Unifying vertical reference surfaces in the North Sea: an overview of developments

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SUMMARY

The creation of reference surfaces has primarily been a national activity in the North Sea countries. A national approach prevents the creation of consistent common references, which are desperately needed for international data distribution in the coastal zone, GNSS-based bathymetric surveying, and the development of hydrodynamic models, on the scale of the North Sea. The BLAST initiative has the potential to create these consistent common references.

1. INTRODUCTION

Merging elevation data on land and at sea is important for coastal management tasks such as search and rescue, protection against flooding, and the conservation of vulnerable habitats. Its success depends on the unification of terrestrial and marine reference surfaces, a task that has not yet been accomplished. Sea level rise at the present rate makes this task even more urgent.

Bathymetric surveys at sea cannot yet use satellite navigation systems to their full potential, as there is no accurate connection between the ellipsoidal reference surface of GNSS heights and the datum for marine charting, defined as Lowest Astronomical Tide (LAT) in some countries, and approaching LAT in others [IHO, 2008a]. The differences between chart datum (CD) and LAT are mostly defined by Hydrographic Offices [Illiffe et al., 2007; Pineau-Guillou, 2008]. Moreover, each country uses its own realization of LAT. Therefore, the combination of national bathymetric data into consistent depth models is still impossible. As an example, such depth models are necessary to develop hydrodynamic models used for e.g. storm surge forecasting [Verlaan et al., 2005].

2. THEORY

Since the LAT surface defined with respect to the reference ellipsoid is not directly observable, an intermediate reference surface is necessary. Examples are Mean Sea Level (MSL) and the geoid [FIG, 2006], for which differences with respect to the LAT are calculated from a hydrodynamic model.

The geoid is the preferred intermediate surface, because it is –in theory– the internal vertical reference of the hydrodynamic model, and it enables the connection with the terrestrial vertical reference surface: the geoid is the natural reference surface for heights on land. This makes the calculation of the marine geoid with respect to the reference ellipsoid a crucial final step in the connection of LAT to the ellipsoid.

3. DEVELOPMENTS

The Tidal Working Group of the North Sea Hydrographic Committee (NSHC) has evaluated differences in national chart datums, and merged these surfaces with respect to the GRS80-ellipsoid [NSHC, 2010]. This work includes the Dutch GEONZ97 Mean Sea Level for the North Sea [De Bruijne et al., 1999] and LAT surface [Elema and Kwanten, 2006], the British VORF reference frames [Illiffe et al., 2007], and the French BathyElli project [Pineau-Guillou, 2008]. For an overview of the available data, see Figure 1.

None of the resulting merged surfaces are consistent, as is shown in Figure 2 for CD by the inconsistent isolines at the maritime boundaries. Inconsistencies in CD at the international boundaries in the North Sea are up to several decimeters, which show up in nautical charts and bathymetric data sets in case GNSS reduction would be used. In general, the inconsistencies are small relative to the stated uncertainties of the reference surfaces. However, they are large with respect to the acceptable uncertainty for bathymetric surveying [IHO, 2008b].

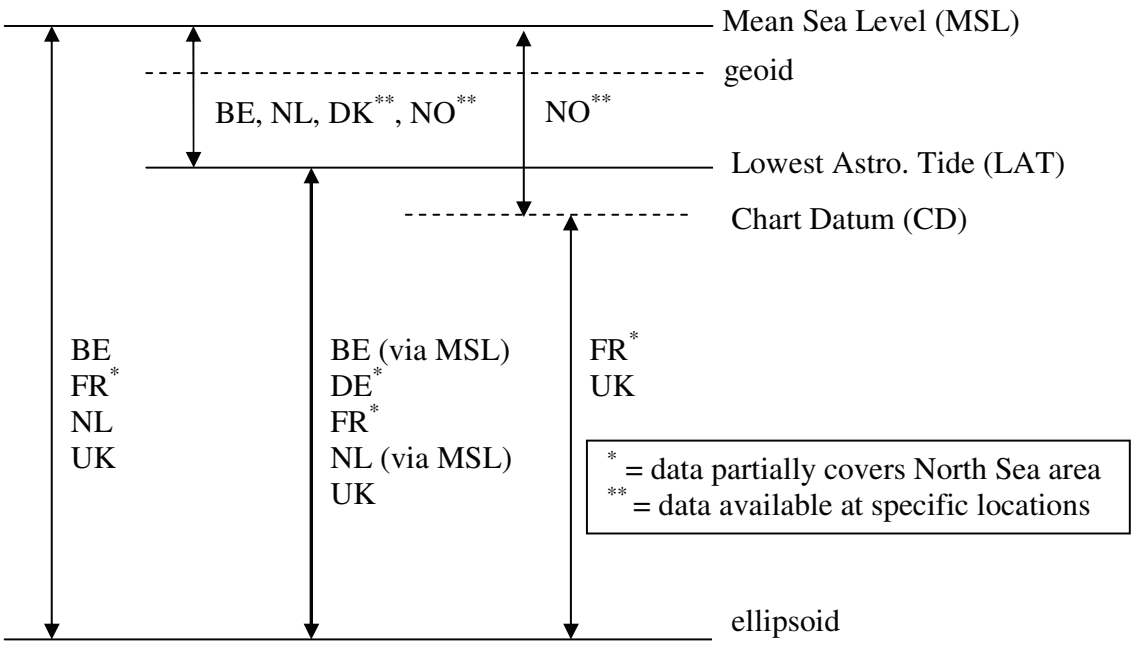

Figure 1: sketch of available data

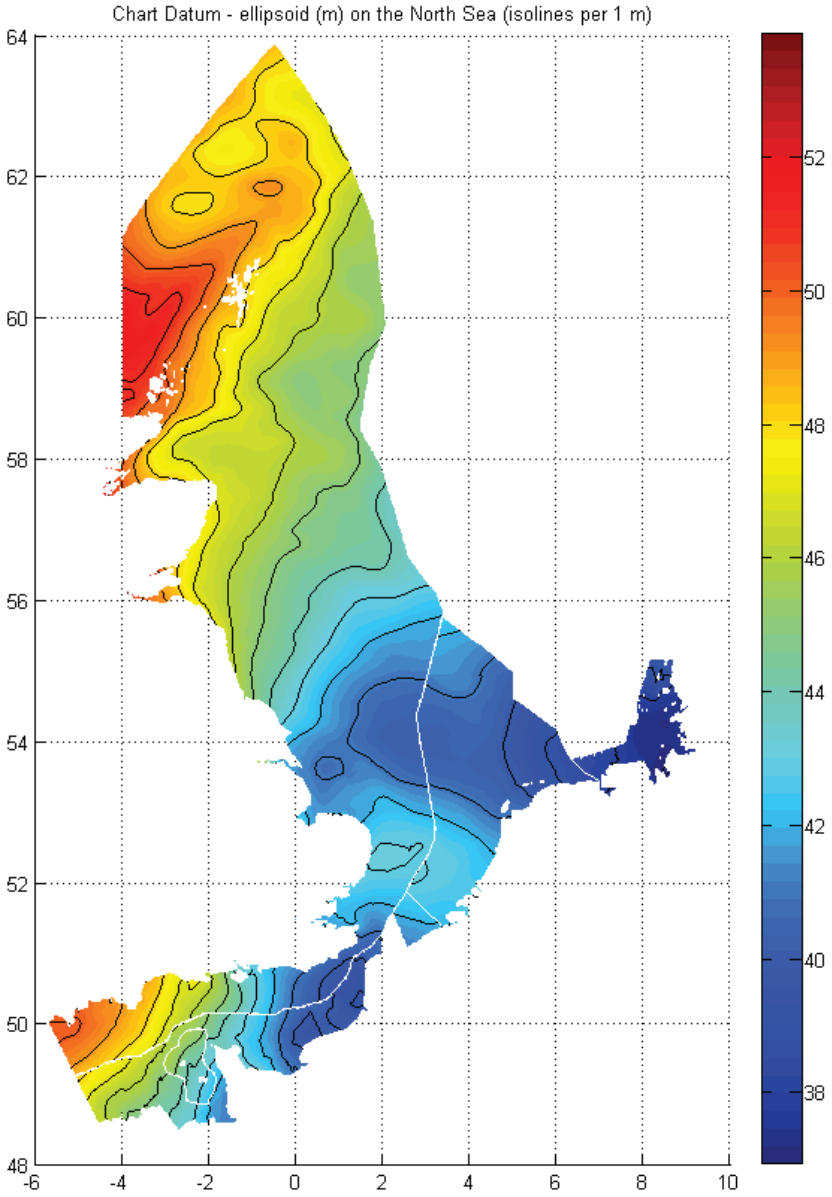

Figure 2: created CD surface in relation to the ellipsoid, shown in ETRS89/WGS84 in Plate Carrée projection, including one metre isolines in black and maritime boundaries in white. As there is no established maritime boundary between the territorial seas of DE and NL, a new line was created for the purpose of DE/NL data comparison only.

The EU Interregion IVB project BLAST aims at relating marine and terrestrial datums to each other by establishing links to the marine geoid [BLAST, 2010]. As a part of that project, we aim to establish a physical connection between the geoid as an intermediate surface, and various other reference surfaces at sea. Our approach is based on the combination of radar altimetry, gravimetric data and the hydrodynamic model DCSM [Verlaan et al., 2005]. This way, the relation between chart datum and the reference ellipsoid is established. Also, the link with terrestrial reference surfaces is guaranteed, and the definition of the reference level of the hydrodynamic model is improved.

The international acceptance of these efforts requires pro-active coordination, which is a shared responsibility of the national hydrographic offices, facilitated by the NSHC. Also, it is essential that the results are easily available to the public, in line with the European INSPIRE Directive [European Commission, 2007].

4. CONCLUSION

The NSHC-TWG has created MSL, LAT and CD surfaces for the North Sea in relation to the ellipsoid that are neither consistent nor fully covering the North Sea area. These surfaces are based on the national efforts of the NSHC countries. In order to create consistent reference surfaces for the full North Sea area, common calculations need to be agreed upon on the full scale of the North Sea. The BLAST initiative provides opportunities to create such common reference surfaces. That potentially is an important step toward the realization of an international reference surface for terrestrial and marine use in the North Sea area without inconsistencies. This surface enables easy data distribution to manage the coastal zone.

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BIOGRAPHICAL NOTES

Leendert Dorst is a Dutch Geodetic Engineer from the Delft University of Technology. He is employed at the Netherlands Hydrographic Service as Head of the Department Geodesy & Tides. His expertise includes hydrographic surveying, maritime positioning, coordinate systems, the tides, and technical aspects of the law of the sea. He participated in the IHO S44 working groups on Standards for Hydrographic Surveys and on Data Quality. In 2009, he obtained a PhD degree from the University of Twente, on the estimation of sea floor dynamics using time series of bathymetric surveys, to improve the resurvey policy of the Netherlands.

Cornelis Slobbe is a Dutch Geodetic Engineer from the Delft University of Technology. He currently works at a PhD-project at Delft University of Technology that aims to estimate a new marine geoid based on the combination of radar altimetric and gravimetric data and a shallow water hydrodynamical model. He also participates in the EU Interregion IVB project BLAST.

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