# Harmonization of Vertical References within the Baltic Sea

**Jyrki MONONEN, Finland**

**Key words**: hydrography, navigation, safety of navigation, harmonization of vertical datums.

## SUMMARY

Within the Baltic Sea area there has not been available any common vertical reference system for hydrographic or navigational tasks. This kind of a situation causes some practical difficulties for the users of navigational information and the co-operation between the Baltic Sea countries concerning hydrographic tasks related to depth and height information.

In June 2005 the International Hydrographic Organization (IHO) Baltic Sea Hydrographic Commission (BSHC) established a working group for the harmonization of the chart datums of the Baltic Sea. The work of the CharDatumWG was continued in June 2007 when the tasks were approved by BSHC 12th Conference. The main task of this ChartDatumWG is to study the feasibility to use the realization of the European Vertical Reference System (EVRS) as a principal alternative for the vertical reference system of Baltic Sea nautical charts. The ChartDatumWG should also study possible time schedules and preconditions with each of the Baltic Sea country could move to use this harmonized datum on nautical charts. The ChartDatumWG should study and develop recommended principles how the transfer period should be implemented. The ChartDatumWG should prepare recommendations how the sea level and its variations should be shown on nautical paper charts and Electronic Navigational Charts (ENCs) and on other nautical publications.

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## 1. INTRODUCTION

This presentation focuses on vertical reference systems used in hydrography, nautical charts and navigation in the area of the Baltic Sea. One goal is to give an overview to existing reference systems in the Baltic Sea nautical charts. Another goal is to present the current situation of the harmonization of the vertical references.

Within the Baltic Sea area there has not been available any common vertical reference system for hydrographic or navigational tasks. Countries have their own national systems which are different from each other. These systems are based principally on mean sea level (MSL), but realization of the MSL varies between countries because it has been determined in different ways. Also there are existing geophysical and oceanographic phenomena affecting to the mean sea level of the Baltic Sea.

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At the first stage the ChartDatumWG should prepare an introductive presentation of existing geodetic height datums in use at the Baltic Sea countries. Also the ChartDatumWG should specify the existing differences of chart datums used in the Baltic Sea area. The ChartDatumWG should report to the BSHC 13$^{th}$ Conference.

## 2. CURRENT SITUATION OF VERTICAL REFERENCE SYSTEMS

The current situation of vertical reference systems used for hydrography and nautical charts in the Baltic Sea region is presented in this chapter. The information is based mainly on the answers to the questionnaire done by the ChartDatumWG.

### 2.1 Present vertical reference systems

Basically in all the countries the vertical reference systems are based on MSL. There are differences how the MSL has been specified in different countries and thus there are e.g. different zero-levels. Also ties to existing geodetic reference frames vary between countries. Present vertical reference systems at the Baltic Sea area are DVR90, BHS-77 (Baltic Height System 1977), MSL (Mean Sea Level), NN (Normal-Null), HN (Höhennull) and $H_{NN55}$. The list is not comprehensive. Here is presented a preliminary and disjointed study of the present situation of reference systems.

In Denmark DVR90 is used in both nautical charts and in land surveying as a vertical reference system. The reference level is the mean of the mean sea levels observed in ten harbours equally distributed over the Danish coast at year 1990. The datum is based on MSL, but the zero level deviates only about two centimetres from the NAP (Normaal Amsterdams Peil).

In Estonia BHS-77 is in use. Datum is determined by connecting it to Kronstad tide gauge zero point using levelling observations.

In Finland MSL is the vertical reference system at the nautical charts. It may be considered that the reference level is the mean water of the year 2000. Finnish Institute of Marine Research publishes every year the official mean water. It is based on the long period observations of 13 mareographs along the Finnish coast. The mareographs are tied to national land survey height datum which is different than the MSL used in nautical charts.

In Germany NN and HN are used as reference systems. At the area of Schleswig-Holstein the datum is NN and zero level is related to NAP. At the area of Mecklenburg-Vorpommern the datum is HN which is tied to Kronstadt datum. HN-14 cm is the mean of MSL at the most important tide gauges at this area.

In Poland $H_{NN55}$ is used as datum for hydrographic surveys. The zero level is related to NAP. Since 1918 Polish mareographs have been related to it. $H_{NN55}$ differs few centimeters from the Kronstadt datum. Differences between $H_{NN55}$ and MSL are negligible at the coast of Poland.

In Sweden MSL 2000 has been the reference level in the production of new nautical charts since 1994. Before the year 1994 the reference level has been MSL for current year. MSL 2000 is defined by using long term water level gauging at each tide gauge station managed by Swedish meteorological an hydrological institute.

In general it can be expected that the maximum differences of chart datum levels between neighbouring countries are not more than one decimeter.

## 2.2 Plans for vertical reference systems in future on Baltic Sea countries

Denmark will be using DVR90 also in the future. DVR90 is tied to a geodetic height reference and it deviates only around two centimeters from NAP. Thus there are not reasons to do changes to the current system.
Estonia supports the harmonization of vertical reference systems at the Baltic Sea area.

Finland is going to change the system based on theoretical, predicted mean sea level to EVRF2000. One reason is the fact that the land uplift is changing continuously depths on the Finnish coast. Another reason is that because of some oceanographic phenomena the long period change of mean sea level has not been linear during the last few years like it has been earlier. It means that for longer periods it is not anymore possible to make reliable predictions of the mean sea level. Figure 2-1 shows observed annual mean sea level, 15-year moving averages and theoretical mean sea level at couple of Finnish mareographs. Theoretical mean sea level is a forecast of time dependent expectation value of the long term sea level. It can be seen that the theoretical mean sea level has followed the 15-year average until 1990's but after that the prediction of the theoretical mean sea level has become more difficult. Thus the theoretical mean sea level has lost its value and usability as the vertical reference in the area of Finland. The Finnish Maritime Administration has decided that the nautical charts on Finnish coast will be based on the EVRF2000 as soon as feasible in practice.

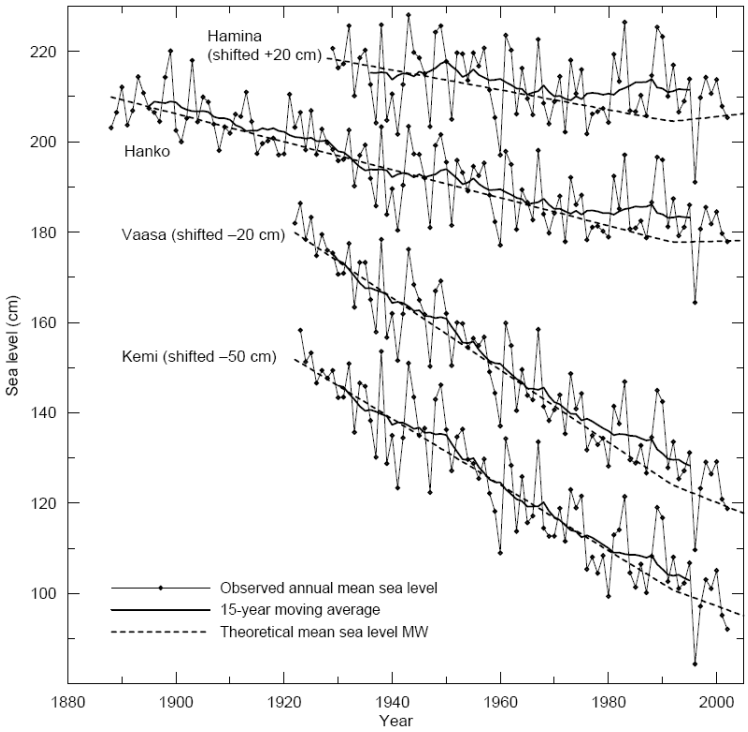


**Figure 2-1:** Observed annual mean sea level, 15-year moving average and theoretical mean sea level at selected Finnish mareographs. (Johansson et. al, 2004)

In Germany the geodetic height reference system is tied to European zero, which is close to the mean sea level at the southern Baltic Sea. NHN is the new vertical reference of the German land survey authorities. It will be the future reference of all tide gauges in Germany and thus a new chart datum. NHN is compatible with EVRF2000.

In Poland resurveys have been carried out for connection to European Reference Frames.
In Sweden the present situation is not efficient for producers of nautical charts or the users of the charts. The land uplift is significant at the Gulf of Bothnia. There is not easy way to access the datum metadata. The usefulness of EVRF2000 as a future vertical datum will be investigated and after that decision will be made.

## 3. DIFFICULTIES OF USING MEAN SEA LEVEL AT THE BLATIC SEA

On nautical charts the depths are measured as distances between the MSL and the sea bottom. Long time series of mareograph observations are required to determine the MSL. Land uplift, especially at the area of the Gulf of Bothnia between Finland and Sweden, has a significant long term effect on the time series. Figure 3-1 illustrates the magnitude of land uplift. Also the sea level may have variations over a long period due to global weather conditions, streams, global and local rise of the sea level. Because of all these reasons exact depth values are epoch dependent. Different epochs cause differences in charts between neighboring countries, which can be seen e.g. in overlapping areas of Estonian and Finnish charts.

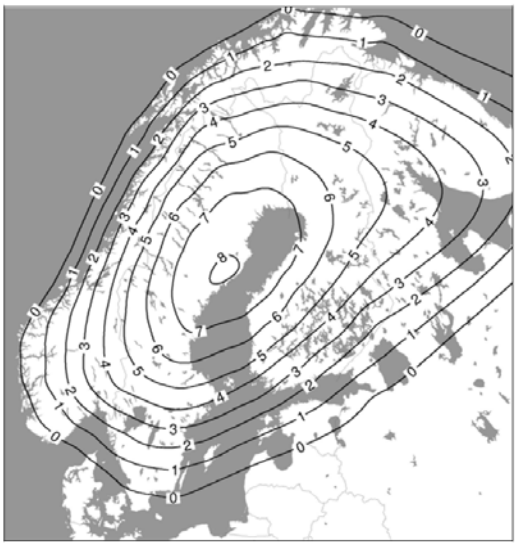

**Figure 3-1:** The magnitude of land uplift, mm/year relative to MSL. (Vestöl, 2005)

The true epoch dependent MSL may deviate from the chart datum up to ten centimeters. A difficult area is the Gulf of Bothnia where the postglacial land uplift rises the sea bottom causing decreasing depths. However, the sea level is rising and thus slightly reducing the effect of land uplift. The effect to the change of MSL is more than 5 cm in one decade. This means that measured depths and depth values in charts are epoch dependent. Also it means

that depths on nautical charts should be updated often – more often than it is possible in practice.

## 4. PROPOSED VERTICAL REFERENCE SYSTEM

### 4.1 The principal alternative

The main task of the ChartDatumWG is to study the feasibility to use the realization of the European Vertical Reference System (EVRS) as a principal alternative for vertical reference system of Baltic Sea nautical charts. Information about EVRS can be found on the EUREF web pages, http://www.euref-iag.net/. There are two basic reasons for selecting it as a principal alternative.

Firstly, it is a common vertical reference system in Europe and the IAG subcommission EUREF defined in year 2000 the principles of the realization of the EVRS called as European Vertical Reference Frame 2000 (EVRF2000). Secondly, the common levelling network around the Baltic Sea, Baltic Levelling Ring (BLR), has been computed and adjusted in 2006 giving the possibility to tie all mareographs to common datum. Figure 4-1 illustrates the BLR levelling network. The zero point of BLR is NAP, which was originally tied to the peak of average spring tide in Amsterdam in the year 1684. Currently it is physically realized as a bench mark in Amsterdam and it is close to the mean sea level at the coast of Netherlands.

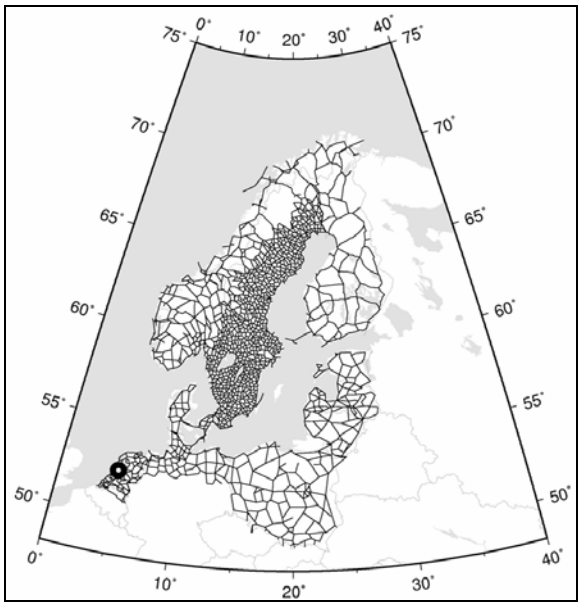


**Figure 4-1:** The Baltic Leveling Ring network. The zero point of it, NAP, is marked as a black ring on the map. (Mäkinen et al, 2005)

The replacement of MSL based systems by EVRF2000 would have practically no effect in southern parts of the Baltic Sea. But at the northern part it would have around 15 – 20 cm effect on depths. Also the mean sea level would differ about the same amount from the chart datum until the land uplift at the Gulf of Bothnia changes the situation.

One important issue has to be remembered while doing this harmonizing. The user of nautical charts, navigator, seldom gives any specific value on which particular datum is in use. But it is important for the navigator that the charted depths and the broadcasted real time information of water levels are in the same reference system. It means that the tide gauges and mareographs, which produce real-time water level height information, have to be tide to same vertical reference system with each other and with nautical charts.

### 4.2 Advantages of EVRF2000 as the new vertical datum

The assumed benefits which can be achieved when moving from the mean sea level based system to common European geodetic height frame, are the following. One well defined international system eliminates confusion between different datums. On national level the confusion between datums will be eliminated when the same datum is in use in hydrographic surveys and land surveys. Data transfers between hydrographic offices will be easier and safer because there is no need for datum conversions. Further on an international datum enhances wider and easier use of the data in accordance with the EU INSPIRE directive.

## 5. STATUS BY APRIL 2008

Currently the ChartDatumWG has completed the questionnaire of the existing situation concerning vertical reference systems in use at the Baltic Sea area. ChartDatumWG will continue its work and the BSHC 13th Conference in August may decide on further actions. The following issues should be reported to the BSHC 13th Conference:

- existing status of the reference systems within the Baltic Sea area
- forecasted time schedules and necessary preconditions with each of the Baltic Sea country could move to use the harmonised datum on their nautical charts
- recommended principles how the transfer period should be implemented
- recommendations how the sea level and its variations should be shown on nautical paper and ENC charts and publications
- methods and equipment for distribution of real time sea level data to mariners.

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## BIOGRAPHICAL NOTES

**Mr. Jyrki Mononen**, born in 1968. Graduated in 1995 at the Helsinki University of Technology as M.Sc. in surveying. Since 2006 working in Finnish Maritime Administration at Hydrographic Department. Since 2007 national delegate of Finland in the FIG Commission 4.

## CONTACTS

Mr. Jyrki Mononen
Finnish Maritime Administration, Hydrographic Department
Porkkalankatu 5
P.O.BOX 171
00181 Helsinki
FINLAND
Tel. + 358 20 448 4422
Fax + 358 20 448 4355
Email: jyrki.mononen@fma.fi
Web site: http://www.fma.fi