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TIME VARYING OBJECTS IN ECDIS
Today, tomorrow and soon after

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Abstract

ECDIS is about to become a commercial reality. However, the full potential of the system is not likely to be realised until Time Varying Objects (TVOs) like tides, currents etc., are incorporated to represent the constantly changing conditions that meet the navigators every day. The relevant standards need to be urgently developed to prevent uncoordinated development of incompatible systems. A coordination of the efforts of several Working Groups of IHO is required to provide a viable solution.

1. INTRODUCTION

As the idea of an Electronic Navigational Chart is being developed into a commercially viable system of ECDIS, the question of the time variable aspects of depths (and overhead clearances) within ECDIS, needs to be addressed. Incorporation of other Time Varying Objects (TVOs) like currents, tidal streams, magnetic variation, ice, etc. also needs to be examined. The matter is becoming more pressing despite, or rather because of, the lack of international agreement regarding the relevant standards. Last year, the IHO Tidal WG met in Cape Town and, having examined their aspects of the TVOs, advised the IHB of the need for such standards regarding representation of tides and tidal streams. Other Working Groups and Committees also realised the urgency of the problems associated with TVOs and commenced working on solutions.

The mechanisms and standards for exchange, distribution and updating of digital data for ECDIS are being developed but the tidal and other TVO aspects of ECDIS seem to be left behind, with only the simplest tabular representation of tides having been seriously considered until recently.

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The present constraints imposed on the ENC by the lack of digital bathymetry data, especially in the areas which have been surveyed some time ago, may imply that ECDIS is just an electronic version of a paper chart with an added facility of a self-plotting ship position and routing. TVOs, such as tides, are to be presented in a tabular form, possibly even on a separate screen, together with other ancillary information. This need not to be so; even at the present level of development, the time variables, especially the tides, can be incorporated into ECDIS much more efficiently. There are considerable differences in the ideas underlying the paper and digital charts, and the same applies to different forms of tidal information. The whole relationship of tidal and other TVO information to the chart needs to be re-assessed in view of the dynamic abilities of ECDIS.

A "paradigm shift" is needed. So far, the dynamic time variables have been presented in a static form to suit the constraints of the paper chart, i.e. of the print technology. Today, there is a chance of moving towards a dynamic presentation of tides and other time variables. This chance may be wasted if we continue to adhere to the traditional, static approach which is not relevant to ECDIS. The TVOs and charts have been considered as two sides of the same dynamic entity, and not as separate issues.

The ENC Database supporting ECDIS operations is being developed as a complete world-wide system. Tidal and other TVO information, in some form, will be a part of this database, and we should look at this data as a part of digital chart service rather than a stand-alone service like tide tables. It is expected that there will be demand for separate tide tables for several years yet, but these requirements, like those for paper charts, can be easily met either using the existing methodology, or as a selective printout from the ENC database.

However, several questions need to be answered before addressing the technical problems connected with introducing the time variables into ECDIS. To answer them, we need to look towards future possibilities as much as at the solutions viable at present. Should the Hydrographic Organisations fail to address the TVO problems, they will be overtaken by the events driven by the customers' demand.

2. PRESENT OPTIONS

The IMO Performance Standard for ECDIS requires that ECDIS displays all chart information necessary for safe and efficient navigation. This should not restrict us to an equivalent of a paper chart in digital form. Much more can be achieved even within present constraints, but care should be taken to frame any standards and regulations to allow for future developments without the need for amendments at a later date.

ECDIS works on a cell principle. Both, the temporal and spatial dimensions of cells are well defined, but a single piece of TVO data can refer to a complete cell, several cells at once, or a part of one. A mega-polygonal approach within a cell proposed for other data can be also easily adapted for TVOs. Each TVO, however, has its own specific needs.

2.1 Tides

While ECDIS objects are vector based, tidal predictions (like tide tables), although site specific, are not suitable for representation as vectorial point objects. They will need to be represented pictorially (raster visual display) until a dynamic version of ECDIS is developed. At present, IHO Special Publication S-52 prohibits adjusting depth by tidal heights and recommends tidal information be displayed on an auxiliary screen. Raster representation of the current chart tidal panels was recommended in the first instance. There are however several better ways to incorporate tidal height information in ECDIS at the present stage of development.

i. The simplest option is to present tidal predictions in a tabular form. Operator selects position, and gets pictorial representation of tide tables for the nearest standard port, either high-low predictions as at present, or equispaced at e.g. 20 min.- interval. This can be interfaced with the current position of a vessel. Spatial limits of application of predictions for a given standard port will need to be determined by the relevant Hydrographic Office. Provision of tidal levels and time differences for secondary ports would enhance this option which is simple to implement. However, it does not provide any more information than the tide tables read in conjunction with a paper chart. ECDIS has a potential to do much more that.

ii. A more useful option is to provide time related predictions with respect to the vessel's position. Predictions can be updated at frequent intervals (e.g. 20 min.) for the nearest standard port and its approaches, and tidal height with its relative position to the tidal cycle, displayed on the screen. This easily implemented option will be further improved by incorporation of a prediction routine for secondary ports and graphic representation of tidal heights. Again, the spatial limits of the application would need to be determined by the relevant Hydrographic Office. This option is restricted to a block representation of tides for the immediate vicinity of ports and it does not provide for outlying areas. ECDIS potential is not fully utilised, even with a graphic display of tides.

iii. The most sophisticated option applicable today would allow basic modelling of tides, at least in the areas with sufficient tidal information. Each ENC cell can carry all necessary tidal information in form of harmonic constants for the suitable ports, with flags for different levels of accuracy, encoded by the relevant Hydrographic Office, while a tidal prediction routine should be supplied by ECDIS manufacturers. This option can display tidal height for the vessel's position at preset intervals, or as required by the operator, using an interpolation routine. While there are several possible ways of interpolation, a triangular model is preferred for its proven simplicity, accuracy and absence of datum discontinuities; it also allows for both: linear inter- and extrapolation, and for block adjustment as required. Spatial limits and other aspects of the model, including the number of tidal stations, would need to be determined by the relevant Hydrographic Office.

Tidal heights are relatively slow changing and tidal information is rarely required in real time; in most cases, updates of depth correction at 20 min. interval are expected to be sufficient. Thus, the model would place only small additional load on the ECDIS computational capability.

Any other chosen position and/or time can be substituted for that of a vessel if required. Thus, an operator can build a complete tidal model for a voyage, including present and future times of safe under-keel and/or overhead clearances, etc. Seamless representation of tidal heights is possible, with source data (e.g. ports used for modelling) available in a lower layer at the operator's request. The model can also supply timing information regarding the shortest time within which depth may alter by the depth accuracy amount (e.g. 0.1m) or by any other selectable amount.

The system can be further enhanced by interfacing with the transmitting tide gauges. It would then be able to provide real time tidal heights in critical areas. Inclusion of an algorithm for an equation for streams in a channel is another possible enhancement, as it would permit predictions of streams rate and direction for the immediate future. The combination of these two enhancements would be a safety feature in the critical locations like Torres Strait where there are several transmitting tide gauges, and for which an empirical equation for short-term tidal stream predictions, using the data from these gauges, has been developed.

2.2 Tidal Streams

Tidal stream information can be shown as vectorial objects and can be incorporated in ECDIS at the present stage of development. Information now contained in the stream panels can be interfaced with tidal predictions for the relevant reference ports. Tidal streams can then be represented as vectorial objects for discrete sites (diamonds on paper charts) - e.g. rotating arrows of variable length/width. Where tidal streams are represented only by arrows on the paper charts, these can be also converted to vectorial objects to show direction of flood/ebb and different rates for springs and neaps, with the information on the stage of the tidal cycle derived from the relevant predictions. A mariner's object depicting tidal streams already exists. The effect of the tidal streams (and other currents) on the vessel's course can be incorporated in ECDIS watchdog applications without difficulty as they are all vectorial objects.

2.3 Ocean Currents

Ocean currents and sets have been represented so far by a cartographic symbol, frequently with varying levels of accuracy of the information, especially in view of temporal variations of the current velocity and direction. A new TVO has been proposed at the last DBWG meeting to cover the ocean currents and the matter will require additional study, with satellite data being envisaged as one of the main near real-time sources of the information. Cooperation will be sought from the oceanographic community to determine the parameters of the ocean currents and their variability.

2.4 Magnetic Variation

This is a seemingly simple Time Varying Object. All the mariners are used to the depiction of the Magnetic North on the compass rose on a chart, but behind that simple arrow lies a complex theory and practice of determining magnetic variation and its rate of change. Assistance from the geomagnetic scientific bodies will have to be sought to determine the most practical way of incorporating this TVO.

2.5 Ice

Ice is possibly the most complex TVO as it defies any attempts at the long term predictions of its movements. At present, only the permanent ice is depicted on charts, and even its limits are constantly changing. The Ice Charts showing dynamic ice are produced by non-hydrographic organisations, and close cooperation with them will have to be developed to provide the up-to-date information for ECDIS updating.

3. FUTURE

All the options pertaining to tides and tidal streams listed above can be implemented now. The ECDIS of the future is expected to be a four-dimensional dynamic system providing a seamless presentation of temporally varying depths, streams, currents, and other TVOs. Developments in tidal applications in ECDIS aiming for such a system will depend on two main factors: availability of data and computing power available to ECDIS. The latter is probably less of a problem, as the computer industry foresees a hundredfold increase in the computing speed for a typical PC within 5 years, with a corresponding increase in data storage capability.

The question of data availability is more complex, as it concerns not only the sea level data but also digital depth data which will be required to produce a fully dynamic ECDIS. Digitised depth information is frequently based on surveys conducted with pre-digital technology not meeting the current standards, and the resultant chart data are often of an accuracy not comparable with that of the navigator or with modern tidal data. Until this worldwide problem is overcome, the accuracy of ECDIS will be not as high as it should be, as lack of digital source data will impede the progress in handling the contour lines, coastline, intertidal areas, etc. with respect to sea level variations. The sea level data, i.e. tidal heights and other factors affecting the sea level enumerated below, whether predicted or real time, are already available in a variety of digital formats, and can be easily incorporated in ECDIS.

In addition to the usual tidal predictions based entirely on the gravitational factors, there is a need for accurate information on other time varying factors affecting depth in ports, straits and at their approaches. The modern deep-draft ships require data not only on tides, tidal streams and currents, but also on storm surges, coastally trapped waves, other sea level anomalies (bulges and depressions) moving along the coast, etc. These factors may, on occasions, be more significant than tides. As the under-keel clearances are being reduced in some ports, this information is vital to the maritime safety and the operational efficiency of both, ships and ports. Short-term sea level forecasting service using mathematical models is required in several critical areas, and there have been already some promising developments in such environmental modelling. At present, the data from these environmental models, whether operational or under development, is not available to ECDIS. It is expected however, that, with time, this will change and that the data from these models will be made available to the ECDIS users; the format, and the method of transmission or interfacing will need to be decided in due time.

Even further in the future lies direct input of the satellite altimetry data which by now has achieved the accuracy required for navigational charts. This information could be used continuously to provide near real time tidal heights in critical areas or, what is more practical, intermittently, to correct tidal predictions. IHO is discussing at present the problems of a proposed global geocentric vertical reference system. Such a datum would create unnecessary problems for the users of paper charts and tide tables, but could be made completely transparent in ECDIS, facilitating interface with the satellites which utilise the geocentric system of coordinates.

Ocean currents data can also be sourced from the satellites; each current has its own thermal signature which is easily recognisable by the infra-red sensors of the satellites. While at present this information is usually restricted to the scientific organisations, there is no reason why it cannot be provided to ECDIS, especially if a viable price structure is first developed.

The aim should be to interface sea level and water movement transmissions from any source and to incorporate the predicted tidal heights and environmental modelling data into ECDIS to obtain the highest accuracy of depth and current information. The cost of provision of real or near real-time data from transmitting gauges and satellites, and of the short-term forecasts from environmental models will have to be balanced against the benefits to safety and operational efficiency.

However, the availability of digital sea level data may not be sufficient to produce a fully dynamic, four-dimensional ECDIS without digital depth sounding source data. Adjusting the single spot depth soundings for tides should not present great problems, irrespective of the original format, but contour lines which were compiled for paper charts and then digitised, are at present a source of serious delays in developing a fully dynamic ECDIS. It is expected that more digital source data will become available in time to facilitate this process, leading to an ENC database without contour lines, or even without spot depths. In the meantime, computational methods to bypass this problem may need to be developed.

A fully dynamic, four-dimensional ECDIS may be a long way ahead of us, but should be aimed for as the advantages of such a system reflecting tidal and other environmental factors affecting the sea level and water and ice movements are of prime importance. In addition, the ability to load a vessel in port with an accurate knowledge of the sea level at the ETD carries obvious economical advantages to the ship owners, at the same time enhancing the safety to shipping and environment.

Route planning would be made more complicated but safer, as all spatial/temporal combinations could be examined before arrival at a difficult location or a shallow port. Should the vessel be on course but off in time, then the next safe window can be obtained from the tidal/environmental model. In general, using the time variables the navigator will be able to determine the water level, depth, and hence the safety contour for any position that he may require.

Magnetic variation, despite wide usage of gyro-compasses will remain with us for ever. It is expected that an algorithm to determine its value and the rate of change will become available to ECDIS in the near future. A relevant TVO has been proposed for incorporation in the object catalogue.

Ice will always present a serious problem due to difficulty in predicting its movements, and will have to rely on real-time or near real-time information from different sources – from satellites to helicopters, operated by several outside agencies. The standard of accuracy of such information will have to be ascertained before being allowed to be displayed in ECDIS.

4. STANDARDS

While some basic ideas have already been discussed, notably by Tidal WG and DBWG, standards for at least the following TVO aspects of ECDIS need to be developed:

i. Set of symbols for TVOs, vector based objects where possible.

ii. Formats for TVO data for incorporation in the ENC database, and for all methods of TVO information display in ECDIS, whether direct or implied by temporal variability of depth data in case of sea level information.

iii. Tidal Datums. The variability of datums is a serious problem concerning ENC as a whole, but particularly important for tidal implementation. The older digitised charts are one source of this variability, different datum standards in different countries the other. While it may not be obvious on a single paper chart, the datum discontinuities will be visible on ECDIS screen unless a common datum is agreed upon. The proposed global geocentric vertical reference system may become in time the underlying common standard with ECDIS providing a seamless connection to a more practical navigational datum which will have to be agreed upon.

iv. Accuracy of tidal predictions obtained from built-in prediction routine. Different levels of accuracy may be acceptable in different areas; these must be determined and flagged accordingly. While it is unrealistic to expect a global uniformity, a compatible level of accuracy should be aimed for.

v. Accuracy of equations, environmental models, etc., where used to calculate TVO information.

vi. Accuracy of the real time data that can be accepted from transmitting tide gauges, and looking further into the future - that of the remotely sensed data. Different levels of accuracy may be acceptable in different areas, e.g. in the open ocean waters where only numerical models, like Schwiderski's, are available at present, and nearshore areas where other sources are available.

vii. Frequency and methodology of TVO data updates. This should not be confused with the possible interfacing to the transmitting tide gauges, satellites and environmental models which would supply real or near real-time data and short term forecasts. Updating of ice information may need a different approach to the more predictable TVOs.

viii. Spatial limits for TVOs, including cut-off depth for tidal data.

ix. Accuracy of dynamic contouring, including that of the coastline.

The above list may need to be extended as new subjects requiring standardisation are likely to appear when the TVO aspects of ECDIS are examined in greater detail. All should be studied as another dimension of the evolving ECDIS standards, to be integrated into S-52 or S-57 where applicable.

5. APPLICATION OF TVOs WITHIN ECDIS

The mechanism by which TVO information is applied within deployable ECDIS is the matter for the individual ECDIS manufacturers to determine, but the main points that will need to be addressed can be inferred from the above discussion. Assuming sufficient computing power of a deployable ECDIS for a dynamic four-dimensional operation, they would include at least:

i. Method of accessing predicted and observed tides and other TVO data
ii. Algorithms to handle ECDIS tidal and other TVO demands
iii. Temporal operation with the emphasis on Route Planning and Verification
iv. Options for user interface to depth corrections
v. Treatment of tides, tidal streams etc. in uniform depth areas (e.g. dredged)
vi. Treatment of intertidal areas
vii. Contouring and depth polygon closures

viii. Treatment of 0 level (coastline)
ix. Treatment of tidal streams, ocean currents, ice.
x. Interface with real-, near real-time, and short-term forecasting systems.
xi. Methodology of updating TVO data, interfacing with providers.

Some of these matters may present significant research problems, and it is possible that new methods of describing depth polygons and other tide related standards will need to be developed and integrated into S-57.

6. SUMMARY

As ENC and ECDIS are about to become reality, the questions related to handling time variables, especially the tides, need to be addressed urgently to enable the development of the system towards fully dynamic, four-dimensional operation.

Only few Hydrographic Offices can provide four-dimensional ENC data at present. No tidal or other time variable data have been incorporated so far anywhere, even when the Hydrographic Offices are capable of it. The problems outlined above in this paper are the main reason for this situation. Establishing the relevant standards is the first step towards overcoming these problems, with additional research effort from Hydrographic Offices and ECDIS manufacturers needed to fulfil the ECDIS potential.

Incorporation of tides and other time variables will make ECDIS more versatile but also more complex. Teaching the navigators to use ECDIS efficiently will be vital to enable them to access its full potential. The reward will be improved operational efficiency for ports and vessels, and enhanced safety to navigation, human life and environment.

The DBWG at their last meeting in Sweden (Norrköping, 29 May - 2 June, 1995) made recommendations for minimum representation of the currently recognised TVOs. The Group acknowledged the need for implementing the TVOs in ECDIS, as well as the ongoing nature and the complexity of the matter. One of their recommendations to the IHO Committee on ECDIS was to establish a permanent COE Working Group on Time Varying Objects (TVOWG), tasked to develop the relevant standards and methodologies, and to become a focal point for exchange of ideas between various Working Groups in this field. The TVOWG is expected to become an important tool in preparing the ground for a true dynamic ECDIS of the future.

References

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