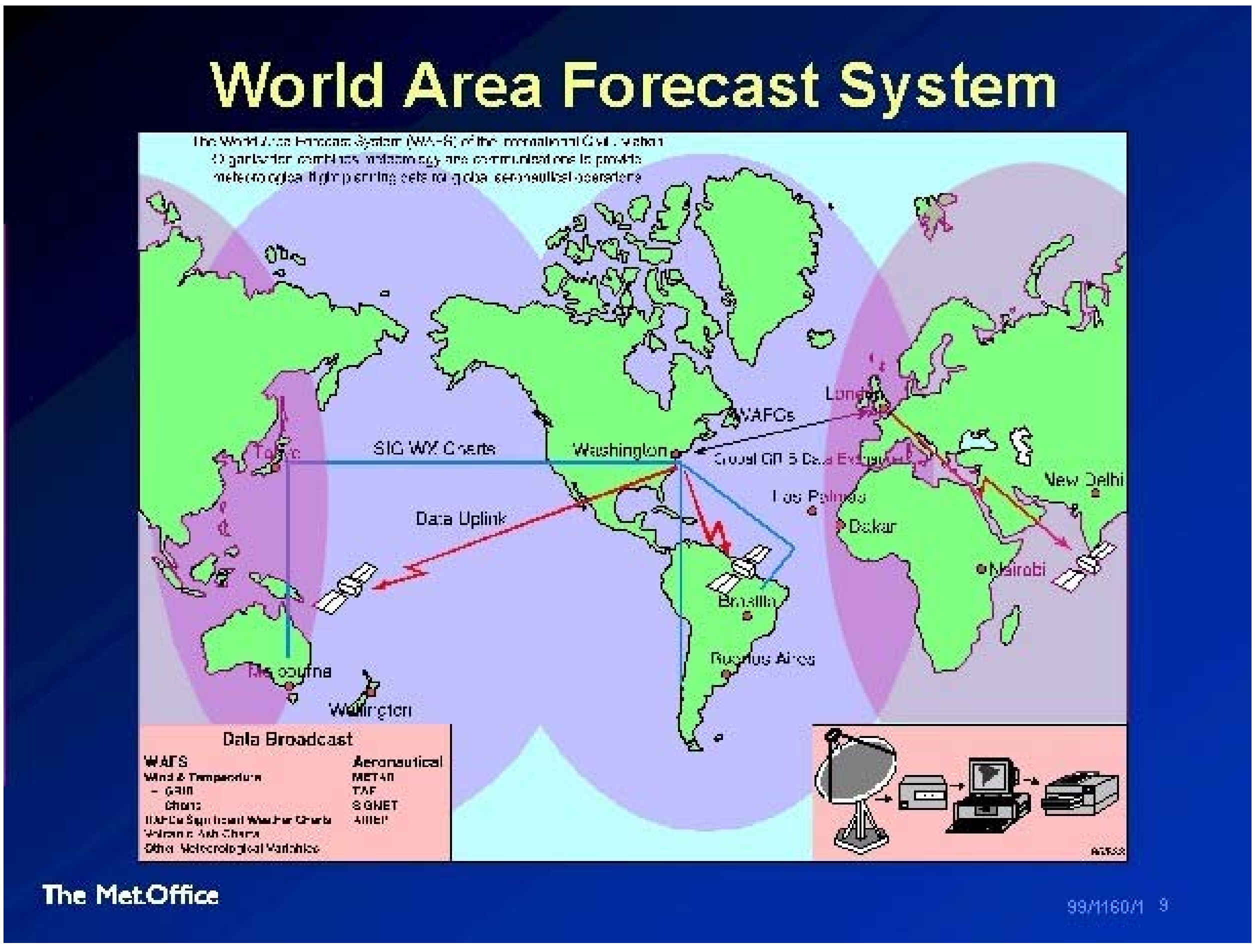
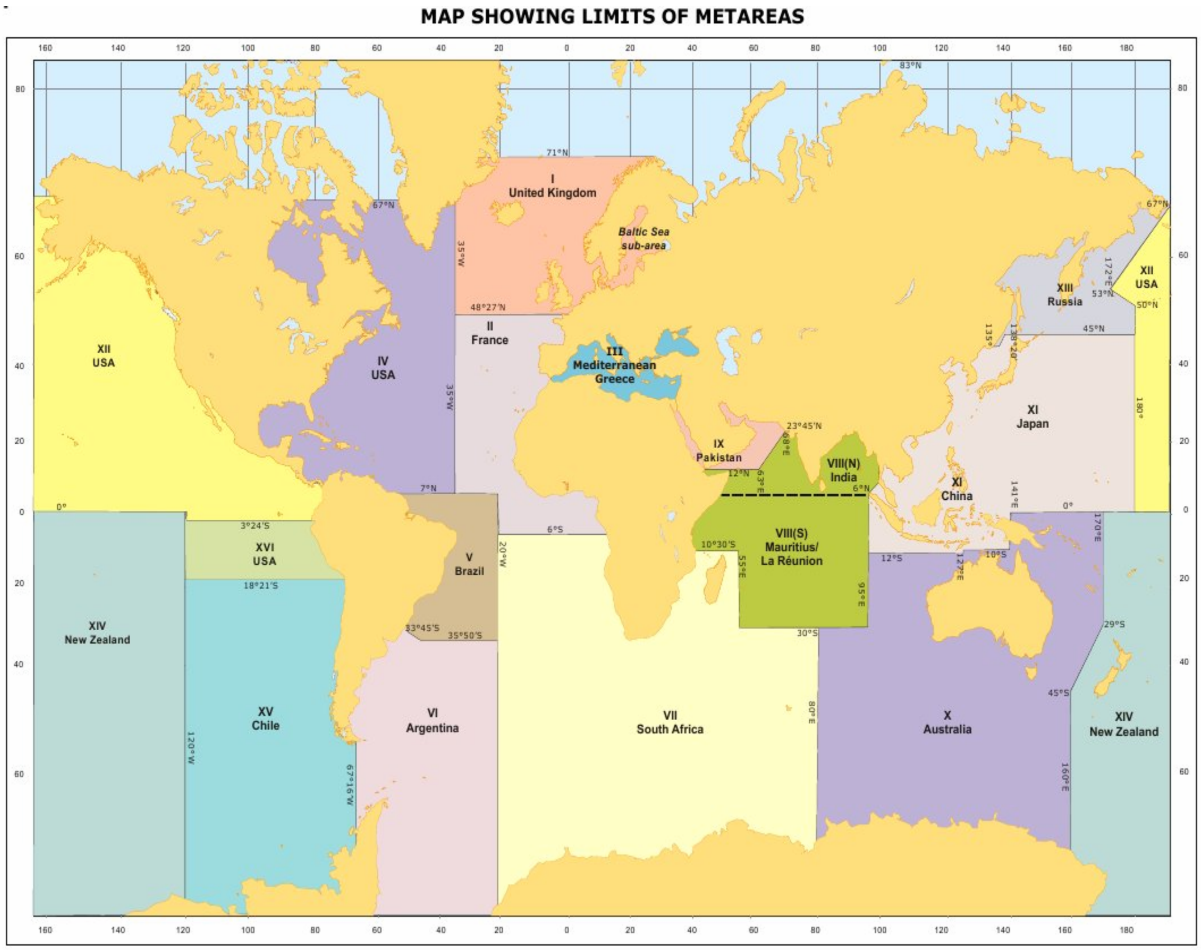


Figure 3

NAVAREAS



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