Articles

THE BALTIC SEA CHART DATUM 2000 (BSCD2000)

Implementation of a common reference level in the Baltic Sea

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Abstract

The *Baltic Sea Chart Datum 2000* (BSCD2000) is a geodetic reference system adopted for Baltic Sea hydrographic surveying, hydrographic engineering, nautical charts, navigational publications and water level information. It is based on the common geodetic standards for the height system (EVRS) and the spatial reference system (ETRS89) in Europe. In particular, the zero level of BSCD2000 is in accordance with the Normaal Amsterdams Peil (NAP). BSCD2000 is about to be adopted as unified chart datum by all the countries around the Baltic Sea. It agrees with most national height realizations used on land. BSCD2000 will facilitate effective use of GNSS methods like GPS, GLONASS and Galileo for accurate navigation and hydrographic surveying in the future.

Résumé

Le *Baltic Sea Chart Datum 2000* (BSCD2000) est un système de référence géodésique adopté pour les levés hydrographiques, l'ingénierie hydrographique, les cartes marines, les publications nautiques et les informations sur le niveau de l'eau de la mer Baltique. Il est basé sur les normes géodésiques communes au Système de Référence Vertical Européen (EVRS) et au Système de Référence Terrestre Européen (ETRS89). En particulier, le zéro hydrographique du BSCD2000 est conforme au *Normaal Amsterdams Peil* (NAP). Le BSCD2000 est sur le point d'être adopté en tant que niveau de référence des cartes commun par l'ensemble des pays bordant la mer Baltique. Il correspond à la plupart des mesures de hauteur nationales utilisées à terre. Le BSCD2000 facilitera l'utilisation efficace des méthodes du GNSS comme le GPS, GLONASS et Galileo pour une navigation et des levés hydrographiques précis à l'avenir.

Articles

Resumen

El *Dátum 2000 de la Carta del Mar Báltico* (BSCD2000) es un sistema de referencia geodésico adoptado para los levantamientos hidrográficos del Mar Báltico, la ingeniería hidrográfica, las cartas náuticas, las publicaciones náuticas y la información sobre el nivel del mar. Se basa en las normas geodésicas comunes para el sistema de alturas (EVRS) y en el sistema de referencias espaciales (ETRS89) en Europa. En particular, el nivel cero del BSCD2000 está en consonancia con el *Normaal Amsterdams Peil* (NAP). El BSCD2000 está a punto de ser adoptado como datum de cartas unificado por todos los países que rodean el Mar Báltico. Concuerda con la mayoría de las realizaciones de alturas nacionales utilizadas en tierra. El BSCD2000 facilitará el uso efectivo de los métodos GNSS como el GPS, GLONASS y Galileo para la navegación precisa y los levantamientos hidrográficos en el futuro.

1. Motivation

The Baltic Sea is an international shallow, non-tidal area in the northern part of Europe with dense traffic. Accurate depth data and water level information is of absolute importance to preserve the safety of navigation in the area. So far, numerous local reference levels were used in the Baltic Sea for nautical charts and water level information, such as water level observations, forecasts and warnings. The exact definition of the chart datum may vary between countries, regions as well as over time. The matter of these existing Baltic Sea chart datums is a rather complex issue, not only for the navigators, but also for the responsible hydrographic offices and other users of depth data in general. Thus, a unified vertical reference system is important to improve navigation in the Baltic Sea region.

For centuries, the chart datums in the Baltic Sea were defined as the "mean sea level" (MSL), which was observed at tide gauges, i.e., a height obtained by a long-term average of the sea level readings measured with respect to the land at the particular tide gauge location. This implies that the chart datum is influenced by two different quantities – long term sea level changes as well as possible height changes of the land. Both quantities could not be observed separately. This has a great impact especially in the Baltic Sea region which is strongly affected by the postglacial Scandinavian land uplift phenomenon. While the climate-induced sea level rise has an order a few millimeter per year, the land uplift affects the heights by up to one centimeter per year. This results in a lowering of the depth in major areas of the Baltic Sea and is well observable by mareographs (see ***Figure 1).***

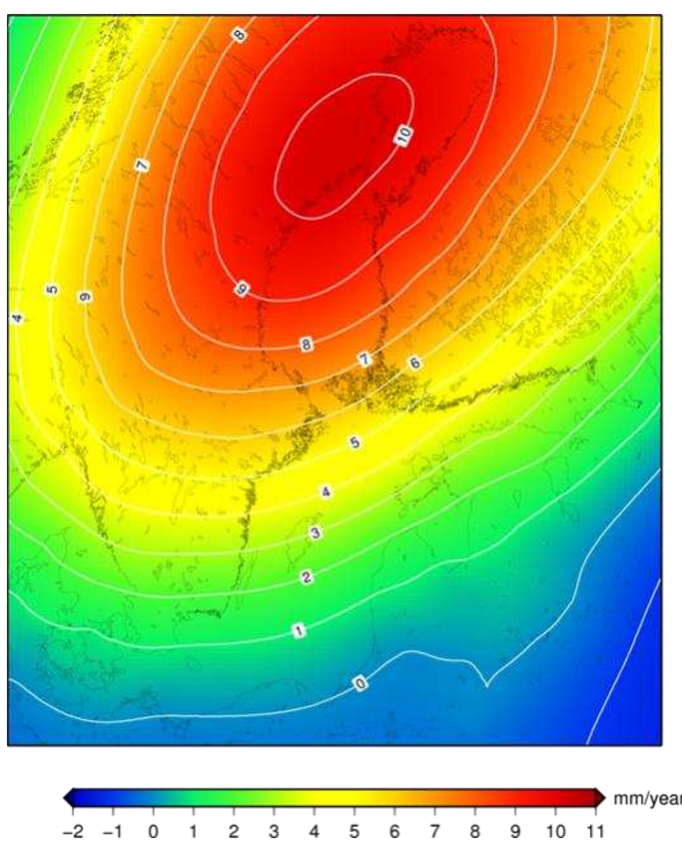


Figure 1: *Land uplift in Fennoscandia according to the NKG2016LU model (Vestøl et al. 2019)*

The MSL-based chart datum is only well-known at the tide gauge location. With increasing distance it is hard to predict the actual height difference of the sea level with respect to the tide gauge location. The uncertainty of the sea level predictions may reach the order of several decimeters and limits the accuracy of the depth information in nautical charts. Updating nautical charts and references for different kind of water level information implied large work in the past, especially in Sweden and Finland (see ***Section 4***).

Meanwhile, digital maps, satellite positioning and wireless internet have fundamentally changed the way we navigate in daily life. Regarding marine traffic, electronic nautical charts (ENC) replace paper charts. GNSS is used in hydrographic surveying not only to define the position in the horizontal direction but also in the vertical direction when measuring depths. To get the benefits of GNSS, the chart datum has to be well defined and compatible with GNSS positioning.

Modern hydrography is more than ship navigation and charted depths with respect to tide gauges. Spreading from environmental protection to economy, novel applications are typically multidisciplinary connecting the fields of hydrography and modern space-borne geodesy with for instance geophysics and telemetry. This is stimulated by increasing use of the sensitive coastal zones (e.g., offshore energy, safe vessel navigation, etc.). Another most relevant example is, of course, the monitoring of (global and regional) sea level changes by combining classical and modern geodetic space techniques (i.e., water level stations, geometric levelling, satellite altimetry and GNSS). Finally, GNSS based 3-D navigation becomes more common in commercial shipping and accuracy requirements of the depth information will increase. Future marine traffic will potentially see autonomous vessels which will require remote GNSS-based surveillance of the under keel clearance (UKC).

All these applications rely on observations on or of the sea surface by modern space-geodetic techniques. Thanks to GNSS and satellite radar altimetry, the height and the changes of both sea surface and land surface can nowadays be observed in a global Earth-fixed three-dimensional coordinate system with high spatial resolution. Heights obtained from these 3-D coordinates are related to a mathematical defined global mean earth ellipsoid, which can differ as much as 100m from mean sea level. Therefore, the ellipsoidal GNSS heights are not directly suitable for the most practical applications and have to be transformed to a meaningful physical height reference surface (HRS). This enables to realize a datum for nautical charts based on a geodetic height reference surface (see ***Section 3***).

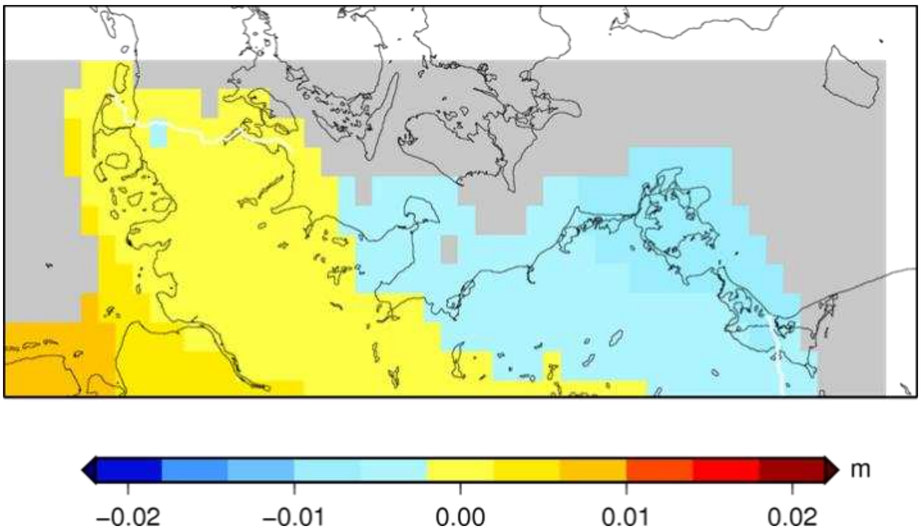
For practical applications on land, the use of GNSS-based height determination together with a compatible model of the HRS (called geoid in geodesy) have become standard and have replaced classic surveying techniques for height determination (mainly geometric levelling) in many geodetic applications. The European spatial and vertical reference systems

⇒ European Terrestrial Reference System 1989 (ETRS89) and

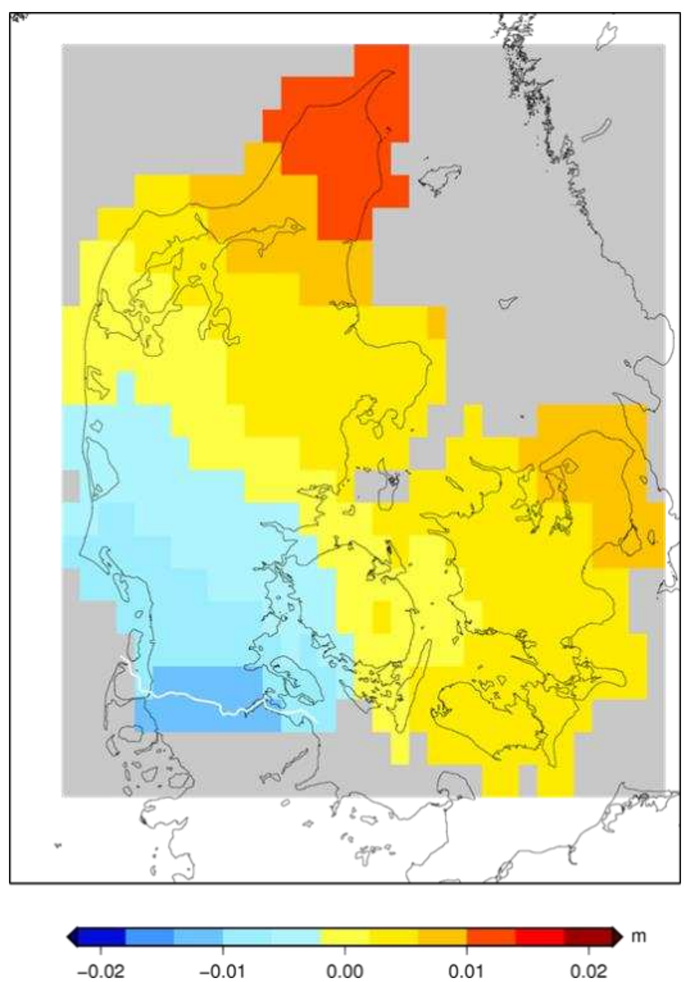
⇒ the European Vertical Reference System 2000 (EVRS2000)

are well developed and widely distributed. They are part of the INSPIRE directive of the European Commission and are supported by the member states. The respective national geodetic infrastructures have either adopted these reference frames or are in very close agreement to it (see ***Table 1*** and ***Figures. 2a-e***). The same reference systems and technologies are already in use out at sea to reference modernized hydrographic surveys.

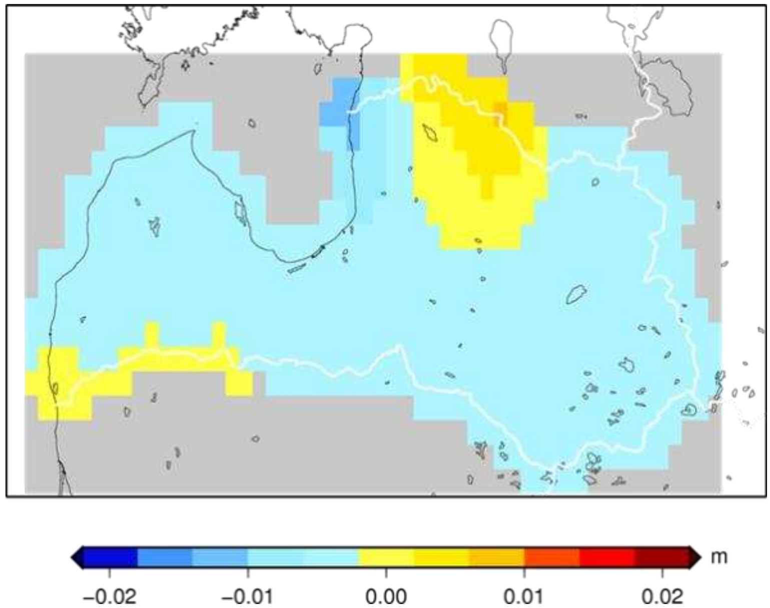
Figure 2 (a-e): *Examples of differences between national heights and zero-tide EVRF2019 heights.*



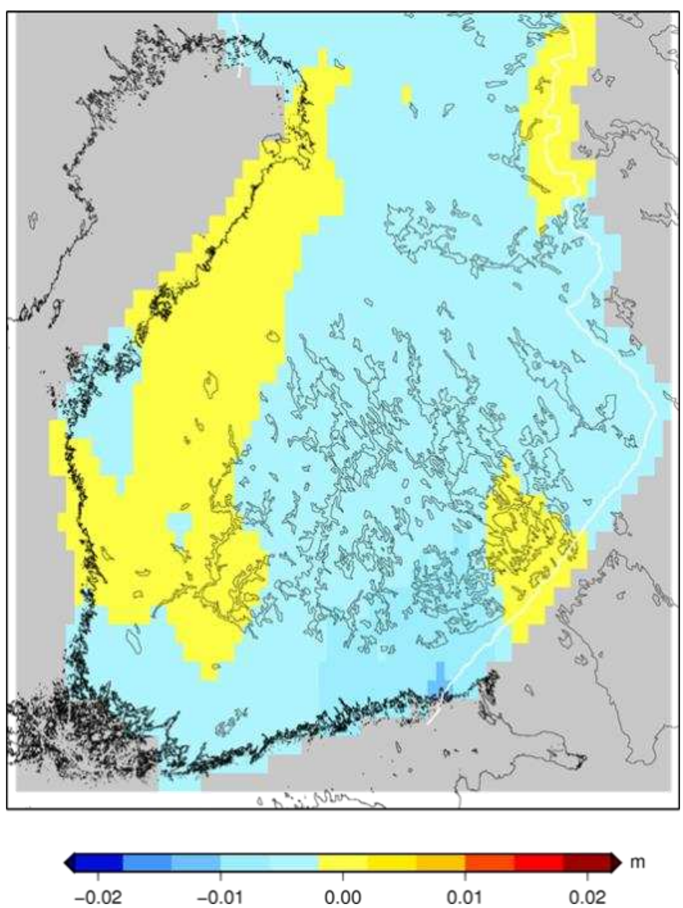
a) Height differences going from the national height reference frame of Germany (DHHN2016, north of the 53.5° parallel) to zero-tide EVRF2019 (mean –1 mm; min. –8 mm; max. +4 mm)



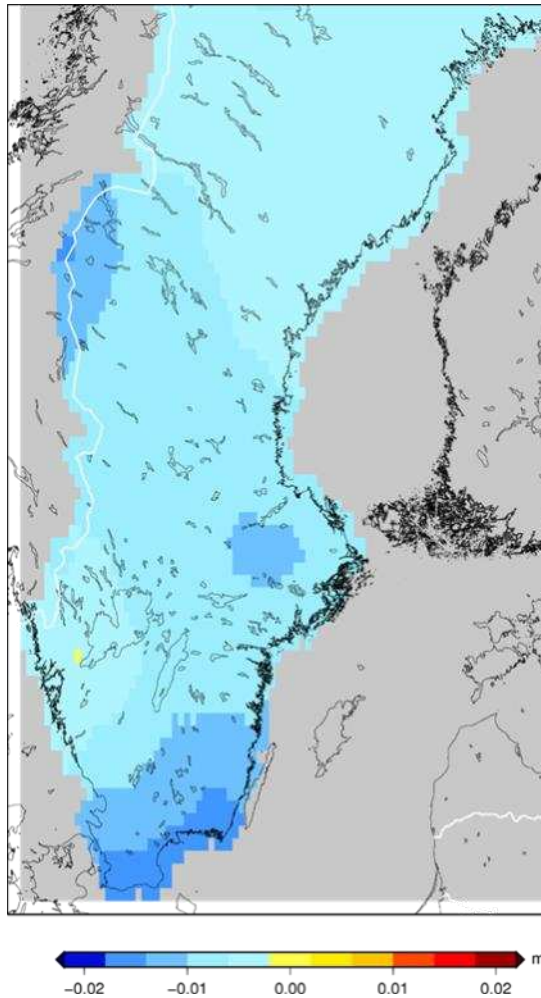
b) Height differences going from the national height reference frame of Denmark (DVR90) to zero-tide EVRF2019 (mean +1 mm; min. –12 mm; max. +13 mm)



c) Height differences going from the national height reference frame of Latvia (LAS-2000,5) to zero-tide EVRF2019 (mean –3 mm; min. difference –12 mm; max. +5 mm)



d) Height differences going from the national height reference frame of Finland (N2000) to zero-tide EVRF2019 (mean –3 mm; min. difference –11 mm; max. difference +0 mm)



e) Height differences going from the national height reference frame of Sweden (RH 2000) to zero-tide EVRF2019 (mean –7 mm; min. –19 mm; max. –2 mm)

Keeping the aforementioned developments in mind, the common reference level Baltic Sea Chart Datum 2000 (BSCD2000) has been specified with the aim to

- ⇒ replace the existing variety of reference levels by a seamless chart datum definition for the entire Baltic Sea;
- ⇒ simplify the determination and use of bathymetric charts by using the existing European geodetic standards (European Terrestrial Reference System 1989 and European Vertical Reference System 2000) and to make the marine infrastructure of the Baltic Sea fully interoperable with the national geodetic infrastructure, namely the national satellite-based positioning services (e.g., SAPOS, SWEPOS, FinnRef) and the national height systems; thereby
- ⇒ provide an optimal support for current and future marine GNSS aided applications and
- ⇒ comply with future S-10X standards of the International Hydrographic Organization (IHO).

In particular, the main benefit for the mariner is a seamless transition from chart to chart, from country to country, and from sea to land, based on a unified height datum. This comes at the "price" of potentially changed reference levels in harbors and shifted charted depths (see ***Sections 3 and 4***). Wherever possible, these changes will be introduced together with major updates of anyway outdated map sheets.

2. Organisational background for the establishment of the BSCD2000

BSCD2000 was initiated by the Baltic Sea Hydrographic Commission (BSHC). The BSHC (http://www.bshc.pro) is an integrant part of the International Hydrographic Organisation (IHO), promotes the technical cooperation in the domain of hydrographic surveying, marine cartography and nautical information among the neighboring countries of the Baltic Sea region. The main objectives of the Commission are the coordination of the production of the Baltic Sea INT Charts, the coordination of hydrographic re-surveys, harmonization of chart datums, harmonization of Baltic Sea ENCs, and the exchange of information and the harmonization of practices with regard to various issues related to hydrography. Its member states are visualized in ***Figure 3***.

Figure 3: *Members states of the Baltic Sea Hydrographic Commission (BSHC)*

In 2005, the Baltic Sea Hydrographic Commission (BSHC) recognized the issue of the incompatible chart datums in the Baltic Sea and established the Chart Datum Working Group (CDWG) to develop a concept of a harmonized chart datum. The CDWG (http://www.bshc.pro/working-groups/cdwg) reports to the BSHC Conferences and aims to implement the Baltic Sea Chart Datum 2000 as a common reference level in the Baltic Sea. The working group cooperates with relevant bodies, reviews the progress of national plans and proposes harmonization actions. The working group also liaises with relevant IHO bodies and studies relevant IHO resolutions and specifications. It is currently chaired by Mr Thomas Hammarklint (SMA, Sweden) with Mr Jyrki Mononen (Traficom, Finland) as ordinary secretary.

After a feasibility study, it was decided and agreed that the harmonized vertical datum will be based on the European Vertical Reference System (EVRS). In September 2013, the 18th Baltic Sea Hydrographic Commission Conference decided to continue the work of the Chart Datum Working Group (CDWG) and wished the harmonized Baltic Sea vertical reference to be implemented. IHO BSHC has approved the name and the adoption of the Baltic Sea Chart Datum 2000 and the abbreviation BSCD2000.

BSCD2000 has been registered as Chart Datum number 44 in the IHO Geospatial Information (GI) Registry and can therefore be used as a reference datum in all future S-100[1] products. It applies to all national realizations of the European Vertical Reference System (EVRS).

The basic prerequisite for the realization and introduction of the BSCD2000 is the determination of a model of the height reference surface with sufficient accuracy. The practical works were significantly supported by the FAMOS project (www.famosproject.eu) which was co-financed by the European Commission. FAMOS stands for “Finalizing Surveys for the Baltic Motorways of the Sea” and is part of the “Motorways of the Seas”, a concept to develop European maritime traffic infrastructure within the framework of the Trans-European Transport Network (TEN-T) policy. Major activities within FAMOS consisted of the coordination and execution of shipborne campaigns to measure the gravity data needed to compute an improved geoid model as the HRS for the BSCD2000, as well as the computations of the geoid[2] model itself.

3. Definition and realization of BSCD2000

In the following, only a general overview shall be given from the user’s perspective. For the full geodetic detail, the reader is referred to the BSCD2000 paper (Ågren et al., 2019).

> *The first of the two most important characteristics of BSCD2000 is that it is not anymore defined with respect to the (changing) local mean sea level (MSL).*

Instead, a well-defined uniform and accessible height reference surface (HRS) is used that is equal to the distinct equipotential surface of the Earth’s gravity field called the *geoid*.

The instantaneous sea surface is deflected from the above equilibrium surface due to ocean dynamics (induced by currents, temperature, salinity variations, wind etc.) in combination with the coastal shape and bathymetry. The long-term average of these deflections is not zero, hence the mean sea surface is offset from the geoid. The static part of this difference, which can reach up to approximately ±2 m worldwide, is called mean dynamic topography (MDT). It can be observed and computed either from oceanographic models or from combined space-geodetic observations (altimetry and gravity satellite missions). In the Baltic Sea, the MDT is generally positive (compared to the MSL/MDT of the North Sea) with a slope of approx. 30 cm towards the North-east, corresponding mainly to decreasing salinity. ***Figures 4 and 5*** show examples for a geoid model and a space-geodetic MDT model of the Baltic Sea, respectively.

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[1] - The S-100 Standard (https://iho.int/en/s-100-universal-hydrographic-data-model, last access May 15, 2020) is a framework document that is intended for the development of digital products and services for hydrographic, maritime and GIS communities. It comprises multiple parts that are based on the geospatial standards developed by the International Organization for Standardization (IHO).

[2] - The geoid describes the undisturbed sea level in equilibrium as if there were no external forces (wind, currents, temperature, salinity). In geodesy, it is the classic height reference surface for the realization of “heights above sea level” on land.

This change of chart datum to a zero level that is a little offset from MSL may at first glance appear unnatural to the mariner. However, the advantage of the geoid-based definition of the chart datum is that the geoid is virtually independent from changes of sea level and can be determined to high accuracy without sea level observation (see next paragraph). Thus, as motivated in Section 2, the geoid provides the required unified reference surface in order to monitor absolute and relative sea level changes by combination of space-geodetic techniques (GNSS, satellite altimetry) and classic local sea level observations along the coast (water level stations, geometric levelling). This holds true also for the Baltic Sea where global sea level rise (i.e., dynamic ocean) is contrasted by postglacial land uplift (i.e., dynamic Earth), since the latter effect can be modelled with high accuracy.

Geoid-based HRS are realized by so-called geoid models, i.e., gridded values of the geoid height with respect to the reference ellipsoid used for GNSS applications. They can be computed from gravimetric measurements with a typical internal standard uncertainty of 1-2 cm in areas with good gravity data coverage. For practical use, the gravimetric geoid models are fitted to the ellipsoidal and physical heights of co-located GNSS and levelling benchmarks in order to become compatible with the national height system realizations. The HRS for the BSCD2000 will be an adopted quasigeoid[3] model referenced to a common zero level.

In this respect, *BSCD2000 replaces the so-far heterogeneous and inconsistent historical MSL realizations between countries, or even between map sheets or harbors within the same country.*

The computation of this geoid model was stimulated by preparation works co-financed by the EU. Acquisition and measurement of the necessary data and the computation of interim (i.e. preliminary) geoid models were organized and performed within the project “Finalizing Surveys for the Baltic Motorways of the Sea” (FAMOS). Unfortunately, the last phase of the FAMOS project (2019 -2020) could not be realized, so that the finalization of the BSCD2000 HRS is now coordinated by the CDWG and planned for the end of 2022.

> *The second most important characteristic is the new and unified zero level. BSCD2000 will be linked to the Normaal Amsterdams Peil (NAP).*

NAP is the zero level for the European Vertical Reference System (EVRS) but also for most countries around the Baltic Sea. All states formerly referring to the Kronstadt datum have changed their national height systems or are in transition to change to the EVRS, except for Russia[4]. Numerically, these national realizations of the NAP coincide at the centimeter level, as demonstrated in Figs. 2a-e and Table 1 in comparison with EVRF2019, the last official release of the European height system EVRS (Sacher et al. 2019). Consequently, the respective national height systems can be considered as ready-to-use realizations of the BSCD2000 within its specification (overall standard uncertainty better than 5 cm, sufficient for the typical precision of charted depths; see further Ågren et al. 2019).

3 - The conceptional difference between geoid and quasigeoid is a geodetic subtlety that is only relevant on land at high altitudes.

4 - Only for Russia, simple transformation models between national heights and BCSD2000 will be necessary, probably by means of local datum shifts for the areas of Oblast Kaliningrad and the Gulf of Finland/St. Petersburg.

Likewise, the HRS of the BSCD2000 will be aligned to the respective national HRS on land with smooth transitions from country to country. The ellipsoidal height part of the quasigeoid model is referenced to the GRS 80[5] ellipsoid (Moritz 1980) of the national realizations of the European spatial reference system ETRS89 used for GNSS, whereas the physical height part is again consistent with the national levelling heights[6].

By that, BSCD2000 is inherently connected with the existing geodetic standards for height determination (European reference systems ETRS89 and EVRS), making it compatible with the national geodetic infrastructure, such as GNSS positioning services. In particular, the connection to the height systems on land facilitates the planning and construction of offshore projects mainly in the energy sector.

In other words, BSCD2000 shares the "common European zero levels for levelling and GNSS".

Hence, BSCD2000 for the first time enables seamless cross-border use of real-time GNSS positioning in combination with ENC for ship navigation in the Baltic Sea. This also forms the foundation of novel techniques that are emerging under the term "Sea Traffic Management". Based on real-time GNSS, high-resolution ENC and unified water level forecasting, the ship can continuously monitor its current and projected UKC without echo sounding. One highlight application of this "situation-aware navigation" that also has been studied within the EU co-funded FAMOS project are ship routes optimized for fuel efficiency, because the fuel consumption of a large vessel increases considerably for low UKC due to the hydrodynamic squat effect.

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5 - The geometric shapes of the GRS 80 and the WGS84 ellipsoids are identical at the sub-mm level.

6 - The Scandinavian countries are particularly affected by postglacial land uplift. BSCD2000 assumes the land uplift epoch 2000.0. This means that all relevant coordinates and quantities (ellipsoidal heights, physical heights, quasigeoid heights) refer to this common epoch, as opposed to the previously inconsistent MSL epochs. Compared to that major geophysical effect, the impact of expert-level details – such as treatment of the permanent tide – are within the uncertainty specifications of BSCD2000 and the national EVRS realizations, so that they are not discussed in this paper. For such geodetic details, the reader is again referred to the BSCD2000 specification paper (Ågren et al. 2019).

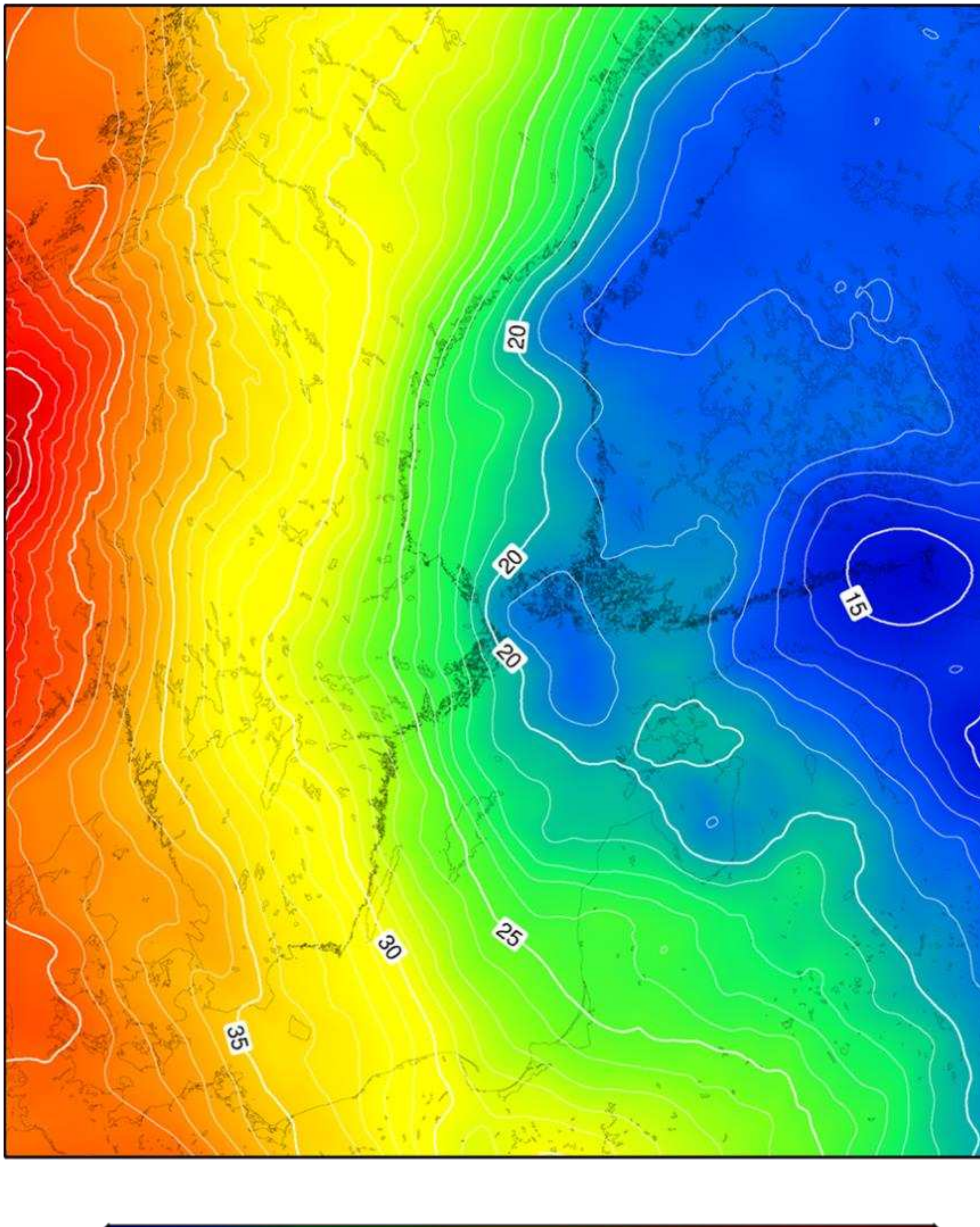

Figure 4: *LM6a, an interim geoid model for the FAMOS project by Jonas Ågren (Lantmäteriet)*

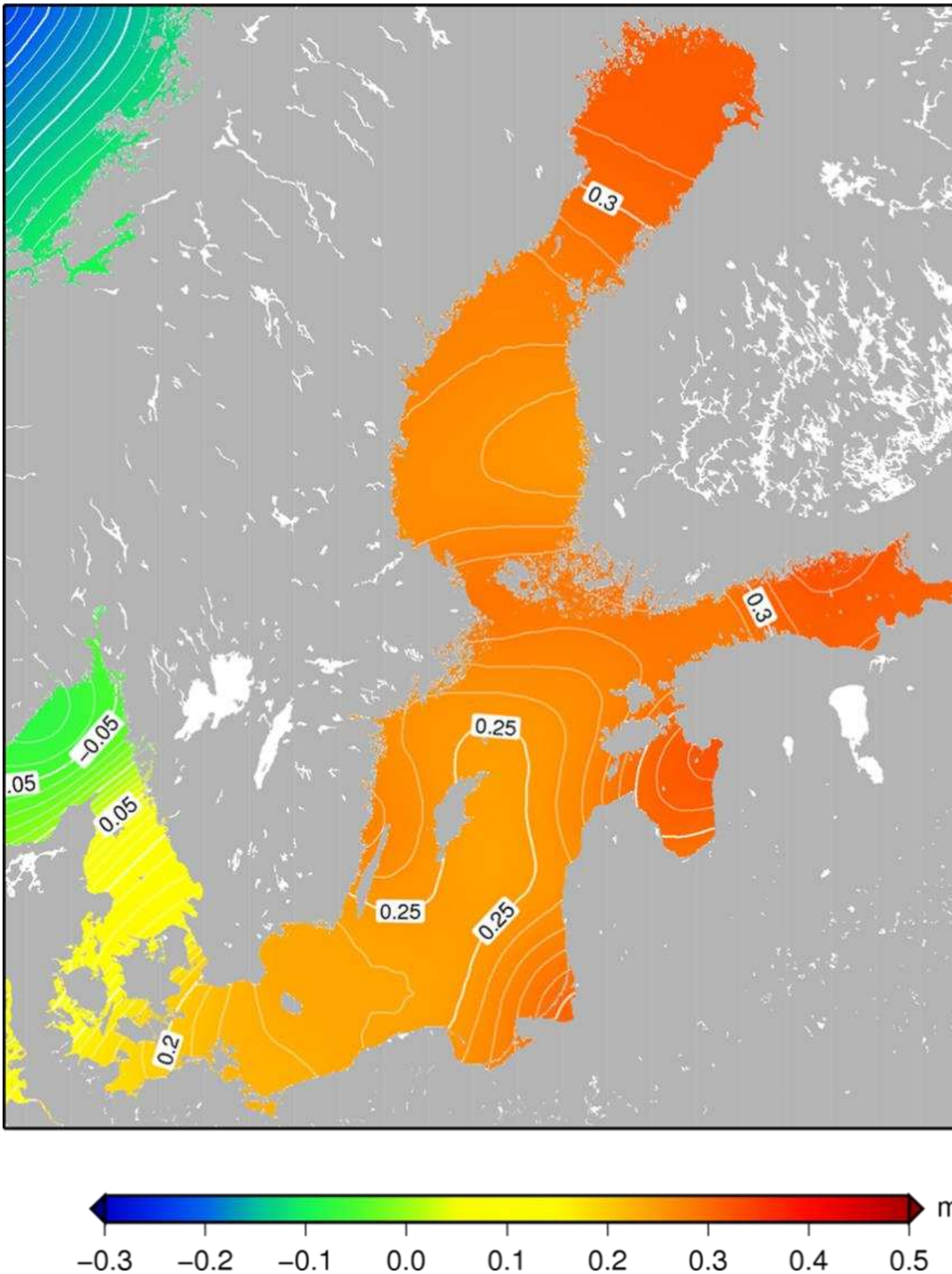

Figure 5: *DTU19MDT (Andersen and Knudsen 2009), a specimen for a geodetic model of the mean dynamic topography, over the Baltic Sea. It can be considered as a smooth proxy for the height of the recent MSL above the BSCD2000 height reference surface.*

The model was derived by combining multi-mission altimetry over a 20 year period with the latest state-of-the-art global potential model derived using the GOCE satellite. Consequently, the model is only a proxy for wavelength longer than 100 km. For this plot, the zero level has been shifted approximately from a global geoid to NAP to roughly match the definition of the BSCD2000.

4. Practical implications

New nautical products that use BSCD2000 are identified by the chart datum name BSCD2000$^{<X>}$, where $^{<X>}$ denotes the respective national height system realization according to ***Table 2*** (e.g., BSCD2000^{RH2000} for Sweden).

The main consequence for the mariner is that the *charted depth* in BSCD2000 changes by a constant value compared to the old zero level. The offset is individual per country or per map sheet, depending on the former MSL-related chart datum. In most cases, this offset will be negative, since the new zero level of the BSCD2000 is in general below the present day MSL for the Baltic Sea (see ***Figure 6*** for a generalized visualization and ***Figure 7*** for a map of the national MSL realizations currently in use). However, for charts of areas strongly affected by postglacial uplift and referring to very old MSL realizations, the change to BSCD2000 may be considerable. ***Figure 1*** gives an impression of the land uplift rates according to the model NKG2016LU (Vestøl et al. 2016).

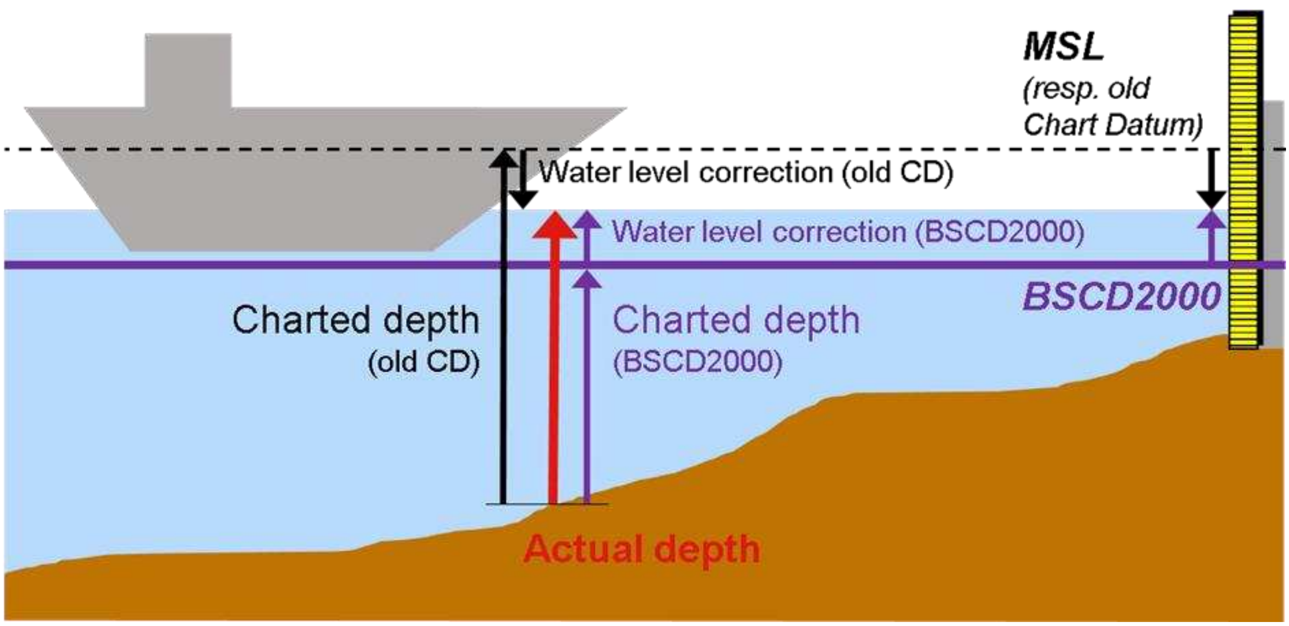

Figure. 6: *Schematic cartoon of the old MSL-based chart datum and the new BSCD2000*

At the same time, *real-time water level information* (water level observations, corrections to the charted depths, forecasts, etc.) will also be changed accordingly to comply with the new chart datum. This also allows for a better and easier monitoring and prediction of the current and future sea states out at sea, since real-time oceanographic models can be simply interpolated (***Figure 8***), whereas switching between the sometimes far-distant mareographs and their local references may introduce a large error margin (***Figure 9***).

The transition from the numerous MSL-based chart datums of each country to BSCD2000 is a complex and stretched process from the first decisions to the final implementation in the chart products. In particular, paper charts need longest to be switched due to the long production cycles. Some countries, like Estonia, have already informed mariners about the changes to BSCD2000 and have published the first products. Others, like Denmark, are about to formally adopt BSCD2000 as the name of their chart datum without having to actually change their charted depths. Therefore, this section only gives an overview about the general situation in the respective countries. ***Table 2*** summarizes the national geodetic reference frames, positioning services and HRS realizations that can be used with BSCD2000. Regularly updated details about the implementation status as well as instructions for users, e.g. leaflets, are provided via the CDWG website (http://www.bshc.pro/working-groups/cdwg).

In ***Sweden and Finland***, a *calculated MSL* has been used as reference level (chart datum) for nautical charts and water level information. The reference level for regularly updated epochs (estimated present-day MSL) was estimated from long time series of annual mean values of mareograph observations. Depths from printed charts needed to be converted semi-automatically by means of a correction formula in order to correct for the time difference and to make the charted depth compatible with the provided water level information. As motivated in ***Section 2,*** this two-step approach implied a lot of work to keep the nautical products updated and consistent. At the same time, it was not straightforward and error-prone for the mariner.

Thus, decisions to make a transition to BSCD2000 in Sweden and Finland have come a long way. In Sweden, both water level information and 50% of all nautical charts are now using BSCD2000. In Finland, part of the bathymetric and chart data have already been transformed to BSCD2000. Water level information is ready to be provided in BSCD2000 when first charts will be published in the new datum. ***Figure 7*** details the estimated height of the *current calculated MSL* relative to BSCD2000 for selected mareographs in Sweden and Finland.

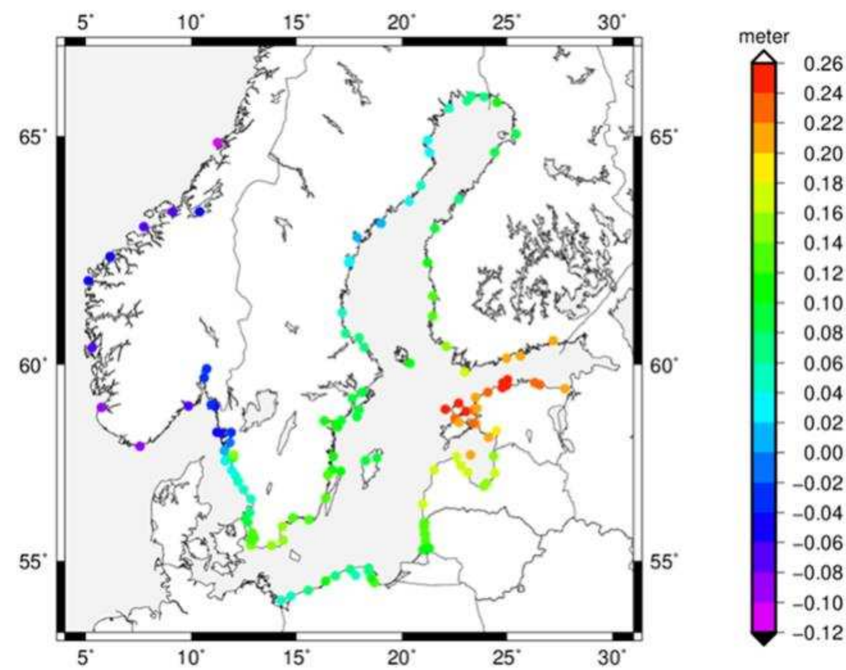

Figure. 7: *Differences between the reference levels of the old national chart datums with respect to Baltic Sea Chart Datum (BSCD2000). In Sweden and Finland, the old reference levels are equal to the calculated MSL in the year 2020 (according to different national conventions). The values from Norway shows the MSL over the period 1996-2014, relative* $BSCD2000^{NN2000}$*. In Estonia, Latvia and Lithuania, the Kronstadt reference level is used as old chart datum. In Poland, the local Polish Height System Amsterdam* NH_{55} *is used as chart datum. Notice how postglacial rebound reduces the magnitude of the calculated MSL relative BSCD2000 in the Bay of Bothnia; it is now just a few cm close to the location of maximum uplift. The values are taken from BOOS (2020).*

In the Baltic Sea regions of ***Denmark***, a reference level close to the national height system DVR90 is already being used as chart datum, which can now be considered as a national realization of the BSCD2000. This means that for a user in Denmark nothing changes and the official national geoid model can still be used at sea.

Likewise, chart datum and MSL observations in ***Germany*** have traditionally been linked to the national height system. In 2016, the previous realization DHHN92 was replaced by DHHN2016. Both old and new realization are consistent with the EVRS, and the differences between the two are small and well within the specifications of the BSCD2000. Germany is now in the process to formally adopt BSCD2000^{DHHN2016} as the chart datum name in its Baltic Sea products, yet without actual changes for the user.

In ***Norwegian*** waters, on southern Skagerrak, a reference 20 cm below Lowest Astronomical Tide (LAT) is used as chart datum.

On the eastern side of the Baltic, in ***Estonia, Latvia, Lithuania and Poland***, the transition from Kronstadt-based datums into the new system has come a long way, even if the old and new reference systems will be working in parallel for many more years to come. The transition into the new system for the paper charts will take longest time to change.

Table 1: Differences between EVRF2019 (zero-tide) and EVRS-compatible national height reference frames in mm.

Country	Mean	Std. dev.	Min.	Max.
Denmark	+1	6	–12	+13
Estonia	–7	8	–22	+16
Finland	–3	2	–11	+0
Germany north of 53.5° latitude	–1	4	–8	+12
Latvia	–3	2	–12	+6
Lithuania	–4	5	–11	+5
Norway south of 60.0° latitude	–14	7	–42	+3
Sweden	–7	3	–19	–2

Table 2: National reference frames and services complying with BSCD2000 (as of May 2020, without responsibility for correctness).

Country	3-D position	Physical height	Height ref. surface	GNSS pos. service
Denmark	EUREF89	DVR90	DKgeoid12	GPSnet.dk, SmartNet
Estonia	EUREF-EST97	EH2000	EST-GEOID2017	ESTPOS
Finland	EUREF-FIN	N2000	FIN2005N00	FinnRef
Germany	ETRS89/DREF91 Realization 2016	DHHN2016	GCG2016	SAPOS
Latvia	LKS92	LAS2000,5	LV14	LatPOS
Lithuania	LKS94	LAS07	LIT15G	LitPOS
Norway	EUREF89	NN2000	HREF2018B_NN2000	SATREF
Poland	PL-ETRF2000	PL-EVRF2007-NH	PL-geoid-2011	ASG-EUPOS
Sweden	SWEREF 99	RH2000	SWEN17_RH2000	SWEPOS

5. Summary and Outlook

So far, several countries around the Baltic Sea are using BSCD2000 as the common reference level for nautical charts as well as for water level information. According to the time schedule and the roadmap (http://www.bshc.pro/media/documents/CDWG/CDWG+RoadMap.pdf), the plan is to implement the common reference level until 2023. Almost all countries have taken the necessary decisions to move further in the implementation process, however this ambitious goal will most probably not be reached by all countries. For paper charts, the implementation will take longer time and there will be a significant transition period that will last for several years after 2023. Hydrographic offices will publish information concerning the national plans and progress of implementation since there will be differences in schedules of publication of charts and water level information between countries.

There are many benefits to be achieved with the implementation of BSCD2000. All depth and water level information will be provided in the same datum within the whole Baltic Sea. This eliminates the confusion between different chart datums and makes data transfer between national Hydrographic Offices and other organizations safer and easier, thereby contributing to safety of navigation in the highly frequented Baltic Sea. Further, on it enhances wider and easier use of depth data and promotes utilization of future navigation systems based on International Hydrographic Organization (IHO) S-10X standards.

BSCD2000 is based on the common European Vertical Reference System to which many national height systems are linked. Thus, depths on sea and heights on land will be referenced to the same reference system, facilitating e.g. offshore engineering in the sensitive coastal zones of the Baltic Sea. BSCD2000 can be used with GNSS applications by means of a consistent height reference surface, which will be realized by a high-resolution geoid model. The computation of this model was promoted by the EU co-financed project FAMOS and is now being finalized. It is planned to adopt the “FAMOS geoid” as the recommended physical height reference surface (HRS) for the BSCD2000 and make it available at no charge latest 2023. Compared to the national HRS, that are also compatible with BSCD2000 and can still be used (see ***Table 2***), this model will provide the advantage of a seamless transition across the national borders.

Finally, BSCD2000 facilitates future applications that require an integrated spatial reference at sea and, thus, responds to the growing interrelationships between disciplines like hydrography, oceanography, geodesy, geophysics, climate research, coastal protection, and traffic management.

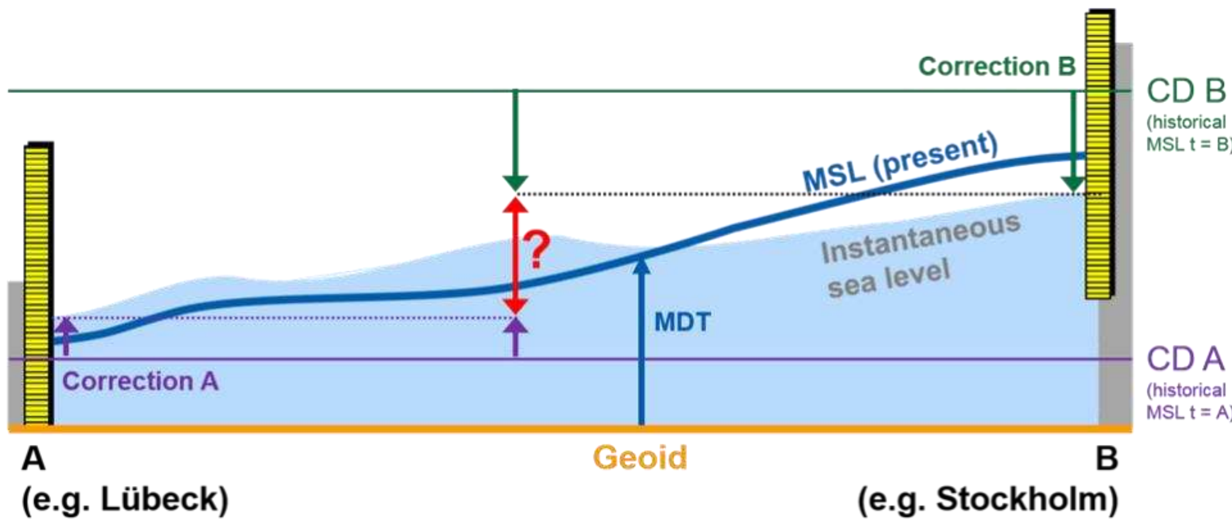

Fig.ure 8: *Illustration how mismatching chart datums affect the prediction of the actual water level correction between harbors*

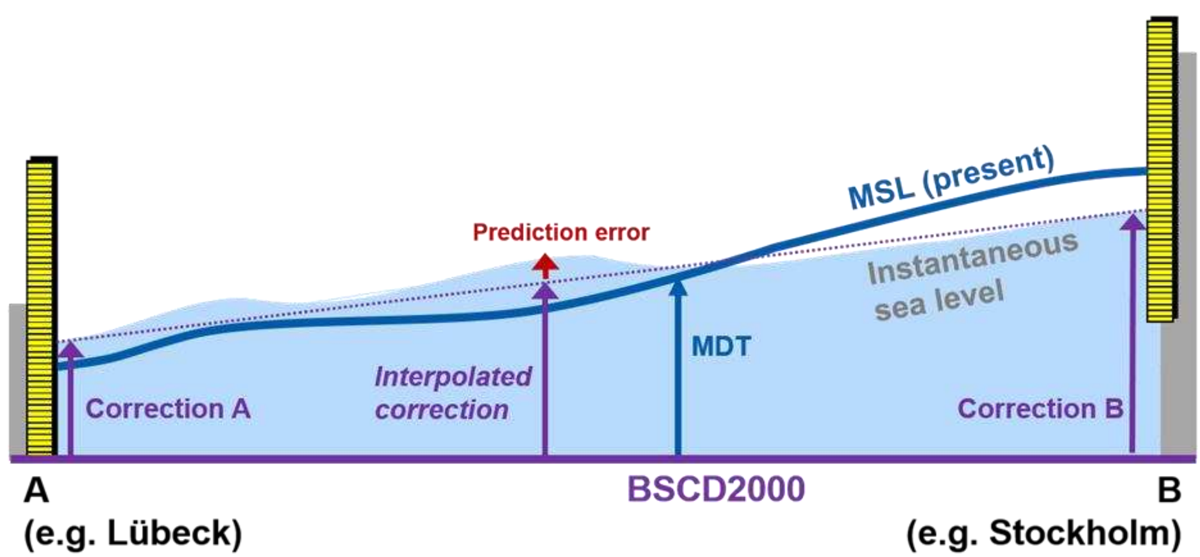

Figure. 9: *Illustration of consistent water level correction with BSCD2000.*

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