Specification of the Baltic Sea Chart Datum 2000 (BSCD2000)

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Version 5d, 2025-03-25

1. Definition

The Baltic Sea Chart Datum 2000 (BSCD2000) is a geodetic reference system adopted for the Baltic Sea hydrographic surveying, hydrographic engineering, nautical charts and publications. It is based on the definitions for the European Vertical Reference System (EVRS) as well as the European Terrestrial Reference System 89 (ETRS89a, b, c). The reference epoch for height changes due to the postglacial land uplift in Fennoscandia is 2000.0. According to this definition:

a) The height reference surface of BSCD2000 over the sea area is an equipotential surface of the Earth's gravity field. The zero level of BSCD2000 is in accordance with the Normaal Amsterdams Peil (NAP).
b) The vertical coordinate is specified by normal heights. The normal potential is defined by the Geodetic Reference System 1980 (GRS80).
c) Corrections of the permanent solid earth tides are made so that the normal heights are in the zero tide system.
d) Temporal height changes due to the postglacial land uplift will be reduced to the epoch 2000.0.
e) The unit of the normal heights is meter.

2. Realization

The realization of the Baltic Sea Chart Datum is based on the following principles:

a) The realization of BSCD2000 shall make use of the existing national geodetic infrastructure, i.e. the official national vertical and spatial reference frames and corresponding services.
b) It is the goal that the geodetic infrastructure for the realization of BSCD2000 shall provide a standard uncertainty better than 5 cm over the whole Baltic Sea including the costal zones.
c) BSCD2000 will be realized by the official national vertical and spatial national reference frames if
    - the official national reference systems are in accordance with the definition given in Section 1 respectively or
    - the official national reference frames agree with the official realization of the European vertical reference system EVRS (with postglacial land uplift epoch 2000.0) and with the official European ETRS89 realization within the level of 2-3 centimeters.

If the national reference frames do not fulfil these requirements, then BSCD2000 will have to be realized by the national reference frames together with transformations that are sufficiently accurate to fulfil the accuracy requirement in item 2b above.

d) Offshore, BSCD2000 is realized based on the national GNSS positioning services (e.g. SWEPOS, FINNREF or SAPOS), the corresponding official national spatial reference frames (SWEREF 99, EUREF-FIN and ETRS89/DREF91) and a consistent model of the BSCD2000 height reference surface. The BSCD2000 height reference surface is primarily realized by a gravimetric quasigeoid model. It shall take into account the necessary corrections due to the existing differences in the definition and realization of the reference frames, especially
   - differences of the permanent solid earth tide conventions for physical and ellipsoidal heights,
   - differences caused by the datum transformation between the international and European spatial reference frames (Fig. 6) and
   - remaining discrepancies between the national vertical and spatial reference frames according to Section 2, item c.

   On land and along the coasts, BSCD2000 is realized by the official national height reference frames, typically based on levelling. The BSCD2000 height reference surface shall then continue in over land and be aligned with the official national height reference frames with an accuracy better than about 1 cm. It is recommended to agree on the same model of the height reference surface for the whole Baltic Sea as soon as a corresponding model is available.

   The above BSCD2000 realization allows for traditional tide gauge-based methods with about the same accuracy limitations as when using Mean Sea Level as chart datum. This requires that the tide gauges are determined in BSCD2000.

e) Land uplift corrections shall be applied in areas with significant land uplift. The corrections have to be computed with a common up-to date land uplift model in the way specified by the national surveying authorities; see further the comment in Section 3.

3. Comments and Remarks:

Section 1, item a

The BSCD2000 height reference surface is not identical with the mean sea level of the Baltic Sea. Due to the definition, the zero level of BSCD2000 deviates from the current mean sea level of the Baltic Sea by about 0 to 25 cm (Figs. 2, 4a and 4b). The differences are caused by long-term temporal sea level changes as well as the mean dynamic topography. Besides this, postglacial land uplift successively reduces mean sea level in BSCD2000 as time passes, which can be seen by comparing Figs. 2 and 4b.

Section 1, item b

At sea, normal heights are practically equivalent to orthometric heights.

Section 1, item c

This convention is in accordance with the EVRS definition. It differs from the recent IAG resolution for the definition and realization of an International Height Reference System (resolution No. 1 adopted at the IUGG General Assembly in Praha in 2015) which recommends the mean tidal system.

Normal heights in the zero and mean tide system differ maximally about 5 cm over the Baltic Sea (Fig. 1). The zero tide convention causes an additional artificial slope of the sea surface heights with respect to BSCD2000 (Figs. 2 and 3).

Section 1, item d

There are many different geodynamical effects that cause vertical deformation. Currently only models of the postglacial uplift are available with the necessary accuracy. Therefore, other reasons for height change are not taken into account in this definition.

Section 2, item c

The official realizations of the European reference systems will be adopted by the EUREF Governing Board. The current official realizations are EVRF2019, EVRF2007 and ETRF2000.

The official national height systems (height reference frames) in Sweden (RH 2000), Norway (NN2000), Finland (N2000) and Latvia (LAS-2000,5) fulfill the definition of BSCD2000 according to Section 1. Heights have been reduced to the common epoch 2000.0 subject to the postglacial land uplift, using the land uplift model NKG2005LU. The specification of the land uplift epoch 2000.0 rules out older height reference frames with a deviating land uplift epoch in the middle and the northern parts of the Baltic Sea, e.g. the reference frames RH 70 (Sweden, epoch 1970.0), N60 (Finland, epoch 1960.0) and EVRF2000 (Europe, epoch 1960.0 in Sweden, Finland and Norway). These epochs imply differences of up to around 30-40 cm along the Bay of Bothnia coast compared to a BSCD2000 realization.

The official national height reference frames from Denmark (DVR 90) and Germany (DHHN92 and DHHN2016, the latter valid from 2017), which do not strictly fulfill the definition of Section 1 are valid realizations of BSCD2000 since their differences to EVRF2019 and EVRF2007 are within the specified limits (CRS-EU). The differences of these height reference frames with respect to EVRF2007 are below the 2 cm level and do not exceed the usual differences between different height reference frames which follow strictly the same definition (Fig. 5).

Section 2, item d

A model of the height reference surface shall be computed within the EU FAMOS project until 2020.

Section 2, item e

Postglacial land uplift corrections shall be applied if the resulting effect on the height/depth is significant (i.e. larger than 2-3 cm considering the uncertainty goal of 5 cm in Section 2, item b). The correction should be based on the latest official land uplift model of the Nordic Geodetic Commission (NKG), currently NKG2016LU (Vestøl et al. 2019); see Figs. 7 and 8.

In case a national GNSS positioning service like Network RTK is used, then the delivered coordinates are customarily in the national ETRS89 realization in question (with its internal realization epoch). A land uplift correction has then normally already been applied by the "measurement system" (if needed). If this is the case, no additional correction should be made.

In case a PPP/SSR GNSS (globally referenced) positioning service is used, then the coordinates are obtained in the latest International Terrestrial Reference Frame (ITRFXXXX) with current epoch (epoch of observation). A full transformation is then needed to the national ETRS89 realization (cf. Häkli et al. 2016), which will include a postglacial land uplift correction from current epoch to national realization epoch based on NKG2016LU_abs.

Relative height/depth differences determined by traditional tide gauge-based methods shall be converted from the observation epoch to the epoch 2000.0 of BSCD2000 (if significant according to above). The NKG2016LU_lev model or later realization is then to be used, which gives the uplift relative to the geoid.

5. References

CRS-EU: http://www.crs-geo.eu, last access February 8, 2016

ETRS89a: http://etrs89.ensg.ign.fr/, last access February 8, 2016

ETRS89b: Boucher, C. and Altamimi, Z., The EUREF Terrestrial Reference System and its first realizations, EUREF Meeting, Bern, Switzerland March 4-6, 1992

ETRS89c: European Commission, Joint Research Centre, Space Applications Institute Proceedings & Recommendations of Spatial Reference Workshop, November 1999, http://www.crs-geo.eu/crseu/EN/References/Elemente/pub03ProceedingsWS1999, templateId=raw,property=publicationFile.pdf/pub03ProceedingsWS1999.pdf, last access February 8, 2016

EVRS: http://www.bkg.bund.de/nn_164794/geodIS/EVRS/EN/DefEVRS/evrs__node.html__nnn=true, last access February 8, 2016

GRS80: H. Moritz: Geodetic reference system 1980.
Bulletin Géodésique (1984) 58(3):388-398; Bulletin Géodésique (1988) 62(3):348-358; Journal of Geodesy (2000) 74(1):128-133

Häkli P, Lidberg M, Jivall L, Nørbech T, Tangen O, Weber M, Pihlak P, Liepins I, Paršeliunas E (2016). The NKG2008 GPS campaign – final transformation results and a new common Nordic reference frame. Journal of Geodetic Science. 6:1-33.

Vestøl O, Ågren J, Steffen H, Kierulf H, Tarasov L (2019) NKG2016LU - A new land uplift model for Fennoscandia and the Baltic Region. Submitted to Journal of Geodesy.

6. Figures

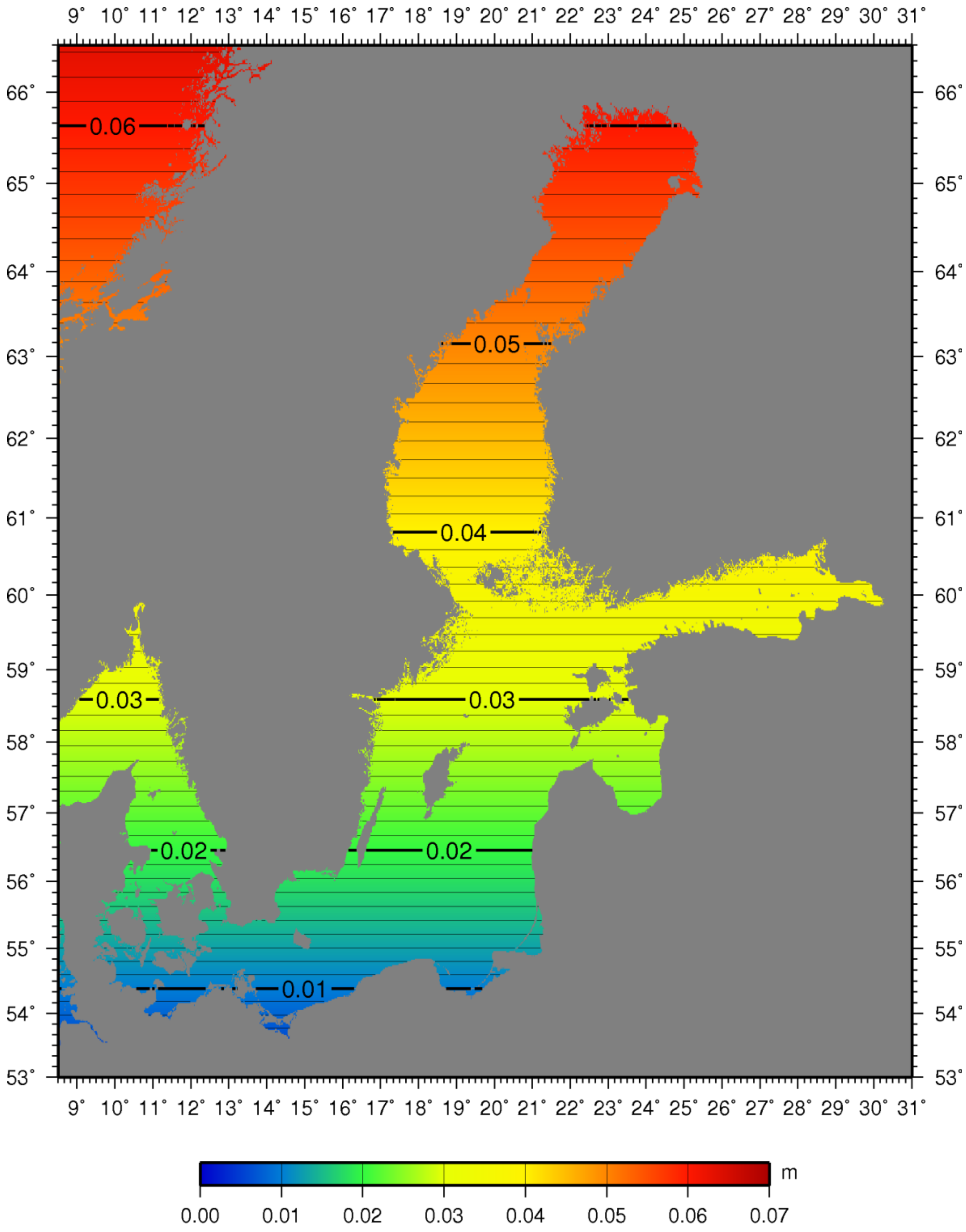


Fig. 1: Differences of the normal heights due to different solid Earth tide conventions (differences of mean and zero tide system)

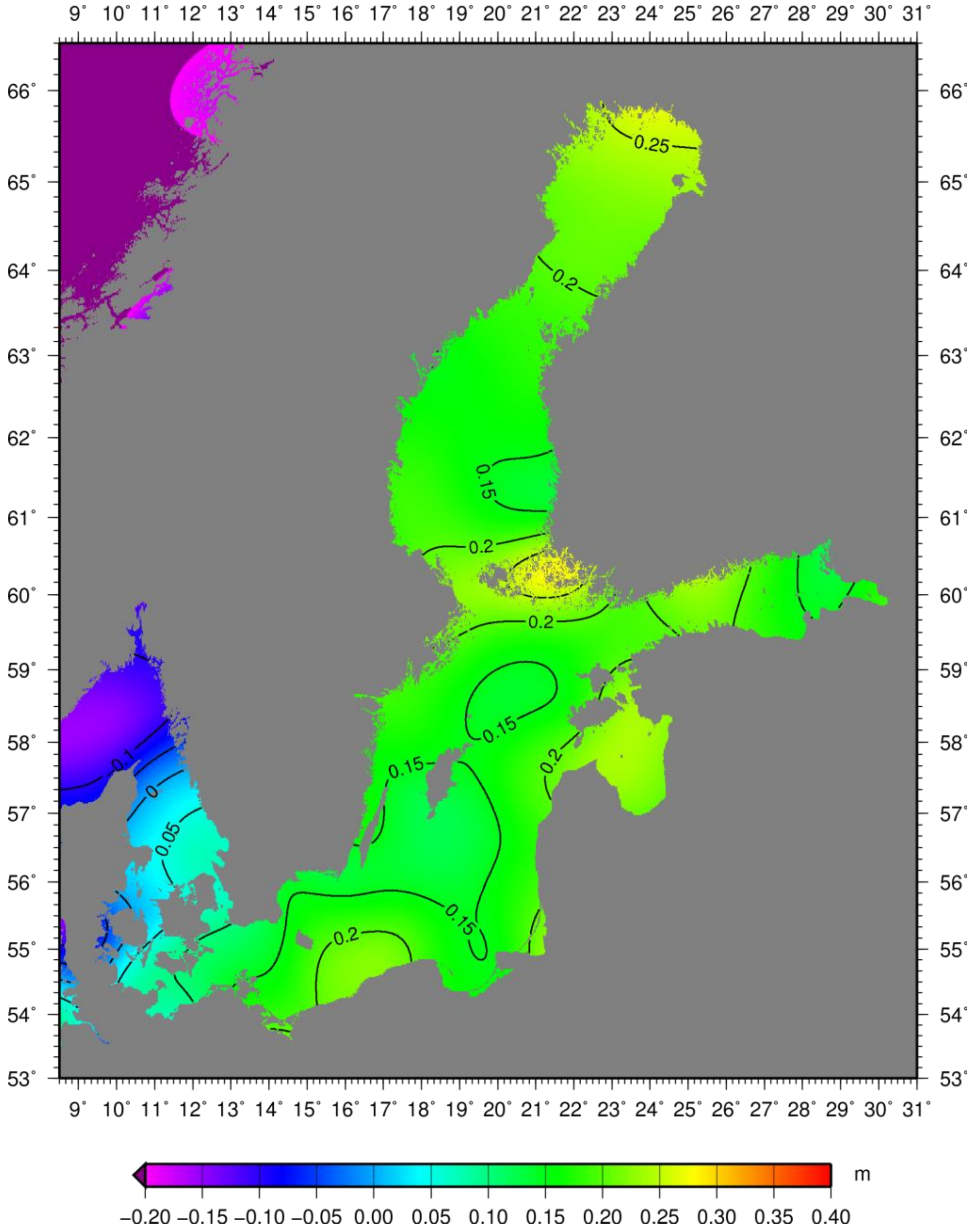


Fig. 2: Estimation of the mean dynamic topography in the zero tide system.

The figure shows a low-pass filtered version of the difference between the mean sea surface model DTU15_MSS and the quasigeoid model EGG08, both related to the GRS80 reference ellipsoid and the zero tide system according to the EVRS definition (filter length 50 km). The mean sea surface model as well as the quasigeoid model still show some errors (e.g. DTU15_MSS in the area of the Åland Islands, EGG08 in the southern Baltic Sea).

The purpose of Figures 2-3 is only to illustrate the main features of the mean dynamic topography in the Baltic Sea and to show the dependence on the tide system. It should be stressed that what is shown are approximations affected by measurement/modelling errors.

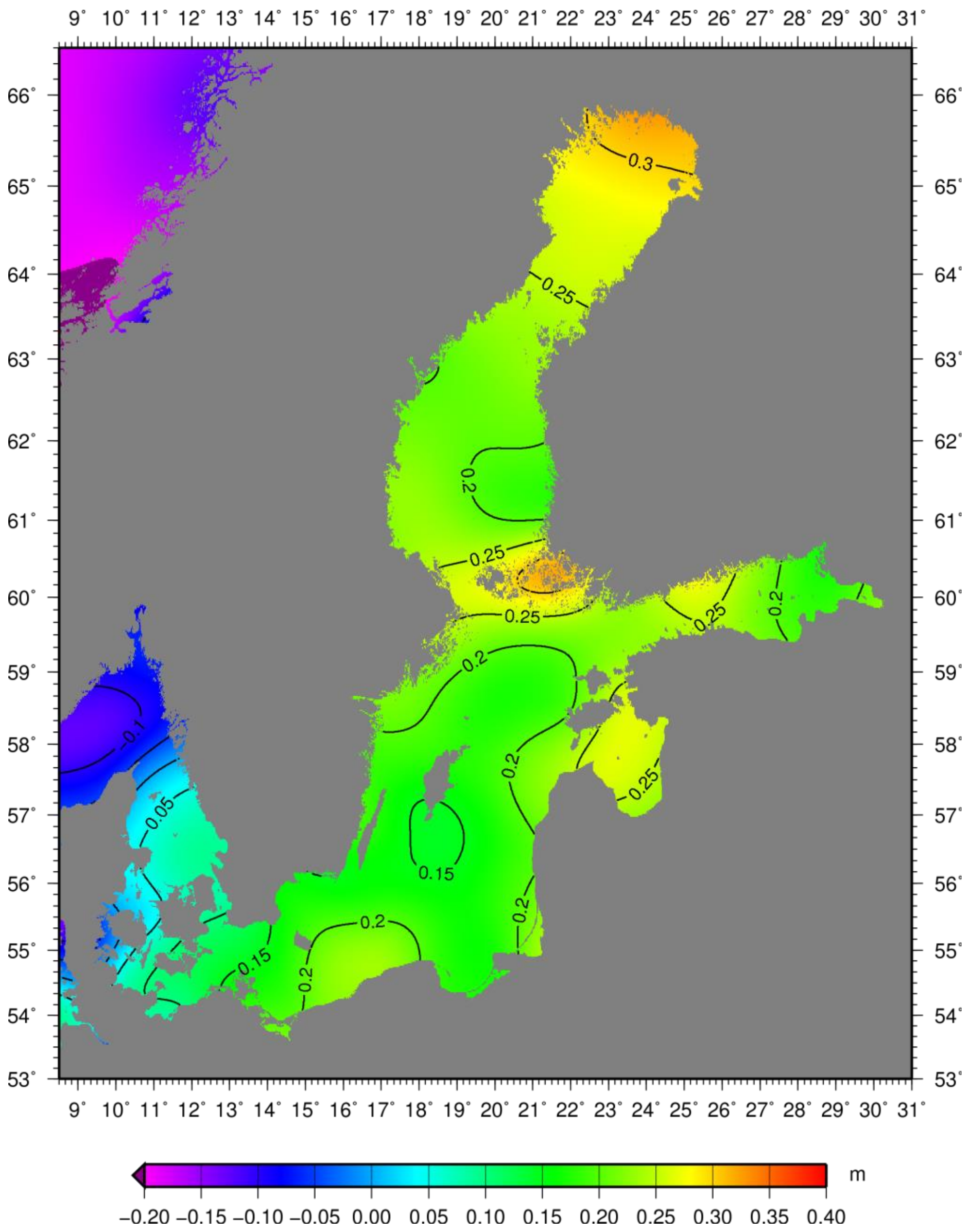


Fig. 3: Estimation of the mean dynamic topography in the mean tide system.

Same as figure 2 transformed to the mean tide system.

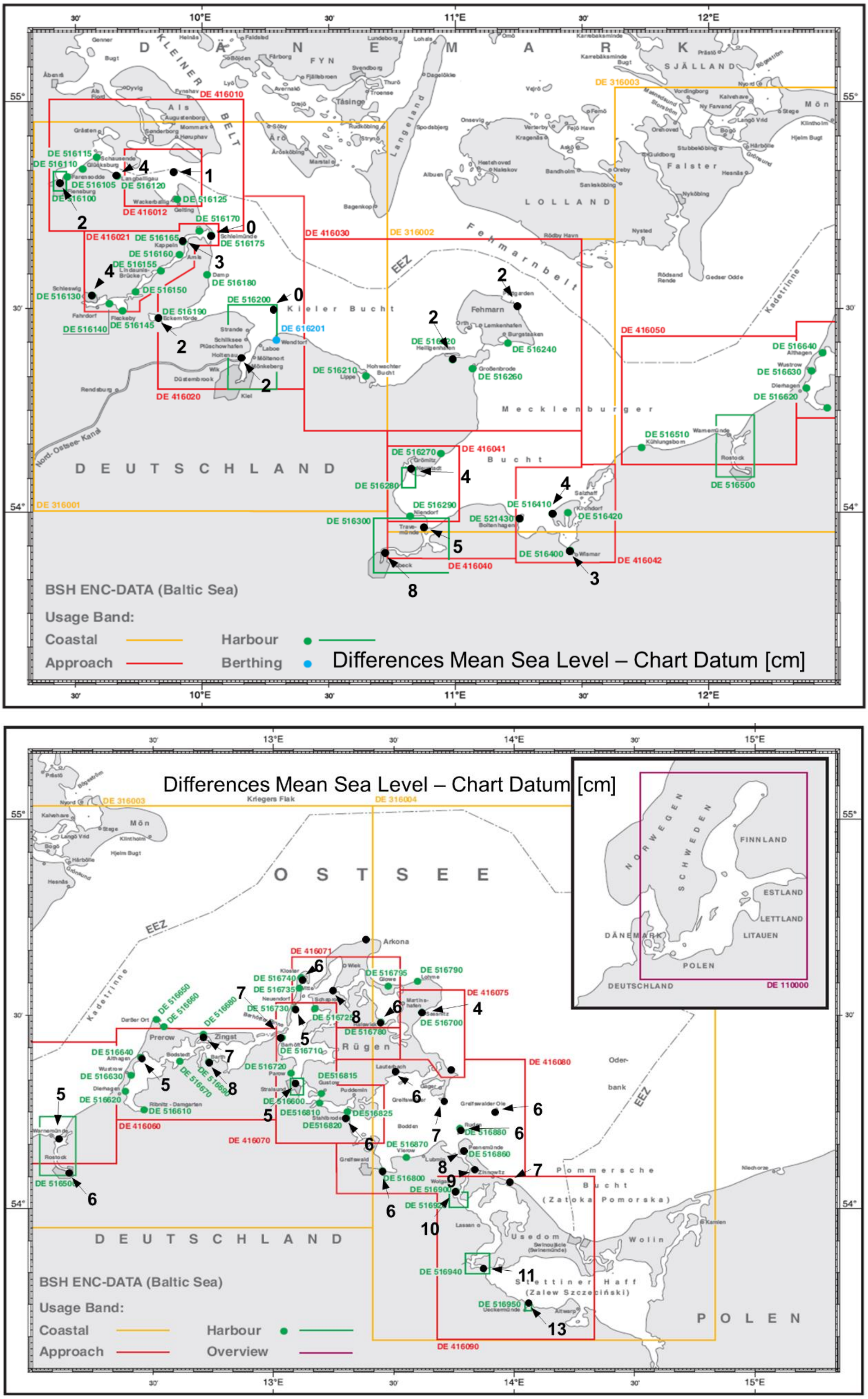


Fig. 4a: Mean sea level with respect to the chart datum

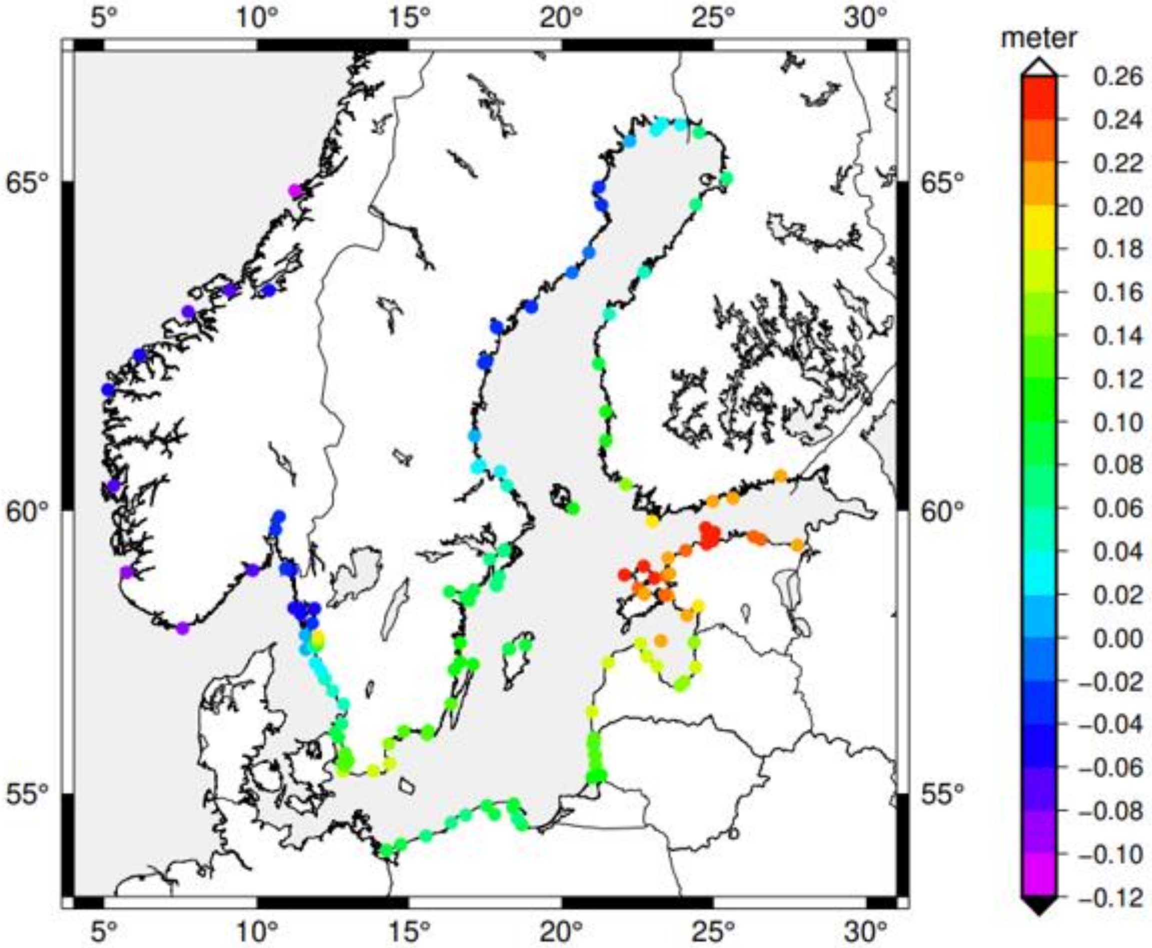
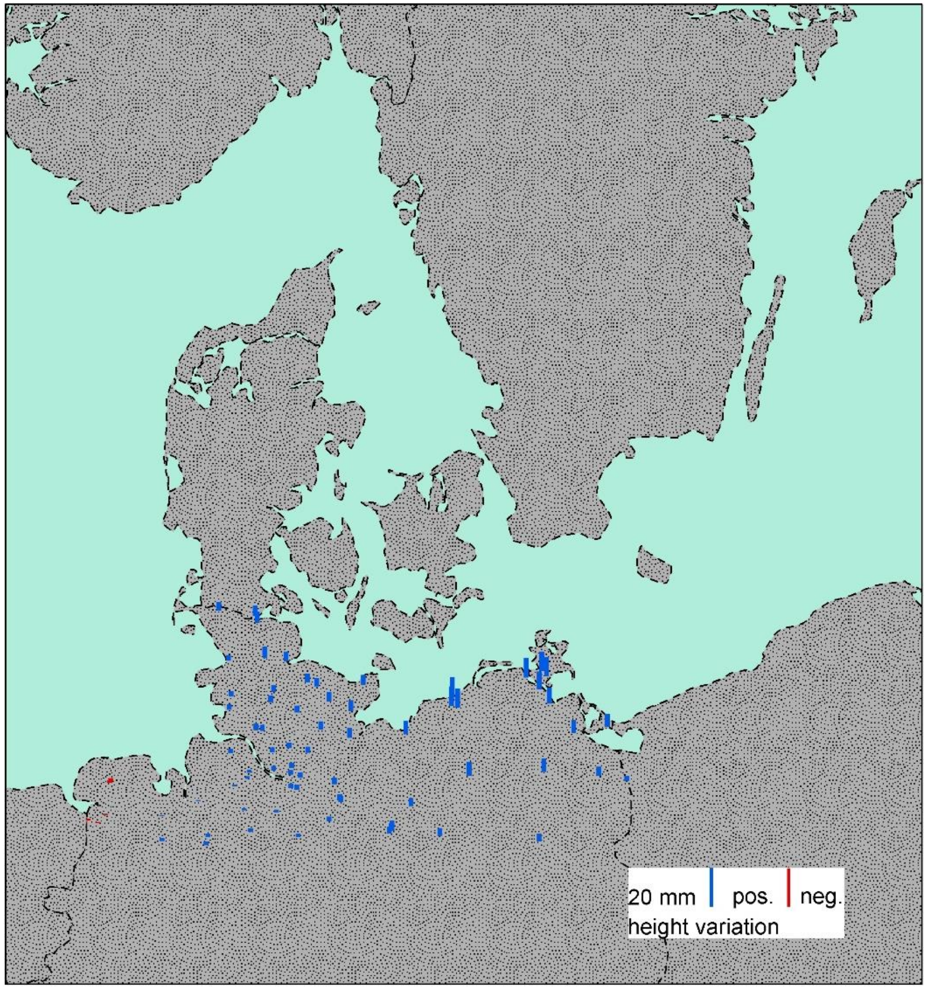
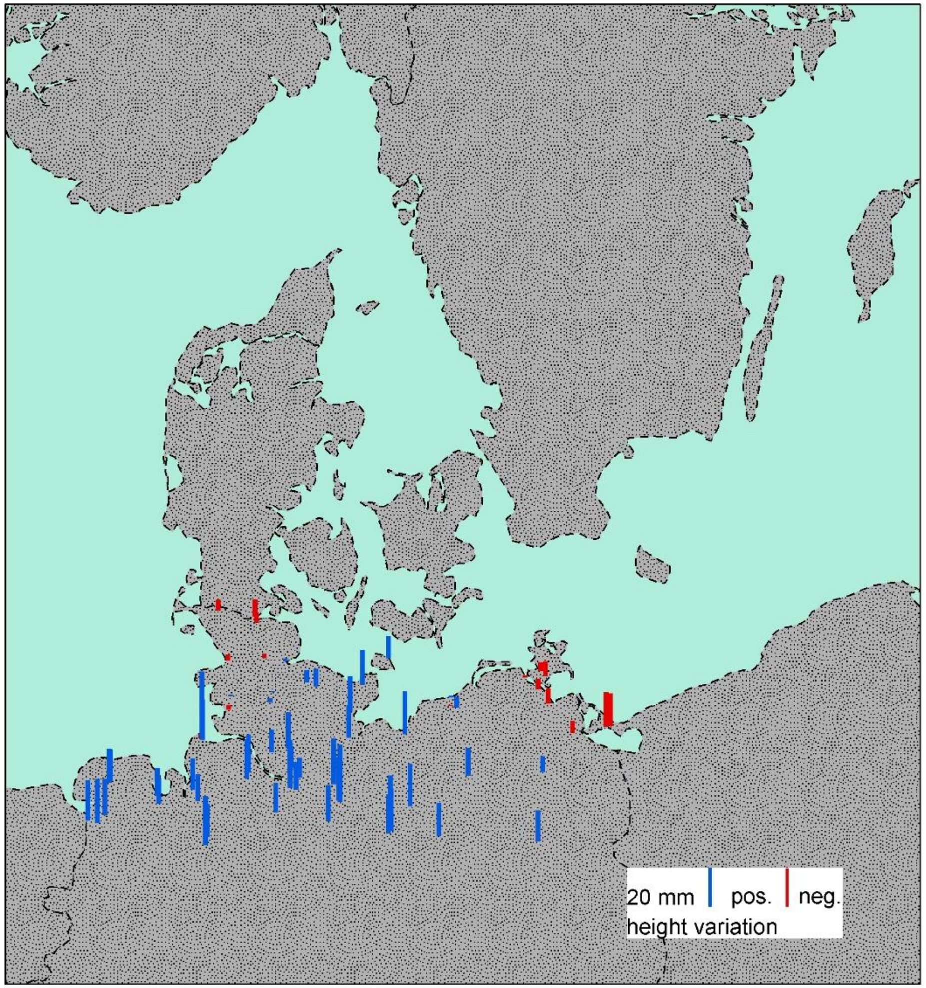


Fig. 4b: Differences between the reference levels of the old national chart datums with respect to Baltic Sea Chart Datum (BSCD2000). In Sweden and Finland, the old reference levels are equal to Mean Sea Level transferred to year 2025 (according to different national conventions). The values from Norway shows the Mean Sea Level over the period 1996-2014, relative NN2000/BSCD2000. In Estonia, Latvia and Lithuania, the Kronstadt datum was previously used as old chart datum. In Poland, the local Polish Height System Amsterdam NN_{55} was used as chart datum. Notice how postglacial rebound reduces the magnitude of the mean sea level in the Bay of Bothnia. The values are shown in this Table.

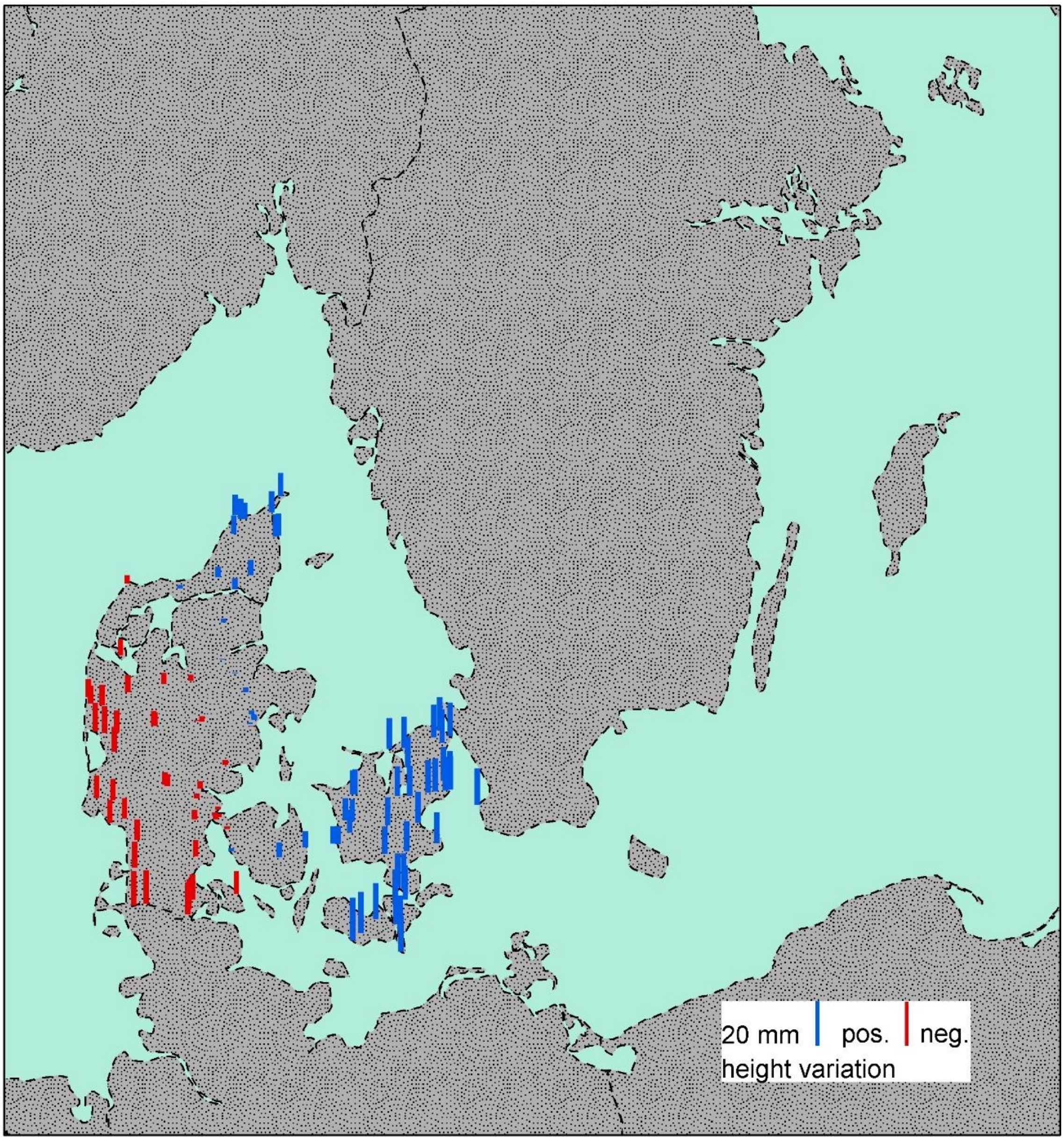
Figs. 5: Differences between height reference frames



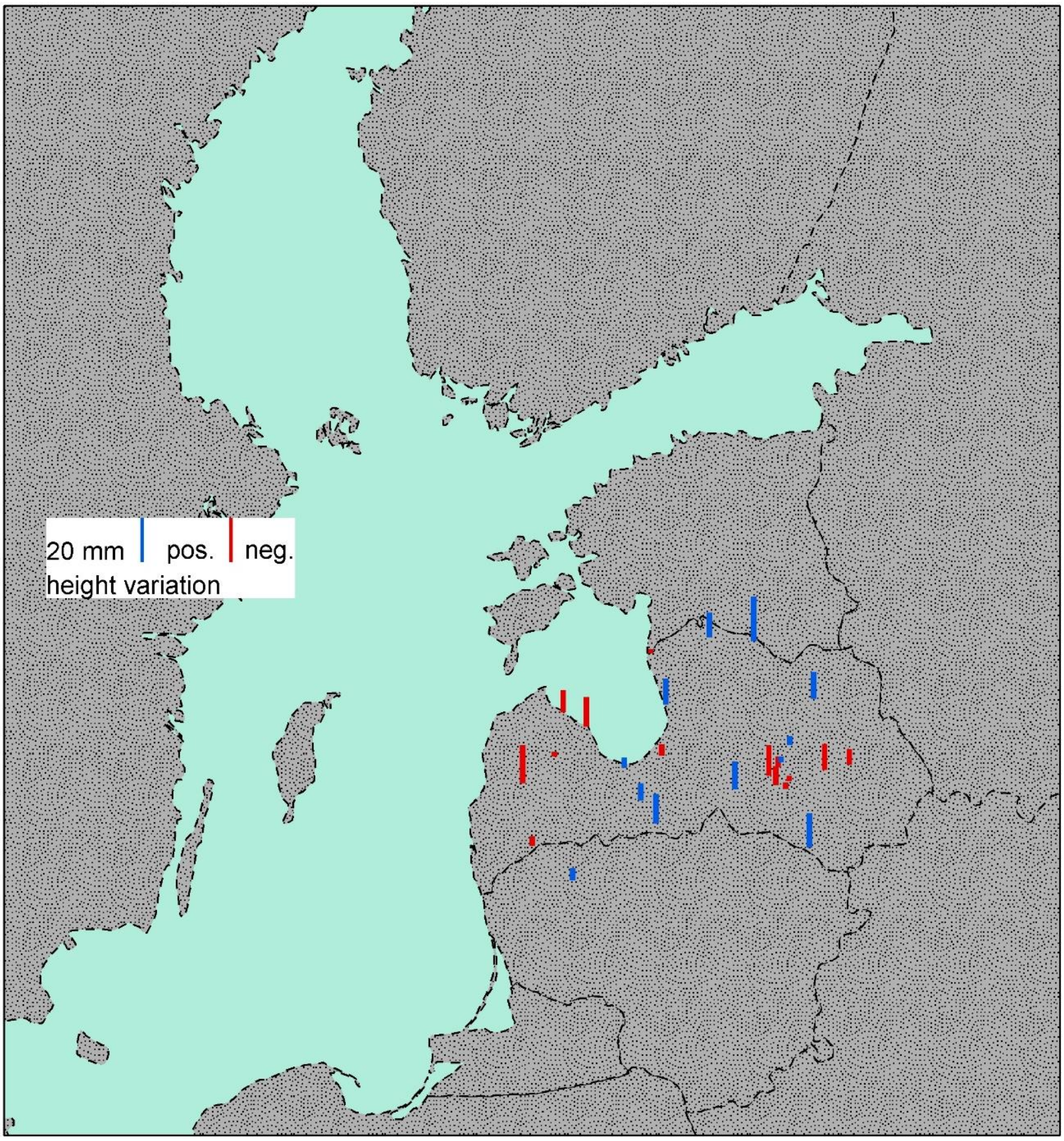
a) Height differences between national height reference frame of Germany (DHHN92, northern part) and EVRF2007 (mean difference 3.8 mm; min. difference -1.4 mm; max. difference 10.7 mm)



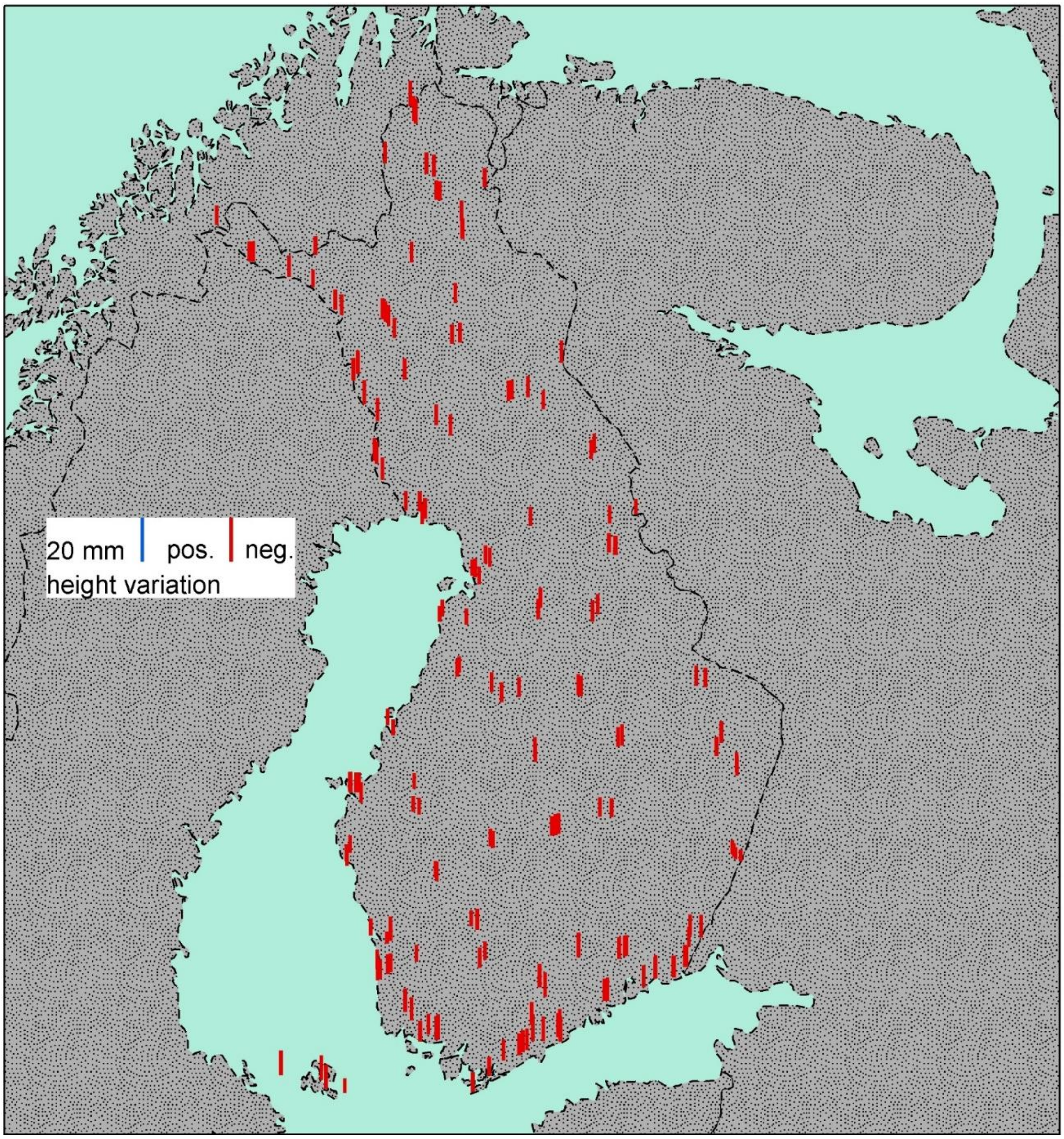
b) Height differences between national height reference frame of Germany (DHHN2016, northern part) and EVRF2007 (mean difference 10.3 mm; min. difference -18.0 mm; max. difference 34.2 mm)



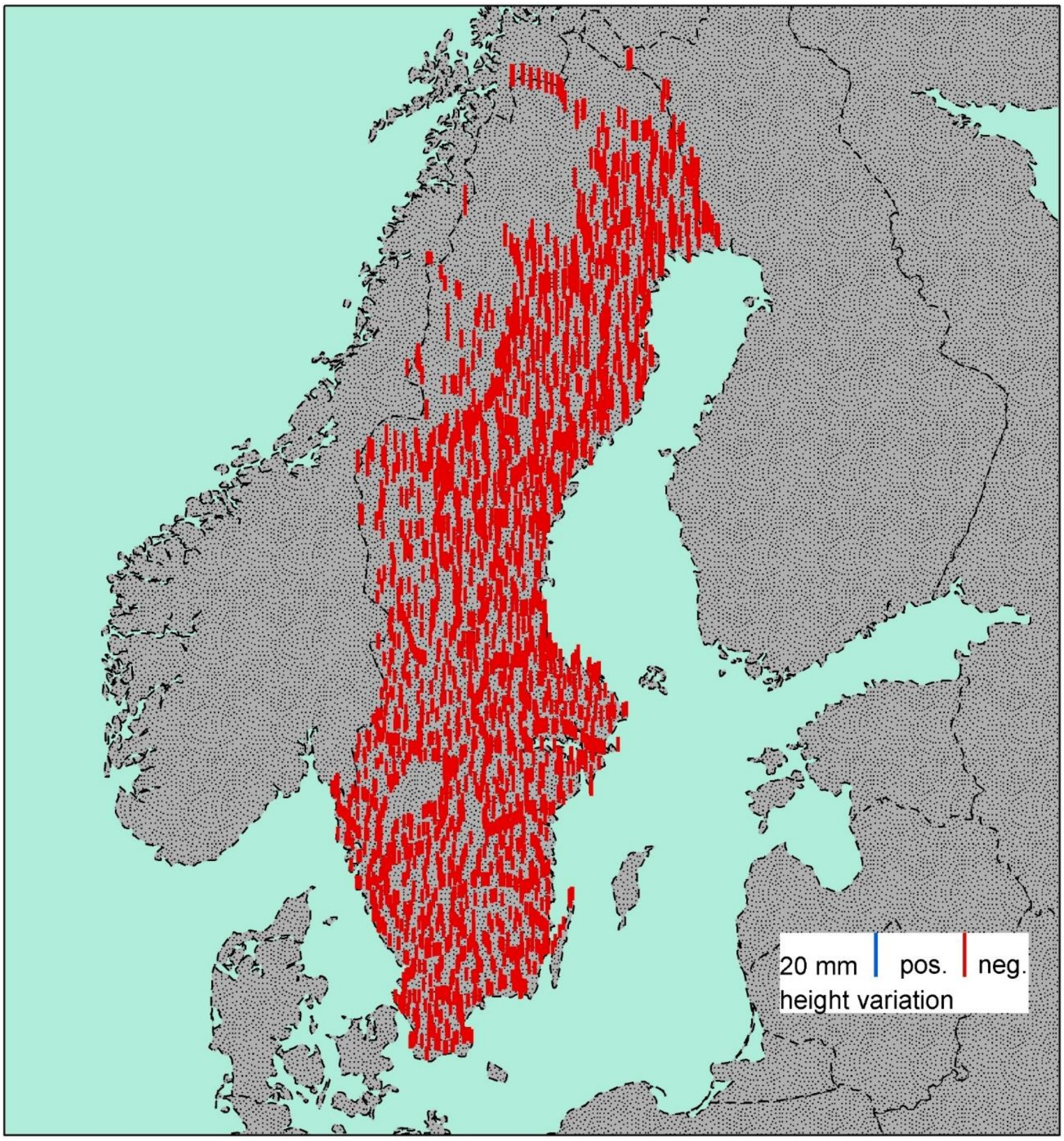
c) Height differences between national height reference frame of Denmark (DVR90) and EVRF2007 (mean difference 3.5 mm; min. difference -15.6 mm; max. difference 19.3 mm)



d) Height differences between national height reference frame of Latvia (LAS-2000,5) and EVRF2007 (mean difference 0.6 mm; min. difference -17.1 mm; max. difference 20.0 mm)



e) Height differences between national height reference frame of Finland (N2000) and EVRF2007 (mean difference -9.1 mm; min. difference -12.1 mm; max. difference -5.3 mm)



f) Height differences between national height reference frame of Sweden (RH 2000) and EVRF2007 (mean difference -7.3 mm; min. difference -13.8 mm; max. difference -2.6 mm)

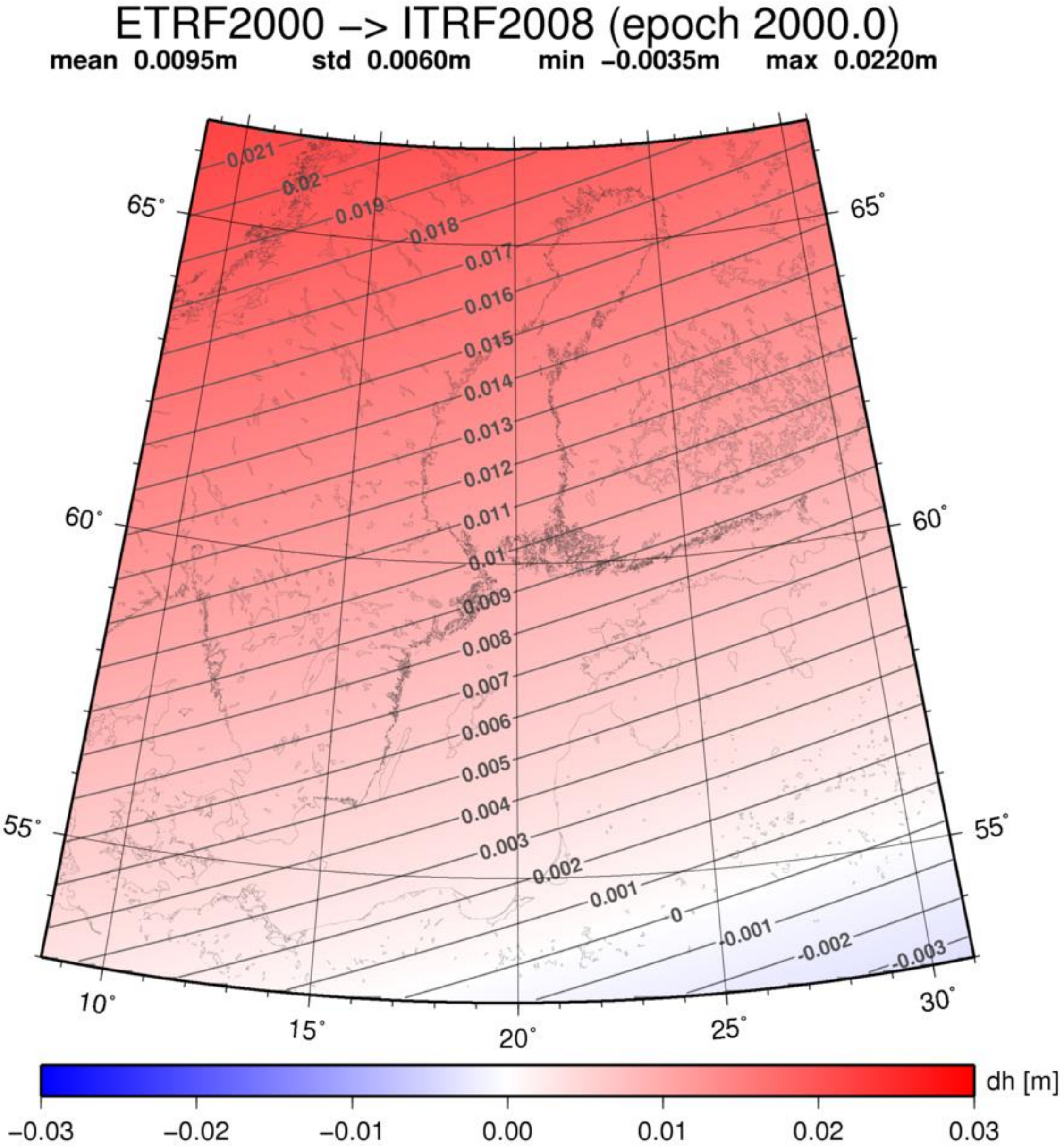


Fig. 6: Differences of the ellipsoidal height between ETRF2000 and ITRF2008 (epoch 2000.0)

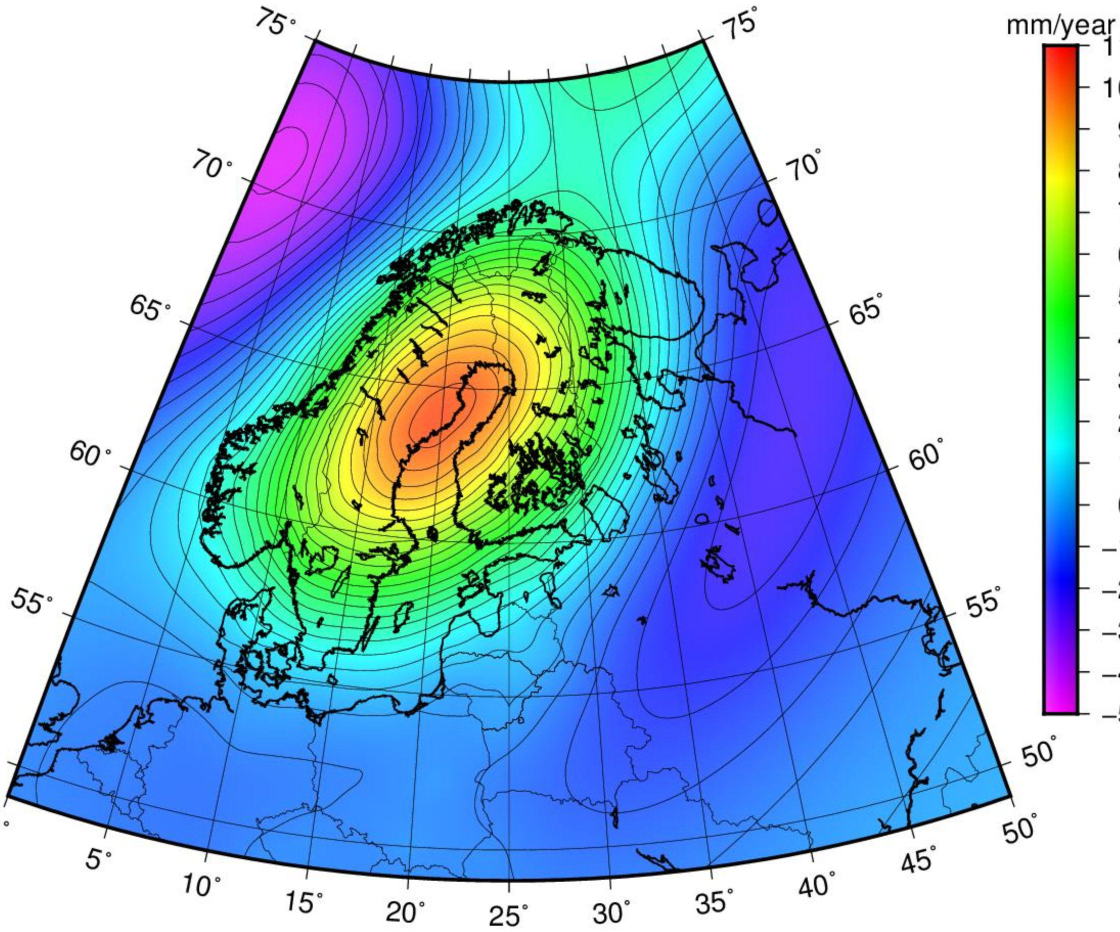


Fig. 7: Absolute land uplift according to NKG2016LU_abs (Vestøl et al. 2019).

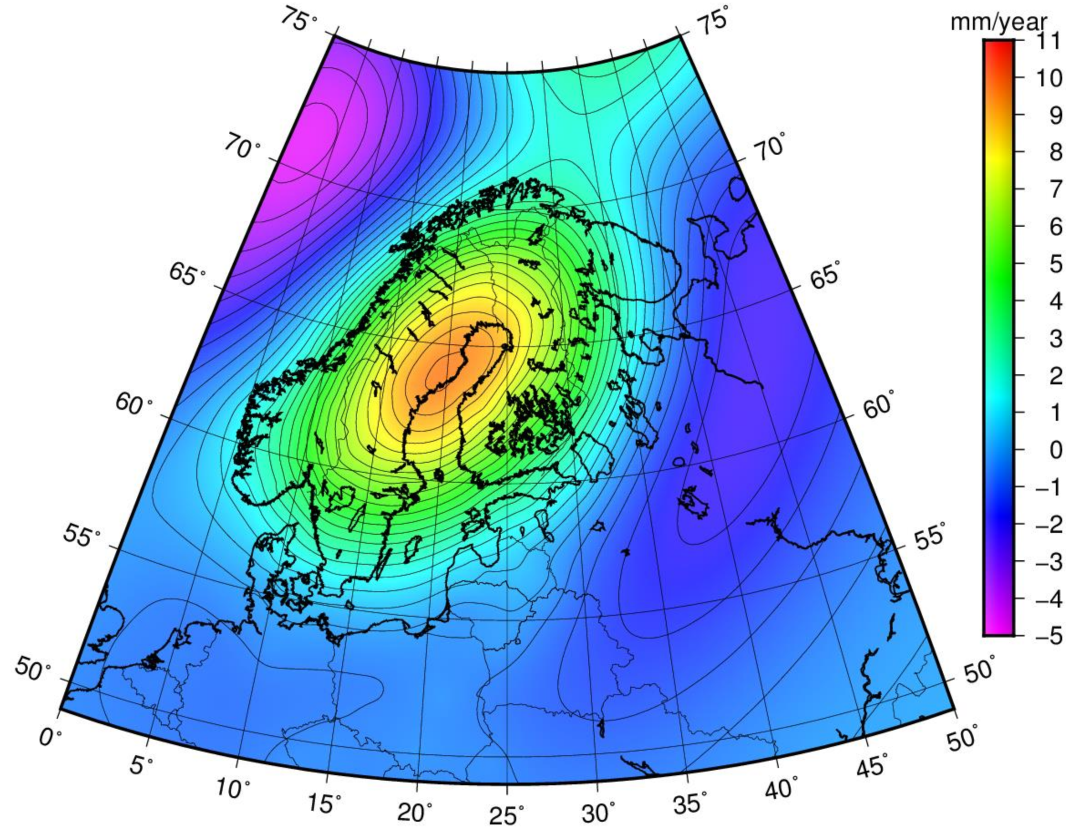


Fig. 8: Postglacial land uplift relative to the geoid according to NKG2016LU_lev (Vestøl et al. 2019).