

Adding Oceanographic Marine Information Objects to the Electronic Chart Display and Information System

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Abstract-Marine Information Objects (MIOs) consist of supplementary information needed by the mariner to be displayed on the Electronic Chart Display and Information System (ECDIS) that are not Electronic Navigation Chart (ENC) objects nor Digital Navigational Chart (DNC®) features. Several organizations are working on writing the standards that will be used in displaying these MIOs. The Naval Oceanographic Office has taken the lead in the field of oceanographic object attribution.

First, we need to identify the type of oceanographic data needed by the mariner for display on an ECDIS. This would include the physical properties of the water column, the ocean circulation, the characteristics of the ocean floor, and coastal processes. Next, with these new oceanographic data sets comes the need to establish object and attribution classes. NAVOCEANO is working to establish international standards for these MIOs as a member of the International Hydrographic Organization International Electro-Technical Commission Harmonization Group of Marine Information Objects and the NATO initiative to establish Additional Military Levels. Finally, we will look for the best means to visually display these MIOs on the ECDIS with the DNC or ENC, and other MIOs.

I. INTRODUCTION

Marine Information Objects (MIOs) consist of supplementary information used with Electronic Chart Display and Information Systems (ECDIS) that are not Electronic Navigational Chart (ENC) objects nor Digital Navigational Chart (DNC®) objects. Supplementary means non-mandatory navigational information that is in addition to those required by existing ECDIS-related standards and specifications. MIOs may be either chart- or operational-related, and often include a vertical three-dimensional spatial or temporal dimension. At the meeting of the International Hydrographic Organization (IHO)/International Electro-Technical Commission (IEC) Harmonization Group of Marine Information Objects (HGMIO) held on 15-16 January 2002 at the University of New Hampshire, the following MIOs were agreed to be further investigated:

- Ice Systems
- Tides and Water Levels
- Current Flow
- Oceanographic
- Meteorological
- Marine Mammals
- Environmental Protection

- Security
- Vessel Traffic System
- Search and Rescue
- Imagery

The Naval Oceanographic Office (NAVOCEANO) has taken on the task of examining where oceanographic standard objects and specifications are today and propose oceanographic objects that would interest the mariner and the warfighter for display on an ECDIS in the near future. The guiding principle from the HGMIO is to formulate the development of specifications related to the use of MIOs on ECDIS that supplement the minimum chart- and navigation-related information required for safety of navigation.

Additional Military Layer (AML), a North American Treaty Organization (NATO) initiative being developed by the United Kingdom Hydrographic Office (UKHO), is designed as a unified series of discrete data products for use in a modular manner. They can act as an overlay to a chart display, or as a complete display in their own right. The current AML products fall into the following categories:

- MFF – Maritime Foundations and Facilities
- RAL – Routes/Areas/Limits
- CLB – Bathymetric Contour
- LBO – Large Bottom Objects
- SBO – Small Bottom Objects
- ESB – Environmental/Seabed/Beach
- NMB – Network Model Bathymetry
- IWC – Integrated Water Column
- AMC – Atmospheric/Meteorological/Climatology

AML is a core component of two wider and related initiatives. First, it provides the initial data load necessary for planning within NATO's Rapid Environmental Assessment concept. Secondly, AML lies at the heart of the United Kingdom Maritime Foundation Data Concept. This builds on the existing, land-based initiative and has been defined by the Director Naval Surveying, Oceanography, and Meteorology working closely with the United Kingdom's Defence Geographic and Imagery Intelligence Agency. A third significant area is the adoption by the NATO Mine Warfare Data Centre's use of AML as the standard format for high volume exchange of environmental information.

The UKHO, along with NAVOCEANO has taken the lead in developing the standards for the Integrated Water Column (IWC) layer. The presentation of oceanographic data on a current 2D ECDIS is not necessarily a simple matter. The ocean is best related as a 3D environment. Other considerations include the use of real-time data or climatic data since it is very difficult to obtain real-time oceanographic data worldwide. One other major difficulty is how to relate oceanographic data with other display parameters without over cluttering the display.

With an AML, the drive is to move away from publishing several products, each designed to meet a single need of a small subset of the overall mariner population, to the specification of a single product set designed to meet the needs of all users. This also avoids publishing the same information many times to publishing it just once.

II. OCEANOGRAPHIC DATA FOR NAVIGATION

The main reason you would add oceanographic data to a ECDIS is to support route optimization for navigational efficiency and to increase navigation safety by avoiding areas where the ocean could cause both the everyday mariner and the naval warfighter harm. Tidal and surface currents, wind waves, and swell data would greatly help in route optimization for navigational efficiency and assist in avoiding areas of severe seas.

At present, this mission falls to the Maritime Safety Information (MSI) Division within the National Imagery and Mapping Agency (NIMA), which collects and analyzes maritime safety information in support of a nautical database. At the same time, produce, promulgate, and provide worldwide access to standard nautical, digital, and customer tailored hydrographic and bathymetric safety of navigation data. Two of the products provided by the MSI division are the Hydrographic Products Catalog and the Daily Memorandum. The NIMA Hydrographic Products Catalog contains textual and graphic information on all of NIMAs hydrographic products to assist customers in ordering products over their area of interest. Although this publication is not available in its entirety on the website, database queries are available for all of the textual data concerning each product contained within it. Daily Memorandum is a summary of all Broadcast Warnings and Special Warnings promulgated from the WorldWide Navigational Warning Service (WWNWS) Broadcast Watch Desk during the previous 24-72 hours. It is generated on a daily basis (Monday-Friday) and consists of an Atlantic and Pacific Edition. The Atlantic Edition contains all HYDROLANT and NAVAREA IV warnings, while the Pacific Edition is comprised of all HYDROPAC and NAVAREA XII warnings. Both editions include any Special Warning(s) that may have been promulgated. The most current editions are available in their entirety on the web site, and database queries are also available to query for any or all current and in-force Broadcast Warnings and Special Warnings. Currently none of the MSI products can be overlaid onto an

ECDIS navigational chart. Many of the products are textual and would require the mariner to hand plot onto a paper chart.

Optimum Track Ship Routing (OTSR), the ship routing service of the United States Navy, utilizes short-range and extended-range forecasting techniques in route selection and surveillance procedures. These forecasts are computed at least every 12 hours from a database of meteorological and oceanographic forecasts. These routing recommendations are then broadcast to each individual ship in a form of a naval message. A different approach would be to assemble and process the weather and sea condition data and transmit the data to the ships at sea for on-board processing and generation of route recommendations. This would allow the Naval forecasting centers to create one forecast product versus a separate product for each naval vessel. This would provide greater flexibility to the ship's master in changing parameters, evaluating various scenarios, selecting routes, and displaying data.

III. OCEANOGRAPHIC HIERARCHY

The first step taken was to break the oceanographic data into general parameters to determine what would be beneficial to the mariner. The properties of the ocean were broken into the following six categories: Physical, Chemical, Biological, Optical, Acoustic, and Seabed. We will focus on the physical properties of the ocean with the understanding that the same concepts can be applied to the other properties of the ocean.

Physical oceanography is the exploration and study of the physics and geography of the ocean currents and water properties. Some major components of physical oceanography are the dynamics of ocean currents on scales from centimeters in the littoral environment to kilometers on the global scale. The variability on these ocean currents is on a time-scale from seconds to millennia. Ocean wave phenomena, the distribution of heat and salt and their transport through the ocean basins, the exchange of momentum, heat and freshwater between the ocean and the atmosphere, and interactions between oceans and rivers, estuaries, ice and marginal seas are all key to working on the ocean. Physical oceanography has important applications in global climate, oceanic mixing, and coastal studies. To limit the focus, we will look at the physical oceanographic features of sea temperature and ocean swell, the effects these have on the mariner, the use of ECDIS in navigation, and how to best relate these features to the mariner and/or warfighter.

The next step is to determine the attributes required to best relay the information about each physical oceanographic feature object. Using version 3.1 of the S-57 IHO exchange standard for hydrographic information as the starting point, we will establish objects and attribution in each oceanographic datasets. The exchange standard consists of three primary components. The first is the IHO S-57 catalog of Objects and Attributes. The second is the specification of S-57 Exchange Format. The third is the Product

Specification for Electronic Navigational Charts. By designing the oceanographic objects in a manner compatible with S-57, we will be able to use the update mechanism designed for ECDIS for oceanographic information. This is very important since the oceanographic datasets are continuously changing.

For sea temperature or ocean swells the object class would be broken into a point, line, or area classification. Set attribution would be defined for use with each object class. For temperature the following attribute classes would be recommended: Exposition, Quality, Technique, Accuracy, Units, Range, Value, Period, and Depth. For ocean swells, a different set of attribution would be required, such as: Height, Wavelength, Direction, Units, Quality, Accuracy, and Period.

Next we would need to determine the frequency in which the oceanographic information will need to be updated. For most navigational products, the data are static with infrequent updates and the data can be loaded onto the EDCIS for quick display. This is true of historical oceanographic data, where the data could be provided to the mariner in a static format for upload onto an EDCIS, which could be overlaid onto a nautical chart. This is not true for dynamic features of the ocean like ocean swells. The mariner would require frequent updates, which would overwrite the previous datasets. At present, NAVOCEANO updates the ocean swell model every 12 hours.

The final step would be determining how to best relate the physical oceanographic data with the current navigational display through the use of point, line, and area feature objects with attribute. This is the most challenging step in the process since the current ECDIS systems are limited to two-dimensional, planer space, and oceanography is best related in a three-dimensional volumetric space.

IV. INCORPORATION OF OCEANOGRAPHIC DATA INTO ECDIS

Oceanographic data will need to overlay onto the current navigational charts that are displayed on an ECDIS. The example used for this paper will be an approach chart viewed at a scale of 1:50,000 over Southern California near Newport Beach (fig. 1).

1. ECDIS Related Standards and Terms

The unqualified use of the electronic chart in the integrated bridge depends on the legal status of the electronic chart system in use. The IMO has defined the ECDIS as the integrated bridge system that complies with the up-to-date chart carrying requirements of international law. The ENC, DNC, or AML is the ship's electronic chart database used in an ECDIS system. ECDIS performance standards for AML's are still under development.

One question in the development of ECDIS has been whether the nautical chart and related information should be

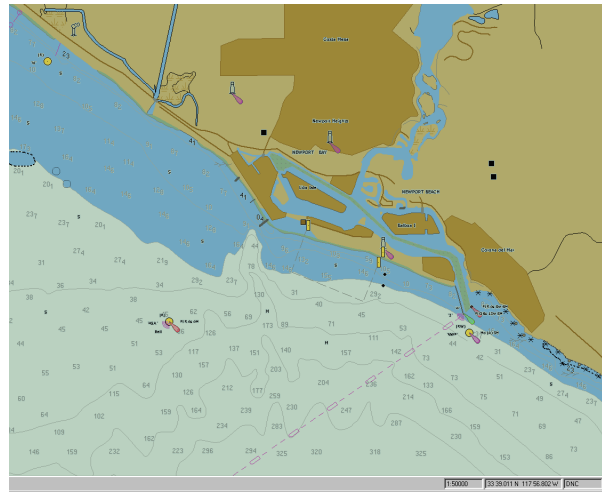


Figure 1 – DNC viewed in 7Cs See My DENC

digitized in raster or vector format. **Raster** chart data is a digitized “picture” of a chart. All data are in one layer and one format. The video display simply reproduces the picture from its digitized data file. With raster data, it is difficult to change individual elements of the chart since they are not separated in the data file. Raster data files tend to be large, since a data point must be entered for every picture element (pixel) on the chart. Currently oceanographic data like ocean swells are sent to the mariner in raster format. **Vector** chart data are organized into many separate files. The chart contains graphics programs to produce certain symbols, lines, area colors, and other chart elements. Vector files are smaller and more versatile than raster files of the same area. Therefore the mariner can selectively display vector data, adjusting the display as needed. Current IMO/IHO standards for ECDIS recognize only the vector format as adequate. Several Organizations like the UKHO and NAVOCEANO are working on the object and attribution requirements to change the oceanographic datasets to vector format.

Resolution or scale indicates the size of an image pixel with respect to the actual ground distance represented by the pixel. Scale units normal within an ECDIS are expressed as meters (1:50,000). NAVOCEANO resolution units within the ocean models are expressed as pixels per degrees (15 minutes).

2. Data Encoding, Transfer, and Updating

Current oceanographic data are encoded in formats best suited to the data models in which the information is generated. Historical data are generated in a format most requested by oceanographers. Changing the format would not be feasible, and creating new datasets will require the ability to transfer the data from their current format to the IMO/IHO standards.

Nautical charts are currently loaded into ECDIS through the use of libraries. These libraries have specific resolutions

based on the type of use, like approach charts or harbor charts, as an example. These charts are static in nature, requiring limited updates only when specific items within the nautical chart change. Therefore the mariner needs to load the data only once prior to the voyage.

Oceanographic data are not created in the same library structure as nautical charts and are normally best described in a volumetric structure. In addition many of the variables change on the order of minutes in the littoral environment. An updating frequency needs to be addressed. NAVOCEANO provides a forecasted significant wave height and direction graphic for specific areas that is updated every 12 hours. The forecast is presented as five separate .jpg images covering the periods of nowcast, 12hr, 24hr, 36hr, and 48hr forecasts (fig. 2). The resolution of the pixels is 15 minutes by 15 minutes. This type of product would be helpful in route planning at the scale of a general or coastal nautical chart, but would be very limited in the littoral environment.

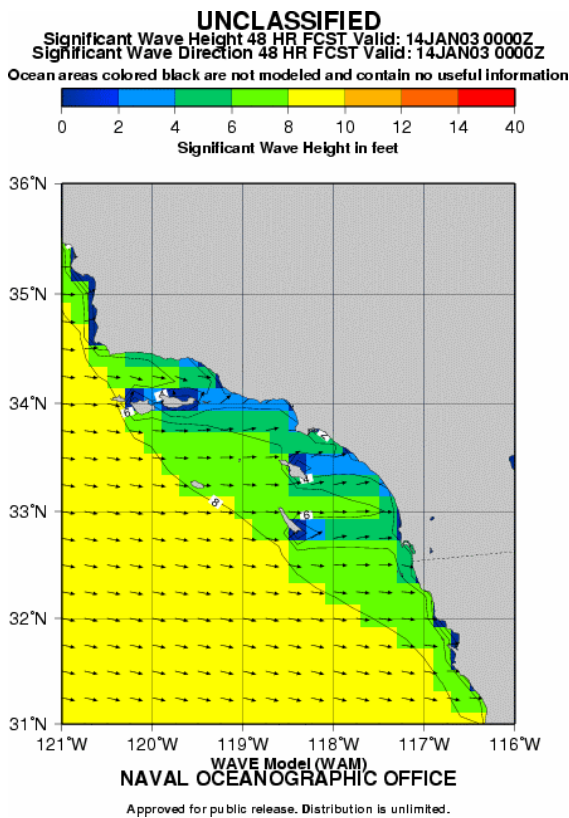


Figure 2 – 48 Hour Significant Wave Height and Direction Forecast for Southern California

3. Symbolization and Data Presentation

Oceanographic MIO data will need to follow set ECDIS symbolization. Currently there are two sets of standards for symbolization. For DNC products, the symbolization standard is Geospatial Symbols for digital displays

(GeoSym). This performance specification defines the format and content of the symbol graphics and symbol assignment tables that comprise the geospatial symbols for digital displayed products. Symbols and symbol assignment tables are provided to support the display of the VPF products. For ENC products, the symbolization standard is S52 presentation library. The IHO has produced specifications for the chart content and display aspects of ECDIS that appear in S52 and its appendices. This ensures that hydrographic data are supplied in a manner that will enhance the safety and efficiency of navigation by satisfying the requirements set in the IMO Performance Standards for ECDIS.

The main concern with oceanographic symbolization is similarity to both meteorological and navigational symbolization. Ocean temperature contours on current displays look just like temperature contours on a meteorological chart or depth contours on a navigational chart (fig. 3). The mariner or warfighter would have a difficult time discerning what the line meant if all three contours were displayed at the same time on an ECDIS system.

Another issue that needs to be addressed is the masking of area data when more than one area color fill is displayed. Color-filled data must be displayed on an ECDIS system as the lowest layer or it will mask the underlying datasets. This means the ECDIS needs to know the hierarchy of color-filled layers to determine which datasets will be masked. NAVOCEANO currently provides a graphical product of ocean current and temperature at different depths. The temperature area feature object in an ECDIS system would mask the depth contour area feature of the current navigational chart if overlaid at the same time.

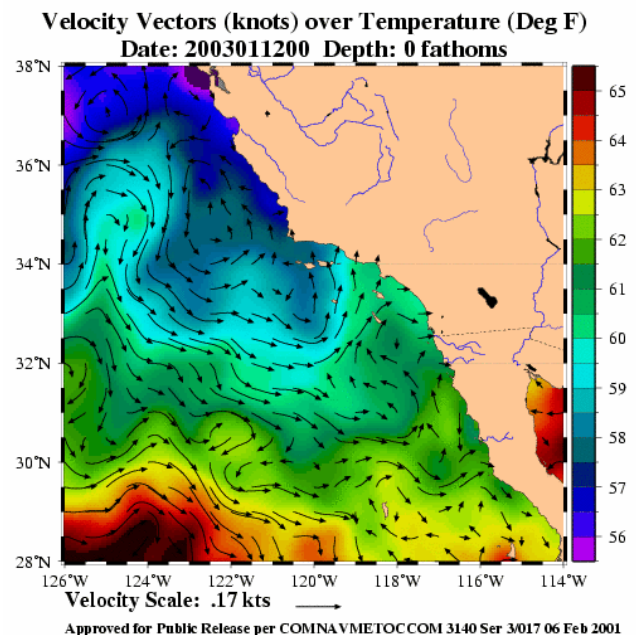


Figure 3 – Sea Surface Ocean Temperature and Current Over Southern California

4. Integration and Use of Data

Oceanographic data on an ECDIS system will be used primarily for route planning and route monitoring. Ocean waves and current data, along with meteorological MIO datasets, could be used to calculate ship speed over time for different preplanned routes to determine the most efficient route and get a more accurate estimated time of arrival or modify the route for a safer voyage. For route monitoring, the mariner would establish threshold values, which would generate an alarm within the ECDIS. An example would be if the mariner were required to stay out of 8-foot seas due to the limitation of his vessel. The mariner would set the 8-foot wave height contour as a safety contour, as he would a depth safety contour, and the ECDIS system would alarm if the vessel crossed the wave-height safety contour. This would require an IMO buy-in to change the performance specification within ECDIS.

Another oceanographic monitoring tool is to view physical oceanographic data in a vertical cross section (fig. 4). This would provide a mariner with a snap shot of the physical properties either in a historical aspect that could be related to current environment or actual data collected within the area.

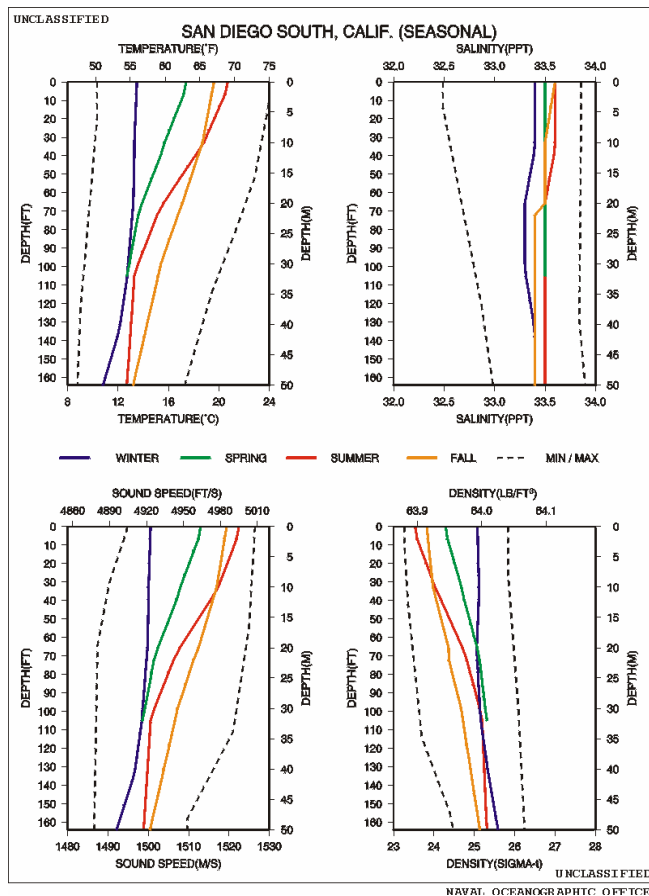


Figure 4 – Vertical Cross Section of the Physical Properties of the Ocean near San Diego, California

The concept is to create a tag with specific attribution that would display a vertical cross section of the ocean's physical properties for a specific location. NAVOCEANO currently provides vertical cross sections of the ocean from historical databases, but the data are not in a format that could be displayed on an ECDIS today.

V. THE FUTURE OF OCEANOGRAPHIC DATASETS

Before oceanographic datasets on an ECDIS can become a reality the following areas will need to be addressed by the IHO-IEC Harmonization Group on Marine Information Objects:

- Agree upon which oceanographic objects need to be addressed on an ECDIS
- Determine which set of symbolization criteria to use, with S52 as a recommendation
- Assign attribution and color tables to oceanographic objects that are unique from meteorological and navigational attribution
- Establish hierarchy for display of more than one color-filled area dataset
- Create a means to update/replace oceanographic and meteorological forecast products that change on the order of every 12 hours
- Put together an example dataset of oceanographic objects for testing on an ECDIS

VI. CONCLUSION

The incorporation of oceanographic information into ECDIS, along with the other AML's will make ECDIS a more versatile tool by making navigation more efficient and safer. The integration of these new AML's including oceanography has been proven to be feasible. However we need to make sure we don't over task ECDIS with too much information that the primary tool of safe navigation is lost. Therefore further investigation and development is needed before the maximum benefits from this integration can be obtained.

REFERENCES

1. IMO Resolution A.817(9) on Performance Standards for ECDIS, adopted in November 1995.
2. IHO S57 Transfer Standards for Digital Hydrographic Data, 3rd ed., November 1996.
3. IHO S52 Specifications for Chart Content and Display Aspects of ECDIS, 5th ed., December 1996.
4. MIL-PRF-89045 Performance Specification Geospatial Symbols for Digital Displays, February 1998.
5. Meeting Minutes, IHO-IEC Harmonization Group of Marine Information Objects for ECDIS, 15-16 January 2002.