A Harmonized Vertical Reference System for the Baltic Sea

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SUMMARY

This paper gives an overview to the harmonization of the vertical references used in nautical charts and navigational information in the Baltic Sea. Baltic Sea Hydrographic Comission (BSHC) has deemed important that all nautical charts and navigational information should refer to a well-defined common vertical reference system in the Baltic Sea. BSHC is one of the regional hydrographic commissions of the International Hydrographic Organization (IHO), all Baltic Sea coastal countries are members of BSHC.

Today chart datums of nautical charts in the Baltic Sea are mainly referred to Mean Sea Level (MSL), but the realization of MSL differs between countries. This kind of a situation is complex for chart users and causes also difficulties in data transfer between different organizations and neighbouring countries.

BSHC has selected the European Vertical Reference System (EVRS) as the harmonized vertical reference system. National realizations of the EVRS are deemed to be feasible realizations of chart datums in the Baltic Sea fulfilling the consistency requirement all over the Baltic Sea for navigational purposes. It should be noted that transition form MSL based chart datum to geodetic one is noteworthy change within marine sector.

This is a topical issue at this moment because many countries in the Baltic Sea region are either starting the transition or planning to change to the new harmonized reference system, called "Baltic Sea Chart Datum 2000".

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1. BACKGROUND FOR HARMONIZATION

1.1 Current situation

Today there are not any common vertical reference systems for hydrographic or navigational purposes in the Baltic Sea. National systems are principally based on mean sea level (MSL), but the realization of MSL differs between countries. Thus there are several national chart datums differing from each other.

1.2 Why harmonization is needed

The current situation with many different reference systems is inconvenient for mariners and complex in respect to data transfer between different purposes and organizations like national hydrographic offices, which are responsible of producing the official nautical charts in each country.

There are also some other reasons why harmonization is needed and why MSL is not anymore as feasible chart datum as it has been. One reason is that postglacial land uplift changes the depths especially in the northern Baltic Sea. The change of depths is around 7-9 mm in a year in the Bay of Bothnia. Another reason is that the prediction of MSL has become difficult.

Baltic Sea Hydrographic Commission (BSHC) deemed that it is important to harmonize vertical references in the Baltic Sea. Chart Datum Working Group (CDWG) was established in 2005 to study and propose the feasible harmonized vertical reference system and foster the transition to the new system. The European Vertical Reference System (EVRS) was approved by BSHC to be the harmonized vertical reference system. (Mononen, 2014).

1.3 Disadvantages of the current situation

Today's complex situation increases risk for mistakes with datums in navigation, data collection, data transfer and production of charts. This might cause environmental, financial or even more severe losses.

Data users have to be aware of different national MSL-realizations and not to think that MSL-based depth figures are referred to same reference level all over the Baltic Sea. Data and chart users have to take into account MSL changes, thus affecting the compatibility of depths measured in different times. Land uplift changes the actual water depth in the northern Baltic Sea and MSL is not the best datum to handle it.

Figure 1 illustrates the current situation with several datums in Finland. Same kind of a situation applies also e.g. in Sweden. In current situation there are different datums to be taken into account, MSL-year used as a chart datum, the survey datum and the water level datum, in which the apparent height of the water surface is referred to. The end users of the data like mariners, fairway planners and fairway builders have to be aware of these differences and capable of applying right reductions dependent on the purpose.

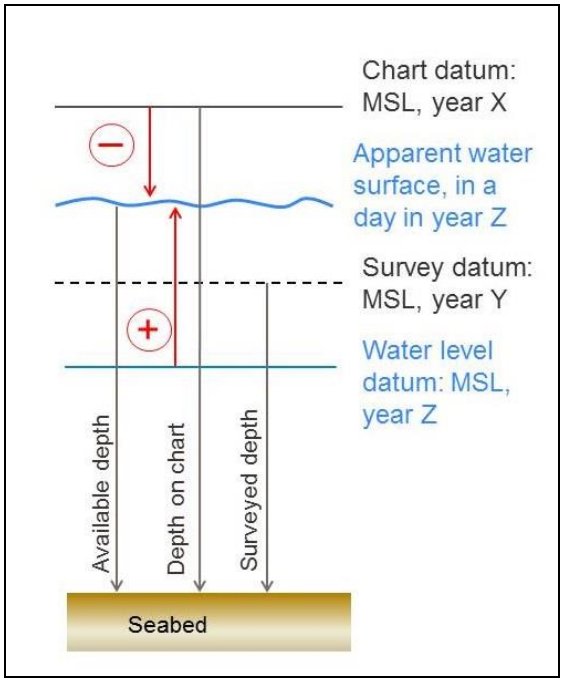

Figure 1. Current situation with many datums.

2. EVRS - THE HARMONIZED VERTICAL REFERENCE SYSTEM

BSHC approved EVRS to be the harmonized vertical reference system for the navigational purposes in the Baltic Sea. There are numerous benefits which can be achieved. EVRS is well-defined, European wide height reference system which is widely used in the countries around the Baltic Sea. Although there are national realizations of EVRS they are well-defined and documented and the differences between them are negligible considering navigational purposes.

2.1 Benefits of the harmonization

All the depth and water level information can be provided in the same datum within the whole Baltic Sea and only one vertical datum is needed. Figure 2 illustrates the situation after the harmonization. Thus confusion between different chart datums can be eliminated and navigation will be safer and cargo carrying capacity can be utilized more effective. Data transfer between national Hydrographic Offices and other organizations for different purposes will be easier.

Further on a wider and easier use of the depth data in accordance with the INSPIRE directive will be enhanced, full utilization of International Hydrographic Organization (IHO) S-100 standards can be achieved supporting in the future 3D-navigation and hydrographic surveying. (Mononen, Ellmer, Hammarklint, Jakobsson, 2014).

Depth information in sea areas and heights on land will be referenced to the same vertical reference system helping the data transfer for different planning and construction purposes applying also fairway planning and construction.

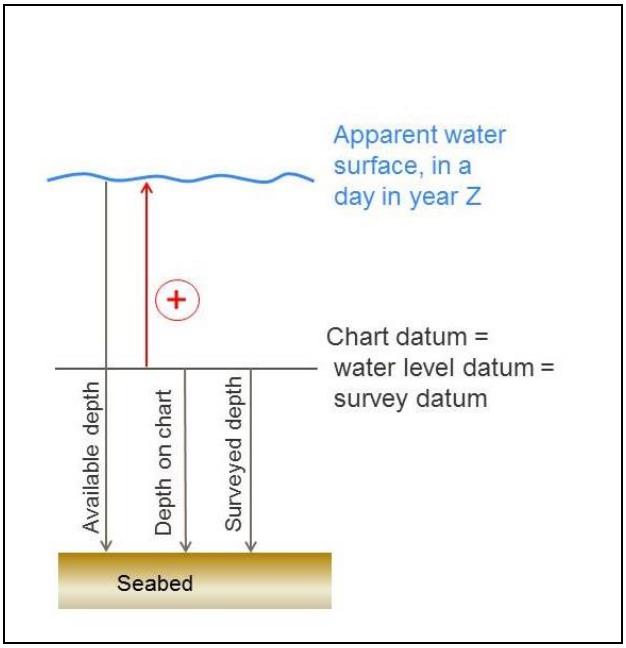

Figure 2. After implementation of the EVRS-based harmonized vertical reference.

2.2 What will change

One fundamental change is the transition from sea level -based reference system to a geodetic reference system. Although the use of geodetic reference level is in accordance with IHO resolutions, mariners are used to charts where depths and water level information is referred to some specific vertical position of water level, like MSL in the Baltic Sea.

In the northern part of the Baltic Sea depth figures on charts will be reduced around 15 – 20 cm or even more if they are originated form old bathymetric surveys. In the southern parts of the Baltic Sea there is practically no effect on depth figures. These effects are dependent on the location and time in respect to age of the depth soundings.

Differences are caused by e.g. mean sea surface topography, postglacial land uplift and other climatic phenomena. The effect of land uplift in the Bay of Bothnia is around 7-9 mm/year. The mean sea surface topography is illustrated in the figure 3 from tide gauges and levelling in

centimeters at epoch 1960. Zero is Normaal Amsterdams Peil (NAP), which is the same for the EVRS.

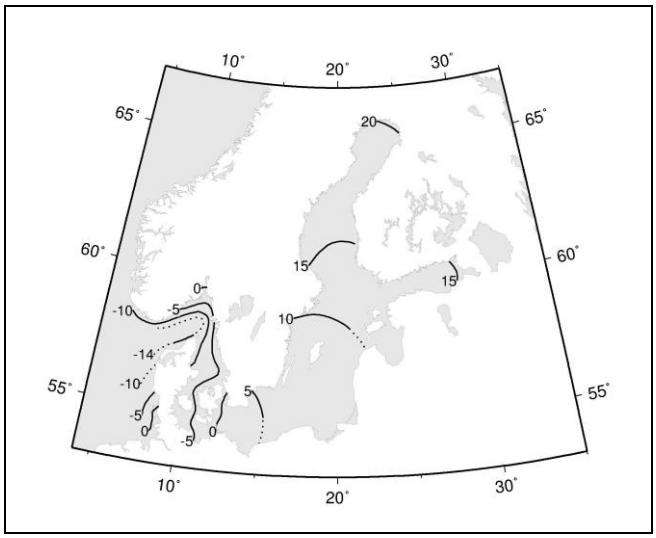

Figure 3. Mean Sea Surface Topography (Mean Dynamic Topography, MDT). (Replotted from Ekman, Mäkinen, 1996, courtesy of Mäkinen).

Table 1 gives an idea of changes to depths in Finland respect to age of the depth data. Numbers represents differences in millimeters between MSL and Finnish EVRS-realization, N2000-height system, in different mareographs in given years. The source of the data is theoretical mean sea level tables of the Finnish Meteorological Institute, http://en.ilmatieteenlaitos.fi/theoretical-mean-sea-level.

Year	1980	2000	2015
Mareograph			
Kemi	331	209	125
Oulu	316	200	122
Raahe	306	178	114
Pietarsaari	300	162	94
Vaasa	302	169	101
Kskinen	304	182	121
Mäntyluoto	288	184	137
Rauma	256	167	131
Turku	229	168	153
Föglö	203	138	121
Hanko	205	171	176
Helsinki	208	186	200
Porvoo	205	185	201
Hamina	197	182	203

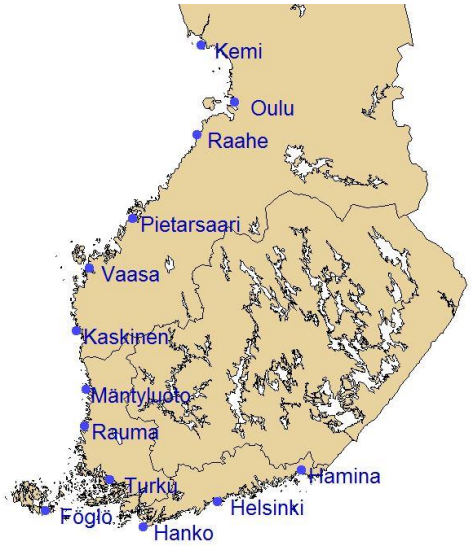

Table 1. Examples of differences between MSL and EVRS-realization in Finland in millimeters.

3. THE BALTIC SEA CHART DATUM 2000

Baltic Sea Chart Datum 2000 was approved by BSHC to be the name for the harmonized vertical reference system. This name will be used in the charts and navigational publications. Figure 2000 stands for the reference epoch for height changes due to postglacial land uplift in Fennoscandia.

3.1 Specification for the Baltic Sea Chart Datum 2000

In CDWG meeting 2015 it was deemed to be important to make specification for the Baltic Sea Chart Datum 2000 to define conventions how EVRS will be applied and to make sure that national realizations are accordance with each other. This chapter gives an overview to the first draft of the specification.

It is defined that the Baltic Sea Chart Datum 2000 is a geodetic reference system which is adopted for nautical charts and navigational publications in the Baltic Sea. It is based on the definitions of EVRS and the European Terrestrial Reference System 89 (ETRS89) and the reference epoch for height changes is 2000.0. The height reference surface over the sea area is an equipotential surface of Earth's gravity field and the zero level is in accordance with the NAP. The vertical coordinate is specified by normal heights and normal potential is defined by the Geodetic Reference System 1980 (GRS80). Corrections of the permanent solid earth tides are made so that the normal heights are in the zero tide system and the unit of normal heights is meter. (Ågren, Liebsch, Mononen, 2016).

The specification aslo describes the principles of realization of the Baltic Sea Chart Datum 2000. The realization shall make use of the existing national geodetic infrastructure and the goal is that the infrastructure provides a standard uncertainty better than 5 cm over the Baltic Sea. Official national vertical and spatial reference frames are used as realization if they are accordance with the definition of the Baltic Sea Chart Datum 2000 and they are in agreement with the official realizations of the EVRS and ETRS89 within a level of a few centimeters. Realization in offshore shall be based on the national GNSS positioning services, the corresponding national reference frames and a consistent model of the height reference surface, primarily realized by a gravimetric quasigeoid model. In areas with significant land uplift corrections shall be applied based on common up-to-date land uplift model in the way specified by national surveying authorities. (Ågren, Liebsch, Mononen, 2016).

4. IMPLEMENTATION OF THE BALTIC SEA CHART DATUM 2000

Implementation of the Baltic Sea Chart Datum 2000 is a long process and there are nationally several issues to be solved before the charts and navigational information can be published referred to it. As described in this paper there is no practically any effect in the southern Baltic Sea but in other parts there will be clear effect on depths.

Water level information has to be provided for mariner in the same vertical reference system to which the nautical charts are published. Thus the implementation effects not only the national organizations responsible for publishing official nautical charts but also the organizations providing the water level information.

It is needed nationally to make the decisions concerning e.g. scope of the transition, technical matters, effects on legislation, synchronization on providing water level information and publication of products in the new chart datum. Also it is important to inform mariners and other users of navigational data about the change and how it effects practically.

There is a good commitment within BSHC member states to take into use the Baltic Sea Chart Datum 2000. The original goal was to get the implementation finalized by 2020, but at now it can be anticipated that it is too optimistic. At this moment it can be summarized that member states have been executing actions to implement the Baltic Sea Chart Datum 2000, although there are differences in degree of readiness of the work.

5. CONCLUSIONS AND DISCUSSION

The harmonized vertical reference system for the whole Baltic Sea, the Baltic Sea Chart Datum 2000, makes the navigation safer. It helps in the future to take full advantage of IHO S-100 based products and to make shipping more effective.

The use of depth data for increasing needs for different purposes today and in the future will be enhanced. Needs for digital seamless depth and height data will be increased for purposes like marine spatial planning, environmental protection, habitat mapping, wind farm planning and utilizing marine energy sources.

In future 3D-navigation and further automated shipping sets high demands for accuracy of depth and navigational data. Thus reliable, accurate and well-defined geodetic infrastructure over the sea areas will be even more important in the future. The implementation of the Baltic Sea Chart Datum 2000 in the Baltic Sea is one step aiming to that goal.

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BIOGRAPHICAL NOTES

Mr Jyrki Mononen is working at the Finnish Transport Agency, Information department, Hydrographic Survey Data Management -unit. He has been working at Helsinki University of Technology, Finnish Road Enterprise and since 2006 at Finnish Maritime Administration which was merged together with parts of road and railroad administration as the Finnish Transport Agency in 2010.

Since 2013 he has been the chairman of the International Hydrographic Organization (IHO) Baltic Sea Hydrographic Commission (BSHC) Chart Datum Working Group (CDWG). He is a Finnish representative in IHO Tides, Water Level and Currents Working Group. He is FIG Commission 4 national delegate of Finland.

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